STUDY ON THE IMPACT OF BUILDING REGULATION ON STREET MORPHOLOGY AND ENSUING MICROCLIMATE IN PLANNED RESIDENTIAL AREA OF DHAKA CITY

By

Iftekhar Rahman

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Department of Architecture

Bangladesh University of Engineering and Technology (BUET)

Dhaka-1000, Bangladesh

The thesis titled **“STUDY ON THE IMPACT OF BUILDING REGULATION ON STREET MORPHOLOGY AND ENSUING MICROCLIMATE IN PLANNED RESIDENTIAL AREA OF DHAKA CITY”** submitted by Iftekhar Rahman, Roll No. 0411012006, Session April 2011, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of MASTER OF ARCHITECTURE on this day ………., 2015.

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Plot-15, Block-B
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Signature:

____

Iftekhar Rahman

Dedicated to my parents

[Late] Dr. A. K. M. Lutfar Rahman

Prof. Begum Lutfun Nahar Bazlee Rahman

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List of Abbreviations

Alt - Altitude

BCR – Building Construction Rule

BNBC – Bangladesh National Building Code

cc – [close – close] Closely placed buildings

Cf - Configuration

DBT – Dry Bulb Temperature

DMINB – Dhaka Mohanagar Imarat Nirman Bidhimala

El - Elevated

FAR – Floor Area Ratio

EW – East west

FS – Field survey

ff – [far – far] Buildings placed apart

GoB - Government of Bangladesh

H/W Ratio – Height Width Ratio

ICT – Information and Communication Technology

INB – Imarat Nirman Bidhimala

K - Kelvin

LoS – Line of Symmetry

MGC – Maximum Ground Coverage

MRT – Mean Radiant Temperature

m/s – meter/second

NS – North south

Og – [On ground] Buildings placed ‘on-ground’

RAJUK – Rajdhani Unnayon Kartipakha

Rd - Road

RH – Relative Humidity

Sqft – Square feet

Sqm – Square meter

ST – Simulation typologies

UHI – Urban Heat Island

WS – Wind Speed

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Abstract

Cities have a tendency to transform through intensifying its land use in urban areas. Bangladesh is a developing country where the expansion of the capital city Dhaka is resulting in one of the mega cities of the world. Buildings are being built to accommodate the increasing inflow of population within this mega city. Recent studies reveal that the impact of urban heat island in Dhaka city is gradually increasing. Thus proper master plan is required for sustainable development and also to improve microclimate within urban areas. Microclimate within the streets is influenced by its morphological character, geometric pattern, orientation, built density and available green space. In residential areas of Dhaka, street morphology is an outcome of the neighboring built forms, usually controlled by building construction rules. The Metropolitan Building Construction Rules [BCR] introduced in 2006 with the application of Floor Area Ratio [FAR] with amendments in 2008 and further in 2013. FAR rule results increased building height, relatively smaller building footprint and potentially free ground floor resulting in an urban street canyon with uneven canyon walls. Thus the research examines the results of an investigation, how FAR impacts outdoor street microclimate with spatio temporal characteristics of the ambient climatic environment. Different microclimate parameters at pedestrian level were studied. Results from an intensive field survey were studied at locations of different street orientations in a planned residential area of Dhaka city. Computer based simulation results as well as observed field data were compared, statistically analyzed and examined in terms of street orientation, aspect ratio, building mass configuration. Comparisons of the present building regulation with the previous are made. Possible urban design considerations are discussed to enhance urban street microclimate for planned residential areas.

Keywords: Urban microclimate, Building regulation, Street morphology, FAR.

Chapter One: Preamble

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1. Preamble

1.1 Introduction

Urban building stock in developing countries is expected to more than double by 2030 (Liu,Meyer and Hogan,2010). As the world population increases and cities expand, it is of great importance to design comfortable cities that provide for the needs of the current population without jeopardizing the security of future generations (Ross, 2012). Yet, urban design and planning policy instruments for the mitigation of the negative impacts of tropical urban climate remains largely unexplored (Emmanuel 2005).

Bangladesh is one of the developing countries in the tropical region of which, the capital city-Dhaka is expanding; resulted as one of the mega cities of the world. Unsurprisingly numbers of buildings are increasing to accommodate the increasing population of this mega city. There are great number of people in Dhaka and not enough land. Buildings will be tall and close to each other. Dhaka is growing at a pace that services and infrastructure are unable to cope with. The planning and design issues related to climate are not well considered over the years. Buildings will typically be constructed to be used for many decades and in some cases, for more than a hundred years. Improvement of buildings' efficiency at planning stage is relatively simple while improvements after construction are much more difficult. (Laustsen, 2008).

Cities can create their own microclimate based on the characteristics of urban form, infrastructure and population habits (Oke, 1977). A given urban density can result from independent design features, which affect urban climate in different ways such as: fraction of urban land covered by buildings, distances between buildings, including streets’ width, average height of buildings (Givoni 2003). ‘The microclimate of urban open spaces is influenced by several parameters such as the urban form and geometry, urban density, the vegetation, the water levels and the properties of surfaces. Streets are considerable parts of urban open spaces have a significant role in creating the urban microclimates.’(Shishegar, 2013). According to the most related studies, street canyon geometry’s parameters [height-to-width ratio (H/W)] and the street orientation are the most relevant urban parameters responsible for the microclimatic changes in a street canyon. (Todhunter P. E. 1990; Yoshida A. et al 1990; Arnfield J., Mills G. 1994). The geometry of a street canyon are expressed by its ‘aspect ratio’ including the ratio of the height of the building (H) to width of the street (W) (Ahmad K. et al, 2005). In case of Colombo, Sri Lanka, it was found that the wide streets with low-rise buildings and no shade trees makes the outdoor conditions worst and the most comfortable conditions were found in the narrow streets with tall buildings, especially if shade trees were present (Johansson and Emmanuel 2006). Studies in Pune, India showed that the unplanned building height causes discomfort in the city (Deosthali 1999).

1.2 Necessity of the Research

The urban landscape is composed of a mosaic of buildings, diverse land uses, and streets with complex shape and arrangement, creating a distinct microclimate. Studies show that one of the causes of this climatic variation is the design or geometry of the city (Arnfield; Grimmond, 1998). According to Ali-Toudert and Mayer (2006), the structure (design) of a street is the key factor for studies on urban bioclimatology, which influences the internal and external micro-climates. A number of useful relationships can be developed between the geometry and the microclimate of urban street canyons and these relationships are very helpful for professionals developing urban design guidelines for the street dimensions and orientations. (Bourbia and Awbi, 2004). Urban planning regulations have a great impact on the microclimate in urban areas (Johansson and Yahia, 2010). There is an urgent need to evaluate the effects of these rules on the thermal climate of the city. As the outdoor spaces are mostly used during daytime, so the assessment of the daytime outdoor temperature is of great importance (Kakon A. N. et al, 2009).

The previous 1996 building by-law which existed from 1996 to 2006 resulted many buildings under that law, as mandatory open space, except the set-back were not present in that law, closely spaced buildings resulted bulk of concrete structures in the city. It is evident from the existing patterns of urban development, that the present planning and building rules do not adequately address the environmental issues, while some may even be regarded as counterproductive (Ahmed, 1995).

Necessity of the new building code, with a provision of mandatory open space to improve the micro climatic condition through providing more green spaces by applying floor area ratio (FAR) came in place, as green spaces decreased day by day applying 1996 by-law, which resulted increase in temperature year after year of different areas of urban Dhaka. New buildings are being constructed under the 2008 building construction act, termed as 'Dhaka mohanagar imarat nirman bidhimala 2008' (GOB,2008) which results more open space, provides more green and the result of applying FAR increased the building height to accommodate the required floor area through providing more open spaces. The temperature of the capital city Dhaka is increasing in a higher rate comparing other parts of the country. There are minimum eight areas in the capital Dhaka where most of the heat is trapped during daytime continues during night also, therefore there is an urgent need to study the impact of existing building regulation on city microclimate.

1.3 Objective of the Research

As the aspect ratio and solar orientation are basic describers of a street microclimate (Toudert F.A., 2005), the research will focus on the impact of orthogonal (north-south and east-west) symmetrical urban canyon in planned residential area; in reference to floor area ratio (FAR) and maximum ground coverage (M.G.C.) relating canyon aspect ratio (h/w ratio) and elevated / non elevated building mass on urban microclimate focusing statistical relationships among different microclimatic parameters i.e.: DBT (dry bulb temperature), MRT (mean radiant temperature), RH (relative humidity) and wind speed (WS) and further compare 1996 and 2013(existing) building regulation.

Therefore, the objectives of the study can be summarized as follows:

1. To study the impact of building regulation and street orientation on outdoor street microclimate [i.e. (DBT)-dry bulb temperature, (MRT)-mean radiant temperature, (RH)-relative humidity and (WS)-wind speed] through *statistical analyses* at pedestrian level in planned residential area; thus considering, *i) orientation* [i.e. orthogonal (north-south and east-west) canyon geometry], *ii) aspect ratio* (h/w

ratio*)* and *iii) building mass configuration* [elevated (El) and non-elevated i.e. on-ground (Og) building mass]

2. Comparative study of 1996 and existing building regulation – whether there are any changes achieved in terms of microclimate through implementation of the existing building regulation

1.4 Methodology

Canyon geometry models derived from building placement by way of ensuring maximum frontal open space allowable as per regulation meeting the maximum ground coverage (M.G.C.) requirement symmetric on both sides of the road. Relating deep canyon geometry model developed by building placement against minimum front setback allowed in the current regulation (Fig 1.1- Fig. 1.3). The method was based on literature review, field survey and software simulation through three dimensional model 'ENVI-met; version 3.1 BETA 5' creating different possible building models from different aspect ratios and elevated / non elevated building mass; through applying relevant building regulations and to see the impact through simulation after applying relevant F.A.R., M.G.C. and to analyze the focused microclimatic parameters through statistical analysis.

Measurement Strategy

Depending upon the building regulation and the objective of the thesis, canyon geometries and measurement strategies for this study are as follows:

Different canyon geometries and building mass configurations are coded as, A, A1, B, B1, B2, B3 - [**A_**1996_Og (buildings placed on-ground under 1996 building regulation), **A1**_1996_El (elevated buildings under 1996 building regulation), **B_**2013_Og_cc (On-ground closely placed buildings under 2013 building regulation), **B1_**2013_Og_ff (On-ground buildings placed apart under 2013 building regulation), **B2_**2013_El_cc (closely placed elevated buildings under 2013 building regulation) and **B3**_2013_El_ff (elevated buildings placed apart under 2013 building regulation)] considering different orientations (North-South and East-West) (Fig. 1.4).

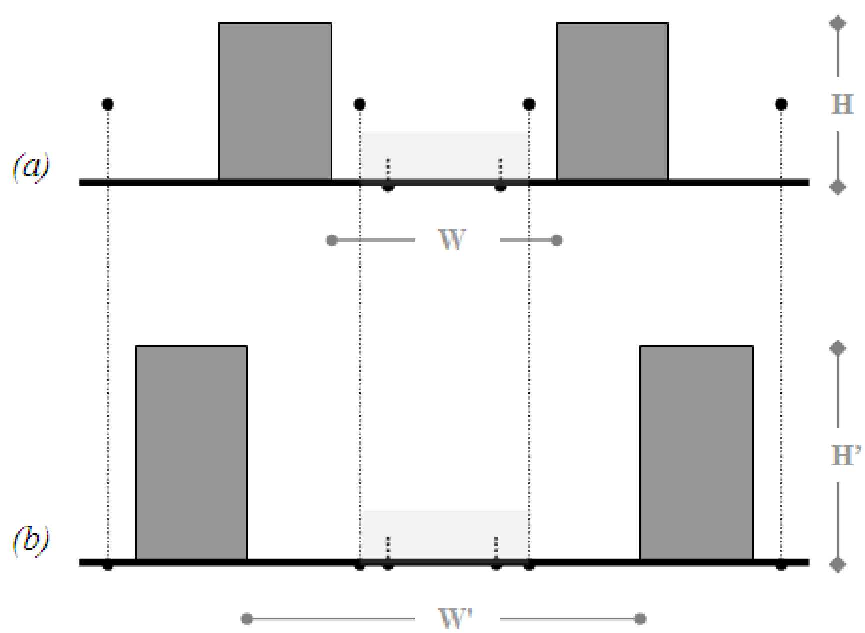

Fig.1.1 Aspect ratio - considering 'On-ground' building masses
(a) Buildings apart with minimum distance
(b) Buildings apart with maximum distance
['H'-building height; 'W'-building to building distance (front side)]

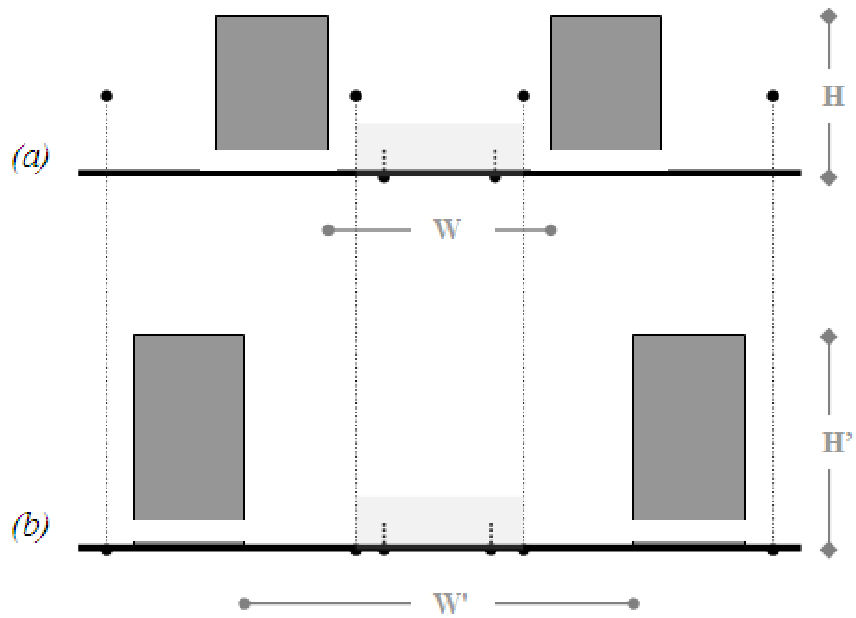

Fig.1.2 Aspect ratio - considering 'Elevated' building masses
(a) Buildings apart with minimum distance
(b) Buildings apart with maximum distance
['H'-building height; 'W'-building to building distance (front side)]

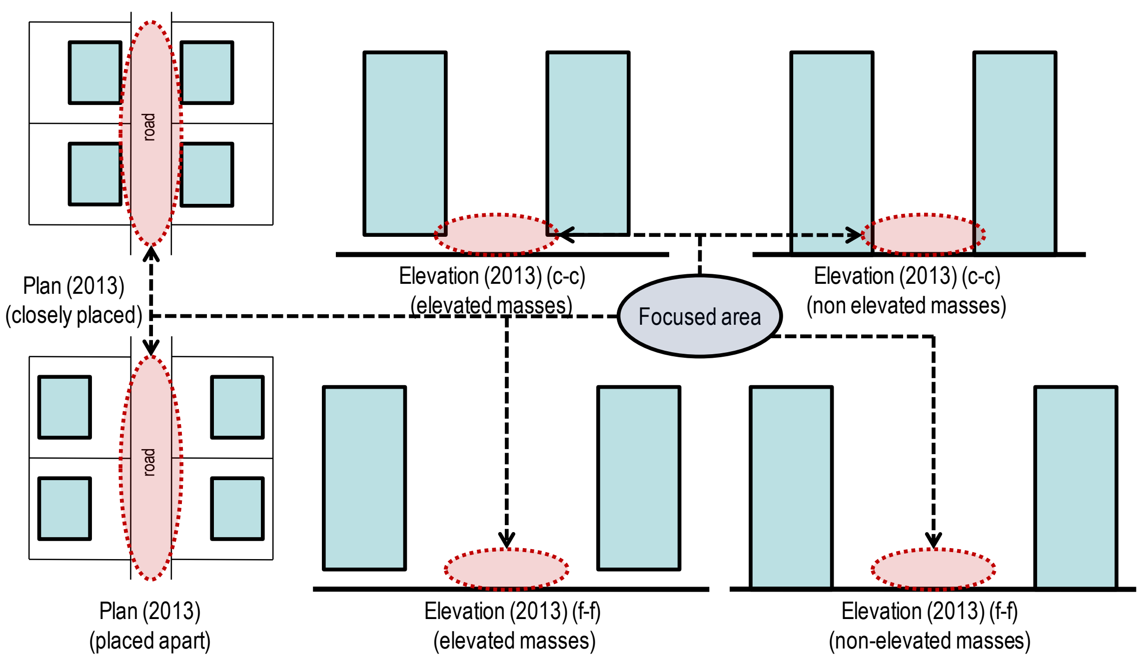

Fig.1.3 Plan and elevation diagram showing 'focused' area for data collection

Thus considered aspect ratios during the research of different canyon geometries of the typologies are as follows:

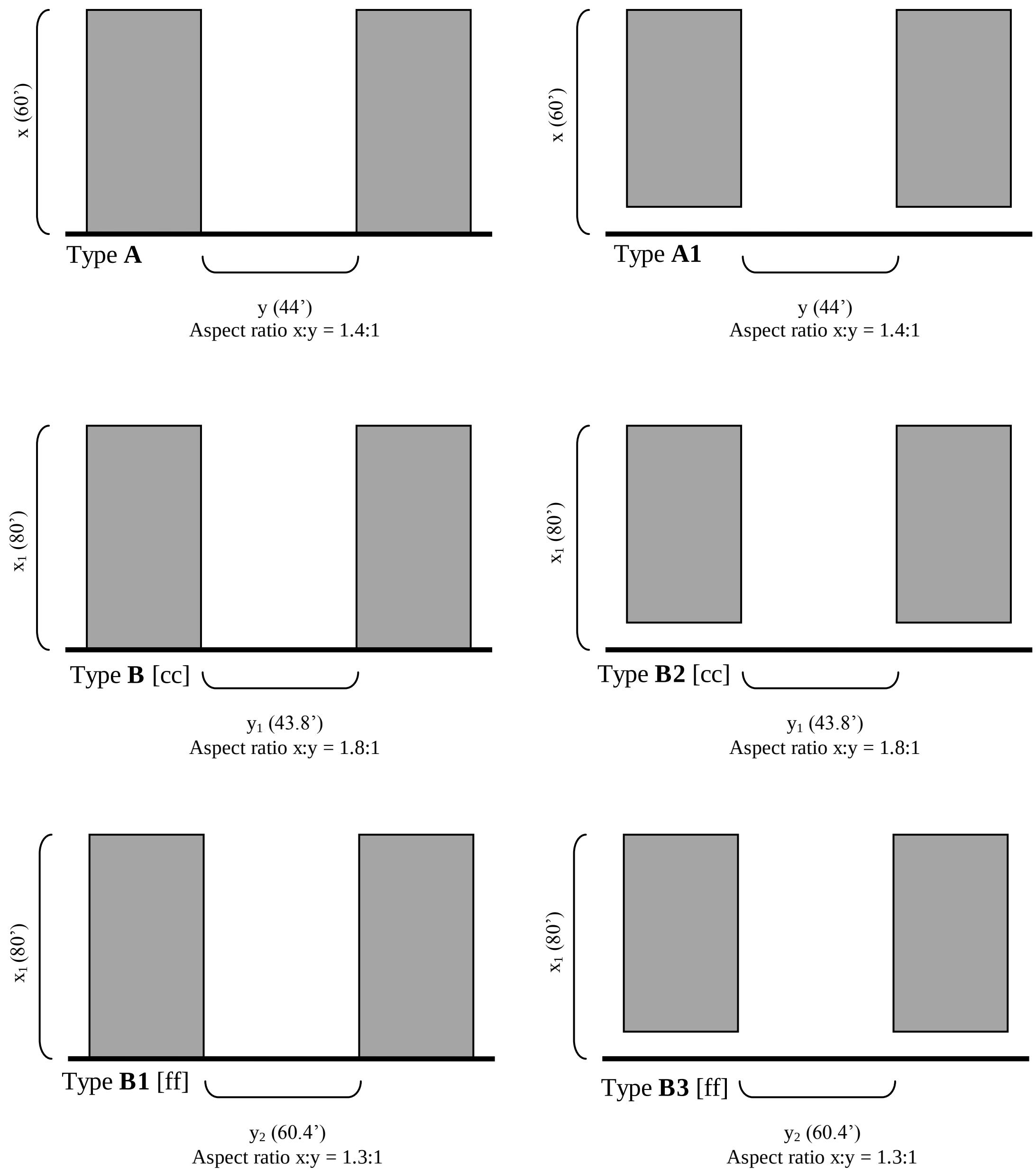

Fig.1.4 Different aspect ratios of the canyon geometries with building mass configurations

Therefore, the aspect ratios considered during the study of different canyon geometries are as follows:

Type A (1.4:1), Type A1 (1.4:1), Type B (1.8:1), Type B1 (1.3:1), Type B2 (1.8:1), Type B3 (1.3:1)

1.4.1 Literature Survey

The literature review was expected to provide the knowledge on the impact of building aspect ratio, street orientation on outdoor street microclimate. At the beginning of the research microclimatic issues in terms of considered parameters were gathered from published articles and books. Previously conducted related researches were studied extensively for other climatic zones as well.

1.4.2 Field Survey

Field survey was done to cross check the performance of the simulation tool and to get an insight of the field condition. The field study was done in the month of March, having no particular interest with regards to overall research work, however generally speaking the month of March represents over heated condition characteristic of the tropics. As the research focuses on planned residential area within Dhaka; 'Uttara model town' had been selected to study as there are three phases at Uttara; of which the first phase having maximum buildings constructed under 1996 act while third phase (under new building regulation) is under construction for which there are scopes of applying research outcome.

Field survey was conducted at Uttara, Dhaka to compare field and simulated data. Later the deviation has been applied in the final simulation results. Through such result it was expected to see the performance of present building construction regulation in terms of urban microclimate comparing the previous act. Total number of six orthogonal streets having same width had been selected to collect data for eight days, in such a manner where all the buildings within the street had been constructed under 1996 act, three of them having north-south and the rest three having east-west oriented. Digital Hygro-Thermometer (Zeal, Model: SH-110) and Vane-anemometer (V&A, Model: VA-8020) had been used to collect microclimatic data (i.e. DBT, MRT, RH and wind speed).

1.4.3 Parametric Study

It is proven that numerical simulation can play a major role for the evaluation of planning and design of buildings and spaces. In a recent review, Arnfield (2003) drew the attention to the growing popularity of numerical simulation, described by a methodology which perfectly suited to deal with the complexities and nonlinearities of urban climate systems. Methodologically, ENVI-met© revealed to be a good tool for the prognosis of the urban microclimate changes within urban areas (Toudert F.A., 2005).

The simulation was divided into two parts:

First part of the simulation followed the time and building models during field survey (buildings constructed under 1996 act) to see the difference between field data and applied the deviation in simulation 'part 2' results.

The second part of the simulation (Fig. 1.5) was focused on the existing building regulation considering: 1) maximum / minimum building aspect ratios (H/W ratio) due to MGC and FAR and 2) elevated / non elevated building mass configuration and 3) street orientation (i.e. north-south and east-west). Microclimate data from such simulation has been collected and statistically analyzed.

Through such simulation it is expected to see the performance of present building construction regulation in terms of urban street outdoor microclimate comparing the previous act.

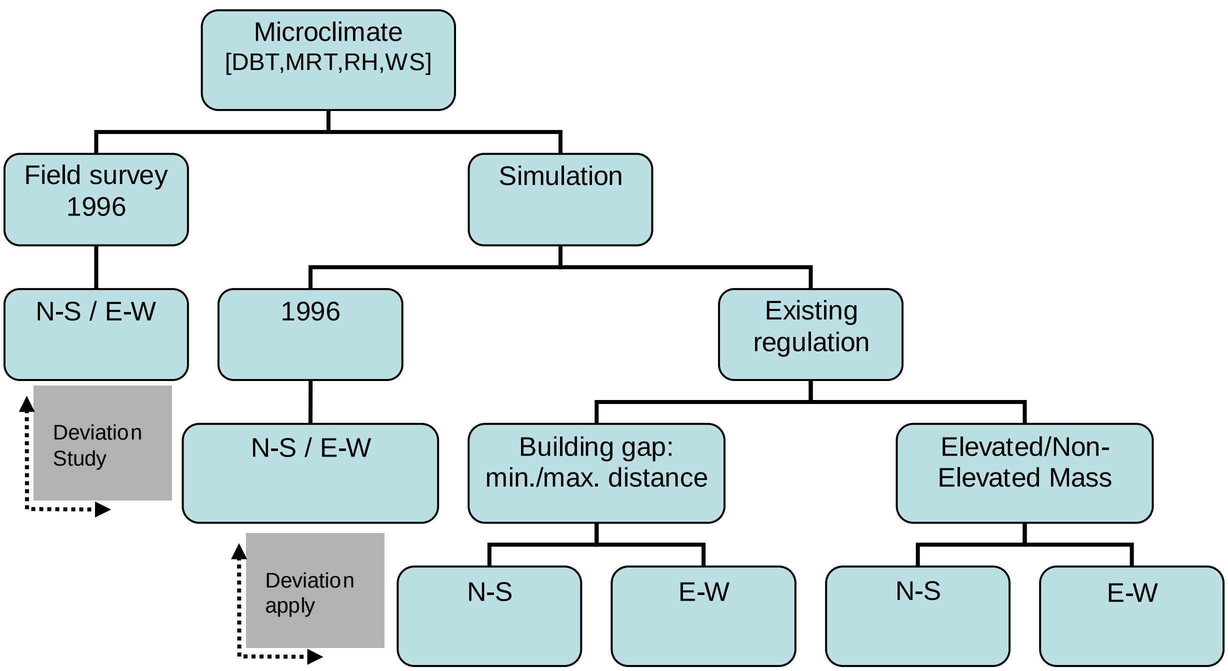

Fig 1.5: Methodology flow diagram

Apart from ENVI-met© for simulation, data will be analyzed through IBM-SPSS Statistics version 21 (Statistical Package for Social Sciences), Microsoft Office Excel 2010 and further prepare various charts, graphs, scatter plot matrices, histograms, tables etc.

1.4.4 Simulation Date Selection

To analyze the results in terms of different microclimatic parameters such as MRT (Mean Radiant Temperature), DBT (Dry bulb Temperature), RH (Relative Humidity) and WS (Wind Speed), it was not possible to run simulation for every month of a year due to time constraints, 'Mahoney Tables' (Koenigsberger, et al., 1973) (Table: 1.1) where gone through to observe different conditions [Hot, Comfortable or Cold] of individual months of a year in terms of day and nighttime condition and seen that from April to October, it is hot during day and night time also.

Table 1.1: Mahoney Tables

The Mahoney Tables

Location: Dhaka

High	**AMT**
35	**24.5**
14.5	**20.5**
Low	**AMR**

Air Temperature [degC]

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean Max.	24	28.5	33	33.5	35	33	33	33	33	32	29	24
Monthly Mean Min.	14.5	16	22	24	26	27	27	27	27	24	19	14.5
Monthly Mean Range	9.5	12.5	11	9.5	9	6	6	6	6	8	10	9.5

Relative Humidity

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean Max.	86.5	79	85	88	89	89	92	91.5	92	90.5	88	94
Monthly Mean Min.	44	25	31	49	53	65	67	66	64	52	46	53
Average	65.5	52	58	68.5	71	77	79.5	79	78	71	67	73.5
Humidity Group	3	3	3	3	4	4	4	4	4	4	3	4

Rain and Wind

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall [mm]	0	20	80	110	280	400	390	320	250	180	30	0

DIAGNOSIS [degC] **AMT : 24.5 degC**

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean Max.	24	28.5	33	33.5	35	33	33	33	33	32	29	24
Day Comfort: Upper	29	29	29	29	27	27	27	27	27	27	29	27
Lower	23	23	23	23	22	22	22	22	22	22	23	22
Monthly Mean Min.	14.5	16	22	24	26	27	27	27	27	24	19	14.5
Night Comfort: Upper	23	23	23	23	21	21	21	21	21	21	23	21
Lower	17	17	17	17	17	17	17	17	17	17	17	17
Thermal Stress: Day	**O**	**O**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**O**	**O**
Night	**C**	**C**	**O**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**O**	**C**

H: Hot
O: Comfortable
C: Cold

	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thermal Stress: Day	**O**	**O**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**O**	**O**
Night	**C**	**C**	**O**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**O**	**C**
Humidity	3	3	3	3	4	4	4	4	4	4	3	4

INDICATORS

	1	2	3	4	5	6	7	8	9	10	11	12	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Humid: H1													**7**
Humid: H2													**1**
Humid: H3													**5**
Arid: A1													
Arid: A2													
Arid: A3													

Thus, data for the month of April were used as an example; since this period was characterized by changeable weather (Erell E., 2007). Besides Mahoney tables it was seen from Met (Meteorology) data [2008-2013] from Bangladesh Meteorological Department of Mean Air Temperature (3 hourly-12pm & 3pm) (Fig: 1.6) to select the month for simulation.

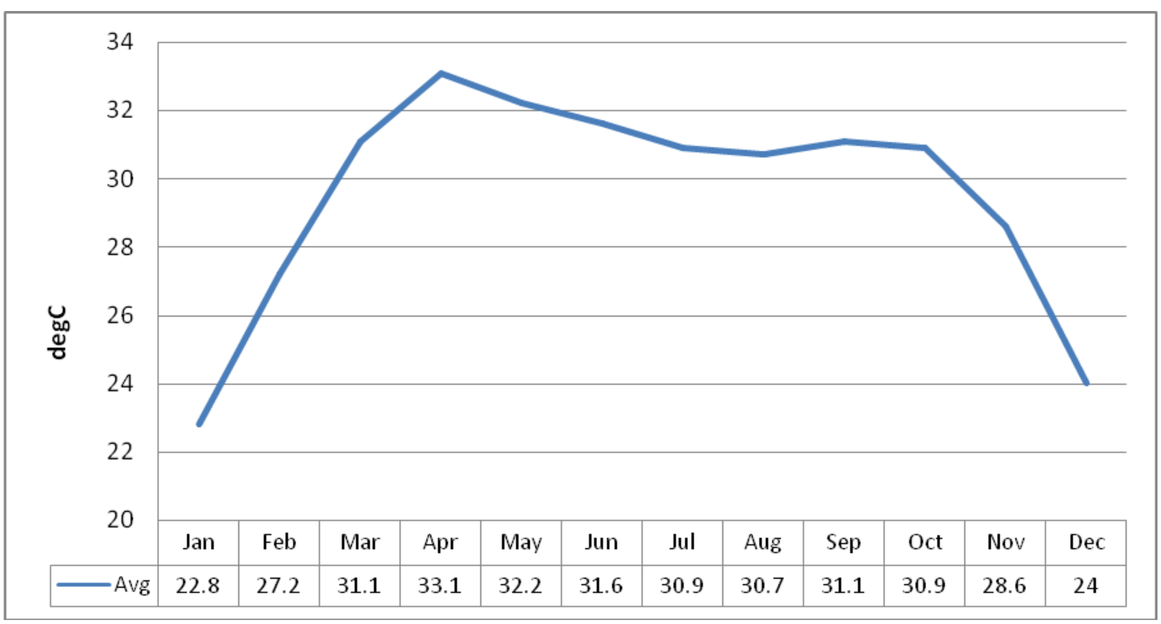

Fig.1.6 Mean Air Temperature (3 hourly-12pm and 3pm of 12 months) [Met data 2008-2013]

After selecting the month; the 'date' was selected from 3hourly average Met data (2008-2013) considering daytime temperature (12pm and 3pm) as Ahmed K.S. (1995) found the critical period is between 11:00 and 14:00 hours, in terms of Urban Design Objectives for Outdoor Comfort in the Context of Dhaka and this research is also focused on daytime temperature, thus while collecting data from simulation the time was considered from 11am to 2pm.

Middel A. (et al) 2014 in a research found: '1.Cooling is not only a function of vegetation and surface materials, but also dependent on the form and spatial arrangements of urban features 2. At the micro scale, urban form has a larger impact on daytime temperatures than landscaping 3. In mid-afternoon, dense urban forms can create local cool islands and 4. Spatial differences in cooling are strongly related to solar radiation and local shading patterns'. Emmanuel and Fernando (2007) found that urban morphology significantly affects daytime air temperatures. High density urban areas provide shading from incoming solar radiation and can therefore result in cooling benefits. This is known as a 'cool island' effect (Pearlmutter, Bitan, & Berliner, 1999), and is primarily a daytime phenomenon (Brazel, Selover, Vose & Heisler, 2000; Georgescu, Moutaoui, Mahalov, & Dudihia, 2011). Thus 24th of April, (Fig: 1.7) was selected for simulation considering the highest mean air temperature which was 2.4 degC above outdoor comfort level with an hypothesis that orientation, aspect ratio and building mass configuration due to building regulation can reduce outdoor temperature at pedestrian level in terms of creating 'cool island' thus resulting outdoor comfort.

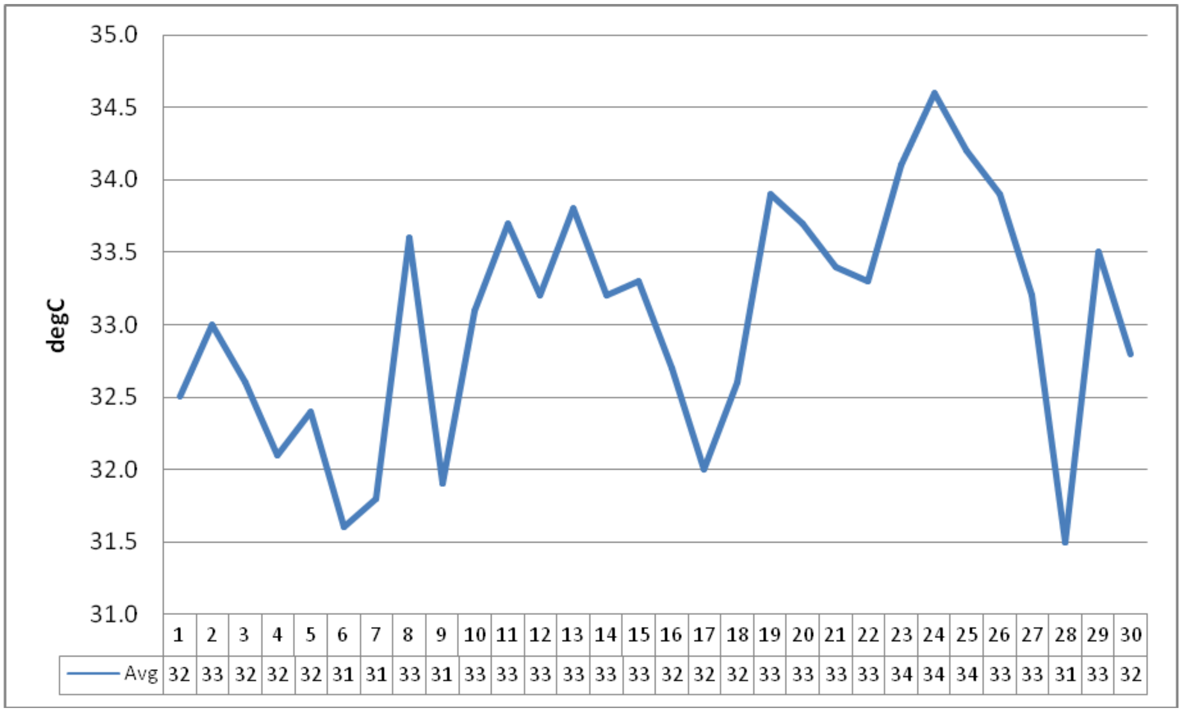

Fig.1.7 Mean Air temperature_3hourly [12pm & 3pm] different days of April [Met data 2008-2013]

In another study Johansson E. (2001) found significant differences in hot dry climate comparing two neighborhoods having different H/W ratios (0.6 and 10) of street canyon where there were 2-4 degC temperature differences in both summer and winter, which signifies that 'aspect ratio' can play a significant role in changing air temperature at pedestrian level in outdoors which in fact justifies the hypothesis assumed above.

1.5 Research Strategy

This research is to be done through experimental research strategy where the researcher tries to find out whether a variable has an effect on behavior and the direction of that effect. Generally one or more variables are manipulated to determine their effect on a dependent variable.

- *Independent Variables* are:
  - Building regulation (1996 and Existing)
  - Street orientation (North-South and East-west)
  - Building aspect ratio (H/W ratio) due to FAR and MGC
    - Elevated and non-elevated building mass
- *Dependent Variables* are:
  - Urban street microclimate (i.e. DBT, MRT, RH, Wind speed)
- *Unit of Assignment* is the: 'Street - in planned residential area'
- *Control group* is the group to which no treatment is applied. In this research Control Groups are as follows:

- Other aspect ratios due to various building heights within same row of buildings
- Various road widths and intermediate cardinal road directions (i.e.NE-SW; NW-SE)
- Building and other surface materials
- Other plot sizes
- Impact of vegetation
- Other FAR and MGCs
- Impact of vehicular movements

- Street pollution
- Impact of plot boundaries

The main aim is to credibly establish a cause effect relationship. Here in this research the Focus on *Causality* may be:

- The effect of street orientation on outdoor street microclimate
- The effect of aspect ratio due to FAR and MGC – H/W ratio on urban microclimate at street level
- The effect of elevated / non elevated building mass on outdoor street microclimate

1.6 Research Quality Consideration

This study will focus on the two building regulations as mentioned earlier for residential buildings in the context of Dhaka, Bangladesh. While considering the quality of the research, the following issues are necessary to be considered:

1.6.1 Internal Validity

The research will be conducted on the microclimatic condition through simulation of residential buildings in context of Dhaka. To increase the internal validity of the research, intensive literature study and computer simulation analysis will be conducted.

1.6.2 External Validity

The research-outcomes for outdoor microclimate can be applicable in the climatic context of Dhaka city and any other countries of similar climatic context. For other countries, the climatic data must be changed while simulating through the software according to the context of that country, while micro climatic parameters are considered.

1.6.3 Reliability

The software/s used for this research is renowned and accepted internationally so the quantitative results would be reliable. (Reported in Toudert F.A., 2005)

1.6.4 Objectivity

According to the literature review and theoretical perspective, there is a physical reality of the objects. All data are quantifiable.

1.7 Structure of the Thesis

The thesis contains a summary of six chapters of which brief description are given below:

Chapter 2 defines microclimate and climate of Dhaka city focusing microclimatic parameters and reviews street morphology, building aspect ratio and residential building regulations of 1996 and existing. Chapter 3 presents field survey and further describes simulations done in the same context for deviation study. Chapter 4 describes the simulation outputs in terms of considered orientation, aspect ratio and building mass configuration based on considered building models. Chapter 5 presents statistical analysis on focused aspects and finally Chapter 6 contains findings with concluding remarks.

1.8 Limitation of the Work

As the study focuses on microclimate and street morphology of planned residential area of Dhaka city due to building regulations, number of variables came in place; where all the variables could not be considered at a time in this research as there were time constrains and also it is not possible to consider all the variables at a time due to complexity of urban typology. Therefore further studies can be done considering the untouched variables.

Issues such as impact of various road widths in front of the plots, various building and road surface materials, vegetation, other FAR and MGCs, impact of vehicular movements on microclimate, other planned residential areas, intermediate cardinal street direction, effects of air pollution, impact of plot boundaries and also impact of various plot sizes on microclimate were not considered during this research.

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Chapter Two: Literature Review

Introduction

Climatic Characteristics of Dhaka, Bangladesh

Urban Microclimate, Outdoor Comfort and Simulation

Building Regulation and Street Morphology

Conclusion

References

2. Literature Review

2.1. Introduction

This chapter reviews the micro climatic of Dhaka city focusing air temperature, relative humidity, wind speed and further discusses the urban micro climate with outdoor comfort and the simulation software used during the research. While going through the urban microclimate, judiciously ‘urban heat island’ (UHI) with its effect and ‘smart city’ concept were also discussed. Since building regulation, street morphology, and micro climate are the key issues of this research; focused ‘building regulation’ and street morphology with a view to aspect ratio with building mass configuration were also gone through along with canyon orientations. Finally different statistical analyses methods which were used during the research were also discussed at the end of the chapter.

2.2. Climatic Characteristics of Dhaka, Bangladesh

2.2.1. Climate of Bangladesh- An Overview

Bangladesh, lying between latitude 20°34’N and 26°33’N and longitude 88°1’E and 92°41’E, is in the Indo-Malayan realm. On three sides it is bounded by landmass and on the south by the Bay of Bengal. According to Atkinson’s classification of tropical climate (Atkinson, 1953), Bangladesh lies in warm humid climate zone, which is located on land masses near the tropic of Cancer and tropic of Capricorn. There are three distinctive seasons, the hot humid, the hot dry and the cool dry season (Ahmed, 1995). Generally the cool, dry season is short while the summer is long and wet. The hot dry period is between March and May when the average maximum temperature is 33.1°C with the rains and the beginning of the hot humid period (June, July, August and September), when the temperature remains more or less constant. The average relative humidity is above 85% and rainfall is high which is above 800mm/month in the north-eastern part of the country. The cool season starts around mid October when the drop in the temperature is noticeable and it last till February. The average temperature during this period is about 19°C with the mean minimum temperature going down to 11.8°C in some parts of the country (Mojumder, 2000).

Meteorologically, the climate of Bangladesh is classified into four distinct seasons – winter, pre-monsoon, monsoon and post-monsoon (Hossain et al, 1993), where the winter is cool and dry (December to February), the pre-monsoon is hot and dry (March to May), monsoon (June to early October) and post-monsoon are hot and wet (late October to November).

The general characteristics of the seasons are as follows:

Winter is relatively cooler and drier, with the average temperature ranging from a minimum of 7.2°C to 12.8°C to a maximum of 23.9°C to 31.1°C. Occasionally minimum temperature falls below 5°C in the north though frost is extremely rare. There is a south to north thermal gradient in winter mean temperature: generally the southern districts are 5°C warmer than the northern districts.

Pre-monsoon is hot with an average maximum temperature of 36.7°C, predominantly in the west for up to 10 days, very high rate of evaporation and erratic but occasional heavy rainfall from March to June. In some places the temperature occasionally rises up to 40.6°C or more. The peak of the maximum temperatures are observed in April, the beginning of pre-monsoon season. In pre-monsoon season the mean temperature gradient is oriented in southwest to northeast direction with the warmer zone in the southeast and the cooler zone in the northeast.

Monsoon is both hot and humid, brings heavy torrential rainfall throughout the season. About four-fifths of the mean annual rainfall occurs during monsoon. The mean monsoon temperatures are higher in the western districts compared to that for the eastern districts. Warm conditions generally prevail throughout the season, although cooler days are also observed during and following heavy downpours.

Post-monsoon is a short living season characterized by withdrawal of rainfall and gradual lowering of night-time minimum temperature.

The mean annual rainfall is about 2300mm, but there exists a wide spatial and temporal distribution. Annual rainfall ranges from 1200mm in the extreme west to over 5000mm in the east and north-east.

There are perceptible differences in the climate of different parts of the country. It can be classified into seven sub-zones (Rashid, 1991). These are South-Eastern Zone, North Zone, Northern part of Northern region, North-Western Zone, Western Zone and South Central Zone (Ahmed, 1995). There are some differences within the patterns of climatic factors in these sub-zones.

2.2.2.Microclimate of Dhaka

The climatic characteristics of Dhaka city differ from other cities of the country due to its adverse physical developments and location. Again within the same city these characteristics are further modified in different locations. It is due to the surface quality of the area – hard or soft, density of built environment, building type, building height and their orientations, proximity between buildings, material used fro construction, dependence on electrical and mechanical appliances and other related factors (Rahman, 2004). Increasing air and water pollution emanating from traffic congestion and industrial waste are serious problems affecting public health and the quality of life in the city. Water bodies and wet lands around Dhaka are facing destruction as these are being filled up to construct multi-storied buildings and other real estate developments. Coupled with pollution, such erosion of natural habitats threatens to destroy much of the regional biodiversity (Hossain et al, 1993).

2.2.3.Temperature

On the basis of meteorological data the temperature profile of Dhaka city shows similarity with that of the regional pattern of that area. The highest temperature is recorded in the month of March, April and May, which reaches to 35.4°C maximum in April. In the monsoon and post monsoon period, from June to October the temperature remains steady at an average of 28.7°C. in cool period it drops to 20.8°C on average.

Overheating due to inexorable urban growth of Dhaka city is now a major environmental concern, which should be handled with care by the urban designer (Ahmed, 1995). Meteorological observation in pre-monsoon period records a maximum temperature of 36.5°C (1994), indicating possible trends towards the increase of temperature and overheating.

2.2.4.Relative Humidity

Like other parts of the country the humidity of Dhaka city is high and the mean annual relative humidity is 77%, which is 2-4% higher than its surrounding countryside. If all conditions remain the same, then the relative humidity is inversely related to the temperature. So, higher temperature yields lower relative humidity levels. Since air temperature and radiation depends on the density of the built form, the humidity varies with the density of the surrounding built environment.

2.2.5.Wind Speed

Wind speed in Dhaka during monsoon period (June to September) is relatively high and the direction is predominantly southerly and southeasterly. In winter, the wind is northerly and northwesterly. Wind speed data provided by the meteorological department is generally wind flow pattern of the country-side (Givoni, 1989) (Ahmed Z. N., 1994). It depends on the surface roughness, orientation, three dimensional characteristics of the surrounding built environment, vegetation and elevation of the surface of the particular site. There may be funneling effect or turbulence created by the mixer of built form of different height, which increases the wind speed in an area (Newberry et al, 1976).

2.3. Urban Microclimate, Outdoor Comfort and Simulation

2.3.1.Urban Microclimate

Urban microclimate can be defined as; a small, local region having a unique pattern of weather or weather effects that differ from the local climate (AED, 2013), in other words microclimate is the distinctive climate of a small-scale area, such as a garden, park, valley or part of a city (Source: National Meteorological Library and Archive - Met Office 2013- http://www.metoffice.gov.uk/learning/library; accessed 23 December 2013). While, Brown and Gillespie (1995) described microclimate as the condition of the solar and terrestrial (existing on the earth) radiation, wind, air temperature, humidity and precipitation in a small outdoor space. Microclimatic parameters are air temperature, solar radiation, relative humidity, and wind speed (Yahia, 2012), while the *aspect ratio* and *solar orientation* are basic describers of a street microclimate (Toudert F.A., 2005). A given urban density can result from independent design features, which affect urban climate in different ways such as: fraction of urban land covered by buildings, distances between buildings, including streets' width, average height of buildings (Givoni 2003). The microclimate of a site is affected by the following factors (Markus and Morris, 1980) (Nayak J.K. et al 1999):

(A) Landform (B) vegetation (C) water bodies (D) street width and orientation (E) Open spaces and built form

Within the urban canopy layer, street canyons illustrate the effect of urban form on microclimates. The height of buildings and orientation of streets creates complex shading patterns over the course of a day that affects air and surface temperatures (Arnfield 1990; Ruffieux et al. 1990; Nichol 1996). Studies show that one of the causes of creating own microclimate is the design or geometry of the city (Arnfield; Grimmond, 1998). According to Ali-Toudert and Mayer (2006), the structure (design) of a street is the key factor for studies on urban bioclimatology. A given urban density can result from independent design features, that affect urban microclimate in different ways such as fraction of urban land covered by buildings, distances between buildings, and average height of buildings (Givoni, 1998). Urban planning regulations have a great impact on the microclimate in urban areas (Johansson and Yahia, 2010). A number of useful relationships can be developed between the geometry and the microclimate of urban street canyons and these relationships are very helpful for professionals developing urban design guidelines for the street dimensions and orientations (Bourbia and Awbi, 2004).

According to Oke (2004), three climate scales apply in urban areas: the micro, local and meso scales. The micro scale includes buildings, streets, squares, gardens, trees, etc. The local scale represents urban neighborhoods, whereas the meso scale represents an entire city. Vertically, the micro-scale falls within the roughness sub-layer, the height of which depends on building density and atmospheric stability (Roth 2000). It has been found to vary between about 1.5 and 4 times the average height of the buildings (Oke 2004). Above this height, microclimate effects from the buildings and objects be low are phased out. The area between the ground and the roof tops is called the 'urban canopy layer'. This layer, which constitutes the lower part of the roughness sub-layer, comprises buildings and the areas around them, such as gardens, streets, squares and parks.

The study focuses on the climate in the urban canopy layer (UCL), that is, the climate between the buildings. Within this layer, the microclimate is site specific and varies greatly within short distances (Arnfield 2003, Oke 2004).

Kakon et al. (2010) investigated the effect of building height on outdoor thermal comfort in the tropical climate of Dhaka, Bangladesh. The authors focused on the building height as an important parameter in urban design and planning regulations in the city development. The study showed that the air temperature decreased to some extent in the canyon by increasing building height. The study concluded that the policy to increase the building height could provide a preferable thermal microclimate in cities with high densities. The conclusions of the study were depending on both measurements and simulations. However, the measurements were only conducted in one summer day and no winter measurements were conducted. In addition, the study was only performed in one specific area in the city of Dhaka and did not study other types of urban morphology.

A number of useful relationships can be developed between the geometry and the microclimate of urban street canyons and these relationships are very helpful for professionals developing urban design guidelines for the street dimensions and orientations (Bourbia and Awbi 2004a and 2004b). Ali-Toudert and Mayer (2006) conducted a simulation study on the effects of aspect ratio (or height to width ratio, H/W) and orientation of urban street canyons on outdoor thermal comfort in the hot dry climate of Ghardaia, Algeria. The study was carried out by using the ENVI-met simulation program. The results show contrasting patterns of thermal comfort between shallow and deep urban canyons as well as between various orientations studied. It also concluded that thermal comfort is very difficult to reach passively in extremely hot and dry climates, but the improvement is possible; the air temperature slightly decreases when the aspect ratio increases, but the radiation fluxes expressed by the mean radiant temperature are by far more decisive. Thus in summer time, the thermal comfort improves when H/W ratio increases. However, the simulations were only run for a typical summer day and the winter time was not taken into account in the thermal comfort analysis.

Johansson (2006a) studied the influence of urban geometry on outdoor thermal comfort in the hot dry of climate of Fez, Morocco. The study was based on measurements during the summer and winter. The study compared a deep canyon and shallow street regarding microclimate and thermal comfort. The study argued that in the summer times, the deep canyon is fairly comfortable whereas the shallow is extremely uncomfortable. On the other hand, the winter results show the opposite. The study concluded that for the hot dry climate, the compact urban design with deep canyons is preferable but for the winter in Fez, the urban design should include some wider streets or open spaces in order to provide solar access. However, the study was only based on measurements and did not include a questionnaire study about the subjective thermal perceptions.

Djenane et al. (2008) investigated the microclimatic behavior of urban forms in the hot dry city of Béni-Isguen located in the M'zab Valley region, Algeria. The aim of the study was to approach the interaction between the climatic constraints and the solutions adapted in terms of occupation modes of the ground and urban morphology in the streets. The study was based on practical microclimatic measurements in four locations during the summer time. The study was conducted in four different morphological areas which varied between high and low urban density with H/W ratios between 1.6 and 9.7 and with plot coverage between 10% and 87%. The authors demonstrated the importance of morphological characteristics of the urban tissue in the hot dry climate regarding H/W ratio. They also showed that the thermal behavior at the street level is related both to the solar exposure and the wind speed effect. And the streets overheating during one day is strongly affected by heat dissipation the previous night. However, the study was conducted only in the summer time and no measurements were conducted in the winter. The results were only based on air temperatures and wind speed and the study did not examine the effect of urban forms on solar radiation, mean radiant temperature, or thermal comfort.

Bourbia and Boucheriba (2010) assessed the impact of geometry on microclimate in Constantine, Algeria during the summer time. A series of site measurements (air and surface temperatures) were conducted in seven sites which varied between high and low H/W ratios from 1 to 4.8 and with sky view factor between 0.076 and 0.58. The study indicated an air temperature difference of about 3–6°C between the urban and its surrounding rural environment. The authors argued that the larger sky view factor, the higher air temperatures were reported. Moreover, the higher H/W ratio, the lower air and surface temperatures were recorded. However, the study was only conducted during one season (summer time). Furthermore, the study did not calculate the mean radiant temperatures and did not use any thermal index to assess the outdoor thermal environment. Comparatively urban microclimate and outdoor thermal comfort are rarely considered in text books while the indoor climate and thermal comfort have received considerable attention (Yahia M.W., 2012). There is a lack of research on the relationship between climate and urban planning regulations. Thus, there is a need to investigate the impact of urban planning regulations on microclimate based on in depth climate analysis (Yahia M.W., 2012).

2.3.2.Microclimate Parameters

Dry Bulb Temperature (DBT)

The temperature of the air measured by the ordinary thermometer is called as the dry bulb temperature of air, commonly referred as DBT. (Source:http://www.brighthub engineering.com /hvac/39619-psychrometric-properties-dry-bulb-wet-bulb-or-dew-point-temperature/; accessed: 23 December 2013). The air temperature, defined as the dry-bulb temperature in the shade, is one of the most important climatic factors influencing thermal comfort. Both the body's convective heat loss and its dry respiration heat loss decrease with increasing air temperature. If the air temperature exceeds the surface temperature of the clothed body, or of the exposed skin, which is around 34°C, body's convective heat loss is negative and there will be convective heat gain (Johansson E., 2006b).

Mean Radiant Temperature (MRT)

The mean radiant temperature is defined as the uniform surface temperature of an imaginary black enclosure with which man exchanges the same heat by radiation as in the actual environment. (Source: http://www.usc.edu/dept-00/dept/architecture /mbs/tools/ thermal/mrt .html; accessed: 23 December 2013). The absorption of solar radiation and the exchange of long-wave radiation strongly affect the state of thermal comfort of the human body. For indoor conditions, the concept of mean radiant temperature (MRT) was developed. This is defined as "the uniform temperature of an imaginary enclosure in which radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure" (ASHRAE 1997). How ever, MRT can also be measured using a globe thermometer (Nikolopoulou et al. 2003).

Relative Humidity (RH)

The relative humidity is a measure of the amount of water vapor in the air (at a specific temperature) compared to the maximum amount of water vapor air could hold at that temperature, and is given as a percentage value. [RH (f)=(e/es)*100 [e-actual vapour pressure; es-saturated vapour pressure]; (Source: http://www.exoticpets.about.com /od/general resources/g/humidity.html; accessed 23 December 2013). A change in the humidity of the atmosphere affects thermal sensation in that a person feels warmer, sweatier and less comfortable (McIntyre 1980). Especially under warm conditions, when both convective and radiative heat losses are small, sweat evaporation is an important mechanism in maintaining comfort. When the liquid sweat on the skin surface evaporates, latent heat is extracted from the body and a cooling effect is produced (Johansson E., 2006b).

Wind Speed (WS)

Wind speed is the rate and force at which air moves horizontally in a given moment or amount of time. (Source:http://www.ehow.com/facts_5031345_definition-wind-speed.html; accessed: 23 December 2013). Air speed is a major factor affecting the state of thermal comfort. Outdoors, winds change speed and direction rapidly and a high degree of turbulence makes the wind speed feel higher than the measured mean value (Glaumann and Westerberg 1988, Bosselmann et al. 1995). Both the convective heat loss and the evaporation of sweat increase with increasing air speed because both the convective and evaporative heat transfer coefficients increase in magnitude (the insulating boundary layer around the body becomes smaller). Strong air movement is thus a disadvantage in cold climates, but a clear advantage in hot climates (Johansson E., 2006b).

2.3.3.Urban Heat Island [UHI] Effect and Urbanization

"Urban heat island is a name to define the heat parameters of atmosphere and surfaces in town and cities to compare with suburban areas (Fig.2.1)." (Voogt, 2005). HI (heat islands) are the reason of urbanization, when roads and paved ,buildings, covering facades gain the heat in day, then gently release it in the evening time keeping urban areas hotter than surrounding locations. Cited in Mobaraki (2012), 'urban heat island effect caused by urban materials absorbing solar radiation which cause an increase temperature in the area with respect to neighboring rural areas' (Mullik et al., 2009, Wan et al., 2009, Haselbach & Gaither, 2008).

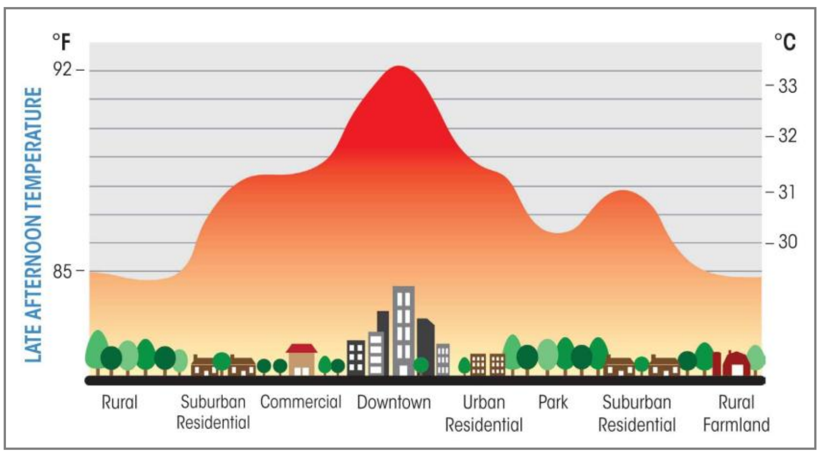


Fig. 2.1 Urban heat island effect
Source: C3: Global Warming: Urban Heat Island Bias. 2013 [online] Available at: http://www.c3headlines.com/global-warming-urban-heat-island-bias/. [Accessed 23 December 2013].

"The urban heat island (UHI) can be described as a pattern of temperatures upper in urban areas than in the surroundings" (Montavez, 2000). "In other words, a heat island is a high density city area which has higher temperature than the surrounding suburb areas" (Mobaraki, 2012). Based on the EPA (Environmental Protection Agency) report of 2005 "urban air can be 2-6°C hotter than the surrounding countryside during summer". In addition, Voogt (2005) mentioned that, “urban heat island is a condition where unexpected climate changes occur when rapid urbanization took place in the city centers. Moreover, the temperature of various exterior surfaces increases and the city air considerably become warmer in the late afternoon”.

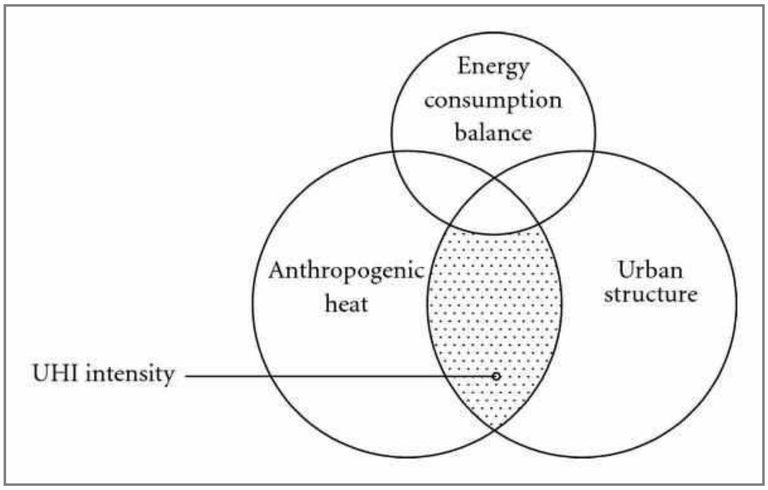


Fig. 2.2 UHI intensity and effect on energy consumption balance
Source: The Impact of Anthropogenic Heat on Formation of Urban Heat Island and Energy Consumption Balance [online] Available at: http://www.hindawi.com/journals/usr/2011/497524/fig3/. [Accessed 23 December 2013].

The adverse effects of UHI includes the deterioration of living environment, increase in energy consumption, elevation in ground-level ozone and even an increase in mortality rates (Fig.2.2). Higher urban heat is appeared because of the anthropogenic heat removed from cars, power plants, air conditioners and also other heat sources, then because of the stored heat and re-radiated by enormous and complex urban foundations (Mobaraki, 2012).

Urban environments can be several degrees warmer than surrounding rural areas, a phenomenon known as the urban heat island (Graves et al., 2001; Wilby, 2003). Building density contributes to the magnitude of the UHI [Source: Oke (1987)]. There is a strong relationship between urban population and UHI intensity (Fig. 2.3) [Source: Oke (1987)] Here, X axis indicates the number of urban population.

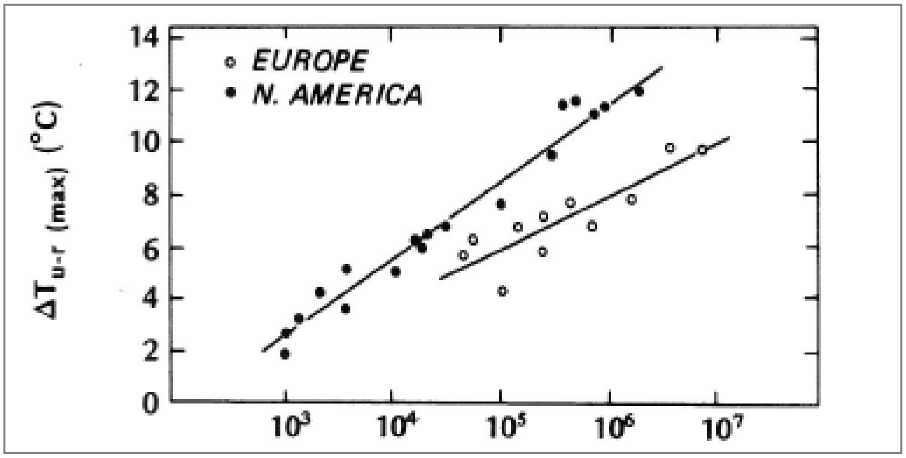


Fig. 2.3 Relation between Population and UHI Intensity (Oke, 1987)

Relatively there is a strong relationship between street geometry and maximum UHI intensity (Fig. 2.4) [Source: Oke (1987)]. Here, H/W is the height and width ratio where H is the mean building height and W is the along-wind spacing (street width), and ΔT u-r (max) is a difference of urban-rural maximum temperature.

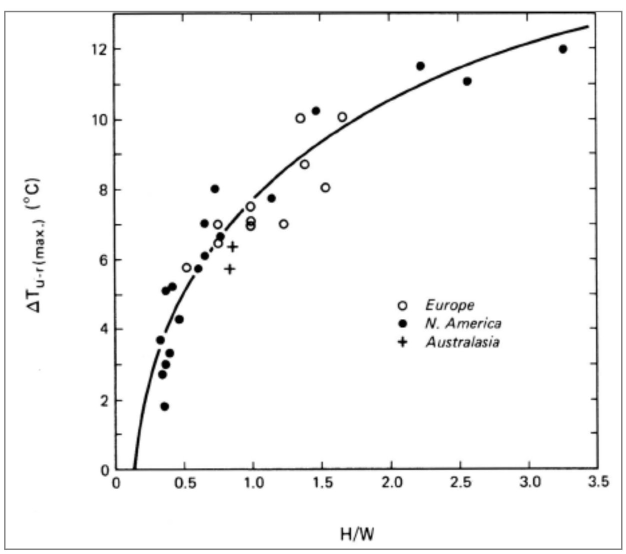
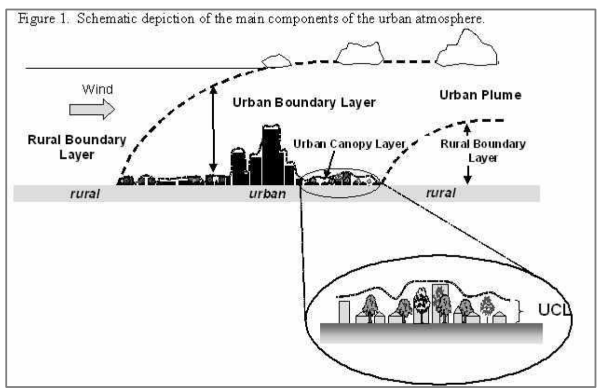


Fig. 2.4 Relationship between Street Geometry and UHI Intensity (Oke, 1987)

Types of Urban Heat Island

The types of urban heat islands that found from literature review as the boundary [Urban Boundary Layer (UBL-above the average height of the buildings)], canopy [Urban Canopy Layer (UCL- below the roof tops in the spaces between buildings)] and surface layer heat island (Oke, 1977, Voogt, 2005). In addition, Voogt (2005) explained: "the increasing temperature of the urban air settings refers to the boundary and canopy layer heat islands. The HI (heat islands) happens in various layers or parts of the urban atmosphere" (Fig. 2.5).



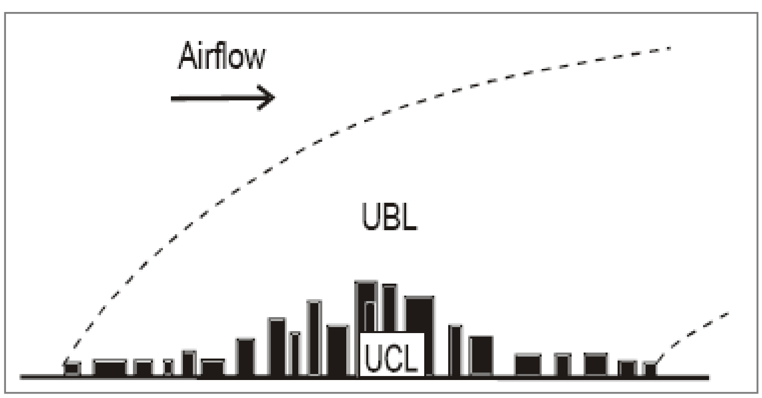


Fig. 2.5 Schematic depiction of the main components of the urban atmosphere
A vertically exaggerated cross-section of the urban atmosphere and its two main layers
Source: Actionbioscience | Urban Heat Islands: Hotter Cities. [online] Available at: http://www.actionbioscience.org/environment/voogt.html. [Accessed 23 December 2013].

Effects of UHI

Urban air can be 2-6°C hotter than the surrounding countryside during summer (EPA, 2005). As has been occurring in many developing countries, UHI events affect the local nature and population in different ways, including the quality degradation of air, hazards to public health and switch the meteorological situations (Mobaraki, 2012). Thus the effects of UHI are as follows:

-Air quality
-Public health
-Global warming
-Meteorological effects

Causes of UHI

Urban heat islands are caused mainly due to the reduced radiant heat loss to the sky from the ground level of densely built urban centers. Most of the radiation is emitted from the roofs and walls of upper story of buildings and lack of greenery in urban spaces and on the building surfaces (Fig.2.6) (Mobaraki, 2012).

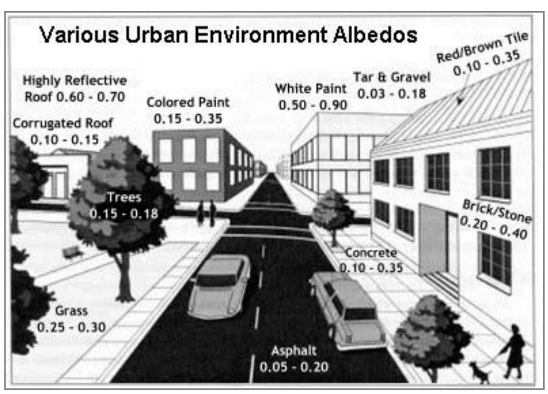


Fig. 2.6 The albedo of some (city) surfaces

Source: NASA/GHCC Project Atlanta [online] Available at: http://www.ghcc.msfc.nasa.gov/urban/urban_heat_island.html [Accessed 23 December 2013]

The weather conditions and geographic location of cities as well as their urban characteristics affect the development of UHI in cities. The Heat Island Group (2005) also has mentioned that: “presence of more gloomy urban surfaces, absence of vegetation and urban geometry are three main causes of UHI”. Thus the causes of UHI can be categorized as follows: (Mobaraki, 2012)

- Urban dark surfaces (low albedo/gloomy surface)
- Lack of Vegetation
- *Urban geometry*

Factors of UHI

“Urban heat island intensity depends on the amount or number (population) of people living in the area, morphology and size of the urban area. The changes between the maximum city temperature and contextual suburban temperature introduced as urban heat island intensity (UHI)” (Terry A. Ferrar, 1976, Oke, 1982). UHI could be separated into two groups which is made by variety of issues: (1) meteorological parameters, like wind speed, cloud cover and humidity; (2) different factors of the urban structure (urban parameters), like the size of cities, the built-up areas density, and the buildings’ heights ratio to the distances between them and population size, anthropogenic heat and urban canyon could strongly affect the size of the urban heat island (Fig.2.7).

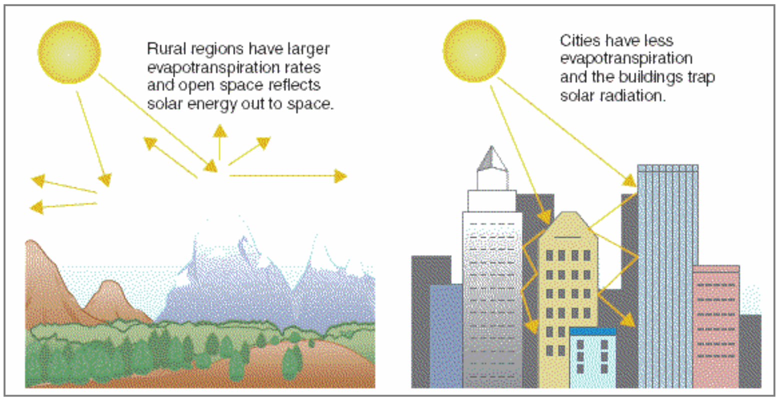


Fig. 2.7 UHI due to urban structures
Source: http://cimss.ssec.wisc.edu/climatechange/globalCC/lesson7/UHI2.html [Accessed 23 December 2013].

Chandler (1976), Landsberg (1981) and Oke (1982) also mentioned vegetation cover, water body of the city, population size, speed of wind, topography, anthropogenic heat, water overflow are the main city and meteorological parameters that increase the intensity of urban heat island. Thus factors of UHI can be categorized as follows: (Mobaraki, 2012)

-Meteorological Factors

-Urban Parameters

Location of the city

The size of the city and population

Density of built-up area

Urban geometry

Thermal properties of fabric

Surface waterproofing

Anthropogenic heat

Air pollution

Land uses

Wind speed

Probable Ways of Reducing UHI:

Combating the UHI effect can be categorized in to four different ways as follows: (Kleerekoper, L. et al 2012)

1. Vegetation strategies, which consist of establishing urban forests and parks, street trees and green roofs or facades to encourage the cooling effects of plants.

2. Water strategies, which consist of ponds, lakes and fountains, as well as green roofs to store water, which absorb heat and cool through evaporation.

3. *Built form strategies*, adjust building density or arrangement, such as lowering building height, increase variation in building height, using shading devices and changing the orientation of the street to improve ventilation.

4. Material strategies, involve using materials that have greater cooling effects through evaporation and heat reflection.

UHI Impact on City Level and Its Growth

Cities can create their own microclimate based on the characteristics of urban form, infrastructure and population habits (Oke, 1977). The climatic conditions within the canopy (canopy is limited to the height of buildings in given location) are directly related to the physical characteristics existing in that area, such as geometry and surface materials (Oke, 1977). Great concern in sub tropic and arid regions, where UHI is usually the most intense. (Ross, 2012). UHI intensity has been increasing in most cities (Ross, 2012).

UHI Global Context

Northern Africa, the Middle East and Western Asia – UHI will continue to increase in these areas, in some cases by over 30% (Mc Carthy etal 2010). In the last 50 years heat islands have been intensely increasing (Akbari etal 1992). Most cities in the U.S. experienced urban temperature increases of 2-4°C from 1950-1990 (Fig.2.8) (Akbari etal 1992). The effects of a rising UHI observed in Singapore that urban temperatures had risen by 1°C in recent history (Tso, 1994).

World-wide Data

- In Copenhagen 12°C is higher than areas outside the city (MOC, 2010)
- UHI intensity has been observed at 9°C in Mexico city (Akbari etal 1992)
- UHI intensity has been observed at 6°C in Bombay (Akbari etal 1992)
- UHI intensity reached 9°C in London during the 2003 August heat wave (Mavrogianni etal 2011)
- The mean UHI intensity for areas of central Athens is 6-12°C (Assimakopoulos etal 2006)

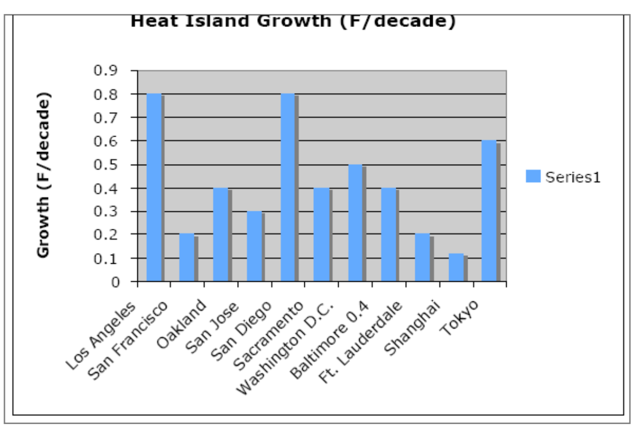


Fig. 2.8 Heat Island growth per decade in deg F, based on data from different time frames 1910-1990, (Akbari etal 1992)

Dhaka Context (In terms of UHI Effect)

UHI intensity of Dhaka has a range of 0.3-2.1K, with the highest differences occurring in March and April (Table 2.1) (Burkart etal 2011).

Table 2.1 Summary of temperature and degree day data (Source: Ross, 2012)
(CDD-cooling degree days; HDD-heating degree days)

City	Urban Mean Temp (C)	Urban Mean Max. temp (C)	Avg. Mean UHI (C)	Total CDD diff. (u-r)	Total HDD diff. (r-u)
Jakarta	28.67	34.14	1.72	1,073	0
Manila	28.22	34.22	.25	1,079	0
Taipei	23.35	32.72	.69	234	98
Athens	20.24	28.03	3.24	427	508
Rome	17.21	26.04	.24	492	-29
Tokyo	16.22	25.94	.13	598	-471
New York	13.95	27.19	1.17	6	642
Paris	13.18	24.37	1.45	96	1106
Dhaka	NA	NA	1.04	764	191

An average UHI intensity of 1.04 deg C for the year 2000 (when Dhaka city station was compared with the smaller city of Mymensingh) which was used as the rural station (Burkart, 2011).

Urbanization

Most tropical countries are developing countries and most are experiencing rapid urbanization (Johansson E., 2006b). During the period from 1990 to 2020, the urban population in the developing world is expected to increase by about 25–45%, except in Latin America and the Caribbean where the urban population already exceeds 70%. By 2020, the urban population is expected to be greater than the rural population in all parts of the world except sub-Saharan Africa and South Asia (World Bank, 2000). Fig.2.9 shows the trends in urbanization by region from 1950 to 2030 (projected) by the United Nations.

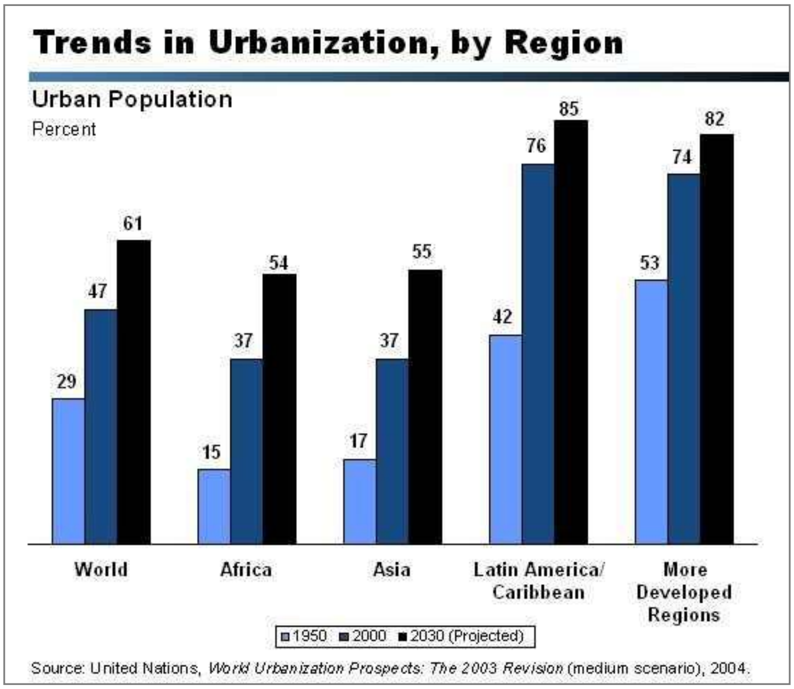


Fig. 2.9 Trends in Urbanization, by region
[United Nations, World Urbanization Prospects: The 2003 Revision (medium scenario, 2004)] Source: Statistics on Poverty, Urbanization and Slums | P.a.p.-Blog // Human Rights Etc.. 2013. (Available at: http://filipspagnoli.wordpress.com/stats-on-human-rights/statistics-on-poverty/statistics-on-poverty-urbanization-and-slums/.) [Accessed 23 December 2013].

Rapid urbanization in developing countries is often regarded as negative, causing poor housing conditions, poverty, environmental problems, ill-health, etc. However, despite the problems brought by urbanization, urban areas are important in a national perspective, since they experience a high level of economic growth (Tannerfeldt and Ljung, 2006). Urban areas act as climate modifiers. Climate elements, such as solar radiation, air temperature, humidity and wind are affected by the urban fabric. Nocturnal urban-rural temperature differences of 6°C or more are common in the centers of major cities (Oke, 1987). This indicates that the average diurnal temperature rise due to urbanization may be greater than the estimated 1–3.5°C rise in temperature due to global climate change over the next 100 years (IPCC, 2001).

The urban climate in temperate regions has been studied extensively, mainly in mid-latitude cities in developed countries. Fewer studies have been con ducted in low-latitude, tropical climates (Arnfield, 2003). Most tropical studies have dealt with urban–rural differences and fewer with micro climate variations within cities. Moreover, few studies have considered intra-urban microclimate differences in relation to urban design (Ali-Toudert and Mayer H., 2006).

2.3.4.Outdoor Comfort

Urban microclimate and outdoor thermal comfort are generally given little importance in the urban design and planning processes (Eliasson, 2000; Johansson, 2006b). Moreover, few studies have dealt with the relationship between urban planning regulations and the local microclimate. Several studies however indicate that the existing planning regulations in hot dry climates are not adapted to the climate. In the city of Fez, Johansson (2006b) found that the intention of the current regulations is to guarantee daylight for buildings. This may be relevant for the winter period when solar elevations are low and passive heating of buildings is desired. However, during the long, warm summer, when there is a need for solar protection, this results in a very poor microclimate at street level.

It is well known that the quality of outdoor urban spaces becomes one of the important items in the urban design process not only for ecological and economical purposes, but also it is important from the social point of view (Yahia M.W. and Johansson E., 2011). The urban form is strongly influenced by urban planning regulations, such as zoning ordinances, which governs spaces between buildings, building heights and building footprints. Consequently, urban planning regulations have a great impact on the microclimate in urban areas (Johansson and Yahia, 2010). The outdoor thermal sensation range is wider than that indoors, spanning from thermal comfort to a stressful environment (Spagnolo and de Dear 2003; Emmanuel 2005).

The need for thermal comfort is ubiquitous, but it seems often to be forgotten in the designs of outdoor spaces. On the other hand human comfort and energy use of buildings are affected by the local climate conditions within the urban canopy (Givoni B., 1998) and the microclimate in the urban environment may have a great influence on thermal comfort and the human body. However, the lack of outdoor thermal comfort has gained little attention in developing countries (Johansson E., 2006b).

In warm climates, it is well known that mental and physical performance deteriorates at high temperatures and that heat stress may lead to heat- related illness (Mc Intyre D.A., 1980). Moreover, when the body's adaptive mechanisms to heat stress fail to keep core body temperature close to 37°C, a number of physiological disorders can occur. Among the more common are: Heat exhaustion, heat stroke, heart attack (Bell P.A. 2001). Studies in Pune, India showed that the unplanned rising of building height causes the discomfort in the city (Deosthali 1999).

Thermal comfort is defined as the condition of mind which expresses satisfaction with the thermal environment (Plumley H.J., 1977). Variables of thermal comfort are the air temperature, radiant temperature, relative humidity, air velocity, activity and clothing (ASHRAE, 2004). The microclimatic factors are affected by the urban surface and at a given point; these factors affect the human activities from ground level up to 2 m height. Recently, the importance of the concept of thermal comfort can be noticed in the latest related scientific researches. Some studies have focused on the influence of urban design and urban geometry on outdoor thermal comfort (Johansson E., 2006a. and 2006b).

Another definition is the absence of thermal discomfort, that is to say, that an individual feels neither too warm nor too cold (McIntyre 1980). The temperature of this state is referred to as the ‘neutral temperature’. However, thermal sensation is subjective, meaning that not all people will experience comfort in the same thermal environment. For indoor conditions, comfort zones are typically implemented to satisfy 80% of people (Fountain and Huizenga, 1994). The comfort zone is often expressed as a temperature range around the neutral temperature. Out doors, the thermal comfort range is wider than in doors, spanning from thermal comfort to a stressful environment (Spagnolo and de Dear 2003, Emmanuel 2005a).

There are four environmental variables affecting the thermal comfort of the human body: air temperature, mean radiant temperature, air humidity and air speed. Additionally, two personal variables influence thermal comfort: clothing and the level of activity. However, other personal factors related to adaptation and acclimatization has proven to affect thermal sensation (Johansson E., 2006b), while the first four environmental variables mentioned above are within the scope of this research.

Cited in Johansson E. (2006b) it can be seen that, in summer time field study in hot humid Dhaka (24°N), Bangladesh, Ahmed (2003) recorded subjective thermal sensation votes and measured environmental variables. He found comfortable conditions at considerably higher temperatures and levels of relative humidity than normally accepted indoors in temperate climates. The reported comfort zone is 27.5–32.5°C, where, however, the upper limit decreases for relative humidity levels exceeding 75%. Ahmed (2003) also found evidence of the influence of psychological factors, such as adaptation, expectations and thermal history.

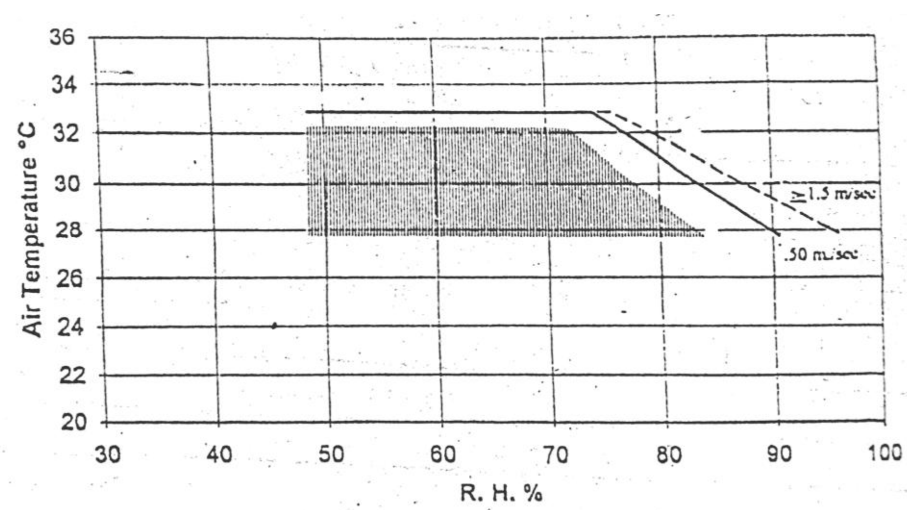


Fig. 2.10 Summer comfort zone (Ahmed, 1995)

Ahmed (1995) derived the comfort zone (in shade), from field study (Fig. 2.10) conducted in summer condition. The zone was derived for people involved in activity of 1 Met wearing 0.35-0.5 Clo under shaded conditions. The shaded area outlines the comfort zone under still conditions. The comfort zone indicates the influence of airflow in increasing the tolerance to higher relative humidity.

Both Spagnolo and de Dear (2003) and Nikolopoulou et al. (2003) compared objective microclimatic measurements (and calculation of thermal indices) with the subjective thermal sensation votes of a large number of subjects in the warm-temperate climates of Sydney, Australia (34°S) and Athens, Greece (38°N) respectively. They found a discrepancy between the measured and calculated thermal comfort and subjective thermal sensation. In general, people accepted a wider range of thermal conditions than indoors. Both studies point out the importance of physical adaptation to the outdoor thermal environment, which includes seasonal variation in clothing, changes in metabolic heat through the consumption of cool drinks and changes in posture and position. Psychological factors, such as expectations and thermal history also explain the discrepancies. For example, when outdoors, people expect more climatic variation than indoors, and this may increase their tolerance.

Urban design has proved to have a considerable impact on urban micro climate in hot dry and hot humid climates. Outdoor thermal comfort generally improves with increasing H/W ratios in urban canyons due to increased shade (Johansson E., 2006b). Main instruments with which we can influence urban microclimates, improve comfort and reduce energy consumption in cities are as follows (Table 2.2): (Yannas S., 2002).

-surface properties
-water bodies
-vegetation

-additive elements and transitional spaces

-*urban morphology*

Table 2.2 Correlation of Means and Objectives for Microclimatic Design of Outdoor Spaces (Yannas S., 2002)

	URBAN MORPHOLOGY	ADDITIVE ELEMENTS	SURFACE PROPERTIES	WATER	GREEN
SOLAR ACCESS SOLAR CONTROL	+/- +	 ++	+ +++	 +	+/- +++
VENTILATION WIND PROTECTION	+/- ++	+/- ++	+	+/-	+/- +
THERMAL INERTIA	+	+	++	++	
NATURAL COOLING	+/-	++	++	+++	+++

Key: + positive influence ++ very positive +++ extremely positive +/- positive or negative influence

Designers need to consider and aim to influence the following for sustainable environmental design: (Yannas S., 2002)

-Built form in order to affect airflow, view of sun and sky, and exposed surface area

-*Street canyon geometry in order to influence warming-up and cooling processes, the resulting thermal and visual comfort conditions at street level, and pollution dispersal*

-Building design to influence building heat gains and losses, and the thermal capacities and reflectances of external surfaces

-Urban materials and surface finishes to influence absorptance, heat storage, and emittance

-Water and vegetation to influence cooling processes

-Traffic reduction to alleviate air and noise pollution, and reduce heat discharges

-Use of renewable energy sources to alleviate pollution

2.3.5.'Smart-City' Concept

Recently we often hear the word 'smart' with different substances such as; 'smart watch', 'smart phone', 'smart car', 'smart access', 'smart bomb', 'smart home', 'smart card', 'smart key' , 'smart growth', 'smart economy', 'smart living', 'smart mobility', 'smart people', 'smart governance'; further more '*Smart City'* and '*Smart Environment'*, which directly relates architects, urban designers and so forth. Though some of us may think, it is too early to think 'smart city' or 'smart environment' in respect to Dhaka city, but why not start thinking now; in fact if we don't start smartly; the city won't be smart by itself. To save the earth and people health, the idea of smart cities emerges, that is, cities able to solve urban issues paying attention to the environment. For this reason, in the nineties, the concept of smart growth has begun to spread: it implies a community-driven reaction to solve traffic congestion, school overcrowding, air pollution, loss of open space and skyrocketing public facilities cost (Pardo and Taewoo, 2011). The Smart City has born from three different sources: the EU source, focusing on the environmental requirements; the digital source, based on the previous experiences of Digital Cities; and the cultural source, that is, the human and social capital able to build the smart community. For these reasons, the Smart City definition analysis discloses a wide range of meanings associated with a smart city, including environmental, social and digital components (Cocchia A., 2014). However, discovering some shared features characterizing Smart Cities, that is, the role of innovation and technology, the environmental requirements, the economic and social development (Cocchia A., 2014).

The concept of Smart City embraces several definitions depending on the meanings of the word “smart”: intelligent city, knowledge city, ubiquitous city, sustainable city, digital city, etc. Many definitions of Smart City exist, but no one has been universally acknowledged yet. It emerges that Smart City and Digital City are the most used terminologies in literature to indicate the smartness of a city (Cocchia A., 2014). Dameri (2013) defines smart city as, “A smart city is a well-defined geographical area, in which high technologies such as ICT (Information and Communication Technologies), logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well-being, inclusion and participation, *environmental quality*, intelligent development; it is governed by a well-defined pool of subjects, able to state the rules and policy for the city government and development”. A city can be defined as ‘smart’ when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement (Caragliu et al. 2009).

Smart City is a broad concept including many aspects of urban life, such as urban planning, sustainable development, environment, energy grid, economic development, technologies, social participation, and so on; therefore, also the word smart assumes a large range of meanings, linked with its different field of application (Cocchia A., 2014).

Smart cities can be identified (and ranked) along *six* main axes or dimensions (Fig.2.11): (Giffinger et al. 2007).

- smart economy
- smart mobility
- smart *environment*
- smart people
- smart living
- smart governance

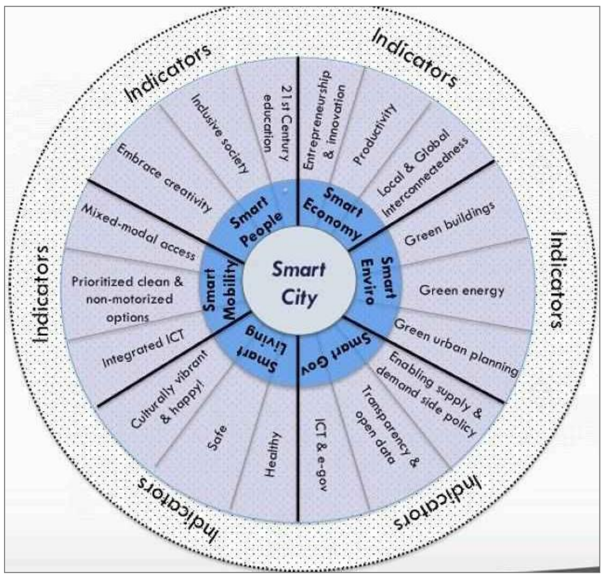


Fig. 2.11 Smart City- Wheel (Fast coexist.com, 2013)
Source: What Exactly Is A Smart City? | Co.Exist | ideas + impact. 2013. [online] Available at: http://www.fastcoexist.com/1680538/what-exactly-is-a-smart-city. [Accessed 23 December 2013].

From the 'smart wheel' (Fig. 2.11) we can see that 'smart environment' is one of the indicators of a smart city where, green buildings, green energy and green urban planning are directly concerned with smart environment thus with 'smart city' concept. As a consequence micro climate of a city can not be overlooked while thinking of a smart city. The Smart City concept develops more than Digital City and it mainly regards the sustainability in terms of pollution reduction and environmental quality improvement.

The Smart City regards the attention to be paid to the environmental quality in cities (Cocchia A., 2014).

2.3.6.Simulation Software – ENVImet

There are few user-friendly computer programs aimed at predicting urban microclimate that provide both reliable results and detailed out put (Johansson E., 2006b). ENVI-met is a computer program that predicts microclimate in urban areas (Bruse 2007). It is based on a three-dimensional CFD (computational fluid dynamics) and energy balance model and is described in detail by Bruse (1999). A comprehensive summary of the model is also provided by Ali-Toudert (2005). The model takes into account the physical processes between the atmosphere, ground, buildings and vegetation and simulates the climate within a defined urban area with a high spatial and temporal resolution, enabling a detailed study of microclimatic variations. The horizontal model size is typically from 100 m x 100 m to 1000 x 1000 m with grid cell sizes of 0.5–5 m. The fact that the program requires limited input data and that the modeling of the urban area is simple, makes it user friendly (Johansson E., 2006b).

Justification of ENVImet

It is proven that numerical simulation can play a major role for the evaluation of planning and design of buildings and spaces. (Yahia M.W., 2012). In a recent review, Arnfield (2003) drew the attention to the growing popularity of numerical simulation, described by a methodology which perfectly suited to dealing with the complexities and nonlinearities of urban parameters. Methodologically, ENVI-met revealed to be a good tool for the prognosis of the urban microclimate changes within urban areas, and also in the assessment of outdoor comfort through a satisfactory estimation of the mean radiant temperature (Toudert F.A., 2005).

Software for Simulation

The adaptive use of a climatic modeling software innovation named ENVI-met (and LEONARDO) developed by Michael Bruse, of the University of Bochum, Germany. Using the advanced 3D-4D numerical models called ENVI-met and LEONARDO, which have the capacity to project small to large-scale climatic impacts, the model can evaluate future parkways in areas of optimal outdoor comfort, optimal citizen use and minimal environmental damage. These two interactive programs are used to model climatic models of general structural changes or structural modifications that include elements of the natural and built environment such as vegetation, buildings, roads, soil (Ozkeresteci et al, 2003). The ENVI-met software uses input values for buildings, vegetation, ground surfaces, climatic conditions, soils, and then simulates the modifications from the proposed building form, additional shading, alternative orientations, etc. ENVI-met is a three-dimensional computer model which analyzes micro-scale thermal interactions within urban environments. The software uses both the calculation of fluid dynamics characteristics, such as air flow and turbulence, as well as the thermodynamic processes taking place at the ground surface, at walls, at roofs and at plants. ENVI-met takes into account all types of solar radiation (direct, reflected and diffused) and calculates the mean radiant temperature, dry bulb temperature, relative humidity, wind speed and so on. The calculation of radiative fluxes includes the plant shading, absorption and shielding of radiation as well as the re-radiation from other plant layers (Bruse 2007).

Simulation Process

First of all, the drawing was done in AutoCAD and then exported in bitmap (bmp), then the drawing was imported in ENVI met using required grids. ENVI-met has two basic steps before the simulation is run (Rosheidat et al, 2008). At first, editing the input of the urban area to be tested. For this task, the horizontal and vertical dimensions of the sample area along with set backs, horizontal surface materials, ground cover, vegetation size and coverage, etc. were given. After giving the data the second step was to create a 'configuration file', where the information about the site location, temperature, wind speed, humidity, PMV parameters, and databases for soil types and vegetation are entered. To minimize boundary effects which may distort the output data, the model uses an area of nesting grids around the core of the model to move the model boundary away from the area of interest (Bruse, 2007). After selecting the required version, the simulation was then processed using both the input and configuration files. Then the file is imported into a visualization program - LEONARDO 3.0, where the mean radiant temperature, dry bulb temperature, relative humidity and wind speed were seen.

2.4. Building Regulation and Street Morphology

Building regulation can be defined as the state of being controlled or governed (of the buildings) (AED, 2013), while Streets can be de3fined as an enclosed, three dimensional space between two lines of adjacent buildings (Moughtin, 2003). Morphology is the study of the rules for forming (AED, 2013). Street canyon refers to the space which is formed by two typically parallel rows of buildings separated by a street - basic unit of modern cities (Syrios K. and Hunt G. R., 2008). Urban canyon is defined as the three-dimensional space bounded by a street and the buildings that enclose the street. (Emmanuel, 2005), while aspect ratio is the ratio of the width to the height / height to width ratio [the ratio of building height (h) to building separation (w) (street side) - h/w ratio]

2.4.1.Building Regulation

The urban form is strongly influenced by urban planning regulations, such as zoning ordinances, which governs spaces between buildings, building heights, building footprints, etc. Consequently, urban planning regulations have a great impact on the microclimate in urban areas (Johansson and Yahia, 2010).

Due to the complexity of urban microclimates and thus of determining thermal comfort in outdoor urban spaces, it is very necessary to deepen our knowledge about these issues. Such knowledge can help us to create useful and realistic guidelines for the urban planning and design processes. It is absolutely needed to improve the physical and climatic aspects of urban spaces, to make it possible to animate underused parts of a city, and to enhance the quality of life by achieving a level of harmony between the microclimate and urban spaces (Yahia M.W., 2012).

Cited in Johansson E. (2006b) it can be seen that, examples of climate-conscious urban planning and design in developing countries in tropical climates are scarce. However, Evans and de Schiller (1990/91, 1996) report a few cases where micro-climate aspects have been successfully implemented in urban design in Argentina. A project for the planned new Capital City included an urban design that provided wind protection and allowed for solar access, although this project was postponed. Moreover, the planning code of a municipality in the Buenos Aires (34°S) region was revised to allow tower blocks in stead of a continuous street frontage along River Plate (Rio de la Plata) to encourage the sea breeze to enter the urban area.

Al-Hemaidi (2001) reports residential area in the hot dry city of Riyadh (25°N), Saudi Arabia, where climate-conscious design principles were successfully implemented. This was achieved by using a compact urban design with courtyard buildings with out setbacks, oriented to maximize shade and wind exposure. Eben Saleh (2001) also reports from some recent, more compact residential areas in Saudi Arabia where a favorable micro climate was one of the priorities, although there is no information on the level of success of the concept.

However, many studies from warm countries report that climate issues are generally ‘not’ considered in contemporary urban design. Both Al-Hemaidi (2001) and Eben Saleh (2001) report that current urban design in Saudi Arabia has led to an undesirable micro-climate around buildings. They explain this with the prescription of an extremely dispersed urban design where the provision of shade is totally lacking. The current urban form is characterized by grid iron plans with wide streets where the detached, low rise “villa” is the most common type of house. Baker et al. (2002) report from a similar experience in hot dry Phoenix (33°N), in Arizona (USA): wide streets dispersed low-rise buildings and over sized parking lots have contributed to urban warming. Bouchair and

Dupagne (2003) found a similar situation in the Mzab valley (32°N), Algeria, where contemporary urban design lacks the microclimatic qualities of the traditional cities in the region.

Building Regulation in Dhaka

Rajdhani Unnayan Kartipakha (RAJUK) controls the construction of buildings in all residential zones within Dhaka city with the help of some rules and regulations (Rahman, 2004). Besides RAJUK, there are proposals for rules and regulations to be introduced by Bangladesh National Building Codes (BNBC) in 1993 for the same purpose. As buildings constructed under 1996 by-law regulation created bulk of concrete structures within the city; necessity of open and green space came in place, for which FAR (floor area ratio) and M.G.C. (maximum ground coverage) were implemented in 2006 building regulation DMINB (Dhaka Mohanagar Imarat Nirman Bidhimala). Later in 2008 there were amendments in the regulation and further there are some modifications in 2013. During this study 2013 modifications were considered, as till date this is the most recent modification done in building regulation (DMINB).

In 1996 by-law, the minimum front setback for any type of plot area was 5ft from the adjacent road. Based on the setback, amount of open spaces around a building for different area of the plots ranges from 28% to 32% of the plot area as per 1996 by-law regulation. 'In the previous version of RAJUK building regulation there was a rule of minimum open space in a plot and that was 1/3 (33%) of the total plot area (Building construction rules, 1984)'.

2.4.2.Aspect Ratio [H/W Ratio]

It is generally agreed that the geometric form of the urban canopy layer greatly influences the urban climate (Arnfield, 2003). A common element within the canopy layer, particularly in city centers, is a street flanked on both sides by rows of buildings. This simplified element of the urban environment, referred to as the urban street canyon is determined geometrically by the ratio between the height of the façades and the width of the street (H/W ratio). For asymmetric canyons with varying building heights, the H/W ratio is calculated using the average building height.

Cited in Johansson E. (2006b) it can be seen that, microclimate in the hot dry desert village of Beni-Isguen (32°N), Algeria, Ali-Toudert et al. (2005) also found that the day time maximum temperature decreased with increasing H/W ratio, although the variation was rather small (2 – 2.5°C), despite extensive variation in average H/W ratios from 0.1 to 6.

As regards urban form, Givoni (1992) points out that, compact urban areas have poor ventilation and high nocturnal heat islands. The best urban configuration in hot humid climate includes dispersed high, slender buildings; preferably tower blocks or with the short end perpendicular to the wind direction. Ainsley and Gulson (1999) recommend that such towers, which could rise above a layer of two to three-storey buildings, should be spaced at least six tower widths apart. This urban form is also the most adequate for building ventilation and enables higher population densities. Givoni (1992), however, points out that, such buildings are expensive to construct, operate and maintain.

In the hot humid summer climate of Dhaka (24°N), Bangladesh, Ahmed K. S. (1994) found that day time temperatures had a tendency to decrease with increasing H/W ratio. He found the average decrease to be 4.5°C when the H/W ratio increased from 0.3 to 2.8. Similarly, the importance of shade for air temperature was investigated by Nichol (1996) in hot humid Singapore (1°N). She found significant differences between shaded and open places - where the ground was shaded by either high-rise buildings or shade trees, the average day time air temperature was 1.5–2°C lower than for non-shaded ground of concrete or grass. Kushol et al (2013) found in Dhaka that, higher H/W ratio (deep street canyon) may be preferable for N-S streets due to the potential shading effect of the built form in reducing MRT and lower H/W ratio (shallow street canyon) may be preferable for E-W streets for better wind ventilation at pedestrian level and low MRT due to the impact of setback.

A majority of the field studies on intra-urban variations show that the urban geometry has a significant influence on air temperature and that day time maximum temperatures tend to decrease with increasing H/W ratios (Johansson E., 2006b).

Streets are considerable parts of urban open spaces have a significant role in creating the urban microclimates (Shishegar, 2013). The microclimate of urban open spaces is influenced by several parameters such as the urban form and geometry, urban density, the vegetation, the water levels and the properties of surfaces (Shishegar, 2013).

The geometry of a street canyon are expressed by its ‘aspect ratio’ - the ratio of the height of the building (H) to width of the street (W) (Ahmad K. et al, 2005). According to the most related studies, street canyon geometry’s parameters [height-to-width ratio (H/W)] and the street orientation are the most relevant urban parameters responsible for the microclimatic changes in a street canyon. (Todhunter P. E. 1990; Yoshida A. et al 1990; Arnfield J. and Mills G. 1994). The effects of H/W ratio and orientation of streets on receiving solar energy by ground and other street surfaces are more significant in latitudes 20°- 40° in different seasons. This illustrates that in the subtropics climates, street geometry is more important for the solar control. (Shishegar, 2013). Among other aspects of urban form such as Aspect ratio, "the ratio of wall height to building separation" is also extremely influential on UHI (Ross, 2012).

Symmetrical canyons have been considered as, the climate of city streets is examined by considering the properties of 'symmetrical canyons' characterized by their length, building height (H) and street width (W) and orientation [Oke and Nunez 1977]. This approach has permitted the discovery of general relationships linking street geometry and climate effect. [IAUC Teaching Resources the Urban Canopy Layer Heat Island_ http://www.urban-climate.org/UHI_Canopy.pdf (accessed 29-01-2014)].

2.4.3.Building Mass Configuration: Elevated and On-ground Structures

De Schiller and Evans (1998) recommend variations in height, irregular spacing and open passages at ground level in order to encourage the channeling of breezes for high-rise buildings, helping direct them to the pedestrian level. They propose a similar strategy for medium-rise buildings including variations in building height, form and spacing between buildings. For low-rise (one to two-storey) buildings, de Schiller and Evans (1998) suggest court-yard buildings, where as Givoni (1998) suggests detached houses. The former gives examples of how to group and design buildings to promote air movements for high, medium and low-rise construction.

2.4.4.Street Orientation

The street is one of the important urban components of a city's physical structure and it acts as the physical interface between urban and architectural scales. The form of the street can climatically affect both outdoor and indoor environments (Yahia M.W., 2012). Consequently, the shape of the street influences the outdoor thermal comfort – which affects people's human health and well-being – as well as the energy use of buildings in the urban areas. Therefore, designing streets is essential for an environmental urban design (Ali-Toudert, 2005).

Cited in Johansson E. (2006b) it can be seen that, canyon study in a hot dry desert climate, Pearlmutter et al. (1999) examined the influence of orientation on the canyon air temperature. They found that, by day the north-west oriented street was slightly (<1°C) cooler than the east-west oriented street. By night there was no difference between the canyons. In a similar climate, Bourbia and Awbi (2004) also found that during day time the north-south oriented streets were 1–2°C cooler than the east-west oriented streets.

As regards street orientation in terms of hot humid climates, Givoni (1992) emphasizes that; this is of importance in densely developed rather than sparsely built areas. He argues that the optimum orientation of wide avenues is at an angle of 30–60° to the prevailing wind direction to enable the wind not only to penetrate into the city but also to provide cross-ventilation of individual buildings.

Ali-Toudert and Mayer (2005, 2006) simulated the microclimate of the desert city of Beni-Isguen (32°N), Algeria using the computer program ENVI-met (Bruse 2007). They found that during hot dry summer conditions, the temperature decreased by about 3°C when the H/W ratio increased from 0.5 to 4 and that north-south streets were slightly cooler than those oriented east-west. Their investigations were restricted to the summer season. Swaid and Hoffman (1990) also found lower air temperatures for north-south than east-west streets at Tel Aviv (32°N), Israel.

Streets with long rows of closely spaced buildings perpendicular to the wind directions should be avoided as they may block the wind for entire urban areas. This is particularly important in coastal areas where the afternoon sea breeze can improve comfort conditions considerably. Consequently, urban spaces should, if possible, be aligned in the direction of the breeze. Ainsley and Gulson (1999) recommend that coastal urban spaces have a width at least four times the height of surrounding buildings.

In the summer, Pearlmutter et al. (2005) found that day time energy gain diminished with increasing H/W ratio. Moreover, they concluded that street orientation is important: north-south oriented streets were significantly more comfortable due to more efficient shading of direct-beam radiation. Kushol et al (2013) found from the field survey at Dhaka that overall N-S canyons are cooler than the E-W canyons and suggests that N-S canyons should be continuous without any staggering for better wind flow at pedestrian level.

(Ali-Toudert and Mayer, 2005 and 2006) using ENVI-met (Bruse 2007) pointed out that MRT decreases much more than the air temperature as the H/W ratio increases.

Additionally, they found north-south streets to be more comfortable than east-west streets. Finally, they suggested that streets be oriented north east-south west or north west-south east to achieve a favorable compromise between summer comfort and solar access in the winter.

‘Studies reviewed, show that calculated heat stress diminishes with increasing H/W ratios, at least for H/W above about 1, and that the heat stress is lower for north-south oriented streets than east-west streets. However, studies dealt mainly with the summer season in hot dry and warm-temperate climates and no studies of this kind have been conducted in hot humid climates’ (Johansson E., 2006b).

2.5. Conclusion

To some extent, the existing guide lines do not define or quantify design aspects such as the space between buildings, building heights, H/W ratios, etc. This probably is due to the fact that these guidelines are general for a larger region. De Schiller and Evans (1998) pointed out that their guide lines must be adjusted to local climatic factors and to other local conditions, such as topography, existing urban form and building traditions. However, the “vagueness” of the guidelines may also be a result of lack of research on the actual effects of urban design on the micro-climate. (Johansson E., 2006b). For hot humid climates, the majority of the guide lines argue for an open, dispersed city plan. This conflicts with the need in many tropical countries to increase population densities in cities (Johansson E., 2006b).

Eliasson (2000) found evidence that climate had low priority in the planning process. Issues such as traffic safety and building design were considered more important. Moreover, she identified the lack of knowledge on urban climate as a major constraint, hampering planners' arguments in disputes on conflicting interests. She also found that the use of tools for climate-conscious urban design was limited. Urban codes are often mentioned as a constraint for climate conscious urban design. Severe problems caused by inappropriate building codes have been reported from hot dry climates. Al-Hemaidi (2001) and Eben Saleh (2001) both blame the poor out door comfort conditions in Saudi Arabian cities on Western inspired planning codes. Baker et al. (2002) report a similar experience from Phoenix, Arizona, where current planning codes follow principles developed in cold climates and lacking requirements for shading. Distances between buildings were, for example in many western cities, designed to allow for a sufficient number of hours of solar exposure per year (Pinson 1994). Many of the world's urban codes have their roots in Western planning ideals from the first half of the 20th century (Johansson E., 2006b).

Evans and de Schiller (1996) urge the development of easily under stood guide lines and design recommendations including the graphic presentation of urban design aspects. They claim that planners need guidance on factors such as building densities, maximum building heights and building forms. Bitan and Potchter (1995), Evans and de Schiller (1996) and Eliasson (2000) all stress planners' need for guidance early in the planning process and the fact that climatic issues should be incorporated through out the process. They point out the importance of establishing a dialogue between climatologists, planners, architects and others involved in urban development. Eliasson (2000) claims that if climate aspects are brought in late in the process, planners and architects tend to be unwilling to change their designs. Similarly, de Schiller and Evans (1998) emphasize that incorrect decisions at the town planning level are normally impossible to correct at a later stage. Ainsley and Gulson (1999) argue that outdoor thermal comfort should be a routine aspect of urban development and that climatic aspects should be included in urban codes at different planning levels.

Climate is rarely considered in urban planning and design, and also indicates that codes and regulations are poorly adapted to local climatic conditions, often acting as obstacles to climate-conscious urban design (Johansson E., 2006b). However, there are few studies from hot dry and, particularly, hot humid climates. Most of the studies stress the importance of increasing knowledge on climate aspects among urban planners and designers and of increasing cooperation between planners and urban climatologists during the entire planning process (Johansson E., 2006b).

Urban design guidelines in hot dry and hot humid climates are often general in character and not always based on research. They need to be improved through specific guidance on design parameters, such as H/W ratio, orientation, surface properties and the spacing of buildings Johansson E. (2006b).

Climate aspects are rarely considered in urban planning and design and urban codes are often poorly adapted to local climate conditions and may therefore hinder climate-conscious urban design Johansson E. (2006b).

However, although the issues discussed above have gained increased attention in tropical climates in recent years, the number of studies remains small, especially concerning hot humid climates (Johansson E., 2006b).

The study tries to link measurements and simulations of the urban micro climate with an investigation of the climate aspects and an analysis of the effects of existing urban regulation on urban micro climate; in other words, this study is likely to help to improve urban microclimate, while designing new residential master plans; specially for new satellite towns and to see the impact of FAR (floor area ratio) and MGC (maximum ground coverage) through h/w ratio of the canyons and also street orientation on urban microclimate and also to observe the impact of elevated and on-ground built forms on street microclimate at pedestrian level. While differences can also be observed in terms of urban microclimate parameters due to existing building regulation as of 1996 by-law in planned residential area.

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Chapter Three: Field Survey

Introduction

Field Survey

Simulation of Field Survey

Comparative Study: Field Survey and Simulated Field Condition

Conclusion

References

3. Field Survey

3.1. Introduction

This chapter discusses on the field survey done for the research; selection of survey area, method of data collection and compiling data. Simulation was also done in this chapter which was based on field survey to find the deviation between field data and simulated data which was part of the research. The deviation has been applied in the following chapter on simulation results gathered from desired different model typologies of interest, which has later been used for analysis.

3.2. Field Survey

Extensive reconnaissance surveys were done at Uttara (Fig.3.1) to identify the desired area for survey with a target of having rows of buildings constructed under 1996 by-law on both sides with little or no vegetations. While selecting the area it was a difficult task, as desired canyons were rarely seen because of various low height buildings from single or double storey within the canyons to presence of vacant plots, vegetations, nodal points that were connected in between the canyons. It has been observed from the reconnaissance survey that Uttara first phase still having lots of low height buildings (single / double storey) while there were lots of six storey buildings at Uttara second phase but having lots of vacant plots in between the canyons thus failed to achieve the desired canyons. Having all these difficulties, finally road nos. 5, 6, 7 in

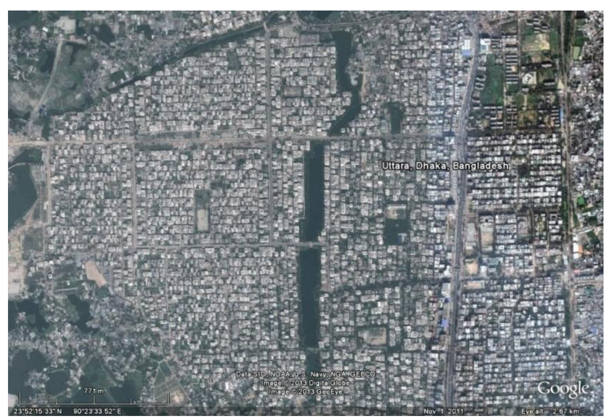

Fig 3.1: Uttara, Dhaka, (eye alt-2.67km)
(source- google earth)

north-south and road nos. 13, 14, 15 in east-west orientation (Fig.3.2 and Fig.3.3) were selected for field survey which are represented through road ‘A(NS)’, ‘B(NS)’, ‘C(NS)’, ‘X(EW)’, ‘Y(EW)’ and ‘Z(EW)’ respectively during the research. Field surveys were done for 8 consecutive days in the month of March.

Fig 3.2: Satellite image _ Google earth _ Uttara Sector 14_Roads Selected [Eye Altitude 341.68m]

Fig 3.3: Orthogonal street canyons Road nos. 5, 6, 7 (NS), 13, 14, 15 (EW)

Fig 3.4: North South street canyons

Fig 3.5: East West street canyons

Measuring Points during Field Survey

Data were collected from these N-S and E-W oriented streets of 10 meter width having 335 sqm [5 katha (1 katha=720sq.ft.)] road- side plots (Ahmed Z. N., 1994) and also photographed (Fig. 3.4 and 3.5). Data were collected (Kushol et al, 2013; Priyadarsini et al, 2005) at 16 spots (Fig. 3.6) with a view to, two opposite points in front of the plots [due to mutual shading of the building blocks] and one point at the middle of each street aligned in between building setbacks due to air movement within the setbacks which are likely to influence data; at each road for eight days, which concluded with [16(spots/road) * 6(total no of roads) * 8(total no of days) * 4(MRT, DBT, RH, WS)] = 3,072 data; collected at 1.6 m above ground level. Air temperature (DBT), radiant temperature (MRT), relative humidity (RH) and air velocity (WS) data were collected within a time range of 11am to 3pm with the help of a digital Hygro-Thermometer (Zeal, Model: SH-110) and Vane anemometer (V&A, Model: VA 8020).

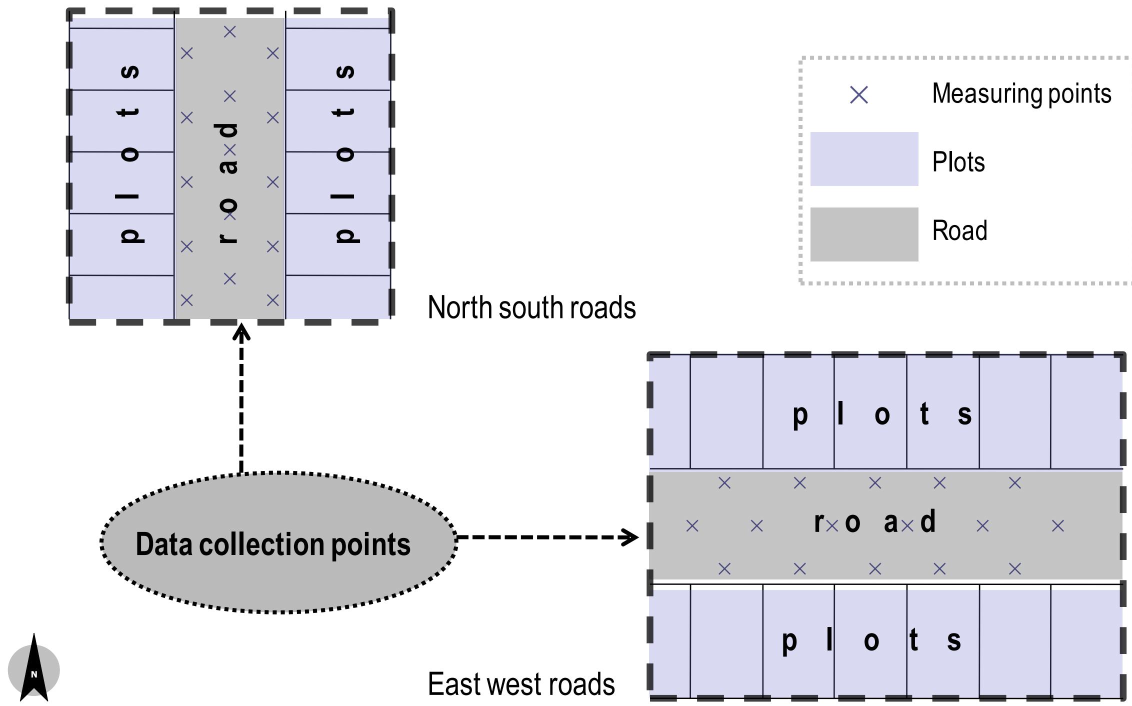

Fig 3.6: Data collection points at NS and EW street canyons

3.2.1. North South Oriented Streets of Field Survey

This section of the chapter discusses north south oriented streets during field survey. Data in terms of DBT [K] (dry bulb temperature), MRT [K] (mean radiant temperature), RH [%] (relative humidity), and WS [m/s] (wind speed) are given below and discussed with graphical presentations. DBT and MRT were collected in degC, later converted into Kelvin which are as follows.

Table 3.1: Field Survey Data of DBT and MRT of North-South oriented streets

[NS]	DBT [K]			MRT [K]		
	A[NS]	B[NS]	C[NS]	A [NS]	B[NS]	C[NS]
Day 01	309.11	307.58	307.18	304.67	304.08	304.44
Day 03	309.60	309.31	308.29	306.94	305.91	305.03
Day 05	311.06	310.31	309.64	308.01	307.14	306.40
Day 07	310.12	308.56	308.14	304.79	303.34	303.29
Day 02	308.93	308.34	305.88	305.36	305.86	304.89
Day 04	309.56	309.68	309.48	306.09	306.37	306.23
Day 06	310.76	310.16	309.01	306.33	305.66	305.68
Day 08	309.53	309.30	308.36	305.81	305.21	305.16
City avg	299.96	299.96	299.96			

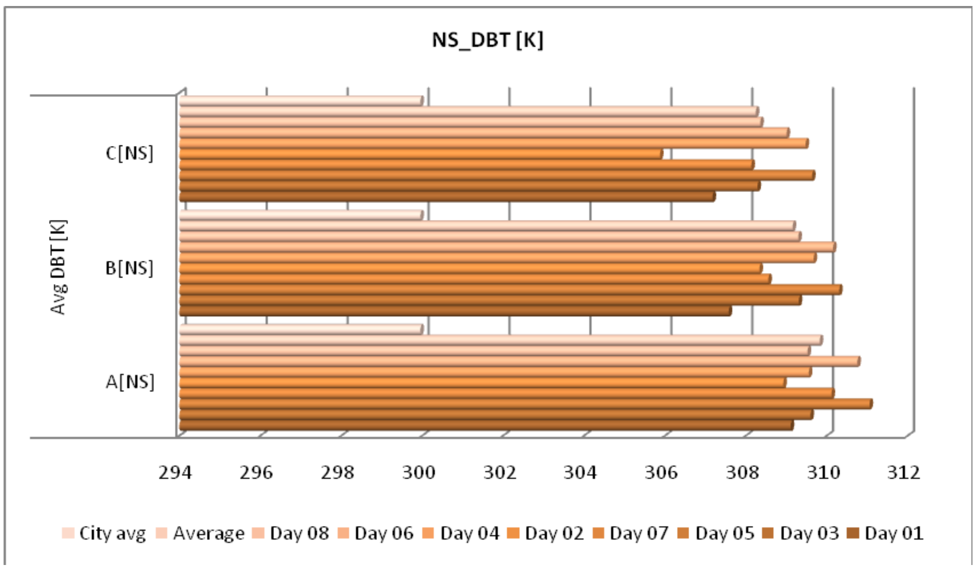

Fig 3.7: Field Survey Data of DBT of North-South oriented streets

From (Table 3.1 and Fig 3.7) it is clear that the city average temperature is much lower than the dry bulb temperature collected within the canyons, of which canyon A tends to be highest among the selected three north south streets. While in terms of MRT (Table 3.1 and Fig 3.8) it can also be seen that road A tends to be highest.

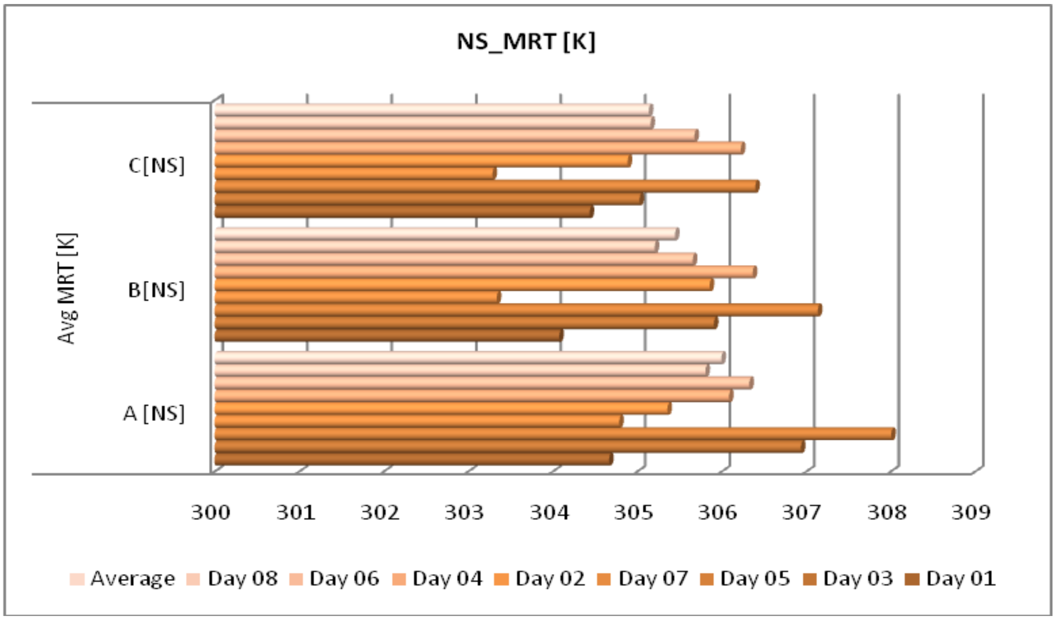

Fig 3.8: Field Survey Data of MRT of North-South oriented streets

Table 3.2: Field Survey Data of RH and WS of North-South oriented streets

[NS]		**RH [%]**			**WS [m/s]**	
	A[NS]	**B[NS]**	**C[NS]**	**A [NS]**	**B[NS]**	**C[NS]**
Day 01	24.00	25.13	24.38	0.54	0.34	0.94
Day 03	23.44	23.06	23.94	0.56	0.26	0.34
Day 05	36.94	39.44	40.88	0.35	0.23	0.35
Day 07	33.00	36.38	36.75	1.00	0.39	0.65
Day 02	25.50	25.63	29.25	0.80	0.68	0.55
Day 04	39.88	42.56	45.31	0.38	0.69	0.37
Day 06	29.50	32.88	37.44	0.30	0.36	0.46
Day 08	40.44	43.13	44.94	0.88	0.31	0.36
City avg	43.29	43.29	43.29	2.60	2.60	2.60

While plotting the data of relative humidity and wind speed (Fig. 3.9, Fig. 3.10 and Table 3.2) it can be seen that RH reaches maximum in street C, while minimum in street A. Relative humidity increases while temperature decreases. Meanwhile it can be seen that the city average wind speed is much higher than the wind speed recorded at the canyons because of built forms and urban geometry which decreases the wind speed at pedestrian level within the canyons.

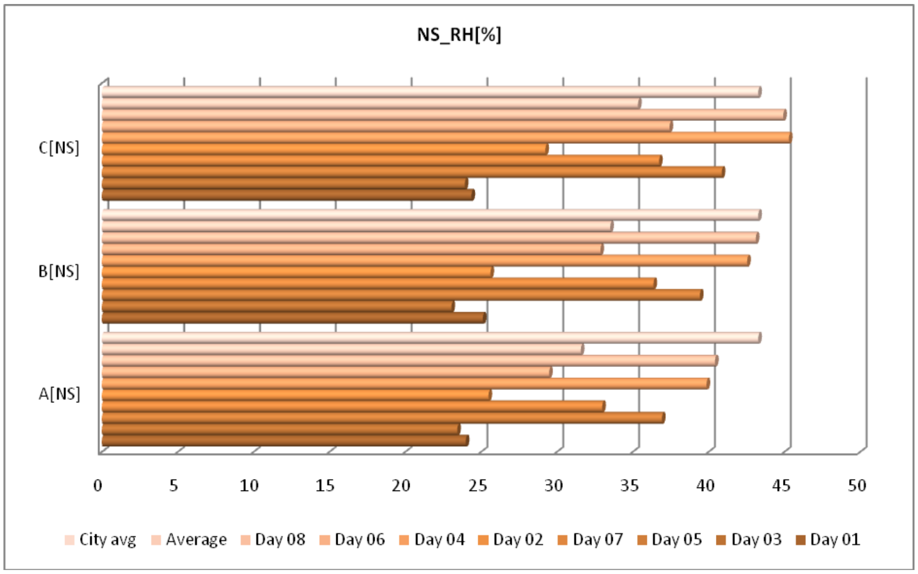

Fig 3.9: Field Survey Data of RH of North-South oriented streets

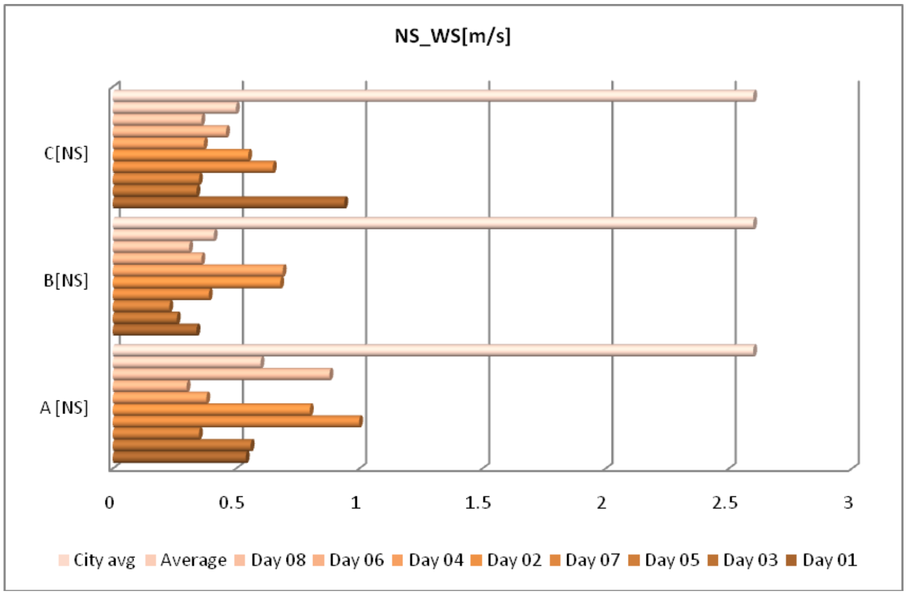

Fig 3.10 Field Survey Data of WS of North-South oriented streets

3.2.2. East West Oriented Streets of Field Survey

Data collected from the east west canyons are presented below through tables and graphs. While plotting DBT (Table 3.3 and Fig. 3.11) it can be seen that the data among the three streets are very close to each other, which again is much higher than the city average temperature, while MRT achieves maximum value at street ‘X’ (Table 3.3 and Fig. 3.12).

Table 3.3: Field Survey Data of DBT and MRT of East-West oriented streets

[EW]	**DBT [K]**			**MRT [K]**		
	X [EW]	**Y [EW]**	**Z [EW]**	**X [EW]**	**Y [EW]**	**Z [EW]**
Day 01	314.49	313.68	314.18	312.46	311.39	310.50
Day 03	313.06	313.41	309.89	311.60	309.65	307.10
Day 05	309.95	311.65	310.61	308.67	308.89	307.73
Day 07	310.14	312.19	311.26	304.88	306.42	305.44
Day 02	307.11	307.57	308.14	304.91	304.71	304.89
Day 04	308.28	308.66	308.63	306.81	306.11	306.54
Day 06	308.93	308.77	309.76	306.72	306.31	305.57
Day 08	307.58	308.16	308.05	304.90	304.98	304.83
City avg	299.96	299.96	299.96			

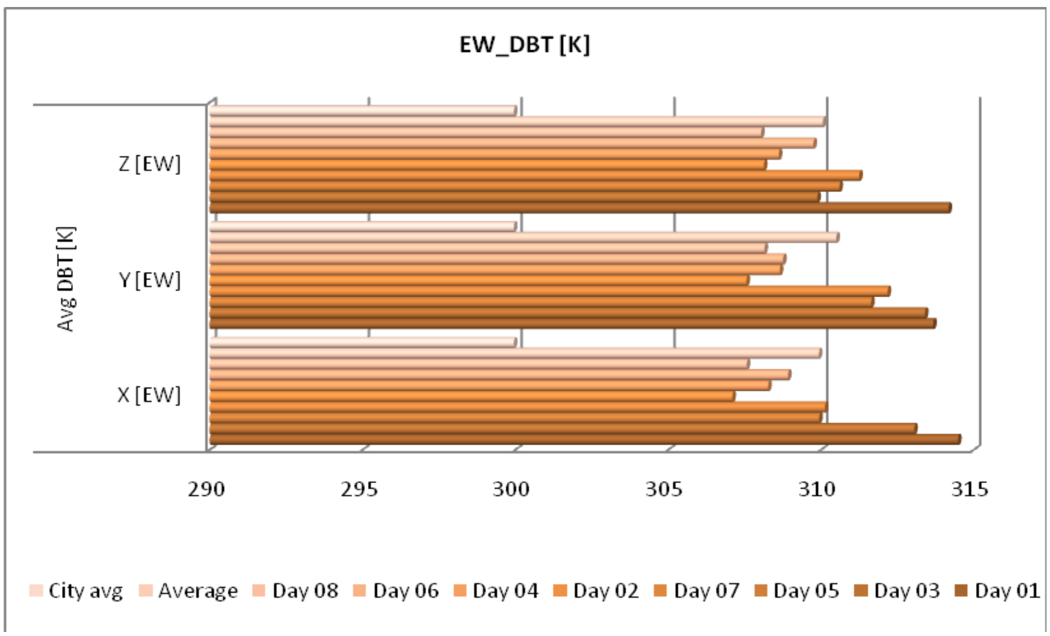

Fig 3.11: Field Survey Data of DBT of East-West oriented streets

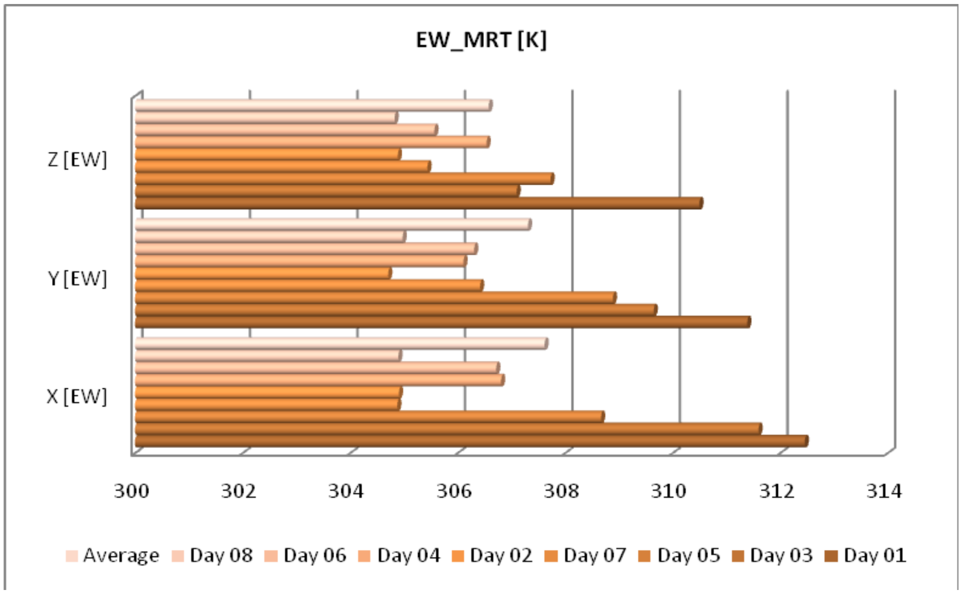

Fig 3.12: Field Survey Data of MRT of East-West oriented streets

Table 3.4: Field Survey Data of RH and WS of East-West oriented streets

[EW]	**RH [%]**			**WS [m/s]**		
	X [EW]	**Y [EW]**	**Z [EW]**	**X [EW]**	**Y [EW]**	**Z [EW]**
Day 01	22.19	20.19	20.75	2.31	1.07	0.79
Day 03	23.75	22.44	21.63	0.74	0.26	1.12
Day 05	41.38	37.19	38.63	0.97	0.59	0.54
Day 07	34.31	32.75	32.38	0.59	0.44	0.52
Day 02	24.94	26.88	27.25	0.95	0.25	0.73
Day 04	38.94	40.19	40.13	0.68	0.35	0.74
Day 06	30.00	28.88	30.13	1.23	0.58	0.55
Day 08	43.44	43.88	42.31	1.08	0.28	0.90
City avg	43.29	43.29	43.29	2.60	2.60	2.60

In terms of RH (Table 3.4 and Fig.3.13) three of the streets are very close to each other while wind speed (Table 3.4 and Fig.3.14) reaches the highest at street ‘X’. This result is due to high wind speed recorded in day one at street ‘X’.

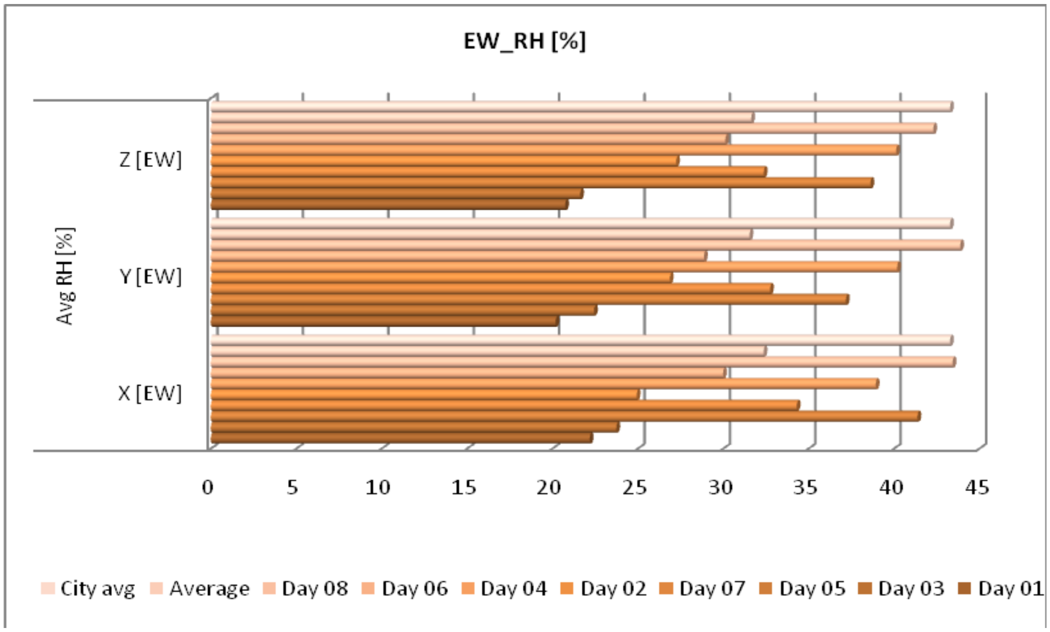

Fig 3.13: Field Survey Data of RH of East-West oriented streets

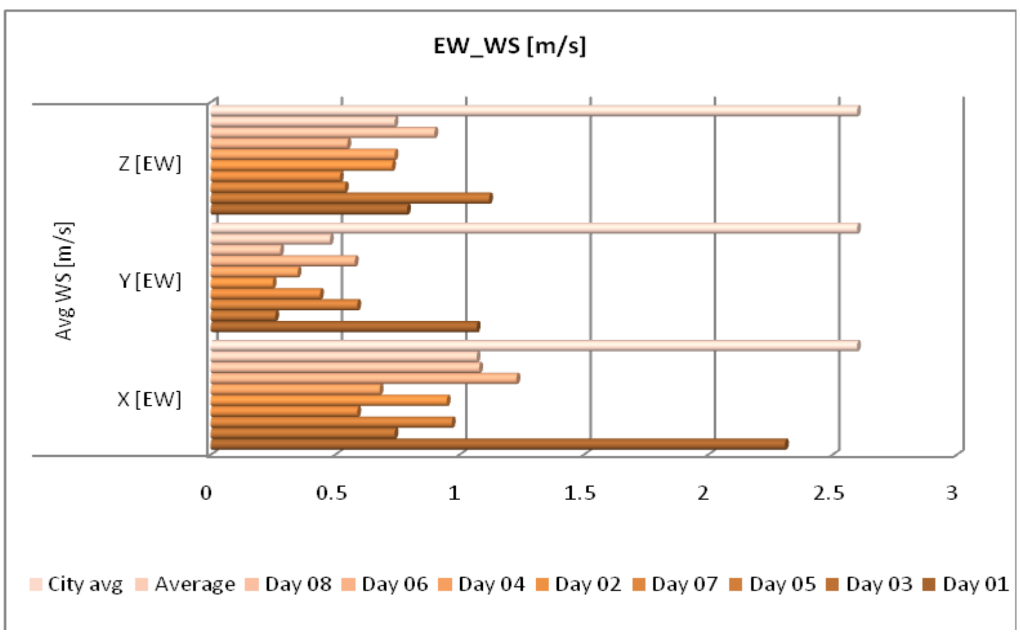

Fig 3.14: Field Survey Data of WS of East-West oriented streets

North South and East West Comparison of Field Survey

While comparing north south and east west orientation streets of field survey data (Fig. 3.15 and 3.16) it can be seen that east west streets have higher dry bulb temperature than north south oriented streets. In all the cases city average temperature is much below than the recorded data within the canyons.

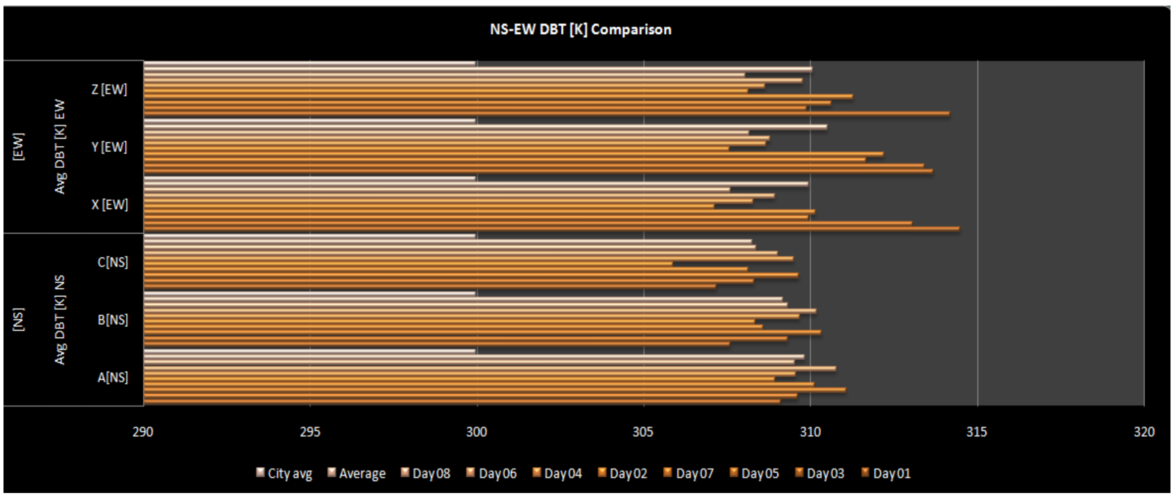

Fig 3.15: Comparing North-South and East-West orientation of Field Survey Data [DBT]

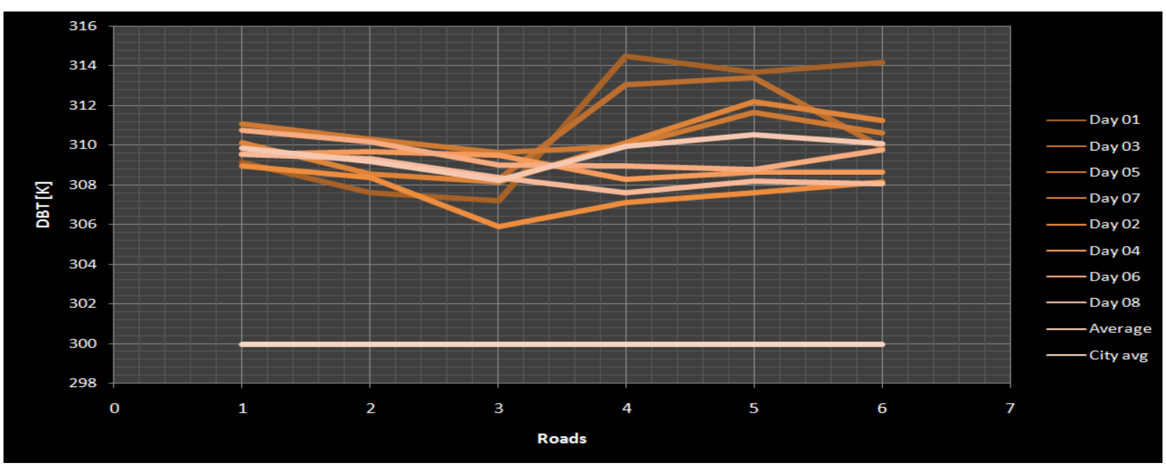

Fig 3.16: DBT Comparing North-South and East-West oriented streets of Field Survey Data with city average data

Similar scenario can be observed while comparing the mean radiant temperature of north south and east west canyons (Fig.3.17 and 3.18), where east west canyons have higher MRT than the north south canyons.

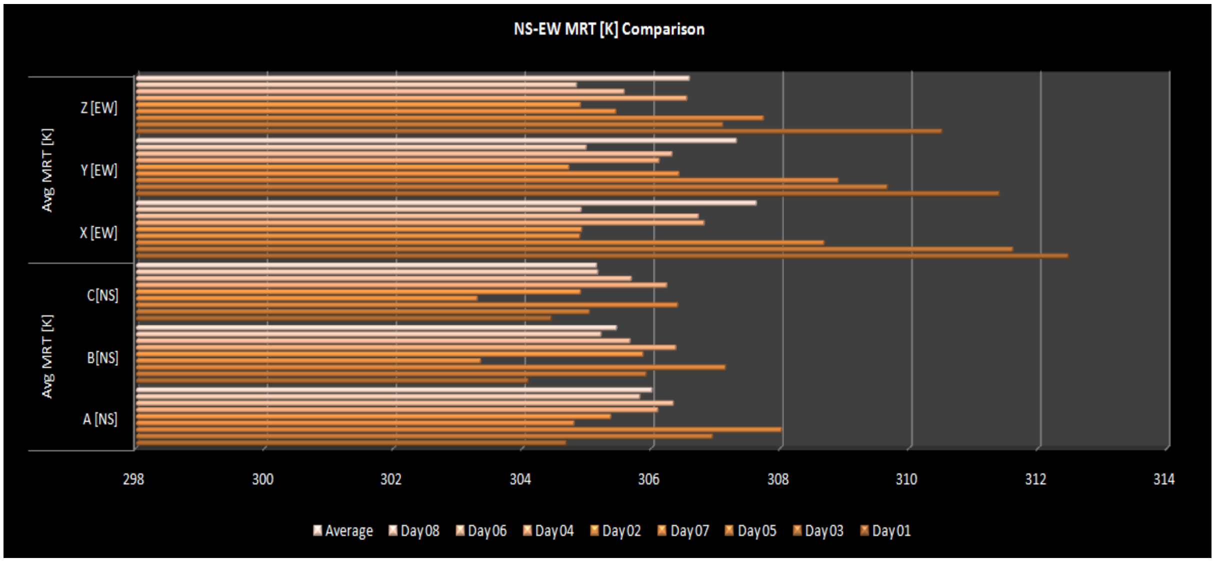

Fig 3.17: Comparing North-South and East-West orientation of Field Survey Data [MRT]

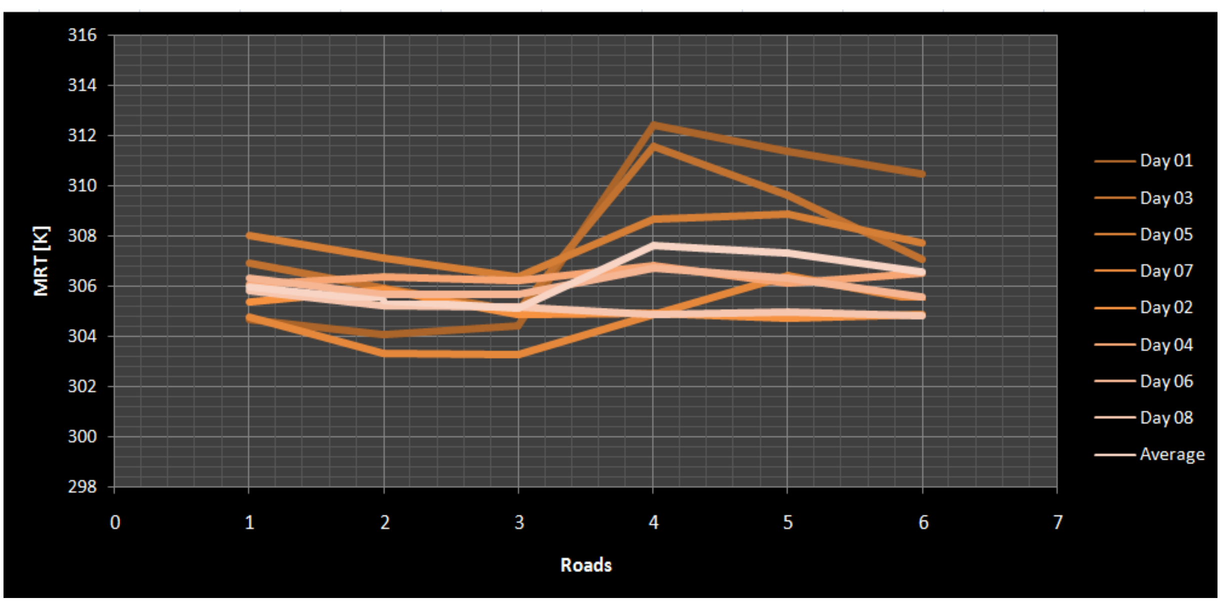

Fig 3.18: MRT Comparing North-South and East-West oriented streets of Field Survey Data in terms of different roads

In terms of relative humidity north south and east west canyons are close to each other while north south canyons are to some extent ahead than the east west (Fig.3.19 and 3.20).

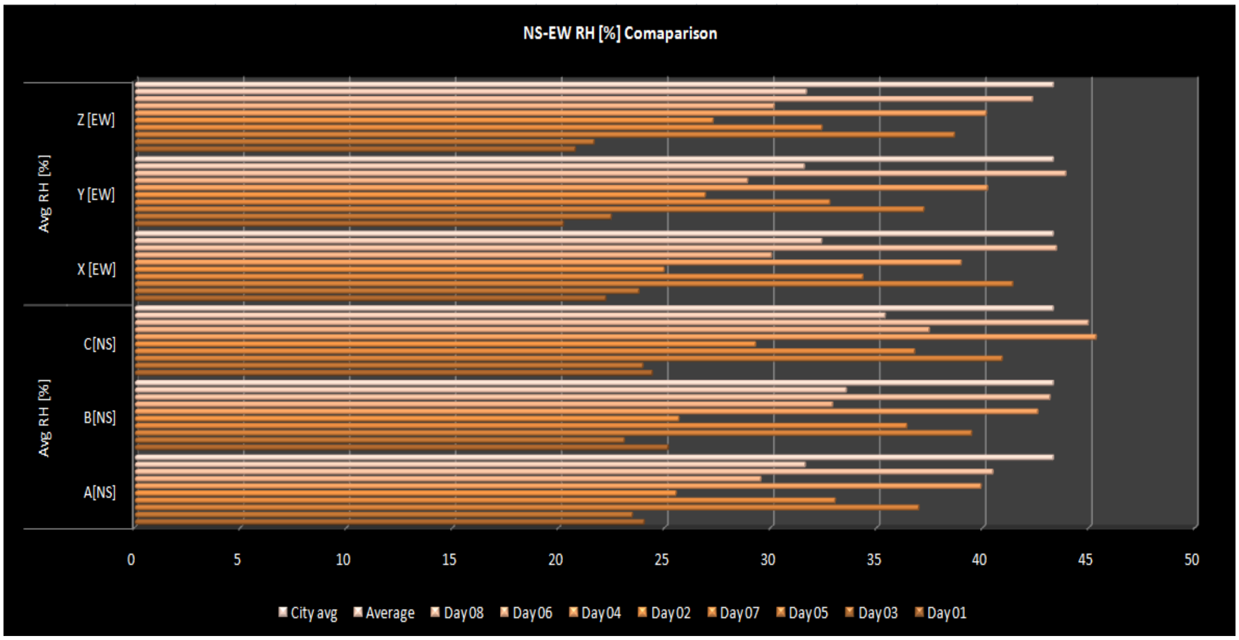

Fig 3.19: Comparing North-South and East-West orientation of Field Survey Data [RH]

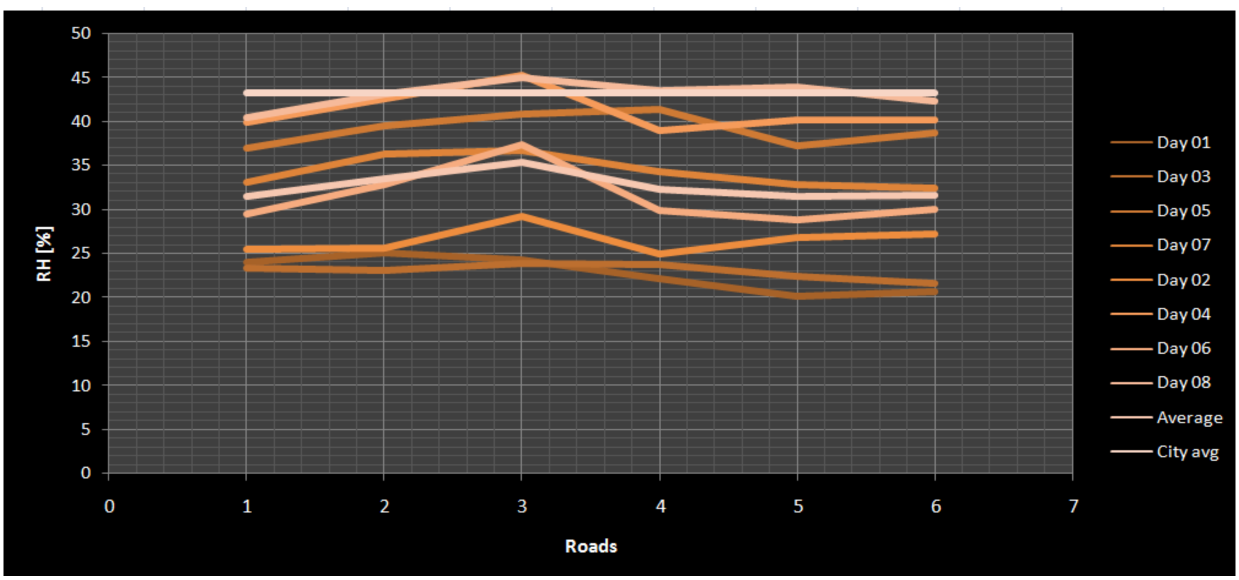

Fig 3.20: RH Comparing North-South and East-West oriented streets of Field Survey Data with city average data

While plotting wind speed of north south and east west canyons it can be seen that the average wind speed is higher in street ‘X’than other east west canyons and road ‘A’ is higher than other north south canyons, while street ‘X’ achieves higher wind speed than street ‘A’. Street ‘X’ and street ‘A’ both are longer than rest of the canyons, thus it can be assumed that longer street achieves higher wind speed than shorter canyons (Fig.3.21 and 3.22).

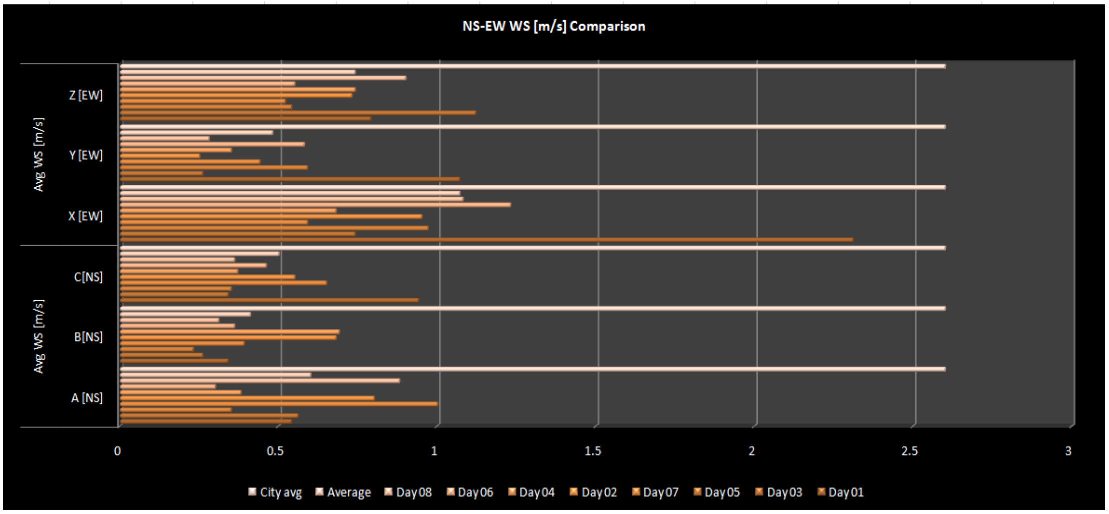

Fig 3.21: Comparing North-South and East-West orientation of Field Survey Data [WS]

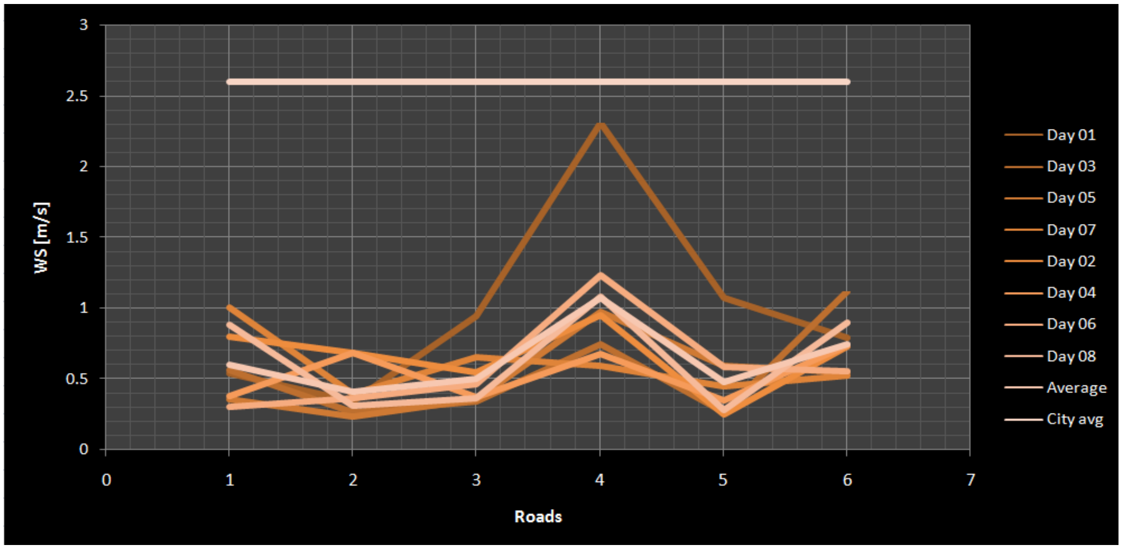

Fig 3.22: WS Comparing North-South and East-West oriented streets of Field Survey Data with city average data

3.3. Simulation of Field Survey

The field surveys discussed earlier was simulated using ENVI-met to compare field and simulated field data. The input data were as follows, required for the configuration (.cf) file before starting the simulation. After simulation, simulated images are presented in the following sections and discussed. Simulation were done from 10am for six hours, model saved at 15 minutes interval. In this chapter simulated images of 2pm only are presented (Fig.3.23 to 3.28) while others are provided at the appendix.

Table 3.5: Input data of field survey simulation for configuration file [.cf]

Start Simulation at Day (DD.MM.YYYY):	18.03.2014
Start Simulation at Time (HH:MM:SS):	10:00:00
Total Simulation Time in Hours:	6
Save Model State each? min	15
Wind Speed in 10 m ab. Ground [m/s]	2.6
Wind Direction (0:N..90:E..180:S..270:W..)	225
Roughness Length z_0 at Reference Point	0.6
Initial Temperature Atmosphere [K]	300.3

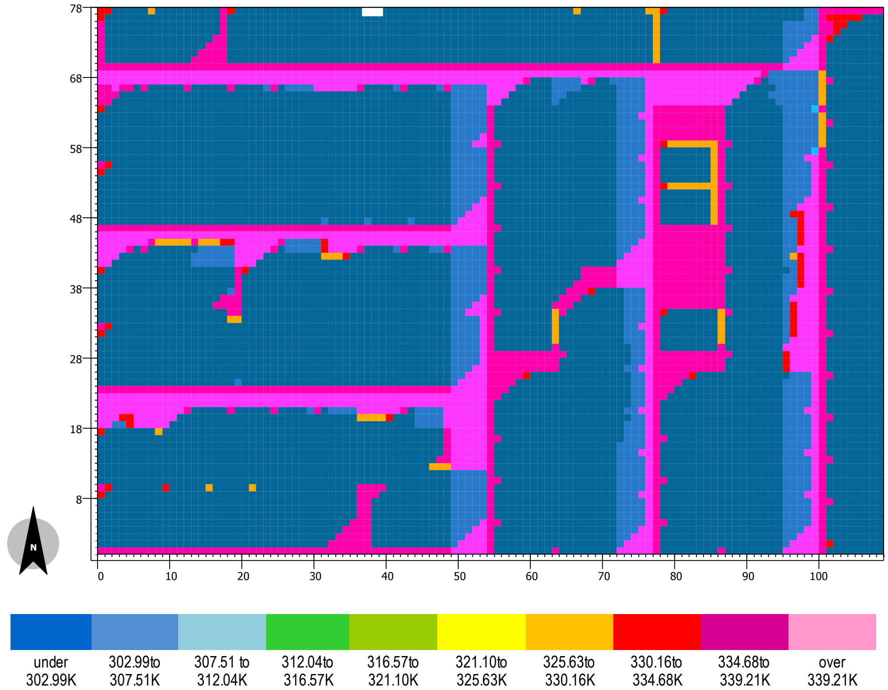

Fig 3.23: Mean radiant temperature at 2pm of field survey

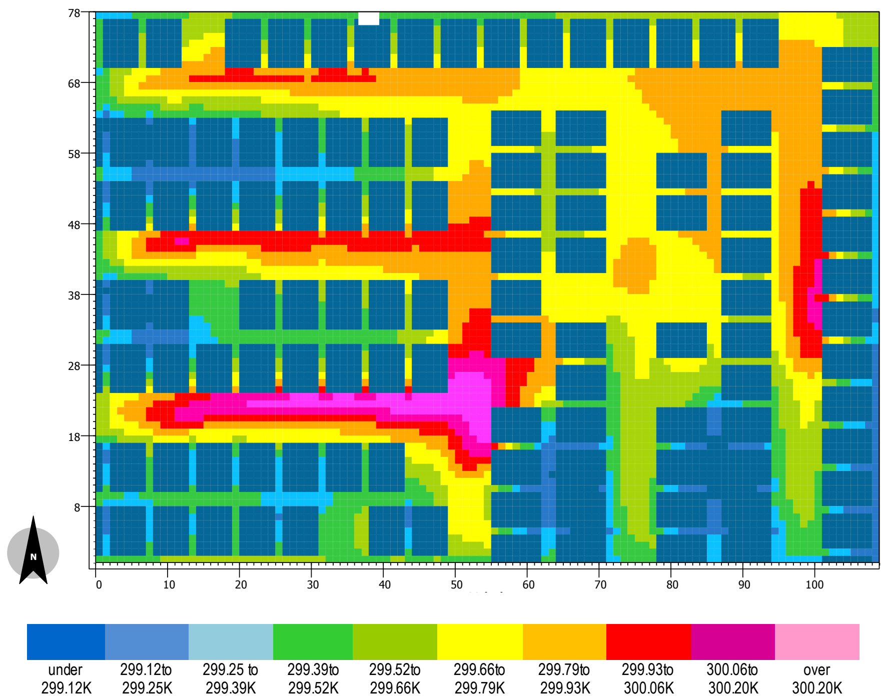

Fig 3.24: Dry bulb temperature at 2pm of field survey

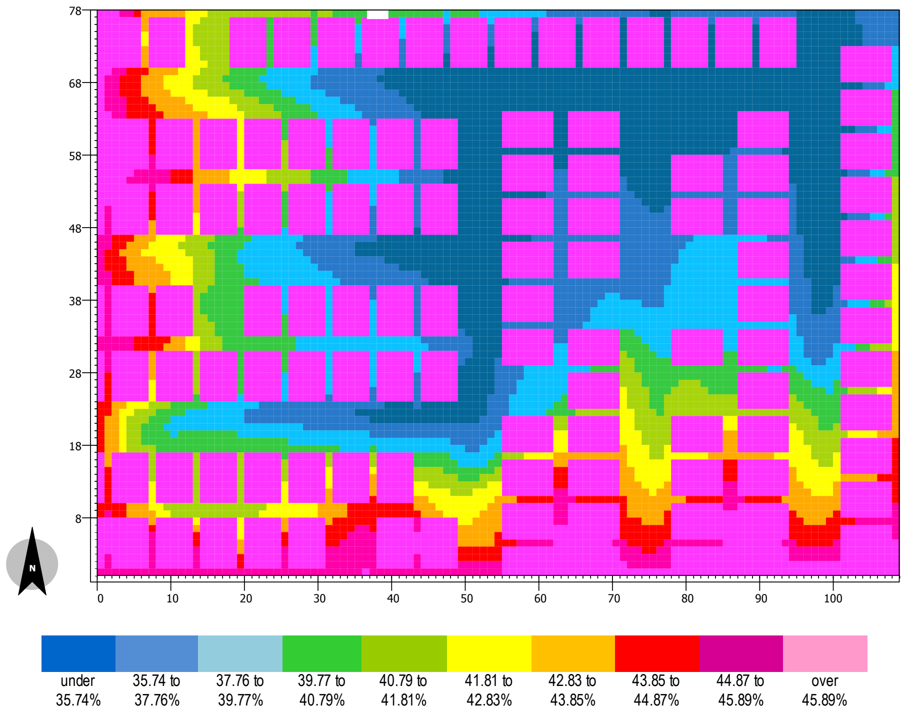

Fig 3.25: Relative humidity at 2pm of field survey

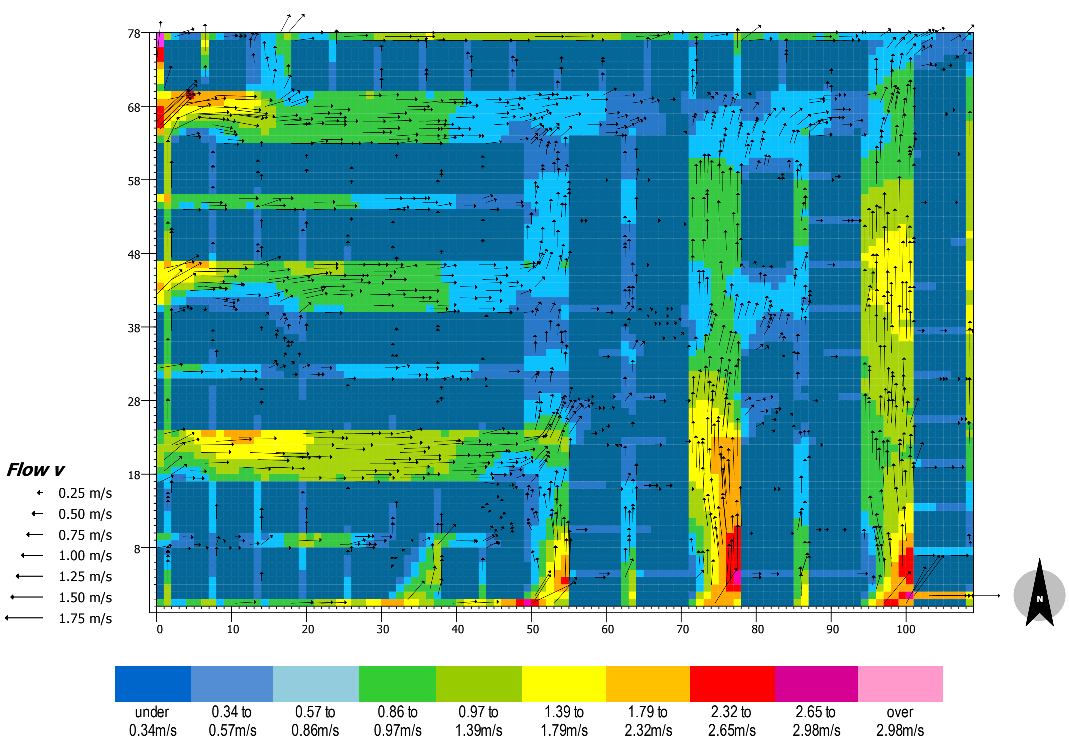

Fig 3.26: Wind speed at 2pm of field survey

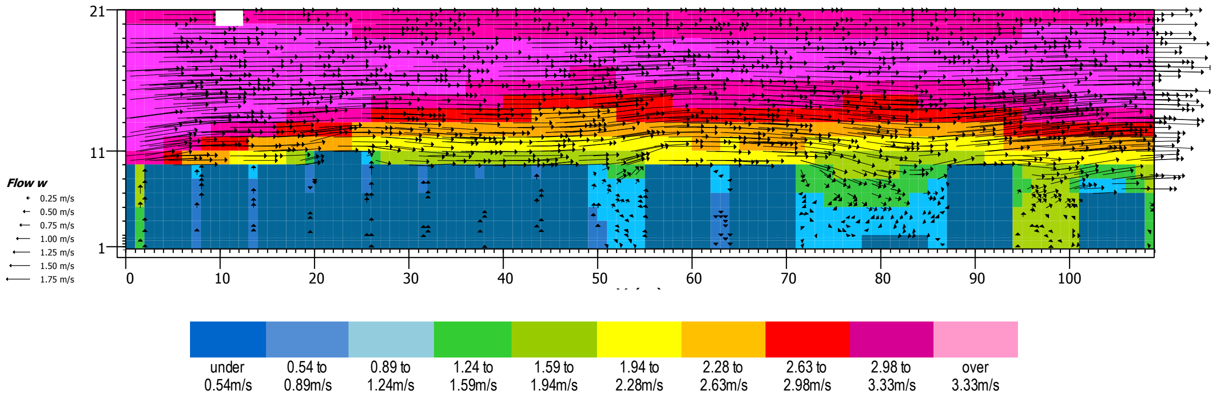

Fig 3.27: Wind speed [NS section] at 2pm of field survey

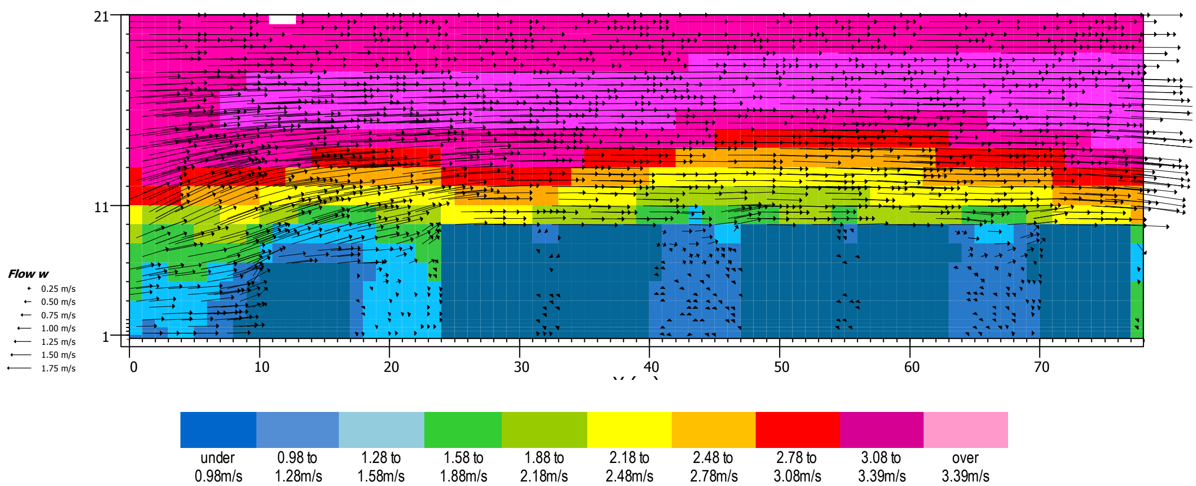

Fig 3.28: Wind speed [EW section] at 2pm of field survey

Data collected from the simulated images of the saved models are presented and discussed in the following section. Deviations in the simulated results are expected from the field survey data as lack of vegetation in simulation, difference in building materials present during field survey, impact of vehicular movement, pollutants within the air and water clogs within the streets were absent during simulation which were observed during field survey.

3.3.1. North-South Oriented Streets of Simulated Field Condition

Simulation results are compiled and presented through tables (Table 3.6 and 3.7) and graphs (Fig.3.29 to 3.32). While considering north south canyons it can be observed the results of dry bulb temperature are close to each other, while street 'A' tends to be more than the rest which supports the field survey data. Considering mean radiant temperature it can be observed that canyon 'C' represents the highest.

[NS]	DBT [K]			MRT [K]		
	A[NS]	B[NS]	C[NS]	A [NS]	B[NS]	C[NS]
11:00am	298.34	298.24	298.15	309.98	320.65	309.23
11:30am	299.11	299.00	298.86	310.78	320.12	322.89
12:00pm	299.60	299.45	299.38	311.35	320.69	323.46
12:30pm	299.92	299.77	299.69	312.83	321.18	323.97
01:00pm	300.08	299.96	299.81	312.32	312.32	324.88
01:30pm	300.17	300.01	299.87	312.70	312.70	325.78
02:00pm	300.14	299.98	300.11	312.89	312.89	326.48

Table 3.6: Simulated field condition: DBT and MRT of NS oriented roads

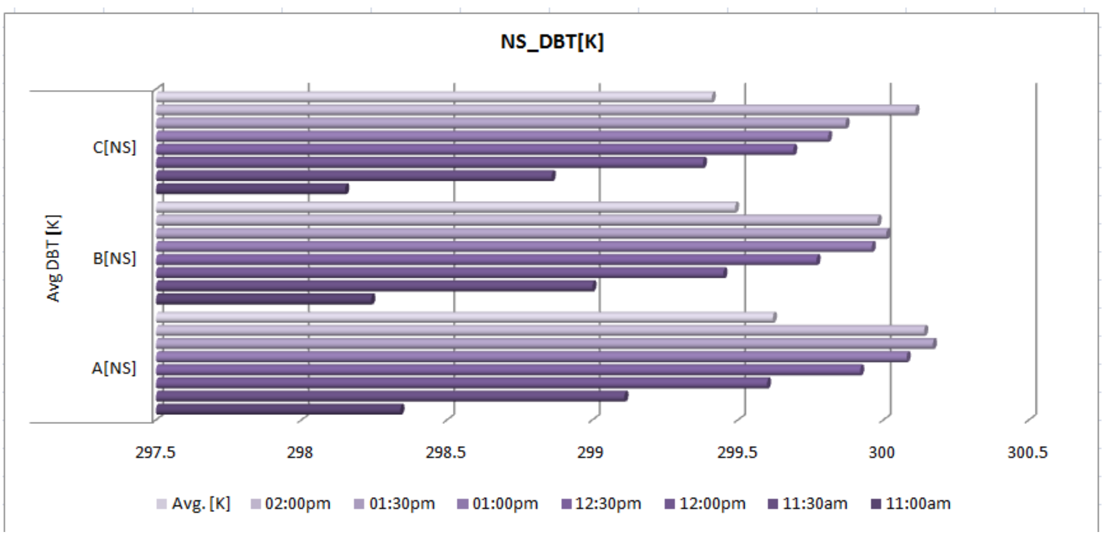

Fig 3.29: Simulated field condition: DBT [K] of NS oriented roads

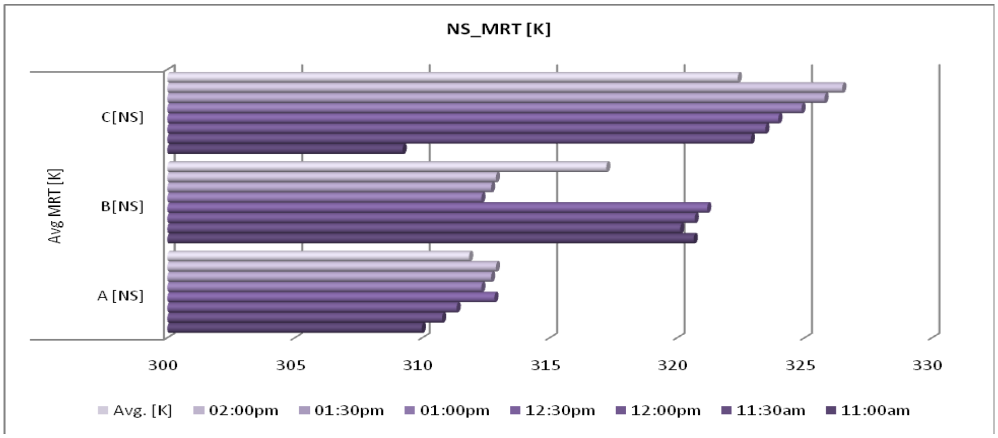

Fig 3.30: Simulated field condition: MRT [K] of NS oriented roads

[NS]	RH [%]			WS [m/s]		
	A[NS]	**B[NS]**	**C[NS]**	**A [NS]**	**B[NS]**	**C[NS]**
11:00am	43.69	44.23	44.08	1.23	0.86	0.92
11:30am	43.25	41.39	42.47	1.21	0.88	0.92
12:00pm	42.47	40.88	40.49	1.19	0.89	0.93
12:30pm	41.79	41.20	41.91	1.32	0.91	0.93
01:00pm	41.31	39.77	39.69	1.28	0.92	0.92
01:30pm	41.07	39.21	39.75	1.10	0.92	0.92
02:00pm	40.10	40.89	37.06	0.90	0.99	0.89

Table 3.7: Simulated field condition: RH [%] and WS [m/s] of NS oriented roads

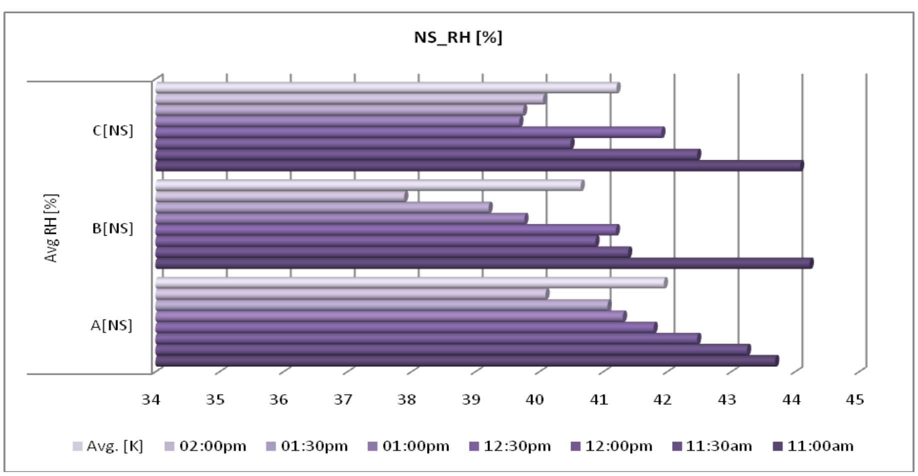

Fig 3.31: Simulated field condition: RH [%] of NS oriented roads

In terms of relative humidity the results are close to each other but on an average canyon 'A' is higher than the rest; while street 'A' achieves the highest average wind speed than the rest canyons of north south.

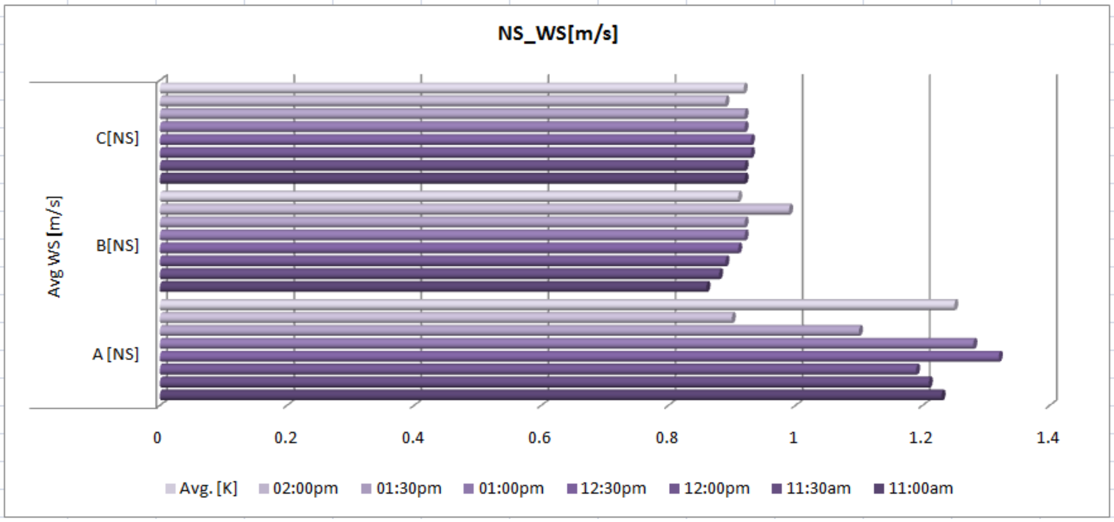

Fig 3.32: Simulated field condition: WS [m/s] of NS oriented roads

3.3.2. East-West Oriented Streets of Simulated Field Condition

Considering east west canyons dry bulb temperature (Table3.8, Fig.3.33) represents very close to each other, which supports the field survey. While mean radiant temperature (Fig.3.34) of street 'X' gains the highest than the rest of the canyons, which also supports the field survey result.

Table 3.8: Simulated field condition: DBT [K] and MRT [K] of EW oriented roads

[EW]	DBT [K]			MRT [K]		
	X [EW]	Y [EW]	Z [EW]	X [EW]	Y [EW]	Z [EW]
11:00am	298.47	298.54	298.43	332.73	327.5	309.98
11:30am	298.96	299.24	299.21	330.86	327.18	327.69
12:00pm	299.88	299.69	299.62	331.86	328.65	329.52
12:30pm	300.21	300.07	299.93	332.31	331.56	316.20
01:00pm	300.28	300.22	300.11	328.93	323.31	309.98
01:30pm	300.36	300.21	300.15	322.23	322.51	311.34
02:00pm	300.24	300.17	299.93	316.29	304.56	308.93

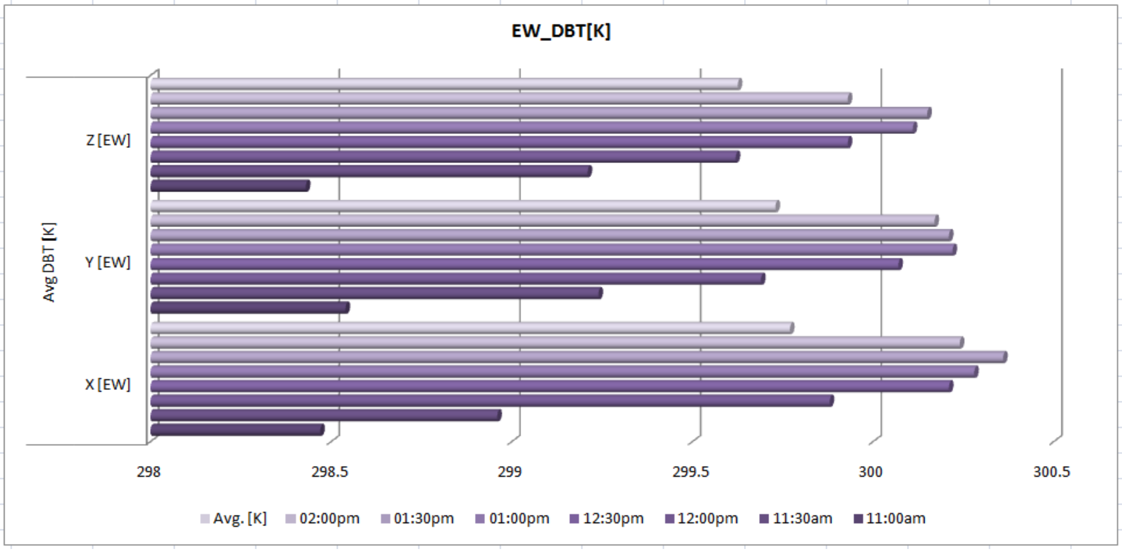

Fig 3.33: Simulated field condition: DBT [K] of EW oriented roads

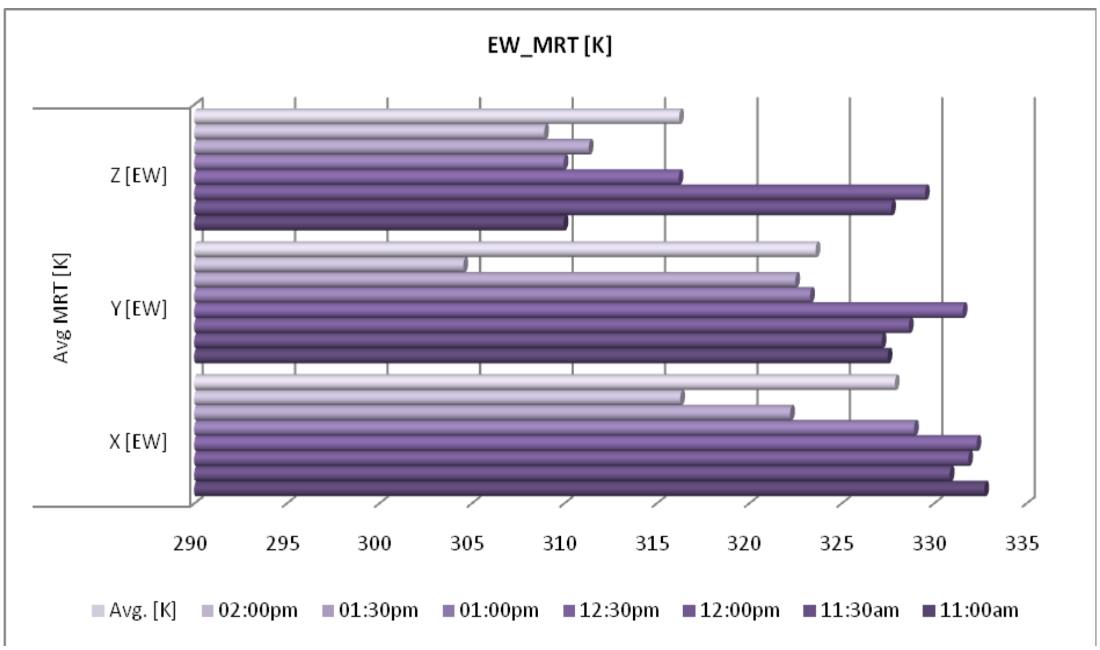

Fig 3.34: Simulated field condition: MRT [K] of EW oriented roads

Table 3.9: Simulated field condition: RH [%] and WS [m/s] of EW oriented roads

[EW]	RH [%]			WS [m/s]		
	X [EW]	**Y [EW]**	**Z [EW]**	**X [EW]**	**Y [EW]**	**Z [EW]**
11:00am	42.67	42.96	36.71	1.39	1.05	0.68
11:30am	43.22	43.23	34.43	1.32	1.19	0.56
12:00pm	42.71	41.27	32.05	1.31	0.87	0.60
12:30pm	42.17	41.85	31.96	1.47	0.86	0.57
01:00pm	41.91	41.76	32.53	1.18	1.03	0.59
01:30pm	38.31	38.50	31.28	1.18	1.02	0.61
02:00pm	35.71	36.10	36.70	1.21	0.87	0.71

In terms of relative humidity (Table 3.9 and Fig. 3.35) canyon 'X' and 'Y' are close to each other while considering wind speed (Table 3.9 and Fig. 3.36) it can be seen that canyon 'X' achieves highest average value among the studied east west canyons, which also supports field survey results.

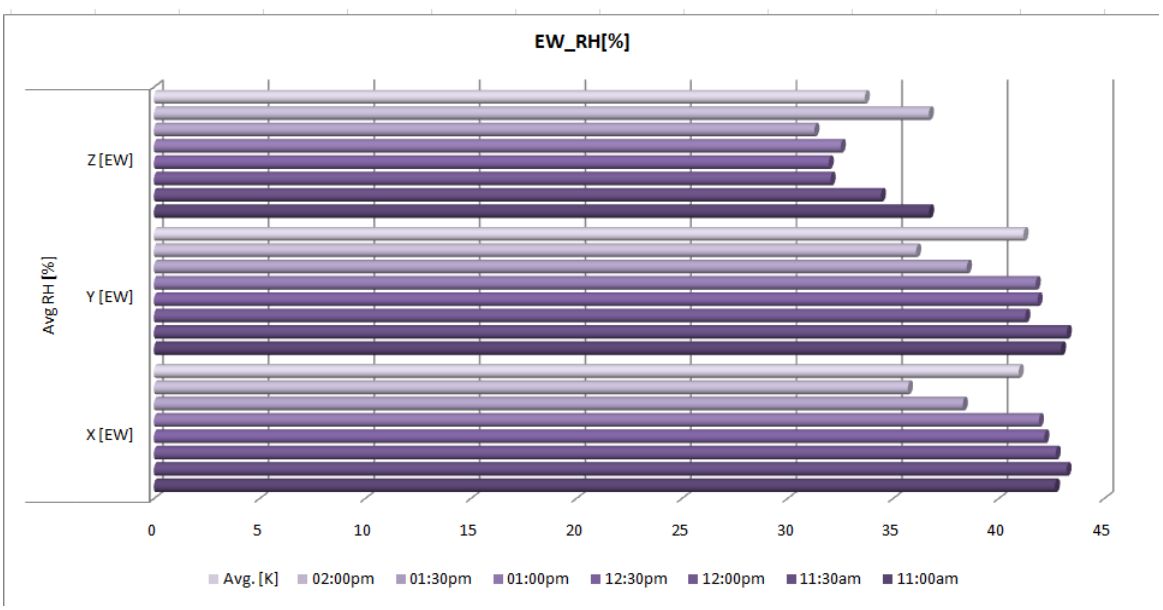

Fig 3.35: Simulated field condition: RH [%] of EW oriented roads

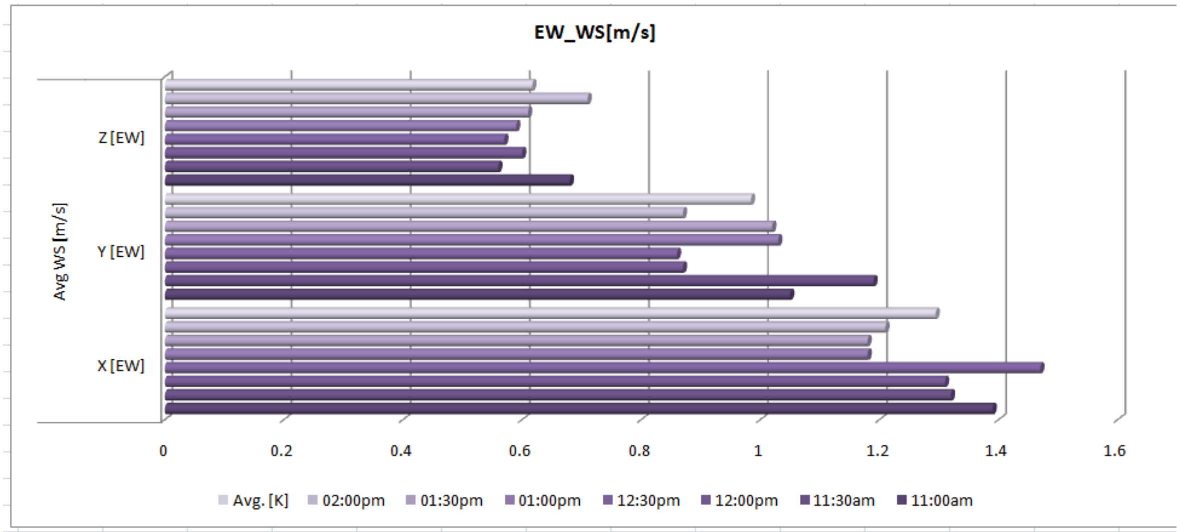

Fig 3.36: Simulated field condition: WS [m/s] of EW oriented roads

Comparing North South and East West Canyons of Simulated Field Condition

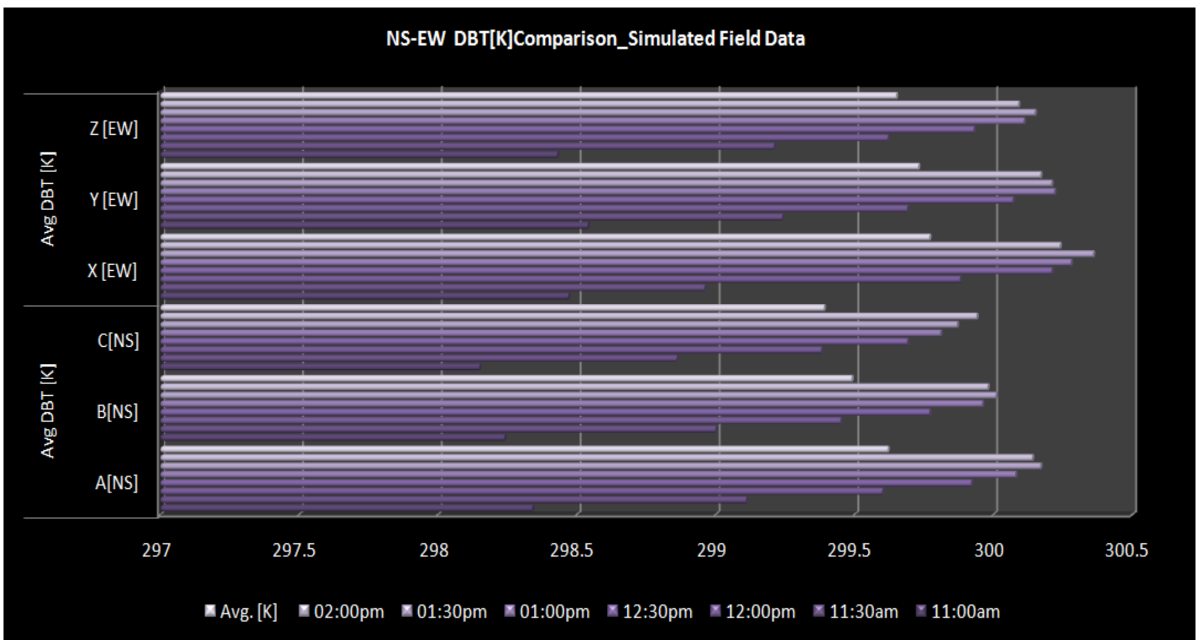

Fig 3.37: NS-EW canyon comparison of DBT [K] of simulated field condition

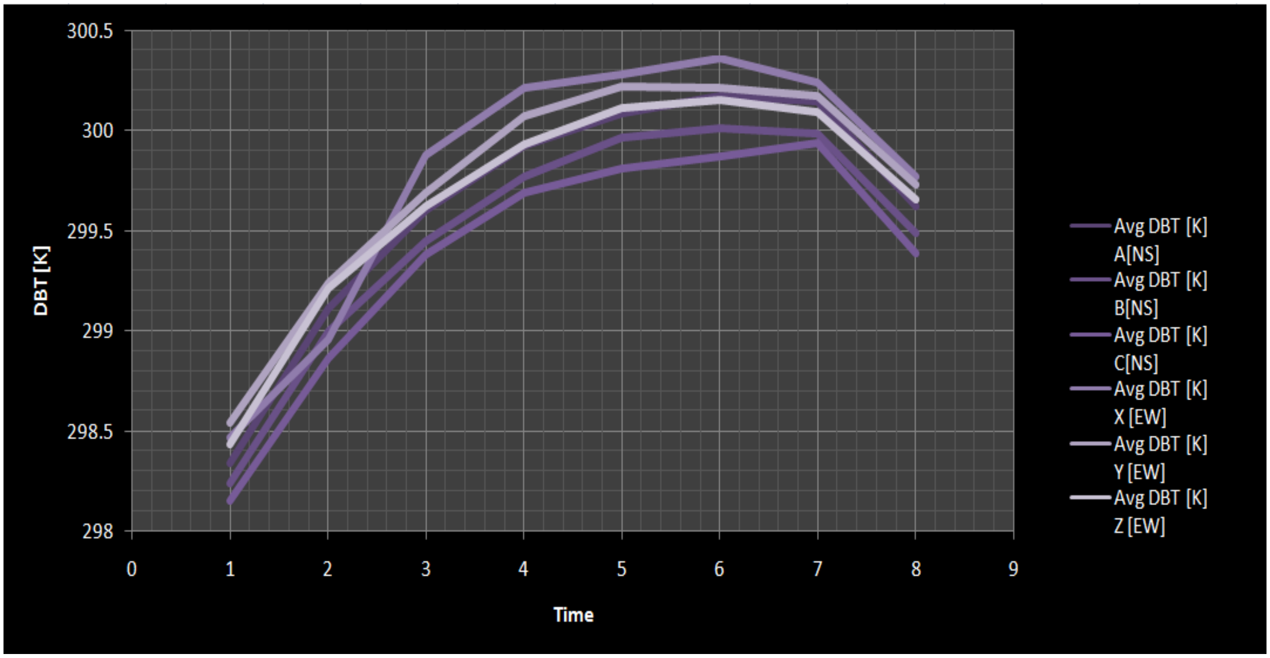

Fig 3.38: NS-EW canyon comparison of DBT [K] of simulated field condition in terms of time

Comparing dry bulb temperature of north south and east west canyons it can be seen that (Fig. 3.37 and Fig. 3.38) east west canyons achieved higher temperature than the north south which again supports the field survey results.

Considering mean radiant temperature of north south and east west canyons it can be seen that (Fig. 3.39 and Fig. 3.40) east west canyons are ahead than the north south canyons which supports the field survey results. Canyon 'X' gains the highest value of MRT among the rest.

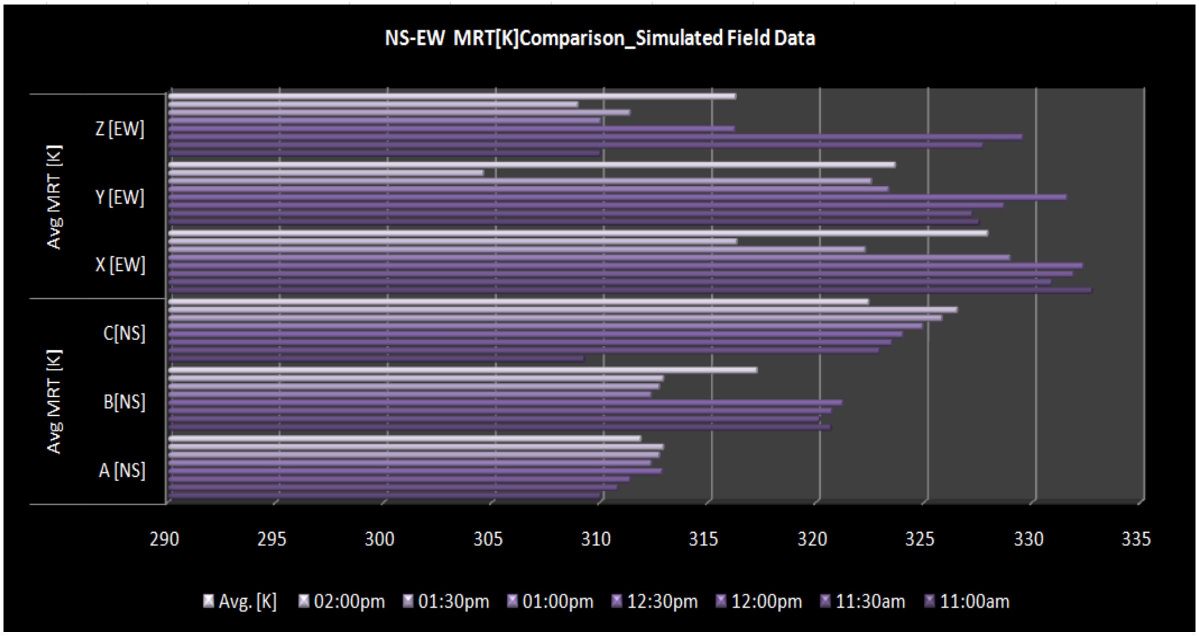

Fig 3.39: NS-EW canyon comparison of MRT [K] of simulated field condition

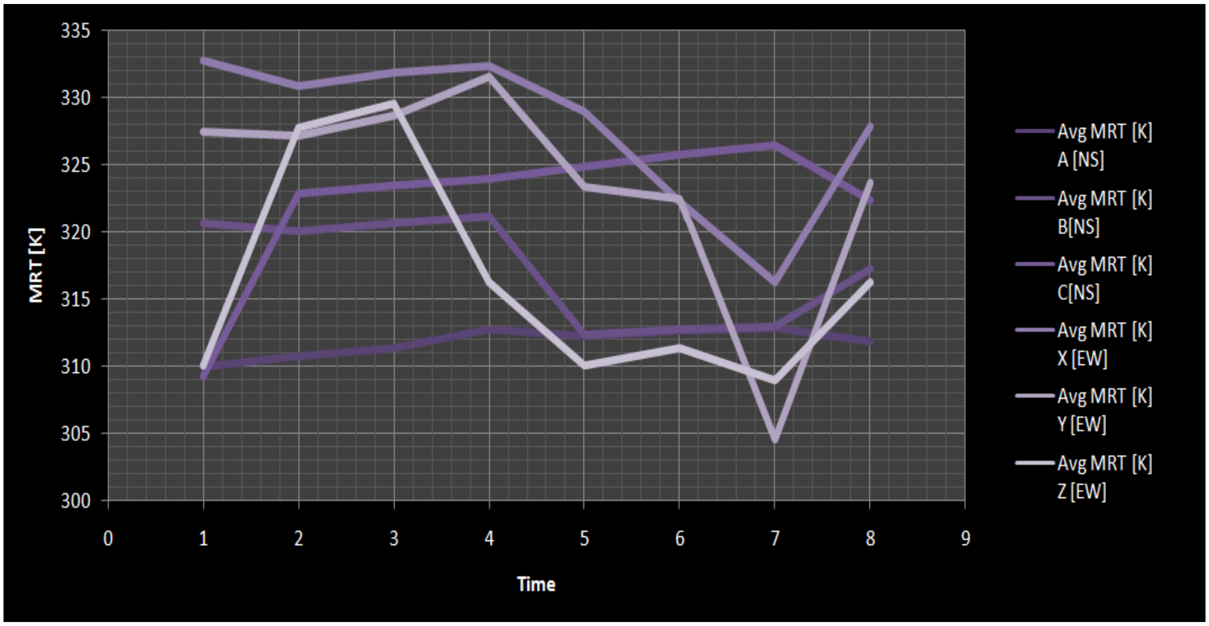

Fig 3.40: NS-EW canyon comparison of MRT [K] of simulated field condition in terms of time

In terms of relative humidity (Fig. 3.41 and Fig. 3.42) the results show close variations among the canyons except 'Z' canyon, while canyon 'A' tends to be higher than the rest which relates the filed survey data.

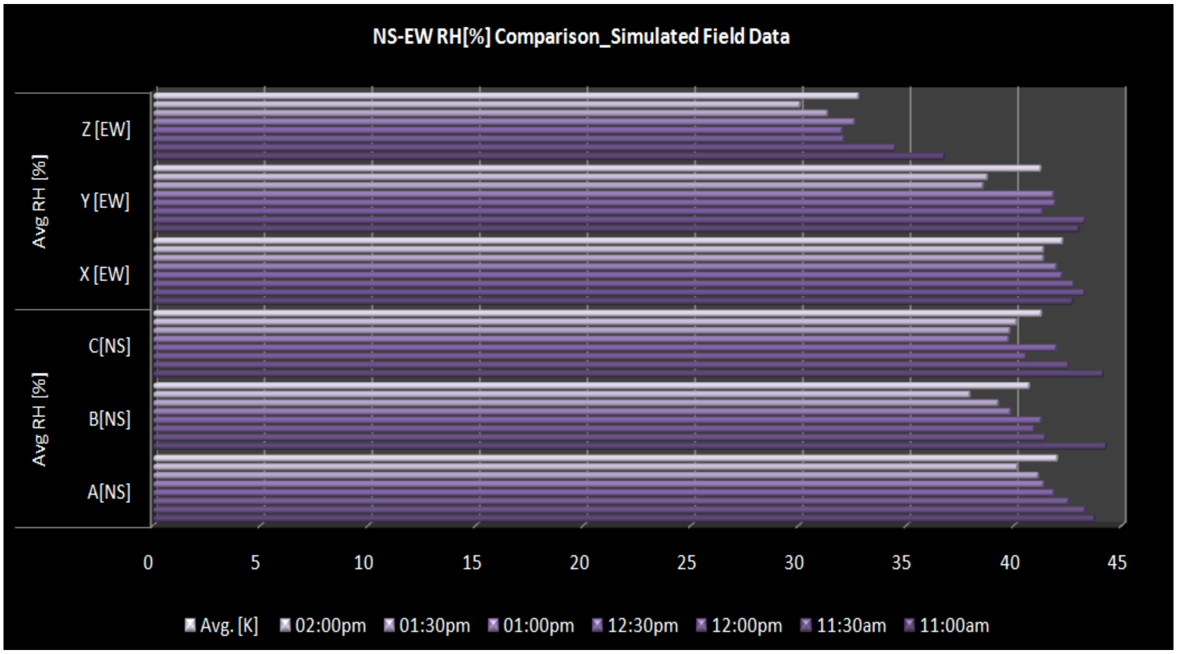

Fig 3.41: NS-EW canyon comparison of RH [%] of simulated field condition

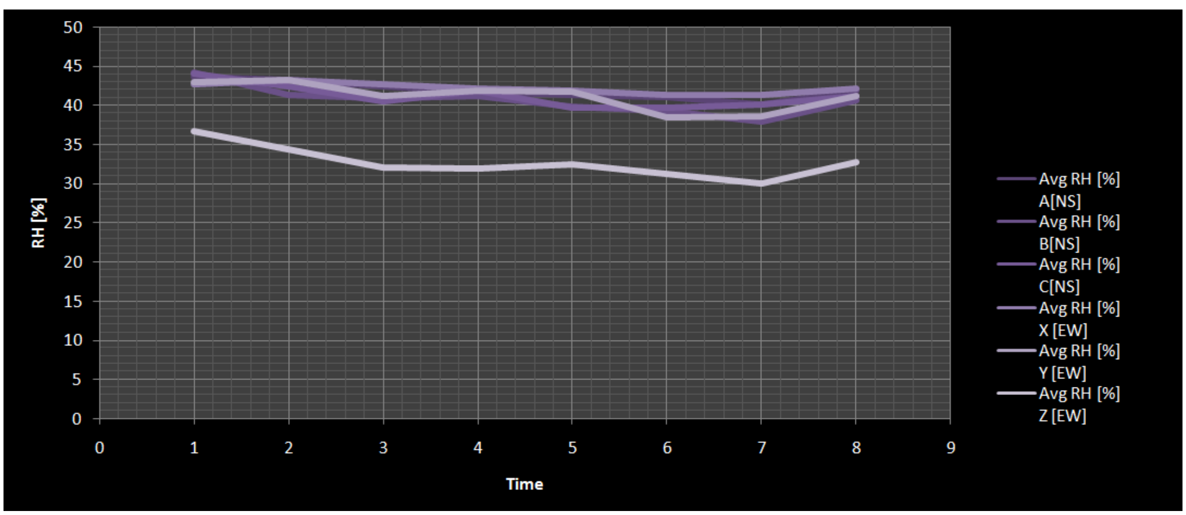

Fig 3.42: NS-EW canyon comparison of RH [%] of simulated field condition in terms of time

Considering wind speed data analysis it can be seen that (Fig. 3.43 and Fig. 3.44) the canyon ‘X’ is higher than ‘Y’ and ‘Z’ in terms of east west canyons and average wind speed of canyon ‘A’ is higher than canyon ‘B’ and ‘C’, while canyon ‘X’ achieves more wind speed than canyon ‘A’ which fully supports the field survey results.

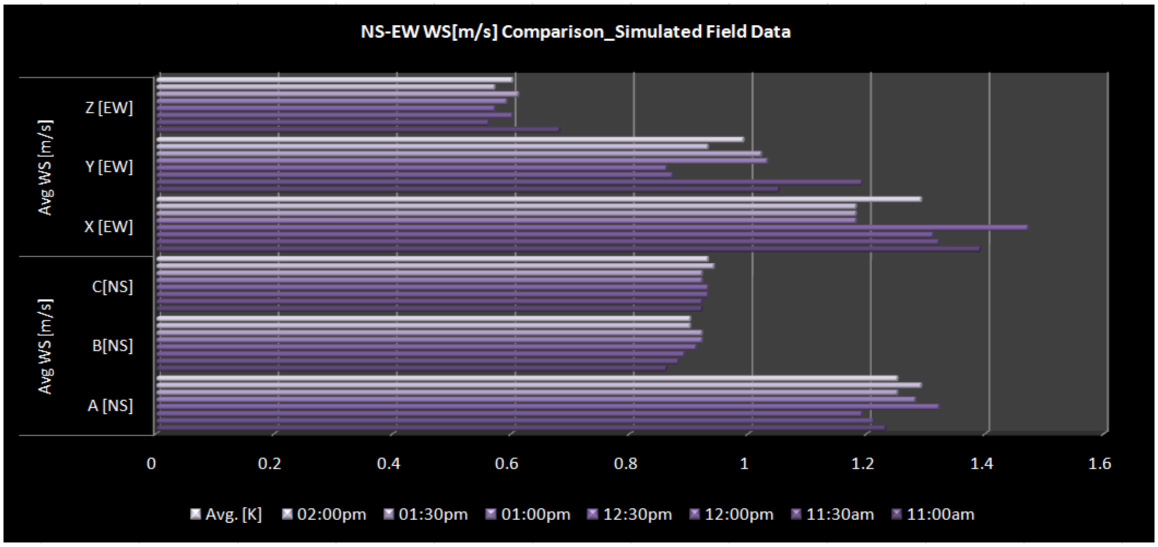

Fig 3.43: NS-EW canyon comparison of WS [m/s] of simulated field condition

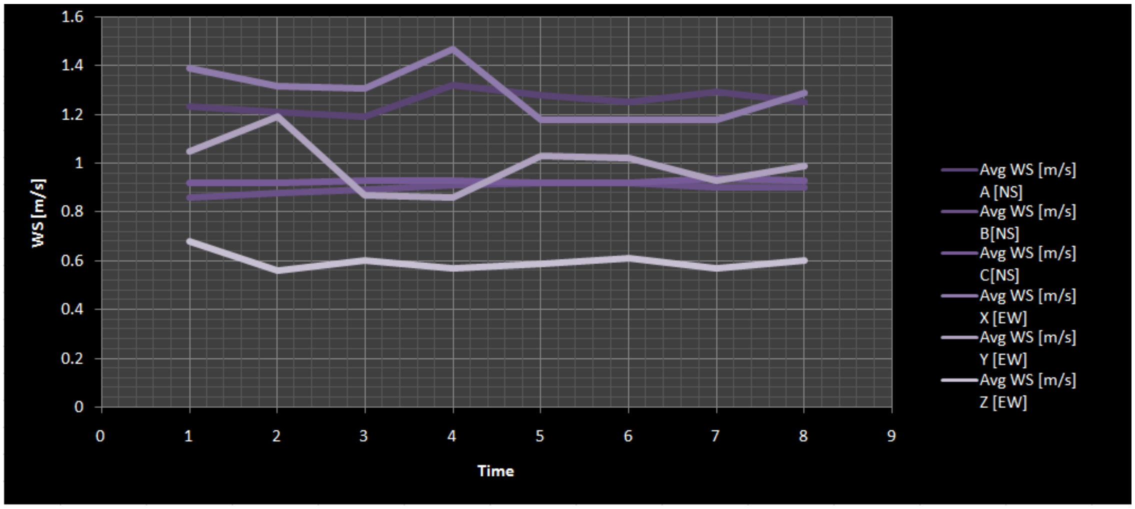

Fig 3.44: NS-EW canyon comparison of WS [m/s] of simulated field condition in terms of time

3.4. Comparative Study: Field Survey and Simulated Field Condition

In this part of the chapter deviation will be studied in terms of gathered field survey data and simulated data of the filed survey. In other words percentage difference will be studied which will be applied in the following chapter i.e. to the simulated data of various building model simulations.

While considering north south orientation during field survey it can be observed that the average value of mean radiant temperature came up to 305.53K, dry bulb temperature 309.08K, relative humidity 33.49% and wind speed 0.59 m/s; while in terms of east west orientation the results were 307.17K, 310.17K, 31% and 0.76 m/s respectively.

On the other hand from simulated field survey considering north south orientation it can be seen that the average value of mean radiant temperature was 317.15K, dry bulb temperature 299.5K, relative humidity was 41.27% and wind speed 0.9m/s, while in terms of east west orientation mean radiant temperature was 322.58K, dry bulb temperature was 299.7K, relative humidity came up to 38.48% and wind speed was 0.97m/s.

Thus calculating percentage differences in terms of north south orientation we get 3.73% for mean radiant temperature, 3.15% for dry bulb temperature, 20.81% for relative humidity and 41.61% for wind speed. Considering east west orientation the results are 4.89% for mean radiant temperature, 3.43% for dry bulb temperature 18.82% for relative humidity and 24.28% for wind speed.

3.5. Conclusion

This chapter concludes with the percentage difference study of the filed survey data and simulated field condition which have been applied in chapter four on the simulation results to get an overview of the condition in terms of factual situations. The deviations are expected as during simulation the building models were done following the building regulation while in reality there are deviations in buildings (Rahman, 2004), also vegetations were not provided during simulation; but in reality there were various green in front of the buildings within the canyons which influences the microclimate within the canyons, also there are various building materials within the buildings, while in simulation there were no variations. During field survey in some spots within the roads there were various water clogs, presence of building materials on the streets and movement of vehicles at different velocities and also the pollutants within the canyons which are likely to influence the microclimatic data.

3.6. References

Ahmed, Z. N. (1994), Assessments of Residential Sites in Dhaka with Respect to Solar Radiation Gains, a thesis submitted in partial fulfillment of the requirements of de Montfort University for the degree of Doctor of Philosophy.

Kushol S.A.S., Ahmed K.S., Hossain M.M., Rahman I. (2013), 'Effect of Street Morphology on Microclimate in Residential Areas Following FAR Rule in Dhaka City', PLEA2013 (Passive and Low Energy Architecture) - 29th Conference, Sustainable Architecture for a Renewable Future, Munich, Germany10-12 September 2013.

Priyadarsini, R., and Wong, N.H., (2005), 'Parametric Studies on Urban Geometry, Air Flow and Temperature', International Journal on Architectural Science, Volume 6, Number 3, p.114-132, 2005.

Rahman, A., (2004), 'Climatic Evaluation of Planned Developments in the Context of Dhaka City', M. Arch. Thesis (unpublished), Bangladesh University of Engineering and Technology, Bangladesh.

Chapter Four: Simulation Study

Introduction

Microclimate Study as per 1996 by-law

Microclimate Study as per 2013 Building Regulation

Graphical Outputs

Conclusion

References

4. Simulation Study

4.1. Introduction

This chapter will discuss on the outcomes of simulation considering all the typologies [typologies A 1996 Og (buildings placed on-ground under 1996 by-law), A1 1996 El (elevated buildings under 1996 by-law), B 2013 Og cc (On-ground closely placed buildings under 2013 building regulation), B1 2013 Og ff (On-ground buildings placed apart under 2013 building regulation), B2 2013 El cc (closely placed elevated buildings under 2013 building regulation) and B3 2013 El ff (elevated buildings placed apart under 2013 building regulation] considering North-South and East-West orientation, aspect ratio (H/W) and building mass configuration (Og/El) in terms of both 1996 and present building regulation. Line of symmetry (LoS) were considered while simulating, through advanced simulation tool, three dimensional model 'ENVI-met; version 3.1 BETA 5' used to create different possible building models. As the study focuses on Uttara third phase where it has (15+15) =30 plots within a block, microclimate data were collected from one third (central part) of the block consisting (5+5) =10 plots at total of 16 spots on both sides to avoid the nodal effect of microclimate within the canyons at both ends.

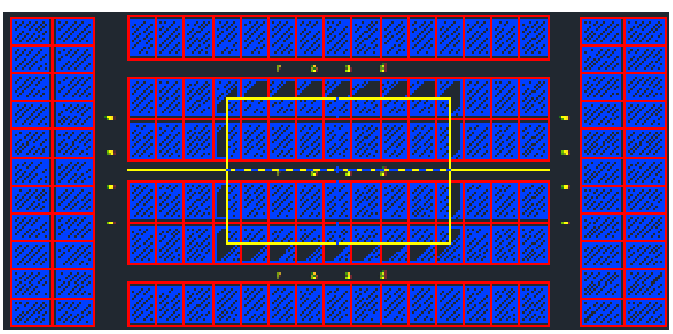

Fig 4.1 Plot arrangements - data collection area (EW oriented street) with line of symmetry [LoS]

Simulations were done from 10am for 6 hours of which data were collected from 11am to 2pm as (Ahmed K.S., 1995) found the critical period is between 11:00 and 14:00 hours, in terms of Urban Design Objectives for Outdoor Comfort in the Context of Dhaka and this research is also focused on daytime temperature, thus while collecting data from simulation the time was considered from 11am to 2pm at 30 minutes interval (i.e. 11am, 11.30am, 12pm, 12.30pm, 1pm, 1.30pm and 2pm for each simulation typologies) of which in this chapter simulation results at '2pm' only of all simulation typologies in terms of MRT, DBT, RH, WS and WS (in section) of the street canyons are shown while the rest are provided in the appendix. Within these simulation images data charts (after applying the deviation from previous chapter of field survey study) and graphs are provided. Finally compiled data with comparative graphs and tables are presented and discussed at the end of the chapter in terms of orientation, simulation typologies at different times which are used for statistical analysis in chapter 5.

Data used for Simulation in Configuration File [.cf] are as follows:

Following data were set for the simulations while configuring the configuration (.cf) file. Simulation date and time were discussed in chapter 1, while the meteorological data were taken from (BMD, 2013) and the roughness length is approximately 1/30 the height of the average roughness element protruding from the surface (Jacobson M. Z., 2005).

Table 4.1: Input data for simulation

Start Simulation at Day (DD.MM.YYYY):	24.04.2013
Start Simulation at Time (HH:MM:SS):	10:00:00
Total Simulation Time in Hours:	6
Save Model State each? min	30
Wind Speed in 10 m ab. Ground [m/s]	3.7
Wind Direction (0:N..90:E..180:S..270:W..)	225
Roughness Length z_0 at Reference Point	0.6 [1996] 0.8 [2013]
Initial Temperature Atmosphere [K]	302.25

4.2. Microclimate Study as per 1996 by-law

In this section of the chapter building models under 1996 regulation are presented for microclimate study of the desired canyons. The sub-sections discusses on, 'on-ground' and 'elevated' buildings separately in terms of both, north-south and east-west orientations.

4.2.1. **North South Oriented Streets:** [Building Mass Configuration]

Simulation results considering north south orientated streets with building models under 1996 by law are presented (simulation results of 2pm) in terms of building mass configuration (on-ground and elevated) are shown below with different microclimatic parameters i.e. MRT, DBT, RH, WS and ‘WS in section’.

4.2.1.1. **On-Ground Buildings:** [Type A _ North South oriented canyons]

DBT

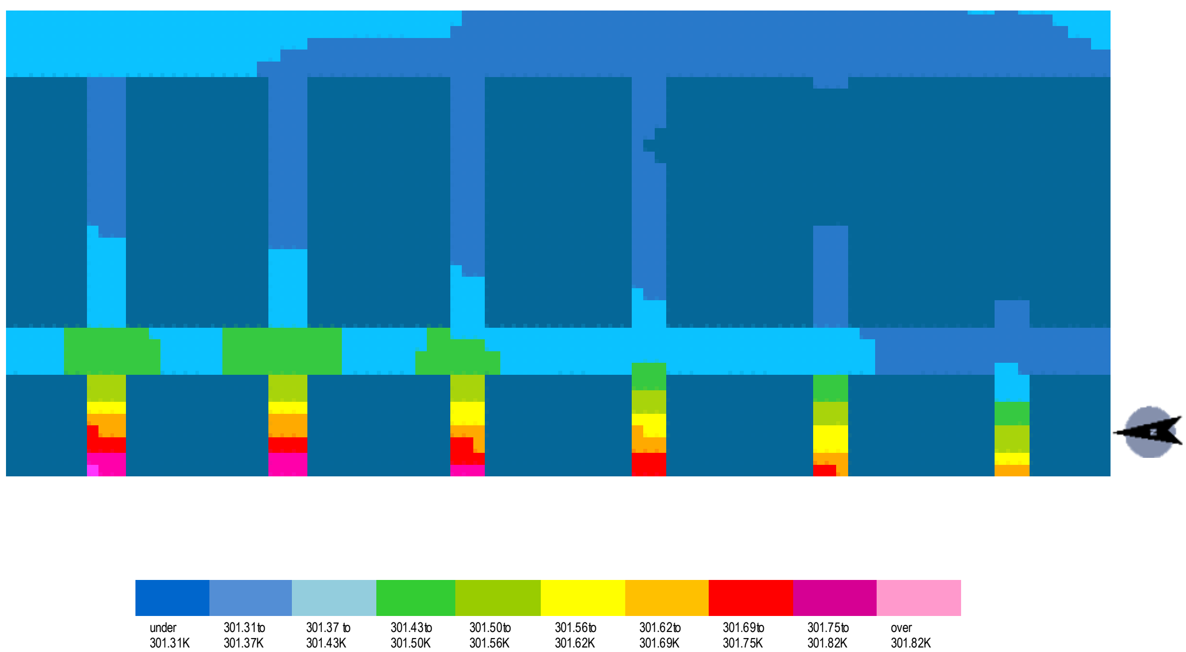

Fig 4.2: Dry bulb temperature of type A-NS Og structures

In terms of ‘type A’ structures it can be seen that (Fig. 4.2) the southern part of the canyon is cooler than the northern in terms of DBT, as wind direction is at 225; i.e. from south-west.

MRT

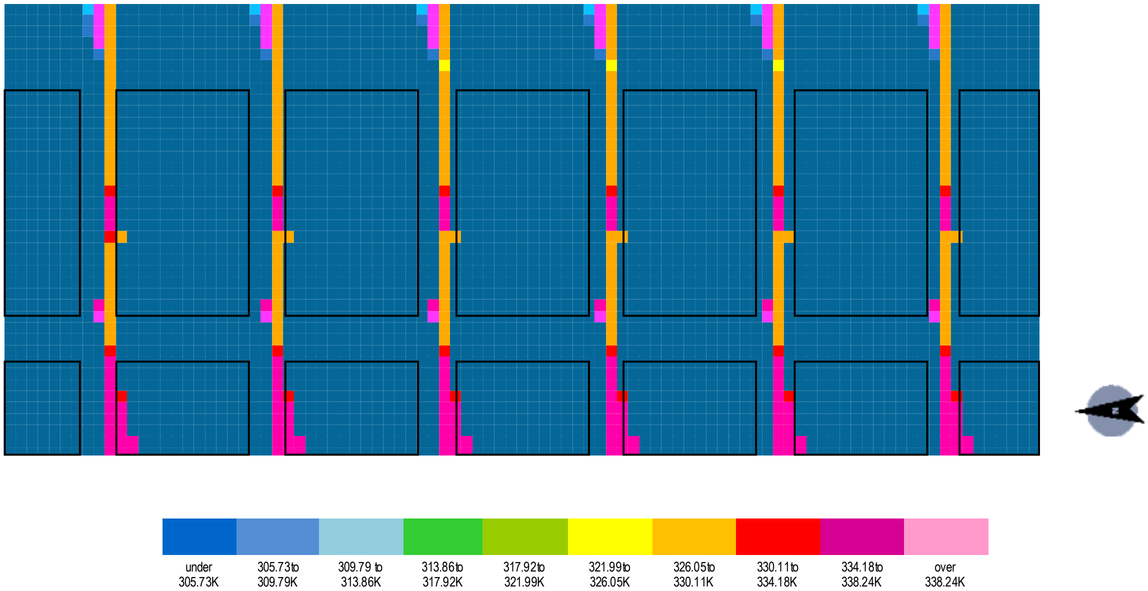

Fig 4.3: Mean radiant temperature of type A-NS Og structures

While considering MRT it can be seen (Fig. 4.3) that the building setbacks have impact within the canyons.

RH

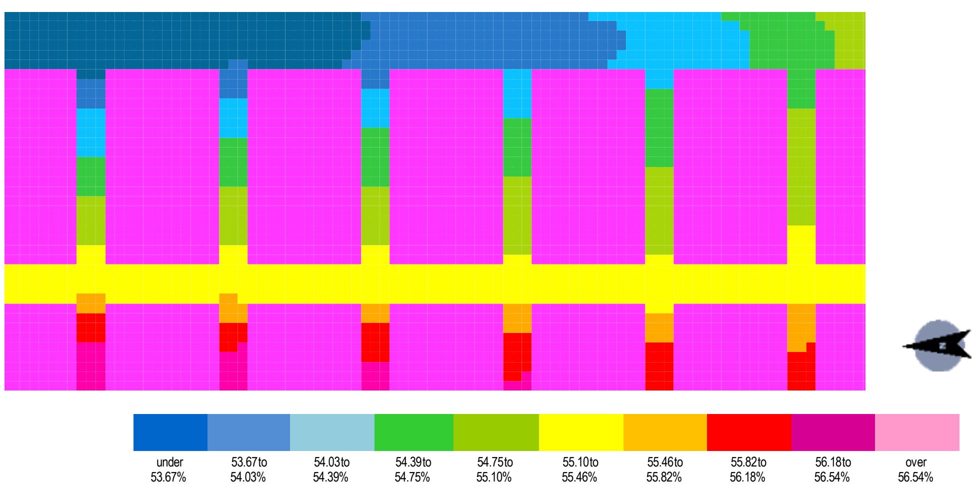

Fig4.4:Relative humidity of type A-NS Og structures

Relative humidity is less at north part of the canyon than the south, while moderate to high between the rear setbacks of the buildings (Fig. 4.4).

WS

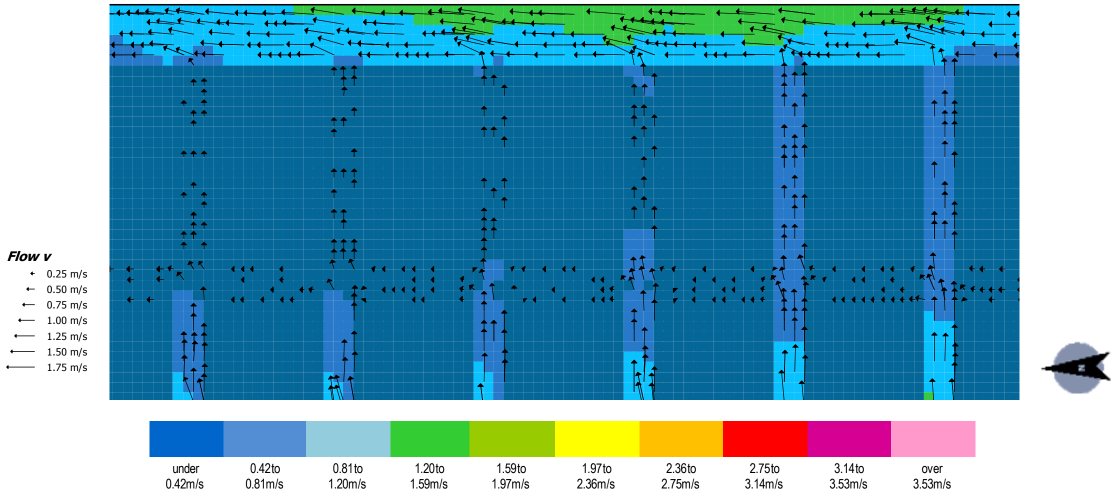

Fig 4.5: Wind speed of type A-NS Og structures

Wind speed increases at the centre part of the canyons, while lowest in between the building setbacks (Fig. 4.5), while vertically increases (Fig. 4.6).

WS_Section

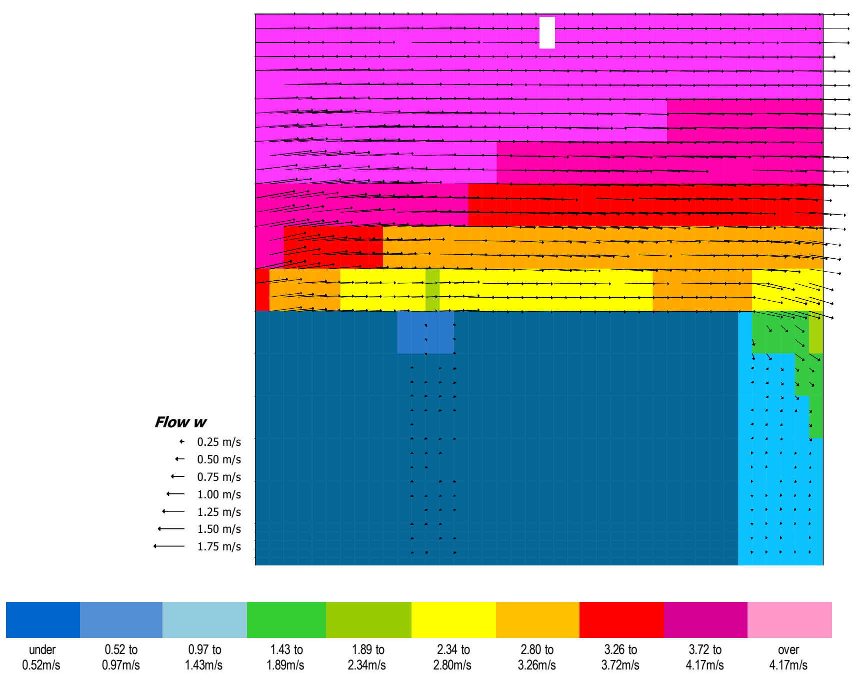

Fig 4.6: Wind speed-section of type A-NS Og structures

4.2.1.2. **Elevated Buildings [El]:** [Type A1 _ North South oriented canyons]

DBT

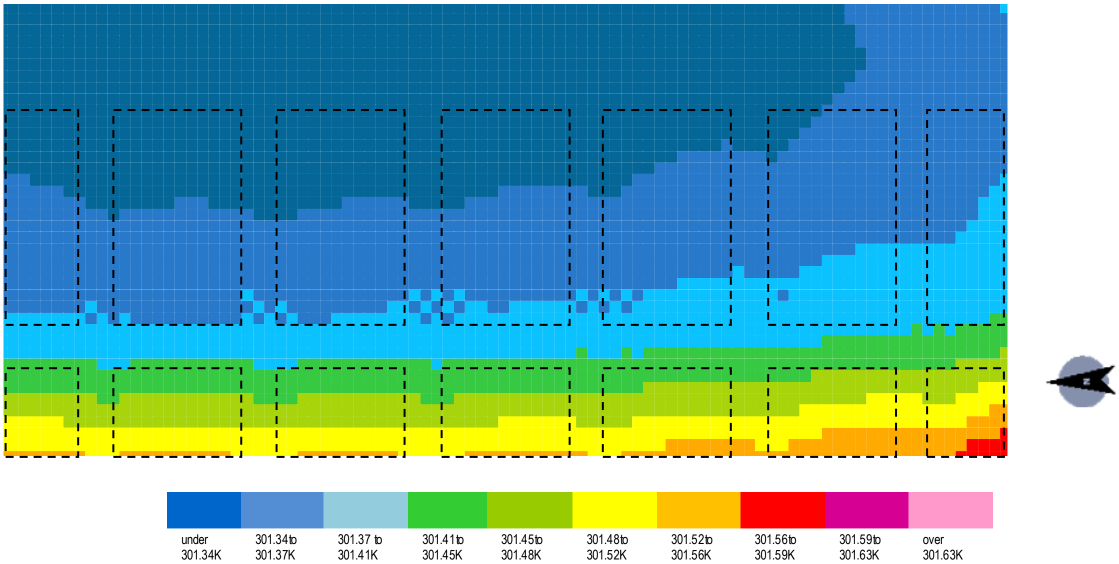

Fig 4.7: Dry bulb temperature of type A1-NS El structures

DBT increases at the southern part of the canyon (Fig. 4.7), while building setbacks have

MRT

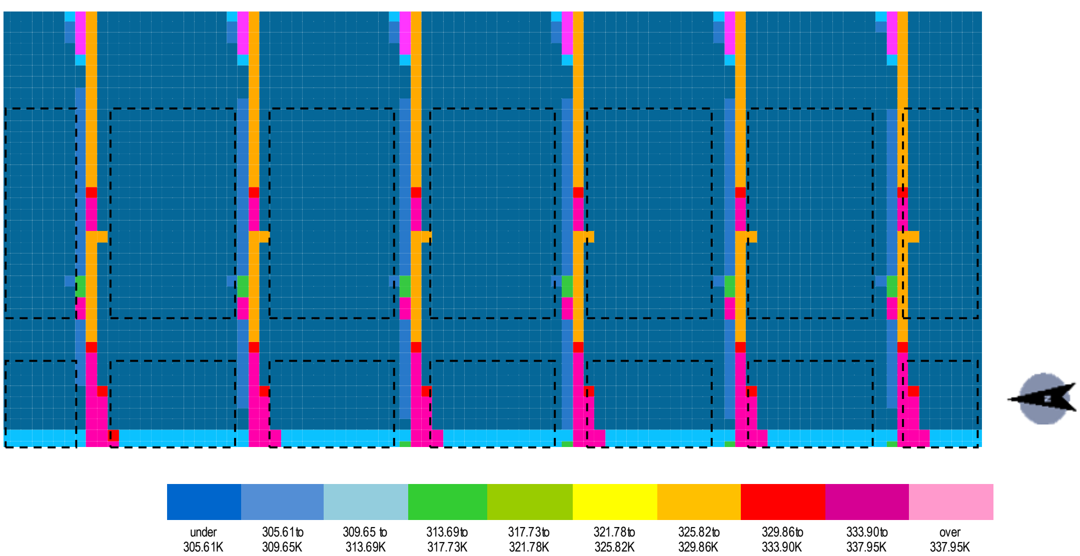

Fig 4.8: Mean radiant temperature of type A1-NS El structures

impact within the canyons in terms of MRT (Fig.4.8).

RH

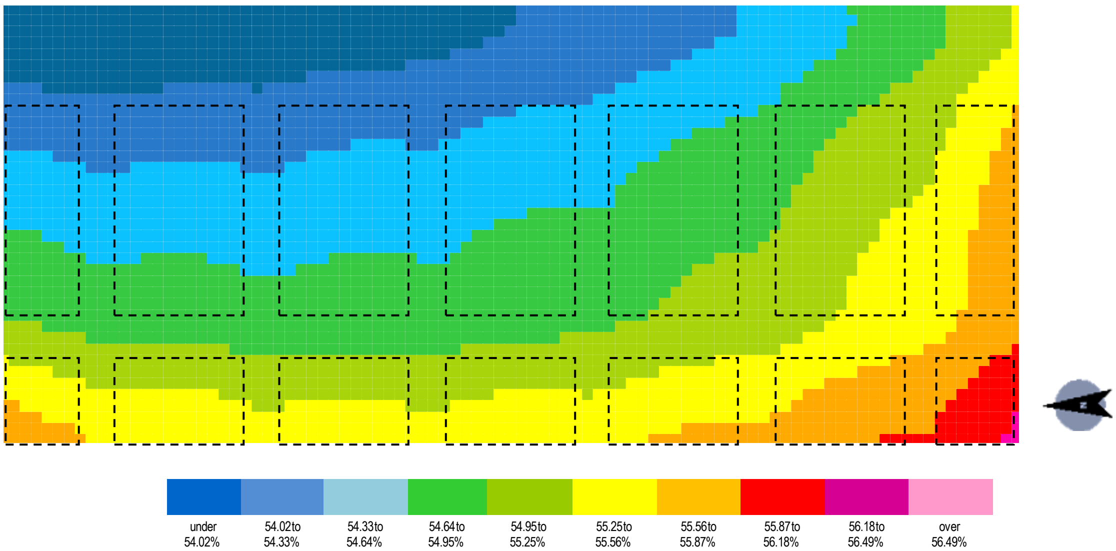

Fig 4.9: Relative humidity of type A1-NS El structures

Relative humidity gradually increases at the southern part of the canyon (Fig. 4.9).

WS

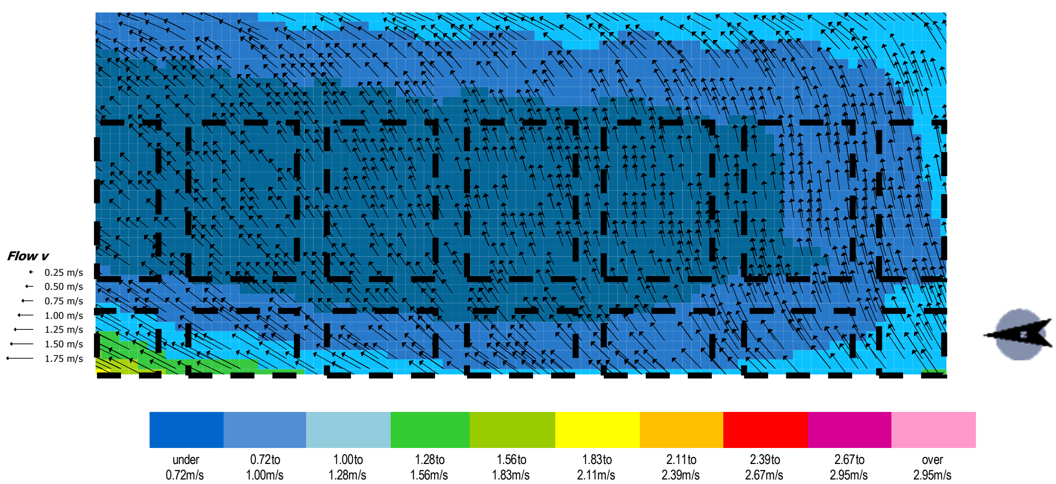

Fig 4.10: Wind speed of type A1-NS El structures

Wind speed increases at the south part of the canyon (Fig. 4.10).

WS_Section

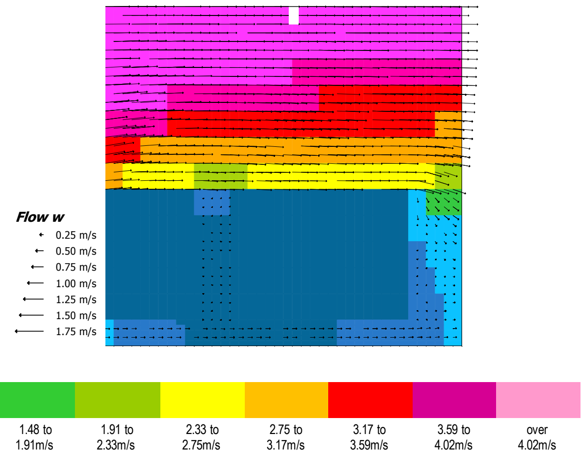

Fig 4.11: Wind speed-section of type A1-NS El structures

4.2.2. **East West Oriented Streets:** [Building Mass Configuration]

4.2.2.1. **On-Ground Buildings** [Og]: [Type A _ East West oriented canyons]

Fig 4.12-4.16 illustrates conditions of DBT, MRT, RH and WS respectively in terms of east west oriented canyons considering on-ground buildings of 'type A'.

DBT

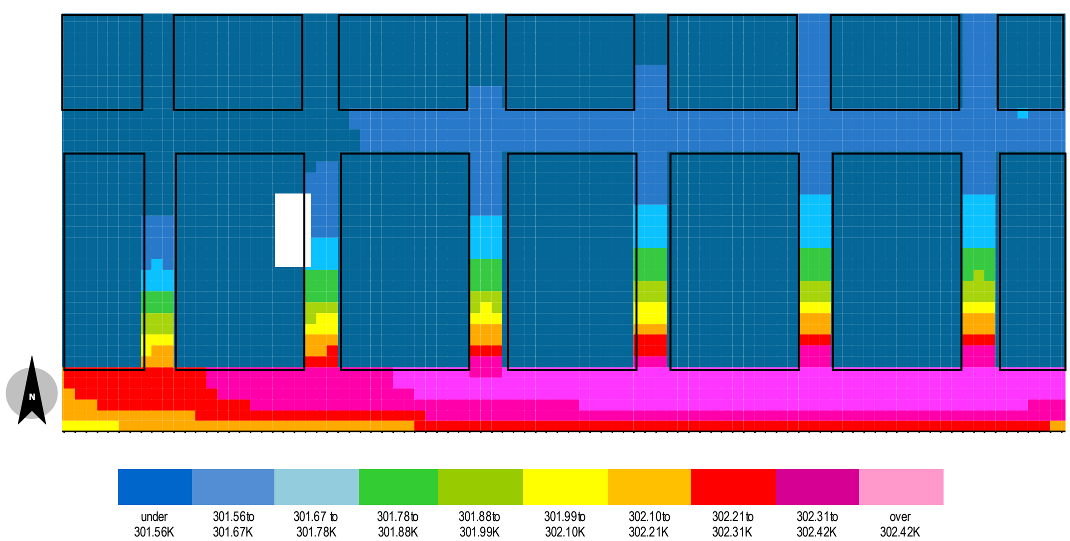

Fig 4.12: Dry bulb temperature of type A-EW Og structures

MRT

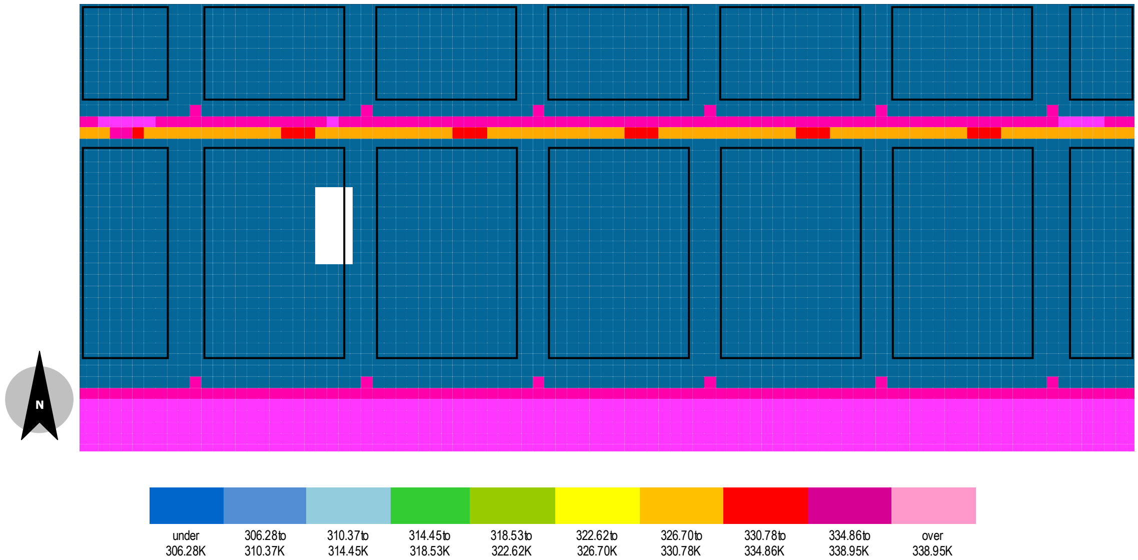

Fig 4.13: Mean radiant temperature of type A-EW Og structures

RH

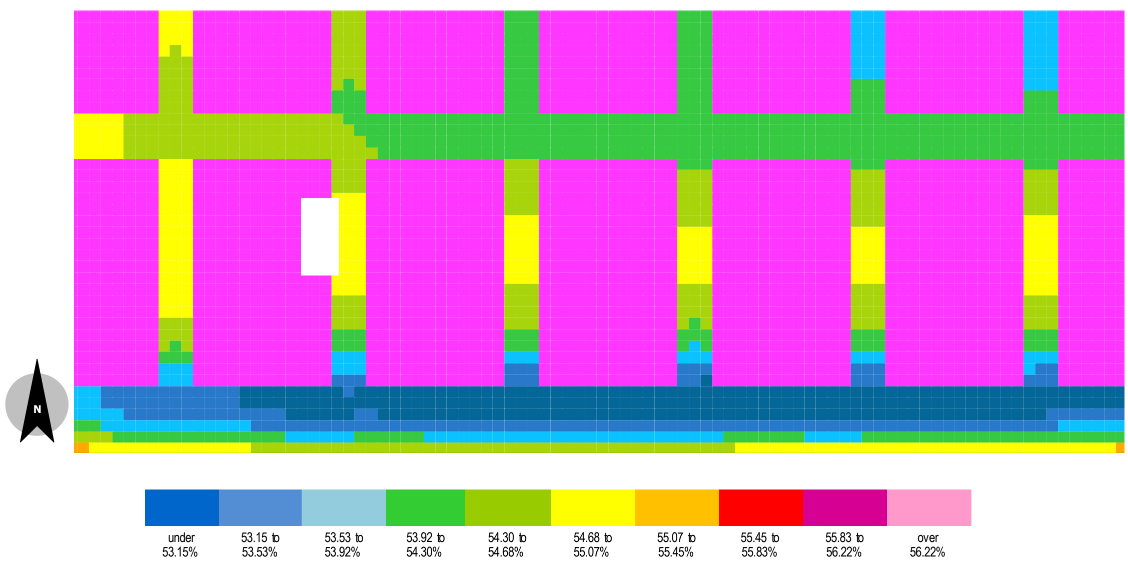

Fig 4.14: Relative humidity of type A-EW Og structures

WS

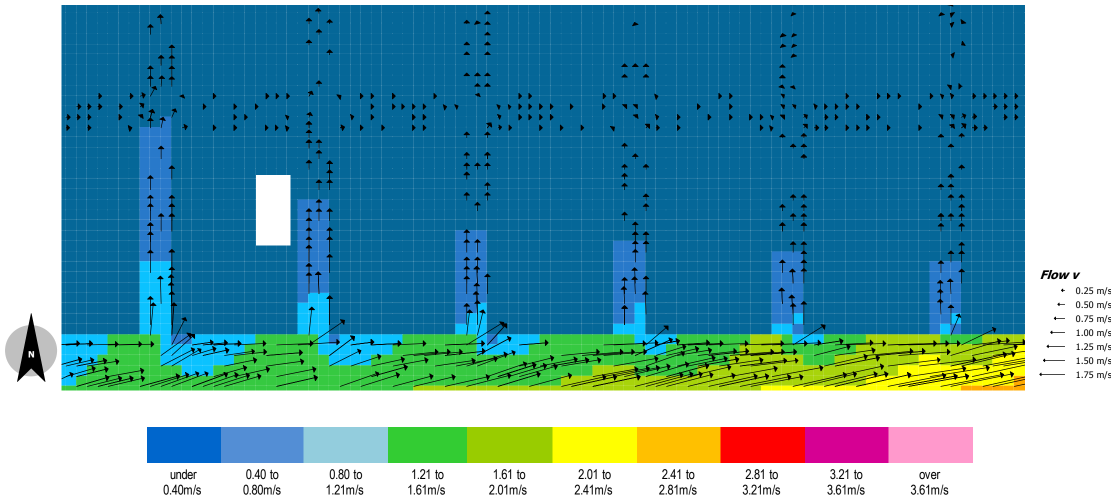

Fig 4.15: Wind speed of type A-EW Og structures

WS_Section

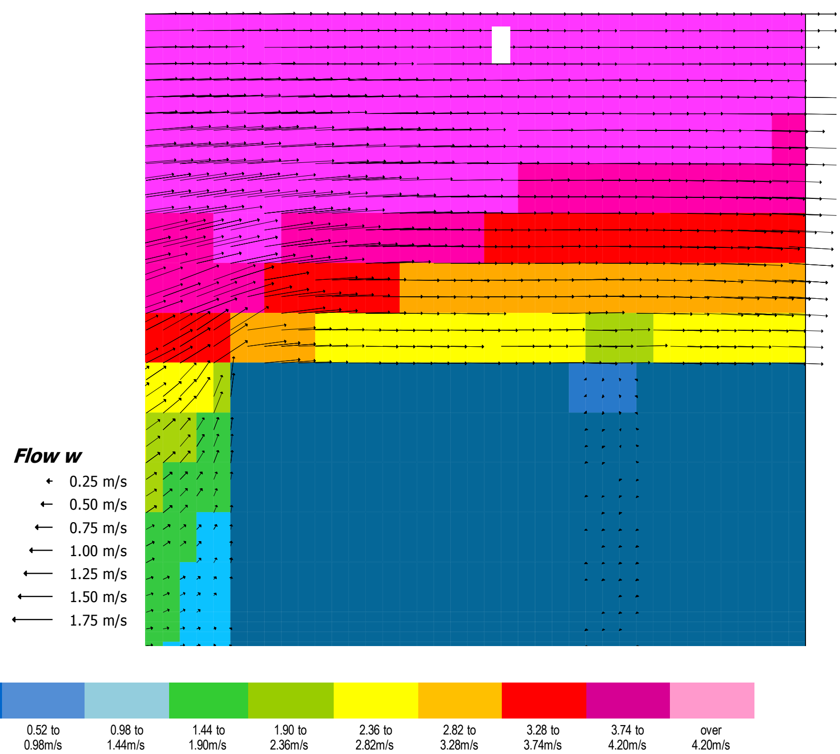

Fig 4.16: Wind speed-section of type A-EW Og structures

4.2.2.2. **Elevated Buildings** [El]: [Type A1_East West oriented canyons]

Fig 4.17-4.21 illustrates conditions of DBT, MRT, RH and WS respectively in terms of east west oriented canyons considering elevated buildings of ‘type A1’.

DBT

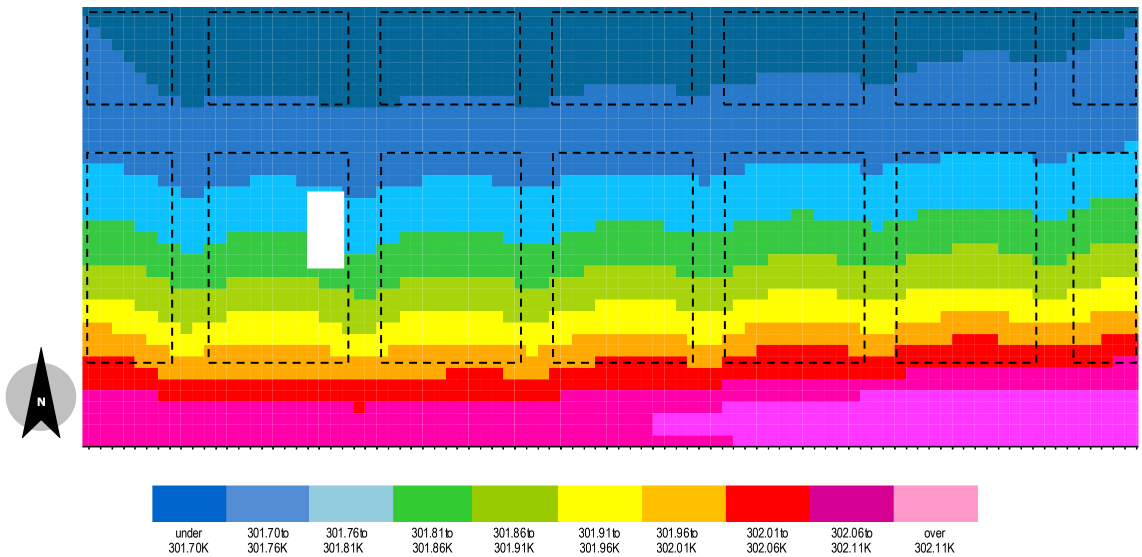

Fig 4.17: Dry bulb temperature of type A1-EW El structures

MRT

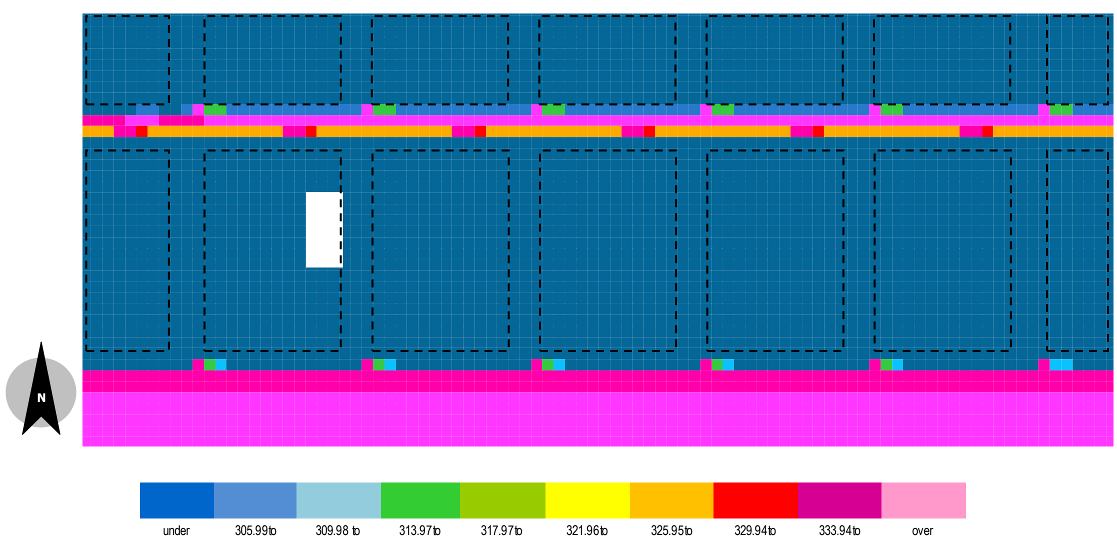

Fig 4.18: Mean radiant temperature of type A1-EW El structures

RH

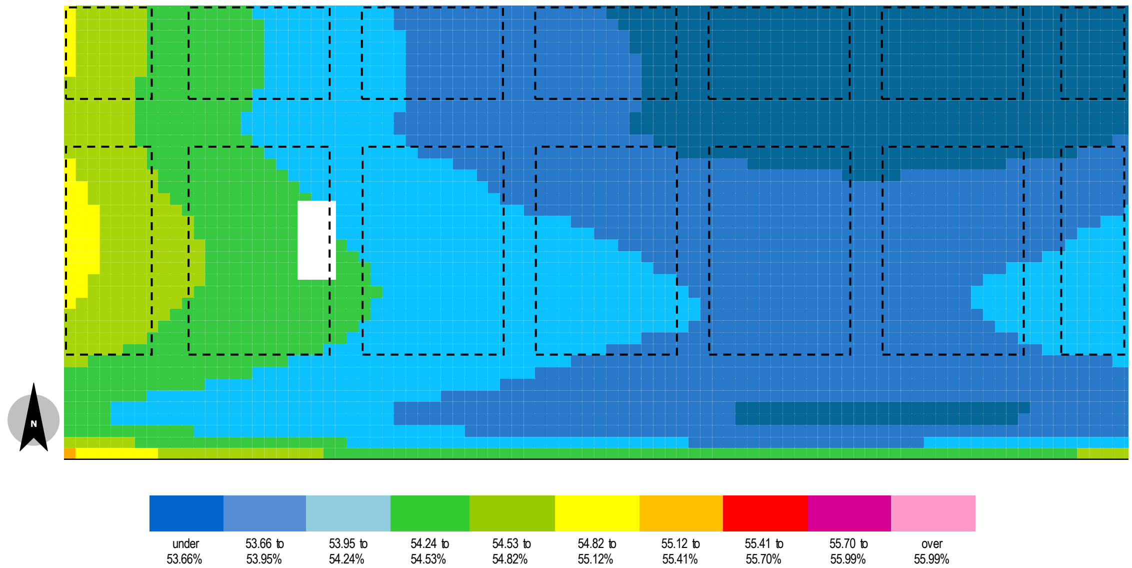

Fig 4.19: Relative humidity of type A1-EW El structures

WS

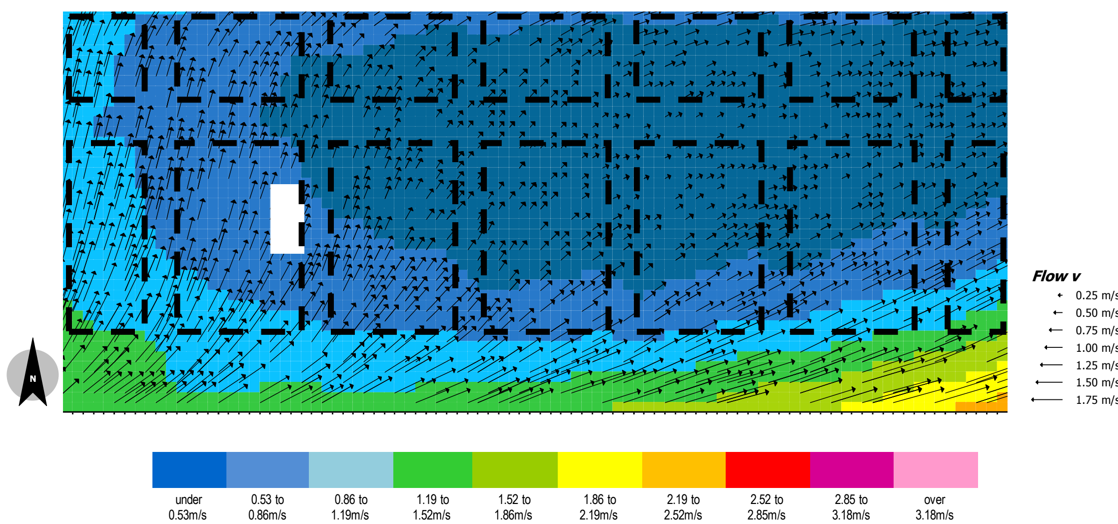

Fig 4.20: Wind speed of type A1-EW El structures

WS_section

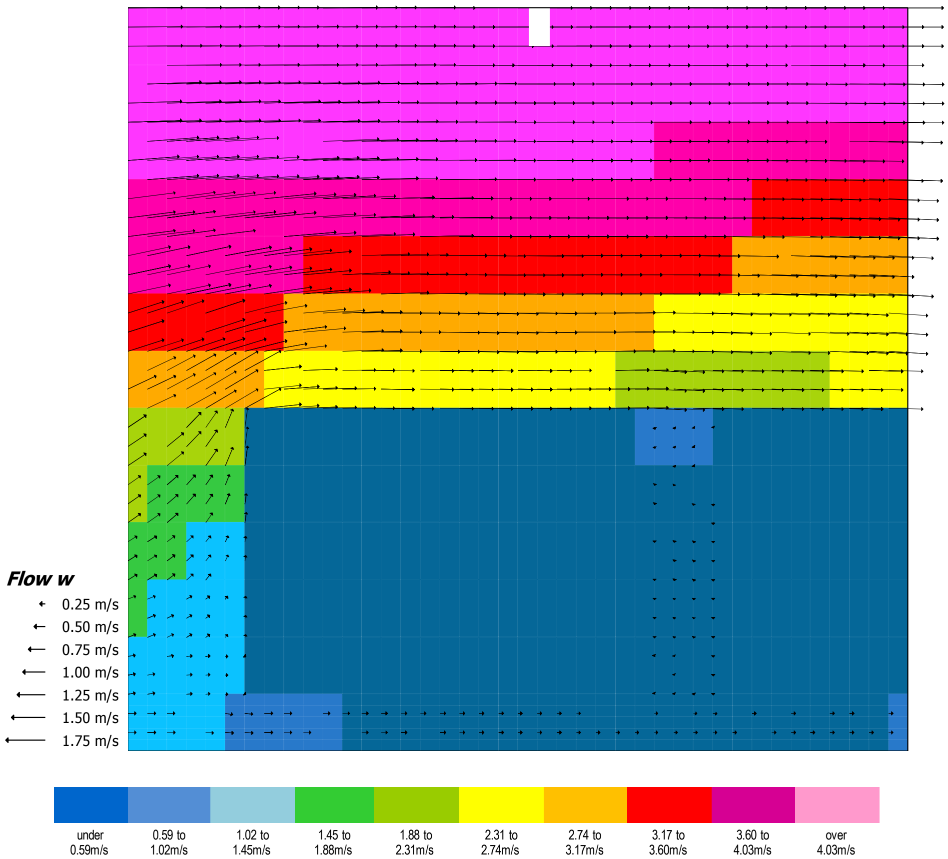

Fig 4.21: Wind speed-section of type A1-EW El structures

4.3. Microclimate Study as per 2013 Building Regulation

These parts of the chapter building models under existing building regulation are presented for microclimate study of the desired canyons. The sub-sections discusses on, ‘on-ground’ and ‘elevated’ buildings in terms of closely placed (cc) buildings and buildings placed apart (ff) separately in terms of both, north-south and east-west orientations.

4.3.1. **North South Oriented Streets:** Aspect Ratio due to MGC

Simulation results considering north south orientated streets with building models under existing building regulation are presented (simulation results at 2pm) in terms of building mass configuration (‘Og’ and ‘El’) and aspect ratio (‘cc’ and ‘ff’) separately with different microclimatic parameters i.e. MRT, DBT, RH, WS and WS in section.

4.3.1.1. **Buildings Closely Placed [cc]**

4.3.1.1.1. **On-Ground Buildings** [Og]: [Type B_North South oriented canyons]

Fig 4.22-4.26 illustrates conditions of DBT, MRT, RH and WS respectively in terms of north south oriented canyons considering on-ground buildings of ‘type B’.

DBT

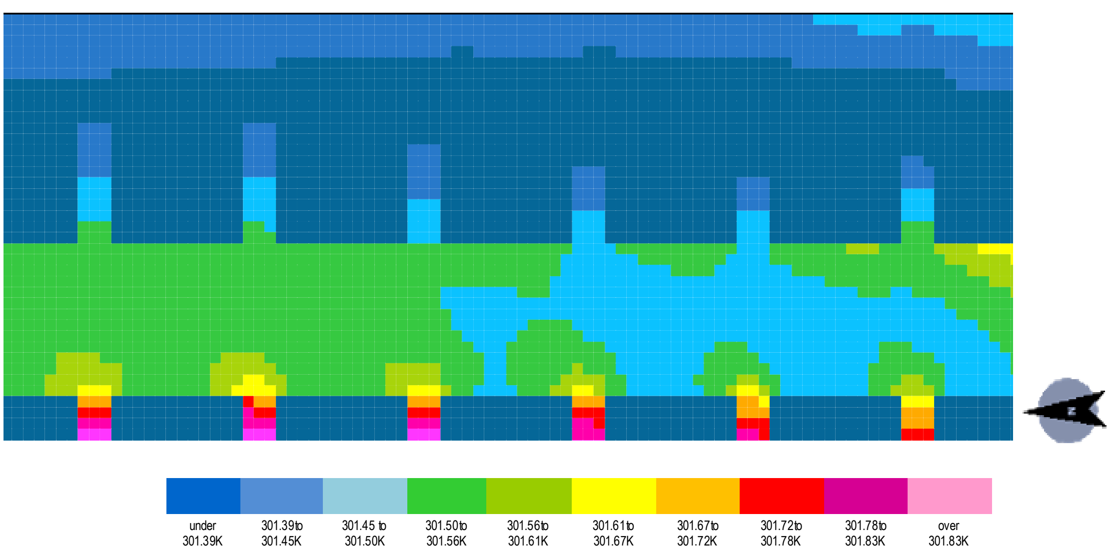

Fig 4.22: Dry bulb temperature of type B-NS Og structures

MRT

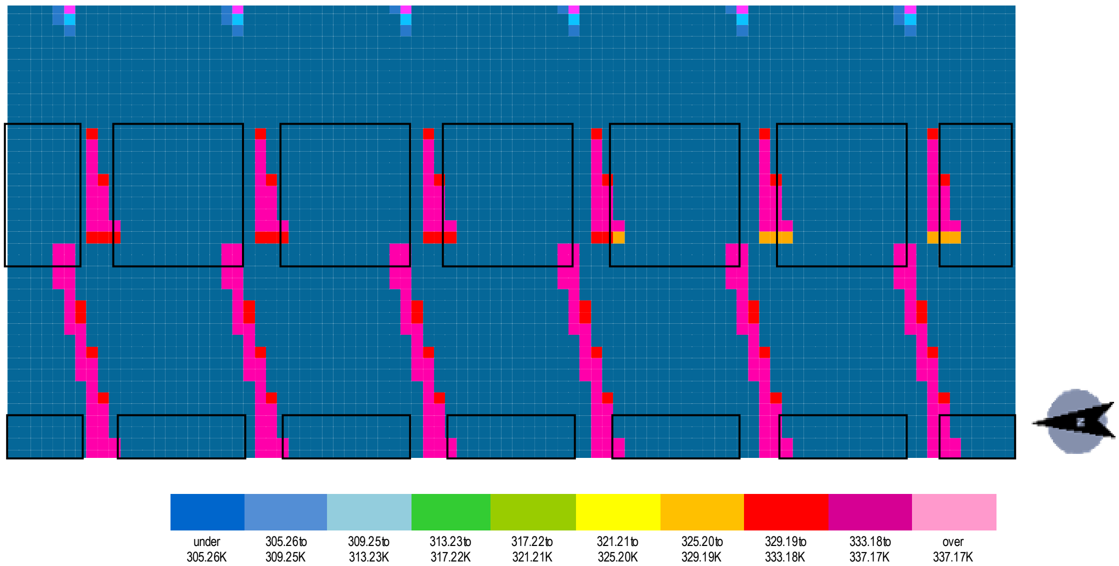

Fig 4.23: Mean radiant temperature of type B-NS Og structures

RH

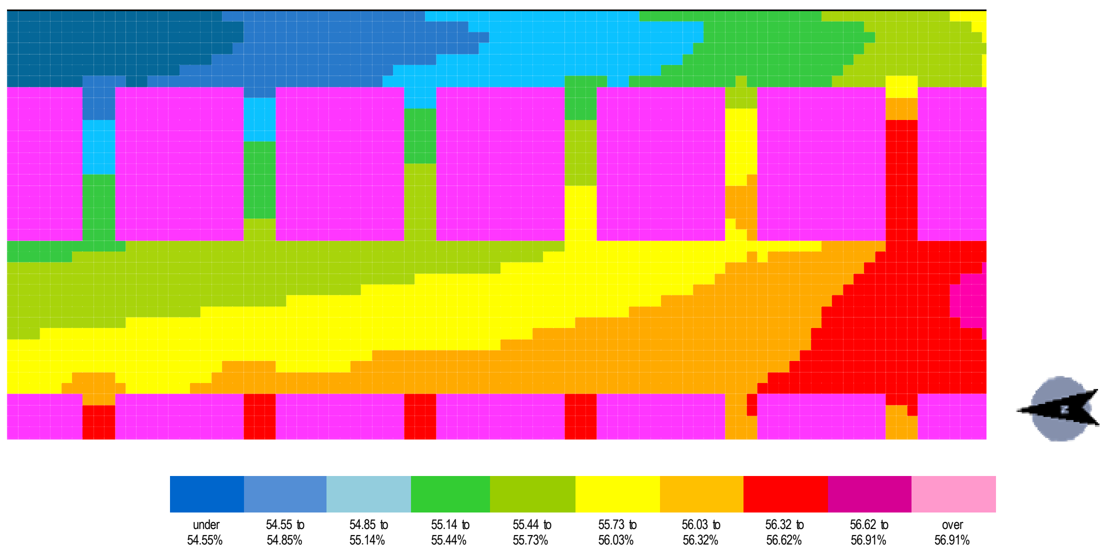

Fig 4.24: Relative humidity of type B-NS Og structures

WS

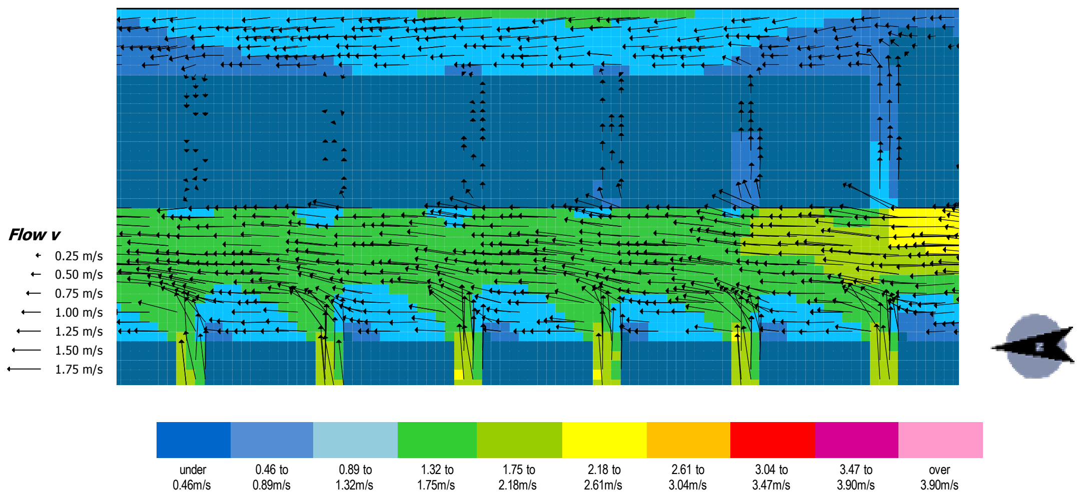

Fig 4.25: Wind speed of type B-NS Og structures

WS_Section

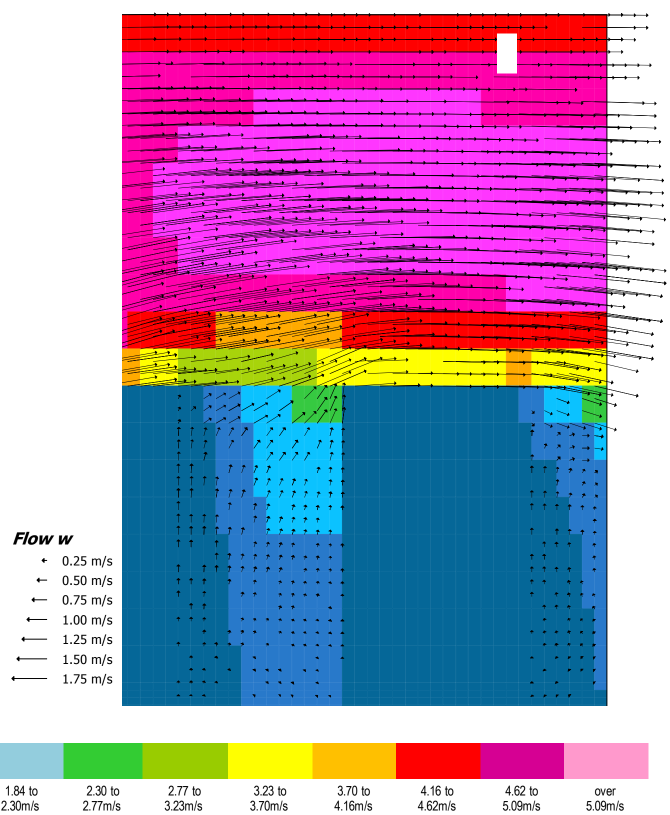

Fig 4.26: Wind speed-section of type B-NS Og structures

4.3.1.1.2. **Elevated Buildings** [El]: [Type B2_North South oriented canyons]

Fig 4.27-4.31 illustrates conditions of DBT, MRT, RH and WS respectively in terms of north south oriented canyons considering elevated buildings of ‘type B2’.

DBT

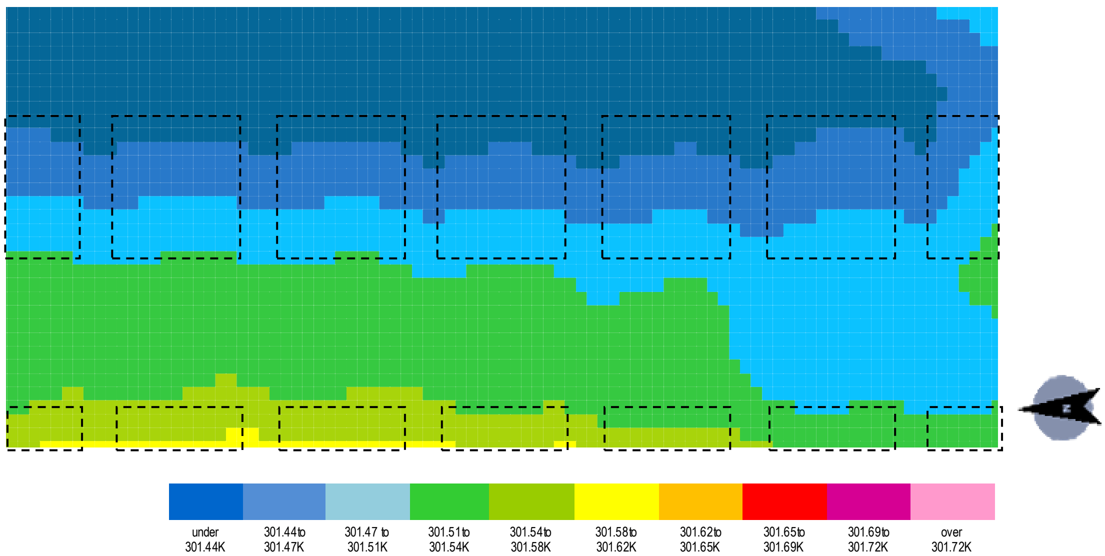

Fig 4.27: Dry bulb temperature of type B2-NS El structures

MRT

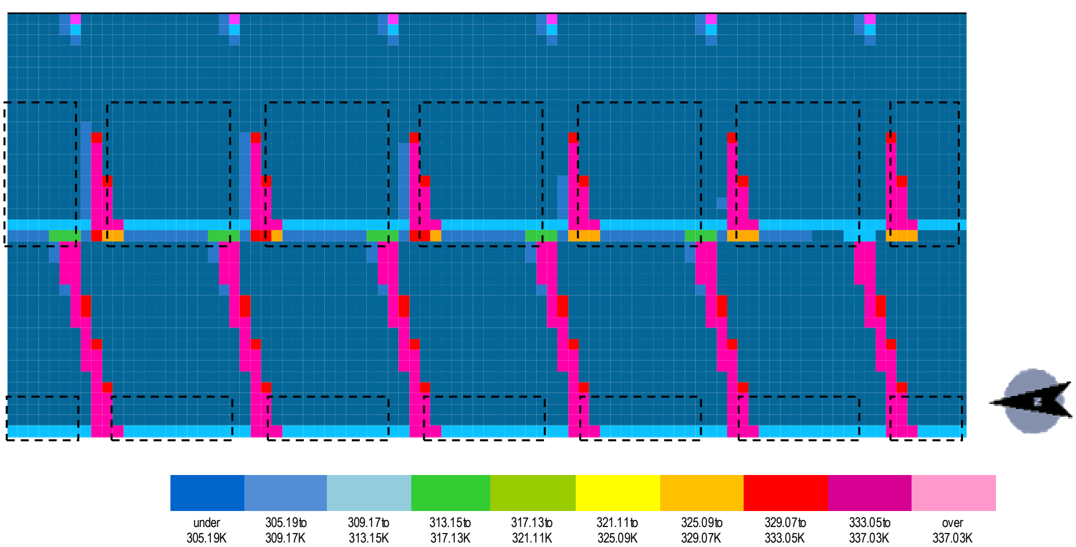

Fig 4.28: Mean radiant temperature of type B2-NS El structures

RH

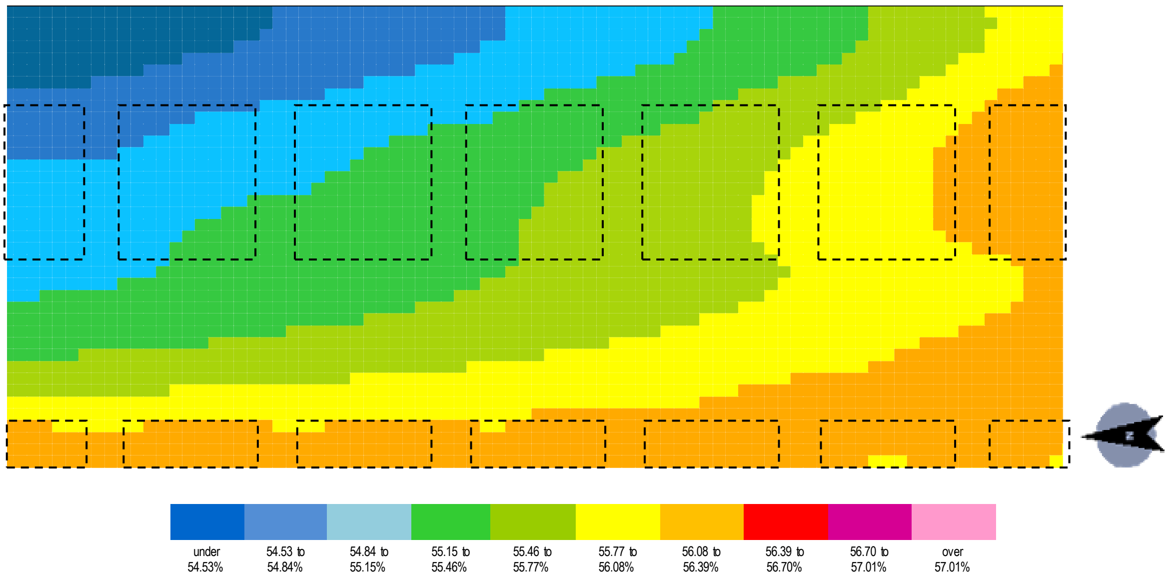

Fig 4.29: Relative humidity of type B2-NS El structures

WS

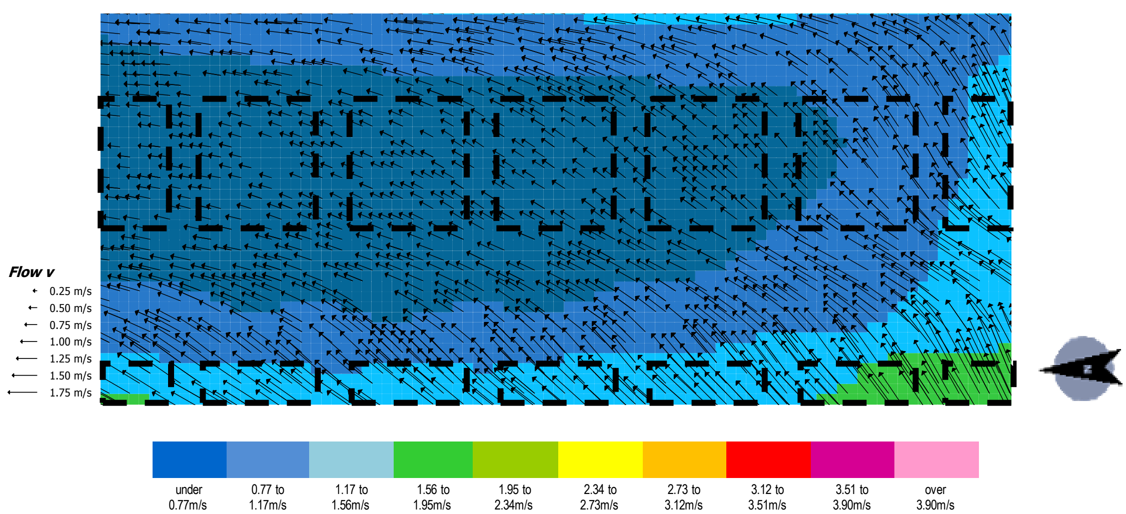

Fig 4.30: Wind speed of type B2-NS El structures

WS_Section

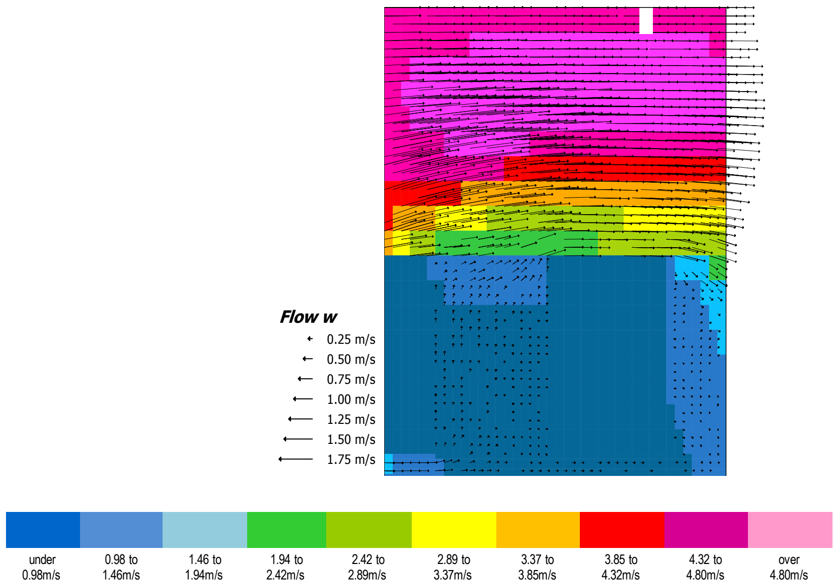

Fig 4.31: Wind speed-section of type B2-NS El structures

4.3.1.2. Buildings Placed Apart [ff]

4.3.1.2.1. On-Ground Buildings [Og]:[Type B1_North South oriented canyons]

Fig 4.32-4.36 illustrates conditions of DBT, MRT, RH and WS respectively in terms of north south oriented canyons considering on-ground buildings of type B1.

DBT

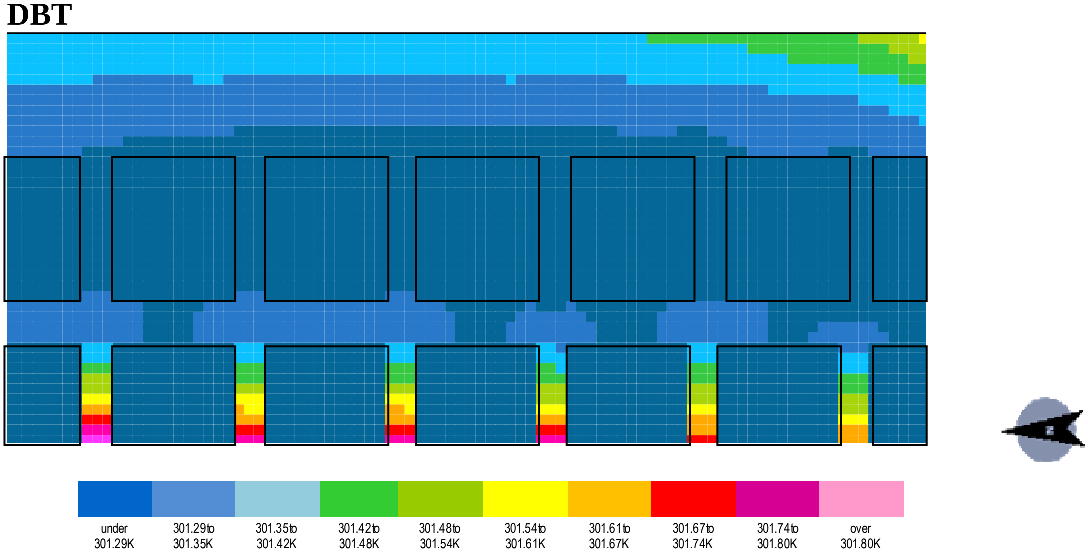

Fig 4.32: Dry bulb temperature of type B1-NS Og structures

MRT

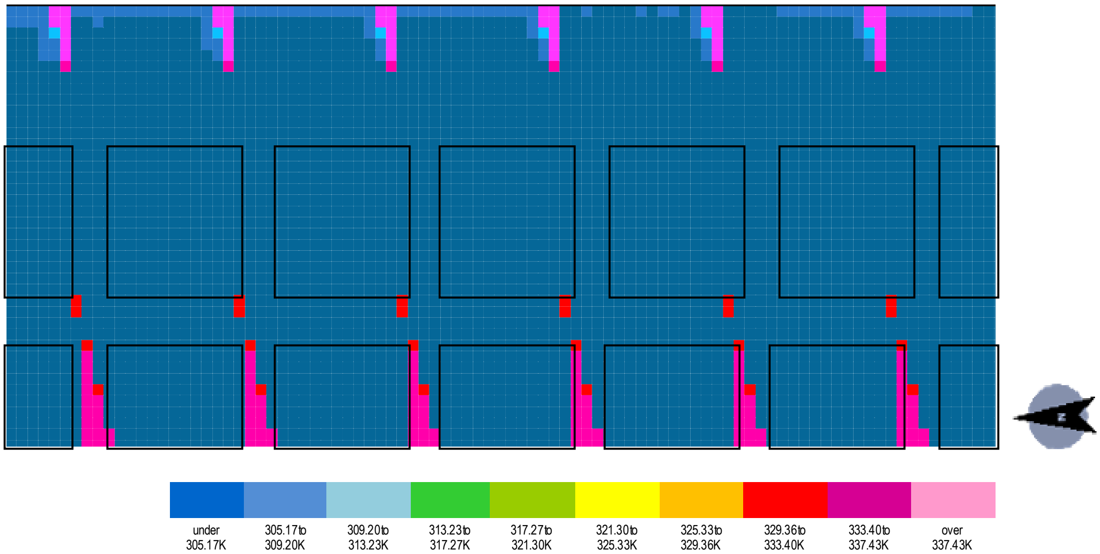

Fig 4.33: Mean radiant temperature of type B1-NS Og structures

RH

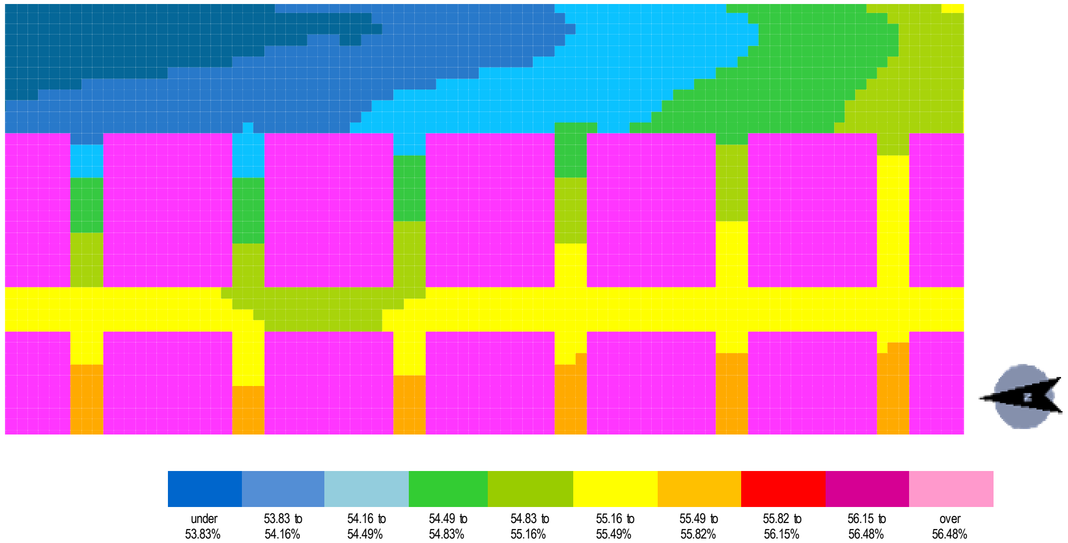

Fig 4.34: Relative humidity of type B1-NS Og structures

WS

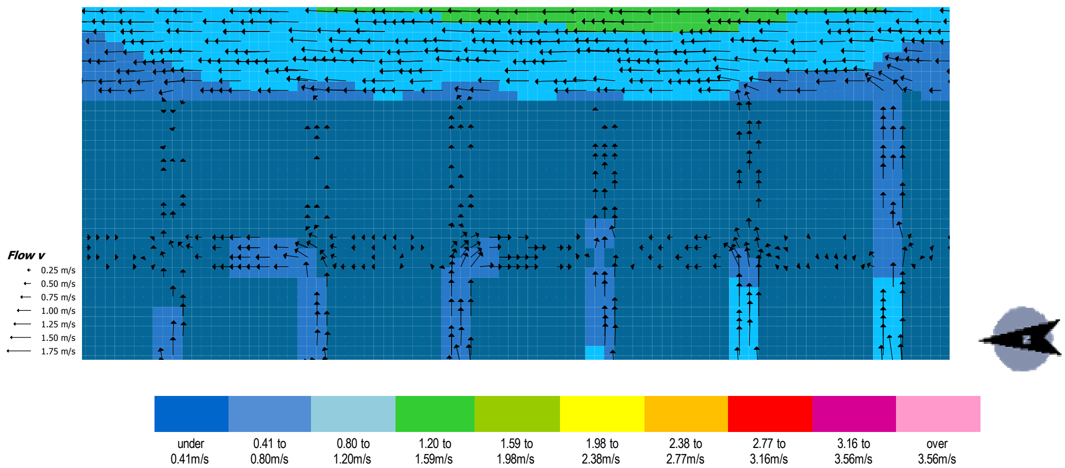

Fig 4.35: Wind speed of type B1-NS Og structures

WS_Section

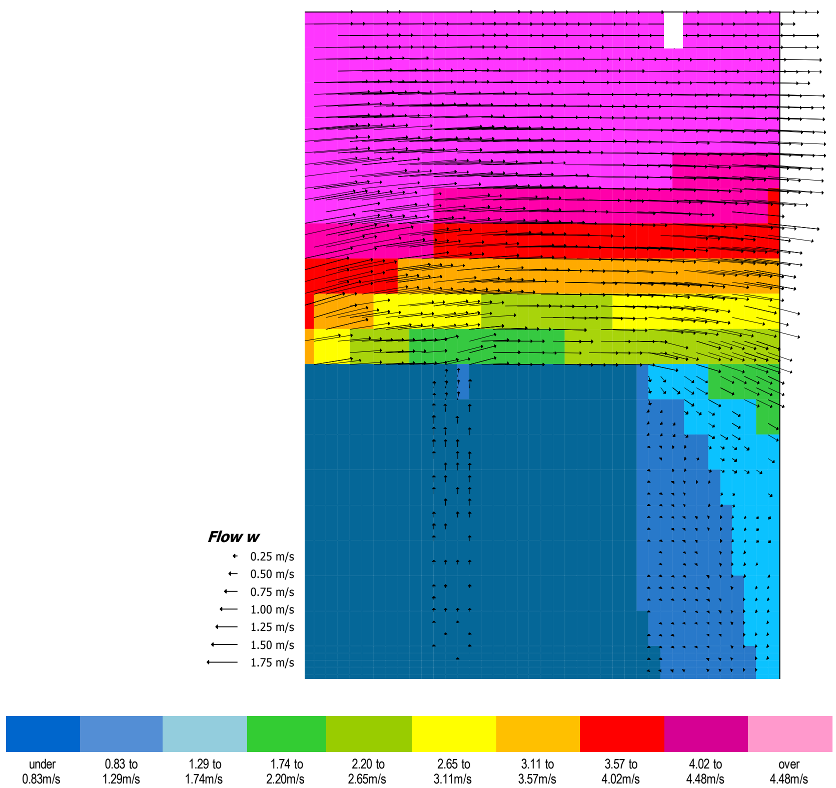

Fig 4.36: Wind speed-section of type B1-NS Og structures

4.3.1.2.2. **Elevated Buildings** [El]: [Type B3_North South oriented canyons]

Fig 4.37-4.41 illustrates conditions of DBT, MRT, RH and WS respectively in terms of north south oriented canyons considering elevated buildings of 'type B3'.

DBT

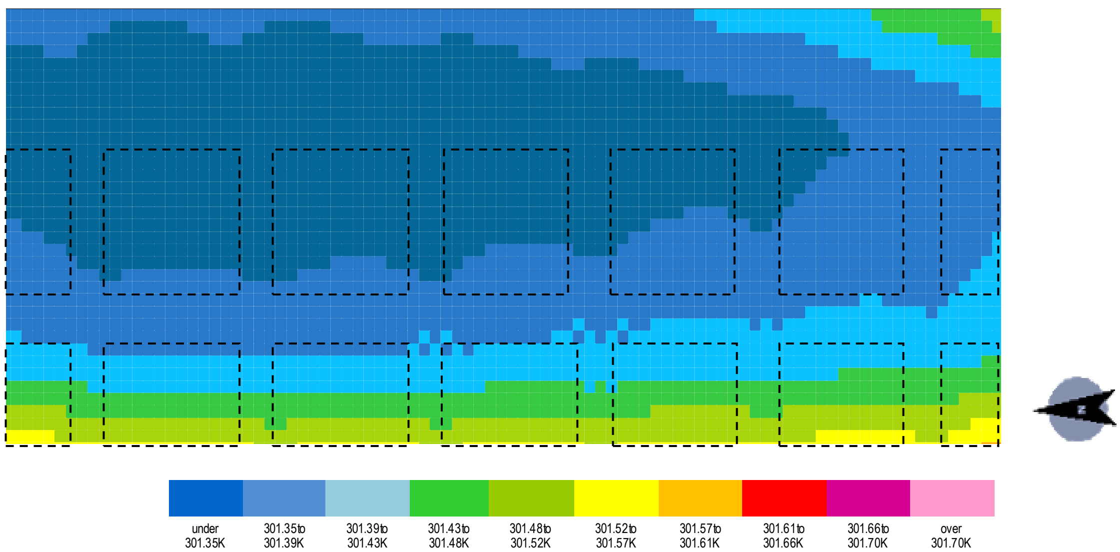

Fig 4.37: Dry bulb temperature of type B3-NS El structures

MRT

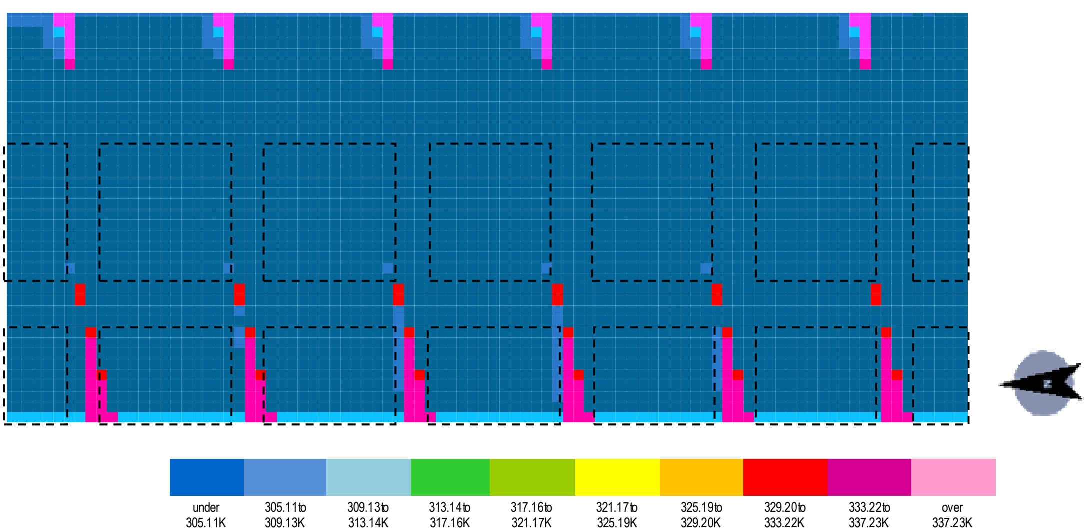

Fig 4.38: Mean radiant temperature of type B3-NS El structures

RH

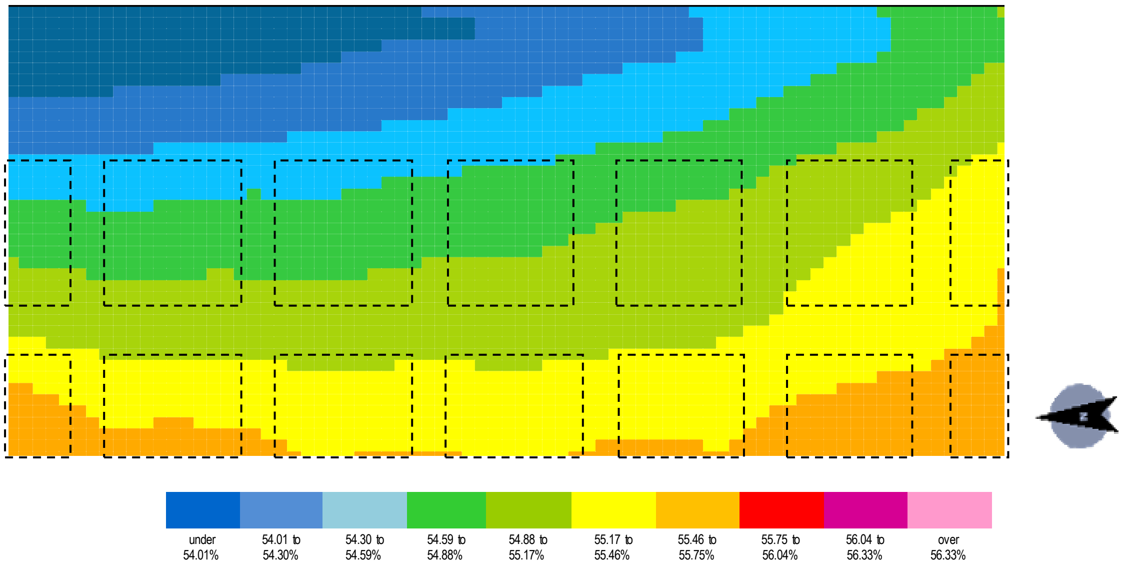

Fig 4.39: Relative humidity of type B3-NS El structures

WS

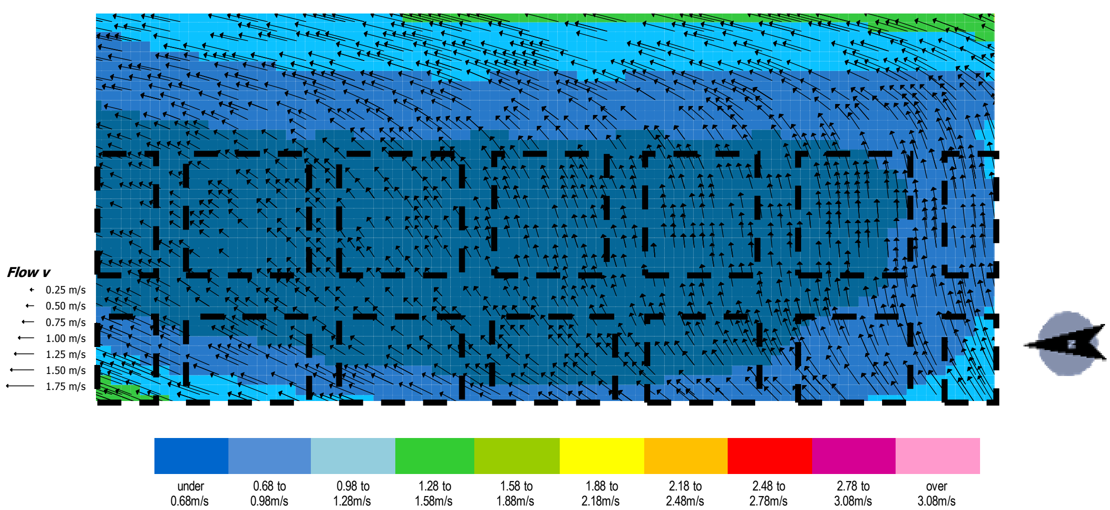

Fig 4.40: Wind speed of type B3-NS El structures

WS_Section

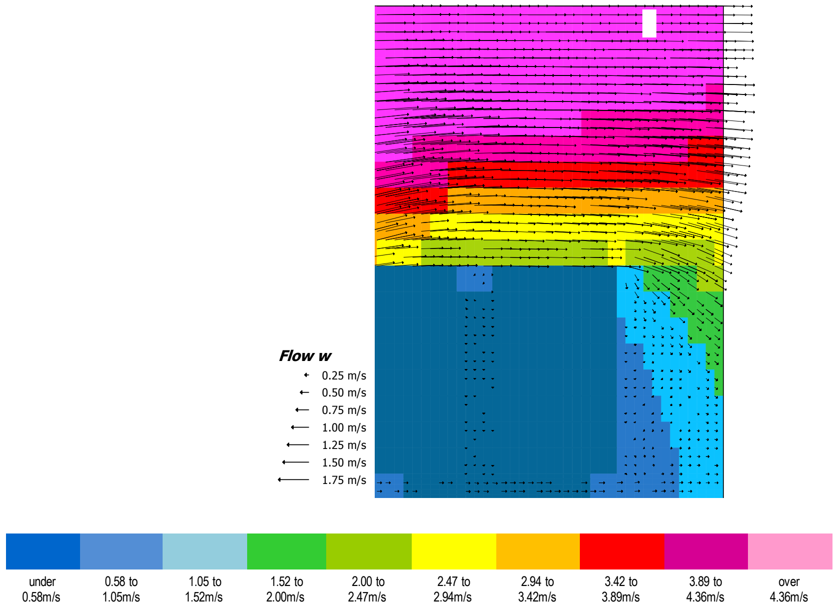

Fig 4.41: Wind speed-section of type B3-NS El structures

4.3.2. **East West Oriented Streets**: Aspect Ratio due to MGC

4.3.2.1. **Buildings Closely Placed [cc]**

4.3.2.1.1. **On-Ground Buildings** [Og]: [Type B_ East West oriented canyons]

DBT

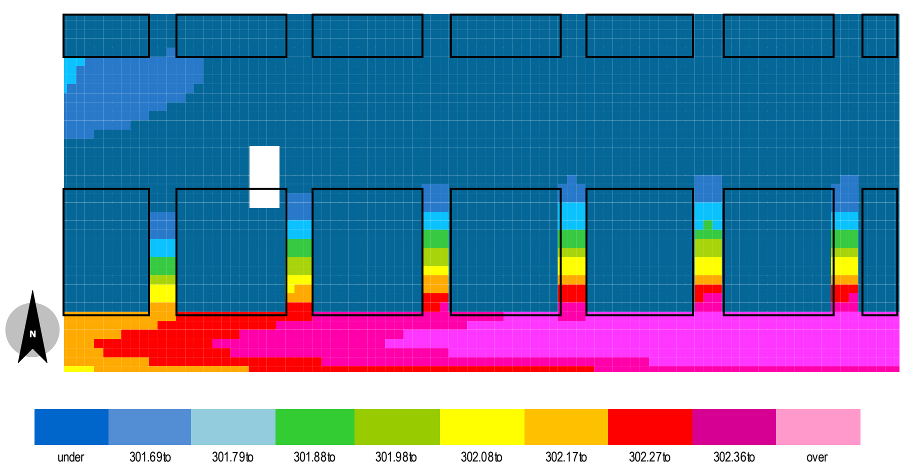

Fig 4.42: Dry bulb temperature of type B-EW Og structures

Fig 4.42-4.46 illustrates conditions of DBT, MRT, RH and WS respectively in terms of east west oriented canyons considering on-ground buildings for 'type B'.

MRT

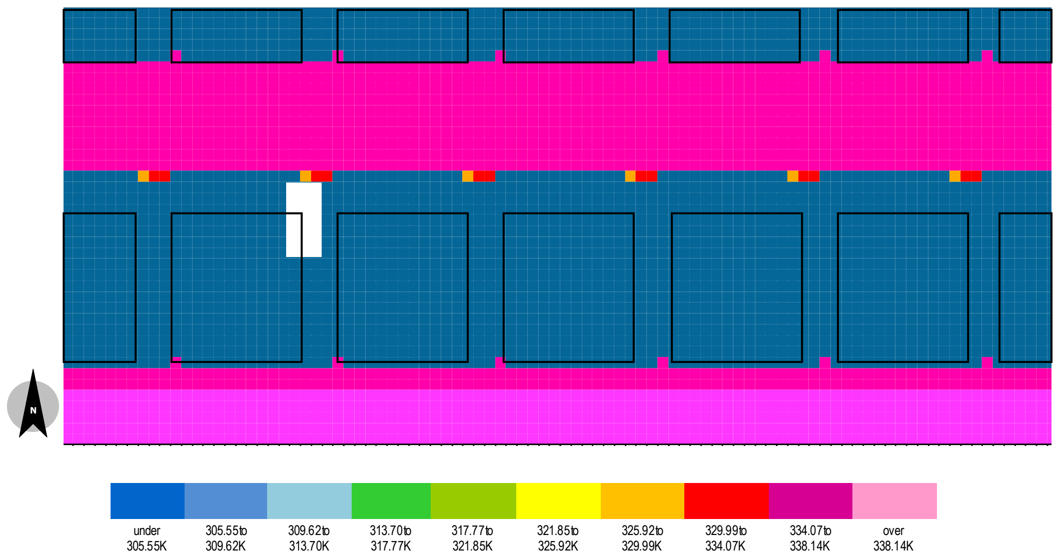

Fig 4.43: Mean radiant temperature of type B-EW Og structures

RH

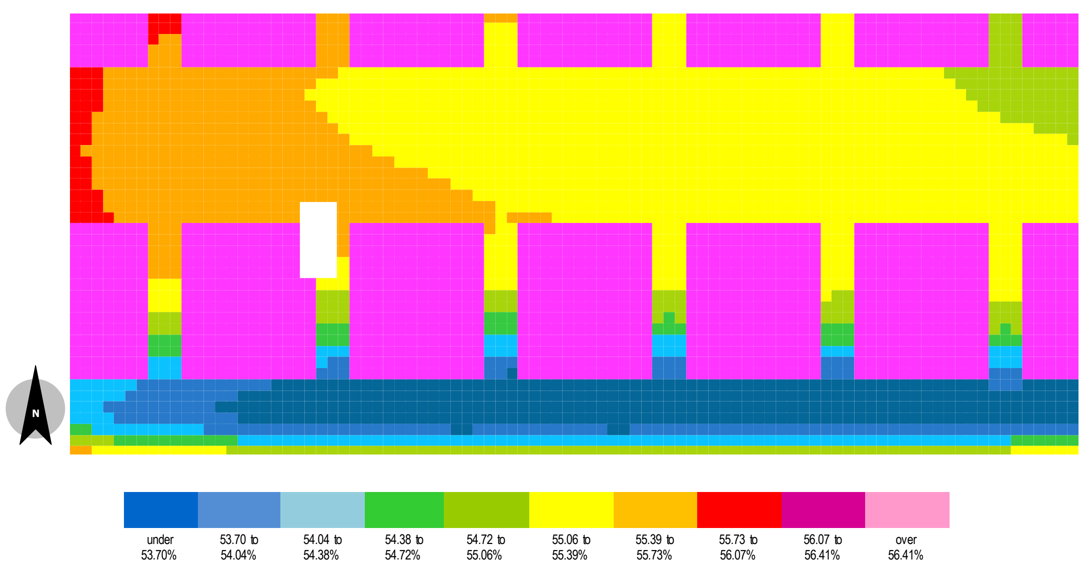

Fig 4.44: Relative humidity of type B-EW Og structures

WS

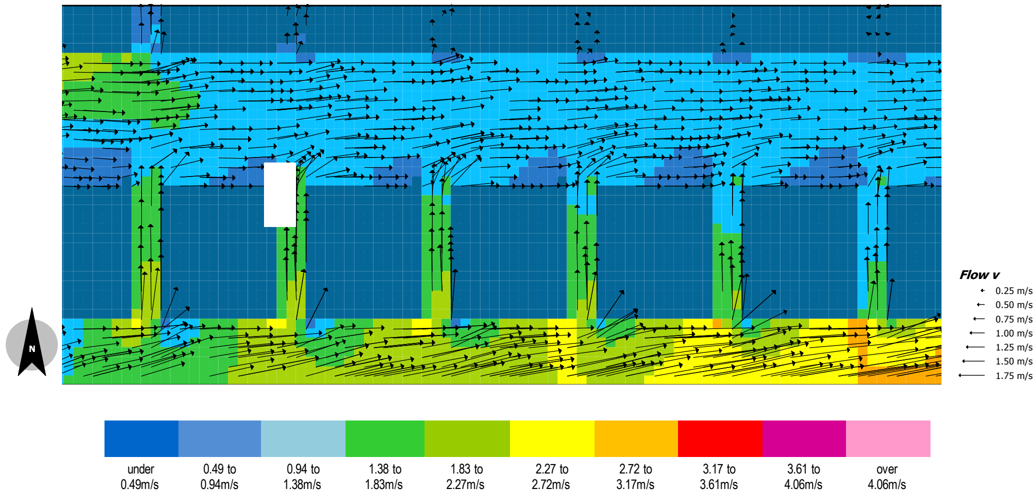

Fig 4.45: Wind speed of type B-EW Og structures

WS_Section

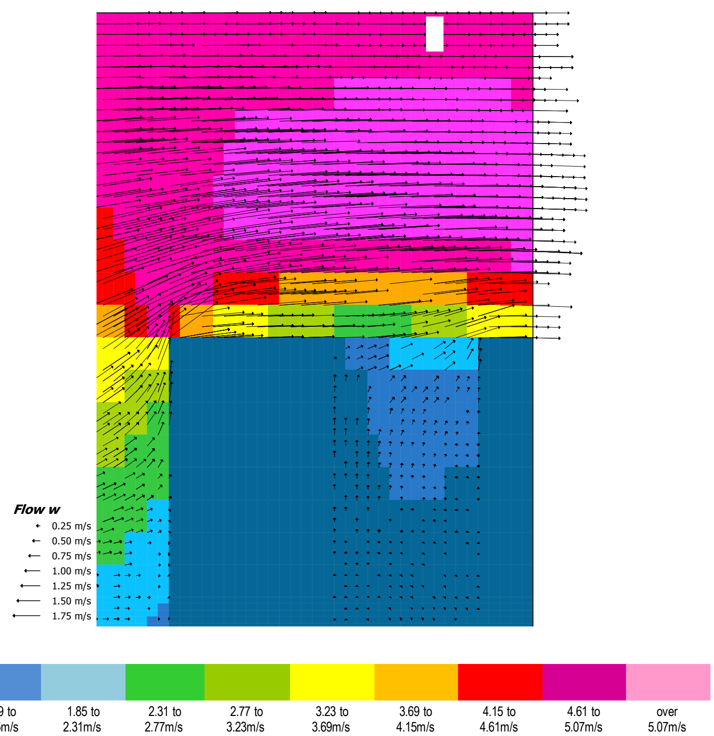

Fig 4.46: Wind speed-section of type B-EW Og structures

4.3.2.1.2. **Elevated Buildings** [El]: [Type B2_East West oriented canyons]

Fig 4.47-4.51 illustrates conditions of DBT, MRT, RH and WS respectively in terms of east west oriented canyons considering elevated buildings of 'type B2'.

DBT

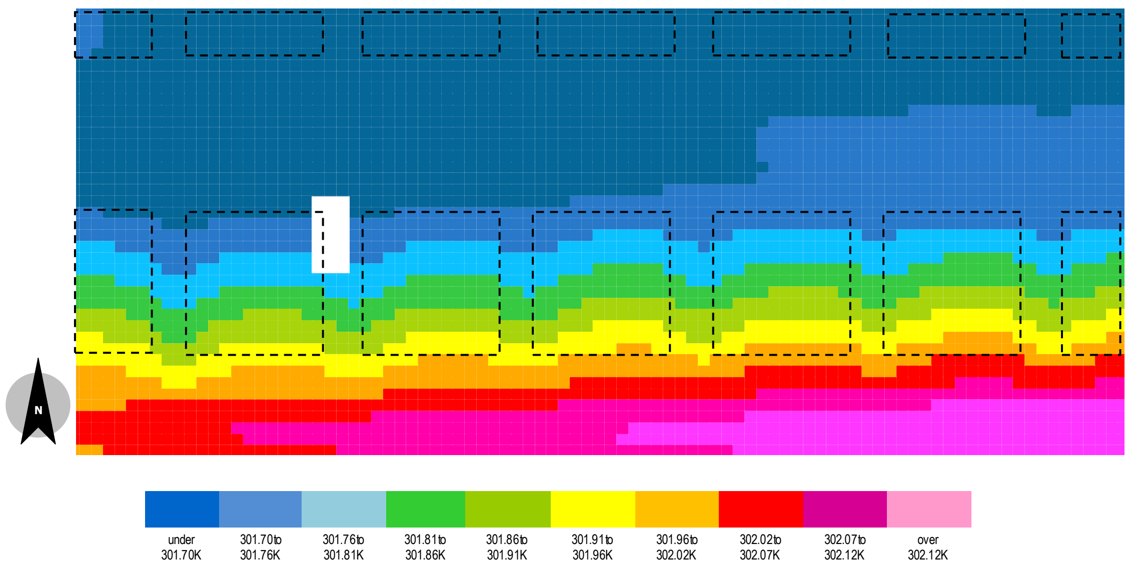

Fig 4.47: Dry bulb temperature of type B2-EW El structures

MRT

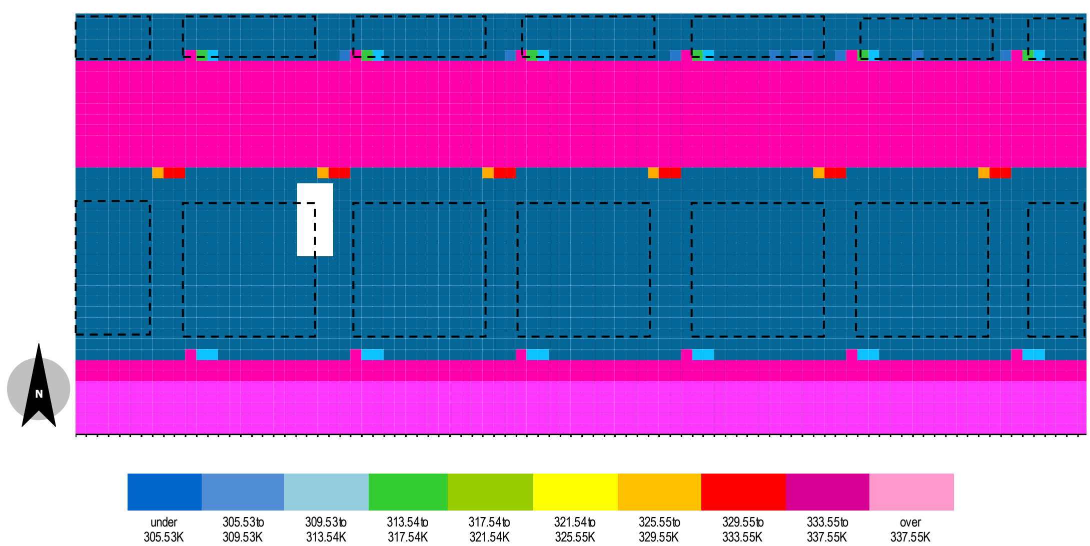

Fig 4.48: Mean radiant temperature of type B2-EW El structures

RH

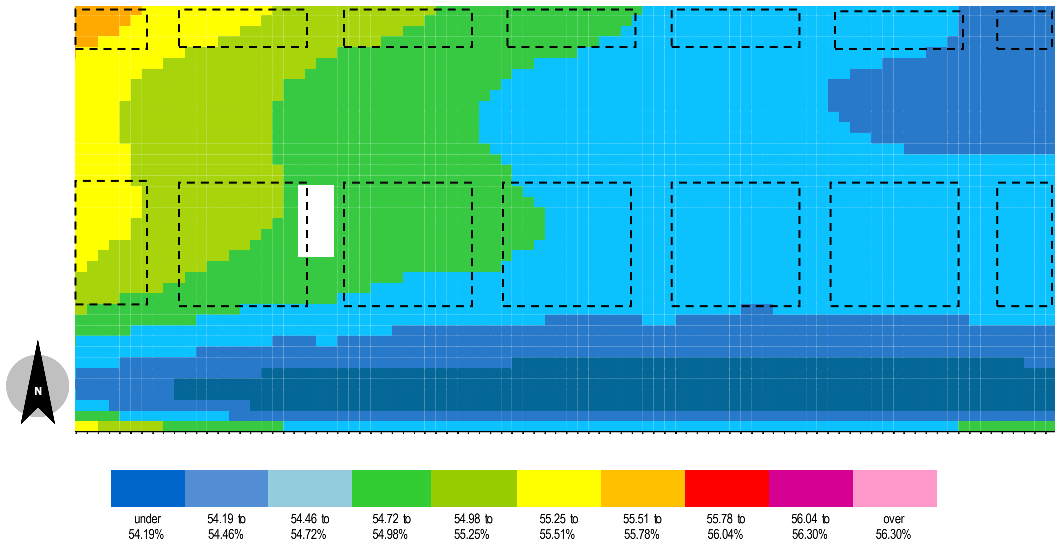

Fig 4.49: Relative humidity of type B2-EW El structures

WS

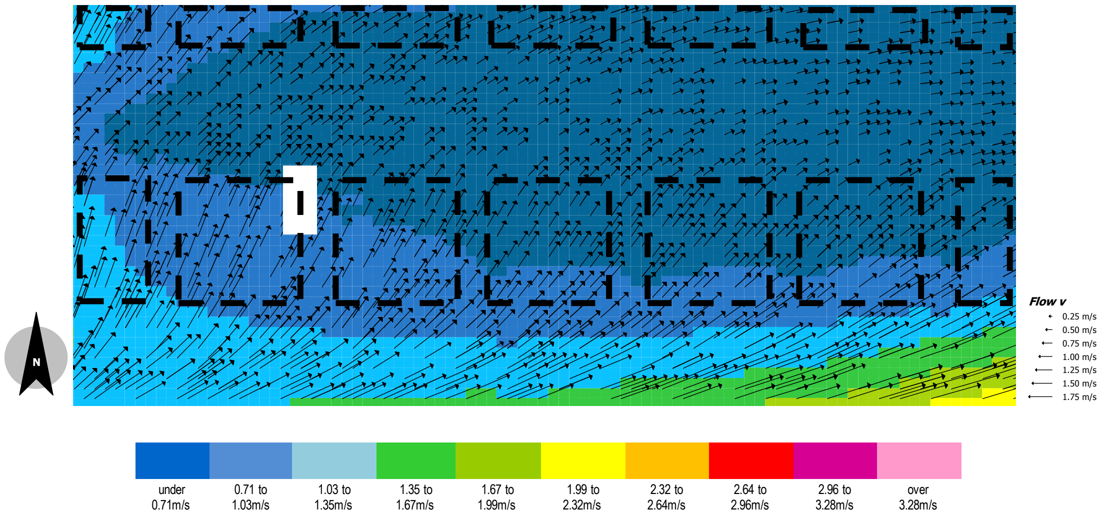

Fig 4.50: Wind speed of type B2-EW El structures

WS_Section

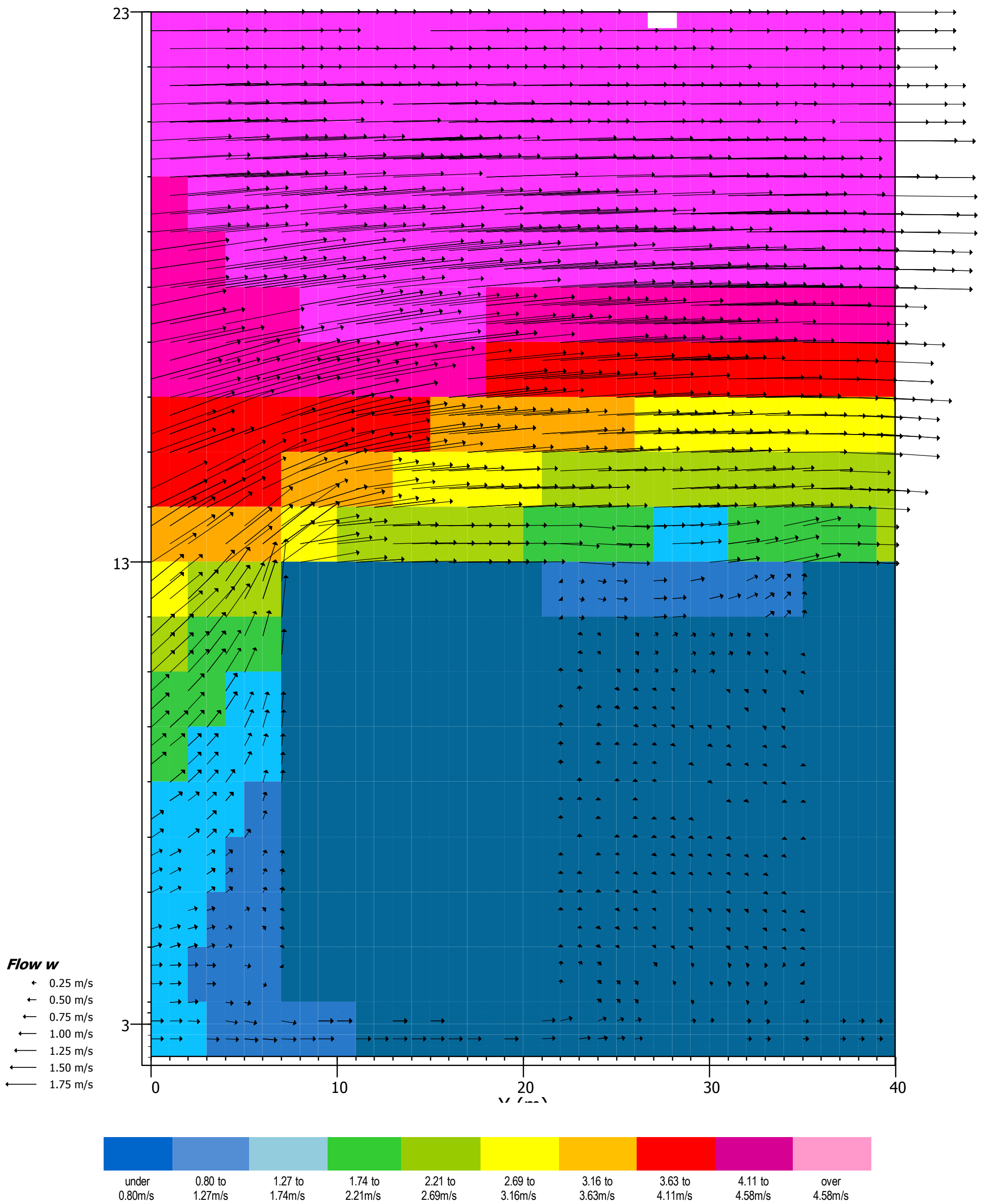

Fig 4.51: Wind speed-section of type B2-EW El structures

4.3.2.2. Buildings Placed Apart [ff]

4.3.2.2.1. On-Ground Buildings [Og]: [Type B1_East West oriented canyons]

Fig 4.52-4.56 illustrates conditions of DBT, MRT, RH and WS respectively in terms of east west oriented canyons considering on-ground buildings of 'type B1'.

DBT

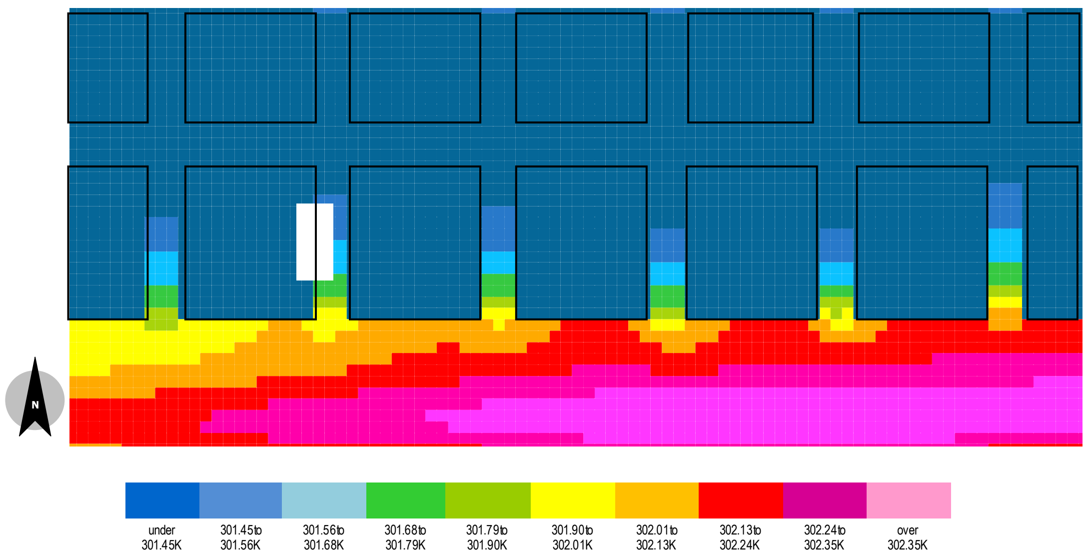

Fig 4.52: Dry bulb temperature of type B1-EW Og structures

MRT

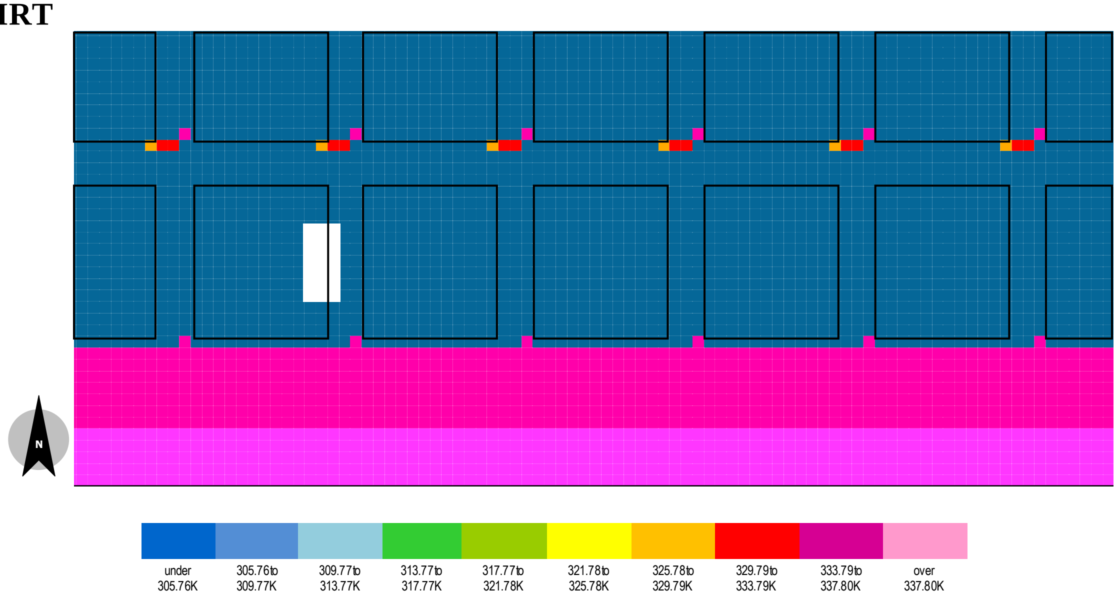

Fig 4.53: Mean radiant temperature of type B1-EW Og structures

RH

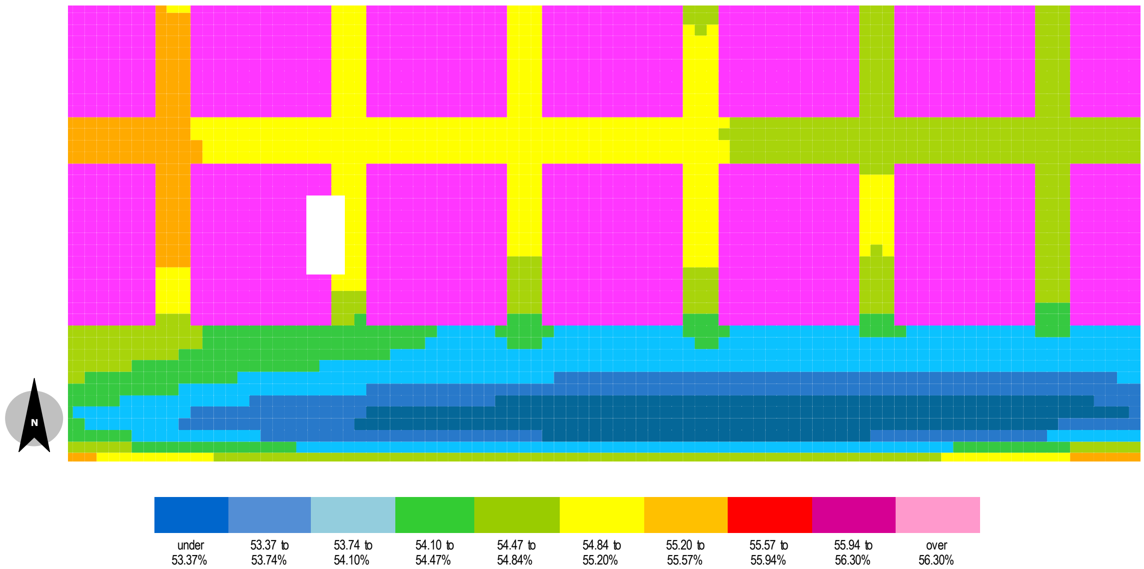

Fig 4.54: Relative humidity of type B1-EW Og structures

WS

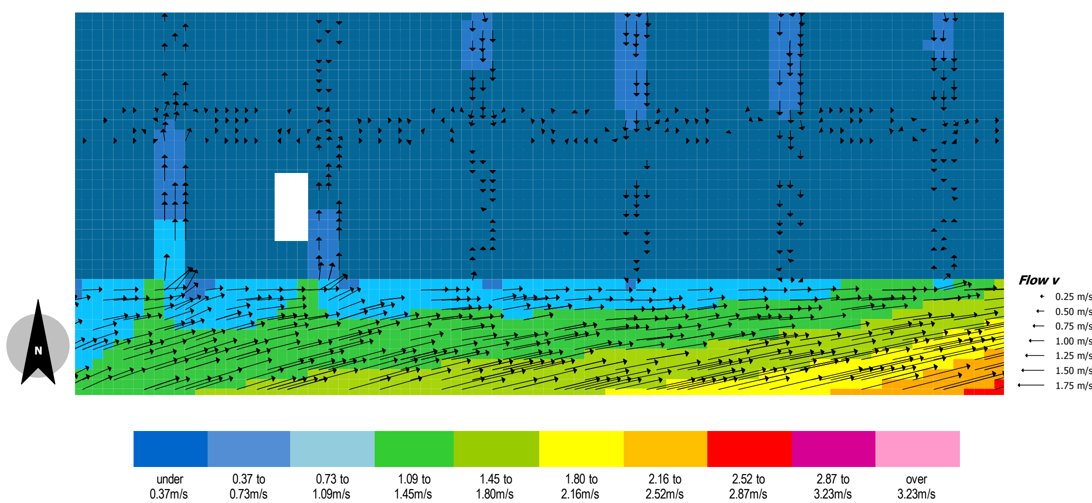

Fig 4.55: Wind speed of type B1-EW Og structures

WS_Section

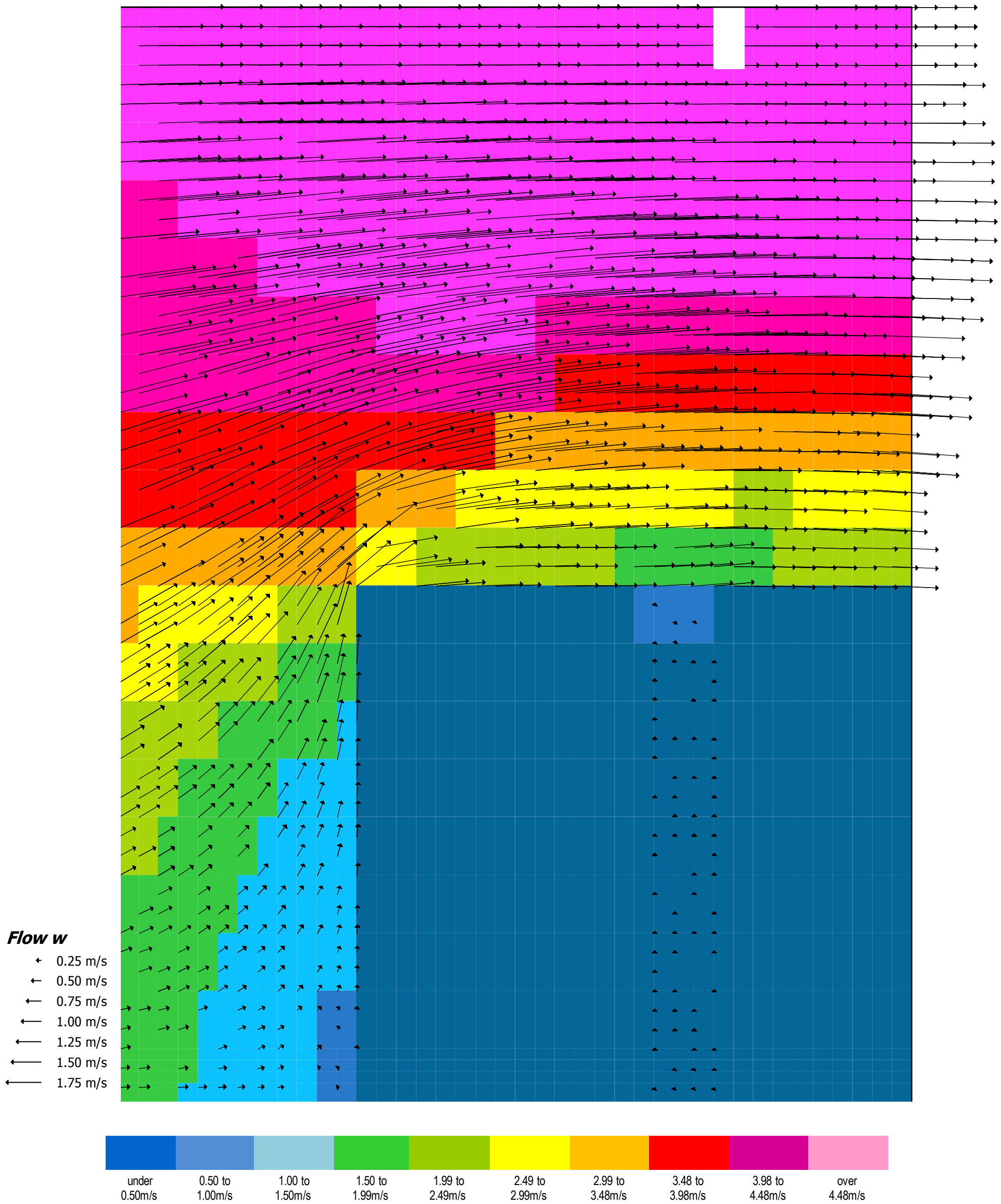

Fig 4.56: Wind speed-section of type B1-EW Og structures

4.3.2.2.2. **Elevated Buildings** [El]: [Type B3_East West oriented canyons]

Fig 4.57-4.61 illustrates conditions of DBT, MRT, RH and WS respectively in terms of east west oriented canyons considering elevated buildings of ‘type B3’.

DBT

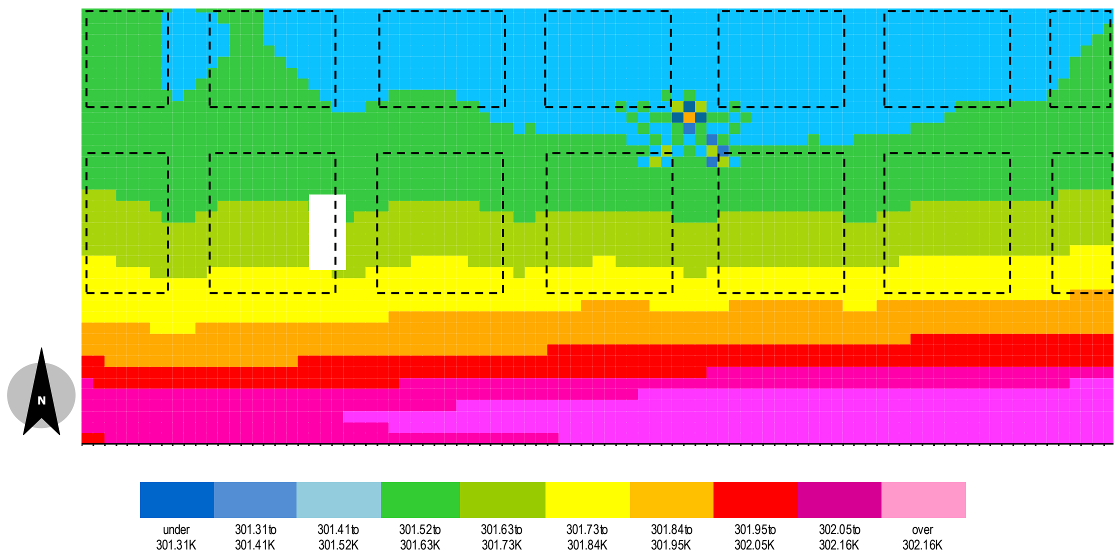

Fig 4.57: Dry bulb temperature of type B3-EW El structures

MRT

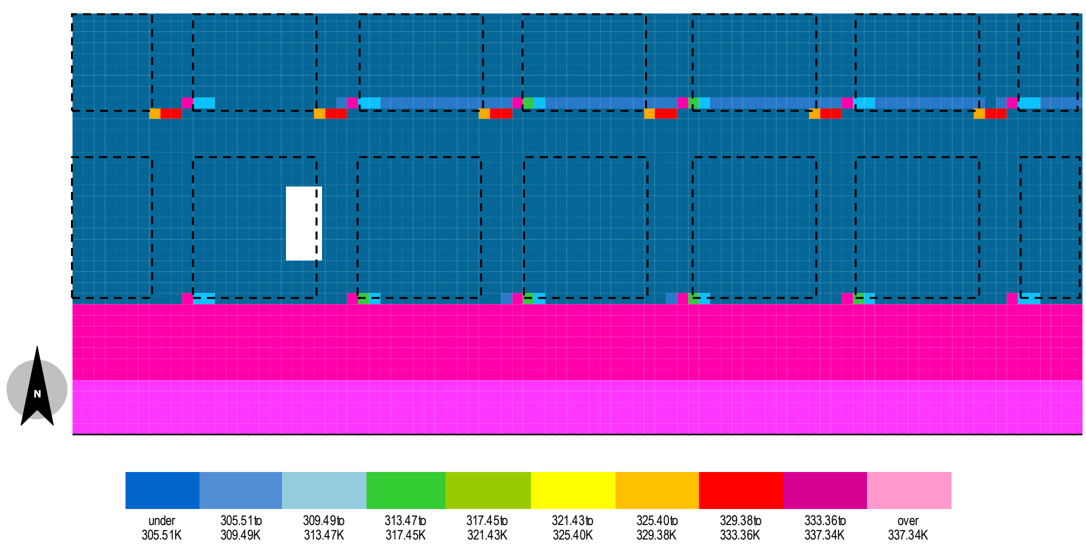

Fig 4.58: Mean radiant temperature of type B3-EW El structures

RH

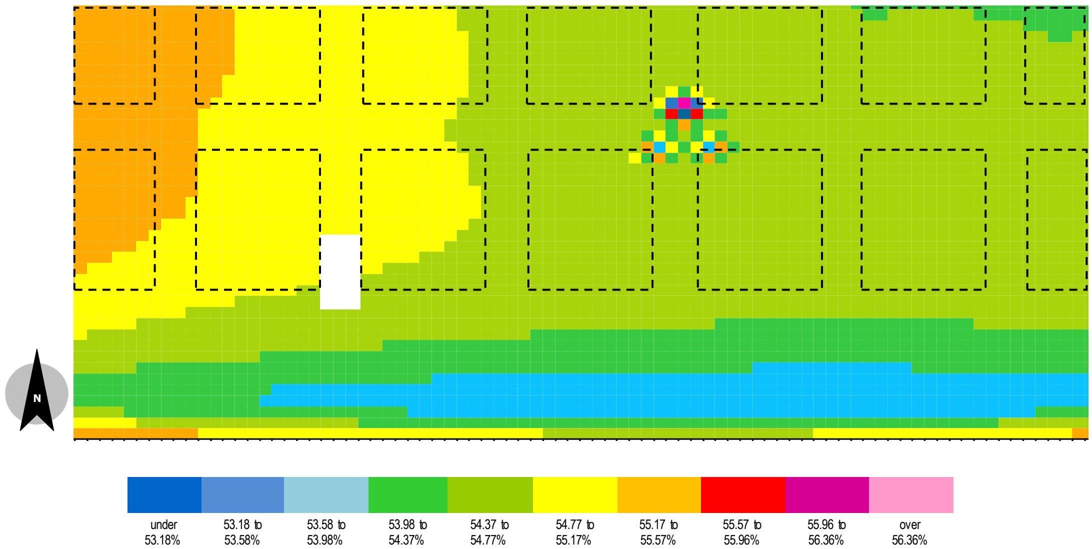

Fig 4.59: Relative humidity of type B3-EW El structures

WS

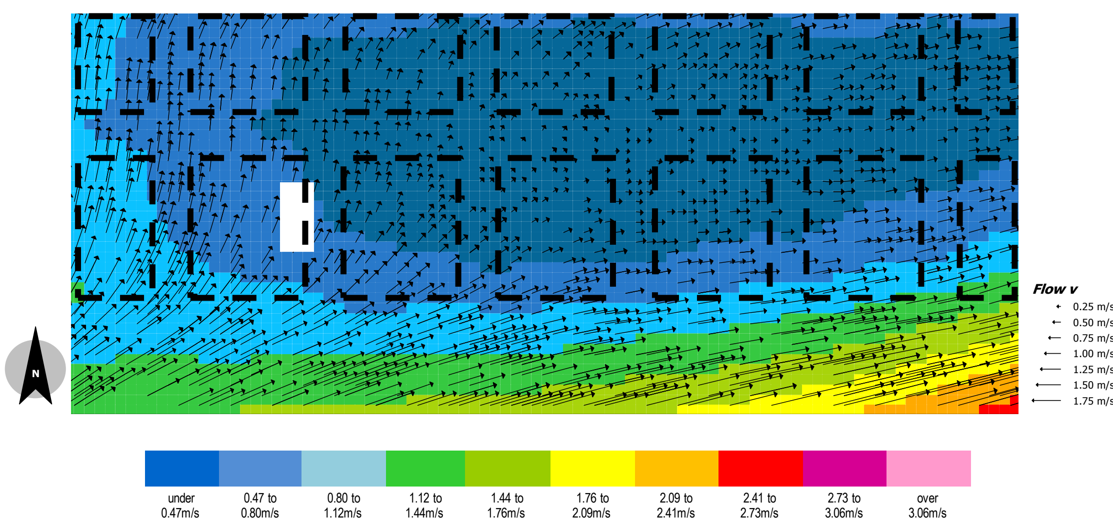

Fig 4.60: Wind speed of type B3-EW El structures

WS_Section

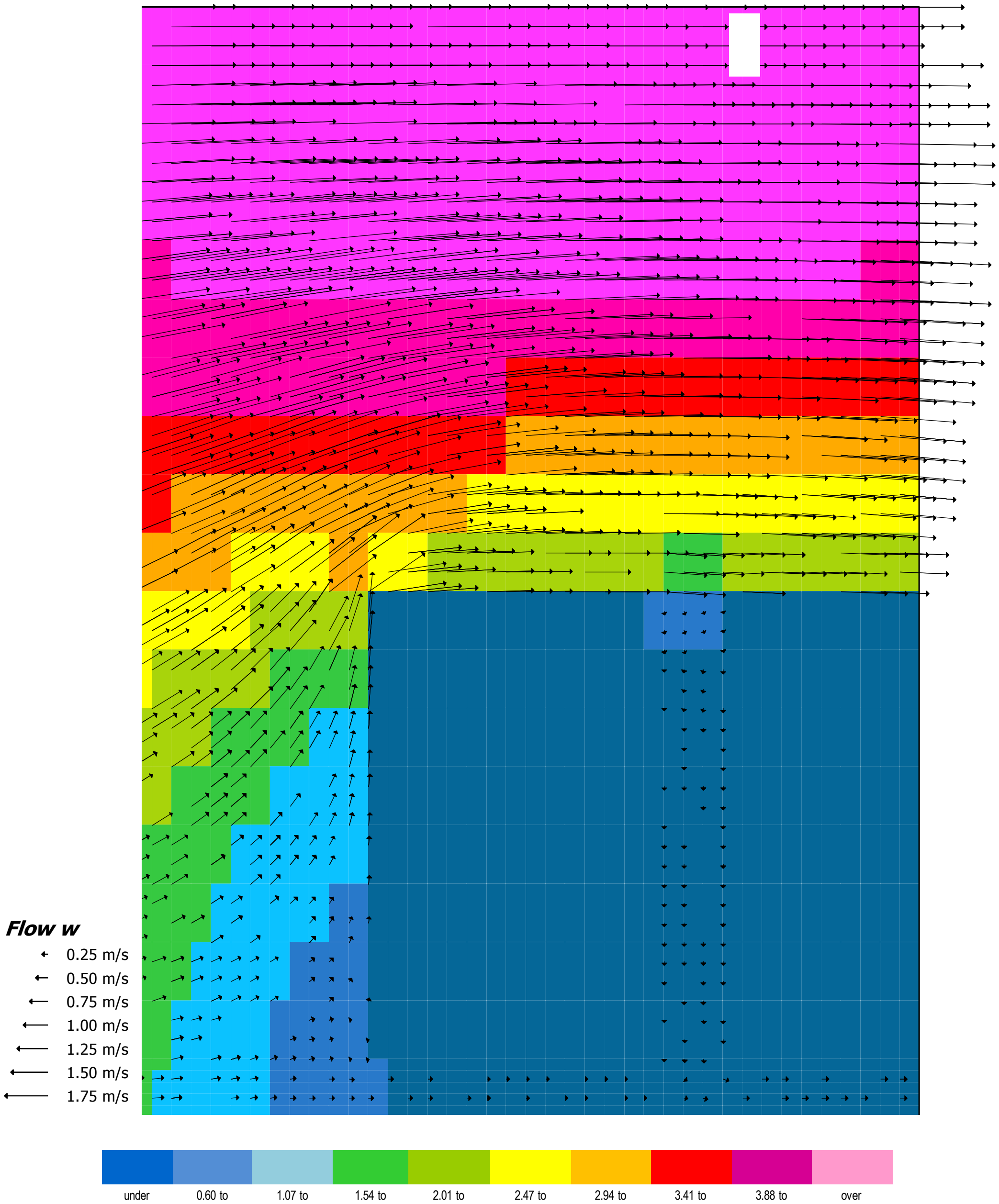

Fig 4.61: Wind speed-section of type B3-EW El structures

Table 4.2: Simulation data table of microclimatic parameters after applying deviation considering all simulation typologies, orientation and timing

NS	A				A1				B				B1				B2				B3			
	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]
11:00am	311.68 [38.53]	310.14 [36.99]	39.42	0.80	311.55 [38.40]	309.90 [36.75]	40.13	0.87	298.00 [24.85]	310.30 [37.15]	40.14	0.76	310.94 [37.79]	310.01 [36.86]	39.04	0.74	297.77 [24.62]	310.14 [36.99]	40.74	0.69	299.70 [26.55]	310.01 [36.86]	39.42	0.75
11:30am	309.67 [36.52]	310.94 [37.79]	39.27	0.78	309.37 [36.22]	310.70 [37.55]	39.85	0.93	309.50 [36.35]	311.10 [37.95]	39.61	0.70	308.86 [35.71]	310.85 [37.70]	39.39	0.72	298.50 [25.35]	310.97 [37.82]	40.04	0.70	308.72 [35.57]	310.77 [37.62]	39.03	0.75
12:00pm	310.07 [36.92]	311.42 [38.27]	39.01	0.77	309.58 [36.43]	311.23 [38.08]	39.60	0.89	309.94 [36.79]	311.69 [38.54]	39.46	0.67	309.11 [35.96]	311.33 [38.18]	39.38	0.73	309.39 [36.24]	311.45 [38.3]	39.85	0.70	308.89 [35.74]	311.29 [38.14]	39.03	0.78
12:30pm	310.38 [37.23]	311.70 [38.55]	38.77	0.81	299.78 [26.63]	311.53 [38.38]	39.31	0.79	300.33 [27.18]	311.85 [38.70]	39.25	0.73	309.65 [36.50]	311.61 [38.46]	38.96	0.66	298.04 [24.89]	311.72 [38.57]	39.46	0.71	299.31 [26.16]	311.14 [37.99]	39.23	0.79
01:00pm	298.64 [25.49]	311.81 [38.66]	38.69	0.80	298.40 [25.25]	311.70 [38.55]	39.16	0.74	291.99 [18.84]	311.89 [38.74]	39.32	0.61	308.13 [34.98]	311.75 [38.60]	38.79	0.67	291.83 [18.68]	311.84 [38.69]	39.42	0.72	300.35 [27.20]	311.63 [38.48]	39.00	0.77
01:30pm	291.16 [18.01]	311.83 [38.68]	38.78	0.80	288.83 [15.68]	311.79 [38.64]	39.08	0.70	287.56 [14.41]	311.79 [38.64]	39.37	0.60	298.77 [25.62]	311.82 [38.67]	38.76	0.67	290.67 [17.52]	311.66 [38.51]	39.33	0.70	297.97 [24.82]	311.70 [38.55]	38.82	0.75
02:00pm	291.12 [17.97]	311.86 [38.71]	38.76	0.75	291.00 [17.85]	311.85 [38.70]	39.09	0.79	290.67 [17.52]	311.85 [38.7]	39.35	0.57	300.67 [27.52]	311.83 [38.68]	38.82	0.67	287.56 [14.41]	311.92 [38.77]	39.18	0.66	288.52 [15.35]	311.79 [38.64]	39.02	0.71

EW	A				A1				B				B1				B2				B3			
	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]	MRT K[degC]	DBT K[degC]	RH [%]	WS [m/s]
11:00am	315.46 [42.31]	309.78 [36.63]	41.26	0.65	316.55 [43.40]	310.22 [37.07]	40.95	0.63	314.97 [41.82]	309.90 [36.75]	42.06	0.92	314.71 [41.56]	309.65 [36.50]	41.78	0.51	310.12 [36.97]	309.78 [36.63]	41.78	0.61	315.63 [42.48]	309.29 [36.14]	41.39	0.76
11:30am	313.48 [40.33]	310.76 [37.61]	40.70	0.63	313.64 [40.49]	310.78 [37.63]	40.53	0.65	312.79 [39.64]	310.74 [37.59]	41.06	0.86	313.30 [40.15]	310.47 [37.32]	40.96	0.53	313.73 [40.58]	310.53 [37.38]	40.95	0.58	312.40 [39.25]	310.43 [37.28]	40.68	0.74
12:00pm	313.82 [40.67]	311.34 [38.19]	40.14	0.62	313.54 [40.39]	311.21 [38.06]	40.20	0.66	313.00 [39.85]	311.29 [38.14]	40.44	0.84	312.82 [39.67]	311.02 [37.87]	40.32	0.50	312.75 [39.60]	310.98 [37.83]	40.49	0.59	312.56 [39.41]	310.97 [37.82]	40.07	0.78
12:30pm	315.61 [42.46]	311.65 [38.50]	39.68	0.72	315.01 [41.86]	311.45 [38.30]	39.79	0.70	314.71 [41.56]	311.58 [38.43]	40.12	0.69	314.53 [41.38]	311.31 [38.16]	39.90	0.55	314.38 [41.23]	311.31 [38.16]	40.12	0.61	316.05 [42.90]	311.25 [38.10]	39.80	0.81
01:00pm	317.87 [44.72]	311.83 [38.68]	39.42	0.72	319.24 [46.09]	311.60 [38.45]	39.62	0.71	318.27 [45.12]	311.81 [38.66]	39.70	0.67	318.89 [45.74]	311.56 [38.41]	39.72	0.57	313.51 [40.36]	311.54 [38.39]	39.92	0.64	318.50 [45.35]	311.57 [38.42]	39.66	0.78
01:30pm	322.30 [49.15]	311.99 [38.84]	39.22	0.72	321.43 [48.28]	311.70 [38.55]	39.42	0.71	321.49 [48.34]	311.96 [38.81]	39.29	0.71	321.21 [48.06]	311.71 [38.56]	39.44	0.52	321.00 [47.85]	311.66 [38.51]	39.56	0.64	320.80 [47.65]	311.74 [38.59]	39.42	0.81
02:00pm	324.08 [50.93]	311.98 [38.83]	39.08	0.64	323.16 [50.01]	311.76 [38.61]	39.35	0.70	323.32 [50.17]	312.03 [38.88]	39.36	0.65	323.02 [49.87]	311.85 [38.70]	39.34	0.56	322.79 [49.64]	311.75 [38.60]	39.45	0.66	322.59 [49.44]	311.80 [38.65]	39.39	0.75

4.4. Graphical Outputs

4.4.1. Orientation

DBT

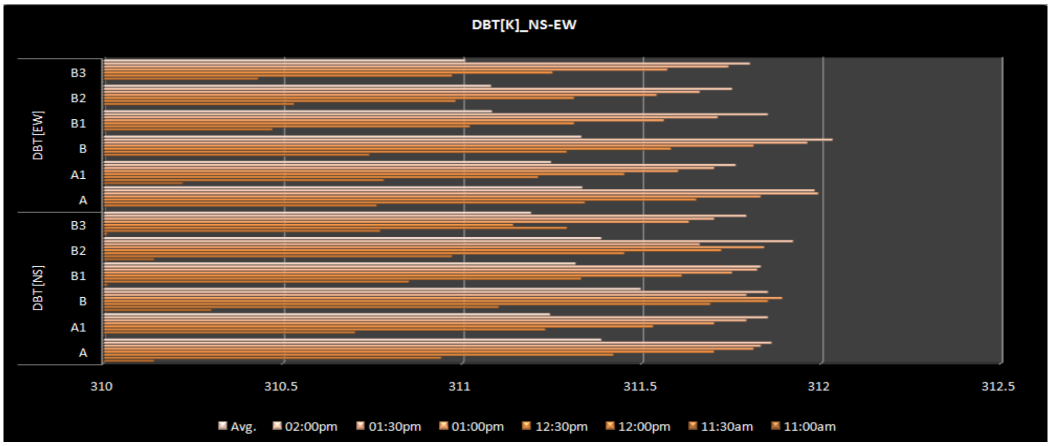

Fig 4.62: DBT [K] in terms of orientation of all simulation typologies

MRT

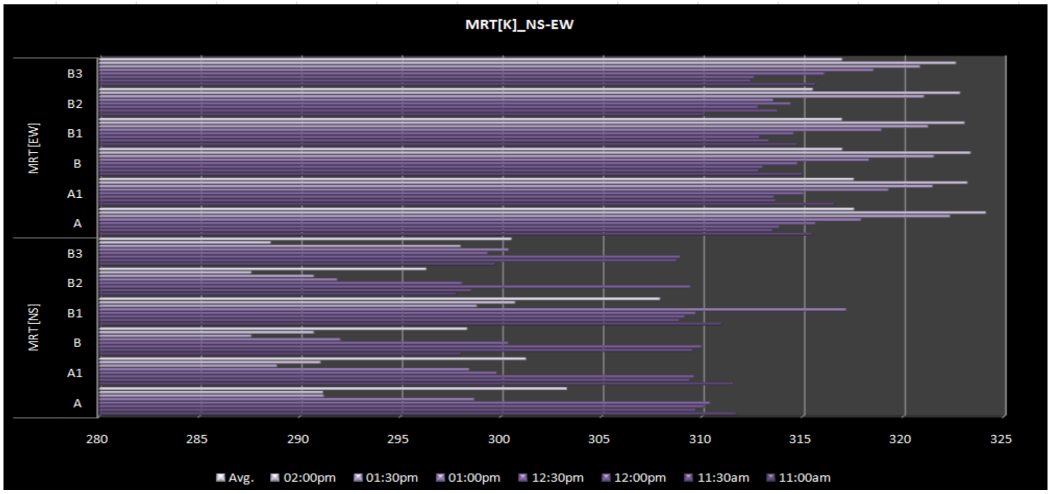

Fig 4.63: MRT [K] in terms of orientation of all simulation typologies

Considering orientation from Fig 4.62 and Fig 4.63 it is clear that in terms of DBT type B in east west orientation reaches the highest temperature while, in terms of MRT east west for all simulation typologies are far more than the north south canyons.

RH

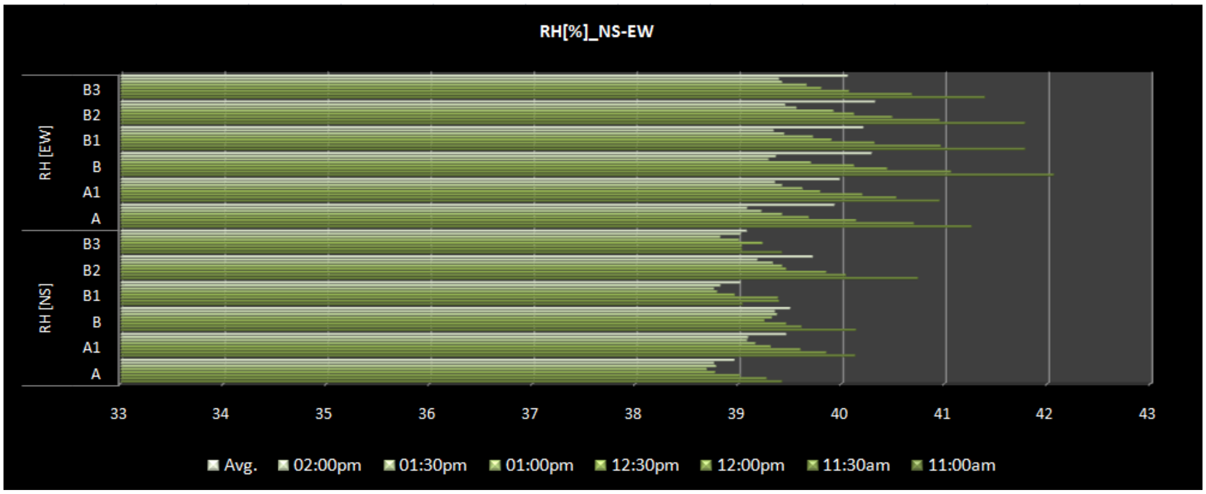

Fig 4.64: RH [%] in terms of orientation of all simulation typologies

WS

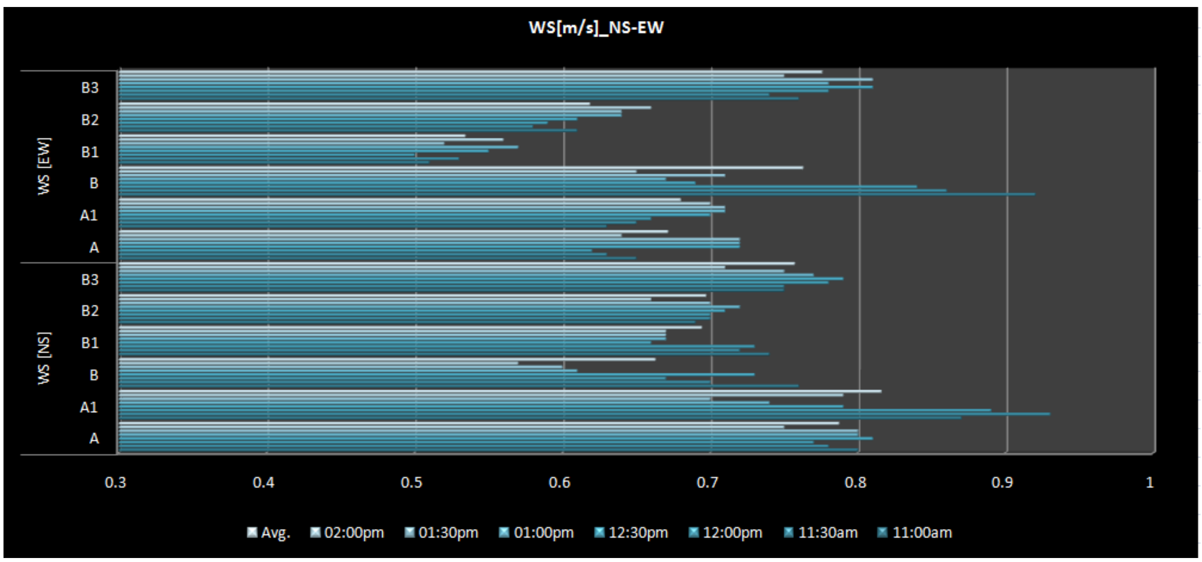

Fig 4.65: WS [m/s] in terms of orientation of all simulation typologies

In terms of RH and WS from Fig 4.64 and 4.65 respectively it can be seen that variation of wind speed is higher than the relative humidity, where average wind speed of type B1 reaches the lowest in terms of east west canyons.

4.4.2. Aspect Ratio

On-ground Buildings [Og]

DBT

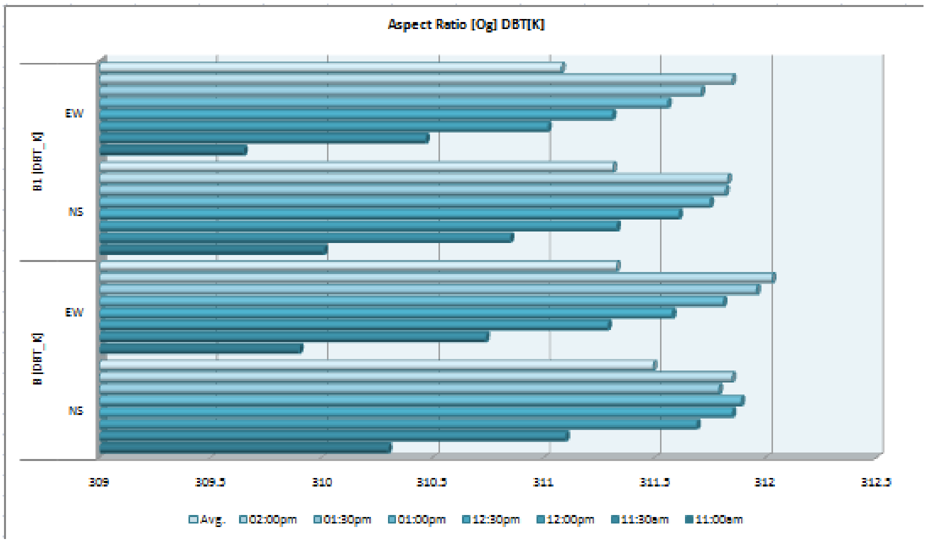

Fig 4.66: DBT [K] in terms of aspect ratio comparing type B and B1 for Og buildings

MRT

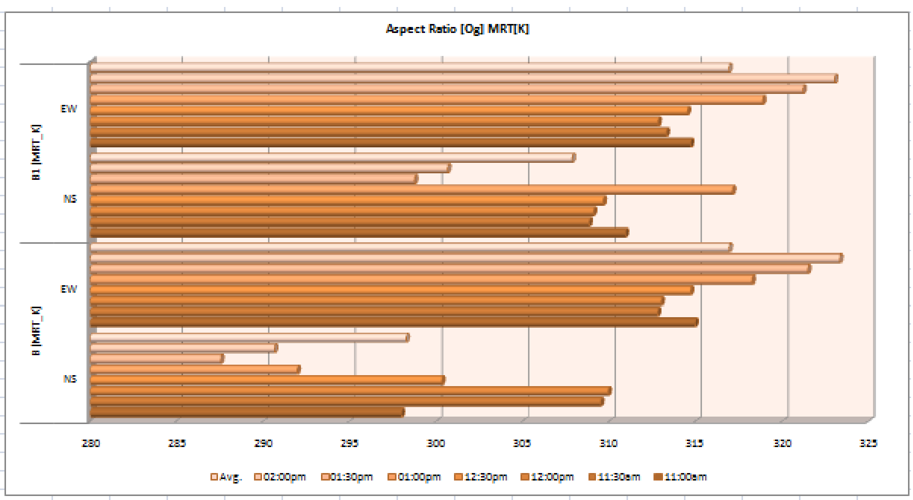

Fig 4.67: MRT [K] in terms of aspect ratio comparing type B and B1 for Og buildings

The changes in DBT in terms of on ground buildings from Fig 4.66 is close to each other while MRT for type B in north south canyons is the lowest (Fig. 4.67).

RH

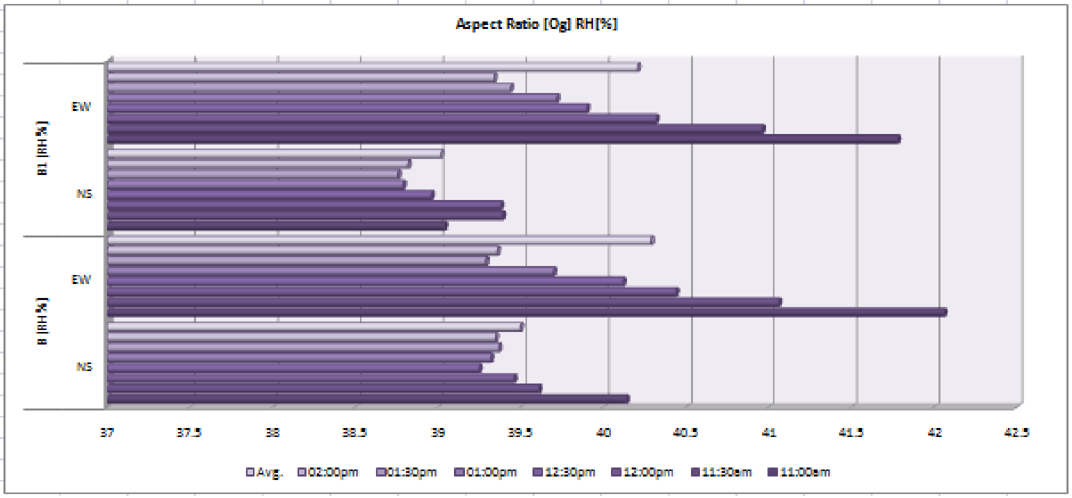

Fig 4.68: RH [%] in terms of aspect ratio comparing type B and B1 for Og buildings

WS

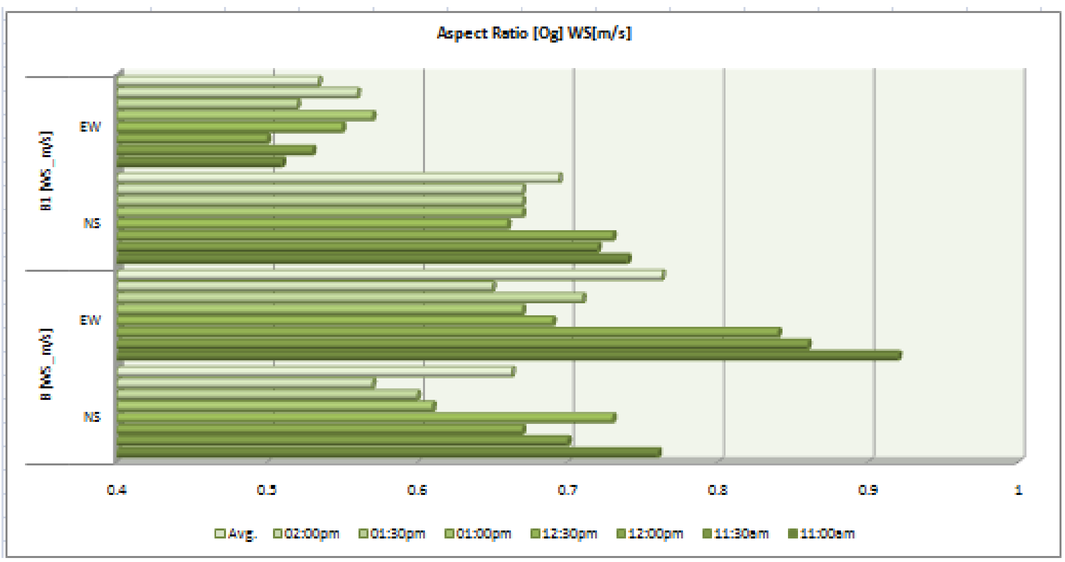

Fig 4.69: WS [m/s] in terms of aspect ratio comparing type B and B1 for Og buildings

Relative humidity for on ground buildings considering east west canyons, in terms of aspect ratio for type B and B1 is higher than north south (Fig. 4.68), while wind speed achieves highest for east west canyons (Fig. 4.69).

Elevated Buildings [El]

DBT

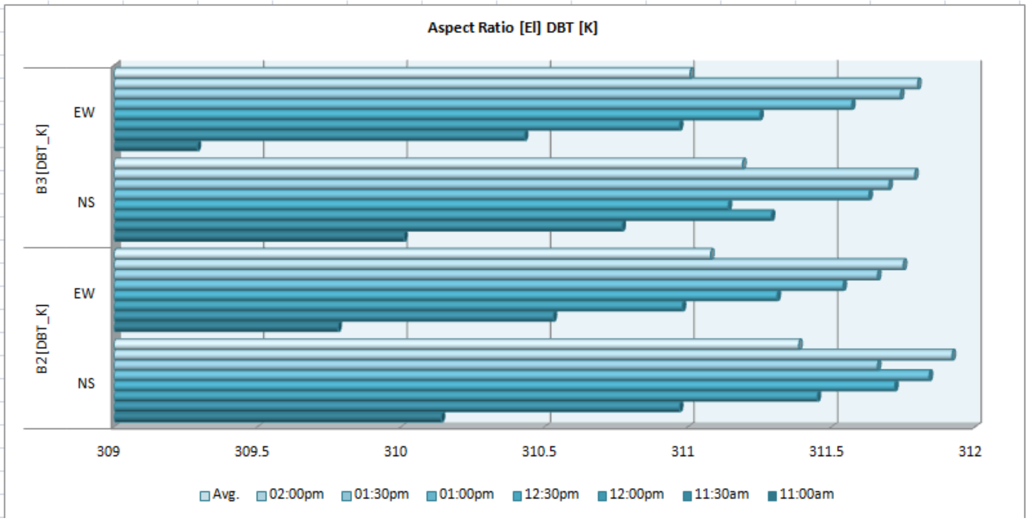

Fig 4.70: DBT [K] in terms of aspect ratio comparing type B2 and B3 for El buildings

MRT

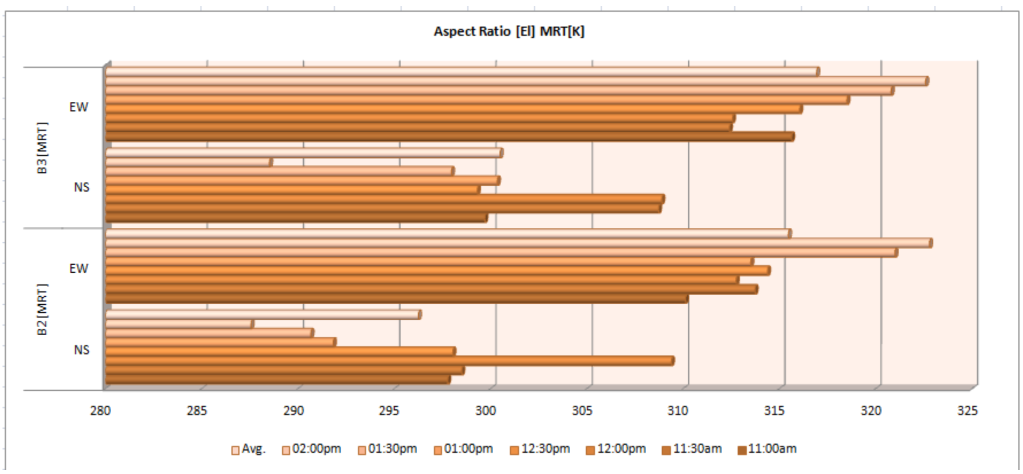

Fig 4.71: MRT [K] in terms of aspect ratio comparing type B2 and B3 for El buildings

Considering elevated buildings, overall MRT in east west canyons is much higher than the north south canyons (Fig. 4.71), while the changes in terms of DBT are close to each other.

RH

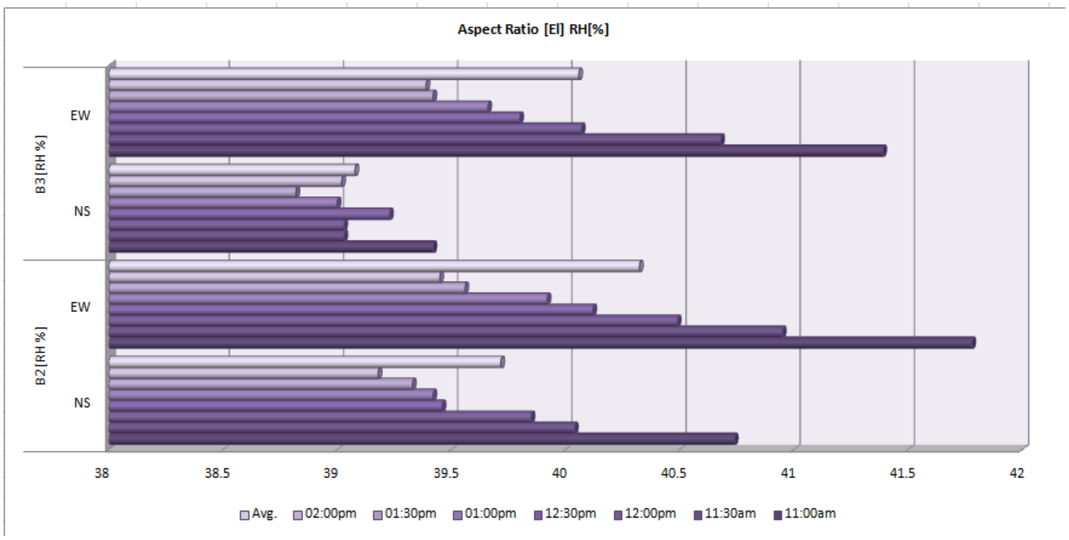

Fig 4.72: RH [%] in terms of aspect ratio comparing type B2 and B3 for El buildings

WS

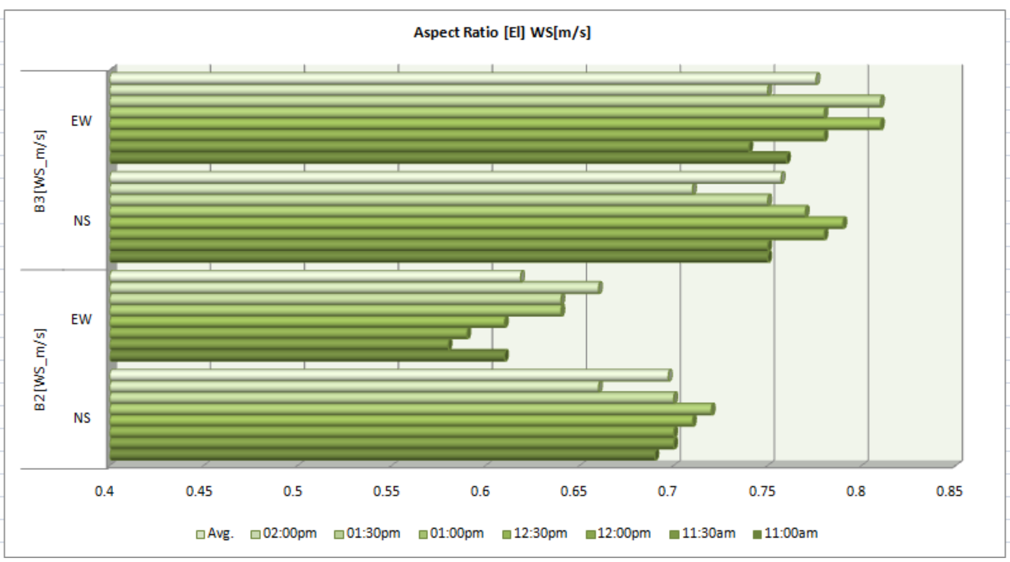

Fig 4.73: WS [m/s] in terms of aspect ratio comparing type B2 and B3 for El buildings

Relative humidity in terms of aspect ratio for elevated buildings type B2 for east west canyons achieves higher than B3 (Fig. 4.72), while in terms of wind speed B3 achieves higher than B2 for north south as well as east west canyons (Fig. 4.73).

4.4.3. Building Mass Configuration

1996 by-law

DBT

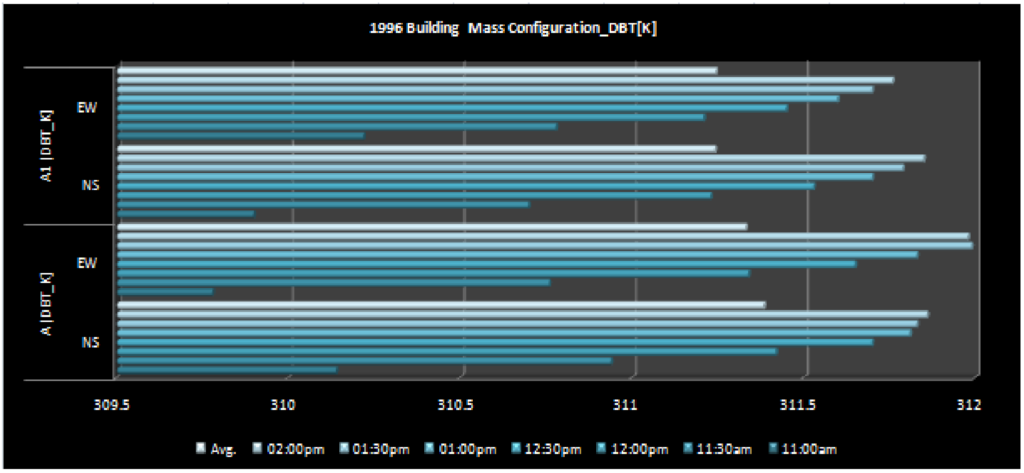

Fig 4.74: DBT [K] in terms of building mass configuration comparing type A and A1 buildings

MRT

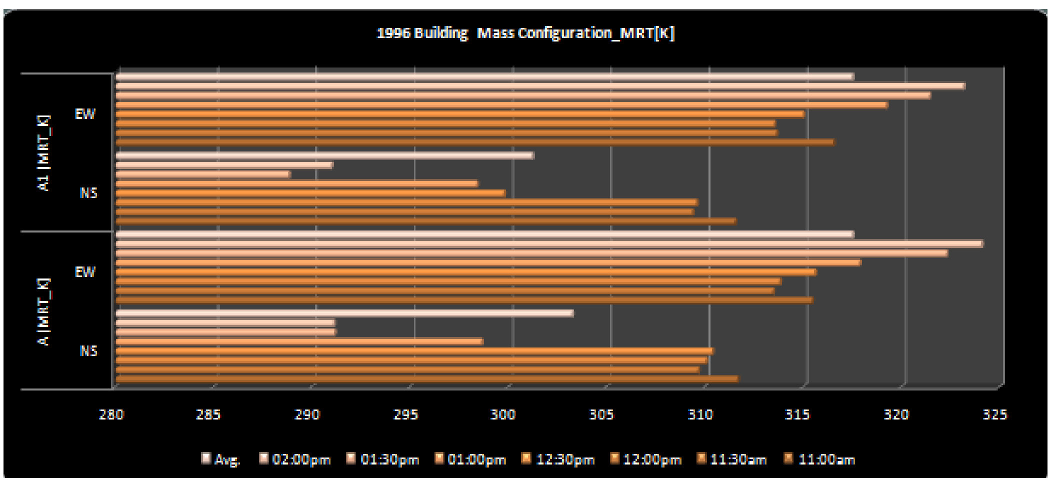

Fig 4.75: MRT [K] in terms of building mass configuration comparing type A and A1

Considering building mass configuration for 1996 by-law DBT for type A in east west canyons achieves highest (Fig. 4.74); while MRT for both types A and A1, east west canyons are much higher than the north south canyons.

RH

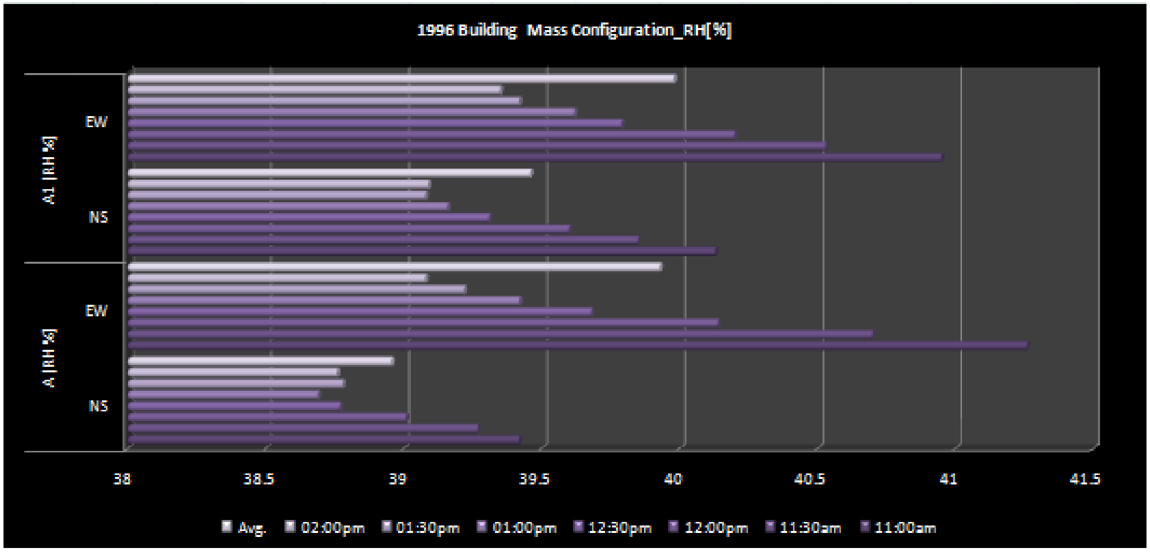

Fig 4.76: RH [%] in terms of building mass configuration comparing type A and A1

WS

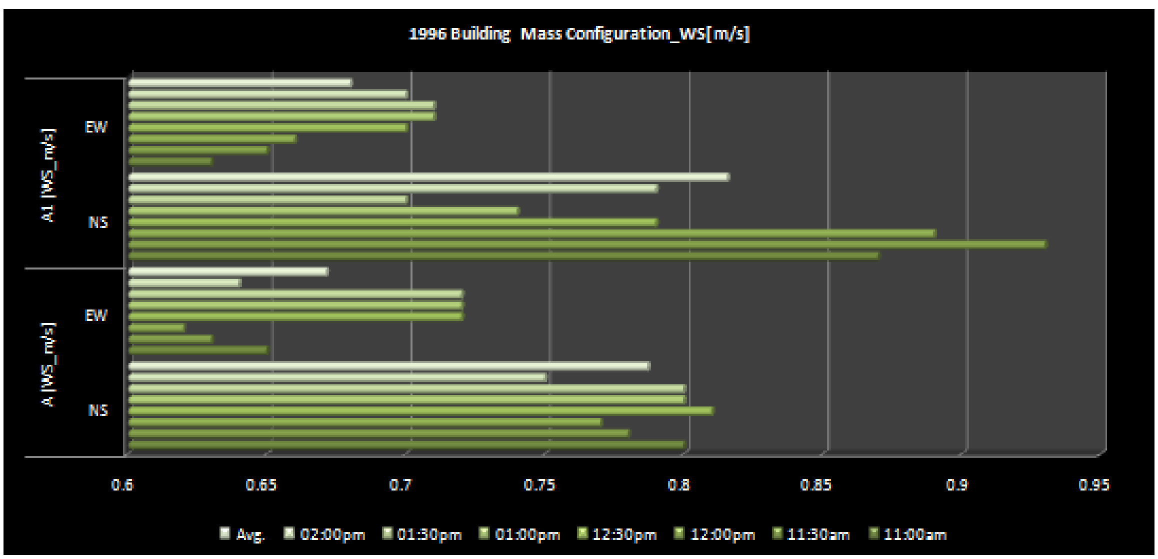

Fig 4.77: WS [m/s] in terms of building mass configuration comparing type A and A1

In terms of relative humidity east west canyons are higher for both simulation typologies type A and A1 (Fig. 4.76), while wind speed for north south canyons in terms of type A1 achieves highest as the buildings are elevated (Fig. 4.77).

2013 Building Regulation _ Buildings Closely Placed [cc]

DBT

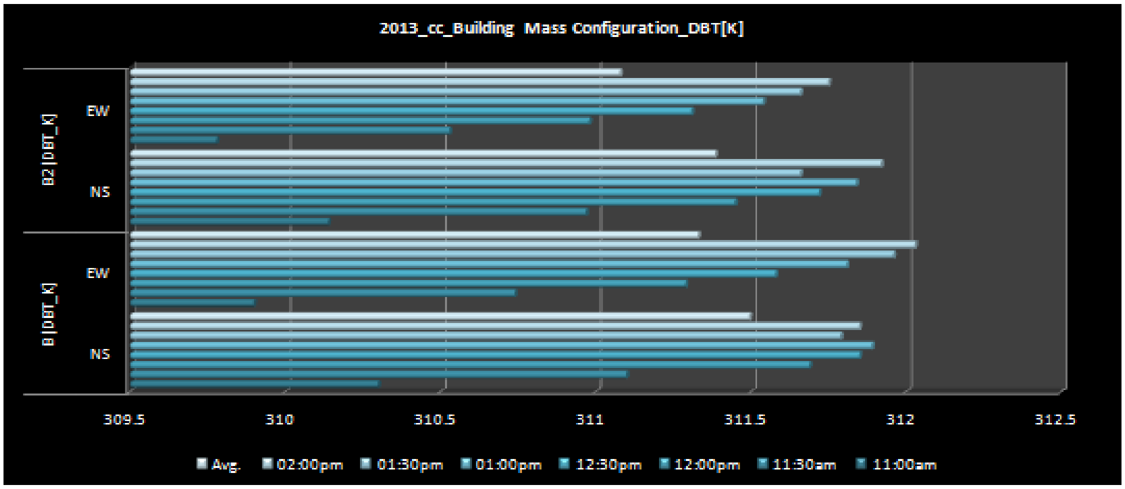

Fig 4.78: DBT [K] in terms of building mass configuration comparing type B and B2 for ‘cc’

MRT

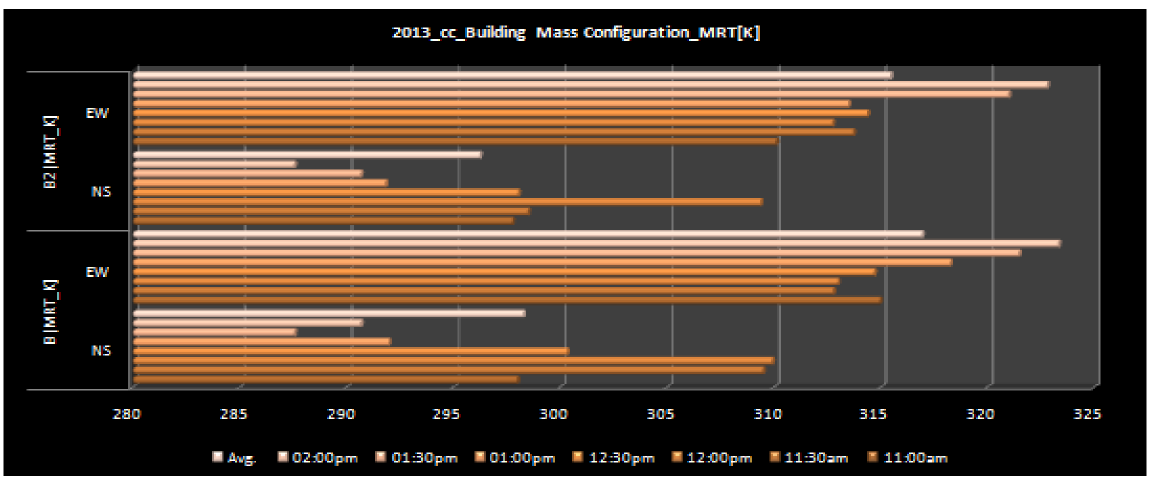

Fig 4.79: MRT [K] in terms of building mass configuration comparing type B and B2 for ‘cc’

Considering 2013 building regulation for closely placed buildings DBT is close to each simulation type i.e. B and B2 (Fig.4.78), while in terms of MRT it is clear that east west canyons are far more than the north south canyons (Fig. 4.79).

RH

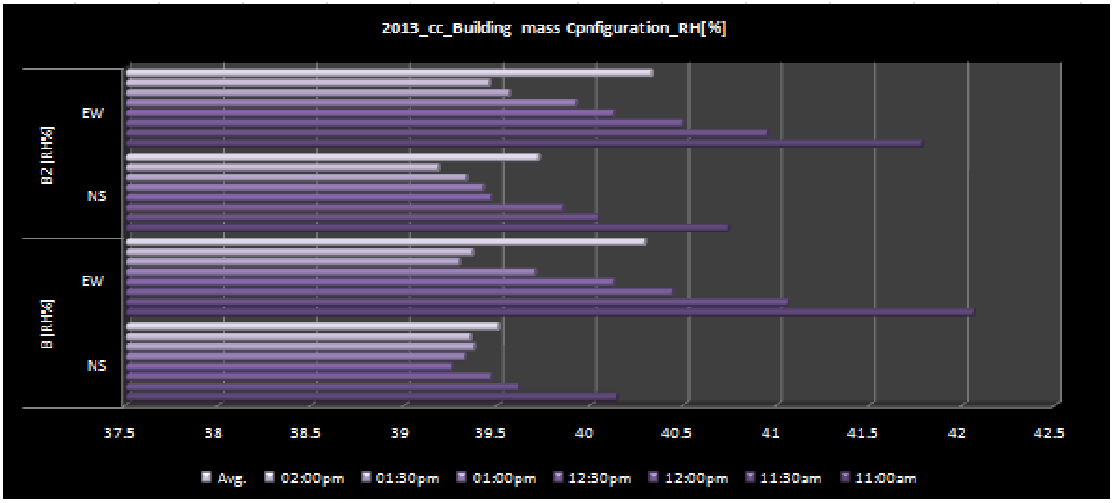

Fig 4.80: RH [%] in terms of building mass configuration comparing type B and B2 for 'cc'

WS

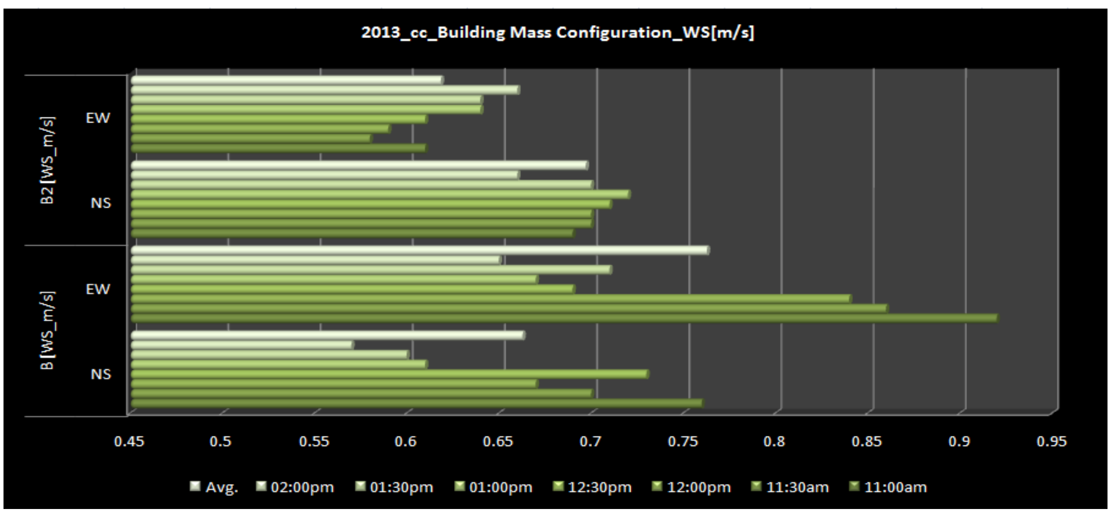

Fig 4.81: WS [m/s] in terms of building mass configuration comparing type B and B2 for 'cc'

The changes for relative humidity are similar for both the simulation typologies comparing north south and east west canyons (Fig. 4.80), while the changes for wind speed, it can be seen that east west canyons for type B achieves maximum (Fig. 4.81), which proves, elevated buildings doesn't always increase wind speed at pedestrian level.

2013 Building Regulation _ Buildings Placed Apart [ff]

DBT

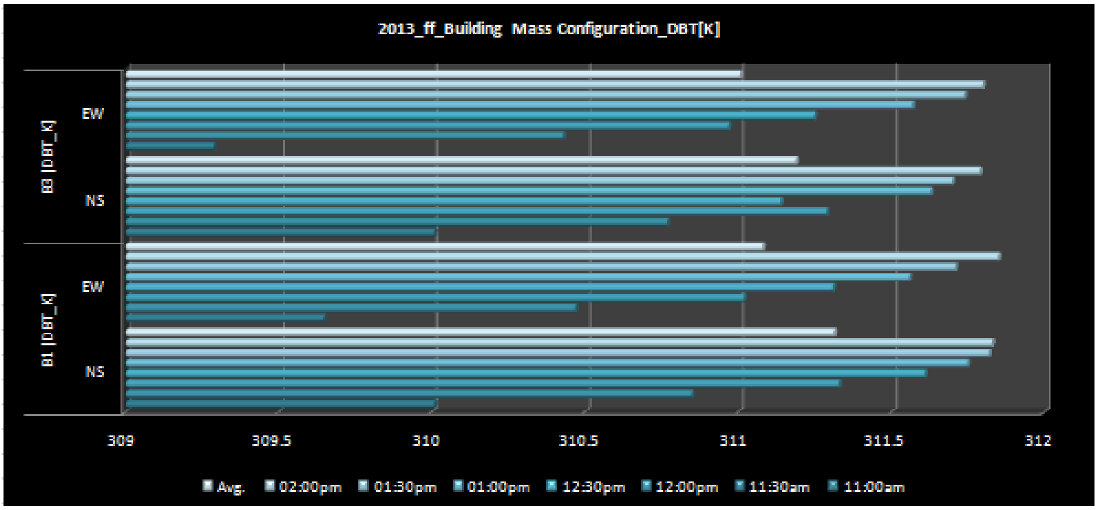

Fig 4.82: DBT [K] in terms of building mass configuration comparing type B1 and B3 for 'ff'

MRT

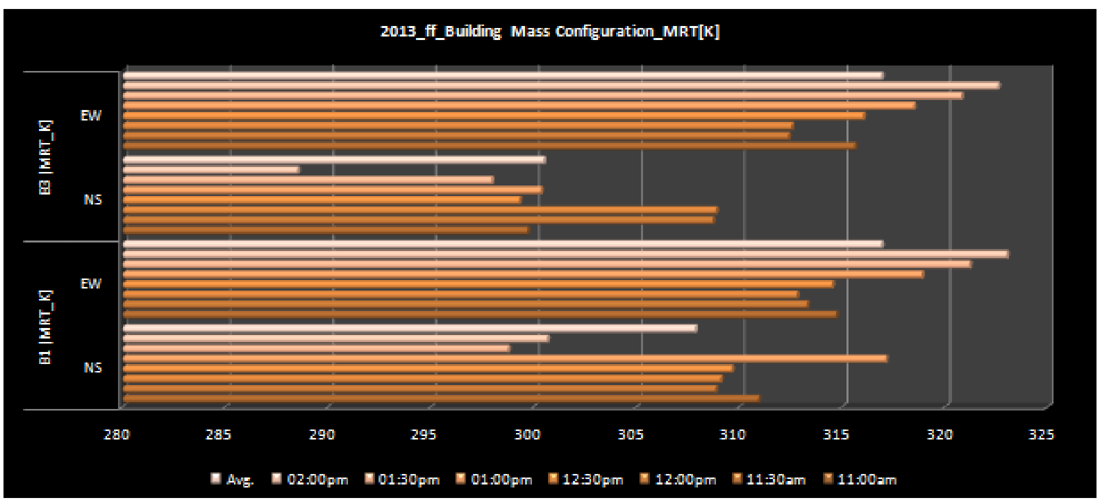

Fig 4.83: MRT [K] in terms of building mass configuration comparing type B1 and B3 for 'ff'

Considering 'ff' buildings that is buildings placed apart for 2013 building regulation MRT for simulation type B3 in terms of north south canyons achieved the lowest, while east west canyons is higher than north south canyons and close to each other(Fig 4.83)

RH

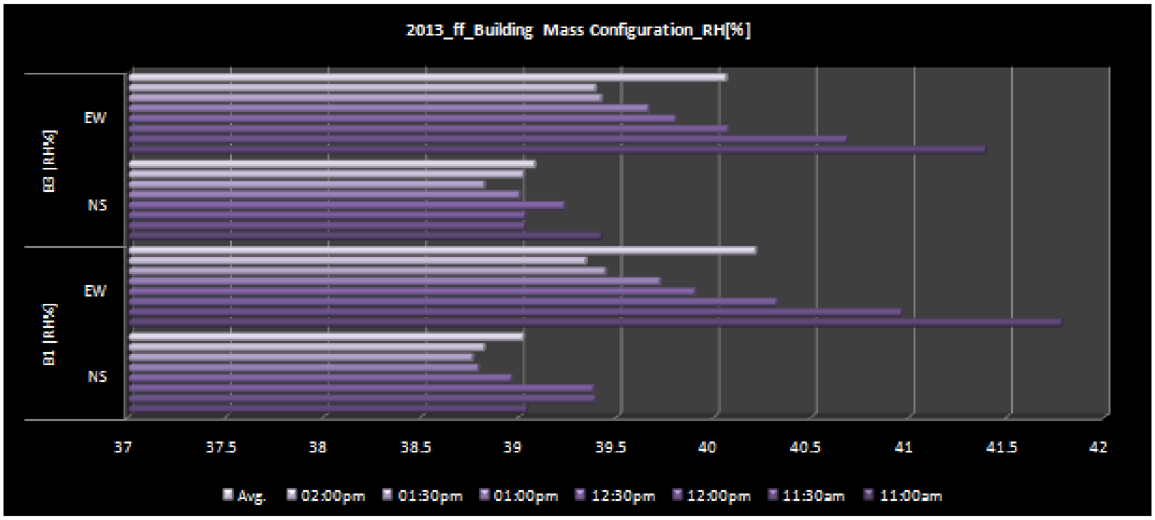

Fig 4.84: RH [%] in terms of building mass configuration comparing type B1 and B3 for 'ff'

WS

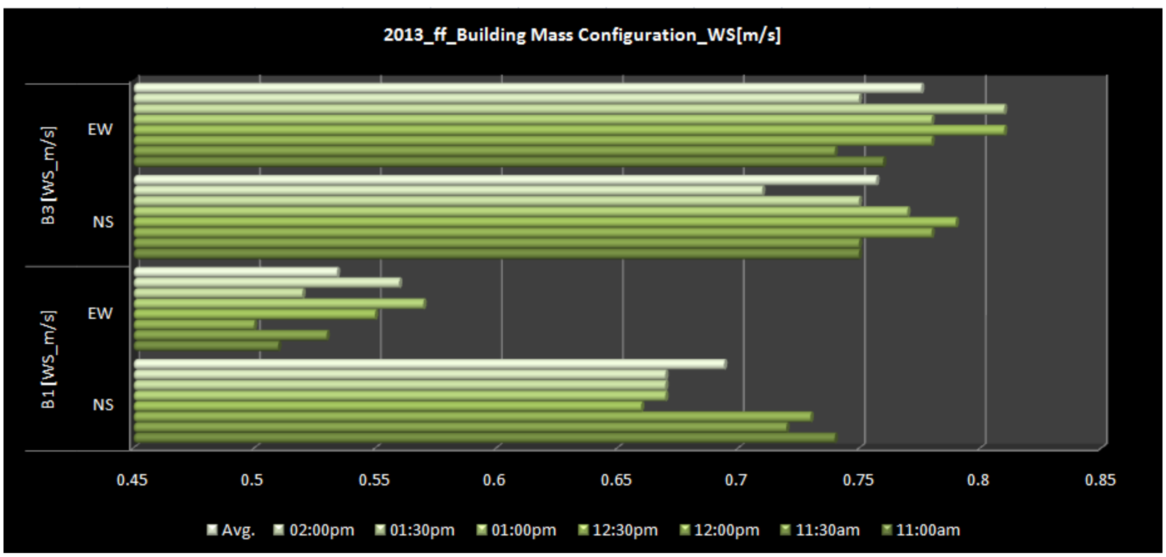

Fig 4.85: WS [m/s] in terms of building mass configuration comparing type B1 and B3 for 'ff'

Relative humidity achieves highest both for east west canyons for type B1 and B3 (Fig. 4.84), while wind speed for type B1 drops (Fig. 4.85).

4.4.4. Comparing 1996 by-law and Present Building Regulation

This section of the chapter compares the simulation results in terms of 1996 and present building regulation, which has been sub divided based on 'on-ground' and 'elevated' structures.

On-ground Structures

DBT

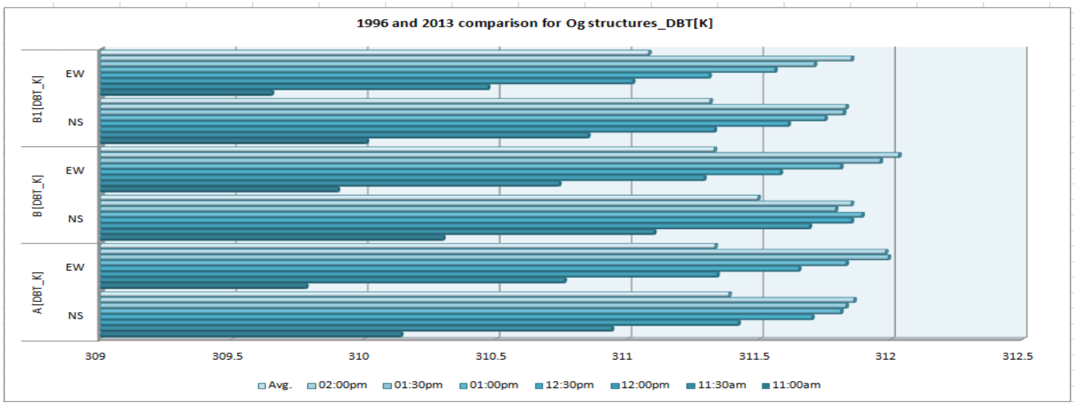

Fig 4.86: Comparing 1996 and 2013 for Og structures _ DBT [K]

MRT

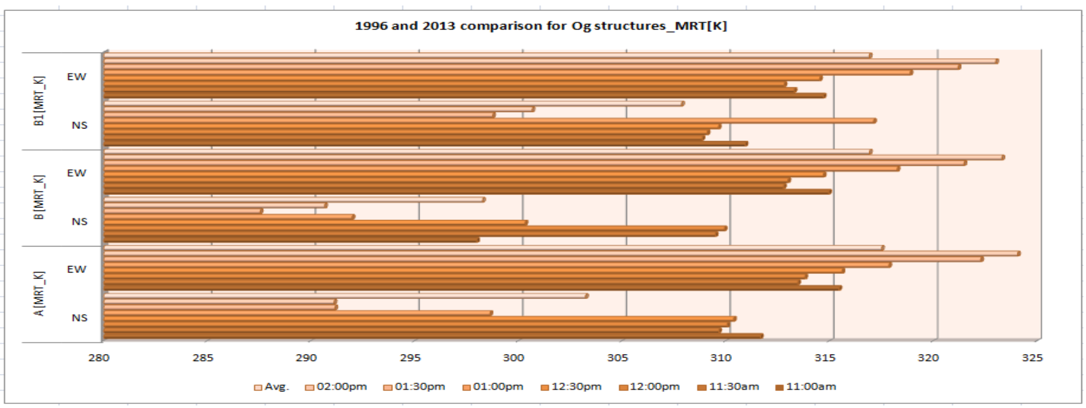

Fig 4.87: Comparing 1996 and 2013 for Og structures _ MRT [K]

Considering average value of MRT for 'Og' buildings, it can be seen that buildings under 1996 by law is in between type B and B1 i.e. 'cc' and 'ff' buildings where, 'cc' buildings are lower than 'ff' buildings for north south canyons, while results of east west canyons are close to each other, where buildings constructed under 1996 achieves highest MRT (Fig 4.87)

RH

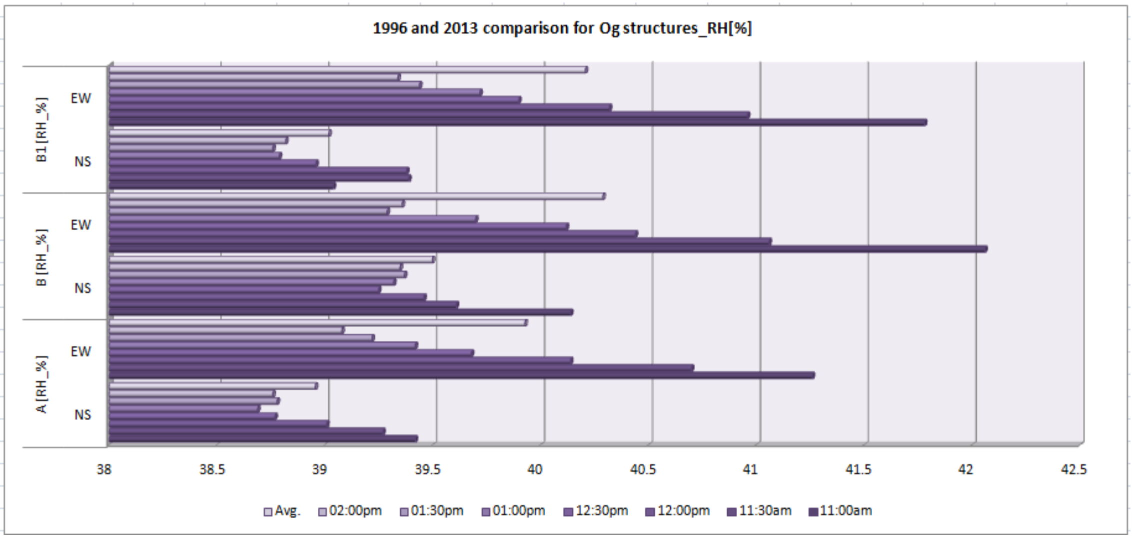

Fig 4.88: Comparing 1996 and 2013 for Og structures _ RH [%]

WS

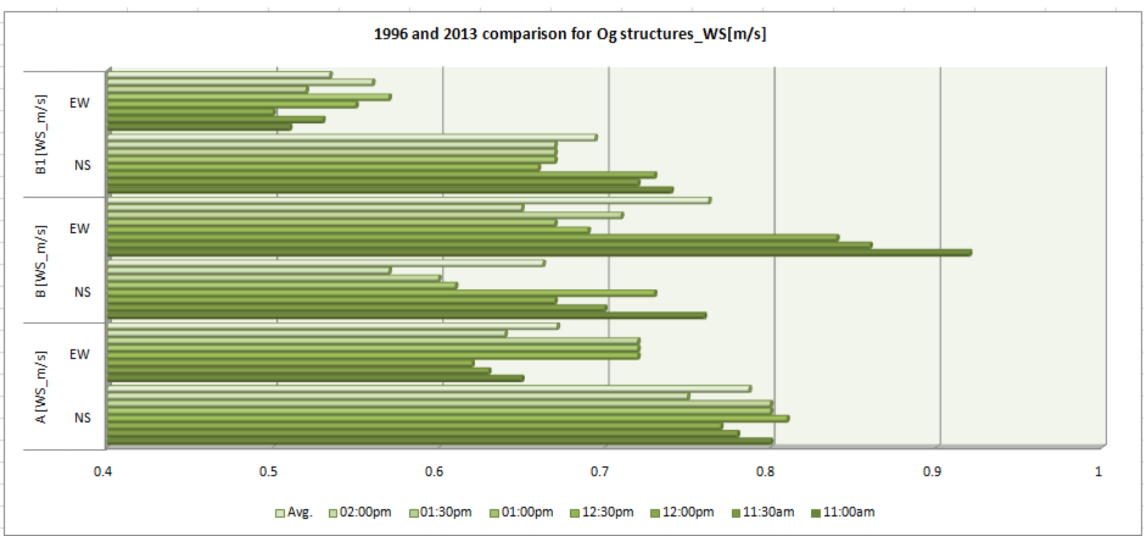

Fig 4.89: Comparing 1996 and 2013 for Og structures _ WS [m/s]

In terms of wind speed it is clear that east west canyons of type B are way ahead than buildings under 1996 and also buildings under 2013 placed apart i.e. 'ff', where B1type achieves lowest wind speed (Fig 4.89), while type A gains maximum in north south.

Elevated Structures

DBT

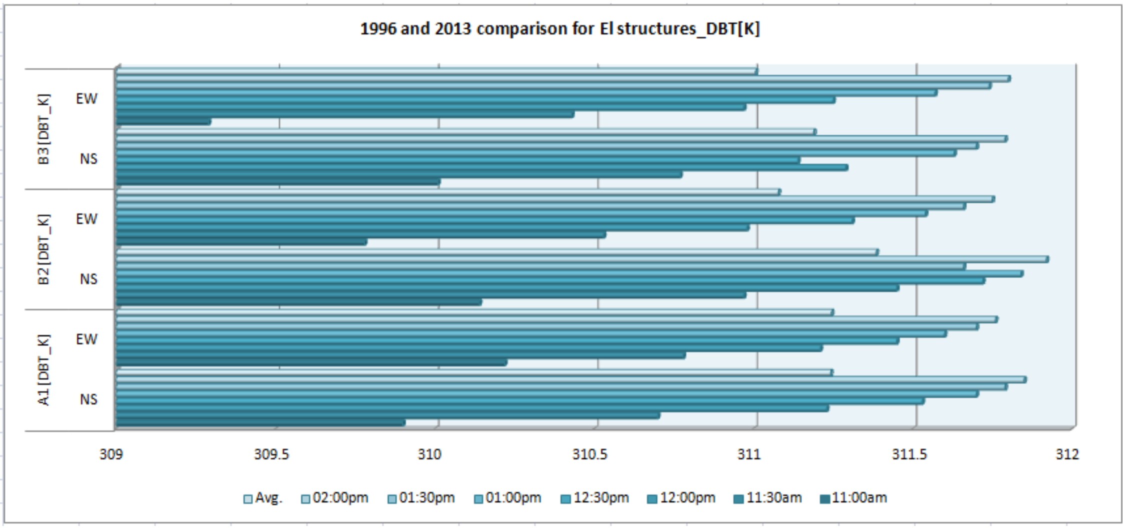

Fig 4.90: Comparing 1996 and 2013 for El structures _ DBT [K]

MRT

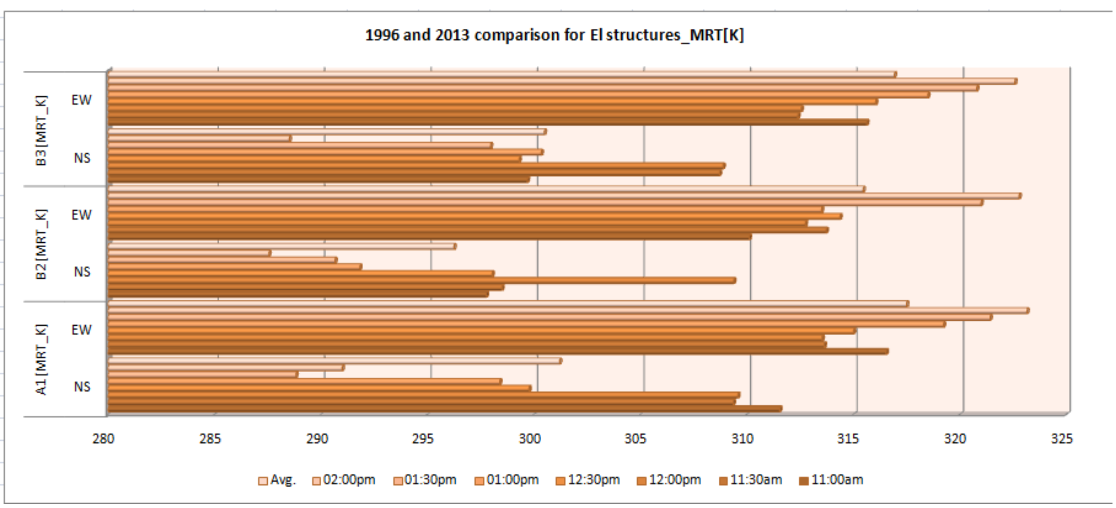

Fig 4.91: Comparing 1996 and 2013 for El structures _ MRT [K]

Considering MRT for elevated buildings comparing 1996 and 2013, it can be seen that overall east west canyons achieved higher MRT than the north south canyons, where buildings under 1996 gains the highest value (Fig 4.91).

RH

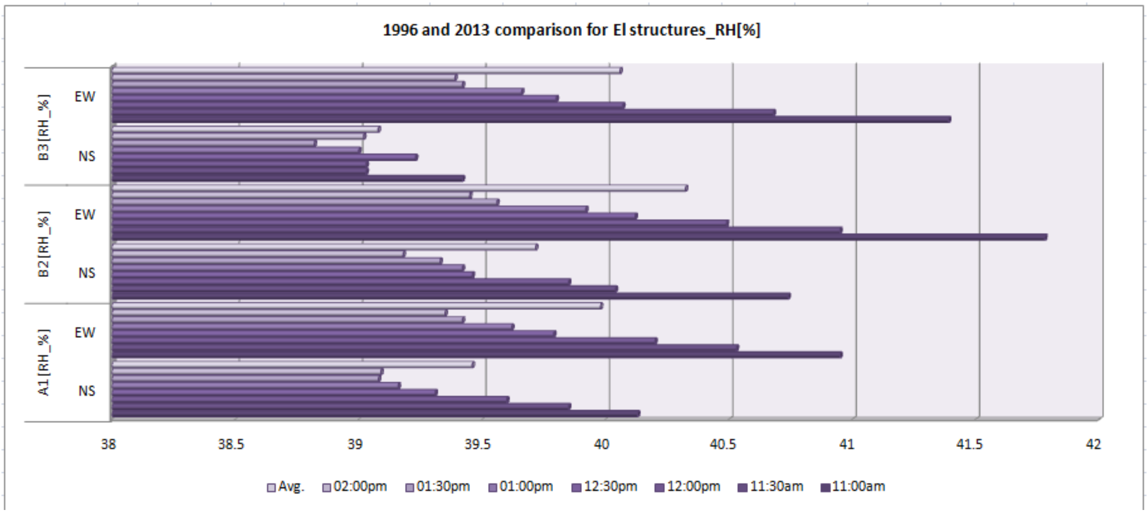

Fig 4.92: Comparing 1996 and 2013 for El structures _ RH [%]

WS

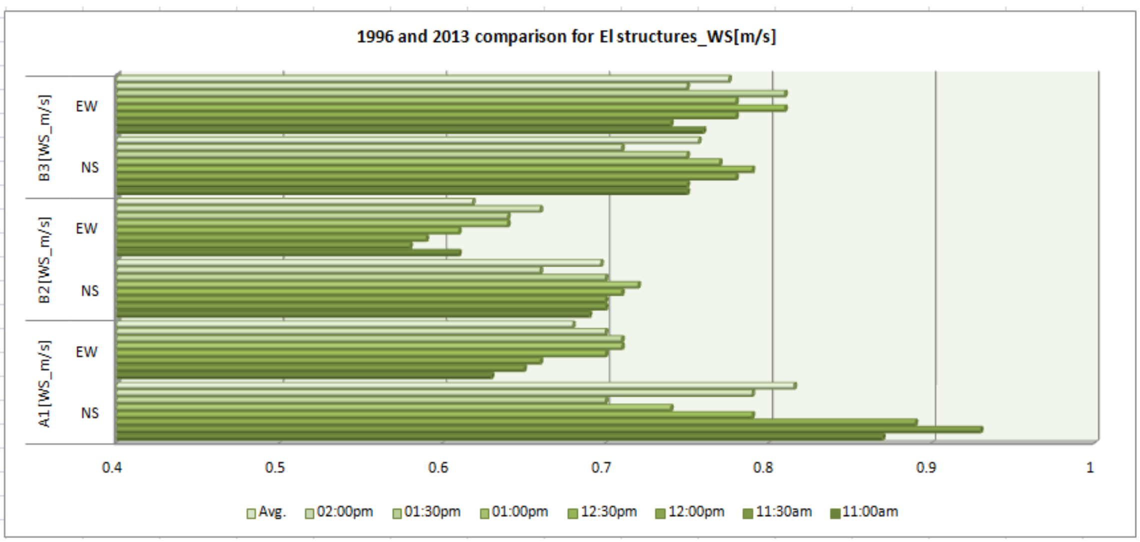

Fig 4.93: Comparing 1996 and 2013 for El structures _ WS [m/s]

Comparing wind speed for elevated structures it can be seen that type B2 for east west canyons achieves lowest wind speed, while north south canyons with buildings constructed under 1996 by-law gains the highest value of wind speed (Fig. 4.93).

4.5 Conclusion

Orientation

Table 4.3: Percentage changes of micro climate parameters for different typologies considering orientation

Orientation						
	A_DBT	***A1_DBT***	***B_DBT***	***B1_DBT***	***B2_DBT***	***B3_DBT***
NS	311.39	311.24	311.5	311.31	311.39	311.19
EW	311.33	311.25	311.33	311.08	311.08	311.01
diff	-0.06	0.01	-0.17	-0.23	-0.31	-0.18
avg	311.36	311.245	311.415	311.195	311.235	311.1
%chge	-0.02	0.00	-0.05	-0.07	-0.10	-0.06
	A_MRT	***A1_MRT***	***B_MRT***	***B1_MRT***	***B2_MRT***	***B3_MRT***
NS	303.25	301.22	298.28	307.88	296.25	300.49
EW	317.52	317.51	316.94	316.93	315.47	316.93
diff	14.27	16.29	18.66	9.05	19.22	16.44
avg	310.39	309.37	307.61	312.41	305.86	308.71
%chge	4.71	5.41	6.26	2.94	6.49	5.47
	A_RH	***A1_RH***	***B_RH***	***B1_RH***	***B2_RH***	***B3_RH***
NS	38.96	39.46	39.5	39.02	39.72	39.08
EW	39.93	39.98	40.29	40.21	40.32	40.06
diff	0.97	0.52	0.79	1.19	0.6	0.98
avg	39.45	39.72	39.90	39.62	40.02	39.57
%chge	2.49	1.32	2.00	3.05	1.51	2.51
	A_WS	***A1_WS***	***B_WS***	***B1_WS***	***B2_WS***	***B3_WS***
NS	0.79	0.82	0.66	0.69	0.7	0.76
EW	0.67	0.68	0.76	0.53	0.62	0.78
diff	-0.12	-0.14	0.1	-0.16	-0.08	0.02
avg	0.73	0.75	0.71	0.61	0.66	0.77
%chge	-15.19	-17.07	15.15	-23.19	-11.43	2.63

Considering mean radiant temperature in terms of orientation it can be seen that (Table 4.3) the percentage changes are significant while east west oriented canyon achieves more temperature than the north south canyons and maximum changes can be seen for B2 type canyons i.e. closely placed elevated buildings constructed under 2013 building regulation and the least changes are applicable for type A, i.e. buildings constructed on-ground under 1996 by-law. In terms of relative humidity maximum changes is for type B1 i.e. on-ground buildings placed apart under present building regulation. Wind speed increases in east west canyons for type B and B3, while decreases for type A, A1, B1 and B2, i.e. buildings constructed under 1996 by-law whether on-ground or elevated wind speed decreases in east west canyons.

Aspect ratio

Table 4.4: Percentage changes of micro climate parameters for different typologies considering aspect ratio for 'on-ground' buildings

Aspect ratio [Og]					
	NS	*EW*		*NS*	*EW*
B_MRT	298.28	316.94	B_DBT	311.5	311.33
B1_MRT	307.88	316.93	B1_DBT	311.31	311.08
diff	9.6	-0.01	diff	-0.19	-0.25
avg	303.08	316.94	avg	311.41	311.21
%chge	3.22	0.00	**%chge**	-0.06	-0.08
	NS	*EW*		*NS*	*EW*
B_RH	39.5	40.29	B_WS	0.66	0.76
B1_RH	39.02	40.21	B1_WS	0.69	0.53
diff	-0.48	-0.08	diff	0.03	-0.23
avg	39.26	40.25	avg	0.68	0.65
%chge	-1.22	-0.20	**%chge**	4.55	-30.26

Considering aspect ratio for different simulation typologies percentage changes for different microclimatic parameters are shown in terms of 'on-ground' buildings and 'elevated' buildings separately, while for 'on-ground' buildings, buildings placed apart in north south canyons achieves more mean radiant temperature than closely placed buildings. Wind speed drops significantly in east west canyons for on-ground buildings, while increases for north south canyons (Table 4.4).

Table 4.5: Percentage changes of micro climate parameters for different typologies considering aspect ratio for 'elevated' buildings

Aspect ratio [El]					
	NS	*EW*		*NS*	*EW*
B2_MRT	296.25	315.47	B2_DBT	311.39	311.08
B3_MRT	300.49	316.93	B3_DBT	311.19	311.01
diff	4.24	1.46	diff	-0.2	-0.07
avg	298.37	316.2	avg	311.29	311.05
%chge	1.43	0.46	**%chge**	-0.06	-0.02
	NS	*EW*		*NS*	*EW*
B2_RH	39.72	40.32	B2_WS	0.7	0.62
B3_RH	39.08	40.06	B3_WS	0.76	0.78
diff	-0.64	-0.26	diff	0.06	0.16
avg	39.4	40.19	avg	0.73	0.7
%chge	-1.61	-0.64	**%chge**	8.57	25.81

Considering aspect ratio for different simulation typologies in terms of 'elevated' buildings;' buildings placed apart' in north south canyons achieves more mean radiant temperature than closely placed buildings. Wind speed increases more in east west canyons for elevated buildings, than north south (Table 4.5).

Building mass configuration

Table 4.6: Percentage changes of micro climate parameters for different typologies considering 'building mass configuration' for 'closely placed buildings'

Building Mass Configuration [2013_cc]					
	NS	*EW*		*NS*	*EW*
B_MRT	298.28	316.94	B_DBT	311.5	311.33
B2_MRT	296.25	315.47	B2_DBT	311.39	311.08
diff	-2.03	-1.47	diff	-0.11	-0.25
avg	297.27	316.21	avg	311.45	311.21
%chge	-0.68	-0.46	**%chge**	-0.04	-0.08
	NS	*EW*		*NS*	*EW*
B_RH	39.5	40.29	B_WS	0.66	0.76
B2_RH	39.72	40.32	B2_WS	0.7	0.62
diff	0.22	0.03	diff	0.04	-0.14
avg	39.61	40.31	avg	0.68	0.69
%chge	0.56	0.07	**%chge**	6.06	-18.42

Considering 'building mass configuration' for different simulation typologies percentage changes for different microclimatic parameters are shown in terms of 'closely placed buildings' and 'buildings placed apart' separately; while for 'closely placed buildings', it can be seen that (Table 4.6) north south and east west canyons achieve lower mean radiant temperature. Wind speed drops 0.14m/s in east west canyons for elevated buildings, while increases for north south canyons. Relative humidity increases in terms of both north south and east west canyons, where percentage difference is more in north south canyons than east west.

Table 4.7: Percentage changes of micro climate parameters for different typologies considering 'building mass configuration' for 'buildings placed apart'

Building Mass Configuration [2013_ff]					
	NS	*EW*		*NS*	*EW*
B1_MRT	307.88	316.93	B1_DBT	311.31	311.08
B3_MRT	300.49	316.93	B3_DBT	311.19	311.01
diff	-7.39	0	diff	-0.12	-0.07
avg	304.19	316.93	avg	311.25	311.05
%chge	-2.40	0.00	**%chge**	-0.04	-0.02
	NS	*EW*		*NS*	*EW*
B1_RH	39.02	40.21	B1_WS	0.69	0.53
B3_RH	39.08	40.06	B3_WS	0.76	0.78
diff	0.06	-0.15	diff	0.07	0.25
avg	39.05	40.14	avg	0.73	0.66
%chge	0.15	-0.37	**%chge**	10.14	47.17

Building mass configuration in terms of 'buildings placed apart' it can be seen that (Table 4.7) 'elevated' buildings under present building regulation achieves lower mean radiant temperature than 'on-ground' buildings; while considering wind speed, percentage change for 'elevated' buildings both for north south and east west canyons are significantly higher than 'on-ground' buildings.

Comparing 1996 and 2013 building regulation

Table 4.8: Comparing 1996 and 2013 in terms of 'on-ground' structures

1996 and 2013 comparison [Og]											
	NS	*EW*		*NS*	*EW*		*NS*	*EW*		*NS*	*EW*
A_MRT	303.25	317.52	A_DBT	311.39	311.33	A_RH	38.96	39.93	A_WS	0.79	0.67
B_MRT	298.28	316.94	B_DBT	311.5	311.33	B_RH	39.5	40.29	B_WS	0.66	0.76
diff	-4.97	-0.58	diff	0.11	0	diff	0.54	0.36	diff	-0.13	0.09
avg	300.77	317.23	avg	311.45	311.33	avg	39.23	40.11	avg	0.73	0.72
%chge	-1.64	-0.18	**%chge**	0.04	0.00	**%chge**	1.39	0.90	**%chge**	-16.46	13.43
	NS	*EW*		*NS*	*EW*		*NS*	*EW*		*NS*	*EW*
A_MRT	303.25	317.52	A_DBT	311.39	311.33	A_RH	38.96	39.93	A_WS	0.79	0.67
B1_MRT	307.88	316.93	B1_DBT	311.31	311.08	B1_RH	39.02	40.21	B1_WS	0.69	0.53
diff	4.63	-0.59	diff	-0.08	-0.25	diff	0.06	0.28	diff	-0.1	-0.14
avg	305.57	317.23	avg	311.35	311.21	avg	38.99	40.07	avg	0.74	0.6
%chge	1.53	-0.19	**%chge**	-0.03	-0.08	**%chge**	0.15	0.70	**%chge**	-12.66	-20.90

Table 4.9: Comparing 1996 and 2013 in terms of 'elevated' structures

1996 and 2013 comparison [El]											
	NS	*EW*		*NS*	*EW*		*NS*	*EW*		*NS*	*EW*
A1_MRT	301.22	317.51	A1_DBT	311.24	311.25	A1_RH	39.46	39.98	A1_WS	0.82	0.68
B2_MRT	296.25	315.47	B2_DBT	311.39	311.08	B2_RH	39.72	40.32	B2_WS	0.7	0.62
diff	-4.97	-2.04	diff	0.15	-0.17	diff	0.26	0.34	diff	-0.12	-0.06
avg	298.74	316.49	avg	311.32	311.17	avg	39.59	40.15	avg	0.76	0.65
%chge	-1.65	-0.64	**%chge**	0.05	-0.05	**%chge**	0.66	0.85	**%chge**	-14.63	-8.82
	NS	*EW*		*NS*	*EW*		*NS*	*EW*		*NS*	*EW*
A1_MRT	301.22	317.51	A1_DBT	311.24	311.25	A1_RH	39.46	39.98	A1_WS	0.82	0.68
B3_MRT	300.49	316.93	B3_DBT	311.19	311.01	B3_RH	39.08	40.06	B3_WS	0.76	0.78
diff	-0.73	-0.58	diff	-0.05	-0.24	diff	-0.38	0.08	diff	-0.06	0.1
avg	300.86	317.22	avg	311.22	311.13	avg	39.27	40.02	avg	0.79	0.73
%chge	-0.24	-0.18	**%chge**	-0.02	-0.08	**%chge**	-0.96	0.20	**%chge**	-7.32	14.71

Considering canyons with buildings constructed under 1996 by-law and 2013 building regulation percentage changes for different simulation typologies in terms of different microclimatic parameters are shown for ‘on-ground’ and ‘elevated’ buildings separately. Table 4.8 compares percentage changes for on-ground buildings constructed under 1996 by-law with on-ground buildings ‘closely placed’ and ‘placed apart’ due to 2013 building regulation separately, while table 4.9 compares ‘elevated’ buildings. In terms of, mean radiant temperature it can be seen that closely placed buildings under 2013 is less than canyons under 1996, while for buildings placed apart in north south canyons are more. Wind speed decreases within the canyons applying 2013 building regulation comparing 1996 both for cc (closely placed buildings) and ff (buildings placed apart) buildings in north south canyons, while increases in east west canyons for closely placed buildings. Mean radiant temperature reduces both for ‘cc’ and ‘ff’ buildings under 2013 comparing 1996 by-law in north south and east west canyons (table 4.9), while wind speed significantly increases in east west canyons with elevated buildings placed apart under 2013 building regulation.

4.6 References

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Chapter Five: Analysis

Introduction

Analysis of Simulation Results

Statistical Analysis

Orientation

Aspect Ratio

Building Mass Configuration

Comparing 1996 and 2013 Building Regulation

References

Chapter 5: Analysis

5.1 Introduction

Simulation results were analyzed followed by statistical analysis through group differences and degree of relationship. Statistical table has been created to compare the impact of different building typologies from 1996 by-law and present building regulation in terms of different studied microclimatic parameters on orientation, aspect ratio and building mass configuration. Later in the chapter, analyses considering orientation (north-south and east-west), aspect ratio (h/w ratio) and building mass configuration (on-ground / elevated buildings) are discussed separately in terms of the microclimatic parameters through 'test of hypothesis', 'regression' and 'correlation'. Finally, outcomes of 1996 by-law and 2013 building regulation have been compared through point-biserial correlation and histograms for frequency distributions to see the impact of respective building regulations on studied microclimatic parameters within the street at pedestrian level.

5.2 Analysis of Simulation Results

Plotting the simulated data of different microclimate parameters (MRT, DBT, RH and WS) with respect to different simulation typologies [A_1996_Og (buildings placed on-ground under 1996 building regulation), A1_1996_El (elevated buildings under 1996 building regulation), B_2013_Og_cc (On-ground closely placed buildings under 2013 building regulation), B1_2013_og_ff (On-ground buildings placed apart under 2013 building regulation), B2_2013_El_cc (closely placed elevated buildings under 2013 building regulation) and B3_2013_El_ff (elevated buildings placed apart under 2013 building regulation)] in terms of different orientations (North-South and East-West) we get the following graphs:

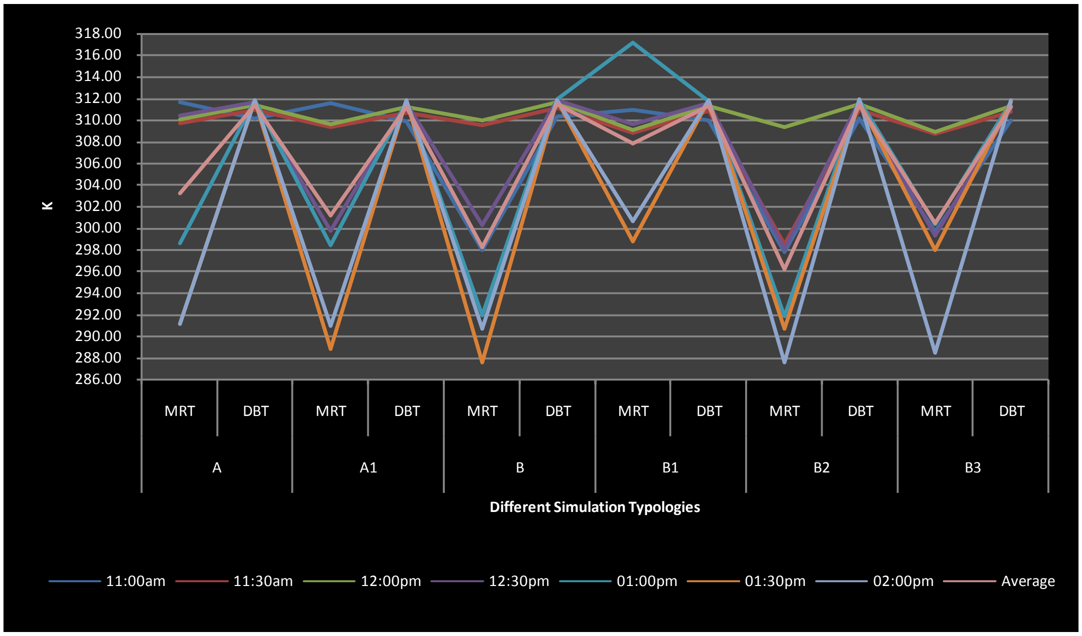


Fig 5.1: MRT and DBT of Different Simulation Typologies at Different Times [North-South]

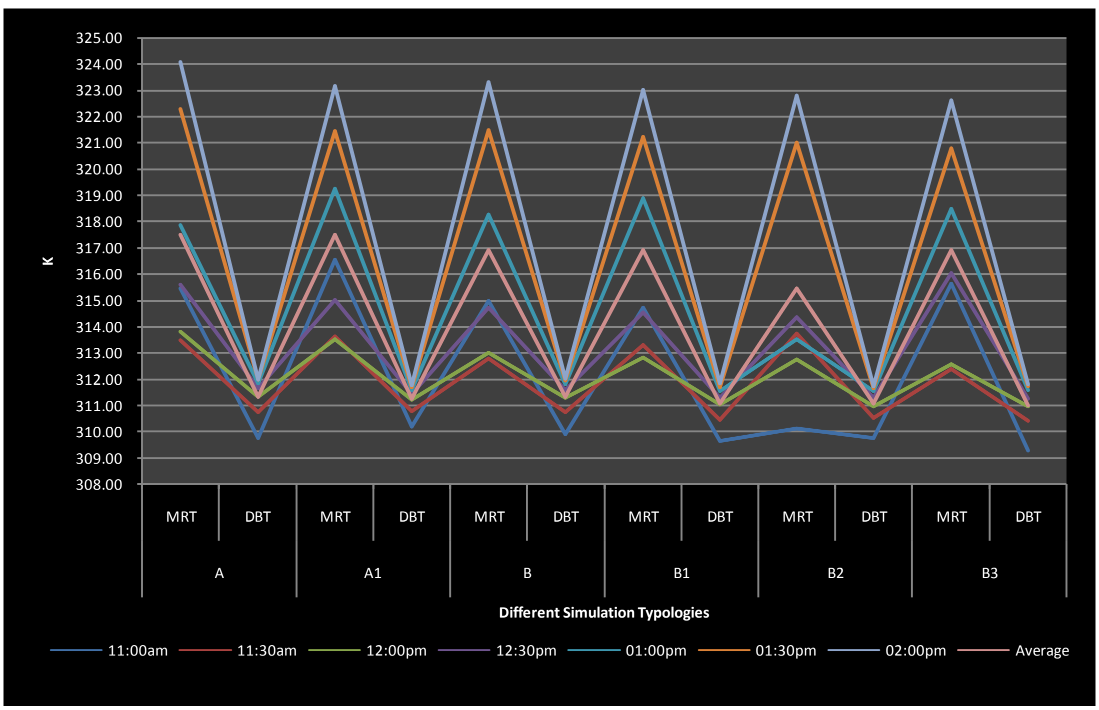


Fig 5.2: MRT and DBT of Different Simulation Typologies at Different Times [East-West]

Fig 5.1 and Fig 5.2 illustrates that radiant temperature differs much in terms of orientation, where it can be seen, east west orientated streets have higher RT (radiant temperature) than north south oriented streets while DBT (dry bulb temperature) doesn't differ in the same way; while MRT of type B2 in east west oriented canyons drops significantly; on the other hand MRT of type B1 is highest for north south canyons.

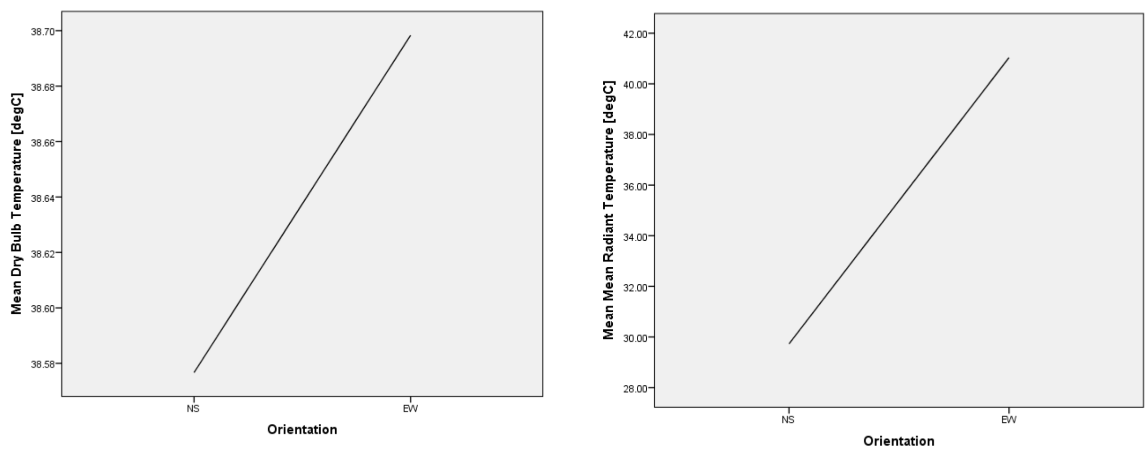


Fig 5.3: Mean value difference of DBT and MRT in terms of orientation

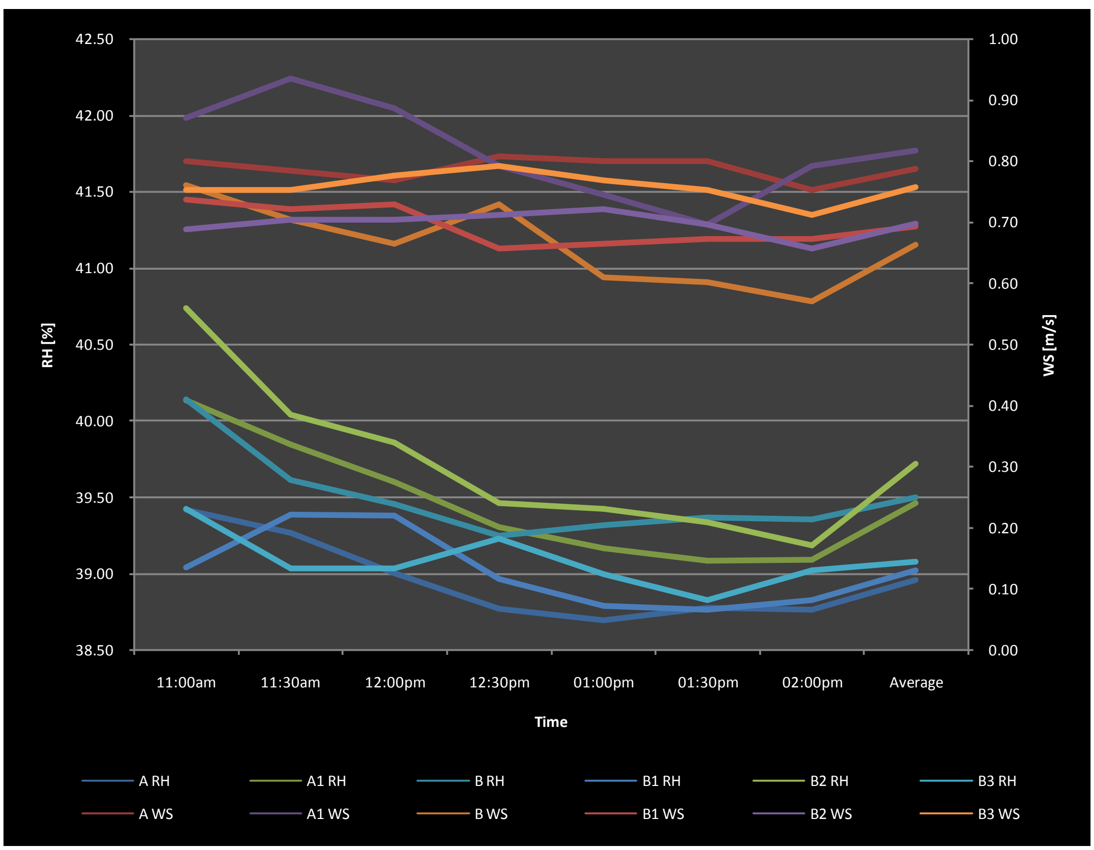


Fig 5.4: RH and WS at Different Times of Different Simulation Typologies [North-South]

Fig 5.4 and Fig 5.5 illustrates that relative humidity differs much in terms of orientation, where it can be seen, east west orientated streets have higher RH (relative humidity) than north south oriented streets, specially at early hours of the studied time of the day, while variations in WS (wind speed) among the simulation typologies are significant.

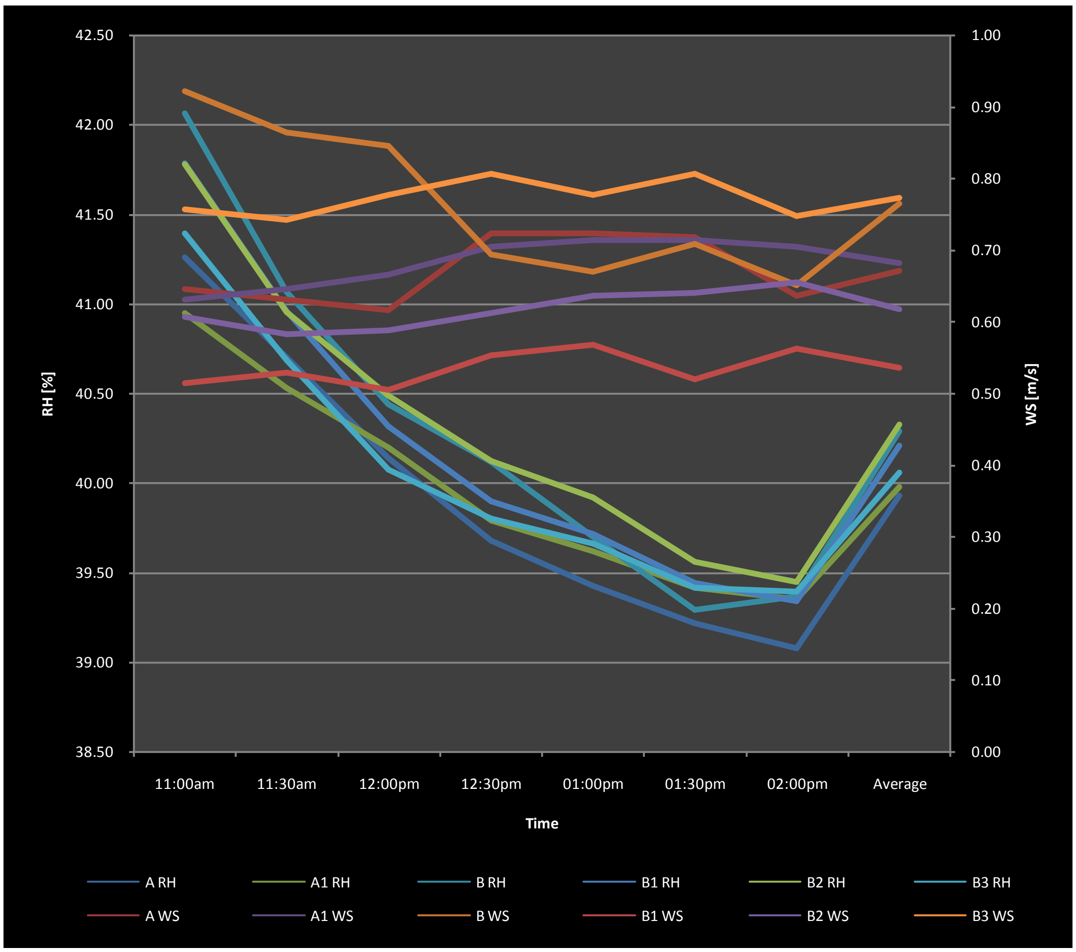


Fig 5.5: RH and WS at Different Times of Different Simulation Typologies [East-West]

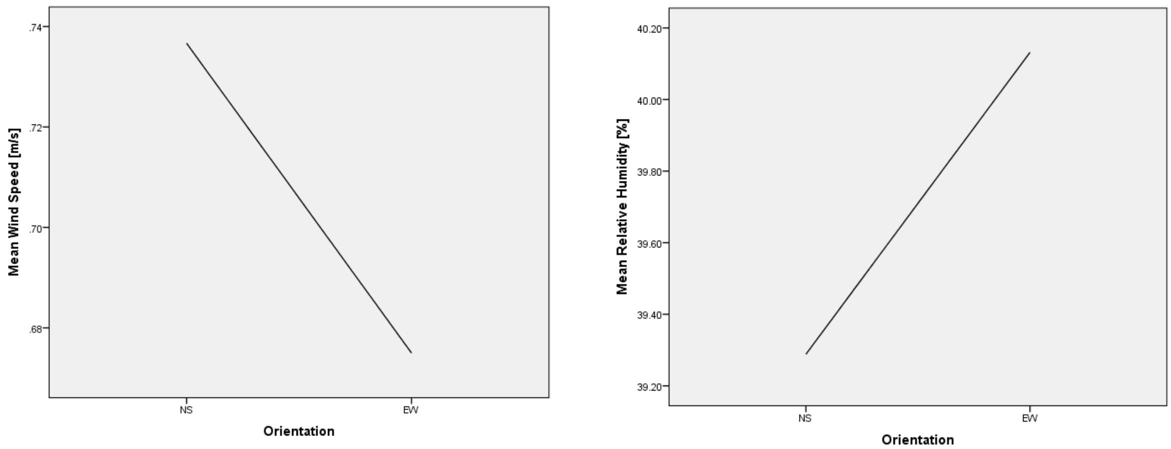
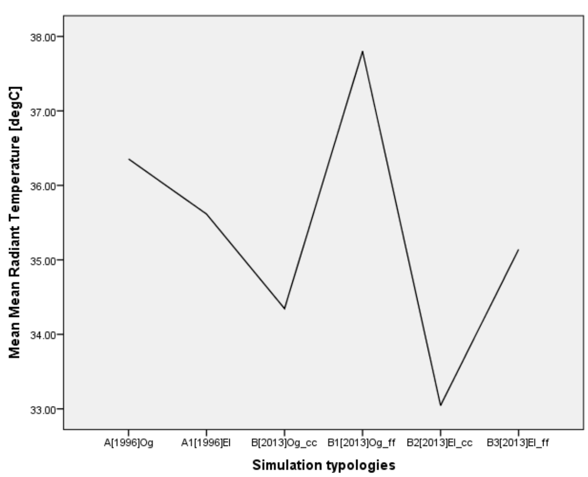


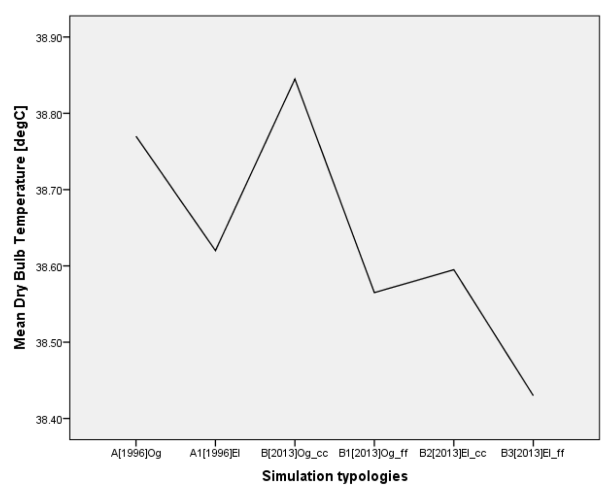
Fig 5.6: Mean difference of WS and RH in terms of orientation

Fig 5.3 and Fig 5.6 illustrates that mean values of MRT, DBT and RH are less in north-south oriented canyons compare to east-west; whereas wind speed is higher in north-south compare to east-west oriented street canyons.

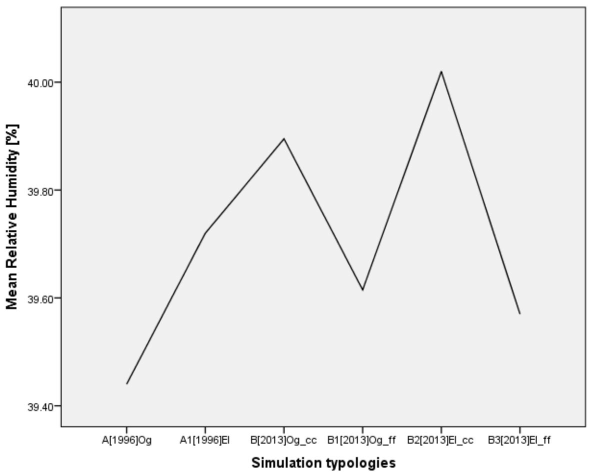
Mean Difference Study in terms of Simulation Typologies:



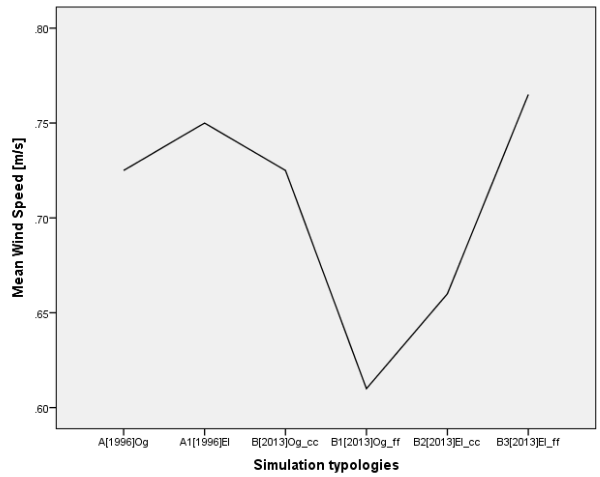
(1)



(2)



(3)



(4)

Fig 5.7: Mean differences of MRT (1), DBT (2), RH (3) and WS (4) in terms of simulation typologies

While comparing the mean values of different simulation typologies we can see that (Fig 5.7-1) in terms of MRT [mean radiant temperature] the highest value can be seen in B1 [on-ground buildings placed apart constructed under 2013 building regulation], while the lowest is in B2 [closely placed elevated buildings under 2013 building regulation, which signifies H/W ratio and building configuration has impact on MRT. While considering DBT [dry bulb temperature], the highest is for B [on-ground closely placed buildings under 2013] and the lowest can be seen for B3 [elevated buildings placed apart under 2013 building regulation]. In terms of DBT (Fig. 5.7-2) it can be seen that for all simulation typologies the range exceeds outdoor comfort level.

While considering RH [relative humidity] (Fig. 5.7-3), B2 [closely placed elevated buildings under 2013 building regulation] is the maximum while A [on-ground buildings under 1996 building regulation] have the lowest, which means building placement seems have impact on RH.

In terms of WS [wind speed] it is clear that (Fig. 5.7-4) the maximum speed can be observed for B3 [elevated buildings placed apart under 2013 building regulation], while the minimum value can be seen for B1 [on-ground buildings placed apart constructed under 2013 building regulation], which seems placement of the buildings have an impact on wind speed at pedestrian level.

From the results discussed above it is clear that neither previous nor existing building regulation in terms of aspect ratio (created after using maximum ground coverage within the plots), orientation and building mass configuration failed to provide outdoor comfort during hot summer days within the streets at pedestrian level thus failed to create 'cool islands'. Further analysis within this context are expected to help for creating comparatively better outdoor environment through comparing different built forms constructed under existing building regulation.

5.3 Statistical Analysis

Statistical techniques used during analysis are as follows: (Mertler C. A. & Vannatta R. A. 2002)

'T-tests' were done at the first phase. Having one independent categorical variable [Orientation (North-South / East-West)] or [Aspect ratio / Building mass configuration under (Simulation Typologies)] can be termed as 'predictors' and one quantitative dependent variable respectively [MRT or DBT or RH or WS] can be termed as 'responses'.

When there are 2+ categories and one quantitative dependent variable were taken into account then 'One way ANOVA [Analysis of Variance] were considered.

After 't-tests' depending upon research question, analyses were done in terms of 'Group Differences' and 'Degree of Relationship'. Thus the analyses were done in 2 phases.

a. Phase 1 analysis – Group differences
b. Phase 2 analysis – Degree of relationship

't-tests' were done to justify whether the data are statistically significant in terms of 90% confidence level, which were judged by 'P value'(Probability value). When $P < 0.1$, null hypothesis (H_0) was rejected and when $P > 0.1$, null hypothesis was not rejected; where null hypothesis signifies that there are no relationships among the selected variables, while on the other hand alternative hypothesis (H_1) signifies that there are relationships among the respective variables.

Phase 1 Analysis: Group Differences

Goal of analysis: To determine significance of mean group differences through 'One way ANOVA' (Analysis of Variance)

Phase 2 Analysis: Degree of Relationship

Goal of analysis: To determine strength of relationship among the variables and for prediction, Point Biserial Correlation and Simple Linear Regression were used respectively. 'Point Biserial Correlation' was used as the independent variables were in nominal scale at 2 levels i.e. 'Categorical Dichotomous' using Pearson Correlation co-efficient.

5.3.1 Analysis in terms of 'Group Differences' - ANOVA:

Analysis of variance is an extension of the notion of testing for difference between sample means. The possibility of difference in variance between three or more samples can be tested. The statistical method for testing the null hypothesis, that the means of several populations are equal is accomplished by what is known as 'F-test'. The 'F-test' is based on the technique of analysis of variance, abbreviated ANOVA (Stephen and Hornby, 1997). The term 'analysis of variance' describes a technique whereby the total variation embedded in data being analyzed is divided into meaningful components due to independent causes. The ANOVA is a very powerful technique of statistical analysis (Islam, 2012). ANOVA was completed in two phases, considering each simulation type in terms of orientation (North-South and East-West) separately. The independent variables were 'simulation typologies' which are coded as A, A1, B, B1, B2 & B3 and the dependent variables were microclimatic parameters (MRT, DBT, RH and WS). Post Hoc tests were carried out through LSD method.

ANOVA:

From fig 5.8 it illustrates that the mean group differences are highest in terms of wind speed among different simulation typologies where next stands the relative humidity. Furthermore the best treatment according to descriptive statistics it can be seen that simulation type B2, B3, B2 and A1 stands respectively for MRT, DBT, RH and WS for north-south orientation and simulation type B2, B3, B2 and B3 stands respectively for MRT, DBT, RH and WS for east-west oriented street canyons. Thus in terms of wind speed simulation type changes from A1 to B3 in terms of orientation.

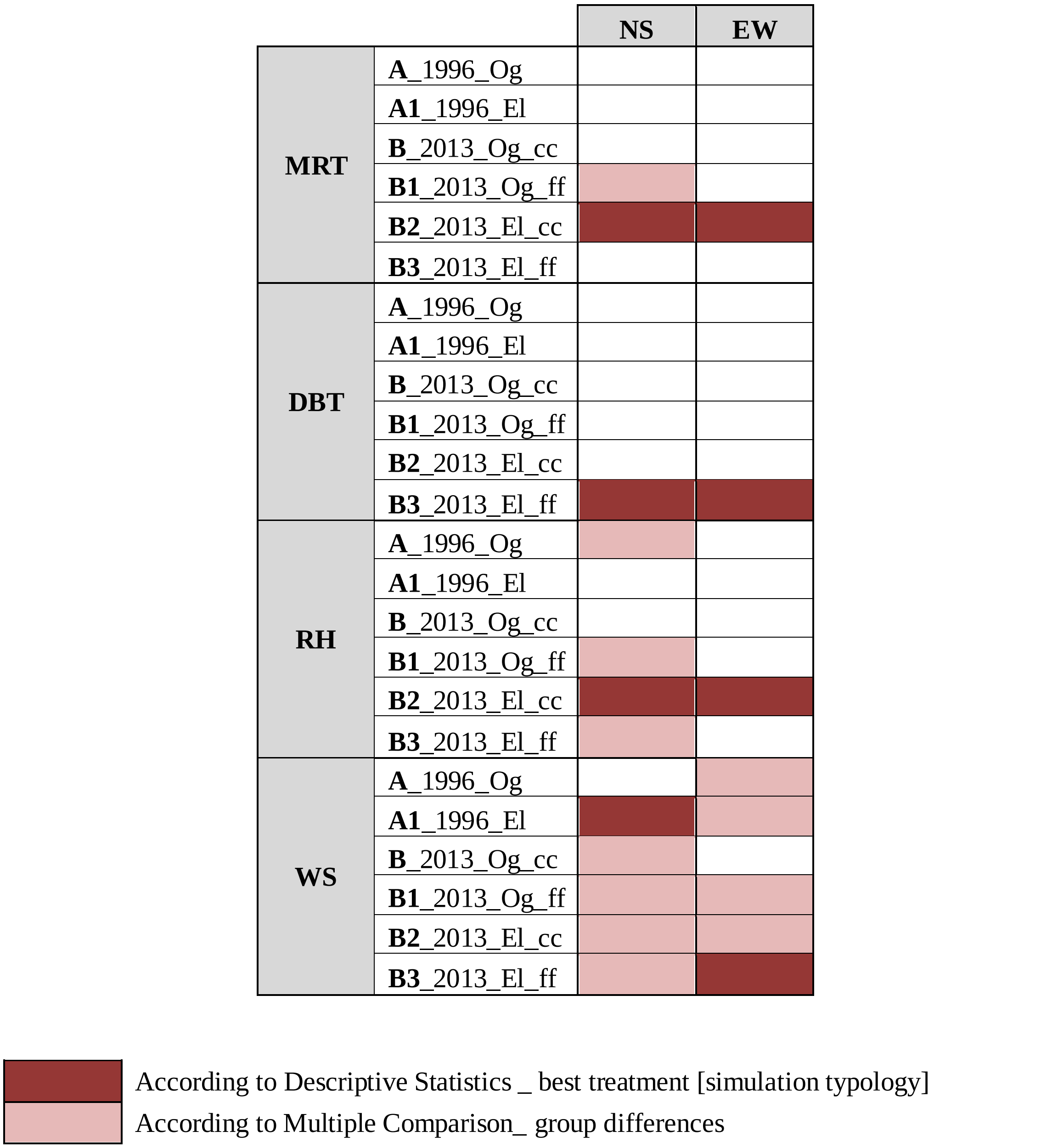


Fig 5.8: ANOVA chart for North-South & East-West [Post Hoc test: LSD method]

5.3.2 Analysis in terms of 'Degree of Relationship'

To study the degree of relationship 'table of statistical outputs' are created which is as follows:

Table of Statistical Outputs:

STATISTICAL TABLE for COMPARATIVE ANALYSIS - CONSIDERING ALL ASPECTS				MRT					DBT					RH					WS				
			Simulation Typologies	r -pb	R^2	P	Ho	Mean [K]	r -pb	R^2	P	Ho	Mean [K]	r- pb	R^2	P	Ho	Mean [%]	r-pb	R^2	P	Ho	Mean [m/s]
ORIENTATION	1996	A	NS [Og]	0.729	0.531	.003 [x]	x	303.25	-0.037	0.001	.901 [√]	√	311.38	0.653	0.427	.011 [x]	x	38.96	-0.861	0.741	.000 [x]	x	0.79
			EW [Og]					317.52					311.33					39.93					0.67
		A1	NS [El]	0.78	0.608	.001 [x]	x	301.22	0.002	0	.995 [√]	√	311.24	0.478	0.228	.084 [x]	x	39.46	-0.748	0.559	.002 [x]	x	0.82
			EW [El]					317.51					311.24					39.98					0.68
	2013	B	NS [Og cc]	0.822	0.676	.000 [x]	x	298.29	-0.13	0.017	.658 [√]	√	311.5	0.501	0.251	.068 [x]	x	39.5	0.513	0.264	.060 [x]	x	0.66
			EW [Og cc]					316.94					311.33					40.29					0.76
		B1	NS [Og ff]	0.679	0.461	.008 [x]	x	307.87	-0.17	0.029	.562 [√]	√	311.31	0.699	0.489	.005 [x]	x	39.02	-0.944	0.891	.000 [x]	x	0.69
			EW [Og ff]					316.92					311.08					40.21					0.53
		B2	NS [El cc]	0.864	0.741	.000 [x]	x	296.25	-0.238	0.057	.413 [√]	√	311.39	0.424	0.18	.131 [√]	√	39.72	-0.872	0.761	.000 [x]	x	0.7
			EW [El cc]					315.47					311.08					40.32					0.62
		B3	NS [El ff]	0.844	0.712	.000 [x]	x	300.49	-0.128	0.016	.663 [√]	√	311.19	0.701	0.491	.005 [x]	x	39.08	0.312	0.097	.278 [√]	√	0.76
			EW [El ff]					316.93					311.01					40.06					0.78
ASPECT RATIO	2013	Og	B [cc]	0.249	0.062	.201 [√]	√	307.61	-0.16	0.025	.417 [√]	√	311.41	-0.168	0.028	.392 [√]	√	39.89	-0.475	0.226	.011 [x]	x	0.71
			B1 [ff]					312.4					311.2					39.61					0.61
		El	B2 [cc]	0.135	0.018	.492 [√]	√	305.86	-0.097	0.009	.625 [√]	√	311.23	-0.304	0.093	.115 [√]	√	40.02	0.824	0.68	.000 [x]	x	0.66
			B3 [ff]					308.71					311.1					39.57					0.77
Building Mass Configuration	1996		A [Og]	-0.05	0.003	.800 [√]	√	310.38	-0.09	0.008	.647 [√]	√	311.36	0.208	0.043	.287 [√]	√	39.44	0.128	0.016	.515 [√]	√	0.73
			A1 [El]					309.36					311.24					39.72					0.75
	2013	cc	B [Og]	-0.078	0.006	.694 [√]	√	307.61	-0.139	0.019	.480 [√]	√	311.41	0.083	0.007	.673 [√]	√	39.89	-0.341	0.117	.075 [x]	x	0.71
			B2 [El]					305.86					311.23					40.02					0.66

		ff	B1 [Og]	-0.216	0.046	.270 [√]	√	312.4	-0.07	0.005	.723 [√]	√	311.2	-0.029	0.001	.884 [√]	√	39.61	0.775	0.601	.000 [x]	x	0.61
			B3 [El]					308.71					311.1					39.57					0.77
ASPECT RATIO	2013	Og	B[cc]_B1[ff]_NS	0.56	0.311	0.038 [x]	x	303.08	-0.15	0.024	0.6 [√]	√	311.41	-0.67	0.447	0.009 [x]	x	39.26	0.28	0.08	0.327 [√]	√	0.68
			B[cc]_B1 [ff]_EW	-0.001	0	0.996 [√]	√	316.93	-0.169	0.029	0.563 [√]	√	311.21	-0.047	0.002	0.873 [√]	√	40.25	-0.842	0.71	.000 [x]	x	0.65
		El	B2 [cc]_B3[ff]_NS	0.308	0.095	0.283 [√]	√	298.37	-0.163	0.027	0.577 [√]	√	311.29	-0.649	0.421	0.012 [x]	x	39.4	0.817	0.667	.000 [x]	x	0.73
			B2[cc]_B3 [ff]_EW	0.182	0.033	0.534 [√]	√	316.2	-0.048	0.002	0.87 [√]	√	311.04	-0.179	0.032	0.54 [√]	√	40.19	0.953	0.91	.000 [x]	x	0.7
Building Mass Configuration	1996		A [Og]_A1 [El]_NS	-0.117	0.014	0.69 [√]	√	302.23	-0.112	0.013	0.702 [√]	√	311.31	0.611	0.374	0.02 [x]	x	39.21	0.251	0.063	0.387 [√]	√	0.8
			A [Og]_A1 [El]_EW	-0.001	0	0.999 [√]	√	317.51	-0.069	0.005	0.814 [√]	√	311.29	0.038	0.001	0.897 [√]	√	39.95	0.149	0.022	0.61 [√]	√	0.68
	2013	cc	B [Og]_B2 [El]_NS	-0.134	0.018	0.647 [√]	√	297.27	-0.097	0.009	0.741 [√]	√	311.44	0.261	0.068	0.368 [√]	√	39.61	0.339	0.115	0.236 [√]	√	0.68
			B [Og]_B2 [El]_EW	-0.177	0.031	0.545 [√]	√	316.2	-0.179	0.032	0.54 [√]	√	311.2	0.019	0	0.948 [√]	√	40.31	-0.708	0.502	0.005 [x]	x	0.69
		ff	B1 [Og]_B3 [El]_NS	-0.516	0.266	0.059 [x]	x	304.18	-0.101	0.01	0.73 [√]	√	311.25	0.135	0.018	0.647 [√]	√	39.05	0.762	0.581	0.002 [x]	x	0.73
			B1 [Og]_B3 [El]_EW	0.001	0	0.996 [√]	√	316.93	-0.048	0.002	0.87 [√]	√	311.04	-0.098	0.01	0.74 [√]	√	40.13	0.981	0.962	.000 [x]	x	0.65

Point Biserial Correlation [r-pb]	Ho [Null hypothesis]	P value [probability value] @ 90% confidence level
r-pb: > 0.80 [very strong relation]		P < 0.1 [null hypothesis (Ho) rejected] - [x]
r-pb: 0.49-0.80 [strong]	**Regression [R^2]**	P > 0.1 [null hypothesis (Ho) not rejected] - [√]
r-pb: 0.25-0.48 [moderate]	Simple Linear regression	
r-pb: 0.00-0.24 [weak relation]		

Simulation type-explanation:

A : 1996_Og [On ground]
A1 : 1996_El [Elevated]
B : 2013_Og_cc [Closely placed]
B1 : 2013_Og_ff [Buildings apart]
B2 : 2013_El_cc
B3 : 2013_El_ff

Table 5.1: Statistical Table - considering all aspects

5.4 Orientation

Considering orientation test of hypothesis, regression and correlation are discussed below in terms of MRT, DBT, RH and WS:

5.4.1 Test of Hypothesis

MRT

While considering ‘orientation’ null hypothesis is rejected for all typologies, i.e. there are relationship in terms of orientation for 1996 & 2013 building regulation on MRT. (Table 5.1 & Fig. 5.9)

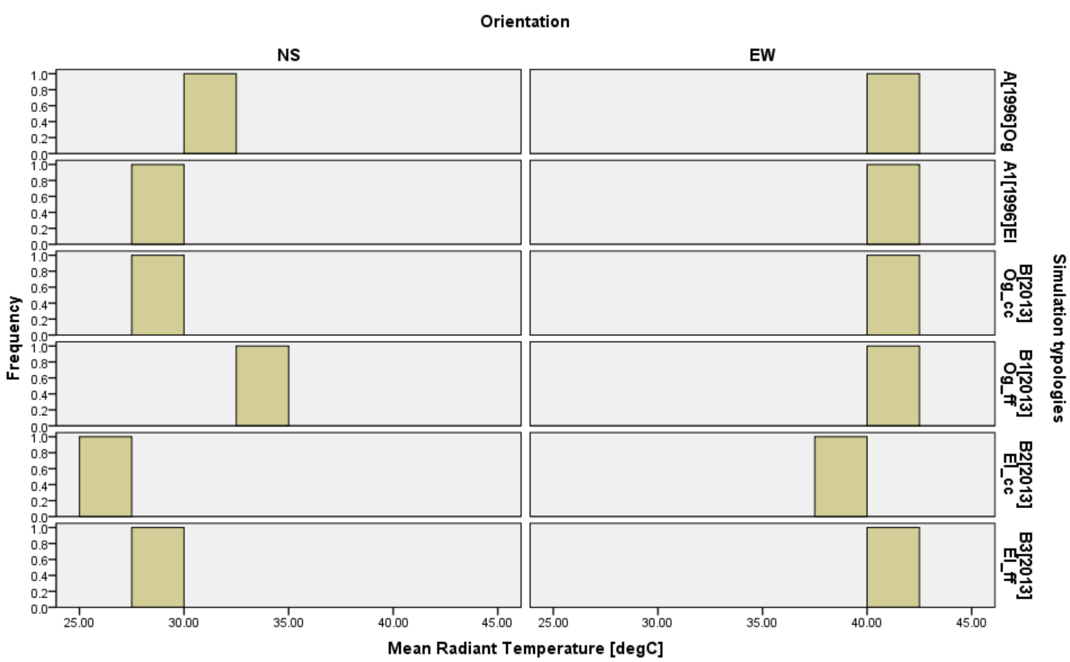


Fig 5.9: Histogram showing frequency distribution of MRT in terms of orientation

DBT

Considering DBT, null hypothesis is not rejected for all typologies, i.e. there seems no significant relationship in terms of 'orientation' for 1996 and 2013 building regulation on DBT. (Table 5.1 & Fig. 5.10)

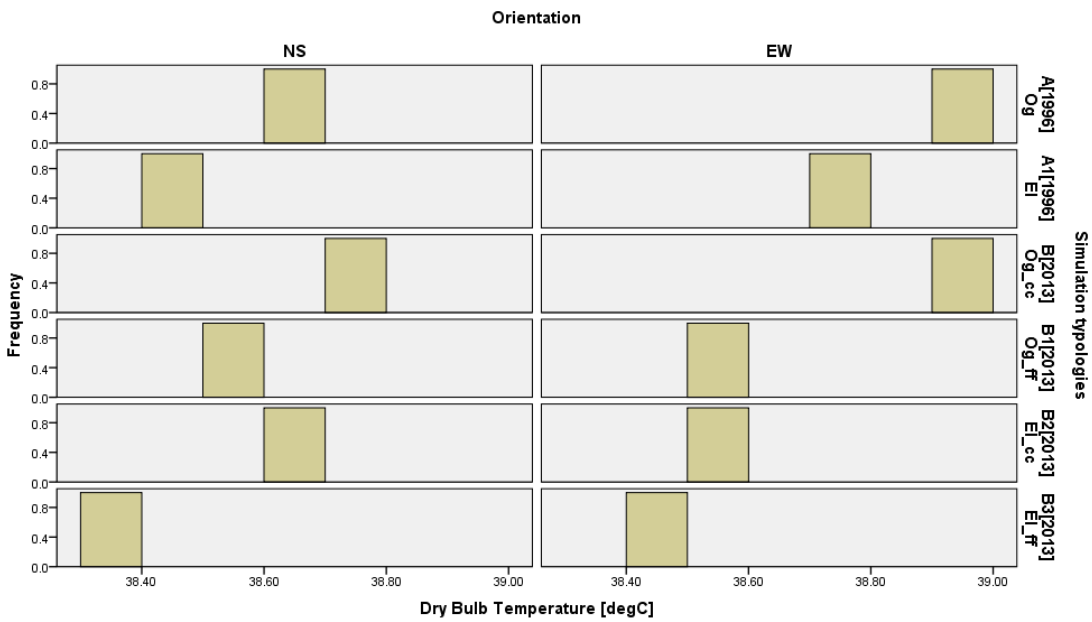


Fig 5.10: Histogram showing frequency distribution of DBT in terms of orientation

RH

There is significant relationship while considering type A, B1, B3 on RH in terms of orientation while other types don't. (Table 5.1 & Fig. 5.11)

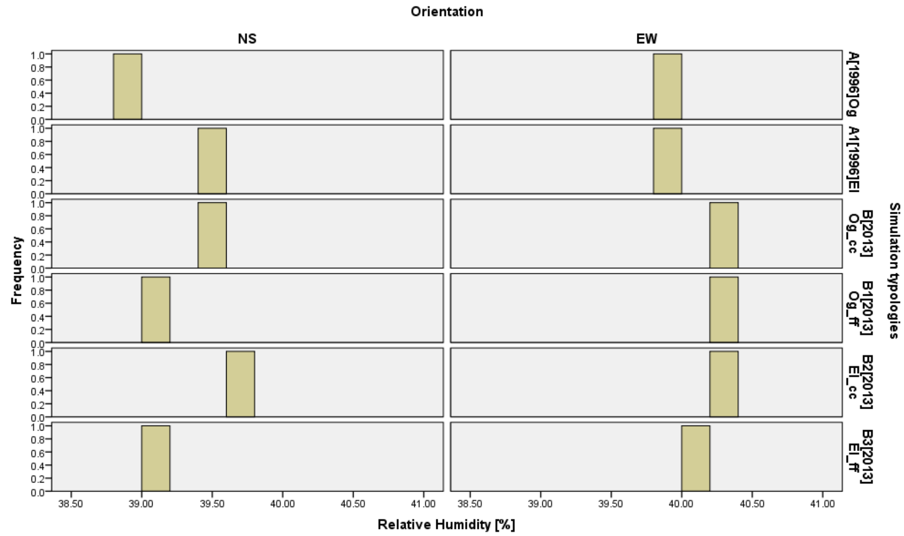


Fig 5.11: Histogram showing frequency distribution of RH in terms of orientation

WS

While considering type A, A1, B1, B2; there is significant relationship on 'wind speed' in terms of orientation while other types such as type B & B3 doesn't. (Table 5.1 & Fig. 5.12)

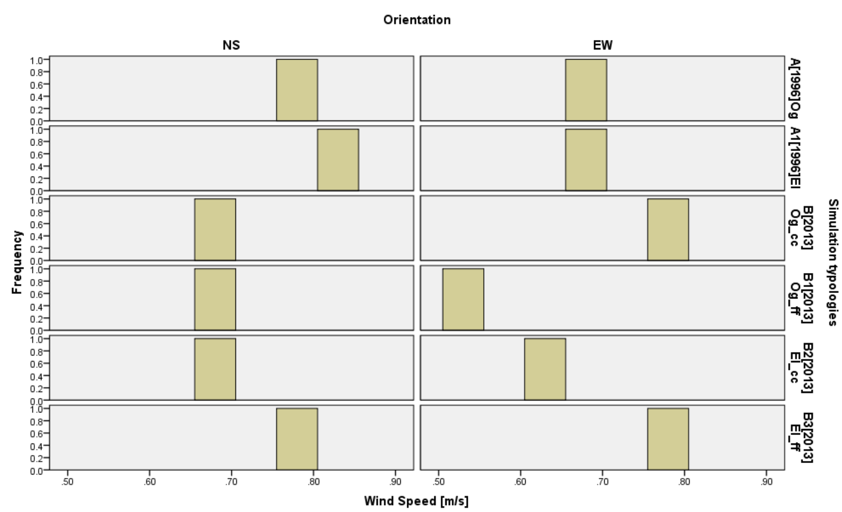


Fig 5.12: Histogram showing frequency distribution of WS in terms of orientation

5.4.2 Regression

MRT

Type B2, B3 have greater impact on MRT; while A1 have greater impact than type A considering orientation.

DBT

In terms of orientation simulation typologies have less impact on DBT. Comparing all typologies, B2 having greater impact of all.

RH

B1, B3 have greater impact on RH while B2 have the lowest of all typologies.

WS

B3 has least impact on wind speed considering orientation; while B1 have the highest. 'On-ground [Og]' buildings have greater impact on wind speed than elevated [El] while considering 1996 building regulation. Considering 2013 building regulation in terms of 'Og' buildings, buildings placed apart [ff] has greater impact than closely placed buildings [cc]; while 'cc' elevated buildings have greater impact elevated 'ff' buildings.

5.4.3 Correlation

MRT

2013 building regulation has greater correlation comparing 1996 [except for type B1] in terms of orientation while considering MRT. (Table 5.1 & Fig. 5.13)

DBT

Considering DBT the correlation is 'weak linear relation' in terms of 1996 and 2013 building regulation, where 1996 have weaker relationship comparing 2013. (Table 5.1 & Fig. 5.13)

RH

Type B3 has strong linear relation in terms of RH while other typologies have moderate linear relationship in terms of orientation. (Table 5.1 & Fig. 5.13)

WS

Surprisingly Type B1 has strongest relationship in terms of wind speed while considering orientation, while type B & B3 have moderate linear relationship. Rest typologies have strong relationship in terms of orientation. (Table 5.1 & Fig. 5.13)

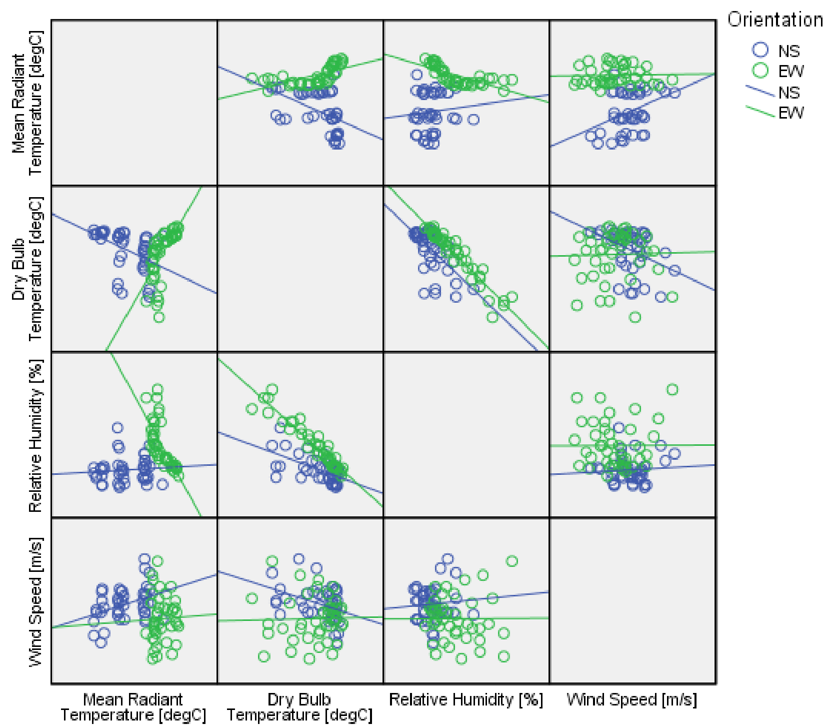


Fig 5.13: Correlation matrix of MRT, DBT, RH and WS in terms of orientation

5.5 Aspect Ratio [H/W ratio]

Considering aspect ratio test of hypothesis, regression and correlation are discussed below in terms of MRT, DBT, RH and WS:

5.5.1 Test of Hypothesis

As ‘null hypothesis’ is rejected for wind speed for both cases [Og & El structures] (Table 5.1), therefore wind speed has significant relationship considering ‘Aspect ratio’, while ‘null hypothesis’ can’t be rejected in terms of other parameters [i.e. MRT, DBT and RH] for both Og & El structures.

5.5.2 Regression

MRT

In terms of aspect ratio Og structures have greater impact on MRT comparing El structures.

DBT

Considering DBT, Og buildings have greater impact than ‘elevated’ structures.

RH

RH in terms of aspect ratio ‘elevated’ structures have greater impact ‘on ground’ buildings.

WS

Highest impact can be seen in terms of wind speed while considering 'aspect ratio'; where 'elevated' structures have greater impact than 'on-ground' structures.

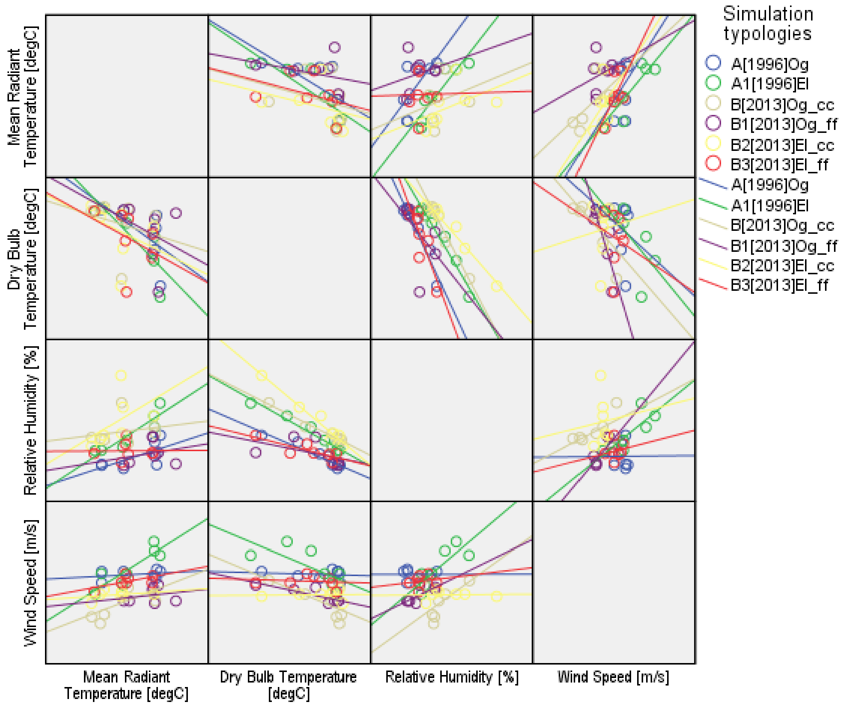


Fig 5.14: Correlation matrix of MRT, DBT, RH and WS in terms of different simulation typologies

5.5.3 Correlation

MRT

While considering 'aspect ratio', whether buildings are 'on-ground' or 'elevated' there seems weak linear correlation in terms of MRT, where 'on-ground' buildings have stronger relationship than 'elevated buildings (Table 5.1 & Fig 5.14).

DBT

While considering ‘aspect ratio’, whether buildings are ‘on-ground’ or ‘elevated’ there seems weak linear correlation in terms of DBT, where ‘on-ground’ buildings have stronger relationship than ‘elevated buildings (Table 5.1 & Fig 5.14).

RH

In terms of RH ‘elevated’ buildings have stronger relationship than ‘on-ground’ buildings. “Elevated’ have moderate linear relationship, while ‘on-ground’ buildings have weak linear relationship. (Table 5.1 & Fig 5.14)

WS

‘Elevated’ buildings have strong linear relationship on wind speed, while ‘on-ground’ buildings have moderate linear relationship. (Table 5.1 & Fig 5.14)

5.6 Building Mass Configuration [Og/El Structures]

Considering on-ground and elevated structures test of hypothesis, regression and correlation are discussed below in terms of MRT, DBT, RH and WS:

5.6.1 Test of Hypothesis

Buildings placed apart [ff] under 2013 building regulation have relationship in terms of wind speed, while other typologies [i.e. MRT, DBT & RH] seems have no significant relationship as null hypothesis is rejected for wind speed for buildings placed apart, while considering MRT, DBT and RH null hypothesis can't be rejected in case of 'Building mass configuration'.(Table 5.1)

5.6.2 Regression

Overall impact of buildings under 1996, 2013[cc] & 2013[ff] is less on MRT, DBT & RH; while comparatively 2013[cc] & 2013[ff] have greater impact on 'wind speed' where 2013 [ff] have the highest impact of all.

5.6.3 Correlation

MRT

Though buildings under 1996 & 2013 [cc &ff] have weak linear relationship in terms of building mass configuration [Og & El]; while comparing them it can be seen that buildings under 2013[ff] has greater relationship.

DBT

In terms of DBT it can be seen that overall relationship among buildings under 1996, 2013[cc] & 2013[ff] have weak linear relationship while 2013[cc] have the highest relationship among them.

RH

Buildings under 2013[cc] have strong linear relationship while considering RH while buildings under 1996 & 2013 [ff] has weak relationship.

WS

While considering wind speed it can be seen that buildings under 2013[ff] has strong relationship while 2013[cc] have moderate and buildings under 1996 have weak linear relationship.

Analyses were done in two phases, where in the first phase aspect ratio and building mass configuration were compared in a cumulative mode, regardless orientation; while in the second phase orientation was considered in dichotomous approach, to see the impact of orientation on the mentioned variables separately.

5.7 Comparing 1996 and 2013 Building Regulation

Analysis of different microclimatic parameters of the canyons due to 1996 and 2013 building regulation has been done in two steps i.e. comparing 1996 and 2013, considering 'on ground' and 'elevated' buildings in terms of north south and east west orientations separately.

i) Simulation type A NS: A NS - B NS B1 NS

ii) Simulation type A EW: A EW – B EW B1 EW

iii) Simulation type A1 NS: A1 NS – B2 NS B3 NS

iv) Simulation type A1 EW: A1 EW – B2 EW B3 EW

Histogram Analysis

Analysis through frequency distribution using histograms in terms of orientation and different simulation typologies we can get the following graphs (Fig. 5.15-5.30).

Simulation type A NS: A NS - B NS B1 NS

MRT

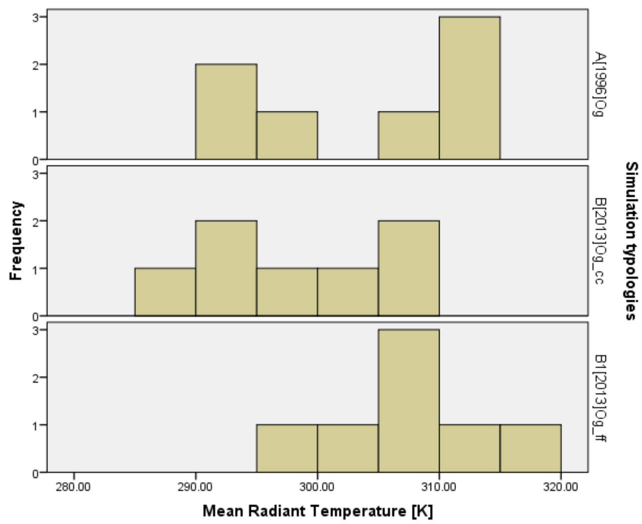


Fig 5.15: Frequency distribution of MRT considering Simulation type A NS_B NS_B1 NS

DBT

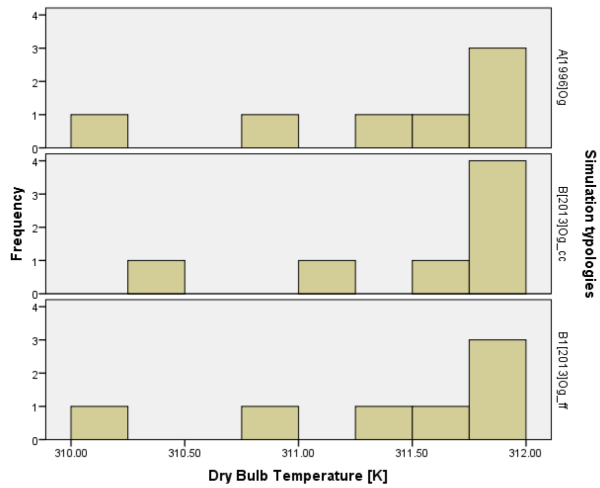


Fig 5.16: Frequency distribution of DBT considering Simulation type A NS_B NS_B1 NS

RH

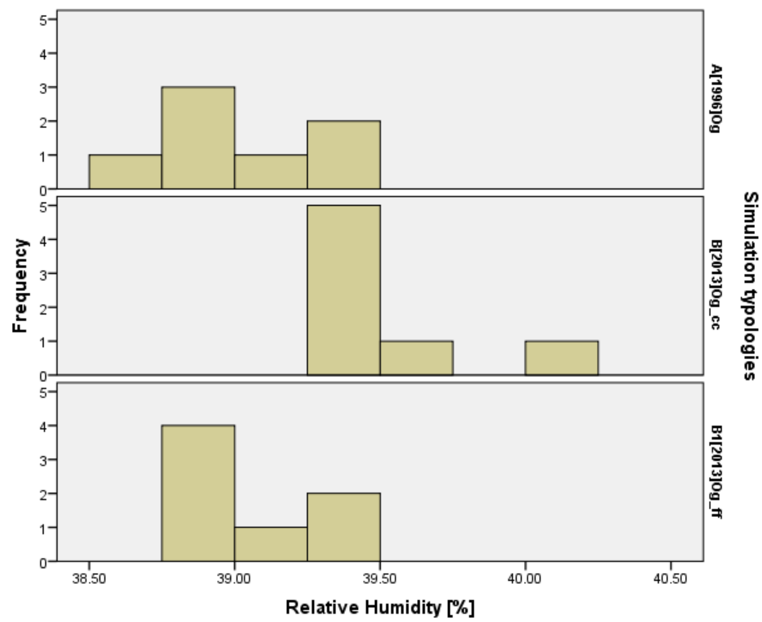


Fig 5.17: Frequency distribution of RH considering Simulation type A NS_B NS_B1 NS

WS

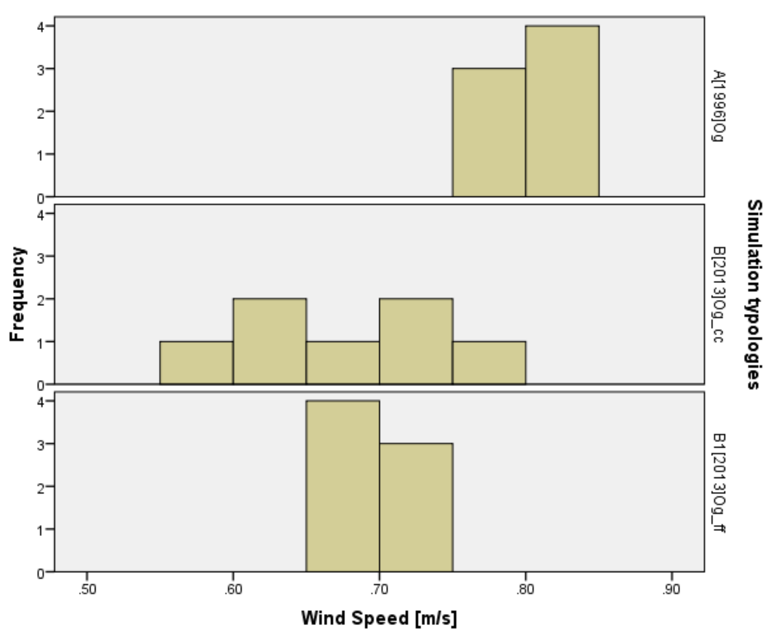


Fig 5.18: Frequency distribution of WS considering Simulation type A NS_B NS_B1 NS

Simulation type A EW: A EW – B EW B1 EW

MRT

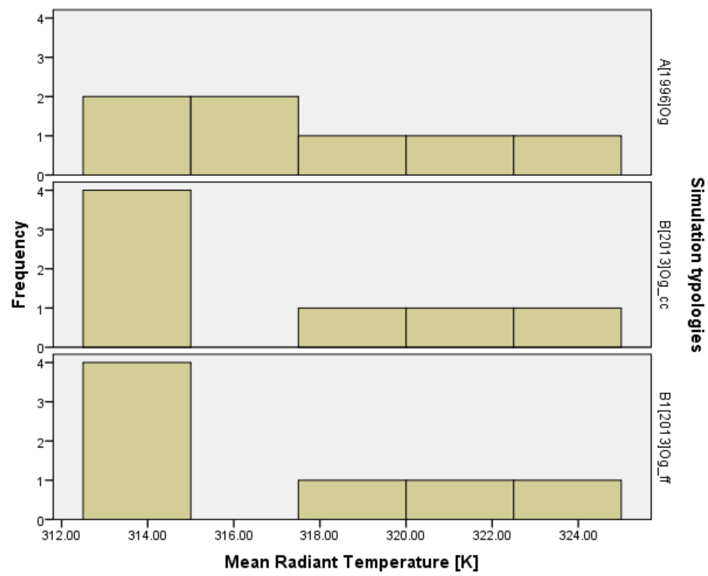


Fig 5.19: Frequency distribution of MRT considering Simulation type A EW_B EW_B1 EW

DBT

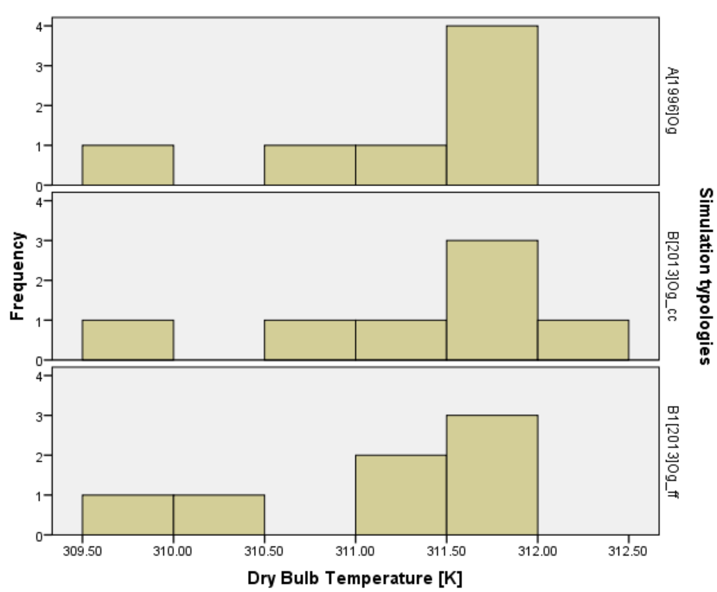


Fig 5.20: Frequency distribution of DBT considering Simulation type A EW_B EW_B1 EW

RH

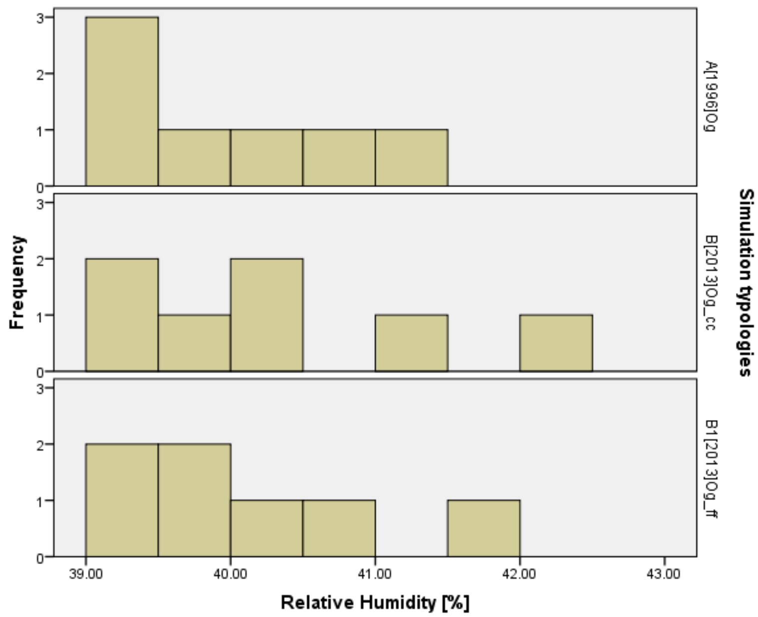


Fig 5.21: Frequency distribution of RH considering Simulation type A EW_B EW_B1 EW

WS

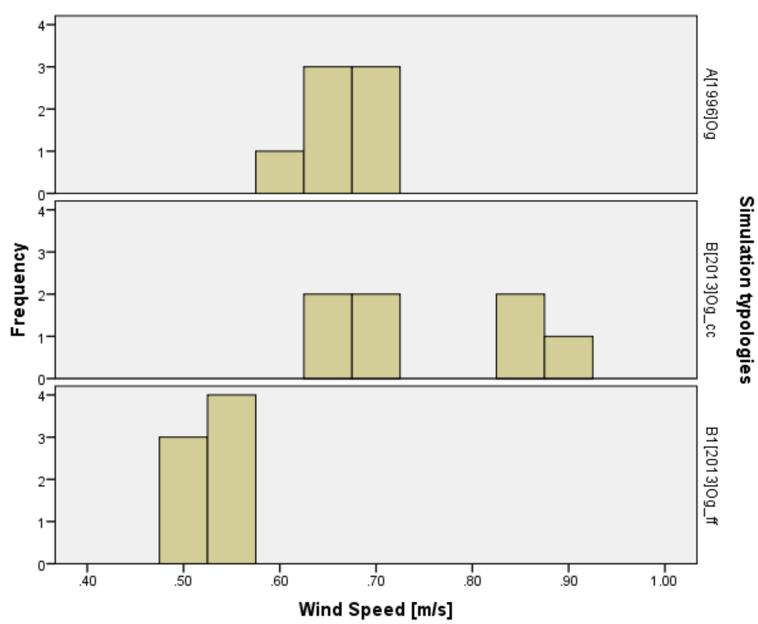


Fig 5.22: Frequency distribution of WS considering Simulation type A EW_B EW_B1 EW

Simulation type A1 NS: A1 NS – B2 NS B3 NS

MRT

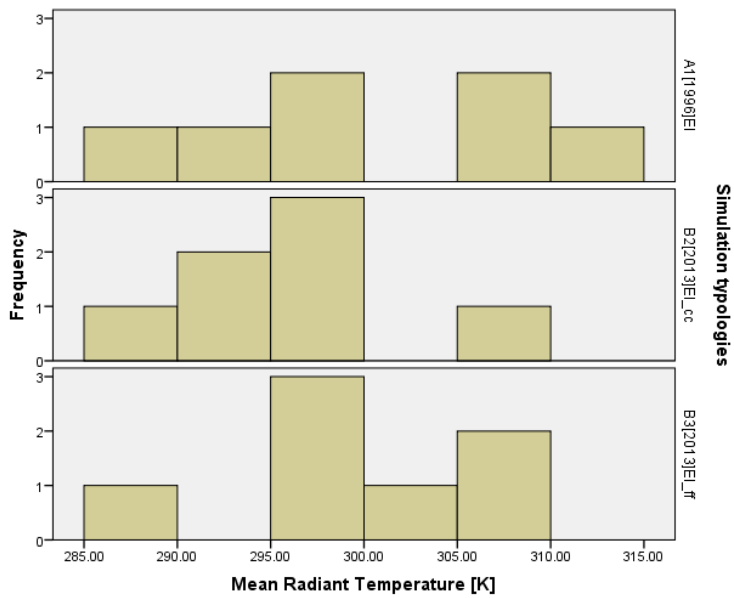


Fig 5.23: Frequency distribution of MRT considering Simulation type A1 NS_B2 NS_B3 NS

DBT

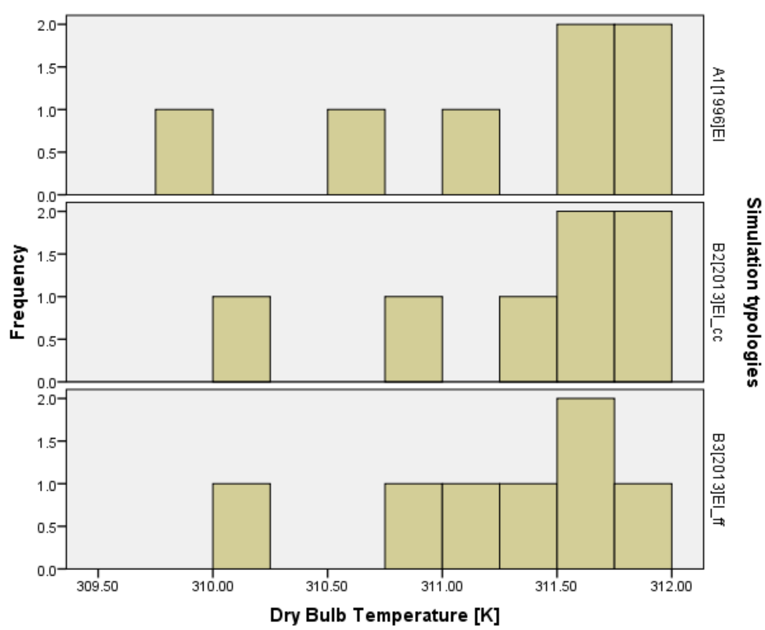


Fig 5.24: Frequency distribution of DBT considering Simulation type A1 NS_B2 NS_B3 NS

RH

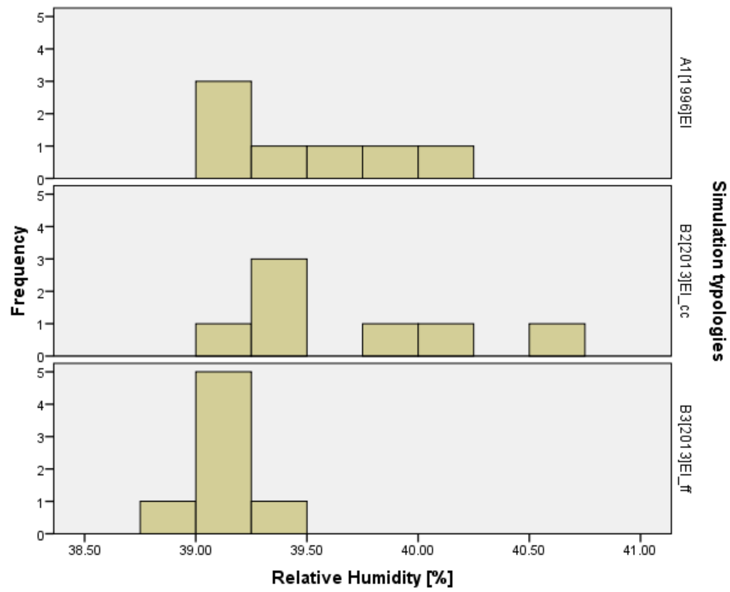


Fig 5.25: Frequency distribution of RH considering Simulation type A1 NS_B2 NS_B3 NS

WS

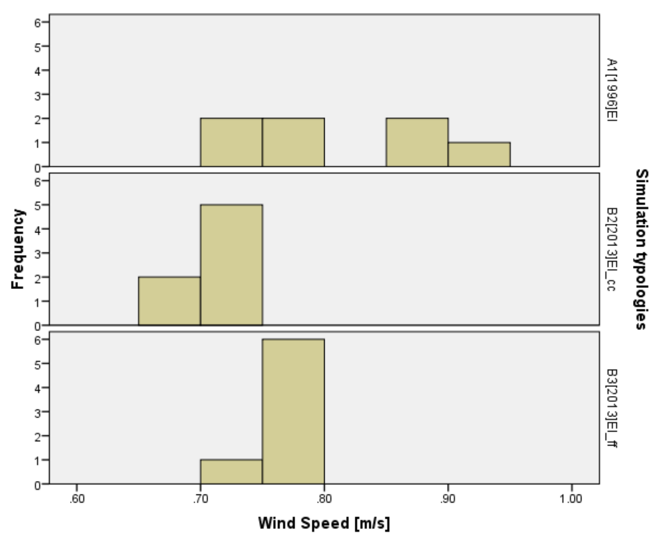


Fig 5.26: Frequency distribution of WS considering Simulation type A1 NS_B2 NS_B3 NS

Simulation type A1 EW: A1 EW – B2 EW   B3 EW

MRT

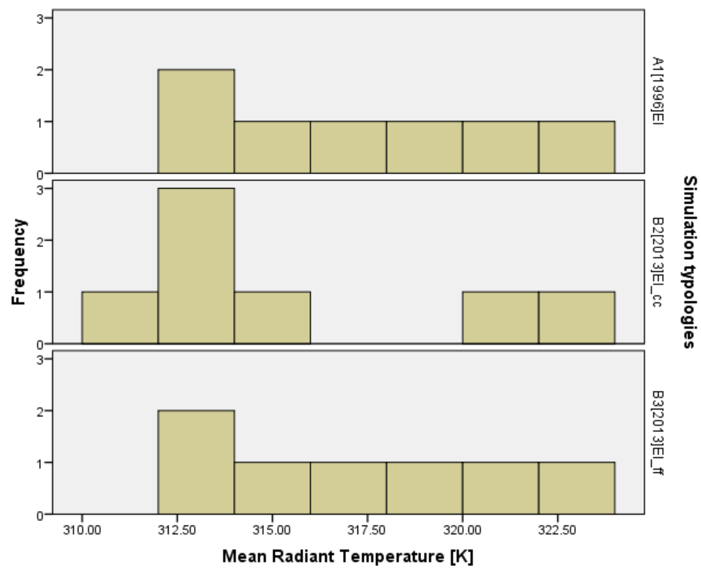


Fig 5.27: Frequency distribution of MRT considering Simulation type A1 EW_B2 EW_B3 EW

DBT

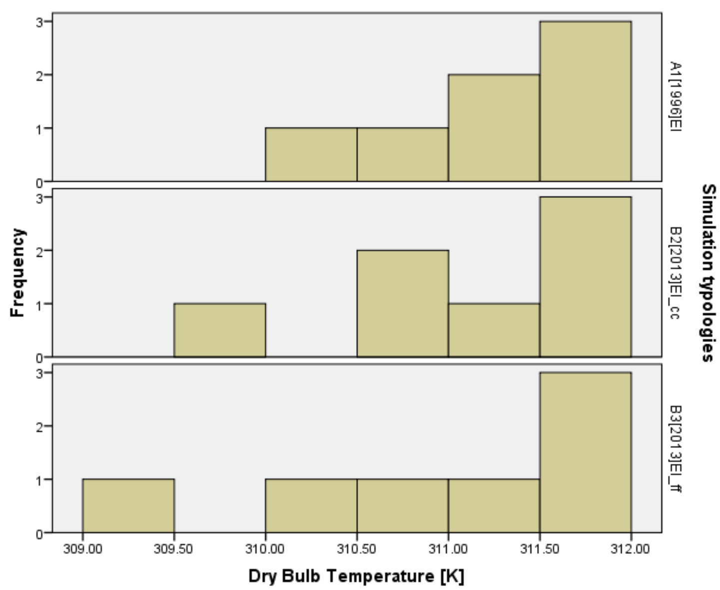


Fig 5.28: Frequency distribution of DBT considering Simulation type A1 EW_B2 EW_B3 EW

RH

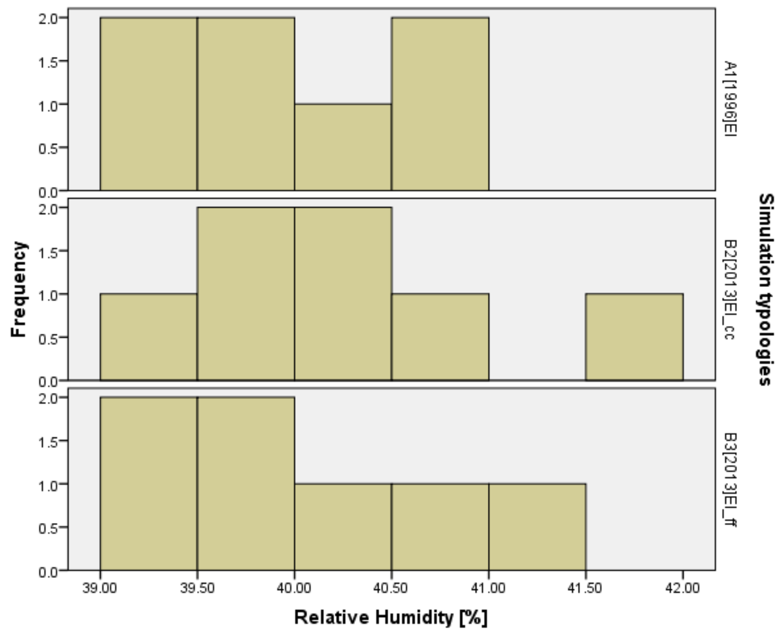


Fig 5.29: Frequency distribution of RH considering Simulation type A1 EW_B2 EW_B3 EW

WS

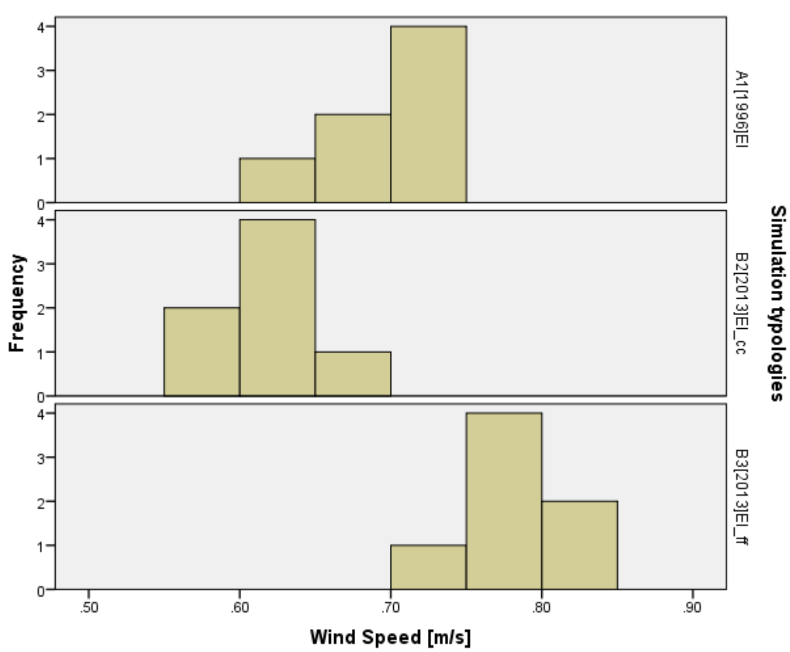


Fig 5.30: Frequency distribution of WS considering Simulation type A1 EW_B2 EW_B3 EW

Table 5.2: Point calculation of microclimatic parameters among different simulation typologies comparing 1996 and 2013 building regulation

1996 and 2013 Microclimate parameters comparison					
	MRT	DBT	RH	WS	*Pts*
A (NS)	2	2	1	3	*8*
B (NS)	3	1	3	2	*9*
B1 (NS)	1	2	2	1	*6*
A (EW)	1	2	1	2	*6*
B (EW)	2	1	3	3	*9*
B1 (EW)	2	3	2	1	*8*
A1 (NS)	1	3	2	3	*9*
B2 (NS)	3	1	3	1	*8*
B3 (NS)	2	2	1	2	*7*
A1 (EW)	2	1	1	2	*6*
B2 (EW)	3	2	3	1	*9*
B3 (EW)	2	3	2	3	*10*

From the frequency distribution of the histogram analysis (Fig. 5.15-5.30) we can easily observe different microclimate parameters in terms of frequencies among different simulation typologies considering north south and east west orientation. Thus, we can create Table 5.2 through 'point' analysis for different simulation typologies (both orientations) for MRT, DBT, RH and WS from 1 to 3, where 1 denotes lowest and 3 denotes highest among the three types of each case. For example, 'temperature' being lower is better while 'wind speed' being higher is better for outdoor comfort for the studied time that is for the month of April. After calculating the respective points it can be seen that out of 12 points [4 (no. of parameters)*3] canyon types A1 and B of north south canyons and type B3 of east west canyons are preferable; while type B1 for north south and type A, A1 (i.e. canyons due to 1996 by-law) for east west canyons are not preferable in view of frequency of distribution. Therefore, north south canyons closely placed buildings i.e. deep canyons are preferable; while shallow canyons are preferable considering east west orientation, where 2013 is preferable to 1996 by-law.

While considering 'point biserial correlation' it can be seen (Table: 5.3) that canyons created under 2013 building regulation have significant variations comparing 1996 building regulation.

Table 5.3: Point Biserial Correlation coefficient [r_{pb}]-chart comparing 1996 and 2013 Building Regulation

		North-South				East-West			
		MRT	**DBT**	**RH**	**WS**	**MRT**	**DBT**	**RH**	**WS**
A 1996 Og	**B**_2013_Og-cc	-0.281	0.098	0.704	-0.788	-0.075	-0.003	0.21	0.517
	B1_2013_Og-ff	0.30	-0.057	0.126	-0.877	-0.077	-0.168	0.175	-0.883
	B2_2013_El-cc	-0.413	0.001	0.691	-0.92	-0.244	-0.177	0.252	-0.589
	B3_2013_El-ff	-0.178	-0.161	0.265	-0.572	-0.078	-0.202	0.091	0.819
A1 1996 El	**B**_2013_Og-cc	-0.172	0.205	0.057	-0.728	-0.077	0.068	0.20	0.483
	B1_2013_Og-ff	0.415	0.056	-0.566	-0.72	-0.08	-0.127	0.161	-0.934
	B2_2013_El-cc	-0.309	0.114	0.279	-0.723	-0.252	-0.137	0.25	-0.747
	B3_2013_El-ff	-0.048	-0.04	-0.541	-0.455	-0.08	-0.169	0.065	0.849

Point Biserial Correlation [r_{pb}]
r_{pb}: > 0.80 [very strong relation]
r_{pb}: 0.49-0.80 [strong]
r_{pb}: 0.25-0.48 [moderate]
r_{pb}: 0.00-0.24 [weak relation]

Among all the microclimatic parameters it can be seen that wind speed has very strong correlation with 1996 and present building regulation in terms of north-south, as well as in east-west. While in terms of dry bulb temperature and mean radiant temperature the correlation is weak to moderate and the correlation of relative humidity is strong for north-south oriented canyons while weak in east-west canyons.

5.8 References

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Chapter Six: Findings and Conclusion

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Orientation

Aspect Ratio

Building Mass Configuration

Design Considerations

Findings

Suggestions for Further Work

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Chapter 6: Findings and Conclusion

6.1 Introduction

In this research; impact of orientation, aspect ratio and building mass configuration on outdoor street microclimate referring 1996 building by-law and present building regulation were studied in the context of Dhaka city. The main aim of this research was to investigate the above mentioned variables and also to compare previous and present building regulation through statistical analysis. Moreover simulation technique was used to explore various urban contexts within the research scopes. 'Chapter one' of this dissertation described briefly about the overall objective of the work, methodology, quality consideration and scope of this research. The literature review related to street morphology due to building regulations, outdoor street microclimate and climatic context of Dhaka city were briefly illustrated in 'chapter two', while in 'chapter three' the field survey carried out during the research; to cross check the simulation results were discussed. In 'chapter four' the simulations which were carried out with different building models considering orientation, aspect ratio and building mass configuration influencing outdoor street microclimatic parameters were discussed elaborately. In 'chapter five' analyses were done including different statistical analyses to get a clear perception on the impact of different urban contexts within the scope of the research on outdoor street microclimate due to 1996 and present building regulation. Analyzing the results discussed in the previous chapter, significant relations can be observed. Thus findings from statistical analyses have been described in this chapter in terms of orientation, aspect ratio and building mass configuration separately. Outcomes of 1996 and 2013 building regulation have been compared in terms of the studied microclimatic parameters and finally concluded this chapter with design considerations.

6.2 Orientation [NS/EW canyons]

- Considering all simulation typologies it is seen that MRT is lower in NS than EW orientation which supports Kushol et al (2013).
- DBT is comparatively higher in EW orientation for simulation type A, A1 and B; while lower in type B1, B2 and B3.
- RH is comparatively higher in EW orientation for all simulation typologies.
- WS is comparatively higher in NS oriented canyons which supports (Shisheger, 2013), for all simulation typologies except for type B [on-ground closely placed buildings under 2013 building regulation] & B3 [elevated buildings placed apart under 2013 building regulation] (i.e. 2013 building regulation can change wind speed through changes in H/W ratio & Og/El structures). Therefore 'aspect ratio' and 'building mass configuration' has impact on wind speed. It further shows that generally 'on-ground' buildings may require lower H/W ratio while 'elevated' buildings higher ratio to increase wind circulation at pedestrian level.
- Thus, the canyon ratio can be manipulated by building regulation affecting the wind pattern and above all the microclimate.
- Orientation has significant impact on MRT, RH & WS no matter what the simulation typologies are.
- WS have strong negative correlation in terms of simulation type A, A1, B1 & B2.
- DBT has negative weak correlation considering simulation typologies.

6.3 Aspect Ratio [H/W Ratio]

- While considering 'elevated' [El] buildings under 2013 building regulation it is clear that buildings in NS canyons have strong positive correlation [0.817 & 0.953 respectively] which means increasing H/W ratio for El buildings in NS canyons will increase wind speed at pedestrian level within the respective canyons.

- While considering orientation for aspect ratio in terms of DBT and RH in all cases i.e. for NS and EW canyons there is negative correlation; which means no matter what the orientation is it is likely to decrease DBT and RH while increasing H/W ratio.
- Regardless orientation while considering 'aspect ratio' elevated buildings under 2013 building regulation have positive strong correlation [0.824] in terms of wind speed; while considering 'on-ground' buildings the relation is moderate negative correlation [-0.475] i.e. wind speed will increase at pedestrian level with aspect ratio, while decrease in terms of on-ground buildings.
- While considering 'aspect ratio' it can be seen that buildings 'on-ground' in EW canyons have very strong negative correlation [-0.842], while 'elevated' buildings in NS & EW canyons have very strong positive correlation [0.817 & 0.953 respectively], which means in terms of elevated buildings, regardless orientation it is likely that wind speed may increase at pedestrian level in terms of aspect ratio, while for buildings in EW canyons may decrease.
- Therefore the wind speed for 'on-ground' structures of EW canyons at pedestrian level low H/W ratio (shallow canyons) of the canyon is preferable; whereas high H/W ratio (deep canyons) for 'elevated' buildings for NS canyon is preferable for increasing wind speed at pedestrian level.
- Buildings placed 'on-ground' in NS canyons show lesser impact in terms of wind speed.
- MRT shows negative correlation in terms of 'aspect ratio' [H/W ratio] for 'on-ground' buildings in EW canyons. This means increasing H/W ratio for 'on-ground' buildings in

EW canyons will decrease MRT which supports Toudert F.A. (2005); while, low H/W ratios in EW canyons decreases the MRT in terms of elevated buildings.

- DBT & RH shows negative correlation for all simulation types in terms of aspect ratio; which means increasing H/W ratio will decrease DBT & RH. RH having moderate correlation for 'on-ground' & 'elevated' buildings in NS canyons.
- In simulation study, MRT in the NS canyons in all cases, that is orientation, aspect ratio (H/W ratio); building mass configuration (Og/El structures) is always lower than the EW canyons. It illustrates that built form has a significant role in providing shade in NS canyons.

6.4 Building Mass Configuration [On-ground / Elevated Structures]

- In terms of 'Building Mass Configuration' buildings placed apart [ff] under 2013 building regulation have positive strong correlation in terms of wind speed for both NS & EW canyons [0.762 & 0.981 respectively]; which means elevated buildings placed apart in NS and EW canyons will increase wind speed at pedestrian level. While closely placed [cc] buildings in EW canyons have strong negative correlation [-0.708], while moderate positive correlation in NS canyons [0.339] which means elevated closely placed buildings in EW canyons are likely to decrease wind speed at pedestrian level while increase in NS canyons, thus elevated buildings placed apart in NS and EW canyons will increase wind speed at pedestrian level.
- Regardless orientation it can be seen that closely placed buildings in terms of wind speed have moderate negative correlation [-0.341] while buildings placed apart it is positive strong correlation [0.775]

- Considering MRT & DBT, buildings under 1996 & 2013 building regulation have negative correlation; which means elevating buildings will decrease MRT and DBT; where buildings placed apart in NS canyons it is moderate negative correlation [-0.516]. While considering buildings under 1996 the relation of MRT & DBT in terms of building mass configuration is weak. Buildings under 2013 'placed apart' in EW canyons have weak correlation in terms of MRT.
- While considering 'building mass configuration' it can be seen that wind speed has negative strong correlation [-0.708] in terms of closely placed buildings in EW canyons [which means elevating buildings are likely to decrease wind speed] & positive strong correlation in terms of buildings placed apart in NS as well as EW canyons [0.762 & 0.981 respectively] which means elevating buildings placed apart [ff] in NS & EW canyons are likely to increase wind speed at pedestrian level. Buildings placed apart in EW canyons have the highest impact on wind speed, thus placing buildings away from each other both in NS & EW canyons will increase wind speed while the buildings are elevated, but in terms of EW canyons buildings closely placed are likely to decrease the wind speed while buildings are being elevated.
- Buildings placed apart in EW canyons have the highest impact on wind speed.
- MRT & DBT is negatively correlated which means; buildings elevated have an inverse relationship with MRT & DBT, but the relation is weak.
- Considering 1996 building regulation in terms of Og/El it can be seen that there is no significant relationship in terms of WS, MRT & DBT.
- In terms of 2013 building regulation significant relationship can be seen in terms of MRT, RH & WS for H/W ratio and also building mass configuration.

Thus it is quite clear from the above discussion that at pedestrian level; not only aspect ratio but also building mass configuration has impact on street microclimate parameters especially in terms of wind speed having significant impact at street level which are interrelated in terms of different orientations and vice versa.

6.5 Design Considerations

- Overall as NS canyons are cooler than the EW canyons, it is preferable to design plots in such a manner where the streets are north-south oriented to improve street microclimate at pedestrian level.
- Rear setback can be provided to the plots adjacent to NS roads. In case of using front setback, building blocks should be elevated.
- To provide front setback to the plots adjacent to EW roads; rear setback can't be provided as closely placed elevated buildings in EW canyons are likely to decrease wind speed at pedestrian level.
- In terms of building mass configuration:
    - Wind speed is likely to increase in terms of NS canyons for elevated buildings
    - While decrease in EW canyons for closely placed elevated buildings

Thus we get the following *'if'-'then'* chart (Table 6.1) in terms of aspect ratio and building mass configuration respectively as follows:

Table 6.1: '*if*' - '*then*' Chart for 2013 Building Regulation [considering Aspect Ratio]

	Pre-condition			**Consequents**
Condition	**Orientation**	**Aspect Ratio**	***State***	**Building Mass Configuration**
if	North-South [NS]	[cc] closely placed buildings	***then***	Elevated-[in terms of MRT] Elevated-[in terms of DBT] Elevated-[in terms of RH] Elevated-[in terms of WS]
if	North-South [NS]	[ff] buildings placed apart	***then***	Elevated-[in terms of MRT] Elevated-[in terms of DBT] Elevated-[in terms of RH] Elevated-[in terms of WS]
if	East-West [EW]	[cc] closely placed buildings	***then***	Elevated-[in terms of MRT] Elevated-[in terms of DBT] Elevated-[in terms of RH] On-ground-[in terms of WS]
if	East-West [EW]	[ff] buildings placed apart	***then***	On-ground-[in terms of MRT] Elevated-[in terms of DBT] On-ground-[in terms of RH] On-ground-[in terms of WS]

While considering aspect ratio elevated buildings are preferred (Table 6.1) in terms of MRT, DBT, RH and WS for north-south streets; closely placed as well as for buildings placed apart. Such configuration is also preferred for buildings having east-west oriented streets except for WS in terms of closely placed and MRT, RH and WS for buildings placed apart, where on ground buildings are preferred rather than elevated ones.

Considering wind speed:

As from Fig. 5.8 it is clear that mean group differences are highest in terms of wind speed among different simulation typologies, thus in terms of better wind speed we can consider following aspect ratios [among the studied ratios] and building placement in terms of orientation. While aspect ratio was considered it was assumed that the buildings within the plots used maximum allowable ground coverage as other options were out of the scope of this research.

Considering aspect ratio for better wind speed [in view of descriptive statistics and degree of relationship from Table 5.1]

	NS	EW
Buildings 'on-ground'	1.4:1	1.3:1
Buildings 'elevated'	1.4:1	1.3:1

Thus, for better wind speed shallow canyons are preferable in east-west, while deeper canyons for north-south (Table 5.1 and Fig. 5.12).

Considering Og/El structures for better wind speed [in view of descriptive statistics and degree of relationship from Table 5.1]

		NS	EW
Aspect ratio	1.3:1	Elevated	On-ground
Aspect ratio	1.4:1	Elevated	On-ground
Aspect ratio	1.8:1	Elevated	On-ground

While considering building mass configuration, elevated buildings are preferred in north-south, while on-ground buildings are preferred in east-west canyons in terms of better wind speed at street level (Table 5.1 and Fig. 5.12).

Regression equations for prediction:

From Table 5.1 considering the rejected null hypotheses in terms of aspect ratio we get the following simple linear regression equations (Table 6.2) to project respective ratios for on-ground and elevated buildings, where y denotes desired respective microclimatic parameters and x denotes corresponding aspect ratios.

Table 6.2: Equations for projecting respective Aspect Ratios [of statistically significant parameters]

Orientation	Building placement	Parameters	Equation
North-South	On-ground Buildings	MRT	**y=9.589x+269.52**
North-South	On-ground Buildings	RH	**y=-0.478x+40.932**
North-South	Elevated buildings	RH	**y=-0.639x+42.912**
North-South	Elevated buildings	WS	**y=0.060x+0.398**
East-West	On-ground Buildings	WS	**y=-0.229x+1.451**
East-West	Elevated buildings	WS	**y=0.156x-0.163**

For an example, considering wind speed for elevated buildings placed in north-south oriented streets we will consider (y=0.060x+0.398) equation. If our desired wind speed at pedestrian level is 0.5m/s, then the equation stands (0.5=0.060x+0.398); thus required aspect ratio ‘x’ will be 1.7 for elevated buildings placed in north-south oriented streets.

6.6 Findings

Thus it can be concluded with the following remarks:

- North-south canyons are better than east-west canyons in terms of outdoor comfort at pedestrian level which supports Ali Toudert and Mayer (2006) and Johansson (2006), thus while master planning north-south oriented streets should be encouraged to improve outdoor street microclimate at pedestrian level.

- Elevated deep canyons are better in terms of north-south canyons to increase wind speed at pedestrian level; which means tall buildings creating high aspect ratio are preferable in north-south canyons. Thus tall elevated buildings in north-south canyons are preferable with minimum front setback from maximum ground coverage.
- On-ground buildings creating shallow canyons are better in terms of east-west canyons to increase wind speed at pedestrian level; which means low height buildings creating low height width ratio are preferable in east-west canyons. Thus low height on-ground buildings in east-west canyons are preferable with maximum front setback from maximum ground coverage, to increase wind speed at pedestrian level, above all improving outdoor microclimate in the streets at pedestrian level.
- 1996 and present building regulation cannot create outdoor comfort at pedestrian level in extreme conditions during summer failing to create ‘cool islands’.
- While considering building regulations it can be seen that canyons created under 2013 building regulation have significant variations comparing 1996 building regulation. Among all the microclimatic parameters it can be seen that wind speed has very strong correlation with 1996 and present building regulation in terms of north-south, as well as in east-west. While in terms of dry bulb temperature and mean radiant temperature the correlation is weak to moderate and the correlation of relative humidity is strong for north-south oriented canyons while moreover weak in east-west canyons.
- Maximum impact is on ‘wind speed’ (WS) among the studied microclimate parameters due to different urban contexts studied, followed by ‘relative humidity’ (RH) and ‘mean radiant temperature’ (MRT). The least impact is on ‘dry bulb temperature’ (DBT).

6.7 Suggestions for Further Work

As the study was focused on microclimate and street morphology of planned residential area of Dhaka city due to building regulations, number of variables came in place; where all the variables could not be considered at a time in this research as there were time constrains and also it is not possible to consider all the variables at a time due to complexity of urban typology. Therefore further studies can be done considering the untouched variables.

Issues such as impact of various road widths in front of the plots, various building and road surface materials, vegetation, other FAR and MGCs, impact of vehicular movements on microclimate, other planned residential areas, intermediate cardinal street direction, microclimate condition in terms of other seasons i.e. study for other months within a year, asymmetric canyons, effects of air pollution, impact of plot boundaries and also impact of various plot sizes on microclimate can be considered for further research.

6.8 Conclusion

As this research was based on the impact of building regulation on street morphology and ensuing microclimate through statistical analyses at pedestrian level in planned residential area; considering orientation, aspect ratio and building mass configuration and also comparing previous and existing building regulation; significant findings and various relationships can be observed. Therefore the outcomes and the findings of this research can be applied in urban master plans and also engendering 'smart / scientific building regulations' through keeping these issues in mind; which in due course likely to influence energy issues as well. Thus it is of great importance to study and research such issues which will directly help and improve building regulation which will be scientific and persuade an important role in urban environment.

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Appendices

Appendix – 1: Simulation Outputs

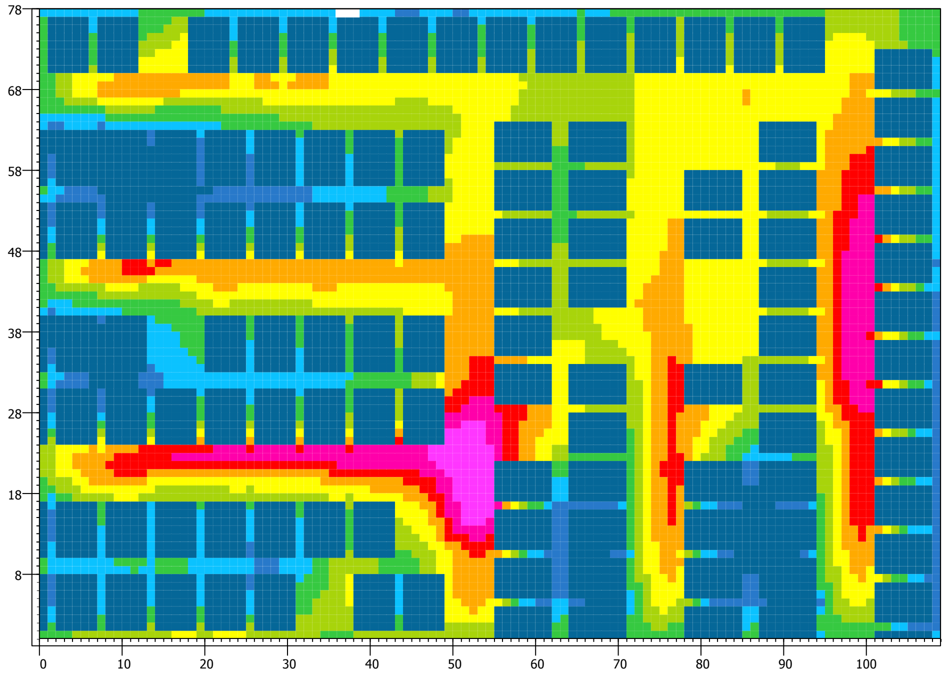


Fig 1: Simulation output _ Field survey [FS] _ DBT at 11am

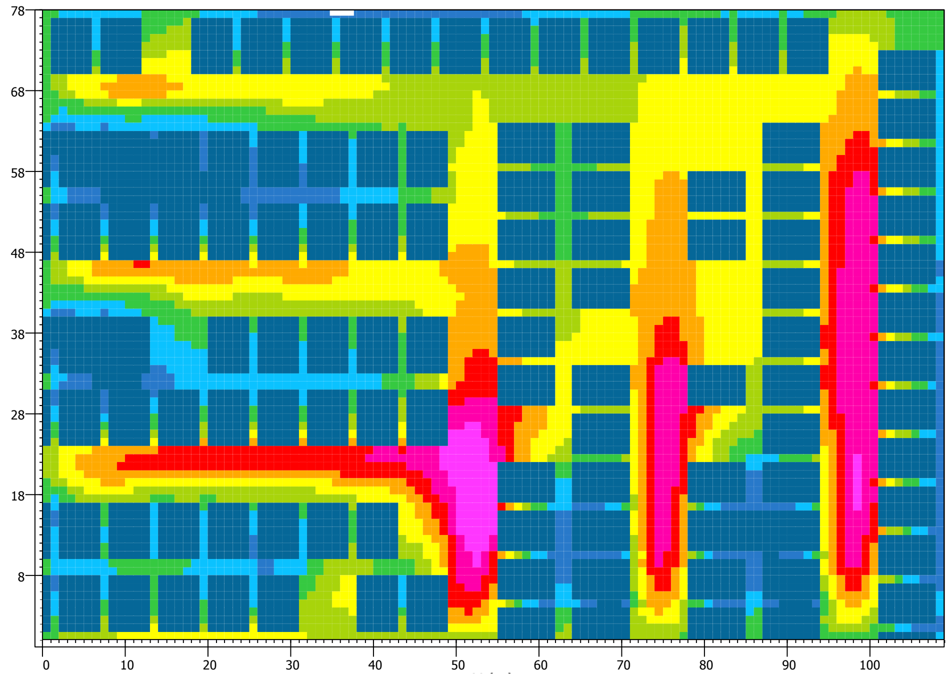


Fig 2: Simulation output _ Field survey [FS] _ DBT at 11.30am

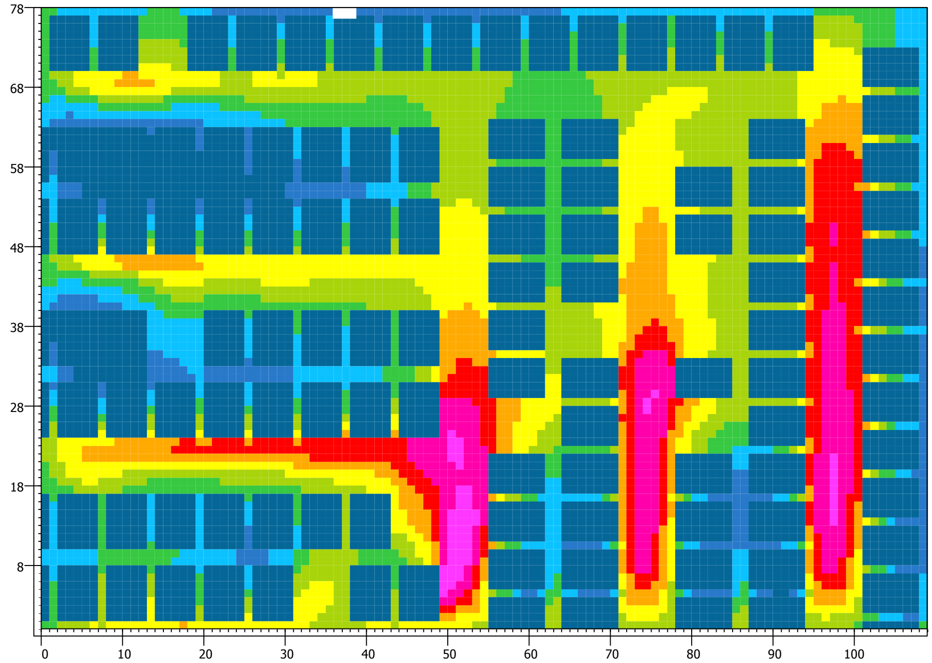


Fig 3: Simulation output _ Field survey [FS] _ DBT at 12pm

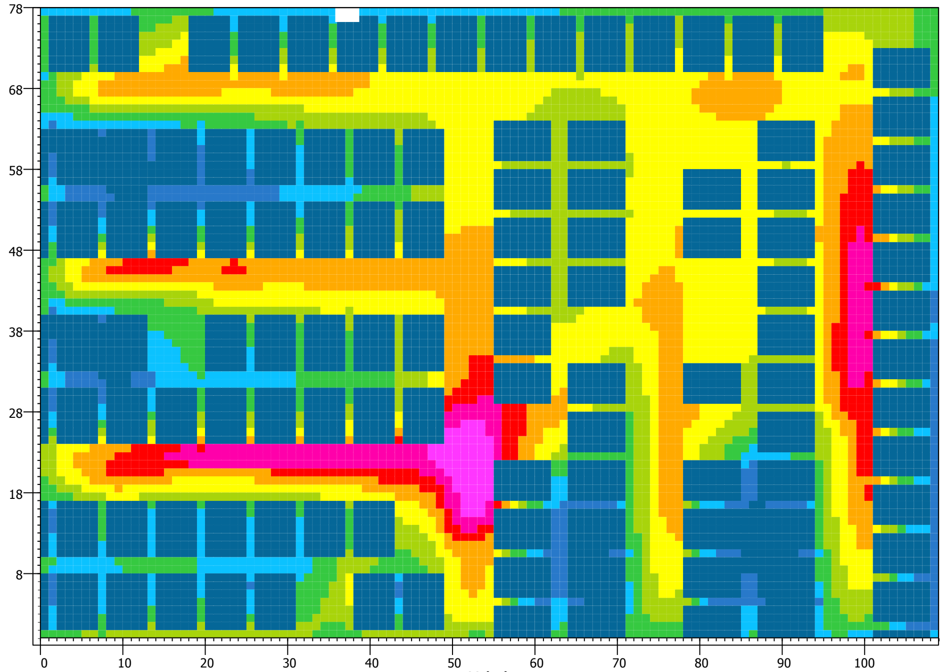


Fig 4: Simulation output _ Field survey [FS] _ DBT at 12.30pm

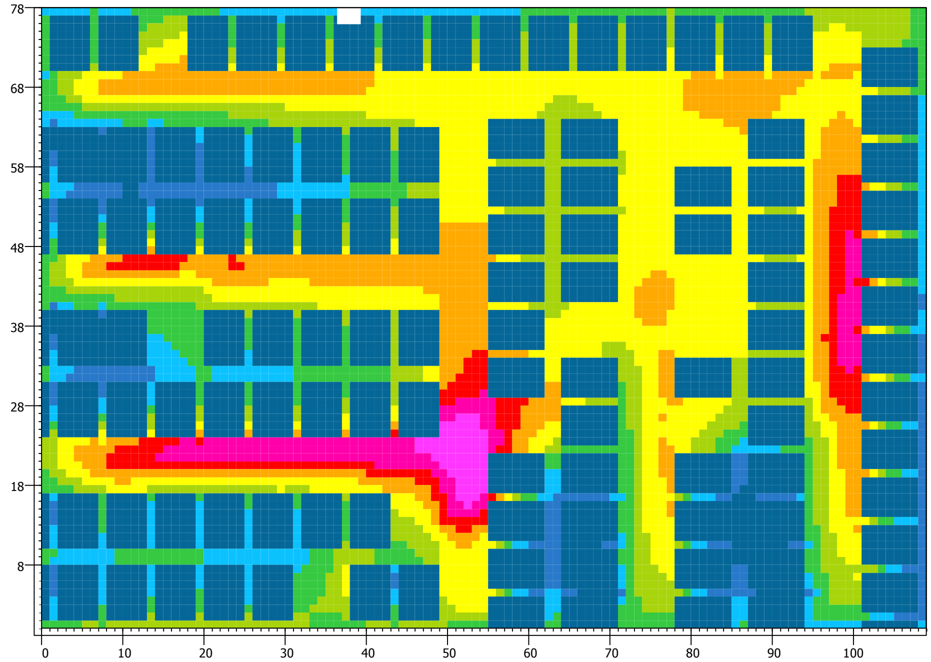


Fig 5: Simulation output _ Field survey [FS] _ DBT at 1pm

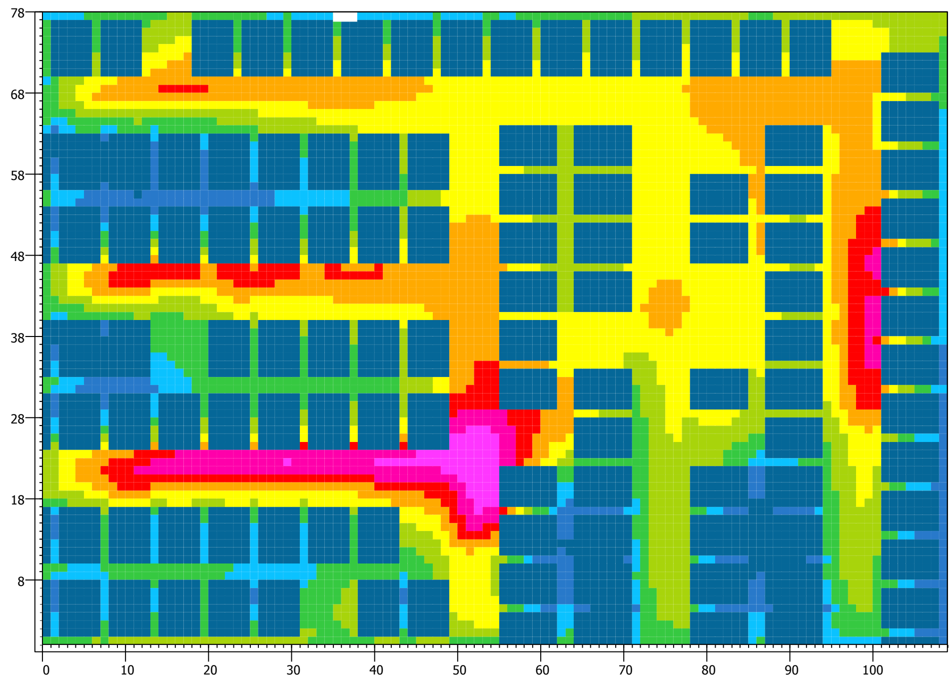


Fig 6: Simulation output _ Field survey [FS] _ DBT at 1.30pm

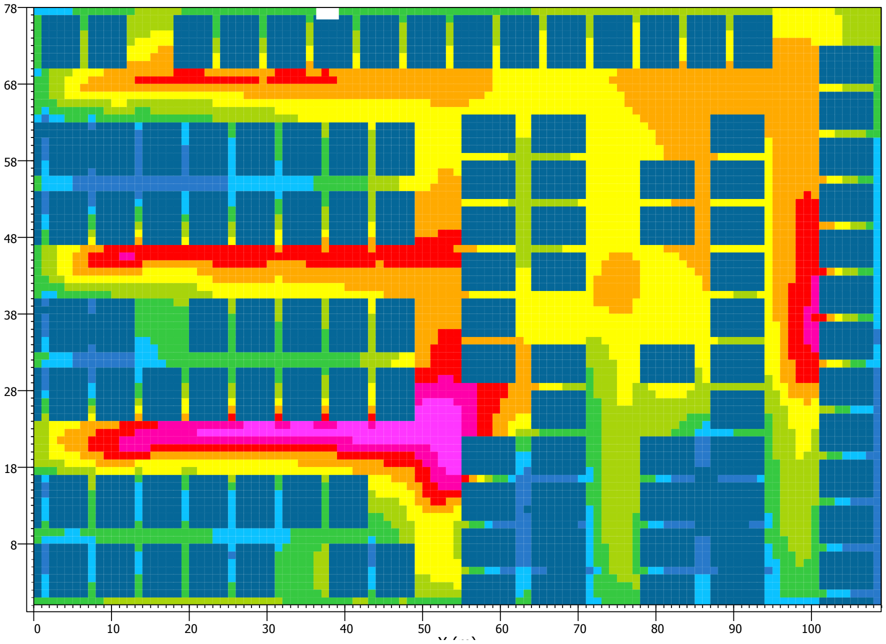
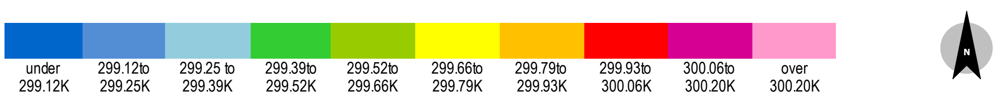


Fig 7: Simulation output _ Field survey [FS] _ DBT at 2pm



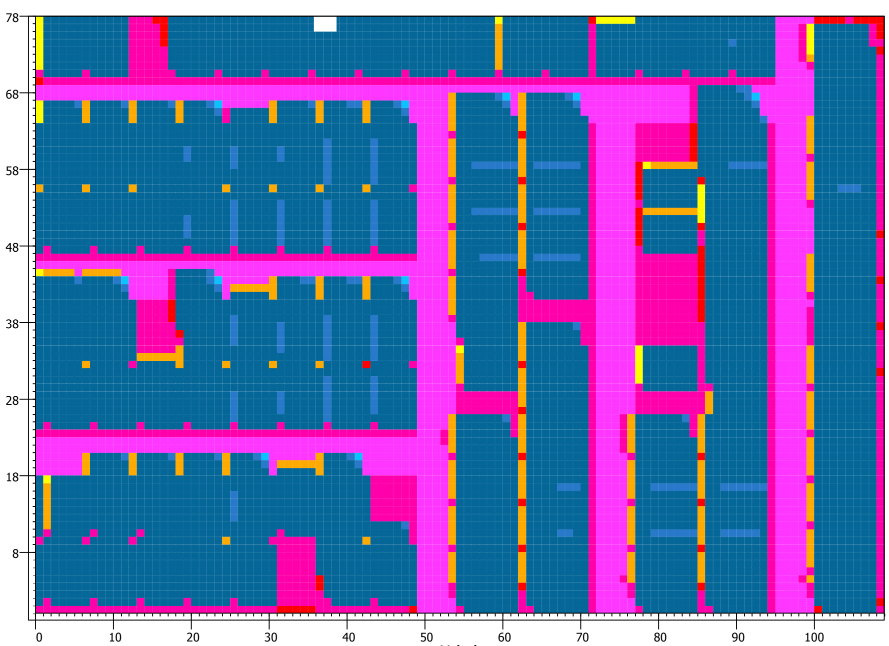


Fig 8: Simulation output _ Field survey [FS] _ MRT at 11am

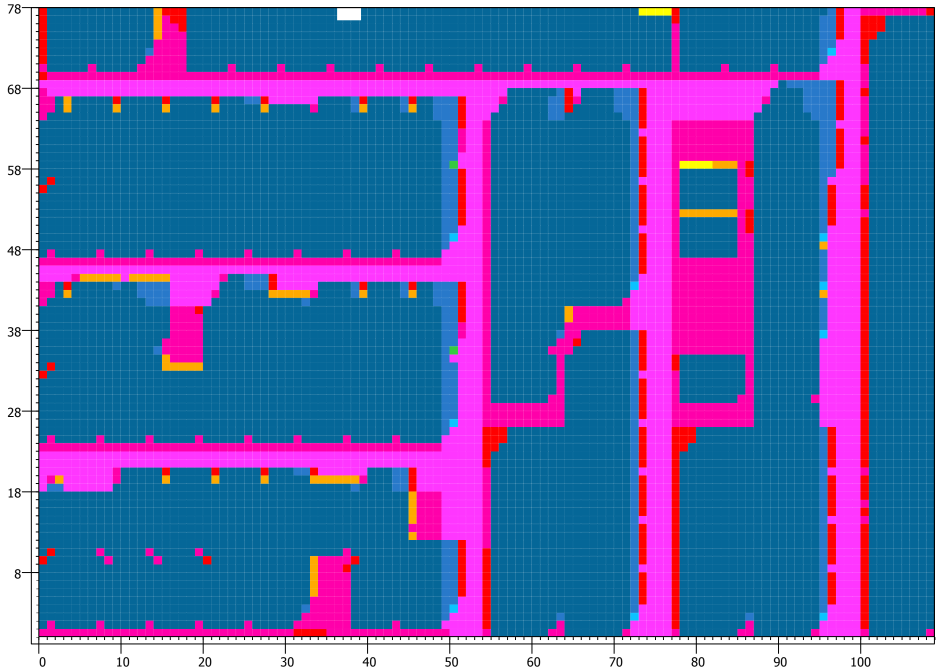


Fig 9: Simulation output _ Field survey [FS] _ MRT at 11.30am

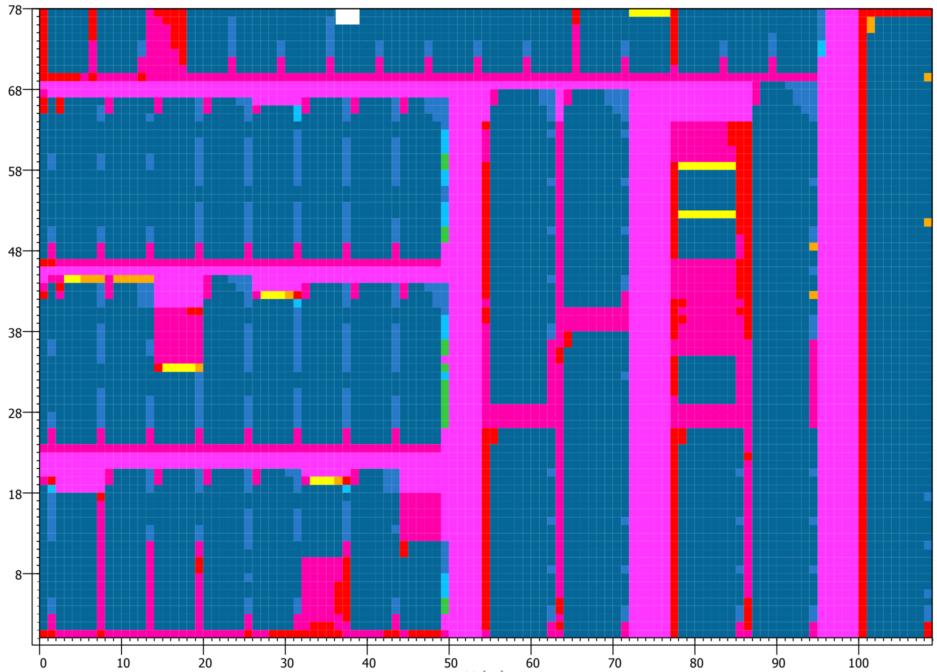


Fig 10: Simulation output _ Field survey [FS] _ MRT at 12pm

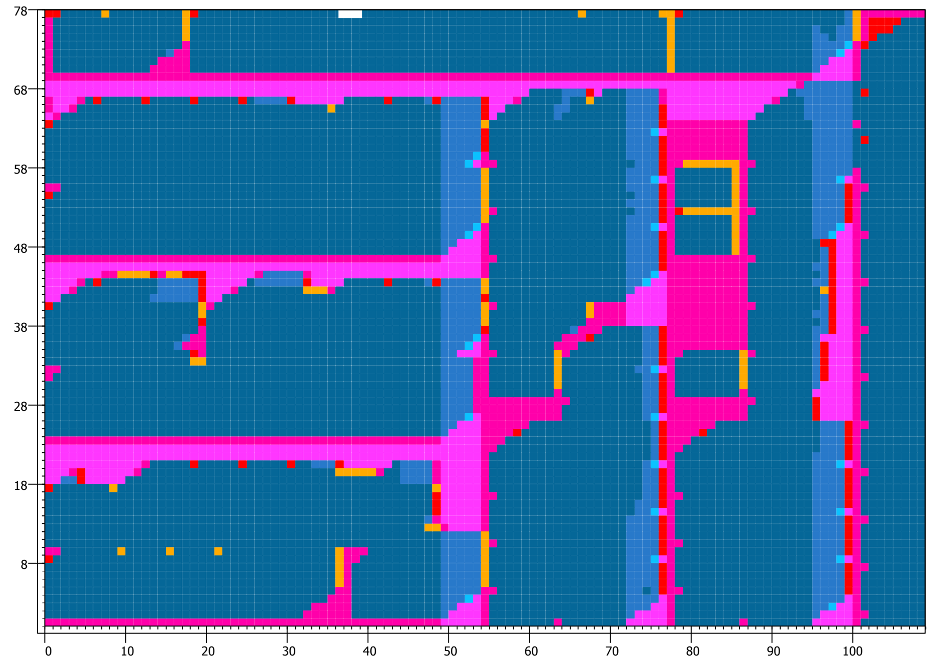


Fig 11: Simulation output _ Field survey [FS] _ MRT at 12.30pm

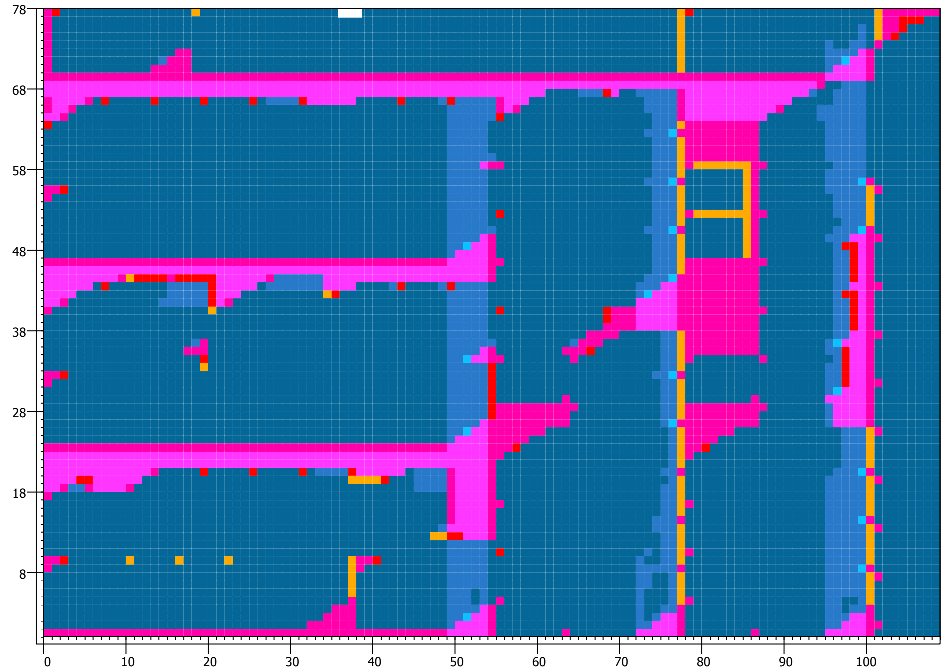


Fig 12: Simulation output _ Field survey [FS] _ MRT at 1pm

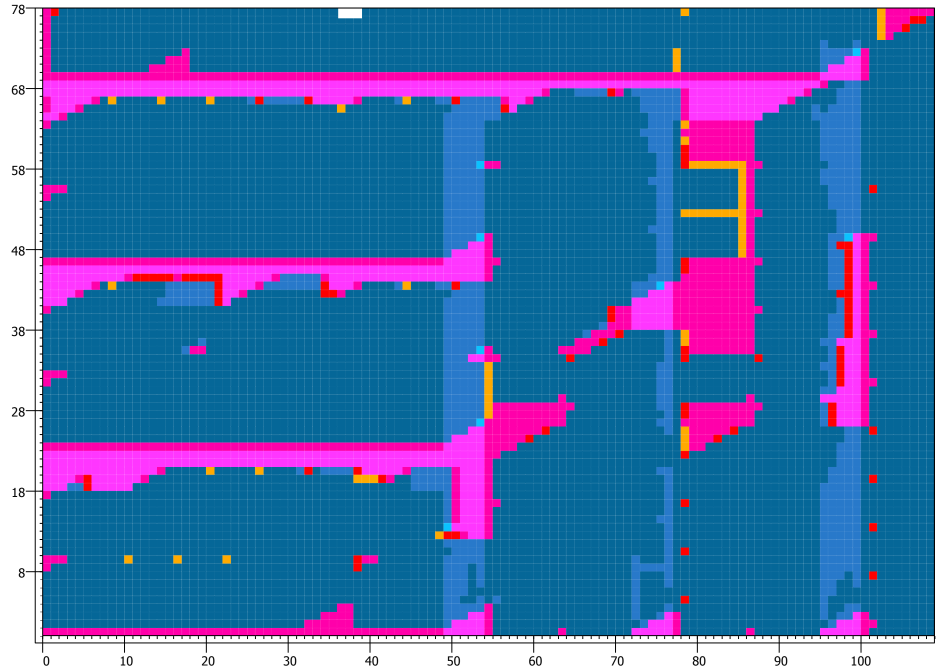


Fig 13: Simulation output _ Field survey [FS] _ MRT at 1.30pm

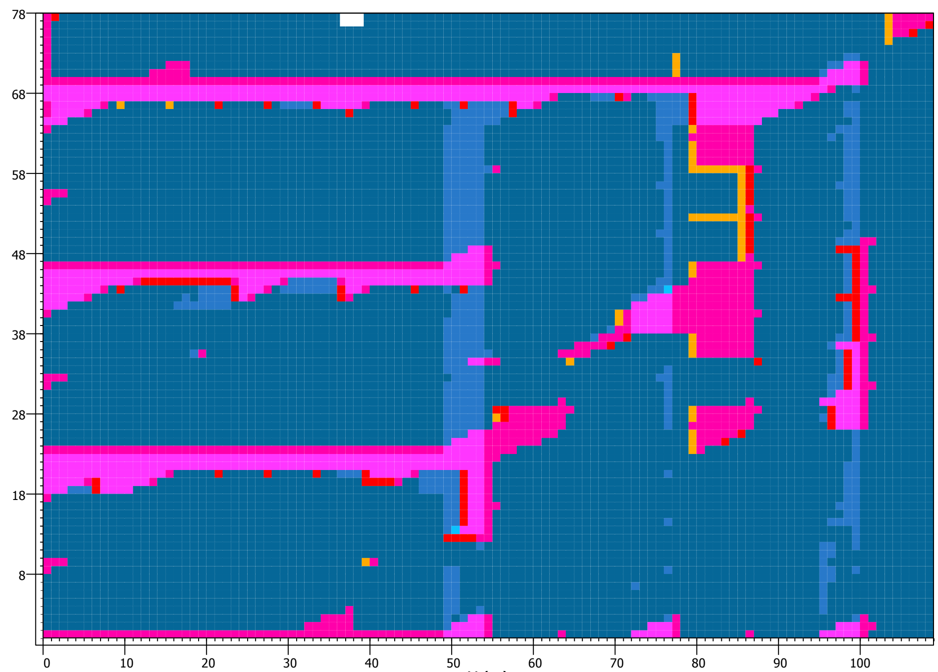
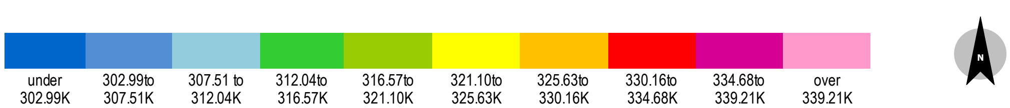


Fig 14: Simulation output _ Field survey [FS] _ MRT at 2pm



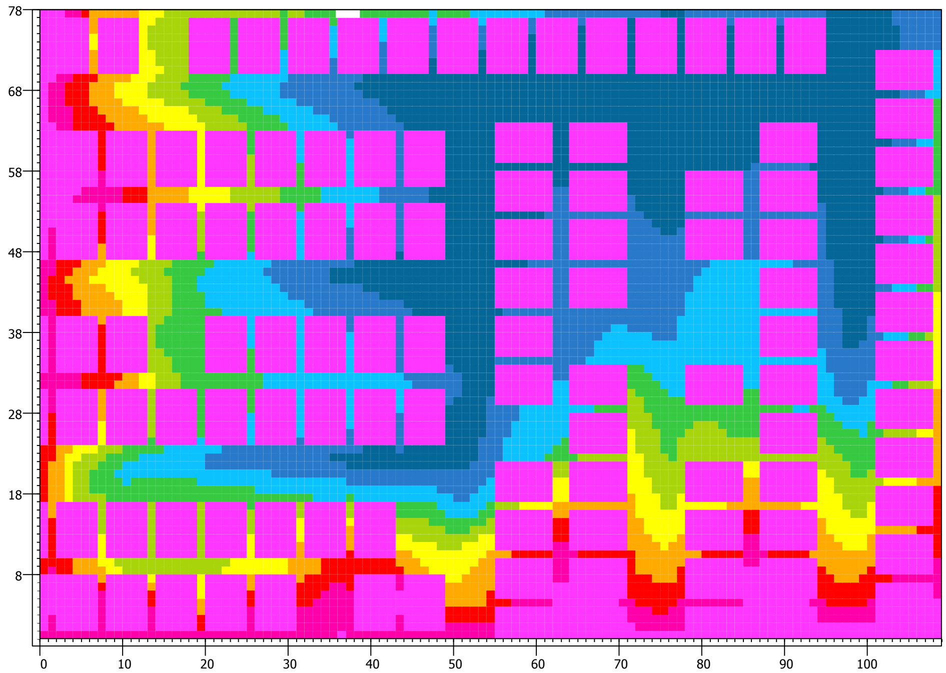


Fig 15: Simulation output _ Field survey [FS] _ RH at 11am

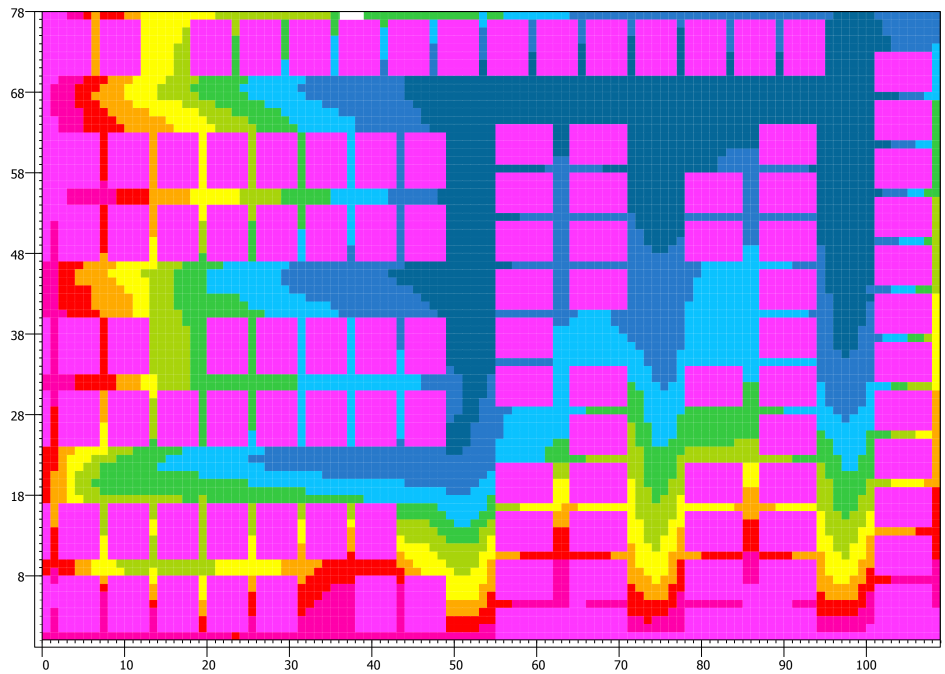


Fig 16: Simulation output _ Field survey [FS] _ RH at 11.30am

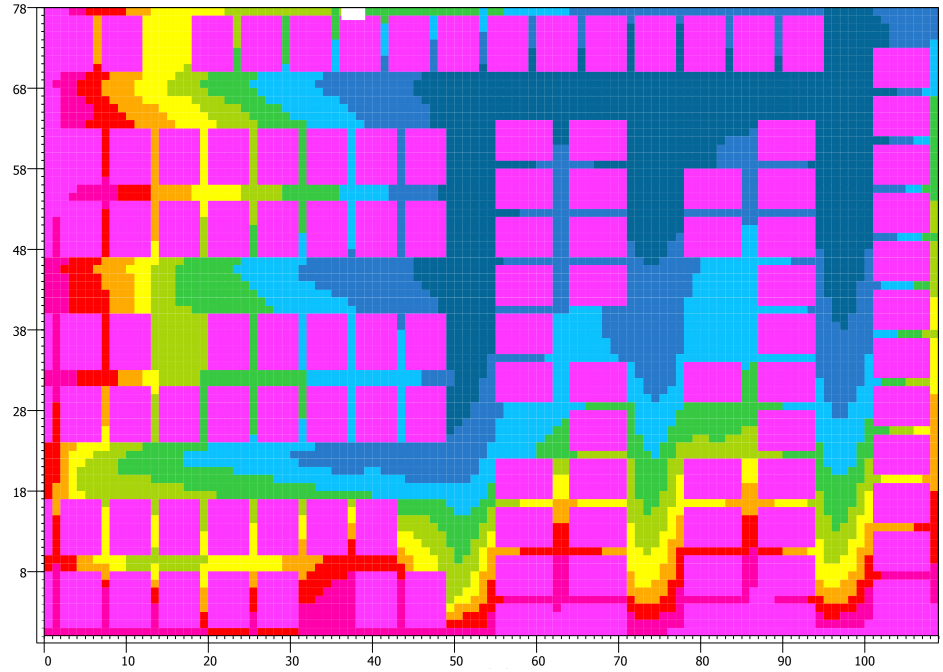


Fig 17: Simulation output _ Field survey [FS] _ RH at 12pm

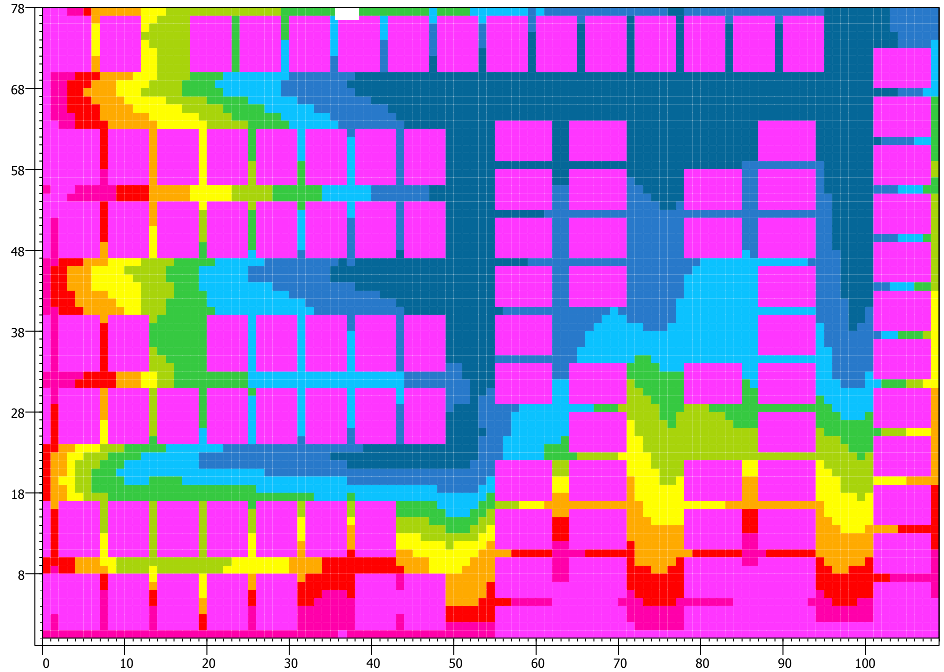


Fig 18: Simulation output _ Field survey [FS] _ RH at 12.30pm

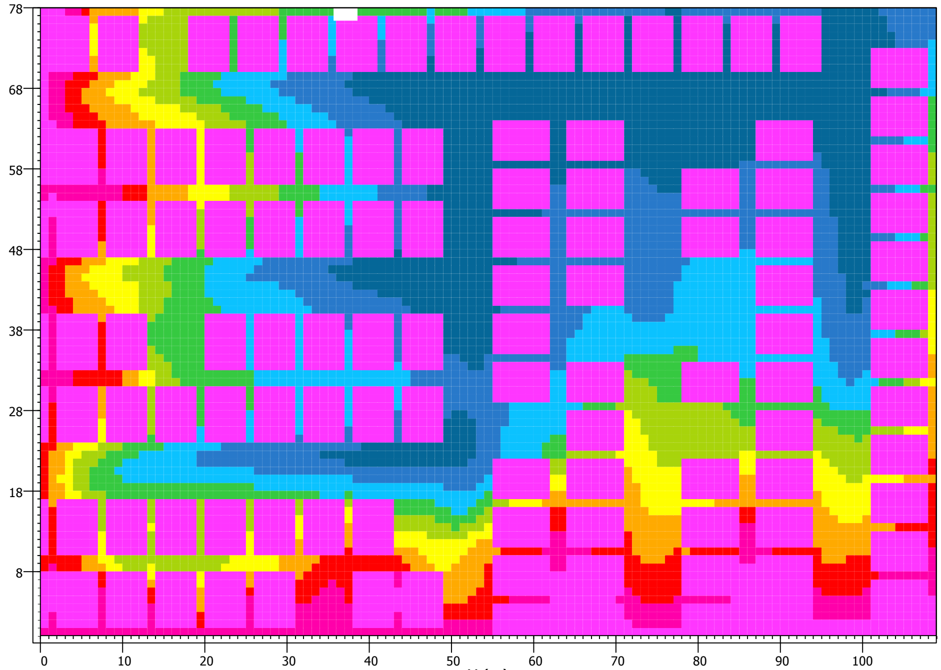


Fig 19: Simulation output _ Field survey [FS] _ RH at 1pm

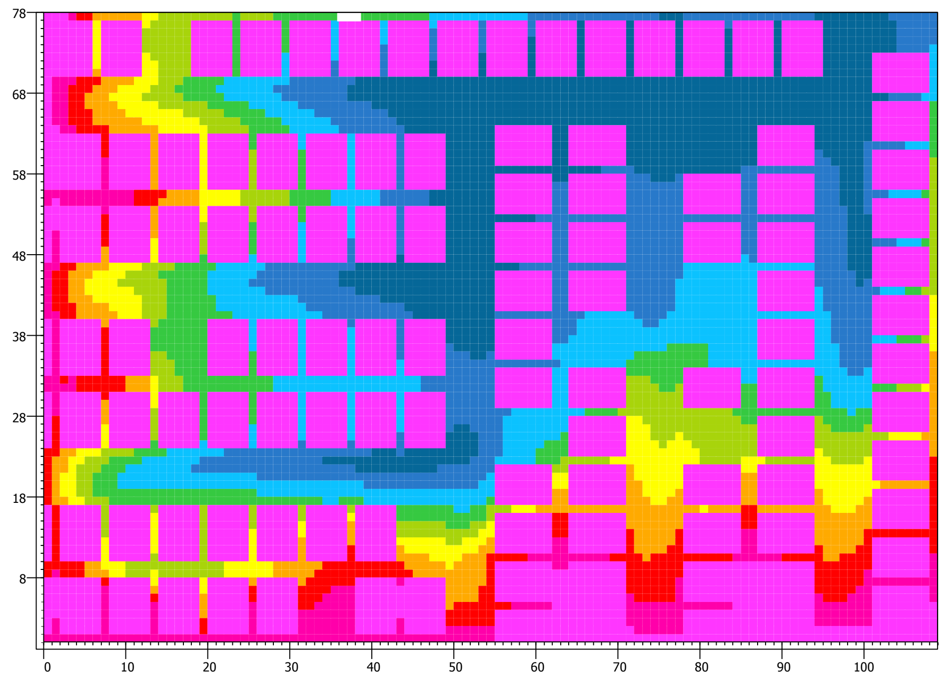


Fig 20: Simulation output _ Field survey [FS] _ RH at 1.30pm

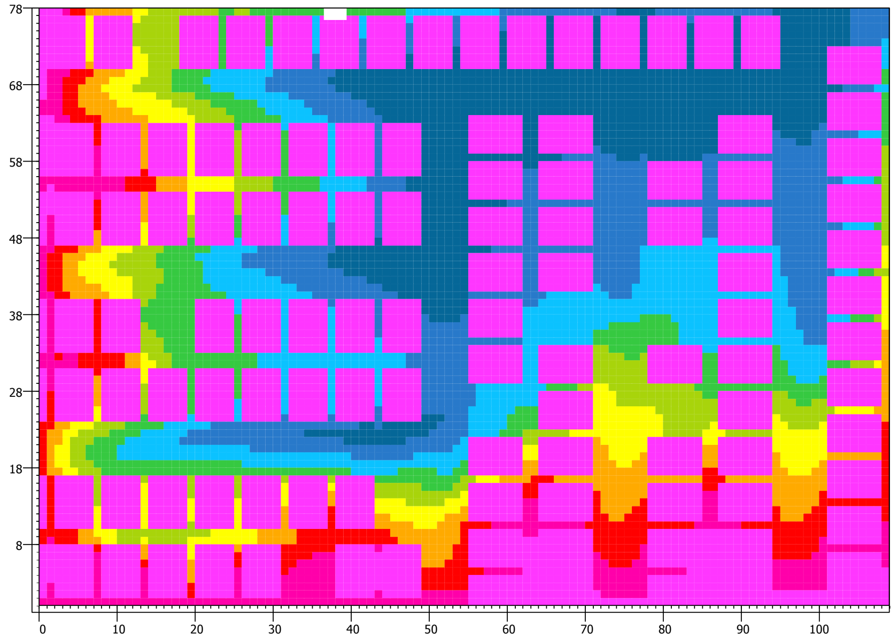
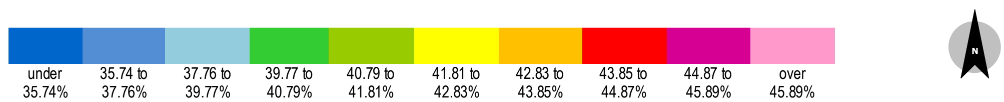


Fig 21: Simulation output _ Field survey [FS] _ RH at 2pm



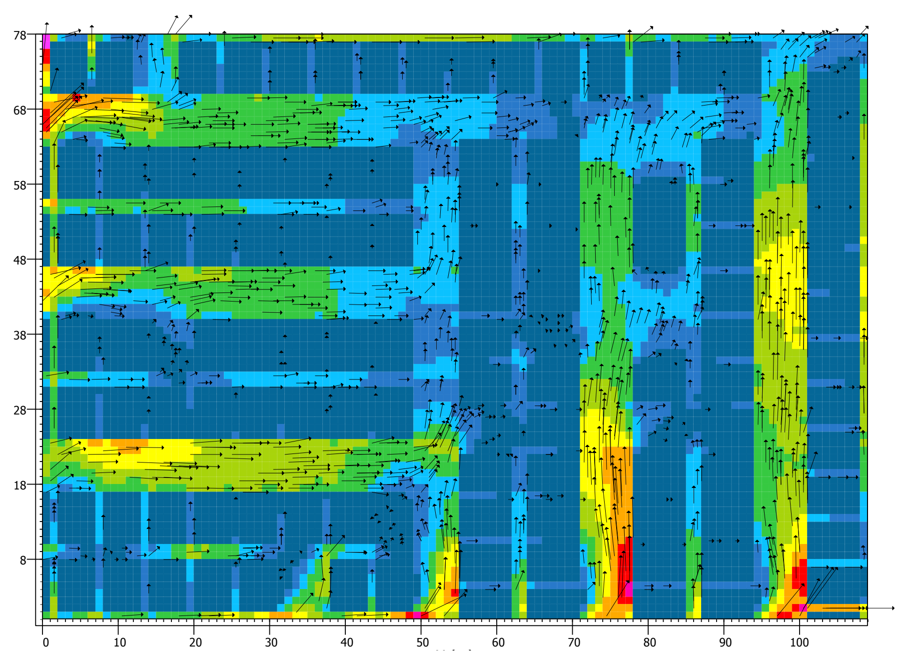


Fig 22: Simulation output _ Field survey [FS] _ WS at 11am

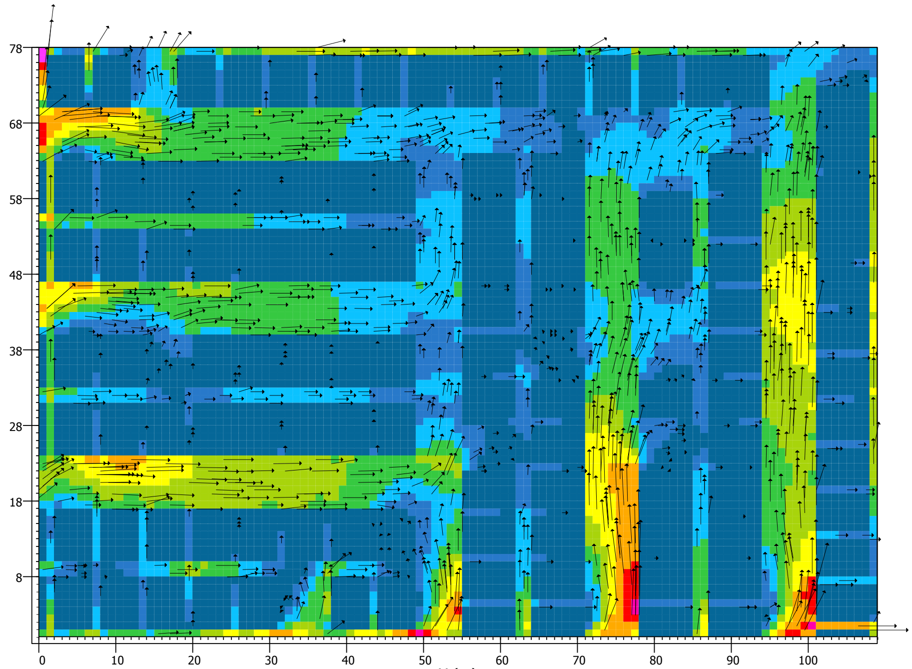


Fig 23: Simulation output _ Field survey [FS] _ WS at 11.30am

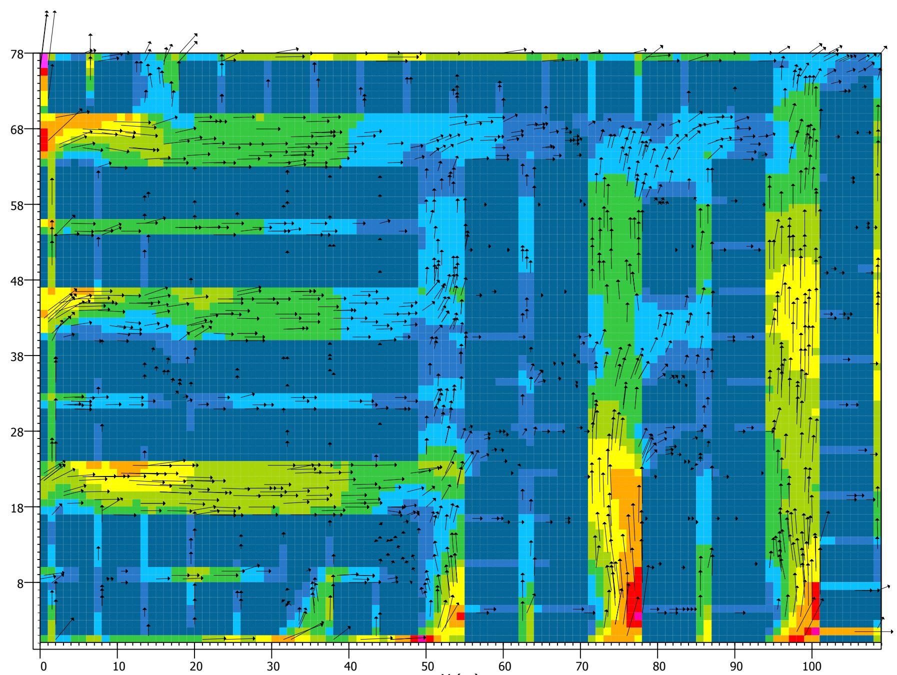


Fig 24: Simulation output _ Field survey [FS] _ WS at 12pm

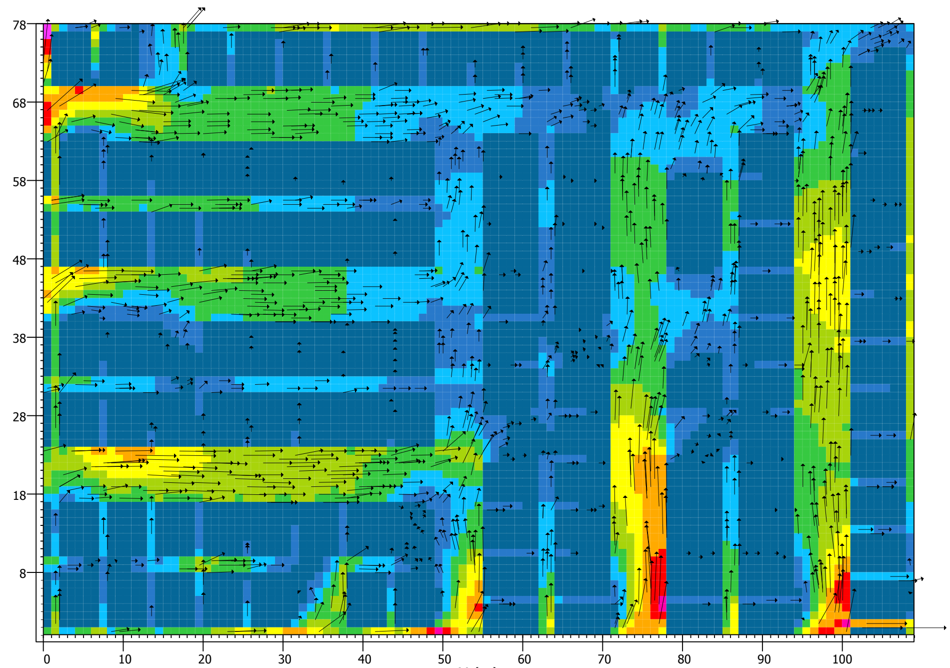


Fig 25: Simulation output _ Field survey [FS] _ WS at 12.30pm

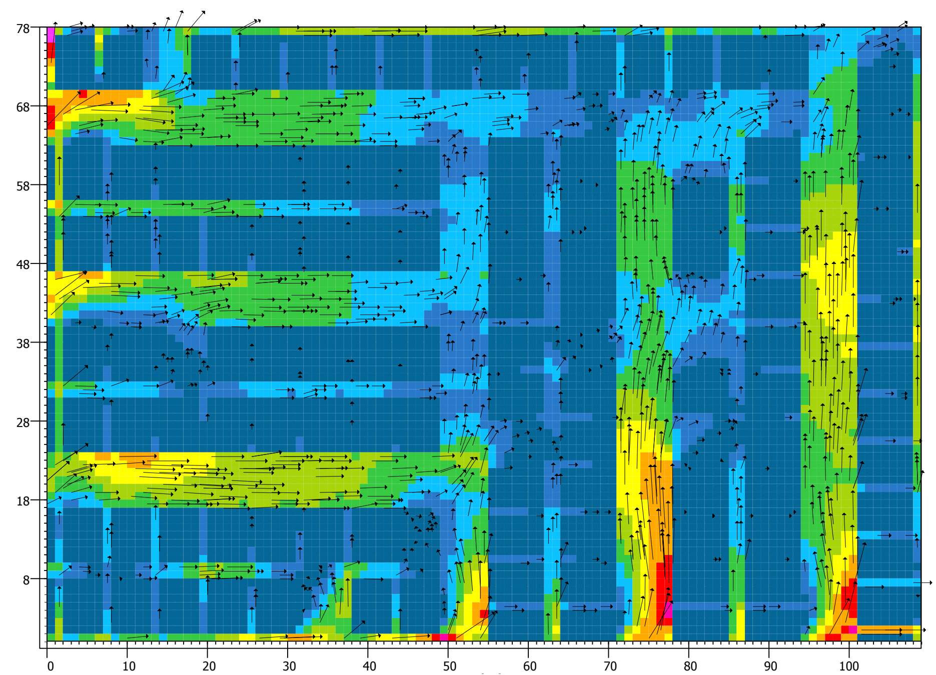


Fig 26: Simulation output _ Field survey [FS] _ WS at 1pm

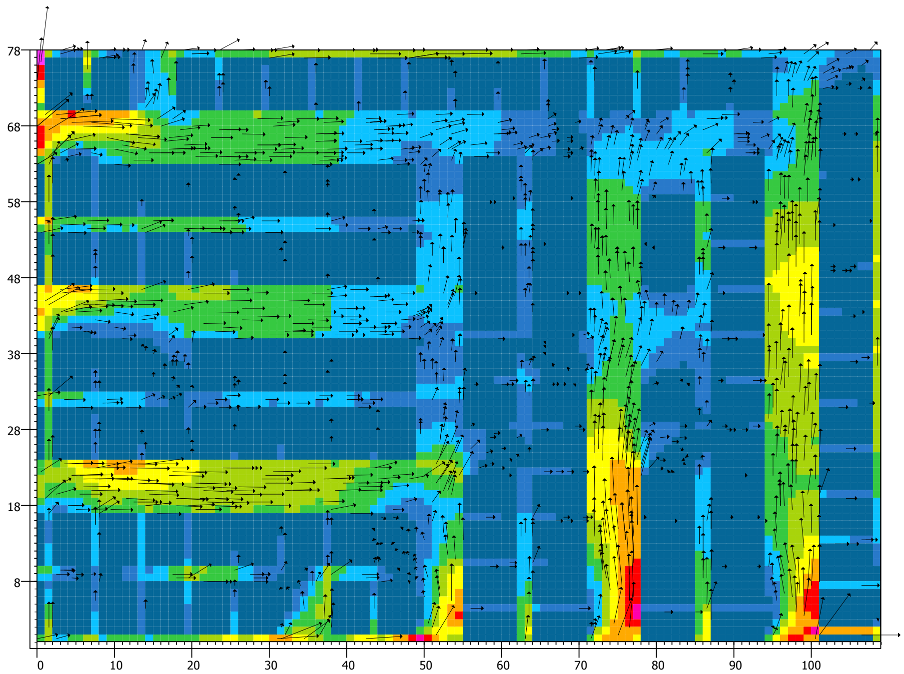


Fig 27: Simulation output _ Field survey [FS] _ WS at 1.30pm

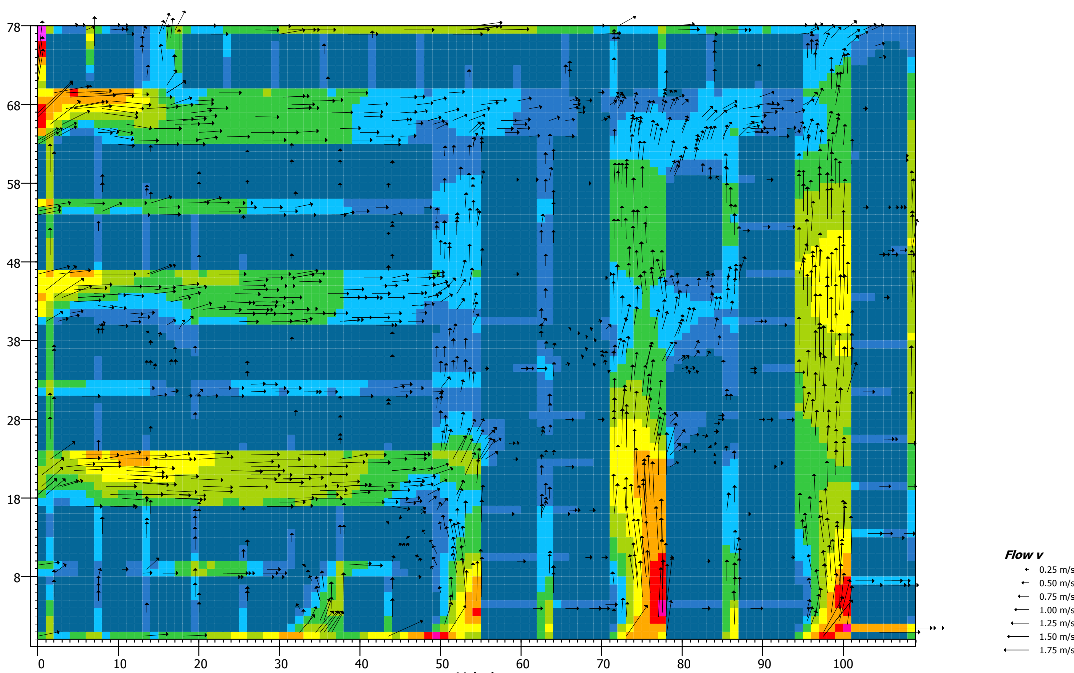
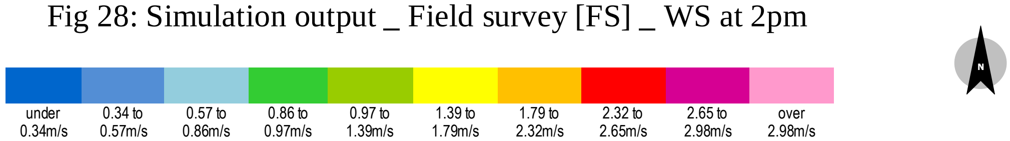


Fig 28: Simulation output _ Field survey [FS] _ WS at 2pm



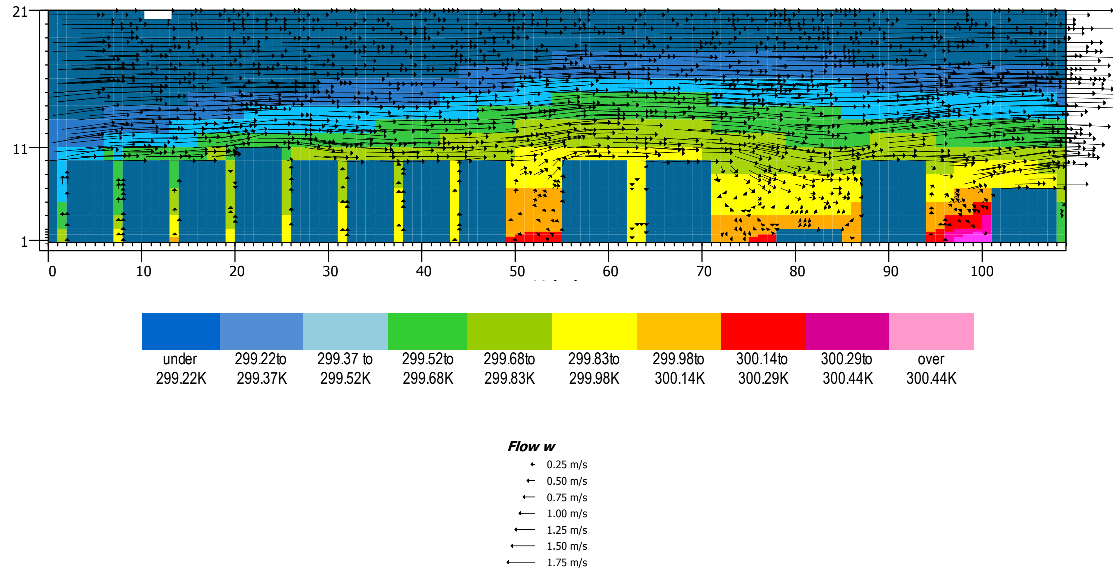


Fig 29: Simulation output _ Field survey [FS] _ DBT _NS rds_ section _ cut at y=48m_ at 2pm

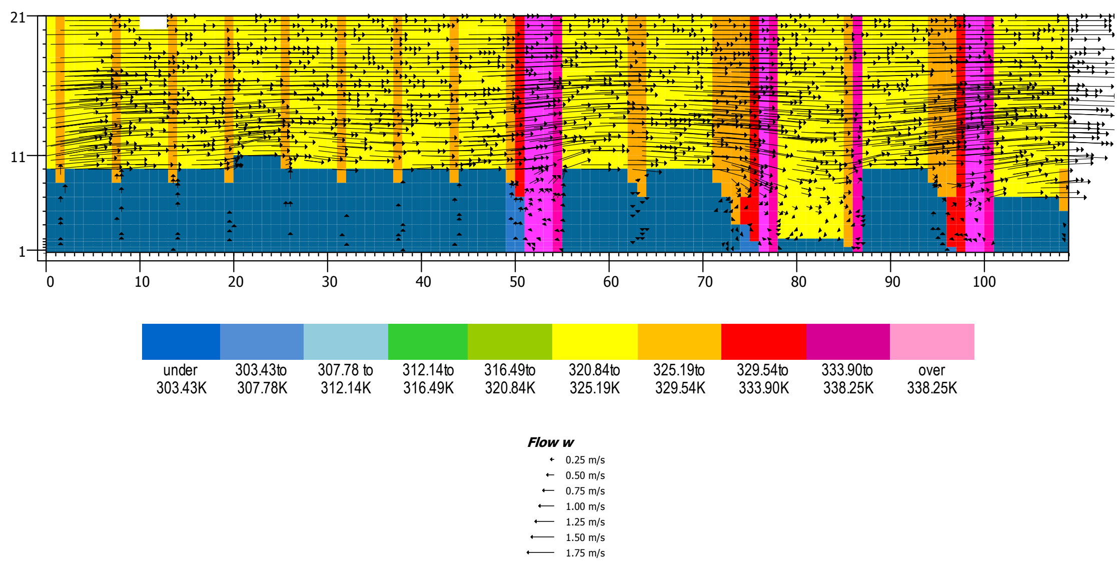


Fig 30: Simulation output _ Field survey [FS] _ MRT _NS rds_ section _ cut at y=48m_ at 2pm

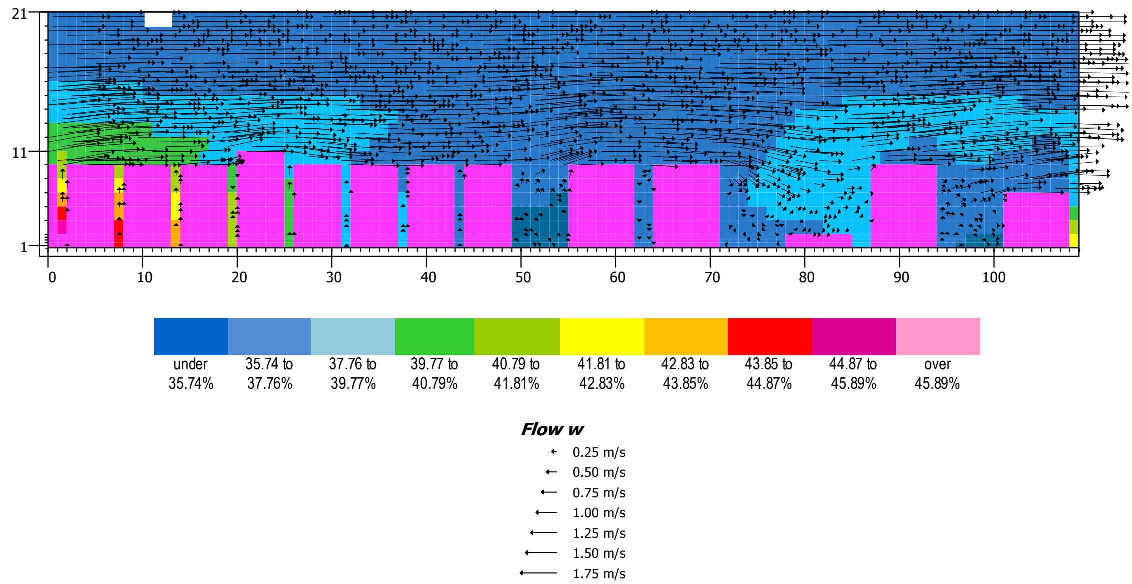


Fig 31: Simulation output _ Field survey [FS] _ RH _NS rds_ section _ cut at y=48m_ at 2pm

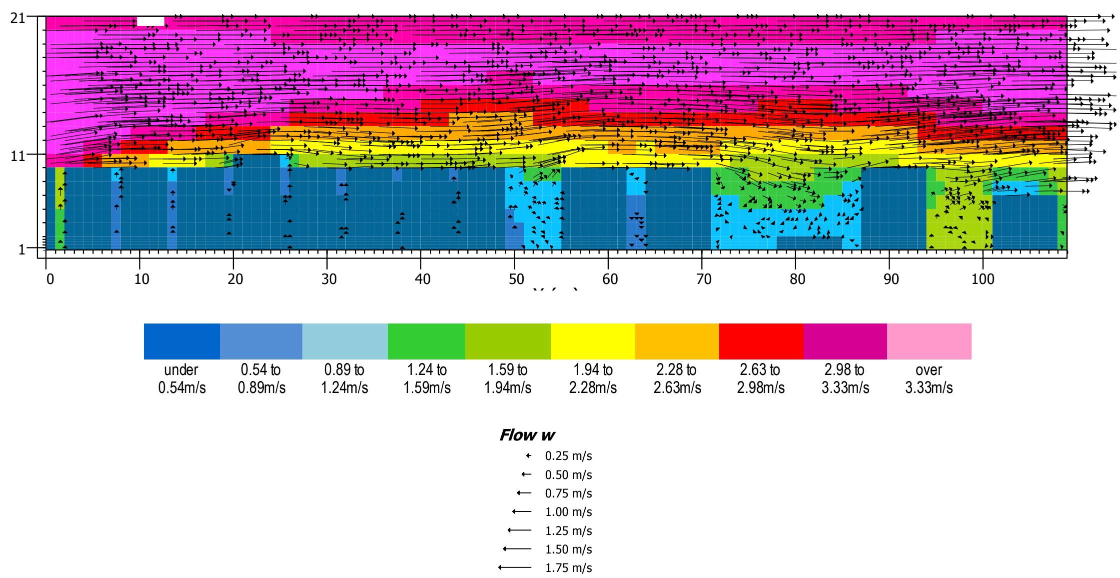


Fig 32: Simulation output _ Field survey [FS] _ WS _NS rds_ section _ cut at y=48m_ at 2pm

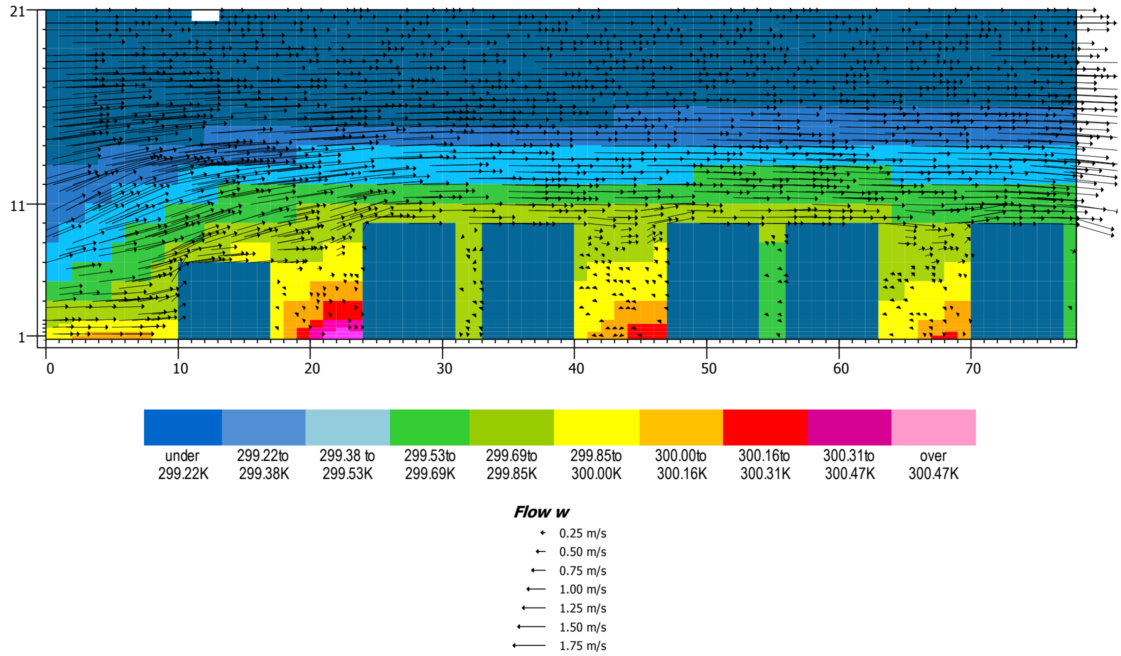


Fig 33: Simulation output _ Field survey [FS] _ DBT _ EW rds_ section _ cut at x=36m_at 2pm

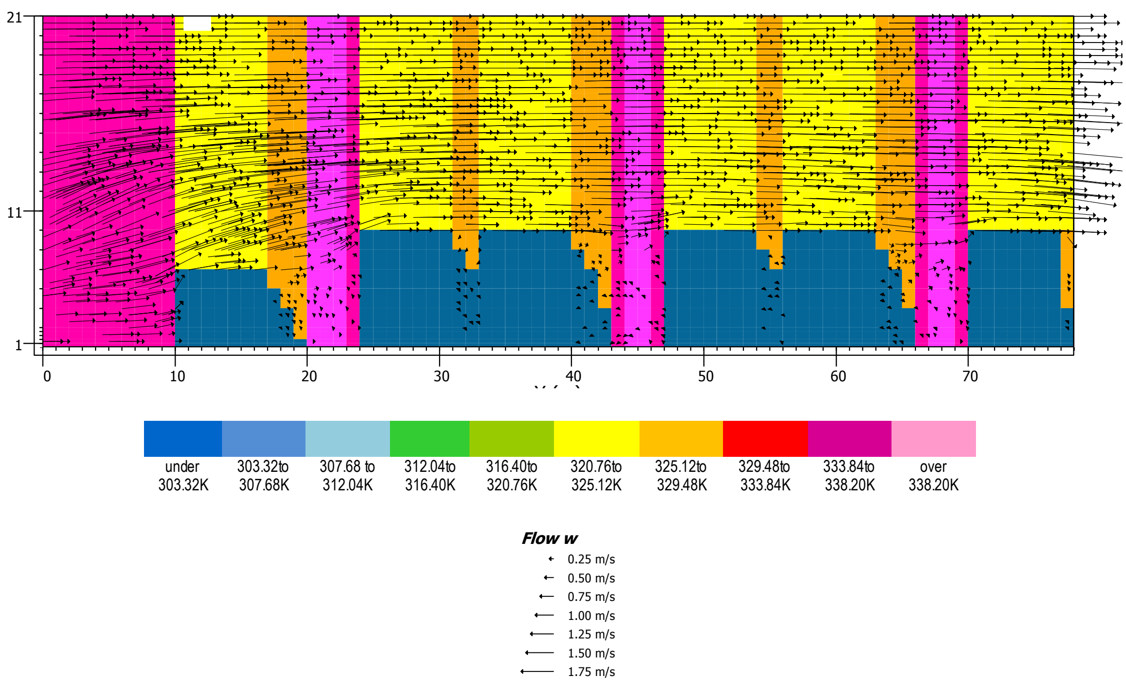


Fig 34: Simulation output _ Field survey [FS] _ MRT _ EW rds _ section _ cut at x=36m_at 2pm

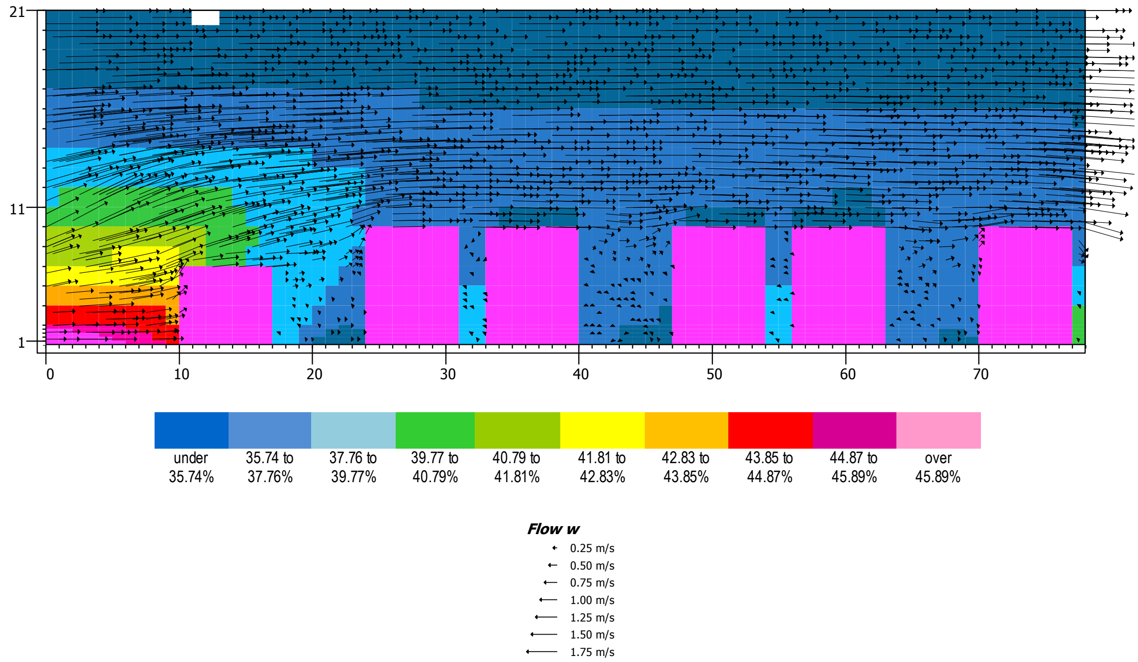


Fig 35: Simulation output _ Field survey [FS] _ RH _ EW rds _ section _ cut at x=36m_at 2pm

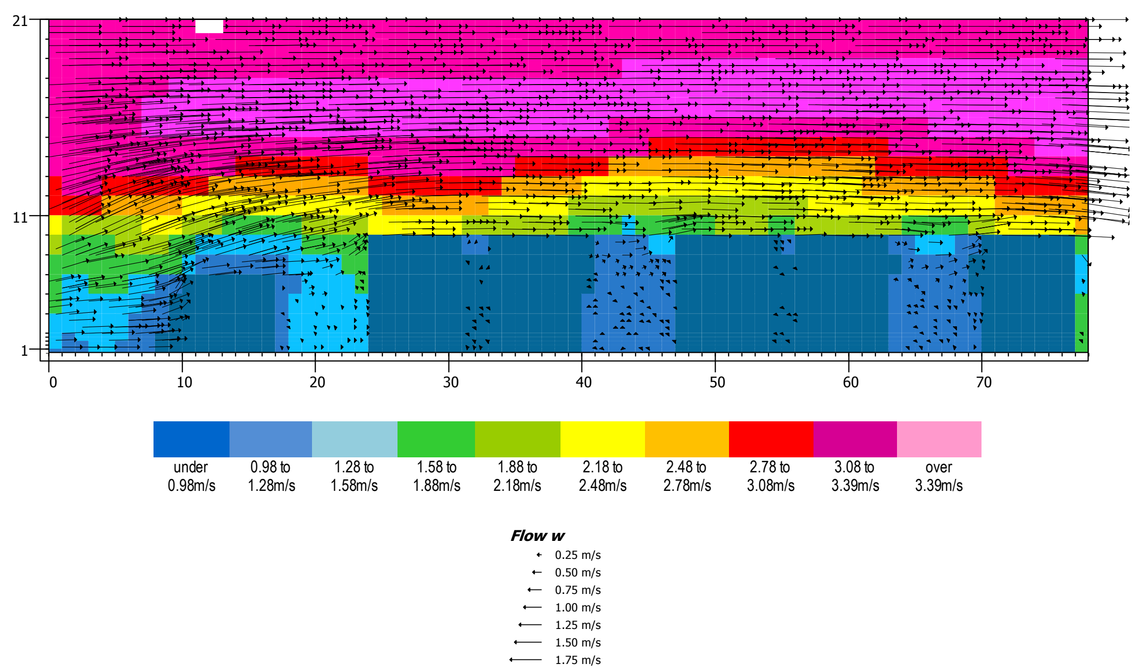


Fig 36: Simulation output _ Field survey [FS] _ WS _ EW rds _ section _ cut at x=36m_at 2pm

Simulation Outputs _ Simulation Typologies [ST]: North-South [NS] Orientation

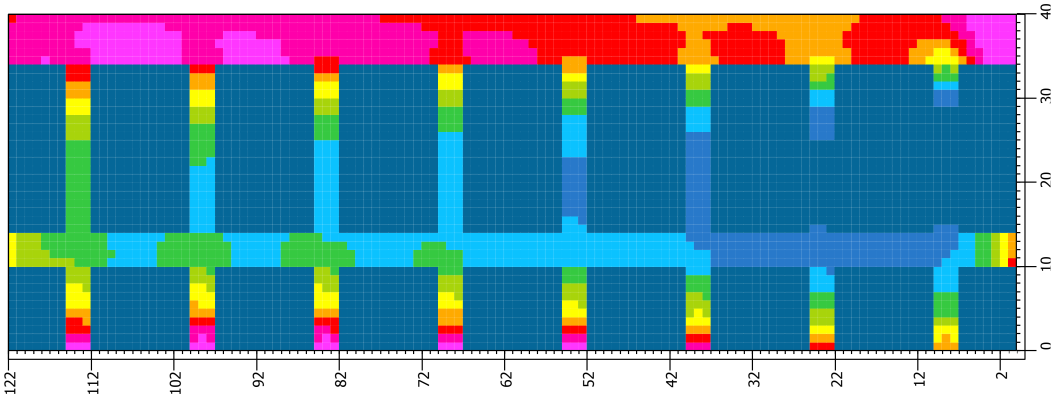


Fig 37: Simulation output _ Simulation type A _ NS _ DBT at 11am

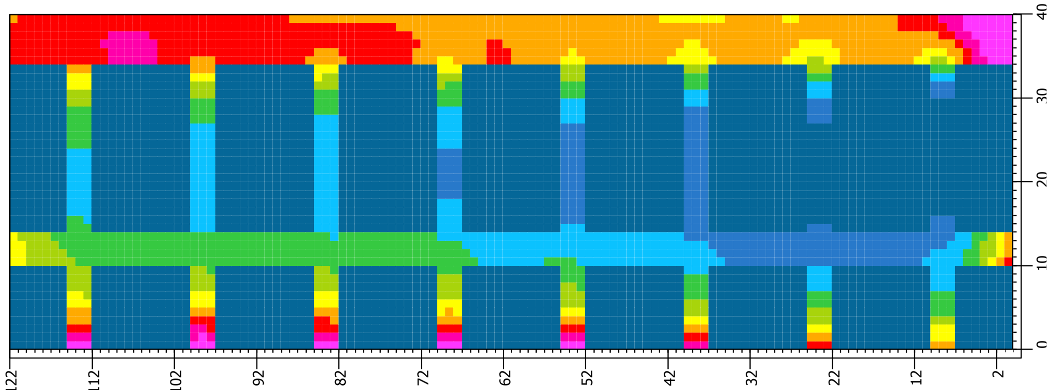


Fig 38: Simulation output _ Simulation type A _ NS _ DBT at 11.30am

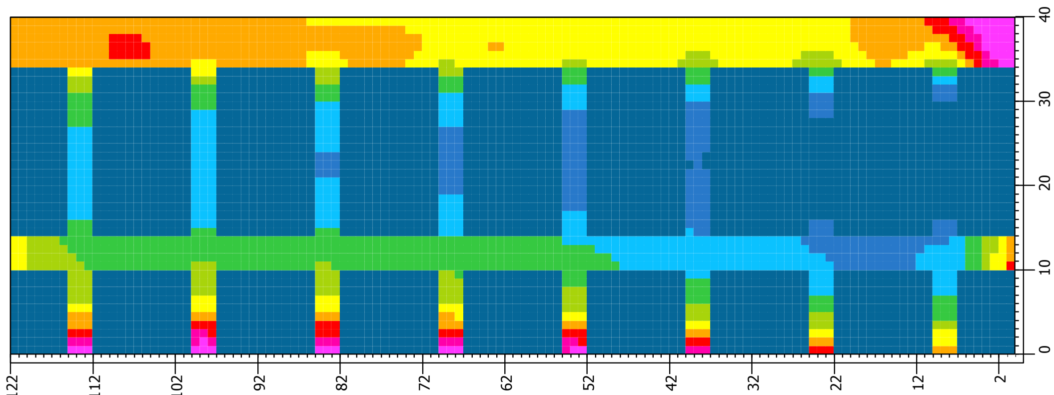


Fig 39: Simulation output _ Simulation type A _ NS _ DBT at 12pm

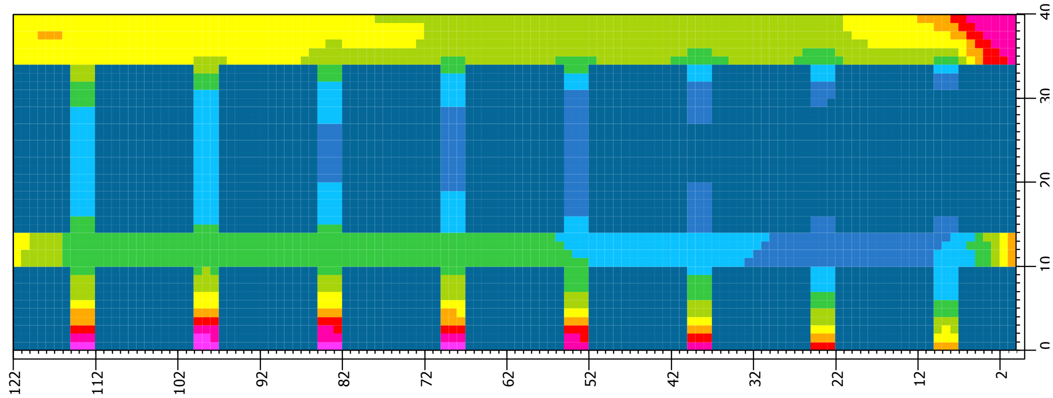


Fig 40: Simulation output _ Simulation type A _ NS _ DBT at 12.30pm

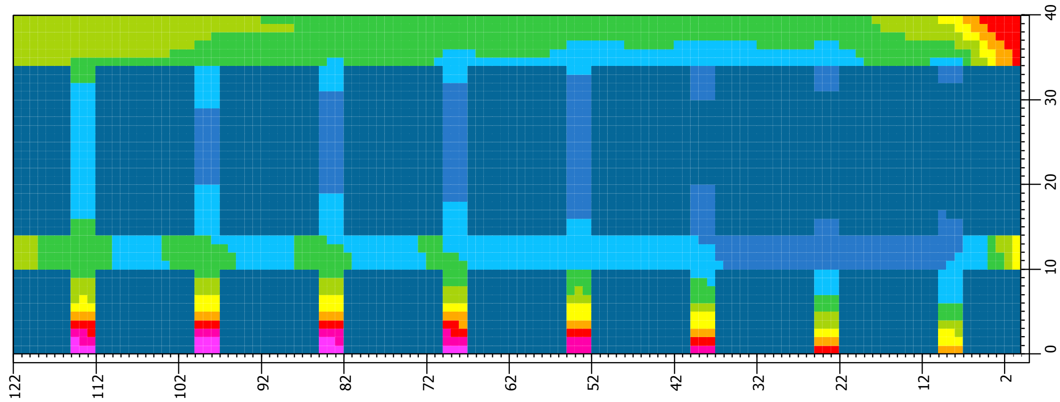


Fig 41: Simulation output _ Simulation type A _ NS _ DBT at 1pm

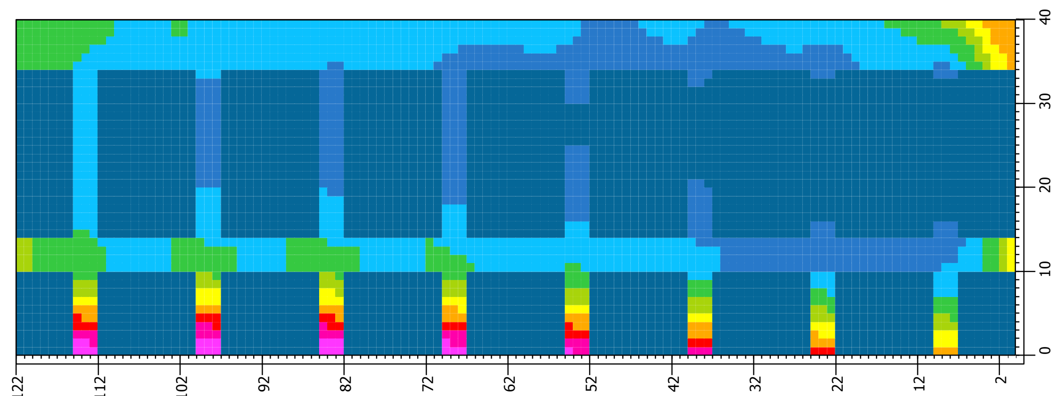


Fig 42: Simulation output _ Simulation type A _ NS _ DBT at 1.30pm

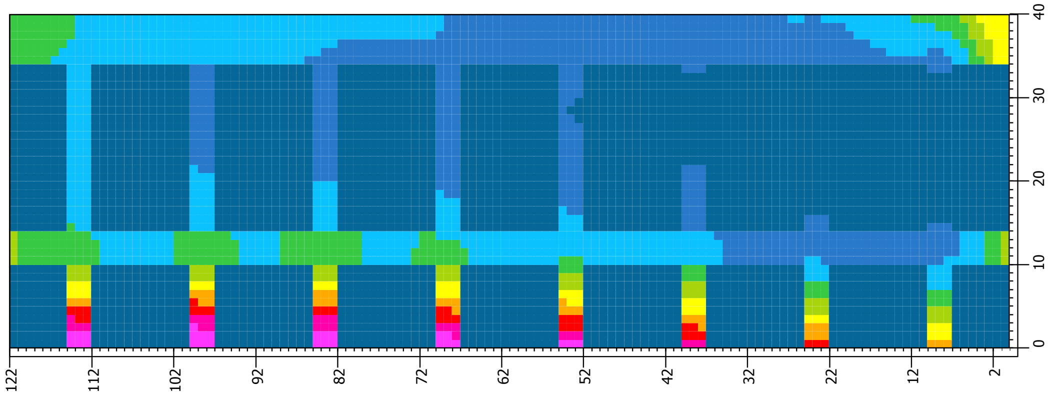
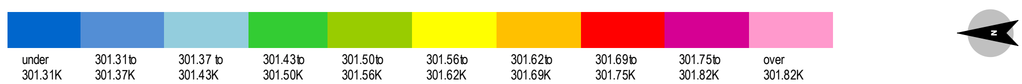


Fig 43: Simulation output _ Simulation type A _ NS _ DBT at 2pm



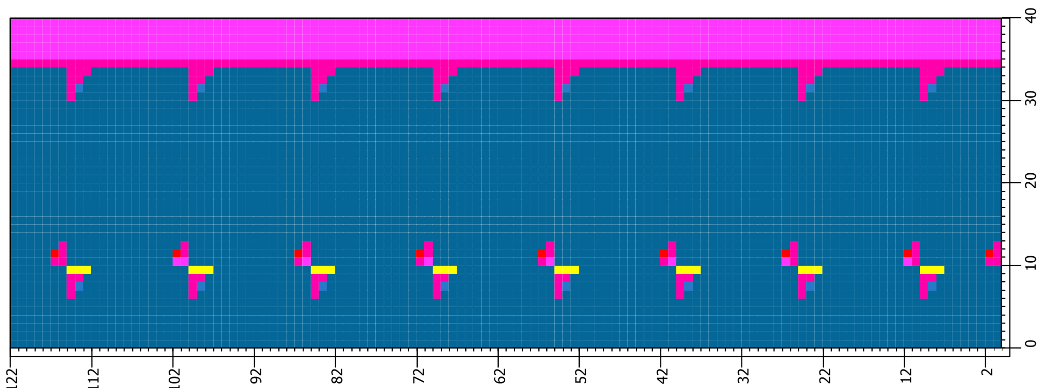


Fig 44: Simulation output _ Simulation type A _ NS _ MRT at 11am

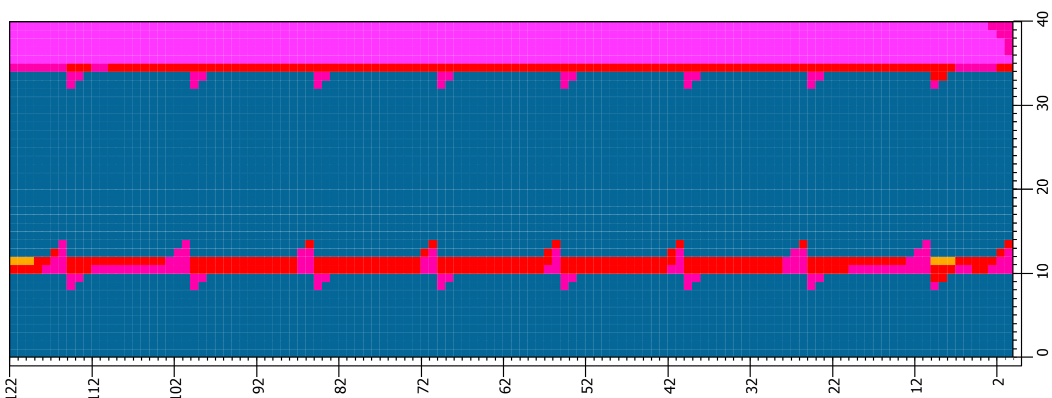


Fig 45: Simulation output _ Simulation type A _ NS _ MRT at 11.30am

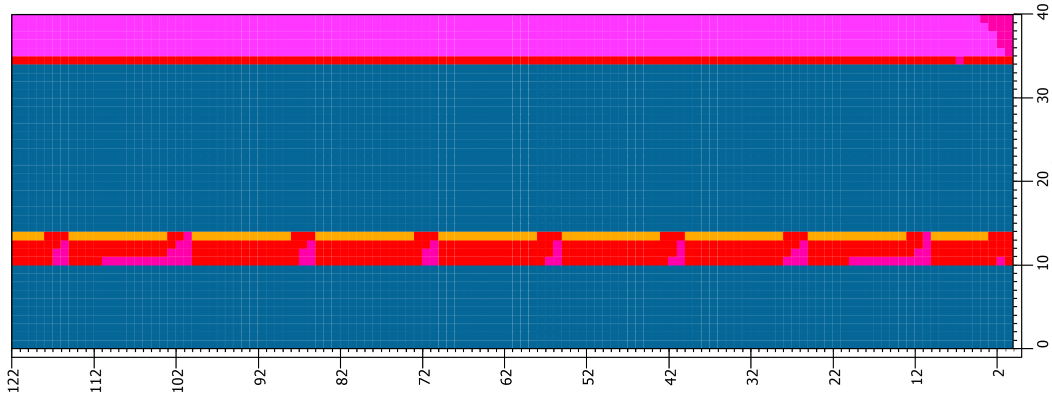


Fig 46: Simulation output _ Simulation type A _ NS _ MRT at 12pm

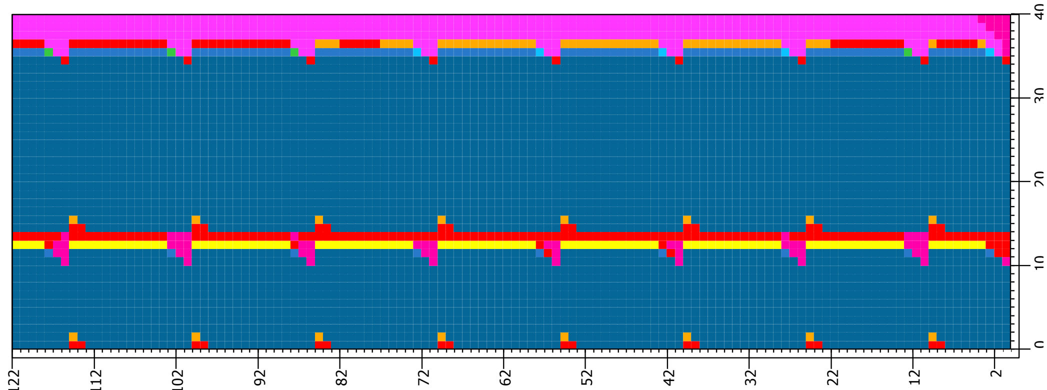


Fig 47: Simulation output _ Simulation type A _ NS _ MRT at 12.30pm

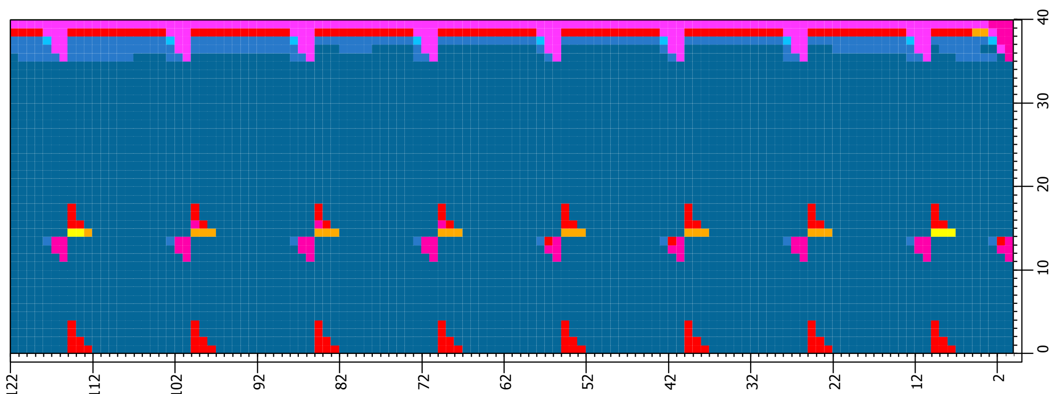


Fig 48: Simulation output _ Simulation type A _ NS _ MRT at 1pm

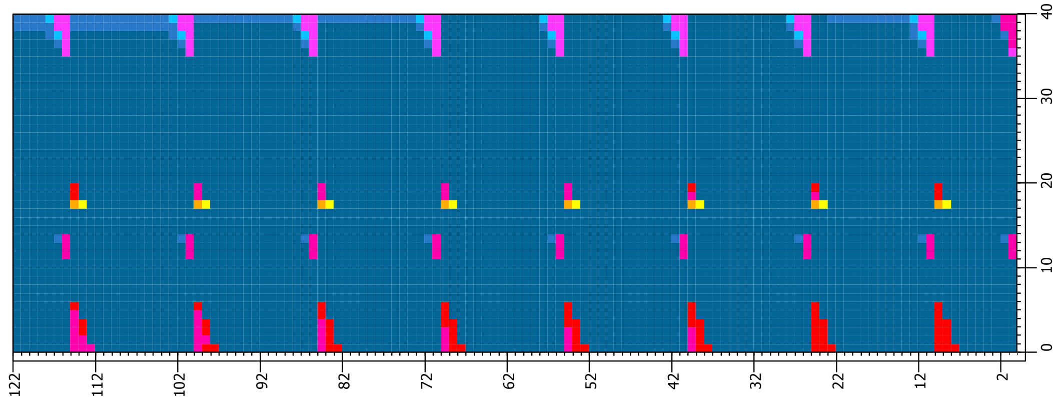


Fig 49: Simulation output _ Simulation type A _ NS _ MRT at 1.30pm

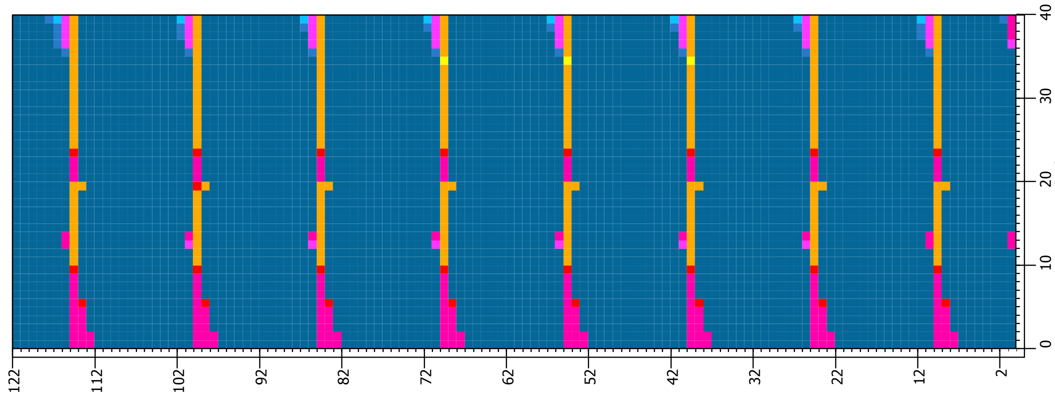
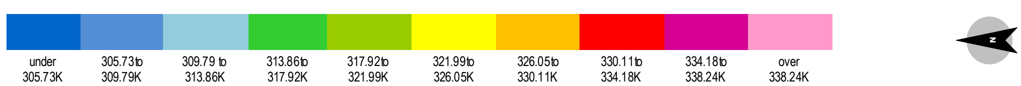


Fig 50: Simulation output _ Simulation type A _ NS _ MRT at 2pm



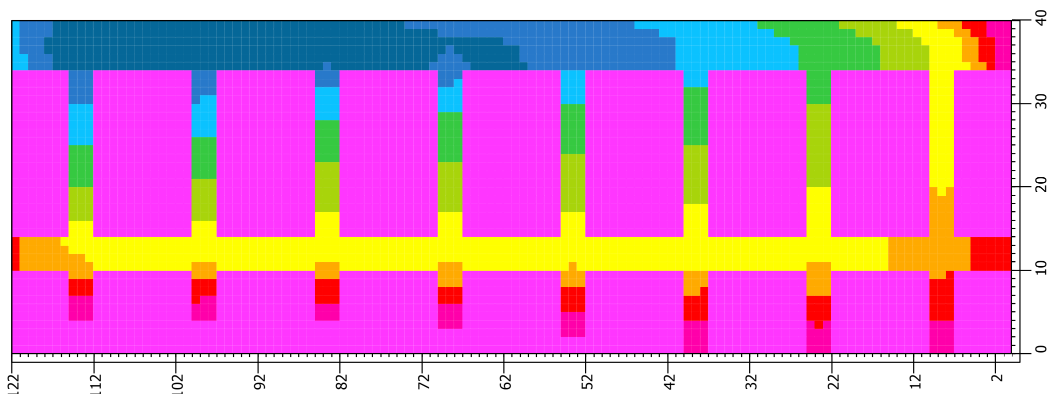


Fig 51: Simulation output _ Simulation type A _ NS _ RH at 11am

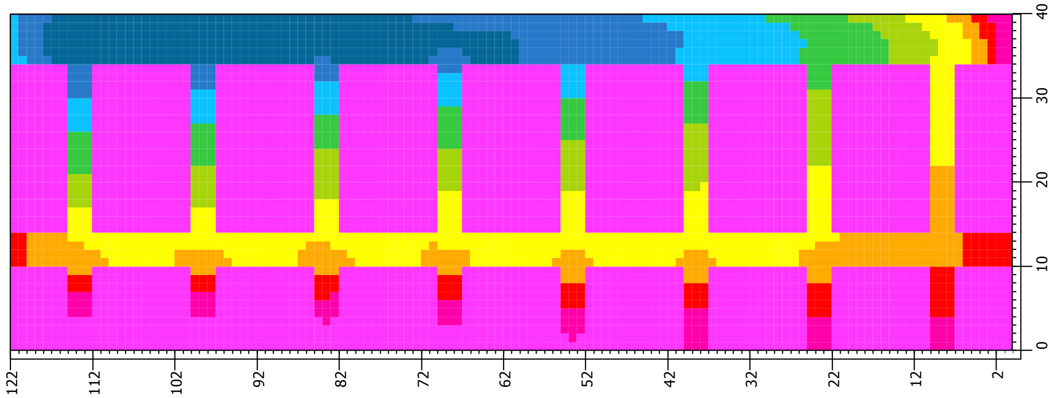


Fig 52: Simulation output _ Simulation type A _ NS _ RH at 11.30am

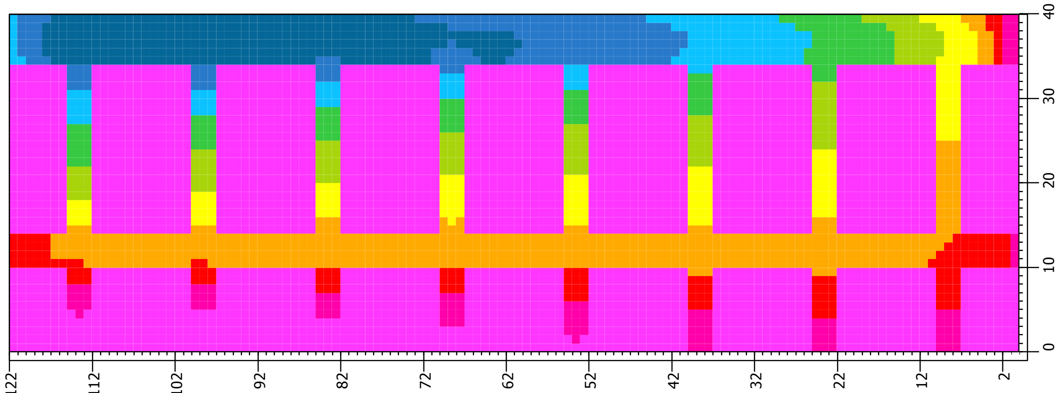


Fig 53: Simulation output _ Simulation type A _ NS _ RH at 12pm

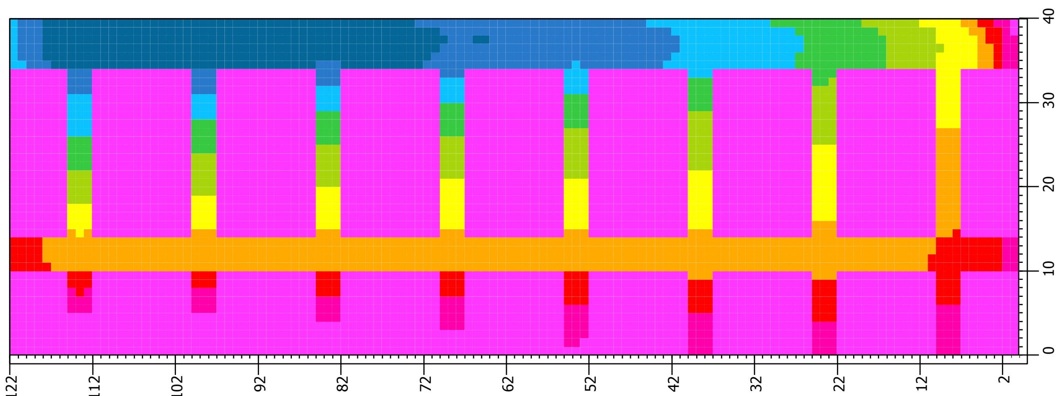


Fig 54: Simulation output _ Simulation type A _ NS _ RH at 12.30pm

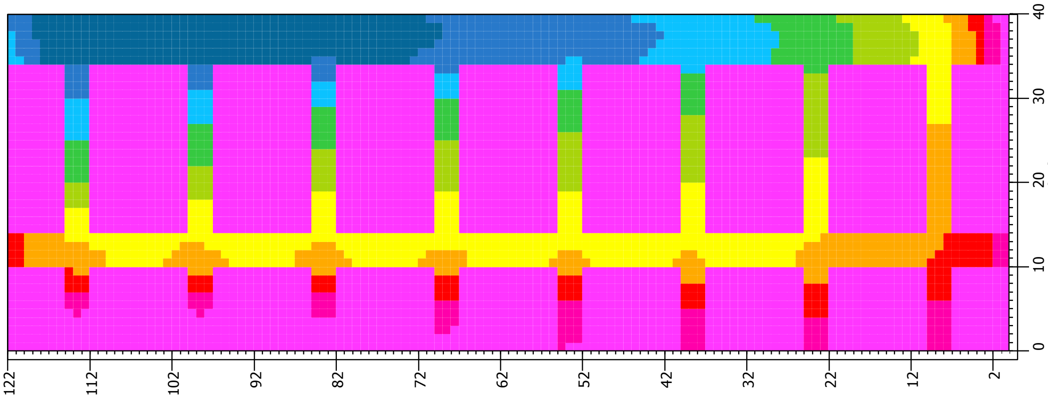


Fig 55: Simulation output _ Simulation type A _ NS _ RH at 1pm

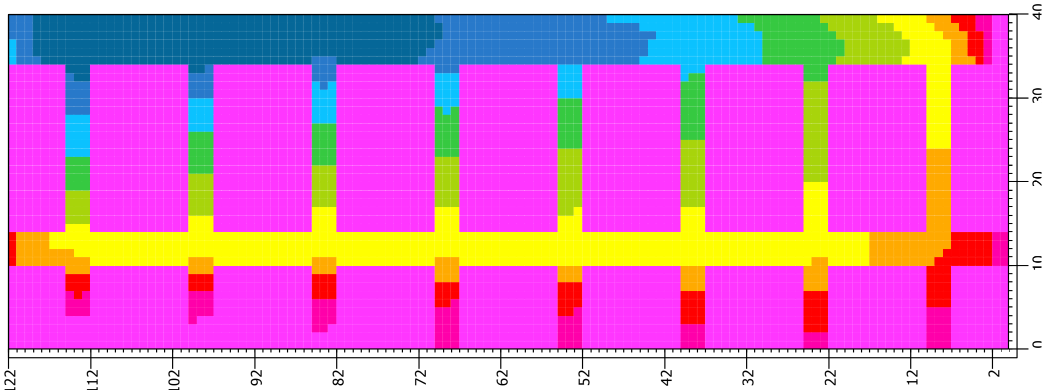


Fig 56: Simulation output _ Simulation type A _ NS _ RH at 1.30pm

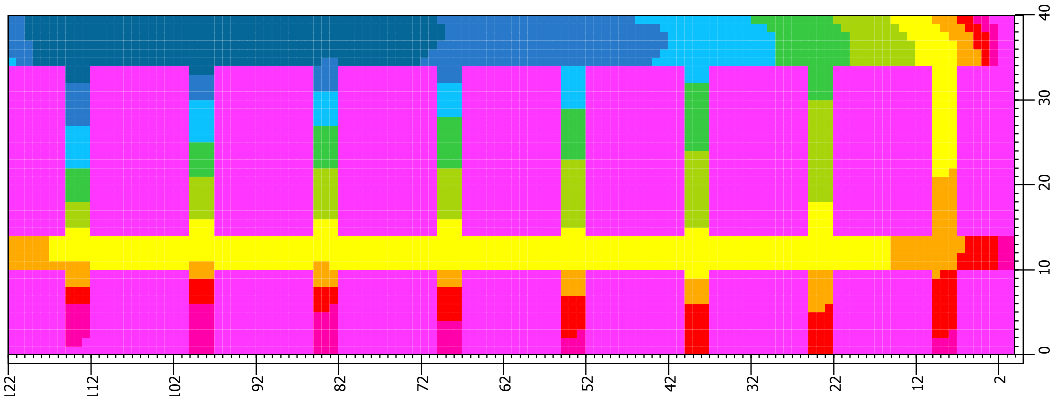
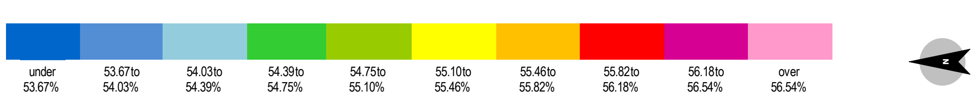


Fig 57: Simulation output _ Simulation type A _ NS _ RH at 2pm



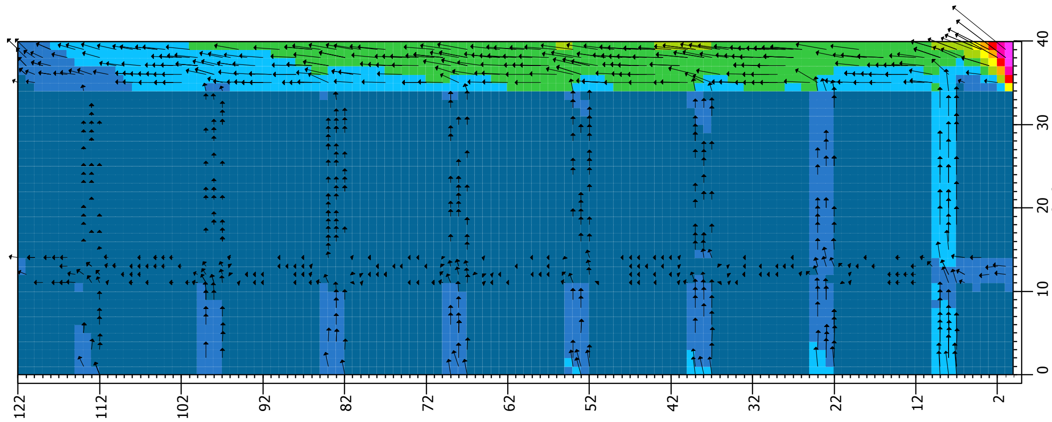


Fig 58: Simulation output _ Simulation type A _ NS _ WS at 11am

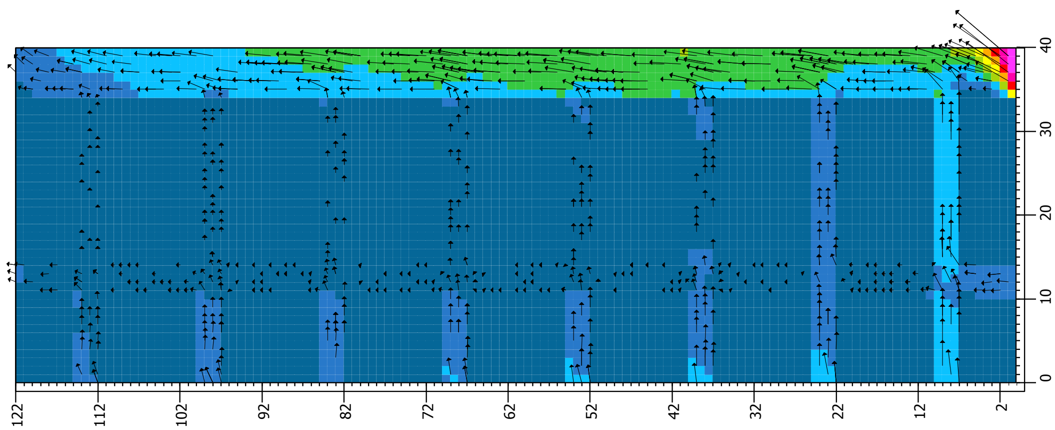


Fig 59: Simulation output _ Simulation type A _ NS _ WS at 11.30am

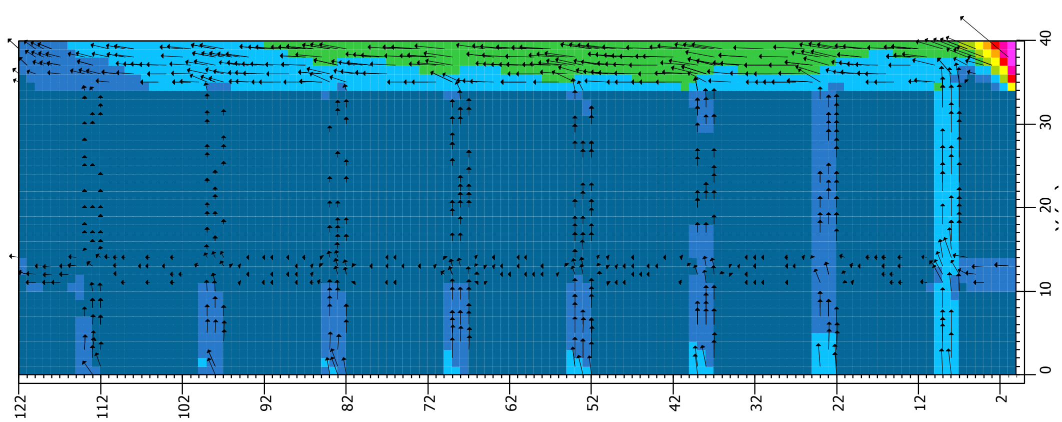


Fig 60: Simulation output _ Simulation type A _ NS _ WS at 12pm

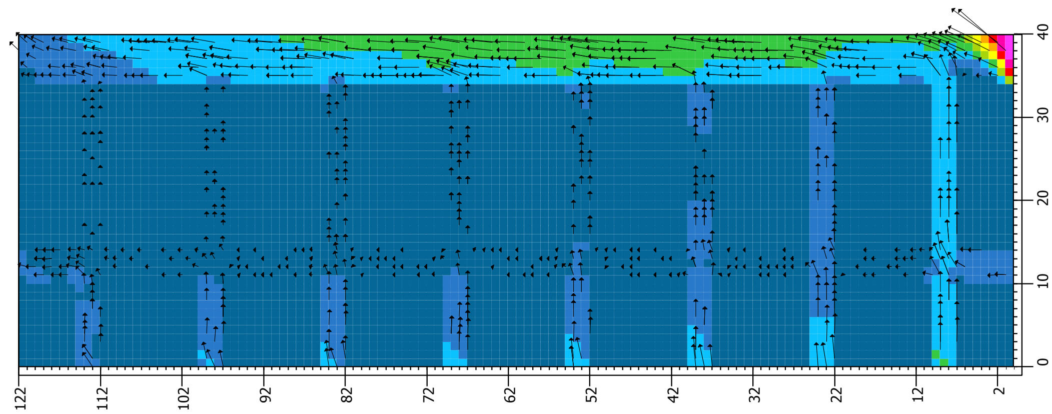


Fig 61: Simulation output _ Simulation type A _ NS _ WS at 12.30pm

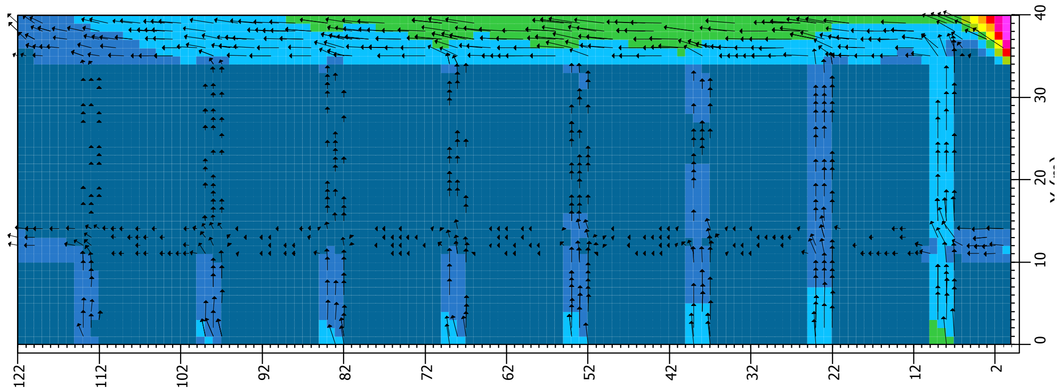


Fig 62: Simulation output _ Simulation type A _ NS _ WS at 1pm

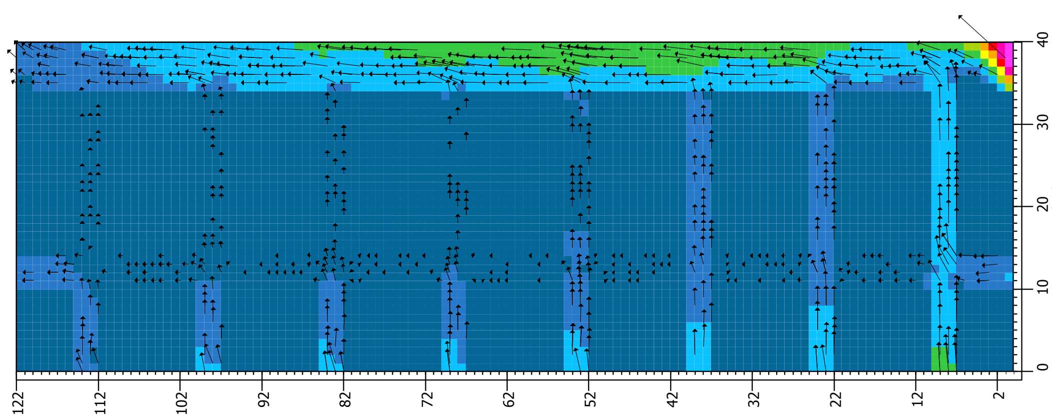


Fig 63: Simulation output _ Simulation type A _ NS _ WS at 1.30pm

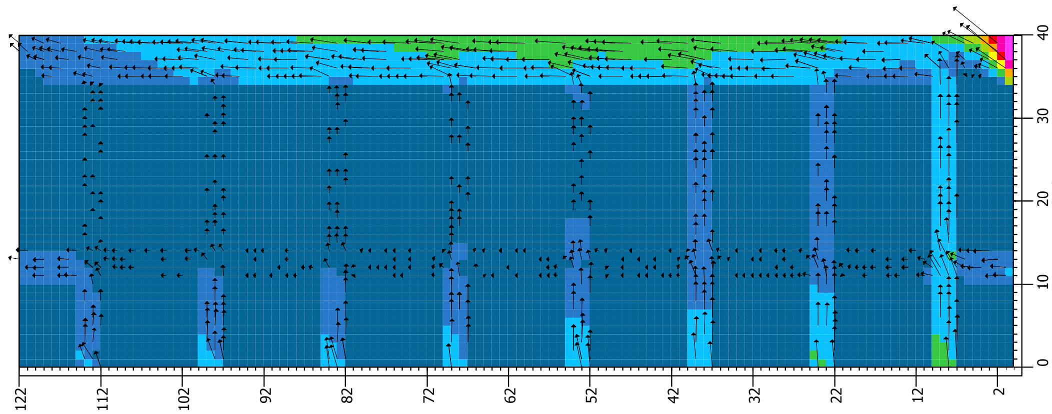
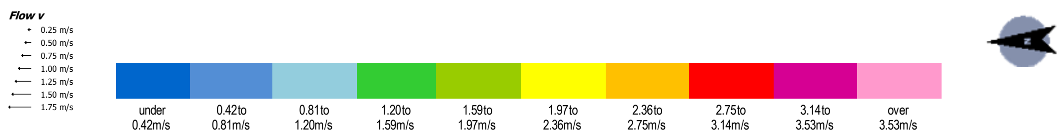


Fig 64: Simulation output _ Simulation type A _ NS _ WS at 2pm



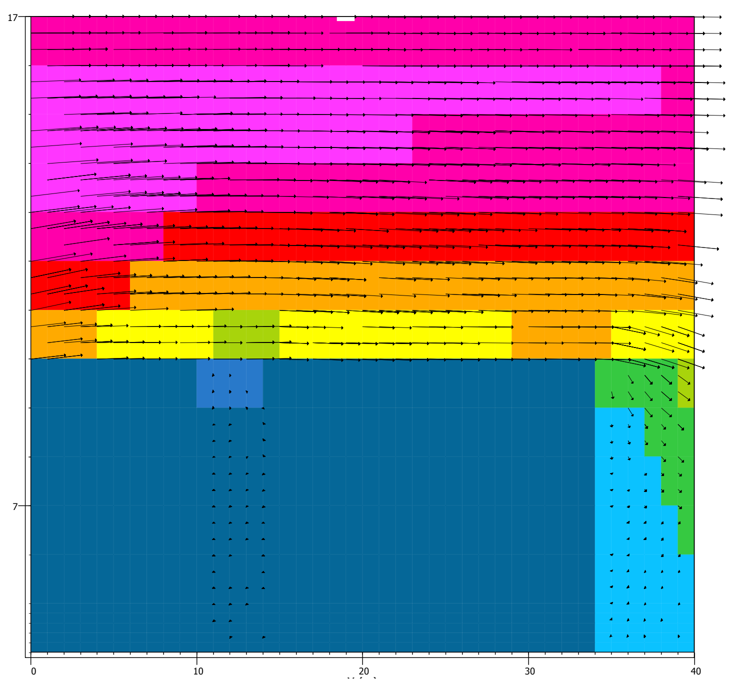


Fig 65: Simulation output _ Simulation type A _ NS _ WS _ section_ at 11am

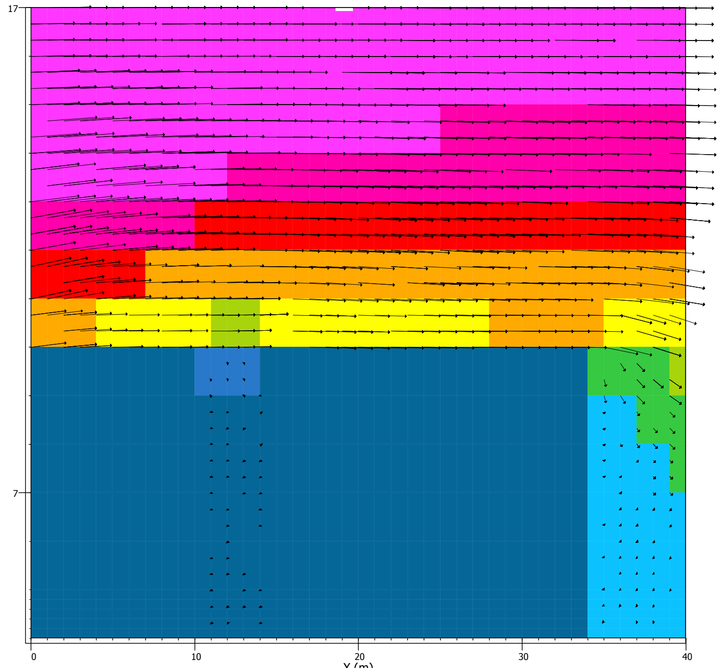


Fig 66: Simulation output _ Simulation type A _ NS _ WS _ section_ at 12pm

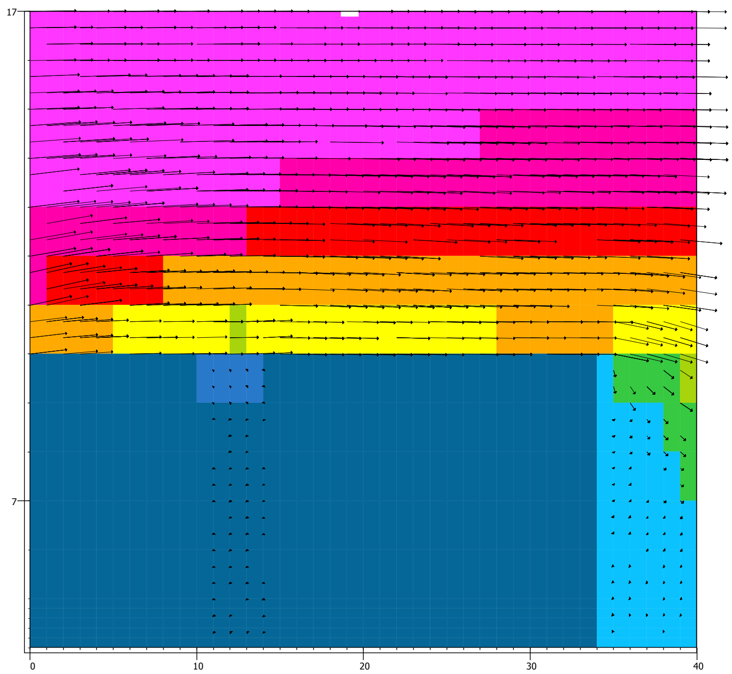


Fig 67: Simulation output _ Simulation type A _ NS _ WS _ section_ at 1pm

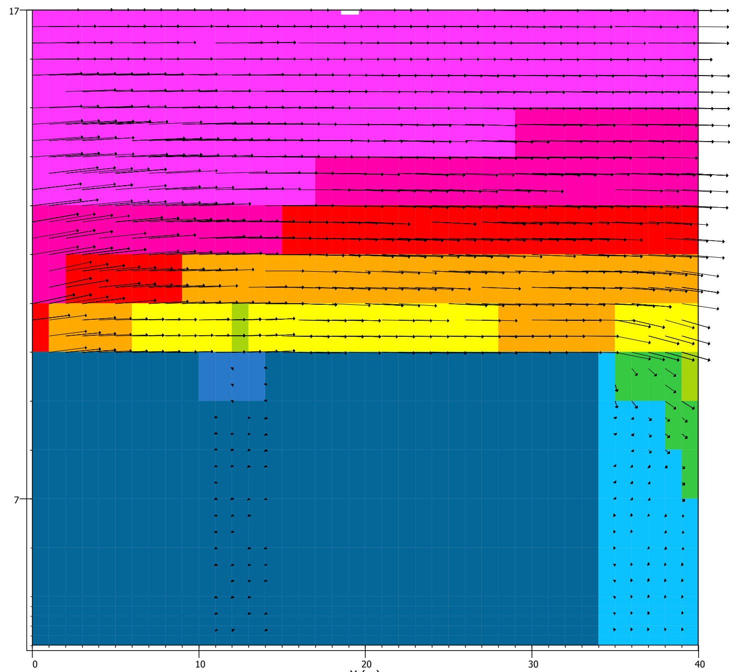
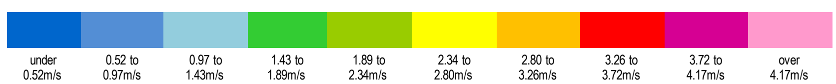


Fig 68: Simulation output _ Simulation type A _ NS _ WS _ section_ at 2pm



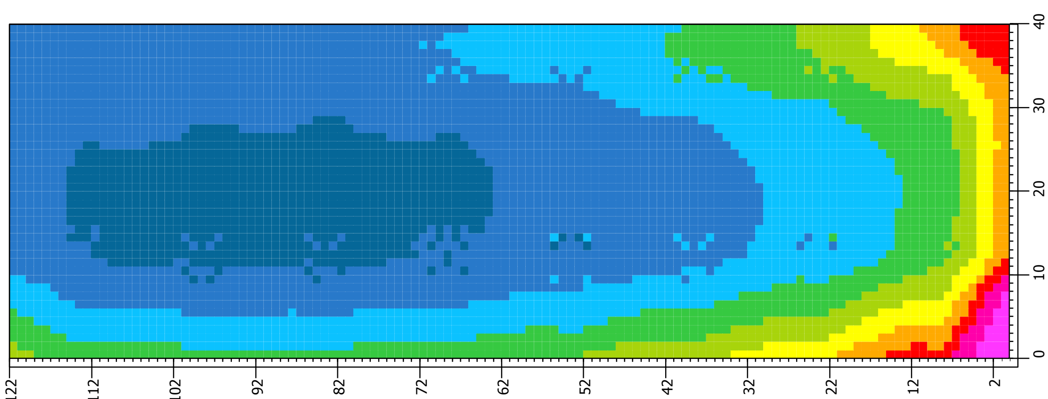


Fig 69: Simulation output _ Simulation type A1 _ NS _ DBT at 11am

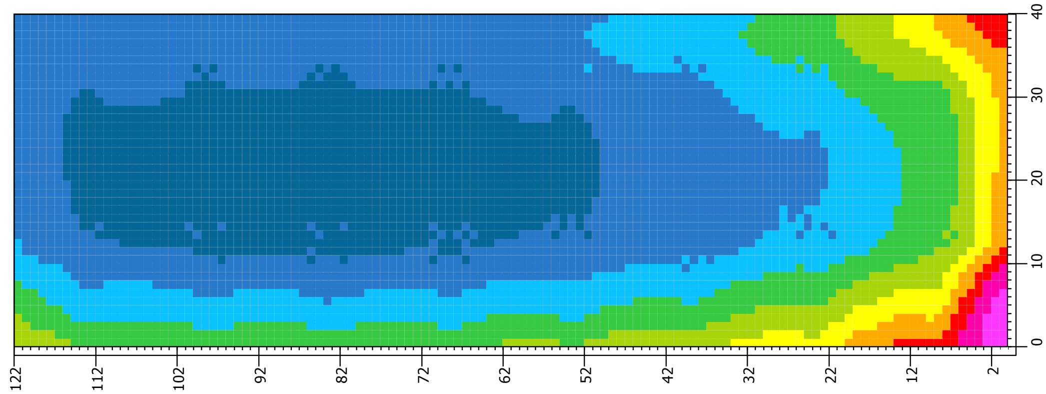


Fig 70: Simulation output _ Simulation type A1 _ NS _ DBT at 11.30am

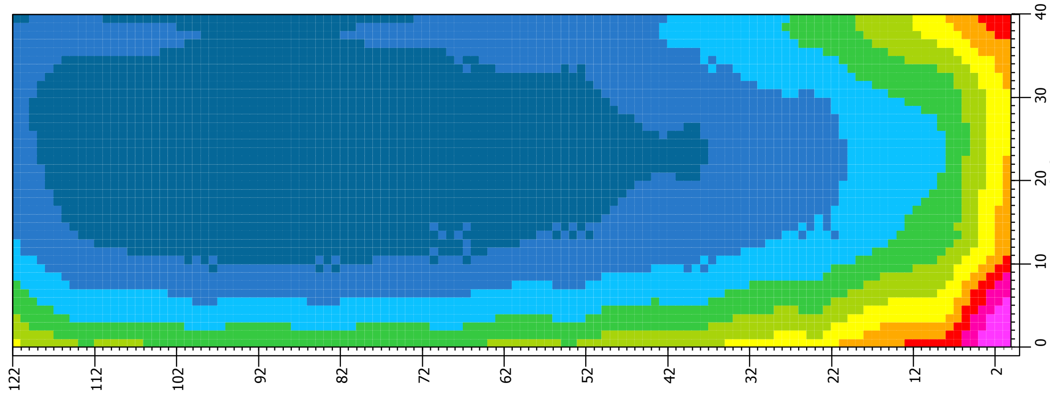


Fig 71: Simulation output _ Simulation type A1 _ NS _ DBT at 12pm

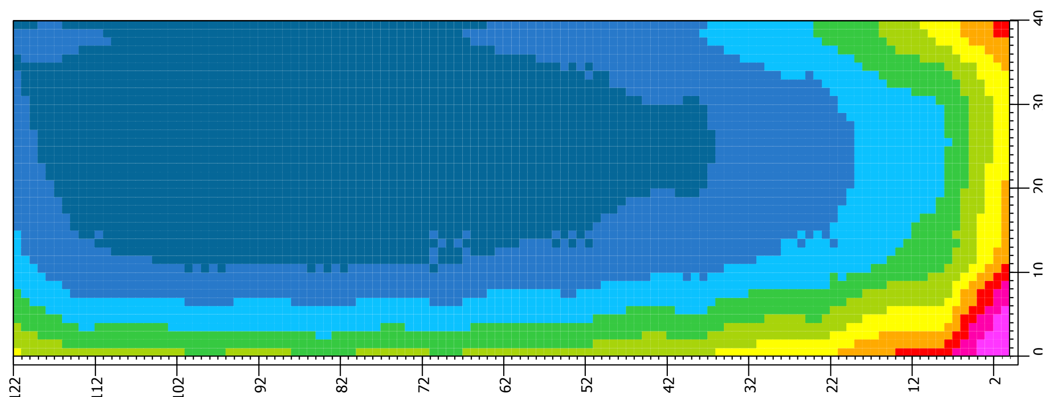


Fig 72: Simulation output _ Simulation type A1 _ NS _ DBT at 12.30pm

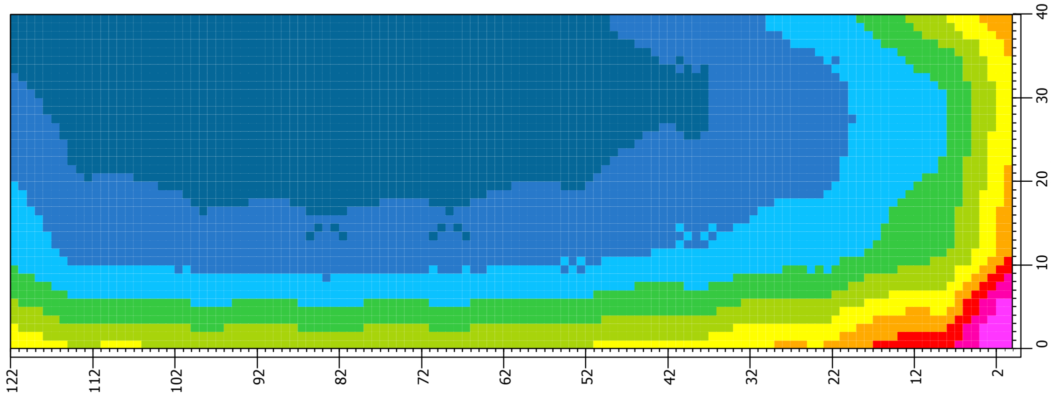


Fig 73: Simulation output _ Simulation type A1 _ NS _ DBT at 1pm

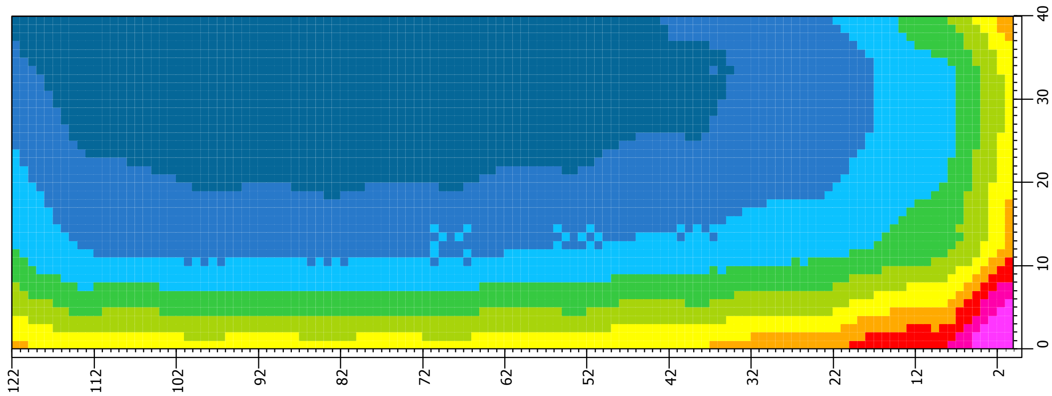


Fig 74: Simulation output _ Simulation type A1 _ NS _ DBT at 1.30pm

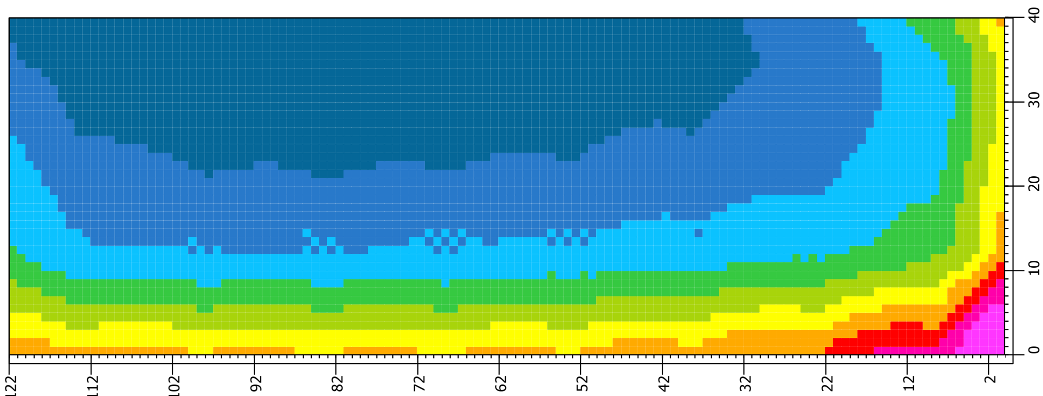
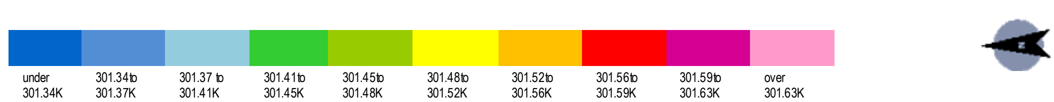


Fig 75: Simulation output _ Simulation type A1 _ NS _ DBT at 2pm



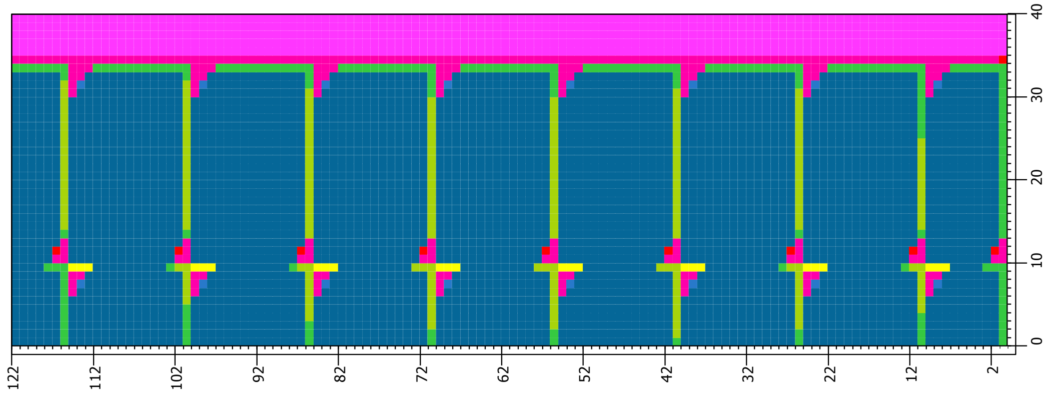


Fig 76: Simulation output _ Simulation type A1 _ NS _ MRT at 11am

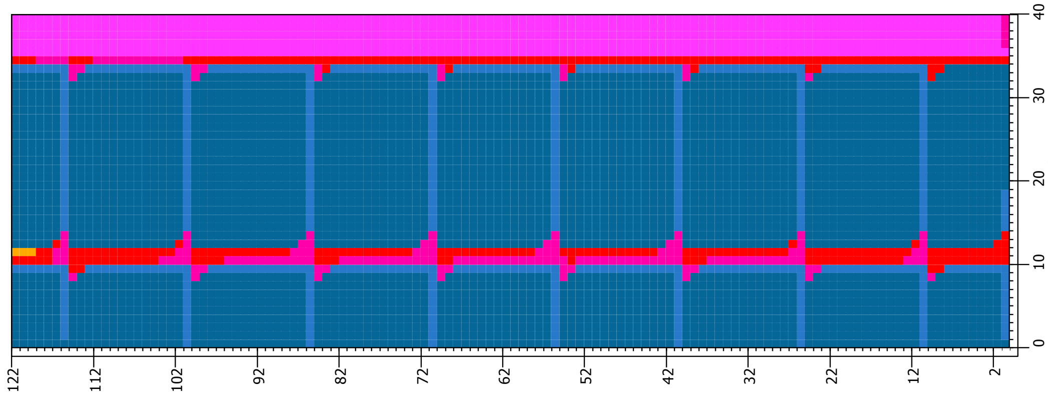


Fig 77: Simulation output _ Simulation type A1 _ NS _ MRT at 11.30am

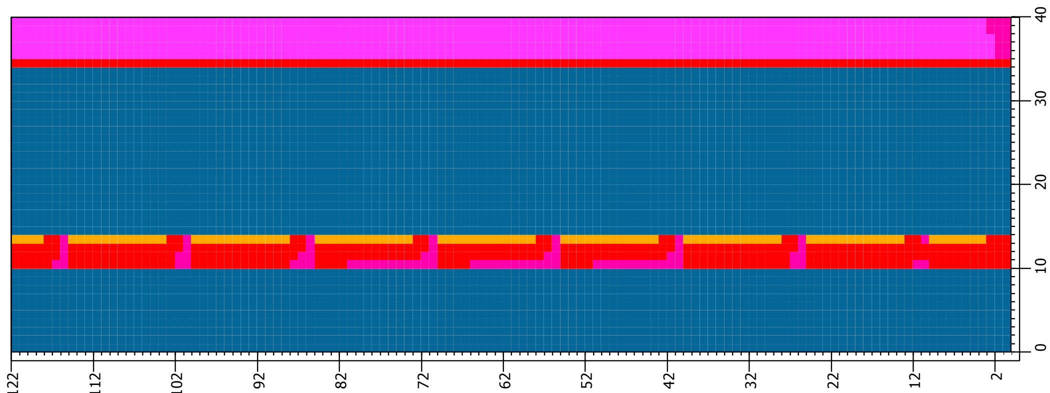


Fig 78: Simulation output _ Simulation type A1 _ NS _ MRT at 12pm

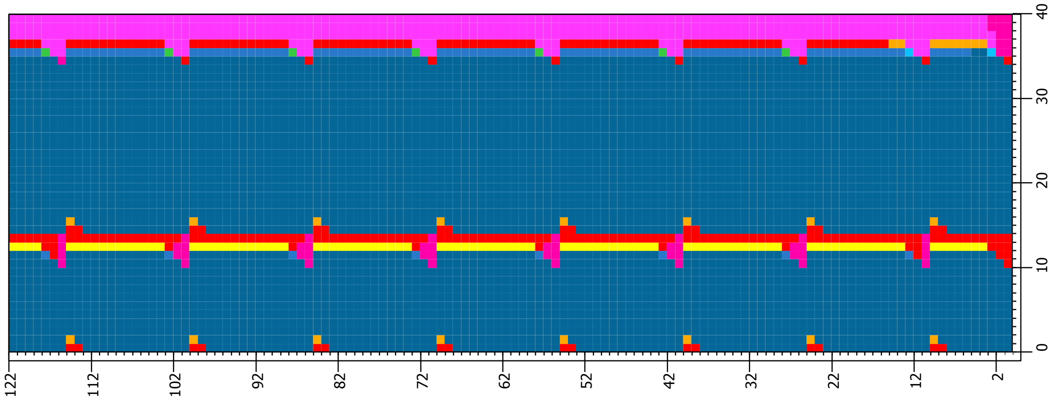


Fig 79: Simulation output _ Simulation type A1 _ NS _ MRT at 12.30pm

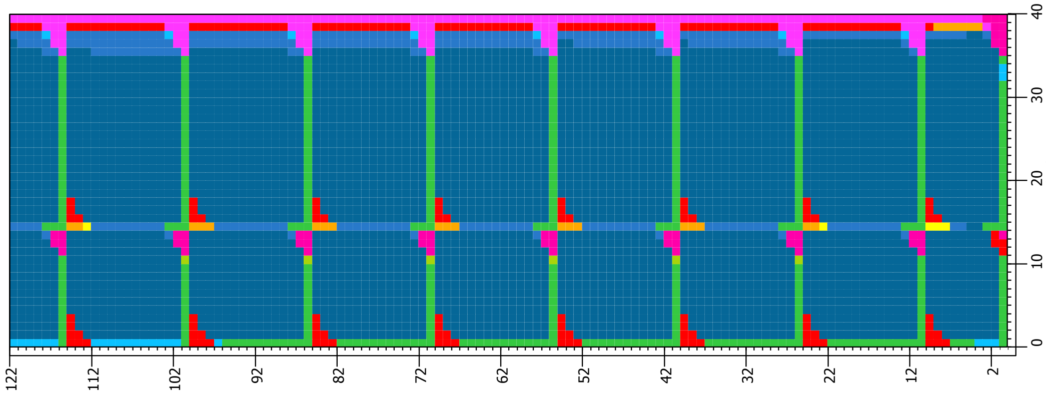


Fig 80: Simulation output _ Simulation type A1 _ NS _ MRT at 1pm

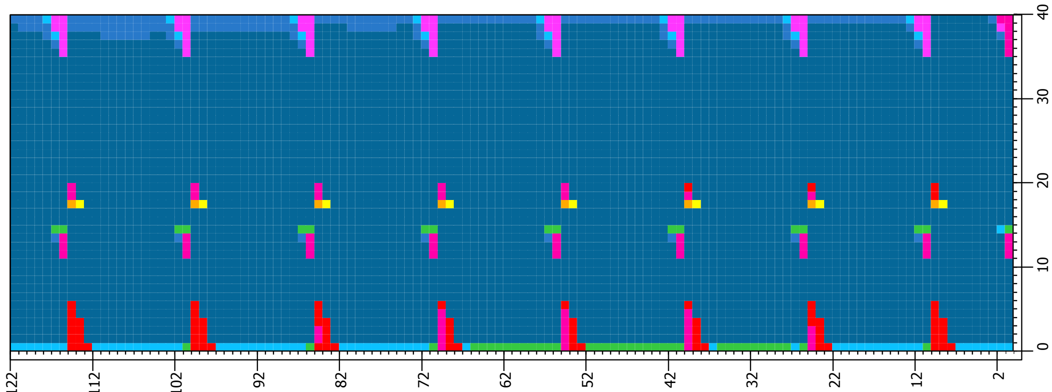


Fig 81: Simulation output _ Simulation type A1 _ NS _ MRT at 1.30pm

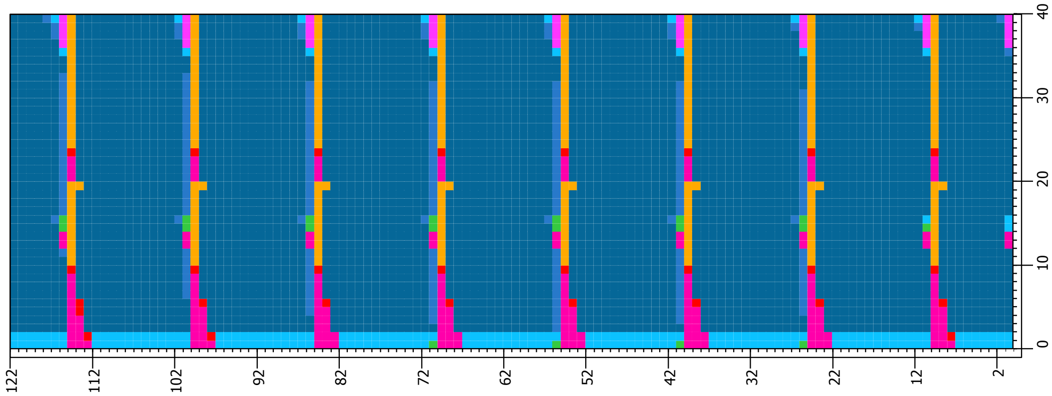
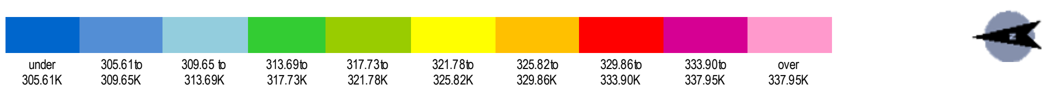


Fig 82: Simulation output _ Simulation type A1 _ NS _ MRT at 2pm



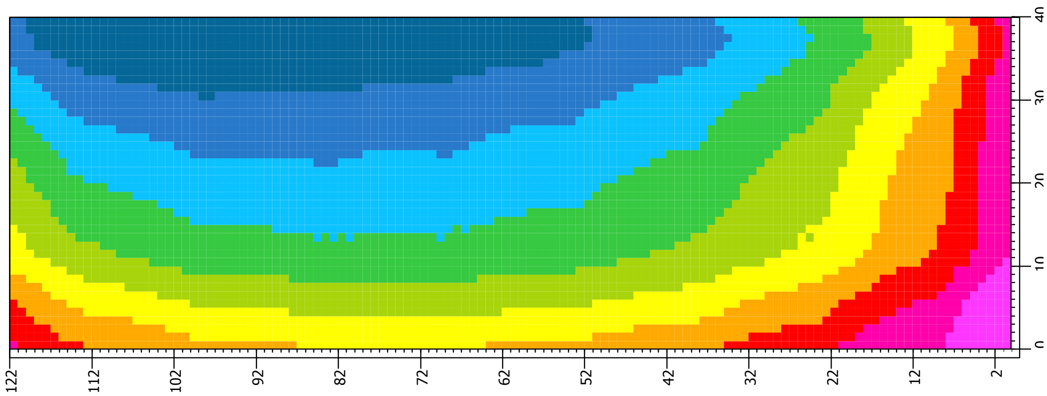


Fig 83: Simulation output _ Simulation type A1 _ NS _ RH at 11am

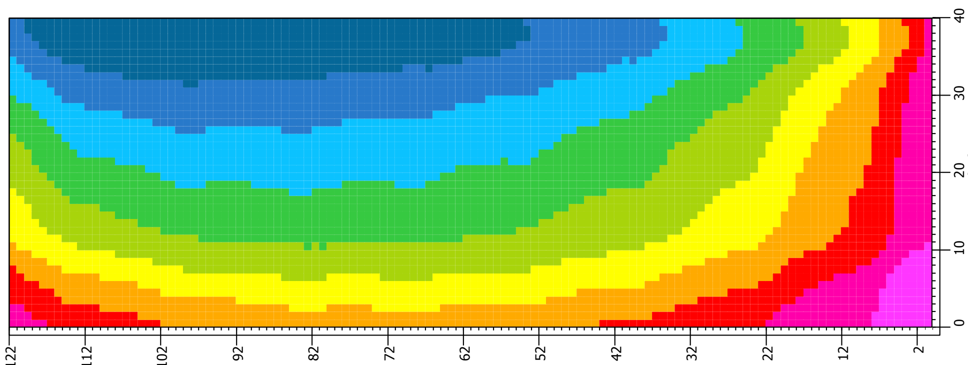


Fig 84: Simulation output _ Simulation type A1 _ NS _ RH at 11.30am

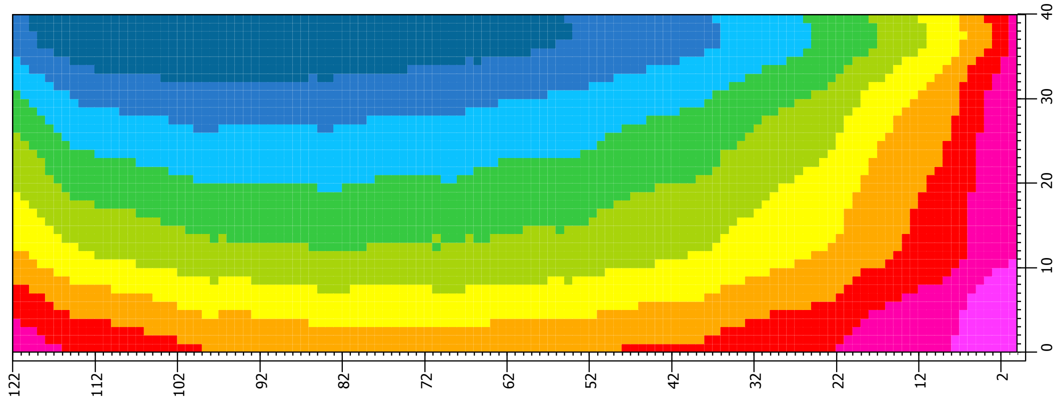


Fig 85: Simulation output _ Simulation type A1 _ NS _ RH at 12pm

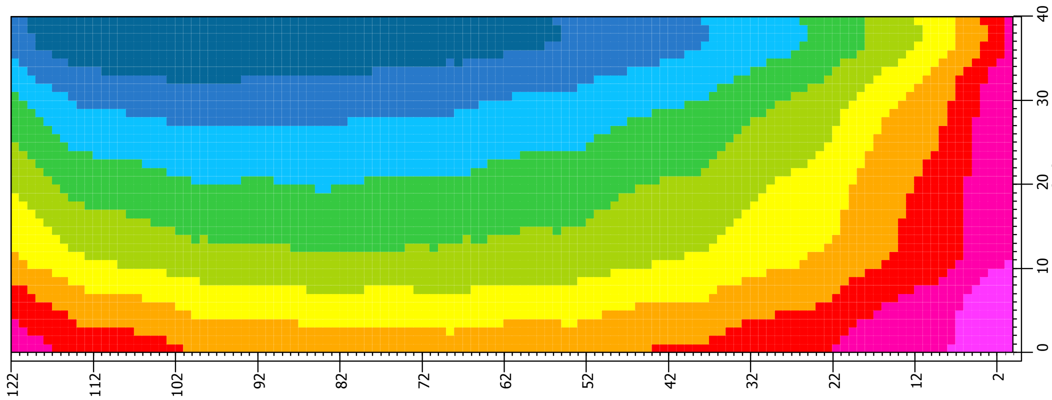


Fig 86: Simulation output _ Simulation type A1 _ NS _ RH at 12.30pm

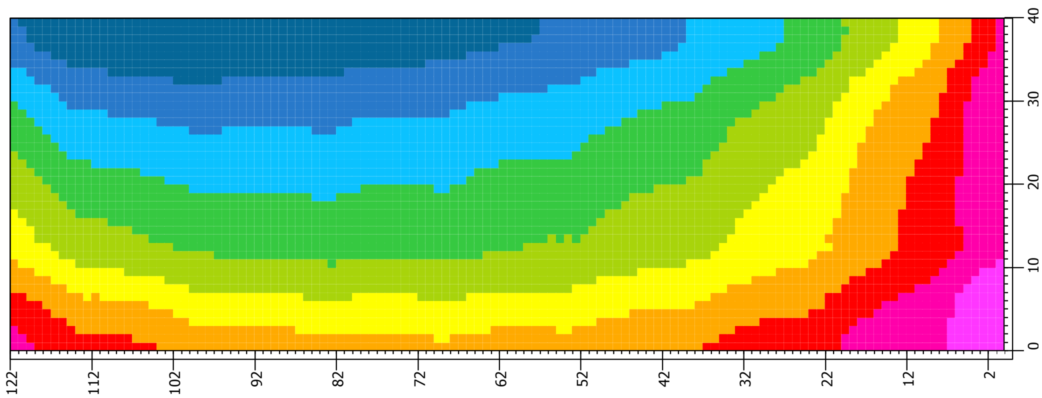


Fig 87: Simulation output _ Simulation type A1 _ NS _ RH at 1pm

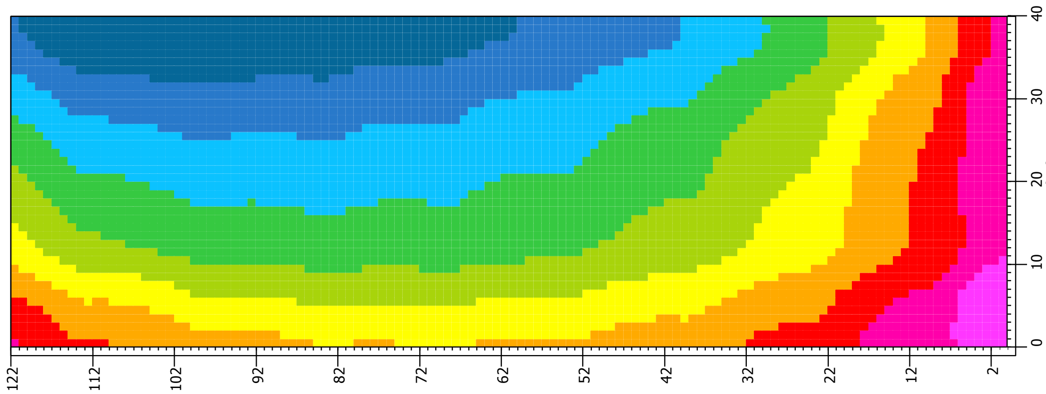


Fig 88: Simulation output _ Simulation type A1 _ NS _ RH at 1.30pm

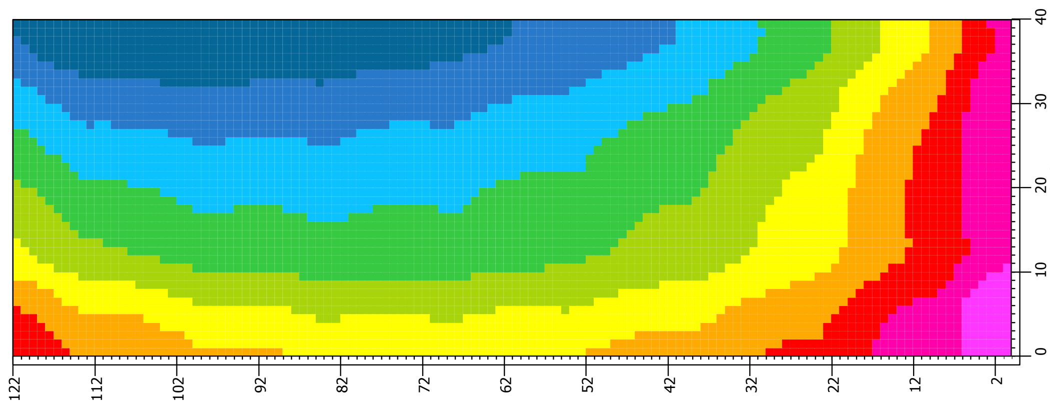
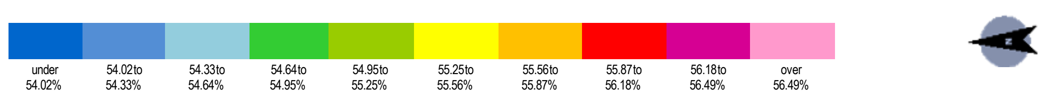


Fig 89: Simulation output _ Simulation type A1 _ NS _ RH at 2pm



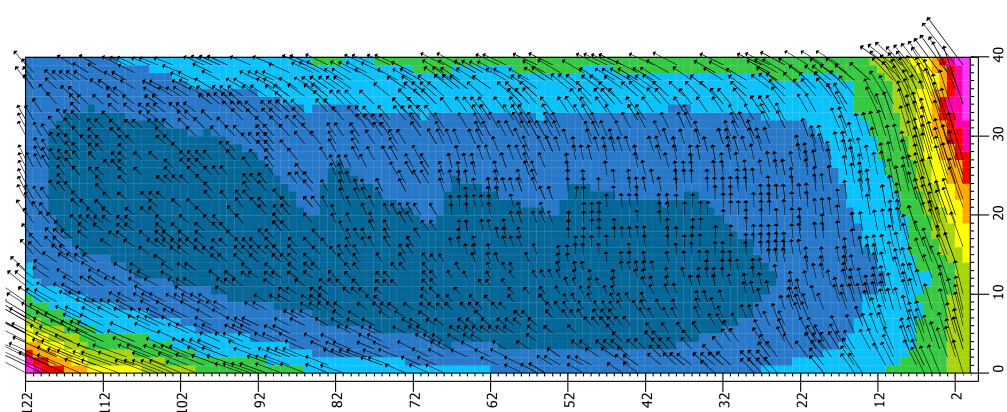


Fig 90: Simulation output _ Simulation type A1 _ NS _ WS at 11am

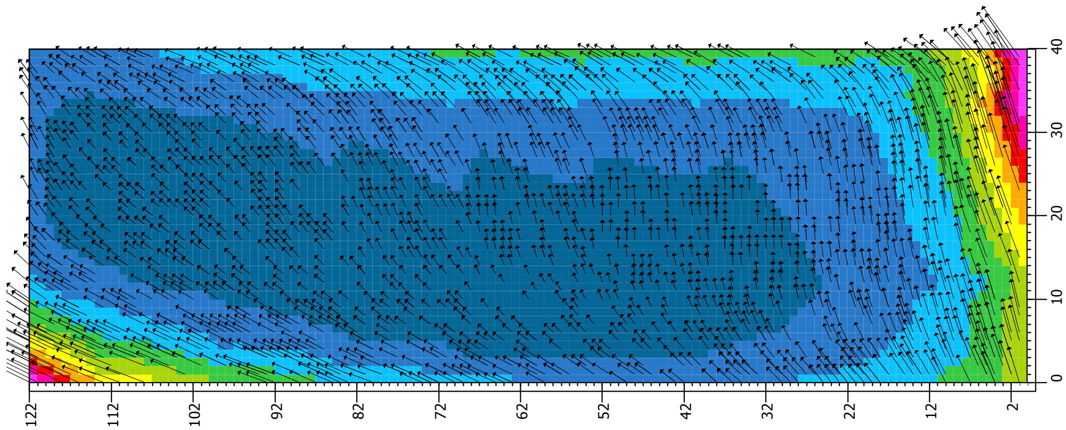


Fig 91: Simulation output _ Simulation type A1 _ NS _ WS at 11.30am

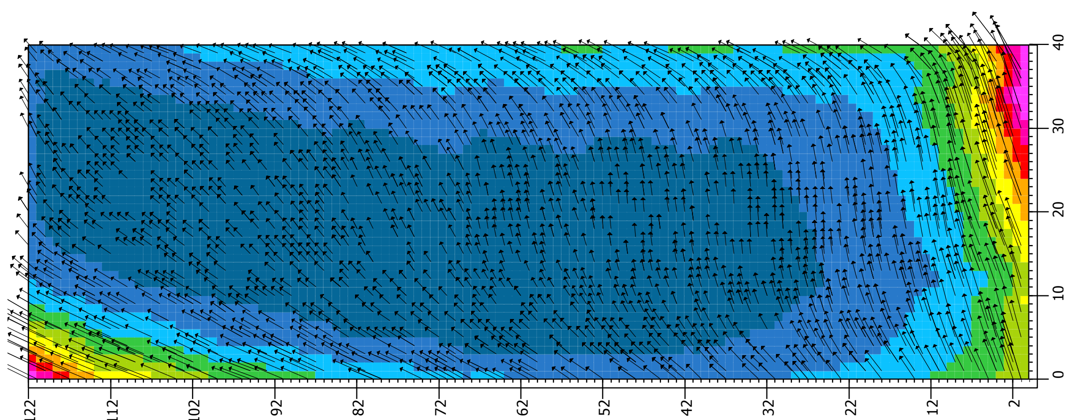


Fig 92: Simulation output _ Simulation type A1 _ NS _ WS at 12pm

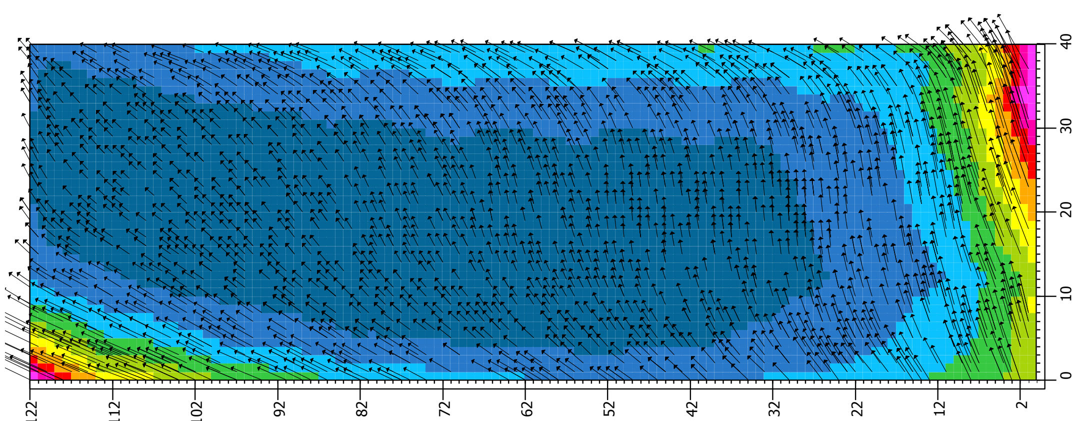


Fig 93: Simulation output _ Simulation type A1 _ NS _ WS at 12.30pm

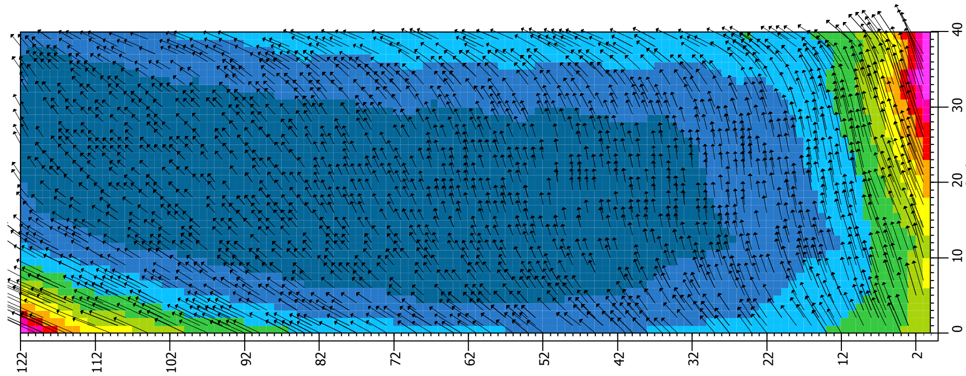


Fig 94: Simulation output _ Simulation type A1 _ NS _ WS at 1pm

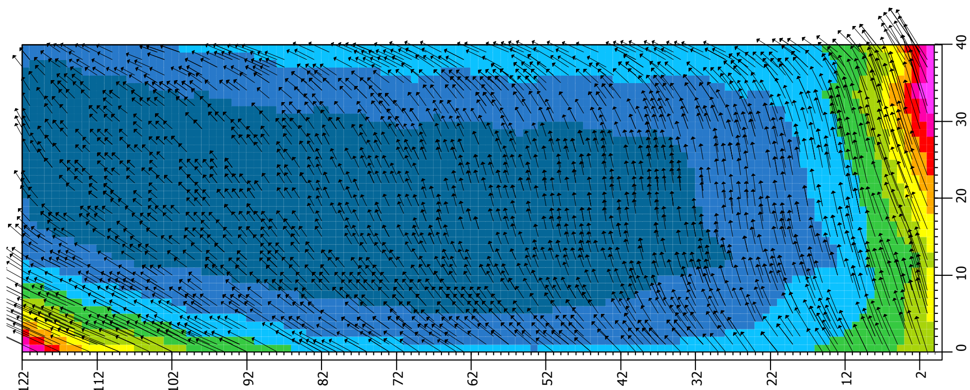


Fig 95: Simulation output _ Simulation type A1 _ NS _ WS at 1.30pm

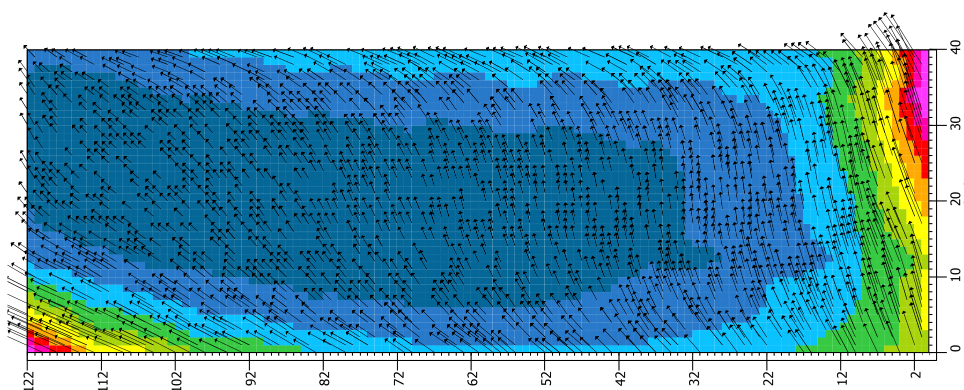
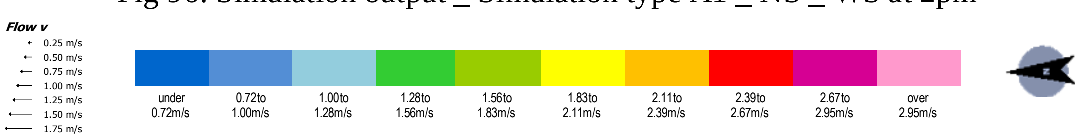


Fig 96: Simulation output _ Simulation type A1 _ NS _ WS at 2pm



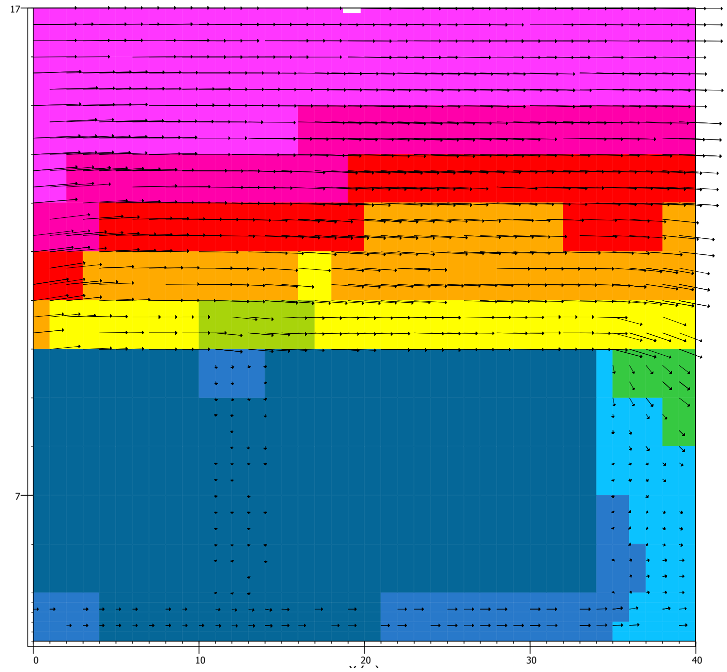


Fig 97: Simulation output _ Simulation type A1 _ NS _ WS _section _ at 11am

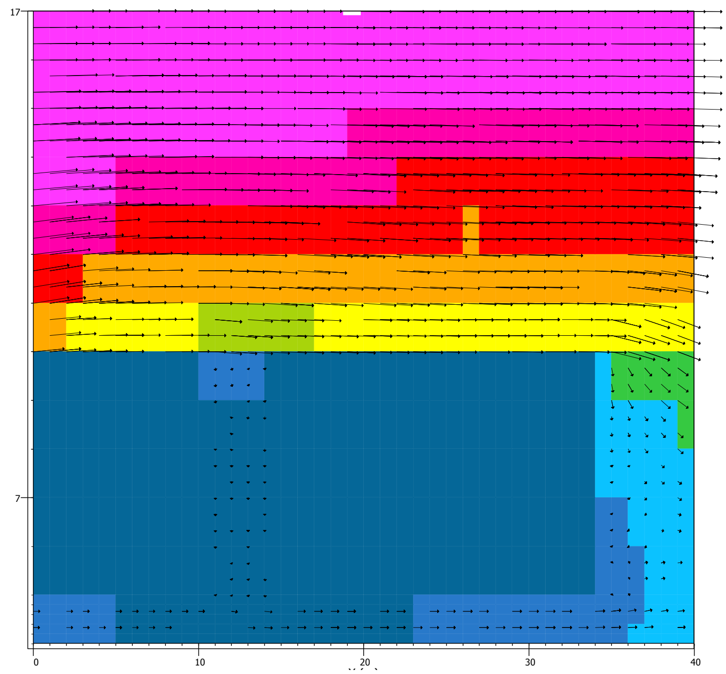


Fig 98: Simulation output _ Simulation type A1 _ NS _ WS _section _ at 12pm

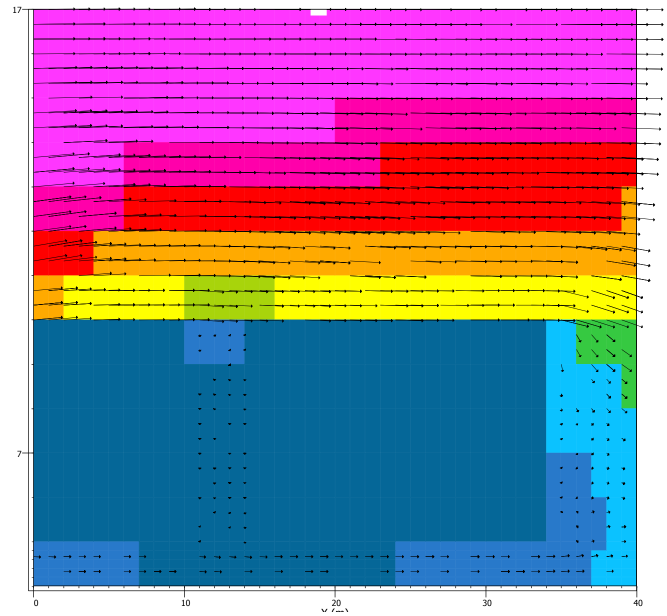


Fig 99: Simulation output _ Simulation type A1 _ NS _ WS _section _ at 1pm

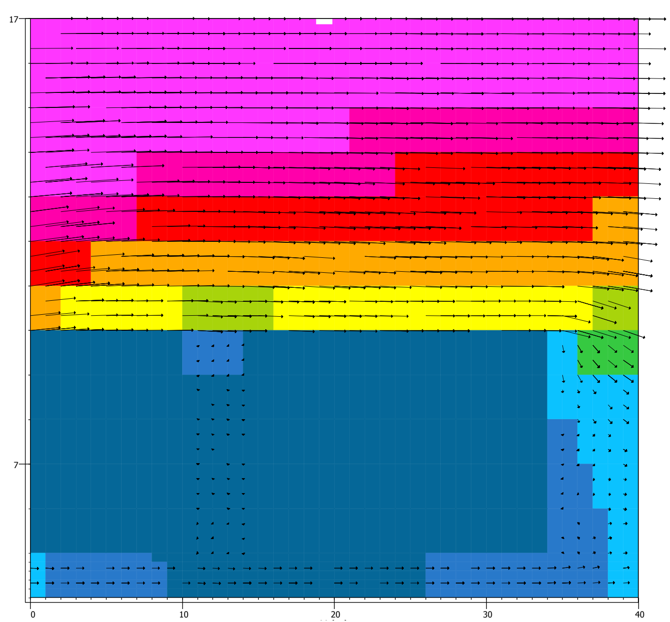
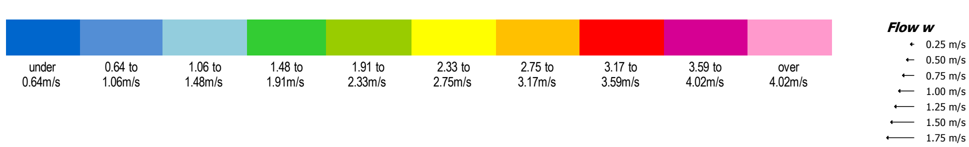


Fig 100: Simulation output _ Simulation type A1 _ NS _ WS _section _ at 2pm



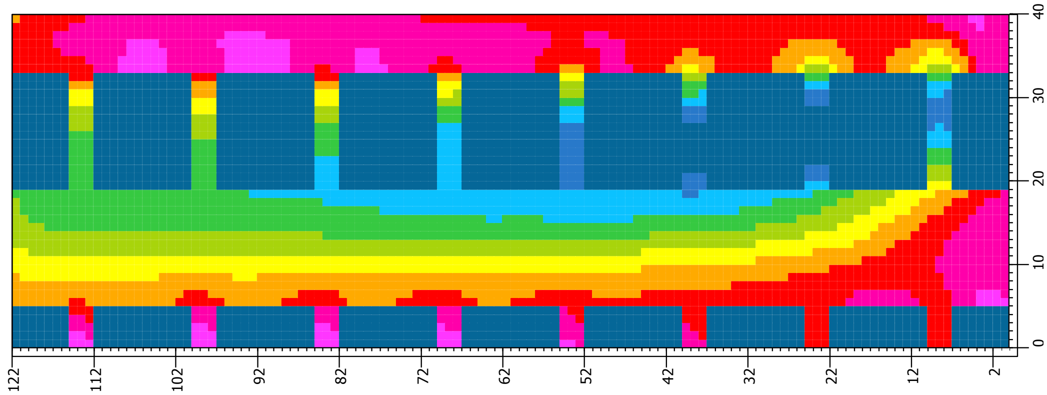


Fig 101: Simulation output _ Simulation type B _ NS _ DBT _ at 11am

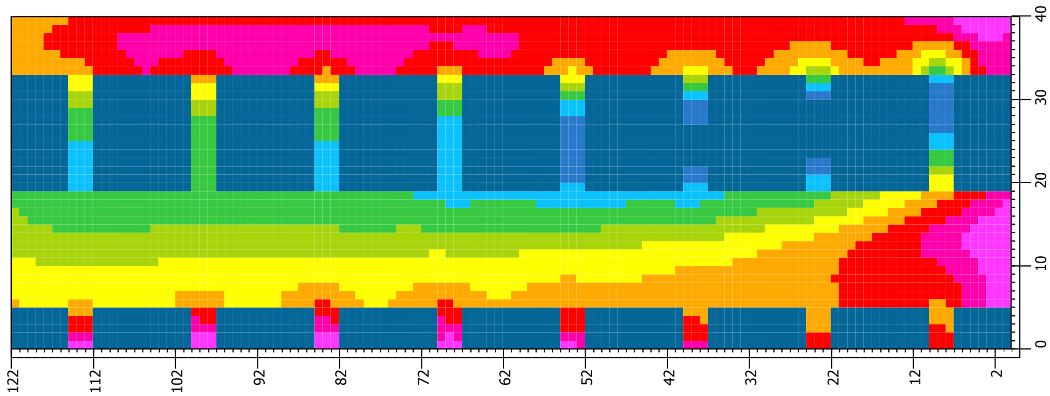


Fig 102: Simulation output _ Simulation type B _ NS _ DBT _ at 11.30am

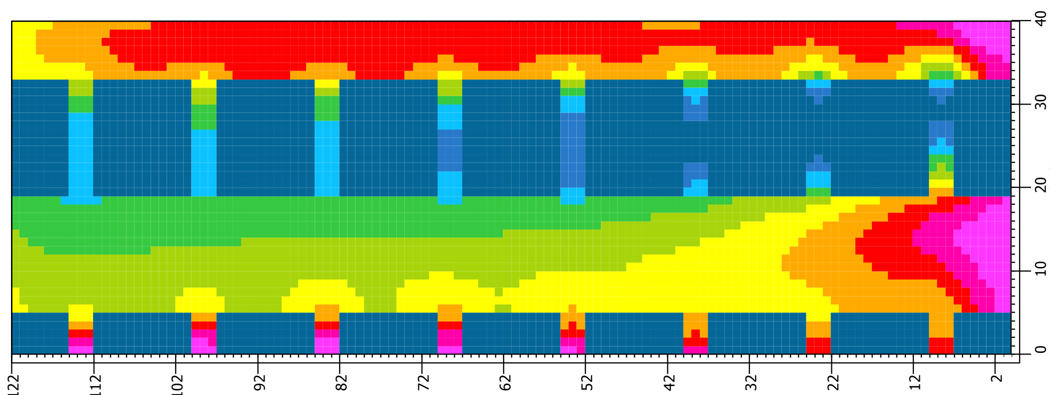


Fig 103: Simulation output _ Simulation type B _ NS _ DBT _ at 12pm

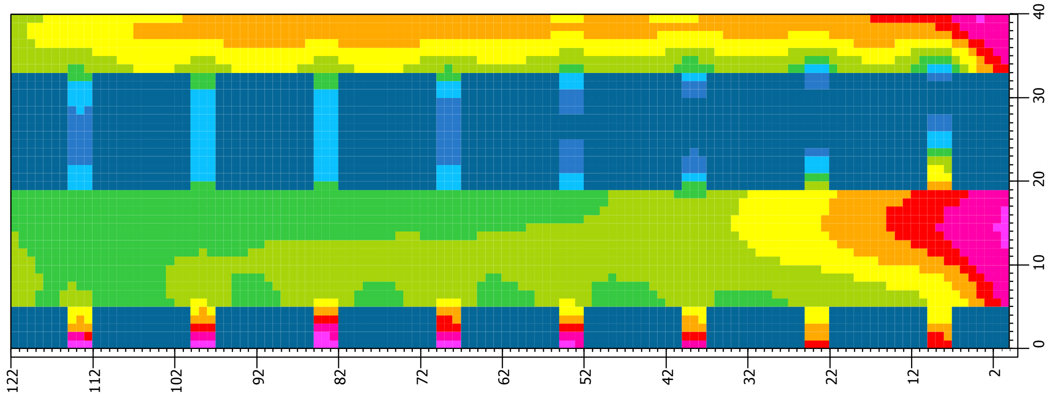


Fig 104: Simulation output _ Simulation type B _ NS _ DBT _ at 12.30pm

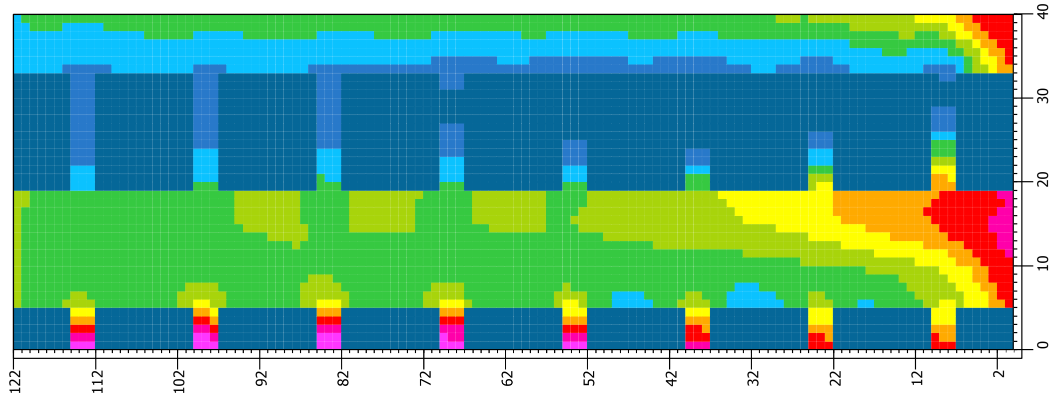


Fig 105: Simulation output _ Simulation type B _ NS _ DBT _ at 1pm

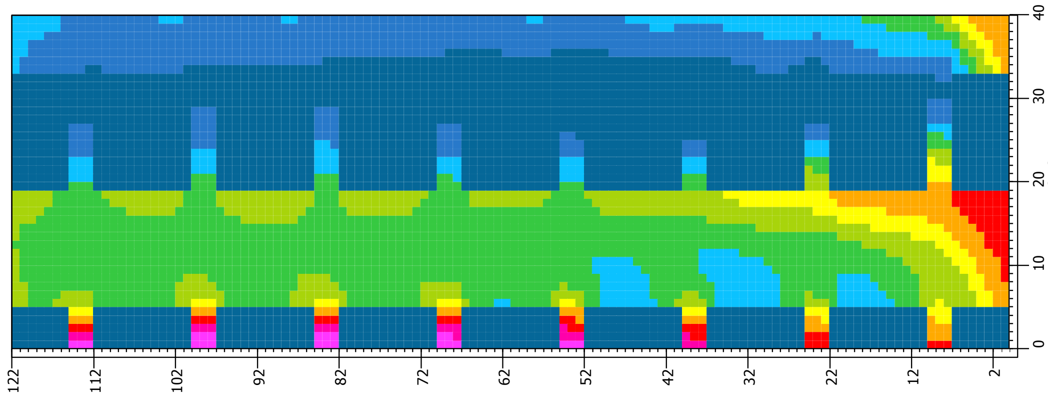


Fig 106: Simulation output _ Simulation type B _ NS _ DBT _ at 1.30pm

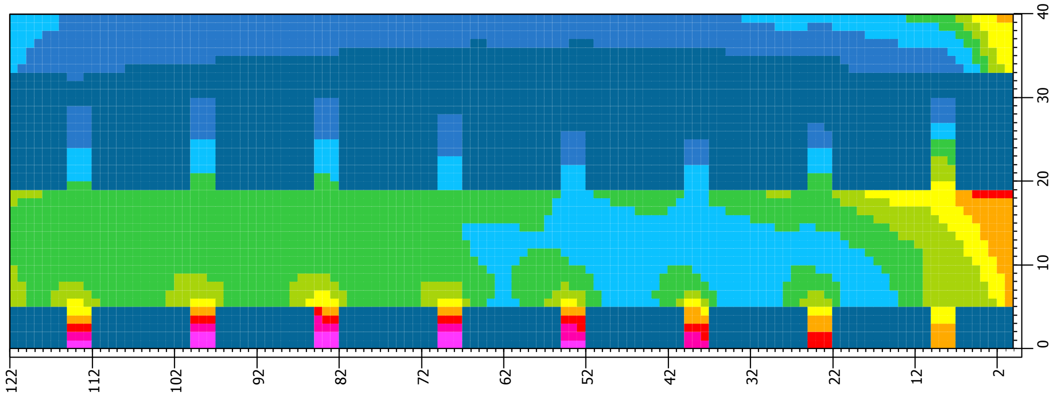
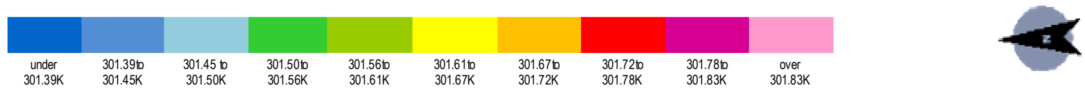


Fig 107: Simulation output _ Simulation type B _ NS _ DBT _ at 2pm



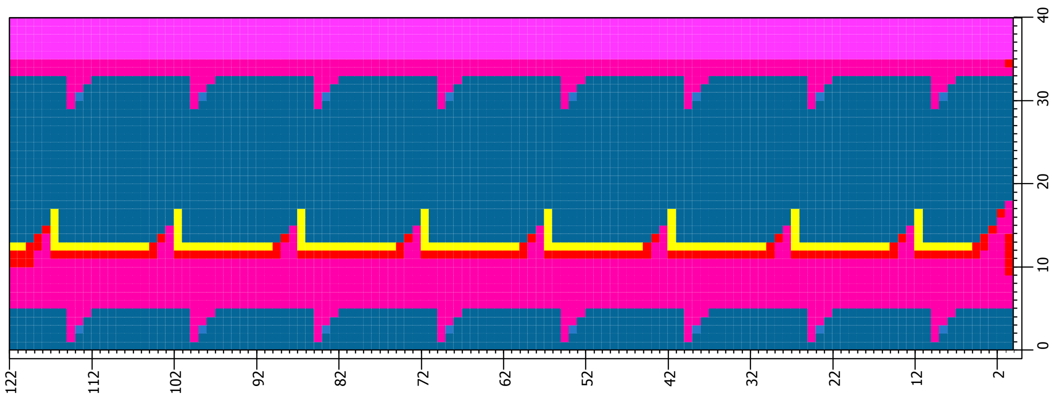


Fig 108: Simulation output _ Simulation type B _ NS _ MRT _ at 11am

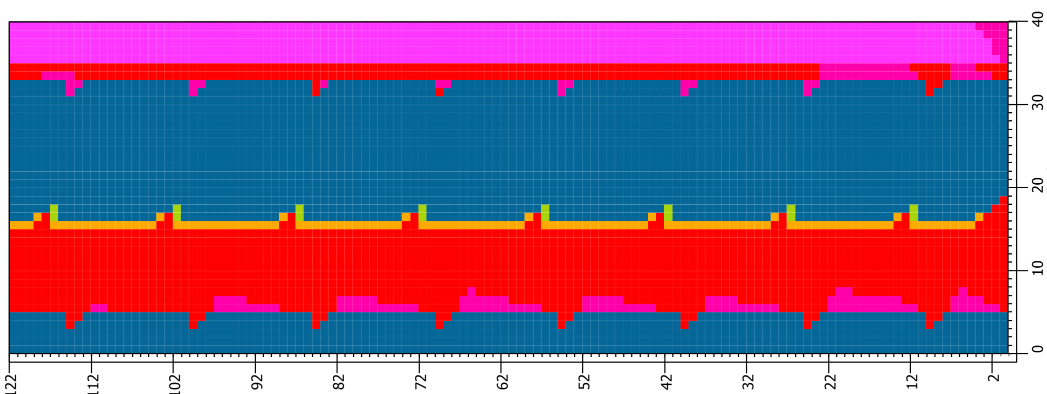


Fig 109: Simulation output _ Simulation type B _ NS _ MRT _ at 11.30am

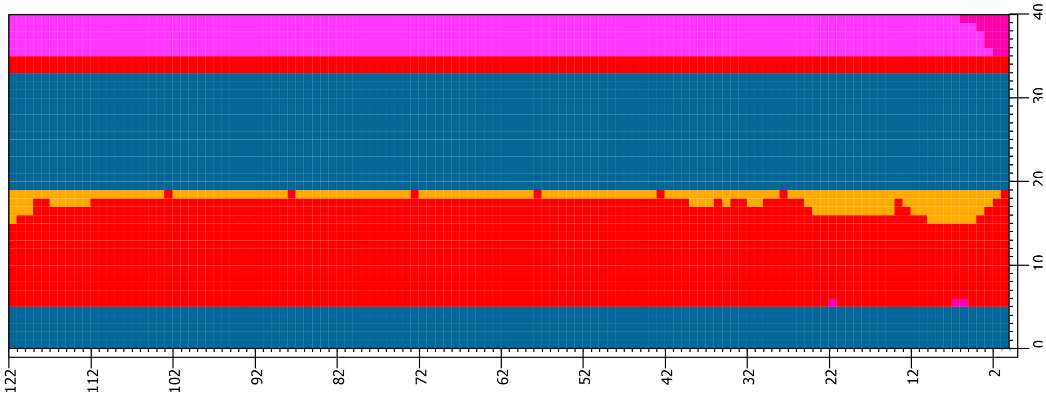


Fig 110: Simulation output _ Simulation type B _ NS _ MRT _ at 12pm

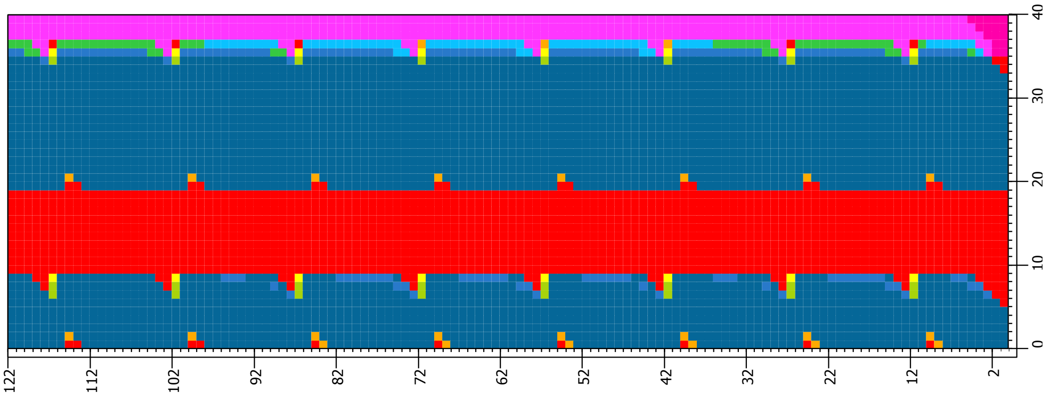


Fig 111: Simulation output _ Simulation type B _ NS _ MRT _ at 12.30pm

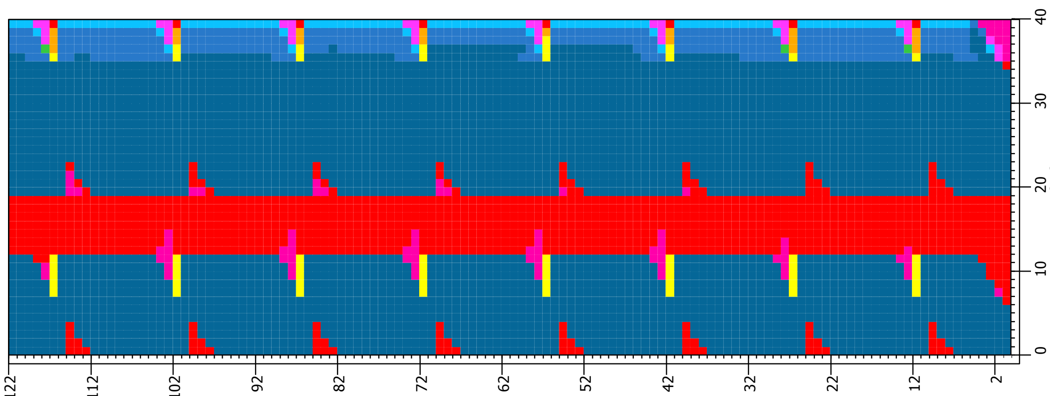


Fig 112: Simulation output _ Simulation type B _ NS _ MRT _ at 1pm

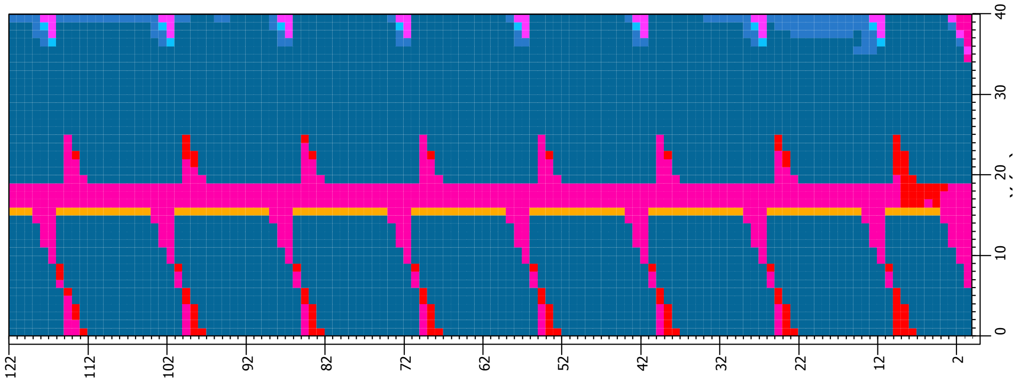


Fig 113: Simulation output _ Simulation type B _ NS _ MRT _ at 1.30pm

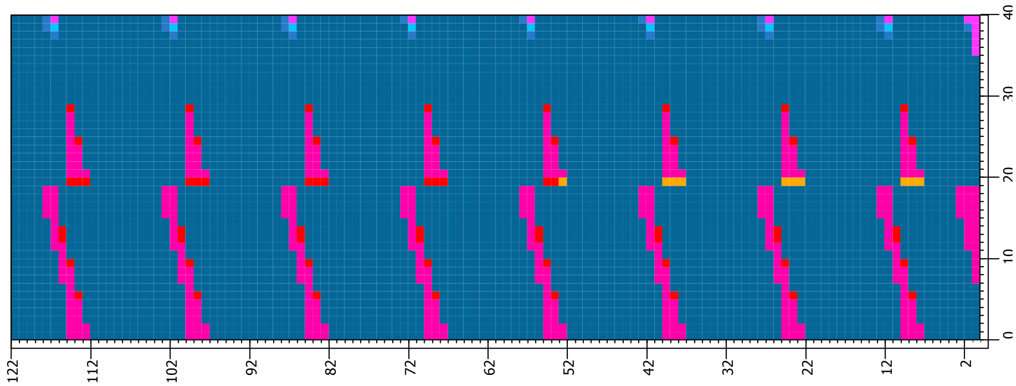
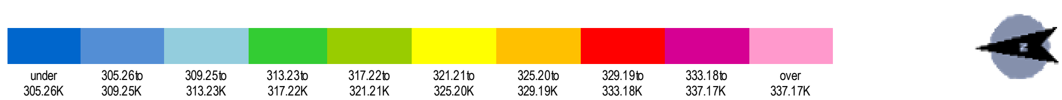


Fig 114: Simulation output _ Simulation type B _ NS _ MRT _ at 2pm



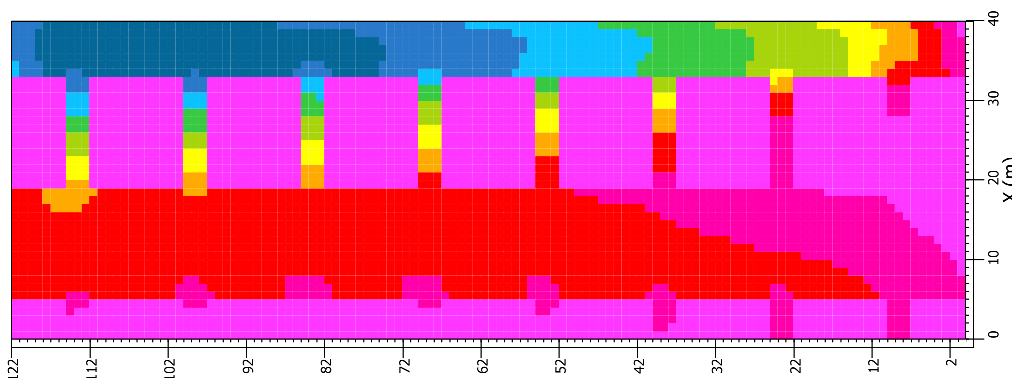


Fig 115: Simulation output _ Simulation type B _ NS _ RH _ at 11am

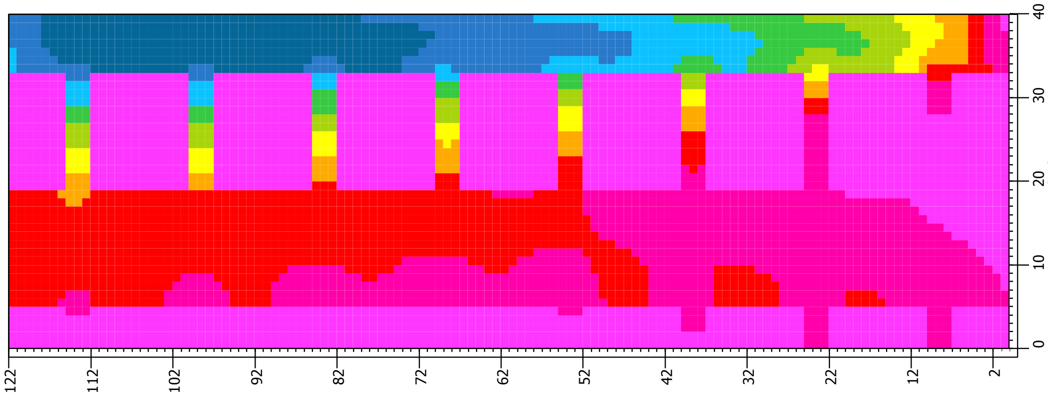


Fig 116: Simulation output _ Simulation type B _ NS _ RH _ at 11.30am

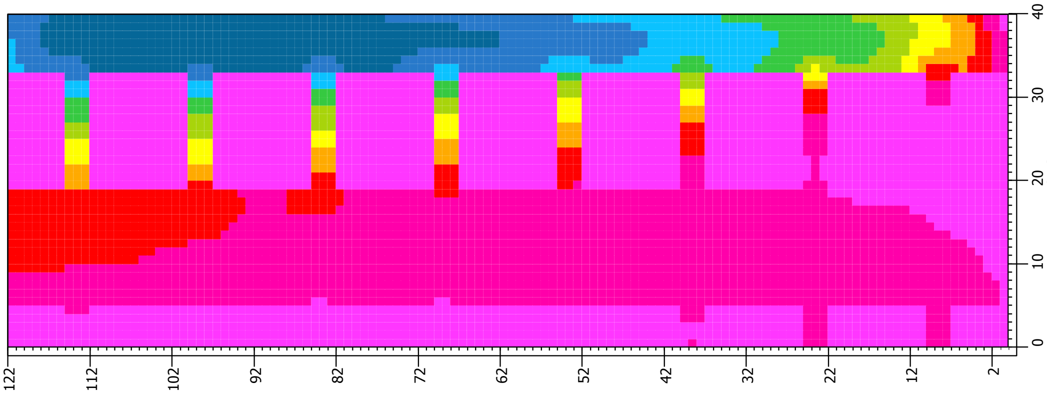


Fig 117: Simulation output _ Simulation type B _ NS _ RH _ at 12pm

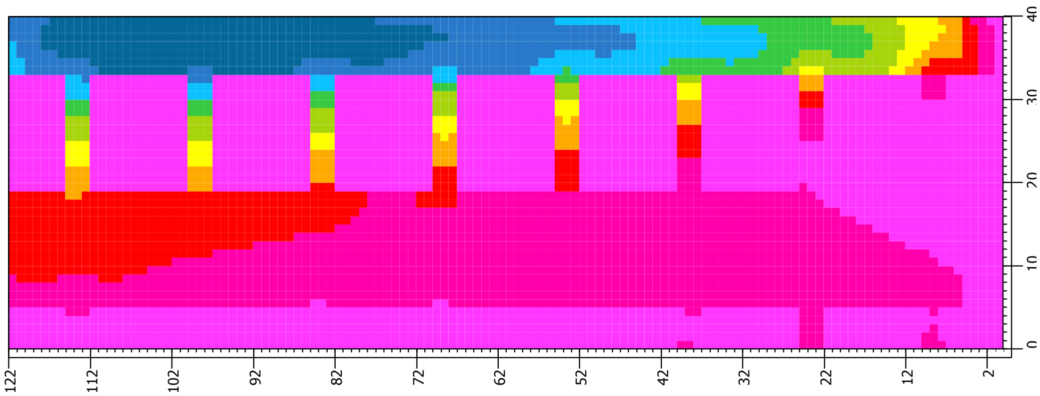


Fig 118: Simulation output _ Simulation type B _ NS _ RH _ at 12.30pm

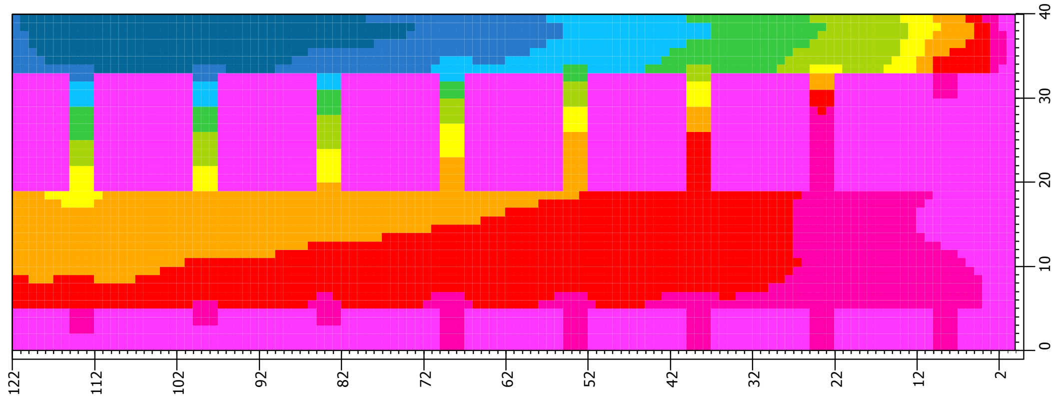


Fig 119: Simulation output _ Simulation type B _ NS _ RH _ at 1pm

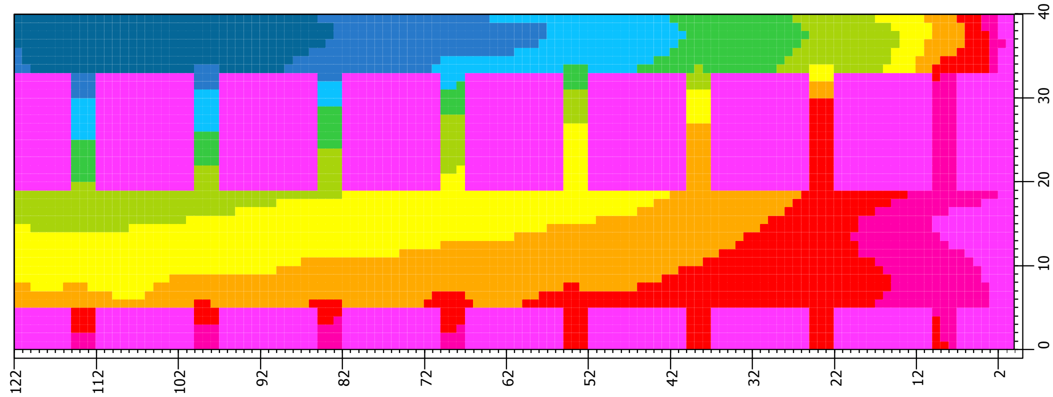


Fig 120: Simulation output _ Simulation type B _ NS _ RH _ at 1.30pm

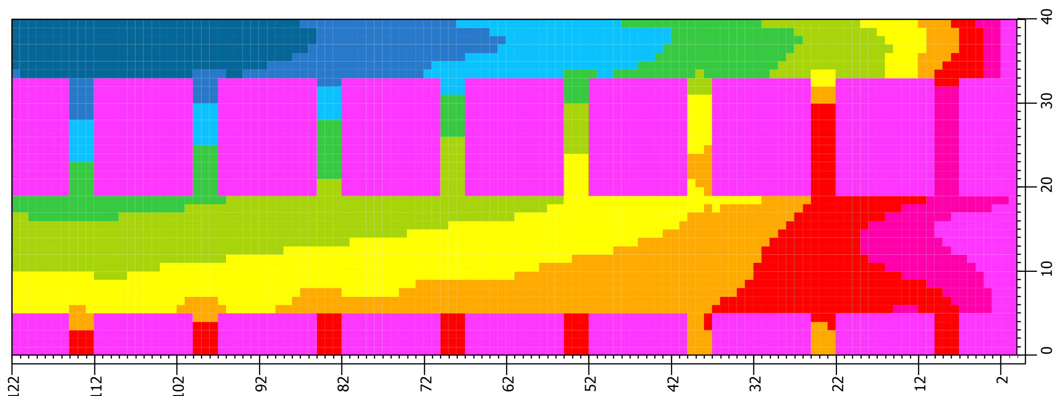
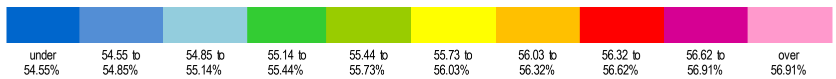


Fig 121: Simulation output _ Simulation type B _ NS _ RH _ at 2pm



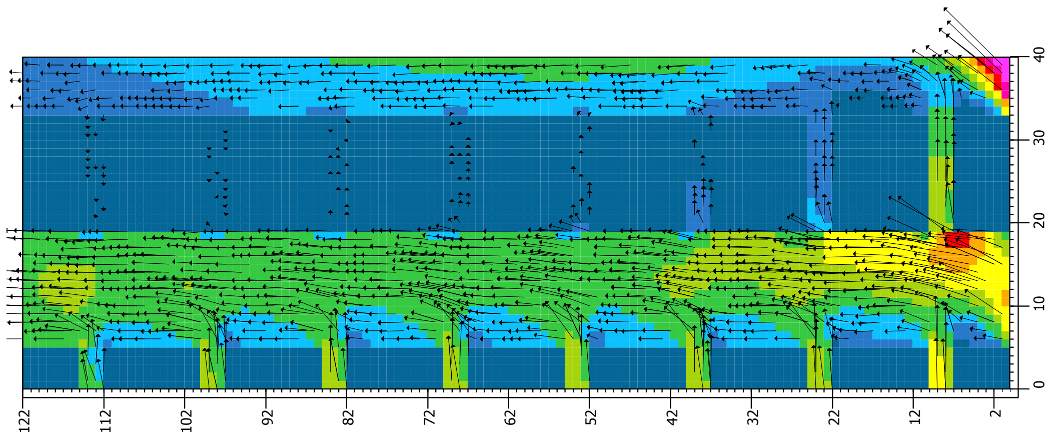


Fig 122: Simulation output _ Simulation type B _ NS _ WS _ at 11am

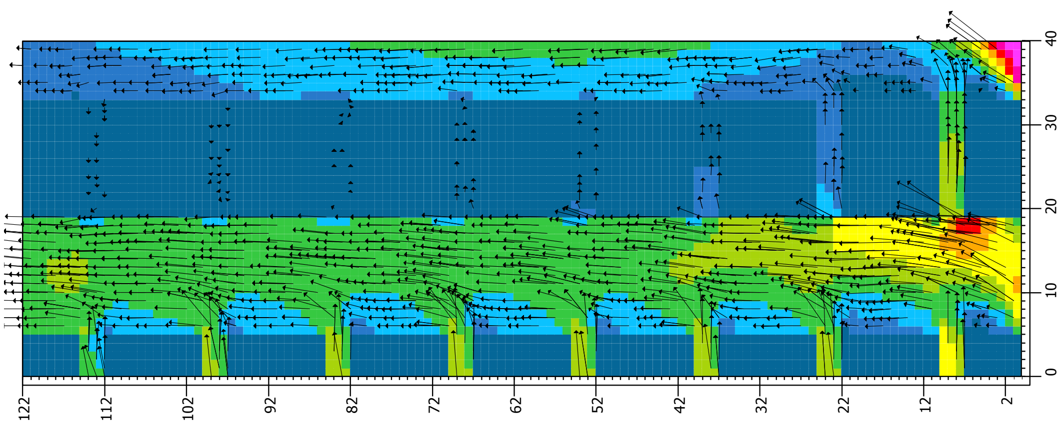


Fig 123: Simulation output _ Simulation type B _ NS _ WS _ at 11.30am

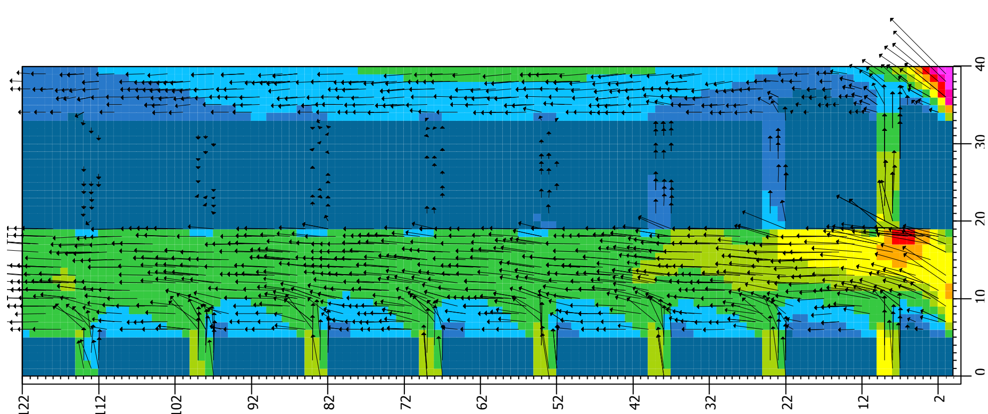


Fig 124: Simulation output _ Simulation type B _ NS _ WS _ at 12pm

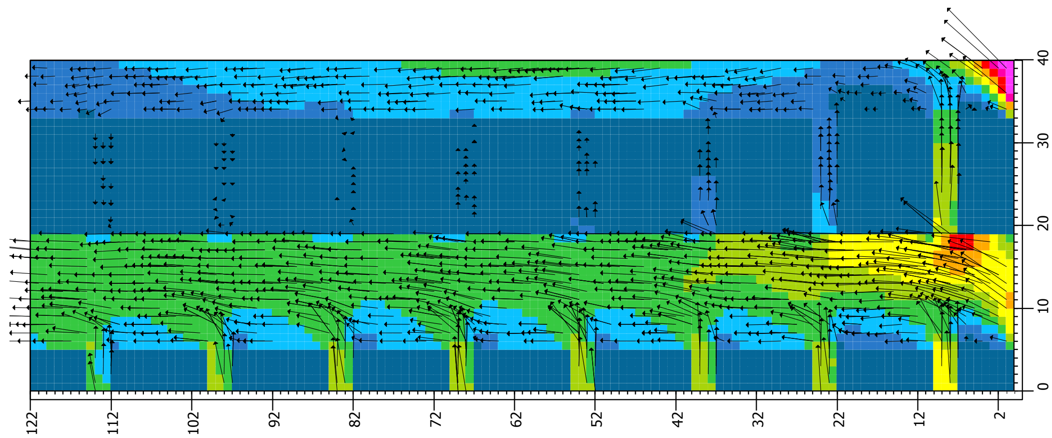


Fig 125: Simulation output _ Simulation type B _ NS _ WS _ at 12.30pm

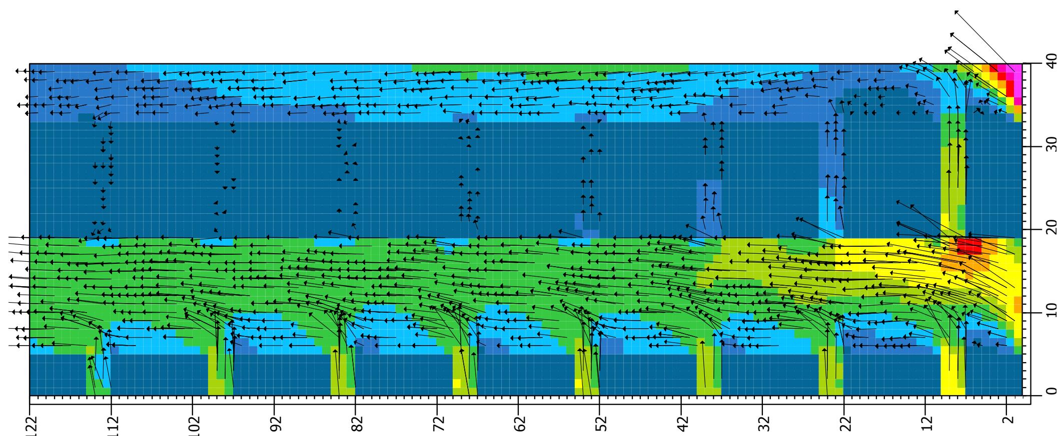


Fig 126: Simulation output _ Simulation type B _ NS _ WS _ at 1pm

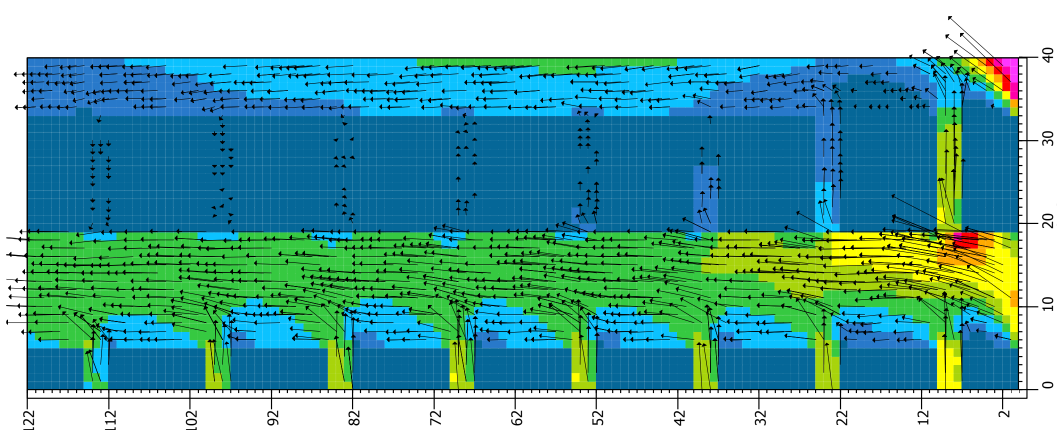


Fig 127: Simulation output _ Simulation type B _ NS _ WS _ at 1.30pm

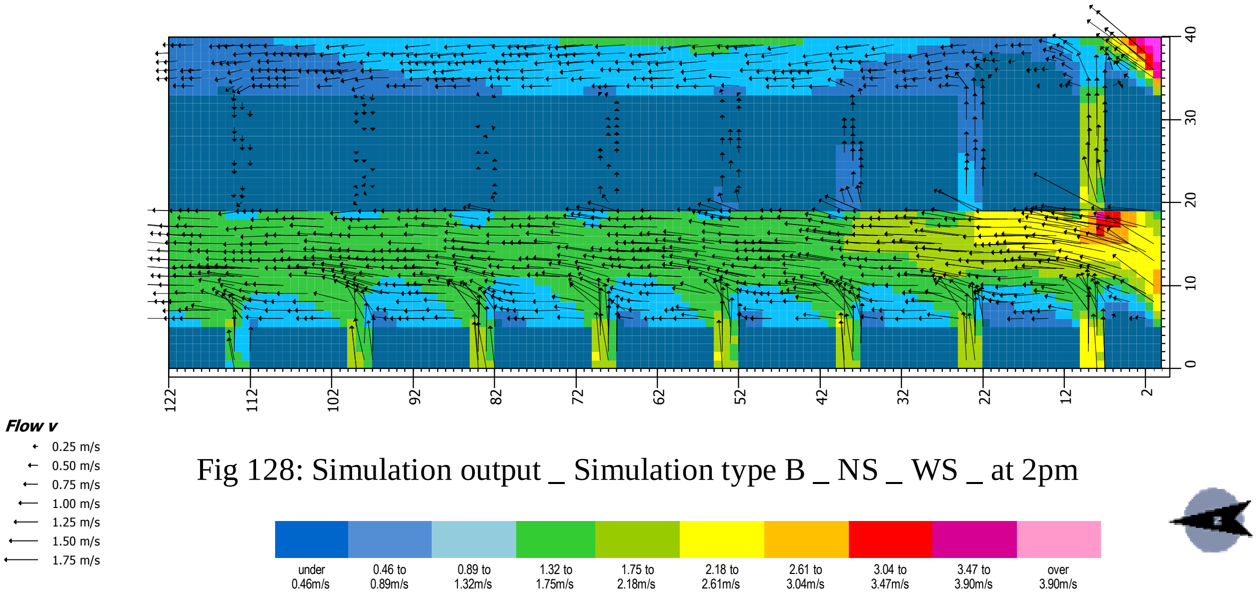


Fig 128: Simulation output _ Simulation type B _ NS _ WS _ at 2pm

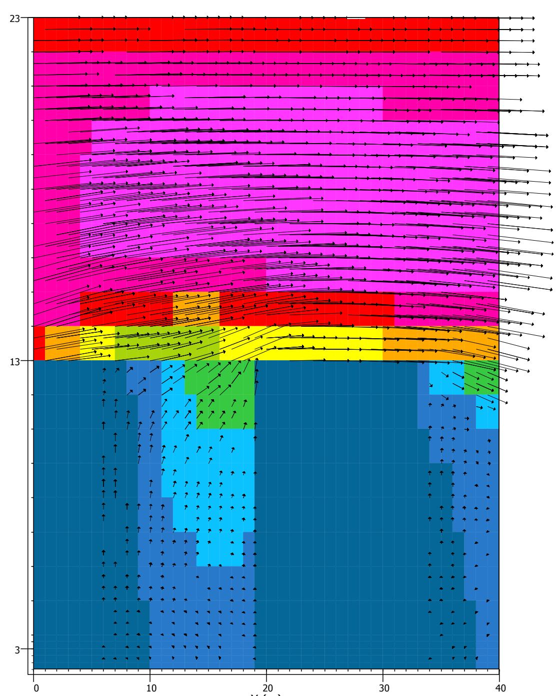


Fig 129: Simulation output _ Simulation type B _ NS _ WS _ section _ at 11am

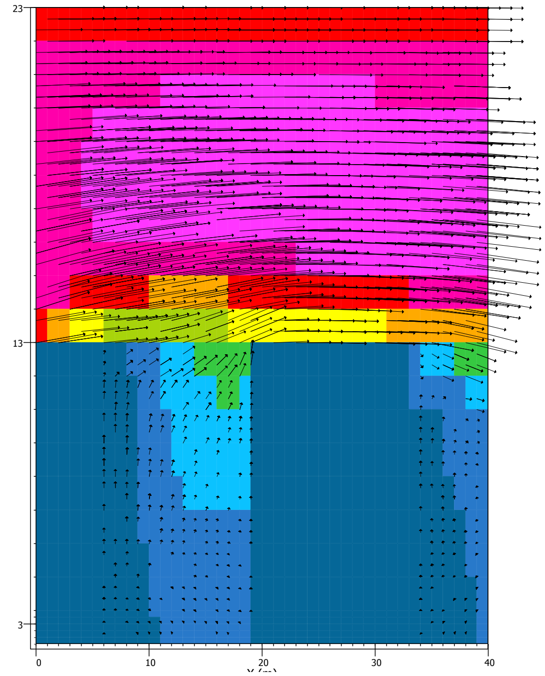


Fig 130: Simulation output _ Simulation type B _ NS _ WS _ section _ at 12pm

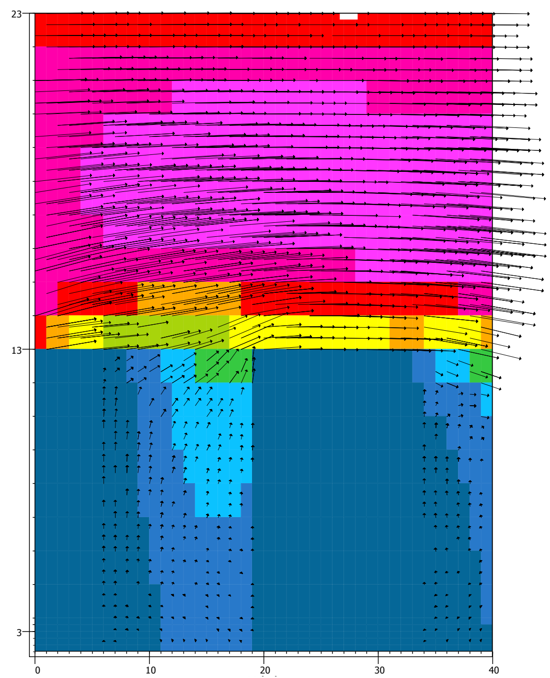


Fig 131: Simulation output _ Simulation type B _ NS _ WS _ section _ at 1pm

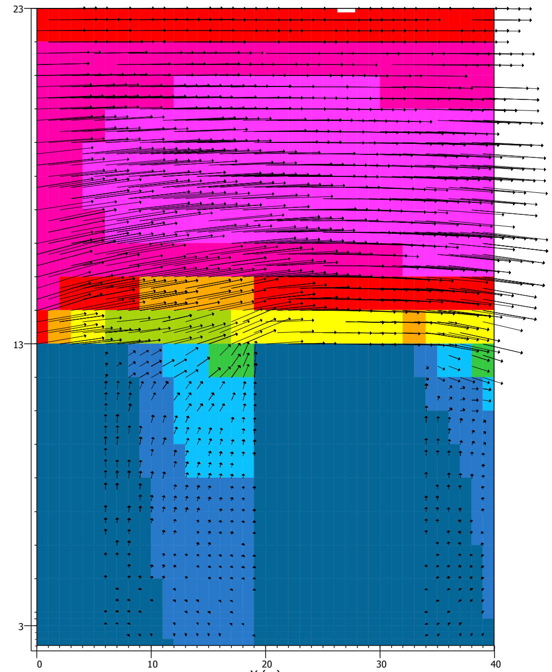
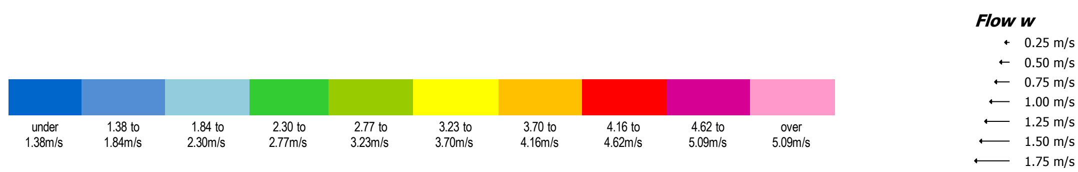


Fig 132: Simulation output _ Simulation type B _ NS _ WS _ section _ at 2pm



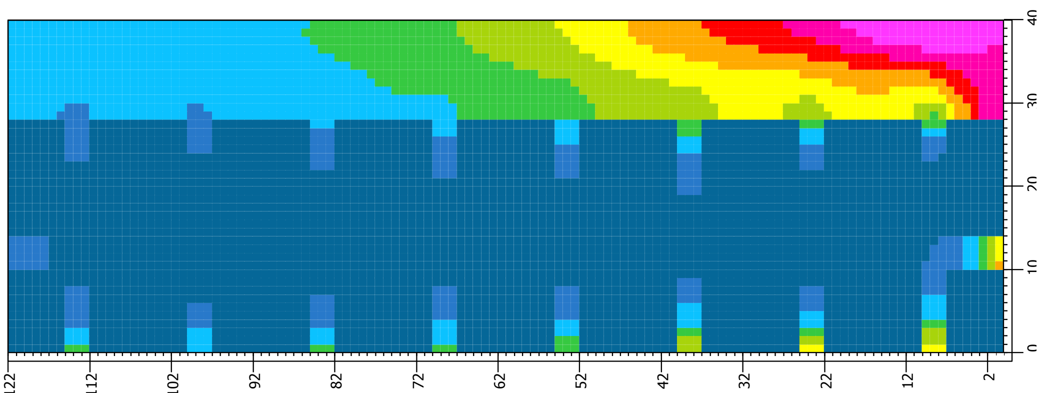


Fig 133: Simulation output _ Simulation type B1 _ NS _ DBT _ at 11am

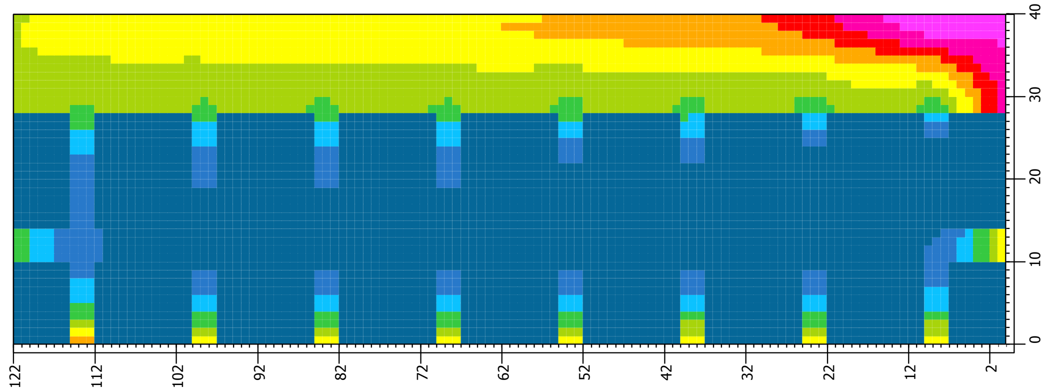


Fig 134: Simulation output _ Simulation type B1 _ NS _ DBT _ at 11.30am

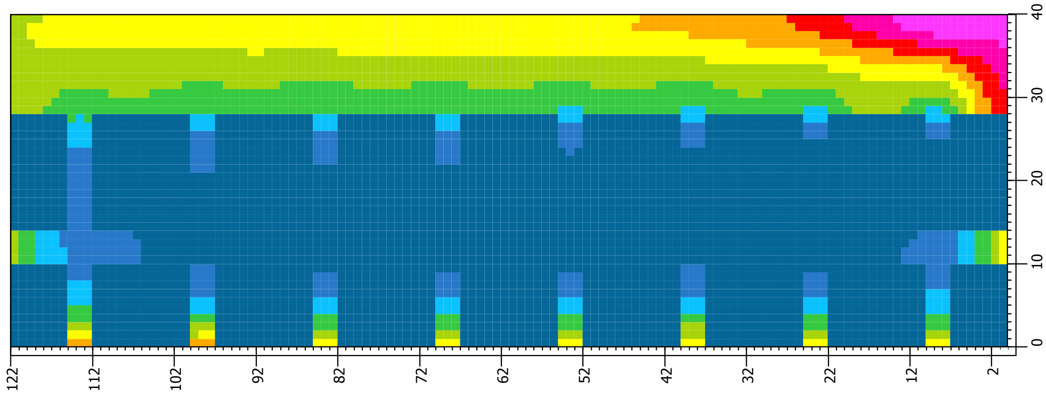


Fig 135: Simulation output _ Simulation type B1 _ NS _ DBT _ at 12pm

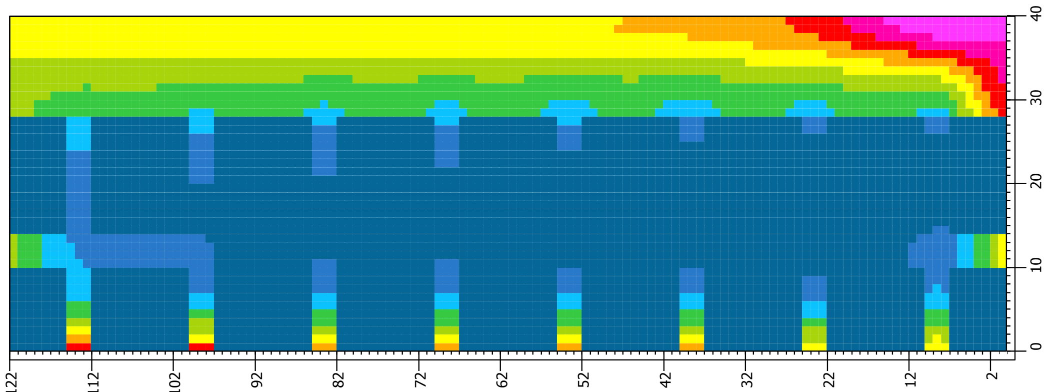


Fig 136: Simulation output _ Simulation type B1 _ NS _ DBT _ at 12.30pm

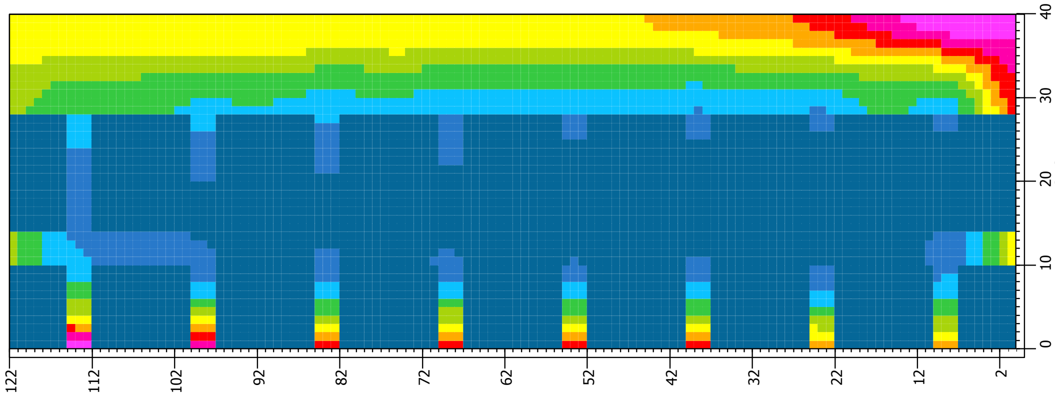


Fig 137: Simulation output _ Simulation type B1 _ NS _ DBT _ at 1pm

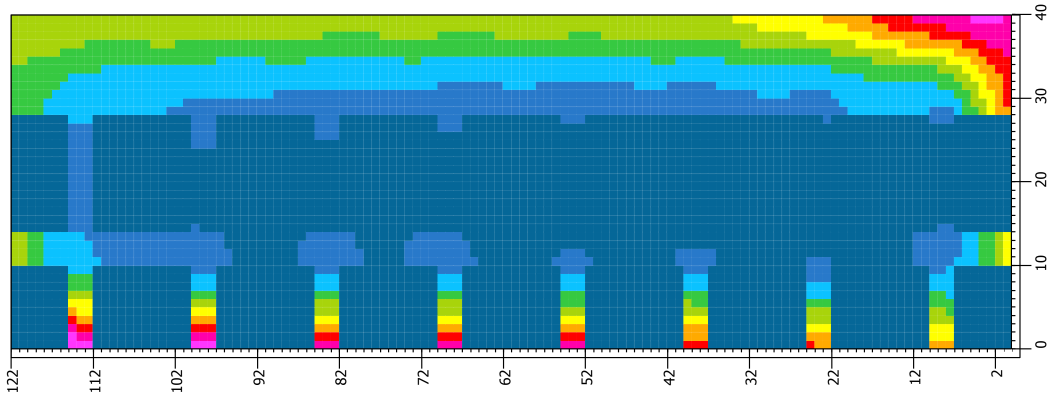


Fig 138: Simulation output _ Simulation type B1 _ NS _ DBT _ at 1.30pm

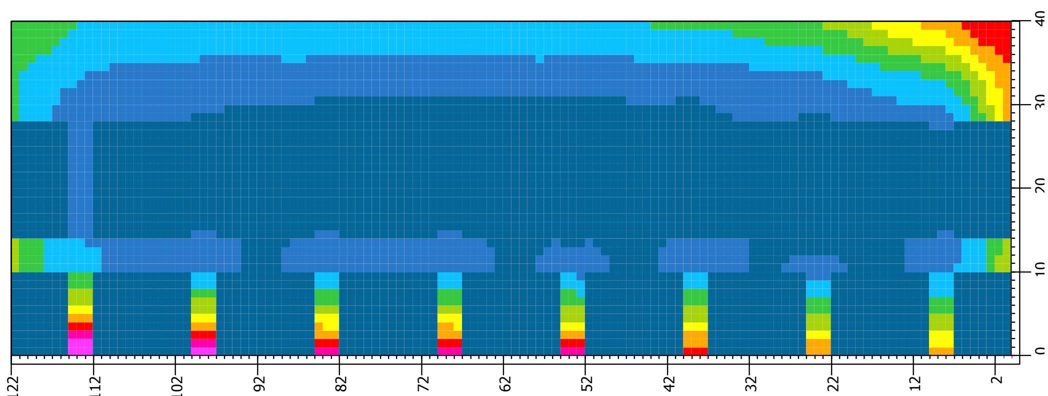
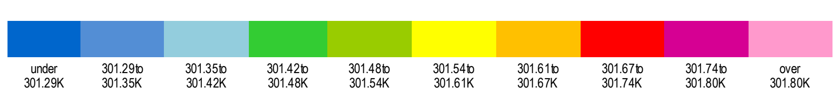


Fig 139: Simulation output _ Simulation type B1 _ NS _ DBT _ at 2pm



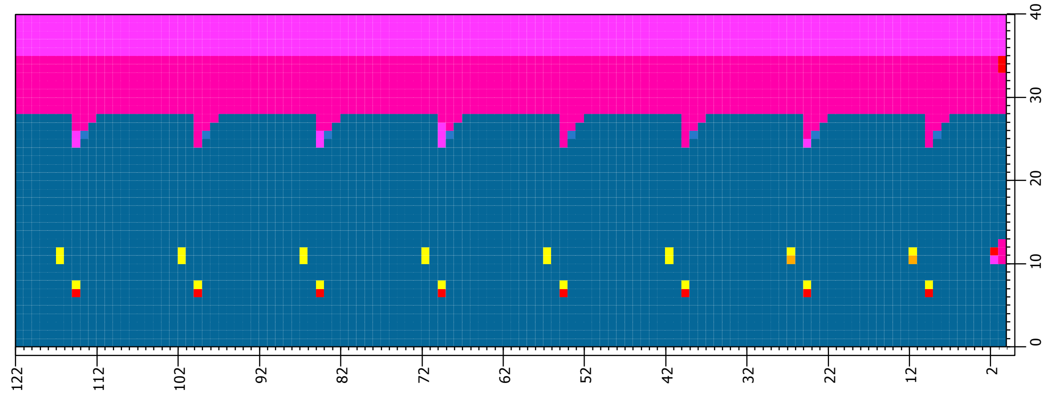


Fig 140: Simulation output _ Simulation type B1 _ NS _ MRT _ at 11am

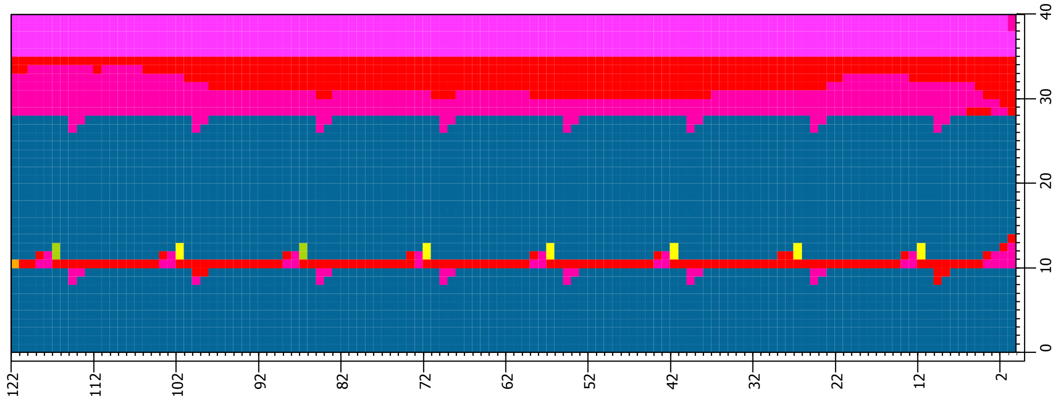


Fig 141: Simulation output _ Simulation type B1 _ NS _ MRT _ at 11.30am

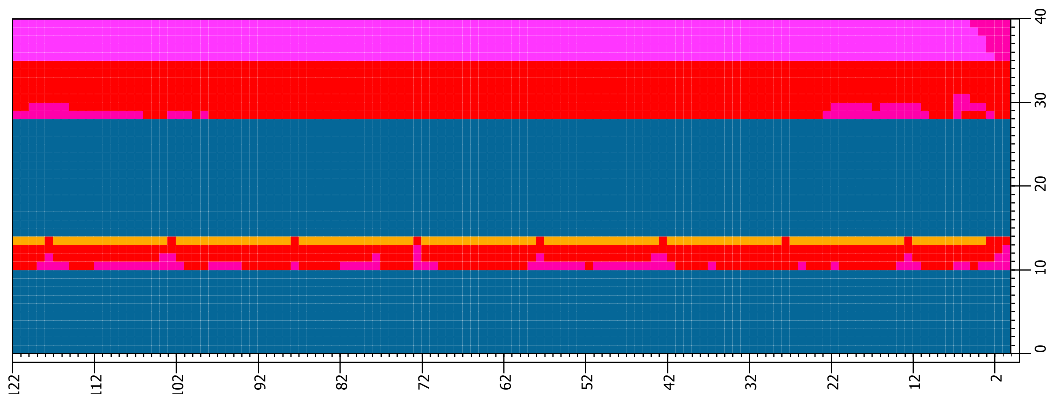


Fig 142: Simulation output _ Simulation type B1 _ NS _ MRT _ at 12pm

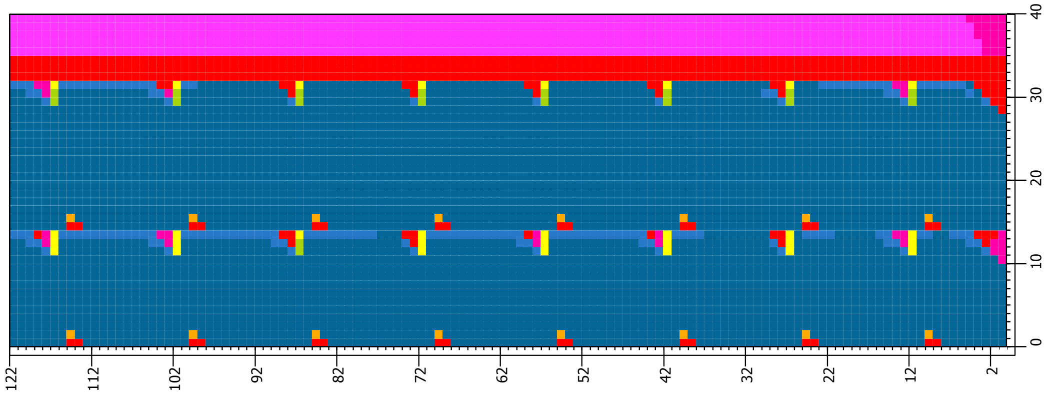


Fig 143: Simulation output _ Simulation type B1 _ NS _ MRT _ at 12.30pm

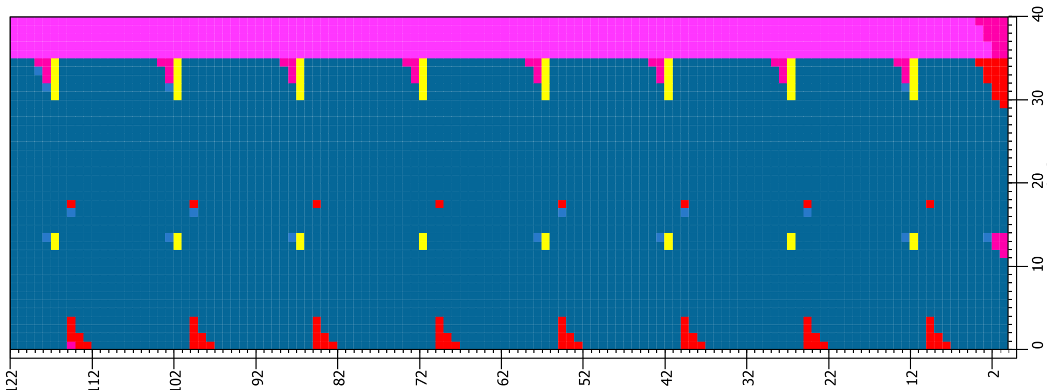


Fig 144: Simulation output _ Simulation type B1 _ NS _ MRT _ at 1pm

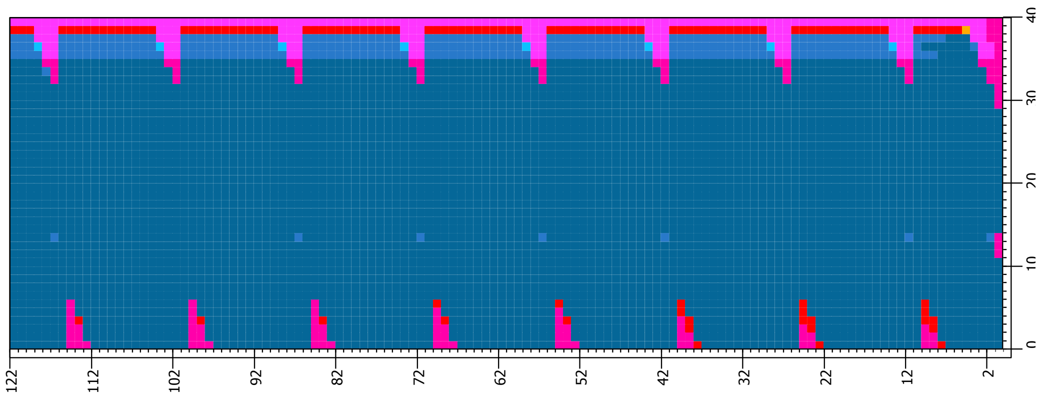


Fig 145: Simulation output _ Simulation type B1 _ NS _ MRT _ at 1.30pm

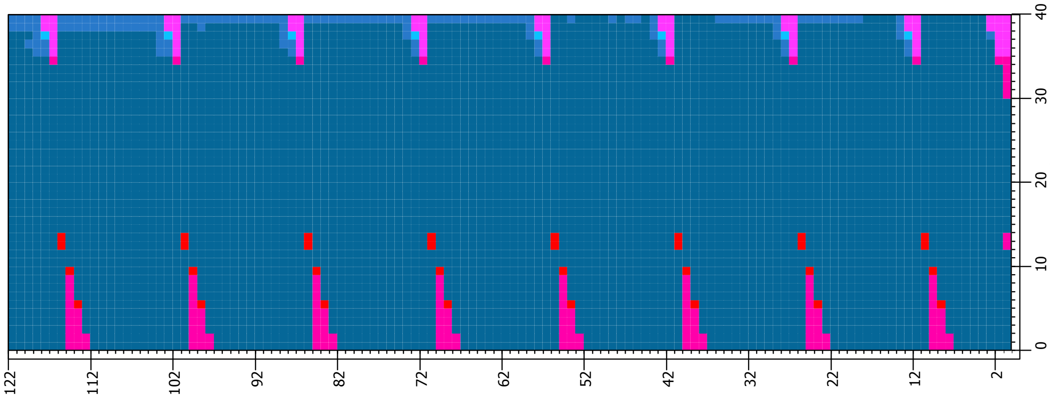
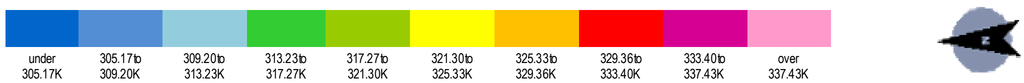


Fig 146: Simulation output _ Simulation type B1 _ NS _ MRT _ at 2pm



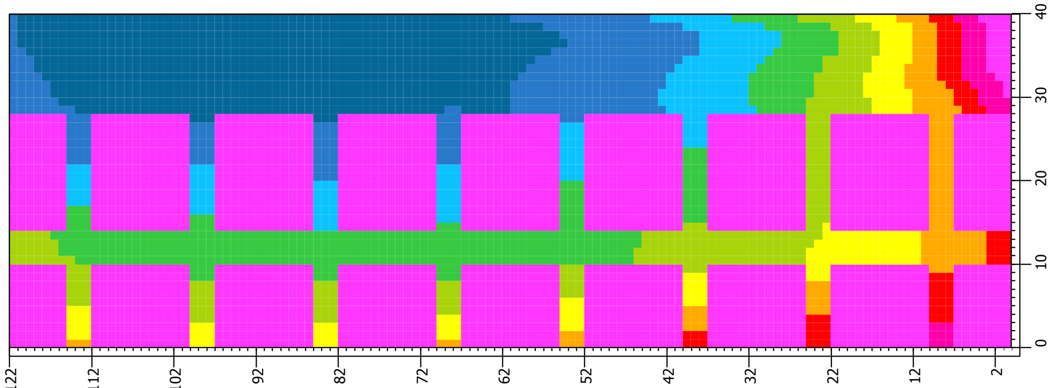


Fig 147: Simulation output _ Simulation type B1 _ NS _ RH _ at 11am

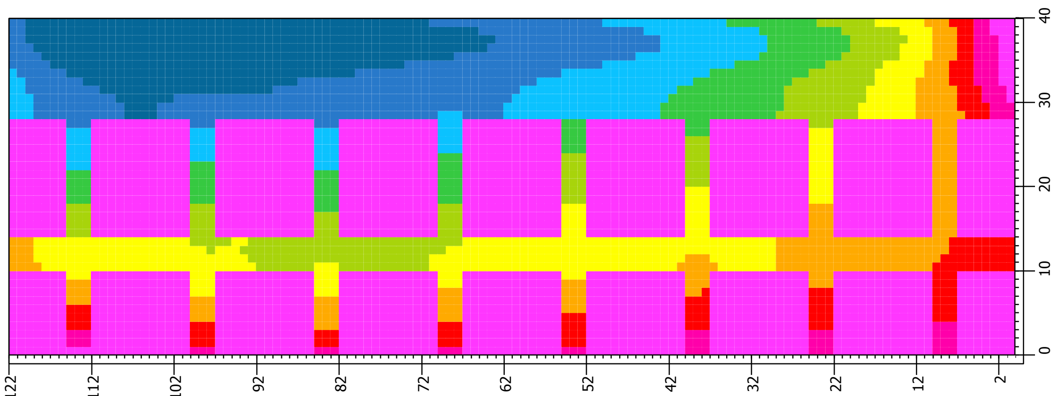


Fig 148: Simulation output _ Simulation type B1 _ NS _ RH _ at 11.30am

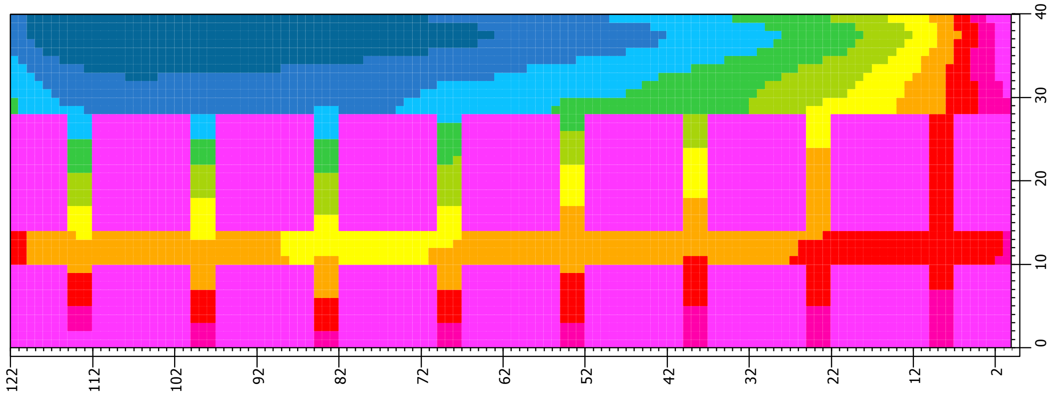


Fig 149: Simulation output _ Simulation type B1 _ NS _ RH _ at 12pm

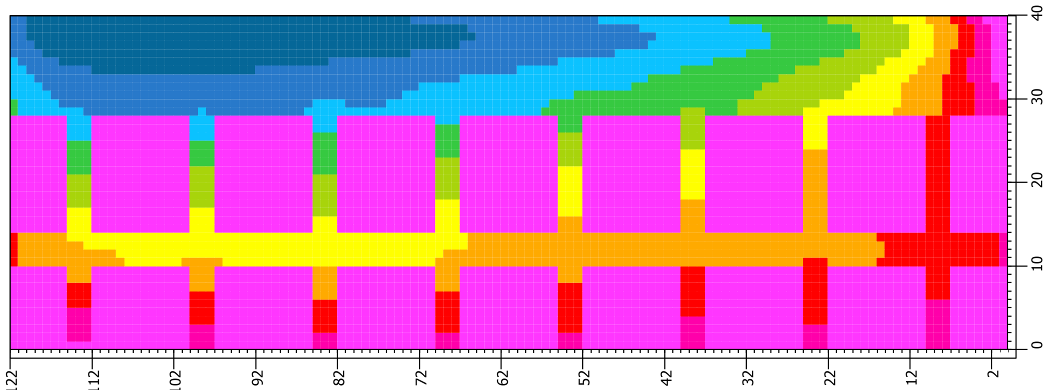


Fig 150: Simulation output _ Simulation type B1 _ NS _ RH _ at 12.30pm

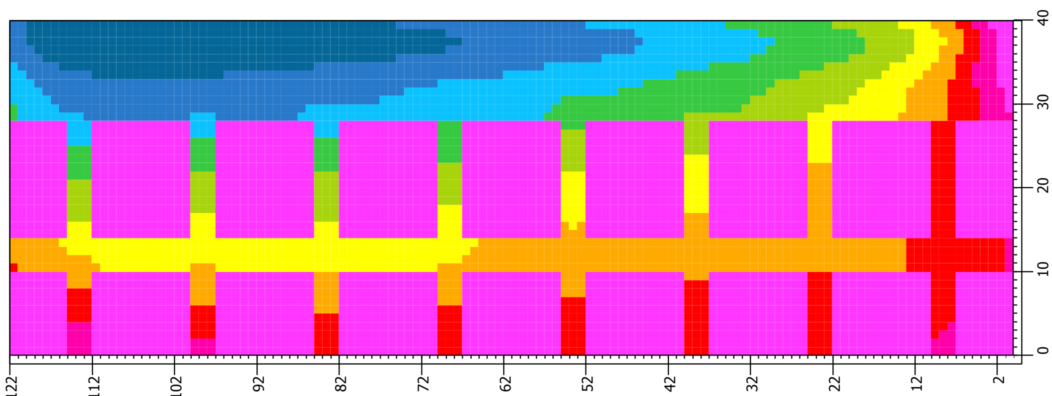


Fig 151: Simulation output _ Simulation type B1 _ NS _ RH _ at 1pm

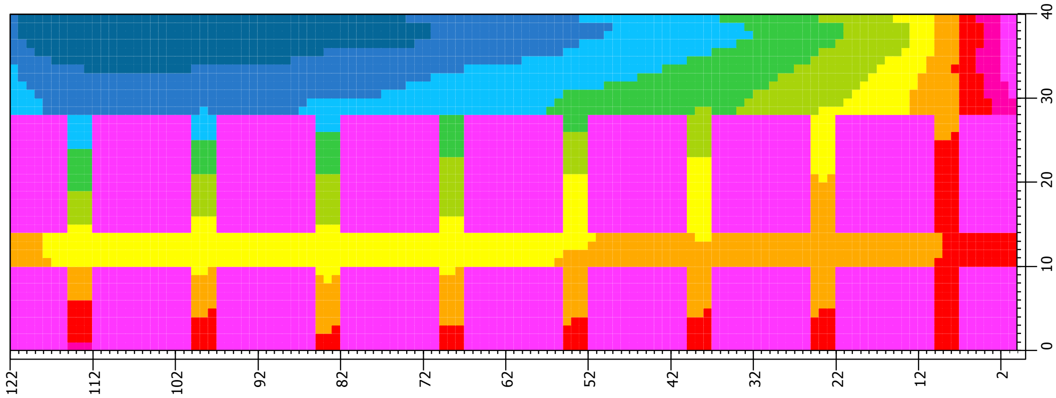


Fig 152: Simulation output _ Simulation type B1 _ NS _ RH _ at 1.30pm

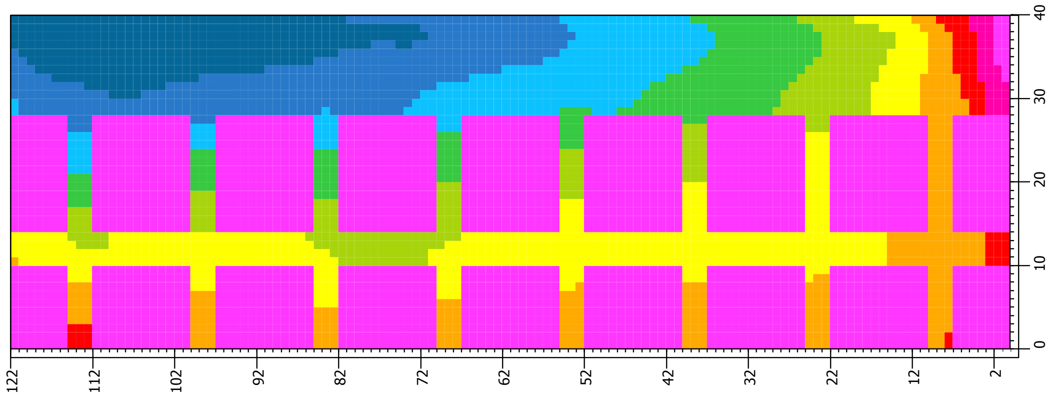
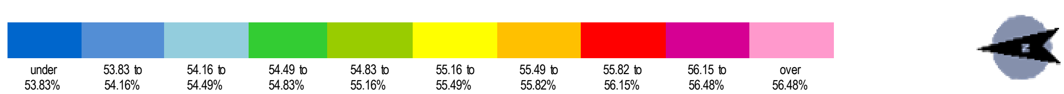


Fig 153: Simulation output _ Simulation type B1 _ NS _ RH _ at 2pm



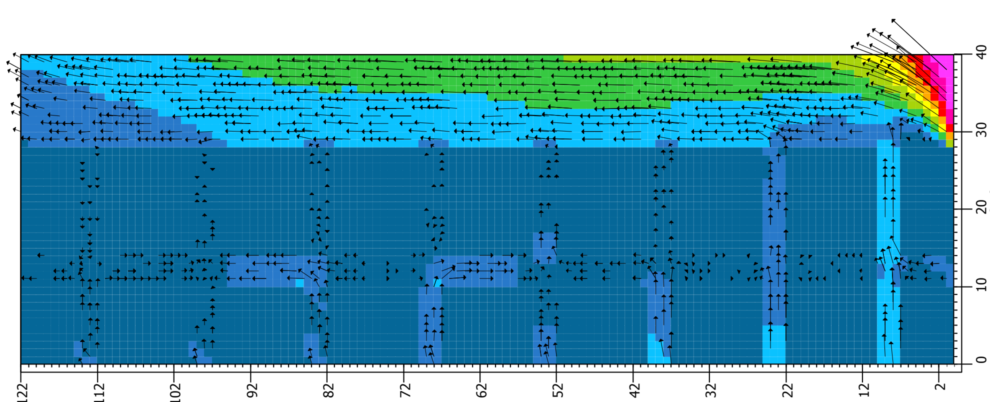


Fig 154: Simulation output _ Simulation type B1 _ NS _ WS _ at 11am

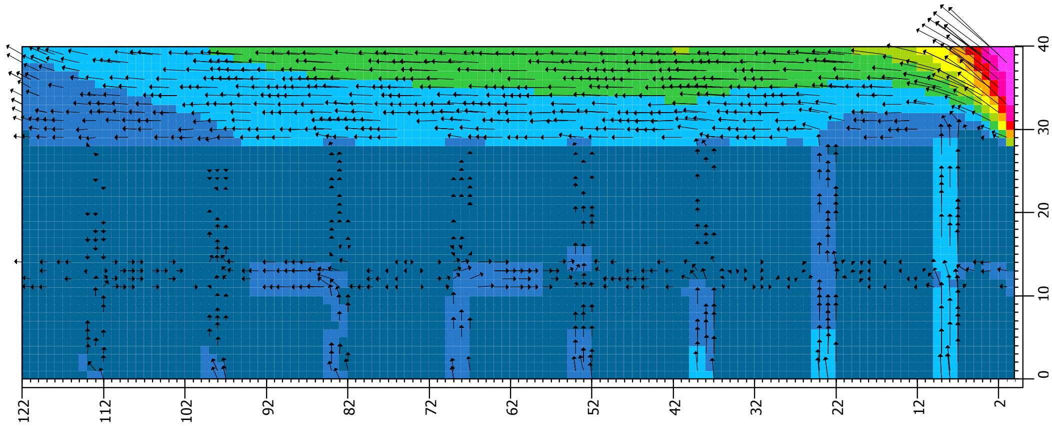


Fig 155: Simulation output _ Simulation type B1 _ NS _ WS _ at 11.30am

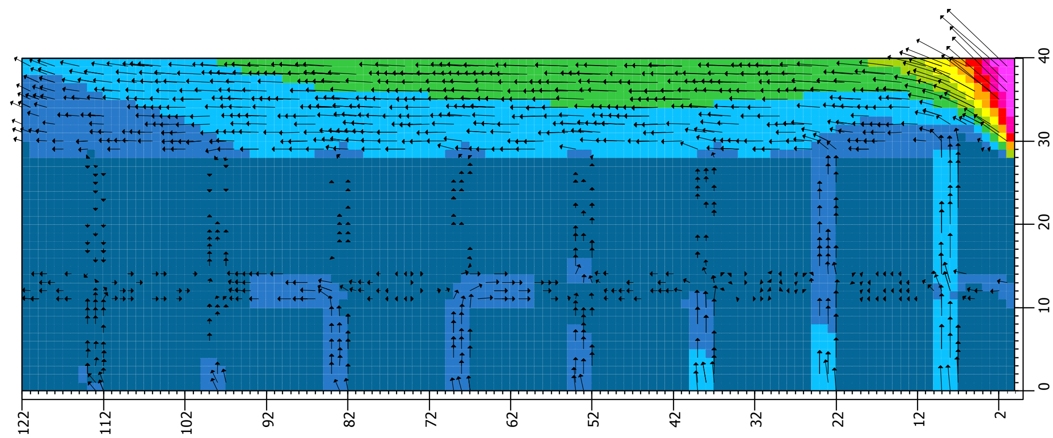


Fig 156: Simulation output _ Simulation type B1 _ NS _ WS _ at 12pm

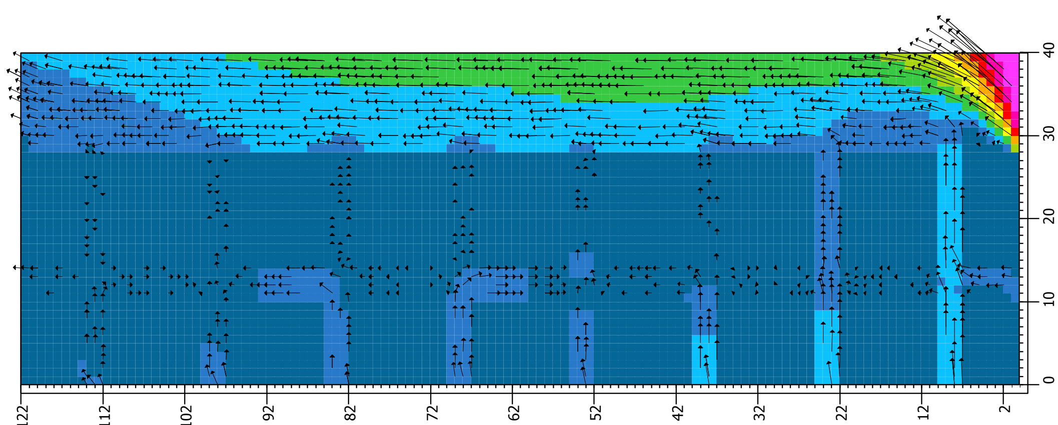


Fig 157: Simulation output _ Simulation type B1 _ NS _ WS _ at 12.30pm

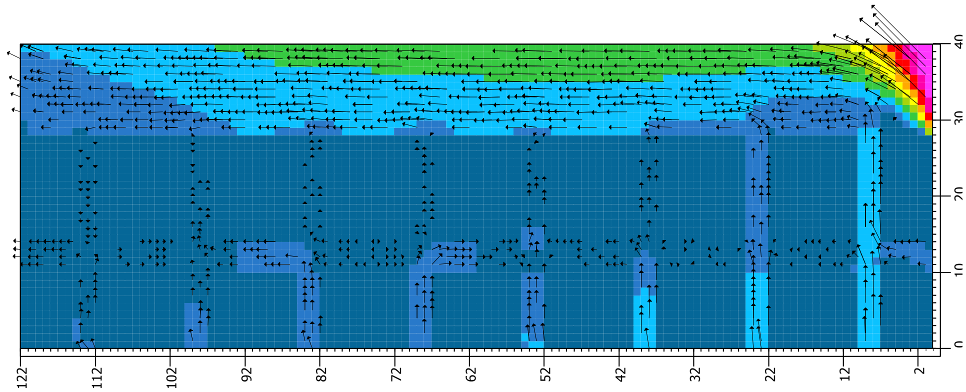


Fig 158: Simulation output _ Simulation type B1 _ NS _ WS _ at 1pm

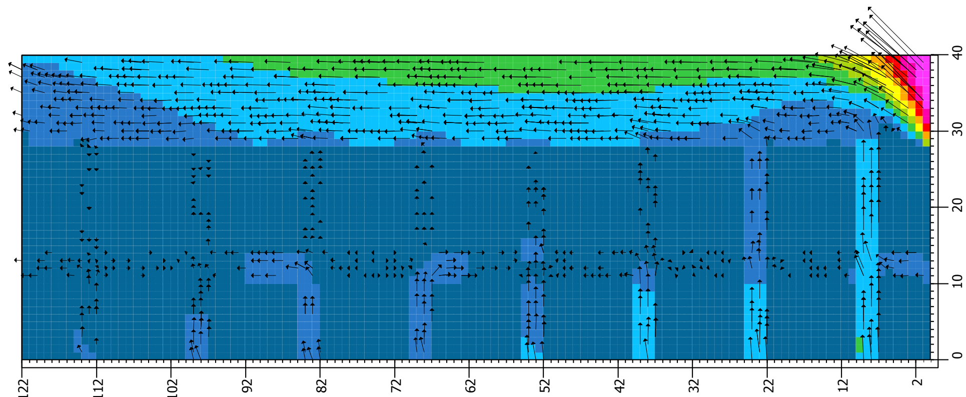


Fig 159: Simulation output _ Simulation type B1 _ NS _ WS _ at 1.30pm

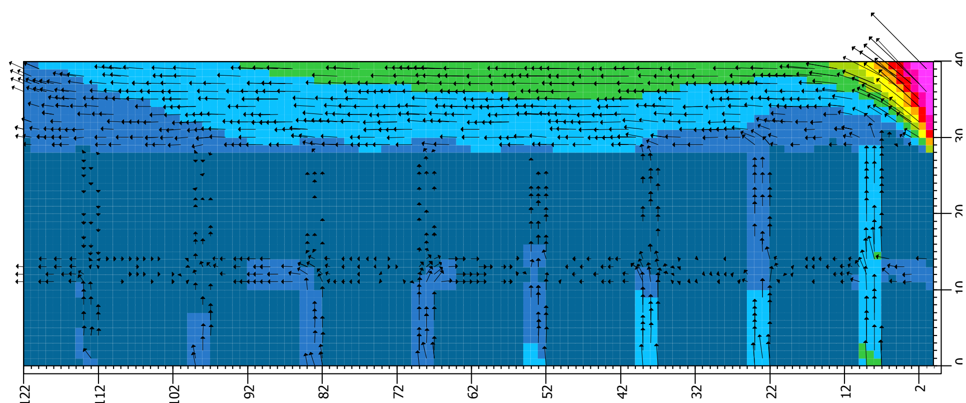
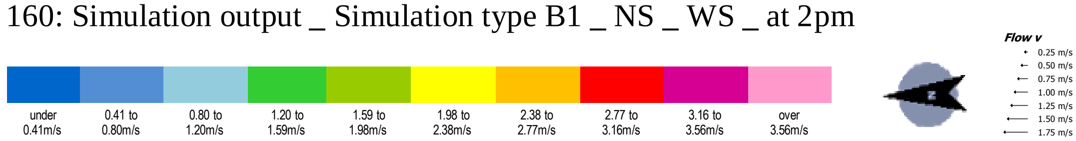


Fig 160: Simulation output _ Simulation type B1 _ NS _ WS _ at 2pm



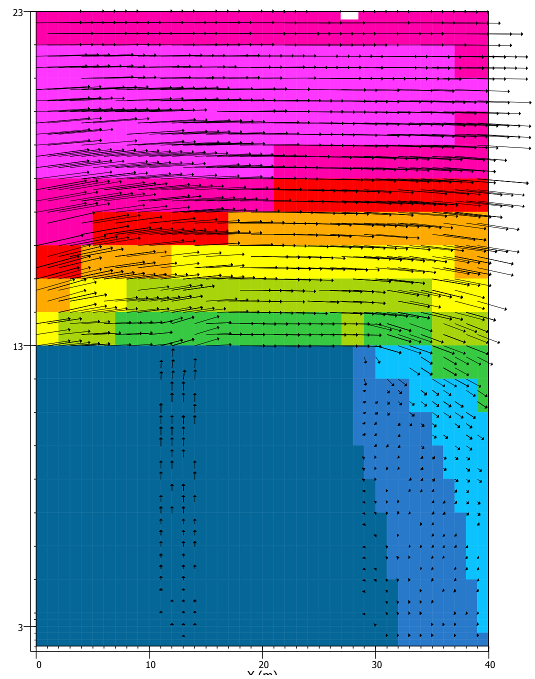


Fig 161: Simulation output _ Simulation type B1 _ NS _ WS _ section _ at 11am

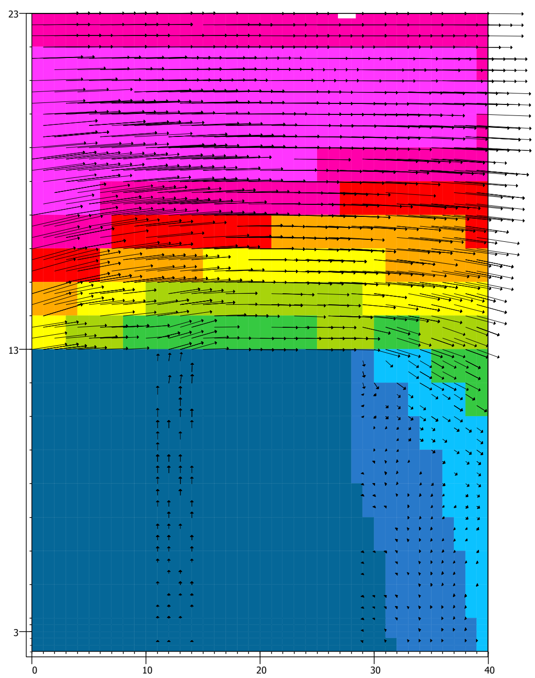


Fig 162: Simulation output _ Simulation type B1 _ NS _ WS _ section _ at 12pm

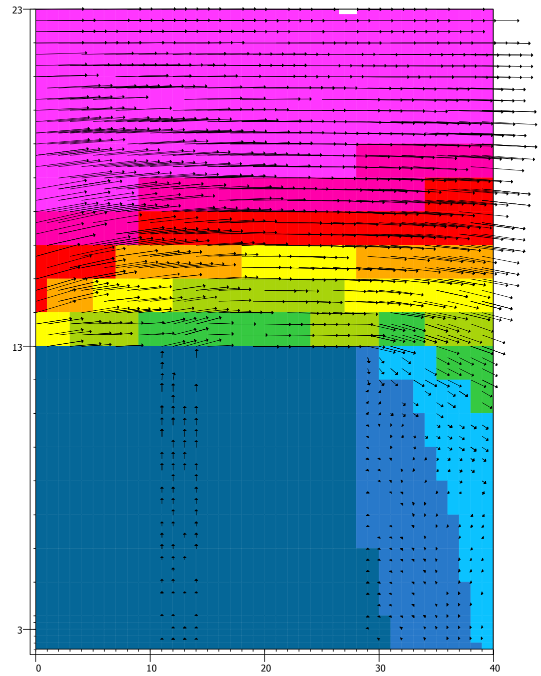


Fig 163: Simulation output _ Simulation type B1 _ NS _ WS _ section _ at 1pm

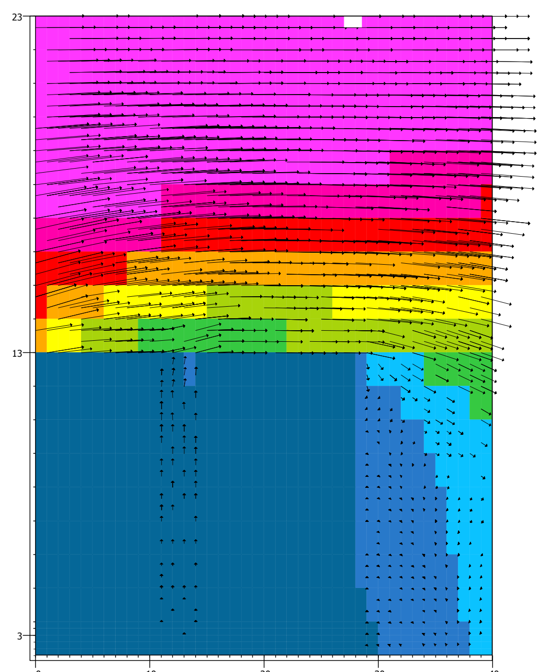
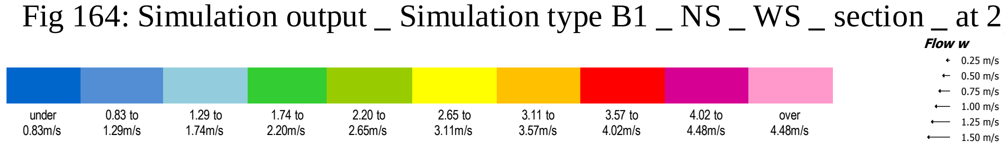


Fig 164: Simulation output _ Simulation type B1 _ NS _ WS _ section _ at 2pm



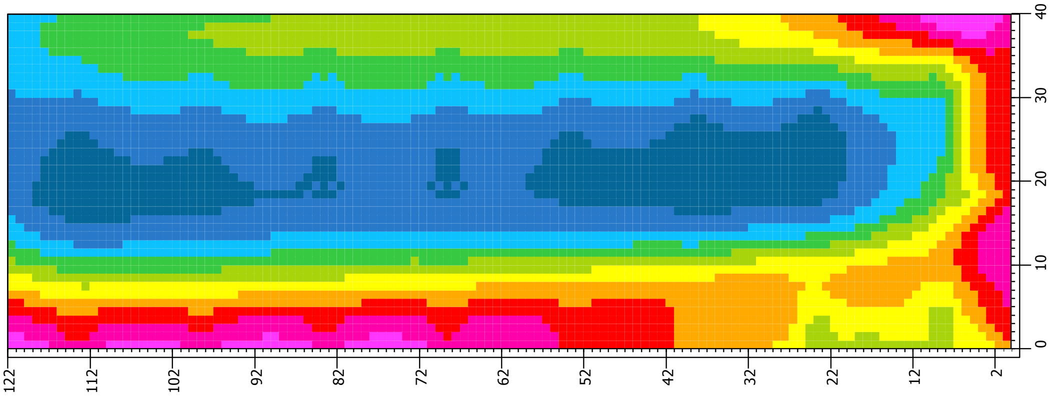


Fig 165: Simulation output _ Simulation type B2 _ NS _ DBT _ at 11am

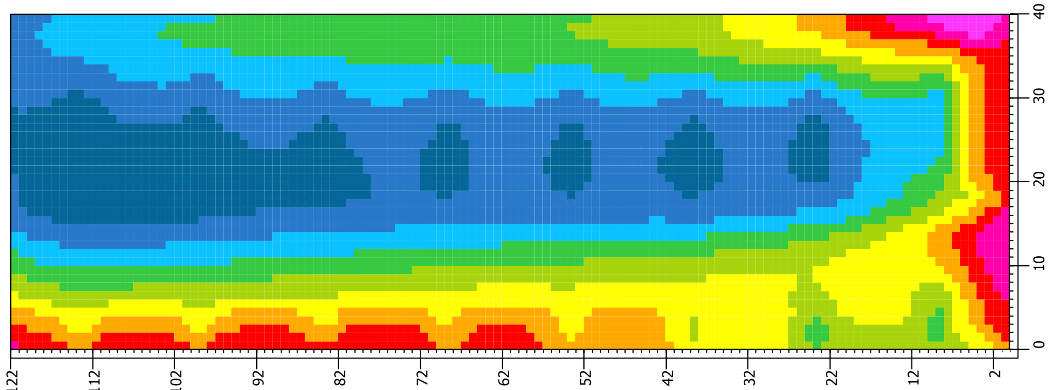


Fig 166: Simulation output _ Simulation type B2 _ NS _ DBT _ at 11.30am

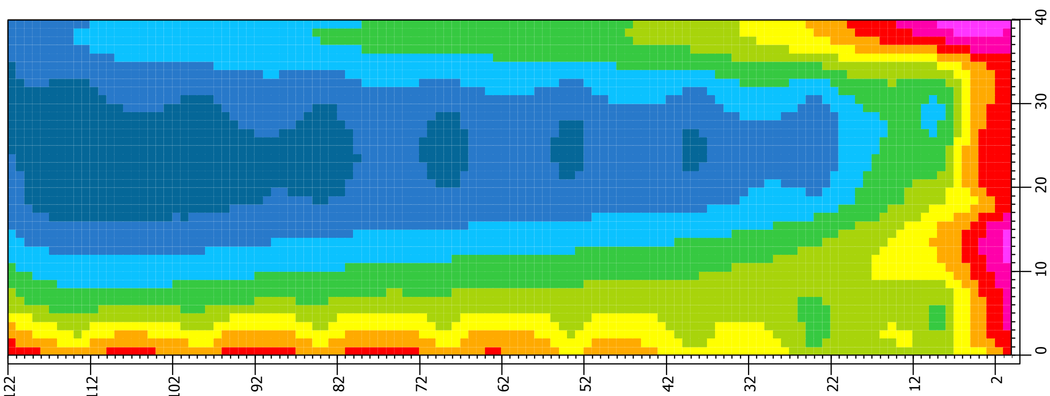


Fig 167: Simulation output _ Simulation type B2 _ NS _ DBT _ at 12pm

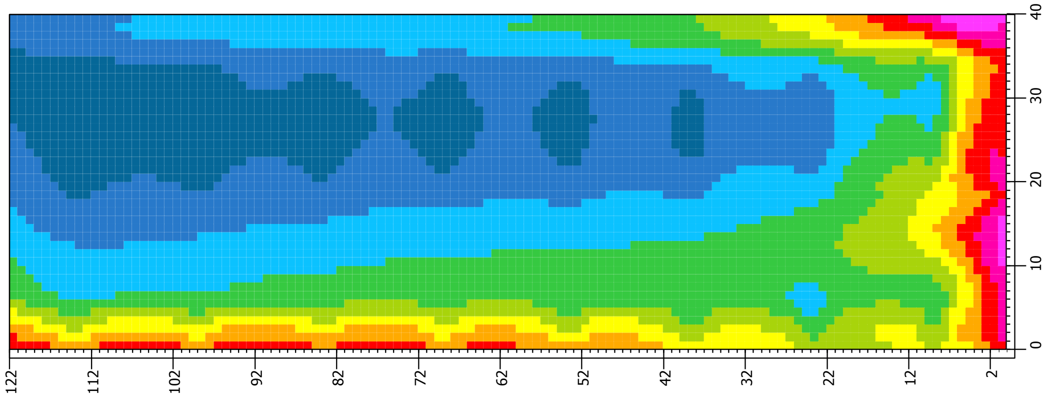


Fig 168: Simulation output _ Simulation type B2 _ NS _ DBT _ at 12.30pm

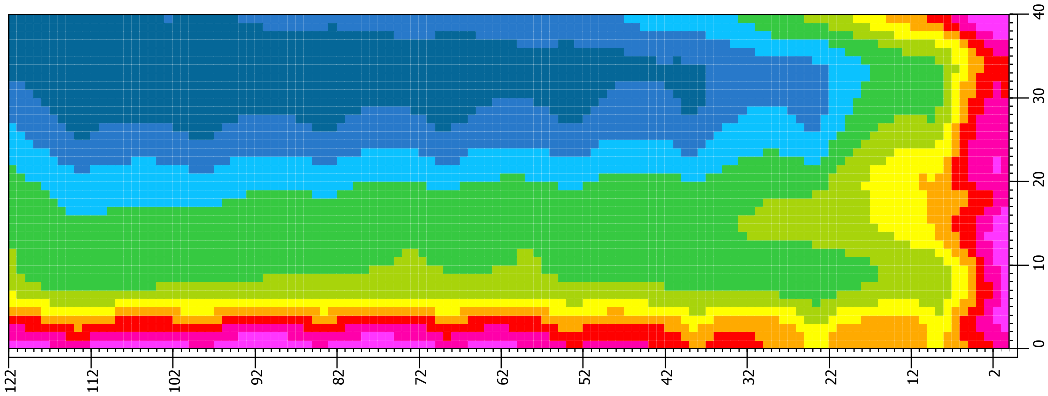


Fig 169: Simulation output _ Simulation type B2 _ NS _ DBT _ at 1pm

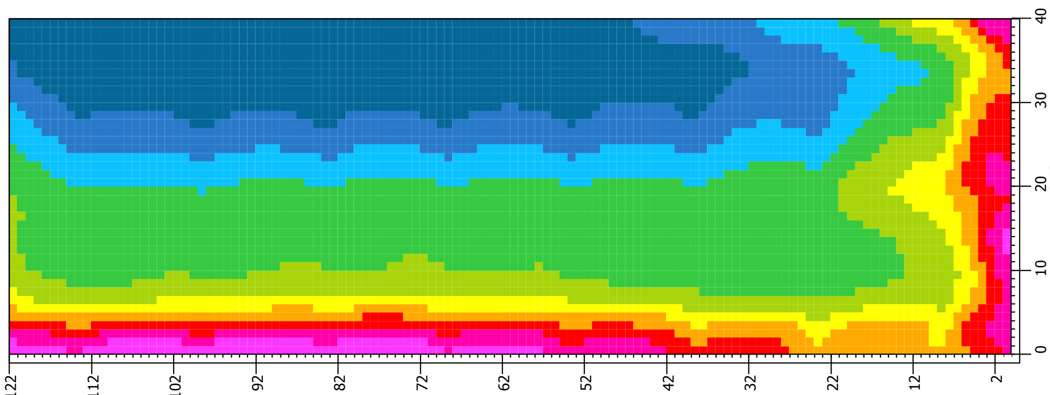


Fig 170: Simulation output _ Simulation type B2 _ NS _ DBT _ at 1.30pm

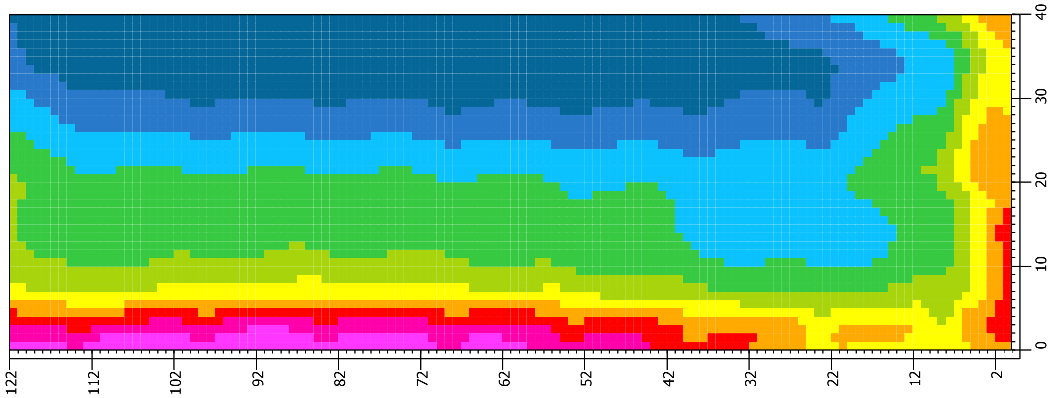
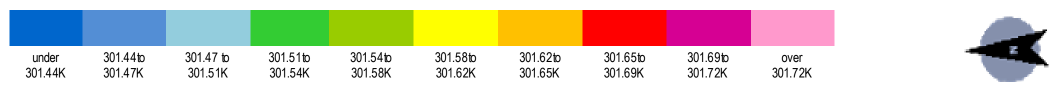


Fig 171: Simulation output _ Simulation type B2 _ NS _ DBT _ at 2pm



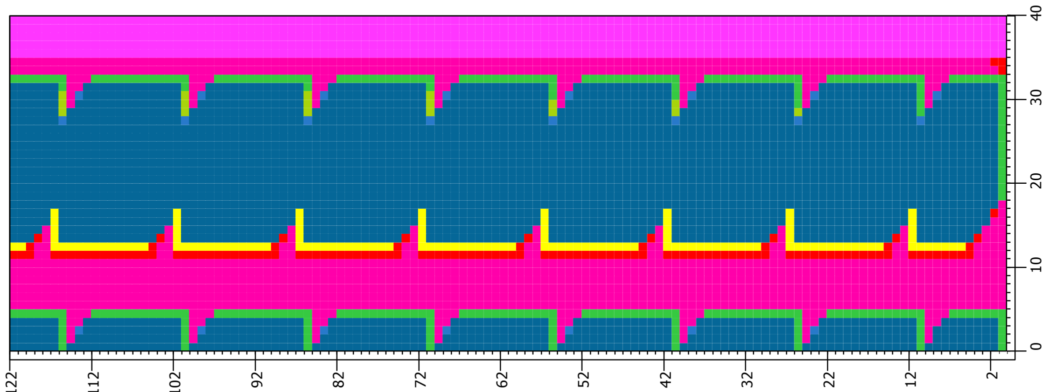


Fig 172: Simulation output _ Simulation type B2 _ NS _ MRT _ at 11am

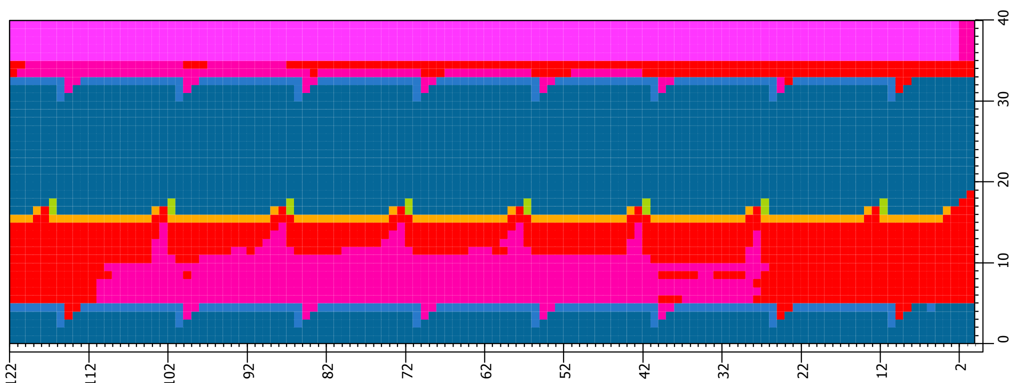


Fig 173: Simulation output _ Simulation type B2 _ NS _ MRT _ at 11.30am

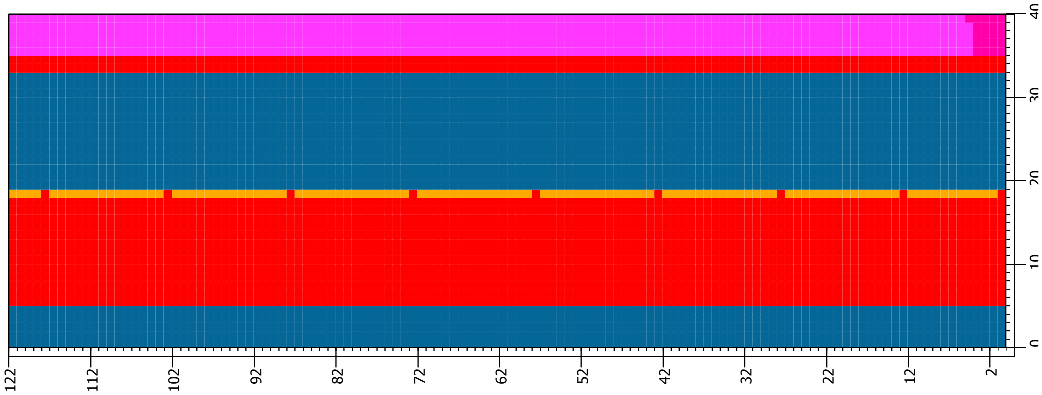


Fig 174: Simulation output _ Simulation type B2 _ NS _ MRT _ at 12pm

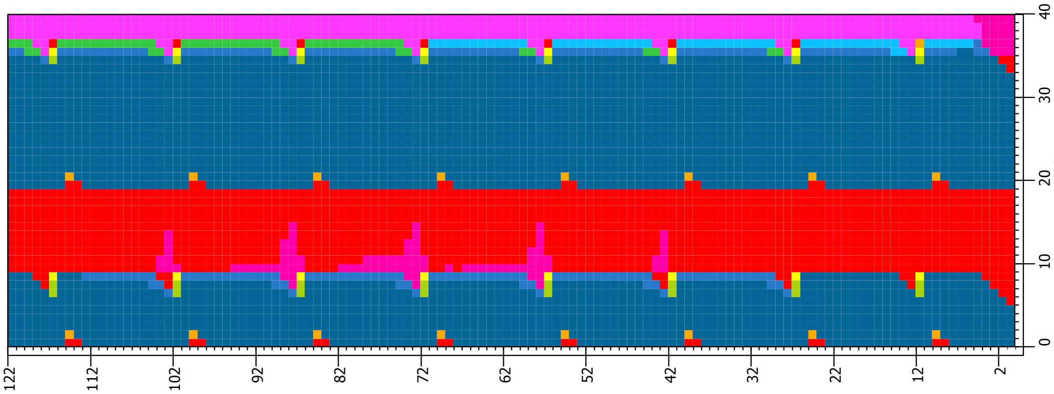


Fig 175: Simulation output _ Simulation type B2 _ NS _ MRT _ at 12.30pm

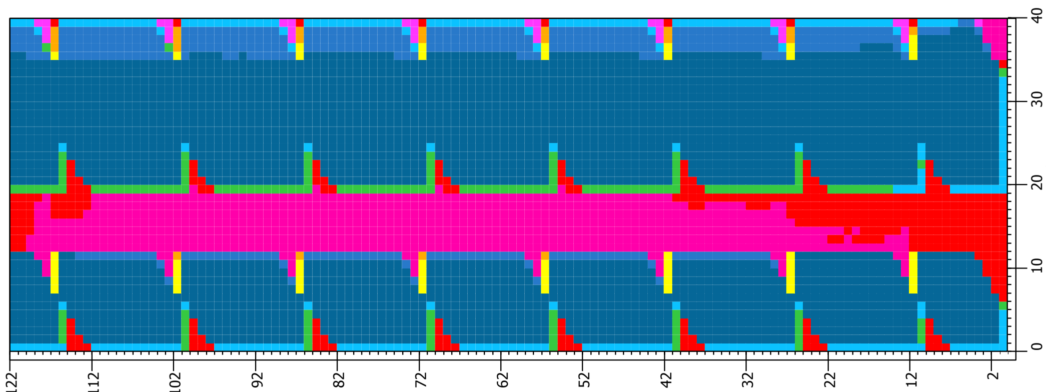


Fig 176: Simulation output _ Simulation type B2 _ NS _ MRT _ at 1pm

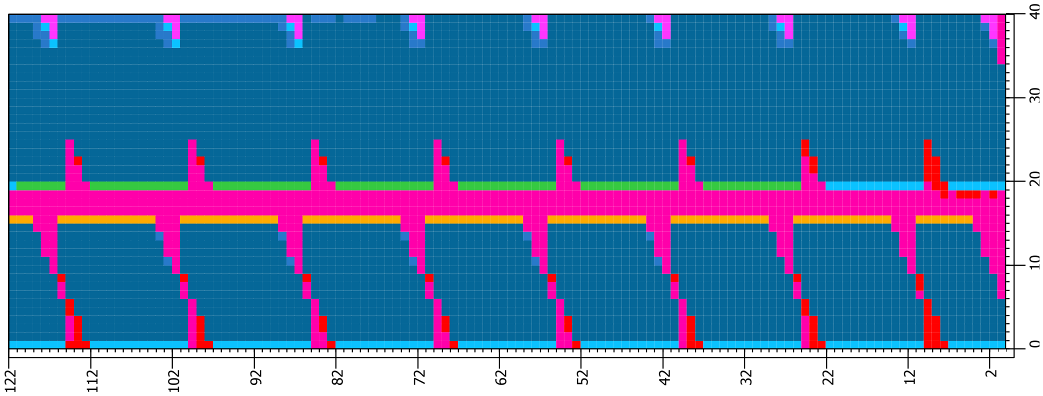


Fig 177: Simulation output _ Simulation type B2 _ NS _ MRT _ at 1.30pm

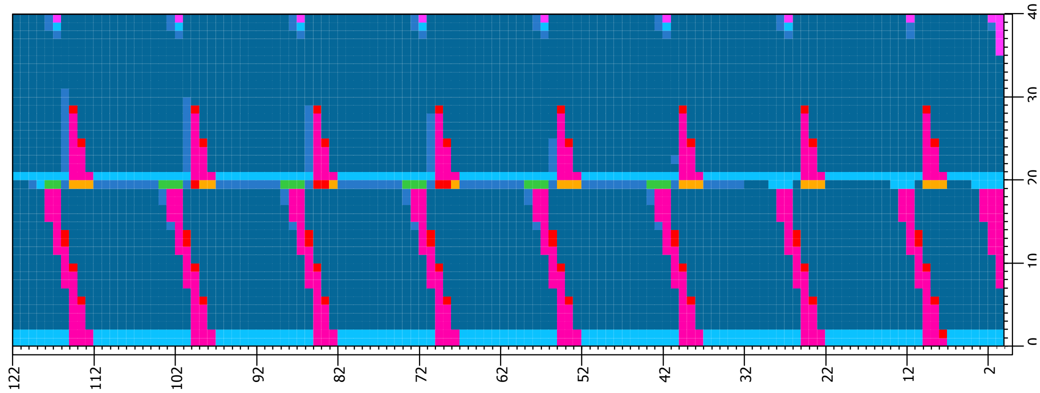
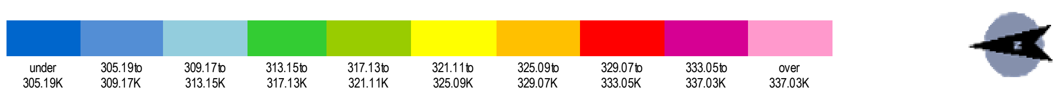


Fig 178: Simulation output _ Simulation type B2 _ NS _ MRT _ at 2pm



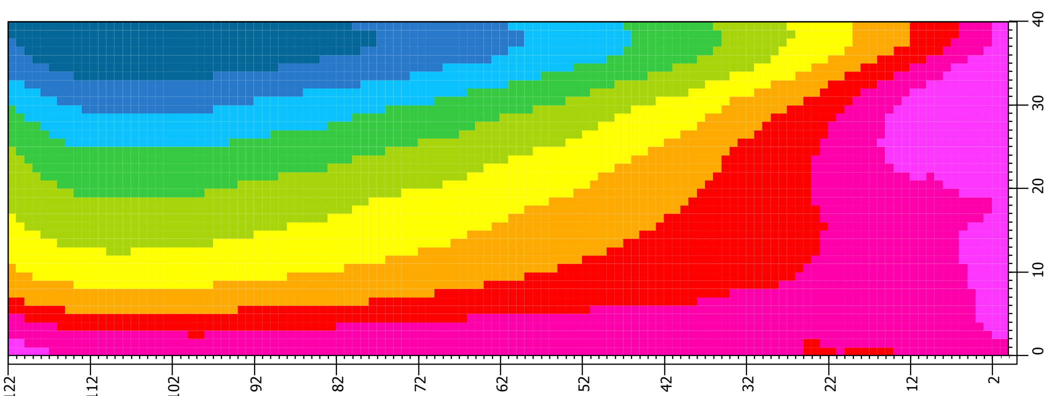


Fig 179: Simulation output _ Simulation type B2 _ NS _ RH _ at 11am

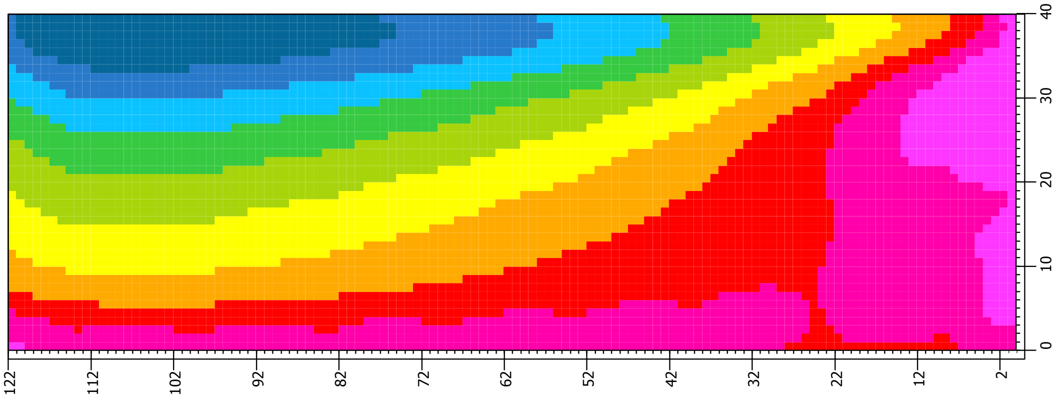


Fig 180: Simulation output _ Simulation type B2 _ NS _ RH _ at 11.30am

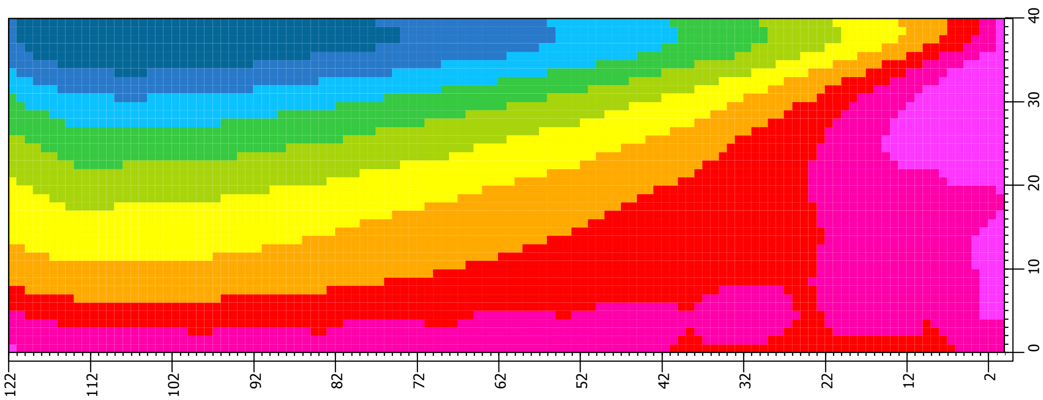


Fig 181: Simulation output _ Simulation type B2 _ NS _ RH _ at 12pm

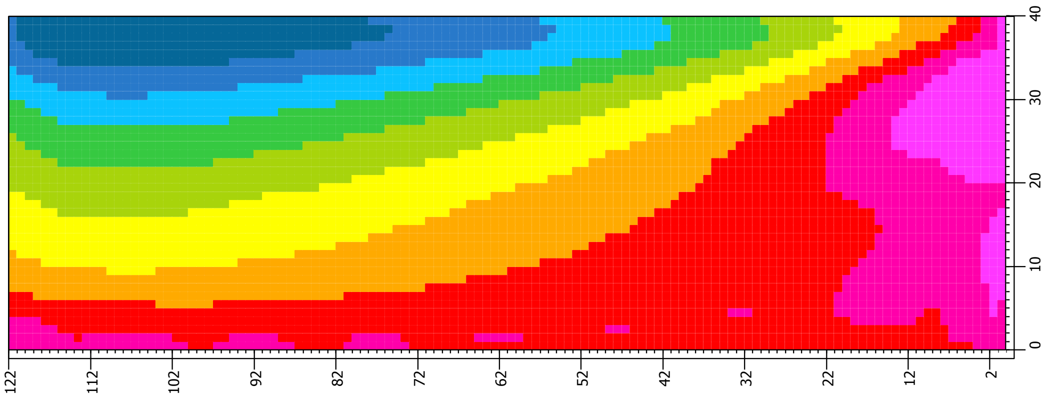


Fig 182: Simulation output _ Simulation type B2 _ NS _ RH _ at 12.30pm

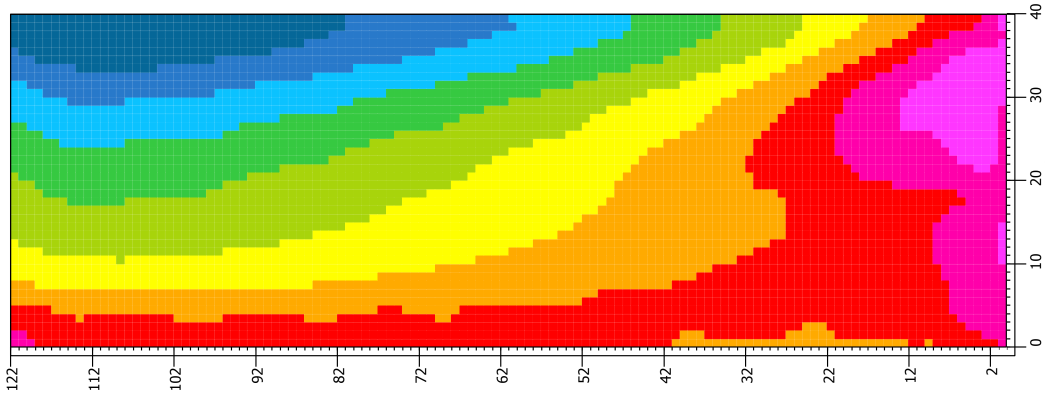


Fig 183: Simulation output _ Simulation type B2 _ NS _ RH _ at 1pm

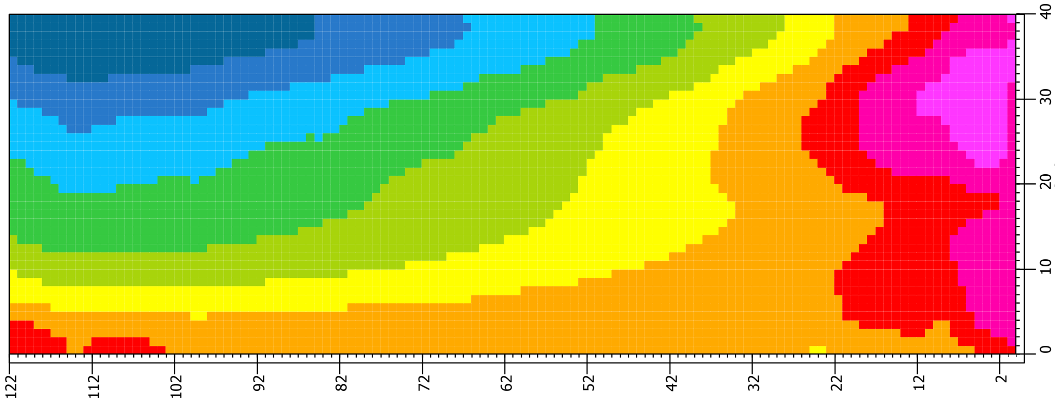


Fig 184: Simulation output _ Simulation type B2 _ NS _ RH _ at 1.30pm

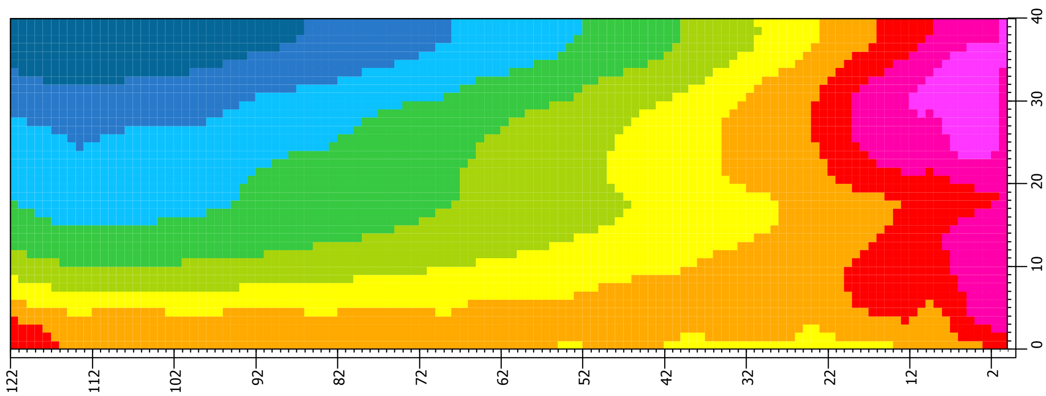
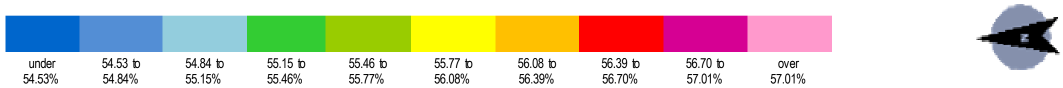


Fig 185: Simulation output _ Simulation type B2 _ NS _ RH _ at 2pm



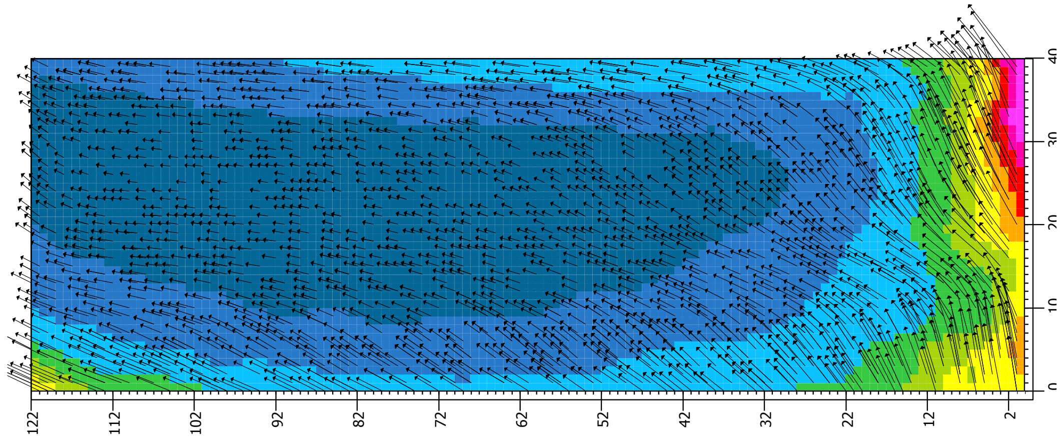


Fig 186: Simulation output _ Simulation type B2 _ NS _ WS _ at 11am

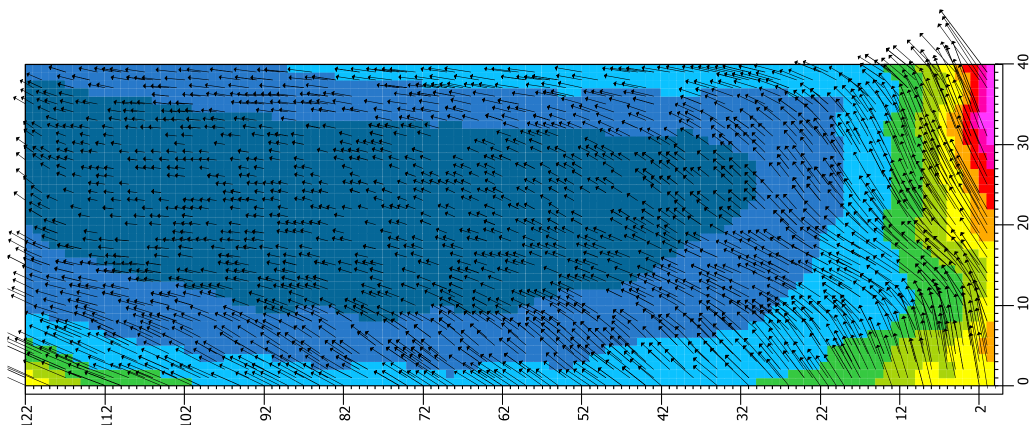


Fig 187: Simulation output _ Simulation type B2 _ NS _ WS _ at 11.30am

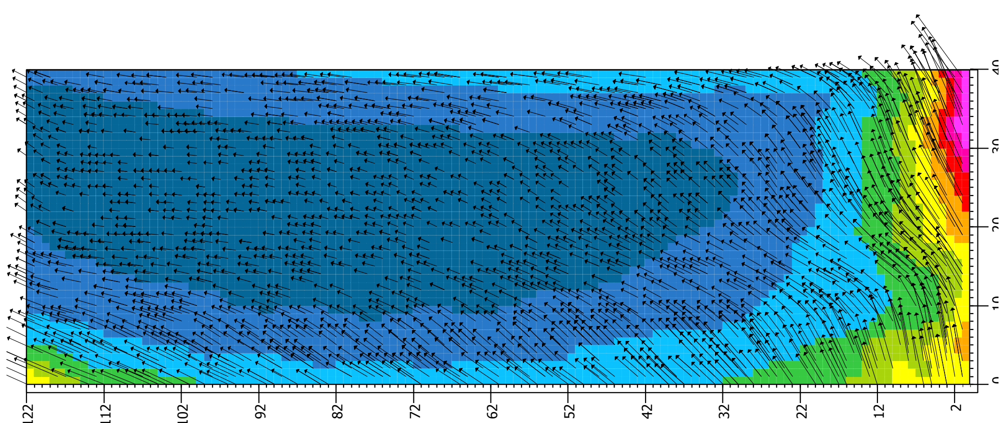


Fig 188: Simulation output _ Simulation type B2 _ NS _ WS _ at 12pm

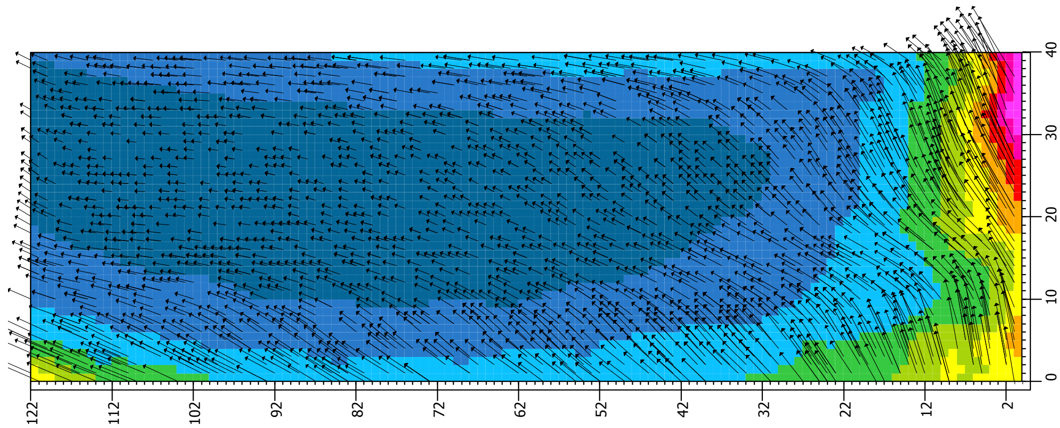


Fig 189: Simulation output _ Simulation type B2 _ NS _ WS _ at 12.30pm

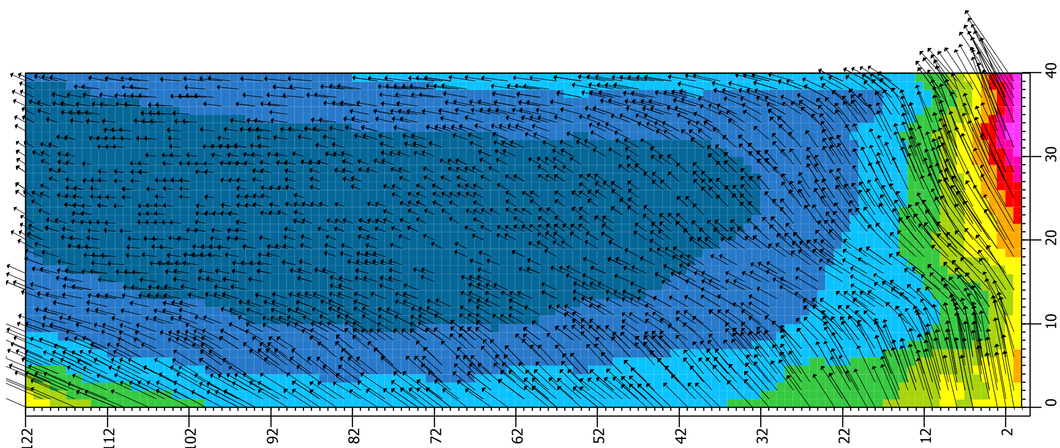


Fig 190: Simulation output _ Simulation type B2 _ NS _ WS _ at 1pm

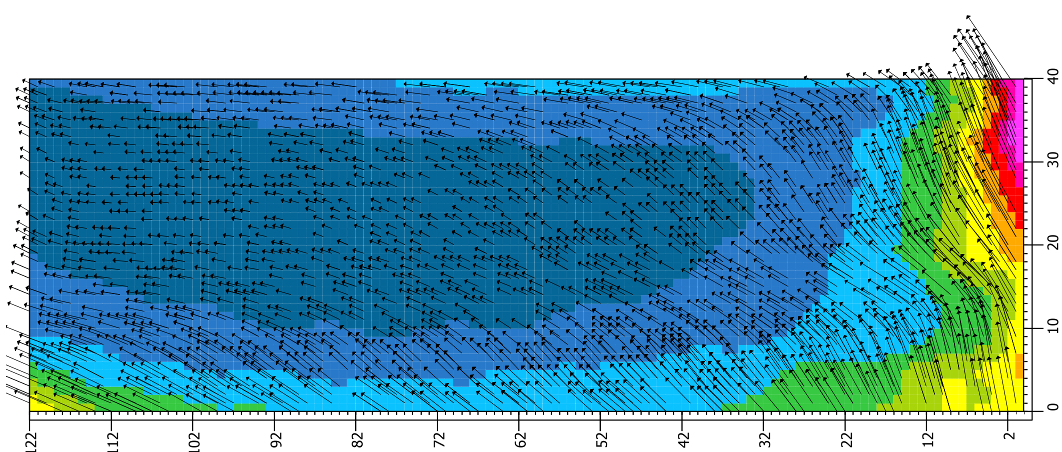


Fig 191: Simulation output _ Simulation type B2 _ NS _ WS _ at 1.30pm

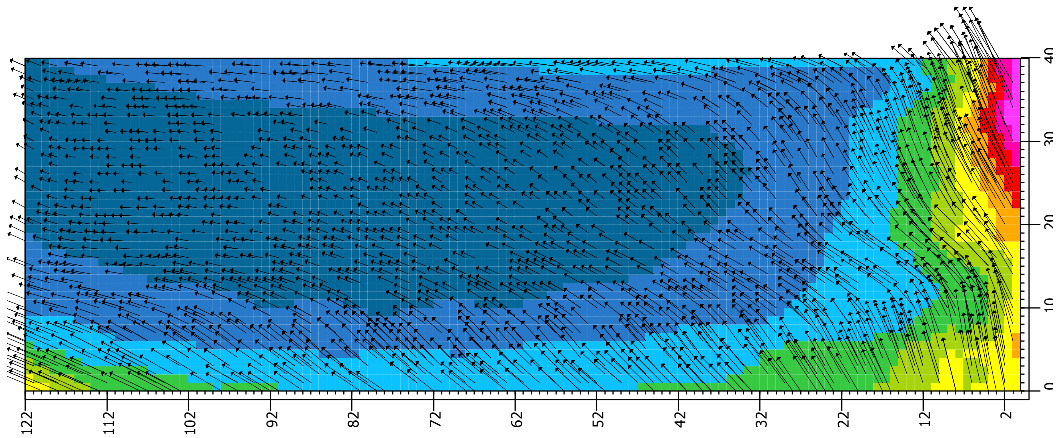
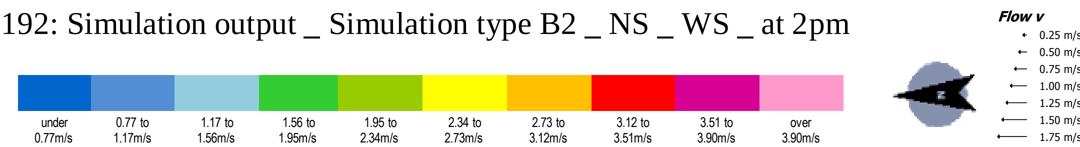


Fig 192: Simulation output _ Simulation type B2 _ NS _ WS _ at 2pm



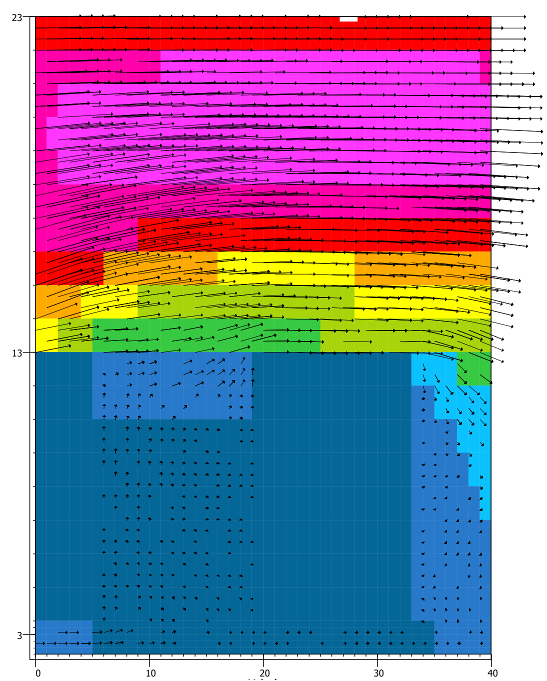


Fig 193: Simulation output _ Simulation type B2 _ NS _ WS _ section _ at 11am

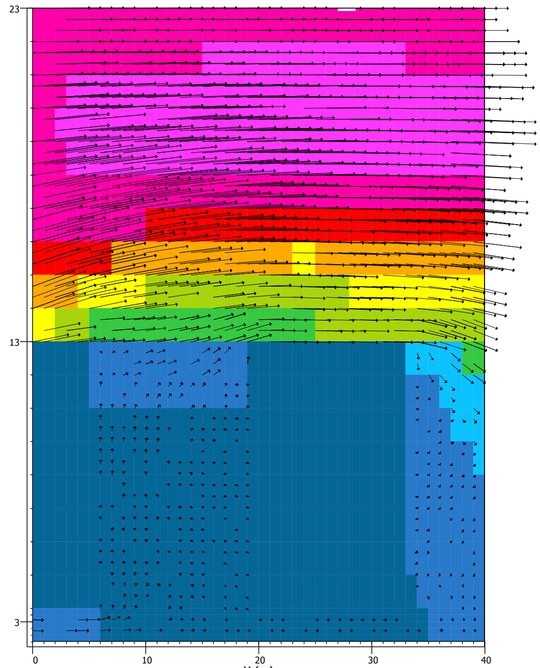


Fig 194: Simulation output _ Simulation type B2 _ NS _ WS _ section _ at 12pm

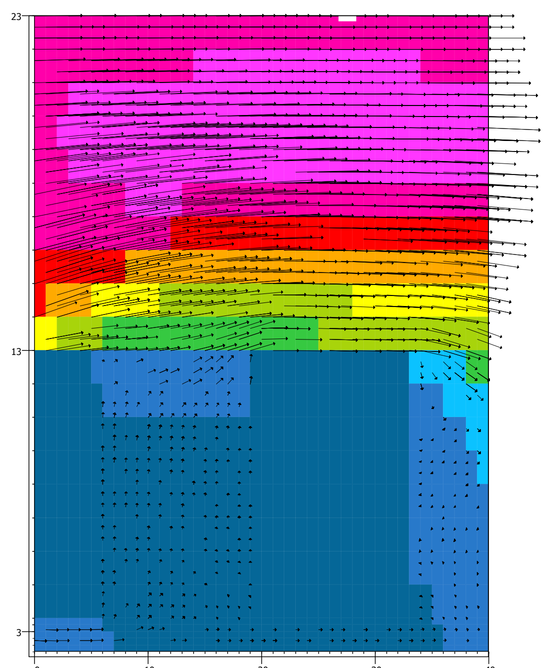


Fig 195: Simulation output _ Simulation type B2 _ NS _ WS _ section _ at 1pm

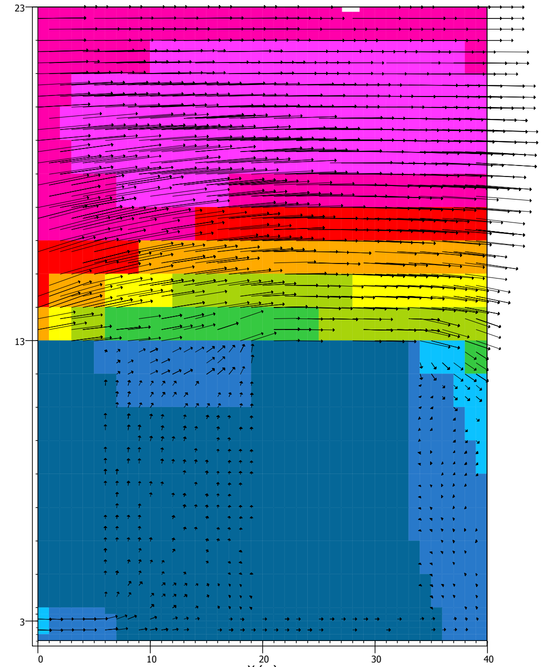
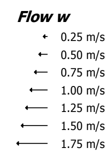
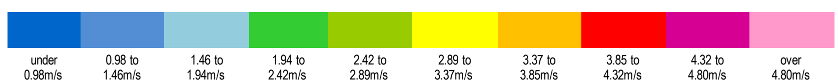


Fig 196: Simulation output_Simulation type B2_NS_WS_section_at 2pm





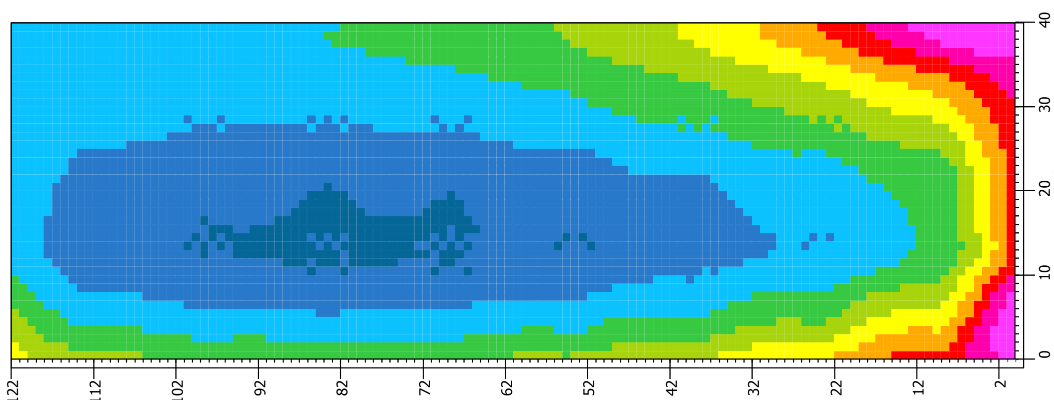


Fig 197: Simulation output _ Simulation type B3 _ NS _ DBT _ at 11am

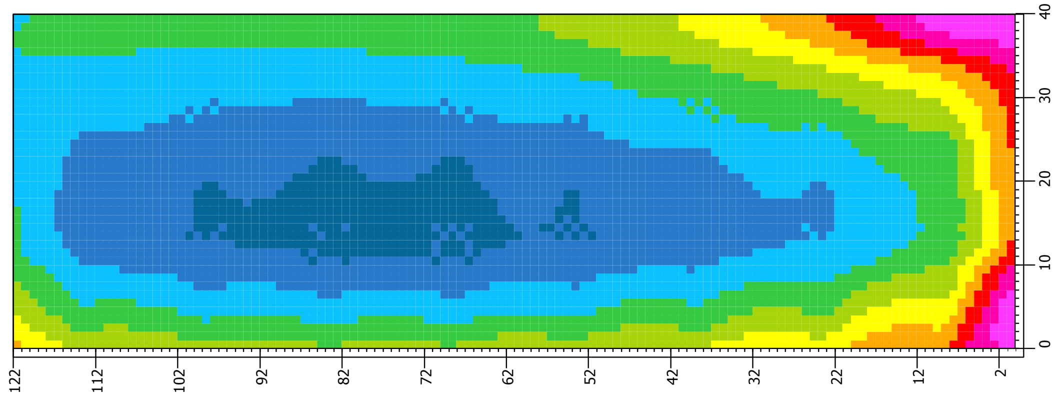


Fig 198: Simulation output _ Simulation type B3 _ NS _ DBT _ at 11.30am

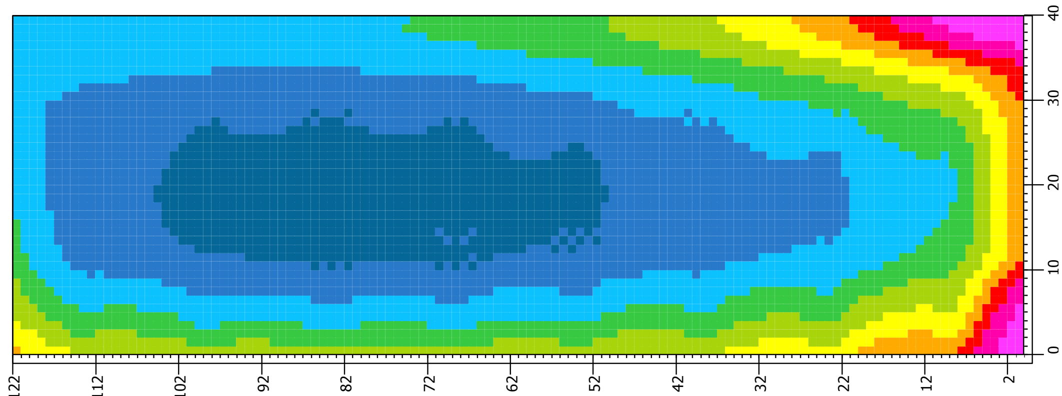


Fig 199: Simulation output _ Simulation type B3 _ NS _ DBT _ at 12pm

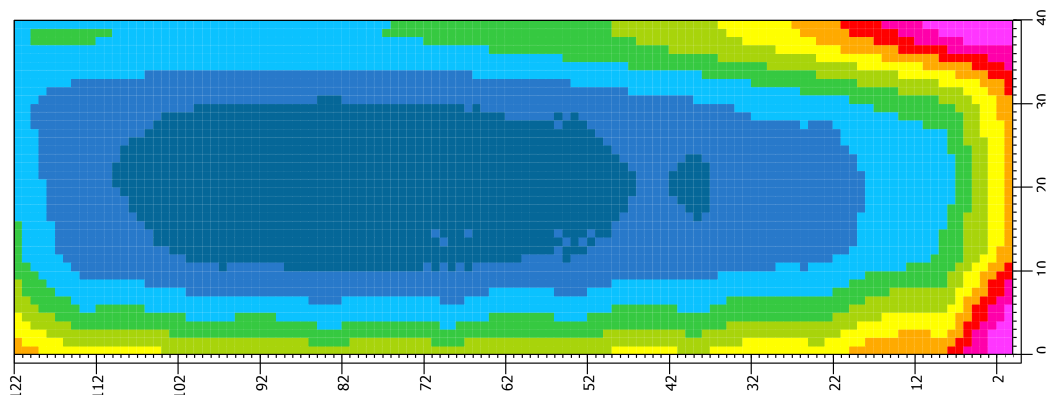


Fig 200: Simulation output _ Simulation type B3 _ NS _ DBT _ at 12.30pm

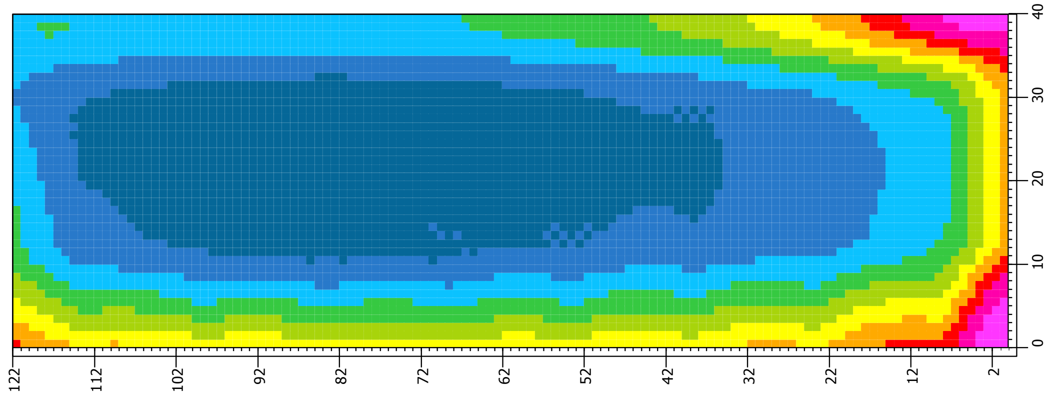


Fig 201: Simulation output _ Simulation type B3 _ NS _ DBT _ at 1pm

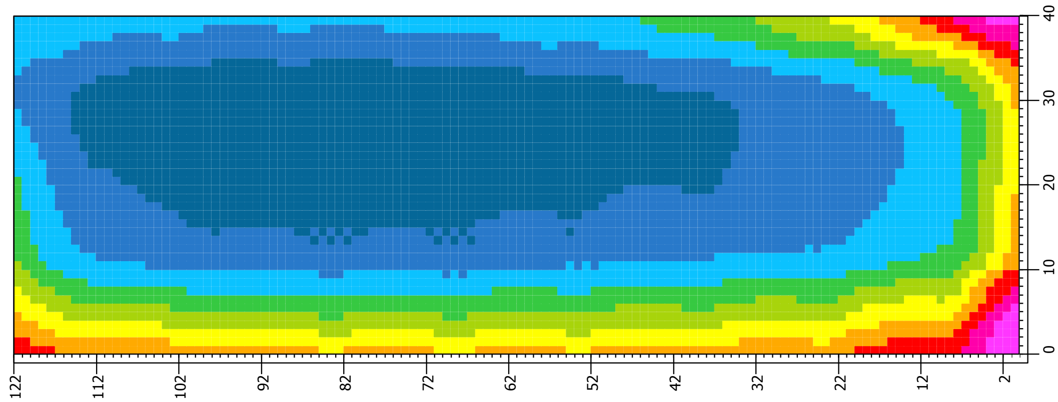


Fig 202: Simulation output _ Simulation type B3 _ NS _ DBT _ at 1.30pm

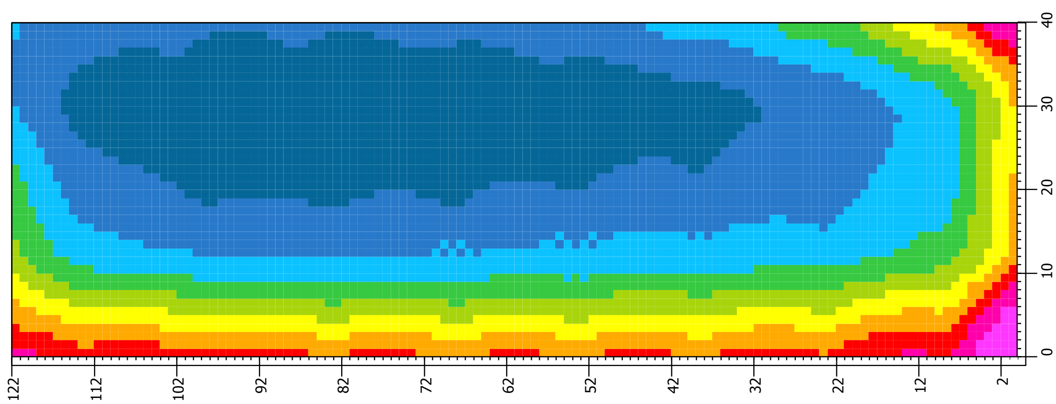
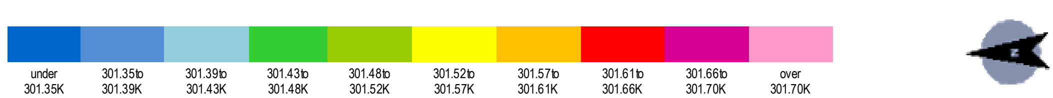


Fig 203: Simulation output _ Simulation type B3 _ NS _ DBT _ at 2pm



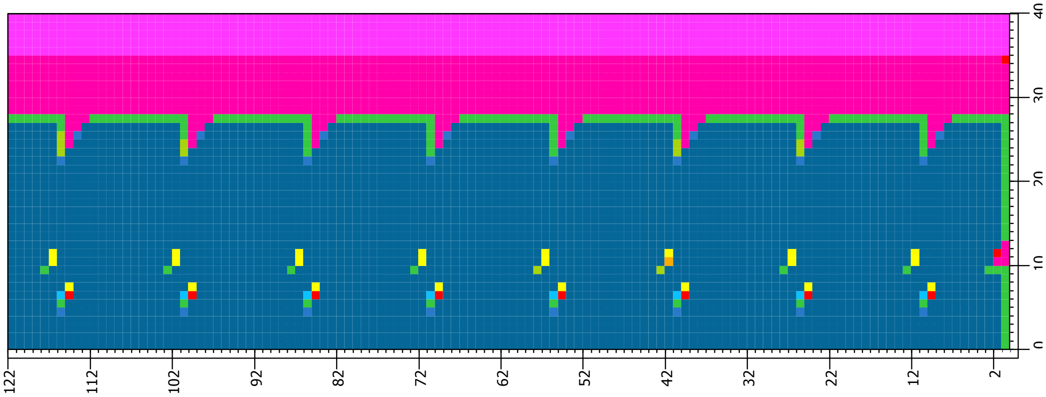


Fig 204: Simulation output _ Simulation type B3 _ NS _ MRT _ at 11am

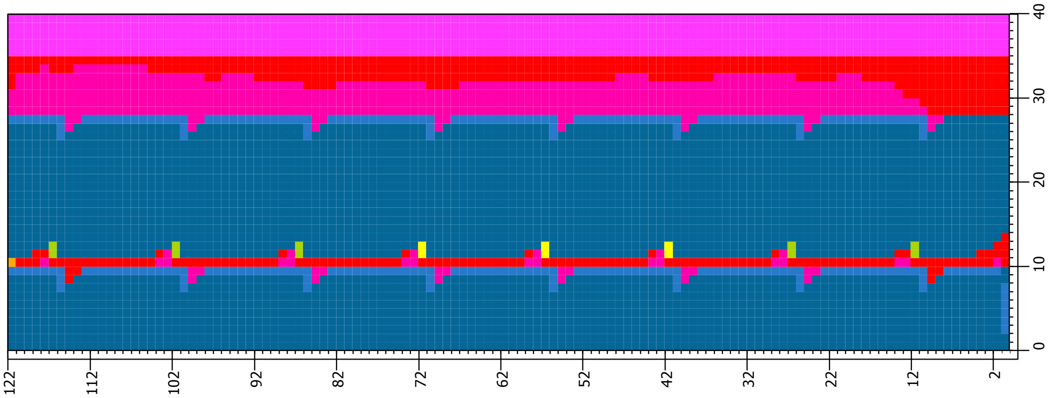


Fig 205: Simulation output _ Simulation type B3 _ NS _ MRT _ at 11.30am

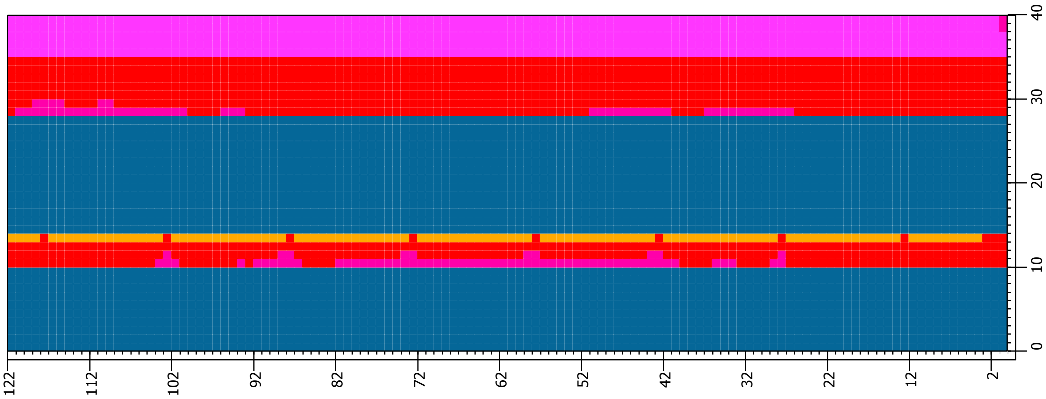


Fig 206: Simulation output _ Simulation type B3 _ NS _ MRT _ at 12pm

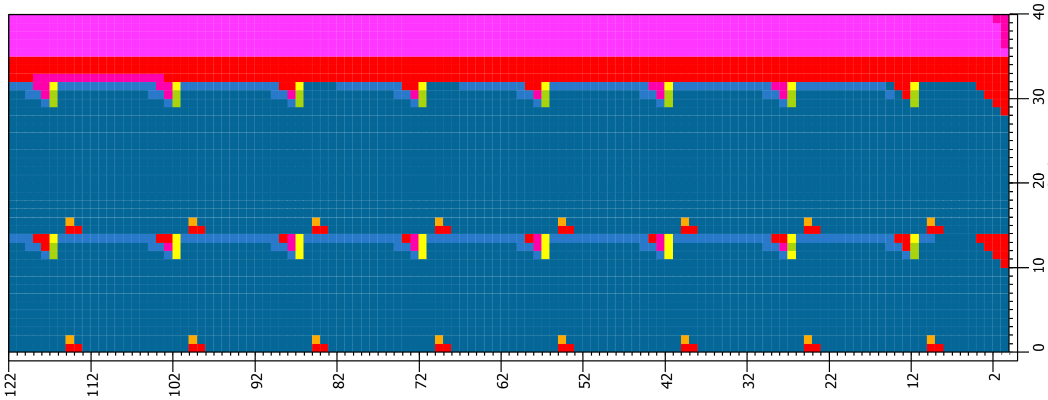


Fig 207: Simulation output _ Simulation type B3 _ NS _ MRT _ at 12.30pm

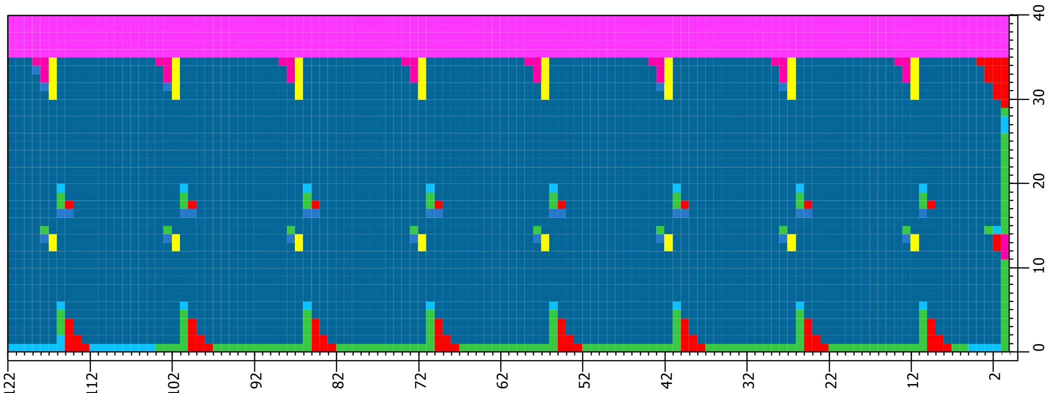


Fig 208: Simulation output _ Simulation type B3 _ NS _ MRT _ at 1pm

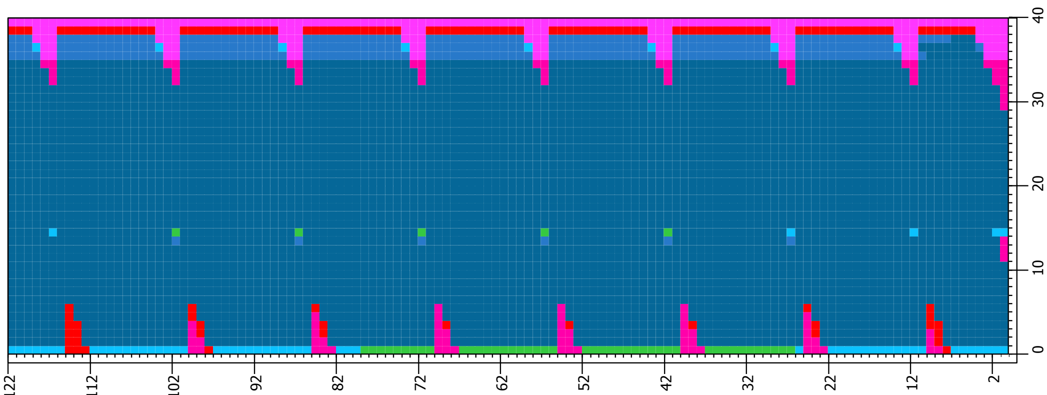


Fig 209: Simulation output _ Simulation type B3 _ NS _ MRT _ at 1.30pm

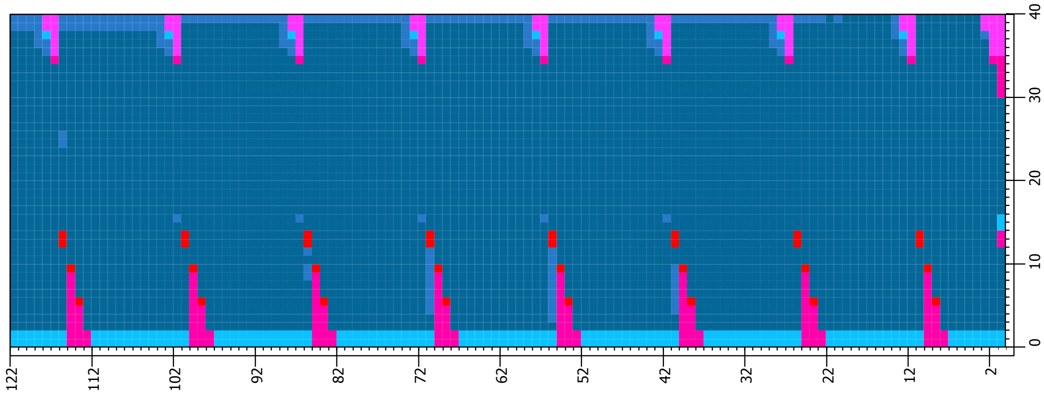
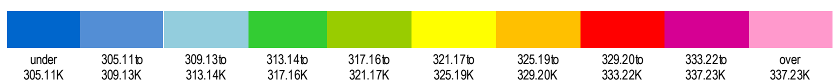


Fig 210: Simulation output _ Simulation type B3 _ NS _ MRT _ at 2pm



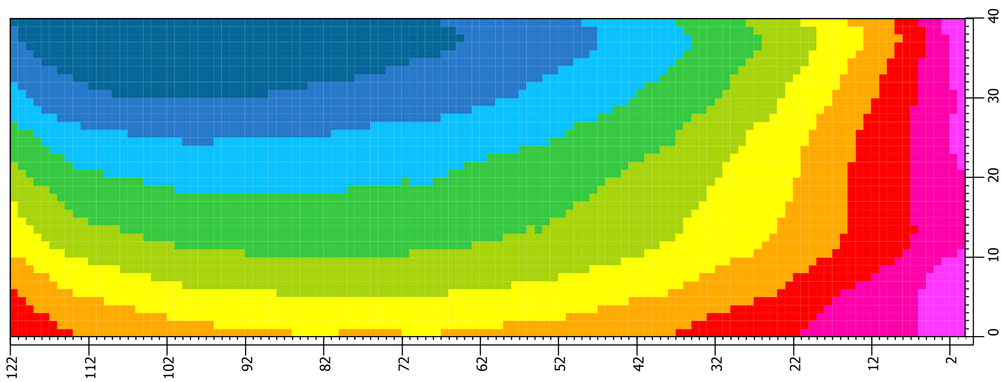


Fig 211: Simulation output _ Simulation type B3 _ NS _ RH _ at 11am

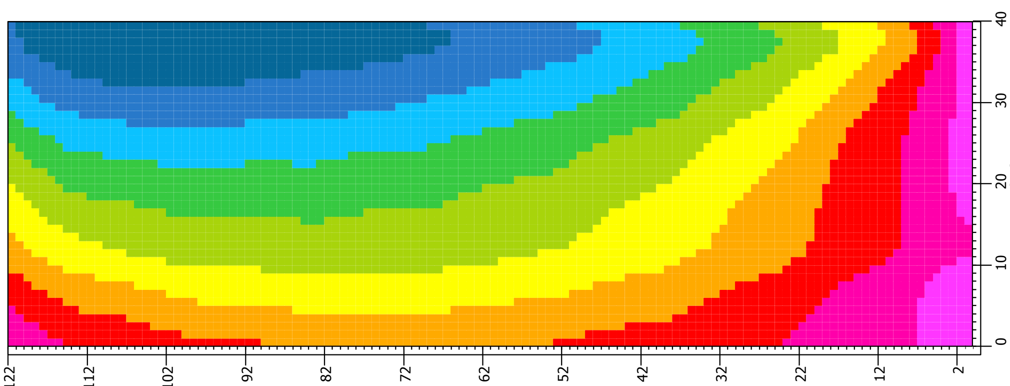


Fig 212: Simulation output _ Simulation type B3 _ NS _ RH _ at 11.30am

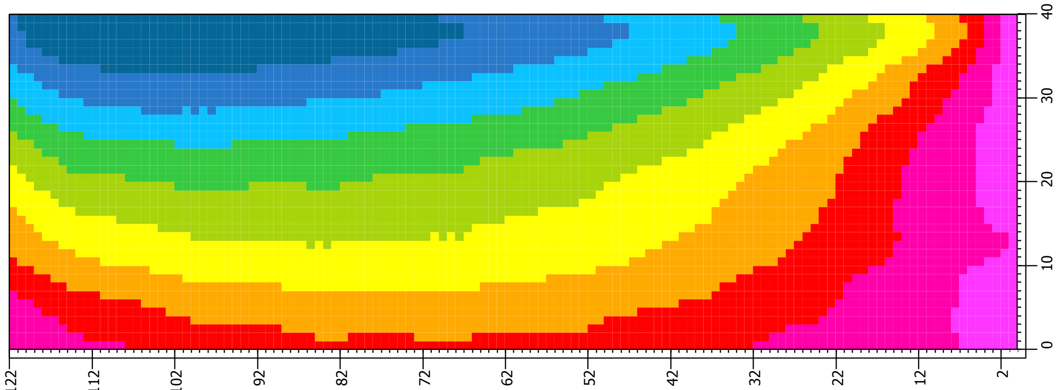


Fig 213: Simulation output _ Simulation type B3 _ NS _ RH _ at 12pm

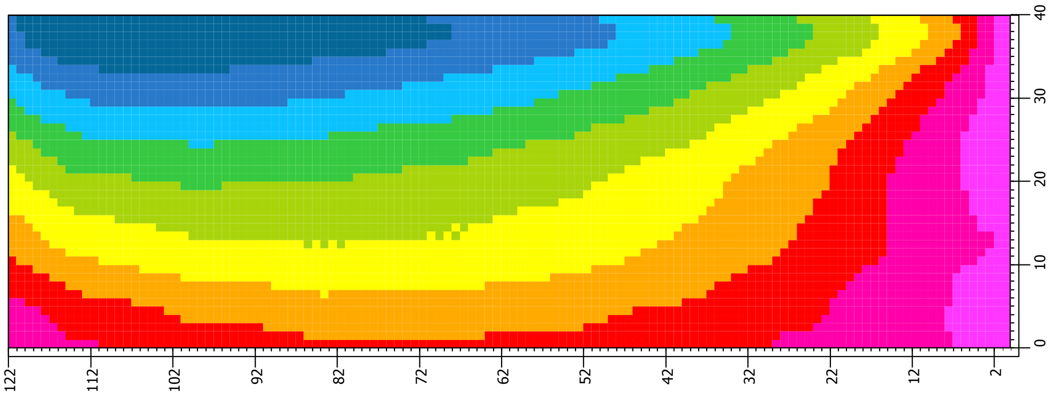


Fig 214: Simulation output _ Simulation type B3 _ NS _ RH _ at 12.30pm

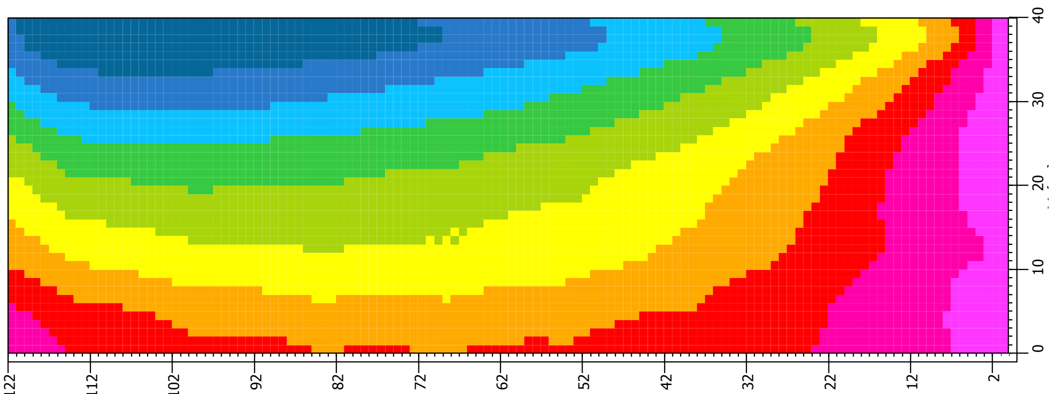


Fig 215: Simulation output _ Simulation type B3 _ NS _ RH _ at 1pm

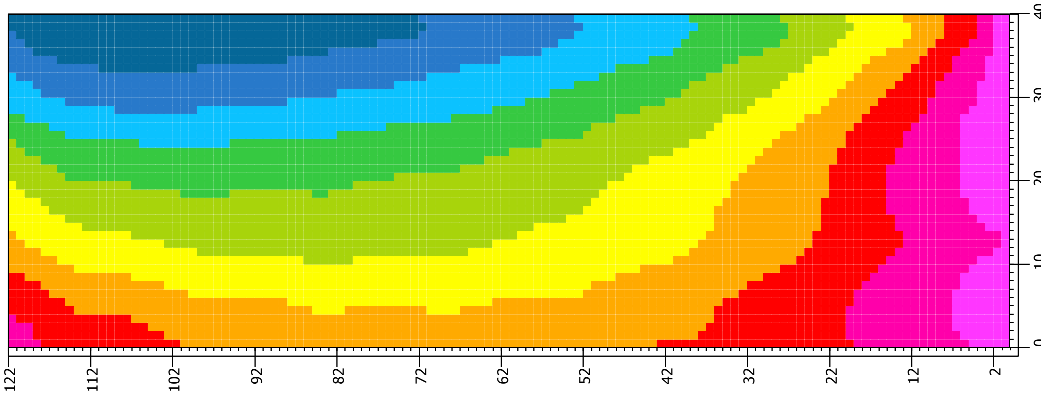


Fig 216: Simulation output _ Simulation type B3 _ NS _ RH _ at 1.30pm

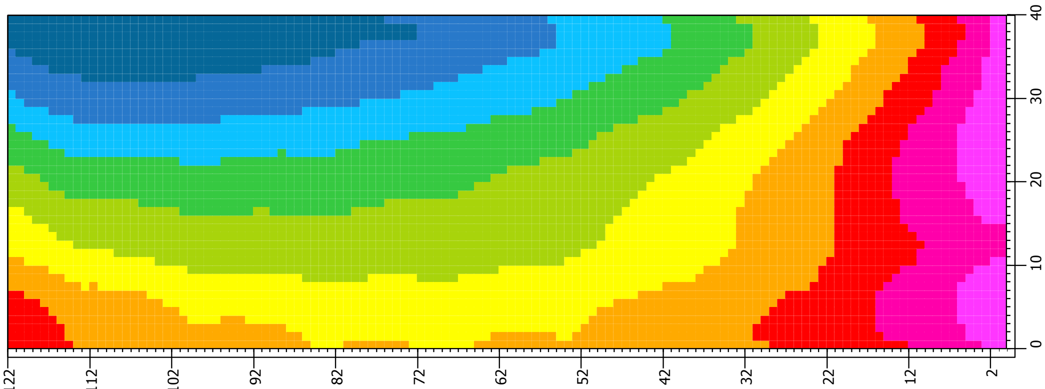
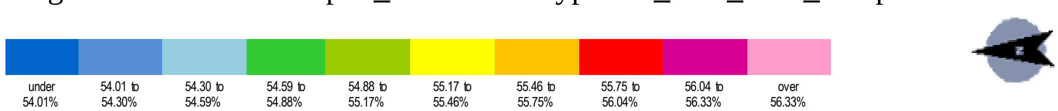


Fig 217: Simulation output _ Simulation type B3 _ NS _ RH _ at 2pm



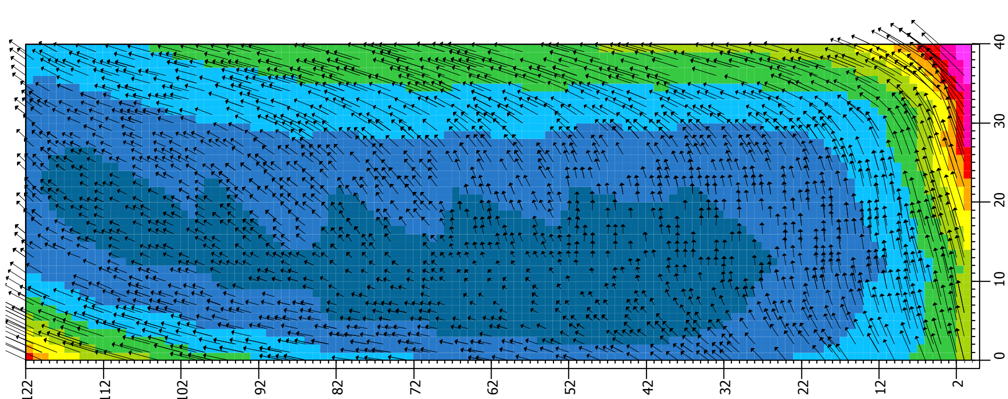


Fig 218: Simulation output _ Simulation type B3 _ NS _ WS _ at 11am

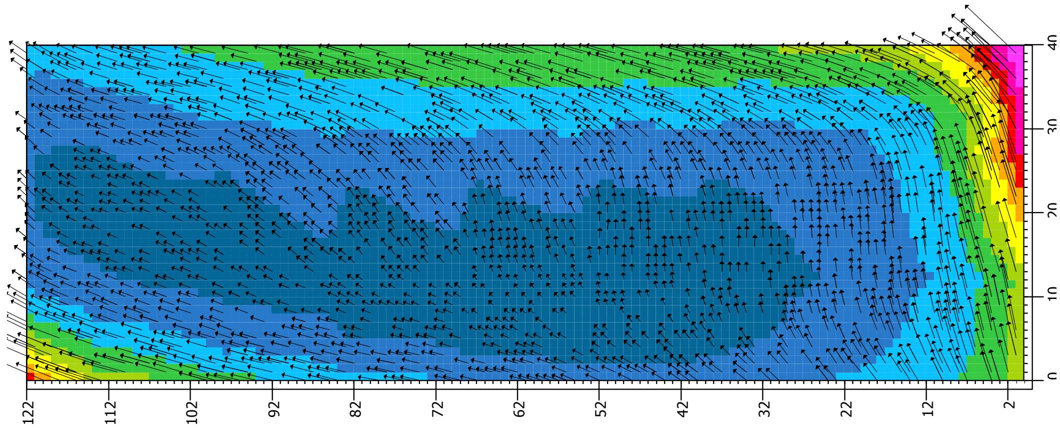


Fig 219: Simulation output _ Simulation type B3 _ NS _ WS _ at 11.30am

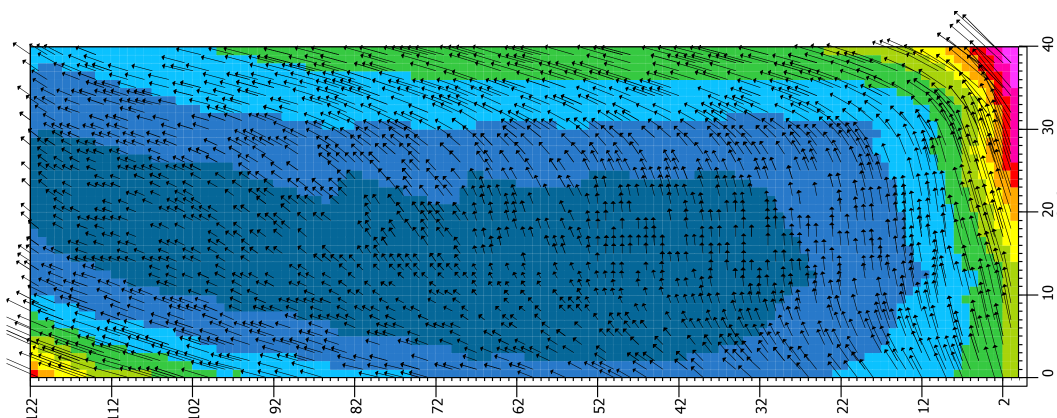


Fig 220: Simulation output _ Simulation type B3 _ NS _ WS _ at 12pm

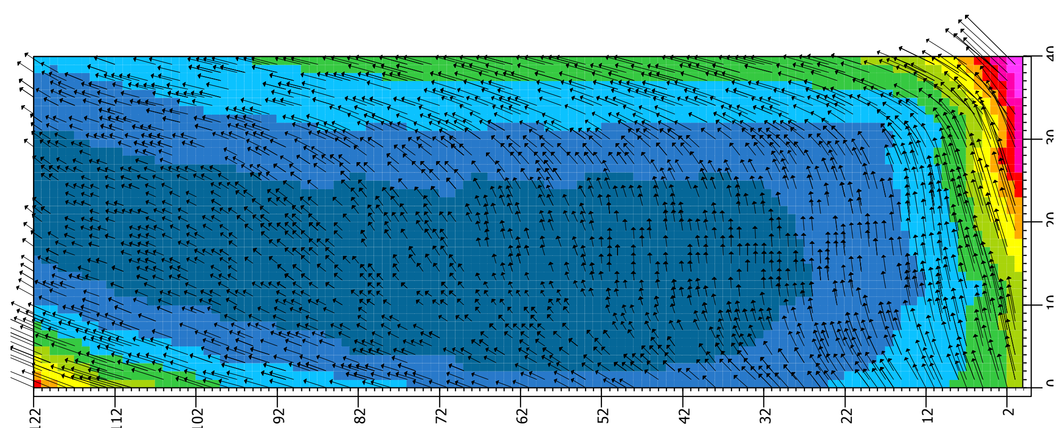


Fig 221: Simulation output _ Simulation type B3 _ NS _ WS _ at 12.30pm

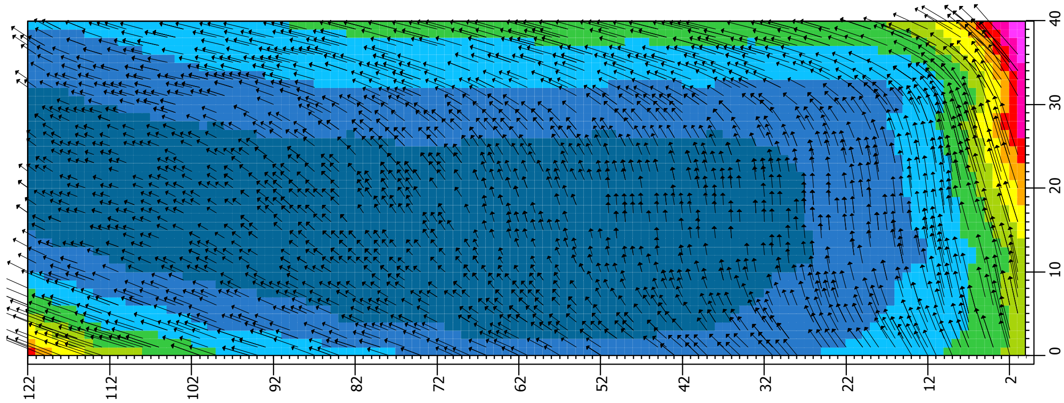


Fig 222: Simulation output _ Simulation type B3 _ NS _ WS _ at 1pm

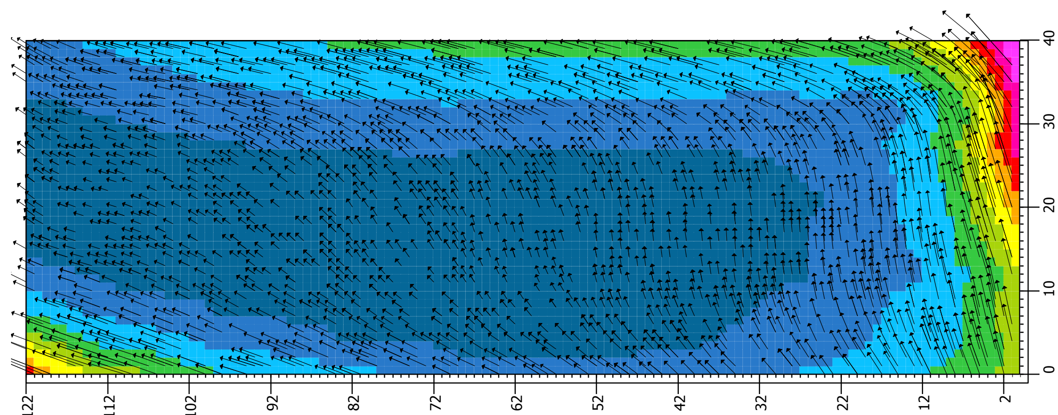


Fig 223: Simulation output _ Simulation type B3 _ NS _ WS _ at 1.30pm

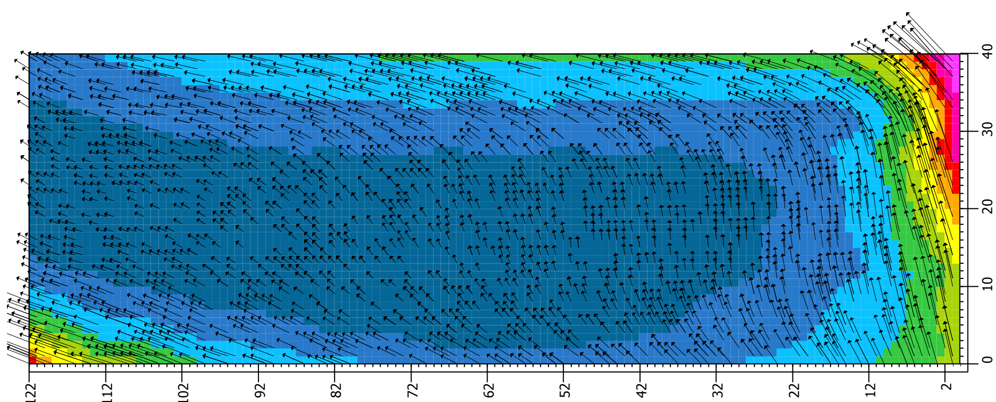
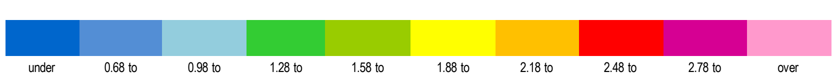
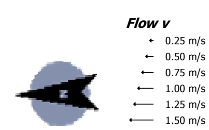


Fig 224: Simulation output _ Simulation type B3 _ NS _ WS _ at 2pm





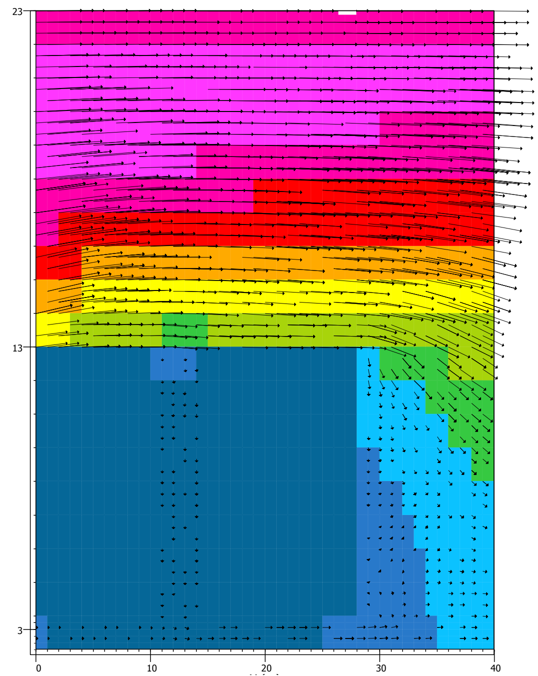


Fig 225: Simulation output _ Simulation type B3 _ NS _ WS _ section _ at 11am

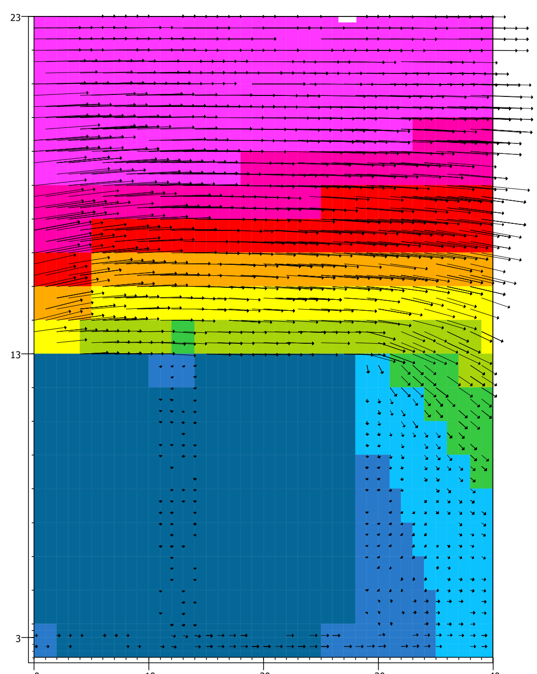


Fig 226: Simulation output _ Simulation type B3 _ NS _ WS _ section _ at 12pm

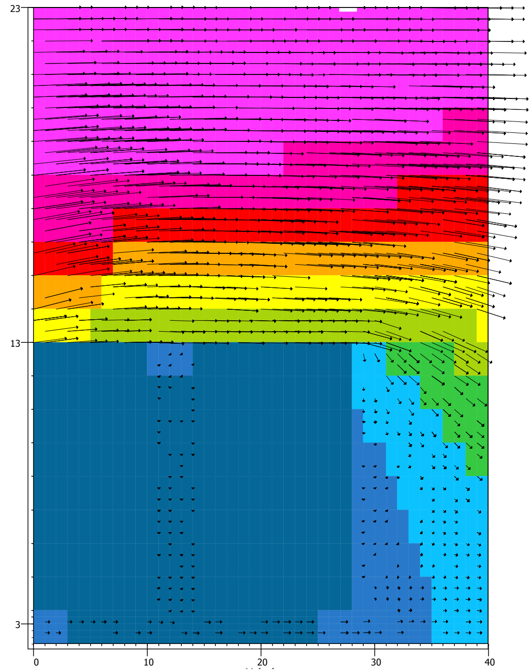


Fig 227: Simulation output _ Simulation type B3 _ NS _ WS _ section _ at 1pm

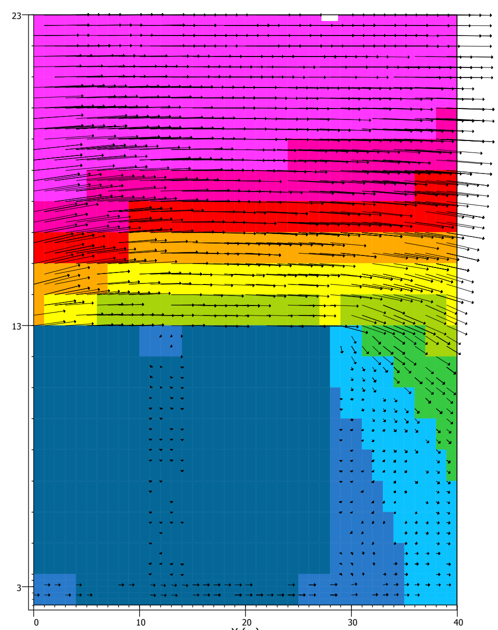
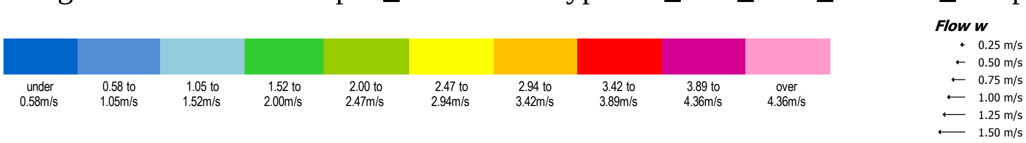


Fig 228: Simulation output _ Simulation type B3 _ NS _ WS _ section _ at 2pm



Simulation Outputs _ Simulation Typologies [ST]: East-West [EW] Orientation

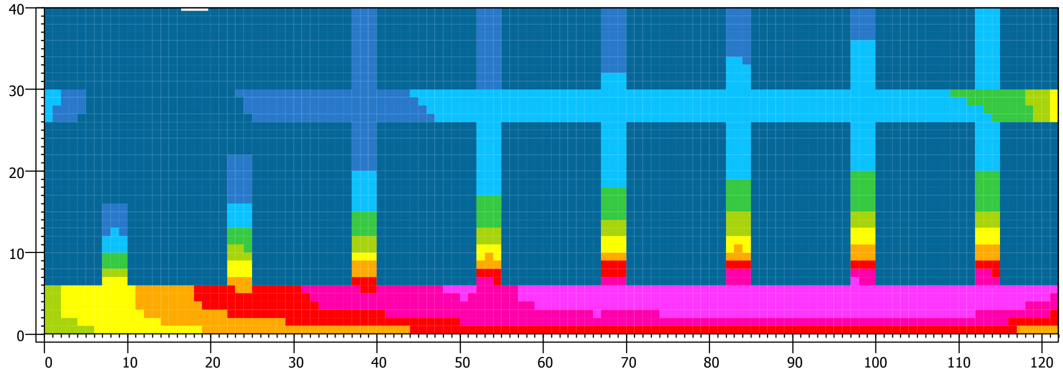


Fig 229: Simulation output _ Simulation type A _ EW _ DBT at 11am

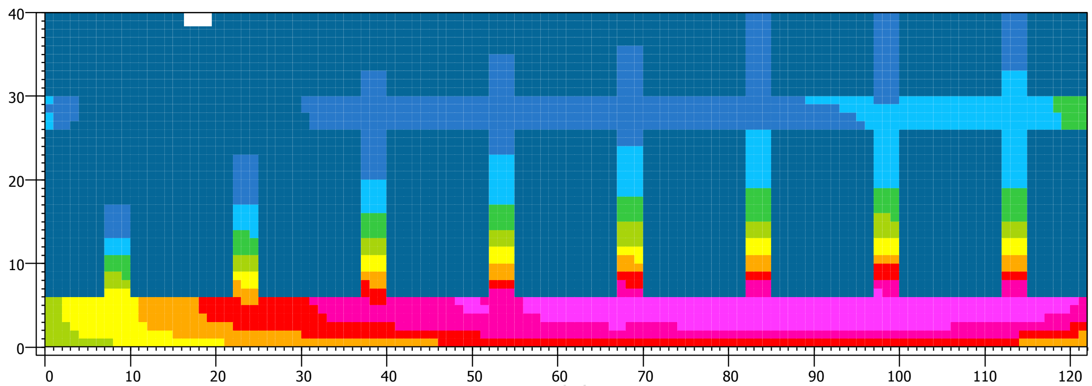


Fig 230: Simulation output _ Simulation type A _ EW _ DBT at 11.30am

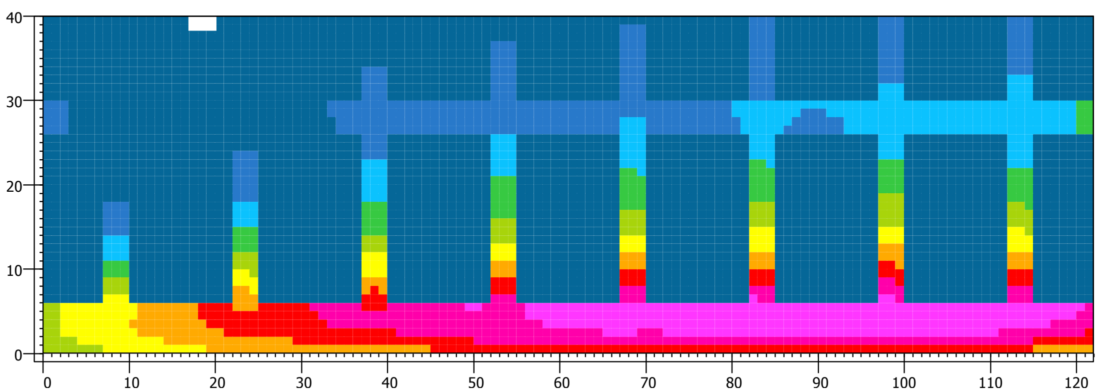


Fig 231: Simulation output _ Simulation type A _ EW _ DBT at 12pm

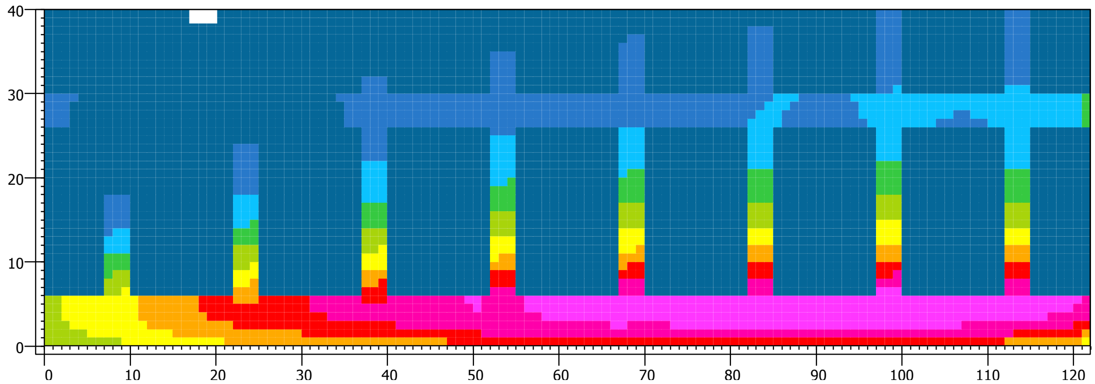


Fig 232: Simulation output _ Simulation type A _ EW _ DBT at 12.30pm

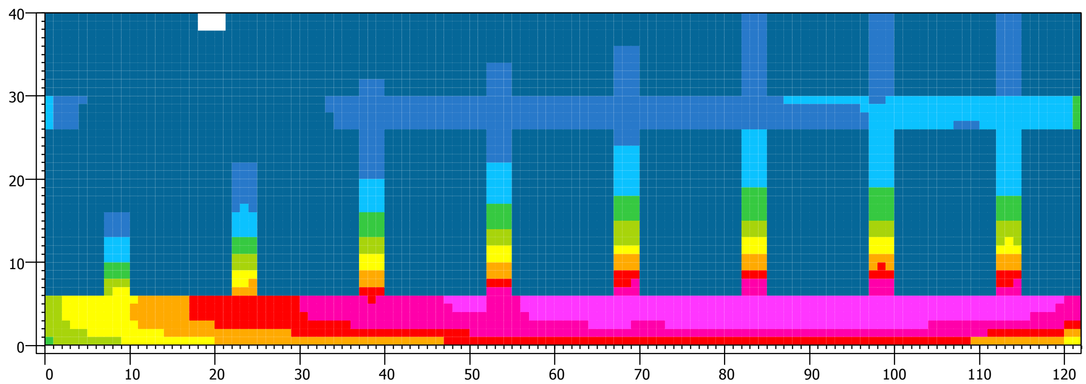


Fig 233: Simulation output _ Simulation type A _ EW _ DBT at 1pm

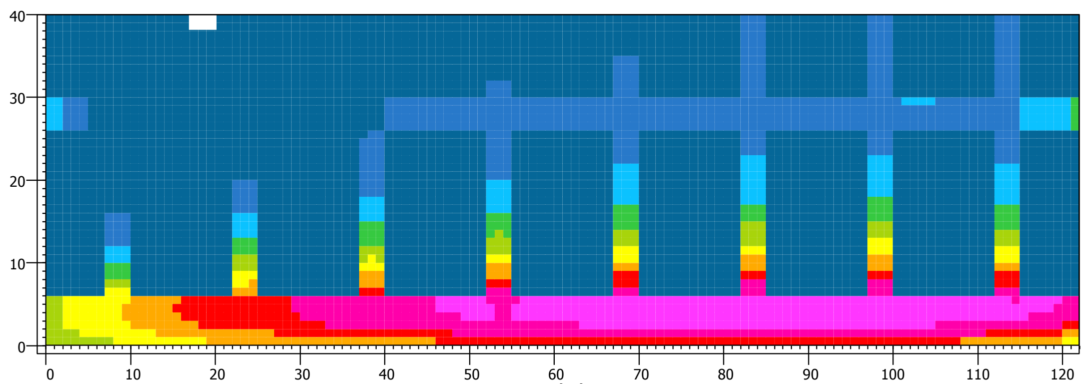


Fig 234: Simulation output _ Simulation type A _ EW _ DBT at 1.30pm

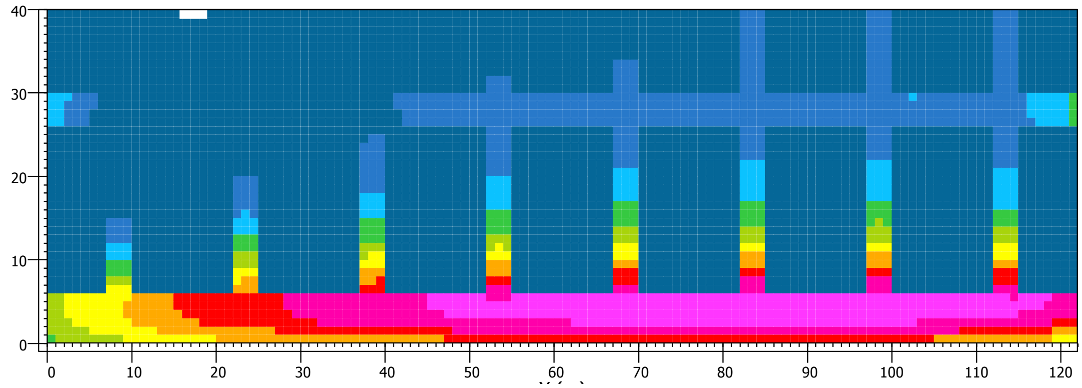
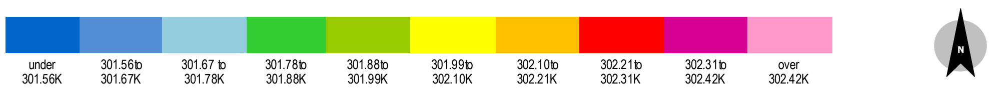


Fig 235: Simulation output _ Simulation type A _ EW _ DBT at 2pm



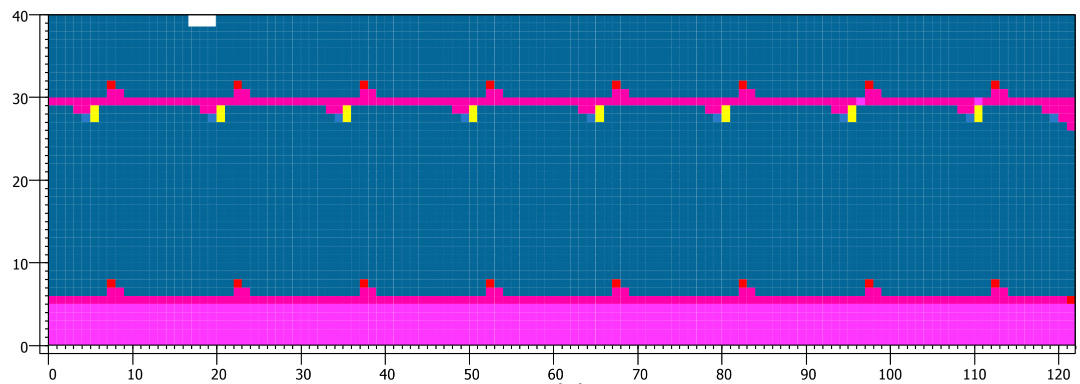


Fig 236: Simulation output _ Simulation type A _ EW _ MRT at 11am

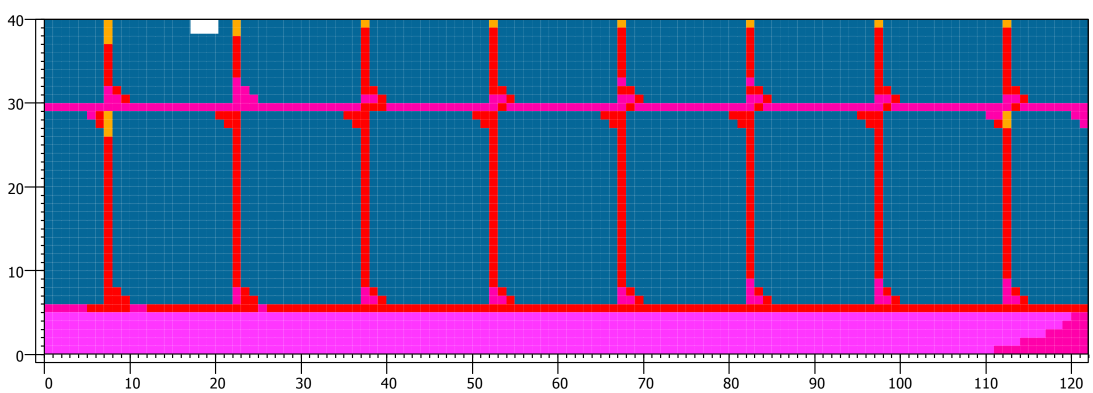


Fig 237: Simulation output _ Simulation type A _ EW _ MRT at 11.30am

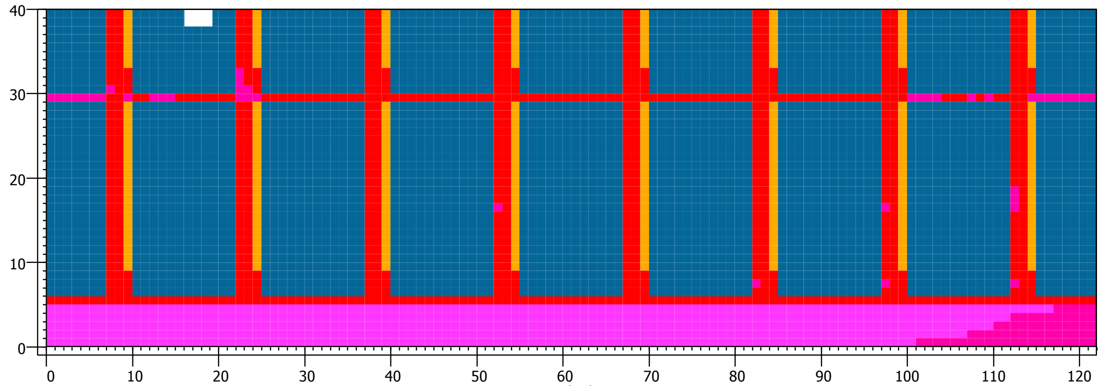


Fig 238: Simulation output _ Simulation type A _ EW _ MRT at 12pm

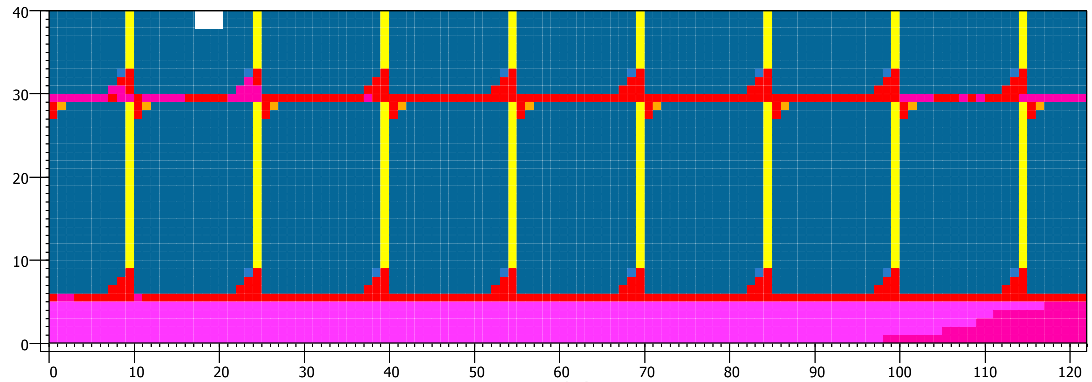


Fig 239: Simulation output _ Simulation type A _ EW _ MRT at 12.30pm

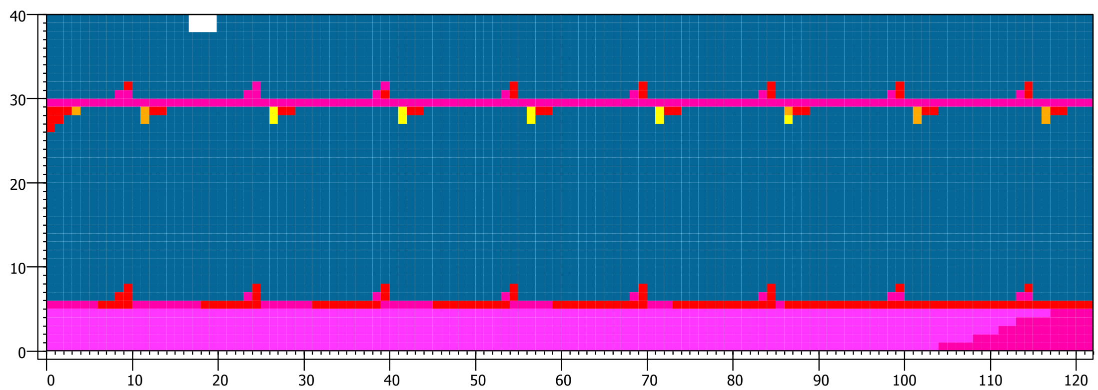


Fig 240: Simulation output _ Simulation type A _ EW _ MRT at 1pm

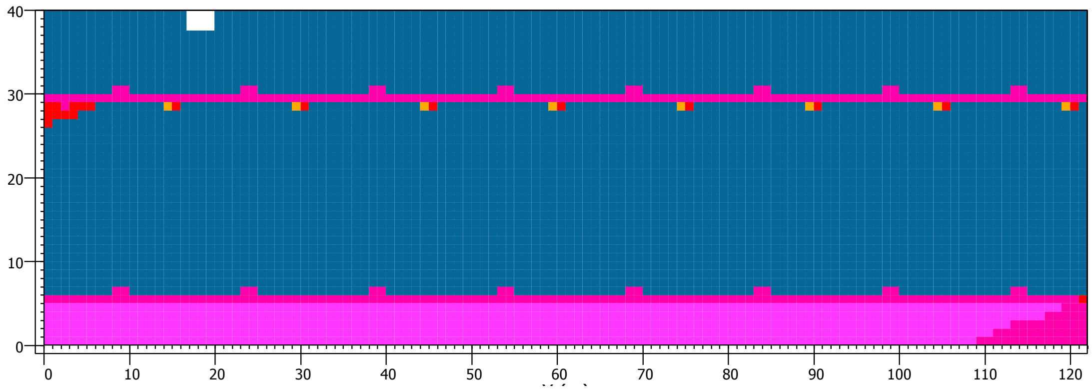


Fig 241: Simulation output _ Simulation type A _ EW _ MRT at 1.30pm

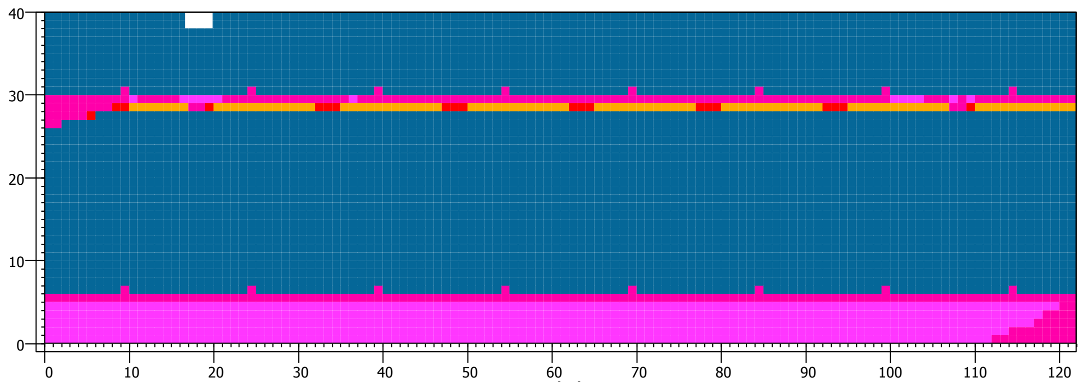
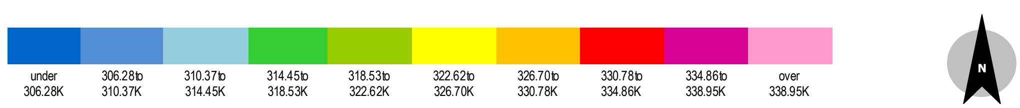


Fig 242: Simulation output _ Simulation type A _ EW _ MRT at 2pm



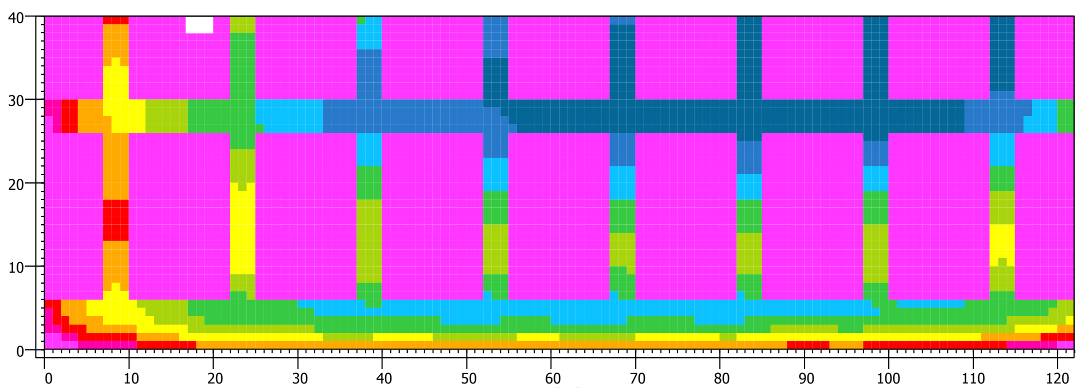


Fig 243: Simulation output _ Simulation type A _ EW _ RH at 11am

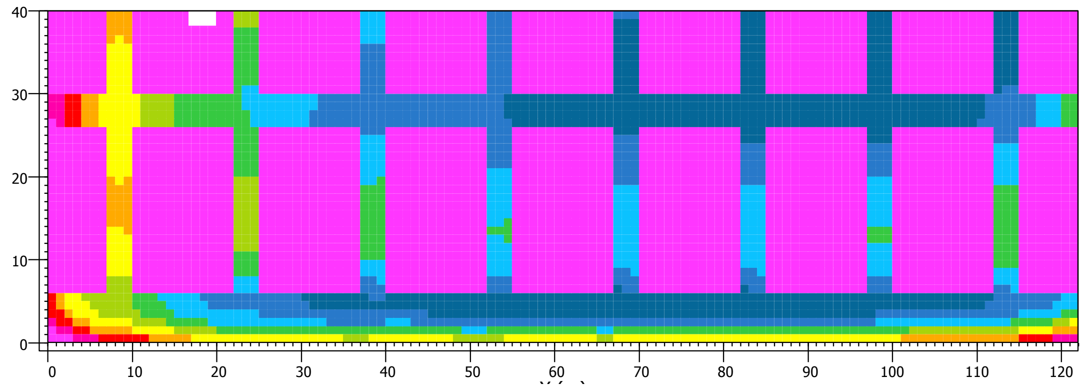


Fig 244: Simulation output _ Simulation type A _ EW _ RH at 11.30am

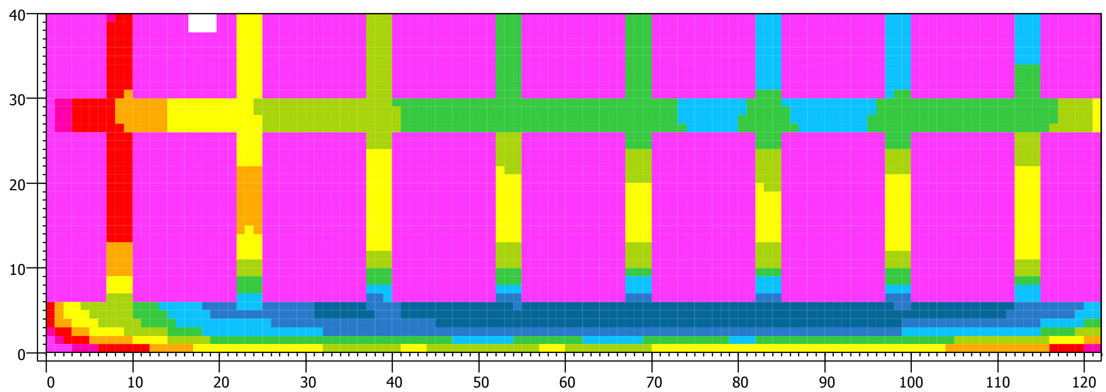


Fig 245: Simulation output _ Simulation type A _ EW _ RH at 12pm

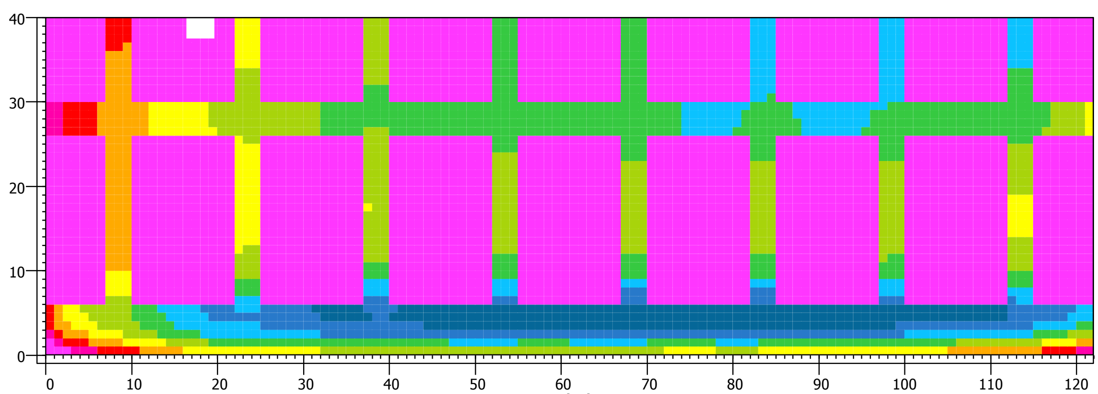


Fig 246: Simulation output _ Simulation type A _ EW _ RH at 12.30pm

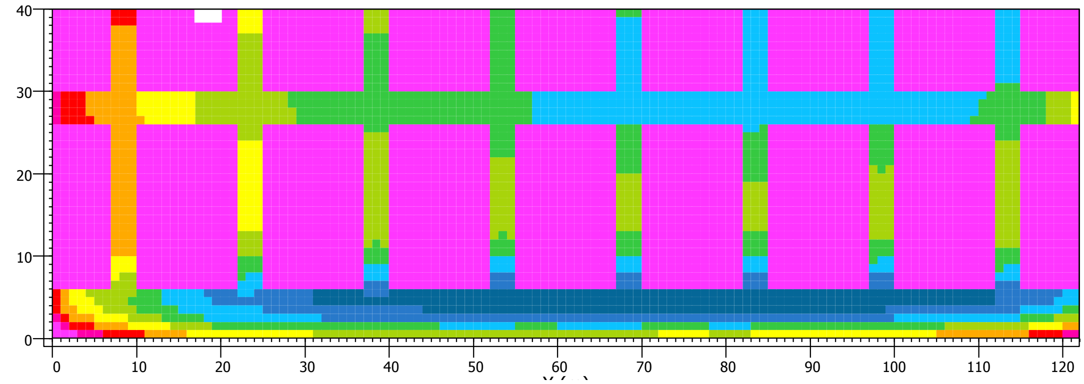


Fig 247: Simulation output _ Simulation type A _ EW _ RH at 1pm

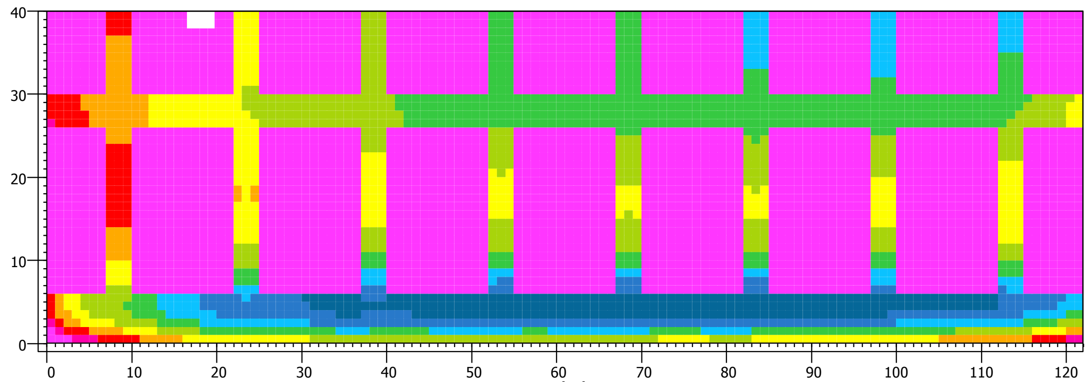


Fig 248: Simulation output _ Simulation type A _ EW _ RH at 1.30pm

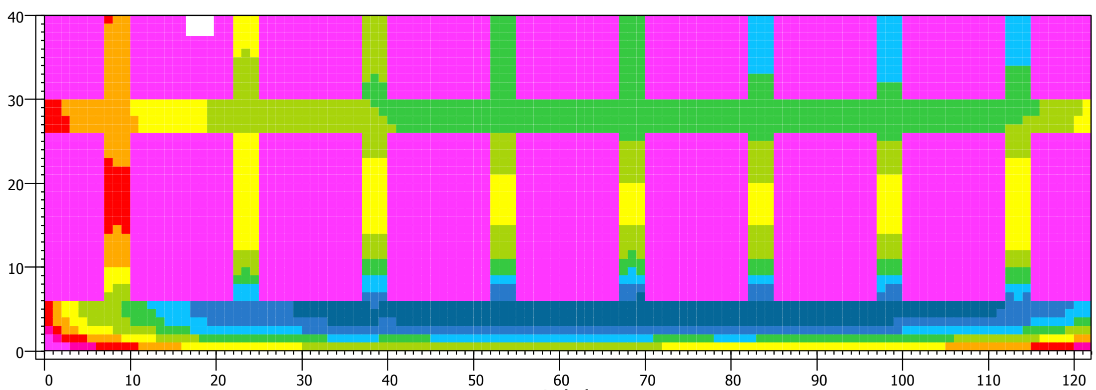
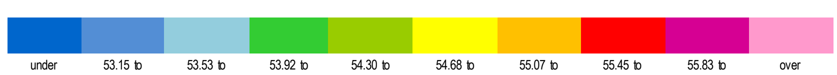
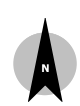


Fig 249: Simulation output _ Simulation type A _ EW _ RH at 2pm





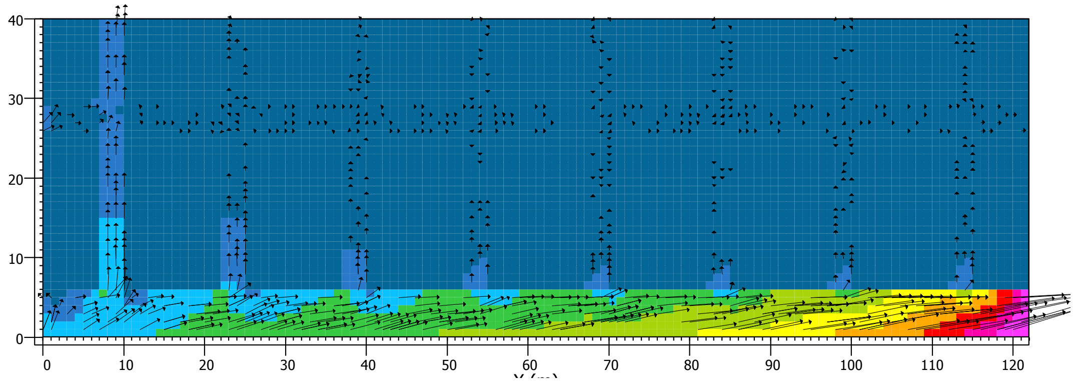


Fig 250: Simulation output _ Simulation type A _ EW _ WS at 11am

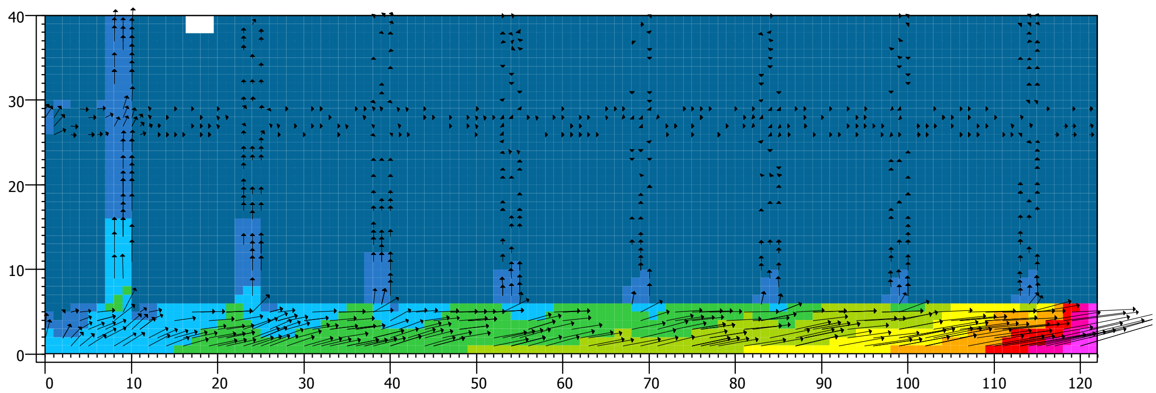


Fig 251: Simulation output _ Simulation type A _ EW _ WS at 11.30am

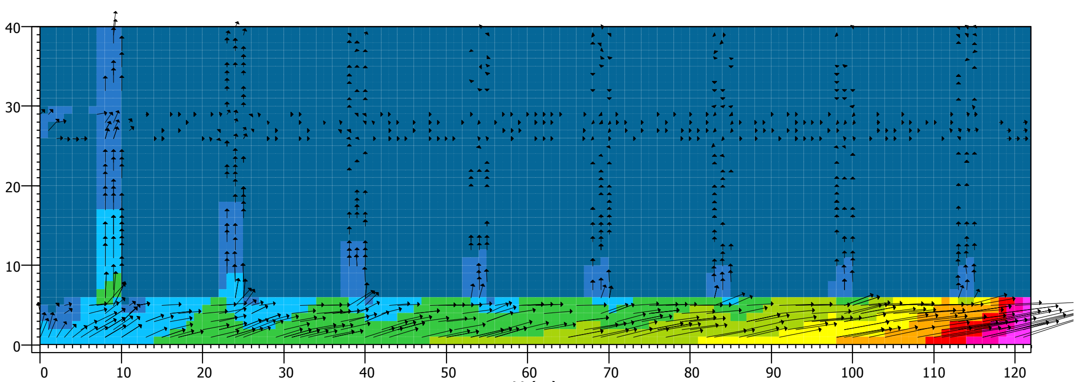


Fig 252: Simulation output _ Simulation type A _ EW _ WS at 12pm

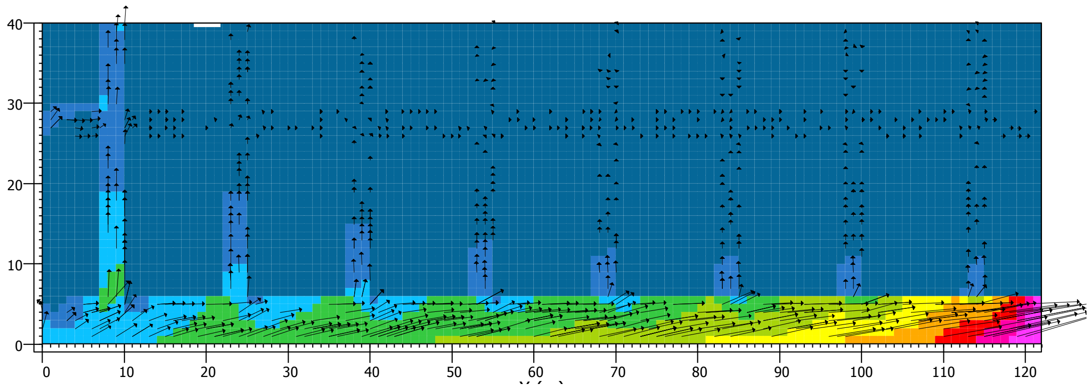


Fig 253: Simulation output _ Simulation type A _ EW _ WS at 12.30pm

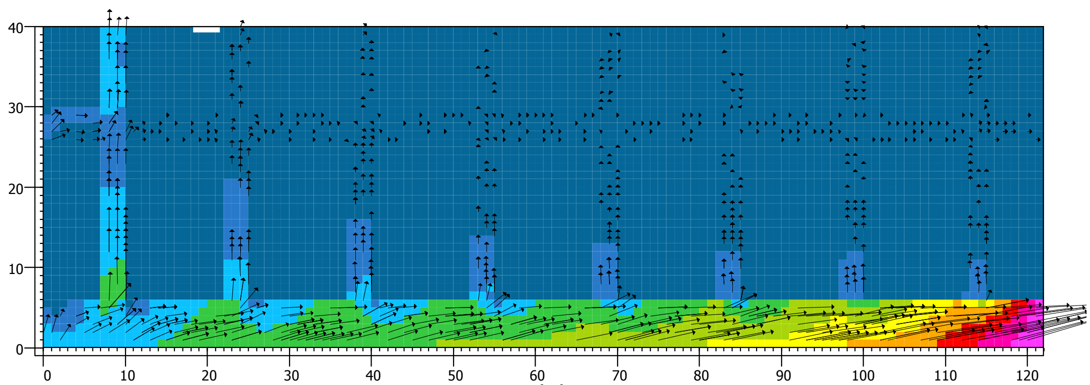


Fig 254: Simulation output _ Simulation type A _ EW _ WS at 1pm

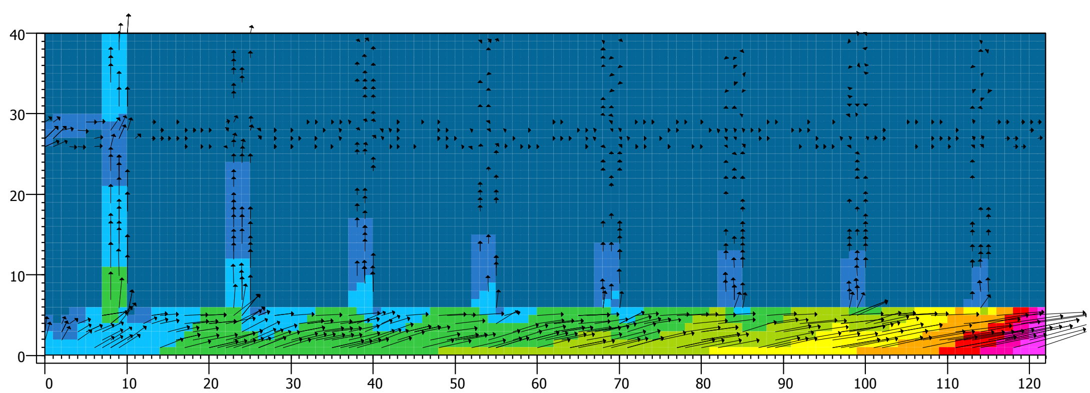


Fig 256: Simulation output _ Simulation type A _ EW _ WS at 1.30pm

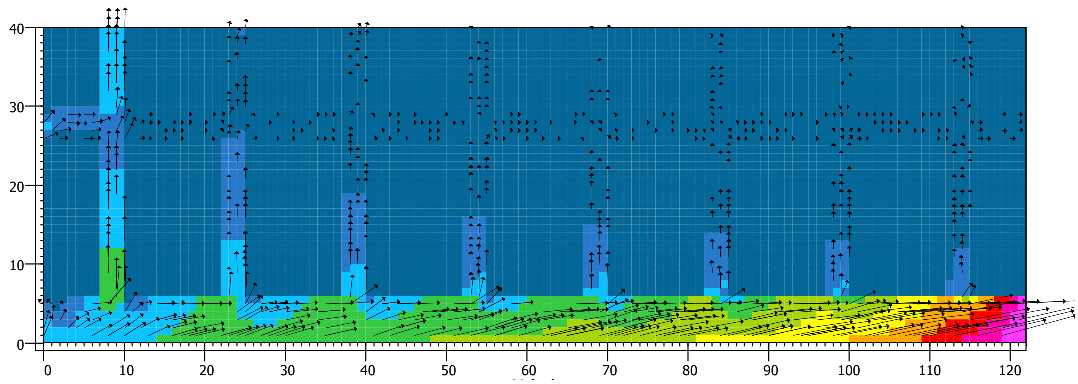
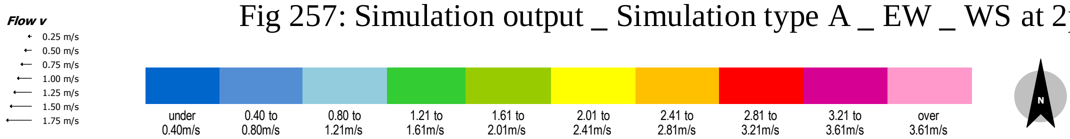


Fig 257: Simulation output _ Simulation type A _ EW _ WS at 2pm



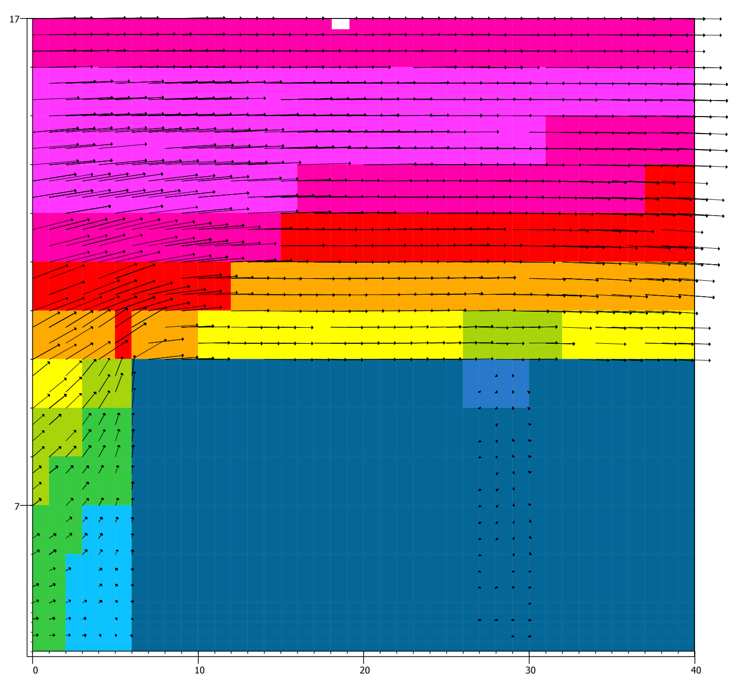


Fig 258: Simulation output _ Simulation type A _ EW _ WS _section _ at 11am

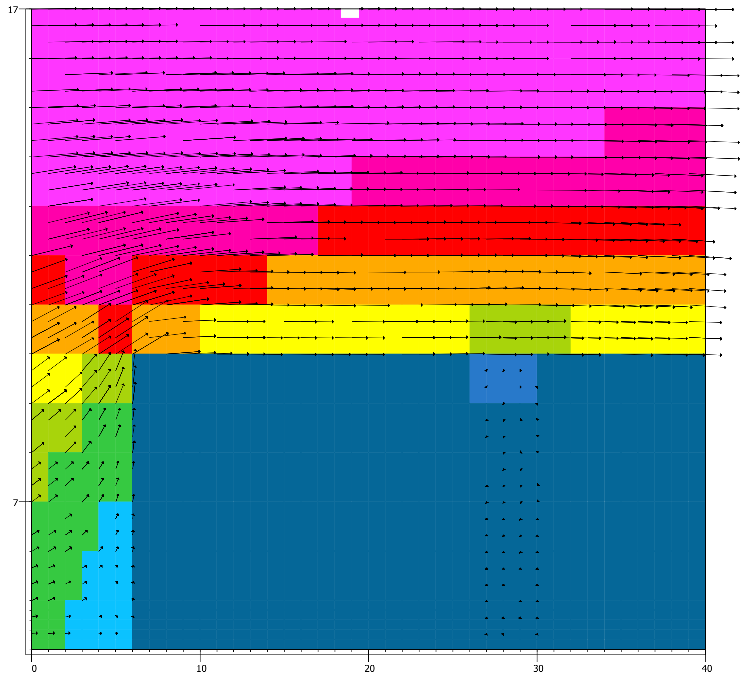


Fig 259: Simulation output _ Simulation type A _ EW _ WS _section _ at 12pm

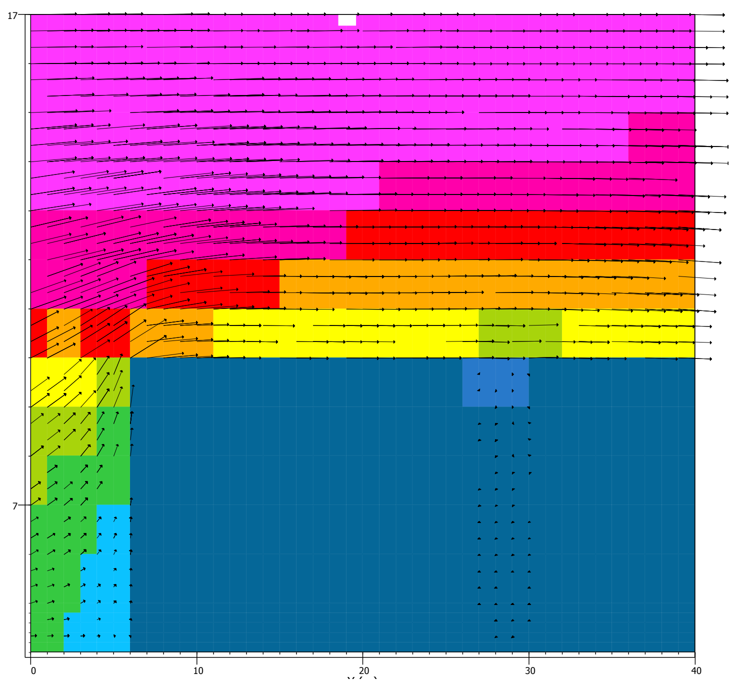


Fig 260: Simulation output _ Simulation type A _ EW _ WS _section _ at 1pm

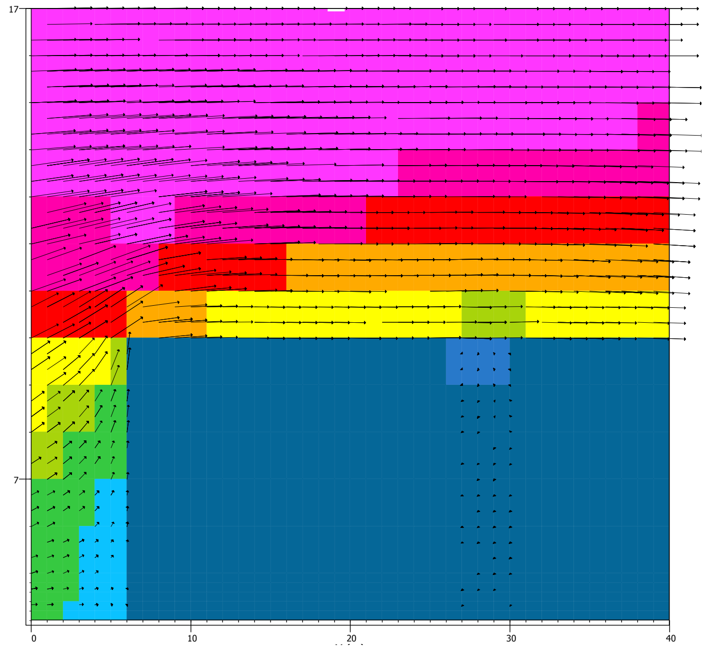
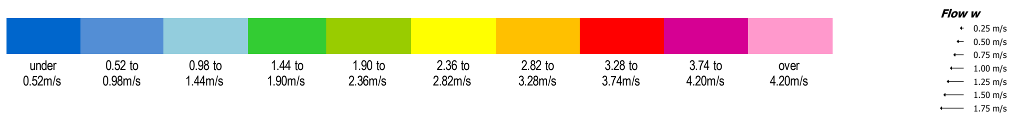


Fig 261: Simulation output _ Simulation type A _ EW _ WS _section _ at 2pm



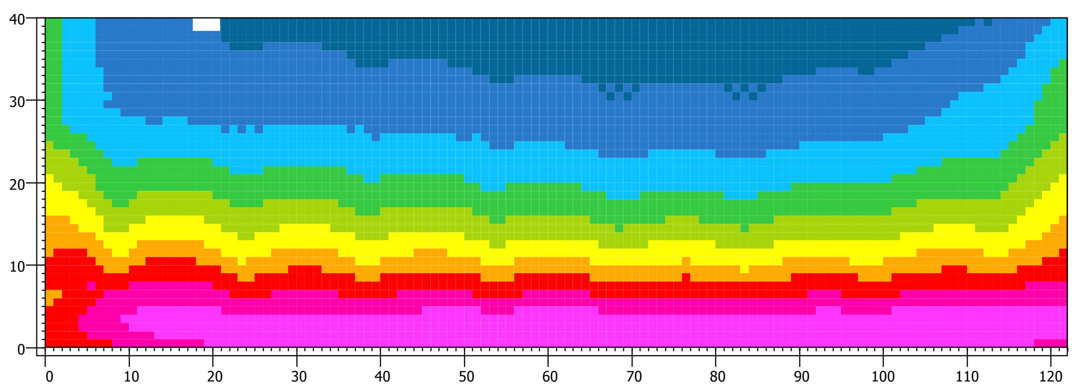


Fig 262: Simulation output _ Simulation type A1 _ EW _ DBT _ at 11am

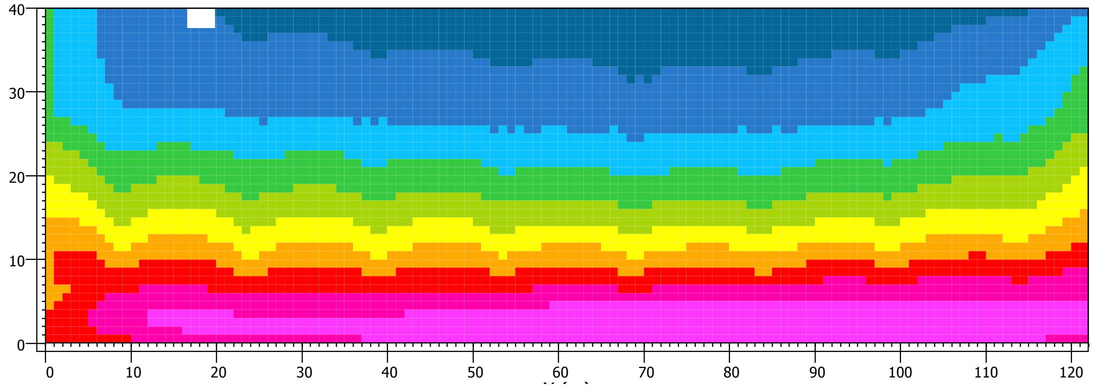


Fig 263: Simulation output _ Simulation type A1 _ EW _ DBT _ at 11.30am

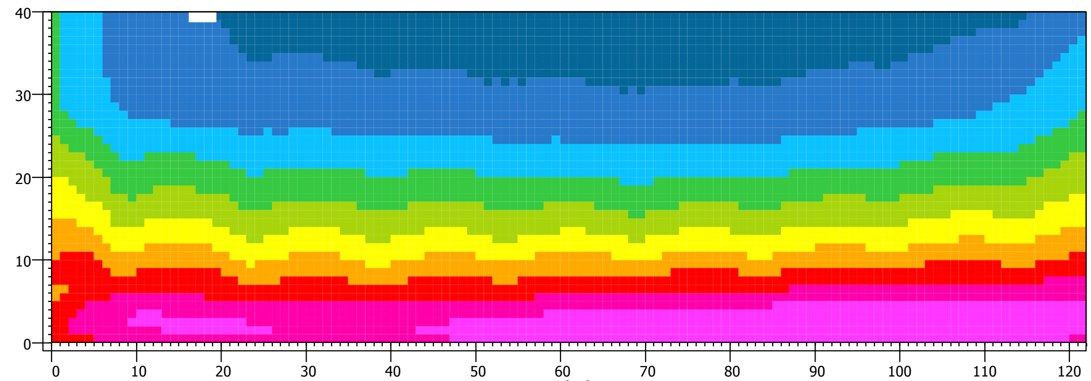


Fig 264: Simulation output _ Simulation type A1 _ EW _ DBT _ at 12pm

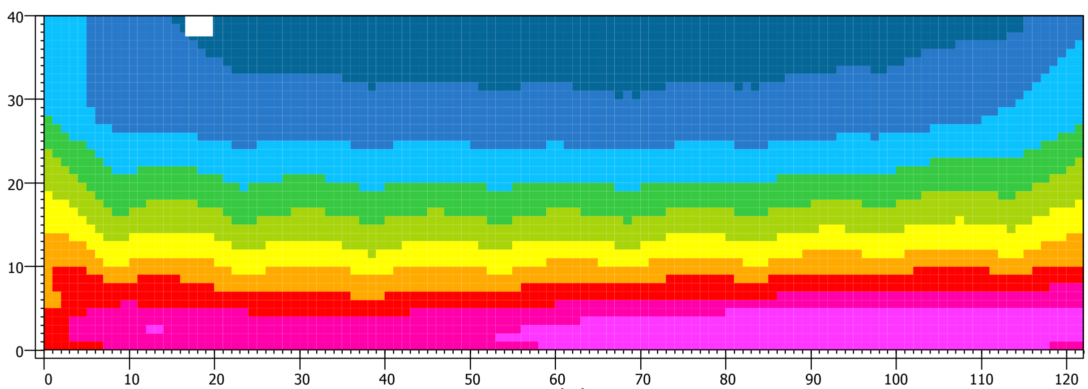


Fig 265: Simulation output _ Simulation type A1 _ EW _ DBT _ at 12.30pm

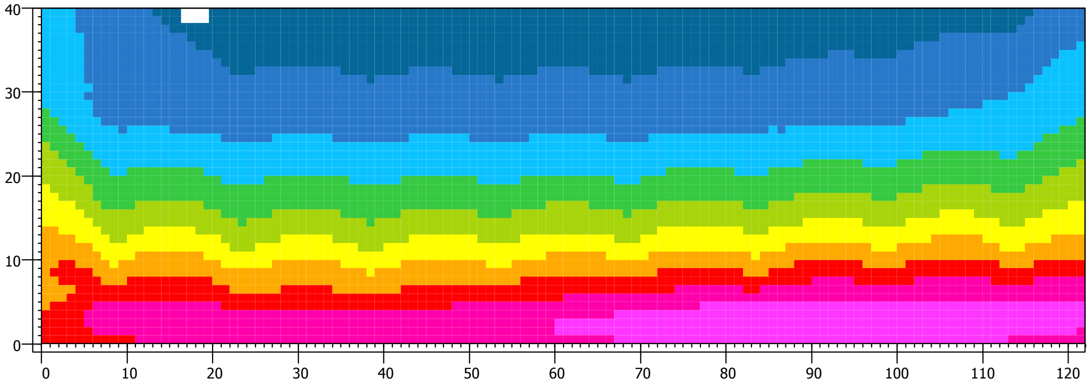


Fig 266: Simulation output _ Simulation type A1 _ EW _ DBT _ at 1pm

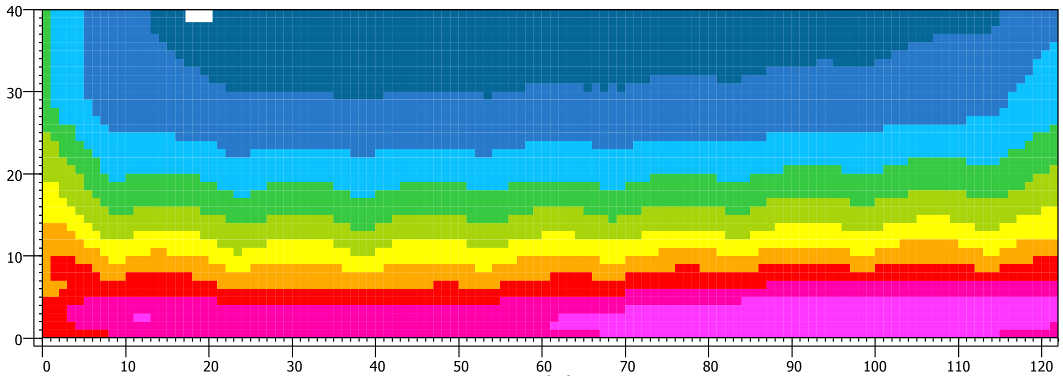


Fig 267: Simulation output _ Simulation type A1 _ EW _ DBT _ at 1.30pm

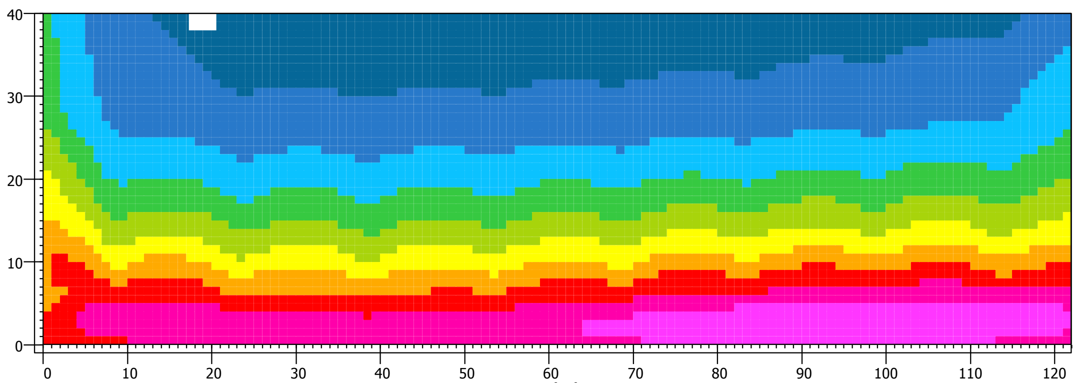
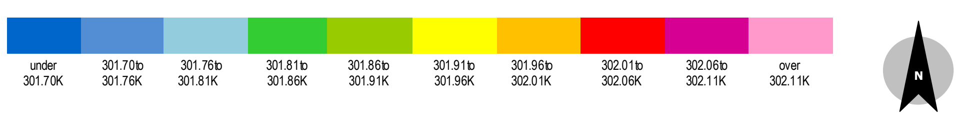


Fig 268: Simulation output _ Simulation type A1 _ EW _ DBT _ at 2pm



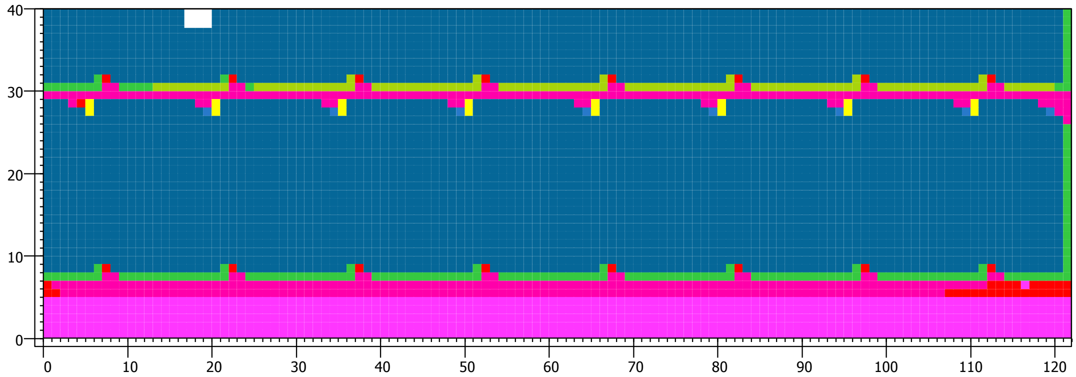


Fig 269: Simulation output _ Simulation type A1 _ EW _ MRT _ at 11am

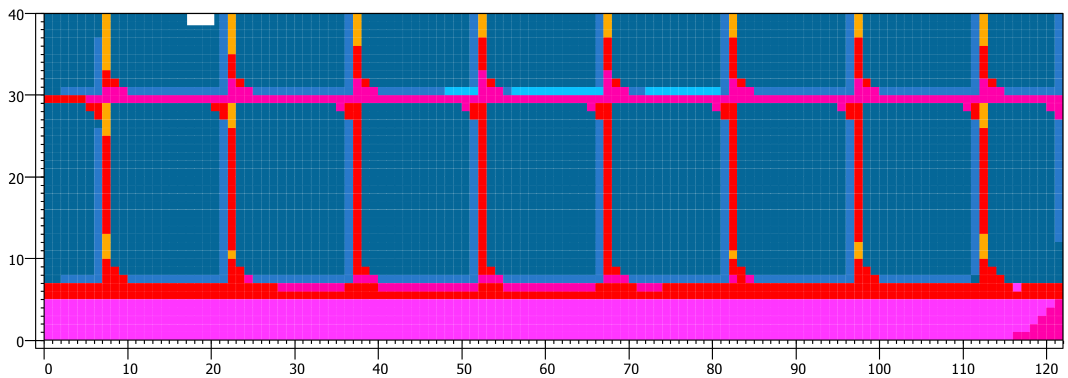


Fig 270: Simulation output _ Simulation type A1 _ EW _ MRT _ at 11.30am

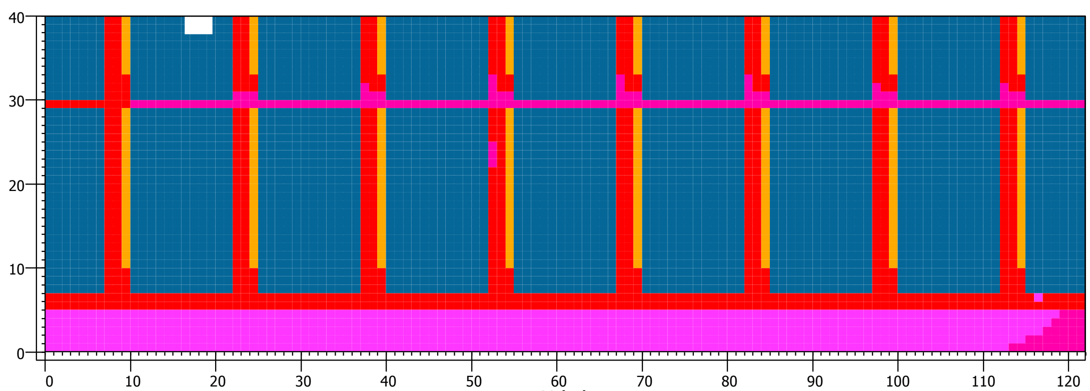


Fig 271: Simulation output _ Simulation type A1 _ EW _ MRT _ at 12pm

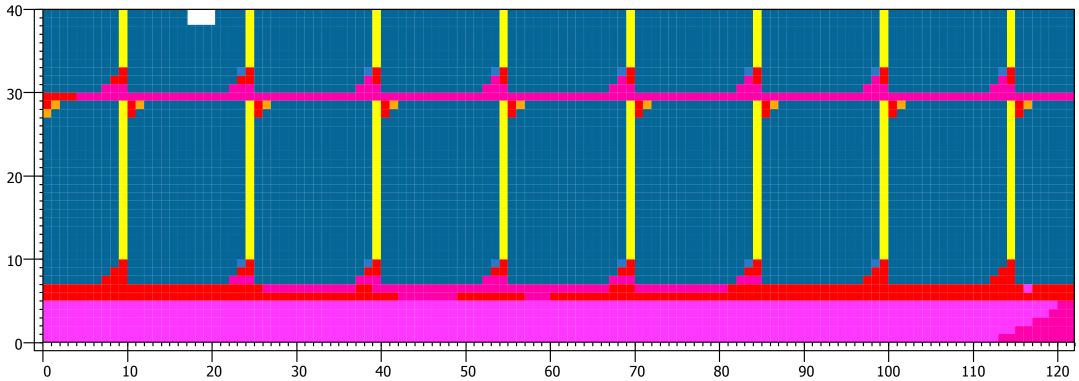


Fig 272: Simulation output _ Simulation type A1 _ EW _ MRT _ at 12.30pm

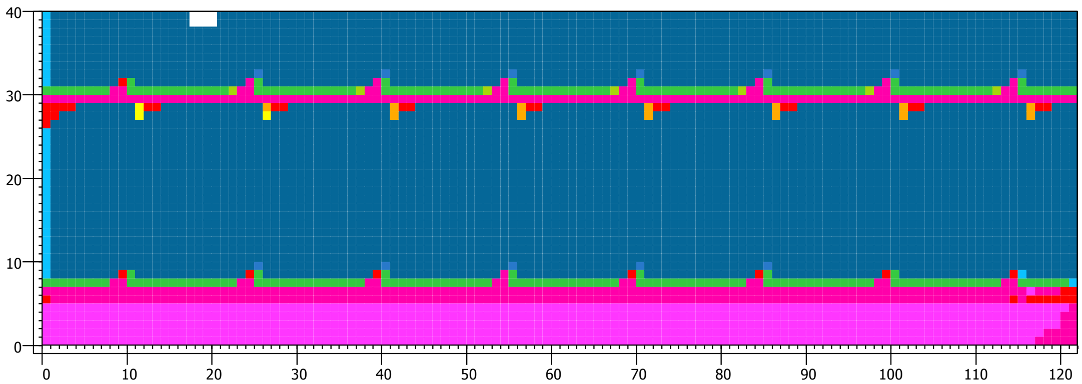


Fig 273: Simulation output _ Simulation type A1 _ EW _ MRT _ at 1pm

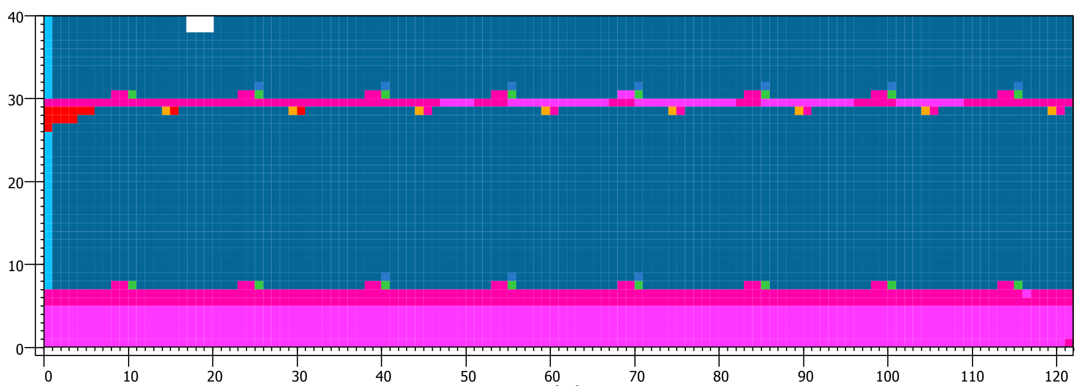


Fig 274: Simulation output _ Simulation type A1 _ EW _ MRT _ at 1.30pm

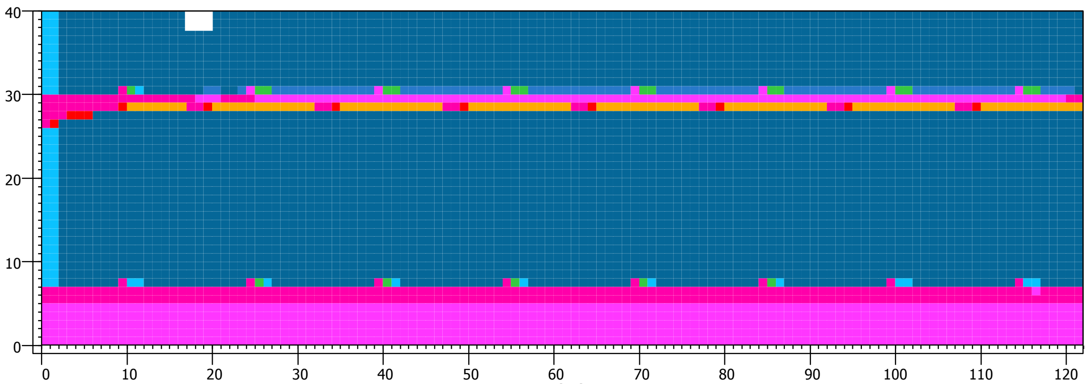
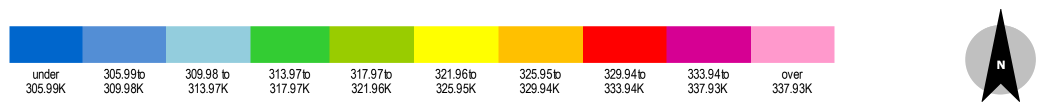


Fig 275: Simulation output _ Simulation type A1 _ EW _ MRT _ at 2pm



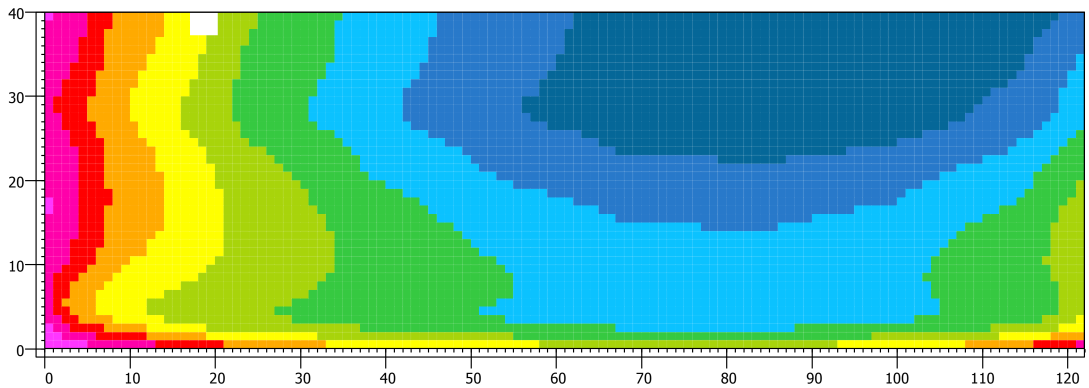


Fig 276: Simulation output _ Simulation type A1 _ EW _ RH _ at 11am

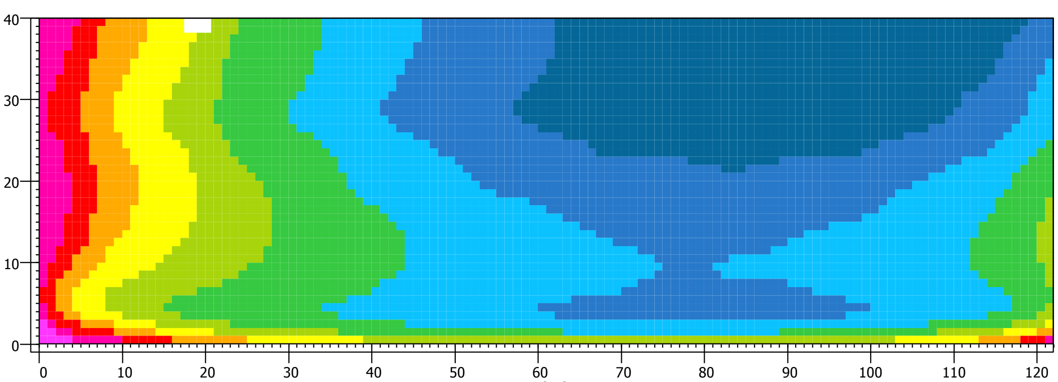


Fig 277: Simulation output _ Simulation type A1 _ EW _ RH _ at 11.30am

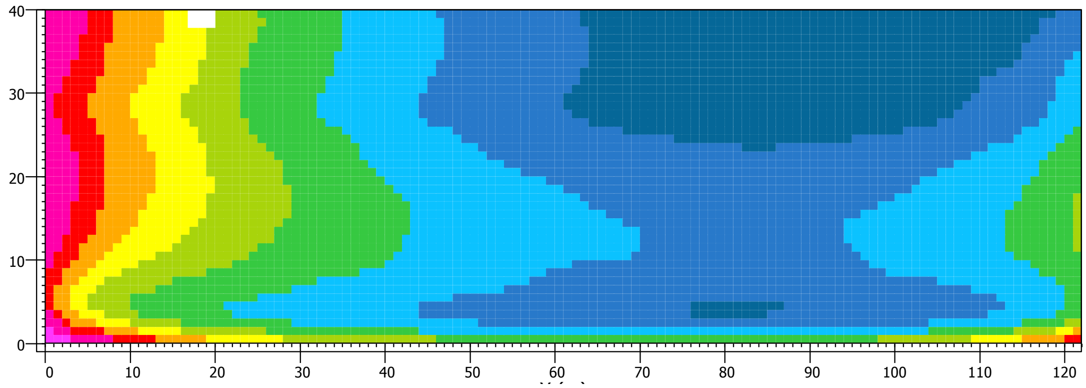


Fig 278: Simulation output _ Simulation type A1 _ EW _ RH _ at 12pm

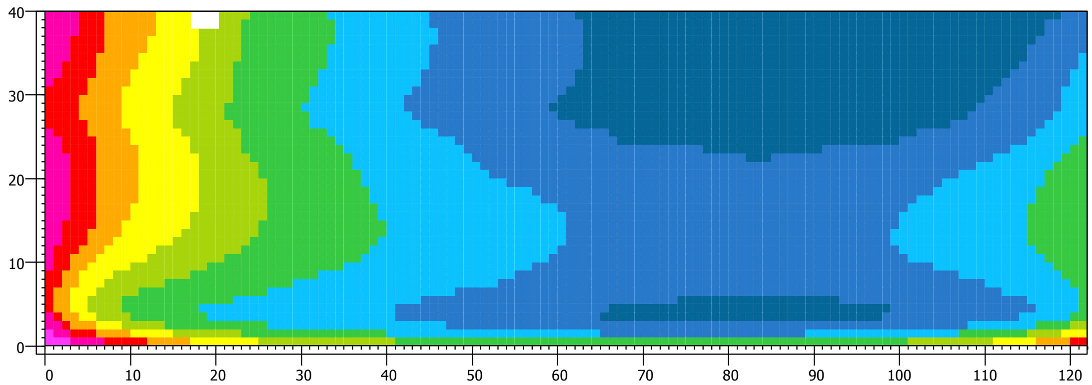


Fig 279: Simulation output _ Simulation type A1 _ EW _ RH _ at 12.30pm

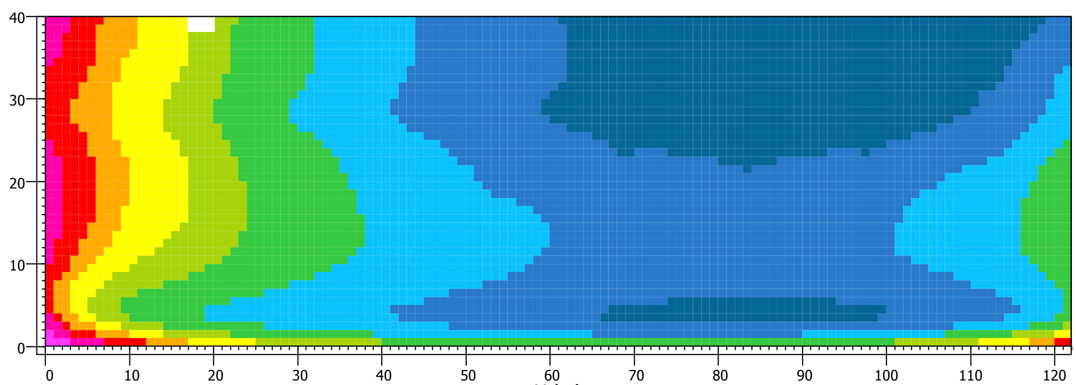


Fig 280: Simulation output _ Simulation type A1 _ EW _ RH _ at 1pm

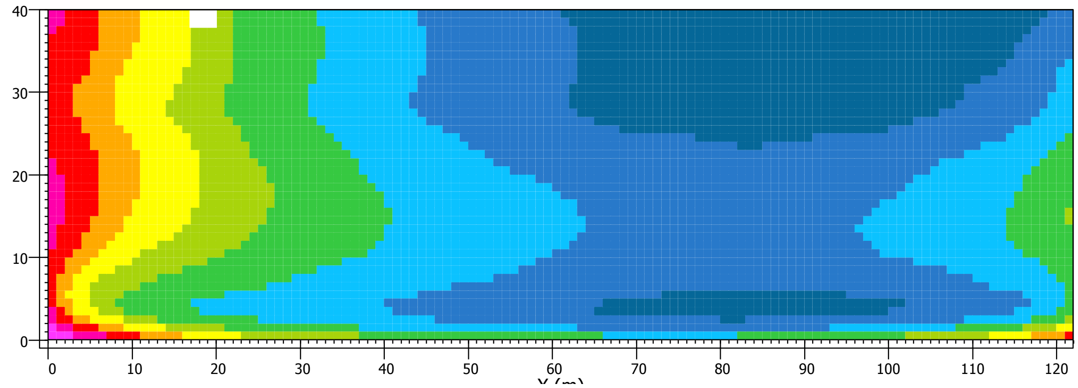


Fig 281: Simulation output _ Simulation type A1 _ EW _ RH _ at 1.30pm

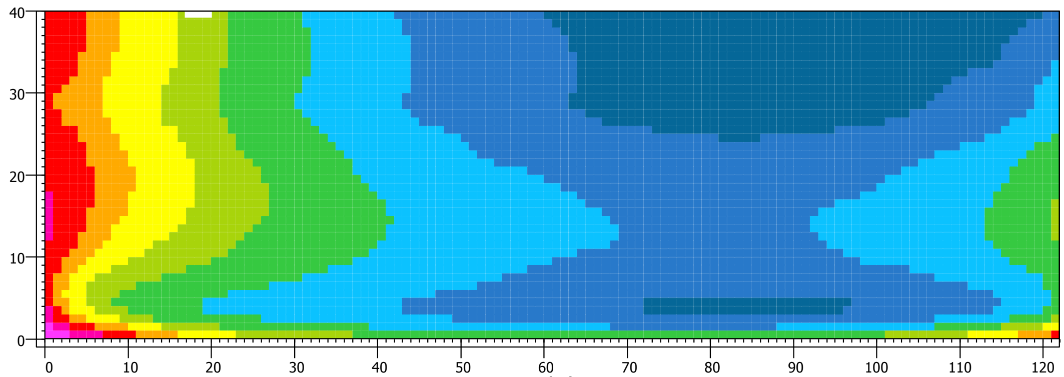
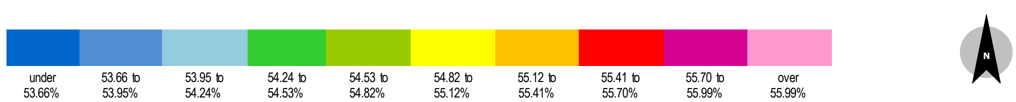


Fig 282: Simulation output _ Simulation type A1 _ EW _ RH _ at 2pm



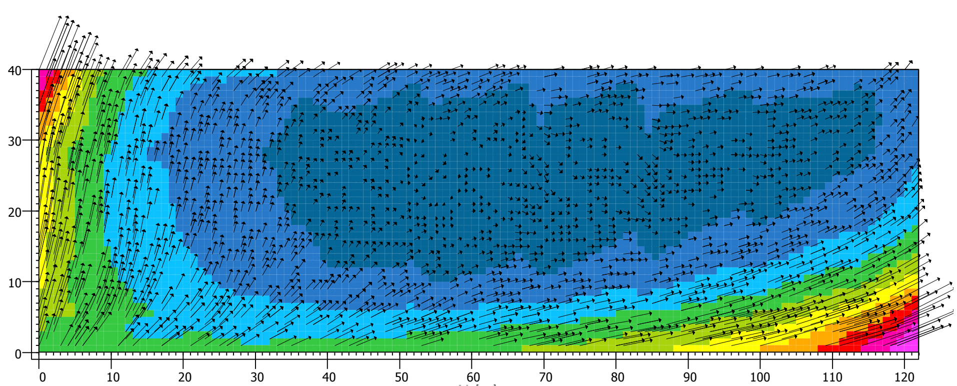


Fig 283: Simulation output _ Simulation type A1 _ EW _ WS _ at 11am

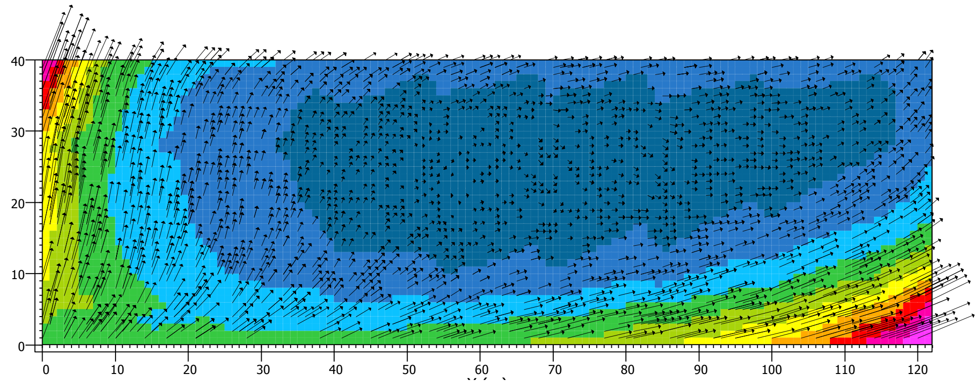


Fig 284: Simulation output _ Simulation type A1 _ EW _ WS _ at 11.30am

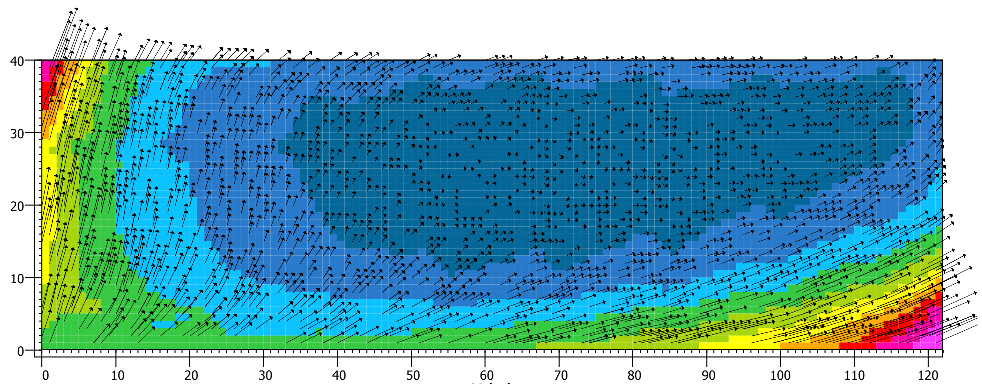


Fig 285: Simulation output _ Simulation type A1 _ EW _ WS _ at 12pm

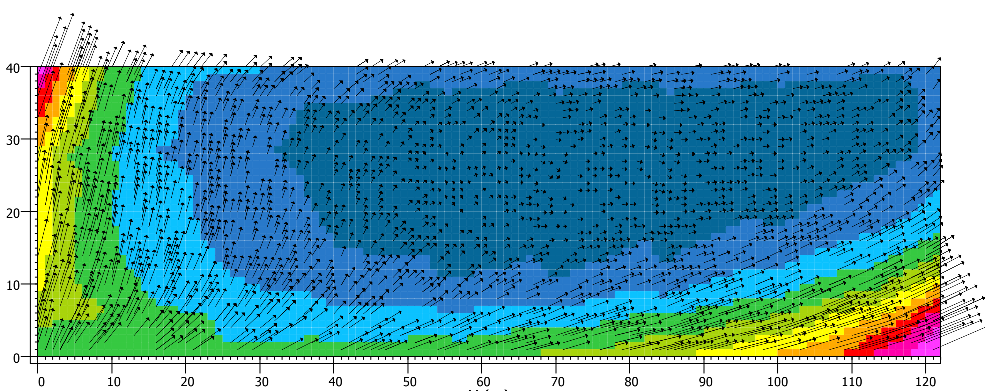


Fig 286: Simulation output _ Simulation type A1 _ EW _ WS _ at 12.30pm

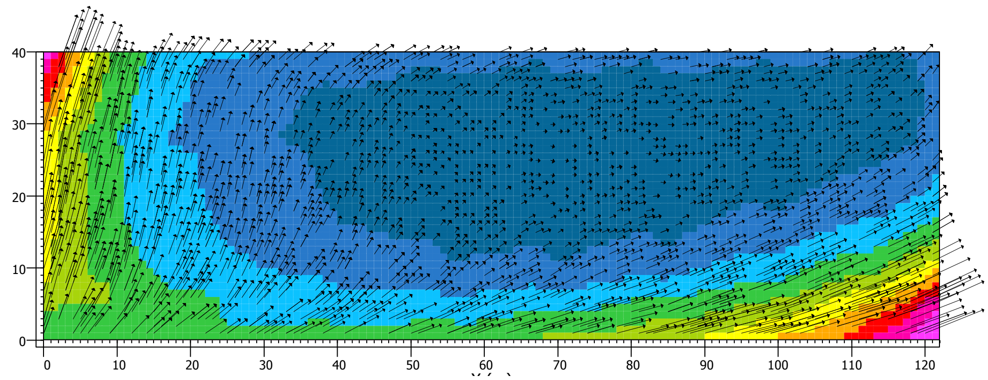


Fig 287: Simulation output _ Simulation type A1 _ EW _ WS _ at 1pm

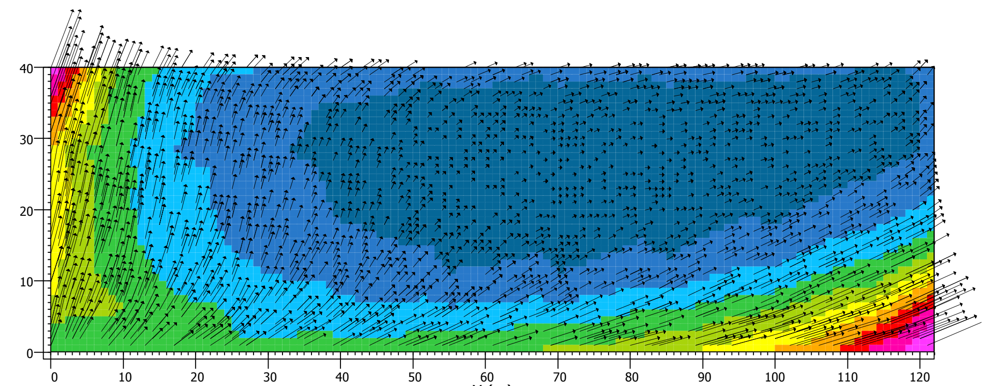


Fig 288: Simulation output _ Simulation type A1 _ EW _ WS _ at 1.30pm

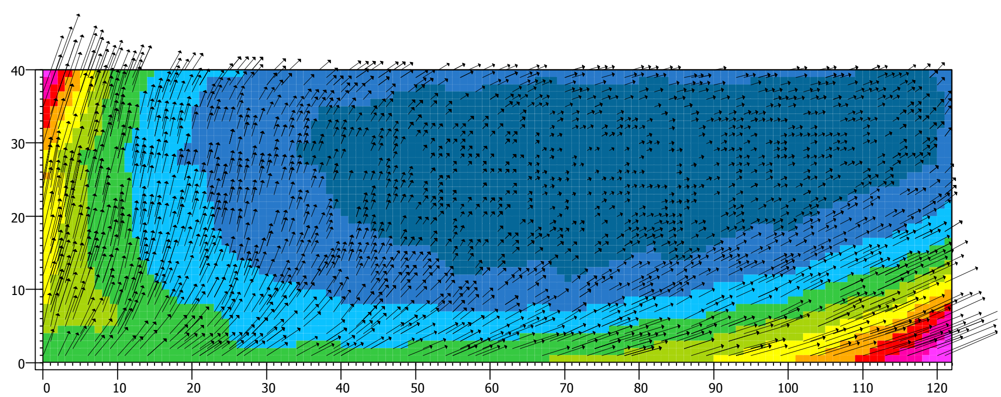
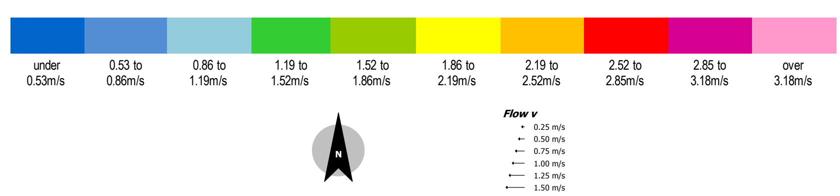


Fig 289: Simulation output _ Simulation type A1 _ EW _ WS _ at 2pm



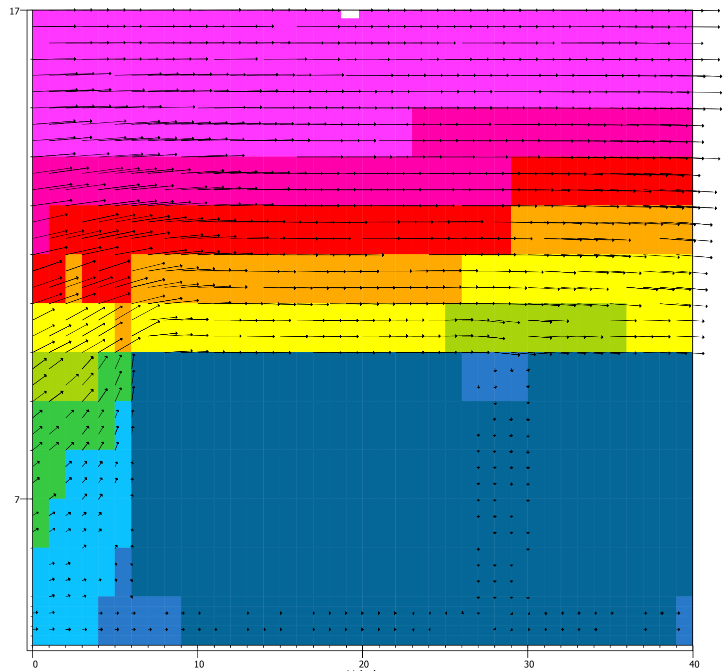


Fig 290: Simulation output _ Simulation type A1 _ EW _ WS _ section _ at 11am

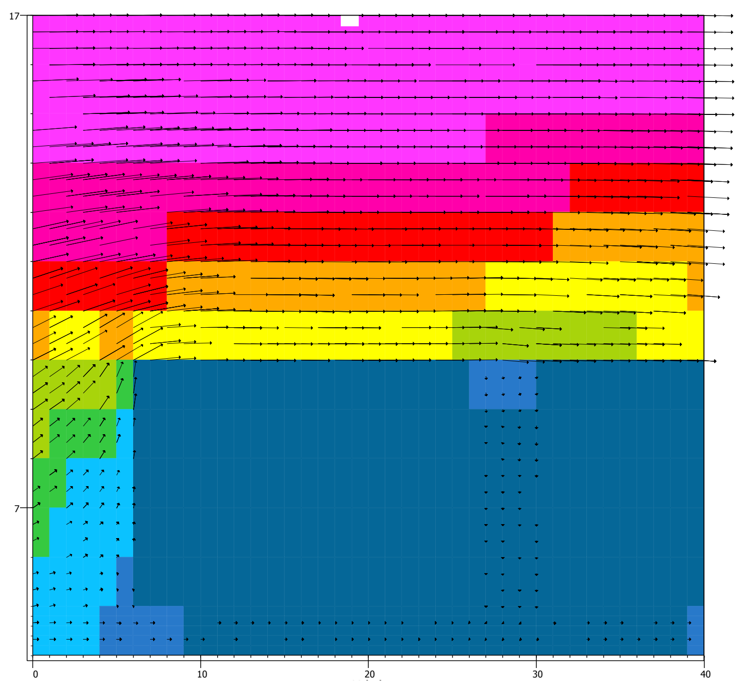


Fig 291: Simulation output _ Simulation type A1 _ EW _ WS _ section _ at 12pm

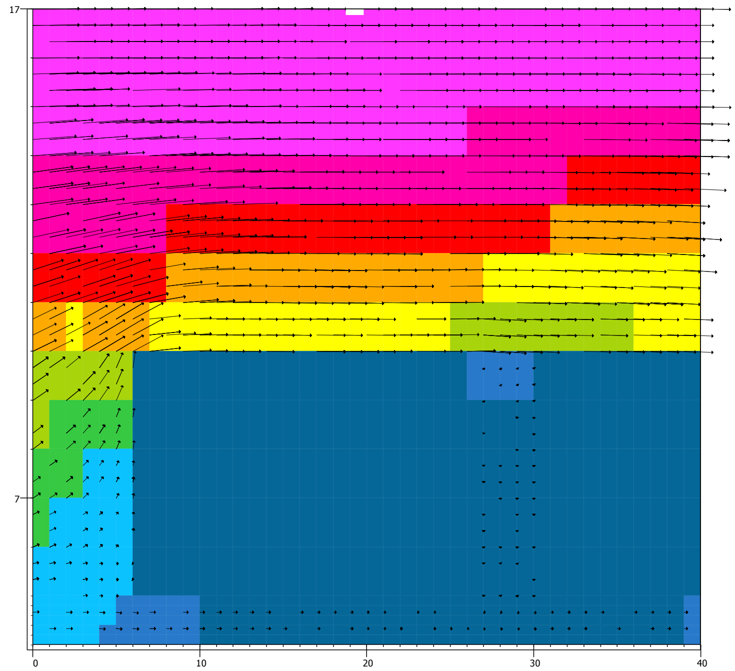


Fig 292: Simulation output _ Simulation type A1 _ EW _ WS _ section _ at 1pm

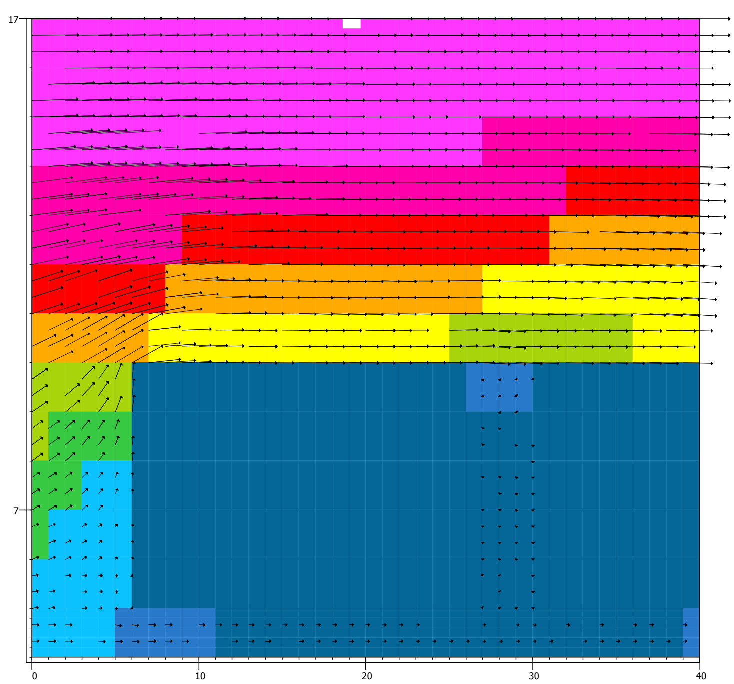
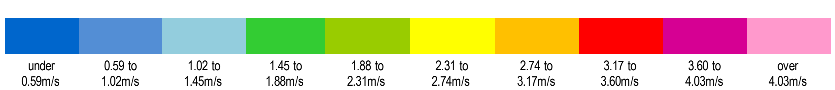
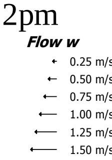


Fig 293: Simulation output _ Simulation type A1 _ EW _ WS _ section _ at 2pm





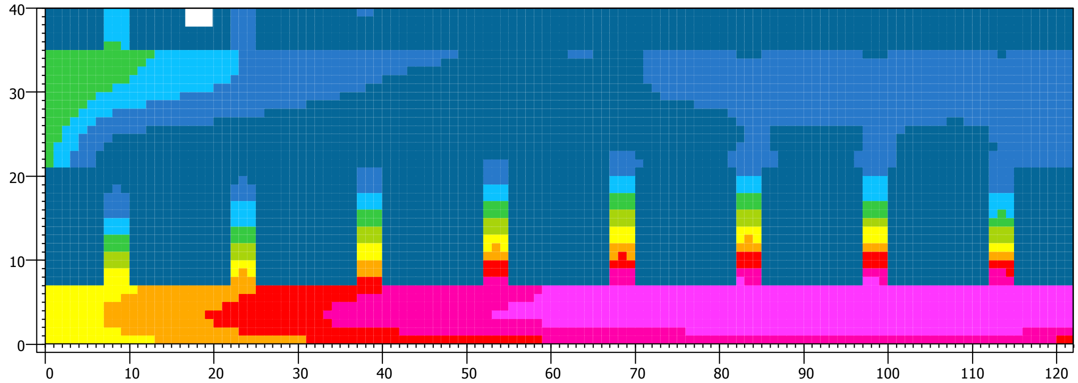


Fig 294: Simulation output _ Simulation type B _ EW _ DBT _ at 11am

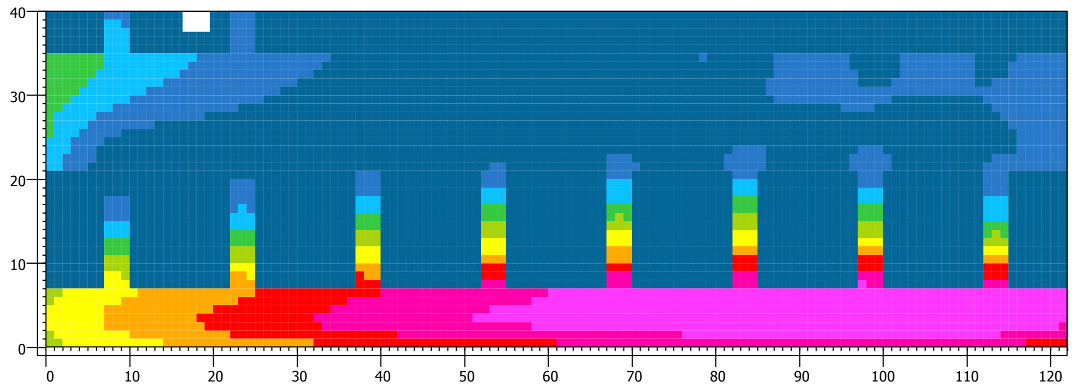


Fig 295: Simulation output _ Simulation type B _ EW _ DBT _ at 11.30am

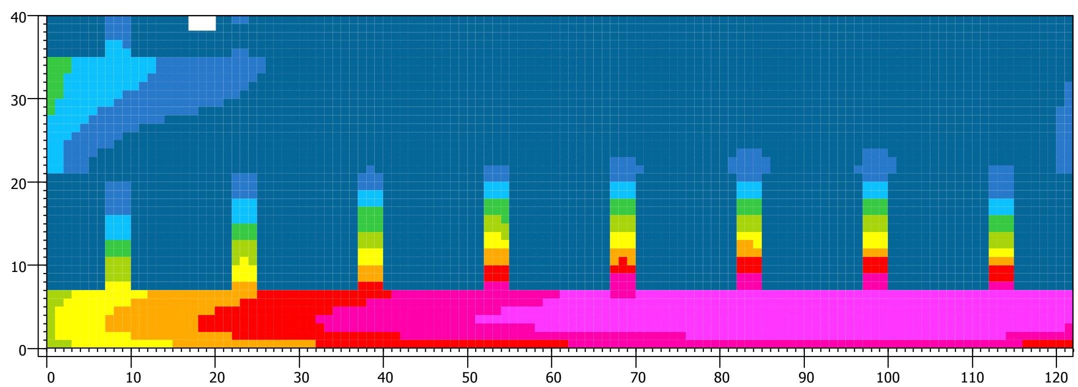


Fig 296: Simulation output _ Simulation type B _ EW _ DBT _ at 12pm

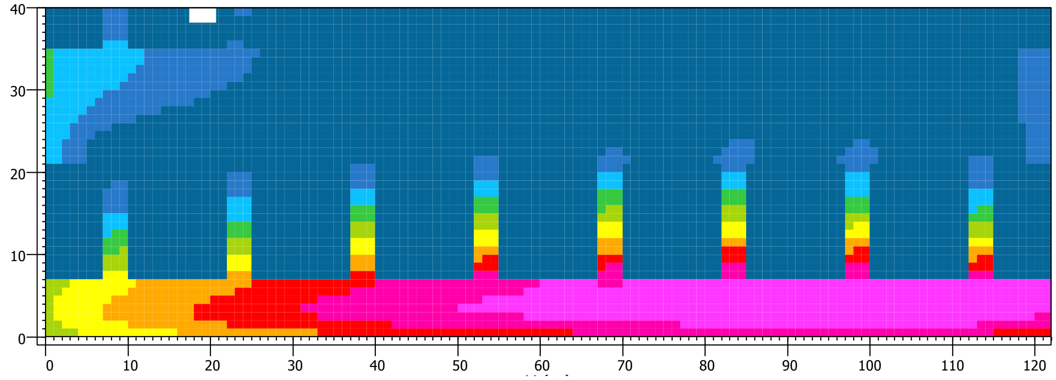


Fig 297: Simulation output _ Simulation type B _ EW _ DBT _ at 12.30pm

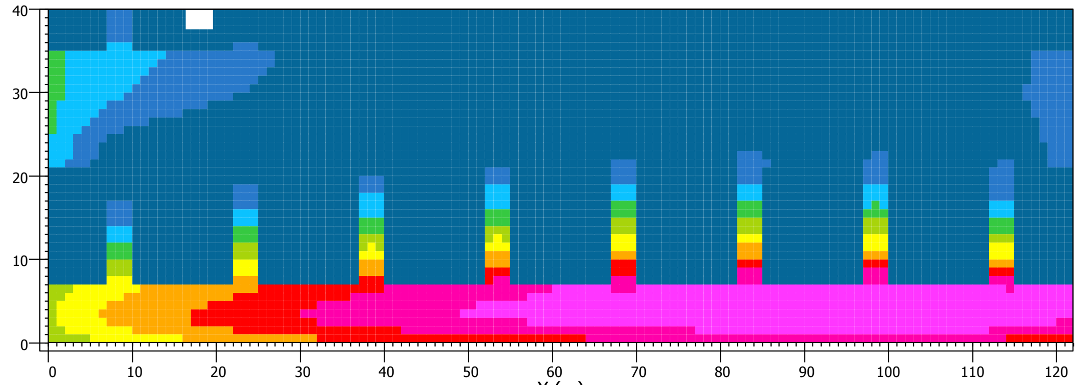


Fig 298: Simulation output _ Simulation type B _ EW _ DBT _ at 1pm

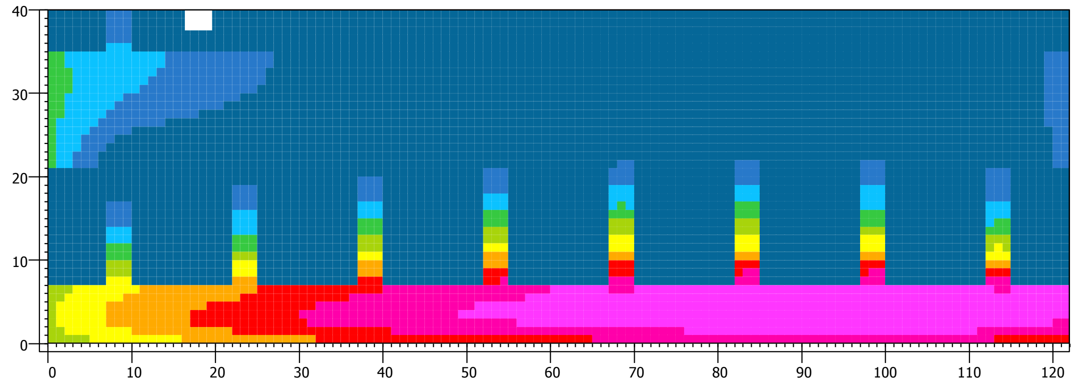


Fig 299: Simulation output _ Simulation type B _ EW _ DBT _ at 1.30pm

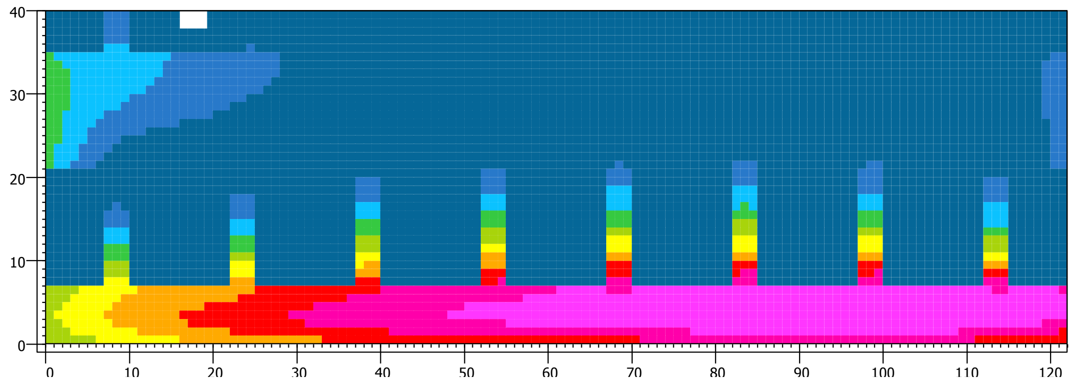
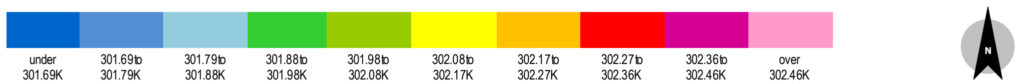


Fig 300: Simulation output _ Simulation type B _ EW _ DBT _ at 2pm



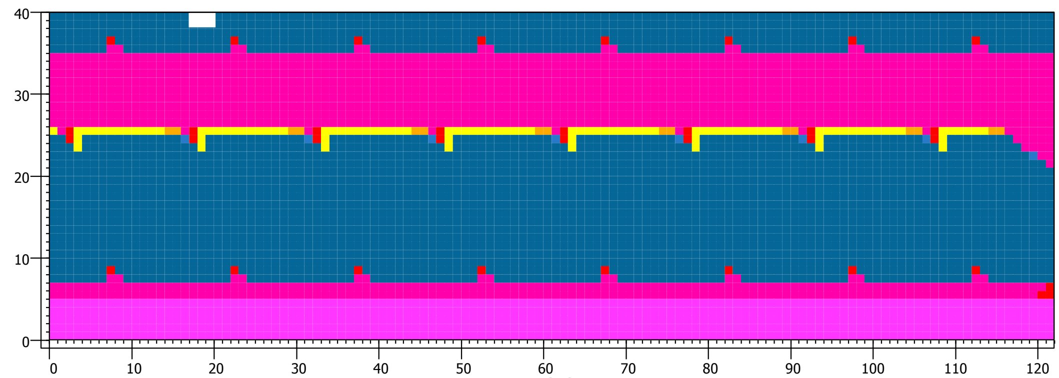


Fig 301: Simulation output _ Simulation type B _ EW _ MRT _ at 11am

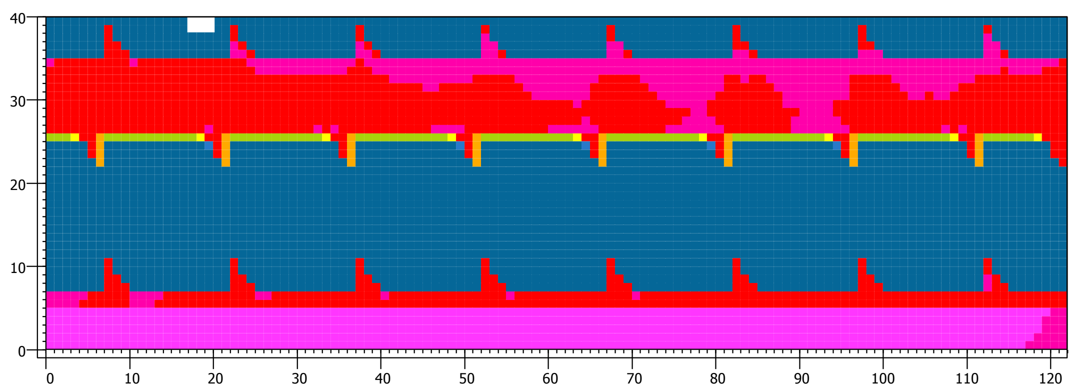


Fig 302: Simulation output _ Simulation type B _ EW _ MRT _ at 11.30am

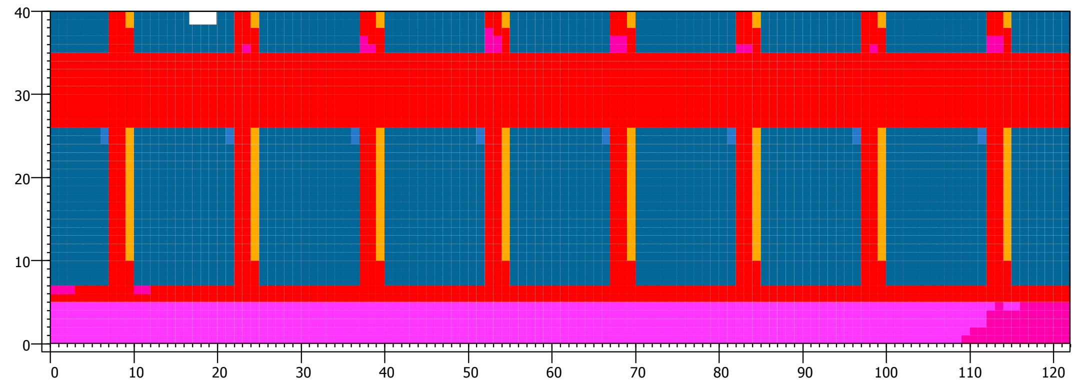


Fig 303: Simulation output _ Simulation type B _ EW _ MRT _ at 12pm

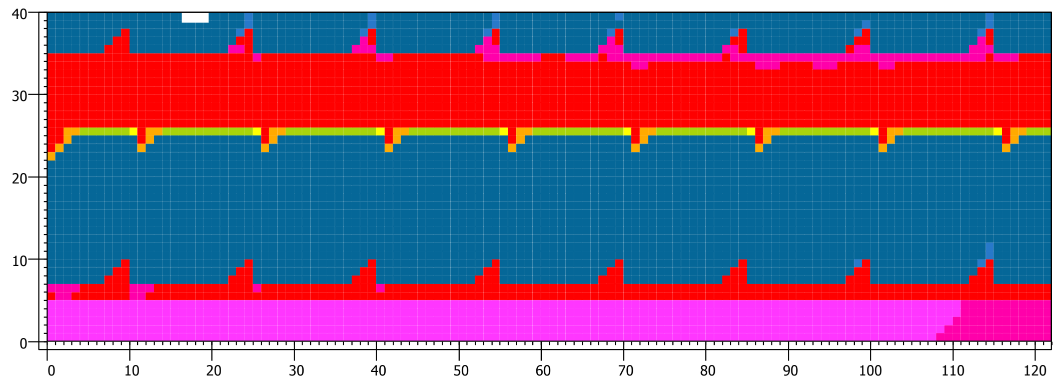


Fig 304: Simulation output _ Simulation type B _ EW _ MRT _ at 12.30pm

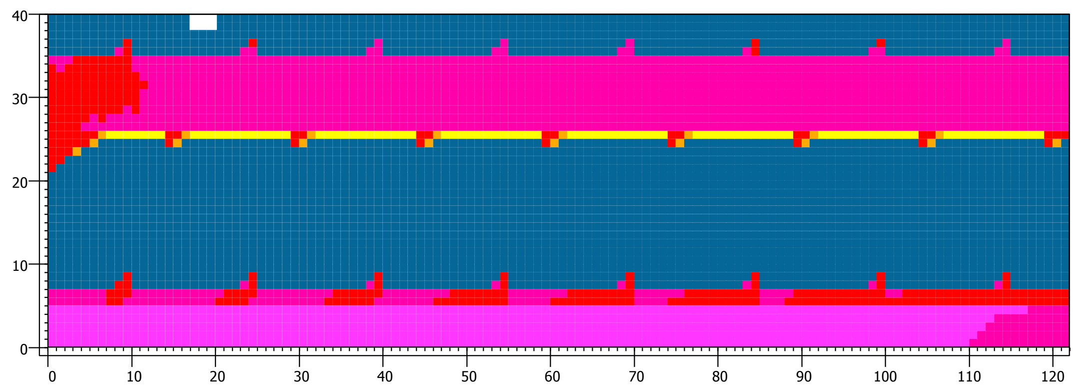


Fig 305: Simulation output _ Simulation type B _ EW _ MRT _ at 1pm

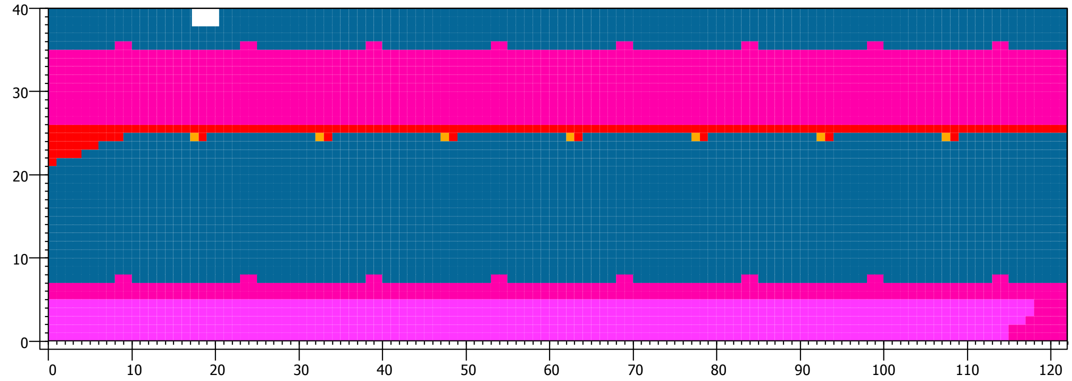


Fig 306: Simulation output _ Simulation type B _ EW _ MRT _ at 1.30pm

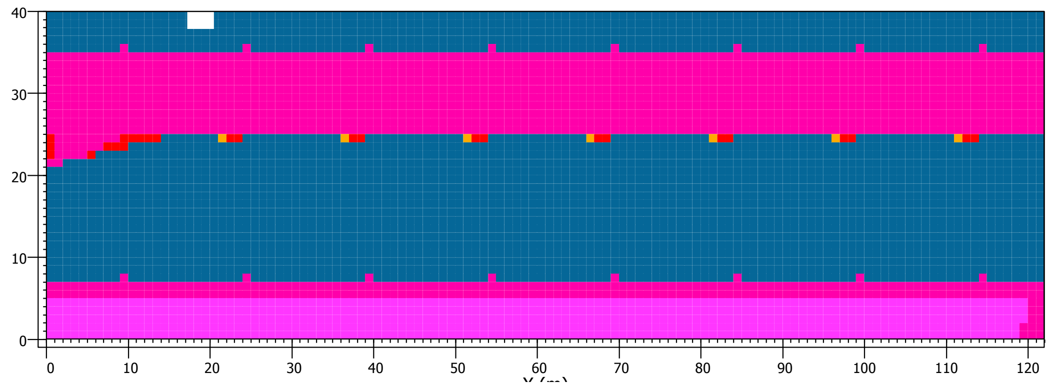
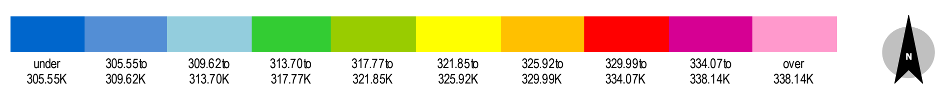


Fig 307: Simulation output _ Simulation type B _ EW _ MRT _ at 2pm



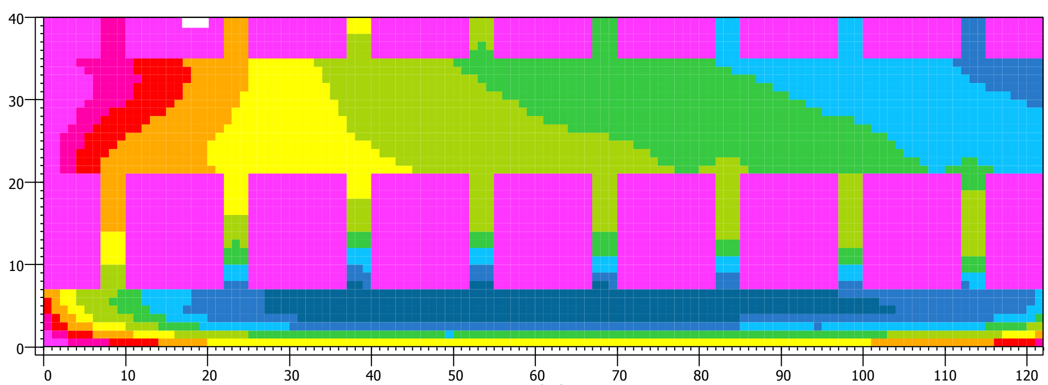


Fig 308: Simulation output _ Simulation type B _ EW _ RH _ at 11am

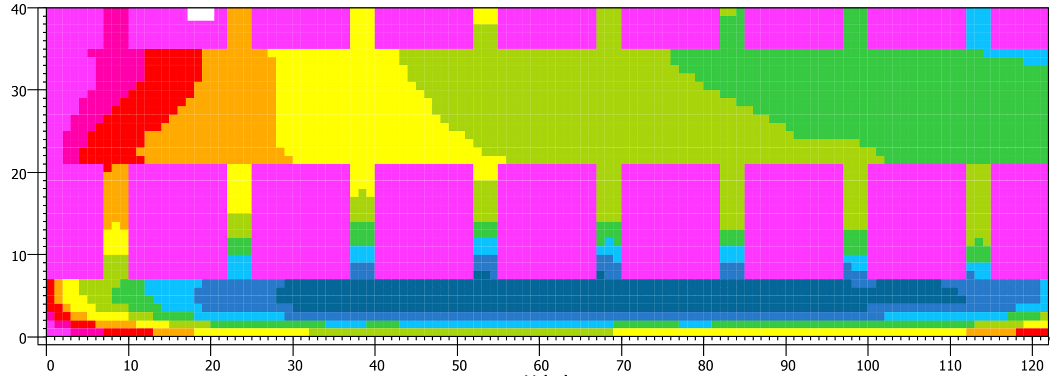


Fig 309: Simulation output _ Simulation type B _ EW _ RH _ at 11.30am

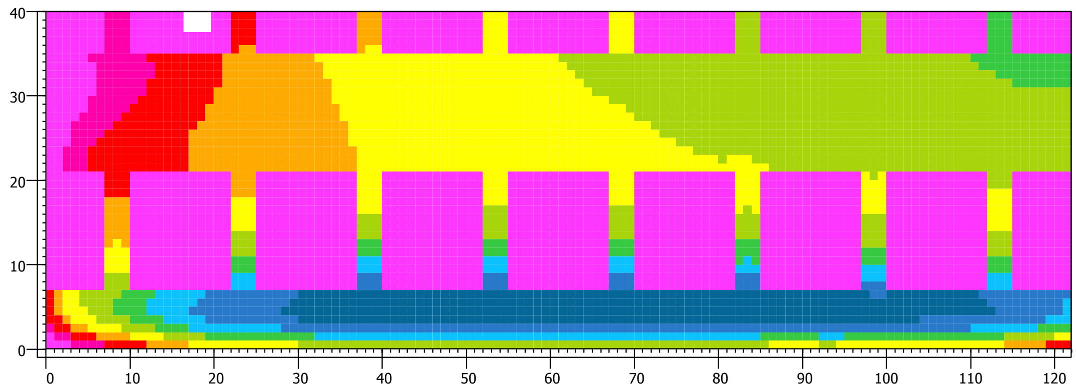


Fig 310: Simulation output _ Simulation type B _ EW _ RH _ at 12pm

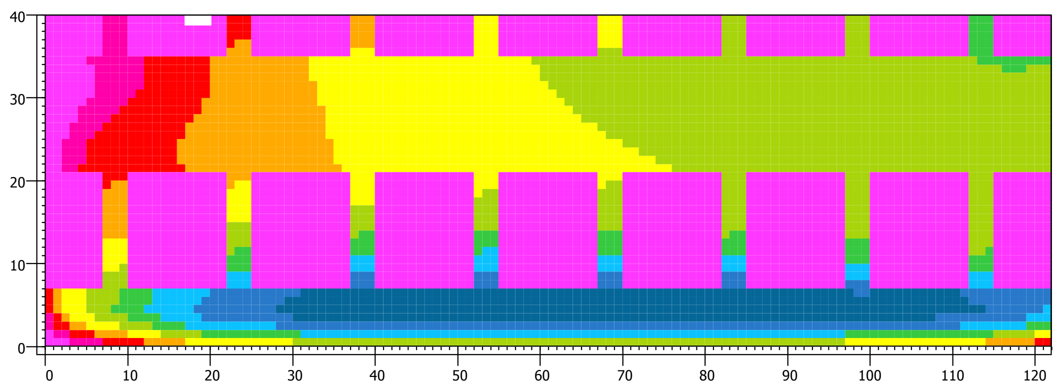


Fig 311: Simulation output _ Simulation type B _ EW _ RH _ at 12.30pm

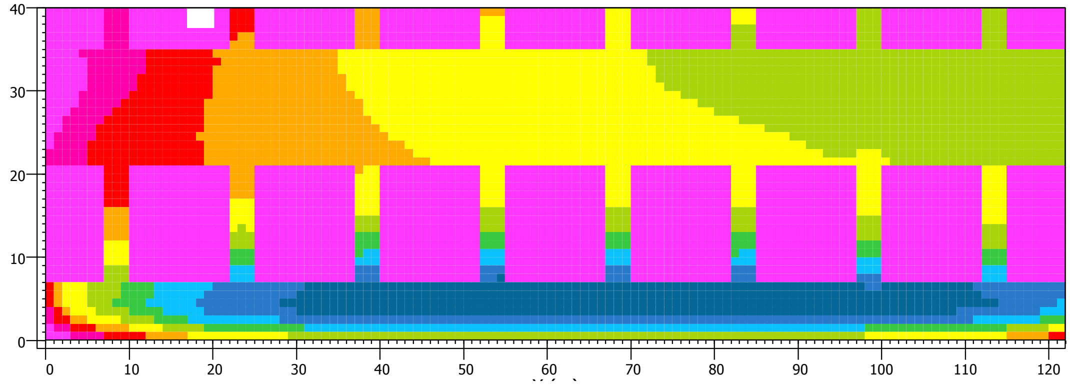


Fig 312: Simulation output _ Simulation type B _ EW _ RH _ at 1pm

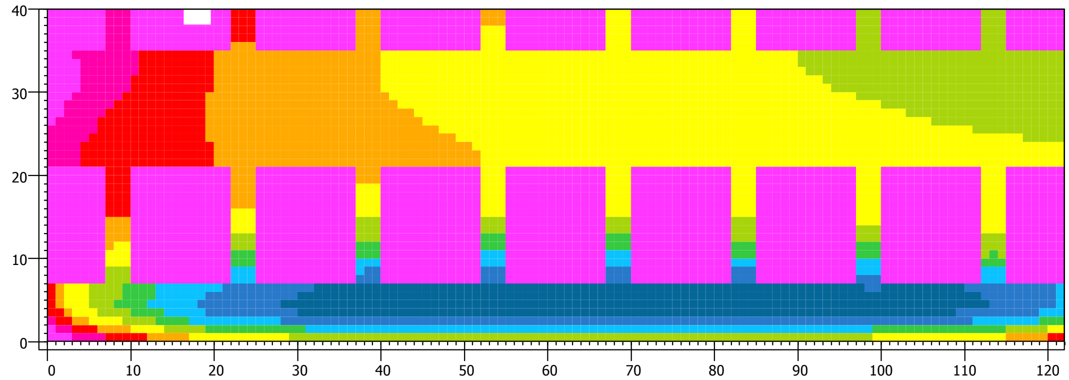


Fig 313: Simulation output _ Simulation type B _ EW _ RH _ at 1.30pm

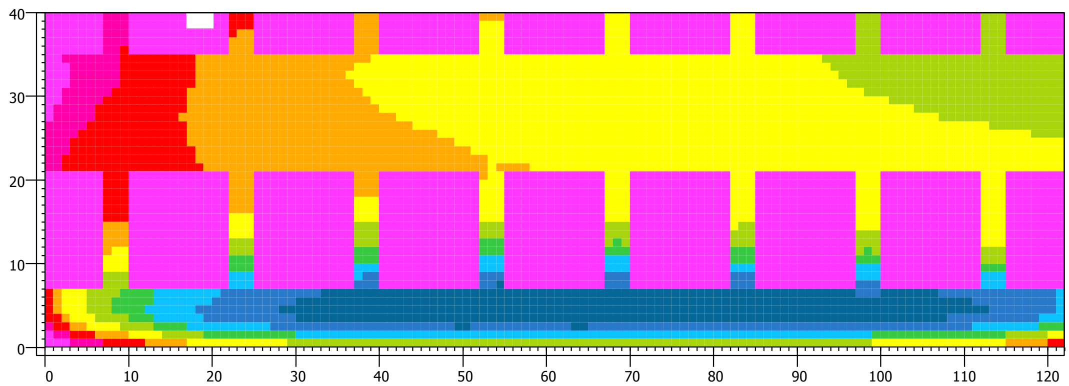
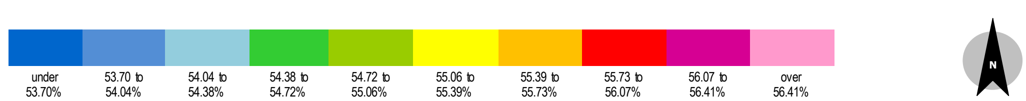


Fig 314: Simulation output _ Simulation type B _ EW _ RH _ at 2pm



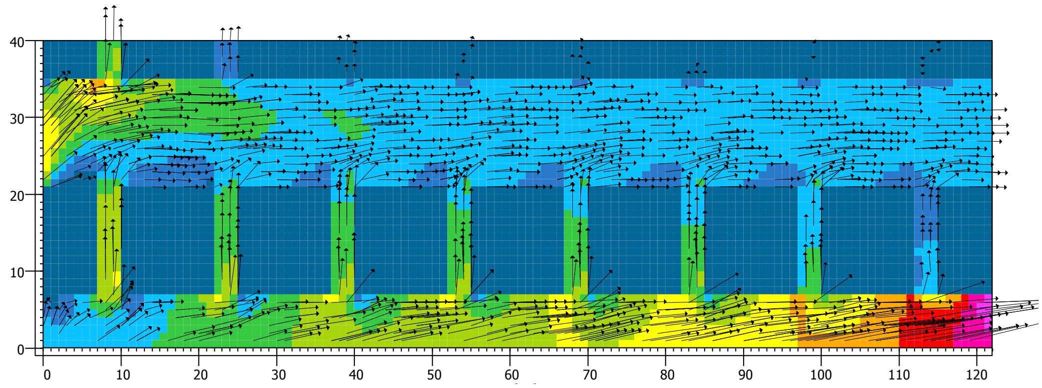


Fig 315: Simulation output _ Simulation type B _ EW _ WS _ at 11am

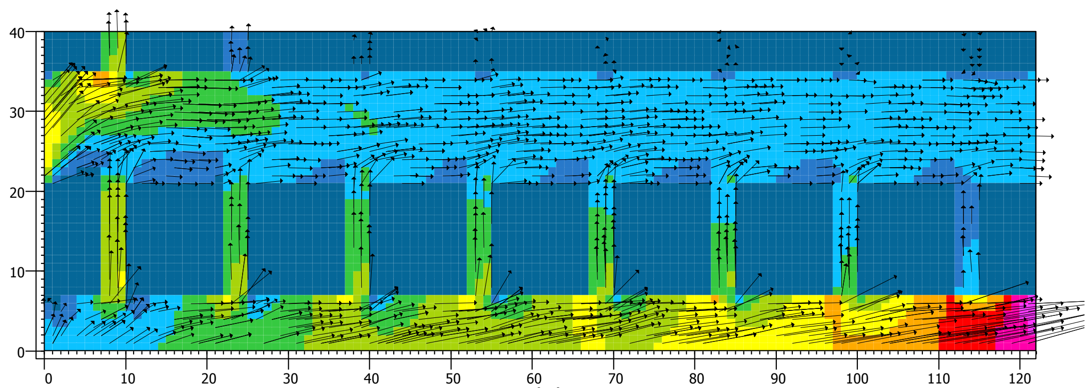


Fig 316: Simulation output _ Simulation type B _ EW _ WS _ at 11.30am

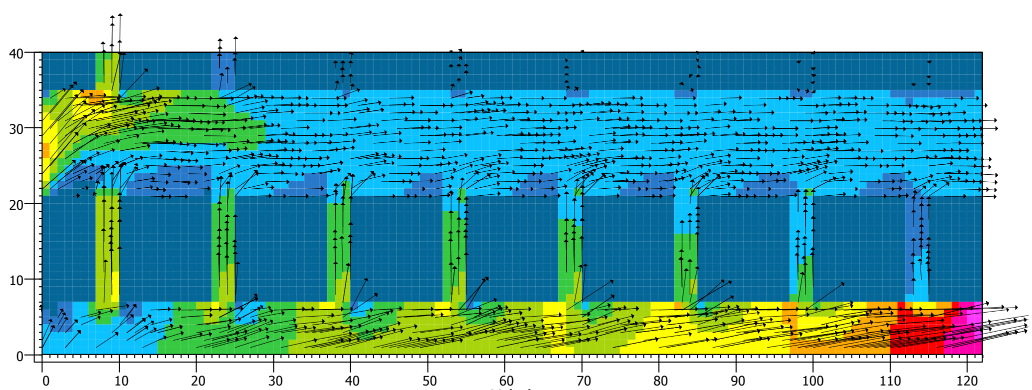


Fig 317: Simulation output _ Simulation type B _ EW _ WS _ at 12pm

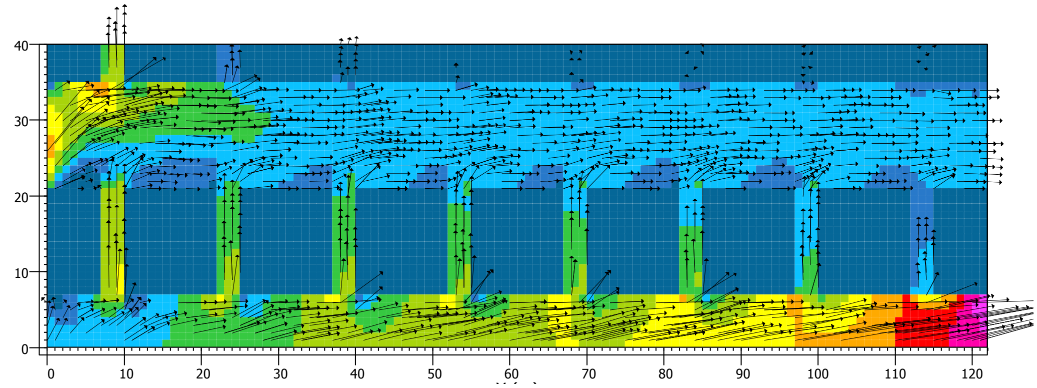


Fig 318: Simulation output _ Simulation type B _ EW _ WS _ at 12.30pm

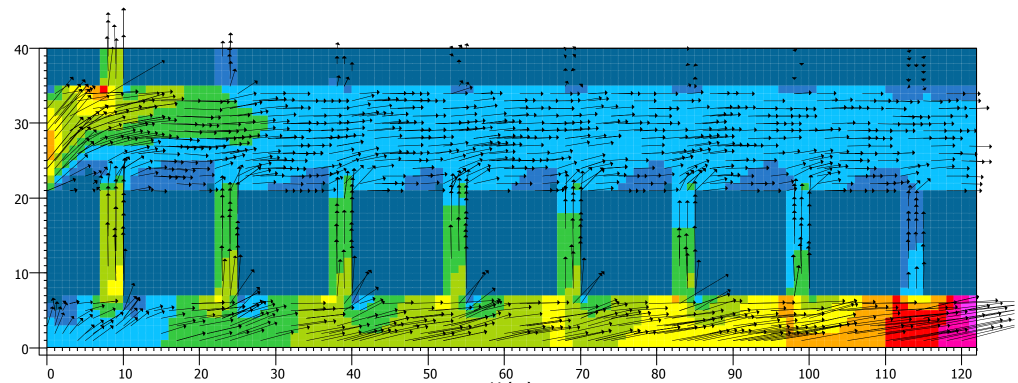


Fig 319: Simulation output _ Simulation type B _ EW _ WS _ at 1pm

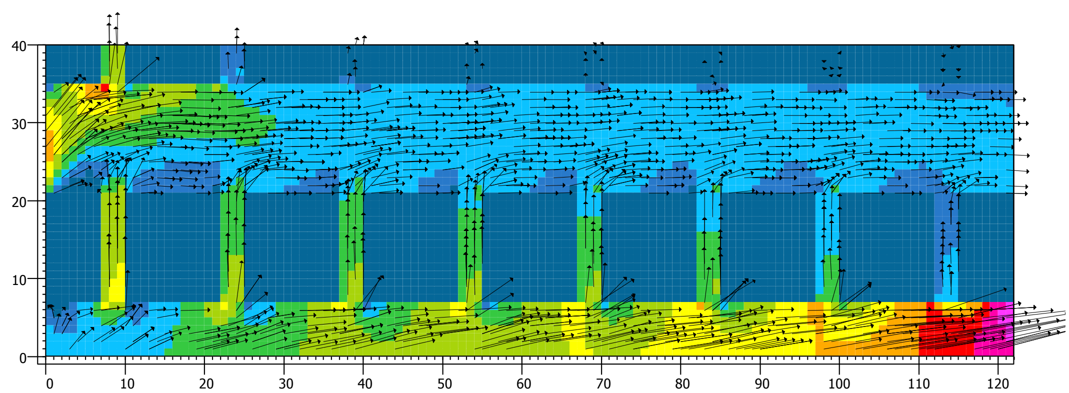


Fig 320: Simulation output _ Simulation type B _ EW _ WS _ at 1.30pm

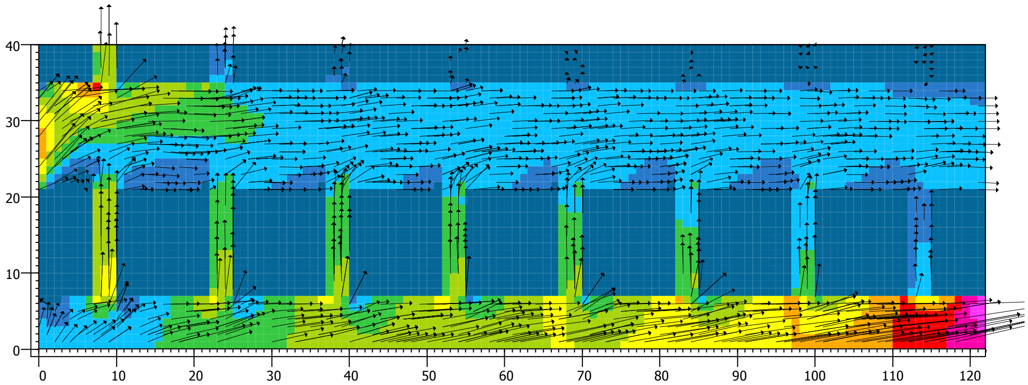
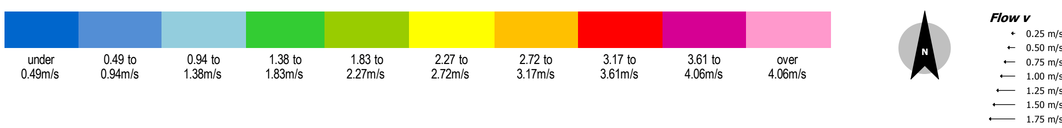


Fig 321: Simulation output _ Simulation type B _ EW _ WS _ at 2pm



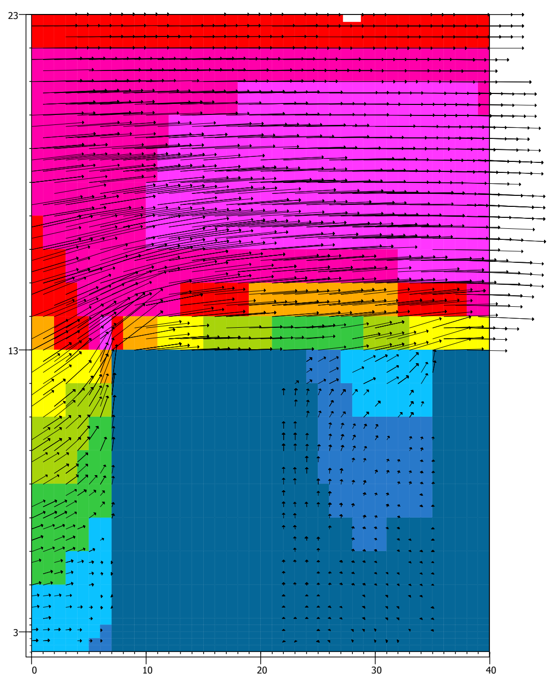


Fig 322: Simulation output _ Simulation type B _ EW _ WS _ section _ at 11am

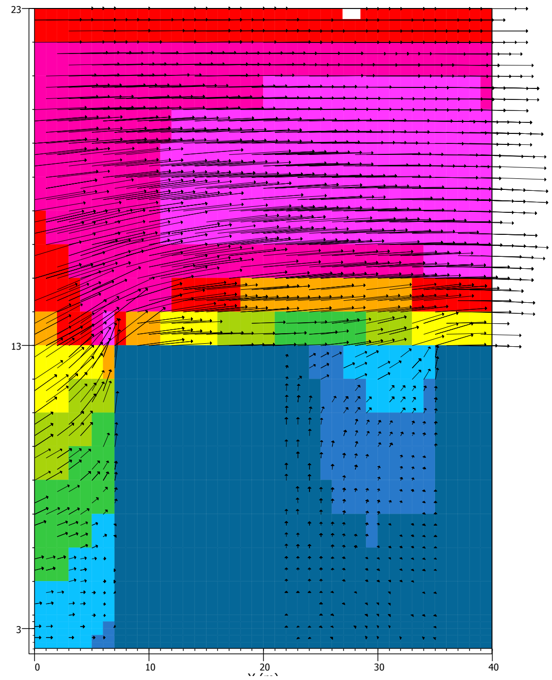


Fig 323: Simulation output _ Simulation type B _ EW _ WS _ section _ at 12pm

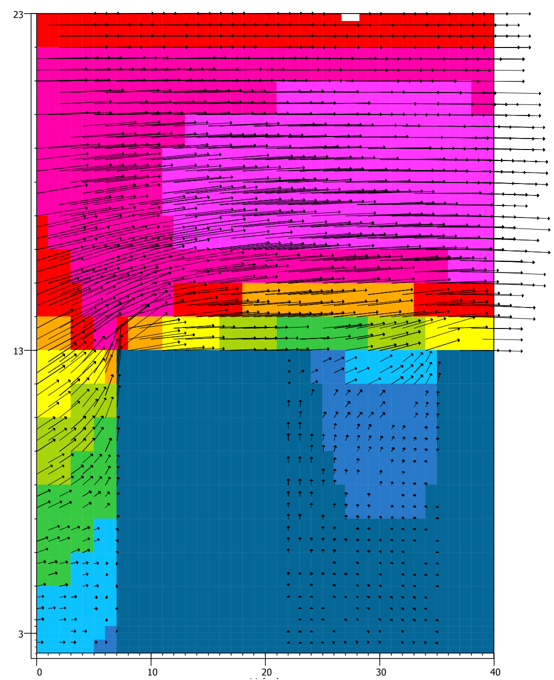


Fig 324: Simulation output _ Simulation type B _ EW _ WS _ section _ at 1pm

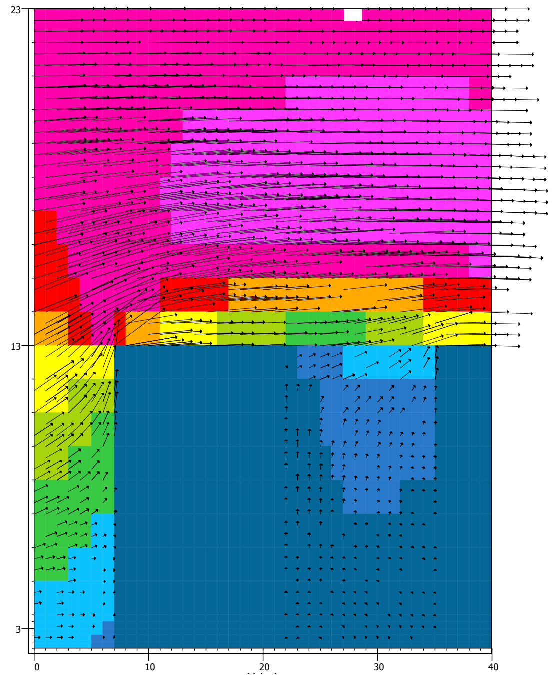
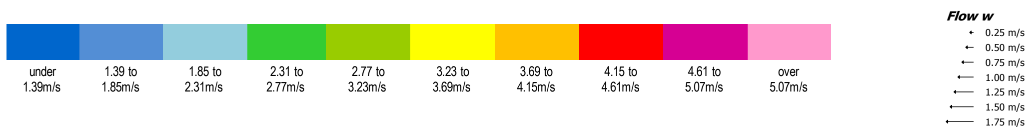


Fig 325: Simulation output _ Simulation type B _ EW _ WS _ section _ at 2pm



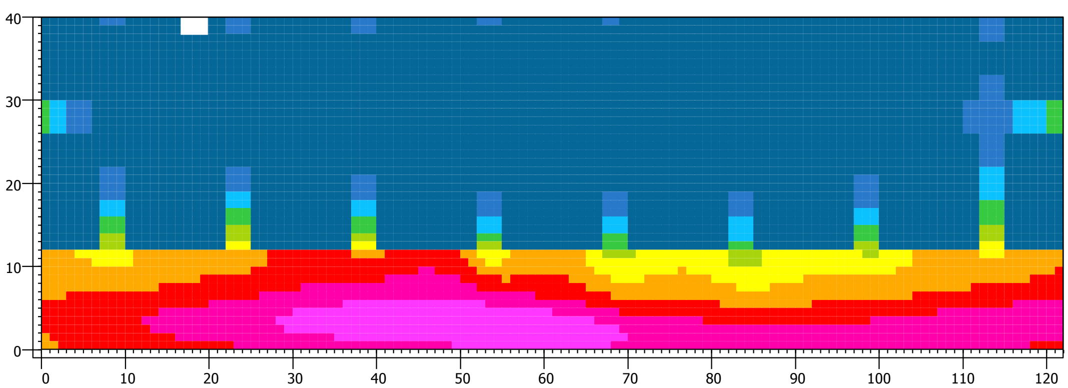


Fig 326: Simulation output _ Simulation type B1 _ EW _ DBT _ at 11am

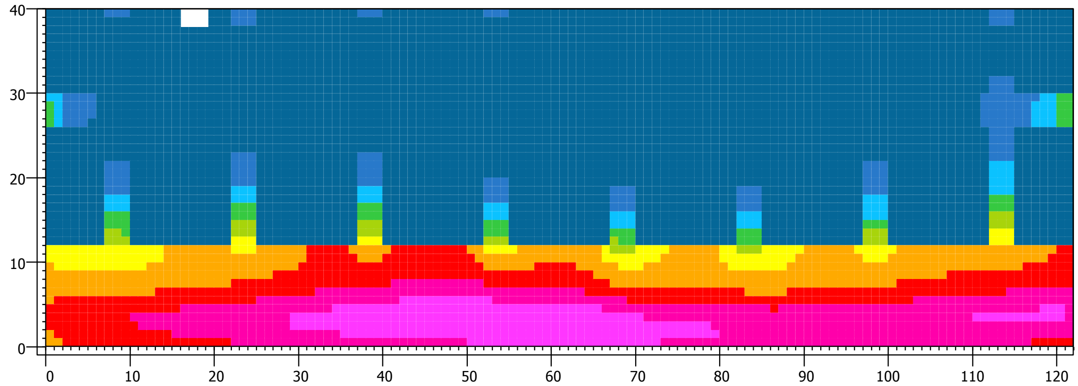


Fig 327: Simulation output _ Simulation type B1 _ EW _ DBT _ at 11.30am

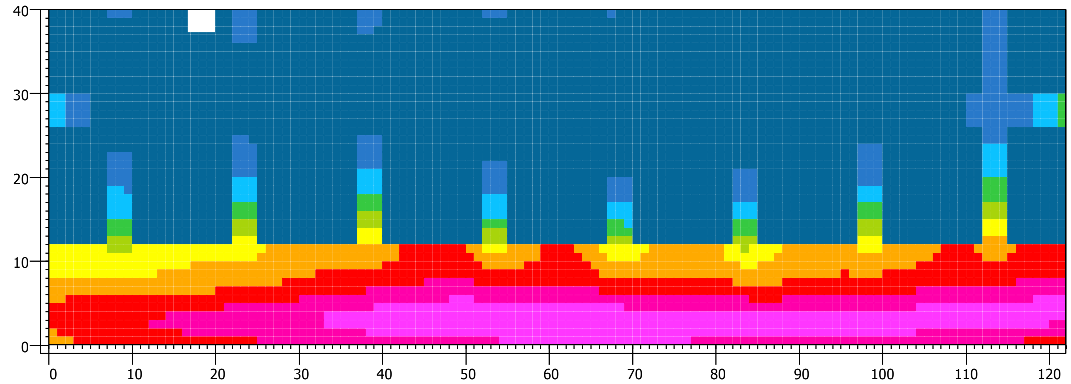


Fig 328: Simulation output _ Simulation type B1 _ EW _ DBT _ at 12pm

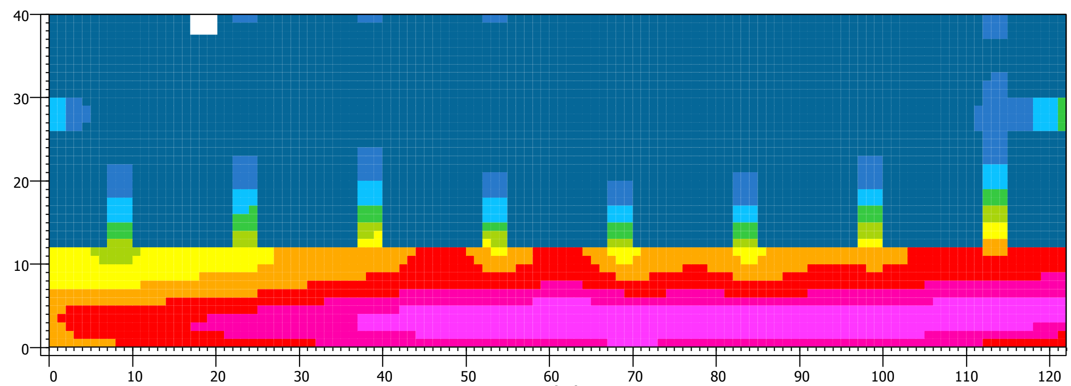


Fig 329: Simulation output _ Simulation type B1 _ EW _ DBT _ at 12.30pm

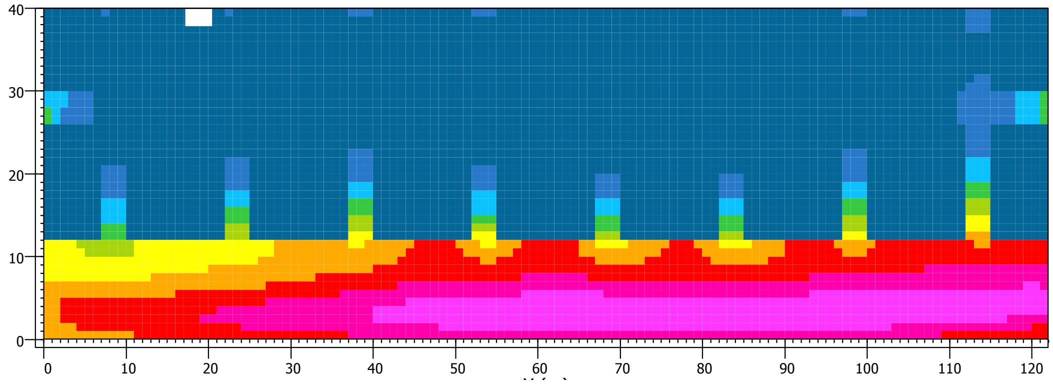


Fig 330: Simulation output _ Simulation type B1 _ EW _ DBT _ at 1pm

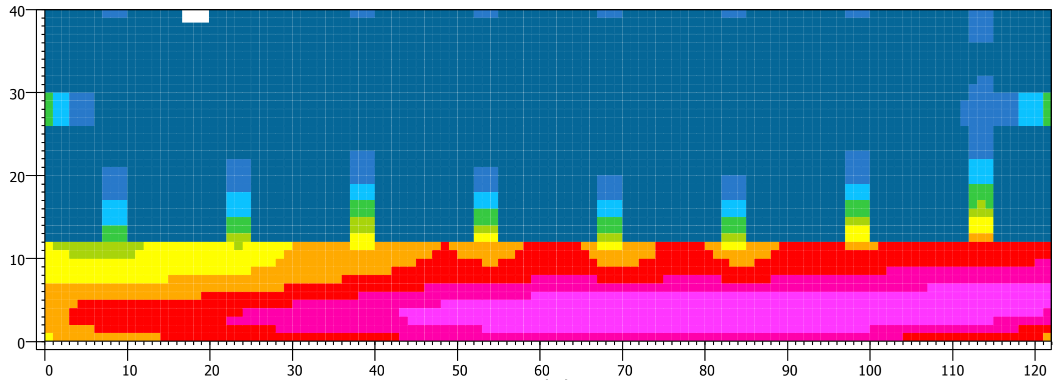


Fig 331: Simulation output _ Simulation type B1 _ EW _ DBT _ at 1.30pm

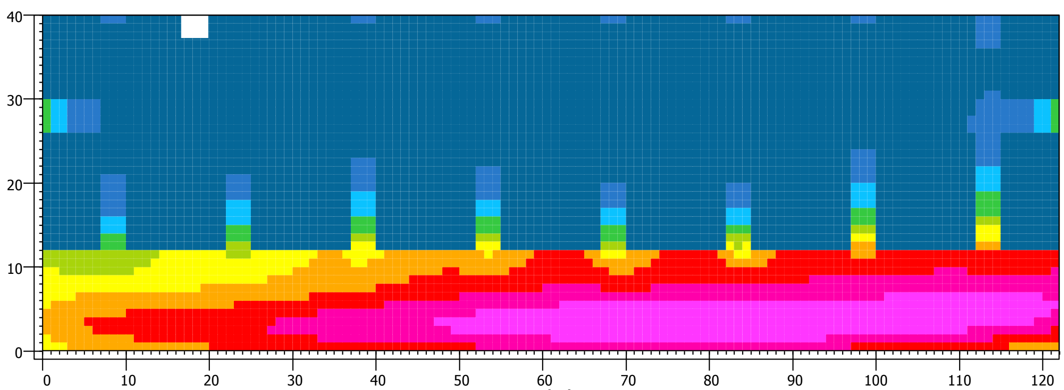
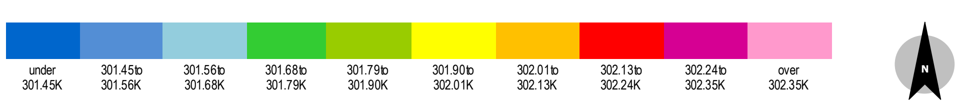


Fig 332: Simulation output _ Simulation type B1 _ EW _ DBT _ at 2pm



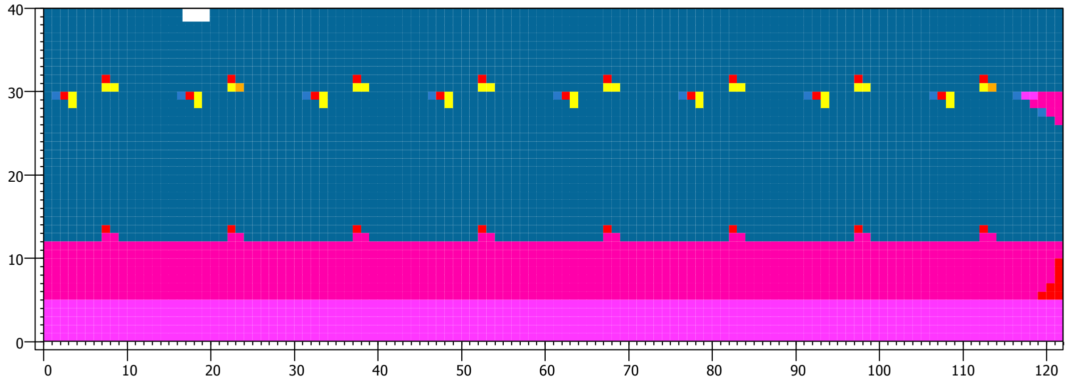


Fig 333: Simulation output _ Simulation type B1 _ EW _ MRT _ at 11am

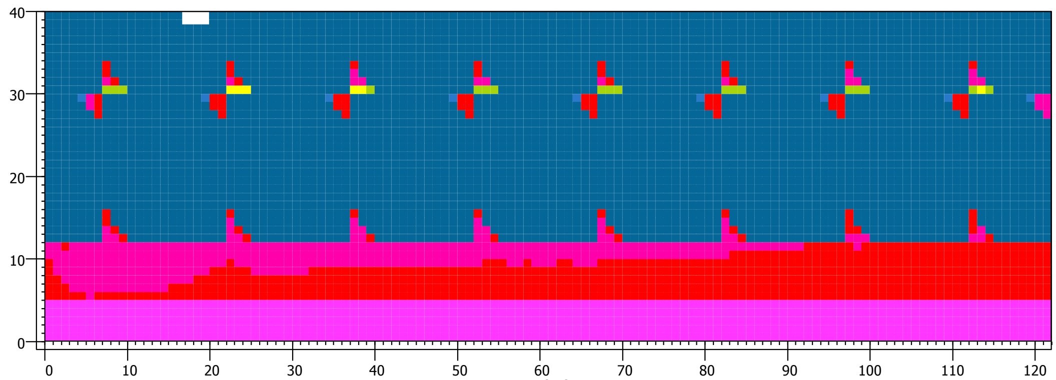


Fig 334: Simulation output _ Simulation type B1 _ EW _ MRT _ at 11.30am

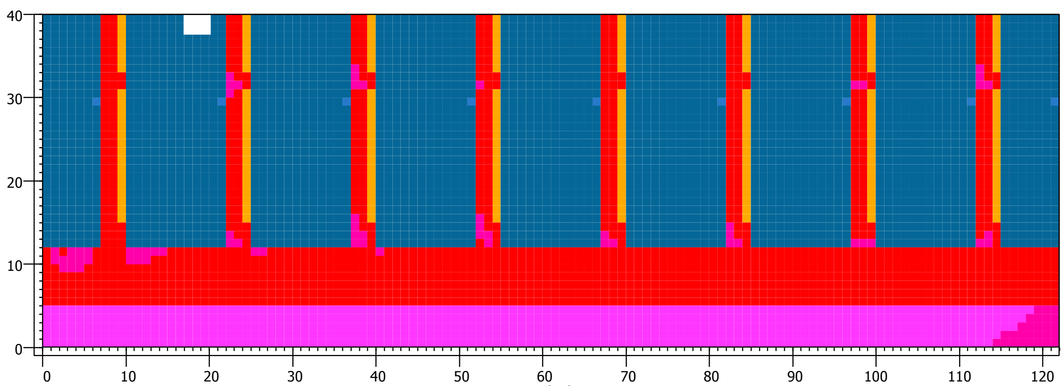


Fig 335: Simulation output _ Simulation type B1 _ EW _ MRT _ at 12pm

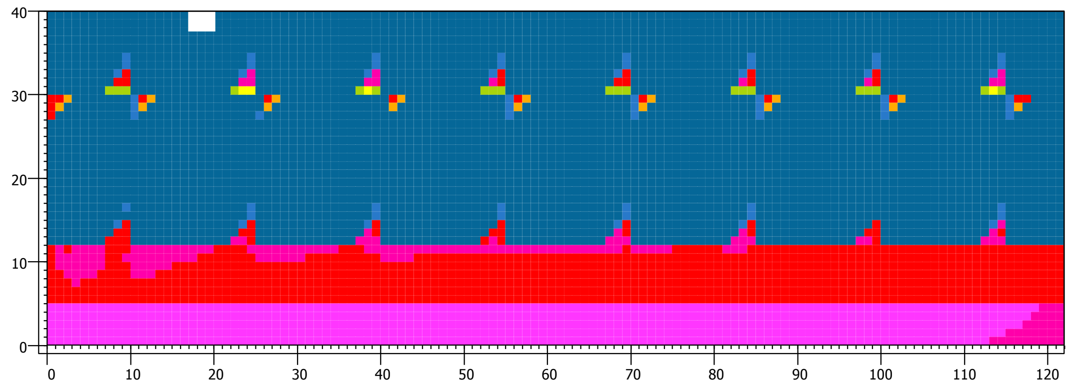


Fig 336: Simulation output _ Simulation type B1 _ EW _ MRT _ at 12.30pm

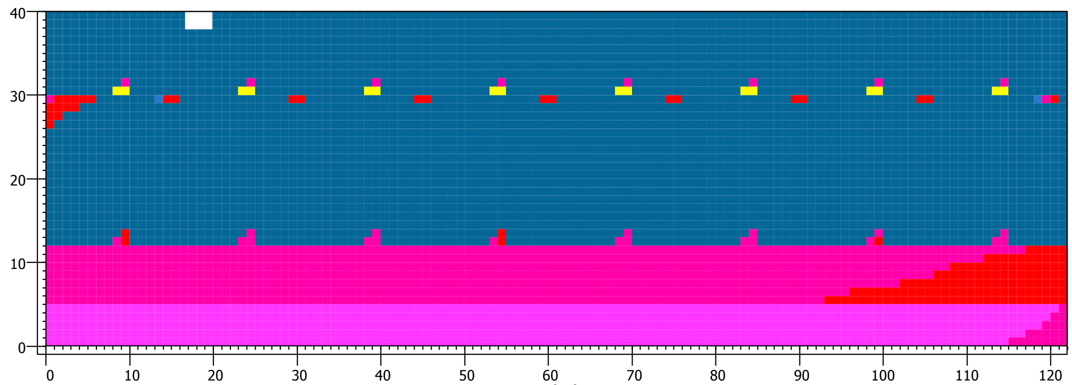


Fig 337: Simulation output _ Simulation type B1 _ EW _ MRT _ at 1pm

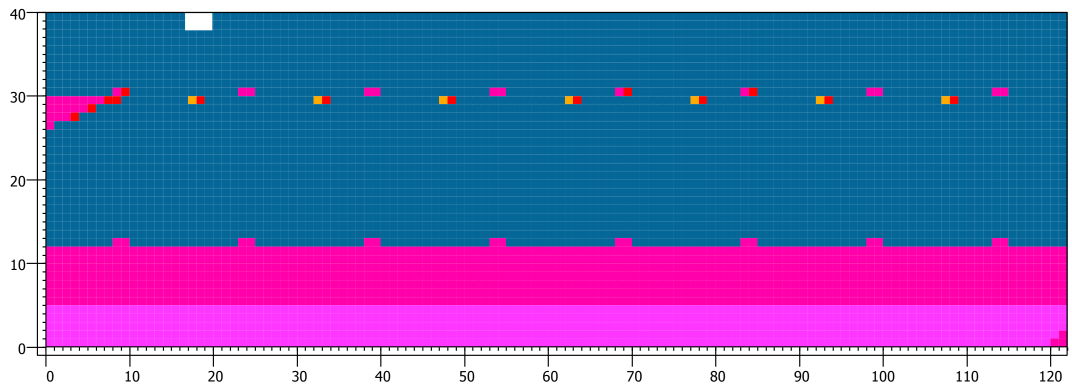


Fig 338: Simulation output _ Simulation type B1 _ EW _ MRT _ at 1.30pm

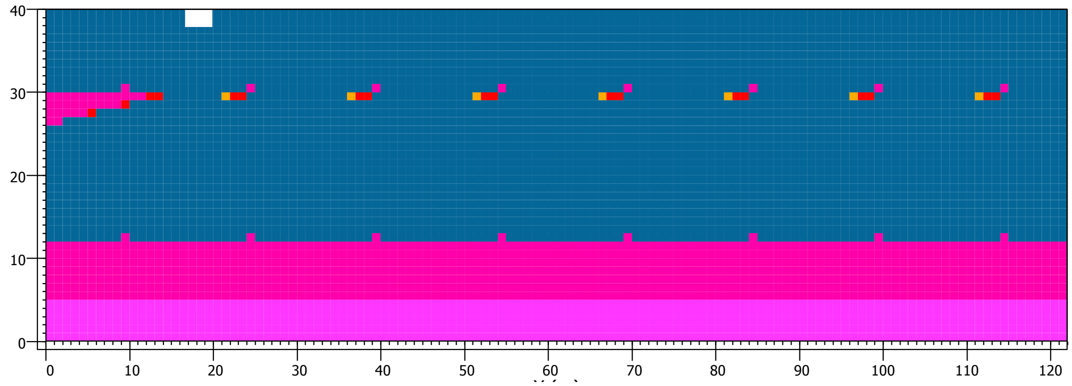
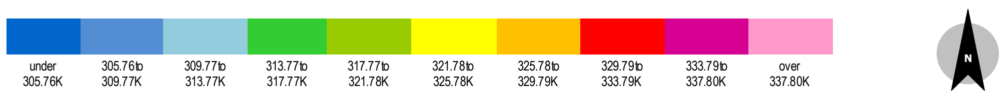


Fig 339: Simulation output _ Simulation type B1 _ EW _ MRT _ at 2pm



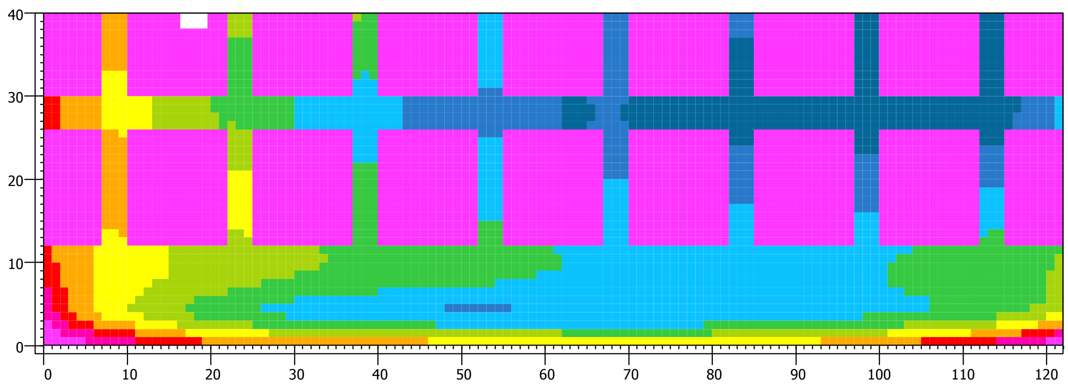


Fig 340: Simulation output _ Simulation type B1 _ EW _ RH _ at 11am

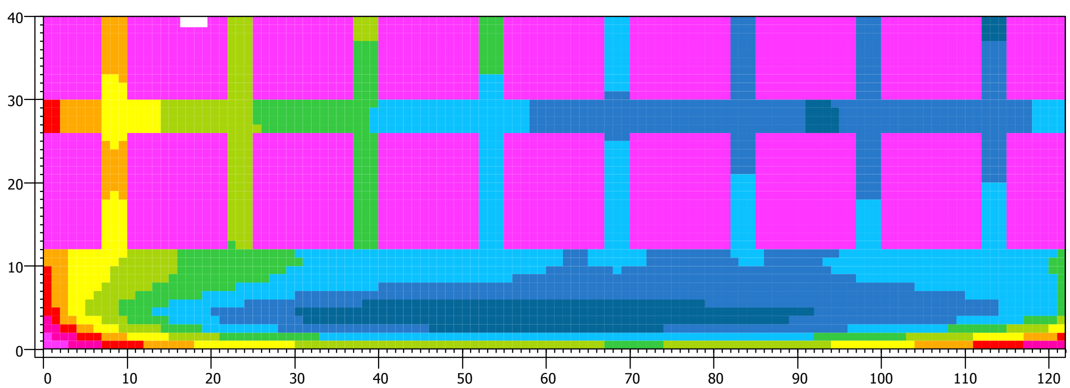


Fig 341: Simulation output _ Simulation type B1 _ EW _ RH _ at 11.30am

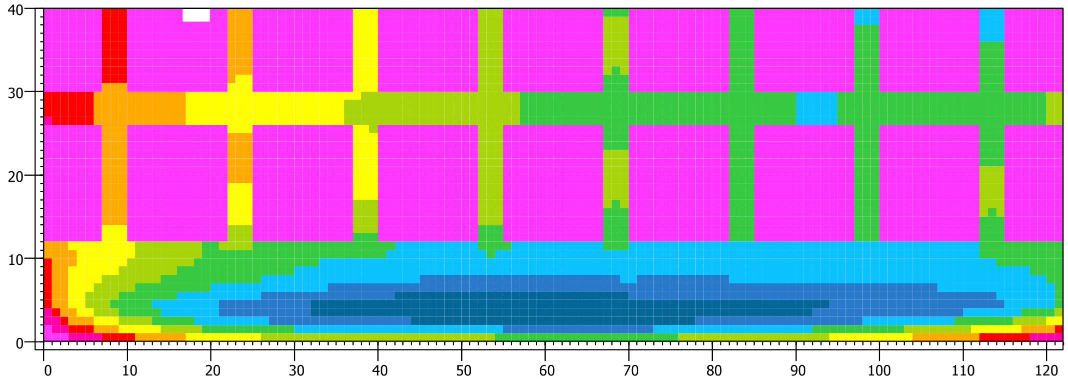


Fig 342: Simulation output _ Simulation type B1 _ EW _ RH _ at 12pm

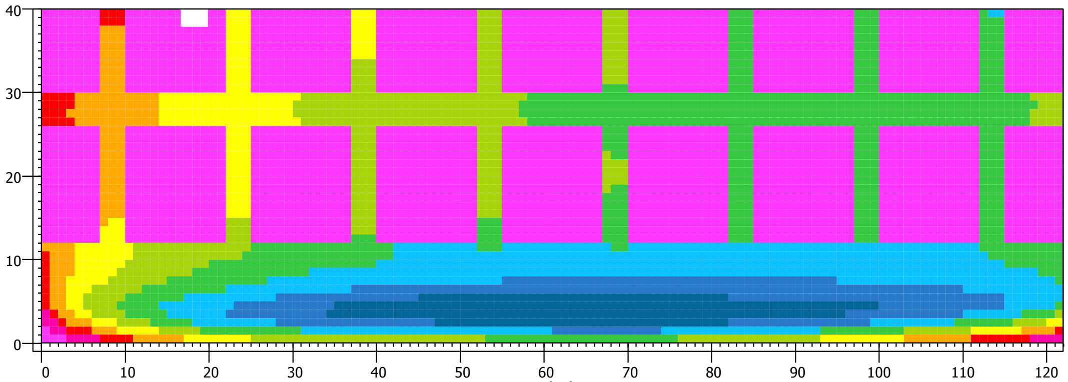


Fig 343: Simulation output _ Simulation type B1 _ EW _ RH _ at 12.30pm

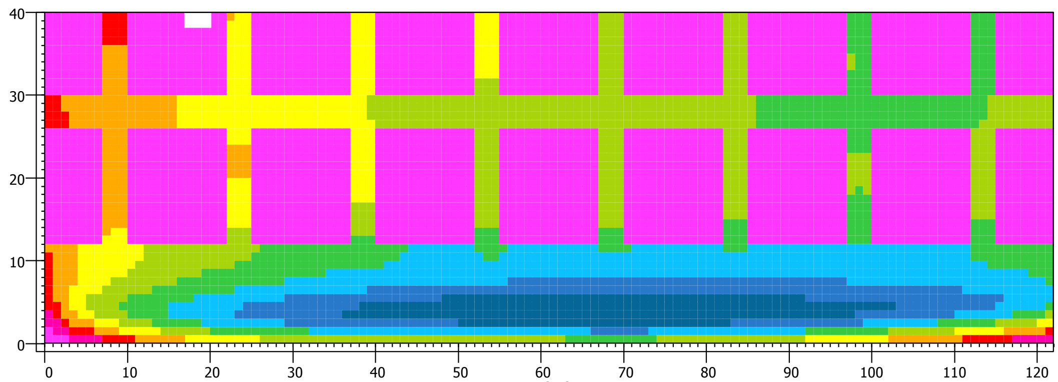


Fig 344: Simulation output _ Simulation type B1 _ EW _ RH _ at 1pm

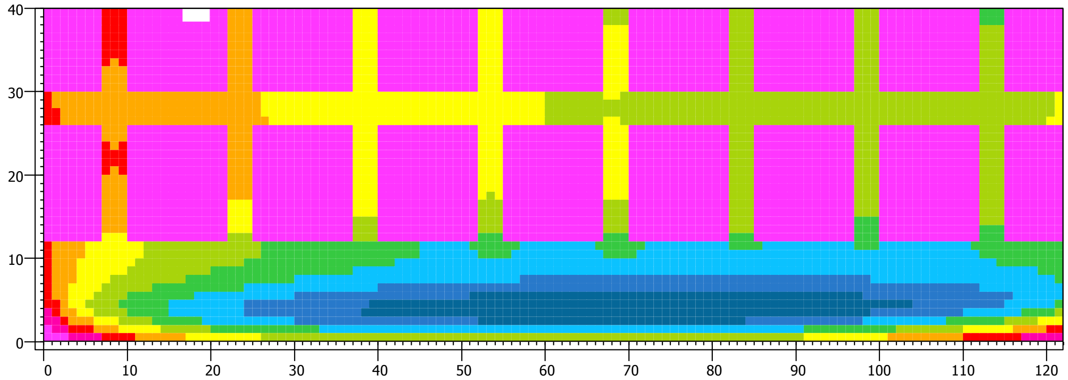


Fig 345: Simulation output _ Simulation type B1 _ EW _ RH _ at 1.30pm

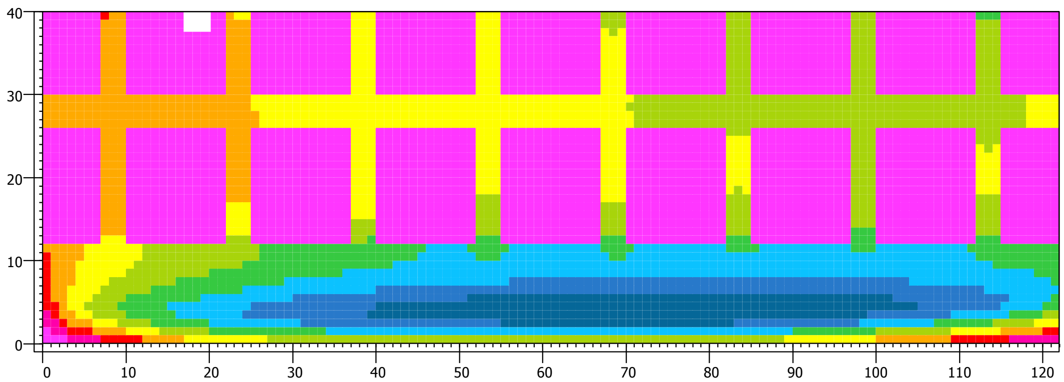
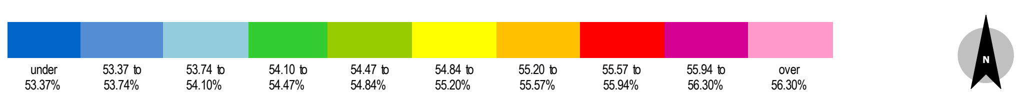


Fig 346: Simulation output _ Simulation type B1 _ EW _ RH _ at 2pm



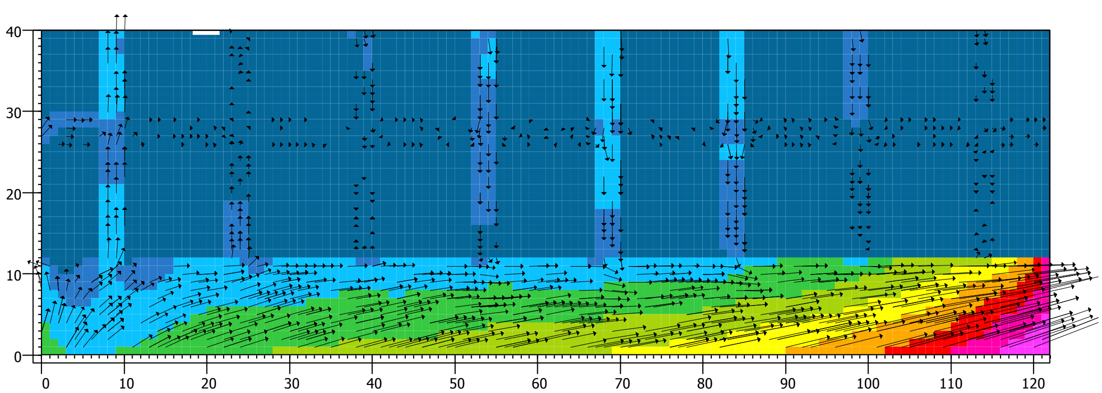


Fig 347: Simulation output _ Simulation type B1 _ EW _ WS _ at 11am

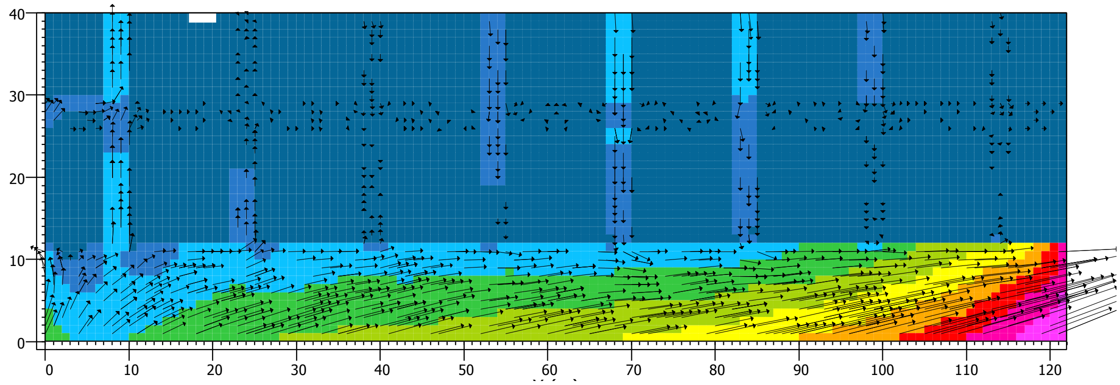


Fig 348: Simulation output _ Simulation type B1 _ EW _ WS _ at 11.30am

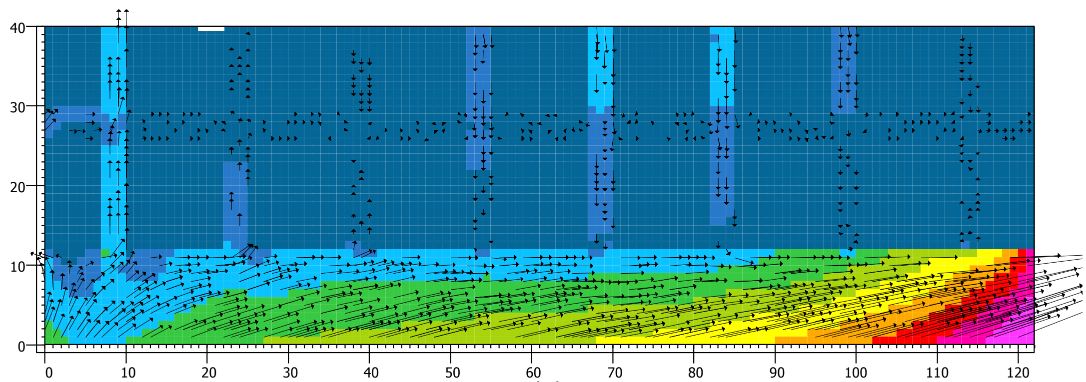


Fig 349: Simulation output _ Simulation type B1 _ EW _ WS _ at 12pm

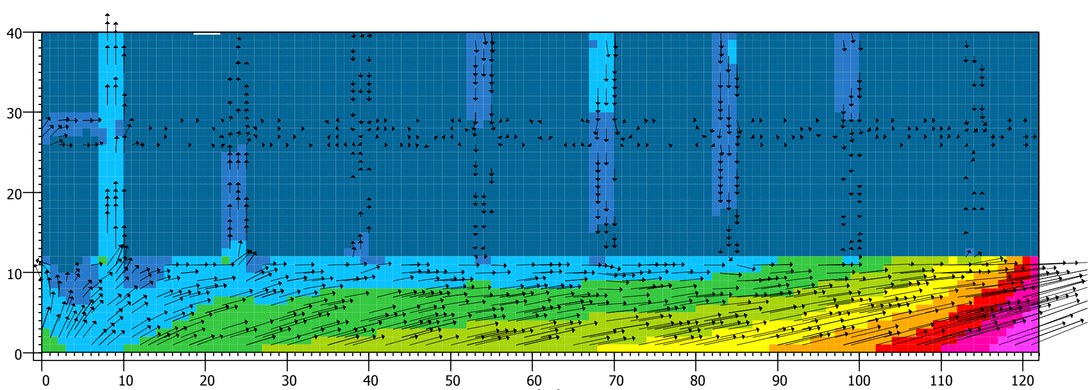


Fig 350: Simulation output _ Simulation type B1 _ EW _ WS _ at 12.30pm

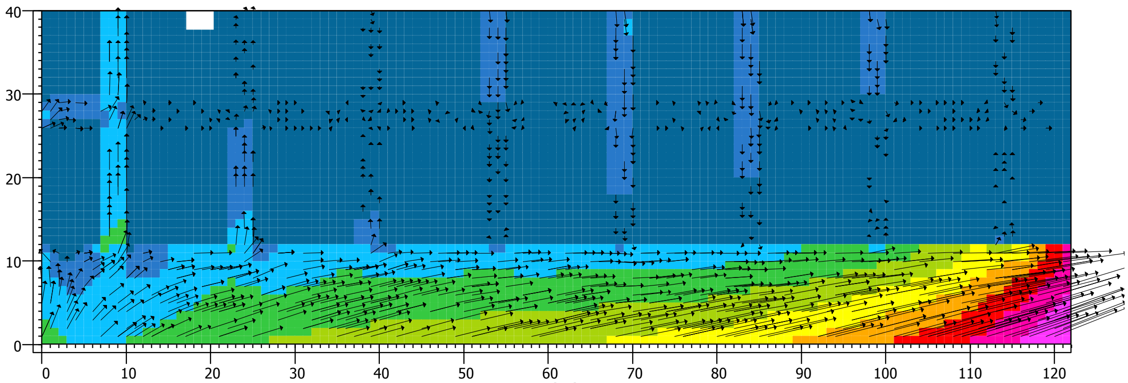


Fig 351: Simulation output _ Simulation type B1 _ EW _ WS _ at 1pm

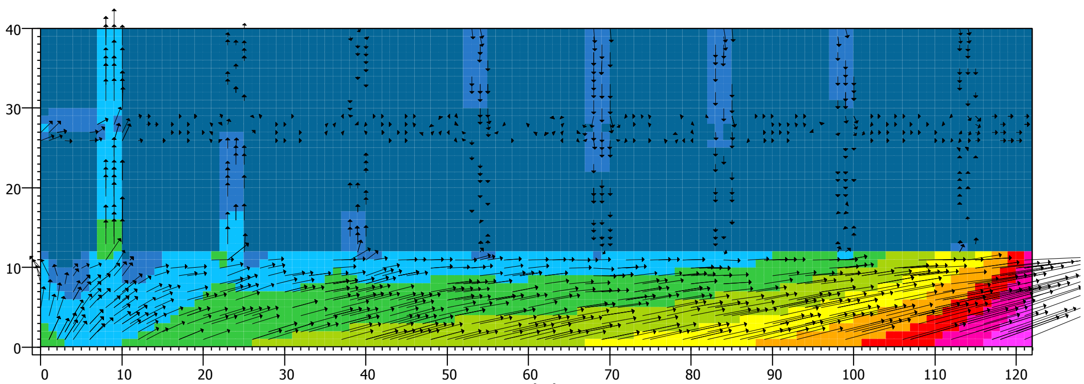


Fig 352: Simulation output _ Simulation type B1 _ EW _ WS _ at 1.30pm

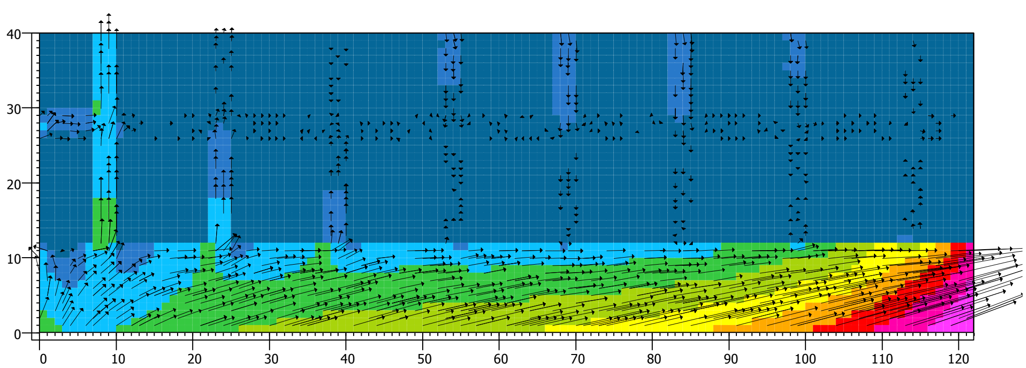
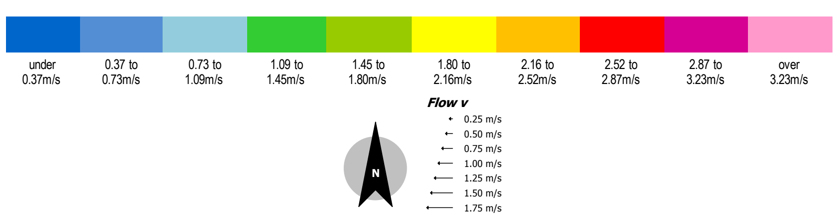


Fig 353: Simulation output _ Simulation type B1 _ EW _ WS _ at 2pm



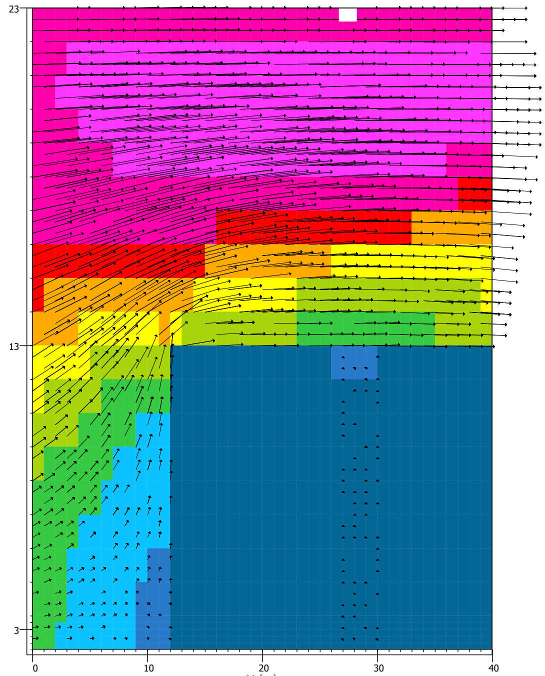


Fig 354: Simulation output _ Simulation type B1 _ EW _ WS _ section _ at 11am

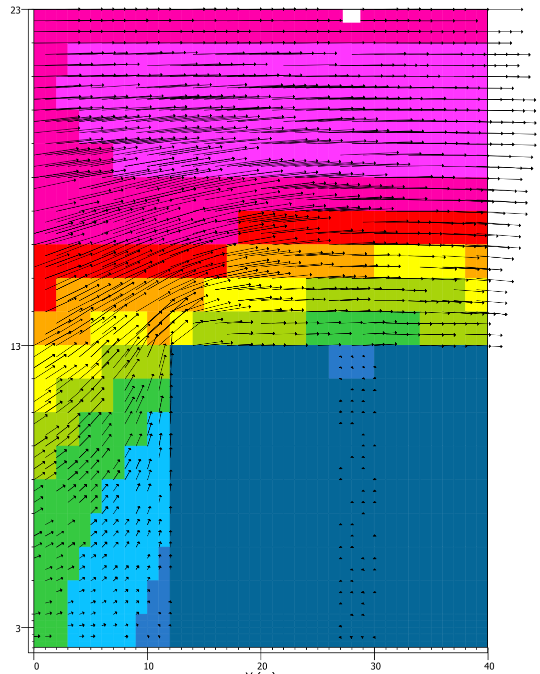


Fig 355: Simulation output _ Simulation type B1 _ EW _ WS _ section _ at 12pm

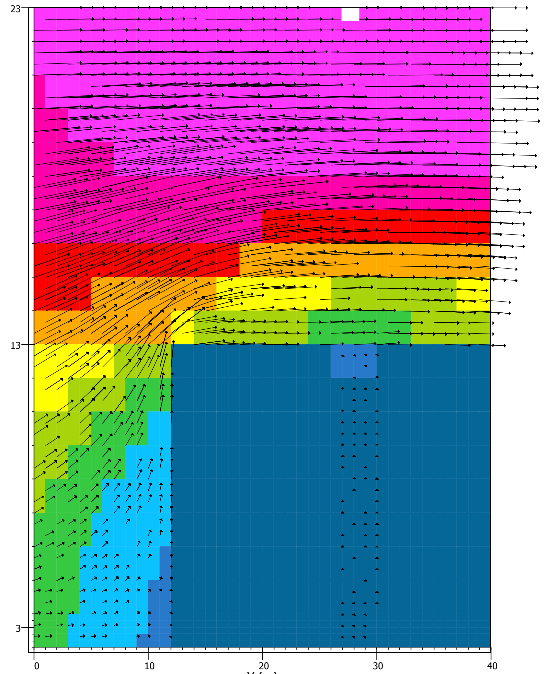


Fig 356: Simulation output _ Simulation type B1 _ EW _ WS _ section _ at 1pm

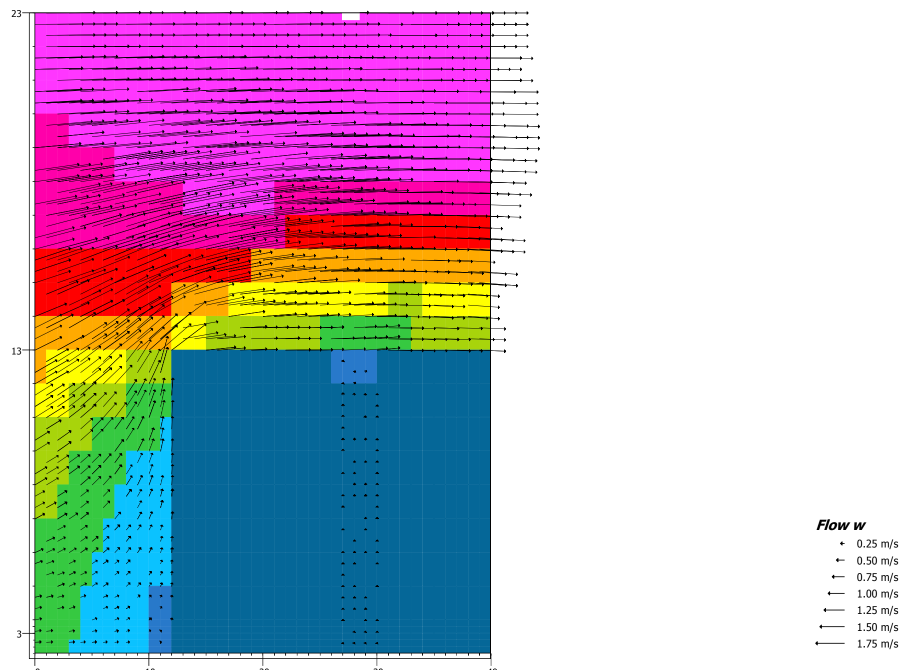
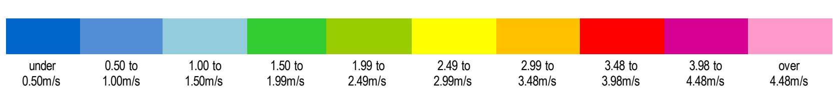


Fig 357: Simulation output _ Simulation type B1 _ EW _ WS _ section _ at 2pm



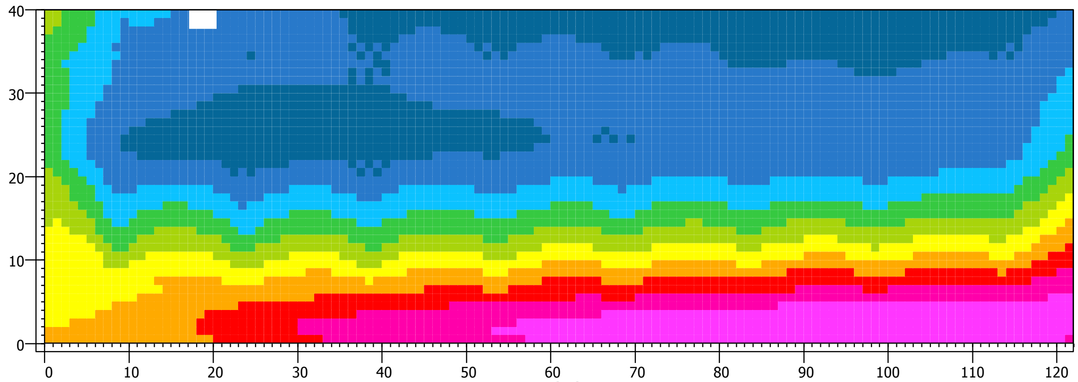


Fig 358: Simulation output _ Simulation type B2 _ EW _ DBT _ at 11am

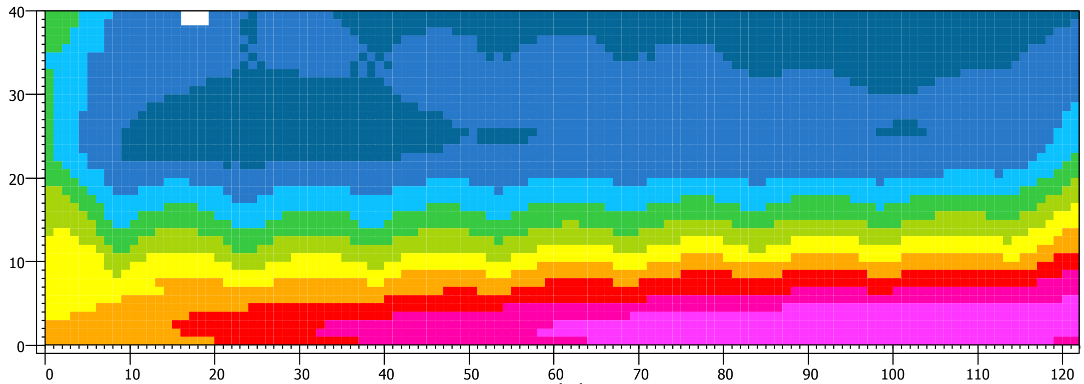


Fig 359: Simulation output _ Simulation type B2 _ EW _ DBT _ at 11.30am

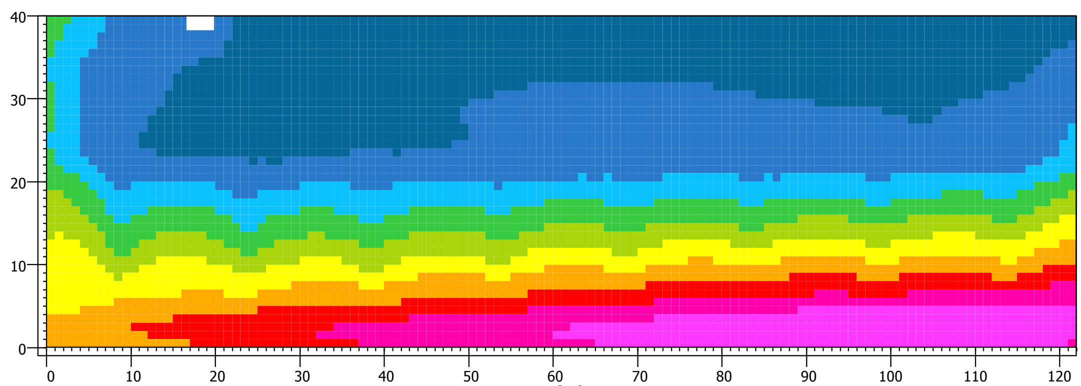


Fig 360: Simulation output _ Simulation type B2 _ EW _ DBT _ at 12pm

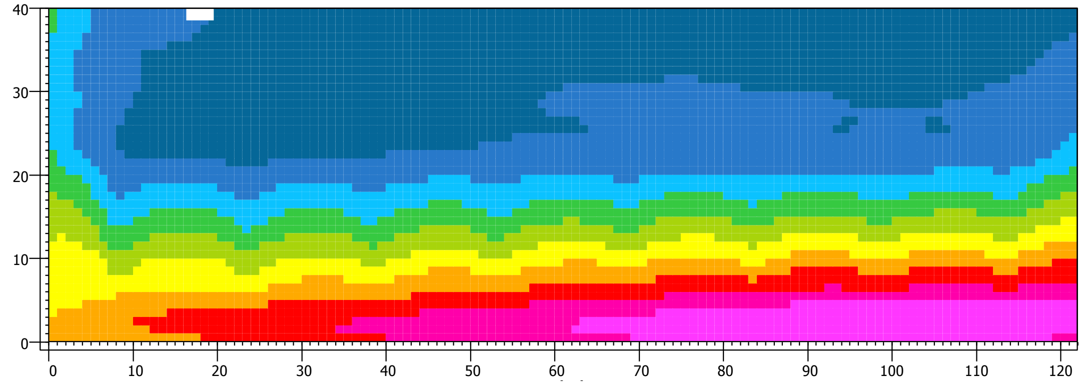


Fig 361: Simulation output _ Simulation type B2 _ EW _ DBT _ at 12.30pm

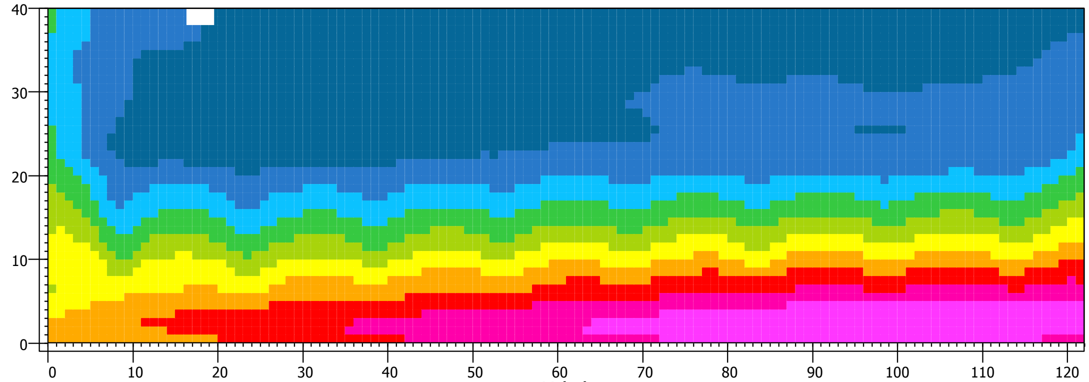


Fig 362: Simulation output _ Simulation type B2 _ EW _ DBT _ at 1pm

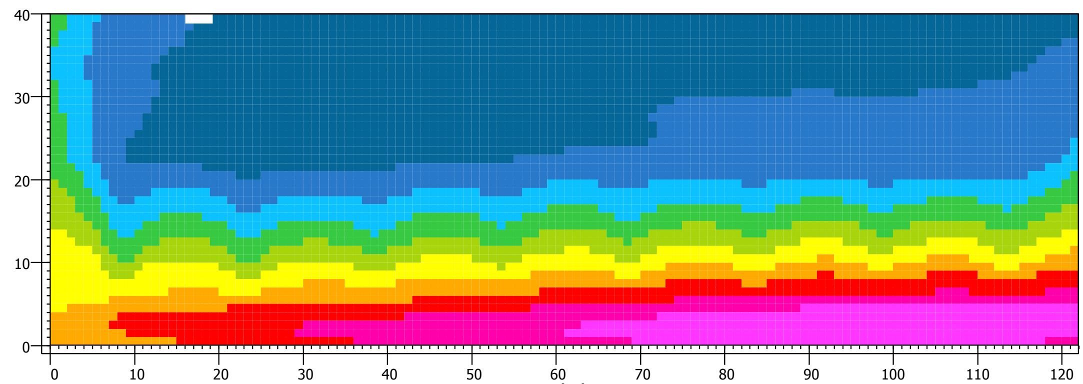


Fig 363: Simulation output _ Simulation type B2 _ EW _ DBT _ at 1.30pm

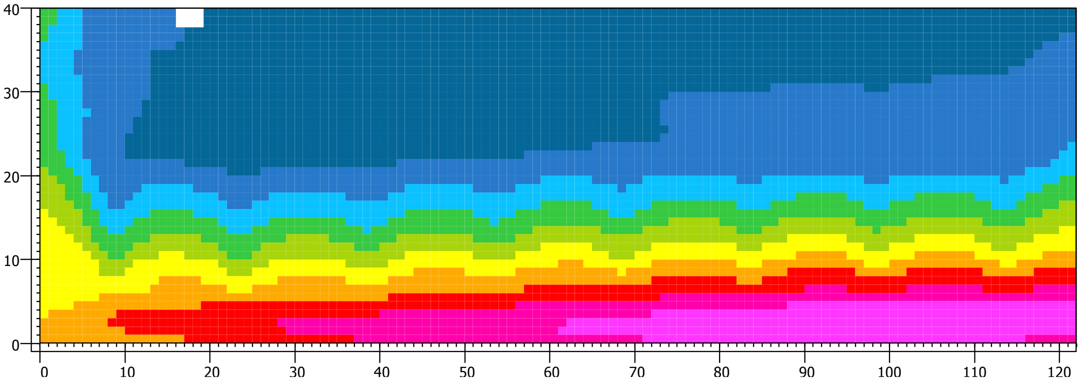
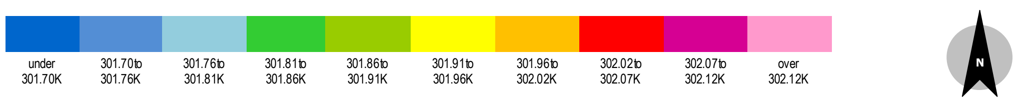


Fig 364: Simulation output _ Simulation type B2 _ EW _ DBT _ at 2pm



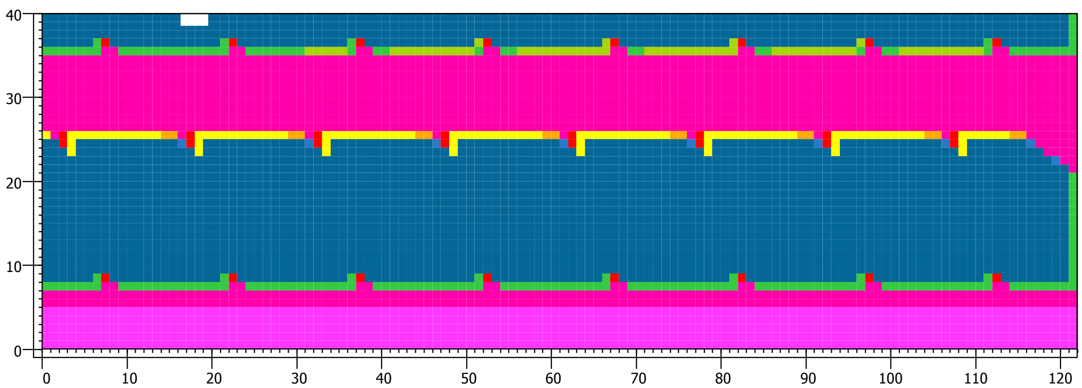


Fig 365: Simulation output _ Simulation type B2 _ EW _ MRT _ at 11am

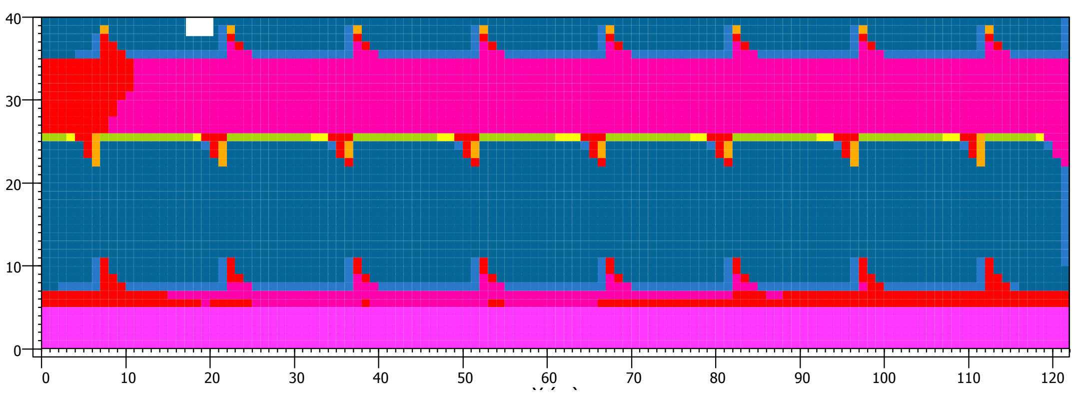


Fig 366: Simulation output _ Simulation type B2 _ EW _ MRT _ at 11.30am

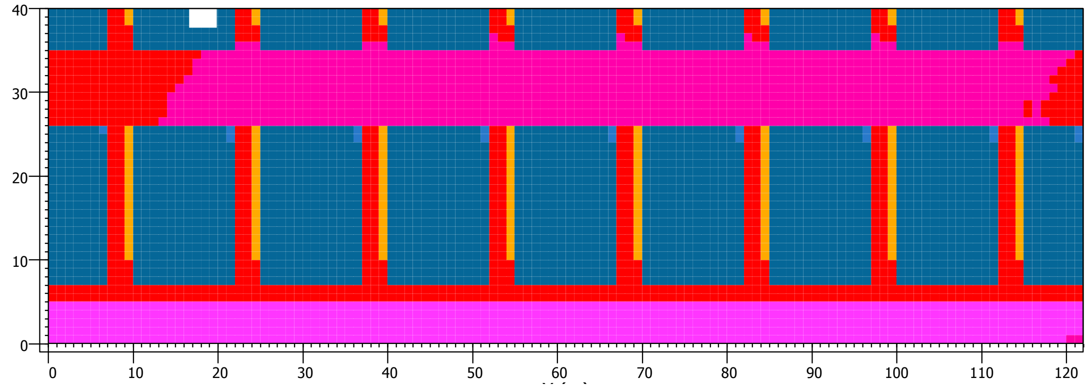


Fig 367: Simulation output _ Simulation type B2 _ EW _ MRT _ at 12pm

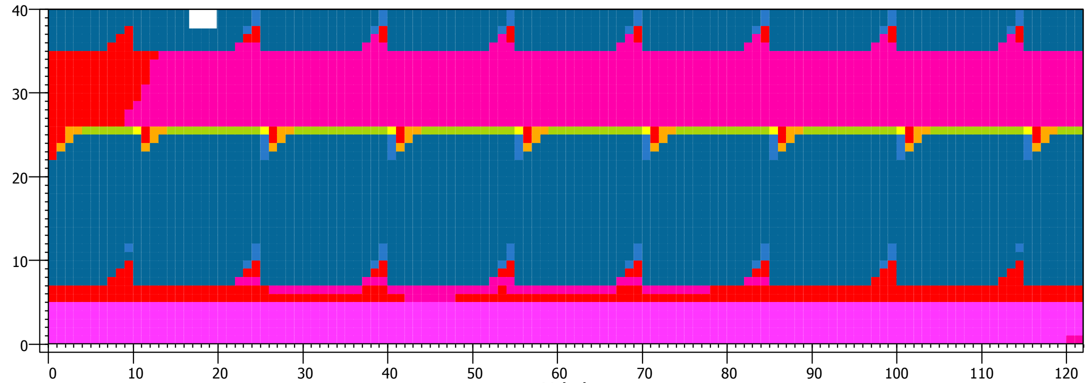


Fig 368: Simulation output _ Simulation type B2 _ EW _ MRT _ at 12.30pm

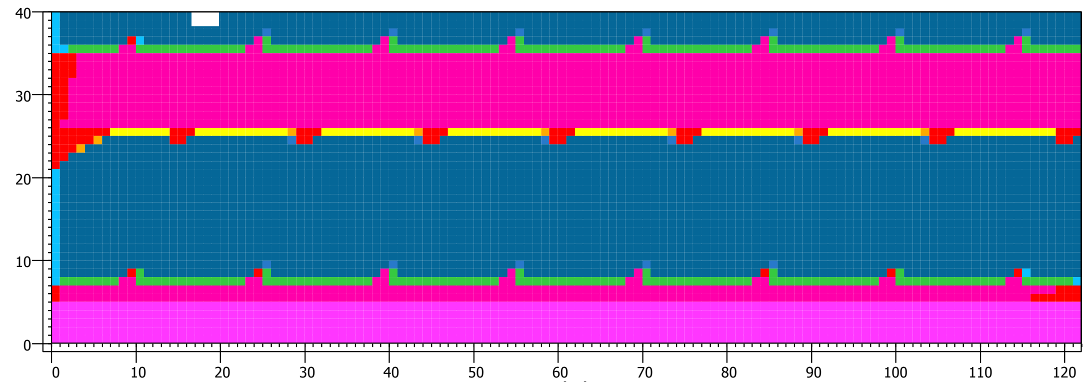


Fig 369: Simulation output _ Simulation type B2 _ EW _ MRT _ at 1pm

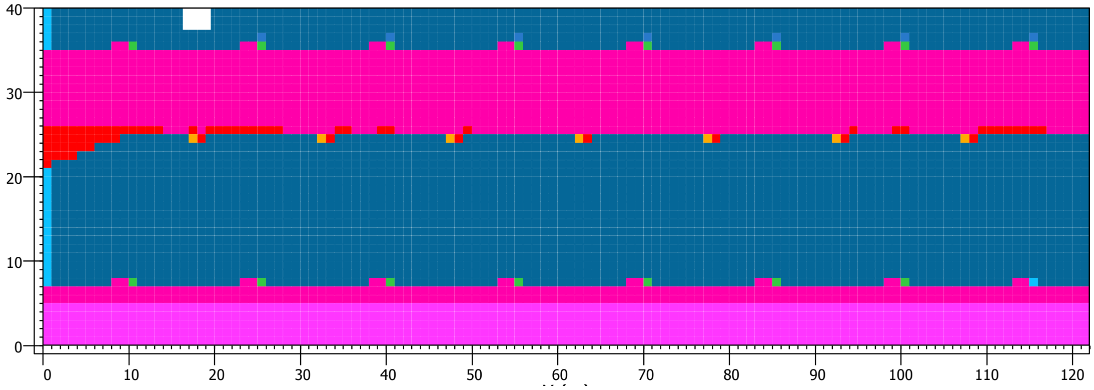


Fig 370: Simulation output _ Simulation type B2 _ EW _ MRT _ at 1.30pm

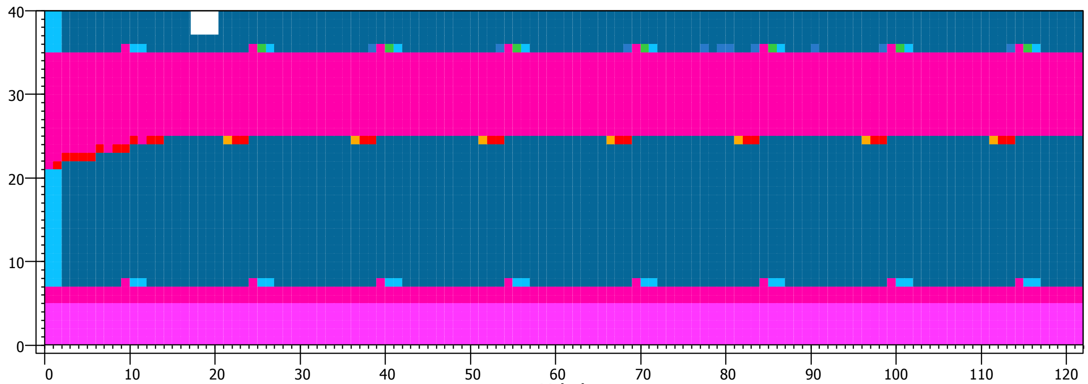
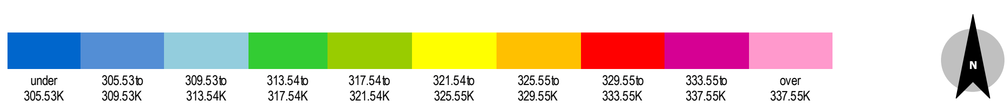


Fig 371: Simulation output _ Simulation type B2 _ EW _ MRT _ at 2pm



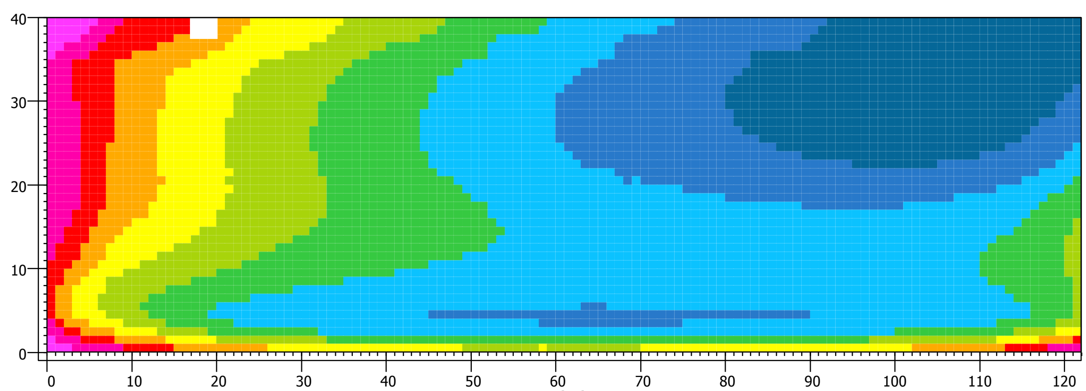


Fig 372: Simulation output _ Simulation type B2 _ EW _ RH _ at 11am

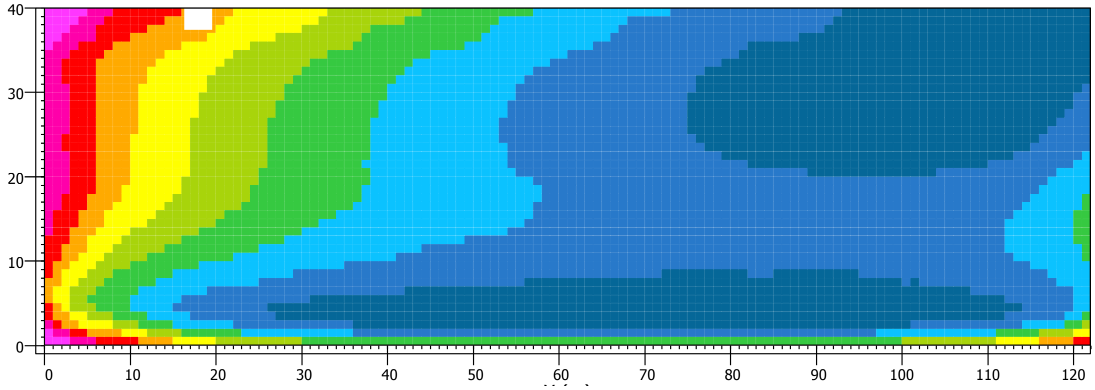


Fig 373: Simulation output _ Simulation type B2 _ EW _ RH _ at 11.30am

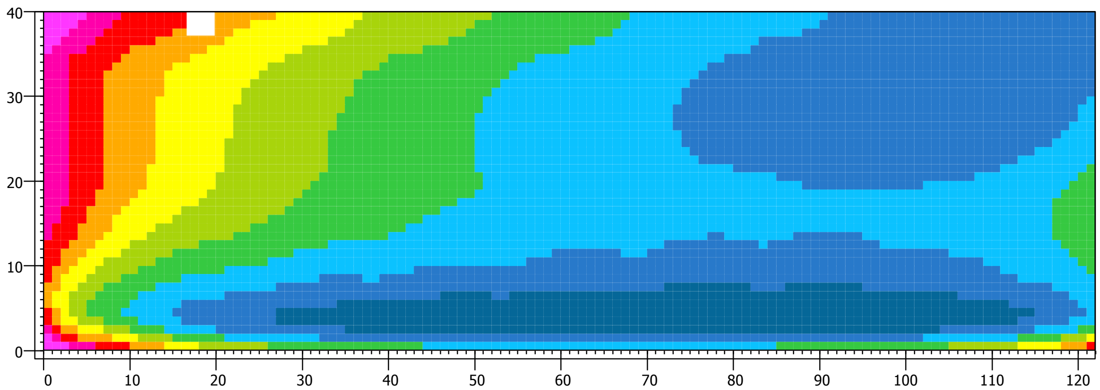


Fig 374: Simulation output _ Simulation type B2 _ EW _ RH _ at 12pm

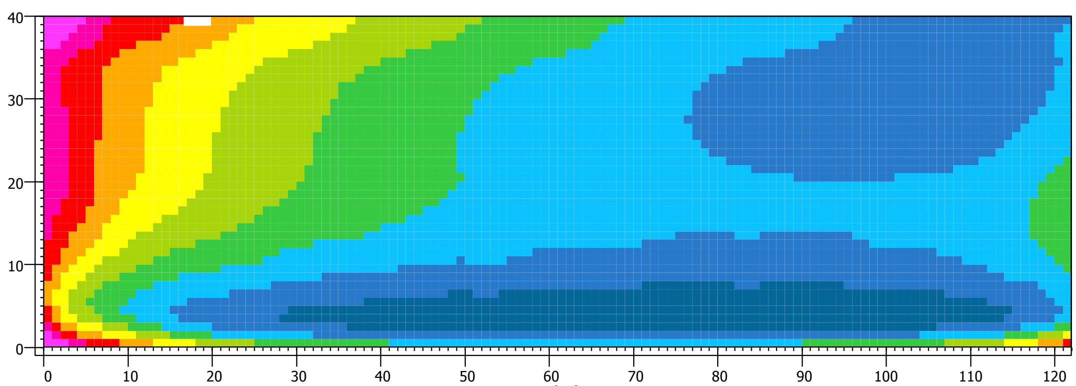


Fig 375: Simulation output _ Simulation type B2 _ EW _ RH _ at 12.30pm

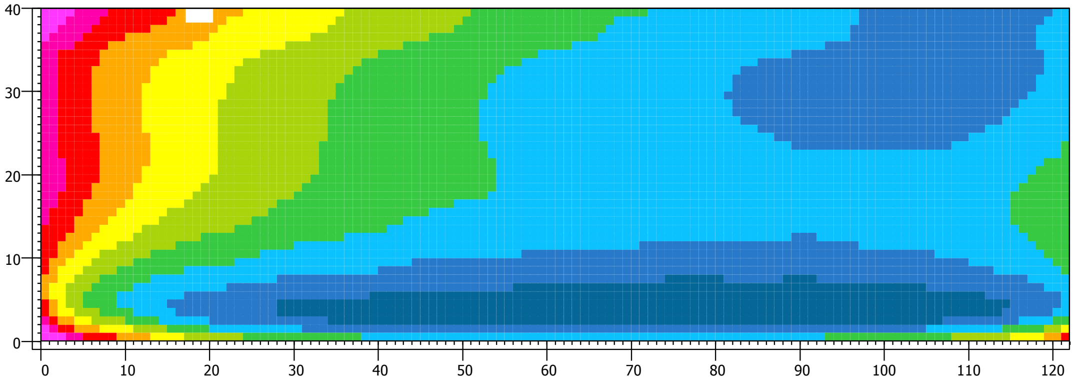


Fig 376: Simulation output _ Simulation type B2 _ EW _ RH _ at 1pm

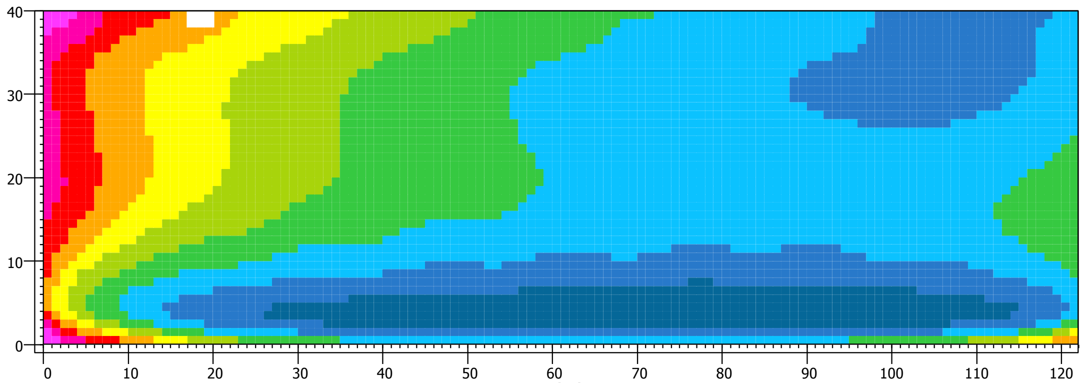


Fig 377: Simulation output _ Simulation type B2 _ EW _ RH _ at 1.30pm

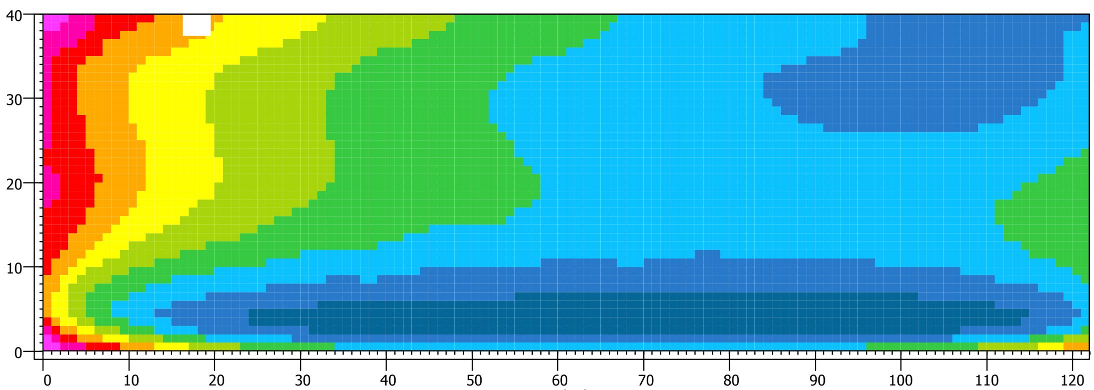
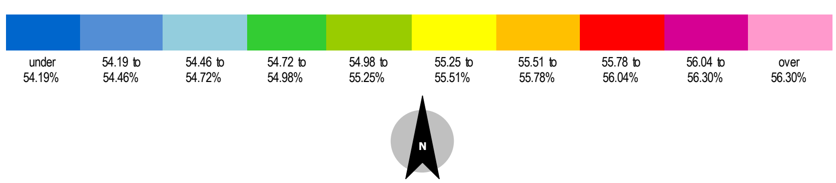


Fig 378: Simulation output _ Simulation type B2 _ EW _ RH _ at 2pm



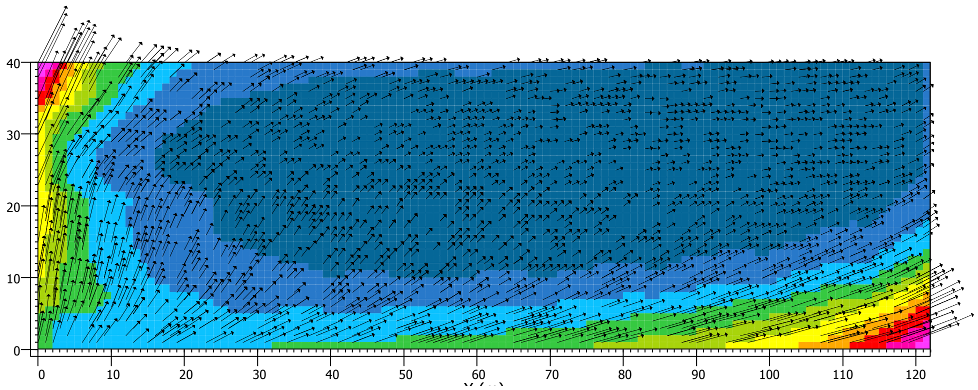


Fig 379: Simulation output _ Simulation type B2 _ EW _ WS _ at 11am

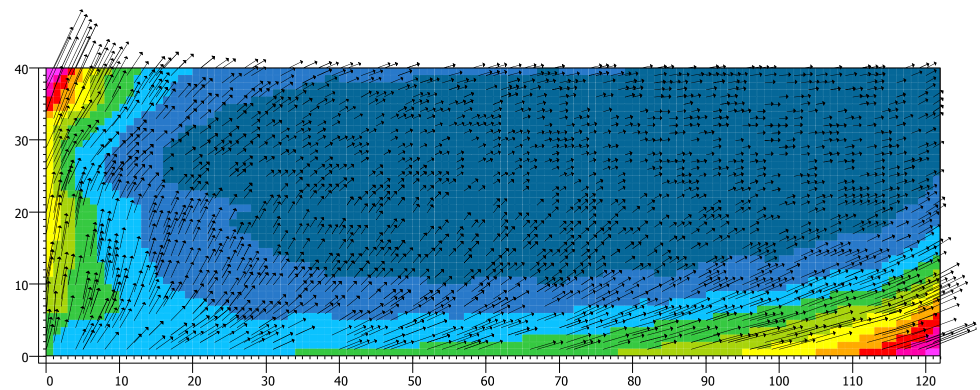


Fig 380: Simulation output _ Simulation type B2 _ EW _ WS _ at 11.30am

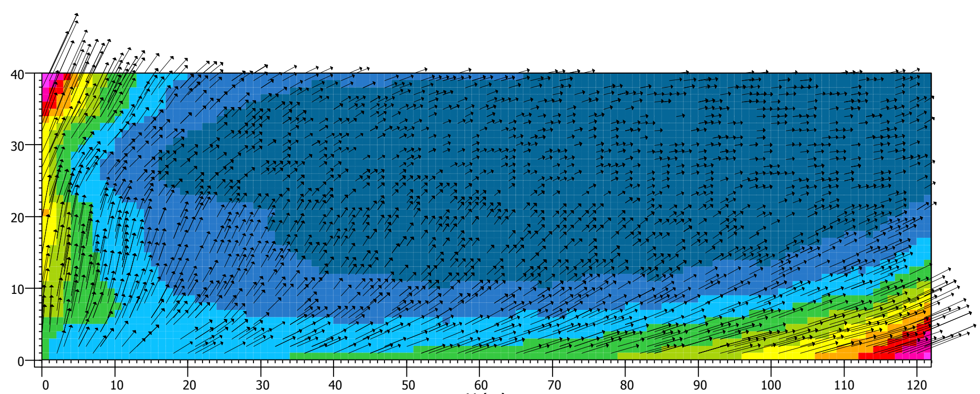


Fig 381: Simulation output _ Simulation type B2 _ EW _ WS _ at 12pm

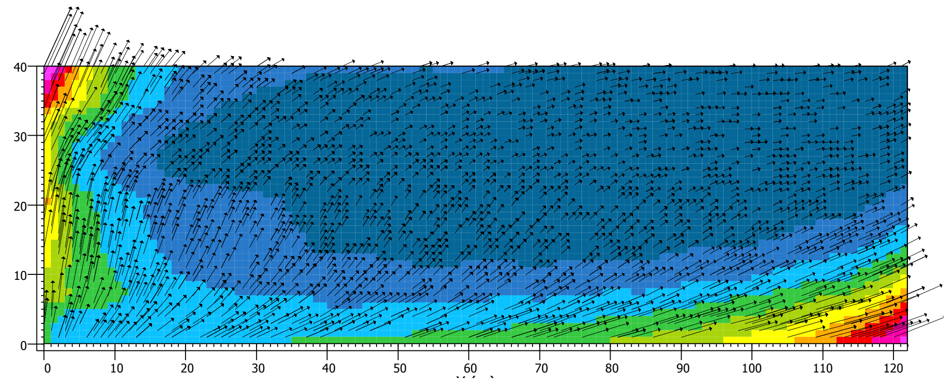


Fig 382: Simulation output _ Simulation type B2 _ EW _ WS _ at 12.30pm

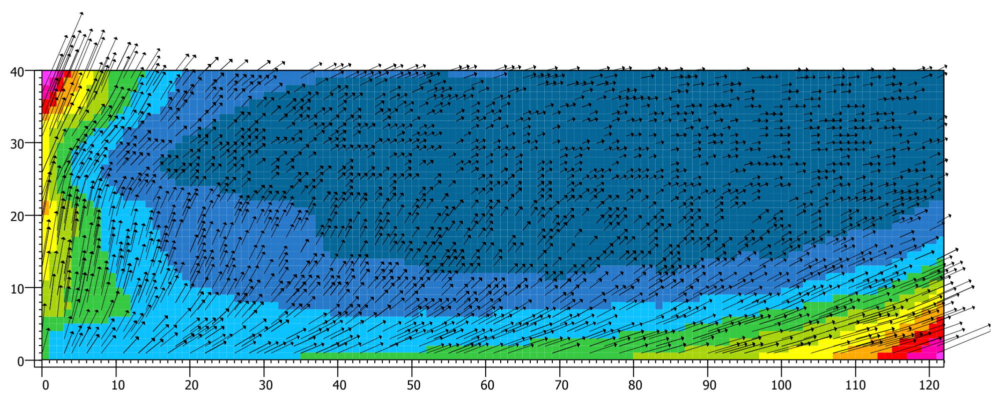


Fig 383: Simulation output _ Simulation type B2 _ EW _ WS _ at 1pm

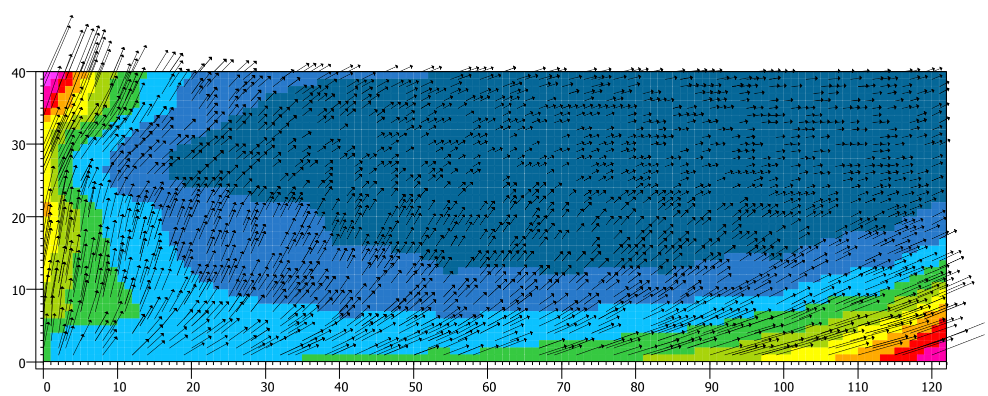


Fig 384: Simulation output _ Simulation type B2 _ EW _ WS _ at 1.30pm

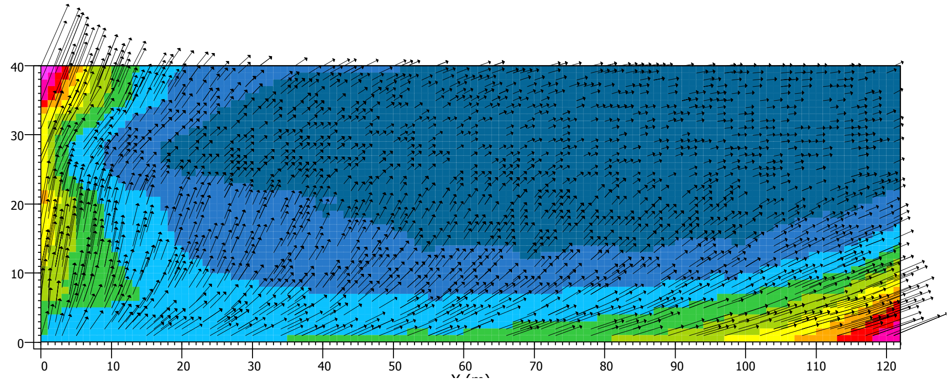
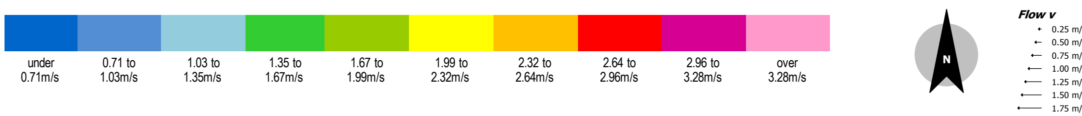


Fig 385: Simulation output _ Simulation type B2 _ EW _ WS _ at 2pm



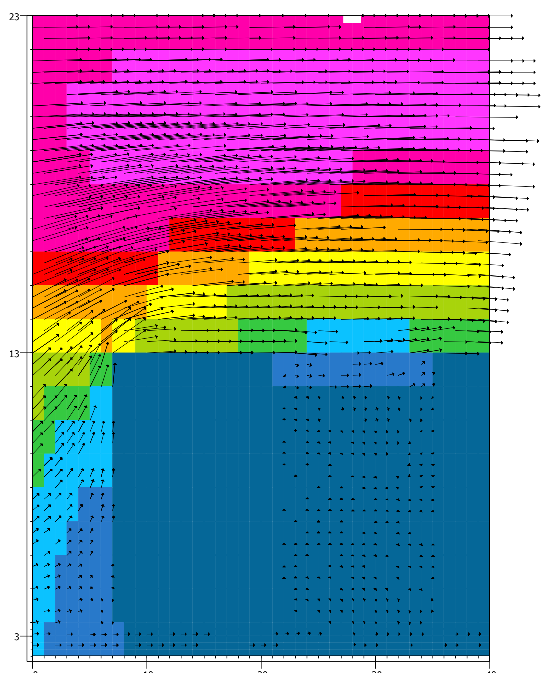


Fig 386: Simulation output _ Simulation type B2 _ EW _ WS _ section _ at 11am

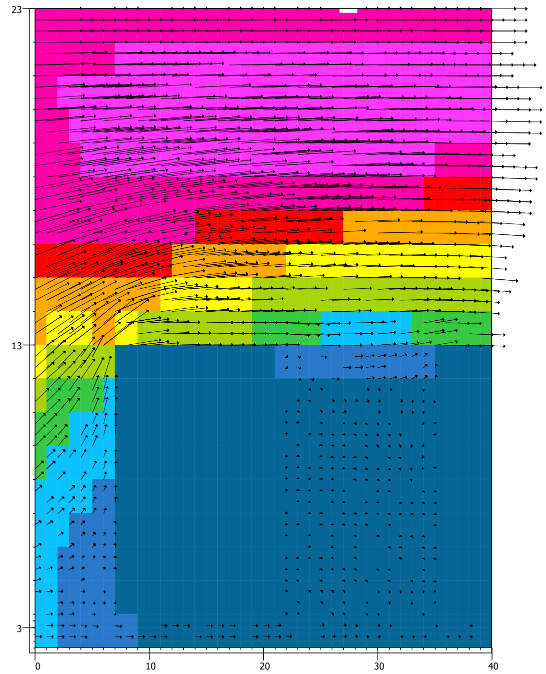


Fig 387: Simulation output _ Simulation type B2 _ EW _ WS _ section _ at 12pm

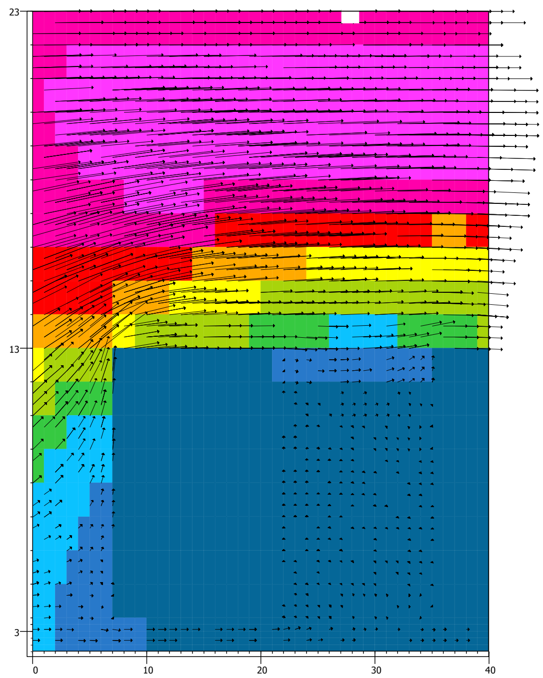


Fig 388: Simulation output _ Simulation type B2 _ EW _ WS _ section _ at 1pm

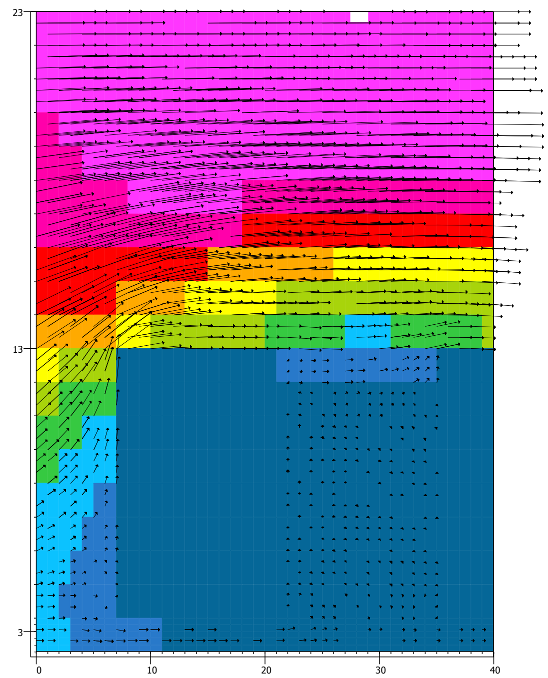
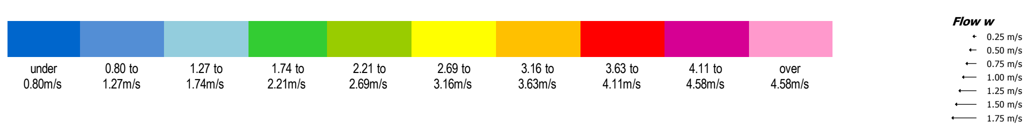


Fig 389: Simulation output _ Simulation type B2 _ EW _ WS _ section _ at 2pm



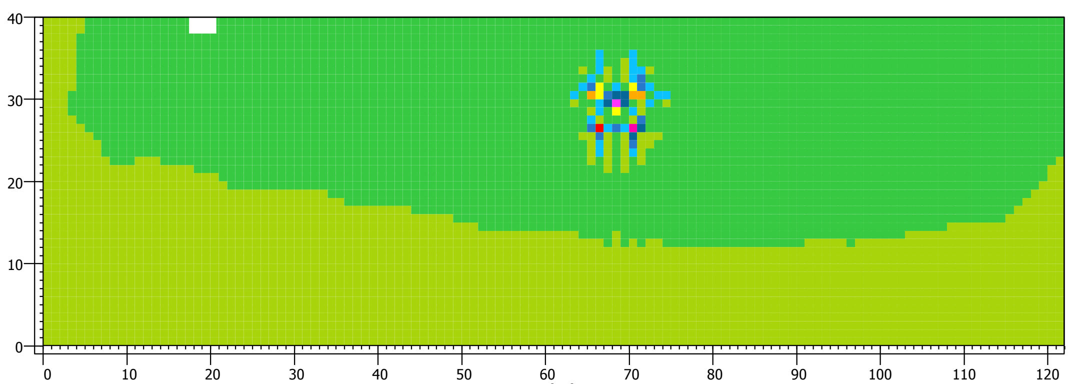


Fig 390: Simulation output _ Simulation type B3 _ EW _ DBT _ at 11am

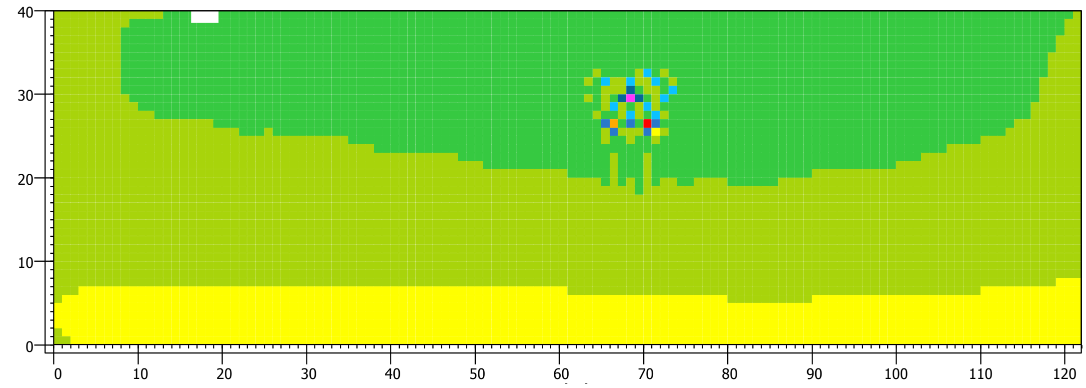


Fig 391: Simulation output _ Simulation type B3 _ EW _ DBT _ at 11.30am

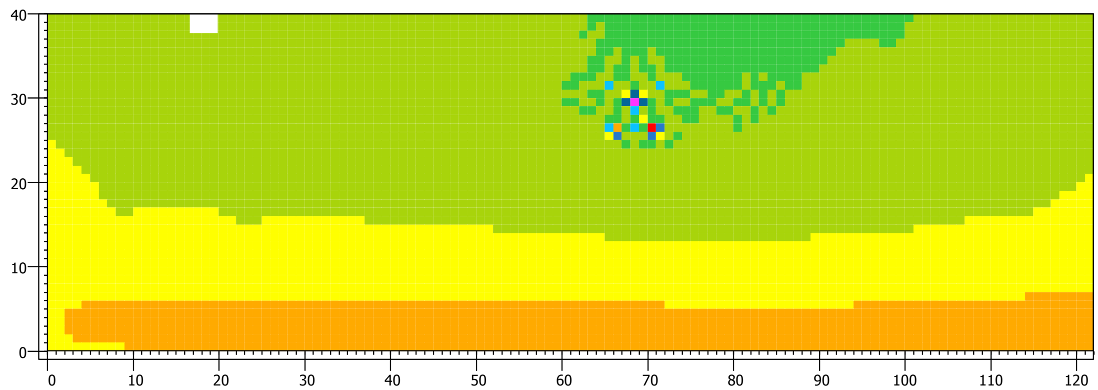


Fig 392: Simulation output _ Simulation type B3 _ EW _ DBT _ at 12pm

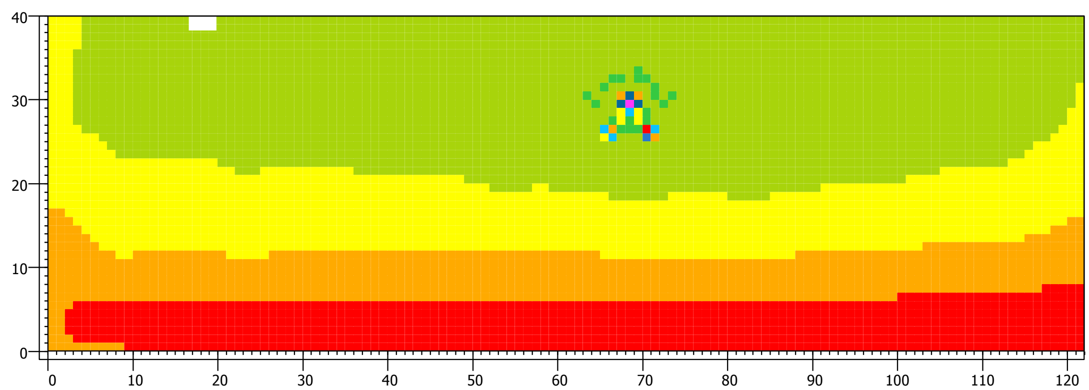


Fig 393: Simulation output _ Simulation type B3 _ EW _ DBT _ at 12.30pm

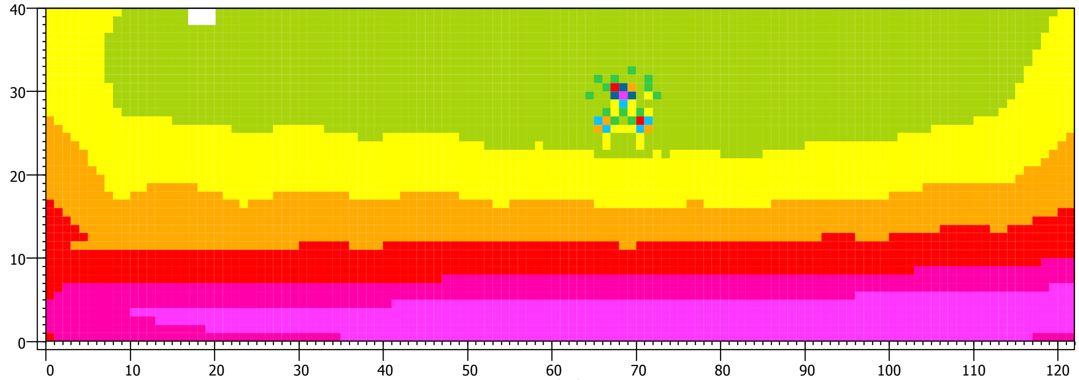


Fig 394: Simulation output _ Simulation type B3 _ EW _ DBT _ at 1pm

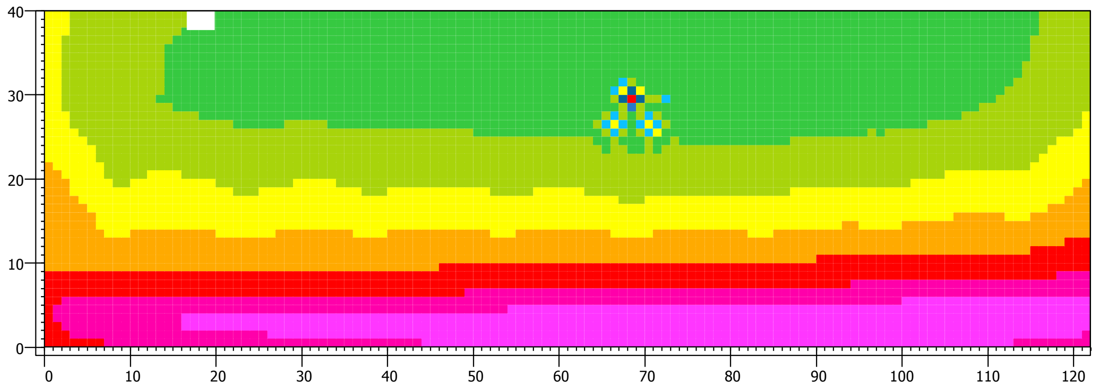


Fig 395: Simulation output _ Simulation type B3 _ EW _ DBT _ at 1.30pm

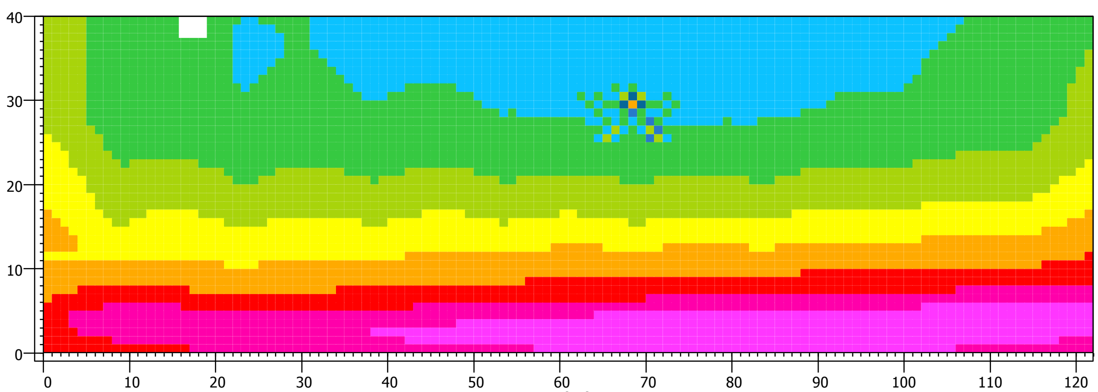
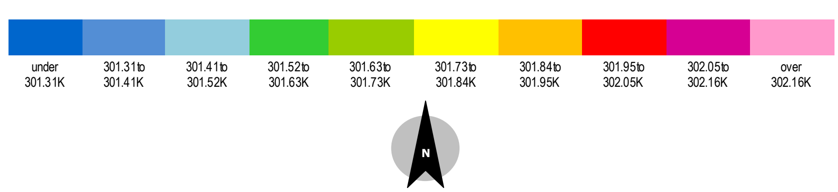


Fig 396: Simulation output _ Simulation type B3 _ EW _ DBT _ at 2pm



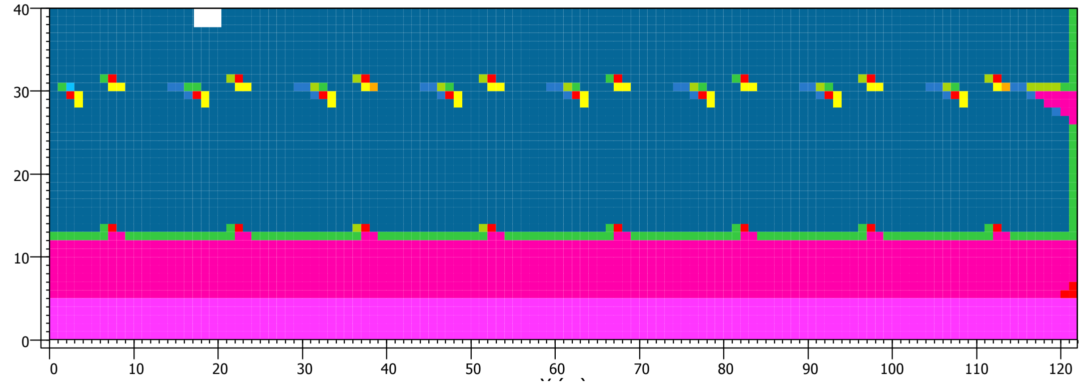


Fig 397: Simulation output _ Simulation type B3 _ EW _ MRT _ at 11am

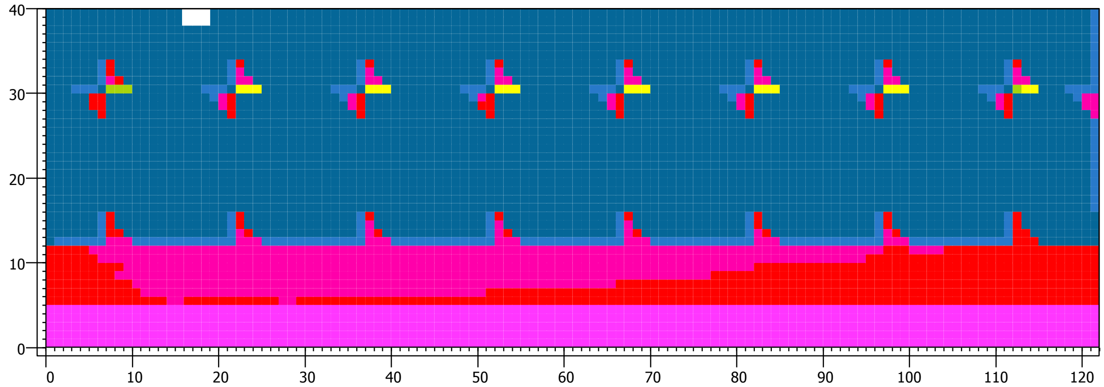


Fig 398: Simulation output _ Simulation type B3 _ EW _ MRT _ at 11.30am

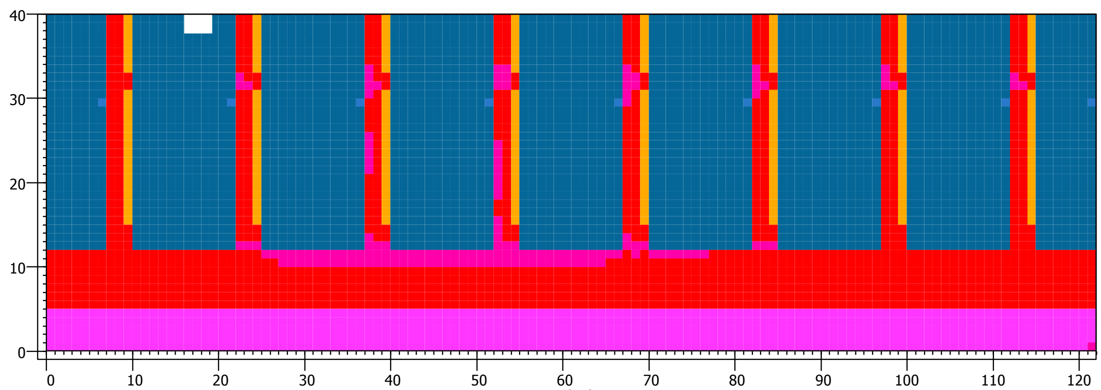


Fig 399: Simulation output _ Simulation type B3 _ EW _ MRT _ at 12pm

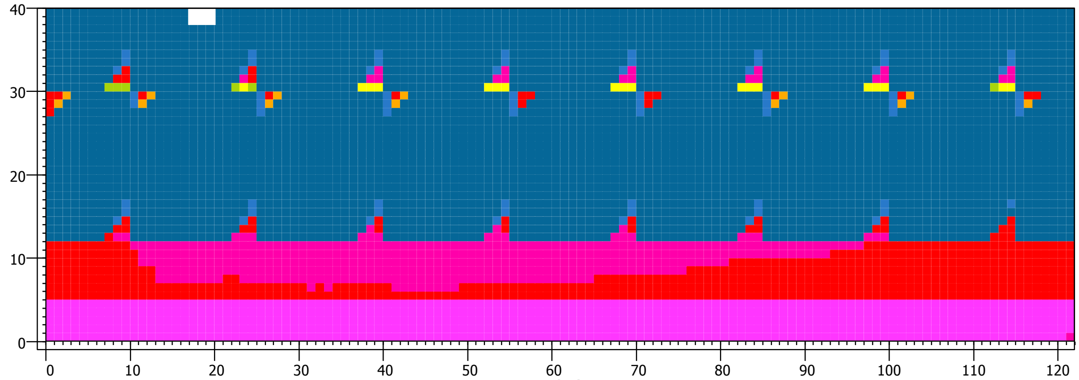


Fig 400: Simulation output _ Simulation type B3 _ EW _ MRT _ at 12.30pm

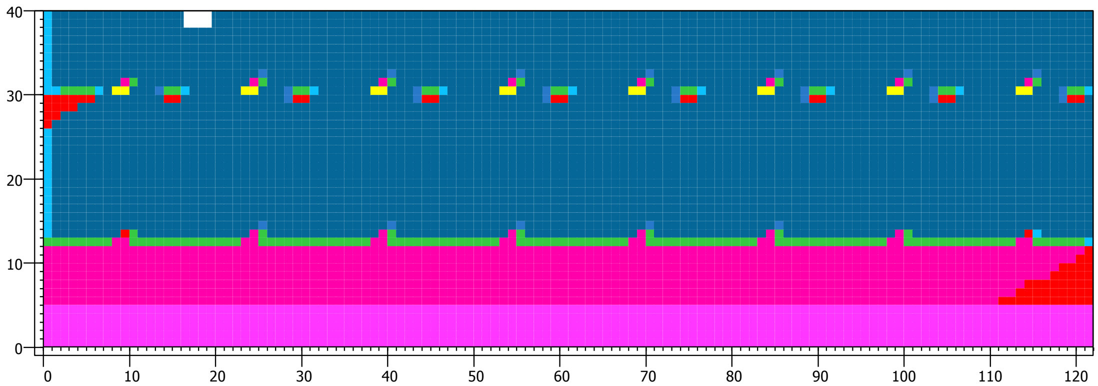


Fig 401: Simulation output _ Simulation type B3 _ EW _ MRT _ at 1pm

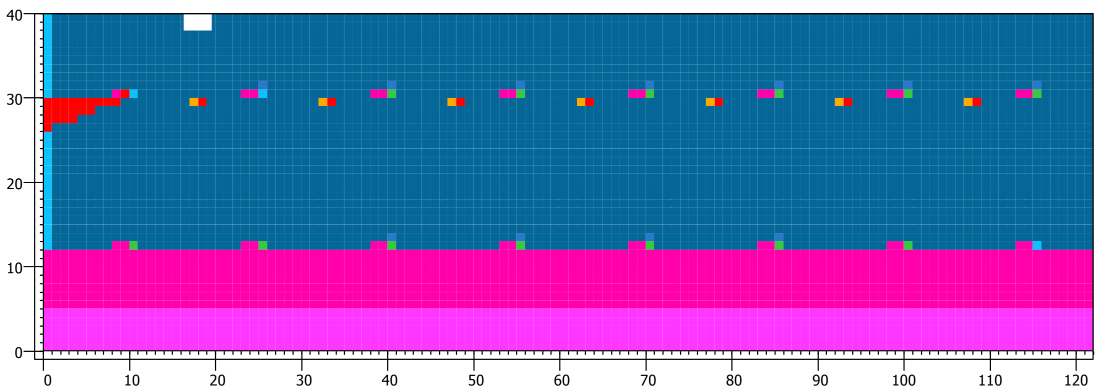


Fig 402: Simulation output _ Simulation type B3 _ EW _ MRT _ at 1.30pm

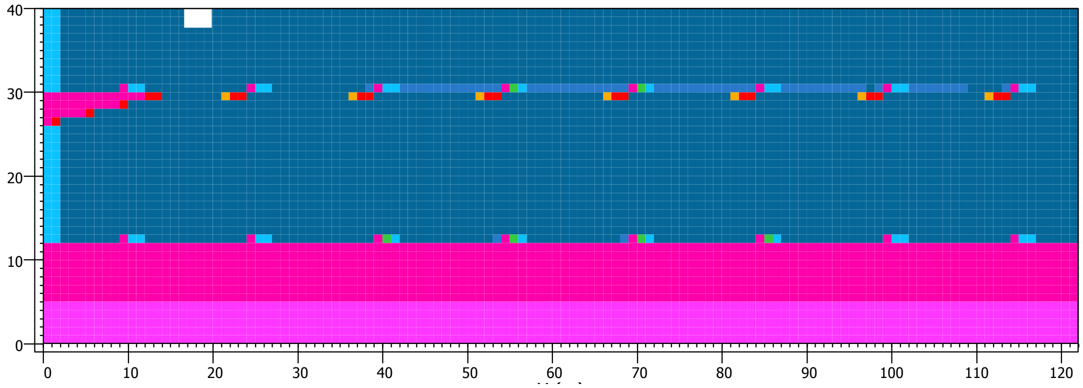
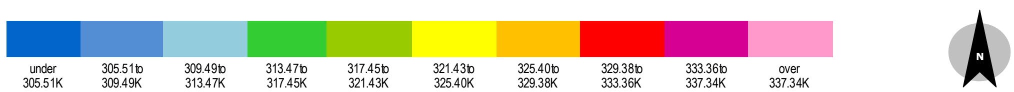


Fig 403: Simulation output _ Simulation type B3 _ EW _ MRT _ at 2pm



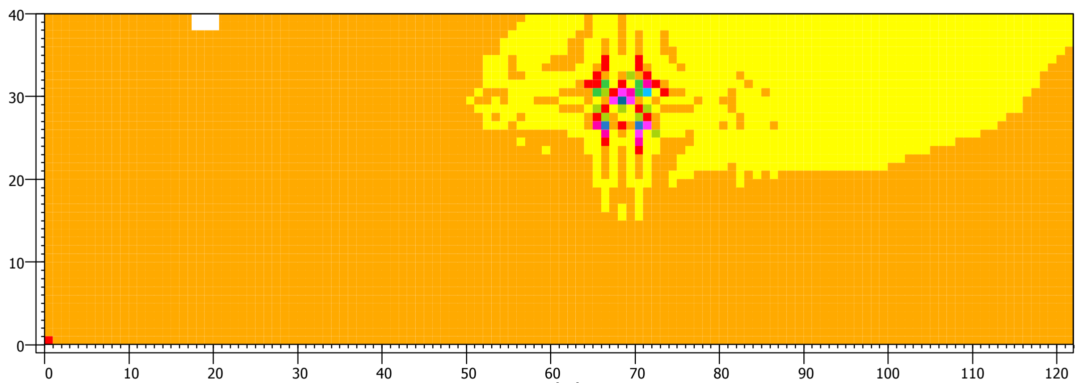


Fig 404: Simulation output _ Simulation type B3 _ EW _ RH _ at 11am

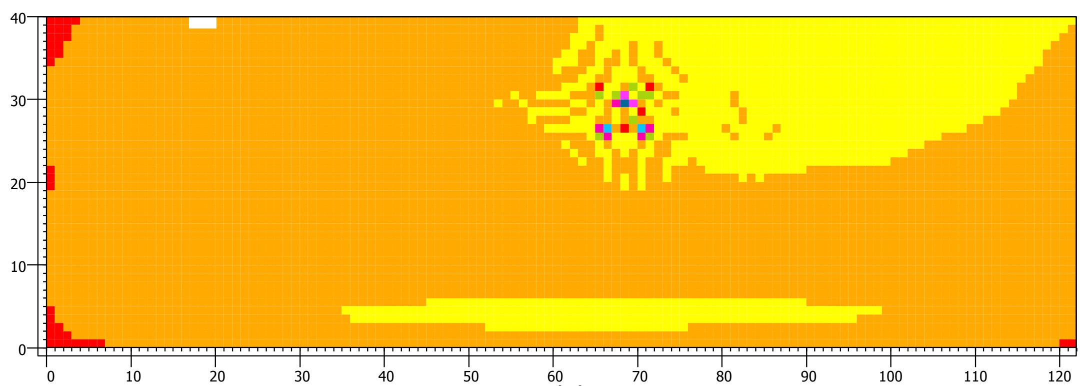


Fig 405: Simulation output _ Simulation type B3 _ EW _ RH _ at 11.30am

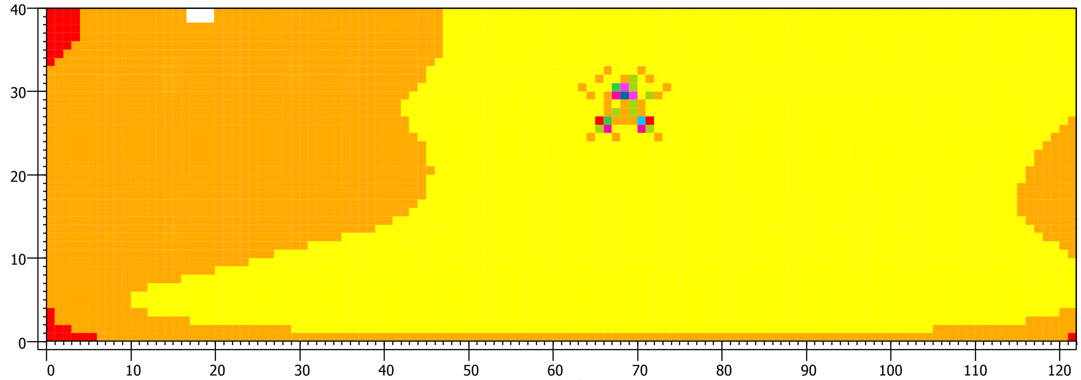


Fig 406: Simulation output _ Simulation type B3 _ EW _ RH _ at 12pm

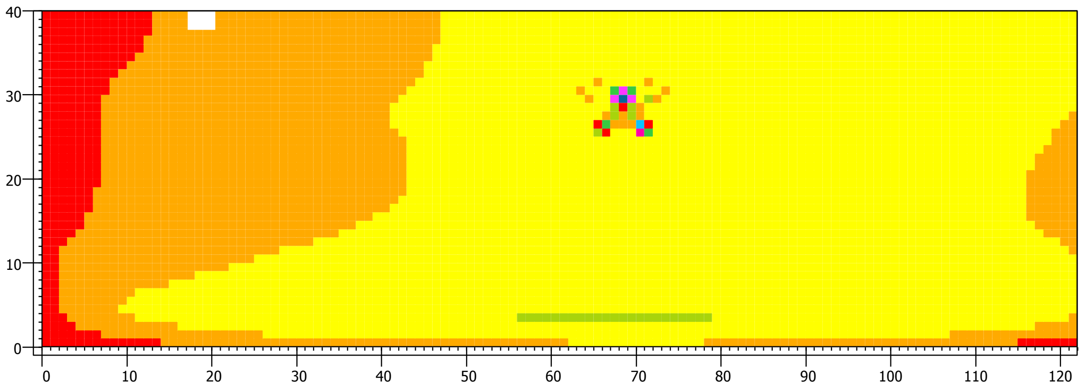


Fig 407: Simulation output _ Simulation type B3 _ EW _ RH _ at 12.30pm

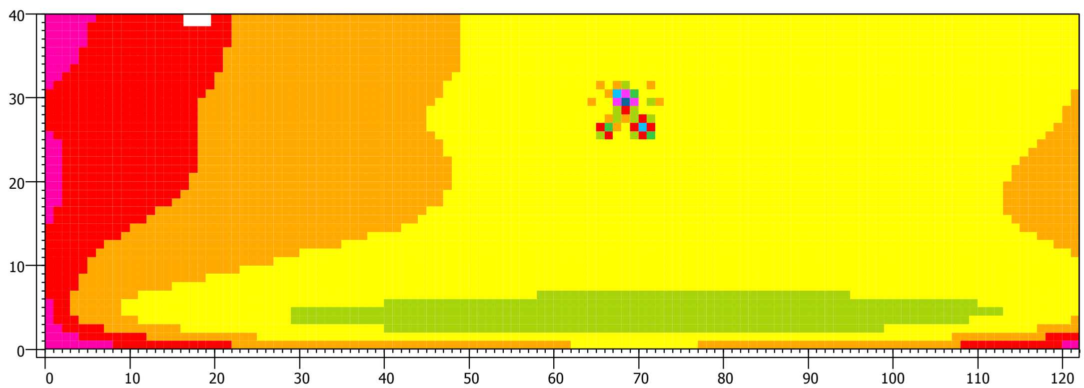


Fig 408: Simulation output _ Simulation type B3 _ EW _ RH _ at 1pm

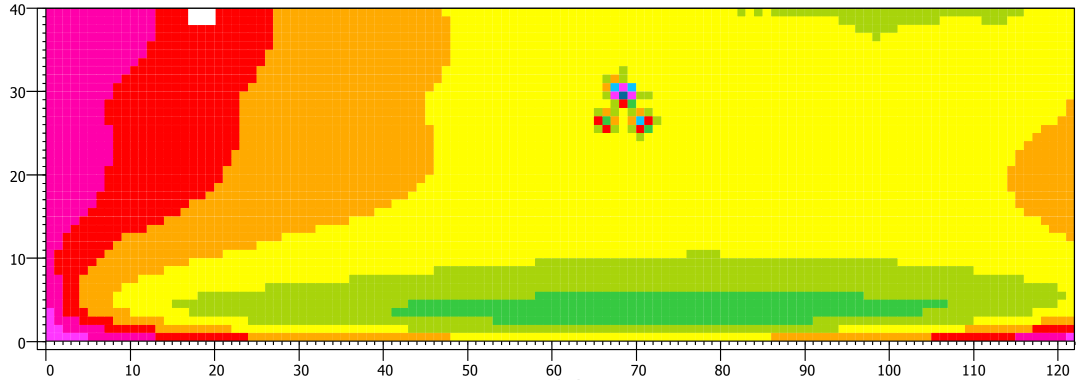


Fig 409: Simulation output _ Simulation type B3 _ EW _ RH _ at 1.30pm

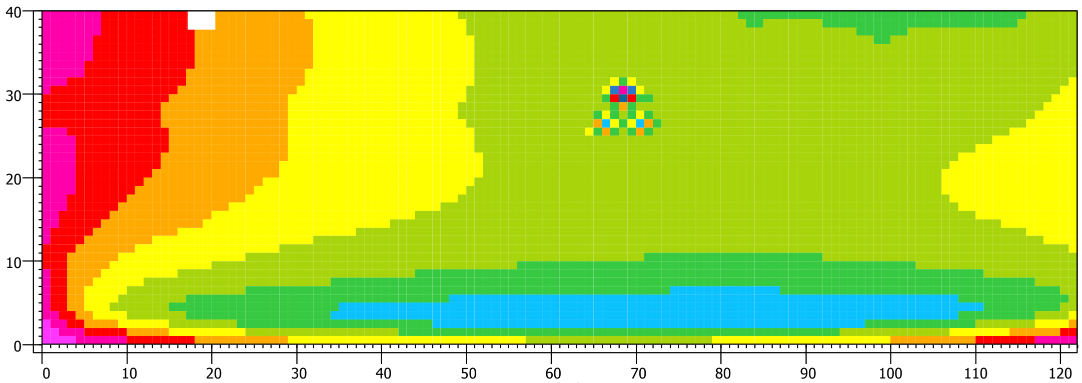
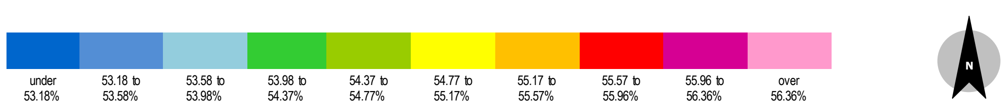


Fig 410: Simulation output _ Simulation type B3 _ EW _ RH _ at 2pm



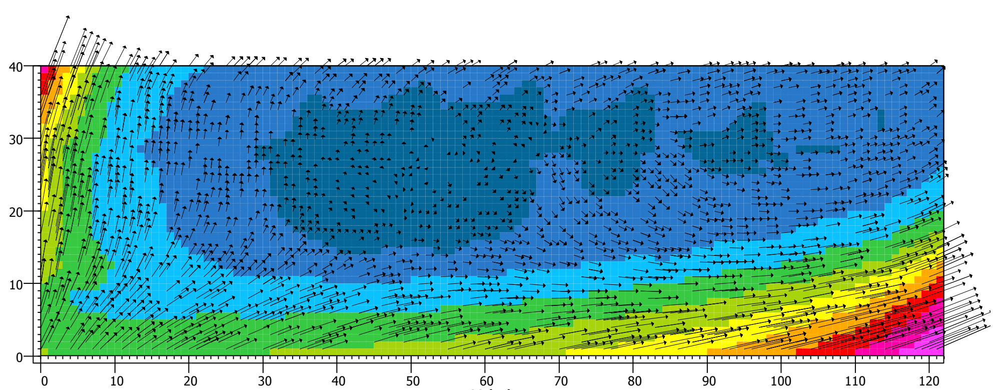


Fig 411: Simulation output _ Simulation type B3 _ EW _ WS _ at 11am

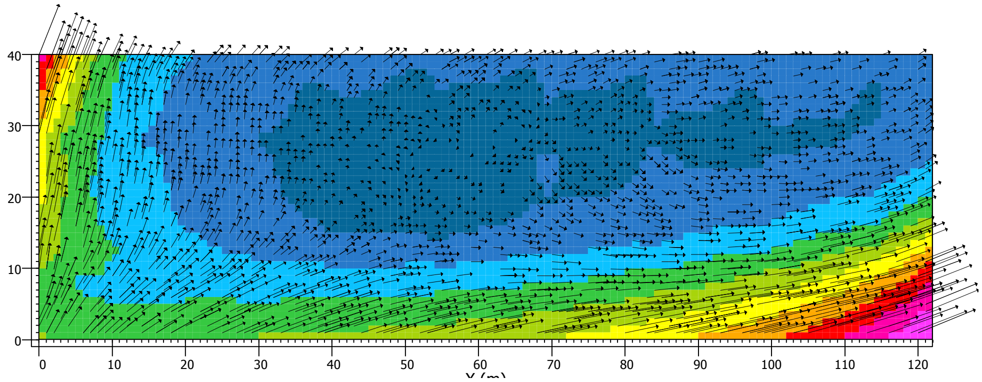


Fig 412: Simulation output _ Simulation type B3 _ EW _ WS _ at 11.30am

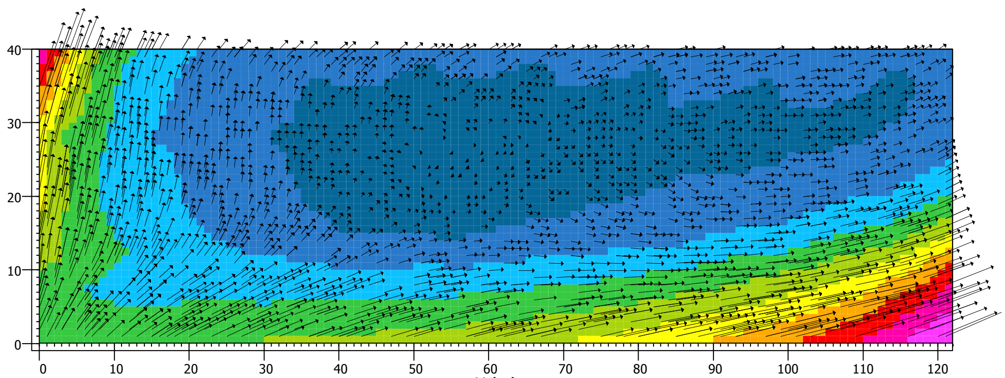


Fig 413: Simulation output _ Simulation type B3 _ EW _ WS _ at 12pm

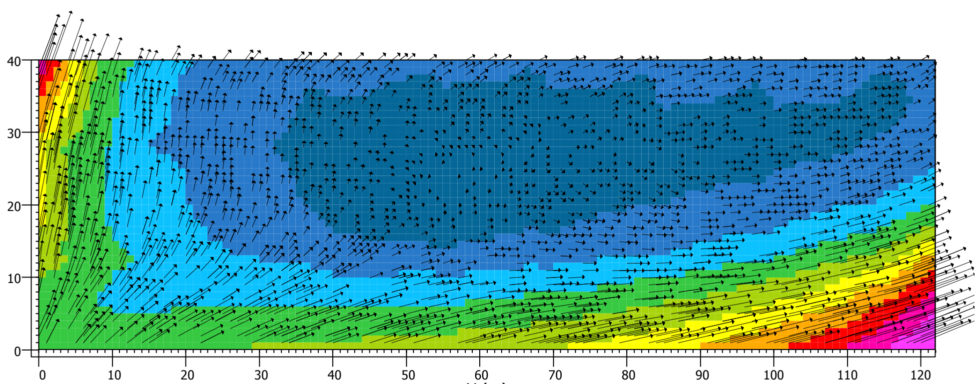


Fig 414: Simulation output _ Simulation type B3 _ EW _ WS _ at 12.30pm

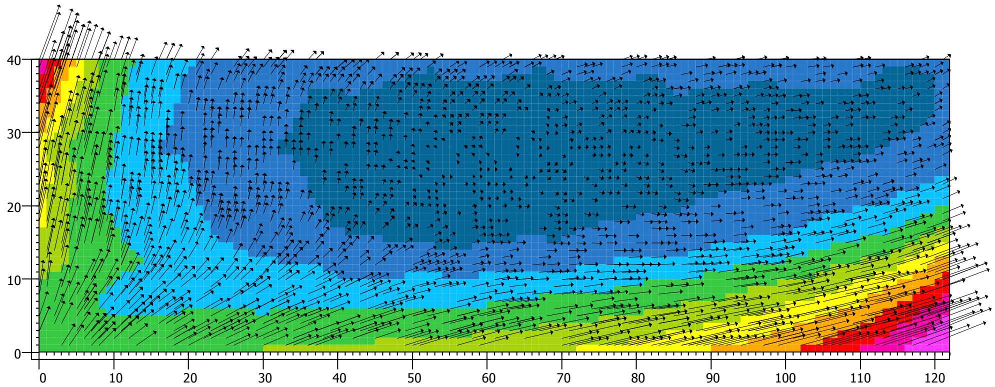


Fig 415: Simulation output _ Simulation type B3 _ EW _ WS _ at 1pm

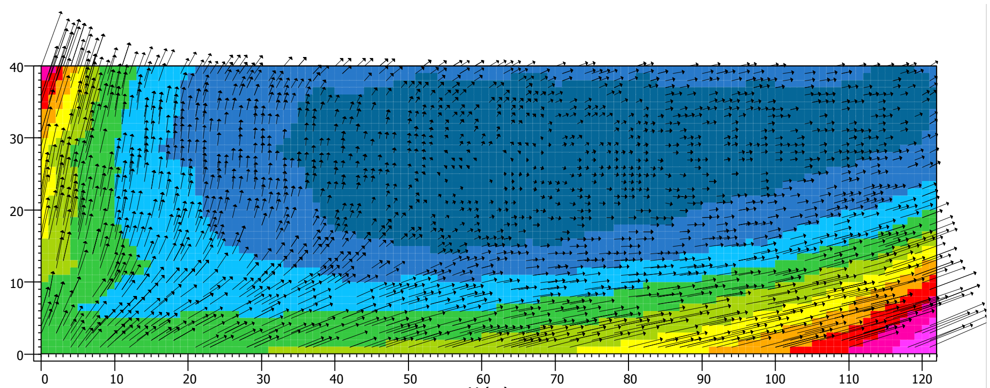


Fig 416: Simulation output _ Simulation type B3 _ EW _ WS _ at 1.30pm

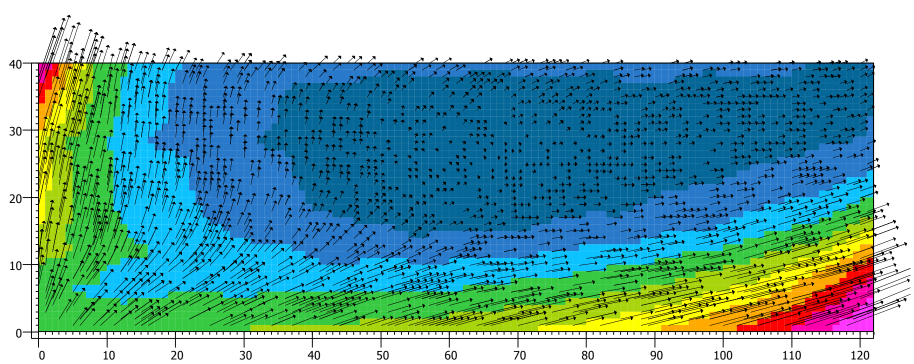
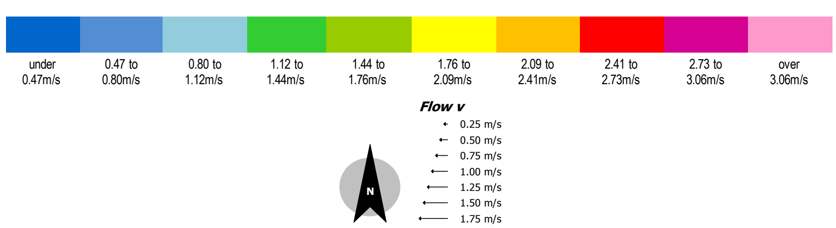


Fig 417: Simulation output _ Simulation type B3 _ EW _ WS _ at 2pm



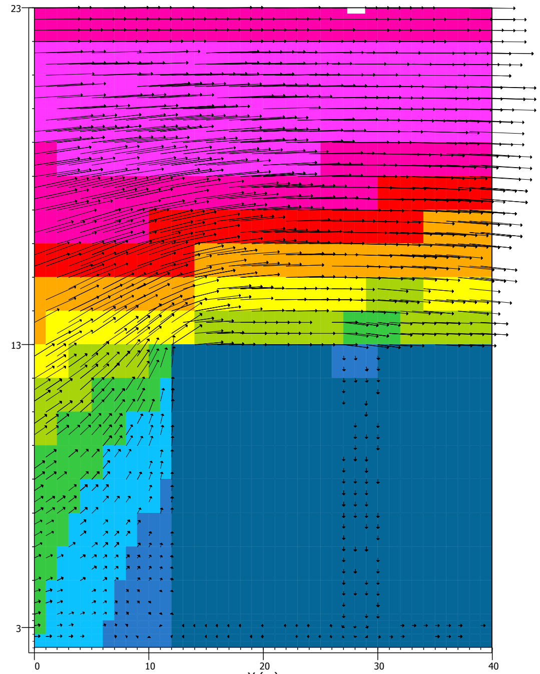


Fig 418: Simulation output _ Simulation type B3 _ EW _ WS _ section _ at 11am

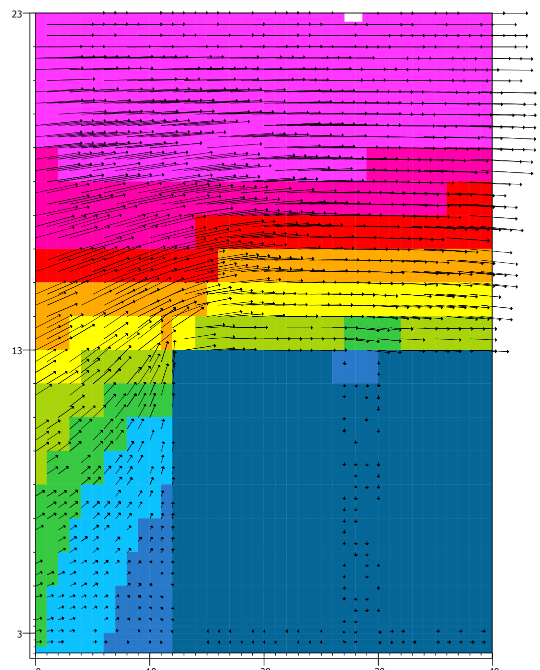


Fig 419: Simulation output _ Simulation type B3 _ EW _ WS _ section _ at 12pm

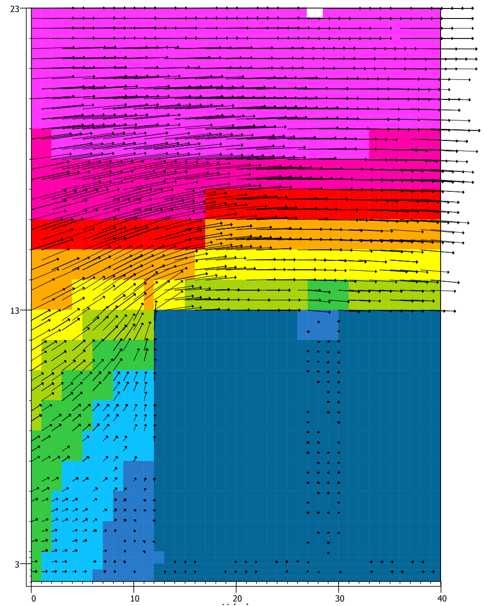


Fig 420: Simulation output _ Simulation type B3 _ EW _ WS _ section _ at 1pm

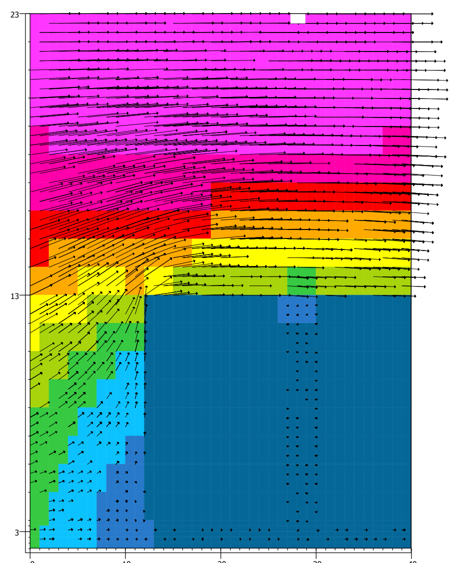
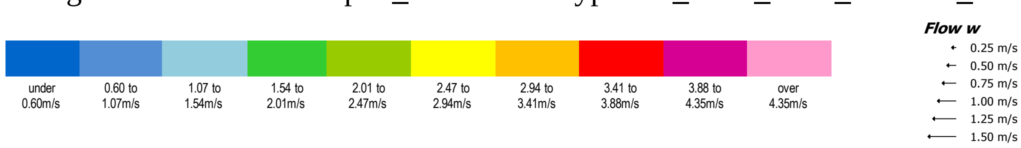


Fig 421: Simulation output _ Simulation type B3 _ EW _ WS _ section _ at 2pm



Appendix – 2: Data Tables

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

	Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Date: 15/03/2014						
Day: 1	**Spot-01**	37.5	33.2	23	0.8	S
Orientation: NS	**Spot-02**	37.4	32.6	21	1.1	S
Time: 1.15 pm	**Spot-03**	37.2	32.3	22	1.4	S
Road no. A [NS]	**Spot-04**	36.9	32.0	21	1.3	S
Sky condition: clear	**Spot-05**	36.1	31.5	23	1	S
Rd. 5	**Spot-06**	35.7	31.1	24	0	-
	Spot-07	35.5	31.1	24	0.4	S
	Spot-08	35.1	30.7	25	0.7	S
	Spot-09	34.8	30.3	26	0	-
	Spot-10	34.6	29.9	25	0.6	N
	Spot-11	34.5	29.9	25	0	-
	Spot-12	34.3	29.8	26	0.7	N
	Spot-13	35.9	30.9	24	0.7	S
	Spot-14	36.4	31.9	26	0	-
	Spot-15	36.5	33.0	24	0	-
	Spot-16	36.9	34.1	25	0	-

City data

Temp.	32.1 degC (max)		19 degC (min)
Humidity	40% (max.)		24% (min.)
Country max. Temp.	Cox's Bazar	34.5 degC	
Country min. Temp.	Sri Mangal	14.6 degC	
Source:	'The Daily Prothom Alo', 16th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 15/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 1	**Spot-01**	34.7	31.4	26	0.6	N
Orientation: NS	**Spot-02**	34.5	31.1	26	0	-
Time: 1.40 pm	**Spot-03**	34.4	30.7	25	0	-
Road no. B [NS]	**Spot-04**	34.4	30.6	23	1.2	S
Sky condition: clear	**Spot-05**	34.3	30.4	24	0	-
Rd. 6	**Spot-06**	34.1	30.3	26	0	-
	Spot-07	34.1	30.3	24	1	S
	Spot-08	34.0	30.2	25	0.7	N
	Spot-09	34.2	30.3	25	0.4	N
	Spot-10	34.7	31.2	25	0	-
	Spot-11	34.7	31.7	26	0	-
	Spot-12	34.6	31.5	26	0	-
	Spot-13	34.4	31.3	25	0.9	N
	Spot-14	34.4	31.1	25	0	-
	Spot-15	34.7	31.2	26	0	-
	Spot-16	34.7	31.5	25	0.6	S

City data			
Temp.	32.1 degC (max)		19 degC (min)
Humidity	40% (max.)		24% (min.)
Country max. Temp.	Cox's Bazar	34.5 degC	
Country min. Temp.	Sri Mangal	14.6 degC	
Source:	‘The Daily Prothom Alo', 16th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 15/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 1	**Spot-01**	33.8	30.7	25	2	S
Orientation: NS	**Spot-02**	33.7	30.6	25	1.4	S
Time: 2.00 pm	**Spot-03**	33.7	30.9	24	1.4	S
Road no. C [NS]	**Spot-04**	34.3	31.9	24	1.3	S
Sky condition: clear	**Spot-05**	34.3	32.1	25	1	S
Rd. 7	**Spot-06**	34.2	32.0	25	0.4	S
	Spot-07	34.0	31.6	22	1.8	S
	Spot-08	34.0	31.5	24	0.8	S
	Spot-09	34.1	31.4	24	0	-
	Spot-10	34.2	31.6	24	1.2	N
	Spot-11	34.2	31.4	25	0	-
	Spot-12	34.1	31.1	25	0	-
	Spot-13	34.1	31.1	24	0.6	N
	Spot-14	34.0	31.1	24	0.9	S
	Spot-15	33.9	30.9	26	1.1	S
	Spot-16	33.8	30.8	24	1.1	S

City data			
Temp.	32.1 degC (max)		19 degC (min)
Humidity	40% (max.)		24% (min.)
Country max. Temp.	Cox's Bazar	34.5 degC	
Country min. Temp.	Sri Mangal	14.6 degC	
Source:	‘The Daily Prothom Alo’, 16th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 15/03/2014

Day: 1
Orientation: EW
Time: 12pm
Road no. X [EW]
Sky condition: clear
Rd. 13

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	35.5	34.3	28	3.6	W
Spot-02	37.4	36.2	26	1.3	W
Spot-03	34.7	33.2	34	2.8	W
Spot-04	39.1	38.5	23	6.9	E
Spot-05	40.9	40.0	21	2.4	W
Spot-06	41.2	40.7	22	2.5	W
Spot-07	41.6	41.7	21	0.6	W
Spot-08	43.4	42.7	20	0.7	W
Spot-09	44.5	43.1	20	1.9	E
Spot-10	45.0	43.2	20	1.2	E
Spot-11	44.5	42.6	20	6.6	E
Spot-12	44.1	41.5	20	2.3	W
Spot-13	43.2	38.4	20	1.6	E
Spot-14	42.4	37.4	20	1.3	W
Spot-15	42.2	37.7	20	1.3	E
Spot-16	41.7	37.8	20	0	-

City data

Temp.	32.1 degC (max)	19 degC (min)
Humidity	40% (max.)	24% (min.)
Country max. Temp.	Cox's Bazar 34.5 degC	
Country min. Temp.	Sri Mangal 14.6 degC	
Source:	‘The Daily Prothom Alo', 16th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 15/03/2014

Day: 1
Orientation: EW
Time: 12.30 pm
Road no. Y [EW]
Sky condition: clear
Rd. 14

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	39.9	35.8	21	1.6	E
Spot-02	40.2	36.8	21	1.7	E
Spot-03	40.1	36.6	20	1.4	W
Spot-04	40.8	37.9	20	1.5	E
Spot-05	40.3	37.4	20	0	-
Spot-06	40.0	37.2	20	1	E
Spot-07	39.6	37.9	21	1.1	E
Spot-08	39.4	38.7	20	0.7	E
Spot-09	39.4	38.1	20	0	-
Spot-10	40.9	38.8	20	1	W
Spot-11	42.2	40.6	20	0.8	E
Spot-12	42.2	41.1	20	0.4	W
Spot-13	41.6	40.3	20	1.3	W
Spot-14	40.2	38.8	20	2.6	E
Spot-15	40.6	37.5	20	1	E
Spot-16	41.0	38.3	20	1	E

City data		
Temp.	32.1 degC (max)	19 degC (min)
Humidity	40% (max.)	24% (min.)
Country max. Temp.	Cox's Bazar 34.5 degC	
Country min. Temp.	Sri Mangal 14.6 degC	
Source:	'The Daily Prothom Alo', 16th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 15/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 1	**Spot-01**	38.8	35.1	22	0.5	-
Orientation: EW	**Spot-02**	38.8	35.6	23	0.4	-
Time: 12.55 pm	**Spot-03**	38.5	35.4	20	2.1	W
Road no. Z [EW]	**Spot-04**	39.2	36.0	20	1.2	E
Sky condition: clear	**Spot-05**	39.6	37.0	21	0.5	W
Rd. 15	**Spot-06**	39.6	36.7	25	0	-
	Spot-07	40.6	37.5	20	0.7	E
	Spot-08	40.9	37.6	20	0	-
	Spot-09	40.6	37.2	21	0.8	E
	Spot-10	41.8	37.8	20	0	-
	Spot-11	43.4	39.5	20	1.1	E
	Spot-12	43.9	40.4	20	1.5	E
	Spot-13	43.5	40.0	20	1.4	W
	Spot-14	42.7	37.9	20	0	-
	Spot-15	42.4	36.9	20	1.6	W
	Spot-16	42.2	37	20	0.8	W

City data		
Temp.	32.1 degC (max)	19 degC (min)
Humidity	40% (max.)	24% (min.)
Country max. Temp.	Cox's Bazar 34.5 degC	
Country min. Temp.	Sri Mangal 14.6 degC	
Source:	'The Daily Prothom Alo', 16th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date:16/03/2014

Day: 2
Orientation: NS
Time: 1:25 pm
Road no. A [NS]
Sky condition: Clear
Rd. 5

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	37.6	34.5	25	0.7	S
Spot-02	36.6	33.2	24	1.4	S
Spot-03	36.4	32.7	23	1.7	S
Spot-04	36.2	32.9	24	1.7	S
Spot-05	35.9	32.6	24	0.9	S
Spot-06	36.1	32.6	26	0	-
Spot-07	36.2	33.3	25	0.5	S
Spot-08	36.0	32.7	25	0.6	S
Spot-09	35.9	32.4	26	0.9	S
Spot-10	35.8	32.1	25	1.3	S
Spot-11	35.3	31.6	25	0	-
Spot-12	35.1	31.2	27	1	S
Spot-13	34.9	30.9	26	1.3	N
Spot-14	34.5	30.6	27	0.8	S
Spot-15	34.6	30.6	28	0	-
Spot-16	35.3	31.4	28	0	-

City data

Temp.	32.6 degC (max)	20.5 degC (min)
Humidity	38% (max.)	25% (min.)
Country max. Temp.	Sylhet & Teknaf 35.0degC	
Country min. Temp.	Chuadanga 14.2degC	
Source:	'The Daily Prothom Alo', 17th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date:16/03/2014

Day: 2
Orientation: NS
Time: 1:10 pm
Road no. B [NS]
Sky condition: Clear
Rd. 6

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	33.6	31.7	28	0.9	S
Spot-02	33.7	31.6	27	0.7	S
Spot-03	33.8	31.5	27	0.7	S
Spot-04	34.4	31.9	25	1.1	S
Spot-05	34.3	31.9	26	0.9	S
Spot-06	34.3	31.7	26	0.6	S
Spot-07	34.2	31.5	27	0.7	S
Spot-08	34.2	31.2	26	0.6	S
Spot-09	34.6	31.2	25	1.4	S
Spot-10	35.9	32.7	25	1	S
Spot-11	36.1	33.8	24	0.6	S
Spot-12	36.2	33.8	25	0.8	S
Spot-13	36.6	34.6	24	0	-
Spot-14	36.5	34.5	25	0	-
Spot-15	37.0	34.3	25	0	-
Spot-16	37.7	35.5	25	0.9	N

City data		
Temp.	32.6 degC (max)	20.5 degC (min)
Humidity	38% (max.)	25% (min.)
Country max. Temp.	Sylhet & Teknaf 35.0degC	
Country min. Temp.	Chuadanga 14.2degC	
Source:	‘The Daily Prothom Alo', 17th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date:16/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 2	**Spot-01**	30.3	30.5	33	0.8	S
Orientation: NS	**Spot-02**	30.6	30.4	33	0.8	N
Time: 12:50 pm	**Spot-03**	31.0	30.4	31	0	-
Road no. C [NS]	**Spot-04**	31.3	30.4	31	0.8	S
Sky condition: Clear	**Spot-05**	31.6	30.6	32	0	-
Rd. 7	**Spot-06**	32.1	31.3	30	0.8	S
	Spot-07	33.0	32.5	29	0	-
	Spot-08	33.1	32.9	29	0	-
	Spot-09	33.2	32.8	31	0	-
	Spot-10	33.3	32.4	28	0.4	S
	Spot-11	33.3	32.1	27	1.1	S
	Spot-12	33.9	32.0	28	0.8	S
	Spot-13	34.3	32.8	27	0.7	S
	Spot-14	34.3	32.6	27	1.1	S
	Spot-15	34.2	32.3	26	0.9	S
	Spot-16	34.1	31.9	26	0.6	S

City data			
Temp.	32.6 degC (max)		20.5 degC (min)
Humidity	38% (max.)		25% (min.)
Country max. Temp.	Sylhet & Teknaf	35.0degC	
Country min. Temp.	Chuadanga	14.2degC	
Source:	'The Daily Prothom Alo', 17th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date:16/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 2	**Spot-01**	34.1	31.2	26	0	-
Orientation: EW	**Spot-02**	33.9	30.9	26	1.1	E
Time: 2:25 pm	**Spot-03**	33.8	30.6	25	1.5	E
Road no. X [EW]	**Spot-04**	33.6	30.4	25	2.1	E
Sky condition: Clear	**Spot-05**	33.4	30.6	25	1.3	E
Rd. 13	**Spot-06**	33.5	30.7	26	0.6	E
	Spot-07	33.5	30.8	25	0.6	W
	Spot-08	33.6	31.0	26	0.6	E
	Spot-09	33.7	31.5	26	1	E
	Spot-10	33.9	31.8	24	1.2	W
	Spot-11	33.9	32.1	25	0.9	E
	Spot-12	33.9	32.3	24	0.9	W
	Spot-13	34.0	32.4	25	1.4	E
	Spot-14	34.8	33.4	25	1.4	E
	Spot-15	35.0	34.3	23	0.6	W
	Spot-16	34.8	34.2	23	0	-

City data			
Temp.	32.6 degC (max)		20.5 degC (min)
Humidity	38% (max.)		25% (min.)
Country max. Temp.	Sylhet & Teknaf	35.0degC	
Country min. Temp.	Chuadanga	14.2degC	
Source:	'The Daily Prothom Alo', 17th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date:16/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 2	**Spot-01**	34.6	31.8	27	0	-
Orientation: EW	**Spot-02**	34.3	31.0	28	0	-
Time: 2:10 pm	**Spot-03**	34.2	30.6	28	0	-
Road no. Y [EW]	**Spot-04**	34.0	30.1	28	0	-
Sky condition: Clear	**Spot-05**	33.9	29.9	28	0	-
Rd. 14	**Spot-06**	33.8	29.9	27	0	-
	Spot-07	33.7	29.8	27	0	-
	Spot-08	33.9	30.1	28	0.5	W
	Spot-09	34.4	31.9	26	0.6	W
	Spot-10	34.8	33.1	26	0.8	E
	Spot-11	35.3	34.6	26	0	-
	Spot-12	35.2	34.2	26	0.5	E
	Spot-13	34.9	32.8	26	0.4	W
	Spot-14	34.7	32.3	26	0.6	E
	Spot-15	34.6	31.6	27	0	-
	Spot-16	34.4	31.3	26	0.6	W

City data			
Temp.	32.6 degC (max)		20.5 degC (min)
Humidity	38% (max.)		25% (min.)
Country max. Temp.	Sylhet & Teknaf	35.0degC	
Country min. Temp.	Chuadanga	14.2degC	
Source:	‘The Daily Prothom Alo’, 17th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date:16/03/2014

Day: 2
Orientation: EW
Time: 1:45 pm
Road no. Z [EW]
Sky condition: Clear
Rd. 15

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	35.3	31.9	29	0.6	W
Spot-02	35.1	31.5	28	0.9	W
Spot-03	35.0	31.3	26	1.6	W
Spot-04	34.9	31.1	27	0	-
Spot-05	34.8	31.0	29	0	-
Spot-06	34.7	30.9	30	0	-
Spot-07	34.6	30.6	28	1.1	E
Spot-08	34.7	31.2	28	0.9	E
Spot-09	34.7	31.2	28	0	-
Spot-10	34.6	31.1	28	1	E
Spot-11	34.6	31.2	28	0.5	E
Spot-12	34.5	31.2	28	0.5	E
Spot-13	35.5	32.5	26	1.3	E
Spot-14	35.8	34.1	25	1	E
Spot-15	35.7	33.8	24	1.3	E
Spot-16	35.4	33.2	24	0.9	E

City data			
Temp.	32.6 degC (max)		20.5 degC (min)
Humidity	38% (max.)		25% (min.)
Country max. Temp.	Sylhet & Teknaf	35.0degC	
Country min. Temp.	Chuadanga	14.2degC	
Source:	‘The Daily Prothom Alo', 17th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

	Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Date: 17/03/2014						
Day: 3	**Spot-01**	38.7	38.2	20	0.9	S
Orientation: NS	**Spot-02**	38.1	36.8	22	0.8	S
Time: 1:40 pm	**Spot-03**	37.8	35.7	21	1.2	S
Road no. A [NS]	**Spot-04**	37.8	35.3	23	0.6	S
Sky condition: clear	**Spot-05**	36.9	34.1	20	2.3	S
Rd. 05	**Spot-06**	37.0	33.6	21	0	-
	Spot-07	36.9	33.2	23	0.6	S
	Spot-08	35.6	32.8	25	0	-
	Spot-09	35.5	33.0	25	0	-
	Spot-10	35.4	32.1	26	0.4	S
	Spot-11	36.1	33.9	24	0	-
	Spot-12	35.9	33.4	25	0	-
	Spot-13	35.1	31.5	26	0.4	S
	Spot-14	34.9	31.1	26	1.1	S
	Spot-15	35.2	31.7	24	0.6	S
	Spot-16	36.3	34.2	24	0	-

City data		
Temp.	33.6 degC (max)	18.2 degC (min)
Humidity	36% (max.)	25% (min.)
Country max. Temp.	Rangamati 35.3degC	
Country min. Temp.	Sylhet 15.2degC	
Source:	‘The Daily Prothom Alo', 18th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 17/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 3	**Spot-01**	35.5	32.5	24	0.6	N
Orientation: NS	**Spot-02**	35.2	32.3	25	0.7	S
Time: 2:05 pm	**Spot-03**	35.3	32.3	25	0	-
Road no. B [NS]	**Spot-04**	35.8	32.4	25	0	-
Sky condition: clear	**Spot-05**	35.6	32.1	25	0	-
Rd. 06	**Spot-06**	36.3	32.7	23	1.1	S
	Spot-07	36.7	33.2	23	0	-
	Spot-08	36.4	33.1	20	0.8	S
	Spot-09	36.6	33.1	22	0	-
	Spot-10	36.4	33.4	24	0	-
	Spot-11	36.4	33.2	21	0.4	S
	Spot-12	36.5	32.7	24	0	-
	Spot-13	36.7	33.0	23	0.5	S
	Spot-14	36.5	32.8	23	0	-
	Spot-15	36.4	32.7	21	0	-
	Spot-16	36.2	32.6	21	0	-

City data		
Temp.	33.6 degC (max)	18.2 degC (min)
Humidity	36% (max.)	25% (min.)
Country max. Temp.	Rangamati 35.3degC	
Country min. Temp.	Sylhet 15.2degC	
Source:	‘The Daily Prothom Alo', 18th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 17/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 3	**Spot-01**	35.3	31.9	24	0	-
Orientation: NS	**Spot-02**	35.1	31.7	24	0	-
Time: 2:25 pm	**Spot-03**	35.1	31.7	24	0	-
Road no. C [NS]	**Spot-04**	35.4	32.4	23	0.6	S
Sky condition: clear	**Spot-05**	35.3	32.5	23	0.5	S
Rd. 07	**Spot-06**	35.3	32.4	23	0	-
	Spot-07	35.2	32.2	24	0.4	S
	Spot-08	35.1	32.1	25	0	-
	Spot-09	35.0	31.8	25	0	-
	Spot-10	35.0	31.7	24	0	-
	Spot-11	34.8	31.4	25	0.7	N
	Spot-12	34.9	31.3	25	0.7	N
	Spot-13	35.4	32.0	24	0	-
	Spot-14	35.3	32.0	24	0	-
	Spot-15	35.2	31.7	24	0	-
	Spot-16	34.8	31.2	22	2.6	S

City data		
Temp.	33.6 degC (max)	18.2 degC (min)
Humidity	36% (max.)	25% (min.)
Country max. Temp.	Rangamati 35.3degC	
Country min. Temp.	Sylhet 15.2degC	
Source:	'The Daily Prothom Alo', 18th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 17/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 3	**Spot-01**	33.9	34.0	29	1.5	W
Orientation: EW	**Spot-02**	35.4	35.2	29	0	-
Time: 12:45 pm	**Spot-03**	36.4	36.5	30	0	-
Road no. X [EW]	**Spot-04**	37.0	36.2	26	1.2	E
Sky condition: clear	**Spot-05**	38.4	36.9	25	1.2	E
Rd. 13	**Spot-06**	39.2	38.0	25	0.9	W
	Spot-07	41.0	39.2	22	2	E
	Spot-08	41.6	40.1	22	0.6	E
	Spot-09	42.0	40.5	22	0.9	E
	Spot-10	41.9	39.8	22	0.8	E
	Spot-11	42.1	39.9	22	0.9	E
	Spot-12	41.7	39.5	20	0	-
	Spot-13	41.9	39.5	22	0.7	E
	Spot-14	42.1	40.2	20	0.6	W
	Spot-15	41.9	39.9	22	0.6	W
	Spot-16	42.0	39.8	22	0	-

City data		
Temp.	33.6 degC (max)	18.2 degC (min)
Humidity	36% (max.)	25% (min.)
Country max. Temp.	Rangamati 35.3degC	
Country min. Temp.	Sylhet 15.2degC	
Source:	‘The Daily Prothom Alo', 18th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 17/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 3	**Spot-01**	40.4	37.2	22	0	-
Orientation: EW	**Spot-02**	40.7	36.5	23	0	-
Time: 1:00 pm	**Spot-03**	40.4	36.3	23	0	-
Road no. Y [EW]	**Spot-04**	39.7	35.4	23	0	-
Sky condition: clear	**Spot-05**	39.5	35.2	23	0.5	W
Rd. 14	**Spot-06**	39.7	36.0	23	0	-
	Spot-07	40.0	35.9	23	0.7	E
	Spot-08	40.6	36.9	23	0	-
	Spot-09	41.2	37.7	22	0.7	E
	Spot-10	41.5	38.6	22	0	-
	Spot-11	41.6	39.2	22	0	-
	Spot-12	40.9	37.9	20	0.9	E
	Spot-13	40.3	37.0	21	0.8	E
	Spot-14	39.8	35.7	21	0	-
	Spot-15	39.3	34.9	25	0	-
	Spot-16	38.6	33.6	23	0.6	E

City data			
Temp.	33.6 degC (max)		18.2 degC (min)
Humidity	36% (max.)		25% (min.)
Country max. Temp.	Rangamati	35.3degC	
Country min. Temp.	Sylhet	15.2degC	
Source:	'The Daily Prothom Alo', 18th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 17/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 3	**Spot-01**	36.8	32.7	24	1.4	W
Orientation: EW	**Spot-02**	36.8	32.5	20	2.6	W
Time: 1:20 pm	**Spot-03**	36.5	32.4	21	1.3	W
Road no. Z [EW]	**Spot-04**	36.0	32.3	20	1.9	W
Sky condition: clear	**Spot-05**	35.8	32.5	21	1	W
Rd. 15	**Spot-06**	35.8	32.6	20	0.8	W
	Spot-07	35.6	32.4	22	0.8	E
	Spot-08	35.7	32.5	24	0	-
	Spot-09	36.2	33.6	24	0.7	E
	Spot-10	36.5	33.9	23	0	-
	Spot-11	37.7	35.1	23	0.7	E
	Spot-12	37.8	35.8	23	0	-
	Spot-13	37.5	35.4	20	2.5	E
	Spot-14	37.9	35.6	21	2.1	E
	Spot-15	37.2	36.1	20	1.1	E
	Spot-16	38.1	37.8	20	1	E

City data		
Temp.	33.6 degC (max)	18.2 degC (min)
Humidity	36% (max.)	25% (min.)
Country max. Temp.	Rangamati 35.3degC	
Country min. Temp.	Sylhet 15.2degC	
Source:	‘The Daily Prothom Alo', 18th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 18/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 4	**Spot-01**	37.1	34.3	39	0.7	S
Orientation: NS	**Spot-02**	36.9	34.1	40	0	-
Time: 2:00 pm	**Spot-03**	36.8	33.9	40	0	-
Road no. A [NS]	**Spot-04**	36.5	33.4	40	1	S
Sky condition: clear	**Spot-05**	36.3	33.0	39	0	-
Rd. 05	**Spot-06**	36.3	32.8	41	0.4	S
	Spot-07	36.5	32.8	38	0.5	S
	Spot-08	36.3	32.6	40	0	-
	Spot-09	36.4	32.3	40	0.7	S
	Spot-10	36.5	32.7	39	1.1	S
	Spot-11	36.4	32.7	40	0	-
	Spot-12	36.3	32.6	40	0.6	S
	Spot-13	36.2	32.5	40	0.6	S
	Spot-14	36.0	32.4	41	0.5	S
	Spot-15	36.0	32.4	41	0	-
	Spot-16	36.0	32.6	40	0	-

City data		
Temp.	33.8degC (max)	20.5degC (min)
Humidity	62% (max.)	47% (min.)
Country max. Temp.	Jessore 36degC	
Country min. Temp.	Sri Mangal 15.2degC	
Source:	‘The Daily Prothom Alo', 19th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 18/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 4	**Spot-01**	35.7	32.2	46	1	N
Orientation: NS	**Spot-02**	35.6	32.2	46	0.6	S
Time: 1:40 pm	**Spot-03**	35.9	32.2	45	0.9	S
Road no. B [NS]	**Spot-04**	36.2	32.7	43	1	S
Sky condition: clear	**Spot-05**	36.2	32.7	45	0	-
Rd. 06	**Spot-06**	36.5	33.0	45	0	-
	Spot-07	36.9	33.7	45	0.5	S
	Spot-08	36.7	33.5	44	0.9	S
	Spot-09	36.8	33.1	43	0	-
	Spot-10	37.0	33.4	42	0	-
	Spot-11	36.8	33.3	45	0	-
	Spot-12	36.9	33.3	42	0.7	S
	Spot-13	36.7	33.9	39	2.2	S
	Spot-14	36.7	33.7	37	1.6	S
	Spot-15	36.9	33.8	38	0	-
	Spot-16	37.0	34.8	36	1.7	S

City data			
Temp.	33.8degC (max)		20.5degC (min)
Humidity	62% (max.)		47% (min.)
Country max. Temp.	Jessore	36degC	
Country min. Temp.	Sri Mangal	15.2degC	
Source:	‘The Daily Prothom Alo', 19th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 18/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 4	**Spot-01**	36.3	34.3	43	1.5	N
Orientation: NS	**Spot-02**	36.0	33.4	45	0	-
Time: 1:20 pm	**Spot-03**	36.1	32.8	47	0	-
Road no. C [NS]	**Spot-04**	36.1	33.0	47	0	-
Sky condition: clear	**Spot-05**	36.0	33.0	47	0	-
Rd. 07	**Spot-06**	36.0	32.9	47	0	-
	Spot-07	36.6	33.3	45	0	-
	Spot-08	36.5	33.2	46	0	-
	Spot-09	36.4	32.9	44	0.8	N
	Spot-10	36.3	32.7	47	0.4	N
	Spot-11	36.2	32.5	44	0.7	S
	Spot-12	36.5	32.8	44	0.5	S
	Spot-13	36.7	33.6	43	0.7	S
	Spot-14	36.6	33.4	45	0	-
	Spot-15	36.5	33.0	45	1.3	N
	Spot-16	36.4	32.5	46	0	-

City data		
Temp.	33.8degC (max)	20.5degC (min)
Humidity	62% (max.)	47% (min.)
Country max. Temp.	Jessore 36degC	
Country min. Temp.	Sri Mangal 15.2degC	
Source:	‘The Daily Prothom Alo', 19th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 18/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 4	**Spot-01**	34.9	32.6	39	0.9	W
Orientation: EW	**Spot-02**	34.6	32.6	41	0.6	W
Time: 2:50 pm	**Spot-03**	34.6	32.7	40	0.4	W
Road no. X [EW]	**Spot-04**	34.5	32.6	41	0	-
Sky condition: clear	**Spot-05**	34.6	32.7	41	0.6	W
Rd. 13	**Spot-06**	34.6	32.9	40	0	-
	Spot-07	34.7	32.8	41	1.9	W
	Spot-08	34.9	33.5	42	0.6	W
	Spot-09	35.1	33.7	38	1.8	W
	Spot-10	35.1	33.8	39	1.2	W
	Spot-11	35.3	34.2	38	1.1	W
	Spot-12	35.7	34.8	36	0.6	W
	Spot-13	35.6	34.8	36	0	-
	Spot-14	35.8	34.8	38	0	-
	Spot-15	35.8	35.0	36	1.1	W
	Spot-16	36.2	35.1	37	0	-

City data			
Temp.	33.8degC (max)		20.5degC (min)
Humidity	62% (max.)		47% (min.)
Country max. Temp.	Jessore	36degC	
Country min. Temp.	Sri Mangal	15.2degC	
Source:	'The Daily Prothom Alo', 19th March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 18/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 4	**Spot-01**	35.8	34.0	40	0	-
Orientation: EW	**Spot-02**	35.6	33.6	39	0.7	W
Time: 2:40 pm	**Spot-03**	35.5	33.2	38	0	-
Road no. Y [EW]	**Spot-04**	35.4	32.8	41	0	-
Sky condition: clear	**Spot-05**	35.3	32.4	41	0	-
Rd. 14	**Spot-06**	35.2	31.9	40	1.1	E
	Spot-07	35.1	31.7	41	0	-
	Spot-08	35.4	32.0	40	0.7	W
	Spot-09	35.6	33.0	40	0	-
	Spot-10	35.7	33.3	41	0	-
	Spot-11	35.8	33.9	40	0.9	E
	Spot-12	35.8	33.9	39	0.4	E
	Spot-13	35.7	33.7	40	0	-
	Spot-14	35.6	33.1	41	0.7	E
	Spot-15	35.4	32.6	40	0.5	W
	Spot-16	35.3	32.3	42	0.6	W

City data			
Temp.	33.8degC (max)		20.5degC (min)
Humidity	62% (max.)		47% (min.)
Country max. Temp.	Jessore	36degC	
Country min. Temp.	Sri Mangal	15.2degC	
Source:	‘The Daily Prothom Alo', 19th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 18/03/2014

Day: 4
Orientation: EW
Time: 2:15 pm
Road no. Z [EW]
Sky condition: clear
Rd. 15

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	35.8	34.1	42	0	-
Spot-02	35.7	33.6	41	0	-
Spot-03	35.5	33.0	40	1.3	W
Spot-04	35.3	32.6	40	1.4	W
Spot-05	35.1	32.5	42	0.7	W
Spot-06	35.1	32.3	40	0.6	W
Spot-07	35.1	32.4	42	0.7	W
Spot-08	35.3	33.2	40	0.7	E
Spot-09	35.3	33.2	41	1.1	E
Spot-10	35.3	33.0	41	1.1	E
Spot-11	35.1	32.9	40	0.7	E
Spot-12	35.2	33.0	40	1.2	E
Spot-13	35.5	33.2	40	0	-
Spot-14	36.0	35.0	38	0.9	W
Spot-15	36.1	35.2	39	0.9	W
Spot-16	36.2	35.1	36	0.6	W

City data

Temp.	33.8degC (max)	20.5degC (min)
Humidity	62% (max.)	47% (min.)
Country max. Temp.	Jessore 36degC	
Country min. Temp.	Sri Mangal 15.2degC	
Source:	'The Daily Prothom Alo', 19th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 19/03/2014

Day: 5
Orientation: NS
Time: 2:00 pm
Road no. A [NS]
Sky condition: Partly cloudy [Sunny]
Rd. 05

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	38.8	36.9	37	0.6	S
Spot-02	38.7	36.7	37	0.6	S
Spot-03	38.4	36.1	37	0	-
Spot-04	38.2	35.7	37	0	-
Spot-05	38.1	35.4	37	0	-
Spot-06	38.0	35.0	39	0	-
Spot-07	38.2	34.9	39	0	-
Spot-08	38.0	34.6	38	0.5	S
Spot-09	37.8	34.3	38	0	-
Spot-10	37.9	34.5	36	0	-
Spot-11	37.7	34.3	37	0.9	S
Spot-12	37.6	34.1	37	0	-
Spot-13	37.3	33.9	35	0.9	S
Spot-14	37.3	33.8	34	1.2	S
Spot-15	37.1	33.8	37	0	-
Spot-16	37.4	33.8	36	0.9	S

City data			
Temp.	34degC (max)		24.2degC (min)
Humidity	73% (max.)		35% (min.)
Country max. Temp.	Ishwardi	36.5degC	
Country min. Temp.	Feni,SriMangal,Rajshahi,Dinajpur	19.0degC	
Source:	'The Daily Prothom Alo', 20th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 19/03/2014

Day: 5
Orientation: NS
Time: 2:15 pm
Road no. B [NS]
Sky condition: Partly cloudy [Sunny]
Rd. 06

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	36.8	34.2	38	0.5	S
Spot-02	36.7	34.0	39	0	-
Spot-03	36.7	33.6	40	0	-
Spot-04	37.0	33.6	41	0	-
Spot-05	36.9	33.5	40	0	-
Spot-06	37.0	33.4	40	0	-
Spot-07	37.4	33.8	40	0.5	N
Spot-08	37.1	33.9	40	0	-
Spot-09	37.1	33.9	40	0	-
Spot-10	37.5	34.1	40	0	-
Spot-11	37.4	34.2	40	0	-
Spot-12	37.5	34.0	39	0	-
Spot-13	37.6	34.7	40	0.8	S
Spot-14	37.5	34.6	38	0.9	S
Spot-15	37.3	34.3	39	0.9	S
Spot-16	37.1	34.1	37	0	-

City data

Temp.	34degC (max)		24.2degC (min)
Humidity	73% (max.)		35% (min.)
Country max. Temp.	Ishwardi	36.5degC	
Country min. Temp.	Feni,SriMangal,Rajshahi,Dinajpur	19.0degC	
Source:	‘The Daily Prothom Alo', 20th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 19/03/2014

Day: 5
Orientation: NS
Time: 2:30 pm
Road no. C [NS]
Sky condition: Clear
Rd. 07

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	36.3	33.2	39	0.8	N
Spot-02	36.1	33.1	42	0.6	N
Spot-03	36.1	32.9	41	0	-
Spot-04	36.4	33.2	41	0	-
Spot-05	36.3	33.2	42	0	-
Spot-06	36.4	33.0	39	1.5	N
Spot-07	36.7	33.4	41	0.5	S
Spot-08	36.7	33.5	41	0	-
Spot-09	36.7	33.4	41	0.7	S
Spot-10	36.7	33.5	41	0	-
Spot-11	36.6	33.4	42	0.4	N
Spot-12	36.7	33.4	40	0	-
Spot-13	36.7	33.6	41	0	-
Spot-14	36.6	33.5	41	0	-
Spot-15	36.5	33.0	41	0	-
Spot-16	36.4	32.7	41	1.1	S

City data			
Temp.	34degC (max)		24.2degC (min)
Humidity	73% (max.)		35% (min.)
Country max. Temp.	Ishwardi	36.5degC	
Country min. Temp.	Feni,SriMangal,Rajshahi,Dinajpur	19.0degC	
Source:	‘The Daily Prothom Alo', 20th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 19/03/2014

Day: 5
Orientation: EW
Time: 1:10 pm
Road no. X [EW]
Sky condition: Partly cloudy [Sunny]
Rd. 13

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	33.9	33.3	49	1.1	W
Spot-02	34.3	33.6	45	2.3	W
Spot-03	34.9	34.2	44	1.2	W
Spot-04	35.3	34.0	43	1	W
Spot-05	35.4	34.2	43	2.6	W
Spot-06	35.7	34.5	44	0	-
Spot-07	35.9	34.7	43	0.8	W
Spot-08	36.4	35.7	44	1.4	E
Spot-09	36.9	36.2	41	0	-
Spot-10	37.6	36.5	41	0.9	E
Spot-11	38.2	36.8	40	0.7	E
Spot-12	38.2	36.7	38	0	-
Spot-13	38.1	36.4	39	0.8	W
Spot-14	38.9	36.9	37	0.6	W
Spot-15	39.5	37.3	36	1.2	W
Spot-16	39.6	37.3	35	0.9	E

City data

Temp.	34degC (max)		24.2degC (min)
Humidity	73% (max.)		35% (min.)
Country max. Temp.	Ishwardi	36.5degC	
Country min. Temp.	Feni,SriMangal,Rajshahi,Dinajpur	19.0degC	
Source:	'The Daily Prothom Alo', 20th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 19/03/2014

Day: 5
Orientation: EW
Time: 1:30 pm
Road no. Y [EW]
Sky condition: Partly cloudy [Sunny]
Rd. 14

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	37.9	35.6	38	0.7	E
Spot-02	37.8	35.0	38	1	W
Spot-03	37.5	35.0	38	0	-
Spot-04	37.5	34.6	39	0.5	W
Spot-05	37.5	34.7	40	0.7	E
Spot-06	38.1	35.4	40	0.7	W
Spot-07	37.6	35.3	40	0.8	E
Spot-08	38.6	35.5	40	0	-
Spot-09	39.3	36.7	38	1.6	E
Spot-10	39.8	37.0	34	0.8	W
Spot-11	39.9	37.3	34	0	-
Spot-12	39.4	37.1	33	0.7	E
Spot-13	39.5	36.7	35	0	-
Spot-14	38.8	36.0	35	0	-
Spot-15	38.5	35.2	38	0.5	W
Spot-16	38.3	34.7	35	1.4	W

City data

Temp.	34degC (max)		24.2degC (min)
Humidity	73% (max.)		35% (min.)
Country max. Temp.	Ishwardi	36.5degC	
Country min. Temp.	Feni,SriMangal,Rajshahi,Dinajpur	19.0degC	
Source:	'The Daily Prothom Alo', 20th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 19/03/2014

Day: 5
Orientation: EW
Time: 1:45 pm
Road no. Z [EW]
Sky condition: Partly cloudy [Sunny]
Rd. 15

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	37.2	34.0	36	1.4	W
Spot-02	37.1	33.9	37	0	-
Spot-03	36.8	33.8	40	0	-
Spot-04	36.8	33.7	40	0	-
Spot-05	36.9	33.6	40	0	-
Spot-06	36.8	33.6	40	0.4	W
Spot-07	36.8	33.6	39	0.7	W
Spot-08	37.2	34.3	39	0.8	E
Spot-09	38.2	35.5	38	0	-
Spot-10	38.3	36.0	39	0.8	W
Spot-11	38.0	35.6	38	0.8	W
Spot-12	38.0	35.4	37	0	-
Spot-13	37.6	34.9	40	1	E
Spot-14	37.6	34.7	39	0.9	E
Spot-15	37.7	34.9	37	1.1	E
Spot-16	38.3	35.7	39	0.8	E

City data

Temp.	34degC (max)		24.2degC (min)
Humidity	73% (max.)		35% (min.)
Country max. Temp.	Ishwardi	36.5degC	
Country min. Temp.	Feni,SriMangal,Rajshahi,Dinajpur	19.0degC	
Source:	‘The Daily Prothom Alo', 20th March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 22/03/2014

Day: 6
Orientation: NS
Time: 1:35 pm
Road no. A [NS]
Sky condition: Clear
Rd. 05

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	38.0	34.3	25	1.6	S
Spot-02	37.9	34.1	28	1.2	S
Spot-03	37.9	33.8	28	0	-
Spot-04	38.0	34.0	30	0	-
Spot-05	37.6	33.6	31	0	-
Spot-06	37.8	33.4	31	0	-
Spot-07	37.9	32.2	31	0	-
Spot-08	37.7	33.5	30	0	-
Spot-09	37.5	33.2	30	0	-
Spot-10	37.6	32.6	30	0.5	N
Spot-11	37.3	32.8	31	0	-
Spot-12	37.5	32.7	31	0	-
Spot-13	37.6	32.9	31	0	-
Spot-14	37.1	32.7	30	0.7	N
Spot-15	36.9	32.2	29	0	-
Spot-16	37.4	32.9	26	0.8	S

City data		
Temp.	34.1degC (max)	21.3degC (min)
Humidity	55% (max.)	38% (min.)
Country max. Temp.	Rajshahi 35.4degC	
Country min. Temp.	Ishwardi,Dinajpur 16.0degC	
Source:	'The Daily Prothom Alo', 23rd March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 22/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 6	**Spot-01**	36.2	31.8	33	0.4	S
Orientation: NS	**Spot-02**	36.1	31.9	34	0	-
Time: 1:20 pm	**Spot-03**	36.1	32.0	36	0	-
Road no. B [NS]	**Spot-04**	36.8	32.5	34	0.6	N
Sky condition: Clear	**Spot-05**	36.7	32.4	35	0	-
Rd. 06	**Spot-06**	36.7	32.3	36	0	-
	Spot-07	36.8	32.3	35	0.5	S
	Spot-08	36.7	32.3	34	0	-
	Spot-09	36.7	32.3	35	0.4	N
	Spot-10	37.3	32.4	34	0.7	S
	Spot-11	37.1	32.3	33	0	-
	Spot-12	37.4	32.4	32	0.9	S
	Spot-13	37.6	32.8	31	0	-
	Spot-14	37.3	32.9	28	0.6	N
	Spot-15	37.7	33.1	29	0	-
	Spot-16	38.9	34.4	27	1.7	S

City data			
Temp.	34.1degC (max)		21.3degC (min)
Humidity	55% (max.)		38% (min.)
Country max. Temp.	Rajshahi	35.4degC	
Country min. Temp.	Ishwardi,Dinajpur	16.0degC	
Source:	‘The Daily Prothom Alo', 23rd March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 22/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 6	**Spot-01**	34.2	33.7	37	0.7	N
Orientation: NS	**Spot-02**	34.2	33.0	42	0	-
Time: 1:00 pm	**Spot-03**	34.6	32.8	40	0	-
Road no. C [NS]	**Spot-04**	35.0	32.7	37	0.9	N
Sky condition: Clear	**Spot-05**	35.1	32.6	40	0.7	N
Rd. 07	**Spot-06**	35.4	32.5	40	0.6	N
	Spot-07	35.9	32.6	40	0	-
	Spot-08	35.4	32.1	41	0	-
	Spot-09	35.8	32.0	40	0.7	N
	Spot-10	36.4	32.4	36	0	-
	Spot-11	36.3	32.3	36	0	-
	Spot-12	37.0	32.4	32	1	S
	Spot-13	37.5	32.8	33	1.2	S
	Spot-14	37.4	32.7	35	0	-
	Spot-15	37.0	32.2	35	0.9	N
	Spot-16	36.6	31.7	35	0.7	N

City data			
Temp.	34.1degC (max)		21.3degC (min)
Humidity	55% (max.)		38% (min.)
Country max. Temp.	Rajshahi	35.4degC	
Country min. Temp.	Ishwardi,Dinajpur	16.0degC	
Source:	‘The Daily Prothom Alo', 23rd March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 22/03/2014

Day: 6
Orientation: EW
Time: 2:25 pm
Road no. X [EW]
Sky condition: Clear
Rd. 13

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	35.3	32.6	29	2.5	W
Spot-02	35.1	32.5	29	3	W
Spot-03	35.1	32.4	30	0.9	W
Spot-04	34.8	32.2	30	0.7	W
Spot-05	34.8	32.3	30	1.3	W
Spot-06	34.7	32.4	31	1.3	W
Spot-07	34.8	32.4	32	1.1	W
Spot-08	35.2	33.1	31	0.4	E
Spot-09	35.8	33.5	32	0.5	W
Spot-10	35.9	34.0	31	2	W
Spot-11	36.2	34.1	30	2.2	W
Spot-12	36.6	34.6	30	1	W
Spot-13	36.5	34.5	31	0	-
Spot-14	37.3	35.3	29	0.4	W
Spot-15	37.3	35.6	27	0.5	E
Spot-16	37.0	35.6	28	1.9	W

City data

Temp.	34.1degC (max)		21.3degC (min)
Humidity	55% (max.)		38% (min.)
Country max. Temp.	Rajshahi	35.4degC	
Country min. Temp.	Ishwardi,Dinajpur	16.0degC	
Source:	‘The Daily Prothom Alo', 23rd March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 22/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 6	**Spot-01**	35.6	32.6	28	1.9	W
Orientation: EW	**Spot-02**	35.4	31.8	29	0.4	W
Time: 2:10 pm	**Spot-03**	35.3	32.4	28	0.6	W
Road no. Y [EW]	**Spot-04**	35.2	32.4	29	0.9	W
Sky condition: Clear	**Spot-05**	35.1	32.5	30	0.6	W
Rd. 14	**Spot-06**	35.1	32.6	30	0	-
	Spot-07	35.1	32.5	31	0.8	W
	Spot-08	35.6	32.9	28	0.8	W
	Spot-09	35.7	33.5	30	0.6	W
	Spot-10	36.0	33.8	30	0.7	W
	Spot-11	36.3	34.5	27	0	-
	Spot-12	36.1	34.4	27	0.6	E
	Spot-13	35.9	34.3	28	0.8	E
	Spot-14	36.0	33.9	29	0	-
	Spot-15	35.9	33.5	29	0	-
	Spot-16	35.6	33.0	29	0.5	E

City data			
Temp.	34.1degC (max)		21.3degC (min)
Humidity	55% (max.)		38% (min.)
Country max. Temp.	Rajshahi	35.4degC	
Country min. Temp.	Ishwardi,Dinajpur	16.0degC	
Source:	‘The Daily Prothom Alo', 23rd March 2014		

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 22/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 6	**Spot-01**	36.9	32.8	32	0.5	W
Orientation: EW	**Spot-02**	36.7	32.2	32	0	-
Time: 1:50 pm	**Spot-03**	36.5	32.4	29	1.1	W
Road no. Z [EW]	**Spot-04**	36.2	25.7	31	0	-
Sky condition: Clear	**Spot-05**	36.1	29.5	31	0	-
Rd. 15	**Spot-06**	36.0	31.9	32	0	-
	Spot-07	35.8	31.8	33	0	-
	Spot-08	36.1	31.9	33	0	-
	Spot-09	36.4	32.4	33	0	-
	Spot-10	37.3	33.6	29	1	W
	Spot-11	37.7	34.5	29	0.7	W
	Spot-12	37.5	34.4	28	0.7	E
	Spot-13	37.2	34.4	28	0.6	W
	Spot-14	36.5	34.0	28	1.8	E
	Spot-15	36.5	33.8	27	0.6	E
	Spot-16	36.3	33.4	27	1.8	E

City data			
Temp.	34.1degC (max)		21.3degC (min)
Humidity	55% (max.)		38% (min.)
Country max. Temp.	Rajshahi	35.4degC	
Country min. Temp.	Ishwardi,Dinajpur	16.0degC	
Source:	'The Daily Prothom Alo', 23rd March 2014		

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 23/03/2014

Day: 7
Orientation: NS
Time: 1:30 pm
Road no. A [NS]
Sky condition: Clear
Rd. 05

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	38.8	34.4	31	1.9	S
Spot-02	38.1	33.3	32	2	S
Spot-03	37.8	32.6	32	0.8	S
Spot-04	37.6	32.5	32	0.8	S
Spot-05	37.4	32.1	33	0.6	S
Spot-06	37.3	31.8	33	0	-
Spot-07	37.0	31.4	33	2	S
Spot-08	36.6	31.3	33	1.2	S
Spot-09	36.6	31.0	33	0.8	S
Spot-10	36.6	31.0	35	1.1	S
Spot-11	36.3	30.9	34	1	S
Spot-12	36.2	30.7	33	1.4	S
Spot-13	36.8	31.0	33	0	-
Spot-14	36.4	31.0	34	0	-
Spot-15	36.0	30.7	33	1.6	S
Spot-16	36.0	30.5	34	0.8	S

City data		
Temp.	31.4degC (max)	20.0degC (min)
Humidity	56% (max.)	32% (min.)
Country max. Temp.	Rangamati 32.8degC	
Country min. Temp.	Ishwardi 17.0degC	
Source:	'The Daily Prothom Alo', 24th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

	Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Date: 23/03/2014						
Day: 7	**Spot-01**	35.9	30.5	37	0	-
Orientation: NS	**Spot-02**	35.7	30.7	37	0.5	S
Time: 1:45 pm	**Spot-03**	35.7	30.4	37	0	-
Road no. B [NS]	**Spot-04**	35.8	30.7	37	0	-
Sky condition: Clear	**Spot-05**	35.7	30.6	36	1.1	S
Rd. 06	**Spot-06**	35.5	30.0	36	0	-
	Spot-07	35.7	30.5	36	0.9	S
	Spot-08	35.4	30.4	35	0.5	S
	Spot-09	35.3	29.6	35	0	-
	Spot-10	35.1	29.9	36	1.1	S
	Spot-11	34.9	29.9	36	0	-
	Spot-12	34.9	29.8	38	0	-
	Spot-13	35.3	29.9	37	0	-
	Spot-14	35.3	30.0	36	0.9	S
	Spot-15	35.1	30.0	37	0.6	S
	Spot-16	35.3	30.1	36	0.6	S

City data

Temp.	31.4degC (max)	20.0degC (min)
Humidity	56% (max.)	32% (min.)
Country max. Temp.	Rangamati 32.8degC	
Country min. Temp.	Ishwardi 17.0degC	
Source:	'The Daily Prothom Alo', 24th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 23/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 7	**Spot-01**	34.7	29.8	38	0.6	S
Orientation: NS	**Spot-02**	34.6	29.7	36	0	-
Time: 2:00 pm	**Spot-03**	34.7	29.7	38	0	-
Road no. C [NS]	**Spot-04**	35.1	30.1	37	0	-
Sky condition: Clear	**Spot-05**	35.0	30.3	37	0.4	S
Rd. 07	**Spot-06**	35.0	30.2	37	0	-
	Spot-07	35.0	30.3	37	0	-
	Spot-08	35.0	30.2	39	0	-
	Spot-09	35.3	30.0	38	1.2	S
	Spot-10	35.3	30.1	37	1.2	S
	Spot-11	35.3	30.2	35	0	-
	Spot-12	35.2	30.2	36	0.9	S
	Spot-13	35.1	30.5	36	1.7	S
	Spot-14	35.0	30.4	35	1.1	S
	Spot-15	34.9	30.3	35	2.6	S
	Spot-16	34.7	30.3	37	0.7	S

City data		
Temp.	31.4degC (max)	20.0degC (min)
Humidity	56% (max.)	32% (min.)
Country max. Temp.	Rangamati 32.8degC	
Country min. Temp.	Ishwardi 17.0degC	
Source:	‘The Daily Prothom Alo', 24th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 23/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 7	**Spot-01**	34.6	30.5	36	0.7	W
Orientation: EW	**Spot-02**	35.3	30.9	36	1.2	W
Time: 12:30 pm	**Spot-03**	35.7	31.2	38	0	-
Road no. X [EW]	**Spot-04**	36.2	31.3	37	0	-
Sky condition: Clear	**Spot-05**	37.0	31.8	35	0.8	W
Rd. 13	**Spot-06**	37.6	32.5	34	0.8	W
	Spot-07	37.6	32.6	32	1.1	W
	Spot-08	37.8	32.5	34	0.7	E
	Spot-09	38.0	32.3	33	1.2	W
	Spot-10	37.9	32.2	34	0	-
	Spot-11	37.8	32.1	34	0	-
	Spot-12	37.5	31.8	34	1.1	W
	Spot-13	37.4	31.5	32	0.4	E
	Spot-14	37.2	31.5	33	0.5	W
	Spot-15	37.0	31.4	34	0	-
	Spot-16	37.2	31.6	33	1	W

City data		
Temp.	31.4degC (max)	20.0degC (min)
Humidity	56% (max.)	32% (min.)
Country max. Temp.	Rangamati 32.8degC	
Country min. Temp.	Ishwardi 17.0degC	
Source:	‘The Daily Prothom Alo', 24th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

Date: 23/03/2014

Day: 7
Orientation: EW
Time: 1:00 pm
Road no. Y [EW]
Sky condition: Partly Cloudy [Sunny]
Rd. 14

Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Spot-01	36.3	30.9	35	0	-
Spot-02	36.4	30.8	37	0	-
Spot-03	36.7	31.0	35	0	-
Spot-04	37.0	31.3	38	0	-
Spot-05	37.9	32.2	36	0	-
Spot-06	38.2	33.0	34	0	-
Spot-07	38.2	32.9	33	0.8	W
Spot-08	38.9	33.5	34	1.1	W
Spot-09	39.7	34.2	32	0.8	W
Spot-10	40.6	35.0	31	1.5	W
Spot-11	41.3	35.5	31	0.6	W
Spot-12	41.3	35.7	30	0.9	W
Spot-13	40.8	34.8	28	0	-
Spot-14	40.9	34.5	30	0	-
Spot-15	40.4	33.9	30	0	-
Spot-16	40.1	33.1	30	1.3	W

City data

Temp.	31.4degC (max)	20.0degC (min)
Humidity	56% (max.)	32% (min.)
Country max. Temp.	Rangamati 32.8degC	
Country min. Temp.	Ishwardi 17.0degC	
Source:	‘The Daily Prothom Alo', 24th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 23/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 7	**Spot-01**	37.8	31.4	31	1.4	E
Orientation: EW	**Spot-02**	37.7	31.3	32	0.7	W
Time: 1:15 pm	**Spot-03**	38.0	31.6	32	0	-
Road no. Z [EW]	**Spot-04**	37.7	31.3	33	0	-
Sky condition: Clear	**Spot-05**	37.9	31.4	33	0	-
Rd. 15	**Spot-06**	37.9	31.6	34	0.4	W
	Spot-07	37.7	31.5	34	0	-
	Spot-08	37.9	31.5	34	0.7	E
	Spot-09	38.3	32.0	33	0	-
	Spot-10	38.0	32.1	33	0	-
	Spot-11	38.3	33.4	31	0.7	W
	Spot-12	39.4	34.0	29	1.9	W
	Spot-13	38.3	33.4	30	0.7	E
	Spot-14	38.3	33.0	33	0.7	W
	Spot-15	38.1	33.3	33	0.5	W
	Spot-16	38.4	33.8	33	0.6	W

City data		
Temp.	31.4degC (max)	20.0degC (min)
Humidity	56% (max.)	32% (min.)
Country max. Temp.	Rangamati 32.8degC	
Country min. Temp.	Ishwardi 17.0degC	
Source:	‘The Daily Prothom Alo', 24th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 24/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 8	**Spot-01**	36.7	33.2	42	0	-
Orientation: NS	**Spot-02**	36.5	33.2	41	0	-
Time: 1:50 pm	**Spot-03**	36.8	33.1	41	0	-
Road no. A [NS]	**Spot-04**	36.6	32.9	39	2.2	S
Sky condition: Clear	**Spot-05**	36.3	32.6	41	0	-
Rd. 05	**Spot-06**	36.3	32.3	42	0.5	S
	Spot-07	36.3	32.6	42	2.1	S
	Spot-08	36.2	32.5	39	1.1	S
	Spot-09	36.3	32.4	41	1.3	S
	Spot-10	36.5	32.7	41	0	-
	Spot-11	36.4	32.6	40	1.1	S
	Spot-12	36.4	32.4	41	0.9	S
	Spot-13	36.4	32.6	38	1.3	S
	Spot-14	36.3	32.6	38	2.4	S
	Spot-15	36.0	32.4	41	0	-
	Spot-16	36.0	32.5	40	1.2	S

City data		
Temp.	34.1degC (max)	23.6degC (min)
Humidity	70% (max.)	31% (min.)
Country max. Temp.	Ishwardi 36.7degC	
Country min. Temp.	SriMangal 19.5degC	
Source:	'The Daily Prothom Alo', 25th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 24/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 8	**Spot-01**	35.4	31.0	43	0.6	S
Orientation: NS	**Spot-02**	35.5	31.6	46	0	-
Time: 1:30 pm	**Spot-03**	35.7	31.5	45	0	-
Road no. B [NS]	**Spot-04**	36.1	31.8	46	0	-
Sky condition: Clear	**Spot-05**	35.8	31.4	46	0.8	S
Rd. 06	**Spot-06**	35.8	31.3	47	0.6	S
	Spot-07	36.3	31.8	45	0.6	S
	Spot-08	36.1	31.9	41	0.9	S
	Spot-09	36.1	31.9	43	0	-
	Spot-10	36.2	32.5	42	0	-
	Spot-11	36.3	32.5	42	0	-
	Spot-12	36.3	32.4	42	0	-
	Spot-13	36.9	32.8	42	0	-
	Spot-14	36.7	32.8	40	0.8	S
	Spot-15	36.5	32.7	41	0	-
	Spot-16	36.7	33.1	39	0.7	S

City data		
Temp.	34.1degC (max)	23.6degC (min)
Humidity	70% (max.)	31% (min.)
Country max. Temp.	Ishwardi 36.7degC	
Country min. Temp.	SriMangal 19.5degC	
Source:	‘The Daily Prothom Alo', 25th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 24/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 8	**Spot-01**	33.5	31.9	45	0	-
Orientation: NS	**Spot-02**	33.4	31.6	47	0	-
Time: 1:15 pm	**Spot-03**	33.5	31.5	48	0	-
Road no. C [NS]	**Spot-04**	34.6	31.8	45	1	S
Sky condition: Clear	**Spot-05**	34.8	31.9	44	0	-
Rd. 07	**Spot-06**	34.9	31.9	45	0	-
	Spot-07	35.4	32.2	45	0	-
	Spot-08	35.5	32.3	44	0	-
	Spot-09	35.6	32.1	46	0	-
	Spot-10	36.0	32.2	44	0.6	N
	Spot-11	35.8	32.1	46	0	-
	Spot-12	35.9	32.0	46	0.7	S
	Spot-13	36.3	32.4	44	0	-
	Spot-14	36.2	32.4	45	0	-
	Spot-15	36.1	32.2	43	2.1	S
	Spot-16	35.9	31.6	42	1.3	S

City data		
Temp.	34.1degC (max)	23.6degC (min)
Humidity	70% (max.)	31% (min.)
Country max. Temp.	Ishwardi 36.7degC	
Country min. Temp.	SriMangal 19.5degC	
Source:	‘The Daily Prothom Alo', 25th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 24/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 8	**Spot-01**	34.7	31.3	42	0.9	E
Orientation: EW	**Spot-02**	34.4	31.2	43	0.8	E
Time: 2:40 pm	**Spot-03**	34.3	31.1	44	0.7	E
Road no. X [EW]	**Spot-04**	34.1	30.9	43	1.8	W
Sky condition: Clear	**Spot-05**	34.0	31.0	44	1.8	W
Rd. 13	**Spot-06**	34.1	31.2	46	0.7	W
	Spot-07	34.1	31.3	44	1.1	W
	Spot-08	34.4	31.7	44	1.8	W
	Spot-09	34.5	31.9	44	1	W
	Spot-10	34.5	32.1	44	0.6	W
	Spot-11	34.6	32.3	43	2.2	W
	Spot-12	34.7	32.3	44	0.7	W
	Spot-13	34.6	32.3	43	1.4	W
	Spot-14	34.6	32.4	43	0	-
	Spot-15	34.7	32.5	42	0.8	W
	Spot-16	34.6	32.5	42	0.9	W

City data		
Temp.	34.1degC (max)	23.6degC (min)
Humidity	70% (max.)	31% (min.)
Country max. Temp.	Ishwardi 36.7degC	
Country min. Temp.	SriMangal 19.5degC	
Source:	‘The Daily Prothom Alo', 25th March 2014	

Data Collection Chart [Field Survey]

DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]

	Location	DBT(degC)	RT(degC)	RH(%)	Wind speed(m/s)	Wind direction
Date: 24/03/2014						
Day: 8	**Spot-01**	35.3	32.8	42	0.9	W
Orientation: EW	**Spot-02**	35.0	32.4	42	0	-
Time: 2:25 pm	**Spot-03**	34.9	32.0	42	0	-
Road no. Y [EW]	**Spot-04**	34.6	31.6	42	0	-
Sky condition: Clear	**Spot-05**	34.5	31.4	44	0.4	W
Rd. 14	**Spot-06**	34.5	31.1	45	0.5	W
	Spot-07	34.3	30.9	46	0	-
	Spot-08	34.5	30.9	46	0	-
	Spot-09	35.1	30.6	45	0.6	E
	Spot-10	35.4	32.0	44	0.5	E
	Spot-11	35.7	33.0	43	0.4	E
	Spot-12	35.7	33.2	42	0	-
	Spot-13	35.5	32.5	43	0.8	W
	Spot-14	35.2	32.1	46	0	-
	Spot-15	35.1	31.6	45	0	-
	Spot-16	34.8	31.1	45	0.4	W

City data

Temp.	34.1degC (max)	23.6degC (min)
Humidity	70% (max.)	31% (min.)
Country max. Temp.	Ishwardi 36.7degC	
Country min. Temp.	SriMangal 19.5degC	
Source:	‘The Daily Prothom Alo', 25th March 2014	

Data Collection Chart [Field Survey]						
DBT[Dry Bulb Temperature]; RT[Radiant Temperature]; RH[Relative Humidity]; WS[Wind Speed]						
Date: 24/03/2014	**Location**	**DBT(degC)**	**RT(degC)**	**RH(%)**	**Wind speed(m/s)**	**Wind direction**
Day: 8	**Spot-01**	35.8	32.2	40	1.5	W
Orientation: EW	**Spot-02**	35.5	31.8	42	0.5	W
Time: 2:10 pm	**Spot-03**	35.3	31.6	42	0.6	W
Road no. Z [EW]	**Spot-04**	35.2	31.5	42	0	-
Sky condition: Clear	**Spot-05**	35.0	31.2	44	1.4	W
Rd. 15	**Spot-06**	34.9	31.1	45	0.8	W
	Spot-07	34.8	31.1	44	0.5	W
	Spot-08	34.5	31.3	40	1.9	E
	Spot-09	34.6	31.5	41	0	-
	Spot-10	34.7	31.6	42	1.1	E
	Spot-11	34.7	31.7	42	0.4	W
	Spot-12	34.7	31.8	42	1.1	W
	Spot-13	34.4	31.8	42	2.5	E
	Spot-14	34.4	31.8	42	1.6	E
	Spot-15	34.6	32.0	44	0.5	W
	Spot-16	35.3	32.8	43	0	-

City data		
Temp.	34.1degC (max)	23.6degC (min)
Humidity	70% (max.)	31% (min.)
Country max. Temp.	Ishwardi 36.7degC	
Country min. Temp.	SriMangal 19.5degC	
Source:	'The Daily Prothom Alo', 25th March 2014	

Appendix – 3: Statistical Tables

North-South Orientation

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Mean Radiant Temperature [K]	Between Groups	575.534	5	115.107	1.764	.145
	Within Groups	2348.816	36	65.245		
	Total	2924.350	41			
Dry Bulb Temperature [K]	Between Groups	.424	5	.085	.202	.960
	Within Groups	15.104	36	.420		
	Total	15.528	41			
Relative Humidity [%]	Between Groups	3.388	5	.678	5.489	.001
	Within Groups	4.445	36	.123		
	Total	7.833	41			
Wind Speed [m/s]	Between Groups	.128	5	.026	10.352	.000
	Within Groups	.089	36	.002		
	Total	.216	41			

Post Hoc Tests:

Multiple Comparisons [LSD]

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Mean Radiant Temperature [K]	A[1996]Og	A1[1996]El	2.03	4.32	.64	-6.73	10.79
		B[2013]Og_cc	4.96	4.32	.26	-3.80	13.72
		B1[2013]Og_ff	-4.63	4.32	.29	-13.38	4.13
		B2[2013]El_cc	7.00	4.32	.11	-1.76	15.75
		B3[2013]El_ff	2.75	4.32	.53	-6.00	11.51
	A1[1996]El	A[1996]Og	-2.03	4.32	.64	-10.79	6.73

		B[2013]Og_cc	2.93	4.32	.50	-5.83	11.69
		B1[2013]Og_ff	-6.66	4.32	.13	-15.42	2.10
		B2[2013]El_cc	4.97	4.32	.26	-3.79	13.72
		B3[2013]El_ff	.72	4.32	.87	-8.03	9.48
	B[2013]Og_cc	A[1996]Og	-4.96	4.32	.26	-13.72	3.80
		A1[1996]El	-2.93	4.32	.50	-11.69	5.83
		B1[2013]Og_ff	-9.59*	4.32	.03	-18.35	-.83
		B2[2013]El_cc	2.03	4.32	.64	-6.72	10.79
		B3[2013]El_ff	-2.21	4.32	.61	-10.96	6.55
	B1[2013]Og_ff	A[1996]Og	4.63	4.32	.29	-4.13	13.38
		A1[1996]El	6.66	4.32	.13	-2.10	15.42
		B[2013]Og_cc	9.59*	4.32	.03	.83	18.35
		B2[2013]El_cc	11.62*	4.32	.01	2.87	20.38
		B3[2013]El_ff	7.38	4.32	.10	-1.38	16.14
	B2[2013]El_cc	A[1996]Og	-7.00	4.32	.11	-15.75	1.76
		A1[1996]El	-4.97	4.32	.26	-13.72	3.79
		B[2013]Og_cc	-2.03	4.32	.64	-10.79	6.72
		B1[2013]Og_ff	-11.62*	4.32	.01	-20.38	-2.87
		B3[2013]El_ff	-4.24	4.32	.33	-13.00	4.51
	B3[2013]El_ff	A[1996]Og	-2.75	4.32	.53	-11.51	6.00
		A1[1996]El	-.72	4.32	.87	-9.48	8.03
		B[2013]Og_cc	2.21	4.32	.61	-6.55	10.96
		B1[2013]Og_ff	-7.38	4.32	.10	-16.14	1.38
		B2[2013]El_cc	4.24	4.32	.33	-4.51	13.00
Dry Bulb Temperature [K]	A[1996]Og	A1[1996]El	.14	.35	.68	-.56	.84
		B[2013]Og_cc	-.11	.35	.75	-.81	.59
		B1[2013]Og_ff	.07	.35	.84	-.63	.77
		B2[2013]El_cc	.00	.35	1.00	-.70	.70

		B3[2013]El_ff	.19	.35	.58	-.51	.89
	A1[1996]El	A[1996]Og	-.14	.35	.68	-.84	.56
		B[2013]Og_cc	-.25	.35	.47	-.96	.45
		B1[2013]Og_ff	-.07	.35	.84	-.77	.63
		B2[2013]El_cc	-.14	.35	.68	-.85	.56
		B3[2013]El_ff	.05	.35	.89	-.65	.75
	B[2013]Og_cc	A[1996]Og	.11	.35	.75	-.59	.81
		A1[1996]El	.25	.35	.47	-.45	.96
		B1[2013]Og_ff	.18	.35	.60	-.52	.88
		B2[2013]El_cc	.11	.35	.75	-.59	.81
		B3[2013]El_ff	.30	.35	.38	-.40	1.01
	B1[2013]Og_ff	A[1996]Og	-.07	.35	.84	-.77	.63
		A1[1996]El	.07	.35	.84	-.63	.77
		B[2013]Og_cc	-.18	.35	.60	-.88	.52
		B2[2013]El_cc	-.07	.35	.84	-.77	.63
		B3[2013]El_ff	.12	.35	.73	-.58	.82
	B2[2013]El_cc	A[1996]Og	.00	.35	1.00	-.70	.70
		A1[1996]El	.14	.35	.68	-.56	.85
		B[2013]Og_cc	-.11	.35	.75	-.81	.59
		B1[2013]Og_ff	.07	.35	.84	-.63	.77
		B3[2013]El_ff	.19	.35	.58	-.51	.90
	B3[2013]El_ff	A[1996]Og	-.19	.35	.58	-.89	.51
		A1[1996]El	-.05	.35	.89	-.75	.65
		B[2013]Og_cc	-.30	.35	.38	-1.01	.40
		B1[2013]Og_ff	-.12	.35	.73	-.82	.58
		B2[2013]El_cc	-.19	.35	.58	-.90	.51
Relative Humidity [%]	A[1996]Og	A1[1996]El	-.50*	.19	.01	-.89	-.12
		B[2013]Og_cc	-.54*	.19	.01	-.92	-.16

	B1[2013]Og_ff	-.06	.19	.73	-.45	.32
	B2[2013]El_cc	-.76*	.19	.00	-1.14	-.38
	B3[2013]El_ff	-.12	.19	.52	-.50	.26
A1[1996]El	A[1996]Og	.50*	.19	.01	.12	.89
	B[2013]Og_cc	-.04	.19	.84	-.42	.34
	B1[2013]Og_ff	.44*	.19	.03	.06	.82
	B2[2013]El_cc	-.26	.19	.18	-.64	.12
	B3[2013]El_ff	.38*	.19	.05	.00	.76
B[2013]Og_cc	A[1996]Og	.54*	.19	.01	.16	.92
	A1[1996]El	.04	.19	.84	-.34	.42
	B1[2013]Og_ff	.48*	.19	.02	.10	.86
	B2[2013]El_cc	-.22	.19	.25	-.60	.16
	B3[2013]El_ff	.42*	.19	.03	.04	.80
B1[2013]Og_ff	A[1996]Og	.06	.19	.73	-.32	.45
	A1[1996]El	-.44*	.19	.03	-.82	-.06
	B[2013]Og_cc	-.48*	.19	.02	-.86	-.10
	B2[2013]El_cc	-.70*	.19	.00	-1.08	-.32
	B3[2013]El_ff	-.06	.19	.76	-.44	.32
B2[2013]El_cc	A[1996]Og	.76*	.19	.00	.38	1.14
	A1[1996]El	.26	.19	.18	-.12	.64
	B[2013]Og_cc	.22	.19	.25	-.16	.60
	B1[2013]Og_ff	.70*	.19	.00	.32	1.08
	B3[2013]El_ff	.64*	.19	.00	.26	1.02
B3[2013]El_ff	A[1996]Og	.12	.19	.52	-.26	.50
	A1[1996]El	-.38*	.19	.05	-.76	.00
	B[2013]Og_cc	-.42*	.19	.03	-.80	-.04
	B1[2013]Og_ff	.06	.19	.76	-.32	.44
	B2[2013]El_cc	-.64*	.19	.00	-1.02	-.26

Wind Speed [m/s]	A[1996]Og	A1[1996]El	-.03	.03	.28	-.08	.02
		B[2013]Og_cc	.12*	.03	.00	.07	.18
		B1[2013]Og_ff	.09*	.03	.00	.04	.15
		B2[2013]El_cc	.09*	.03	.00	.04	.14
		B3[2013]El_ff	.03	.03	.28	-.02	.08
	A1[1996]El	A[1996]Og	.03	.03	.28	-.02	.08
		B[2013]Og_cc	.15*	.03	.00	.10	.21
		B1[2013]Og_ff	.12*	.03	.00	.07	.18
		B2[2013]El_cc	.12*	.03	.00	.06	.17
		B3[2013]El_ff	.06*	.03	.03	.00	.11
	B[2013]Og_cc	A[1996]Og	-.12*	.03	.00	-.18	-.07
		A1[1996]El	-.15*	.03	.00	-.21	-.10
		B1[2013]Og_ff	-.03	.03	.26	-.08	.02
		B2[2013]El_cc	-.04	.03	.19	-.09	.02
		B3[2013]El_ff	-.10*	.03	.00	-.15	-.04
	B1[2013]Og_ff	A[1996]Og	-.09*	.03	.00	-.15	-.04
		A1[1996]El	-.12*	.03	.00	-.18	-.07
		B[2013]Og_cc	.03	.03	.26	-.02	.08
		B2[2013]El_cc	.00	.03	.87	-.06	.05
		B3[2013]El_ff	-.06*	.03	.02	-.12	-.01
	B2[2013]El_cc	A[1996]Og	-.09*	.03	.00	-.14	-.04
		A1[1996]El	-.12*	.03	.00	-.17	-.06
		B[2013]Og_cc	.04	.03	.19	-.02	.09
		B1[2013]Og_ff	.00	.03	.87	-.05	.06
		B3[2013]El_ff	-.06*	.03	.03	-.11	-.01
	B3[2013]El_ff	A[1996]Og	-.03	.03	.28	-.08	.02
		A1[1996]El	-.06*	.03	.03	-.11	.00

B[2013]Og_cc	.10*	.03	.00	.04	.15
B1[2013]Og_ff	.06*	.03	.02	.01	.12
B2[2013]El_cc	.06*	.03	.03	.01	.11

*. The mean difference is significant at the 0.05 level.

East-West Orientation

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Mean Radiant Temperature [K]	Between Groups	19.636	5	3.927	.229	.947
	Within Groups	616.658	36	17.129		
	Total	636.293	41			
Dry Bulb Temperature [K]	Between Groups	.700	5	.140	.240	.942
	Within Groups	21.030	36	.584		
	Total	21.731	41			
Relative Humidity [%]	Between Groups	.966	5	.193	.287	.917
	Within Groups	24.197	36	.672		
	Total	25.163	41			
Wind Speed [m/s]	Between Groups	.283	5	.057	19.421	.000
	Within Groups	.105	36	.003		
	Total	.388	41			

Post Hoc Tests:

Multiple Comparisons [LSD]

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Mean Radiant Temperature [K]	A[1996]Og	A1[1996]El	.00	2.21	1.00	-4.48	4.49
		B[2013]Og_cc	.58	2.21	.79	-3.91	5.07
		B1[2013]Og_ff	.59	2.21	.79	-3.89	5.08
		B2[2013]El_cc	2.05	2.21	.36	-2.44	6.53
		B3[2013]El_ff	.58	2.21	.79	-3.90	5.07
	A1[1996]El	A[1996]Og	.00	2.21	1.00	-4.49	4.48
		B[2013]Og_cc	.58	2.21	.80	-3.91	5.06
		B1[2013]Og_ff	.59	2.21	.79	-3.90	5.07
		B2[2013]El_cc	2.04	2.21	.36	-2.44	6.53
		B3[2013]El_ff	.58	2.21	.80	-3.91	5.06
	B[2013]Og_cc	A[1996]Og	-.58	2.21	.79	-5.07	3.91
		A1[1996]El	-.58	2.21	.80	-5.06	3.91
		B1[2013]Og_ff	.01	2.21	1.00	-4.48	4.50
		B2[2013]El_cc	1.47	2.21	.51	-3.02	5.95
		B3[2013]El_ff	.00	2.21	1.00	-4.49	4.49
	B1[2013]Og_ff	A[1996]Og	-.59	2.21	.79	-5.08	3.89
		A1[1996]El	-.59	2.21	.79	-5.07	3.90
		B[2013]Og_cc	-.01	2.21	1.00	-4.50	4.48
		B2[2013]El_cc	1.46	2.21	.51	-3.03	5.94
		B3[2013]El_ff	-.01	2.21	1.00	-4.50	4.48

	B2[2013]El_cc	A[1996]Og	-2.05	2.21	.36	-6.53	2.44
		A1[1996]El	-2.04	2.21	.36	-6.53	2.44
		B[2013]Og_cc	-1.47	2.21	.51	-5.95	3.02
		B1[2013]Og_ff	-1.46	2.21	.51	-5.94	3.03
		B3[2013]El_ff	-1.47	2.21	.51	-5.95	3.02
	B3[2013]El_ff	A[1996]Og	-.58	2.21	.79	-5.07	3.90
		A1[1996]El	-.58	2.21	.80	-5.06	3.91
		B[2013]Og_cc	.00	2.21	1.00	-4.49	4.49
		B1[2013]Og_ff	.01	2.21	1.00	-4.48	4.50
		B2[2013]El_cc	1.47	2.21	.51	-3.02	5.95
Dry Bulb Temperature [K]	A[1996]Og	A1[1996]El	.09	.41	.83	-.74	.92
		B[2013]Og_cc	.00	.41	.99	-.82	.83
		B1[2013]Og_ff	.25	.41	.54	-.58	1.08
		B2[2013]El_cc	.26	.41	.54	-.57	1.08
		B3[2013]El_ff	.33	.41	.43	-.50	1.16
	A1[1996]El	A[1996]Og	-.09	.41	.83	-.92	.74
		B[2013]Og_cc	-.09	.41	.84	-.91	.74
		B1[2013]Og_ff	.16	.41	.69	-.67	.99
		B2[2013]El_cc	.17	.41	.69	-.66	.99
		B3[2013]El_ff	.24	.41	.56	-.59	1.07
	B[2013]Og_cc	A[1996]Og	.00	.41	.99	-.83	.82
		A1[1996]El	.09	.41	.84	-.74	.91
		B1[2013]Og_ff	.25	.41	.55	-.58	1.08
		B2[2013]El_cc	.25	.41	.54	-.58	1.08
		B3[2013]El_ff	.32	.41	.43	-.51	1.15
	B1[2013]Og_ff	A[1996]Og	-.25	.41	.54	-1.08	.58
		A1[1996]El	-.16	.41	.69	-.99	.67

		B[2013]Og_cc	-.25	.41	.55	-1.08	.58
		B2[2013]El_cc	.00	.41	.99	-.83	.83
		B3[2013]El_ff	.08	.41	.85	-.75	.90
	B2[2013]El_cc	A[1996]Og	-.26	.41	.54	-1.08	.57
		A1[1996]El	-.17	.41	.69	-.99	.66
		B[2013]Og_cc	-.25	.41	.54	-1.08	.58
		B1[2013]Og_ff	.00	.41	.99	-.83	.83
		B3[2013]El_ff	.07	.41	.86	-.76	.90
	B3[2013]El_ff	A[1996]Og	-.33	.41	.43	-1.16	.50
		A1[1996]El	-.24	.41	.56	-1.07	.59
		B[2013]Og_cc	-.32	.41	.43	-1.15	.51
		B1[2013]Og_ff	-.08	.41	.85	-.90	.75
		B2[2013]El_cc	-.07	.41	.86	-.90	.76
Relative Humidity [%]	A[1996]Og	A1[1996]El	-.05	.44	.91	-.94	.84
		B[2013]Og_cc	-.36	.44	.41	-1.25	.53
		B1[2013]Og_ff	-.28	.44	.53	-1.17	.61
		B2[2013]El_cc	-.40	.44	.37	-1.28	.49
		B3[2013]El_ff	-.13	.44	.77	-1.02	.76
	A1[1996]El	A[1996]Og	.05	.44	.91	-.84	.94
		B[2013]Og_cc	-.31	.44	.48	-1.20	.58
		B1[2013]Og_ff	-.23	.44	.60	-1.12	.66
		B2[2013]El_cc	-.35	.44	.44	-1.23	.54
		B3[2013]El_ff	-.08	.44	.85	-.97	.81
	B[2013]Og_cc	A[1996]Og	.36	.44	.41	-.53	1.25
		A1[1996]El	.31	.44	.48	-.58	1.20
		B1[2013]Og_ff	.08	.44	.85	-.81	.97
		B2[2013]El_cc	-.03	.44	.94	-.92	.86

		B3[2013]El_ff	.23	.44	.60	-.66	1.12
	B1[2013]Og_ff	A[1996]Og	.28	.44	.53	-.61	1.17
		A1[1996]El	.23	.44	.60	-.66	1.12
		B[2013]Og_cc	-.08	.44	.85	-.97	.81
		B2[2013]El_cc	-.12	.44	.79	-1.00	.77
		B3[2013]El_ff	.15	.44	.74	-.74	1.04
	B2[2013]El_cc	A[1996]Og	.40	.44	.37	-.49	1.28
		A1[1996]El	.35	.44	.44	-.54	1.23
		B[2013]Og_cc	.03	.44	.94	-.86	.92
		B1[2013]Og_ff	.12	.44	.79	-.77	1.00
		B3[2013]El_ff	.26	.44	.55	-.62	1.15
	B3[2013]El_ff	A[1996]Og	.13	.44	.77	-.76	1.02
		A1[1996]El	.08	.44	.85	-.81	.97
		B[2013]Og_cc	-.23	.44	.60	-1.12	.66
		B1[2013]Og_ff	-.15	.44	.74	-1.04	.74
		B2[2013]El_cc	-.26	.44	.55	-1.15	.62
Wind Speed [m/s]	A[1996]Og	A1[1996]El	-.01	.03	.69	-.07	.05
		B[2013]Og_cc	-.09*	.03	.00	-.15	-.04
		B1[2013]Og_ff	.13*	.03	.00	.08	.19
		B2[2013]El_cc	.05	.03	.07	-.01	.11
		B3[2013]El_ff	-.10*	.03	.00	-.16	-.04
	A1[1996]El	A[1996]Og	.01	.03	.69	-.05	.07
		B[2013]Og_cc	-.08*	.03	.01	-.14	-.02
		B1[2013]Og_ff	.15*	.03	.00	.09	.20
		B2[2013]El_cc	.07*	.03	.03	.01	.12
		B3[2013]El_ff	-.09*	.03	.00	-.15	-.03

B[2013]Og_cc	A[1996]Og	.09*	.03	.00	.04	.15
	A1[1996]El	.08*	.03	.01	.02	.14
	B1[2013]Og_ff	.23*	.03	.00	.17	.29
	B2[2013]El_cc	.15*	.03	.00	.09	.21
	B3[2013]El_ff	-.01	.03	.77	-.07	.05
B1[2013]Og_ff	A[1996]Og	-.13*	.03	.00	-.19	-.08
	A1[1996]El	-.15*	.03	.00	-.20	-.09
	B[2013]Og_cc	-.23*	.03	.00	-.29	-.17
	B2[2013]El_cc	-.08*	.03	.01	-.14	-.02
	B3[2013]El_ff	-.24*	.03	.00	-.30	-.18
B2[2013]El_cc	A[1996]Og	-.05	.03	.07	-.11	.01
	A1[1996]El	-.07*	.03	.03	-.12	-.01
	B[2013]Og_cc	-.15*	.03	.00	-.21	-.09
	B1[2013]Og_ff	.08*	.03	.01	.02	.14
	B3[2013]El_ff	-.16*	.03	.00	-.21	-.10
B3[2013]El_ff	A[1996]Og	.10*	.03	.00	.04	.16
	A1[1996]El	.09*	.03	.00	.03	.15
	B[2013]Og_cc	.01	.03	.77	-.05	.07
	B1[2013]Og_ff	.24*	.03	.00	.18	.30
	B2[2013]El_cc	.16*	.03	.00	.10	.21

*. The mean difference is significant at the 0.05 level.

Appendix – 4: Building Regulation Tables

Setbacks for sides and back of plots are given in Table 1.

Table 1: Minimum rear and side setbacks required for a plot (1996 by-law)

Plot area (Sft)	Rear setback	Side setback
Upto 1440	3'	2'6"
Above 1440 upto 2160	3'	3'
Above 2160 upto 2880	5'	3'
Above 2880 upto 3600	6'6"	4'
Above 3600 upto 7200	*6'6"*	*4'*
Above 7200	6'6"	4'

In INB 2008 (Imarat Nirman Bidhimala) we can see the amount of FAR and MGC from the following table 2:

Table 2: Plot size, front road width, FAR and MGC (INB 2008)

Plot size (Sqm)		Type of structure (A1-A4) Residential structures		
Sqm	Katha	Road width (m)	FAR	MGC (%)
Less than or upto 134 sqm	2 or less	6.0	3.15	67.5
More than 134sqm upto 201sqm	>2 to 3	6.0	3.35	65.0
More than 201sqm upto 268sqm	>3to 4	6.0	3.50	62.5
More than 268sqm upto 335sqm	>4 to 5	6.0	3.50	62.5

More than 335sqm upto 402sqm	*>5 to 6*	*6.0*	*3.75*	*60.0*
More than 402sqm upto 469sqm	>6 to 7	6.0	3.75	60.0
More than 469sqm upto 535sqm	>7 to 8	6.0	4.00	60.0
More than 535sqm upto 603sqm	>8 to 9	6.0	4.00	60.0
More than 603sqm upto 670sqm	>9to 10	6.0	4.25	57.5
More than 670sqm upto 804sqm	>10 to 12	9.0	4.50	57.5
More than 804sqm upto 938sqm	>12 to 14	9.0	4.75	55.0
More than 938sqm upto 1072sqm	>14 to 16	9.0	5.00	52.5
More than 1072sqm upto 1206sqm	>16 to 18	9.0	5.25	52.5
More than 1206sqm upto 1340sqm	>18 to 20	9.0	5.25	50.0
More than 1340sqm	>20 to 22	12.0	5.50	50.0
Any plot size	Any amount	18.0	6.00	50.0
Any plot size	Any amount	24.0	6.50	50.0

Following table 3 shows rear and side setbacks of INB 2008 (Imarat Nirman Bidhimala 2008):

Table 3: Plot size with front, rear and side setback (INB 2008)

Height of the structure: 33meters or upto 10 storeys				
Plot size		Minimum setback		
Sqm	katha	Front (m)	Rear (m)	Side (m)
Less than or upto 134 sqm	2 or less	1.50	1.00	0.80
More than 134sqm upto 201sqm	>2 to 3	1.50	1.00	1.00
More than 201sqm upto 268sqm	>3to 4	1.50	1.50	1.00
More than 268sqm upto 335sqm	>4 to 5	1.50	2.00	1.25

More than 335sqm upto 402sqm	*>5 to 6*	*1.50*	*2.00*	*1.25*
More than 402sqm upto 469sqm	>6 to 7	1.50	2.00	1.25
More than 469sqm upto 535sqm	>7 to 8	1.50	2.00	1.25
More than 535sqm upto 603sqm	>8 to 9	1.50	2.00	1.25
More than 603sqm upto 670sqm	>9to 10	1.50	2.00	1.25
More than 670sqm upto 804sqm	>10 to 12	1.50	2.00	1.25
More than 804sqm upto 938sqm	>12 to 14	1.50	2.00	1.25
More than 938sqm upto 1072sqm	>14 to 16	1.50	2.00	1.25
More than 1072sqm upto 1206sqm	>16 to 18	1.50	2.00	1.25
More than 1206sqm upto 1340sqm	>18 to 20	1.50	2.00	1.25
More than 1340sqm	>20	1.50	2.00	1.50

After amendments of 2013 we get the following tables (4-6):

Table 4: Plot size with road width and FAR (INB 2013)

Type of structure	Sub classes of structures	Road width and allowable FAR								
		1.8m-<2.5m	2.5m-<3.62m	3.62m-<4.8m	4.8m-<6.0m	6.0m-<9.0m	9.0m-<12.0m	12.0m	18.0m	>24m
		FAR	FAR	FAR	FAR	FAR	FAR	FAR	FAR	FAR
A: Residential	A1	1.25	1.75	2.00	2.50	3.00	3.50	3.75	4.00	4.50
	A2	1.25	1.75	2.00	2.50	3.00	3.50	3.75	4.00	4.50
	A3	1.00	1.75	3.00	3.50	4.00	*4.50*	5.00	5.50	6.00NR
	A4	1.25	1.75	2.75	3.25	3.50	4.50	5.00	6.00	6.50NR
	A5	-	-	-	-	4.00	4.50	7.00	8.00	9.50NR

Table 5: Plot size with maximum ground coverage (MGC) (INB 2013)

Plot size		MGC (%)
Sqm	katha	
134sqm or less	2 katha or less	70.00
More than 134 sqm upto 201 sqm	More than 2 katha upto 3 katha	67.50
More than 201 sqm upto 268 sqm	More than 3 katha upto 4 katha	65.00
More than 268 sqm upto 402 sqm	*More than 4 katha upto 6 katha*	*62.50*
More than 402 sqm upto 603 sqm	More than 6 katha upto 9 katha	60.00
More than 603 sqm upto 937 sqm	More than 9 katha upto 14 katha	55.00
More than 937 sqm upto 1339 sqm	More than 14 katha upto 20 katha	50.00
More than 1339 sqm upto 2677 sqm	More than 20 katha upto 40 katha	45.00
More than 2677 sqm	More than 40 katha	40.00

Table 6: No of storeys with side and rear setback (INB 2013)

No. of storeys	Side setback (m)	Rear setback (m)
Upto 3	1.00	1.25
4	1.00	1.25
5	1.00	1.25
6	1.00	1.25
7	1.15	1.45

8	*1.30*	*1.60*
9	1.45	1.80
10	1.60	2.00
11	2.40	3.00
12-13	2.80	3.50
14-15	3.20	4.00
16-17	3.60	4.50
18-19	4.00	5.00
20-22	4.60	5.75
23-25	5.40	6.75
26-28	6.00	7.50
29-31	6.60	8.25
32-34	7.20	9.00
35-37	7.80	9.75
38-40	8.00	10.00
More than 40	10.00	12.50