

An aerial photograph of Dubai, UAE, featuring the Burj Khalifa as the central focus. The image shows a dense urban landscape with numerous skyscrapers, some under construction with cranes. In the foreground, a complex multi-level highway interchange with multiple overpasses and ramps is visible, with cars and trucks moving through it. The sky is a clear, bright blue, suggesting a sunny day. The overall scene depicts a modern, high-density city environment.

ENVI  
\_MET

# Adapting Dubai's fabric for pedestrian comfort

Dubai, UAE

Studio 4215

## Introduction

# Why Dubai ?

As the world turned to Dubai for the World Expo 2020/2021 (2021/2022), it becomes important to highlight the lessons the city of Dubai has to offer for developments in extreme (hot) climates.

As the world turns to Dubai for the World Expo 2020/2021 (2021/2022), it becomes important to highlight the lessons the city of Dubai has to offer for developments in extreme (hot) climates. Several characteristics in Dubai make it an ideal case study, some of which are listed below:

1. The contrast between different parts of the city in terms of the urban density, building heights and general 'tightness or looseness' of its urban fabric.
2. Extreme weather conditions and learnings for our warming cities (effect of climate change).
3. Day to Night variations and changes in occupancy patterns of outdoor public spaces.
4. Importance of passive design measures such as shading, landscape and water features in providing relief from extreme weather conditions.
5. Understanding various factors associated with outdoor comfort. Often only the air temperature is considered. Dubai provides an opportunity to understand the significant change in conditions one could experience even within short walking distances.

The study analyses the current conditions and proposes a set of passive design interventions to improve the environmental performance of outdoor open spaces. Undoubtedly, the study could be expanded further in passive design and comfort improvement measures/opportunities, in both the scenarios of Deira and the Burj.

### Disclaimer

The study is for academic purposes only and even though every care has been taken to accurately depict the current scenario in terms of existing buildings, temperature and humidity conditions and other parameters, there may be instances where some discrepancies exist.

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# Urban fabric comparisons



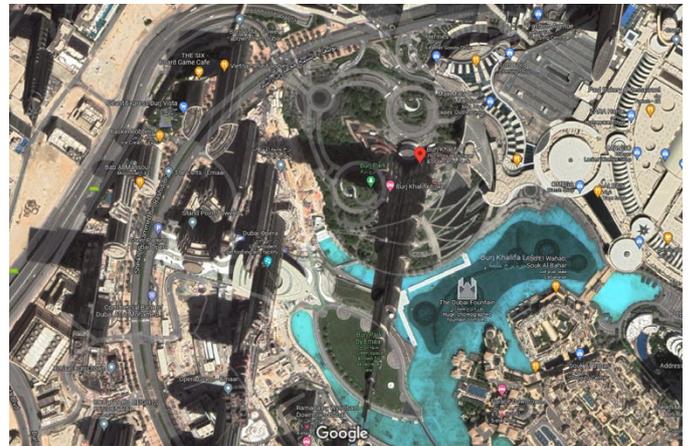
Representation of (Deira's) dense and compact urban fabric.



Representation of the open and loose urban fabric (near the Burj Khalifa).



Satellite images for Deira (Source: Bing Maps)



Satellite images for area near Burj Khalifa (Source: Google Maps)

## Research question

# Impact of urban density

The first part of the research compares and investigates the differences between the urban fabric of what could be considered as old and new Dubai.

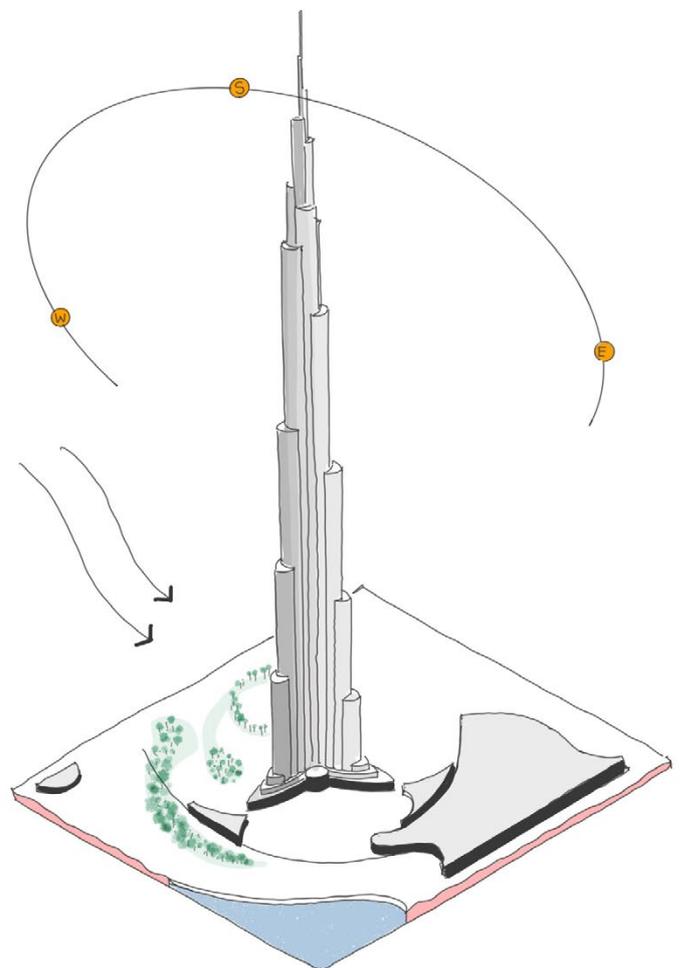
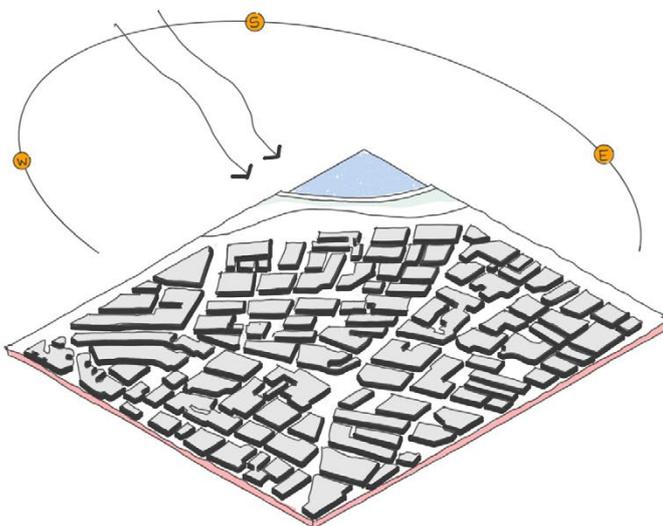
The differences in looseness/tightness of the urban fabric, the ability of the buildings to protect/shade each other and shade the public spaces in between. As new parts of Dubai get iconic buildings, the old part of Dubai, Deira, once the commercial centre of the city, continues to function with an equally high footfall.

The research investigates the differences in the built density and its impact on the pedestrian comfort conditions.

This research becomes relevant as the world turns to Dubai for the World Expo 2020/2021 (2021/2022) and the lessons it has for developments in extreme (hot) climates.

The study begins introducing the 2 sites and modelling the current situation in ENVI-met. Based on the simulation results, improvements in the outdoor thermal comfort are developed through changes in the landscape and urban fabric.

The study analyses the current environmental performance of the two sites/areas and suggests some initial passive design interventions to improve pedestrian comfort. To evaluate and quantify these interventions, the microclimate model ENVI-met is used.



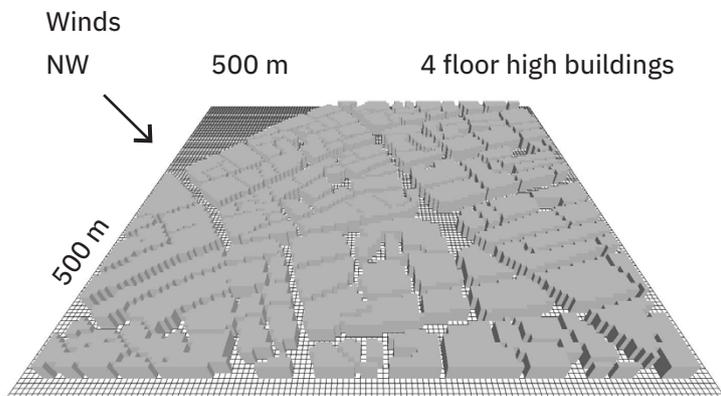
Images from Deira, Dubai highlighting the tight urban fabric.



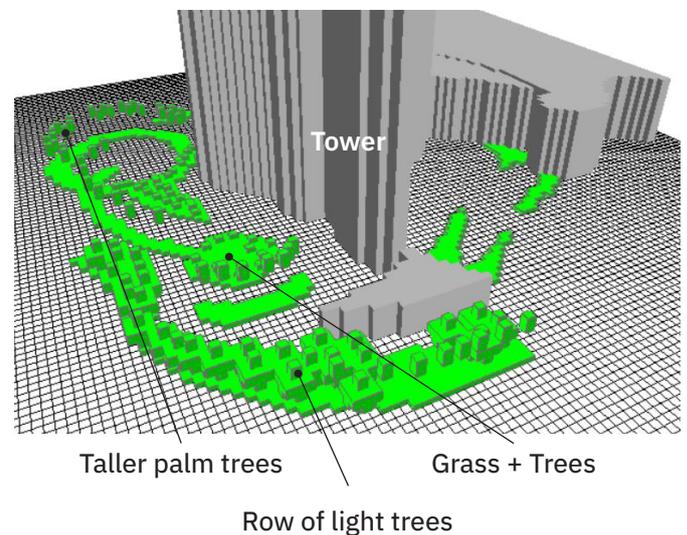
Images from the Burj Dubai area highlight the open/loose urban fabric with landscape elements of some greens and large water features.



ENVI-met model analysed for Deira

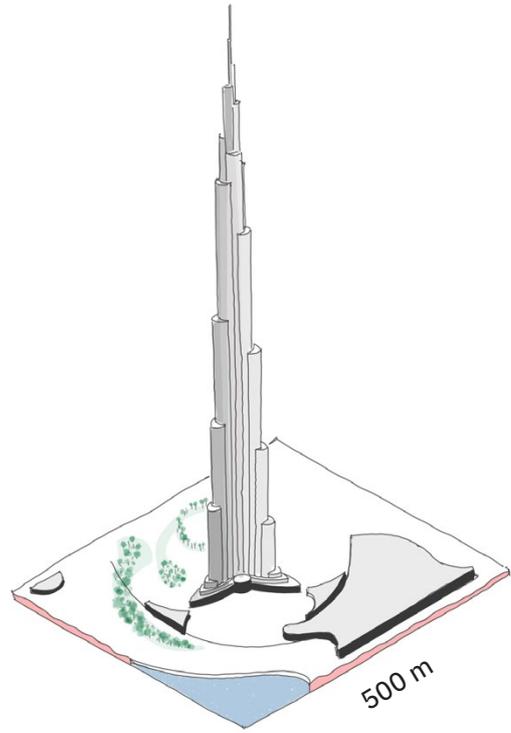
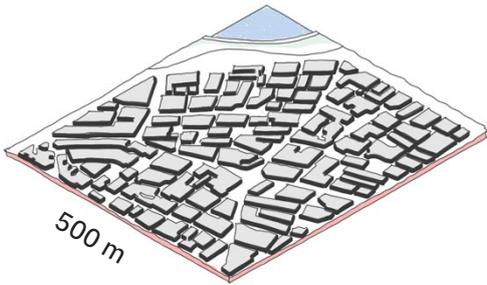


ENVI-met model analysed for Burj

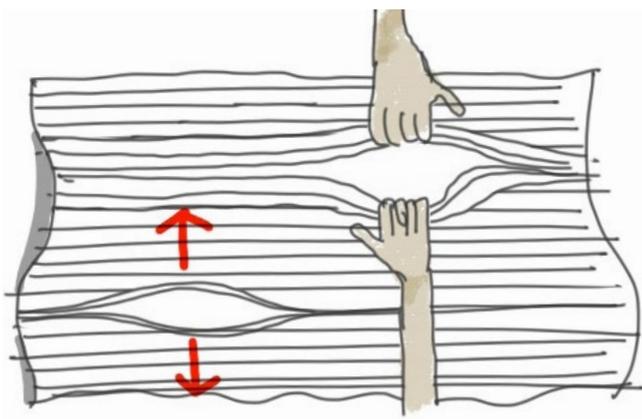


Opening up the dense urban fabric to allow for airflow, vegetation and other passive cooling measures.

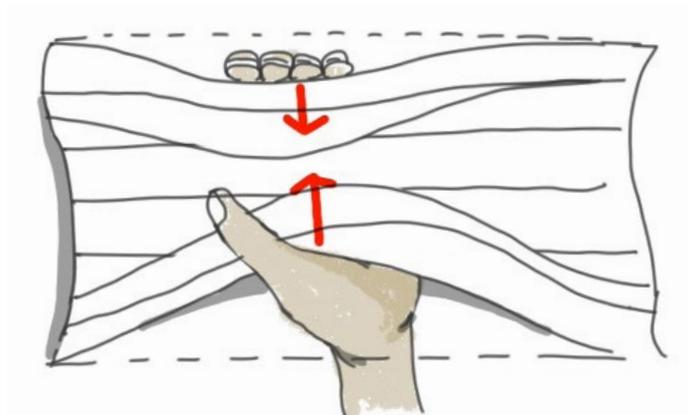
Creating a denser urban fabric at low level that responds to people and their comfort needs.



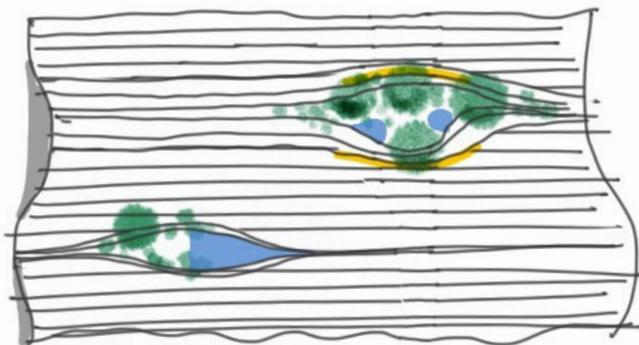
### Suggested interventions



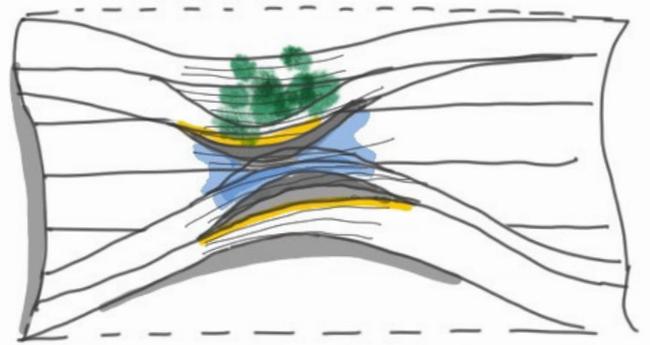
Opening up the dense urban fabric...



Creating a denser urban fabric at low level...



... to allow for airflow, vegetation and other passive cooling measures.



...that responds to people and their comfort needs.

## Analysis tools

# Components of outdoor comfort

Various factors define and determine outdoor comfort.

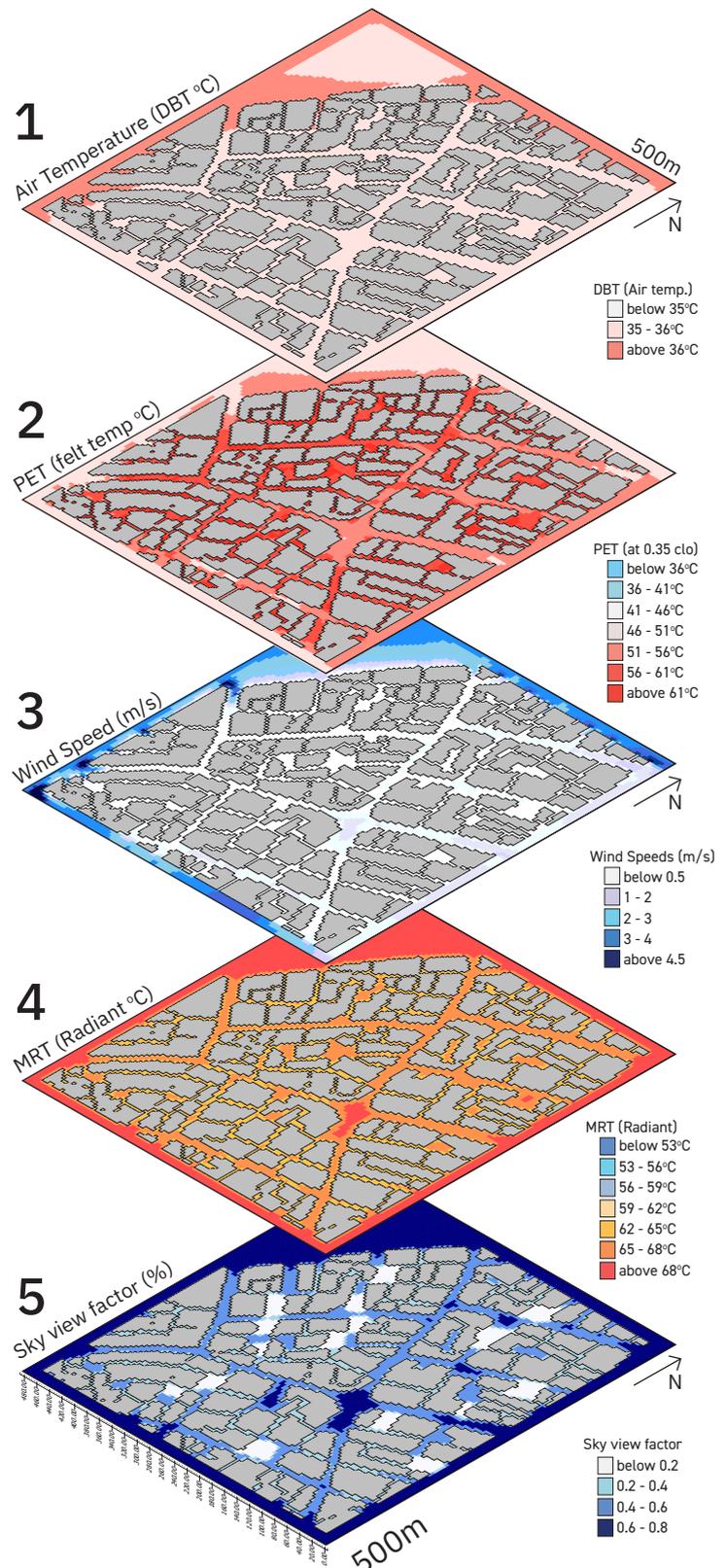
Often air temperature is understood to be the measure of comfort but as can be seen from layer 1 on the right, air temperature does not tend to vary significantly, mainly due to air movement.

Layer 2, representing Physiological Equivalent Temperature (PET) is a much more accurate measure of what a person would feel as it is a combined effect of air temperature, radiation from sun and heating/cooling of surrounding surfaces, clothing level, humidity and wind speed. PET, therefore, represents precisely the level of detail one needs to go into to understand 'feels like' conditions and also large variations that even small parts of an urban fabric can offer.

Aspects like Mean Radiant Temperature (MRT) and sky view factors are also used in the study to understand the heat gains (due to direct solar radiation) during the day and heat losses (to the far sky via longwave radiation losses) during night respectively.

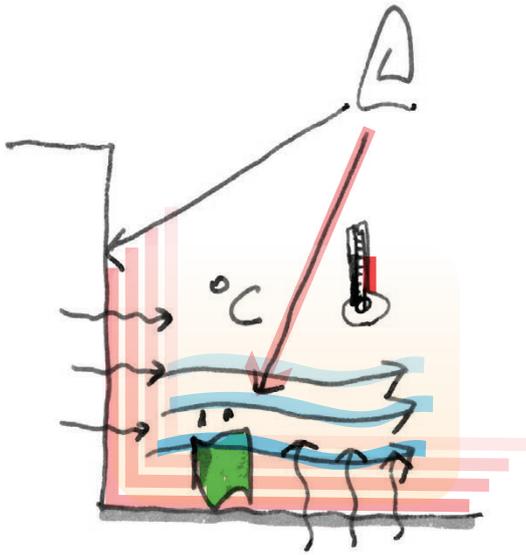
The analysis included in this study is based on the following assumptions:

- Day/time: 21<sup>st</sup> June at 12:00 (mid day)
- Max. Air Temp (at 16:00): 43°C
- Min. Air Temp (at 06:00): 27°C
- Humidity: 50%
- Wind Direction: NW
- Wind Speed: 5m/s
- Clothing level: 0.35 Clo = light summer clothing
- Analysis plane: 1m above ground

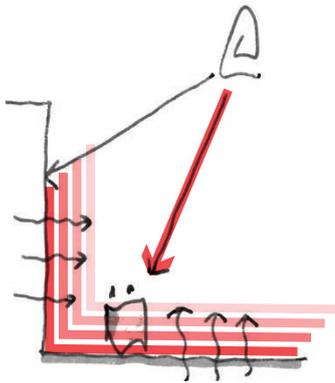


# PET - Physiological Equivalent Temperature

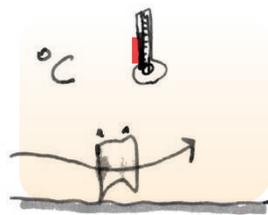
Images showing the factors considered during the calculation of the PET and why it is a more accurate measure of comfort rather than air / dry bulb temperature. Measured in degree C (°C), difference measured in Kelvin (K).



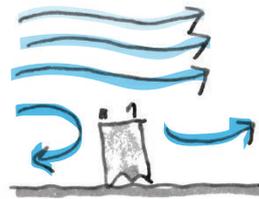
+ Metabolic rate  
+ Clothing level (clo value)



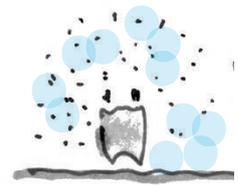
Effect of radiation (Mean Radiant Temp - MRT - °C)



Air Temperature (Dry Bulb - DBT - °C)



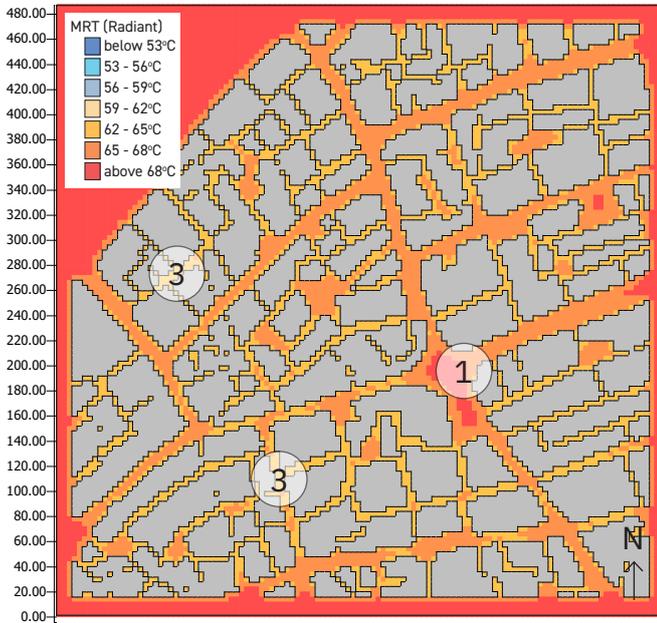
Air Movement (Wind Speed- m/s)



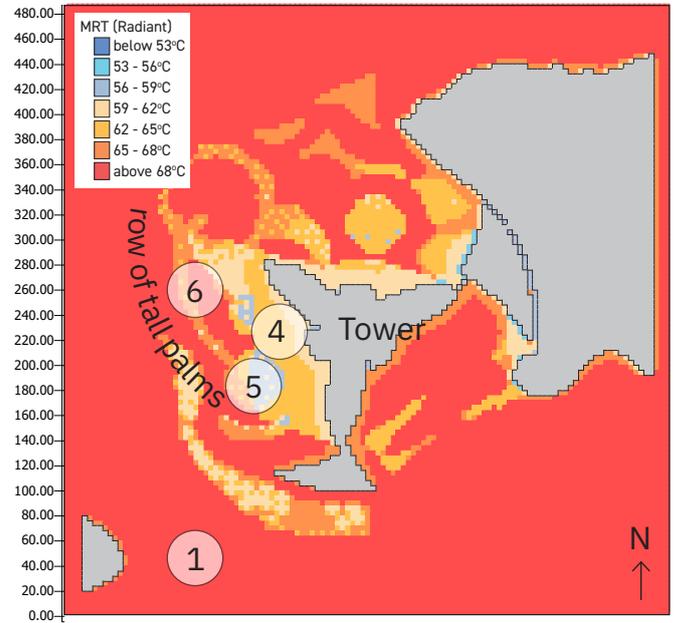
Humidity (Relative Humidity %)

# Current environmental performance

Deira at Daytime at 12:00, 21/06



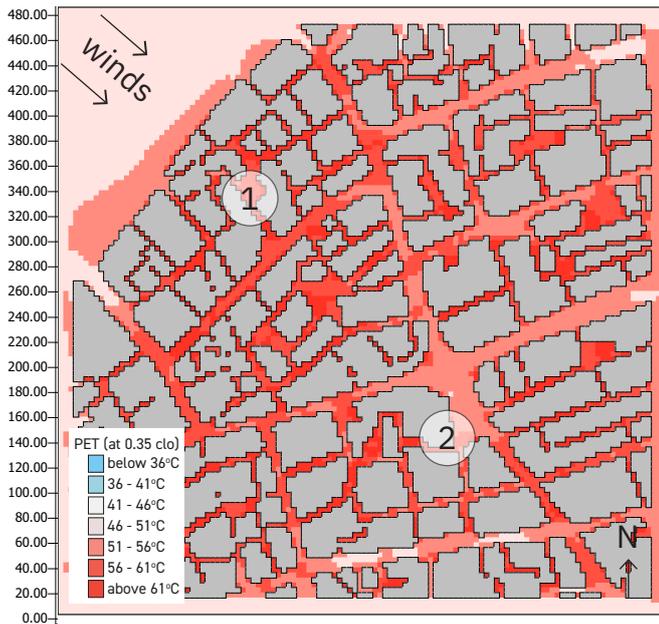
Burj at Daytime at 12:00, 21/06



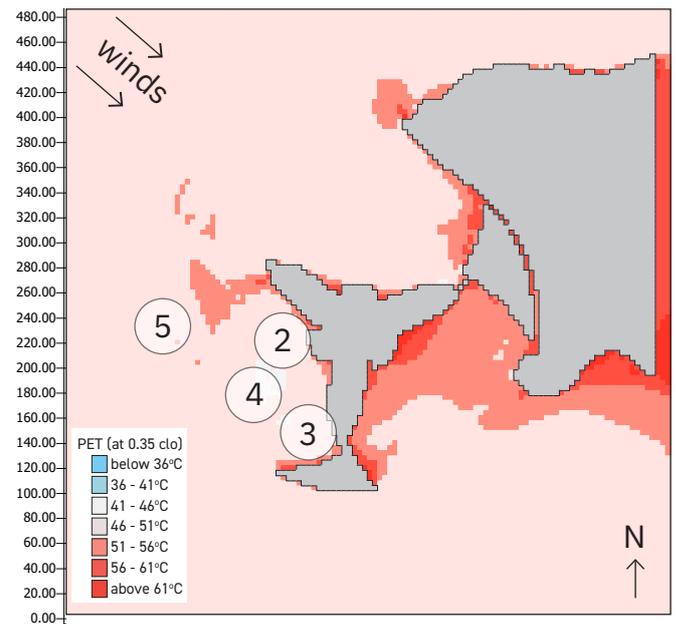
## Mean Radiant Temp. - MRT (°C)

1. The highest radiant temperatures are less prominent in Deira's dense urban fabric due to mutual shading from buildings.
2. Average MRT values over the 500x500m area for Deira are around 2-3K lower compared to Burj.
3. Narrow streets offer the most shaded routes.
4. The Burj being a tall building provides a large patch of shade on the ground.
5. The lowest temperatures are seen in areas with a group of trees/denser patches of vegetation.
6. Less dense vegetation in form of tall palms has a less significant impact on MRT.

## Deira at Daytime at 12:00, 21/06



## Burj at Daytime at 12:00, 21/06



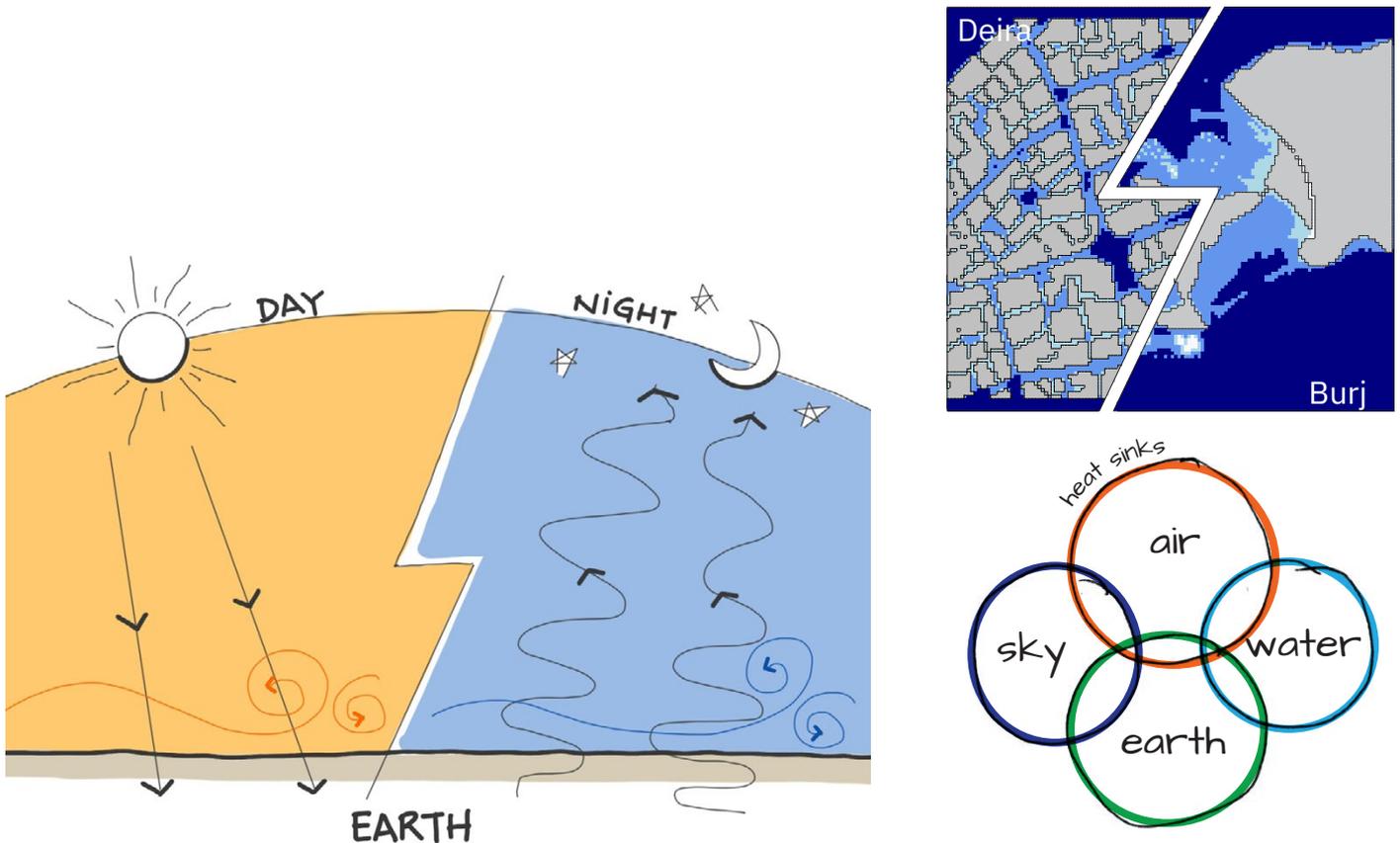
## Physiological Equivalent Temp. - PET (oC)

1. Narrow streets also limit air movement which is an important comfort factor for high temperature and low clothing (clo) values.
2. Impact of shading from the tower.
3. Impact of air movement, though both points are in shade (from sun).

4. Impact of dense vegetation cluster.
5. Lack of comfort provided by tall palm trees.

# Passive design strategies

On one hand Dubai experiences extremely high daytime air temperatures, while at night the heat ceases to offer relief from the daytime heat stress.



The night time cooling is a result of lower air temperatures, cooler sea breezes as well as longwave radiation losses through the clear night sky.

Larger open areas/spaces are easily able to lose heat to the night sky (one of the four natural heat sinks) due to their high sky view factor. For this very reason, the area around the Burj cools faster at night and is a popular and comfortable destination for people during the late evening/night hours.

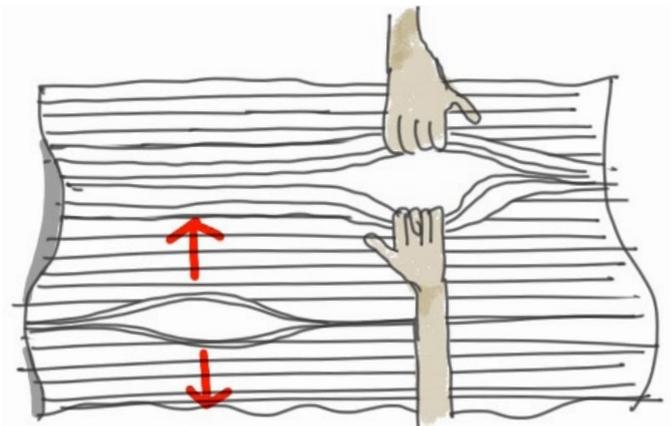
Most open spaces (streets and squares) in Deira have a sky view factor of 0.4 to 0.6. While the narrow streets offer shade during the day, their lower sky view factor

reduces the potential for radiative cooling at night.

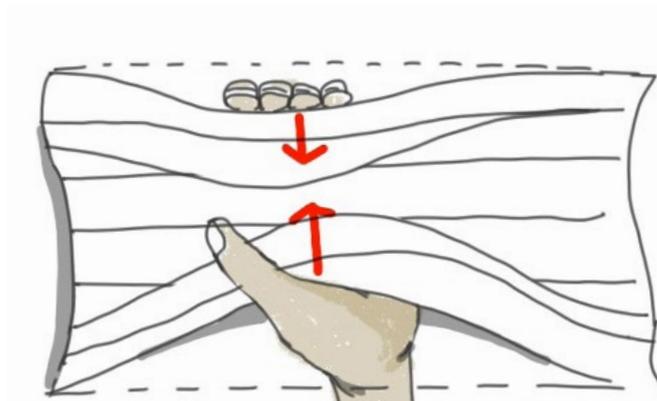
Hence Deira and Burj represent good examples of day and night time performance respectively.

An idea solution sits in between the two, loosening up of the Deira fabric and allowing provisions for landscaping and comfortable night-time spaces, while tightening of the Burj Fabric at pedestrian level creating a weather protected walking environment.

These interventions were tested using ENVI-met and are presented on the subsequent pages.

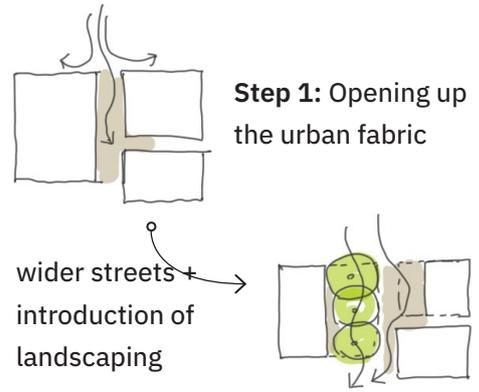
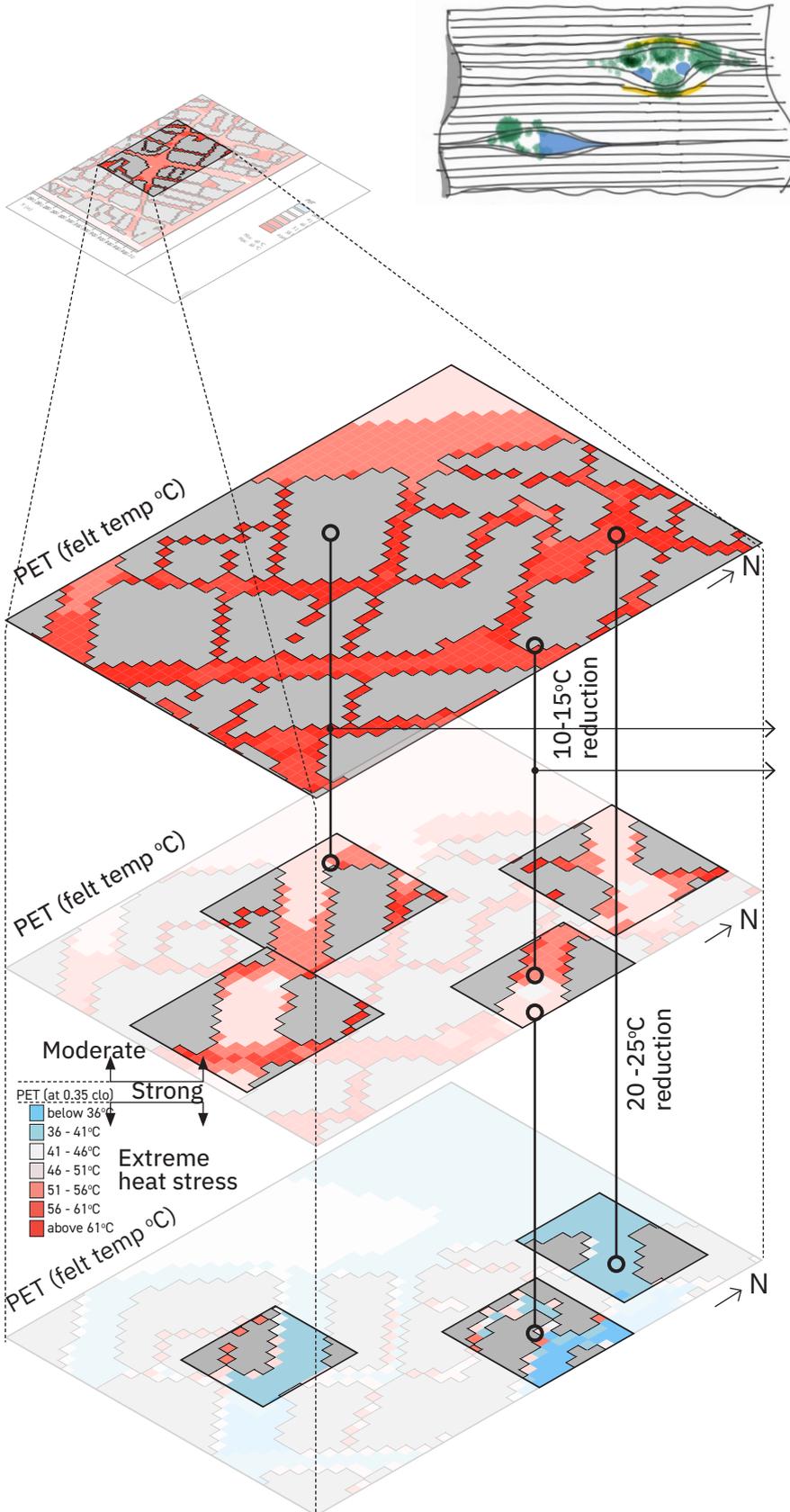


Opening Deira urban fabric to allow night time losses and cooling through radiation and convection



Tighter urban fabric for Burj to create shading and weather protection opportunities

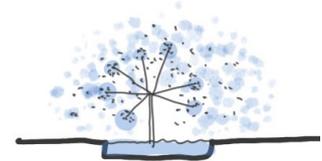
# Passive design strategies - Deira



A 10-15 degrees relief in PET (felt like temperatures) can be achieved by opening of the urban fabric and allowing space for both vegetation and airflow. The conditions are now comparable to the open environment experienced around the Burj.

PET heat stress levels reduced from Extreme to Strong.

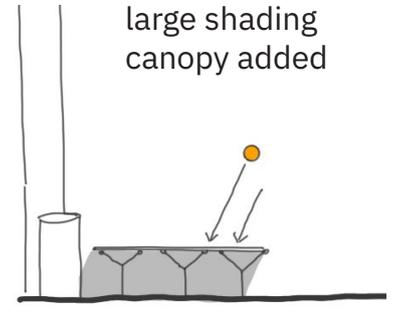
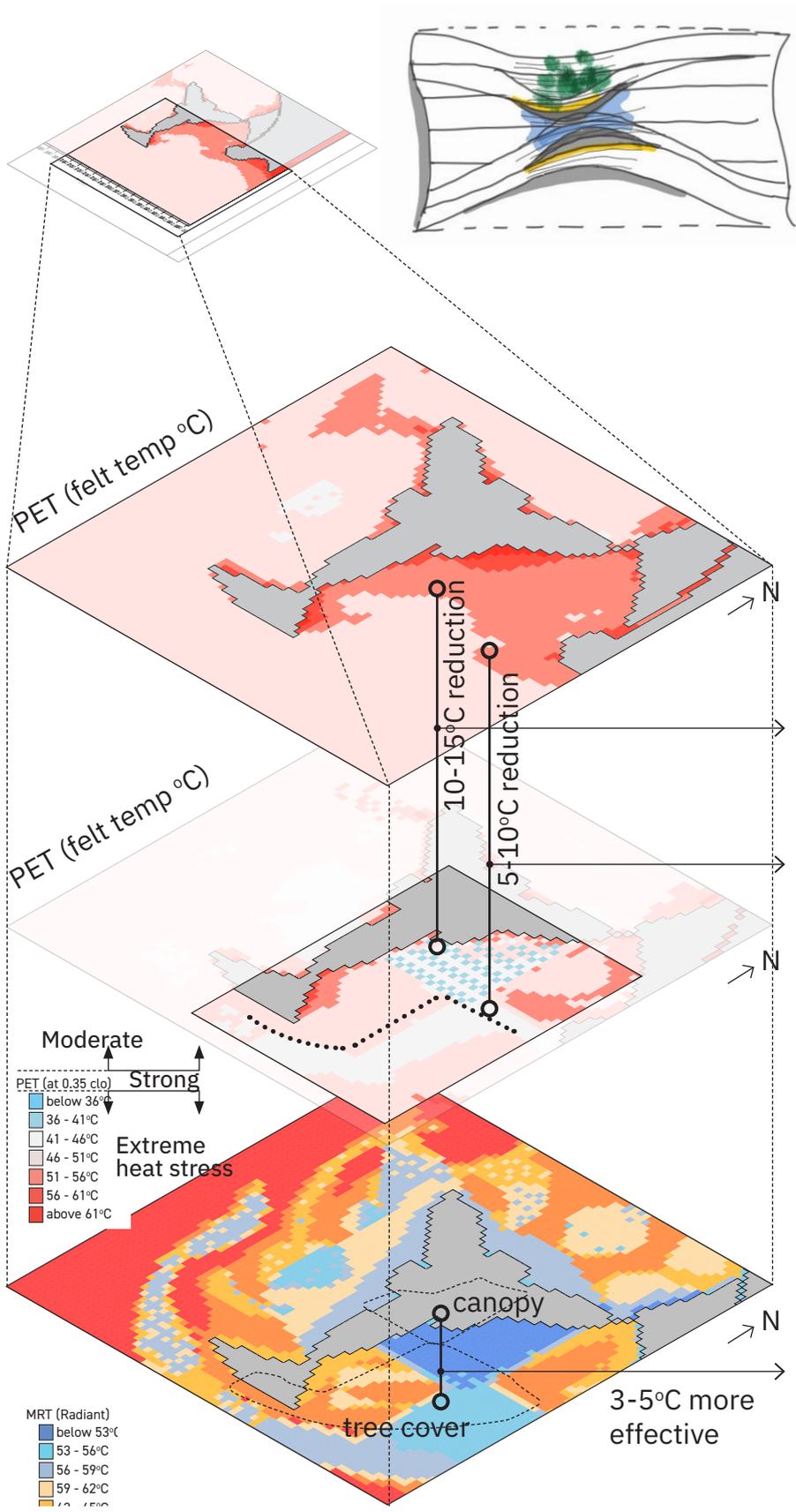
**Step 2: adding local water features**



Further from effects of increased air movement and vegetation, passive evaporative cooling from water sprays (in specific locations) was adopted as the next step to improve outdoor comfort.

The collective benefit from the interventions offered 20-25K improvement in PET conditions, reducing the heat stress scale from Extreme down to Moderate in specific areas.

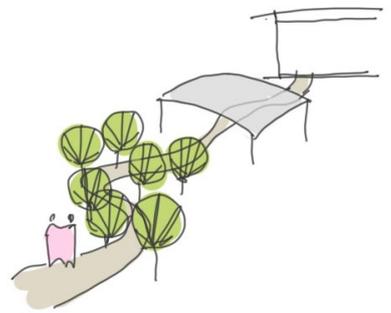
# Passive design strategies - Burj



large shading canopy added

With the introducing of shading in form of a large canopy, the area around the Burj saw a reduction of 15K in PET conditions.

Also, the row of trees located on the SE of the tower were extended to form a continuous shaded path, offering a 5-10K reduction in PET.



landscaping extended to form a continuous shaded route

Since native plants/tree species were adopted for creating the shaded path, a medium rather than a high density vegetation cover is considered.

It can be seen here that a solid canopy is more effective than landscaping alone in reducing both Mean Radiant and PET temperatures.

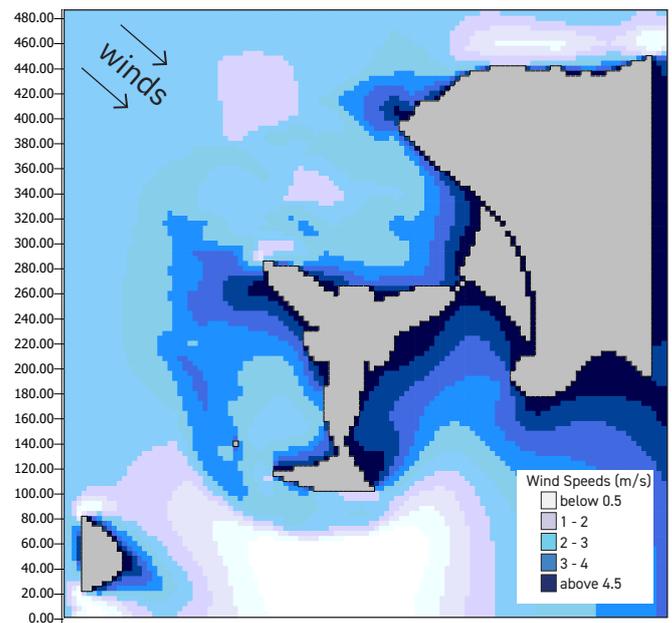
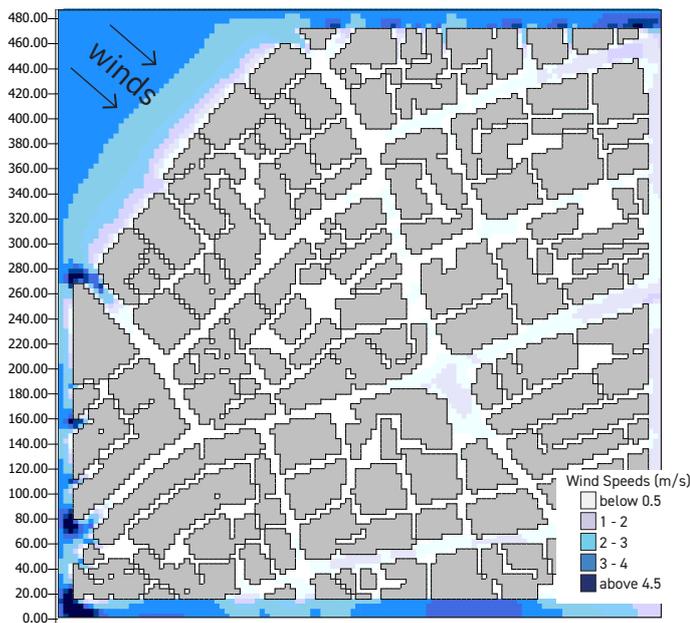
## Conclusion

# Dubai offers a huge diversity in its urban fabric and open spaces.

The combination of the extreme climatic conditions and the diversity of the urban fabric makes Dubai an ideal case to explore strategies for mitigating urban heat and improving pedestrian comfort.

The dense urban fabric of Deira showed significant improvements and responded well to the applied passive/low energy design strategies, reducing heat stress levels from Extreme to Moderate. This is largely due to a dense urban fabric and its ability to 'contain' the effect of the applied strategies.

The area next to the Burj, due to its shear scale, showed moderate improvements to the applied strategies but nonetheless offers a continuous scope for improvement in pedestrian comfort.



The wind plots for both Deira and Burj. Direction: NW, Speed: 5m/s