Understanding the local climate of Lagos

Numerical Simulations Methods for Sustainable Planning

Seminar report
at the TUM School of Engineering and Design
at the Technical University of Munich

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1. Introduction to the climate of Lagos

Lagos being situated along the Gulf of Guinea, Nigeria (See Figure 1). Lagos State has a tropical wet and dry climate that borders on a tropical monsoon climate. Lagos experiences two rainy seasons, with the heaviest rains falling from April to July and a weaker rainy season in October and November. There is a brief relatively dry spell in August and September and a longer dry season from December to March. The main dry season is accompanied by harmattan winds from the Sahara Desert, which between December and early February can be quite strong. [1]

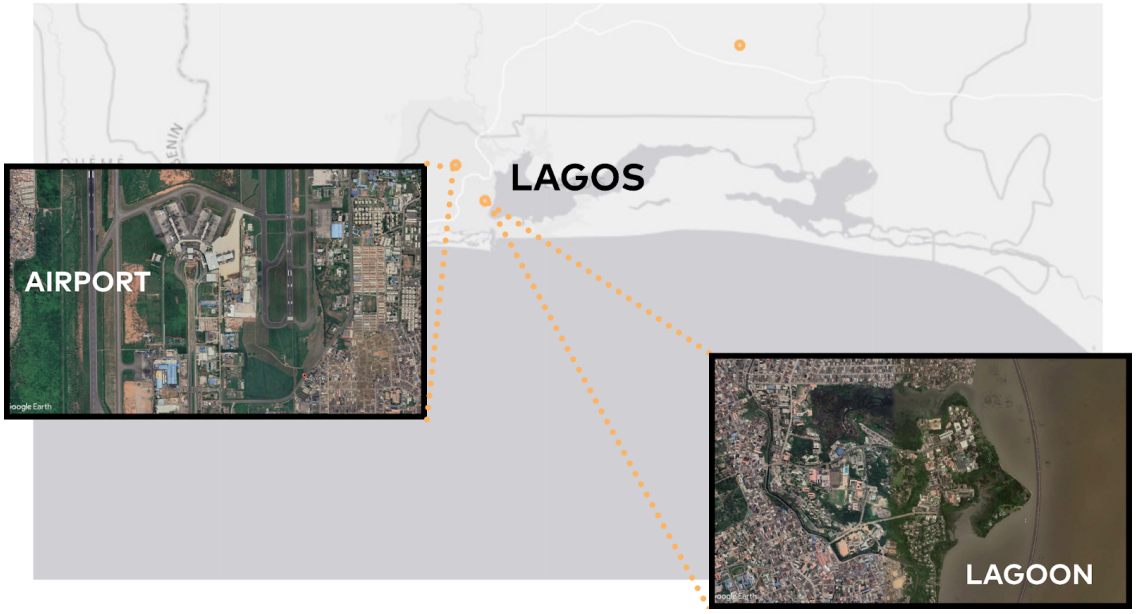


Fig. 1: The two existing weather files for Lagos

When comparing the two existing weather files, the one located at Lagos airport has a higher temperature amplitude and hence can be seen as the worst scenario (See. Fig. 2-3).

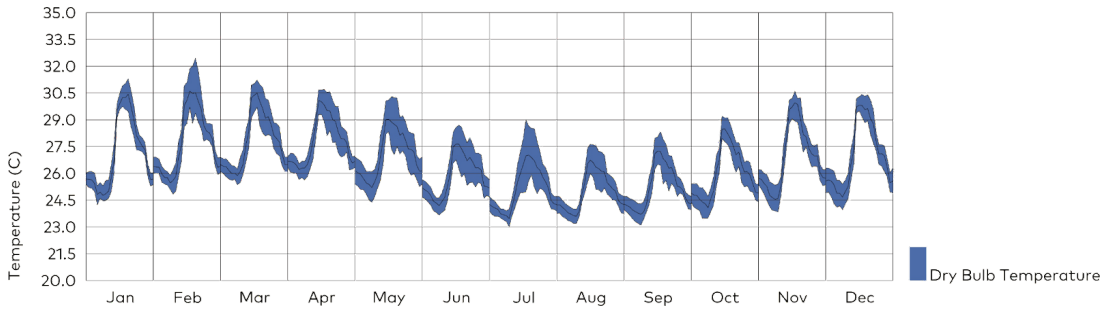


Fig. 2: Dry Bulb Temperature Lagos, Airport

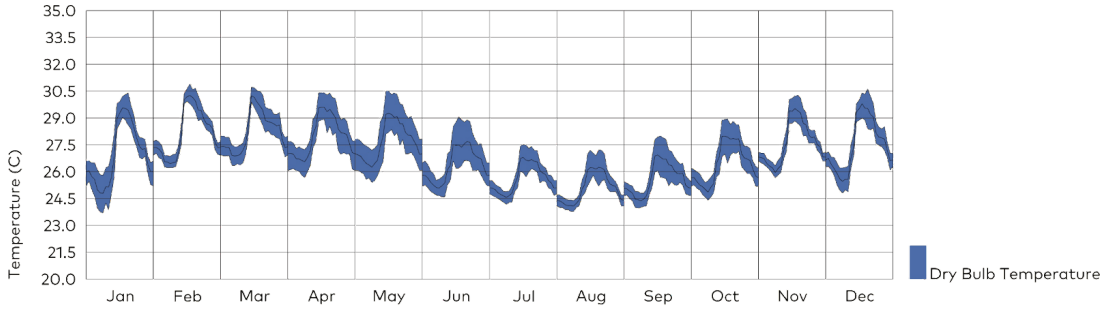


Fig. 3: Dry Bulb Temperature Lagos, Lagoon

This can be seen in February when it climbs above 32 °C, as well as in July when it drops to 23 °C. Also taking into account the better comparability with Munich's weather file, which is also located at the airport, the decision is in favor of the Lagos Airport. Therefore, it will be the foundation for further investigations.

2. Climate comparison with Munich

When comparing the climate of Lagos with Munich, significant differences can be seen (See. Table 1).

Climate	**Sun angles**	**Horizontal solar radiation (dir. + diff.)**	**Air temp. (seasonal)**	**Air temp. (daily)**	**Relative humidity**	**Avg wind speed (10m) + prevailing -direction**
Lagos	Very high (up to 87°)	Much higher (1695 kWh/m²a)	Relatively constant (23-33 °C)	Smaller amplitudes (~6 K in Jan.)	Higher (driest month on average in January)	3.1 m/s, south-west
Munich	Flat in winter (20°), higher in summer (65°)	One of the highest n Germany (1123 kWh/m²a)	Higher fluctuation (-13-29 °C)	Higher amplitudes (~11 K in May)	Lower (driest month on average in July)	5.5 m/s, west

Table 1: Climate Comparison with Munich

This wealth of information can be visualized with sun paths (See Fig. 4). While Lagos with its almost perpendicular sun angles is characterized by air temperatures constantly above 23 °C, much lower values down to -13 °C can be seen especially during Munich's winter months with very low sun angles.

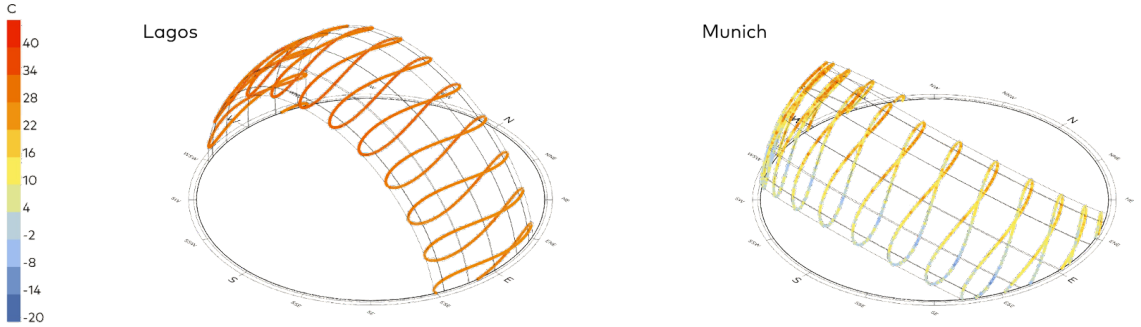


Fig. 4: Sun Path Comparison

With Lagos being located in the southern hemisphere, the lowest temperatures occur in July. Overall, Lagos' annual temperature amplitude of 10 K is significantly lower compared to Munich's with 42 K (See Fig. 5-6). The reasons are discussed in more detail in chapter 3, "Climate factors specific for Lagos". On closer inspection, the maximum daily average temperature changes in Lagos (6 K in January) are lower than in Munich (11 K in May).

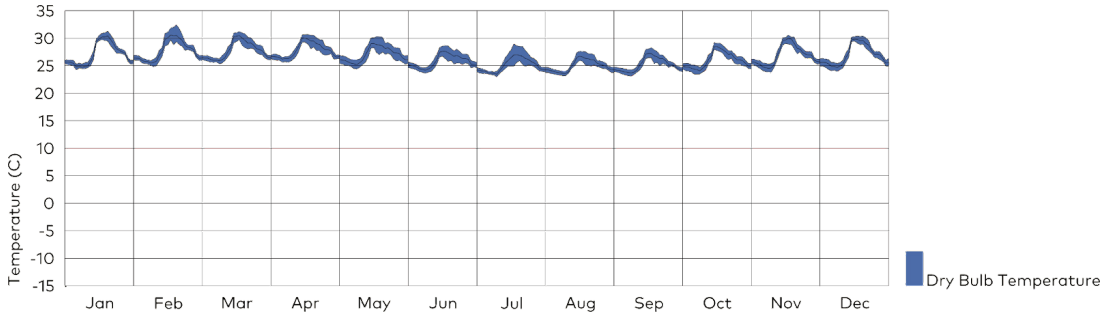


Fig. 5: Dry Bulb Temperature Lagos

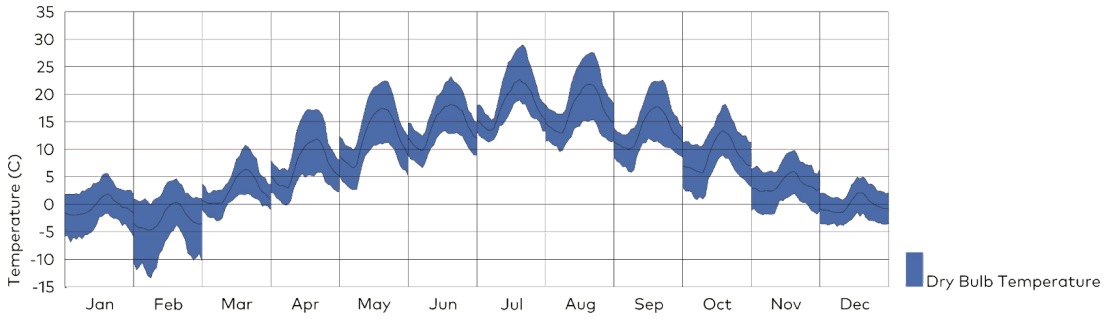


Fig. 6: Dry Bulb Temperature Munich

The high sun angles of Lagos also impact the solar radiation gains. These are split up into direct and diffuse radiation on a horizontal surface (See Fig. 7). Here, a strong correlation of high (direct) radiation with the hottest months can be seen. In total, Lagos with 1,695 kWh/m²a has approximately 1.5 times the global radiation of Munich with 1,123 kWh/m².

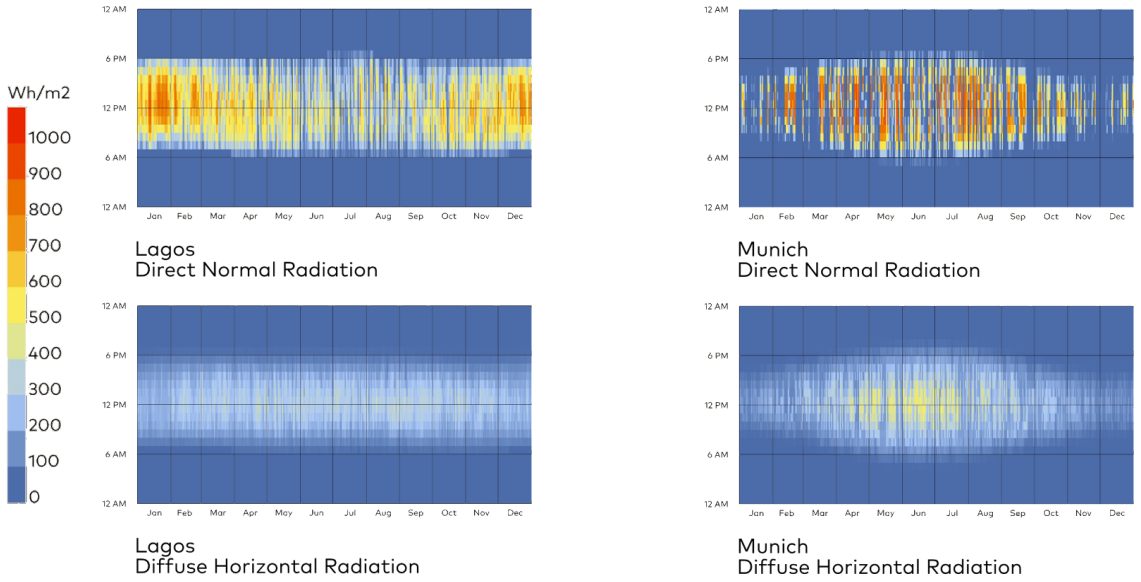


Fig. 7: Radiation (direct + diffuse) Comparison

Ultimately, two wind roses are provided (See Fig. 8). While in Lagos the prevailing wind direction is south-west, it shifts more to the west in Munich.

Fig. 8: Wind Rose Comparison

Overall, Munich has the highest average wind speed around 5.5 m/s. Lagos only reaches 3.1 m/s. Consequences for thermal comfort will be explained in chapter 4, “Challenges for human comfort”.

3. Climate factors specific for Lagos

Lagos, positioned near the equator at a latitude of 6°35'N and a longitude of 3°20'E, experiences a nearly uniform annual sun path, resulting in consistently high temperatures throughout the year. Therefore it falls within the tropical savanna climate classification according to the Köppen climate classification. Also, Lagos is aligned with the southern hemisphere's seasons. Its proximity to the Atlantic Ocean plays a crucial role in shaping its wet and (slightly) dry seasons, moderating temperature fluctuations, and contributing to elevated humidity levels (See Fig. 10). The low altitude of Lagos, approximately 39 meters, further contributes to its warmer climate compared to cities at higher elevations. [2]

Fig. 9: Makoko, an informal settlement of Lagos

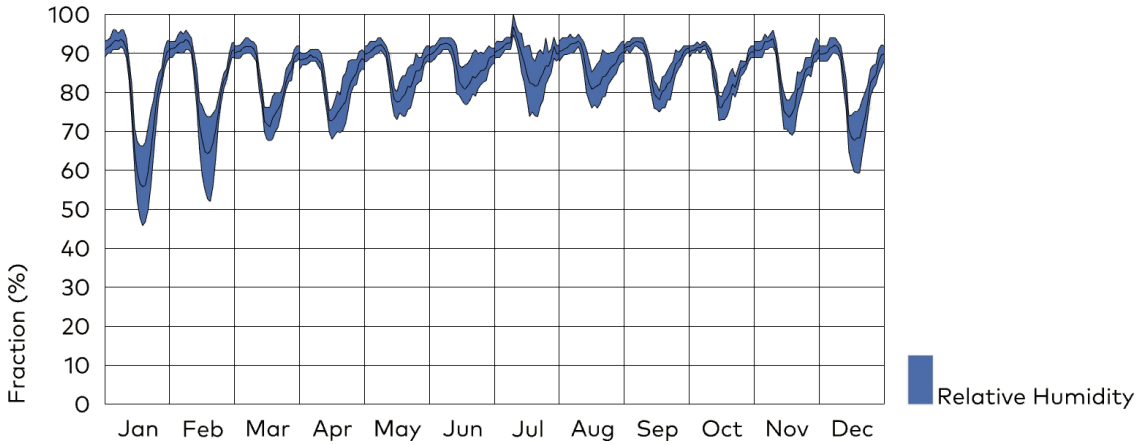


Fig. 10: Relative Humidity Lagos

Climate change affects Lagos by rising sea levels, threatening coastal areas with erosion and flooding (See Fig. 9). Altered precipitation patterns and temperature increases could exacerbate water scarcity, impacting agriculture, infrastructure, and public health. Adaptation strategies and global efforts are crucial to mitigate these risks and enhance the city's resilience to the complex challenges posed by climate change. [3]

4. Challenges for human comfort

The biggest challenges for human comfort resulting from Lagos' specific climate can be assessed by the so-called Universal Thermal Climate Index, UTCI (See Fig. 10). It describes the physiological comfort under certain weather conditions. These are air temperature, relative humidity (both at 2m), wind speed (at 10m) and mean radiant temperature [4]. To begin with, the weather of Lagos under standard conditions is perceived as comfortable for about a quarter of the year (2129 h).

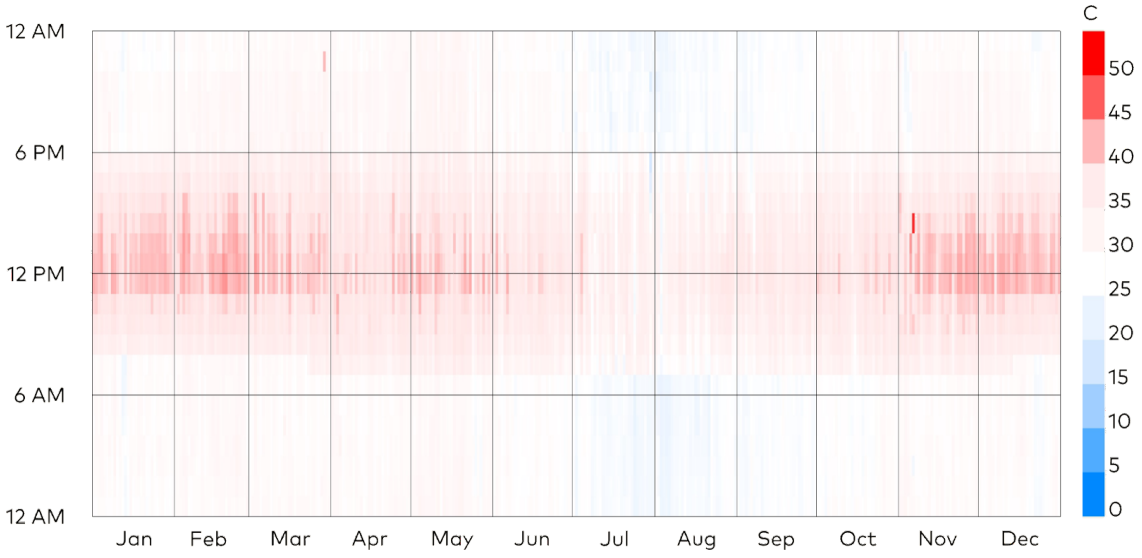


Fig. 11: UTCI Lagos

As a response to the predominating high sun angles and high direct radiation values, the latter are set to 0 to see their effect on the UTCI (See Fig. 11). Thereby, the heat stress around midday significantly decreases, resulting in a gain of over 100 comfortable hours (2231 h).

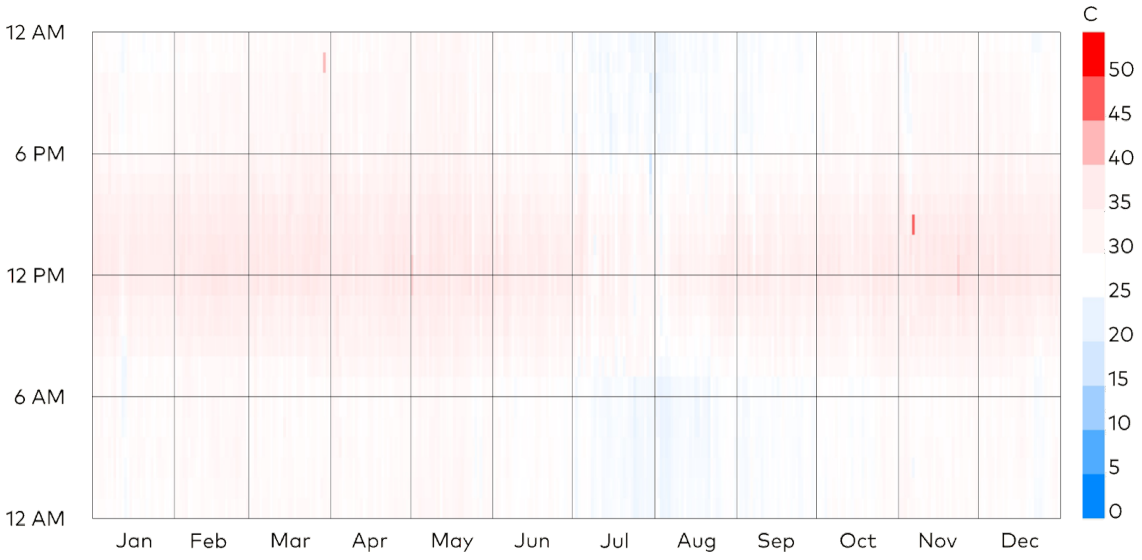


Fig. 12: UTCI Lagos, no direct Radiation

As a last step, the wind speed is set to 0 (See Fig. 12). In contrast to the first measure, extra heat stress is added. More precisely, only 2% of the annual comfortable hours remain (175 h). With the given information, low-tech building design strategies regarding the local climate of Lagos will be deepened in the last chapter 5, “Climate responsive design measures”.

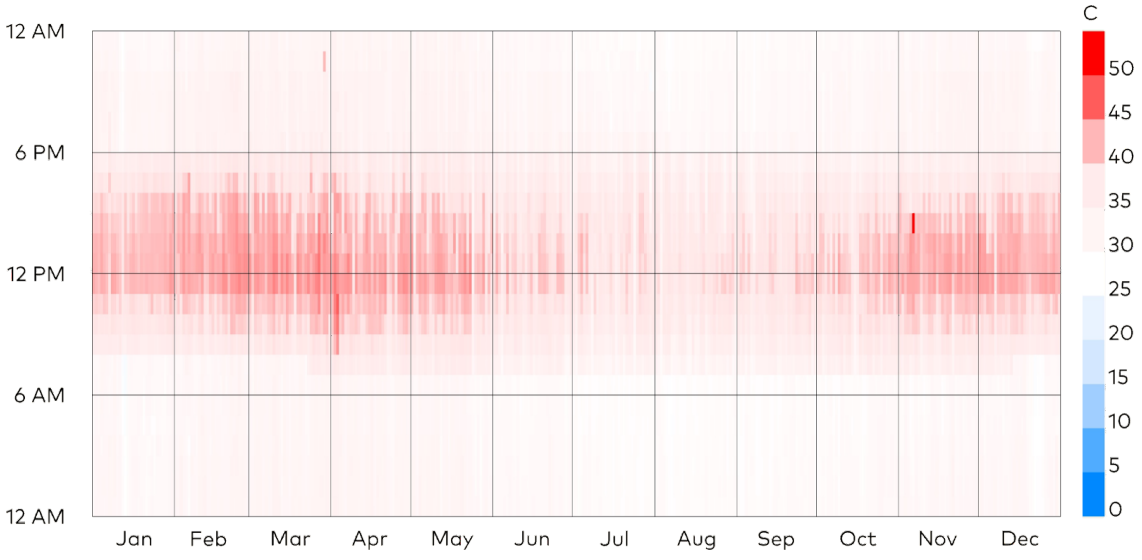


Fig. 13: UTCI Lagos, no Wind

5. Climate responsive design measures

According to the given climatic conditions and challenges of the climate according to human comfort, adapting sustainable and climate responsive design strategies are essential for energy efficiency and human comfort.

Thermal Comfort: From the climate study it is understood that Lagos has a warmer climate and different measures can be adapted to overcome this issue. Some solutions for this are as follows: optimizing building orientation to minimize direct sun exposure and using shading devices to protect against intense sunlight, particularly on the east and west sides. Moreover, incorporating materials with high thermal mass and insulating walls and ceilings can further contribute to a more stable indoor temperature and enhance overall energy efficiency. [5]

Wind Comfort: It is important for Lagos primarily due to the city's warm and humid tropical climate. Sufficient wind comfort provides thermal relief, allowing residents to feel more comfortable in warm conditions by promoting natural ventilation and cooling. Aligning buildings in a way that captures the prevailing west-winds and promotes cross-ventilation. Designing the building heights to avoid obstructing the natural path of the wind, also tapering or shaping the building to reduce the wind resistance and to enhance airflow around and through the building.

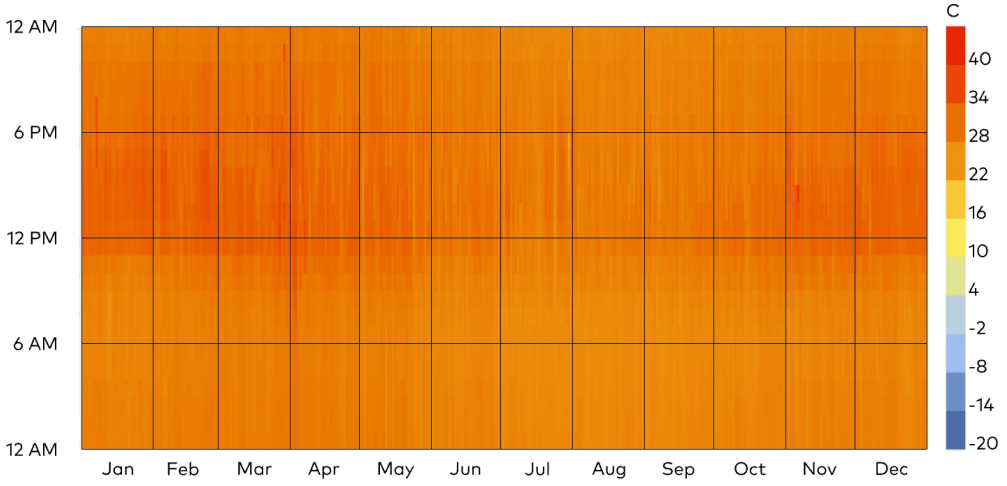
Humidity Comfort: Maintaining optimal humidity implies the well-being of residents, prevents discomfort, health issues, and contributes to overall indoor air quality in homes, workplaces, and public spaces. Natural ventilation with cross-ventilation strategies, utilizing breathable and moisture-resistant materials, and integrating green spaces for moisture regulation are some good engineering techniques. Designing proper drainage systems and using moisture resistant furniture should be implemented to prevent moisture issues and ensure sustained humidity comfort.

UTCI: To sum up, including the above-mentioned measures like natural ventilation and ensuring cross ventilation, shading of the windows, orienting the buildings and the windows in the optimal way and humid and wind responsive buildings can provide better comfort for humans.

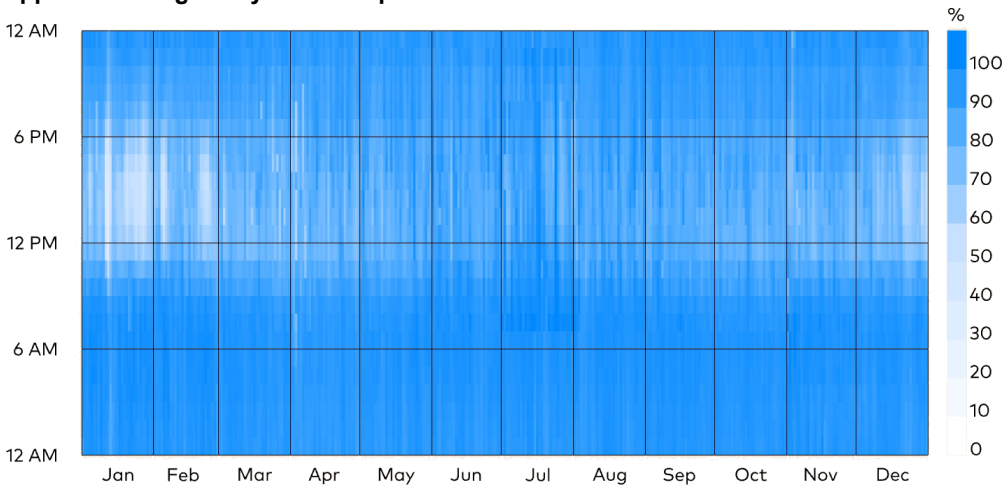
6. Conclusion

Lagos has a tropical climate which is warm and humid. It is a challenge to achieve human comfort considering the existing climatic conditions. Nonetheless, the climate analysis done with Ladybug Tools and the interpretation of the generated graphs are a big support in early design stages. Ultimately, climate-responsive design is the path to sustainable construction, energy efficiency, and human comfort.

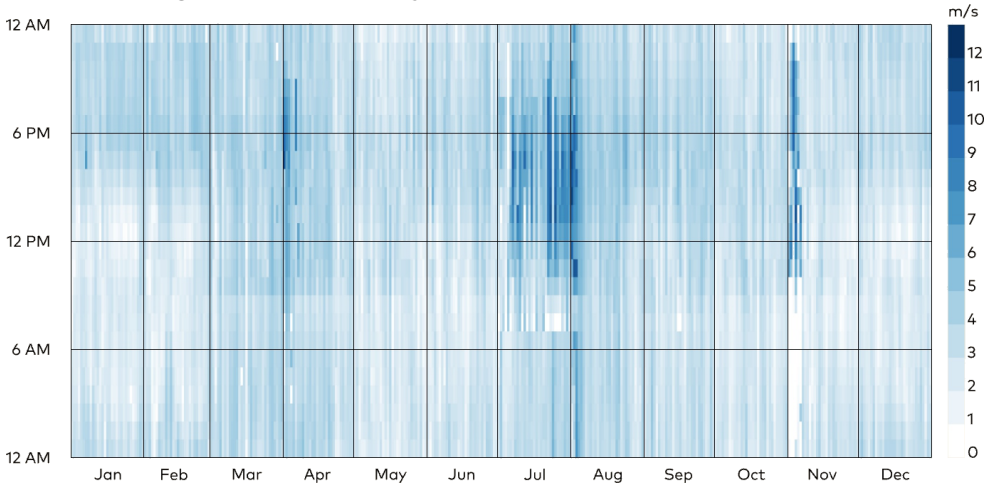
1. Appendix



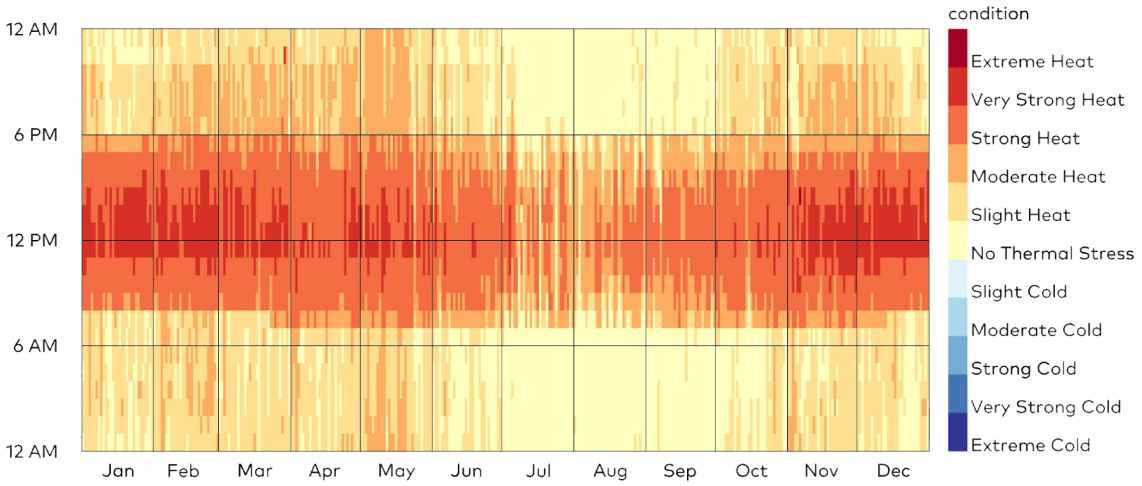
Appendix 1: Lagos Dry Bulb Temperature



Appendix 2: Lagos Relative Humidity



Appendix 3: Lagos Wind Speed



Appendix 4: Lagos Thermal Condition (Eleven Point)

2. Bibliography

List of literature

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