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# Thermal environment

The users' experience of outdoor spaces in an urban setting is not only influenced by wind. To maximise annual usage of outdoor urban spaces and support the effective design of climate-resilient cities, a positive thermal experience of the outdoors is essential. Wind, though, can significantly change the thermal environment. The first direct mechanism is that it moves upstream air over a person with a slightly modified air temperature as it passes over nearby surfaces. The second indirect mechanism is that it changes the temperature of a surface as the air, if at a different temperature, passes over it. This modifies the (mean) radiant temperature of the person in sight of that surface. Similar to wind, sunlight directly falling or reflecting onto a person at a point in time or surface-absorbed solar heat reradiating onto a person several hours later can have a significant influence on their thermal experience.

As a person stands on the ground, the ground surface temperature nearby has a significant influence on the overall longwave radiant heat exchange that the person experiences with all surrounding surfaces and the sky. Well-designed 'cool surfaces', such as cool pavements [1] / urban albedo environments [2] can, therefore, generate some protection from overheating risk. Blue-green infrastructure, though, can also act as a temperature (air and radiant) moderator throughout the year [3]. We can therefore design for urban cool islands as well as trying to understand the impact of urban heat island effects [4].

In summary, some of the many factors that play a vital role in defining the outdoor thermal comfort within an urban environment include:

- geometry and materiality of the surrounding surfaces and buildings
- local air temperature, relatively humidity and air speed
- mean radiant temperature including the effect of shading from the sun combined with the temperature of the surrounding surfaces and sky
- and type of clothing and level of activity of the users themselves.

In design terms, it is a complex exercise to understand the impact of surface materiality and other design elements, such as evapotranspiration from urban vegetation systems, on the thermal environment. Computational modelling, such as computational fluid dynamics (CFD) possibly combined with light ray tracing and/or dynamic thermal models, can help explore to some degree the impact of different design options, including how the outdoor environment impacts the indoor environment. Some significant challenges still exist, including:

- Understanding the effect of different time constants within any given urban morphology and surface materiality. For example, solar exposure for a surface can change in minutes whereas the ground can reradiate heat over the course of hours.
- Although sunlight and wind are primary drivers for evaporation from urban vegetation systems [5], the level of water stress will also lead to different thermal performances at different times of day and season.
- Understanding the impact of different scales. For example, designing for street-scale impacts on building energy demand versus typical individual building-scale assessments [6].
- Urban heat island (UHI) intensity (the difference between the rural air temperature and that in the city centre) can be as large as 10K for the major cities such as London and some simple empirical models are under development to support our understand of it on the built environment [7]. UHI application and understanding of it in building design, though, is still extremely limited. This uncertainty extends to seasonal variations, representative 'rural' conditions acting as a baseline for intensity

calculations, use in building simulation models and understanding the application of many types of temperature sensors for validation purposes. For example, land and sea surface temperature data taken from satellites could vary from local air temperatures by 20K or more and high resolution, simultaneous measurements may not be possible for all measurement types, especially if the impacts of building facades on the thermal environment are to be taken into account.

- Wind chill, the combined influence of colder air temperatures with higher wind speeds, is often reported as a 'feels like' temperature. In many types of spaces it could become critically important to design for / moderate against adverse levels as this could negatively impact reputation and limit commercial success under certain climate conditions.
- There are many outdoor thermal comfort indices, such as UTCI and SET. Greater clarity is needed on their usage for performance-driven design and how buildings and building sites might influence heat stress, at the extreme, as well as thermal comfort. Although the thermal comfort guidelines published by the City of London Corporation [8] represent a step in the right direction, the complexity and the interplay of the different computational models that are required to holistically assess the microclimate conditions within the urban morphology of a city are such that this process has yet to become common practice in industry. The approach also oversimplifies the effect of varying ambient surface temperatures by assuming mean radiant temperature being equal to air temperature. It can therefore only be considered a compliance and not a performance method, designed to be relatively easy to apply and used to improve previous low-quality environments across the board.

**References**

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