



Optimization of Heat Warning Thresholds for Improved Risk Communication

Current Heat Warning Thresholds

T _{max} 30-32 °C or (T _{max} > 32 °C and T _{mean} (D-1) ≤ 23°C)	T _{max} 33-35 °C and T _{mean} (D-1) > 23°C	T _{max} > 35 °C and T _{mean} (D-1) > 23°C

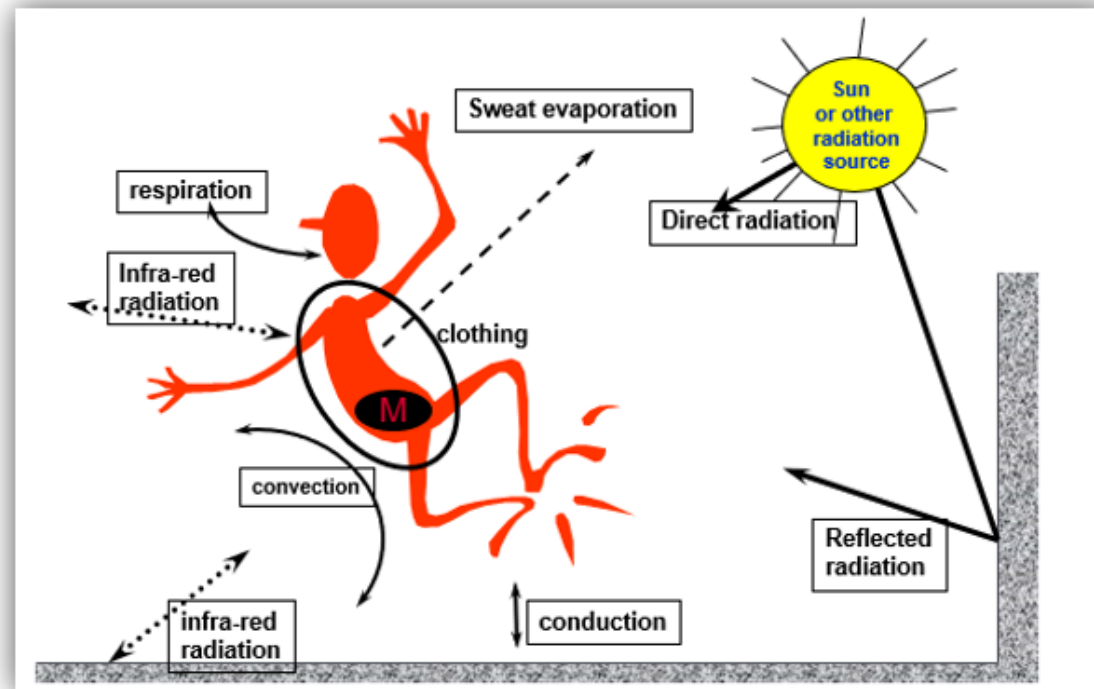
Major shortcoming:

Air temperature alone is an insufficient indicator of the actual thermal stress experienced by the human body !

Human Heat Budget (Havenith 2001)

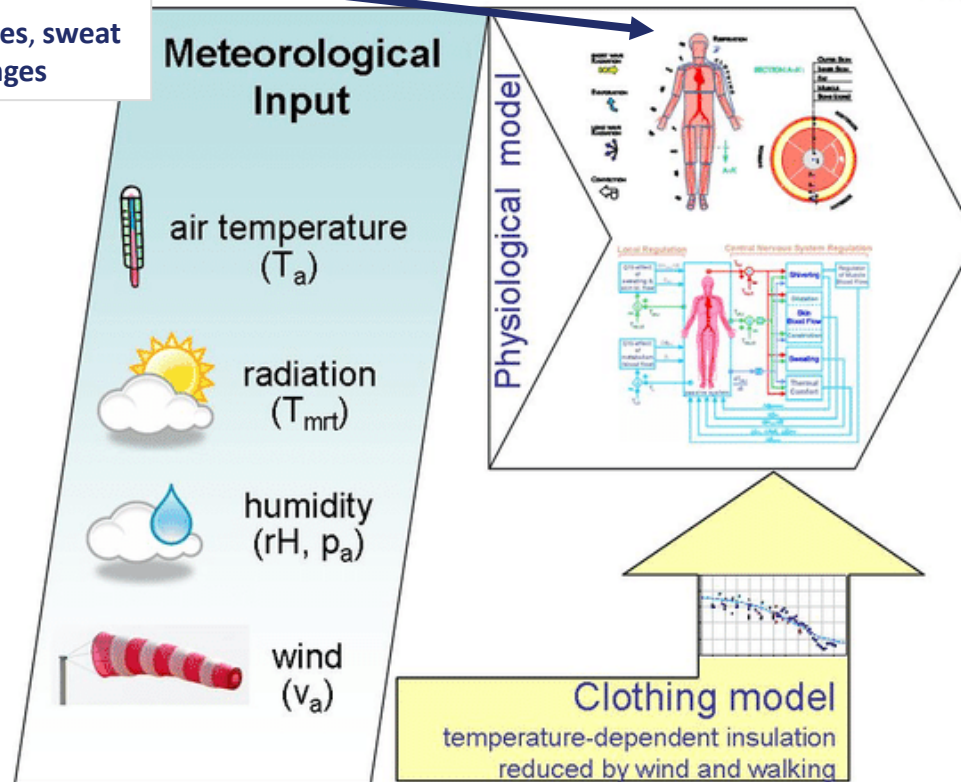
Thermal stress is influenced by multiple environmental factors.

In addition to air temperature, **humidity, solar and longwave radiation, and wind speed** significantly affect how heat is experienced.

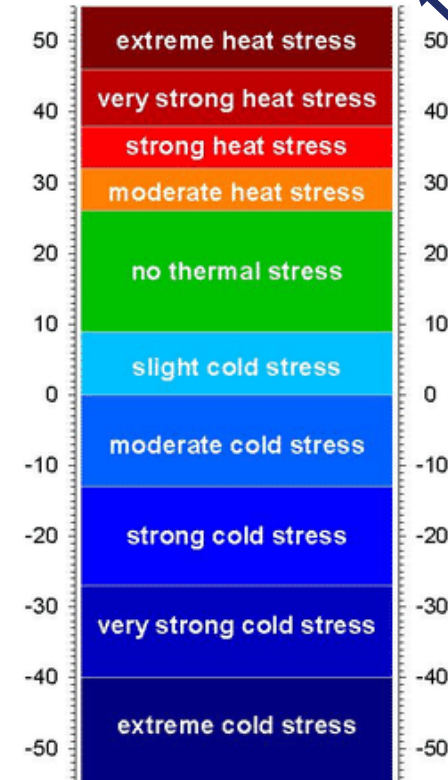


Universal Thermal Climate Index

- **12 body segments** (e.g., head, torso, limbs) modeled with **187 tissue nodes**
- Simulates **heat transfer** within and across tissues (skin, fat, muscle, organs)
- Predicts **core and skin temperatures, sweat rate, shivering, and blood flow changes**



UTCI Equivalent Temperature ($^{\circ}C$)



- **Direction-independent** (not affected by wind direction)
- **Globally applicable** across climates and seasons
- **More accurate** than simple indices like Heat Index or Wind Chill

$$UTCI(T, MRT, v, p) = T + \sum_i \sum_j \sum_k \sum_l c_{ijkl} T^i MRT^j v^k p^l$$



UTCI Statistics (2001-2025)

Di Napoli et al. (2018)¹ and Urban et al. (2021)² highlight UTCI's **strong correlation with heat-related mortality**, supporting its use in **early warning systems** and **public health planning**.

→ ERA5 reanalysis by ECMWF provides **hourly climate data** at 0.25° x 0.25° resolution

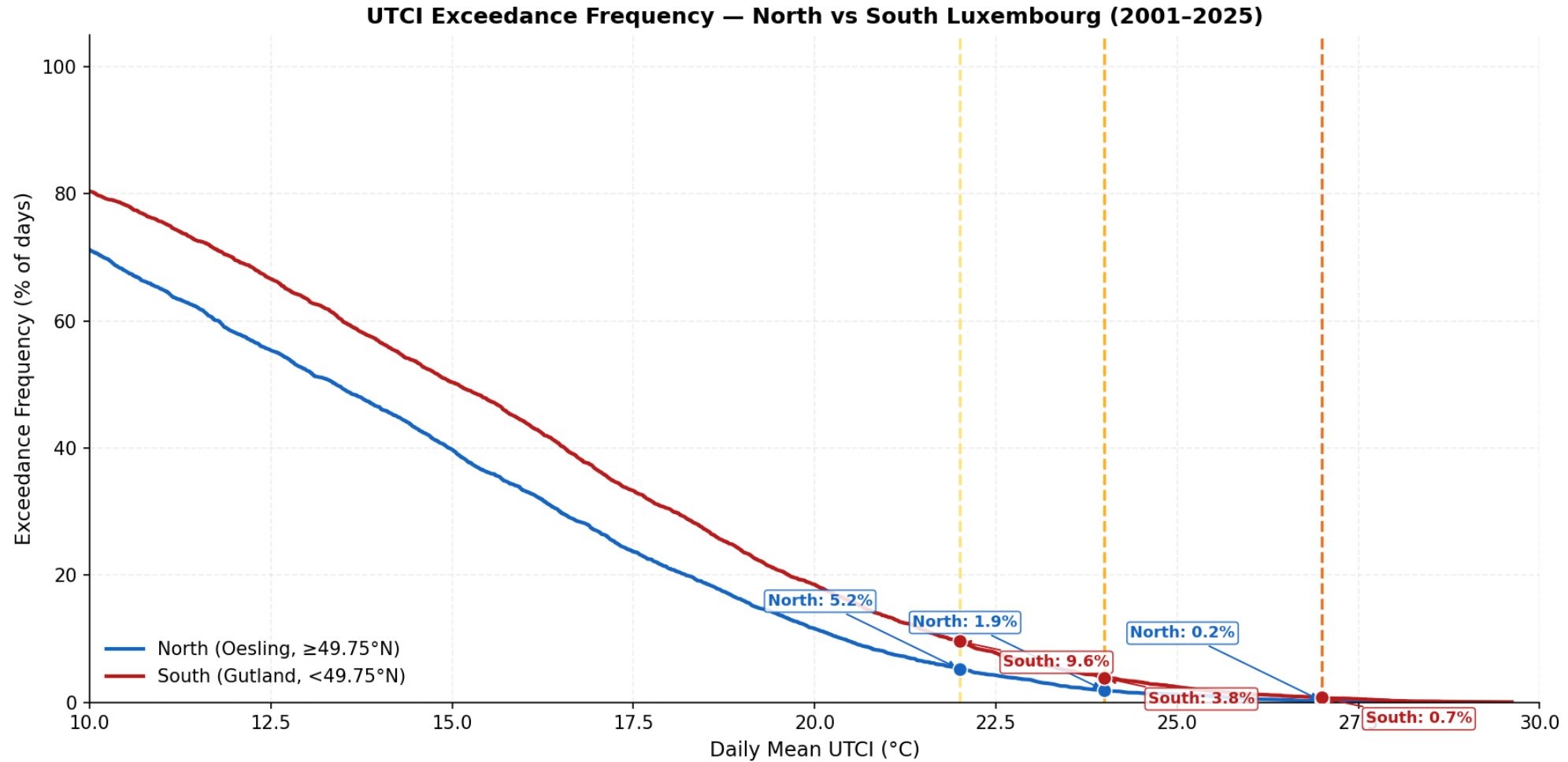
→ Period: **May to September**

¹ <https://doi.org/10.1007/s00484-018-1518-2>

² <https://doi.org/10.1016/j.envres.2021.111227>

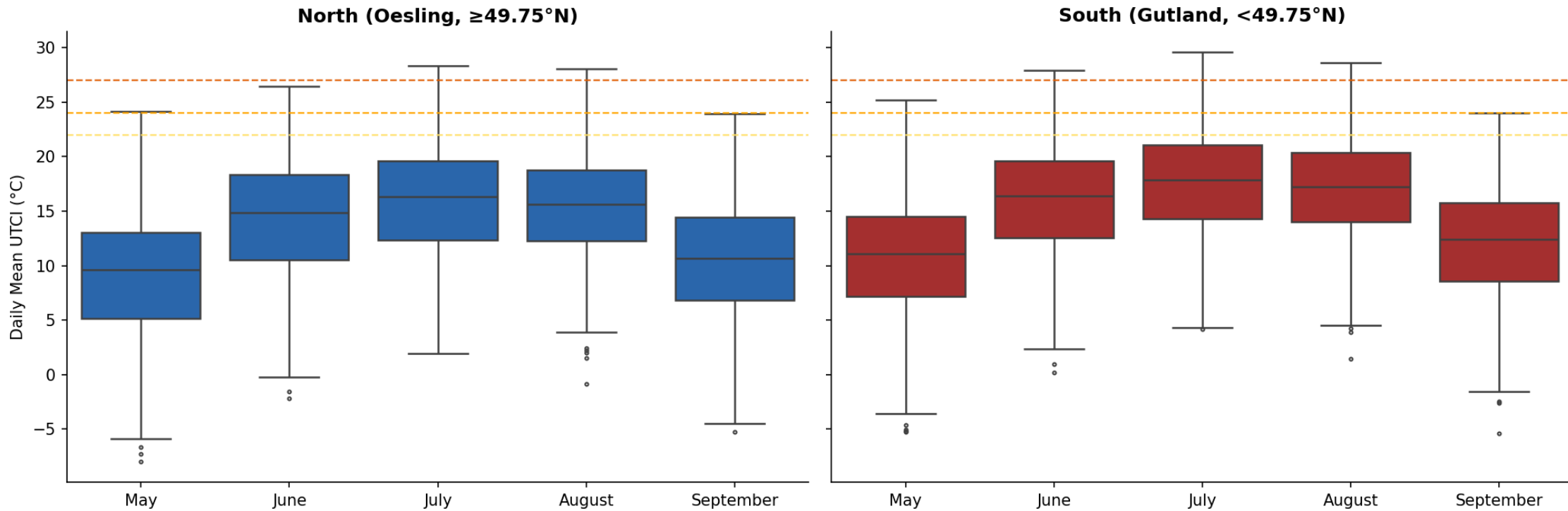


UTCI Statistics (2001-2025)



UTCI Statistics (2001-2025)

UTCI Distribution by Month — North vs South (2001-2025)



Heat Warning Guidance Matrix

Number of consecutive days above threshold

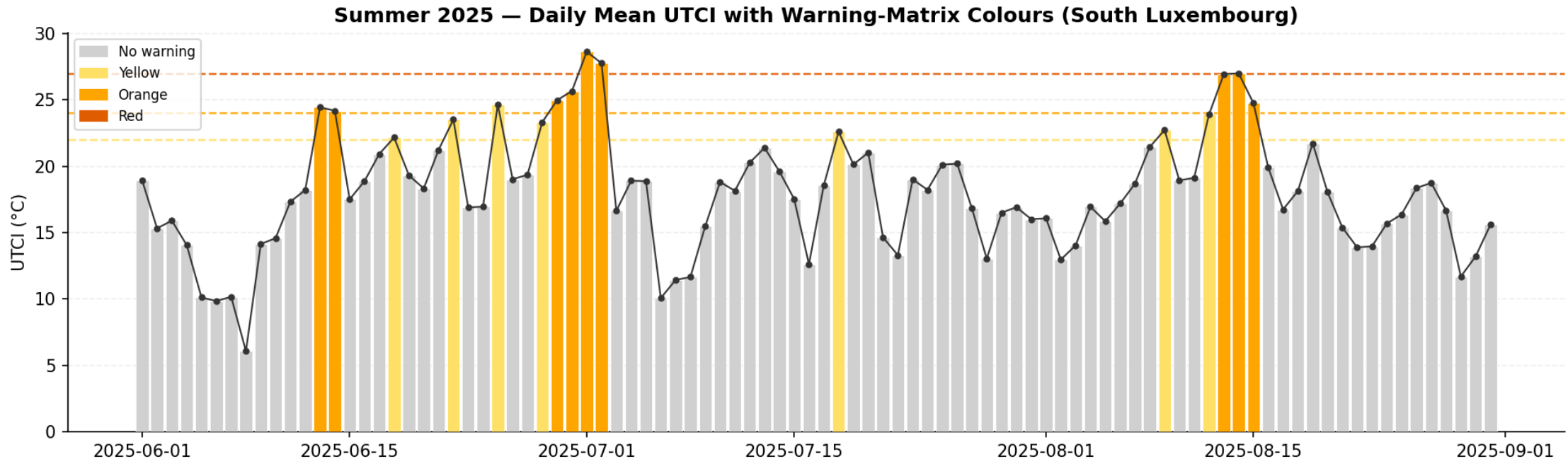


Daily mean UTCI	Day 1	Day 2	Day 3	Day 4	Day 5
$\geq 27\text{ }^{\circ}\text{C}$	Yellow	Orange	Red	Red	Red
$\geq 24\text{ }^{\circ}\text{C}$	Yellow	Orange	Orange	Orange	Orange
$\geq 22\text{ }^{\circ}\text{C}$	Yellow	Yellow	Yellow	Yellow	Yellow
$< 22\text{ }^{\circ}\text{C}$	Green	Green	Green	Green	Green

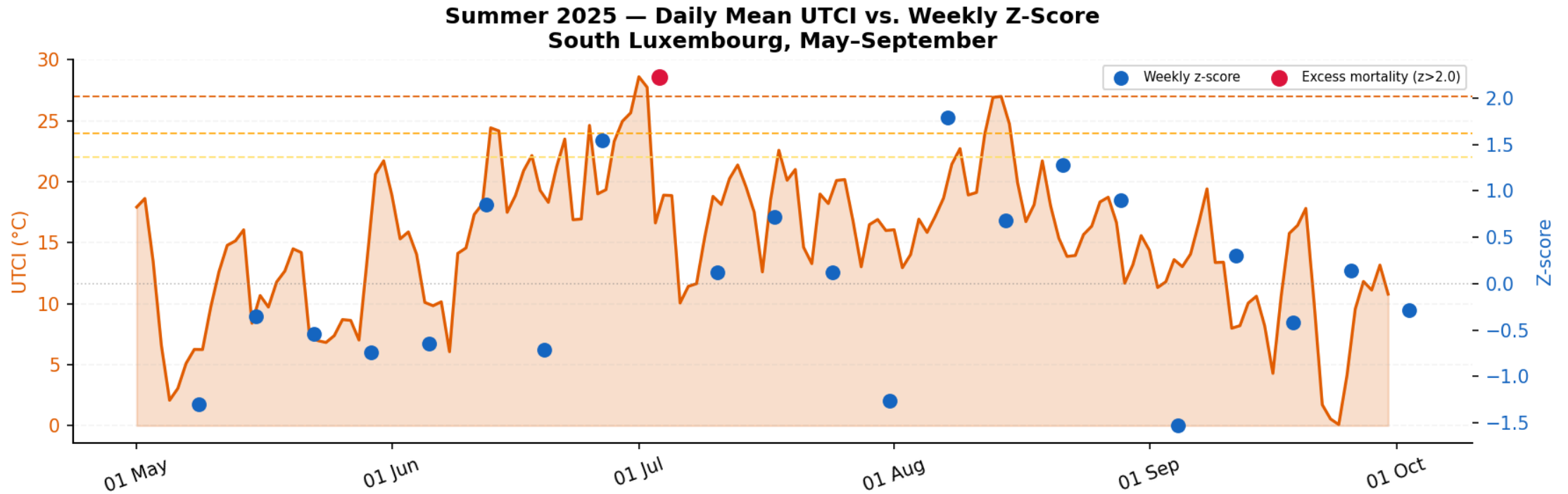
■ No warning
 ■ Yellow — Moderate heat stress
 ■ Orange — Strong heat stress
 ■ Red — Extreme heat stress



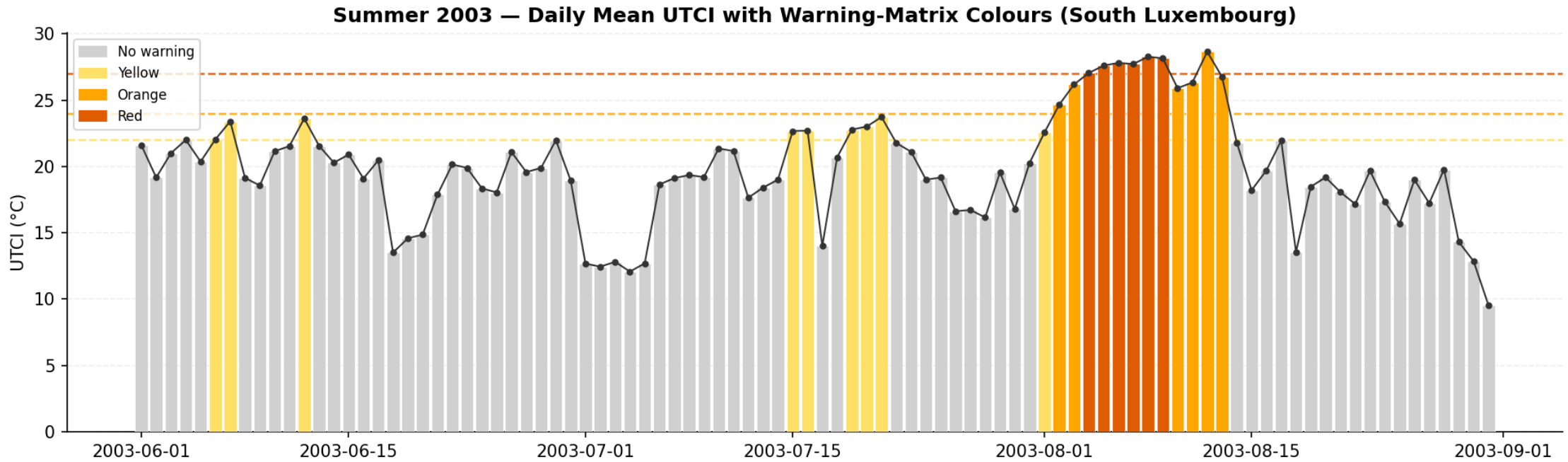
Example: Summer 2025



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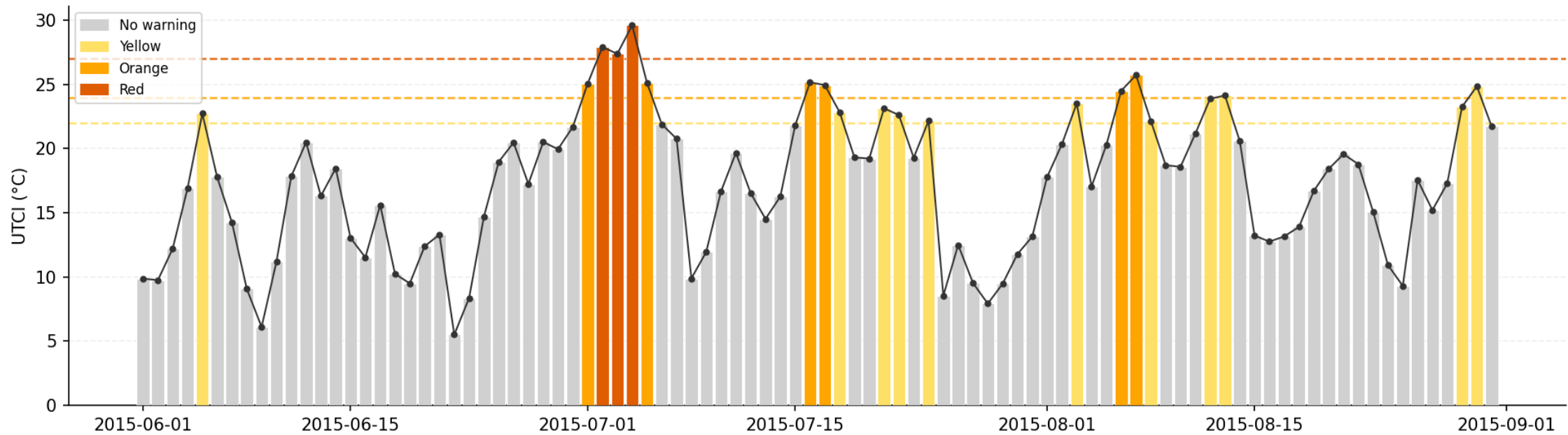


Example: Summer 2003



Example: Summer 2015

Summer 2015 — Daily Mean UTCI with Warning-Matrix Colours (South Luxembourg)



Example: Summer 2019

Summer 2019 — Daily Mean UTCI with Warning-Matrix Colours (South Luxembourg)

