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Ventilative Cooling Potential of Outdoor Air – Now and in the future

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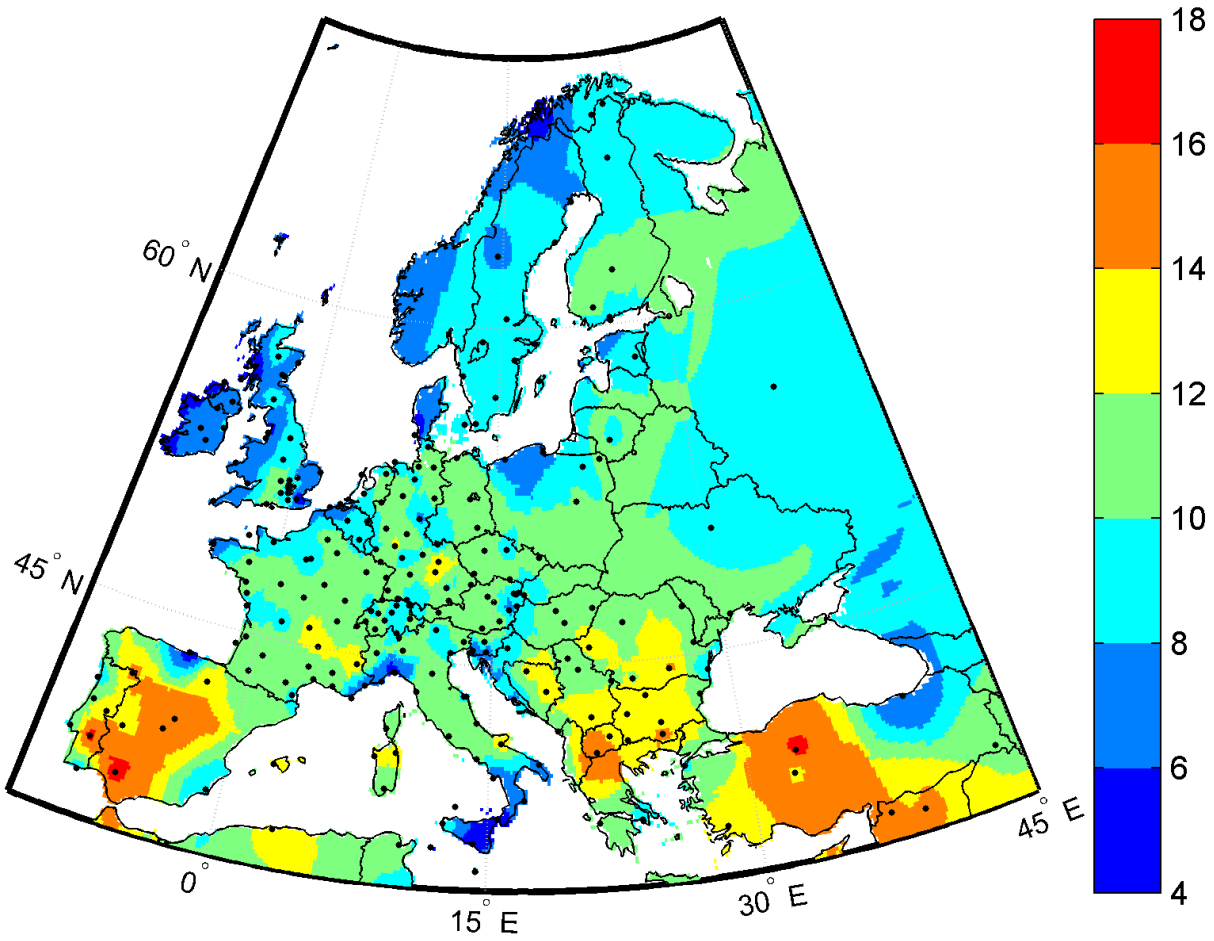
Mean Temp. Difference between Max. and Min. in July



Meteonorm Data

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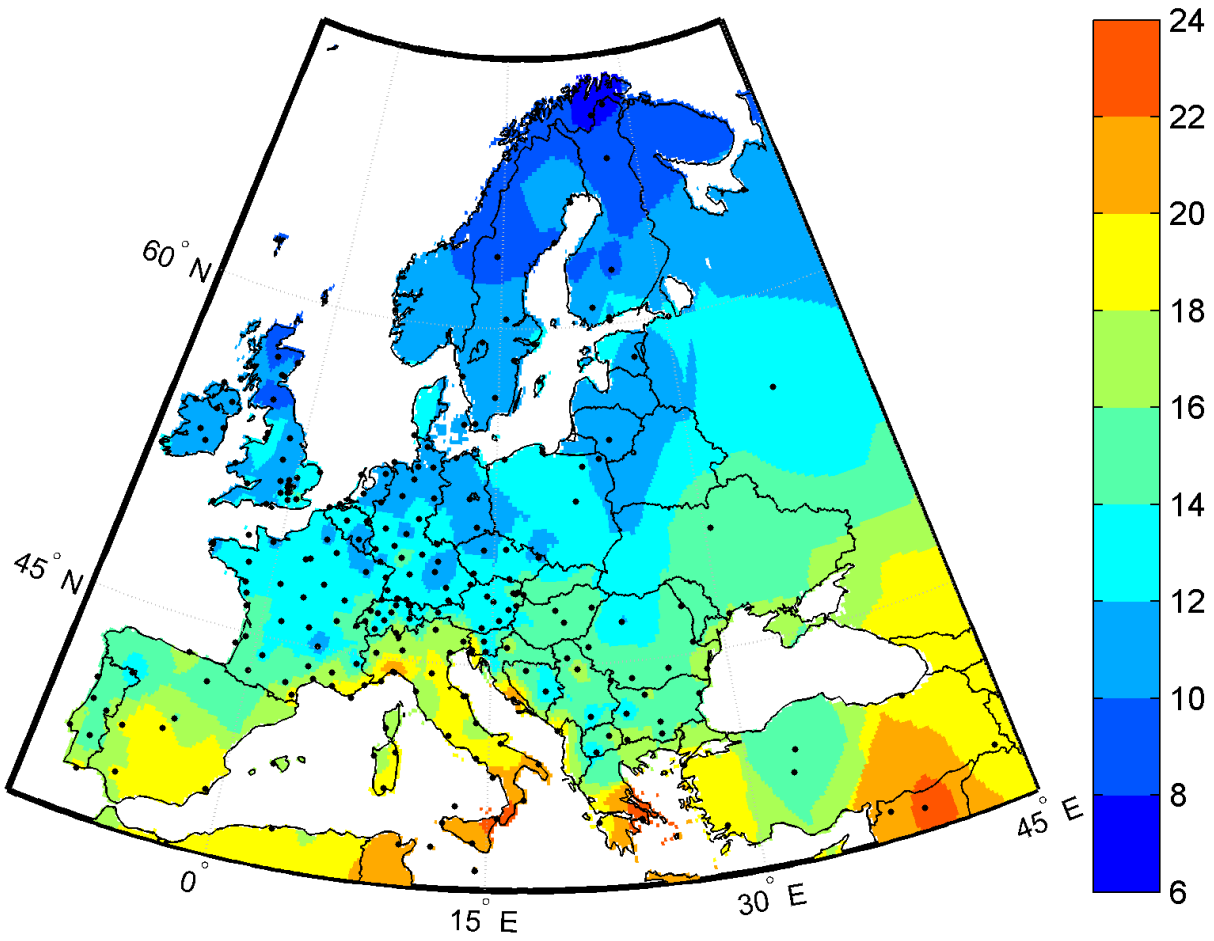
Daily Minimum Temperature July



Meteonorm Data

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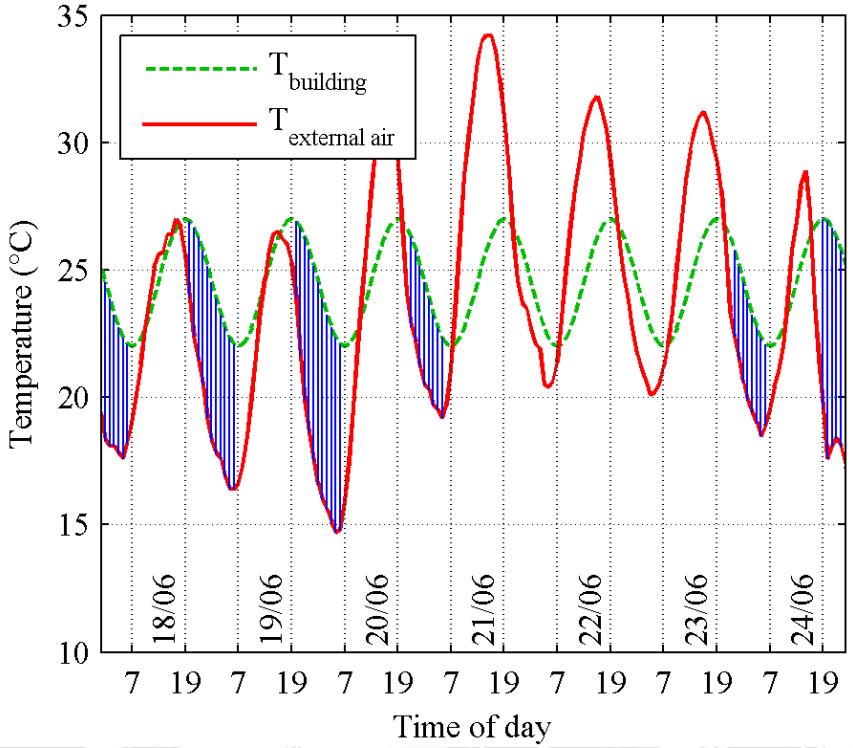
Climatic potential for night-time cooling

- Degree hours method to quantify the climatic cooling potential (CCP)
- Harmonically oscillating building temperature within a range of thermal comfort:
  $T_b = 24.5°C \pm 2.5°C$
- Ventilation period:
  7 pm – 7 am
- Minimum temperature difference:
  $\Delta T_{crit} = 3K$

➔ *CCP* (K h)



Shaded areas show the climatic cooling potential during one exceptionally hot week in summer 2003 for Zurich SMA (ANETZ data)

$$CCP_d = \sum_{t=t_i}^{t_f} m_{d,t} \left(T_{b(d,t)} - T_{e(d,t)}\right)$$

$$\begin{cases} m = 1\,h & \text{if } T_b - T_e \geq \Delta T_{crit} \\ m = 0 & \text{if } T_b - T_e < \Delta T_{crit} \end{cases}$$

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Practical significance of CCP

Example:

- **Internal and solar heat gains:** $\dot{Q} = 20W/m^2 + 30W/m^2 = 50W/m^2$
- **Occupancy time:** $t_{occ} = 8h$
- **Effective air change rate:** $ACR\,\eta = 6h^{-1};$ $\left(\eta = \frac{T_{out} - T_e}{T_b - T_e}\right)$
- **Room height:** $H = 2.5m$
- **Air properties:** $\rho = 1.2kg/m^3; c_p = 1000J/(kgK)$

Climatic cooling potential: $CCP = \frac{\dot{q} \cdot t_{occ}}{H\,ACR\,\eta\,\rho\,c_p} = 80Kh$

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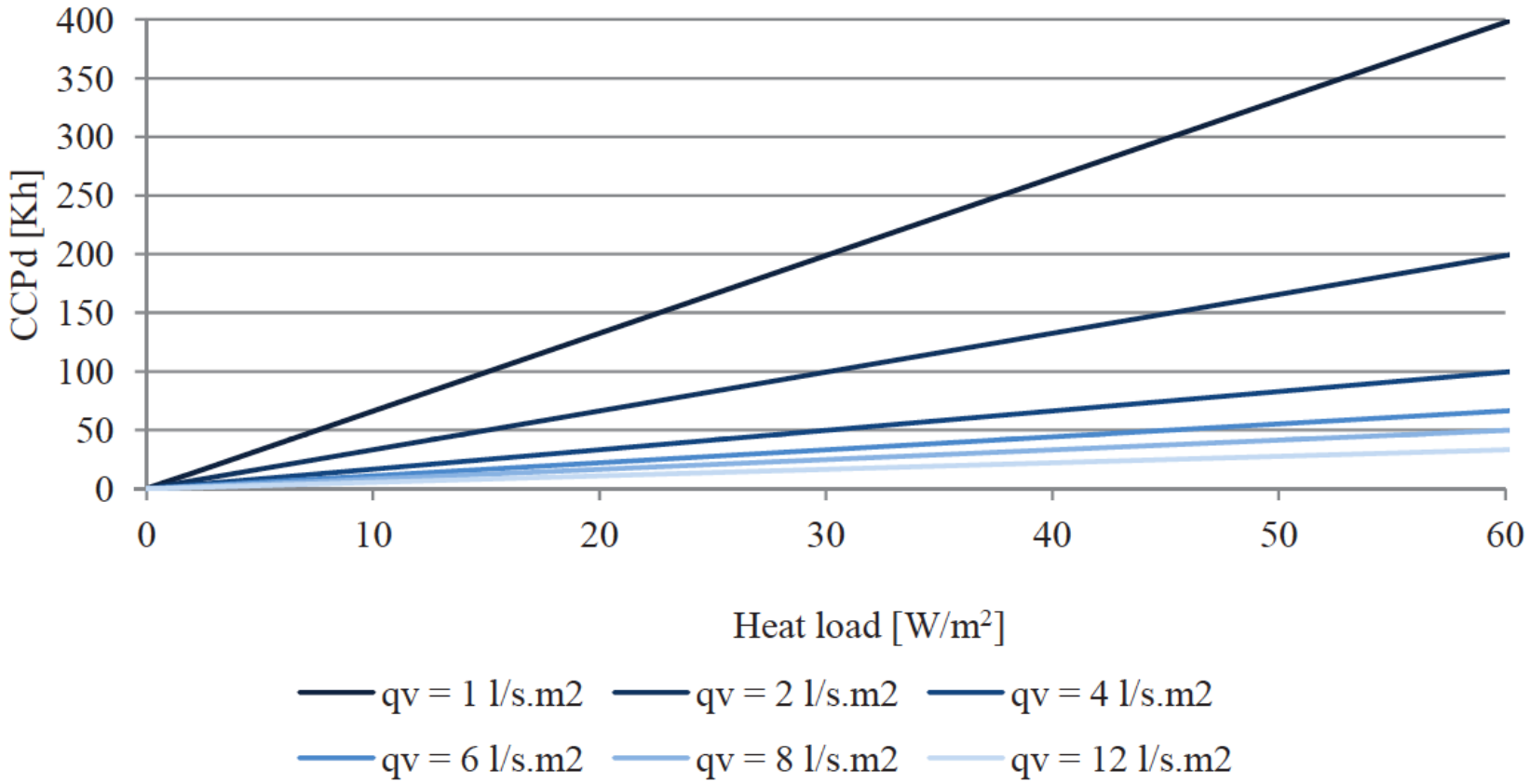
Necessary CCP

As a function of heat load and ventilation air flow rate



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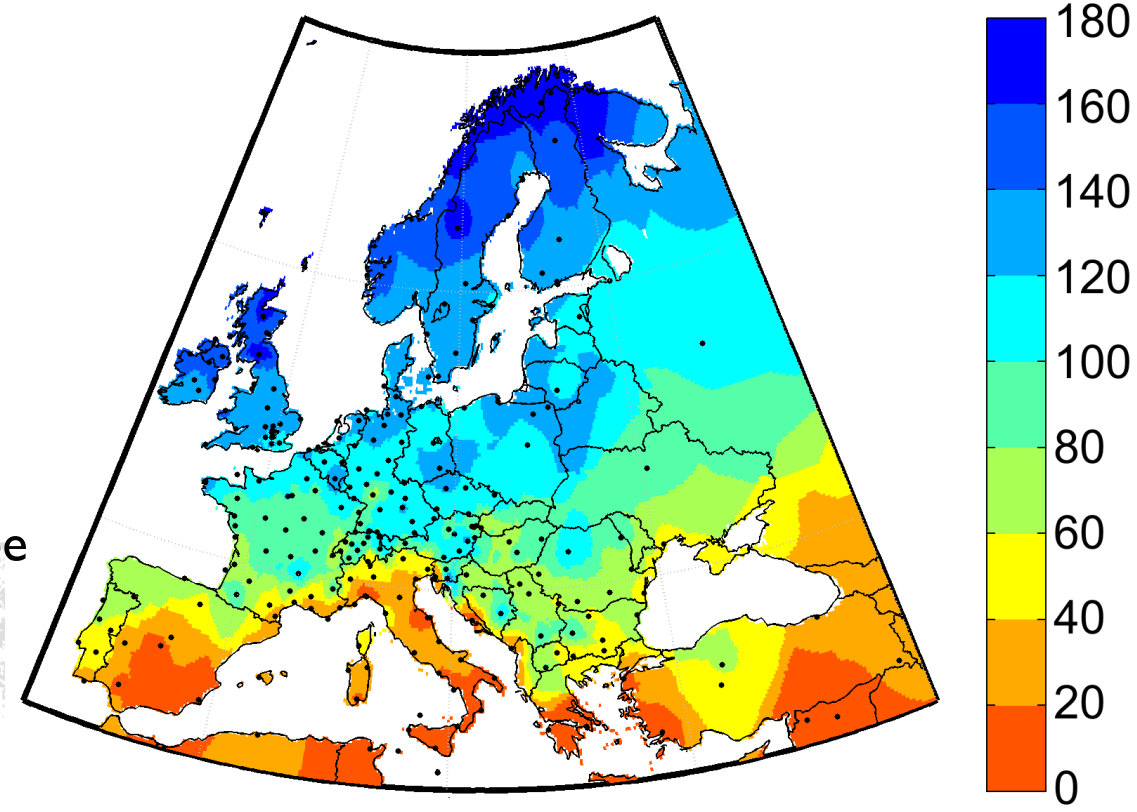
Local variability

Semi-synthetic data (Meteonorm) from 259 locations in Europe

- Very high potential of 120 – 180 Kh in Northern Europe (incl. British Isles)
- High cooling potential 80 – 140 Kh in Central, Eastern and parts of Southern Europe
- Low cooling potential in Southern Europe: 0 – less than 80 Kh



Map of mean climatic cooling potential (K h / night) in July (Meteonorm data)

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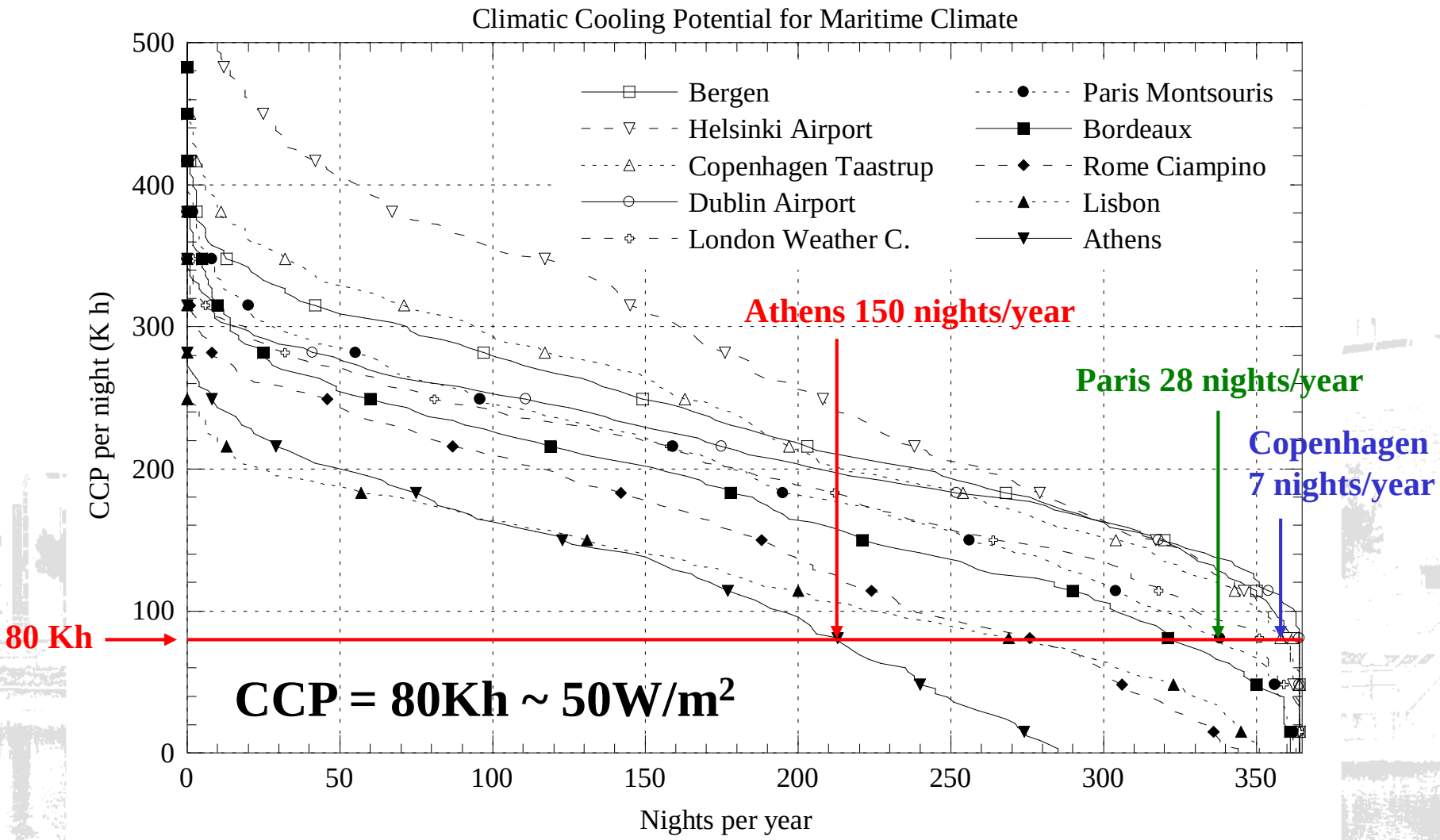
Cumulative frequency distribution of CCP



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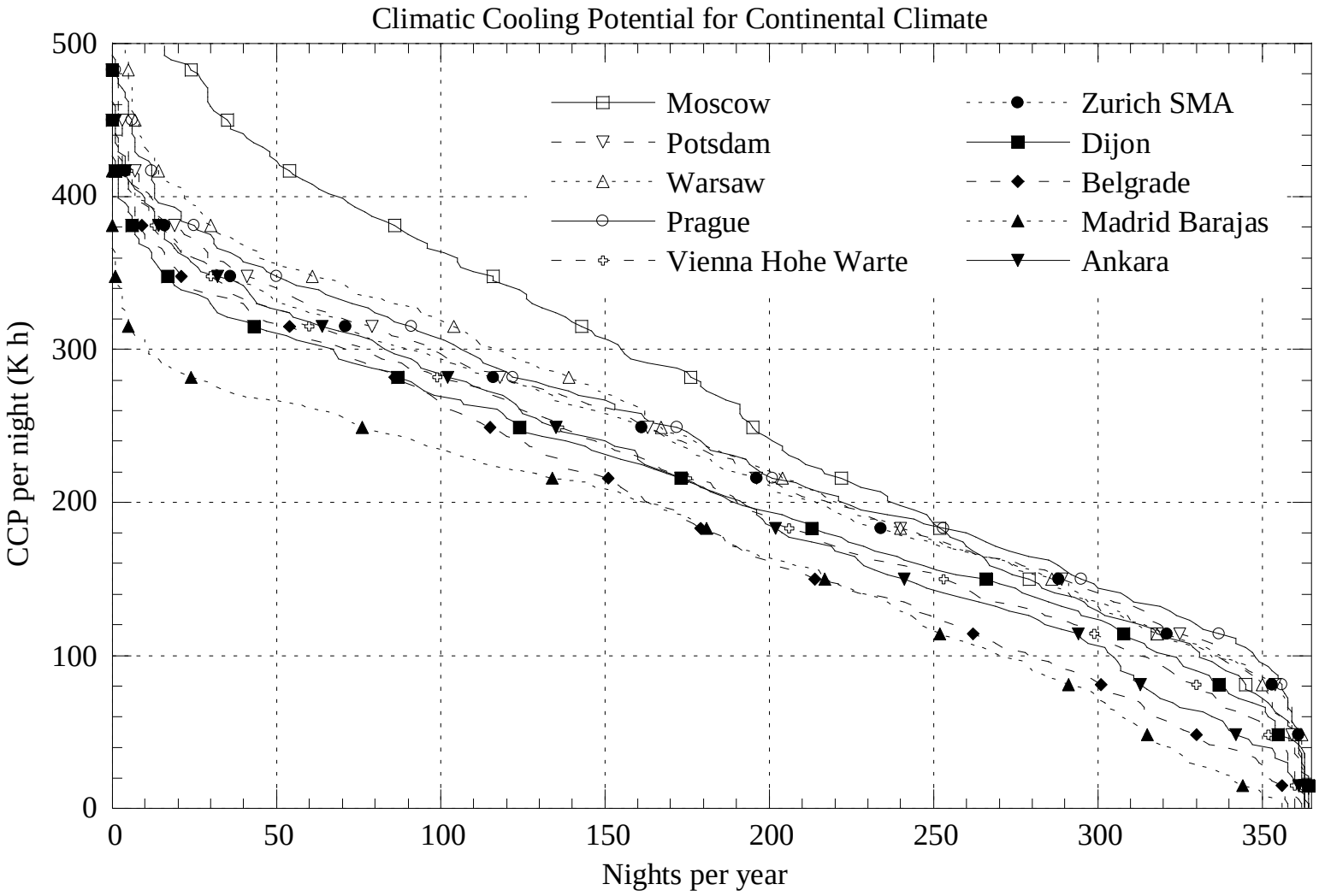

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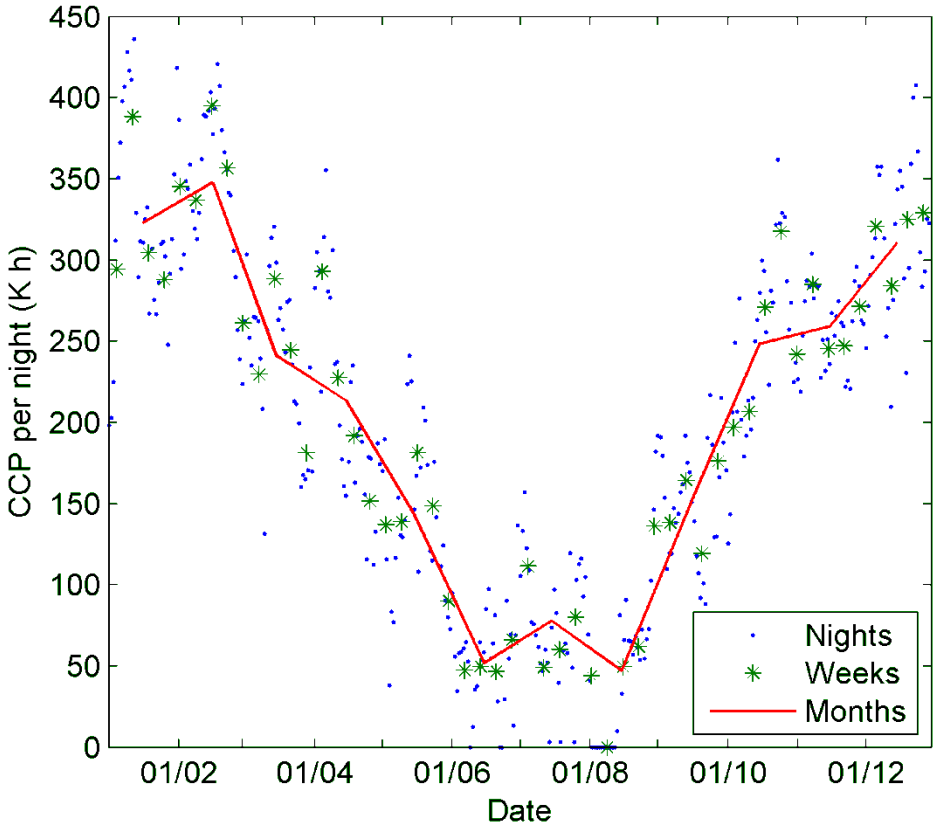
CCP in different time

Stochastic weather patterns

- **High variation of CCP within few nights: ~ 100 - 200 K h**
- **Variation of weekly mean values: ~ 50 – 100 K h**
- **Heat waves with high daily cooling demand and low cooling potential during nights**
- **Example:**

  First week of August ~ 0 K h

  ⟷ August mean ~ 50 K h



Climatic cooling potential per nights, weeks and months for Zurich SMA in 2003 (ANETZ data)

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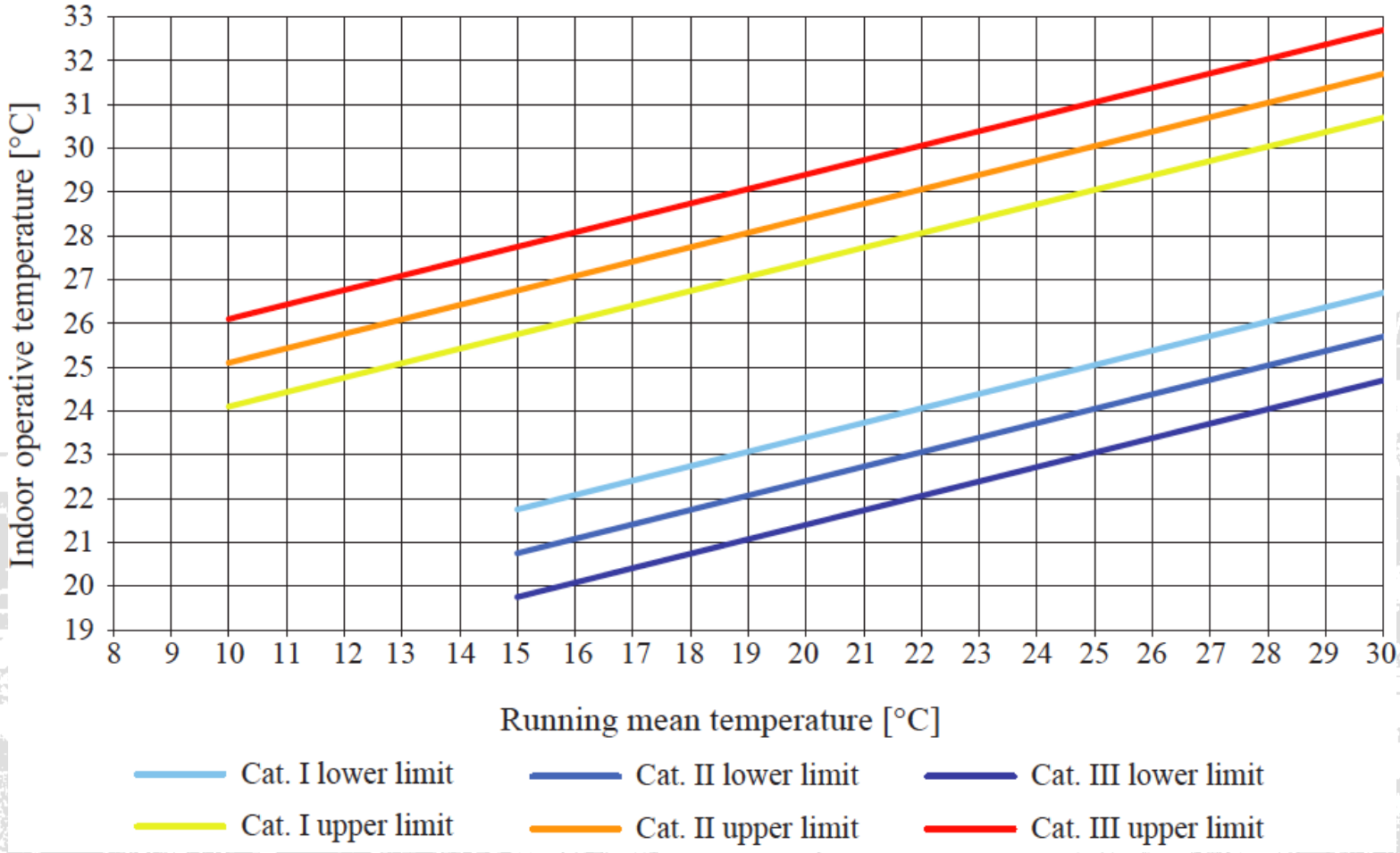
Adaptive comfort approach

Operative temperature as function of external running mean, EN 15251



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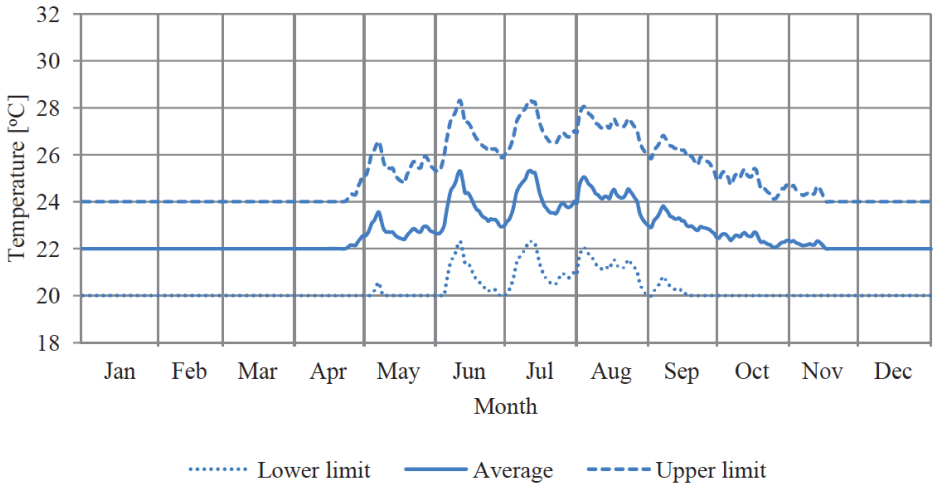
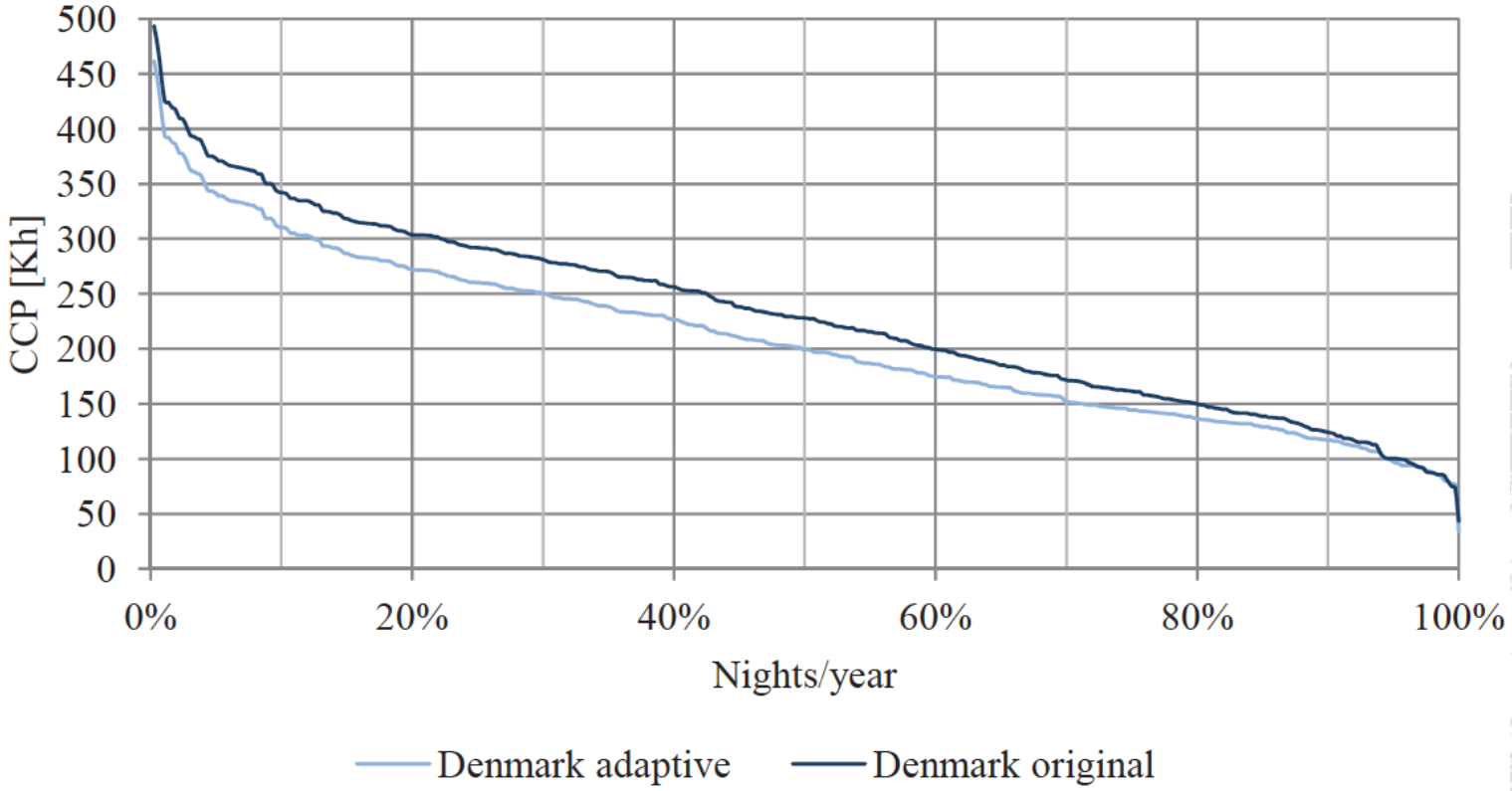
Impact in cool climates Denmark





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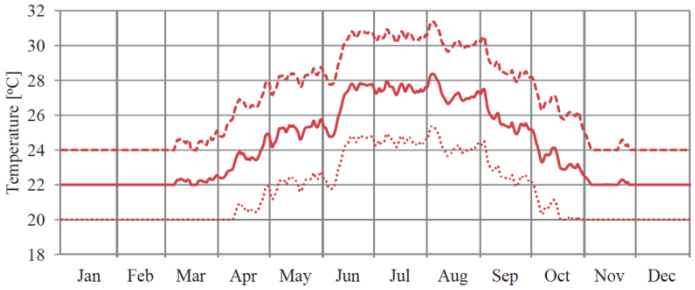
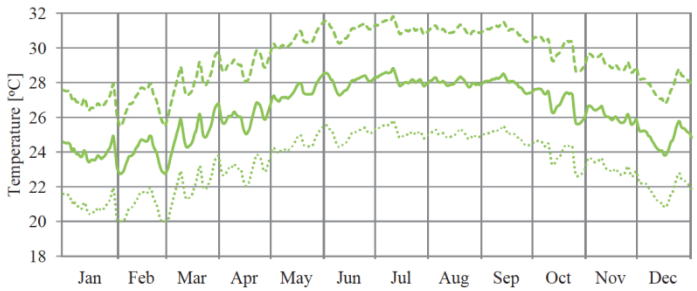
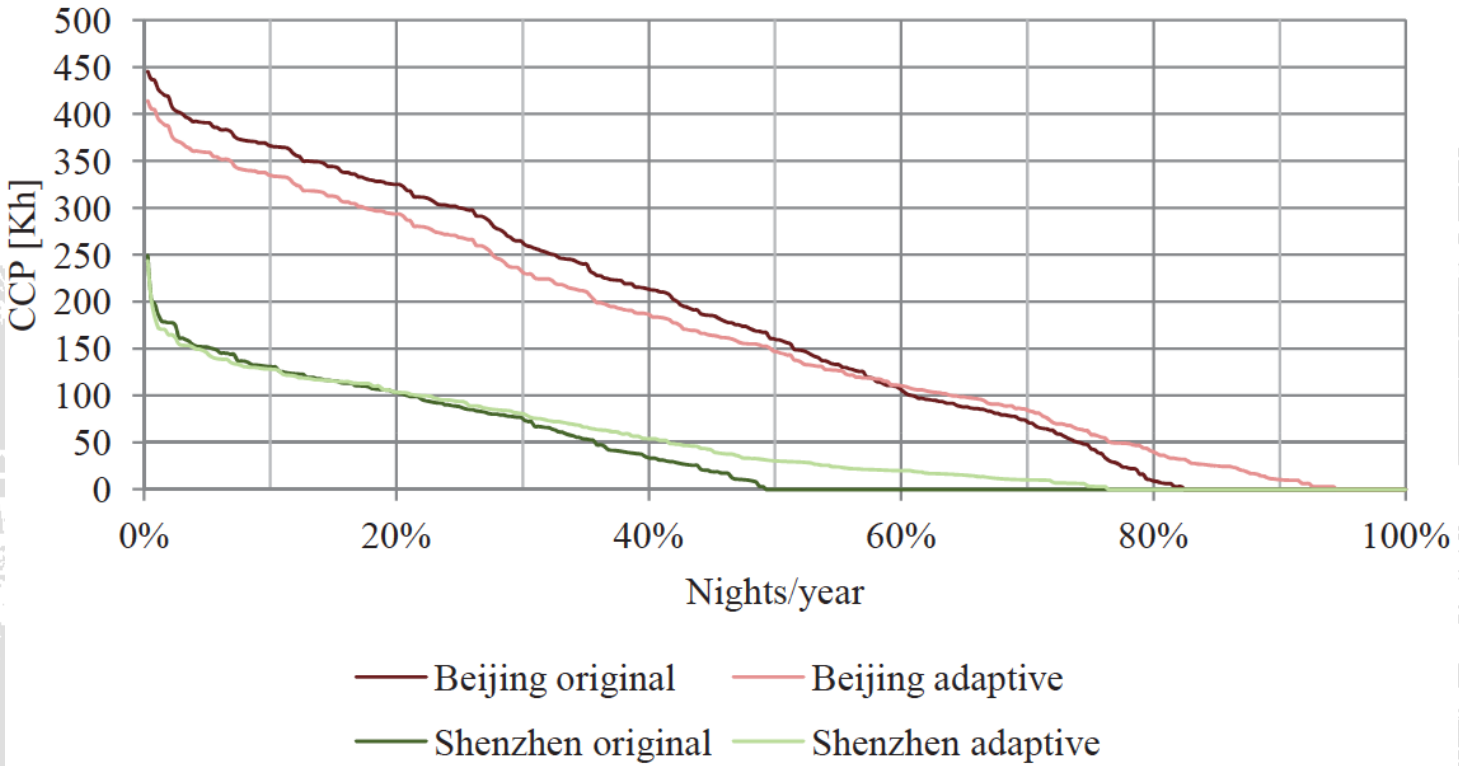
Impact in warmer climate, Beijing, Shenzhen







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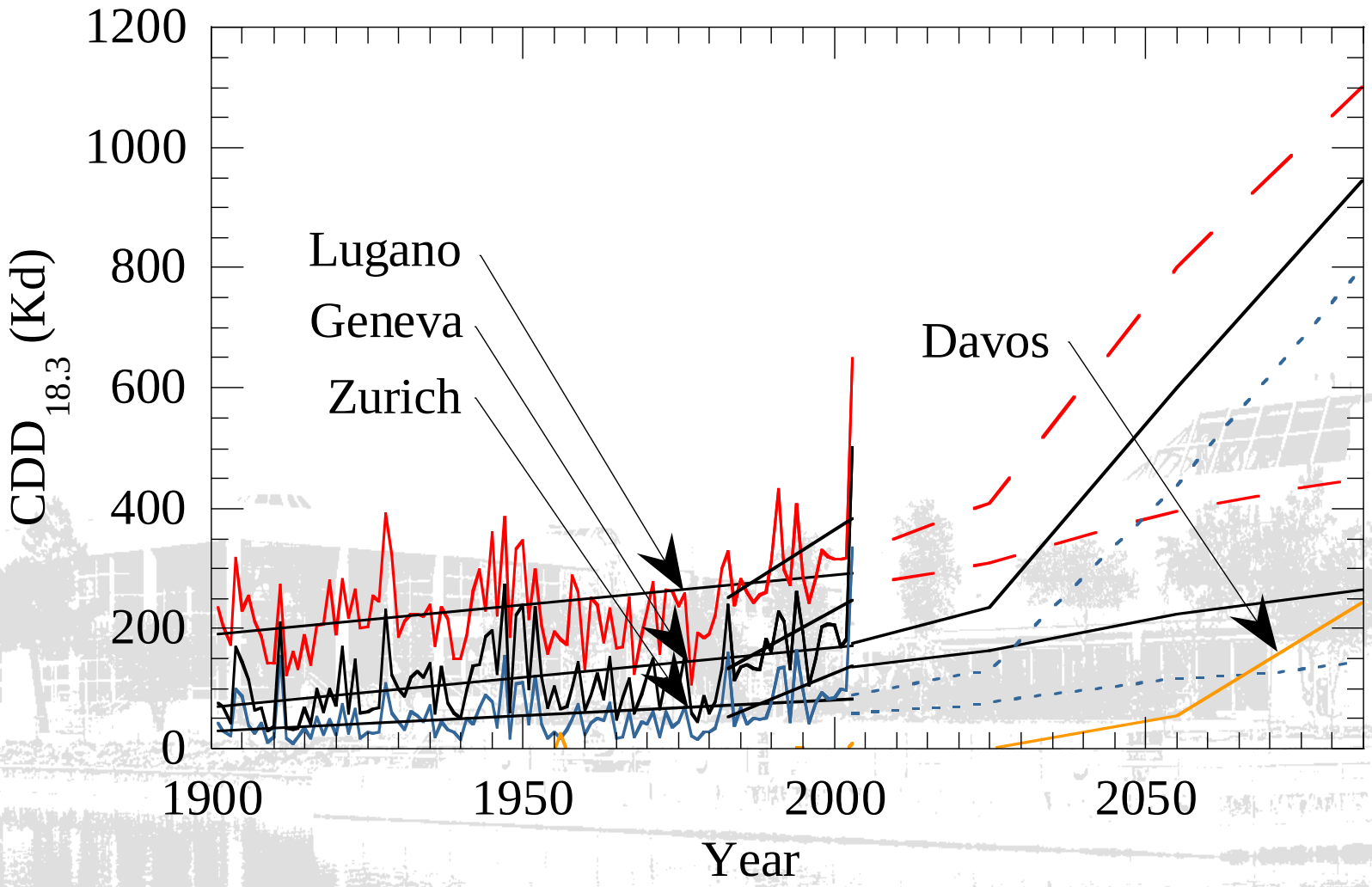
Increase in cooling degree days



Source:
M Christenson, H Manz, D Gyalistras, 2005

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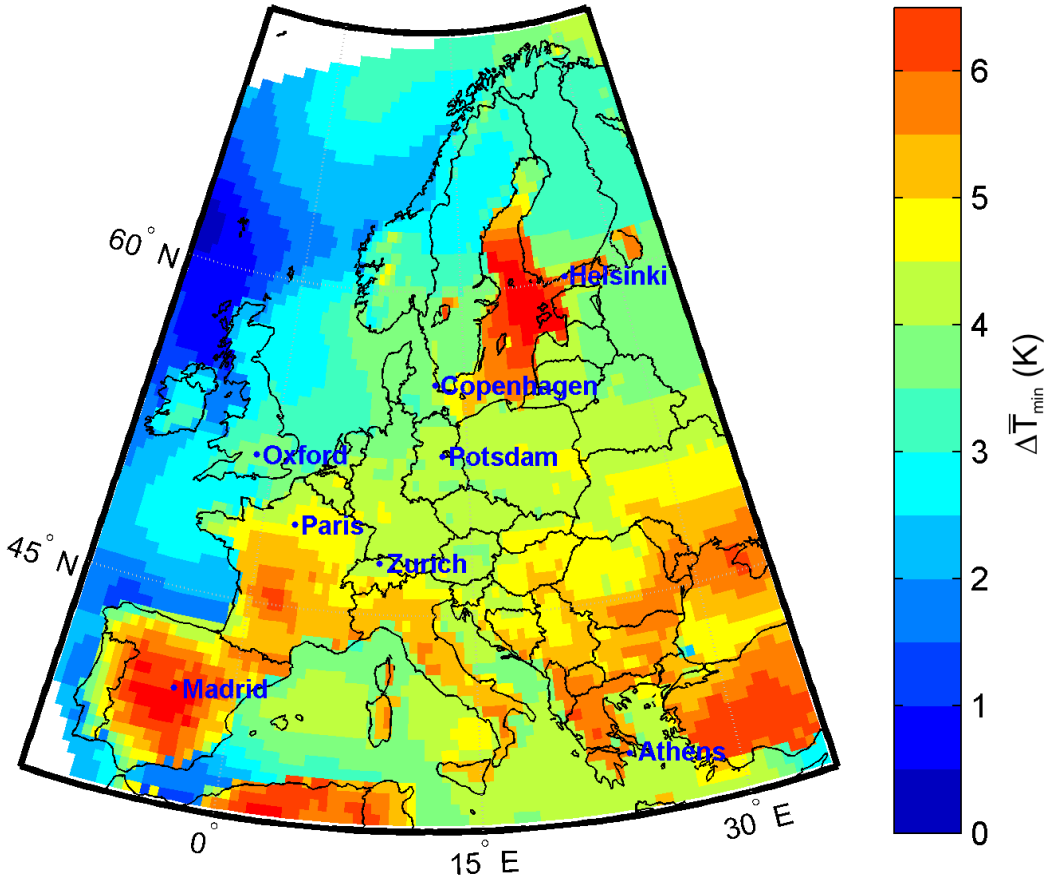
Change in long-term mean daily minimum temperature in summer (JJA)

- "A2" emissions scenario for the years 2071-2100 relative to the baseline 1961-1990, as simulated by the Danish Meteorological Institute regional climate model. Simulations were based on boundary conditions from the HadAM3H atmospheric general circulation model (Table A1: Scenario No S1). Data from PRUDENCE (2006).



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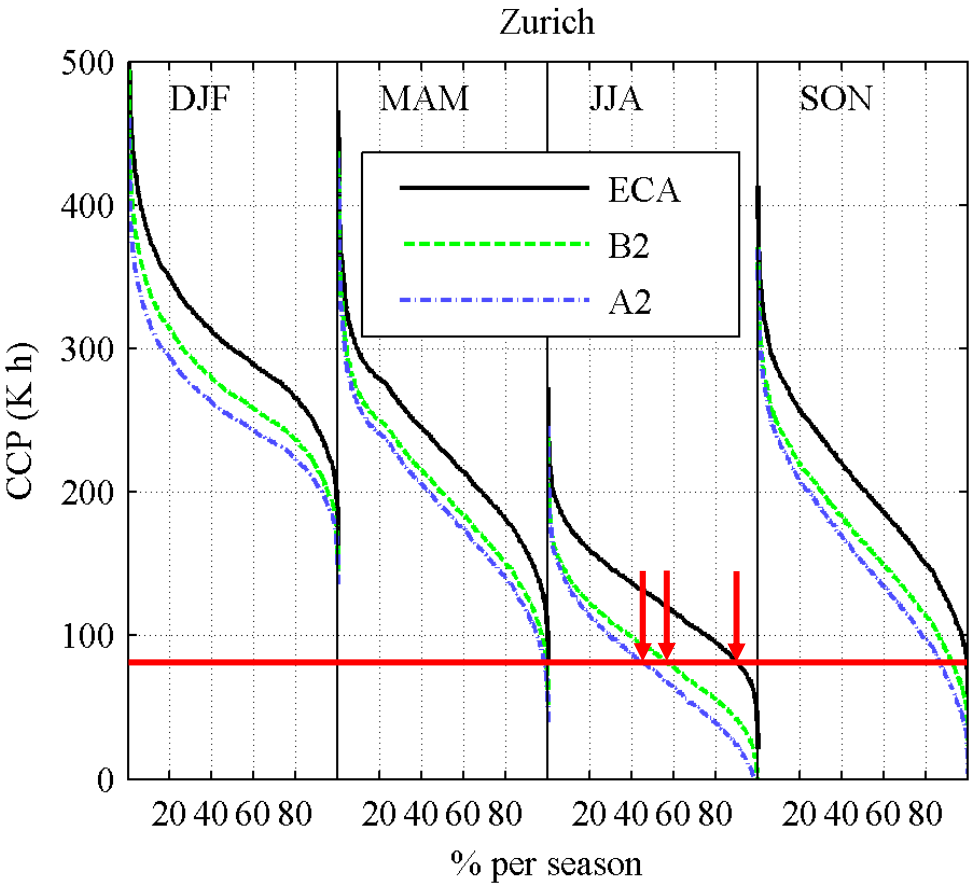
Cumulative distribution

Percentage of summer nights when CCP exceeds e.g. 80 Kh

- **Current climate: 90 %**
- **Future climate: 45-55 %**

Significant increase in risk of overheating



Seasonal cumulative distribution functions of CCP in Madrid for current climate (ECA data) and selected simulation runs with mean values for forcing scenarios A2 and B2

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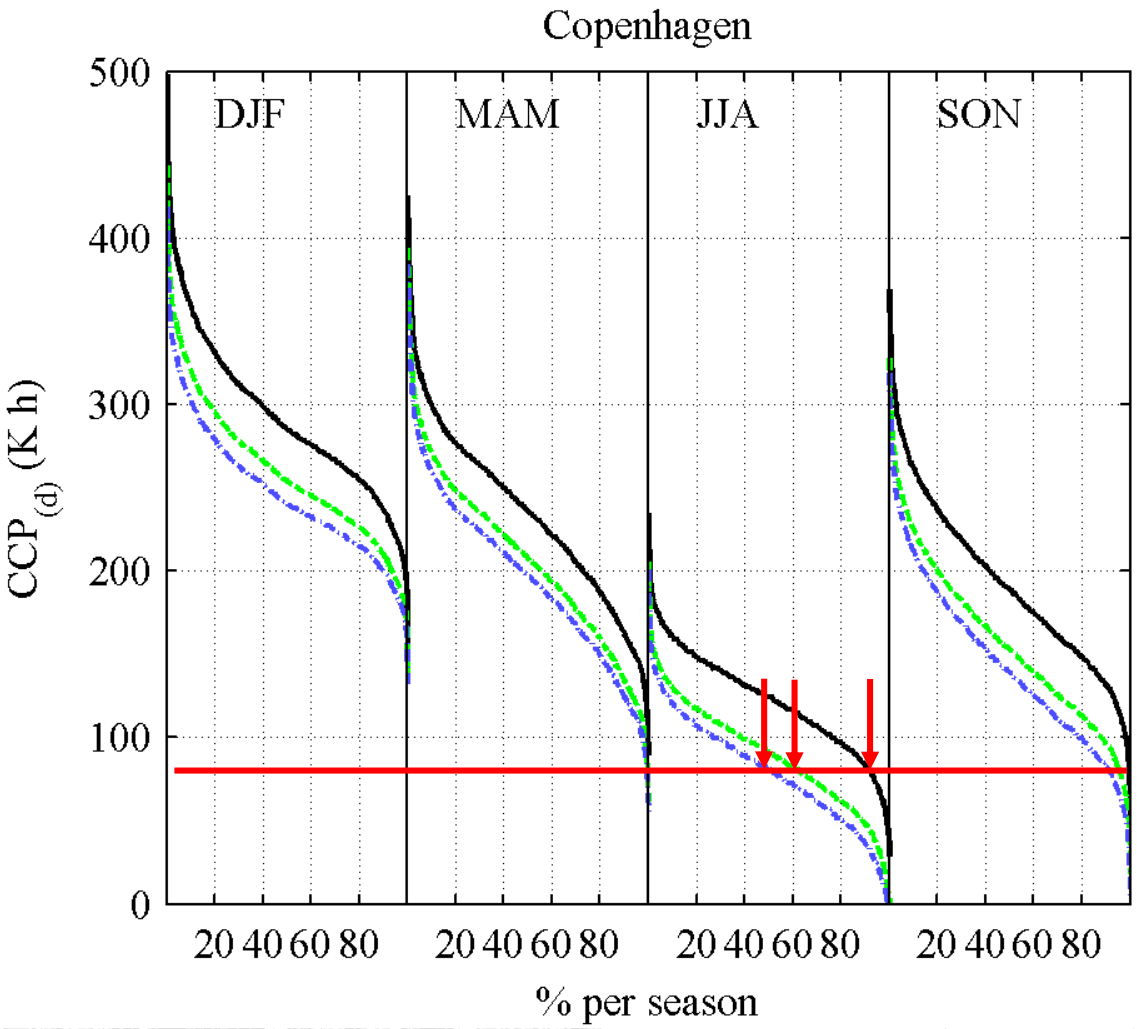
Passive Cooling Potential



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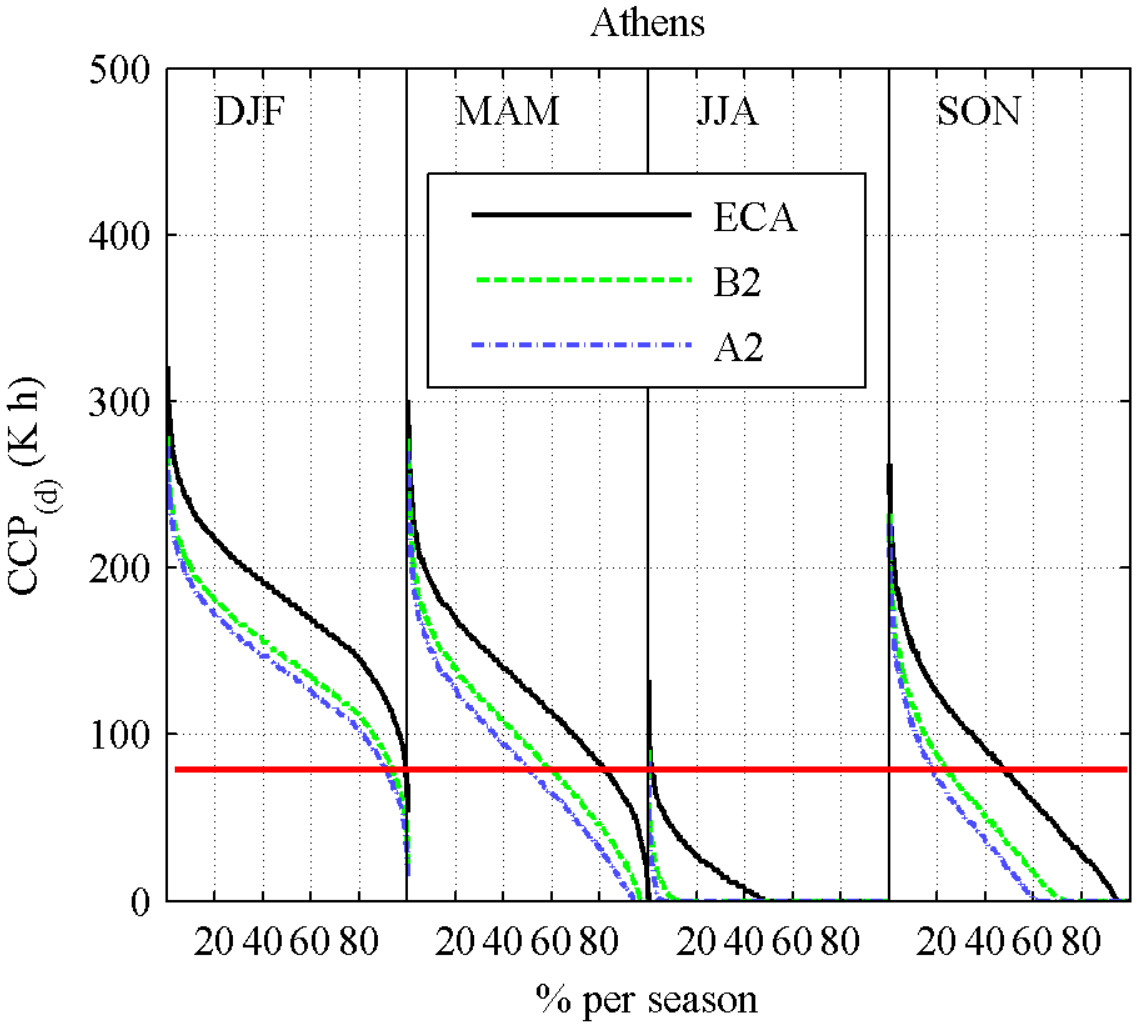
Passive Cooling Potential



Summary

- Application of the CCP approach is a fast method to evaluate the night cooling potential considering both outdoor climate, building heat load and ventilation flow rate
- Application of the adaptive comfort approach increases the night cooling potential in warm periods
- According to predicted scenarios for climate change the night cooling potential will be reduced critically in the summer periods, but even in warm European climate as Greece a potential will be present more than 50% of the year.