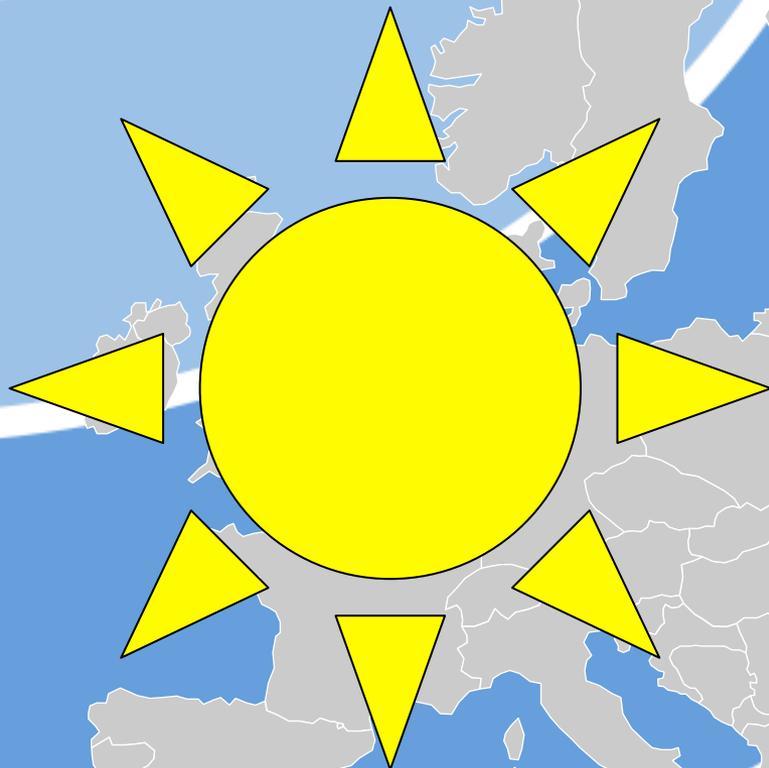




# Europe's heat waves in a changing climate





# Heat waves

## Warming in Europe



Annual

In 2015, the average annual temperature over the European land area had increased by **1.45°C to 1.59°C**, relative to the pre-industrial period. This increase is larger than that for global average temperature and makes it the warmest decade on record.

Summer

The relatively rapid warming trend since the 1980s is **most clearly evident in the summer**. Nocturnal temperatures have increased more than daytime values.

Extreme events

**High-temperature extremes** like hot days, tropical nights, and heat waves have become **more frequent**, while low-temperature extremes (e.g. cold spells, frost days) have become less frequent.

Geographic

In the past 30 years, warming was strongest over **Scandinavia, especially in winter**, whereas the Iberian Peninsula warmed strongly in summer.

Altitude

The **mountains experience more rapid warming** than environments at lower elevations.

This rise in mean European summer temperatures **has contributed** to the intensity of recent European heat waves, like the ones in 2003, 2010, 2015, and 2018.



# Heat waves



## Recent heat waves

Many cities in **Eastern Europe** recorded extremely high values of daytime and night-time temperatures. The 2010 event exceeded the 2003 episode in terms of amplitude and spatial extent. The severe 2010 heat wave was influenced both by natural climate variability and anthropogenic climate change.

2014 was especially warm in **Central Europe and Scandinavia**. 'With high confidence' anthropogenic climate change has made Europe's warm year of 2014 at least 500 times more likely. The fact that relatively high temperatures covered a large part of Europe made the situation of 2014 extreme and point at a significant effect of climate change.

**Again!**



Much of Europe was affected by a heat wave during June, July and August. It is estimated that this was the hottest summer since at least 1500. Seasonal temperatures were the highest on record in **Germany, Switzerland, France and Spain**.

The magnitude of warming in the summer of 2013 was slightly less but comparable with the previous hot summers in **Western Europe**, such as 2003 and 2010.

A sequence of four intense heat waves struck **an area stretching from France to western Russia** from the end of June to early September. Century-old record values of minimum and maximum temperatures were broken in Prague (since 1775) and Vienna (since 1855). The summer of 2015 ranked third after 2003 and 2010. Human-induced climate change has contributed to the increase in the frequency and intensity of events like the of 2015.



## Heat waves



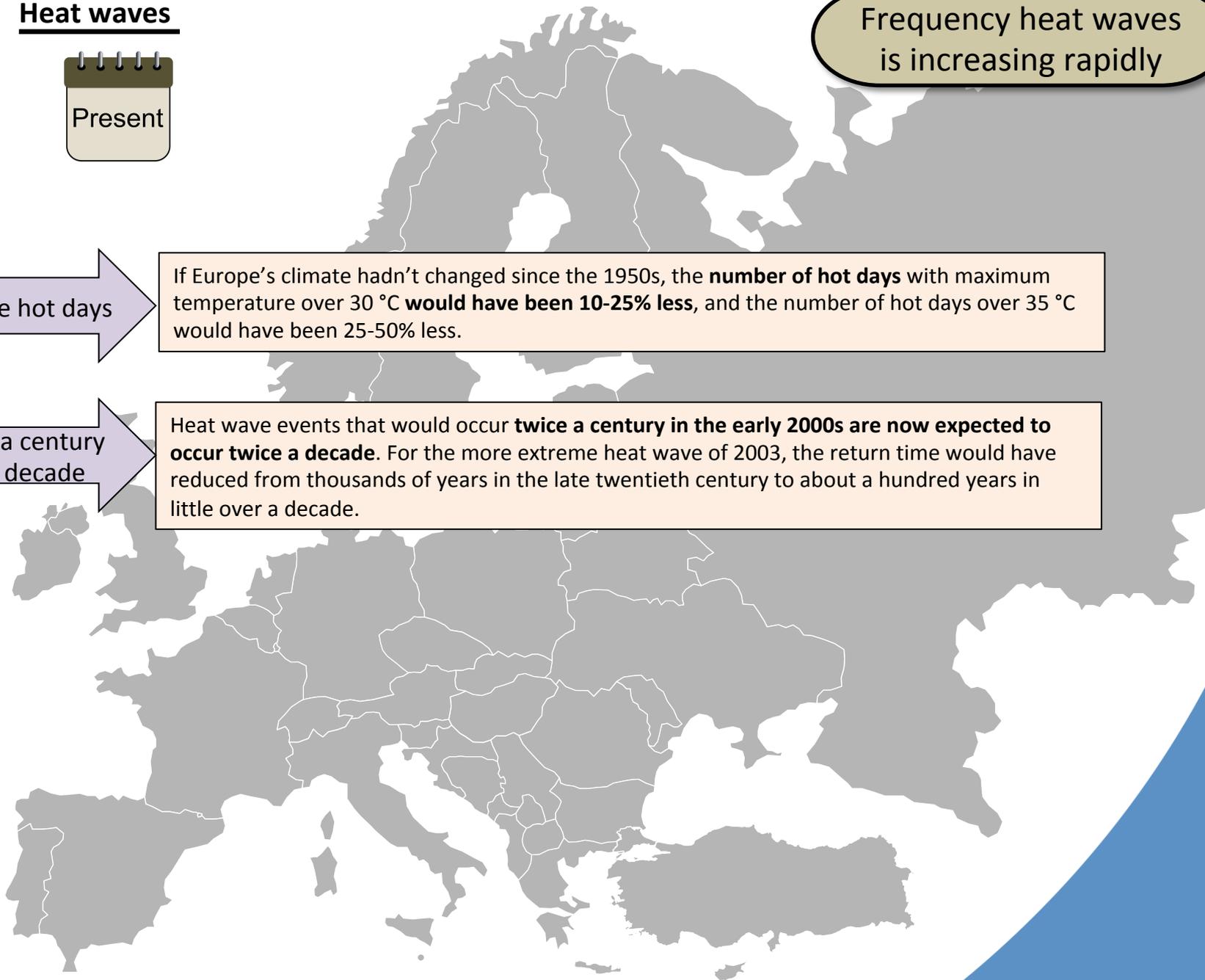
Frequency heat waves is increasing rapidly

10-25% more hot days

If Europe's climate hadn't changed since the 1950s, the **number of hot days** with maximum temperature over 30 °C **would have been 10-25% less**, and the number of hot days over 35 °C would have been 25-50% less.

From twice a century to twice a decade

Heat wave events that would occur **twice a century in the early 2000s are now expected to occur twice a decade**. For the more extreme heat wave of 2003, the return time would have reduced from thousands of years in the late twentieth century to about a hundred years in little over a decade.





## Heat waves



Heat waves amplify the urban heat island effect

Urban heat island effect: cities are warmer than the surrounding land

European cities over the period 2006-2011:

- Daytime, summer: effect typically 2°C in July, but up to 3°C
- Night-time: up to 7°C (for London and Rotterdam) or even 10.5°C (Hamburg)

The urban heat island effect is most pronounced during calm nights with clear skies

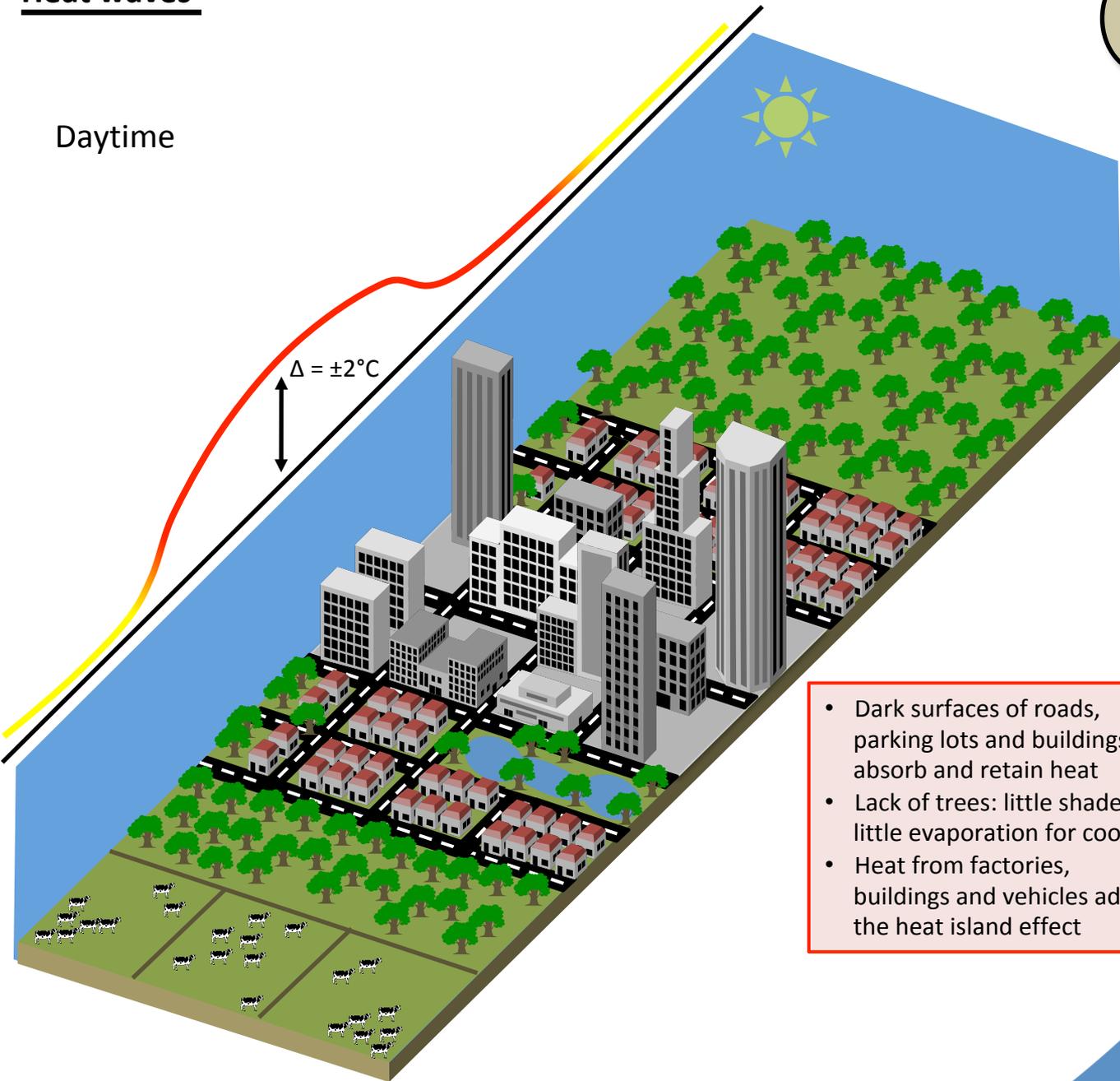
For New York City a difference between urban and rural temperature at night as high as 8°C was observed during a heat wave in 2016



# Heat waves

## Urban Heat Island

Daytime



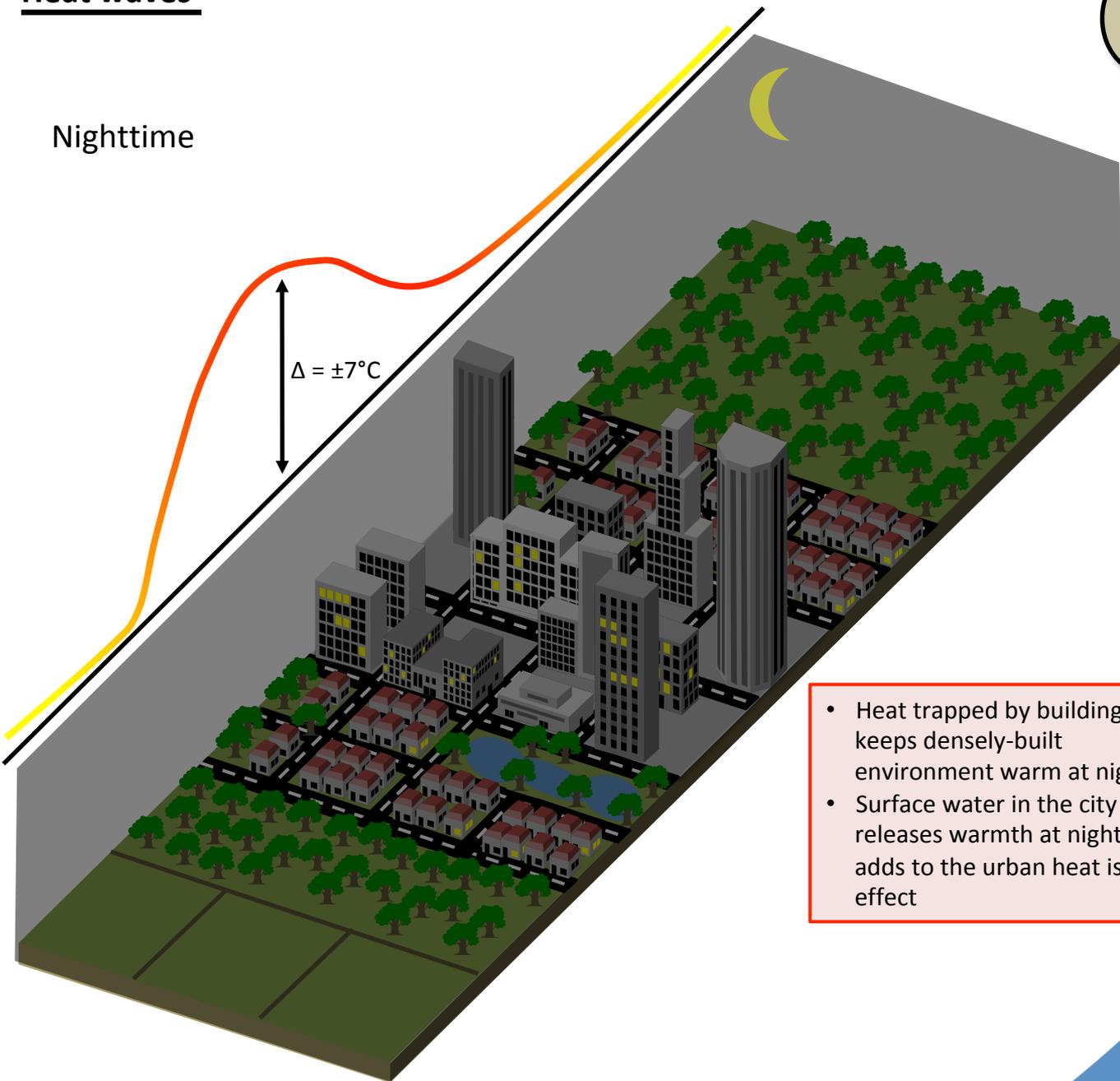
- Dark surfaces of roads, parking lots and buildings absorb and retain heat
- Lack of trees: little shade and little evaporation for cooling
- Heat from factories, buildings and vehicles add to the heat island effect



# Heat waves

Urban Heat Island

Nighttime

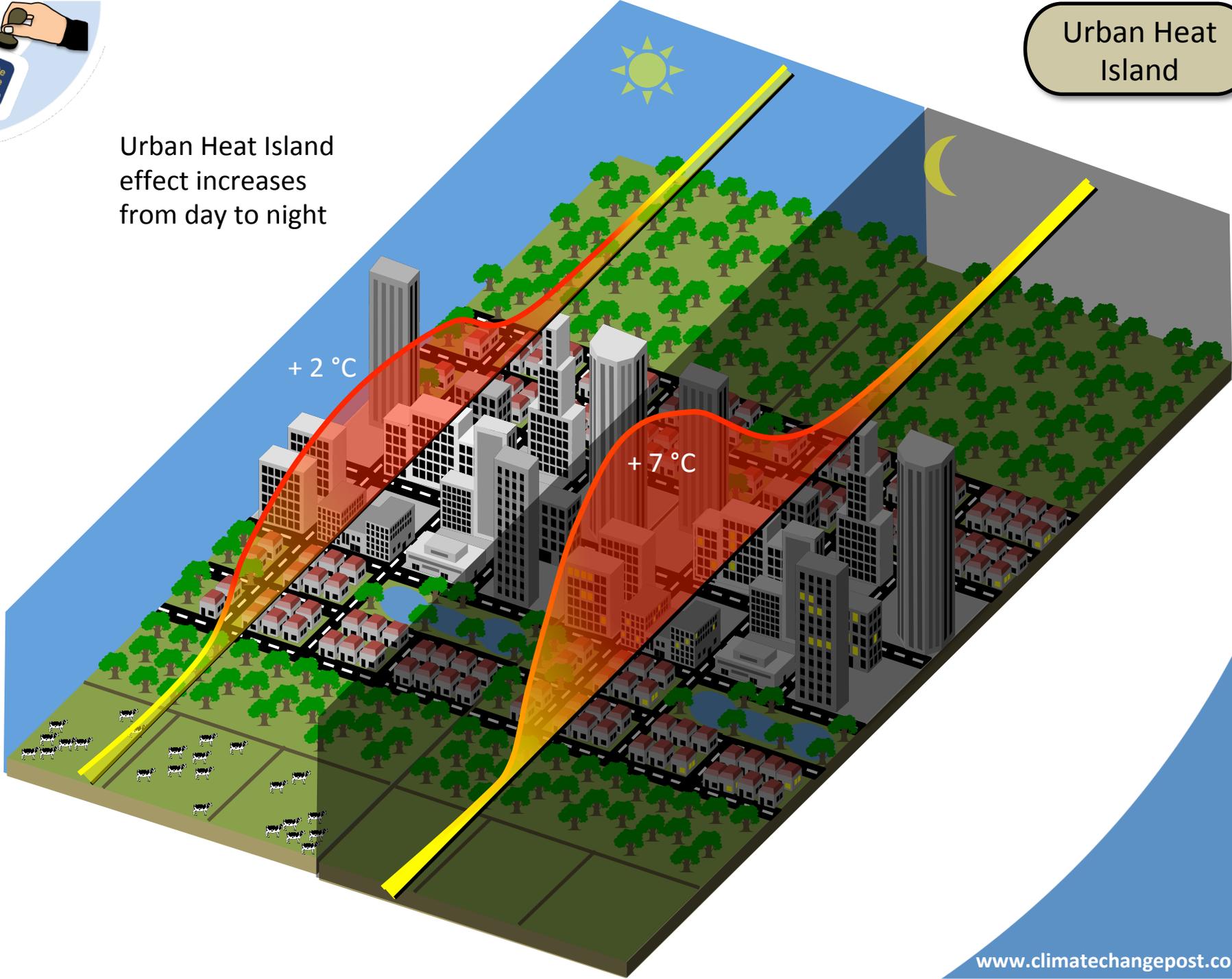


- Heat trapped by buildings keeps densely-built environment warm at night
- Surface water in the city releases warmth at night and adds to the urban heat island effect



# Urban Heat Island

Urban Heat Island effect increases from day to night





# Heat waves

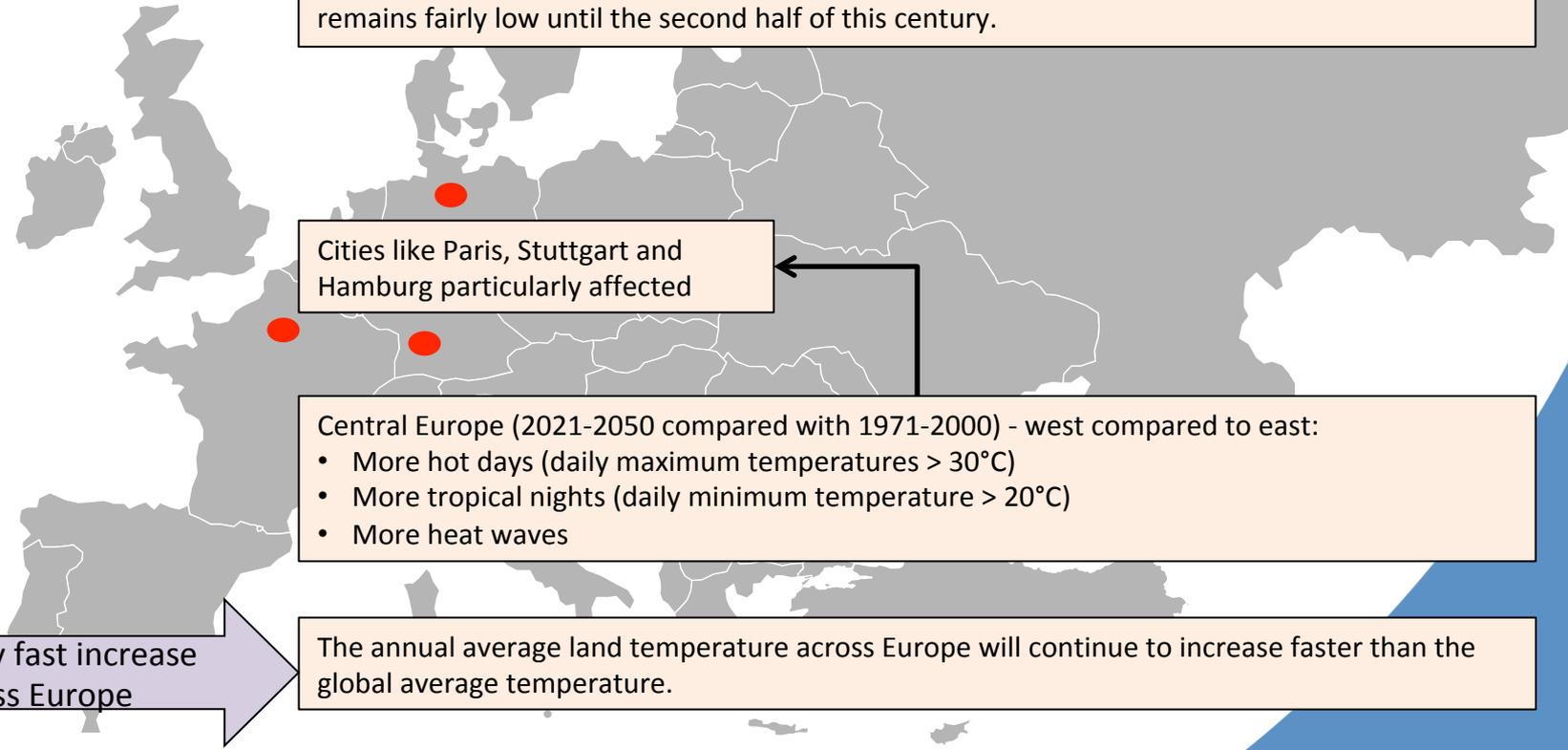


Frequency heat waves continues to increase rapidly

Within 40 years: mega heat waves 5-10 times more likely

The frequency of heat waves in Central Europe is projected to increase by a factor 2 in the near future (2020 - 2049) compared with the period 1970 - 1999. Other studies show a more modest increase of 17%. The number of hot days and tropical nights will increase, the number of frost days will decrease.

Models indicate that the probability of a summer experiencing mega heat waves will increase by a factor of 5 to 10 within the next 40 years. The magnitude of the 2010 event was so extreme that despite this increase, the likelihood of a similar event over the same region remains fairly low until the second half of this century.



Cities like Paris, Stuttgart and Hamburg particularly affected

- Central Europe (2021-2050 compared with 1971-2000) - west compared to east:
- More hot days (daily maximum temperatures > 30°C)
  - More tropical nights (daily minimum temperature > 20°C)
  - More heat waves

Relatively fast increase across Europe

The annual average land temperature across Europe will continue to increase faster than the global average temperature.



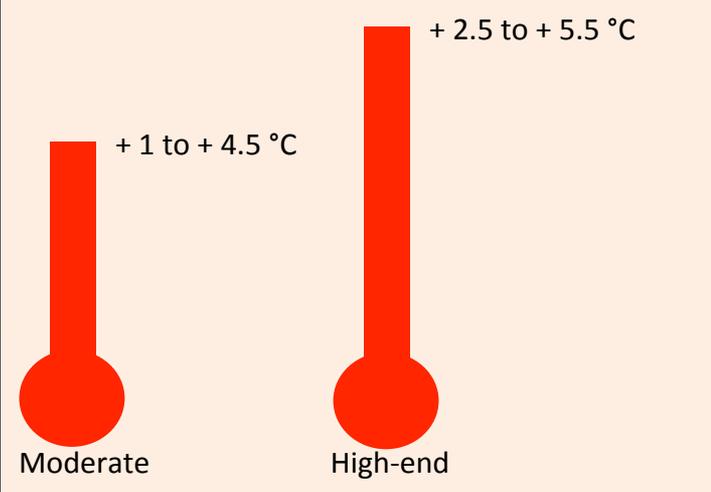
# Heat waves



Summer: greatest warming in the South  
Winter: greatest warming in the North

The warming is projected to be greatest over Eastern Europe, Scandinavia and the Arctic in **winter** (December to February).

By the end of this century (2071-2100 compared with 1971-2000), annual average land temperature over Europe is projected to increase in the range of 1°C to 4.5°C under a moderate, and 2.5°C to 5.5°C under a high-end scenario of climate change.



The yearly maximum temperature is expected to increase much more in southern and central Europe than in northern Europe. It is estimated that countries in Central Europe may experience the same number of hot days as currently occur in Southern Europe.

The warming is projected to be greatest over South-western and Mediterranean Europe in **summer** (June to August).



## Heat waves



Frequency heat waves continues to increase rapidly

2-3 heat waves per season

The average number of heat waves in Europe increases from one every 3-5 summers in the past (period 1961-1990) to about **2-3 heat waves per season** at the end of this century (2071-2100).

Heat waves 1-8 times as long

The extreme summer heat waves of 2003, 2006, 2007, 2010, 2014 and 2015 are projected to occur as often as **every two years** in the second half of the 21st century **under a high-end scenario of climate change**. The mean **duration** of heat waves may increase by a **factor of between one and eight over most of Europe**. Much higher increases of at least a **factor of seven** are predicted for mean **heat wave intensity**.

Heat wave 2003 still rare

At the end of this century, heat waves with similar or higher severity than observed for the **2003 heat wave remain rather rare**, except for a high-end scenario of climate change.

# Heat waves

Heat kills!



Paris agreement (2015):  
Global warming should be kept below 2 °C above pre-industrial levels, and preferably be limited to 1.5 °C.

Compared with 2 °C warming, limiting global warming to 1.5 °C will result in around 1.7 billion fewer people frequently (every 5 years) exposed worldwide to severe heat waves, and 420 million and 65 million fewer people frequently exposed to extreme heat waves and exceptional heat waves, respectively.

Warming Scenario	Severe heat wave (like Balkans 2007):	Extreme heat wave (like France 2003):	Exceptional heat wave (like Russia 2010):
+ 2 °C			
+ 1.5 °C	1.7 billion fewer people exposed	420 million fewer people exposed	65 million fewer people exposed



For the whole of summer 2003, the number of heat related deaths in Western Europe is believed to amount to over 44,000

