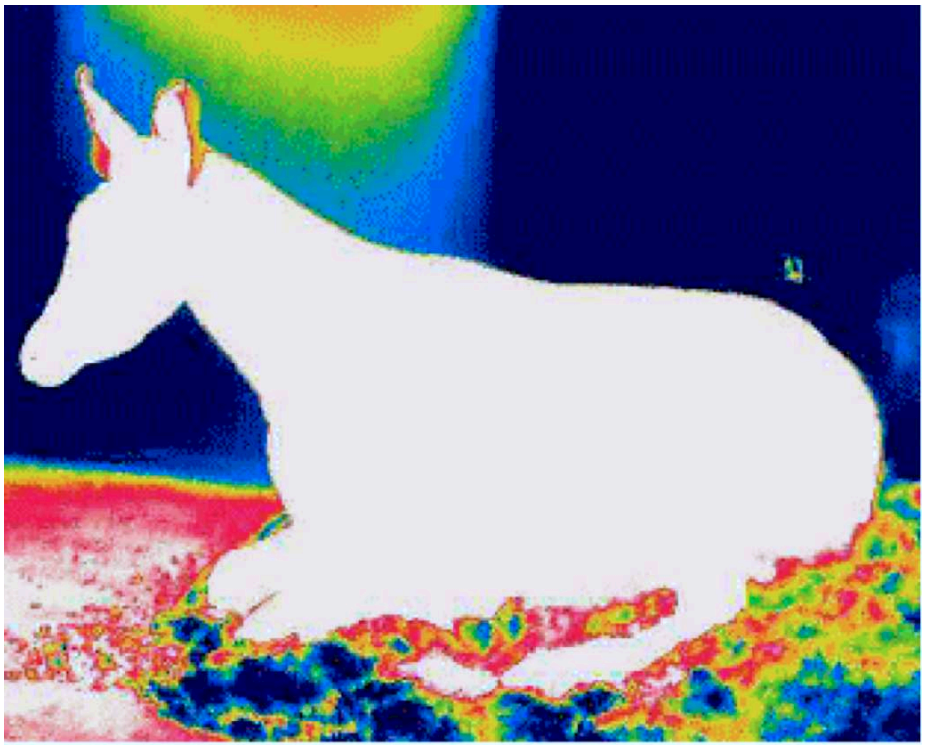
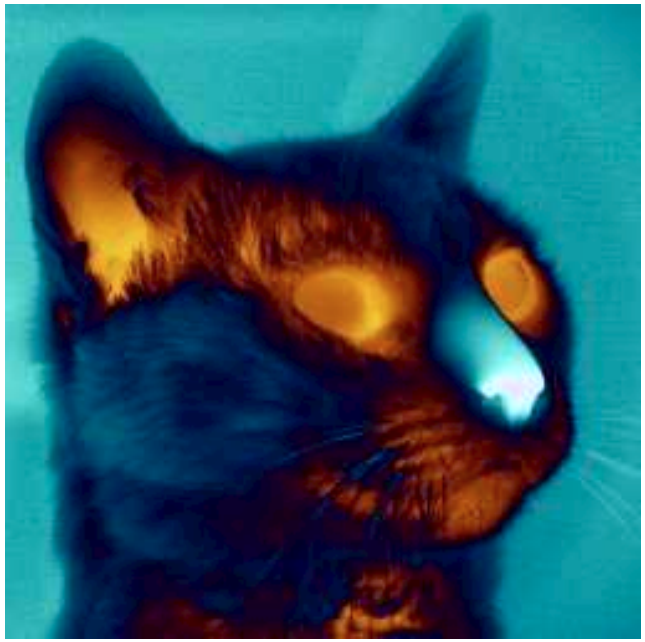
Welcome to ATMS 111 Global Warming

http://www.atmos.washington.edu/2010Q1/111



http://www.seedgen.com/thermallondon/index.html

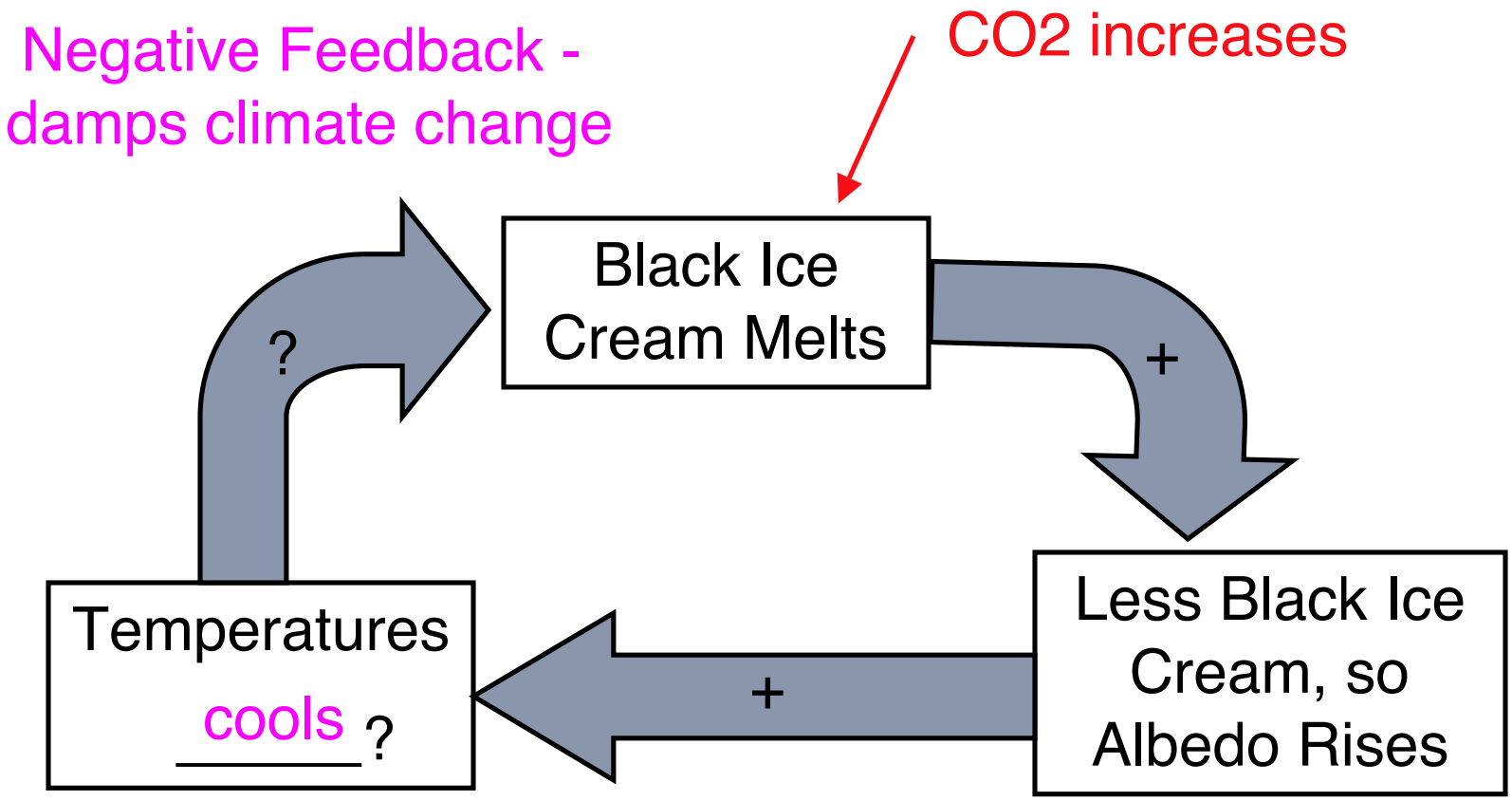


The whole cat is cooled by IR.
Why is the cat's nose
colder than elsewhere?

Evaporation cools
(on Earth too)

Black Carbon on snow
is like a bagel with poppy seeds.
Which one has a higher albedo?

Planet BLIC is covered in Black Licorice Ice Cream



No relation to black carbon, which is a forcing, while this imaginary ice cream is part of a feedback

Part 2 The Symptoms

Extreme heat (RG p. 45-56)

2009-2010: a record of records

The human cost of heat

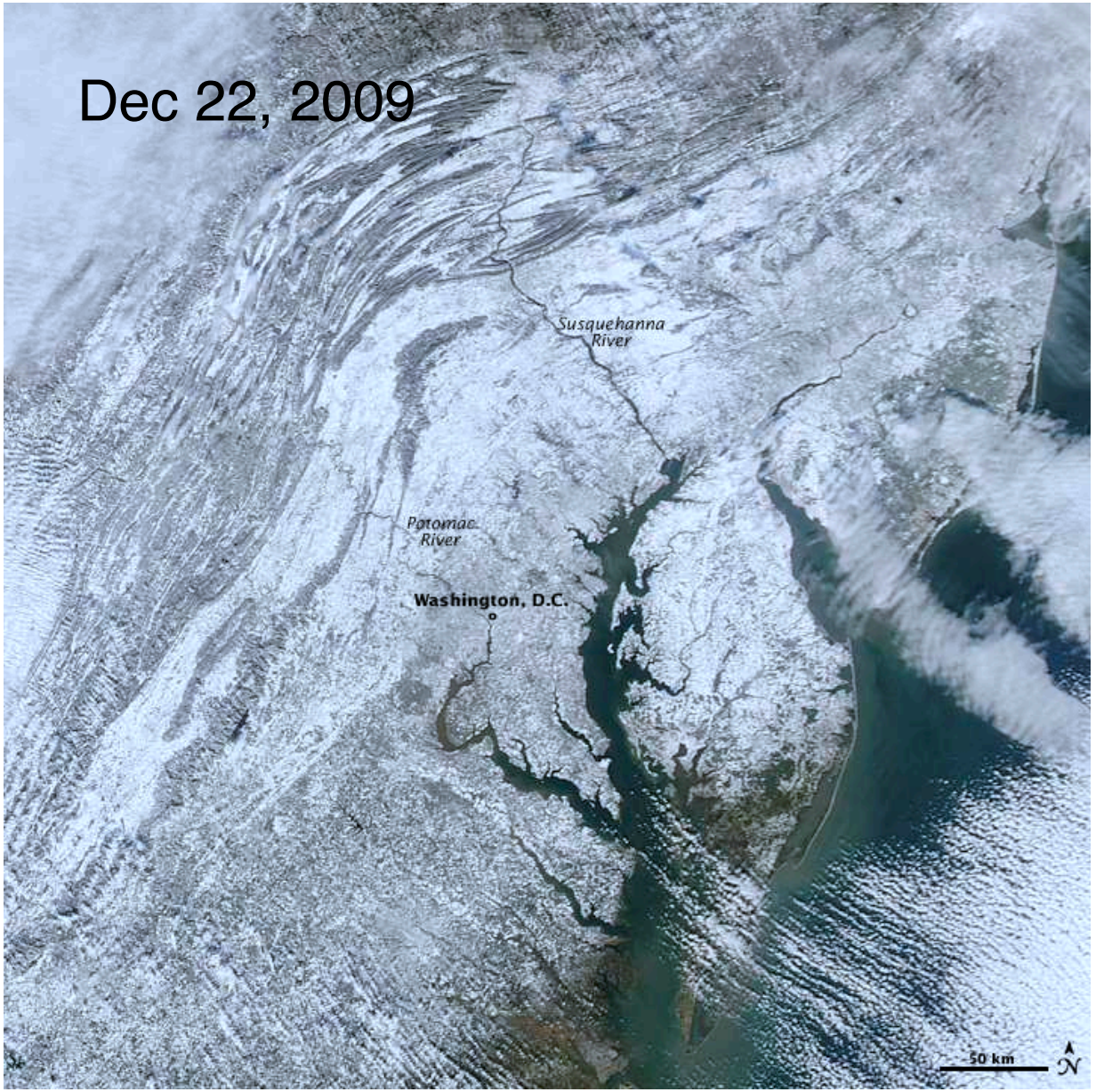
Can record heat waves be attributed to greenhouse warming?

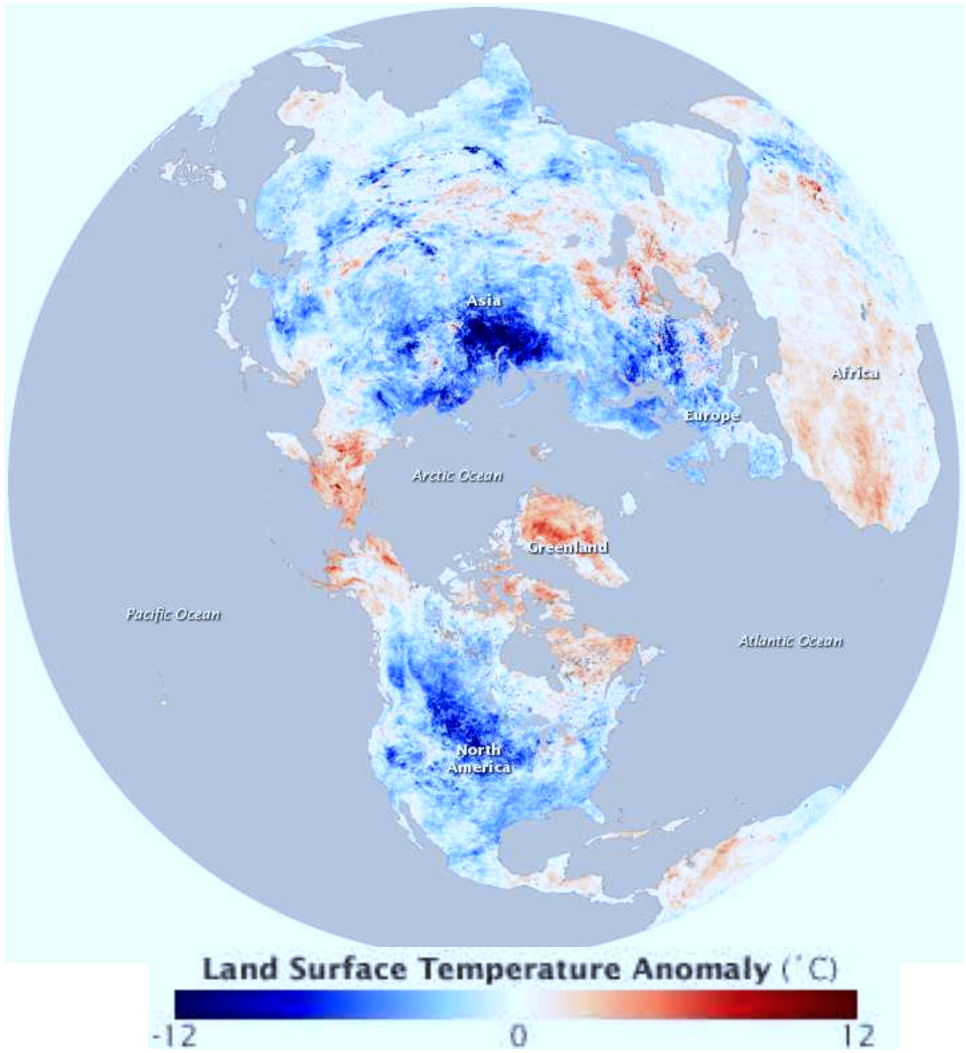
The future of summer sizzle

A wildcard in the Atlantic

Handling the heat

Can this year's record cold be attributed to global cooling?





Dec 2009
anomaly = departure from average

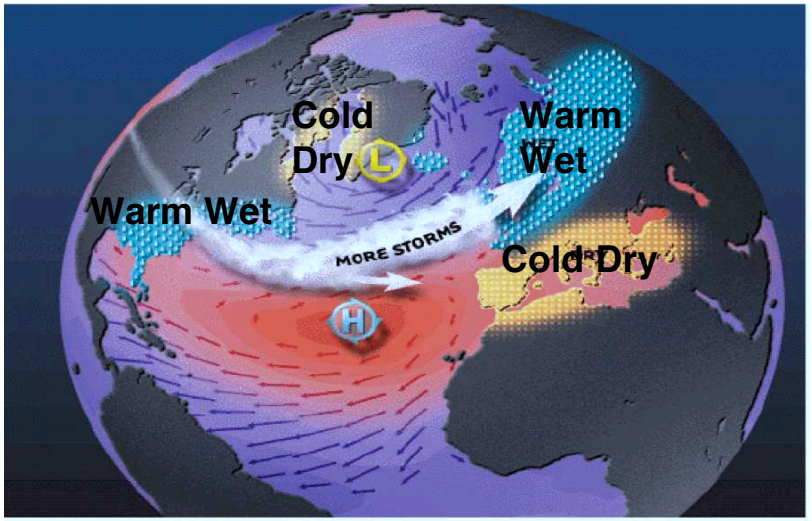
Mark Serreze,
on NPR
last Saturday

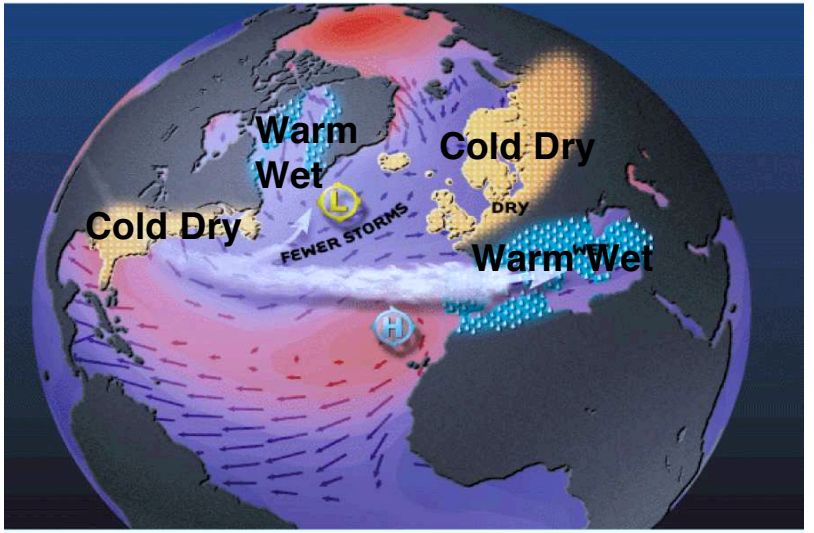
“What we’re seeing has nothing to do with global warming. What we’re seeing is crazy weather.”

Wintertime Atlantic Climate Variability

Wobbling between these two pictures is very common, called the Northern Annular Mode (NAM)

(also called North Atlantic Oscillation, NAO and Arctic Oscillation, AO)





This winter has been more often like this. Note, cold-dry is still moist enough to snow a lot.

Jan 7, London under snow for 14 days

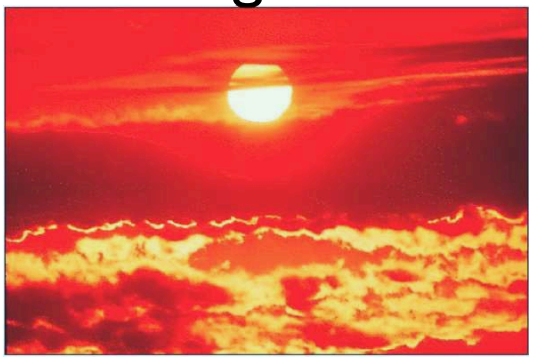
One swallow does not a summer make, neither does one fine day.

Aristotle

Cold records can be set in a year that is warm in comparison to the long-term global-mean climate.

Hence,

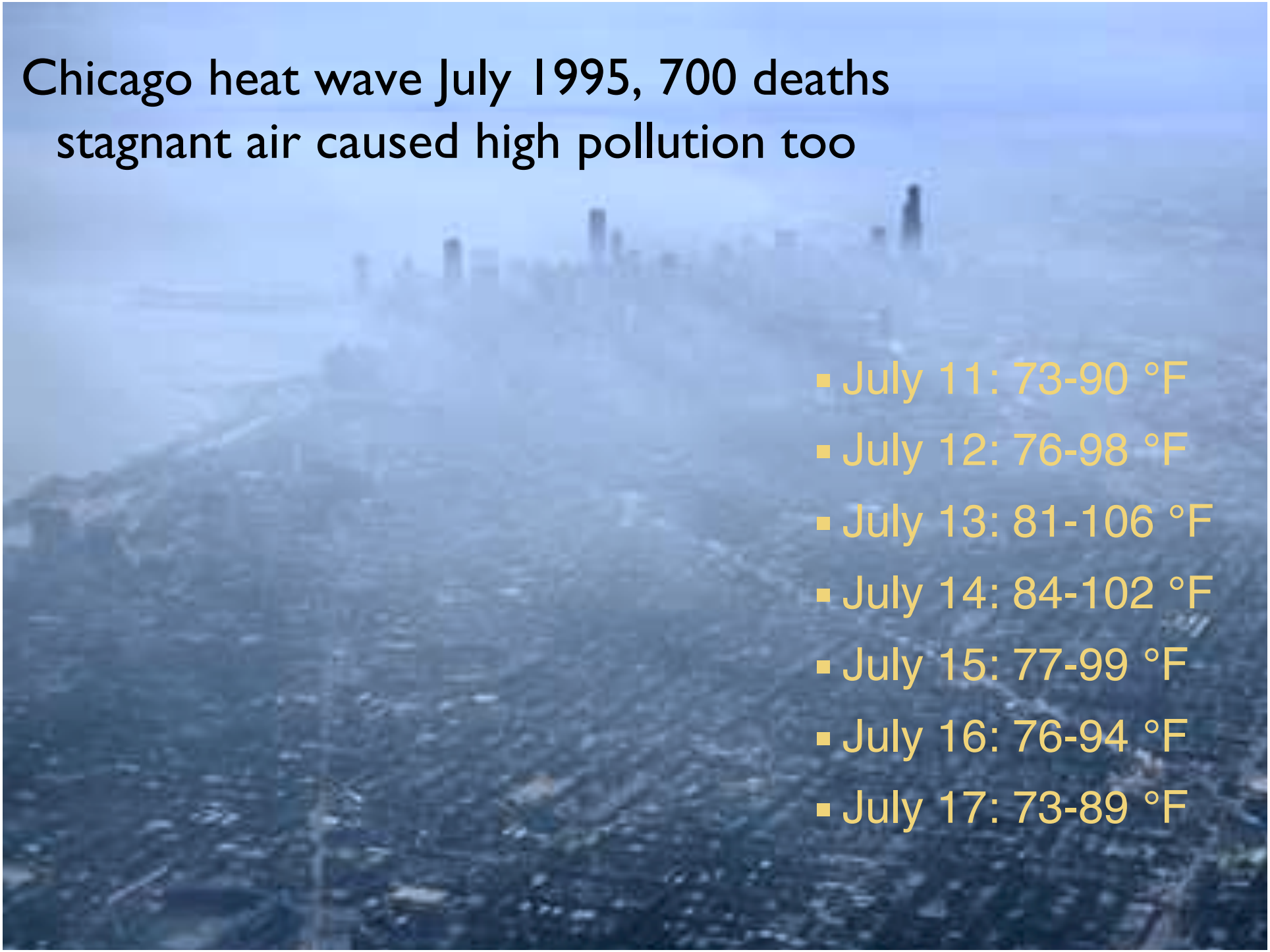
Record heat waves can occur in years in which global-mean temperature is not especially warm.



Warm nights are major problem, as cool night time temperatures are needed relief

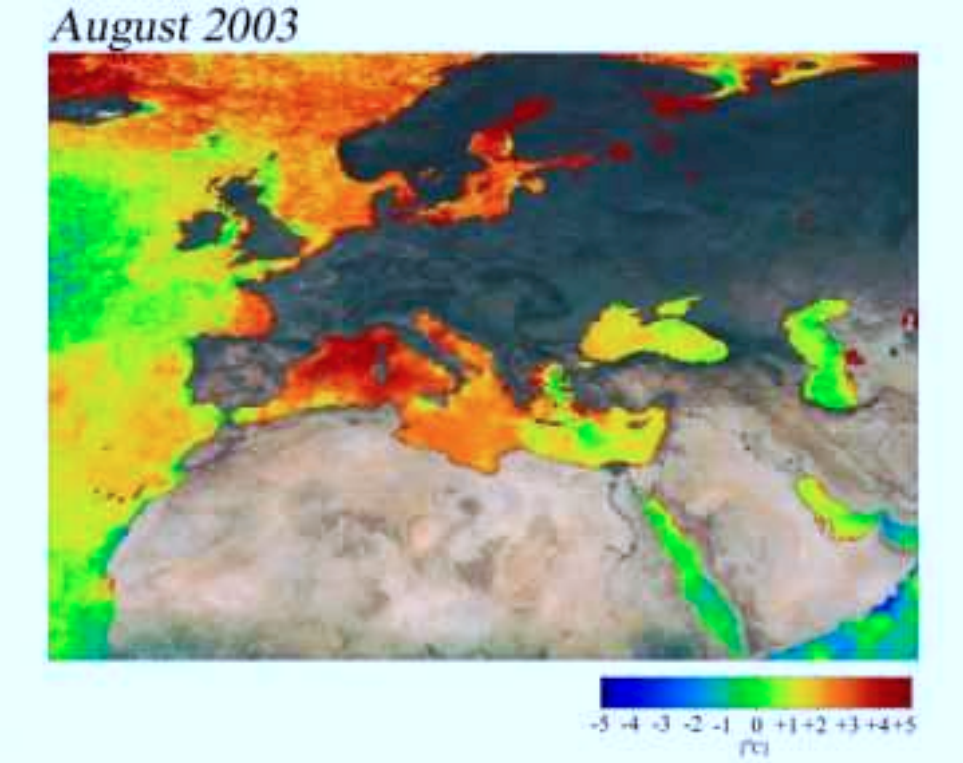
High humidity enhances warming (natural GHE), especially at night when IR dominates temperature (no solar to play a role) recall nights are cool in deserts.

Individual heat waves cannot be attributed to global warming. More about that later in this lecture, but first, let's look at the human health effects of heat waves.


Chicago heat wave July 1995, 700 deaths
stagnant air caused high pollution too
July 11: 73-90 °F
July 12: 76-98 °F
July 13: 81-106 °F
July 14: 84-102 °F
July 15: 77-99 °F
July 16: 76-94 °F
July 17: 73-89 °F

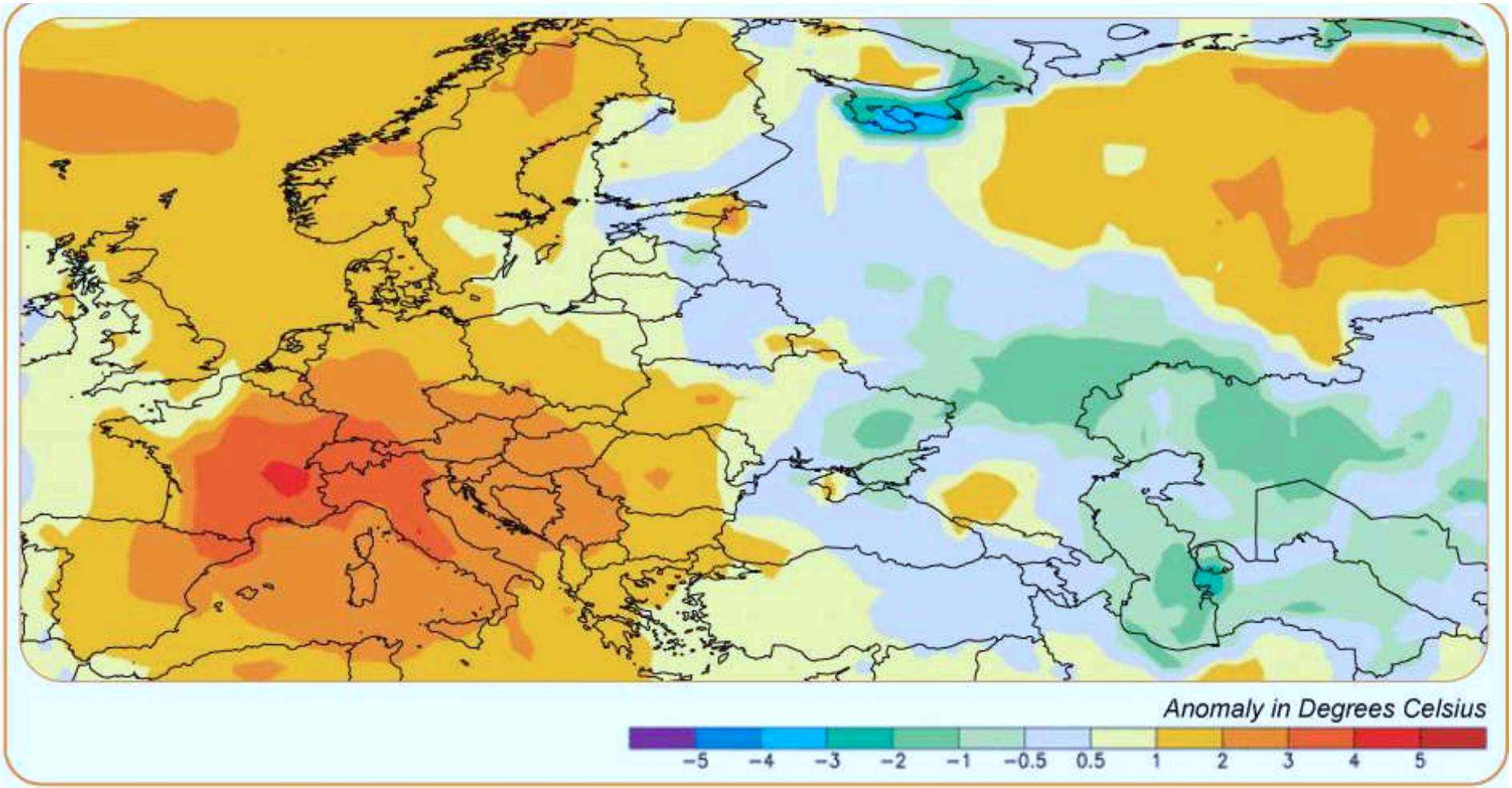
2003: a record of records

The great European heat wave - **50,000 deaths**

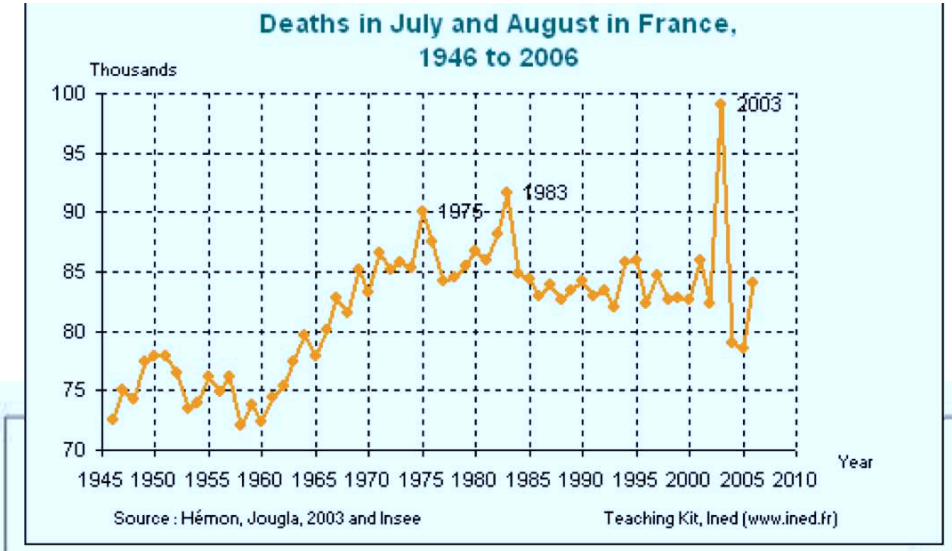


Unusually warm surface ocean temperature

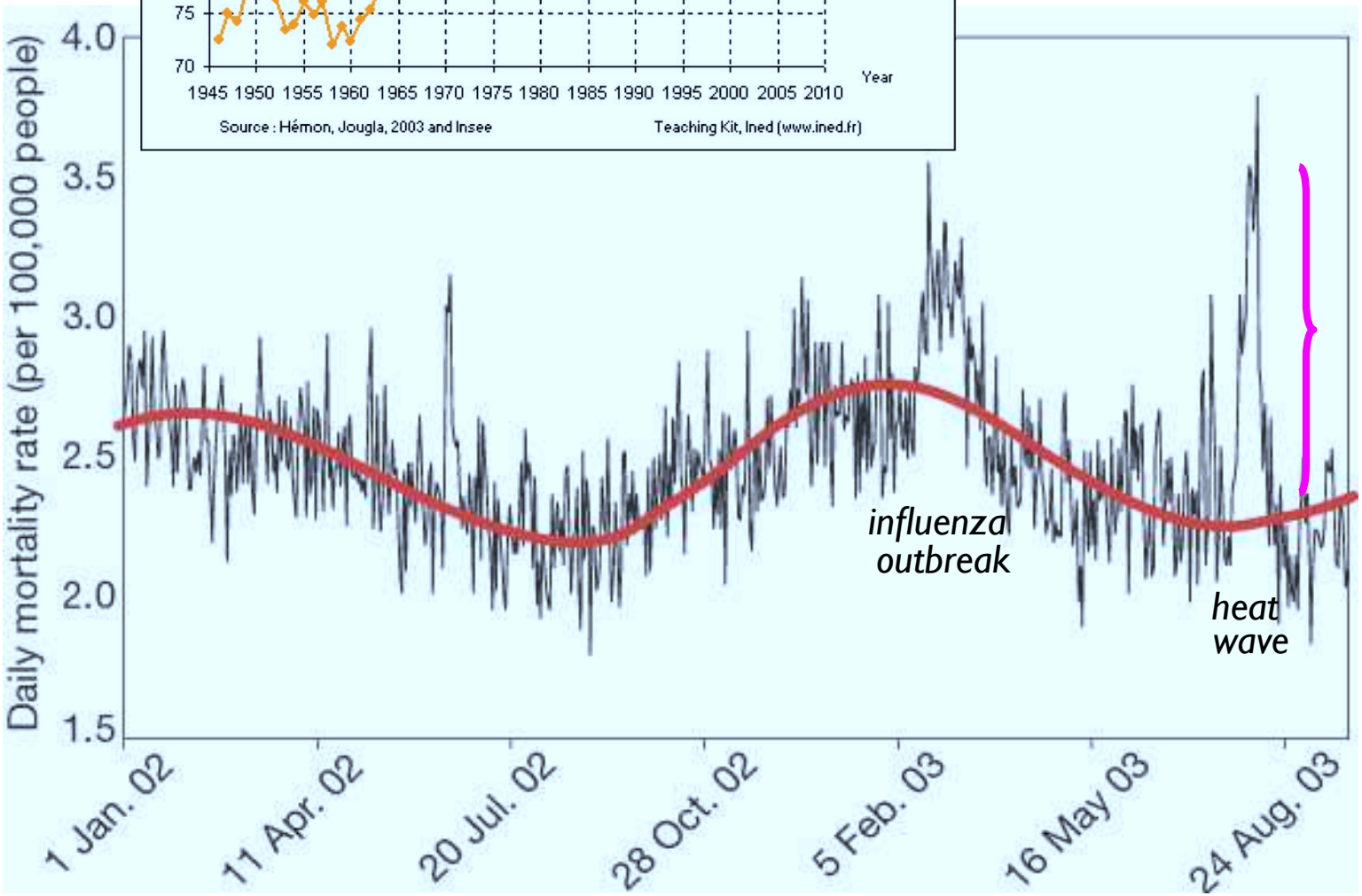
Unusually warm surface air temperature



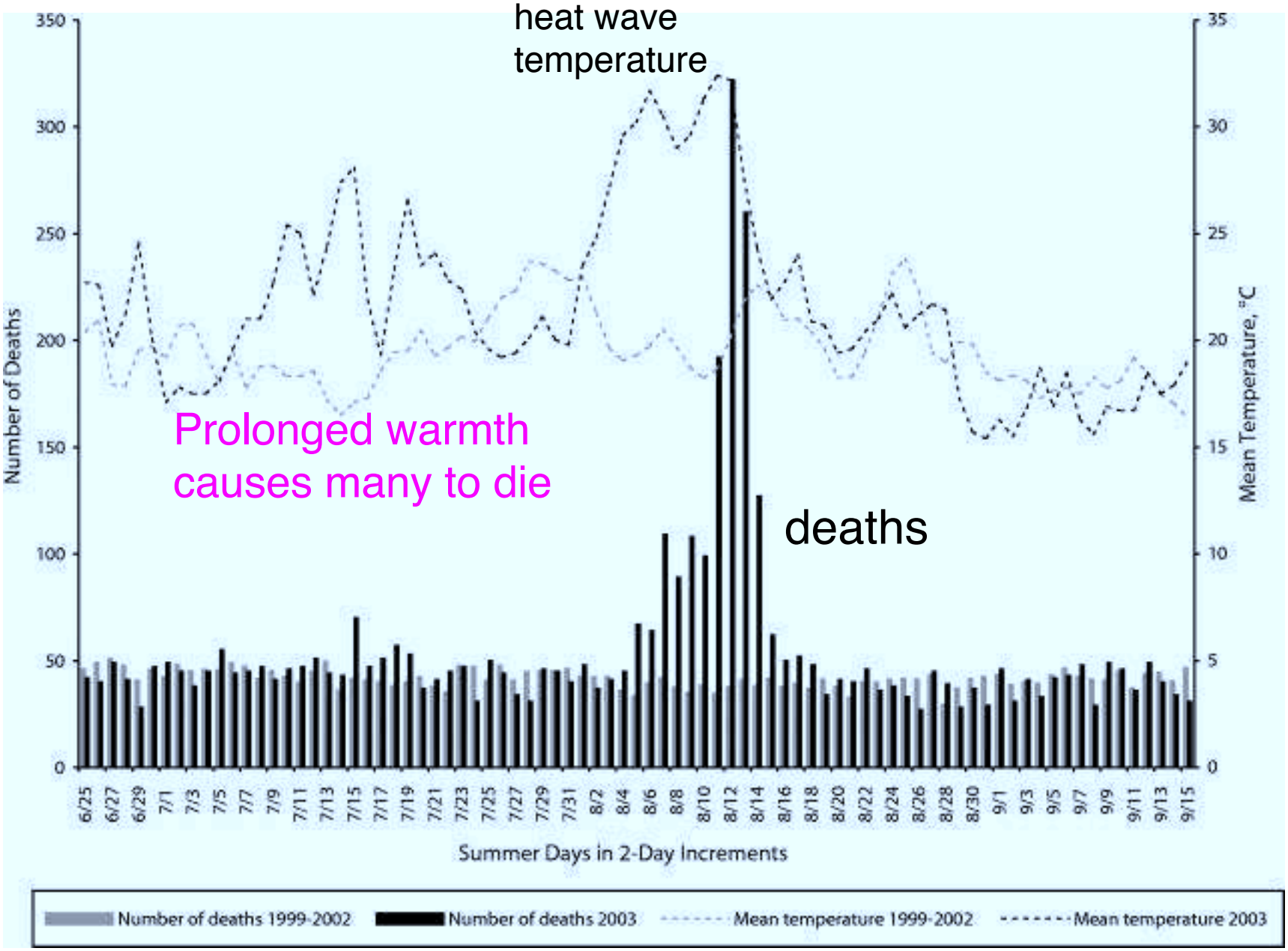
This map, produced from both in situ and satellite information (NDC/NOAA), shows the extreme deviation from the average as recorded from June to August 2003. In some areas the difference exceeds 4°C. Climatological base period is 1988-2003.



small dip after heat wave means 20-30% of peak were fated to die shortly



daily mortality rate in Baden-Württemberg, Germany


heat wave
temperature
Prolonged warmth
causes many to die
deaths
Number of Deaths
Mean Temperature, °C
Summer Days in 2-Day Increments
Number of deaths 1999-2002
Number of deaths 2003
Mean temperature 1999-2002
Mean temperature 2003

Paris 2003

2003 heat wave in India

BBC article June 3, 2003

- At least 1065 heat-related deaths in state of Andhra Pradesh
- Similar occurrence a year earlier
- Most fatalities people over 50 but some children
- People urged to stay indoors during daytime
- Keep heads and ears covered with cloth
- Temperatures much above normal

Record high 51.3°C (124°F)

May, early June, pre-monsoon

Seattle, July 2009, 4-day heat wave (above 90 F)

July 29 all time records broken at SeaTac

71 F highest minimum nighttime temp
103 F highest temp

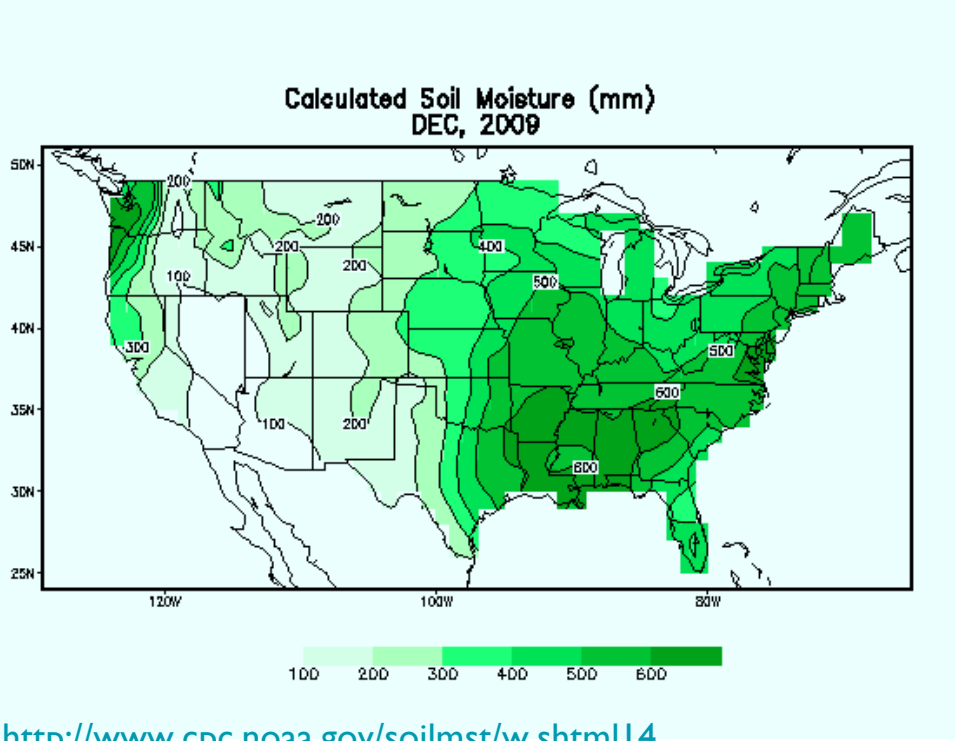
Dozens of cooling centers were opened

1 death

Office of the Washington State Climatologist

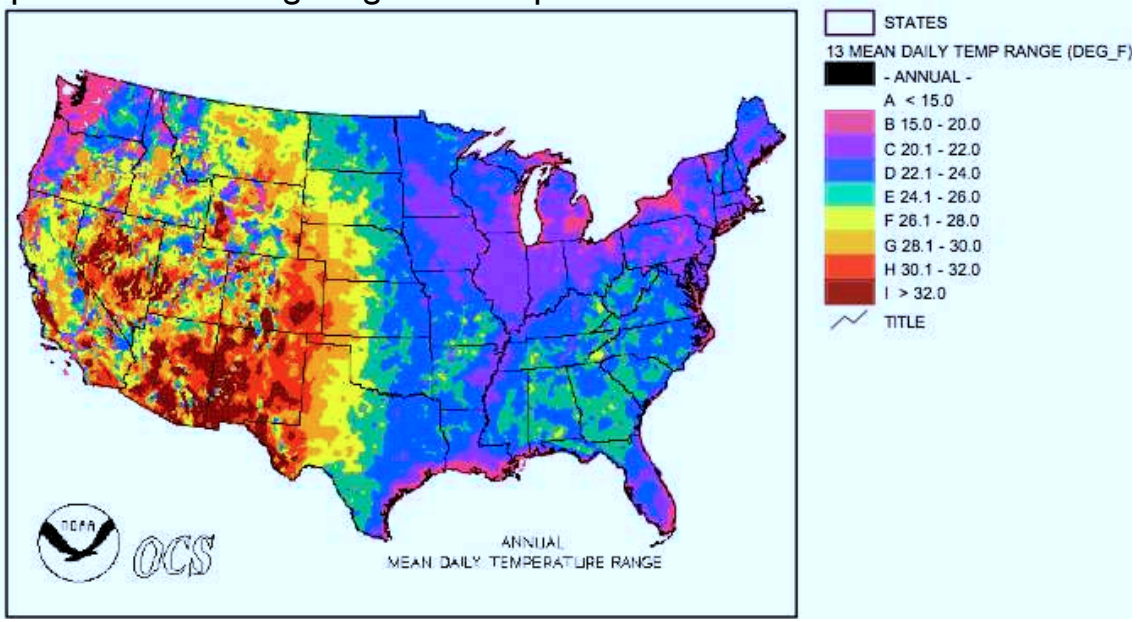
Dessert climates (low soil moisture) have high daily temperature range

We share small daily temperature range with half the country where heat waves are common. These regions often have high nighttime temperatures



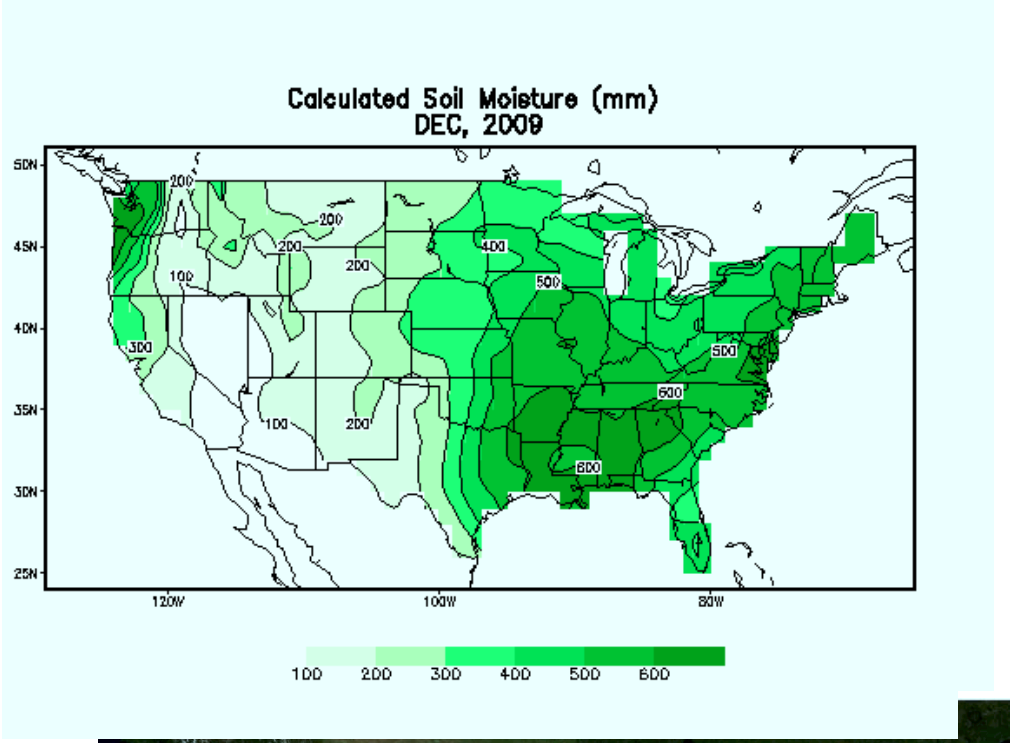
http://www.cpc.noaa.gov/soilmst/w.shtml14

http://cdo.ncdc.noaa.gov/cgi-bin/climaps



Forests Recycle Moisture

High soil moisture -> high evaporation -> high humidity/rainfall -> forest growth -> back to start



July Vegetation from MODIS

Hyperthermia, in its advanced state referred to as **heat stroke** or **sunstroke**, is an acute condition which occurs when the body produces or absorbs more heat than it can dissipate. Hyperthermia is a medical emergency which requires immediate treatment.

Why do some cities fare better?

High population density is a benefit because people help each other.

Air conditioning

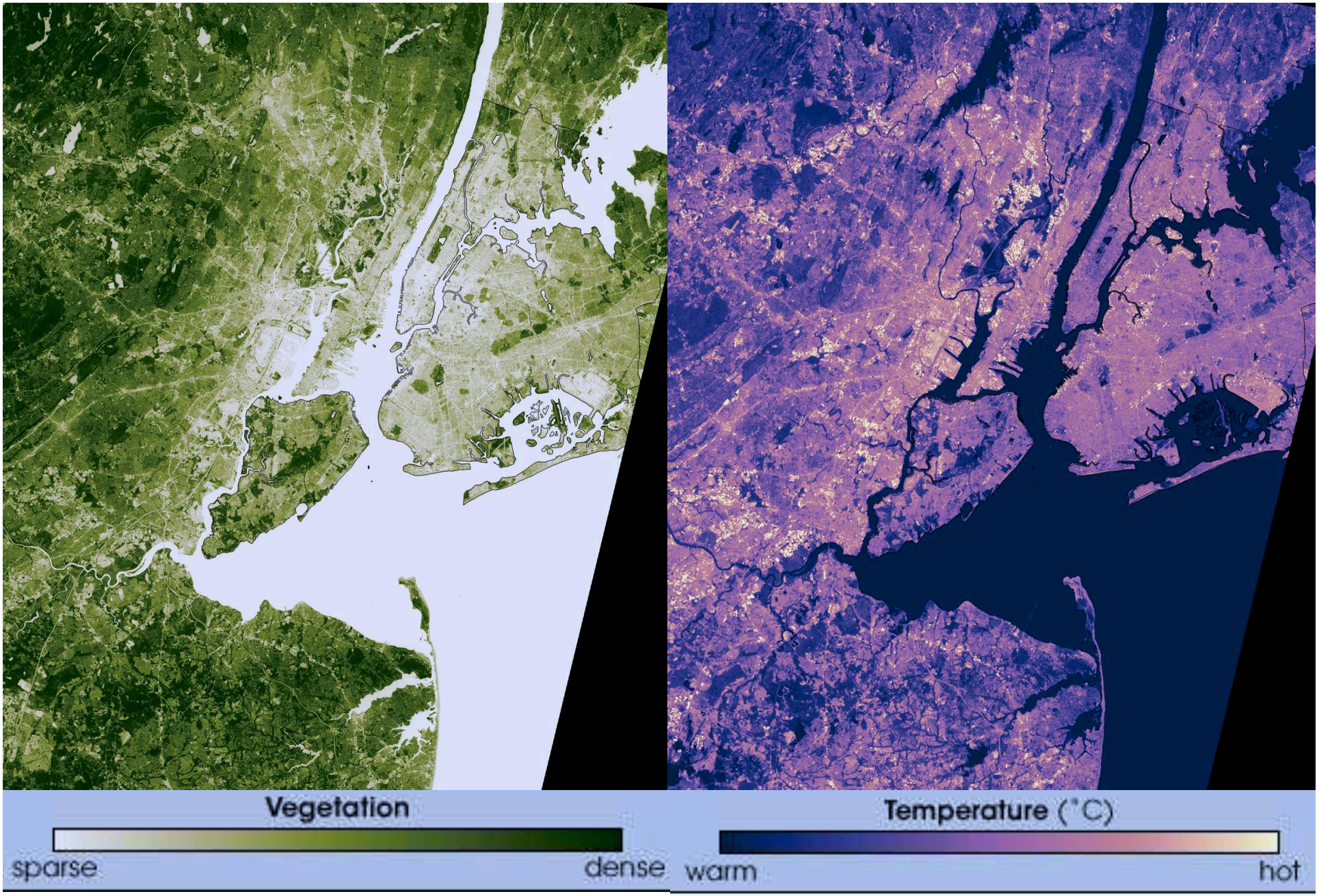
Social planning

Can record heat waves be attributed to greenhouse warming?

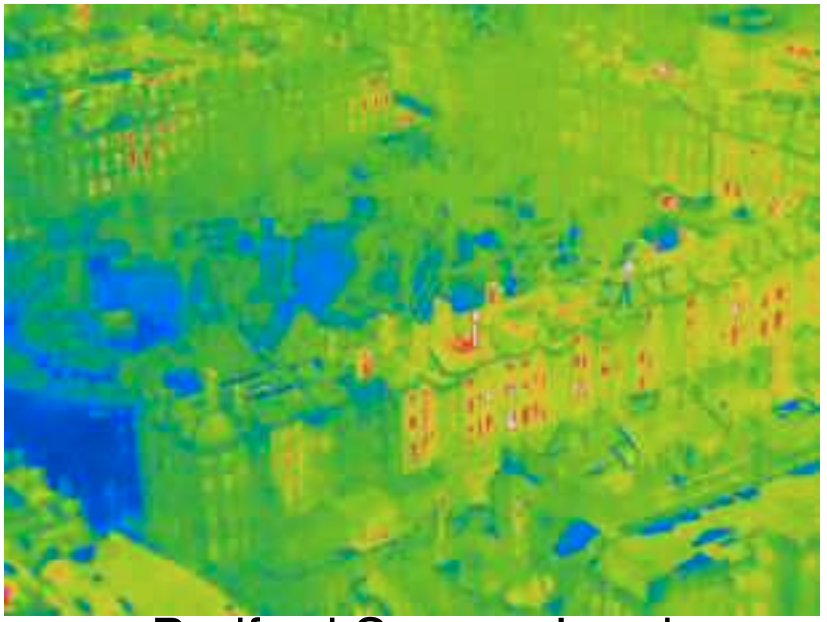
No, but greenhouse warming can increase the likelihood of heat waves.

Plus buildings cause **urban heat islands**

New York City, one day in summer 2002

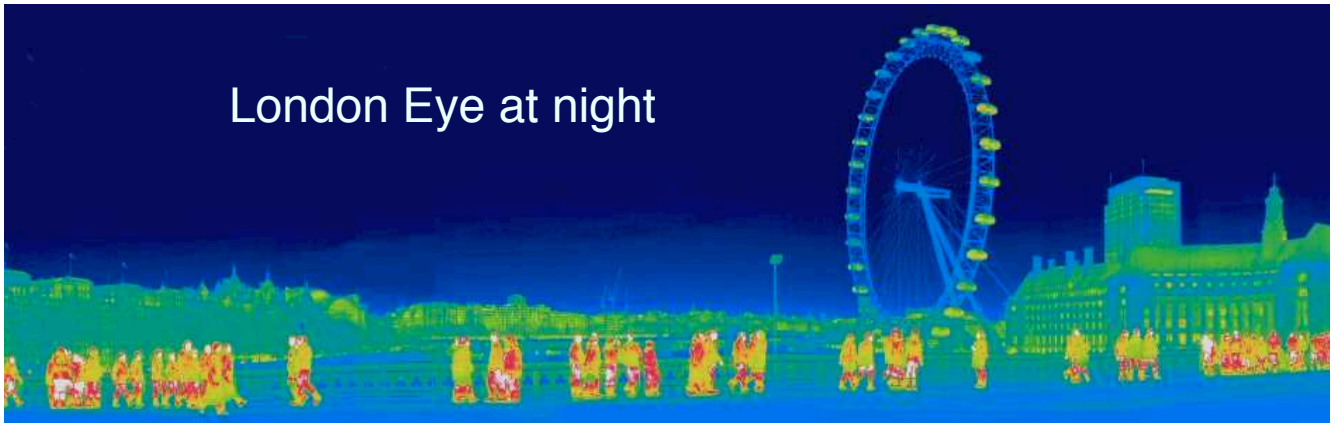


Buildings act like low clouds
to return IR back towards surface



Bedford Square, London
greenspace in square

Here
pink=hottest
blue=coolest



http://www.seedgen.com/thermallondon/

Urban Heat Island

Bigger effect at night, when air is stagnant

Doesn’t occur over ocean

Thermometry records strongly corrupted by it are not used to compute global mean temperature

Other records are corrected

Attribution of temperature extremes to global warming

Actual Temperature =

Natural climate influence on Temperature +

Human influence on Temperature

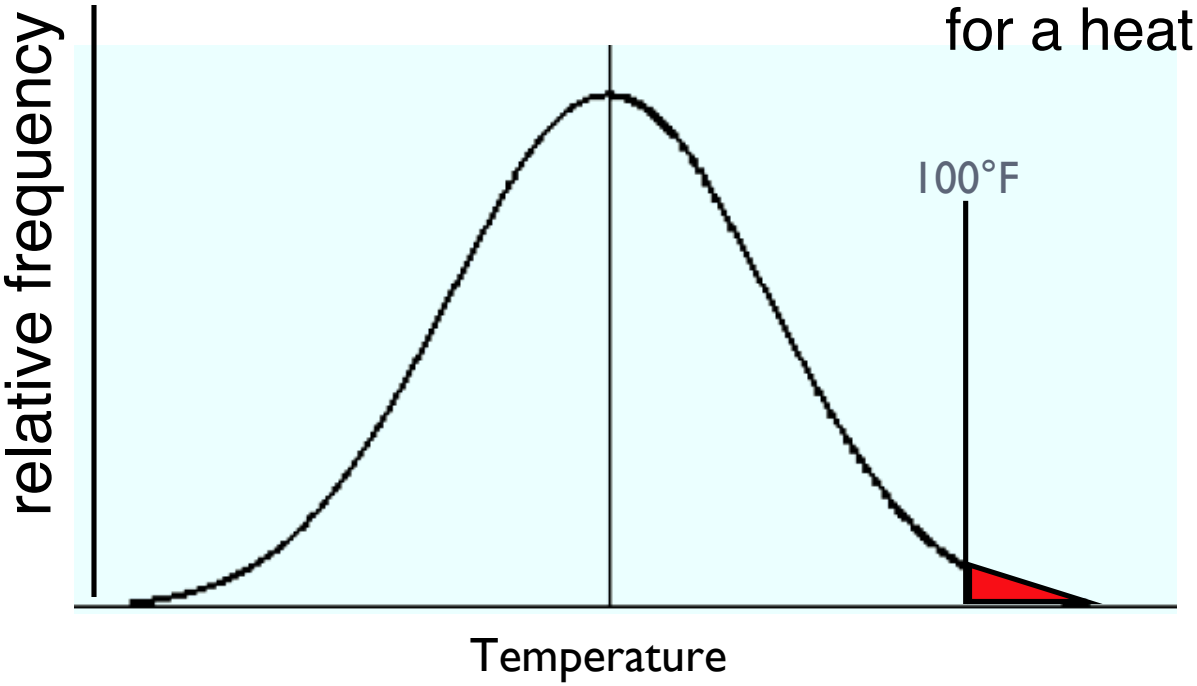
The latter is now ~0.7°C

Could grow to 2°C or more by 2100

The natural range may be quite large compared to human influence depending on averaging area

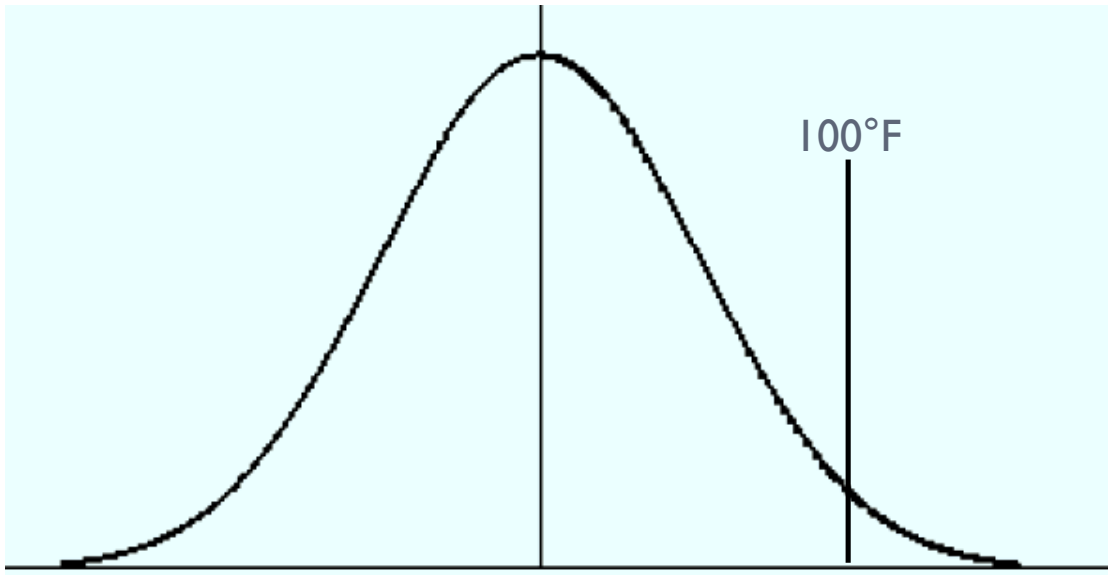
Histogram or "frequency distribution" of daily maximum temperature gives the natural range

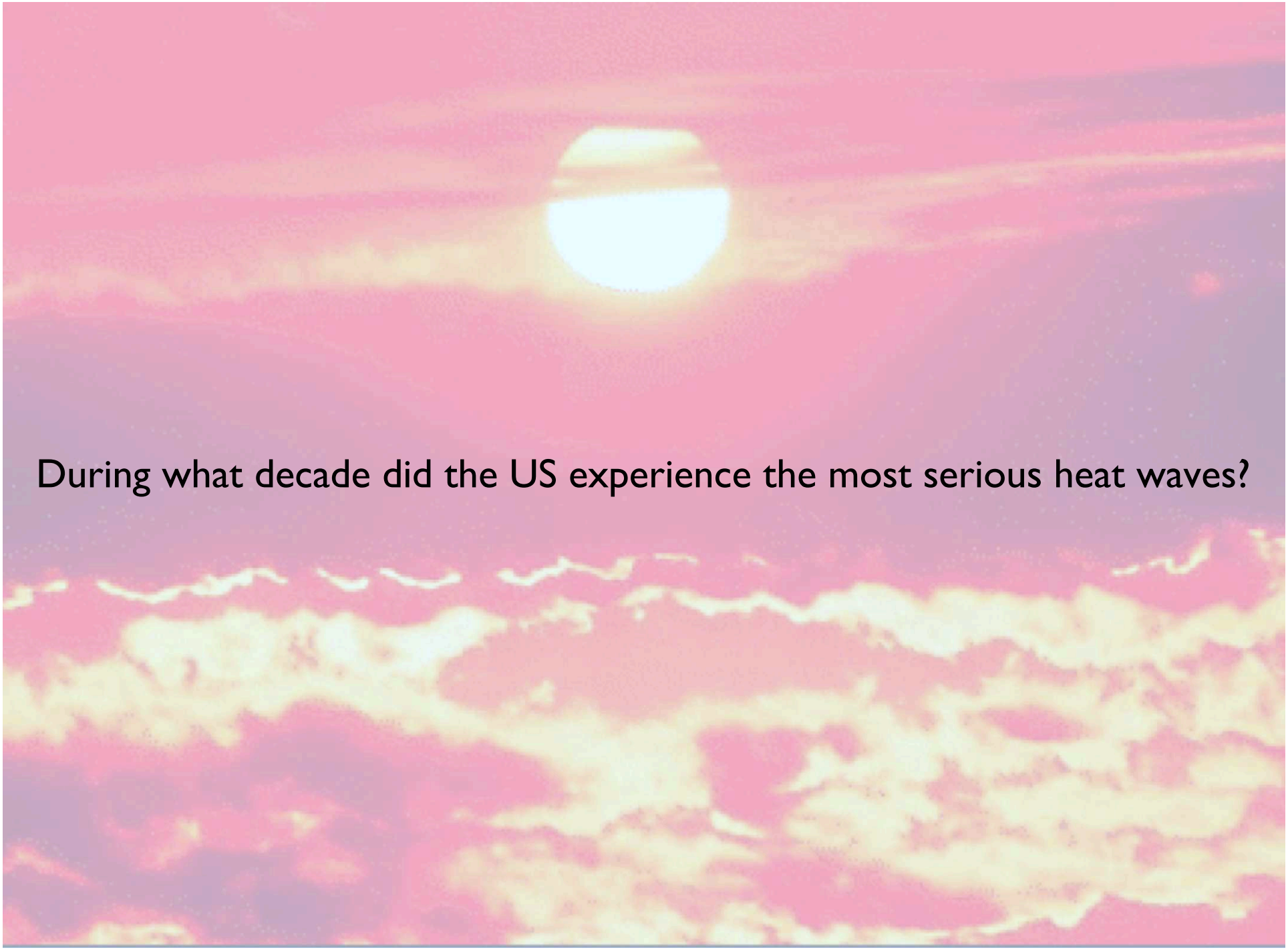
Let 100° F
be the threshold
for a heat wave

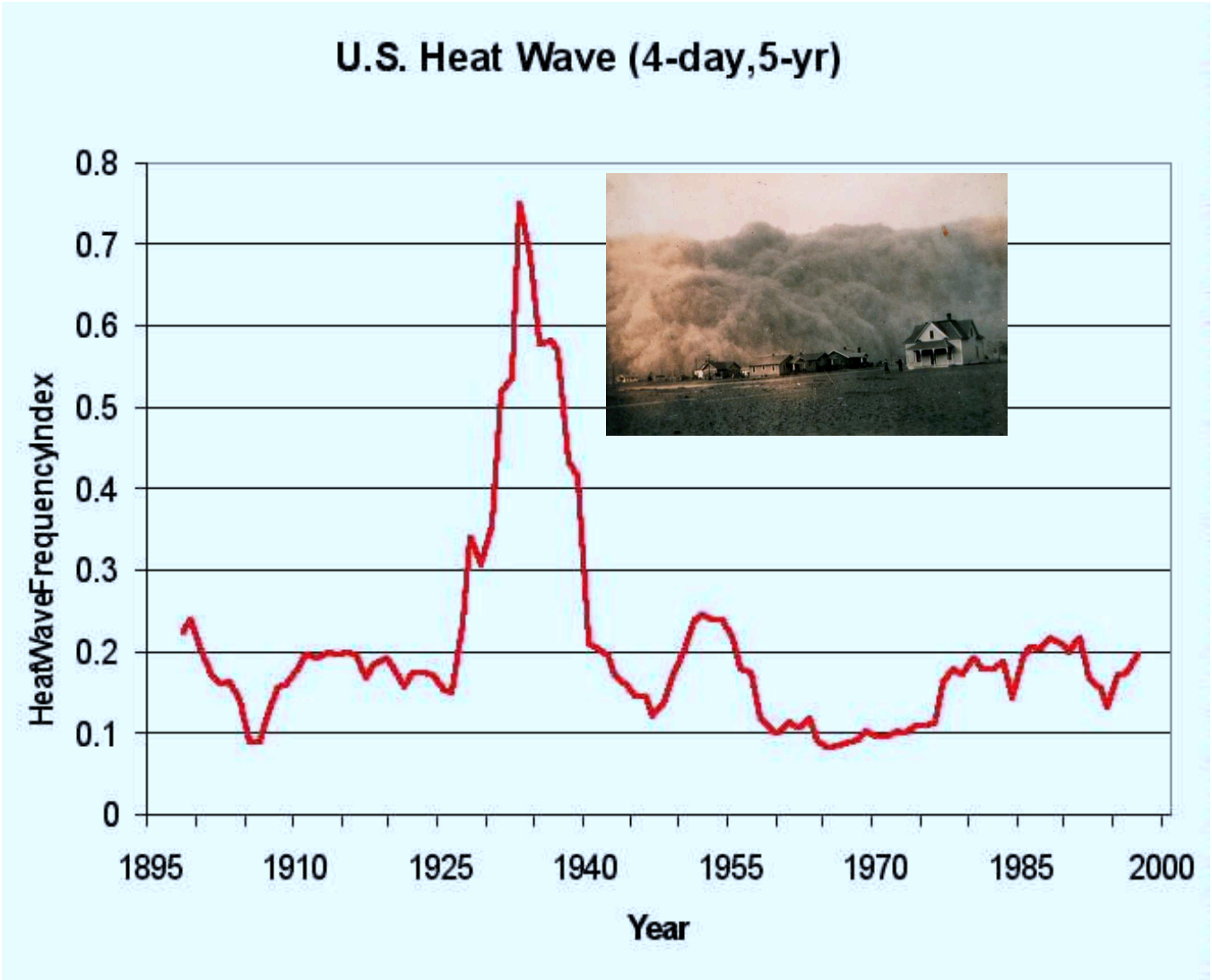


The chance of one occurring is the area in red divided by total area under the curve

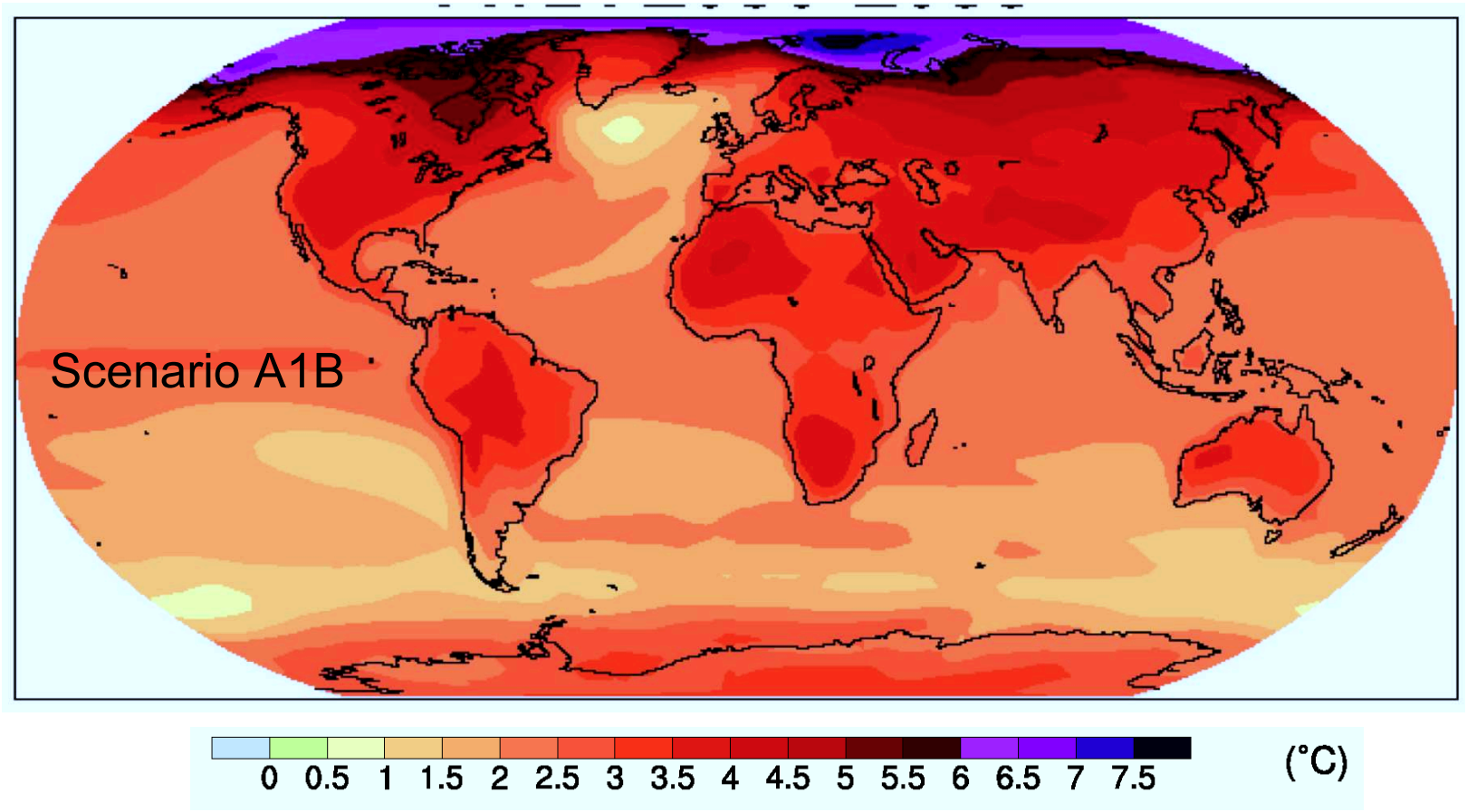
Global warming makes the peak approach the threshold, or the chance of a heat wave much more probable




During what decade did the US experience the most serious heat waves?


U.S. Heat Wave (4-day,5-yr)
HeatWaveFrequencyIndex
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1895
1910
1925
1940
1955
1970
1985
2000
Year

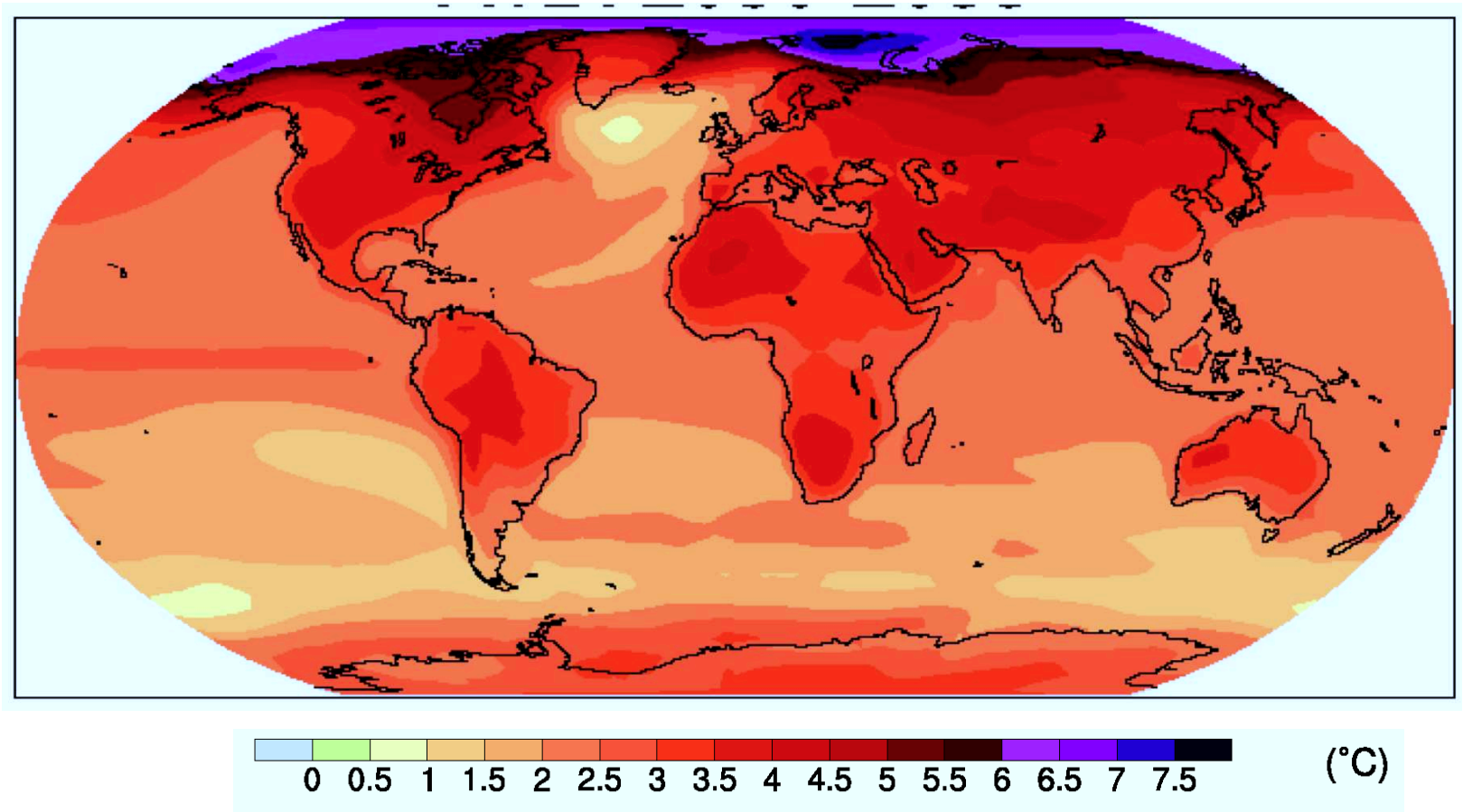
Projected Annual Average Surface Temperature Change: "2080-2099" minus "1980-1999"



Average of 21 climate models forced by Scenario A1B.
Multiply by ~1.2 for A2 and ~0.7 for B1

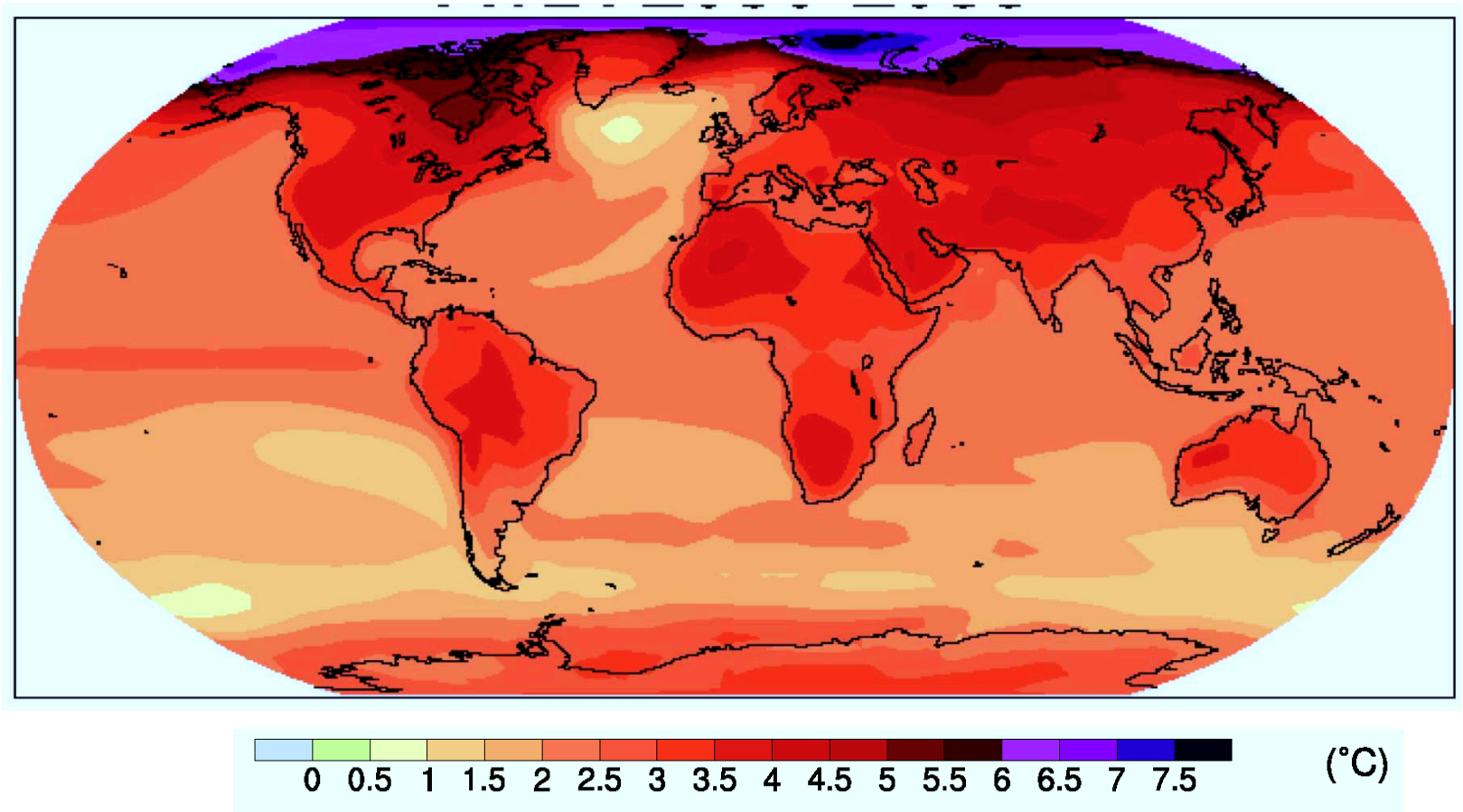
Anomaly = departure from a reference

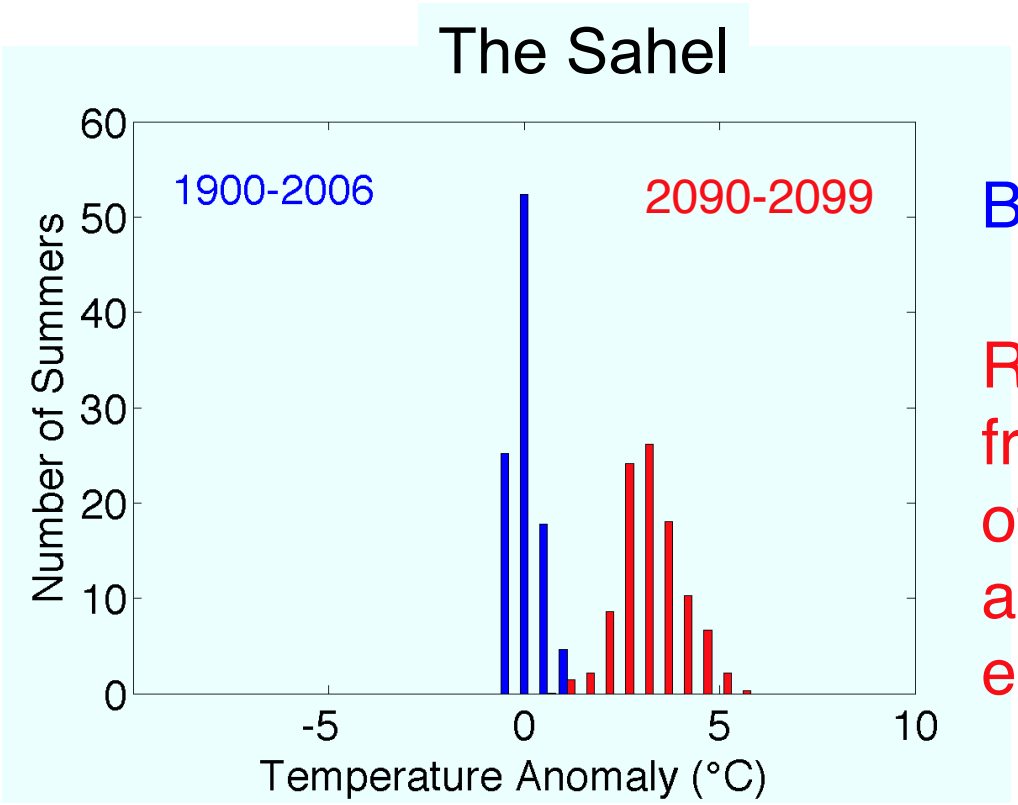
Example of an anomaly: Surface temperature
"2080-2099" minus "1980-1999"



Ensemble average = average of many samples

In this case the samples are individual models. The goal is to remove the natural climate variability and individual model errors from the mean.

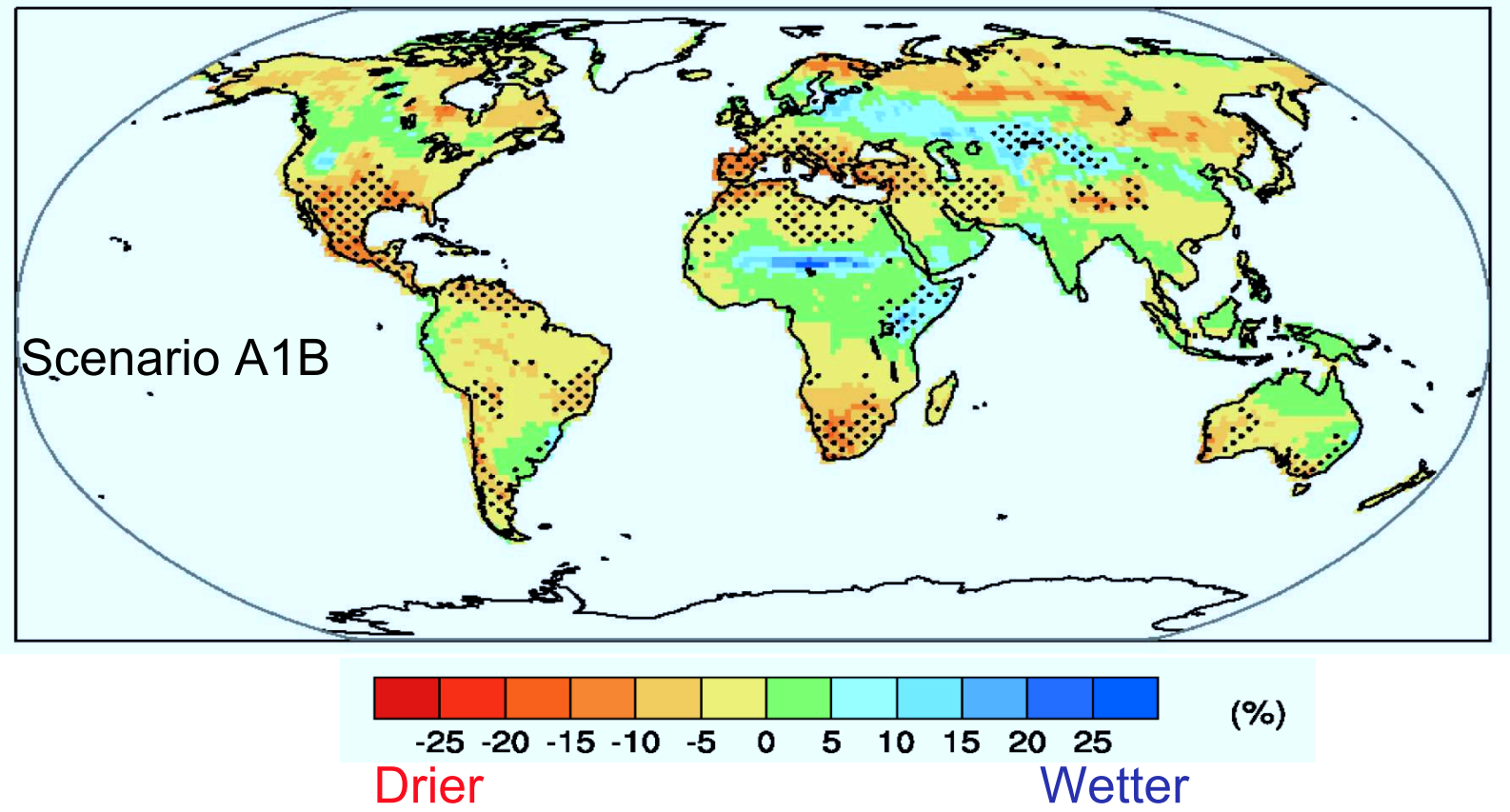




Blue = observations

Red = projections from an ensemble of models to accumulate ~100 estimates

Projected Soil Moisture Change: "2080-2099" minus "1980-1999"



drying -> even higher daytime temperature

moistening -> even higher nighttime temperatures

The future of summer sizzle

- the worst heat waves will be more intense
- heat waves of a prescribed intensity will occur more frequently
- some regions may become more susceptible to heat waves
- shift toward higher daytime summer temperatures
- vegetated land may give way to desert.

Floods and droughts (RG p. 58-74)

Floods and droughts: two sides of a catastrophic coin

A wetter world (but not everywhere)

Are floods increasing?

Defining drought

What do the oceans have to do with drought?

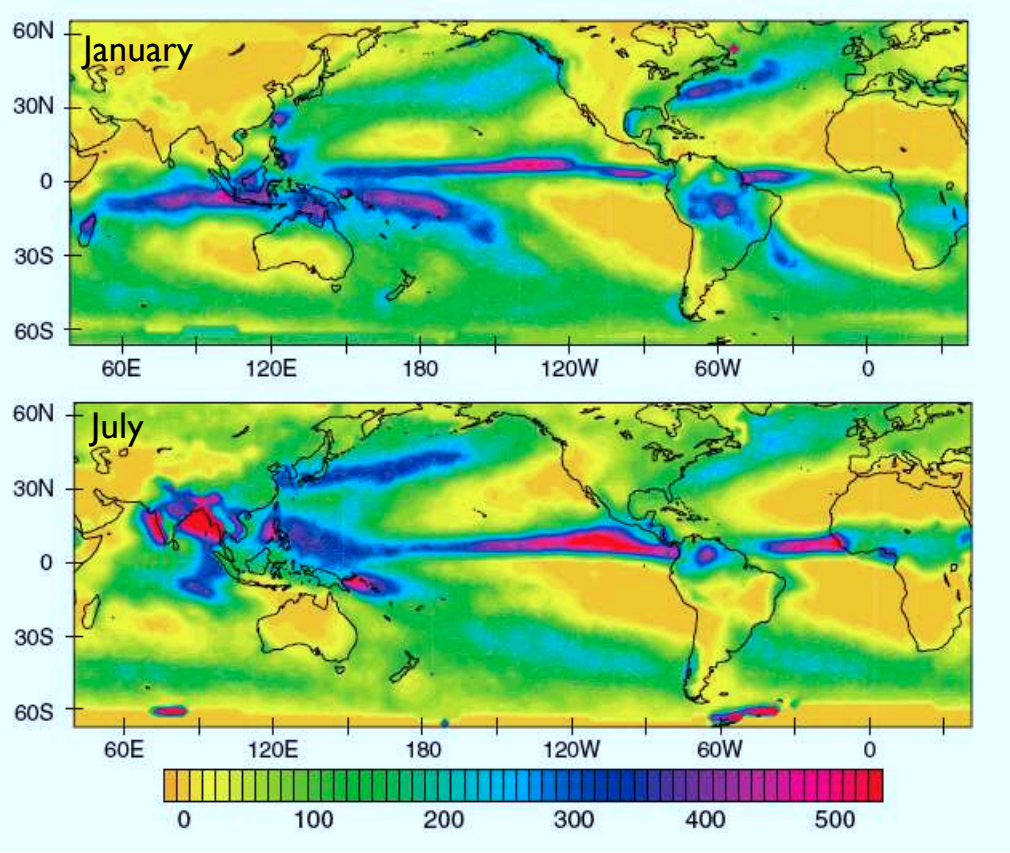
The drying of southern Australia

The plough and its followers: farming and rainfall

Floods and droughts: two sides of a catastrophic coin

How will global warming affect rainfall?

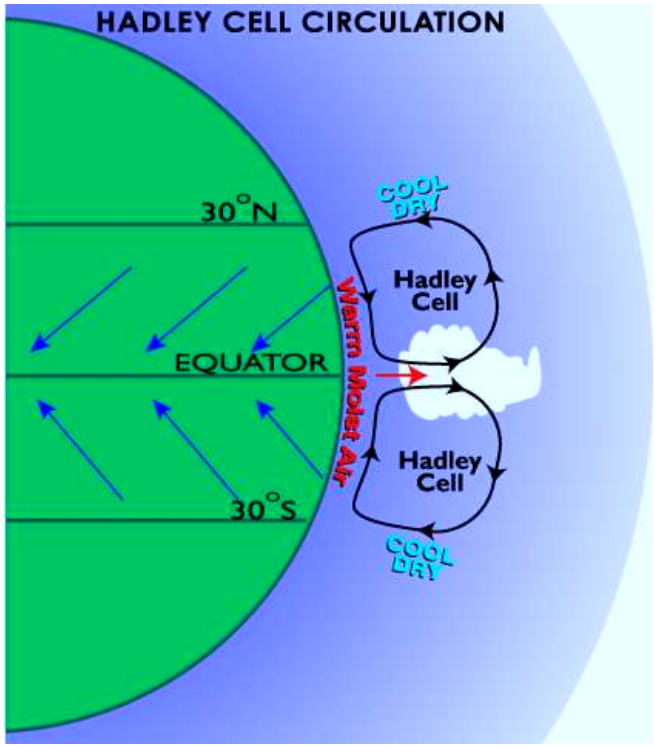
Wet regions become wetter while dry regions become drier

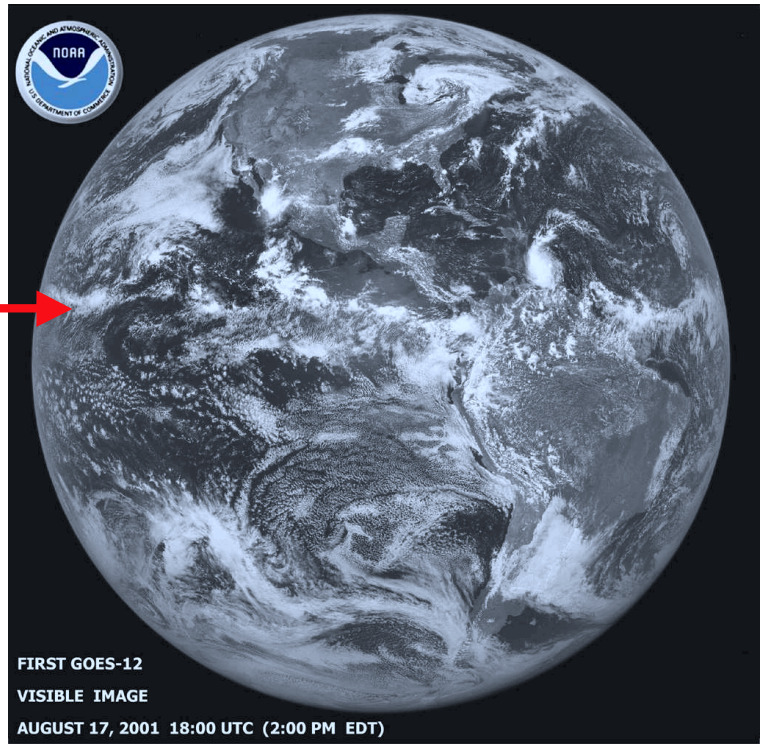


Observed Precipitation in mm/yr

Hadley Circulation

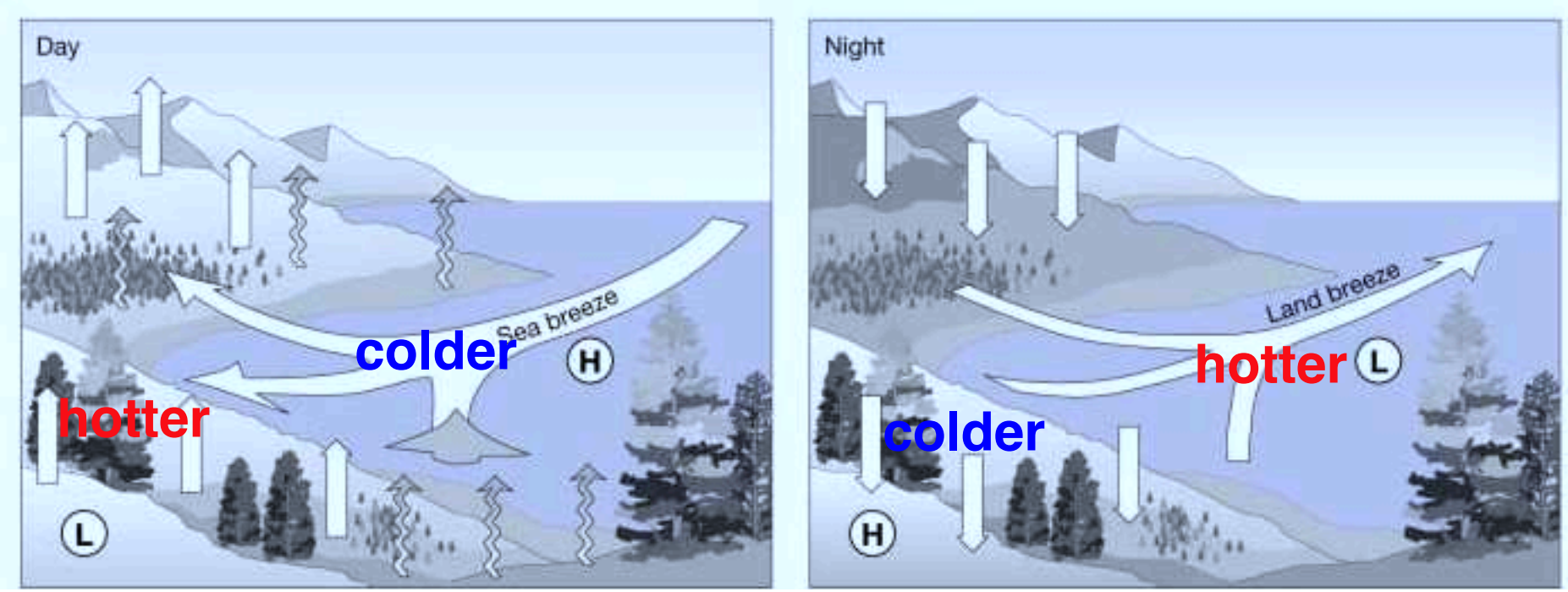
Air rises above the warmest ocean surface
Creates the InterTropical Convergence Zone ITCZ





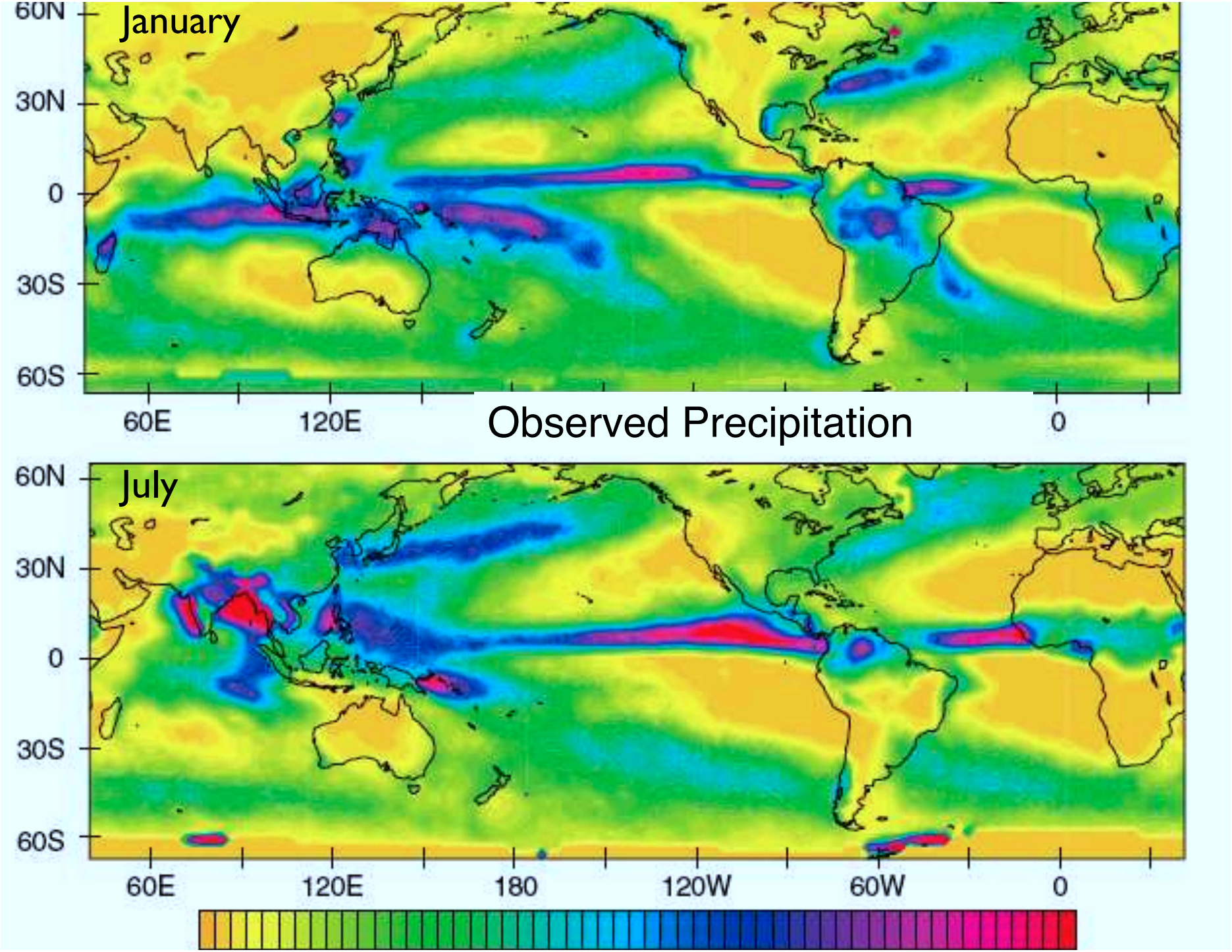
The ITCZ moves a few degrees into the NH during our summer

Monsoon Circulation

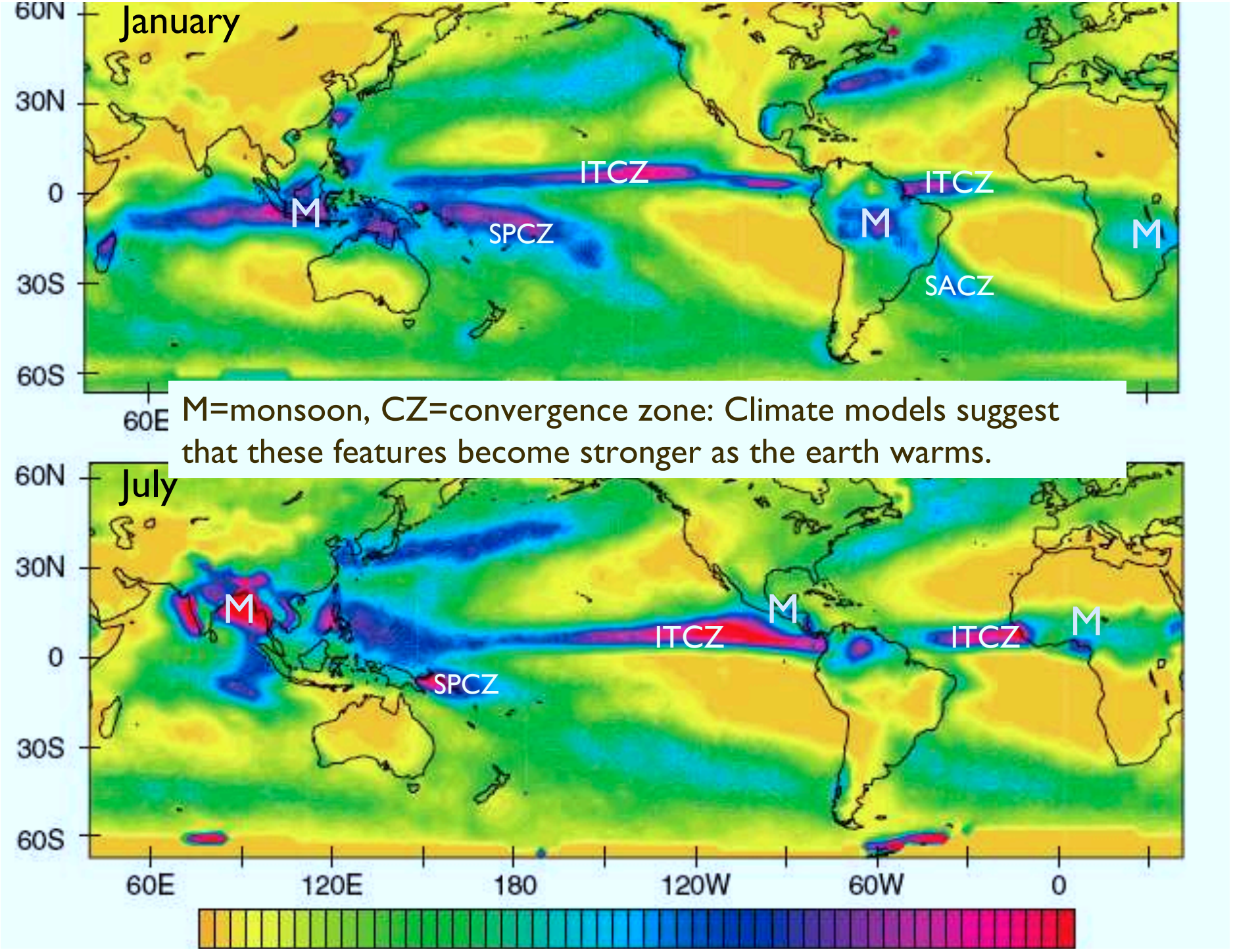


Differential heating of land and sea is key

Daily = “Sea Breeze” caused by daily solar cycle
Seasonally = Monsoon (a persistent version of the sea breeze) caused by seasonal solar cycle



Observed Precipitation

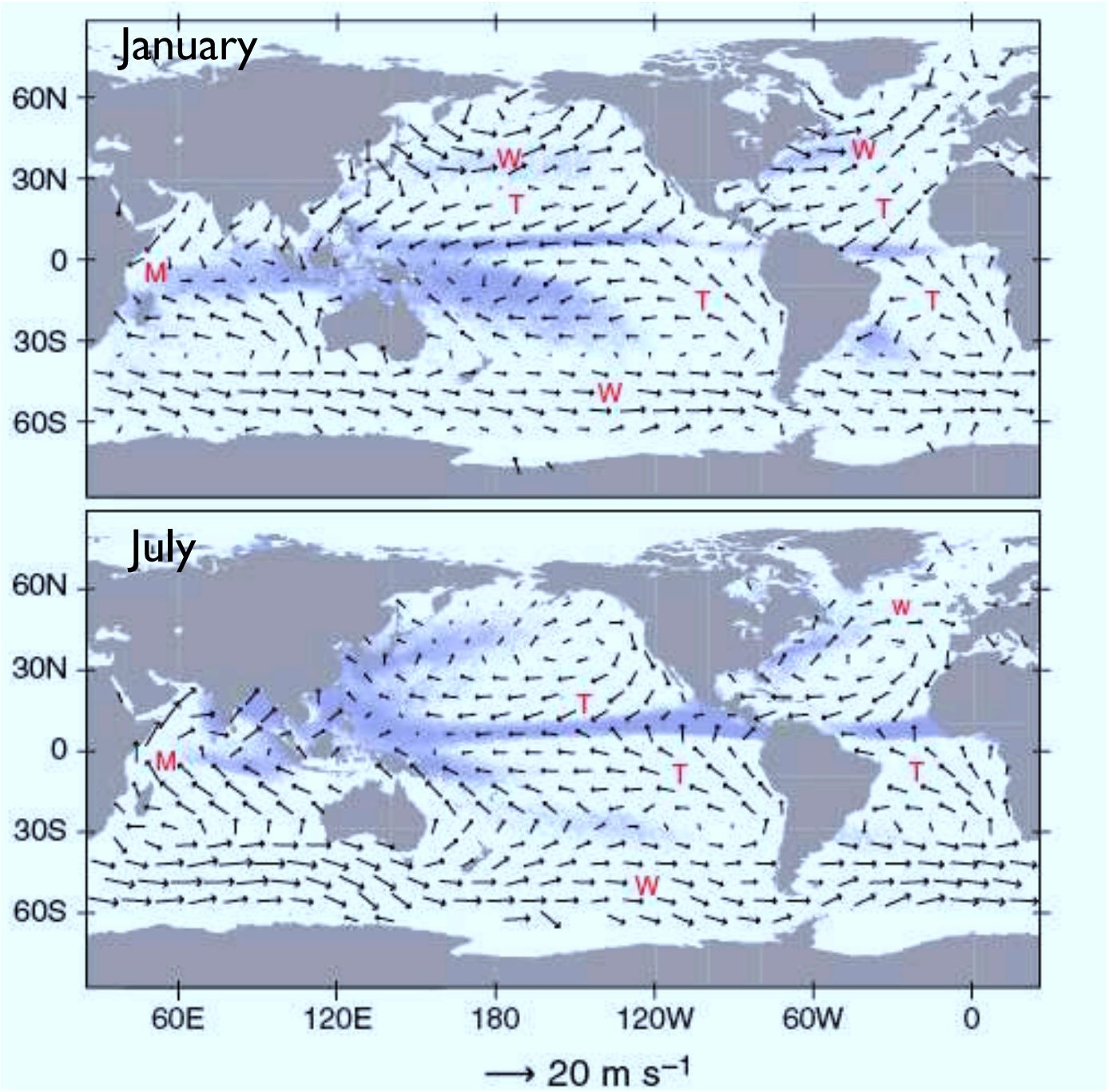


M=monsoon, CZ=convergence zone: Climate models suggest that these features become stronger as the earth warms.

How will global warming affect rainfall?

The Intensity of downpours is believed to be proportional to water vapor concentration

Thus, heavy rainfall events become more extreme



W = wind from west
T = wind from NE
blue = rainbelts

As the atmosphere warms, water vapor concentrations increase

Winds move even water vapor more from dry to wet regions.

The rain belts get more intense while the dry zones become even drier.

1990-2000, Flood Impacts

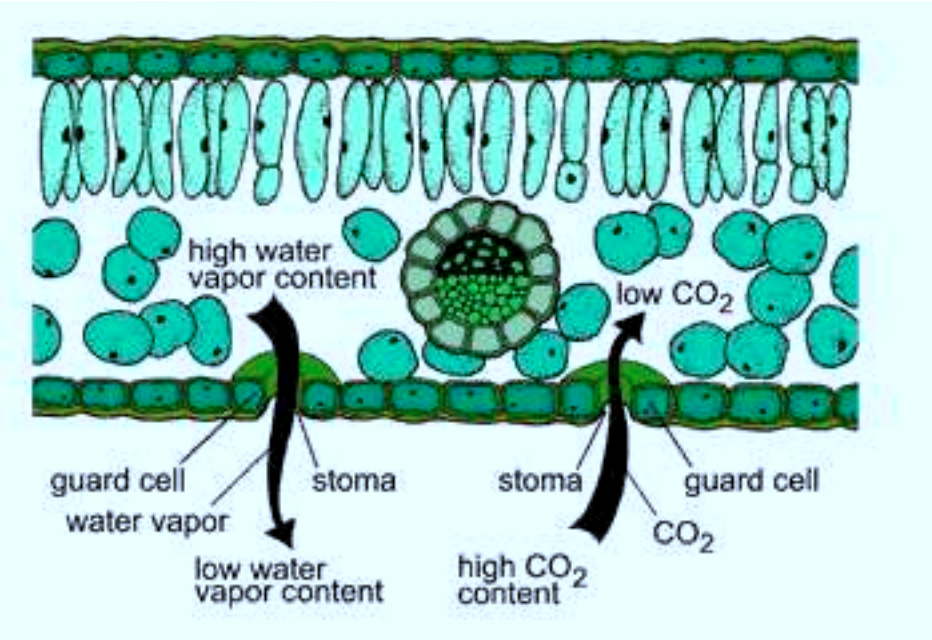
Nearly 100,000 people were killed

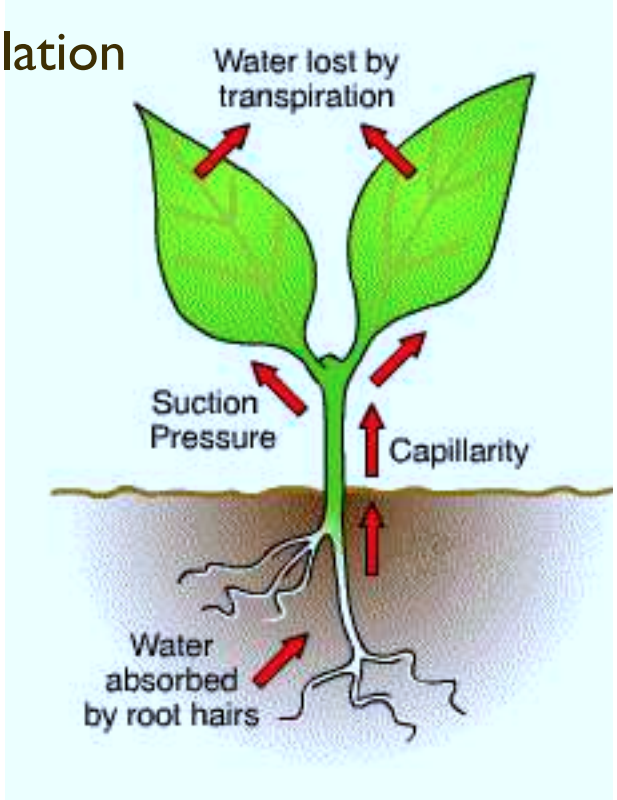
320 million people were displaced by floods

Total reported economic damages exceeding a trillion dollars

Bradshaw, et al. *Global Change Biol.* **13**, 1-17 (2007).

Plants recycle less water vapor as CO2 rises, but population changes may be more important





Plants return water to the sky and buffer flooding.

CO2 enters pores (or stomata) for photosynthesis. Increased CO2 and plants open pores less and transpire less.