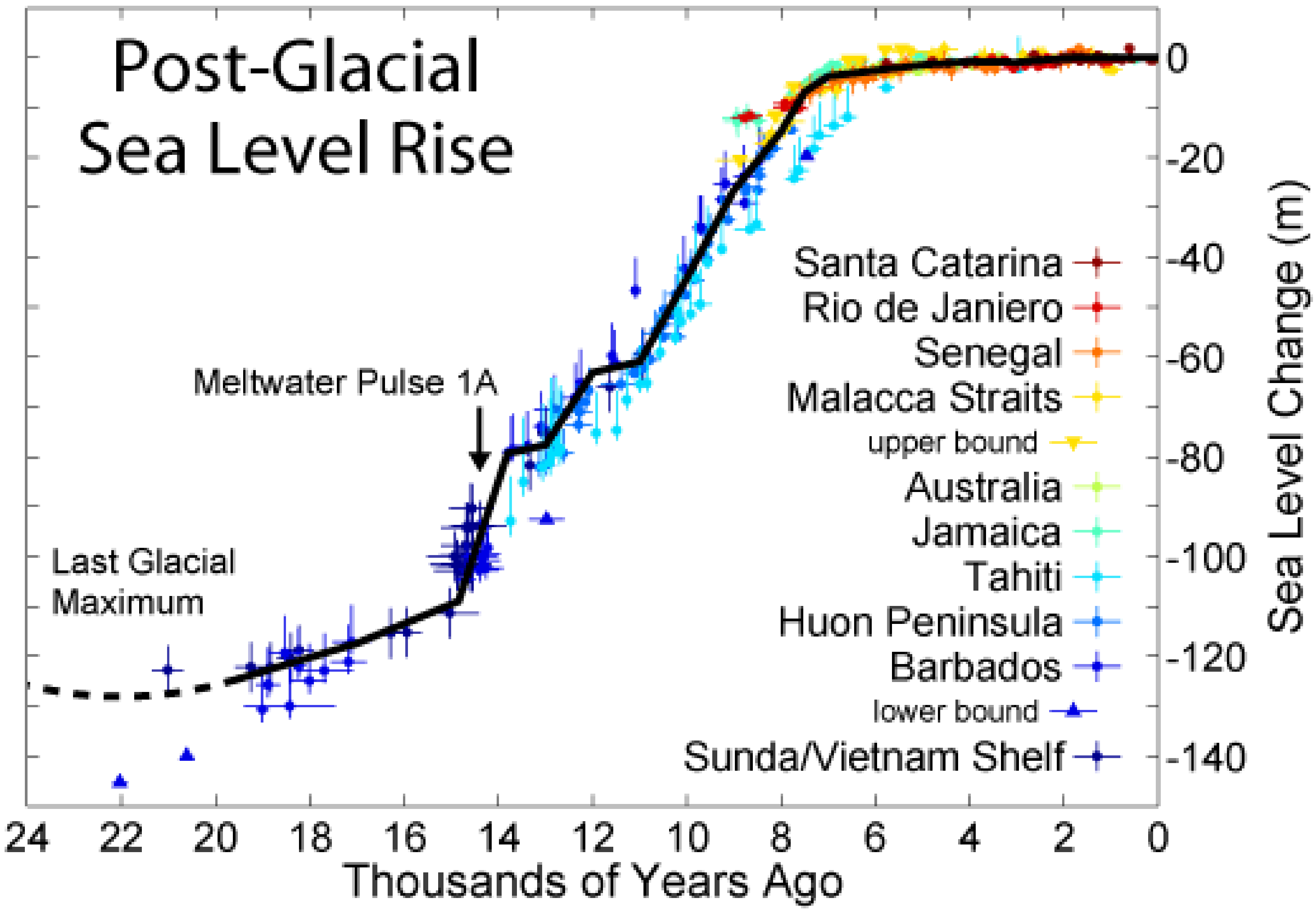
Global Warming Effects

Possible Benefits of Warming:

- Fewer deaths from exposure
- More vigorous plant growth
- Increase of arable land at high latitudes
- Increased mining potential in current permafrost regions
- Arctic waterways become navigable
- Reduced heating costs

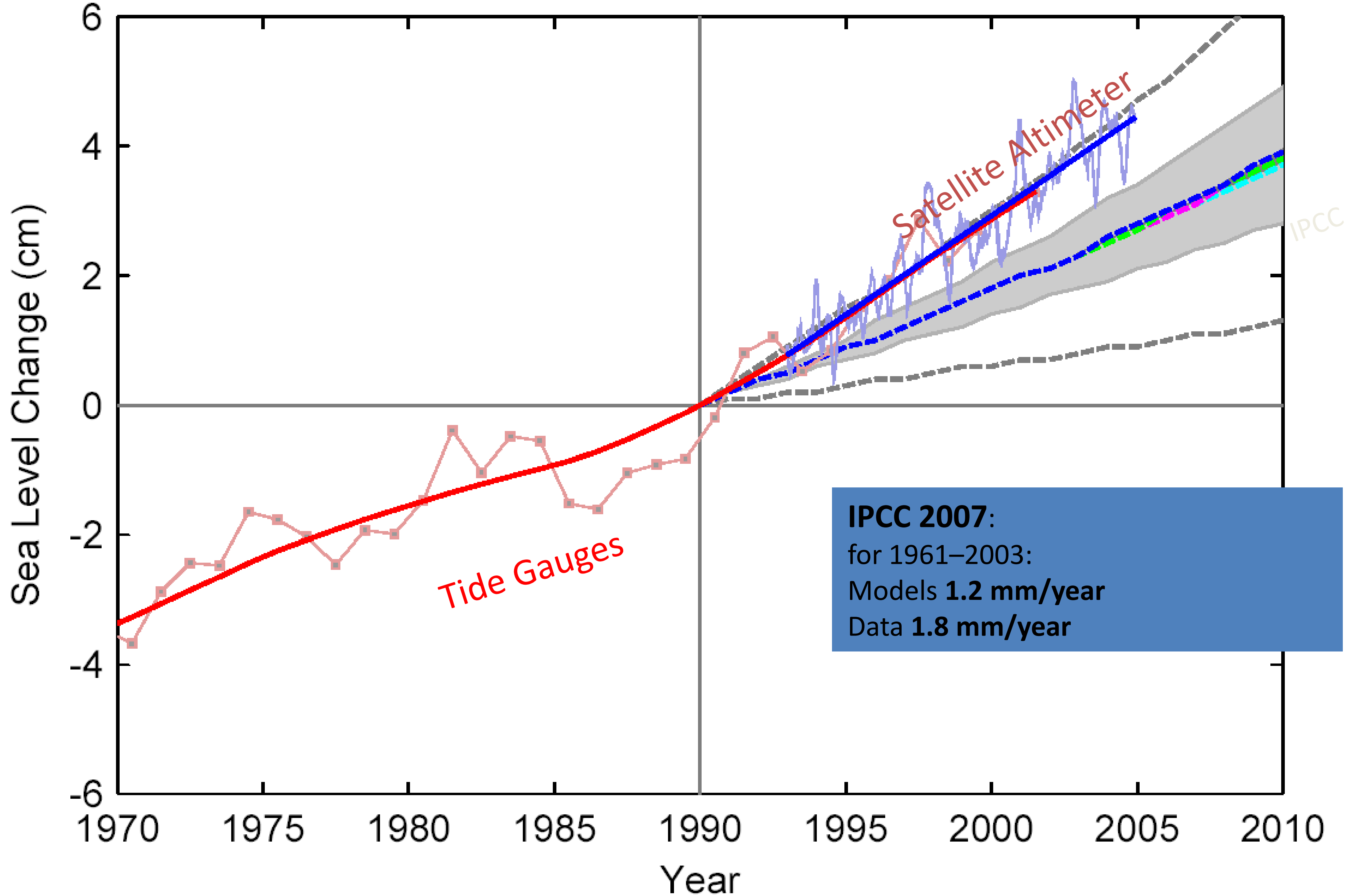
Warming Risks

- Rising sea level
- Concentration of rainfall into fewer but more intense events...more drought, floods
- Increased incidence of some diseases
- Increased production of allergens
- Increased mortality from heat waves
- Increased consumption of electricity
- Possible increase in violent storms
- Ocean acidification, increased species extinctions

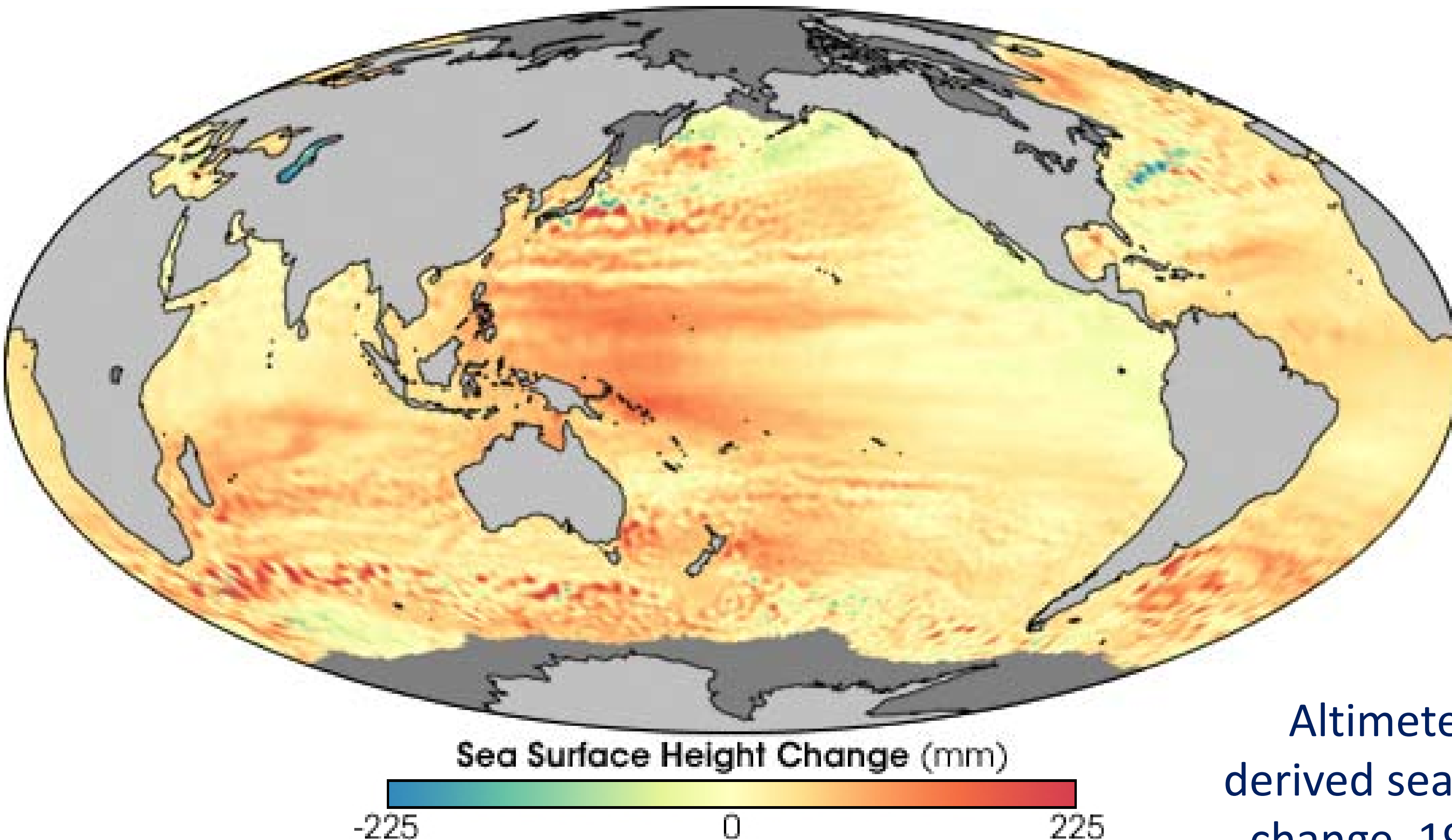


Post-Glacial
Sea Level Rise
Meltwater Pulse 1A
Last Glacial
Maximum
Santa Catarina
Rio de Janiero
Senegal
Malacca Straits
upper bound
Australia
Jamaica
Tahiti
Huon Peninsula
Barbados
lower bound
Sunda/Vietnam Shelf
0
-20
-40
-60
-80
-100
-120
-140
Sea Level Change (m)
24
22
20
18
16
14
12
10
8
6
4
2
0
Thousands of Years Ago

Sea Level Rise

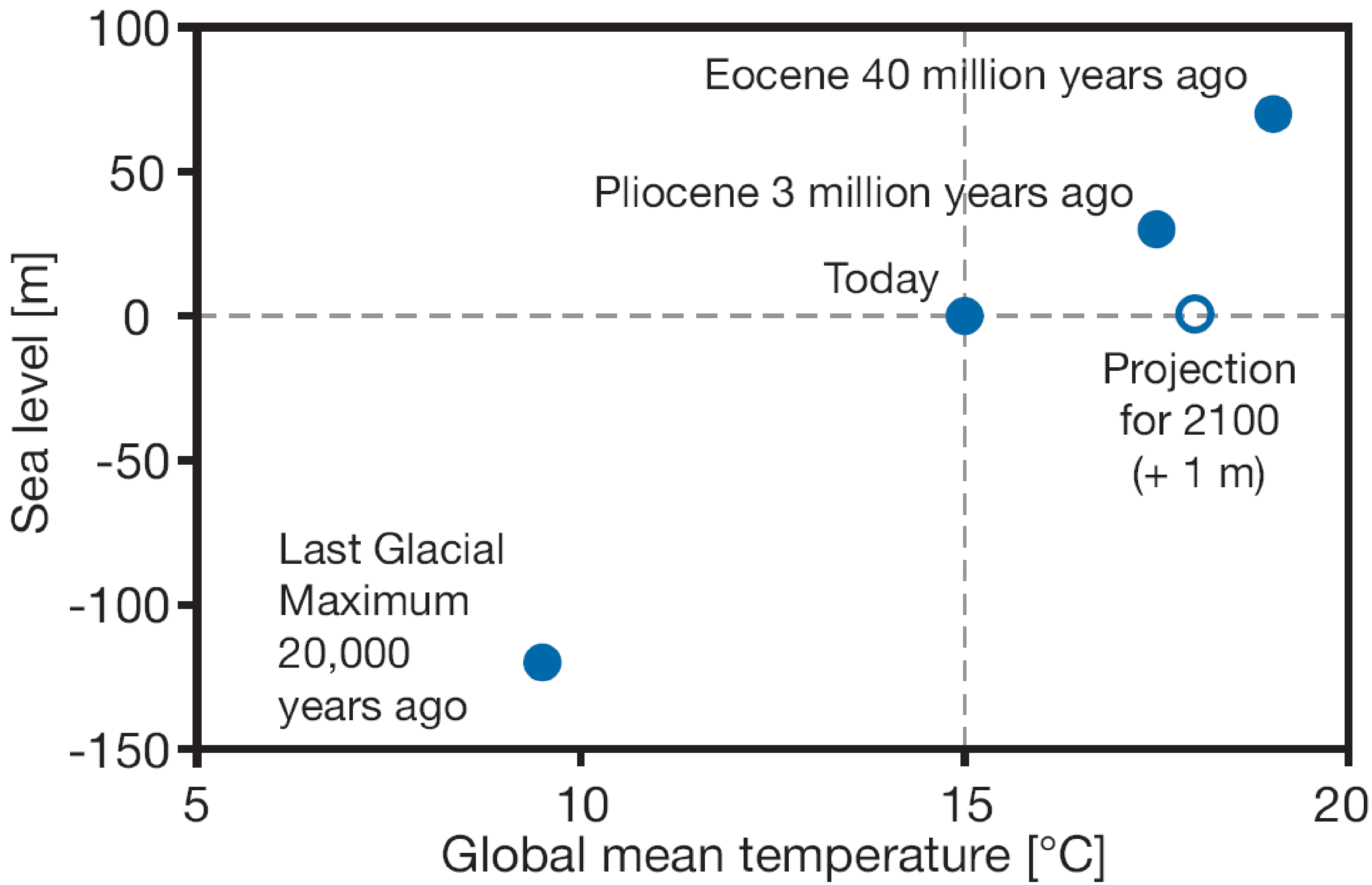


But Sea Level Change is Highly Non-Uniform



Altimeter-derived sea level change, 1993-2007

Past Sea Level vs. Temperature



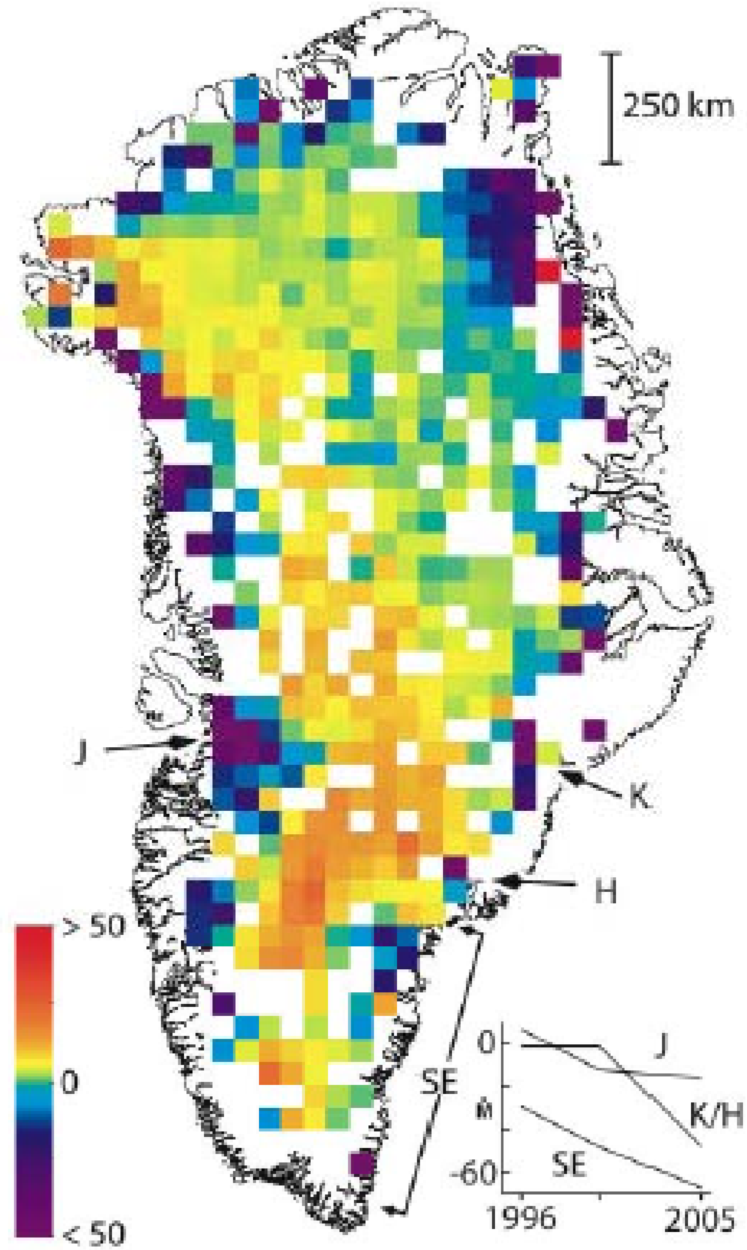
(Source: WBGU after David Archer 2006)

Ice can be self-lubricating

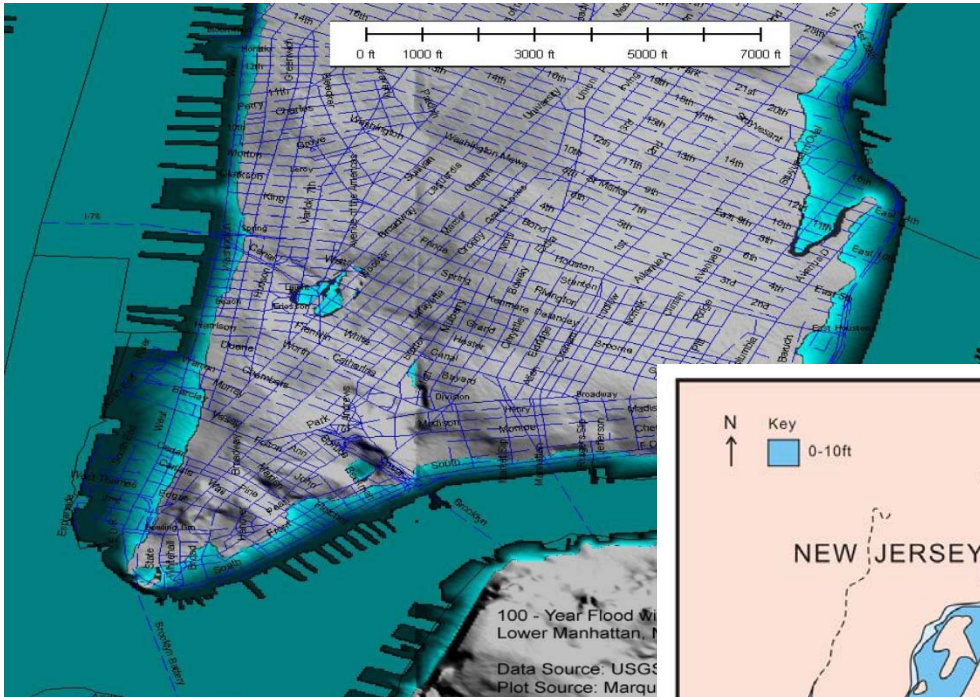
- In places, ice rests on a water-and-mud-lubricated "pancake griddle", in other places on a bumpy bedrock "waffle iron"; these can be mapped through two miles of ice, but job is far from done;
- Where surface meltwater plunges to bottom, bed is more slippery, so warming may bring faster flow--size of response depends on griddle vs. waffle iron character.

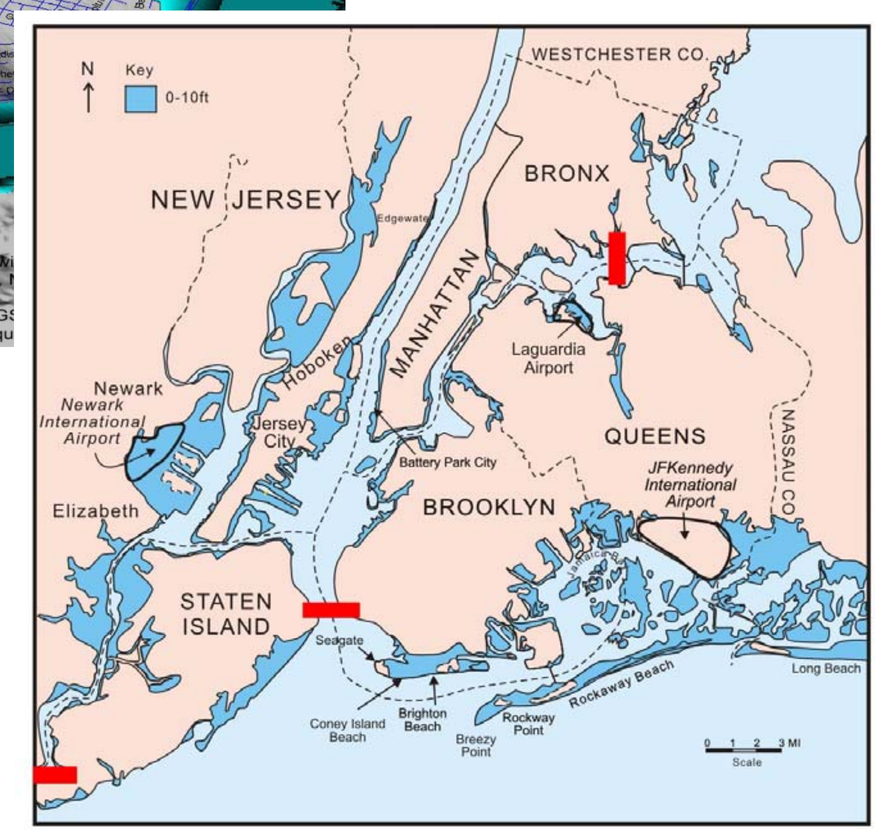
Zwally et al., 2002, Science

Greenland surface elevation change, 1989-2005



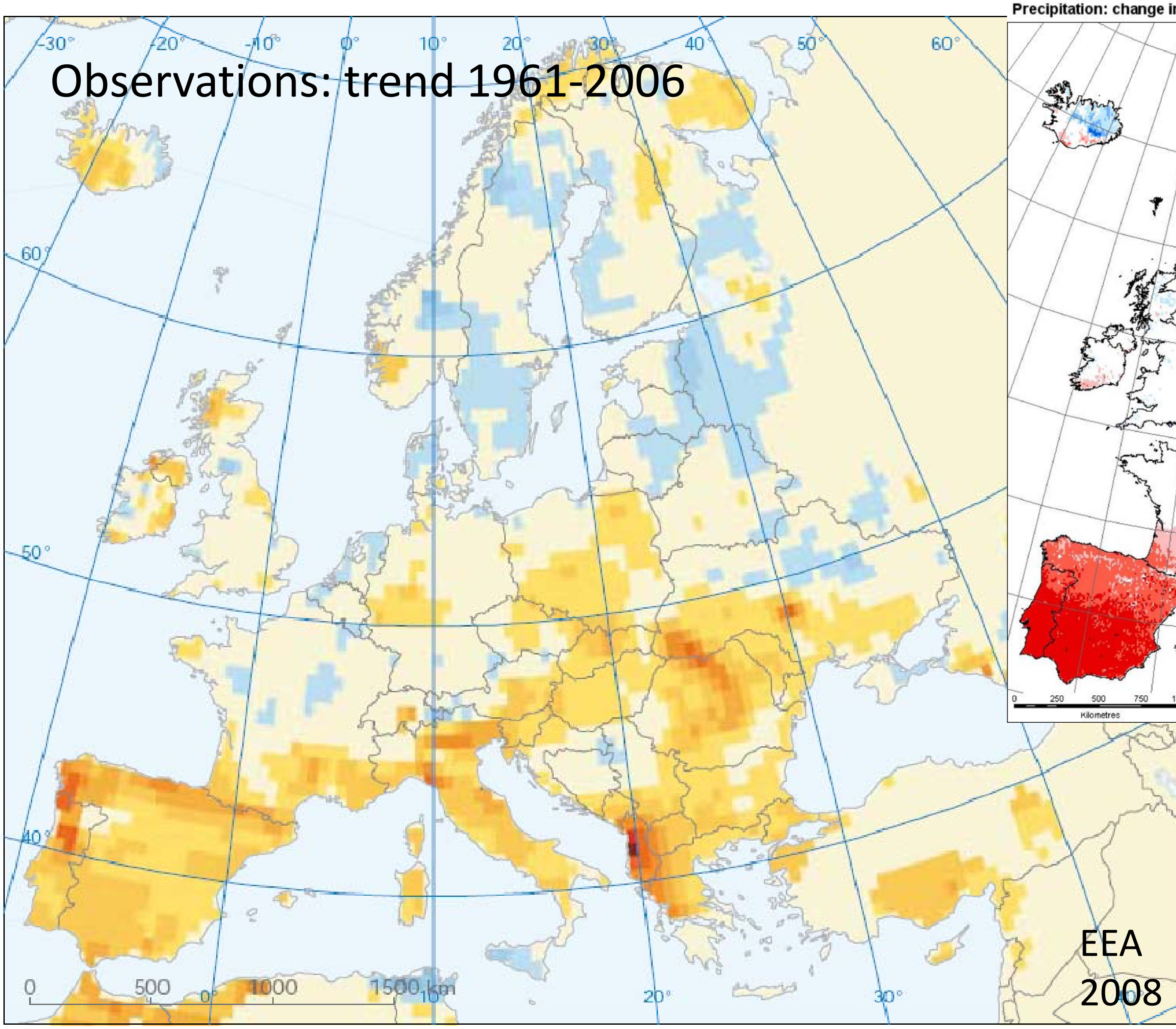
Storm Surge Risk in New York



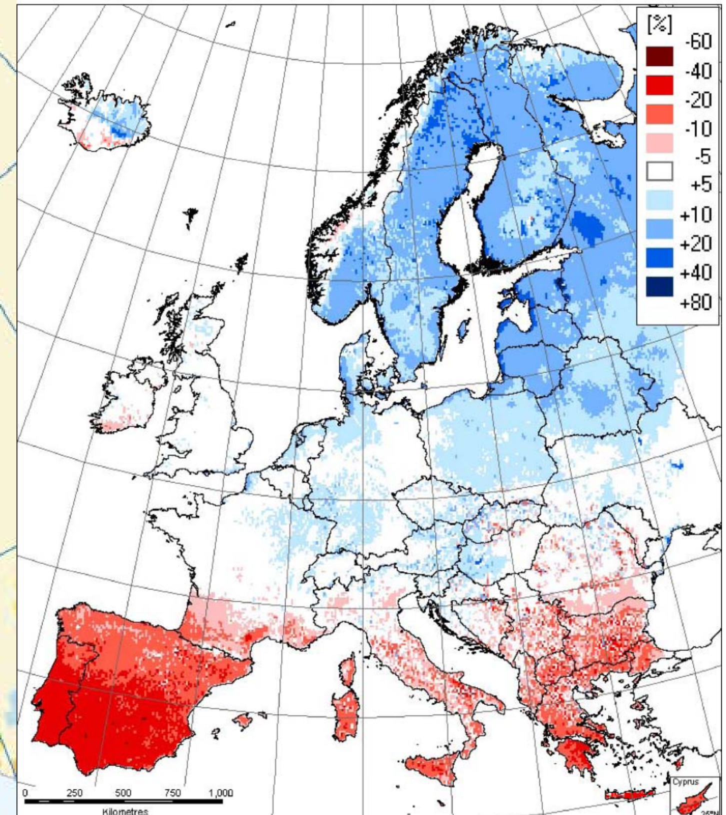


- Today: once in 100 years
- After 1 m rise: once in 3 years

Changes in Precipitation



Precipitation: change in annual amount [%]

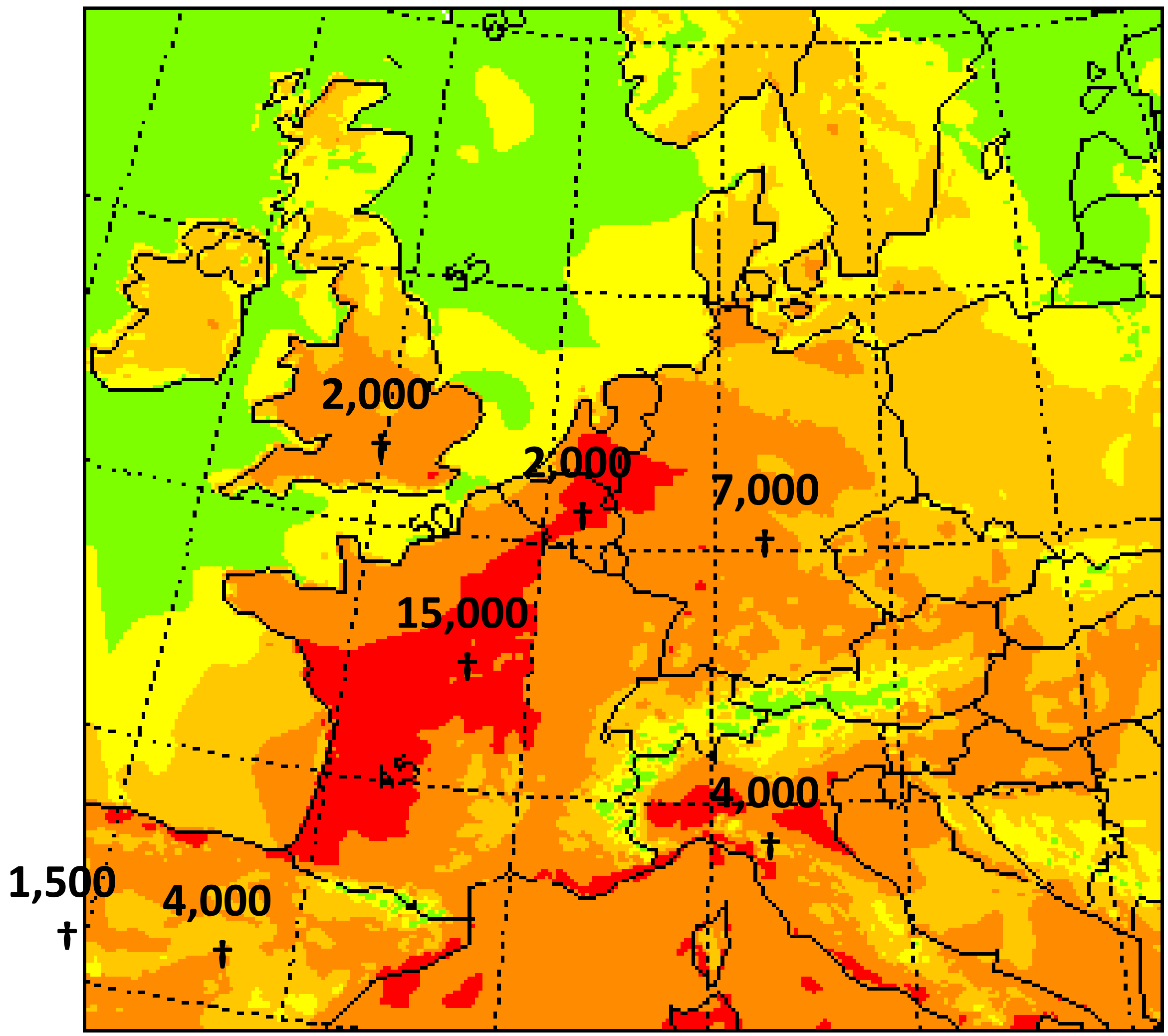


Model simulation

Southern Europe
Is drying out

Heat Waves

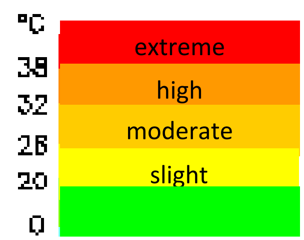
Mortality and heat stress (8. August 2003, 13 UTC)



Summer 2003, greatest natural disaster in Europe

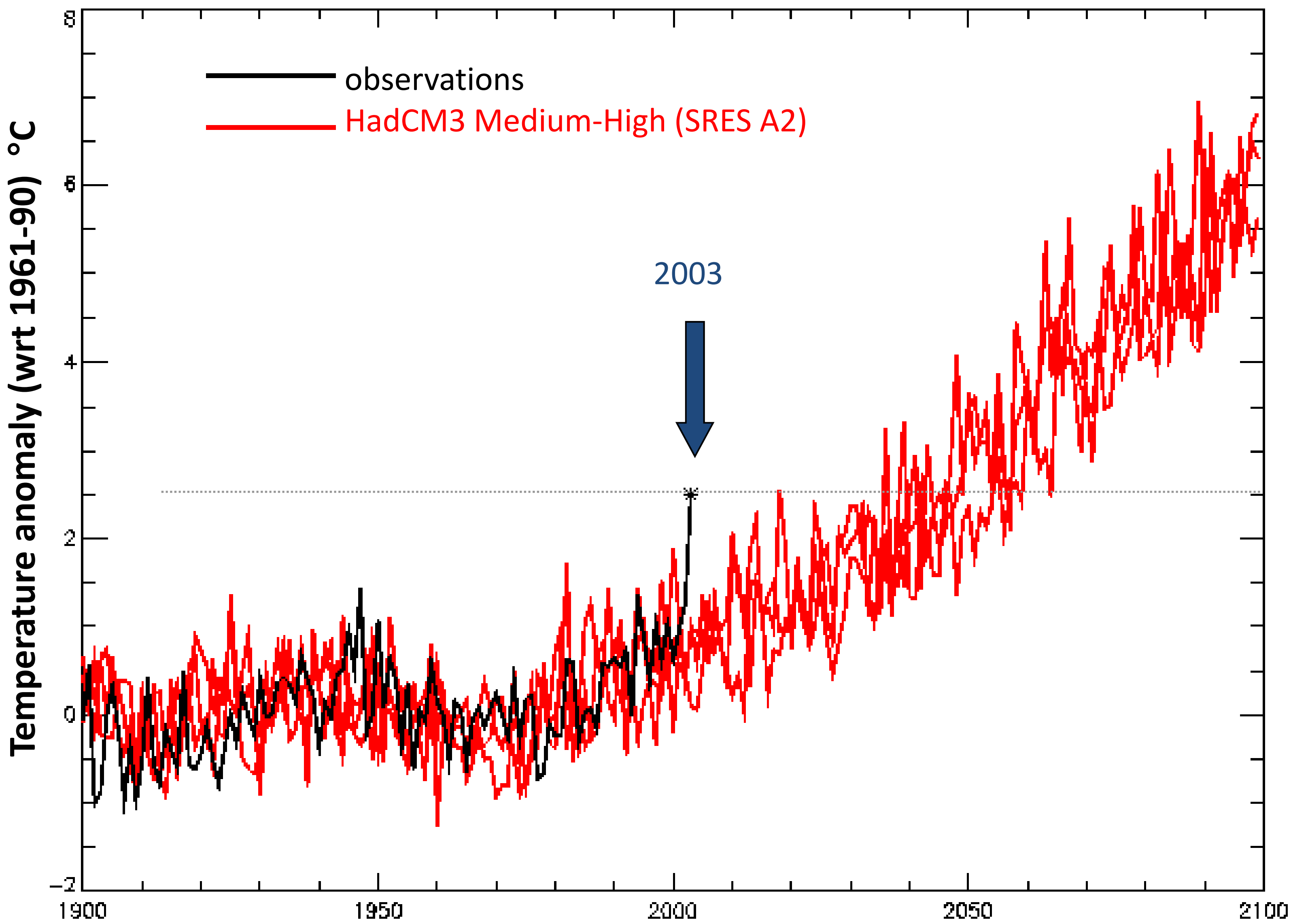
ca. 35.000 fatalities

Heat Stress



Mortality data: Earth Policy Institute
Heat Stress: Deutscher Wetterdienst

Heat Waves



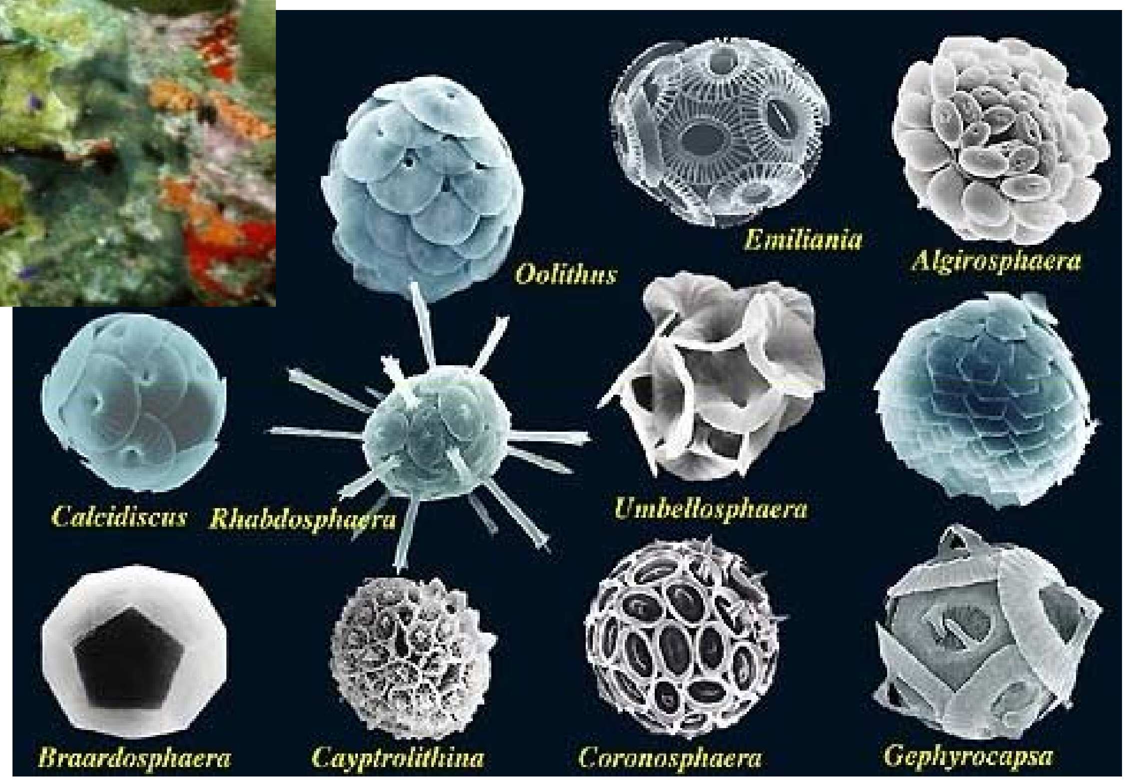
observations
HadCM3 Medium-High (SRES A2)
2003
Temperature anomaly (wrt 1961-90) °C
8
6
4
2
0
−2
1900
1950
2000
2050
2100

Ocean Acidification

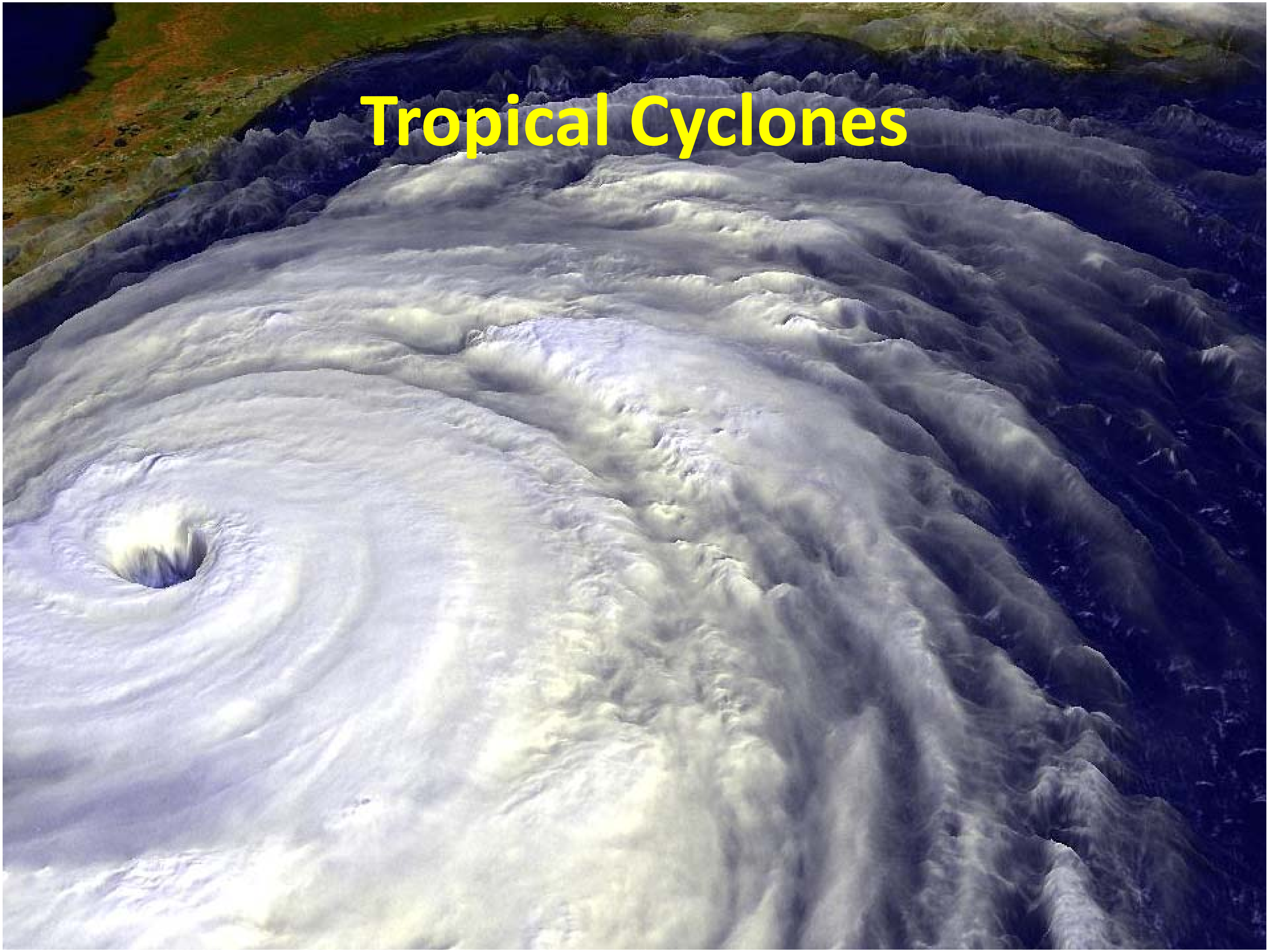
- Acidification through CO_2 threatens marine life

Coral Reefs

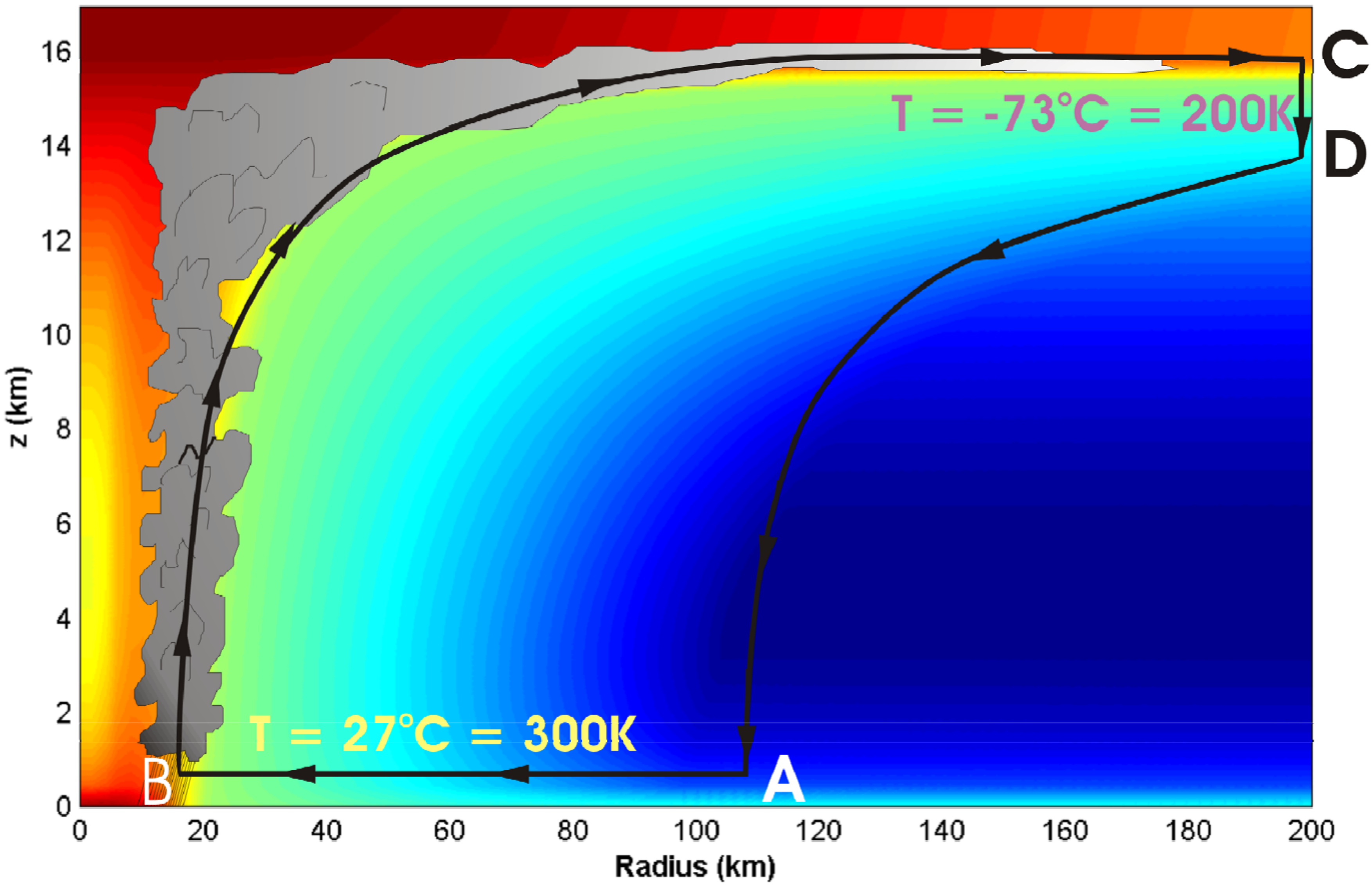
Plankton



Tropical Cyclones



Energy Production Cycle



Theoretical Upper Bound on Hurricane Maximum Wind Speed:

Surface temperature

$$|V_{pot}|^2 \cong \frac{C_k}{C_D} \frac{T_s - T_o}{T_o} T_s \left(s_0^{\ *} - s_b \right)$$

Ratio of exchange coefficients of enthalpy and momentum

Outflow temperature

Air-sea enthalpy disequilibrium

s_0^* = **saturation entropy** of sea surface

s_b = **actual entropy** of subcloud layer

$$s^* = C_p \ln\left[\frac{T}{T_0}\right] - R\ln\left[\frac{p}{p_0}\right] + \frac{L_v q^*}{T}$$

Condition of convective neutrality:

s_b = s* of free troposphere

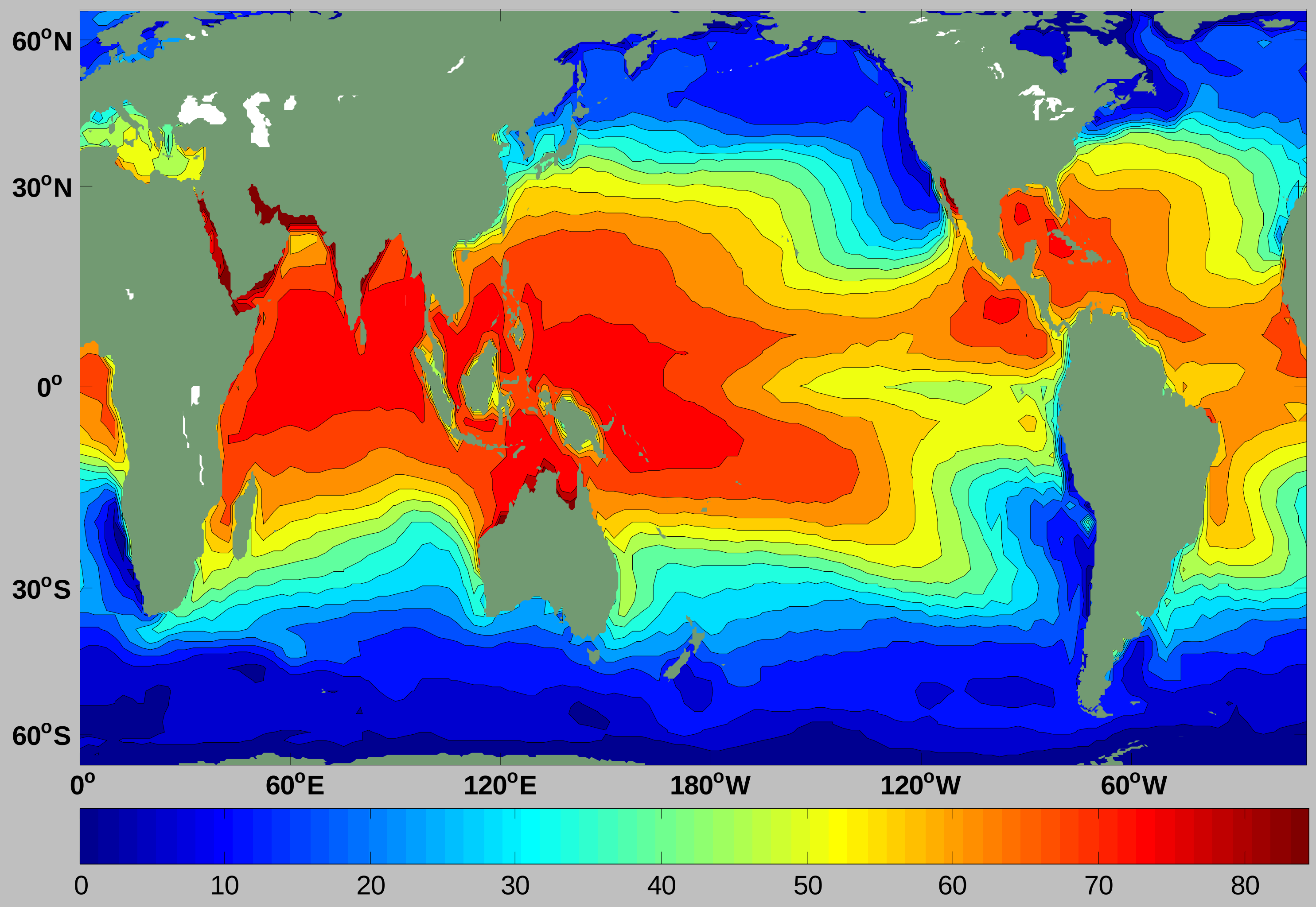
Also, s* of free troposphere is approximately spatially uniform (WTG approximation)

$$|V_{pot}|^2 \cong \frac{C_k}{C_D} \frac{T_s - T_o}{T_o} T_s \left(s_0{}^* - s^* \right)$$

approximately constant

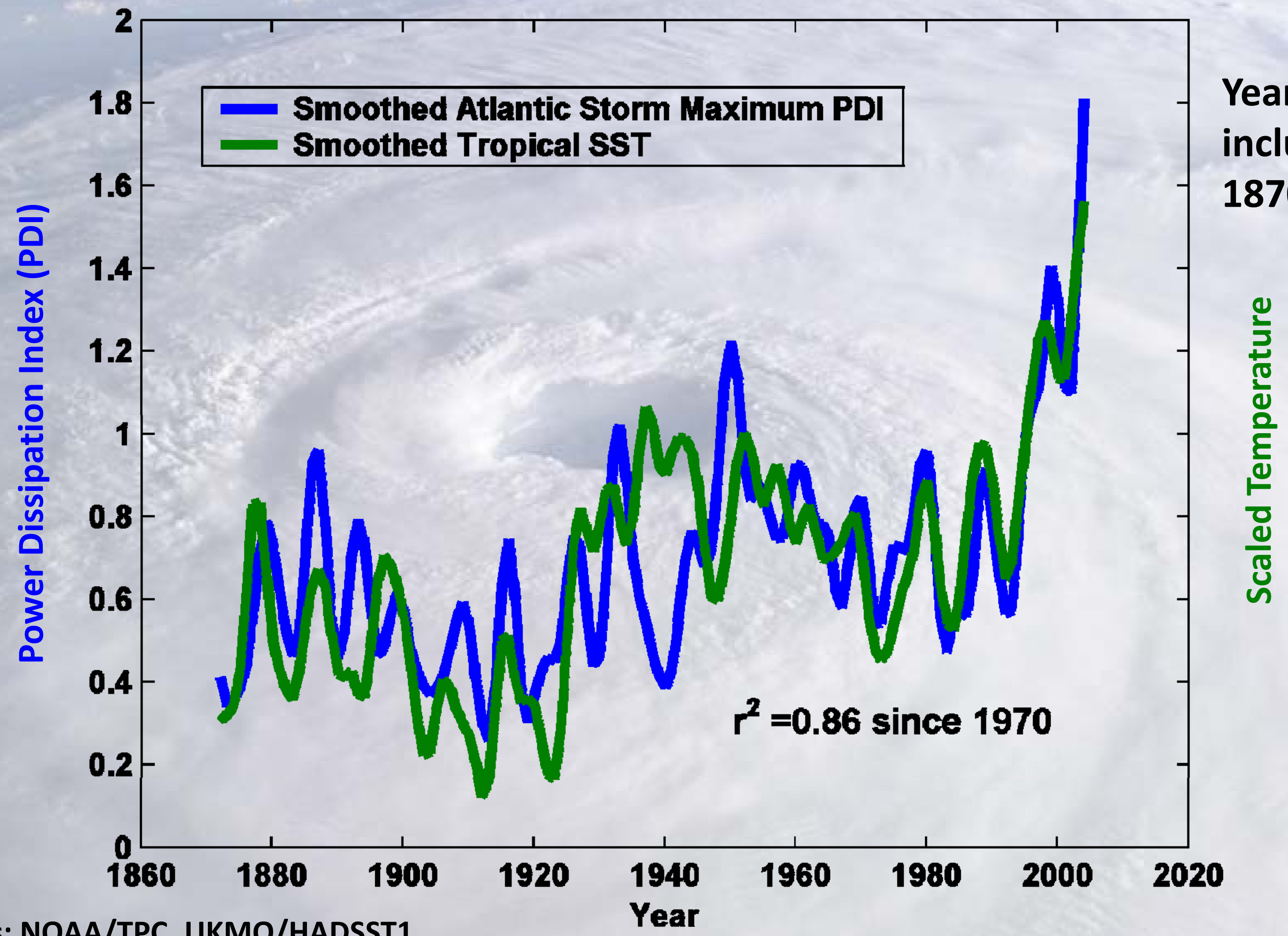
What matters, apparently, is the SST (s_0*) relative to the tropospheric temperature (s*)

Annual Maximum Potential Intensity (m/s)



Atlantic Sea Surface Temperatures and Storm Max Power Dissipation

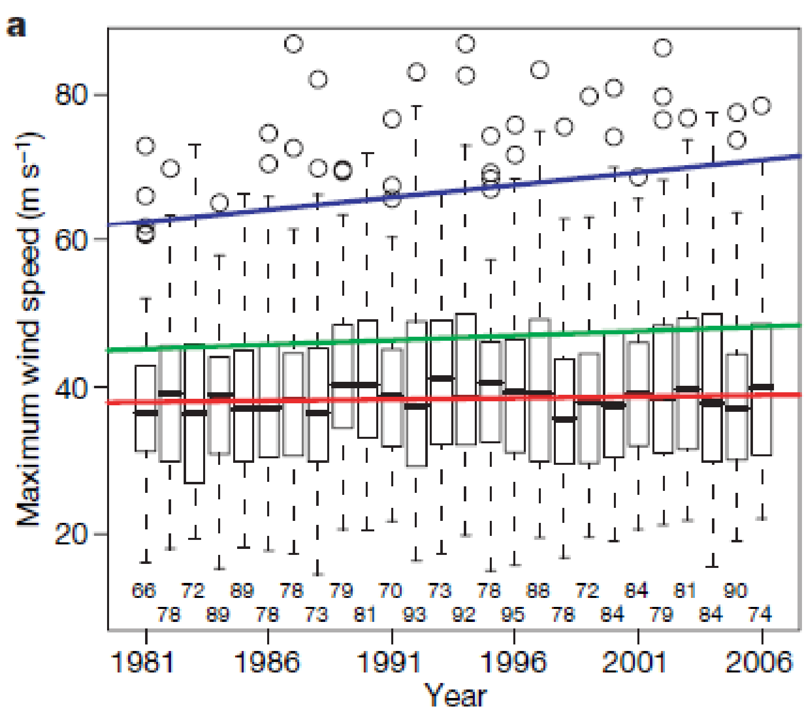
(Smoothed with a 1-3-4-3-1 filter)



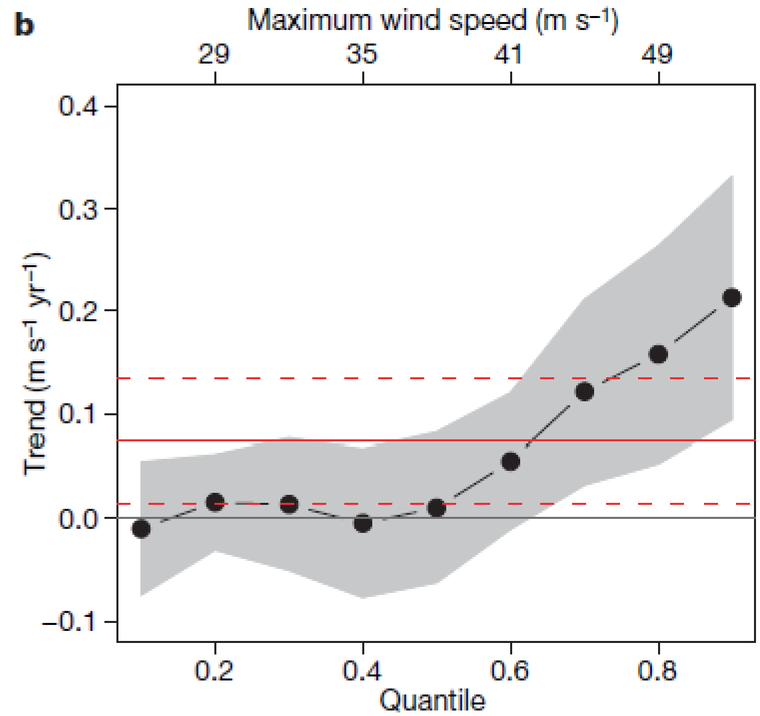
Years included: 1870-2006

Data Sources: NOAA/TPC, UKMO/HADSST1

Analysis of satellite-derived tropical cyclone lifetime-maximum wind speeds



Box plots by year. Trend lines are shown for the median, 0.75 quantile, and 1.5 times the interquartile range



Trends in global satellite-derived tropical cyclone maximum wind speeds by quantile, from 0.1 to 0.9 in increments of 0.1.

Elsner, Kossin, and Jagger, *Nature*, 2008