Welcome to ATMS 111 Global Warming

EACH DAY HUMBLE SUPPLIES ENOUGH *ENERGY* TO MELT 7 MILLION TONS OF GLACIER!

This giant glacier has remained unmelted for centuries. Yet, the petroleum energy Humble supplies—if converted into heat—could melt it at the rate of 80 tons each second! To meet the nation's growing needs for energy, Humble has applied science to nature's resources to become America's Leading Energy Company. Working wonders with oil through research, Humble provides energy in many forms—to help heat our homes, power our transportation, and to furnish industry with a great variety of versatile chemicals. Stop at a Humble station for new Enco Extra gasoline, and see why the "Happy Motoring" Sign is the World's First Choice!

HUMBLE
OIL & REFINING COMPANY
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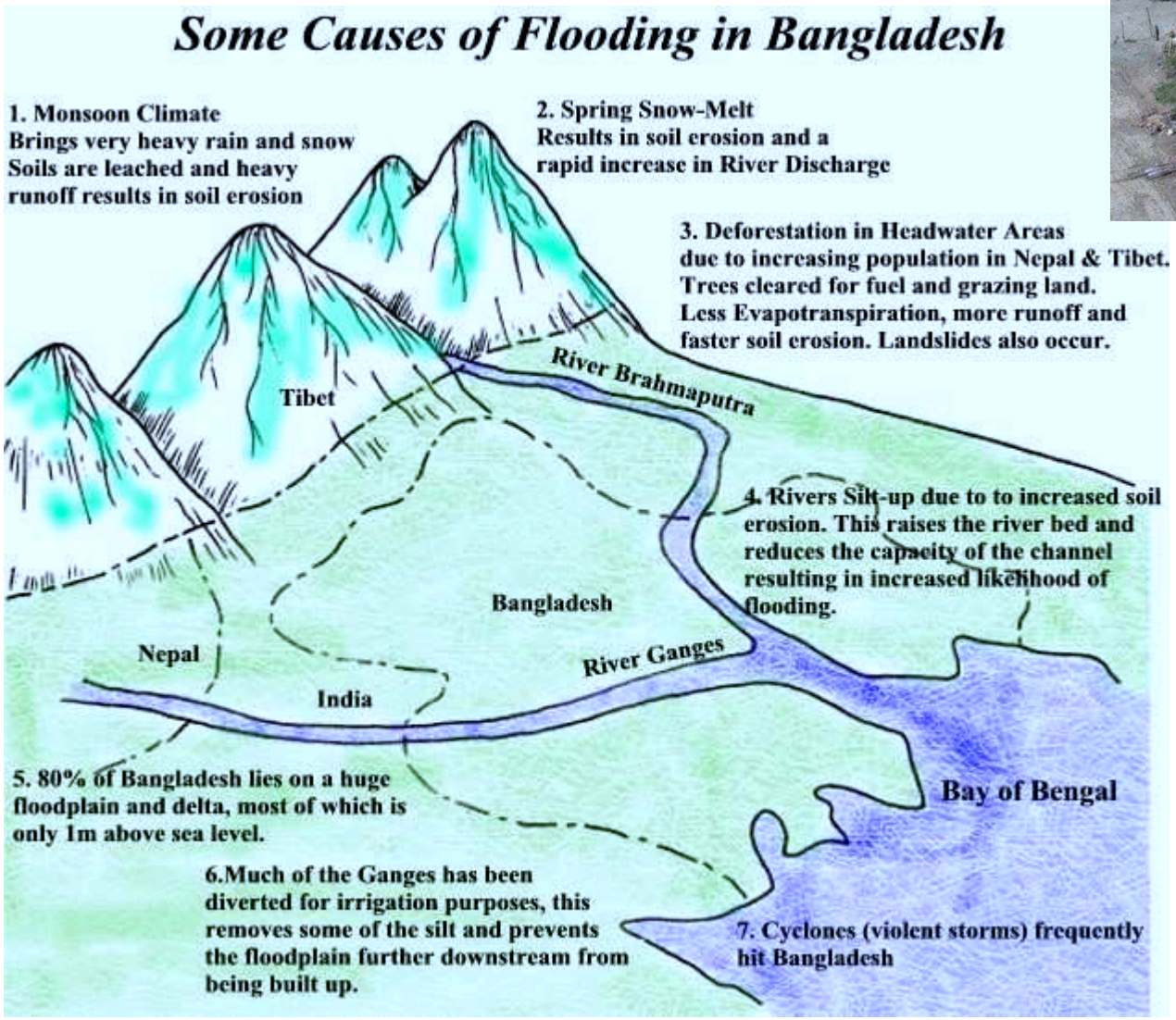


http://cgz.e2bn.net/e2bn/leas/c99/schools/cgz/accounts/staff/rchambers/GeoBytes/GCSE/Case%20Studies/Causes_of_Flooding_in_Bangladesh.jpg

Do forest really prevent flooding?

2005 influential report by the UN Food and Agricultural Organization concluded that the evidence is weak

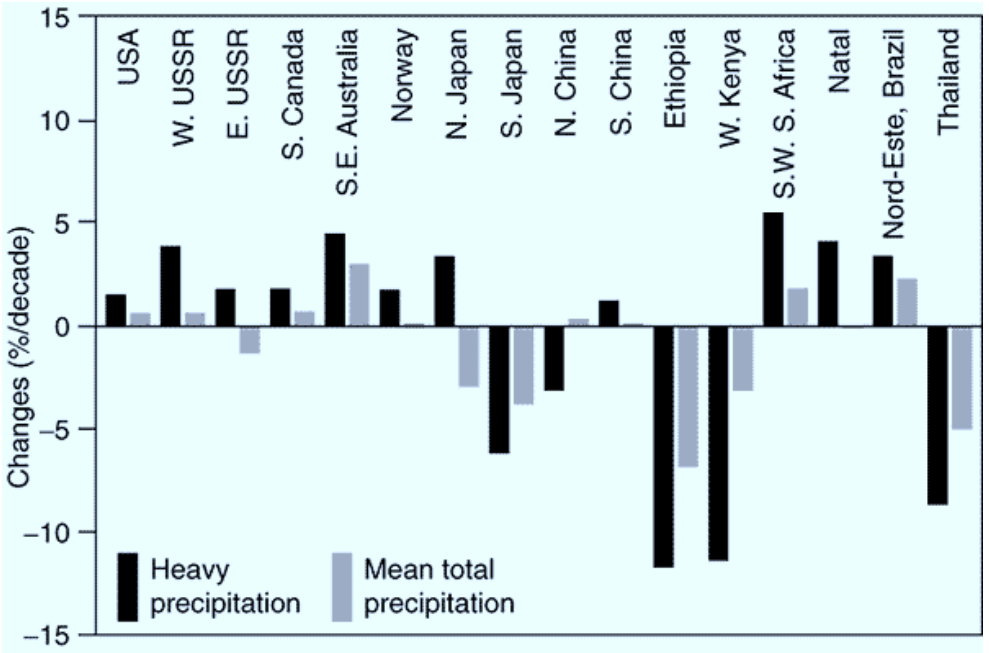
Bradshaw, et al *Global Change Biol.* **13**, 1-17 (2007)
Analyzed broader scale data and found deforestation explained 14% of floods.

They predict that arbitrarily decreasing forest area by 10%, would increase flood frequency 4-28% and duration 4-8%.

Are floods increasing?

Thus far, the changes are fairly subtle

Examples of observational results in the scientific literature that suggest an increase on the frequency of heavy rain events.



Are floods increasing?

Trends in the frequency of flood events are difficult to quantify because

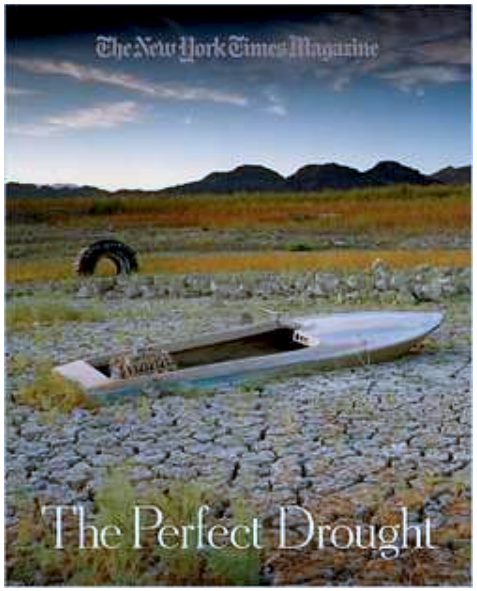
River configurations and land use are continually changing

Hourly rainfall data are available only over limited regions of the globe
the data are expensive and there are restrictions on their use

Rare events, especially when considered season-by-season
it's difficult to establish statistical significance when dealing with rare events.

The latter two are true for heat waves too

Defining drought



Months or years with below normal water supply.

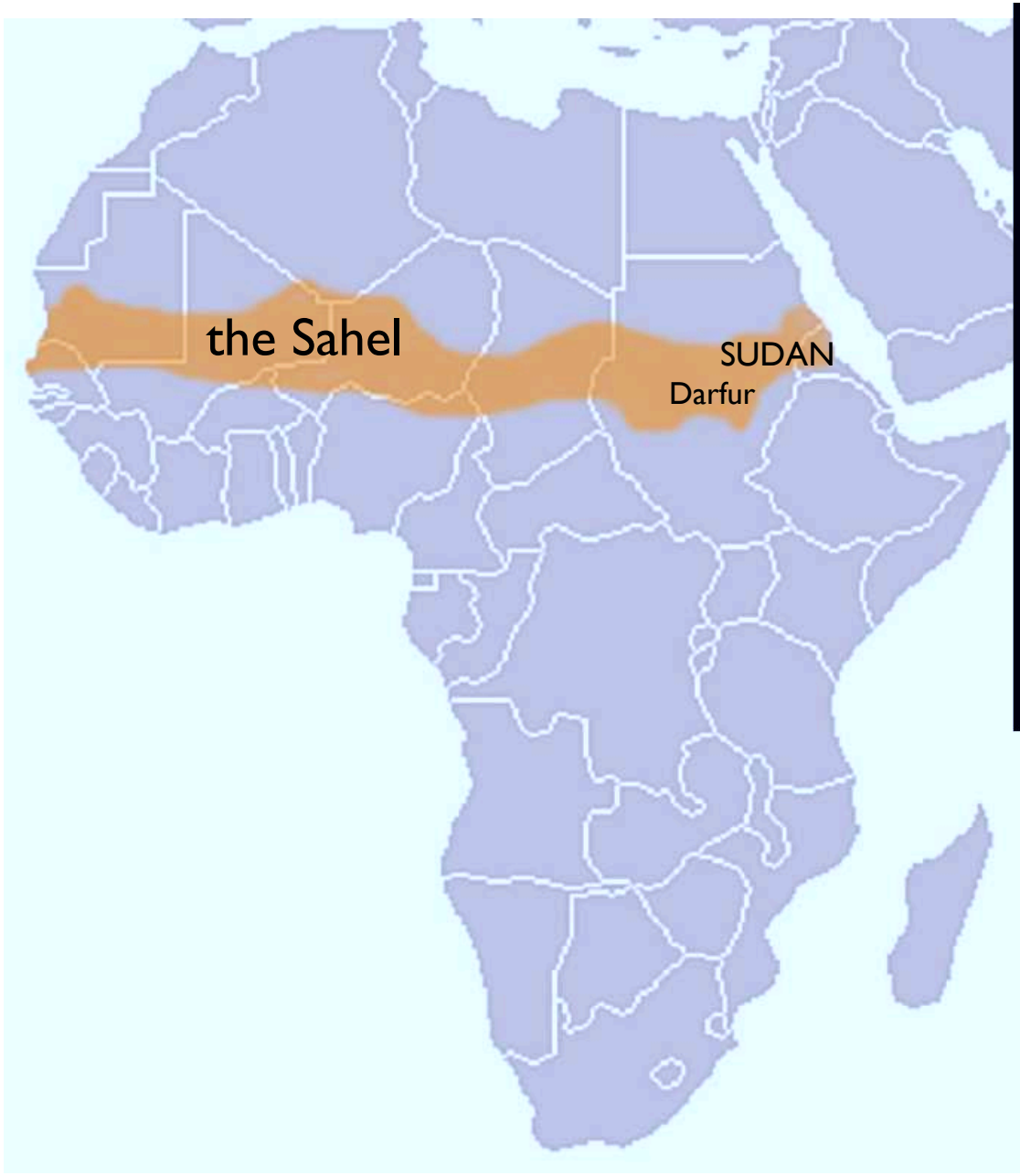
Usually from below average precipitation.

The definition is not quantitative.

Specific criteria (e.g., how long, how severe...) need to be specified.

Other factors such as population growth can create deficiencies in water supply (ie Lake Chad)

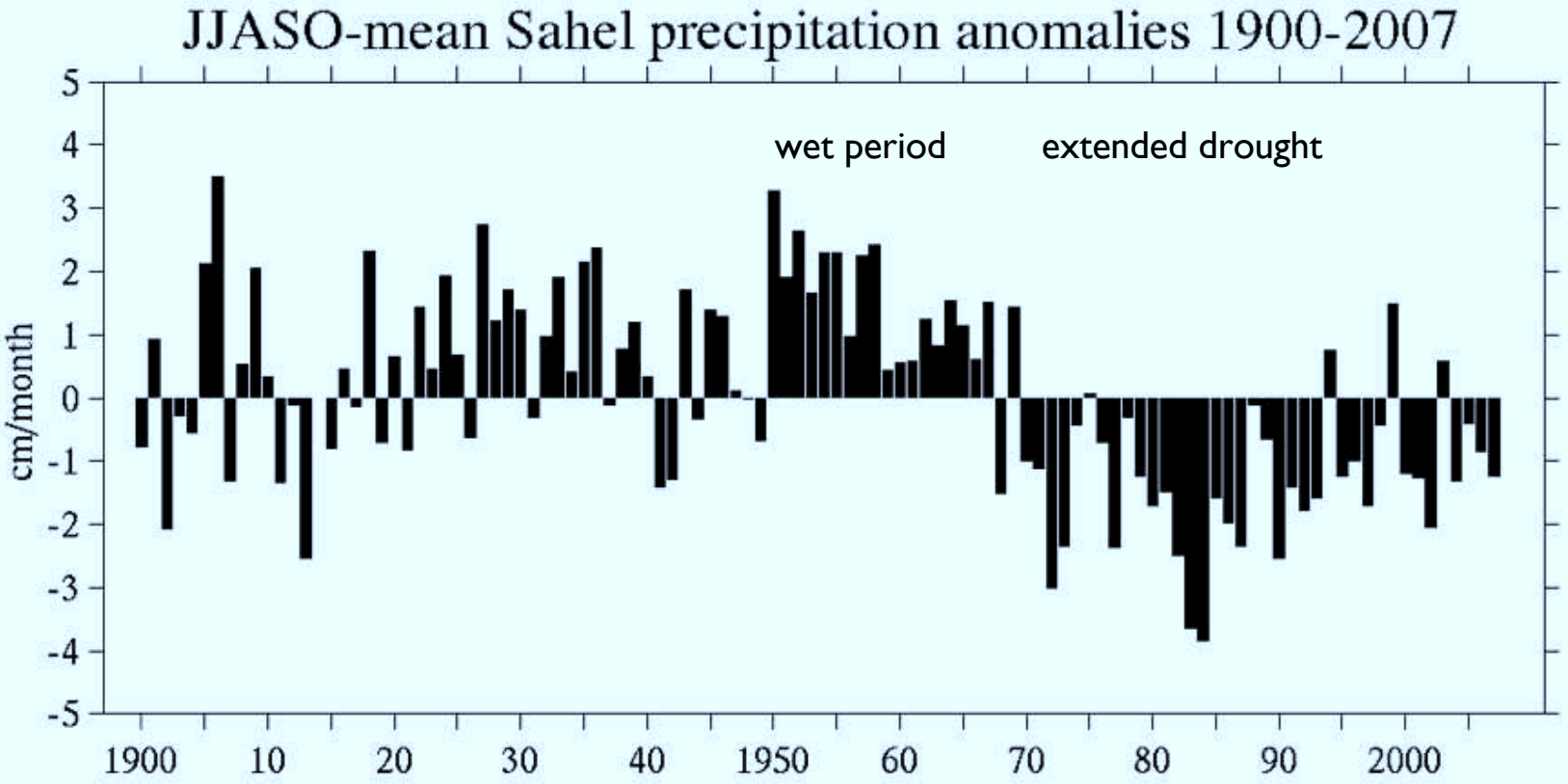
Which way will the Sahel go?



The Sahel is in between desert and the region drenched by the African monsoon

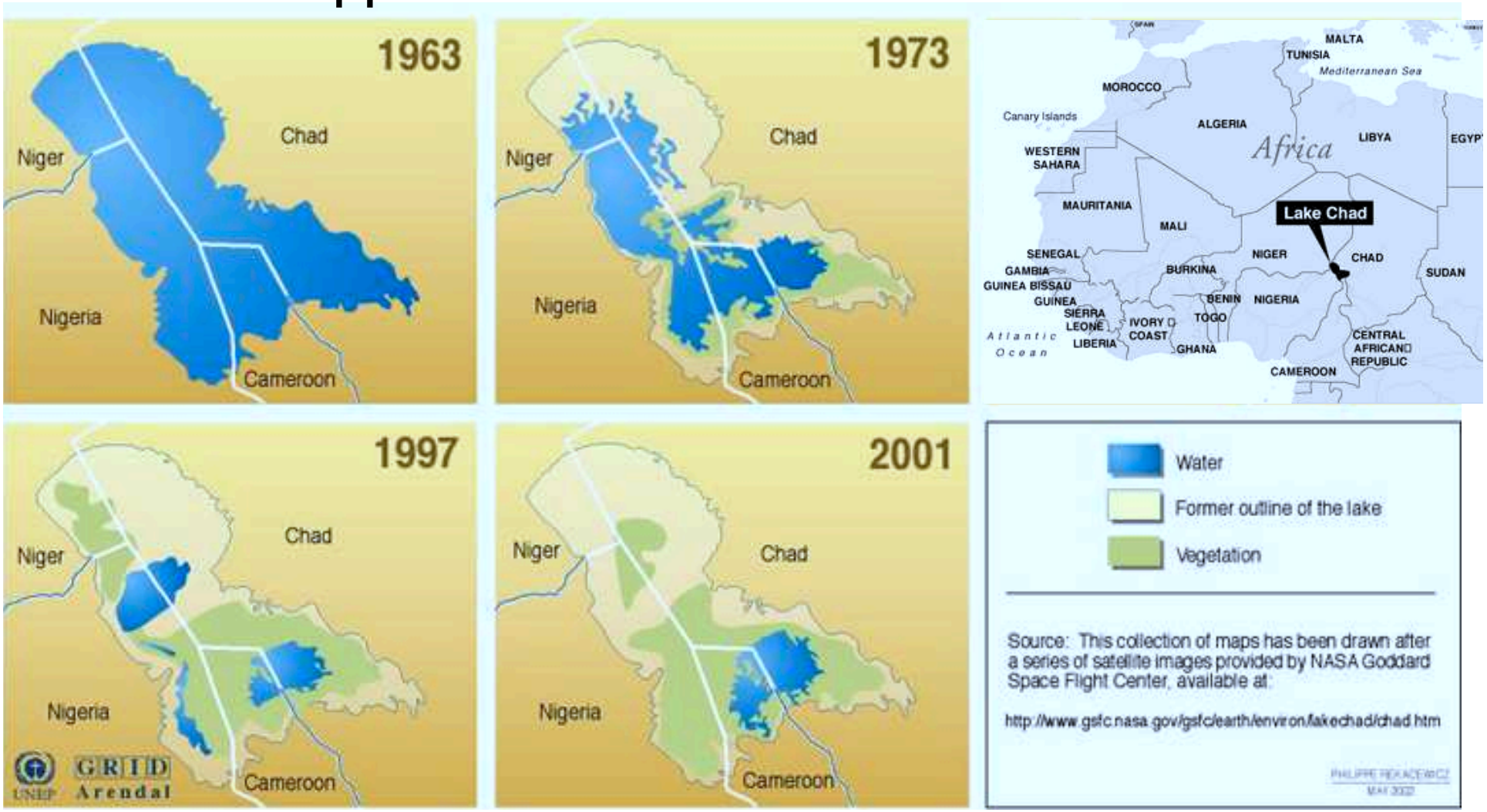
The African Monsoon in full swing

Which way will the Sahel go?

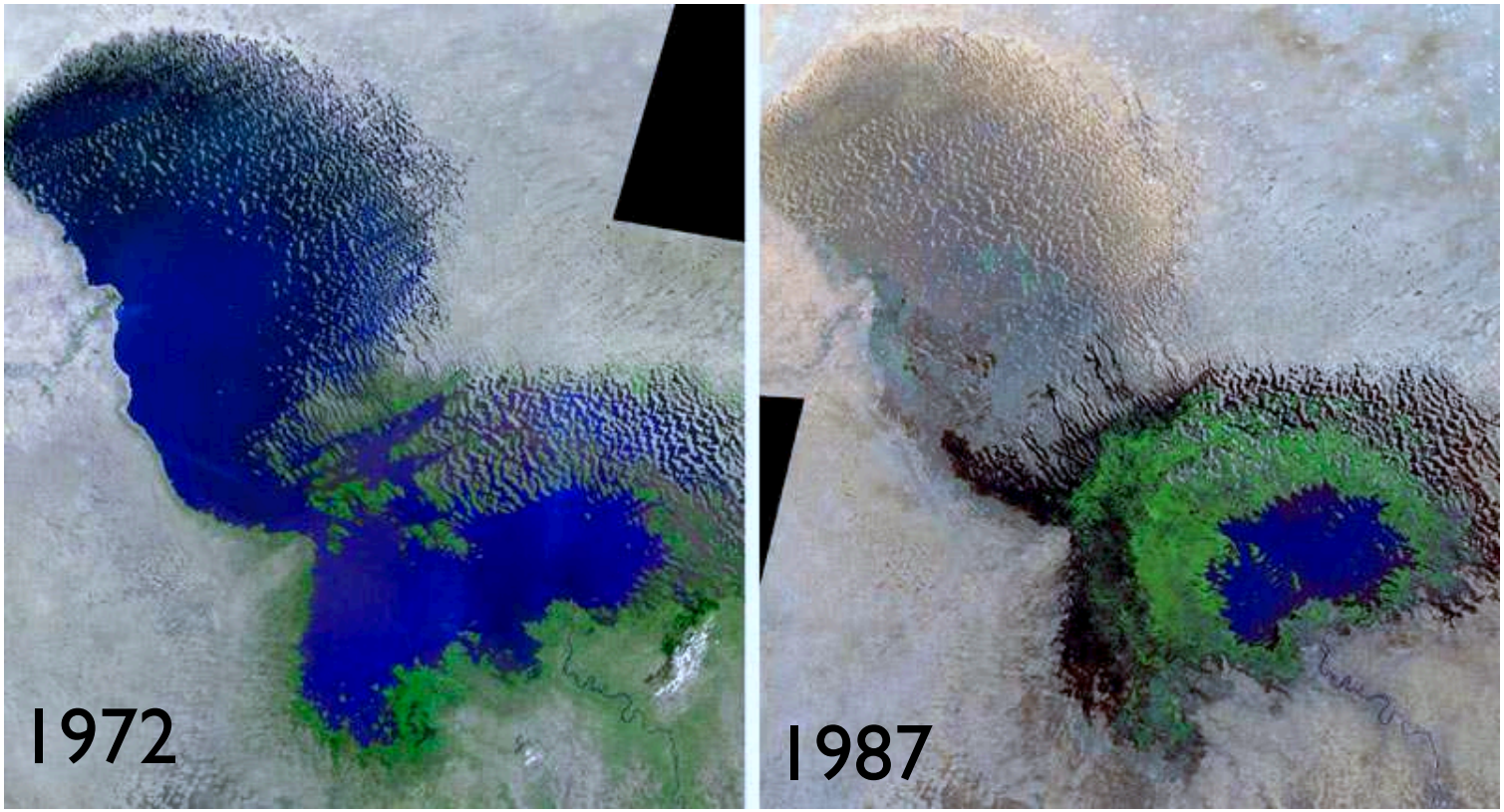


The shift around 1970 is believed to be due to changing sea surface temperature patterns in the tropical Atlantic.

The disappearance of Lake Chad

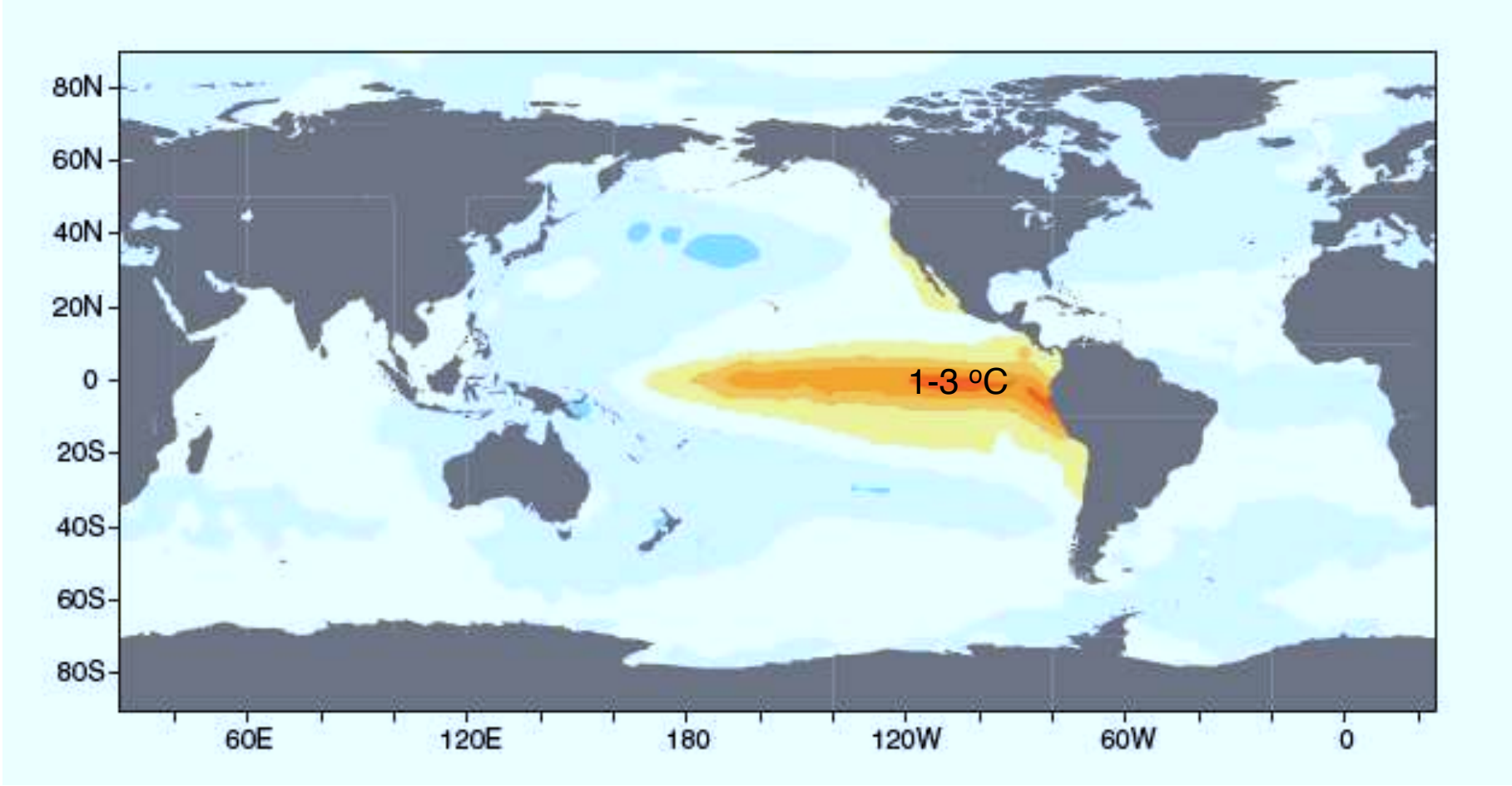


Lake Chad

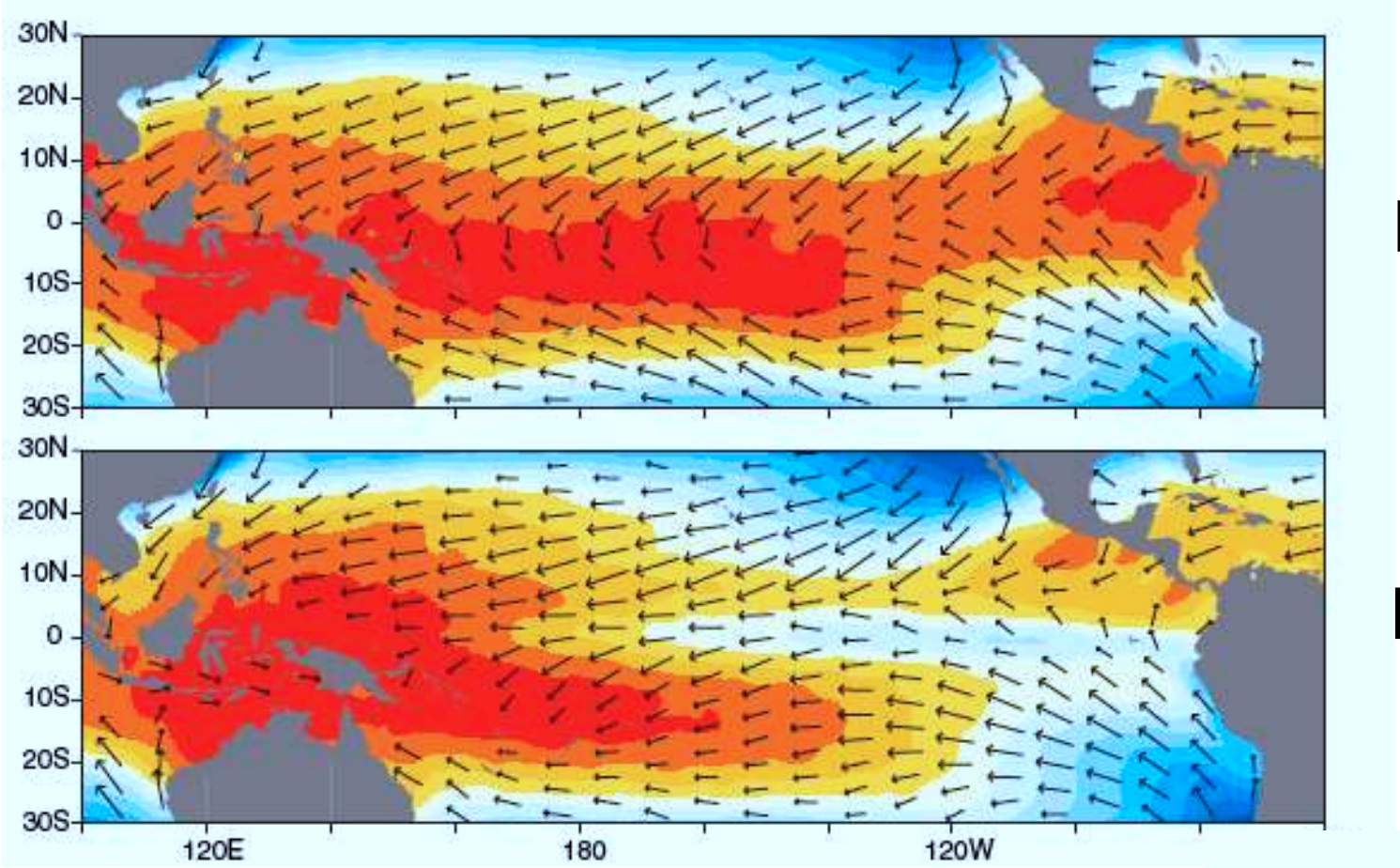


What do the oceans have to do with drought?

The most striking example is El Niño



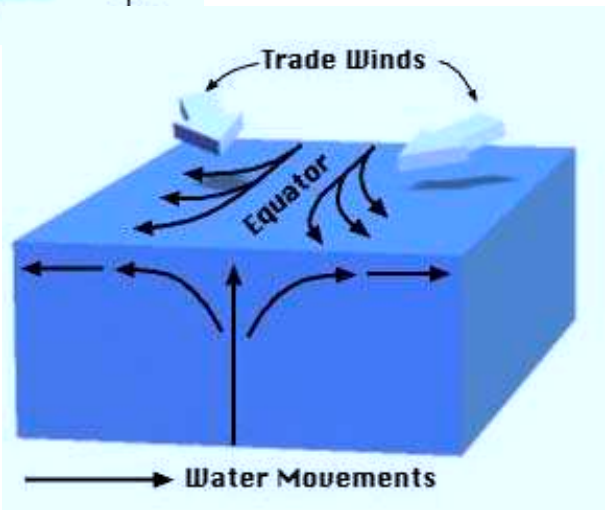
The sea surface temperature SST *anomaly* of El Nino

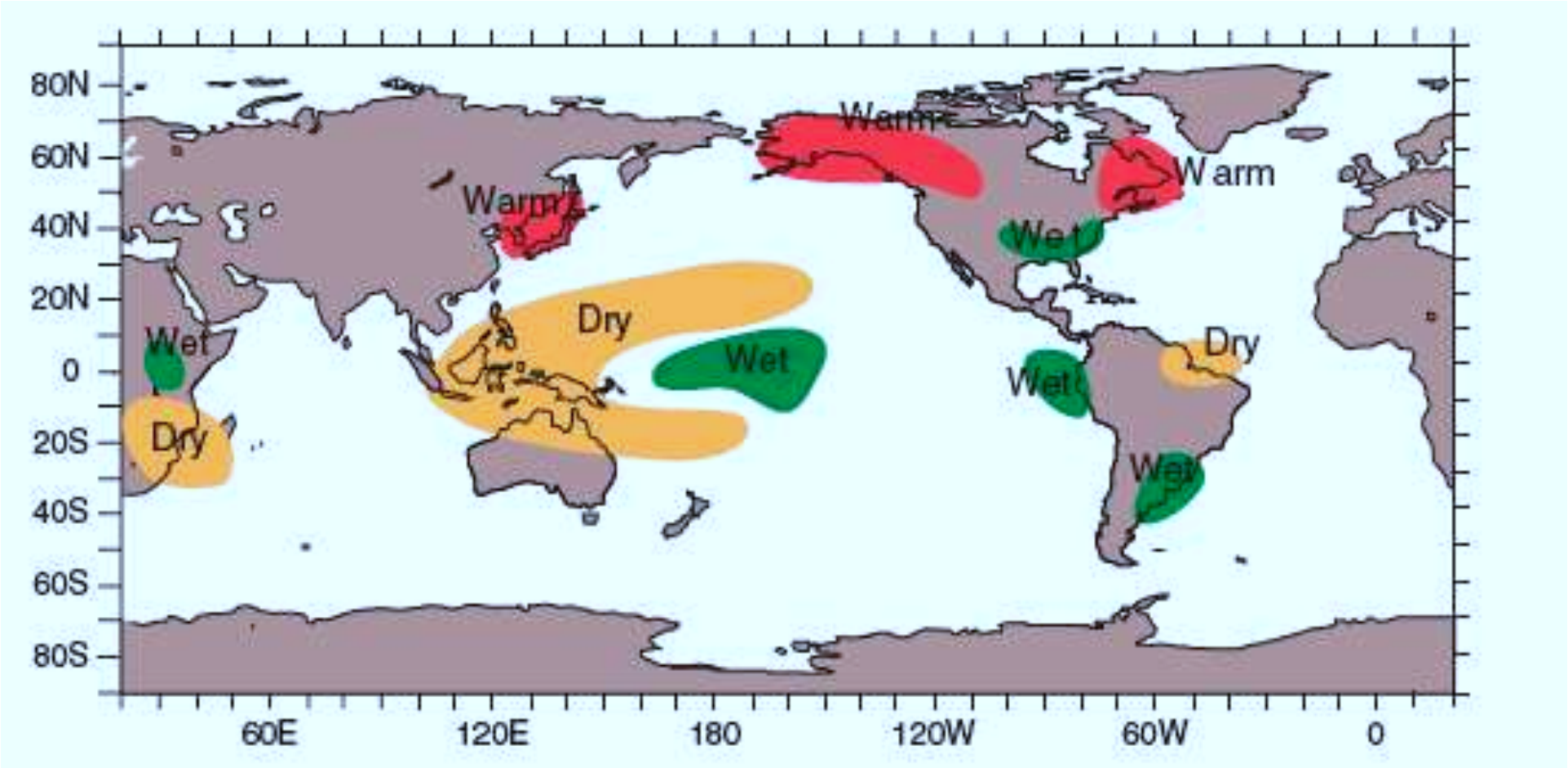


El Niño

La Niña

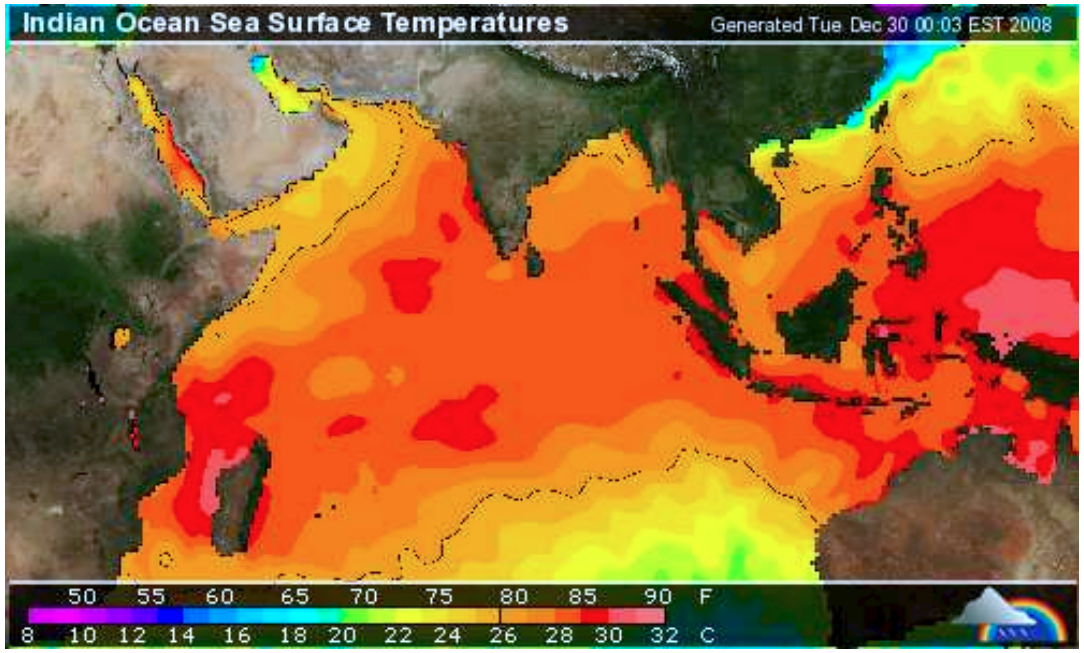
Note the winds tend to converge where temperature is high





Anomalies during El Niño: December-February

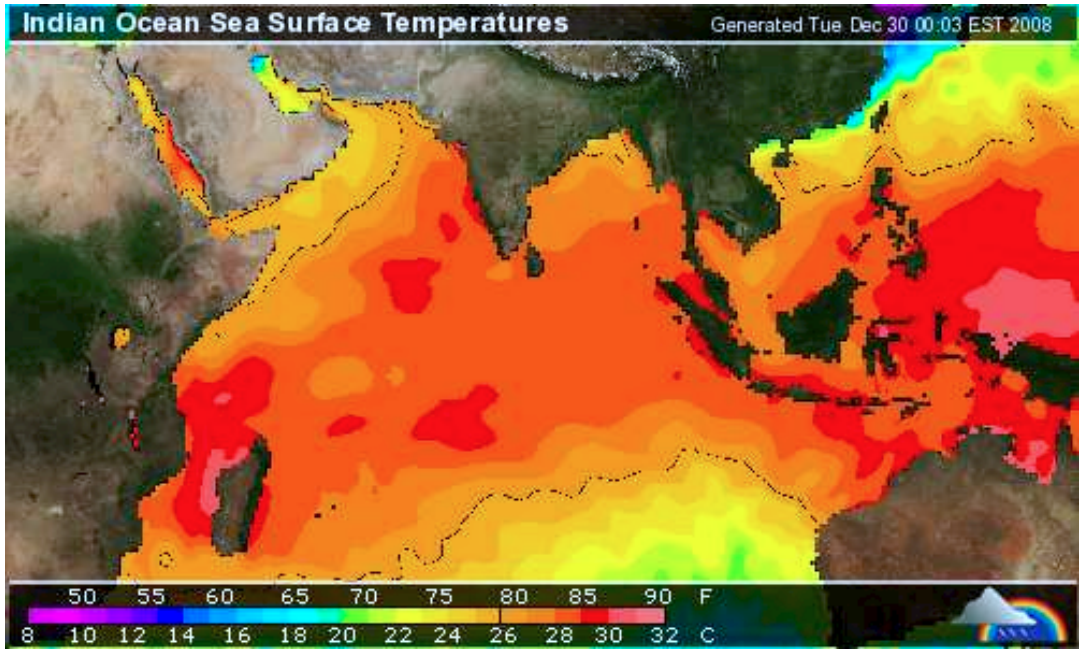
(only strongest associations)



Indian and tropical Atlantic SST also affect precipitation over the tropical as well

Hence, it's not clear how much of the long term trends in the tropics are due to global warming

Source: weather underground: data from NOAA



How will the Indian Monsoon change?

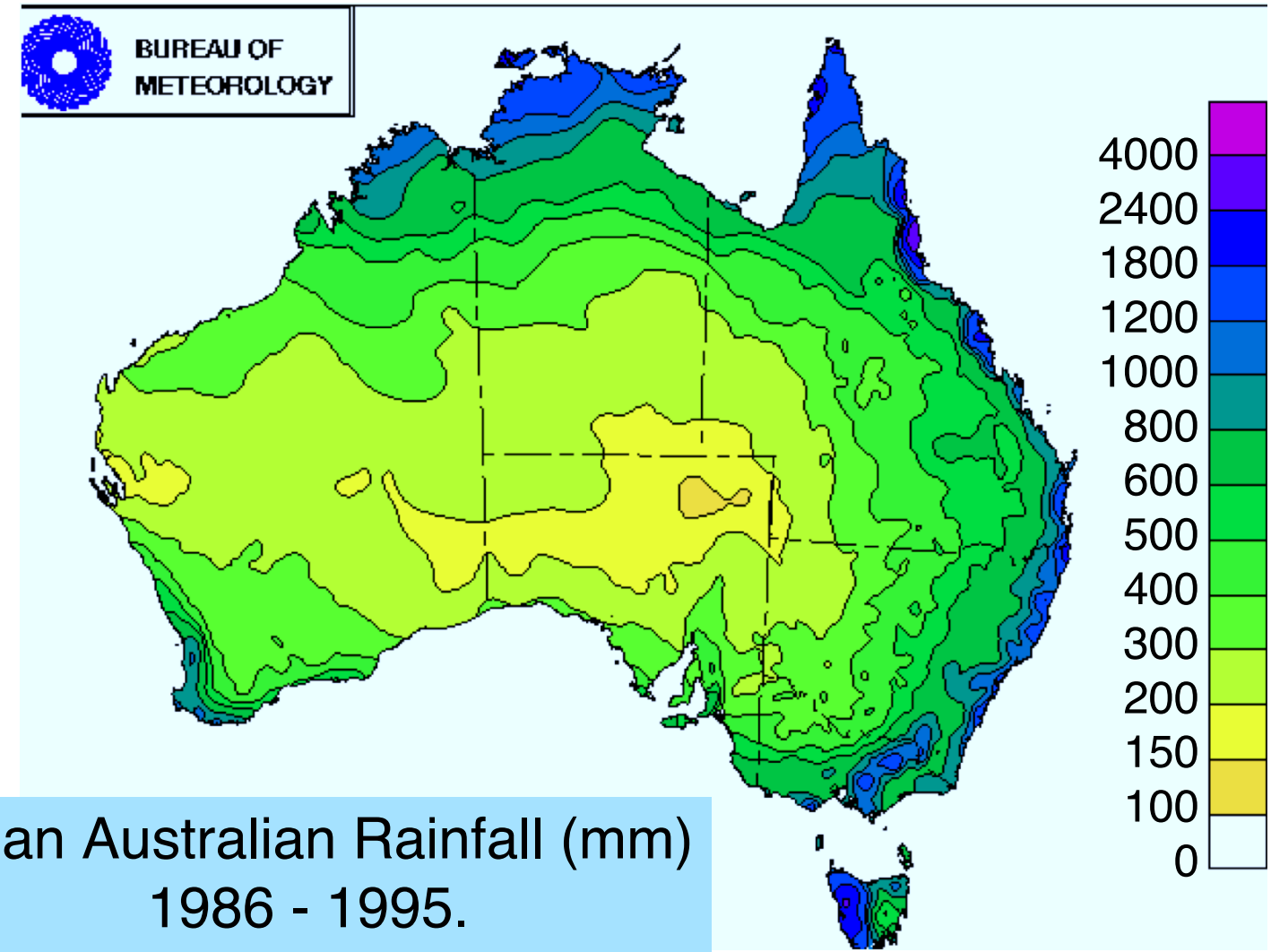
Warmer SST alone should reduce differential land/ocean heating and weaken the monsoon

Aerosols further complicate the issue:

Sulfate aerosols from burning fossil fuels reflect sunlight back to space and cool locally, which should weaken the monsoon

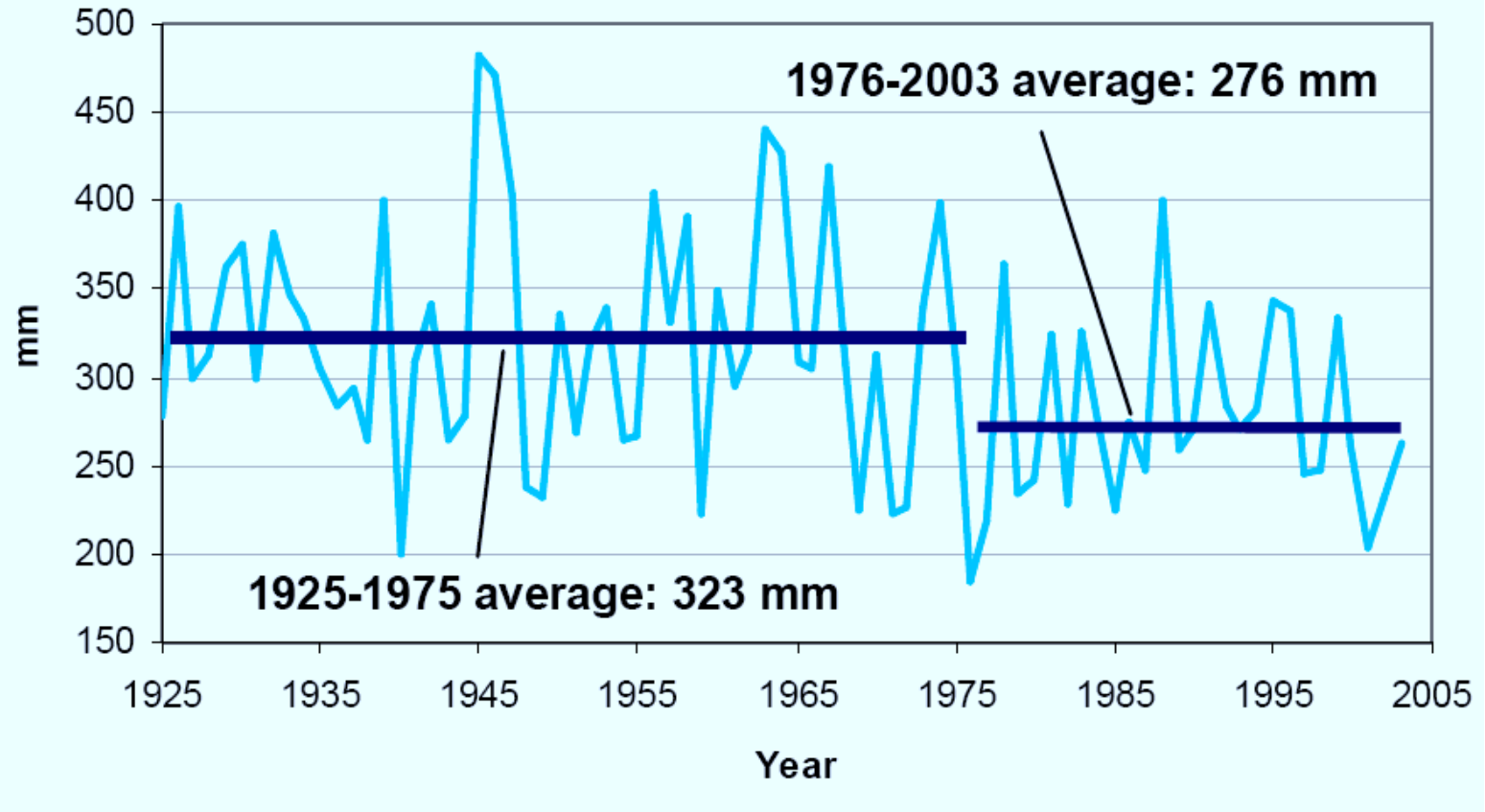
But black carbon from biomass burning (lots of it there) also absorbs sunlight and heats the atmosphere and surface, which should strengthen the monsoon

The drying of southern Australia



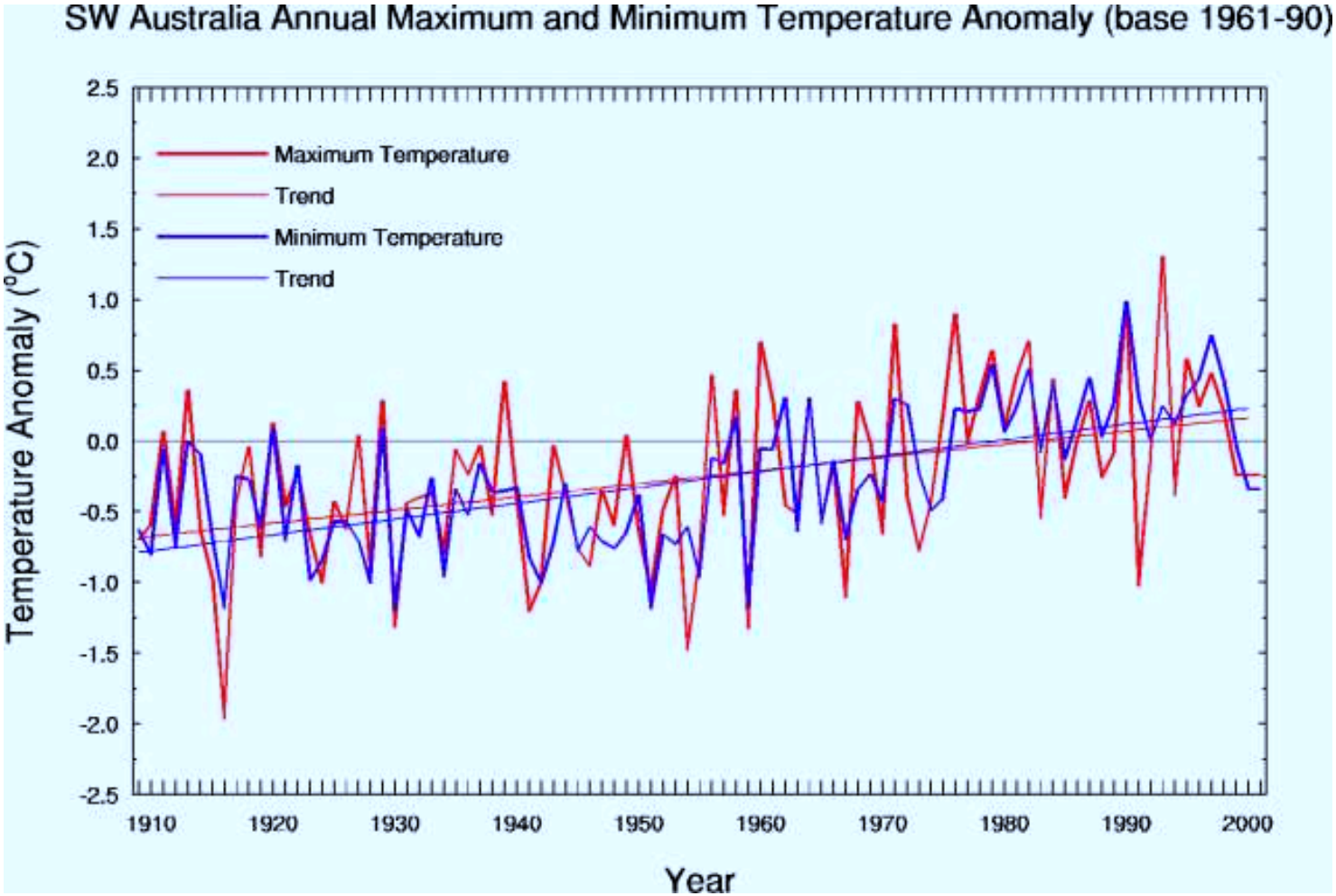
Mean Australian Rainfall (mm)
1986 - 1995.

The drying of southern Australia



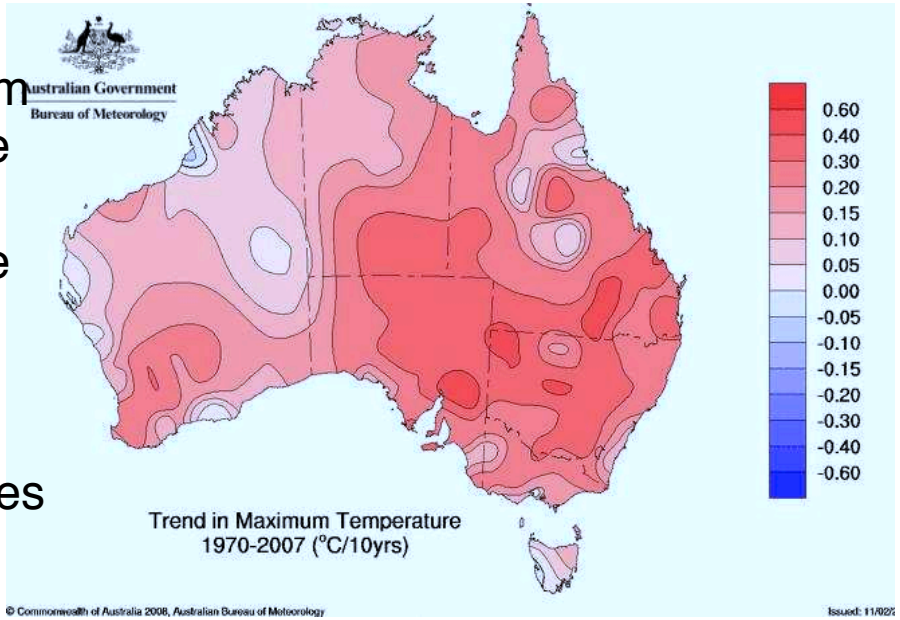
The decline in rainfall in south-western Australia since the 1960s.
Source:http://www.ioci.org.au/publications/pdf/IOCI_Notes_Series2.pdf**.**

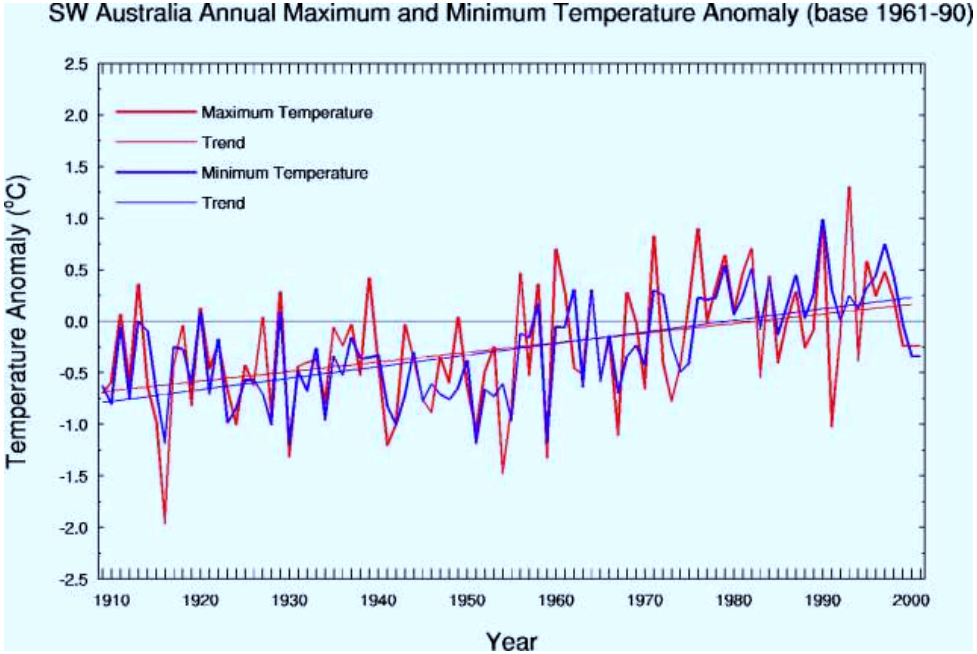
The drying of southern Australia

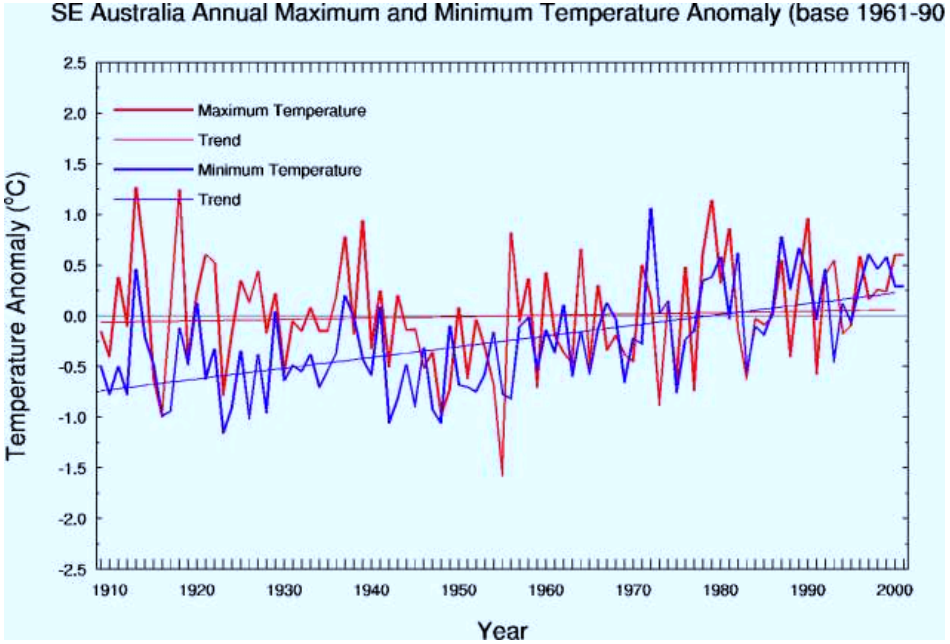


In most areas (as in SE Australia) the minimum temperature is trending upward faster than the maximum. This is likely because water vapor and/or cloud cover is increasing, which reduce heat loss especially at night. An increase in scattering sunlight could play a role too.

Note that in SW Australia, the drying out causes very high maximum temperature rise too.





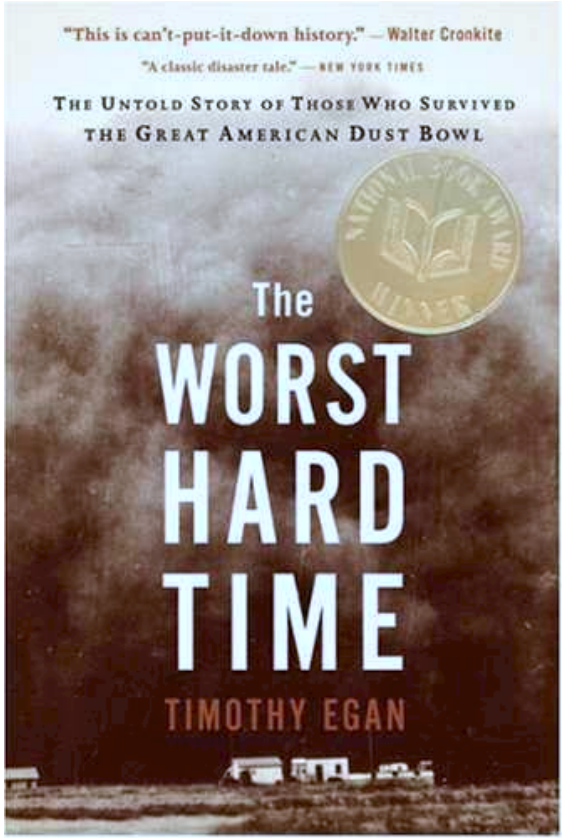


The drying of southern Australia

Other factors that may be playing a role

- southward shift in the storm track due to the ozone hole
- increased water demand due to rising temperatures
- increased water demand due to population growth

Do the rains follow the plough....
... or does agriculture promote desertification?



Dust Clouds Rolling Over the Prairie

The big melt (text p. 75-105)

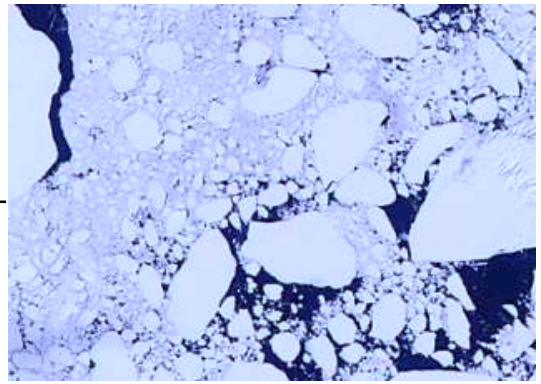
- On thin ice
- People, animals and ice
- A softening landscape
- How will Greenland's fate affect ours?
- What about Antarctica?
- Tropics and mid-latitudes: Goodbye glaciers
- Trouble towards the equator?
- Mid-latitude belt
- More than melting?


The big melt
elements of the cryosphere
documenting the changes

*The **cryosphere***

sea ice

a.k.a. *pack ice*



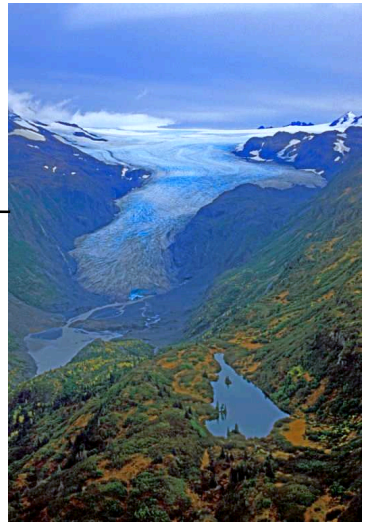
continental ice sheets

ice caps

permafrost

mountain glaciers

alpine glaciers



snow cover

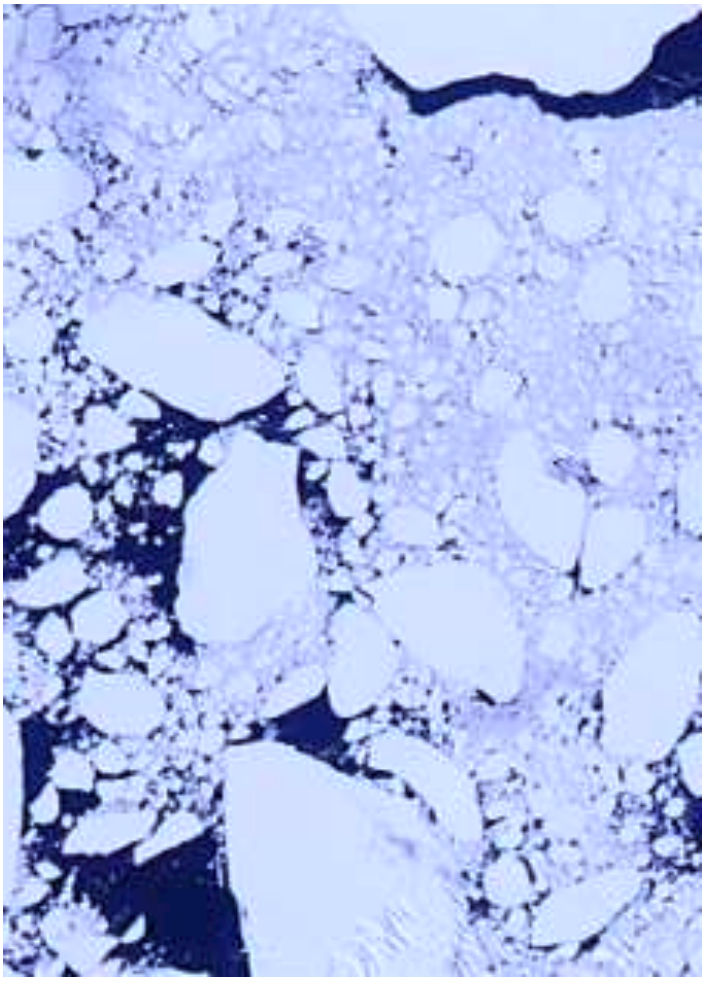
snow pack

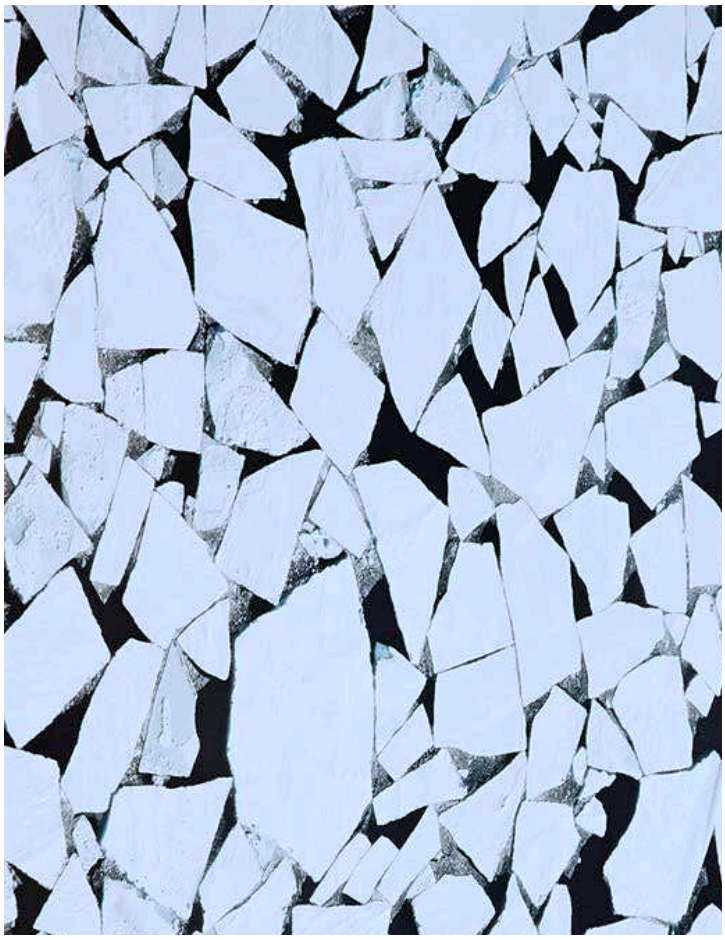
Tour of the Cryosphere 2009

http://svs.gsfc.nasa.gov/vis/a000000/a003600/a003619/

Sea Ice cover Jan 1 - Sep 14, 2007
false color AMSR-E passive microwave satellite

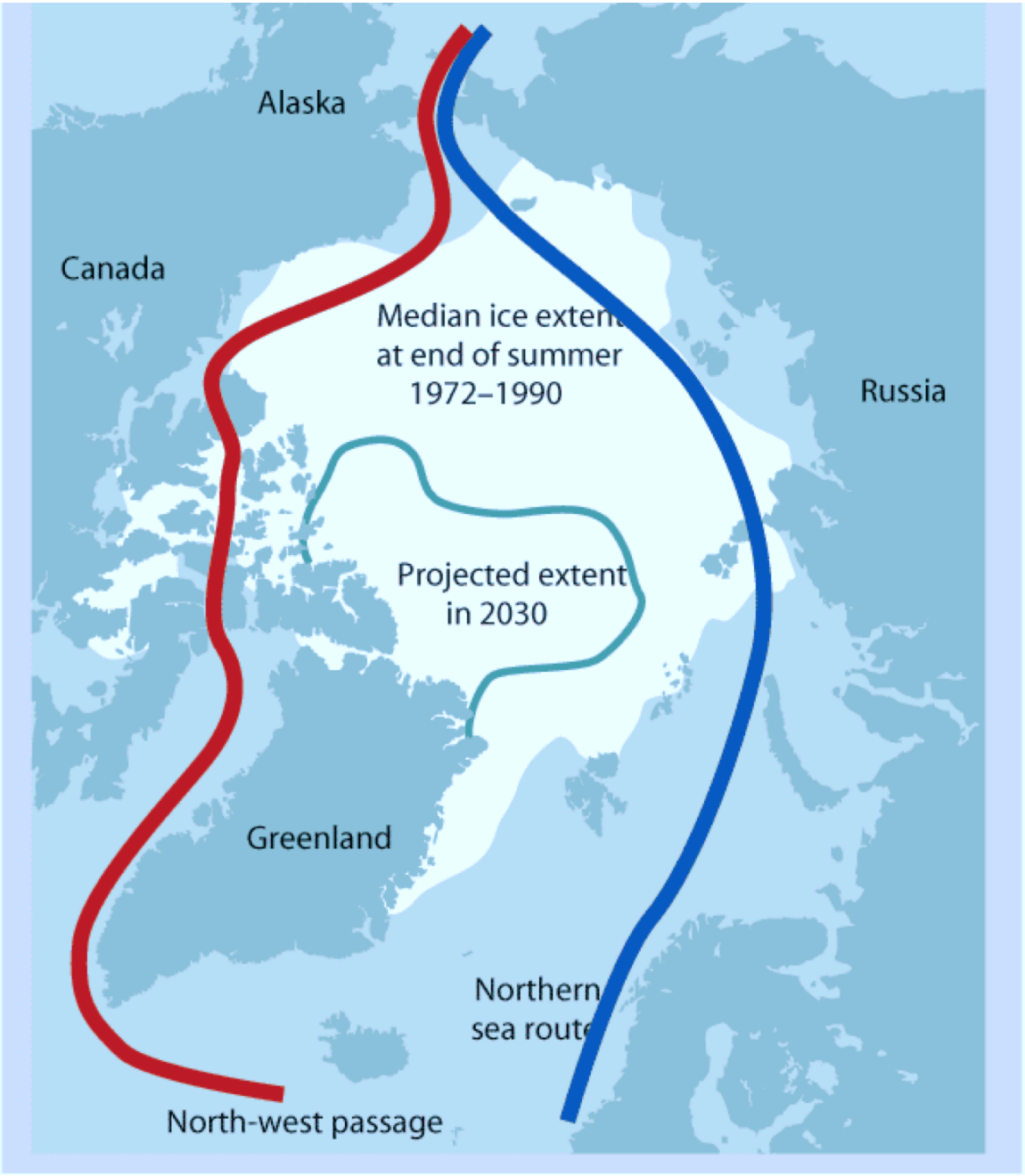
http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003456/





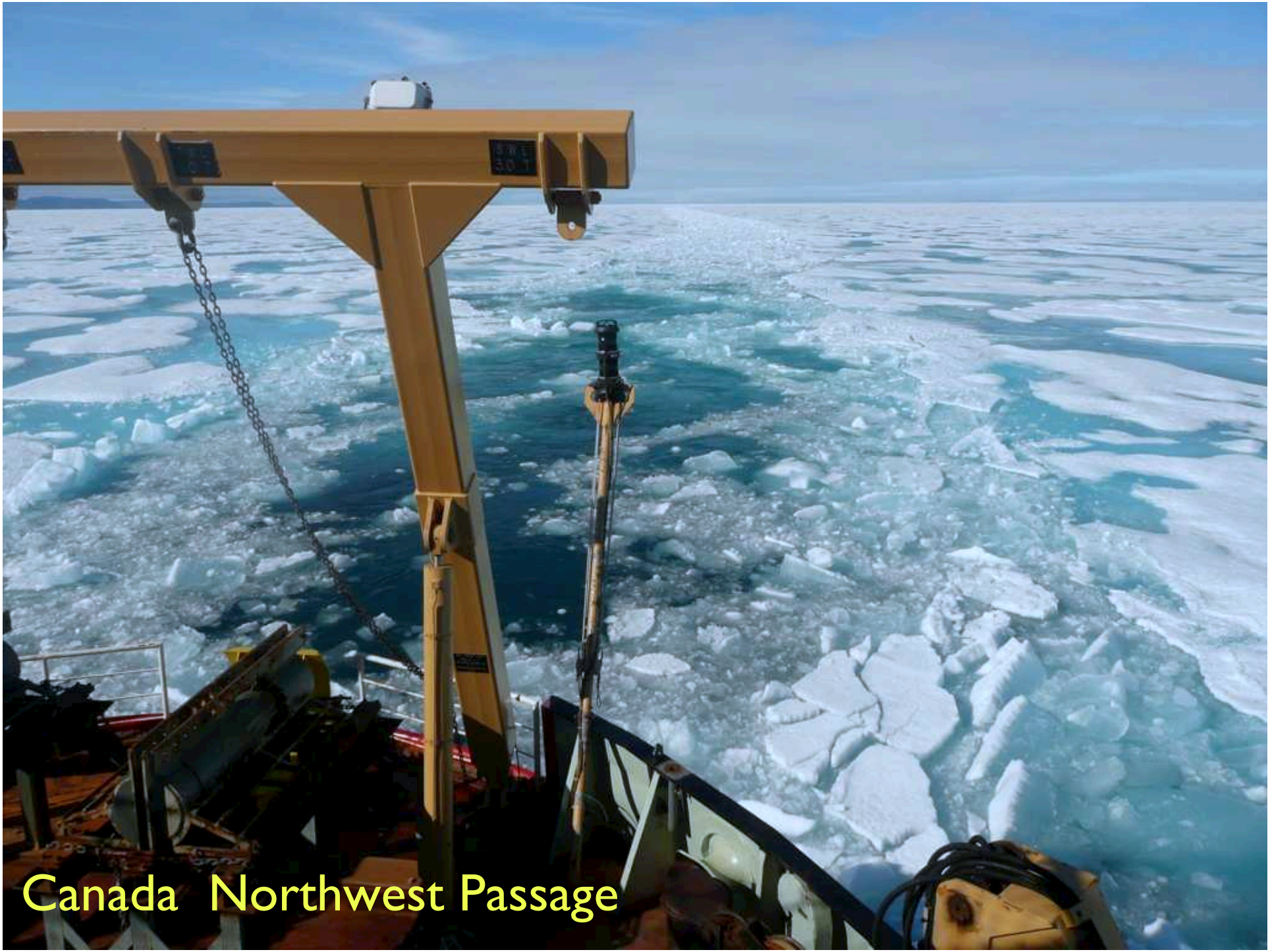
Pressure ridges

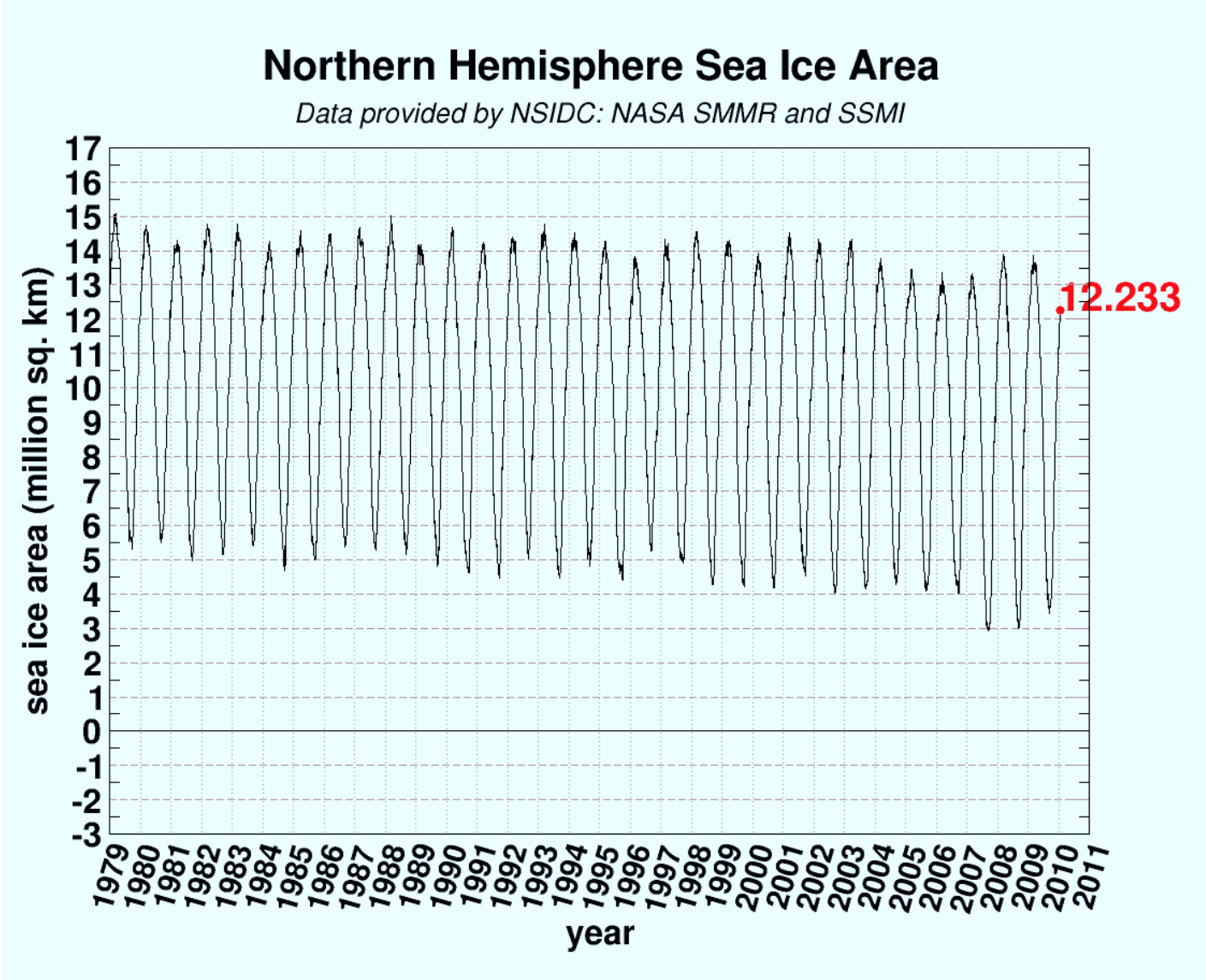
Arctic Sea Ice is typically 0.5 to 3 m thick, except in pressure ridges like these, which can be 10-30 m thick



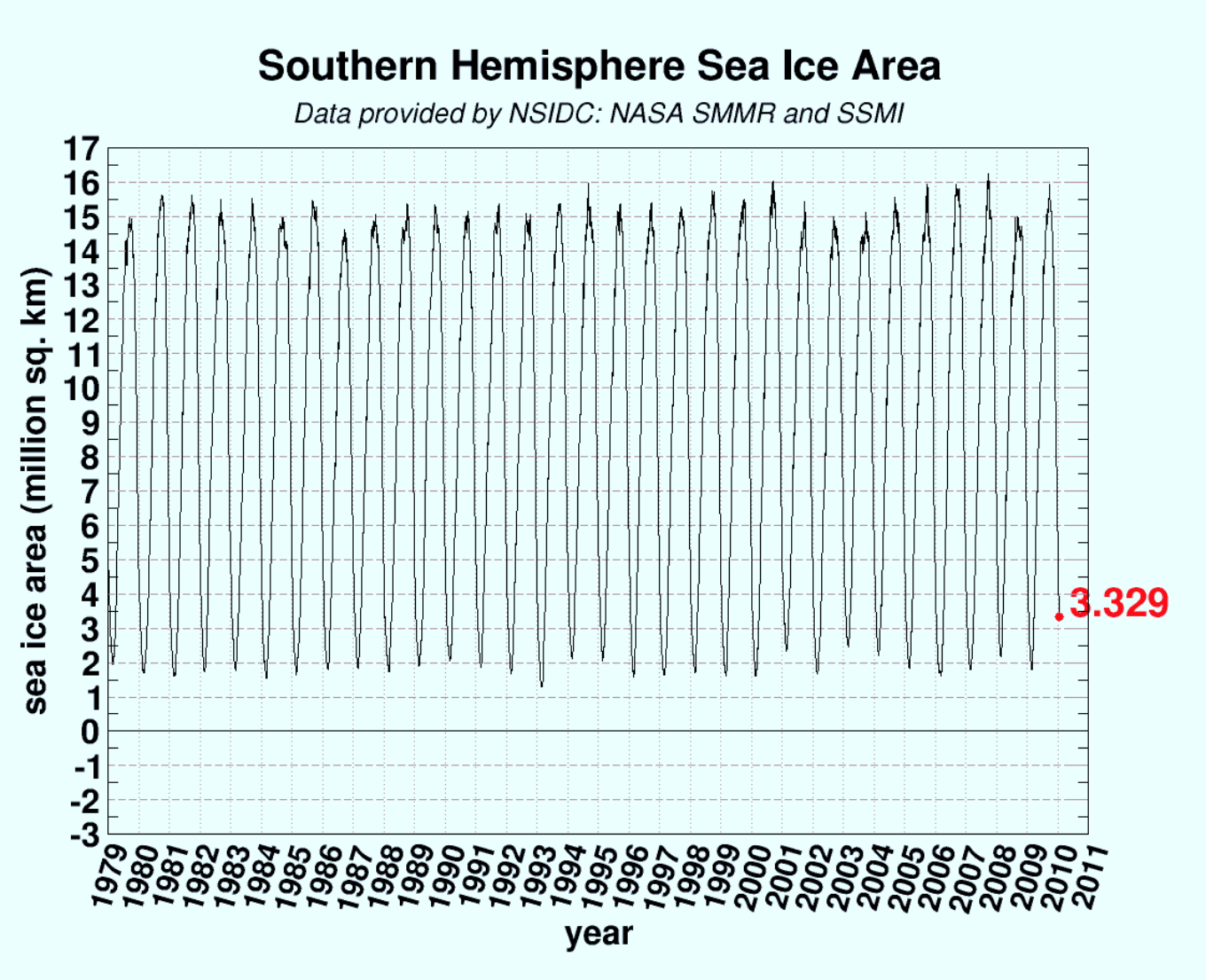
Projected summer shipping routes

Photo by J.M. Wallace. Northwest Passage, July 2008.

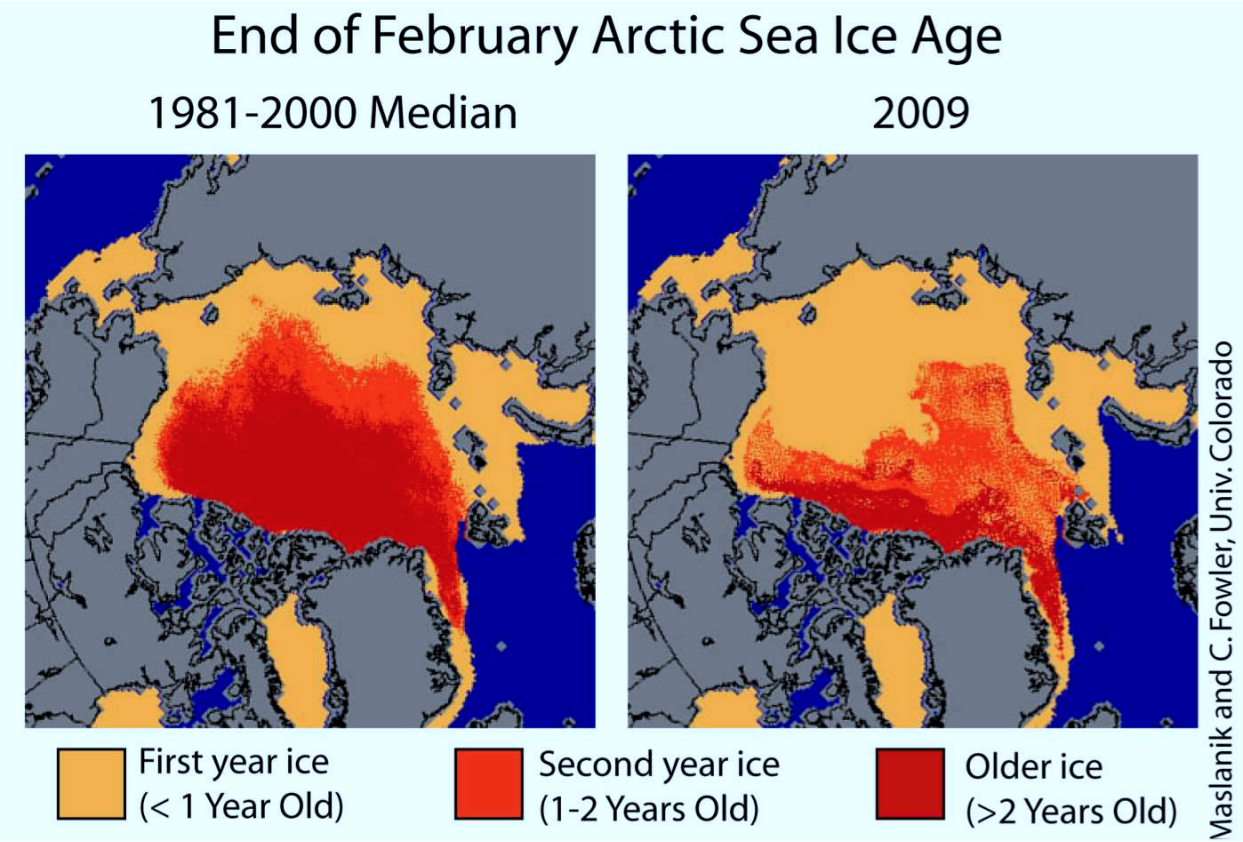

Canada Northwest Passage



Downward trend at minimum is ~1%/year



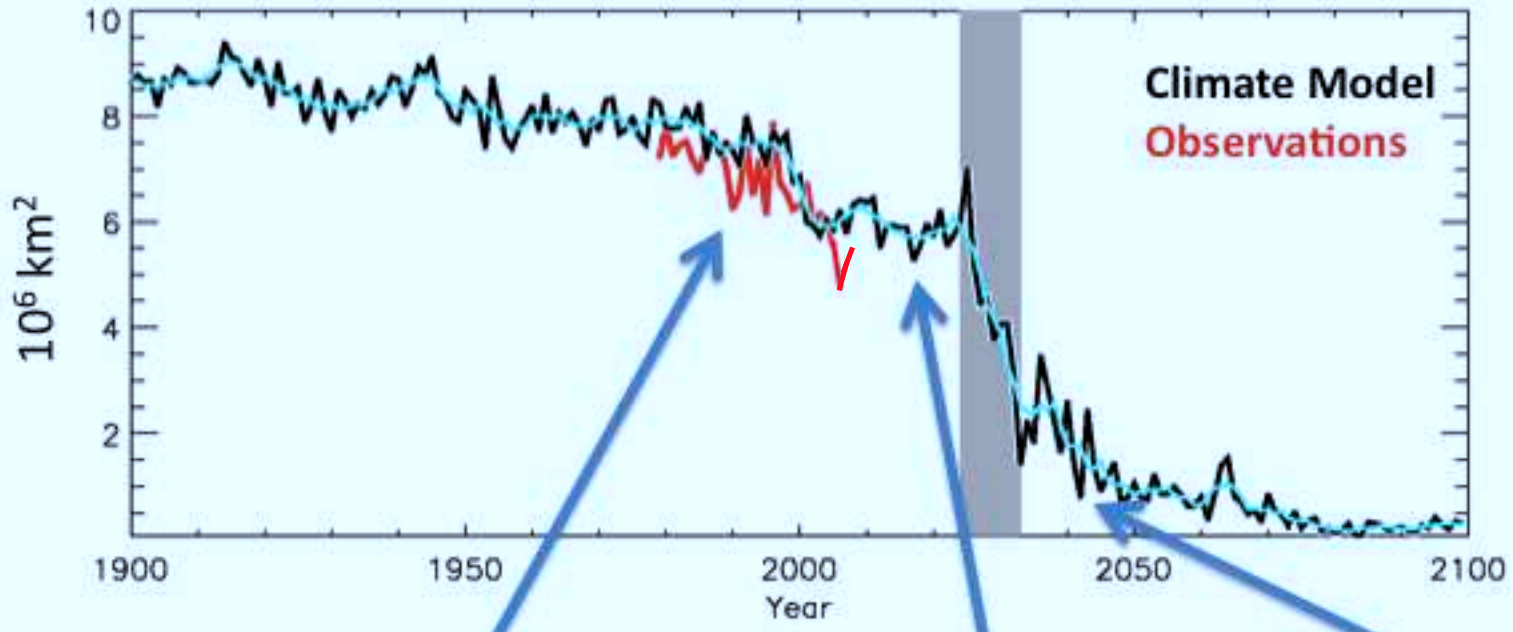
No significant trend

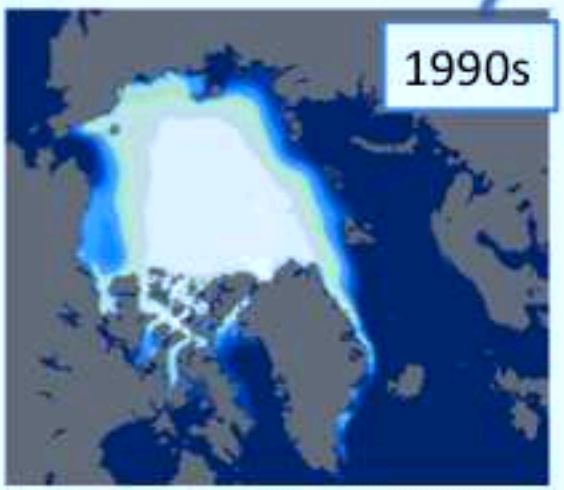


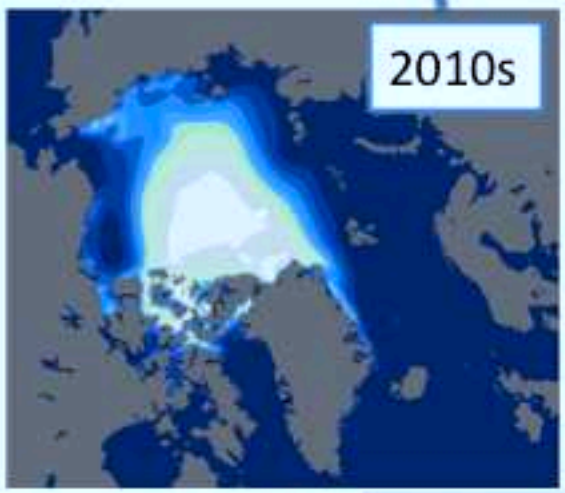
Arctic sea ice is younger and thinner and hence more vulnerable to variability in atmosphere and ocean

Maslanik and Fowler

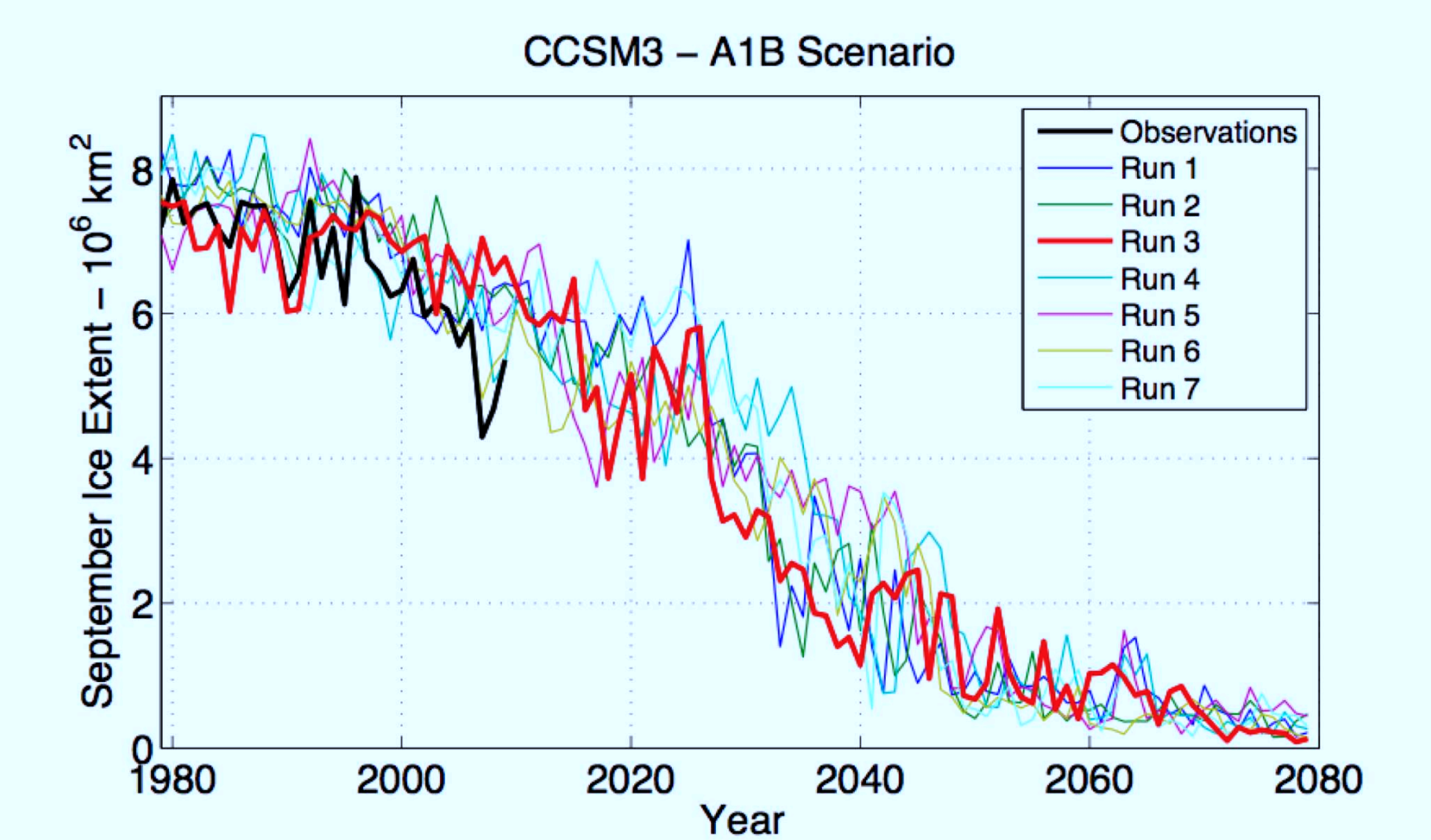
September Sea Ice Extent







Holland, Bitz, and Tremblay, 2006



Trend and Interannual variability is well represented in some models
note occasional decade of little change

Holland et al 2006, 2008

What is so special about climate in the polar regions?

Ice-albedo positive feedback amplifies warming

Poleward amplification reduces pole-to-equator temperature gradient, which then reduces atmospheric heat engine. Heat is drawn less towards pole and tropics warm more too.

Rising water vapor concentration and its transport poleward is expected to increase precipitation and possibly cloudiness

In winter, clouds have almost no albedo effect, so their GHE dominates

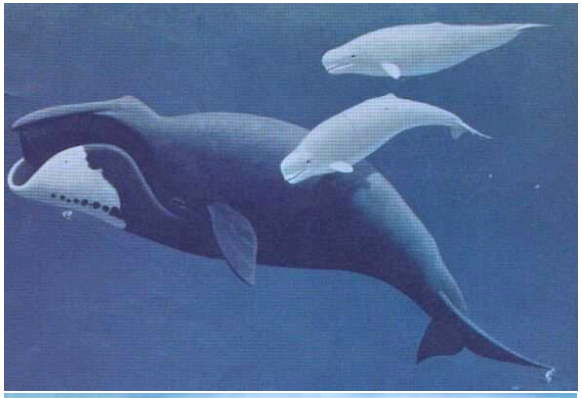
In summer, not so clear (but it is already ridiculously cloudy in summer anyway)

What is so special about climate ***impacts*** in the polar regions?

Fragile and specialized ecosystems

Erosion if sea ice disappears (it damps waves) and permafrost causes surfaces to soften

Rising sea level problem



Bowhead and Beluga whales

Harp seal

Northern fur seals

Walrus

Polar bear

Arctic wildlife

Listing the polar bear as a threatened species

Feb 2005 petition from Center for Biological Diversity later joined by Natural Resource Defense Council and Greenpeace

Dec 2005, the petitioners filed a complaint for failure to issue a 90-day finding in response to the petition as required by section the Endangered Species Act.

Feb 2006, Secretary of the Interior Dirk Kempthorne said scientific information indicating that listing the polar bear may be warranted; initiated 12 month review by the Fish and Wildlife Service

Dec 2007 12 scientific reports filed; Secretary Kempthorne proposed threatened listing is warranted. One-year comment period for final decision

http://www.interior.gov/secretary/speeches/081405_speech.html

U.S. Department of the Interior

Remarks By Secretary Kempthorne
Press Conference On Polar Bear Listing
May 14, 2008

Today I am listing the polar bear as a "threatened" species under the Endangered Species Act.

I believe this decision is most consistent with the record and legal standards of the Endangered Species Act – perhaps the least flexible law Congress has ever enacted.

I am also announcing that this listing decision will be accompanied by administrative guidance and a rule that defines the scope of impact my decision will have, in order to protect the polar bear while preventing unintended harm to the society and economy of the United States.

In taking these actions, I accept the recommendations of the Assistant Secretary for Fish and Wildlife and Parks, Lyle Laverty, and the Director of the U.S. Fish and Wildlife Service, Dale Hall. I also relied upon scientific analysis from the Director of the U.S. Geological Survey, Dr. Mark Myers, and his team of scientists.

The ESA protects vulnerable animals with two classifications:

- An "endangered" species is in danger of extinction
- A "threatened" species is likely to become an endangered species in the foreseeable future.

Today's decision is based on three findings. First, sea ice is vital to polar bear survival. Second, the polar bear's sea-ice habitat has dramatically melted in recent decades. Third, computer models suggest sea ice is likely to further recede in the future.

Emperor penguins (a)

Albatross

Krill

(c)

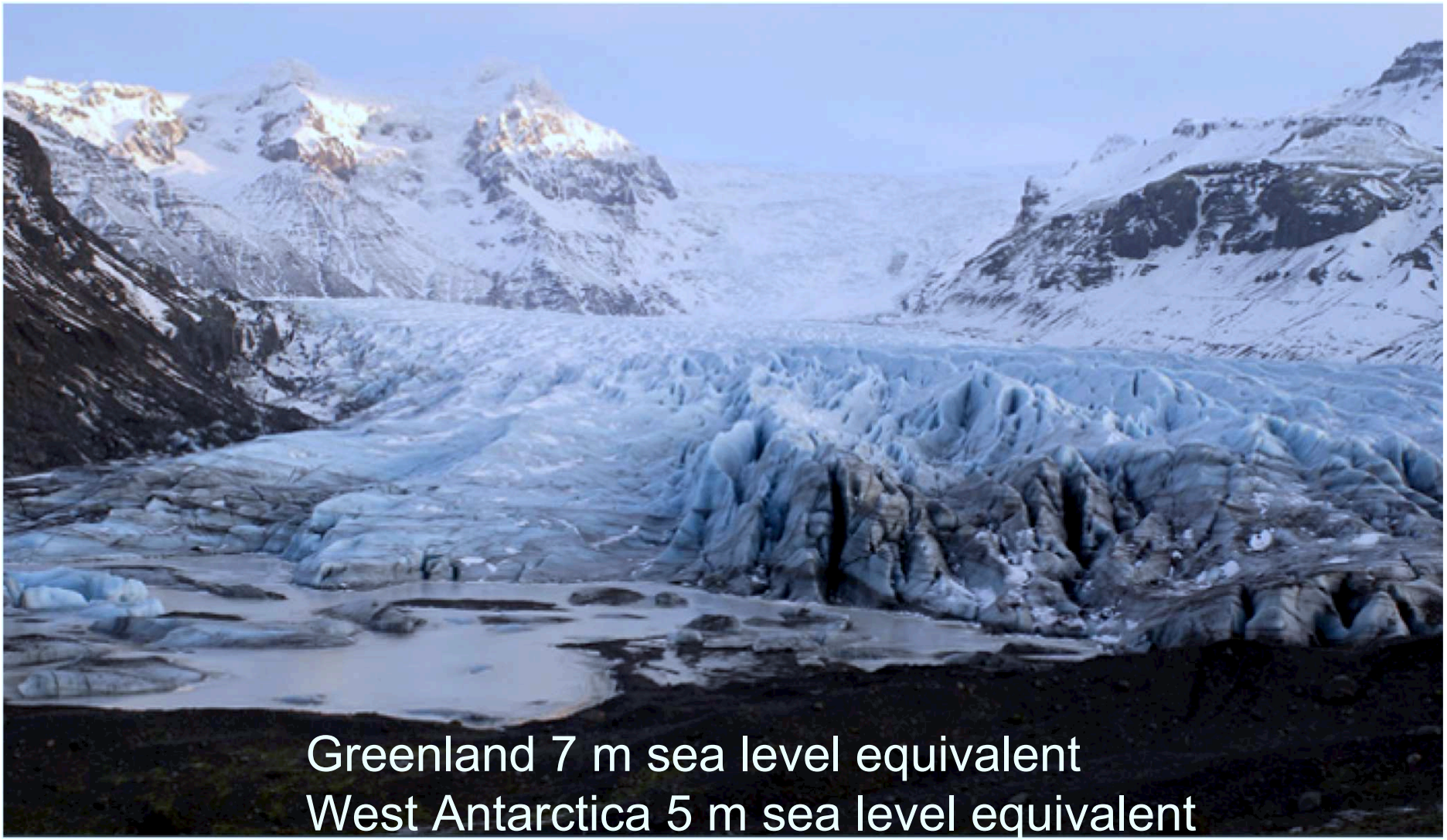
Leopard seal

Antarctic wildlife

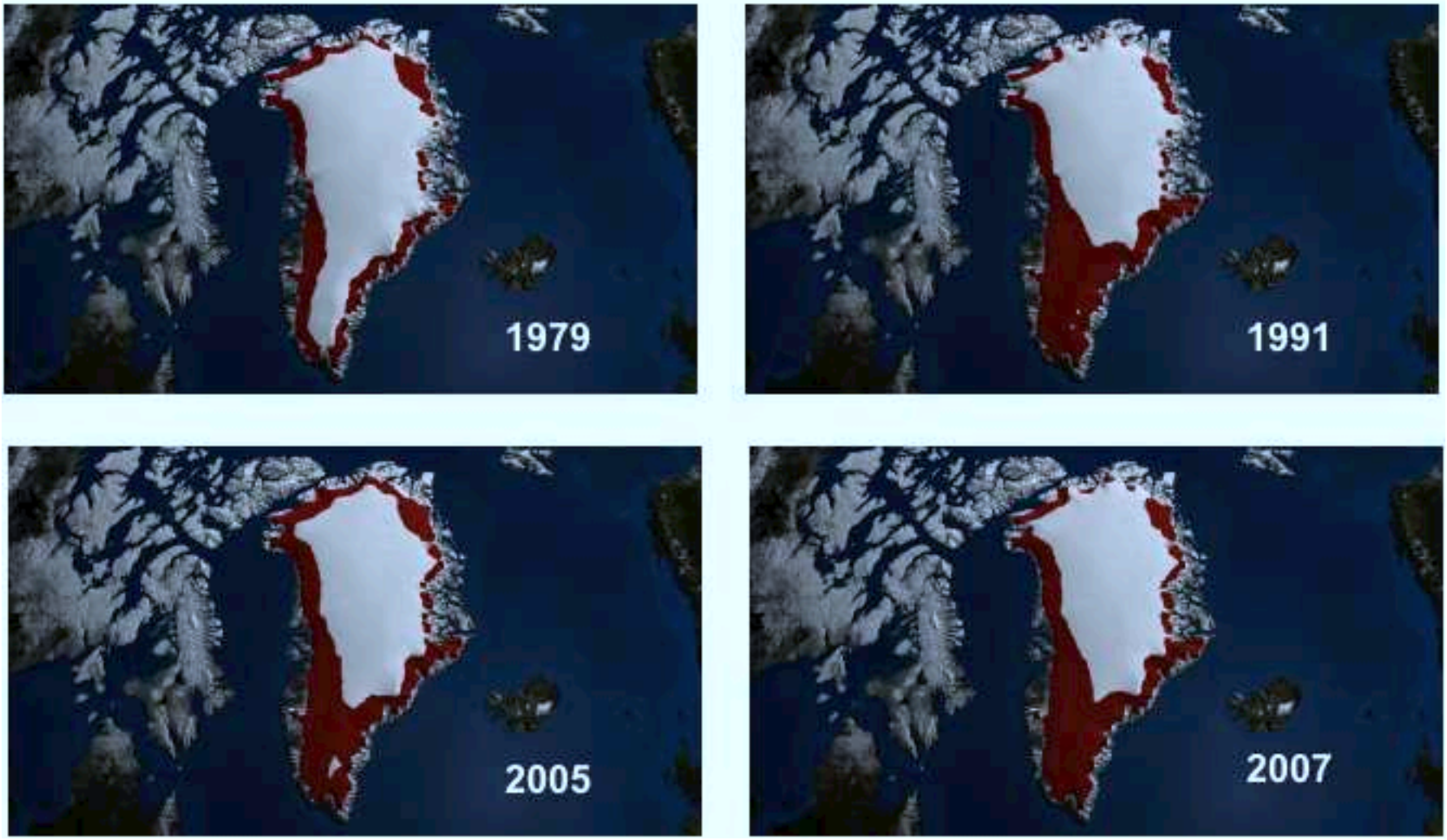
Does the water level change when the ice melts?

Does sea ice melting cause sea level rise?

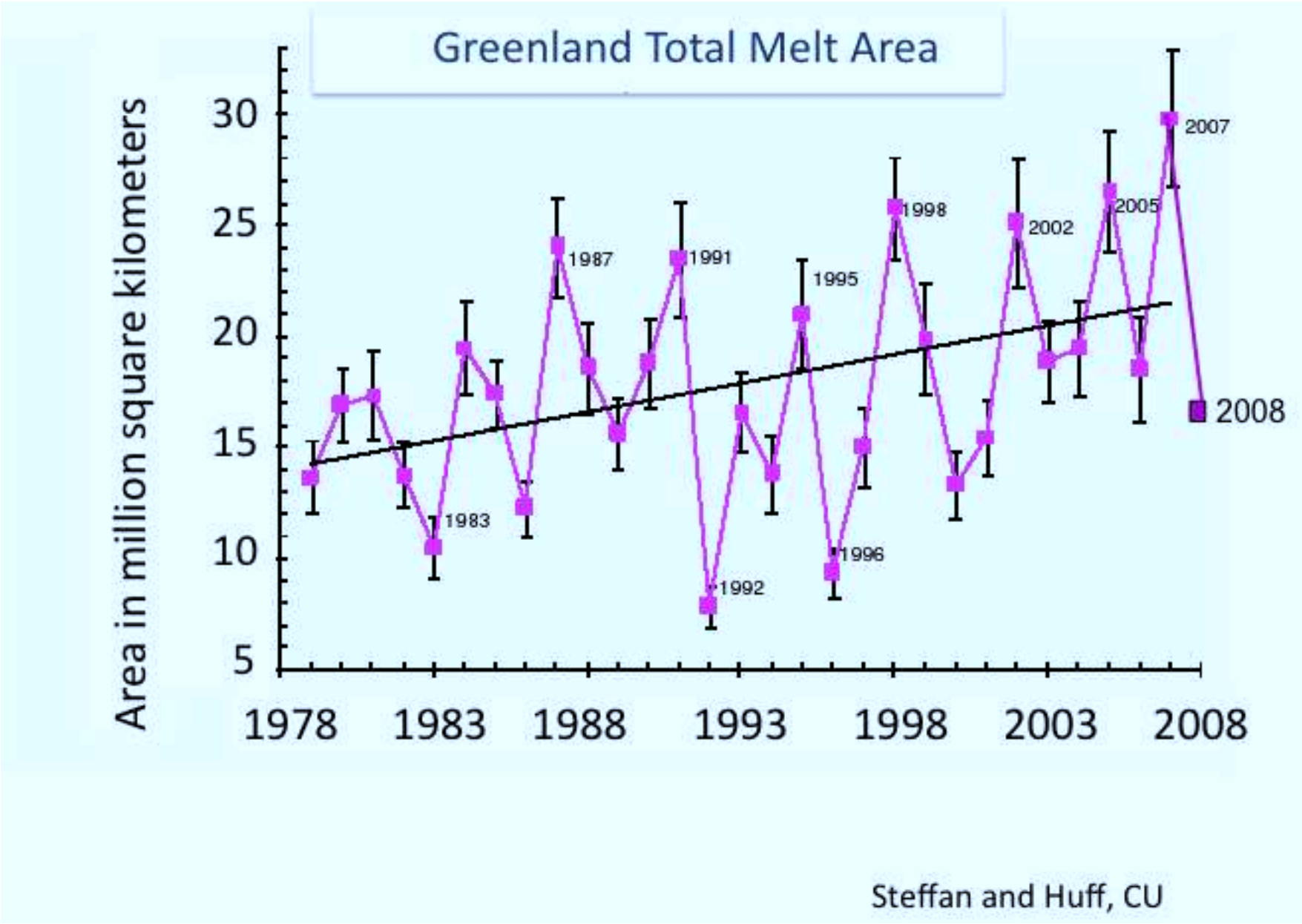
What about land ice?



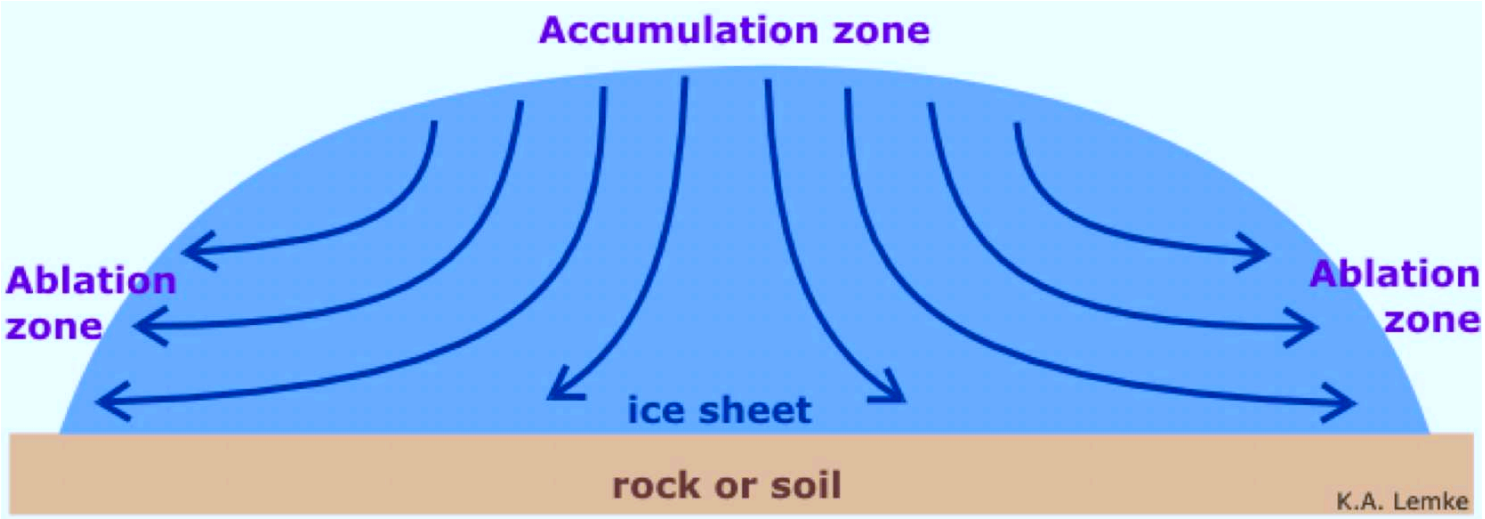
Area of Greenland Experiencing Melt



The latter three are unusually high years



Melting so far has amounted to a minute fraction of total volume



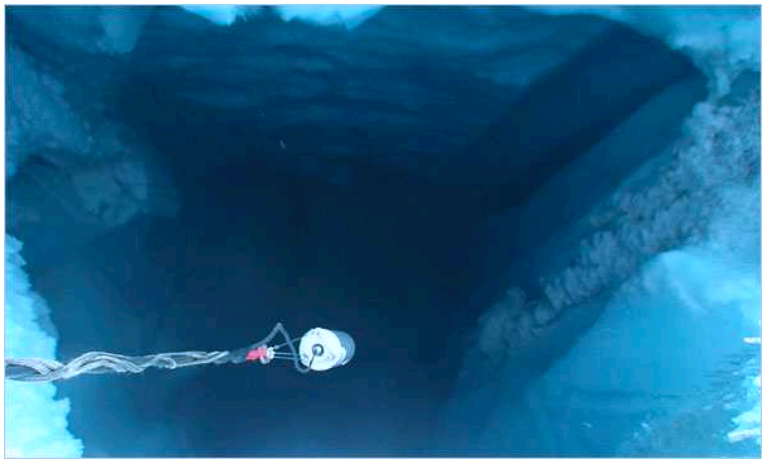
Mass balance of an ice sheet

Rate of change of mass = Rate of accumulation – Rate of ablation

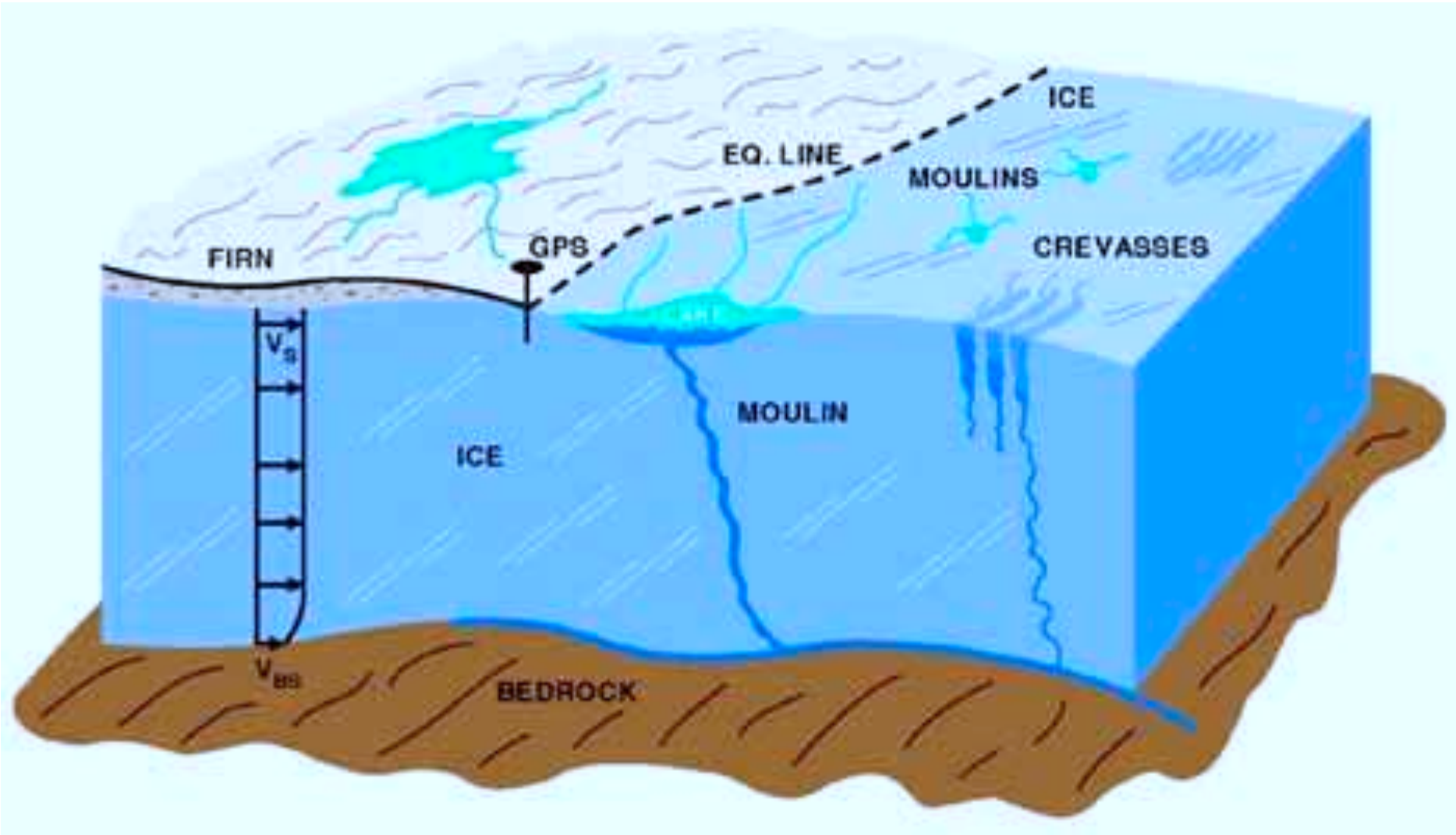
Ablation is the rate of loss of mass of the ice sheet

which can include **dynamic losses by calving**

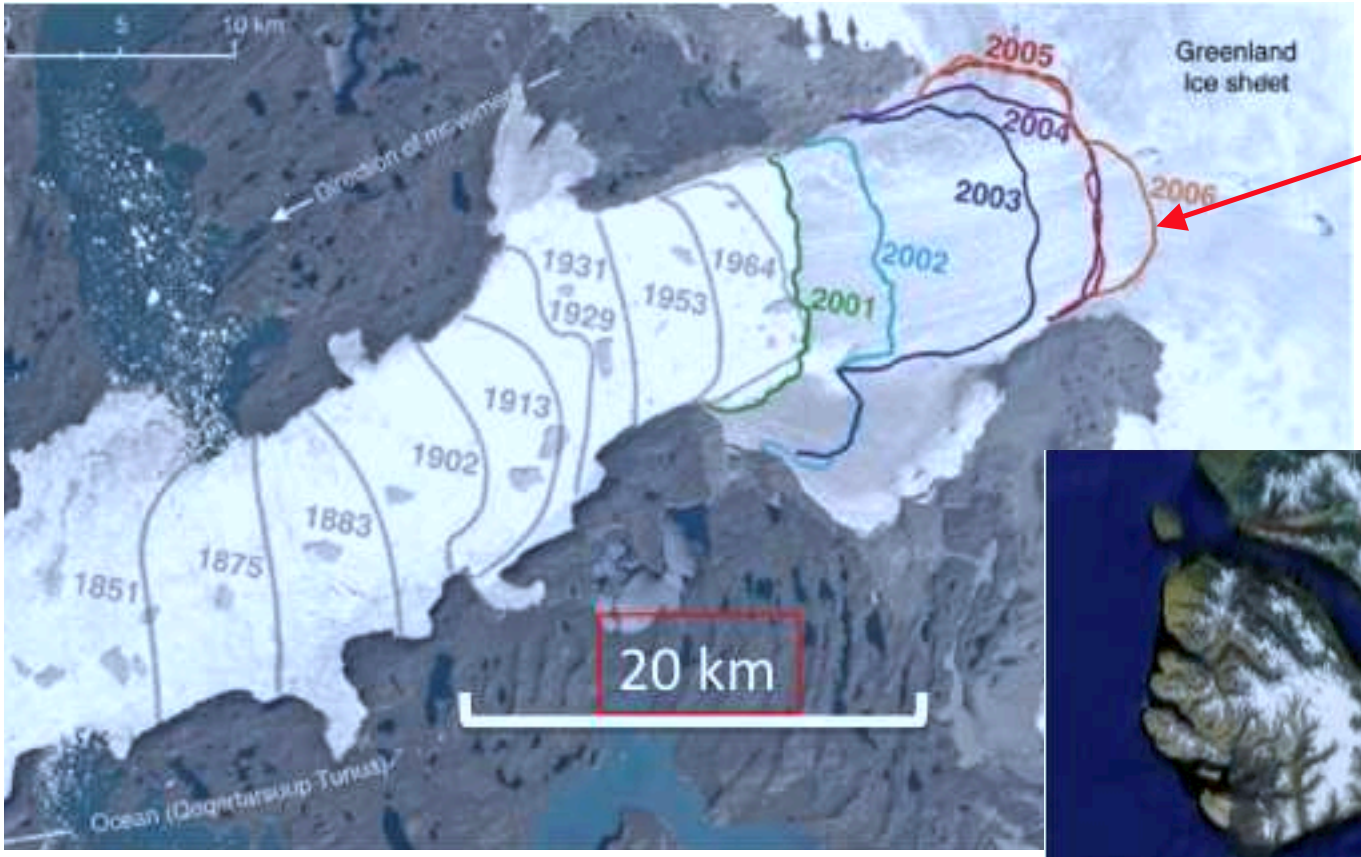
Higher melt may cause greater dynamic loss



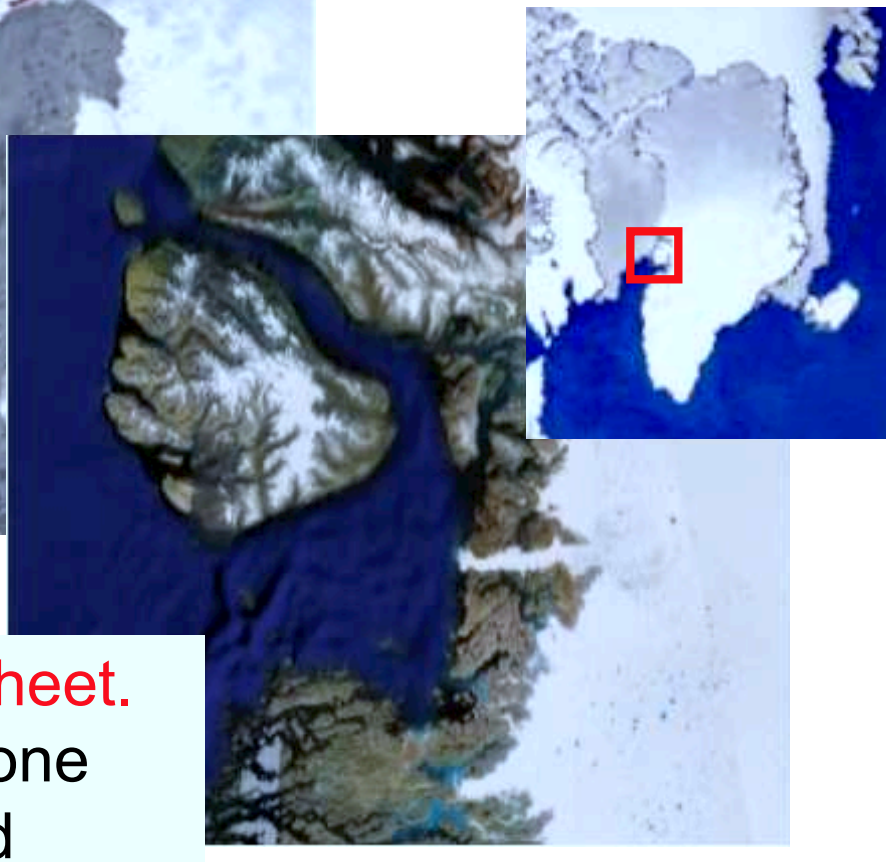
The melt water can fall through cracks that reach the bedrock


ICE
EQ. LINE
MOULINS
GPS
FIRN
CREVASSES
MOULIN
ICE
BEDROCK

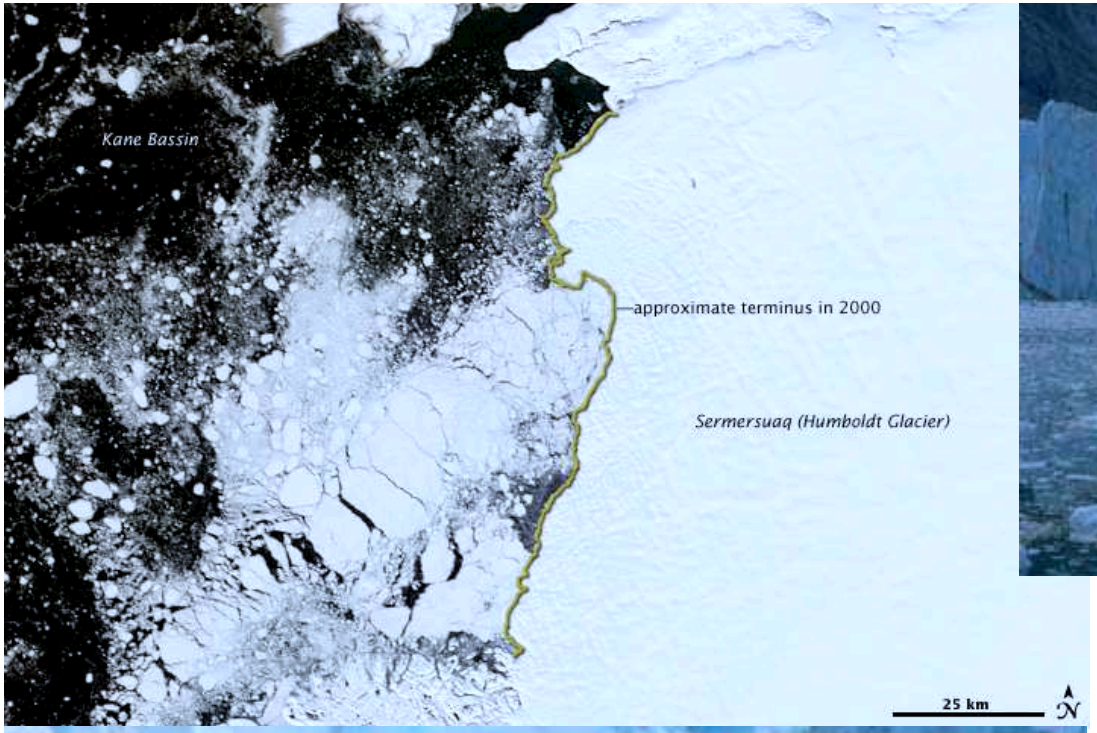
Greenland is surrounded by fjords filled with ice streams



calving front, now at grounding line



Fjords serve to buttress the ice sheet.
They reduce dynamic loss. This one drains 6.5% of Greenland ice and makes most bergs in N. Atlantic.



Glacier calving

A natural process but terminus of many glaciers is retreating

Ayles ice sheet movie

http://svs.gsfc.nasa.gov/vis/a000000/a003400/a003430/