GEOL/ENVS 3520

section 002

Prof. Scott Lehman, Geol. Sci. and INSTAAR
(Leilani Arthurs, SEI Scholar)

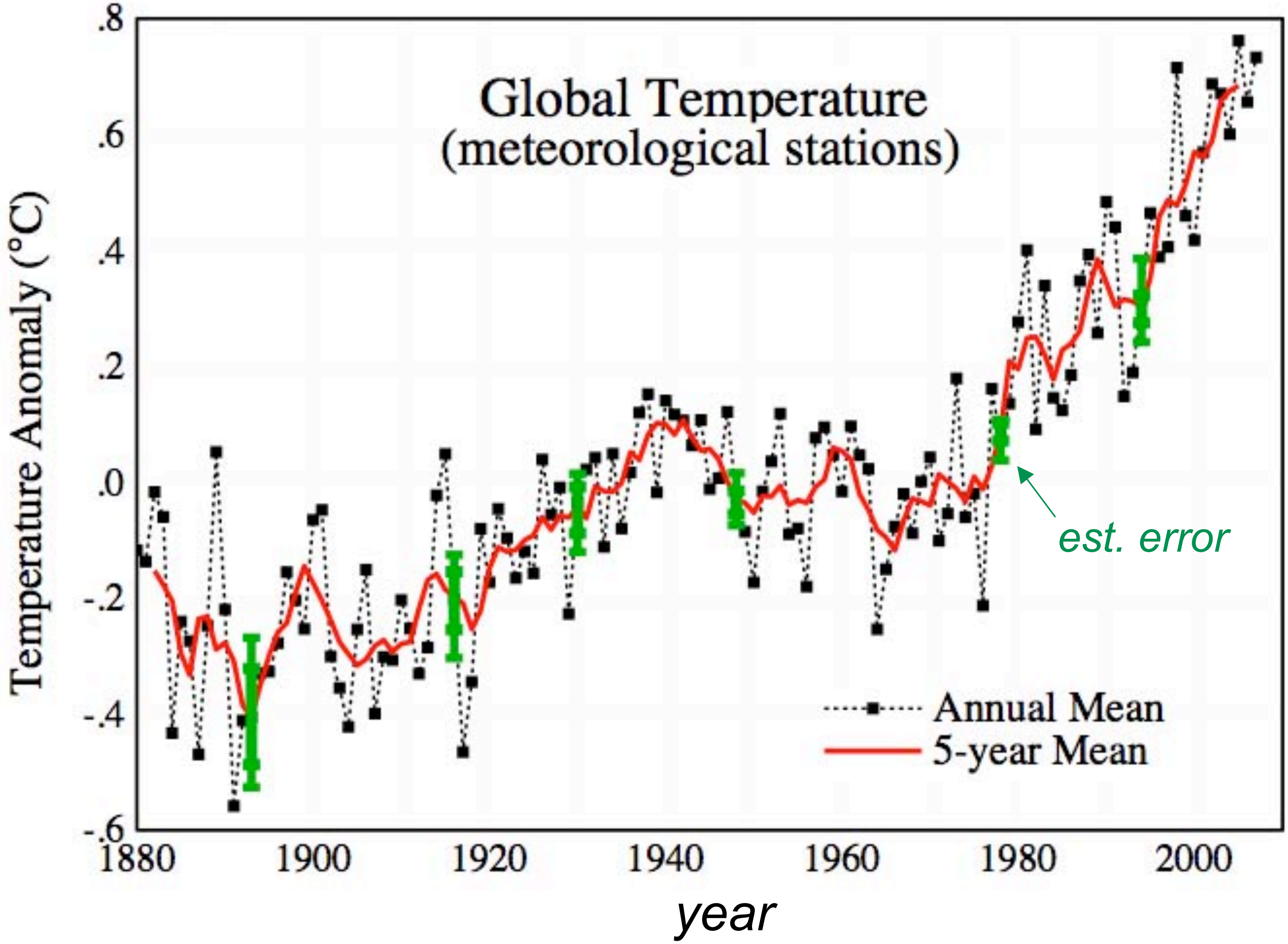
What is the single biggest environmental issue facing society today?

What is the single biggest environmental issue in the the Earth sciences today?

Is the Earth warming?

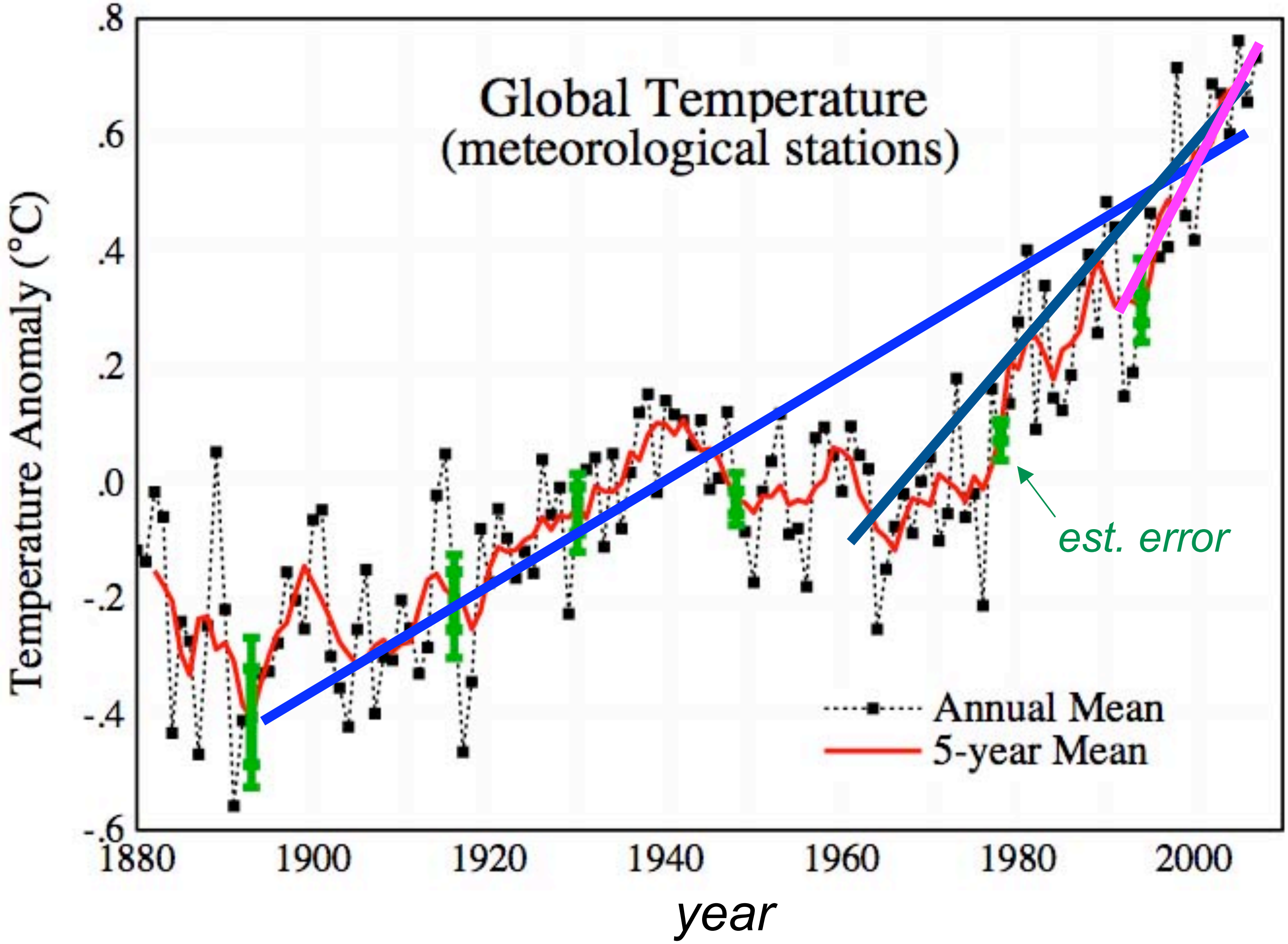
How do we know?

150 yrs of thermometer measurements



NASA-GISS

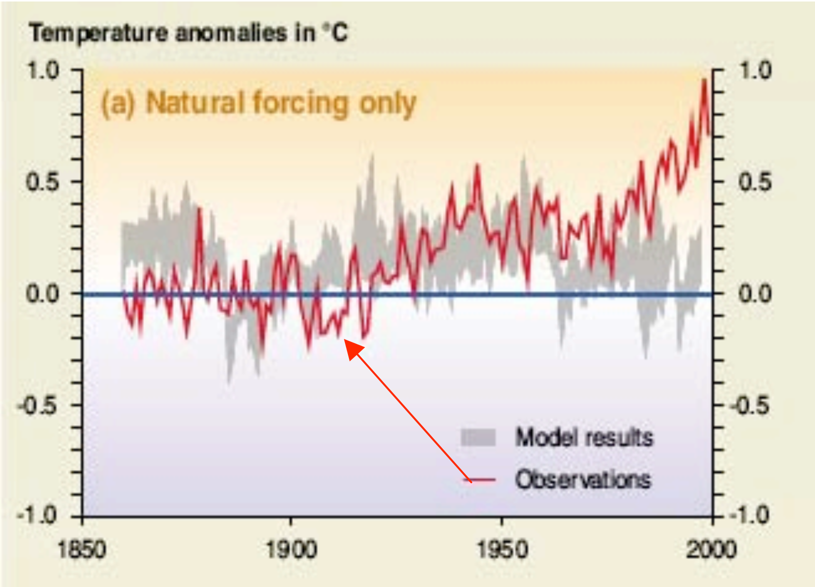
150 yrs of thermometer measurements



and the rate of warming is increasing NASA-GISS

Global warming is an over-whelmingly robust observation (as we shall see), but how much of recent global warming is “man made”?

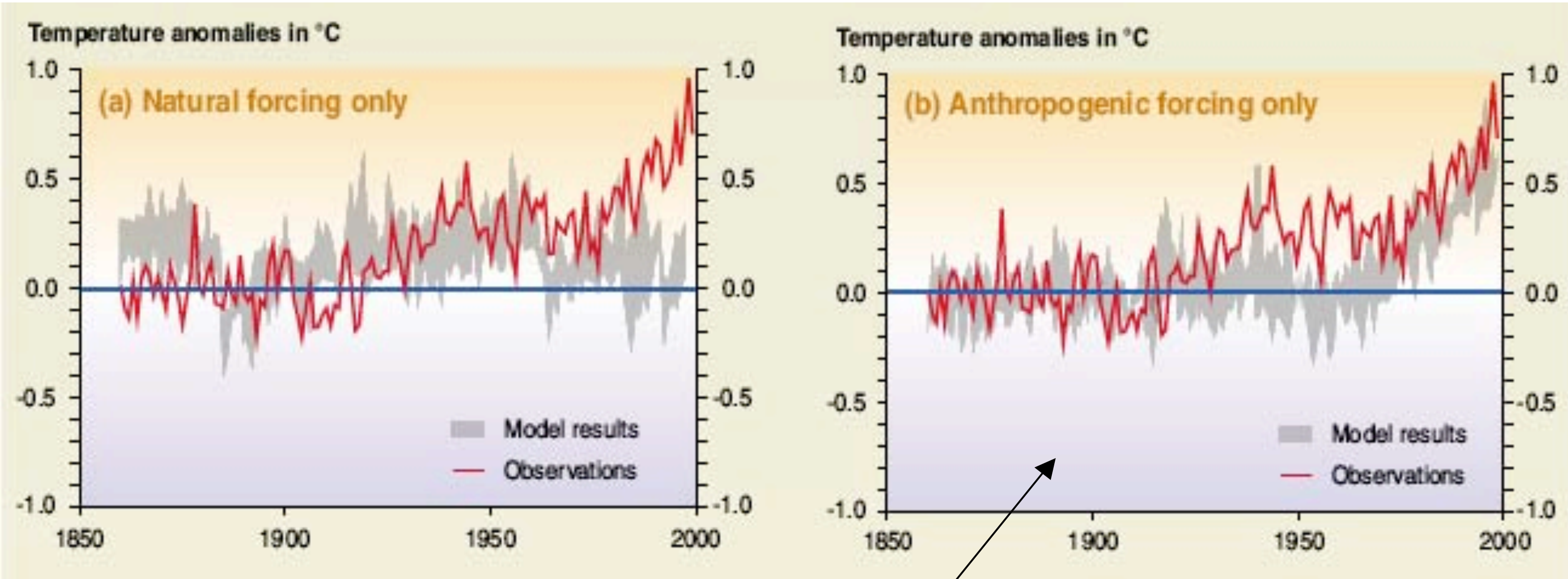
global temperature change since 1860



climate model
“hindcast”:
natural
causative
factors
(“forcings”)
only

IPCC TAR (2001)

global temperature change since 1860



climate model
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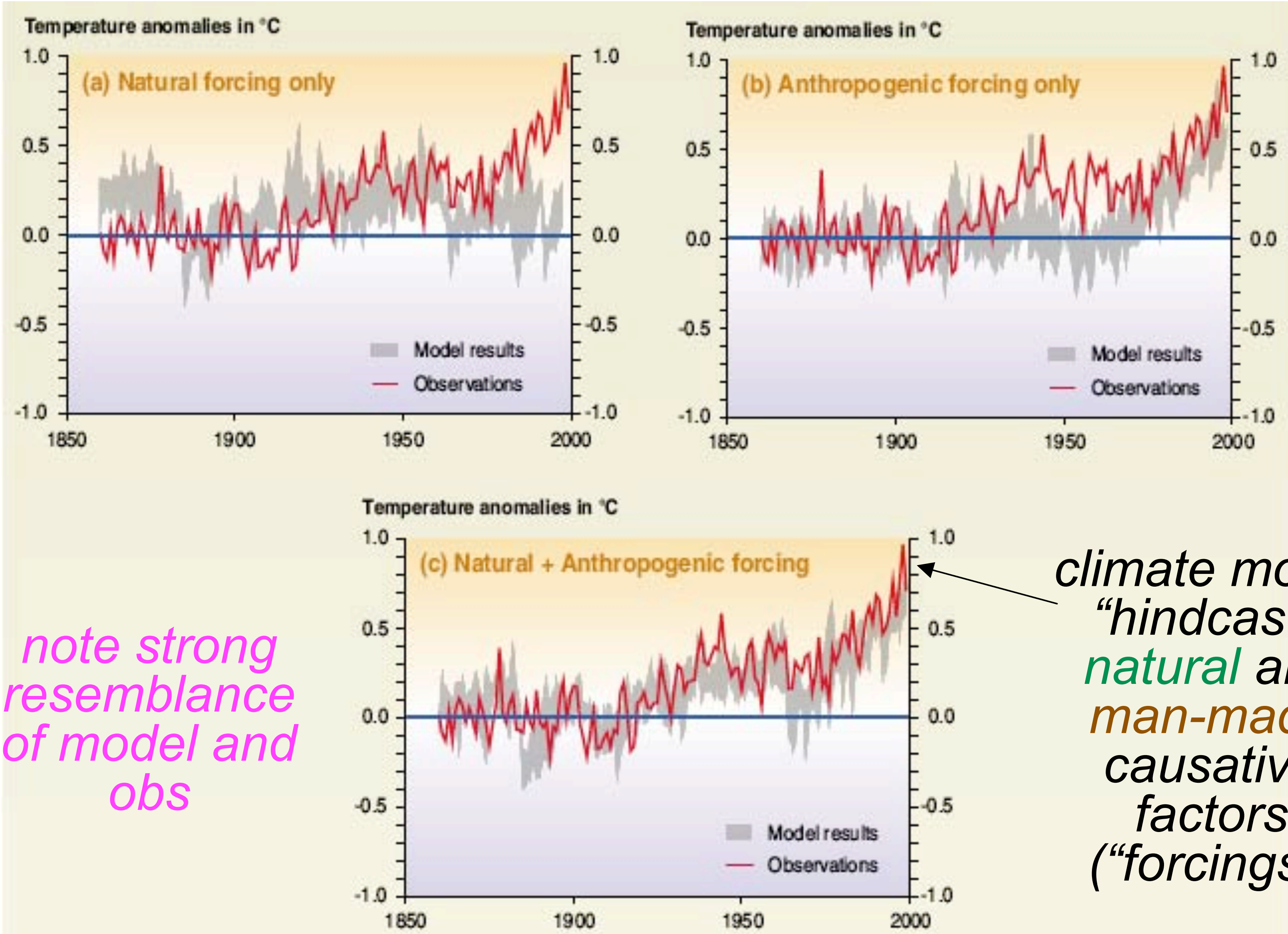
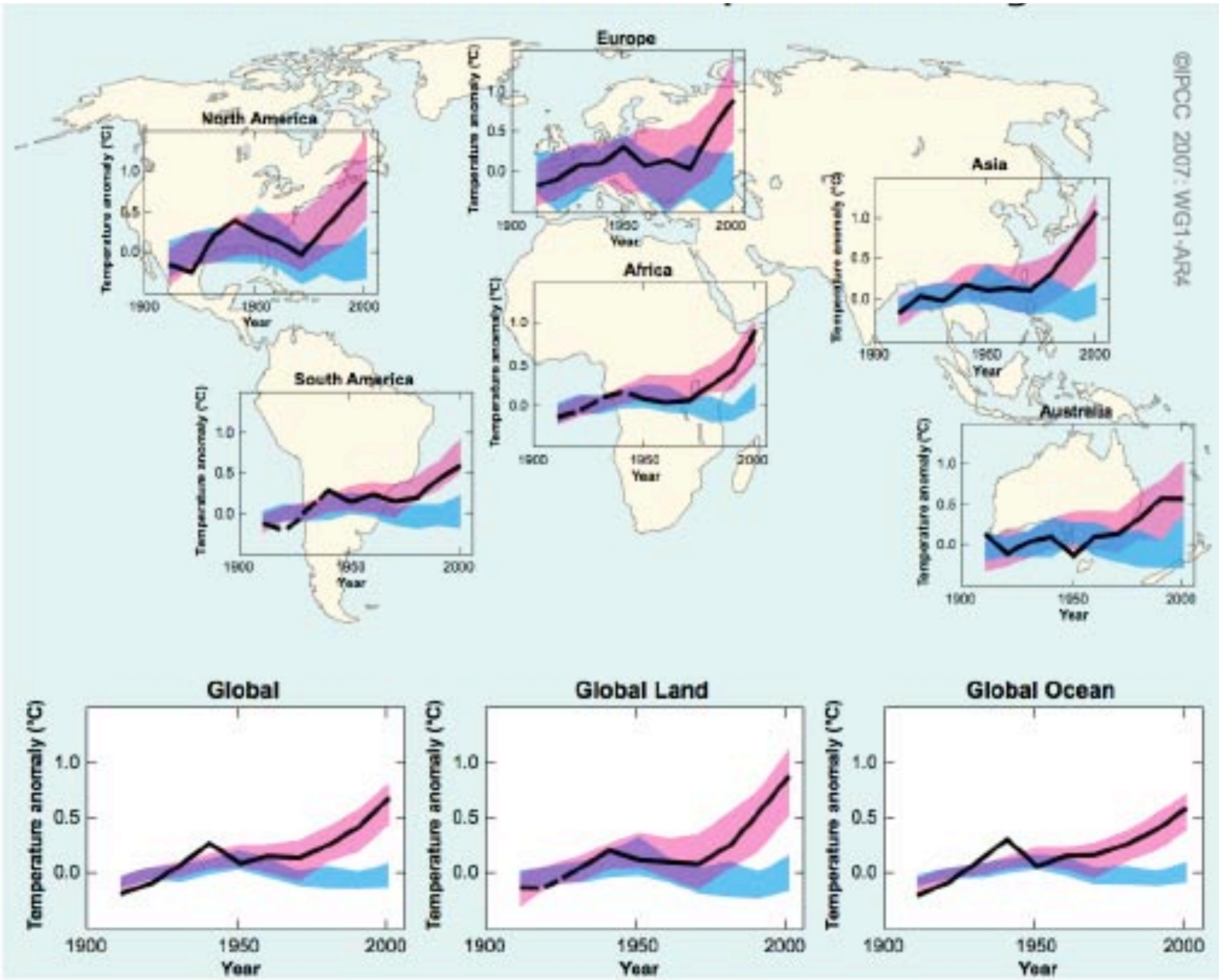


note strong resemblance of model and obs

climate model "hindcast": natural and man-made causative factors ("forcings")

IPCC TAR (2001)

temperature change since 1900



<u>model “</u>hindcasts” considering all factors (incl. GHG’s),
natural factors only, *black is* ***<u>observed</u> temperatures***

source: IPCC ‘07

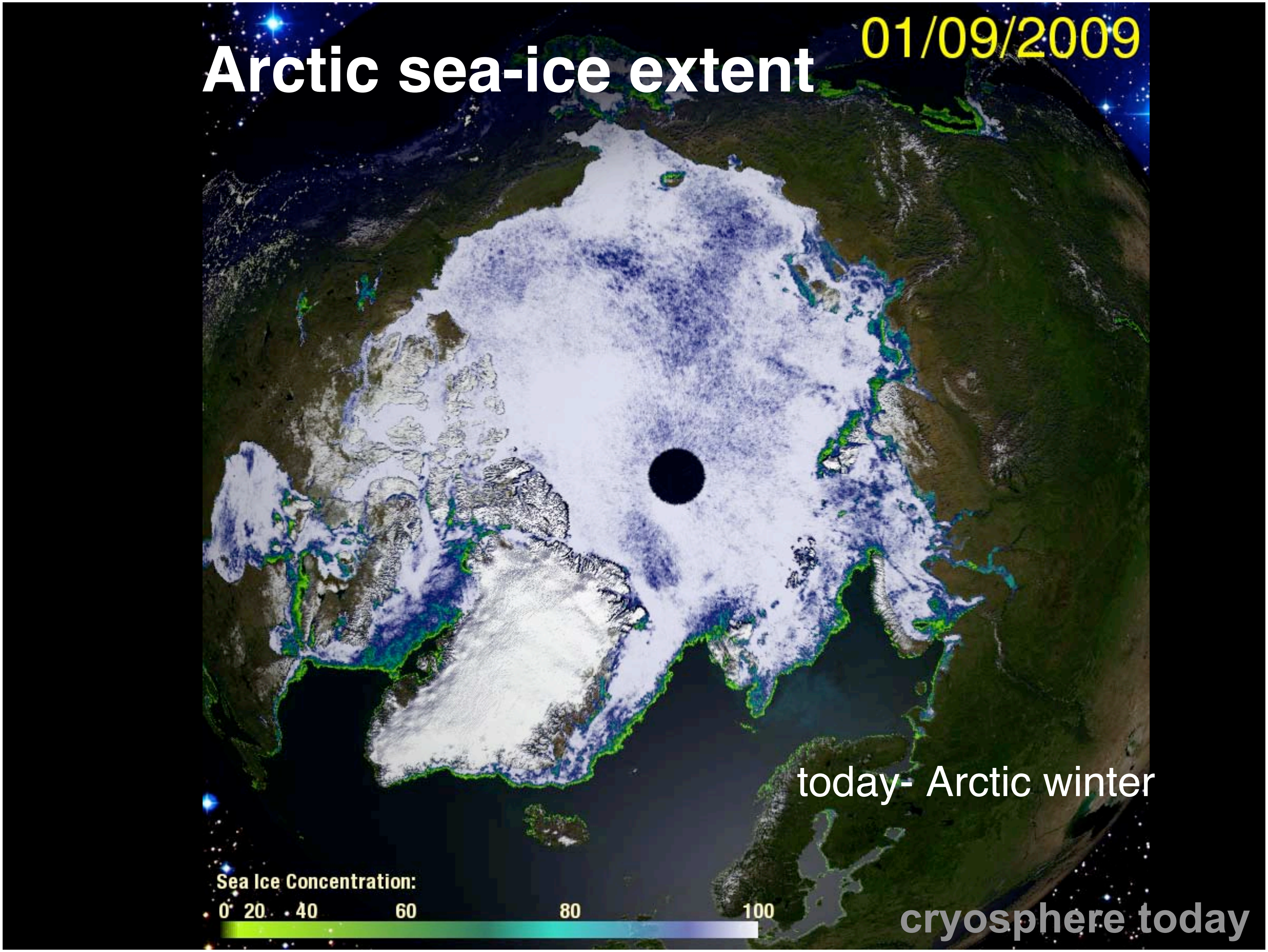
The question is no longer "whether" there is man-made warming or whether it will continue, but "by how much and how fast", and "what are the risks", and "what can or should we do about them"….

The problem of "man-made" warming and what to do about it is one of the most complex and serious issues facing society.

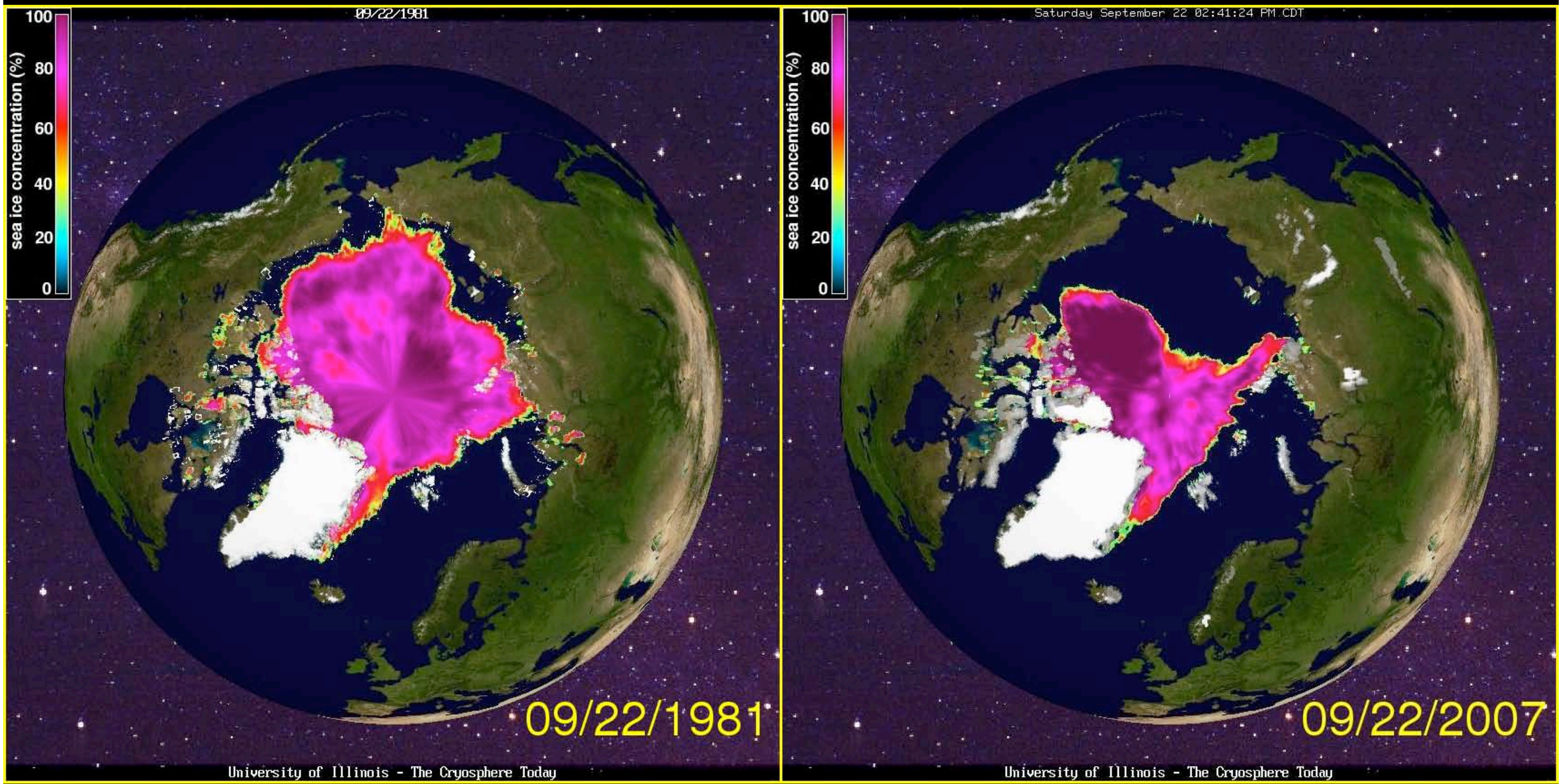
This course attempts to provide a analytical understanding of the changing Earth based on a <u>systems</u> <u>approach</u> for use in deciphering the complex and uncertain forecast…

some examples…

NOTE *(added to lecture for download): The following examples are for illustrative purposes and will be covered in later lectures. You are not (yet) responsible for the concepts and terms that follow….*

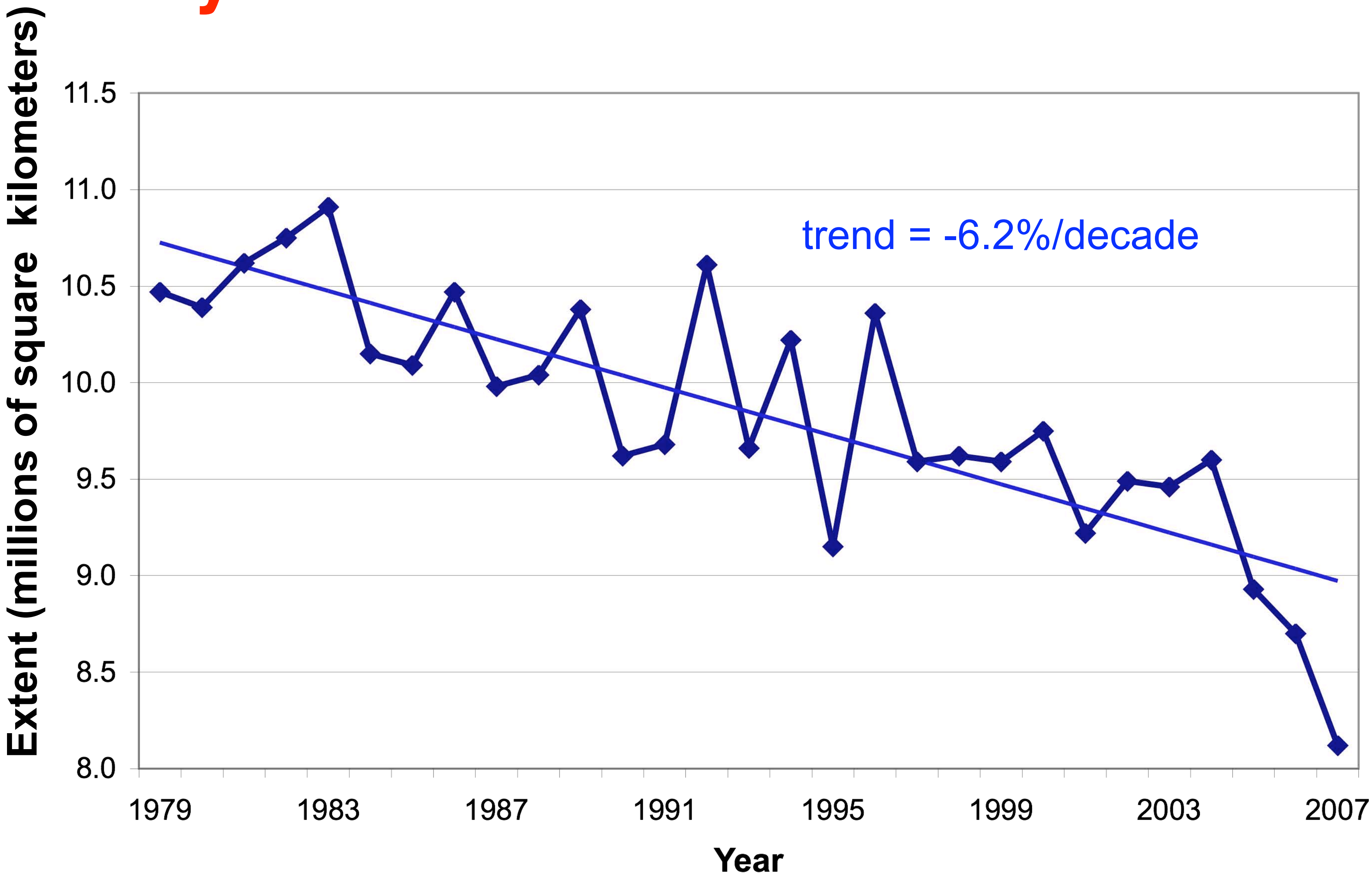

Arctic sea-ice extent
01/09/2009
today- Arctic winter
Sea Ice Concentration:
0 20 40 60 80 100
cryosphere today

end-of-summer sea ice extent
1981 v. 2007



cryosphere today

July Arctic Sea Ice Extent '79 - '07



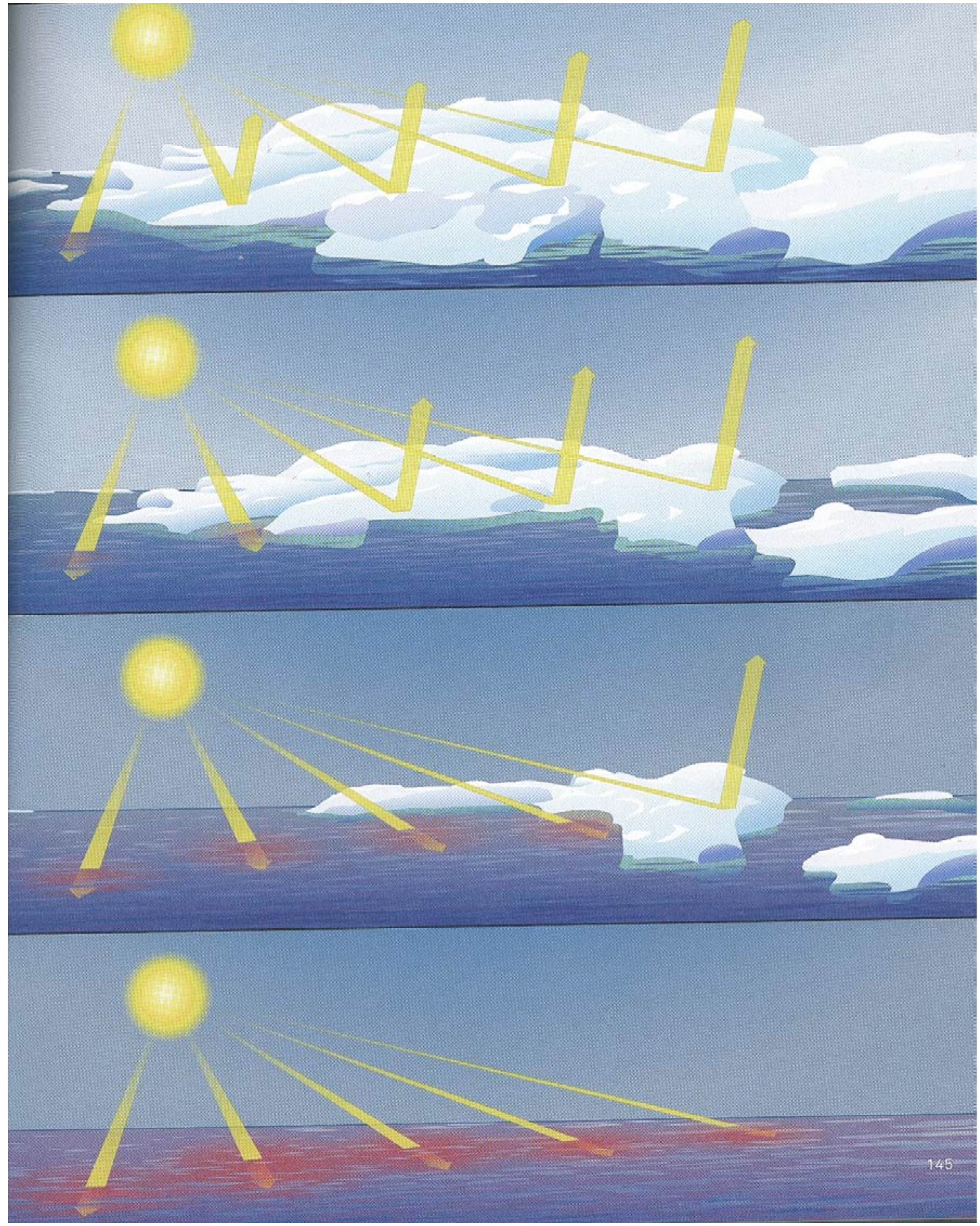
but, is the trend long enough to make a prediction?

CU-NSIDC

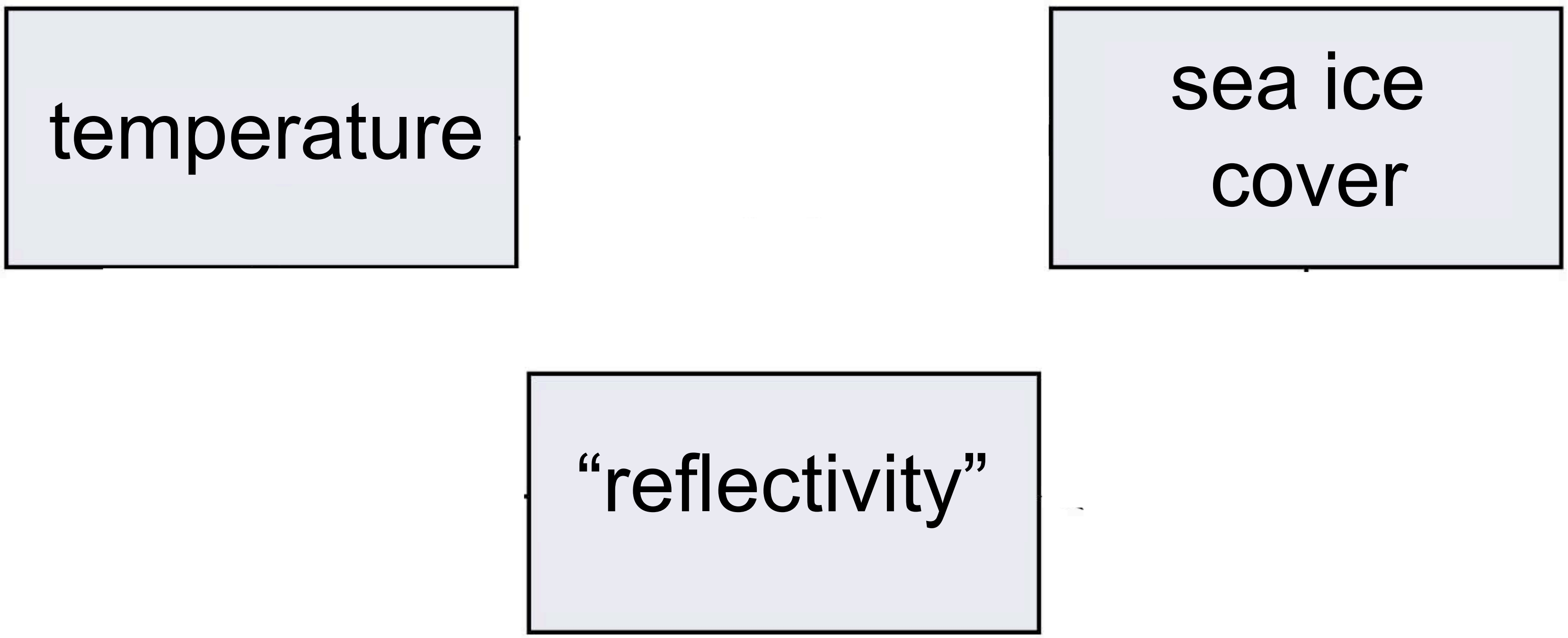
What is the interaction shown here ?

Think about this: sea ice is bright and reflects ~90% of the suns rays, sea water is dark and absorbs ~90% of the suns rays

source: A. Gore's "AIT"

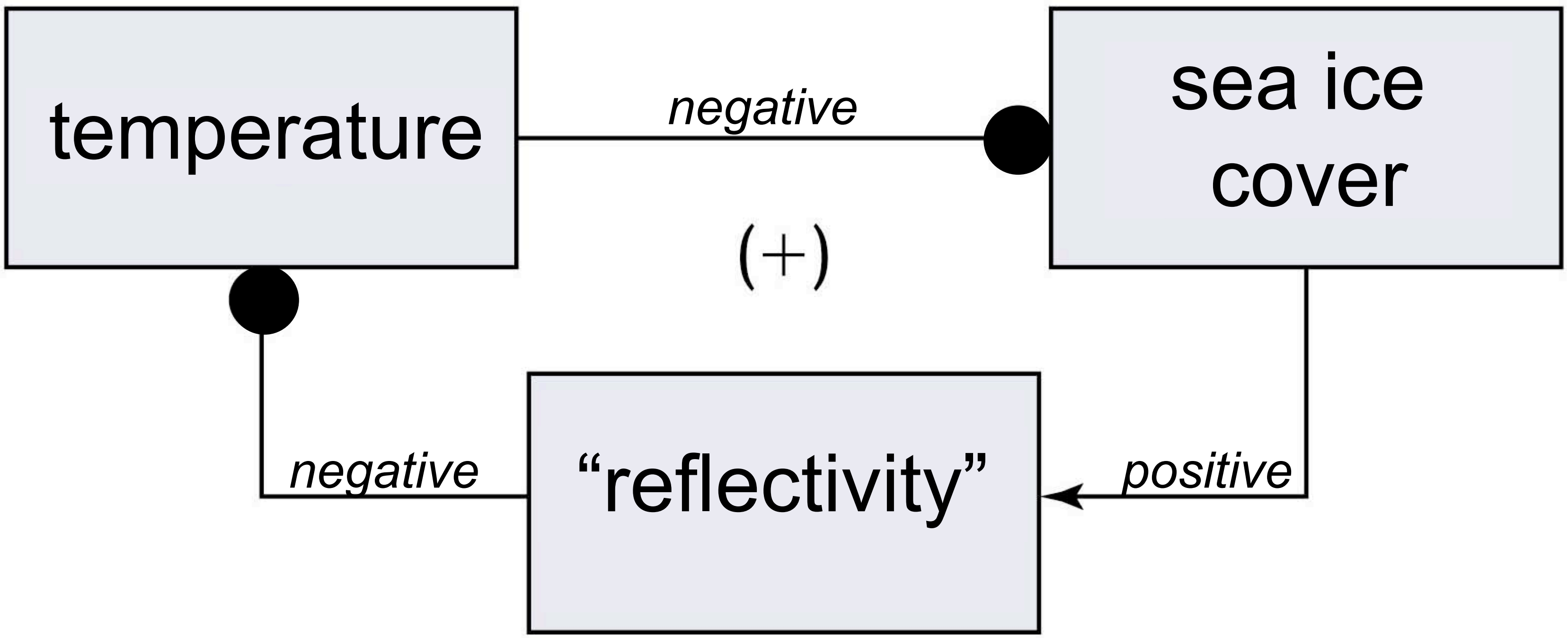


a feedback involving sea ice



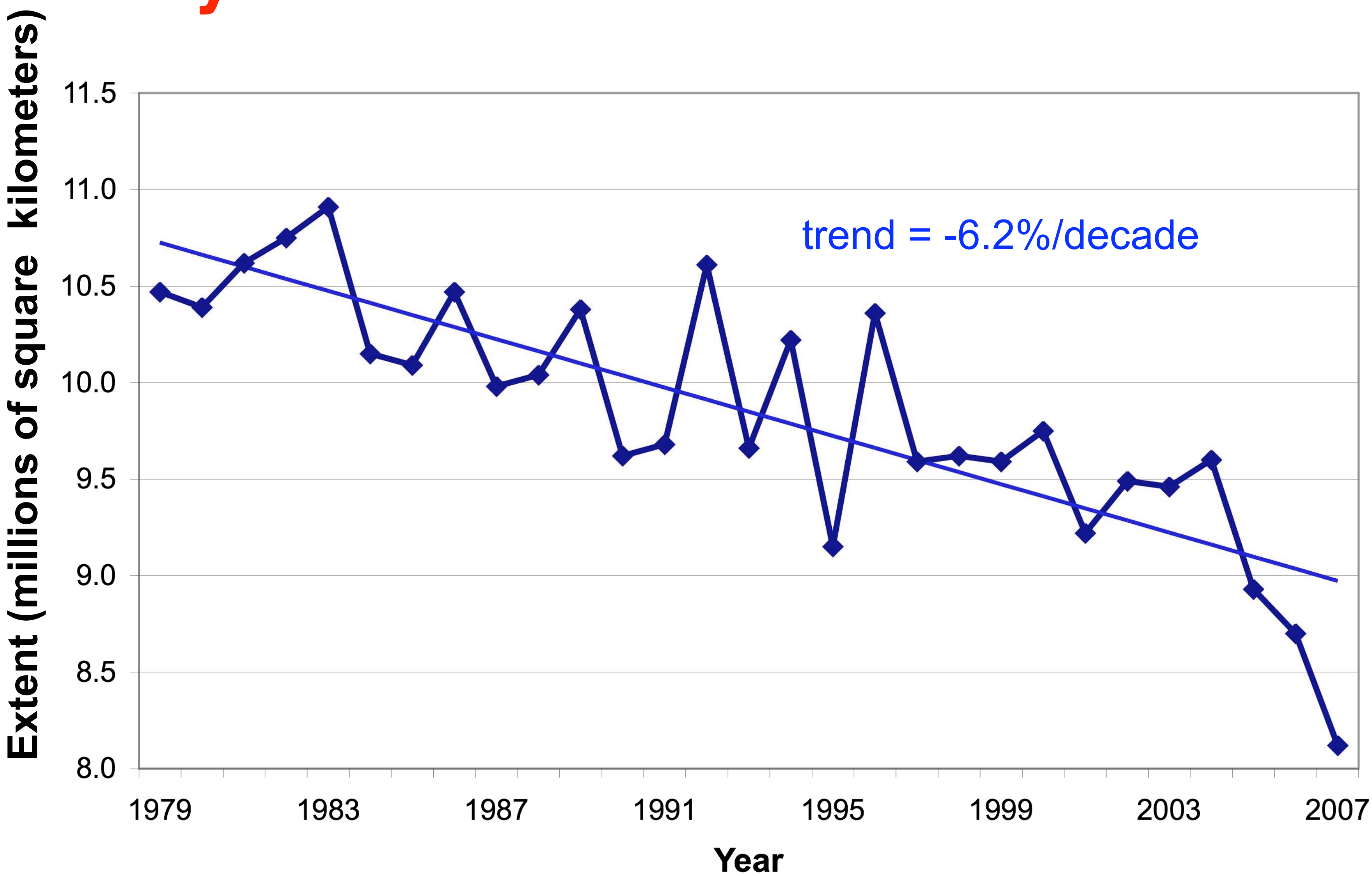
what is the “sign” of the one way interaction?

a feedback involving sea ice



together the interactions produce a <u>positive</u> <u>feeback</u>, which is <u>destabilizing</u> (we'll formalize this concept next class)

July Arctic Sea Ice Extent '79 - '07



does understanding a key interaction assist in making a prediction?

CU-NSIDC

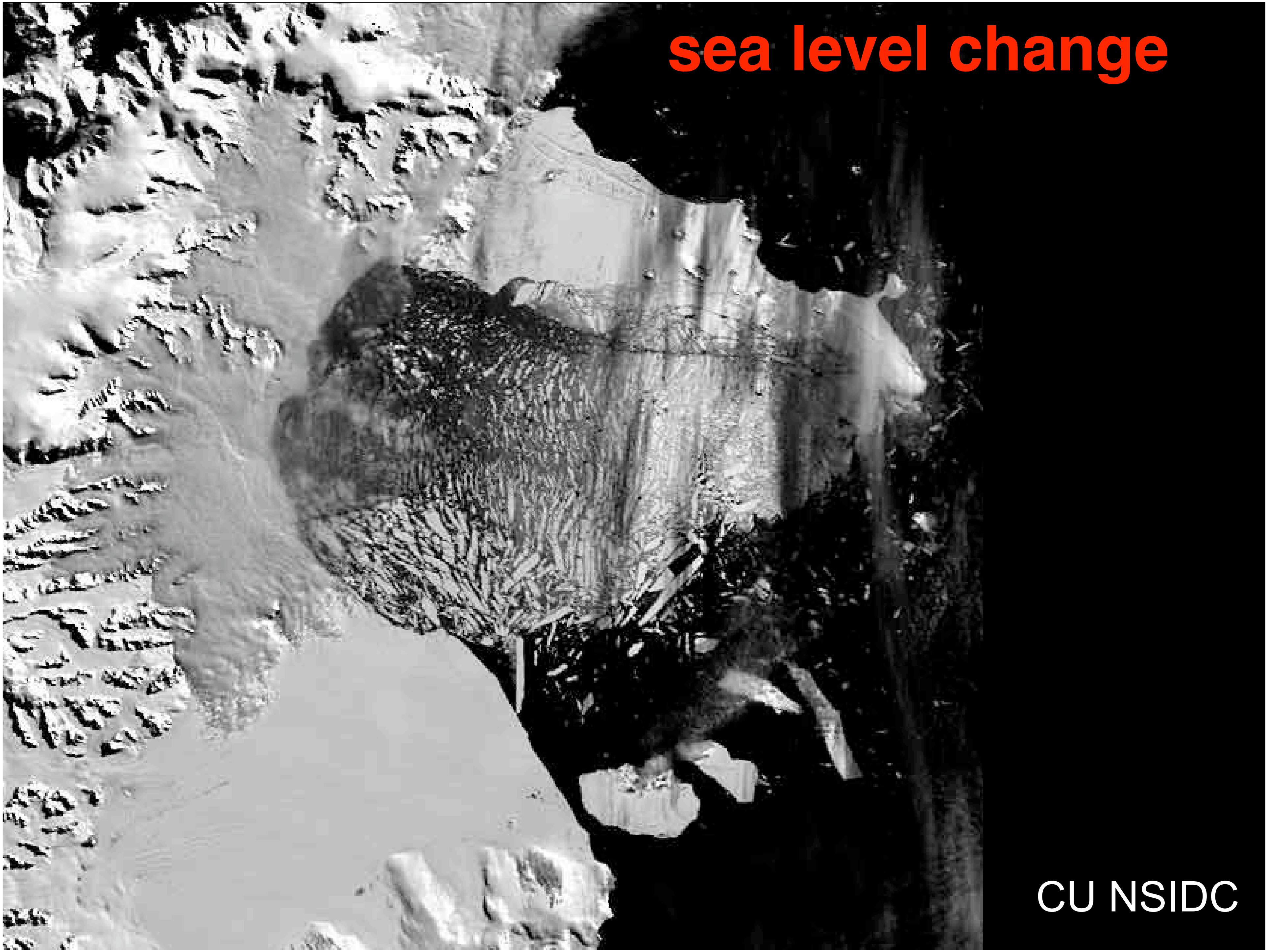
scientific thinking ……

or ?

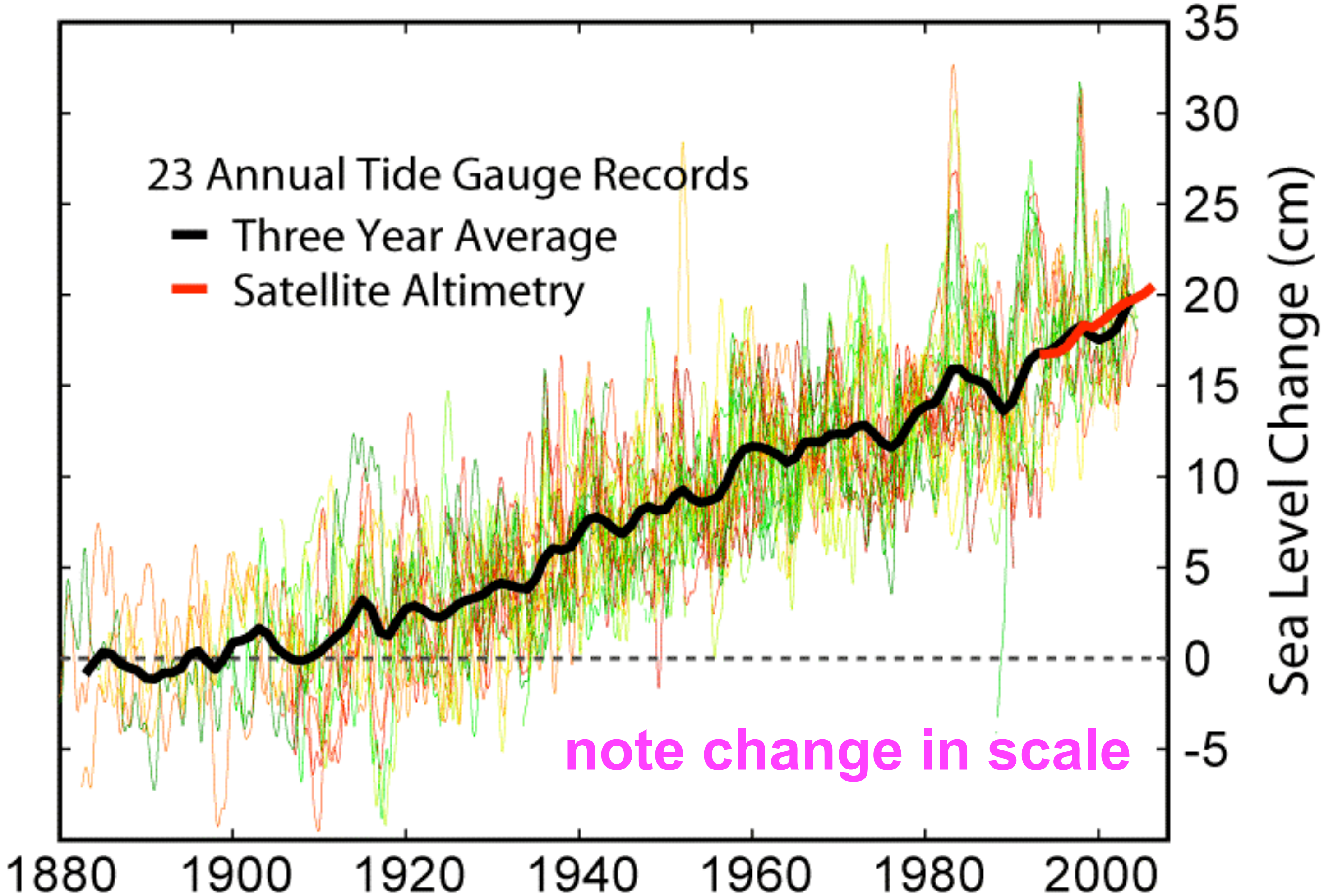
- ***we need more than factual knowledge or observations***

- ***we need a theoretical or conceptual framework in which to place and make sense of observations (facts we can always look up)***

source: CU-SEI

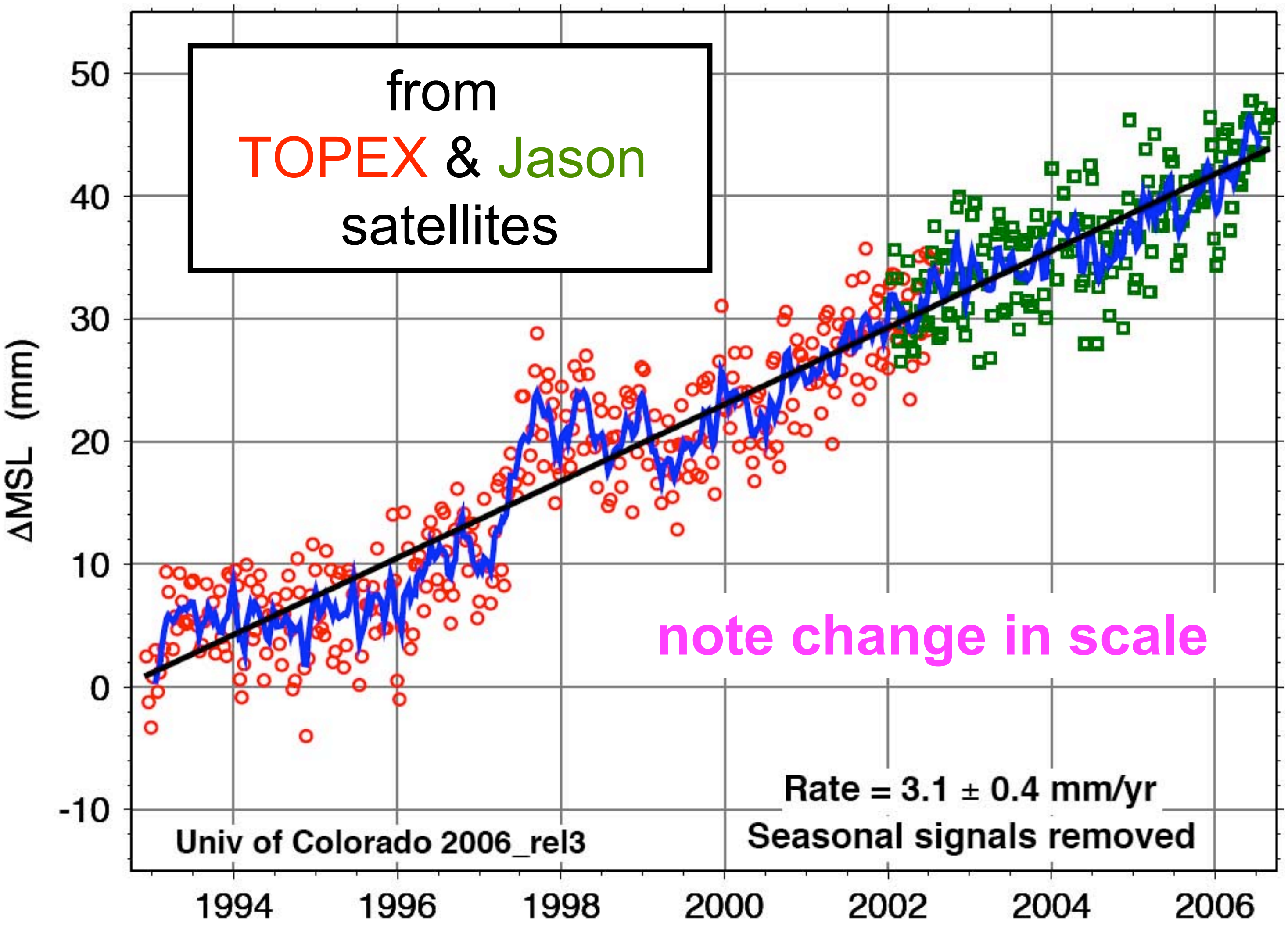

sea level change
CU NSIDC

the last century......



during the last century sea level rose ~ 2mm/yr

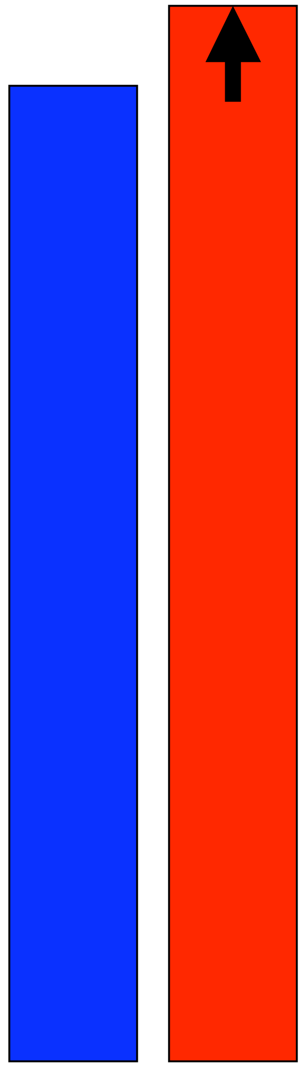
the last decade +.......



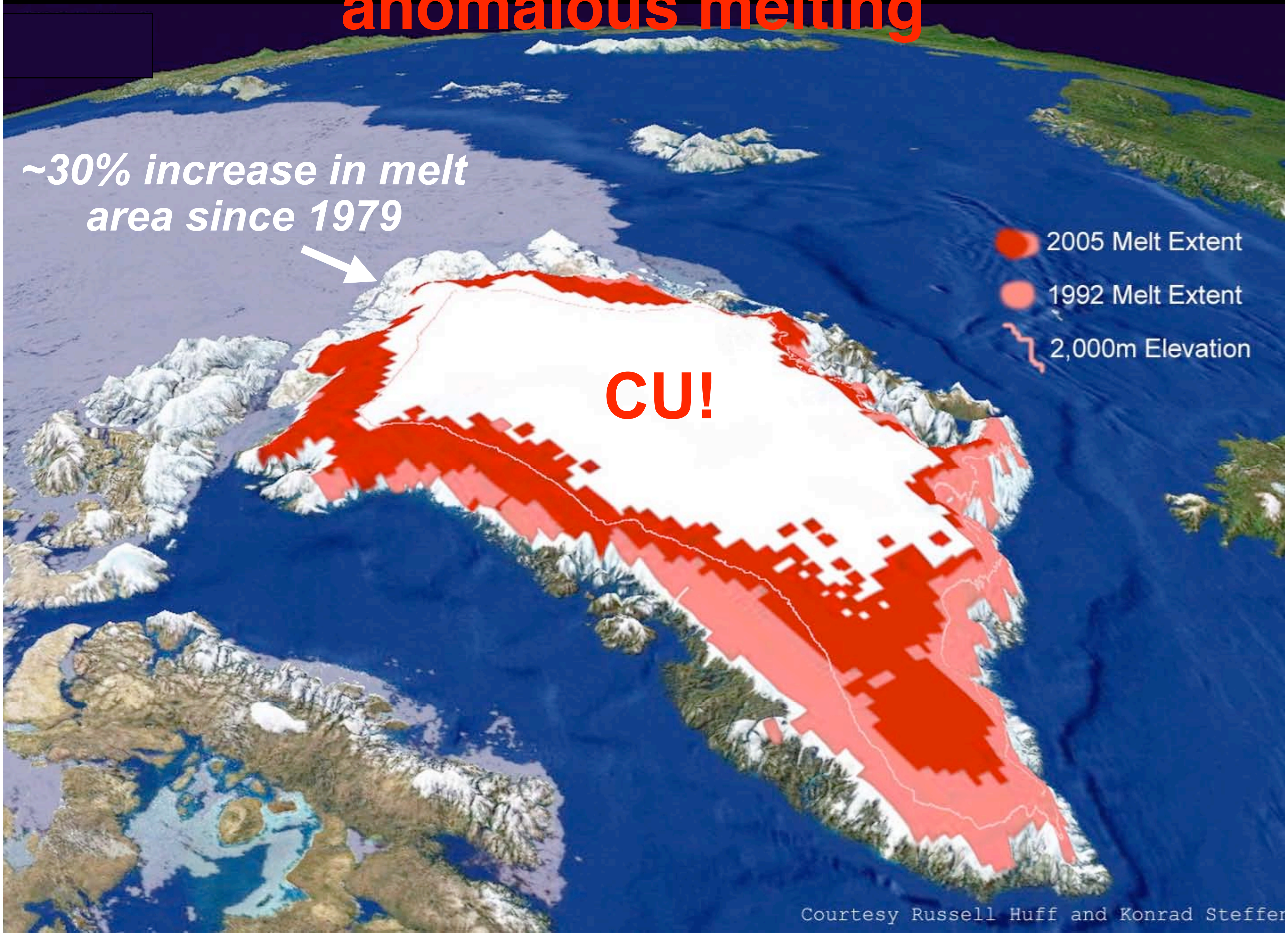
during the last decade sea level rose ~3.1 mm/yr

warm water expands!

- sea water expands by, roughly, ~0.33% for every K (or °C) of warming
- so for every K of warming in upper 1 km of ocean, level would rise ~3.3 m due to thermal expansion
- precise measurements of ocean temperature change indicate ~0.05K warming of upper few km over last ~50 yr due to global warming
- this would explain much of sea rise of   ~20 cm observed fr. tide gauges



anomalous melting

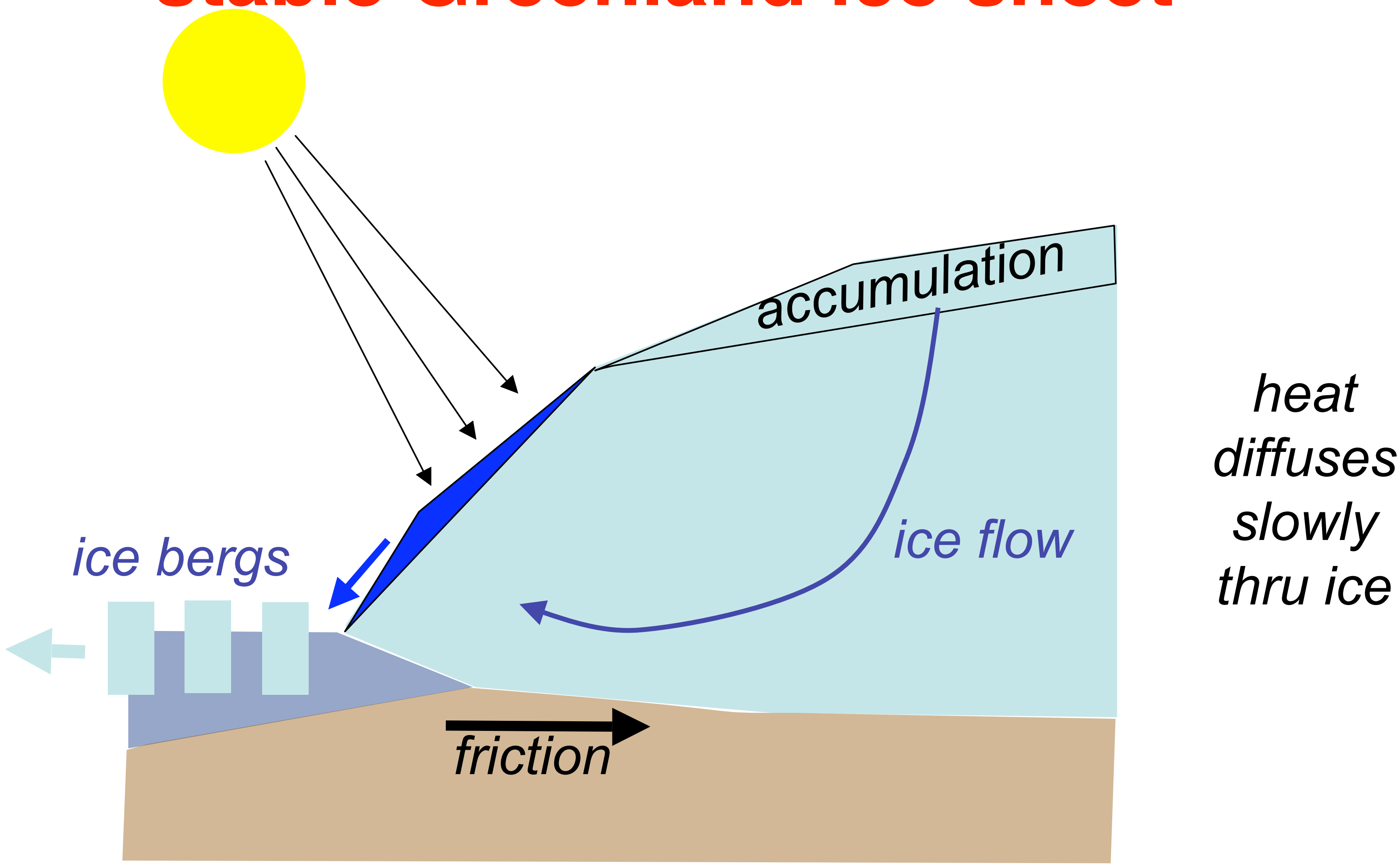


sea level

Warm water expands and ice melts.

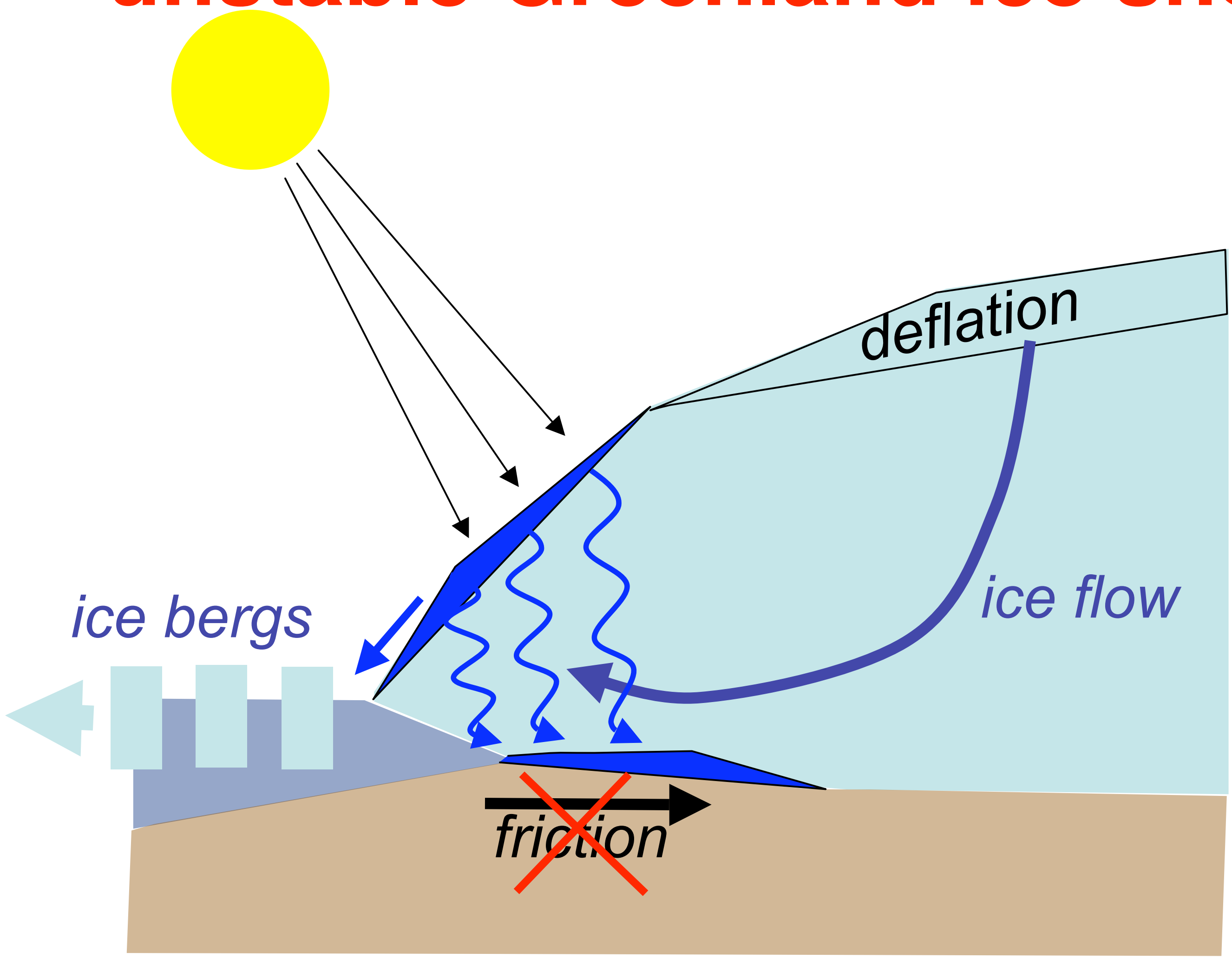
If that were the whole picture, the forecast would be relatively straightforward…

stable Greenland ice sheet



at steady state ice gain is matched by ice loss from
melting and ice berg calving at ice streams
melting is a slow process
friction limits flow through ice streams

unstable Greenland ice sheet

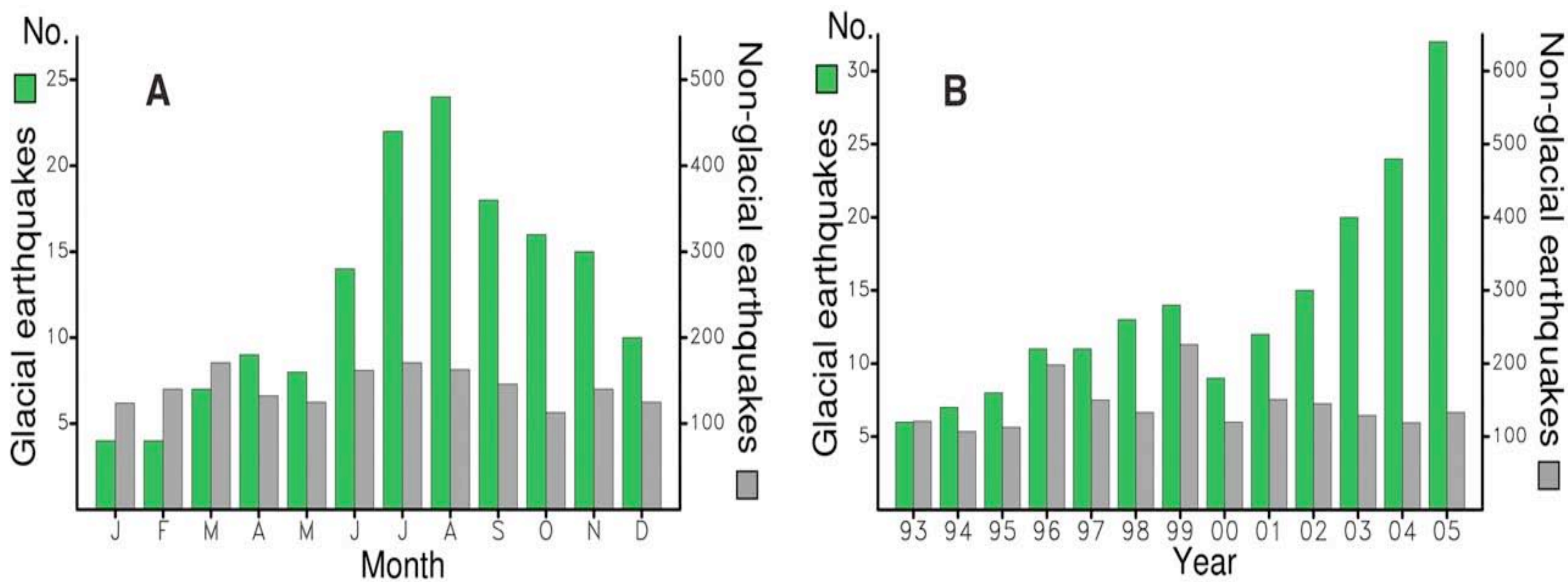


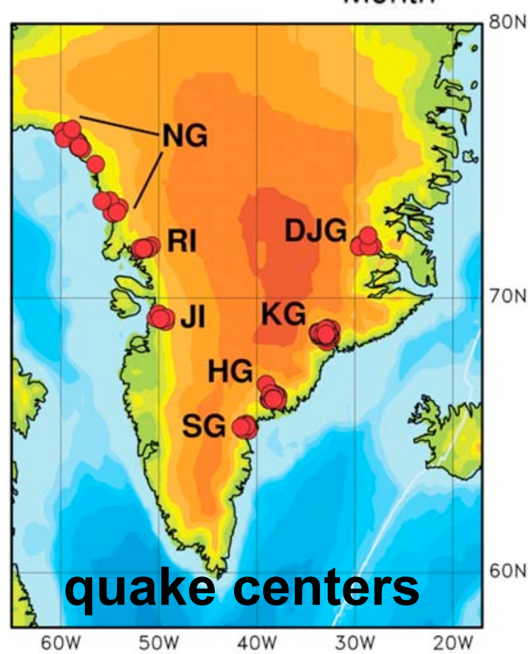
water moves quickly thru ice (we don't know exactly how)

melt water reaches the ice sheet bed, greatly reducing friction and permitting accelerated sliding and flow through ice streams, increased ice berg calving and ice sheet thinning

what if gradual melting triggers fast sliding?

ice sheet quakes!





Lurching of Greenland ice streams creates tremors that are recorded world wide. They occur more frequently in warm months (due to melt lubrication). Their annual occurrence has doubled in the last 5 years!

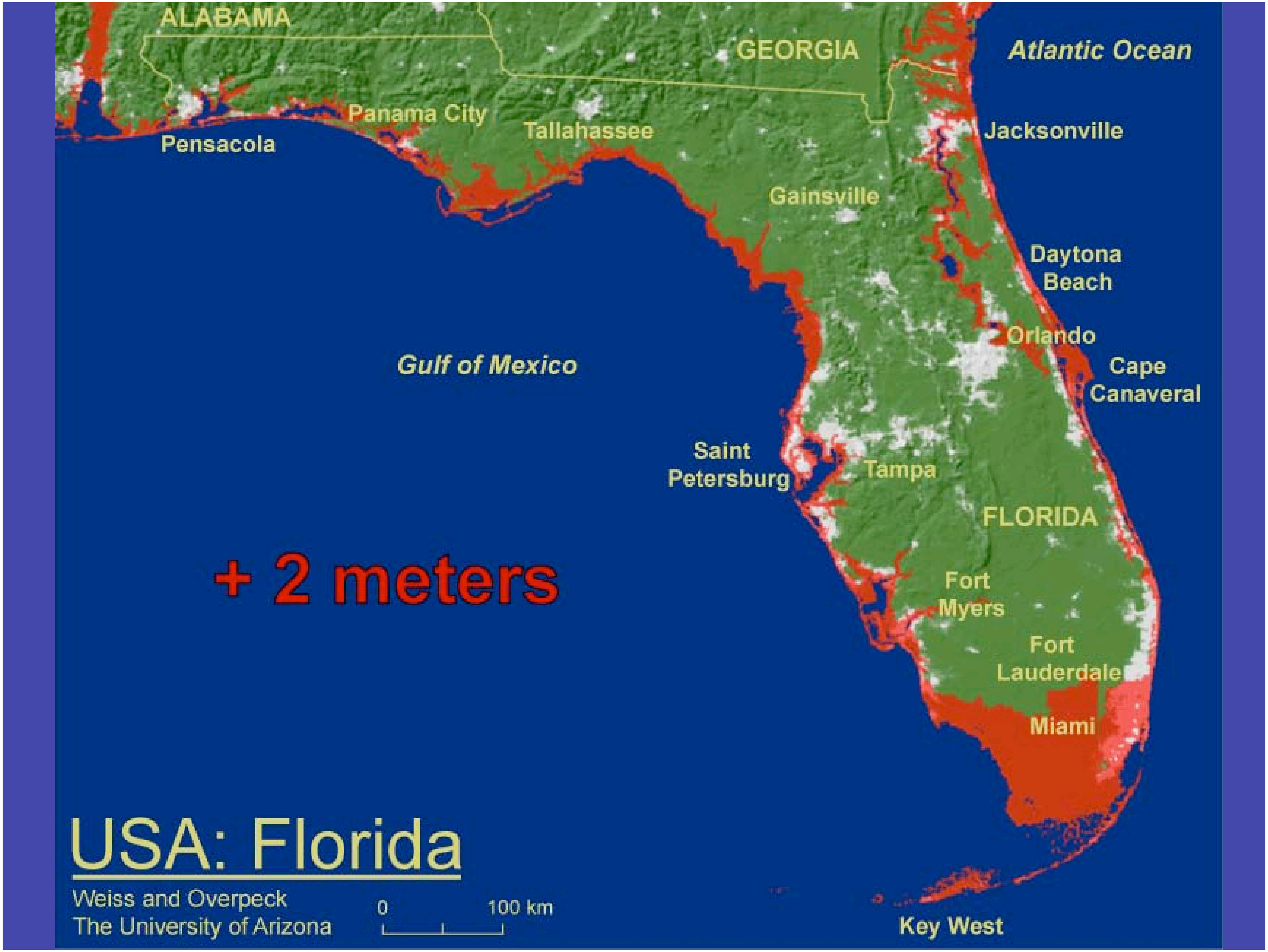
Ekstrom et al., '06

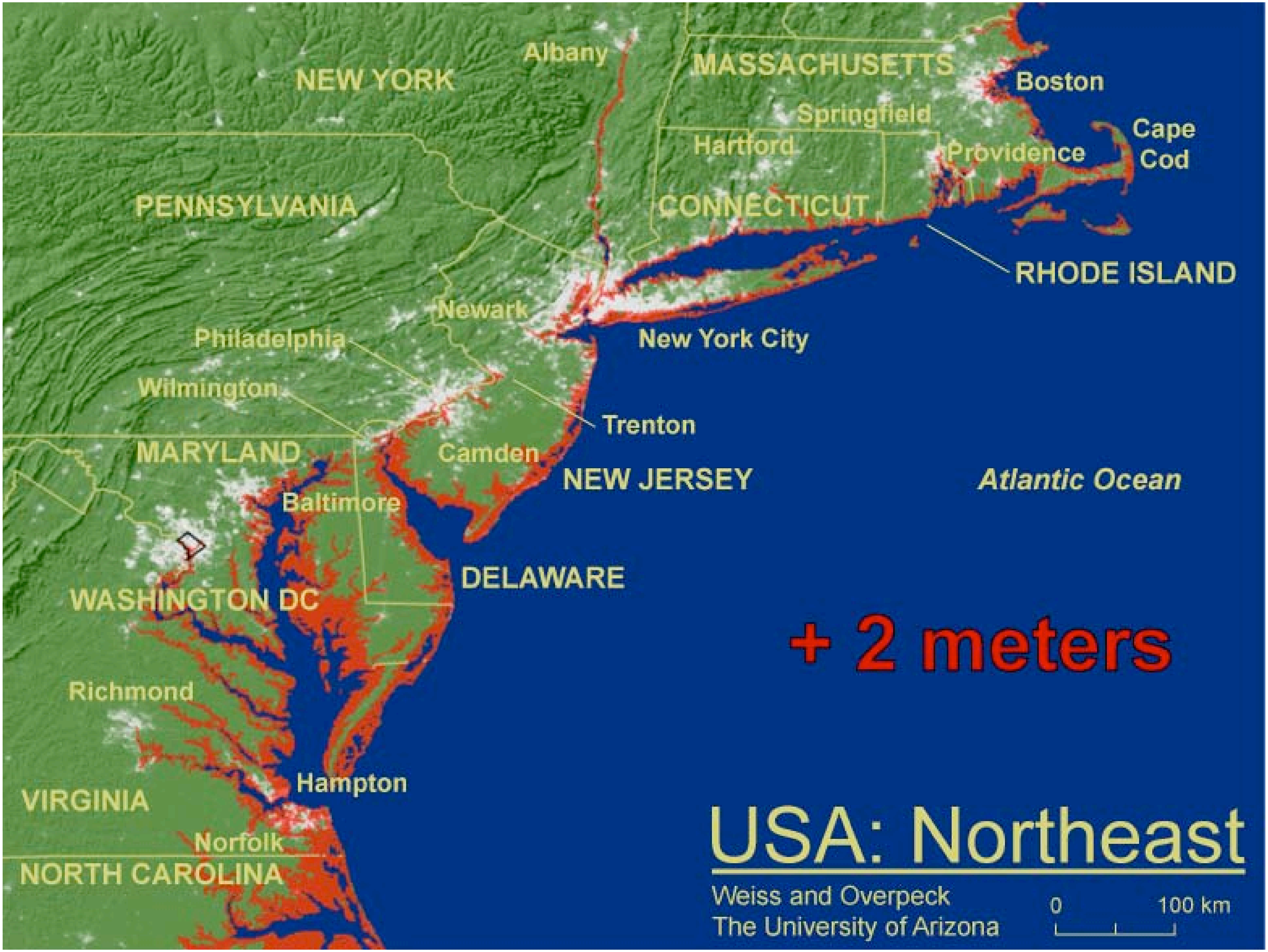
consider impact of small (but uncertain) fractional loss of Greenland or West Antarctic Ice Sheets

1 meter SL rise would submerge:

- 18% of Bangladesh
- 6% of The Netherlands
- ~960 of the 1200 Maldive Islands

2 meters looks like this....


ALABAMA
GEORGIA
Atlantic Ocean
Pensacola
Panama City
Tallahassee
Jacksonville
Gainsville
Daytona
Beach
Orlando
Cape
Canaveral
Gulf of Mexico
Saint
Petersburg
Tampa
FLORIDA
+ 2 meters
Fort
Myers
Fort
Lauderdale
Miami
USA: Florida
Weiss and Overpeck
The University of Arizona
0
100 km
Key West

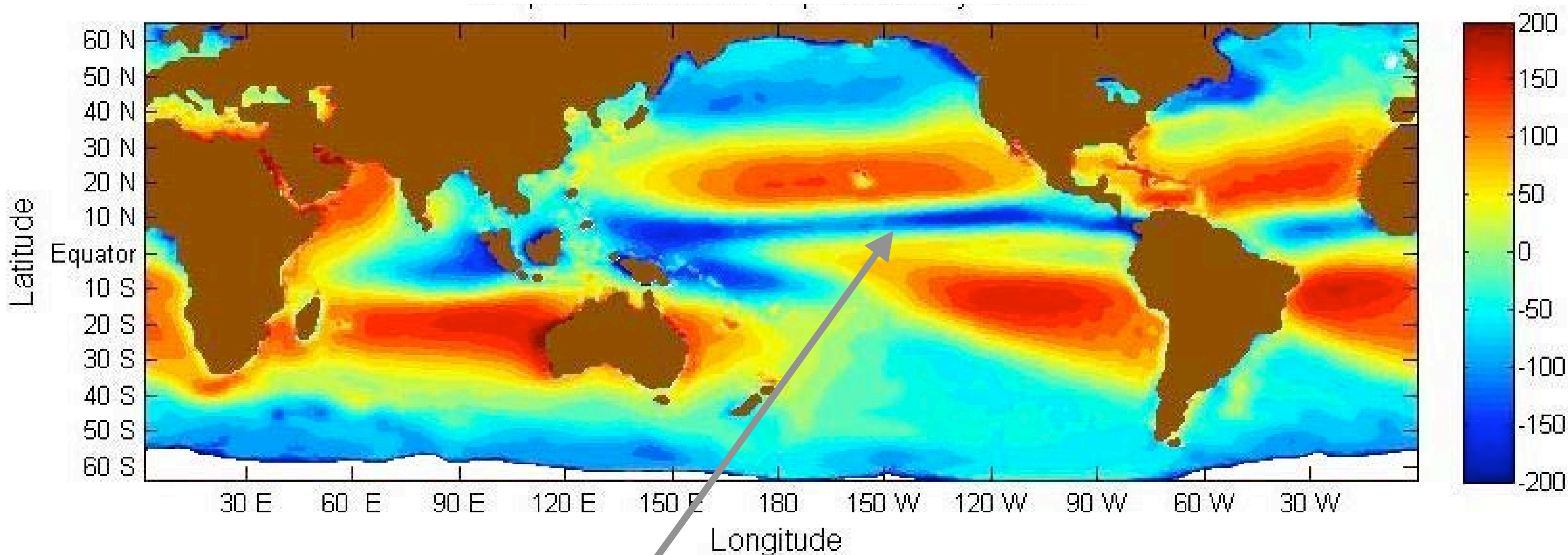


Albany
NEW YORK
MASSACHUSETTS
Boston
Springfield
Cape
Cod
Hartford
Providence
PENNSYLVANIA
CONNECTICUT
RHODE ISLAND
Newark
Philadelphia
New York City
Wilmington
Trenton
MARYLAND
Camden
NEW JERSEY
Atlantic Ocean
Baltimore
DELAWARE
WASHINGTON DC
+ 2 meters
Richmond
Hampton
VIRGINIA
USA: Northeast
Norfolk
NORTH CAROLINA
Weiss and Overpeck
The University of Arizona
0
100 km


the global water cycle

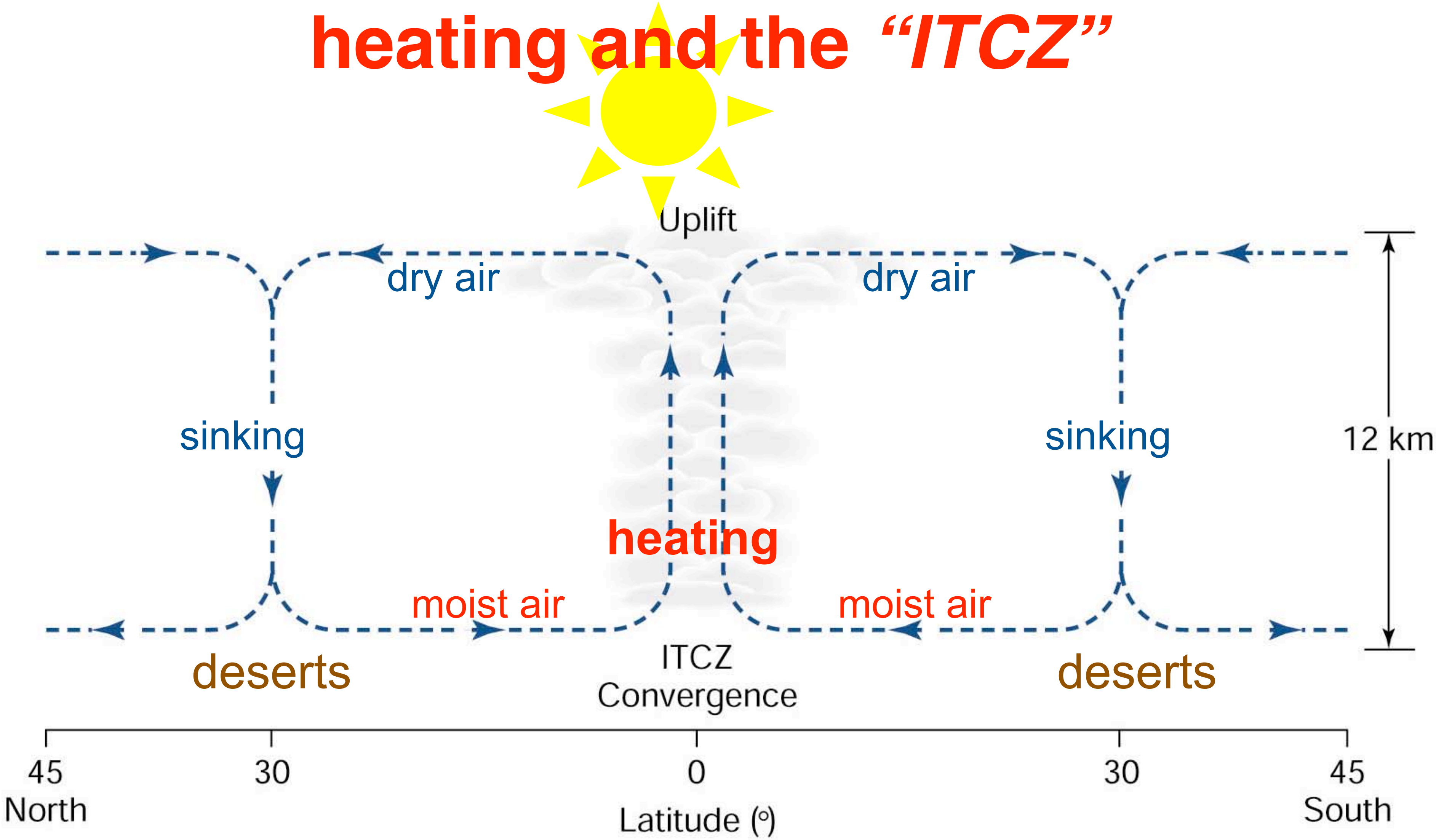
signature of the global water cycle

evaporation minus precipitation (cm/yr)



("Inter-Tropical Convergence Zone")

heating and the *"ITCZ"*



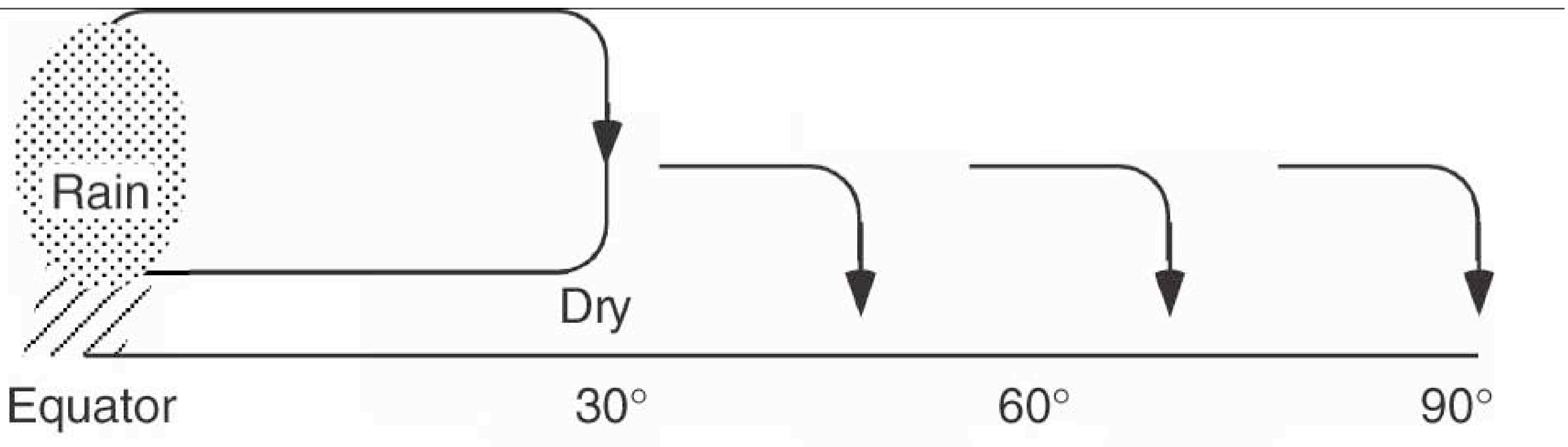
heating = expansion = buoyancy = uplift

rising air replaced by moist air converging from below

sinking air is dry

a simple mechanistic forecast

(in response to heating due to greenhouse warming)



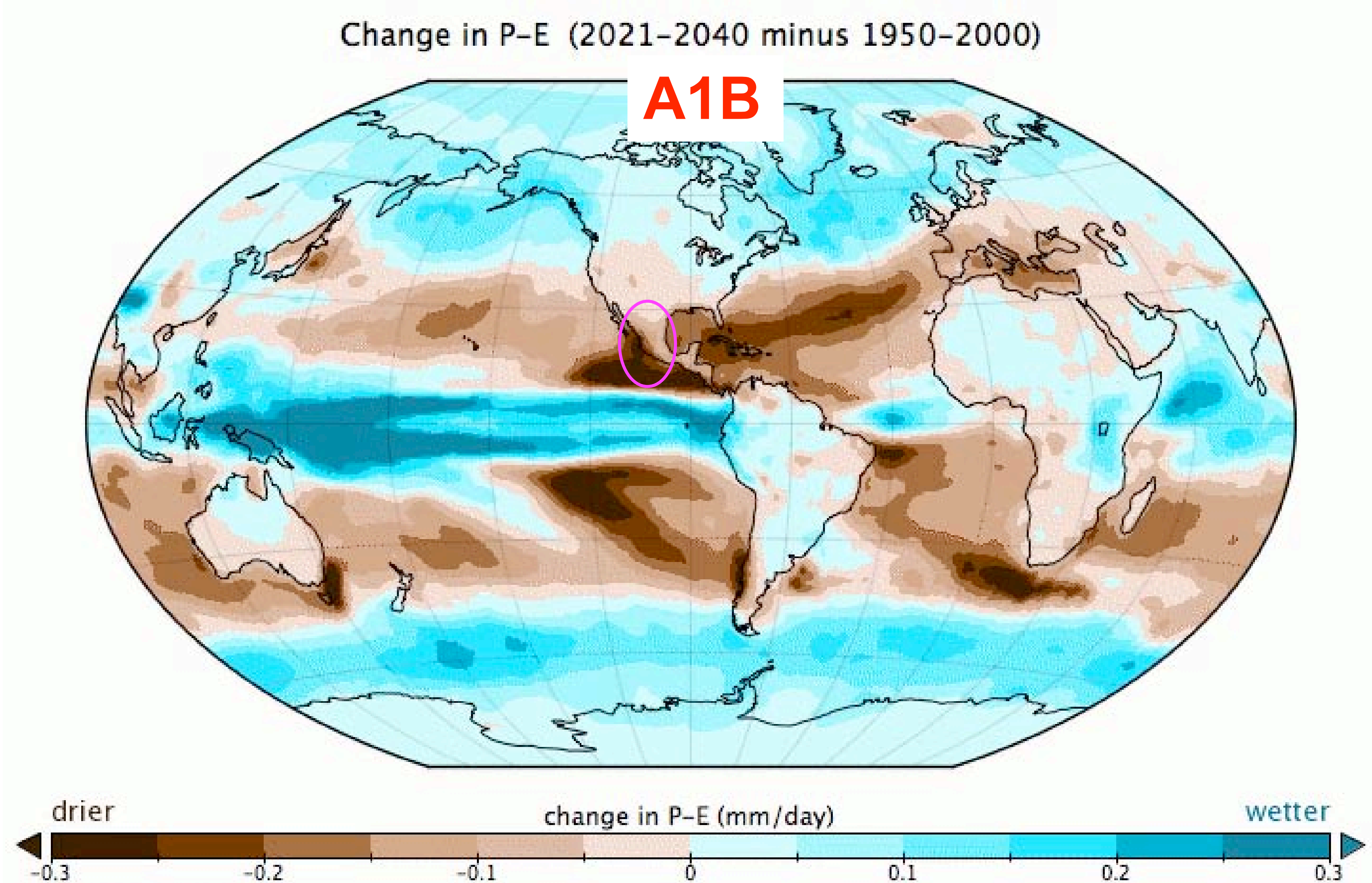
more intense heating, more convection, rainfall and flooding

more descending dry air, more & longer drought

warmer, wetter, more snowfall

Archer

the (ensemble) model forecast…..



“Results averaged across 19 different models. P-E is net flux of water at surface that, over land, sustains soil moisture, ground water, and river runoff”

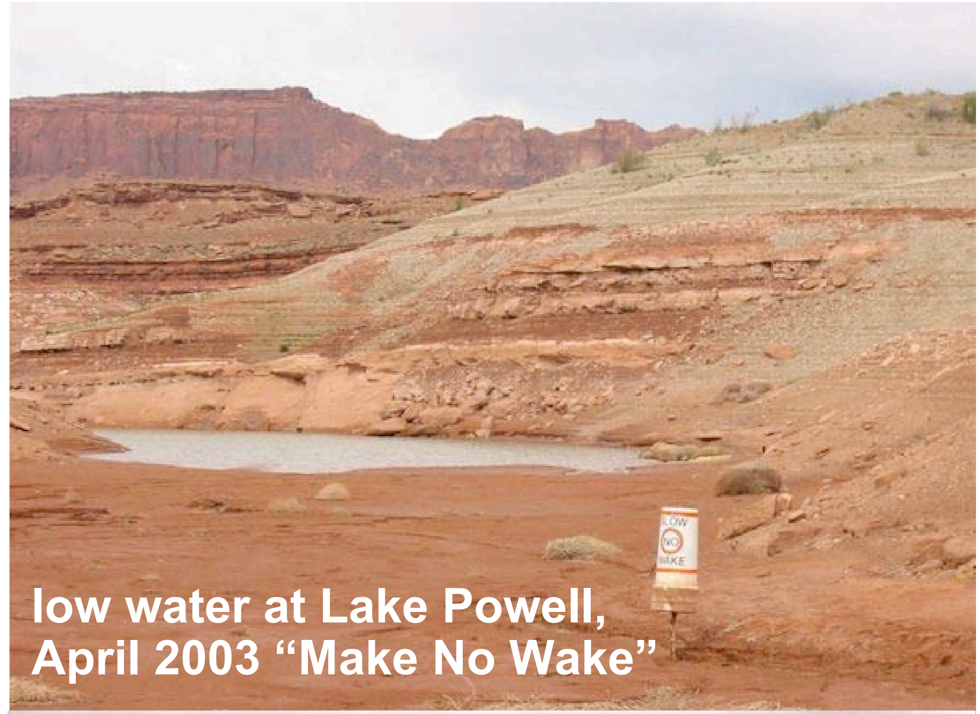
Seager et al., Science in press

widespread drought

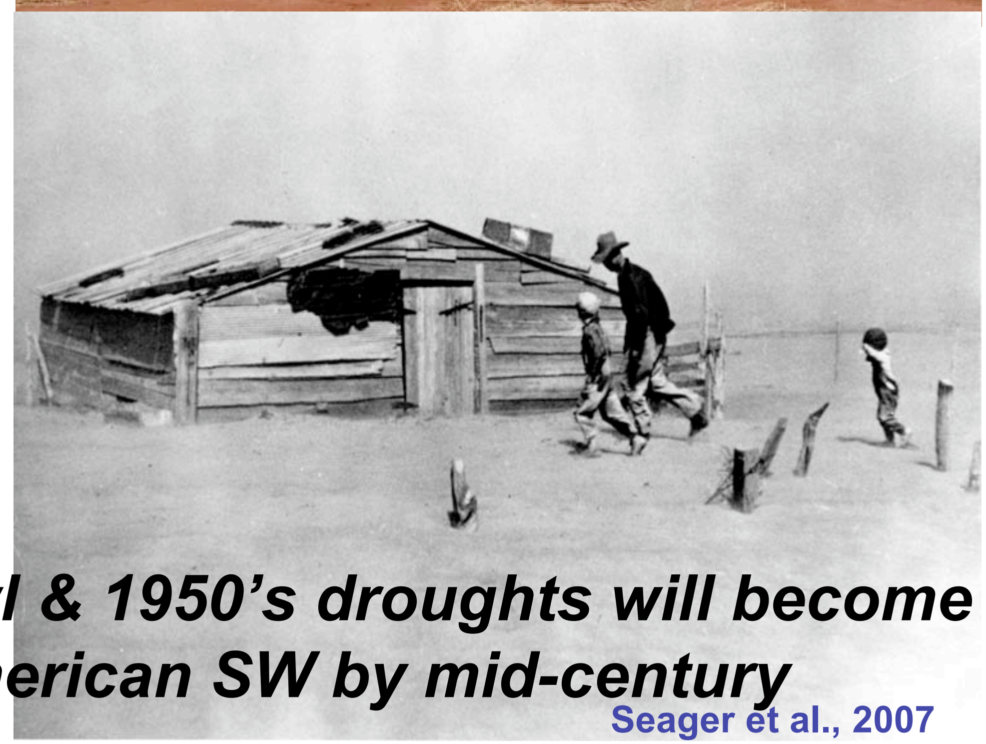
American SW *and other subtropical regions* will become increasingly arid

transition to drier climate *already underway* and will become well established in coming decades with "permanent drought"

a robust finding across 19 IPCC model projections- assoc. with amplification and poleward displacement of the hydrologic cycle



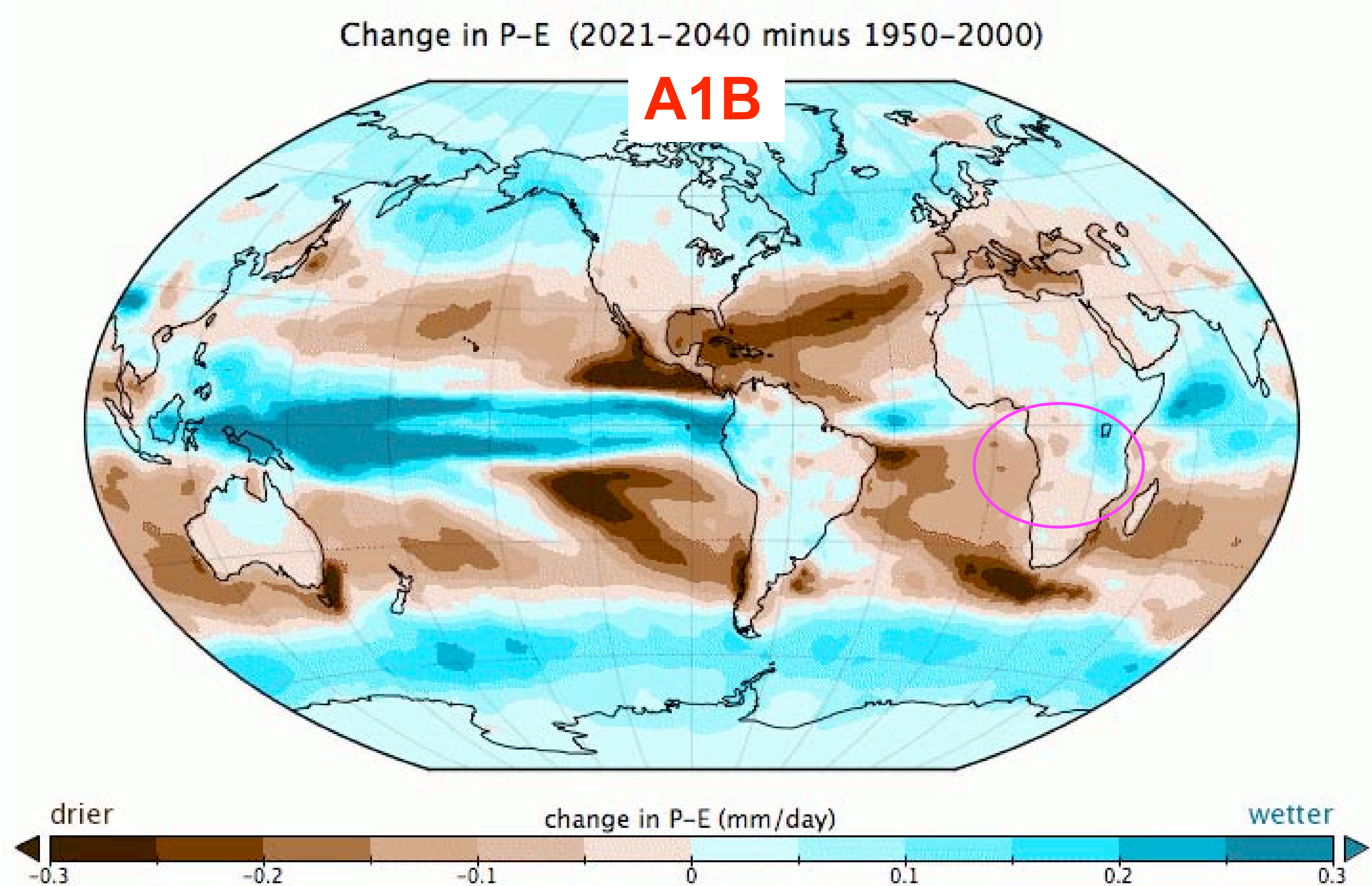
low water at Lake Powell, April 2003 "Make No Wake"



Aridity levels of The Dust Bowl & 1950's droughts will become the new climatology of the American SW by mid-century

Seager et al., 2007

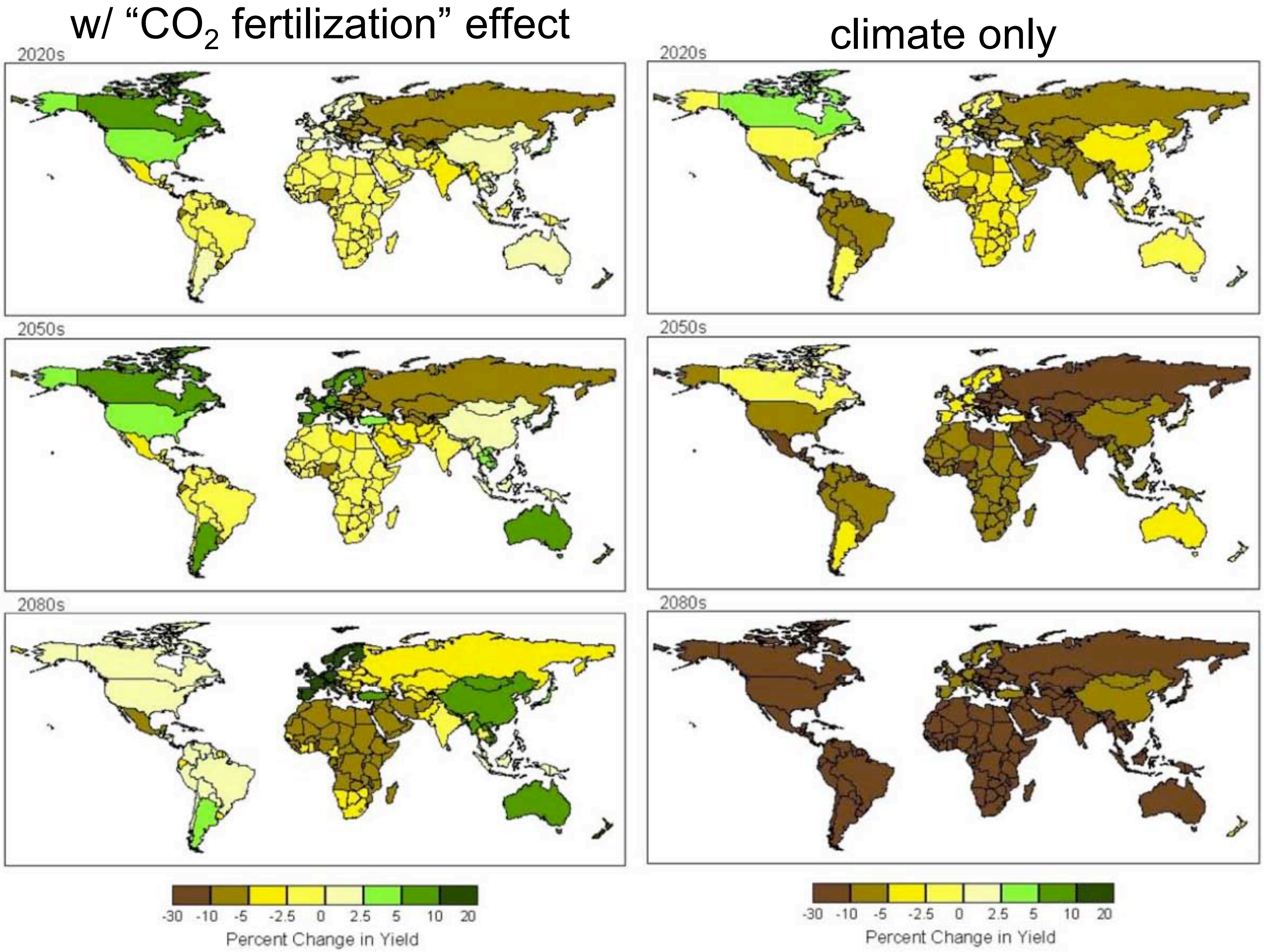
amplification of the hydrologic cycle.......



"Results averaged across 19 different models. P-E is net flux of water at surface that, over land, sustains soil moisture, ground water, and river runoff"

Seager et al., Science in press

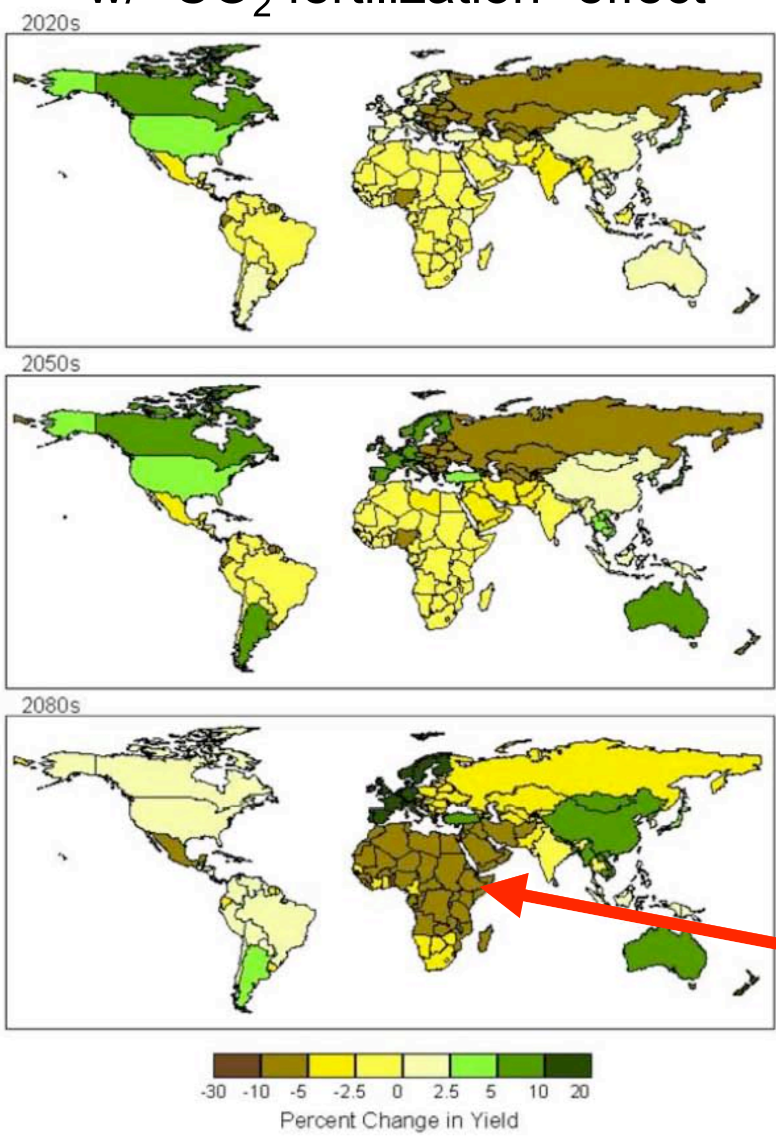
projected crop yield (as % of 1990), <u>A2</u>



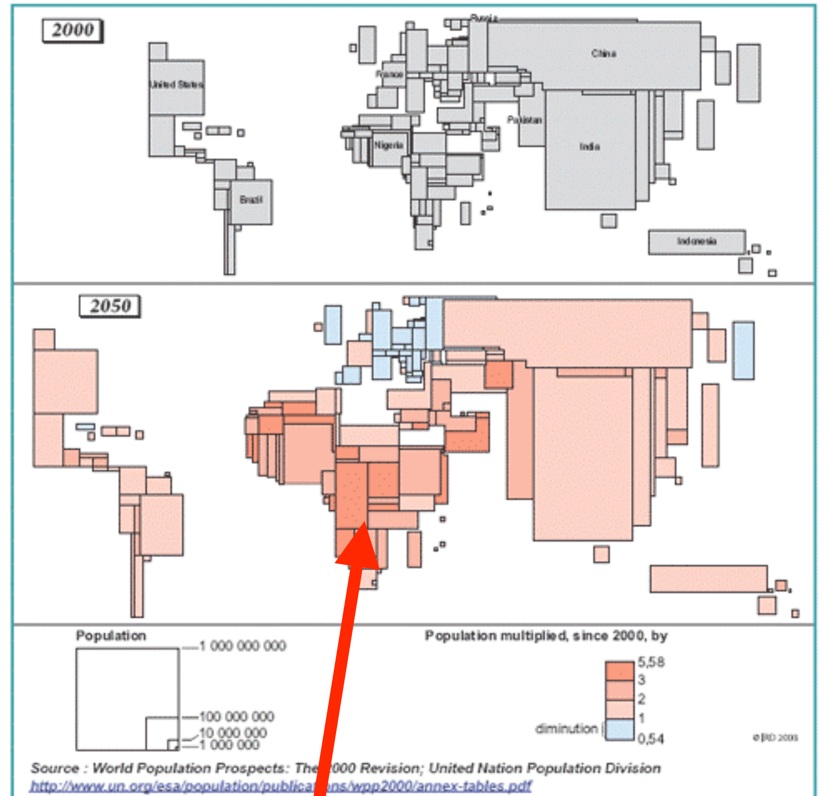
projected deficits are primarily in developing countries
(CO_2 fertilization effect is uncertain) **Parry et al. 2004**

projected crop yield (as % of 1990), A2

w/ “CO_2 fertilization” effect

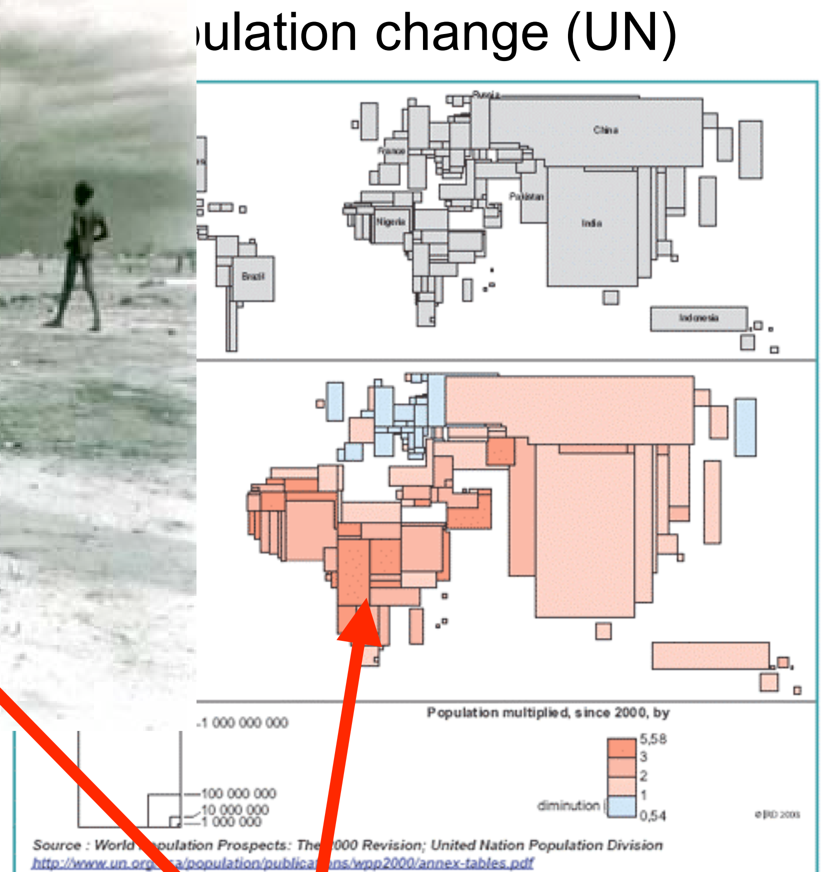


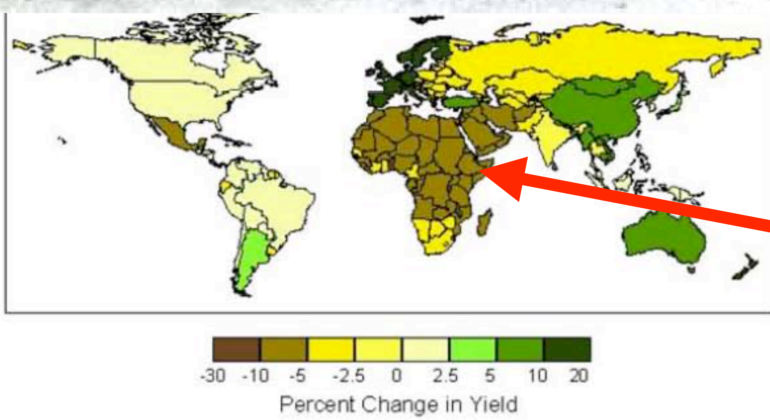
population change (UN)



projected deficits are greatest in areas of greatest expected population growth

projected crop yield (as % of 1990), <u>A2</u>





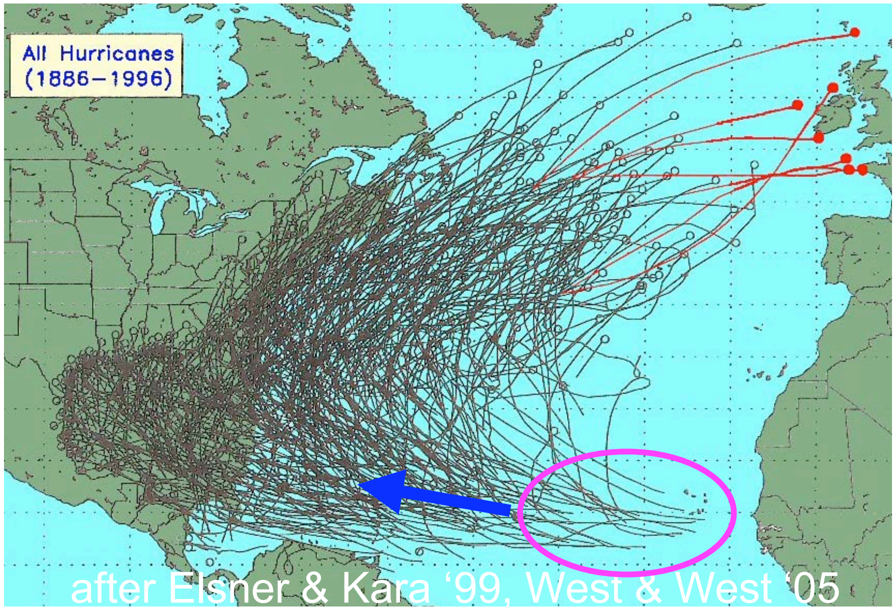
these areas are seriously vulnerable to food shortages already!

hurricanes

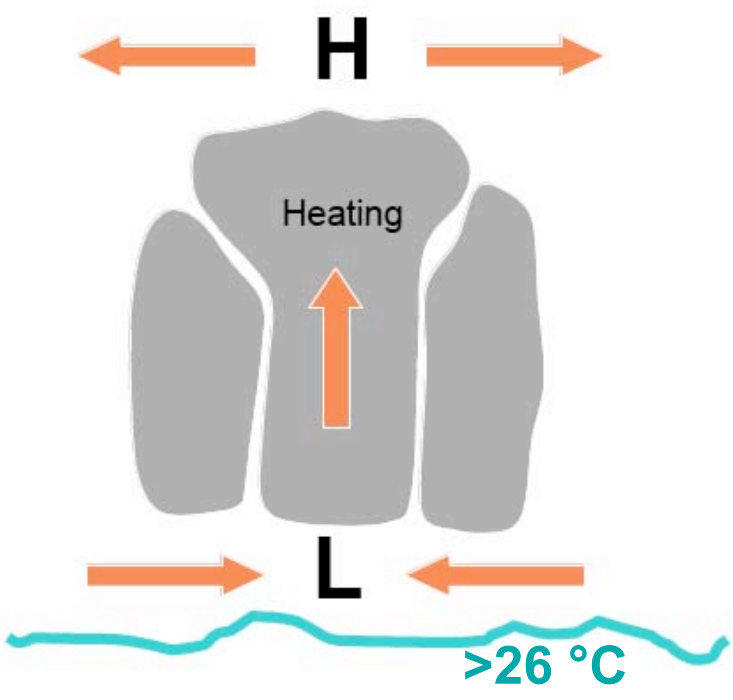
Hurricane Isabel as seen from the
International Space Station
Tuesday, 16 September 2003

hurricanes

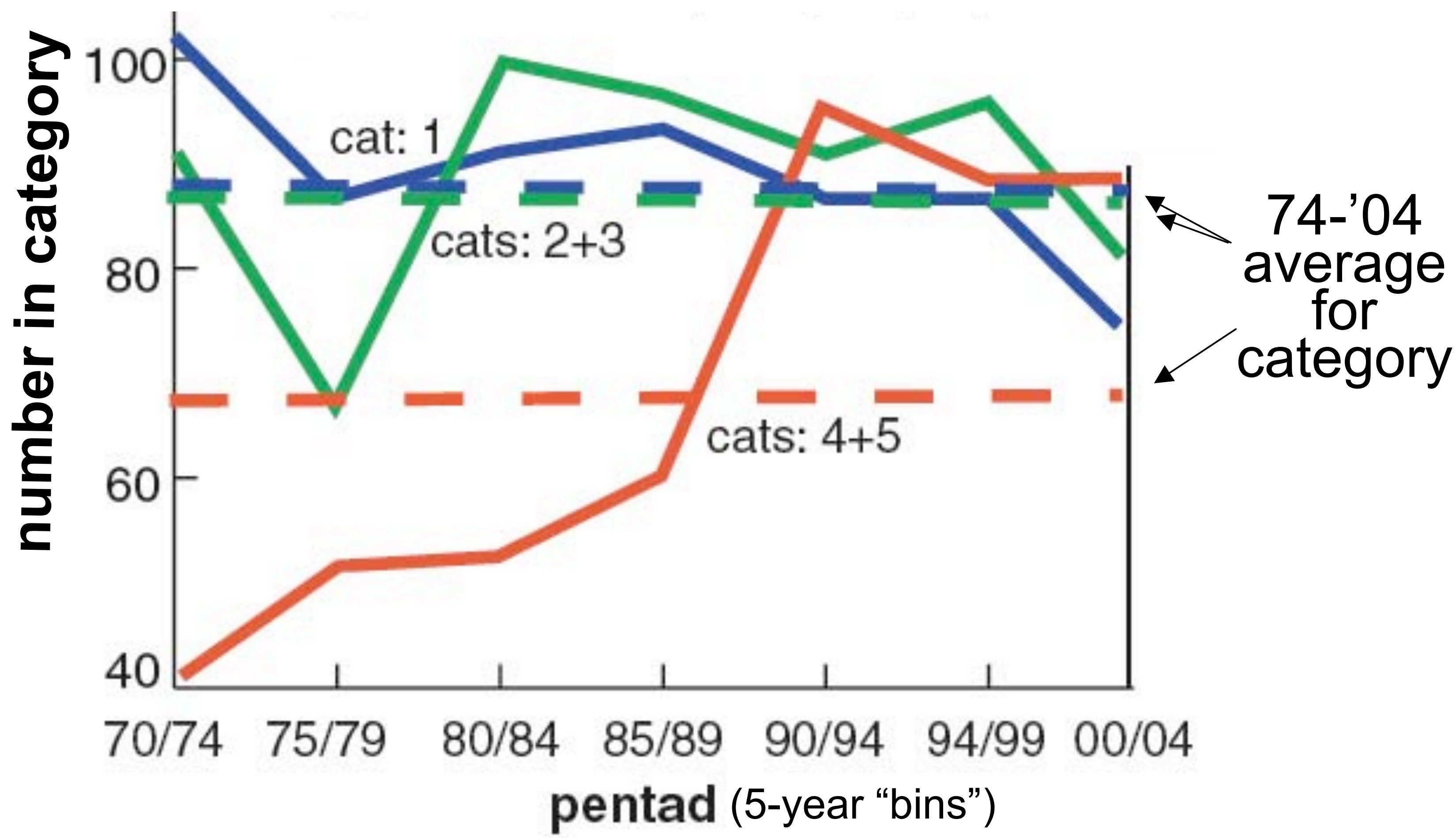
- large topical storm systems that form and develop over warm waters near equator from small tropical depressions
- brought westward by gentle steering winds (trades)
- fueled by heating over warm ocean and moisture convergence
- generally require waters warmer than 26 °C to form and develop



after Elsner & Kara '99, West & West '05



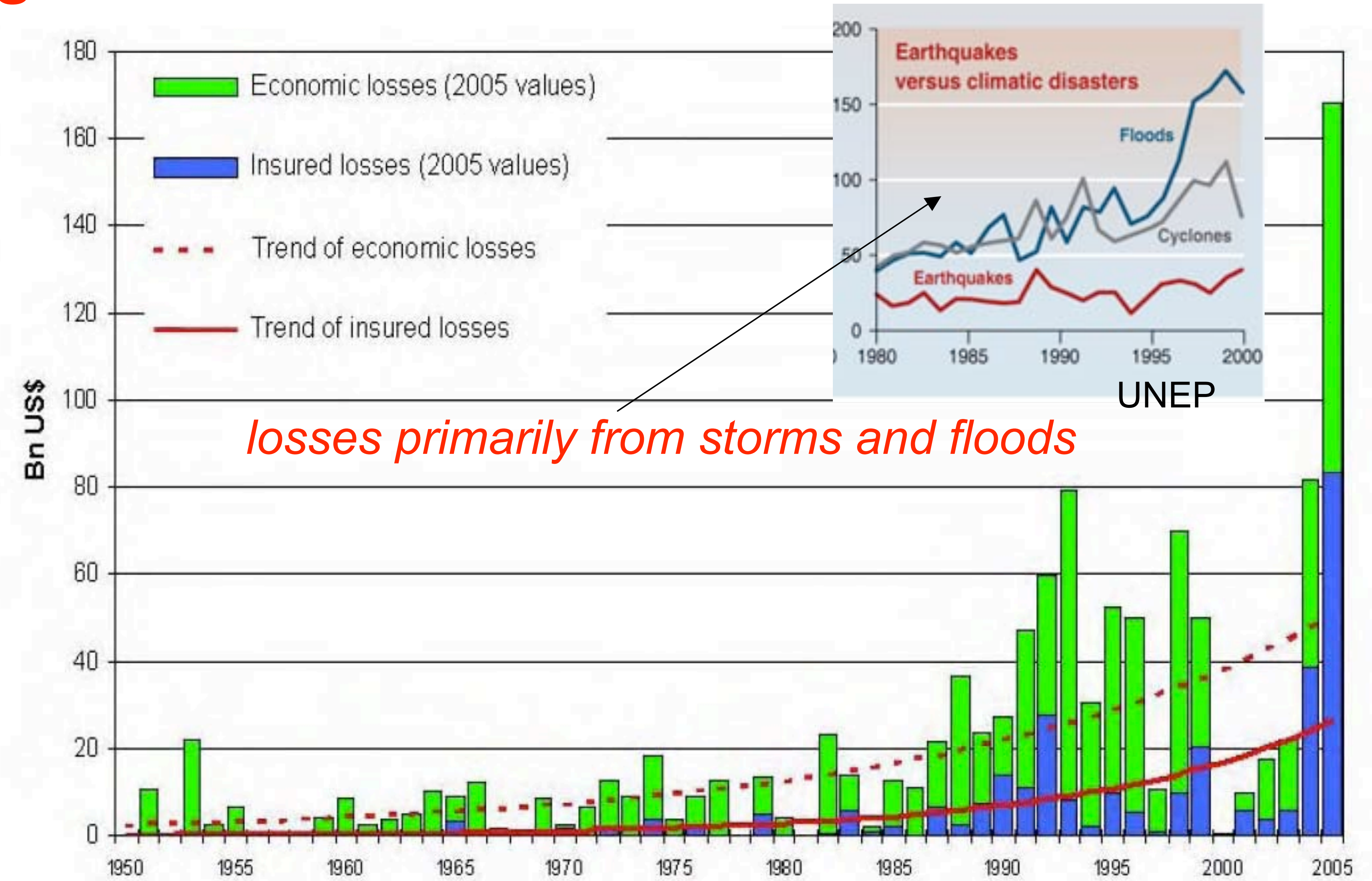
number of intense hurricanes



the frequency of the most powerful (category 5) hurricanes has doubled in the last 30 years.....

Webster et al. '05

global economic losses from weather disasters



Georisk Research, Munich Re (2006)

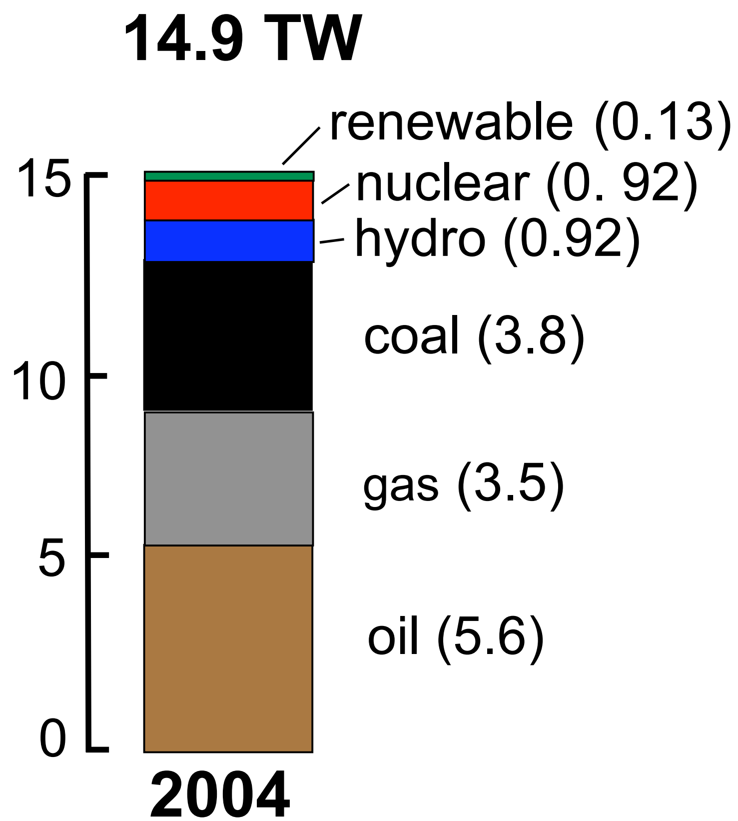
powering the planet

following slides drawn from

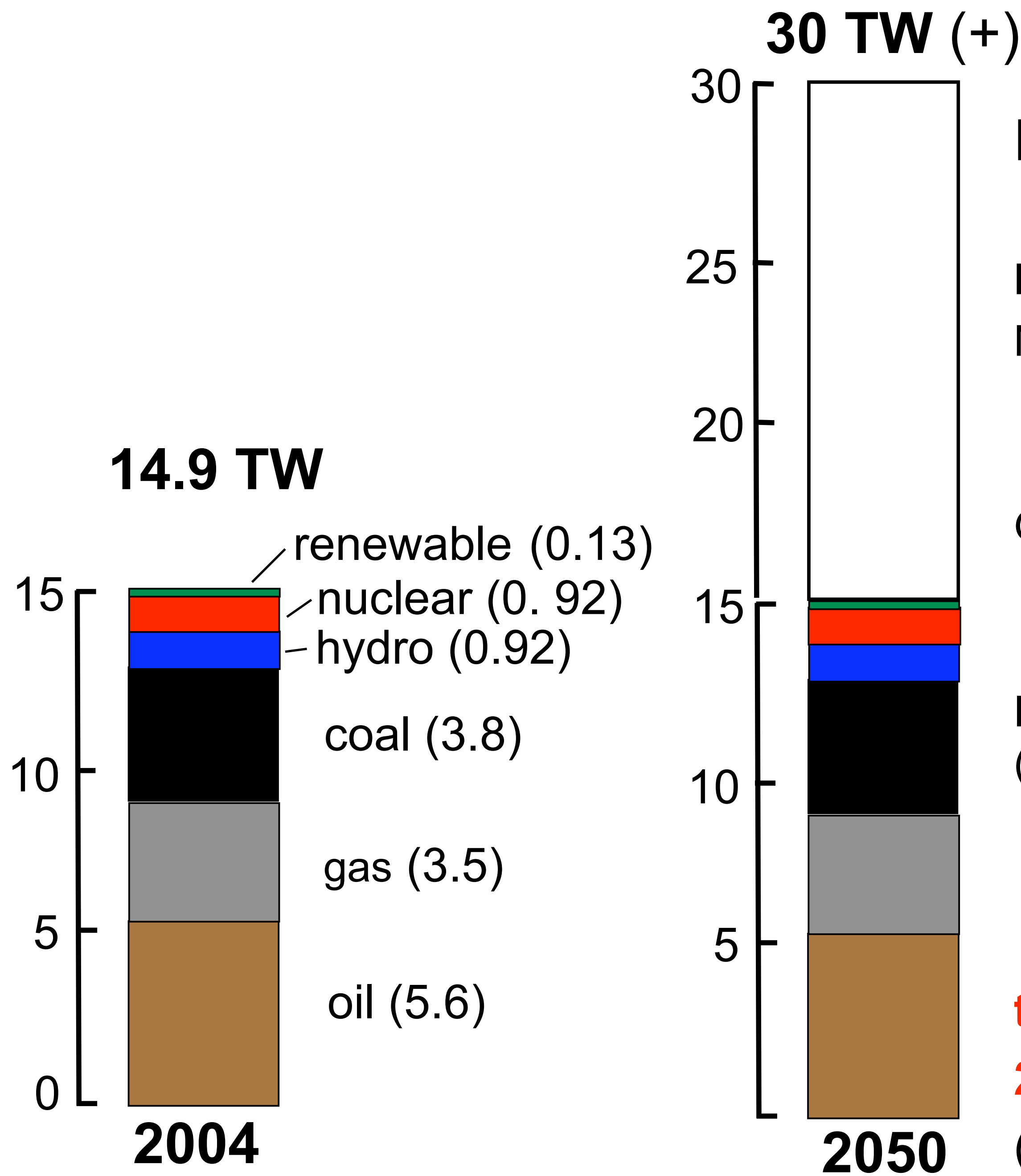
Prof. Dan Nocera, MIT

global energy use by source (and projected)

this is simply a global "burn rate" expressed in quadrillions of Watts



global energy use by source (and projected)



$E = N \times (GDP/N) \cdot (E/GDP)$

E = world energy consumption (TW)

N is population

N growth = +0.9%/yr

i.e. from 6 to 9.4 billion

GDP/N is *per capita* GDP

GDP/N growth = +1.4%/yr

i.e. from $7500 to $15000

E/GDP is *energy intensity*
(energy consumed per unit of GDP)

0.294 W/($/yr) > 0.20 W/($/yr)

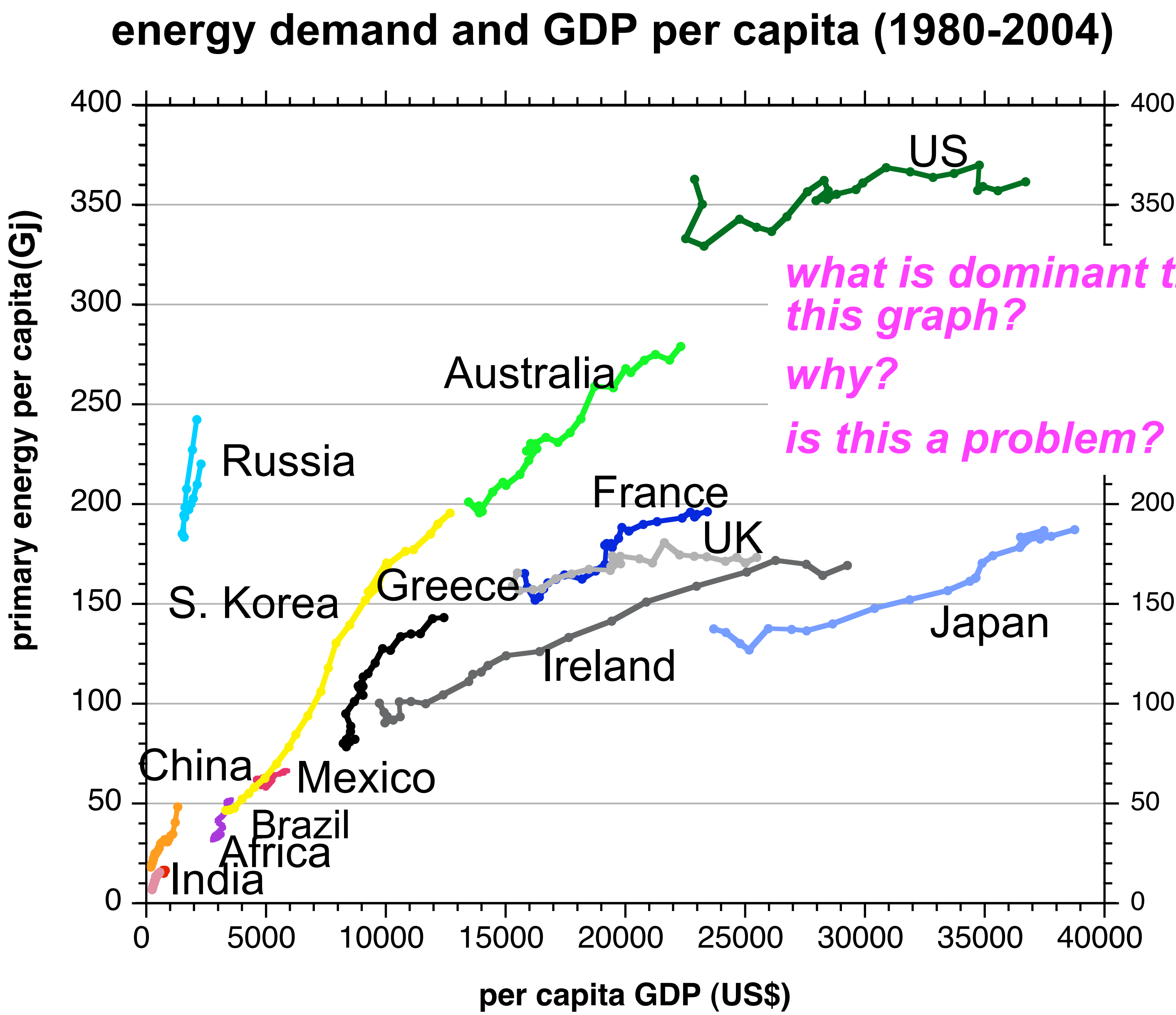
E/GDP decrease = 0.8 %/yr

therefore E will grow at:

2.3%/yr - 0.8%/yr = 1.5%/yr

(i.e. doubling by 2050)

energy use per person in different countries

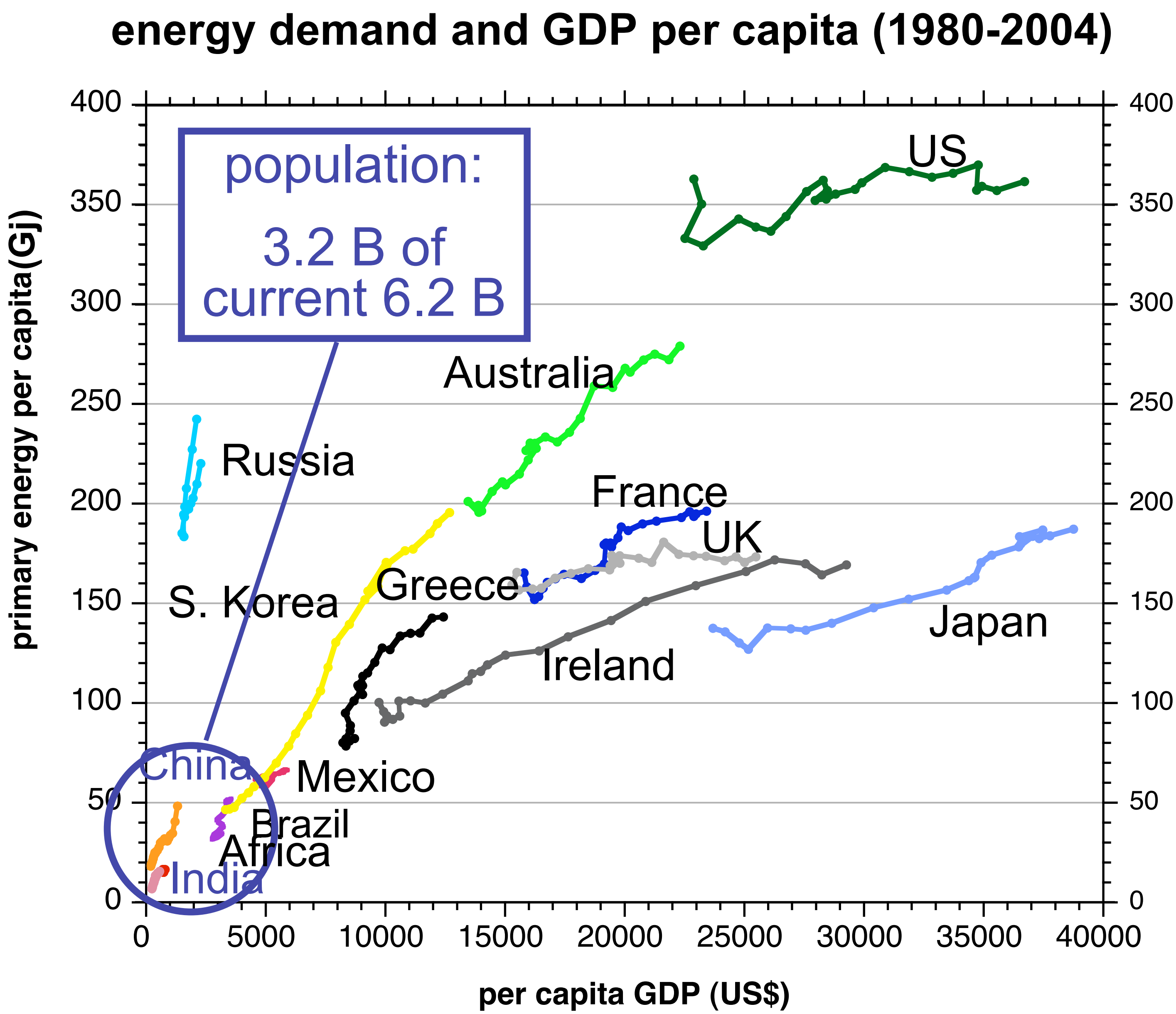


what is dominant trajectory in this graph?

why?

is this a problem?

energy use per person in different countries



Meeting the global energy demand while reducing carbon emissions and addressing climate change is <u>the</u> challenge of the century…

overview of class topics

(download at http://instaar.colorado.edu/lehman/env-issues/)

- Earth System interactions
- radiation, energy and the Greenhouse Effect
- composition and structure of the atmosphere
- heat, winds and currents (I-III)
- water in the climate system
- *case study*: Lessons from the ice age
- fossil fuels and the carbon cycle
- *case study*: natural CO_2, climate and sea level change
- recent warming, evidence and attribution
- commitment warming & sea level rise
- *case study*: sea-ice, glacier and ice-sheet melting
- projected impacts of warming
- powering the planet
- decisions, decisions
- carbon policy

requirements and resources:

- ***required text:***
  "Global Warming: Understanding the Forecast"
  D. Archer (U. Chicago), Blackwell Publ., 2007.
- ***supplemental text:***
  "Dire Predictions: Understanding Global Warming"
  M. Mann & L. Kump (U. Penn.), DK Publ., 2009

- ***grading***:
  Two 1-Hour Exams (30%)
  Final Exam (30%)
  Homework and **in-class exercises** (30%)
  iClicker participation (10%)

- ***exams will be based on learning goals & key concepts and terms identified in lectures and assigned readings*** *(called "take home points" in the required text).*

- ***Class web site:*** http://instaar.colorado.edu/lehman/env-issues/
  will be your most up-to-date resource for lecture notes, reading and homework assignments.

- ***Remember to get an iClicker and register it (at CuConnect)***

office hours & syllabus

Offices

- BESC,   Room 246F, ph. 492-5478

  Office Hours: 10:00 – 11:00 A.M., TR, or by e-mail (best) or phone appointment

- East Campus, RL-1 (INSTAAR), Room 157, ph. 492-8980

Syllabus

we all have responsibilities- be sure to read and understand them at:
http://instaar.colorado.edu/lehman/env-issues/

semester goals....

make use of a single, big problem, namely, assessing the risk of global warming.....

- ***to develop an analytical understanding of interactions within the Earth System***

- ***as an opportunity to learn how scientists think about complex issues***

  ("Do I understand this? How can I check?")

- ***to evaluate possible mitigation and adaptation strategies***

next class:

- *Earth system components and interactions (coupling, feedback and equilibrium)*

- ***assigned reading: Archer Ch.1***

- *bring your clicker!*