Global warming: Coming ready or not!

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NCAR

NCAR Earth System Laboratory
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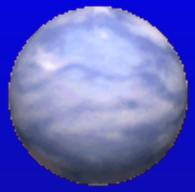
Climate

The atmosphere is a "global commons." Air over one place is typically half way round the world a week later, as shown by manned balloon flights.

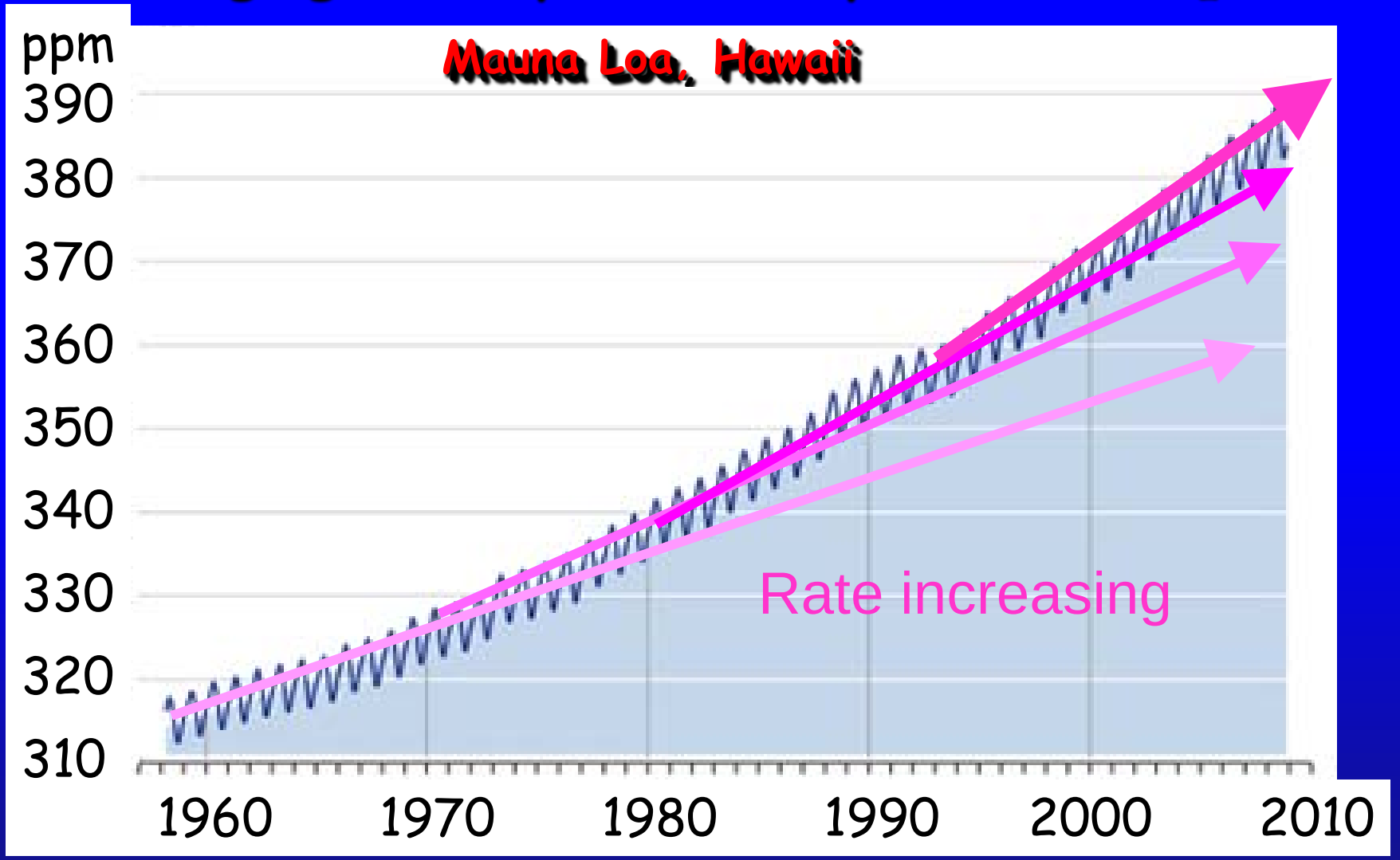


The atmosphere is a dumping ground for all nations for pollution of all sorts. Some lasts a long time and is shared with all. **One consequence is global warming!**

Running a fever: Seeing the doctor

- **Symptoms**: the planet's temperature and carbon dioxide are increasing
- **Diagnosis**: human activities are causal
- **Prognosis**: the outlook is for more warming at rates that can be disruptive and will cause strife
- **Treatment**: mitigation (reduce emissions) and adaptation (planning for consequences)

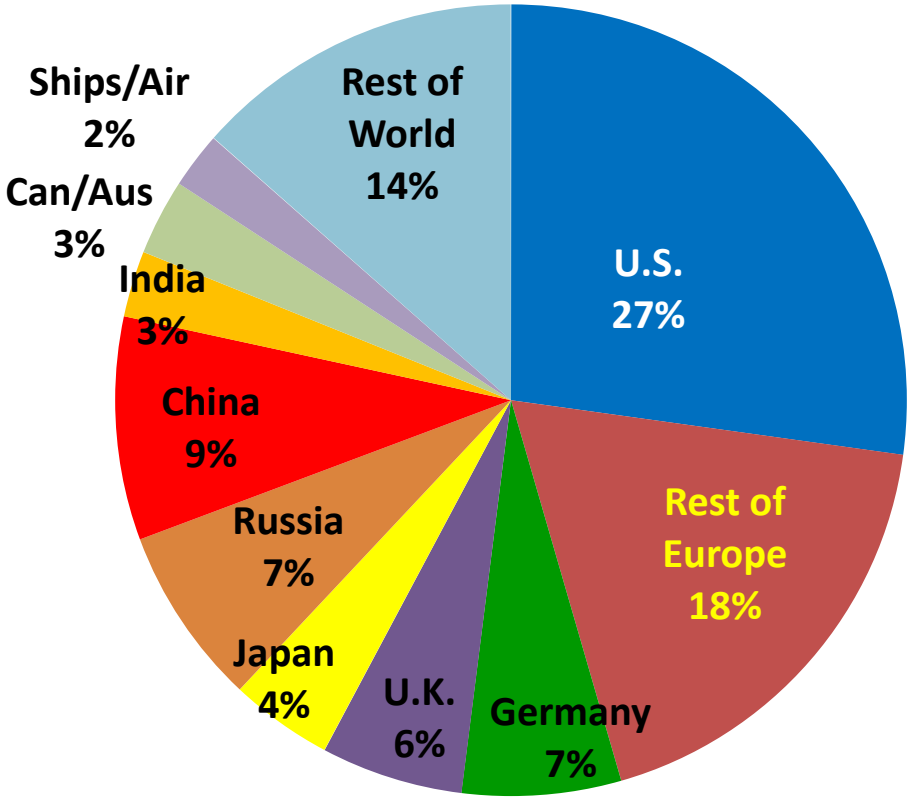
Changing atmospheric composition: CO_2



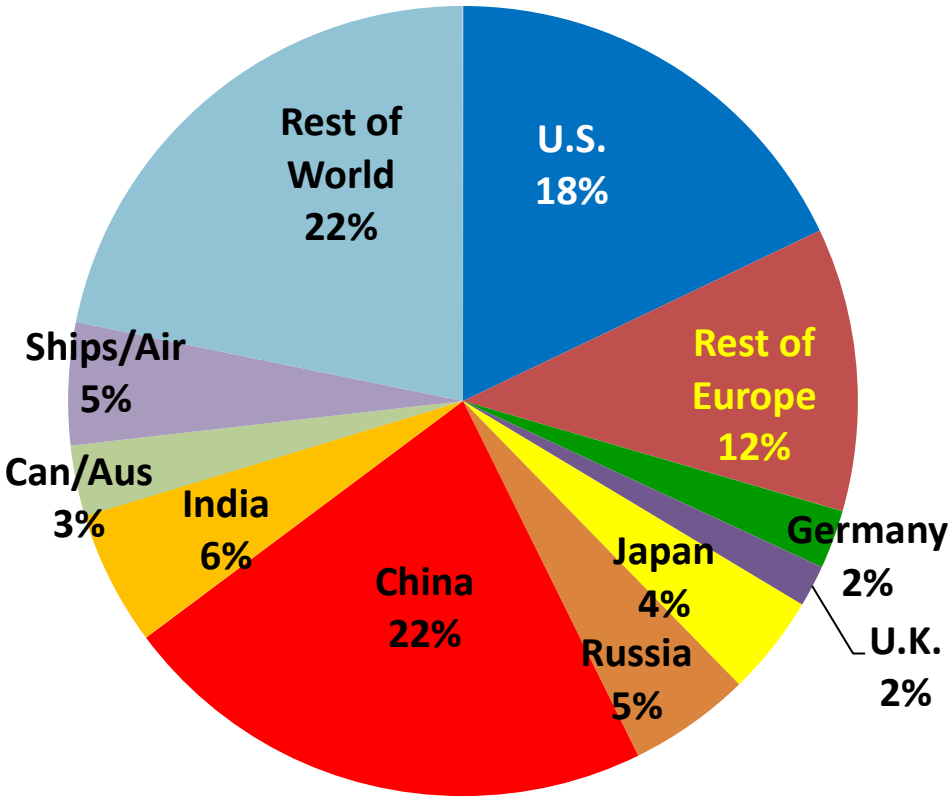
Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1974 from C. Keeling, Scripps Inst. Oceanogr.

Fossil Fuel Emissions

Percent cumulative emissions of CO_2 to 2008



2008 Annual Mean Emissions

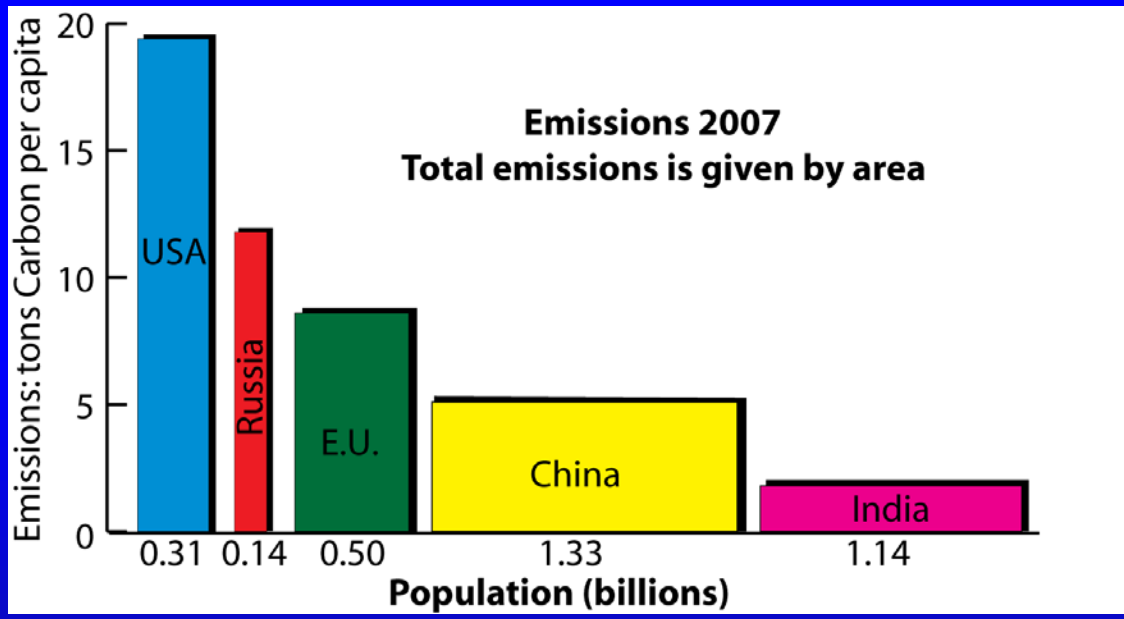


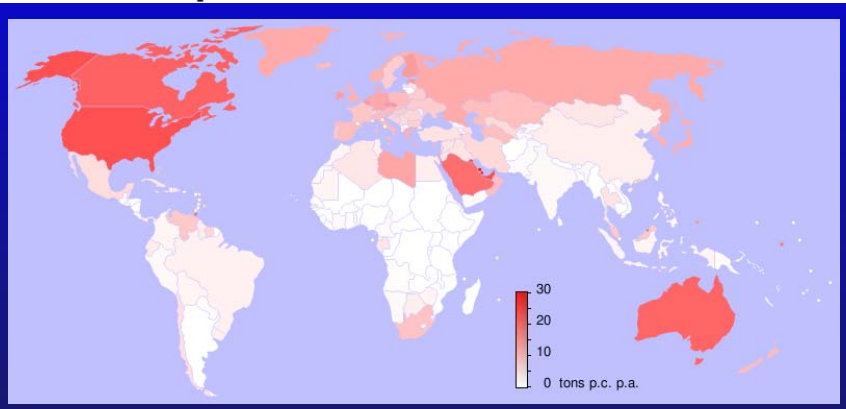
2007 emissions:

China biggest emitter (up 8% in 2007)

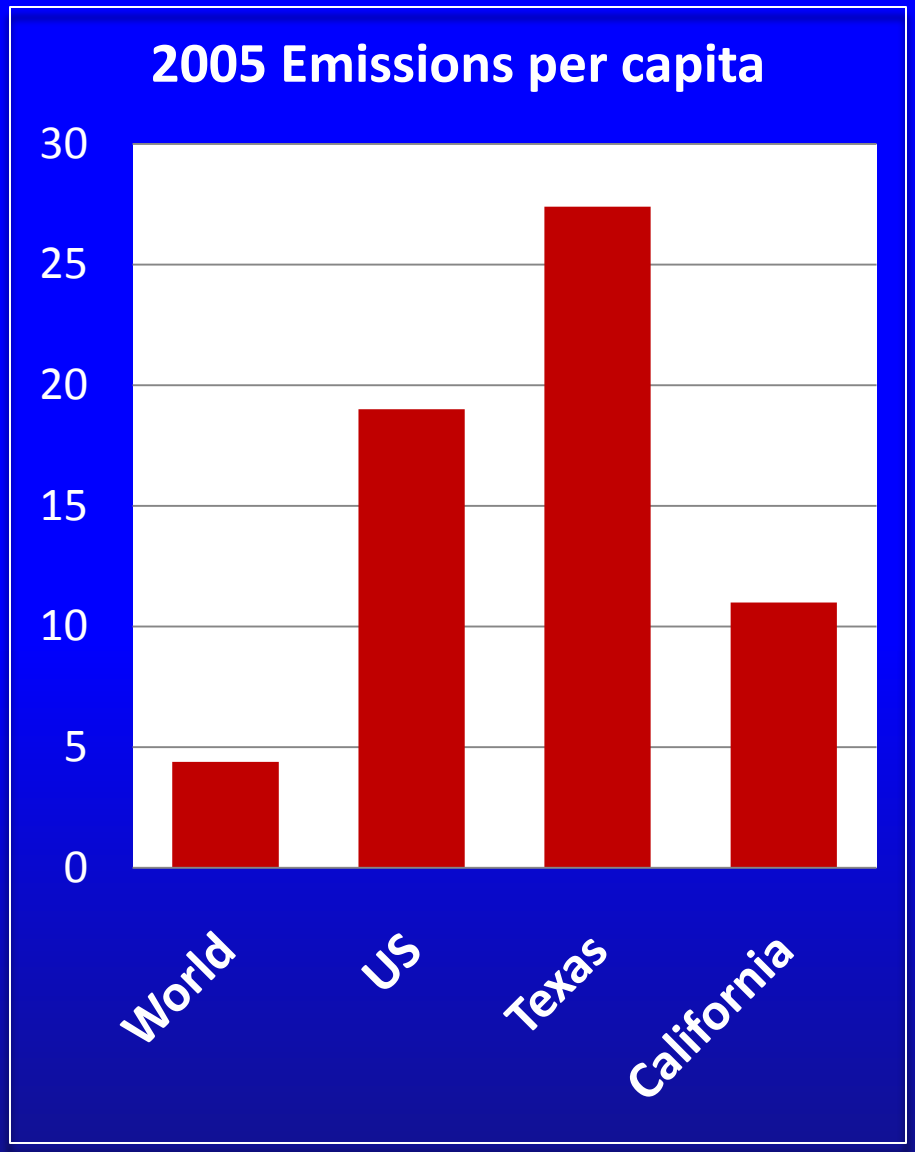
- 14% more than US
- Per capita Pop.

U.S.:	19.4	0.31
Russia:	11.8	0.14
E. U.:	8.6	0.50
China:	5.1	1.33
India:	1.8	1.14
	tons	Billions





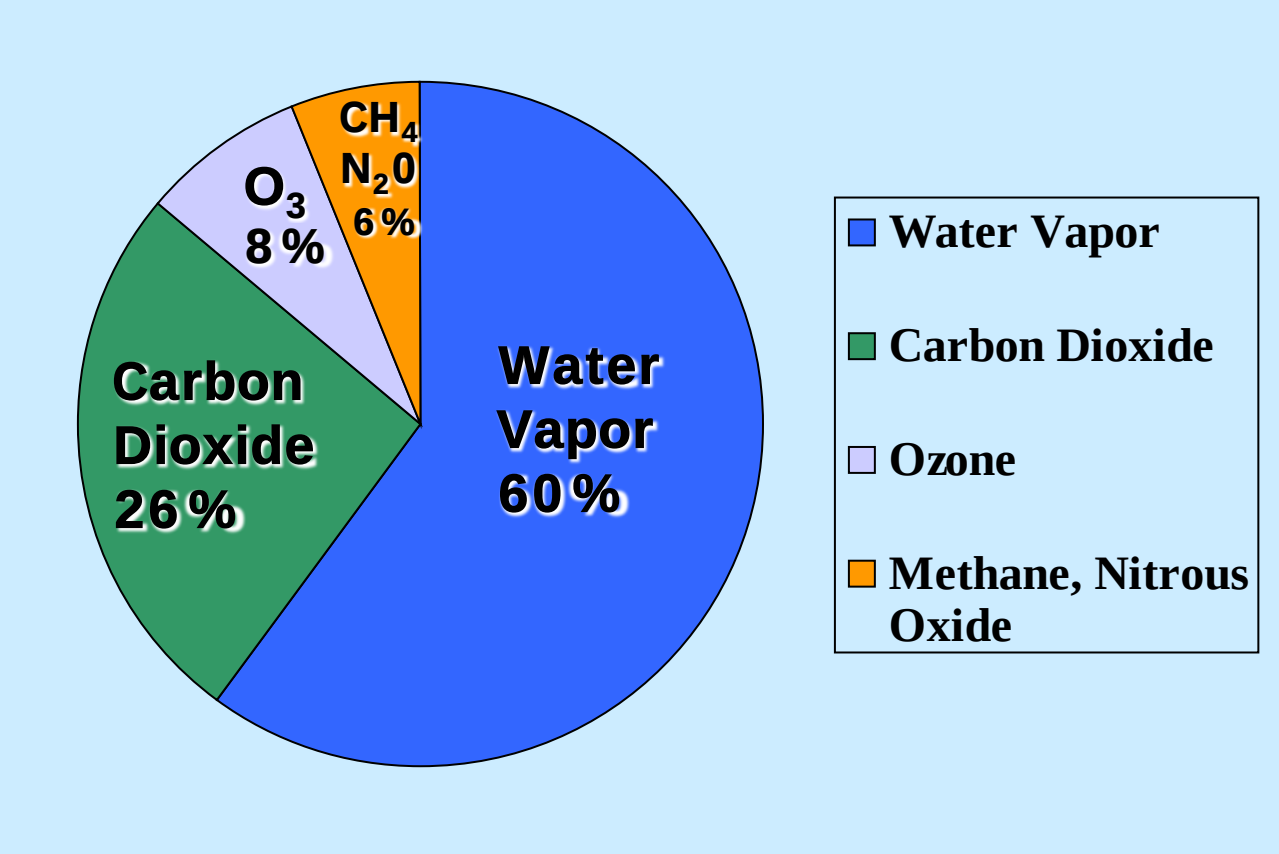
Netherlands Environmental Assessment Agency 2008



LOWEST	HIGHEST
D. Columbia	Wyoming
Connecticut	Alaska
Rhode Island	North Dakota
Vermont	West Virginia
California	Louisiana
Idaho	Montana
New York	Indiana
Oregon,	Kentucky
Massachusetts	Alabama
Washington	New Mexico

Tonnes CO_2 per capita
US Energy Inf. Agency

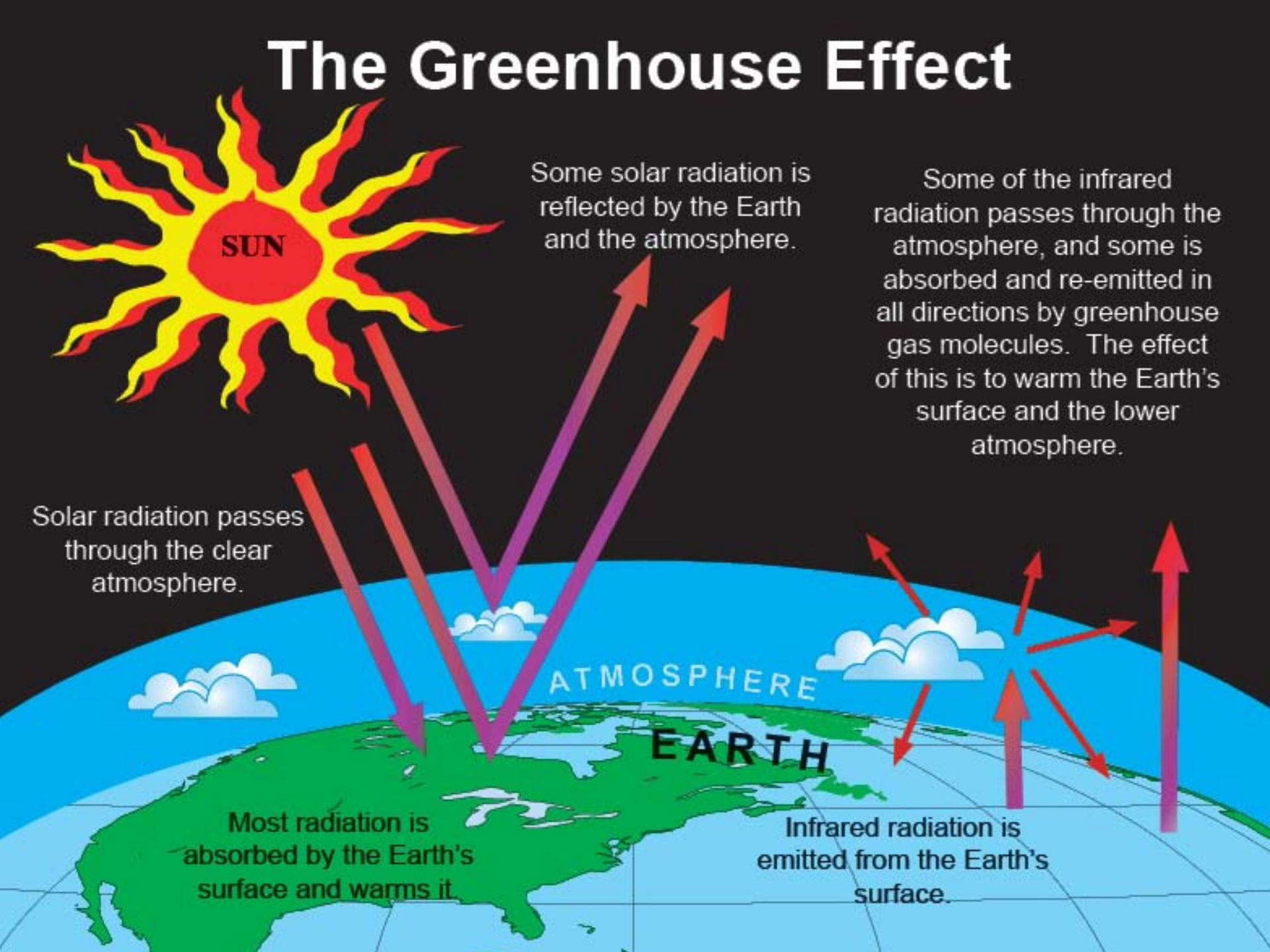
The Natural Greenhouse Effect: clear sky



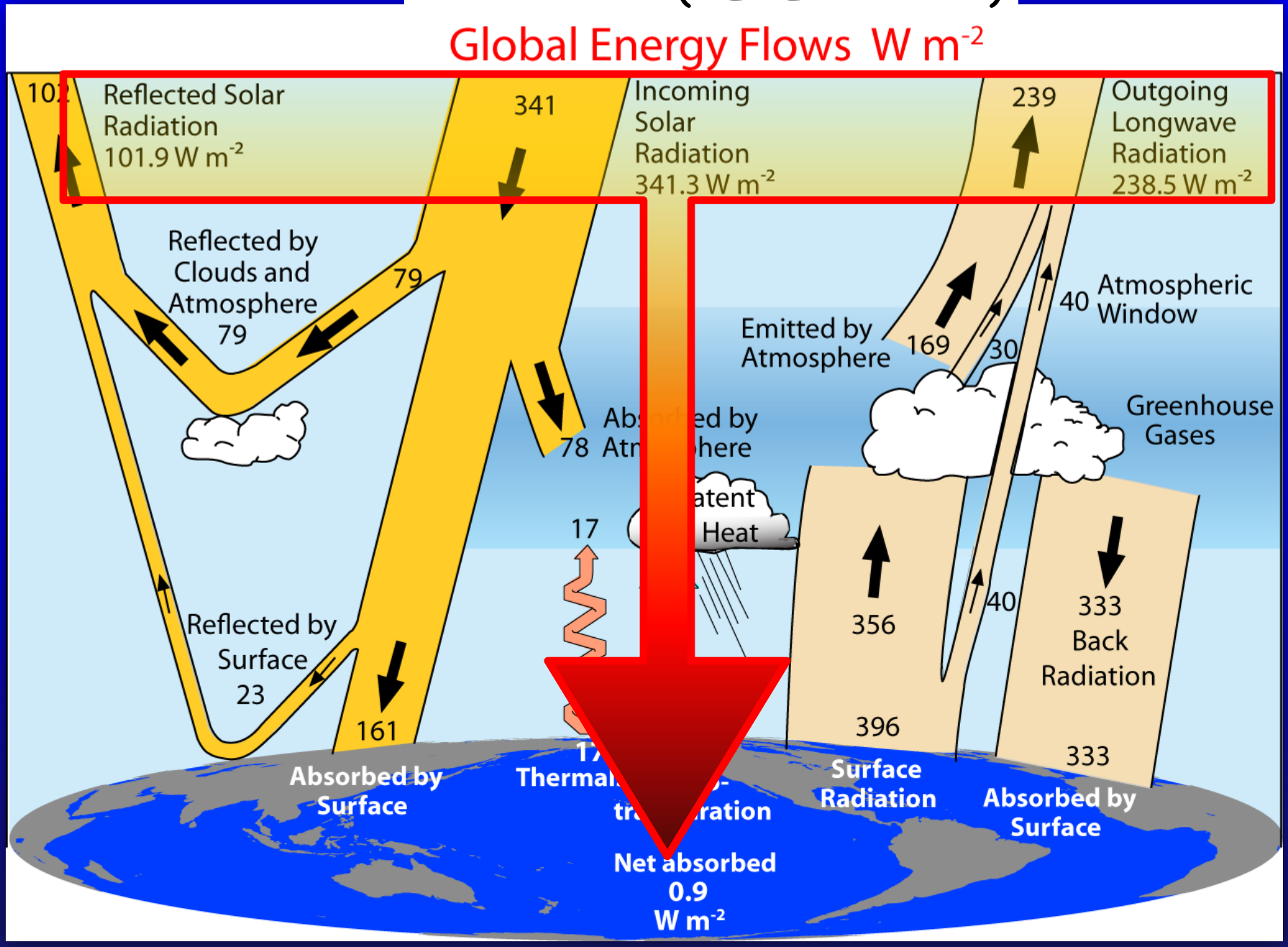
Clouds also have a greenhouse effect

Kiehl and Trenberth 1997

The Greenhouse Effect

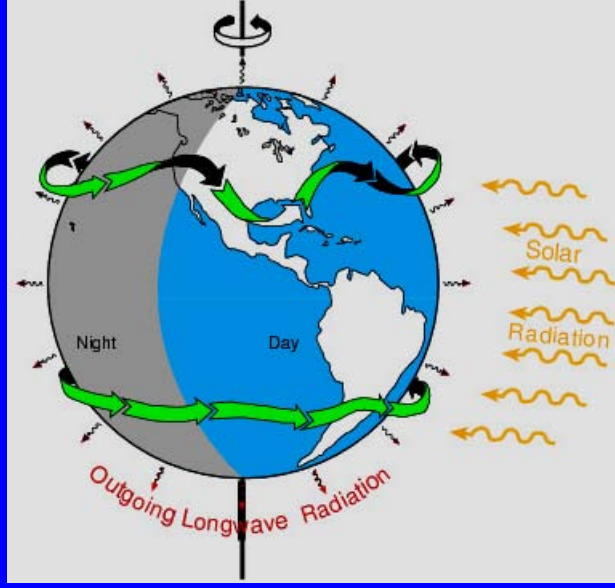


2000-2005 (CERES Period)



Trenberth et al 2009

The incoming energy from the sun is 341 W m^{-2}: annual global mean:
It amounts to 175 PetaWatts
=175,000,000 billion Watts.
About 122 PW is absorbed.

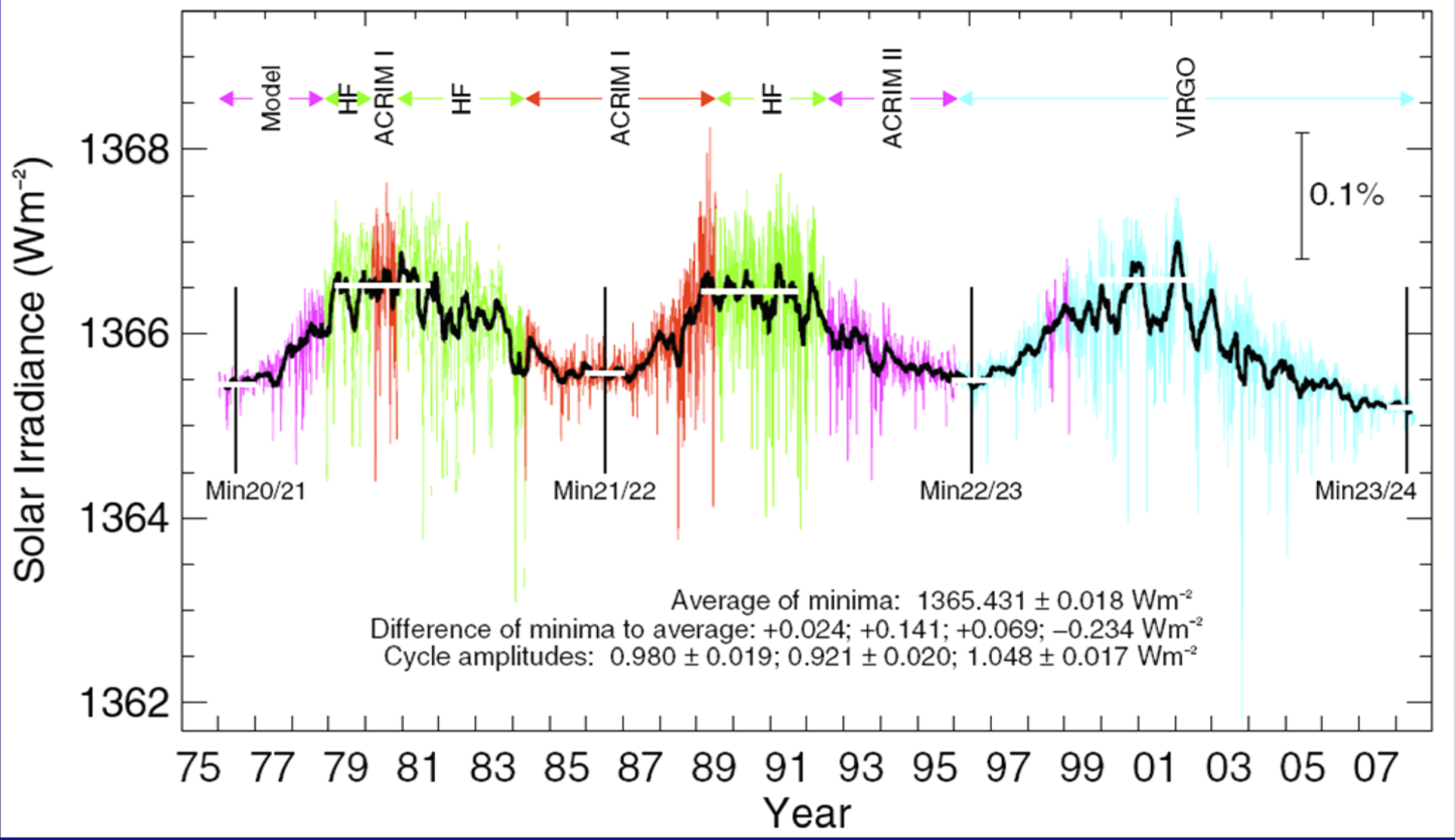


The biggest power plants in existence are 1000 MegaWatts and we normally think of units of 1 KiloWatt (= 1 bar heater), or a 100 W light bulb.

So the energy from the sun is 122 million of these power stations. It shows:

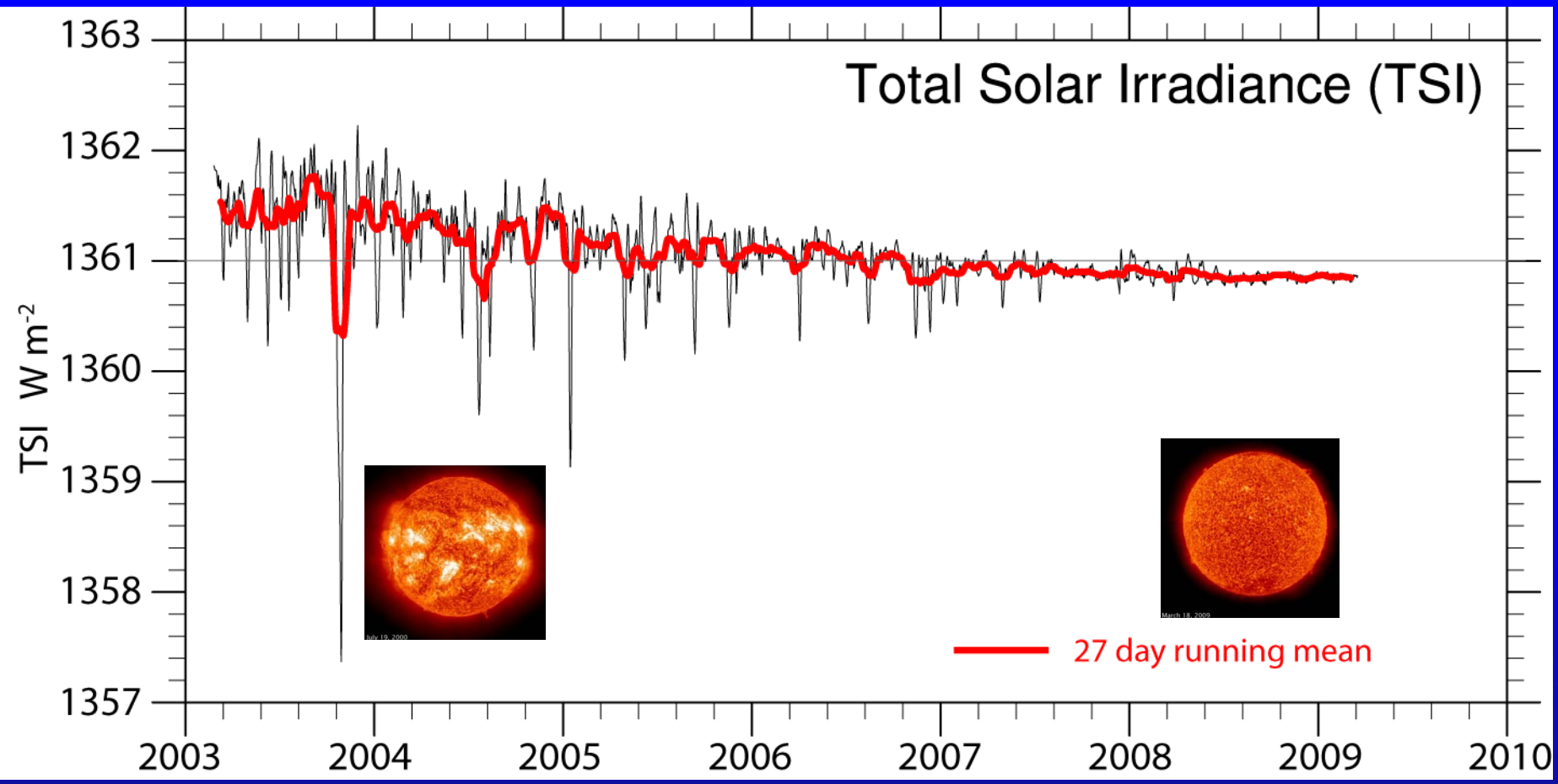
1) **Direct human influences are tiny vs nature.**
2) **The main way human activities can affect climate is through interference with the natural flows of energy such as by changing the composition of the atmosphere**

Changes in the sun



Solar irradiance from composite of several satellite-measured time series based on Frohlich & Lean (1998; http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant)

Solar irradiance



The drop of 0.5 W m^{-2} since 2003 is equivalent to -0.1 Wm^{-2} in radiative forcing

Global Warming is Unequivocal

IPCC: approved 113 govts

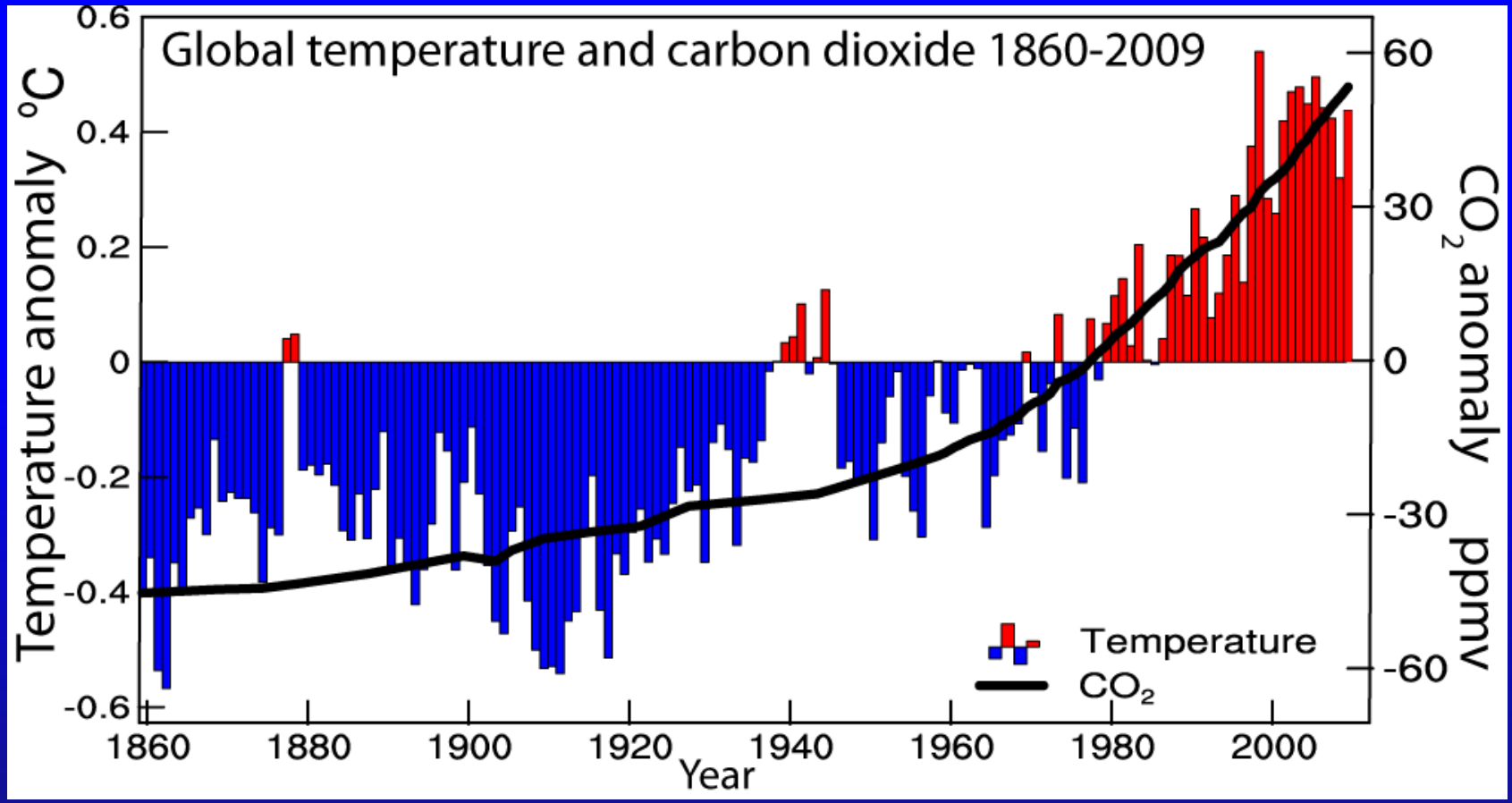
Since 1970, rise in:

- Global surface temperatures
- Tropospheric temperatures
- Global SSTs, ocean Ts
- Global sea level
- Water vapor
- Rainfall intensity
- Precipitation extratropics
- Hurricane intensity
- Drought
- Extreme high temperatures
- Heat waves
- Ocean acidity

Decrease in:

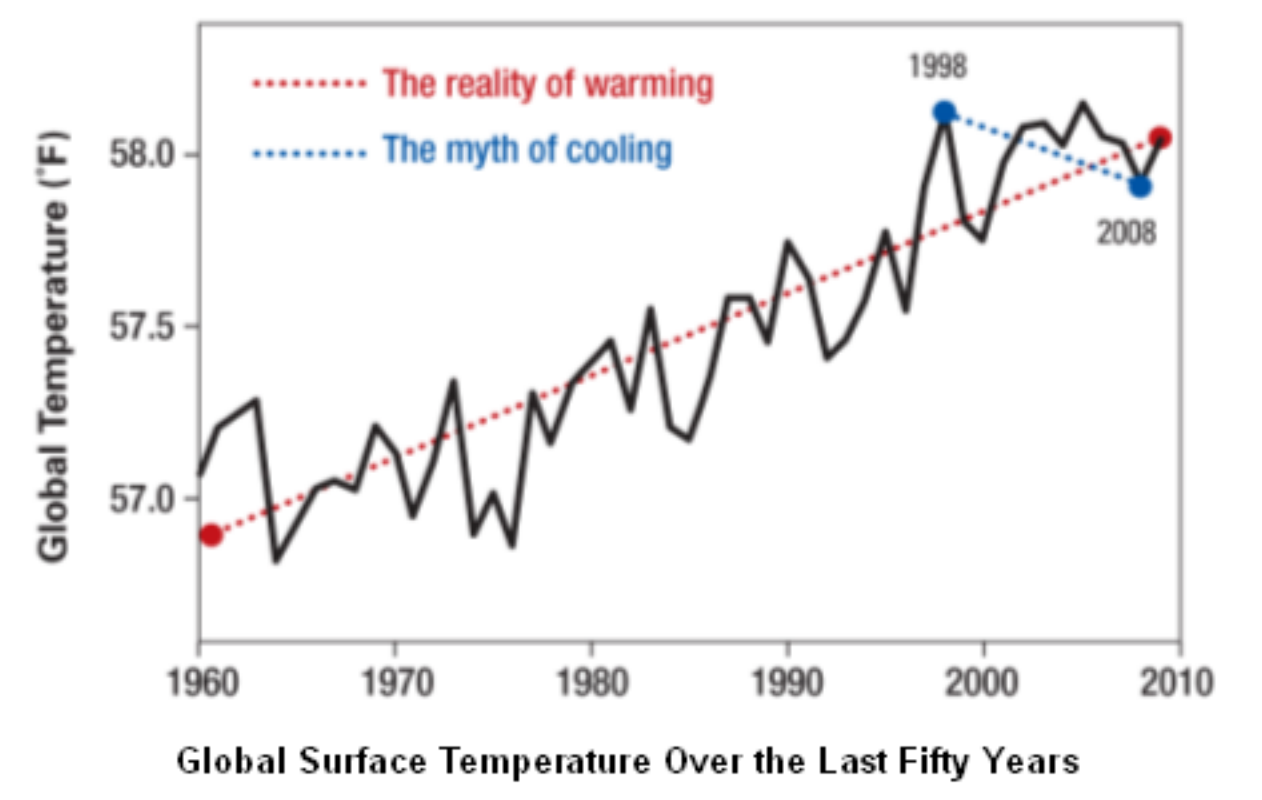
- NH Snow extent
- Arctic sea ice
- Glaciers
- Cold temperatures

Global temperatures and carbon dioxide through 2009



Base period 1961-90

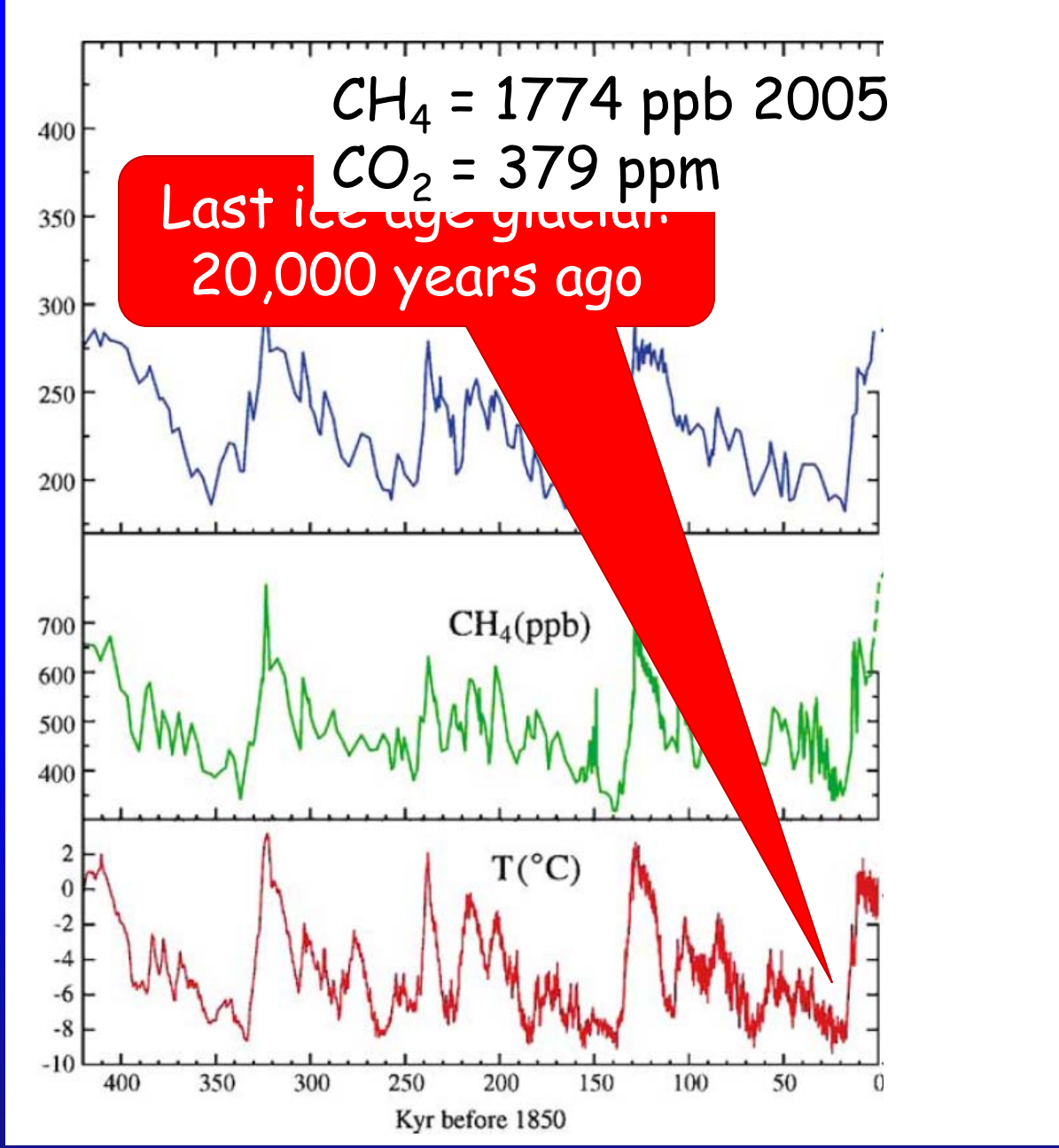
A few cooler years do not mean global warming is not happening!



1998 was especially warm from the major El Nino, but by cherry picking points one can infer the wrong trend (blue) vs the correct one (red). From NOAA/NCDC

Context:

400,000 years of Antarctic ice core records (bubbles of trapped air) of Temperatures, Carbon dioxide and Methane.



Source: Hansen, Climatic Change 2005, based on Petit, Nature 1999

Controlling Heat

Human body: sweats

Homes: Evaporative coolers (swamp coolers)

Planet Earth: Evaporation (if moisture available)

e.g., When sun comes out after showers,

the first thing that happens is that the puddles dry up: before temperature increases.

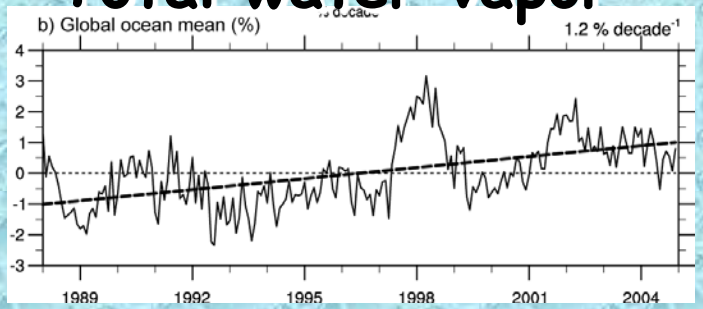
Air holds more water vapor at higher temperatures

A basic physical law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature. (4% per °F)

Observations show that this is happening at the surface and in lower atmosphere: 0.55°C since 1970 over global oceans and 4% more water vapor.

This means more moisture available for storms and an enhanced greenhouse effect.

Total water vapor



How should precipitation P change as the climate changes?

- With increased GHGs: increased **surface** heating
  evaporation E⇑ and P⇑
- With increased aerosols, E⇓ and P⇓
- **Net global effect is small and complex**

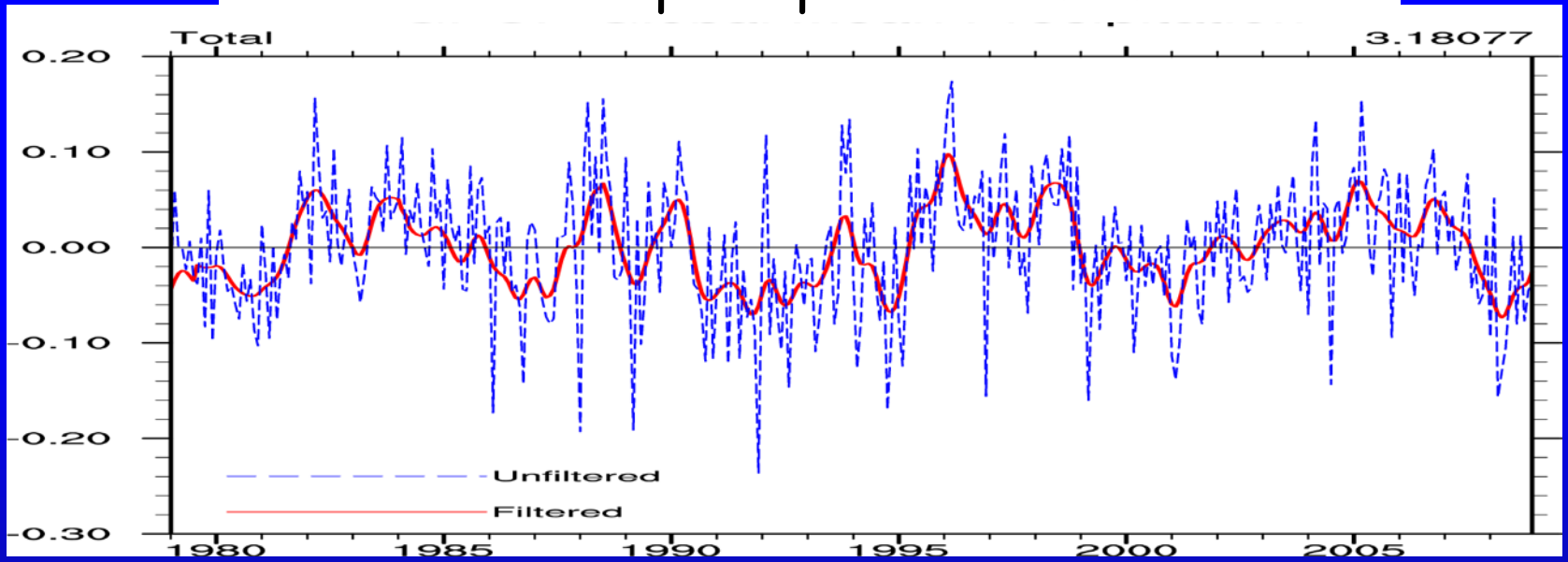
- Warming and T⇑ means water vapor ⇑ as observed
- Because precipitation comes from storms gathering up available moisture, **rain and snow intensity ⇑ : widely observed**
- But this must reduce lifetime and frequency of storms
- Longer dry spells

When it rains, it pours!

Trenberth et al 2003

There is no trend in global precipitation amounts

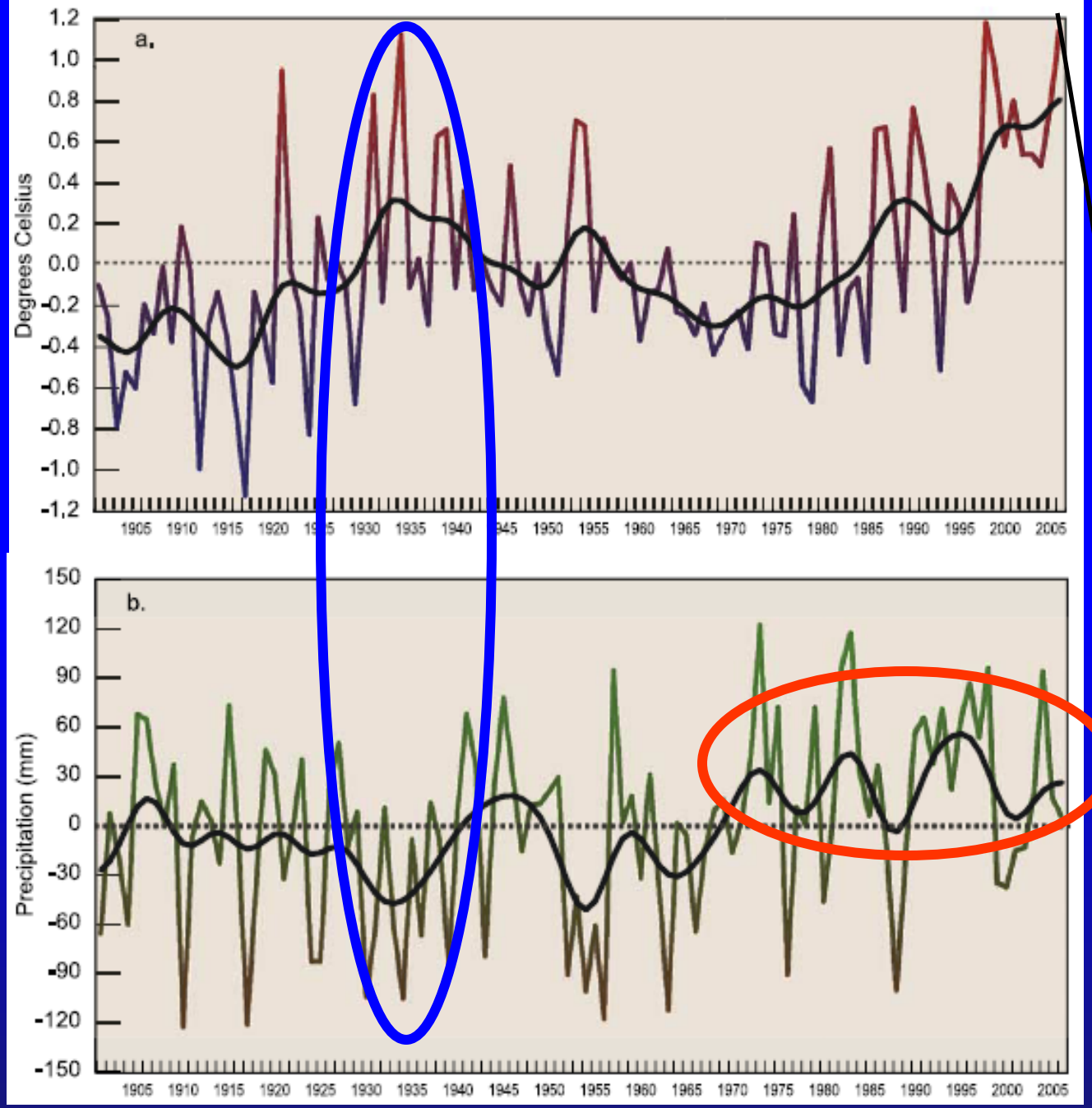
GPCP Global precipitation 1979-2008



Biggest changes in absolute terms are in the tropics, and there is a strong El Niño signal.

Declining Snow Pack in many mountain and continental areas contributes to drought

- more **precipitation** falls as **rain** rather than **snow**, especially in the fall and spring.
- **snow melt** occurs faster and sooner in the spring
- **snow pack** is therefore less
- **soil moisture** is less as summer arrives



1900 1950 2000

US changes in Temperature

Precipitation

Much wetter

1930s:
Hot and dry

Easterling et al 2007 GRL

Climate change and extreme weather events

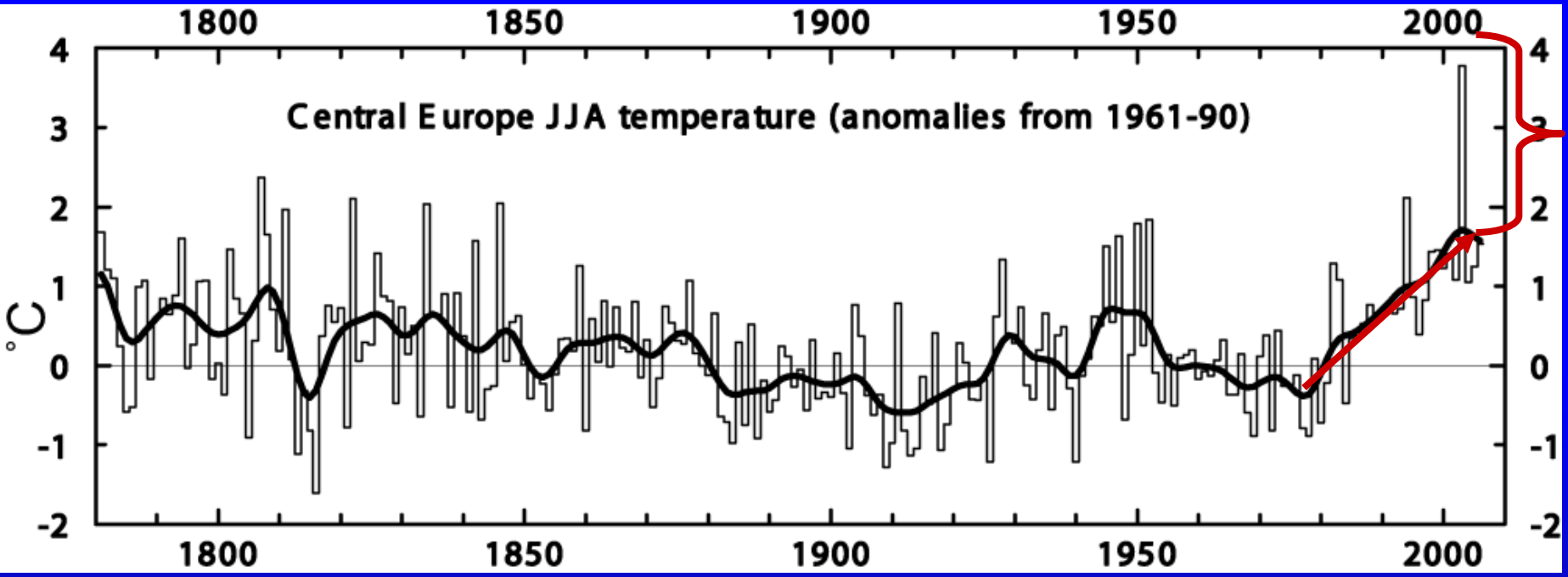
Changes in extremes matter most for society and human health

With a warming climate:

- More high temperatures, heat waves
- Wild fires and other consequences
- Fewer cold extremes.

- More extremes in hydrological cycle:
  - Drought
  - Heavy rains, floods
  - Intense storms, hurricanes, tornadoes

Heat waves are increasing: an example

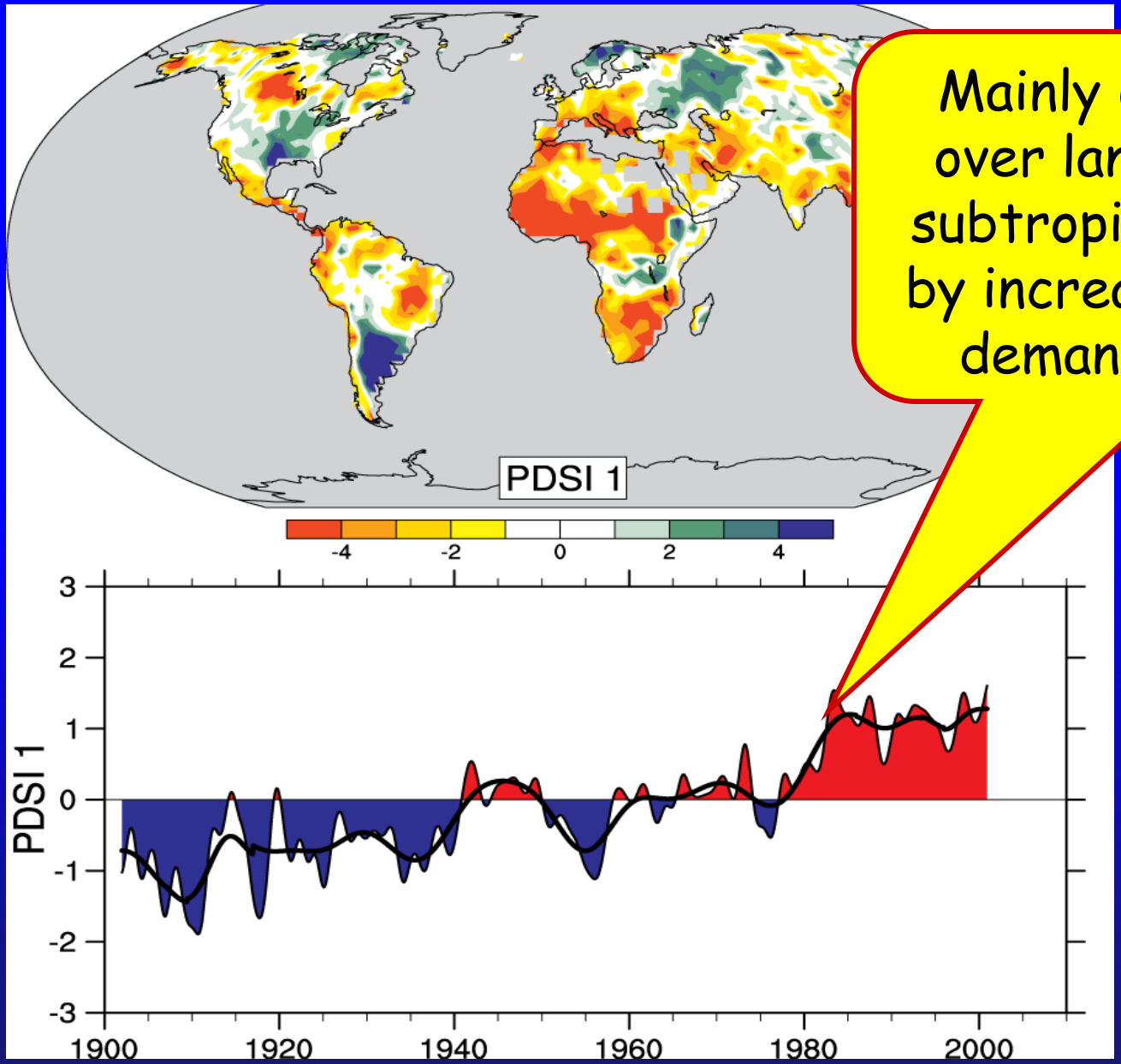


Extreme Heat Wave
Summer 2003
Europe
>50,000 deaths

Trend plus variability?

IPCC

Drought is increasing most places



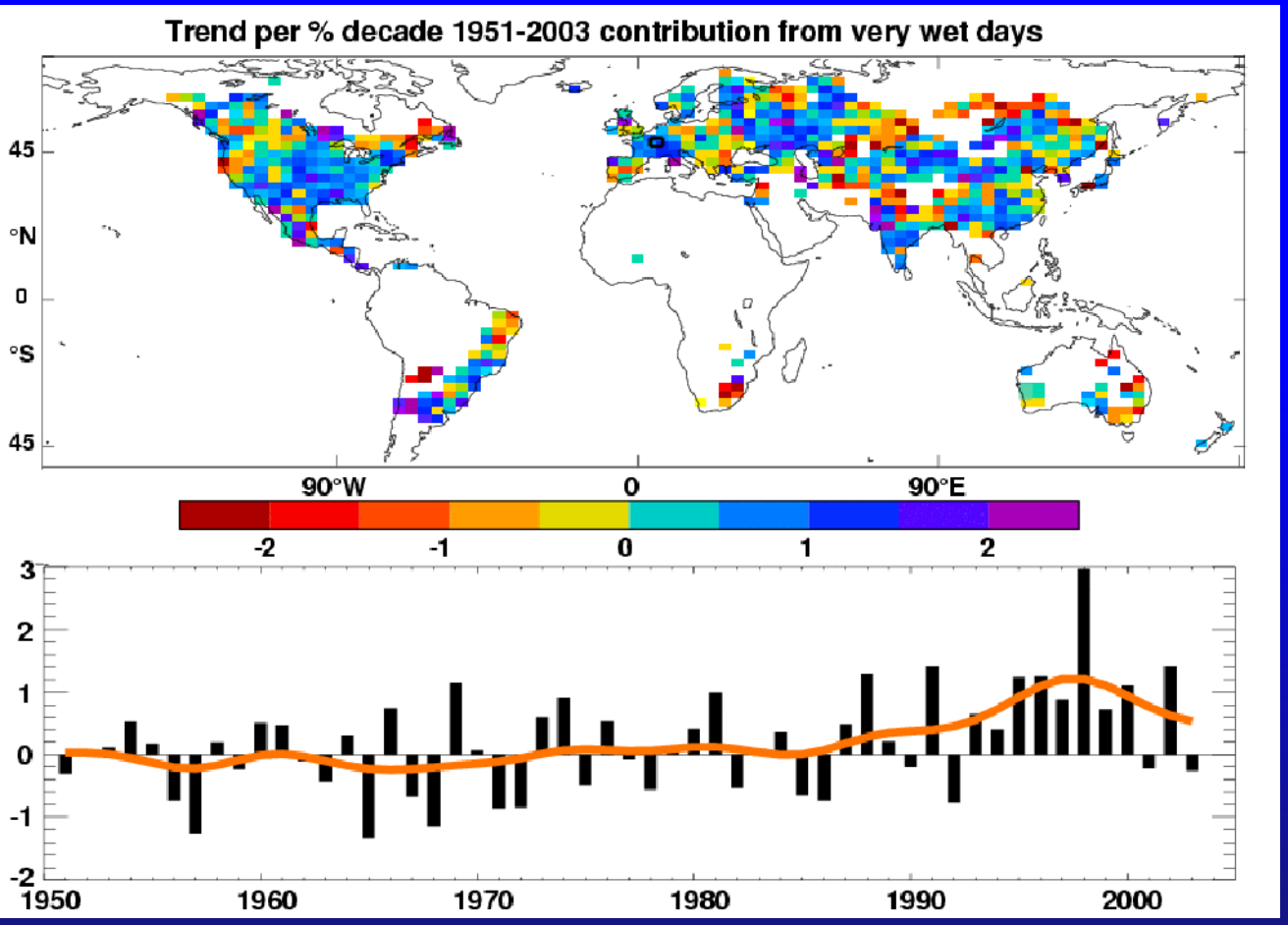
Mainly decrease in rain over land in tropics and subtropics, but enhanced by increased atmospheric demand with warming

Severity Index (PDSI) for 1900 to 2002.

The time series (below) accounts for most of the trend in PDSI.

IPCC

Heavy precipitation days are increasing even in places where precipitation is decreasing.

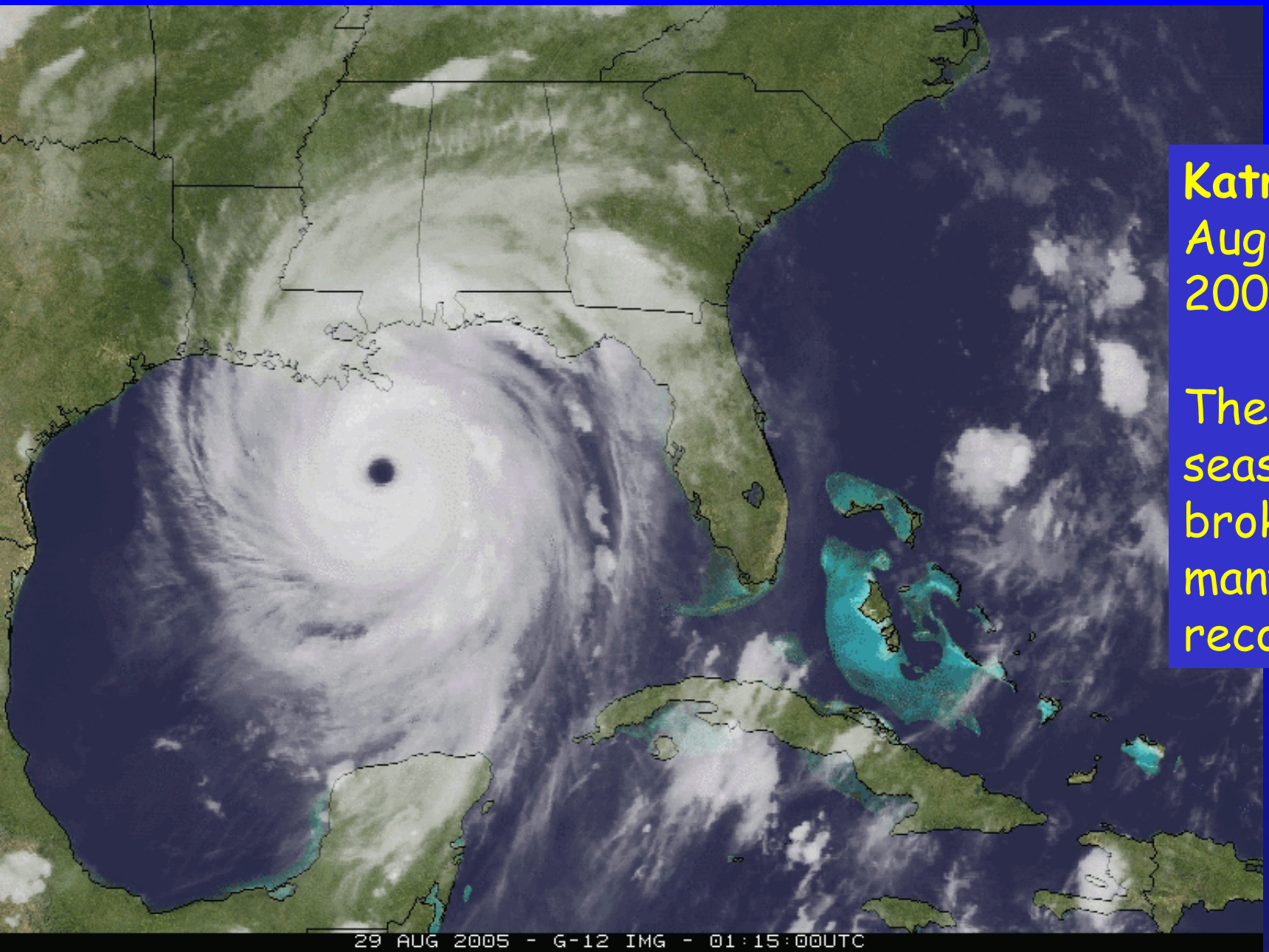


Precipitation

Observed trends (%) per decade for 1951-2003 contribution to total annual from **very wet days** > 95th %ile.

Alexander et al 2006
IPCC AR4

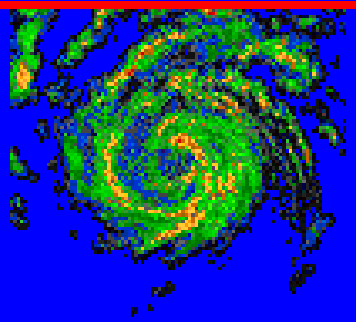
North Atlantic hurricanes have increased with SSTs

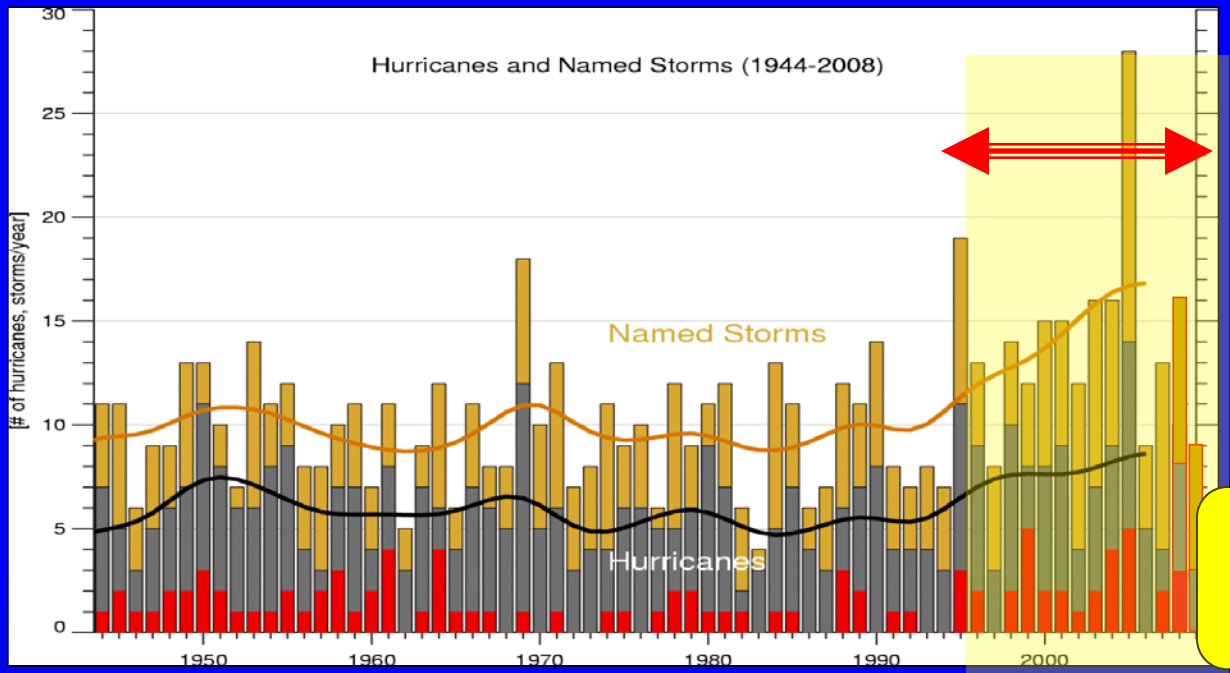


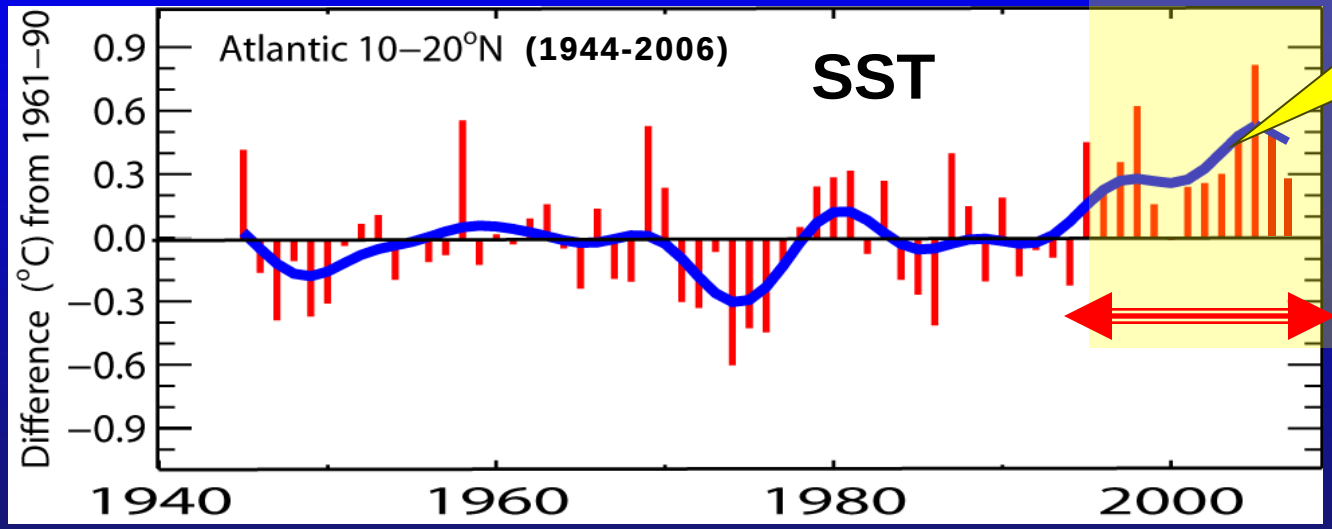
Katrina
August
2005

The 2005
season
broke
many
records

North Atlantic hurricanes have increased with SSTs







N. Atlantic hurricane record best

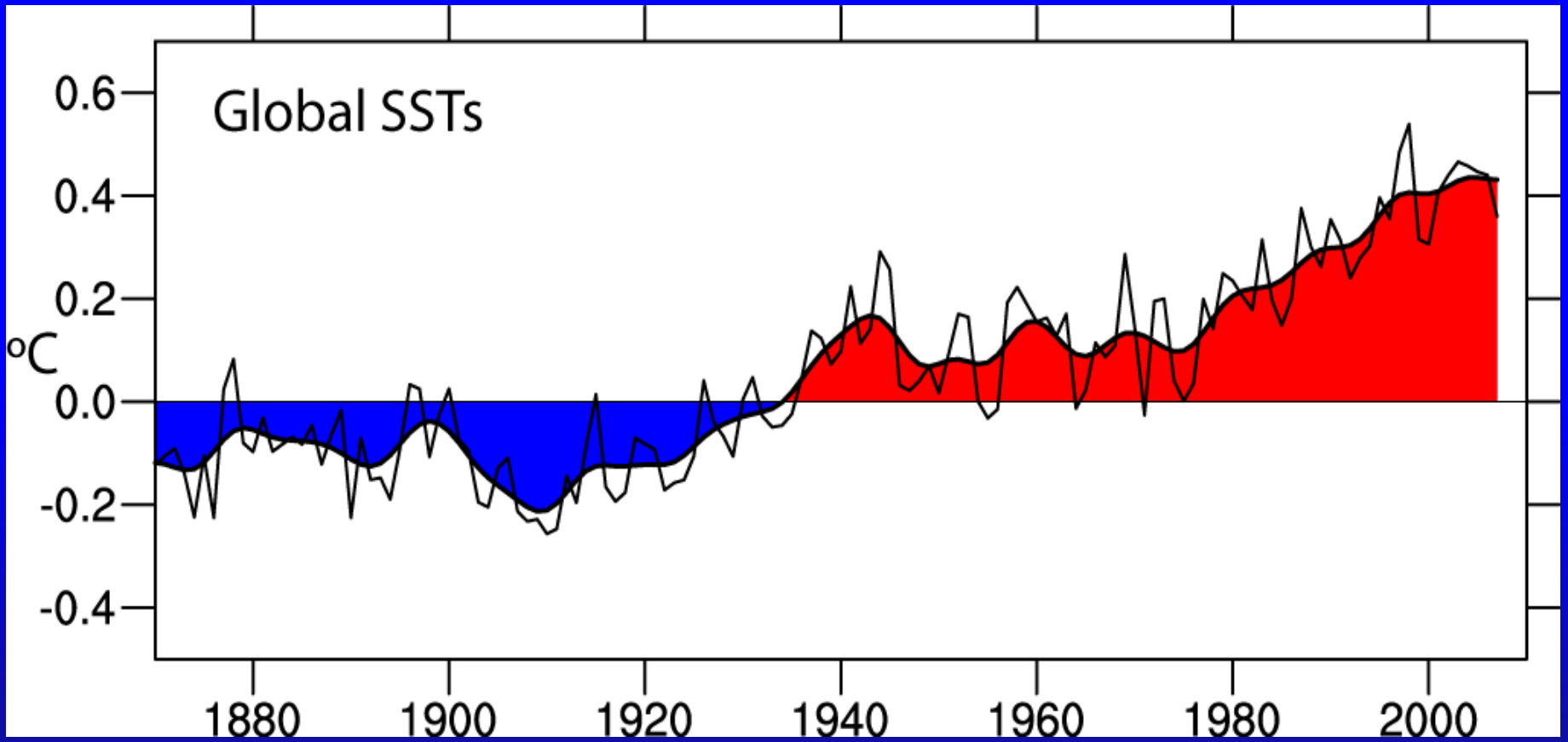
Marked increase after 1994

Global number and percentage of intense hurricanes is increasing

Thru 2009

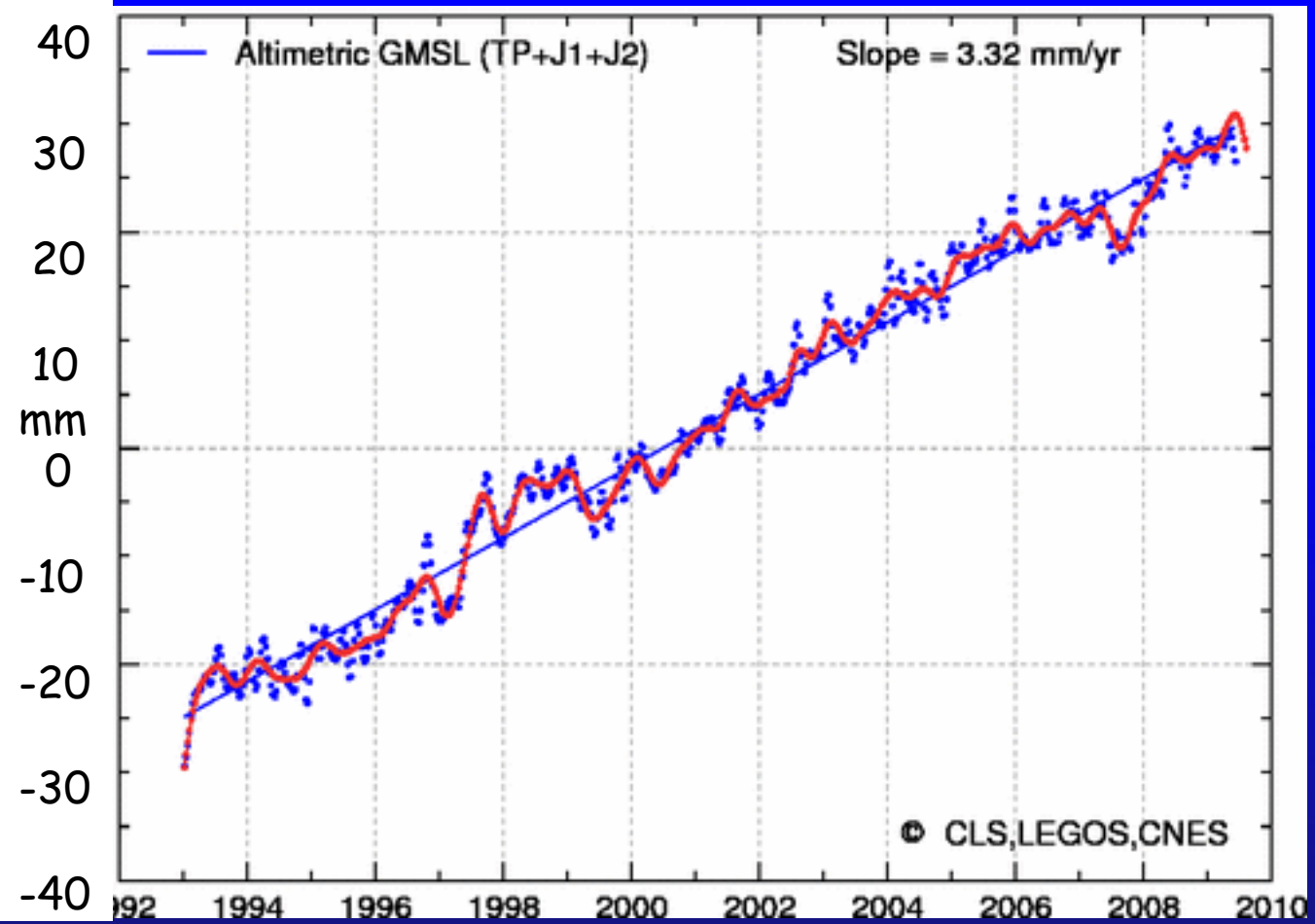
IPCC

Global SSTs are increasing: base period 1901-70



Through 2007
Data: Hadley Centre, UK

Sea level is rising:
from ocean expansion and melting glaciers



Since 1992 Global sea level has risen 55 mm (2.2 inches)

To 2003: 60% from expansion as ocean temperatures rise, 40% from melting glaciers

AVISO: from TOPEX, Jason 1, Jason 2. Ann cy removed, IB, GIA applied

Evidence for reality of climate change

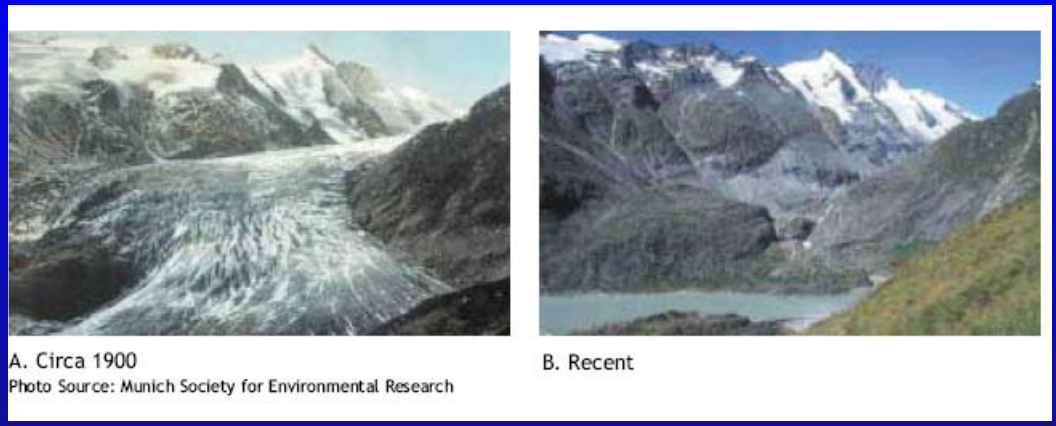
Glaciers melting

Muir Glacier, Alaska

1909

Toboggan Glacier Alaska

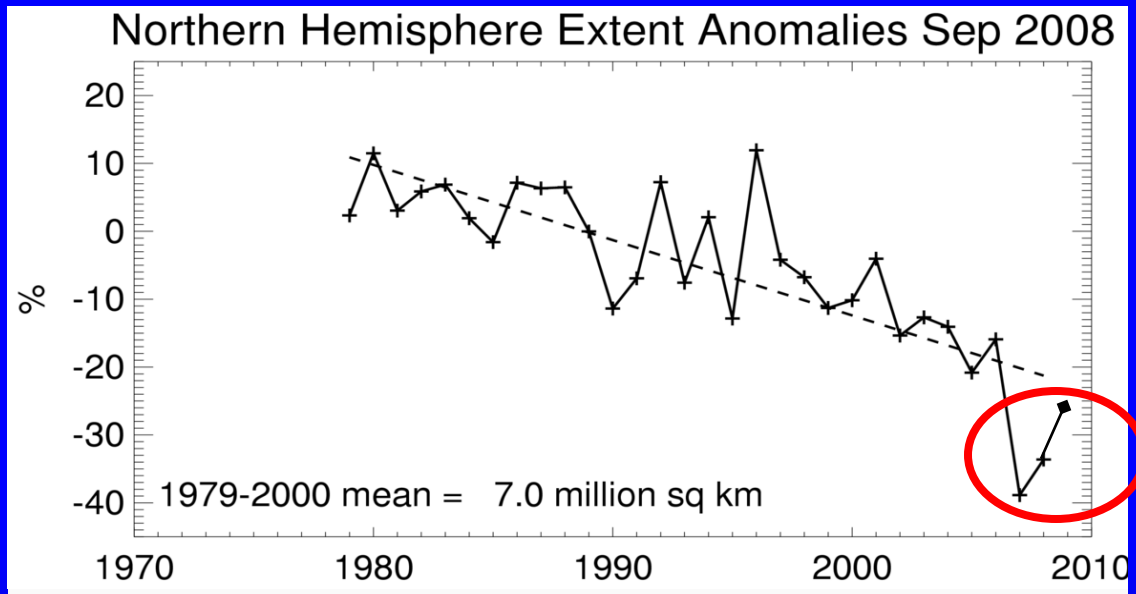
2000

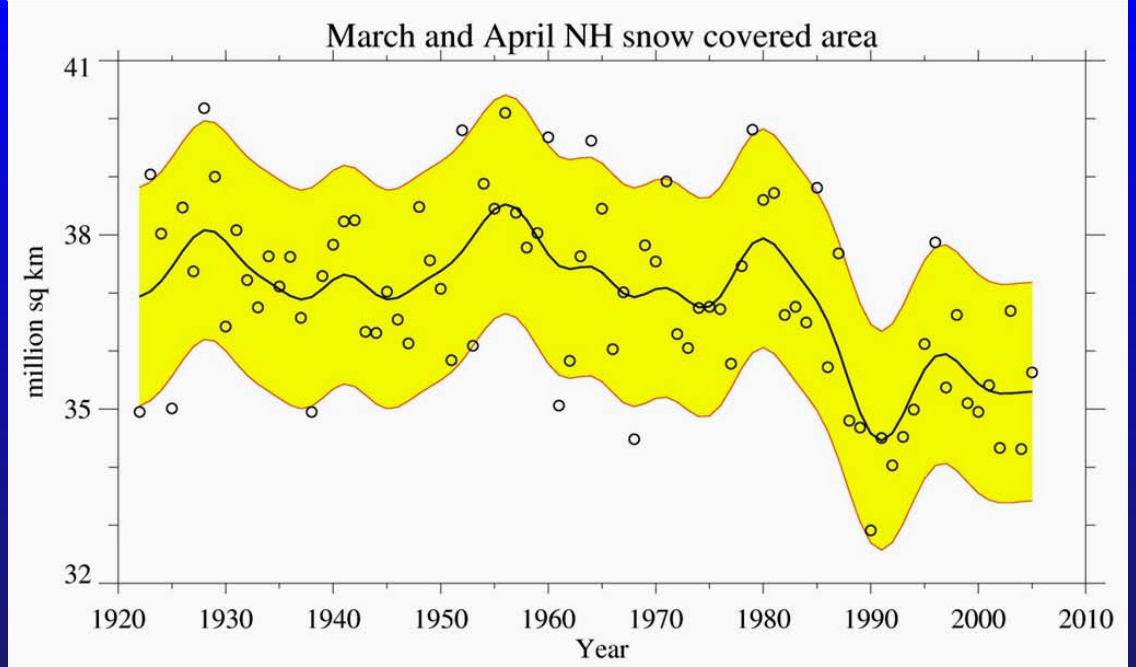


1900 2003

Alpine glacier, Austria

Snow cover and Arctic sea ice are decreasing



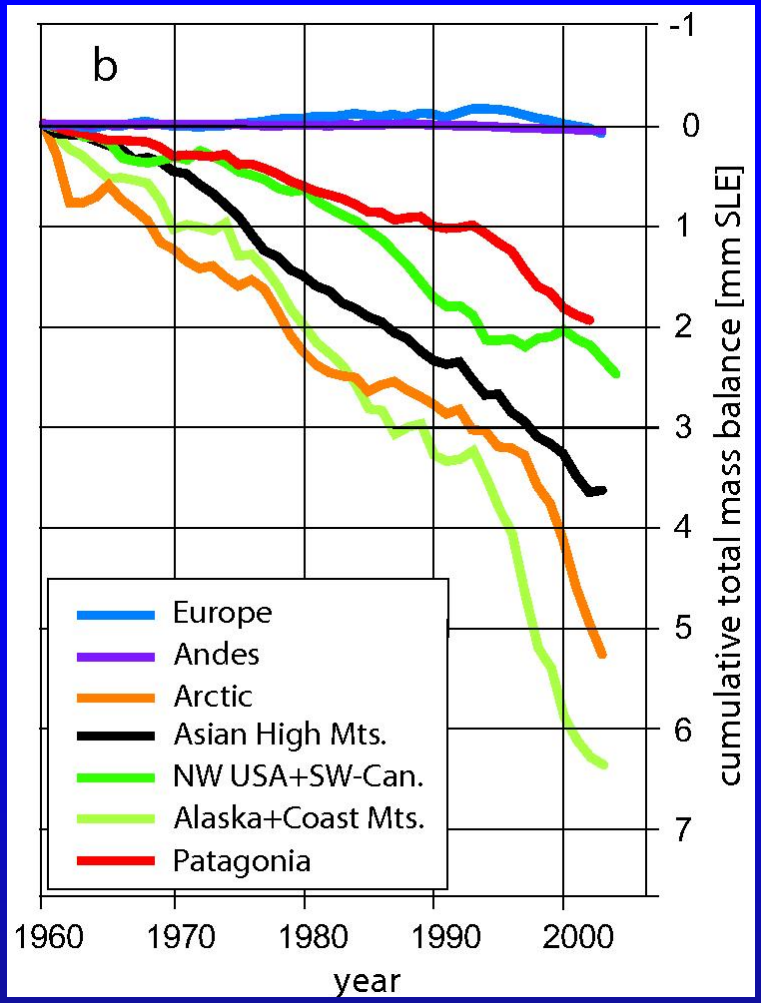


Arctic sea ice area decreased by 2.7% per decade (Summer: -7.4%/decade)
up to 2006:
2007: 22% (10^6 km^2) lower than 2005
2008: second lowest
2009: third lowest

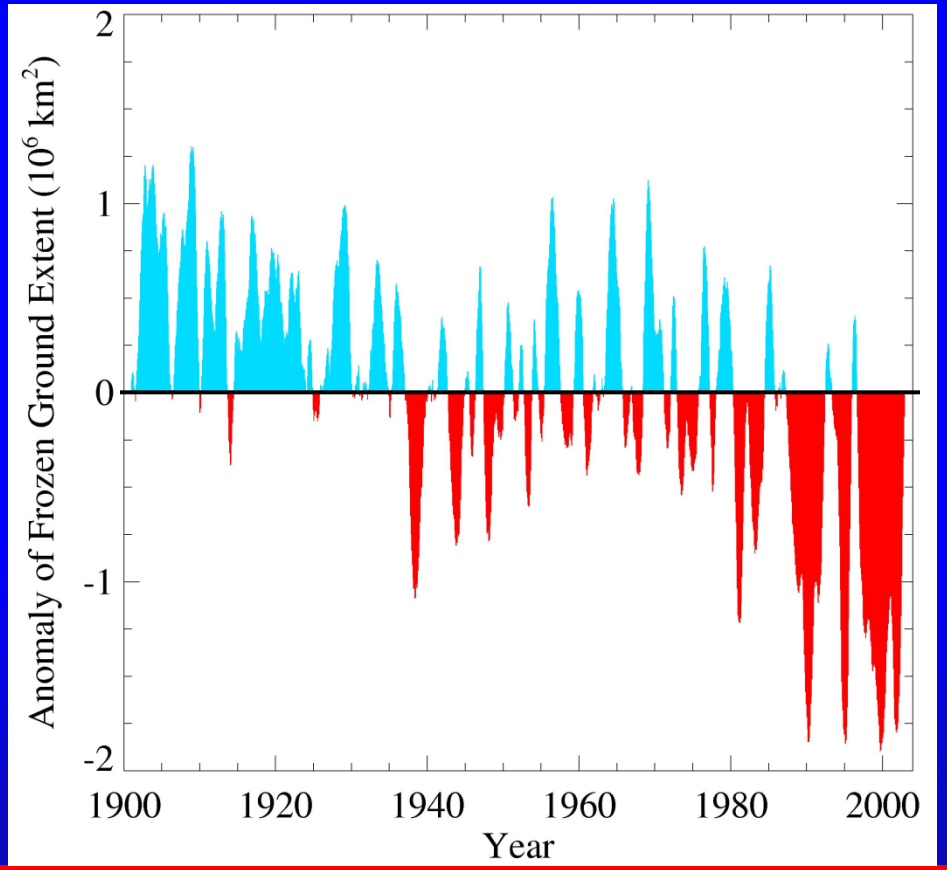
Spring snow cover shows 5% stepwise drop during 1980s

IPCC

Glaciers and frozen ground are receding

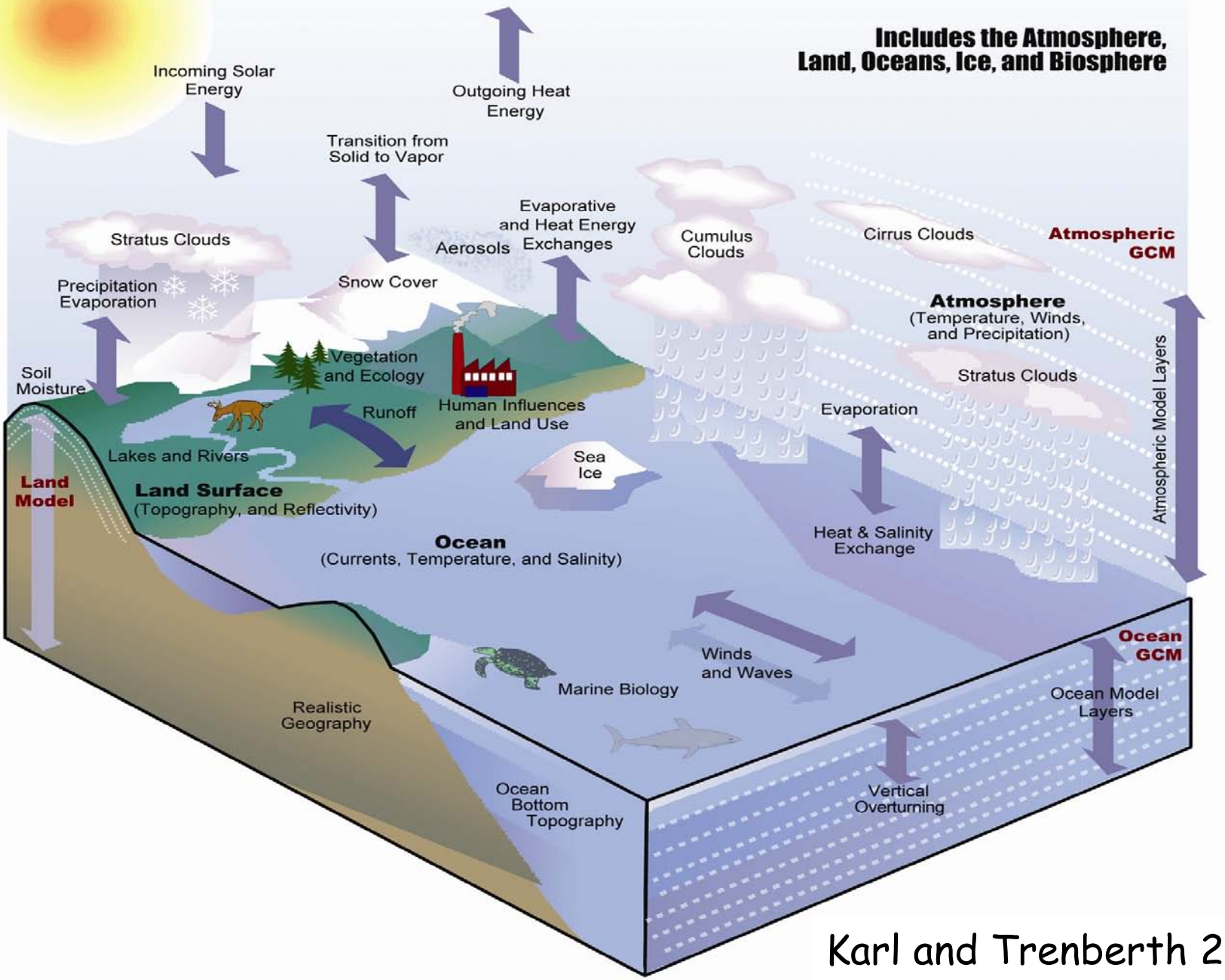


Increased Glacier retreat since the early 1990s



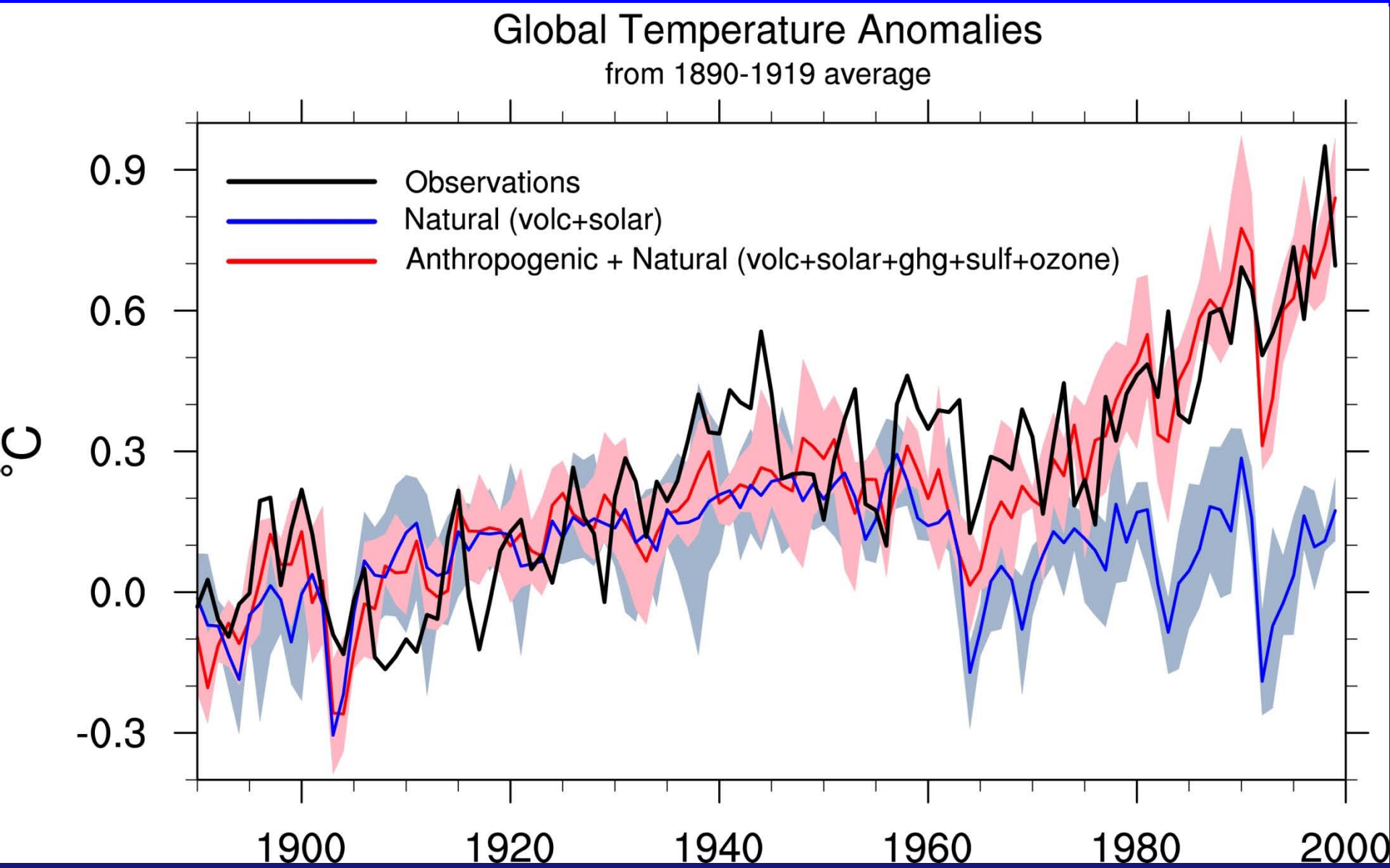
Area of seasonally frozen ground in NH has decreased by 7% from 1901 to 2002

Modeling the Climate System



Karl and Trenberth 2003

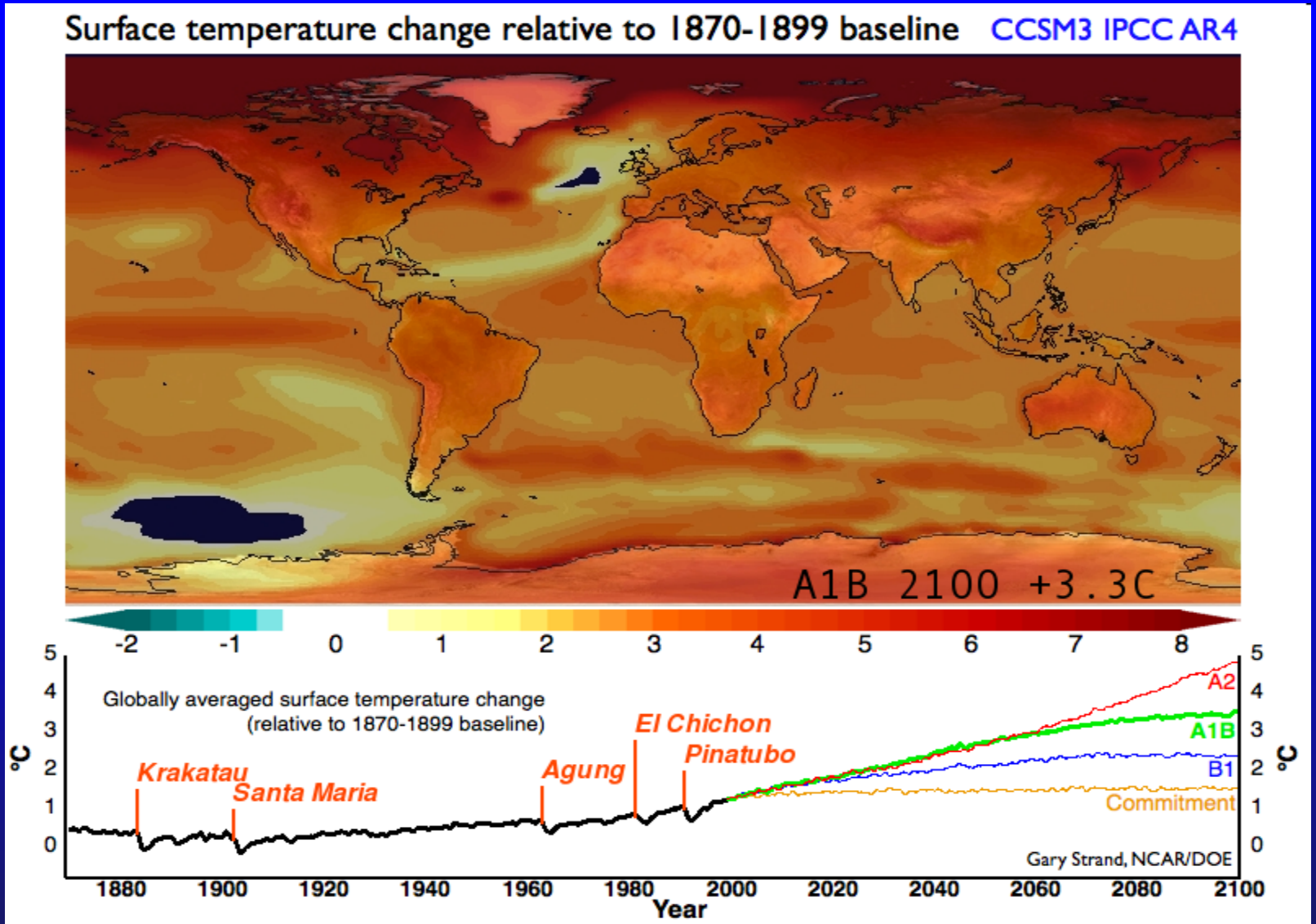
Natural forcings do not account for observed 20th century warming after 1970



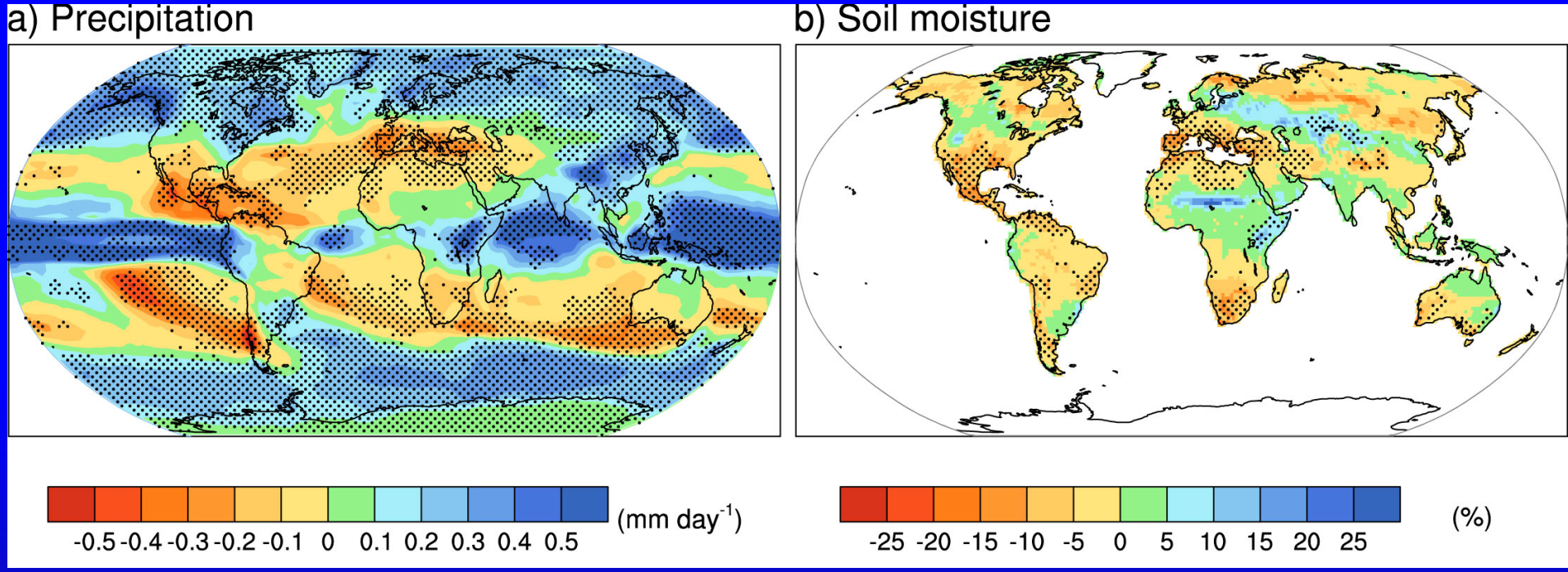
Meehl et al, 2004: J. Climate.

Projected temperature change

CCSM Movie



Projected Patterns of Precipitation Change 2090-2100



Combined effects of increased precipitation intensity and more dry days contribute to mean precipitation changes

Global warming effects from humans are already identifiable

- Rising sea level: coastal storm surges, salt water intrusions, flooding
- Heavier rains, floods: water contamination, water quality
- Drought: water shortages, agriculture, water quality
- Heat-waves: wildfires
- Stronger storms, hurricanes, tornadoes: damage, loss of life, loss of habitat
- Changes in climate: crops, famine, discontent and strife, more insects (range, seasons), fungal and other disease; vector-borne disease.
- Sea ice loss: habitat loss
- Permafrost melting: infrastructure at risk

Multi-dimensional problem

- Environmental
- Economic
- Human strife
- Trade (tariffs)
- Foreign policy
- Security
- Sustainability

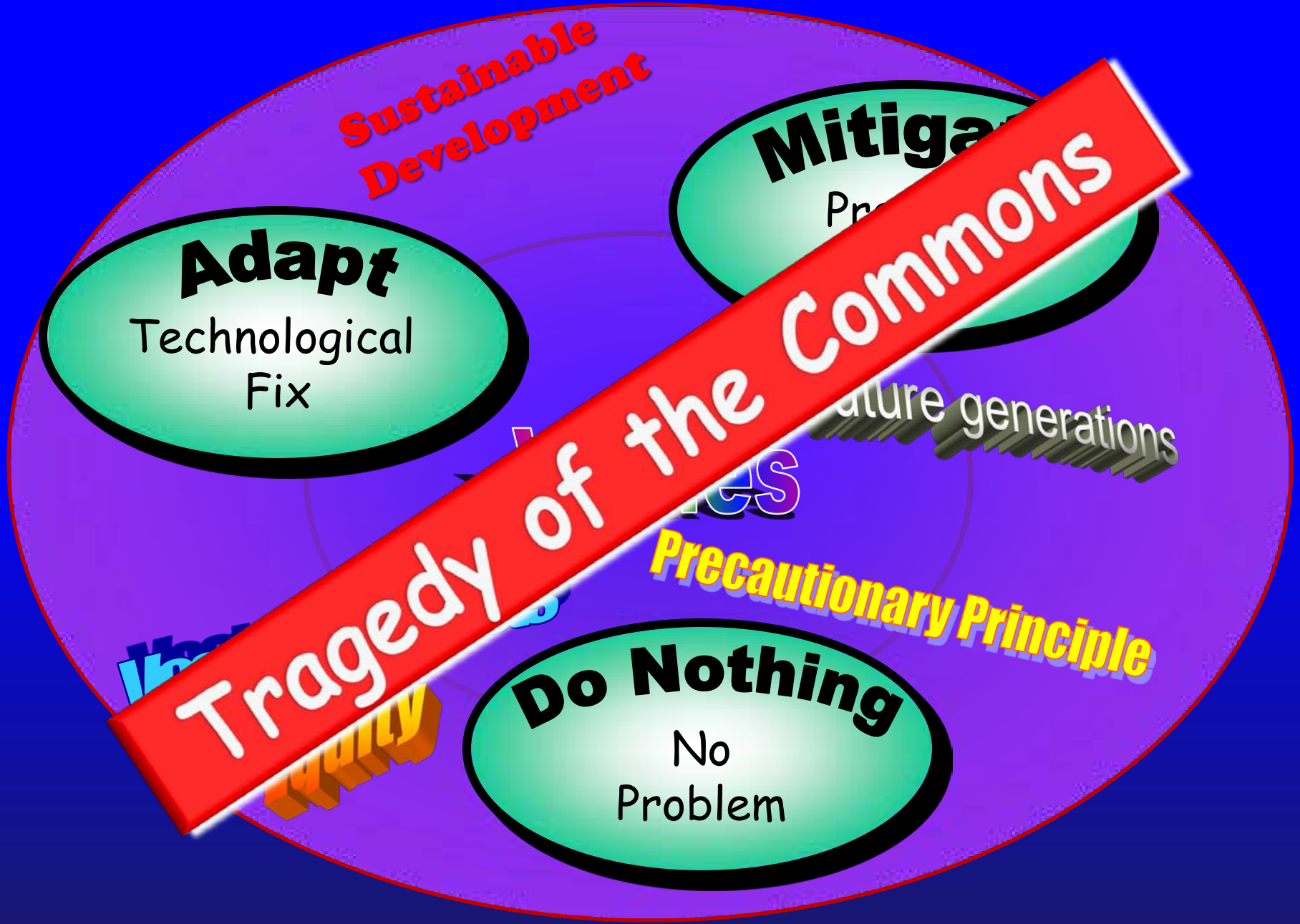
Security and Climate Change

9 Aug 2009

- "We will pay for this one way or another. We will pay to reduce greenhouse gas emissions today, and we'll have to take an economic hit of some kind. Or we will pay the price later in military terms. And that will involve human lives."

GEN. ANTHONY C. ZINNI, former head of the Central Command, on climate change.

Global Warming Actions



What is your carbon footprint?

- You will be affected by climate change (you are already)
- You will be affected by legislation designed to address climate change (whether good or bad)

Many things you can do:

Going Green!

The Challenge:
Sustainable Manag ng Planet

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