

Earth's Climate: Past, Present and Future

Fall Term - OLLI West: week 1, 9/16/2014

**Paul Belanger,
Geologist/Paleoclimatologist**

- **Introductions**
- **Key principles of climate change**
- **The difference between weather and climate**
- **Climate system: feedbacks, cycles and self-regulation (climate, not government)**
- **What determines Earth's climate**

Intro:

- **Intro:**
 - my background,
 - web page
<http://denverclimatestudygroup.com/>
(OLLI tab) and
 - DU portfolio
<http://portfolio.du.edu/earthclimate> ,
 - CV (about tab)
- **Logistics**
- **Stan Hamilton: classroom assistant, liaison to me/OLLI**

Intro:

Going to:

- my word document
- web page:
<http://denverclimatestudygroup.com/>
- DU portfolio:
<http://portfolio.du.edu/earthclimate>

Three books to consider:

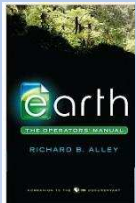
- Simple succinct Summary:

- [What We Know About Climate Change \(Boston Review Books\)](#) by Kerry Emanuel (Nov 30, 2012)



- Intermediate Level Book:

- [Earth: The Operators' Manual](#) by [Richard B. Alley](#) (Apr 18, 2011)



–

<http://earththeoperatorsmanual.com/>

- More comprehensive book:

[Experimenting on a Small Planet: A Scholarly Entertainment](#) by [William W. Hay](#) (Dec 14, 2011)



GREENHOUSE

- Visible vs. Infrared/longer wave – a function of “black body” temperature: instead of glass keeping the heat in it’s the gas properties keeping the heat of infrared in; blanket effect.

GREENHOUSE GASES

- Water – H_2O – the amount is a feedback of temperature held in by the “blanket” of other GHGs
- Carbon dioxide - CO_2
- Methane - CH_4
- Ozone - O_3
- Nitrous oxide- N_2O
- others

Blanket Earth

- **Blanket Earth:**
- <http://climate.nasa.gov/causes/>

VIDEO - what is climate

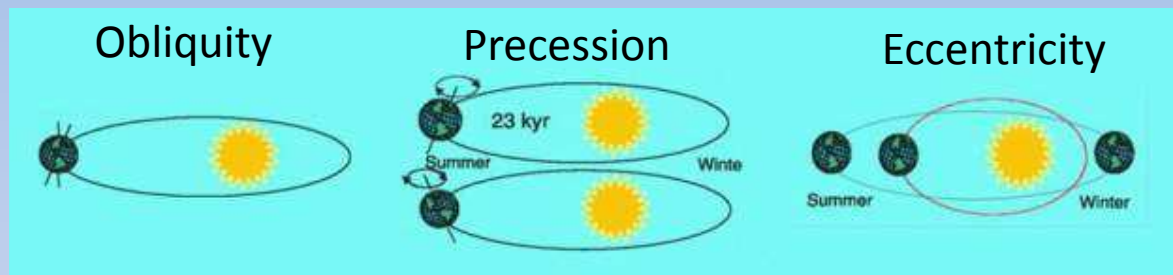
- <https://www.futurelearn.com/courses/climate-change-challenges-and-solutions/todo/123>
- And go to 1.4

What determines Earth's climate

INTRODUCTION: Definitions:

•First order Forcings: EXTERNAL Influences (3):

SOLAR input:



Atmospheric Opacity

(gases that absorb radiation in or out)

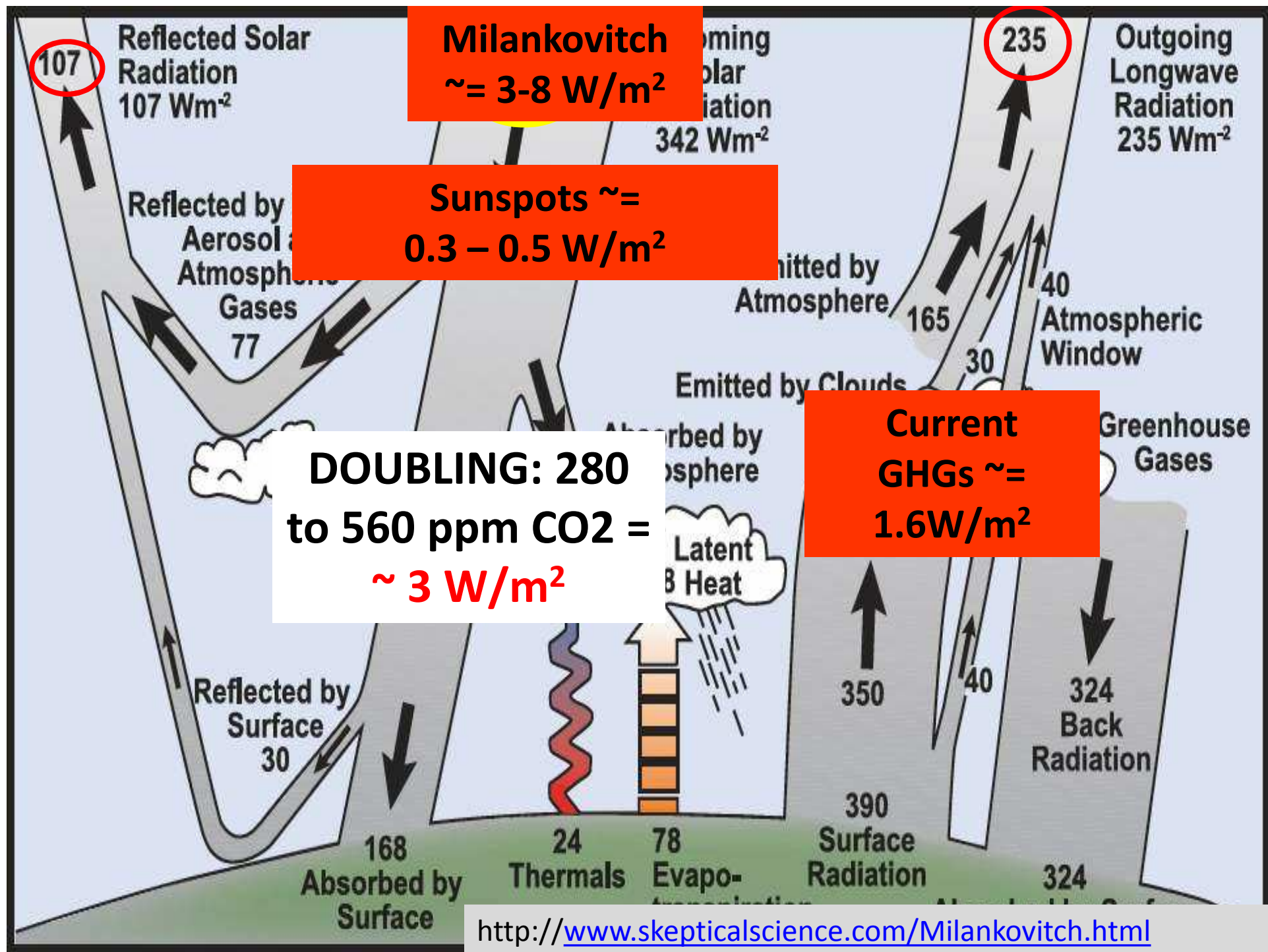


Albedo (30-85%)

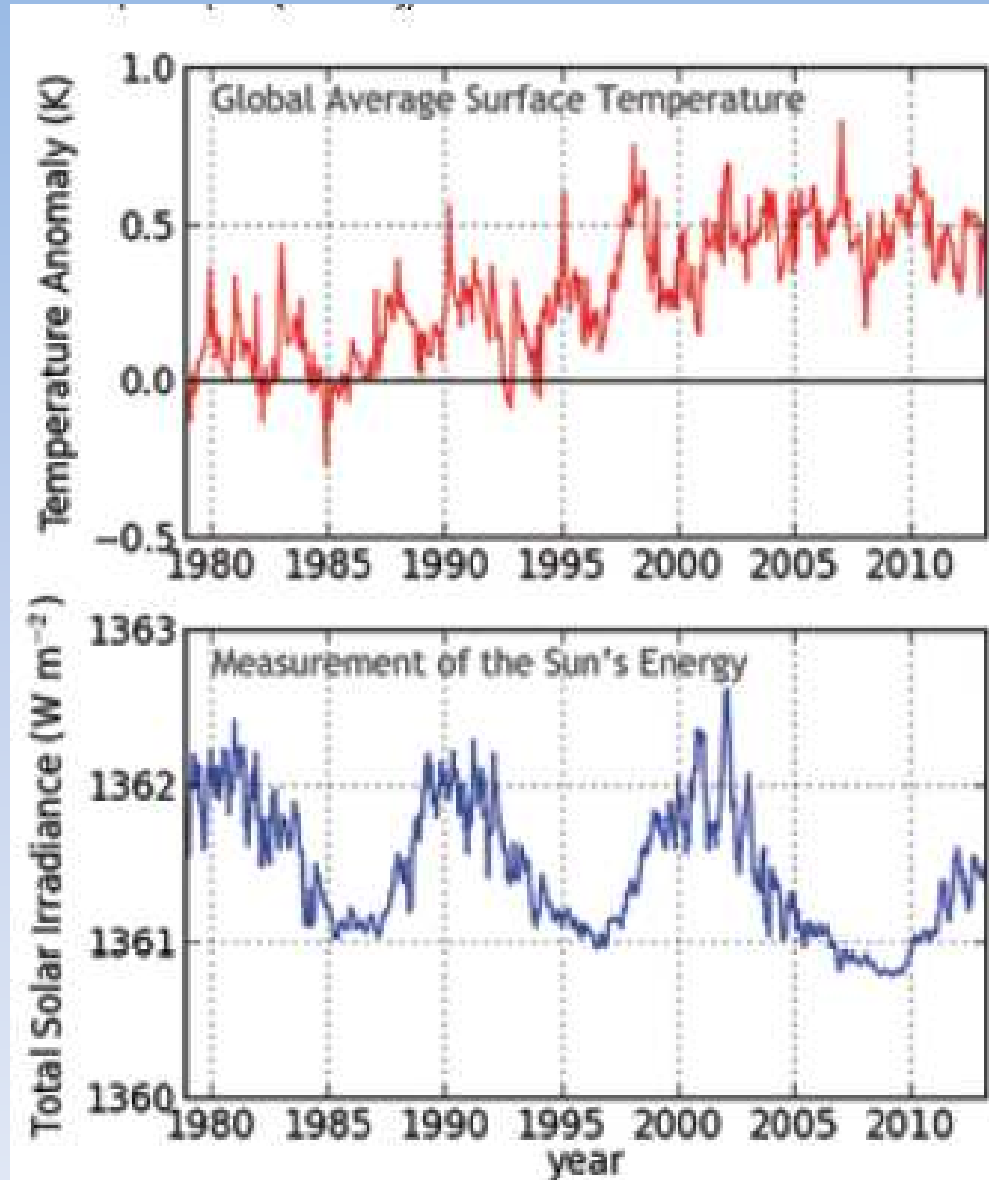


•Feedbacks: INTERNAL dynamics and responses

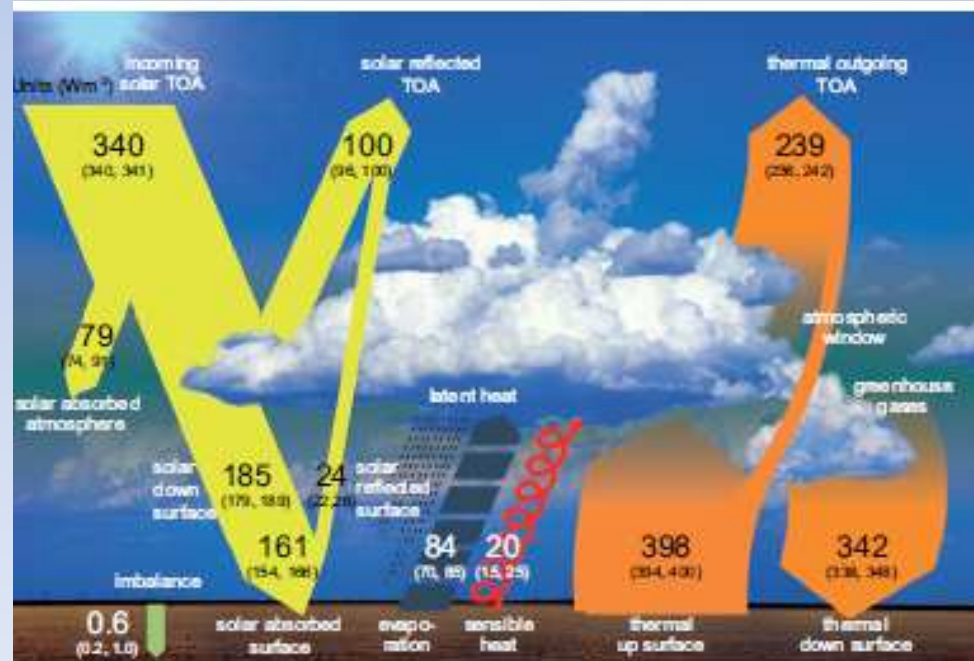
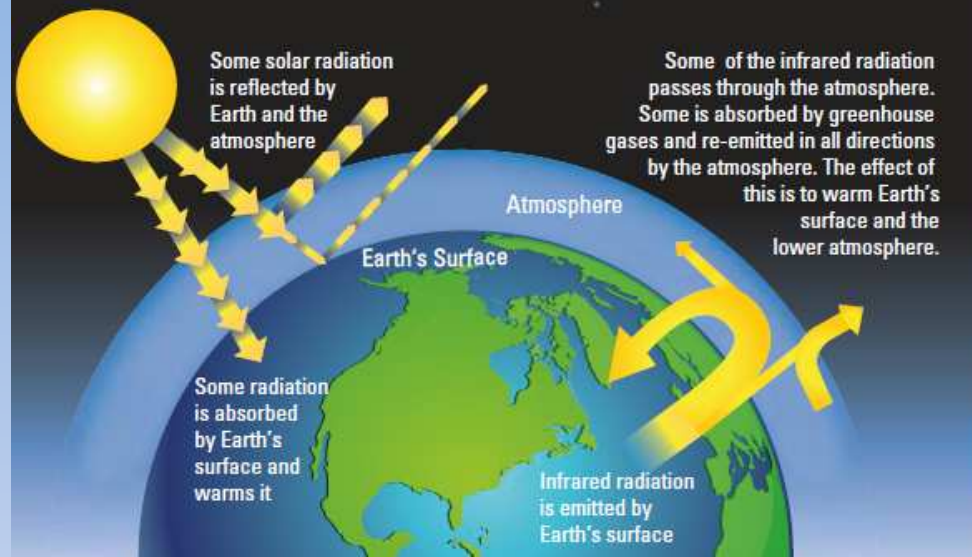
- e.g. higher water vapor in atm. due to heating of atm



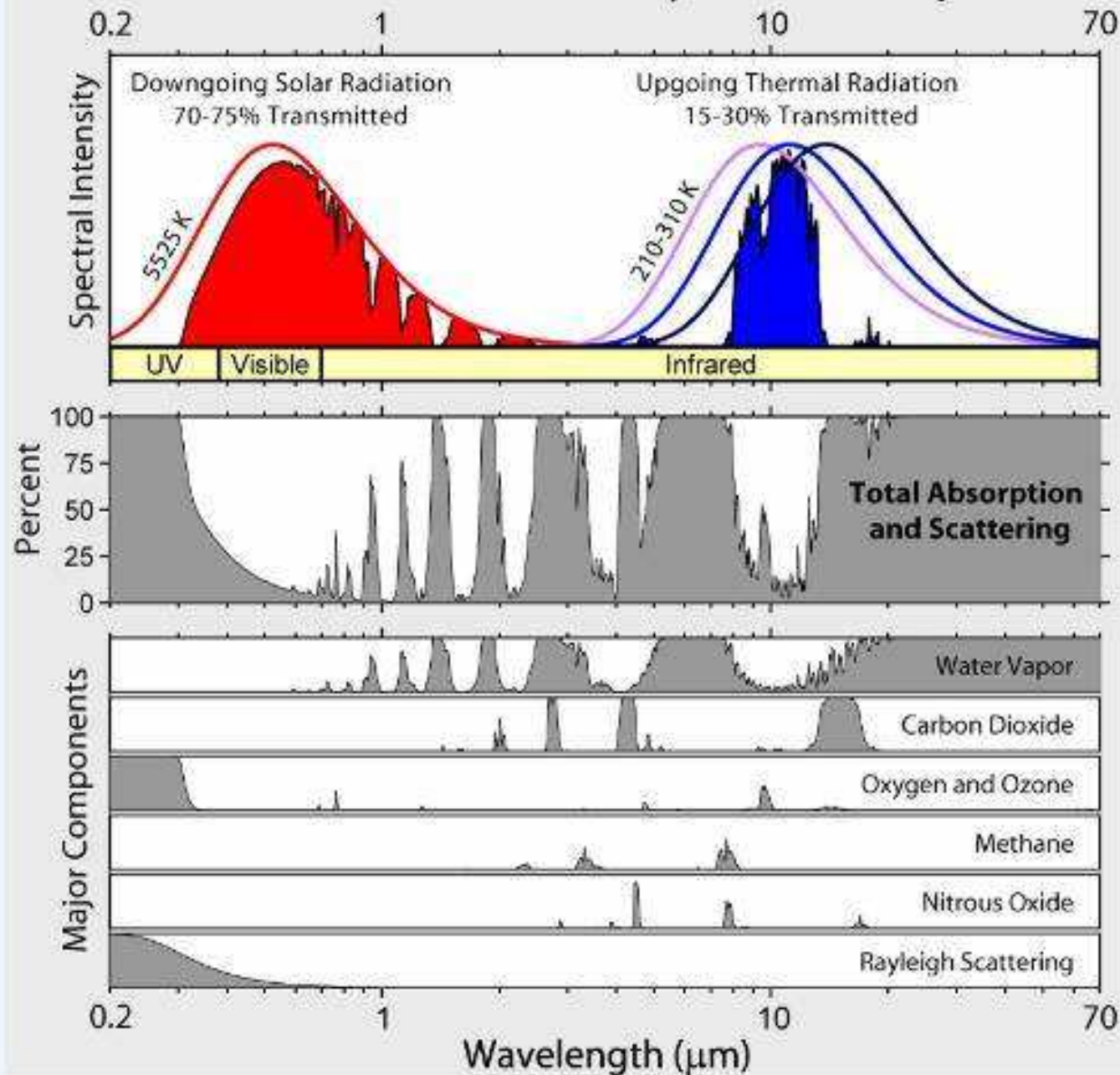
4: THE SUN'S ROLE IS MINIMIZING



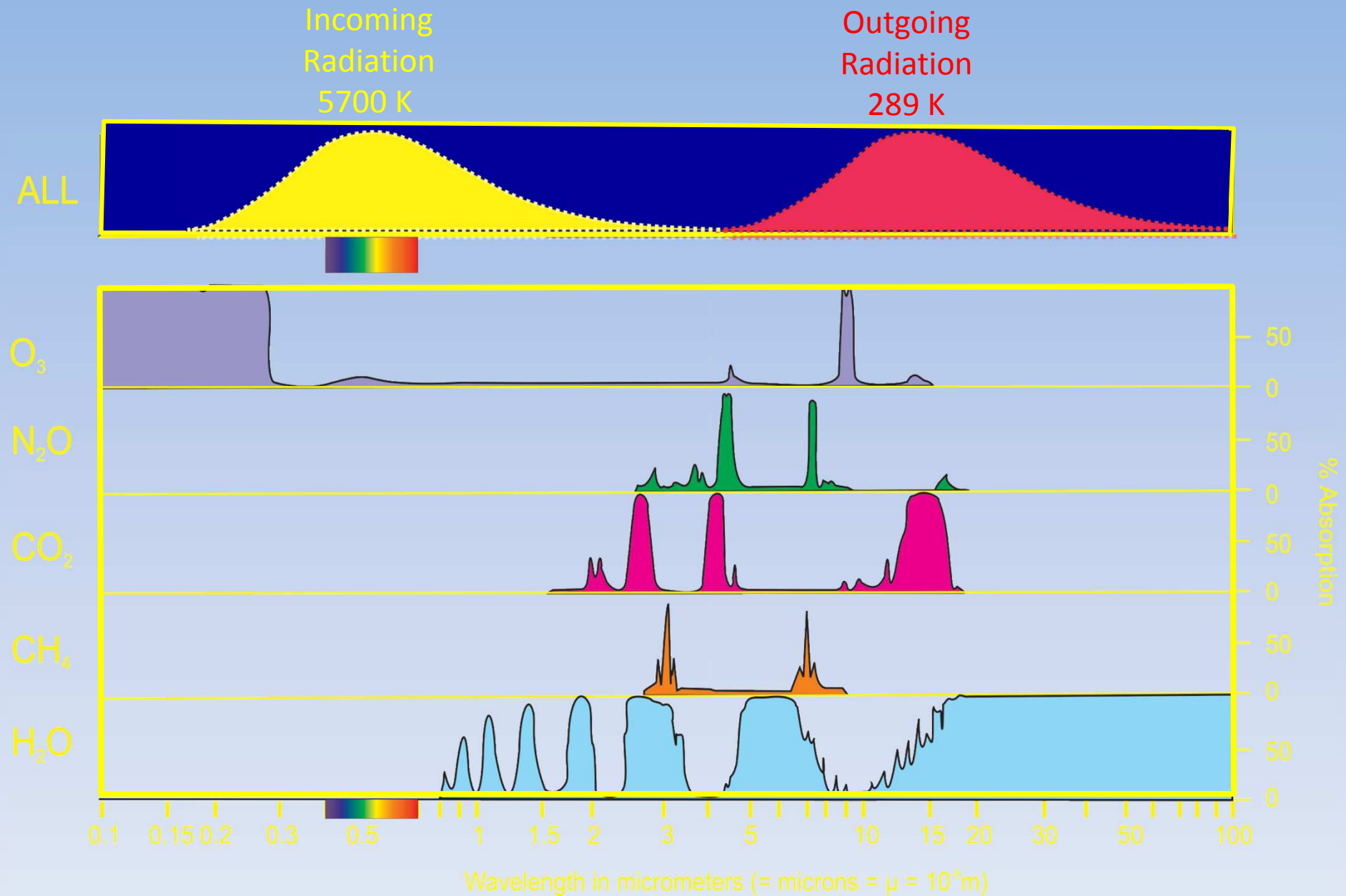
THE GREENHOUSE EFFECT



Radiation Transmitted by the Atmosphere

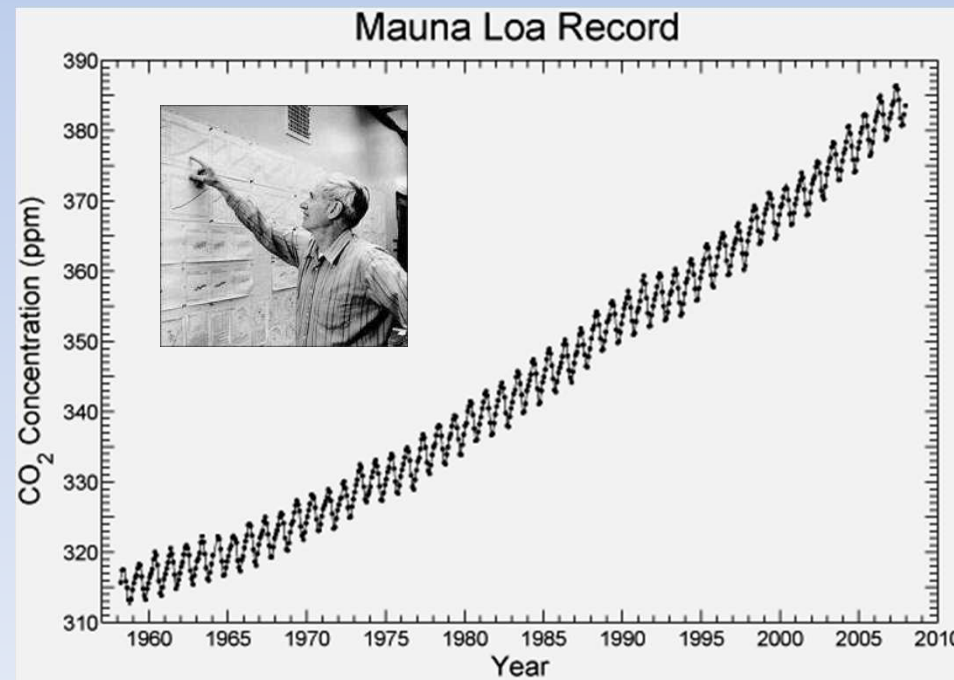


Absorption of Radiation by Greenhouse Gases



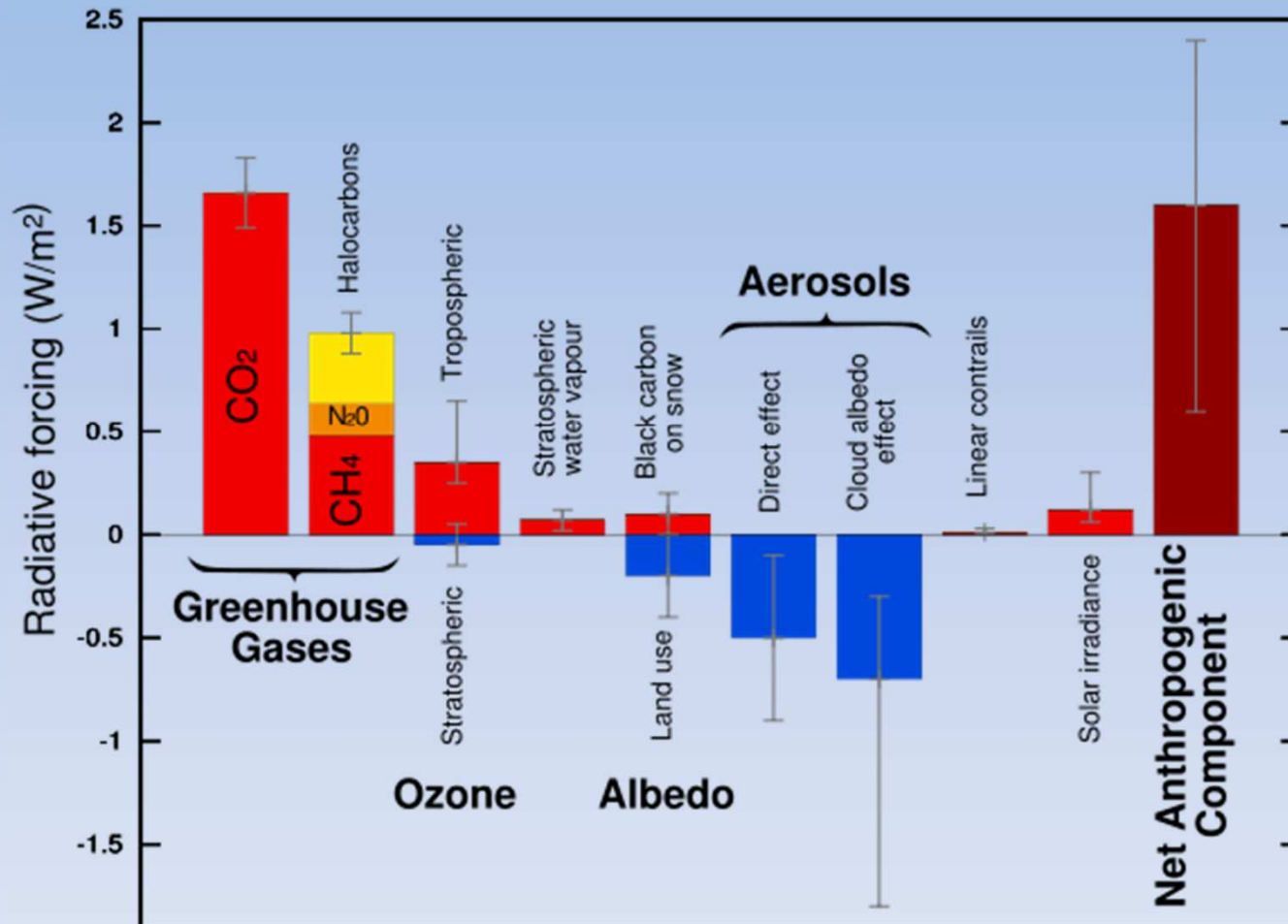
3: EMISSIONS FROM HUMAN ACTIVITIES LARGELY TO BLAME

- 40% increase in CO₂
- Dead carbon altering atmospheric C¹⁴
- That Carbon is more negative/enriched in C¹²



GLOBAL WARMING CONCERNS

Radiative Forcing Components

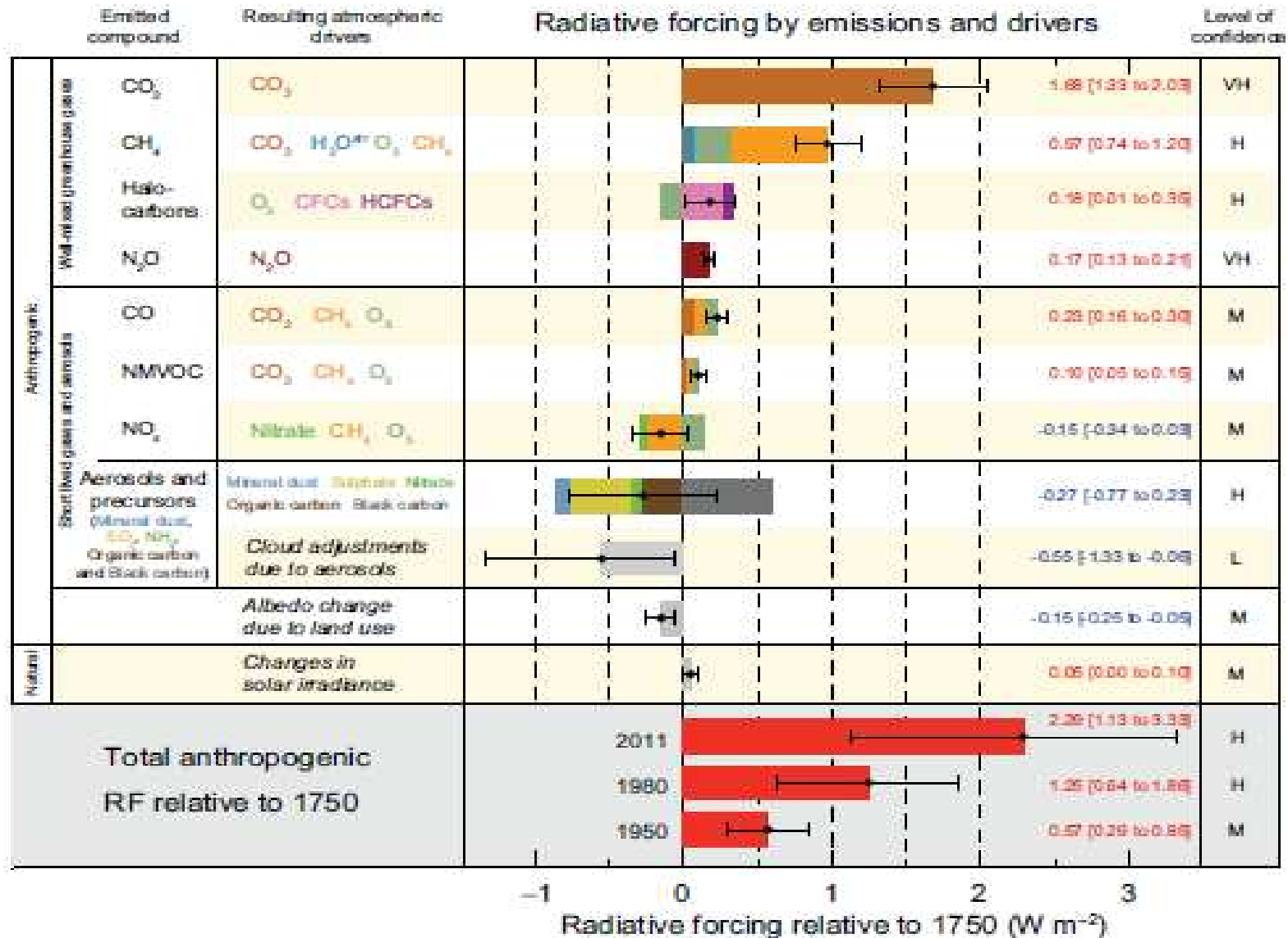


Incoming Solar irradiance: 342 W/m^2

IPCC, 2007

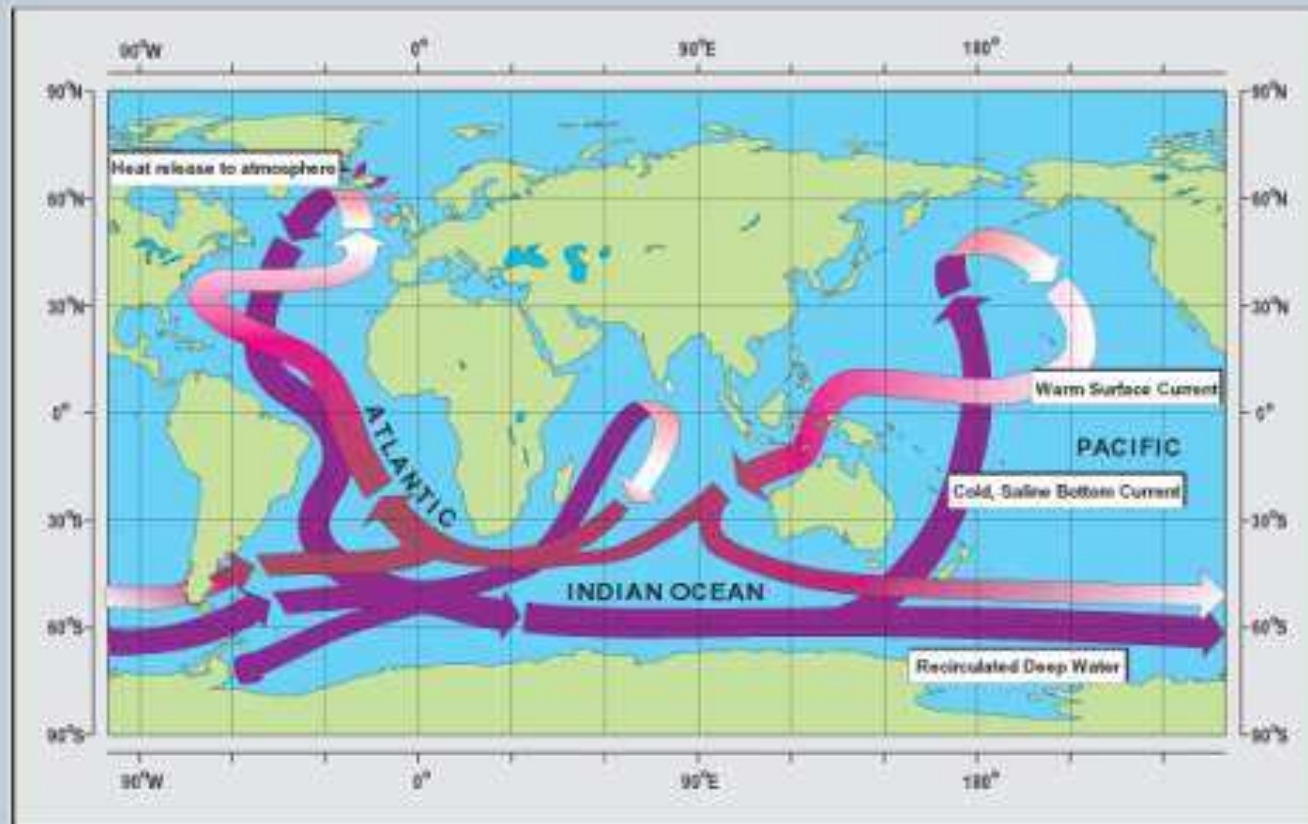
1: THE CLIMATE IS WARMING

- Drivers; aka forcings, i.e. causes



The Atlantic Thermohaline Circulation

- A key Element of the Global Oceanic Circulation -



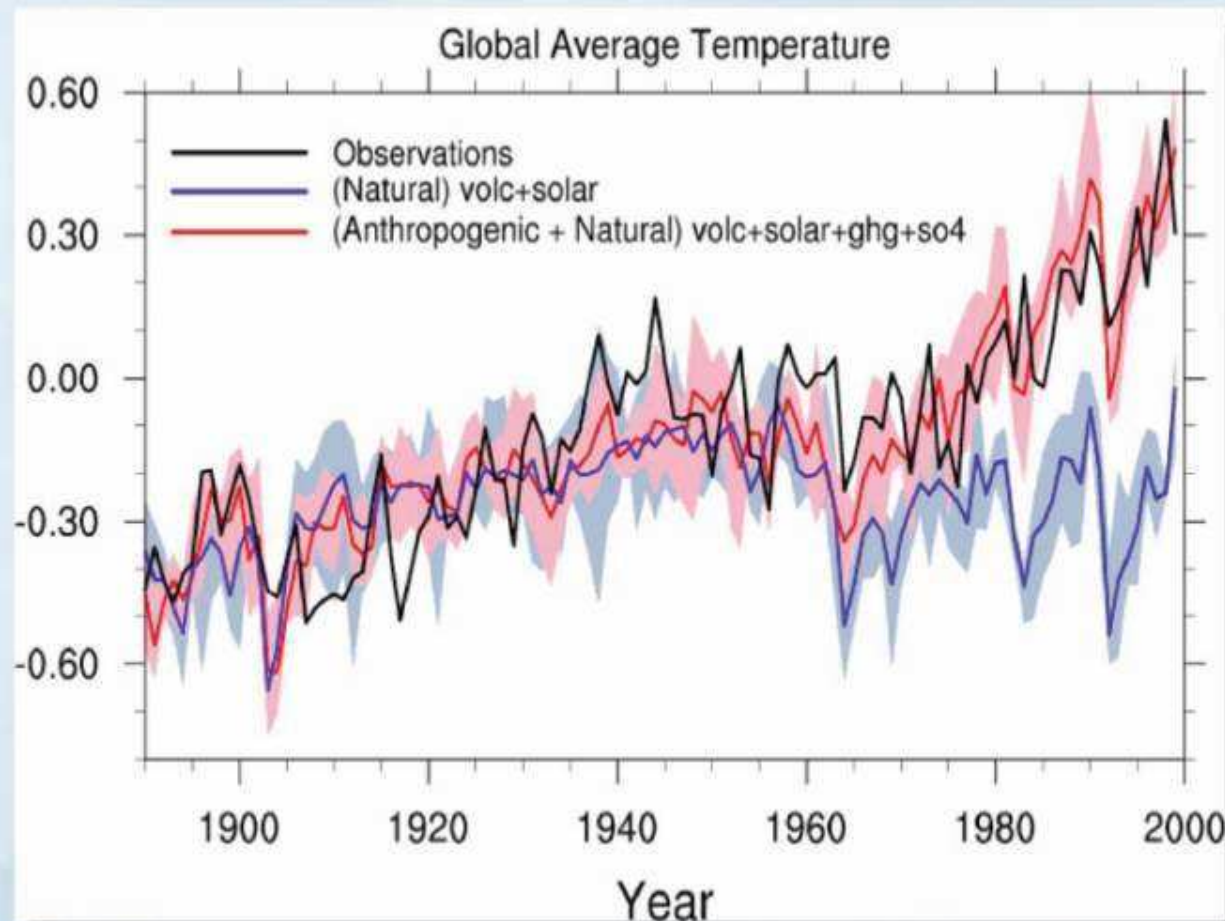
Schematic diagram of the global ocean circulation pathways, the 'conveyor' belt (after W. Broecker, modified by E. Maier-Reimer).

AV/D3/99-2

Simulations of the 20th century: Time



NCAR



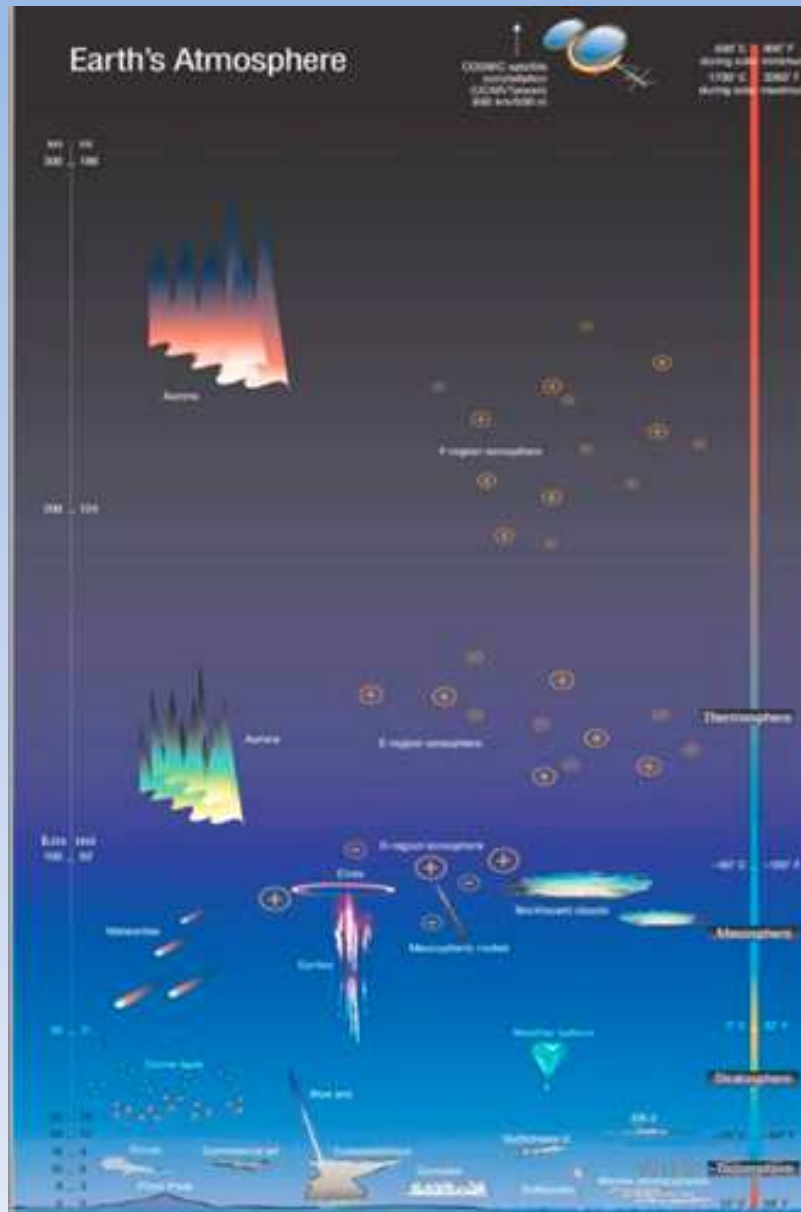
All
forcings

Natural
only

Meehl et al. 2004

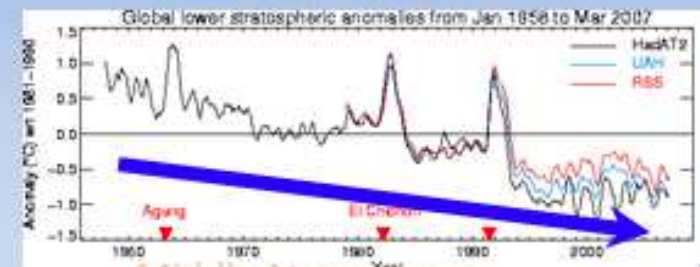


5: SURFACE TO STRATOSPHERE CHANGES

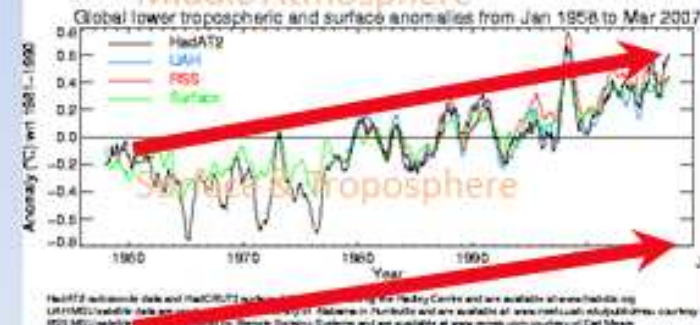


Greenhouse Fingerprint

Middle Atmosphere



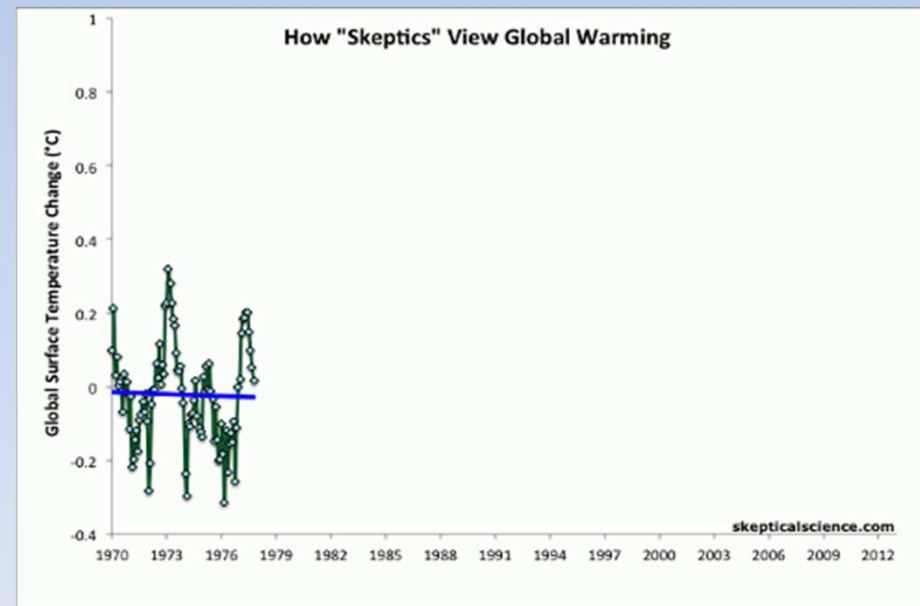
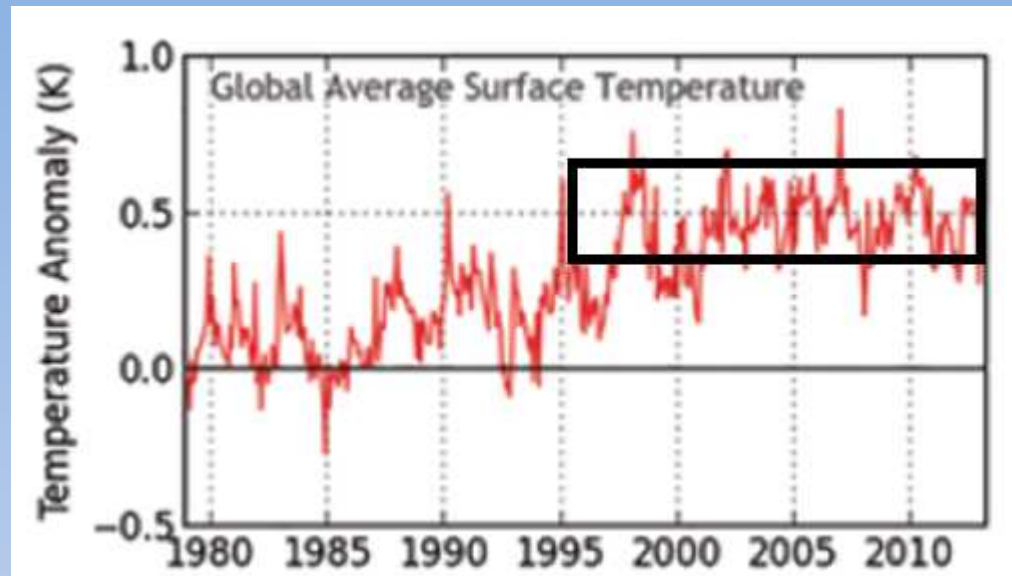
Middle Atmosphere



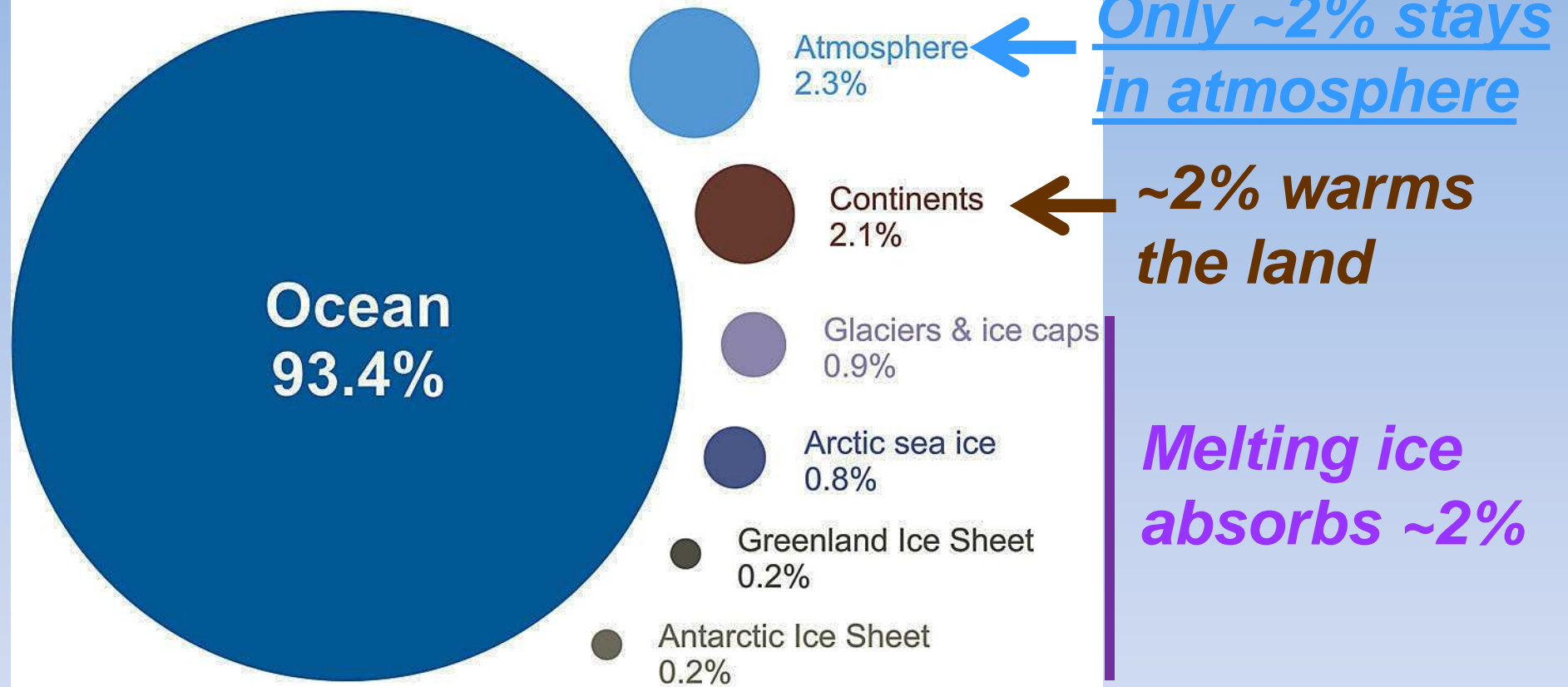
Subsurface (Land/Ocean)

Earth's Climate System

January 14, 08

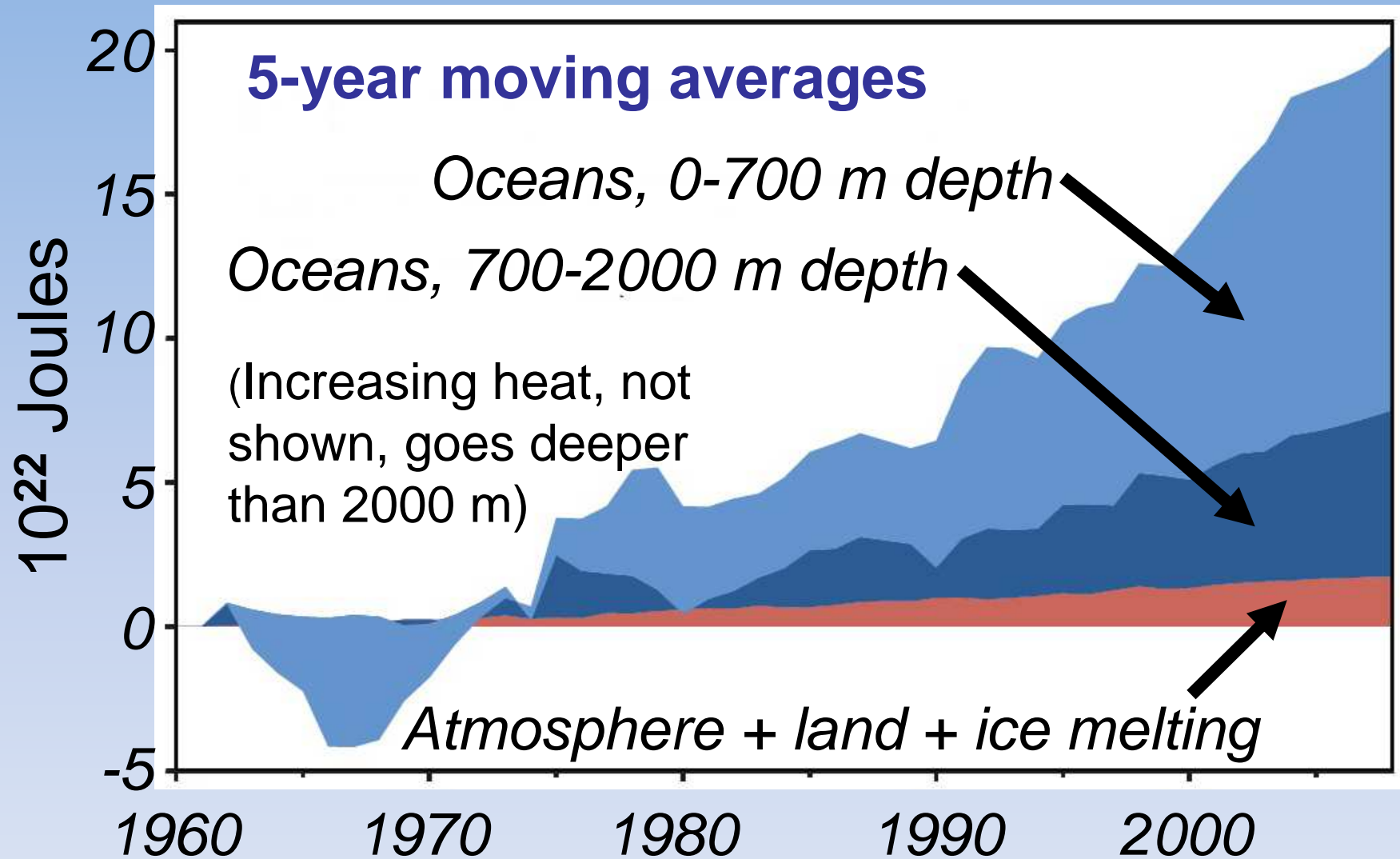


Where is global warming going?

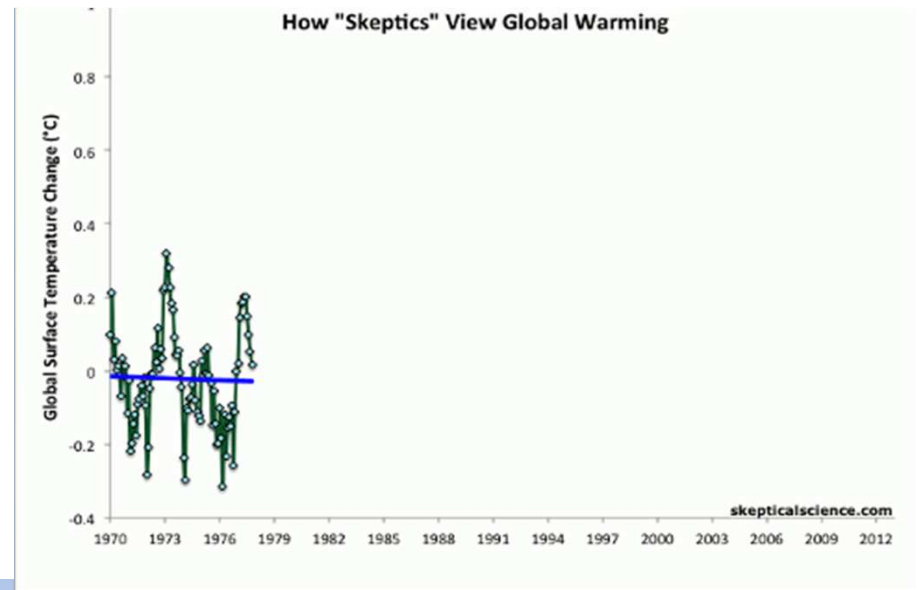
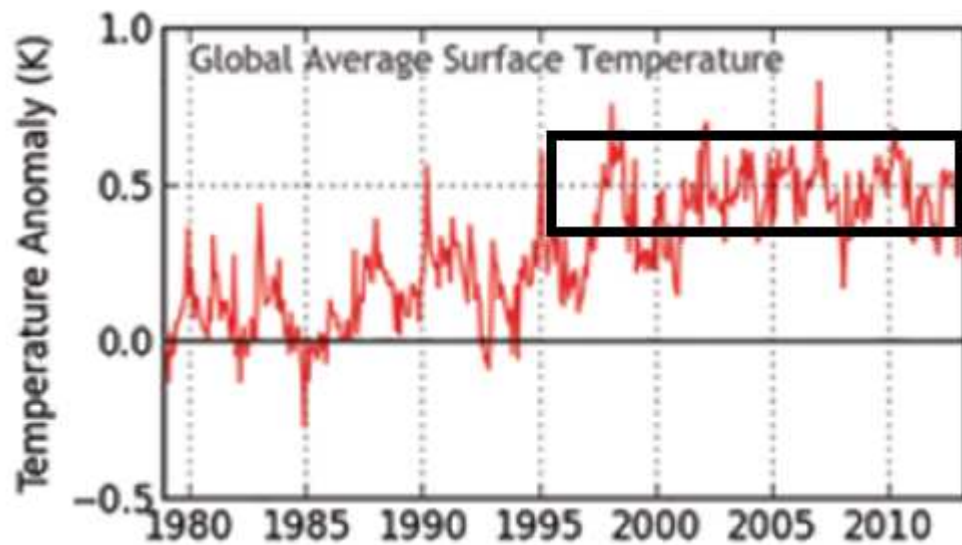


John Cook, from IGPP 2007 data; ~93% to oceans continues (NOAA/NODC, 2012)

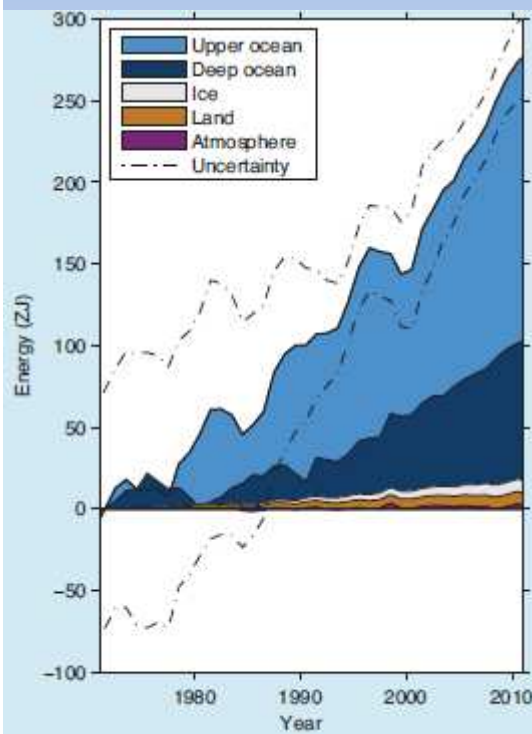
Change in heat content, 1958-2011



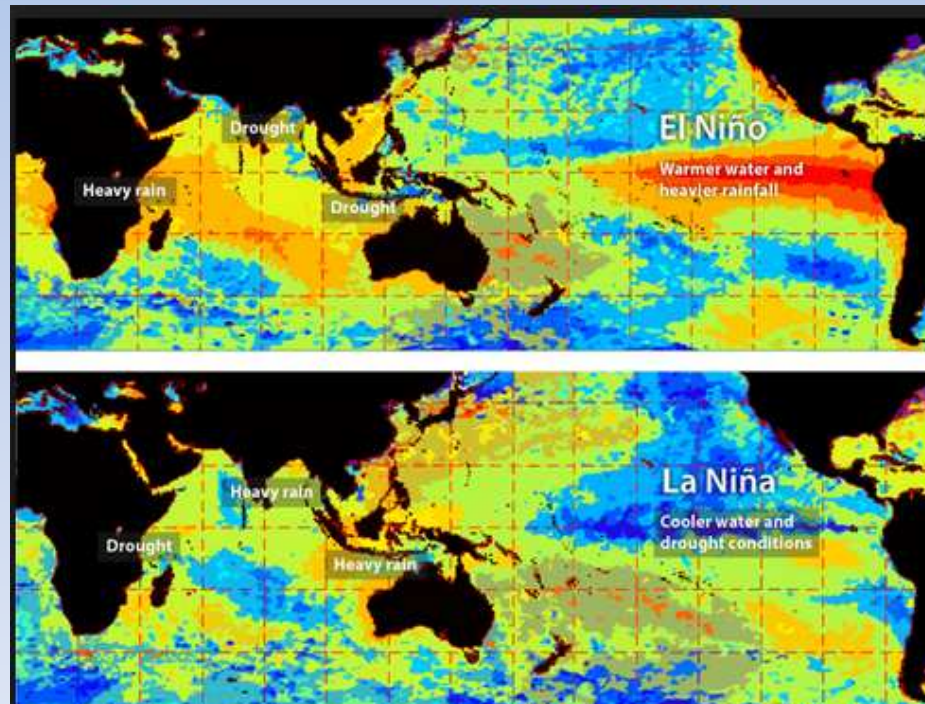
(NOAA 2012 data, Nuccitelli et al. 2012 plot)



<http://www.skepticalscience.com/graphics.php?g=47>



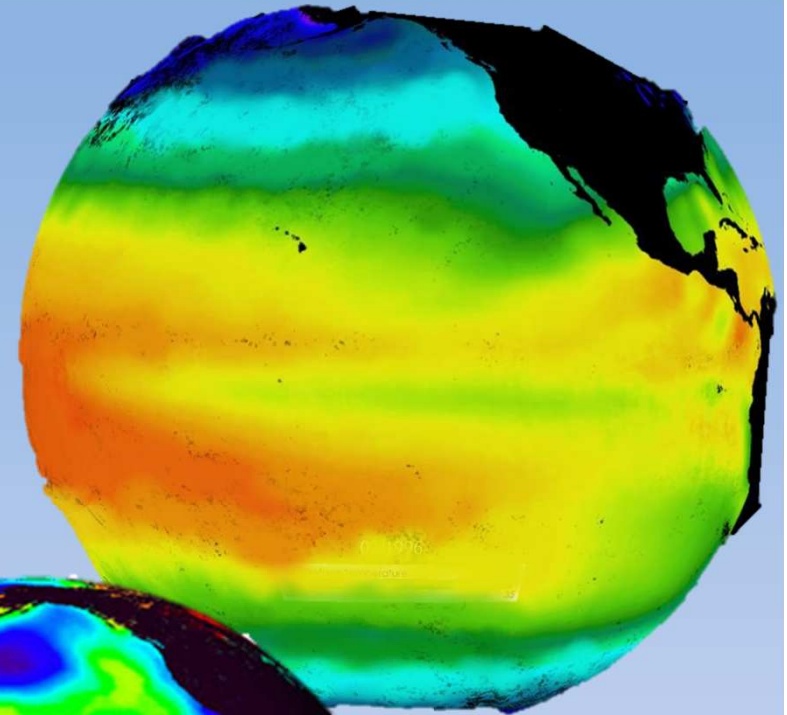
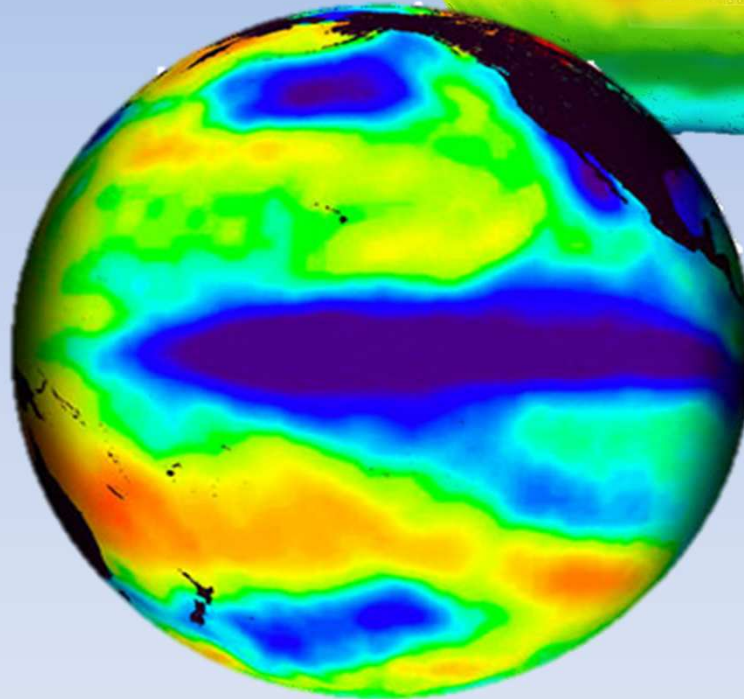
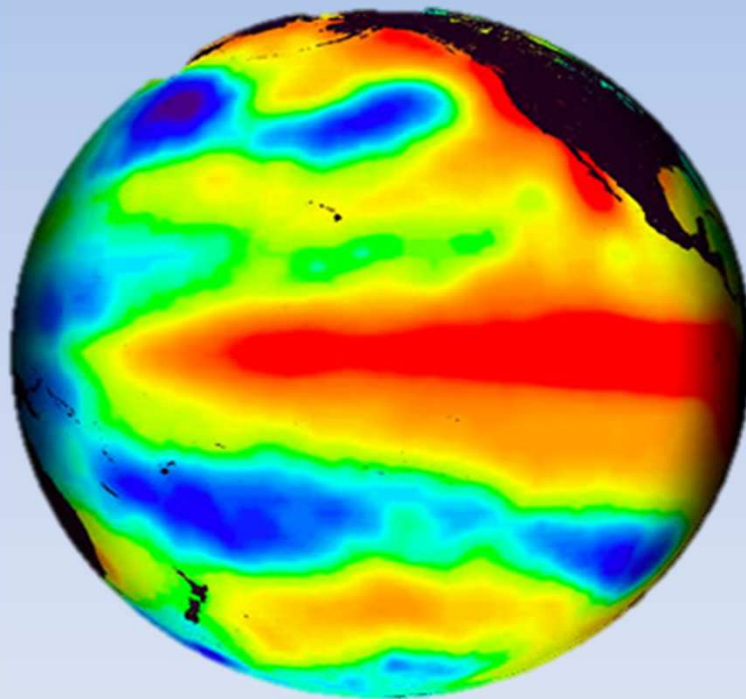
Box 3.1, Figure 1 | Plot of energy accumulation in ZJ ($1 \text{ ZJ} = 10^{21} \text{ J}$) with



The Pacific –
'normal condition'

El Niño

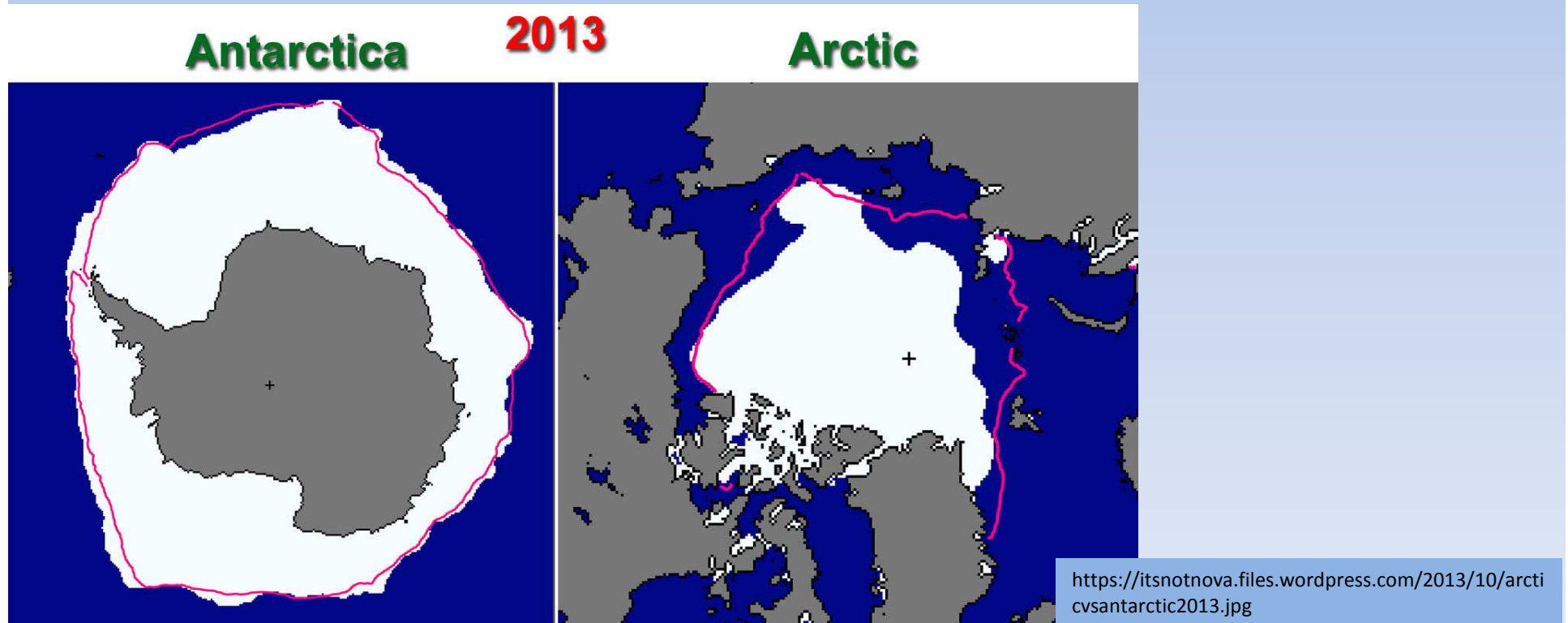
La Niña



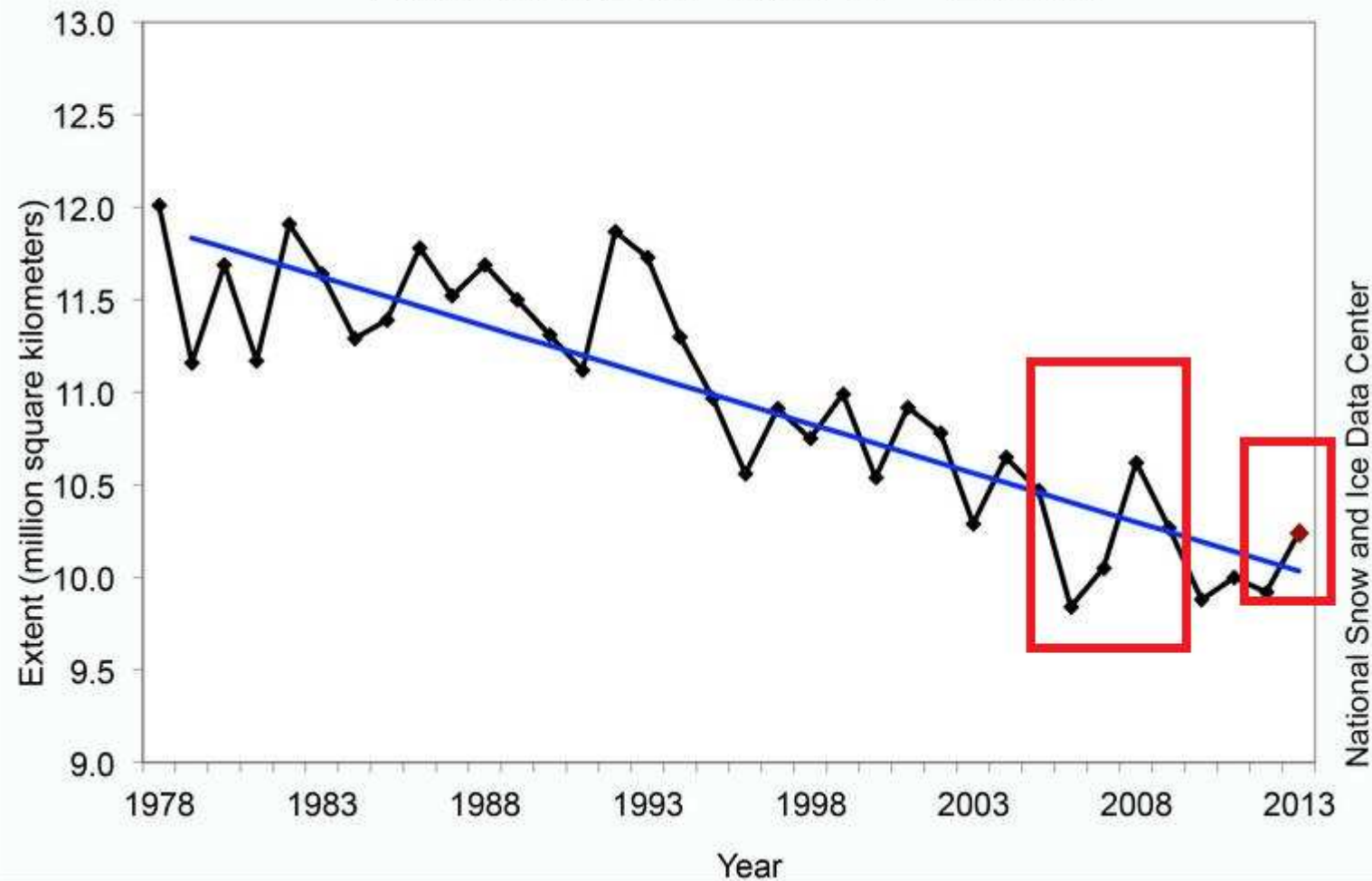
Temperature
Anomaly °C

12. ARCTIC ICE vs. ANTARCTIC SEA ICE

- Ans. More moisture in air around Antarctica (AA) to nucleate sea ice
- Despite $>$ AA is does not compensate for Arctic loss

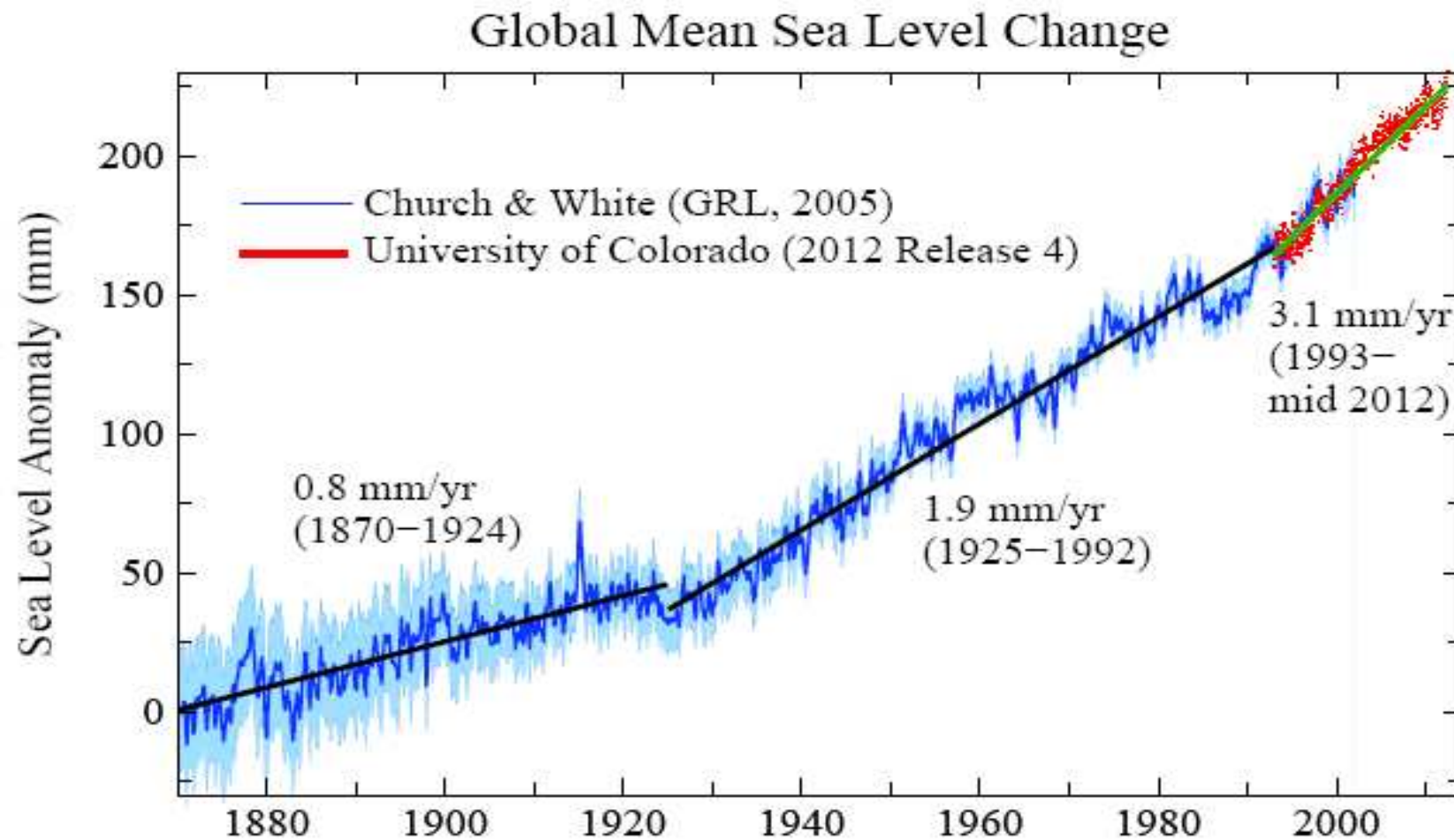


Average Monthly Arctic Sea Ice Extent November 1978 - 2013



For more see: <http://www.skepticalscience.com/melting-ice-global-warming.htm>

14: HOW FAST IS SEA LEVEL RISING?



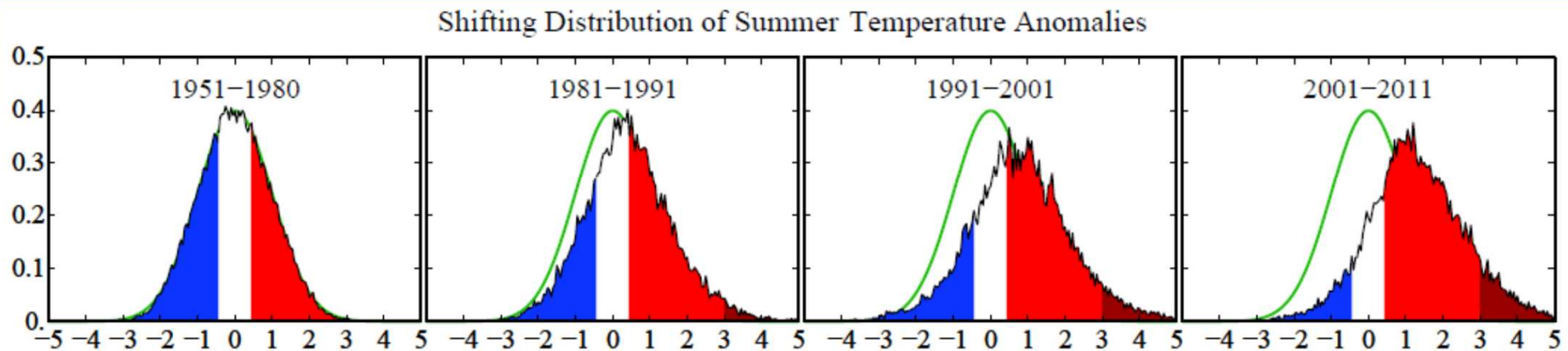
Blue: Sea level change from tide-gauge data (*Church J.A. and White N.J., Geophys. Res. Lett. 2006; 33: L01602*)

Red: Univ. Colorado sea level analyses in satellite era (<http://www.columbia.edu/~mhs119/SeaLevel/>).

Loaded Climate Dice: global warming is increasing extreme weather events.

Extreme summer heat anomalies now cover about 10% of land area, up from 0.2%.

This is based on observations, not models.



Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies (relative to 1951-1980 mean) for Northern Hemisphere land in units of local standard deviation (horizontal axis). Temperature anomalies in the period 1951-1980 match closely the normal distribution ("bell curve", shown in green), which is used to define cold (blue), typical (white) and hot (red) seasons, each with probability 33.3%. The distribution of anomalies has shifted to the right as a consequence of the global warming of the past three decades such that cool summers now cover only half of one side of a six-sided die, white covers one side, red covers four sides, and an extremely hot (red-brown) anomaly covers half of one side.

Source: Hansen, J., Sato, M., and Ruedy, R., Proc. Natl. Acad. Sci., 2012.

End of week 1