Earth's Climate: Past, Present and Future – concerns and solutions

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Geologist/Paleoclimatologist

week 1: 3/30/2016

- 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**:
  - Yourselves – what brought you here
  - my background, ramblings
  - web page http://denverclimatestudygroup.com/ (OLLI tab) and Facebook
  - CV (about tab)
- **Logistics**
- **Paula Morgan: classroom assistant, liaison to me/OLLI**

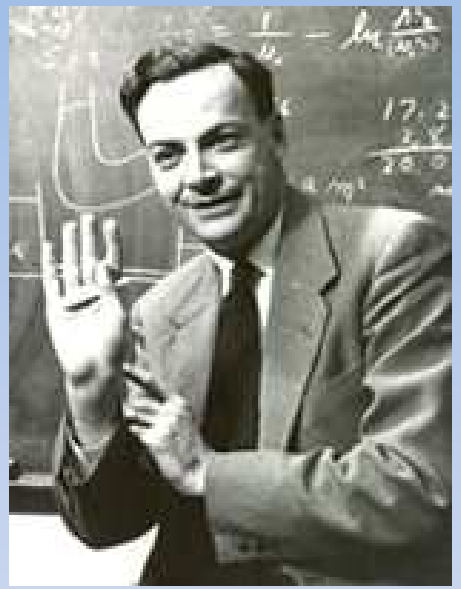
Intro:

Going to:

- **web page:** http://denverclimatestudygroup.com/
- **Facebook too – blog:** https://www.facebook.com/denverclimatestudygroup/?fref=ts

"In this age of specialization, men who thoroughly know one field are often incompetent to discuss another. . . . You must not fool yourself--and you are the easiest person to fool"

Richard Feynman, 1974



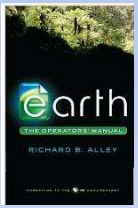
My comment:

We've become a country of self-proclaimed experts on everything.

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/

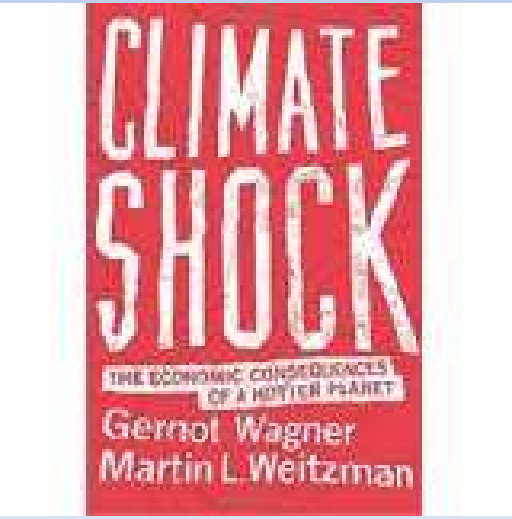


- **More comprehensive book:**

Experimenting on a Small Planet: A Scholarly Entertainment by William W. Hay (Dec 14, 2012)

Another book to consider:

- **Economics:**
  - Climate Shock; the economic consequence of a hotter planet
  - by Gernot Wagner & Martin Weitzman



- If you had a 10 percent chance of having a fatal car accident, you'd take necessary precautions. If your finances had a 10 percent chance of suffering a severe loss, you'd reevaluate your assets. So if we know the world is warming and there's a 10 percent chance this might eventually lead to a catastrophe beyond anything we could imagine, why aren't we doing more about climate change right now? We insure our lives against an uncertain future--why not our planet?
- In *Climate Shock*, Gernot Wagner and Martin Weitzman explore in lively, clear terms the likely repercussions of a hotter planet, drawing on and expanding from work previously unavailable to general audiences. …..

We need a Paradigm shift

- Which led to my email quote from Kerry Emanuel and the need for a social paradigm shift:
- "…there are few, if any, historical examples of civilizations consciously making sacrifices on behalf of descendants two or more generations removed"
- Recent discussions for a new Presidential candidate: **Secretary of the future**

VIDEO - what is climate

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

How we receive and transmit energy in the form of light

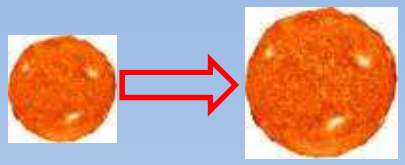
- Visible vs. Infrared/longer wave – a function of “black body” temperature: instead of glass keeping the heat in it’s the gas properties keeping the heat of infrared in; blanket effect.

What determines Earth's climate

INTRODUCTION: Definitions:

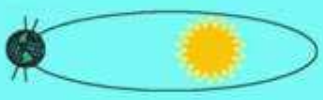
- **<u>First order Forcings:</u>** EXTERNAL Influences (3):

SOLAR input:



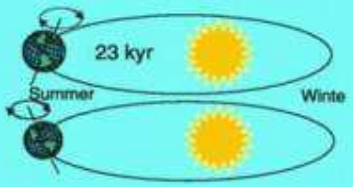
0.9% less
100 My ago

Obliquity



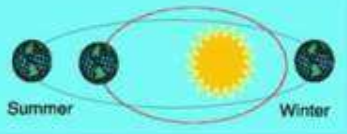
Tilt; 40,000 years:
21.5 – 24.5 degrees

Precession



20,000 years:
summer season

Eccentricity

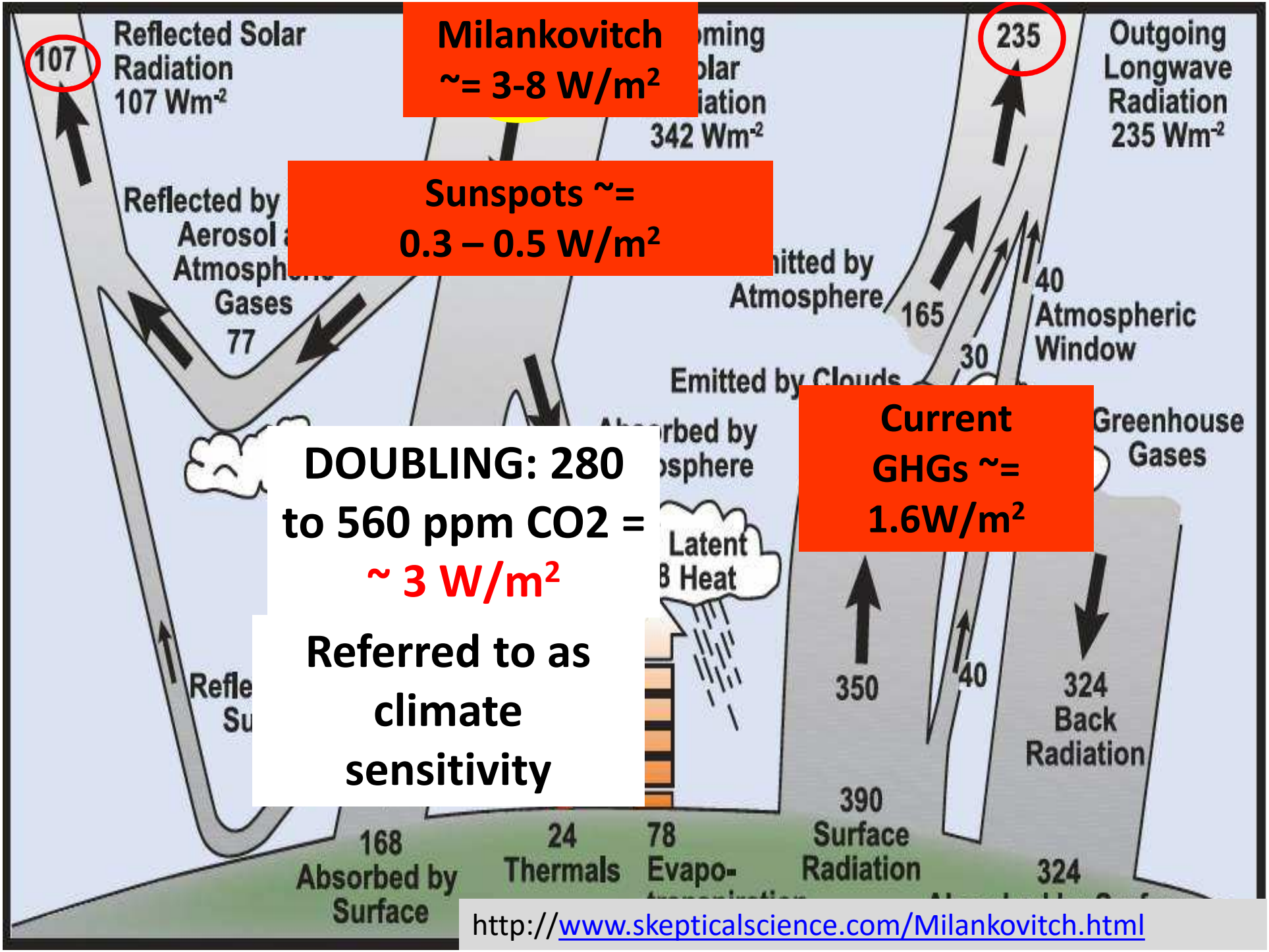


100,000 years

Atmospheric Opacity
(gases that absorb radiation in or out)

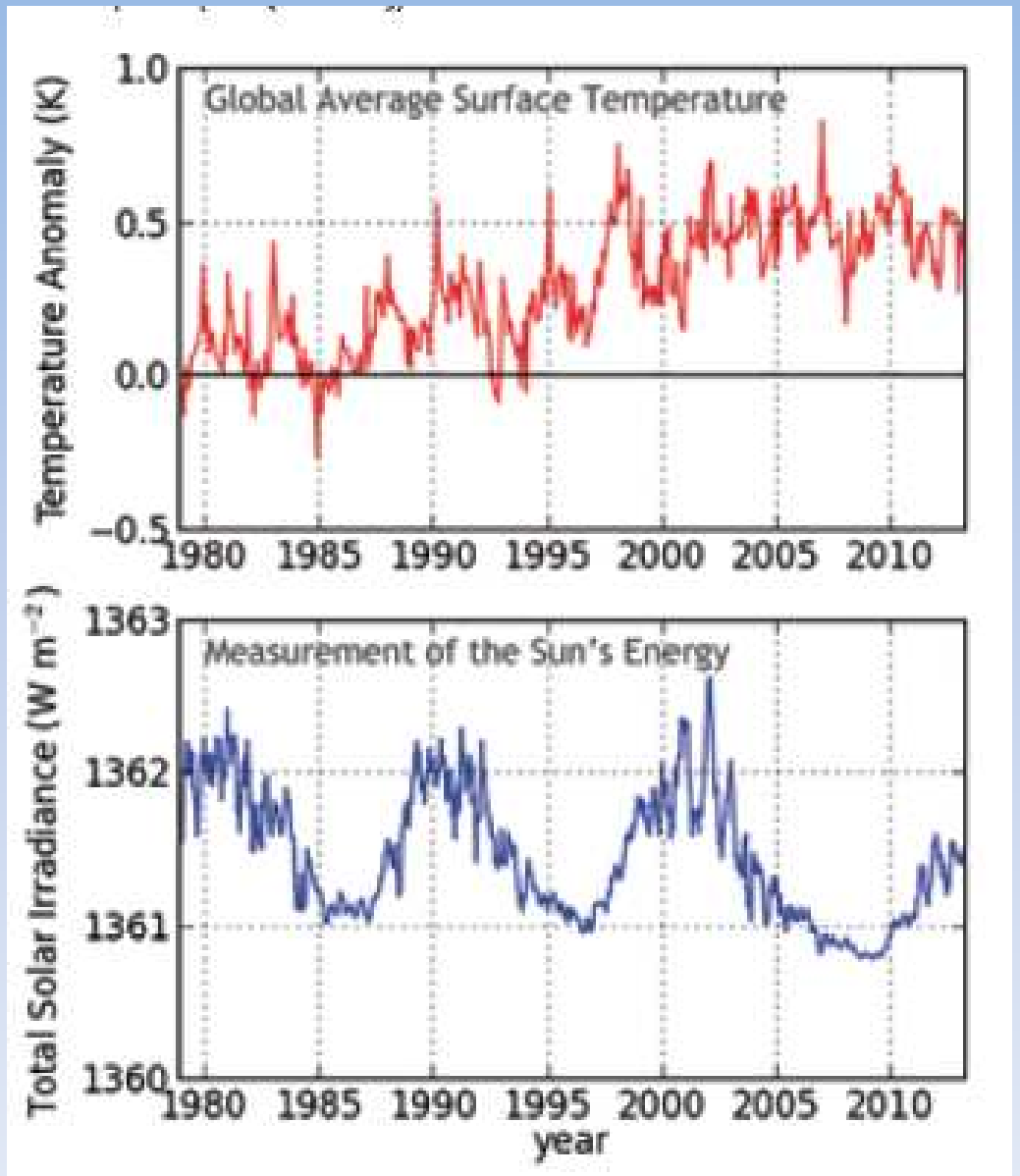
Albedo
(refletivity:30-85%)

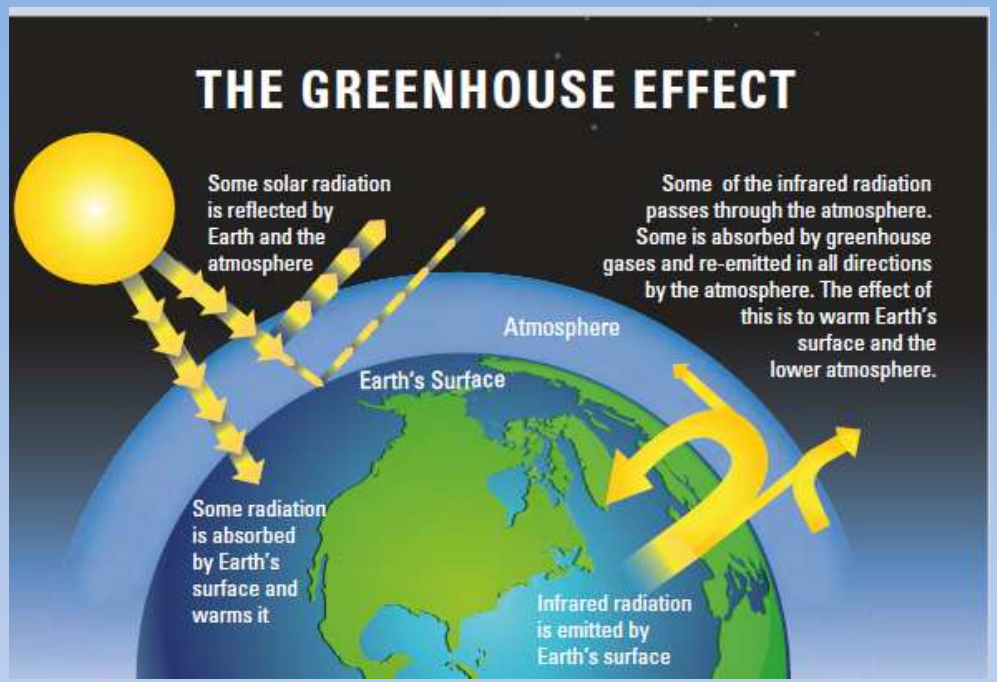
- **<u>Feedbacks:</u>** INTERNAL dynamics and responses
  - e.g. higher water vapor in atm. due to heating of atm

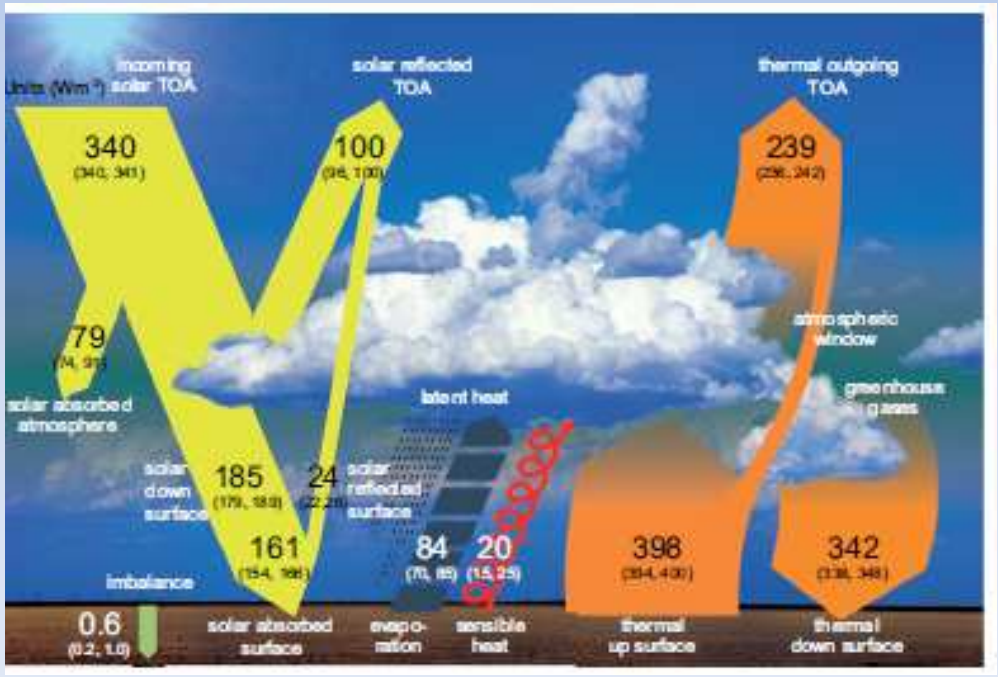


http://www.skepticalscience.com/Milankovitch.html

THE SUN'S ROLE IS MINIMIZING

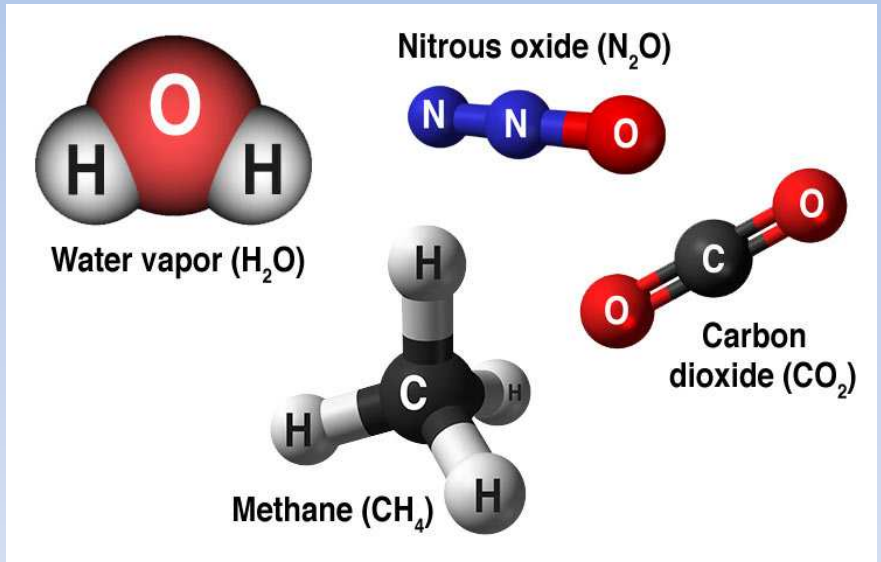



THE GREENHOUSE EFFECT
Some solar radiation is reflected by Earth and the atmosphere
Some of the infrared radiation passes through the atmosphere. Some is absorbed by greenhouse gases and re-emitted in all directions by the atmosphere. The effect of this is to warm Earth's surface and the lower atmosphere.
Atmosphere
Earth's Surface
Some radiation is absorbed by Earth's surface and warms it
Infrared radiation is emitted by Earth's surface


incoming solar TOA
340
(340, 341)
solar reflected TOA
100
(96, 100)
thermal outgoing TOA
239
(236, 242)
79
(74, 97)
solar absorbed atmosphere
atmospheric window
greenhouse gases
latent heat
solar down surface
185
(179, 188)
24
(22, 28)
solar reflected surface
161
(154, 168)
84
(70, 89)
20
(15, 25)
398
(384, 400)
342
(336, 348)
imbalance
0.6
(0.2, 1.0)
solar absorbed surface
evapo-ration
sensible heat
thermal up surface
thermal down surface

GREENHOUSE GASES (GHGs)

- 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



The CO_2 greenhouse gas effect is concentrated in the polar regions ! ! !

The most potent greenhouse gas is H_2O - vapor

The large H_2O greenhouse effect is controlled by temperature – H_2O saturation doubles with every 10°C increase

As a result it is concentrated in the lower atmosphere of the tropics

Particularly in the Arctic !

CO_2 and other Greenhouse gases are evenly distributed throughout the atmosphere

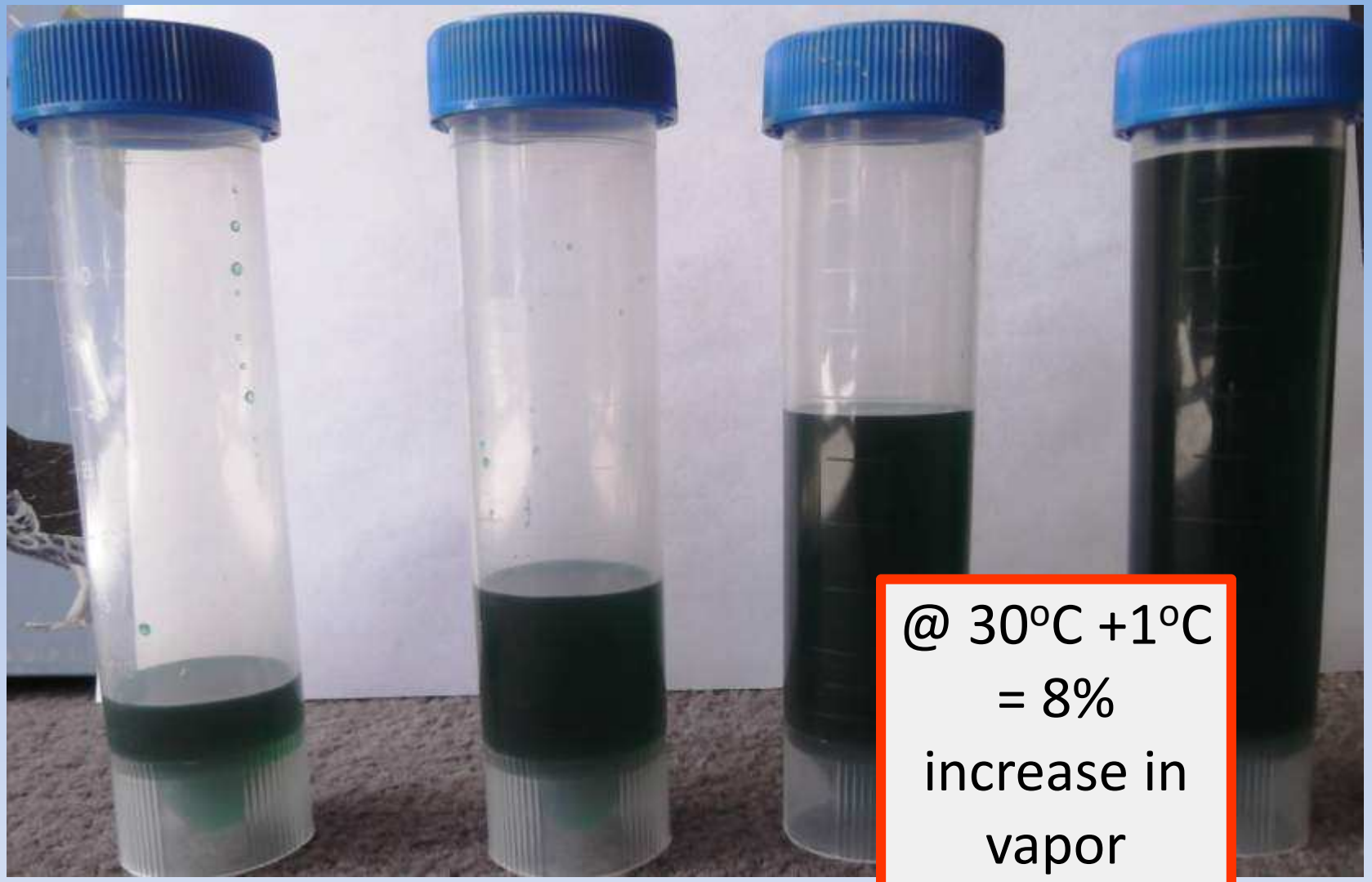
Table 1 Specific humidity of a kilogram of air (at average sea level pressure)

Temp. (°C)	Temp. (°F)	Grams of water vapor per kg of air (g/kg)
-40	-40	0.1
-35	-31	0.2
-30	-22	0.3
-25	-13	0.51
-20	-4	0.75
-10	14	1.8
0	32	3.8
5	41	5
10	50	7.8
15	59	10
20	68	15
25	77	20
30	86	27.7
35	95	35
40	104	49.8

What is the volume of 1 kg of air?

Answer: 0.8562 m^3

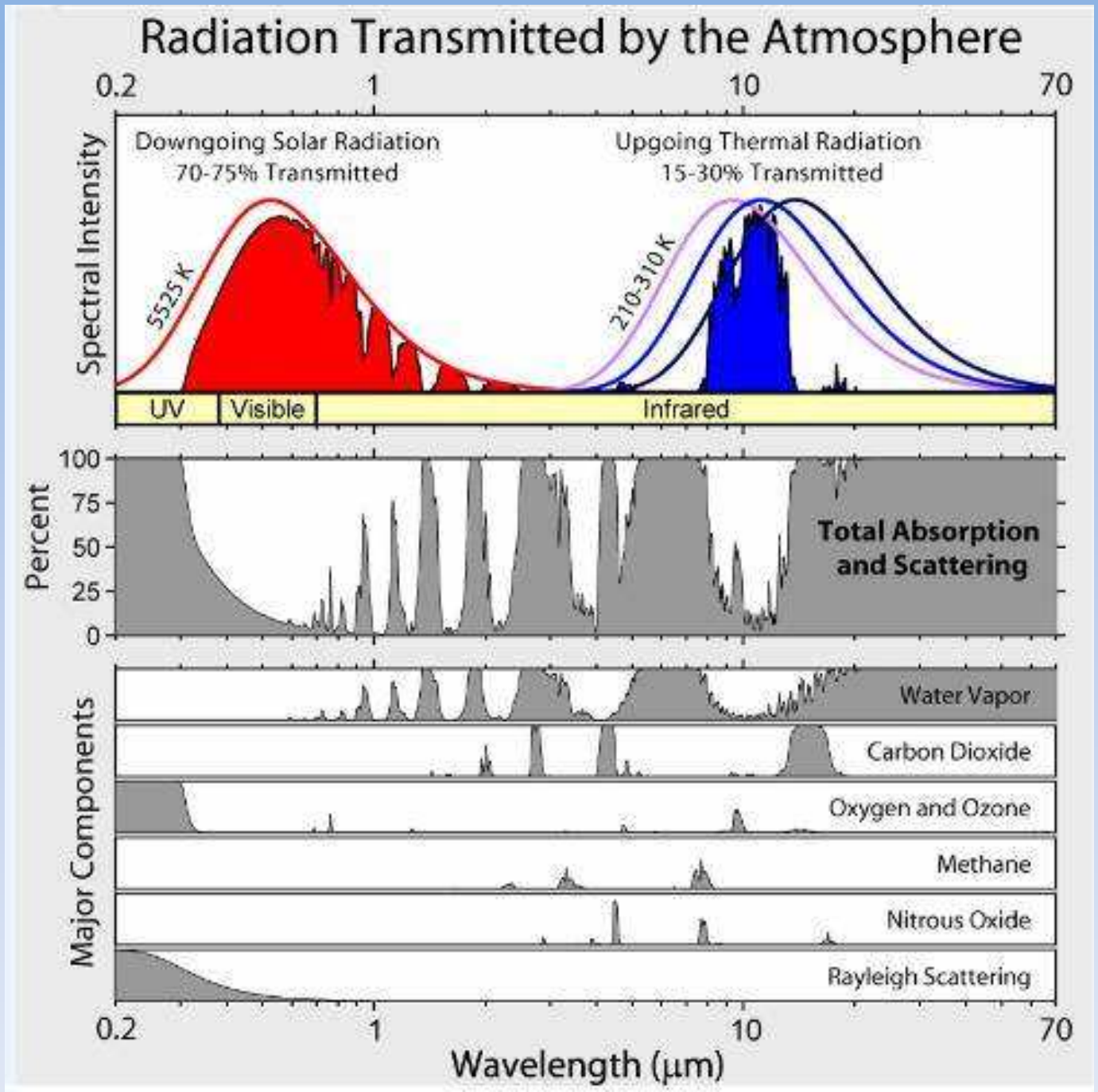
(95 cm x 95 cm x 95 cm)



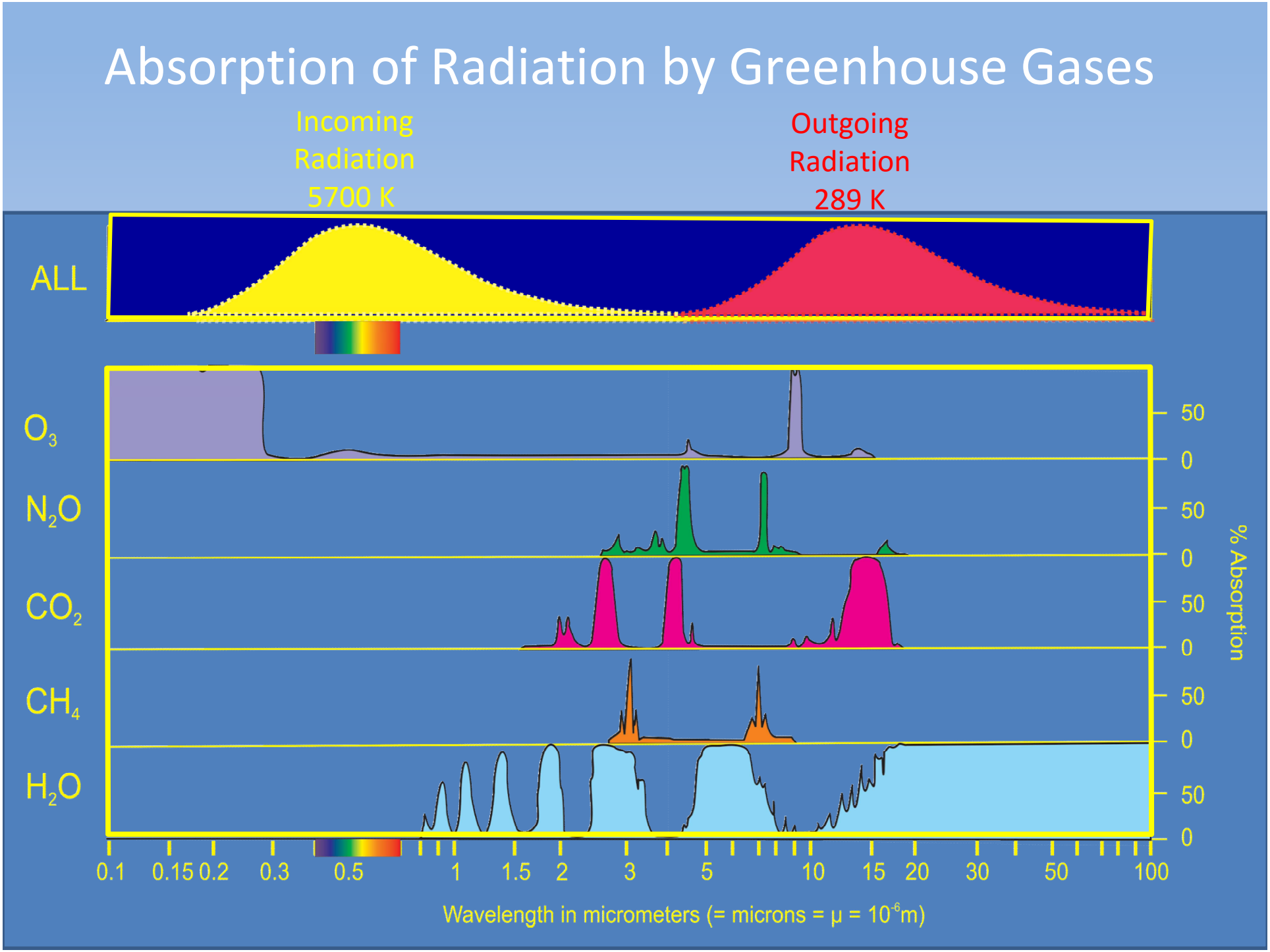
10°C = (50°F)	20°C = (68°F)	30°C = (86°F)	40°C = (104°F)
7.8 cc	15 cc	27.7 cc	49.8 cc

How GHGs Blanket the Earth

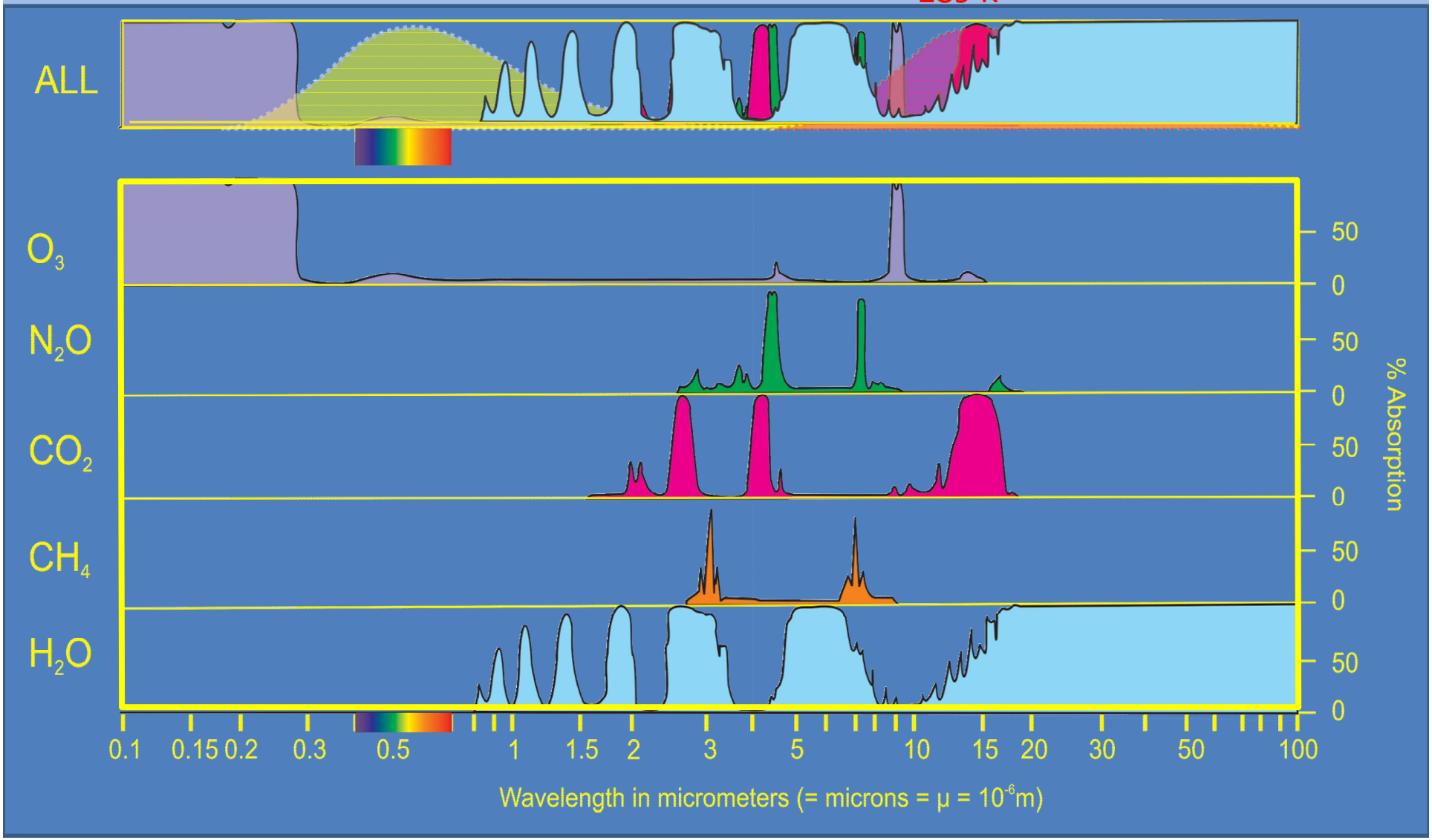
- **Blanket Earth:**
- http://climate.nasa.gov/causes/
- https://www.youtube.com/watch?v=aqkGoCglp_U&feature=youtu.be
- https://www.youtube.com/watch?v=we8VXwa83FQ


Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K
UV
Visible
Infrared
Percent
100
75
50
25
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Oxygen and Ozone
Methane
Nitrous Oxide
Rayleigh Scattering
0.2
1
10
70
Wavelength (μm)

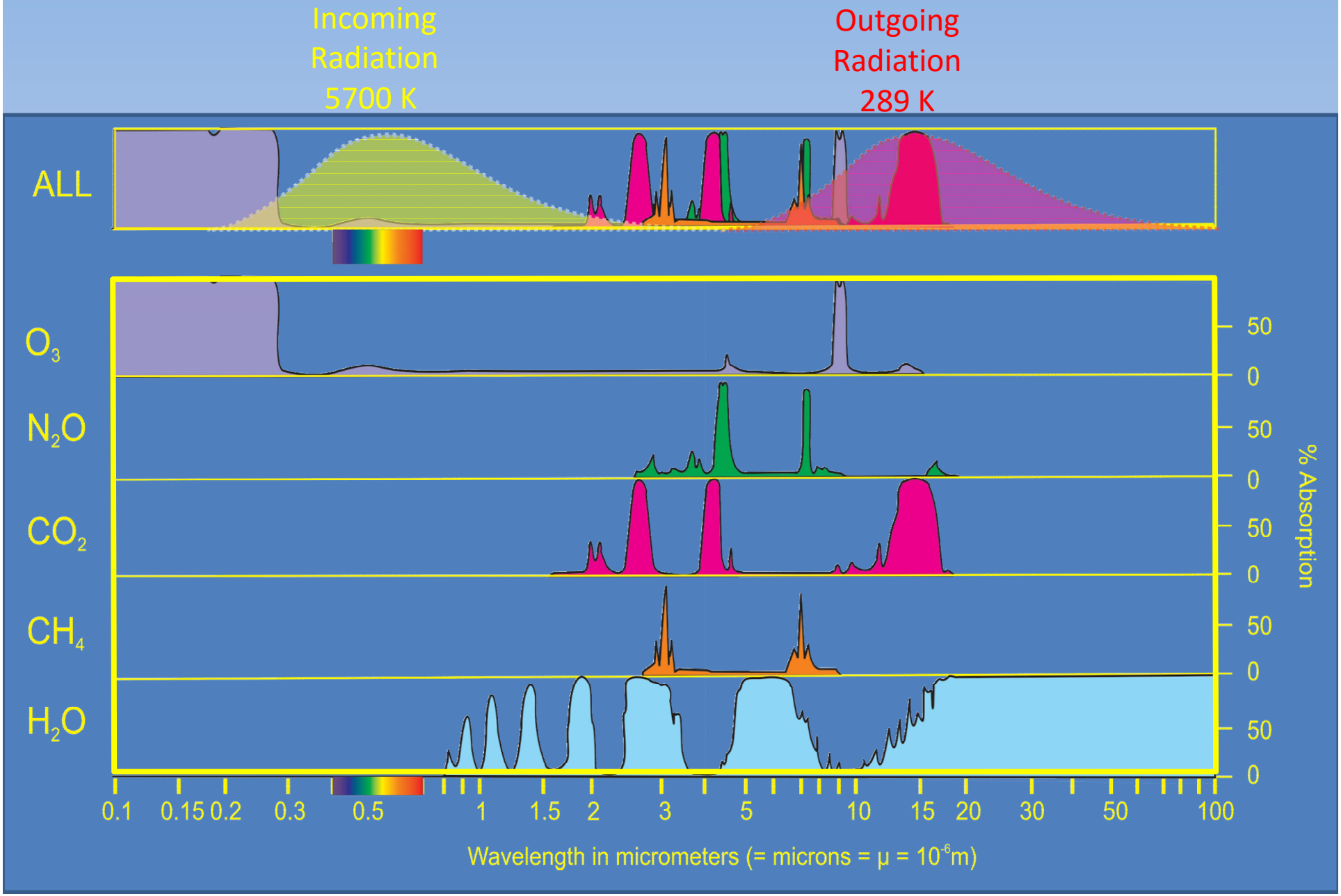
Absorption of Radiation by Greenhouse Gases



Absorption of Radiation by Greenhouse Gases

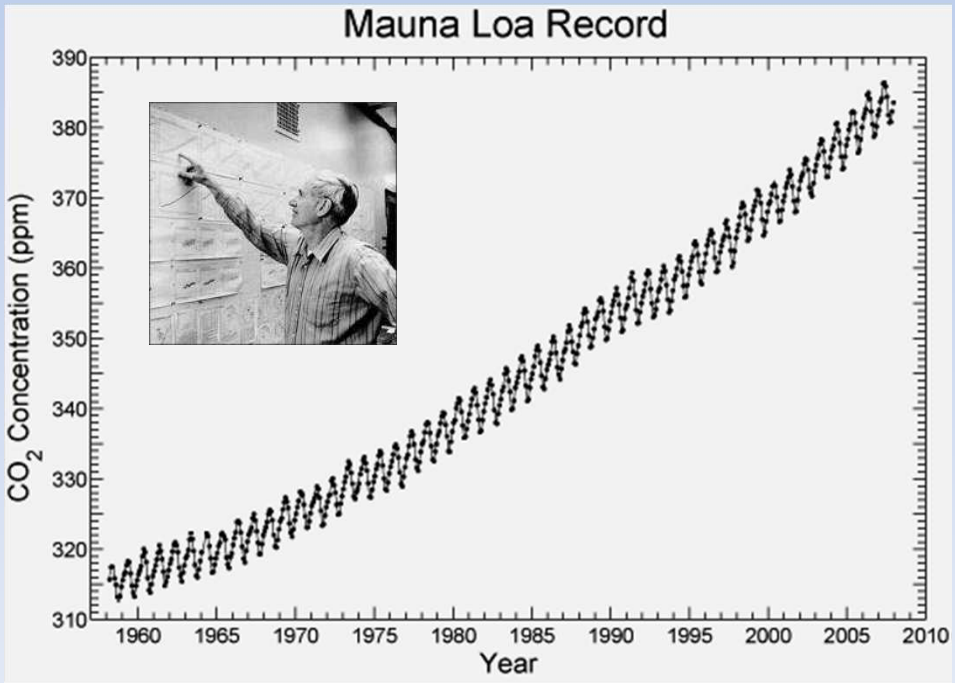


Absorption of Radiation by Greenhouse Gases



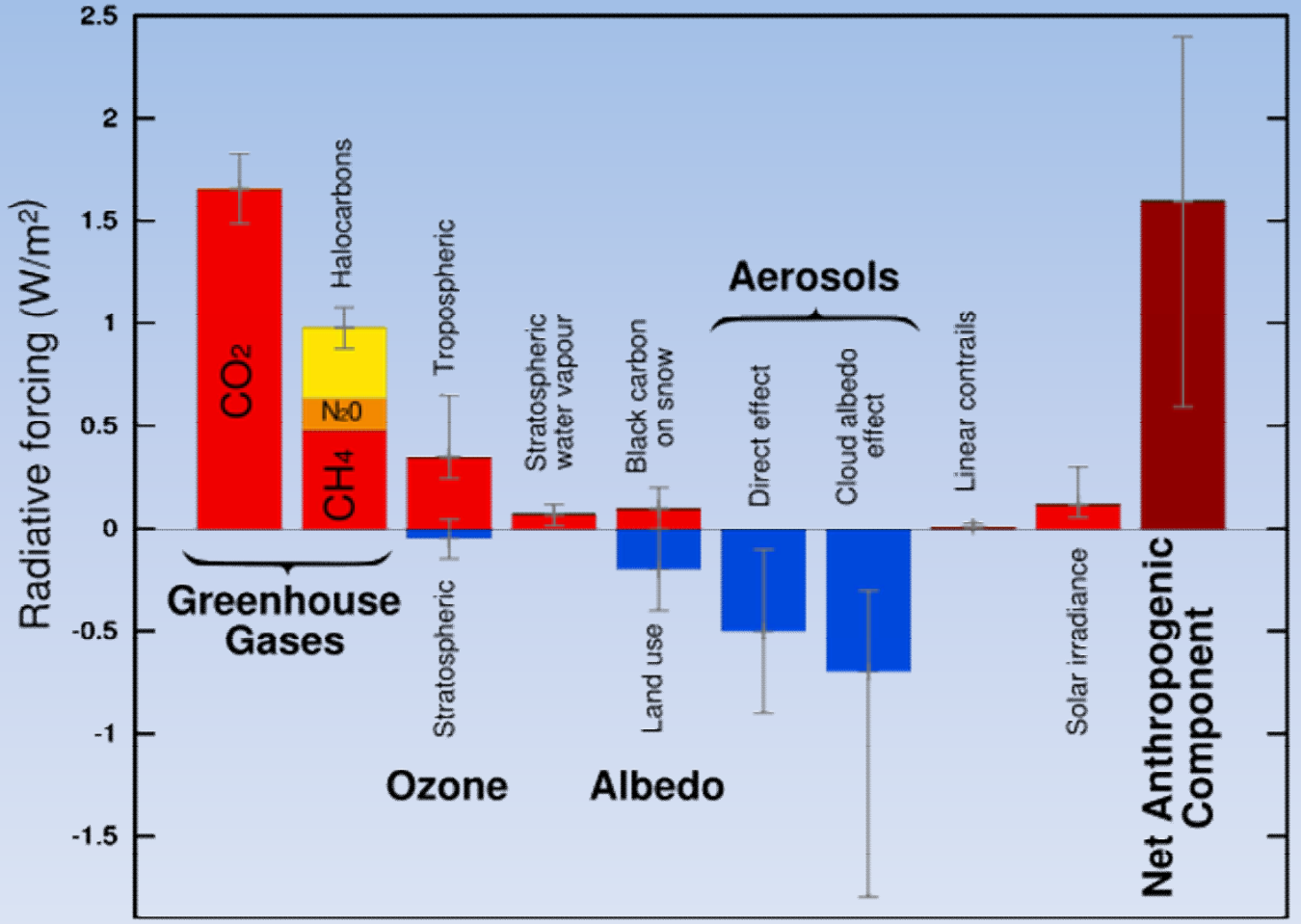
3: EMISSIONS FROM HUMAN ACTIVITIES LARGELY TO BLAME

- 40% increase in CO_2
- Dead carbon altering atmospheric C^{14}
- That Carbon is more negative/enriched in C^{12}



GLOBAL WARMING CONCERNS

Radiative Forcing Components

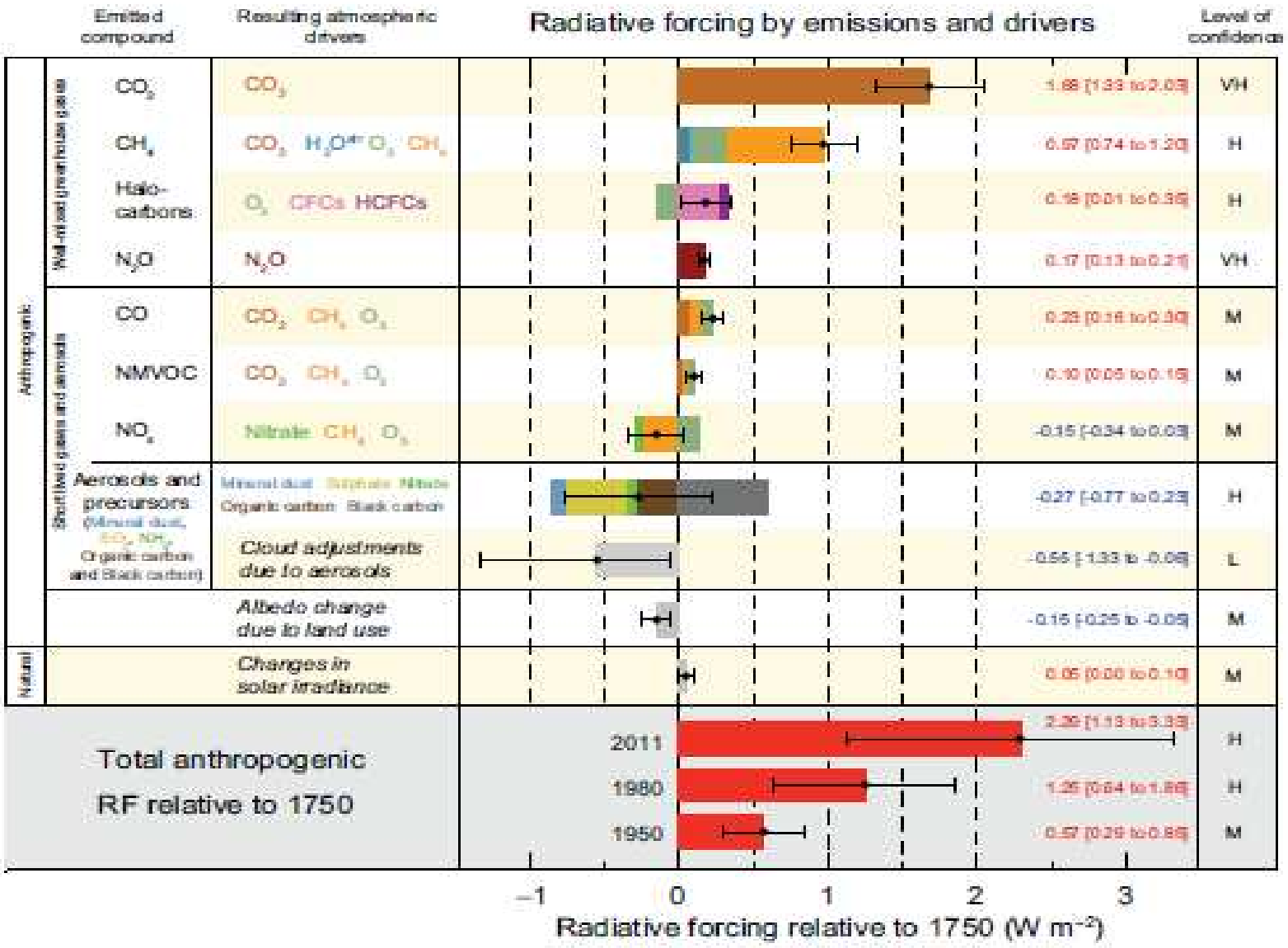


Incoming Solar irradiance: 342 W/m^2

IPCC, 2007

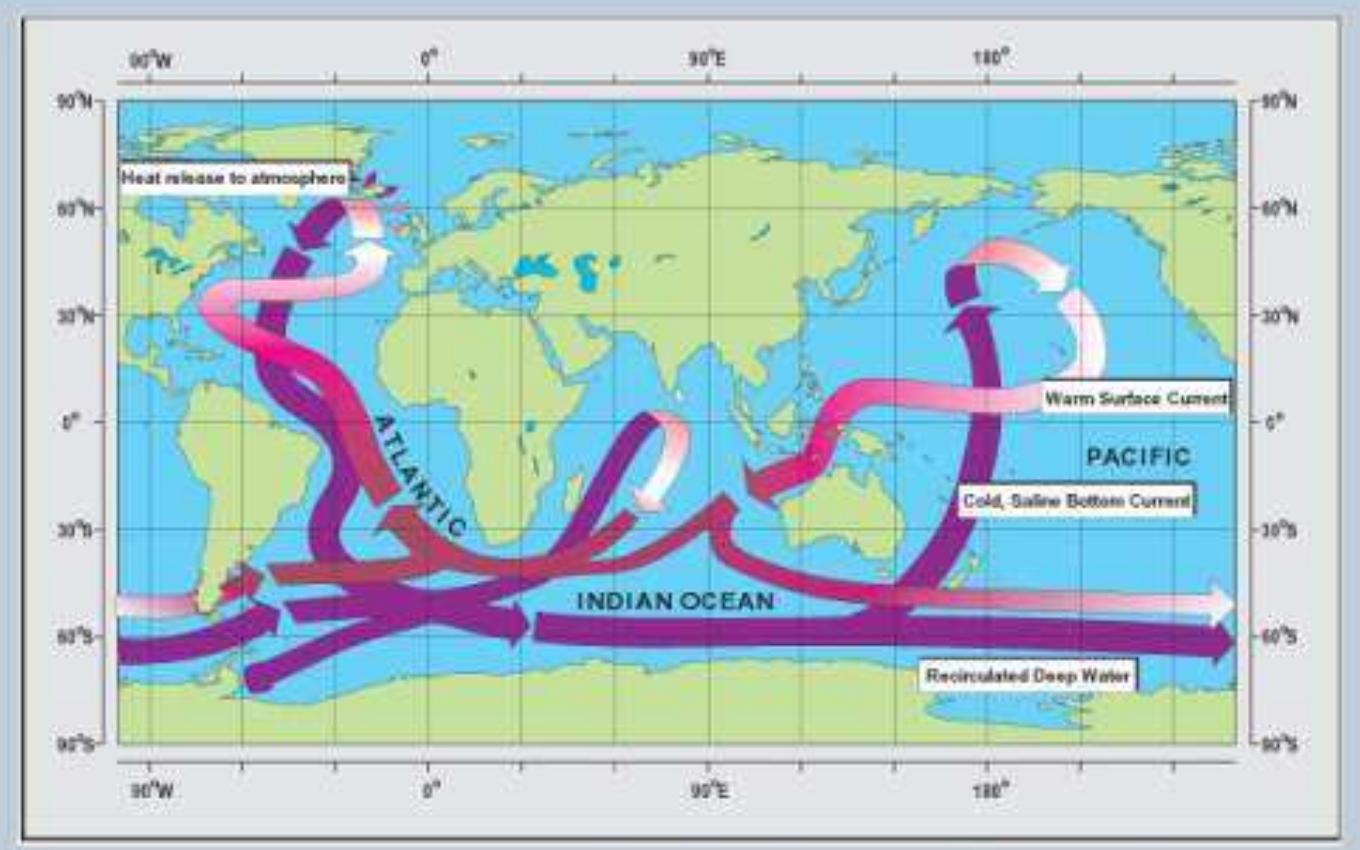
1: THE CLIMATE IS WARMING

- **Drivers; aka forcings, i.e. causes**



The Atlantic Thermohaline Circulation

- A key Element of the Global Oceanic Circulation -

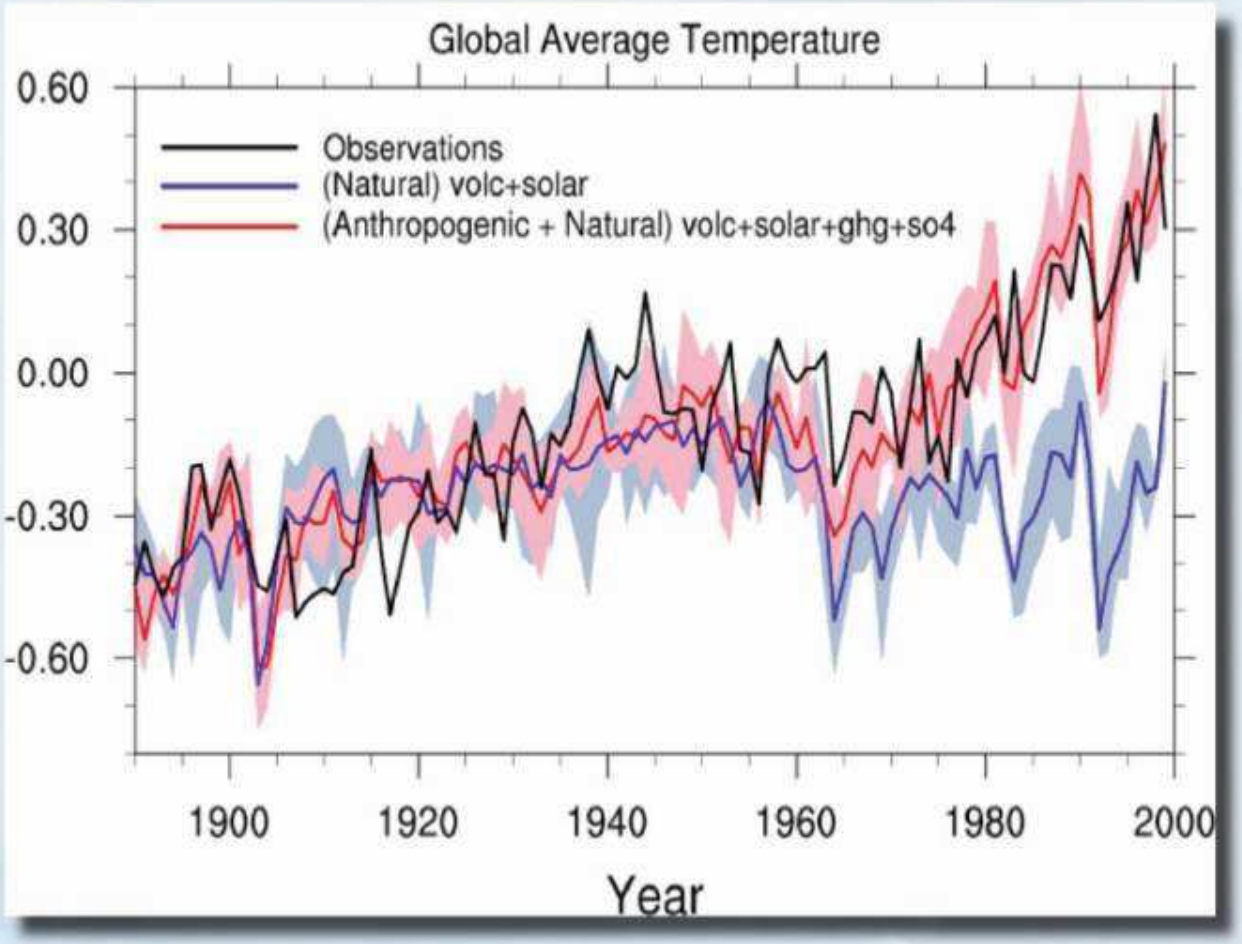


Schematic diagram of the global ocean circulation pathways, the 'conveyer' belt (after W. Broecker, modified by E. Maier-Reimer).

AV/D3/99-2

Simulations of the 20th century: Time

NCAR

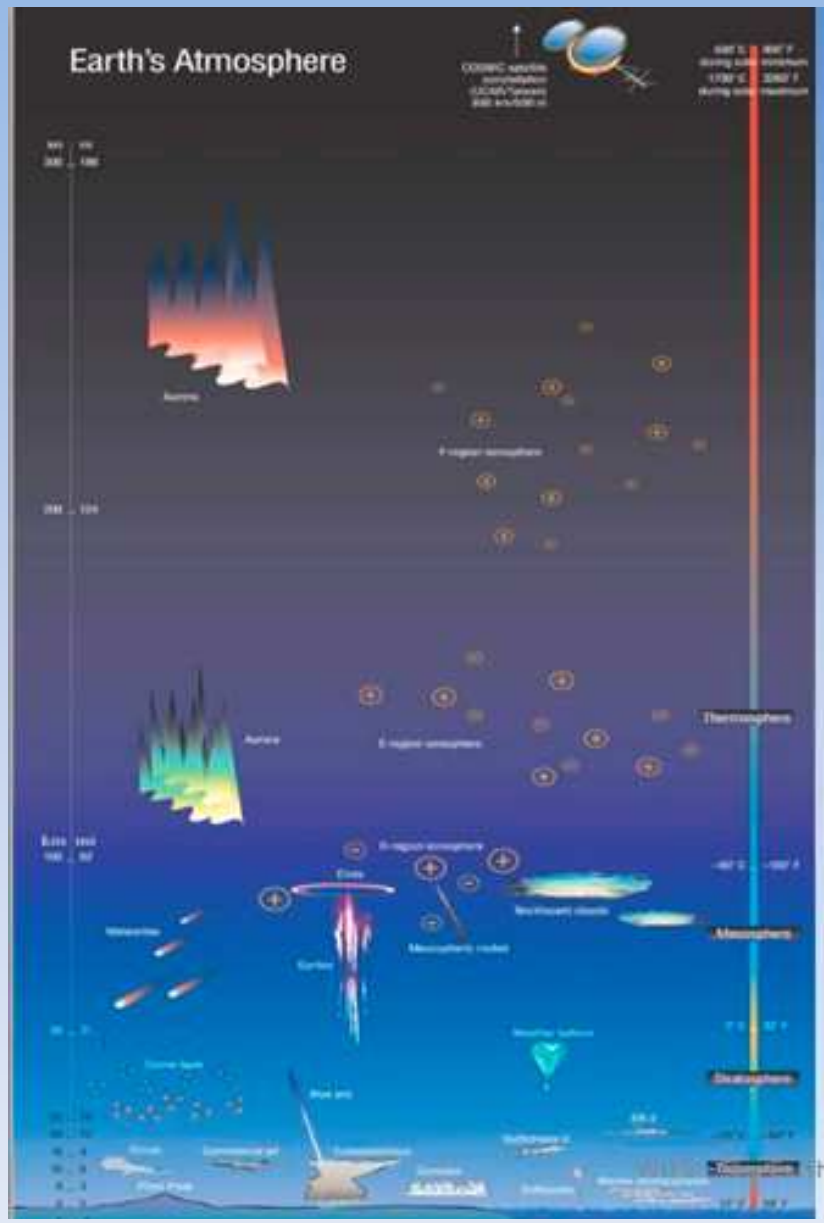


All forcings

Natural only

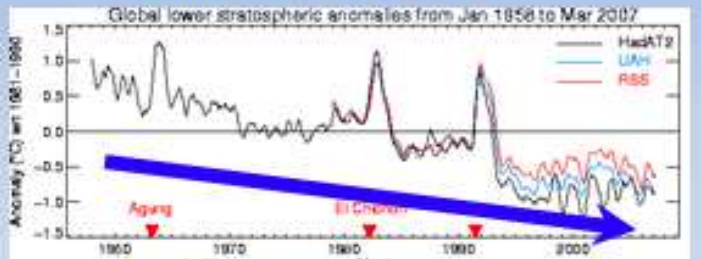
Meehl et al. 2004

5: SURFACE TO STRATOSPHERE CHANGES

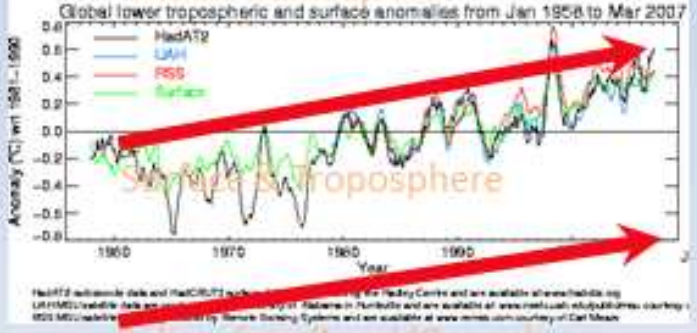


Greenhouse Fingerprint

Middle Atmosphere

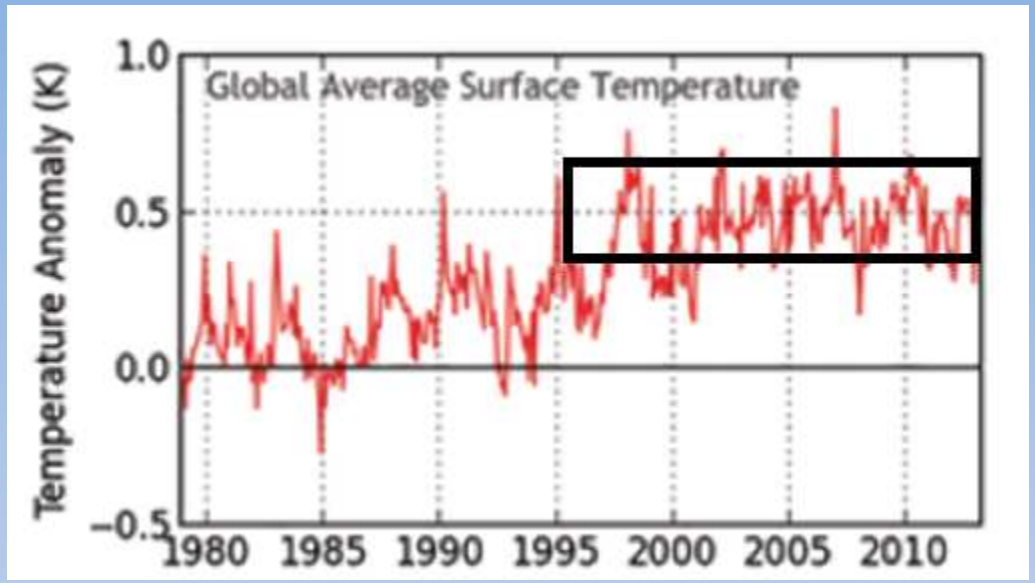


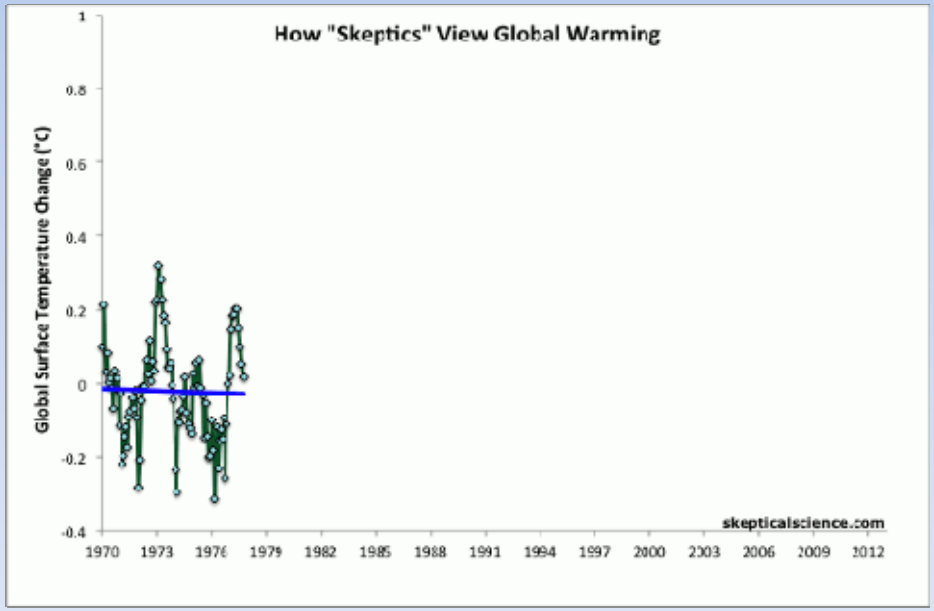
Middle Atmosphere

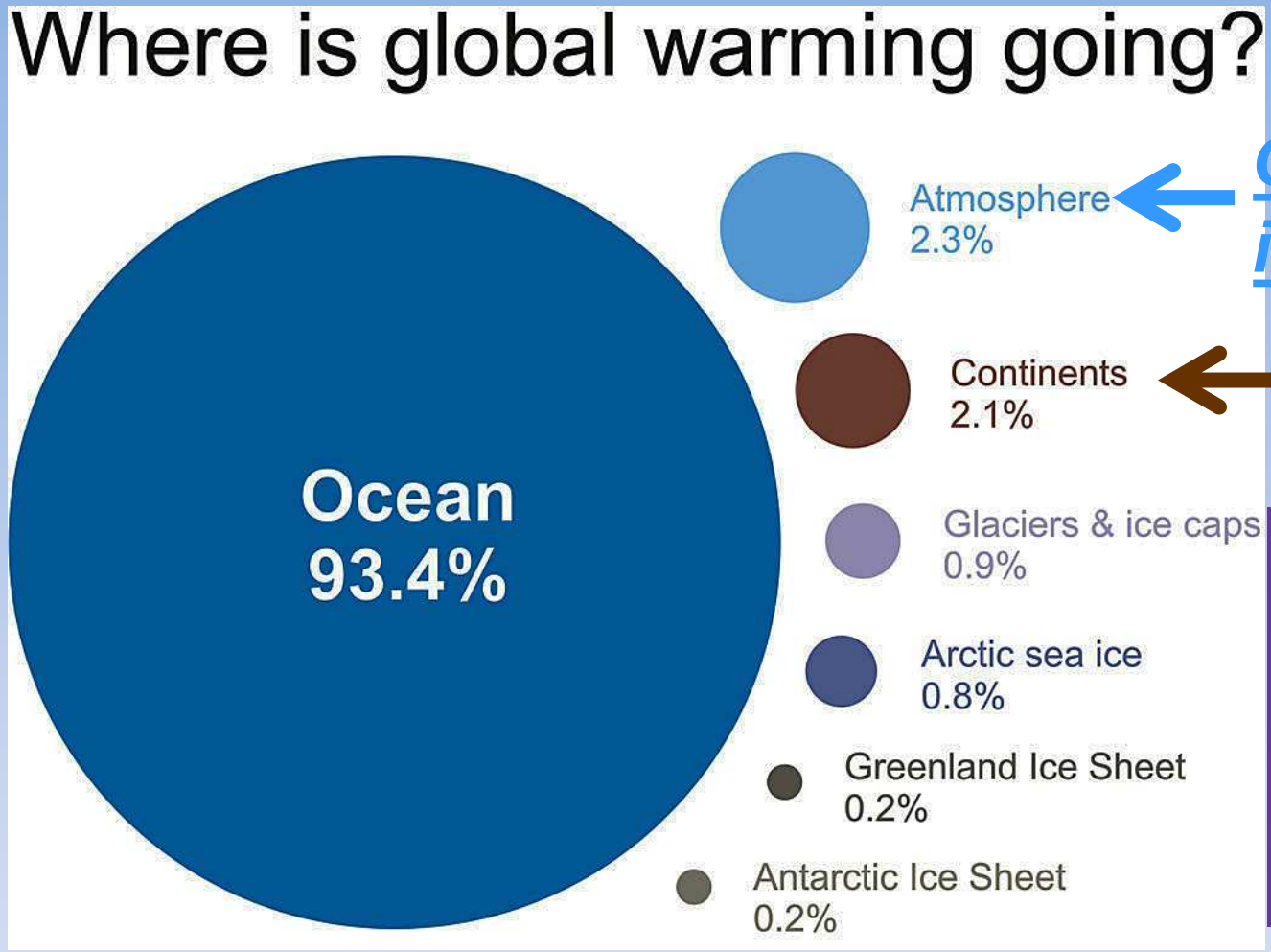


Surface & Troposphere

Subsurface (Land/Ocean)


Global Average Surface Temperature
Temperature Anomaly (K)
1.0
0.5
0.0
−0.5
1980
1985
1990
1995
2000
2005
2010


How "Skeptics" View Global Warming
Global Surface Temperature Change (°C)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
skepticalscience.com



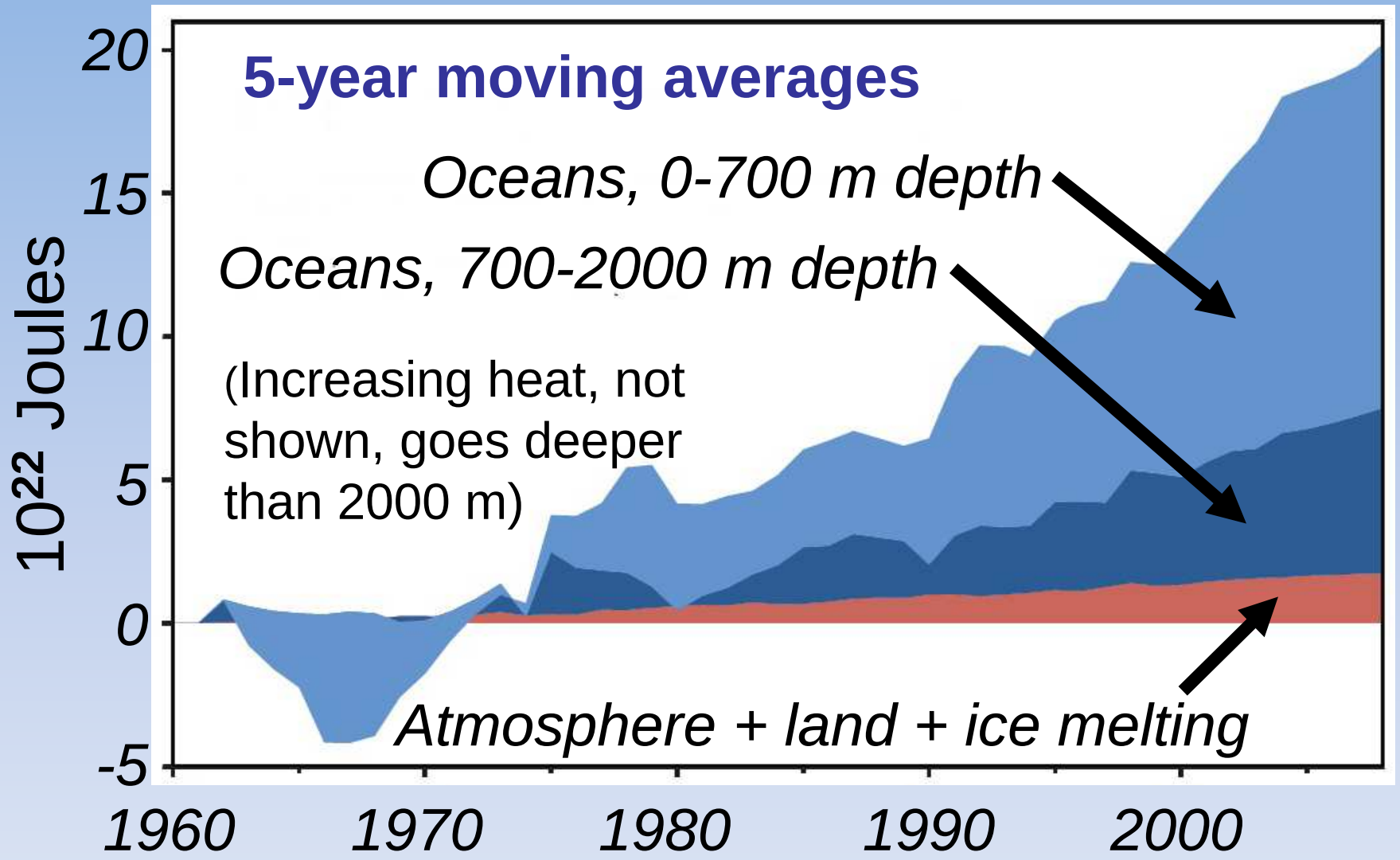
Only ~2% stays in atmosphere

~2% warms the land

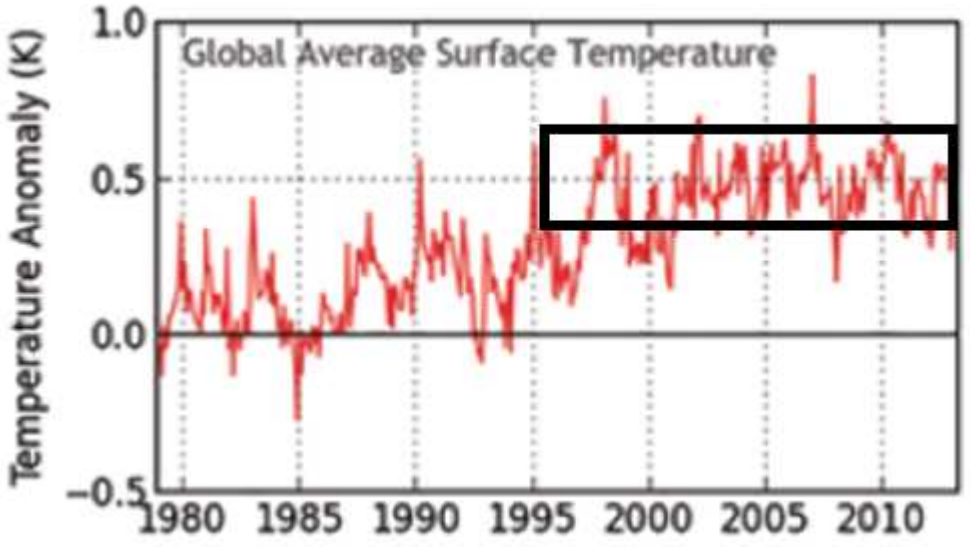
Melting ice absorbs ~2%

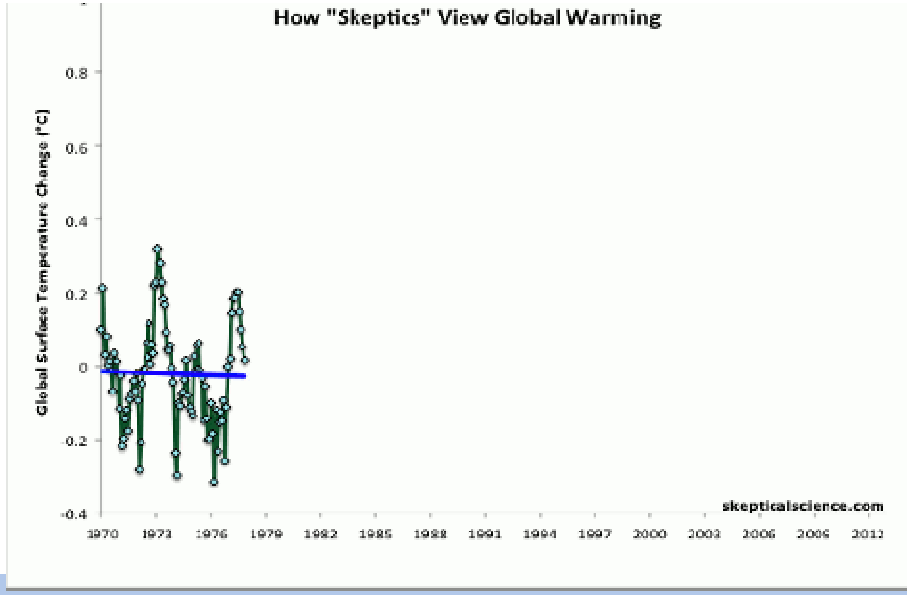
John Cook, from IGPP 2007 data; ~93% to oceans continues (NOAA/NODC, 2012)

Change in heat content, 1958-2011

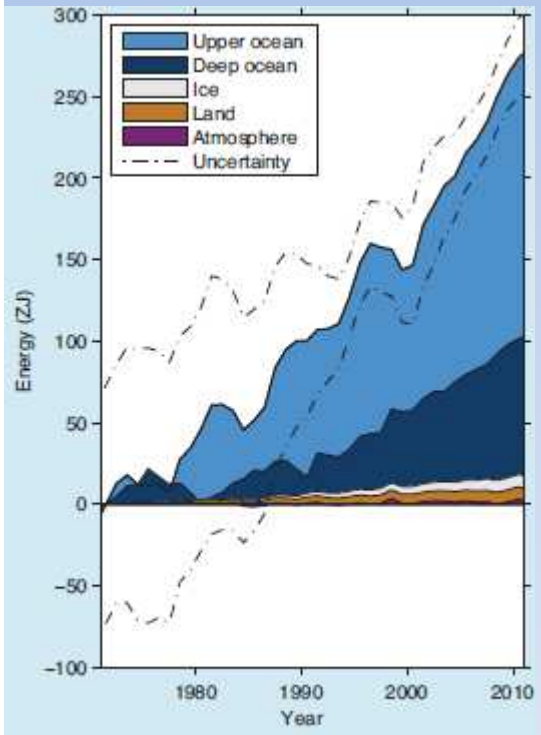


(NOAA 2012 data, Nuccitelli et al. 2012 plot)

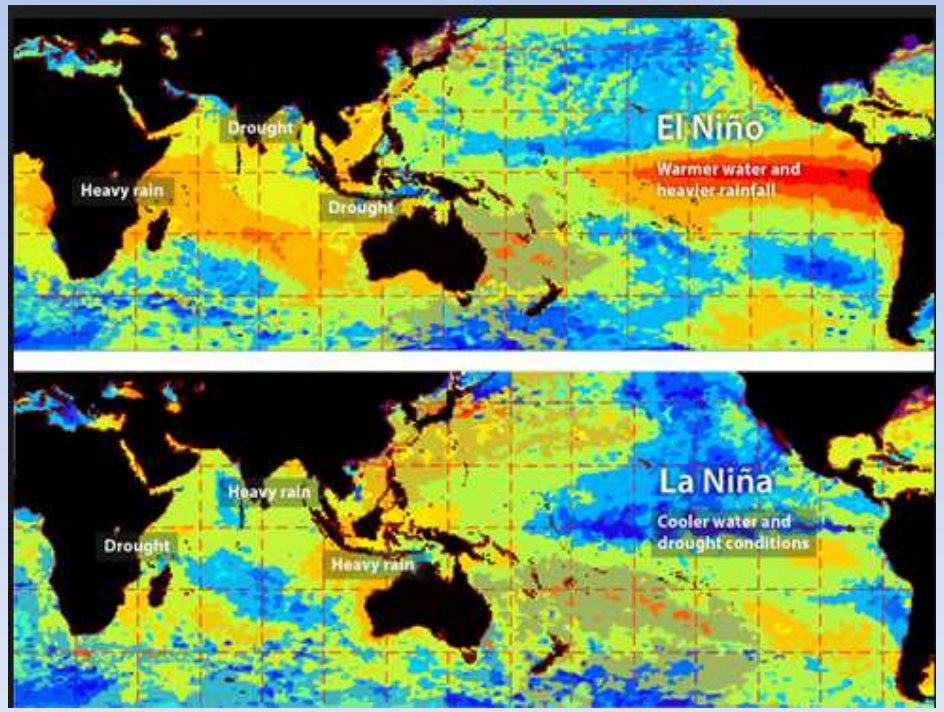




http://www.skepticalscience.com/graphics.php?g=47



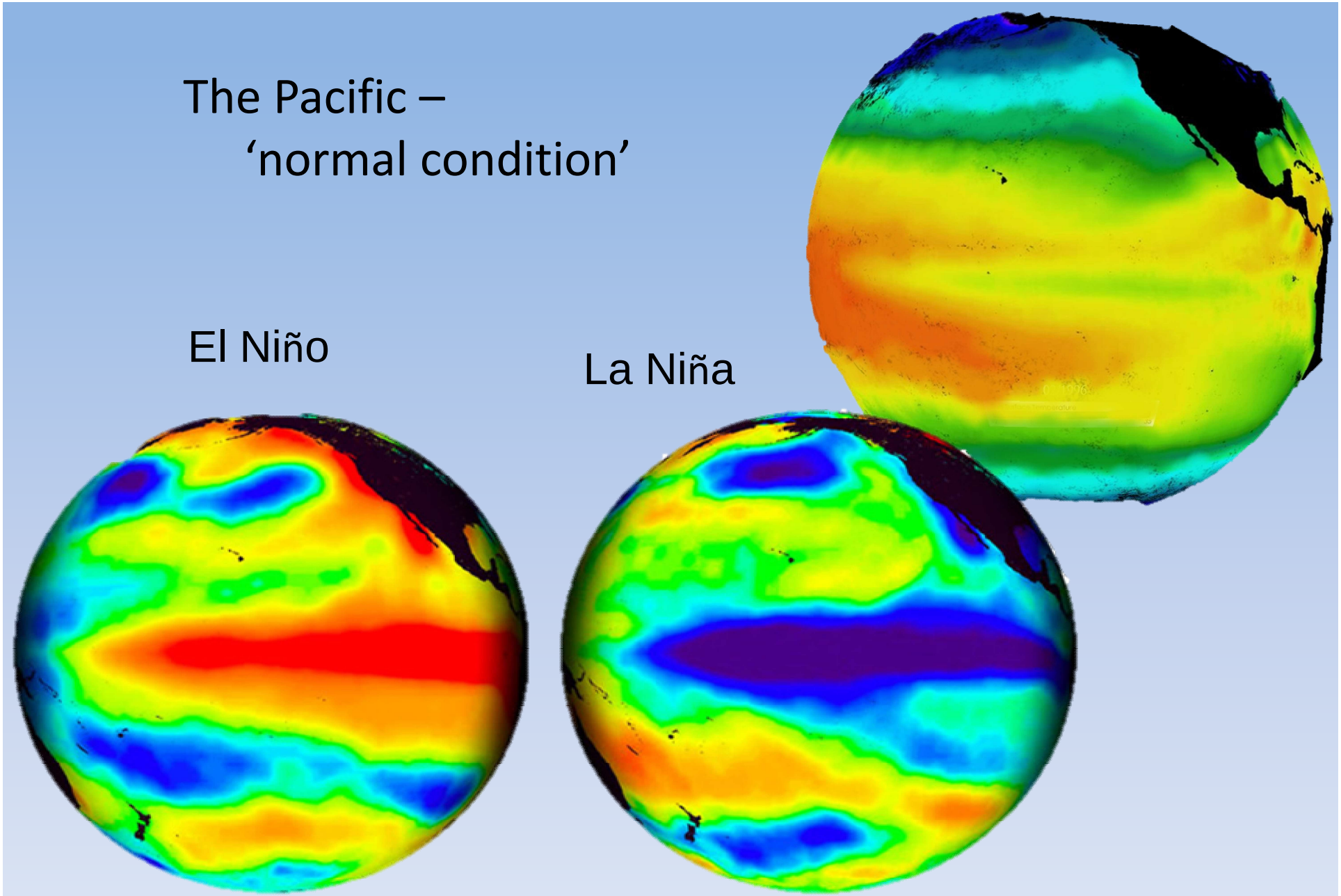
Box 3.1, Figure 1 | Plot of energy accumulation in ZJ (1 ZJ = 10^{21} J) withi



The Pacific –
‘normal condition’

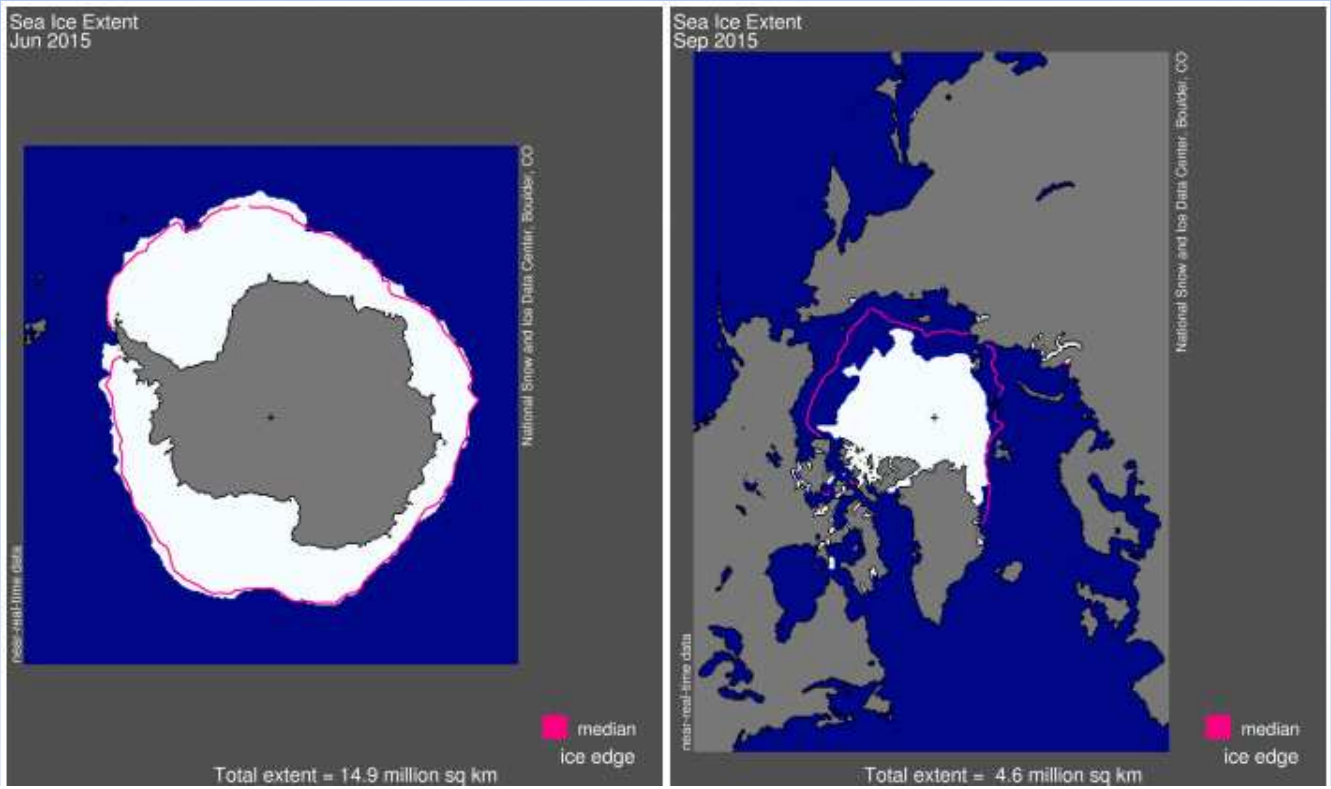
El Niño

La Niña



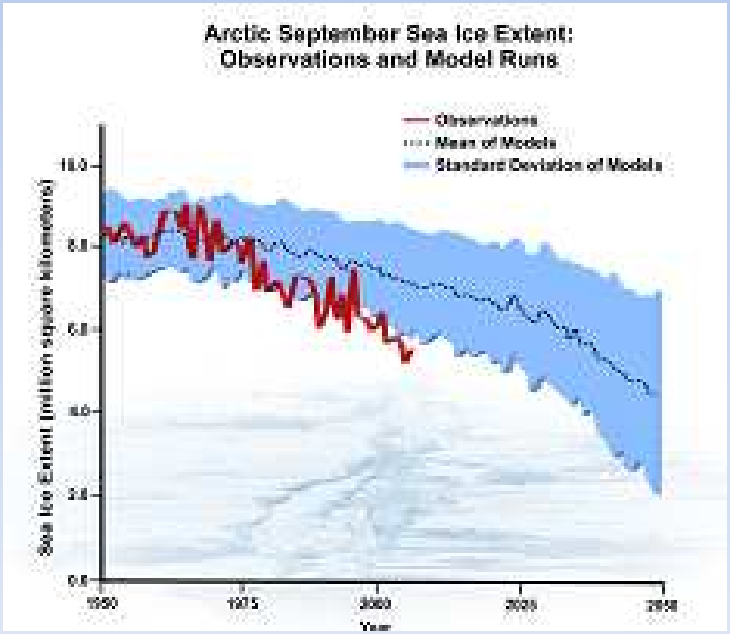
12. ARCTIC ICE vs. ANTARCTIC SEA ICE

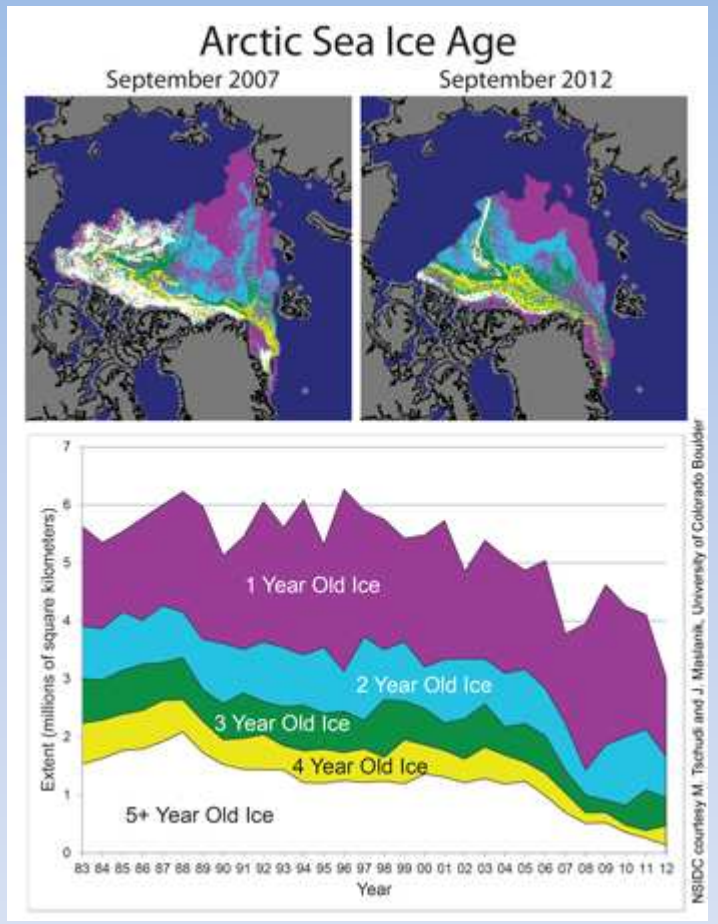
- Ans. More moisture in air around Antarctica (AA) to nucleate sea ice
- Despite > AA is does not compensate for Arctic loss



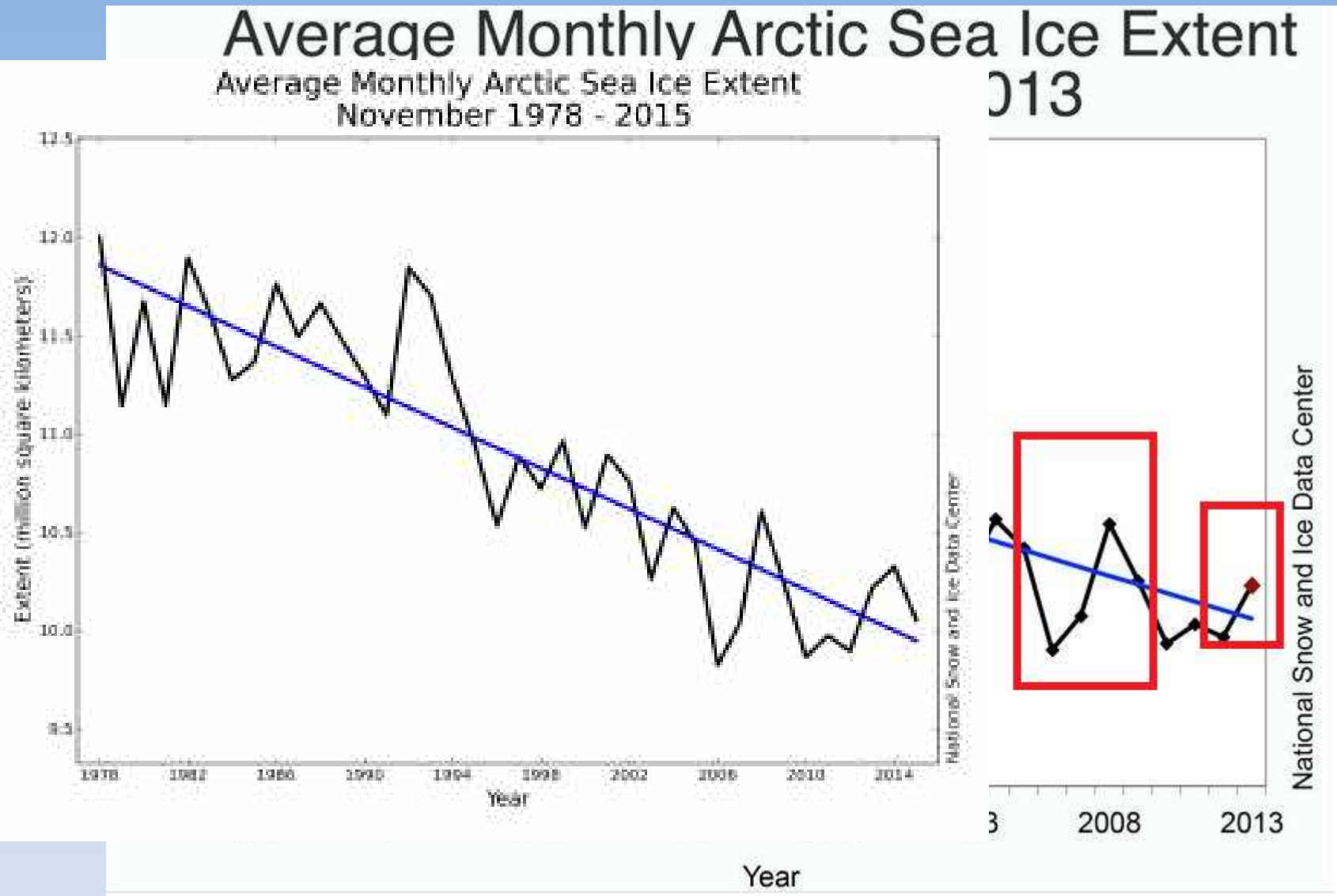
2015

http://nsidc.org/arcticseaicenews/2015/



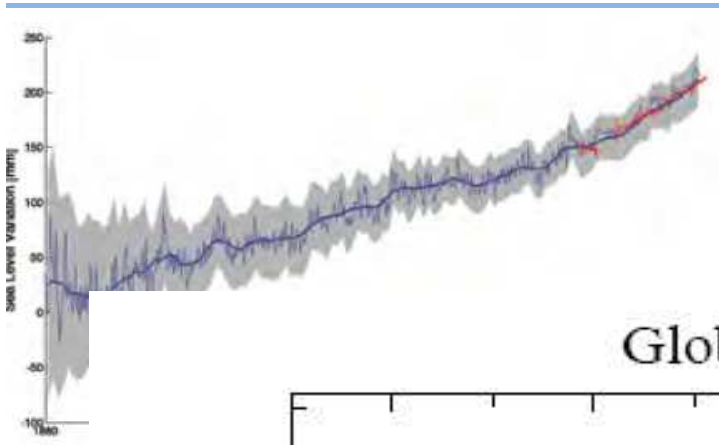


http://nsidc.org/arcticseaicenews/2015/

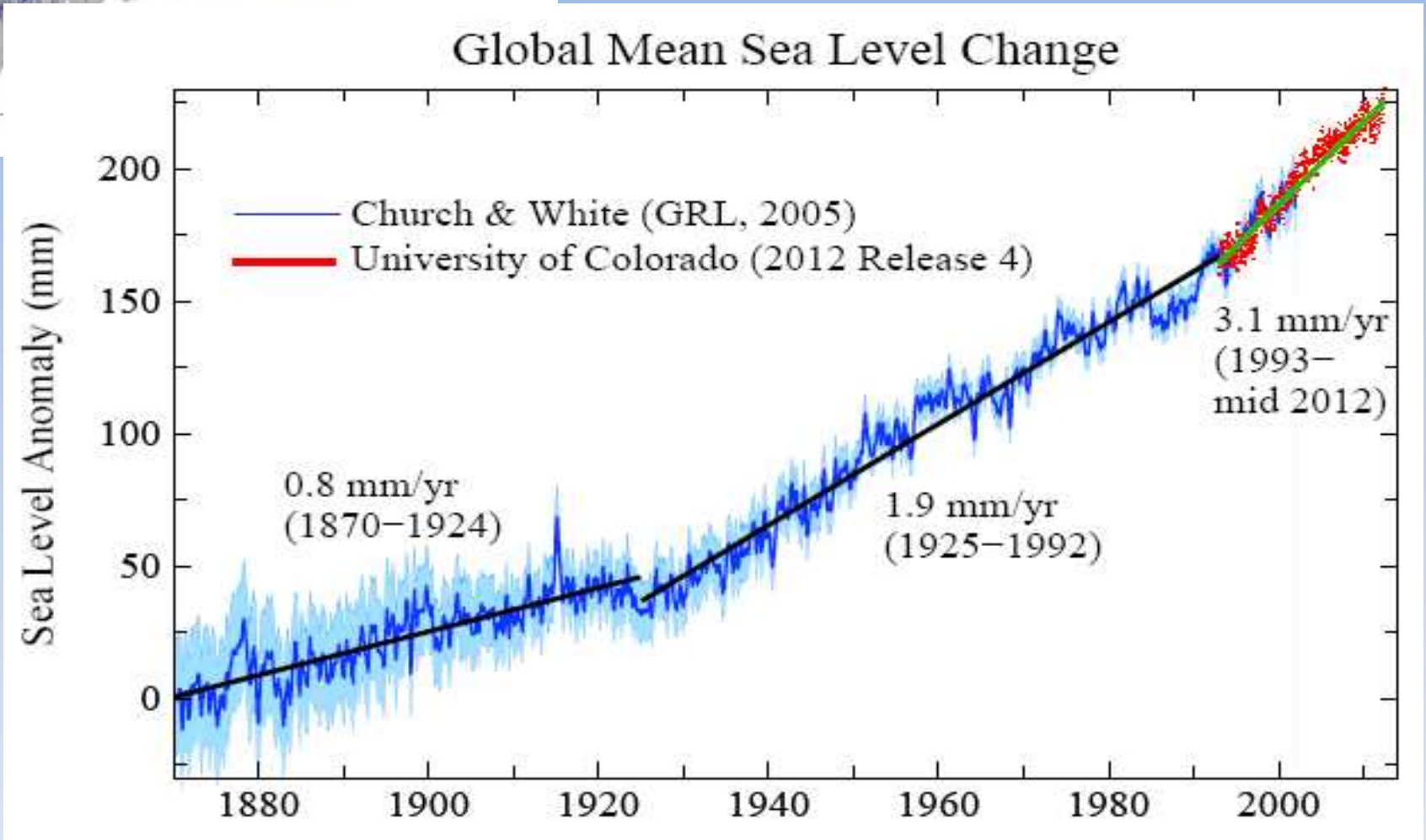


For more see: http://www.skepticalscience.com/melting-ice-global-warming.htm

http://nsidc.org/arcticseaicenews/2015/



14: HOW FAST IS SEA LEVEL RISING?

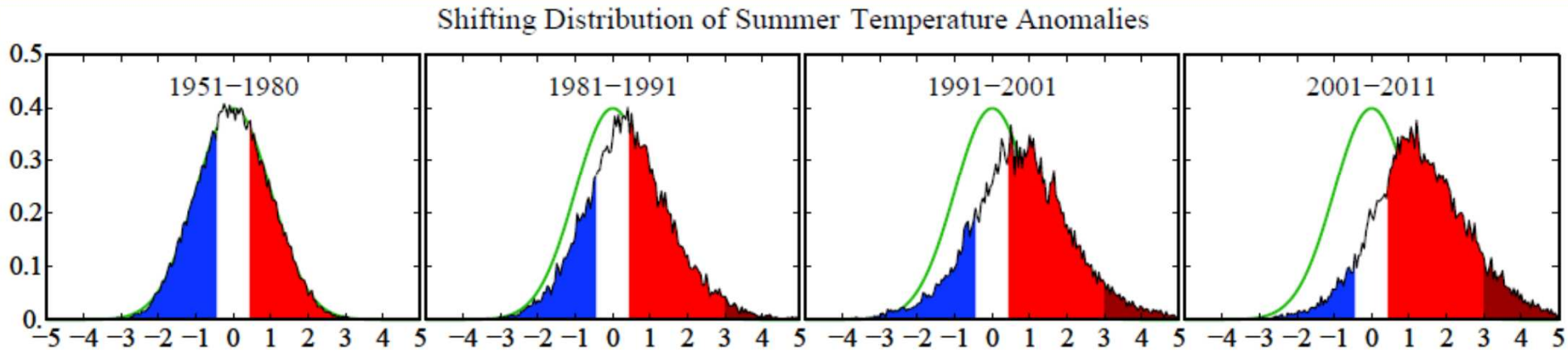


Blue: Sea level change from tide-gauge data *(Church J.A. and White N.J., Geophys. Res. Lett. 2006; 33: L01602)*
Red: Univ. Colorado sea level analyses in satellite era *(http://www.columbia.edu/~mhs119/SeaLevel/)*.

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