

Thursday Nov 20th

**Topic #13 GLOBAL WARMING &
ANTHROPOGENIC FORCING (cont.)**

SIT ANYWHERE TODAY!

But pick up an INDEX CARD when you come it!

ANNOUNCEMENTS:

- **I-4 LESSON 4** on “Intro to Climate Modeling”
is due **TONIGHT** by **11:59 pm**
- **TEST #4** is next **Tuesday Nov 25th**
The **Top 10 Study Guide** will be posted tonight
Study Session will be held next **Monday@ 4:30 – 5:30 pm**
- **LINKING-TO-LIFE PROJECT** – all Parts are awaiting your effort
GO FOR IT !
A few comments to be given in class today.

LINKING-TO-LIFE TERM PROJECT OVERVIEW

(worth a total of 130 pts)



PART A Your Ecological Footprint (25 pts)



PART B Global Change Film & Video Commentaries (15) pts)



PART C Project Report & Powerpoint Slide (90 pts)

OVERALL GOAL: To **link** what you've learned in our Global Change course to aspects of your life that impact the Earth's global climate and environment both positively or negatively -- **and explore what you (and others) can do about it!**

PROJECT OBJECTIVE: To **research and propose** a *viable and practical* **choice, action or solution** for reducing your **Ecological Footprint** or increasing your **Environmental Handprint**.



FOOTPRINTS: the **negative impacts in your use of the environment's finite resources** (usually based on the amount of fossil-fuel-based energy you use and the waste you produce in your everyday actions, as compared to the ability of nature to replenish these resources.)



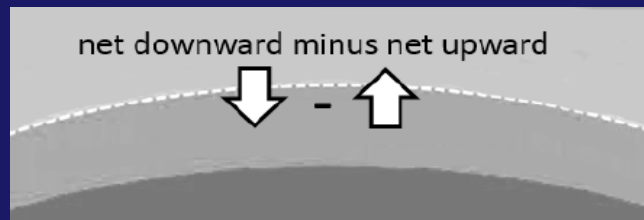
HANDPRINTS: the "**infinite**" good that you can do to make **positive impacts simply by changing the way you do things, at home, at work-- or anywhere** (such as using a refillable water bottle instead of purchasing bottled water; carpooling, taking public transportation and encouraging your friends to ride with you, instead of all driving separately, etc.)

TOPIC # 13

GLOBAL WARMING & ANTHROPOGENIC FORCING (cont.)

Part B

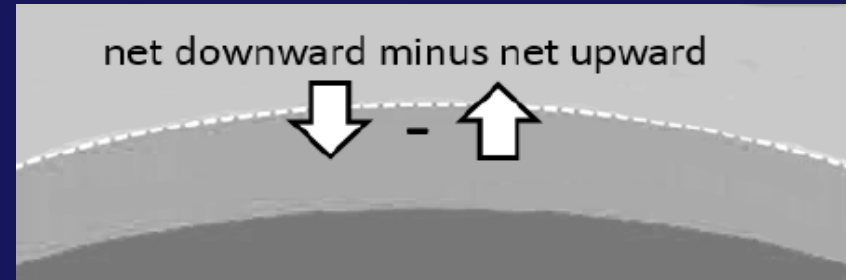
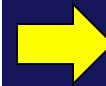
RADIATIVE FORCING




Class Notes pp 86

Radiative Forcing is based on the ENERGY BALANCE at the TROPOPAUSE!

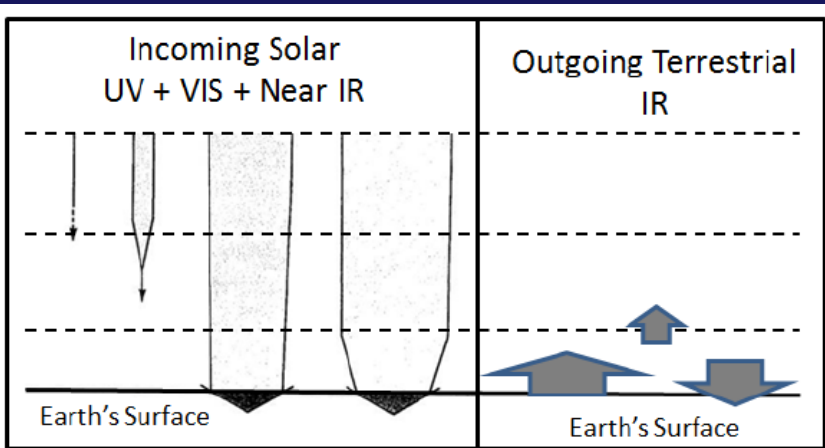
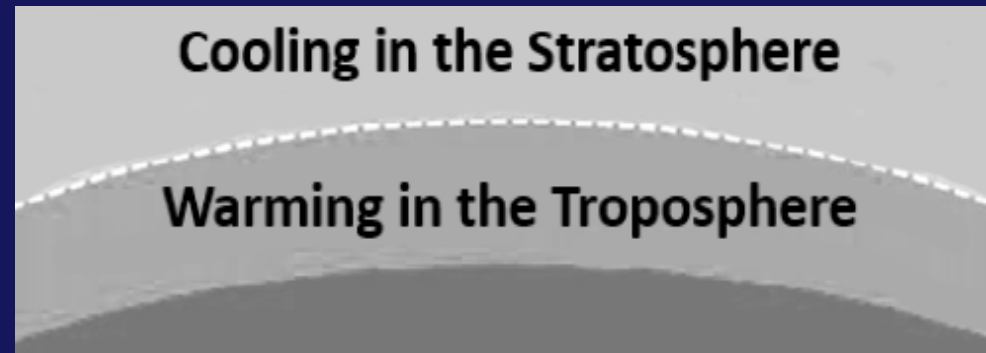
$$R_{NET} = \begin{array}{c} \text{SW} \\ \downarrow \\ \text{SW} \\ \downarrow \\ \text{SW} \\ \searrow \\ \text{LW} \\ \uparrow \\ \text{LW} \\ \downarrow \end{array} + \begin{array}{c} \text{SW} \\ \downarrow \\ \text{LW} \\ \downarrow \end{array} - \begin{array}{c} \text{SW} \\ \searrow \\ \text{LW} \\ \uparrow \end{array} - \begin{array}{c} \text{LW} \\ \uparrow \\ \text{LW} \\ \downarrow \end{array} + \begin{array}{c} \text{LW} \\ \downarrow \end{array}$$



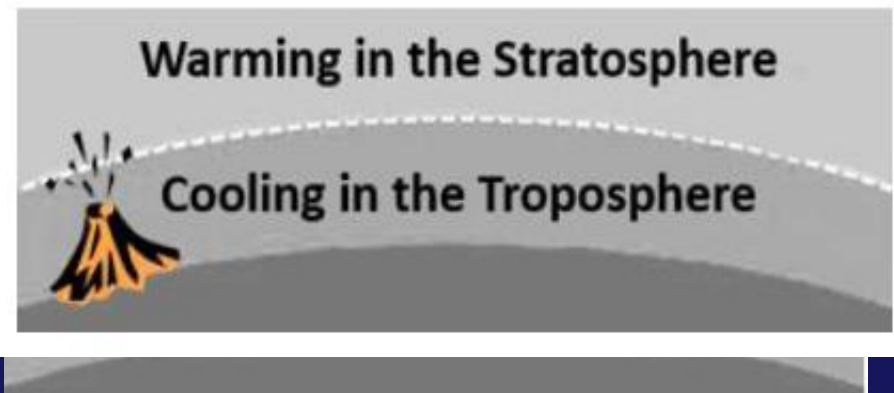
It's an index of the degree to which different factors (like GHG's) INCREASE or DECREASE the amount of energy that accumulates in the TROPOSPHERE.

 **Radiative Forcing (RF)** - Radiative forcing is the change in the net, downward (incoming) minus upward (outgoing), **irradiance** (expressed in W/m^2) at the *tropopause* due to a change in an external driver of *climate change*, such as, for example, a change in the concentration of *carbon dioxide* or the output of the Sun.

Greenhouse Warming Signature



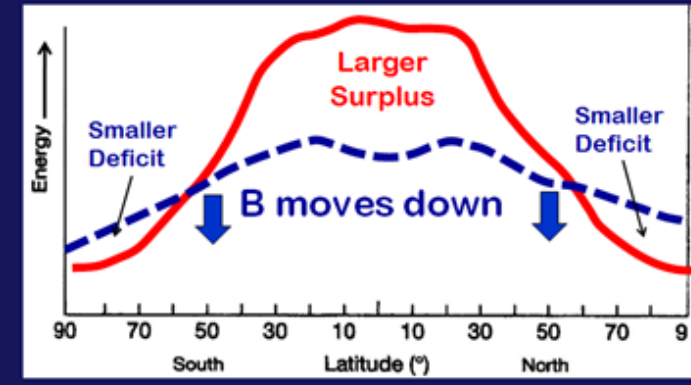
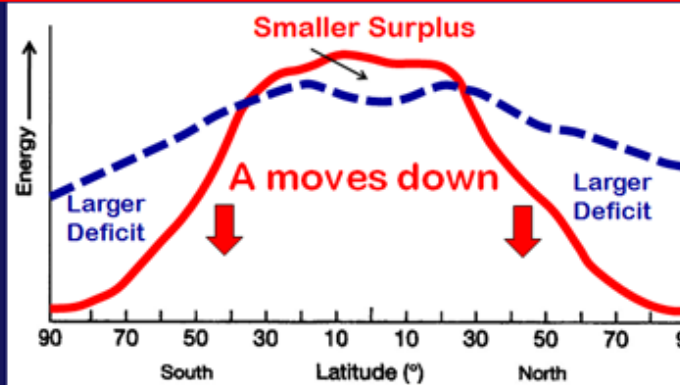
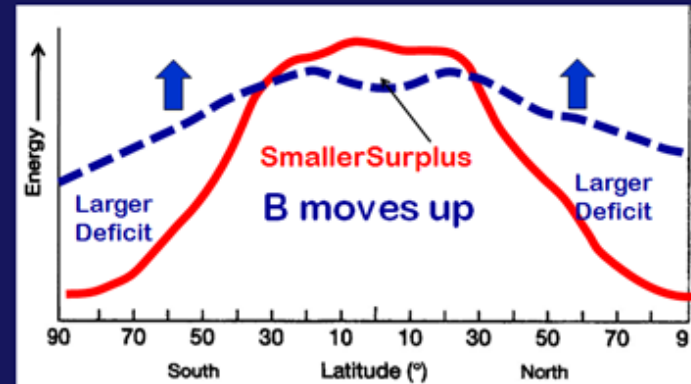
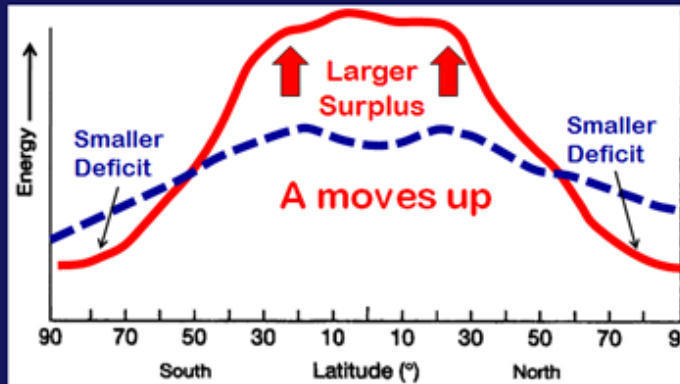
The Volcanic Aerosol Signature:



Earlier info
from p 37

G-5 Volcanism Activity:

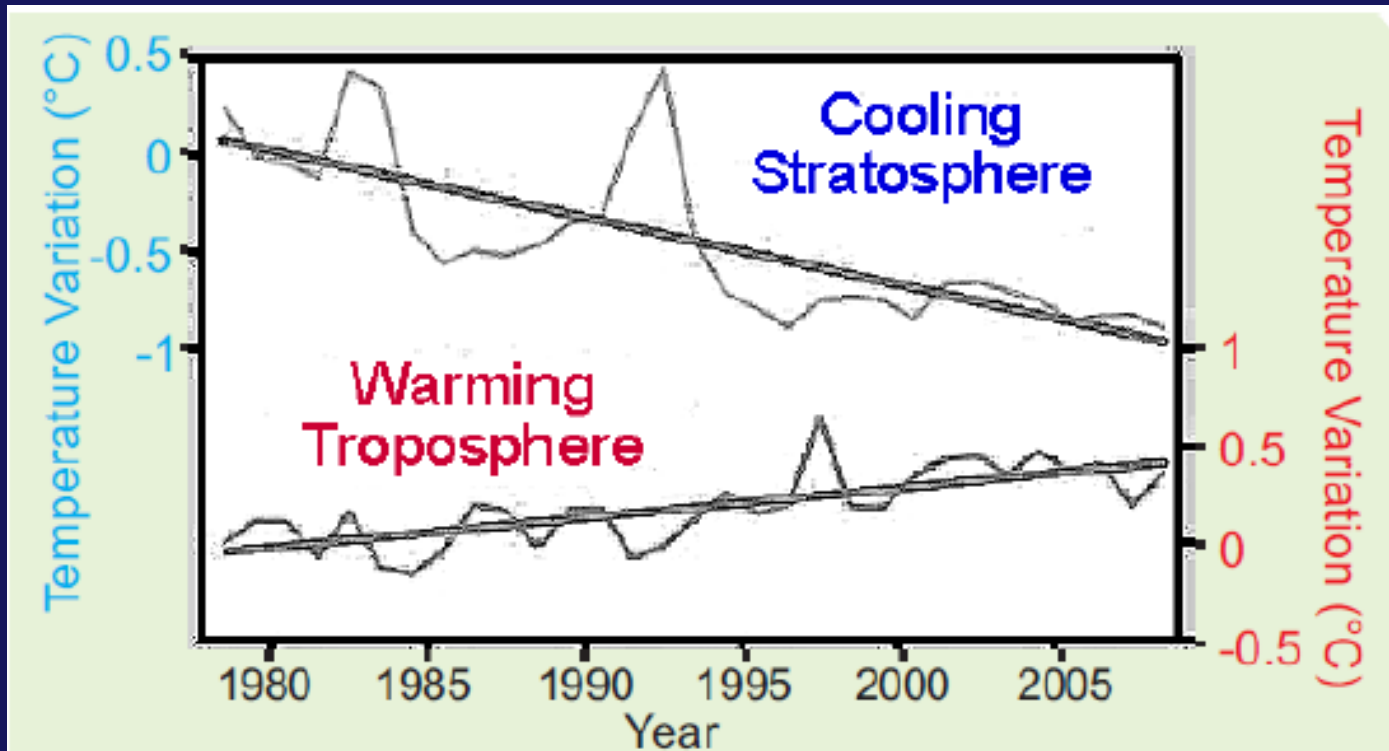
Show how the energy balance would change if a major volcanic eruption occurred:



WHICH ONE IS RIGHT ?

Does the change affect CURVE A or CURVE B?

Here's what's been happening in recent decades:



Graphs showing temperature variations (degrees C)
in the stratosphere and troposphere
(measured by satellites)

THE KEY TO IT ALL:

RADIATIVE FORCING

(linked to the Energy Balance!)

$$R_{\text{NET}} = \begin{array}{c} \text{SW} \\ \downarrow \\ \text{+} \\ \text{SW} \\ \downarrow \\ \text{-} \\ \text{SW} \\ \nearrow \\ \text{-} \\ \text{LW} \\ \uparrow \\ \text{+} \\ \text{LW} \\ \downarrow \end{array}$$

expressed in Watts per square meter (Wm^{-2}) = ENERGY!

(def) a measure of the influence a factor has in altering the balance of **incoming & outgoing energy** in the Earth-atmosphere system

... more specifically →

RADIATIVE FORCING = a measure of the influence a factor has in altering the balance of **incoming ↓ and outgoing ↑ energy** in the Earth-atmosphere system

- ✓ It is an index of the importance of a factor as a potential climate change mechanism.
- ✓ It is expressed in Watts per square meter (W/m^2)

RADIATIVE FORCINGS ARE THE KEY TO WHAT'S GOING ON!

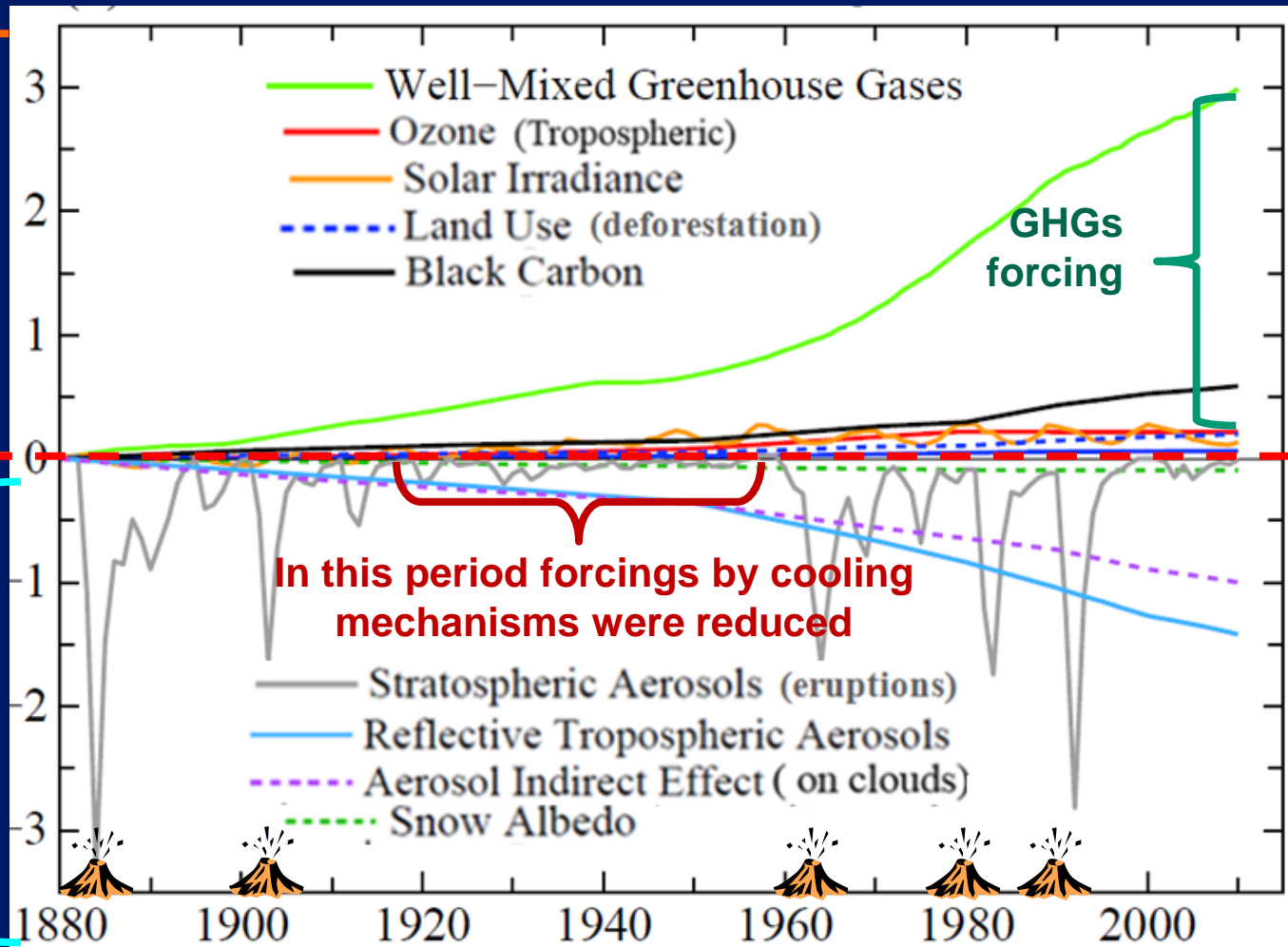
ABOVE THE 0 LINE:

Forcing by mechanisms that cause **warming** in the troposphere

0 line = 1880 value

BELOW THE 0 LINE:

Forcing by mechanisms that cause **cooling** in the troposphere

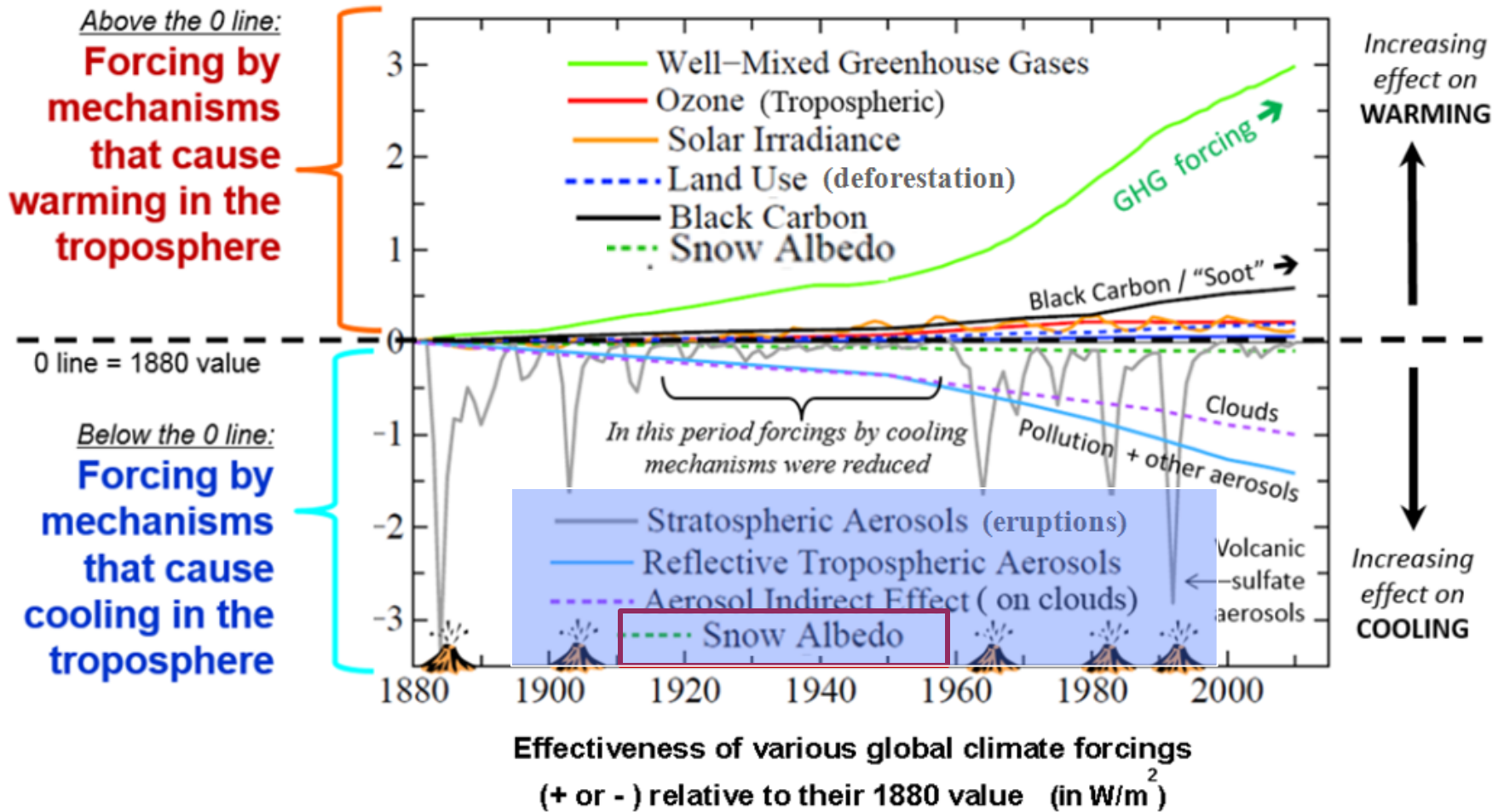


Effectiveness of various global climate forcings (in W/m^2) relative to their 1880 value

(figure from NASA GISS <http://data.giss.nasa.gov/modelforce/>)

How pollution & other human influences affect **RADIATIVE FORCINGS** . . .

RADIATIVE FORCING MECHANISMS





11,000 jet trails in 8 hours
33,000 in 24 hours

Jet Trails, 2007

Photographic artist, Chris Jordan



MOVIE TIME!



“New evidence that **AIR POLLUTION** has masked the full impact of global warming suggests the world may soon face a heightened climate crisis.”

Program segments link:

http://services.oia.arizona.edu/MediaServices/katie/dimming_the_sun.wvx




http://www.pbs.org/wgbh/nova/transcripts/3310_sun.html

Global Solar Dimming effect is about half as strong as Global Warming

Global dimming

aerosols from pollution reflect
 back to space

Less solar reaches the surface

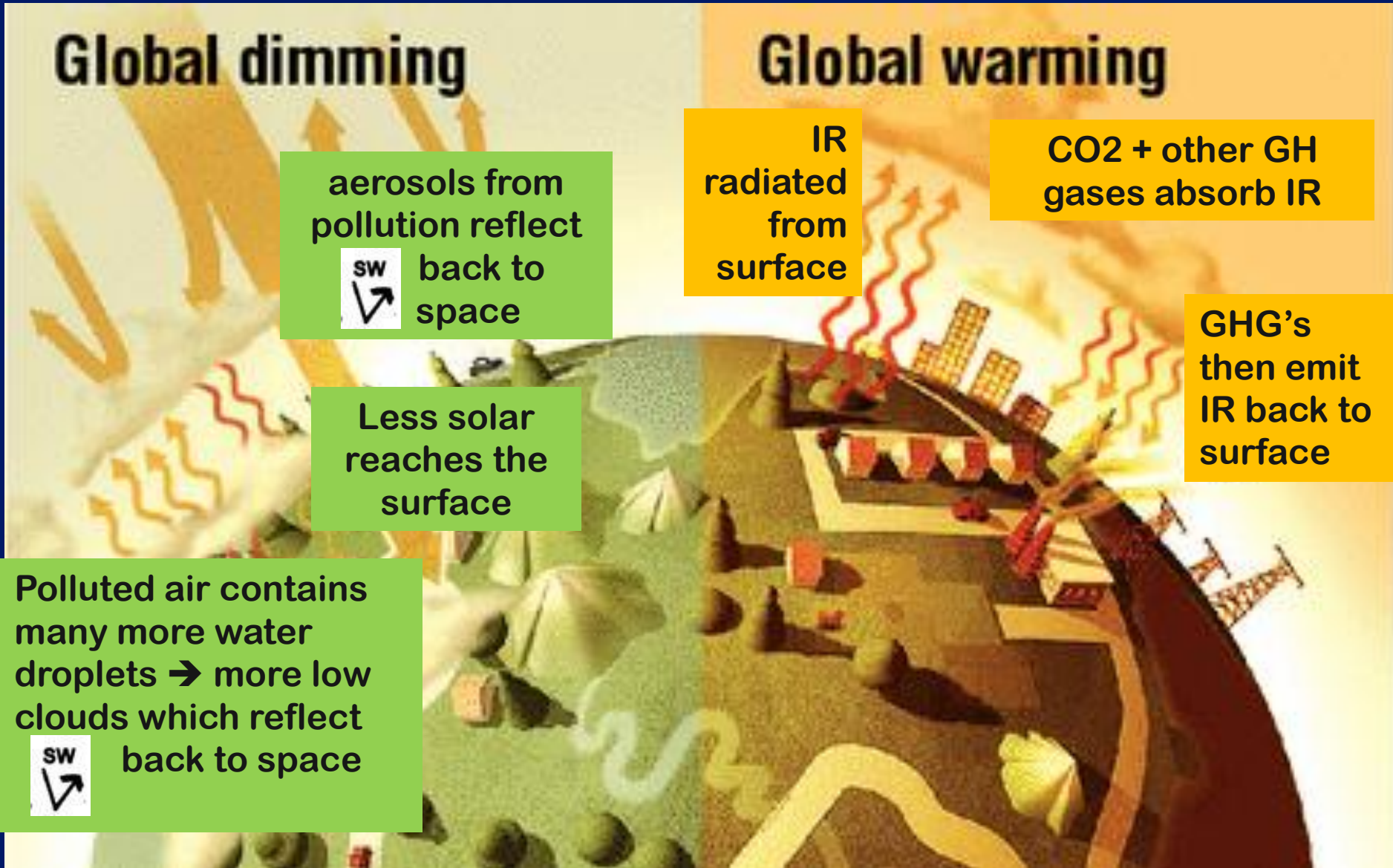
Polluted air contains many more water droplets → more low clouds which reflect
 back to space

Global warming

IR radiated from surface

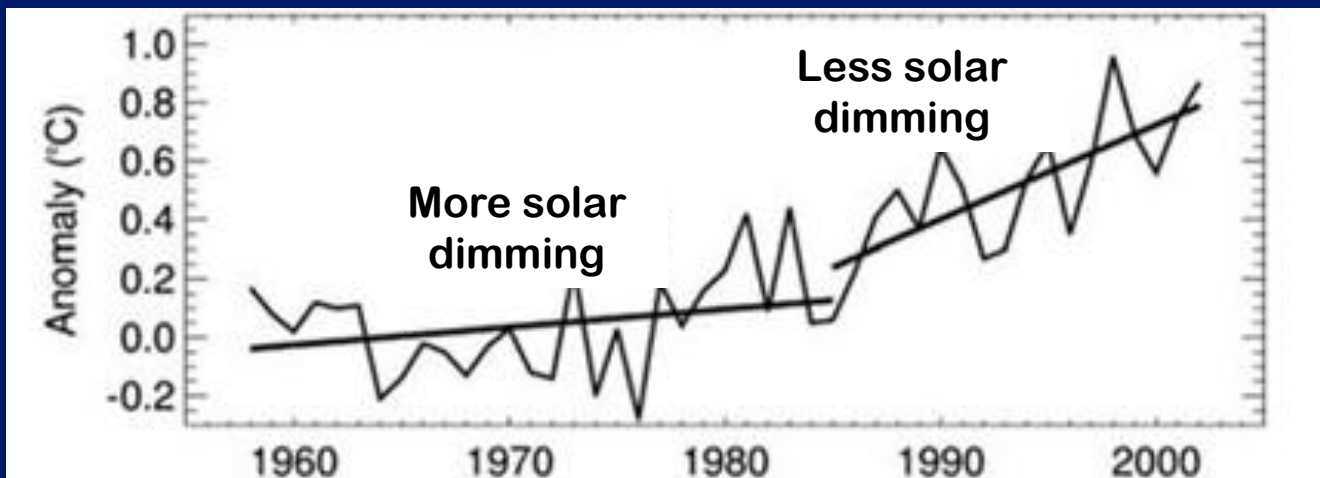
CO₂ + other GH gases absorb IR

GHG's then emit IR back to surface



Solar Dimming may have “masked” the intensity of warming from the Enhanced GH Effect . . . until recently!

Average Temperature Change
over Global Land Surfaces (1958 – 2002)



*Thick-cloud
air pollution common;
health problems, deaths*



**Clean Air
Act of 1970**
*stronger law;
EPA established
later that year*

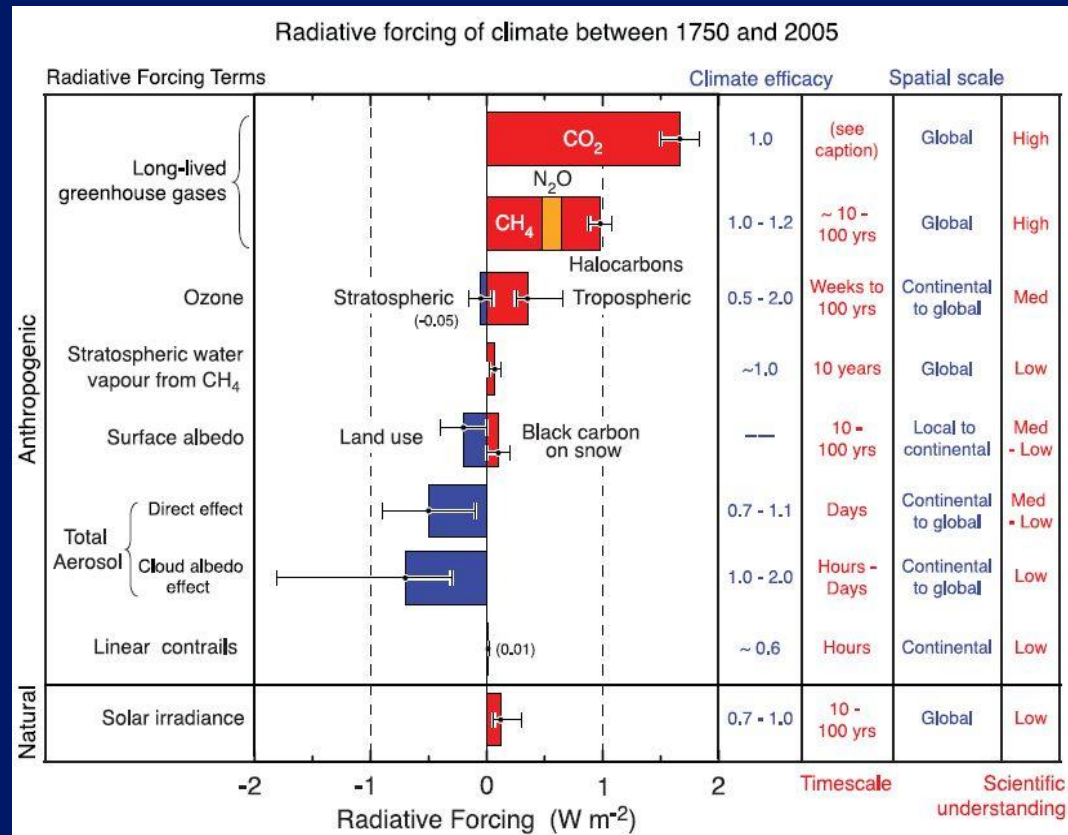
**Clean Air
Act of 1990**
*EPA more implementation +
enforcement authority;
increased emphasis on
cost-effectiveness*

Clean Air Act of 1963
*funding to study health effects; federal
+ state laws promote clean air*



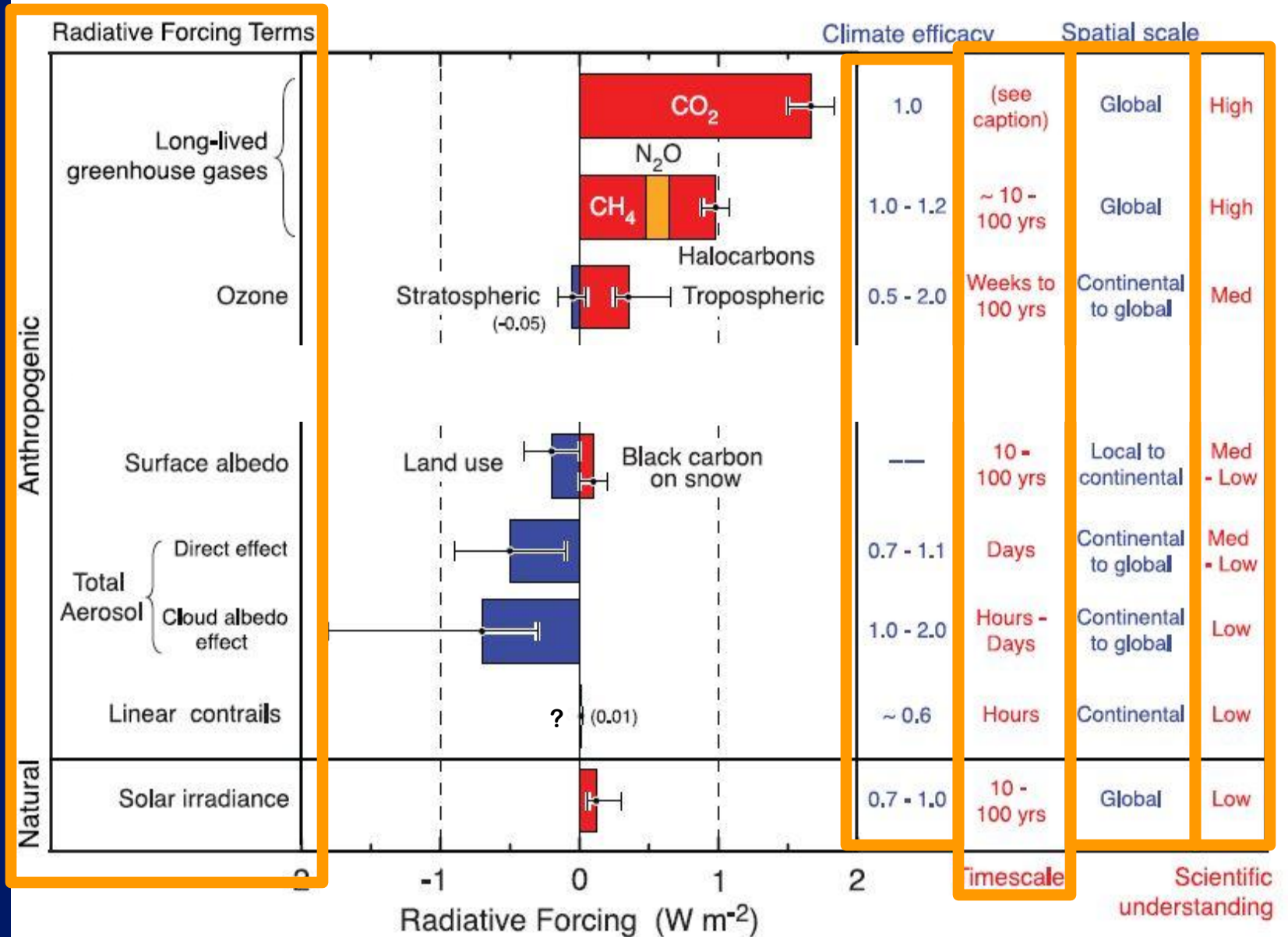
The Key To It All:

RADIATIVE FORCING OF CLIMATE



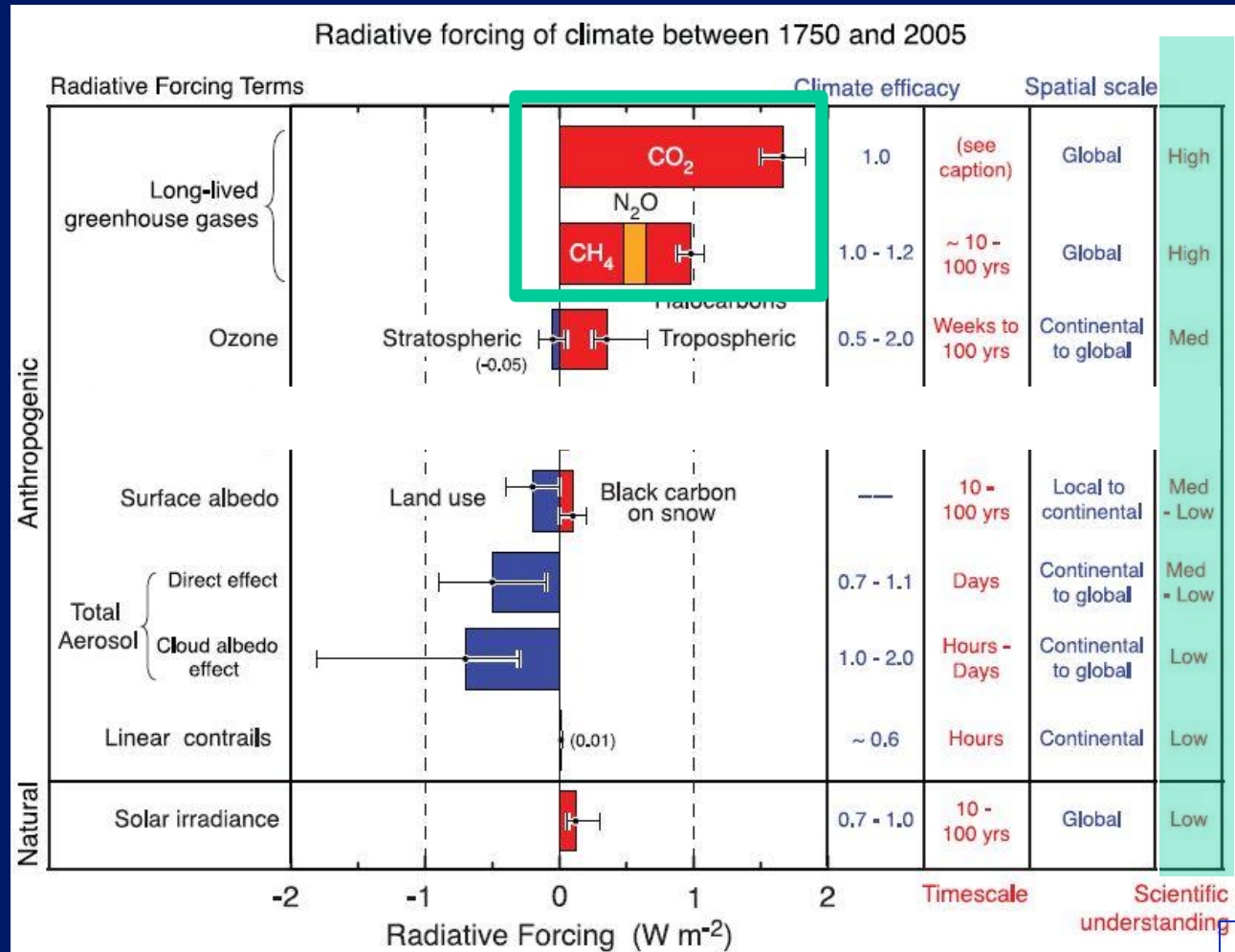
Top graph on p 87 from 2007 IPCC report

Radiative forcing of climate between 1750 and 2005



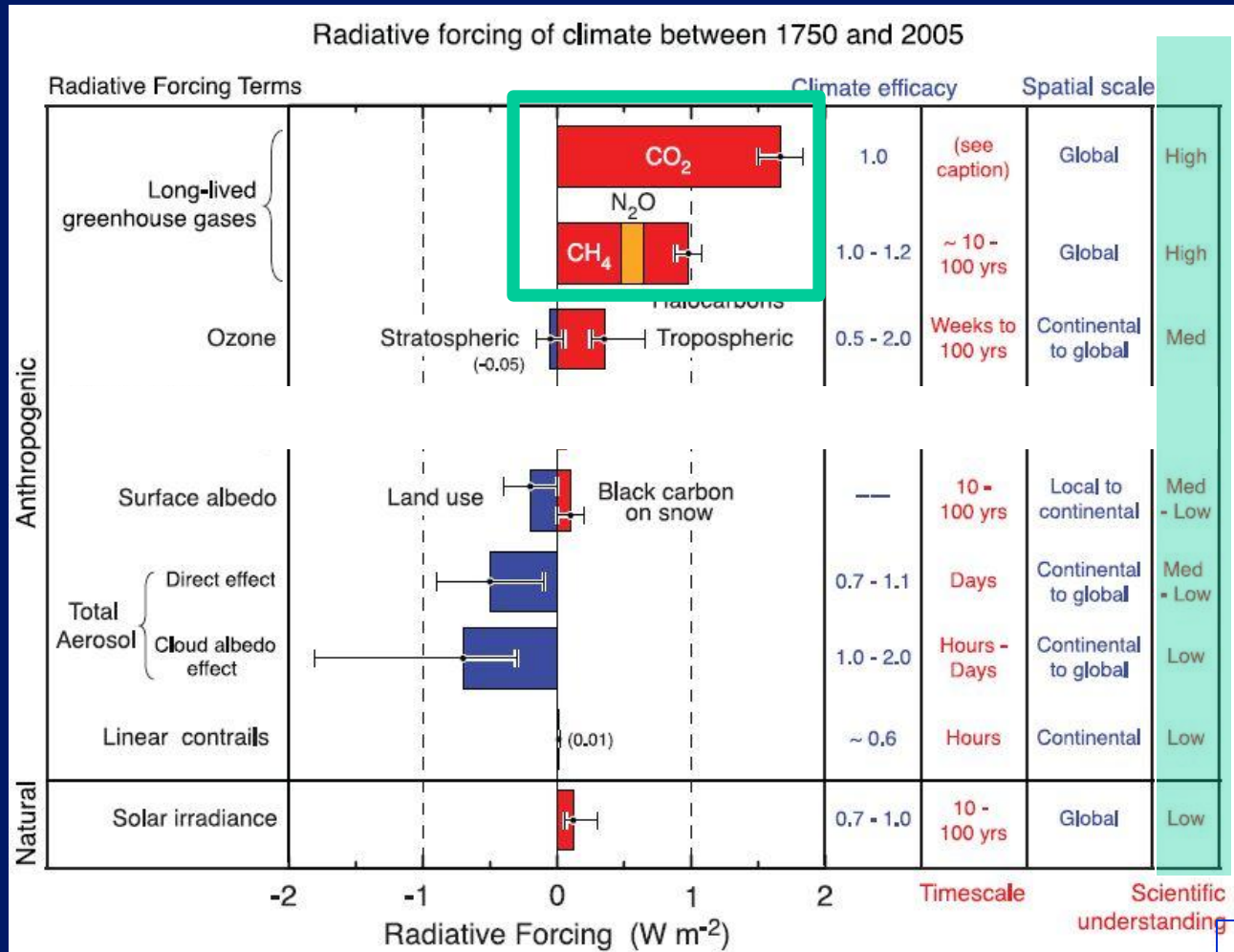
Q1 The figure shows that the forcing mechanism that is **BEST understood** by scientists is also the one that leads to the **greatest climatic impact**.

1. TRUE
2. FALSE



Q1 The figure shows that the forcing mechanism that is **BEST understood** by scientists is also the one that leads to the **greatest climatic impact**.

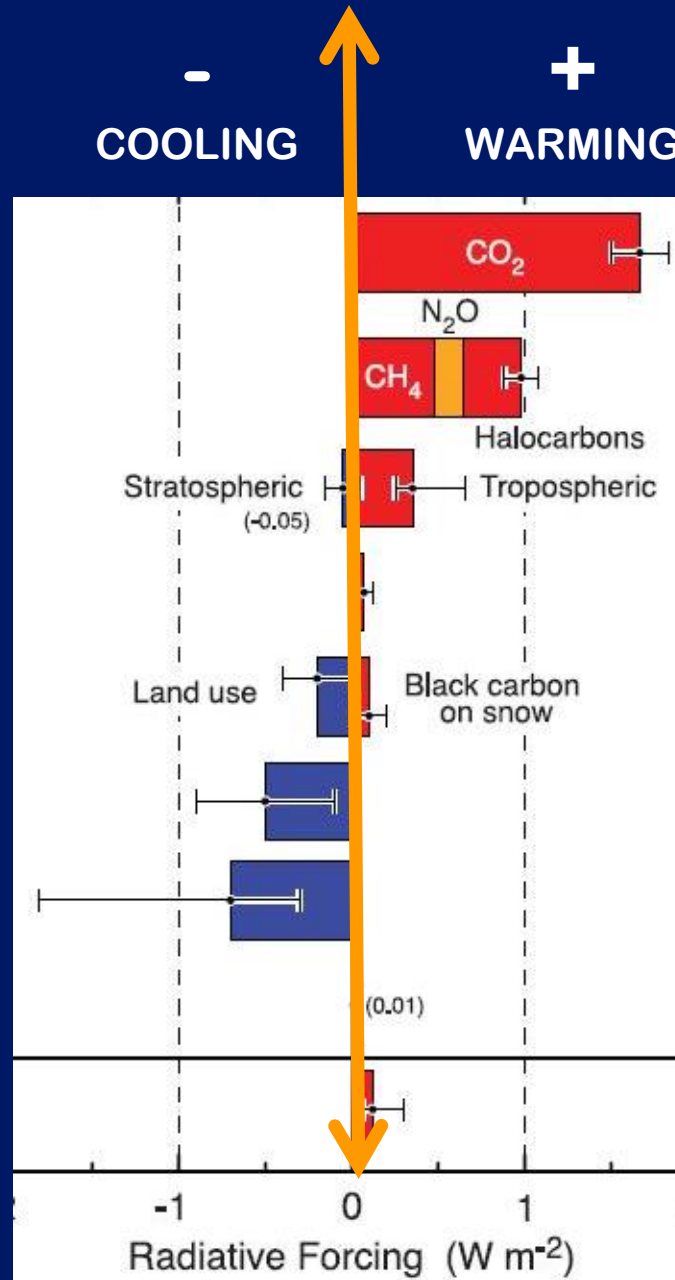
1. TRUE
2. FALSE



WHAT TO KNOW:

If the forcing is NEGATIVE (to left of line)

it means that an increase in that gas or factor contributes to **COOLING** in the troposphere.

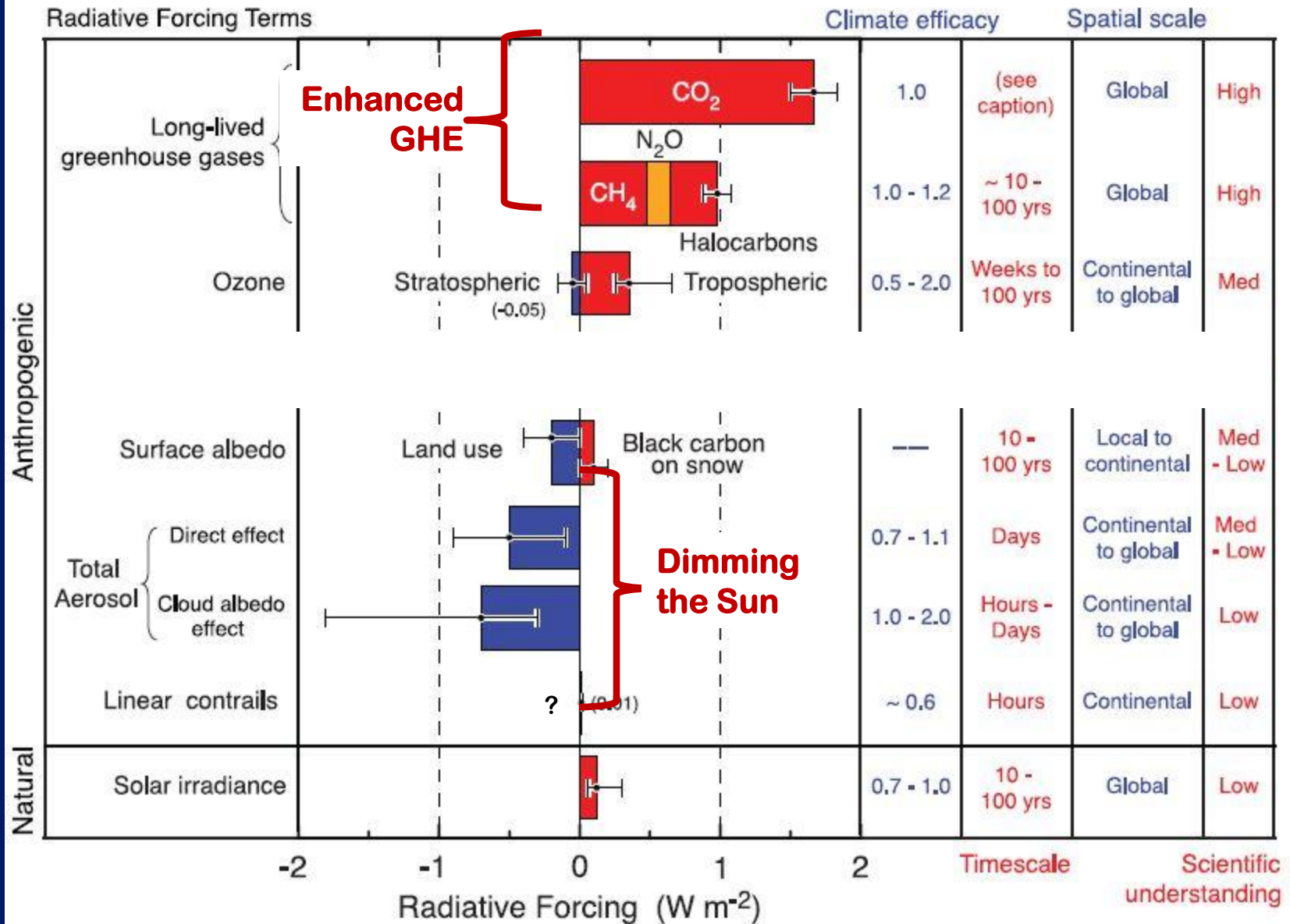


If the forcing is POSITIVE (to right of line)

it means that an increase in that gas or factor contributes to **WARMING** in the troposphere.

Top graph on p 87 from 2007 IPCC report

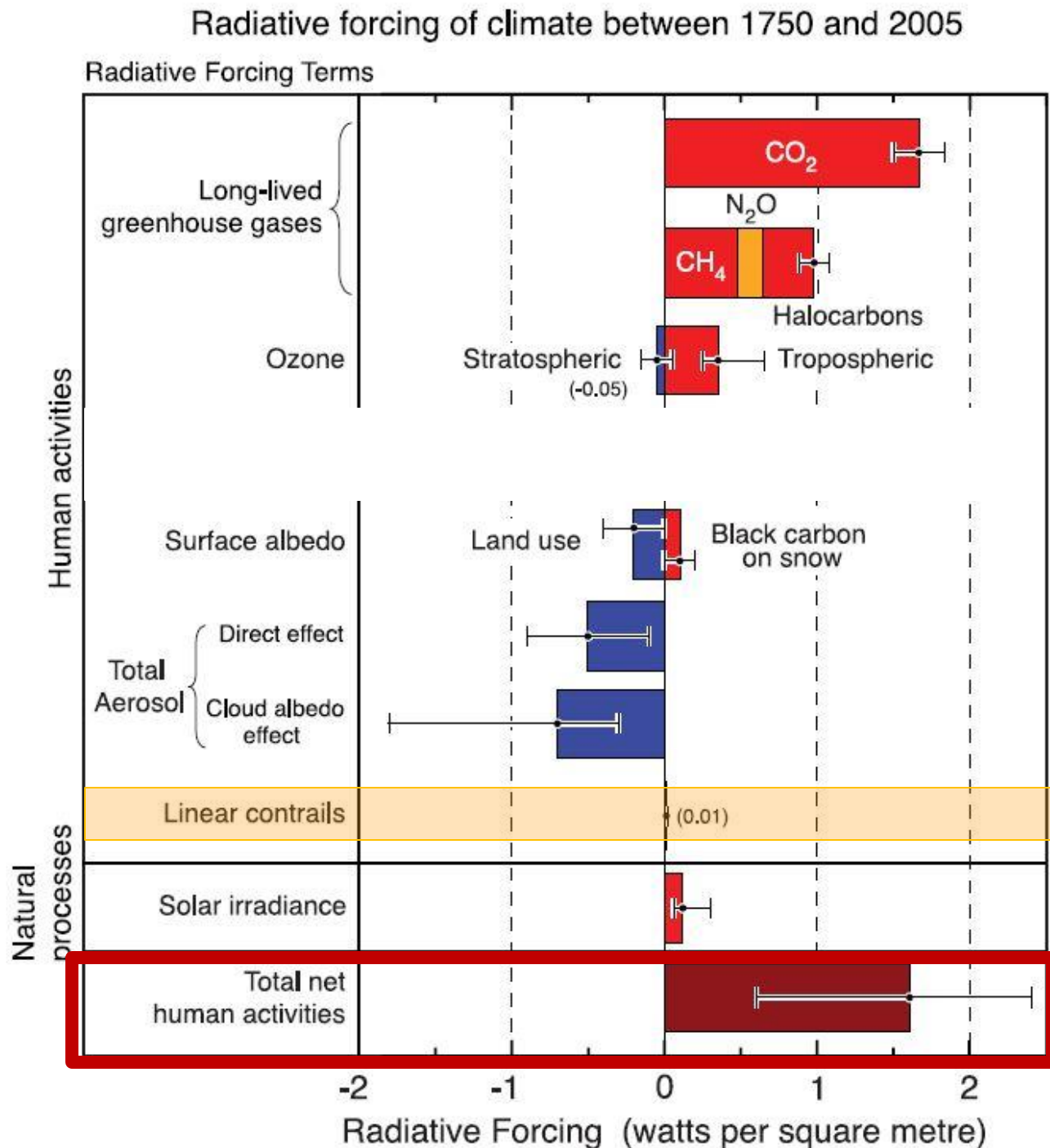
Radiative forcing of climate between 1750 and 2005



Climate Change
2007 - IPCC
The Physical
Science Basis
Working Group 1
Report

FAQ 2.1

How do Human
Activities
Contribute to
Climate
Change and
How do They
Compare with
Natural
Influences?



BOTTOM graph on p 87 from 2013 IPCC:

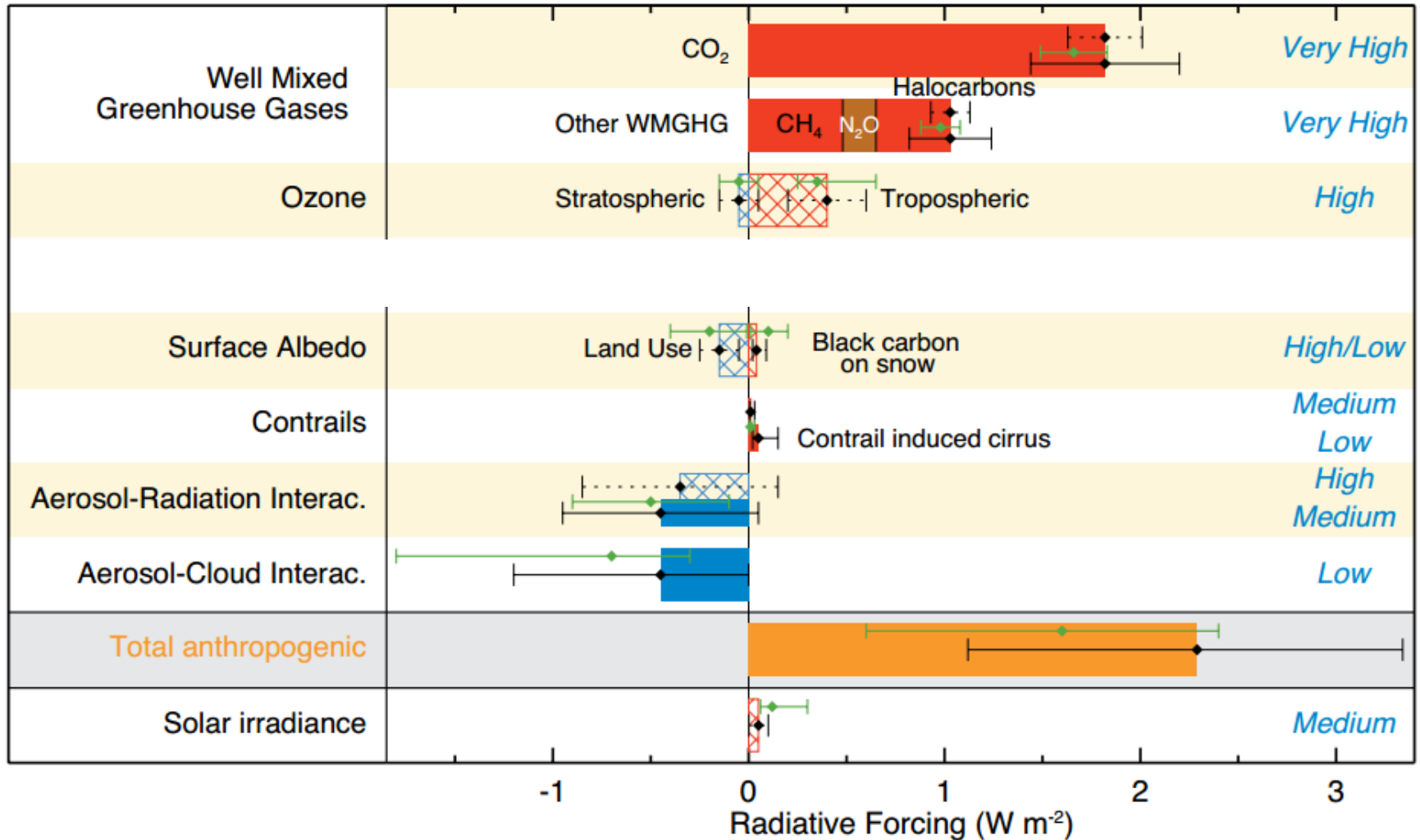
Radiative forcing of climate between 1750 and 2011

Forcing agent

Confidence Level

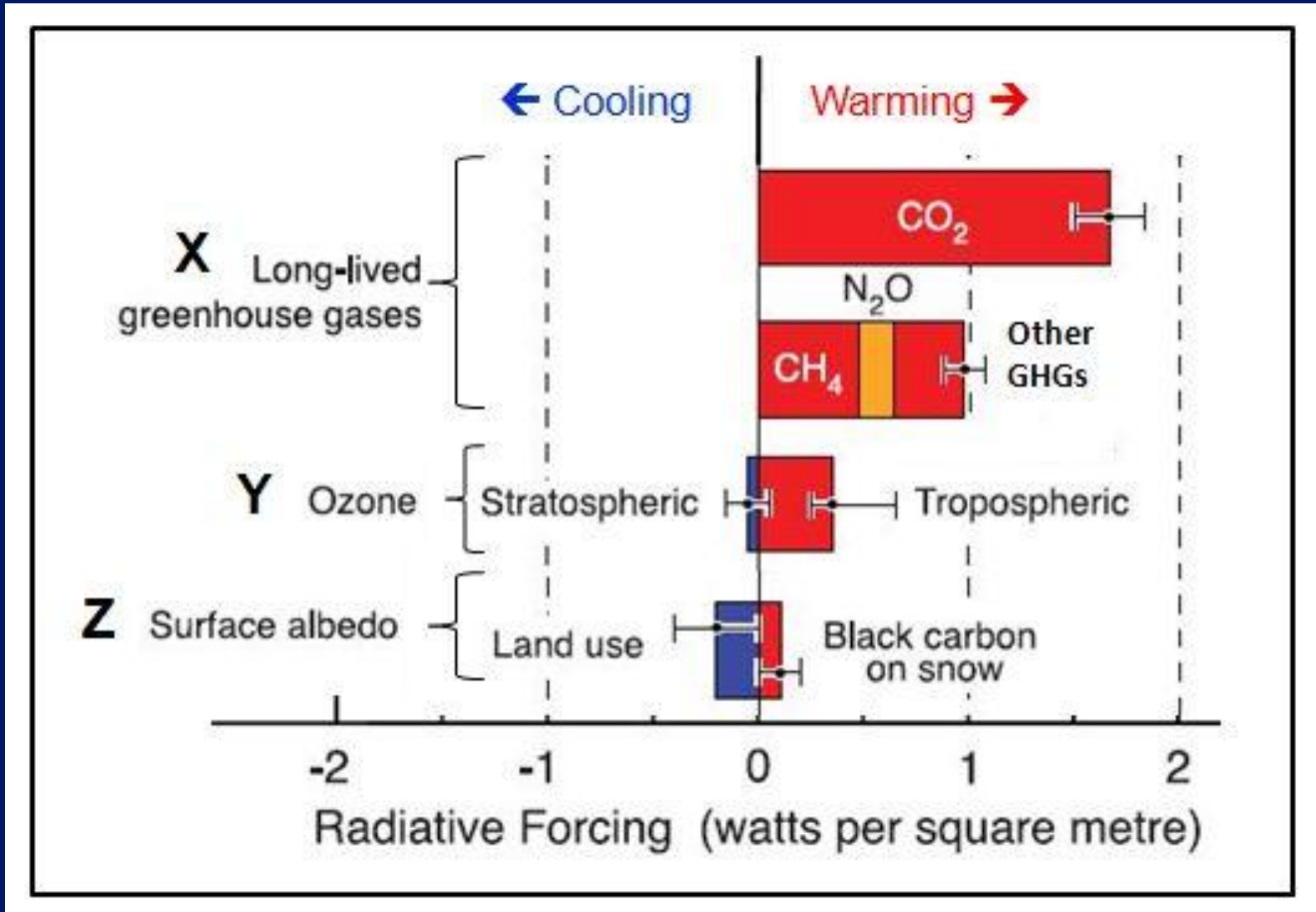
Anthropogenic

Natural



Q -ALL of the forcing mechanisms shown here (X, Y, & Z) are linked to anthropogenic activity in some way:

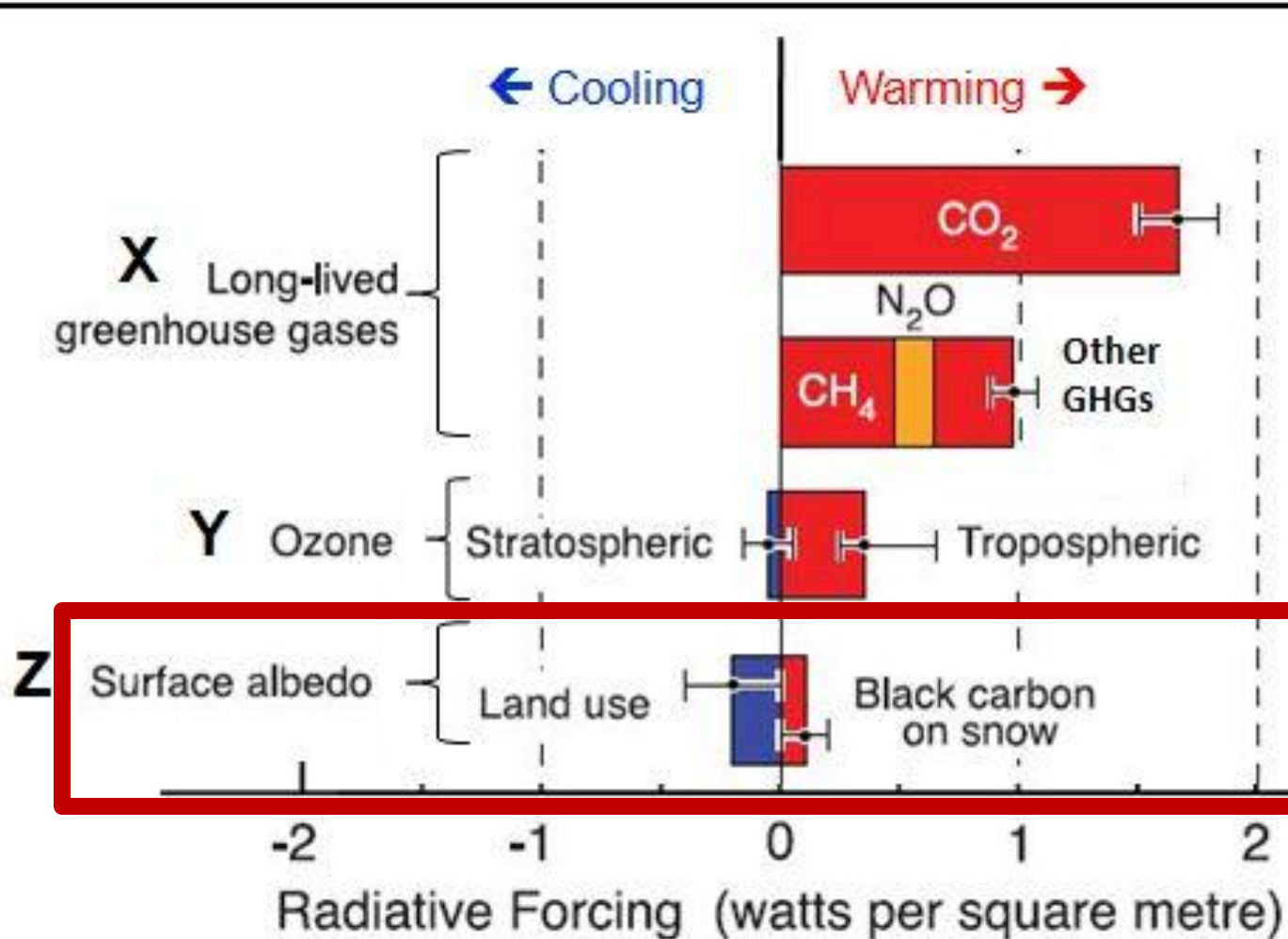
1. TRUE 2. FALSE



Q -ALL of the forcing mechanisms shown here (X, Y, & Z) are linked to anthropogenic activity in some way:

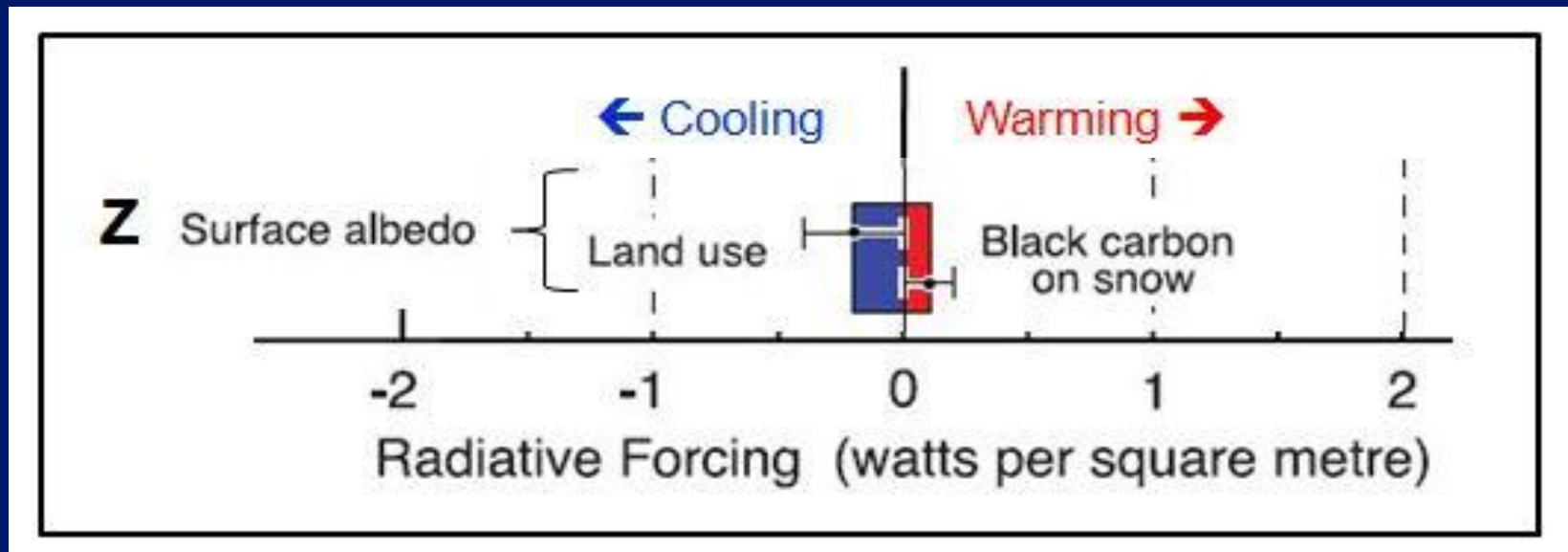
1. TRUE

2. FALSE



Q -The figure shows that **forcing mechanism Z** (Land-use as indicated by albedo) leads to **COOLING** The reason for this is that **cooling** occurs when surface albedo *increases* and hence **MORE** energy is **absorbed**.

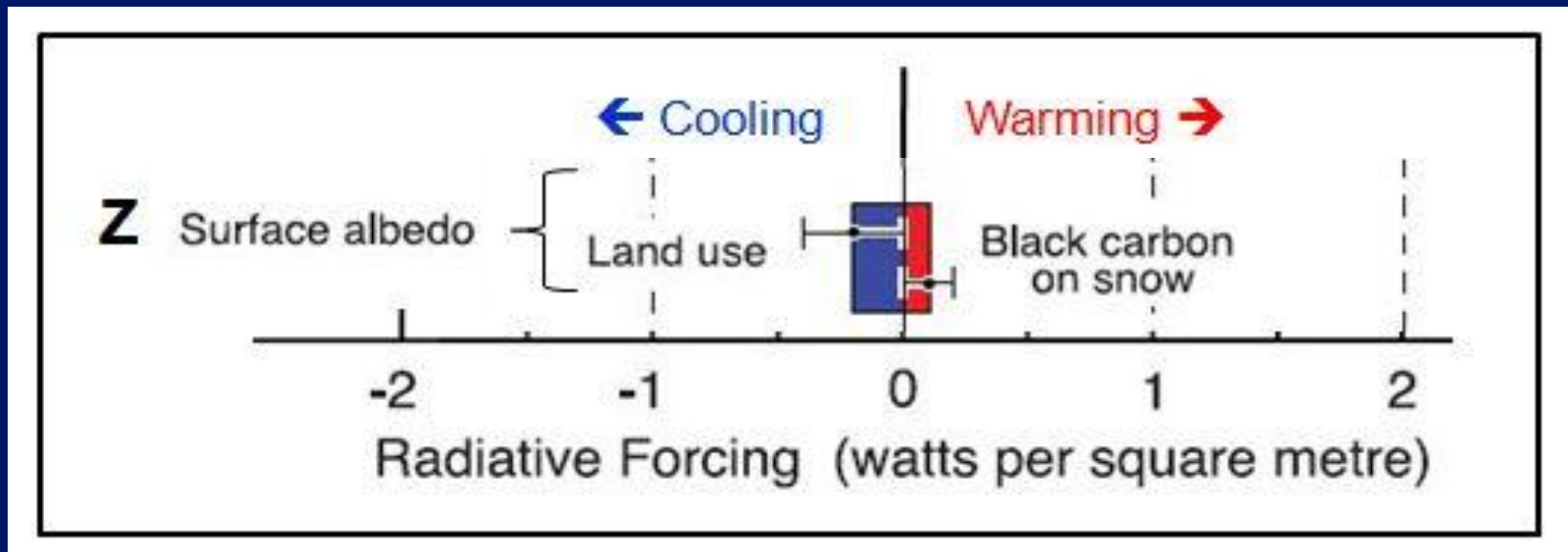
TRUE or FALSE?



LESS energy is absorbed!

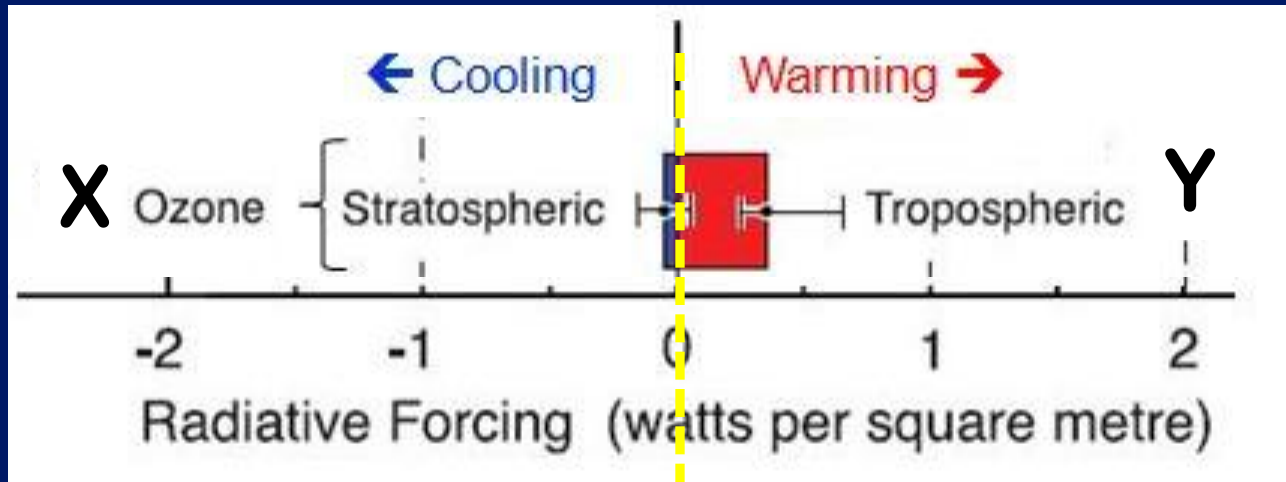
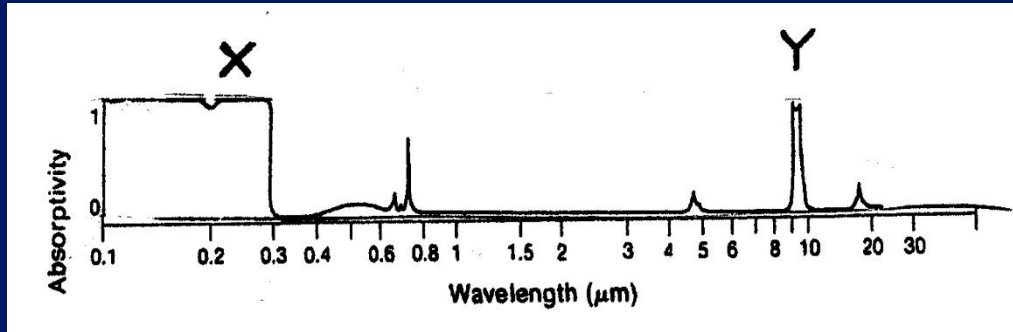
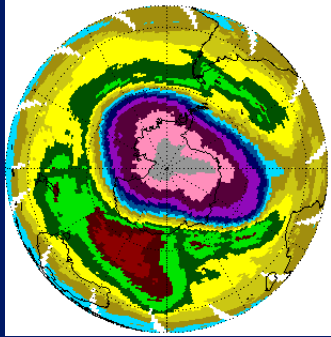
Q -The figure shows that **forcing mechanism Z** (Land-use as indicated by albedo) leads to **COOLING** The reason for this is that **cooling** occurs when surface albedo *increases* and hence **MORE** energy is **absorbed**.

TRUE or FALSE?



LESS energy is absorbed!

OZONE'S DUAL PERSONALITY!

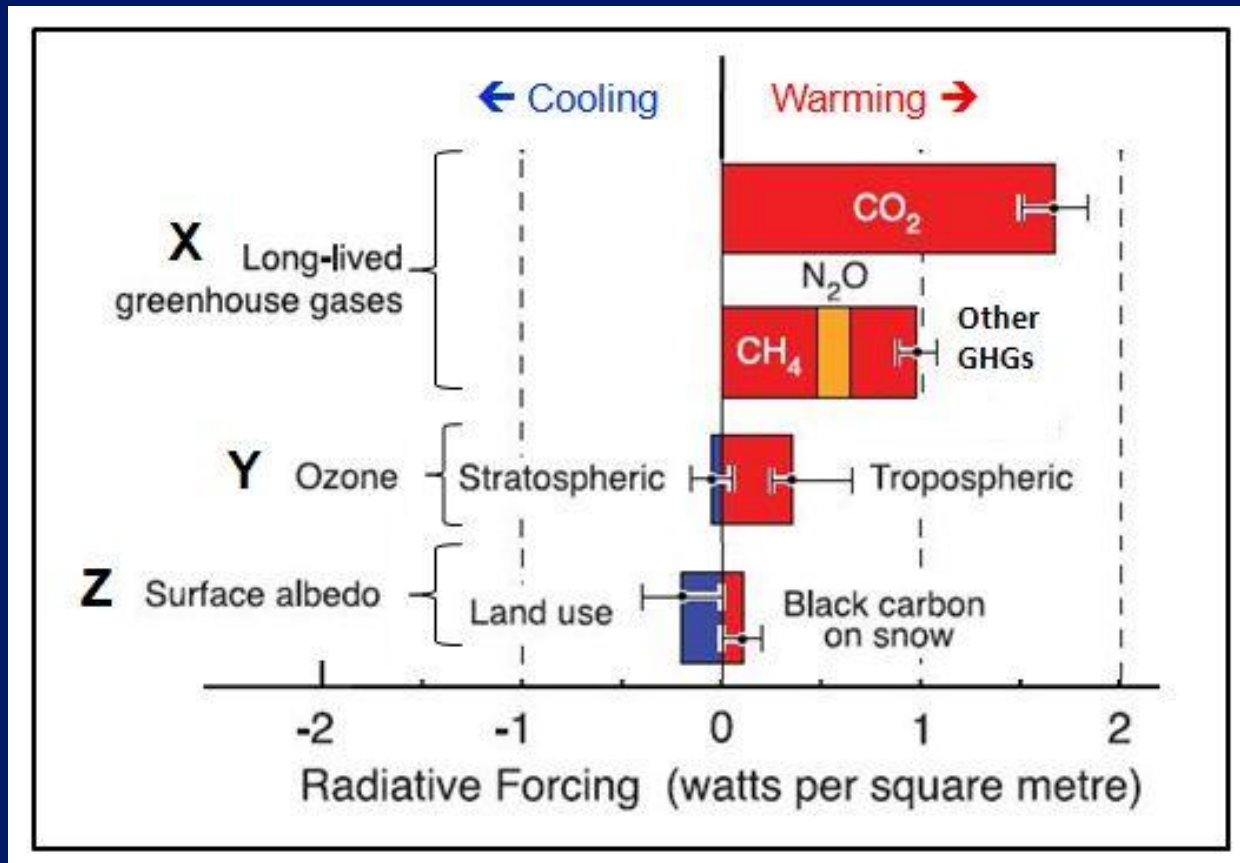


An INCREASE of Stratospheric Ozone will absorb more UV in the stratosphere → less UV getting into the troposphere → a COOLER Troposphere

An INCREASE of Tropospheric (ground-level) Ozone will add to the Greenhouse Effect → more IR staying in the troposphere → a WARMER Troposphere

Q -According to the figure which forcing mechanism has a GREATER influence on global temperature?

Stratospheric OZONE OR Tropospheric OZONE

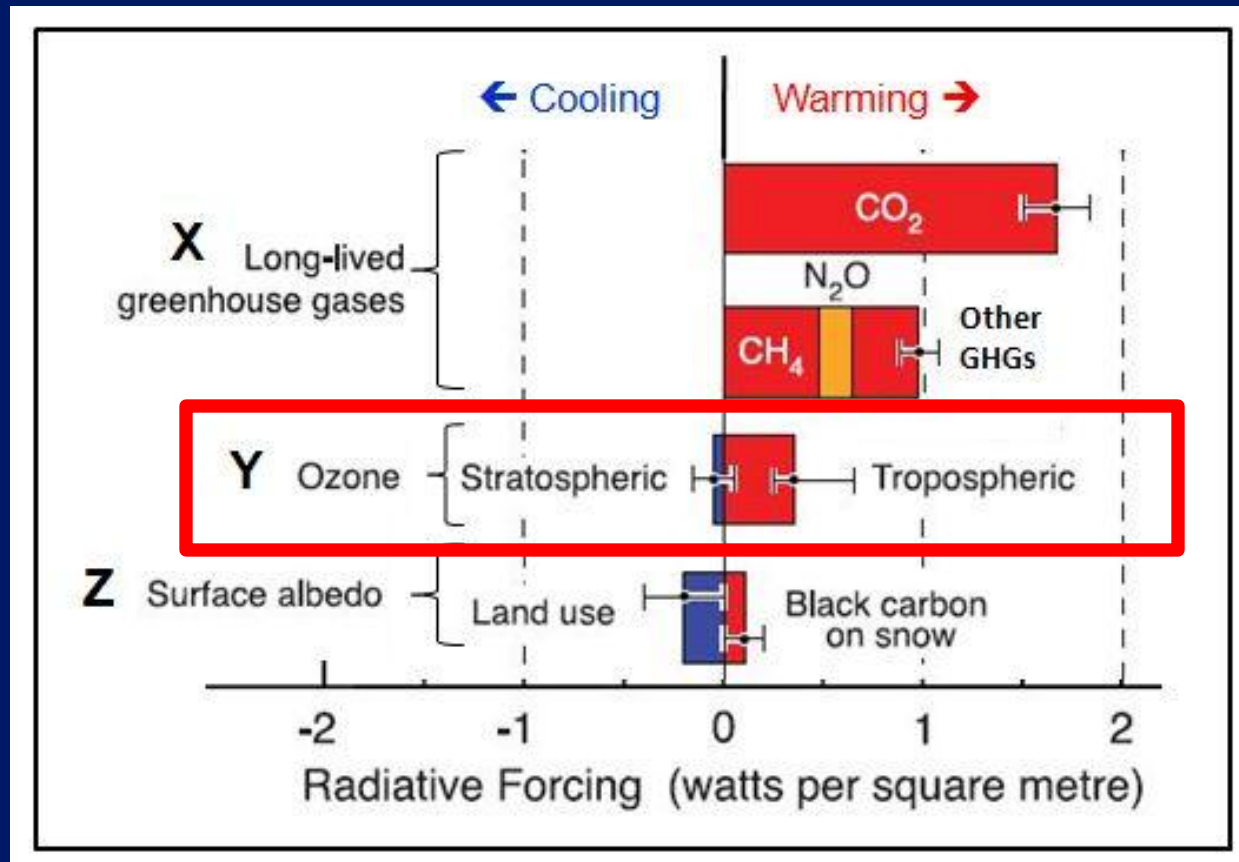


Q -According to the figure which forcing mechanism has a GREATER influence on global temperature?

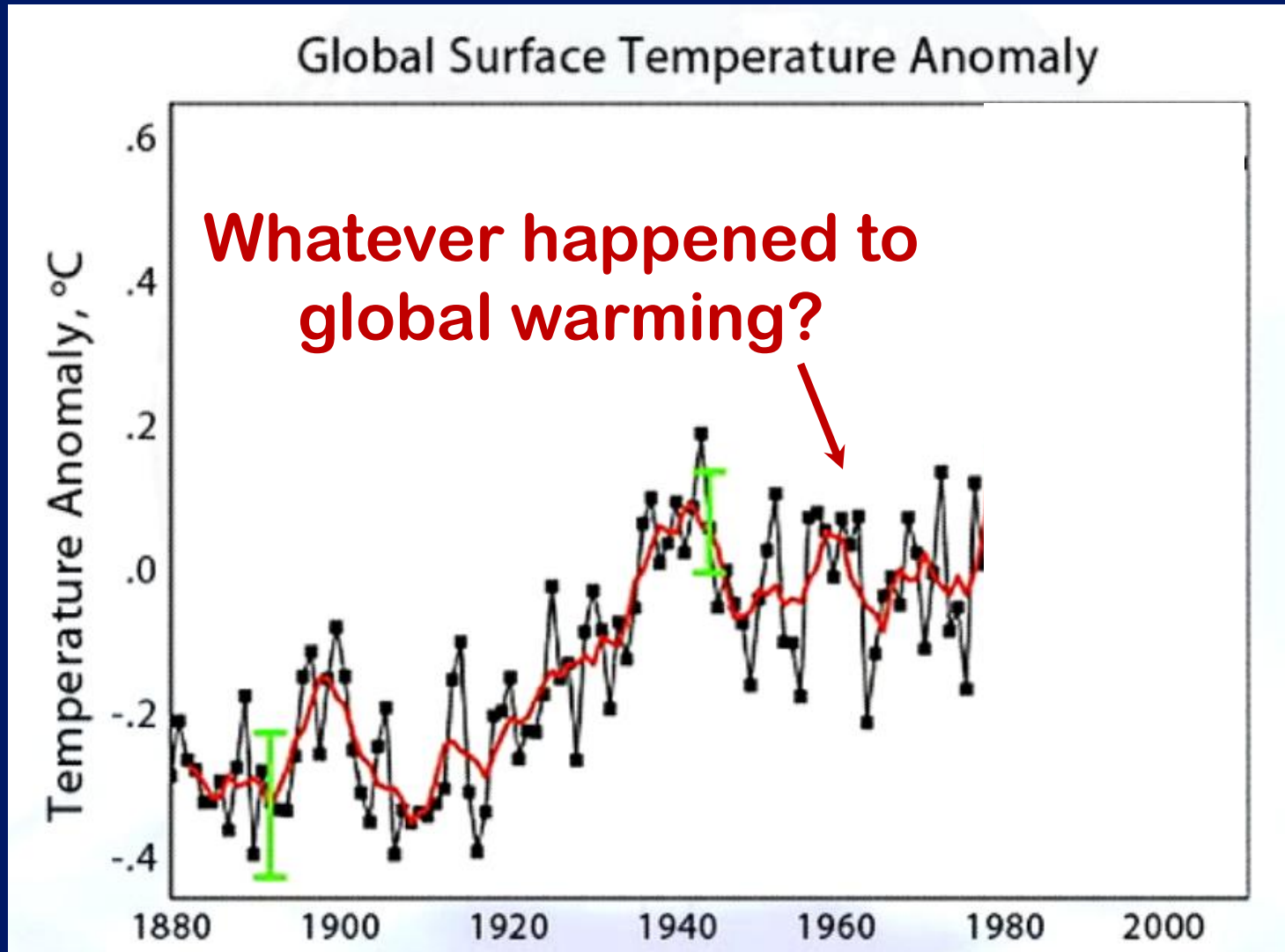
Stratospheric OZONE

OR

Tropospheric OZONE



Therefore, the Stratospheric Ozone Hole is NOT the main cause of global warming!



Buffalo reeling; more snow coming

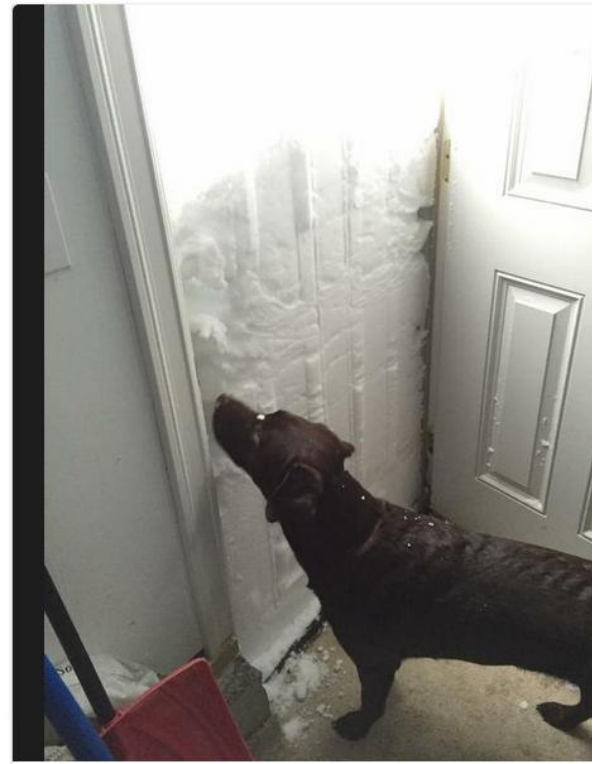
This week's total will come close to its yearly average

By Cindy Doman
 BUFFALO, N.Y. — In a town where snow is a constant companion, the Buffalo, N.Y., residents are used to winter weather. But the heavy snowfall that hit the city last week was a bit different. It was a record-breaking amount of snow for the city, and it was falling on a day when many people were still in their winter coats. The snow was so heavy that it was difficult to walk on the streets. Many people were stuck in traffic, and some were unable to get to work or school. The snow was also a problem for businesses, as many were closed for the day. The snow was a reminder that winter is still here, and it is important to be prepared for more snow.



Children with a five-foot snow drift and a giant in the snow in Buffalo, N.Y., last week. The snow was so heavy that it was difficult to walk on the streets.

Whatever happened to global warming?



Joel D. Smith
 @JoelDReports
 Mother Nature's new Beer Cooler! Available now in Buffalo
 RT@seguifox13
 This is genius! About 6' of #snow in Buffalo

Lake-effect snow machine

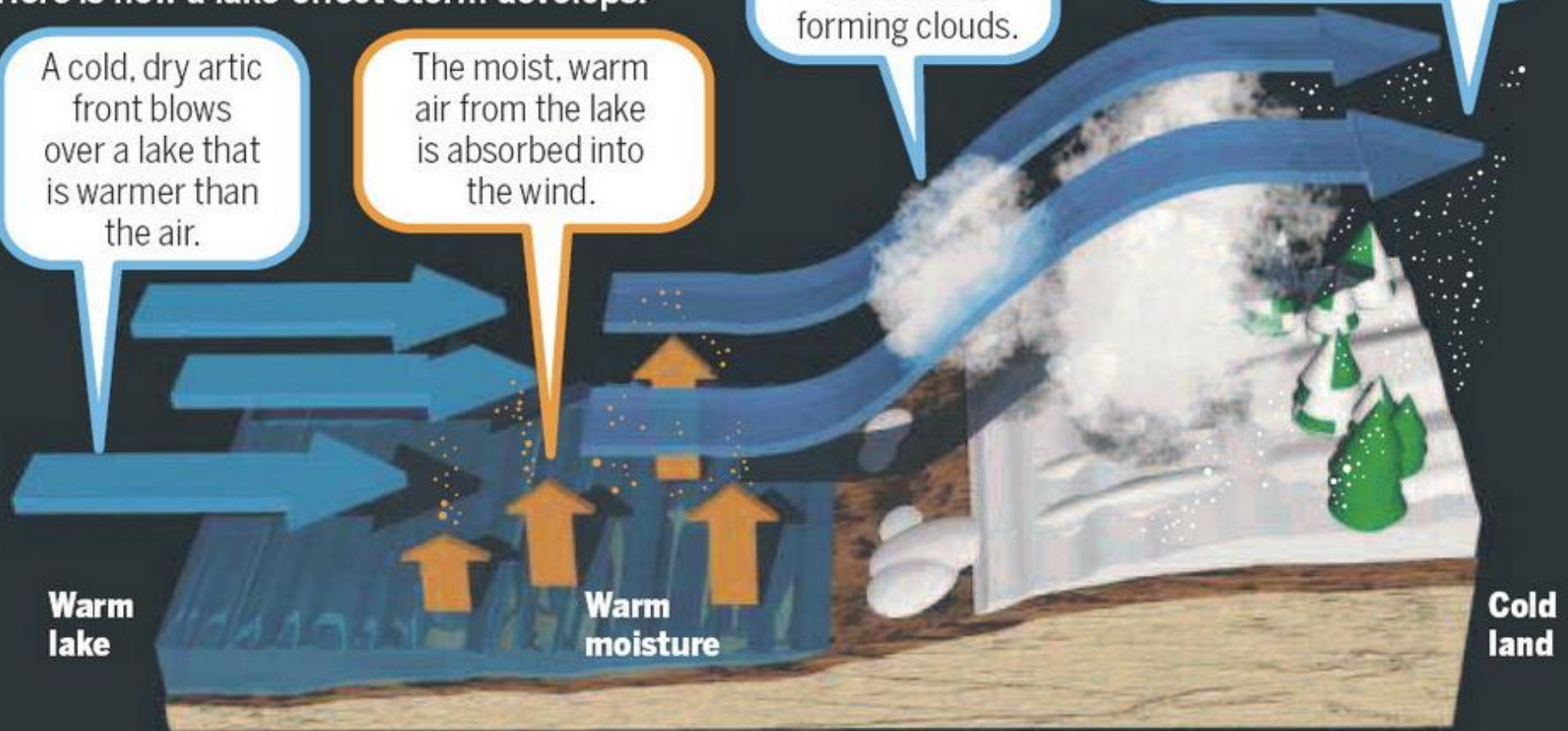
A fierce storm swept off the Great Lakes and buried western New York state under as much as 6 feet of snow, killing at least six people and stranding motorists in cars overnight. Here is how a lake-effect storm develops.

A cold, dry arctic front blows over a lake that is warmer than the air.

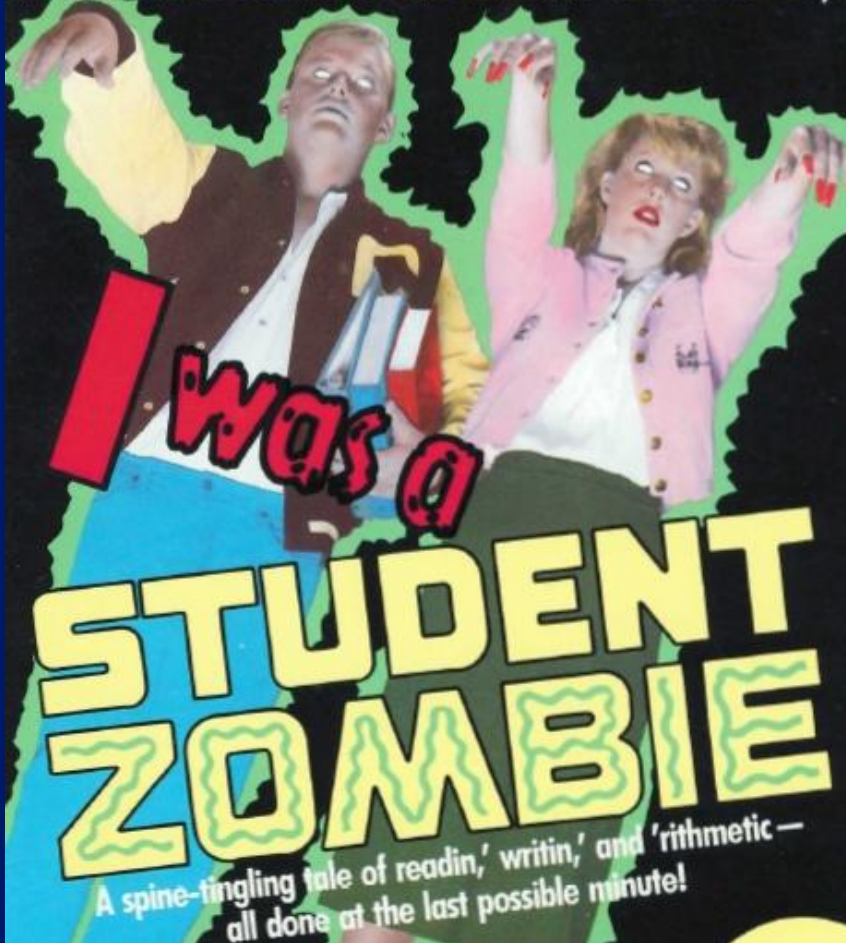
The moist, warm air from the lake is absorbed into the wind.

As the moist air rises, it begins to cool and condenses, forming clouds.

If there is enough moisture in the air, it will begin to snow on the other side of the lake.



It's happening right now...in YOUR town...
in YOUR school...in YOUR class...in YOUR BRAIN!



Mini ZOMBIE BREAK !

<http://www.youtube.com/watch?v=D4Z0S9yRTyw>

CLIMATE CHANGE:

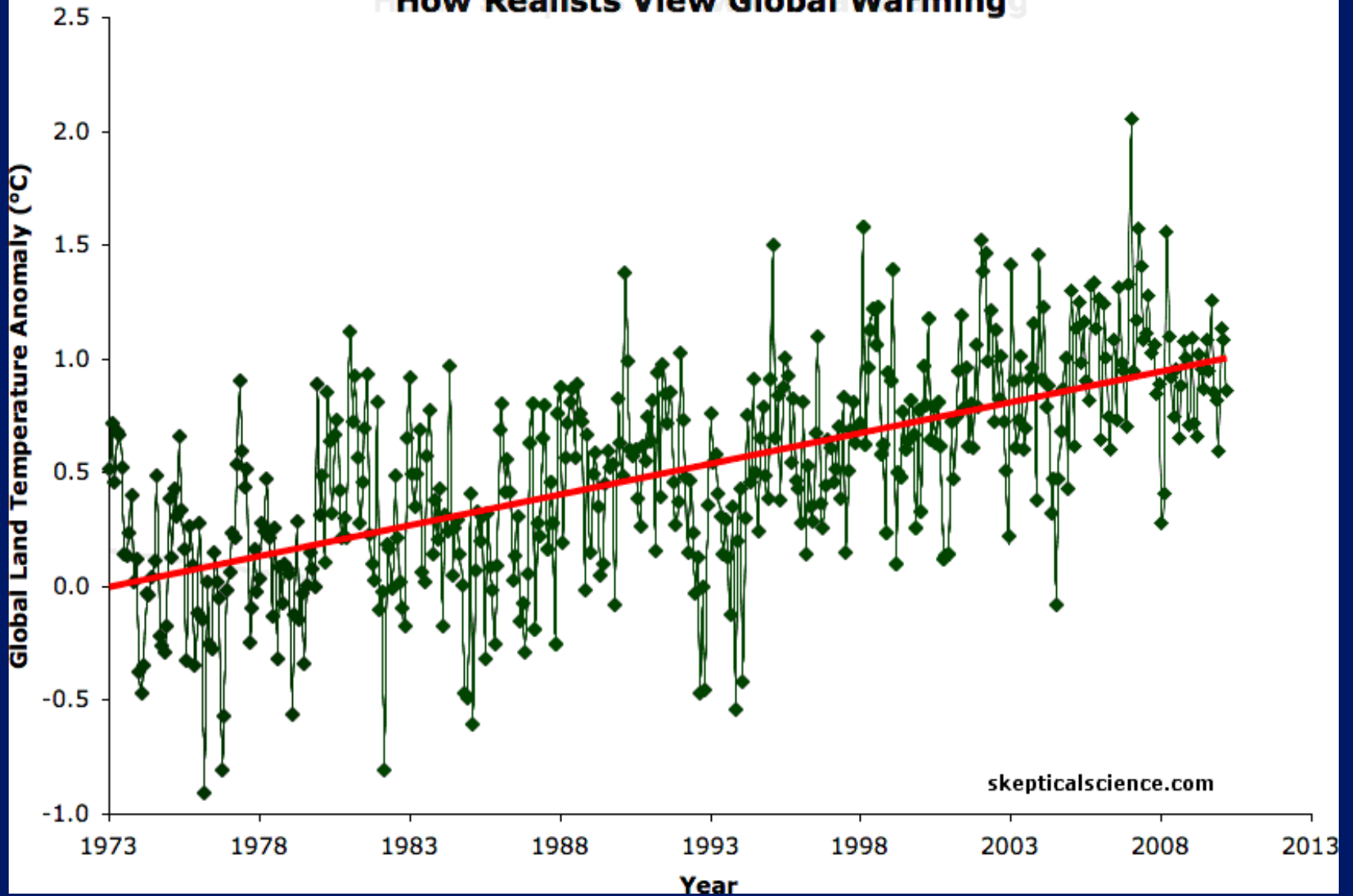
WHAT'S CAUSING IT?

The most used "denier" arguments about the causes and effects of climate change

From: <http://www.skepticalscience.com/>



How Realists View Global Warming



From: skepticalscience.com

... and now

How do we KNOW
that the recent global
warming is due primarily
to human activities
and not just
natural climate forcing?

TOPIC # 13, PART C: Evidence from Natural Archives

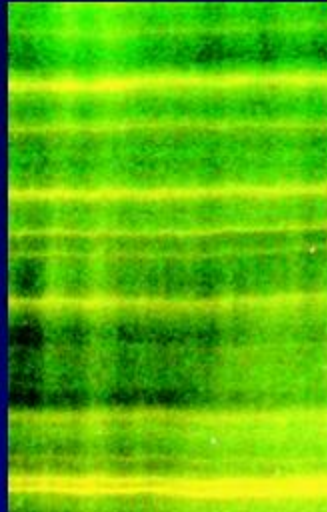
Tree rings



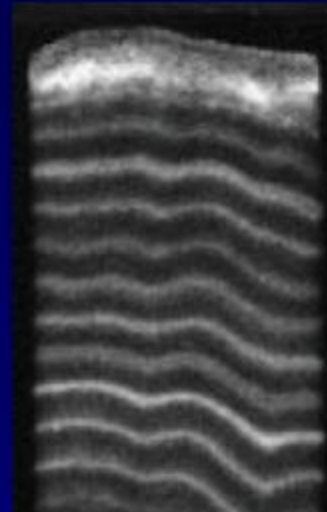
Lake varves
(sediments)



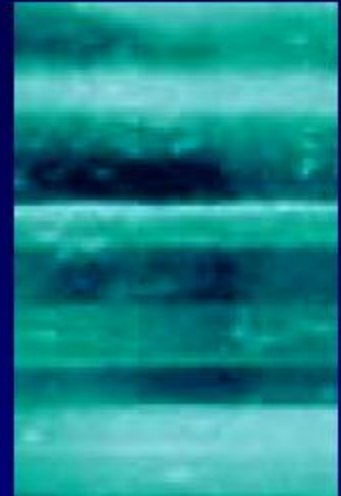
Speleothems
(from cave)



Coral
(annual growth)



Ice Core



*"The farther backward you can look,
the farther forward you are likely to see."*

- Winston Churchill

“PROXY” DATA or NATURAL ARCHIVES of CLIMATE



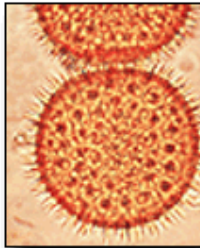
Corals



Ice cores



Lake, bog &
ocean
sediments

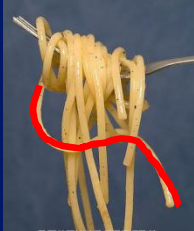


Pollen



Tree rings!

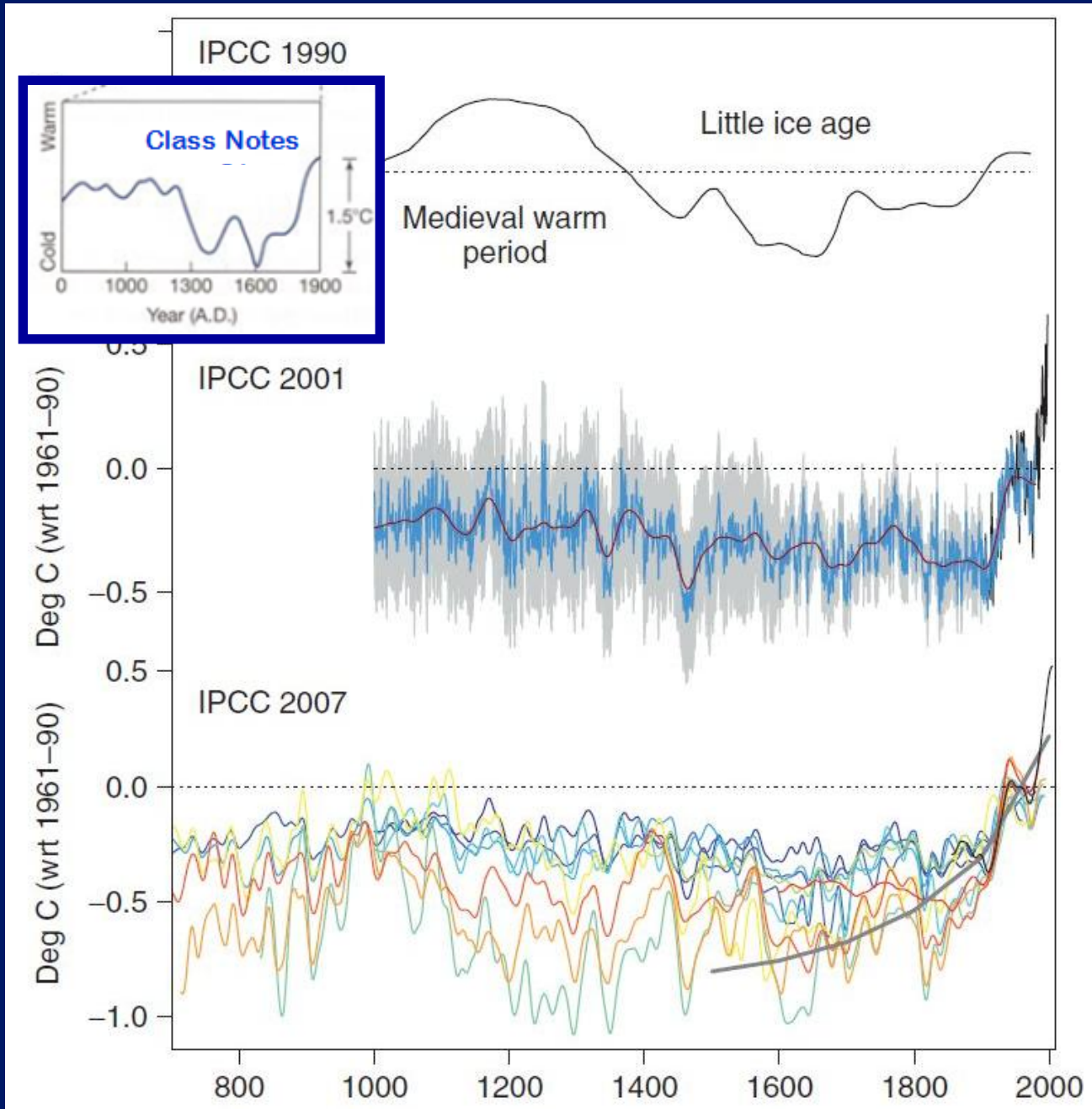
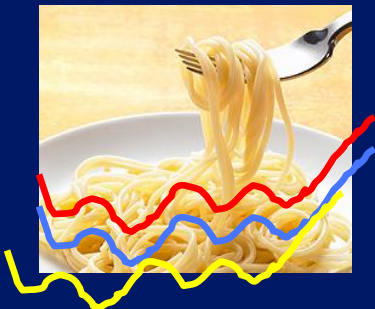
The "Noodle"



The "Hockey Stick"



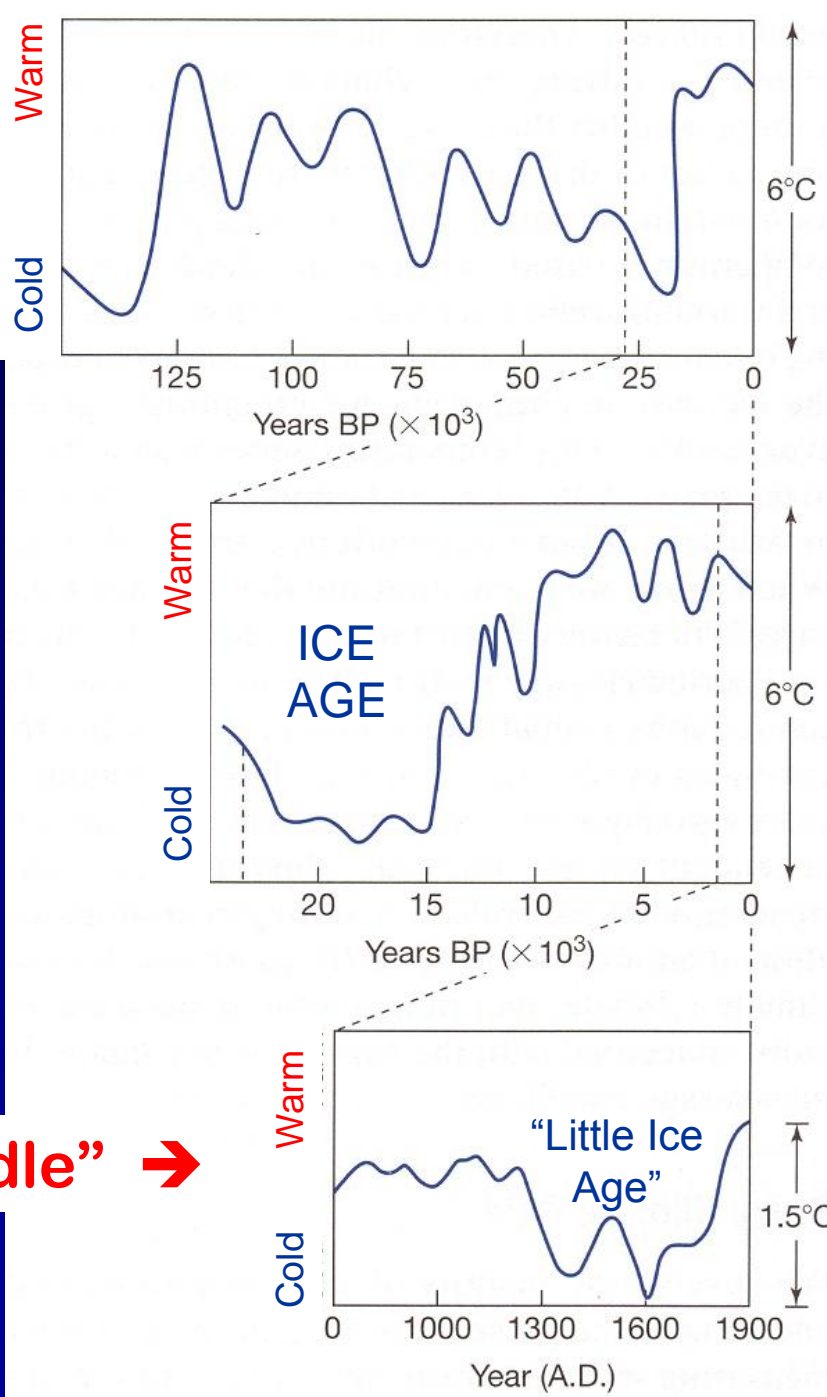
The "Spaghetti Plate"



Review:
from p 17 of
Class Notes:

Estimates of
Mean Global
Temperature
Change --
based on
various types
of archives

The "Noodle" →



deep-sea
sediments

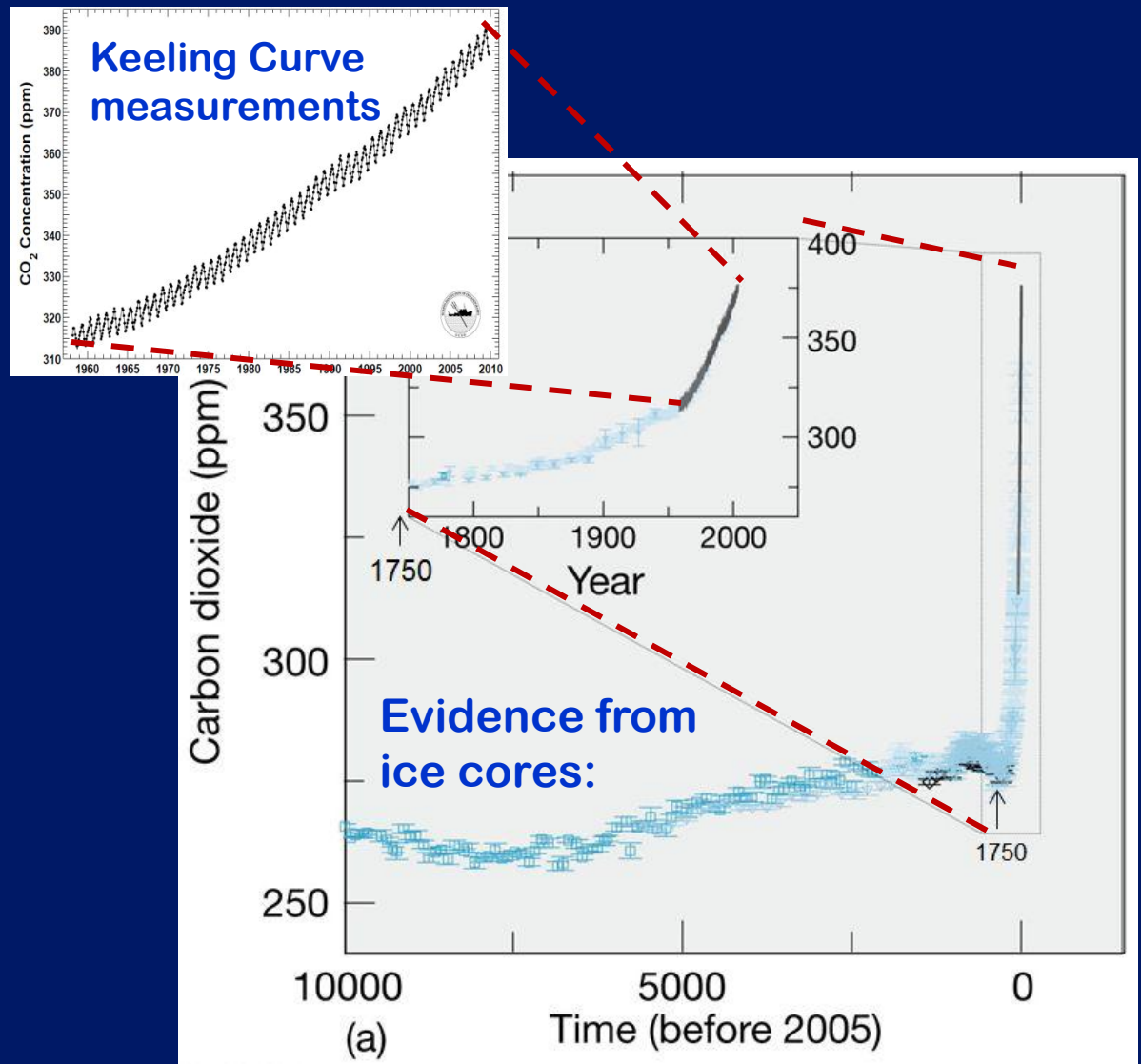
pollen data &
alpine glaciers

historical
documents

(emphasis on the North
Atlantic region)

top graph on p 91

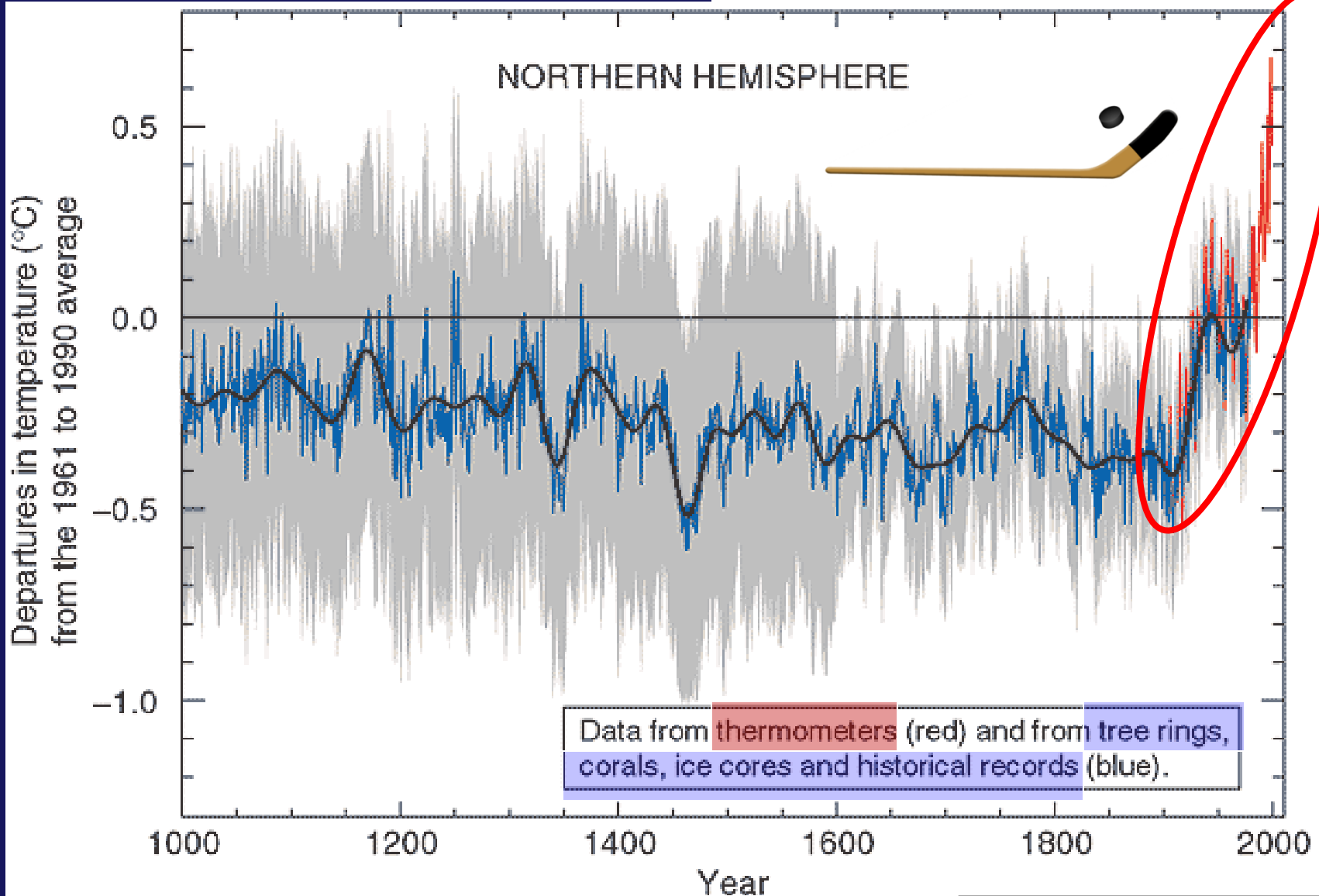
The CO₂ “Hockey Stick” Graph . . .



SGC E-Text
Chapter 1
Fig 1-3a

The Temperature “Hockey Stick” Graph

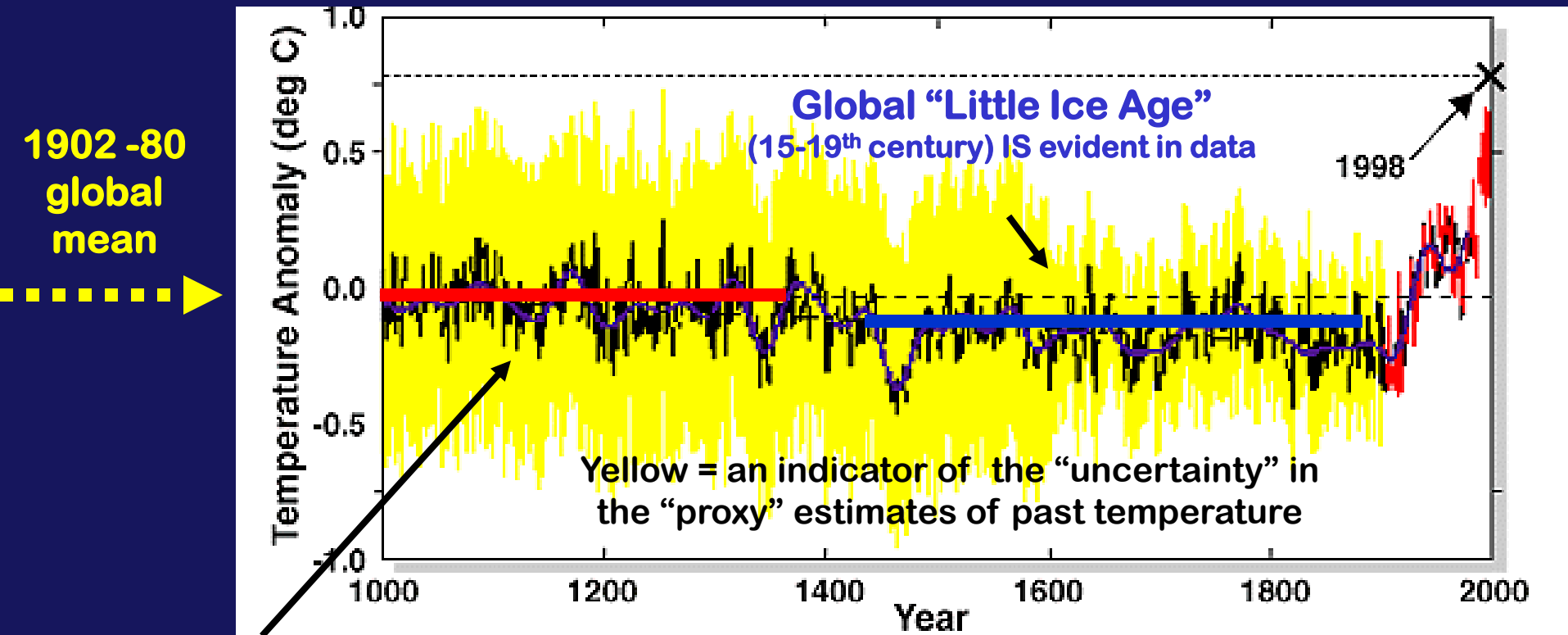
“proxy” data +
thermometer records



middle graph on p 88

The Temperature Hockey Stick Graph (another view)

Temperature change over the last 1000 years from multi-proxy records: shows there is **NO period** of global or hemispheric temperatures **warmer than the 20th century**



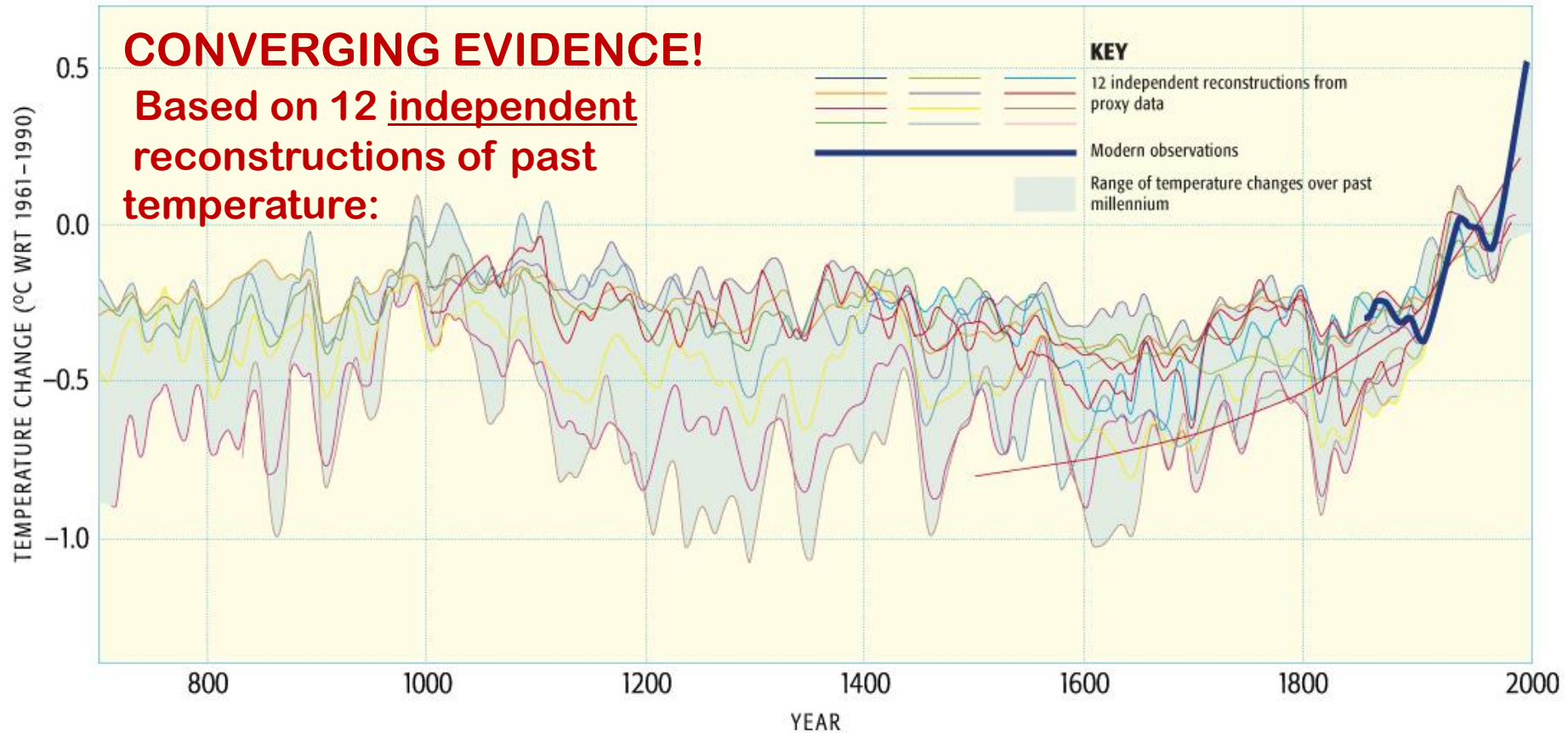
"Medieval Warm Period" (9-14th century) not very evident (more of a regional phenomenon)

- reconstruction (AD 1000-1980)
- instrumental data (AD 1902-1998)
- - - calibration period (AD 1902-1980) mean
- reconstruction (40 year smoothed)
- - - linear trend (AD 1000-1850)

Another version

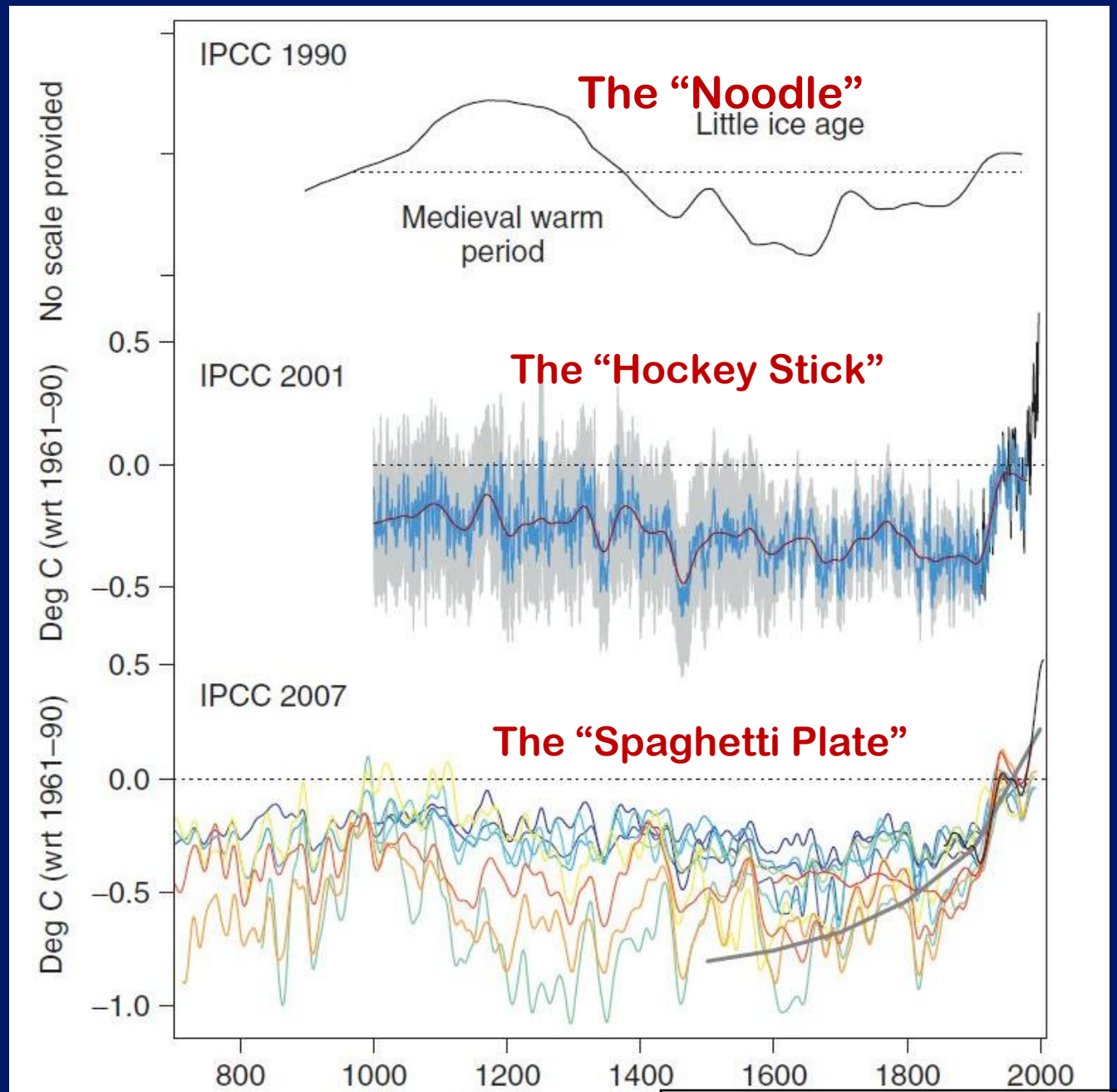
The Temperature “Spaghetti Plate” Graph

NORTHERN HEMISPHERE TEMPERATURE CHANGES OVER THE PAST MILLENNIUM



The general “Hockey Stick” shape has stood the test of time, despite intense scrutiny and debunking attempts!

The Scientific Process “in action”

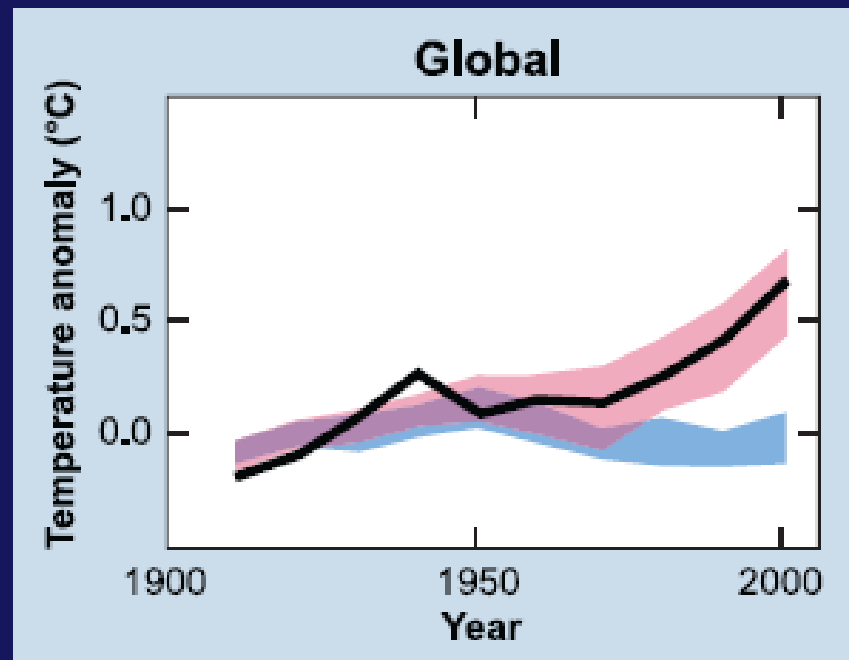


All 3 graphs on p 88

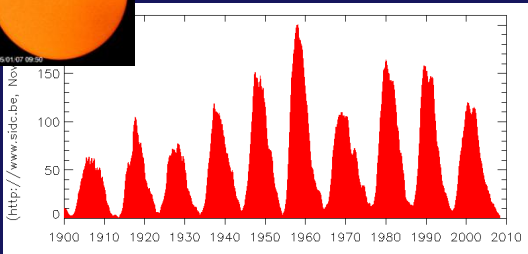
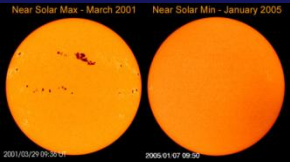
TOPIC # 13, PART D:

Evidence from Model Comparisons

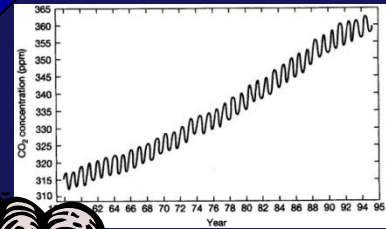
Natural vs. Anthropogenic



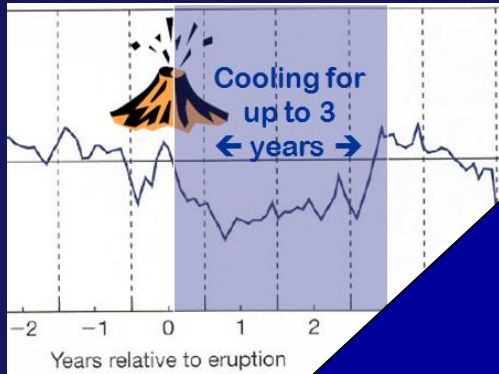
NATURAL FORCING



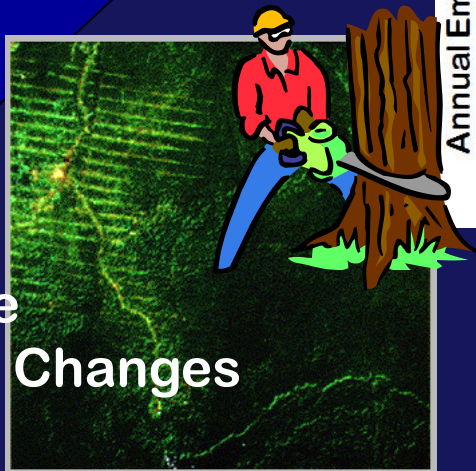
Solar output variations, sunspots



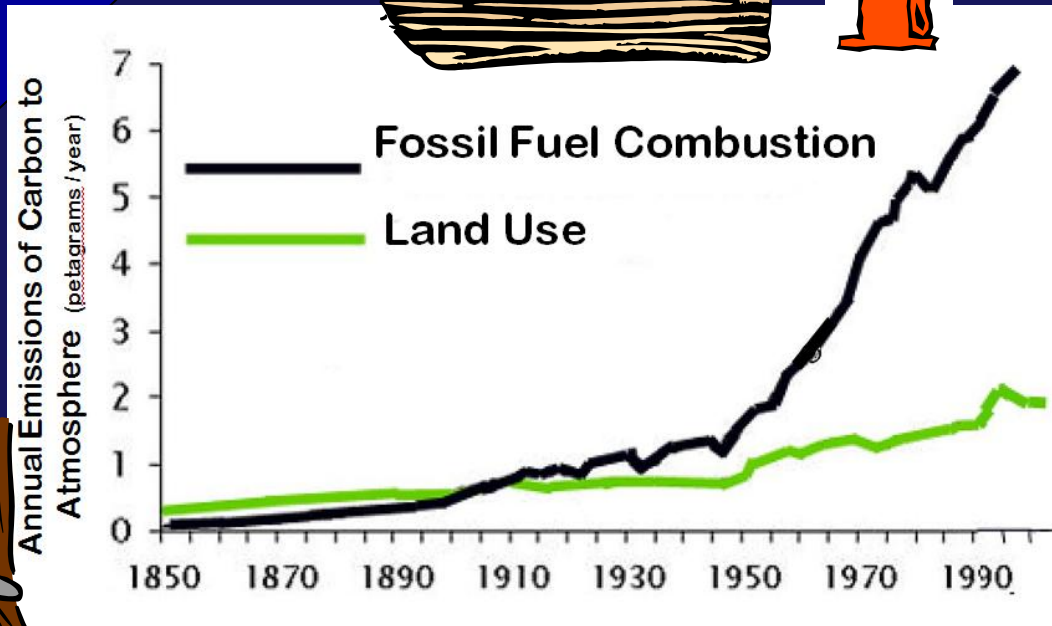
GHG's, soot, SO₂



Volcanic eruptions



Surface Albedo Changes

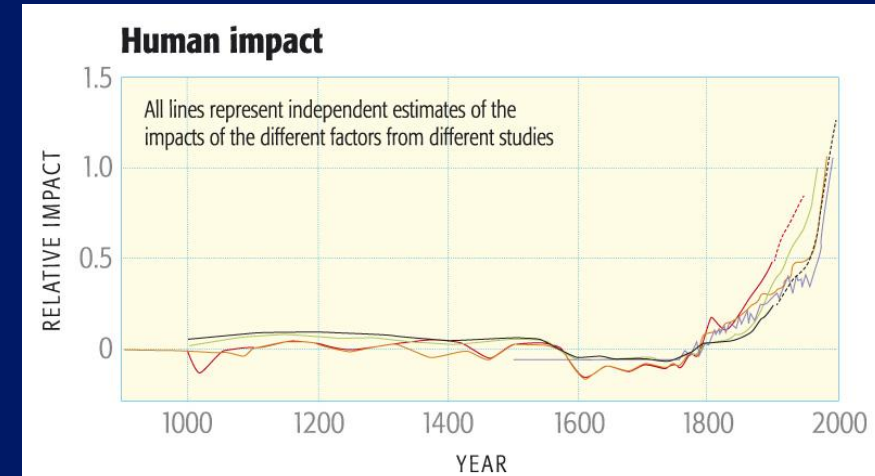
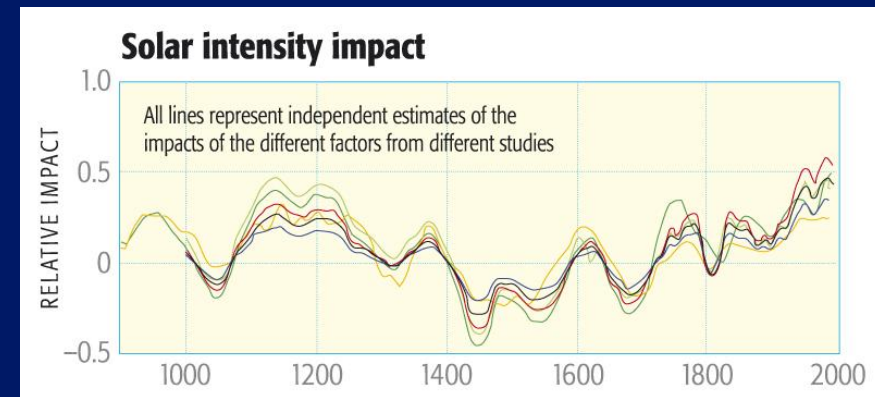
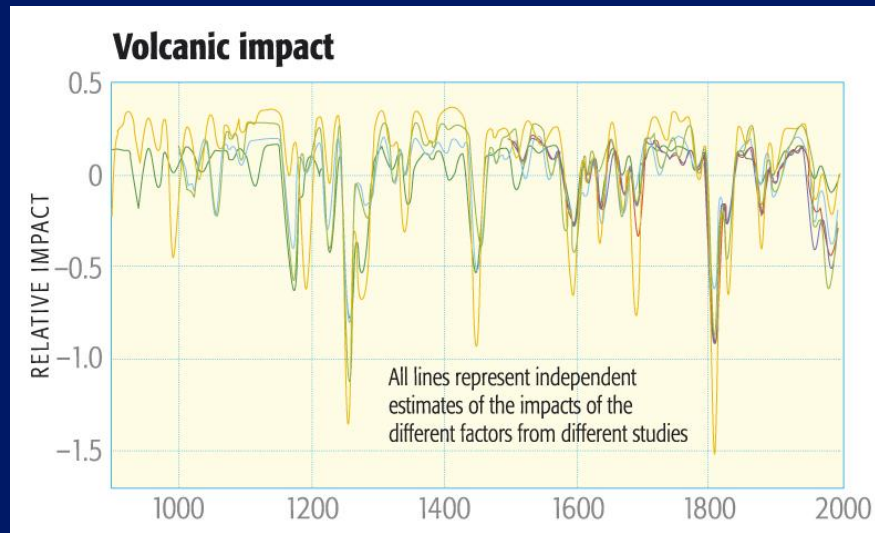


ANTHROPOGENIC FORCING

In addition to the “Natural - Archive – Paleo” Approach, **COMPUTER MODELS** have been created to estimate the radiative forcings of the PAST!

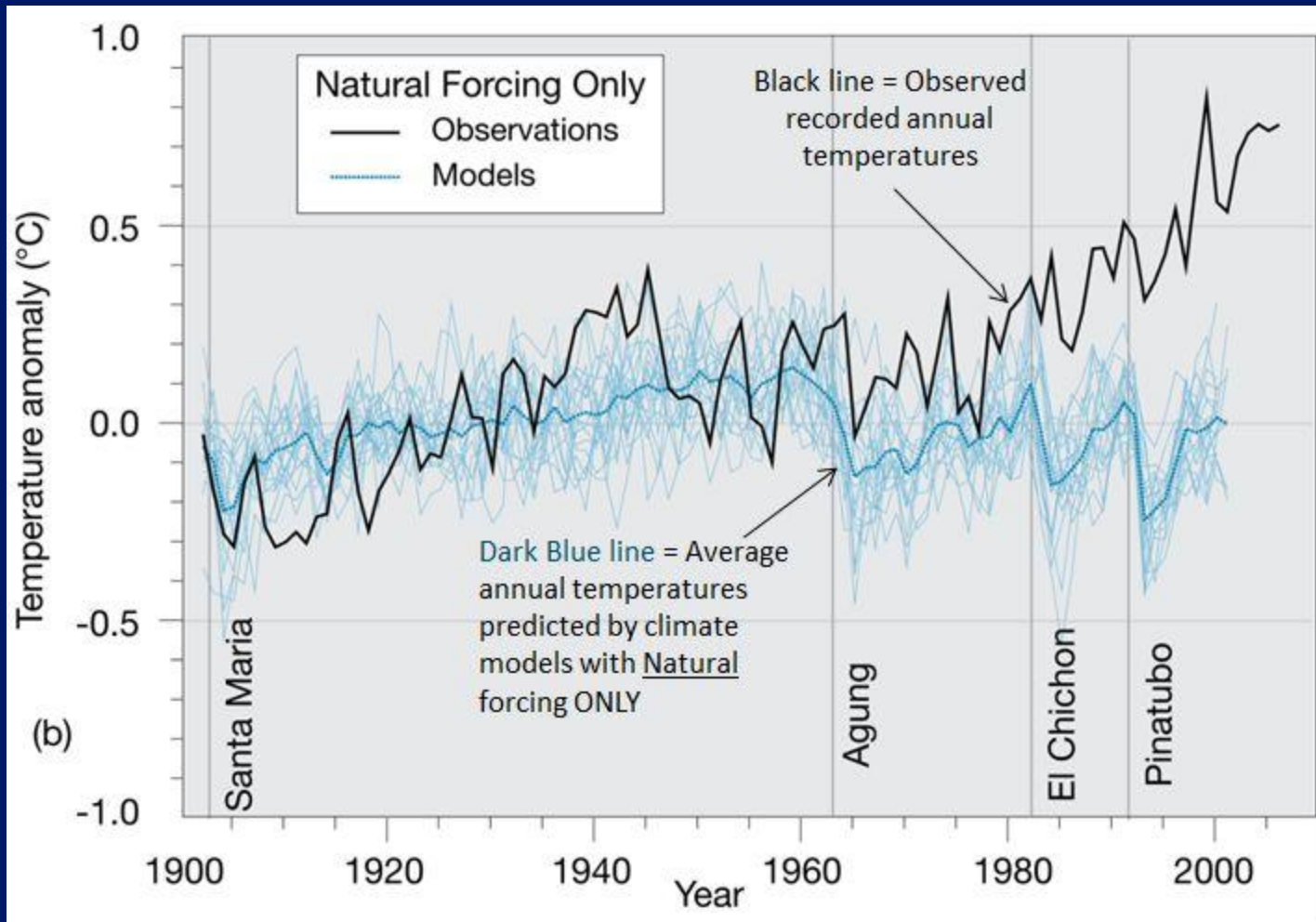
**Estimates Of
Natural & Human
Impacts On
Climate Over The
Past 1000 Years**

From
Dire Predictions
p 81



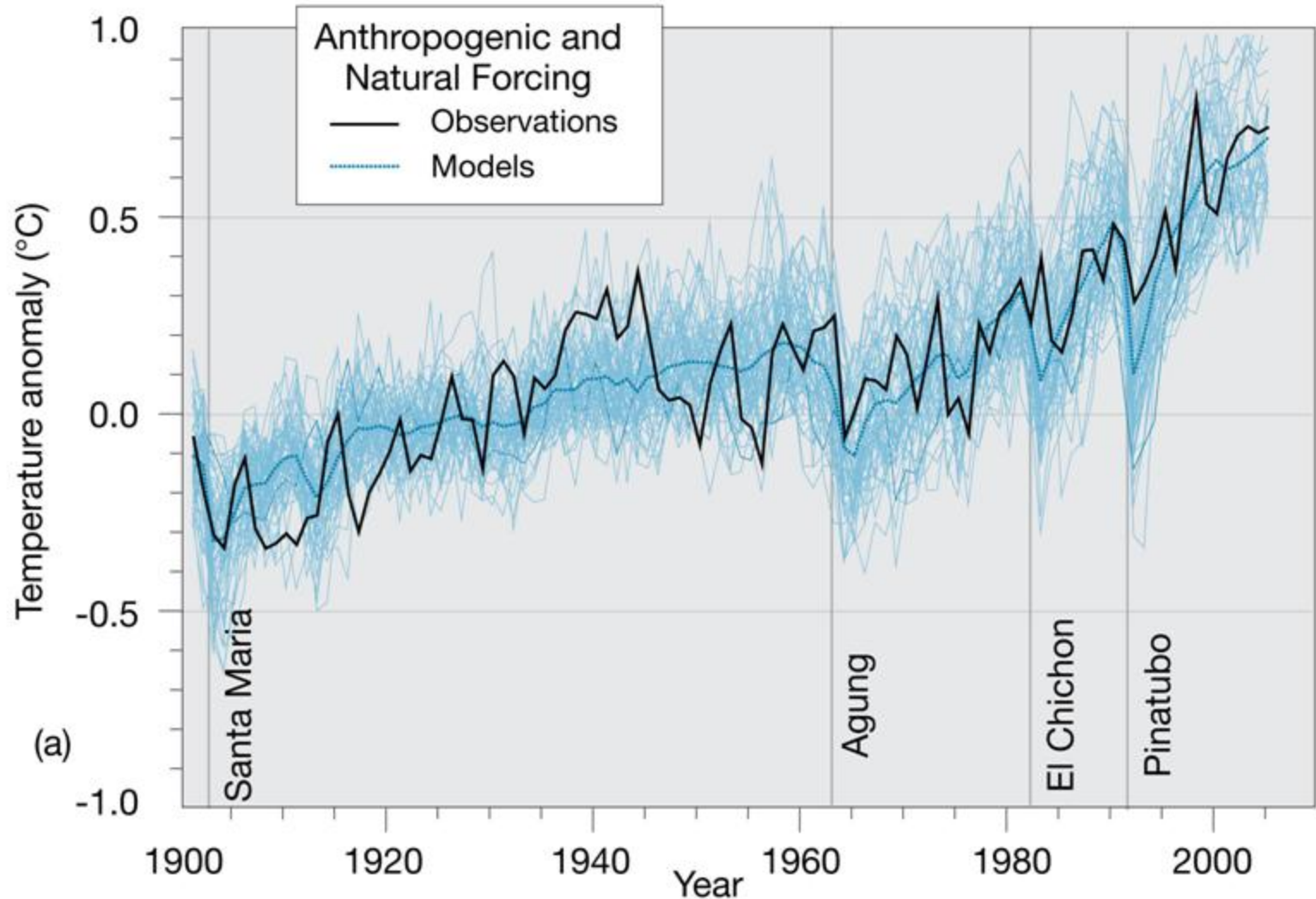
On top of p 89
in Class Notes

MODELED TEMPERATURE based on **NATURAL FORCING ONLY:**

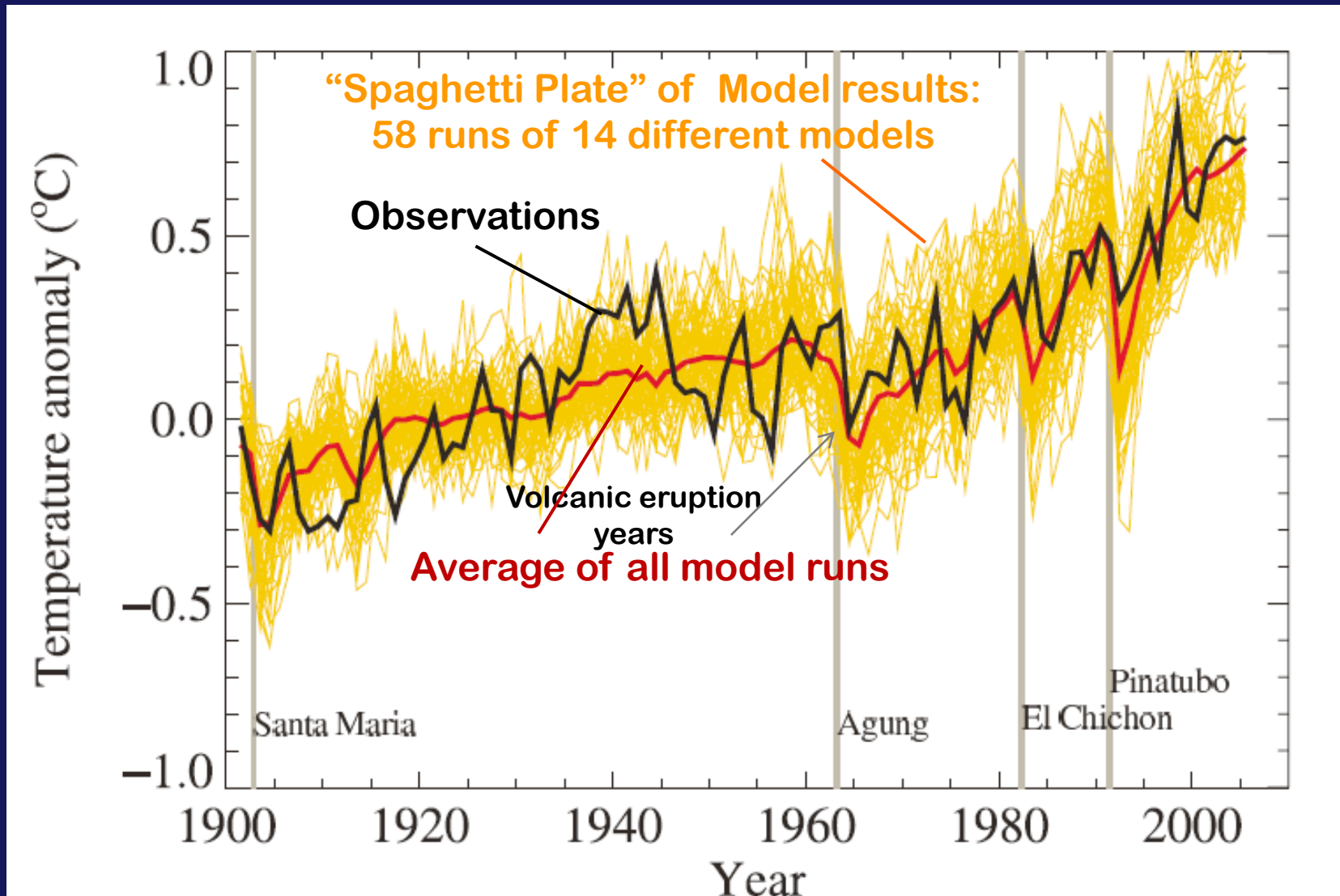


Models cannot reproduce the observed temperature trend since ~ 1980

MODELED TEMPERATURE based on NATURAL + ANTHROPOGENIC FORCING



MODELED TEMPERATURE based on NATURAL + ANTHROPOGENIC FORCING





models using only natural forcings

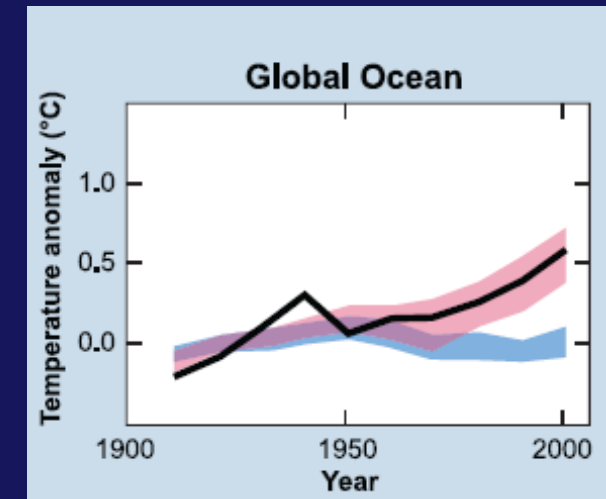
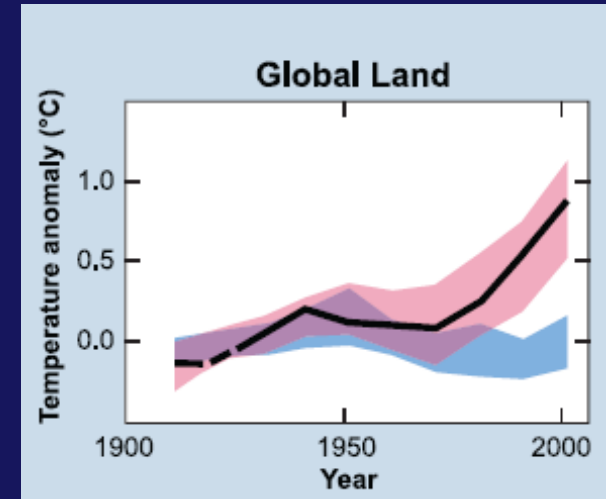
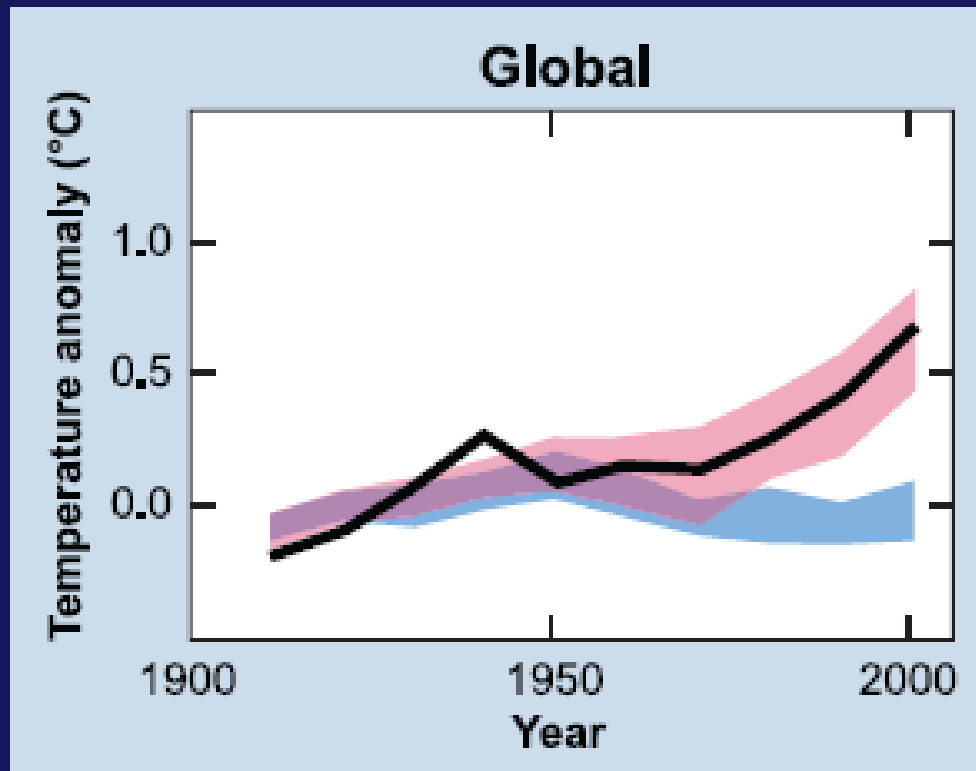


models using both natural and anthropogenic forcings



observations

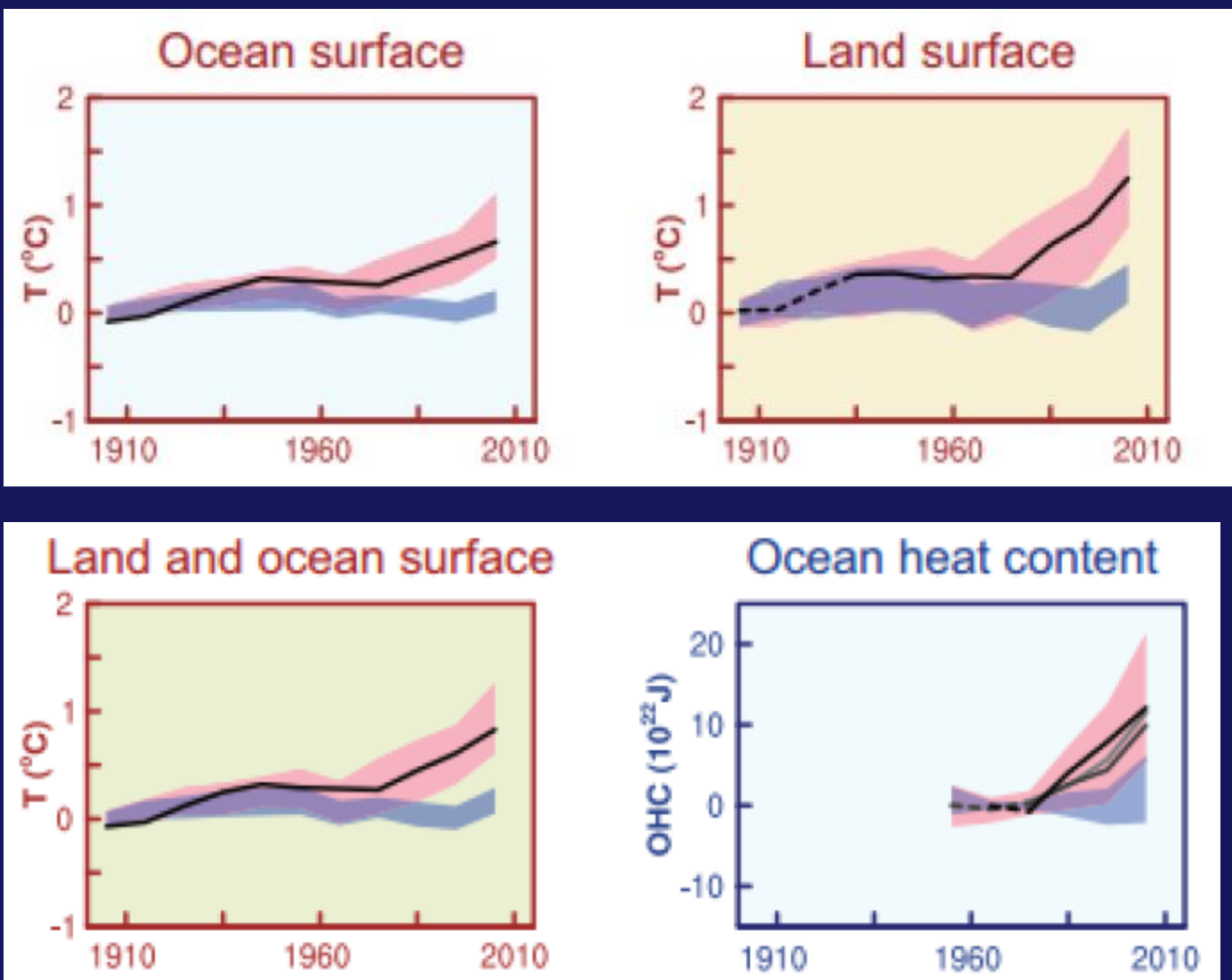
2007 IPCC Report



2013 IPCC Report

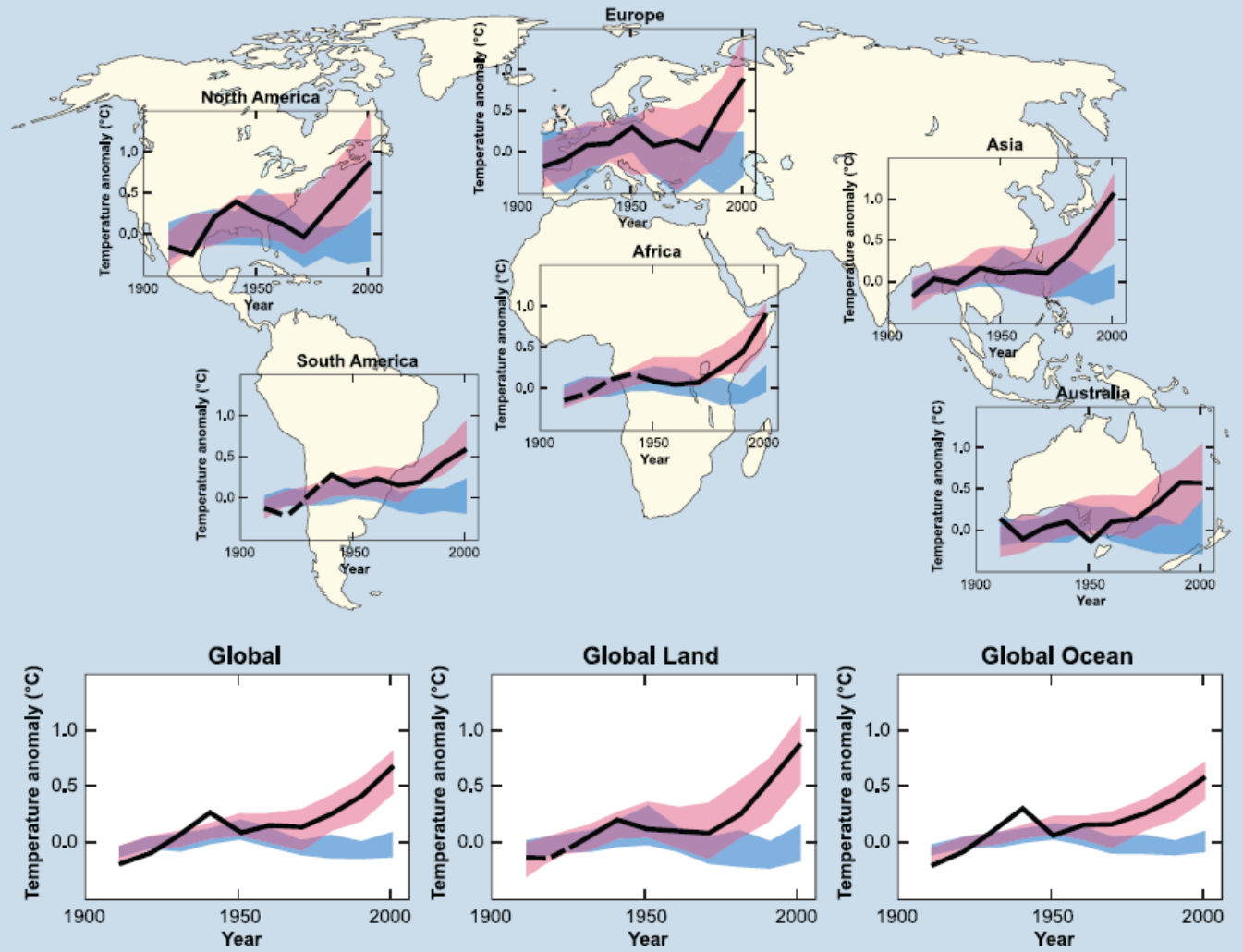
☰ Observations

■ Models using only natural forcings
■ Models using both natural and anthropogenic forcings

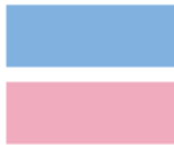


Individual Region Model Runs showed the same results!

2007 IPCC Report



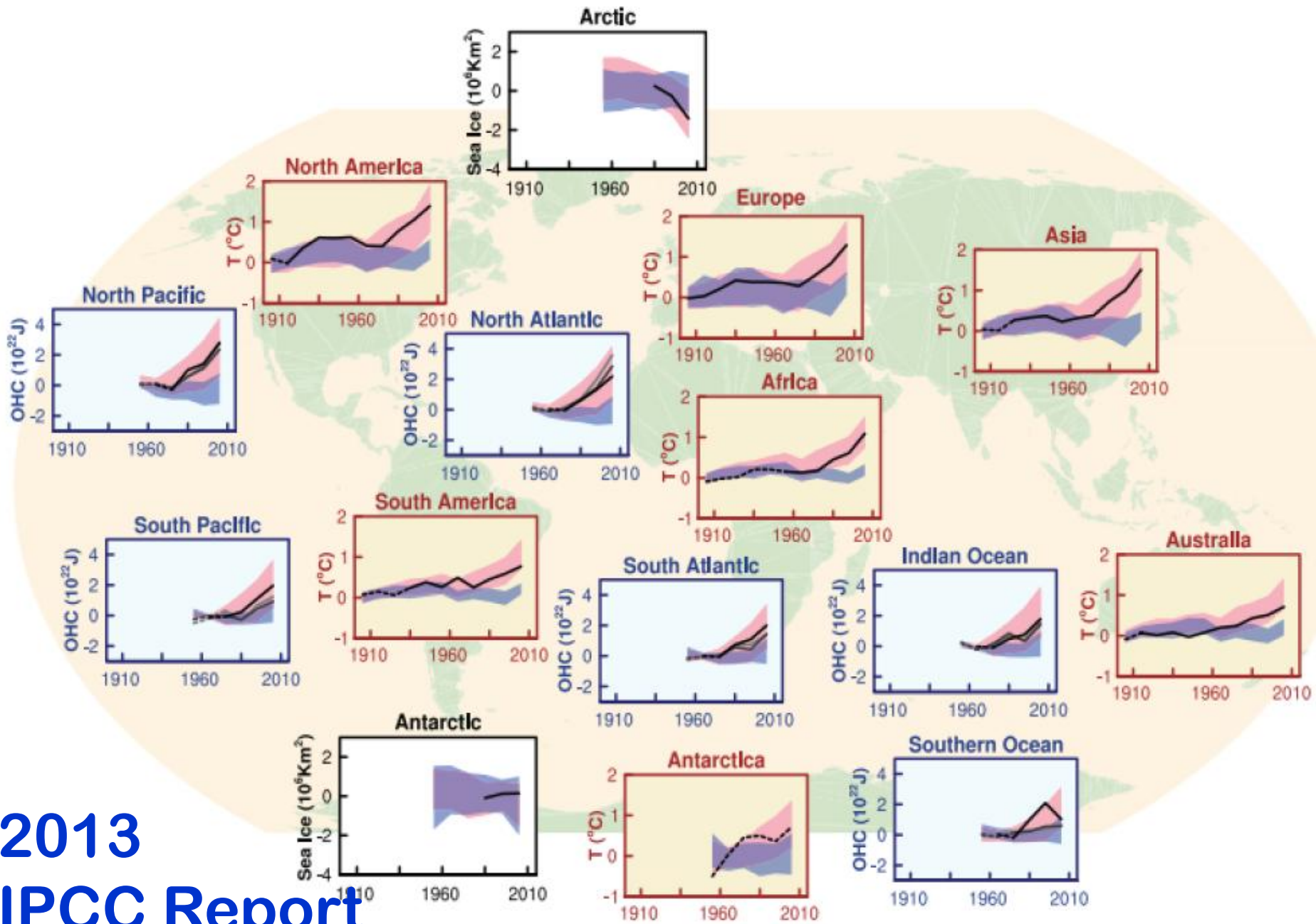
— observations



models using only natural forcings

models using both natural and anthropogenic forcings

Model Comparisons of Natural vs. Anthropogenic Forcing on All Continents



2013
IPCC Report

**GOOD LUCK GETTING YOUR
PROJECT SLIDES IN
TOMORROW NIGHT!**

**SEE YOU NEXT
TUESDAY!**