TOPIC # 13 Global Warming (cont.)

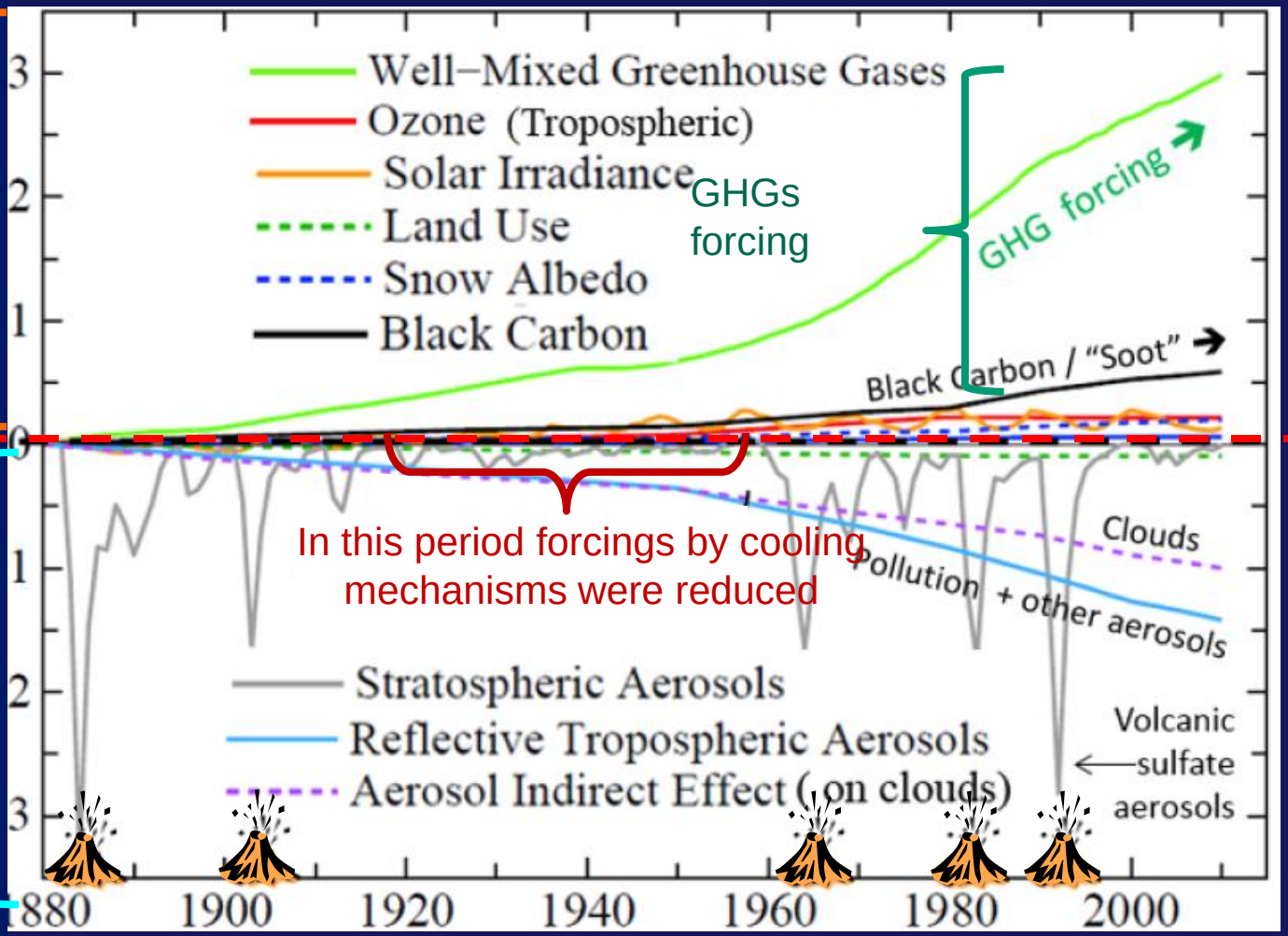
RECAP OF KEY FIGURES
from Topic #13 PART B
LAST WEEK . . .

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



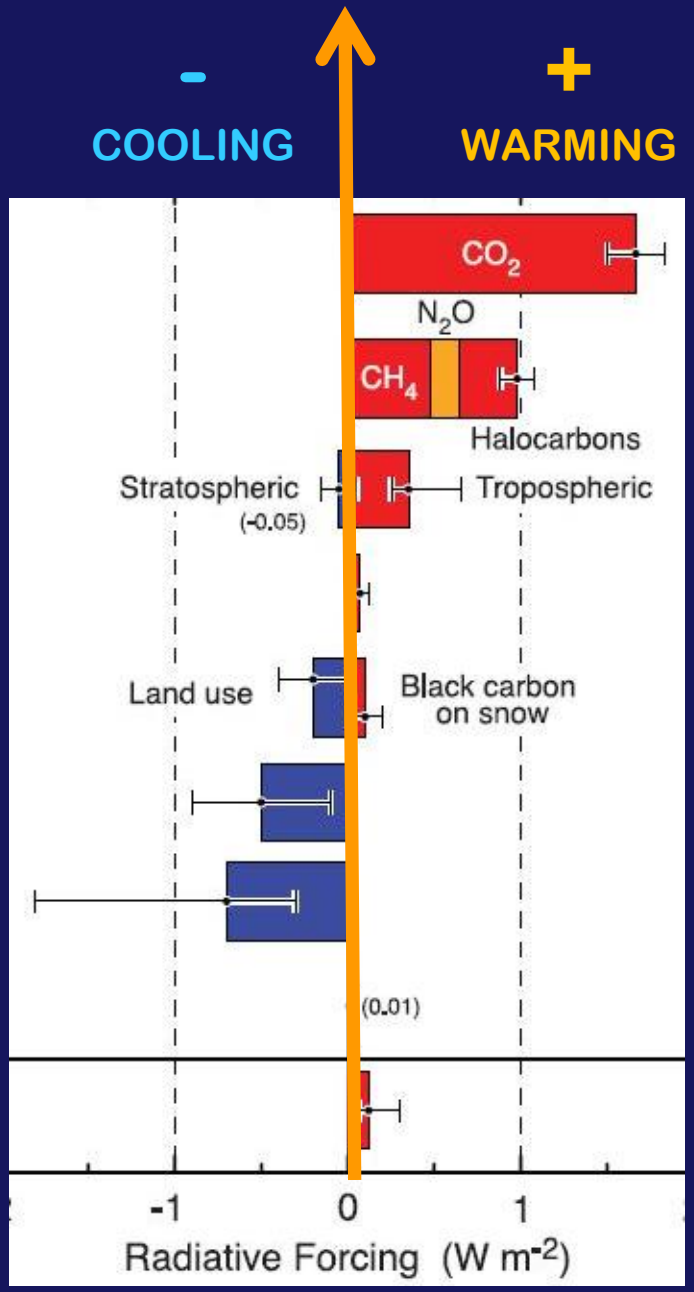
Effectiveness of various global climate forcings (in W/m^2) relative to their 1880 value

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

WHAT TO KNOW:

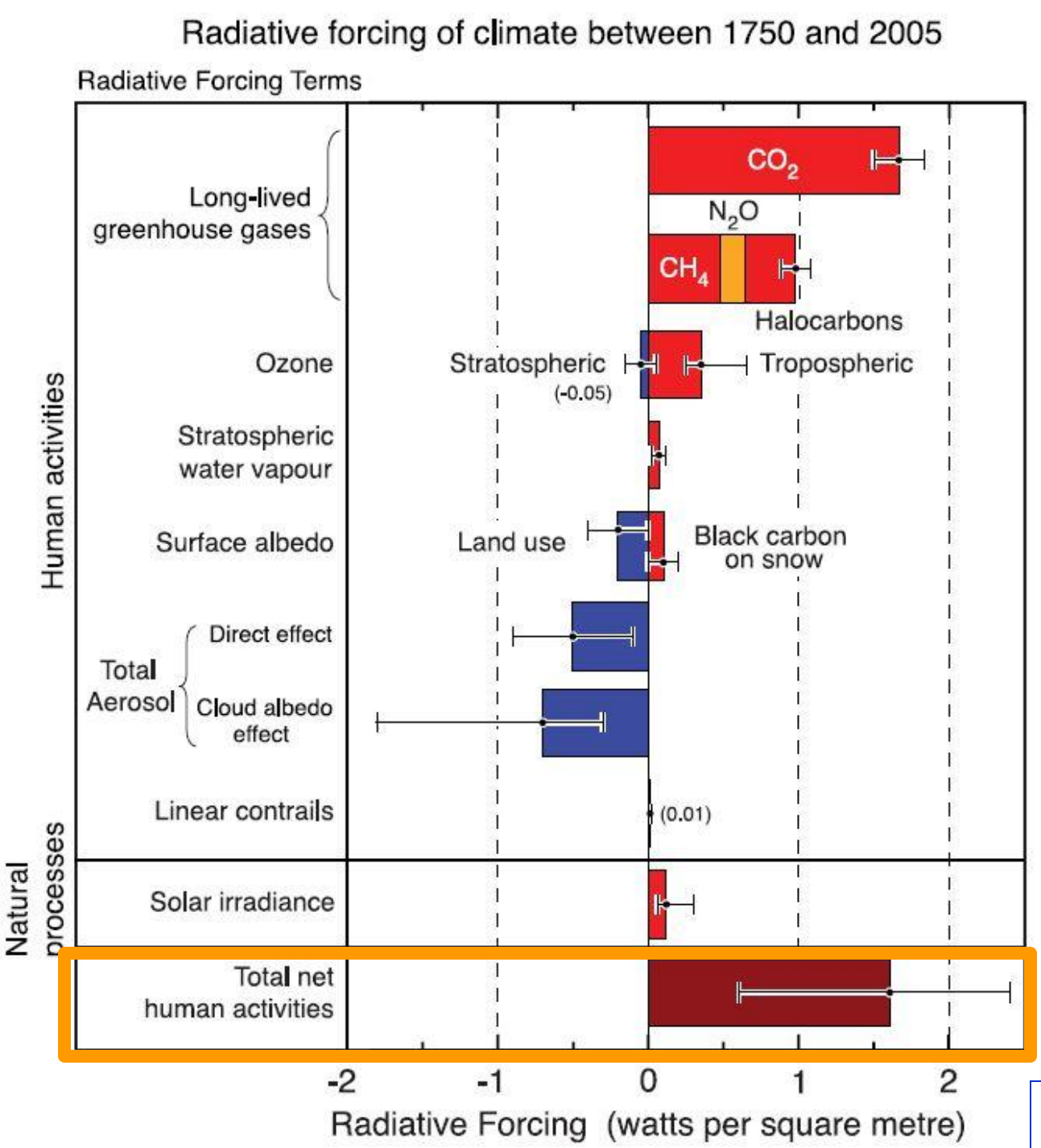
If the forcing is **NEGATIVE** (to left of line)

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.


Radiative forcing of climate between 1750 and 2005
Radiative Forcing Terms
Long-lived greenhouse gases
CO_2
N_2O
CH_4
Halocarbons
Ozone
Stratospheric
(-0.05)
Tropospheric
Stratospheric water vapour
Surface albedo
Land use
Black carbon on snow
Total Aerosol
Direct effect
Cloud albedo effect
Linear contrails
(0.01)
Human activities
Natural processes
Solar irradiance
Total net human activities
-2
-1
0
1
2
Radiative Forcing (watts per square metre)

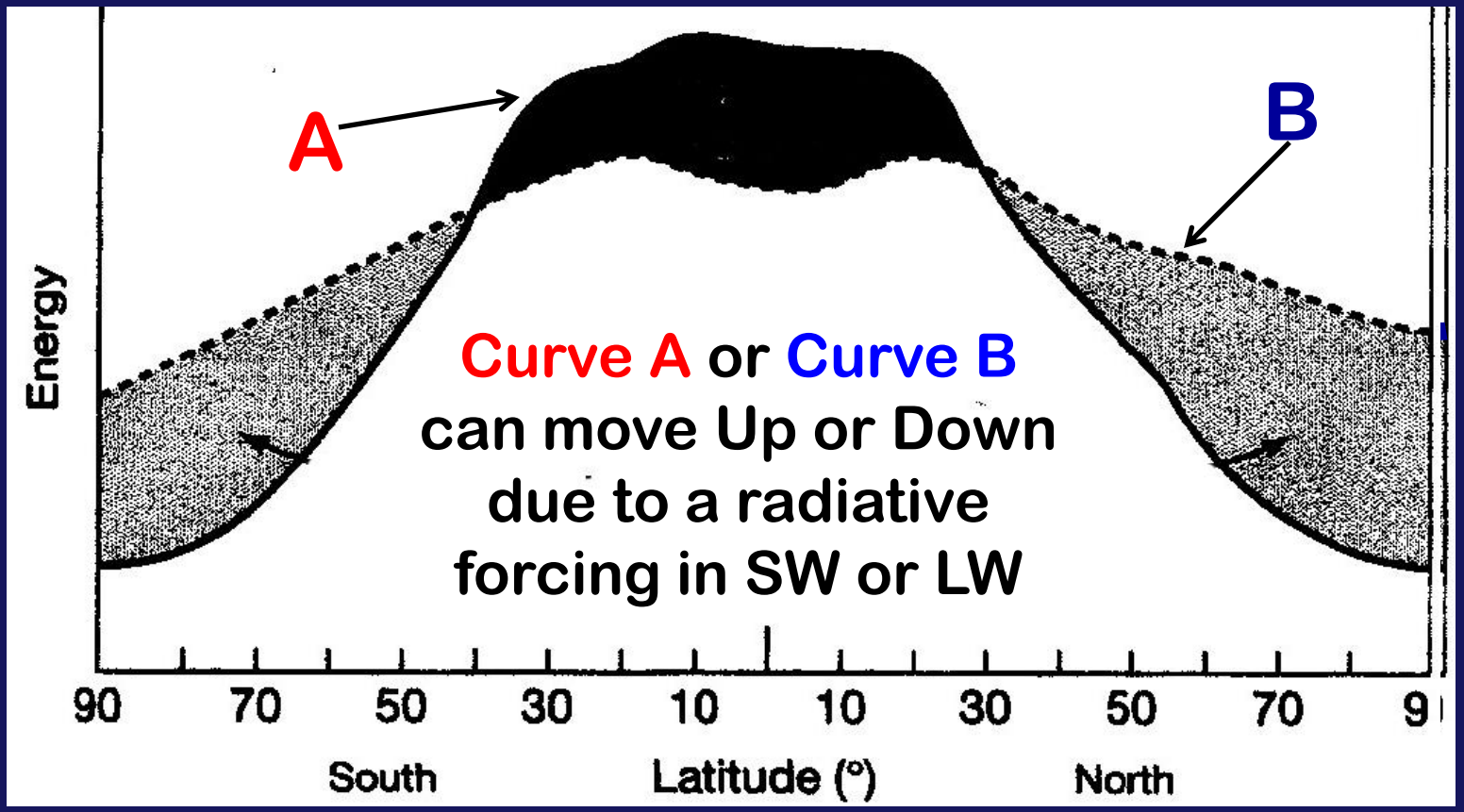
p 83 top

A QUESTION

YOU MIGHT SEE ON TEST #4

or the FINAL EXAM . . . .

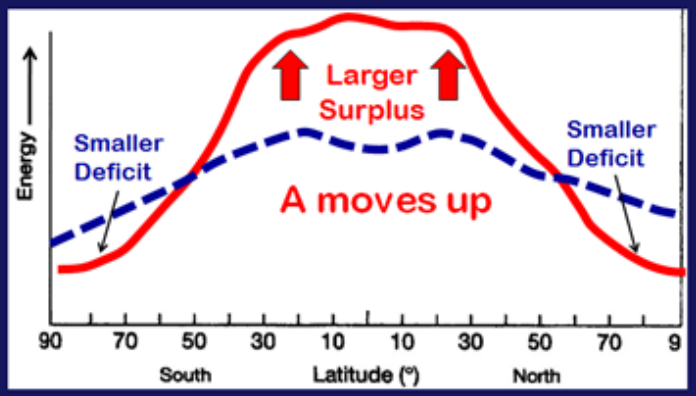
How do different RADIATIVE FORCING MECHANISMS change this figure?

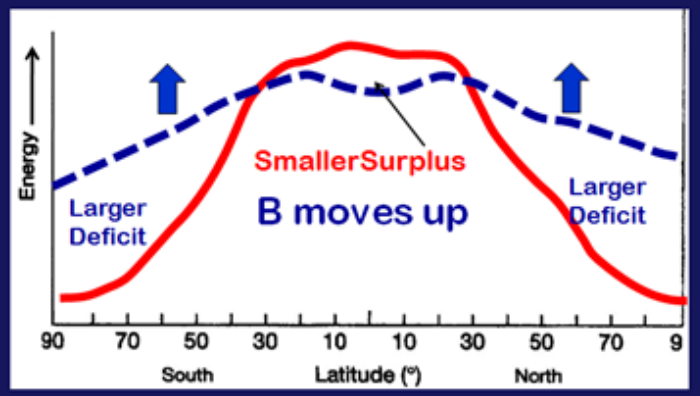


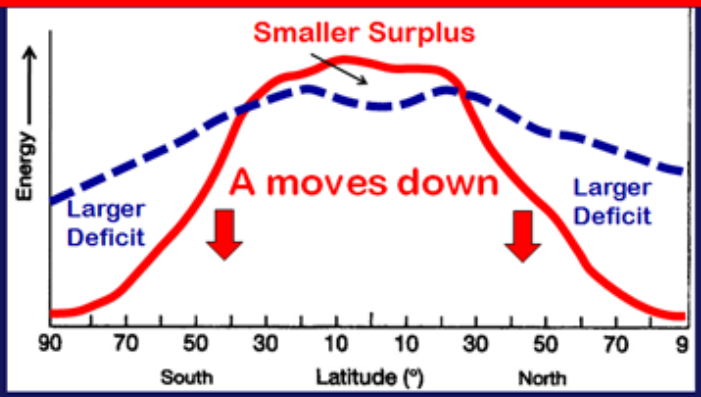
ENERGY BALANCE CHANGES IN THE TROPOSPHERE

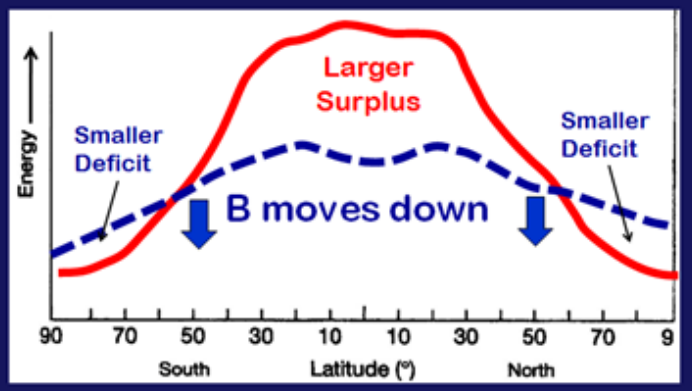
Remember: G-6 Volcanism Activity?

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





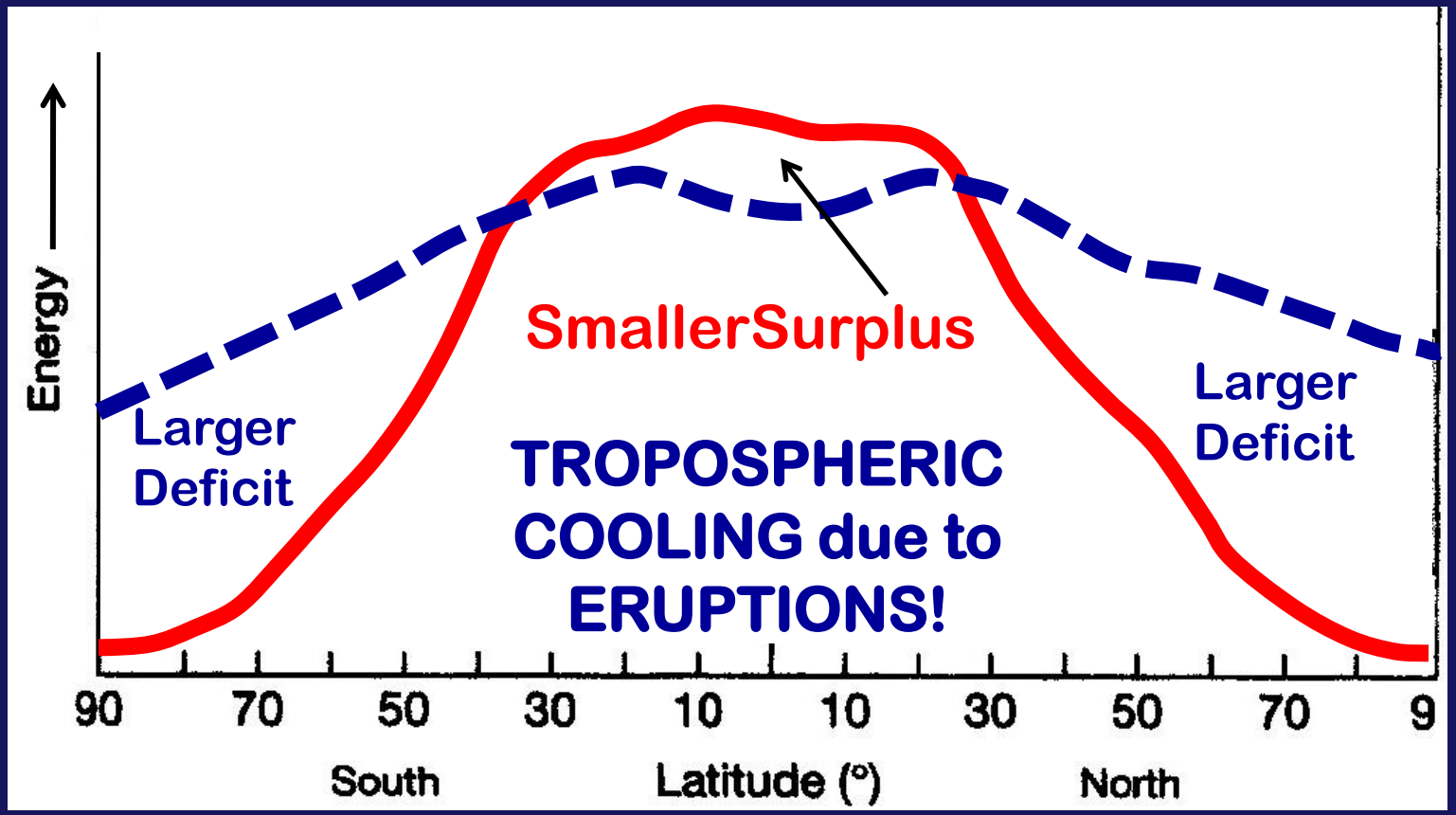




WHICH ONE IS RIGHT ?

Does the change affect CURVE A or CURVE B?

IF CURVE A moves down: SW ↓ + SW ↓ - SW ↘



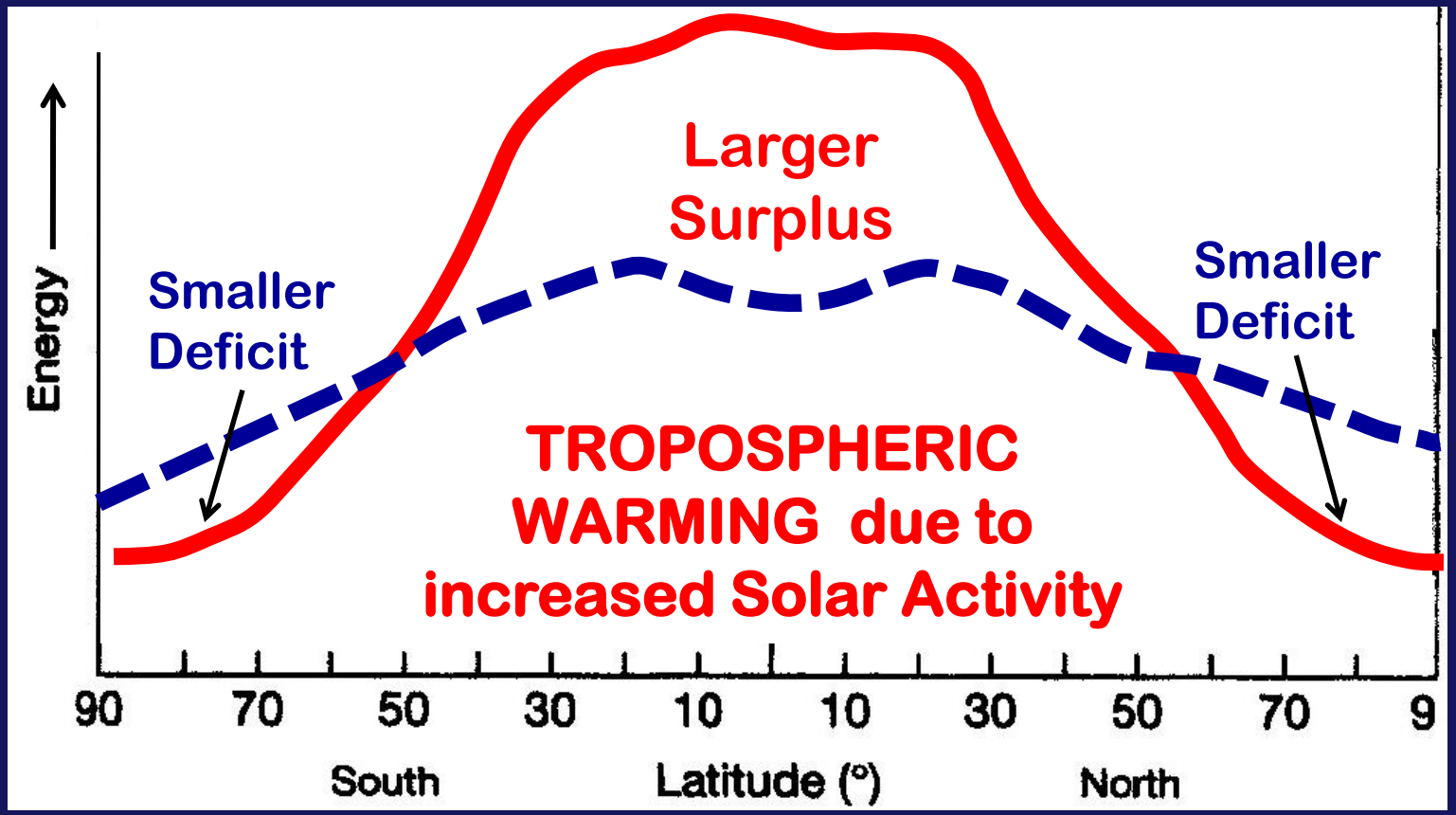
SW ↓ + SW ↓ - SW ↘ If incoming energy represented by Curve A is reduced (A curve goes down)

SW ↓

HOW? Albedo <u>increases</u> SW ↘ due to Eruptions, Deforestation, Sulfur Aerosols, etc.

What if less Volcanism ➔ more Solar Input to Troposphere?

IF CURVE A moves up: SW ↓ + SW ↓ - SW ↗

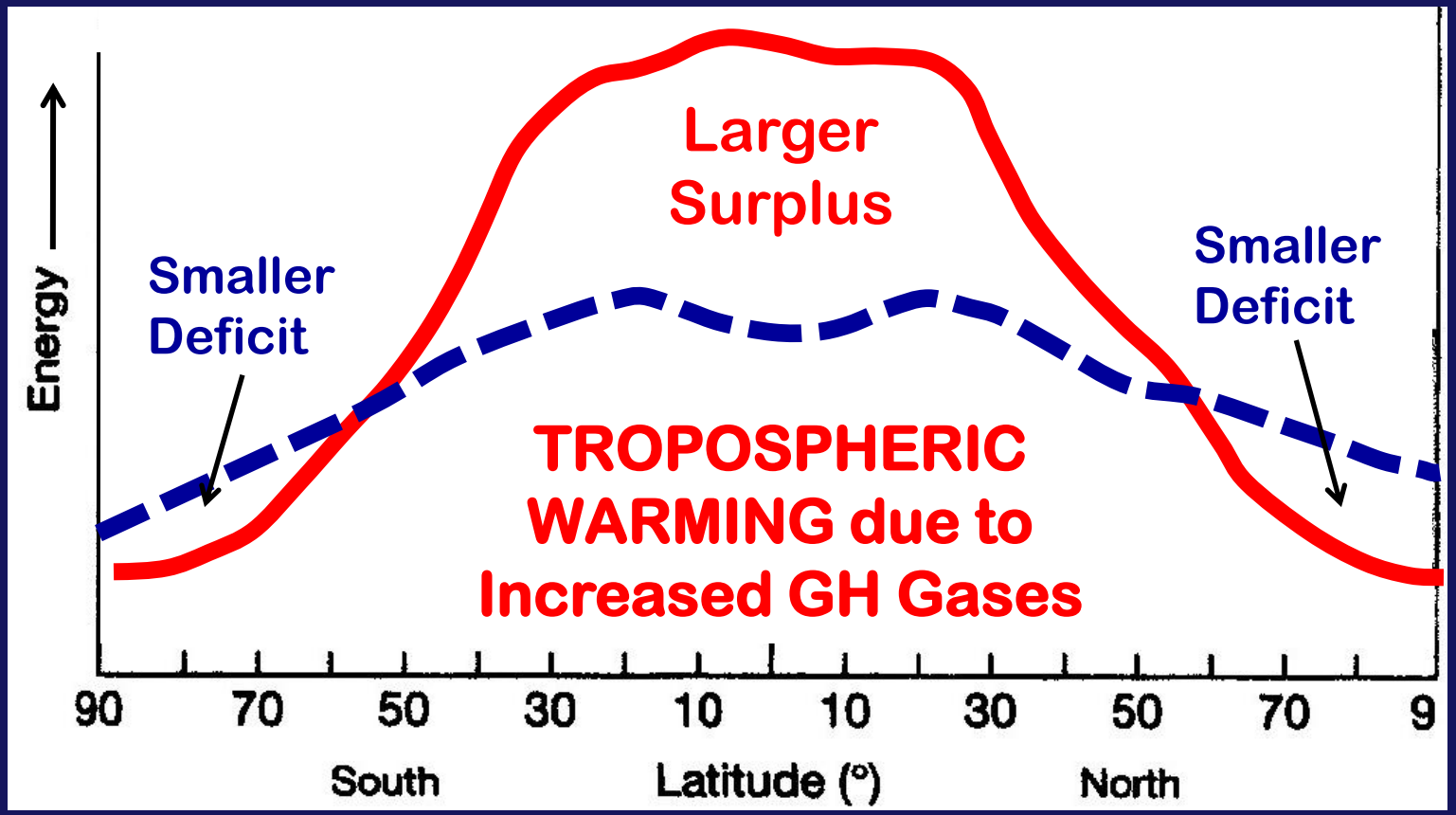


SW ↓ + SW ↓ - SW ↗ If incoming energy represented by Curve A is increased (A curve goes up)

HOW? Stratospheric albedo SW ↓ SW ↗ decreases and / or Solar Input increases

How will curves change with GH Gas increases in Troposphere?

If CURVE B moves down LW

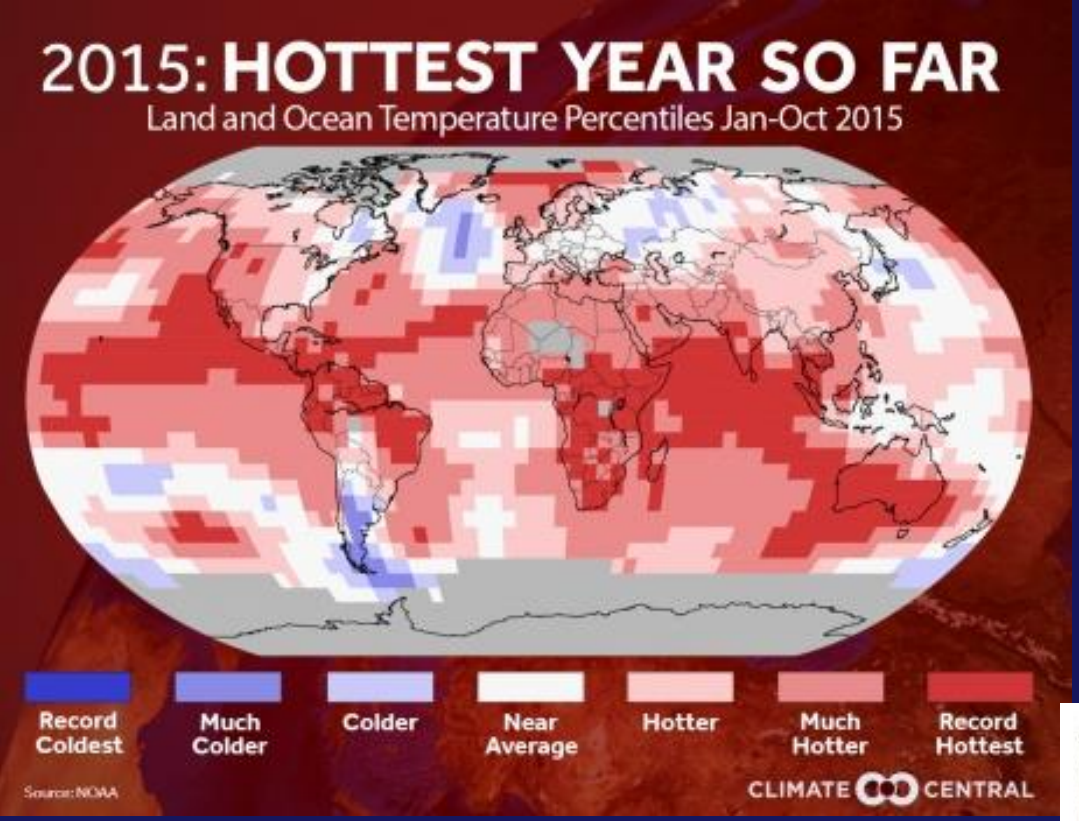


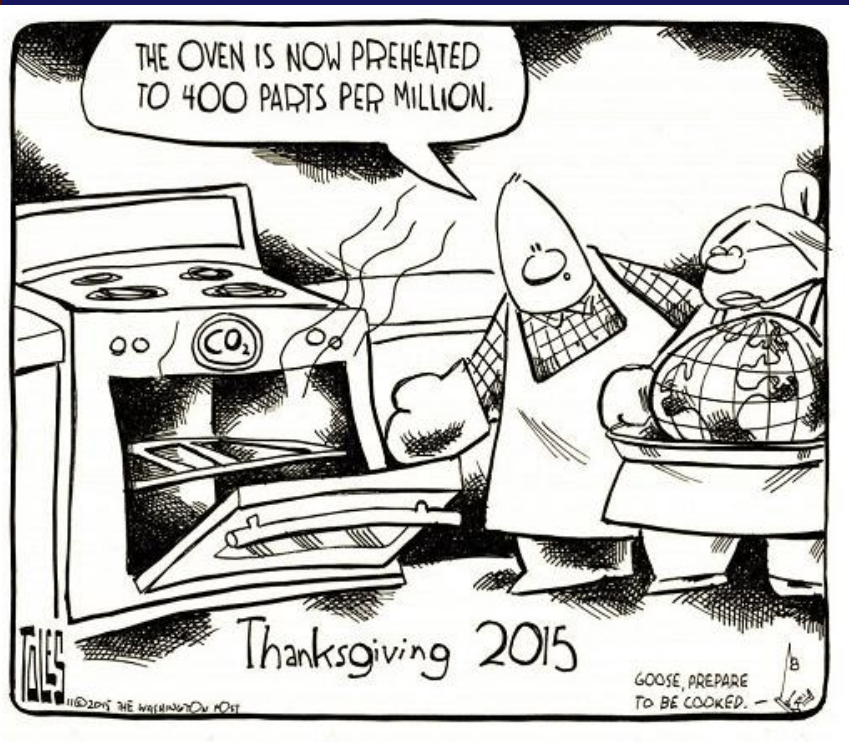
LW

If outgoing energy represented by Curve B is reduced (B curve goes down)

LW LW

HOW? GHG's increase & keep more LW in!


2015: HOTTEST YEAR SO FAR
Land and Ocean Temperature Percentiles Jan-Oct 2015
Record Coldest
Much Colder
Colder
Near Average
Hotter
Much Hotter
Record Hottest
Source: NOAA
CLIMATE CENTRAL


THE OVEN IS NOW PREHEATED TO 400 PARTS PER MILLION.
CO_2
Thanksgiving 2015
GOOSE, PREPARE TO BE COOKED.

21st Conference of the Parties of the United Nations Framework Convention on Climate Change, or COP21

November 30 to December 11, 2015 in PARIS

COP 21 Website:

http://www.cop21.gouv.fr/en/learn/what-is-cop21/

Why it's important in an short video from "GRIST"

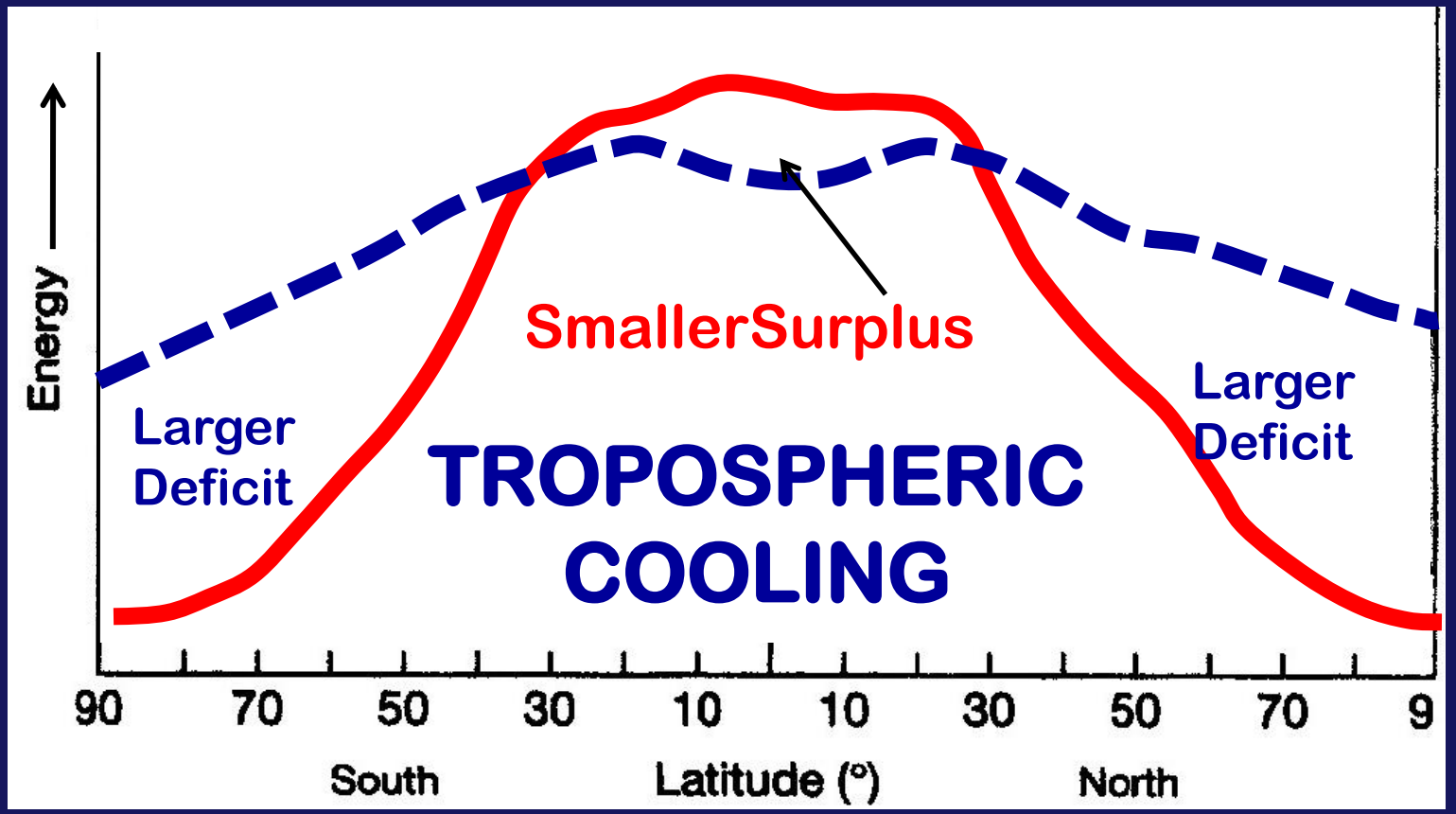
("a source of intelligent, irreverent environmental news and commentary that's been around since 1999")

What is the Climate Conference?

https://www.youtube.com/watch?v=oo5ca1dMbEc

What if PARIS talks are REALLY successful & GH gases decrease?

If CURVE B moves up: LW ↑ LW ↓



LW ↑ If outgoing energy represented by Curve B is increased (B curve goes up)

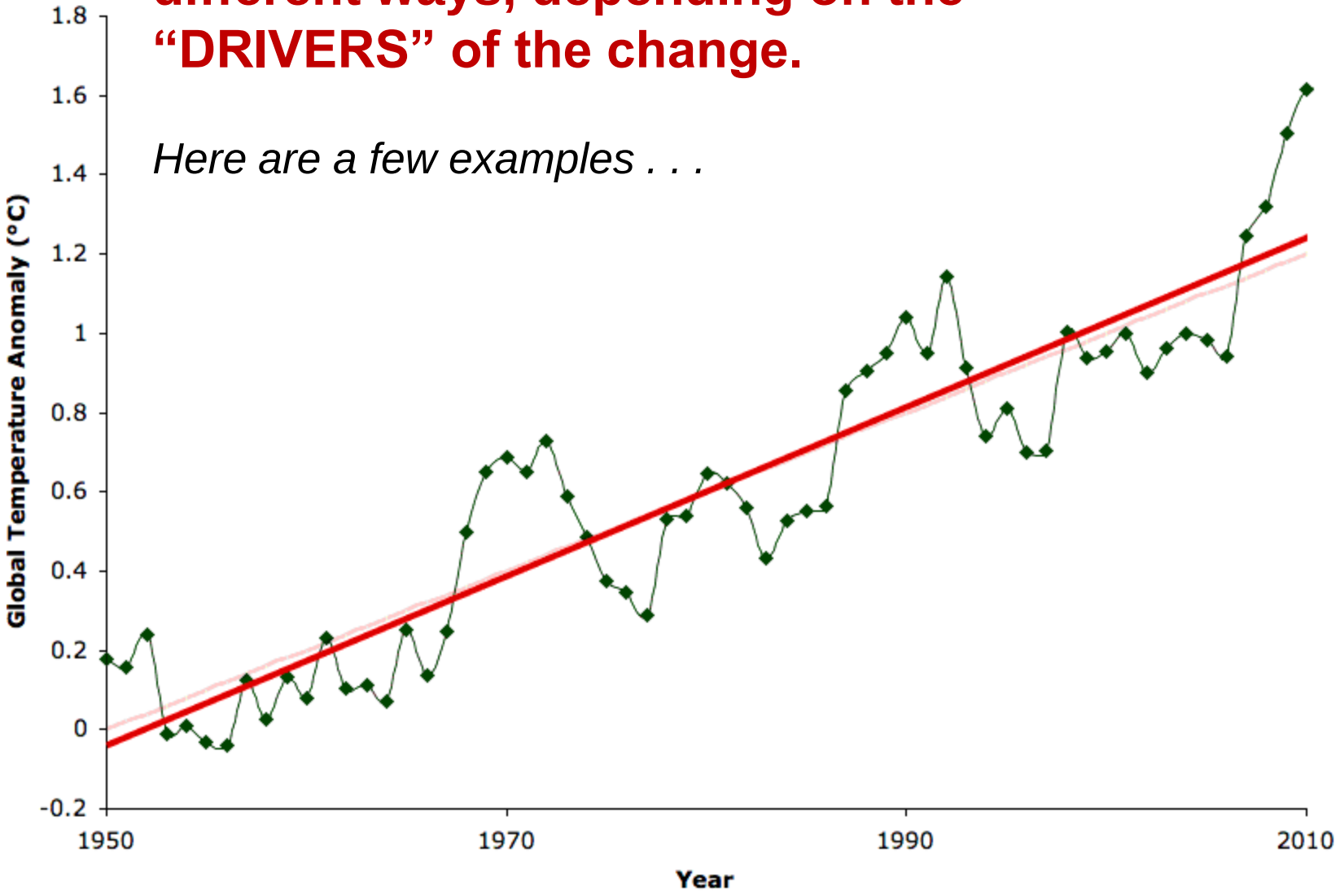
LW ↑ LW ↓ HOW? GHG's decrease & allow more LW out!

PAST & FUTURE
DIRECTIONS
are always described using:

TIME SERIES GRAPHS!

Change over time can proceed in many different ways, depending on the "DRIVERS" of the change.

Here are a few examples . . .



Source: http://www.skepticalscience.com/going-down-the-up-escalator-part-2.html

RECOGNIZING & DESCRIBING DIFFERENT TYPES OF CHANGE AS DEPICTED IN TIME SERIES PLOTS

Here are some terms that will help you describe time changes more precisely in fewer words:

- **Mean** = average (a constant mean stays the same over time and looks like a horizontal line.)
- **Variance** = the range of fluctuations (wiggles) above and below the mean (statistically the variance is the square of the standard deviation about the mean)

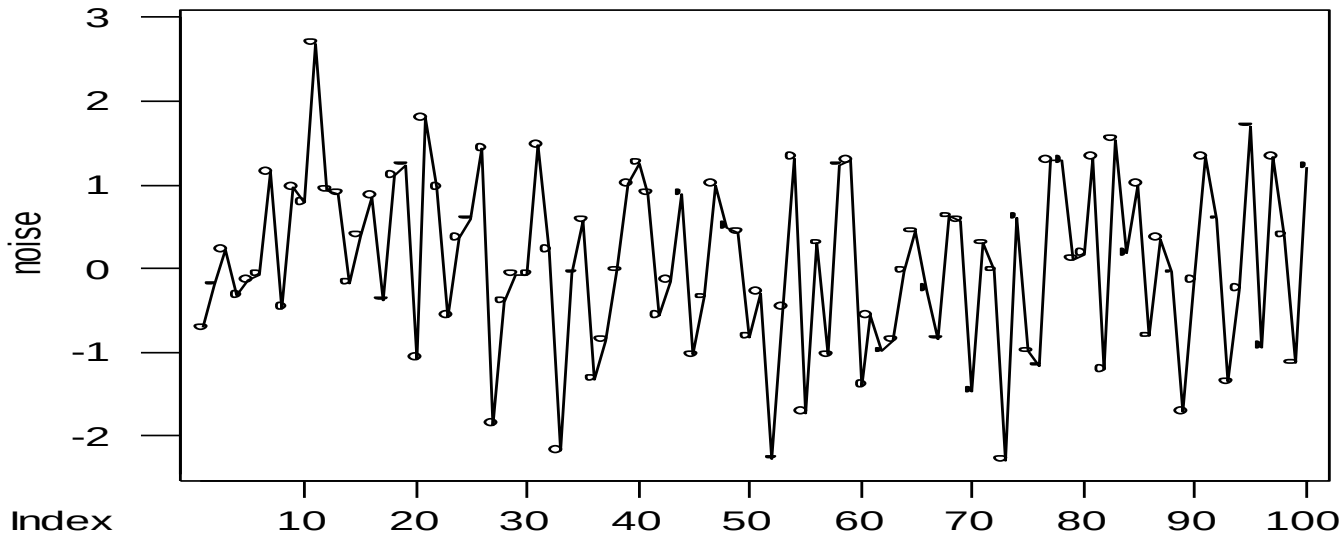
Appendix D
p 103

Terms (cont.)

Periodic = perfect oscillations (fluctuations) (going up and down regularly or in a perfect wave-like motion)

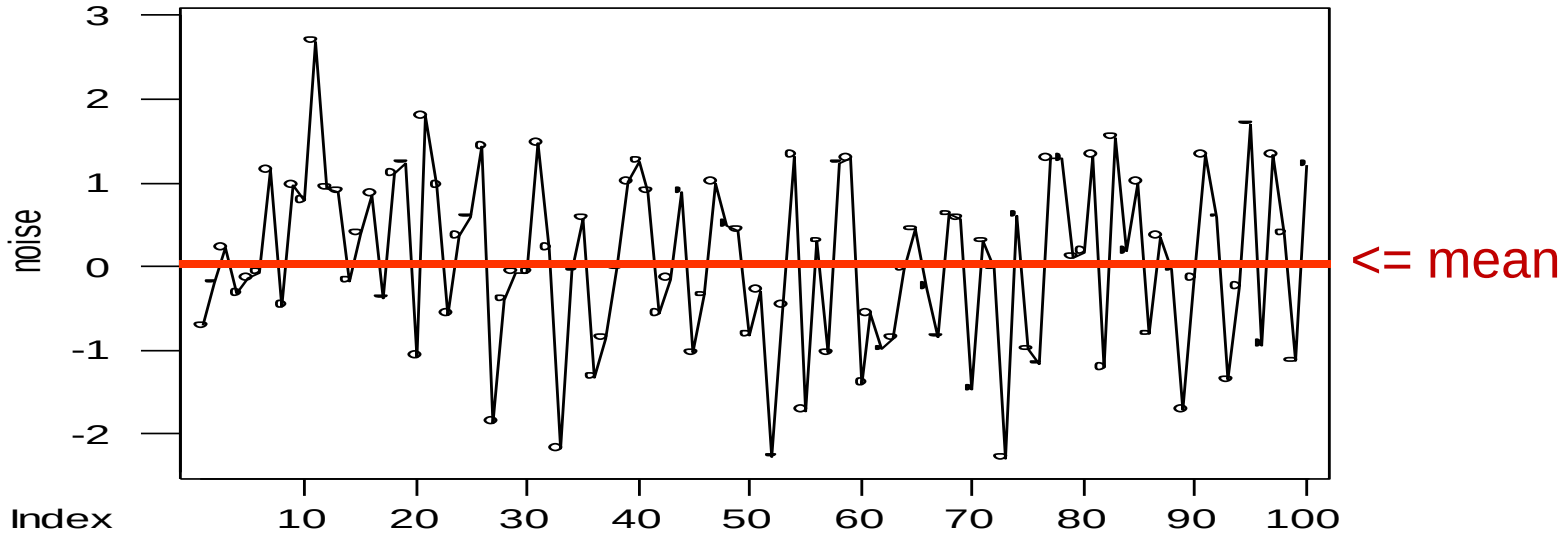
- **Quasi-periodic** = almost regular oscillations (in nature things are quite often quasi-periodic rather than perfect oscillations)
- **Trend** = a line of general direction (increasing or decreasing)

Time Series Plot 1



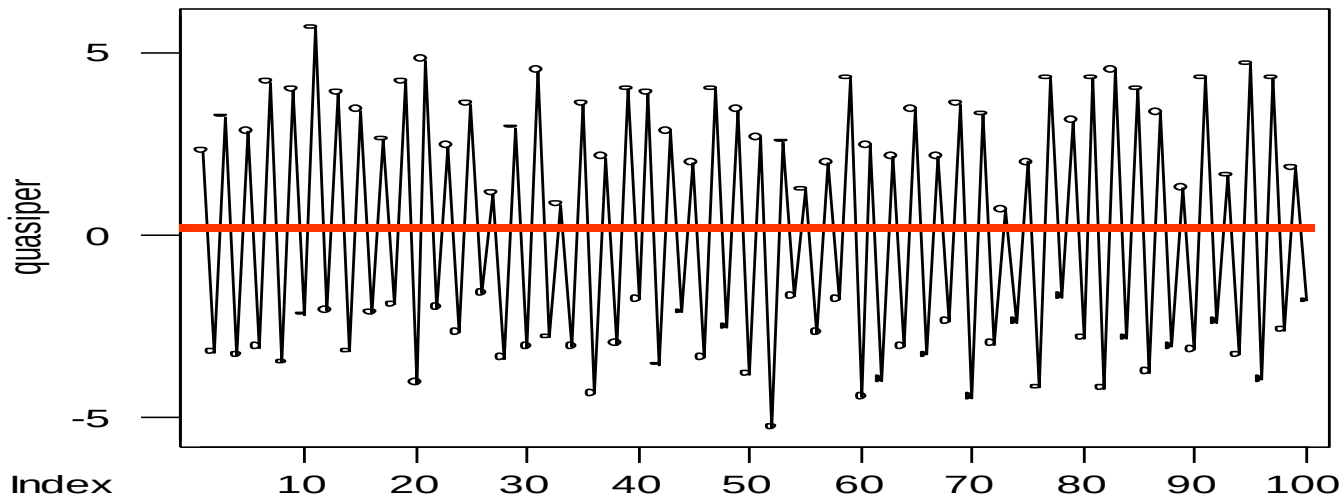
Draw in the MEAN line for this time series.

Time Series Plot 1



“White Noise” or “Random”plot -- This plot appears to go up and down without any regular pattern (e.g., randomly); there are about as many points above the time series mean (average) as below; and the range of wiggles (variance) above and below the mean seems to be about the same over time.

Time Series Plot 2

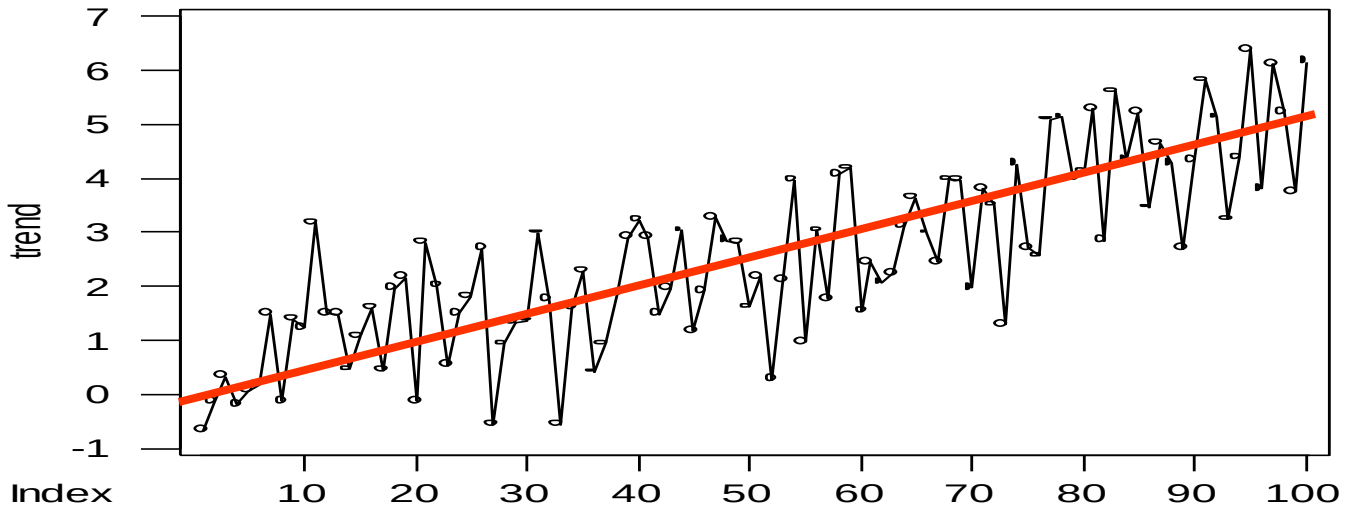


Regular ups and downs . . . but not perfect . .

Is the mean constant?

Is the variance constant?

Time Series Plot 3

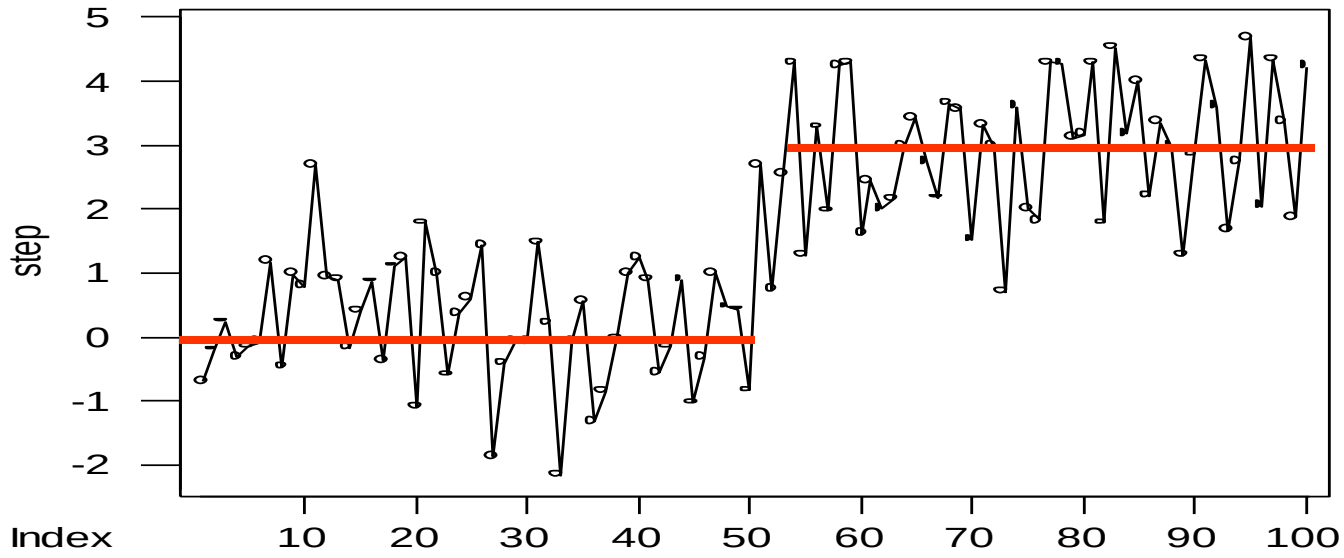


Hmmm, something is changing here . . .

What's happening to the mean?

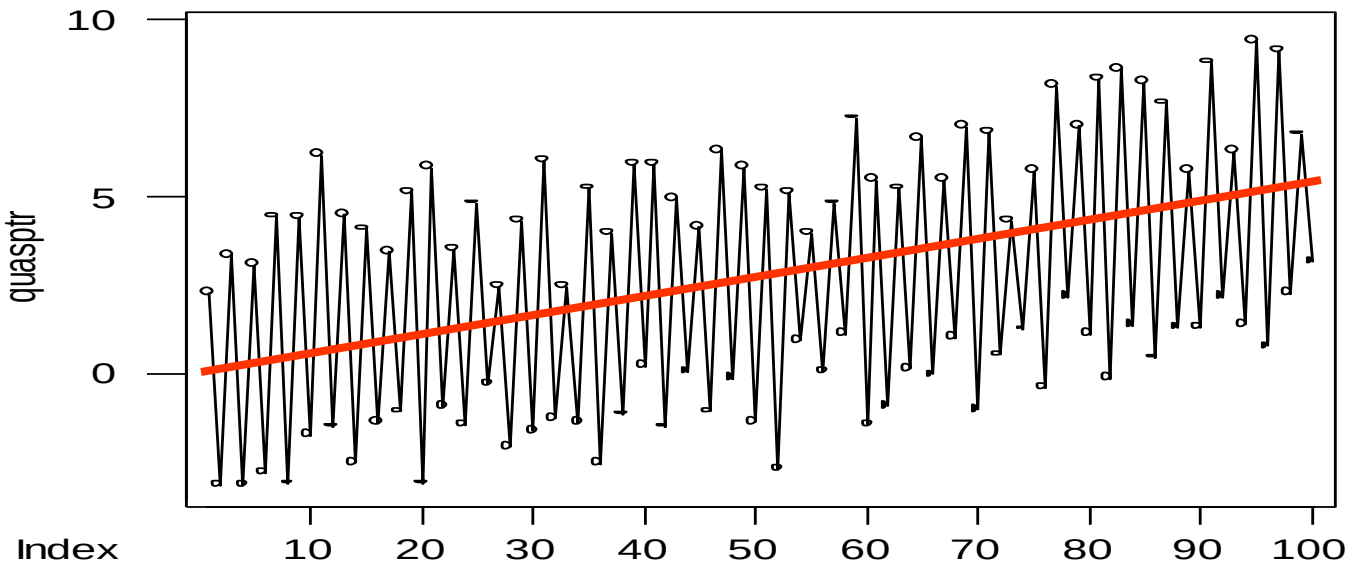
Is the variance constant?

Time Series Plot 4



Looks a little like a “set of stairs” with an abrupt jump between two series, each with a constant _____

Time Series Plot 5

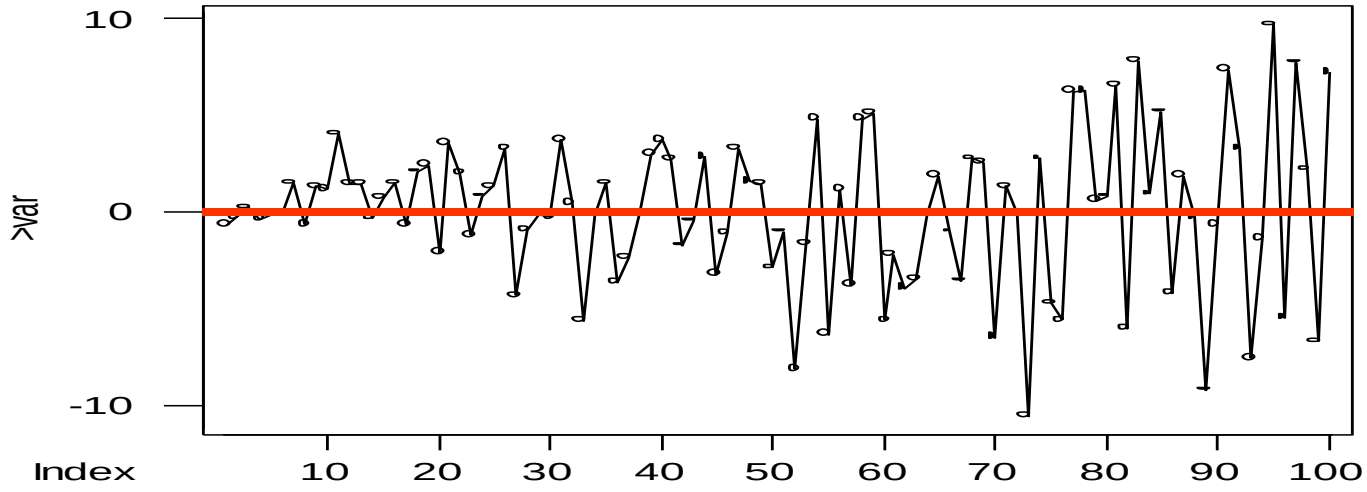


Looks like Plot #3, but it's different – in what way?

What's going on with the mean?

The variance?

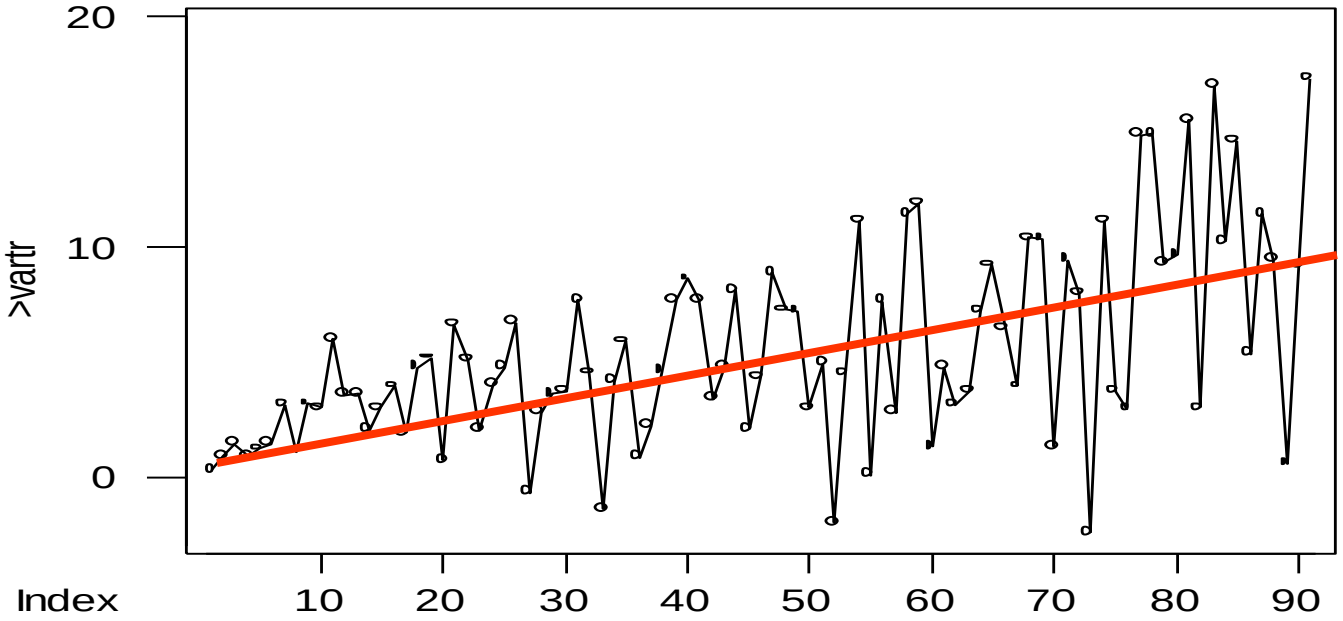
Time Series Plot 6



What's going on with the mean?

The variance?

Time Series Plot 7

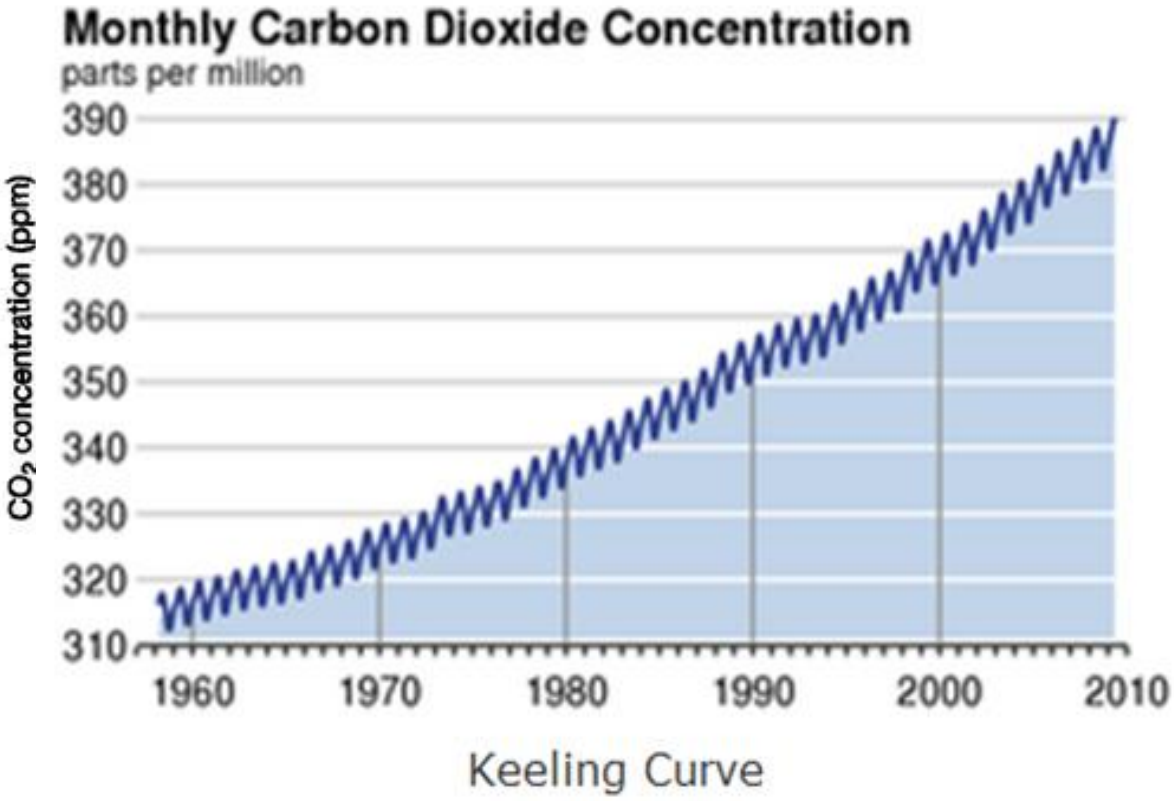


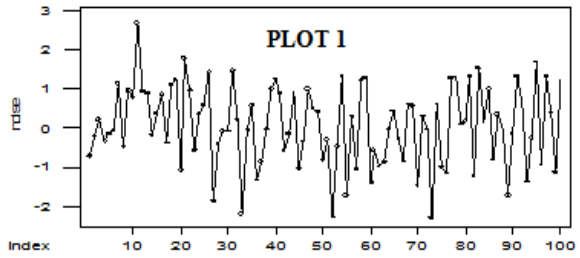
Is there a trend?

What's going on with the mean over time?

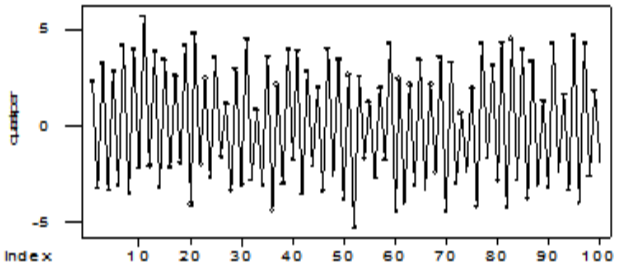
What's going on with the variance?

The “Keeling curve” is most like Plot # ____ ?



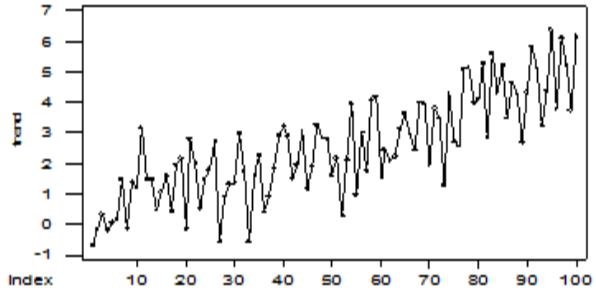


PLOT #1: "White noise" (random fluctuations) but with constant mean and variance *[answer given for you]*



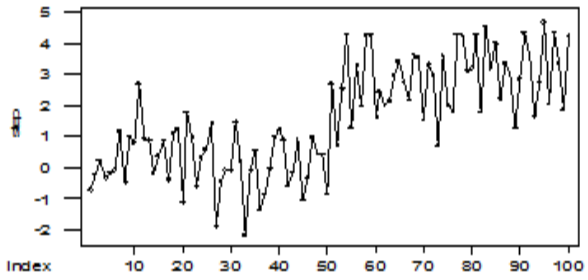
PLOT 2

PLOT #2: "Quasi-periodic plot" with constant mean and variance.
[Graph goes up and down very regularly (periodically); the mean stays the same, the range of fluctuations above and below the mean stays about the same over time.]



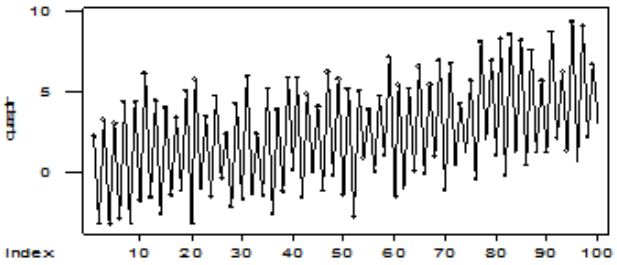
PLOT 3

PLOT #3: "Trend" plot with the mean increasing over time, but a constant variance. *[Graph shows trend of increasing values and increasing mean; the range of fluctuations is about the same.]*



PLOT 4

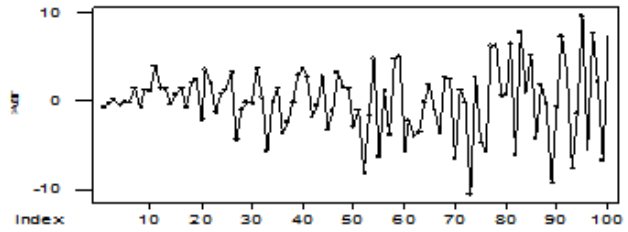
PLOT #4: "Step Change" plot with an abrupt jump between two series like Plot 1.
[Graph shows a "jump" or abrupt change between two different time series, each having a constant mean and variance]



PLOT 5

PLOT #5: "Quasi-periodic with upward trend" plot

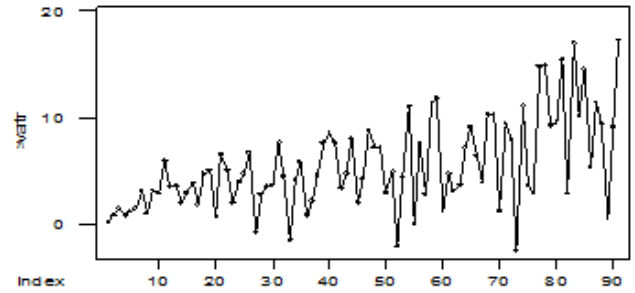
[Graph shows an increasing trend and increasing mean, but has regular periodic ups and downs above and below the increasing mean.]



PLOT 6

PLOT #6 "Increasing variance but constant mean" plot.

[Graph's mean is constant but the range of fluctuations above and below the mean increases over time.]

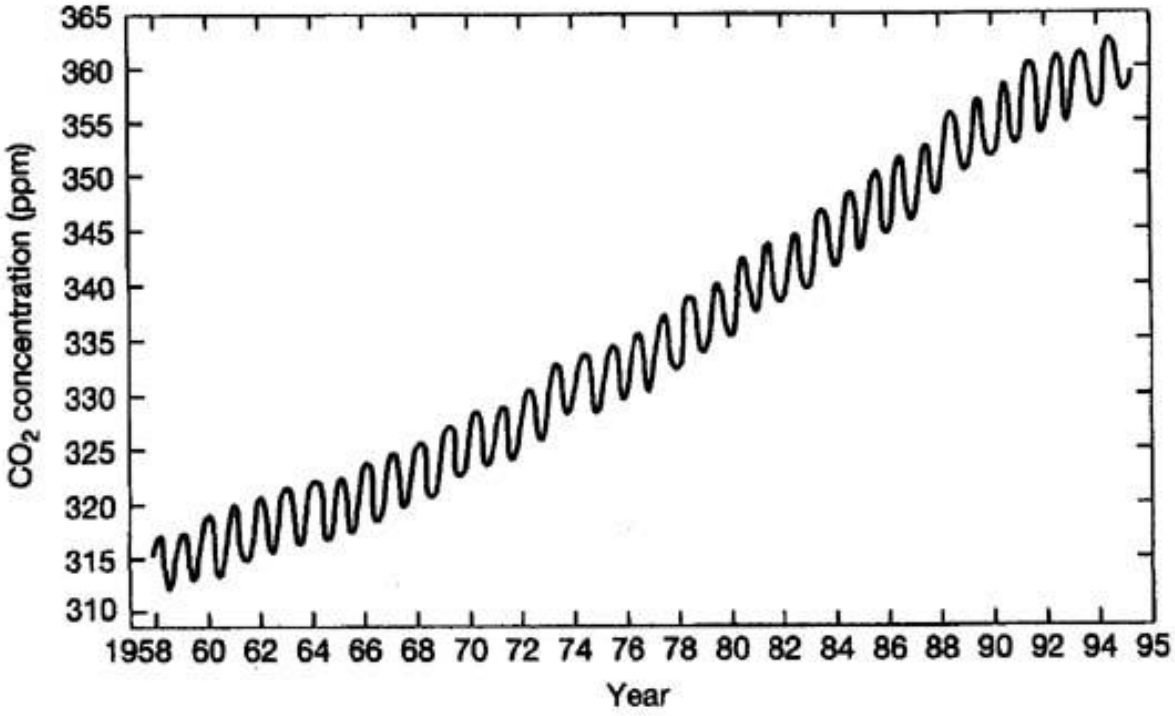


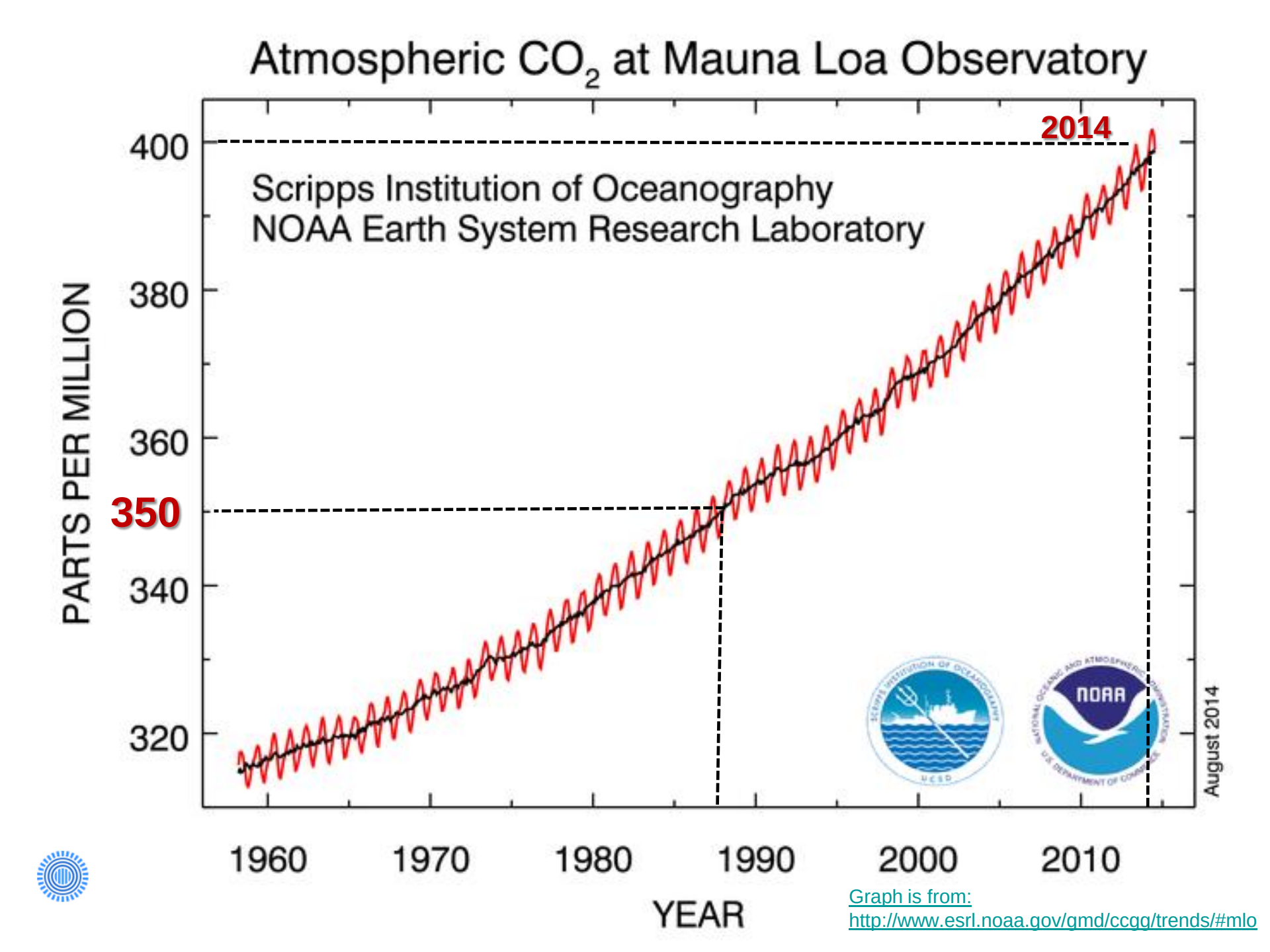
PLOT 7

PLOT #7 "Trend with increasing mean and increasing variance" plot

[Graph had both an increasing mean and an increase in the range of fluctuations above and below the mean over time – the extremes are getting bigger!]

the “Keeling curve” is most like Plot # 3 (or 5)





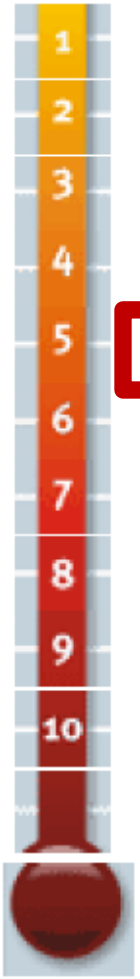
Graph is from:
http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo

CLIMATE CHANGE:

WHAT'S CAUSING IT?

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

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



1. Climate's changed before
2. It's the sun
3. It's not bad
4. There is no consensus
5. It's cooling
6. Models are unreliable
7. Temp record is unreliable
8. Animals and plants can adapt
9. It hasn't warmed since 1998
10. And so forth . . . . .

This semester we will critically examine and evaluate the most used arguments and myths about climate change!

. . . and now

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

To make an incontrovertible case about the role that humans play in global warming, what do scientists need?

1) a long-term temperature record, i.e., centuries
2) over a large part of the globe
3) To be able to say . . . . .

"What's the average been for several hundred years, & is this a significant departure from that?"

"And that's very difficult to do."

(James Trefil, physicist)

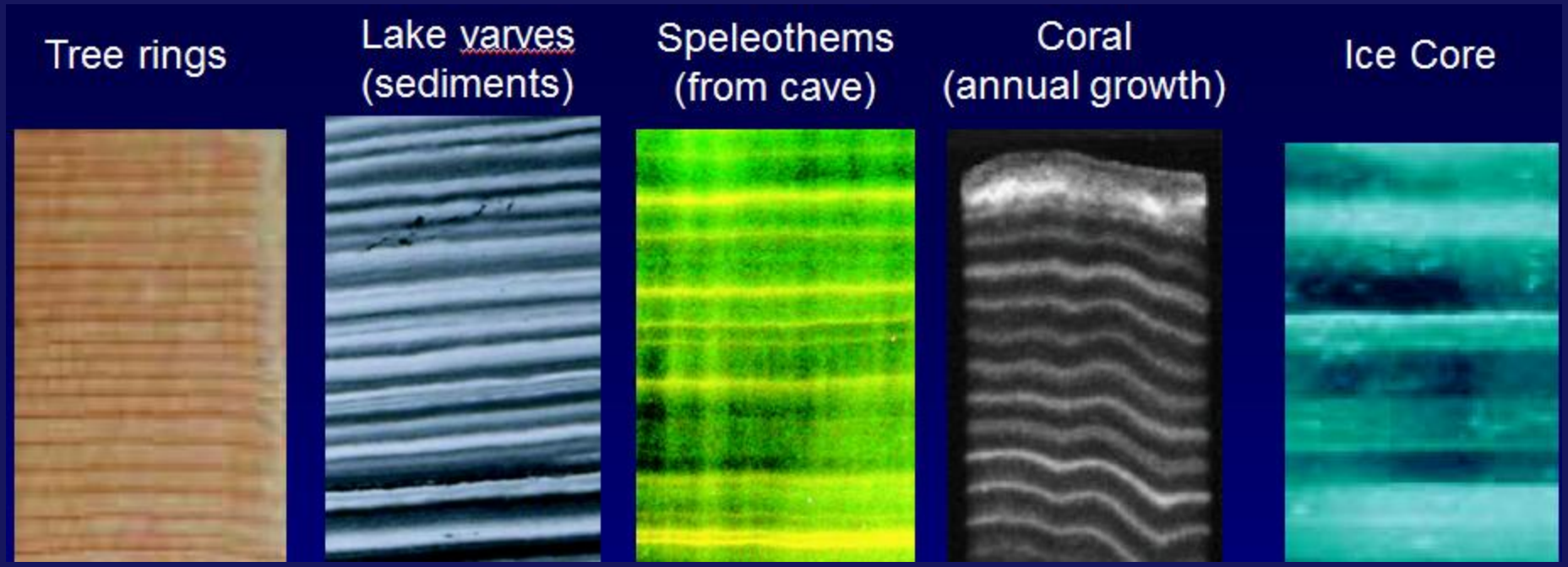
TOPIC # 13
GLOBAL WARMING
& Anthropogenic Forcing

Part C

The Evidence
(from Natural Archives & Computer Models)

Class Notes pp 84

TOPIC # 13 - PART C
Evidence from Natural Archives



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

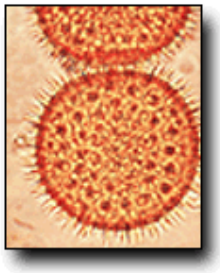
- Winston Churchill

Class Notes p 84

“PROXY” DATA or NATURAL ARCHIVES of CLIMATE

Corals

Ice cores

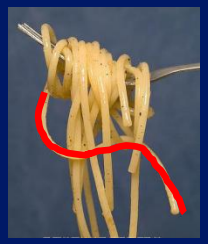


Pollen

Lake, bog & ocean sediments

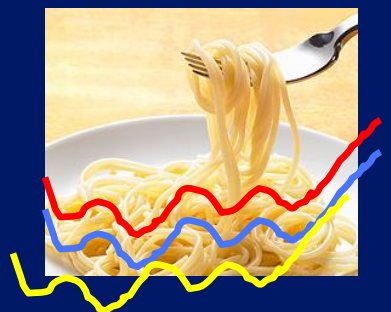
3 "iconic" graphs of GLOBAL CLIMATE CHANGE . . . p 84

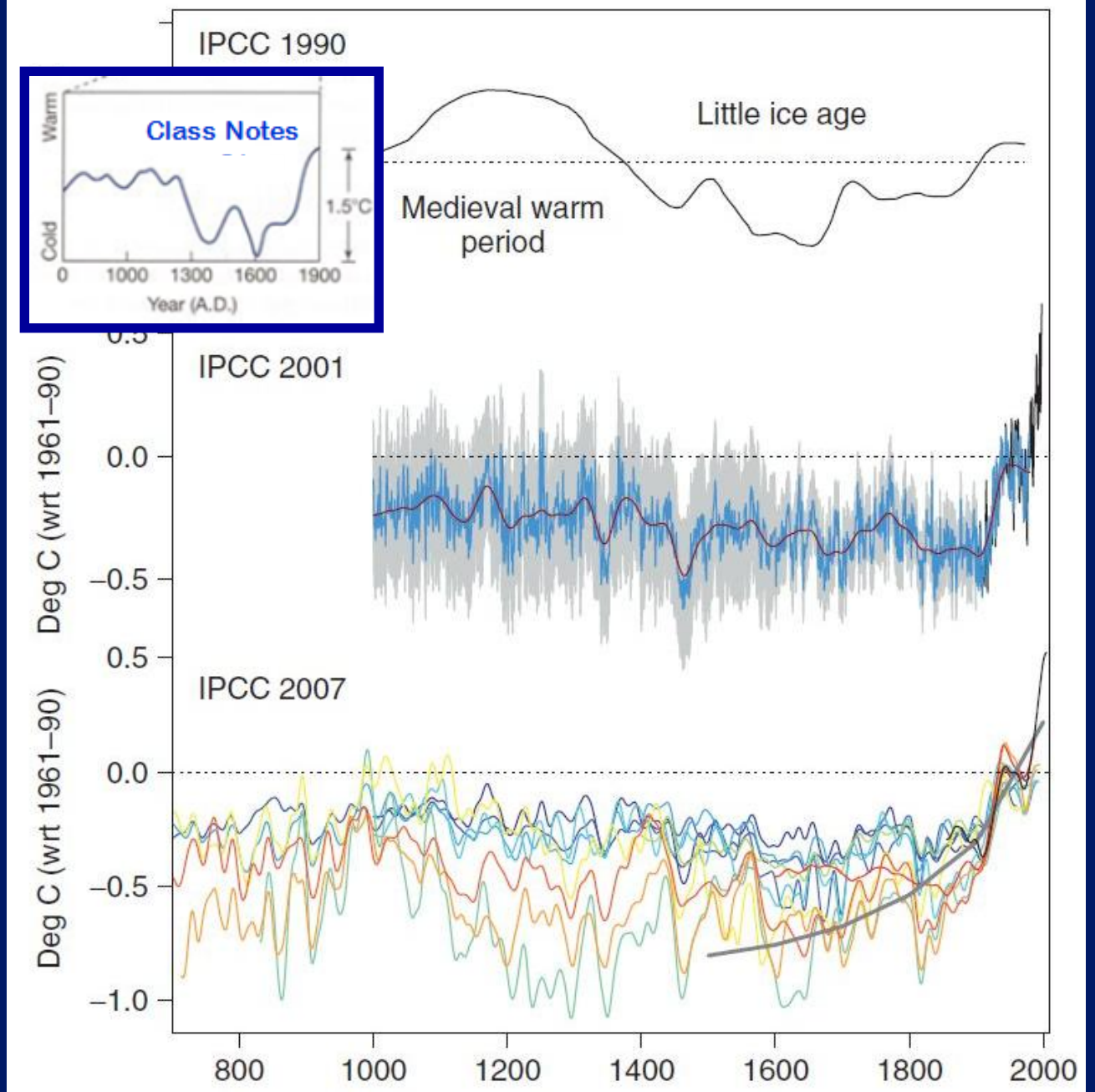
The "Noodle"



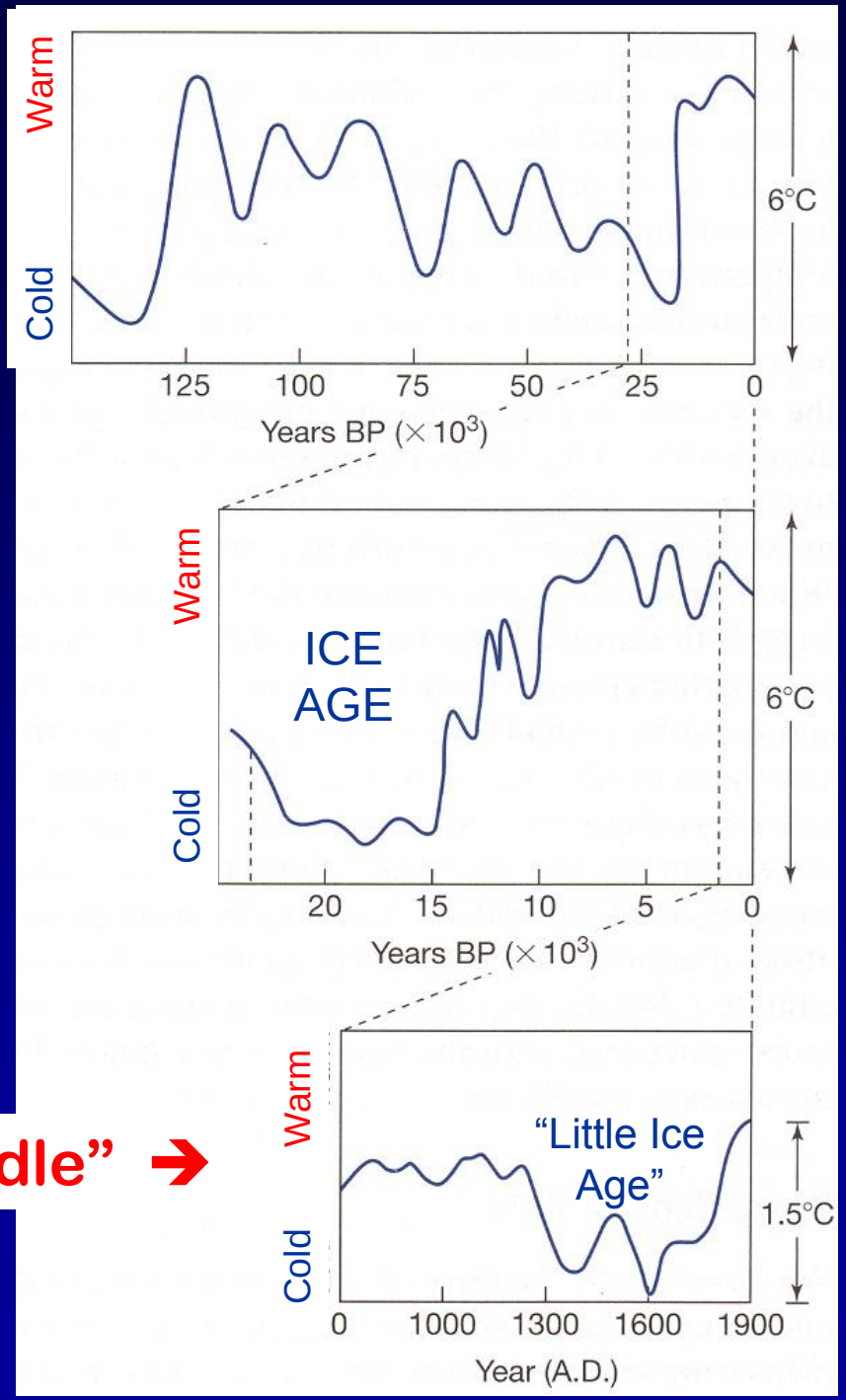
The "Hockey Stick"

The "Spaghetti Plate"





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



deep-sea sediments

pollen data & alpine glaciers

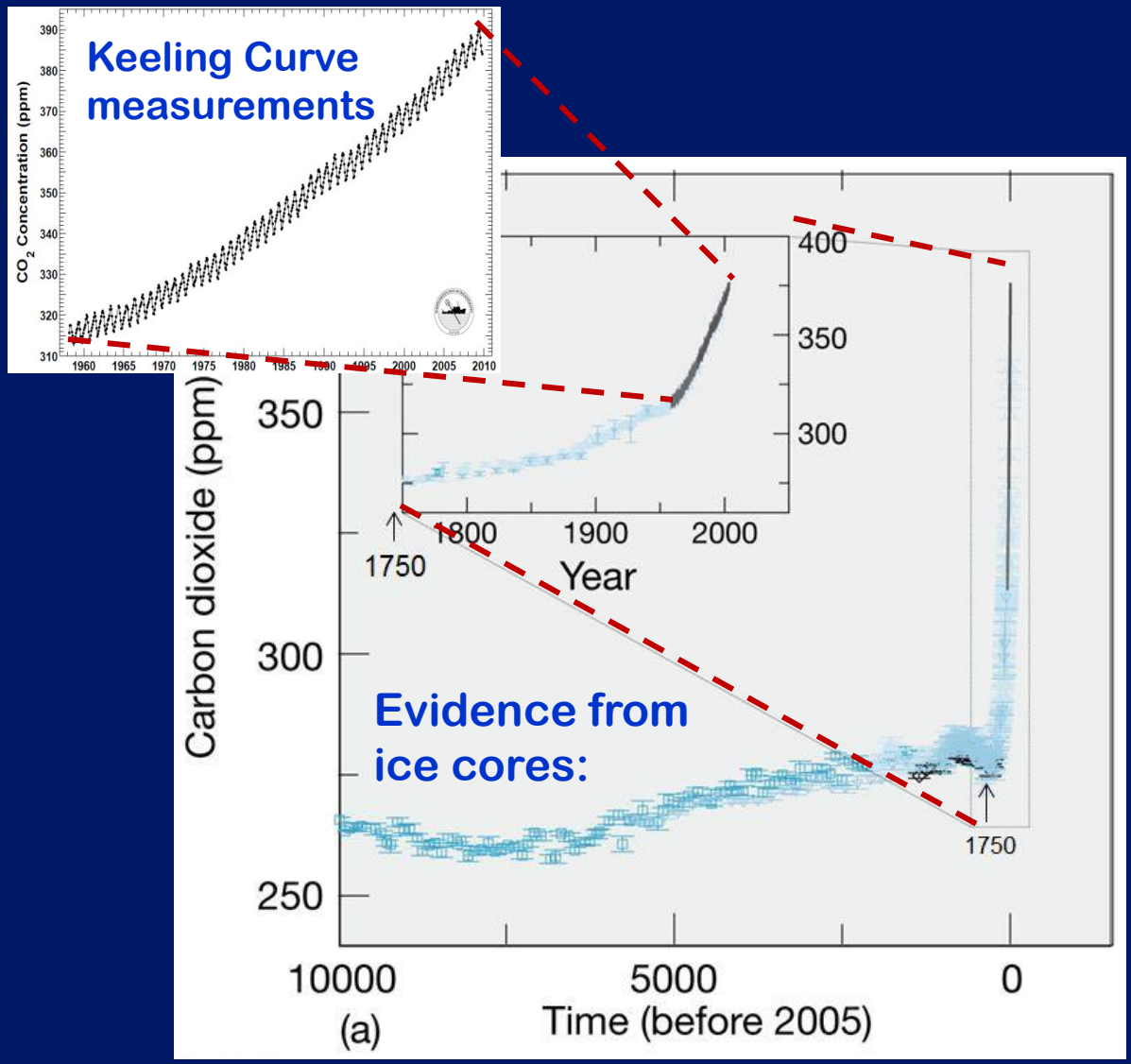
historical documents

(emphasis on the North Atlantic region)

The "Noodle" ➔

top graph on p 84

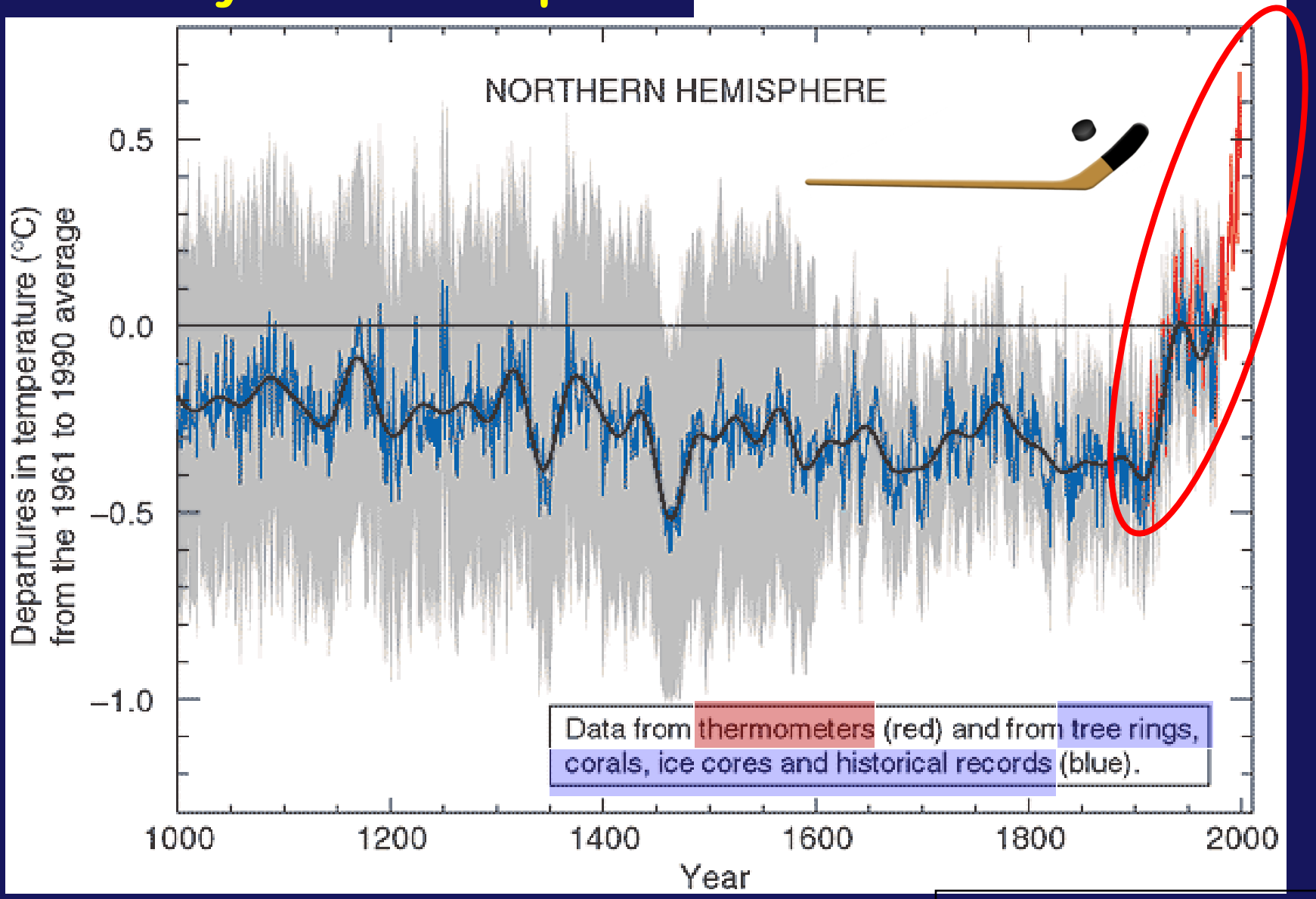
The CO_2 "Hockey Stick" Graph . . .



SGC E-Text
Chapter 1
Fig 1-3a

The Temperature "Hockey Stick" Graph

"proxy" data + thermometer records

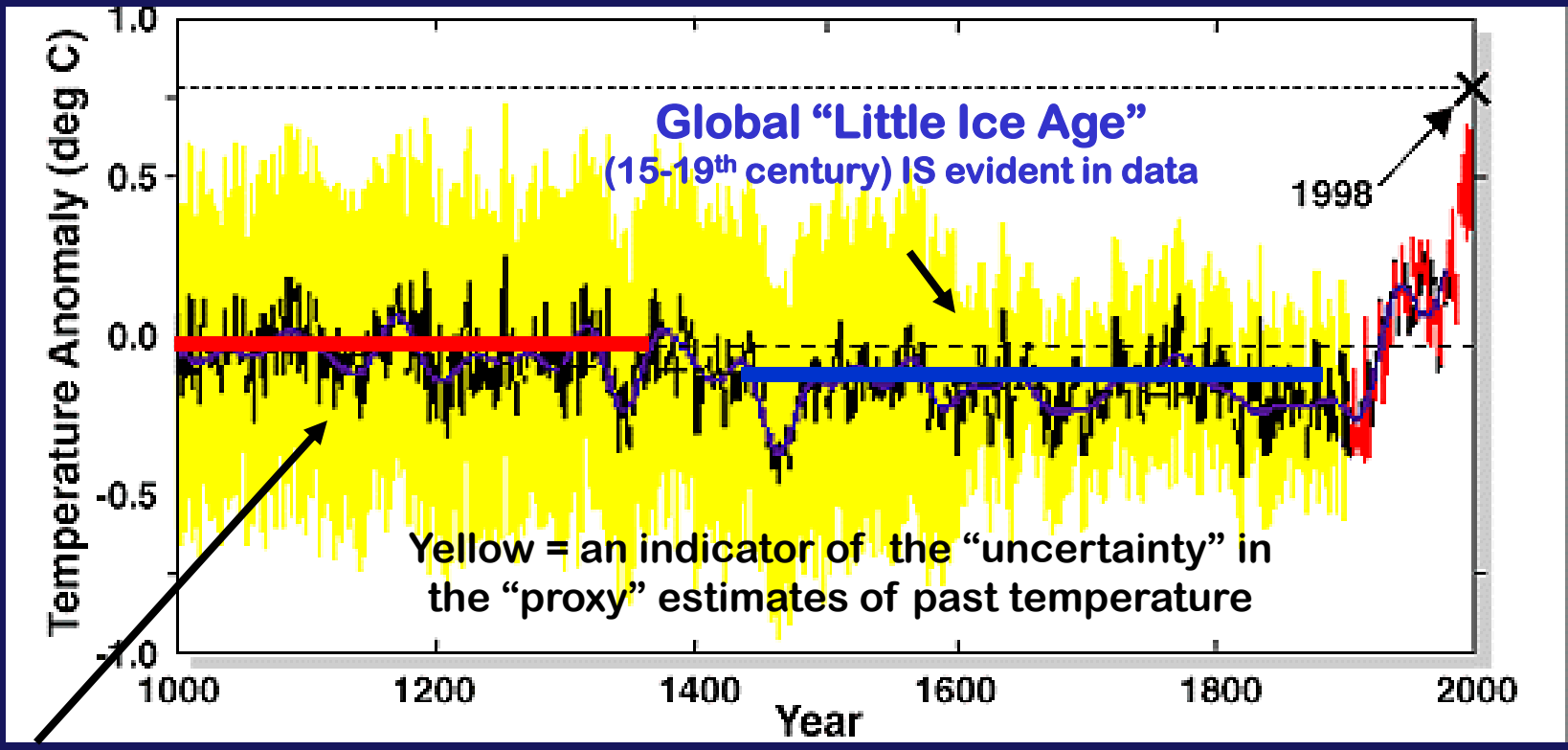


middle graph on p 84

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

1902 -80 global mean

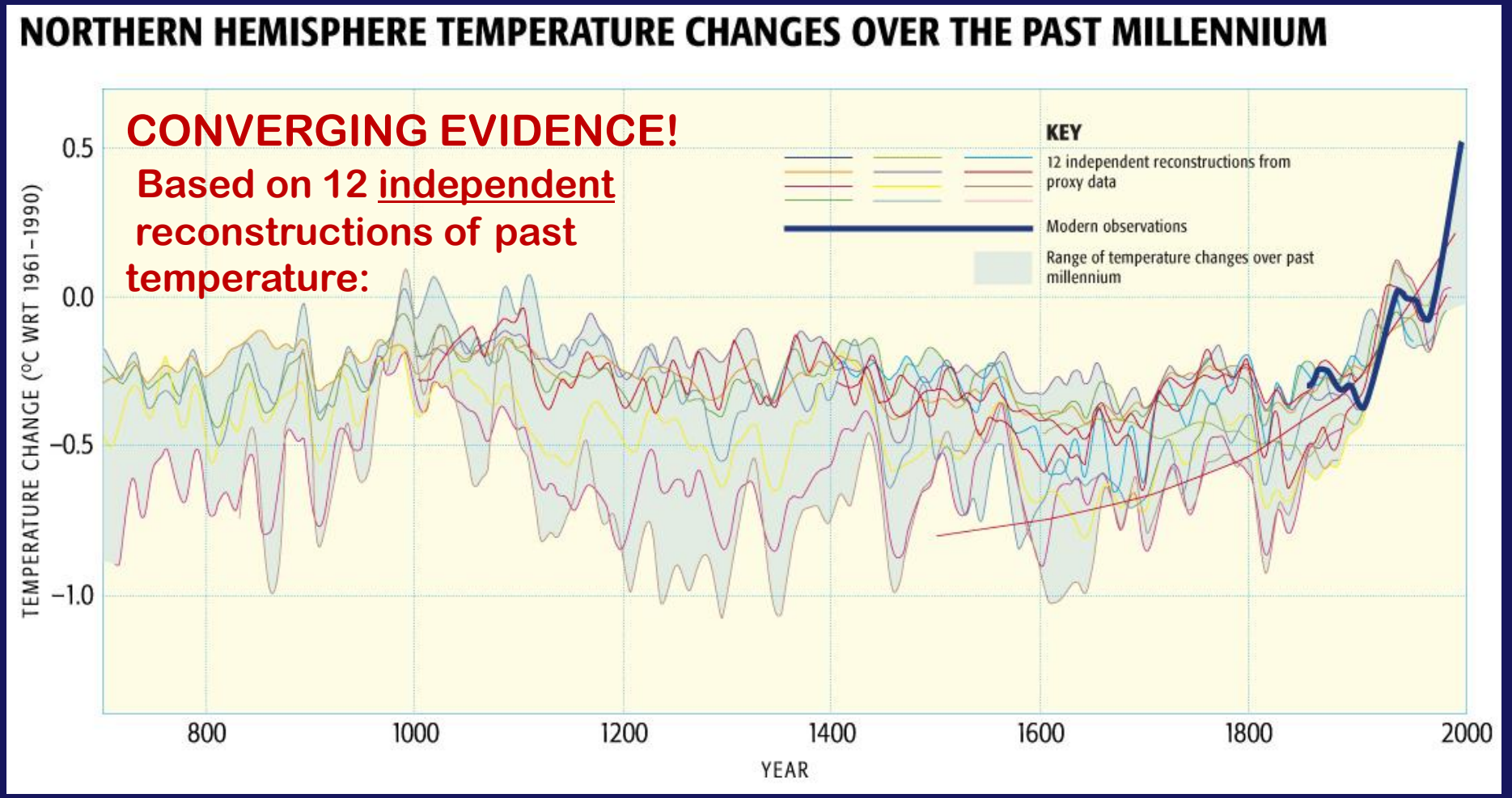


"Medieval Warm Period" (9-14th century) not very evident (more of a regional phenomenon)

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

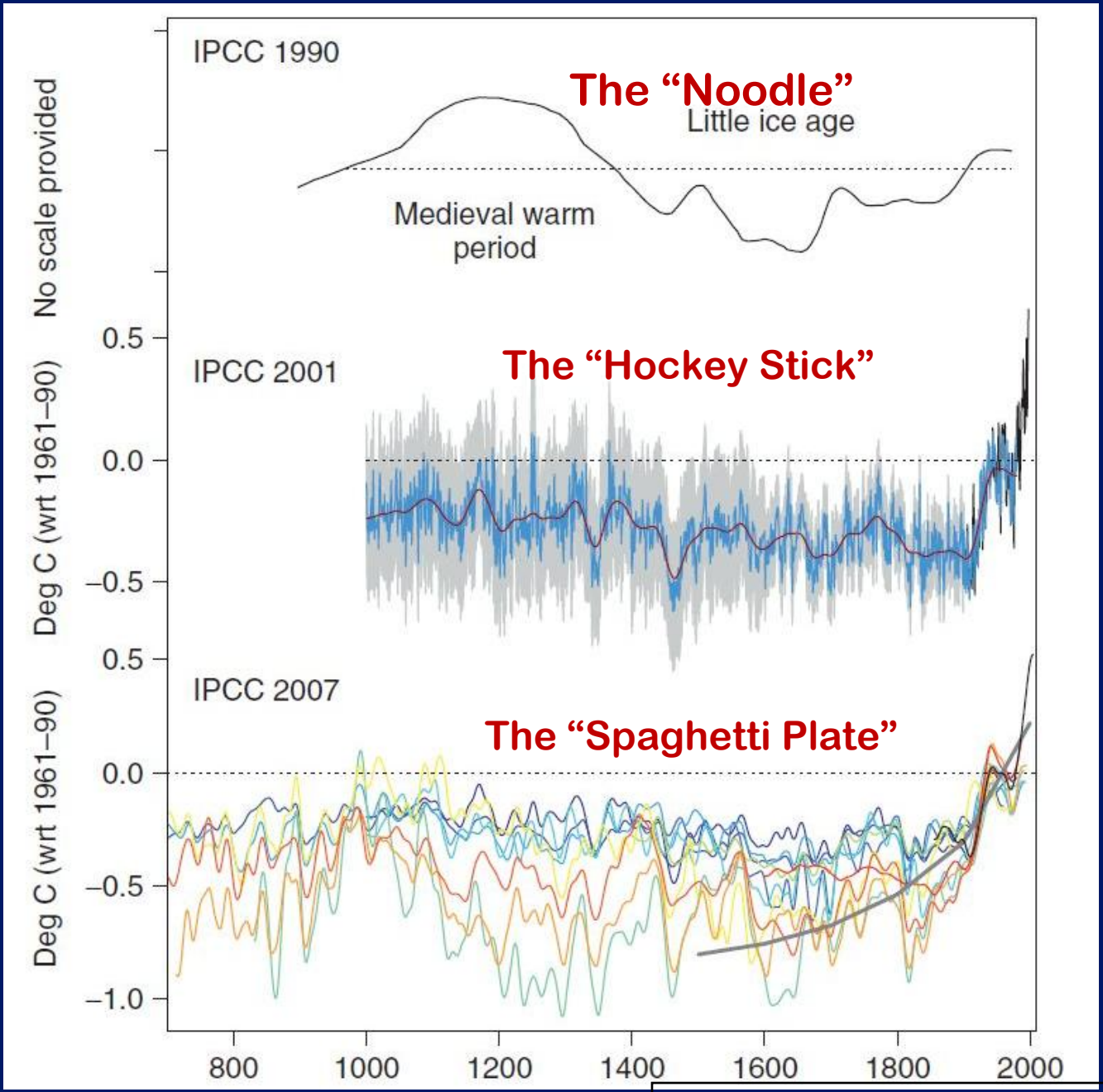
Another version

The Temperature "Spaghetti Plate" Graph



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

The Scientific Process "in action"



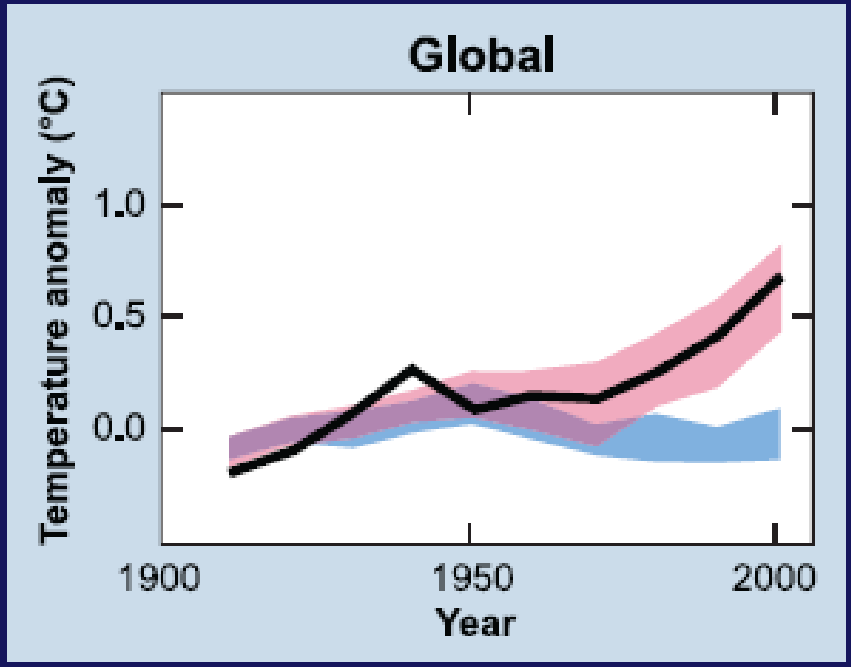
All 3 graphs on p 84

TOPIC # 13 - PART C
Evidence from Model Comparisons
Natural vs. Anthropogenic

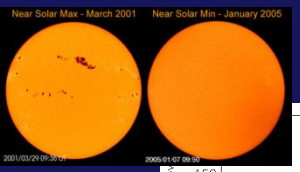
observations

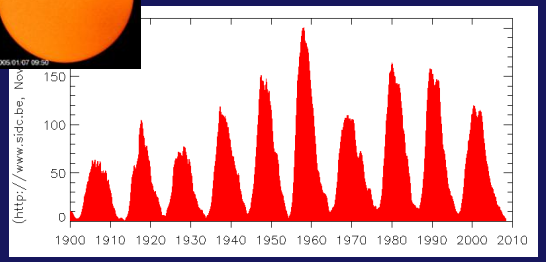
Only Natural Forcing

Natural + Anthropogenic Forcing

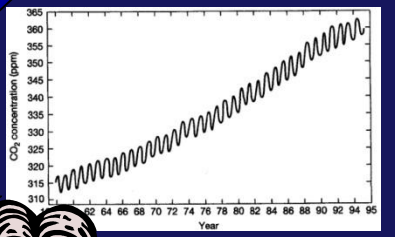


NATURAL FORCING

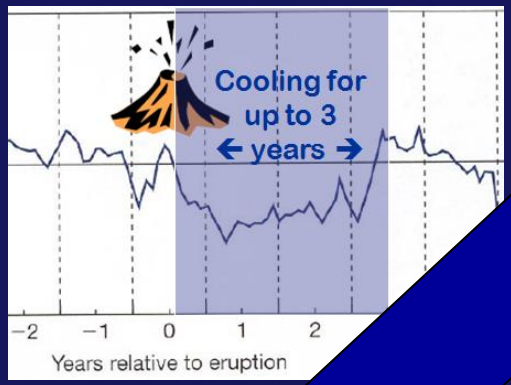




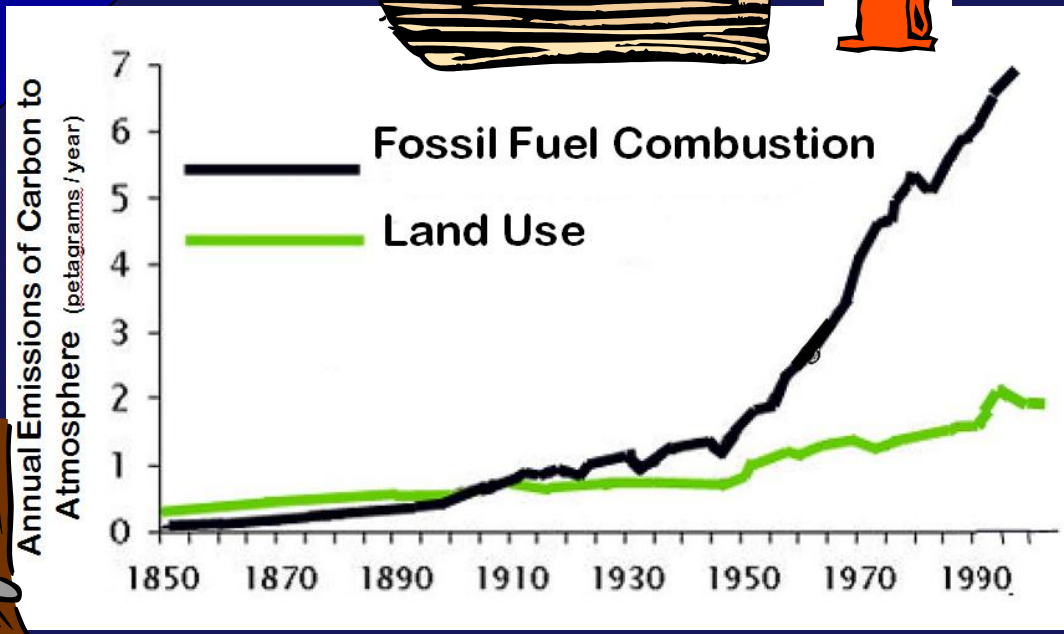
Solar output variations, sunspots

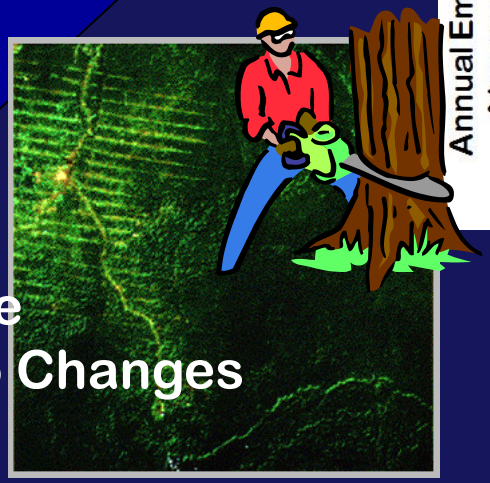


GHG's, soot, SO_2



Volcanic eruptions



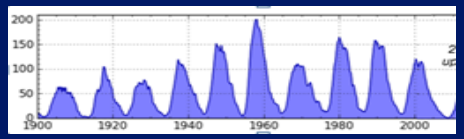


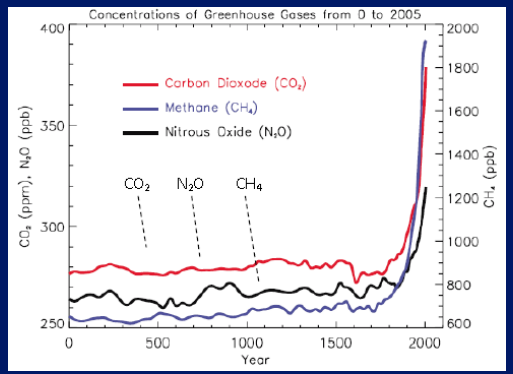
Surface Albedo Changes

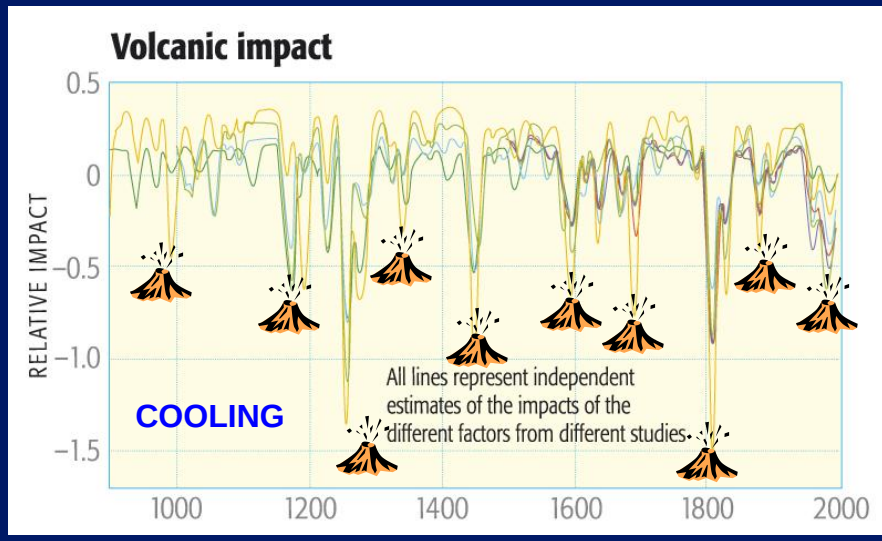
ANTHROPOGENIC FORCING

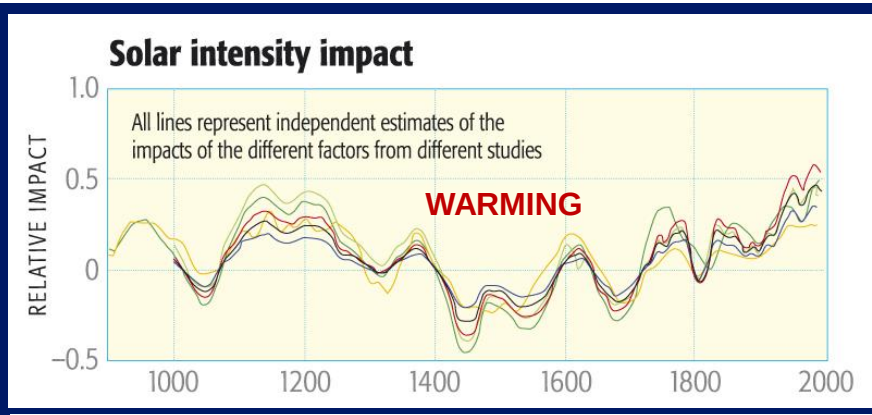
In addition to the "Natural - Archive – Paleo" Approach, **COMPUTER MODELS** have been created to estimate the radiative forcings of the PAST!

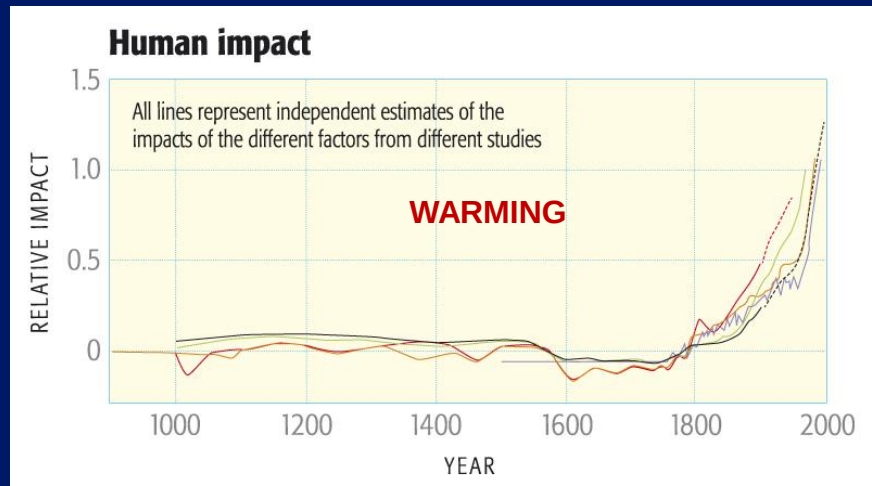
Estimates Of Natural & Human Impacts On Climate Over The Past 1000 Years





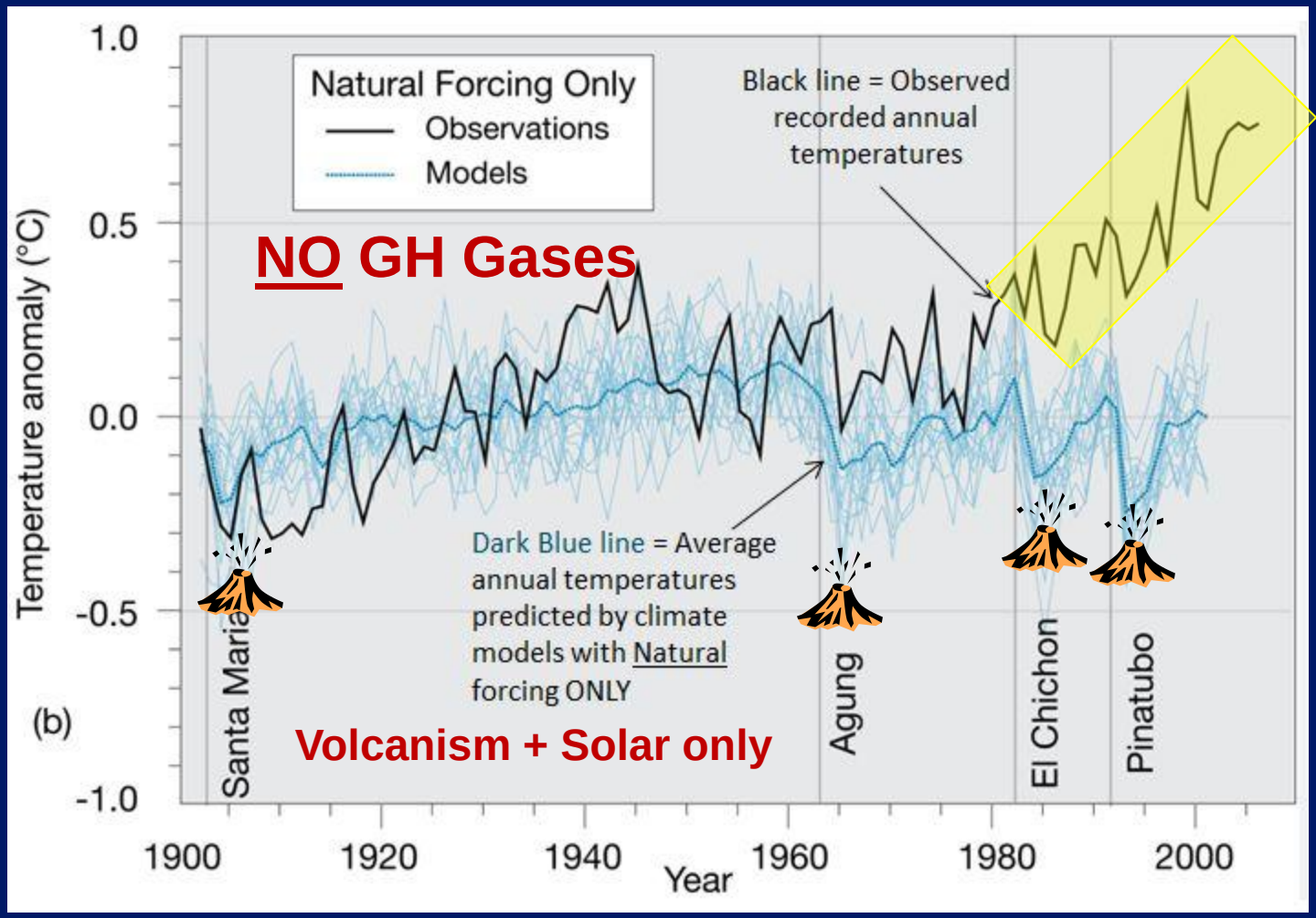






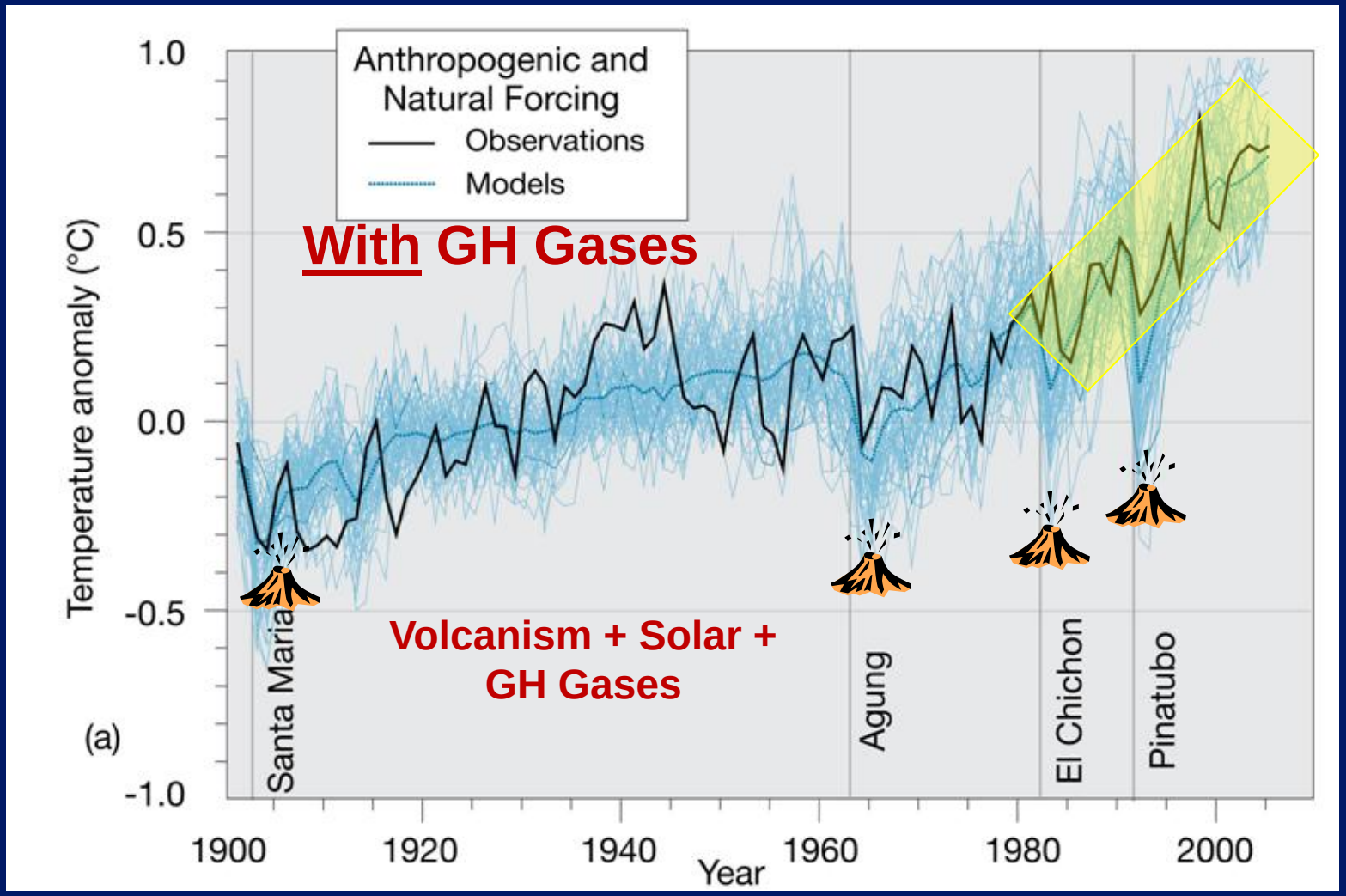
On top of p 85 in Class Notes

MODELED TEMPERATURE based on NATURAL FORCING ONLY:

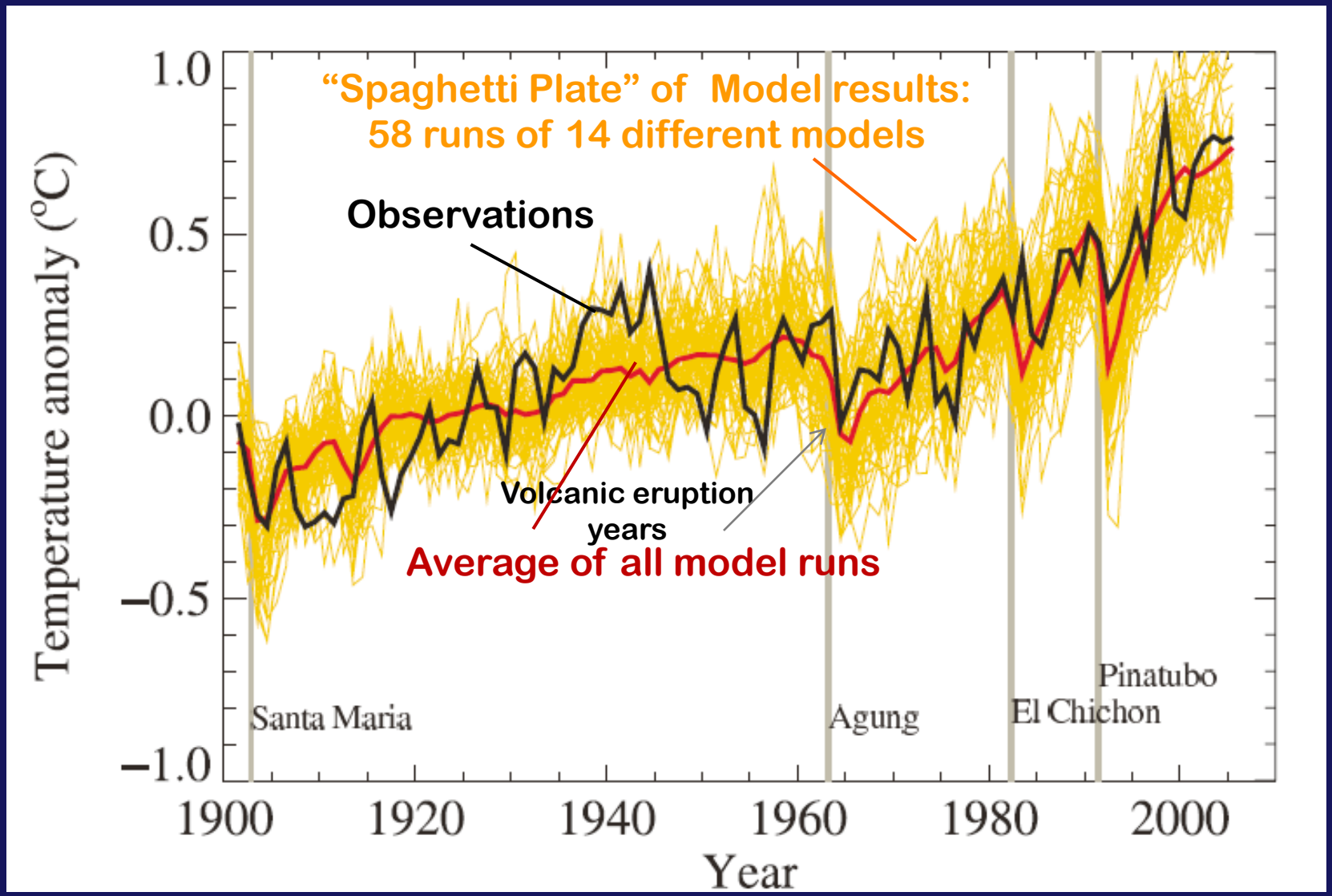


Models cannot reproduce the observed temperature trend since ~ 1980

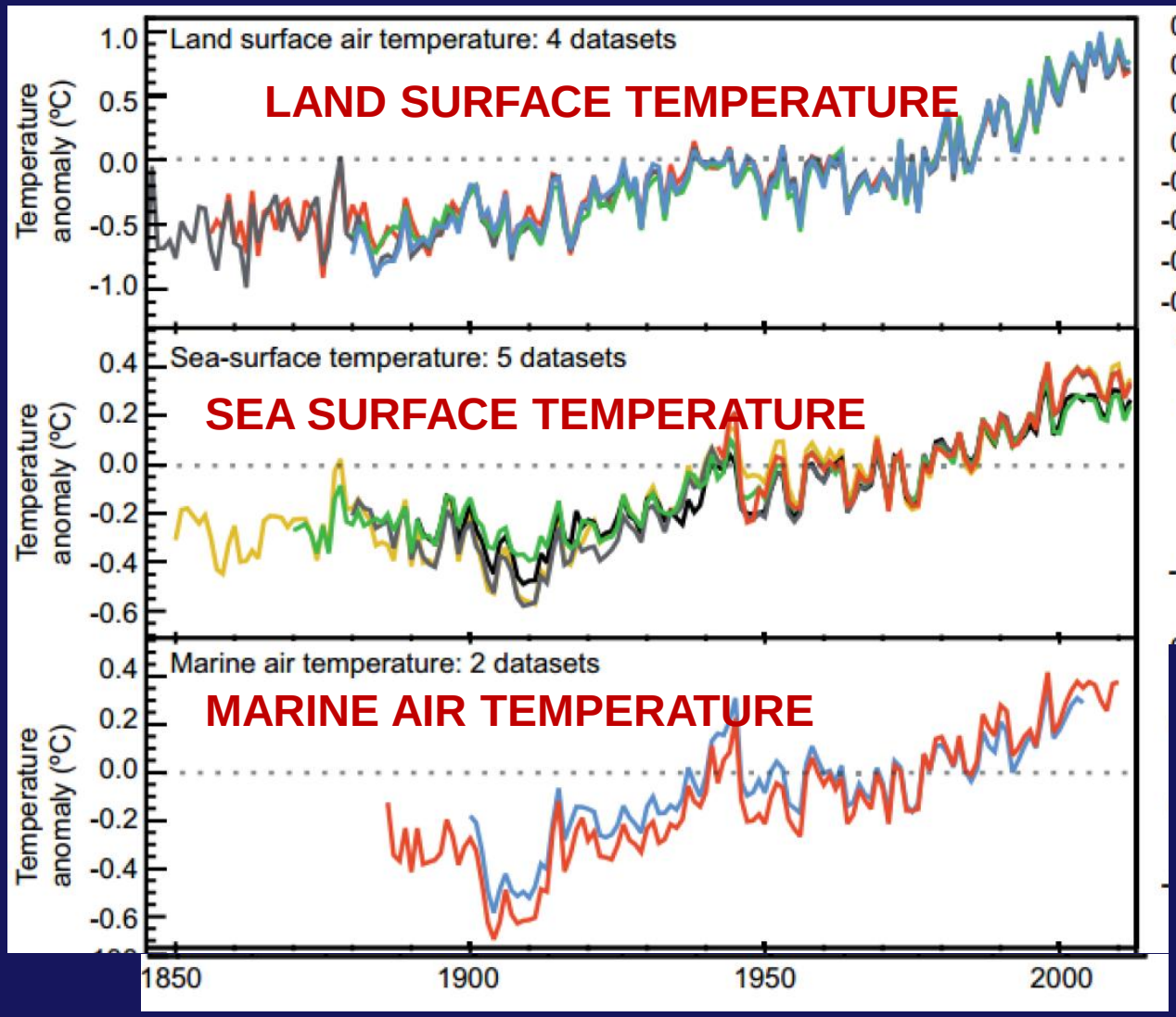
MODELED TEMPERATURE based on NATURAL + ANTHROPOGENIC FORCING

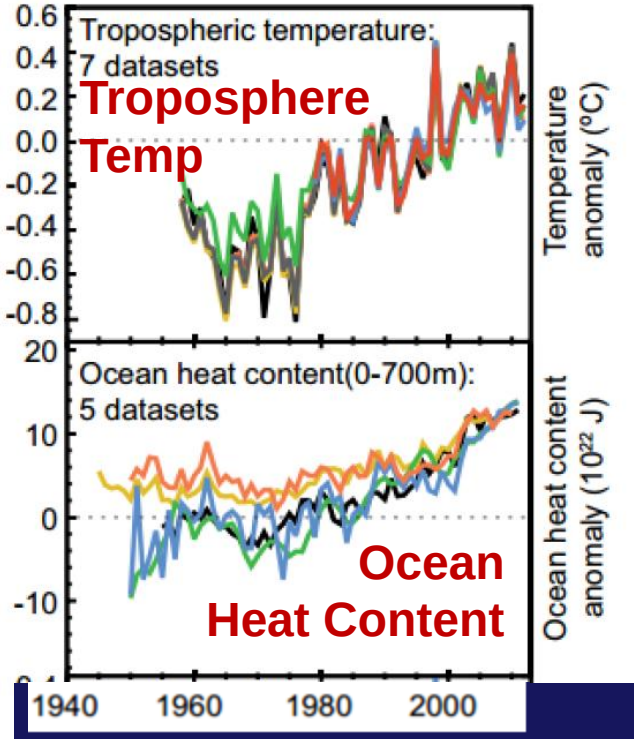


MODELED TEMPERATURE based on NATURAL + ANTHROPOGENIC FORCING



That's what the COMPUTER MODELS say . . . .
What is the EARTH ITSELF
telling us about how it s TEMPERATURE is changing?



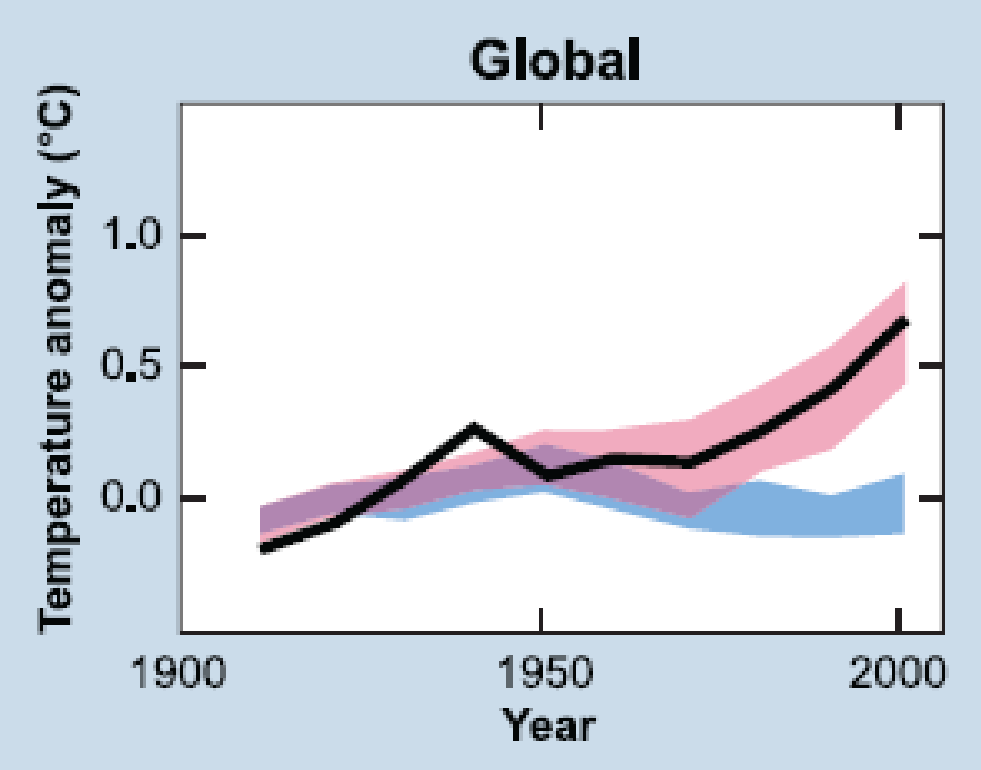


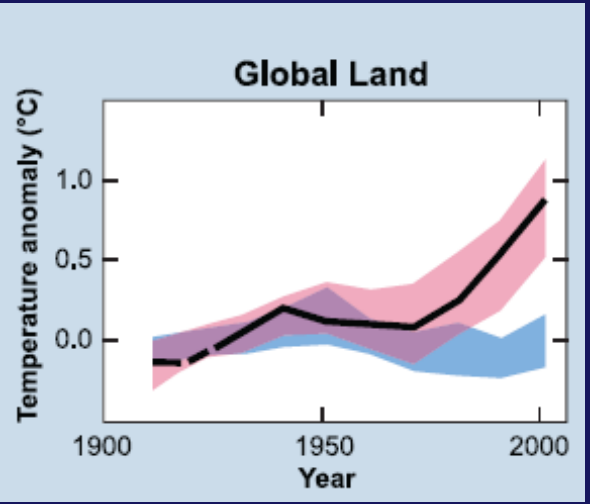
models using only natural forcings

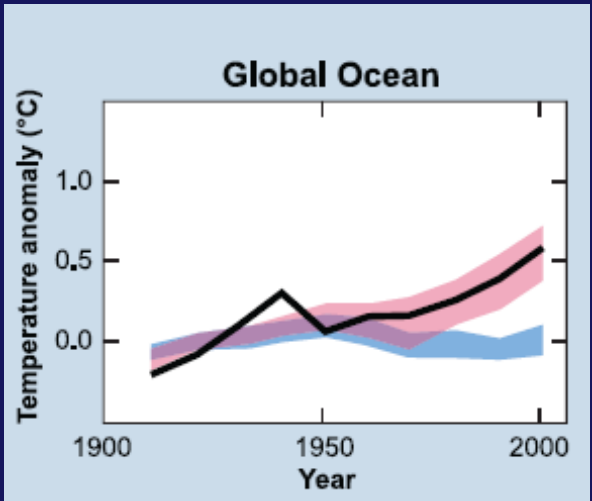
models using both natural and anthropogenic forcings

observations

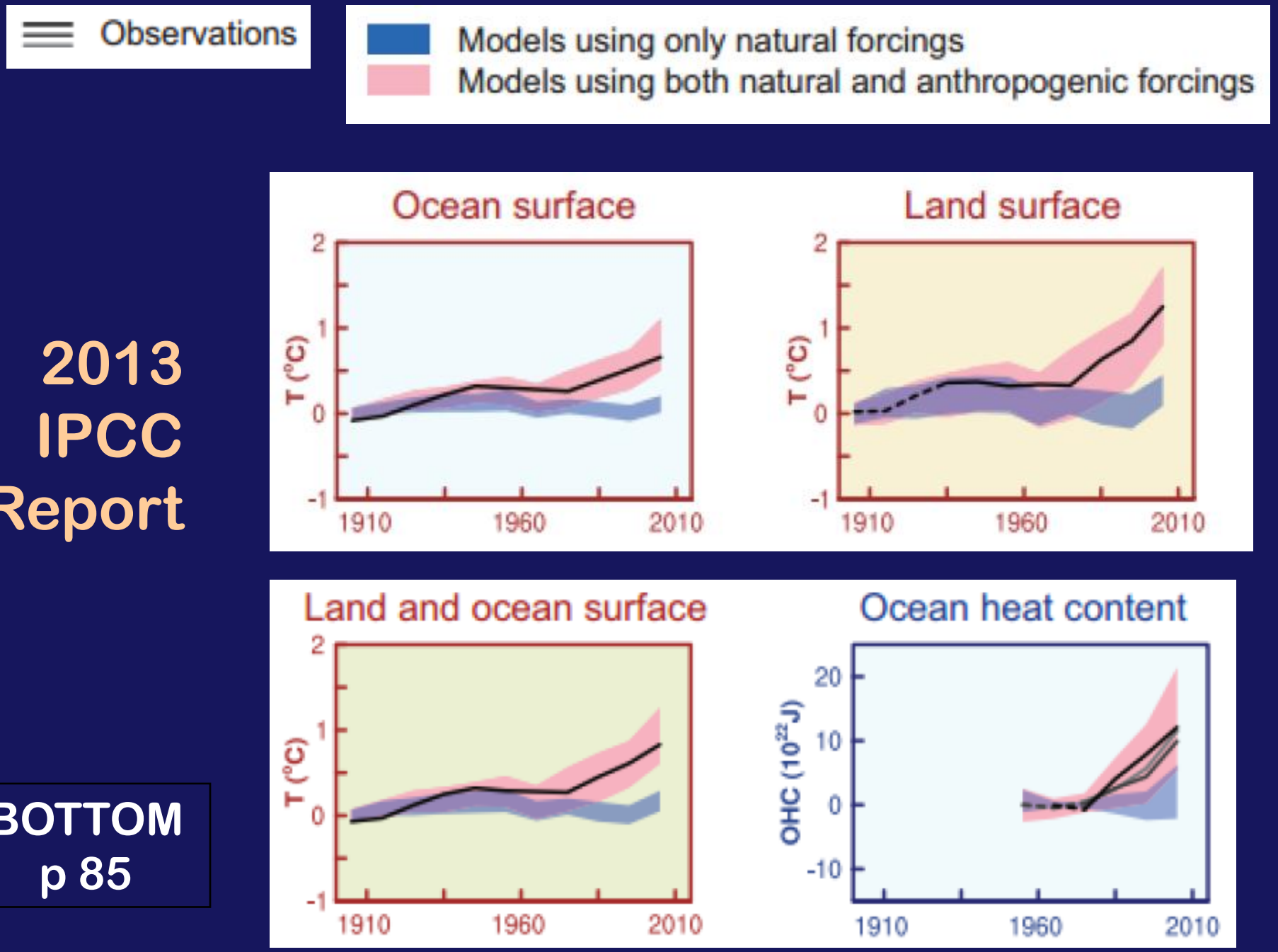
2007 IPCC Report







SOURCE: IPCC 2007 WG-1 Synthesis Report Summary for Policymakers

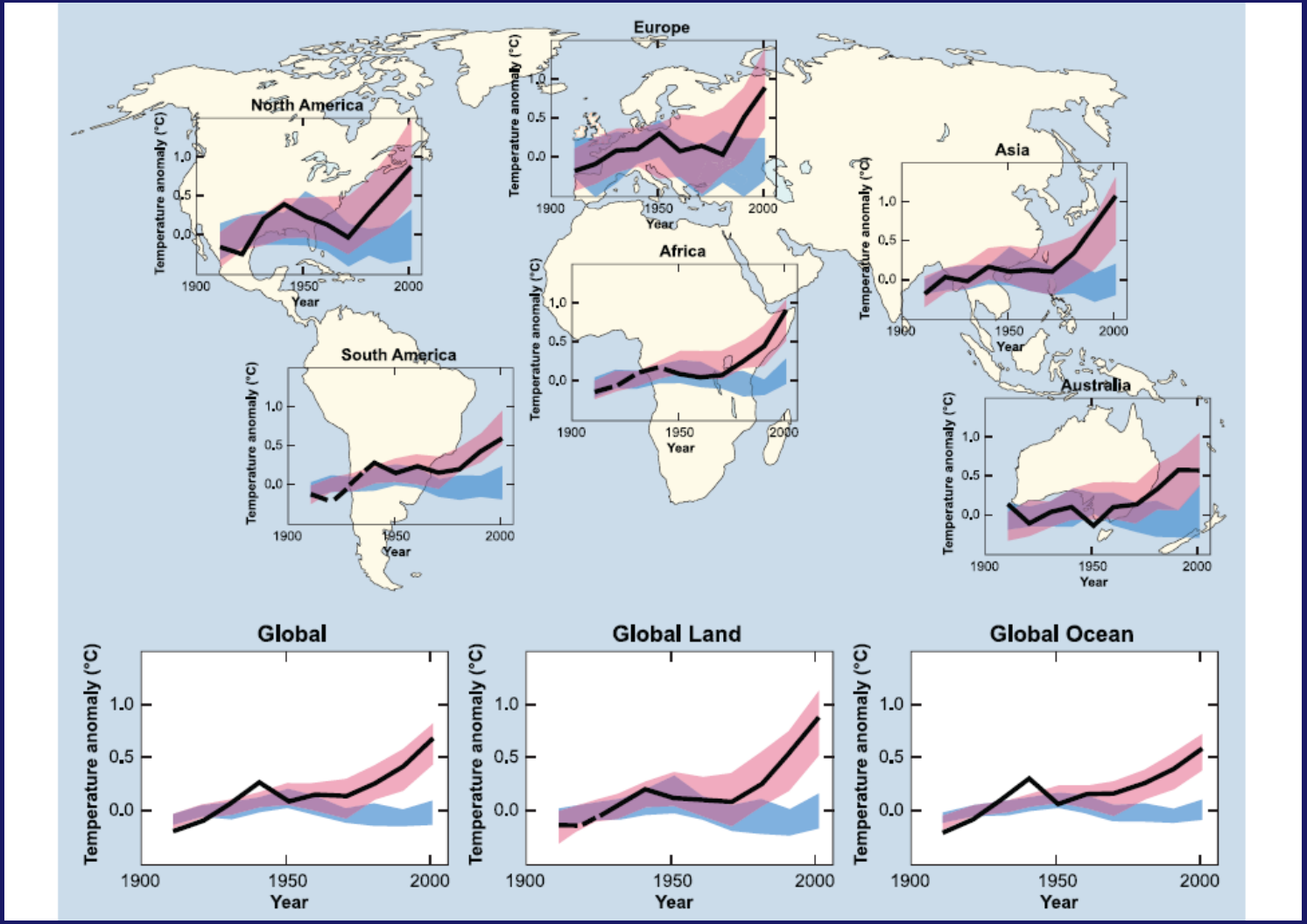


2013 IPCC Report

BOTTOM p 85

Individual Region Model Runs showed the same results!

2007 IPCC Report

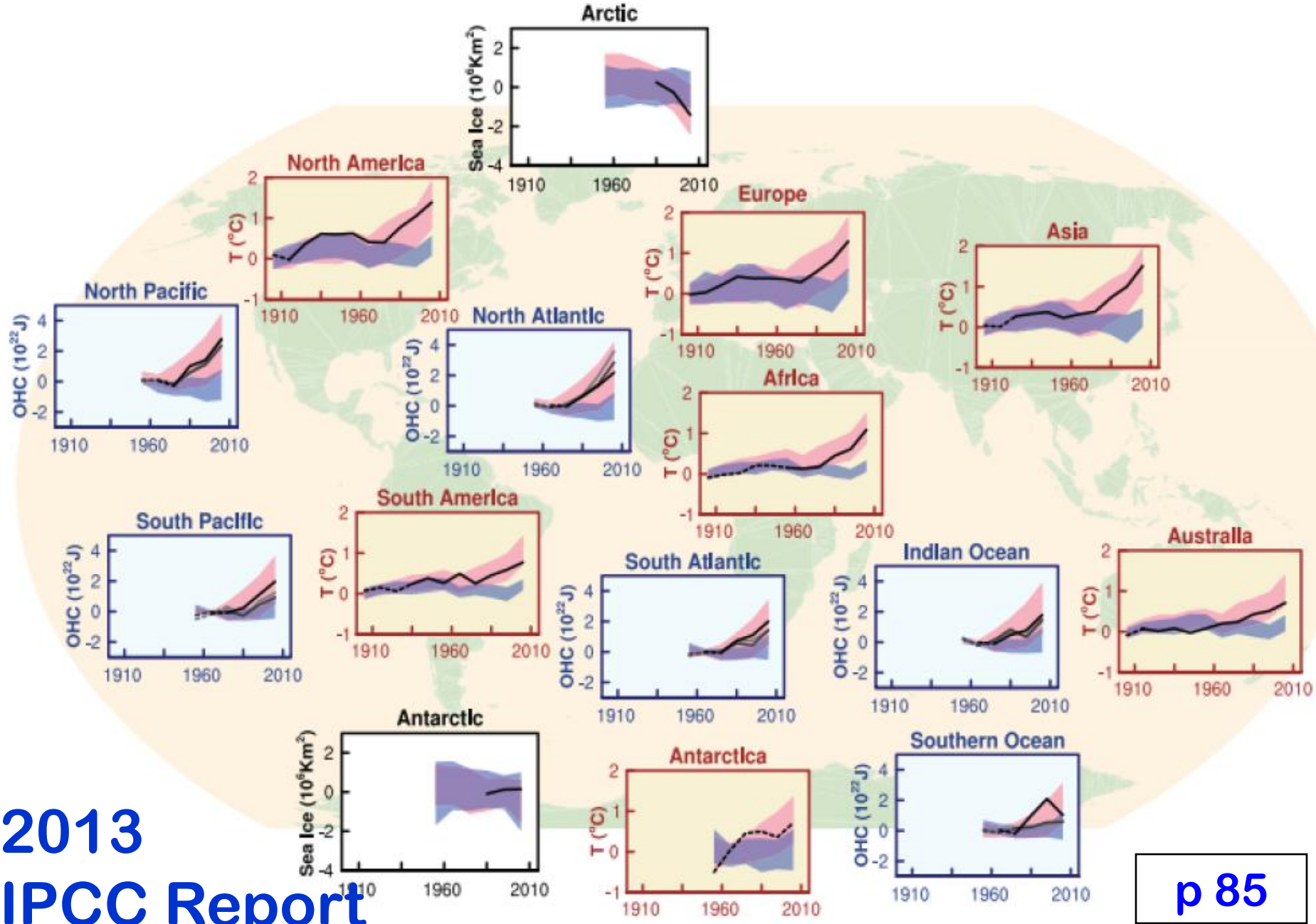


observations

models using only natural forcings

models using both natural and anthropogenic forcings

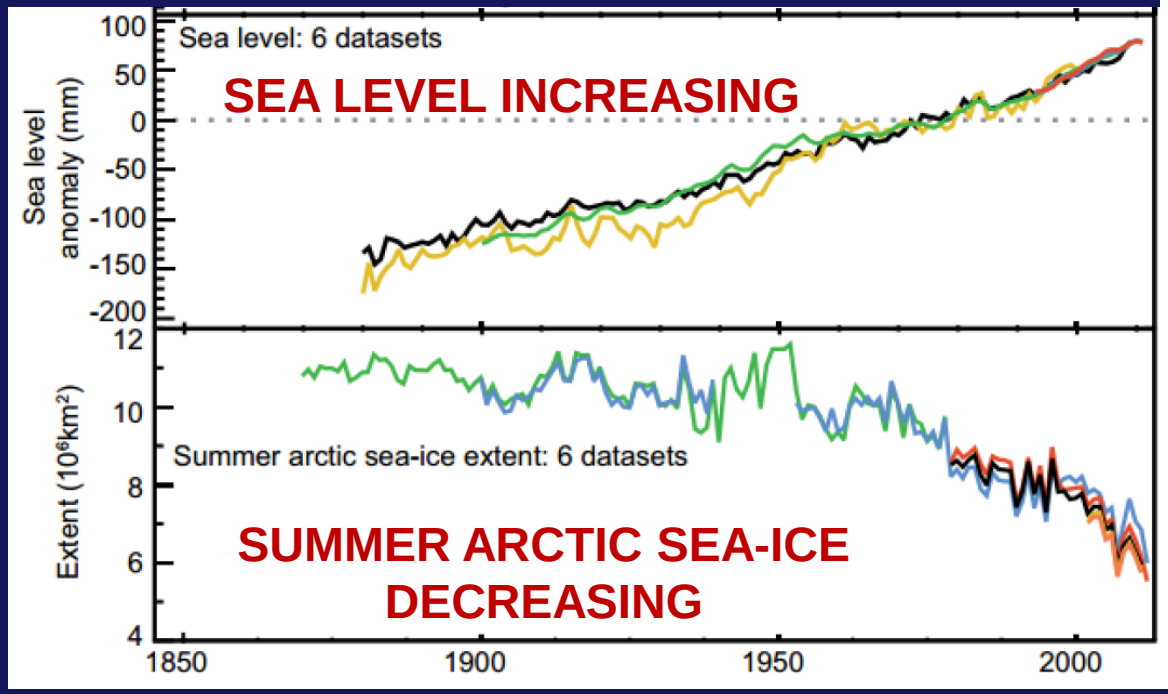
Model Comparisons of Natural vs. Anthropogenic Forcing on All Continents

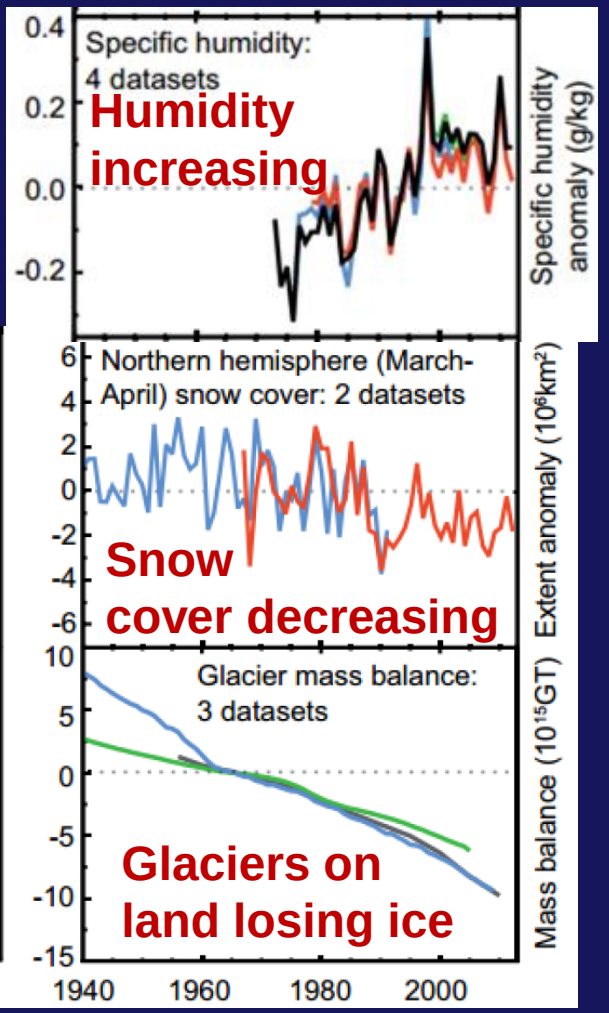


2013
IPCC Report

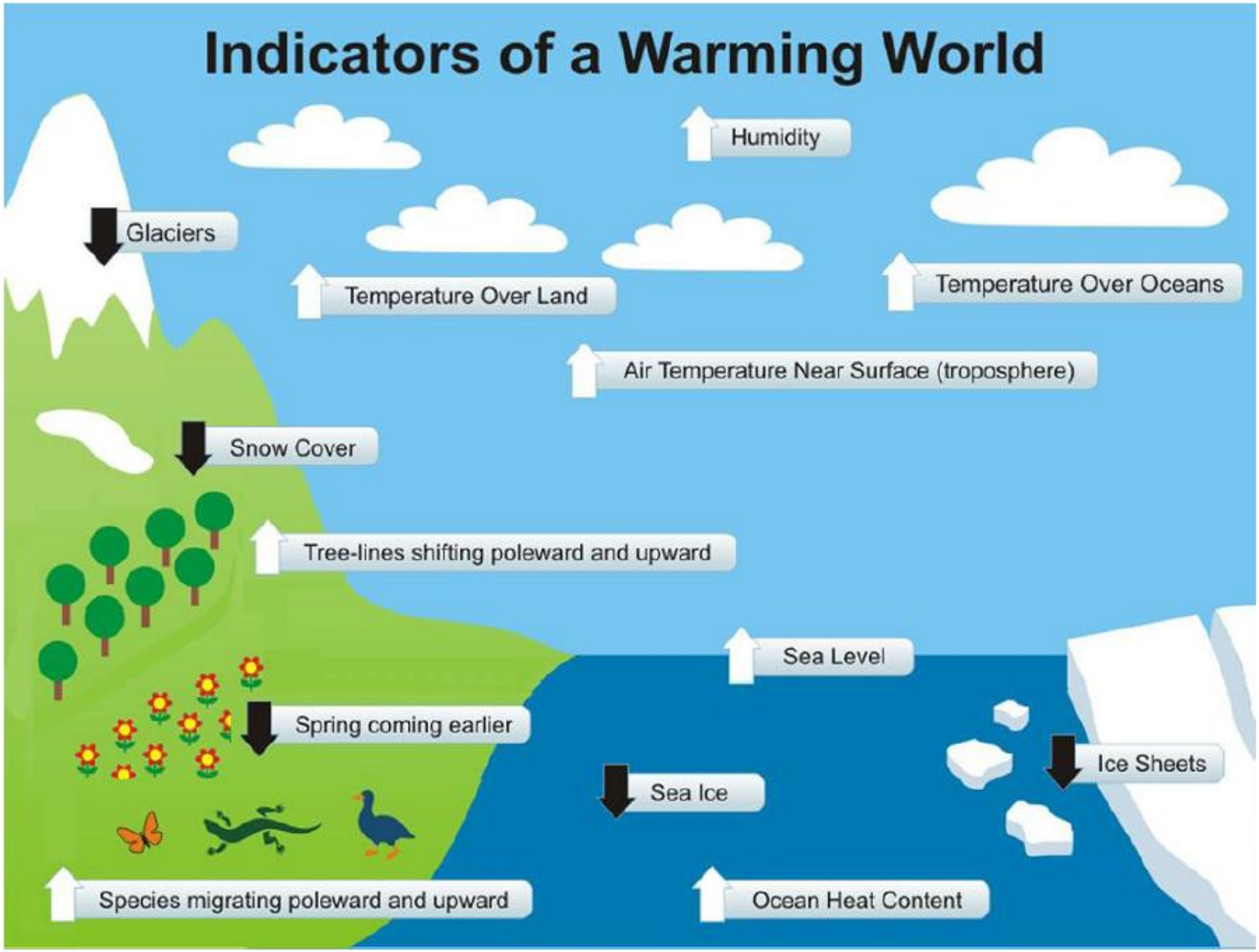
p 85

WHAT ELSE IS CHANGING?

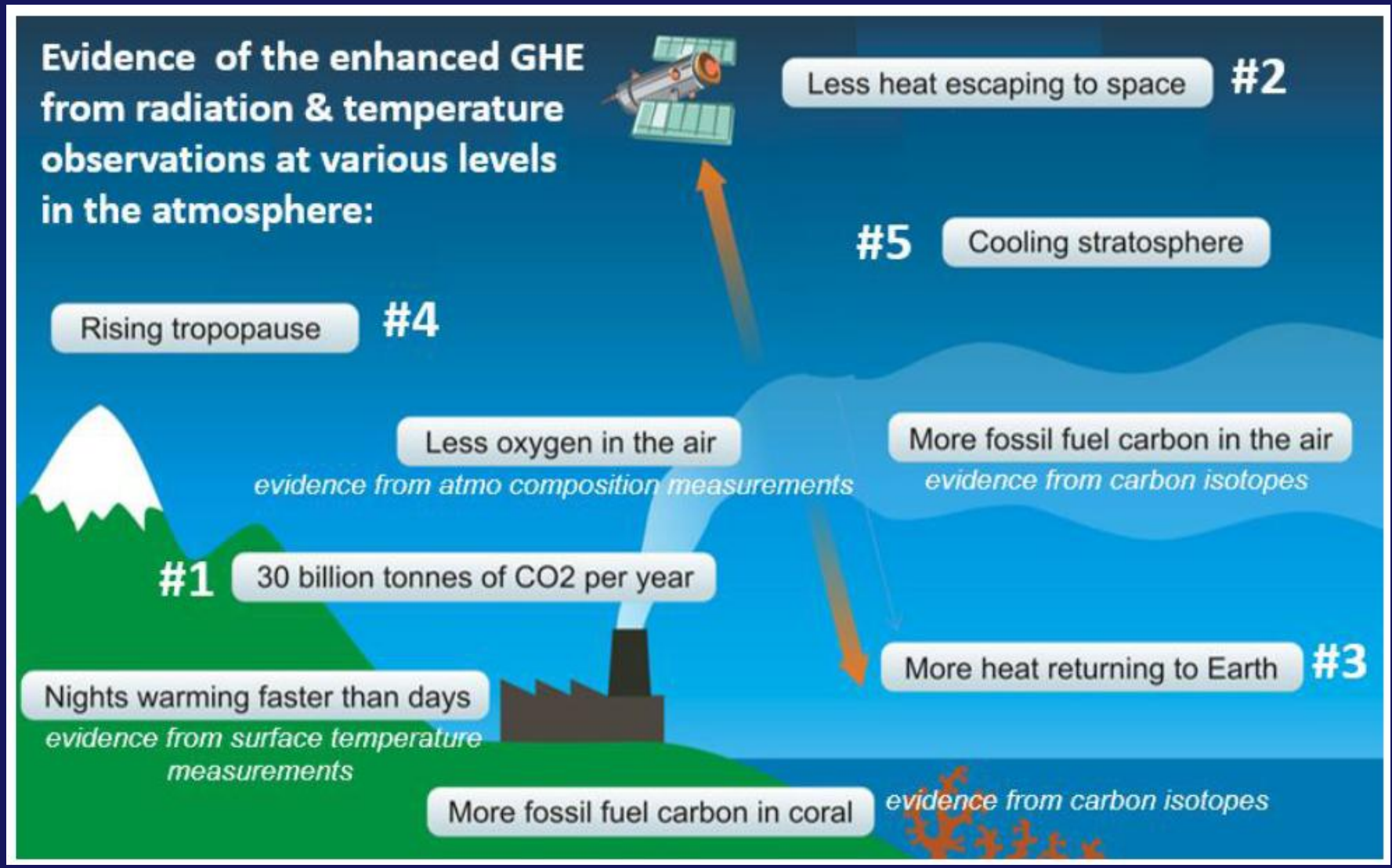




THE SUMMARY: INDICATORS RECAP



What else tells us that the Anthropogenically enhanced GreenHouse Effect is responsible for recent change?



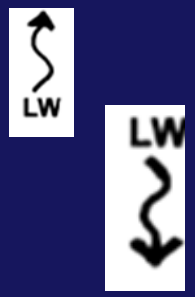
Can you link the indicators in the figure with processes we've covered this semester that are linked to an ANTHROPOGENIC influence?

Can you link the indicators in the figure with processes we've covered this semester that are linked to an Anthropogenic influence?

1. 30 billion tonnes of CO2 emitted into the atmosphere per year: Keeling curve

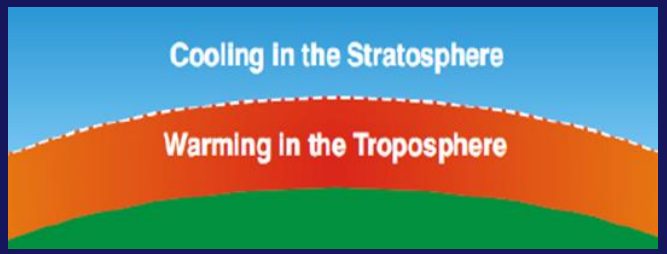
2. Less heat escaping to space at the top of the atmosphere:

3. More heat returning to Earth:



4. Rising tropopause:

5. Cooling stratosphere:



Greenhouse Warming Signature

See you on Wednesday
for TEST #4

Don't forget to submit the photo release request form that is posted as a D2L Quiz before Wednesday's class