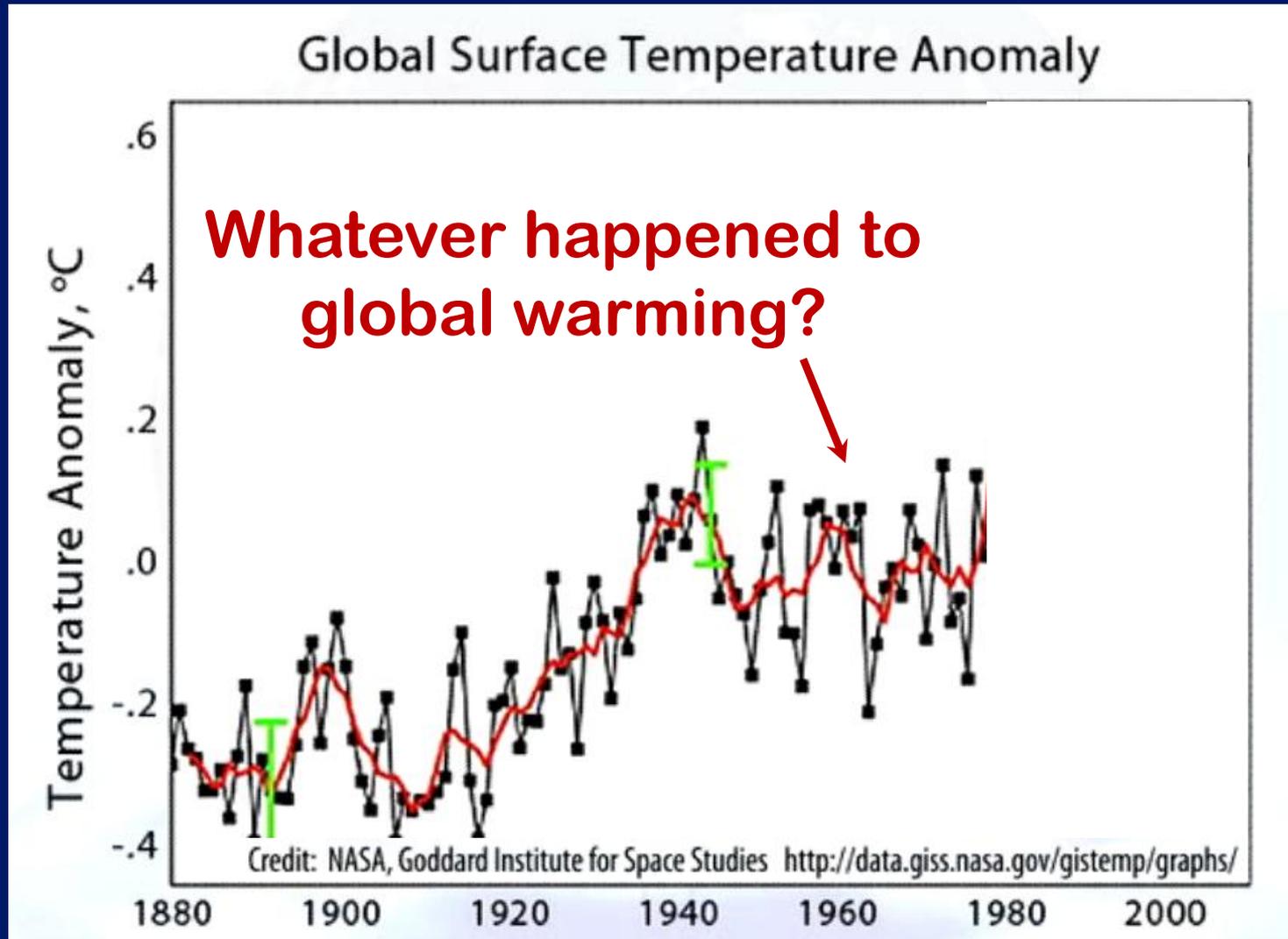
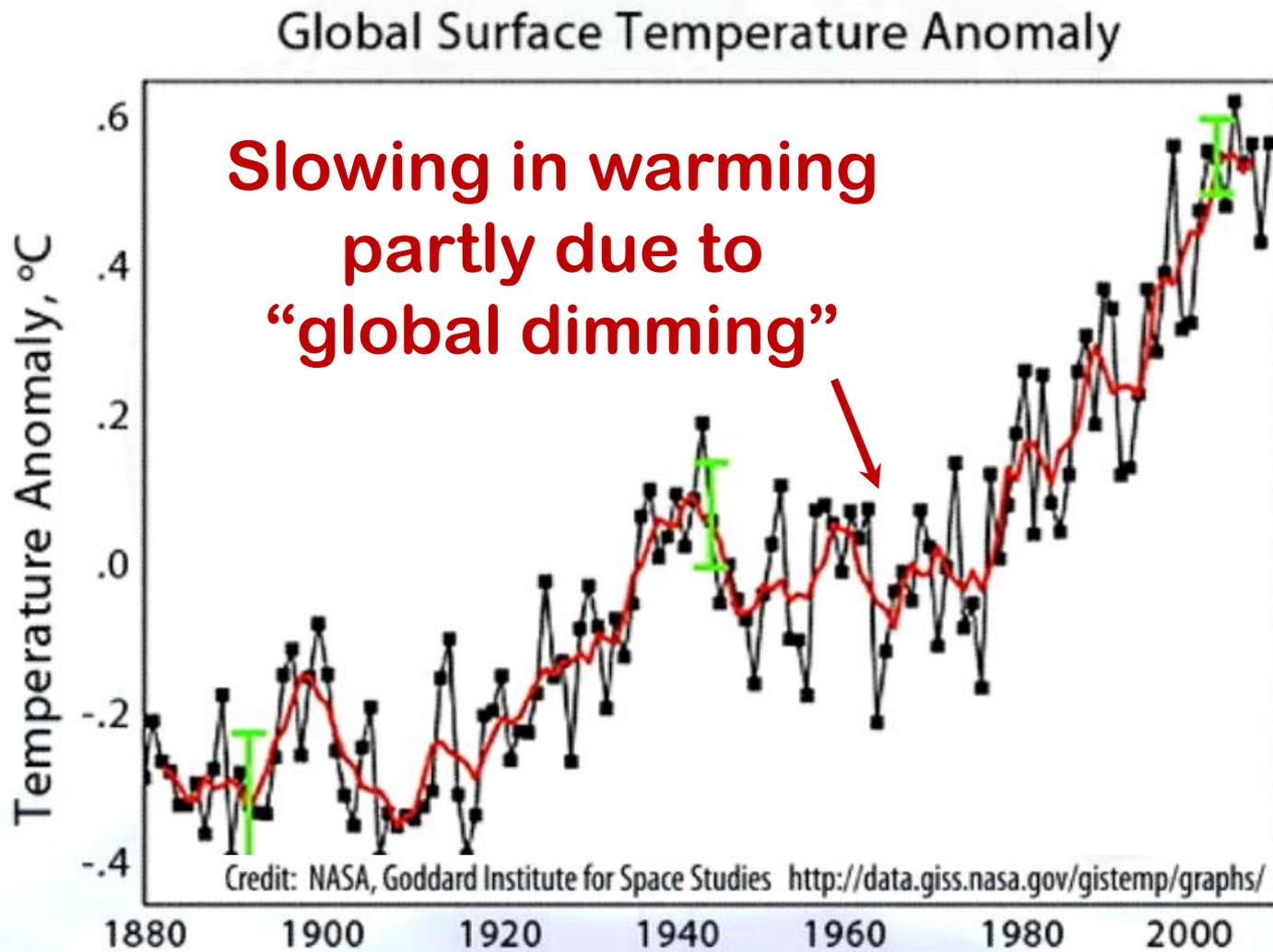


Opening remarks about the  
**GLOBAL TEMPERATURE  
ANOMALY GRAPH . . . .**



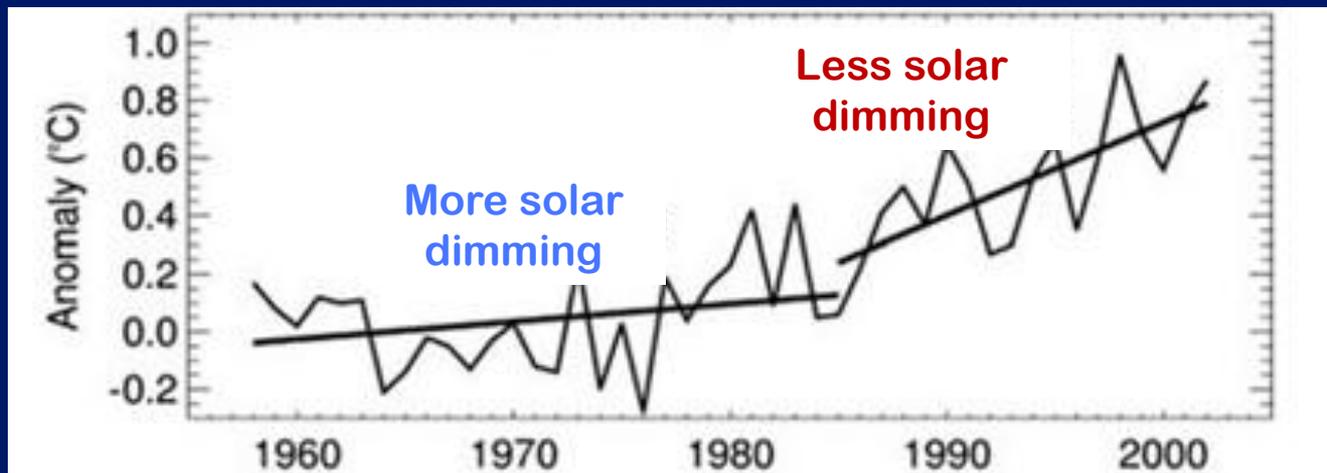
Click here to watch  
humorous weather

vs climate explanation: <http://fp.arizona.edu/kkh/nats101gc/whatever-happened-to-gw.html>



# 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*



# MOVIE TIME (cont.)

Entire  
NOVA  
show is  
now  
posted in  
D2L



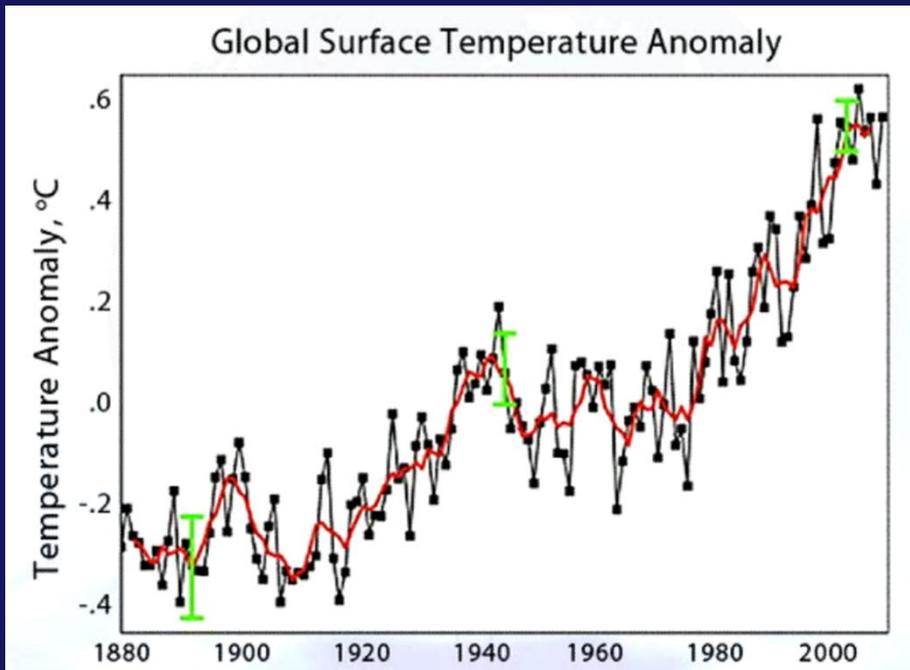
“New evidence that **AIR POLLUTION** has masked the full impact of global warming suggests the world may soon face a heightened climate crisis.”



Transcript available here:

[http://www.pbs.org/wgbh/nova/transcripts/3310\\_sun.html](http://www.pbs.org/wgbh/nova/transcripts/3310_sun.html)

# Global Surface Temperature Trend 1860-2010

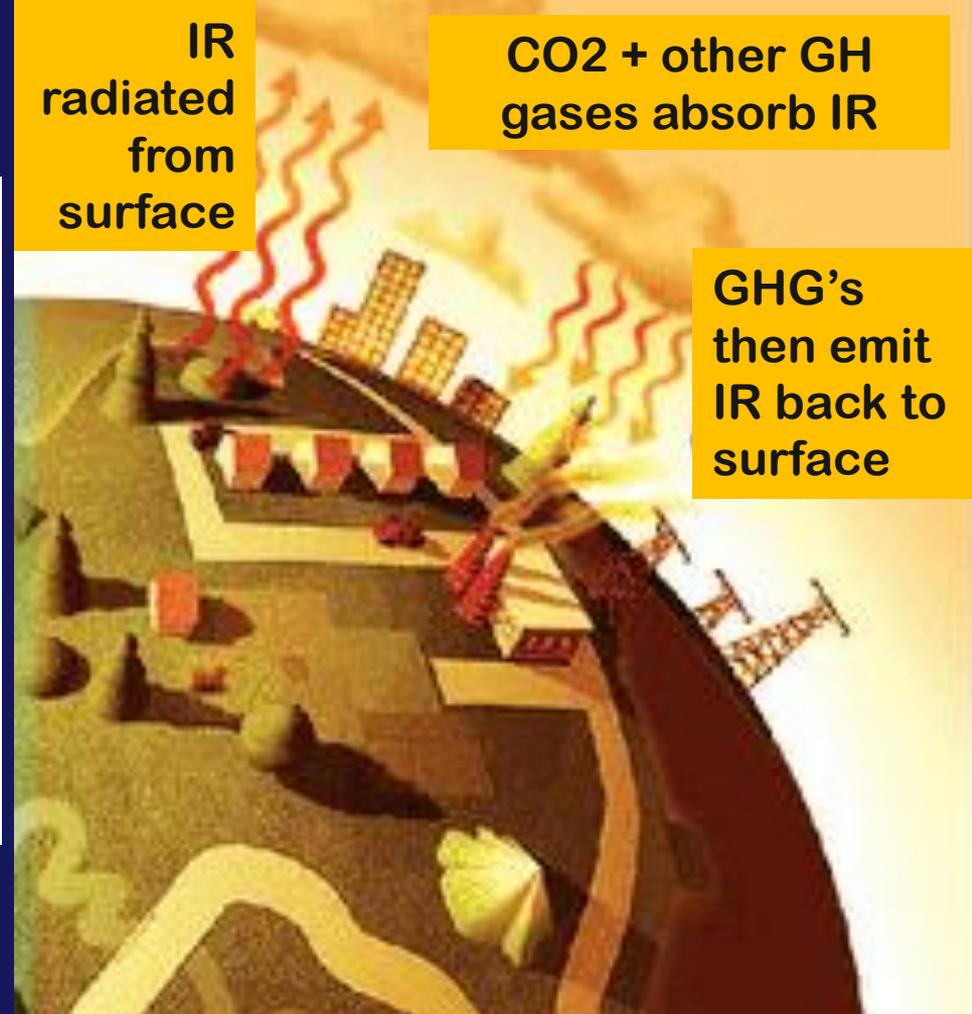


## Global warming

IR radiated from surface

CO<sub>2</sub> + other GH gases absorb IR

GHG's then emit IR back to surface



**Solar Dimming effect is about 1/2 the strength of Global Warming . . . so reducing the dimming could INCREASE GW by up to 50%!**

## Global dimming

aerosols from pollution reflect  
 back to space

Less solar reaches the surface

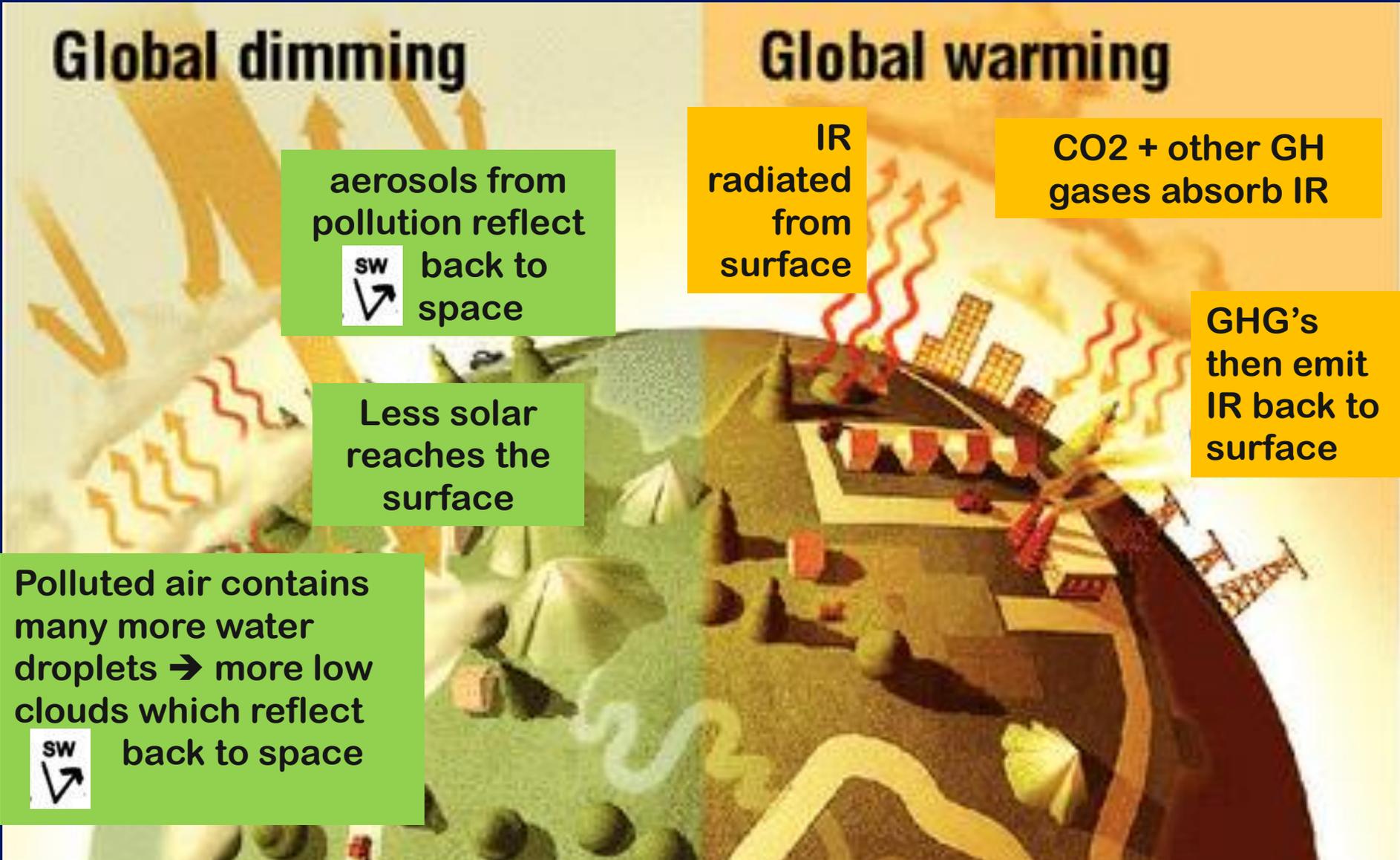
Polluted air contains many more water droplets → more low clouds which reflect  
 back to space

## Global warming

IR radiated from surface

CO<sub>2</sub> + other GH gases absorb IR

GHG's then emit IR back to surface



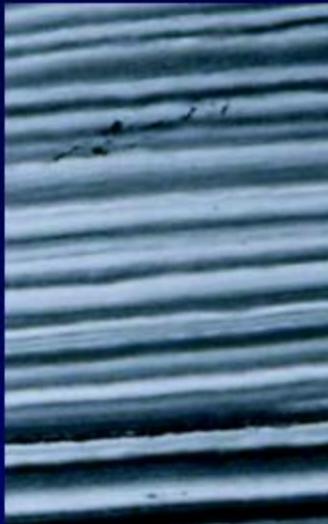
**. . . and now on to Today's Topic**

# TOPIC # 14, PART C: Evidence from Natural Archives

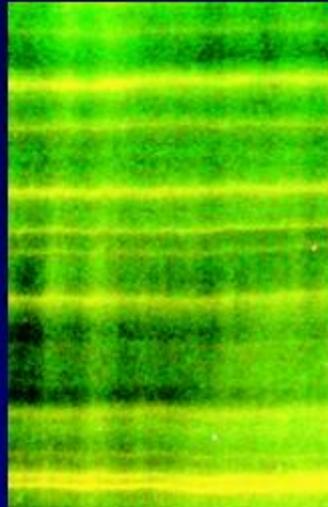
Tree rings



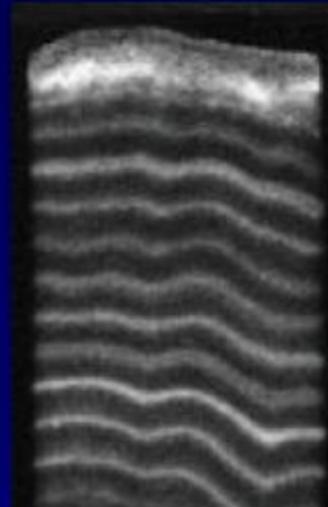
Lake varves  
(sediments)



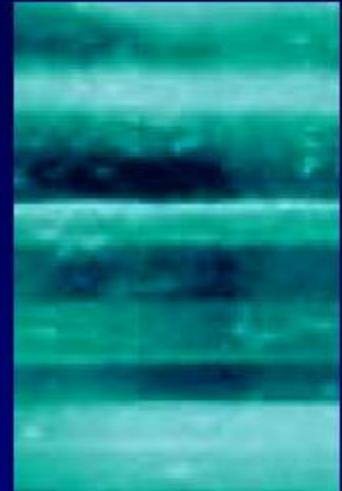
Speleothems  
(from cave)



Coral  
(annual growth)



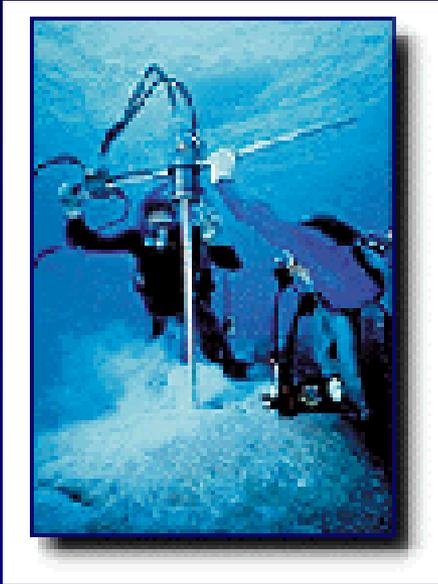
Ice Core



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

*- Winston Churchill*

# “PROXY” DATA or NATURAL ARCHIVES of CLIMATE



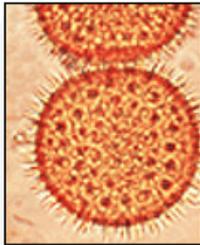
Corals



Ice cores



Lake, bog &  
ocean  
sediments



Pollen



Tree rings!



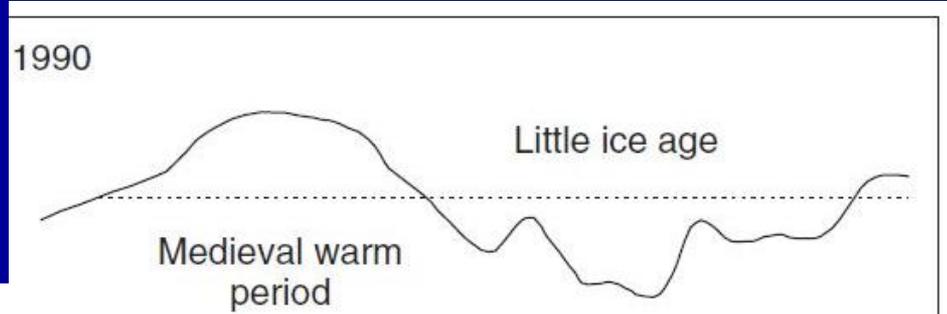
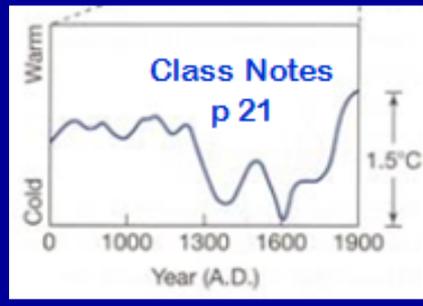
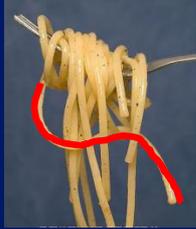
# A noodle, hockey stick, and spaghetti plate: a perspective on high-resolution paleoclimatology

David Frank,<sup>1\*</sup> Jan Esper,<sup>2</sup> Eduardo Zorita<sup>3</sup> and Rob Wilson<sup>4</sup>

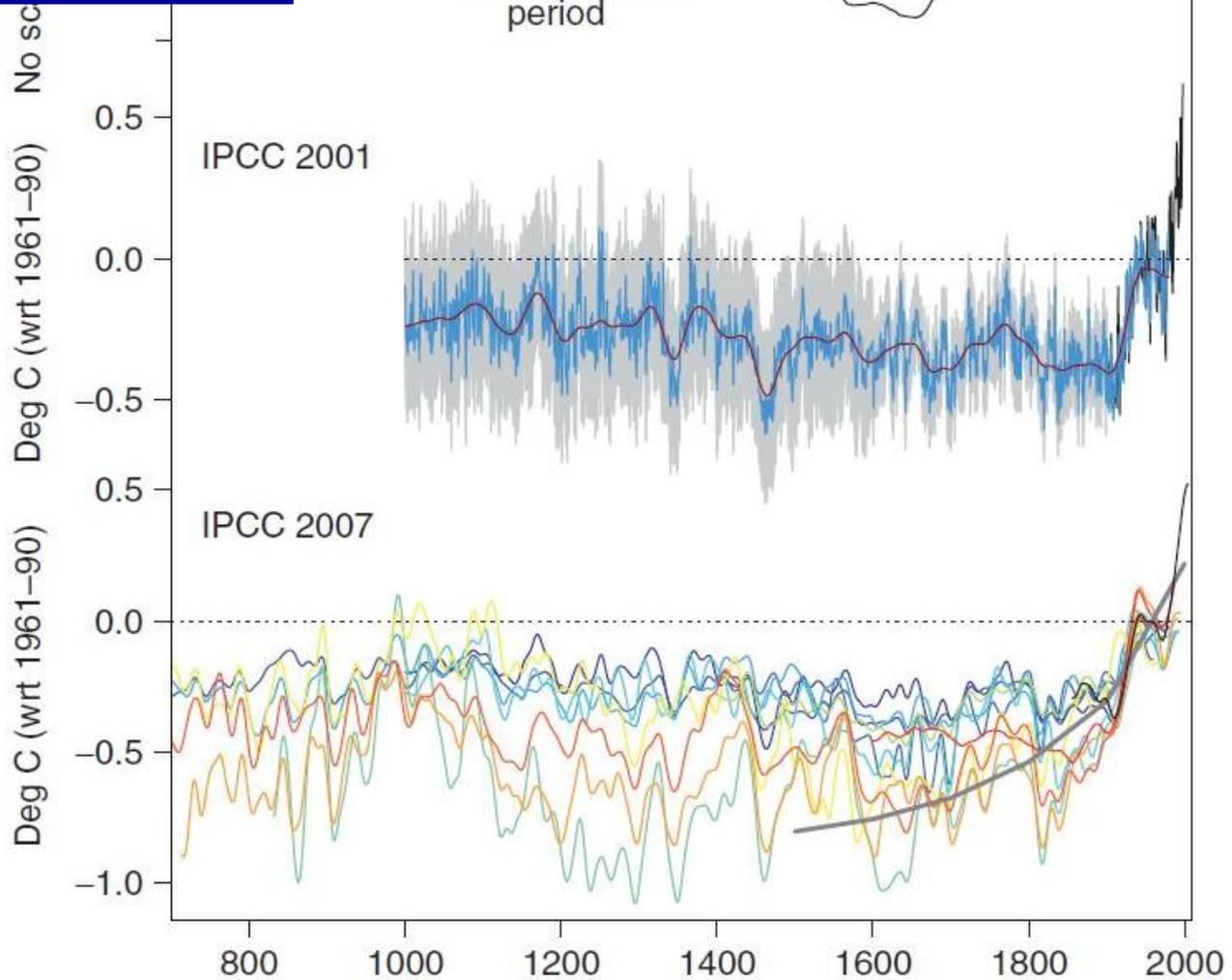
The high-resolution reconstruction of hemispheric-scale temperature variation over the past-millennium benchmarks recent warming against more naturally driven climate episodes, such as the Little Ice Age and the Medieval Warm Period, thereby allowing assessment of the relative efficacies of natural and anthropogenic forcing factors. Icons of past temperature variability, as featured in the Intergovernmental Panel on Climate Change (IPCC) reports over nearly two decades, have changed from a schematic sketch in 1990, to a seemingly well-solved story in 2001, to more explicit recognition of significant uncertainties in 2007. In this article, we detail the beginning of the movement to reconstruct large-scale temperatures, highlight major steps forward, and present our views on what remains to be accomplished. Despite significant efforts and progress, the spatial representation of reconstructions is limited, and the interannual and centennial variation are poorly quantified. Research priorities to reduce reconstruction uncertainties and improve future projections, include (1) increasing the role of expert assessment in selecting and incorporating the highest quality proxy data in reconstructions (2) employing reconstruction ensemble methodology, and (3) further improvements of forcing series. We suggest that much of the sensitivity in the reconstructions, a topic that has dominated scientific debates, can be traced back to the input data. It is perhaps advisable to use fewer, but expert-assessed proxy records to reduce errors in future reconstruction efforts. © 2010 John Wiley & Sons, Ltd. *WIREs Clim Change*

# 3 "iconic" graphs of GLOBAL CLIMATE CHANGE . . .

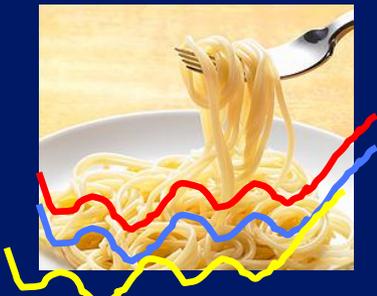
## The "Noodle"



## The "Hockey Stick"



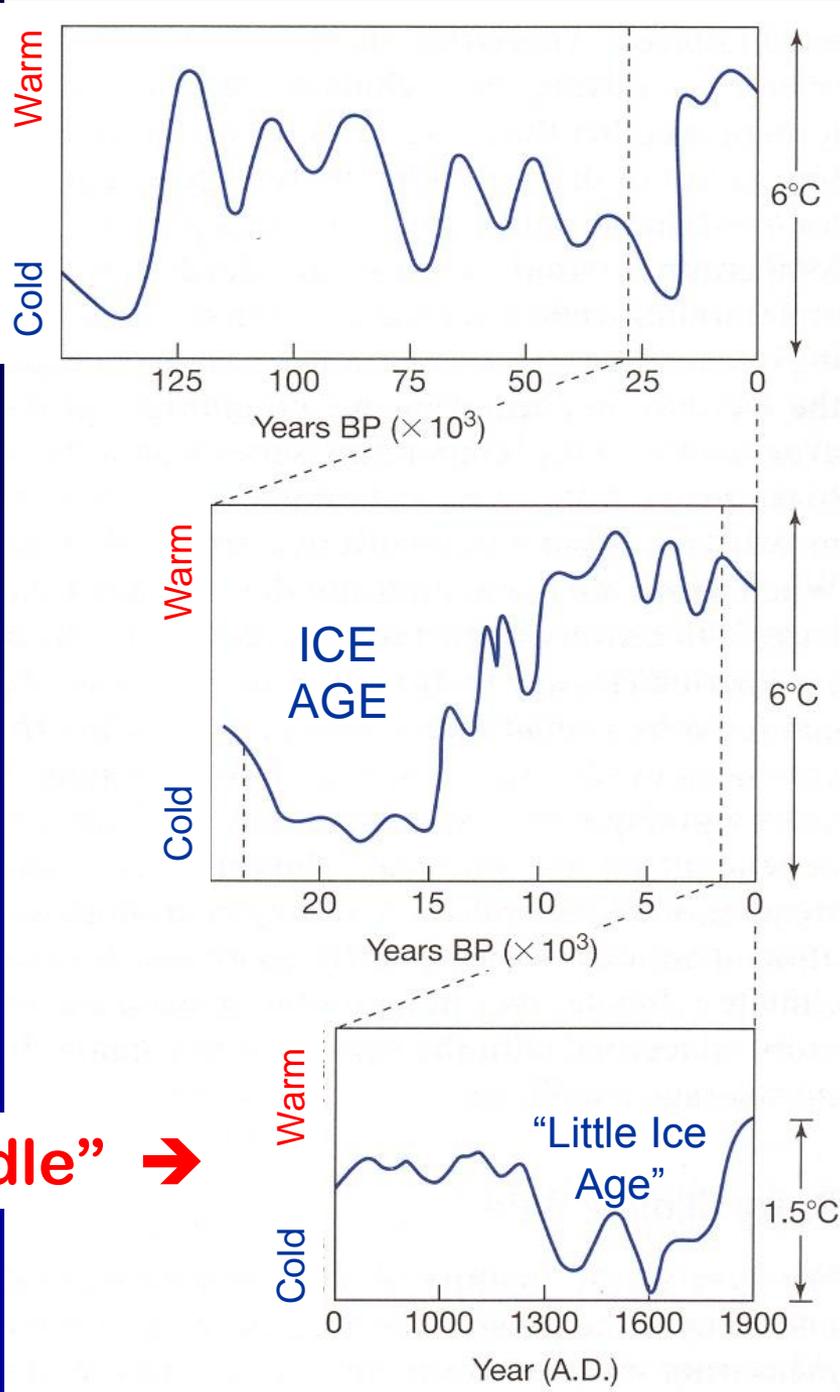
## The "Spaghetti Plate"



**Review:**  
**from p 21 of**  
**Class Notes:**

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

**The “Noodle”** →



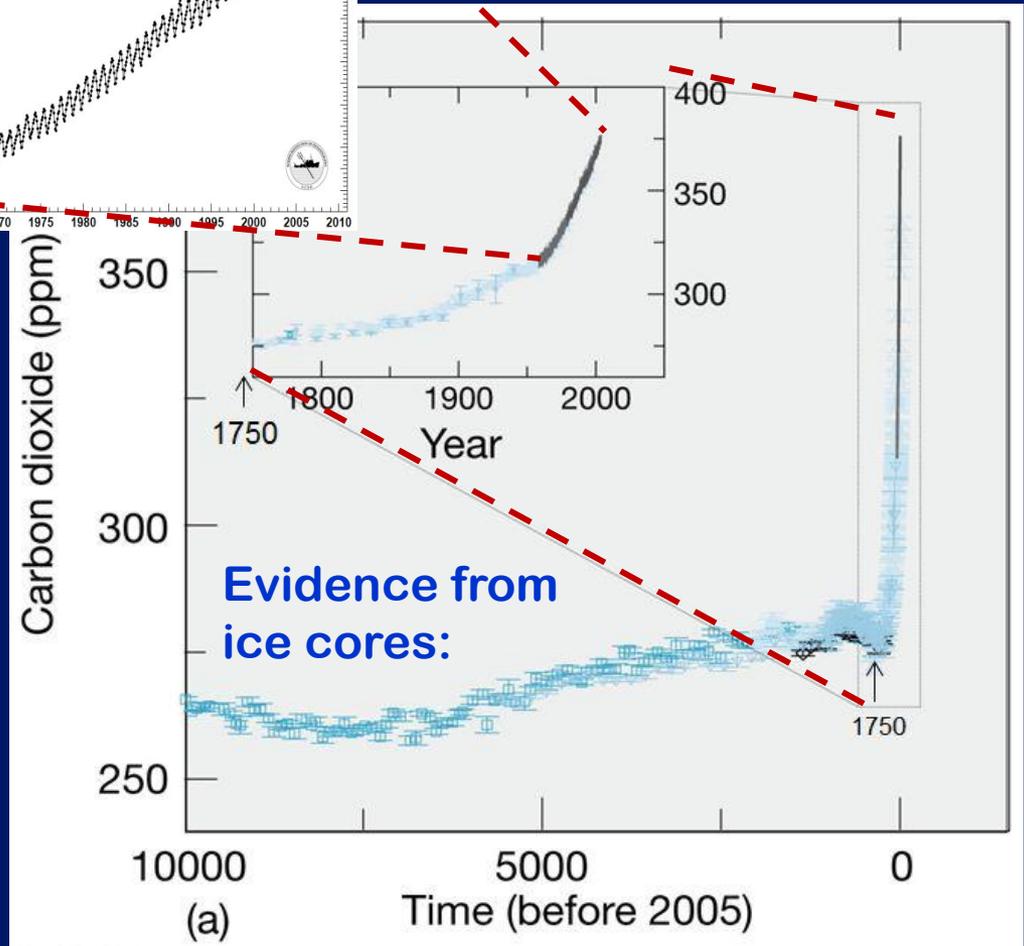
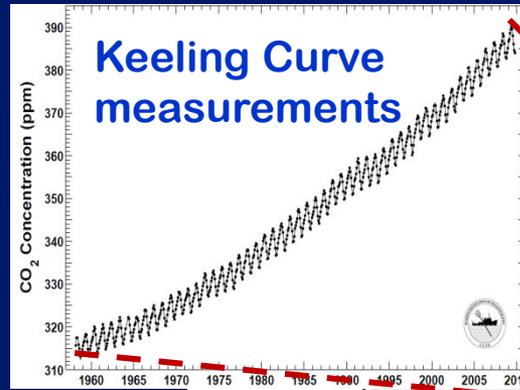
**deep-sea**  
**sediments**

**pollen data &**  
**alpine glaciers**

**historical**  
**documents**

(emphasis on the  
North Atlantic  
region)

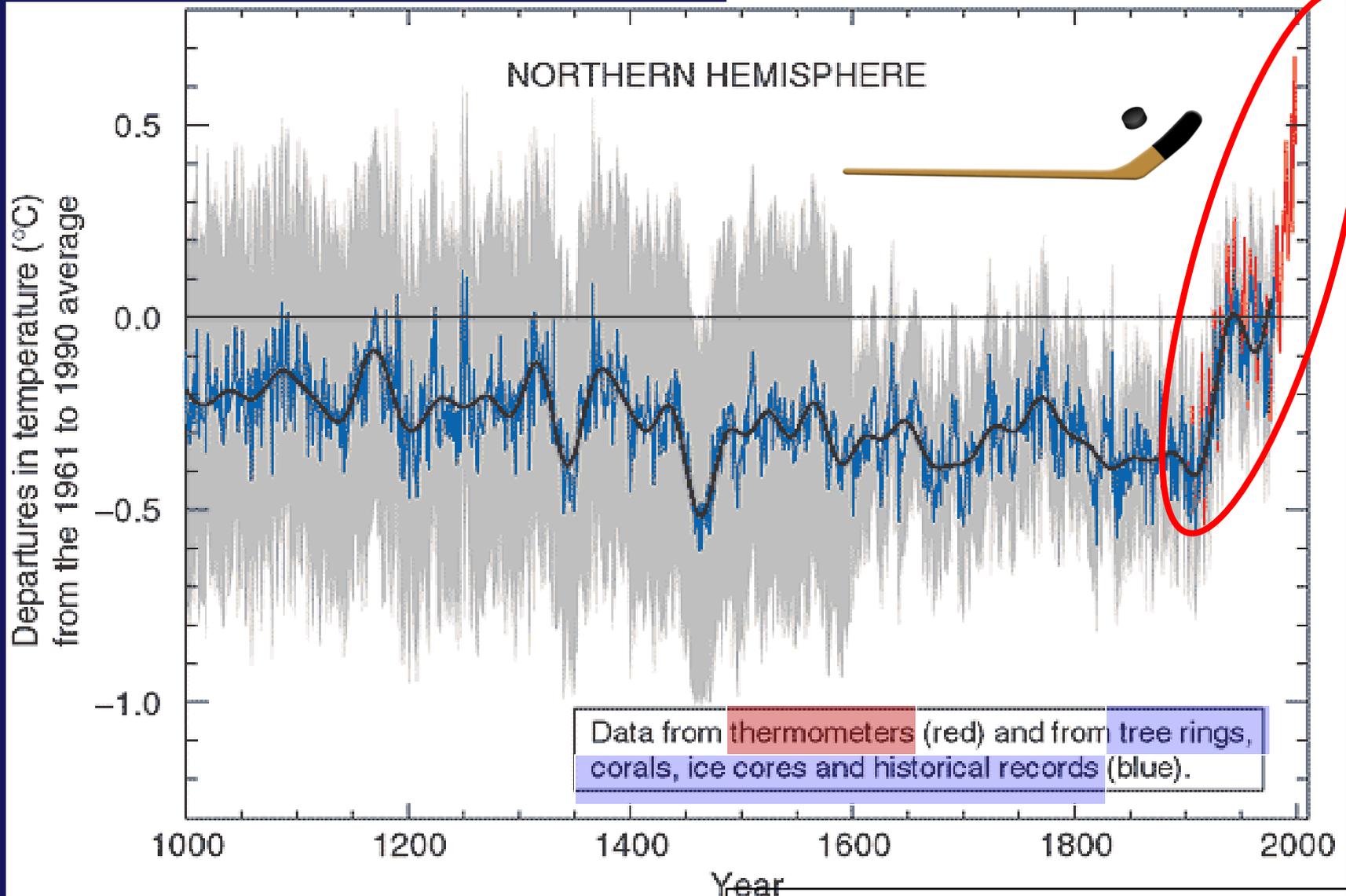
# The CO<sub>2</sub> “Hockey Stick” Graph . . .



SGC E-Text  
Chapter 1  
Fig 1-3a

# The Temperature “Hockey Stick” Graph

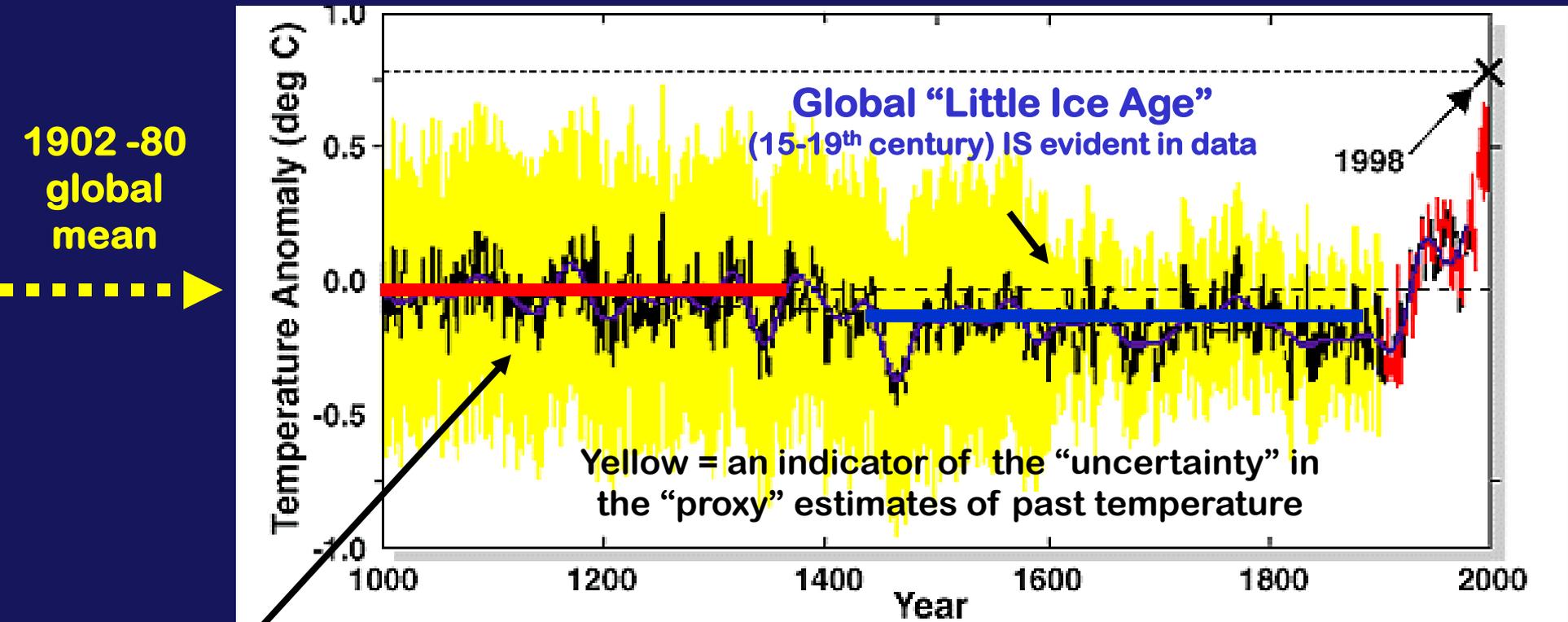
“proxy” data +  
thermometer records



Similar to top 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 20<sup>th</sup> century**

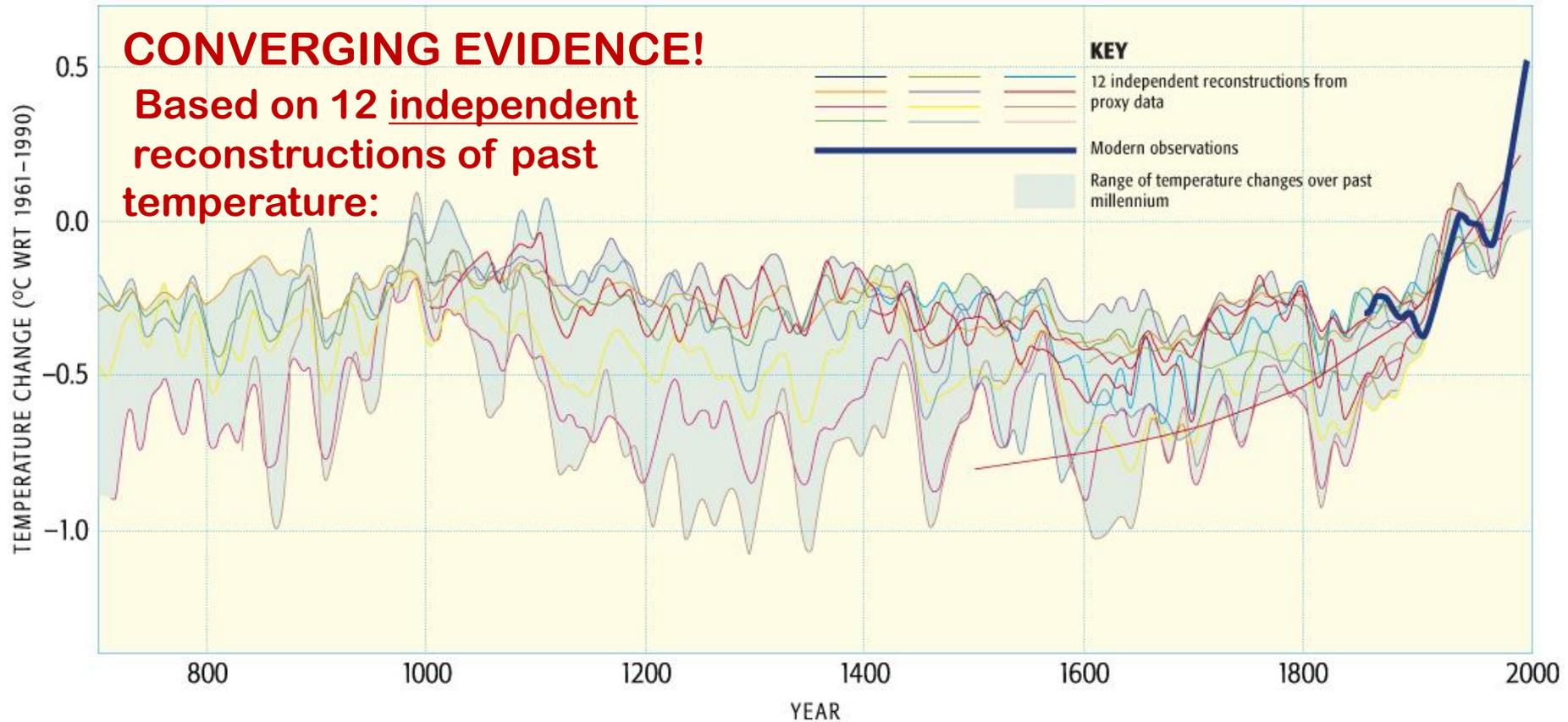


"Medieval Warm Period" (9-14<sup>th</sup> century) not very evident (more of a regional phenomenon)

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

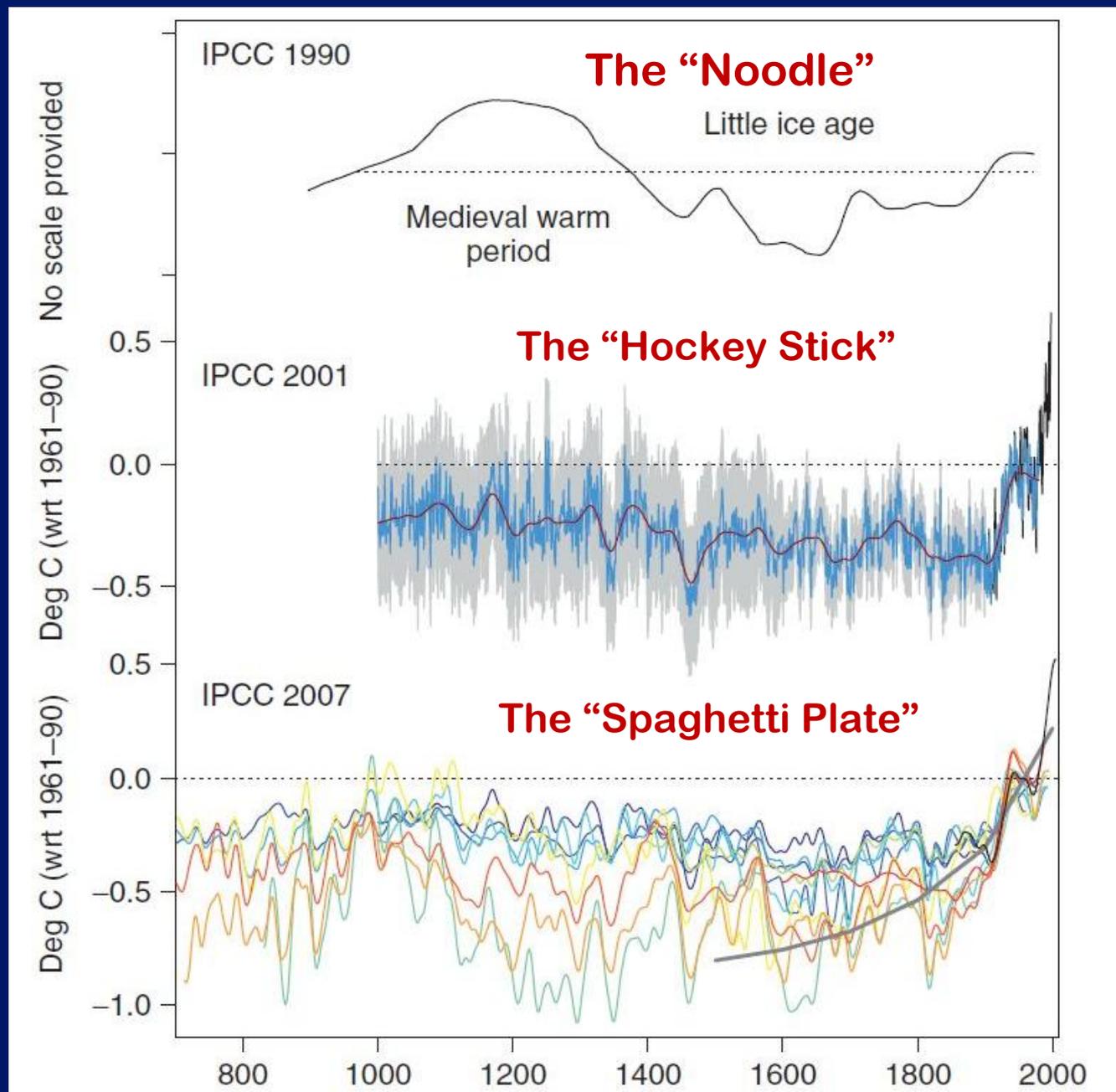
# The Temperature “Spaghetti Plate” Graph

## NORTHERN HEMISPHERE TEMPERATURE CHANGES OVER THE PAST MILLENNIUM

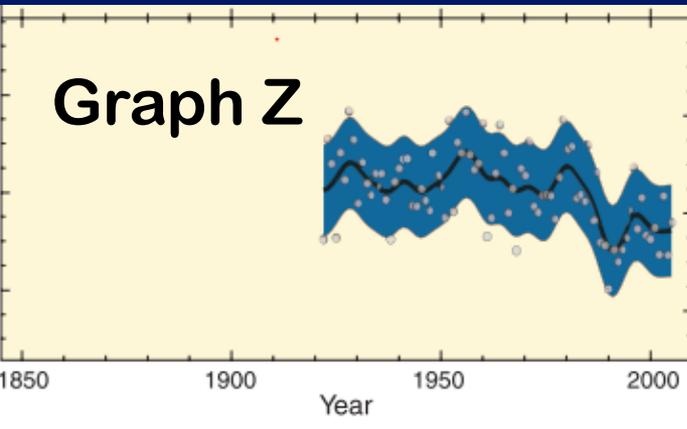
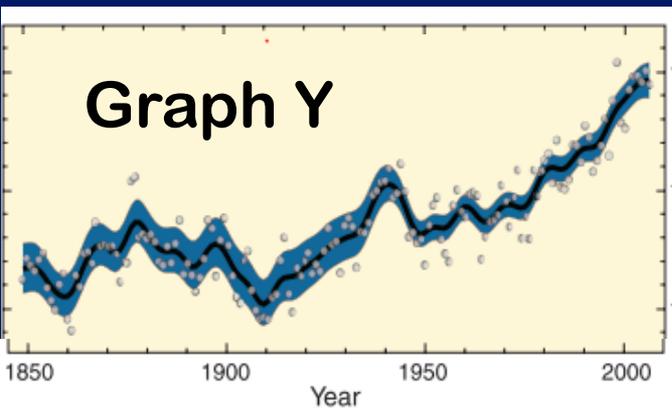
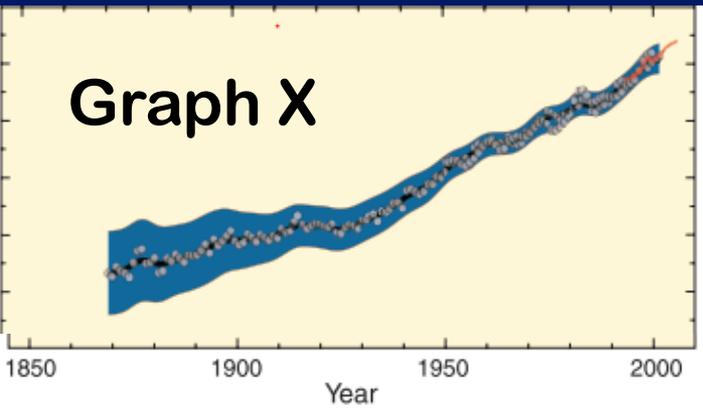


The general “Hockey Stick” shape has stood the test of time, despite intense scrutiny and debunking attempts!

# The Scientific Process “in action”

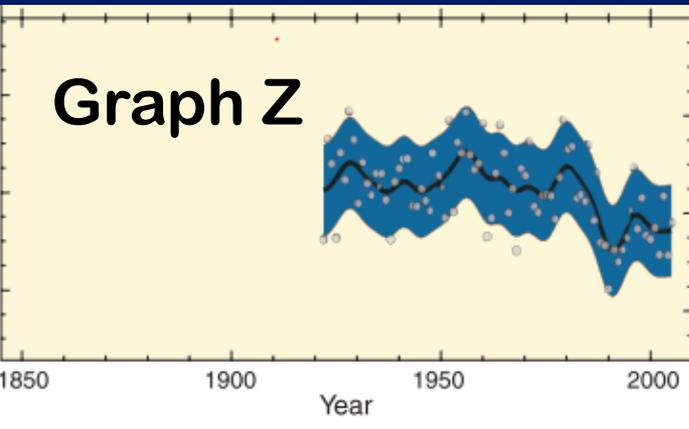
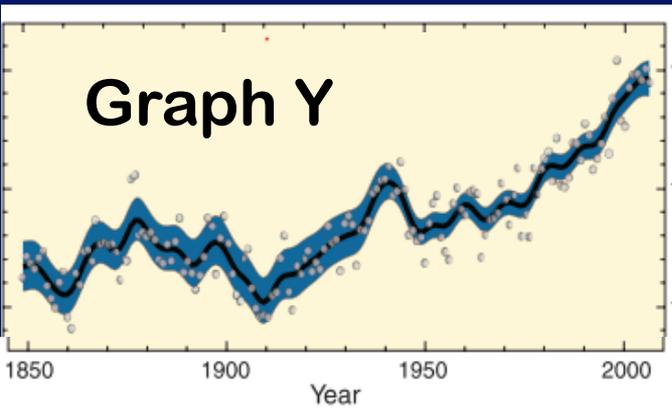
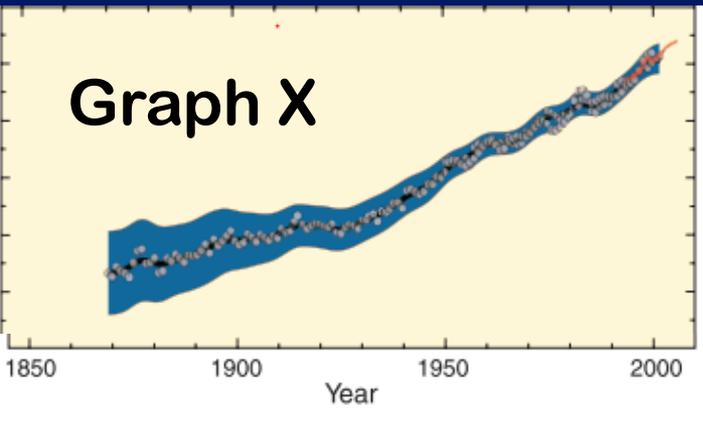


**Q1 - Which choice below presents the correct LABELS for Graphs X, Y & Z?**



- (1) X = Global Temperature  
Y = N. Hemisphere Snow Cover  
Z = Global Sea Level
- (2) X = Global Temperature  
Y = Global Sea Level  
Z = N. Hemisphere Snow Cover
- (3) X = Global Sea Level  
Y = Global Temperature  
Z = N. Hemisphere Snow Cover

**Q1 - Which choice below presents the correct LABELS for Graphs X, Y & Z?**



**(1) X = Global Temperature  
Y = N. Hemisphere Snow Cover  
Z = Global Sea Level**

**(2) X = Global Temperature  
Y = Global Sea Level  
Z = N. Hemisphere Snow Cover**

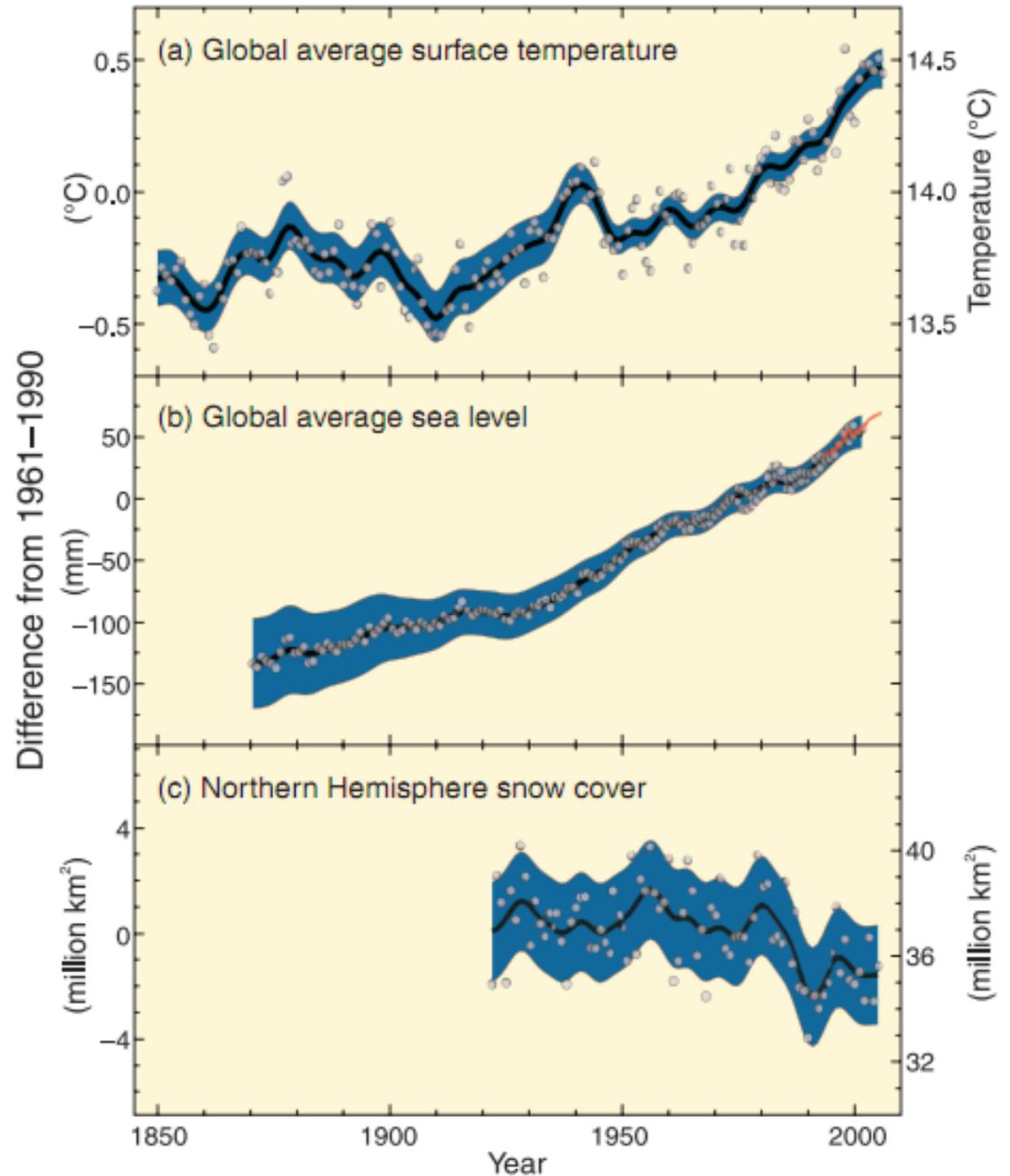
**(3) X = Global Sea Level  
Y = Global Temperature  
Z = N. Hemisphere Snow Cover**

Global  
Temperature

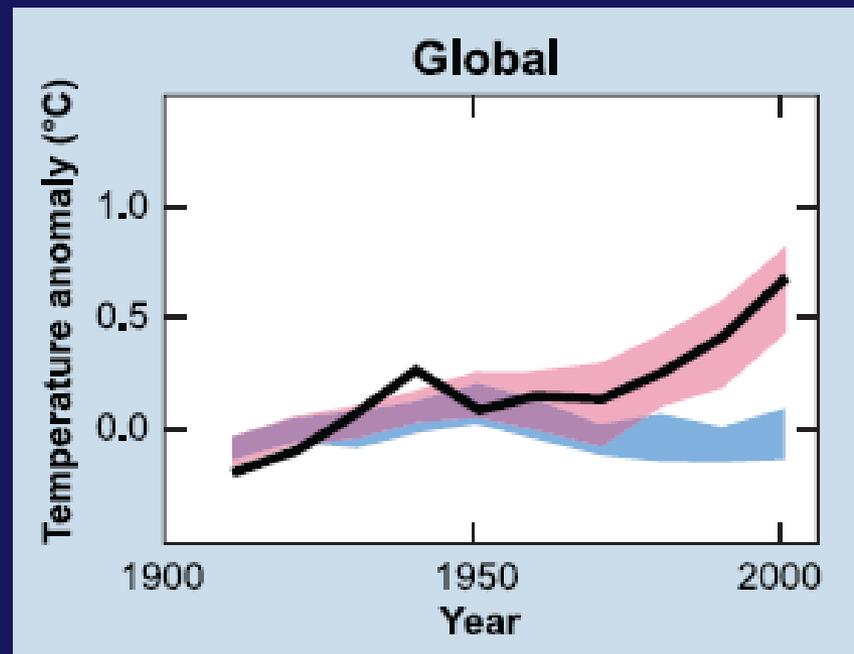
Global  
Sea Level

N. Hemisphere  
Snow Cover

From: Summary for  
Policy Makers reading



# TOPIC # 14, PART D: Evidence from Model Comparisons Natural vs. Anthropogenic

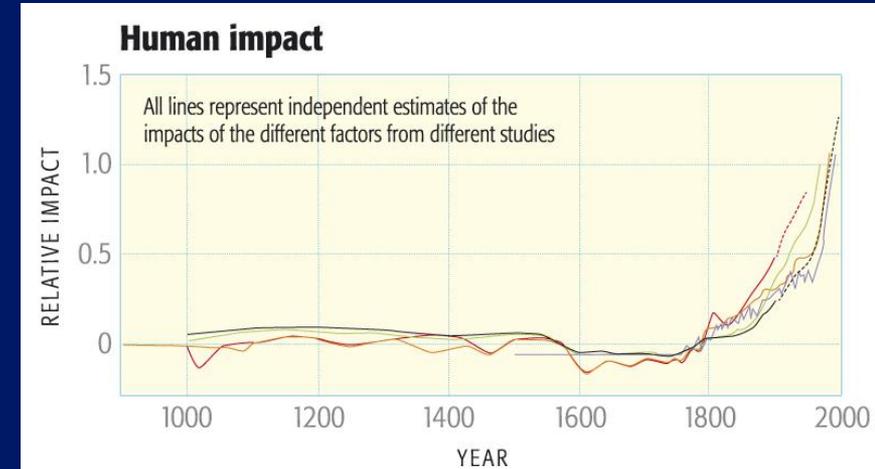
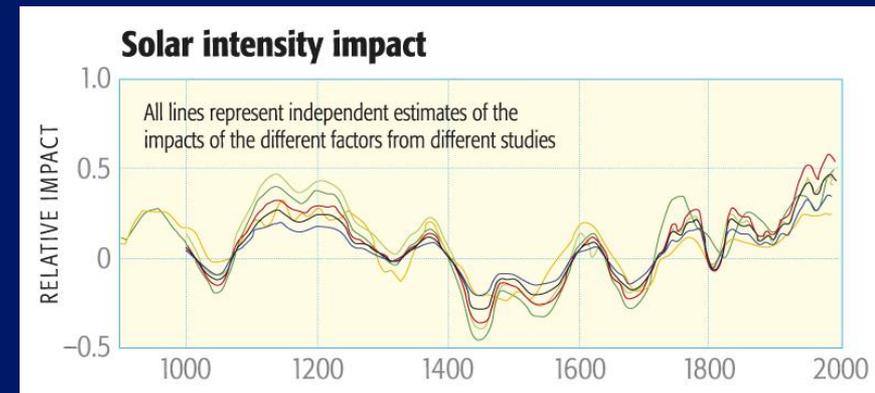
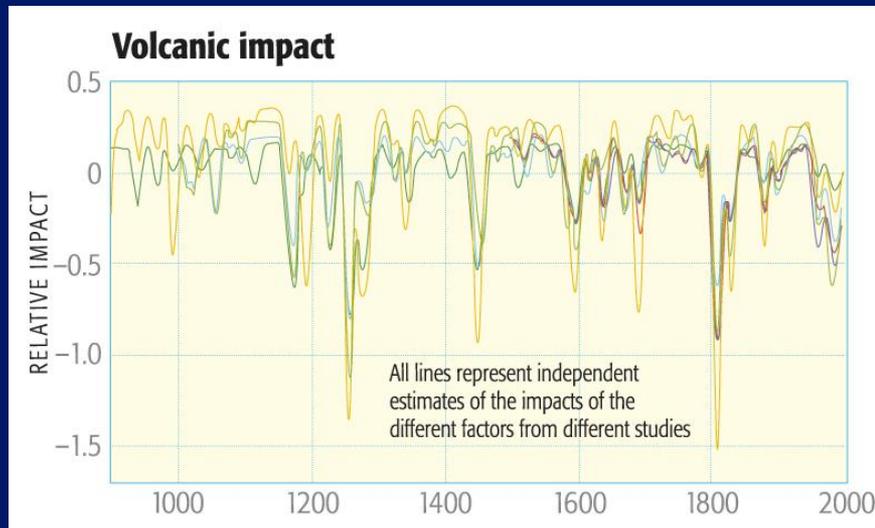


In addition to the “Natural - Archive – Paleo” Approach, **COMPUTER MODELS** have been created to estimate the radiative forcings of the PAST!

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

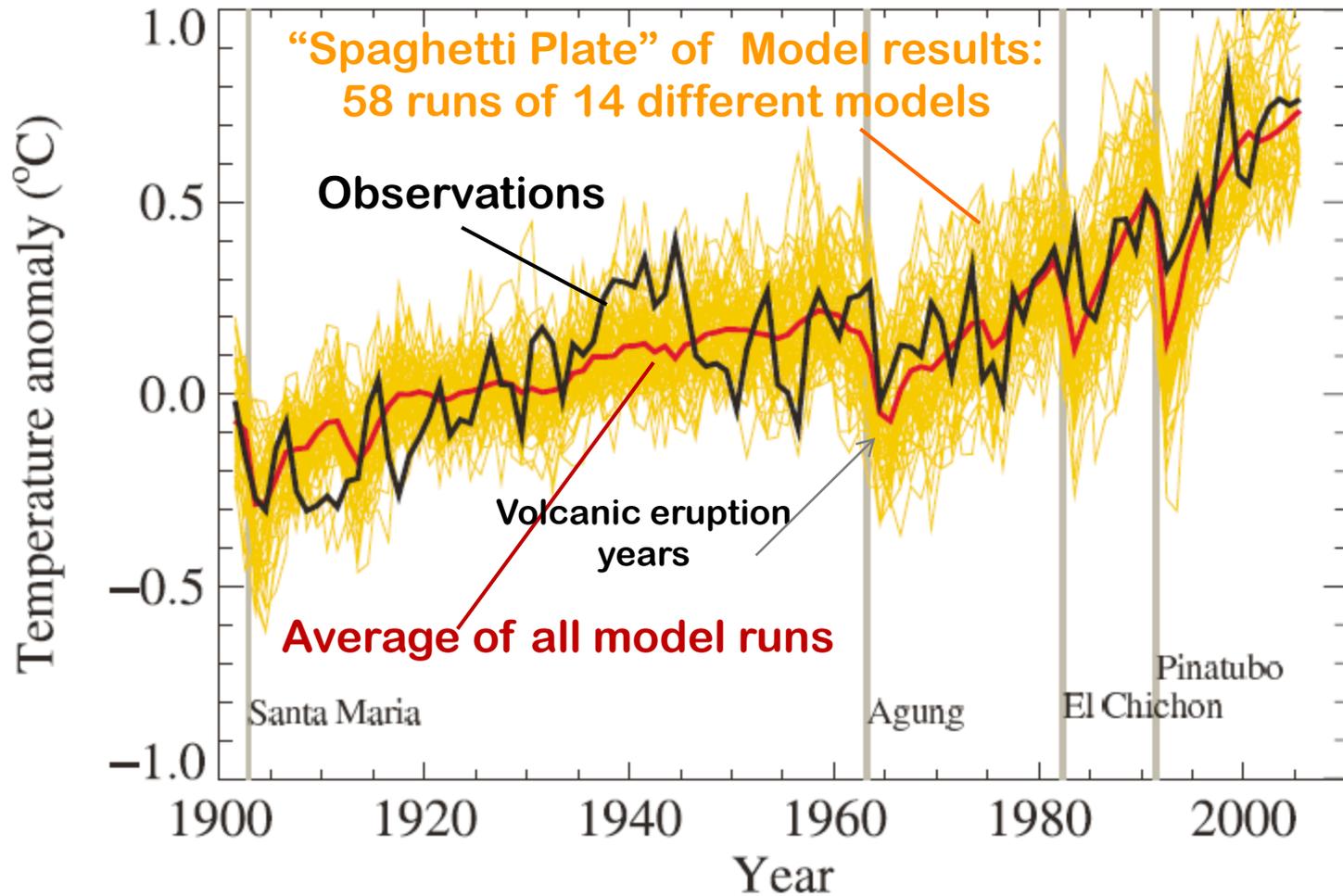
From  
*Dire Predictions*  
p 81

On top of p 85  
in Class Notes

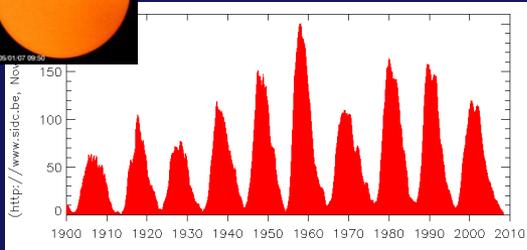
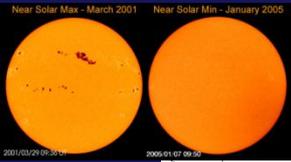


# How Good are the Models?

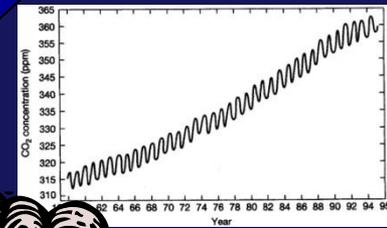
## MODELED GLOBAL MEAN TEMPERATURE:



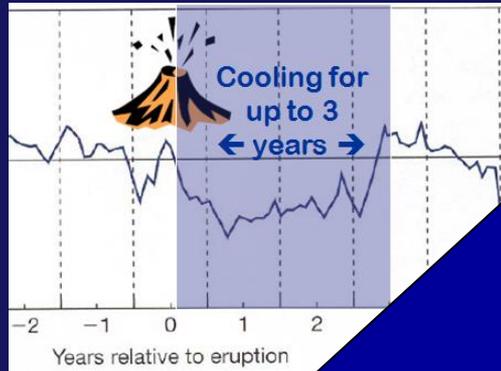
# NATURAL FORCING



Solar output variations, sunspots



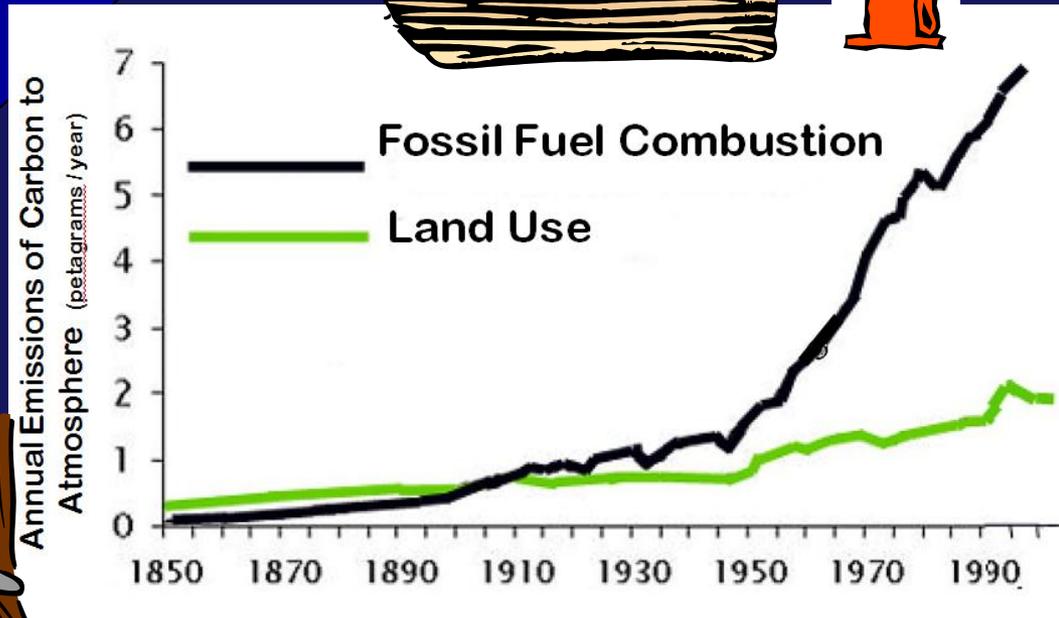
GHG's, soot, SO<sub>2</sub>



Volcanic eruptions

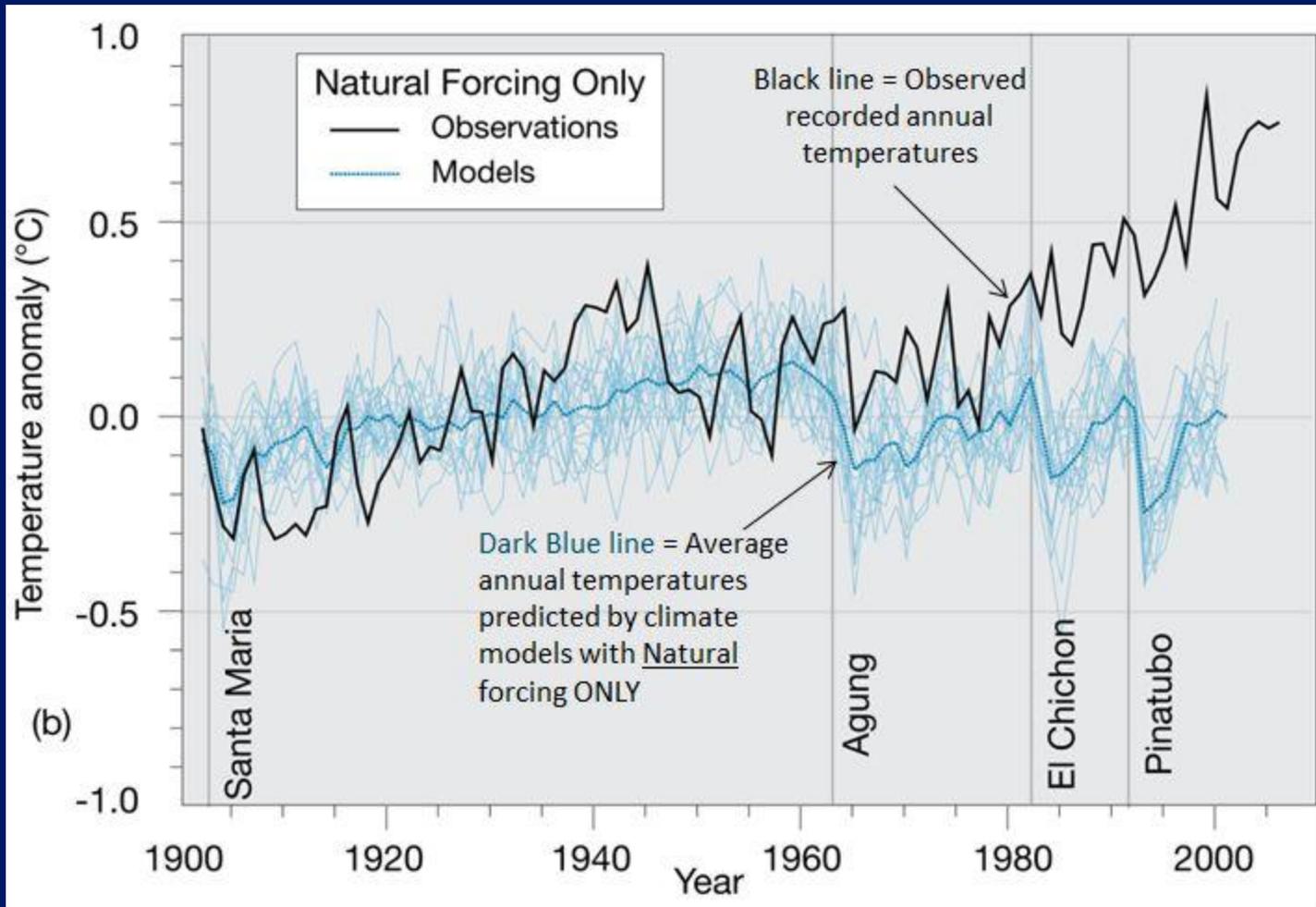


Surface Albedo Changes



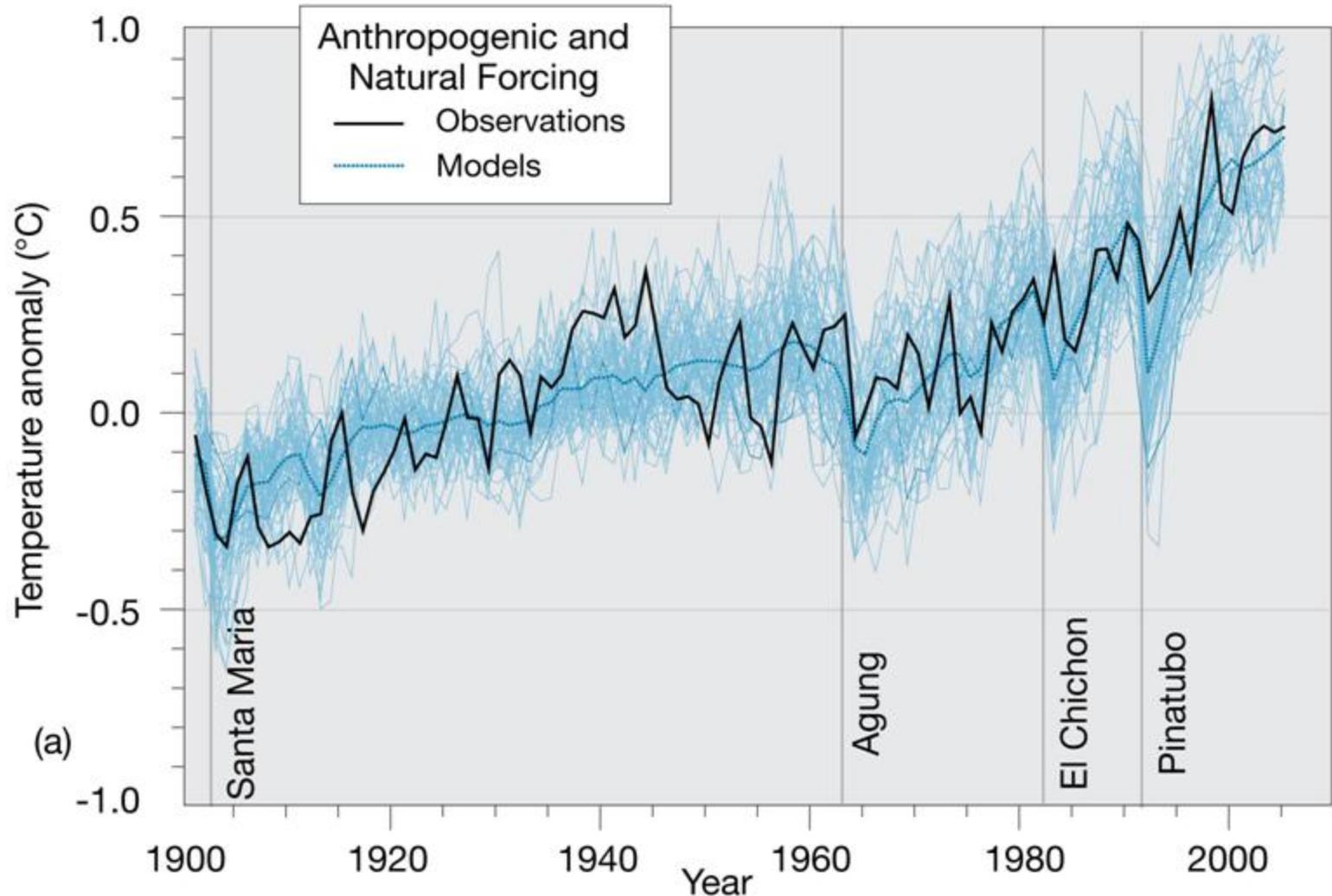
ANTHROPOGENIC FORCING

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

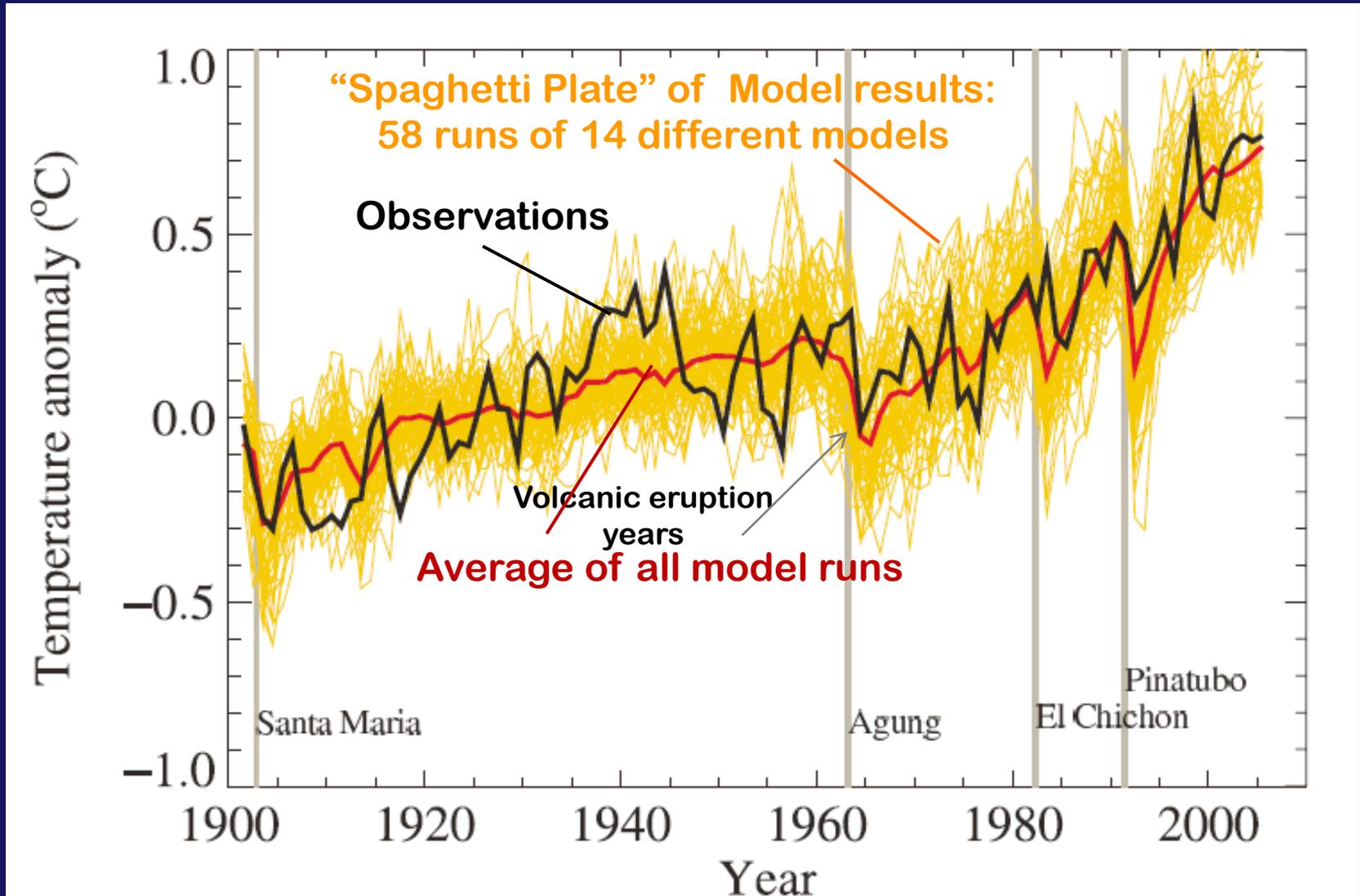


**Models cannot reproduce the observed temperature trend since ~ 1980**

# MODELED TEMPERATURE based on NATURAL + ANTHROPOGENIC FORCING



# MODELED TEMPERATURE based on NATURAL + ANTHROPOGENIC FORCING





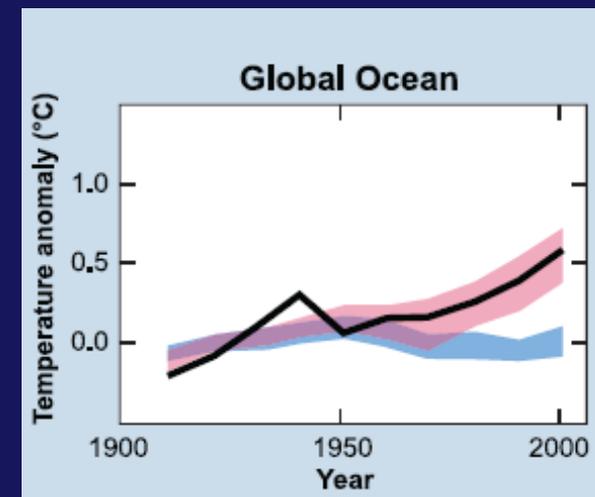
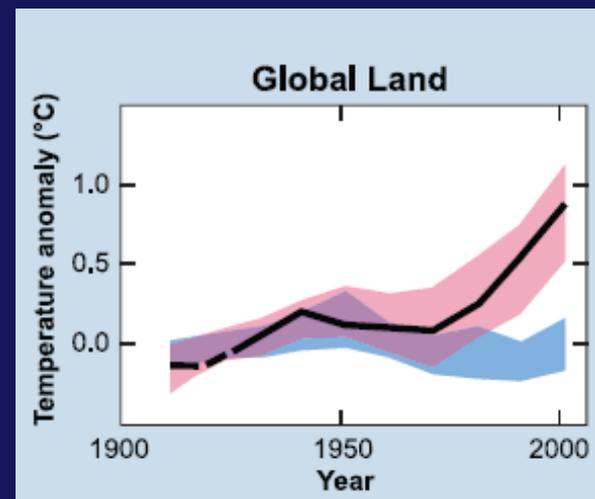
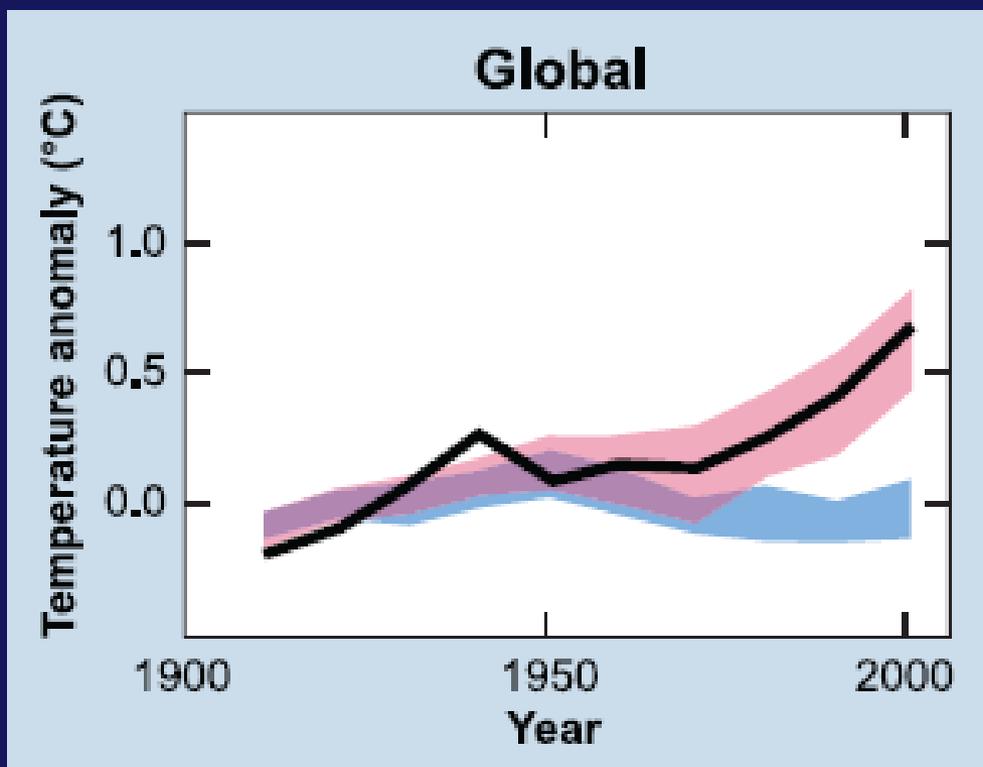
models using only natural forcings



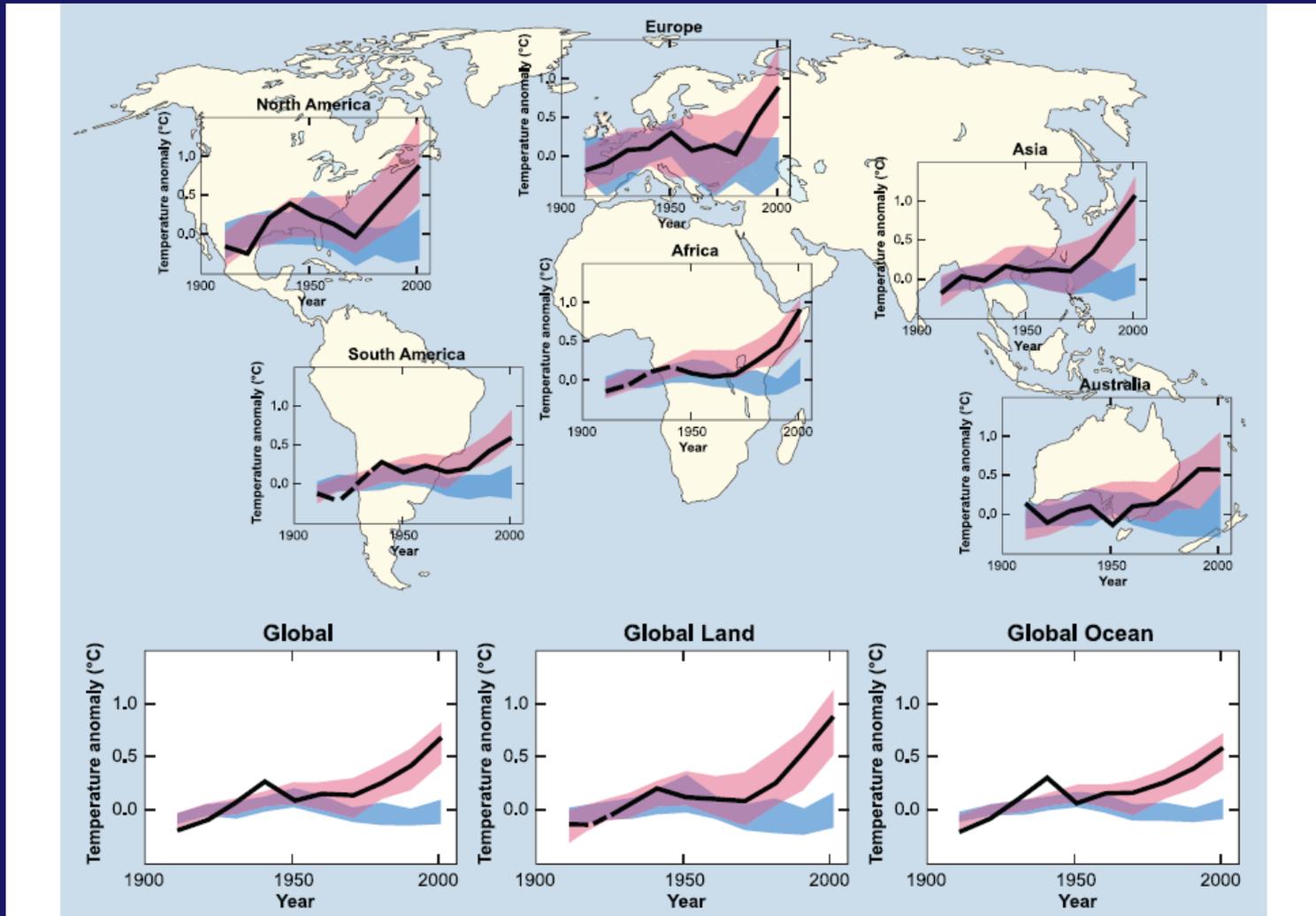
models using both natural and anthropogenic forcings



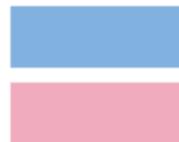
observations



# Individual Region Model Runs showed the same results!



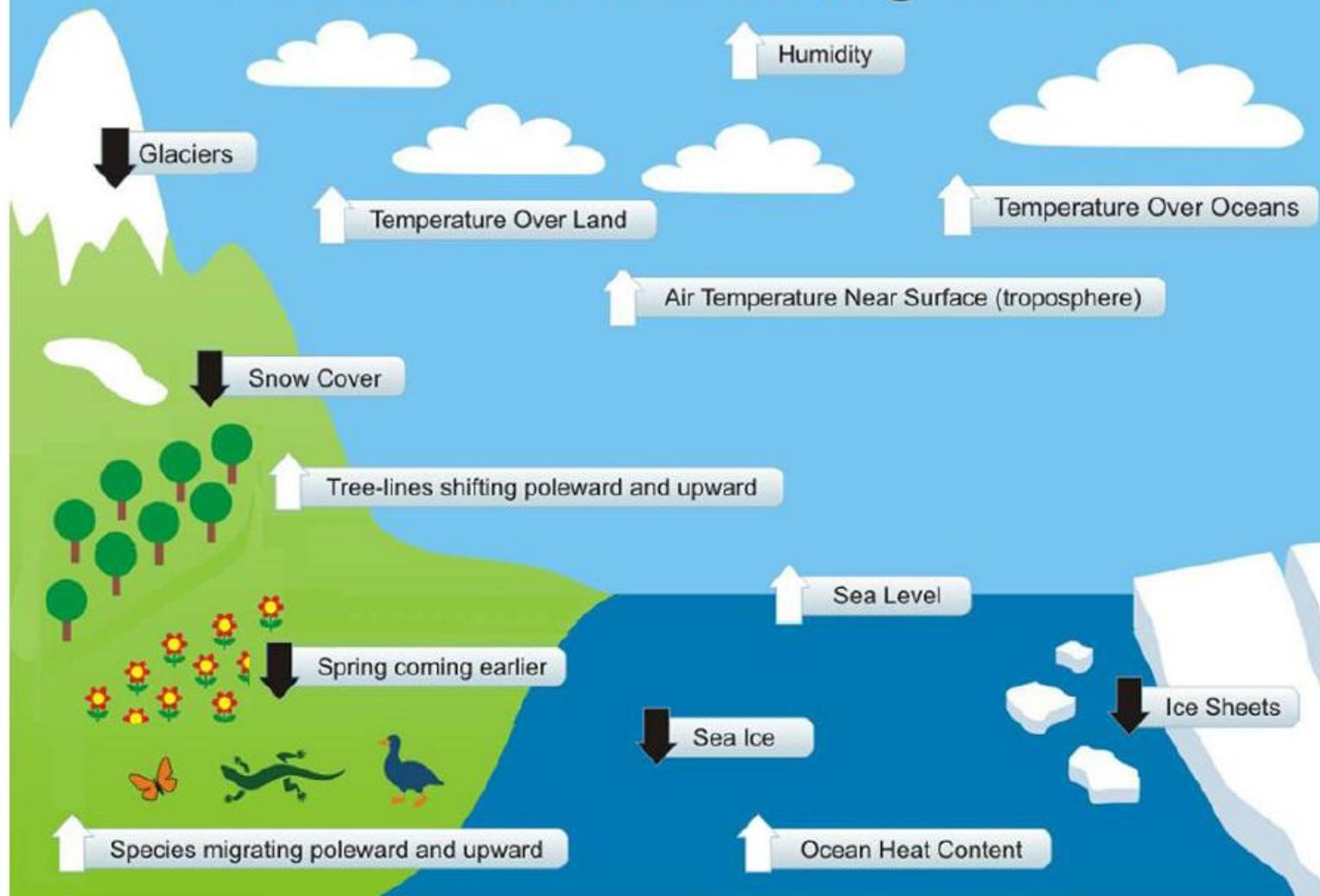
— observations



models using only natural forcings

models using both natural and anthropogenic forcings

# Indicators of a Warming World



**See you Friday!**

**Study hard for Test #4**