

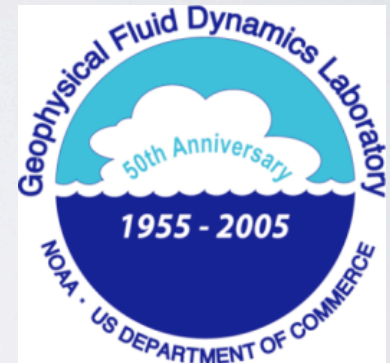
# TEACHERS AS SCHOLARS: UNDERSTANDING GLOBAL WARMING



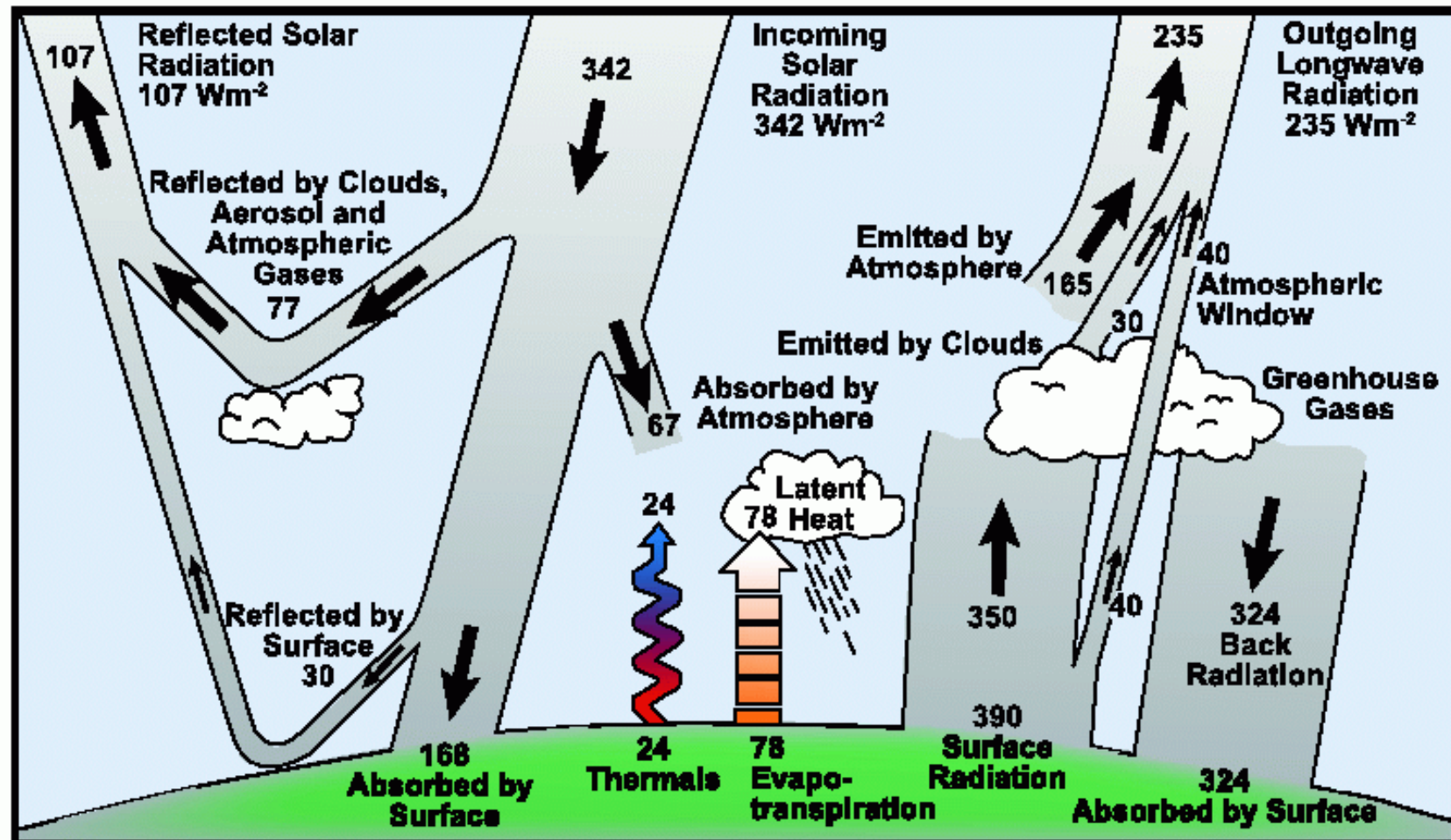
Gabriel Vecchi &  
Mike Winton

18 Jan 2011

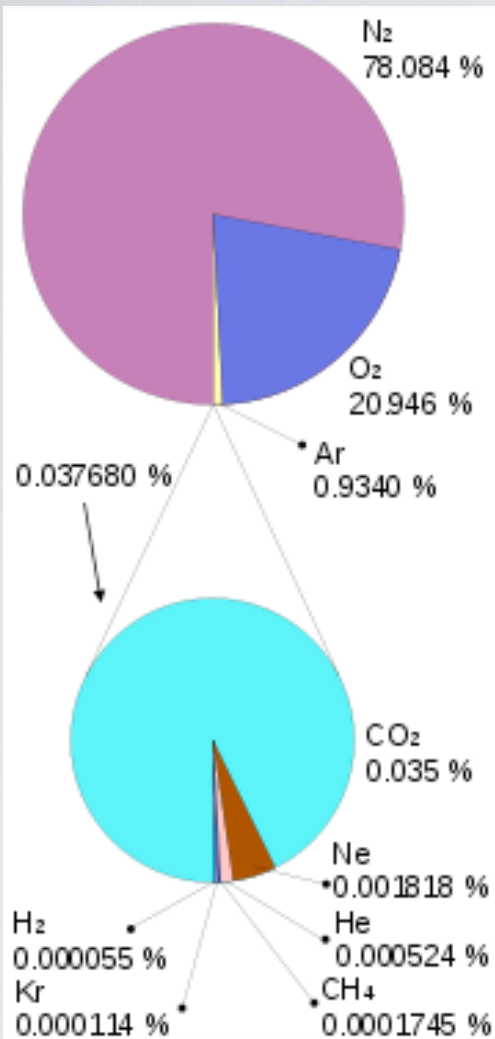
NOAA/GFDL



# EARTH'S ENERGY BALANCE IS THE KEY TO GLOBAL CLIMATE CHANGES



IPCC



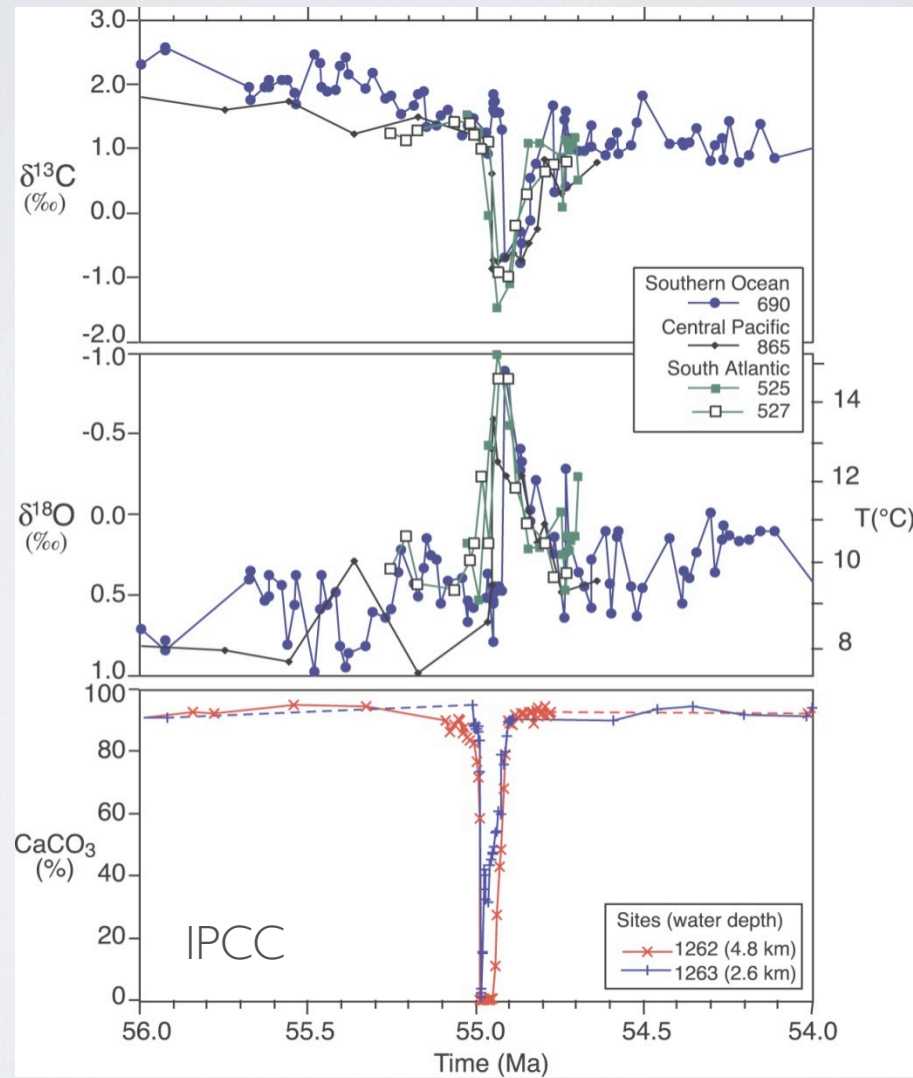
Wikipedia

1) Only a small minority of atmospheric molecules contribute to the greenhouse effect

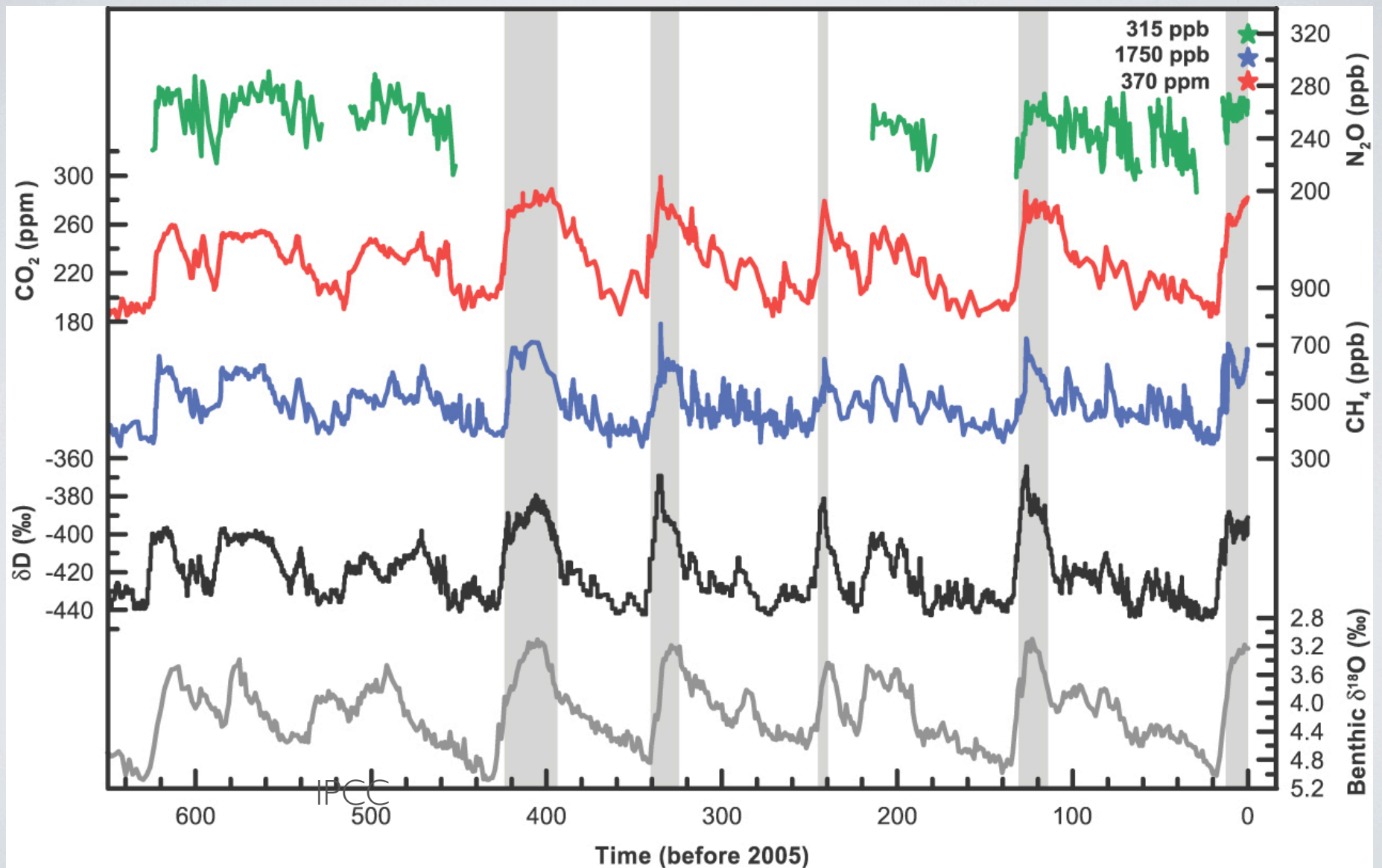
2) Water vapor, the most important greenhouse gas, is present in an amount determined by temperature (it acts as a positive feedback)

3) The change in greenhouse effect from changing a greenhouse gas concentration depends on the fractional change

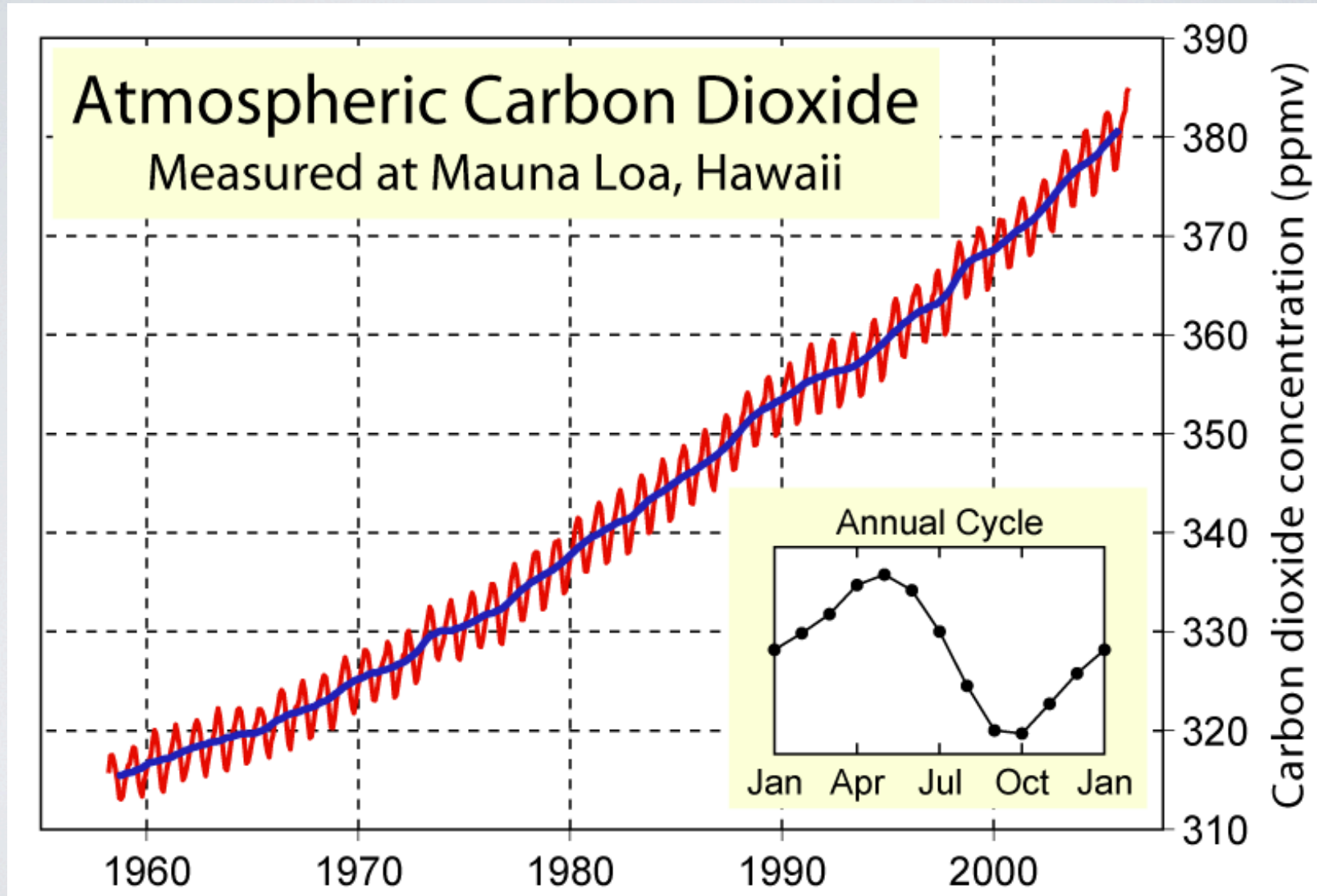
# CO<sub>2</sub> AND CLIMATE: PALEOCENE-EOCENE WARM EVENT



# CO<sub>2</sub> AND CLIMATE: ICE AGE CYCLES

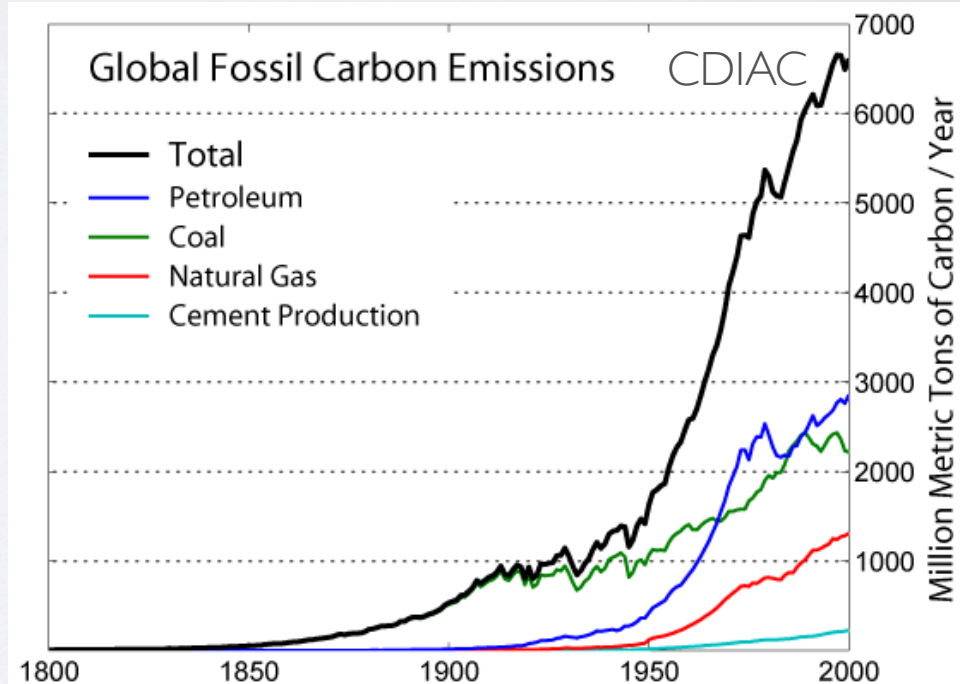
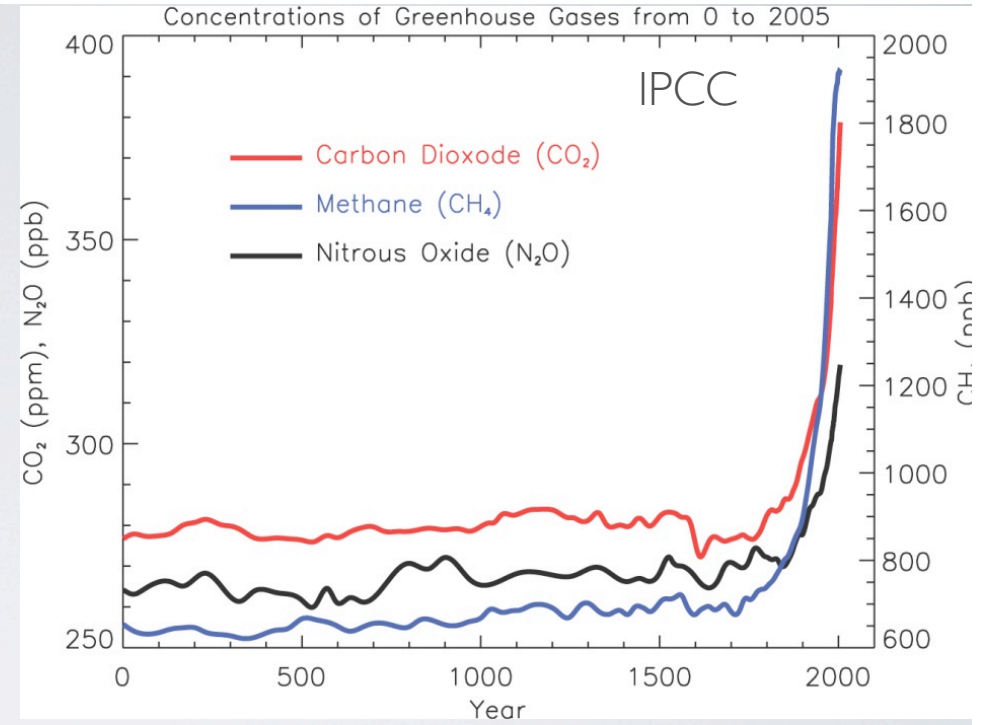


# ATMOSPHERIC CO<sub>2</sub> IS INCREASING



ATMOSPHERIC CO<sub>2</sub> WAS  
STABLE PRIOR TO THE 19<sup>TH</sup>  
CENTURY

THE RISE IN GREENHOUSE  
GASES OCCURRED IN THE  
INDUSTRIAL ERA WITH  
INCREASED USE OF FOSSIL  
FUELS

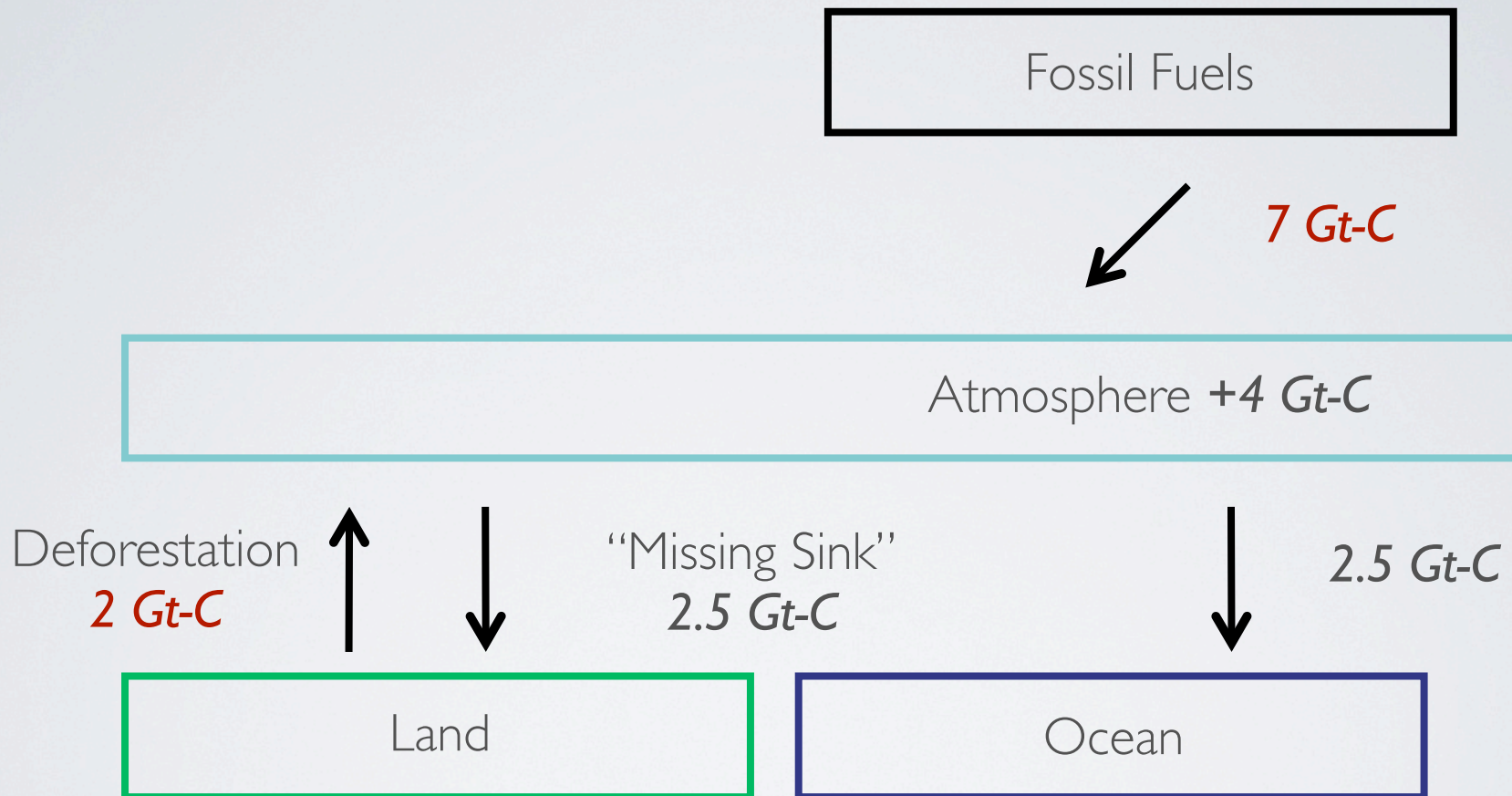


The chemical fingerprint of the atmospheric carbon increase tells us:

- 1) the added carbon is old ( $^{14}\text{C}$  is low)
- 2) it has a biological source ( $^{13}\text{C}$  is low)
- 3) it is produced by combustion or respiration ( $\text{O}_2$  is decreasing)



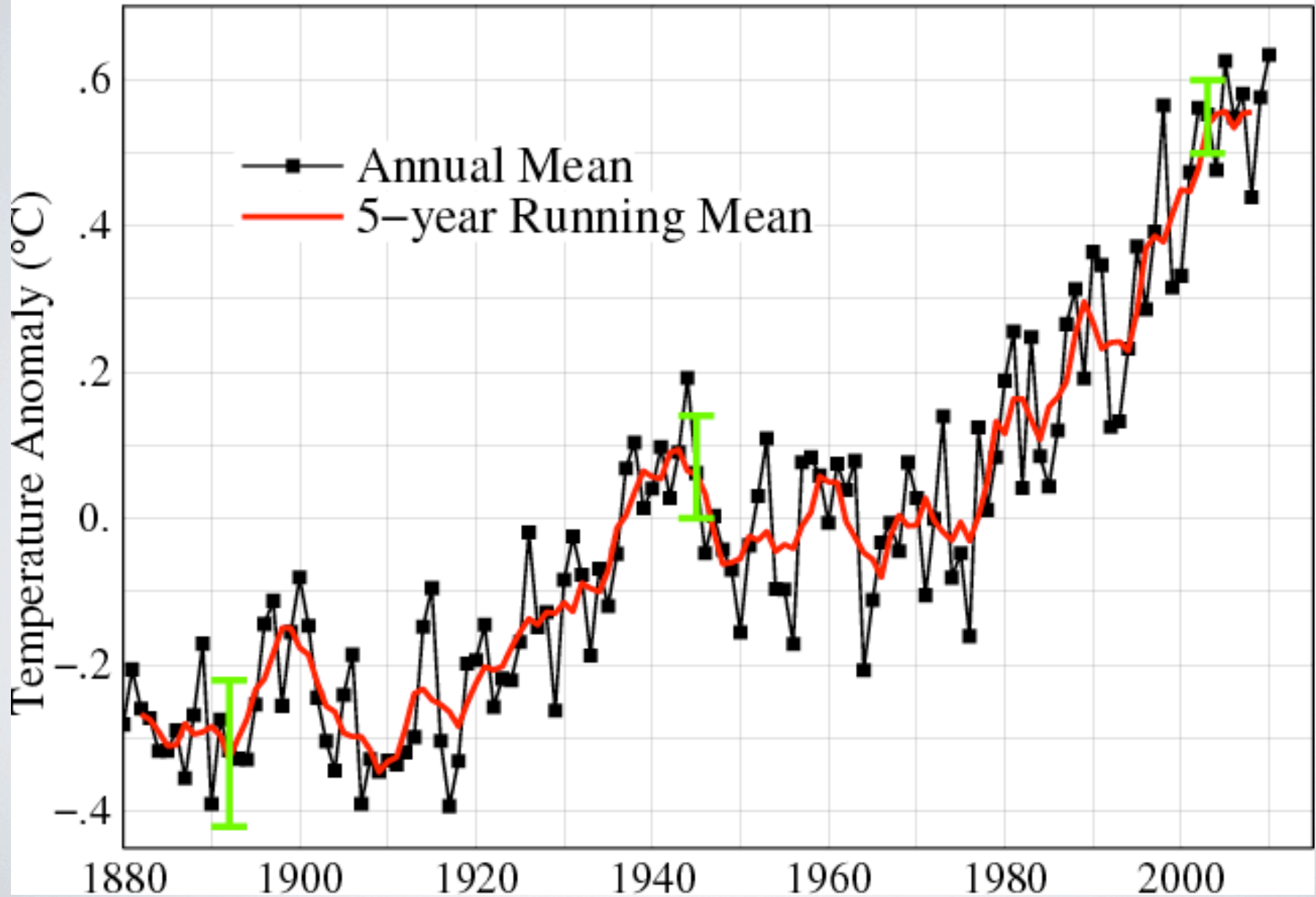
# WHERE DO HUMAN CARBON EMISSIONS GO?



# EARTH'S SURFACE IS WARMING

Base Period:  
1951-1980

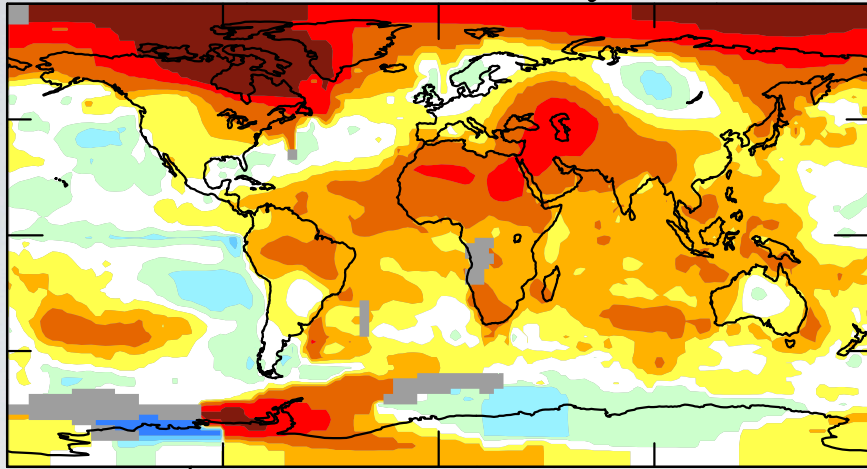
## Global Land-Ocean Temperature Index



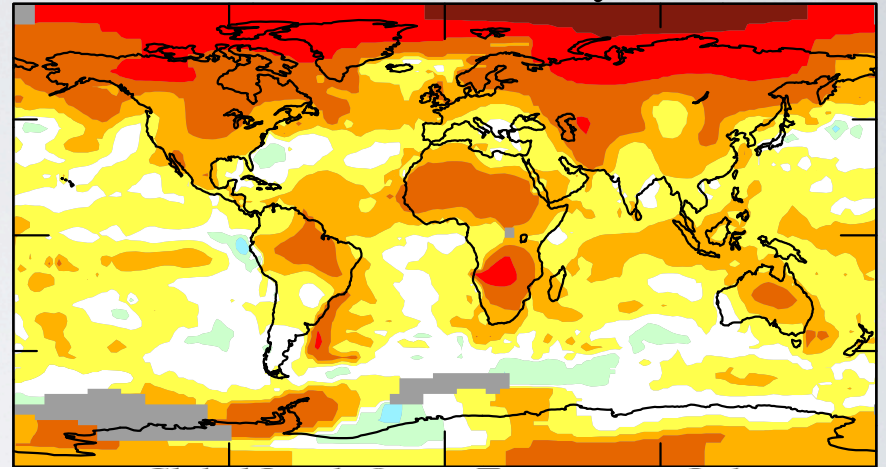
# EARTH'S SURFACE IS WARMING

Annual Mean Surface Temperature Anomaly (°C)

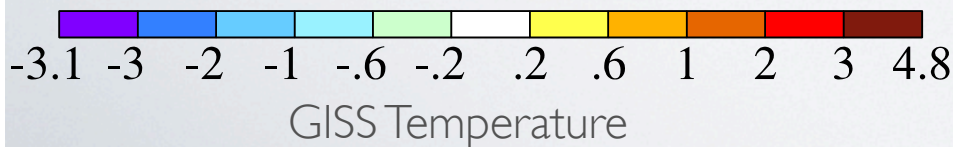
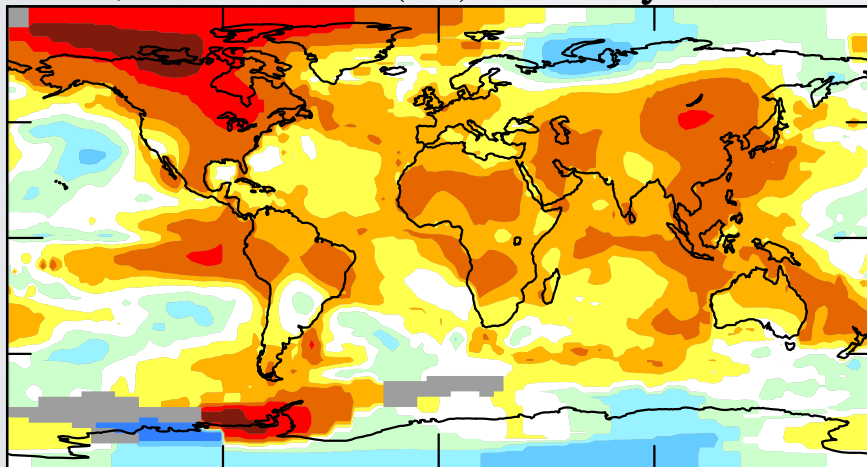
2010, warmest (tie) of 131 years 0.63



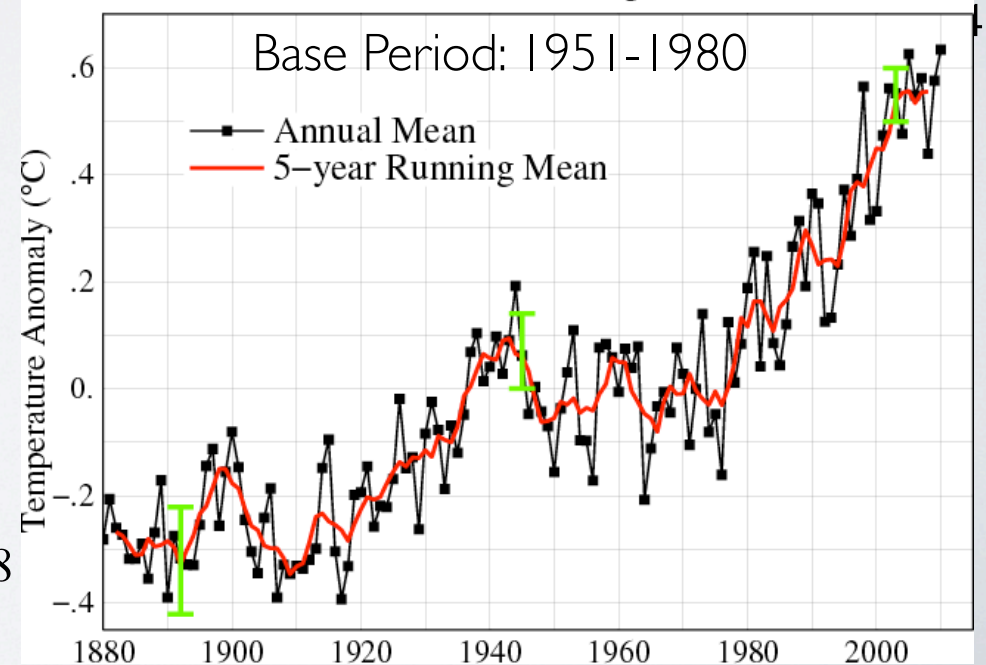
2005, warmest (tie) of 131 years 0.62



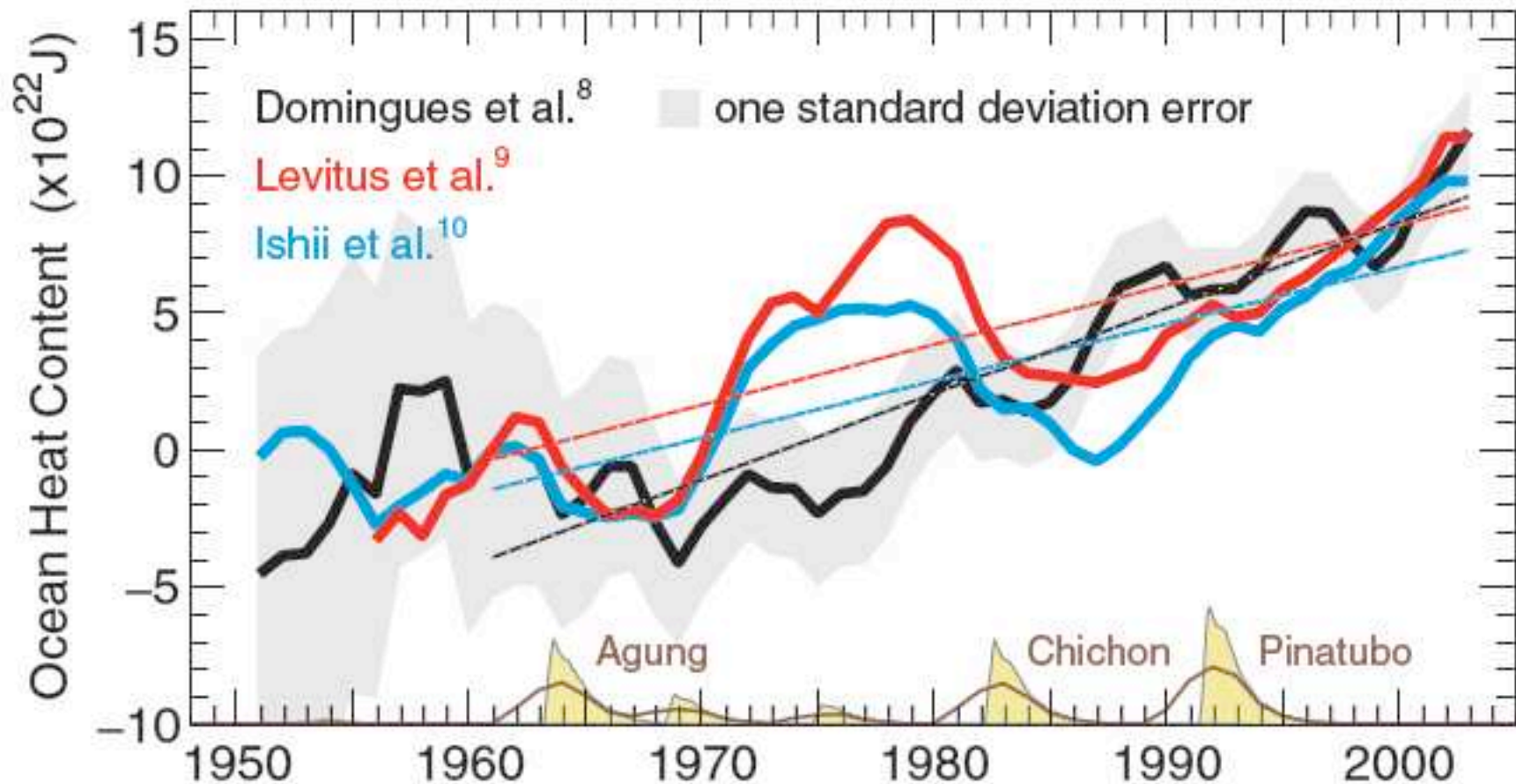
1998, 3<sup>rd</sup> warmest (tie) of 131 years 0.56



Global Land–Ocean Temperature Index



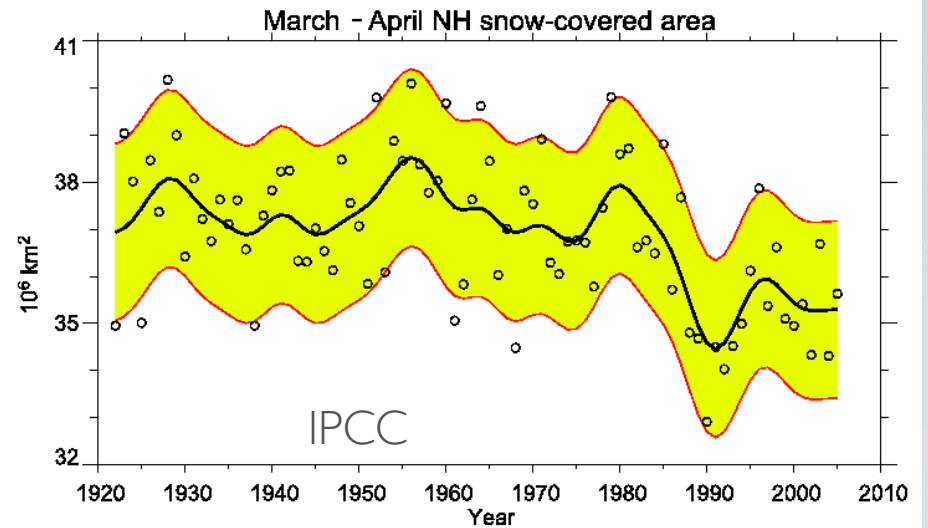
# THE OCEANS ARE WARMING



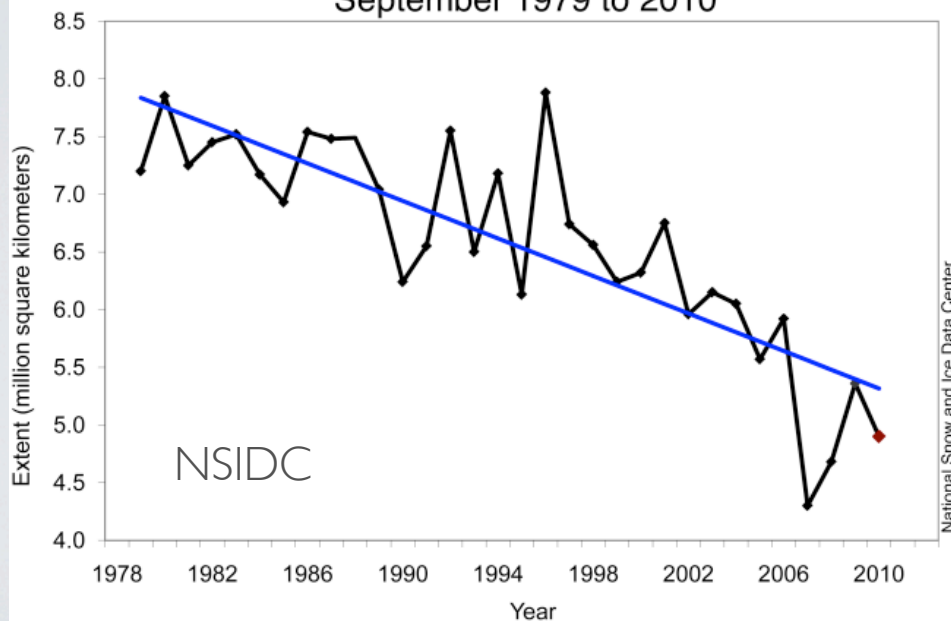
*Domingues et al (2008, Nature)*

# SNOW & ICE ARE DECLINING GLOBALLY

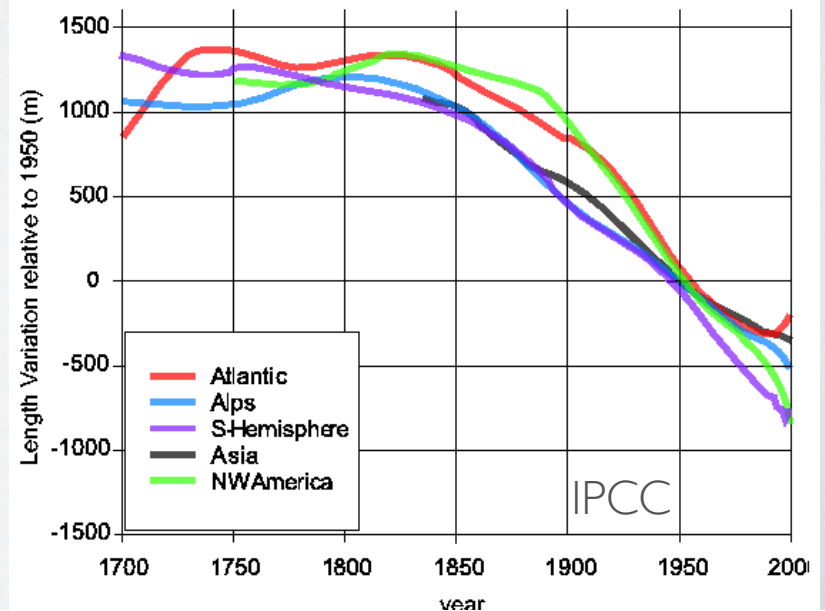
## NH Snow Cover



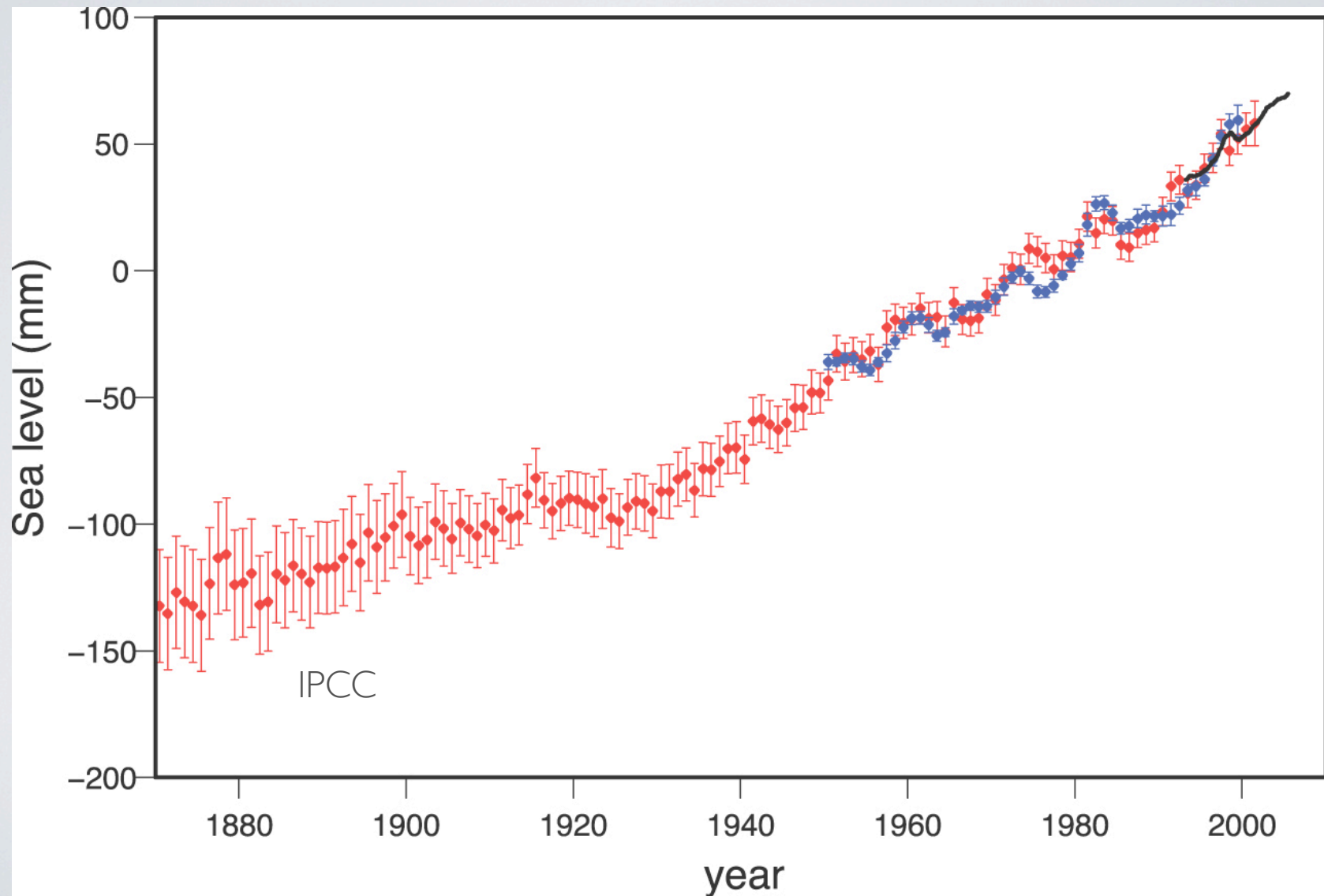
Average Monthly Arctic Sea Ice Extent  
September 1979 to 2010



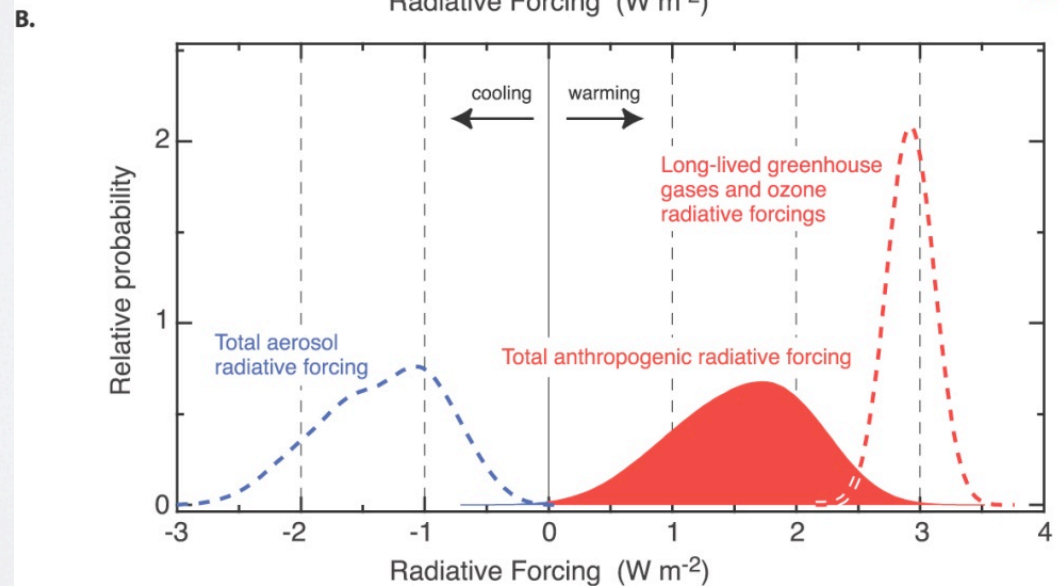
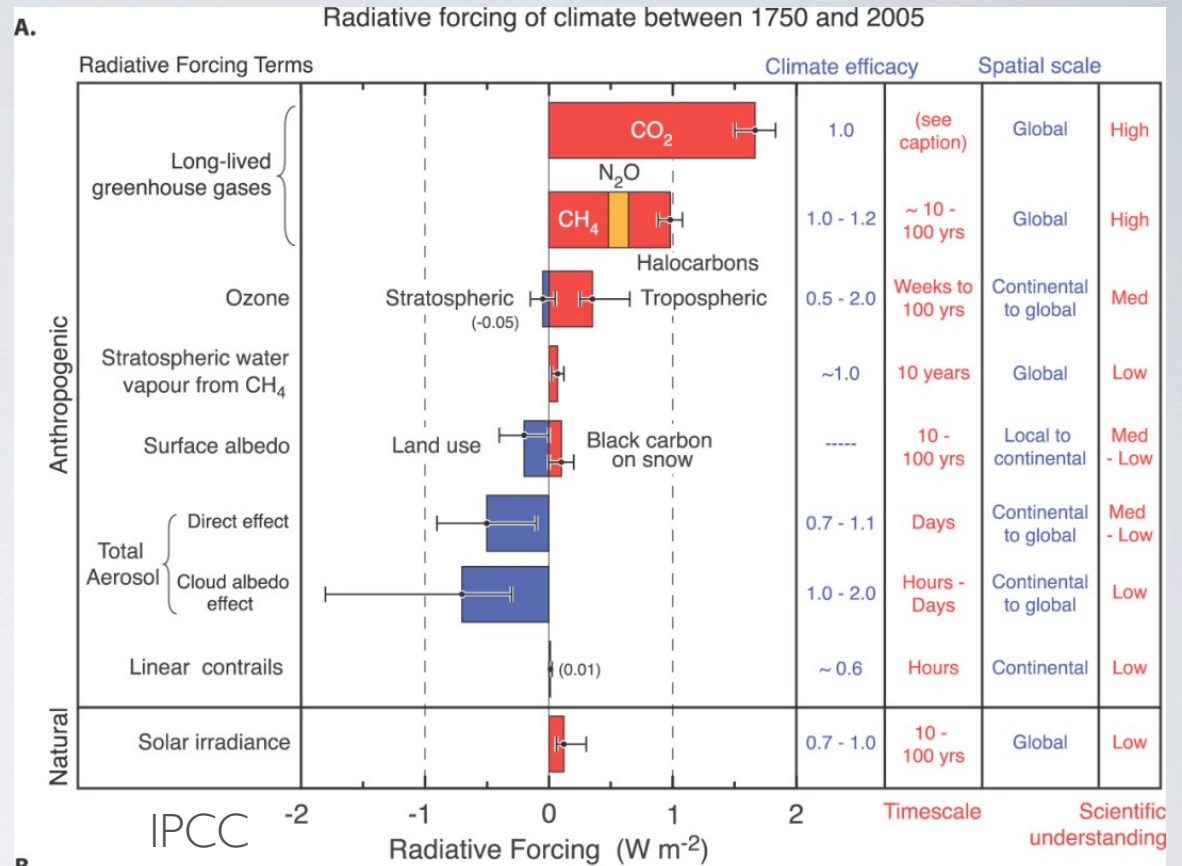
## Glacier Length



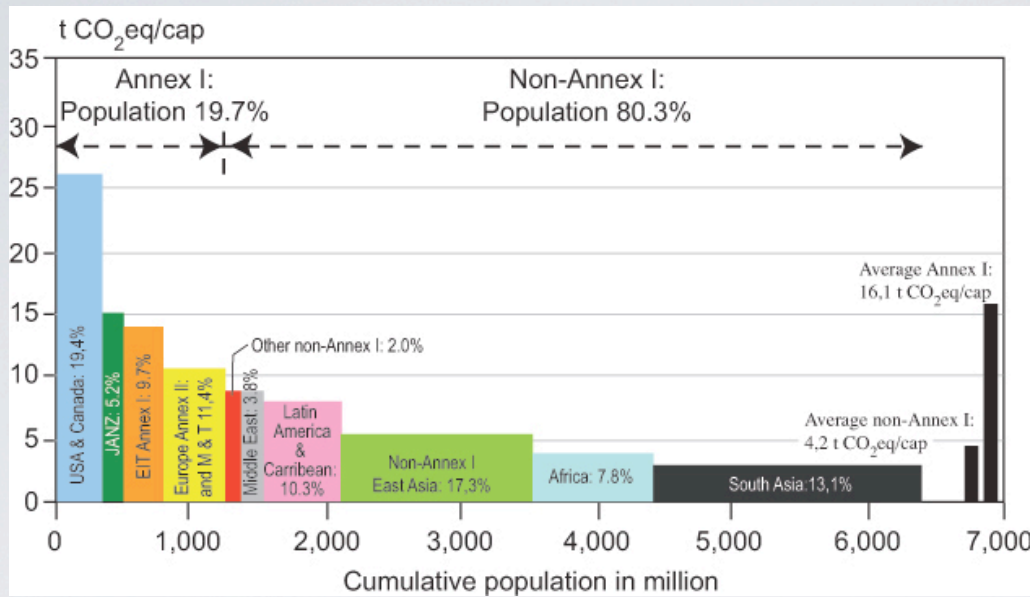
# SEA LEVEL IS RISING (ice melt + seawater expansion)



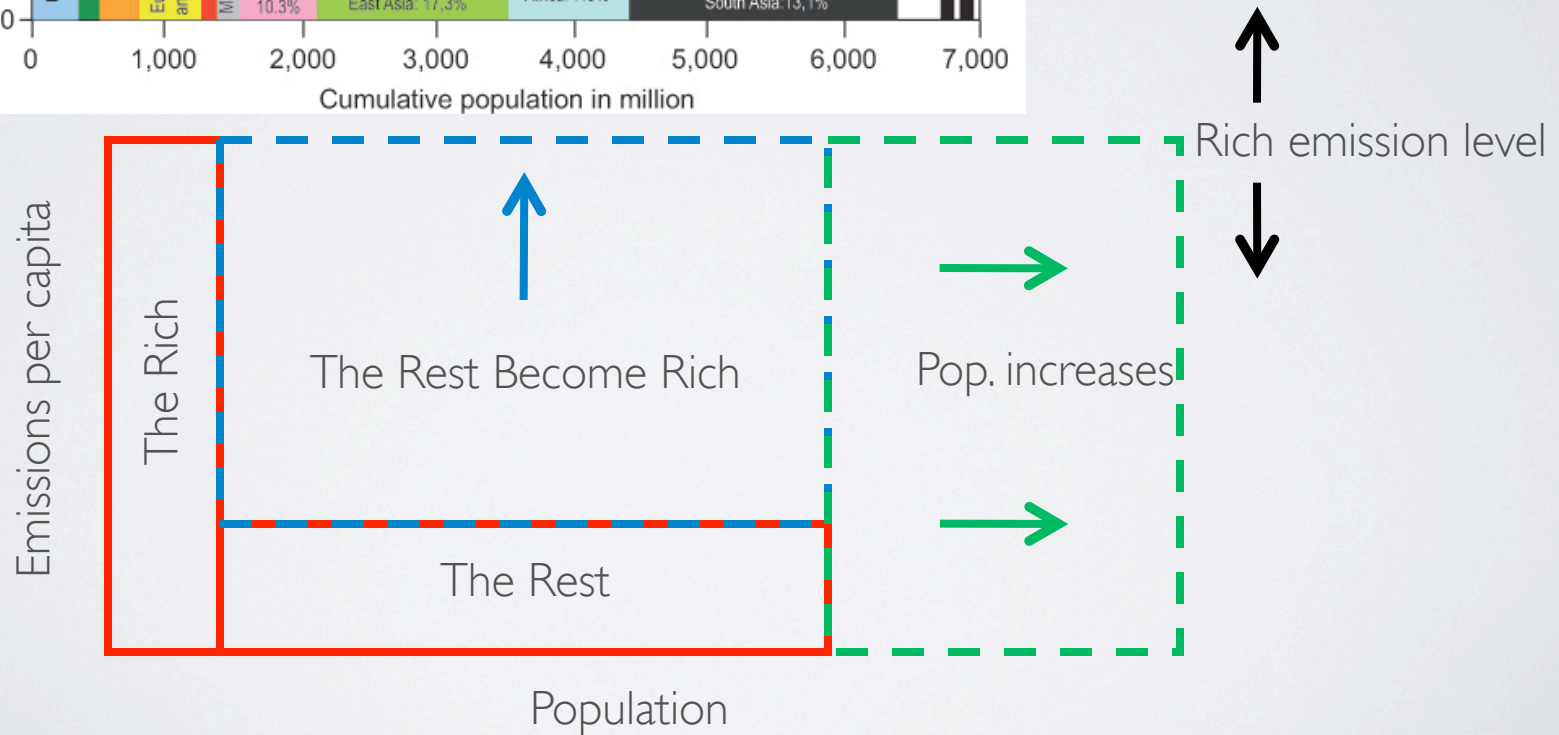
# THERE ARE NUMEROUS ANTHROPOGENIC FORCINGS OF CLIMATE CHANGE



# EMISSIONS GROWTH HAS POWERFUL SOCIO-ECONOMIC DRIVERS

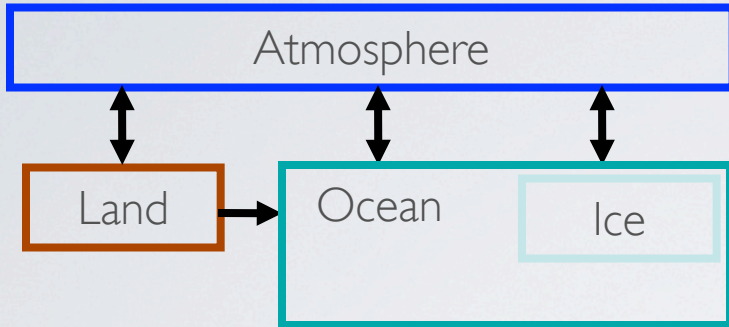


IPCC

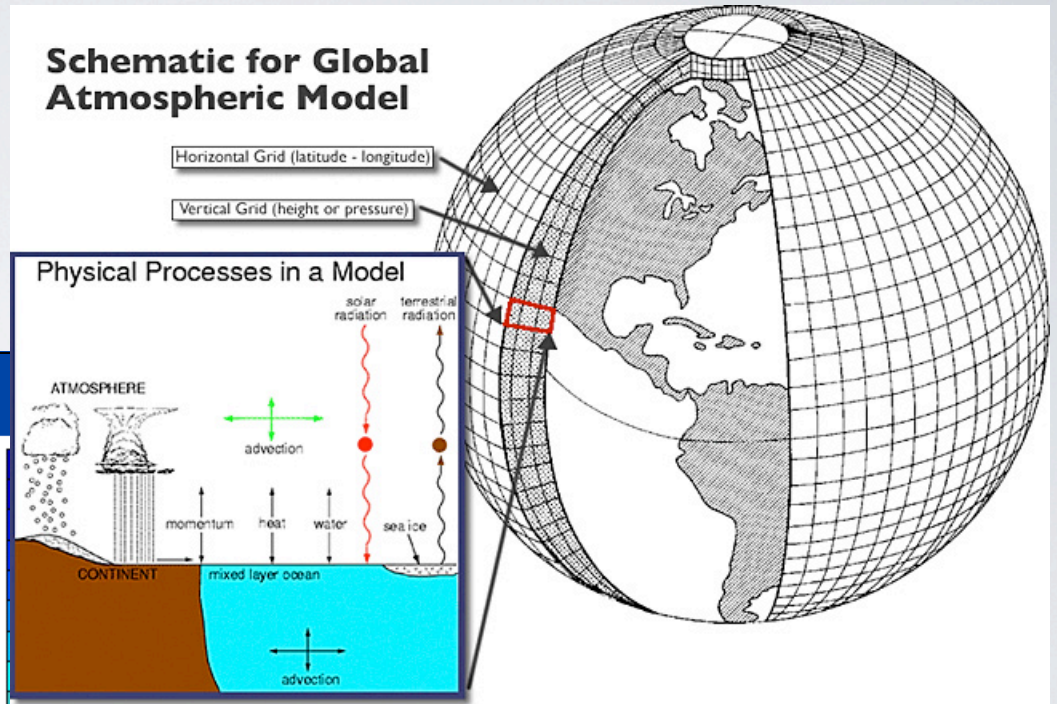




# CLIMATE MODEL EQUATIONS ARE SOLVED ON GLOBAL GRIDS

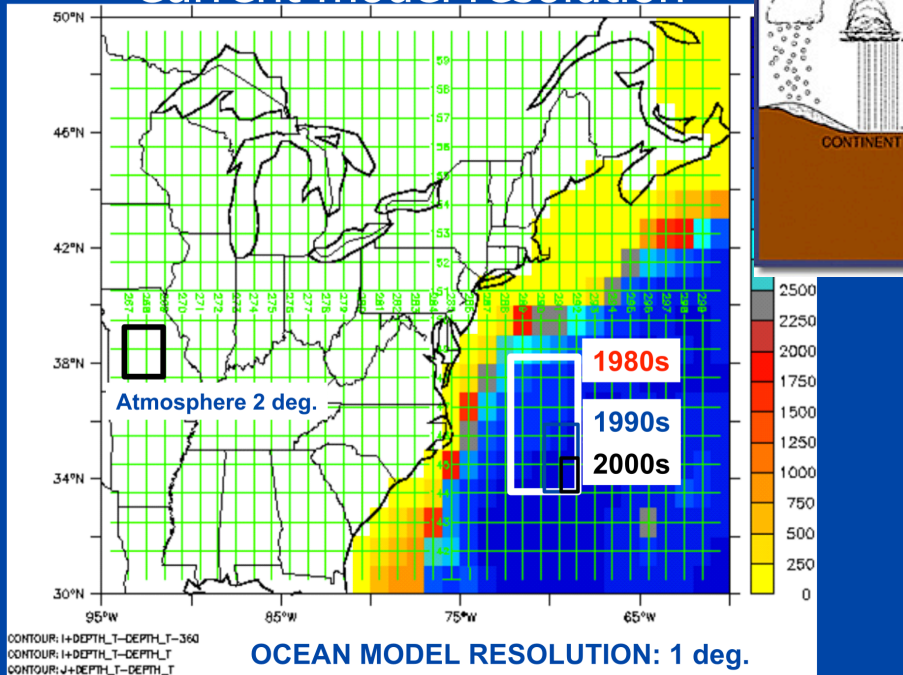


**Schematic for Global Atmospheric Model**



**Physical Processes in a Model**

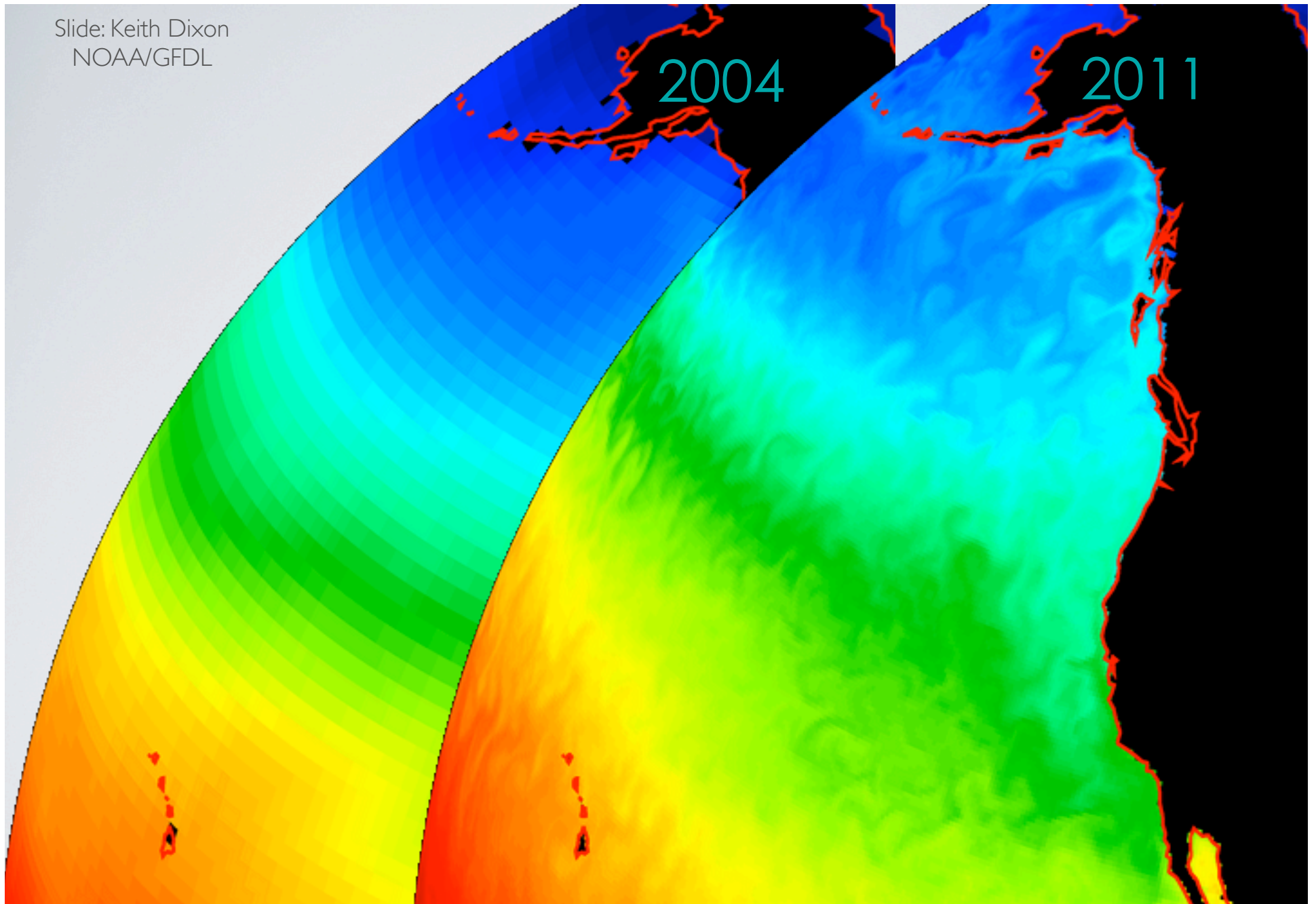
**Current model resolution**



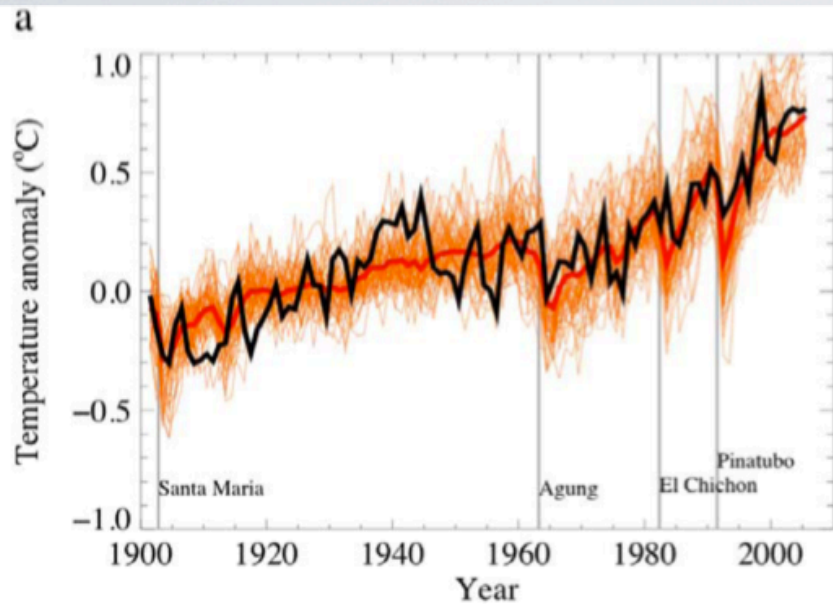
# SIMULATED VS. PARAMETERIZED

- ***Simulated*** processes: larger than grid-scale, based on bedrock scientific principles (conservation of energy, mass and momentum). Example: storms.
- ***Parameterized*** processes: smaller than grid scale, formulations guided by physical principles but also make use of observational data. Example: clouds.
- As model ***resolution*** increases, we are able to simulate some processes that are currently parameterized.
- As model ***comprehensiveness*** increases, we are able to account for more processes (either as parameterized or simulated)

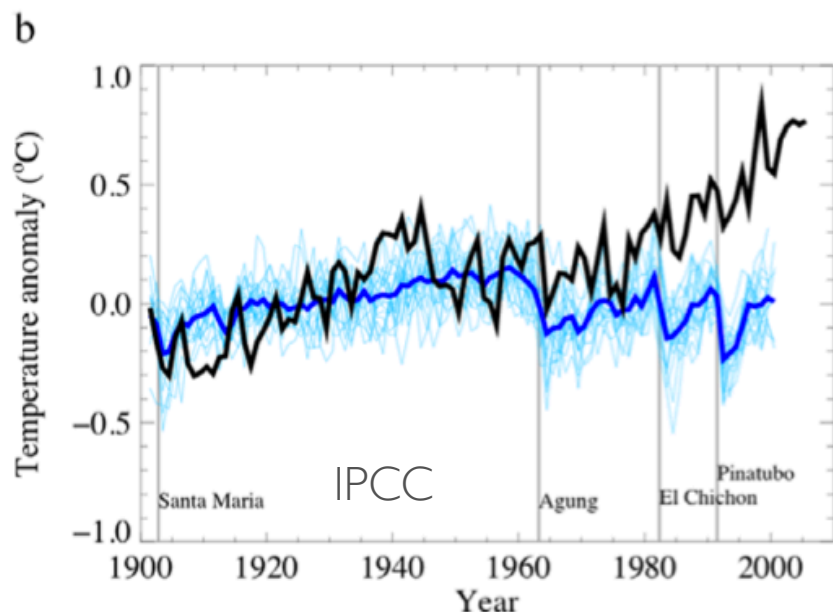
Slide: Keith Dixon  
NOAA/GFDL



# USING CLIMATE MODELS TO UNDERSTAND THE PAST: DETECTION AND ATTRIBUTION

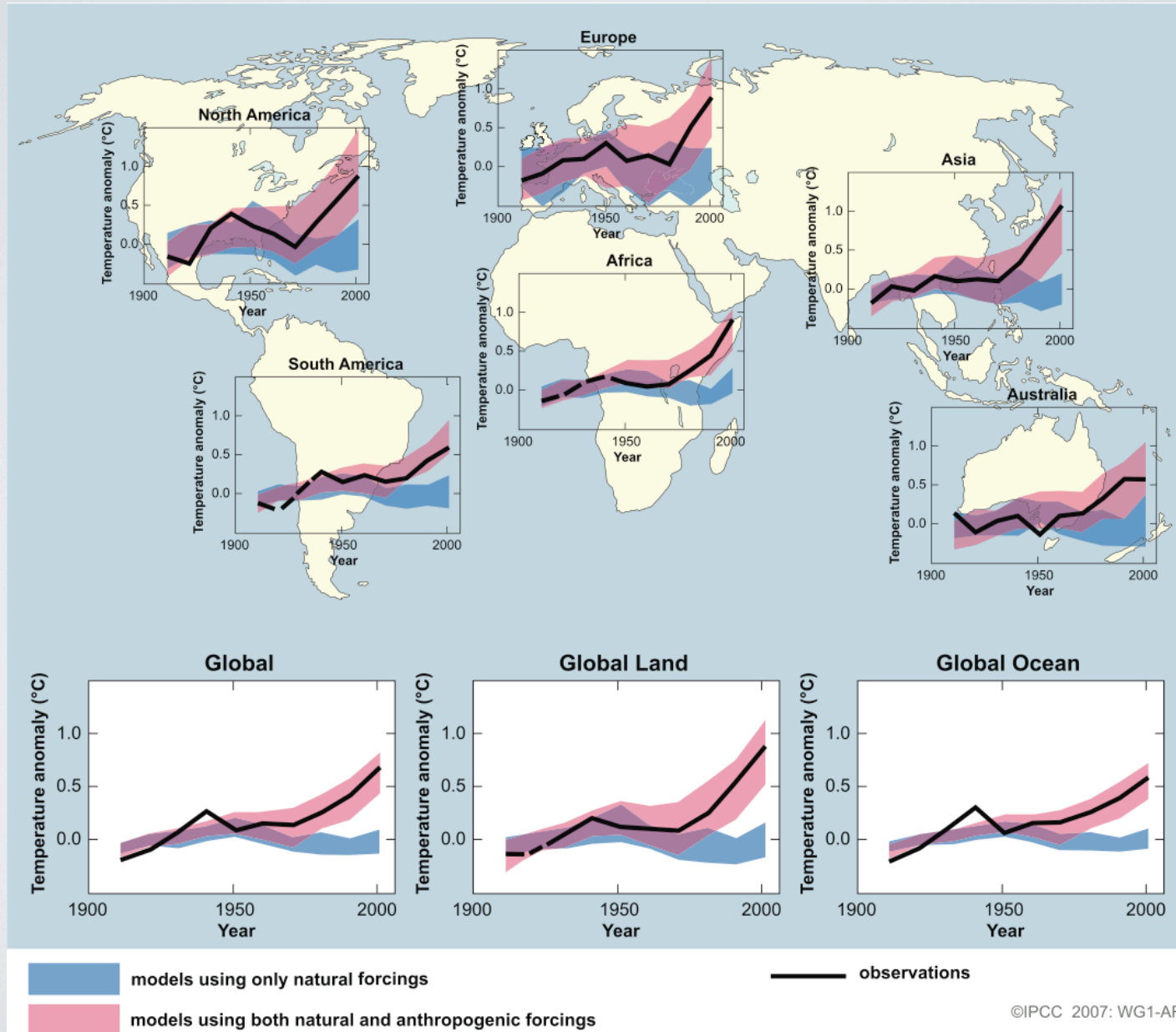


**(2) Attribution: anthropogenic forcing is that “something”**

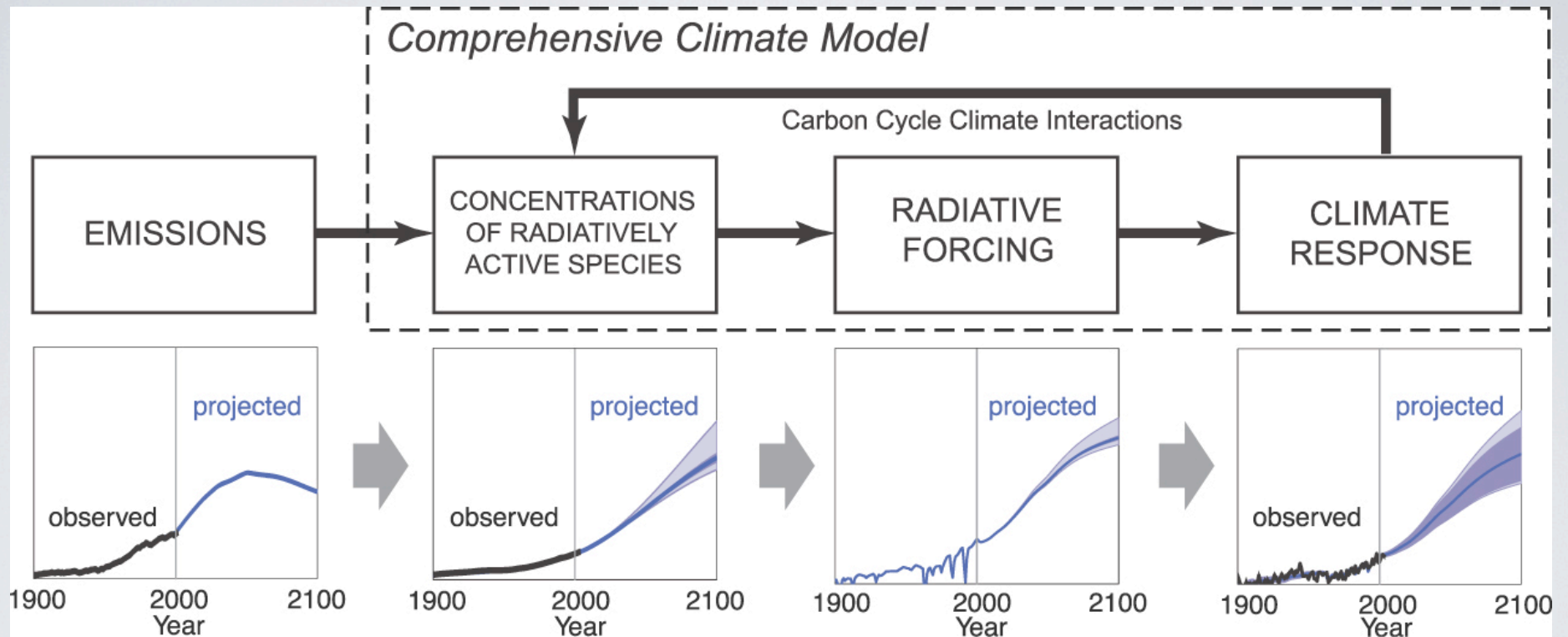


**(1) Detection: something beyond natural variability is happening to the global climate**

# USING CLIMATE MODELS: DETECTION AND ATTRIBUTION AT THE CONTINENTAL SCALE

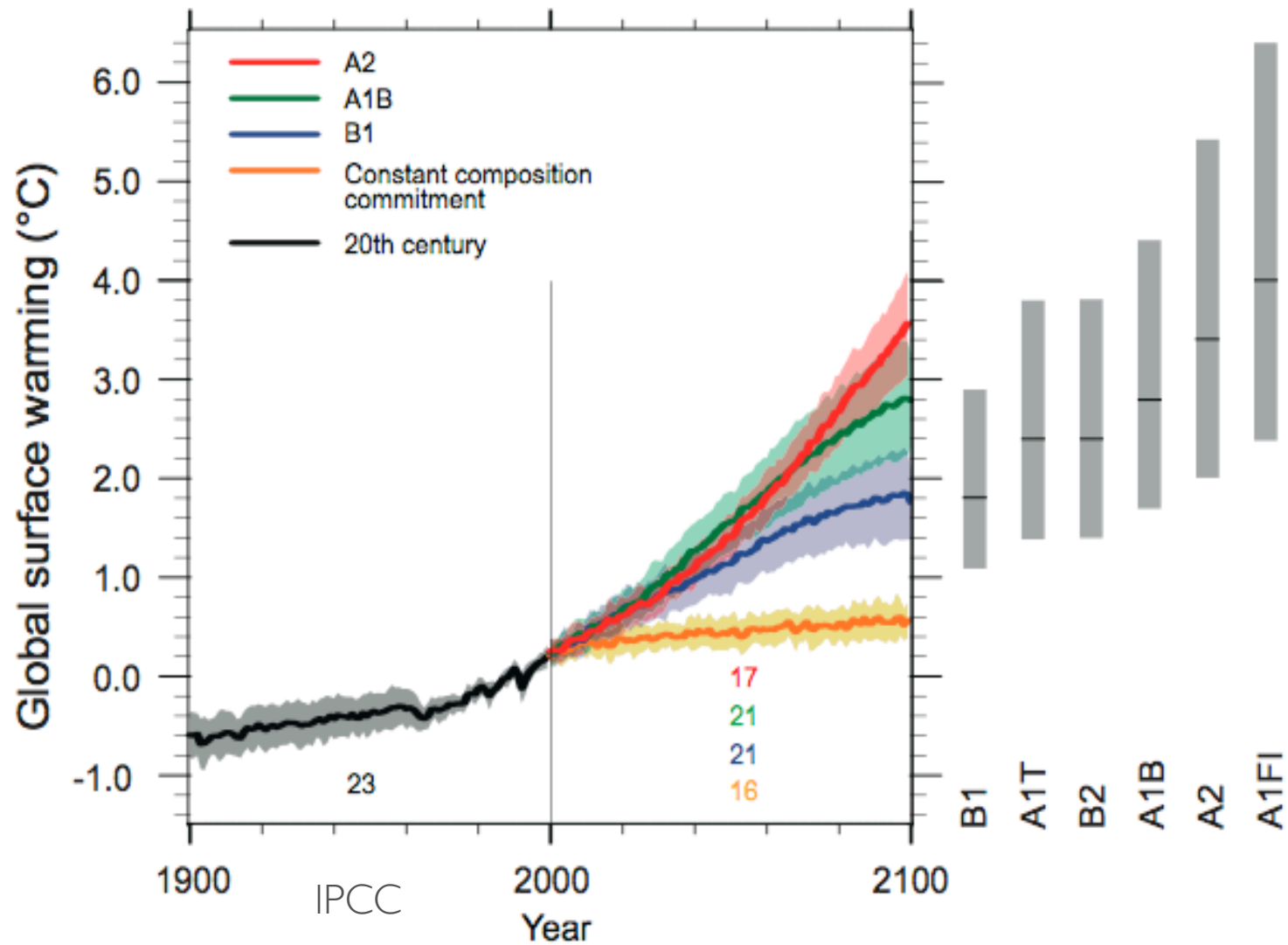


# USING CLIMATE MODELS TO PROJECT FUTURE CLIMATE: NEED EMISSIONS



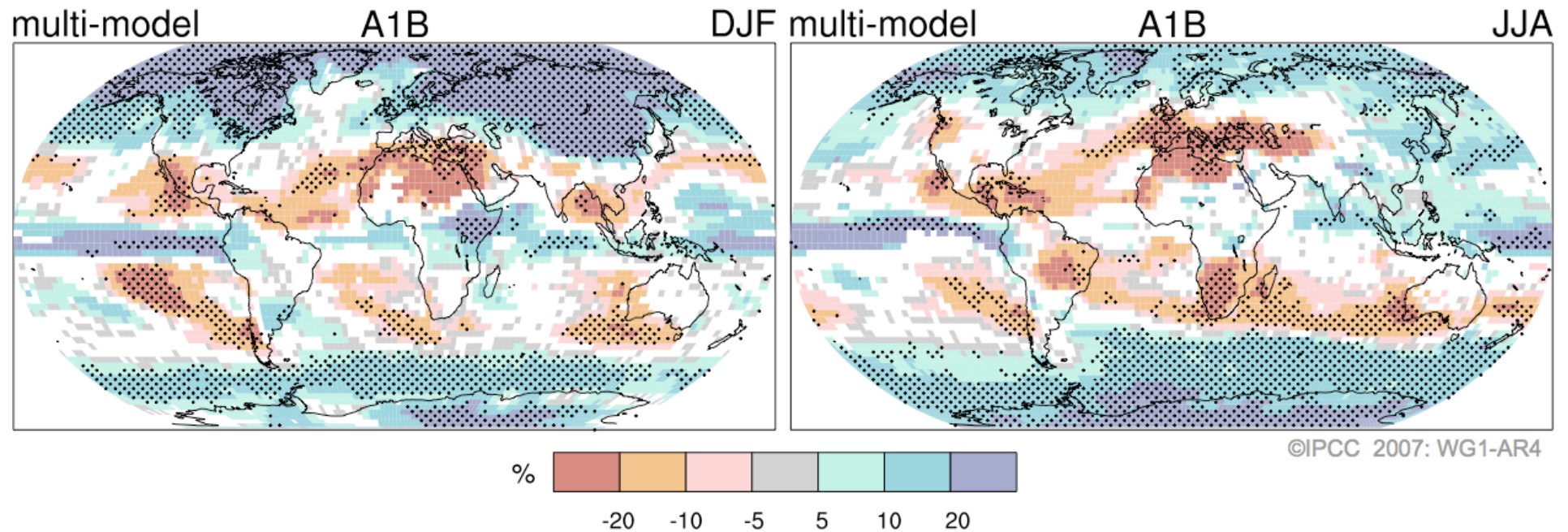
IPCC

# PROJECTION: 21<sup>ST</sup> CENTURY GLOBAL TEMPERATURE RISES FURTHER



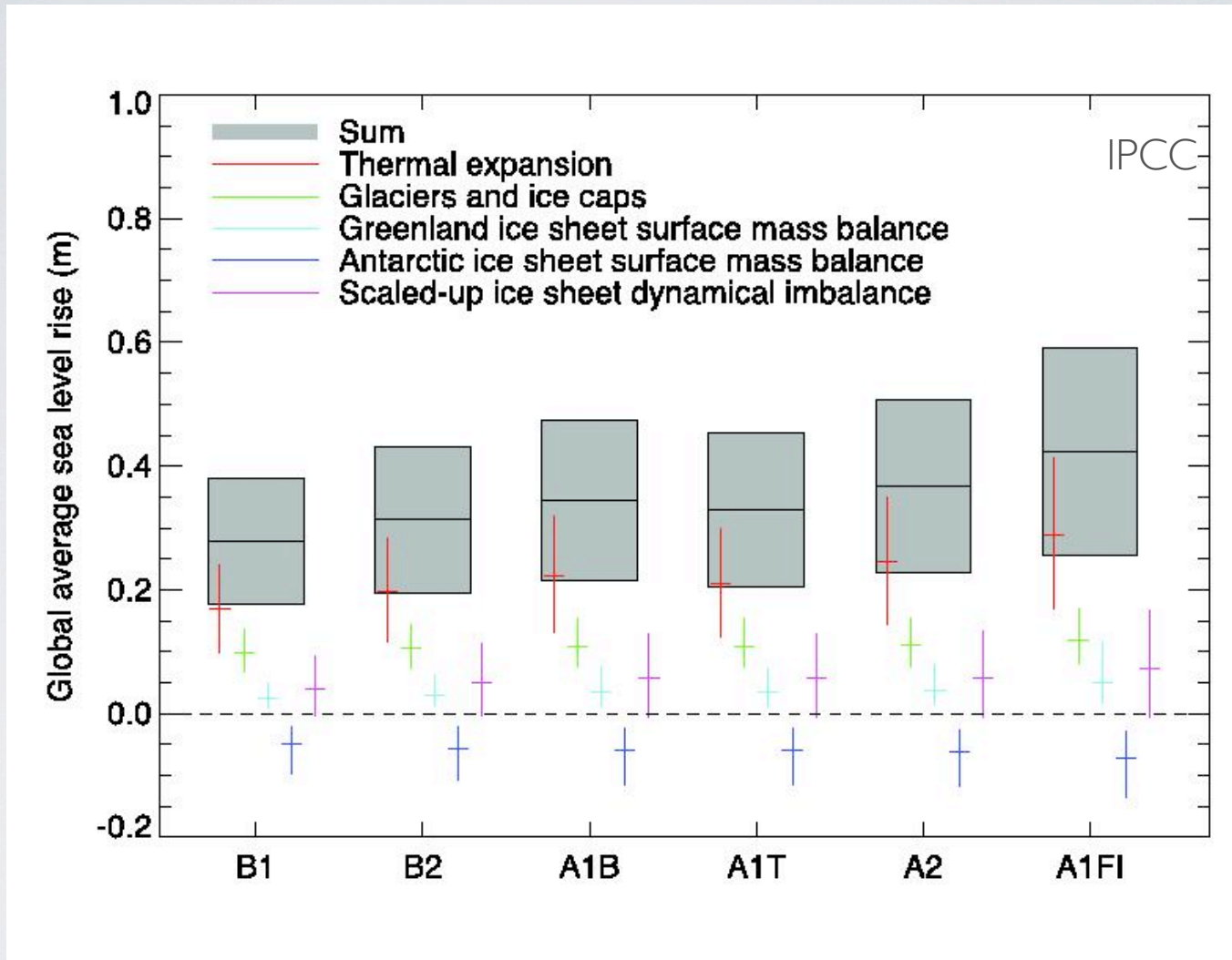
# PROJECTION: THE HYDROLOGIC CYCLE INTENSIFIES

## Projected Patterns of Precipitation Changes



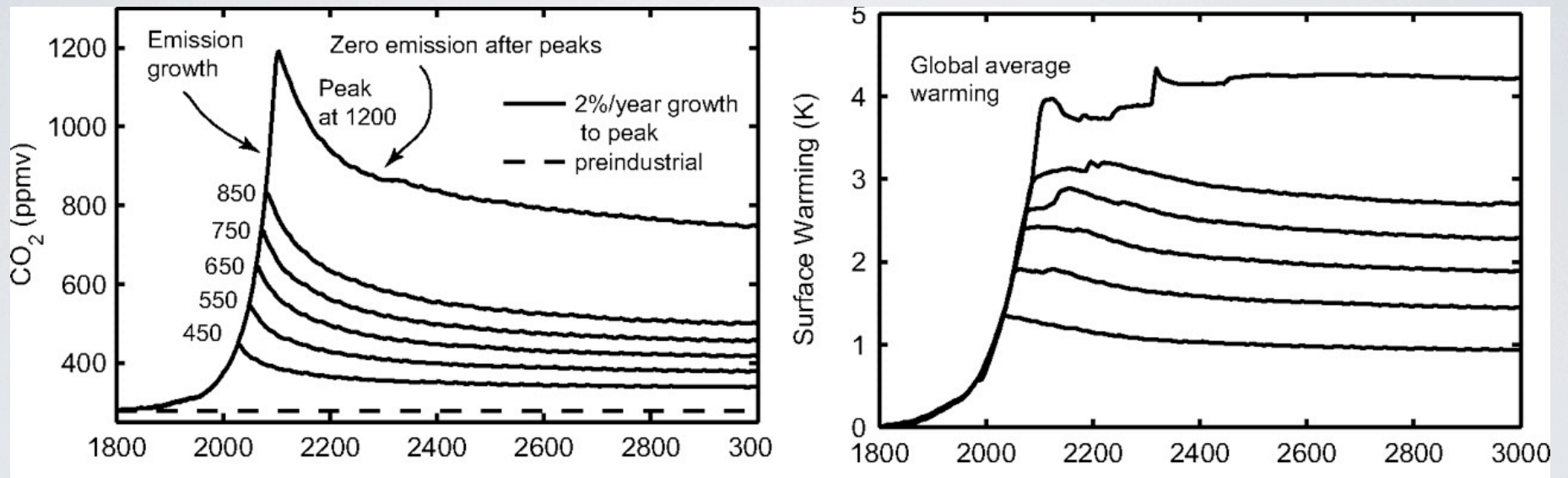


# PROJECTION: SEA LEVEL RISES FURTHER



Caveat: ice sheet dynamic response not fully modeled

Even if emissions were cut to zero, temperature would fall very slowly



# SCIENCE DOES NOT DICTATE ACTION



Values

Action