Climate Change

Brief Overview of Climate Models

Global Warming and Greenhouse Gases

Predicted Climate Changes Due to Global Warming

New Evidence of Abrupt Climate Change

Original Atmospheric Models

Conservation of Momentum

Conservation of Energy

Conservation of Mass

Equation of State

Conservation Equation for Water Vapor

7 Partial Differential Equations

7 Unknowns

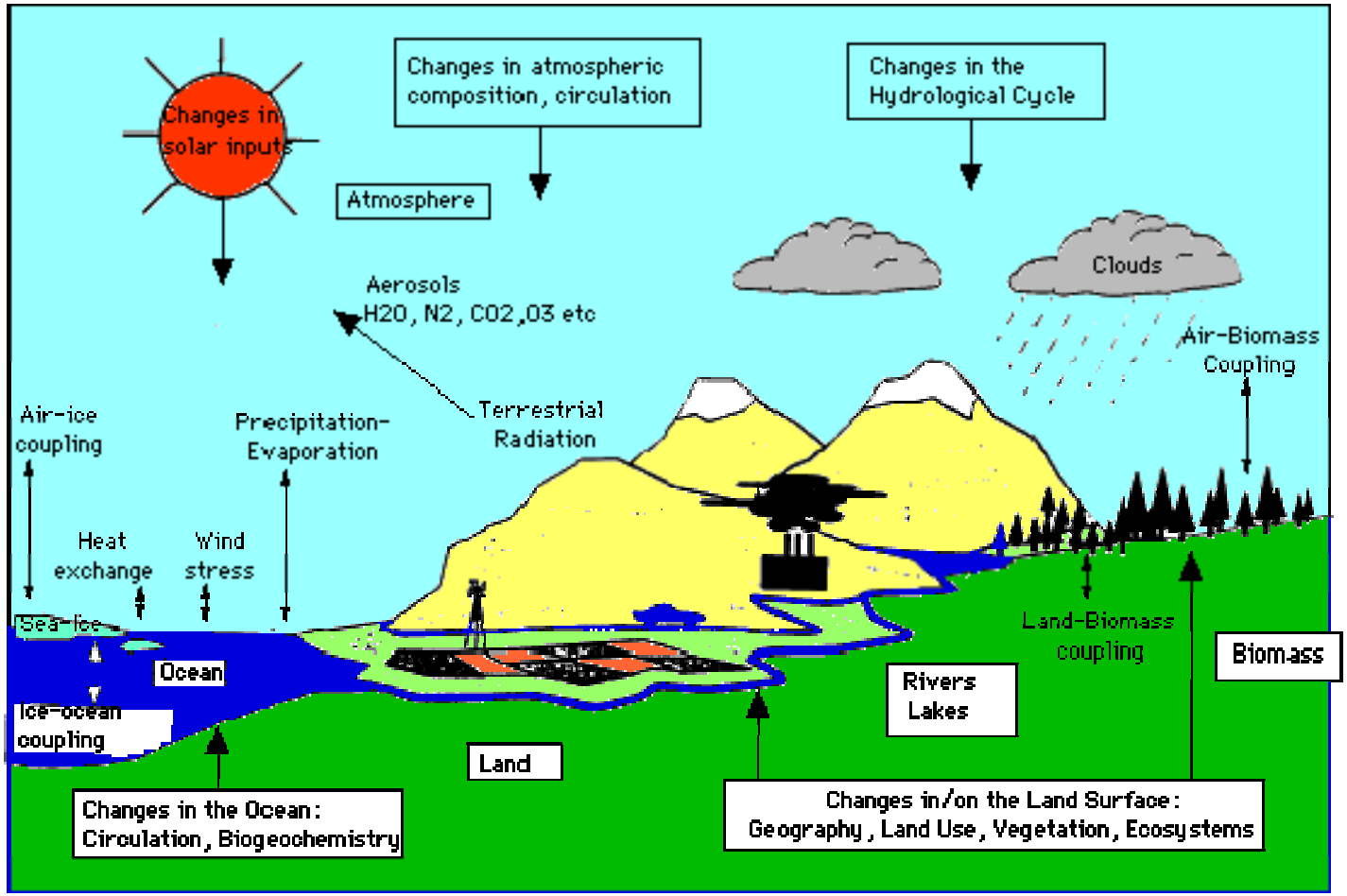
Velocity - 3 components

Pressure

Density

Temperature

Humidity



Feedbacks

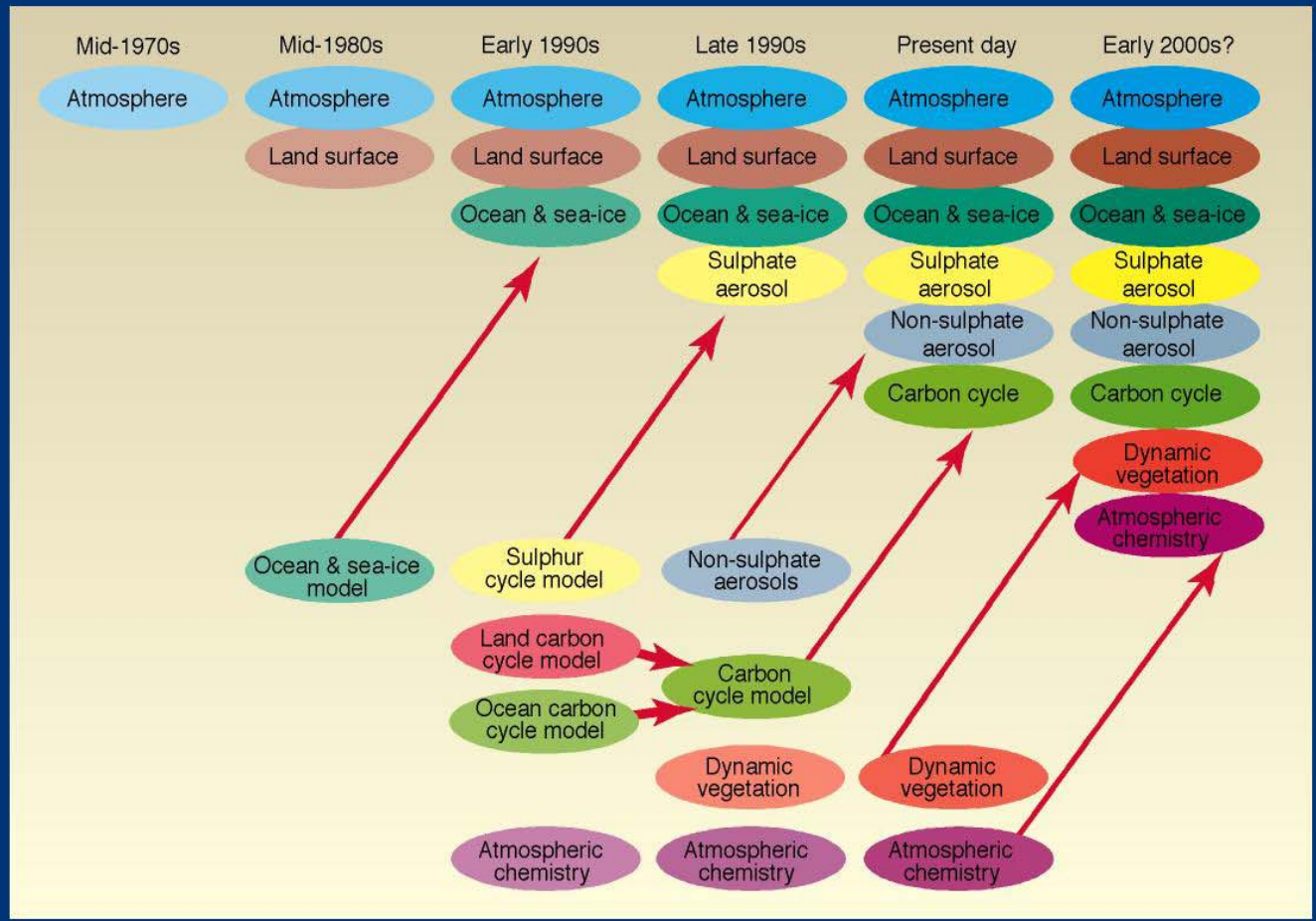
Extent of Ice Cover and Reflectivity ~ Positive or Negative

Water Vapor and Clouds ~ Positive

Clouds and Temperature ~ Positive or Negative

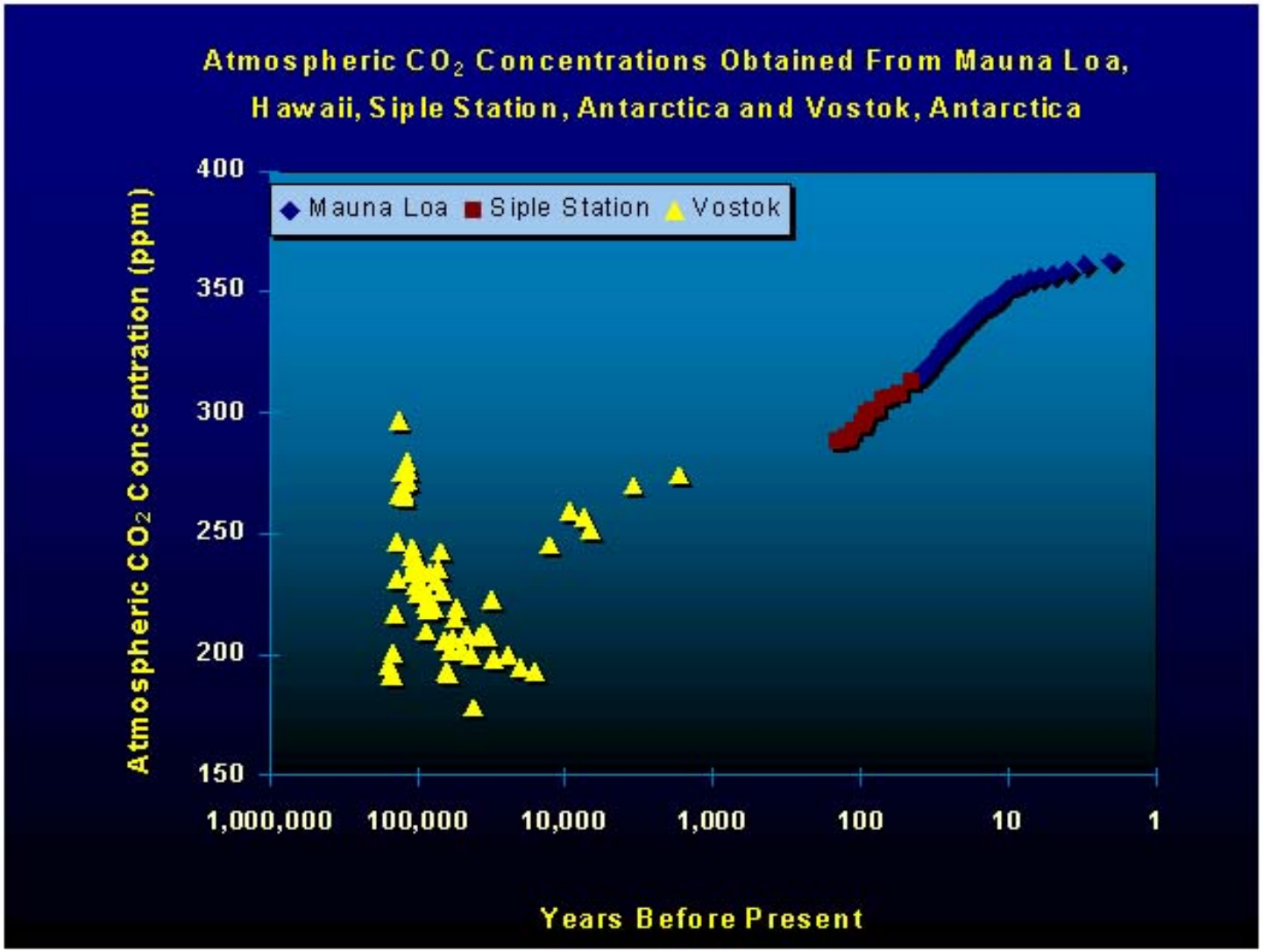
Others

The development of climate models, past, present and future

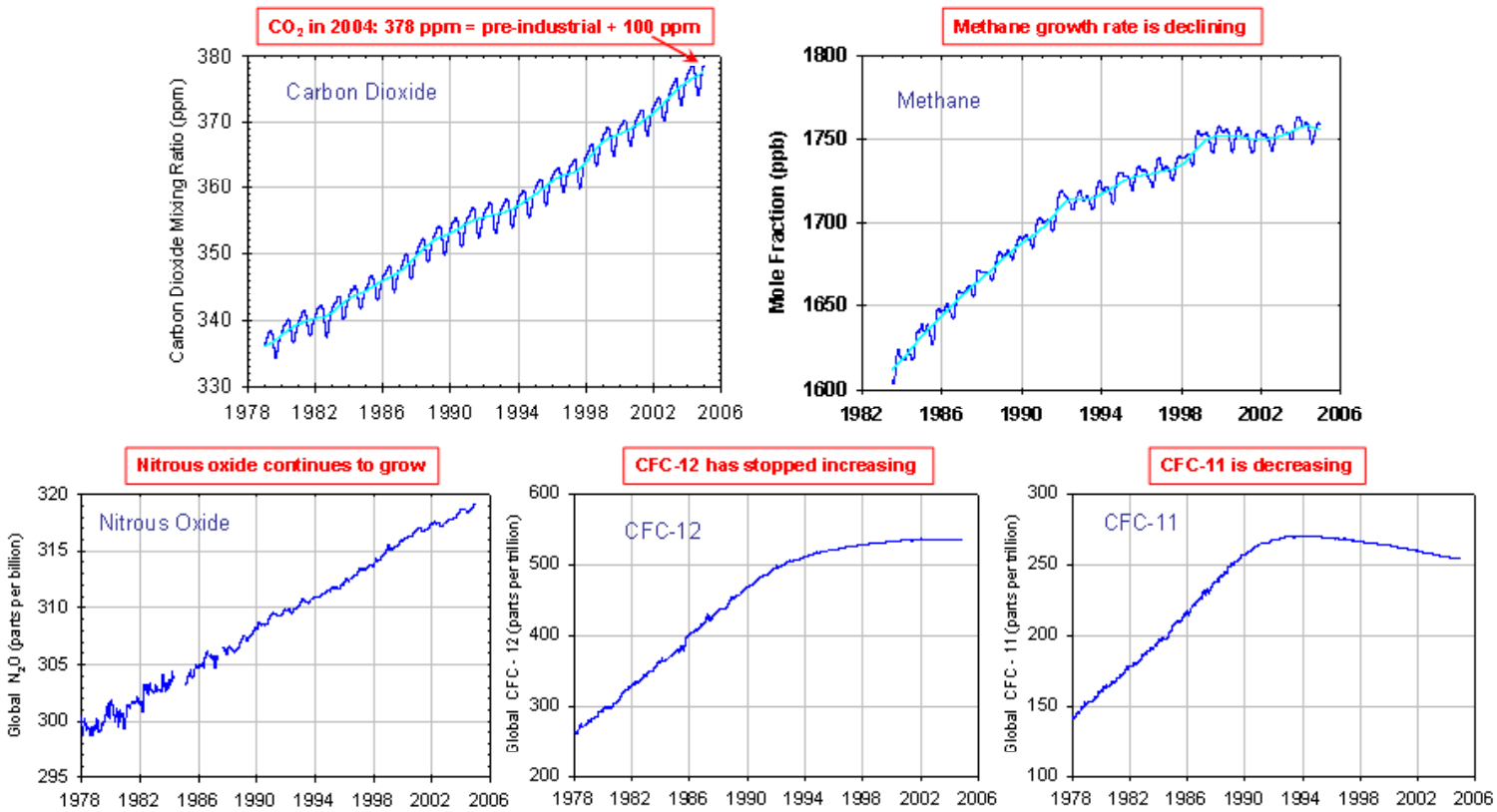


WG1 - TS BOX 3
FIGURE 1

The Big Experiment

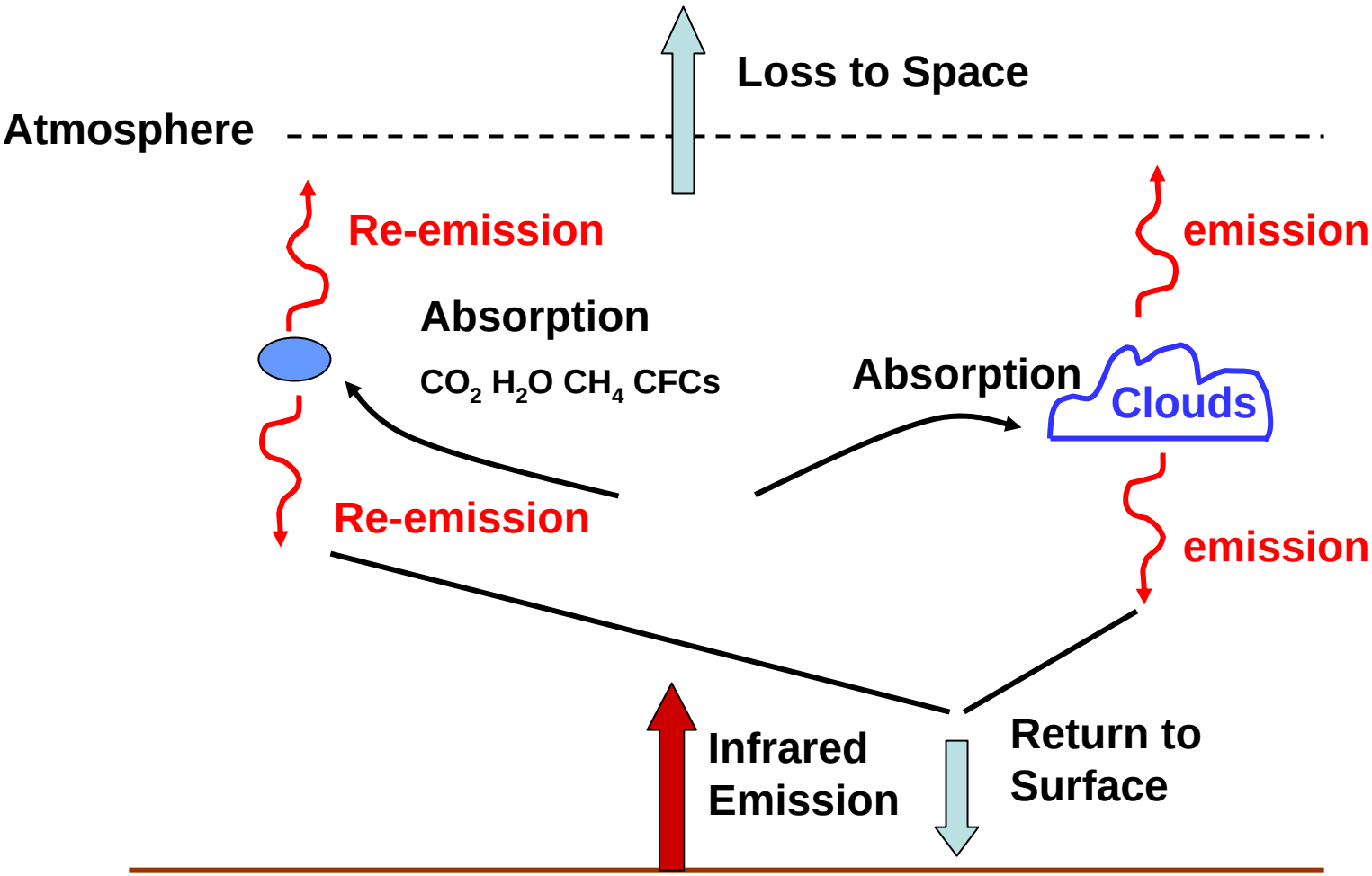


Increases in Major Greenhouse Gases

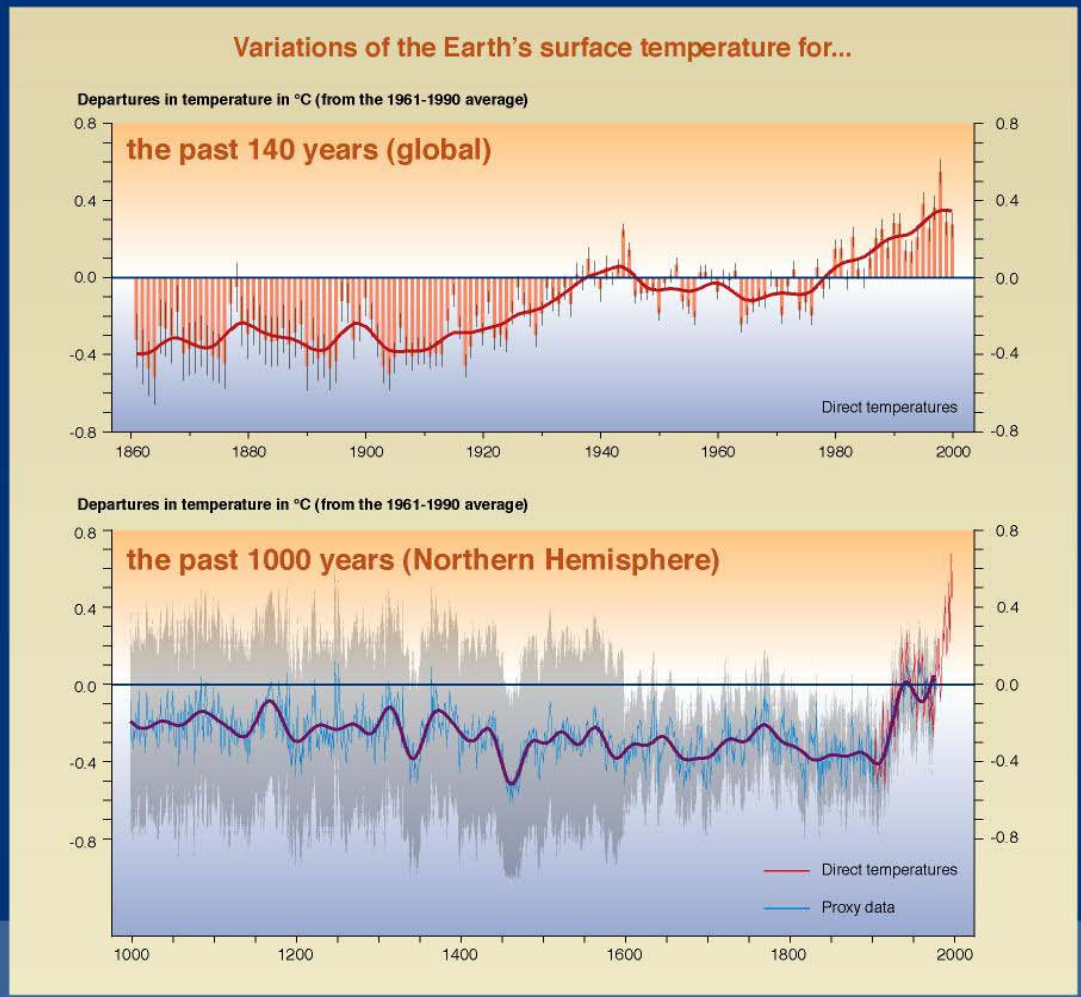


Greenhouse Gases Reduce Infrared Loss to Space

Warm the Atmosphere



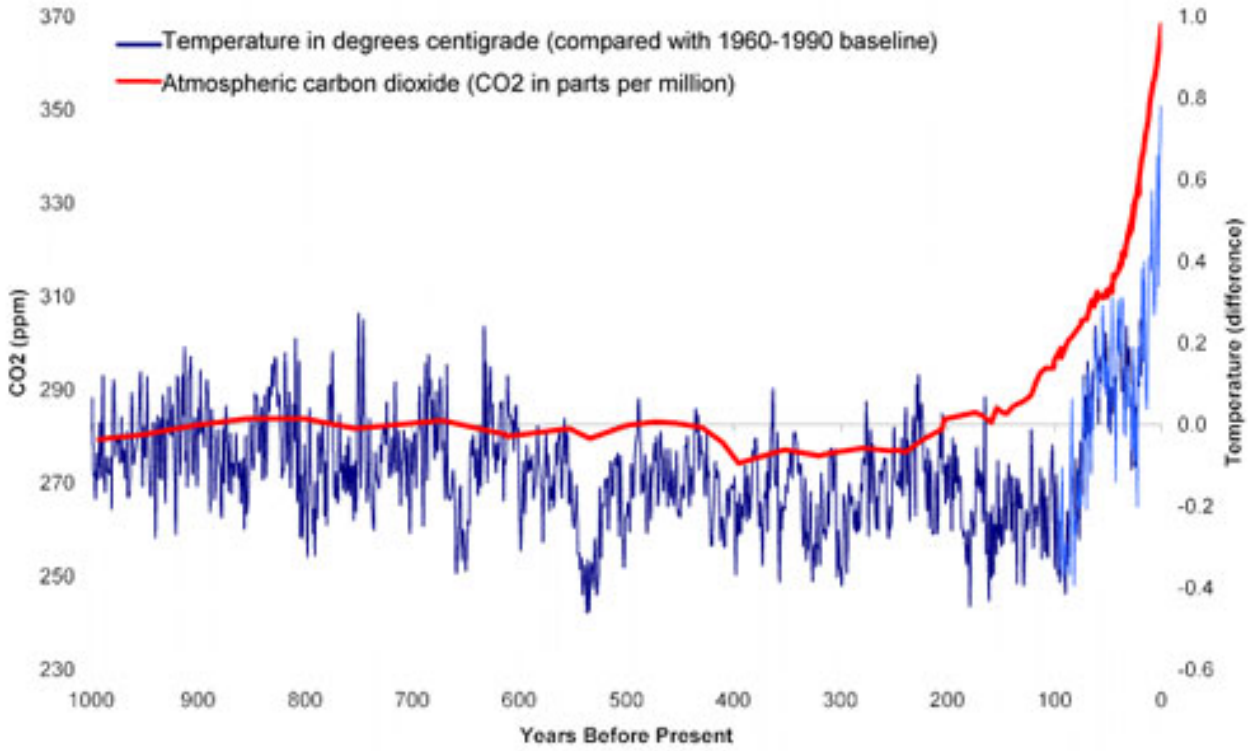
Is the Earth Warming ?



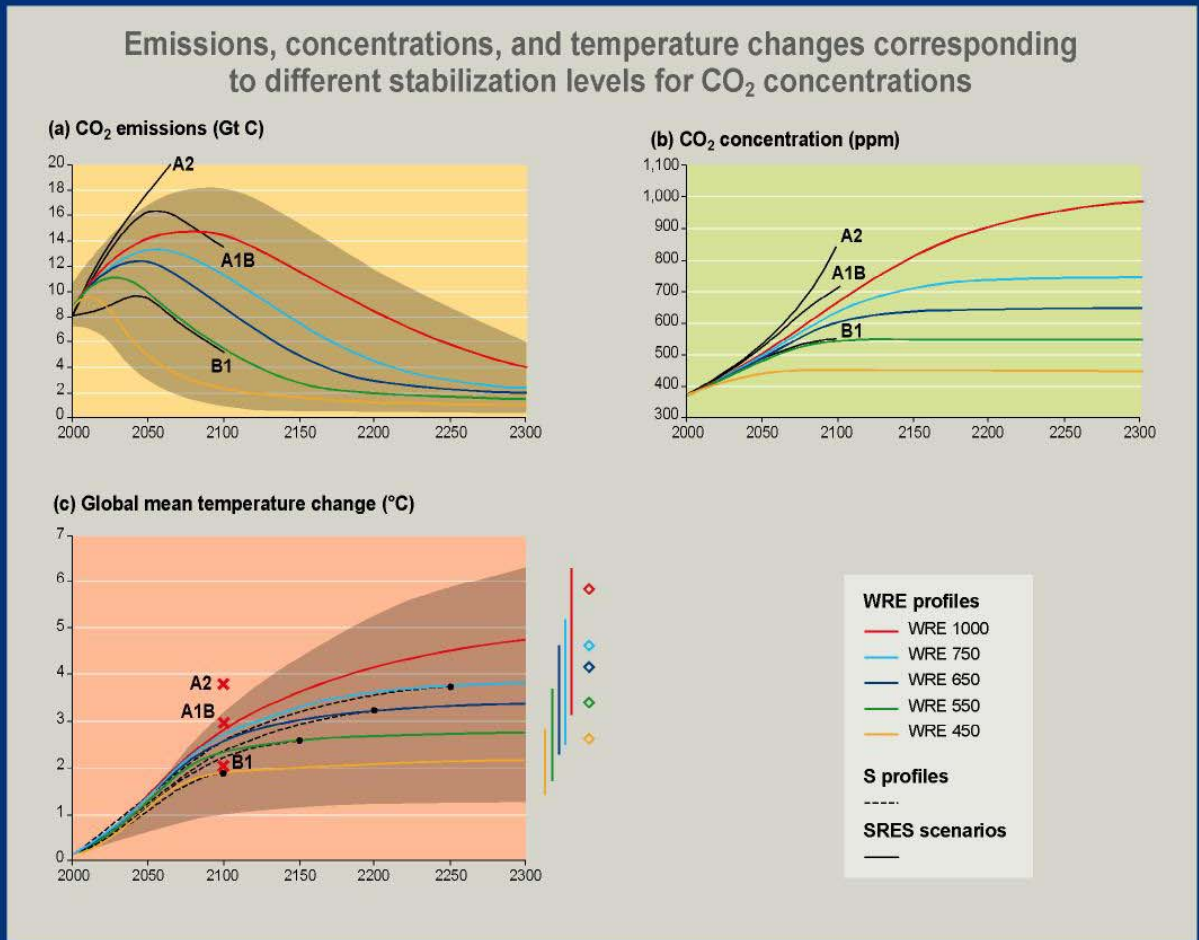
SYR - FIGURE 2-3

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

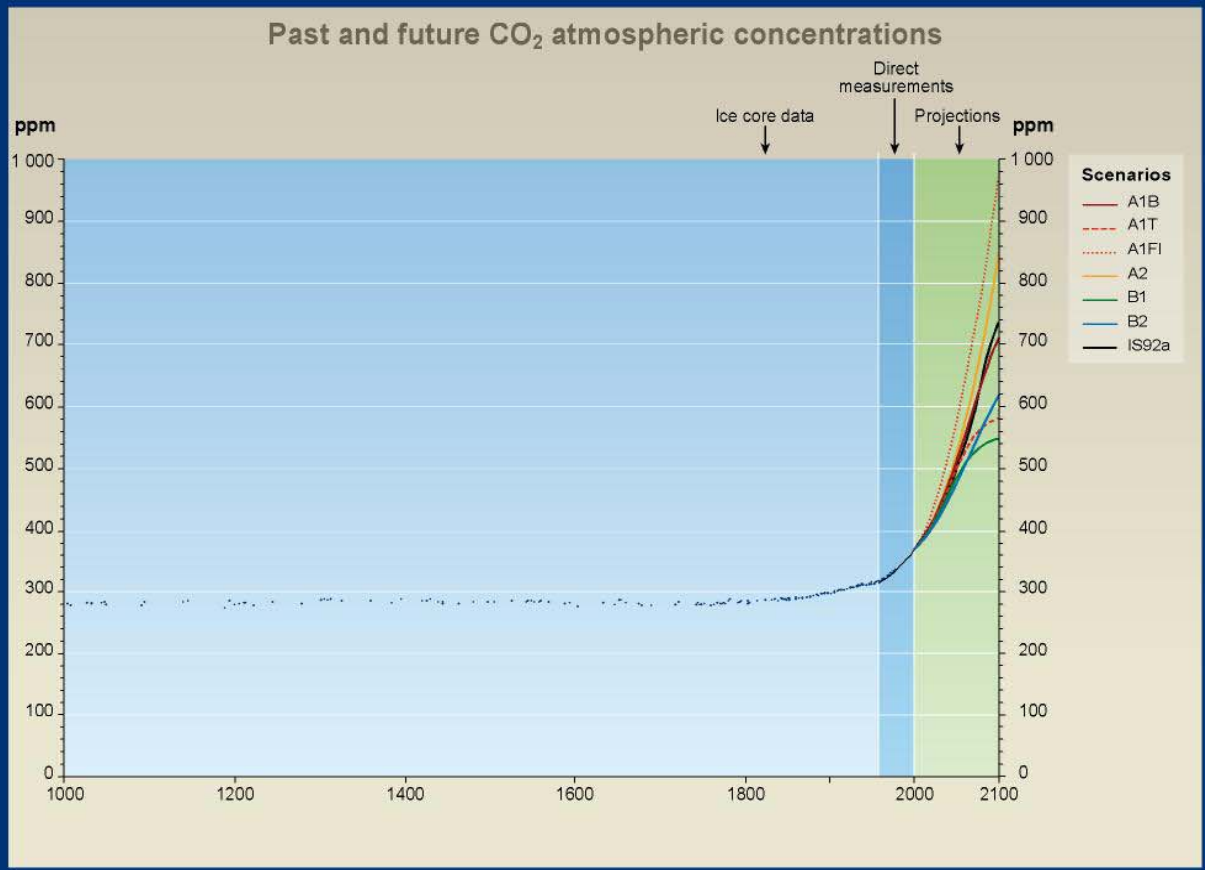
WMO UNEP


Temperature in degrees centigrade (compared with 1960-1990 baseline)
Atmospheric carbon dioxide (CO2 in parts per million)
CO2 (ppm)
370
350
330
310
290
270
250
230
Temperature (difference)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1000
900
800
700
600
500
400
300
200
100
0
Years Before Present

Where Are We Headed?

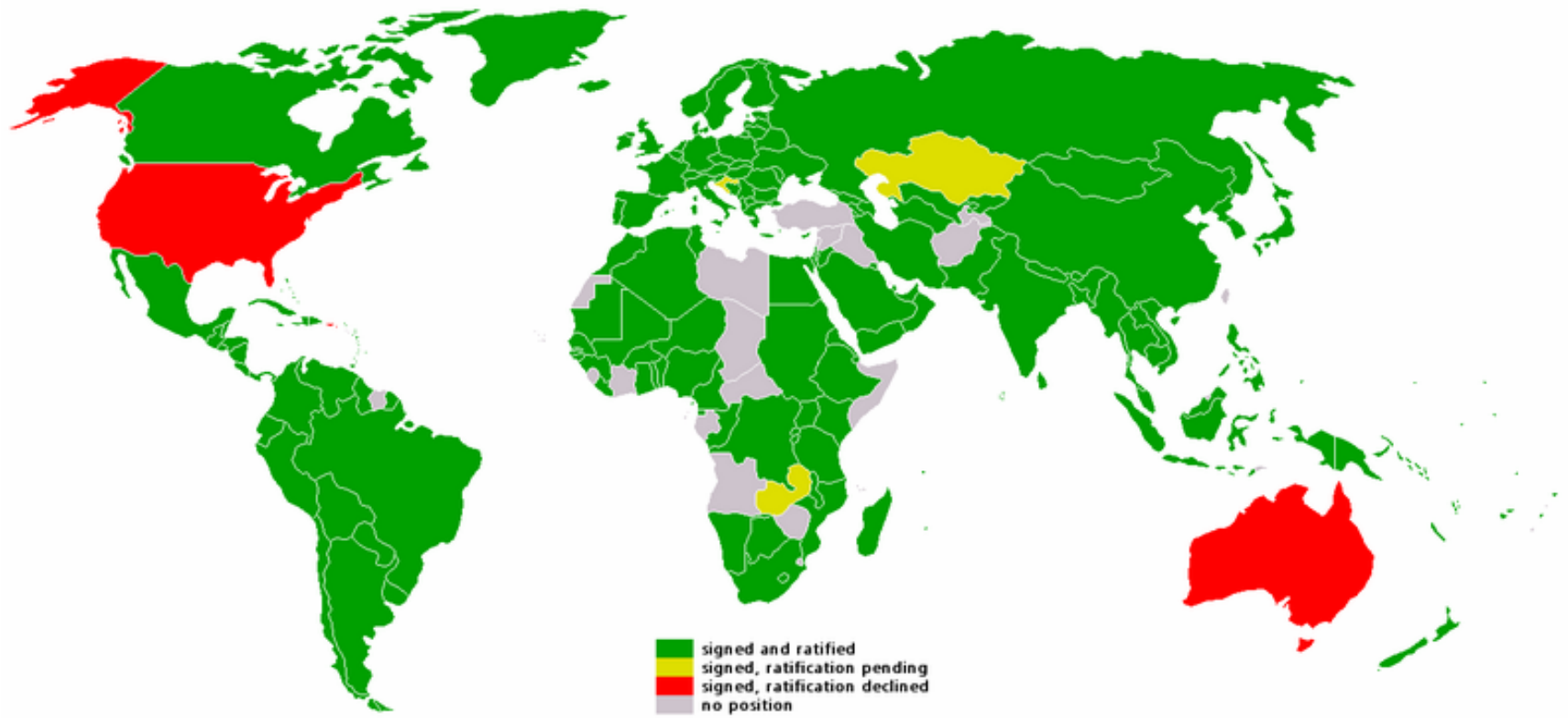


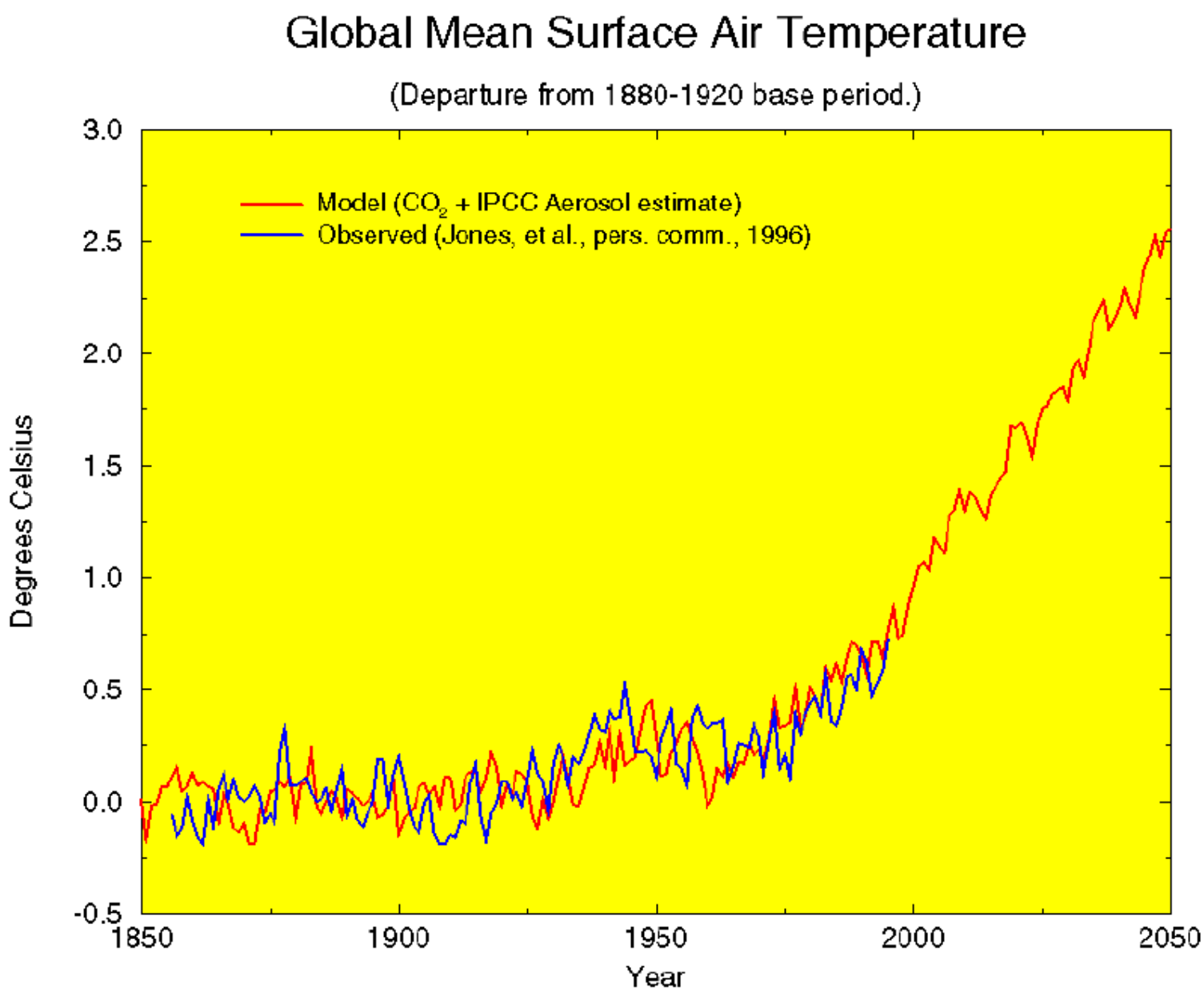
SYR - FIGURE 6-1

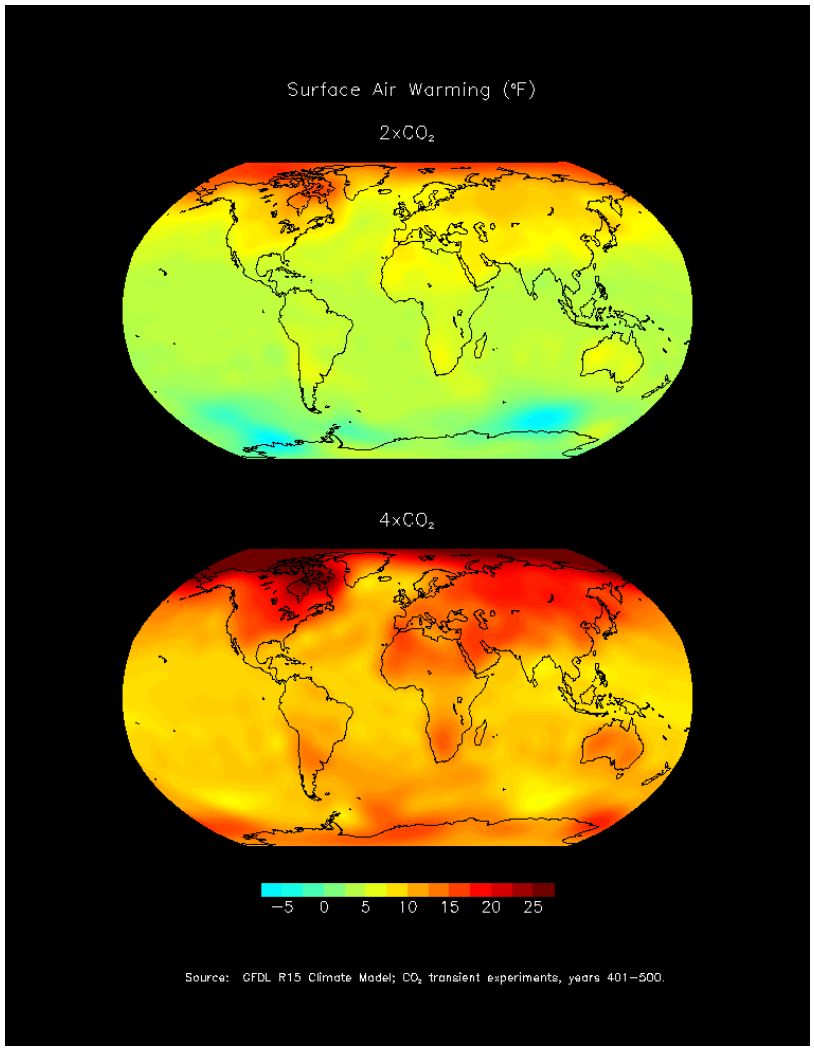


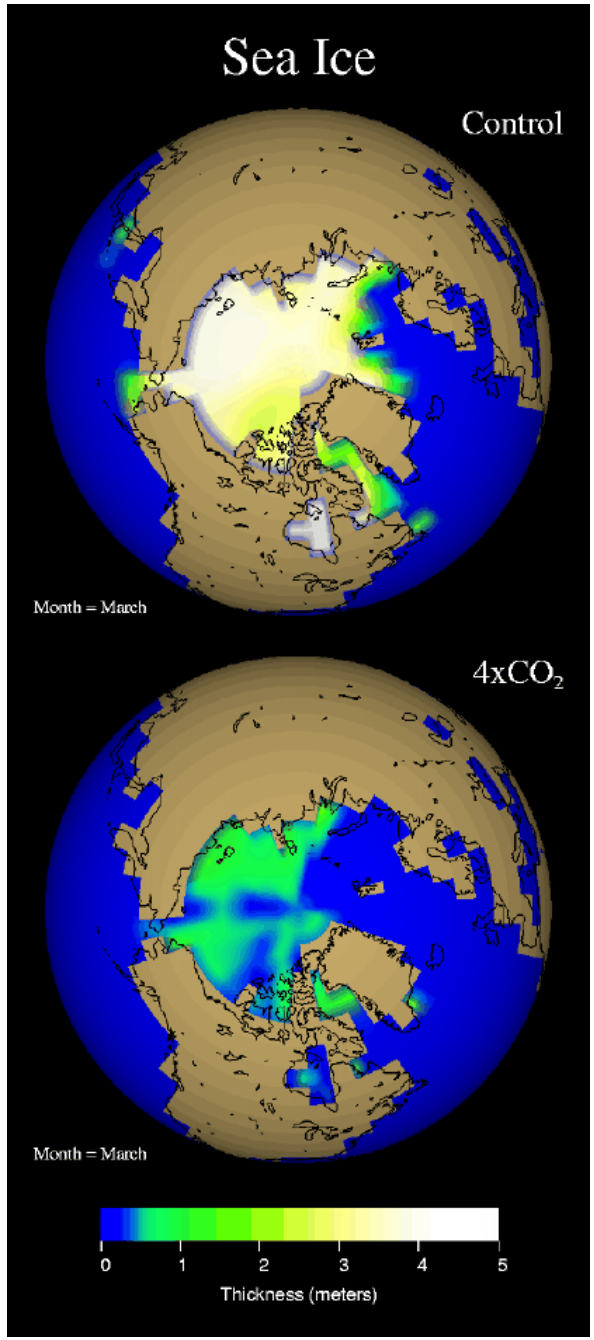
SYR - FIGURE 9-1a

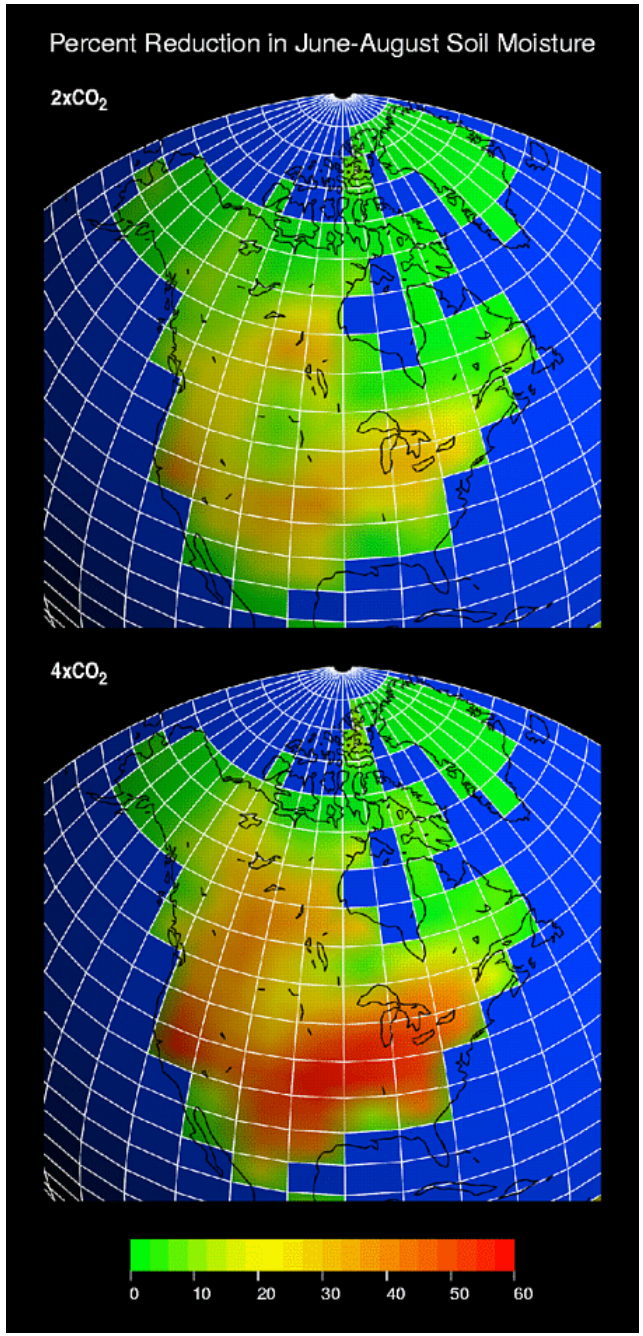
Status of Kyoto Protocol

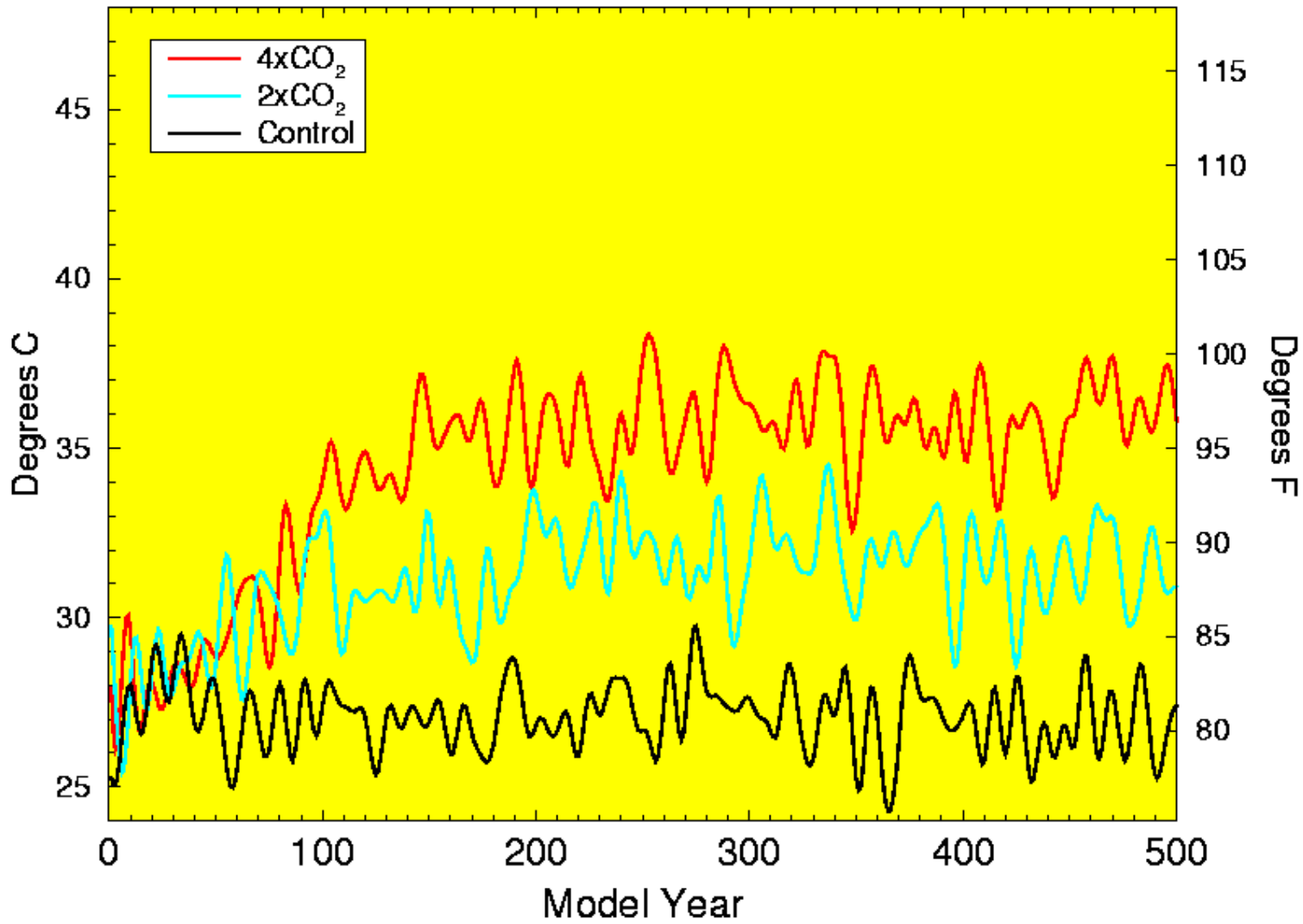


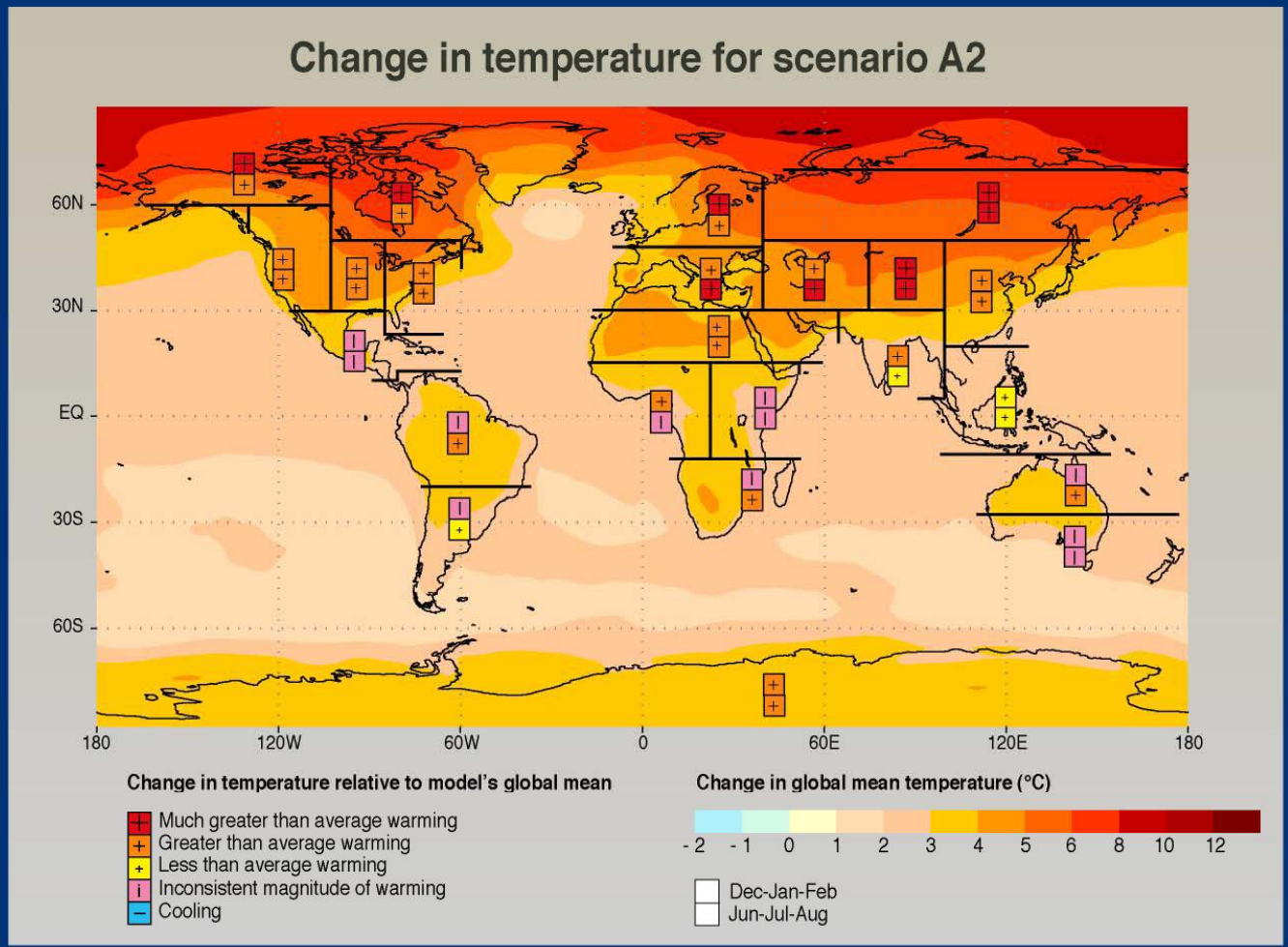

Global Mean Surface Air Temperature
(Departure from 1880-1920 base period.)
Model (CO_2 + IPCC Aerosol estimate)
Observed (Jones, et al., pers. comm., 1996)
Degrees Celsius
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1850
1900
1950
2000
2050
Year


Surface Air Warming (°F)
2xCO2
4xCO2
−5 0 5 10 15 20 25
Source: GFDL R15 Climate Model; CO2 transient experiments, years 401−500.

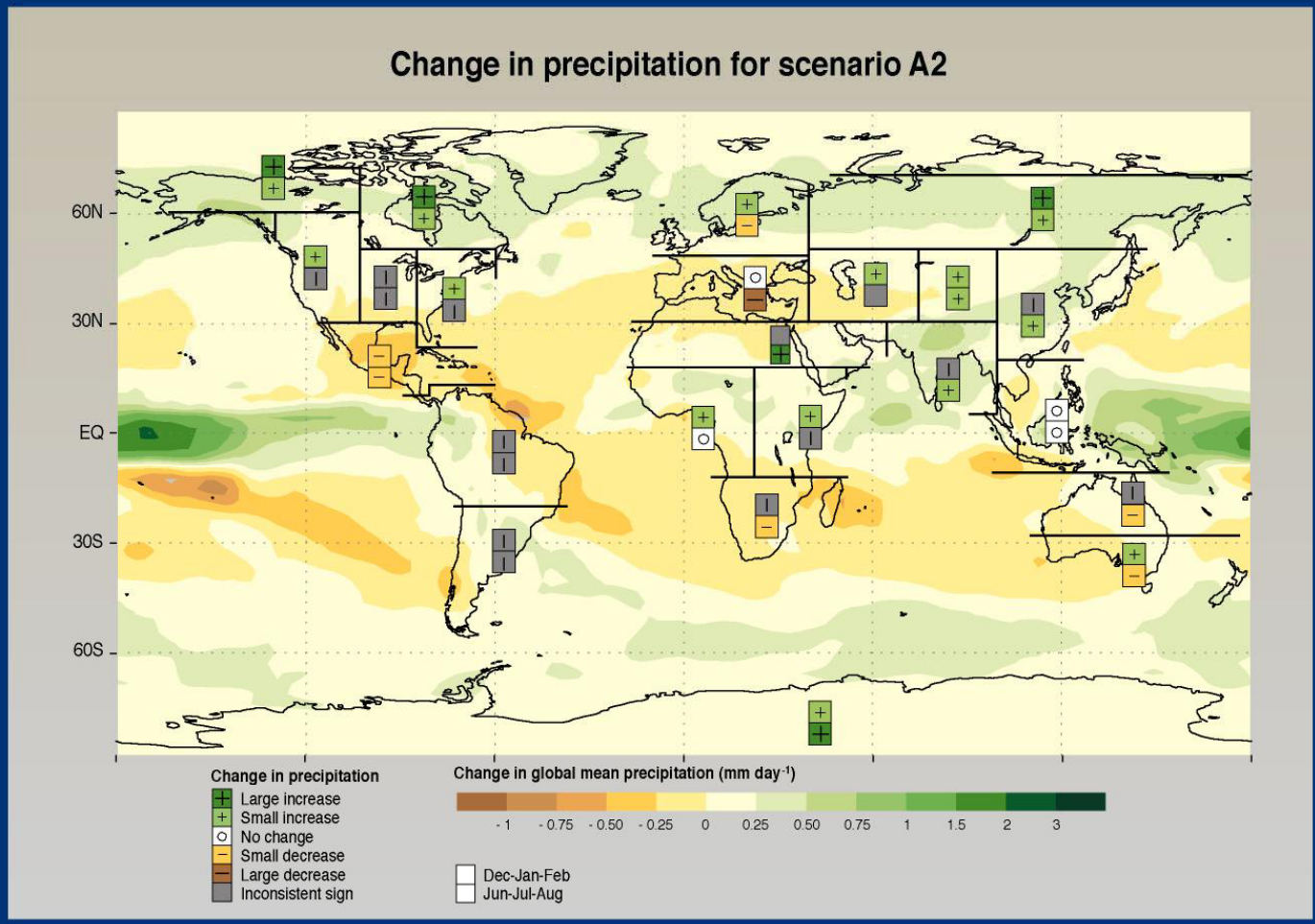

Sea Ice
Control
Month = March
4xCO2
Month = March
0 1 2 3 4 5
Thickness (meters)


Percent Reduction in June-August Soil Moisture
2xCO2
4xCO2
0
10
20
30
40
50
60


July Temperature for Southeastern U.S.
4xCO2
2xCO2
Control
Degrees C
Degrees F
45
40
35
30
25
115
110
105
100
95
90
85
80
0
100
200
300
400
500
Model Year



SYR - FIGURE 3-2 a)



SYR - FIGURE 3-3 a)

Consensus of Scientific Community

Earth is Warming

Overwhelming Evidence It Is Caused By Greenhouse Gases

Climate Models Predict

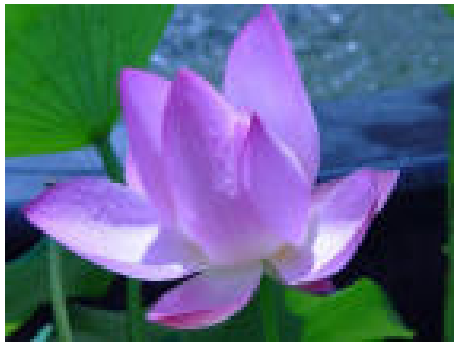
Significant Warming, Especially at High Latitudes

Increases in Sea Level Up to 0.80 m

Regional Changes in Temperature and Precipitation

Increases in Extreme Events

BUT - The Story Is Even More Complicated!!



Modern View of Climate

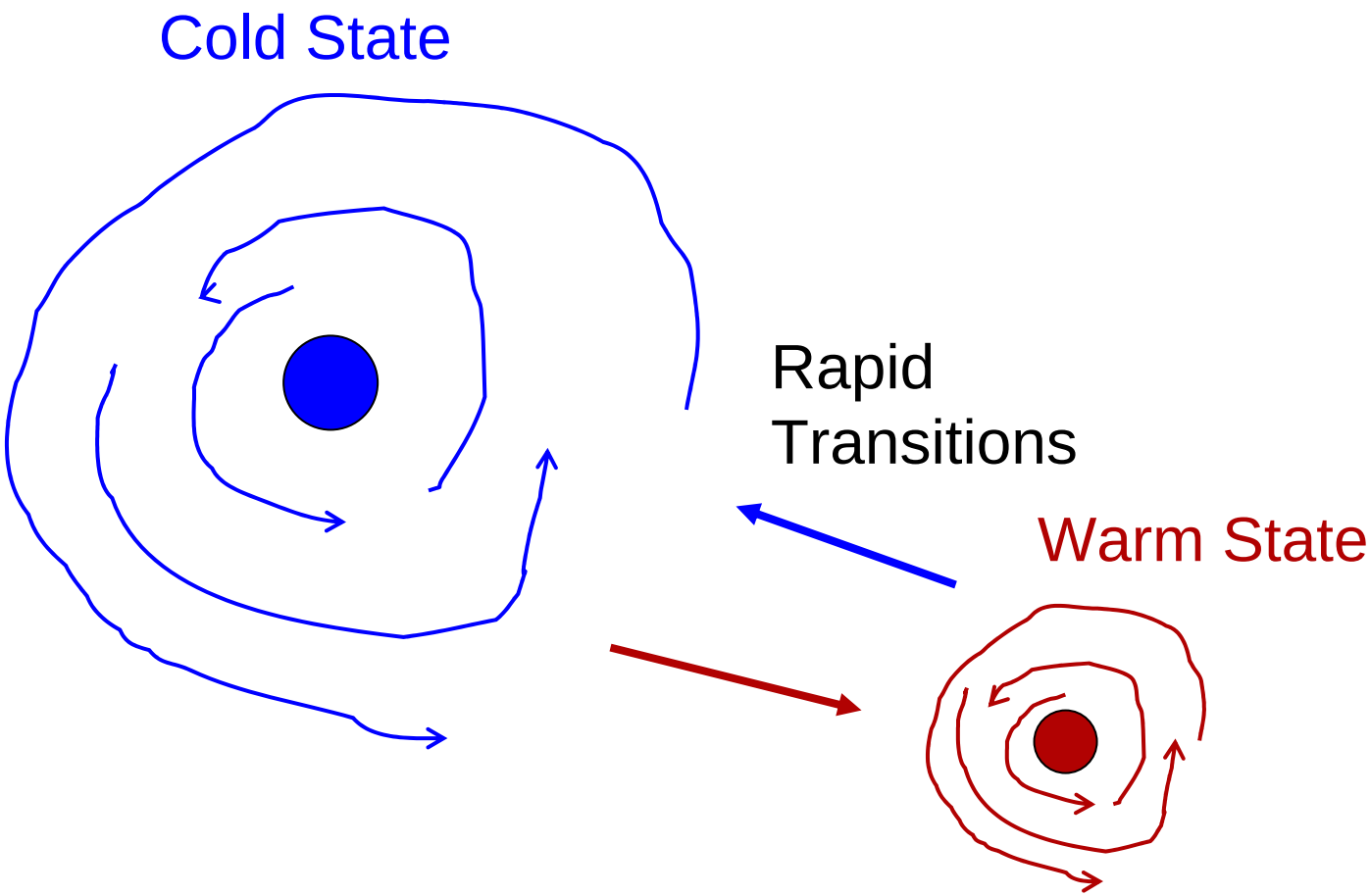
Climate is a Complex System - Tends to Exist in Distinct States

Rapid Transitions Happen From One State to Another

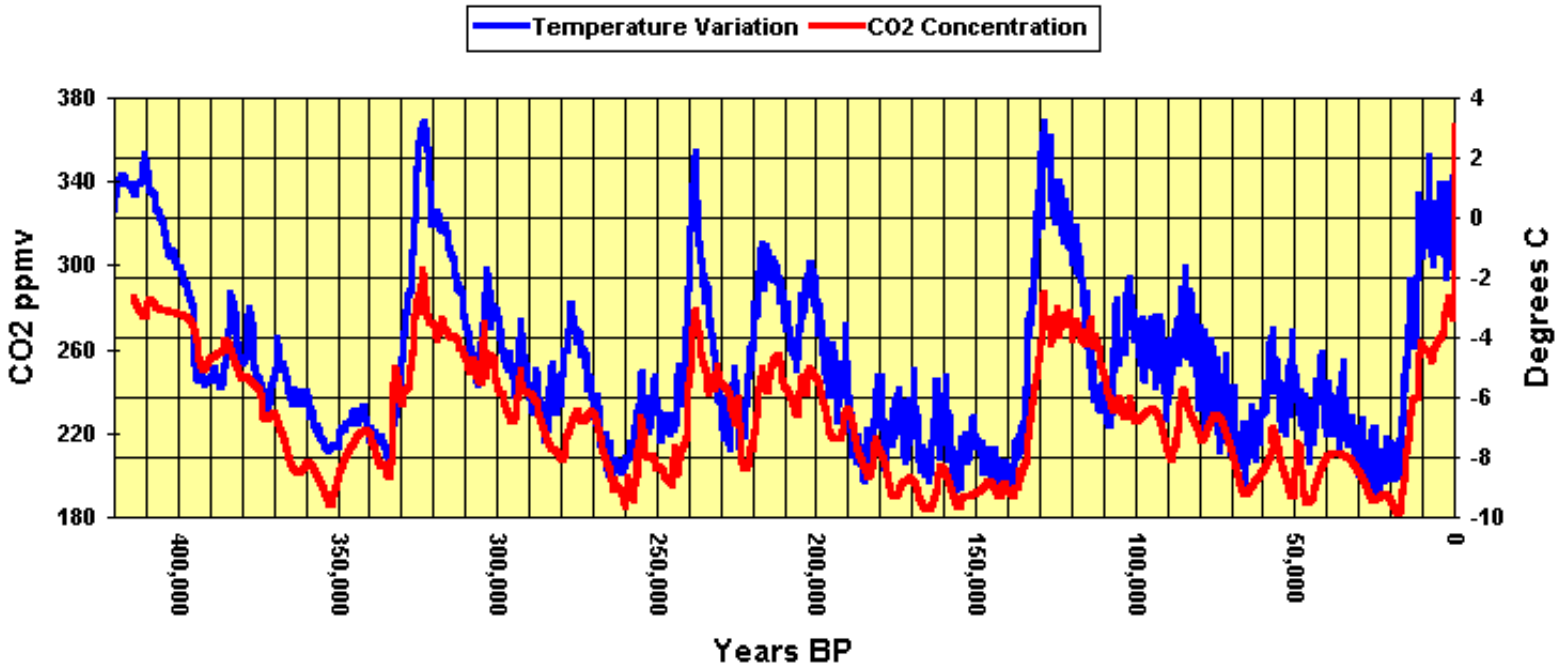
Large Changes Can Occur Without Big Changes in External Forces

Current Models Cannot Simulate These Rapid Transitions

Complex System View of Climate



Antarctic Ice Core Data 1



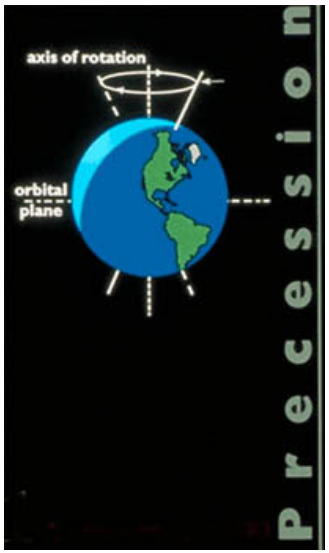
Climate “Prefers” the Cold State

Changes Between Cold and Warm State Are Rapid

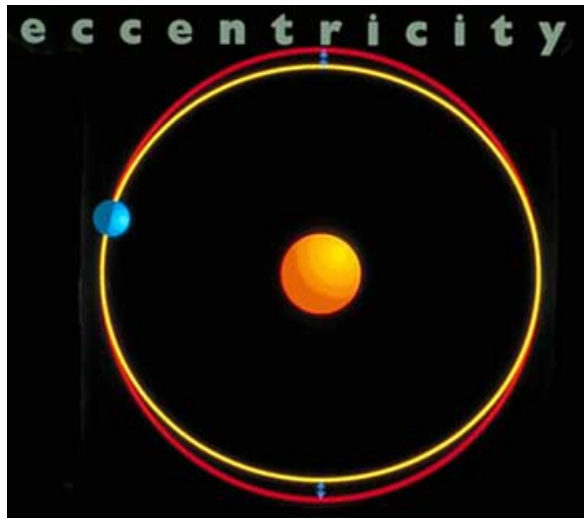
Milankovitch Cycles

Result in Small Changes in Seasonality and Spatial Distribution of Radiation

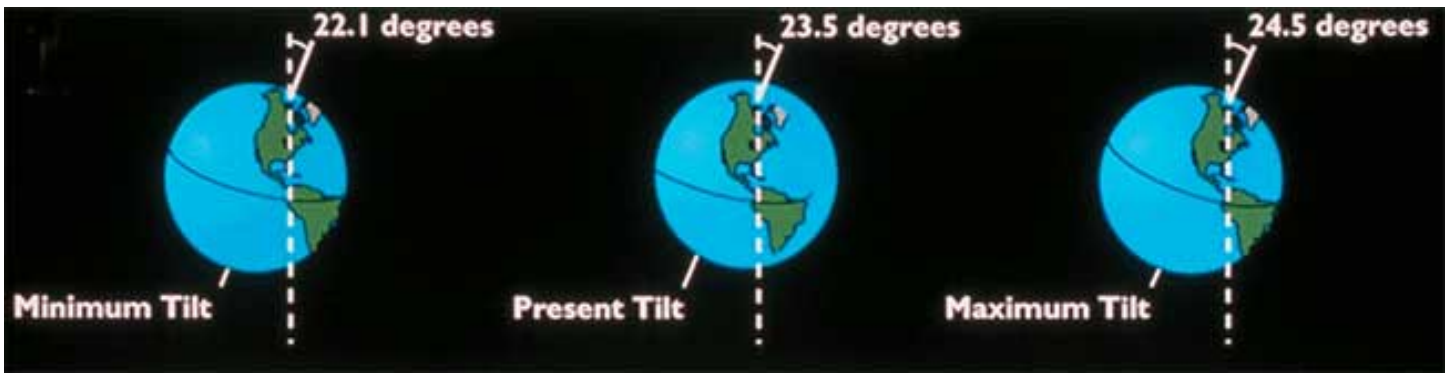
~ 23,000 years

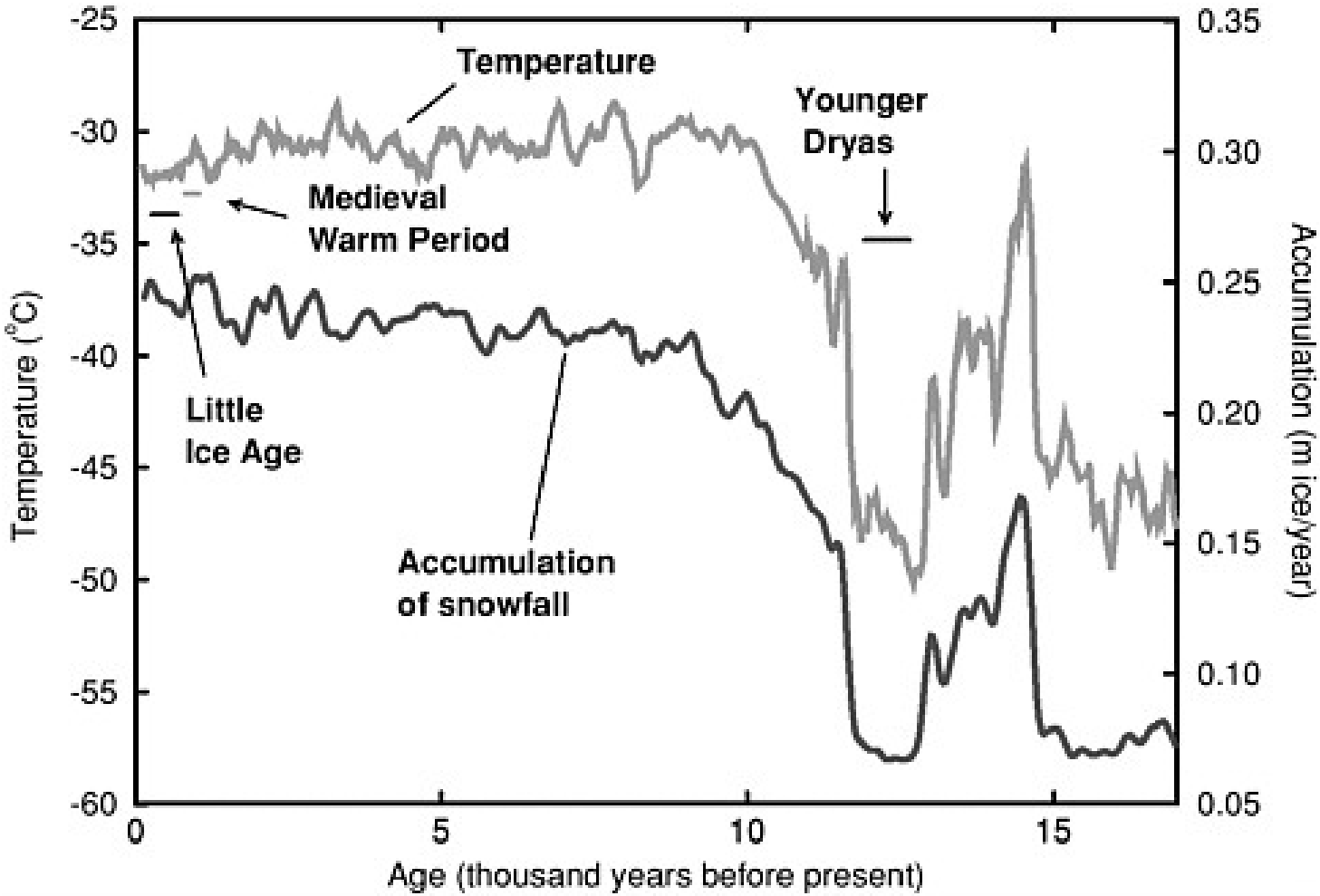


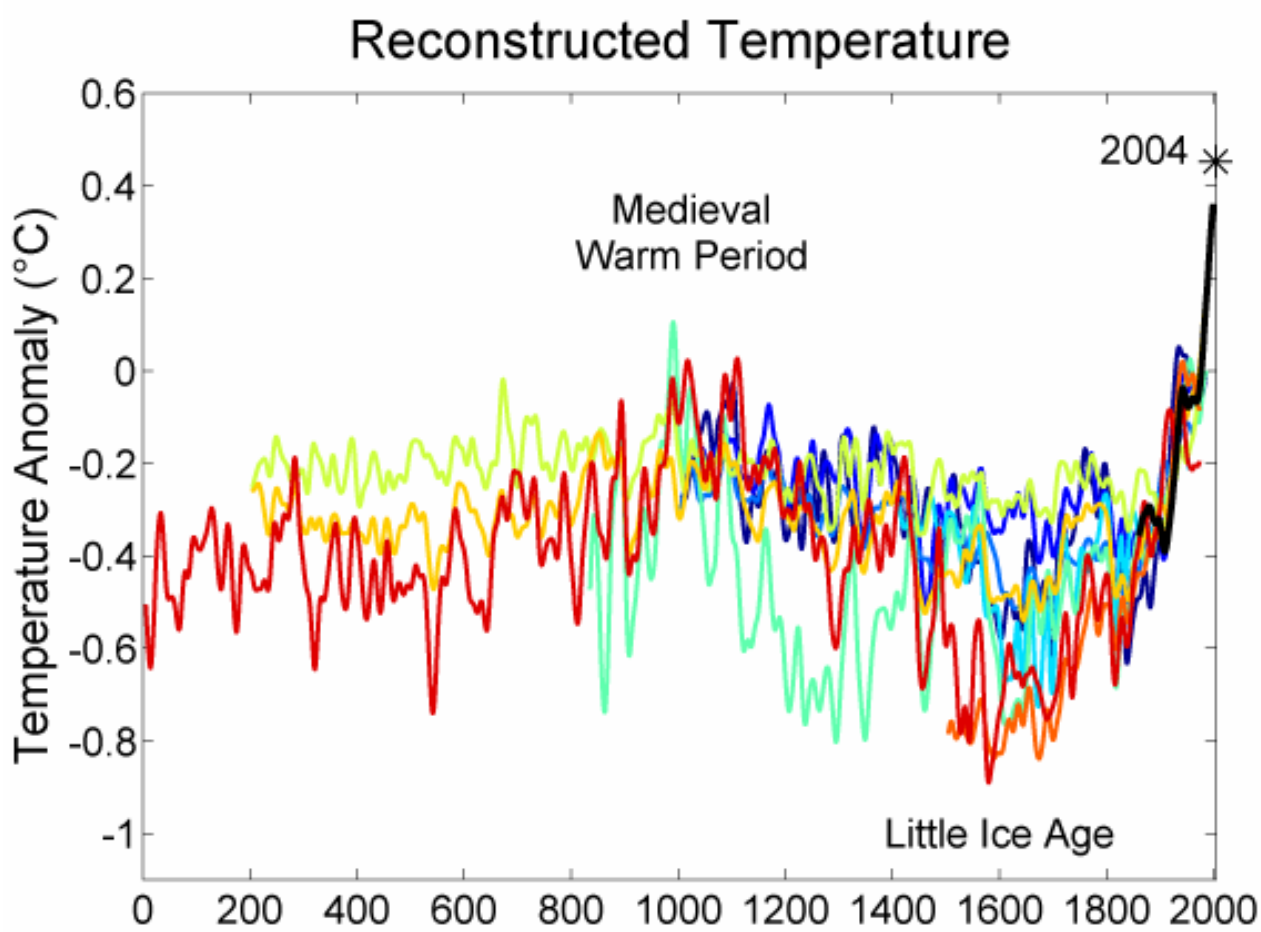
~ 100,000 years

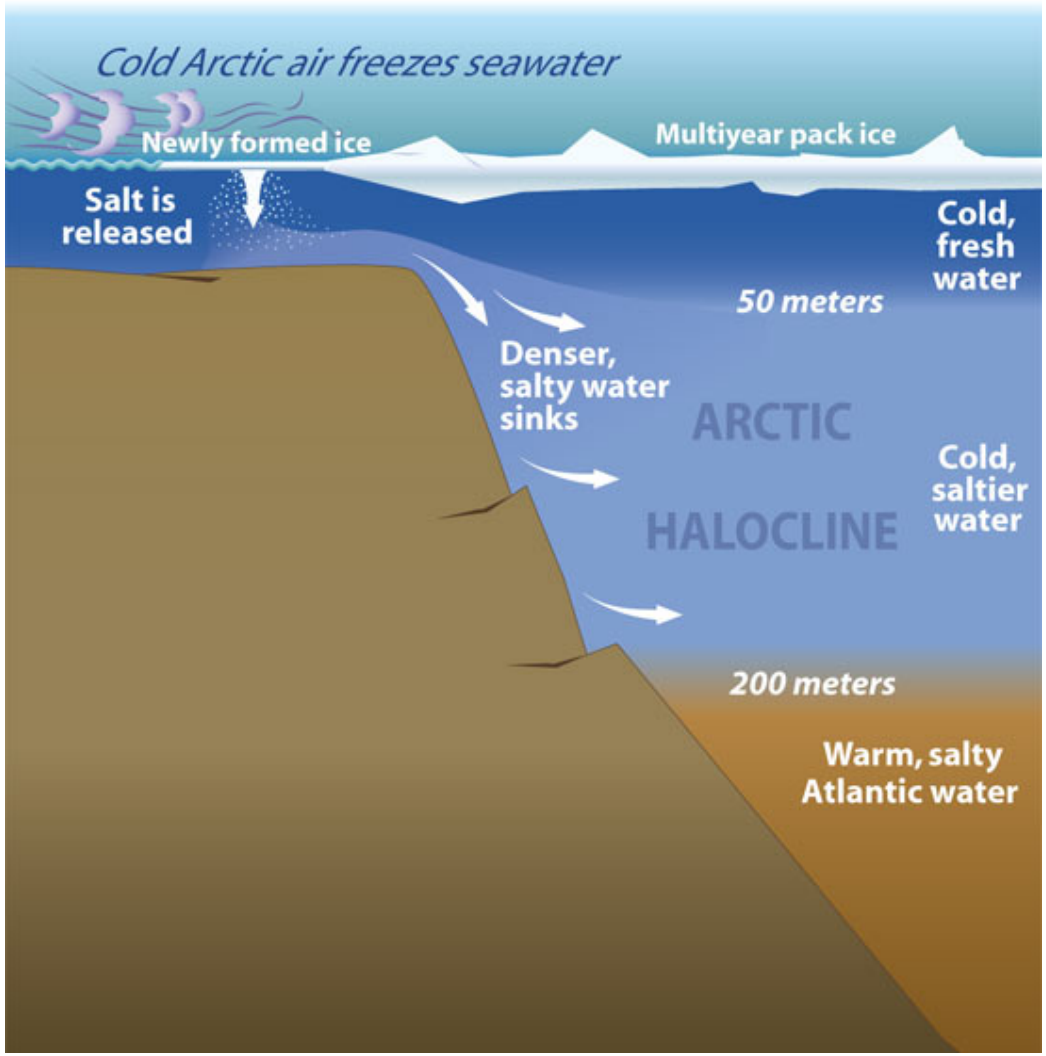


~ 40,000 years

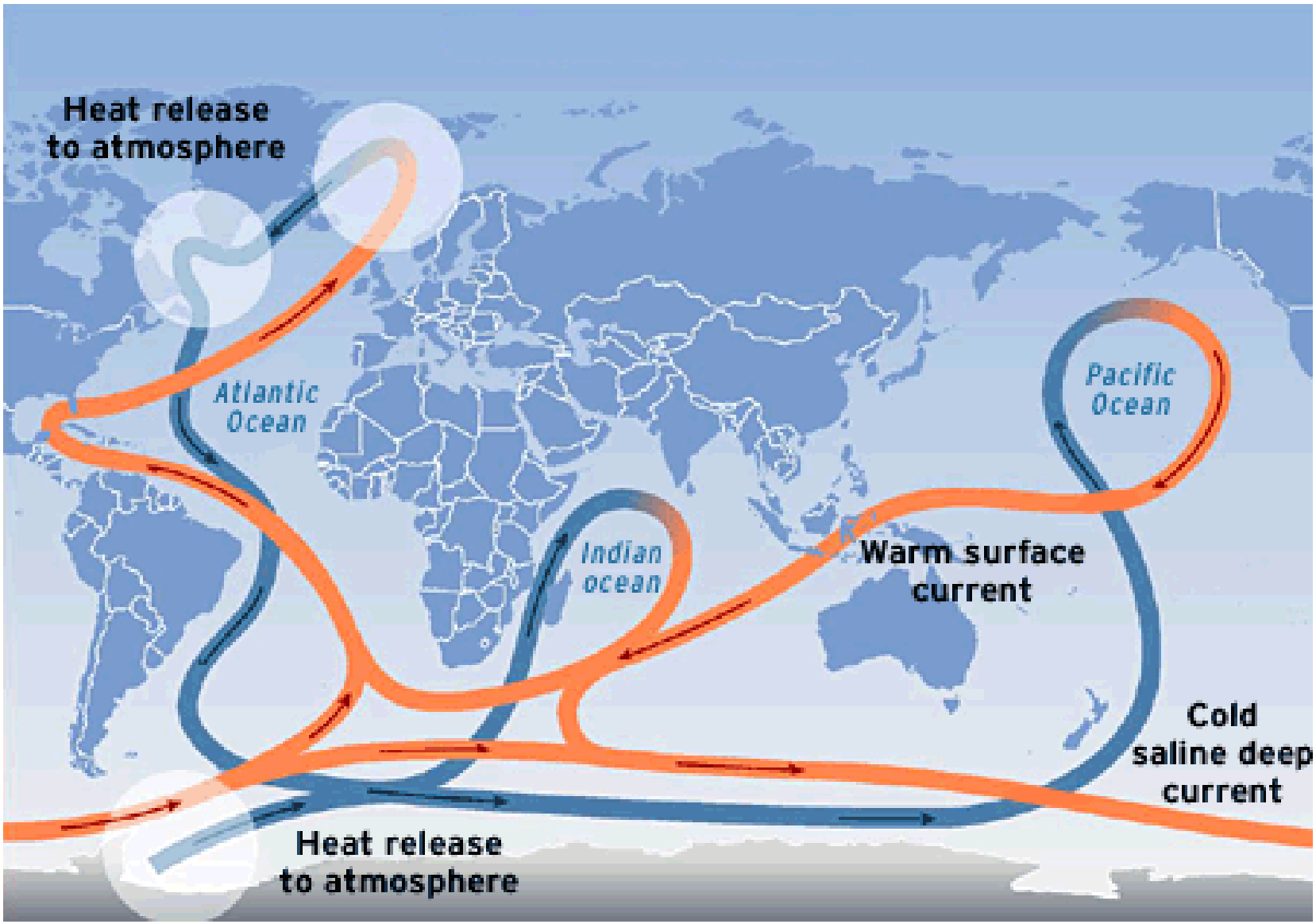



Temperature
Younger
Dryas
Medieval
Warm Period
Little
Ice Age
Accumulation
of snowfall
Temperature (°C)
Accumulation (m ice/year)
Age (thousand years before present)
-25
-30
-35
-40
-45
-50
-55
-60
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
5
10
15


Reconstructed Temperature
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2004
Medieval
Warm Period
Little Ice Age


Cold Arctic air freezes seawater
Newly formed ice
Multiyear pack ice
Salt is released
Cold, fresh water
50 meters
Denser, salty water sinks
ARCTIC
HALOCLINE
Cold, saltier water
200 meters
Warm, salty Atlantic water

Thermohaline Circulation



Thermohaline Circulation

Evidence It Has Large Role in Climate Flip-Flops

Recent Studies Suggest

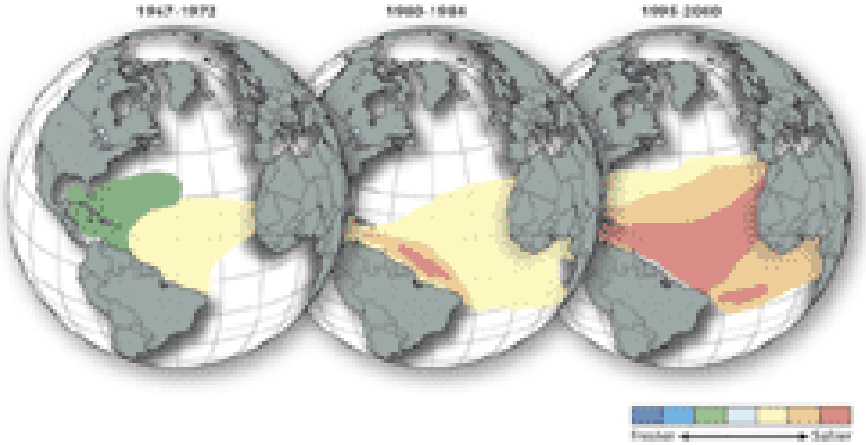
Warming Will Reduce Salinity in North Atlantic

Slow or Possibly Shut Down Thermohaline

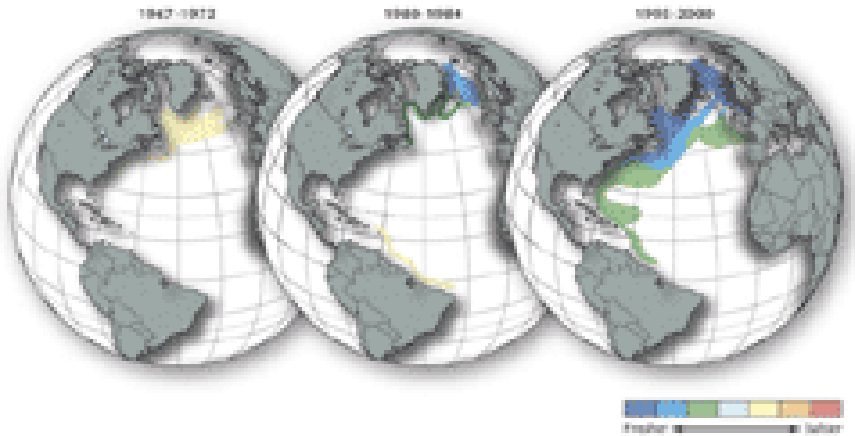
Climate Will Flip to New State?

Minor Ice Age?

Tropical Atlantic surface waters have become saltier...



...while North Atlantic deep water have become fresher



Summary

Scientific Consensus That Earth is Warming Due to Increases in Greenhouse Gases

Most Likely Emission Scenarios Result in ~ 3 C Increase in Global Temperature -- Larger in High Latitudes

Sea Level Rises and More Extreme Weather Events

Significant Changes in Temperature and Precipitation in Many Locations ~ Effects on Agriculture and Other Ecosystems

Big Issues

There May Be Other Feedbacks We Do Not Know

There is No Analogy in The Climate Record for These Changes -- We Are Entering Unknown Territory

Climate is a Complex and Chaotic System That Rapidly Changes State For Reasons Not Completely Understood

Details of Regional Climate Change and Extreme Events Remain Less Certain

“Climate Is An Angry Beast, and We Are Poking It With Sticks”

Wallace Broeker

World Population, Stone Age to Present