UNIVERSITY OF MICHIGAN

OpenClimate.org

Climate Change: The Move to Action (AOSS 480 // NRE 480)

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Winter 2011
February 17, 2011

Class Info

- Ctools site: AOSS_SNRE_480_001_W11
- 2008 and 2010 Class On Line:
  - http://climateknowledge.org/classes/index.php/Climate_Change:_The_Move_to_Action

- Hold your calendars, Monday afternoon, March 14. Joint class with NRE 580. Stuart Pimm. Climate change and ecosystems.

The Current Climate

- Climate Monitoring at National Climatic Data Center.
  - http://www.ncdc.noaa.gov/oa/ncdc.html
- Global Analysis 2010 Annual Summary
- Global Analysis December 2010
- Wunderground climate page

Another type of current climate

- Current political budgetary attack on U.S. Climate Research

- In press?
  - Washington Post: Trends in Precipitation
  - Wall Street Journal: No trends in weather

Reading

- Next Reading: Anderson and Bow, Emissions Scenarios Four degrees and beyond ….Phil Trans Roy Soc January 13, 2011.
  - We will discuss this paper in class
    - My plan is for the February 22, class.

Project Details

- You want to make a knowledge-based evaluation of the problem and present an approach or a set of possible approaches to address the problem. (Want you to be very aware of "advocacy" in your thinking.)

- Project Description

Skill Set

- Analysis
  - Distinguish between facts and inferences
- Judgment
  - What is the quality of the knowledge?
- Synthesis
  - How do pieces fit together?

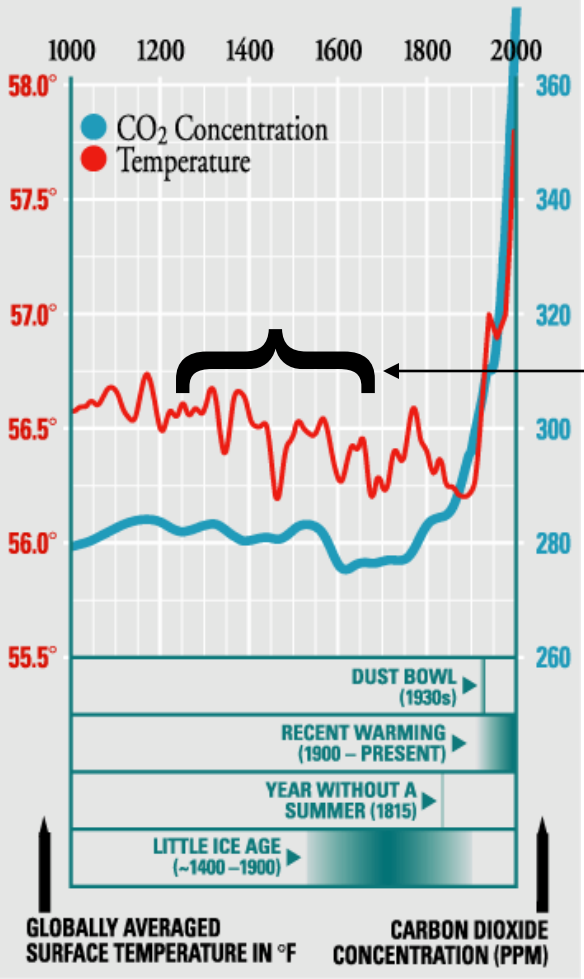
Project Ideas

- Think about Projects for a while
  - Cities, characteristics
  - Wind energy
  - Soil management, waste compost, fertilization

Today

- Scientific investigation of the Earth's climate: Foundational information
  - **Natural variability**
  - Arctic Feedbacks?

Let's look at just the last 1000 years

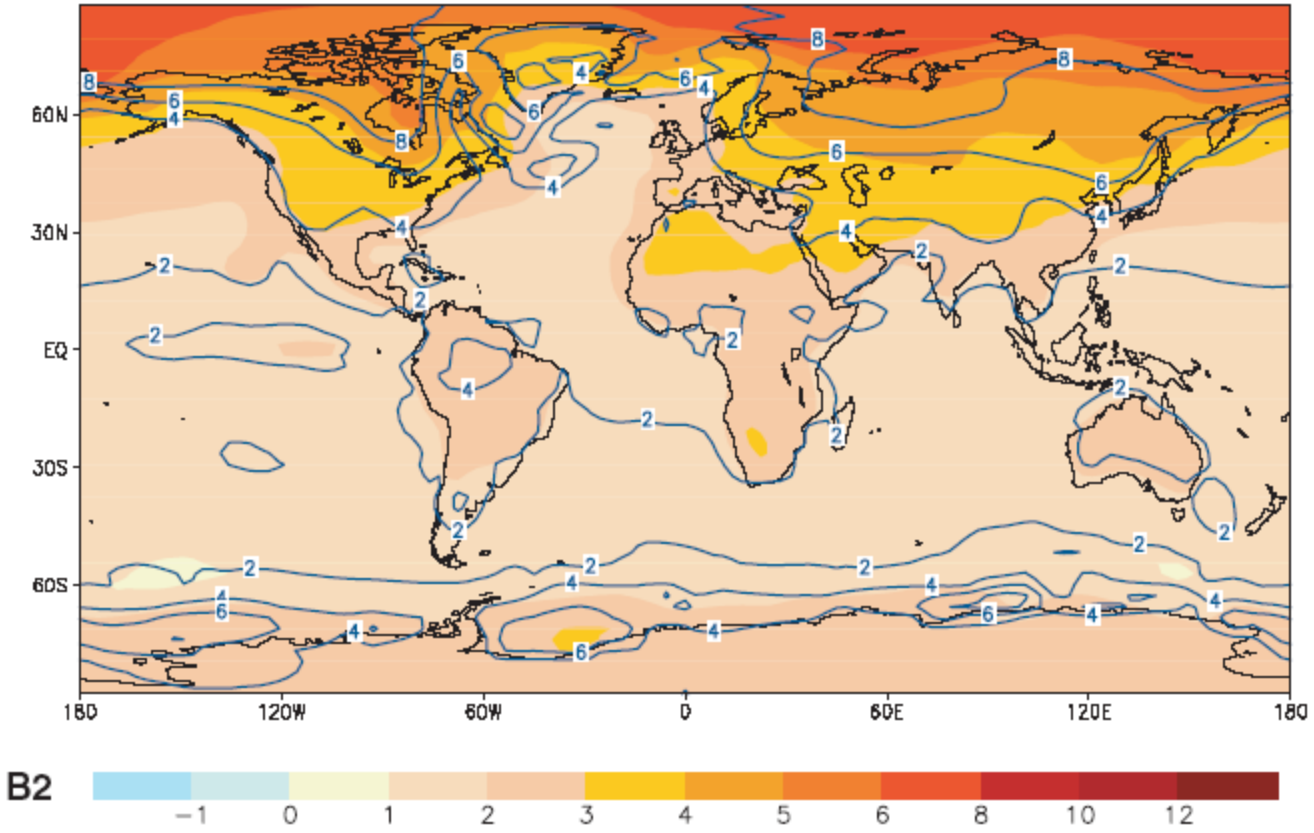


Surface temperature and CO_2 data from the past 1000 years. Temperature is a northern hemisphere average. Temperature from several types of measurements are consistent in temporal behavior.

Note that on this scale, with more time resolution, that the fluctuations in temperature and the fluctuations in CO_2 do not match as obviously as in the long, 350,000 year, record.

This is a span of time with very "stable" climate, by historical records. Stable meaning, low variability. Also it has been warm.

Projected Global Temperature Trends: 2100



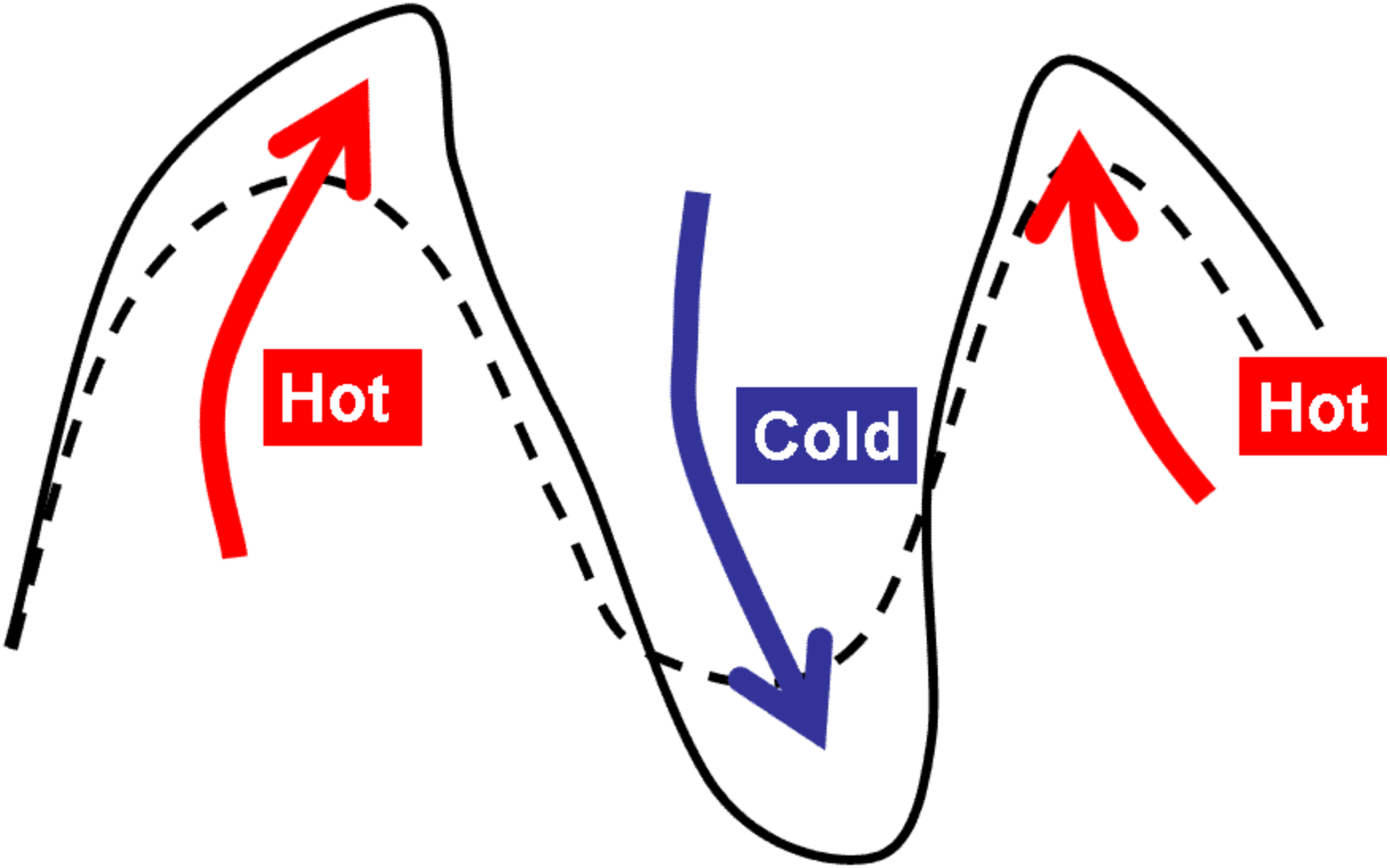
2071-2100 temperatures relative to 1961-1990.
Special Report on Emissions Scenarios Storyline B2 (middle of the road warming).

IPCC 2001

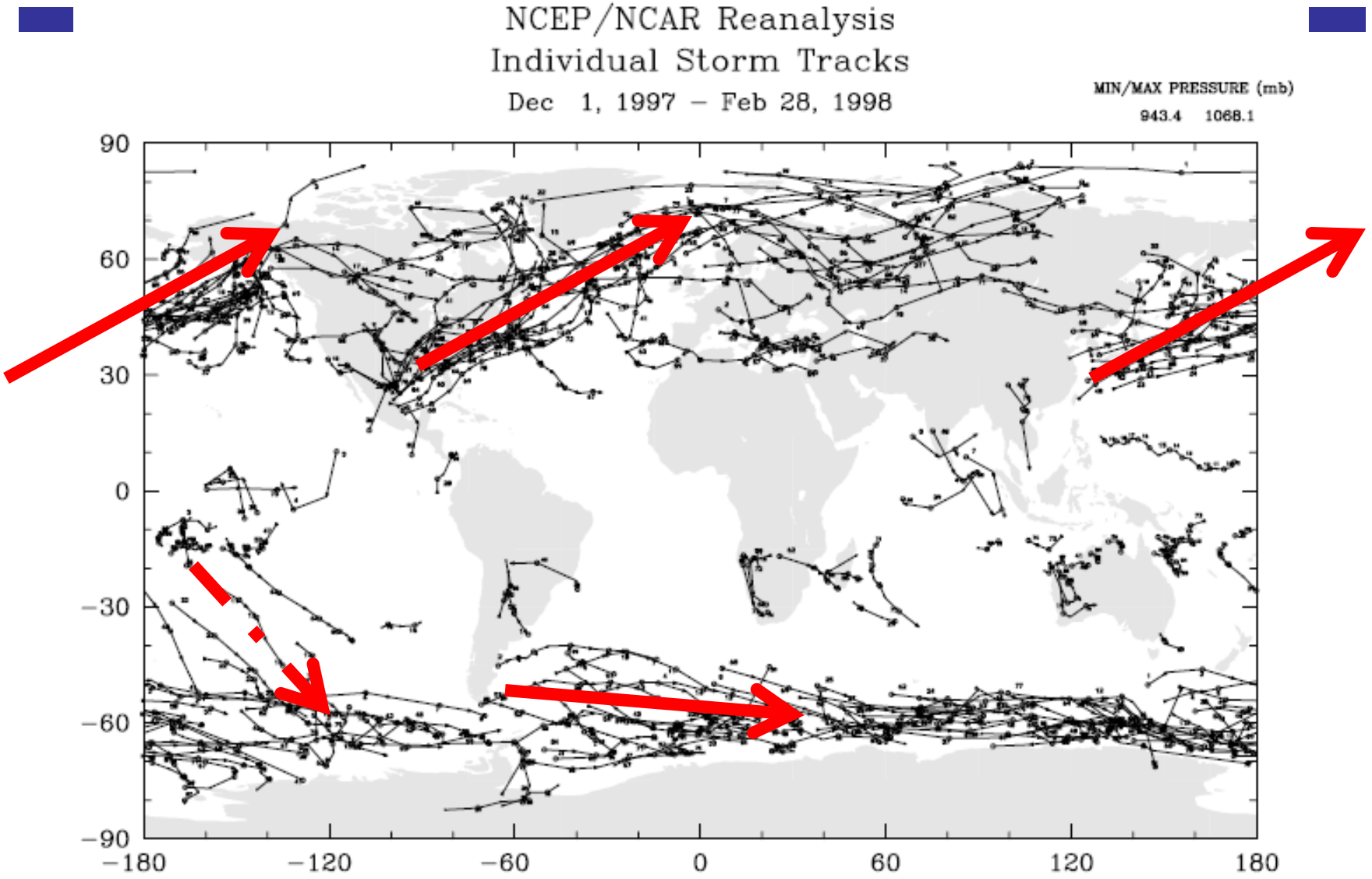
Sources of internal variability

- This is natural variability.
  - Solar variability
  - Volcanic activity
  - Internal “dynamics”
    - Atmosphere - Weather
    - Ocean
    - Atmosphere-ocean interactions
    - Atmosphere-ocean-land-ice interactions
- That does not mean that these modes of variability remain constant as the climate changes.

Cold – Warm – Cold – Warm



Mid-latitude cyclones & Heat



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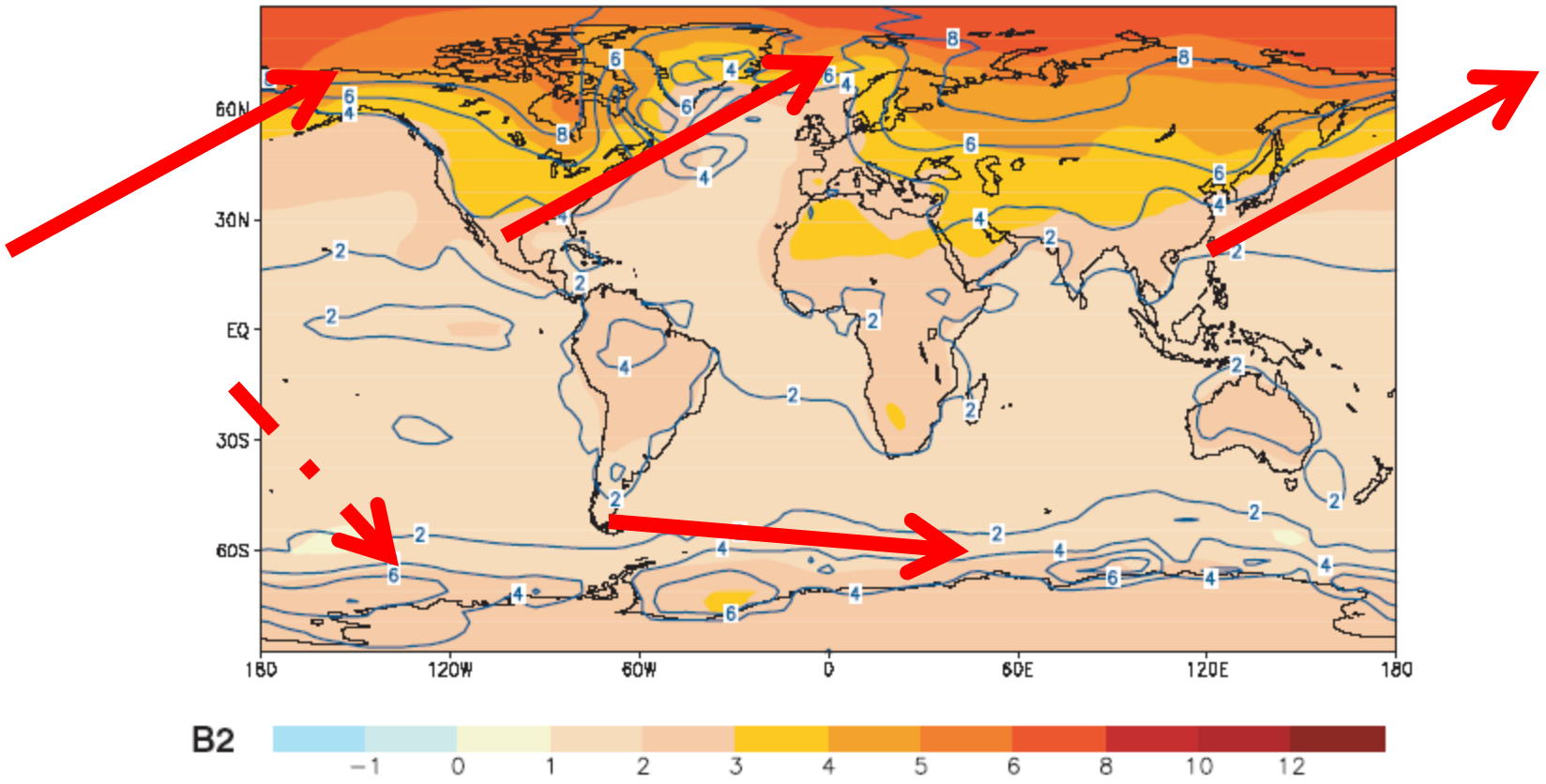

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Internal Variability?

- Weather – single “events” – waves, vortices
- There are modes of internal variability in the climate system which cause global changes.
  - El Nino – La Nina
    - What is El Nino
  - North Atlantic Oscillation
    - Climate Prediction Center: North Atlantic Oscillation
  - Arctic Oscillation, @arctic.noaa.gov
  - Annular Mode
  - Inter-decadal Tropical Atlantic
  - Pacific Decadal Oscillation

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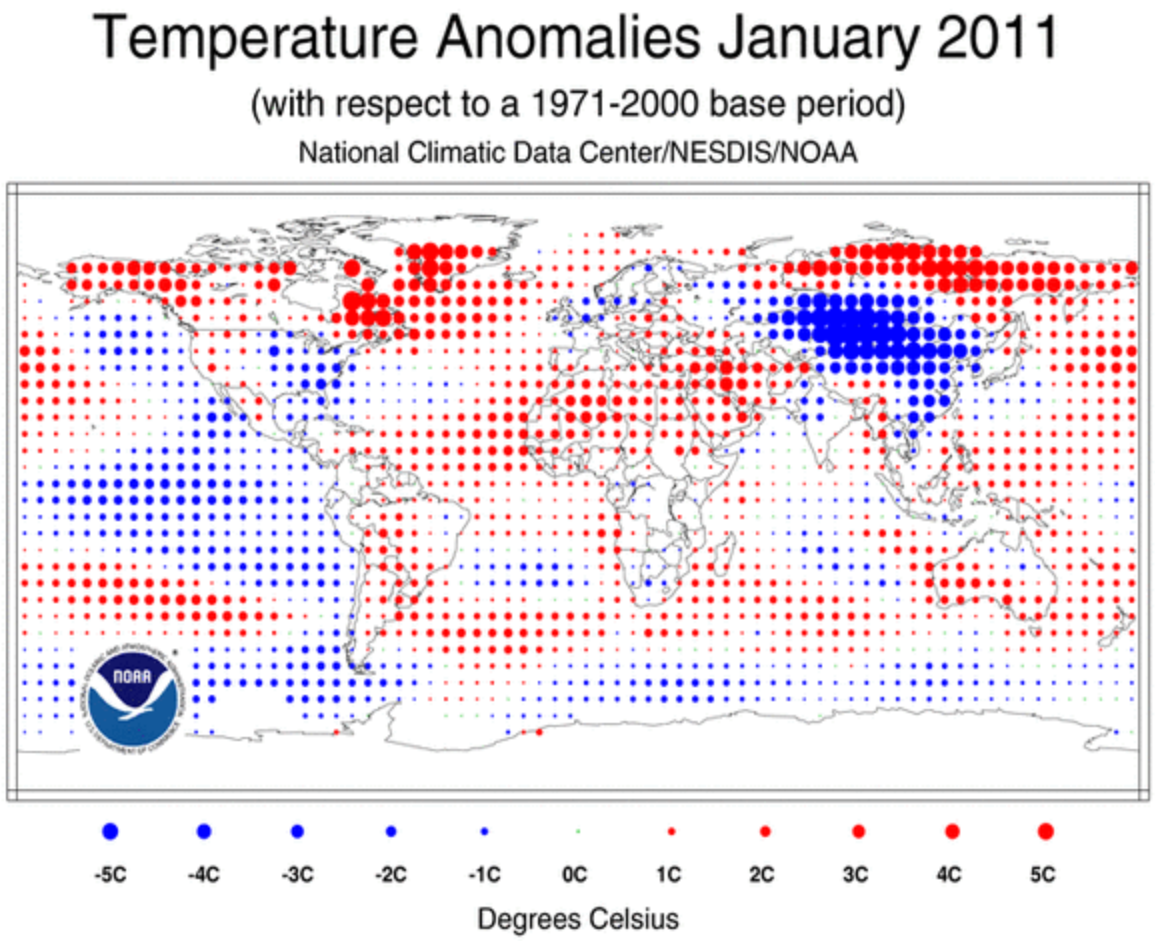
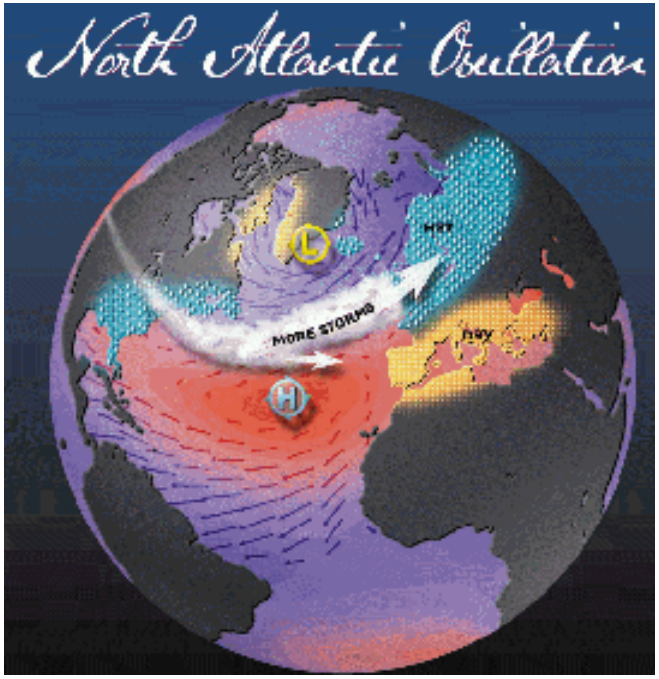
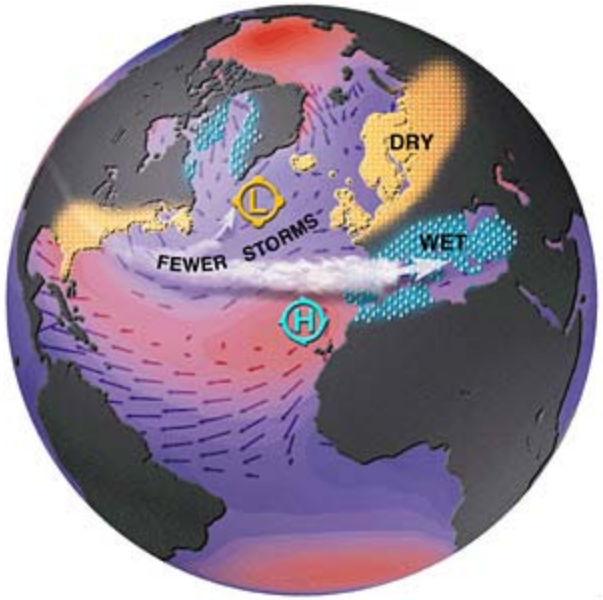
January 2011 Temperature Anomalies



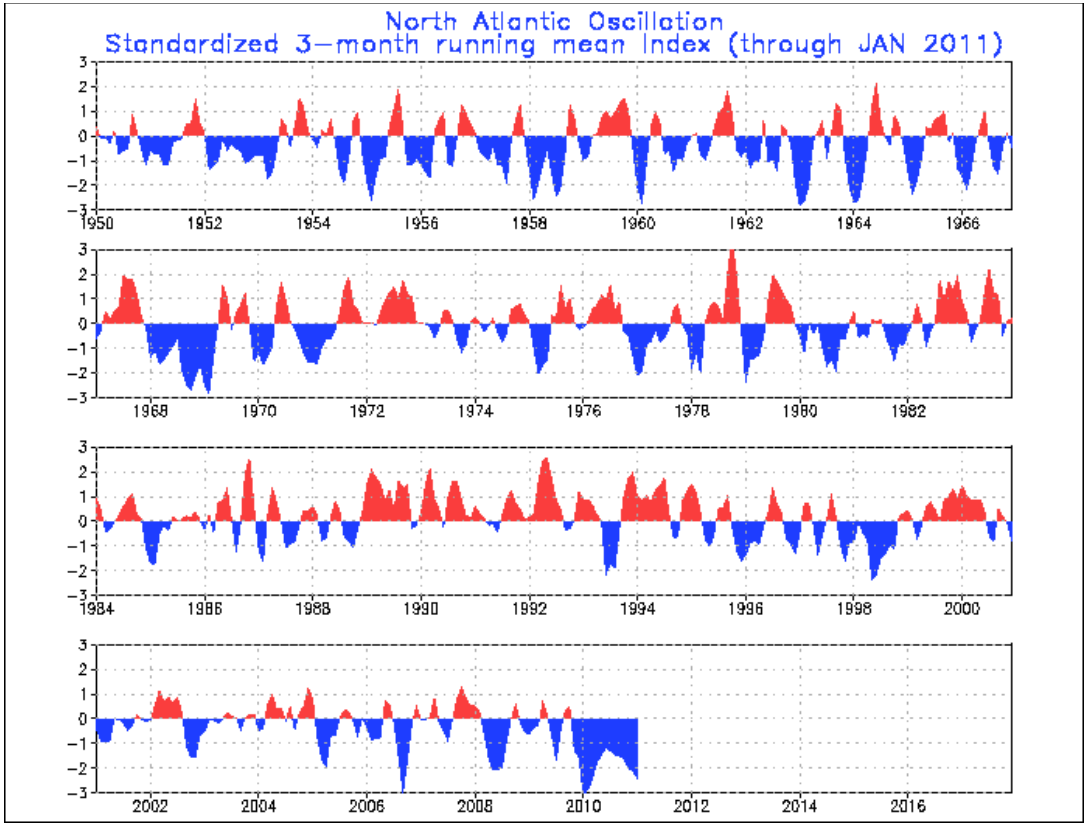
North Atlantic Oscillation





Positive Phase	Negative Phase
U.S. East, Mild and Wet	U.S. East, Cold Air Outbreaks, Snow (dry)
Europe North, Warm and Wet	Europe North, Cold; South, Wet
Canada North & Greenland, Cold and Dry	Greenland, Warm

North Atlantic Oscillation Phase (from Climate Prediction Center)

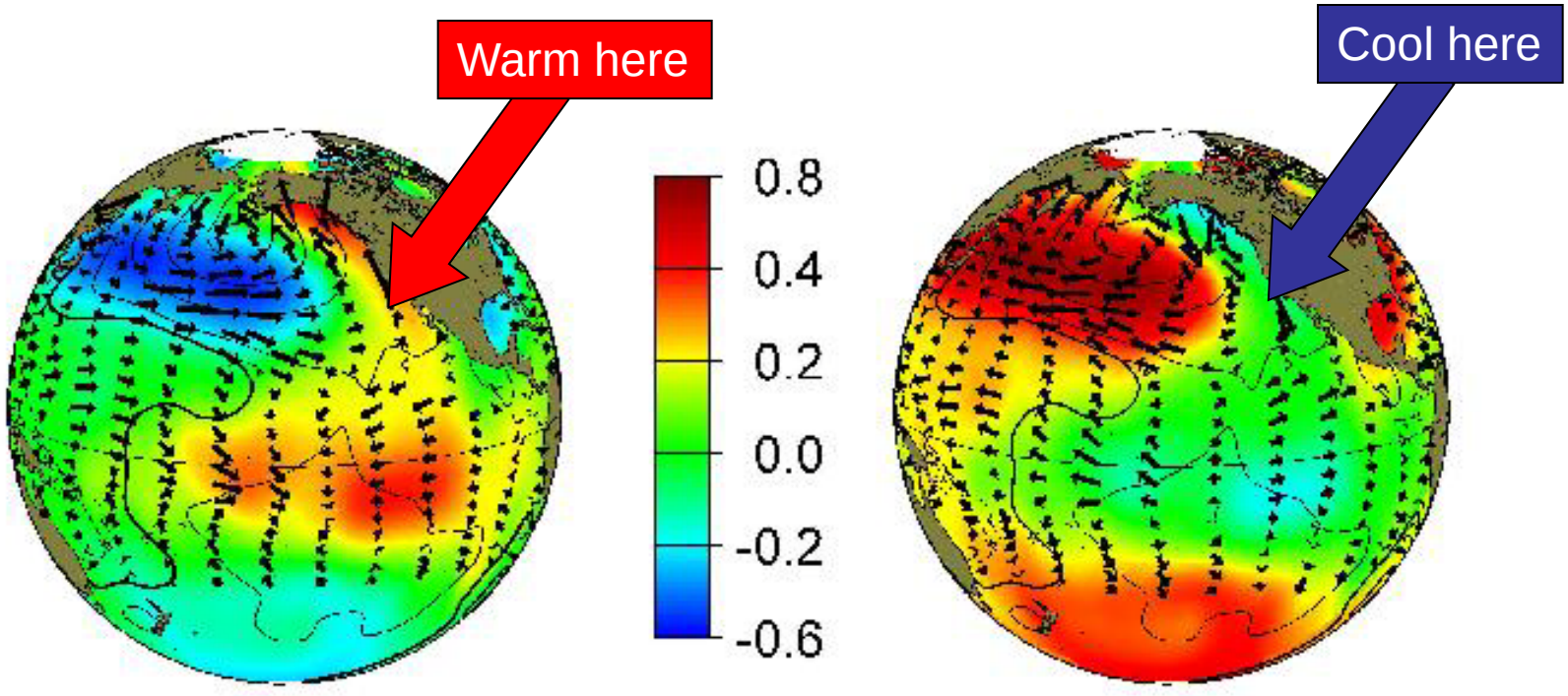


Pacific Decadal Oscillation

- Does the Pacific Decadal Oscillation operate regularly lasting 20-30 years, and does southern California experience droughts during that period?
  - The Pacific Decadal Oscillation is one of several “oscillations” that are important to weather and climate.
  - Some attributes of the Pacific Decadal Oscillation

Pacific Decadal Oscillation: Basics

Colors: Sea Surface Temperature difference from long term average.
Arrows: Stress on the ocean surface caused by winds



Better version of figure from JISAO

Some information on Pacific Decadal Oscillation

- Joint Institute for Study of Atmosphere and Ocean (JISAO):
  - Pacific Decadal Oscillation
- Climate Prediction Center (CPC):
  - 90 Day Outlook Summary
  - Weather and Climate Linkage
- National Climatic Data Center (NCDC):
  - Decadal Oscillations
- Review Paper from Rood Class References
  - Mantua and Hare (2002) J of Oceanography

Internal Variability?

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Some good El Nino Information

- NOAA Climate Prediction: Current El Nino / La Nina
- NOAA CPC: Excellent slides on El Nino
  - This is a hard to get to educational tour. This gets you in the middle and note navigation buttons on the bottom.

Lean and Rind, Next 20 years

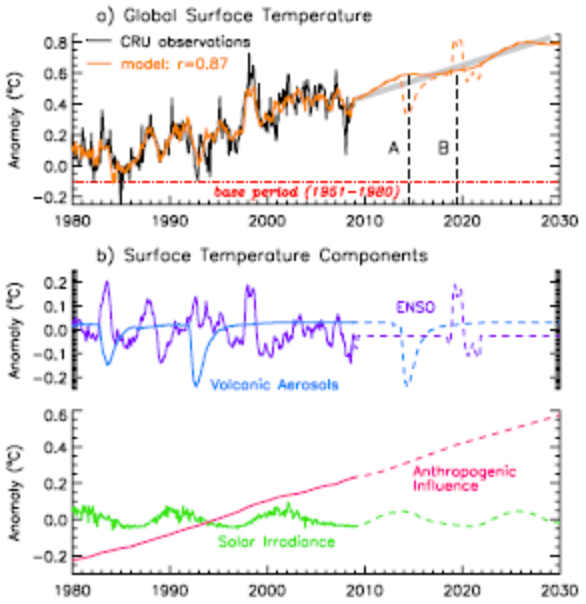
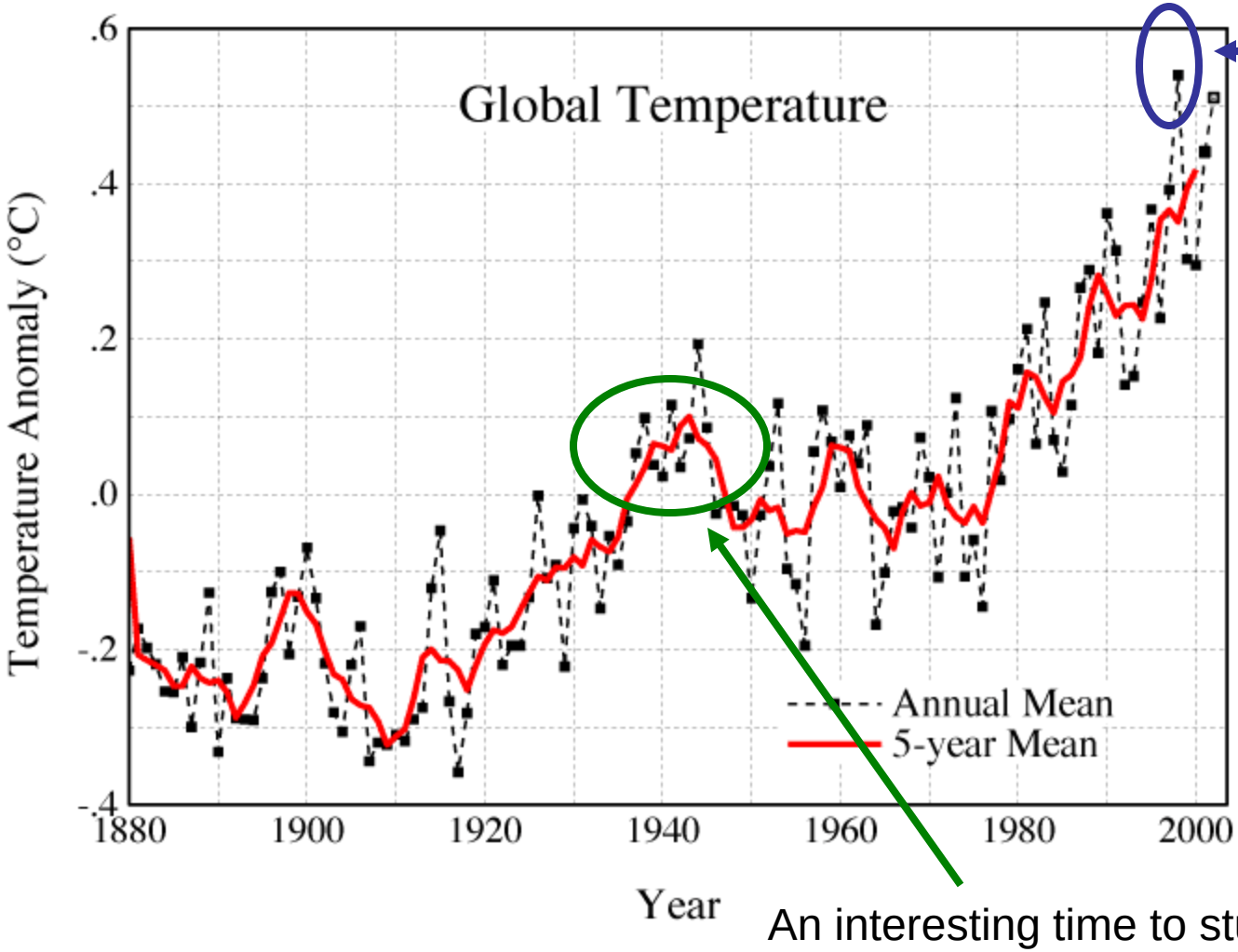


Figure 1. (a) Observed monthly mean global temperatures (black) and an empirical model (orange) that combines four different influences. (b) Individual contributions of these influences, namely ENSO (purple), volcanic aerosols (blue), solar irradiance (green) and anthropogenic effects (red). Together the four influences explain 76% (r^2) of the variance in the global temperature observations. Future scenarios are shown as dashed lines. The vertical black dashed lines in Figure 1a denote 2014 (A) and 2019 (B), at which times corresponding spatial temperature patterns are shown in Figures 3 and 4.

Looking in the past century

GISS Temperature 2002



1997-98 El Nino

An interesting time to study?

A couple of papers

- Bengstsson_20th_Century_Climate_JClimate_2004
- Johannssen_Arctic_20th_Century_Tellus_2004

Abrupt climate change

- The predictions and observations so far are either in the sense of:
  - Relatively small changes in the dynamic balance of the climate system
  - Incremental changes to the stable climate.
- What about “abrupt” climate change?

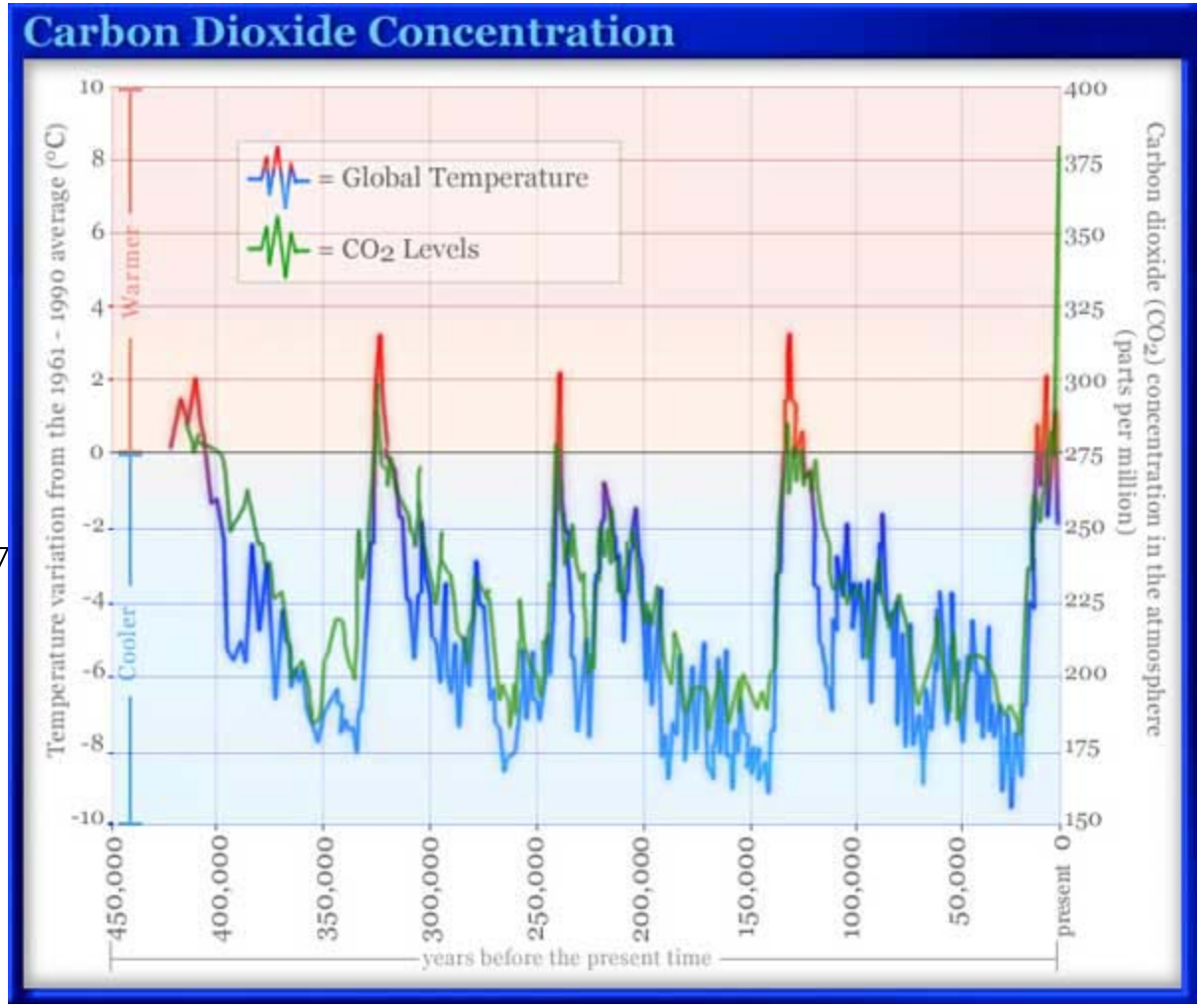
Note to professor: Force students to think and speak

- What might cause something to change abruptly in the climate system?

- Lamont-Doherty: Abrupt Climate Change
- NAS: Abrupt Climate Change
- Wunderground.com: Abrupt Climate Change

What is a stable climate?

LIQUID - ICE

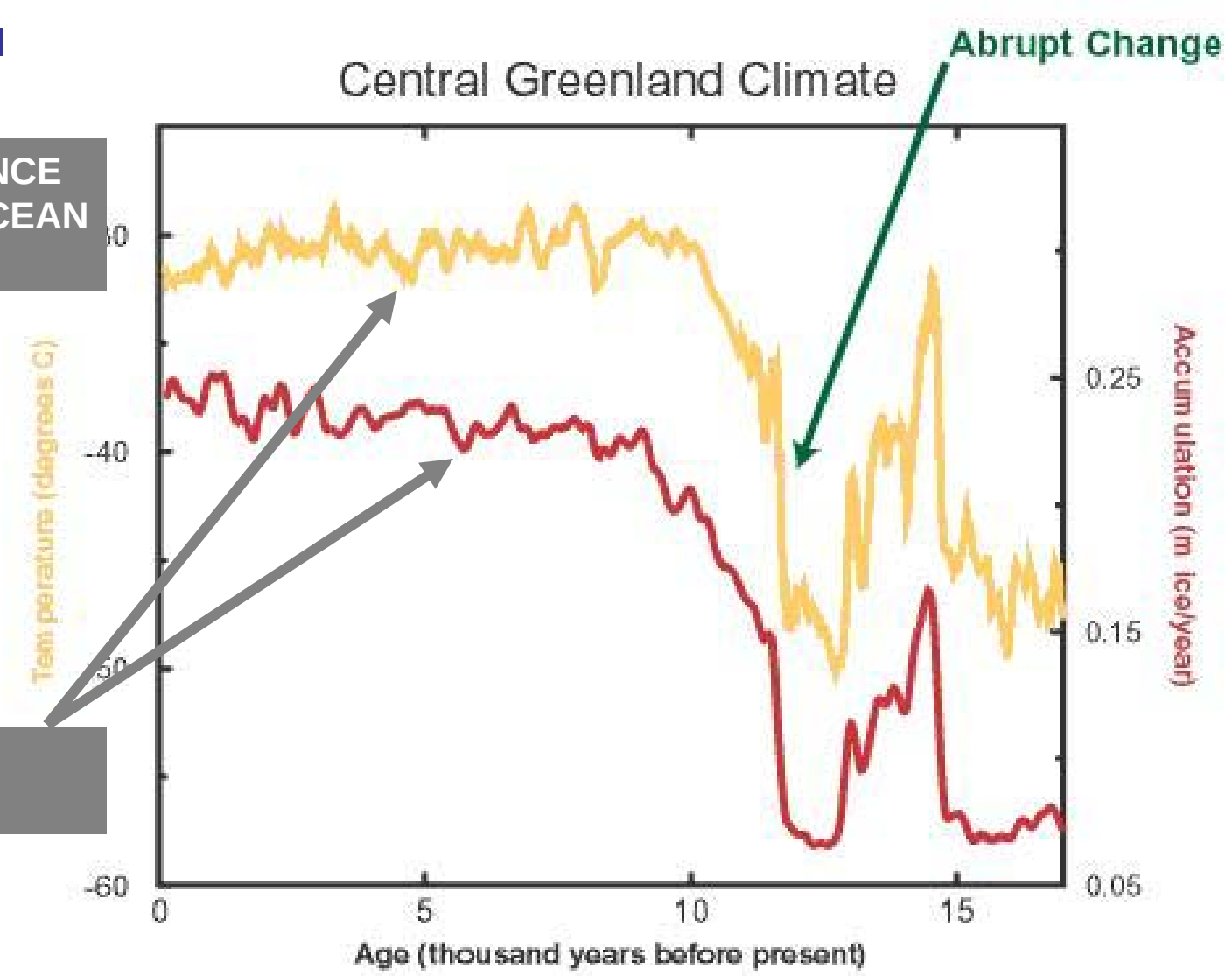


NOAA Paleoclimate
Schlumberger

Younger Dryas

POSSIBLE EVIDENCE OF CHANGE IN OCEAN CIRCULATION

WHAT DOES THIS MEAN?



Abrupt climate change

- Changes in the ocean circulation.
  - Remember Younger Dryas
- Remember the ice-age turn around:
  - Need some sort of positive feedback to amplify the solar forcing
    - Ice-albedo feedback //
      - Sea ice collapse in Arctic?
      - Land ice sheet collapse → sea level rise
    - Sudden release or absorption of greenhouse gas from ocean
      - Schmittner: Oceans & Greenhouse
- Sudden release or absorption of greenhouse gas from land
  - Permafrost
- Sudden change in the biological balance of plants and animals
  - Ocean temperature and acidification

Abrupt Climate Change

- Most scenarios of abrupt climate change are related to a phase change in some way or another. Does the albedo change quickly? Is there a change in the fresh water in the ocean? Is there a release of gas stored in something that is frozen?
- It is also possible to define rapid changes in ocean (land?) ecosystems, that leads to composition changes in the atmosphere. Biology – sensitive to temperature, water, salinity, ph, *etc.*

Lamont-Doherty: Abrupt Climate Change

There could be changes in the way the atmosphere and ocean transport heat

(An excursion to the North Atlantic)

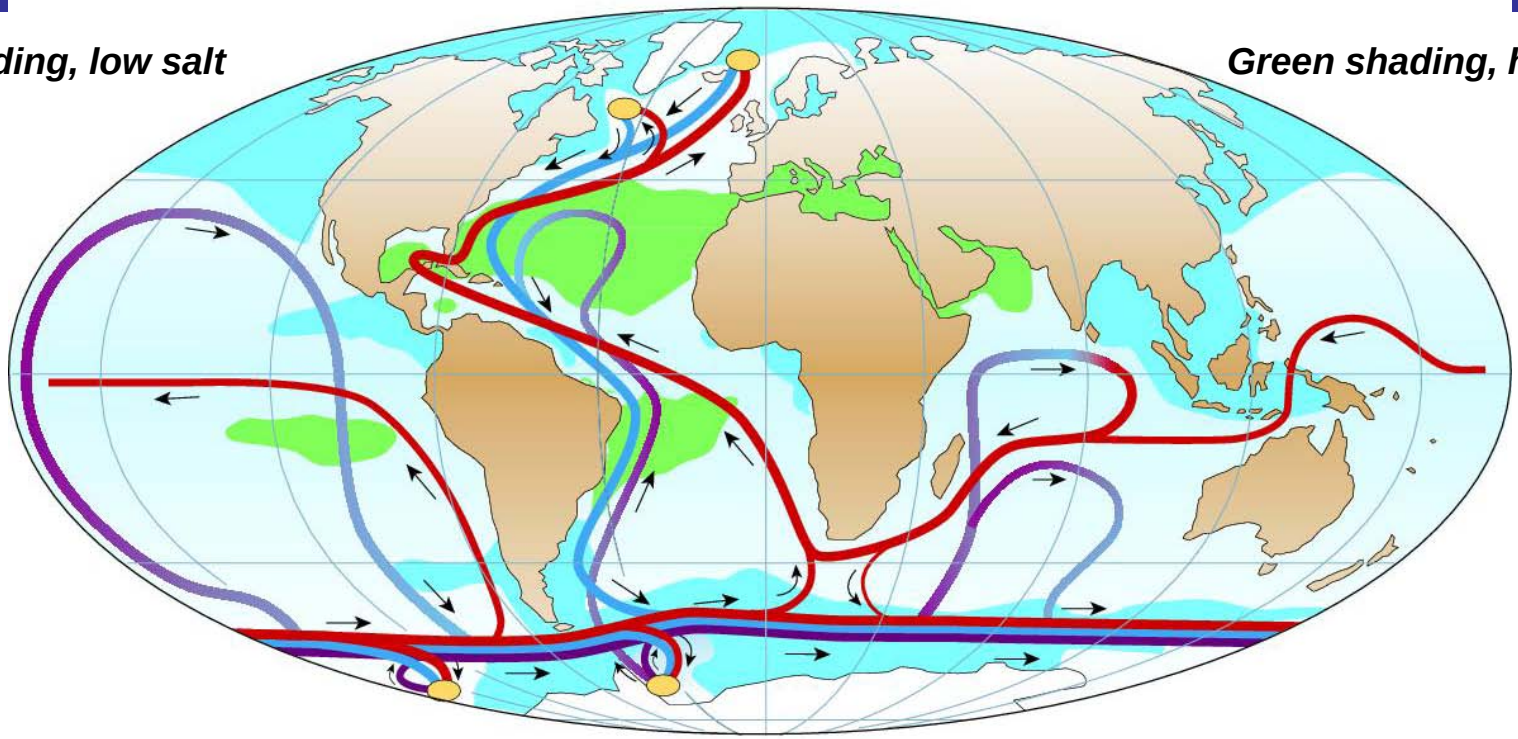
- Remember that the atmospheres and ocean carry heat from the equator to the pole.
  - This is done at preferential locations.
  - One especially important mechanism of heat transport is the Gulf Stream, along the eastern coast of the U.S, which transports heat to the North Atlantic. This keeps much of Europe much warmer than it would be based on the position of the sun.
  - The Gulf Stream is part of a large organized circulation in the oceans.
    - Connects north and south
    - Connects top and bottom of ocean (which is not very common)
  - This organized circulation is sometimes called the ocean “conveyor” belt. It is named the thermohaline circulation because it depends on both the thermal structure and the saltiness (“haline”) of the water.

The Thermohaline Circulation (THC)

(Global, organized circulation in the ocean)
(The "conveyer belt", "rivers" within the ocean)

Blue shading, low salt

Green shading, high salt



Where there is localized exchange of water between the surface and the deep ocean (convection)

Warm, surface currents.

Cold, bottom currents.

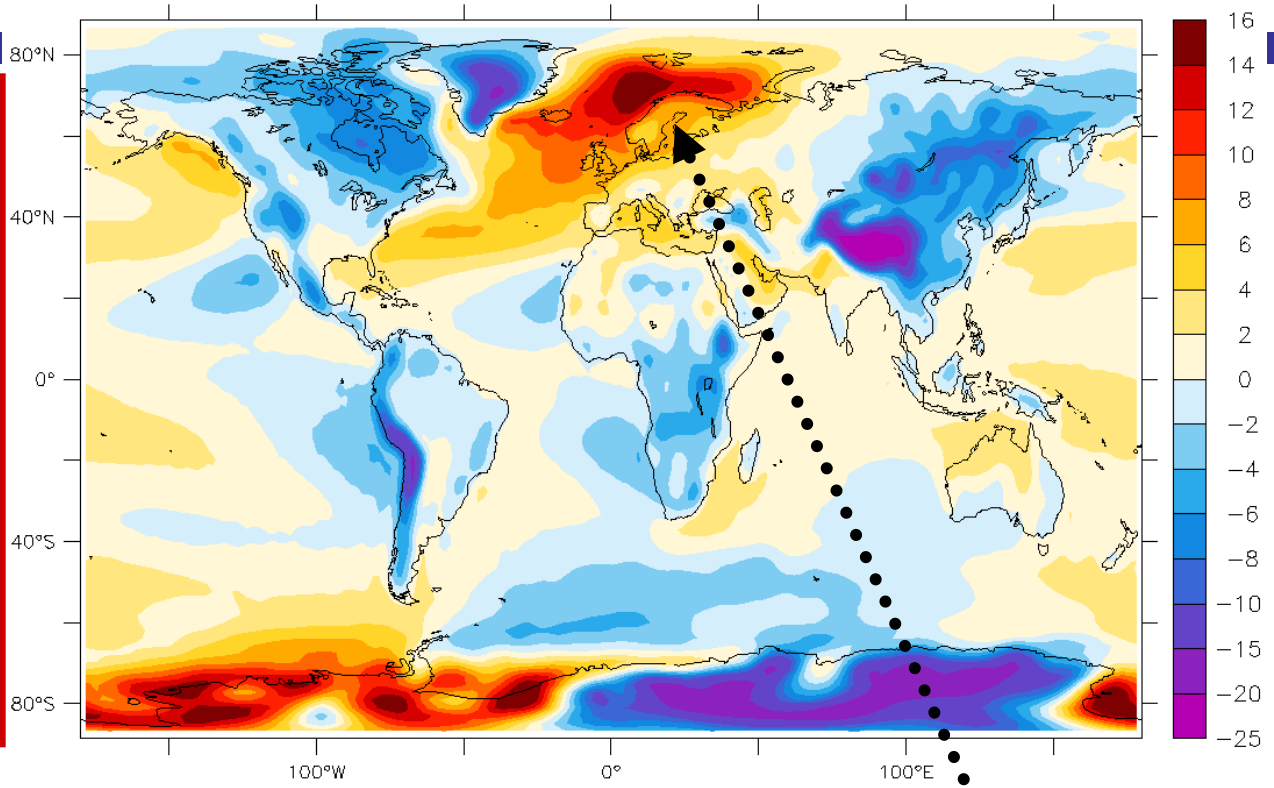
From Jianjun Yin, GFDL, see J. Geophysical Research, 2006

Some aspects of the thermohaline circulation

- Salt is important to the density of sea water.
- Warm, salty water on the surface moves to high northern and southern latitudes, where it sinks.
- The area where there is strong, localized exchange, bottom water currents develop which return cold water towards the equator (heat exchange).
- The area where there is strong localized exchange is significantly warmer than it would be in the absence of the ocean currents. (see next figure)
- Saltiness is very important. If the North Atlantic were flooded with fresh water from Greenland ice melting or much more precipitation, then the thermohaline circulation might shut down.
  - There is evidence that this has happened before (look up the Younger Dryas)
  - Hence melting of Greenland impacts both sea-level rise and the thermohaline circulation

Importance of the Thermohaline Circulation in the Present Climate

If the thermohaline circulation shut down, then the climate, the mean surface temperature, would be abruptly and significantly changed.

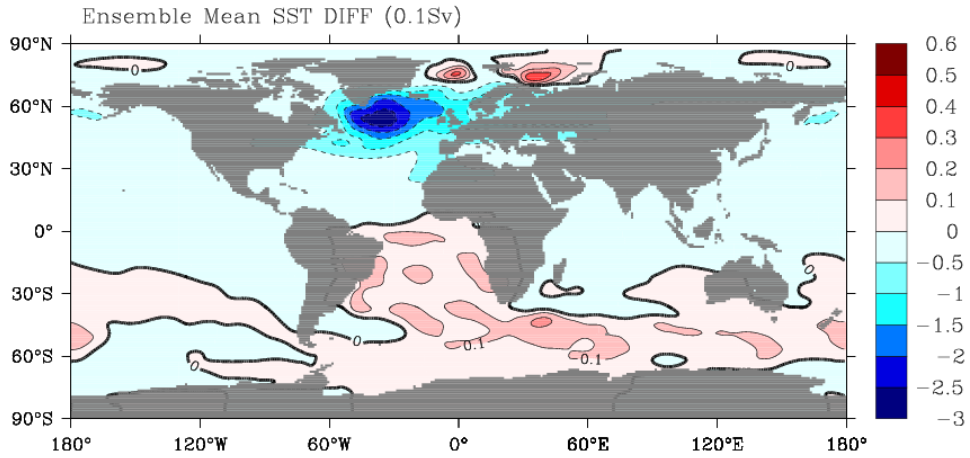


- The deviation of the surface air temperature from the zonal average (NCAR/NCEP reanalyses);
- The THC is responsible for most northward heat transport in the Atlantic (> 1 PetaWatts = 10^{15} Watts);
- High surface air temperature over the North Atlantic and Europe

From Jianjun Yin, GFDL, see J. Geophysical Research, 2006

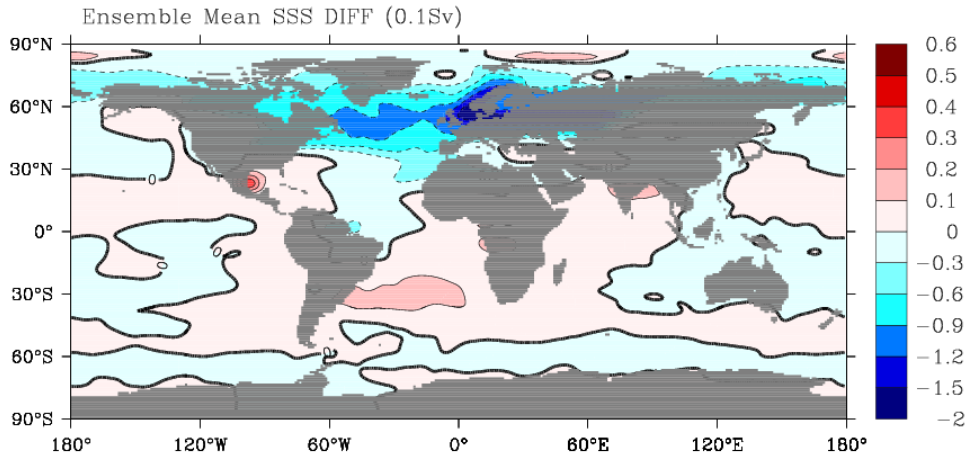
Some model predictions of what would happen if the thermohaline circulation shutdown

- From From Jianjun Yin, GFDL, see J. Geophysical Research, 2006
- Fresh water is added in the model simulation to the North Atlantic, in the vicinity of Greenland and Iceland.
- With the addition of fresh water the thermohaline circulation shuts down
- There are global consequences
  - See plots below.



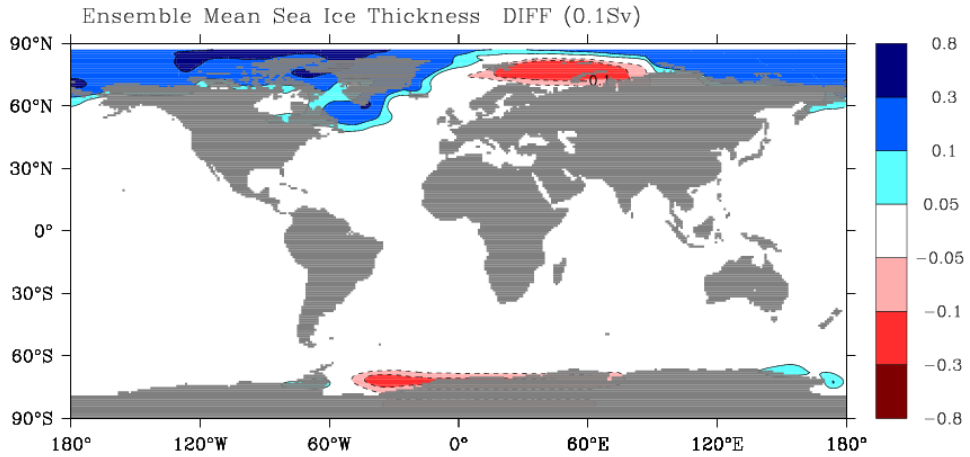
Predicted Sea Surface Temperature

- Bipolar Seesaw 3°C decrease NA
- Extension of icy seawater and sea ice coverage in North Atlantic
- Spread of warmer seawater via ACC
- Feedback on the THC intensity
- (This dipole has the characteristic of a dynamical response)



Predicted Sea Surface Salt (SSS)

- 1.2 psu decrease in 50~70°N belt
- SA and Gulf of Mexico become more saline
- Sharp SSS gradient at 40°N
- Labrador Sea: the most susceptible region to freshwater perturbation



Predicted Sea Ice

- Thickness increases and coverage extends in the Labrador Sea
- Thickness decreases in the Nordic Seas the Barents Sea and the Weddell Sea due to enhancement of deep convection (part of a dynamical response?)

From Jianjun Yin, GFDL, see J. Geophysical Research, 2006

Abrupt Climate Change

- This is a subject of current high interest.
  - Is there a “dangerous” threshold that could have extremely rapid, decades, impact?
  - Is there a dangerous threshold that we could avoid by mitigation?
  - Should we plan for this contingency?

Let's think about the Arctic for a while

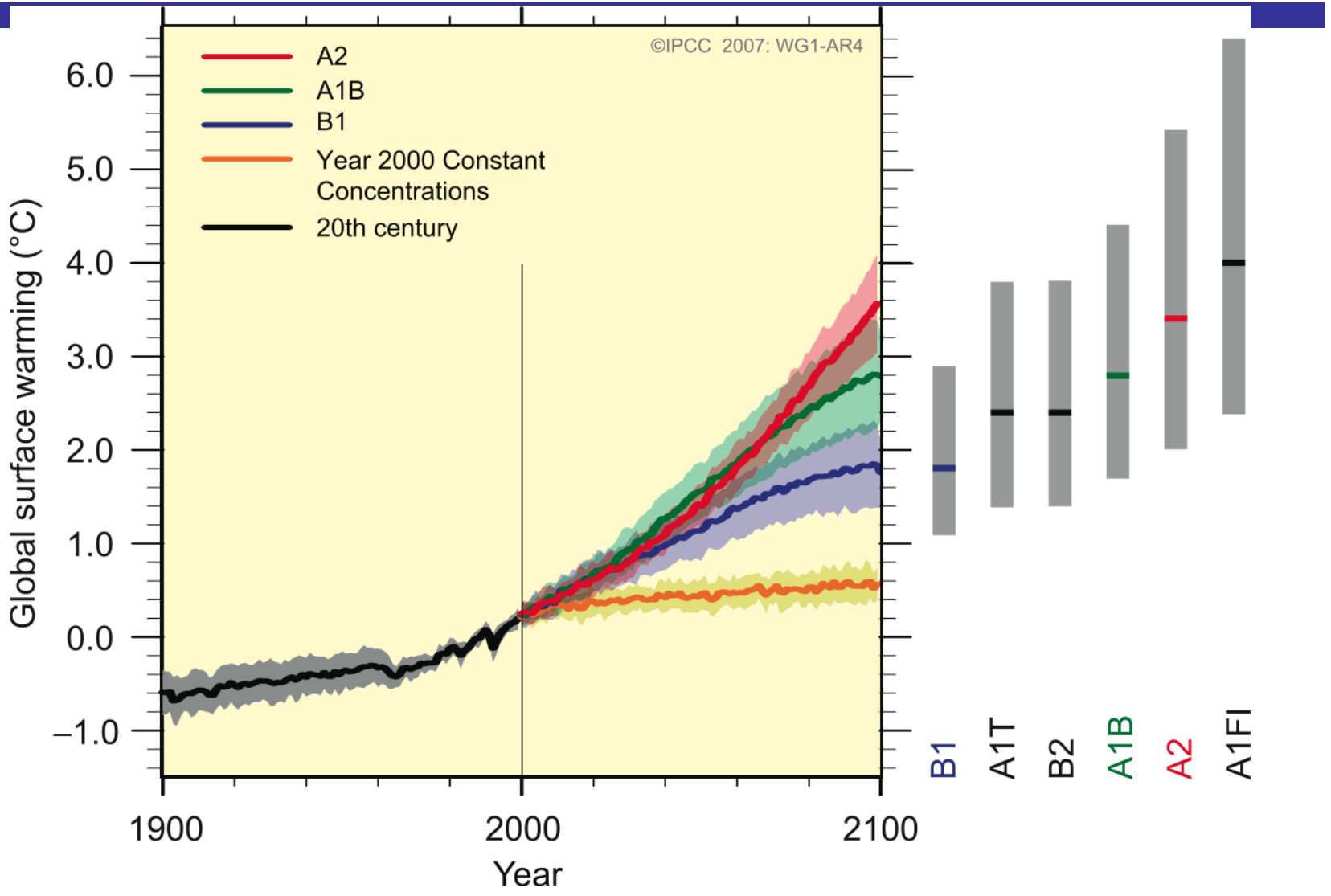
- WWF: Arctic Feedbacks Assessment

- Does this provide a meaningful definition of dangerous climate change?

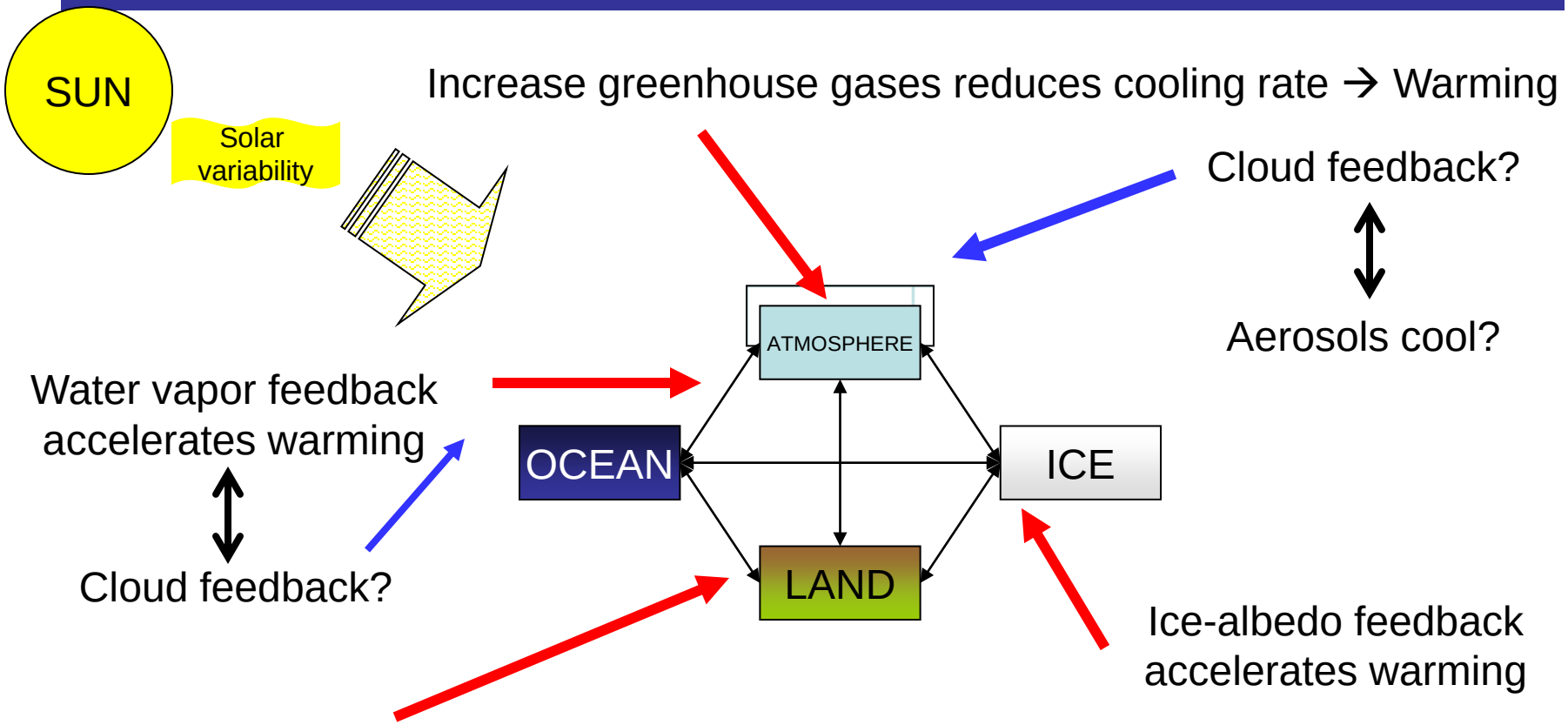
Marching

- We have marched through the fundamentals of the science of climate change.
  - It's a counting problem, where we count energy.
  - The basic physics is simple.
  - The Earth and it's response stunningly complex.
    - Physics, chemistry, biology.

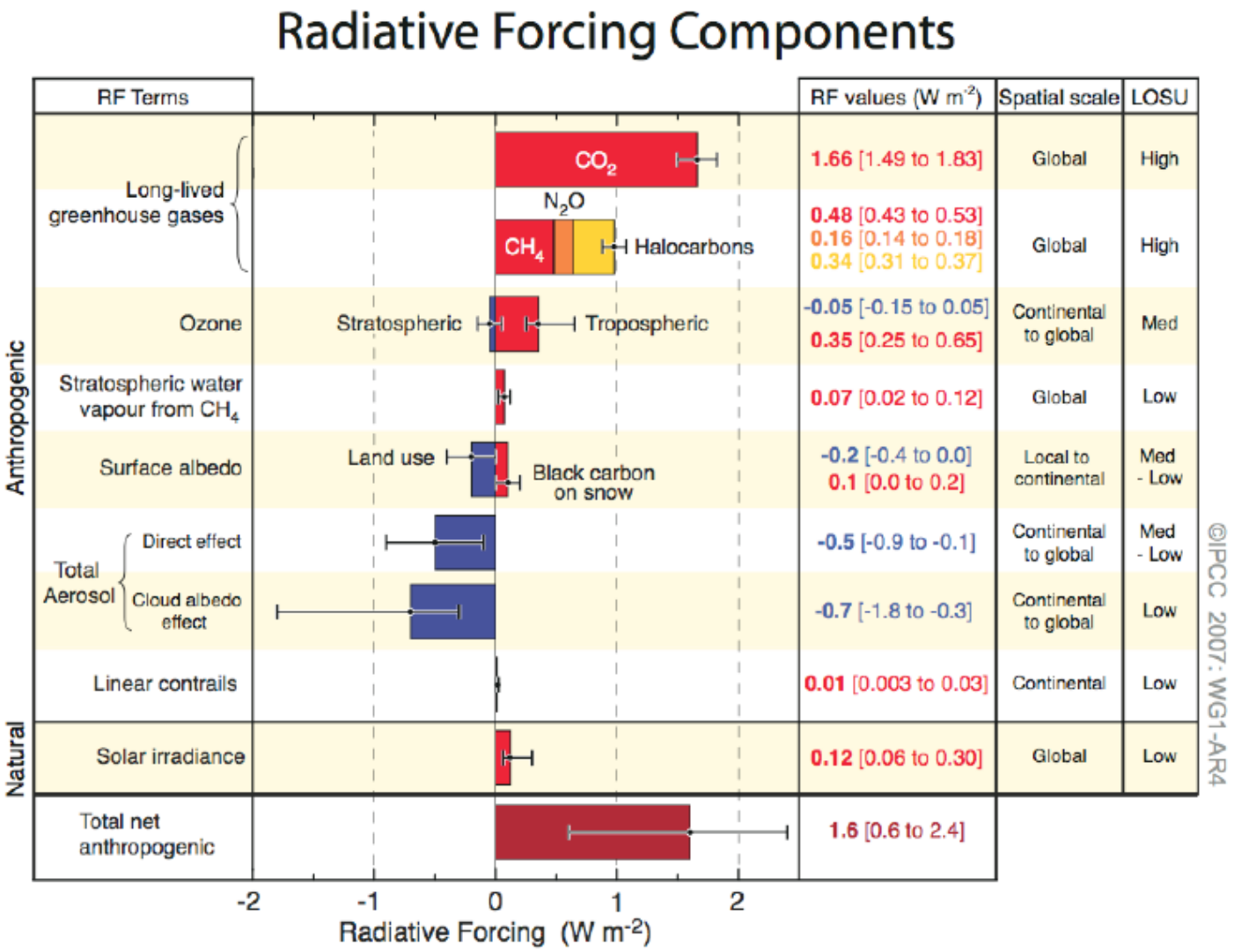
Next time: Fundamental Science of Climate



The Earth System



Radiative Forcing IPCC 2007

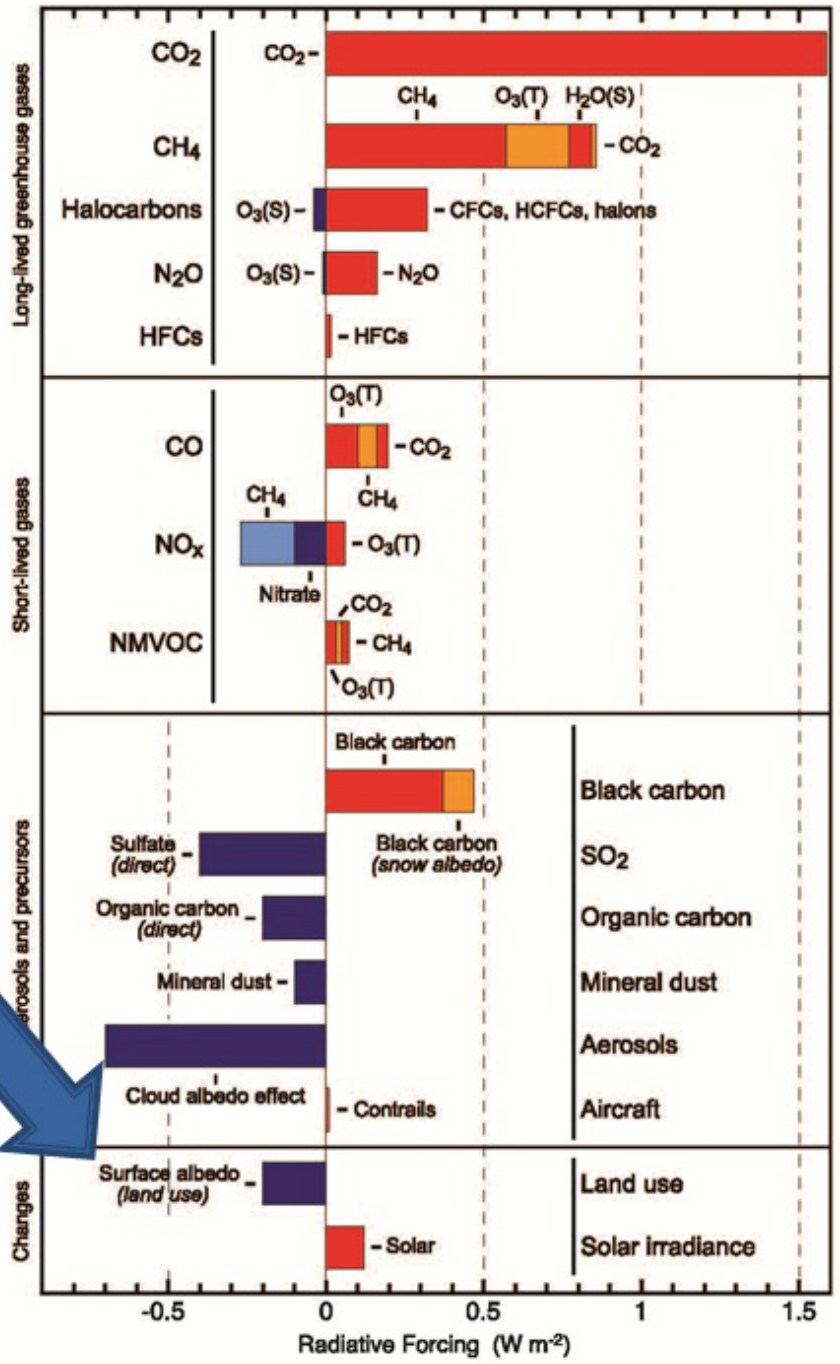


The Cryosphere

- TOUR OF CRYOSPHERE: MAIN NASA SITE

Global radiative forcing due to emissions of aerosols and precursors changes from 1750-2005

Change in surface reflection due to changes in the land surface

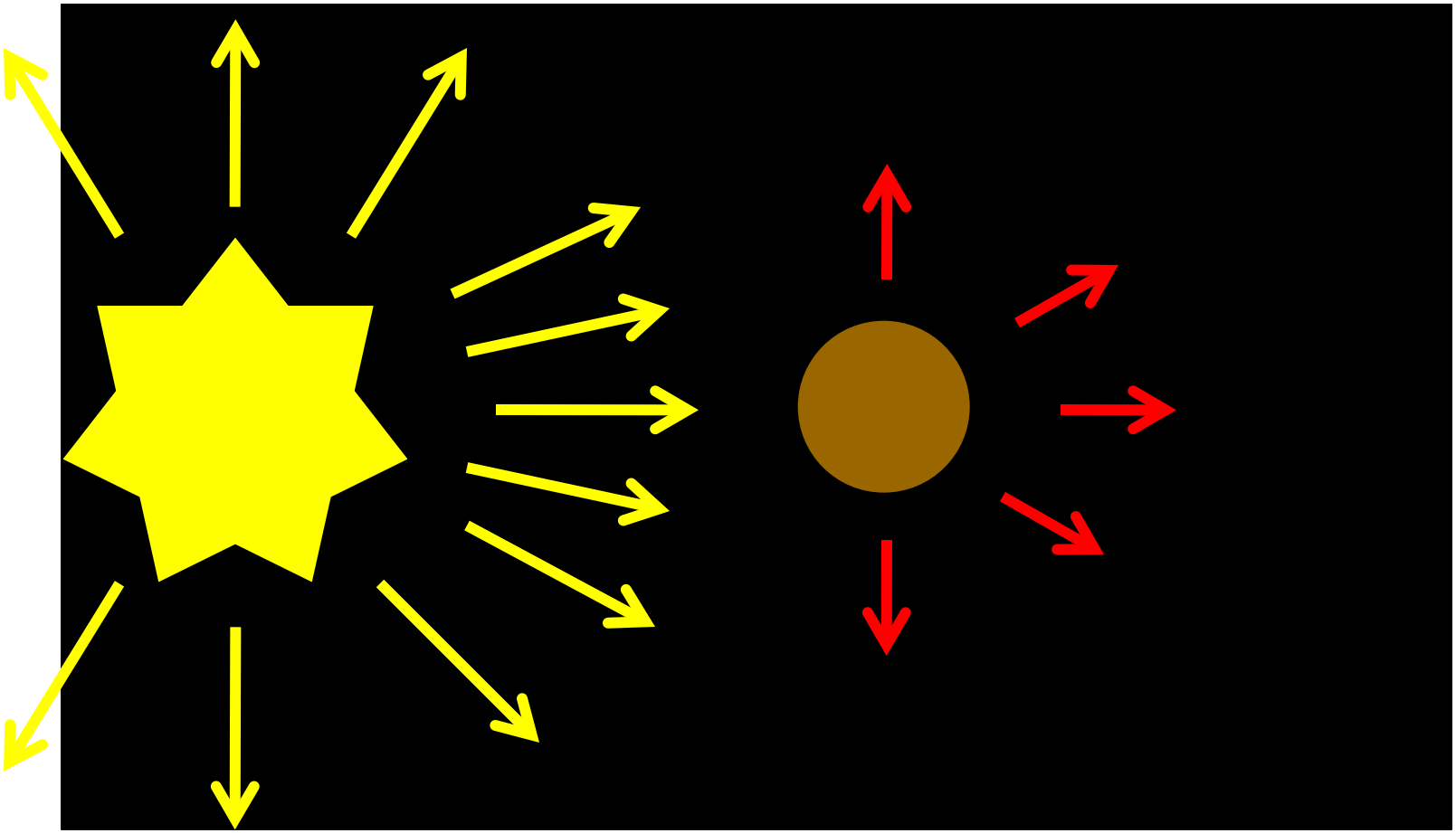


[IPCC, *WG1 4th Assessment Report*, 2007]

Scientific investigation of Earth's climate

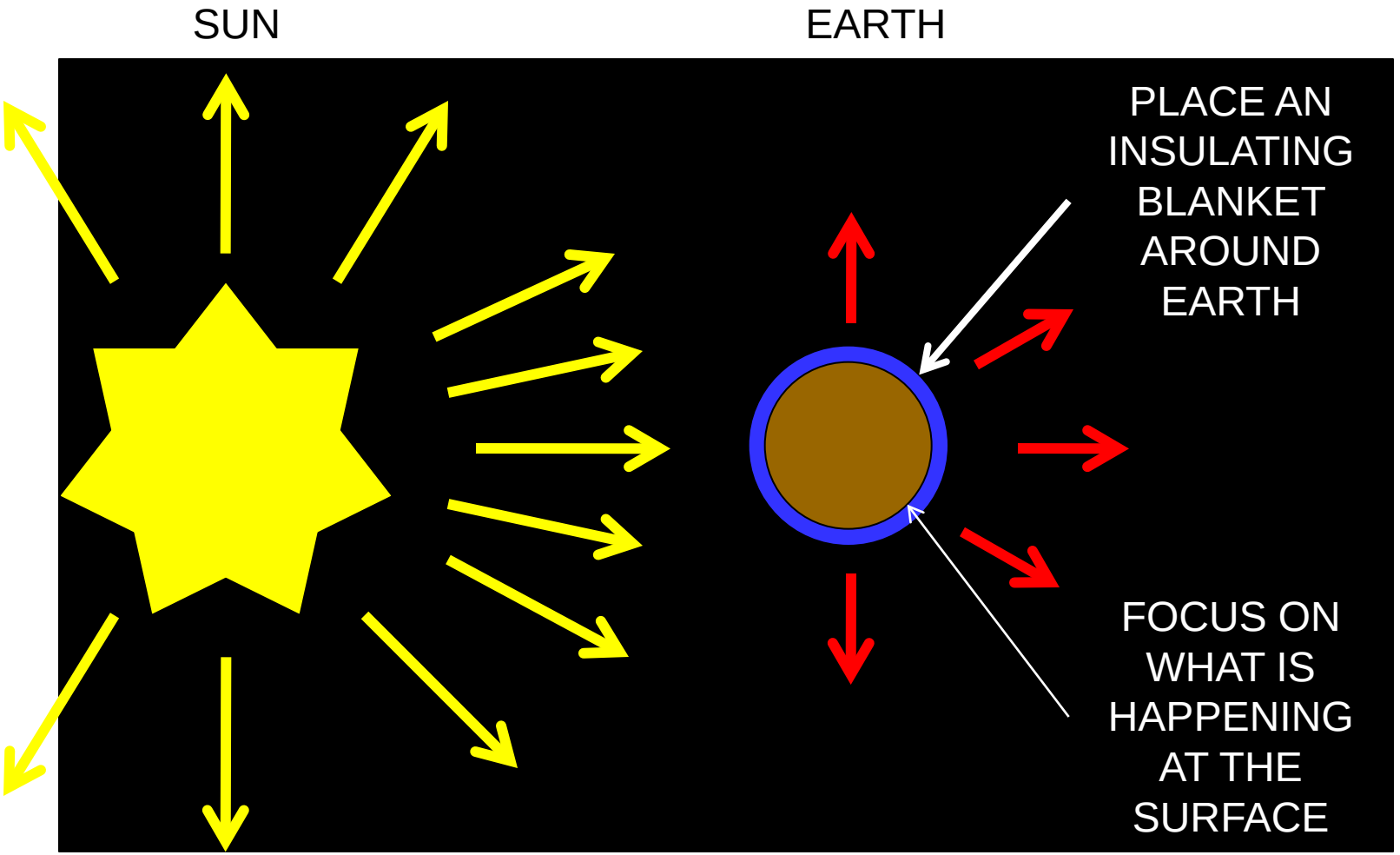
SUN: ENERGY, HEAT

EARTH: ABSORBS ENERGY



EARTH: EMITS ENERGY TO SPACE → BALANCE

Scientific investigation of Earth's climate



EARTH: EMITS ENERGY TO SPACE → BALANCE