Fundamentals of Climate Change (PCC 587): Introduction

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DEPARTMENT OF ATMOSPHERIC SCIENCES

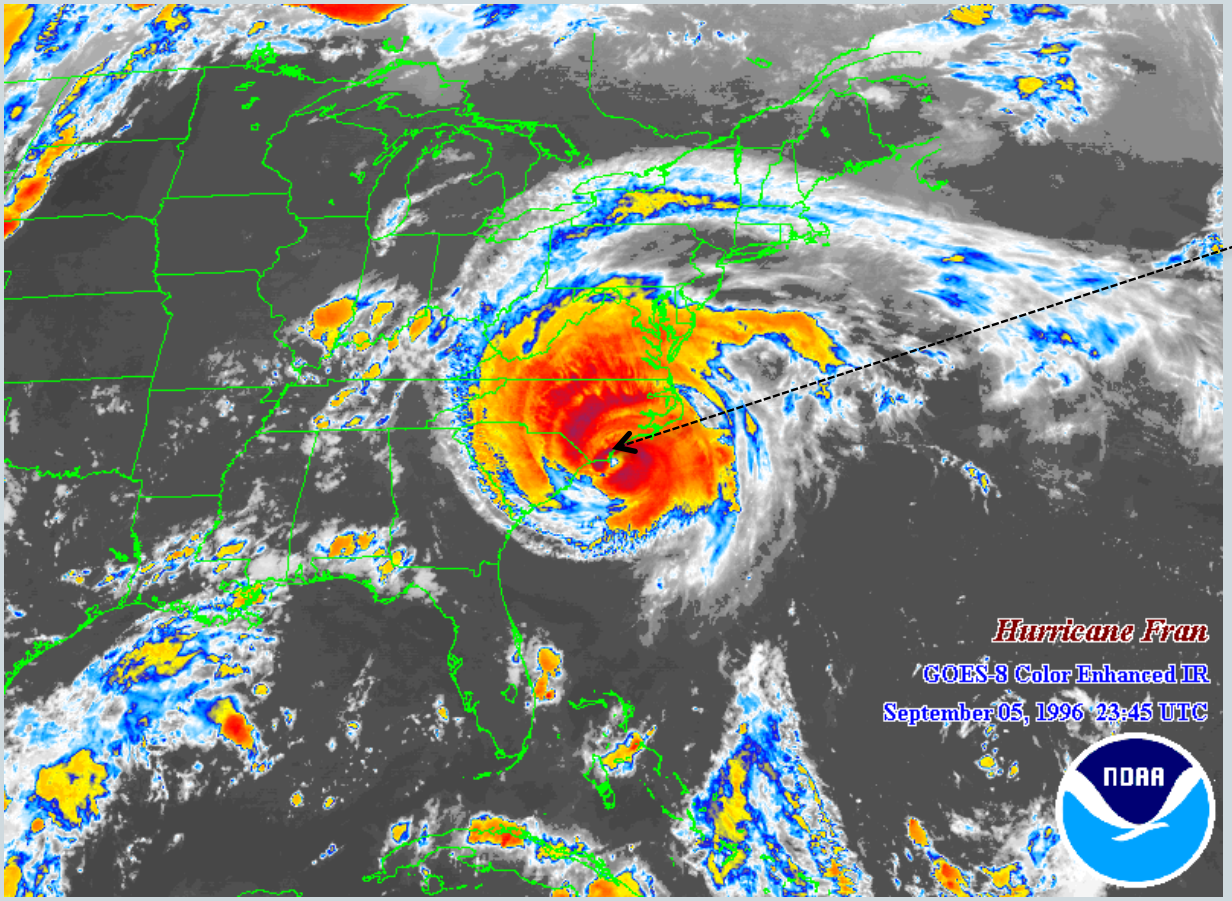
DAY 1: 9-25-13

About Me

- Professor: Dargan Frierson
- Home town: Wilmington, NC
  - Southeastern North Carolina, on the coast

About Me

- Home town: Wilmington, NC

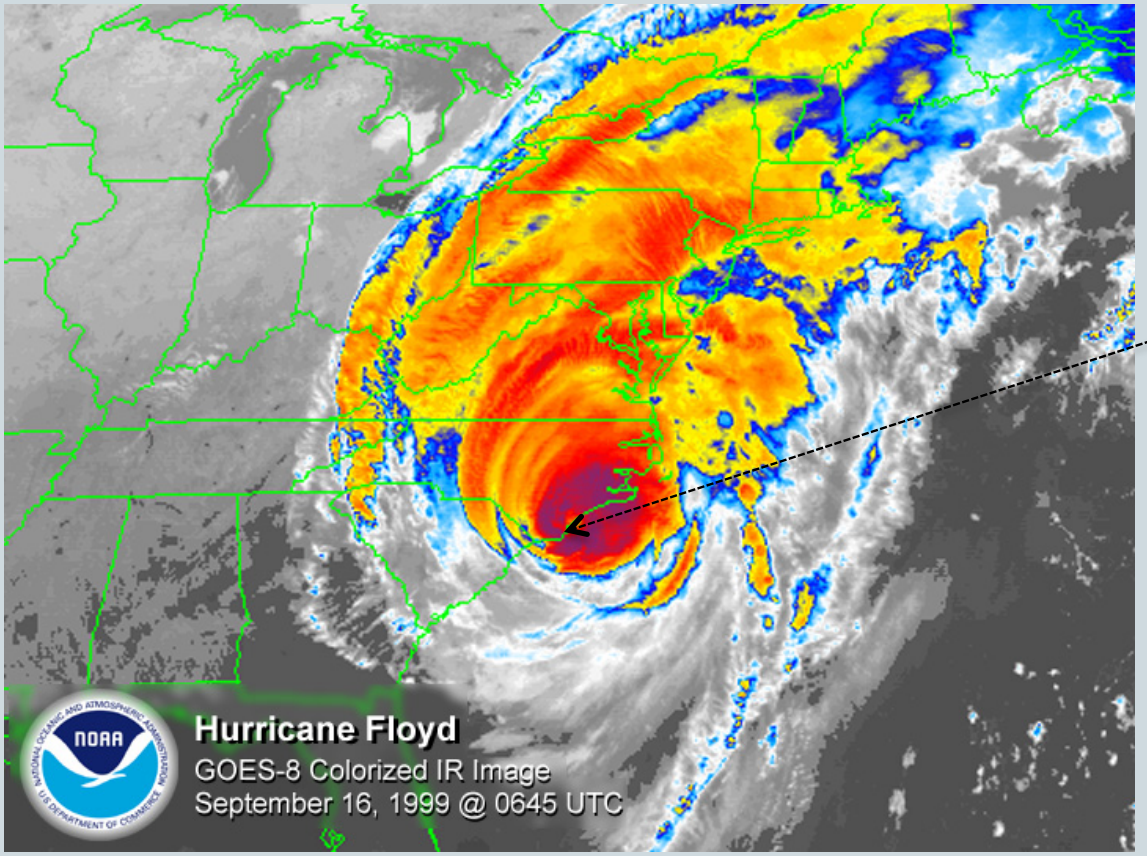


Wilmington, NC

Hurricane Fran, 1996

About Me

- Home town: Wilmington, NC



Wilmington, NC

Hurricane Floyd, 1999

About Me

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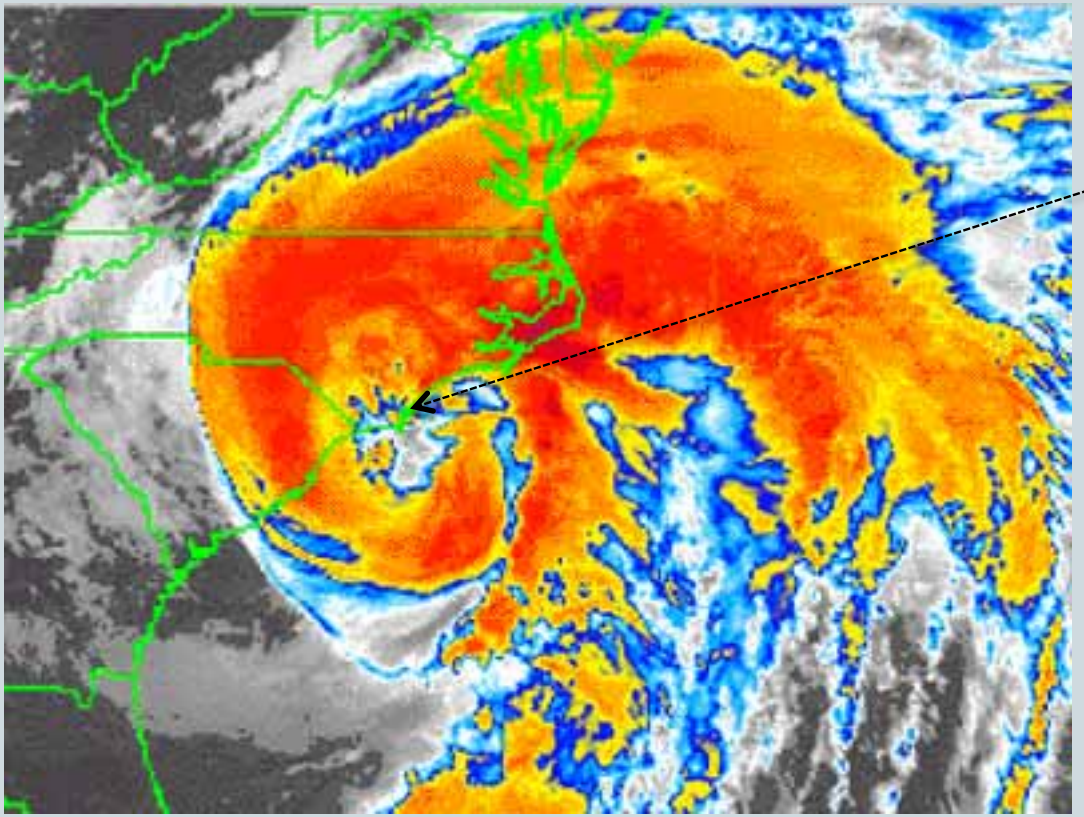

Hurricane Bertha, 1996

About Me

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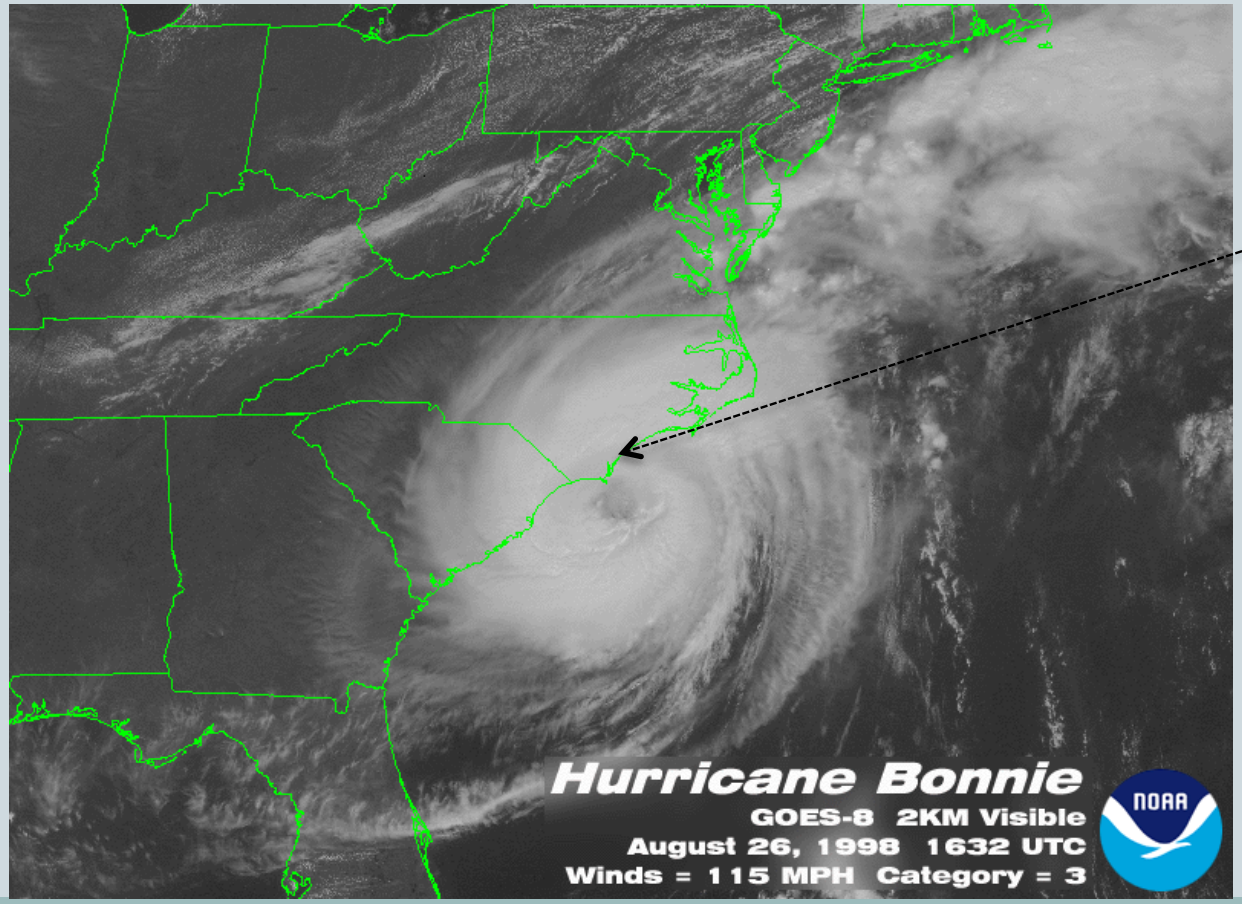
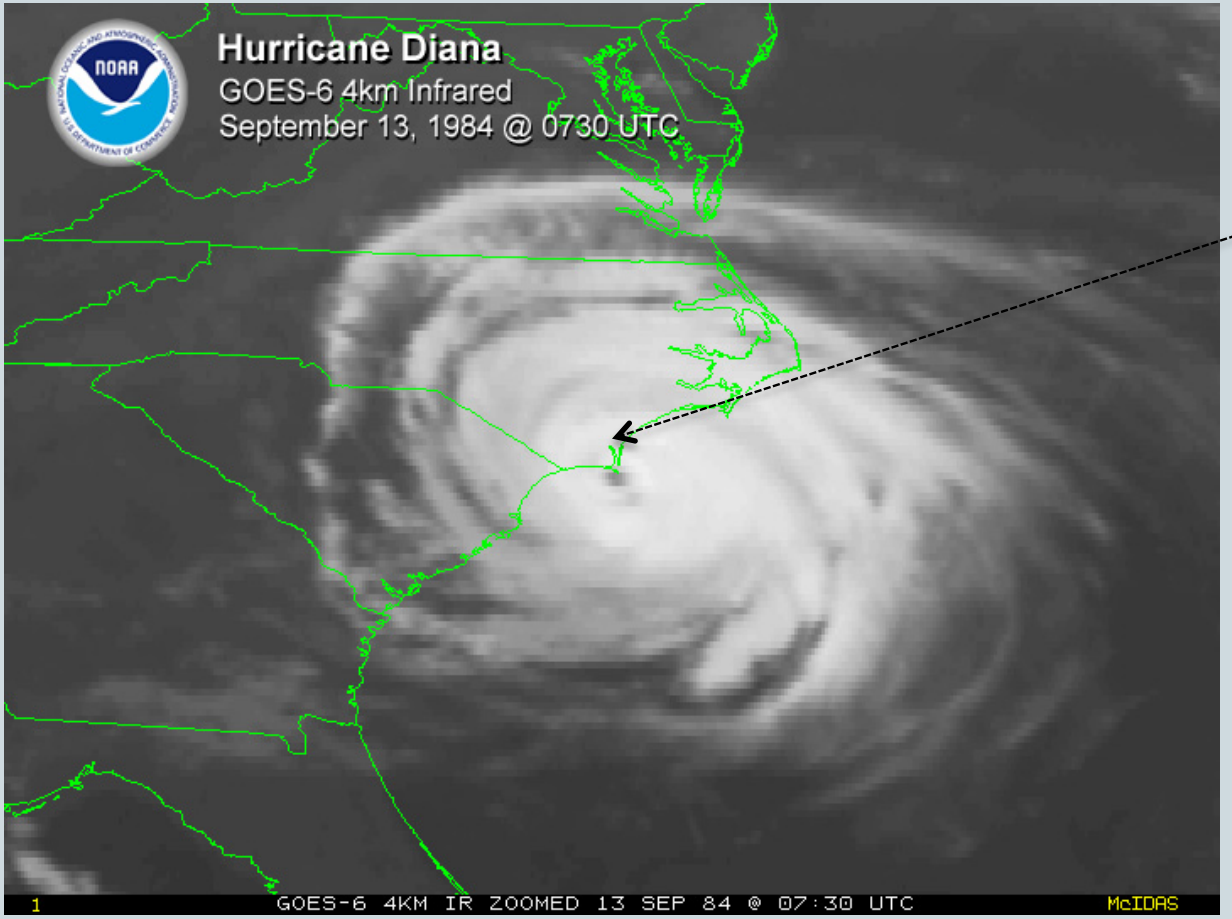


Wilmington, NC

Hurricane Bonnie, 1998

About Me

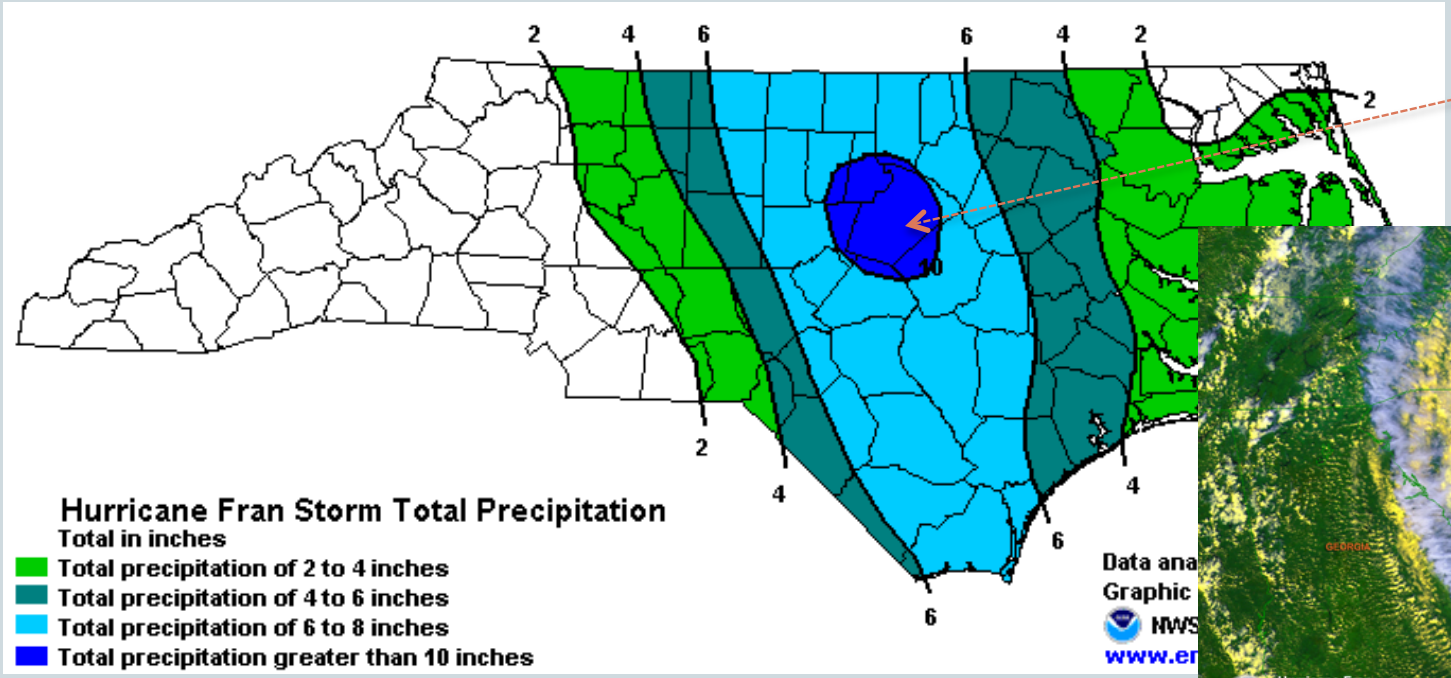
- Home town: Wilmington, NC

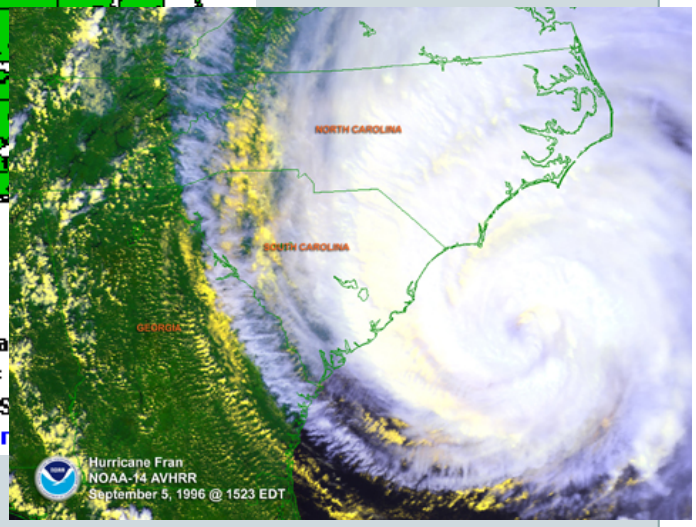


Hurricane Diana, 1984

About Me

- Undergraduate: North Carolina State, Raleigh, NC





Total precipitation from Hurricane Fran, 1996 (my freshman year)

After Grad School

- Grad school at Princeton (applied math)
- Postdoc (2 yrs) at University of Chicago
- Professor at UW starting 2007

At UW

- Research primarily on large-scale atmospheric responses to global warming
  - Both tropical and extratropical dynamics
- I love teaching!
  - I've taught Global Warming, Modeling the General Circulation of the Atmosphere, Atmospheric Motions, Geophysical Fluid Dynamics, Atmospheric Waves and Instabilities, Climate Dynamics, etc
  - Active in creating YouTube videos about atmospheric science with our outreach group

Texts

- Archer, Global Warming: Understanding the Forecast
- Brand new IPCC Report (Working Group I, Fifth Assessment Report)
  - Summary for policymakers will be posted Friday!
  - Final draft chapters will be posted Monday

Grading

- Homework/class participation: 25%
- Group presentation: 15%
  - On a chapter of the new IPCC report
- In-class midterm exam: 25%
  - Tentatively scheduled for Oct 30
- Final paper/short presentation: 35%
  - On topic of your choosing (pre-approved by professor)
  - 6-8 page paper, 5-10 minute presentation of main ideas

Course Webpage

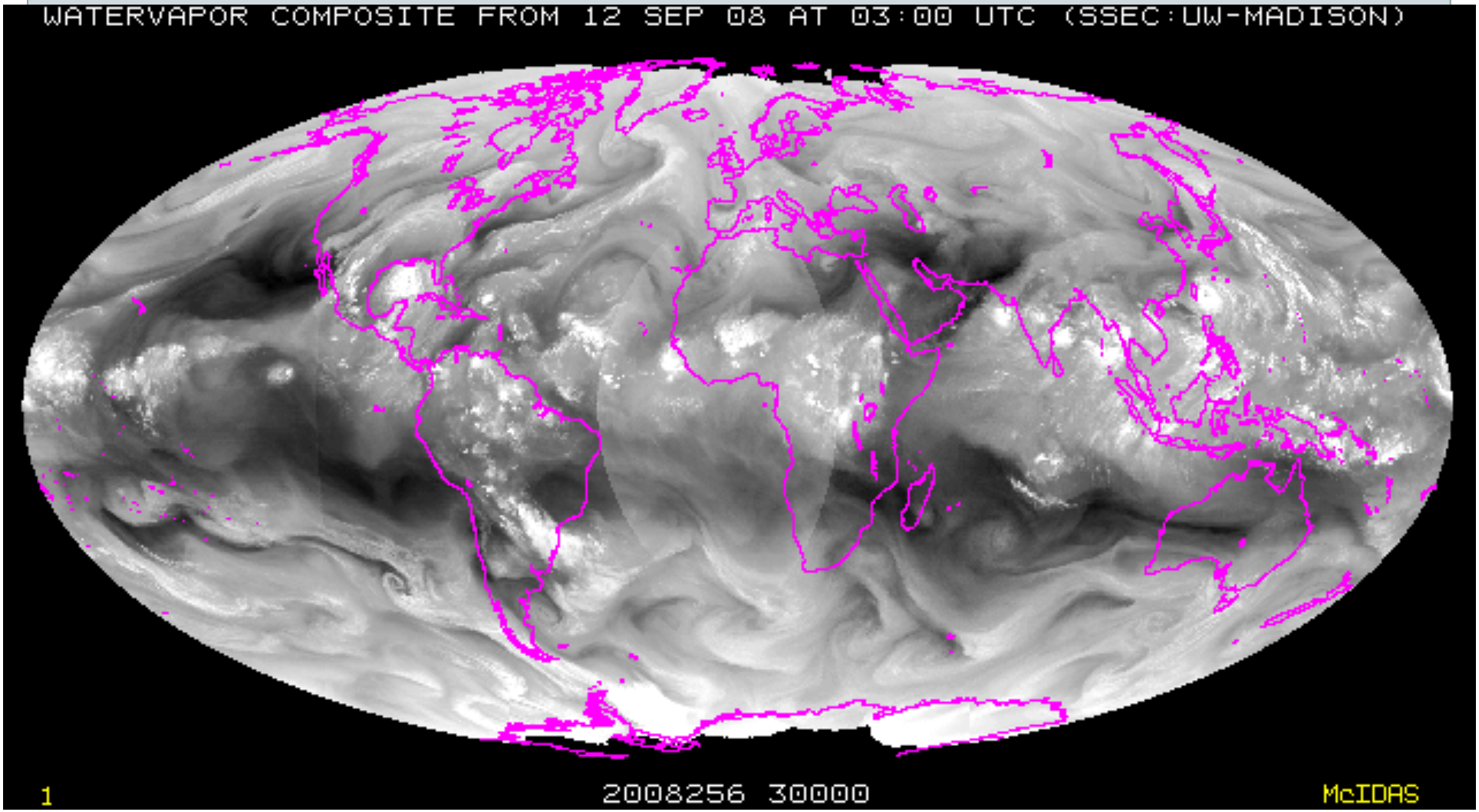
http://www.atmos.washington.edu/~dargan/587.html

Check it often! It'll have all reading assignments, links to the HW, slides from lectures, etc

First…

- A basic summary of the science of global warming
  - Reading assignment for the summary:
    - Archer Chap 1: Humankind and Climate p.1-5
    - IPCC AR5 Summary for Policymakers (as far as you can get)

The Atmosphere From Space



Weather versus Climate

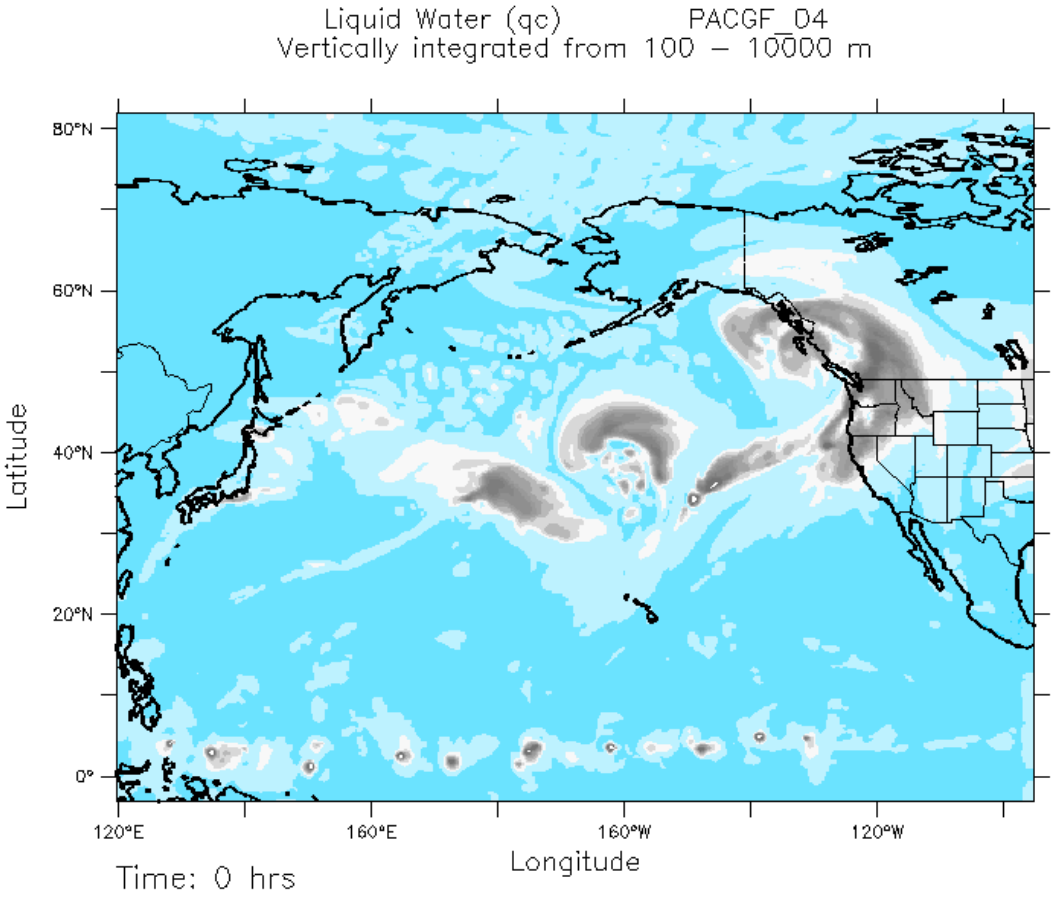
- Weather varies from one **day** to the next
- Climate: averages of the weather over a longer period of time

- Example:
  - You put on clothes for the weather…
    - Should I pack an umbrella?
  - You buy clothes for the climate…
    - *Going where the climate suits my clothes* – lyrics from Lonesome Road Blues (traditional, e.g., Henry Whitter, 1924)

- Both weather and climate can be predicted with some fidelity

Weather vs Climate

- Weather is the **individual storms**
- Climate is the fact that all of them hit western WA!



Animation of cloud thickness from a climate model

What Factors Influence Climate?

- Sunshine
  - And relatedly, latitude
- Topography/mountains
- Proximity to oceans and large lakes
- Ocean currents
- Presence of trees/vegetation
- Etc.

The atmosphere from space…

90% of the mass of the atmosphere is within 16 km (10 miles) of the surface

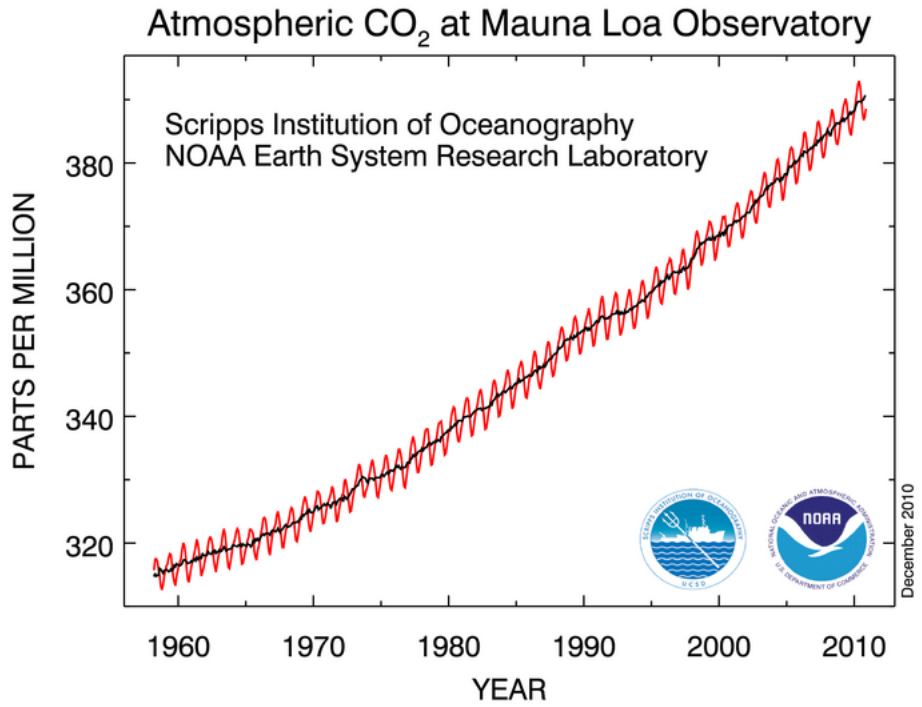
Proportionally, the atmosphere is half as thin as seams on a basketball

It's remarkably thin…

A **thin atmosphere** means **we can change** atmospheric composition

We Modify the Composition of the Atmosphere

- Carbon dioxide (CO_2) has been measured at Mauna Loa, Hawaii since 1958



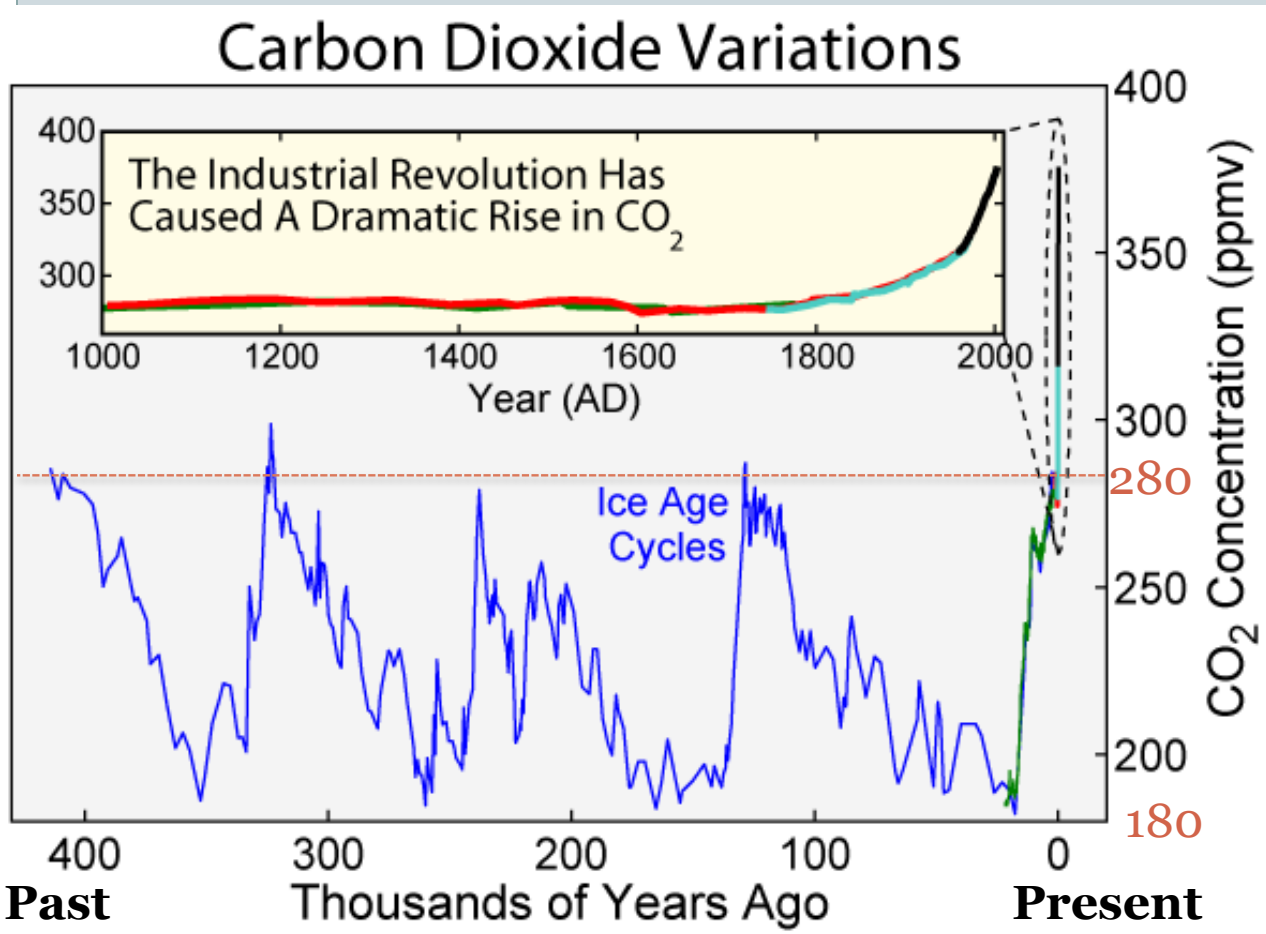
"Keeling curve": first measured by David Keeling in March '58

~ **25% increase** since the first measurement

Human induced:
Due to **fossil fuel burning** (80%) and deforestation (20%)

Let's Look Way Back to 450,000 Years

- We're over **390 ppm** now



Natural variation over Ice Age Cycles: **180-280 ppm**

Current rate of increase is **100-1000 times faster** than nature can change CO_2

Img src: Global Warming Art

CO_2 is a Greenhouse Gas

- Greenhouse gases **slow heat loss to space**
  - Has been known for a long time (J. Fourier in 1824)

Joseph Fourier

This is why it's hot

The Sun heats the Earth.

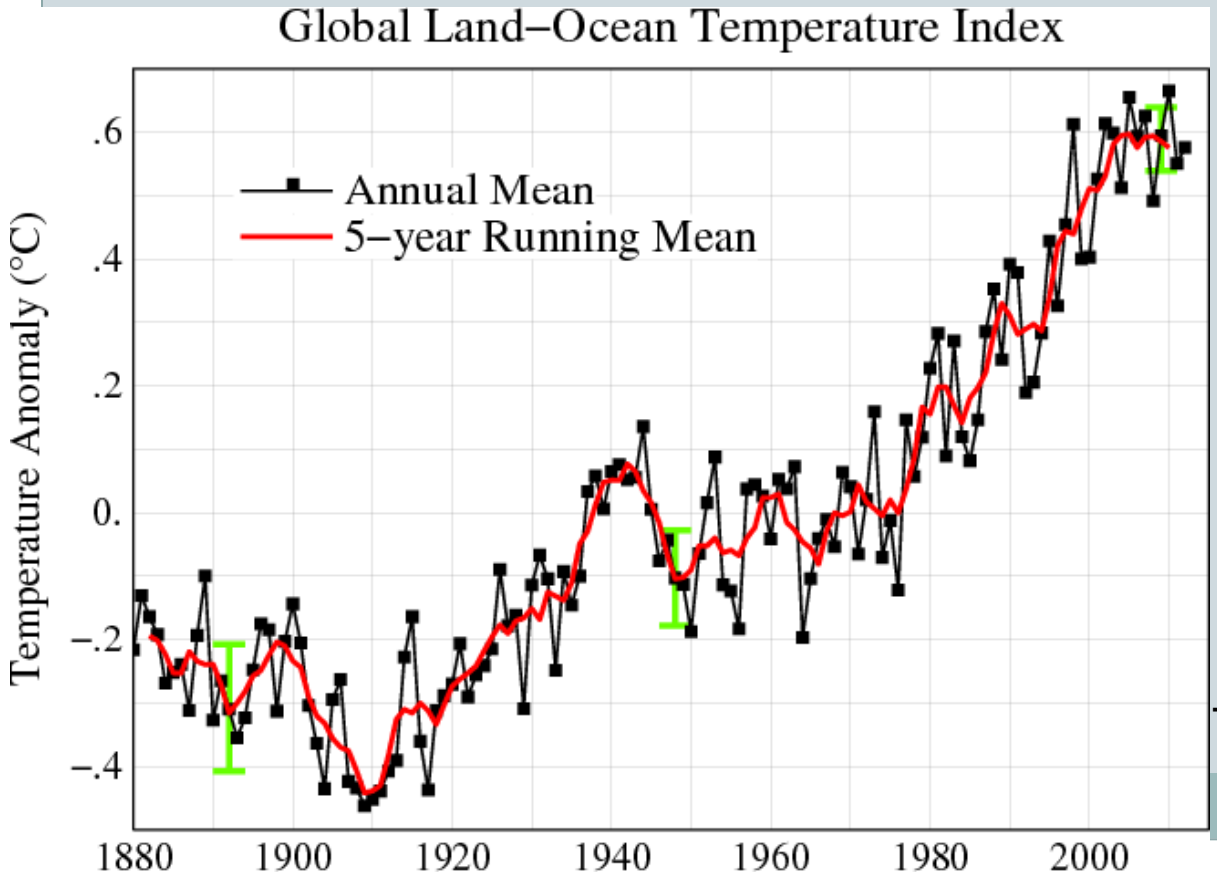
Greenhouse gases cause the Earth to be a lot warmer than if there was no atmosphere:

58° F (32° C) warmer

The natural greenhouse effect

The Earth is Warming

- More CO_2 -> warmer atmosphere (eventually)
- Has it been getting warmer?

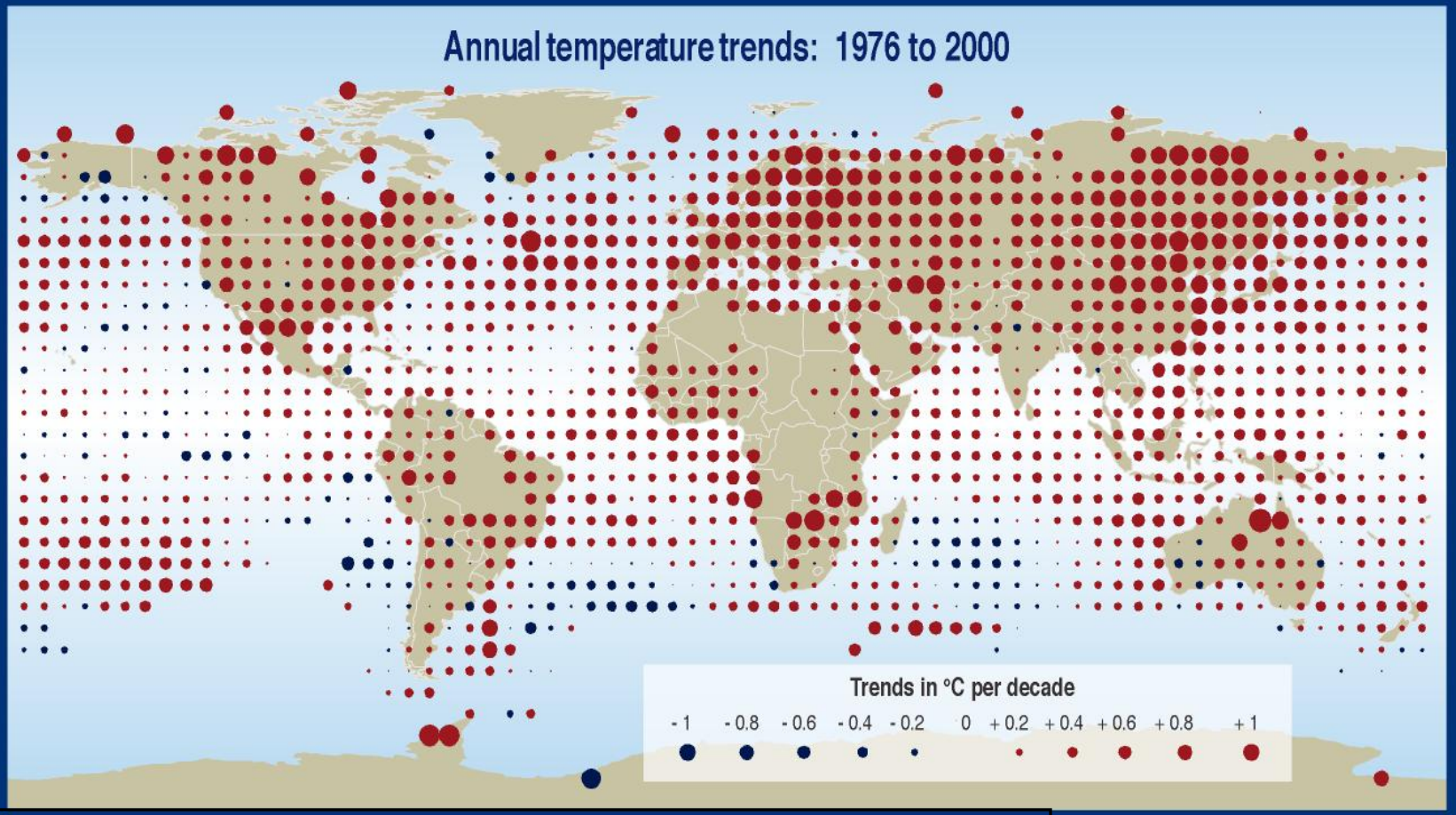


It's warmed about **0.8° C (1.5° F)** in the last 130 years

Especially rapid warming since the mid-'70s

11 out of the top 12 hottest years on record were the **Last 11 years**

Src: NASA GISS



SYR - FIGURE 2-6b

Warming has happened **almost everywhere**.
Northern high latitudes have warmed the most.
Land has warmed more than **ocean**.

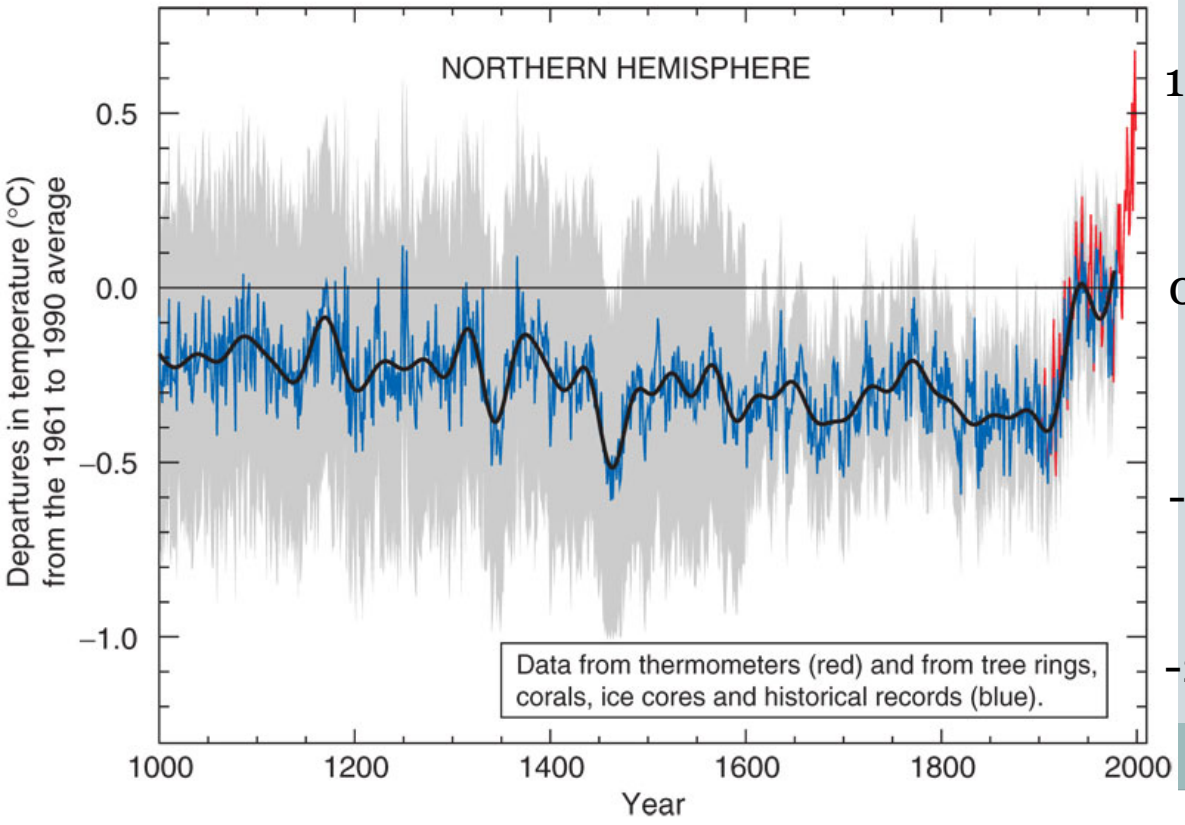
IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP

Src: IPCC AR3

Warm Compared to The More Distant Past?

- Proxy data is used for more distant reconstructions (e.g., the **"hockey stick"**):



This is **less certain**, and only represents the Northern Hemisphere (gray area indicates an uncertainty)

We'll discuss these studies and the related **controversy** more…

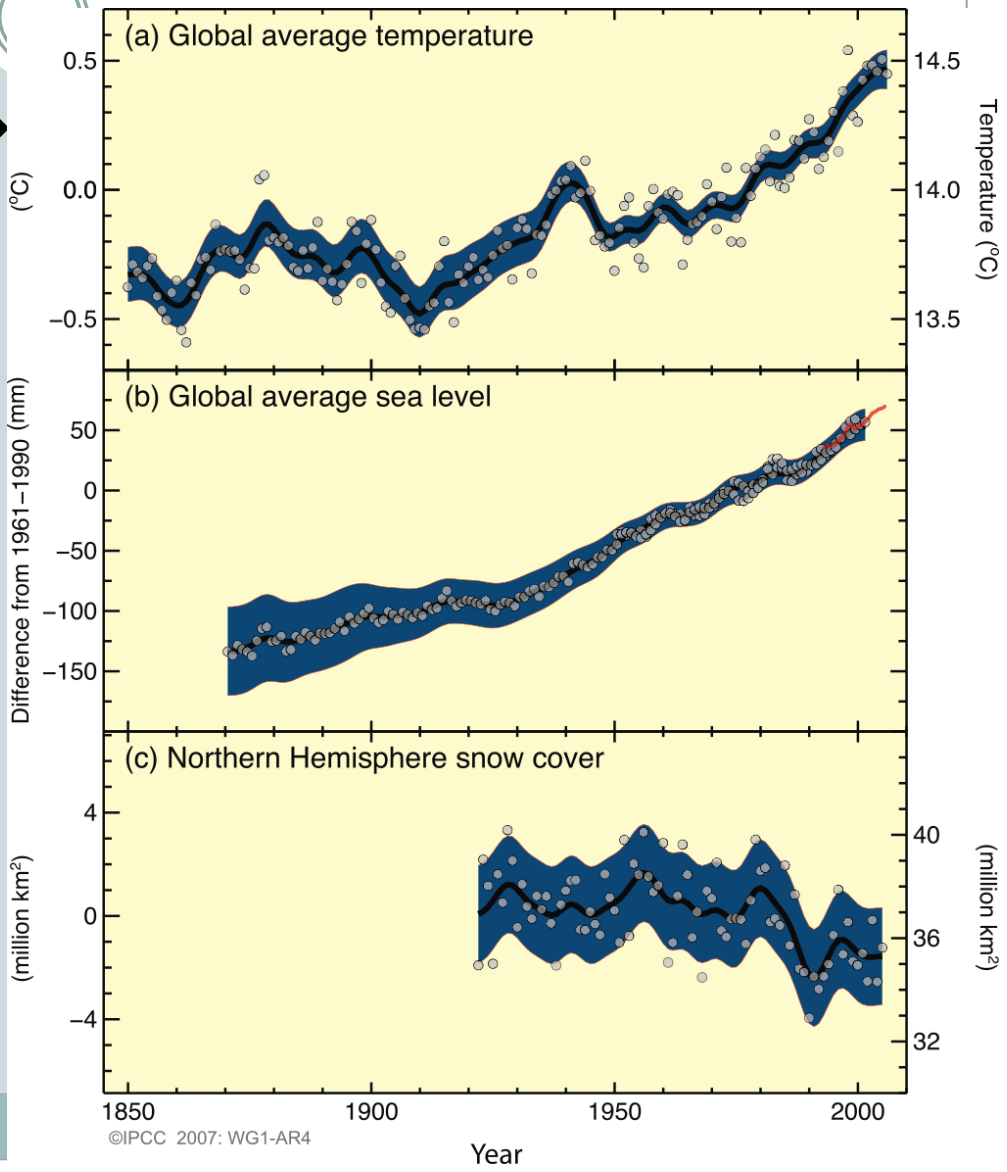
Src: IPCC AR3

What Else is Happening?

- As **temperatures** rise →
- **Sea level** is rising →
  20 cm = 8 inches
- **Snow cover** is decreasing →

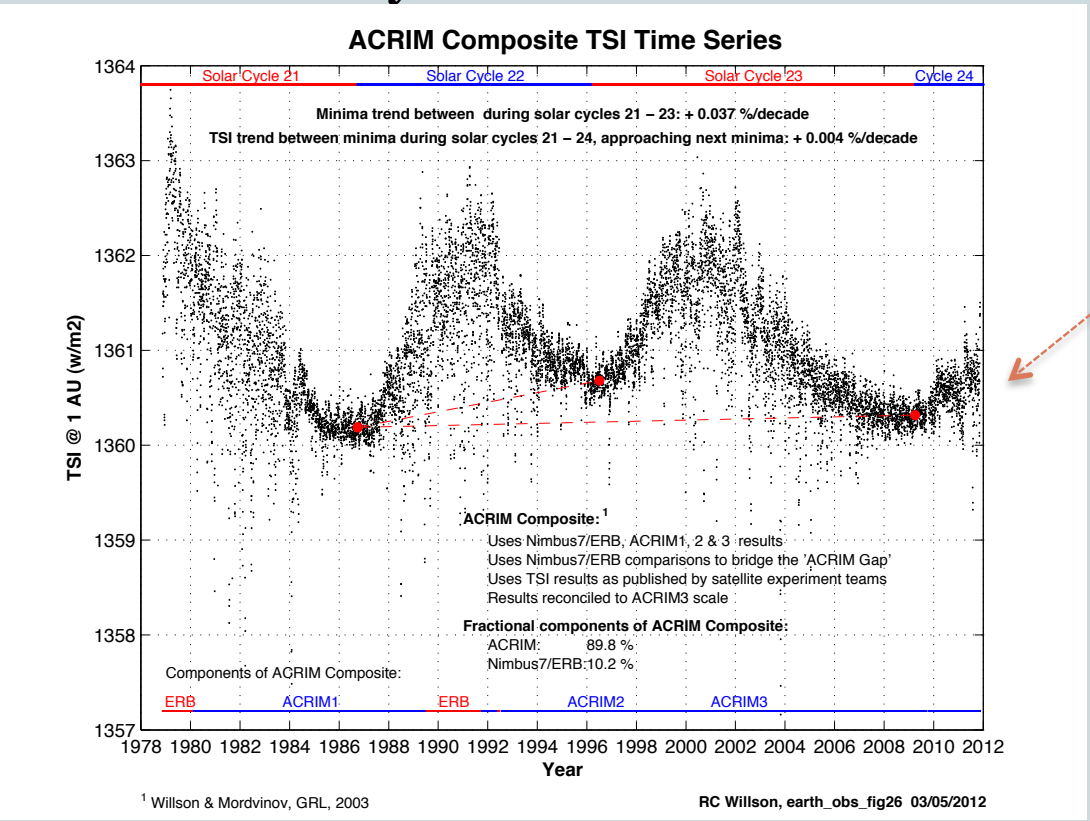
Also glaciers are melting, Arctic sea ice is melting, species are shifting, etc

Src: IPCC AR4



Could the Sun be the Cause?

- The Sun is nearly the **weakest it's been in 35 years**



Solar output

Sun is **weak** now, just coming out of a long minimum

1978 **Year** **2012**

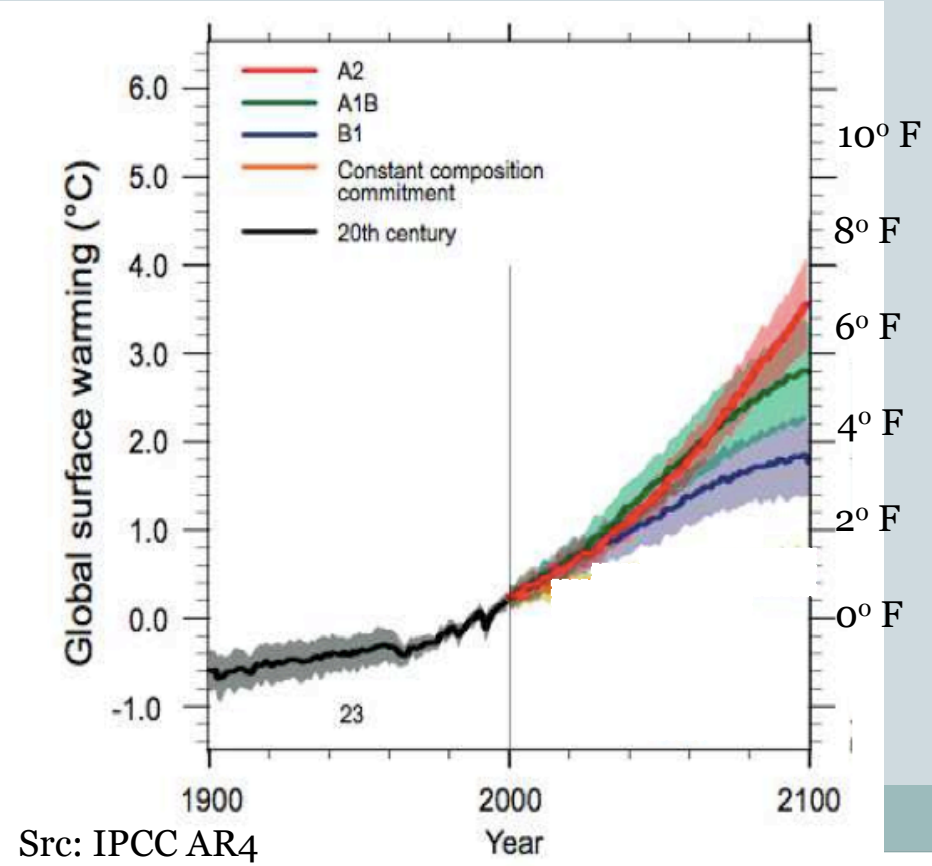
In general, **strength of solar variability is very weak** (0.1% from max to min)

What's Predicted for the Future?

- A fundamental uncertainty is future **human behavior**
  - Will we reduce emissions, or will we burn fossil fuels more and more rapidly?
  - How quickly will developing countries get rich?

Future Temperature Rise Predictions

- Uncertainty both in *human behavior* (colors) and climate *feedbacks* (shaded area around)



Src: IPCC AR4

Climate models are saying ***"you ain't seen nothin yet"***

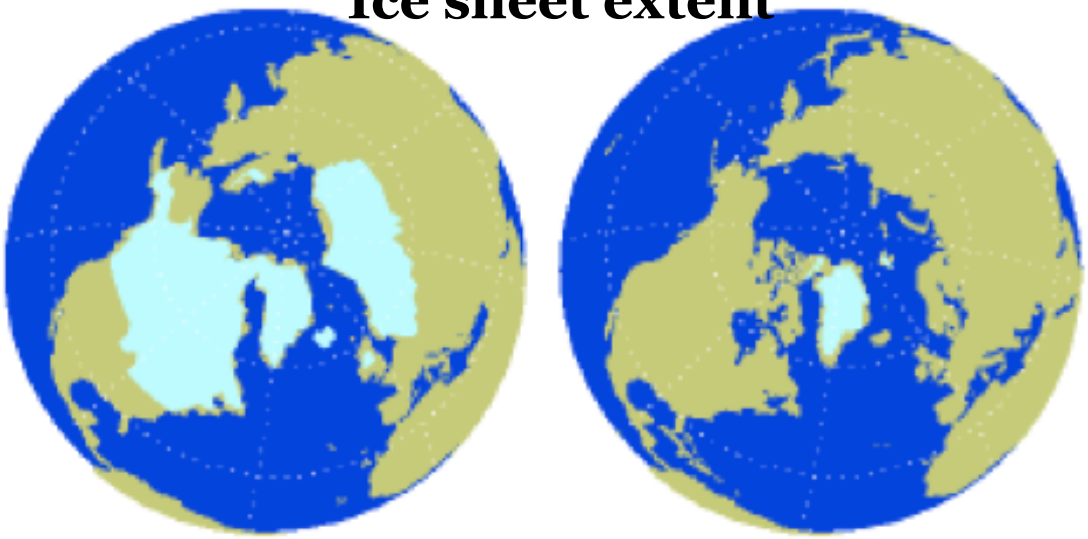
← Business as usual would mean **3-4° C (5.5-7° F)** more warming

←"Utopia": **1.5-2° C (3-4° F)** increase

A Sampling of Future Topics

- Paleoclimate:
  - **Ice Ages** and hot climates of the past like the **Cretaceous**

Ice sheet extent

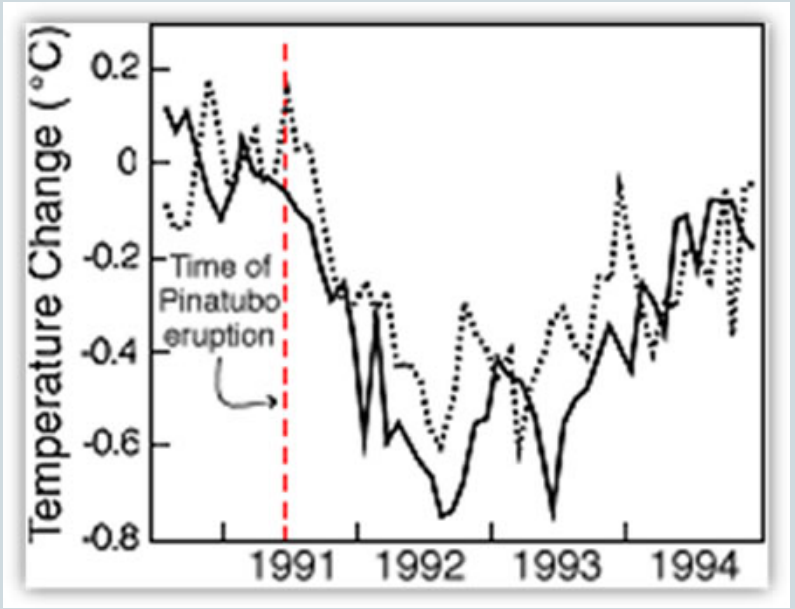


Last Glacial Maximum **Present**

The Cretaceous Seaway

Volcanoes and Climate

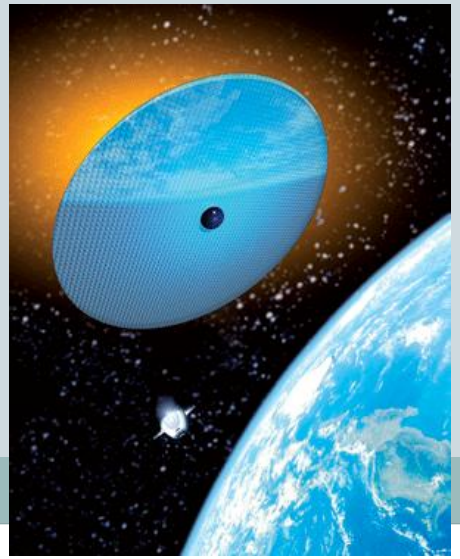
- How the Earth cools after certain types of volcanoes…



Eruption of Mount Pinatubo in June 1991 and its effect on global temperatures

And Man-Made Volcanoes!

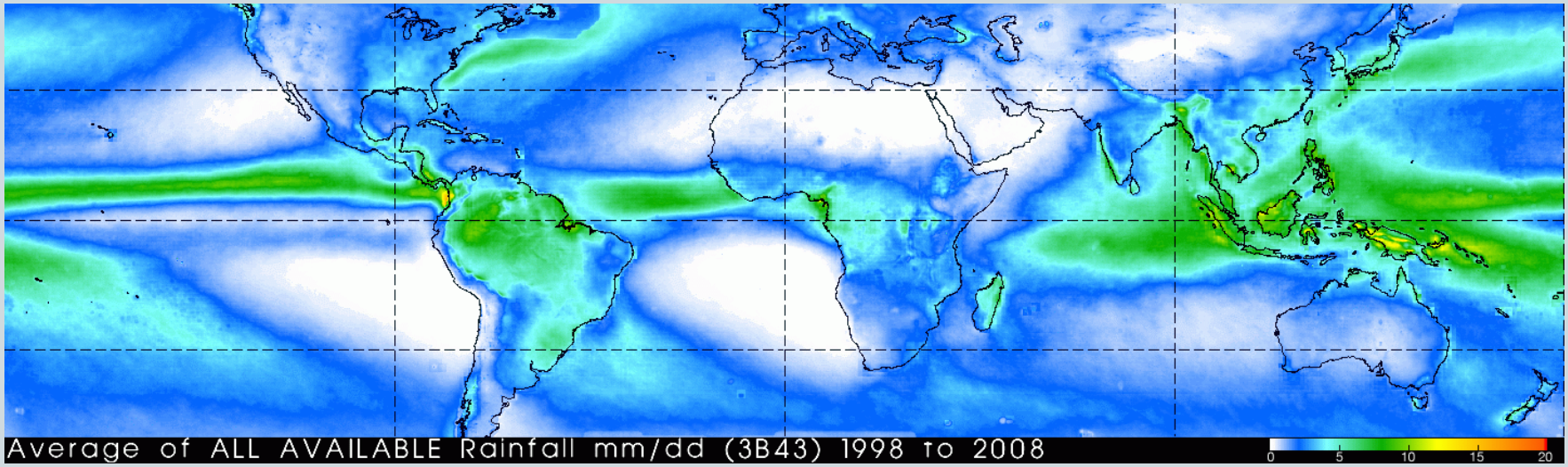
- "Geoengineering": using technology to cool the Earth
- We'll discuss strategies like
  - Putting volcanic-type particles into the stratosphere
  - Space mirrors
  - Cloud machines
  - Fake trees



Right picture from Rolling Stone article "Can Dr. Evil Save the World?"

Why is the Climate like it is today?

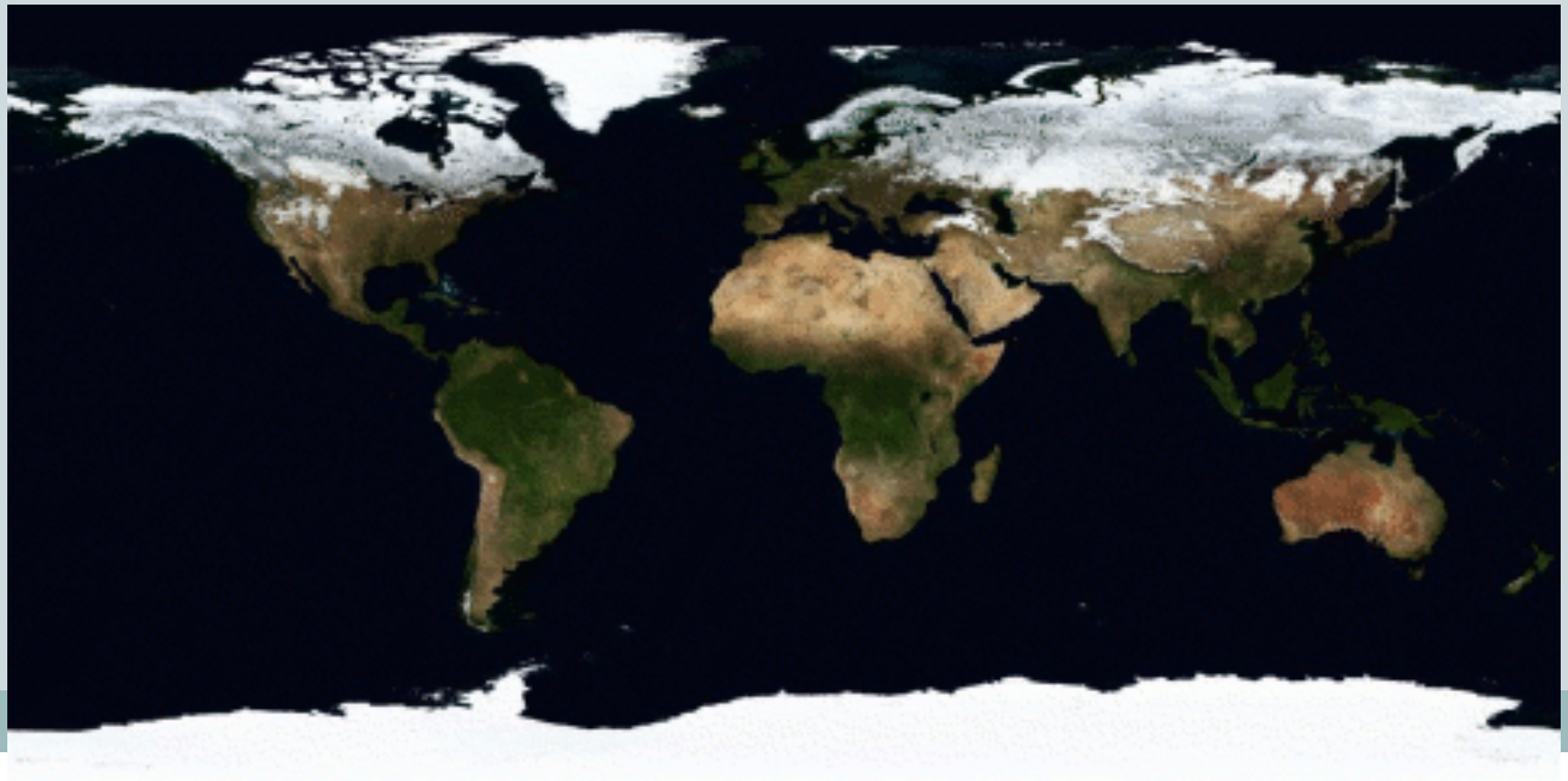
- Questions like:
  - What determines the current climate mean state?
  - Mean precipitation distribution:



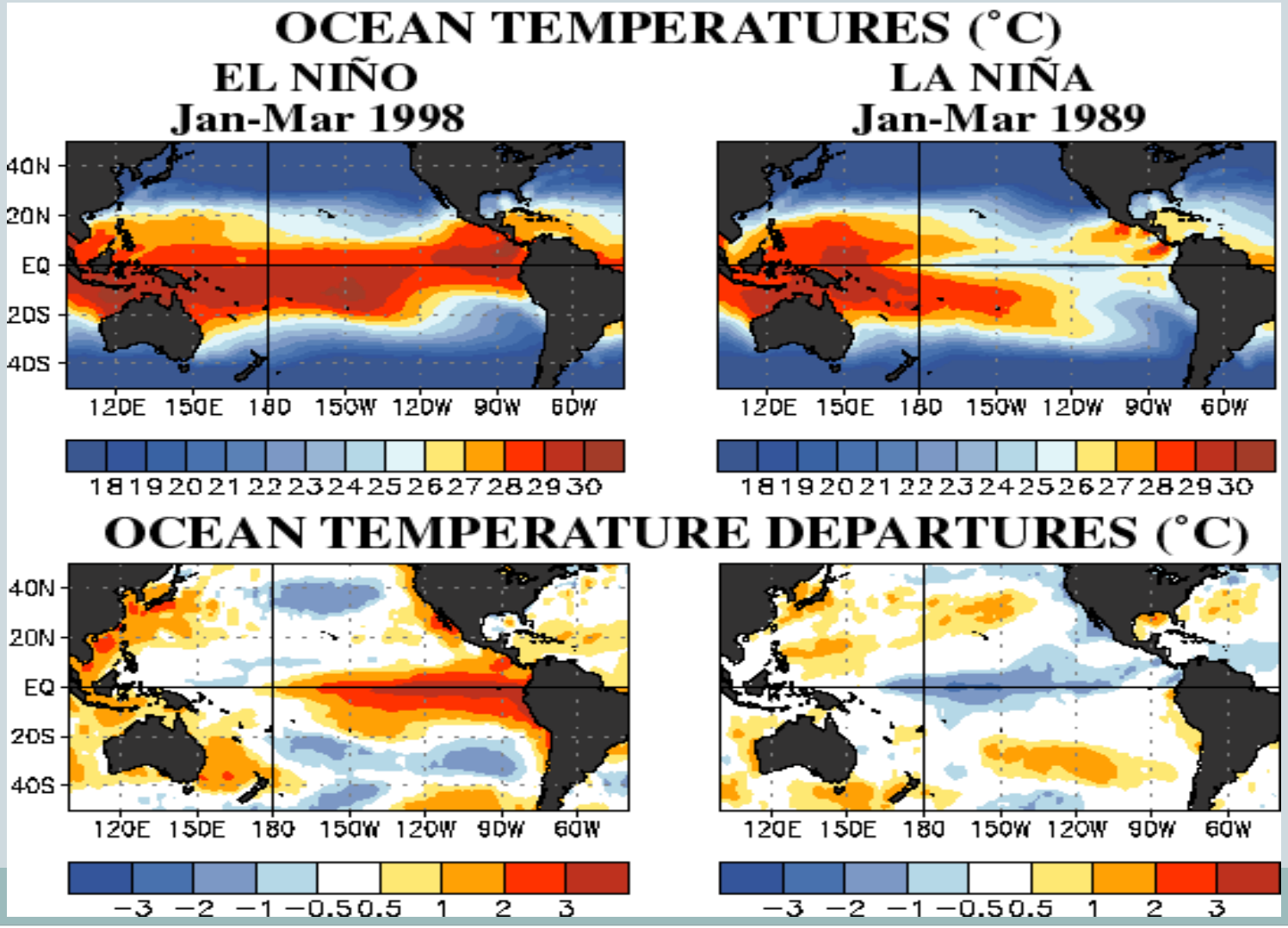
TRMM Climatology (1998-2008)

Questions like…

- Why are the rainforests of the world at similar latitudes? And why are deserts at similar latitudes?



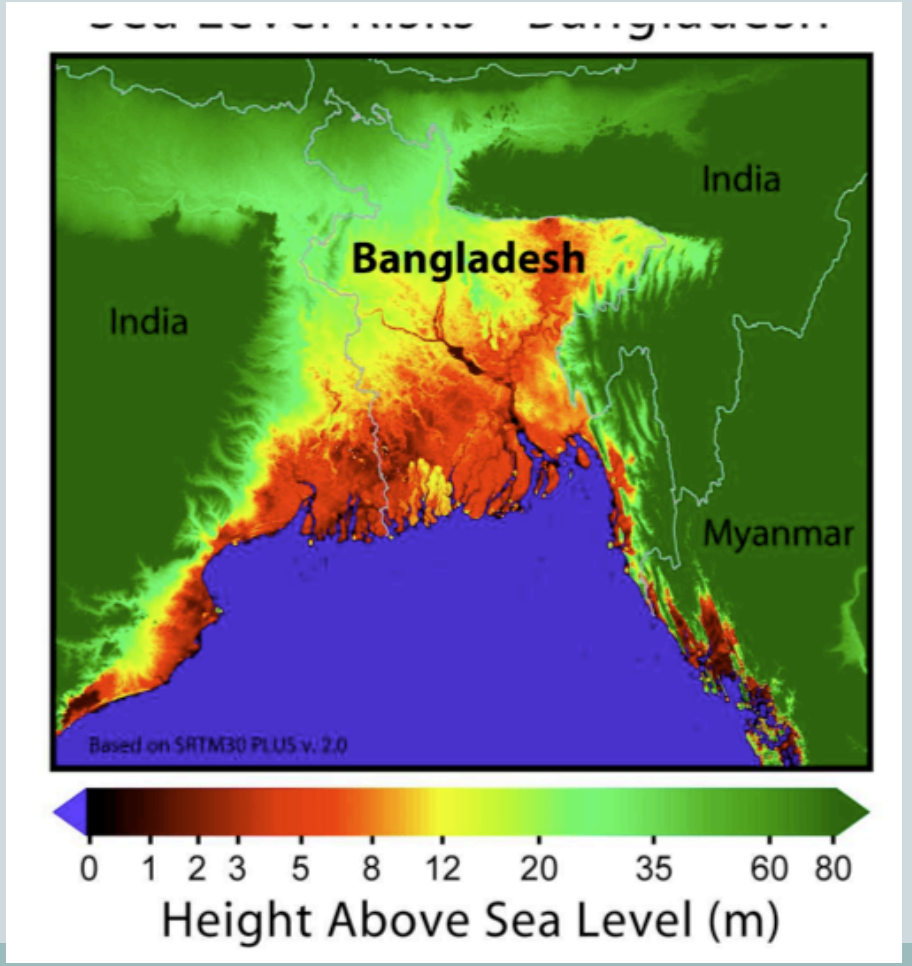
Natural Climate Variability: El Niño



Winners and Losers

- Who will benefit…

- And who will it hurt the most?

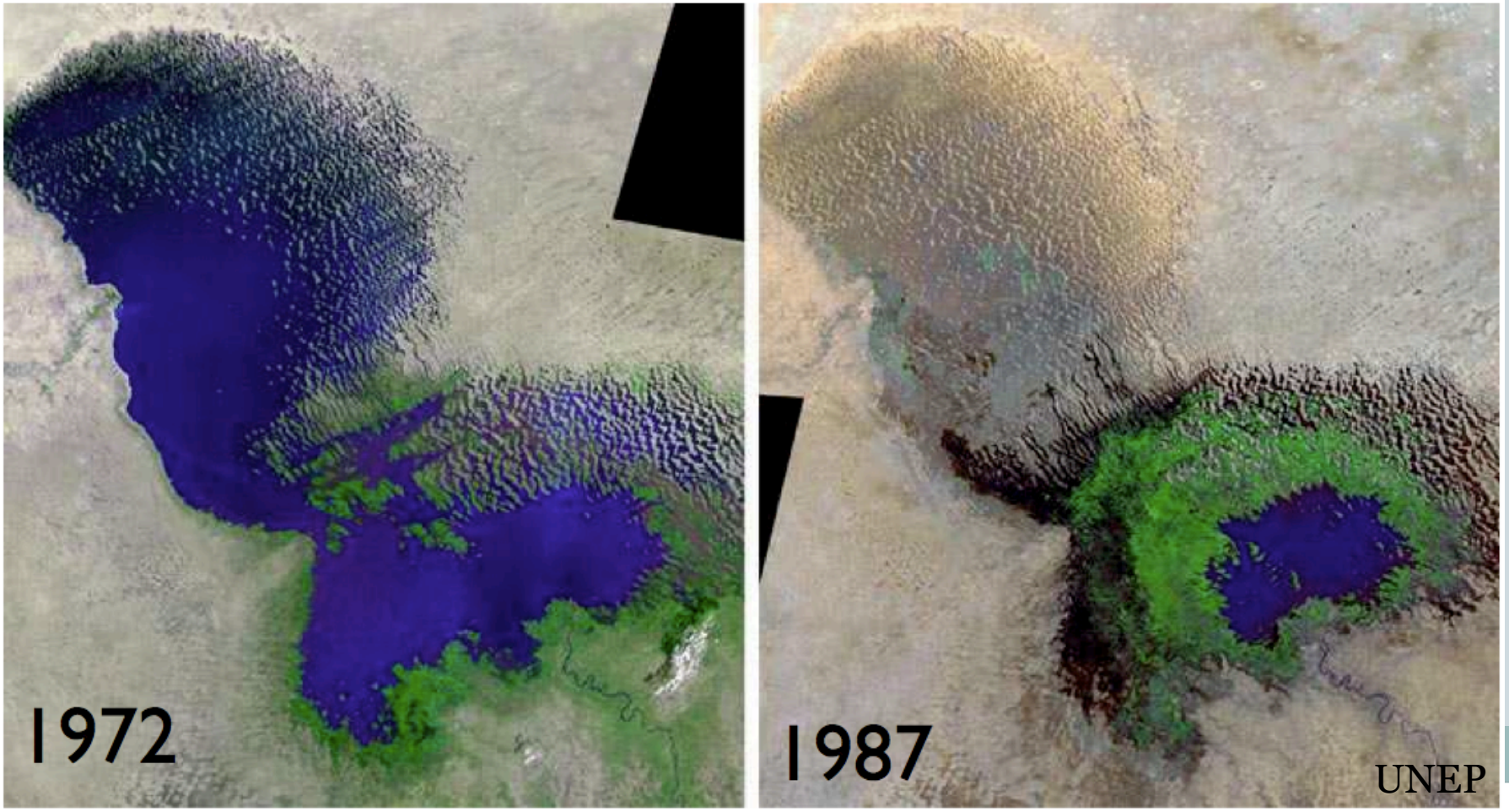


Floods

- Floods in Yemen, October 2008

And Droughts…

- Lake Chad



Let's Get Started!

- First topic: **radiation**
  - How much does the Sun heat the Earth?
  - How does the Earth come into energy balance?
  - How does the greenhouse effect work?