Climate changes (1900 to 2000) due to human activity

HOW DO WE KNOW THIS?

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]

Virtually certain > 99%
Very likely >90%
Likely >66%
More likely than not > 50%

IPCC 2007

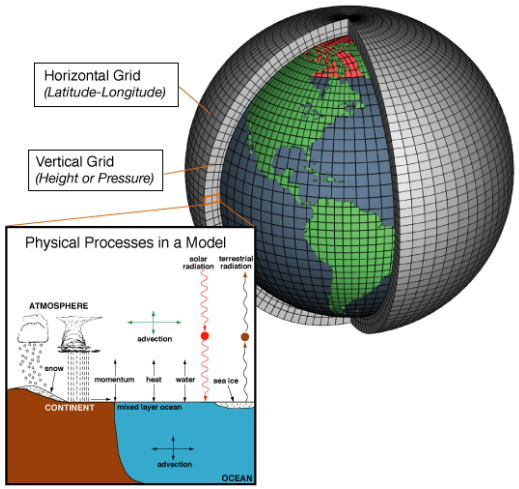
Climate Models

- What is a climate model?
- How long have they been around?
- How good are they?

Climate Models

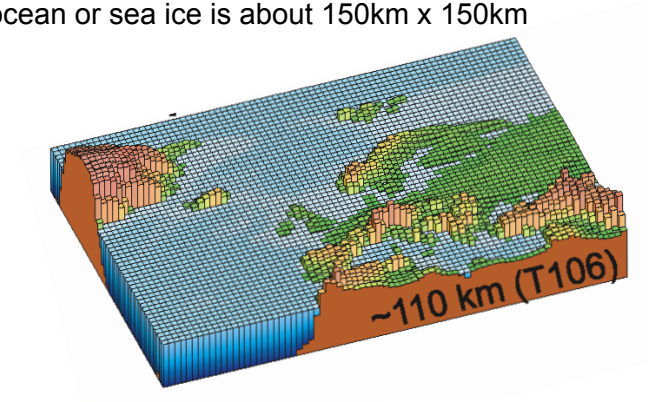
- What is a climate model?
  - Mathematical representations of the atmosphere, ocean, sea ice and land surface
  - For each component, the model is based on the laws of physics and chemistry. For example,
    - the models conserve energy, mass, momentum. They obey the laws of physics (e.g., F=ma) and chemistry
    - Radiation (solar and terrestrial) is based on detailed theory (quantum mechanics).
    - Concentrations of some gases are prescribed because they change very very slowly (N_2, O_2, Ar, CFCs, etc)
    - Other gases are sometimes prescribed and sometimes calculated by the laws of chemistry and thermodynamics
  - The equations are hopelessly complicated to solve by pen and pencil ("analytically"), so we solve them numerically
  - The equations can't be solved at a molecular level, so the climate system is chopped up regular chunks

Climate Models



Climate Models

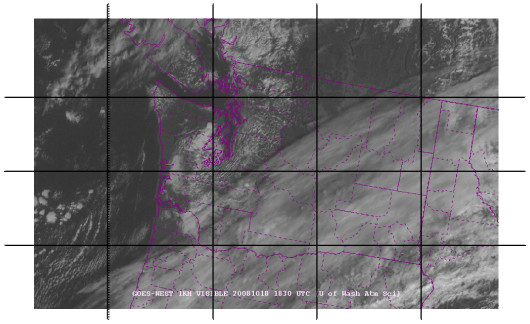
- The current size of a chunk of atmosphere, land, ocean or sea ice is about 150km x 150km



The vertical extent of a box is typically:
Atmosphere/Ocean: 80-500m Sea Ice: 50cm Land: 10cm

Climate Models

- The physical and chemical laws are solved in each of these chunks.
  - Within each chunk, there are things that are not explicitly modelled (e.g., clouds) but must be approximated ("parameterized") as a function of the average state of the chunk (e.g, the fraction of clouds in the chunk as a function of the chunk's temperature, pressure, wind, humidity)



Climate Models

- Information in one chunk affects another because of *motion*
  - Wind (atmosphere)
  - Flow (ice, rivers, groundwater movement)
  - Currents (ocean)

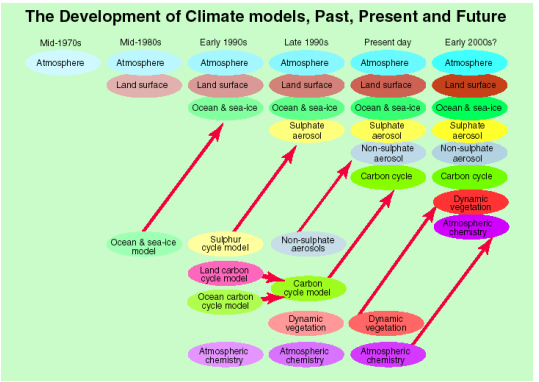
- Motion, in turn, is due to pressure differences that result from temperature differences

- These calculations require enormous computer resources
  - For example, a 100 year run of a typical IPPC AR4 climate model takes

    * Nine months on the world's fastest machines
    * 150,000 Gbytes of disk space (minimal output)

Climate Models

- What is a climate model
- How long have they been around?

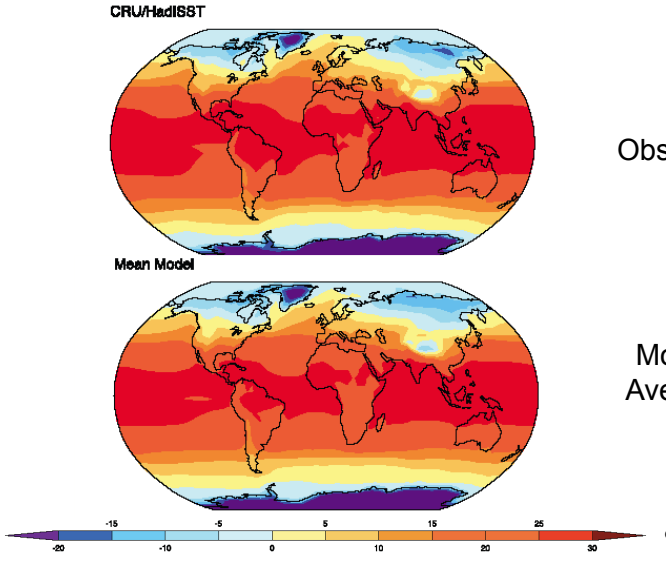


Climate Models are based on the laws of physics and chemistry, and used for ~40 years for various problems.

Climate Models

- What is a climate model?
- How long have they been around?
- How good are they?
  - Some examples from 14 of the 23 climate models used in the most recent IPCC report: Assessment Report #4 (AR4) in 2007.

Annual Average Surface Temperature



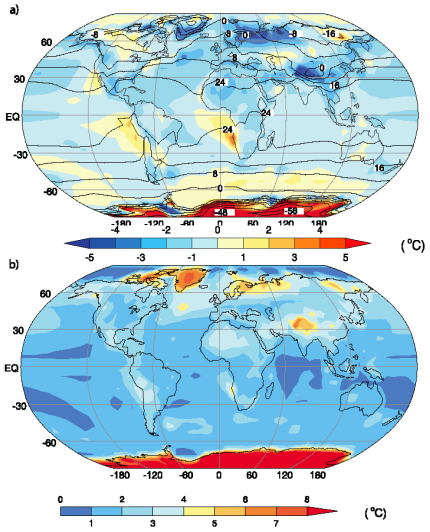
Observed

Model Average

°C

IPCC 2007

Annual Average Surface Temperature



Contoured = Observed

Shaded = error in 'average of the models'
(simulated minus observed)

Error in typical model

IPCC 2007