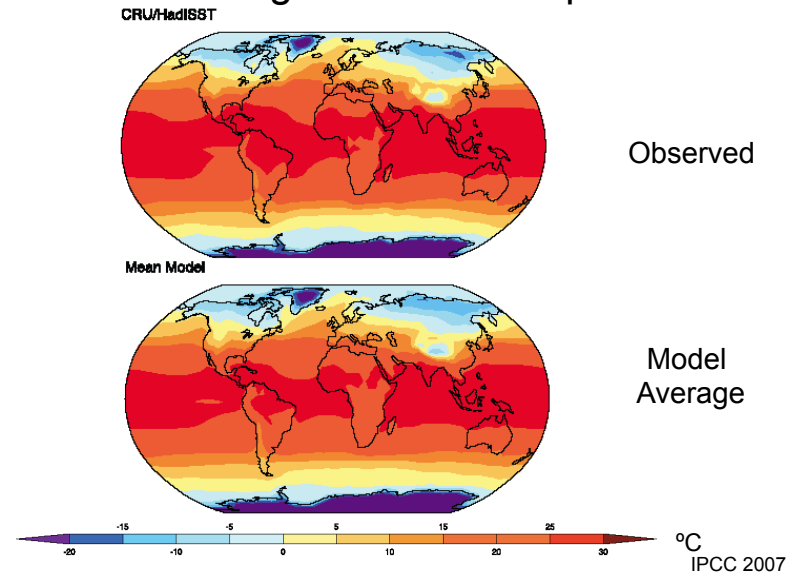


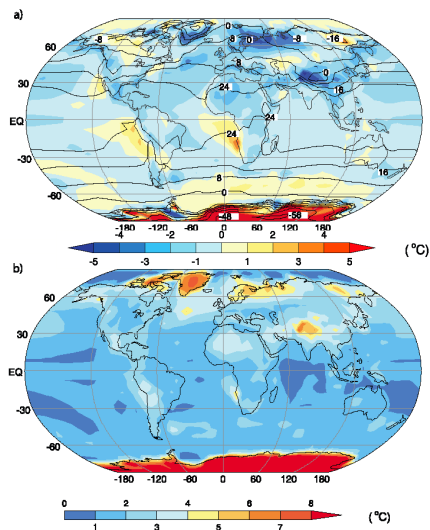
Climate Models

- 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



Annual Average Surface Temperature



Contoured = Observed

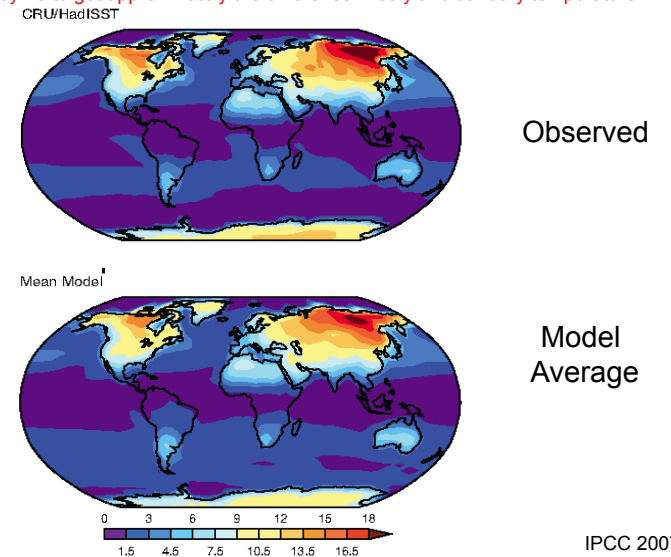
Shaded = error in 'average of the models' (simulated minus observed)

Error in typical model

IPCC 2007

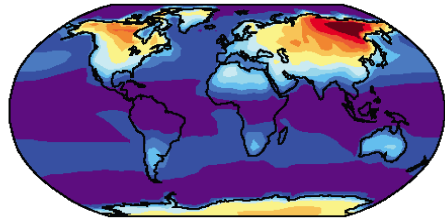
“Annual Cycle*” in Temperature

* Multiply by ~3 to get approximately the difference in July and January temperature

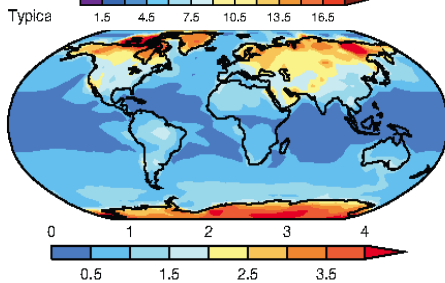


“Annual Cycle*” in Temperature

* Multiply by ~3 to get approximately the difference in July and January temperature
 CRU/HadISST



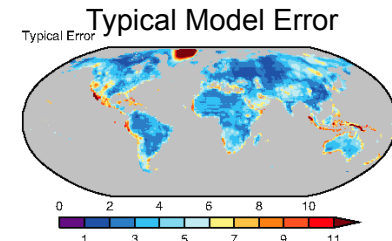
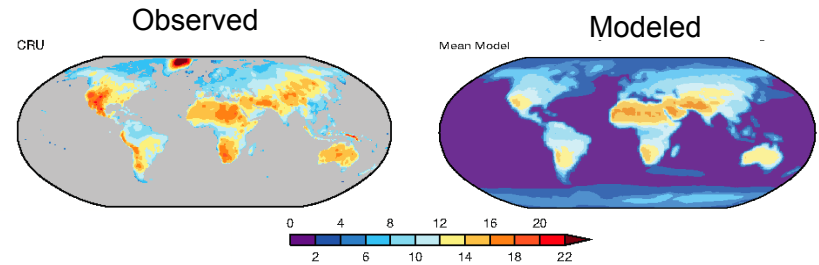
Observed



Typical Model Error

IPCC 2007

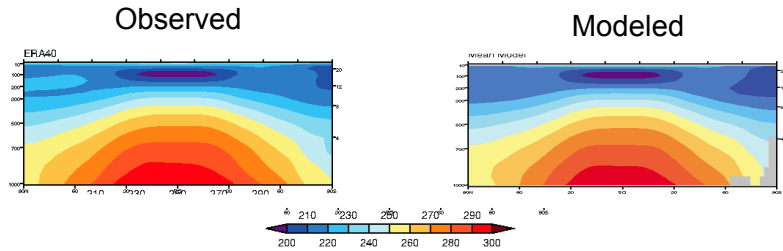
Diurnal (day-night) temperature range



Typical Error

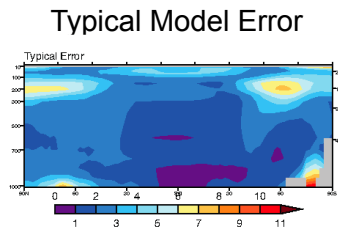
IPCC 2007 Fig. S8.3

Atmospheric Temperature Zonal (east-west) average



Observed

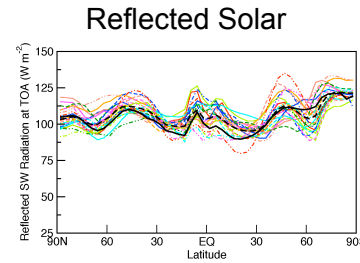
Modeled



Typical Model Error

IPCC 2007

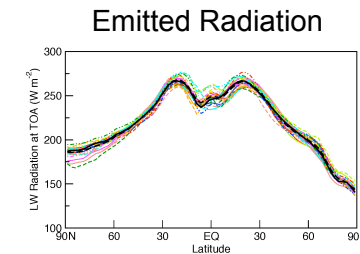
Top of the Atmosphere Radiation Flux (averaged in the east-west direction)



Reflected Solar

- One color line for each model
- Black dashed line for ‘average of models’

• Error

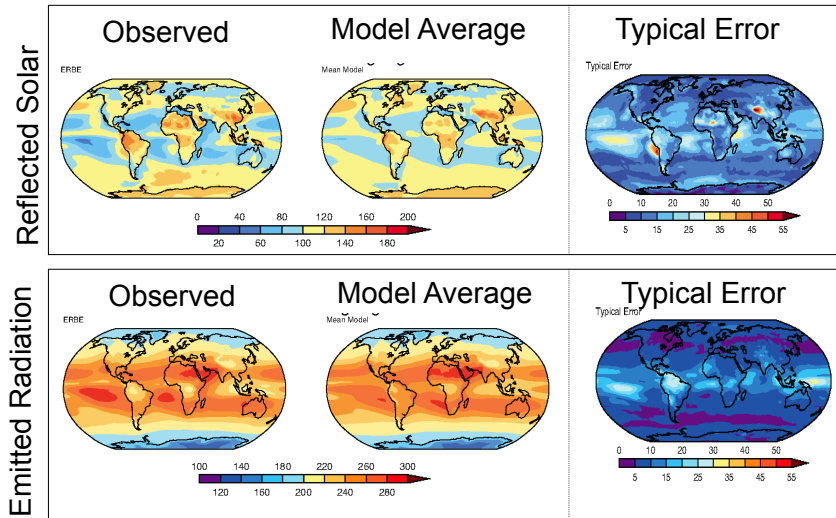


Emitted Radiation

typically 10-15 W/m²
 (10% in reflected shortwave and 5% in emitted outgoing longwave radiation)

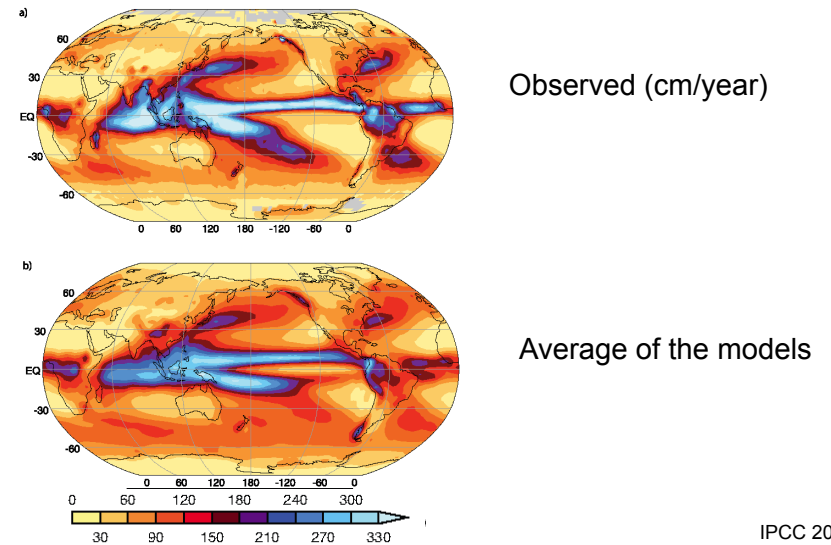
IPCC 2007

Top of the Atmosphere Radiative Flux



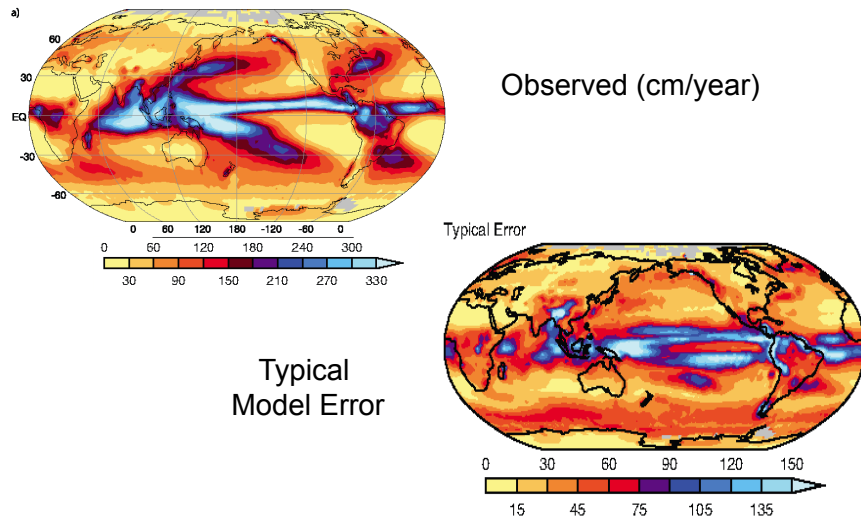
IPCC 2007

Annual Average Precipitation



IPCC 2007

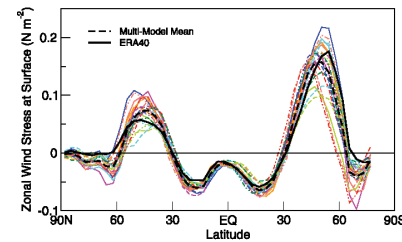
Annual Average Precipitation



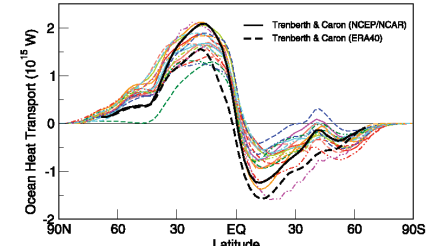
IPCC 2007

Surface Wind Stress and Ocean Heat Transport

Zonal Average Surface Wind Stress



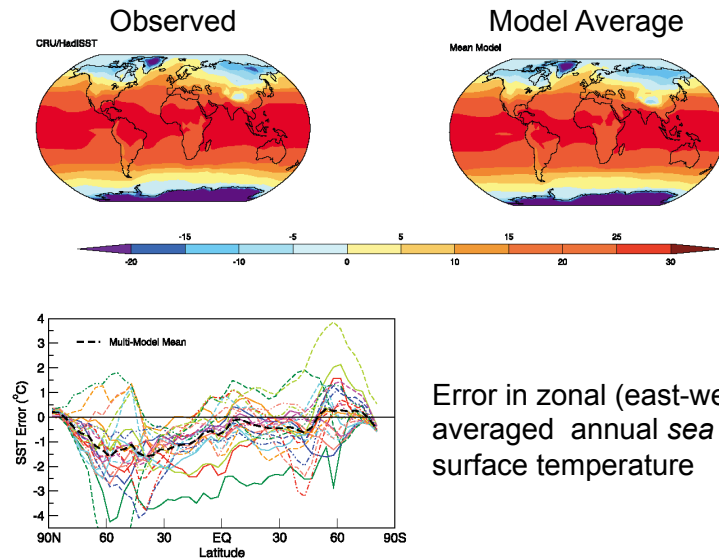
Northward Ocean Heat Transport



One color line for each model

IPCC 2007

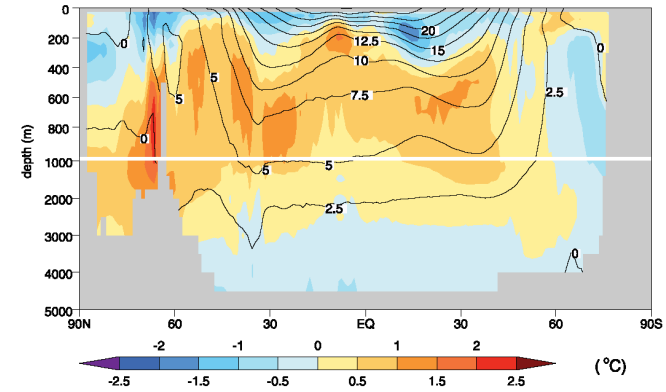
Annual Average Surface Temperature



Error in zonal (east-west) averaged annual sea surface temperature

IPCC 2007

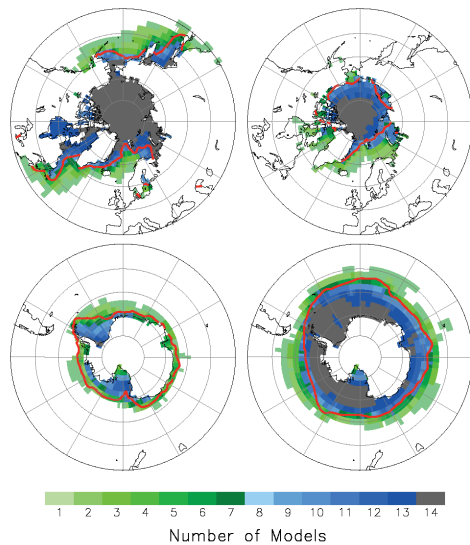
Vertical Distribution of Ocean Temperature



Contours = observed temperature
Color = error in the 'average of the models'

IPCC 2007

Sea Ice Extent



- Red line demarks the position of the 15% sea ice coverage at the end of winter from observations
- Color is the number of models that have at least 15% sea ice coverage

Baseline for observations 1980-1999

Grid size for calculating sea ice coverage is 2.5 x 2.5 latitude-longitude

IPCC 2007

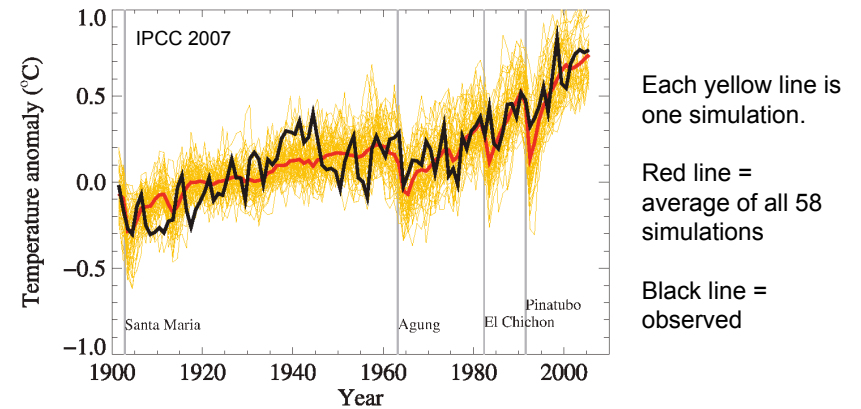
Natural Variability

- The models simulate accurately the weather on 200km scales
- The models simulate accurately the natural patterns of variability in the atmosphere on 200-1000km scales
 - North Atlantic Oscillation, the eastern Atlantic pattern, the Pacific North American pattern, the Western Pacific pattern, etc
- The models do very poorly the El Nino/Southern Oscillation (ENSO) phenomenon
- The models do poorly in places where topography changes markedly on scales that are smaller than the atmospheric grid (e.g., Puget Sound)
 - In these cases, useful information can be obtained by 'downscaling' (mainly for temperature; precipitation in only some cases)

More test of the Models

- They have been used to simulate climates of the past and evaluated against the paleo (proxy) data
 - The Early Holocene: 6000 and 8500 years before present (yr BP), when the Sahara was green
 - The Last Glacial Maximum: 23,000 yr BP, the maximum extent of the most recent glacial period
 - Used to evaluate the relative contributions of changes in insolation, land ice (albedo) and carbon dioxide (180ppm vs 280ppm pre-industrial) to the climate changes.
 - The Eocene: 65 million yr BP, when the earth was ice free and much warmer than today (by ~10-15°C) and CO₂ levels were 2-4 times more than today.
 - Note the AR4 models used to do this systematically underestimate the warming of the Eocene
- They have been used to simulate the climate of the 20th Century

Simulating the Global Average Temperature over the 20th Century



Simulations include natural (solar and volcanic) and human (carbon dioxide, etc) forcing
14 models were used in this figure with a total of 58 simulations

Climate Models: Summary

- Based on the laws of physics and chemistry
- They do some things very well
 - Temperature (in general, they do better on larger space & time scales
 - Diurnal: good
 - Weekly and longer time scale (100km to continental scales): very good
 - Global scale: excellent
 - Storm tracks in the midlatitudes
- Some things ok
 - Natural variability in the midlatitudes (especially winter)
 - Snow
- And some things not so well
 - Precipitation
 - Midlatitudes: good
 - Tropics: poor to fair