Climate modeling

• Current state of climate knowledge
  – What does the historical data (temperature, CO$_2$, etc) tell us
  – What are trends in the current observational data
  – What do we know about the greenhouse effect
Modeling

• What constitutes a climate model?
Input to models: Emission scenarios of carbon SO2, particles, etc

Models calculate the atmospheric concentration of GHGs, aerosol, etc

Models determine the impact of the species interacting with shortwave and long-wave radiation

The atm. parameters such as temp, precip, etc are then determined considering global circulation patterns, etc

Source: IPCC, 2007
The World in Global Climate Models

Mid-1970s

- CO₂
- Rain

Mid-1980s

- Land Surface
- Prescribed Ice
- Clouds

FAR

- Volcanic Activity
- Sulphates
- "Swamp" Ocean

SAR

- Ocean

TAR

- Carbon Cycle
- Aerosols
- Rivers
- Overturning Circulation

AR4

- Chemistry
- Interactive Vegetation
The lack of adequate knowledge on aerosol-cloud interactions is a critical uncertainty in global climate modeling.
The development of climate models, past, present and future

Source: IPCC, 2007
Current state of GCMs

Schematic for Global Atmospheric Model

Physical Processes in a Model

Source: IPCC, 2007
Climate models

• Four components:
  – Atmosphere, land surface, ocean, and sea ice.

• Atmospheric and Oceanic components – Global circulation models (GCM)
  – Simulate large scale circulation of the atmosphere and the oceans.
  – Important variables
    • Temperature, pressure, humidity, winds, and water and ice condensate in clouds
Computational details

• Typical Atmospheric global circulation models (AGCMs):
  – Spatial resolution of ~ 100 km in the horizontal
  – 30 levels in the vertical atmosphere below the altitude of 15-20 km
  – Time step of 10-20 minutes
  – Within the grids, parameterizations are used to simulate processes that are too complex to capture in the climate models.
    • E.g., cloud formation, turbulence

• Oceanic global circulation models (OGCMs) are coupled to the atmosphere and ice models through the exchange of heat, salinity, and momentum at the boundary among components.
  – Resolution of 1 degree latitude and longitude; 30 layers in the oceans
Climate models

- Doubling the resolution will require ~ 10 times more computing power.
- For one year of simulations, need to process data over 2.5 million grid cells more than 27,000 times.
Climate models: Limitations

- Low resolution limits the ability to predict features such as tornadoes, etc.
- Can’t predict East Asian or Indian monsoons well.
- Regional scale climatic features are difficult to predict accurately.
Accuracy of climate model predictions

(a)Observed

(1980-1999)

(b)Predicted

IPCC, 2007
Variability among models

IPCC, 2007
Importance of anthropogenic contribution

- Source: Jerry Meehl, National Center for Atmospheric Research
Tests of global climate model performance

IPCC, 2007
References

• Links:
  – Climate modeling videos
    – NOAA GFDL: About climate modeling
      » http://www.youtube.com/watch?v=HTz2YzoRLIs
  – General climate modeling animation (www.animea.com)
    » http://www.youtube.com/watch?v=ADf8-rmEtNg

• IPCC Report, 2007

• www.giss.nasa.gov/research/modeling/

• http://edgcm.columbia.edu/