Lecture 23. Climate Model Simulation

1. CONSTRUCTING MODEL
   a. Model development

Flexible Modeling System (FMS)

FMS is a software framework for supporting the efficient development, construction, execution, and scientific interpretation of atmospheric, oceanic, and climate system models. FMS provides essentially a framework of standardization of model components.
GFDDL Model Development Teams: Atmosphere (GAMDT), Land (LMDT), Ocean (OMDT), Coupled (CMDT)

Model performance:
Overall improvement of GFDDL atmospheric and coupled models over 2.5 year period:
- Reduction of climate drift.
- Convergence of the quality of the simulations for all seasons

Model intercomparison of climate sensitivity:
Comparison of 2 models (GFDDL/AM2 & NCAR/CAM2) at 1 year interval
No observed data involved, and no (explicit) coordination between the models occurs.
b. Diagnostics tools
   i. Comparison with data
**AEROCOM**: Aerosol Comparisons between Observations and Models

### ii. Model intercomparison

**PCMDI**: Program for Climate Model Diagnosis and Intercomparison includes: Atmospheric models (AMIP), Coupled models (CMIP), Seasonal prediction (SMIP), Aqua planet (APE), Paleoclimate models (PMIP)

**AEROCOM**: Aerosol Comparisons between Observations and Models

**c. Tuning parameters**
d. Flux adjustments

Up to a decade ago, most GCM were using flux adjustments of heat, freshwater and surface stress to reduce climate drift. Actually most models are free of these corrections.

**Motivation of flux adjustments:** The atmosphere and ocean interact through fluxes of heat, momentum and fresh water. In transient GCMs, the atmosphere and ocean models are generally run independently before being coupled together. This coupling of the atmosphere and ocean component models can highlight discrepancies in the surface fluxes that may lead to a drift away from the observed climate. This climate drift may be reduced by flux adjustment whereby the heat and freshwater fluxes, and possibly the surface stresses, are modified before being imposed on the ocean by the addition of a correction or adjustment. Flux adjustment terms are calculated from the difference between the modeled surface fluxes and those required to keep the model close to current climate. After running the model for a period suitable for the calculation of average flux adjustments, these terms are applied throughout the control and climate change experiments. The main purpose of flux adjustment is to ensure that any perturbation in forcing is applied about a realistic reference climate so that distortion of the major climate feedback processes is minimized.
2. IPCC simulations

Climate model simulation for IPCC consists of:

1. One 300 to 500-year control run
2. A 3 to 5-member ensemble simulating the 1860-2000 historical period
3. Four 3 to 5-member ensembles corresponding to the IPCC A2, A1B, B1 and constant-20-th-Century-forcing future scenarios

**Control runs**: Control runs establish the basic climate of the model. Control runs are long integrations where the model input forcings (solar irradiance, sulfates, ozone, greenhouse gases) are held constant and are not allowed to evolve with time. Usually the input forcings are held fixed either at present day values (i.e., for year 2000 or 2000 Control Run) or a pre-industrial values (i.e., for 1870 or 1870 Control Run). Note that in this context, "fixed" can have two different meanings. The solar forcing values are held fixed a constant, non varying number. The sulfate, ozone and greenhouse gases values, however, are fixed to continually cycle over the same 12-month input dataset every year.

Ensembles: Climate models are an imperfect representation of the earth’s climate system and climate modelers employ a technique called ensembling to capture the range of possible climate states. A climate model run ensemble consists of two or more climate model runs made with the exact same climate model, using the exact same boundary forcings, where the only difference between the runs is the initial conditions. An individual simulation within a climate model run ensemble is referred to as an ensemble member. The different initial conditions result in different simulations for each of the ensemble members due to the nonlinearity of the climate model system. Essentially, the earth’s climate can be considered to be a special ensemble that consists of only one member. Averaging over a multi-member ensemble of model climate runs gives a measure of the average model response to the forcings imposed on the model.

SRES Scenarios:

a. **HISTORICAL SIMULATION**
   i. **Time series Boundary conditions**
EDGAR-HYDE emissions of GHG and aerosols (1890 to 1990)

AEROCOM emission (1750 & 2000) of aerosols

GEIA data portal of emission inventories

ii. Ensemble runs from PI to PD
b. PROJECTION OF FUTURE CLIMATE

i. Constructing Scenarios

Future greenhouse gas emissions are the product of very complex dynamic systems, determined by driving forces such as demographic development, socio-economic development, and technological change. Their future evolution is highly uncertain. Scenarios are not specific predictions or forecasts of future climate. Rather, scenarios are plausible alternative futures. Each scenario is an example of what can happen under particular assumptions on use of fossil fuel and other human activities. Scenarios assist in climate modeling, help to examine potential climate change and explore vulnerabilities of humans and ecosystems under a changed climate. IPCC Special Report on Emissions Scenarios (SRES) (Summary for policymakers or Full report) describes these scenarios.
The main characteristics of the four SRES storylines and scenario families

Number of Scenarios

Figure 1: Schematic illustration of SRES scenarios. Four qualitative storylines yield four sets of scenarios called “families”: A1, A2, B1, and B2. Altogether 40 SRES scenarios have been developed by six modeling teams. All are equally valid with no assigned probabilities of occurrence. The set of scenarios consists of six scenario groups drawn from the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterizing alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel). Within each family and group of scenarios, some share “harmonized” assumptions on global population, gross world product, and final energy. These are marked as “HS” for harmonized scenarios. “OS” denotes scenarios that explore uncertainties in driving forces beyond those of the harmonized scenarios. The number of scenarios developed within each category is shown. For each of the six scenario groups an illustrative scenario (which is always harmonized) is provided. Four illustrative marker scenarios, one for each scenario family, were used in draft form in the 1998 SRES open process and are included in revised form in this Report. Two additional illustrative scenarios for the groups A1FI and A1T are also provided and complete a set of six that illustrates all scenario groups. All are equally sound.
c. Future predictions