# Introductory Course Summary

Global climate is controlled by physical processes, and by-and-large we understand what processes are involved and how they work. Actually calculating the climate that results from a given set of forcings is a much more difficult problem. This course is about how physical processes create global climate. "Dynamics" implies forces and change, so most problems of interest are looking at a forcing (such as changing atmospheric composition) and trying to figure out what change it will cause, or looking at a known change (such as Cenozoic ice sheet volume changes) and trying to determine what caused them.

Most climate problems either exceed the timescale of instrumented climate data, require prediciting the future, depend on data from places we have barely begun to measure (deep oceans, ice sheets, interior of the sun), or involve changes to the atmosphere that we cannot or should not study with global experimentation. Numerical models of varying dimension and complexity are the primary tool for figuring things out in climate dynamics. Most of the reading for this course will be about climate modeling. These will include descriptions of models, descriptions of model parameterizations, and examples of applying models of various types to climate problems. We will also survey the techniques involved in climate modeling by building simple climate models and using a complicated one. These three threads—problems, models, and techniques—will be intermingled throughout the course. In misleading outline form, these threads might look like this:

**I. Climate Problems**

1. $CO_2$-induced changes.
2. Ice ages
3. Others (mentioned, but little detail)
   a) Isostasy and tectonics (Ice ages, atmospheric chemistry)
   b) Paleogeography (pre-Pliocene climate)
   c) Dust (volcanoes, comets, nuclear war)
   d) Further anthropogenic meddling (?)

**II. Climate Modeling**

1. Zero-dimensional representation of climate
   a) Steady State
   b) Transient
   c) Multibox
2. One-dimensional, zonal modeling
   a) Budyko, Sellers, and history
   b) Modern hybrid geometry models
3. General Circulation Models—atmosphere
   a) Vertical physics
   b) Horizontal dynamics
   c) Boundary fluxes—ice, water, and land
   d) Boundary fluxes—biosphere submodels
4. Climate System Models and Coupling
   a) Ocean models
   b) Ice models

**III. Technical Issues**

1. Feedback, sensitivity, stability, thermal inertia, and response times
2. Parameterization and tuning
3. Finite differences
   a) Time differencing
   b) Space differencing
4. Partial differential equations
   a) Separation of variables
   b) Spectral methods (now obsolete)
   c) Finite volume methods
5. Vertical scales, terrain-following coordinates

Education will occur primarily by reading and secondarily by modeling projects. Class time will be devoted to discussion of the readings and lectures on technical subjects.

**Grades** will be based on a final exam and a series of modeling projects. The exam will be short and long essays discussing issues that arise from the readings.

Modeling assignments will be of two types. A series of model-building exercises will guide you through programming with finite-differences, iteration, and time-stepping. That will result in a complete, time-dependent zonal energy balance model, written from scratch using Fortran and a few library routines. The second type of modeling assignment will require analyzing data from NCAR's Community Climate System Model, including runs done by students during this class as well as model output from NCAR's CMIP control runs.

**Readings** will be extensively drawn from recent modeling papers, with just a couple of older, historical classics. Reading lists contain references to items discussed in class, sometimes just the source of a figure. Those papers marked with an asterisk are assigned readings for everyone.