Syllabus

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 interesting climate problems exceed the scope of instrumented climate data, so 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. General Circulation Models—subaerial
   a) Ocean models
   b) Ice models
   c) Coupling

III. Technical Issues

1. Feedback, sensitivity, stability, thermal inertia, and response times
2. Parameterization and tuning
3. Finite differences
   a) Crank Nicolson time differencing
   b) Space differencing
4. Partial differential equations
   a) Separation of variables
   b) Spectral methods
      (i) Fourier series, Legendre series, spherical harmonics
      (ii) Fourier transforms
      (iii) Gaussian integration
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 two exams and a series of modeling projects. The exams will be short and long essay exams 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, spectral methods, 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 doing individual experiments with a large general circulation model, currently NCAR's Community Atmospheric Model version 3.0 (CAM3). Both strands of the the modeling projects will culminate in papers that will typically be very short on text and very rich in figures.

Readings will be extensively drawn from recent modeling papers, with just a couple of older historical classics. These readings will be anchored by Warren Washington & Claire Parkinson, 2005, *An Introduction to Three-Dimensional Climate Modeling, 2nd ed.*, University Science Books.