AT605: General Circulation of the Atmosphere

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3 credits

Course web page: http://kiwi.atmos.colostate.edu/group/dave/at605.html

Pre-requisite: AT602 or permission of the instructor

Office visits in connection with the class are welcome any time.

The text consists of class notes, which are in an advanced state of preparation as a textbook. The notes can be downloaded from the class web page.

There are no exams. Grading is based entirely on homework, including some larger projects.

The class meets in the ATS West Seminar Room on MWF from 8:30 - 9:50. Classes will be missed occasionally. Class meetings have been scheduled for more than the usual 50 minutes so that it is not necessary to schedule make-up classes. A calendar showing the days of class meetings will be distributed early in the semester, and past experience suggests that not many changes will be made.

Description of the class

This is an introductory course on the general circulation of the atmosphere, a subject that is closely tied to atmospheric dynamics. A course on dynamics tends to focus on basic physical concepts and methods for their analysis, however, while a course on the general circulation must focus on what the atmosphere actually does, and why. Graduate-level studies in atmospheric dynamics are essential as preparation for this course, and most students will learn some additional dynamics in the process of taking this course.

It is difficult to draw a line between the general circulation and climate. The two subjects appear to be growing closer together, as the roles of heating and dissipation in the general circulation emerge as key issues. Clearly, such topics as monsoons, the hydrologic cycle, and the planetary energy budget can be included under either “climate” or “general circulation,” although perhaps with different slants. Climate is the bigger subject. This course skirts the edges of physical climatology.
Outline of the class content

1. Introduction
   The nature of the subject
   A brief overview
   Fasten your seatbelts

2. What makes it go?
   The Earth’s radiation budget: An “upper boundary condition” on the general circulation
   Surface boundary conditions
   Energy and moisture budgets of the surface and atmosphere
   Summary

3. An overview of the observations
   Introduction
   The global distribution of atmospheric mass
   Zonal wind
   Meridional wind
   Geopotential height
   Vertical velocity and the mean meridional circulation.
   Angular momentum
   Temperature
   A view in potential temperature coordinates
   The global distribution of water vapor
   Precipitation
   Surface fluxes due to turbulence
   A quick introduction to the effects of large-scale eddies on the zonally averaged circulation
   A view from theta coordinates
   Lots of questions

4. Conservation of momentum and energy
   Introduction
   Conservation of momentum on a rotating sphere
   Conservation of kinetic energy and potential energy
   Conservation of thermodynamic energy
   Conservation of total energy
   Static energies
   Entropy
   Approximations
   The mechanical energy equation in other vertical coordinate systems
   The effects of turbulence
   Summary
5. The mean meridional circulation
The observed meridional transports of energy and moisture
A simple theory of the Hadley circulation
Extension to other planetary atmospheres
Particle trajectories on the sphere: A partial explanation of “bandedness"
Summary

6. An overview of the effects of radiation and convection
Convective energy transports
Radiative-convective equilibrium
The observed vertical structure of the atmosphere, and the mechanisms of vertical energy transport
More on moist convection
Summary

7. The Energy Cycle
Available potential energy
The gross static stability
The available potential energies of three simple systems
Variance budgets
Generation of available potential energy, and its conversion into kinetic energy
Eddy kinetic energy, zonal kinetic energy, and total kinetic energy
Observations of the energy cycle
The role of heating
Summary

8. Planetary-scale waves and other eddies
Introduction
Free and forced small-amplitude oscillations of a thin spherical atmosphere
Observations of stationary and transient eddies in middle latitudes
Theory of orographically forced stationary waves
Tropical waves
The response of the tropical atmosphere to stationary heat sources and sinks
Monsoons
The Walker Circulation
The Madden-Julian Oscillation
Summary

9. Wave-Mean Flow Interactions
Interactions and non-interactions of gravity waves with the mean flow
Vertical propagation of planetary waves
Vertical and meridional fluxes due to planetary waves
Sudden warmings
Eliassen-Palm Theorem-Reprise
The Eliassen-Palm theorem in isentropic coordinates
Potential vorticity fluxes
The quasi-biennial oscillation
Blocking
Summary

10. The general circulation as turbulence

Energy and enstrophy cascades
Nonlinearity and scale interactions
Two-dimensional turbulence
Quasi-two-dimensional turbulence
Dimensional analysis of the kinetic energy spectrum
Observations of the kinetic energy spectrum
The general circulation as a blender
The limits of deterministic weather prediction
Quantifying the limits of predictability
Climate prediction
The World’s Simplest GCM
Pushing the attractors around
Summary

11. Tropical atmosphere-ocean interactions

Introduction
The Walker Circulation
The relationship between the Walker Circulation and the sea surface temperature.
Theories of the Walker Circulation
El Niño and the Southern Oscillation
Summary

12. Frontiers

Current problems in general circulation research