Atmospheric Sciences 6150: Cloud System Modeling

Fall 2019

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Visualization of cumulus clouds from a large-domain, high-resolution *simulation* of tropical oceanic deep convection. The realistic structure is associated with entrainment. (Image created by Ian Glenn using SHDOM, a 3D radiative transfer program.)

Classroom: 820 WBB

Class Hours: Tu Th 12:25 to 1:45

Office Hours: Th 3:30 to 4:30 or by appointment

Prerequisites: ATMOS 6010 and 6020 or instructor's consent

Description: Theory and modeling of atmospheric convection and cloud systems. Numerical modeling of turbulent, convective, and mesoscale motions associated with cloud systems. Formulation of physical processes in cloud-resolving models. Role of modeling efforts in understanding the structure and behavior of cloud systems, with an emphasis on convective cloud systems. Representation of convection, clouds, and cloud processes in numerical weather prediction and climate models.

The course complements ATMOS 6010 (Fundamentals of Dynamic Meteorology) by focusing on convective-scale (non-hydrostatic, ageostrophic) dynamics. It also complements ATMOS 5230/6230 (Mesoscale Meteorology) and ATMOS 6510 (Tropical Meteorology) which focus on the observed properties of convection, as well as ATMOS 6500 (Numerical Weather Prediction) which is increasingly concerned with predicting mesoscale and convective-scale phenomena.

Highlights: Many local and regional NWP (numerical weather prediction) models are now using convection-resolving grid sizes of 4 km or less with non-hydrostatic dynamical equations. Some global climate models now use embedded cloud-resolving models with grid sizes of 4 km to represent the subgrid-scale processes in place of conventional parameterizations. Research and operational applications of cloud-resolving (and the closely-related large-eddy simulation) models now include simulating cloud systems (including severe storms and tropical cyclones), boundary layers, flows over complex terrain and around buildings, and dispersion and chemistry of air pollutants.

In this course, you will construct a 2D (x-z) non-hydrostatic model and use it to simulate convection between two parallel horizontal plates, one hot and one cold. After this, you will apply your model to a non-hydrostatic atmospheric flow of your choice. Some possibilities include:

Clouds and precipitation: use a version of the model that already exists (and will be provided) that includes microphysics to study: cumulus life cycle and mesoscale convective systems.

Density current (gust front) in shear (relevant to squall line propagation): dependence of updraft structure on shear.

Microburst downdraft: dependence of outflow speed on lapse rate and boundary layer depth

Thermal: Dependence of entrainment/detrainment rate on size and buoyancy.

Buoyant plume: dependence of height on buoyancy flux and stability.

Buoyant plume and fire spread: interaction of plume and fire spread.

Kelvin-Helmholtz instability: Dependence on shear and stability.

Flow over terrain: mountain waves: Dependence on various parameters of terrain and atmosphere.

Radiatively destabilized cloud layers (stratocumulus, altocumulus, cirrus): dependence of cloud structure on various parameters.

3D dry convective boundary layer : non-local turbulent transport and dispersion.

Optional Textbook: *Atmospheric Convection* by K. A. Emanuel

Supplementary Textbooks: *Cloud Dynamics* by R. A. Houze, Jr., *Storm and Cloud Dynamics* by W. R. Cotton and R. A. Anthes, *An Introduction to Dynamic Meteorology* by James R. Holton, and *Mesoscale Meteorology in Midlatitudes* by Paul Markowski and Yvette Richardson.

Topics Addressed: (E: Emanuel, H: Houze) [See the course web page for a more detailed list.]

1. Cloud system types and occurrence
2. The nature of convection in the atmosphere
3. Fundamental equations for convection (E: 1; H: 2.1, 2.3)
4. Dry convection from local sources (thermals and plumes) (E: 2)
5. Global dry convection (parallel-plate convection) (E: 3)
6. Moist thermodynamics and stability (parcel model)
7. Cumulus clouds: entrainment and mixing (E: 7, 8; H: 7.3)
8. Numerical modeling of convective clouds (E: 10; H: 2.10,3.3-3.6)
9. Precipitating convective cloud systems (E: 9, 11; H: 8, 9)
10. Interaction of convection with large-scale flows (E: 14, 15)
11. Moist convection in large-scale models (cumulus parameterization) (E: 16)
12. Global moist convection (shallow-layer clouds) (E: 13; H: 5)
13. SAM (System for Atmospheric Modeling): An easy-to-use 3D cloud-resolving model

Numerical Modeling Exercises and Projects:

1. Construct a cloudy parcel model for saturated adiabatic ascent (MATLAB).
2. Construct and apply a 2D (x-z) numerical model (Fortran or MATLAB):
   (a) Numerical simulation of 1D conduction
   (b) Numerical simulation of 2D marginally unstable (linear) parallel-plate convection
   (c) Numerical simulation of 2D fully nonlinear parallel-plate convection
   (d) Application to a non-hydrostatic flow of your choice

Grading: The course grade will be determined from problem sets and projects (75%) and a final exam (25%).

Holidays: Oct. 7–11 (Fall break), Nov. 28–29 (Thanksgiving break)

Last day of class: Thursday, December 5

Final exam: Thursday, December 12, 2019, 10:30 am – 12:30 pm (per University)

Drop and Withdrawal dates:

- Last day to drop classes: Friday, August 30 (Students can drop classes by phone or web through this date, and the classes will not appear on their transcripts.)
- Last day to add classes: Friday, August 30
- Last day to withdraw from classes: Friday, October 18. (Students can withdraw from classes by phone or web, but will"W" will appear on their transcript for these courses.)

Disability Services

The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations.

All written information in this course can be made available in alternative format with prior notification to the Center for Disability Services.

Safety

The University of Utah values the safety of all campus community members. To report suspicious activity or to request a courtesy escort, call campus police at 801-585-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit `safeu.utah.edu`.