Atmospheric Sciences 6220: Boundary Layer Meteorology

Spring 2025

Instructor: Professor Steve Krueger
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Classroom: 250 FASB

Class Hours: W F 11:50 am to 1:10 pm

Office Hours: Th 2:30 pm – 3:30 pm. Email works well.

Web page: `http://www.inscc.utah.edu/~krueger/6220/`

Prerequisites: ATMOS 6010 and 6020 (may be concurrent) or instructor's consent

Background: The atmospheric boundary layer is the interface between the free atmosphere and the surface. It plays a central role in the exchange of heat, moisture, momentum, trace gases, and aerosols between land, ocean, and ice surfaces, in cloud formation, and in the general circulation of the atmosphere. We are immersed in the boundary layer. Forecasts of daily high and low temperatures are boundary layer forecasts. The winds that affect buildings, bridges, trucks, boats, ships, and aircraft during take-offs and landings are boundary layer winds. Boundary layer winds create waves on lakes and oceans, resulting in swells and surf. Wildfires are strongly affected by boundary layer winds, including their interaction with complex terrain. Air pollution is generated and chemically modified in the boundary layer. Boundary layer winds vary on the mesoscale due to interactions with surface characteristics and orography. Boundary layer clouds play an important role in climate change, and are poorly represented in global climate models. Boundary layer clouds may respond to increases in carbon dioxide and aerosol concentrations due to anthropengenic sources.

Course Description: The goals of this course are to provide you with a basic understanding of boundary layer structure and physics and expose you to current approaches used to observe and model the boundary layer. You will analyze measurements of turbulence made from aircraft or from over the salt flats in western Utah, and will become familar with three basic modeling approaches: mixed layer modeling, in which only the bulk (vertically averaged) properties are predicted; Reynolds-averaged modeling, in which profiles of statistics (mean, variance, etc) are predicted; and LES (large-eddy simulation), in which the 3D turbulent flow is simulated, but just for the large eddies. You will have an opportunity to analyze LES results.

Topics Addressed:

- Boundary layer characteristics.
- Introduction to turbulence. Convective and shear instabilities.
- Turbulence, Reynolds averaging, turbulent fluxes, equations for turbulent flow.
- Measurement and analysis of boundary layer turbulence.
- Boundary layer wind and thermodynamic profiles. Convective and stably stratified boundary layers.
- The surface layer. Monin-Obukhov similarity theory, surface roughness.
- Surface fluxes over ocean and land. Land surface models. Diurnal cycle.
- Parameterizations and models of turbulent transport in clear boundary layers.
- Cloud-topped boundary layers and their parameterization.
- Nonhomogenous boundary layers. Terrain effects.
- Student projects.

Grading:

- Homework (70 percent). You may collaborate on the homework assignments. They will require some Matlab programming.
- Term project (30 percent). The term project will be on a topic of your choice related to the course. A 5-10 page written report on his or her term project will be due on the last day of classes. Each student will do a 15-20 minute oral presentation on his or her term project during the final exam period.
- Final exam: There will be no final exam.

Required Textbook: Stull, R. B., 1988: *An Introduction to Boundary Layer Meteorology,* Kluwer Publishers, 666 pp. Nice discussion of the methods, observational and computational tools used in boundary layer meteorology.

Some other relevant textbooks:

- Arya, S. P., 2001: *Introduction to Micrometeorology,* Second Edition, Academic Press, 420 pp. A very accessible advanced undergrad introduction to the subject. It emphasizes the surface layer.
- J. R. Garratt, 1992: *The Atmospheric Boundary Layer,* Cambridge University Press, 316 pp. Contains a list of other relevant books at the end of the first chapter, including historically important texts.
- Hartmann, D. L., 1993: *Global Physical Climatology,* Academic Press, 411 pp. Chapter 4 describes the energy balance of the surface from a global climatological perspective.

- Holton, J. R., 2004: *An Introduction to Dynamic Meteorology,* 4th Ed., Elsevier Academic Press, 535 pp. Chapter 5 contains a concise description of the boundary layer and its relevance to dynamic meteorology.
- Lenschow, D. H., 1986: *Probing the Atmospheric Boundary Layer.* American Meteorological Society, 269 pp. An introduction to techniquies for measuring the boundary layer.
- Oke, T. R., 1987: *Boundary Layer Climates.* 2d ed., Methuen, 435 pp. Describes surface-atmosphere interactions in detail.
- Sorbjan, Z., 1989: *Structure of the Atmospheric Boundary Layer,* Prentice-Hall, 317 pp.
- Tennekes, H., and J.L. Lumley, 1972: *A First Course in Turbulence.* MIT Press, 300 pp. An excellent introduction to turbulence.
- Wyngaard, John C., 2010: *Turbulence in the Atmosphere.* Cambridge Univ Press, 393 pp. An excellent introduction to turbulence in the atmosphere and in engineering flows for advanced students, and a reference work for researchers in the atmospheric sciences.

Holidays: (none)

Classes that will be rescheduled: Jan. 15

Term project oral presentation: Friday, April 18

Last day of class: Friday, April 18

Term project written report due: Wednesday, April 30

Final exam: (There will be no final exam.)

Drop and Withdrawal dates:

- Last day to add or drop classes: **Friday, January 19.** (Students can drop classes through this date, and the courses will not appear on their transcripts.)
- Last day to withdraw from classes: **Friday, March 1.** (Students can withdraw from classes, but "W" will appear on their transcript for these courses.)