ME EN 5960/6960: Environmental Fluid Mechanics

Fall 2004

Lecturer: Eric R. Pardyjak
Lecture Time/Location: Tuesday, Thursday 9:10 am-10:30 pm WBB 206
Office Hours: 10:40am-11:40am Tuesday ,Thursday Room 160 KENN B
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Text: *Introduction to Micrometeorology*, S.P. Arya, Second Edition, Academic Press, 2001.
Supplementary Texts:
An Introduction to Boundary Layer Meteorology, R.B. Stull, Klewer Academic Publishers, 1988.
The Atmospheric Boundary Layer, J.R. Garratt, Cambridge University Press, 1992.
Boundary Layer Climates by T.R. Oke, Second Edition, Routledge 1987.

Description of the Course: An introduction to environmental fluid mechanics focusing primarily on micrometeorological processes occurring in the atmospheric boundary layer (the lower 1-3km of the troposphere). Since this is the part of the atmosphere that humans are directly in contact with, it is of great importance to both engineers and atmospheric scientists. For example, the small-scale motions responsible for pollution dispersion are related to surface fluxes of heat and momentum. The class will mostly focus on the micrometeorological processes in the atmospheric boundary layer in both rural and urban settings. The content will include turbulent flow and dispersion around buildings.

Prerequisites: ME EN 3700 Fluid Mechanics (or equivalent)

Scope of the Course: The lecture material will cover much of the material in the textbook, however significant supplemental journal papers will be used. The basic transport equations for mass, momentum and energy will be developed and will include rotation and stratification effects. In addition, to the classroom lecture material students will also be involved in a basic atmospheric boundary layer experiment using a tethered meteorological balloon and sonic anemometer. These data will form the basis for a project on "probing the atmospheric boundary layer."

Homework: Periodic homework assignments will be given during class and then posted on the web site. Homework will be collected in class on the due date. Late homework will generally not be accepted.

Computer Skills: It is expected that at all students will have basic computing skills and knowledge of a programming language (FORTRAN, C, C++, etc) or scientific computing software package (Maple, Matlab, EES, etc).

Grading and Exams: The total course grade is comprised of homework, a midterm and final exams. The midterm exam will be composed of a take home and in class exam. The grading scheme is summarized below.

Homework: 40%
Midterm: 25%
Final Project: 35%

No make up exams will be given unless arrangements are made prior to the exam.

Exemptions: The University of Utah conforms to all standards of the Americans with Disabilities Act. If you wish to qualify for exemptions under this act, notify the instructor and the Center for Disabled Students Services, 160 Union.

1. Introduction
   - The atmospheric boundary layer – basic definitions and concepts, scales of motion, diurnal cycles and introduction to rotation and stratification.
   - Equilibrium and Departures from it.
   - Atmospheric thermodynamics – potential temperature, virtual potential temperature, buoyancy frequency, potential energy.

2. Energy Balances – radiation characteristics, near surface exchanges (fluxes), energy budget near surface, radiation budget near surface.

3. Basic Equations including rotation and stratification – boundary layer simplifications

4. Atmospheric Boundary Layer Turbulence – introduction to the turbulence in environment and the critical effects of buoyancy on turbulence. Turbulent entrainment and stability effects.

5. The Atmospheric boundary layer scaling – Monin-Obukhov similarity theory
   - Neutral boundary layer
   - Convective boundary layer
   - Stable boundary layer

6. Nonhomogeneous Boundary Layers - Urban Fluid Mechanics
   - Surface inhomogeneities (roughness effects, both complex terrain and urban). Terrain induced flows.
   - Atmospheric dispersion concepts and models (ranging from simple Gaussian plume to Lagrangian Dispersion models)
   - Urban Heat Island

7. Measuring Techniques – "Probing the Atmospheric Boundary Layer" – introduction to various measuring techniques including sonic anemometry, balloon borne measurements and remote sensing techniques.

8. Computation Modeling – meso-scale and smaller focusing on turbulent transport
   - Large Eddy Simulation, RANS

Week	Class #	Date	Day	Topics	Reading
1	1	8/26	Th	Introduction to Env. Fluid Dynamics	Ch.1
2	2	8/31	T	Energy Balances Equations	Ch.2
	3	9/2	Th	Surface Energy Balances 1	Ch.3
3	4	9/7	T	Surface Energy Balances 2	Handout
	5	9/9	Th	Boundary Layer Thermodynamics 1	Ch. 5
4	6	9/14	T	Boundary Layer Thermodynamics 2	Handout
	7	9/16	Th	Basic Equations w/rotation & stratification	Ch.6
5	8	9/21	T	Basic Equations w/rotation & stratification	
	9	9/23	Th	Scale Analysis of the Momentum Equation	Ch. 7
8	10	9/28	T	Energy Equation (Mechanical)	
	11	9/30	Th	Energy Equation (Thermodynamic)	
9	12	10/5	T	Midterm Exam	
		10/7	Th	Fall Break	
10	13	10/12	T	Turbulence Intro & Mathematical tools	Handout,Ch8
	14	10/14	Th	Reynolds Averaged Equations	Ch. 9.1-9.2
11	15	10/19	T	Reynolds Averaged Equations	
	16	10/21	Th	Basic Statistical tools	Handout
12	17	10/26	T	Midterm Exam	
	18	10/28	Th	More Turbulence statistical tools	Handout
13	19	11/2	T	Dimensional Analysis & Similarity in ABL	Ch. 9.3
	20	11/4	Th	Spectral Analysis Techniques in turbulence	Handout
14	21	11/9	T	Spectral Analysis Techniques in turbulence	Handout
	22	11/11	Th	Thermally Stratified ABLs	Ch. 13
15	23	11/16	T	Stratified Atmospheric Boundary Layers	Ch. 13
	24	11/18	Th	Non-homogeneous ABL	Ch. 14
16	25	11/23	T	Urban Canyon Flow	Handout
	26	11/25	Th	Thanksgiving	
17	27	11/30	T	Agriculture & Forest Micrometeorology	Ch. 15
	28	12/2	Th	Air Pollution Applications	
18	29	12/7	T	Computational Modeling	
	30	12/9	Th	Oral Projects	
		12/13	M	Final Written Projects Due	