EOS 896 **Concepts in Dynamical Earth System Science** **Spring 2003**

Instructors:
S. Frolking CCCS/EOS, H. Mao CCRC/EOS, M. Prentice CCRC/EOS

Reading
(PEP) Monteith and Unsworth, 1990, *Principles of Environmental Physics*, E. Arnold.
(FAP) Salby, 1996, *Fundamentals of Atmospheric Physics*, Academic Press.
(FAM) Jacobson, 1999, *Fundamentals of Atmospheric Modeling*, Cambridge.
(IDM) Holton, 1992, *Introduction to Dynamic Meteorology*, 3rd, Academic.

Selected papers from the literature.

Room and Schedule: James Hall 115, Tues 2:10-3:30 & James Hall 119, Thurs: 2:10-3:30
Credit: 3

LECTURE TOPICS

Part 1: Dynamical Concepts Common to Earth Systems (~8 weeks)

1. Introduction : (HM and MP) (Jan 21)

2. Atmospheric Structure, Composition, and Thermodynamics: (~2 weeks)
Lecture (Jan 23): ***Atmospheric Composition and Structure*** (MP): Basics. Equation of State: gas laws. Virtual temperature. Hydrostatic equation. Water in the atmosphere.
Reading: FAM Chap 2 (6-38), FAP Chap 1 (1-41), PEP Chap 2.

Lecture (Jan 28): ***Thermodynamics of Gases*** (MP): Concepts. First Law. Heat capacity. Adiabatic processes. Diabatic Processes
Reading: FAM Chap 2 (38- 44). FAP Chap 2.

Lecture (Jan 30): ***Second Law of Thermodynamics and Heterogeneous Systems*** (MP): Natural and reversible processes. Entropy. Equilibrium phase transformations.
Reading: FAP Chap 3, 4.

Lecture (Feb 4): ***Transformations of Moist Air*** (MP): Description. Distribution. Thermodynamic behavior in vertical motion.
Reading: FAP Chap 5.

Lecture (Feb 6): ***Chemical Reactions*** (SF): Reaction thermodynamics, reaction kinetics, reduction-oxidation, phase change.
Reading: Sections from Hobbs, PV, 2000. Basic Physical Chemistry for the Atmospheric Sciences.

3. Hydrostatics and Atmospheric Radiation: (~2 weeks)

Lecture (Feb 11): ***Hydrostatic Equilibrium*** (MP): Effective gravity. Geopotential coordinates. Hydrostatic balance. Stratification.
Reading: FAP Chap. 6.

Lecture (Feb 13): ***Hydrostatic Stability*** (MP): Reaction to vertical displacement. Stability categories. Finite Displacements. Turbulent Dispersion.
Reading: FAM Chap. 7.

Lecture (Feb 18): ***Radiative transfer*** (MP): SW and LW Radiation. Radiative transfer: absorption. emission. scattering. Absorption Characteristics of Gases. Transfer in a plane parallel atmosphere.
Reading: FAM Chap. 8, PEP Chap. 3-4

Lecture (Feb 20): ***Thermal Equilibrium*** (MP): Gray atmosphere radiative equilibrium. Radiative-convective equilibrium. Radiative heating.
Reading: FAP Chap. 8, PEP Chap 5-6.

4. Fluid Dynamics (~2 weeks)

Lecture (Feb 25): ***Conservations Laws*** (HM): Conservation of mass, momentum, and energy
Reading: IDM Chap 2.

Lecture (Feb 27): ***Elementary Application of the Basic Equations*** (HM): Basic equations in isobaric coordinates: horizontal momentum equation, continuity equation. Balanced flow. Trajectories and streamlines. The thermal wind. Vertical motion. Surface pressure tendency.
Reading: IDM Chap 3.

Lecture (Mar 4): ***The Planetary Boundary Layer*** (HM): Turbulence: the Boussinesq approximation, Reynolds averaging. Turbulent kinetic energy. Planetary boundary layer momentum equations: well-mixed boundary layer, the flux-gradient theory, the mixing length hypothesis, the surface layer. Secondary circulations and spin-down.
Reading: IDM Chap 5, PEP Chap 7.

Lecture (Mar 6): ***Synoptic-Scale Motions to General Circulation*** (HM): Quasi-gestrophic analysis: the observed structure of extratropical circulation, the quasi-geostrophic approximation. Baroclinic instability: hydrodynamic instability, baroclinic instability. Mesoscale circulations. The general circulation
Reading: IDM Chap 6.

5. Ecosystems (~2 weeks)

Lecture (Mar 11): ***Basics of autotrophic metabolism*** (SF): photosynthesis, respiration, transpiration
Reading: PEP Chap 15.

Lecture (Mar 13): ***Basics of heterotrophic metabolism*** (SF): decomposition, soil C cycle.

Lecture (Mar 25): ***Controls on surface fluxes (energy, water)*** (SF): soil heat and water transfer
Reading: PEP Chap 13.

Lecture (Mar 27): ***Controls on surface fluxes (trace gases)*** (SF): soil gas diffusion and trace gas fluxes

Reading: PEP Chap 15.
In Andreae MO, Schimel DS (eds)1989. Exchange of Trace Gases Between Terrestrial Ecosystems and the Atmosphere, John Wiley and Sons, NY.
pp. 73-96: What regulates production and consumption of trace gases in ecosystem: biology or physiochemistry? (T. Rosswall, lead author)
pp. 155-174 Extrapolation of flux measurements to regional and global scales (JWB Stewart, lead author)
pp. 249-262, What are the relative roles of biological production, micrometeorology, and photochemistry in controlling the flux of trace gases between terrestrial ecosystems and the atmosphere (PM Virtuosic, lead author)
pp. 303-320, Trace gas exchange and the chemical and physical climate (GP Robertson, lead author)

28 Mar. Take-Home MID-TERM EXAM Distributed

6. Modeling: (~1 week)

Lecture (Apr 1): ***Types, structure, and scope; Calibration and Validation*** (SF)
Reading:
Aber, JD. 1997. Why don't we believe the models? *Bull. Ecological Soc. Am*. 78:232-233.
Rykiel, EJ. 1996. Testing ecological models: the meaning of validation. *Ecological Modeling*. 90:229-244.

Mitchell PL. 1997. Misuse of regression for empirical validation of models. *Agricultural Systems*, 54:313-326.

Lecture (Apr 3): ***Numerical Methods*** (HM/MP)
Reading: FAM Chap 6, 7, 21

4 Apr. (5 PM) Take-Home MID-TERM EXAM Due

Part 2: Sub-discipline Concepts and Modeling (~4 weeks)

Track A: Boundary Layer Processes: Turbulence, Structure, Eddy diffusion in the surface layer, Ekman pumping
Reading: TBA

Track B: Terrestrial Biogeochemical Modeling
Reading: TBA

(Apr 8):
(Apr 10):
(Apr 15):
(Apr 17):
(Apr 22):
(Apr 24):
(Apr 29):
(May 1):

Part 3: Student-project presentations

Presentations (May 6):

Presentations (May 8):

(15-22 May) Final Exam Period
18 May Term-Paper Due

REQUIREMENTS:
Homework/Class Participation: 50%
Term-Paper: 30%
Take-Home Exam: 20% Distributed 28 March. Due 4 April.