METR 3113 – Atmospheric Dynamics I: Introduction to Atmospheric Kinematics and Dynamics

Fall 2017 Syllabus

Instructor

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Class meeting time and place

Mon, Wed, Fri: 9:00 – 9:50am; NWC 1350.

Office hours

By appointment through e-mail (also for office hours with the teaching assistant).

Prerequisites

Grade of C or better in METR 2023/2021, MATH 2443 or 2934, PHYS 1215 or 2524.

Required textbook

Holton, J. R., and G. J. Hakim, 2013: *An Introduction to Dynamic Meteorolog*y, 5th edition, Academic Press (Elsevier), 532 pp. (4th edition of this textbook may also be used).

Supplementary textbooks/materials

Wallace, J. M., and P. V. Hobbs, 2006: *Atmospheric Science: An Introductory Survey*. Elsevier/Academic Press, 483 pp.

Fiedler, B. H., 2015: *Forces and Motion in the Atmosphere*. Manuscript v1.20, University of Oklahoma, 157 pp.

Website

Course materials will be available at https://canvas.ou.edu/.

Proposed grading

Three intermediate tests (September, October, November): 30% each (with the lowest score dropped).

Final exam (December): 40%.

Grade cutoffs. A: ≥85%, B: ≥70%, C: ≥50%, D: ≥20%, F: <20%.

General information

Students will be introduced to the formal mathematical characterization of atmospheric motions, to forces acting in the atmosphere, and to equations of atmospheric kinematics and dynamics. Particular topics include coordinate systems used in meteorology, basics of vector calculus, Newton's laws of motion, conservation of mass and energy, basic force balances and atmospheric motion types, concepts of equilibrium and stability in the atmospheric context, and equations of motion.

COURSE OUTLINE

I. Units and Dimensions

- Standard techniques to operate with physical units.
- Conversions between SI and Imperial units used in atmospheric dynamics.
- Concept of dimension; idea of dimensional (scale) analysis and principle of dimensional homogeneity.

II. Coordinate systems

- Cartesian coordinates.
- Polar coordinates.

III. Fundamentals of Vector Calculus

- Concepts of vector (versus scalar), unit vector, and vector decomposition basis.
- Properties of the vector dot and cross products, commonly employed vector identities and operations.
- Rules of vector differentiation.
- Properties and applications of ∇ (del, nabla) operator in vector analysis.
- Definitions and properties of divergence, gradient, curl, and Laplacian operations; physical meanings of these operations.
- Divergence theorem of vector calculus.

IV. Basics of Newtonian Mechanics

- Notions of inertial and non-inertial reference frames.
- Three Newton’s laws of motion.
- Newton’s law of gravitation.
- One-dimensional equation of motion in inertial frame with different forcing types.
- Notion of angular momentum.

V. Fundamental Atmospheric Forces

- Gravitational force.
- Notion of force per unit area.
- Pressure gradient force.
- Viscous (friction) force.
- Hydrostatic equation; geopotential and geopotential height.
- Pressure as vertical coordinate.

- Archimedes and buoyancy forces in the atmosphere; notion of the buoyancy.
- Apparent forces in a non-inertial reference frame.
- Centrifugal and gravity forces in a rotating reference frame.
- Coriolis force.

VI. Motion in Non-inertial Rotating Frame

- Lagrangian and Eulerian frames; concept of total differentiation.
- Differentiation of a vector in a rotating frame.
- Equation of motion in a rotating frame: vector form of the equation.
- Equation of motion in a rotating frame: components in a spherical coordinate system.
- Relative importance of individual terms in the equation of motion.
- Geostrophic approximation and geostrophic wind.
- Hydrostatic approximation in the equations of motion.

VII. Mass and Energy Conservation

- Conservation of mass; Lagrangian and Eulerian derivations of continuity equation; incompressible and anelastic forms of the continuity equation.
- Adiabatic process; potential temperature.
- Thermodynamic and mechanical energy equations.
- Scale analysis of mass and energy conservation equations.
- Mass and energy conservation equations in isobaric coordinates.

VIII. Balanced Flow in Natural Coordinates

- Natural coordinates.
- Gradient wind approximation; cases of geostrophic flow, inertial flow, and cyclostrophic flow.
- Solutions of gradient wind equation for northern and southern hemispheres.
- Notions of regular vs. anomalous, baric vs. antibaric, and cyclonic vs. anticyclonic gradient flows.

Note: *The University of Oklahoma is committed to providing reasonable accommodation for all students with disabilities. Students with disabilities who require accommodations in this course are requested to speak with Dr. Fedorovich as early in the semester as possible. Students with disabilities must be registered with the Office of Disability Services prior to receiving accommodations in this course.*