

Course Topical Outline

METR 3113, Atmospheric Dynamics I

Fall 2016

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.