ATMO 600: Advanced Atmospheric Dynamics I

Fall 2020, Tuesday & Thursday 12:00-1:15pm, HIG 311

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Course objective:

ATMO 600 is the first part of a two-semester course series on Advanced Atmospheric Dynamics. It is one of the core courses for the Graduate Program at the Department of Atmospheric Sciences, University of Hawaii at Manoa. It introduces fundamental understanding of the most basic processes governing atmospheric motion.

Student Learning Objectives (SLOs):
Upon completion of the course, the student should be able to:

1. Have a basic knowledge of multiple-scale nature of the atmospheric motion and the ways of description of various forms of atmospheric motion associated with weather and climate.

2. Understand how the atmosphere is driving, including solar radiative forcing, energy balance and hydrological cycle in the atmosphere and climate system, the greenhouse effect, and the effects of atmospheric dynamics (convection and baroclinicity) in the energy balance.

3. Understand and mathematical expression of physical principles governing atmospheric motion, including conservation laws of mass, momentum, moisture, and thermodynamic energy.

4. Understand the concepts and numerical modeling of *special features* of atmospheric motions, including dealing with the effects of water vapor, earth's rotation, gravity and stratification, earth's sphericity, and topography.

5. Understand the concept of the internal energy, enthalpy, entropy, moist static energy and various forms of the thermodynamic equations and equation of states.

6. Understand and mathematically express how the Earth's rotation affects atmospheric motion. Master the concept of relative vorticity and circulation, Coriolis force, planetary and absolute vorticity. Understand factors determining changes of the relative vorticity.

7. Know how to explain the effect of Earth's gravity on atmospheric motion. Understand the concept and derivation of the atmospheric stratification and static stability criteria.

8. Know how the water vapor affects equation of state, atmospheric static stability, and how the saturation water vapor changes with temperature.

9. Derive and discuss simple solutions for various atmospheric two-dimensional steady motion, such as geostrophic winds, Ekman flow, gradient wind, cyclostrophic wind, inertial motion and thermal winds.

10. Understand the concept of available energy and derivation of the energy conservation equation.

11. Understand the concept of potential vorticity and know how to derive potential vorticity equations and how to apply it to explain variety of atmospheric phenomena.

12. Understand the concept of shallow water model, and know how to derive it and know how to apply it to explain atmospheric and oceanic phenomena.

13. Understand the concept of barotropic model, know how to derive it and use it to explain atmospheric and oceanic phenomenon.

14. Understand the concept of two-level baroclinic model, know how to derive it and how to apply it to explain real phenomenon.

15. Master perturbation method and normal mode method for analysis of linear wave motion.

16. Learn how to make theoretical approximation and understand physical meanings of important approximations such as Anelastic, Boussinesq, hydrostatic, and quasi-geostrophic approximations.

17. Know how to set up kinematic and dynamic boundary conditions and interface conditions for inviscid and viscous fluids.

18. Understand the mechanisms responsible for acoustic waves, surface gravity and internal gravity waves, Rossby waves. Derive 1-D or 2-D models for these waves and discuss their properties.

19. Understand the concept of wave packet, energy dispersion, wave train, and Rossby wave train theory.

20. Understand and derive equatorial Kelvin wave, Rossby wave, mixed Rossby-gravity wave, and inertia-gravity waves, and know their generation mechanisms and practical application.

21. Master the method of scale analysis and know how to systematic simplify governing equations and use of non-dimensional numbers, such as Rossby number, Ekman number, Reynolds number, Richardson number, Burger number, etc. and Rossby radius of deformation.

22. Derive and understand the quasi-geostrophic system and quasi-geostrophic potential vorticity equation.

23. Understand the causes of the vertical motion in quasi-geostrophic motion and the meaning of Q vector.

24. Understand the mechanisms responsible for mid-latitude cyclone development.

Prerequisites:

ATMO 303, Math 402 or 405, or consent of the Instructor.

Course outline:

1 Introduction
- 1.1. Observed atmospheric circulation
- 1.2. How the atmosphere is driven

2 Fundamental equations governing atmospheric and oceanic motion
- 2.1. Equations of state and thermodynamic energy
- 2.2. Conservation of momentum and vorticity: Effect of Earth's rotation
- 2.3. Density stratification and static stability: Effect of Earth's gravity
- 2.4. Conservation of mass and moisture: Effects of moisture
- 2.5. Spherical and local Cartesian coordinates: Effect of Earth's sphericity
- 2.6. Vertical coordinate systems: Dealing with topography

3 Integral constraints and simple GFD models
- 3.1. Boundary conditions and simple solutions for atmospheric motion
- 3.2. Energy conservation and available potential energy
- 3.3. Potential vorticity
- 3.4. Shallow water and barotropic models
- 3.5. Two-level and two-layer models

4 Wave motion in rotational stratified atmosphere and ocean
- 4.1. Basic concept of perturbation wave motion
- 4.2. Sound waves and Lamb waves
- 4.3. Inertia-internal gravity waves
- 4.4. Barotropic Rossby wave packet
- 4.5 Energy propagation and reflection of Rossby wave packet
- 4.6 Rossby waves in stratified atmosphere and ocean
- 4.7. Equatorial waves 1: dispersion relation and equatorial Kelvin waves
- 4.8. Equatorial waves 2: equatorial Rossby, inertial-gravity, Yanai waves

5. Quasi-geostrophic motion

5.1. Scale analysis for hydrostatic motion
5.2. Quasi-geostrophic regimes
5.3. The quasi-geostrophic system
5.4. Diagnosis of vertical motion
5.5. Development of extratropical cyclone

Major Reference Books:

Holton, J. R.: An Introduction to Dynamic Meteorology, 2004
Pedlosky, J. : Geophysical Fluid Dynamics, Spring-Verlag, 1987.
Gill, A. E. : Atmosphere-Ocean Dynamics, 1982.

Grading Policy:

Homework 40%, mid-term exam 30%, final exam 30%.

Appendix: Title XI Statement

The University of Hawai'i is committed to providing a learning, working and living environment that promotes personal integrity, civility, and mutual respect and is free of all forms of sex discrimination and gender-based violence, including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, and stalking. If you or someone you know is experiencing any of these, the University has staff and resources on your campus to support and assist you. Staff can also direct you to resources that are in the community. Here are some of your options:

As members of the University faculty, your instructors are required to immediately report any incident of potential sex discrimination or gender-based violence to the campus Title IX Coordinator. Although the Title IX Coordinator and your instructors cannot guarantee confidentiality, you will still have options about how your case will be handled. Our goal is to make sure you are aware of the range of options available to you and have access to the resources and support you need.

If you wish to remain ANONYMOUS, speak with someone CONFIDENTIALLY, or would like to receive information and support in a CONFIDENTIAL setting, use the **confidential resources available here**:
http://www.manoa.hawaii.edu/titleix/resources.html#confidential

If you wish to directly REPORT an incident of sex discrimination or gender-based violence including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence or stalking as well as receive information and support, contact: Dee Uwono Title IX Coordinator (808) 956-2299 t9uhm@hawaii.edu.