

# **Syllabus for OC3321 Air-Ocean Fluid Dynamics (4-0)**

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## **Course Description**

A foundation course for studies of atmospheric and oceanographic motions. The governing dynamical equations for rotating stratified fluids are derived from fundamental physical laws. Topics include: the continuum hypothesis, real and apparent forces, derivations and applications of the governing equations, coordinate systems, scale analysis, simple balanced flows, boundary conditions, thermal wind, barotropic and baroclinic conditions, circulation, vorticity, and divergence.

## **Learning Outcomes**

Recognize the links between mathematical equations (including vector and differential equations describing atmospheric motions) and the physical laws governing the Earth's atmosphere and oceans.

Understand the fluid dynamical equations governing the motion of the Earth's atmosphere and oceans, including momentum, continuity, thermodynamic, state and salinity.

Ability to perform a scale analysis on the equations of motion; derive and apply basic balances such as hydrostatic, geostrophic, gradient wind balances, and thermal wind relation.

Ability to distinguish between barotropic and baroclinic thermal flows.

Understand concepts of vorticity and potential vorticity.

Understand potential vorticity conservation and its application to oceanic flows.

## **Course Structure**

### **Chapter 1 Fundamental Features of Atmosphere and Oceans**

- 1.1. Conservation of mass
- 1.2. Some important characteristics of Earth system
- 1.3. Atmosphere and oceans are fluids
- 1.4. Characteristics of atmospheric dynamics

1.5. Characteristic of ocean dynamics

## **Chapter 2 Coordinate Systems and Vector Analysis**

2.1. Cartesian coordinate system

2.2. Vectors

2.3. Vector operators

2.4. Vector calculus operators

2.4.1. Gradient

2.4.2. Divergence

2.4.3. Curl

2.4.4. Laplacian

2.5. Rotating spherical coordinates

2.6. Tangential coordinates

## **Chapter 3 Vorticity and Divergence**

3.1. Rotation

3.2. Definition of vorticity (turning of the flow)

3.3. Vorticity and angular momentum

3.4. Divergence

3.5. Relative vorticity

3.6. Planetary vorticity

3.7. Types of vorticities

3.7.1. Flow around a system

3.7.2. Shear vorticity

## **Chapter 4 Foundation of Air-Ocean Fluid Dynamics**

4.1. Newton's laws of motion

4.2. Equation of motion

4.3. Conventions in air-ocean fluid dynamics

4.4. Gravitation

## **Chapter 5 Forces**

5.1. Definition and types of forces

5.2. Body forces

5.3. Surface forces

5.3.1. Pressure gradient force

5.3.2. Viscous force

5.4. Apparent forces

5.4.1. Centrifugal force

- 5.4.2. Coriolis force
- 5.5. Basic equation of motion in air-ocean fluid dynamics

## **Chapter 6 Scale Analysis**

- 6.1. Time scale
- 6.2. Spatial scale and Rossby Number
- 6.3. Scale analysis on horizontal equation of motion
- 6.4. Scale analysis on vertical equation of motion
- 6.5. Scale analysis of continuity equation
- 6.6. Boussinesq approximation for seawater

## **Chapter 7 Balanced Flows**

- 7.1. Geostrophic wind balance
- 7.2. Gradient wind balance
- 7.3. Hydrostatic balance
- 7.4. Hydrostatic equation
- 7.5. Pressure and mass
- 7.6. Thermal wind relation

## **Chapter 8 Equation of State**

- 8.1. Equation of state for air - ideal gas law
- 8.2. Equation of state for seawater

## **Chapter 9 Vorticity Equation**

- 9.1. Derivation of vorticity equation
- 9.2. Divergence term
- 9.3. Tilting term
- 9.4. Definitions of barotropic and baroclinic
- 9.5. Barotropic and baroclinic terms
- 9.6. Vorticity advection
- 9.7. Planetary vorticity advection

## **Chapter 10 Potential Vorticity**

- 10.1. Barotropic potential vorticity
- 10.2. Determination of ocean circulation from (T, S) data
- 10.3. Baroclinic potential vorticity
- 10.4. P-Vector inverse method

10.4.1. P-Vector

10.4.2. Two-step inverse method

10.5. Example 1

10.6. Example 2

10.7. Example 3