

Syllabus for OC4323 Numerical Air and Ocean Modeling (4-2)

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Course Description

This course provides most advanced theories and techniques for numerical models of atmospheric and oceanic phenomena. Topics include finite difference, finite volume, and finite element techniques for solving partial differential equations, atmospheric forcing functions, linear and nonlinear computational instability, hydrostatic and nonhydrostatic models, and multi-layer and multi-level primitive equation models, treatment of irregular geometry, sigma coordinate system, global /basin scale modeling, regional/coastal modeling, air-ocean coupling, data assimilation, and structured and unstructured grids.

Course Structure

- Chapter 1 Air-Ocean Modeling – the Navy/DOD’s Needs
 - 1.1. Modeling – a Major Component of DoD’s Operational Oceanography
 - 1.2. Numerical Ocean Modeling CONOPS
 - 1.3. Ocean Modeling for Homeland Security
- Chapter 2 Basic Concepts in Air-Ocean Numerical Modeling
 - 2.1. Basic Processes in Air-Ocean Modeling
 - 2.2. Ocean Component in Atmospheric GCM
 - 2.3. Difference Between Atmospheric and Oceanic Models
 - 2.4. Model Initialization
 - 2.5. Air-Ocean Coupled Model
 - 2.6. Classification of Partial Differential Equations
 - 2.7. Numerical Methods
- Chapter 3 Numerical Differentiation
 - 3.1. Taylor Series Expansion
 - 3.2. Forward Differentiation
 - 3.3. Backward Differentiation
 - 3.4. Central Differentiation
 - 3.5. Differentiation Errors
 - 3.6. Lagrange Differentiation
 - 3.7. Partial Derivatives
 - 3.8. Bi-harmonic Operator

- 3.9. Richardson extrapolation
- Chapter 4 Numerical Integration
 - 4.1. Basic Numerical Integration
 - 4.2. Trapezoidal Rule
 - 4.3. Simpson's 1/3 Rule
 - 4.4. Simpson's 3/8 Rule
 - 4.5. Midpoint Rule
 - 4.6. Better Numerical Integration
 - 4.7. Composite Simpson's Rule
 - 4.8. Richardson Extrapolation
 - 4.9. Romberg Integration
 - 4.10. Gaussian Quadratures
- Chapter 5 Numerical Methods for Solving Partial Differential Equations
 - 5.1. Poisson Equation
 - 5.2. Laplace Equation
 - 5.3. Numerical Solutions
 - 5.4. Numerical Solution of Laplace Equation
 - 5.5. Convergence Criteria
 - 5.6. Gauss-Seidel Method
 - 5.7. Successive Over-Relaxation - SOR
- Chapter 6 Atmospheric Forcing in Ocean Models
 - 6.1. Wind and Wind-stress
 - 6.2. Surface Fluxes
 - 6.3. Forcing Data Generated Using Atmospheric Models
- Chapter 7 Computational Instability
 - 7.1. Linear Advection Equations
 - 7.2. Spatial Discretization
 - 7.3. Temporal Discretization
 - 7.4. CFL (Stability) Condition
 - 7.5. Stability of Various Schemes
 - 7.6. "Intuitive" look at stability
 - 7.7. Two-dimensional advection equation
 - 7.8. Nonlinear Instability
- Chapter 8 Hydrostatic and Nonhydrostatic Ocean Models
 - 8.1. Basic Equation
 - 8.2. Boundary Conditions
 - 8.3. Time Stepping
 - 8.4. Horizontally Staggered Grids
 - 8.5. Ocean Modeling History

- 8.6. Contemporary Ocean Models
- 8.7. Model Testing
- Chapter 9 Global/Basin Scale Ocean Models
 - 9.1. Ocean Modeling History
 - 9.2. Transformations of the Vertical Coordinate
 - 9.3. Classification of Global/Basin Scale Ocean Models
 - 9.4. Modular Ocean Model (MOM)
 - 9.5. Layered Models (NLOM, MICOM)
 - 9.6. Finite Volume Model
 - 9.7. Hybrid Coordinate Ocean Model (HYCOM)
 - 9.8. Model Testing
- Chapter 10 Regional/Coastal Ocean Modeling
 - 10.1. Coastal Ocean: A Challenging Environment
 - 10.2. Variability in coastal systems
 - 10.3. Equilibrium and Three Kinds of Variability
 - 10.4. Shelf dynamics overview
 - 10.5. Coastal Model Inventory
 - 10.6. Hydrodynamics of Coastal Regions
 - 10.7. Parameterization of Surface and Bottom Boundary Layers
 - 10.8. Numerical Discretization
 - 10.9. NCOM Ocean Model
 - 10.10. Barotropic Dynamics
 - 10.11. Vertical Diffusion
 - 10.12. Pressure Gradient Force in Sigma Coordinate System
 - 10.13. Wetting and Drying Schemes
- Chapter 11 Air-Ocean Coupling
 - 11.1. Is There a Better Set of Boundary Conditions at the air-ocean interface?
 - 11.2. Atmosphere-Swamp Ocean
 - 11.3. Atmosphere-Mixed Layer Ocean
 - 11.4. Atmosphere-Ocean GCM
 - 11.5. Coupling Methods
 - 11.6. Climate Drift
 - 11.7. Flux Corrections/Adjustments
 - 11.8. Three methods for Air-Ocean Coupling
 - 11.9. Design of Coupled Model Experiments
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 - 11.9. Design of Coupled Model Experiments
- Chapter 12 Data Assimilation
 - 12.1. Why do we need data assimilation?
 - 12.2. Basic Concepts of Data Assimilation
 - 10.3. Statistical Approach to Data Assimilation
 - 12.3. Univariate (scalar) data assimilation
 - 12.4. Multivariate (vector) data assimilation
 - 12.5. Optimal Interpolation
 - 12.6. Kalman Filter
 - 12.7. 3d-Variational (3D VAR) Method
 - 12.8. 4d-Variational (4D VAR) Method
 - Chapter 13 Structured and Unstructured Grids
 - 13.1. What are structured and unstructured grids?
 - 13.2. Finite Difference (Grid Point) Method
 - 13.3. Properties of Horizontal Grids
 - 13.4. Vertical Staggered Grid
 - 13.5. Round-off Errors
 - 13.6. Time Stepping
 - 13.7. Barotropic Dynamics and Time Splitting

Prerequisites:

MR4322, OC4211, MA3132, MA3232 desirable.

Course Grade

Lab 30%

Mid-Term 25%

Final Exam 45%