Spring semester 2024

OEAS-435/605
Introduction to Ocean Modeling and Prediction

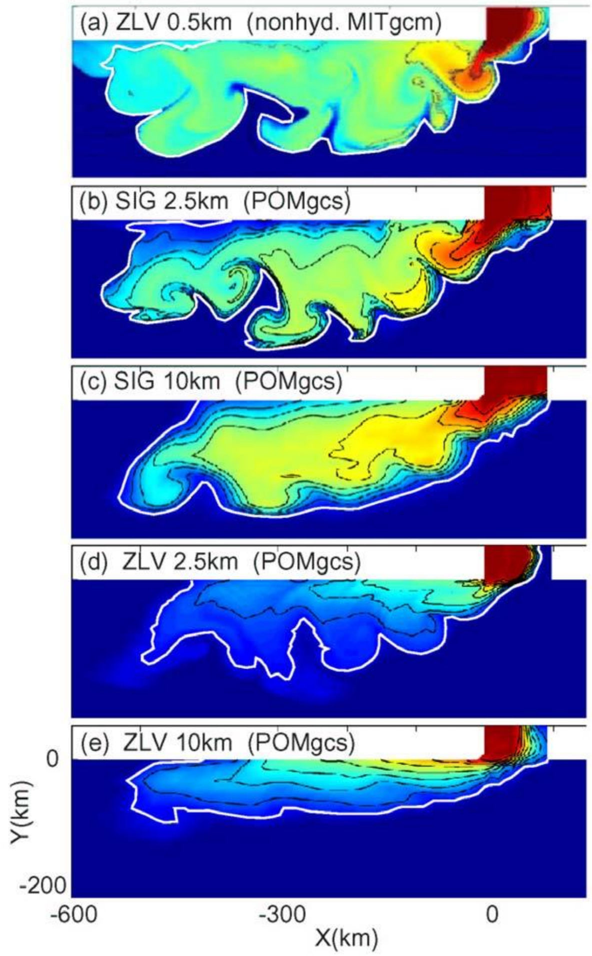

Figure. Example of simulations of the same density plume using different models and different grids.

Time: Tuesday/Thursday, 9:15am-10:30am (first class:1/9/24)

Location: CCPO, 4111 Monarch Way, Res.-I Bldg., Room 3200

Instructor: **Tal Ezer**
(http://www.ccpo.odu.edu/Facstaff/faculty/tezer/ezer.html)
(office: CCPO 3217, Phone: 683-5631, email: tezer@odu.edu)

Office Hours: Mondays 8:00-09:30 (or email for appointment)

Grading: Homework and project assignments (40%)
Mid-term exam, Thursday. 29-Feb-2024 (30%)
Final exam, Thu. 18-Apr-2024 (30%)

Class notes will be posted on the course web site:
http://www.ccpo.odu.edu/~tezer/435_605 and Canvas

Prerequisite: OEAS 604 or 405/505 Physical Oceanography (or permission by instructor). Grad students from modeling and simulation, coastal engineering, or other sciences with background in math/physics are also encouraged to take the class.

Related follow up courses:

- 708/808 Simulation techniques for ocean circulation (Klinck)
- 755/855 Mathematical modeling of marine ecosystems (Hofmann)
- 630/730/830 Dynamical oceanography (Klinck)

Aim of Course

The class will provide students a broad background on basic concepts in ocean modeling and prediction and will demonstrate examples of different usages of ocean models. Computer programming knowledge is not needed. Students will learn about the history of the development of ocean circulation models, about the different types of models, the choices that modelers need to make, and what data are needed to set up models for various applications. Basic knowledge of ocean properties, ocean circulation and the equations of motion, is useful, but a brief review will be provided.

* Students are expected to follow ODU's "code of student conduct" (https://www.odu.edu/oscai), and the vaccination and masking requirements of COVID-19 (https://www.odu.edu/status/covid-19).

Textbook

The class has no official textbook. Various sources such as journal papers, model simulations and online data will be used. Below are some suggestions for further reading.

Ocean modeling:

Haidvogel and Beckmann, *Numerical Ocean Circulation Modeling*, Imperial College Press, 1999.

Kantha and Clayson, *Numerical Models of Oceans and Oceanic Processes*, Academec Press, 2000.

Griffies, *Fundamentals of ocean climate models*, Princeton Univ. Press, 2004.

Forecasting and data assimilation:

Mooers (Ed.), *Coastal Ocean Prediction*, Coastal & Estuarine Studies Ser., 56, AGU Publ., 1999.

Pinardi and Woods (Eds.), *Ocean Forecasting: Conceptual Basis and Applications*, Springer, 2002.

Fu and Cazenave (Eds.), *Satellite Altimetry and Earth Sciences*, International Geophys. Ser., 69, Academic Press, 2001. (chapter 5 on data assimilation)

Numerical Methods:

O'Brien, J. J., Advanced Physical Oceanographic Numerical Modelling, Springer Publ., 1986.

Flannery, Teukolsky and Vetterling, Numerical Recipes in FORTRAN: The Art of Scientific Computing, H.W. Press, 1992.

Review papers:

Ezer et al., Developments in terrain-following ocean models: Intercomparisons of numerical aspects, *Ocean Modelling*, 4, 249-267, 2000.

Griffies et al., Developments in ocean climate modeling, *Ocean Modelling*, 2, 123-192, 2000.

Physical Oceanography background:

Stewart, *Introduction to Physical Oceanography* (online).

Other Phys. Oceanog. textbooks: Knauss, Pond & Pickard, Mellor,…

Syllabus

Introduction

- Review and classification of different ocean models
- Review of physical oceanography properties
- The equation of state used in different ocean models
- Review of terms used in modeling (vorticity, stream function, etc.)
- Data sources (i.e., Altimeter)

Equations and approximations

- Review of the equations of motion (Primitive Equations Models)
- Common assumptions and their impact (Hydrostatic, Boussinesq)

Parameterization of mixing in ocean models

- Horizontal and vertical diffusion & viscosity
- Turbulence schemes & mixed-layer models

Finite differencing and grid choices

- Basic finite differencing schemes and stability analysis
- Staggered grids and their impact
- Time split techniques and their effect on model efficiency
- Horizontal grids (rectangular, curvilinear, triangular, unstructured)

Quasi-Geostrophic and Shallow-Water Models

Classification of ocean models by vertical grid choices

- Z-level models and the BBL problem
- Isopycnal and layer models: from simple 1.5L reduce-gravity models to global hybrid models
- Terrain-following/Sigma-coordinate models
    - the pressure gradient problem
    - the horizontal diffusion problem
- Generalized coordinate models
- Comparison between models (idealized and realistic examples)

Boundary Conditions

- Sea-bed/bottom boundary conditions and sediments
- Surface boundary conditions and air-sea exchange
- Lateral/coastal boundary conditions
  - Special cases: rivers, wetting and drying
- Open boundary conditions
    - Radiation conditions, cyclical, buffer zones
    - Tides

Diagnostic models

- 2D basin scale circulation models based on the vertically integrated vorticity balance equation: the JEBAR effect and climate studies.
- 3D diagnostic models: robust-diagnostic, diagnostic-prognostic adjustment techniques and their applications for climate and coastal simulations

Data assimilation and Ocean Forecast systems

- Assimilation Methods and concepts:
  - Simple methods (insertion, nudging)
  - Sequential methods (Optimal Interpolation, Kalman Filter, 3DVAR)
  - Non sequential methods (4DVAR/adjoin, inverse)
- Examples from assimilations of Altimeter data
- Examples from ocean forecast systems in various locations