270.325: Introduction to (Physical) Oceanography

Instructors:
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This course introduces students to the basic physical structure of the ocean, the laws governing its motion and relates the large-scale circulation to biological and chemical cycling. While the course is centered around ocean physics, there will be a fair amount of chemistry and biology woven in. The goal is to get you to engage with relatively contemporary papers, data, and models.

The bulk of the course grade (~60%) will be from homework assignments. These will have a common format. You'll get a paper to read and will need to write a ~two-page double-spaced commentary on this. In the commentary you'll try to
a.) Summarize what bigger context for the work is (largely based on the class lectures but also potentially from the introduction of the paper).
b.) Summarize the main point/results.
c.) Discuss what questions these results suggest to your own mind.
Aim for an audience of one of your non-scientist classmates or your family.

Each homework will also have an exercise attached to it where you will basically work with a dataset or program in matlab so as to produce a result that either replicates or complements some of the main points in the paper. You may consult with other students on the problem sets but we expect you to write up your own work.

There will be a midterm and final. Basically these will ask questions that will use the material in the papers and lectures. There will also be occasional in-class quizzes that will be graded for completion only (i.e. you get a point for showing up). These are meant to reward those who come to class, but also so that we can figure out what I need to be making clearer and what you know and don't know.

There's no required book for the semester. Robert Stewart's Introductory Physical Oceanography is available online for free and we will a.) highlight where we are following along with the book. b.) try to use the same notation as the book.

Note on math: Mathematics is the language which we use to understand how the ocean works. If you've had calculus, you should be fine in this course. Prof. Gnanadesikan will, however, post some review of mathematical concepts (how to solve the two big classes of differential equations- exponential decay and the wave equation) and will run review sessions in the first couple of weeks. If you're joining the class after that come talk to us.

Office hours will be by arrangement, depending on people's schedules.

Grading; This course is designed so that if you do all the work adequately, you'll get a B. If you do it well, you'll get an A. We have no quotas for either grade but have found that the median grade in recent years is usually a B+.

Outline of the course:

Week 1: Introduction to hydrography (Gnanadesikan)

Ocean basins and the watermasses that fill them. Equation of state.T-S plots. Passive tracers and their use in describing watermasses.

Paper: Johnson, JGR, 2008 describing a modern watermass analysis.
Exercise: Compare Johnson's result to your own analyses with a few watermass types.

Week 2: Linking density anomalies to flows (Gnanadesikan)

Satellite altimetry and why the sea surface isn't flat. The Coriolis force. Geostrophic flow.

Paper: Haine, BAMS,on the Coriolis force.
Exercise: Estimating surface speeds from sea level heights.

Week 3: More on estimating large-scale flows (Haine)

Vertical shear and overturning. Using tracers to put constraints on flows. Atmospheric forcing.

Paper: Broecker et al., 1998
Exercise: Reproduce analysis of Broecker with gridded data.

Week 4: Angular momentum constraints on global circulation (Haine)

Sverdrup dynamics, Topography and stretching Western boundary currents

Paper: Stommel (1948)
Exercise: Run 2D matlab circulation model

Week 5:Wind-driven near-surface flow (Gnanadesikan)

Turbulence and diffusion, the Ekman spiral, Ekman upwelling

Paper: Price, Weller and Schudlich (1987)
Exercise: Find Ekman spiral in SWAPP data.

Week 6: Annual cycling of the upper ocean (Gnanadesikan)

Heat fluxes and heat balance, Annual cycle of temperatures-dependence on MLD Mixed layer dynamics and potential energy as currency

No assignment: Prepare for midterm

Week 7: More on turbulent mixed layers (Haine)

Shear instability and Richardson number, bottom mixed layers and overflows

Midterm

Paper: Price, Weller and Pinkel (1986)
Exercise: Run PWP model.

Week 8: Diffusion, tracers (Haine)

Vertical and lateral diffusion in the ocean.

Why mixing is so weak, yet so important.

Eddies

Advective/diffusive balance

Paper: Ledwell, Watson and Law, 1993

Week 9: Biological cycling (Gnanadesikan)

Biological cycling, light and mixed layer depth. The spring bloom. Satellite measurements of productivity. Nutrient limitation

Assignment: Behrenfeld (2010)
Exercise: Use backscatter, chlorophyll data to evaluate argument

Week 10: Ocean circulation and the carbon cycle (Gnanadesikan)

Ocean carbon chemistry, Ocean carbon pumps Paleoceanography and the LGM

Paper: Sigman et al. Nature, 2010
Exercise: Mechanisms to explain low interglacial carbon 14 in a four box carbon model

Week 11: Global overturning (Haine)

Diffusive scaling of the overturning

Box models of the overturning

Role of winds/eddies.

Paper: Gnanadesikan, Kelson and Sten (2017)
Exercise: Matlab model describing overturning sensitivity

Week 12: Ocean-related climate variability (Gnanadesikan)

El Nino, Overturning variability and climate, 21st century ocean change

Week 13: Ocean circulation at high and low latitudes (Haine)

Arctic, Antarctic, Equatorial Kelvin/Rossby waves

Paper: Haine et al. review paper