EEPS1520 Syllabus
Ocean Circulation and Climate
Or, Notions for the Motions of the Oceans

B. FOX-KEMPER

Brown University Department of Earth, Environmental, and Planetary Sciences,
324 Brook St., Providence, RI 02912, USA
baylor@brown.edu

(Updated 25 February 2021)

Or, Notions for the Motions of the Oceans
Examines physical characteristics, processes, and dynamics of the global ocean to understand circulation patterns and how they relate to ocean biology, chemistry, and climate change. Assignments address ocean's role in the climate system; ocean observations and models; the origin, distribution, and dynamics of large-scale ocean circulation and water masses; energy and freshwater budgets; and variability of the coupled system on seasonal to centennial timescales, e.g., El Nino. Intended for geological and physical sciences undergraduate and graduate students with quantitative skills and an interest in oceans, climate, paleoclimate. Pre-requisite: EEPS0250, EEPS0350, PHYS0720 or APMA 0180. Scientific computing experience helpful. Offered alternate years, previously offered as GEOL1100, GEOL1520. WRIT.

Key Words: Ocean Circulation, Climate, Ocean Data, Research Papers.

---

1. Contacts

The professor for this class is: Baylor Fox-Kemper
baylor@brown.edu
401-863-3979
Office: GeoChem room 133
Zoom Office and Virtual Classroom: `http://brown.zoom.us/my/baylorfk`
`http://fox-kemper.com/teaching`, `http://fox-kemper.com/po`

Portions of the website are password-protected to ensure that fair use and copyrights are correctly obeyed as I share images from books, etc. You can access these by using:
`username: io`
`password: ocean`

2. Getting Help!

I am usually available by email. You can make an appointment other times. Just check my calendar at `http://fox-kemper.com/contact` and suggest a time that works for you.

3. Goals

In this class you will:

1. Learn about many of the physical processes that occur in the ocean.
2. Learn about how these physical processes are observed, budgeted, and quantified.
3. Learn where these processes occur.
4. Learn about and access recent ocean datasets.
5. Get practice writing and thinking scientifically by focused study of processes.
6. Gain a broader perspective and practice by reviewing your peers' efforts.
7. Benefit from reviews of your writing by your peers.

A list of the basic topics covered in this class is:

1. Observations (1 Week)
   What instruments are common to oceanography?
   How are these measurements used?
   How do the types of measurements influence theoretical developments?
2. Fluids Mechanics (2 Weeks)
   The differential equations describing a fluid
   The differential equations describing a Boussinesq fluid
   How the differential equations relate to budgets & conservation of:
   salt, freshwater, energy, entropy, potential temperature, momentum, velocity, vorticity, potential vorticity
   Scale and Dimensional Analysis
   Reduction to a *dominant balance* for a particular phenomena
   Using dimensionless groupings (e.g., Reynolds, Rossby, Ekman, Richardson, Froude) to identify *dominant balances*
3. Rotation (2 Weeks)
   Equations of fluid motion in a rotating frame of reference
   Ekman layers and balance
   Geostrophic balance
4. Stratification (2 Weeks)
   The temperature, salinity, and density stratification of the ocean
   Hydrostasy
   Baroclinic and Barotropic
   Potential temperature and potential density
   Thermal wind balance
5. Vorticity balances (1 Week)
   Taylor-Proudman Flow
   Sverdrup Flow
   Thermal wind as vorticity budget
   Gyre flow as a vorticity budget
6. Ocean Circulation (2.5 Weeks)
   Wind-driven ocean circulation
   Western boundary currents
   Antarctic Circumpolar Current
   Meridional Overturning Circulation
   Theories of the thermocline
   The pressure distribution of the ocean
   The circulation of the ocean and climate
7. Forcing (1 Week)
   Air-sea exchanges of sensible & latent heat, momentum, energy

Radiation forcing (shortwave=solar and longwave)

8. Waves (2 Weeks)
   Dispersive Wave Kinematics: Phase & Group velocity
   Important kinds of ocean waves: surface gravity, internal gravity, tides, Rossby, Kelvin
   Nonlinear waves, eddies, vortices, and coherent structures
   El Nino

4. Meetings and Places

We will meet Tuesdays and Thursdays from 1 to 2:20PM in Friedman Hall 201 or virtually at `http://brown.zoom.us/my/baylorfk`. Office hours will be by appointment (see my schedule at `http://fox-kemper.com/contact`).

You should obtain the software we'll be using (primarily matlab or python if you prefer). You can download a copy of matlab for yourself from `http://software.brown.edu/dist/index.html` for free. Python is also free, we will use the Google colab for consistent environment settings. The website (`http://fox-kemper.com/1520`) has many links to datasets that are freely available. I will provide local access to some of the most convenient ones at `http://fox-kemper.com/data`.

4.1. *Calendar*

The main webpage for the class `http://fox-kemper.com/1520` has the calendar with all assignment deadlines, readings, etc. There are four major projects, which each have five stages toward the final revision of the paper.

4.2. *COVID*

We are likely to have all of our synchronous classes with remote participants, or fully virtual classes. These will always be located at `http://brown.zoom.us/my/baylorfk`. For this reason I plan to work a little differently this spring than in previous years. I will provide links to a set of short lectures for you to watch on your own time, which will be linked from the calendar on the course webpage (`http://fox-kemper.com/po`). We will then use the synchronous class time for discussion, questions, and feedback. For this reason I will not schedule additional office hours, although if you need a private meeting with me do not hesitate to request one during an open spot on my calendar (`http://fox-kemper.com/contact`). As the spring progresses, if the campus safety is high then we may start having in person discussions.

5. Canvas and Websites

The primary resource for this class is the webpage: `http://fox-kemper.com/1520`. The class webpage is where all of your assignments will be announced, links to reading and textbooks will be posted, etc. The second web resource is the canvas page for the class. All homeworks, papers, and peer reviews will be turned in through `http://canvas.brown.edu`.

You will want to familiarize yourself with Google Scholar (`http://scholar.google.com`) and the Web of Science (`http://apps.webofknowledge.com/`). Both are free to you, and they will help you with your paper preparations.

6. Textbooks and Software

We will use three primary textbooks: *Modern Observational Physical Oceanography* (Wunsch 2015) gives information about the ECCO state estimate, traditional observa-

tions, and some basic dynamics; *Ocean Circulation and Climate* (Siedler et al. 2013) gives a recent update on modern observations and regional ocean processes; *Ocean Circulation* (Colling 2001) gives nice illustrations and basic force balances that we will discuss. Electronic versions of most of the books and resources in the class can be accessed electronically through the Brown site/vpn access (you must be on campus or hooked in with VPN or the library's EZproxy to access). More detail can be found in (Vallis 2006; Tomczak and Godfrey 1994), which are accessible through links from the course webpage and the bibliography here.

All of the required readings will be posted on the website. Hard copies of many of these books, as well as some others you should become familiar with are in the Science Library. I recommend browsing a bit and seeing what there is (Library of Congress Call Numbers GC11, GC150, GC228, and QC809 are good places to start).

The class will require use of software and computers capable of opening ocean datasets. I strongly recommend matlab, but you could use Java Ocean Atlas, IDL, Ocean Data View, python, or ferret (although I will be less able to offer help!). All of these are available to you free for PC, Mac, and Linux. A good netcdf browsing software, such as ncview, Panoply, or Ocean Data View will be very helpful!

7. Assignments, (lack of) Exams, and Expected Time for Activities

There will be four major assignments for this class, and all of them will be in the form of short scientific reports. You will often be working on two assignments at a time, reviewing and revising the last one (a little work), and preparing the next one (more work). There will also be short homework assignments based on lectures and reading and building toward the four projects. There will be no additional exams or midterms. The final revision of the final paper is presently scheduled to be turned in at the end of exam week, although I have tried to schedule sufficient time the preceding week so that it can be completed before exams. The weighting of the assignments will be:

- Class meetings (3 hours/week; 39 hours) [Grading: 9% Attendance, participation]
- Reading and reviewing class work (1 hours/week; 13 hours)
- Four reading/paper preparation assignments (4×4 hours; 16 hours) [Grading: 12%]
- Four paper plans assignments (4×4 hours; 16 hours) [Grading: 12%]
- Four sets of calculations on project (4×6 hours; 24 hours)
- Reading literature to support paper/project (4×4 hours; 16 hours)
- Four papers written for first submissions (4×6 hours; 24 hours) [Grading: 40%]
- Three peer reviews (6×3 hours; 18 hours) [Grading: 15% Reviews of peers]
- Revise and resubmit papers. (3×4 hours; 12 hours) [Grading: 12% Revisions]
- Total: 180 hours [Grading: 100%]

What can help me get a good grade? Turn all of the assignments in on time. This is *more important* than turning in complete assignments. For the peer-reviewing format of the course to work, ON TIME for the FIRST SUBMISSIONS is CRITICAL, so we can get to the reviewing. Paper plans also need to be turned in, so that I can give timely feedback on paper plans and you can get started. If you cannot complete an assignment on time let me know *in advance of the deadline*. **Unexpectedly late papers will not be accepted**.

Assignments are to be in pdf file format (so they can be commented on in Canvas) and created according to American Geophysical Union Geophysical Research Letters templates. If you want to use LaTeX, I can help. I strongly recommend you use `http://overleaf.com`, where you can easily open the AGUTeX (for JGR/GRL) as a template

to get started. If you want to use something else, you can download the AGU templates, but you're on your own if things go wrong!

The scheduling of the assignments are listed on the webpage, and other than the exceptional week around fall break will be as follows.

•HW assignment $\#n$ will be due on a Saturday at 11:59 PM two weeks before the paper. They will be submitted electronically, and they establish basic tools for the upcoming paper, and I will comment on them ASAP.
•Plans $\#n$ will be due on a Wednesday at 11:59 PM one and a half weeks before the paper. They will be submitted electronically, and I will comment on them ASAP. Full credit will only be given if you have generated some results and begun reading some references. I will respond by email with suggestions for focus the following week.
•Paper assignment $\#n$ will be due on a Saturday at 11:59 PM. They will be submitted electronically.
•By Sunday at noon, you will receive two of your colleagues' $\#n$ papers to review electronically.
•On Tuesday, we will have class. You can discuss anything with me or the class about your paper or the papers you are reviewing ($\#n$) or paper $\#n+1$ that *you have already begun thinking about*.
•On Wednesday by 5 PM, your reviews of your colleagues' two papers ($\#n$) are done and submitted electronically.
•By Friday midnight, I will have your paper $\#n$ back to you, with my reviews and your peer reviews. Discussion during class or an appointment is encouraged of returned paper $\#n$
•The following Wednesday at 5 PM, a revised version of your paper is due.
•That Saturday, the next HW $\#n+1$ is due.
•The process restarts.

All of this will be charted out on the calendar on the website and in Canvas.

Before you get worried about writing four papers for one class, let me explain the goals of the paper writing. These are *not* supposed to be polished, ready to submit papers detailing years of research. Instead, they are supposed to be practice in writing drafts for your real research. The idea is to get used to pounding out a working draft in only a couple of hours, so that when the time comes for you to do it for real, that part will be easy.

Since you all have different preparation, you will all be able to take advantage of what you know. However, we are working to develop elements in all of the following:

•Quantitative Skills and Equations for the Ocean (Theory/Modeling Component)
•Descriptive Skills and Geography of Ocean Currents (Descriptive Oceanography)
•Understanding of Ocean Observations and Techniques (Observations/Engineering Component)
•Physical Intuition and Dynamical Understanding (Theory/Dynamics Component)
•Implications for Climate, Society, etc. (Policy & Climate Component)

By the end of the semester, you should have addressed each element somewhat in some of your papers.

I hope you will get inspired along the way, and you can revise one of these little papers into a real paper or a prelims or honors project, but don't get upset because you have to hit the ground running. You'll have to do it sometime, and this will be in a friendly environment!

7.1. *Why papers?*

I think that this approach helps to balance the class. Folks with a lot of quantitative experience will be able to use that to their advantage while folks with more substantial preparation in writing, argument, and logical structure will be able to use those abilities. We will be using up-to-date oceanographic datasets, and so the work you are doing is potentially cutting edge research (but that's up to you!). Also, in the future you will be expected to write much more complicated papers in a more tightly constrained time frame, you might as well get some practice now. Please see `http://www.geo.brown.edu/research/Fox-Kemper/classes/EEPS1520_21/notes/paperprimer.pdf` for more details.

7.2. *Peer review*

In addition to writing the papers, you will each be performing anonymous reviews of each others work. This will give you an opportunity to read closely about topics other than the one you chose, and hopefully you will be able to learn about science writing more quickly. Also, there are a lot of quandaries that arise in peer-reviewing (e.g., one reviewer loves it and one hates it, or a reviewer makes incorrect statements), so you'll get some experience with those issues by practice in a friendly environment.

We will be using a rubric based on the AGU guidelines for review. They are a useful guideline to go by, and when you do reviews of your fellow students, I'll expect to get a A1 or B2 or B1 score, etc. Please see `http://www.geo.brown.edu/research/Fox-Kemper/classes/EEPS1520_21/notes/peerprimer.pdf` for more details.

There are a few lessons to be learned here, that will help you write your own papers and will help you provide effective and useful reviews in your career.

- Learning to spot unfounded claims
- Learning how to properly support claims
- Learning to distinguish poor writing from poor thinking
- Learning to label equations, graphs, and numerical information understandably
- Learning about a broader swath of oceanography than those isolated topics you choose for your own papers.

7.3. *Revisions and response to reviewers*

In following along with the expectations of a journal, after receiving your reviews, you will revise your paper. You do not have to take every suggestion made by the reviewers. Indeed, deciding what not to respond to is a critical part of appreciating the content of a review. As such, you will need to prepare a set of responses to the reviews along with the revised paper. You can just make a text file for these responses, and then paste these comments into the comments box on canvas. That way, Baylor can read through your responses alongside the revised paper. You do not have to respond in detail to small critiques, just begin your response to reviewer with "all minor comments were corrected." Then, for the bigger comments, repeat the comment and reply to it. Please see `http://www.geo.brown.edu/research/Fox-Kemper/classes/EEPS1520_21/notes/responseprimer.pdf` for more details.

7.4. *What will we do with all these peer-reviewed papers?*

As the semester continues, there will be some papers of yours that you like quite a bit, or that were very positively reviewed. Either you or me can designate them as 'publishable', so that the whole class can see them and subsequent classes can, too. At the end of the semester, all of you will be able to access the assembled published papers: 'Proceedings of GEOL1520: Notions for the Motions of the Oceans, Spring 2013'. You

can use this proceedings for your future reference, and it will be available for future GEOL1520 inductees. It is up to you which papers you want published (if any).

You can access the previous year's proceedings through the course website with the password I've emailed to you. You will find many good ideas and interesting papers there to help you find your way in writing your own.

Here is the location where your proceedings will go: `http://www.geo.brown.edu/research/Fox-Kemper/classes/EEPS1520_21/proceedings.shtml` Here are all of the past proceedings (username: io, password: ocean):

- `http://www.geo.brown.edu/research/Fox-Kemper/classes/GEOL1520_19/proceedings.shtml`
- `http://www.geo.brown.edu/research/Fox-Kemper/classes/GEOL1520_17/proceedings.shtml`
- `http://www.geo.brown.edu/research/Fox-Kemper/classes/GEOL1520_15/proceedings.shtml`
- `http://www.geo.brown.edu/research/Fox-Kemper/classes/GEOL1100_13/proceedings.shtml`
- `http://www.geo.brown.edu/research/Fox-Kemper/classes/CU/ATOC5051_10/proceedings.shtml`
- `http://www.geo.brown.edu/research/Fox-Kemper/classes/CU/ATOC5051_08/proceedings.shtml`
- `http://www.geo.brown.edu/research/Fox-Kemper/classes/CU/ATOC5051_07/proceedings.shtml`

8. Policies

8.1. *Deadlines*

Because of the reviewing process, the scheduling of assignments is tight. Thus, I will have to insist that all papers be turned in on time. If they are late, they will drop a letter grade. If they are really late (so that they mess up the next step in the reviewing process) they will be counted as missed and can not be made up. If you foresee that there are big problems coming up (medical, family, etc.) let me know *before* an assignment is due and we can figure something out.

8.2. *Collaboration*

I encourage you to work together, and I do not mind at all if you have similar papers or share figures or matlab scripts. However, in this case, I want you to list all of your study group as co-authors or put them in the acknowledgments section of your paper. You are all required to submit a version of each assignment as first author (that is, one that you wrote yourself). You need to be careful to cite your colleagues or the textbooks or papers you might be working from. You can use as much of these resources as is convenient in your version of the paper, but you need to properly cite the sources. We will discuss this topic more as the class (and the inevitable trouble) ensues. These issues of plagiarism and proper sourcing are a big part of what is to be learned in this method of assignments.

A few other items:

- Attendance is expected. If you will miss a class, please let me know when and why so I can be sure you'll get any announcements, etc.
- Clothing and behavior (e.g., cell phone use) should be appropriate for a learning environment.
- Discrimination and harassment will not be tolerated.
- Please contact me if you have any disabilities that require accommodation.

REFERENCES

Colling, A.: 2001, *Ocean circulation*. Butterworth Heinemann, in association with the Open University, Boston, 2nd ed. edition.
URL `http://bit.ly/2j9eSue`

Siedler, G., S. M. Griffies, J. Gould, and J. A. Church, eds.: 2013, *Ocean Circulation and Climate*, volume 103 of *International Geophysics Series*. Academic Press (Elsevier Online), 185–209 pp.
URL `http://bit.ly/2k4v97X`

Tomczak, M. and J. S. Godfrey: 1994, *Regional oceanography: an introduction*. Pergamon, Oxford, England, 1st ed edition.
URL `http://gyre.umeoce.maine.edu/physicalocean/Tomczak/regoc/pdfversion.html`

Vallis, G. K.: 2006, *Atmospheric and Oceanic Fluid Dynamics : Fundamentals and Large-Scale Circulation*. Cambridge University Press, Cambridge.
URL `http://bit.ly/SDSMSK`

Wunsch, C.: 2015, *Modern observational physical oceanography: understanding the global ocean*. Princeton University Press.