

# Syllabus for GEOL1820: Geophysical Fluid Dynamics, Rotating, Stratified Turbulence Edition

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## 1 Course Descriptions

### 1.1 GEOL1820 Geophysical Fluid Dynamics

Explores theories of the large-scale ocean and atmosphere, including quasigeostrophic, planetary geostrophic, and shallow water equations. Topics will vary to focus on features of the general circulation and climate system (e.g. thermocline, westward intensification, jet stream dynamics, polar vortex, meridional overturning circulations), instabilities and waves (e.g. gravity, Rossby, and Kelvin), or rotating stratified turbulence. May be repeated with permission of instructor. Pre-requisites: Pre-requisite: GEOL0350 or PHYS0720 or APMA 0340 and GEOL1510 or GEOL1520.

## 2 Contacts

The professor for this class is Baylor Fox-Kemper:

baylor@brown.edu, 401-863-3979, Office: GeoChem room 133

<http://fox-kemper.com/teaching>, <http://fox-kemper.com/gfd>

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:

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username: io  
password: ocean
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## 3 Getting Help!

I am usually available by email. Office hours will be Thursday 1-2 or by appointment (see my schedule at <http://fox-kemper.com/contact>). You can also drop into the Math Resource Center (MRC, <http://www.math.brown.edu/mrc/>) or sign up or drop in to a tutoring session (<http://www.brown.edu/academics/college/support/tutor>).

## 4 Required Course Activities

### 4.1 Meetings and Places

We will meet Monday, Wednesday, and Fridays from 9:00 to 9:50AM in GeoChem 0290. Office hours will be Thursday 1-2 or by appointment (see my schedule at <http://fox-kemper.com/contact>) in my office (GeoChem 133) or lab (GeoChem 134).

## 4.2 Structure of Classtime

This course has a variety of different topics, with a rotation between them. This particular version will be on rotating and stratified turbulence, following topics drawn from Vallis (2019), (Thorpe, 2007), and Wyngaard (2010), with some added sections on my recent work (Fox-Kemper et al., 2008; Fox-Kemper et al., 2011; Callies et al., 2016; Bachman et al., 2017; Pearson and Fox-Kemper, 2018; Li et al., 2019; Bodner and Fox-Kemper, 2020).

The regular class time will be presentation of new materials and discussion. This format requires buy-in from you, the student, however. You *must at least skim the associated chapters in the book* before class. If an individual student fails to do this, it will negatively influence her or his ability to follow, and if the class fails to do this I will have to expand the lecture mode—decreasing the problem-solving mode—which is not good for learning. We will have student-led discussions of topics in the textbook and papers, as well as lectures from me. The schedule will be decided as soon as the number of students in the class is settled. Friday practicum classes will focus on a discussion of homework problems, with discussion of issues in ongoing problem sets or solutions presented by the students at the board of problem sets already turned in.

Magdalene Lampert, a researcher in math education, has shown that learning and retention in mathematical methods is improved by inverting the common classroom presentation order. Lecture, followed by discussion, followed by individual homework is not as effective as individual effort, group effort, full discussion. We will use the discussions and the practicum sessions to adhere to the latter format as best as possible.

## 4.3 Assignments, Exams, and Expected Time for Activities

There will be homework assignments bi-weekly. There will be no exams, but there will be a final project, which will be a critical written review of a paper of mine in the present literature (e.g., Fox-Kemper et al., 2008; Fox-Kemper et al., 2011; Callies et al., 2016; Bachman et al., 2017; Pearson and Fox-Kemper, 2018; Li et al., 2019; Bodner and Fox-Kemper, 2020) or that of someone else (e.g., Callies et al., 2015; Sullivan and McWilliams, 2018; Wenegrat et al., 2018; Kunze, 2019). The weighting of the assignments will be:

- Scheduled class meetings, which will be suspended in the Reading Period (3 hours/week; 38 hours) [Grading: 20% Attendance, participation, discussion leading]
- Reading and reviewing class work (3 hours/week; 38 hours)
- Bi-weekly assignments (6 hours/week for 12 weeks; 72 hours) [Grading: 50% Weekly homework]
- Bi-weekly peer reviews (1 hours/week for 12 weeks; 12 hours) [Grading: 10% Reviews of other students' assignments]
- Final project (20 hours) [Grading: 20% Final project]
- Total: 180 hours [Grading: 100%]

What can I do to get a good grade? Turn in all of the assignments on time, do the reading in advance of class, and participate in class discussions. For the format of the course to work, on time matters, so that we can get to the reviewing. Also, *BONUS POINTS* are available on homework and exams for spotting typos in the answer keys, homework assignments, and exam problems. The more promptly you point them out (by email), and the more important they are, the more points you get!

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

- Bi-weekly assignment due by class time on Friday (week 2)
- Answer key distributed and discussed in Friday practicum (week 2; assignments not accepted afterward)
- Peer reviews due by following Thursday (week 3)
- Peer review issues discussed in Friday practicum (week 3)
- Assignments graded and returned by Monday (week 4)
- Next bi-weekly assignment due by class time on Friday (week 4)
- Next peer review due by Thursday (week 5)
- *Iterum usque ad finem*

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

#### 4.4 Peer review

In addition to doing the problem sets, you will each be performing reviews of each others work. We will be using a rubric based on the AGU guidelines for review. A-F for presentation quality and 1-5 for science/math. Such a guide is useful 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. An A1 will count for 100%, and presentation and accuracy will be equally weighted (an F5 will be 20%). 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/presentation from poor thinking
- Learning to label equations, graphs, and numerical information understandably
- Revisiting problems from a different student's perspective

You will have each of your homework assignments peer-reviewed by more than one person, and inconsistent results will be rechecked. The assignments for reviewers will rotate (ensuring fairness in grading by randomization). You should feel free to contact me with any concerns about the process or specific issues.

#### 4.5 Calendar

The main webpage for the class <http://fox-kemper.com/1820> will have the calendar with all assignment deadlines, readings, etc. set up by the first class session. The final project will be due at the scheduled time of the final examination.

### 5 Goals

In this class you will:

- Learn how to quantify some of the physical processes of the Earth System.
- Learn about turbulence
- Learn about different types of averaging
- Begin to understand the effects of rotation and stratification on turbulence, and the definition of turbulence in a variety of contexts.
- Get practice solving diverse geophysical and geological problems using new mathematical techniques.
- Gain a broader perspective and more practice by peer reviewing and collaborating.

## 5.1 Applications

Geophysical and geological applications touched on in this class are:

- Geophysical Fluids
  - Equations and fluid dynamics on a rotating planet
  - Equations and fluid dynamics with stratification
  - Quasigeostrophic theory
  - Planetary geostrophic theory
- Turbulence
  - Instability
  - Cascades and inertial ranges
  - Mesoscale, Submesoscale, and Boundary Layer Turbulence
- Parameterizations
  - Oceanic
  - Atmospheric
- Scaling Laws and Dimensional Analysis

## 5.2 Critical Concepts and Outline

A list of the topics to be touched on in this class and rough timeline:

- Review of Fluid Dynamics (1 week)
- Rotating Equations (0.5 weeks)
- Stratified and Boussinesq Equations (0.5 weeks)
- Reynolds and Other Averaging (0.5 weeks)
- Quasigeostrophic Theory (1 week)
- Planetary Geostrophic and Semi-Geostrophic Theory (1 week)
- Kolmogorov Theory (2 weeks)
- Mesoscale Turbulence (2 weeks)
- Submesoscale Turbulence (2 weeks)
- Boundary Layer Turbulence (2 weeks)
- Beyond These Regimes (remaining time)

## 6 Canvas and Websites

The primary resource for this class is the webpage: <http://fox-kemper.com/1820>. The class webpage is where all of your assignments will be announced, solution sets posted, links to additional reading will be posted, etc. Assignments should be turned in and peer reviewed using canvas. The copiers in GeoChem and elsewhere can be used to scan handwritten assignments (for free).

## 7 Textbooks and Software

We will use one primary textbook: Vallis (2019). Another useful reference on turbulence is Wyngaard (2010), which is available online through the Brown library (see url in bibliography). Other textbooks and articles, all of which are available electronically through the Brown Library or just on the web, will be linked through the webpage.

We will solve problems drawn from many geophysics and geology textbooks (Tennekes and Lumley, 1972; Kundu, 1990; Pope, 2000; Drazin and Reid, 2004; McWilliams, 2006; Vallis, 2017; Marshall and Plumb, 2008; Cushman-Roisin and Beckers, 2010), but these books are not required for the course. If electronic copies of them are available at Brown, I have added an url to the bibliography here and on the website. Sufficient background will be provided along with each problem so that no further reading will be required. You may want to use software, which is allowed for homework (although usually not required and you must still be able to explain your work without the program). I strongly recommend Mathematica, but there are lots of others.

## 8 Policies

### 8.1 Deadlines

Because of the peer reviewing process, the scheduling of assignments is tight. Thus, I will have to insist that all problem sets 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 problem sets or share figures or mathematica scripts. However, in this case, I want you to list all of your study group on each homework assignment (so I can avoid you peer-reviewing your group). You are all required to submit a version of each assignment as first author (that is, one that you wrote yourself), so don't submit identical versions of a problem. You need to be careful to cite your colleagues or the textbooks, websites, or papers you might be working from.

### 8.3 Miscellany

- 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 & laptop 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

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