Final Paper for GEOL 1820: Geophysical Fluid Dynamics, Waves and Mean Flows Edition Due Dec. 13, 2016

Baylor Fox-Kemper

November 7, 2016

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

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.

1 Basics

For this final paper, you will write a review paper whose primary task is to compare two sources (two papers, or our textbook and one paper). You may not compare two textbooks; at least one source should be a primary peer-reviewed paper. Some of the papers suggested are on arxiv, rather than in a peer-reviewed journal. These are also acceptable, but you should inform yourself of arxiv and what it is.

You may use additional sources, to provide clearer figures, supporting data, etc. But it is best to keep the primary focus on comparing the approaches from two sources.

Your goal is *not* to summarize the papers in their entirety. Instead, you want to hit on 2-4 ideas that appear in both papers and contrast them. For example, the same equation may appear in both places, but is applied in different ways. The same dataset may be used, but interpreted differently. The two simultaneous goals of a review paper are: 1) to introduce the topic in a direct and simple, though accurate way (leaving most of the details to the primary papers), and 2) to highlight contention between different authors or remaining problems that require future research. Obviously, the latter may require some conjecture on your part, but that's what this project is meant to exercise!

1.1 What Do I Need to Review?

While I am pretty familiar with most of the papers I suggest, and very familiar with the textbook, do not assume that your reader recalls every subtlety of every argument in the papers. Nor should you assume that you need to follow back through every detail of the whole paper to introduce one idea at the end.

You will identify only about 2-4 ideas which are touched on in the two papers. You can basically plan to have one paragraph for each of these ideas from each of the two sources. That will be 4-8 paragraphs (400-1600 words, 1-3 publication units). You will then need at least one paragraph to contrast each idea (2-4 more, 200-800 words, 1-2 publication units). Add about 4 figures (4 units) and the accompanying discussion of them (1-2 units), introduce and conclude and you have the whole paper.

2 General Comments on Papers

Before you get worried about writing a paper, 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 that frames a scientific argument, so that when the time comes for you to do it for real, that part will be easy. These scientific arguments will be longer than you are likely to have in homeworks, so it is a bit of a different logical task as well.

2.1 AGU formats and templates

We will be writing all of the papers according to the style, page length, and guidelines of the American Geophysical Union (AGU) journal: *Geophysical Research Letters* (GRL). GRL is geophysics' own version of *Nature* or *Science*, and it contains only very short focused articles (4 single-spaced, small-type pages, usually 4 figures or fewer). I chose this journal because it has very clear guidelines for formatting and reviews, as well as an online article length checker that we can borrow! Regardless of your specialization, you will probably have an opportunity to write a GRL paper in the near future, so this will be good practice.

The GRL article length is now measured as being 12 or fewer "publication units." One publication unit is either 500 words, one figure, or one table. By words, the abstract, main article, and captions are counted, not author lists, bibliography, and other filler. So, if you use only words, you could have a 6000-word article, which is about 10 pages of single-spaced, 10pt Times. Or, if you have 10 figures or tables, then you have only 1000 words left to use (less than 2 pages)... Figures can have related subpanels, but each new "thought" means a new figure. So, you will need to plan to economize.

You should discuss every figure or table with at least one sentence, to inform the reader why you have included it. You can use Grab or cut and paste out of the pdfs of papers to add figures to your paper. You do not have to worry about copyright (academic use is "fair use"), but you do have to worry about correct attribution, i.e., add a citation within the figure caption telling where you found it.

I love LaTeX, and it is the BEST for writing scientific papers with lots of equations. However, I understand that many of you don't want to learn it and are happy with something you have to spend money on that doesn't look as good (LaTeXis free for download: `http://www.tug.org`). There are AGU LaTeXtemplates at `http://www.latextemplates.com/template/american-geophysical-union`.

Lots of details on formatting and templates are available at
`http://publications.agu.org/author-resource-center/author-guide/text-requirements/`.

2.2 You will submit your paper in pdf format.

You will submit your paper in pdf format. It should be ready to print, and line numbers are super handy for me to comment! We will be adding inline reviews using Crocodoc through canvas, as well as as written statement summarizing the main points of your review. Only a pdf can be marked up in this manner.

2.3 Abstracts: What are they and do you need them?

You need to have an abstract on every paper. It is a summary of what you've done, with enough detail that a reader can decide whether your paper has what they need or not in it, and they can quickly refresh their memory as to which paper of yours it is, too! It's the first thing after the title and authors' names.

Imagine doing a google scholar search for a keyword when you are working on one of these papers. For example, "North Atlantic Deep Water" input to scholar.google.com just got 6,590 hits, so how do you sort through them? 1) The number of citations generally tells you if it is a useful and/or a controversial treatment. 2) You read the titles, 3) You skim the abstract, 4) you skim the figures, reading the captions only. You should write your title, abstract, and captions for this audience: someone skimming a mess of papers on a related topic trying to find the particular treatment or fact that they need without reading all of the papers.

In the particular case of a review article, you will want to introduce your two main sources in the abstract (and maybe even title!), and then proceed to detail the primary comparisons you'll make and any conclusions you draw.

2.4 The Theory & Methods, or Background Section

In a theory section you will state the equations you will be using in every subsequent calculation and every figure beginning from a collection of equations from your sources. You should feel free to change symbols to make your different sources match, but be careful if definitions or conventions differ between the papers.

2.5 Graphics

A figure should be included inside the text just after the figure is mentioned in the text. It makes for easier reading with figures on same page as discussion.[1] (Note: every figure deserves at least one sentence of explanation in the text!) Every figure should have a caption, which should be short but detailed enough to understand the figure without digging in the text. Just like writing the title and abstract for the skimmer, write the figure caption so that by reading just the title, abstract, and figure captions gains an outline of the work.

2.6 Acknowledgements: Pay and Friends

Over time, the acknowledgements has become a place to state who paid for the research (you'll notice journal articles with acknowledgments that begin 'This research was funded under NSF...'). So, you can begin with this if you like, e.g., "This research was funded under a G.R.A. sponsored by (insert advisor/dept. here)." More importantly, if you talked to classmates or other teachers, and they gave you a good idea it is good to mention them here for two reasons: 1) It is a nice way to recognize their help, and 2) it closes the door on plagiarism. What I mean by 2) is, if you state that someone helped you in some regard, then they can't say that you 'stole' the idea from them. Instead, you just borrowed it, with adequate acknowledgement.

2.7 A Special Role for Facts

Because of the special role for facts in the scientific method, scientific papers must be very careful when dealing with statements of fact. There are three ways to make a factual statement in a paper. You can:

1. Prove it (in data presented or analysis)

[1] In LaTeX, use preprint rather than draft.

2. Cite it (and pass the buck to another source)

3. Speculate it (and clearly indicate you're doing so)

If you aren't sure which one you're doing, *you aren't allowed to make the statement*, at least not in a scientific paper.

For example, if you are trying to make a point like, "The oxygen content of NADW is anomalously high." You can 1) make a figure, 2) cite a source, or 3) hypothesize that it should be high because the NADW was recently near the surface (where it equilibrated with the atmosphere) and then sunk quickly below the depths of important biological activity. Or, if it is an important point, you can do all three!

2.8 Citations: When and Why?

Citations are a bit like the acknowledgements in that they shield you from plagiarism, but they also serve another equally important role: they allow you to pass the buck to another author/work who has proven it elsewhere.

2.8.1 How to do citations in LaTeXwith BibTeX

LaTeX has a sister program called BiBTeX, which processes a database of *.bib files to extract and label the citations you use within a particular paper. In the atocsample.tex file that I provided, there is also an atocbibliography.bib file that has some useful references for the class. If you want to add another one, just cut and paste one of the existing ones, and edit it. For example, the first reference in the database *.bib file is:

```
@BOOK{Pedlosky87,
AUTHOR     ="Pedlosky, J.",
TITLE      ="Geophysical Fluid Dynamics",
PUBLISHER  ="Springer",
ADDRESS    ="Berlin",
YEAR       ="1987",
EDITION    ="2nd",
PAGES      ="710"}
```

Most of the listings are obvious, but perhaps the most important is not. It is the reference name (Pedlosky87). If you want to cite this book anywhere in a LaTeX file, you can use

```
\citet{Pedlosky87}
```

When LaTeX sees that, it will automatically pull the reference and put it in the bibliography. The citet command gives you an in sentence form, e.g., "As we can see from Pedlosky (1987)." Another useful command is

```
\citep
```

It gives you a parenthetical reference, e.g., "The ocean is big (Pedlosky, 1987)." There are other examples in LaTeX template files.

Depending on the kind of LaTeX program you are using, you might have to do the following to get this to work (e.g., Mac TeXShop). Run LaTeX, run BiBTeX, run LaTeX, run LaTeX again. The first call sets up the reference, the second one gets the info from the *.bib file, the third one completes the reference, and the last call gets the numbering/labelling right.

2.9 Acronyms

Define upon first use, e.g., The Gulf of Mexico (GOM) is warm. The surface of the GOM is even warmer.

2.10 First Person

No first person. (or at least very infrequently) So, instead of "I downloaded ODV", "ODV was downloaded."

2.11 Dataset versus Plotting Program

Be careful about where the data comes from. For example, the data is not from Matlab or Mathematica. It was from a dataset collected by a group of scientists. Matlab was just used to plot it. Often you will not need to say how you plot something, but you will *always* need to say which dataset it is (usually including a citation), so that someone else can understand what you're showing or look it up.

2.12 Where in the World?

On a similar note, where are your figures located in the world? Any figure you show should be labeled or captioned telling the geographic location. Latitude and Longitude may be quickest but including a map of the section/data point may be nicer (depending on the point you're making). To say that a CTD cast is located in the Atlantic is not really specific enough.

2.13 Piggy-back off of reading or lectures!

Many of you already realize that starting from a statement made in one of the readings makes for an easy start to the paper. This is generally true, because all of the references you need and all of the terminology is probably right there.

However, you may end up with less exciting conclusions, e.g., "Just as Pickard and Emery said it would be, NADW was there." Many of you will take the bolder route of just plotting something up and trying to make sense of it. This is harder, because it's not easy to figure out where to find help. You can ask me, or use google scholar, and that may help, but more importantly, be circumspect about what you say. If you say, the temperature is warmer at the top than the bottom, and that is what your figure shows, then great. If you say, the temperature is warmer at the top because of solar heating, you either need a citation or need to be obviously speculative, e.g., "Presumably, the temperature is warmer at the top due to solar heating."

It is best to be both interesting and correct. If one must choose, it is better to be correct and boring rather than interesting and wrong (at least for the purposes of this class!)

2.14 Where can you make a paper more interesting?

The introduction and conclusion are a good place to stimulate broader interest. In the introduction, you can *motivate the research* with whatever you like (including appropriate citations, of course). In the conclusion, you can often speculate as to the importance of what you've done or directions for potential future investigations. In the middle, don't try to push too hard, just state what's in front of you, and add more figures if you want to show something else.

2.15 Use Google Scholar and Web of Science!

You will learn quickly the importance of writing a good abstract, because you can scan the abstracts of the papers that you find to see if they will answer the question you've got in mind. Also, a good citation will save you pages of discussion and hours of fiddling with figures!

2.16 Who is your audience?

Think about how to make the classroom assignment extend beyond the classroom: Can you address the underlying questions in the assignment, but do so in a way that reads like an article for the general oceanographic community? Or, at the very least, will any student taking any version of an Intro. to GFD class get something out of it? Do not directly address me as the sole reader, or assume that I remember what happened in class.

2.17 Cut off debate when you're out of time/room/ideas

It is not necessary or possible to address everything in one short paper (or even one very long paper)! So, zealously assert your right to stop somewhere, and try to choose that somewhere on a logical basis (e.g., the dataset doesn't extend there or this paper focuses on oxygen not nitrate, or we don't yet know how to calculate the velocity fields from the data we have, etc.) It is O.K. to stop anywhere that is convenient, but be clear about why you stop there. The reader may be interested in following up on your work, and it helps to state what you'd need to go further in that direction. Very, very often the best way to stop conversation is to use a citation, e.g., "The generalization of the problem to three dimensions is found in (...)". You do not need to rehash that argument, too, unless you need it to argue a point.

3 Suggested sources

3.1 Textbooks

You can use either Bühler (2014) or Chapman & Rizzoli (1989) as one source, but do not just compare textbooks. You must use a primary source (i.e., not an educational document, a scientific document reporting research and results).

Here are some suggested papers, that you can examine and select. You can also use other papers, but you may want to discuss those choices with me first. McIntyre (1981) is an interesting paper on the meaning of waves affecting the momentum budget. It would be interesting to contrast against the pseudo-momentum approach of Bühler (2014). (Ardhuin *et al.*, 2009) is an interesting paper about swell waves and ray tracing. Rascle & Ardhuin (2009) is a an alternative to standard treatments of Stokes drift. Mellor (2016) and Mellor (2003) have generated a lot of critiques (Ardhuin *et al.*, 2005). Other approaches, e.g., Ardhuin *et al.* (2008), McWilliams *et al.* (2004), arrive at different answers. Indeed, it is not clear that Mellor (2003) and Longuet-Higgins (1953) agree. Many of these papers address Stokes drift-mean flow equation sets and their instability or modeling (Craik & Leibovich, 1976; Skyllingstad & Denbo, 1995; McWilliams *et al.*, 1997; Holm, 1996; Gjaja & Holm, 1996).

Some more general wave-mean interaction papers of interest, which could be contrasted against Bühler (2014) are: Janssen *et al.* (1989); Buhler & McIntyre (2003); Andrews *et al.* (1983); Grimshaw (1984); Nikurashin & Ferrari (2010, 2011). A fantastic paper pair on Rossby waves, and their observation (or lack thereof), with self-contradiction is Chelton & Schlax (1996) and Chelton *et al.* (2007).

You might also find these interesting on the topic of Stokes drift and its role in GFD, although I'd recommend you discuss with me before choosing my work for this class assignment: Suzuki & Fox-Kemper (2016); Suzuki *et al.* (2016); McWilliams & Fox-Kemper (2013); Van Roekel *et al.* (2012).

References

Andrews, DG, Mahlman, JD & Sinclair, RW 1983 Eliassen-Palm diagnostics of wave-mean flow interaction in the GFDL"SKYHI" general circulation model. *Journal of the atmospheric sciences* **40** (12), 2768–2784.

Ardhuin, Fabrice, Chapron, Bertrand & Collard, Fabrice 2009 Observation of swell dissipation across oceans. *Geophysical Research Letters* **36**.

Ardhuin, Fabrice, Jenkins, Alastair D & Belibassakis, Kostas 2005 Commentary onthe three-dimensional current and surface wave equations' by george mellor. *arXiv preprint physics/0504097* .

Ardhuin, Fabrice, Rascle, Nicolas & Belibassakis, Konstadinos A 2008 Explicit wave-averaged primitive equations using a generalized lagrangian mean. *Ocean Modelling* **20** (1), 35–60.

Bühler, Oliver 2014 *Waves and mean flows*, 2nd edn. Cambridge, United Kingdom: Cambridge University Press.

Buhler, O & McIntyre, ME 2003 Remote recoil: a new wave-mean interaction effect. *Journal of Fluid Mechanics* **492**, 207–230.

Chapman, David C. & Rizzoli, Paola M. 1989 Wave motions in the ocean: Myrl's view. *Tech. Rep.*. MIT/WHOI Joint Program, Woods Hole, Mass.

Chelton, D.B., Schlax, M.G., Samelson, R.M. & de Szoeke, R.A. 2007 Global observations of large oceanic eddies. *Geophysical Research Letters* **34** (15), L15606.

Chelton, D. B. & Schlax, M. G. 1996 Global observations of oceanic Rossby waves. *Science* **272**, 234–238.

Craik, A. D. D. & Leibovich, S 1976 Rational model for Langmuir circulations. *Journal of Fluid Mechanics* **73**, 401–426.

Gjaja, I & Holm, DD 1996 Self-consistent hamiltonian dynamics of wave mean-flow interaction for a rotating stratified incompressible fluid. *Physica D* **98** (2-4), 343–378.

Grimshaw, Roger 1984 Wave action and wave-mean flow interaction, with application to stratified shear flows. *Annual Review of Fluid Mechanics* **16** (1), 11–44.

Holm, DD 1996 The ideal Craik-Leibovich equations. *Physica D* **98** (2-4), 415–441.

Janssen, PAEM, Lionello, P & Zambresky, L 1989 On the interaction of wind and waves. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* **329** (1604), 289–301.

Longuet-Higgins, Michael S 1953 Mass transport in water waves. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* **245** (903), 535–581.

McIntyre, M. E., ME 1981 On the wave momentum myth. *Journal of Fluid Mechanics* **106**, 331–347.

McWilliams, JC, Restrepo, JM & Lane, EM 2004 An asymptotic theory for the interaction of waves and currents in coastal waters. *Journal of Fluid Mechanics* **511**, 135–178.

McWilliams, J. C. & Fox-Kemper, Baylor 2013 Oceanic wave-balanced surface fronts and filaments. *Journal of Fluid Mechanics* **730**, 464–490.

McWilliams, J. C., Sullivan, P. P. & Moeng, C.-H. 1997 Langmuir turbulence in the ocean. *Journal of Fluid Mechanics* **334**, 1–30.

Mellor, George 2003 The three-dimensional current and surface wave equations. *Journal of Physical Oceanography* **33** (9), 1978–1989.

Mellor, George 2016 On theories dealing with the interaction of surface waves and ocean circulation. *Journal of Geophysical Research: Oceans* **121** (7), 4474–4486.

Nikurashin, Maxim & Ferrari, Raffaele 2010 Radiation and dissipation of internal waves generated by geostrophic motions impinging on small-scale topography: Application to the southern ocean. *Journal of Physical Oceanography* **40** (9), 2025–2042.

Nikurashin, Maxim & Ferrari, Raffaele 2011 Global energy conversion rate from geostrophic flows into internal lee waves in the deep ocean. *Geophysical Research Letters* **38**, L08610.

Rascle, Nicolas & Ardhuin, Fabrice 2009 Drift and mixing under the ocean surface revisited: Stratified conditions and model-data comparisons. *Journal of Geophysical Research: Oceans* **114** (C2).

Skyllingstad, E D & Denbo, D W 1995 An ocean large-eddy simulation of Langmuir circulations and convection in the surface mixed-layer. *Journal of Geophysical Research-Oceans* **100** (C5), 8501–8522.

Suzuki, Nobuhiro & Fox-Kemper, Baylor 2016 Understanding Stokes forces in the wave-averaged equations. *Journal of Geophysical Research–Oceans* **121**, 1–18.

Suzuki, Nobuhiro, Fox-Kemper, Baylor, Hamlington, Peter E. & Van Roekel, Luke P. 2016 Surface waves affect frontogenesis. *Journal of Geophysical Research–Oceans* **121**, 1–28.

Van Roekel, L. P., Fox-Kemper, B., Sullivan, P. P., Hamlington, P. E. & Haney, S. R. 2012 The form and orientation of Langmuir cells for misaligned winds and waves. *Journal of Geophysical Research–Oceans* **117**, C05001, 22pp.