Syllabus: SIOC 221B, Analysis of Physical Oceanographic Data (2025)

Sarah Gille
Credits: 4 units (3-4 contact hours + ∼8 hours reading and assigments per week)
Class Meetings: Wednesday and Friday, 2:00-3:20, Spiess 330
Discussion: Monday, 2-2:50, Spiess 330
Final presentations: Monday, March 17, 3:00-5:59, Spiess 330 (and possibly also in class on March 14)
Office hours: NH 348 now, and moving to 407. Stop by to see me any time. I'll post office hours if that would be helpful.

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Course website: see Canvas or for public materials: http://pordlabs.ucsd.edu/sgille/sioc221b
Grading: letter or S/U

Course Description: Techniques for analysis of physical oceanographic data involving many simultaneous processes, including probability densities, sampling errors, spectral analysis, empirical orthogonal functions, correlation, linear estimation, objective mapping.

Course Objectives: During this class you will learn (or advance your knowledge of) data analysis. We will focus on statistical foundations, model fitting, mapping, and interpreting gridded fields. In addition to learning data analysis methods, you should also continue to develop your programming skills so that you are able to put the methods that we discuss in class into practice, and you should refine your skills in interpreting scientific figures.

Course requirements: Complete weekly problem sets (by due dates). You may work on most of the problem sets collaboratively, but you need to work through the problems yourself and write up your own work. If you work in a group, please identify your collaborators. (Science is collaborative, and we always acknowledge our sources and our collaborators.) A mid-term problem set will have about the same scope as the regular problem sets, but you will complete it independently, and you will be asked to sign a statement indicating that the work you submit is your own. The final problem set will be a project based on data that you choose and will also be completed independently. Each problem set will contribute approximately equally to your final grade.

In lieu of a final exam, you will prepare and present a final project based on a data set of your choosing. This will take place during the final exam time slot (Monday 17 March, 3:00-6:00). The final exam will count as two problem sets: one grade for the oral presentation and a second for the write up.

Participation also matters. You should come to class prepared to think and engage, take notes, write code and calculate (using a laptop), and interact with me and with each other. You have multiple ways to demonstrate your engagement in the class. I will post course notes and small segments of textbook reading, which will be available in electronic form. Mini-lectures will also be posted for

you to view on your own schedule. You can review this material in advance of class. Feel free to identify topics that need clarification on the course discussion board on Canvas or via email to me. The themes that you identify will help determine how we use our in-class time. Class time will be split between lecture, discussion, group learning, and questions/answers/work time for problem sets. Please come to class ready to ask questions and to interact. (If you aren't able to attend class, you can catch up through the asynchronous recording, assuming that the podcasting system works correctly.) Bonus points may be awarded for exemplary class participation in any form.

Course Learning Outcomes: By the end of the term you should

1. understand different approaches for fitting a "model" to data
2. understand ways to use a singular value decomposition to assess variability in data
3. understand strategies for mapping observations and coherence,
4. be able to think critically about data analysis problems,
5. have sufficent the programming skills needed to analyze data using these techniques.

Everyone starts this class with a different background, and your goal is to advance your own skills—not to compete against your classmates. Please set learning goals for yourself (e.g. to learn Matlab, learn python, develop skills in latex) that reflect your own starting point. And please support each other, and help everyone to learn.

Grading:

- 8† homeworks: 10% each
- final project presentation: 10%
- final project write-up: 10%

†Note: Each assignment is equally weighted. We might end up with 7 or 9 homeworks, depending on schedule details, in which case each homework, presentation, and write-up would represent 1/9th or 1/11th of your total grade.

Topics:

- Autocovariance functions and degrees of freedom
- Least-squares fitting, weighted least squares, constrained least squares
  - — Uncertainties in fitted coefficients
  - — Underdetermined systesms and singular value decomposition
  - — Nonlinear minimization
- Eigensystems
- Empirical orthogonal functions (principal component analysis)
- Objective mapping

Draft schedule (subject to revision):

- Wednesday, January 8. Introduction to the course. Motivating a statistical framework.
- Friday, January 10. Cumulative distributions and probability density functions as a foundation for statistical thinking.
- Wednesday, January 15. Mapping from one pdf to another, conditional probability.
- Friday, January 17. Correlation, covariance, and rotated variance ellipses.
- Wednesday, January 22. Random walks, sampling error.
- Friday, January 24. Sampling error, autocovariance, and decorrelation.
- Wednesday, January 29. Introduction to models and data.
- Friday, January 31. Models and data: Fitting models to data—practical considerations.
- Wednesday, February 5. Addressing uncertainties in least-squares solutions.
- Friday, February 7. Adding constraints to least-squares solutions.
- Wednesday, February 12. Eigenmodes and modal decomposition.
- Friday, February 14. Linear algebra refresher: Orthogonality and invertibility.
- Wednesday, February 19. Singular value decomposition.
- Friday, February 21. Empirical orthogonal functions.
- Wednesday, February 26. Linear estimation theory and ocean applications.
- Friday, February 28. Linear estimation theory: Dealing with noise.
- Wednesday, March 5. Objective mapping: Specific examples.
- Friday, March 7. Gridding data with big gaps: Intro to machine learning.
- Wednesday, March 12. *Guest lecture:* Steve Diggs, UCOP, Data management for the future.
- Friday, March 14. Connecting course themes and thinking about data assimilation
- Monday, March 17. Final exam: Project presentations

As time permits, we may consider wavelets, complex demodulation, more machine learning, simulated annealing, or other topics.

Academic Integrity: "Academic Integrity is expected of everyone at UC San Diego. This means that you must be honest, fair, responsible, respectful, and trustworthy in all of your actions. Lying, cheating or any other forms of dishonesty will not be tolerated because they undermine learning and the University's ability to certify students' knowledge and abilities. Thus, any attempt to get, or help another get, a grade by cheating, lying or dishonesty will be reported to the Academic Integrity Office and will result sanctions. Sanctions can include an F in this class and suspension or dismissal from the University. So, think carefully before you act by asking yourself: a) is what I'm about to do or submit for credit an honest, fair, respectful, responsible and trustworthy representation of my knowledge and abilities at this time and, b) would my instructor approve of my action? You

are ultimately the only person responsible for your behavior. So, if you are unsure, don't ask a friend-ask your instructor, instructional assistant, or the Academic Integrity Office. You can learn more about academic integrity at academicintegrity.ucsd.edu" (Source: Academic Integrity Office, 2018)

Inclusion: Let's aim to foster an inclusive environment in our classroom and through our in-class and out-of-class discussions. We should aim to establish an environment that supports diversity of thoughts, that draws on the broad range of perspectives and experiences that each of you brings to class, and that respects your identities (including race, gender, class, sexuality, etc.).

If you have a name and/or set of pronouns that differ from those that appear in your official university records, please let me know.

If for any reason you feel that your performance in class is being impacted by your experiences outside of class, please don't hesitate to let me know. I am available as a resource, as are your other faculty, and the department staff.

Please don't hesitate to contact me if you have suggestions to improve the course materials or the way the class operates. Likewise, if anything comes up in class that makes you feel uncomfortable, please chat with me.

Texts useful for SIOC 221B

Resources (available on line and/or in hard copy):

Bendat, J. S. and A. G. Piersol, 2010: *Random Data: Analysis and Measurement Procedures*. John Wiley & Sons, 4th edition.

Lawson, C. L. and R. J. Hanson, 1995: *Solving Least Squares Problems*. SIAM.

Martin, B. R., 2012: *Statistics for Physical Sciences*. Elsevier.

Menke, W., 2018: *Geophysical Data Analysis: Discrete Inverse Theory*. Academic Press.

Thomson, R. E. and W. J. Emery, 2014: *Data Analysis Methods in Physical Oceanography*, 3rd edition, Elsevier.

von Storch, H. and F. W. Zwiers, 2001: *Statistical Analysis in Climate Research*, Cambridge University Press.

Wunsch, C., 1996: *The Ocean Circulation Inverse Problem*. Cambridge University Press.