SCRIPPS INSTITUTION OF OCEANOGRAPHY UC San Diego

Falk Feddersen: SIOC 211A Linear Waves (Winter 2020)

Linear Ocean Waves

SIOC 211A
Falk Feddersen
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Phone: 858.534.4345
Office: Deep Sea Drilling West 003 **Meetings**
Class Time: Monday 12:30-13:50 : IGPP 4301 Revelle Conference Room // Wed 10:30-11:50 : NH 101
Office Hours: Friday 12:30-13:30

Note I took this class over in the 3rd week of the quarter.

Description Most of the class is concerned with linear wave theory as it applies to the ocean. The emphasis is on gravity waves of various types but other waves will also be discussed. The course will begin with an introduction/review of the wave equation and relevant principles that should be familiar from Fourier analysis. The class will principally draw on two sets of lecture notes (see below). In addition, sections of various books will be assigned reading. Lectures will be at the level of SIOC 214 (fluids) and SIO 203A (math A) and make use of material covered in both. You will also make use of tools developed in data analysis.

Course Requirements Students should enroll in four (4) units. First year students should register as letter. Others can register as S/U. Students are expected to complete all the assigned homework, quizes, projects, and a final exam. There will be regularly assigned homework. There will be a short quiz due on the first day of class that does not count toward your grade. There will be two projects on surface gravity and internal waves with a goal to either confirm or reject the theoretical constructs you're learning. The final grade will be based 1/2 on problem sets (HW), 1/4 on projects and 1/4 on final exam.

Syllabus

1. 6-Jan : Shallow Water Equations and the wave equation 1 (JM).
2. 8-Jan : Shallow Water Equations and the wave equation 2 (JM).
3. 13-Jan : Shallow Water Equations and the wave equation 3 (JM).
4. 15-Jan : Waves Across the Pacific and intro to Dispersion (JM)
5. 20-Jan: MLK Holiday
6. 22-Jan : Surface Gravity Waves A. Linear Derivation, Disperison Relationship (FF: Chapter 2, MCH: 1.1-1.3, 3.1-3.5, KUNDU: 7.1, 7.2)
7. 27-Jan : Surface Gravity Waves A. Continued (FF: Chapter 2, MCH: 1.1-1.3, 3.1-3.5, KUNDU: 7.1, 7.2)
8. 29-Jan : Surface Gravity Waves B. Flux-conservation equations, wave energy, energy flux, group velocity (YOUTUBE: Waves across the Pacific, FF Chapter 3, MCH 3.8, KUNDU 7.5), (PROJECT 1)
9. 3-Feb : Surface Gravity Waves C. Dispersion, group velocity, stationary phase (FF Chapter 4 MCH: 1.4 and 1.5, KUNDU 7.5)
10. 5-Feb : Surface Gravity Waves C. Continued (FF Chapter 4 MCH: 1.4 and 1.5, KUNDU 7.5)
11. 10-Feb : Surface Gravity Waves D: Ray theory, Snells law (FF: Chapter 5)
12. 12-Feb : sick (class canceled - makeup 9 March)
13. 17-Feb: Presidents Day Holiday
14. 19-Feb: Ocean Sciences Meeting (makeup 13 March)
15. 28-Jan : Acoustic Waves . Perfect fluid, acoustic waves, transmission, and energetics (FF: Chapter 5,6)
16. 26-Feb : Internal Waves A. Wave equation derivation, solutions and dispersion relationship (FF Chapter 9, KUNDU 7.8, MCH: 4.1 and 4.2, Pedlosky Waves Lecture 7)
17. 2-Mar : Internal Waves B. Energy conservation (FF: Chapter 10)
18. 4-Mar : Internal Waves C. Normal modes (FF: Chapter 11, MCH 4.3 PROJECT 2)
19. 6-Mar : Internal Waves Review
20. 9-Mar : Linear shallow water equations no rotation. (FF: Chapter 15)
21. 11-Mar : Linear shallow water equations with Rotation A. inertial-gravity waves, Kelvin waves, tides (FF: Chapter 16)
22. 13-Mar: Synthesis/Review

Lecture notes
The two principal lecture note sources are the following

- Feddersen Wave Lecture Notes (4 March 2019 version, Ch 1-16 good, not final, denoted FF above)
- Myrl's Wave Lecture Notes by Chapman and Mallanote-Rizzoi (denoted MCH above)

Other Books These books that have relvant material in them. These include

- Kundu, Cohen, Dowling, *Fluid Mechanics:* Chapter 7 on Gravity Waves (same book as SIOC 214 - denoted KUNDU)
- Pedlosky, J. Waves in the Ocean and Atmosphere. Introduction to Wave Dynamics. (in class reserves)
- Vallis, Atmospheric and Oceanic Fluid Dynamics, Electronic Resource (same book as SIOC 212A - denoted Vallis)
- Rick Salmon's Undergraduate Waves Textbook is also a nice resource. It is light on fluid dynamics but strong on inspiration and Fourier analysis
- Mei, CC, The Applied Dynamics of Surface Gravity Waves (in CCS basement). Note that this book is also available electronically from UCSD library: E-BOOK
- Gill A, Atmosphere/Ocean Dynamics. Available electronically from UCSD library E-BOOK and direct from PUBLISHER

- Pedlosky, J. Geophysical Fluid Dynamics (should be in course reserves)
- Myrl's chapter on Ocean Tides
- Lighthill, Waves in Fluids (in class reserves)
- Whitham, Linear and Nonlinear waves (in class reserves)
- Buhler, Oliver, Waves and Mean Flows E-BOOK on UCSD network

YOUTUBE VIDEOS AND WEBSITES

- MIT Opencourseware Lecture 4.5 on Evolution of a Slowly Varying Wave Packet
- MIT Opencourseware Lecture 4.6 on Evolution of a Slowly Varying Wave Packet
- Stormsurf Wave Model Web Site
- CDIP Web Site
- Waves Across the Pacific
- Internal Waves Generated from a cylinder: VIDEO 1, VIDEO 2
- Internal Wave Beam Generation on a Slope VIDEO
- Kraig Winters (SIO): Internal Tide impinging on a slope: Full nonlinear solutions Kraig winters lab
- Linear internal wave generation from seamount: VIDEO
- Internal Tide Generation Luzon Strait YOUTUBE
- Lee Wave Generation over a sinusoidal topography

BACKGROUND TO FOURIER ANALYSIS

- Signals and Systems by Oppenheimer and Willsky. This is the best intro book on Fourier particularly the chapter on "Fourier Analysis for Conintous Time Signals and Systems".
- MIT CourseWare on Signals and Systems: In particular see the lectures 7, 8, 9 at https://ocw.mit.edu/resources/res-6-007-signals-and-systems-spring-2011/lecture-notes/
- YOUTUBE playlist of MIT course lectures

PAPERS
Surface Gravity Waves

- Snodgrass, Hasselman, Munk et al., Propagation of ocean swell across the pacific, Phil. Trans. Royal Soc A, doi:10.1098/rsta.1966.0022, 1966.
- Rascle et al., A global wave parameter database for geophysical applications. Part 1: Wave-current, Ocean Modeling, 25, 154-171, doi:10.1016/j.ocemod.2008.07.006, 2008.
- Okihiro et al., Excitation of Seiche Observed in a Small Harbor, JGR, 1993.
- Ferrari and Wunsch, The distribution of eddy kinetic and potential energies in the global ocean, Tellus, doi:10.1111/j.1600-0870.2009.00432.x 2010. link

Ocean Acoustic Waves

- Dushaw et al., A decade of acoustic thermometry in the North Pacific Ocean, JGR, doi:10.1029/2008JC005124, 2009

Internal Waves

- Alford et al., Near-Inertial Internal Gravity Waves in the Ocean, Annual Rev Marine Sci, 2016. [READ SECTIONS 1, 2, 3]
- Zhao et al. Global Observations of open-ocean mode-one M2 Internal TidesJ. Physical Oceanography, 2016.
- Alford, Sustained, Full-Water-Column Observations of Internal Waves and Mixing near Mendocino Escarpment, J. Physical Oceanography 2010.
- Nikurashin and Ferrari, Global energy conversion rate from geostrophic flows into internal lee waves in the deep ocean, Geophysical Research Letters, 2011.
- Alford Redistribution of energy available for ocean mixing by long-range propagation of internal waves, Nature 2003.
- Alford The formation and fate of internal waves in the South China SeaNature 2015 (super nonlinear waves)
- Garret and Kunze, Internal Tide Generaion in the Deep Ocean, Annual Review of Fluid Mechanics, 2007.
- Cole et al., Observations of Tidal Internal Wave Beams at Kauai Channel, Hawaii, JPO, doi: 10.1175/2008JPO3937.1, 2009, link

If you have any questions or comments, please contact me at falk@coast.ucsd.edu.
