The ocean is dynamic and how it transports and stores tracers in marine environments highlight the crucial role of physics to other areas of marine sciences. This descriptive physical oceanography course introduces concepts, terminology and topics in physical oceanography relevant to anyone involved in ocean/marine sciences, be it in an ecology/biology/chemistry or in an engineering/physics/mathematics capacity, and is compulsory for all OCES majors. While the course will touch on some specialised geographical characteristics of the physical phenomena, the primary focus of the course will be on *dynamical processes* from a descriptive point of view as the latter is more widely applicable.

## Course material

`https://github.com/julianmak/academic-notes/tree/master/OCES2003_descriptive_phys_ocean`

Course notes are in written format as `descriptive_po.pdf`, and the course slides closely follow the course notes.

## Assessment

10% attendance, 4 × 12.5% assignments, 2 × 15% short timed tests, 10% *viva voce*

- Attendance is just turning up. Basically most people get full credit for free.
- I make all assessments (assignments and short exams) to consist mostly on what I would regard as "book work" material, but there will always be "hard + challenging" content. If you do all the "book work" you can expect to be getting around a B+, which will be around 80-85% of the full marks. For those who want an A grade, you actually have to attempt the "hard" stuff.
- The short tests will be conducted in class and will be an hour or so. They are there because there is no guarantee there is no crowd sourcing going on with the assignments.
- The *viva voce* is a one-on-one 15-20 min oral exam during the exam period. From a box with pieces of paper with about 25 topics written on each piece of paper, you pick three pieces of paper out. Out of the three topics you pick, you choose one topic, I choose one topic, and we have a chat about the topics, and the game is for you to convince me you know stuff. The questions will be restricted to descritive ideas, and could include things like:
  - tell me in about 3 mins what you know about BLAH
  - why is BLAH important
  - how is BLAH linked to BLEH
  - some of the descriptive questions like in the assignments

  In reality you have to prepare for every single topic, and given the large sample size and randomness nature it's almost irrelevant trying to crowd source for this.

## Learning outcomes

- appreciate how physics exerts an influence on other marine science topics, certainly on spatial scales larger than around a few meters and time-scales longer than a few minutes [lectures, assignments]

- working knowledge of concepts and terminology in physical oceanography that are commonly in marine/ocean sciences [lectures, assignments]
- be able to carry out basic quantification in relation to the physical principles [assignments]
- be able to describe the underlying principles to observed phenomena in the ocean of relevance to ecology / climate etc. [assignments, viva voce]

## What this course is NOT:

- **a complete description of the physical aspects of the ocean**
  - this course provides a starting point to physical oceanography is about, and how physics plays with other marine/climate science topics, e.g. OCES 2001 (*Introduction to Ocean Sciences*), 3201 (*Biological Oceanography*), 3202 (*Chemical Oceanography*), 4001 (*Ocean and Climate Change*)
  - for those who want a more qualitative description with a bit more 'teeth', see OCES 3203 (*Physical Oceanography*)
- **a maths course with lots of calculations**
  - this is an OCES course with an qualitative focus, we will <u>use</u> concepts from maths (e.g. gradients and integration from calculus, modes, some statistics) but you are not <u>examined</u> on them
  - a descriptive review of calculus and concepts needed in classical physics will be given around Lec 4
  - drawing pictures and descriptive approach can get you fairly far in physical oceanography but arguably it lacks 'teeth' / 'substance'...the devil really is in the details and some calculations are required
  - calculations will be kept <u>simple</u>, e.g. computing a mean or multiplying some numbers together (cf. OCES 4001; only interpretation of formulae and numbers rather than memorisation of the formulae is required)

## Supplementary book list

(Keyword being "supplementary")

- Knauss (1997), "Introduction to physical oceanography", 2nd edn., Waveland Press Inc.
  - good all rounder
- Wunsch (2015), "Modern observational physical oceanography", Princeton University Press
  - plenty of information detail, with the over arching theme being on observations
- Pickard & Emery (1990), "Descriptive physical oceanography", 5th edn., Pergamon Press (see Talley et al 2011 below)
  - Might suit some people. I personally dislike this book: my bias here is that the geographical grouping downplays the common features unified by dynamics. My opinion is also that because the authors are trying to maintain scientific rigour but keeping it "descriptive", and makes the subject look/read harder than it actually is simply

because the descriptive approach is not the optimum tool to achieve quantitative rigour (it's like trying to eat long thin noodles with a spoon, you could but you could also spend a bit of time and go find a fork).

- Talley et al. (2011), "Descriptive physical oceanography", 6th edn., Academic Press
  - A regrouped and updated version of the book above. In my opinion this is what the above book should have been but was not. Building blocks are presented first and motivated accordingly, then revisited and put into full geographical context in the later chapters.

† Williams & Follows (2012), "Ocean dynamics and the carbon cycle", Cambridge University Press
  - one of my favourite books, supposed to target physicists who want to learn some biology and carbon chemistry, and biologists/chemists who want to learn some physics

† Karnauskas (2020), "Physical oceanography and climate", Cambridge University Press
  - more climate focus (suitable for OCES 4001), great explanations of the physical processes and circulation

† Vallis (2006), "Atmospheric and oceanic fluid dynamics" 1st edn, Cambridge University Press
  - has details (waves + instabilities in Part 1, ocean circulation in Part 3)
  - 2nd edition longer, shorter version just as good (book title is "essentials of ..."), maybe more suitable for OCES 3203 and graduate level courses.

Besides these published books, in designing the course I also utilised teaching material from Wang Yan (HKUST), David Marshall (Oxford and previous Reading), Leif Thomas (Stanford) course, and Jim Hench (Duke, made available by Charmaine Yung) as a reference.

## Syllabus

[One lecture of current topic or as a 'slack' lecture in case of over-running.]

L01 General introduction
(W&F Ch.1 + 2; Talley Ch.1 + 14)

L02 Descriptive overview: broad terminology and oceans
(Knauss Ch.1 + 7; Talley Ch.2, 9–13; Wunsch Ch.3; P&E Ch.2 + 7)

L03 Descriptive overview: *not* oceans
(Knauss Ch.11; Talley Ch.2; P&E Ch.8)

L04 Forces, equations and calculus
(Knauss Ch.4 + 5; Talley Ch.7; Wunsch Ch.11; W&F Ch.3 + 4)

L05 Sea water properties and thermodynamic forcing I: temperature and salinity
(Knauss Ch.1, 2, 3, 8; Talley Ch.3, 4, 5; Wunsch Ch.3; W&F Ch.2; P&E Ch.3, 4, 5, 6.5)

T01 Problems class for concepts so far and somewhat for assignment 1

*** assignment 1 (1 week to do) ***

L06 Sea water properties and thermodynamic forcing II: density
(Knauss Ch.2; Talley Ch.3, 4, 5; Wunsch Ch.3; W&F Ch.2, 3, 4; P&E Ch.3)

L07 Mechanical forcing I: pressure + gravity
(Knauss Ch.5; Talley Ch.7; Wunsch Ch.3; W&F Ch.3 + 4)

L08 Mechanical forcing II: rotation (Coriolis)
(Wunsch Ch.3; Talley Ch.7; Knauss Ch. 5 + 6; W&F Ch.3 + 4)

L09 Mechanical forcing III: wind
(Wunsch Ch.3; Knauss Ch.6; Talley Ch.7; W&F Ch.3 + 4; P&E Ch.7.1)

T02 Problems class for concepts so far and somewhat for assignment 2

*** assignment 2 (1 week to do) ***

L10 Mechanical forcing IV: friction and viscosity
(Wunsch Ch.11; Knauss Ch.4; Talley Ch.7; W&F Ch.3 + 4)

L11 Wind driven circulation I: gyres and western boundary currents
(Wunsch Ch.3, 10; P&E Ch.7; Talley Ch.9, 10; W&F Ch.8)

L12 Wind driven circulation II: further details
(Wunsch Ch.10, 11; P&E Ch.7; Talley Ch.9, 10; W&F Ch.8)

*** short test 1 (1hr) ***

L13 Meridional Overturning Circulation I: Southern Ocean and ACC
(Wunsch Ch.9, 11; Talley Ch.1; 3W&F Ch.10 + 12; E&P Ch.7.1, 7.2)

L14 Meridional Overturning Circulation II: ACC + gyres + boundary currents

(Knauss Ch.8; Wunsch Ch.9, 10, 11; Talley Ch. 9, 13, 14; W&F Ch.10 + 12; E&P Ch.7.1, 7.2)

L15 Dynamics I: waves

(Knauss Ch.9; Wunsch Ch.4; W&F Ch.3 + 4)

L16 Dynamics II: types of waves

(Knauss Ch.10; Wunsch Ch.5; Talley Ch.8; W&F Ch.3 + 4)

T03 Problems class for concepts so far and somewhat for assignment 3

*** assignment 3 (1 week to do) ***

L17 Dynamics III: instabilities

(Wunsch Ch.3; W&F Ch.3, 4, 9)

L18 Dynamics IV: tides

(Knauss Ch.10; Wunsch Ch.6 + 7; Talley Ch.8)

L19 Observations I: in-situ

(Knauss Ch.1; Wunsch Ch.2; Talley Ch.6; P&E Ch.6)

L20 Observations II: remote

(Knauss Ch.12; Wunsch Ch.2, 8, 9; Talley Ch.6; P&E Ch.6)

T04 Problems class for concepts so far and somewhat for assignment 4

*** assignment 4 (1 week to do) ***

T05 Review of course + outlooks

*** short test 2 (1hr) ***

*** *viva voce* ***