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<https://github.com/julianmak/academic-notes>

The repository principally contains the compiled products rather than the source for size reasons.

- ▶ Associated Python code (as Jupyter notebooks mostly) will be held on the same repository. The source data however might be big, so I am going to be naughty and possibly just refer you to where you might get the data if that is the case (e.g. JRA-55 data). I know I should make properly reproducible binders etc., but I didn't...
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# OCES 2003 : Descriptive Physical Oceanography

(a.k.a. physical oceanography by drawing pictures)

Lecture 1: “big picture”



# Outline

- ▶ canvas + GitHub and admin things
- ▶ approach of the course
  - focus on qualifying things (e.g. via drawing pictures)
  - little bit of quantification (no more than multiplying some numbers together)
- ▶ what is **physical oceanography** + why should you care?
  - climate, biogeochemistry, ecology, engineering, trade, law, policy etc. (maybe even just curiosity?)

**Ocean physics is not easy, but you need enough of it!!!**

**Key terms:** physical oceanography, dynamics

# Practicalities

## Instructors:

I Julian MAK (jclmak@ust.hk)

TA Hongbin WU (hwuck@connect.ust.hk)

## Course grade breakdown:

method	%
attendance	10
assignments	$4 \times 15 = 60$
exams (mid term + finals)	$2 \times 15 = 30$
error finding	extra 10%
participation	extra, variable

- ▶ midterm is multiple choice, finals is take-home (for this year)
- ▶ course pass mark is 50% cumulative  
→ "A" boundary will be around 85-90%

(I don't grade to a curve)

# Practicalities

## Method of delivery:

- ▶ in person Monday afternoon and Friday morning
- ▶ consultation hours (after lectures)
  - would recommend trying TA first (for a different point of view to me)
  - ask questions on Canvas course forum or e-mail

# Approach of course

## What this course is:

- ▶ a **descriptive** intro to topics in physical oceanography
  - bias from me on topics to do with **dynamics** and large-scale circulation

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  - make some plausible assumption, roll with it and see where it leads to
- ▶ focus on getting you to be able to start digesting/using the facts from books

# Approach of course

What this course certainly is not:

- ▶ a computation based course on physical oceanography  
→ **basic/overall** understanding, but devil is of course always in the details (go to OCES 3203 for the beginnings of that)
- ✓ e.g. **why** you might want to use **potential** over **in-situ temperature** (i.e.  $\theta$  and not  $T$ ) (see Lec 6)
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- ▶ a complete course on physical oceanography  
→ further directions throughout the course notes

# Lecture format

Lectures do not follow any particular book:

1. Pickard & Emery, "*Descriptive physical oceanography*" 5th edn  
→ I actually hate this book but may suit some (IMO it makes oceanography seem much harder than it needs to be)
2. Talley, "*Descriptive physical oceanography*" 6th edn  
→ IMO what the above book should have been, but wasn't...
3. Knauss, "Introduction to physical oceanography", 2nd edn
4. Wunsch, "Modern observational physical oceanography"
5. Williams & Follows, "Ocean dynamics and the carbon cycle"  
→ "harder" but really worth it IMO

**You shouldn't need anything outside the lecture slides**

- ▶ course notes link on Canvas (**continually updated**)

# Syllabus

## Part 1: Basics

- |   |  |
|---|--|
| <p>L01 Big picture</p> <p>L02 Terminology + oceans</p> <p>L03 Seas, shelves, estuaries etc.</p> <p>L04 Forces and equations of motion</p> <p>L05 Sea water properties: temperature and salinity</p> | <p>L06 Sea water properties: some thermodynamics + beyond <i>in situ</i> variables</p> <p>L07 Forces: pressure and gravity</p> <p>L08 Forces: Coriolis</p> <p>L09 Forces: Wind</p> <p>L10 Forces: Viscosity and friction</p> |
|---|--|

- ▶ calculus revision in Lec 4
- ▶ fundamentally revolve the concepts of **buoyancy, hydrostatic balance, geostrophic balance**, and theme and variations thereof

# Syllabus

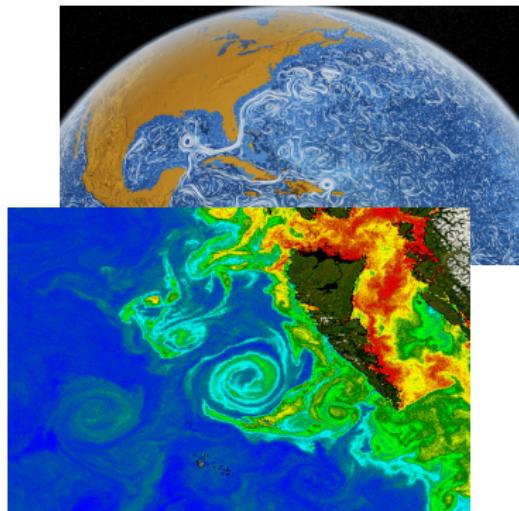
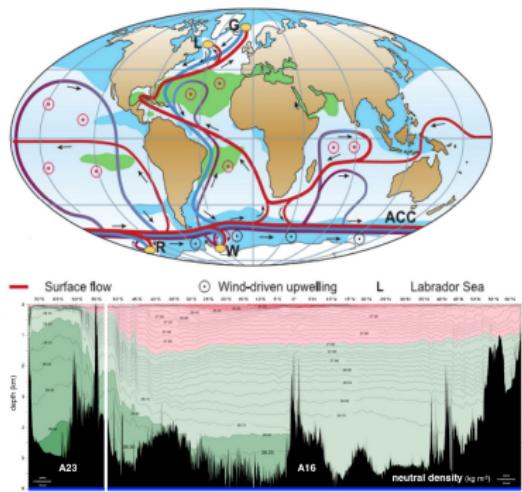
## Part 2: Dynamics

- |   |   |
|---|---|
| <p>L11 Wind driven gyres: geostrophy and Sverdrup balance</p> <p>L12 Wind driven gyres: western boundary currents and vorticity balance</p> <p>L13 MOC: Southern Ocean and ACC</p> <p>L14 MOC: global MOC + boundary currents</p> | <p>L15 Intro to waves</p> <p>L16 Types of waves</p> <p>L17 Tides</p> <p>L18 Intro to sea level</p> <p>L19 Observations: in-situ</p> <p>L20 Observations: remote</p> |
|---|---|
- wind drive gyres theory to demonstrate successes of “**make some assumptions, roll with it and see what you get**” principle  
→ you learn from what it tells you AND what it doesn’t!
- gyres + MOC highlight controls by small-scale dynamic processes
- concepts in dynamics **focusing on waves** (pictures based)

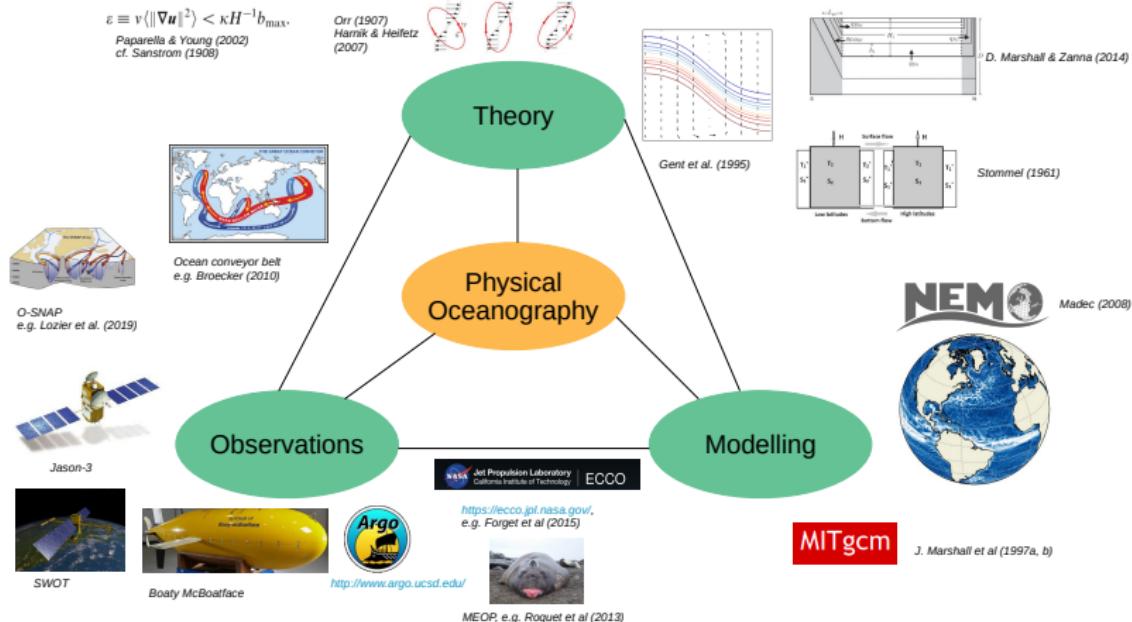
# What is physical oceanography?

Study of physical **features** and **processes** of the ocean

- ▶ **what** does it look like?
- ▶ **why** does it look like the way it does?



# What is physical oceanography



understanding the ocean require  
interdisciplinary + complementary approaches

# Earth overview



from <https://sites.google.com/site/climatetypes/>

# Ocean

The ocean covers > 70% of the Earth's surface:



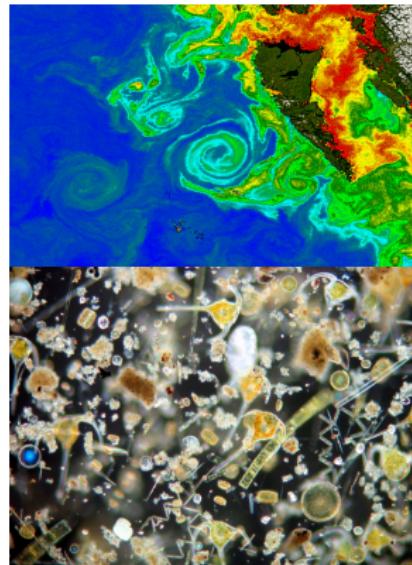
- ▶ holds about **50 times more carbon** than the atmosphere
- ▶ upper **2.5m** holds **as much heat** as the atmosphere

water moves ⇒ **lots/large amounts** of things being moved

# Oceans and weather/climate

“holds about 50 times **more carbon** than the atmosphere”

- ▶ some **inorganic** (e.g. carbonates) but largely **organic**
  
- ▶ role in **carbon cycle + global warming**
- ▶ ocean largely seen as a **sink** for atmospheric carbon
  - physical (e.g. turbulence, **circulation**)
  - biogeochemical (e.g. **biological pump**)

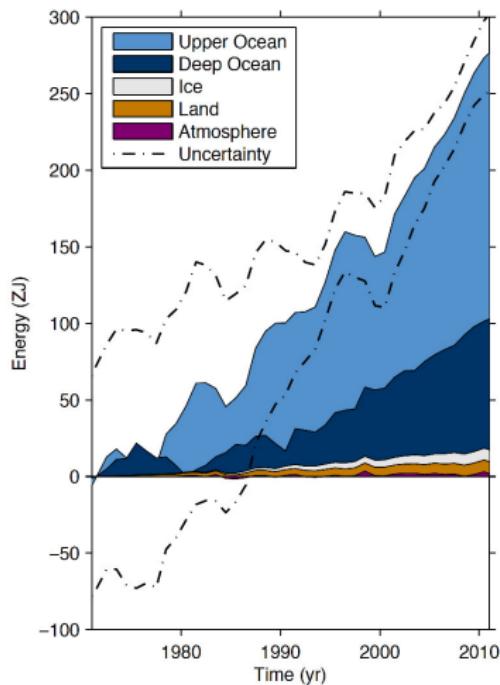


top: false colouring of chlorophyll concentration  
bot: from Annegret Stuhr/GEOMAR

see more in e.g. Williams & Follows (2011), *Ocean Dynamics and Carbon Cycle Principles*, CUP

# Oceans and weather/climate

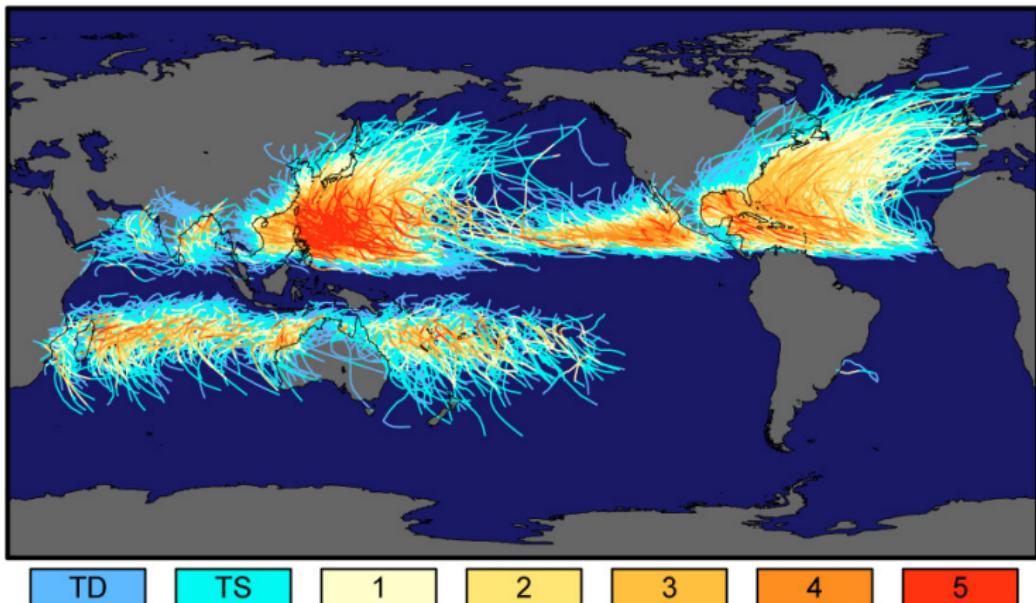
“upper 2.5m holds as much heat as the atmosphere”



- ▶ high heat capacity (see Lec 5)  
→ stores excess energy  
(measured as Ocean Heat Content) (more in OCES 4001)
  
- ▶ ocean important part of energy balance  
→ Earth tilt, uneven Solar heating (see Lec 5)  
→ circulation affects and affected by excess energy redistribution (see Lec 13 + 14)

left: IPCC AR5 (2014)

# Oceans and weather/climate



Saffir-Simpson Hurricane Intensity Scale

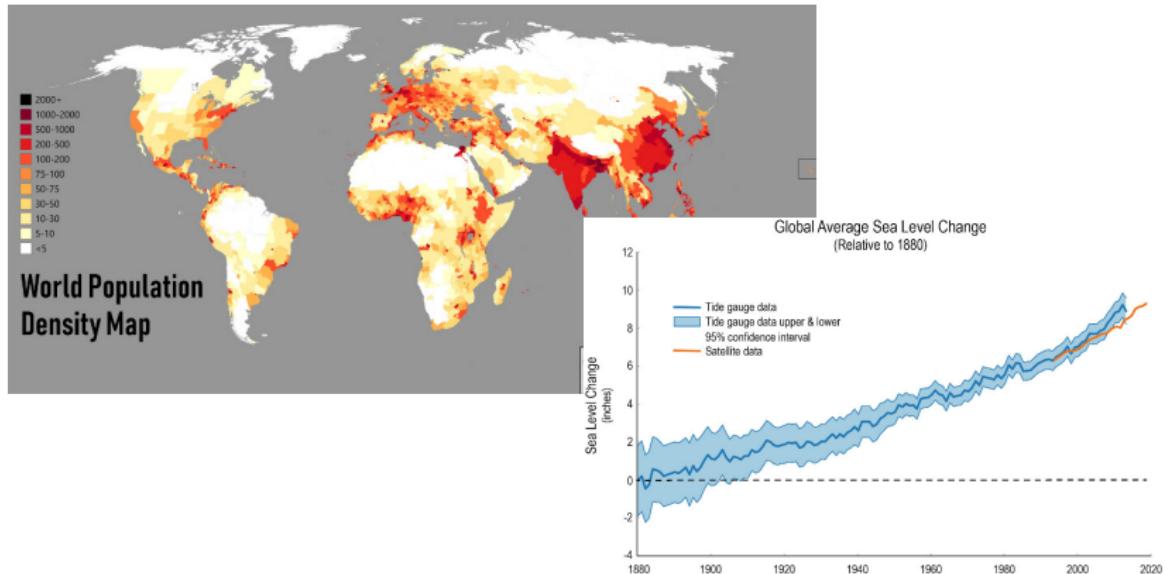
- ▶ ocean affects and is affected by the **atmosphere** (see Lec 9 + OCES 4001)

# Oceans and weather/climate



video: <https://www.youtube.com/watch?v=ASJSrVBPazw>

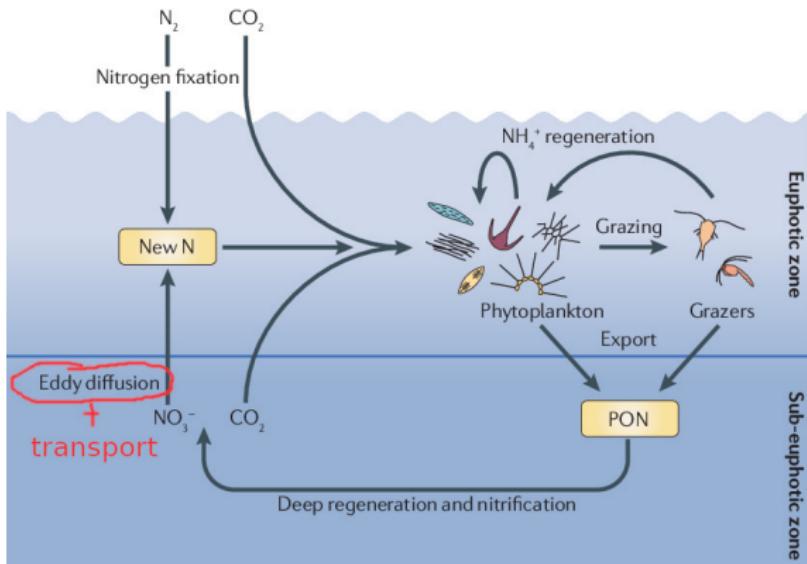
# Oceans and weather/climate



- ▶ global warming ⇒ sea level rise
  - **thermokinetic** vs. **halokinetic** (see Lec 5, 18 + OCES 4001)
  - which sea level (dynamic, relative...)? (see OCES 4001 and a bit in Lec 18)

left: reddit user some\_dawid\_guy; right: from USGCRP

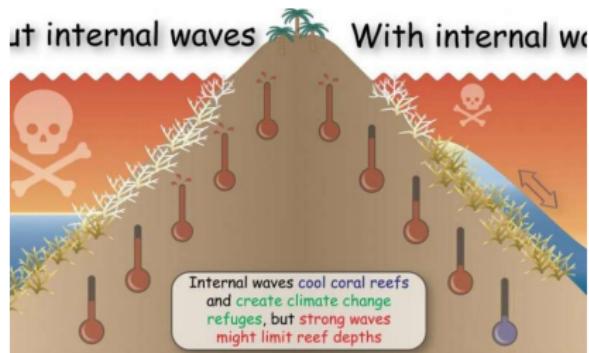
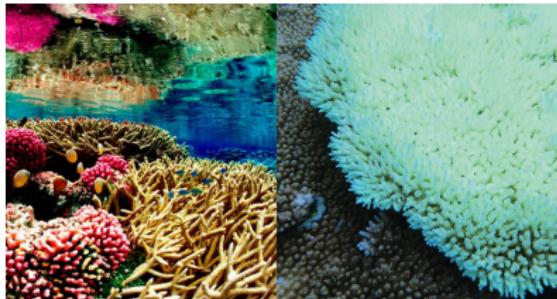
# Oceans and ecology



- ▶ nitrogen cycle as an example
- ▶ nutrient supply particularly through physical upwelling  
→ wind and/or eddy driven?

adapted from Sohm *et al.* (2011), *Nature reviews*

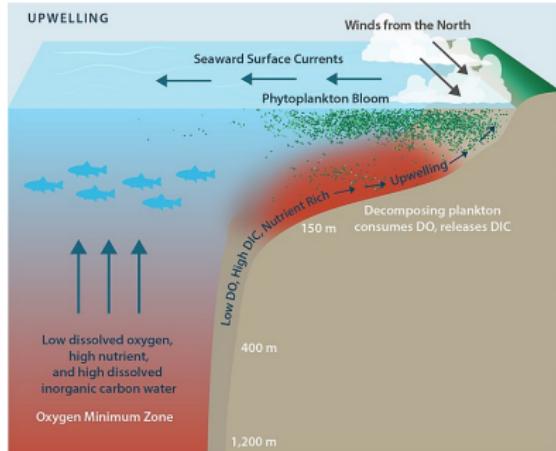
# Oceans and ecology



- ▶ environmental stresses on coral reef ecosystems  
→ internal waves (see Lec 16) and associated heat relief?

left: Jim Maragos / U.S. Fish and Wildlife Service; right: The Pokémon Company; bot: courtesy of Alex Wyatt

# Oceans and ecology



- ▶ **hypoxia** (i.e. low oxygen conditions in water)
  - some naturally occurring (e.g. Black sea see Lec 3)
  - human activity stresses?
  - influences by physical upwelling? (e.g. global warming)
  - ⇒ increased **outgassing**?

left: Gerwin (2010), *Nature*; right: Mobile bay jubilee event + dead stuff, photo from NOAA

# Oceans and economy

## Blue economy

- ▶ “sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem” – The World Bank

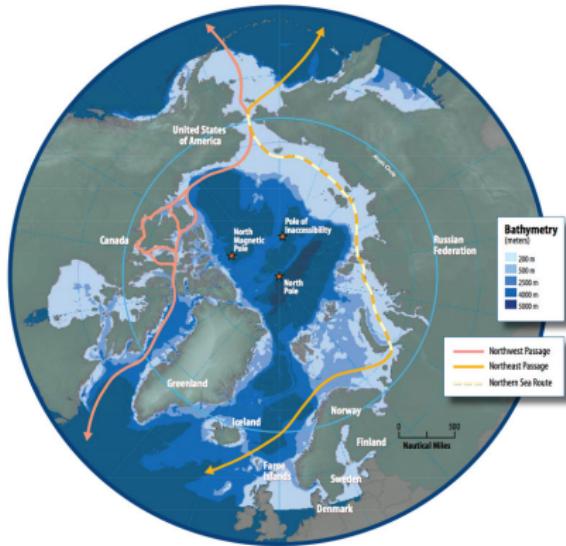


e.g. **fisheries + food security**

- ▶ physics → biogeochemistry  $\rightleftharpoons$  marine ecology  $\rightleftharpoons$  fishing + fishery management

picture from HK AFCD

# Oceans and economy



e.g. **shipping**

- ▶ **weather influences on shipping?**
  - e.g. route planning in South China Sea, one of the busiest regions in the world
- ▶ **climate influences on shipping?**
  - opening up of new routes if ice melts?

- ▶ policy, politics, sustainability etc.

→ physics has implicit influences (not immediate obvious influences maybe!)

image from Wikipedia (Susie Harder - Arctic Council - Arctic marine shipping assessment)

# Oceans and economy



Sketch from Tsumoru Shintake (Okinawa Institute of Science and Technology Graduate University)

e.g. **energy security**

- ▶ harness ocean's vast energy for consumption
  - **waves, tidal, geothermal** etc.?
  - design/build equipment
  - how to **optimise** power generation
  - feedbacks and impacts on environment (physical and/or ecological)?

# Summary

- ▶ physical oceanography is
  - study of **what** the ocean looks like
  - **why** does it look like the way it does
- ▶ ocean physics drives
  - weather and climate
  - ocean biogeochemistry
  - ocean ecology
  - economy, policy, etc...

**Ocean physics is not easy, but you need enough of it!!!**

# Course structure + approach

## Approach:

- ▶ descriptive in nature + focus on dynamics
  - focus on geometric interpretations
  - use calculus, but calculus computations not examined

## Content structure:

- ▶ ocean features we want to explain (Lec 2 - 6)
- ▶ attempt at explaining (Lec 4 - 18)
  - bias on “clean” things
- ▶ how did we observe those features anyway (Lec 19 - 20)