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OCES 2003 :
Descriptive Physical Oceanography

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

Lecture 3: *not* oceans (seas, shelves, lakes etc.)

Outline

- the not oceans + terminology

  → seas, shelves, and the rest of it

- some interesting facts and cases

  → Mediterranean + Labrador + Weddell Sea (overturning circulation)

  → Black sea (anoxia)

  → South China Sea (ecology)

  → Eastern Boundary Current Systems (EBUS)

  → dynamics more complicated (waves, tides, 3d turbulence...)

Key terms: seas, shelves, estuary, anoxia, ecology

Recap: oceans vs. not oceans

Seas, shelves, estuaries etc.

- smaller L, slightly smaller H (usually $<$ 1200 m), H/L small-ish except near coasts (consequences for dynamics)

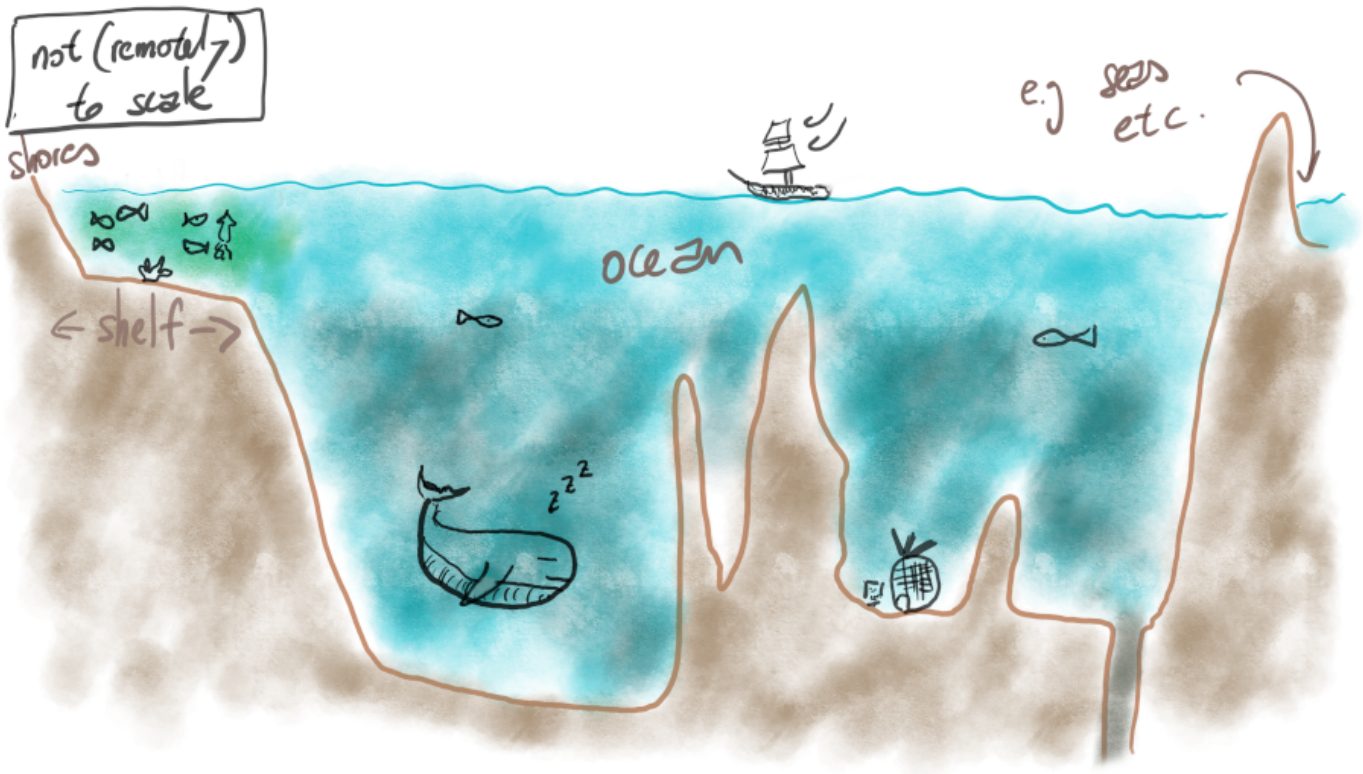


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

Seas

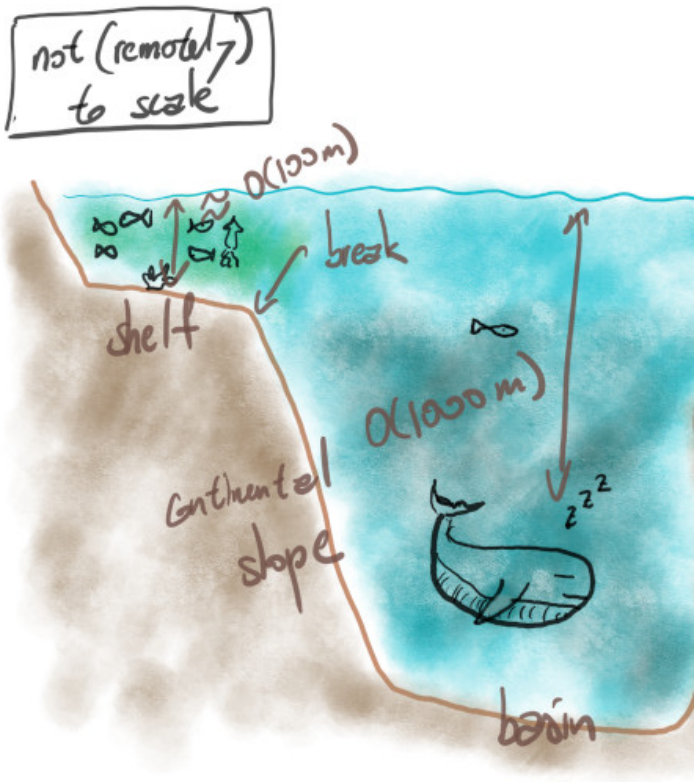


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

Smaller bodies of **salty** water connected to another sea or ocean

- no hard-and-fast definition, sometimes used interchangeably with ocean in US English

  → hence why I refer to oceans and **not**-oceans
- generally shallower than oceans

  → e.g. South China Sea can get quite deep (see later)

Seas

The following are not technically (?) not seas but lakes:

- Sea of Galilee (of the biblical fame)

  → freshwater, sometimes called **Lake Tiberias**
- Dead Sea (of the cosmetics fame?)

  → a *salt* lake
- Caspian Sea (of the caviar fame)

  → a salty lake, fed by the Volga river

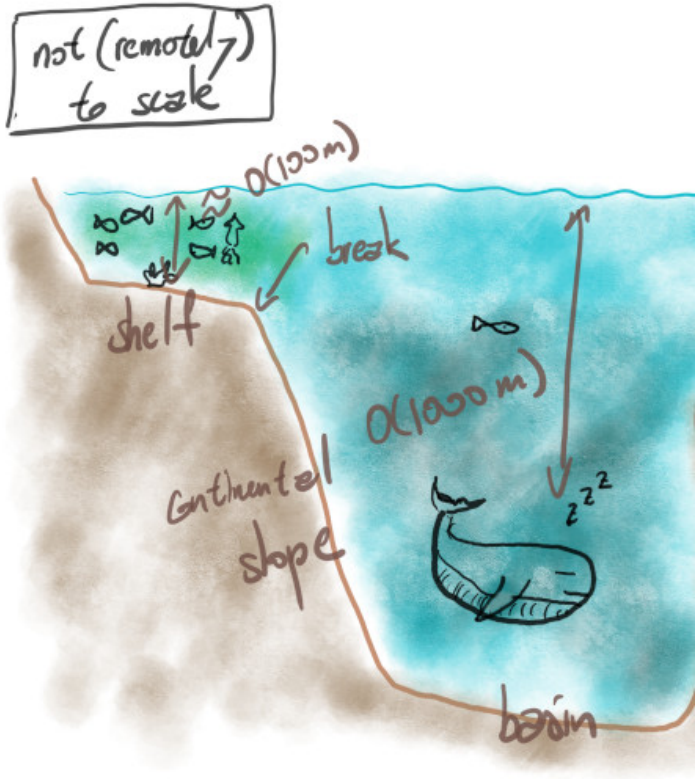
Figure: (Top) Sea of Galilee in 2020 at higher water levels; image from Times of Israel. (bottom left) Lowest point on land near the Dead Sea; taken by either myself or Kevin Adebowale Data of USAID. (bottom right) Beluga sturgeon of the Caspian Sea; image from the Royal caviar club.

Shelf seas

- the sea region over the continental shelf

  $\rightarrow$ not very deep, $O(100\ \mathrm{m})$
- on the side of continental plate, separated by a shelf break

  $\rightarrow$ large slope gradients (steep)
- most of world's fisheries on shelves



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Shelf seas

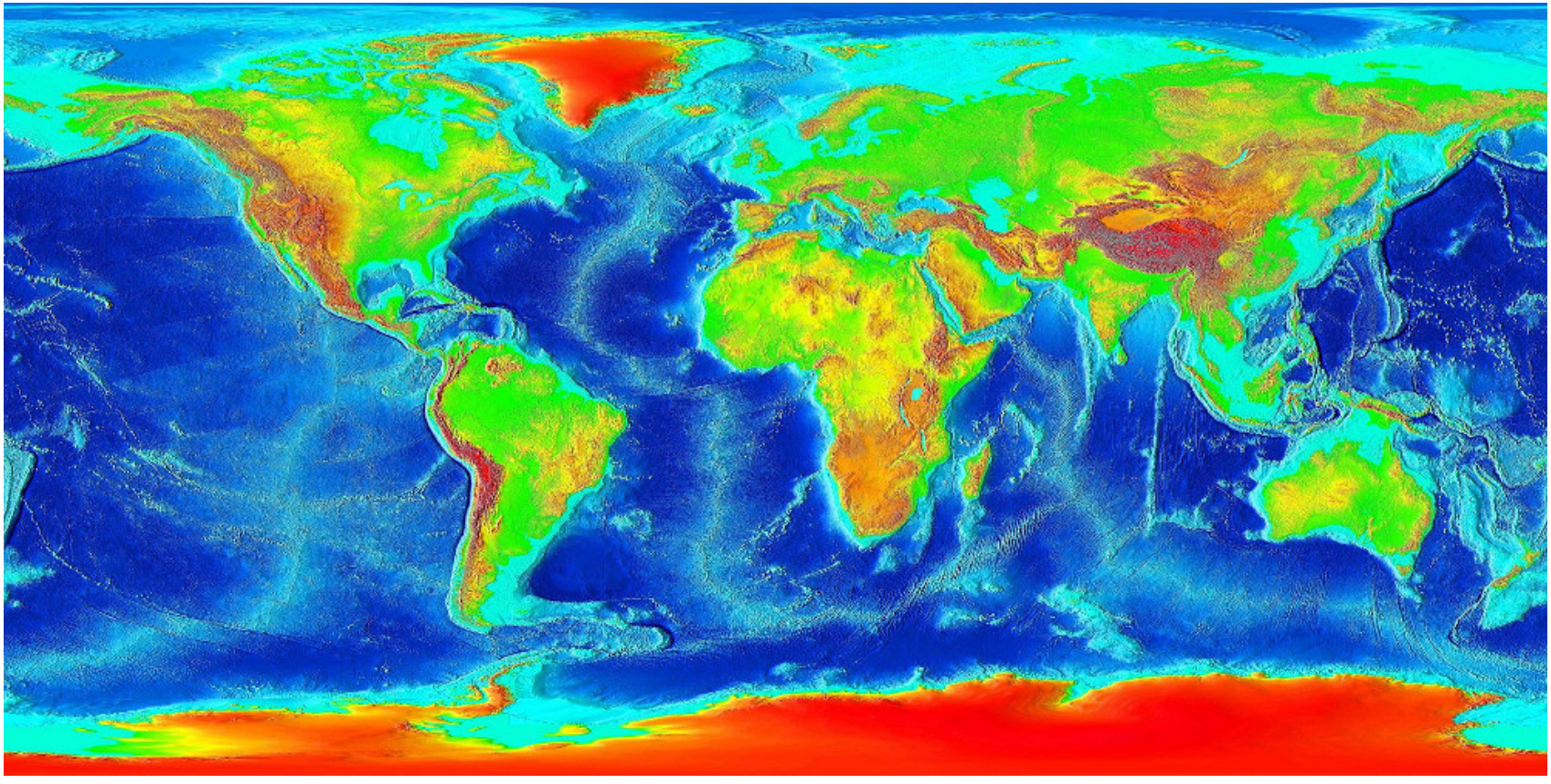

Figure: Locations of shelf seas denoted by the cyan colour. Taken from Wikipedia (`https://en.wikipedia.org/wiki/Continental_shelf`) made from NOAA data.

Shelf seas

shelf seas are relatively shallow, so

- drastic change in H/L, different dynamics (see assignments?)

  $\rightarrow$ tides, waves, Ekman upwelling, rivers etc.

  $\rightarrow$ nutrients

Shelf seas

shelf seas are relatively shallow, so

- drastic change in H/L, different dynamics (see assignments?)

  $\rightarrow$ tides, waves, Ekman upwelling, rivers etc.

  $\rightarrow$ nutrients
- sunlight can reach a reasonable portion of water column

  $\rightarrow$ light + nutrients = primary productivity

  $\rightarrow$ physics + biogeochemistry and ecology

  $\rightarrow \approx 8\%$ of global area, $15 - 20\%$ of primary productivity

- role in carbon cycle + economy? (see assignments?; see OCES 4001)

Marginal/semi-enclosed seas

Sea region that is somewhat shielded from the oceans by land features

- loose definition, degree of "shielding" variable

  → e.g. **North sea** is fairly connected
  → e.g. **Black sea** is not really connected to the ocean (it is to the **Med sea**) (see later)

  → e.g. Arctic sometimes seen as a sea for the Atlantic

- some examples later

Figure: (top) the North Sea, connected to the Atlantic. (bot) The Black Sea, connected to some seas (including the Mediterranean sea) which is then to the Atlantic. Pictures from NASA.

Marginal/semi-enclosed seas

- seas and oceans sometimes connected through straits (or channels)
- straits normally have a sill

  → sill depth restricts water movements/exchanges (see later and Lec. 13 + 14)

  → flow over sills lead to internal waves (see Lec. 15, 16, 18)
- **Strait of Gibraltar** here, details/importance differ for others

  → e.g. **Strait of Malacca** + shipping, mean depth ≈ 25 m

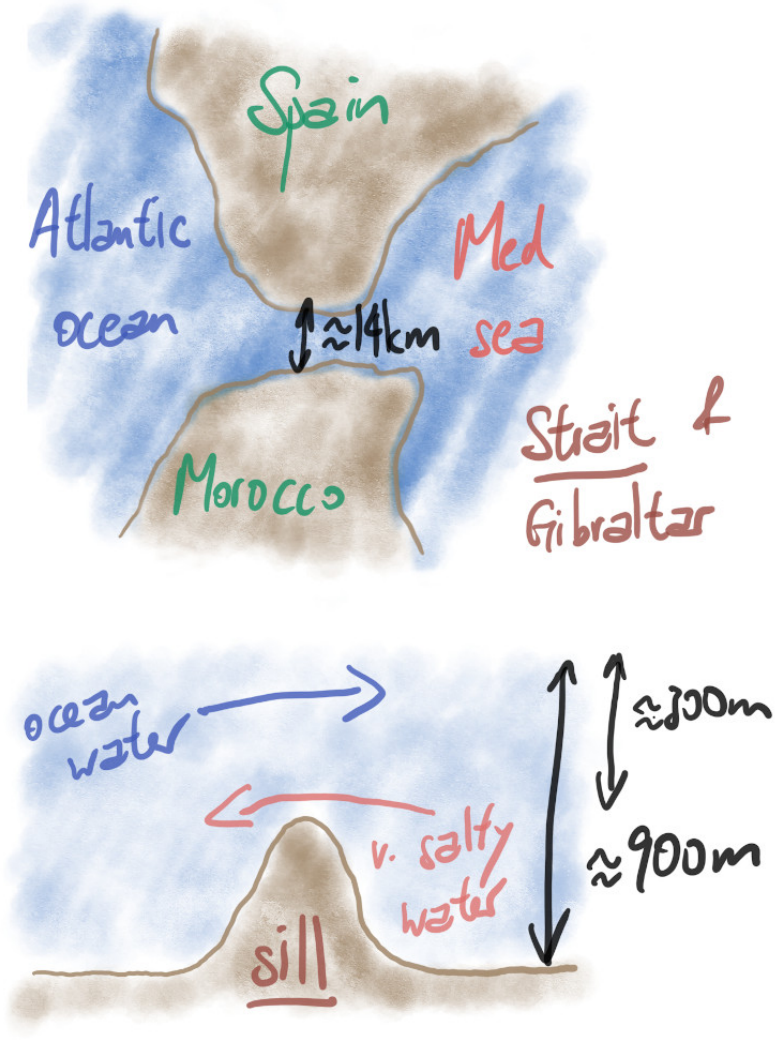

Figure: Strait and sill, using the Strait of Gibraltar as an example.

Estuaries

- estuaries are coastal regions of water

  → normally fed by rivers (freshwater) and affected by tidal flow from the sea (salty water)
- shallow and smaller

  → 3d dynamics, fresh/salty water mixing, waves, tides, and Coriolis effect not entirely negligible...
- classification + characteristics much later (see assignments?)

Figure: (left) Estuary in the Amazon; from Science Photo Library. (right) Pearl River Delta showing Humen bridge; from Wikipedia, user Tung Wu.

Other bodies of water

- fjords are inlets with steep sides carved by glaciers

  → from the Norse word *ferd* for "lake-like"

  → normally has salty water (some in the Great Lakes in N. America don't)

  → only really in higher latitudes (why?)

- some ambiguity with use of the word (like seas), regional variations

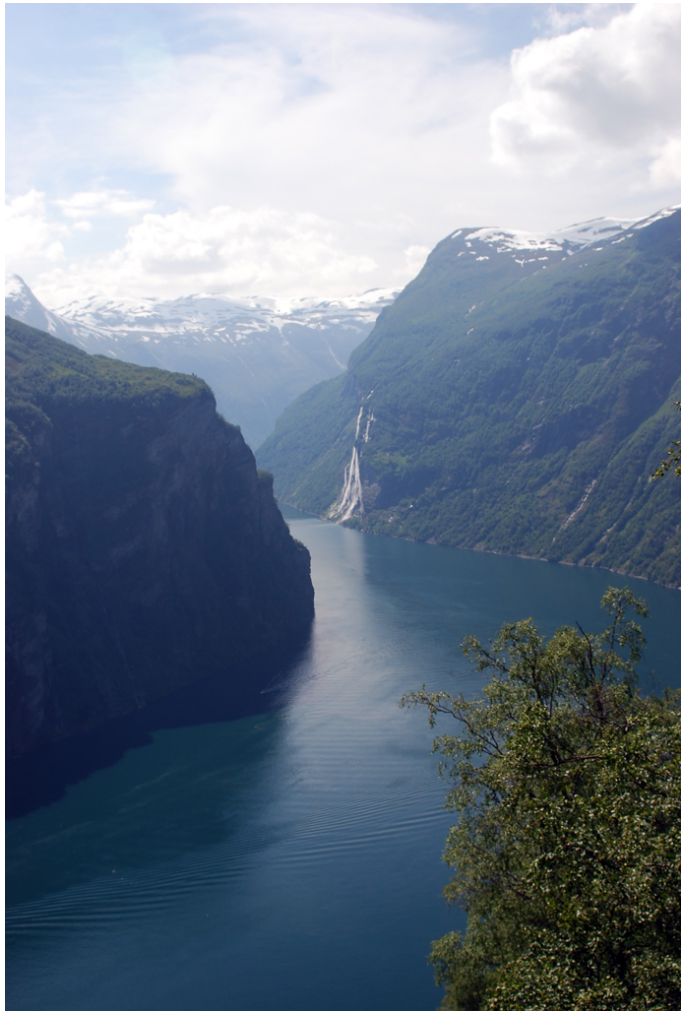

Figure: Geiranger fjord in Norway; notice the steep sides. Taken from Wikipedia.

Other bodies of water

- lakes lie on **land**

  $\rightarrow$ most (!) lakes are freshwater (notable excepts in the Great Salt Lake, Dead Sea)

Figure: What lake am I? Pictures originally from Royal Caribbean website and TopPNG.

- e.g. lagoon, sounds, gulf, cove, ... (see more at Wikipedia)

Features of interest: Med Sea

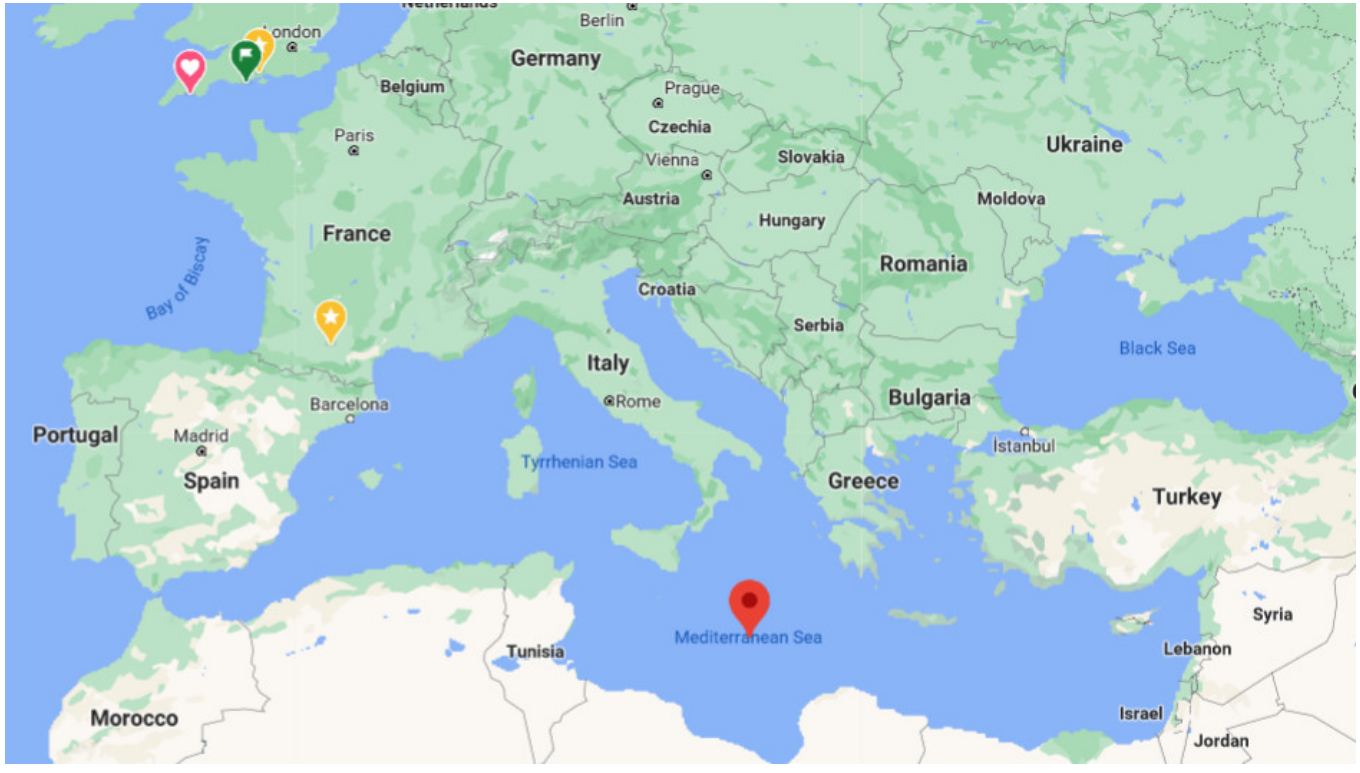

Figure: Geographical map of Mediterranean Sea and Black Sea. From Google maps.

- connected to Atlantic through the **Strait of Gibraltar** (see four slides ago)
- important for climate, food and trade for the surrounding countries (see e.g. OCES 4001)

Features of interest: Med Sea (more in Lec. 5, 13 + 14)

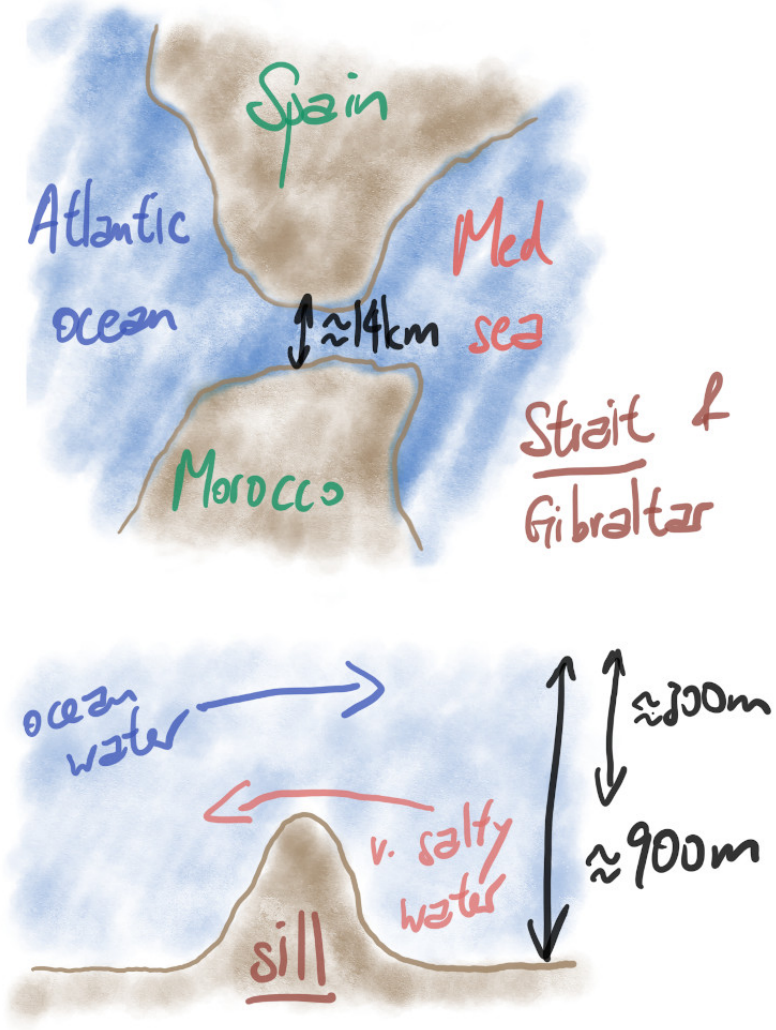

Figure: Strait and sill, using the Strait of Gibraltar as an example.

- cool surface water comes in from ocean and rivers, but region is warm so large evaporation

  → salty denser water
- occasional cold bursts from atmosphere from land

  → cold + saline = very dense! water sinks, fills bottom, flows out eventually
- sill holding some water back, more time for watermass transformation

Features of interest: Lab Sea (more in Lec. 5, 13 + 14)

Figure: Geographical map of the Labrador Sea. From Google maps.

- connected to North Atlantic

  → recall Atlantic surface currents seem to converge mass northwards, so where does it go? (see last Lec, and Lec 13 + 14)

Features of interest: Lab Sea (more in Lec. 5, 13 + 14)

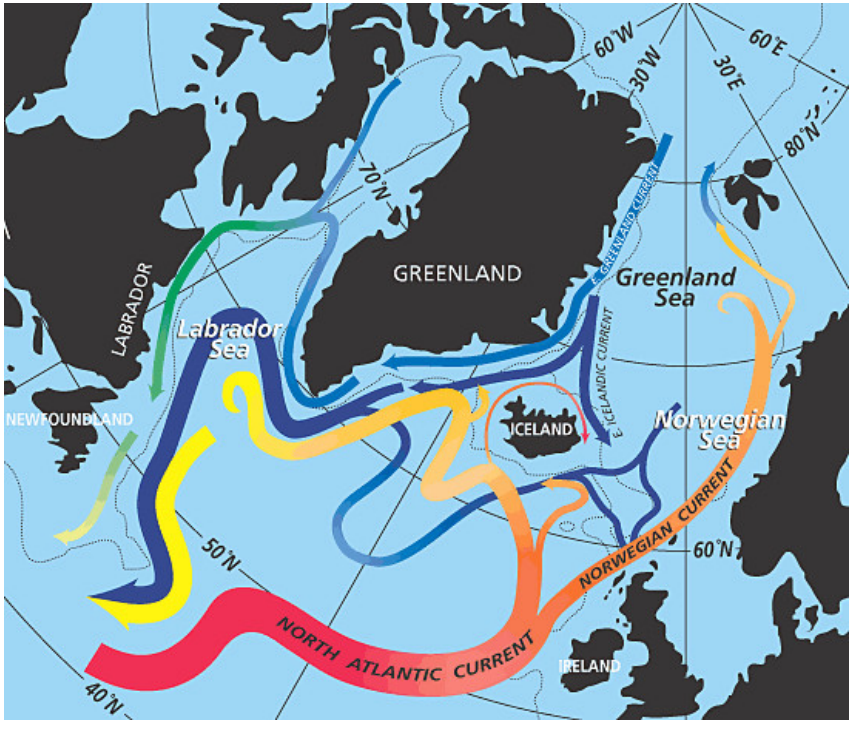

Figure: Schematic of North Atlantic Circulation. Taken from Wikipedia, image from Jack Cook at WHOI.

- return water gets very cold, dense, and sinks in the region

  → deep convection, cabelling etc. (see Lec. 5, 6, 17)
- mass returns southwards at depth, identifiable as the NADW (North Atlantic Deep Water)

  → more on watermass properties later (see Lec. 5 + 6)

- important part of the (A)MOC (see Lec. 13 + 14)

Features of interest: Weddell Sea (more in Lec. 5, 13 + 14)

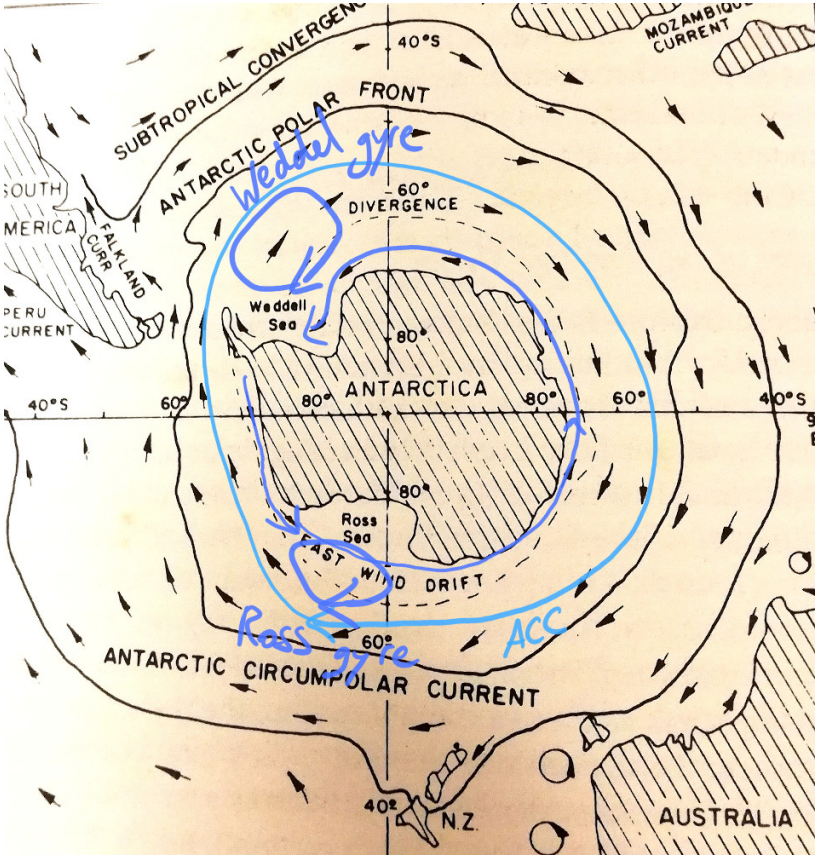

Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn. According to historian Thomas R. Henry, "*The Weddell Sea is, according to the testimony of all who have sailed through its berg-filled waters, the most treacherous and dismal region on earth. The Ross Sea is relatively peaceful, predictable, and safe.*" (from Wikipedia)

- East of **Drake passage** (the bit between Antarctic and S. America)

  → just downstream of the ACC, fairly turbulent region (see quota in the figure caption)
- it's very cold here!

  → sills etc. allow very cold but fresh water to form

  → spills over as overflows forming AABW (Antarctic Bottom Water)

Features of interest: MOC (more in Lec. 5, 13 + 14)

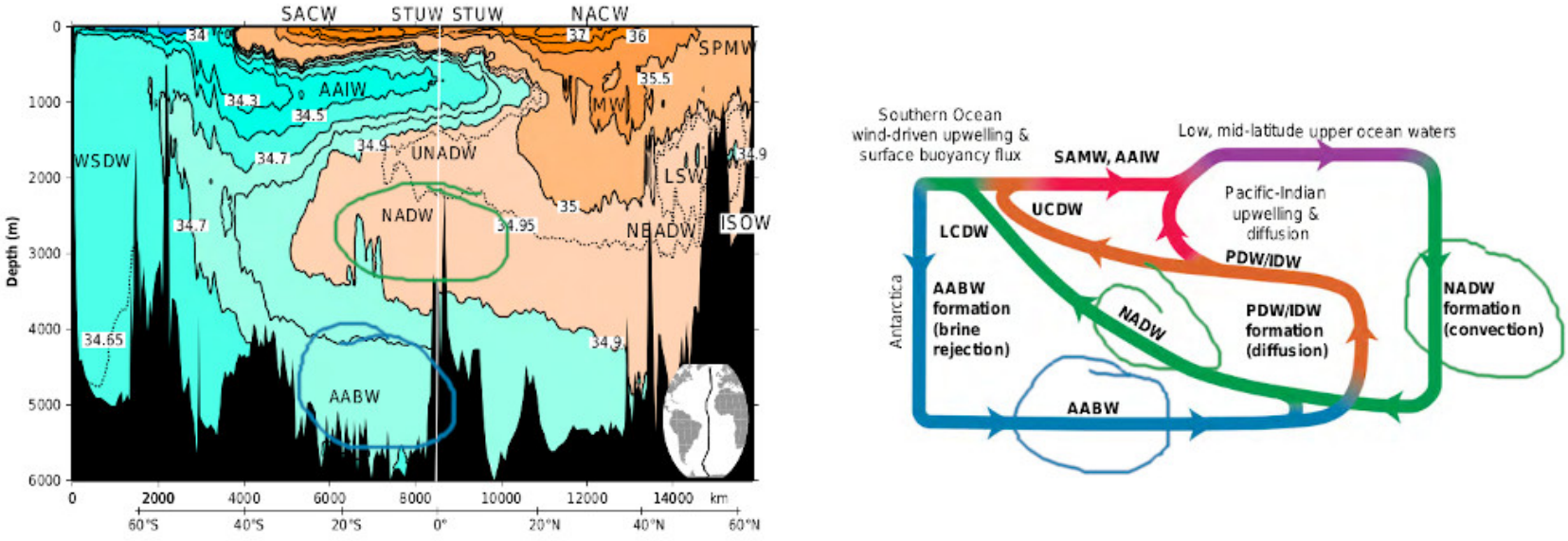

Figure: (left) Meridional sections using salinity as data, over WOCE section A16 and A23). (right) Schematic of branches of MOC. Figure 9.17a and 14.11c of Talley *et al.* (2011), 6th edn.

- more on watermass properties, MOC and related dynamics later in the course (Lec. 5, 6, 13, 14, 17 particularly)

Features of interest: Black Sea

- classic example for anoxia (no oxygen in water)
- fed by rivers (fresh) + exchange with Med sea water (salty)

  → strongly stratified

  → limited mixing (see Lec. 10, 15 - 18) + exchange of water

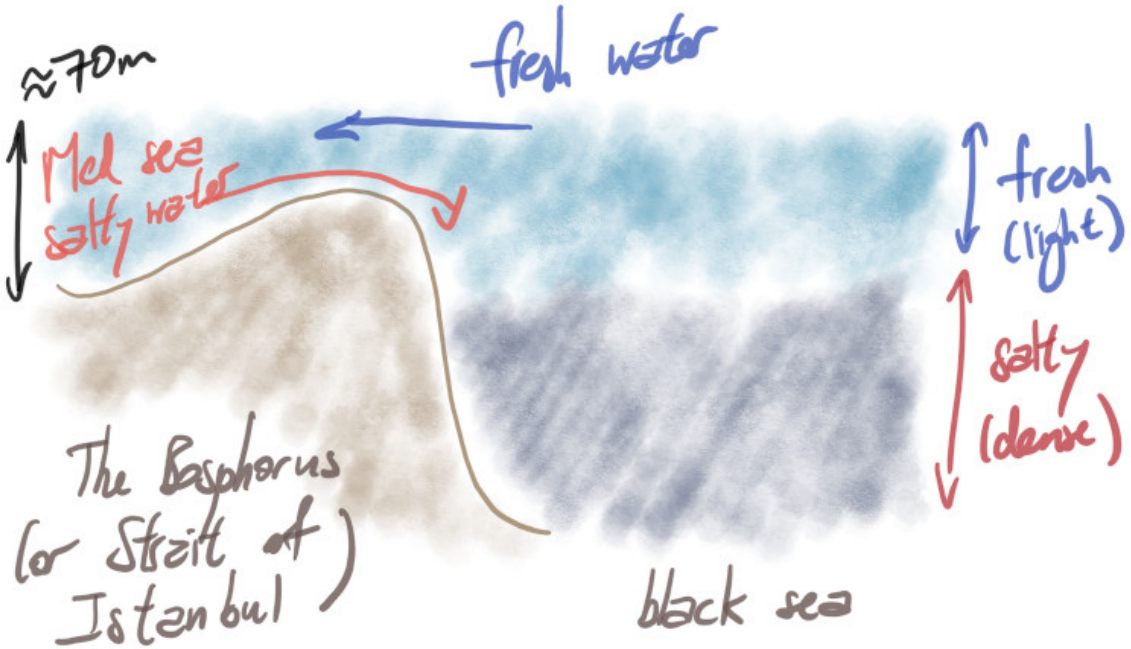

Figure: Black sea schematics water property schematic.

Features of interest: Black Sea

- life only in shallow region, oxygen doesn't reach the deep
  $\rightarrow$ sulfides producing organisms in deep (cf. rotten eggs)
- little decomposing of stuff (because no oxygen)
  $\rightarrow$ reason for black sea being "black"?

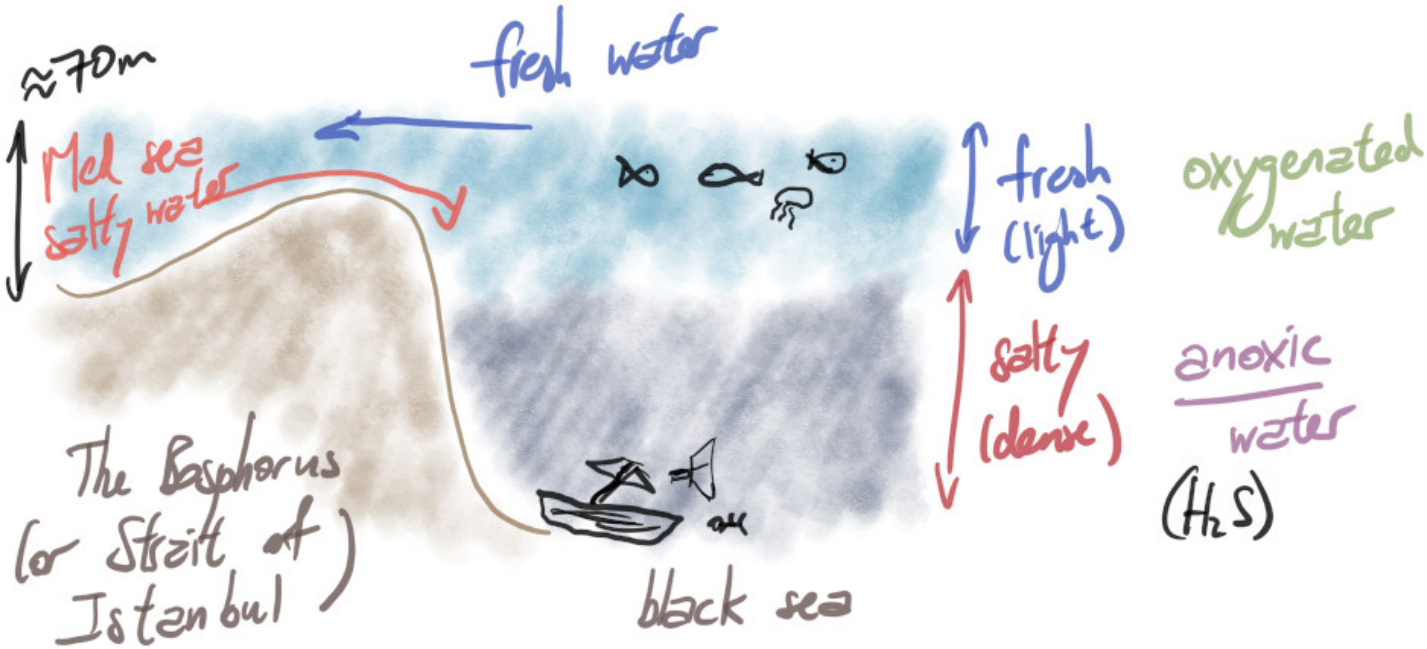

Figure: Black sea schematics water property schematic.

Features of interest: South China Sea

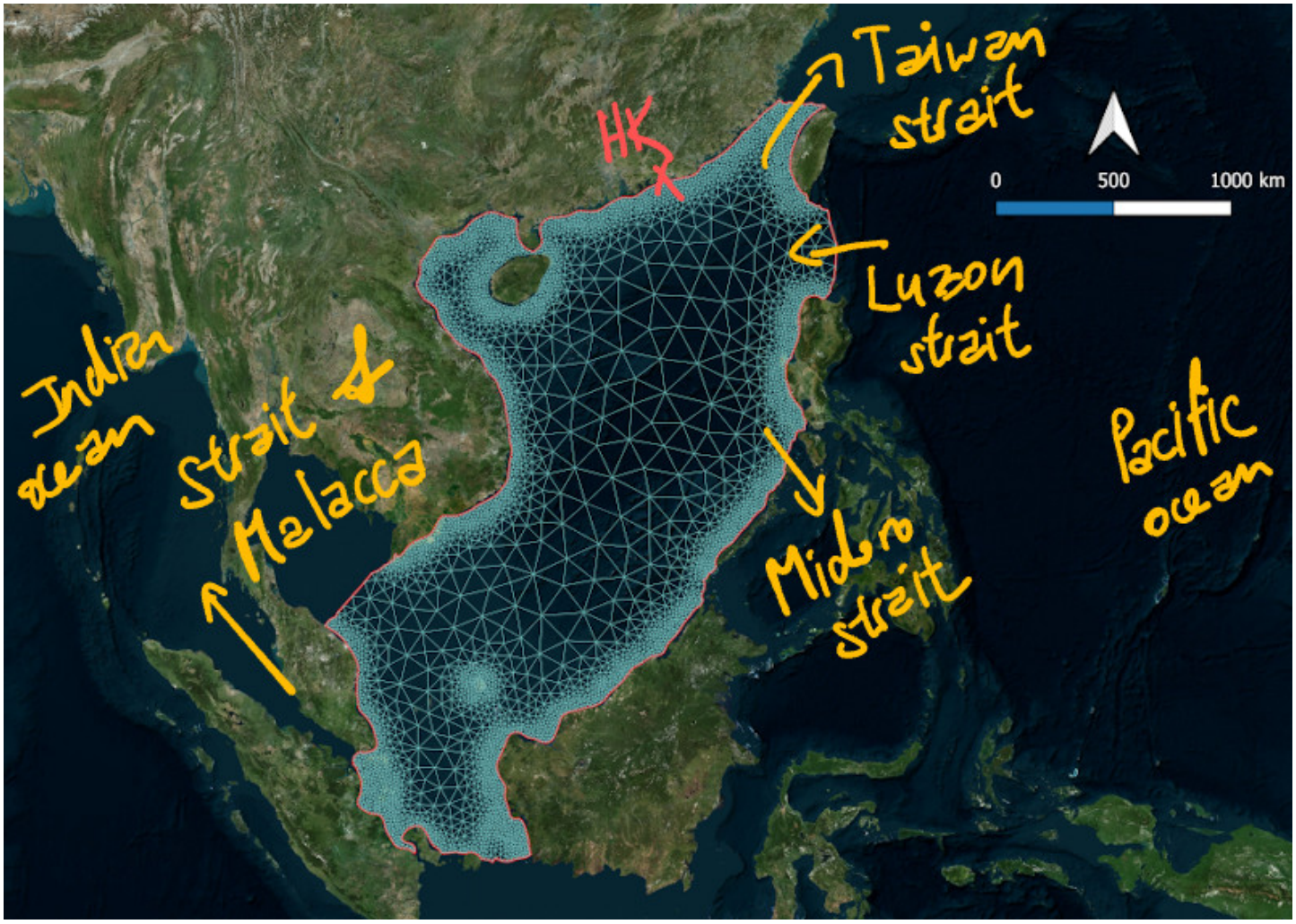

Figure: South China Sea and related straits. Finite element mesh for a recent HKRGC GRF submission, courtesy of Chinmayee Mallick.

Features of interest: South China Sea

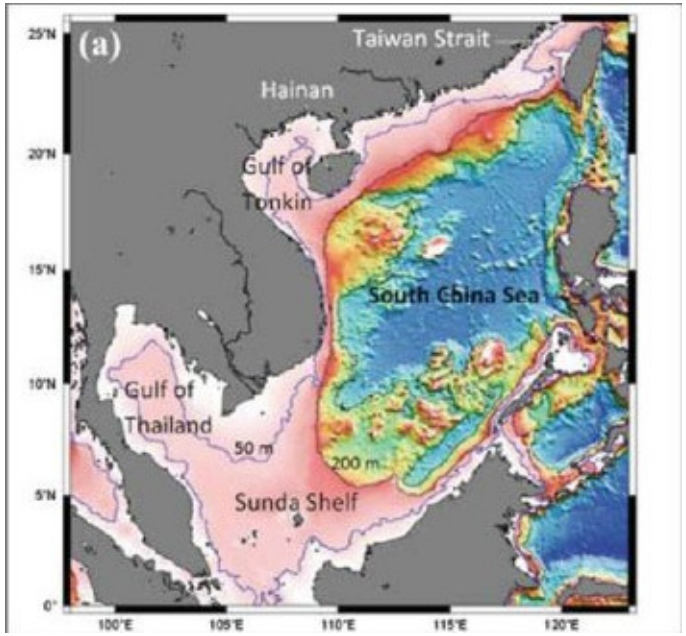

Figure: (top) SCS bathymetry, with shallow regions ($<$ 200 m) in pink. From Liu and Dittert (2010). (bot) Fisherman taking stock of their haul in the South China Sea. Image from Reuters.

- SCS has shelf and deep regions

  $\rightarrow$ deep regions can go down to 4000 m like oceans
- important for shipping and fisheries

  $\rightarrow$ fisheries tend to be on shelf, coincide with nutrient rich water

  $\rightarrow$ monsoon + Ekman upwelling (see Lec. 9)

  $\rightarrow$ river forcing (see Lec. 5, assignments?)

Features of interest: South China Sea

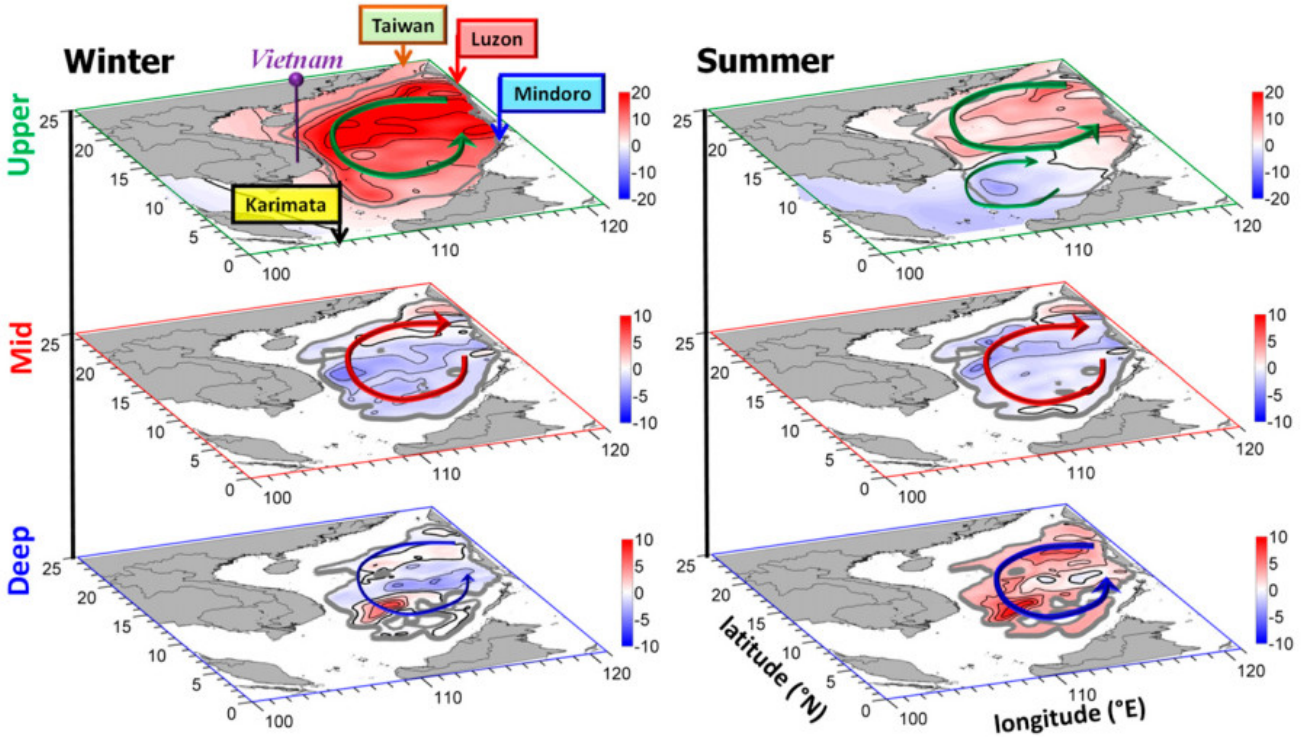

Figure: Schematic of cyclonic-anticyclonic-cyclonic circulation in the SCS, with numerical simulation data. From Gan *et al.* (2016), *J. Phys. Oceanogr.*.

- what drives the sandwich circulation?

  $\rightarrow$ wind (see Lec. 9), eddies (baroclinic instability? see Lec. 17), upwelling (see Lec. 13, 16, 17), in/outflow in Luzon, others.? (ongoing research question)

Summary

- touched on features occurring in seas that we want to explain

  $\rightarrow$ straits + sills, and their influence

  $\rightarrow$ touched on watermass properties (T, S, oxygen)

  $\rightarrow$ influence and role in MOC (Med, Lab, Weddell sea)

  $\rightarrow$ shelf seas and the role in human activity (SCS)

- more on related dynamics in *not* ocean regions later because it is "harder" (or, really, "less clean") (see assignments?)

  $\rightarrow$ H/L not that small and L smaller makes a lot of difference...

Outlooks

- have now highlighted some seemingly disparate features of interest, subsequent lectures to link them through dynamics

1. forces: thermodynamic (Lec. 5 + 6) and mechanical (Lec. 7 - 10)
2. large things: gyres + WBCs (Lec. 11 + 12), MOC (Lec. 13 + 14)
   $\rightarrow$ "easy"(!?)/cleaner because geostrophic constraint
   $\rightarrow$ focus on large scales $\rightleftharpoons$ small scales
3. smaller things: waves, instabilities, tides (Lec. 15 - 18)
4. observations of large and small (Lec. 19 - 20)

$\times$ dynamics in *not* oceans
$\rightarrow$ hard/messy because geostrophic constraint weaker

Mostly by drawing pictures!