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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 2: broad terminology and oceans

Thur 4th Feb

Outline

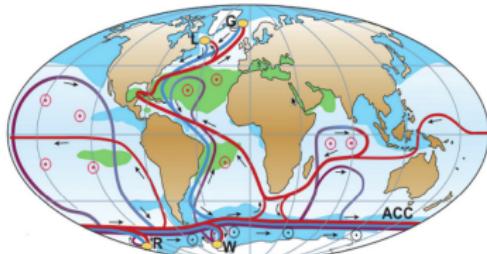
- ▶ some terminology
 - Earth system and **hydrosphere**
 - dimensions and boundaries
 - oceans, seas, lakes, shelves, coasts, etc.
- ▶ **oceans** + mostly **surface** features of interest
 - terminology
 - Atlantic, Pacific, Indian, Arctic, Southern
 - **gyres**, **currents** (W/EBC and equatorial), **eddies**
 - dynamics strongly constrained by **rotation** + **stratification**

Key terms: oceans, continents, overturning circulation, gyres, currents, eddies

Recap from last time

- ▶ admin things
 - course structure, approach, ground rules, mutual expectations, how to use me/TAs etc.
- ▶ ocean physics and impacts
 - weather/climate, ecology, economy etc.

**what does the ocean look like, and
why does it look the way it does**



—	Surface flow
—	Deep flow
—	Bottom flow
●	Deep Water Formation
○	Wind-driven upwelling
○	Mixing-driven upwelling
■	Salinity > 36 ‰
■	Salinity < 34 ‰



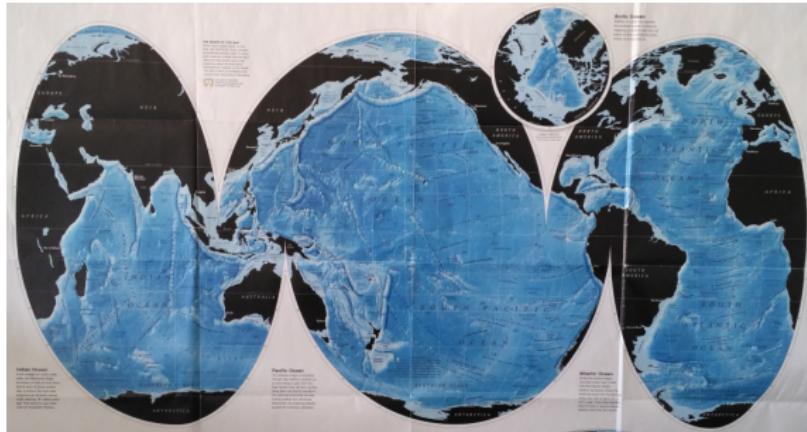
Earth overview



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

Oceans

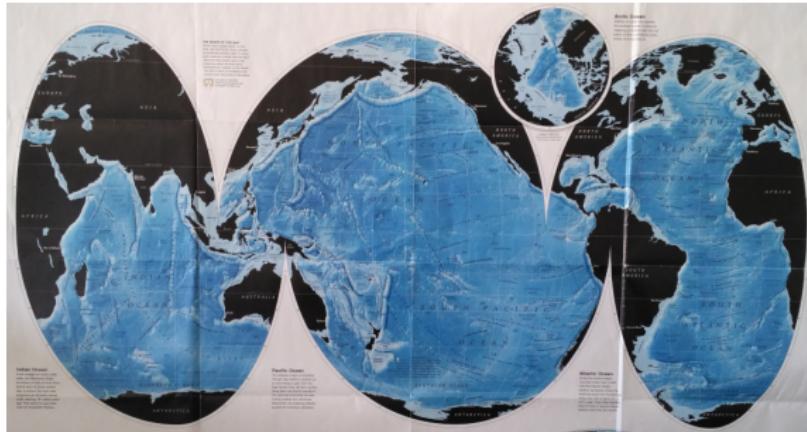
The ocean covers > 70% of the Earth's surface:



- ▶ five **oceans** (and they are...?)

Oceans

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



- ▶ five **oceans** (and they are...?)
- ▶ average **depth** H of ocean ≈ 4000 m
- ▶ horizontal length-scales $L \approx 10000$ km (**units!**)

Oceans

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



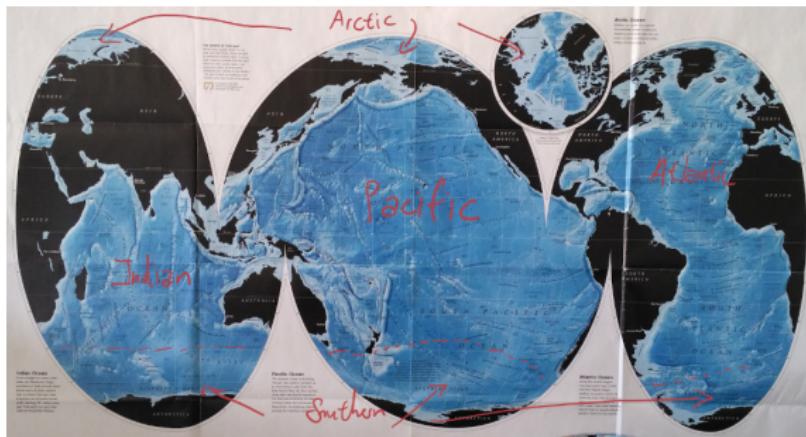
- ▶ five **oceans** (and they are...?)
- ▶ average **depth** H of ocean ≈ 4000 m
- ▶ horizontal length-scales $L \approx 10000$ km (**units!**)

aspect ratio H/L small (important dynamical consequences)

Oceans

Oceans separated horizontally by continental land masses

- ▶ constraints on dynamics + circulation (contrast this to atmosphere)
→ Southern ocean slightly different... (see Lec 13)



Not oceans

Seas, shelves, estuaries etc. (see next Lec.)

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

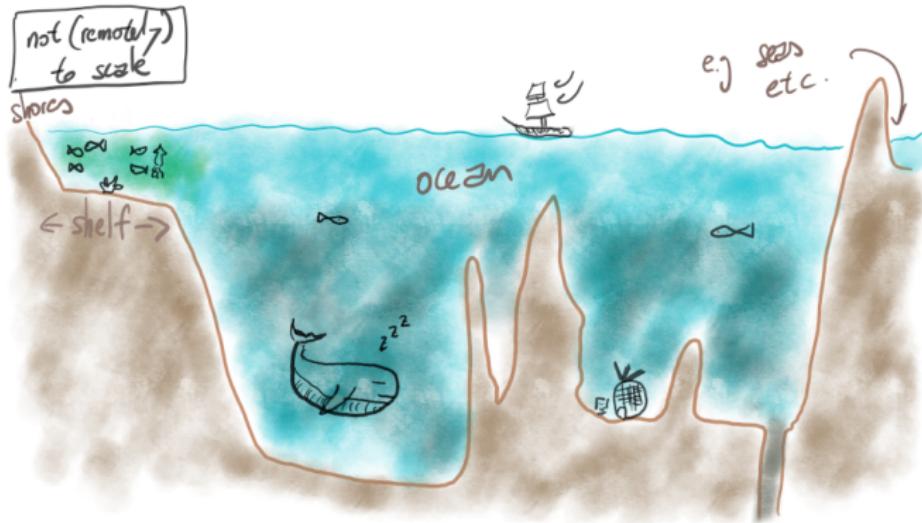


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

Land boundaries

Bottom boundary is land with features

► **topography** and/or **bathymetry**

→ technically it should be **bathymetry** (below sea level)

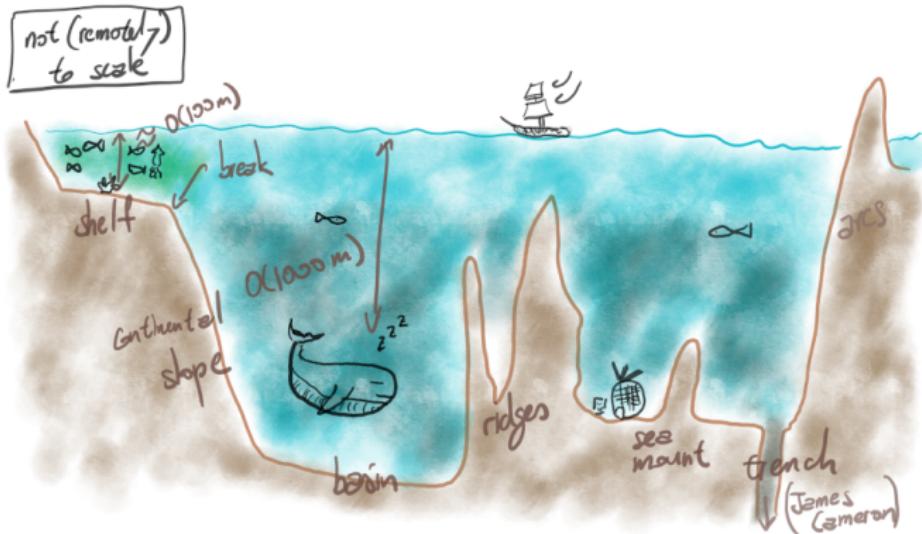


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

Top boundary

Top boundary in contact with atmosphere

- ▶ atmosphere **forces** ocean + **vice-versa**
→ wind, sun, precipitation etc. (see Lec 4 - 10)

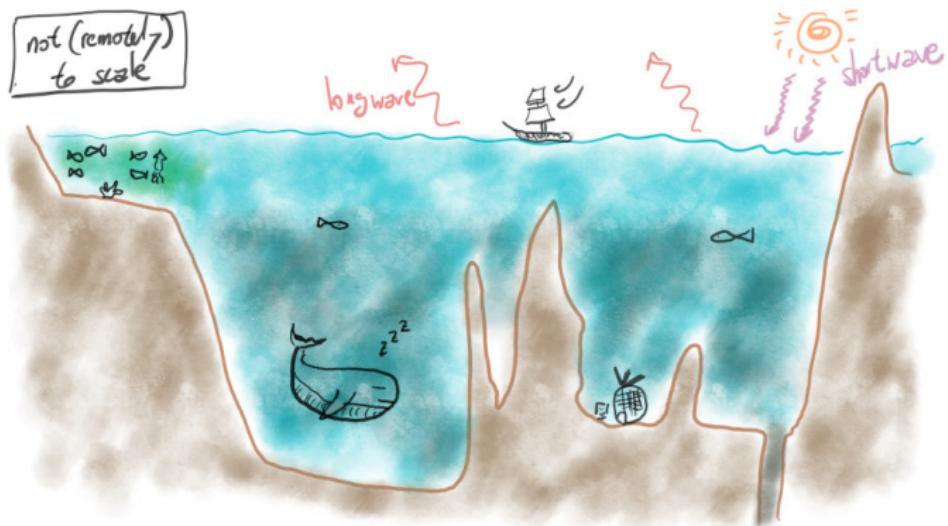


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn. (only solar forcing shown).

Atlantic ocean features

- ▶ following is a **non-exhaustive** list of **features of interest** to motivate the study of **dynamics** (see e.g. Lynne Talley's book for much more)

- ▶ connected mainly to
 - Arctic ocean
 - others oceans principally via the Southern Ocean
 - e.g. Mediterranean and Labrador seas (important for MOC,

Lec 13 - 14)

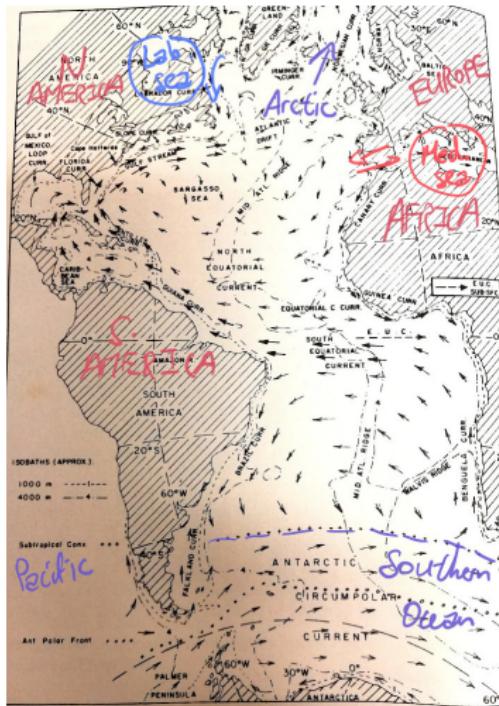


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

Atlantic ocean features

- ▶ two separately driven subtropical gyres
 - clockwise in NH, anti-clockwise in SH
 - anti-cyclonic (see Lec. 8)
 - largely (!) wind-driven
(see Lec. 11 - 12)
 - **Gulf stream** as a part of gyre
- ▶ subtropical gyres separated by E-ward equatorial currents

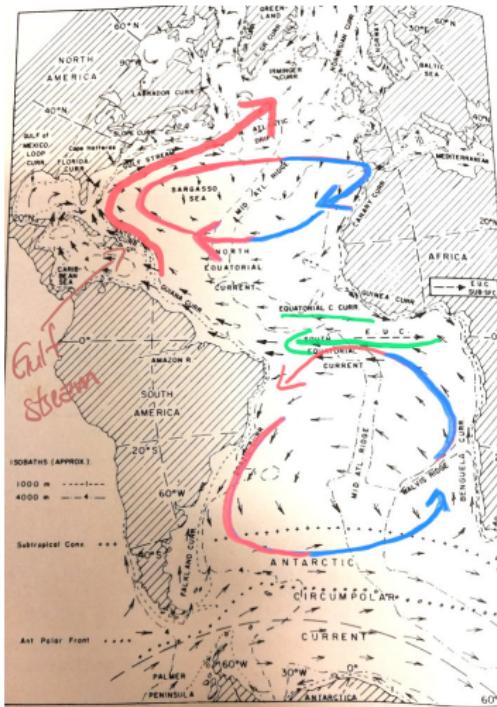


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

Atlantic ocean features

► subpolar gyres

→ anti-clockwise in NH
(clockwise in SH but in Southern Ocean)

→ cyclonic (see Lec. 8)

→ largely (!) wind-driven

(see Lec. 11 - 12)

→ **Gulf stream** as a part of gyre

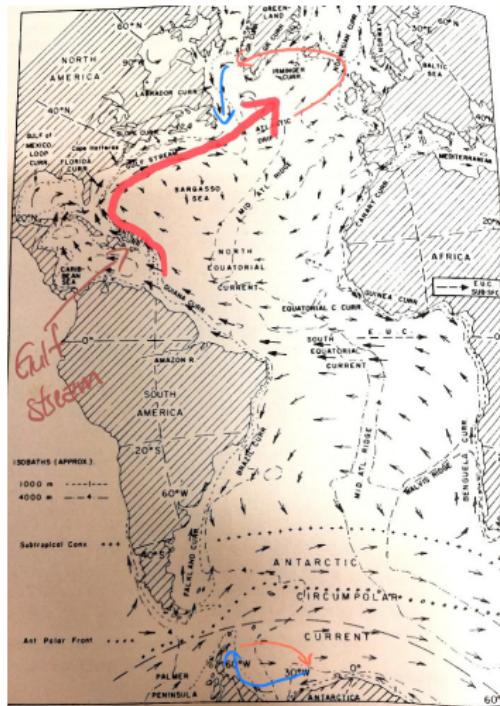


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

Atlantic ocean features

► Western Boundary Current

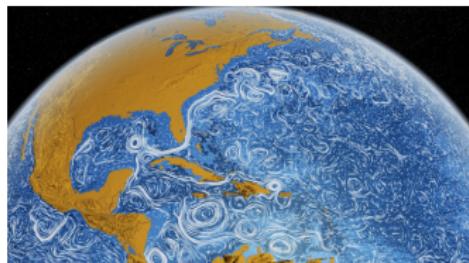
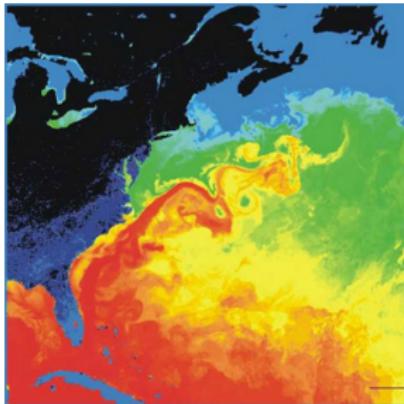
→ gulf stream + eddies

→ transports tropical + warm water towards North Pole

Q. why Western and not Eastern? (see Lec. 12)

Q. processes leading to eddies? (see Lec. 17)

Q. fluctuations + role in climate? (see Lec. 17 + OCES 4001)



Gulf stream in temperature (left) and surface current speed, from NASA

Atlantic ocean features

- ▶ seems to be an overall transport towards the North Pole, where does the water go/return?
 - **deep convection** in Lab sea (see Lec. 5 + 6)
 - **deep western boundary currents** (see Lec. 14)
 - presence of the **Atlantic Meridional Overturning Circulation (AMOC)** (see Lec. 14)

14)

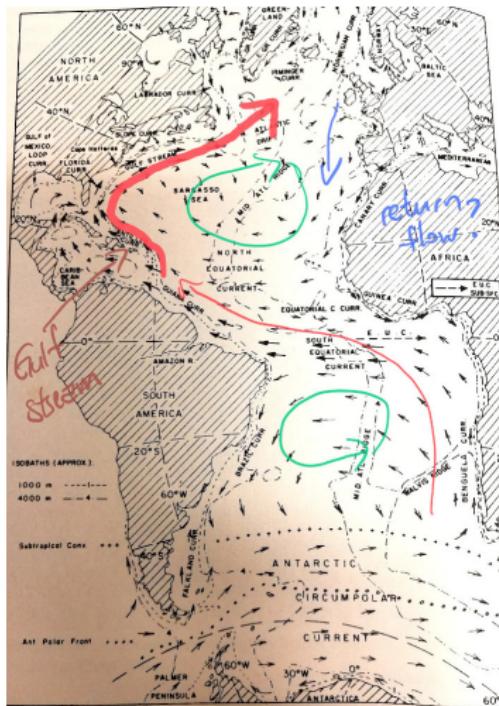


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

Pacific ocean features

- ▶ takes up $\approx 46\%$ of the Earth's surface area (makes it difficult to chart historically)
- ▶ connected principally to Southern Ocean
 - Indian somewhat, Atlantic through Southern Ocean
 - Arctic through the **Bering strait**

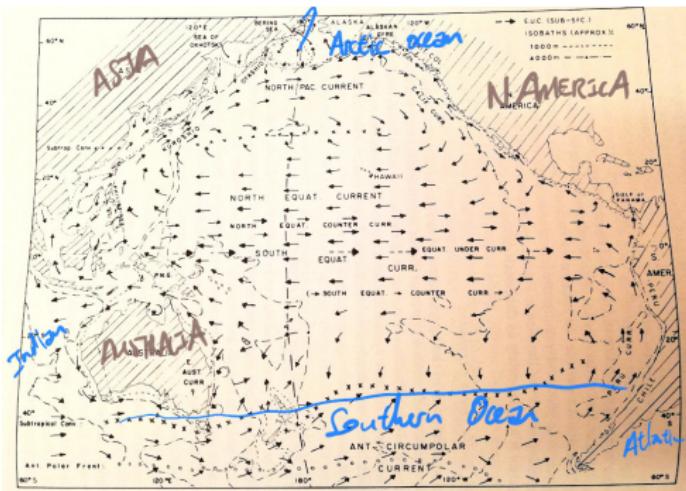


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

Pacific ocean features

- ▶ subtropical/subpolar (cyclonic/anti-cyclonic) gyres + WBC (**kuroshio** + extensions)
→ but no **PMOC** as such?

Q. asymmetry in Equatorial currents? (see Lec. 9)

Q. role in **El Niño** (see OCES 4001)

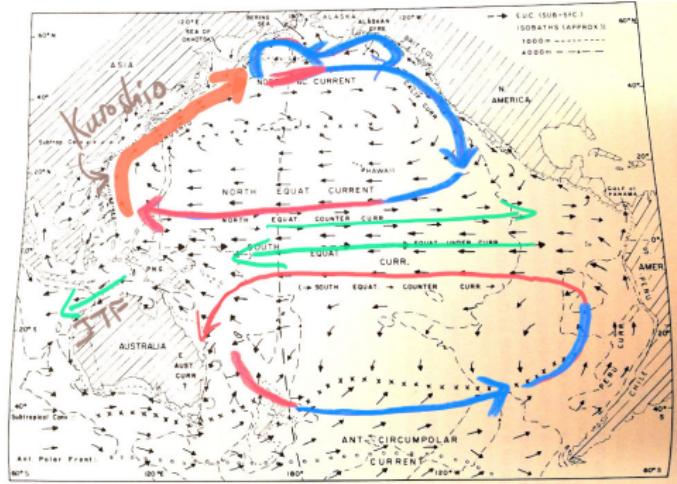


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

Pacific ocean features

► Eastern boundary currents (EBCs)

→ e.g. Peru, Californian

Q. how are these different to WBCs? (see Lec. 9 + 12)

► coincide with locations of fisheries

Q. why? (see Lec. 9)

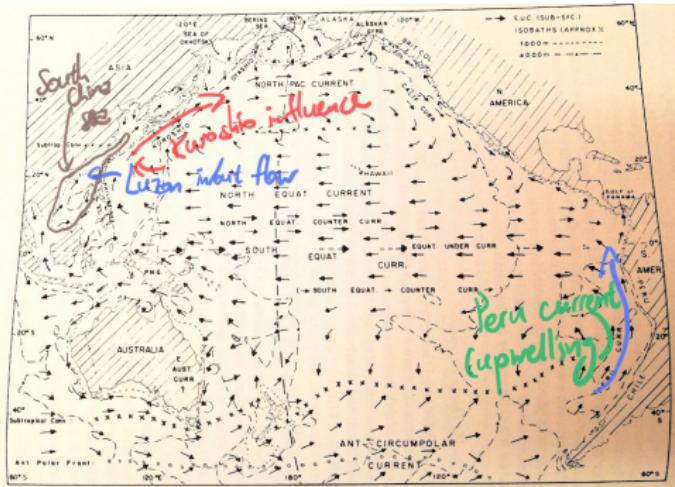


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

Indian ocean features

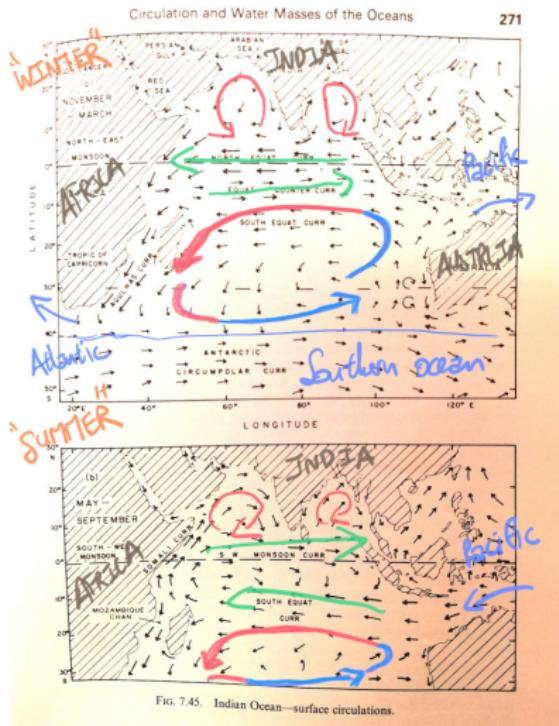


Figure: Features in the Indian Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

- ▶ one set of gyres really (land is in the way)
- ▶ connection to Atlantic, Pacific and Southern
 - connection through **Agulhas** current or the loooong way around to Atlantic?
- ▶ **seasonally** varying (surface) currents
 - why? (see Lec. 9)
- ▶ role in MOC?
 - seen as a Indo-Pacific unit in the MOC (see Lec. 14)

Arctic ocean features

- ▶ mainly connected to Atlantic
 - Pacific via Bering strait
- ▶ Beaufort gyre
 - anti-cyclonic regime drawn here, can reverse
 - feedbacks with ice and atmospheric
- ▶ ice plays a role in dynamics
 - thermodynamic (via fresh meltwater) and mechanical (wind shielding not)



Figure: Features in the Arctic Ocean. Modified Figure 7.26 from Pickard & Emery (1990), 5th edn.

Southern ocean features

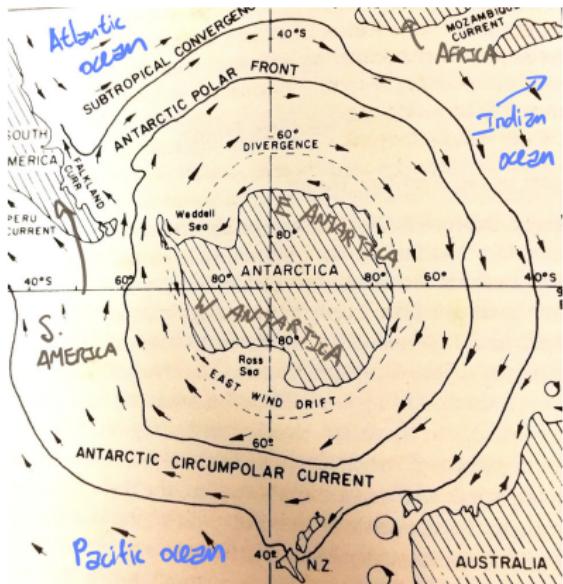


Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

- ▶ connected to all major ocean basins (except Arctic)
 - influences global overturning circulation (see Lec. 13 + 14)
- ▶ dynamics slightly different because of regions with no **zonal** (East-West) land boundaries (see Lec. 13)
 - cf. **atmosphere**
- ▶ ice important

Southern ocean features

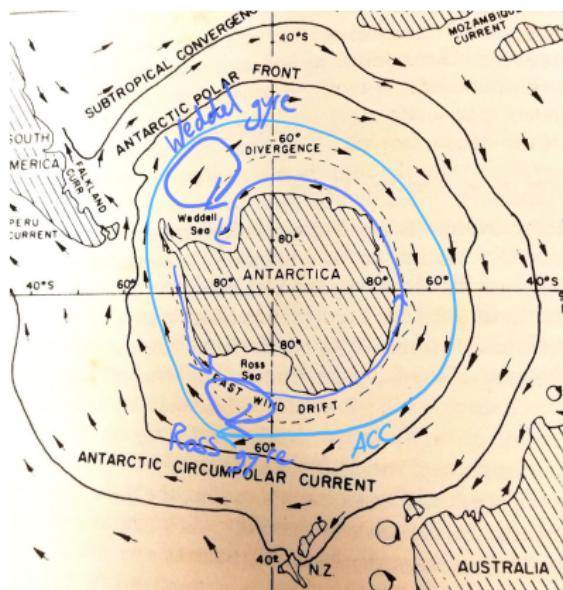


Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

► Antarctic Circumpolar Current (ACC)

→ world's largest current, transport of $\approx 130 \text{ Sv}$ ($1 \text{ Sv} = 10^6 \text{ m}^3 \text{ s}^{-1}$)

→ partly because of lack of landmass, very turbulent/unstable region (see Lec. 17)

► subpolar gyres

→ cyclonic (clockwise in SH), e.g. Ross + Weddell

→ important in global MOC (see Lec. 14)

Southern ocean features

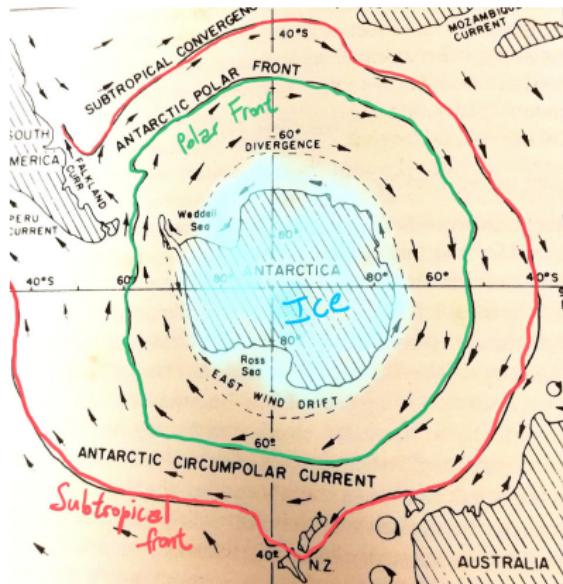


Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

- ▶ “boundary” of Southern Ocean based on location of **fronts**
 - to do with **watermass properties** (see Lec. 5 + 6)
 - moves around seasonally and on longer time-scales

(<https://youtu.be/WQUXbkAdZhg>)

Summary

- ▶ highlighted some features present in the **ocean**
 - $H/L \ll 1 \Rightarrow$ strong constraint on dynamics
 - **topographic/bathymetric** features
- ▶ **circulation** features
 - **gyres, currents, eddies**
 - what leads to and controls these? (Lec 4 - 18)
 - different geographical locations, **united by dynamics**
- ▶ **seas** and others next time
 - H/L starts becoming less small among other things...