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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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- ▶ As said on the repository, I have tried to honestly use content that is self made, open source or explicitly open for fair use, and citations should be there. If however you are the copyright holder and you want the material taken down, please flag up the issue accordingly and I will happily try and swap out the relevant material.

OCES 2003 : Descriptive Physical Oceanography

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

Lecture 2: broad terminology and oceans

Outline

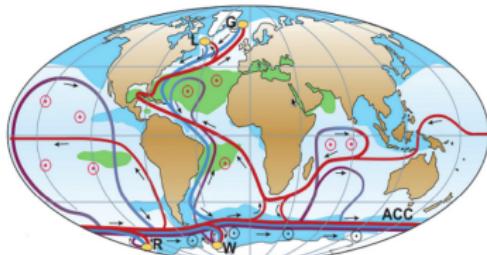
- ▶ some terminology
 - Earth system and **hydrosphere**
 - dimensions and boundaries
 - oceans, seas, lakes, shelves, coasts, etc.
- ▶ **oceans** + mostly **surface** features of interest
 - terminology
 - Atlantic, Pacific, Indian, Arctic, Southern
 - **gyres**, **currents** (W/EBC and equatorial),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



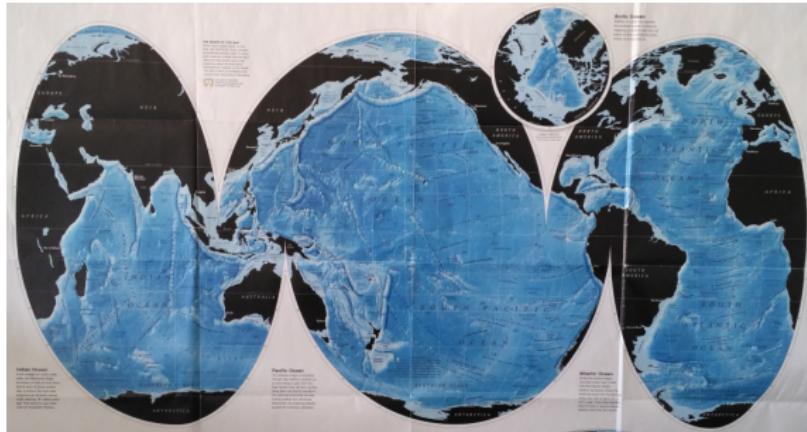
Earth overview



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

Oceans

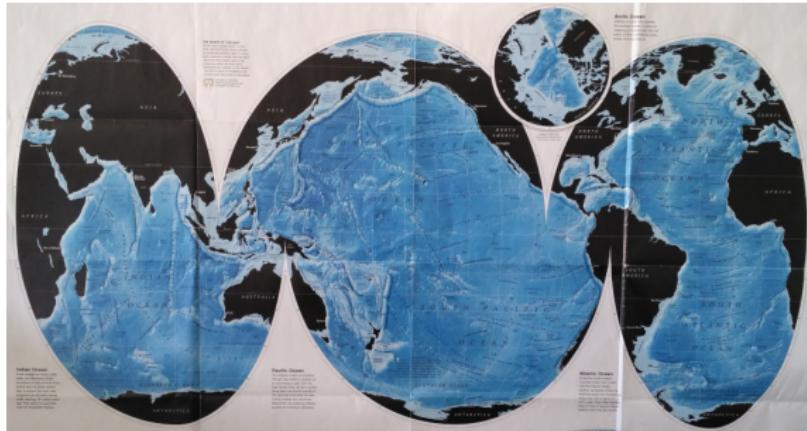
The ocean covers > 70% of the Earth's surface:



- ▶ 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:



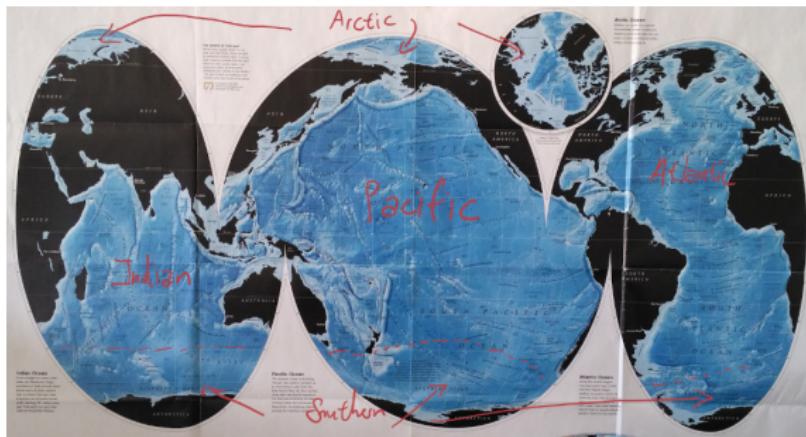
- ▶ five **oceans** (and they are...?)
- ▶ average **depth** H of ocean ≈ 4000 m
- ▶ horizontal length-scales $L \approx 10000$ km (**units!**)

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)

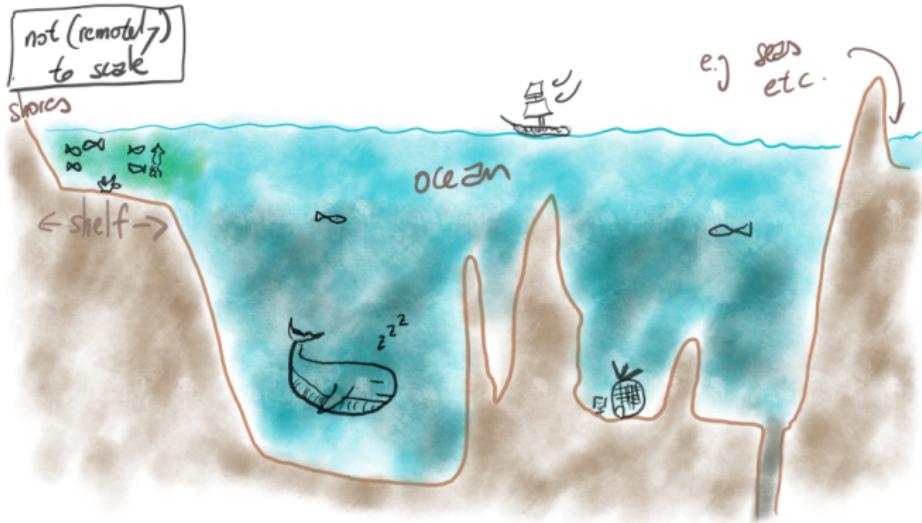


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

Land boundaries

Bottom boundary is land with features

- ▶ **topography** and/or **bathymetry**
→ technically it should be **bathymetry** (below sea level)

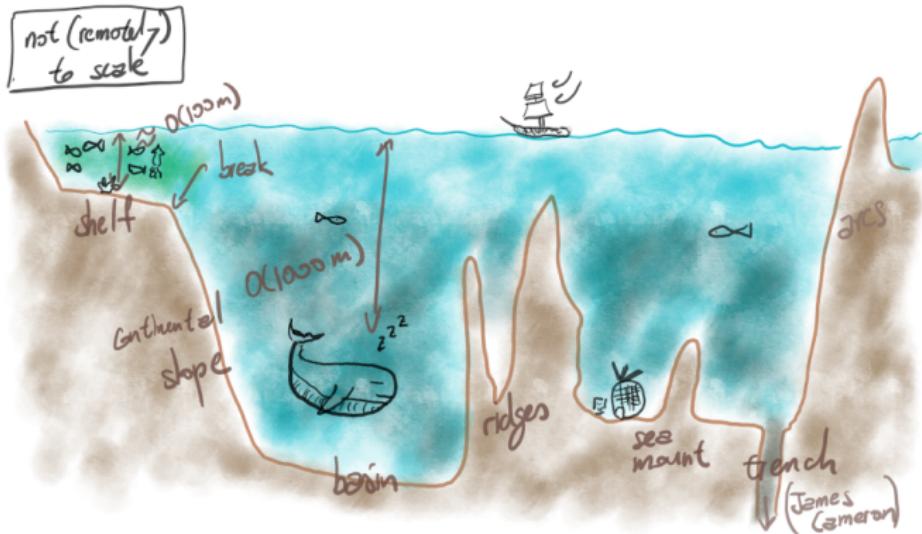


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

Top boundary

Top boundary in contact with atmosphere

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

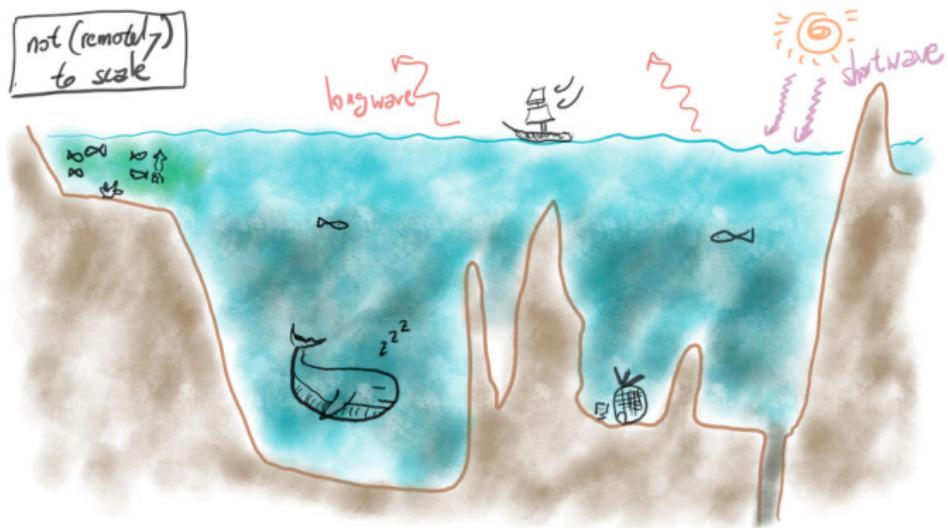


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn. (only solar forcing shown).

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)

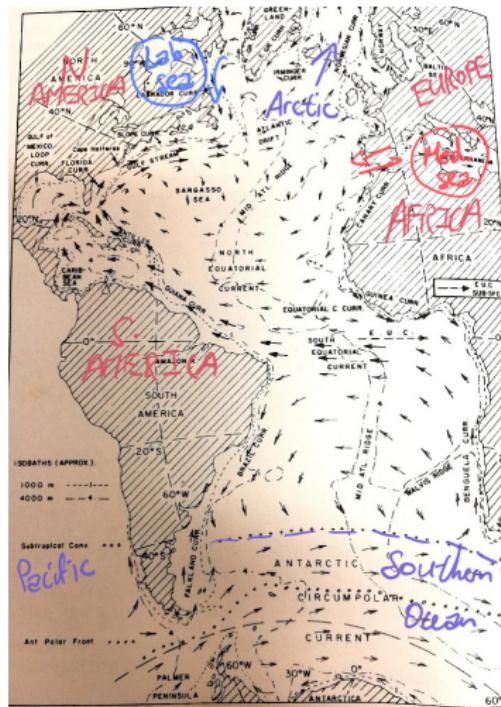


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

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

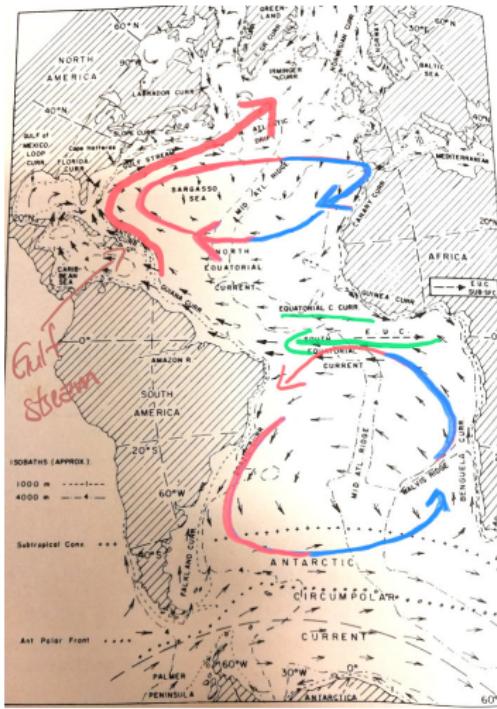


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

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

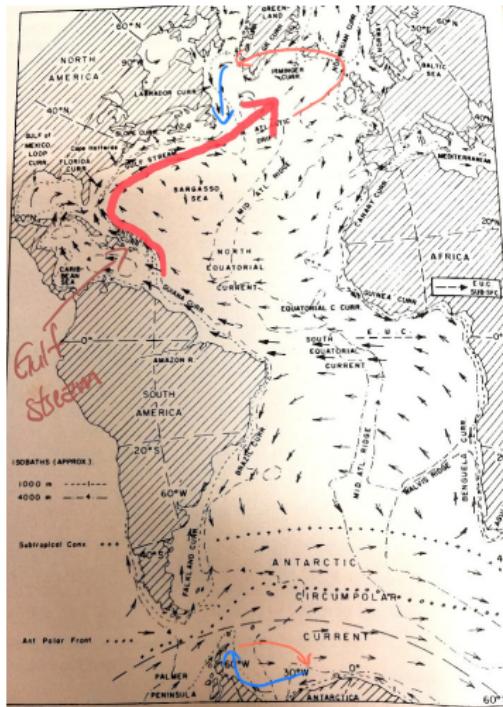


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

Atlantic ocean features

► Western Boundary Current

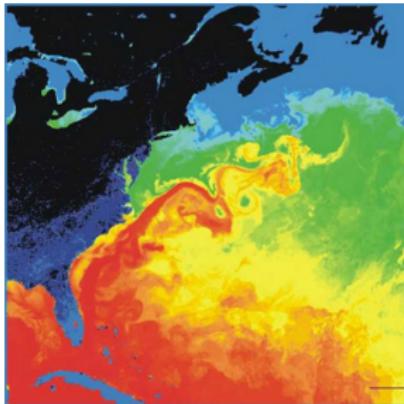
→ gulf stream + eddies

→ 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)

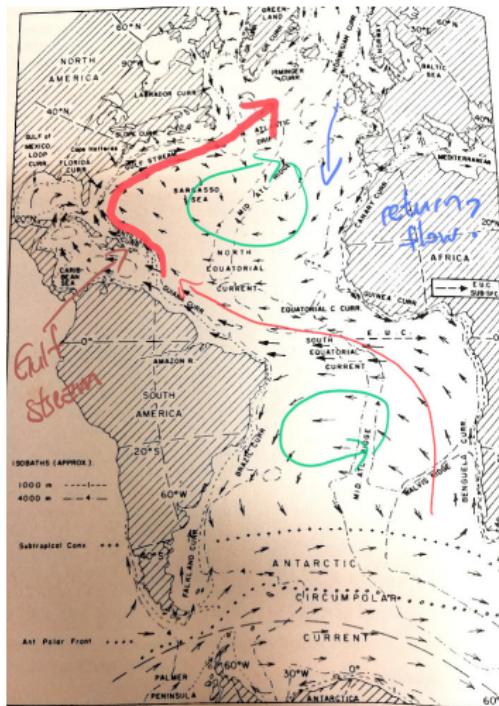


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

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**

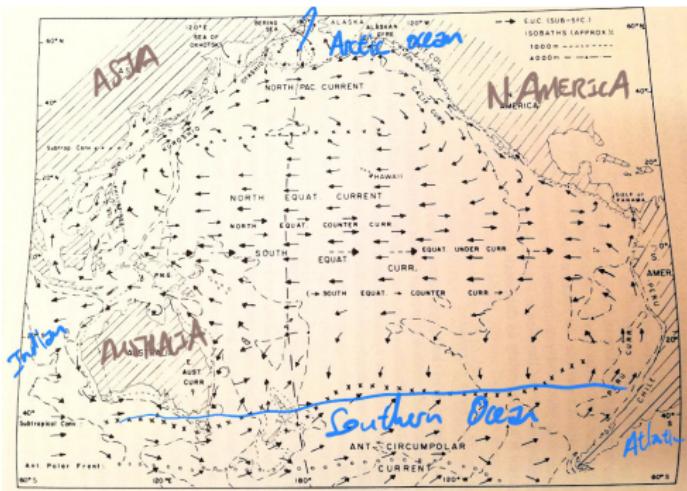


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

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)

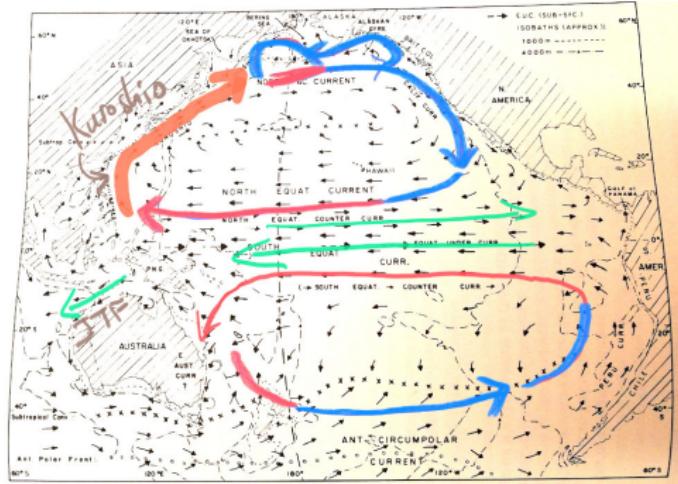


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

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)

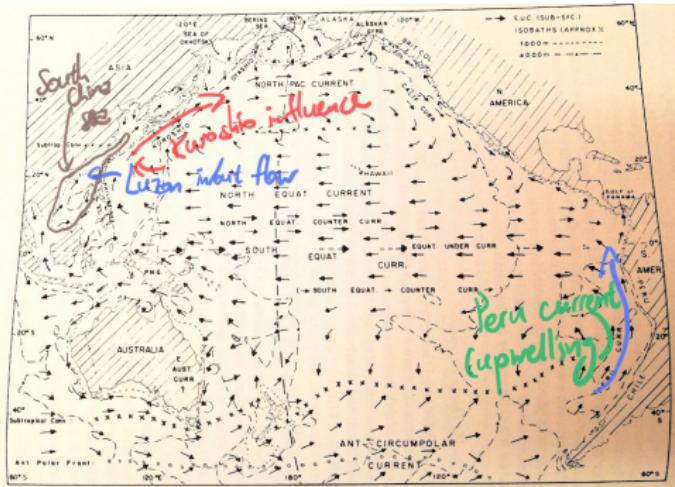


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

Indian ocean features

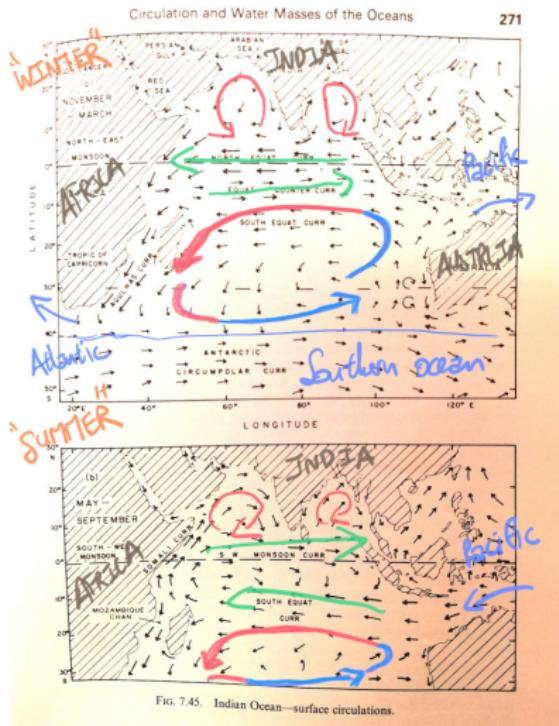


Figure: Features in the Indian Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

- ▶ 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 (e.g. wind shielding)



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

Southern ocean features

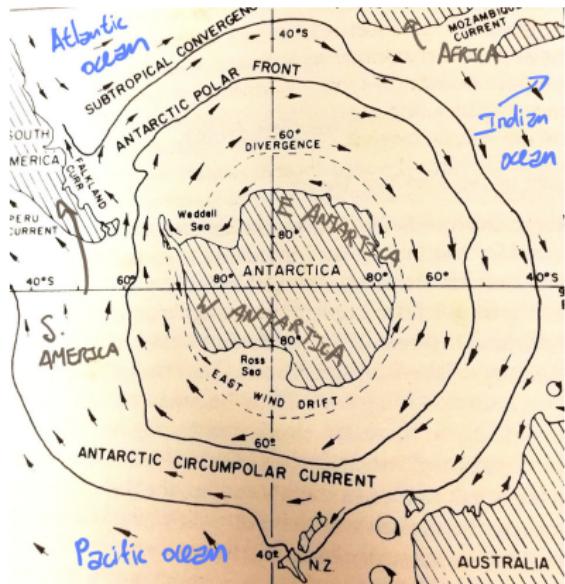


Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

- ▶ 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

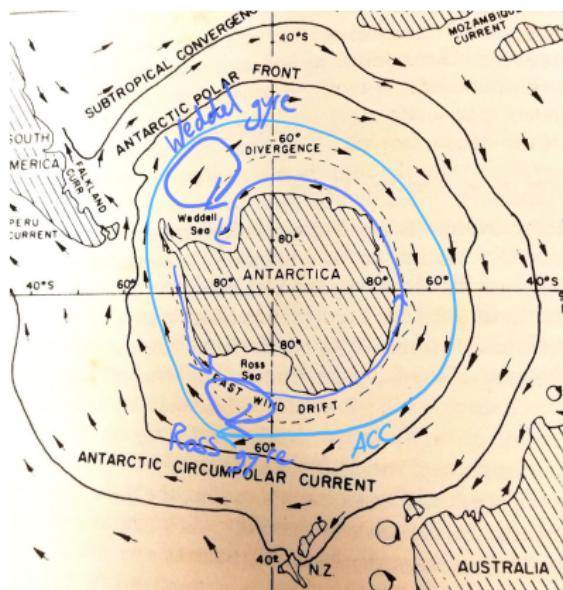


Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

► 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

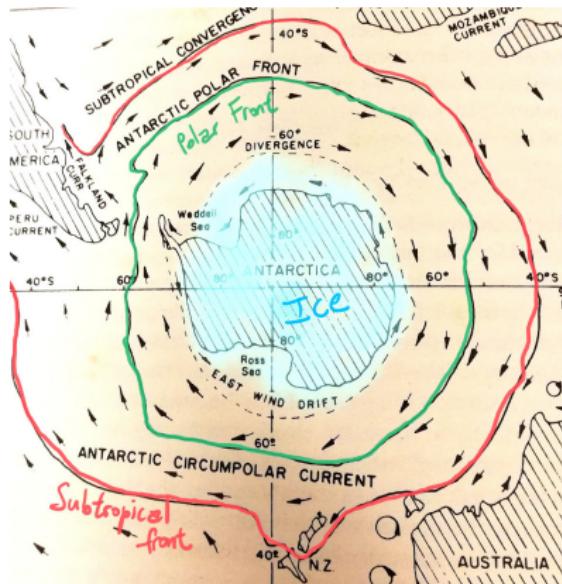


Figure: Features in the Southern Ocean. Modified Figure 7.45 from Pickard & Emery (1990), 5th edn.

- ▶ “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...