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- ▶ 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

# Outline

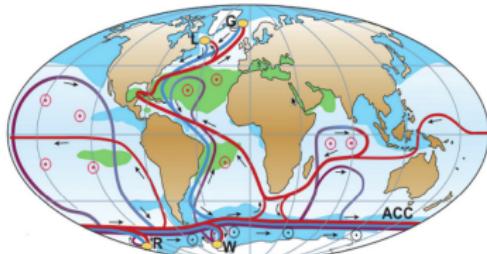
- ▶ some terminology
  - Earth system and **hydrosphere**
  - dimensions and boundaries
  - oceans, seas, lakes, shelves, coasts, etc.
- ▶ **oceans** + mostly **surface** features of interest
  - terminology
  - Atlantic, Pacific, Indian, Arctic, Southern
  - **gyres**, **currents** (W/EBC and equatorial),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



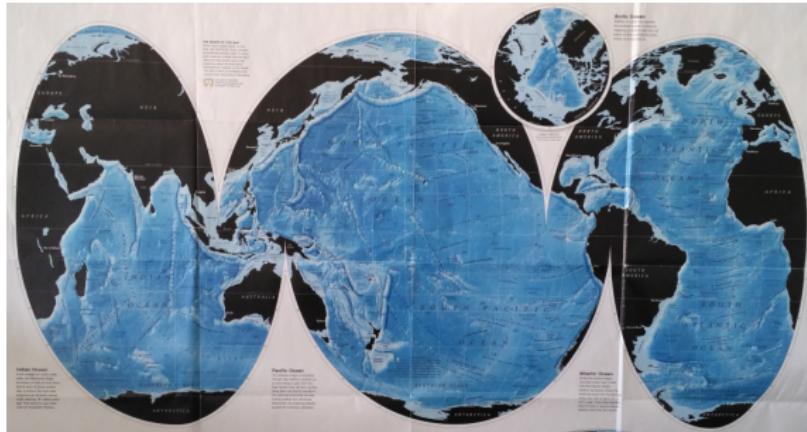
# Earth overview



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

# Oceans

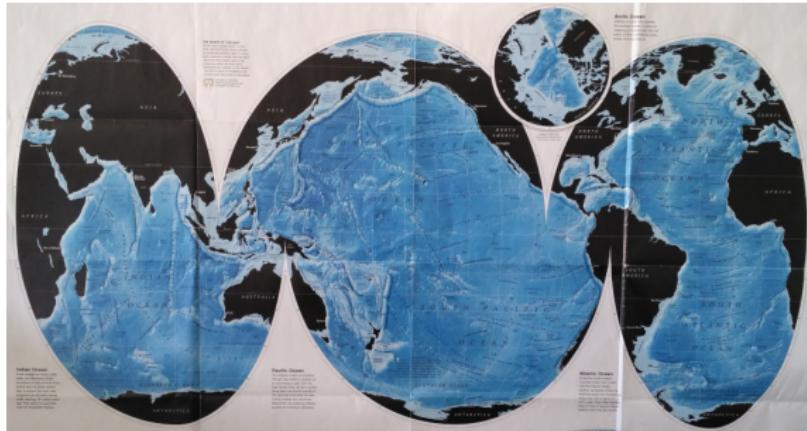
The ocean covers > 70% of the Earth's surface:



- ▶ 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  $\approx 4000$  m
- ▶ horizontal length-scales  $L \approx 10000$  km (**units!**)

# Oceans

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



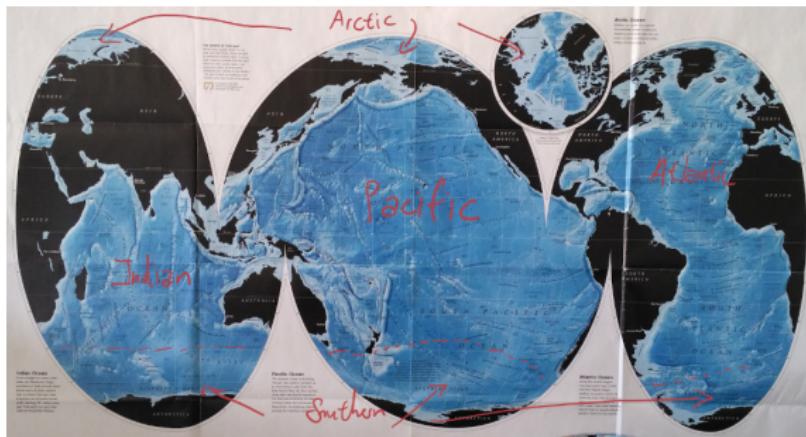
- ▶ five **oceans** (and they are...?)
- ▶ average **depth**  $H$  of ocean  $\approx 4000$  m
- ▶ horizontal length-scales  $L \approx 10000$  km (**units!**)

**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)

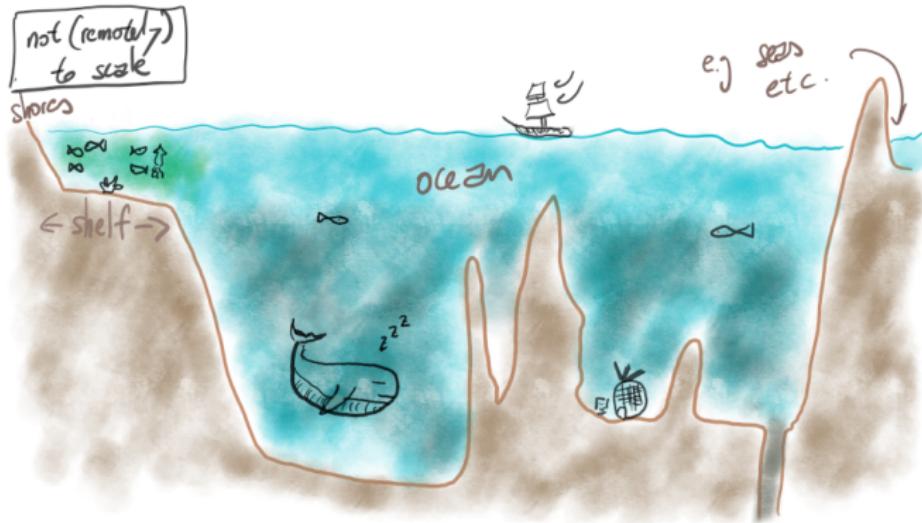


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

# Land boundaries

Bottom boundary is land with features

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

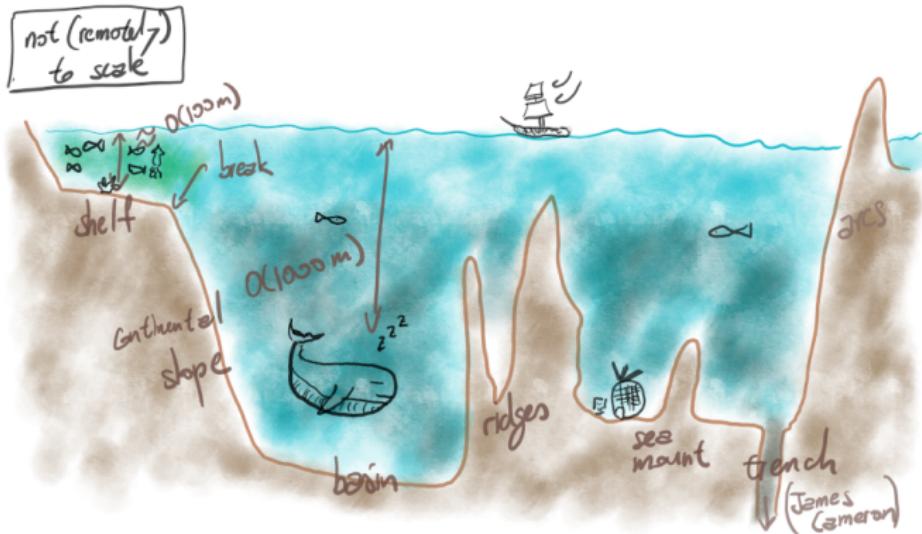
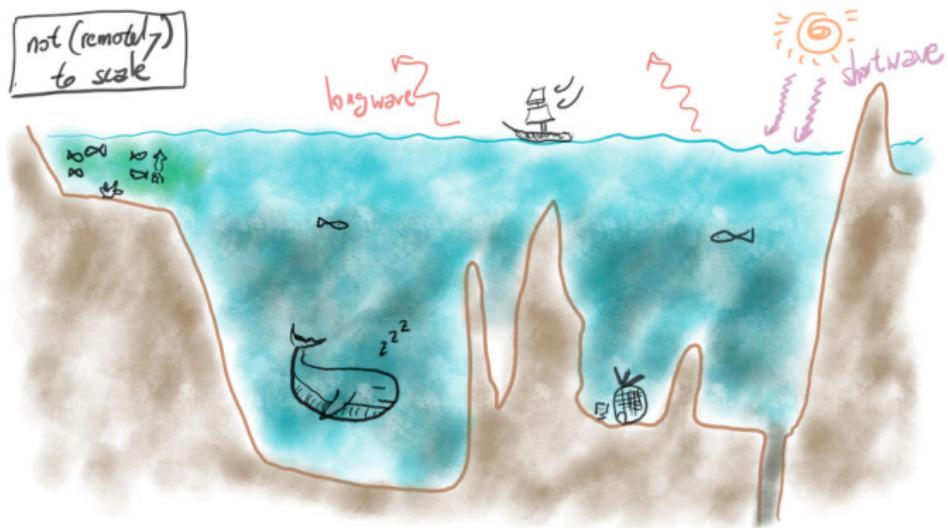


Figure: Figure based on Figure 2.2 of Pickard & Emery (1990), 5th edn.

# 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)

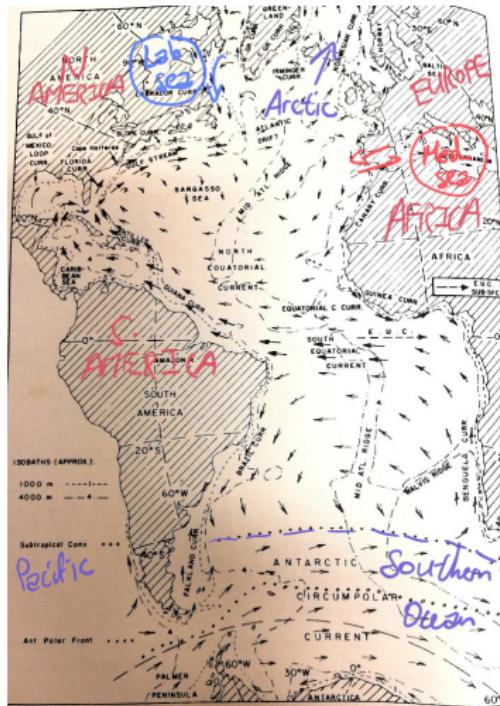


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

# 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

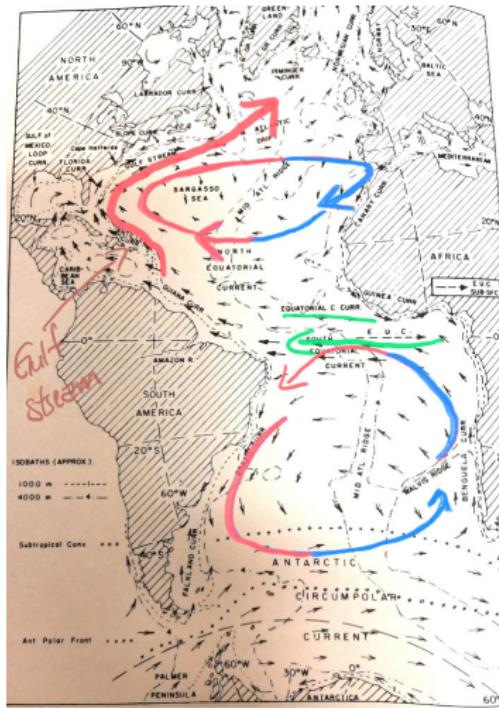


Figure: Features in the Atlantic Ocean. Modified Figure 7.9 from Pickard & Emery (1990), 5th edn.

# Atlantic ocean features

## ► subpolar gyres

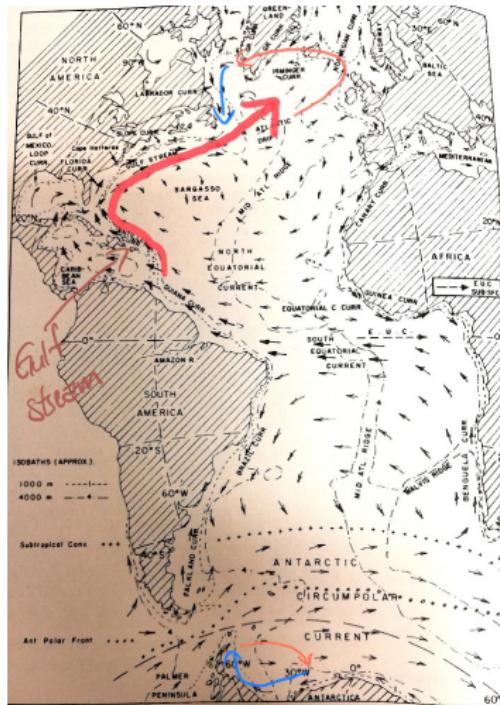
→ anti-clockwise in NH  
(clockwise in SH but in Southern Ocean)

→ 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

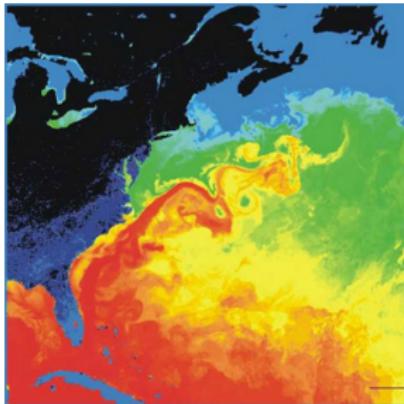
→ gulf stream + eddies

→ transports tropical + warm water towards North Pole

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

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

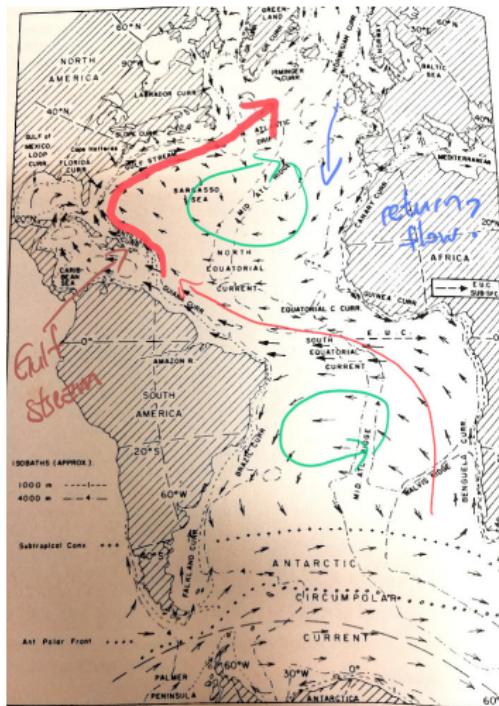
Q. fluctuations + role in climate? (see Lec. 17 + OCES 4001)



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**

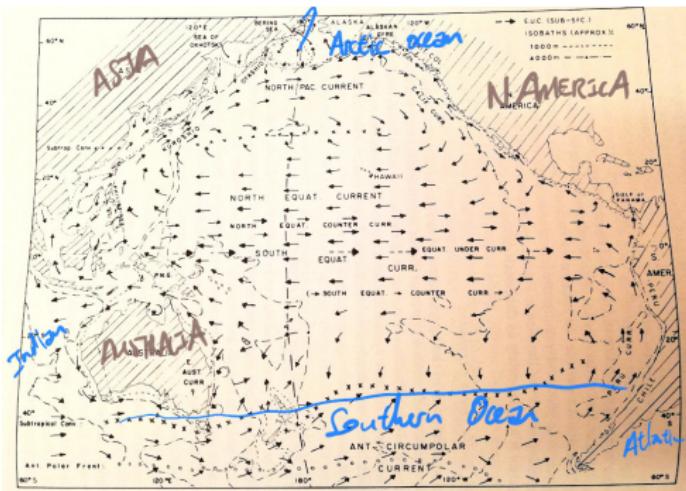


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

# 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)

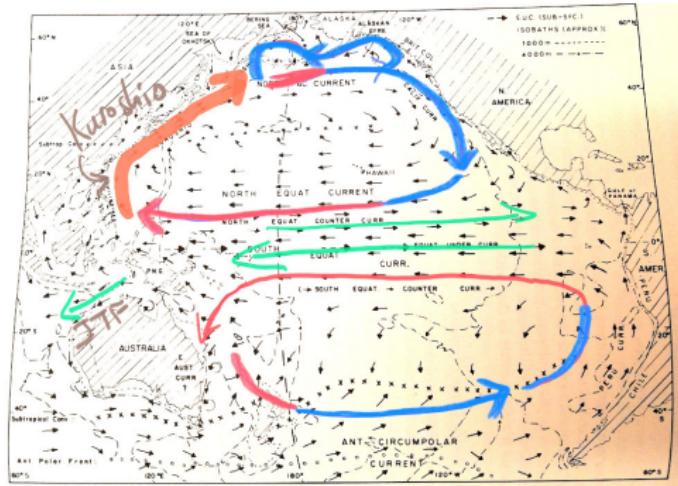


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

# 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)

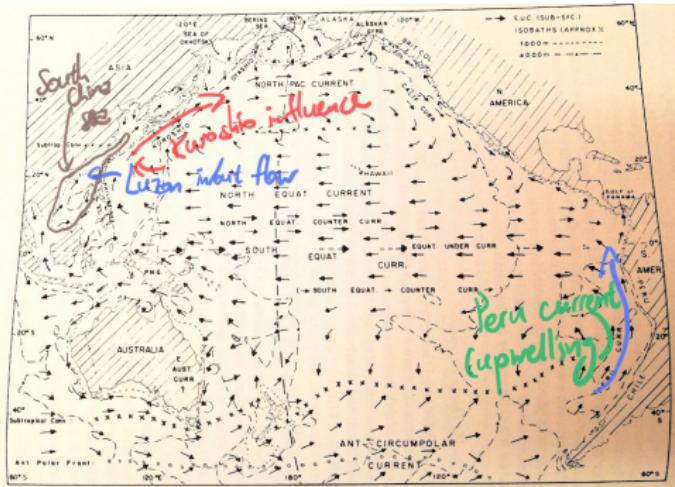
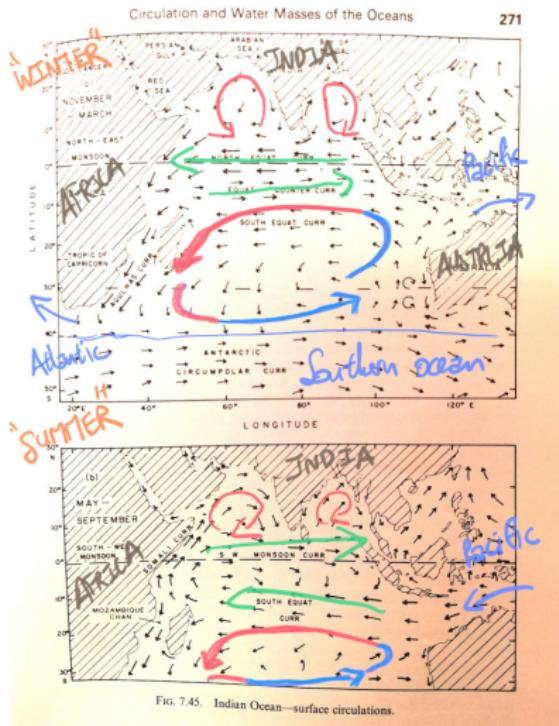


Figure: Features in the Pacific Ocean. Modified Figure 7.31 from Pickard & Emery (1990), 5th edn.

# 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)

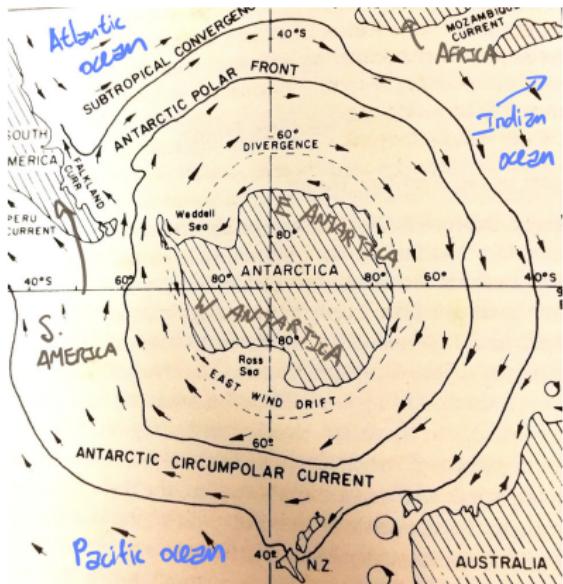
# Arctic ocean features

- ▶ 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 (wind shielding not)



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

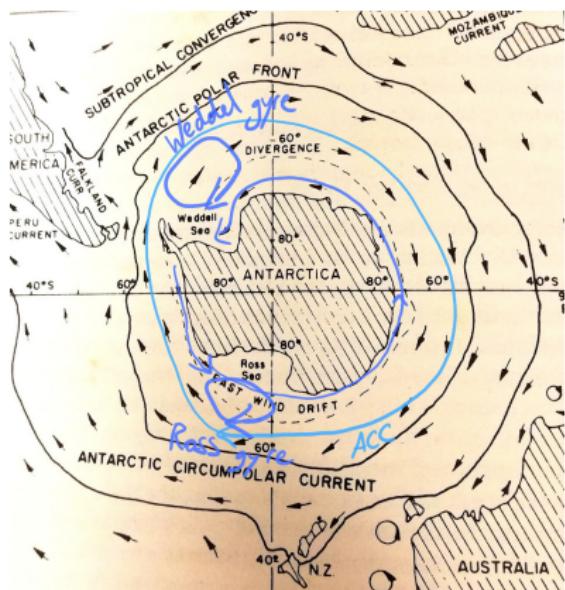
# Southern ocean features



**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  $\approx 130 \text{ Sv}$  ( $1 \text{ Sv} = 10^6 \text{ m}^3 \text{ s}^{-1}$ )

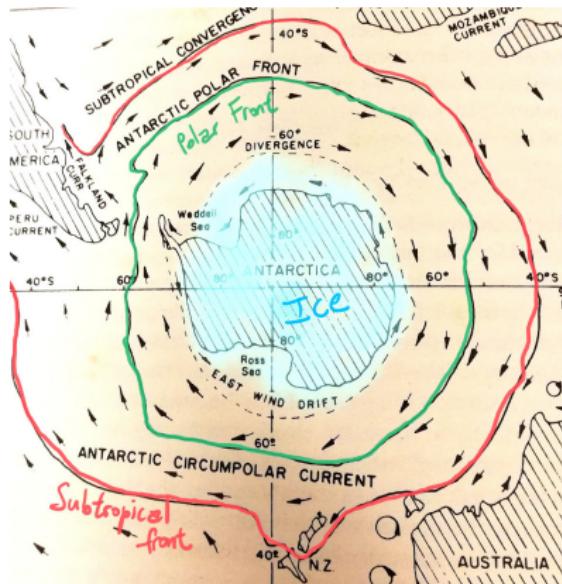
→ partly because of lack of landmass, very turbulent/unstable region (see Lec. 17)

## ► 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...