Horizontal circulation and Coriolis

EPS131, Introduction to Physical Oceanography and Climate

Dept of Earth and Planetary Sciences, Harvard University

Eli Tziperman

NASA, the perpetual ocean, https://www.youtube.com/watch?v=CCmTY0PKGDs

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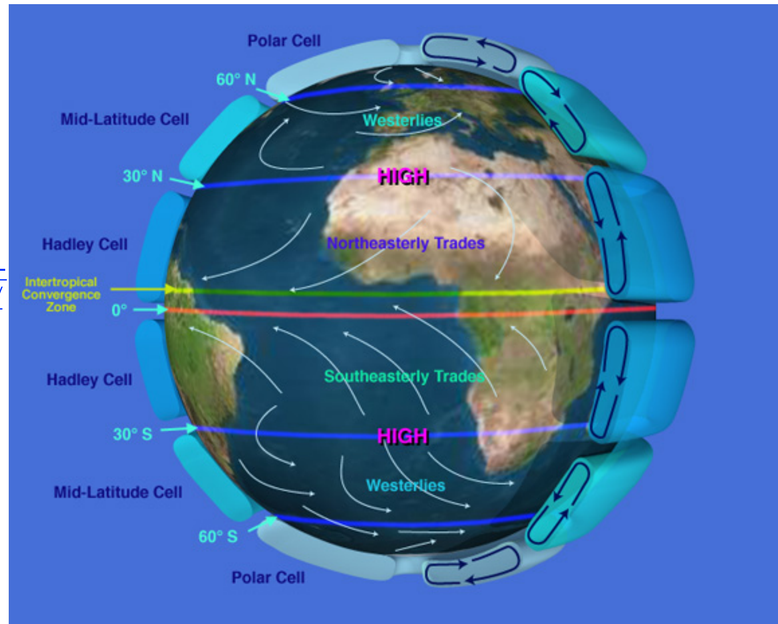
1 Geostrophy - introduction (wind driving of ocean currents)

winds schematic

https://slidetodoc.com/astr-2310-chapter-9-earth-and-moon-earth/



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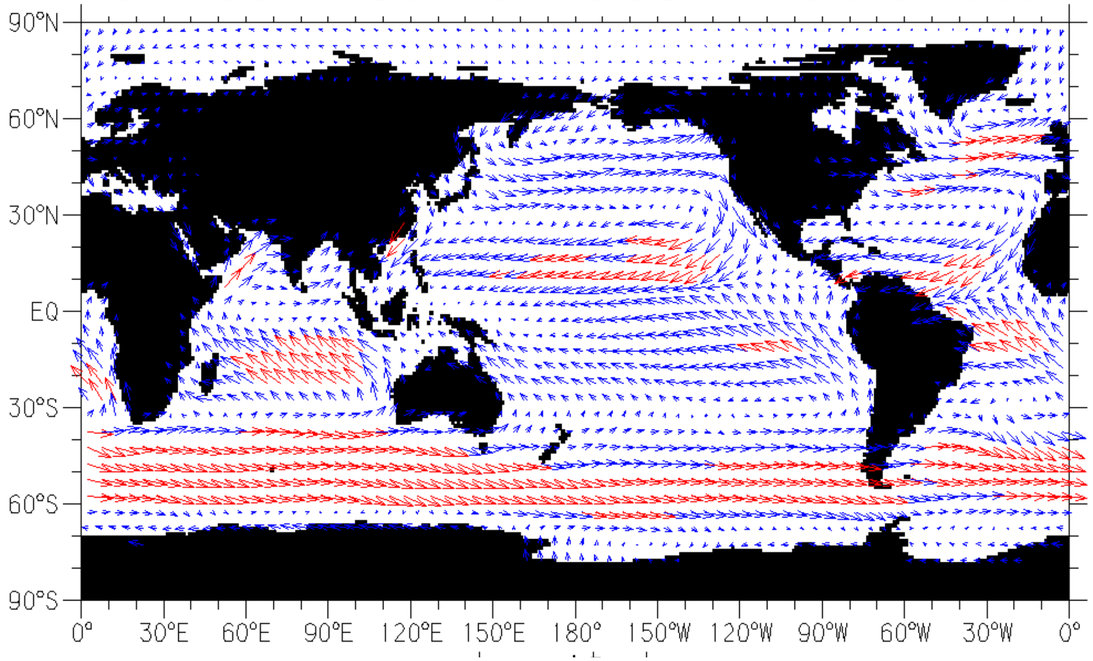
1 Geostrophy - introduction (wind driving of ocean currents)

annual mean surface winds stress



https://dandelionsandthings.blogspot.com/2018/09/33-label-global-winds-worksheet.html

winds schematic

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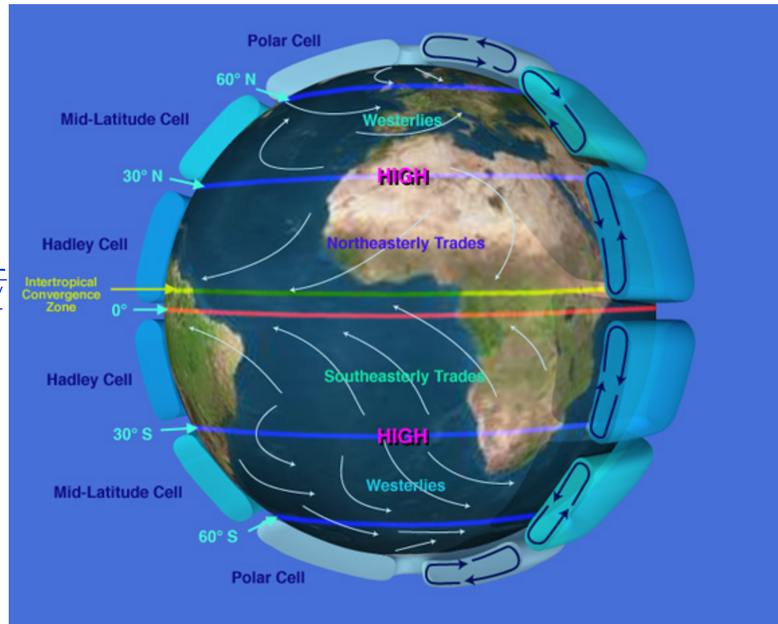

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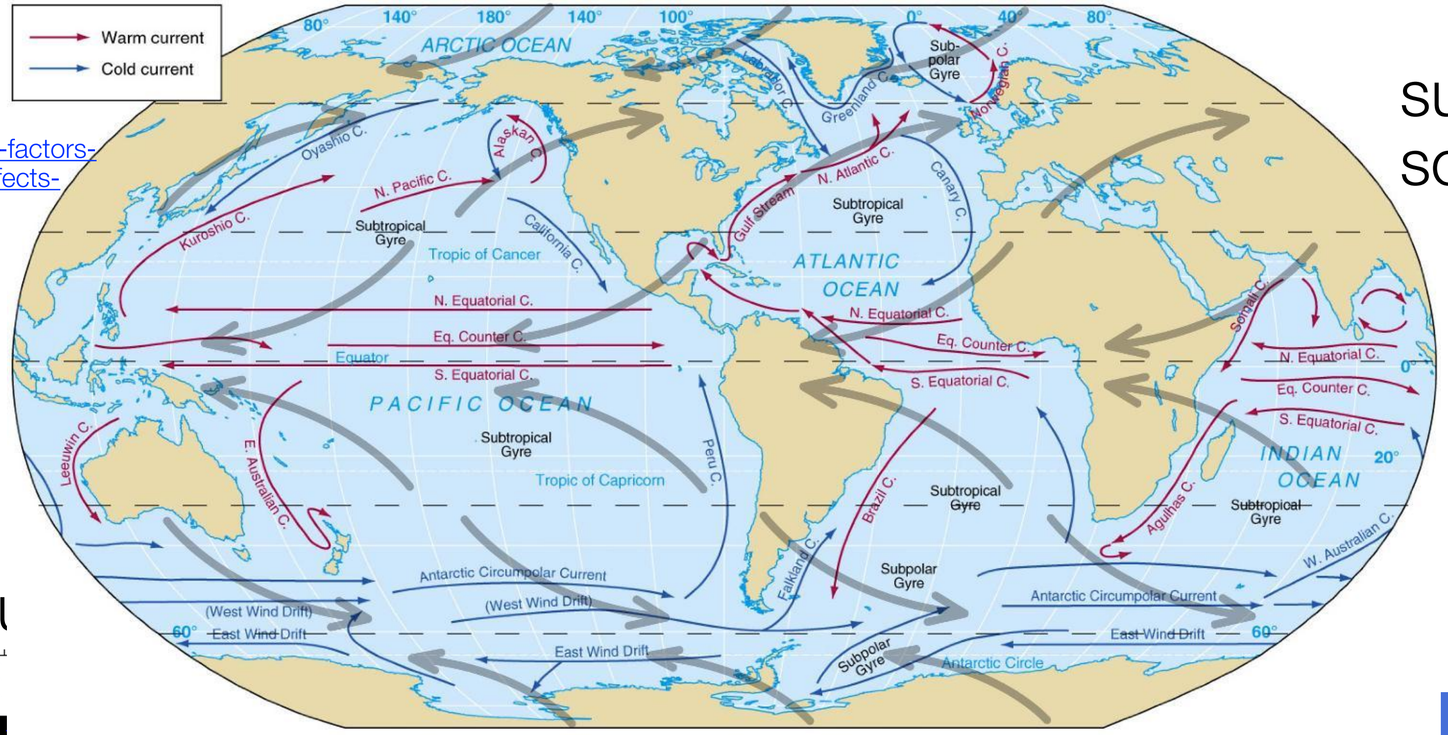
1 Geostrophy - introduction (wind driving of ocean currents)

surface currents schematic

https://www.pmfias.com/ocean-currents-factors-responsible-formation-ocean-currents-effects-ocean-currents/



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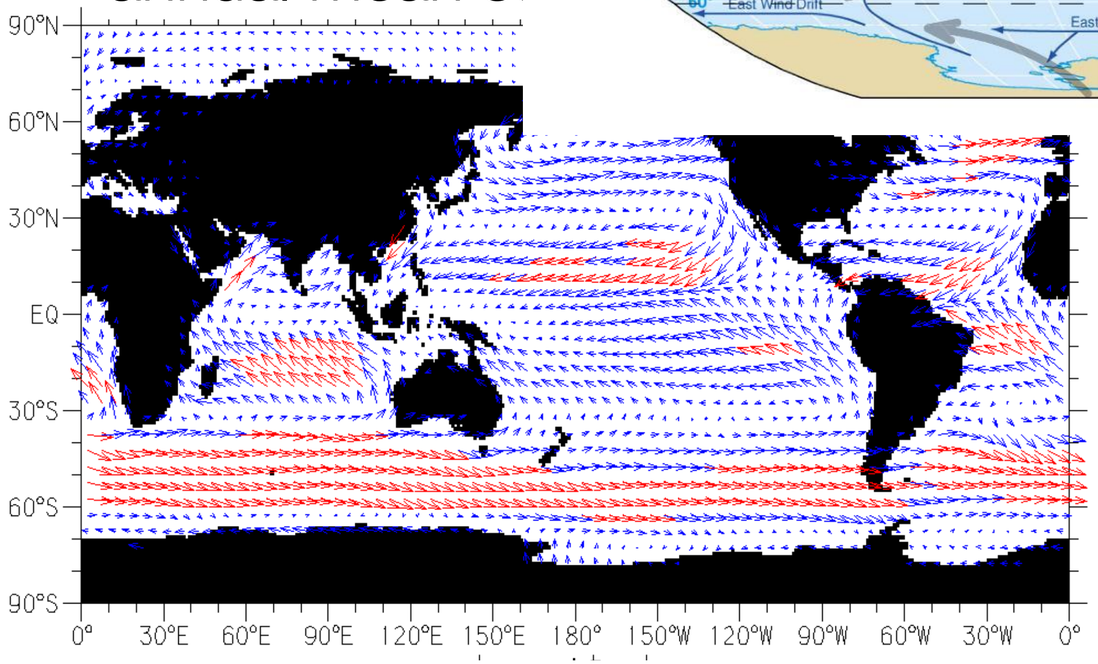
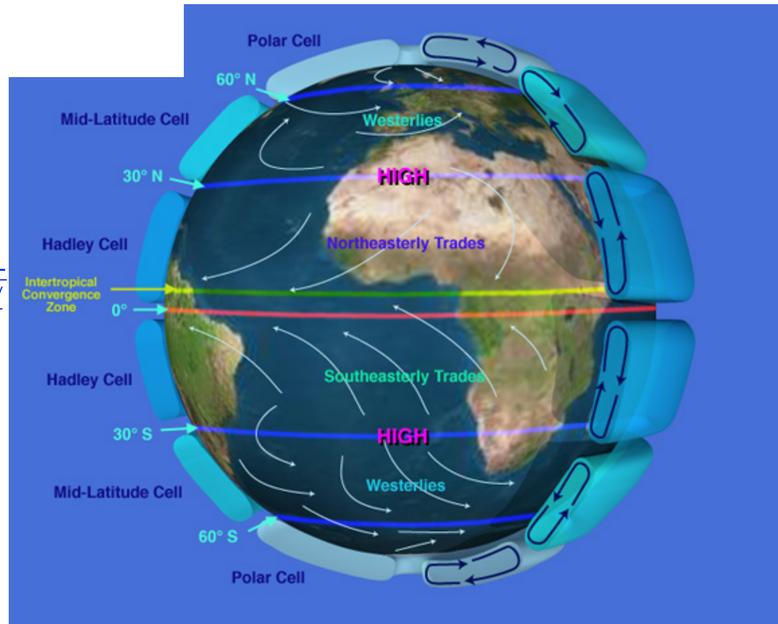
annual mean su



winds schematic



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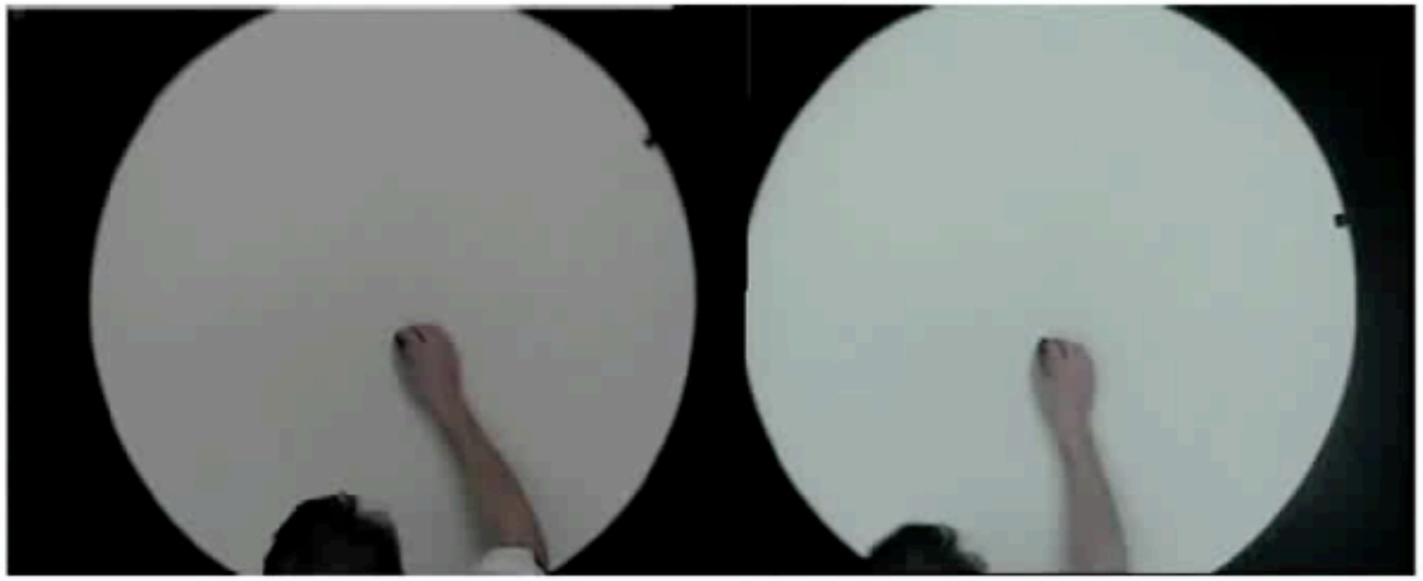
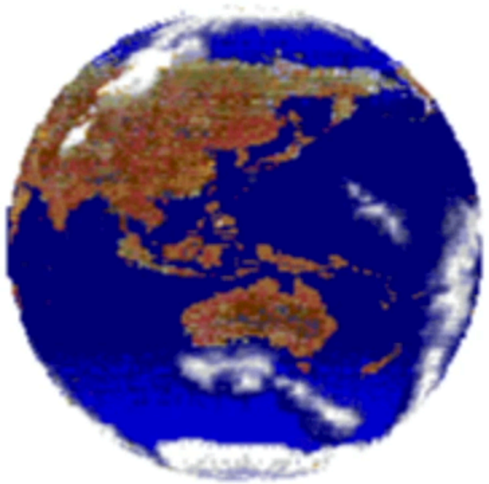
1 Geostrophy - introduction (the Coriolis force)



(https://www.youtube.com/watch?v=RrWKSOvqV-0 J. Marshall, MIT)



https://www.animations.physics.unsw.edu.au//jw/foucault_pendulum.html

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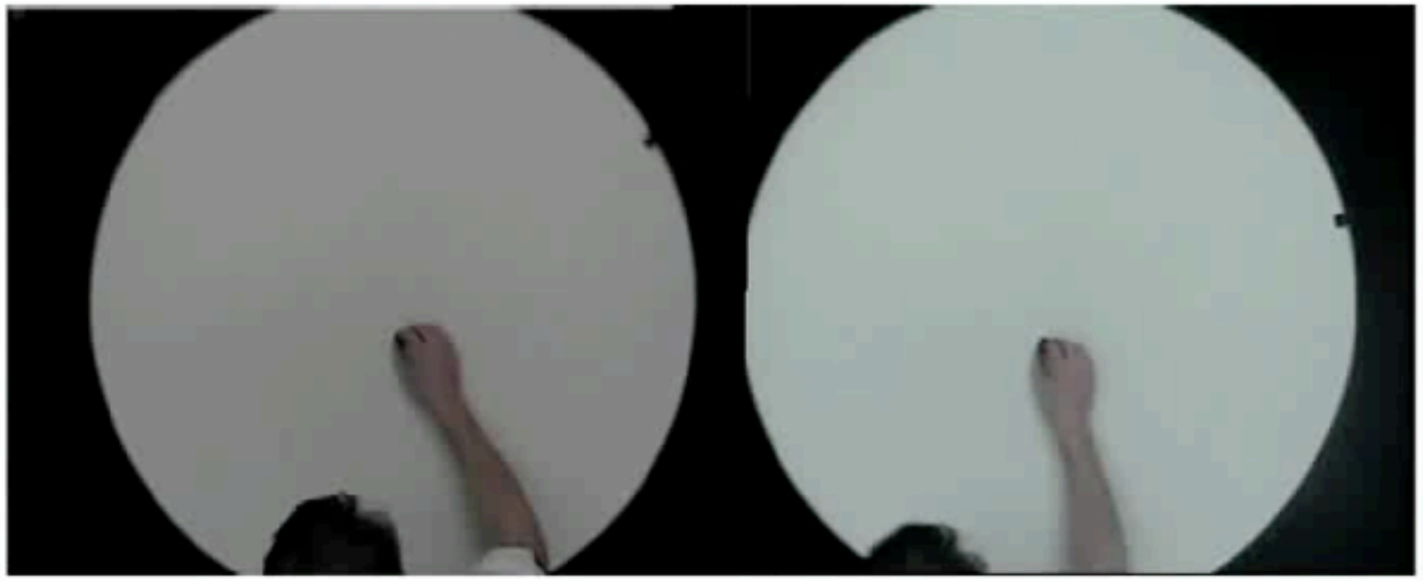

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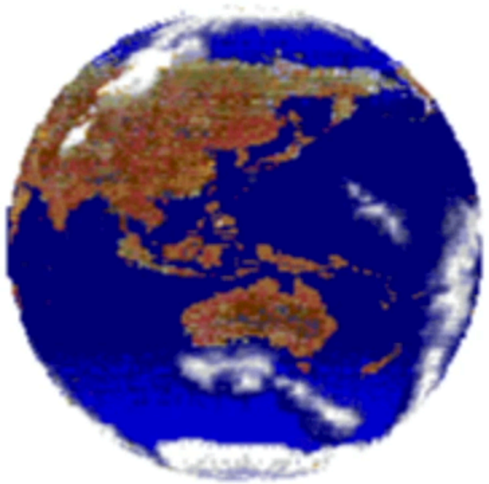

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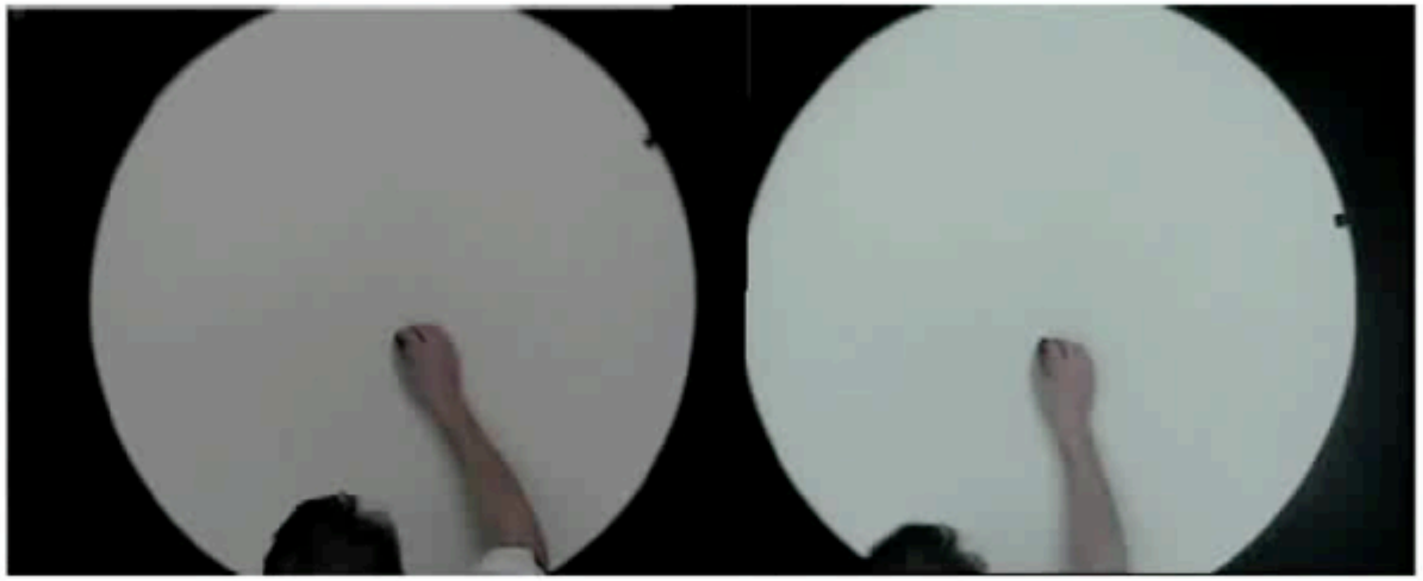

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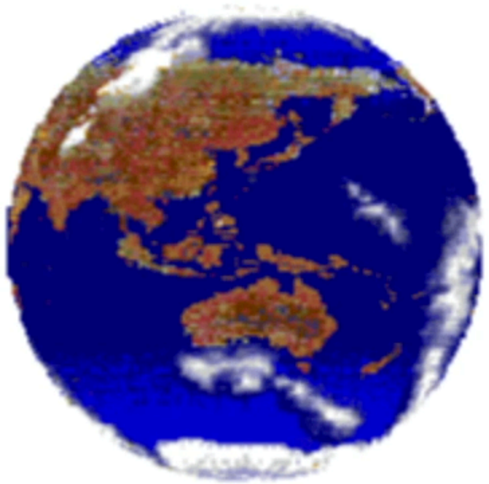

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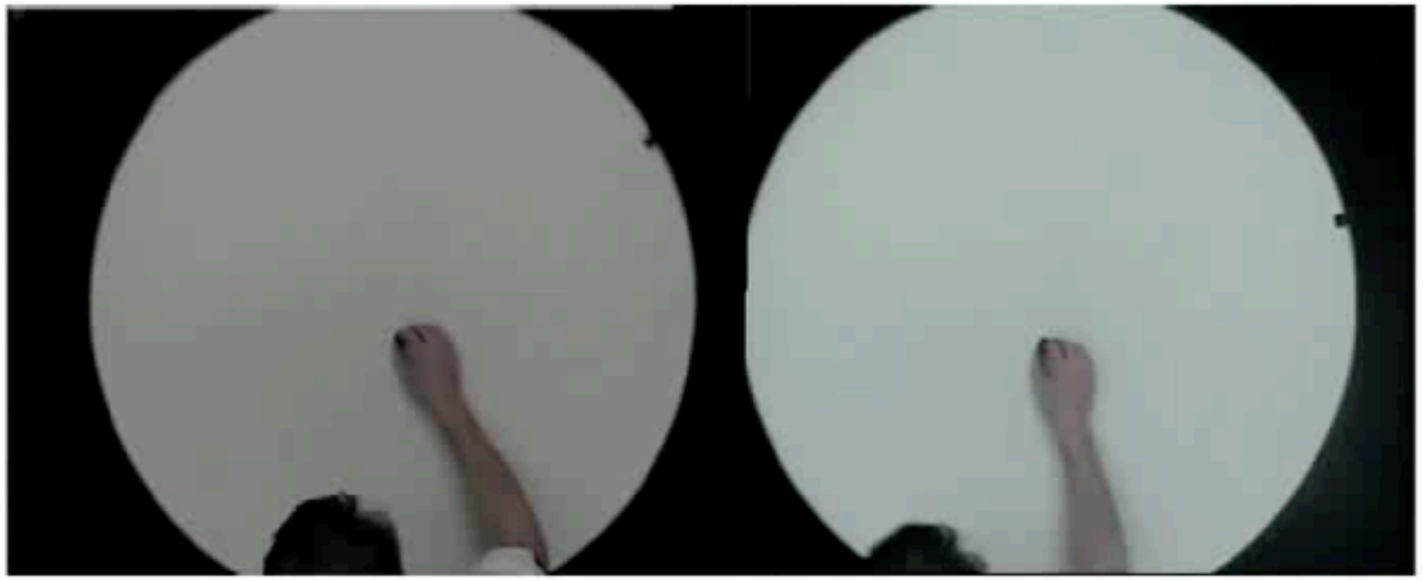

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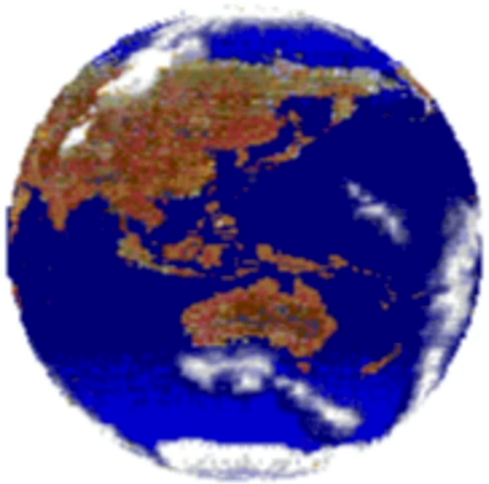

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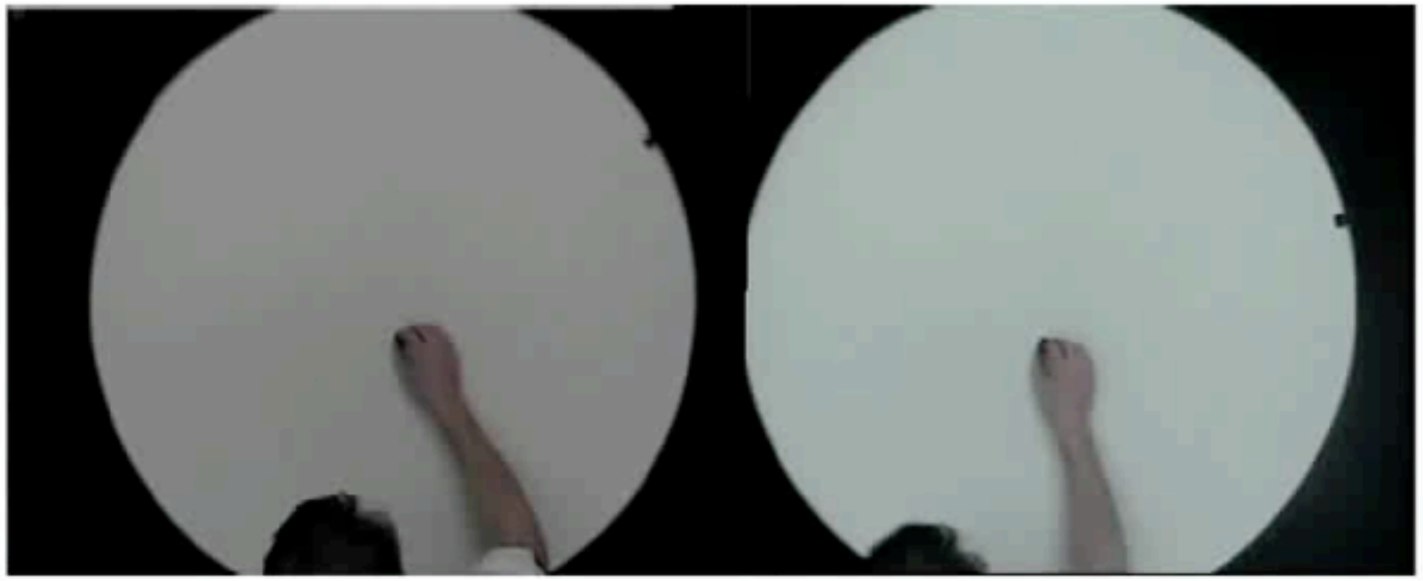

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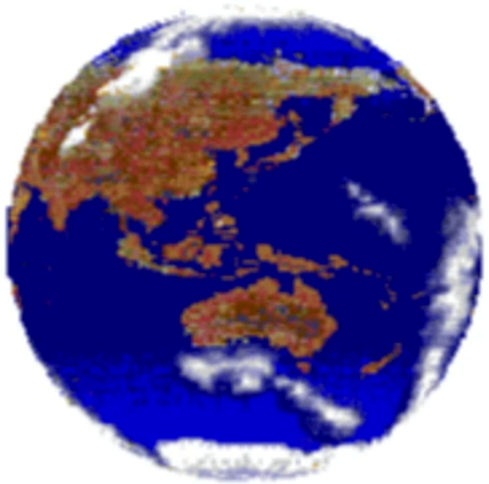

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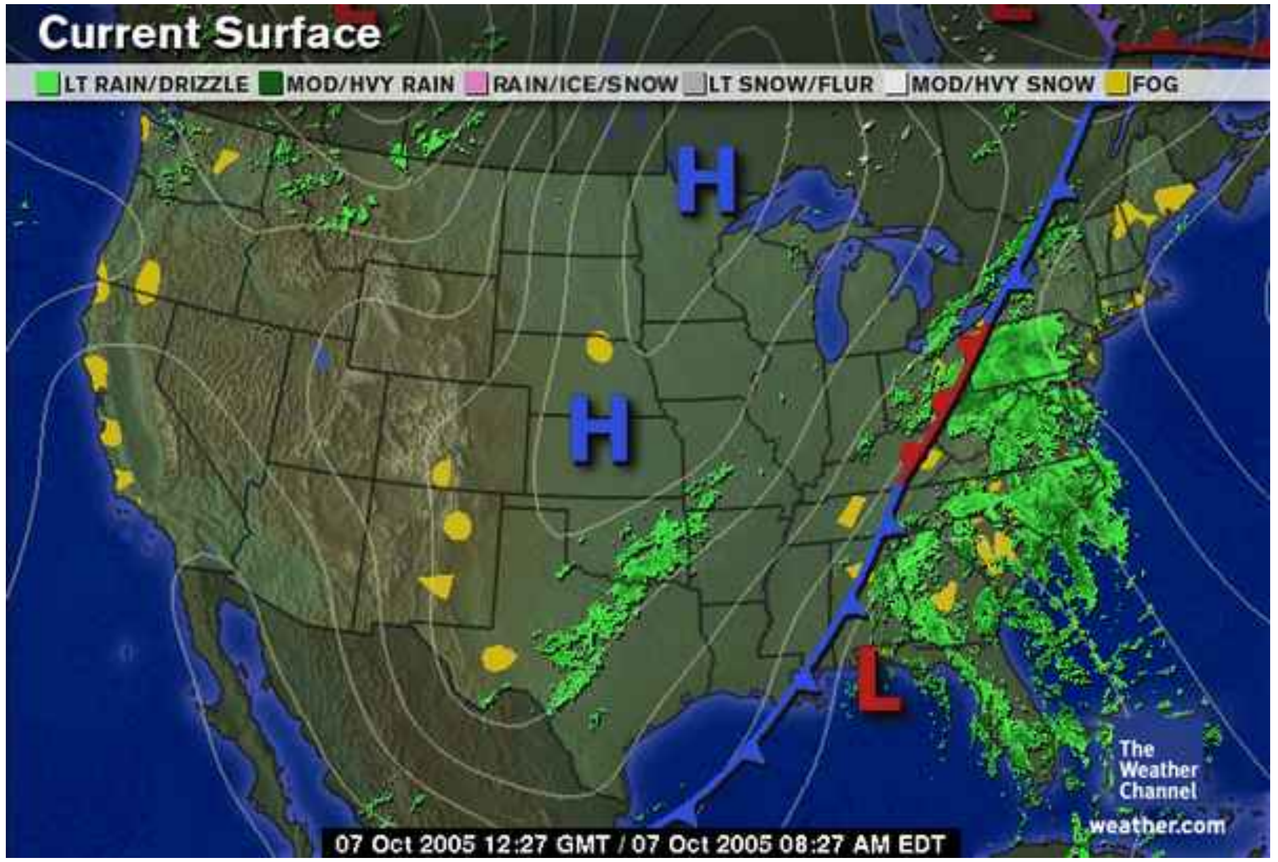
geostrophy - motivation

Atmosphere: sea level pressure and wind direction



The weather channel

Notes
2 Geostrophy - derivation

(see two following slides with mini quizzes)

Miniquiz

Coriolis force form and sign in two horizontal *F=ma*

What is the Coriolis force ($\mathrm{kg\ m\ s^{-2}}$*) acting in the* $(x, y) = (\mathrm{east}, \mathrm{north})$ *directions on a fluid element moving at a speed* (u, v)*, whose volume is* $\Delta x \Delta y \Delta z$*, density is* ρ*, and where the Coriolis parameter (*s^{-1}*) is* f*.*

Miniquiz:

Geostrophy: write the form of the two horizontal momentum equations, that represent $F = ma$ including the Coriolis force and the pressure force, and where acceleration is zero (steady state).

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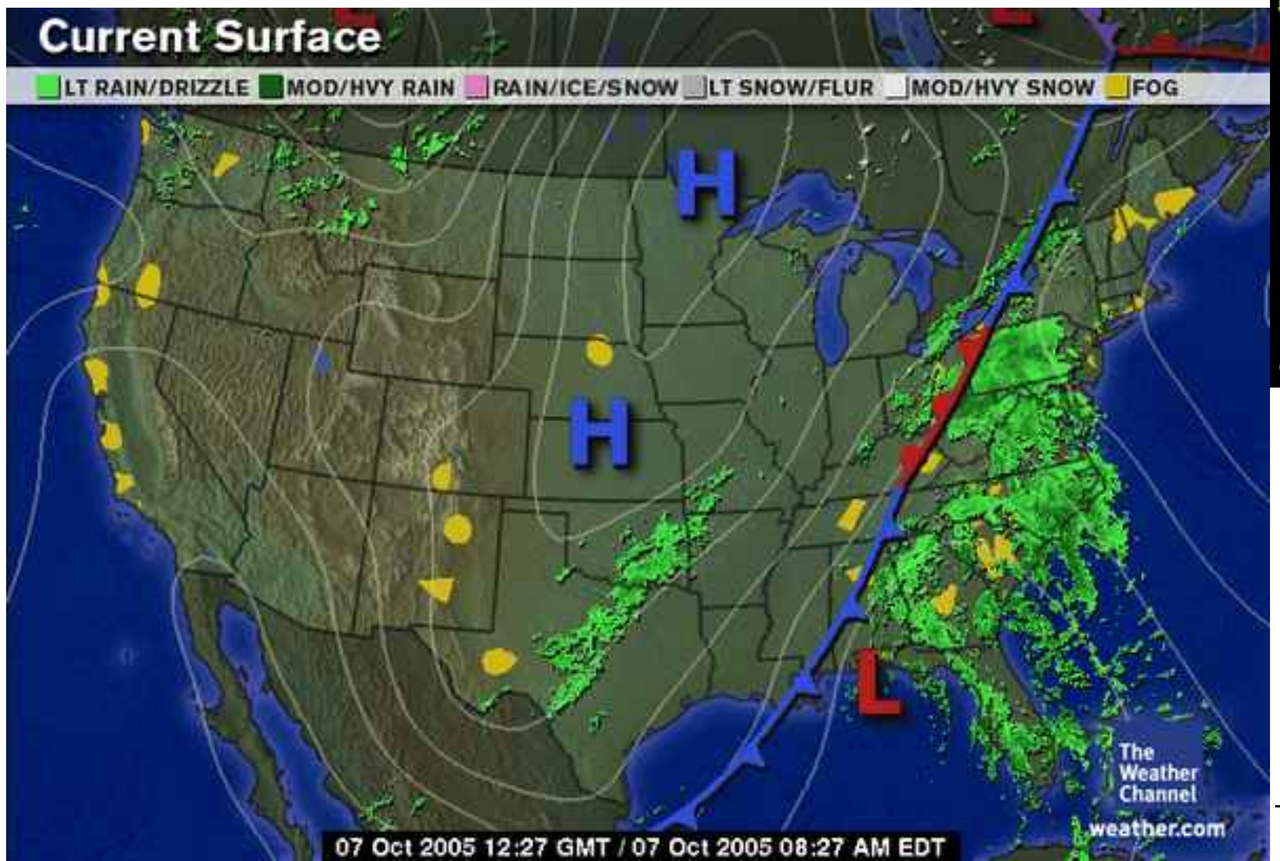
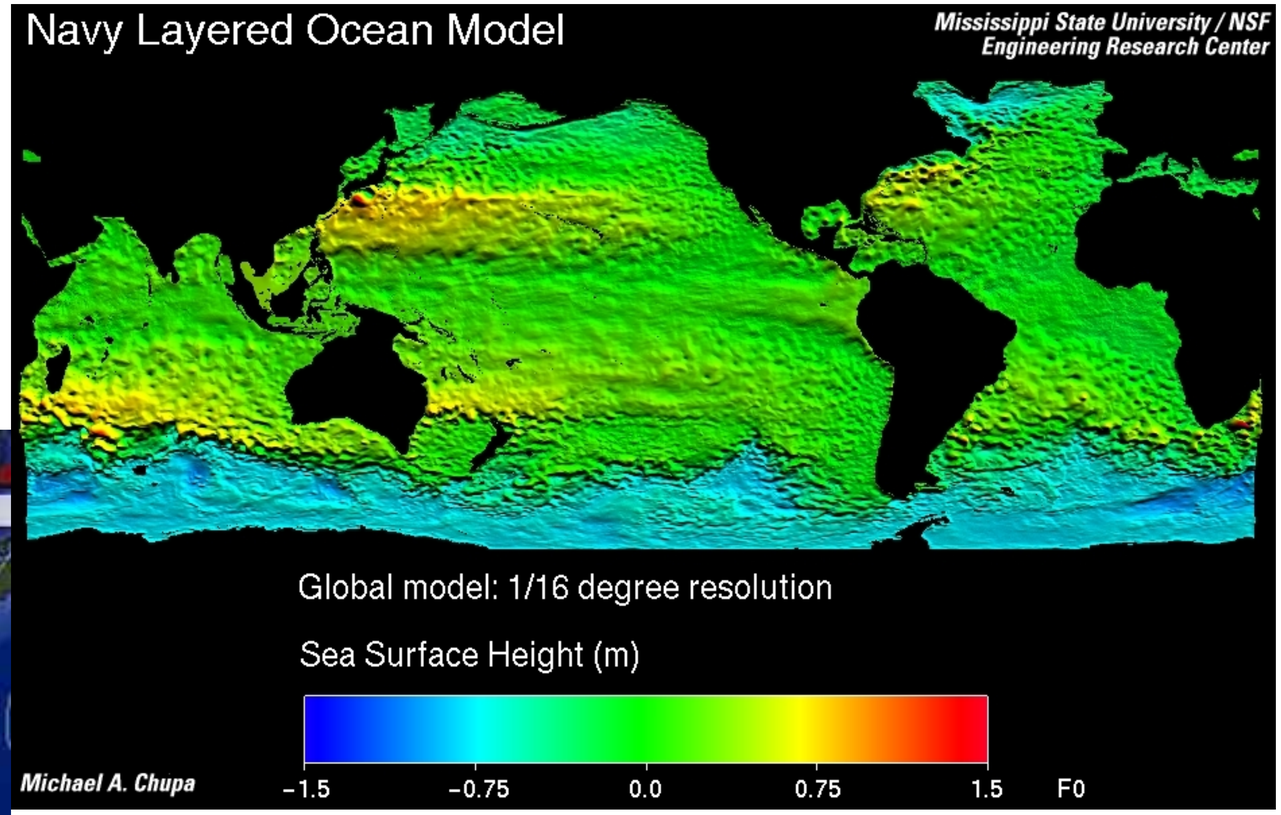
3 Examples of geostrophic balance

Atmosphere: sea level pressure corresponding to winds





Ocean: sea surface height variations involved with major currents: western boundary currents and the Antarctic circumpolar current.

The weather channel

Miniquiz

wind velocity from sea level pressure (SLP) on a weather map

steps:

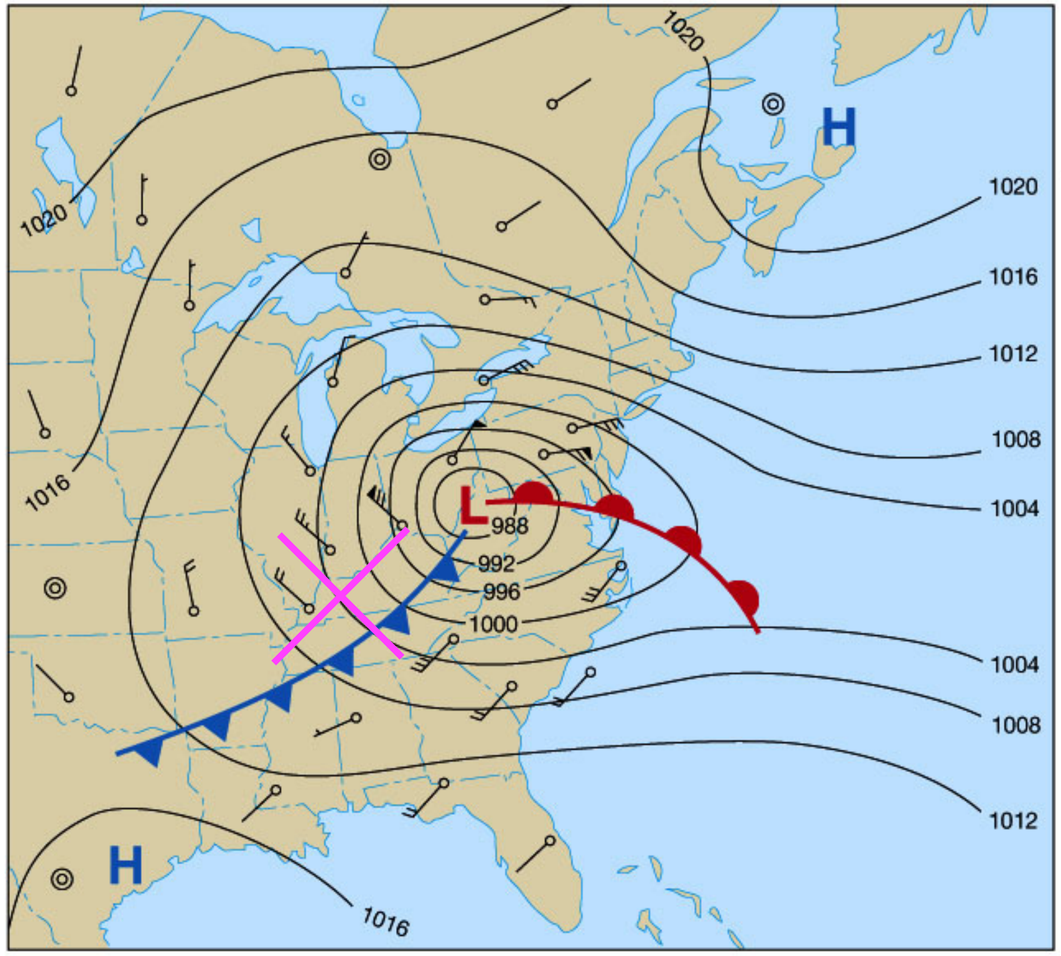
$f = 2\Omega \sin\theta =$

$\Delta p =$

$\Delta x =$

$\rho_{air} =$

$(u, v) =$



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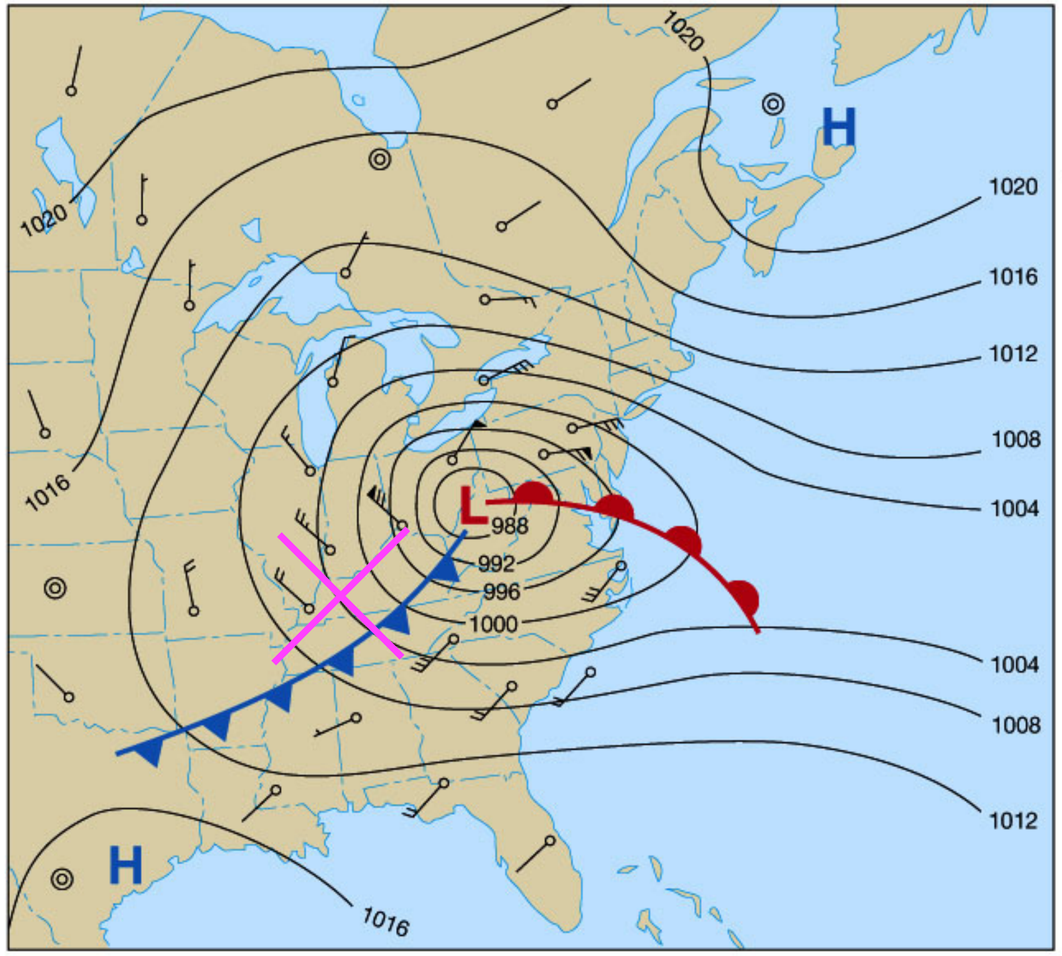


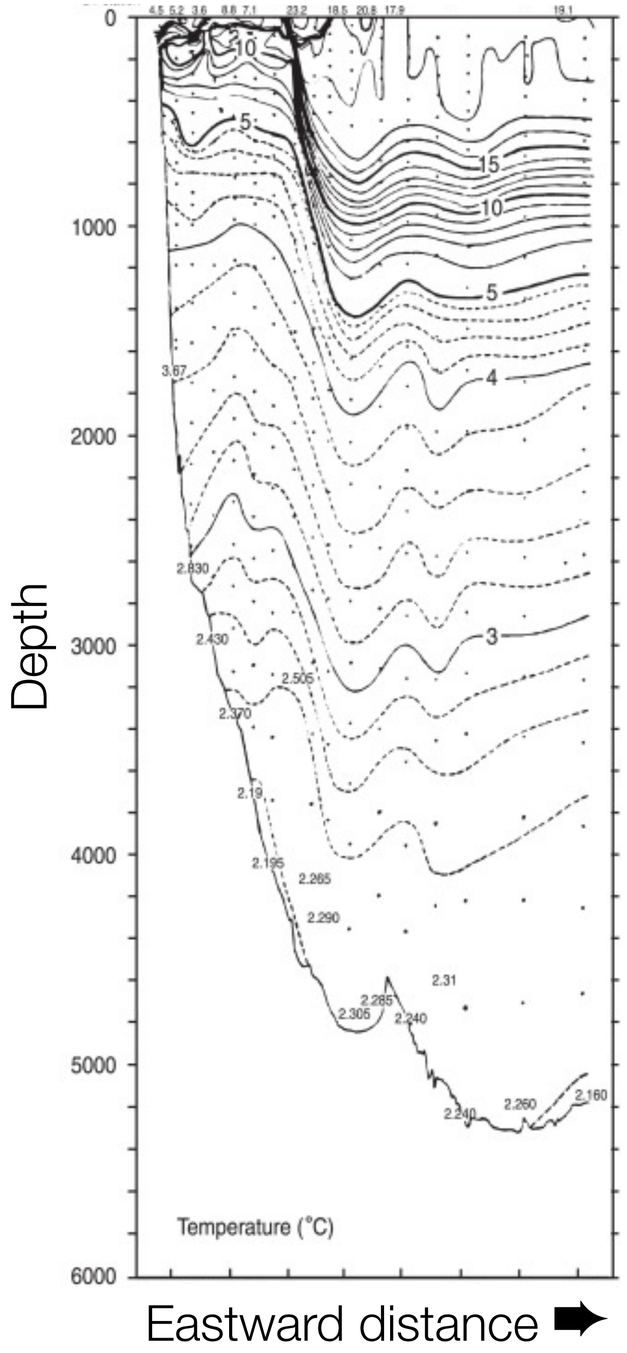
ff	Miles per hour
◎	Calm
	1–2
	3–8
	9–14
	15–20
	21–25
	26–31
	32–37
	38–43
	44–49
	50–54
	55–60
	61–66
	67–71
	72–77
	78–83
	84–89
	119–123

miniquiz:

Derive the vertical momentum budget equation, balancing pressure force with gravity force: consider a fluid parcel of volume $\Delta x \Delta y \Delta z$ and density ρ.

miniquiz:

Find the direction of the long-shore velocity from a temperature section in the Northern Hemisphere



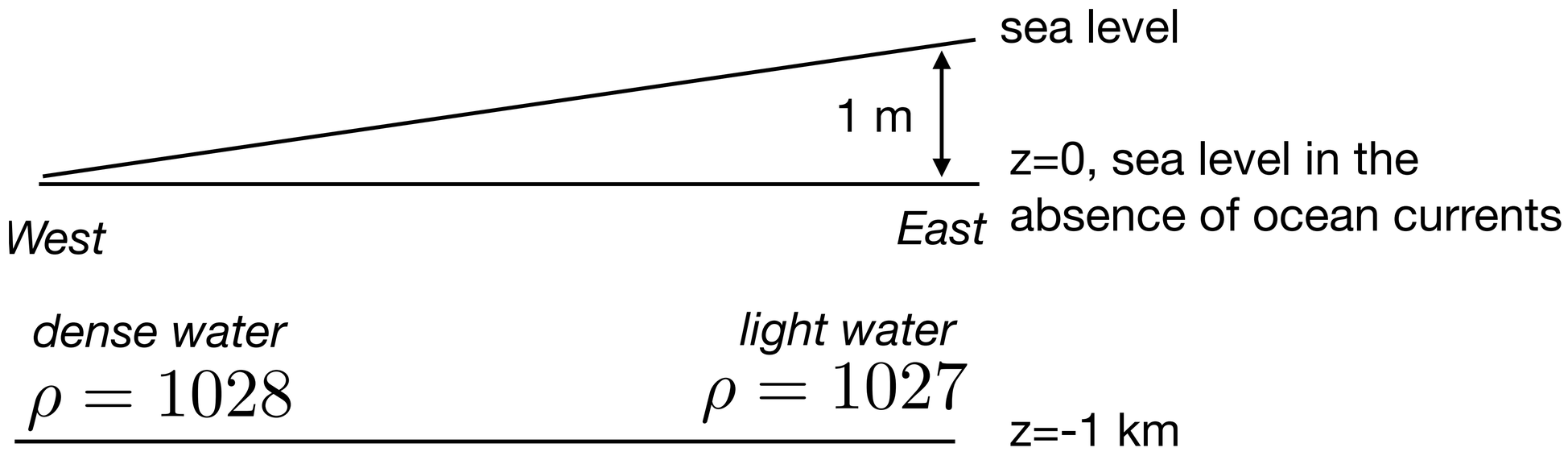
Notes

4 The hydrostatic balance

5 Boussinesq approximation

Notes

6 sea level vs stratification in a stratified geostrophic flow such as the Gulf Stream



Notes

6 sea level vs stratification in a stratified geostrophic flow such as the Gulf Stream

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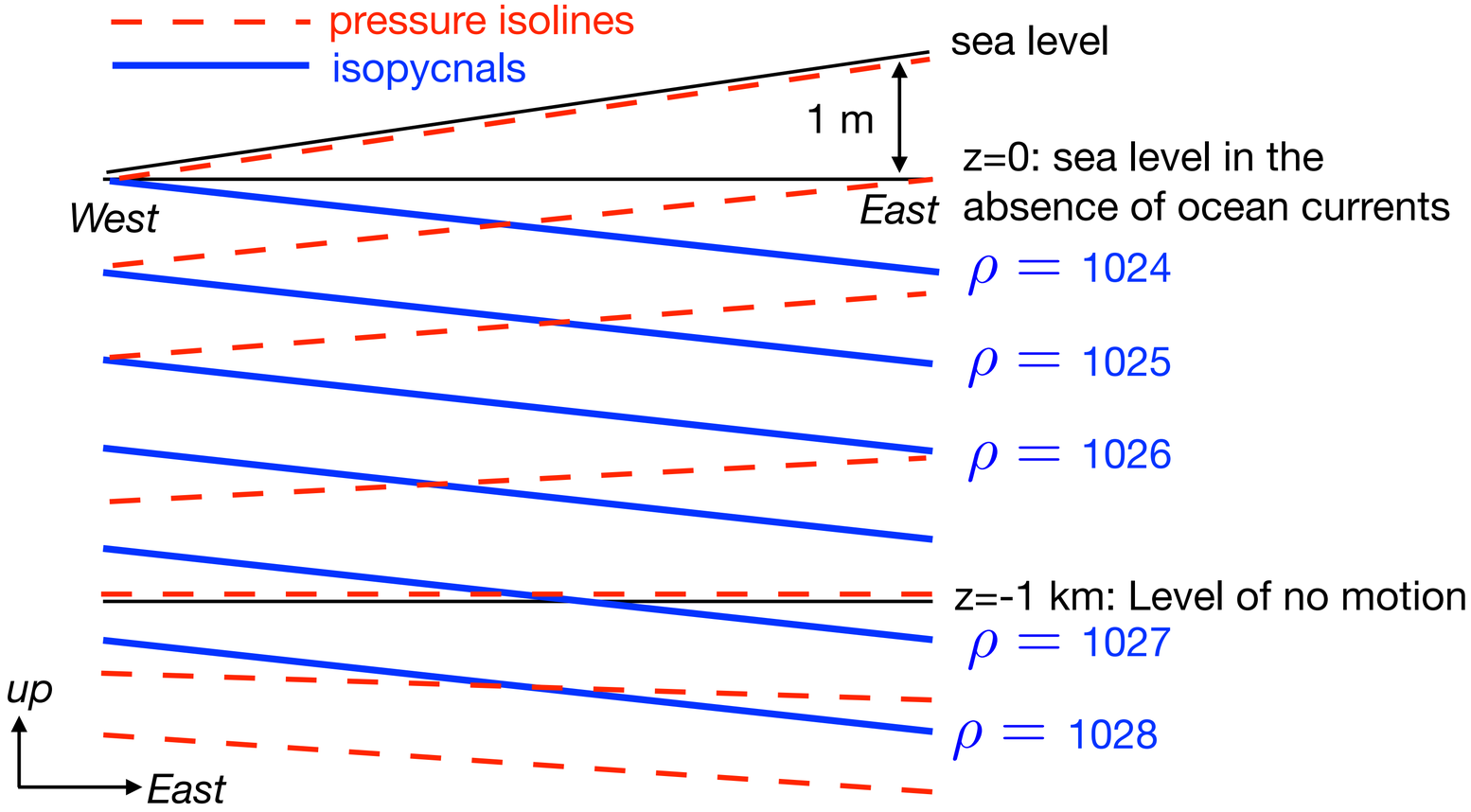

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Notes

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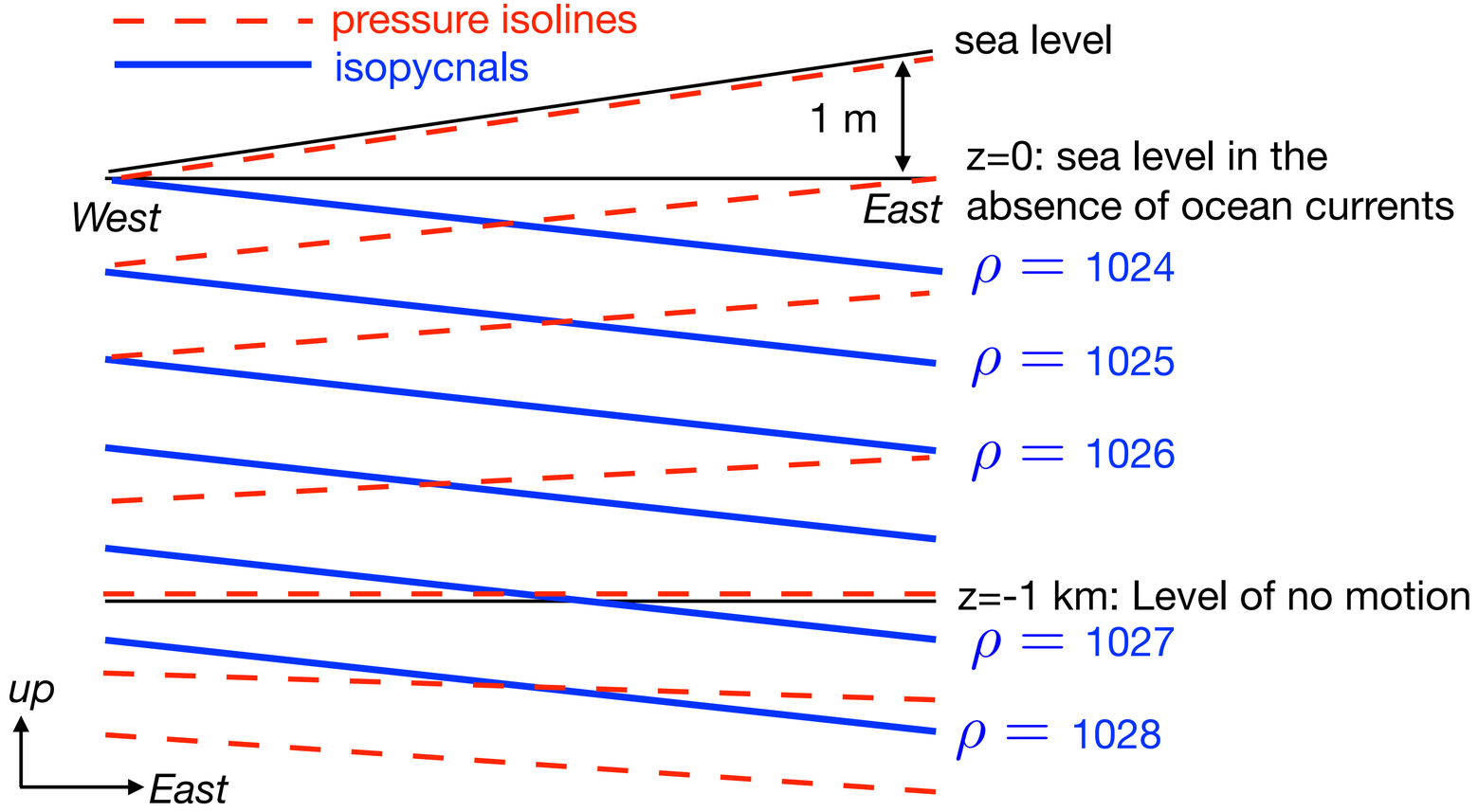

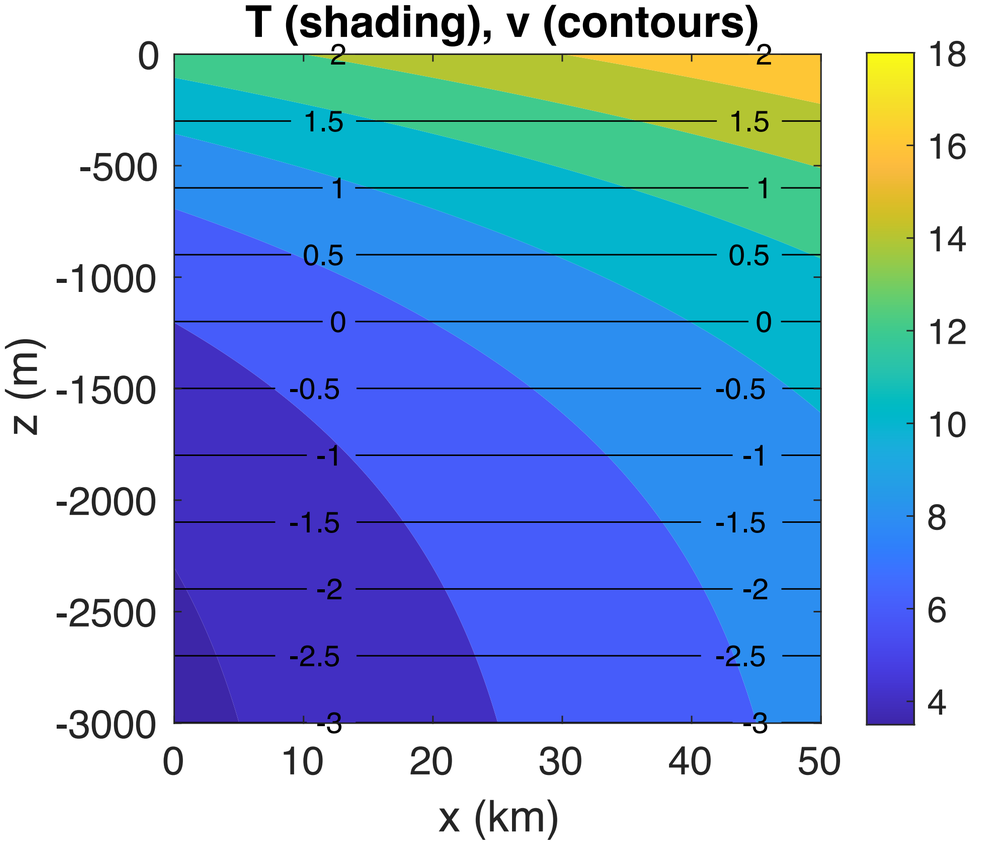

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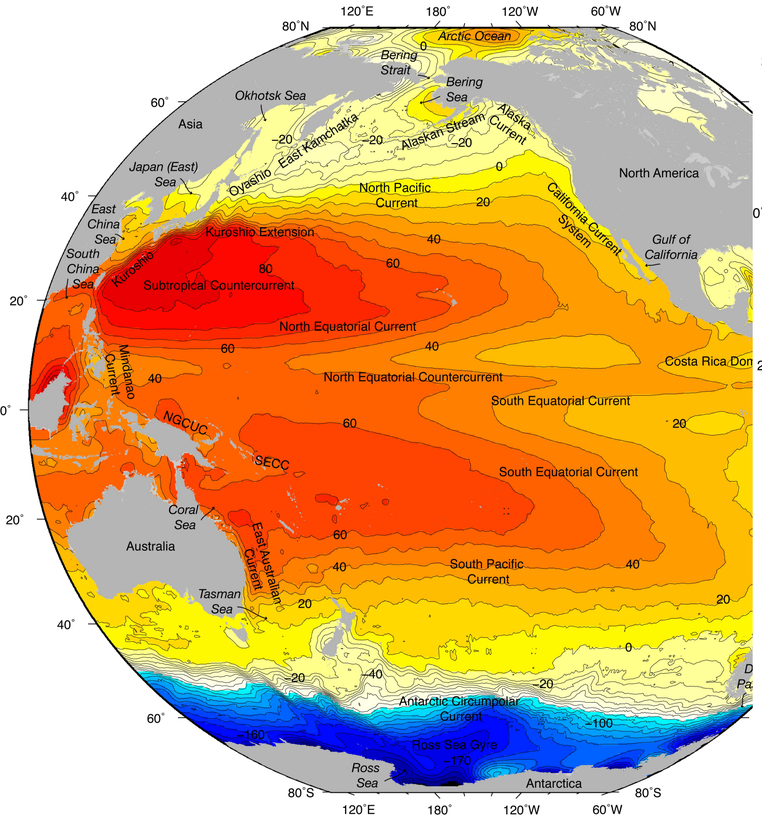
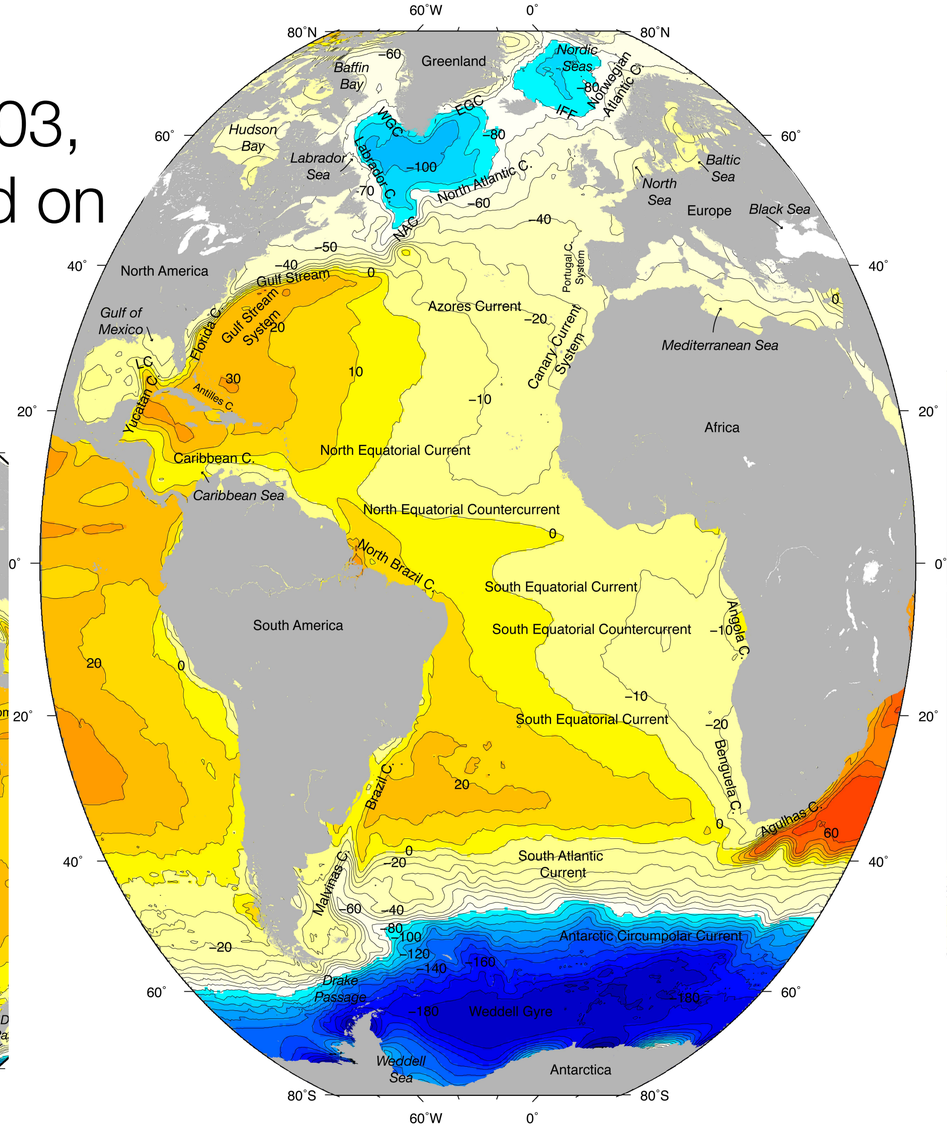
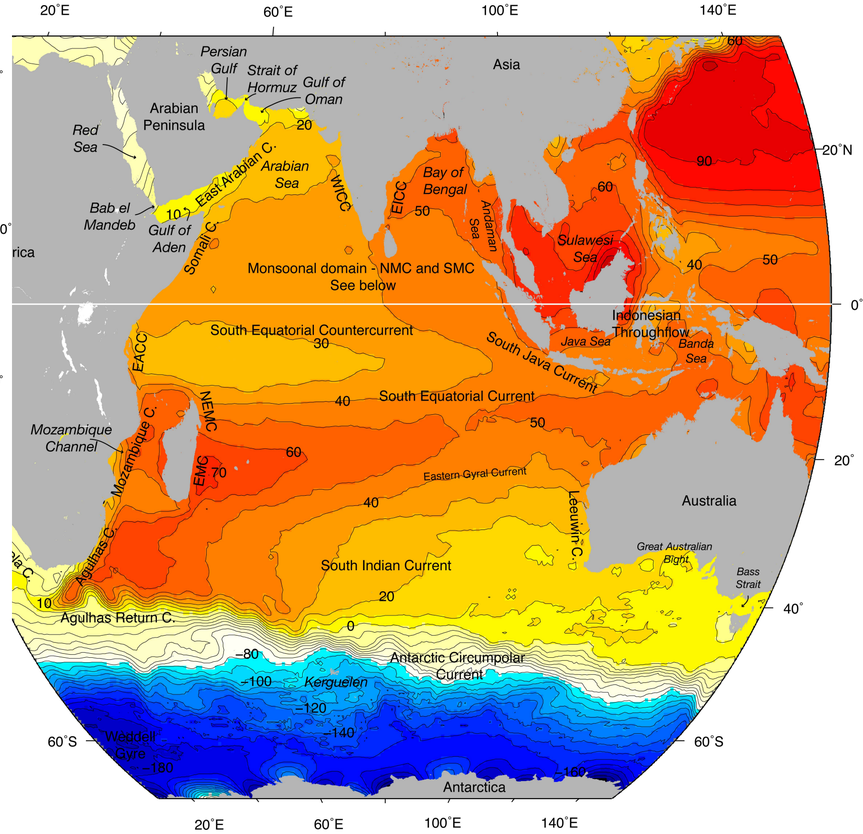
7 Calculating currents from temperature & sea level

"Sea surface height (Using Niiler et al., 2003, surface heights based on drifters)"(*)







(*)From http://talleylab.ucsd.edu/ltalley/sio210/dynamics_rotation/lecture_dynamics_geostrophy.pdf

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RAPID: monitoring the Atlantic Meridional Overturning Circulation at 26.5°N (motivation for calculating currents from T,S and sea surface height)

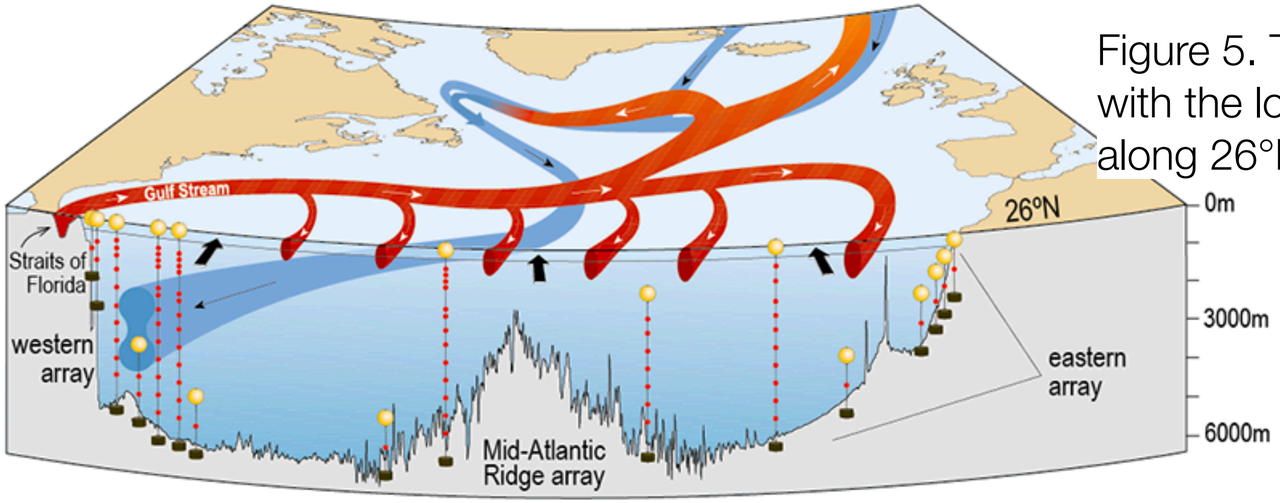
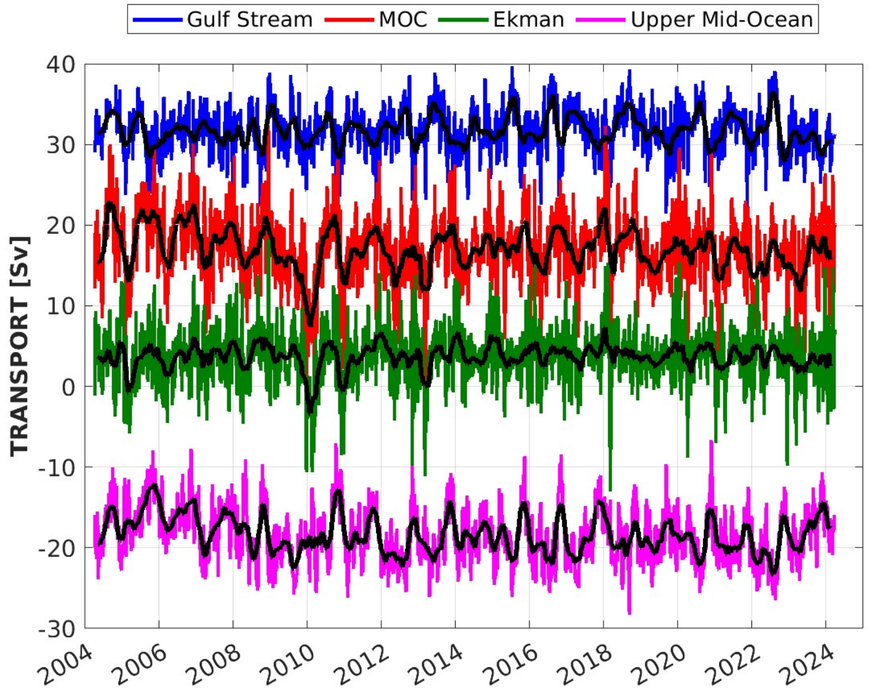


Figure 5. The North Atlantic overturning circulation with the location of the RAPID array moorings along 26°N. Modified from Church, 2007.

https://www.rapid.ac.uk/background.php

RAPID results for AMOC:



https://www.rapid.ac.uk/data.php

A view of the back deck of the RRS James Cook during the RAPID cruise in April 2014.

Notes

8 Thermal wind equations and level of no motion

Miniquiz

Derive thermal wind equations

Miniquiz - calculate the depth of the level of no motion

optional, time permitting:
9 Dynamic height derived from geostrophy

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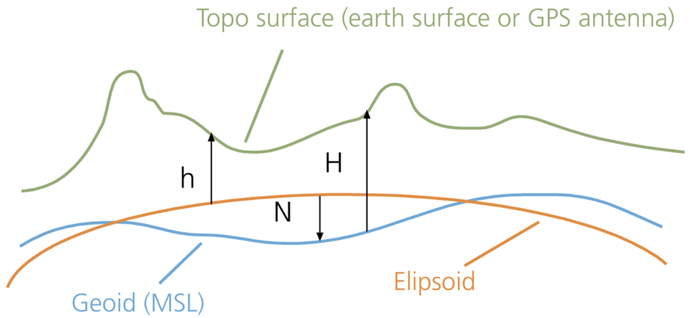
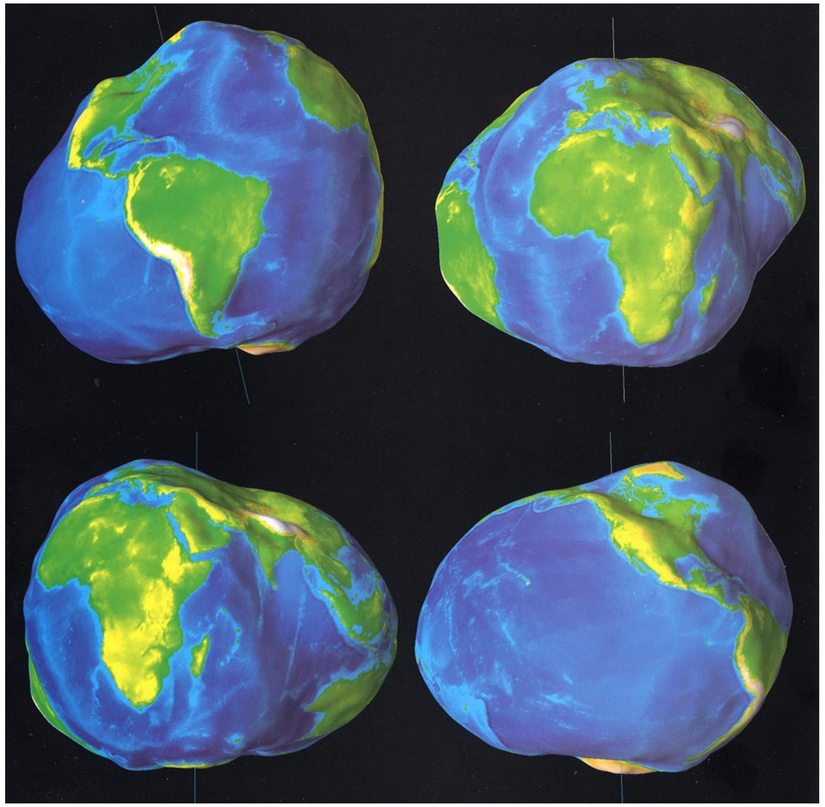
Geoid vs sea surface height

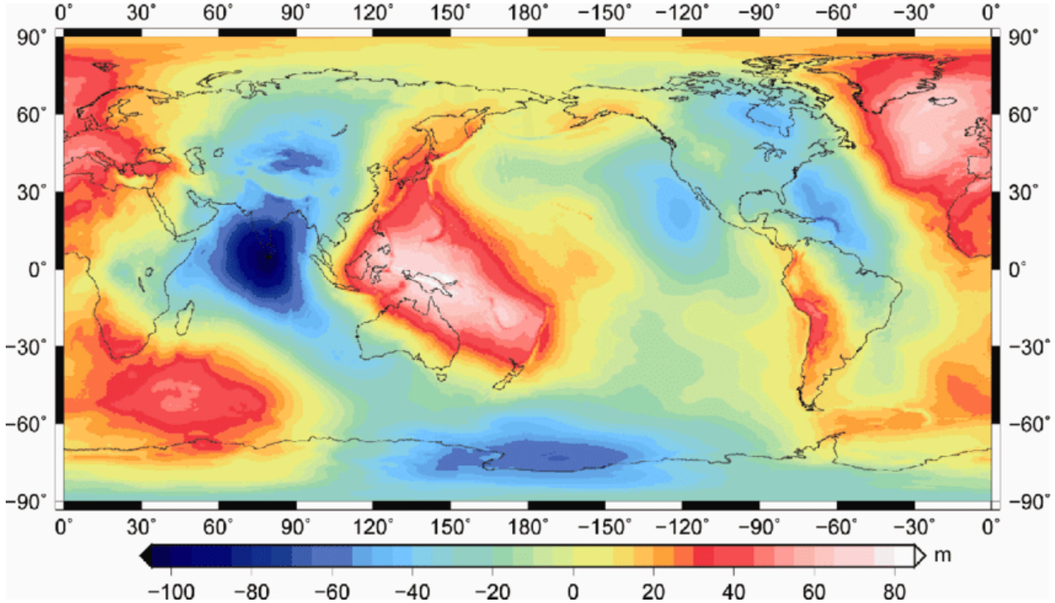
h=H+N



http://www.dspmuranchi.ac.in/pdf/Blog/Basic%20Geodesy.pdf

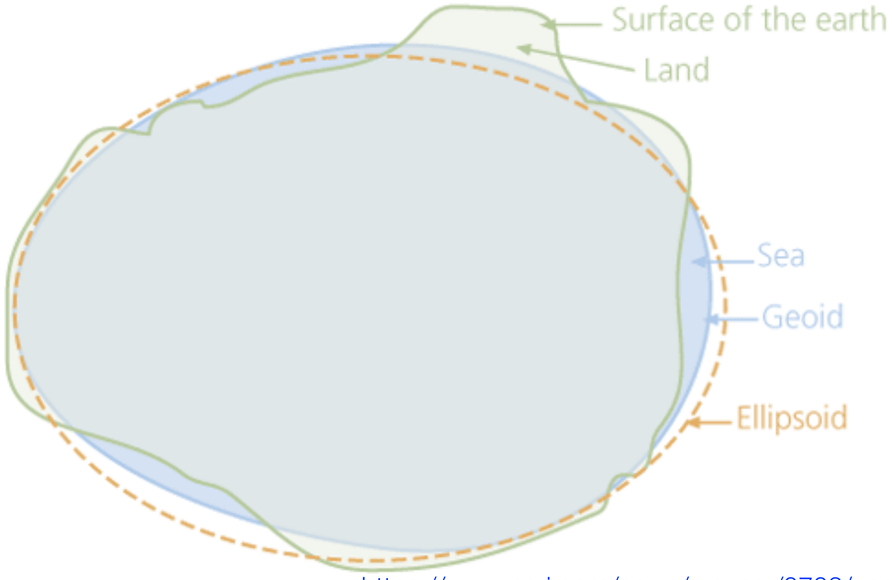
h=elipsoid height
H=orthometric height
N=geoid height





https://www.researchgate.net/figure/Global-geoid-from-EGM-2008-model-137_fig1_316255397

The geoid varies by hundreds of m from place to place, dynamic sea height typically varies by 1 m at most



http://geoide.es/pageID_3506376_3.html

https://www.esri.com/news/arcuser/0703/geoid1of3.html

The End