AdOc 4060 / 5060

2013 Spring
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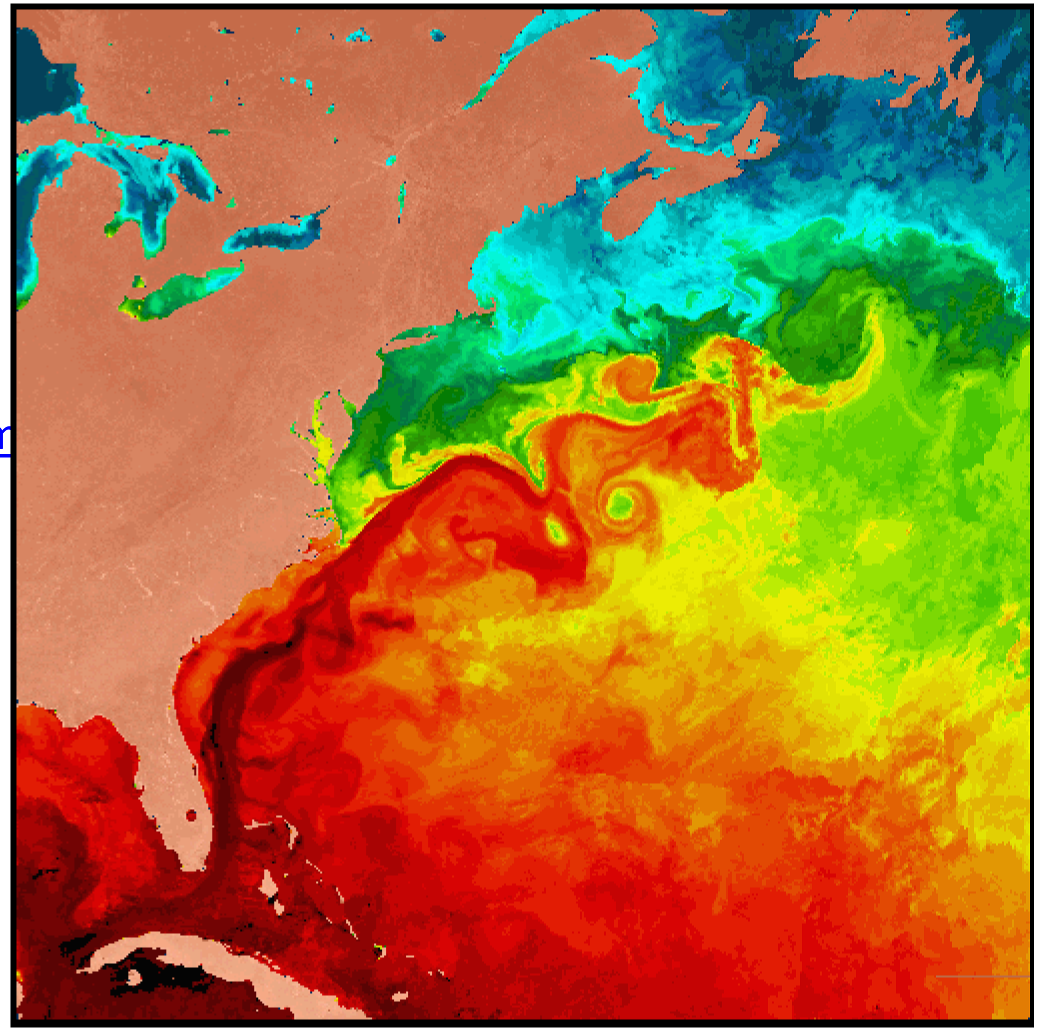
Circulations and Vorticity

Inertial wave:
http://www.youtube.com/watch?v=0dgG6zPxXb0

Free vortex:
http://www.youtube.com/watch?v=uZ8rm

Motion and commotion:
http://www.youtube.com/watch?v=FezsFM5AEsM



Forces include

1. Primary or causal

internal (body forces): gravitation: ocean (density differences)
astronomic (tides)

external (act on surfaces): wind
atmospheric pressure*
sea bottom movements (seismic)

*atmospheric pressure can cause differences in water level, for e.g. a hurricane the air pressure is low and water level tends to rise, and thus water flows towards this center due to continuity

2. Secondary or modifier

Coriolis (apparent force due to earth rotation)
Friction*: boundary
internal (most complex of all)

* friction forces are between the moving water and the ocean basin, or within the water when velocity shear occurs

Do you understand tea leaves in tea cup ? : http://en.wikipedia.org/wiki/Tea_leaf_paradox

Coriolis Rejoinder

It’s a bit slow, but work viewing for revision:
https://www.youtube.com/watch?v=S0_-uITuxYQ

- Wind stress is the frictional force on the sea surface $\tau \approx (U_{wind})^2$
- Surface currents are ≈ 3 to 10% of U_{wind}

- Coriolis is a ‘secondary force’
- Deflection by the Coriolis force is greater for slower currents
- Magnitude of the Coriolis force increases with speed (*mfu*)
- Primary and Secondary Forces drive currents

isobaric surfaces = surfaces of equal pressure within the ocean are parallel to the sea surface

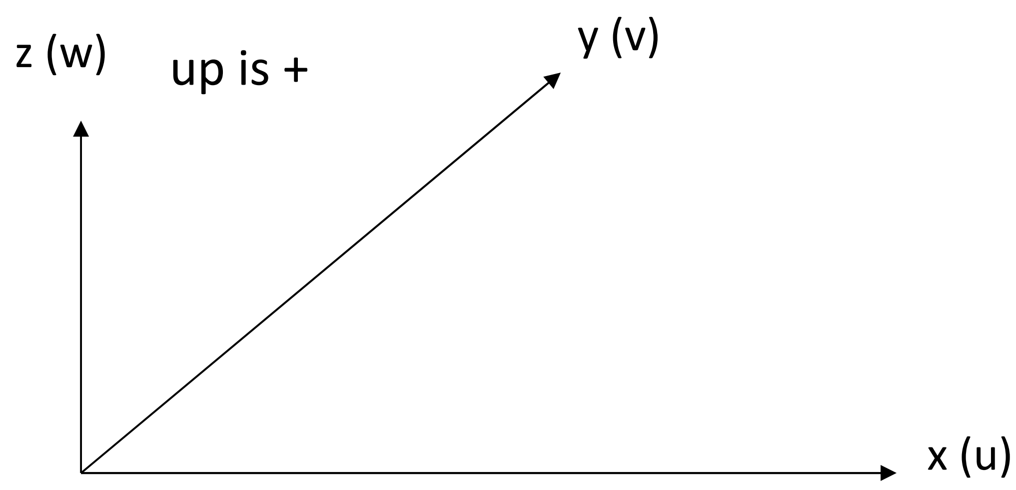
isopycnic surfaces = surfaces of constant density

barotropic conditions = isobaric surfaces are parallel to isopycnic surfaces

baroclinic conditions = isobaric surfaces are NOT parallel to isopycnic surfaces. In other words there are lateral variations in water density.

Geostophic current is a combination of the barotropic velocity plus the baroclinic velocity

Coordinate System

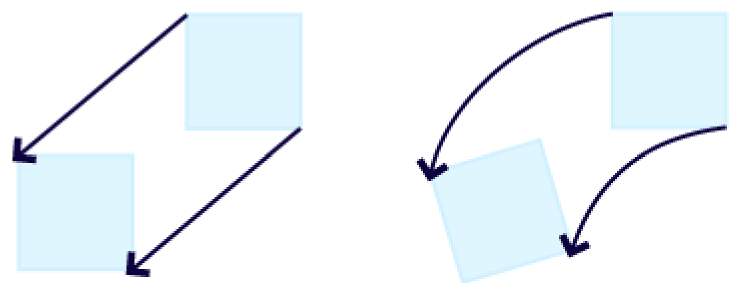


u, v, and w designate velocity

Vorticity

Angular momentum

…." local spinning motion of a fluid near some point, as would be seen by an observer located at that point and traveling along with the fluid."



$$\mathbf{L} = \mathbf{r} \times m\mathbf{v} \,.$$

Angular momentum is conserved in a system where there is no net external torque

Vorticity

Intro, Examples, Definition: http://en.wikipedia.org/wiki/Vorticity

$$\vec{\omega} = \nabla \times \vec{v} = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}\right) \times (v_x, v_y) = \frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}$$

'Curl operator' Δ

Positive vorticity = Cyclonic
(Right hand rule)

Planetary vorticity – rotation of frame:

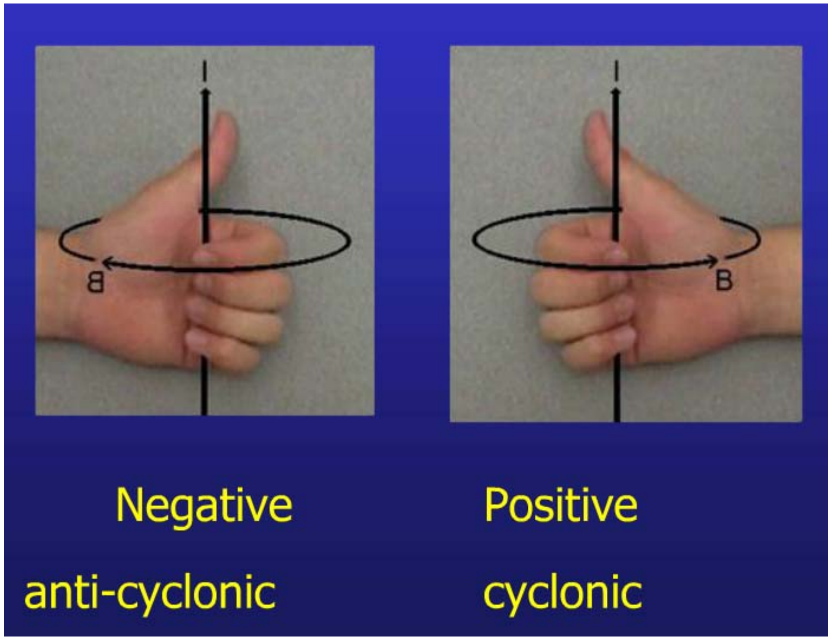
$$f=2\Omega \sin(\Phi)$$

Relative vorticity – shear effects:

$$\zeta = dv/dx-du/dX$$

Potential Vorticity – scaled:

$$(\zeta + f) /D \approx f/D$$



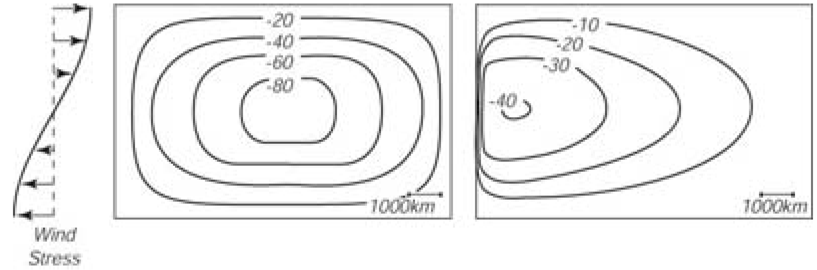
http://www.slideserve.com/ainsley/vorticity

Three main scenarios:

- ocean margin friction
- currents changing latitude
- Topographic steering

How do f & ζ compare on the earth's surface ?

Western Intensification



F+ζ conserved (angular momentum)

-ve wind stress curl from zonal winds

Accelerate next to boundary – more +ve frictional vorticity