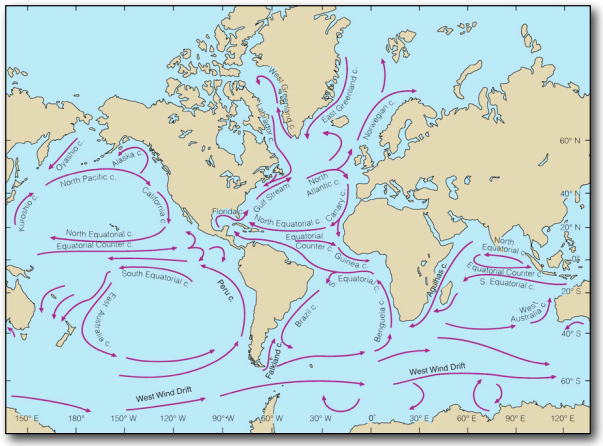
Wind-Driven Ocean Currents

- Similarities between winds & surface currents



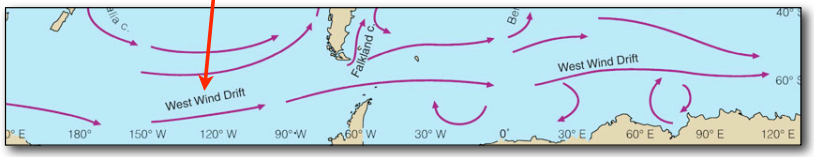
Zonal (East-West) Currents

- Trade winds push currents westward north & south of the equator
  - Equatorial currents. Up to 100 cm/sec.

Zonal (East-West) Currents

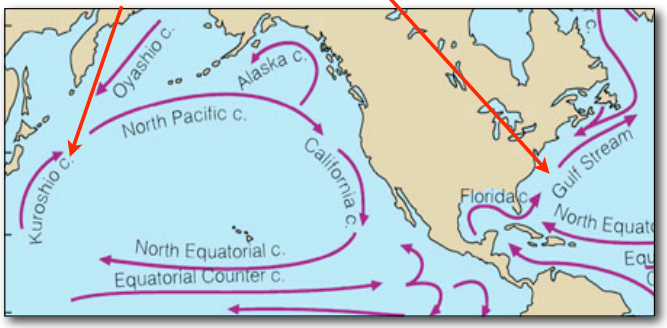
- Westerlies push currents eastward at temperate latitudes
  - North Pacific and N. Atlantic currents

  - West wind drift



Meridional (N-S) Currents

- Zonal currents diverted by continents to make closed loops
  - Northward Gulf Stream in N. Atlantic, Kuroshio in N. Pacific



Meridional (N-S) Currents

- Zonal currents diverted by continents to make closed loops
  - Southward California current in N. Pacific, Canary Current in N. Atlantic

Wind-Driven Ocean Currents

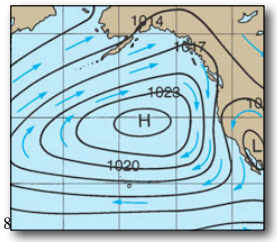
- Gulf Stream & Kuroshio "western boundary currents"
  - Powerful, narrow, fast currents with speeds up to 250 cm/sec
  - Weak upwelling
  - Less productive
- California, Canary "eastern boundary currents"
  - Slower & wider
  - Strong upwelling
  - More productive

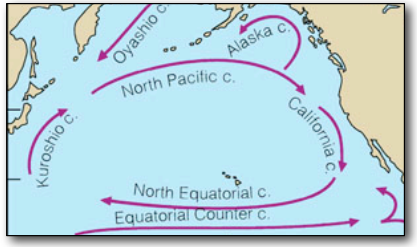
Wind-Driven Ocean Currents

- Centers of oceans have little movement
  - Correspond to the horse latitudes
  - Sargasso Sea with its vast floating seaweeds
  - Dead end of ocean currents
  - N. Pacific has similar feature

The Ocean Gyres

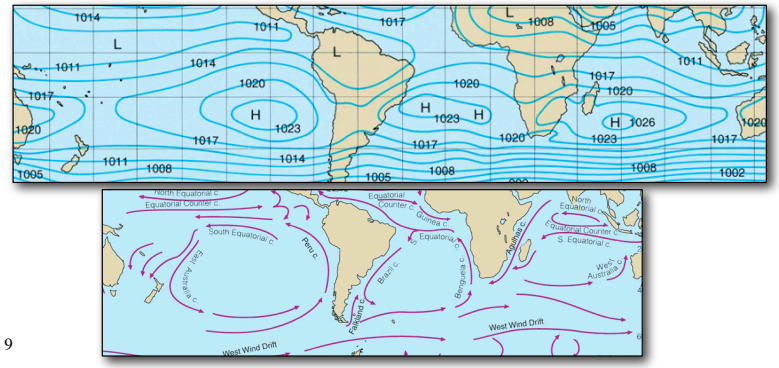
- Closed, roughly circular wind-driven surface current loops called gyres
  - Persistently present in response to winds
  - Match location, extent, and direction of long-term average winds around high and low pressure centers.





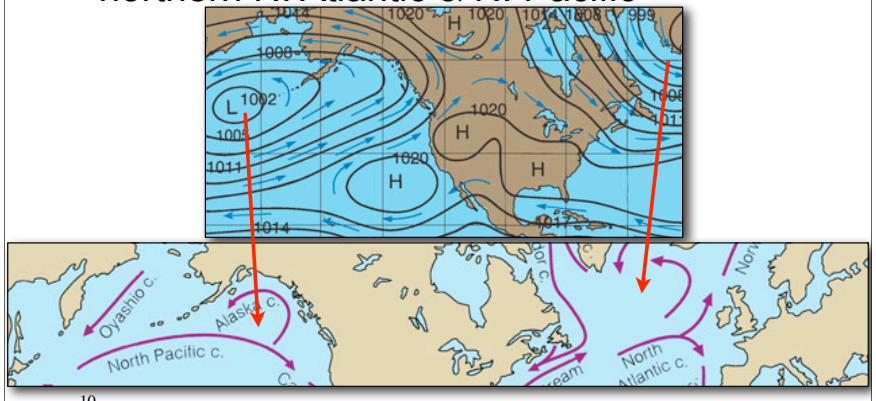
The Ocean Gyres

- Subtropical or central gyres
  - Match mean high pressure centers
  - Clockwise N. Hemisphere, counterclockwise S.



The Ocean Gyres

- Subpolar gyres (counterclockwise) in northern N. Atlantic & N. Pacific



The Ocean Gyres

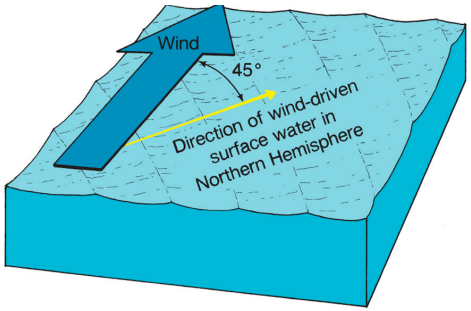
- Appears that currents follow winds
- But it isn't that simple

Effects of Wind on Water

- Appears that currents follow winds
  - But it isn't that simple
- Start with a calm ocean and turn on the wind. What happens?
  - Water begins moving in the direction of the wind.
- What next (two things)?
  - Coriolis Effect causes it to turn
  - Friction slows speed at greater depths

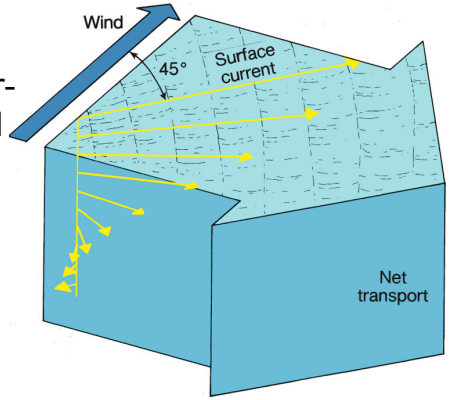
Ekman spiral

- Surface flow at 45˚ angle to wind (right in north, left in south)
  - Balance between friction & Coriolis



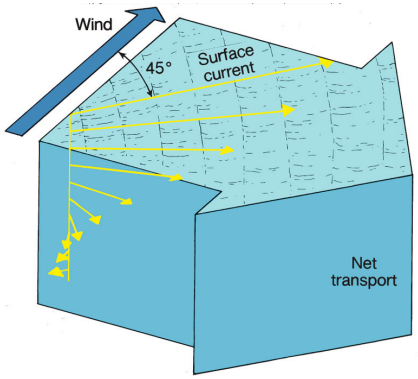
Ekman spiral

- Divide upper water column into arbitrary layers.
  - Moving surface layer affects underlying layer as wind on surface layer.
  - Underlying layer moves slower and at an angle to surface layer.



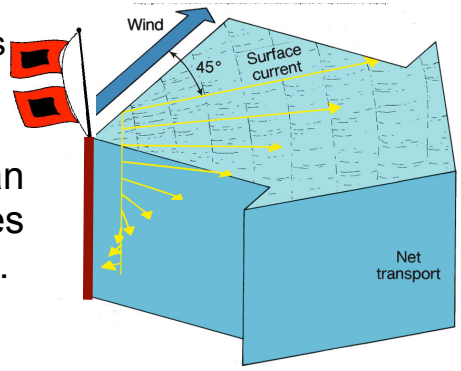
Ekman spiral

- Result is a spiral pattern from surface downward.
  - Currents turn and decrease with depth
  - Current disappears at about 100-150 m depending on wind strength.
  - This is the Ekman Layer.



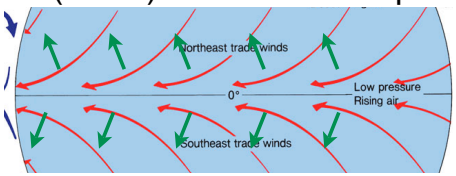
Ekman transport

- Imagine a 100-m pole floating upright in the water
  - Different currents at different depths
  - But pole will drift as a unit
- Over entire Ekman layer, water moves at 90˚ to the wind.
  - Right north
  - Left south



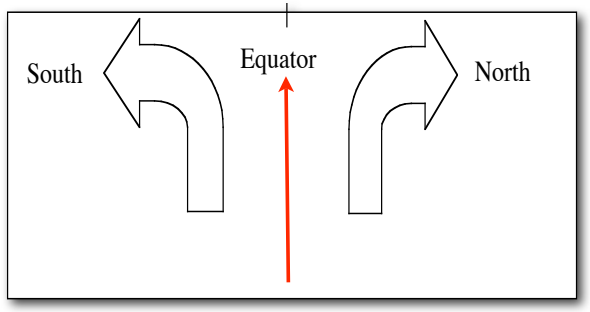
Ekman Divergence

- Ekman transport creates areas of convergence and divergence
  - Subtropical North Pacific as example.
- Trade Wind effects near Equator
  - Ekman transport to the right (north) in the N. Hemisphere
  - To the left (south) in the S. Hemisphere.



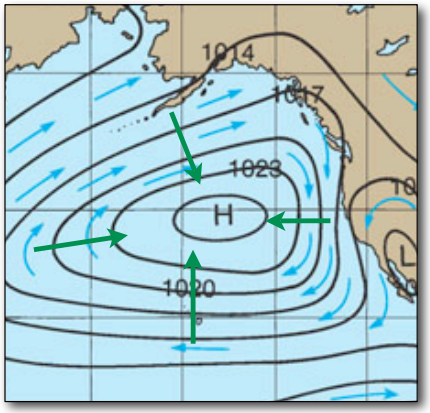
Ekman Divergence

- This causes a divergence.
  - Water flows up from below to replace water diverging at the surface (side view).
  - This is called upwelling.



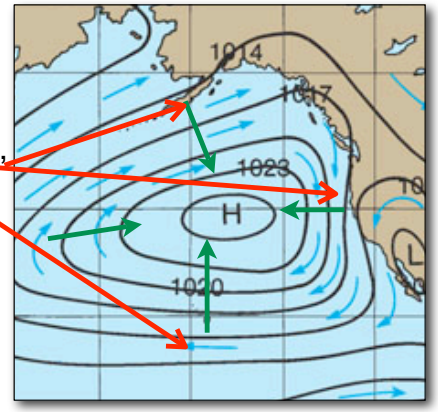
Divergence & Upwelling

- Mean subtropical high pressure center in N. Pacific
  - Ekman transport to the right around the entire periphery
  - Inward to the center of the Pacific



Divergence & Upwelling

- Mean divergence along the edges of the subtropical N. Pacific
  - Surface water moves away from the Equator & the Japanese, Aleutian, & N. American coastline
  - Toward the center of the N. Pacific

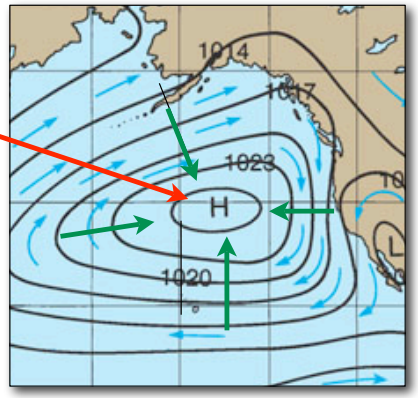


Divergence & Upwelling

- Deep water rises to replace it, so there is upwelling all around the periphery of the subtropical North Pacific.
  - It's a bit more complex than this, of course
  - Some of those complexities in the next lecture

Convergence & Downwelling

- Ekman transport converges in the center of the N. Pacific
- Converging water is forced downward, = downwelling
- So far we have said nothing about geostrophic flow in the oceans.

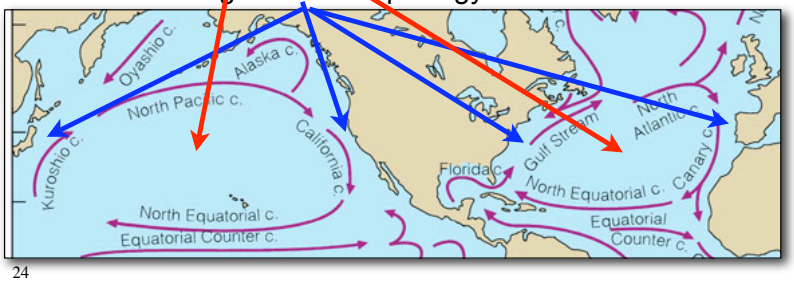


Geostrophic Flow

- Remember the definition of geostrophic
  - Coriolis Effect equal & opposite to pressure
  - Flow parallel to isobars
  - Faster flow with more closely spaced isobars
- Where is the pressure at the ocean surface?
  - Where are the isobars?

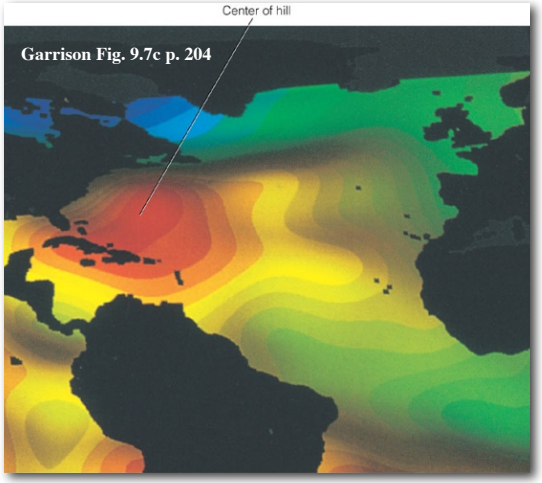
Sea Surface Elevation

- Convergence & divergence affect sea level
  - Sea level is higher where there is convergence
    - In the center of subtropical gyres
  - Sea level is lower where there is divergence
    - At the edges of subtropical gyres.



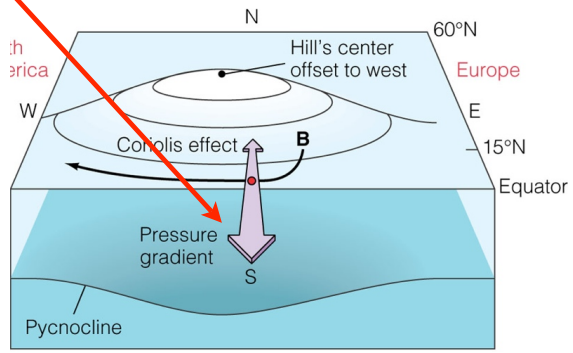
Sea Surface Elevation

- An ocean-wide "hill" of sea water
  - Only about 1 meter high
  - Still a huge volume and mass of water
  - Satellite radar



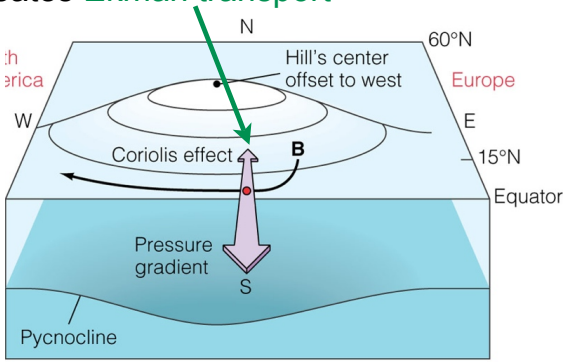
Geostrophic currents

- The sea surface slope generates a pressure
  - Downhill because of gravity
  - Outward from the center of the basin



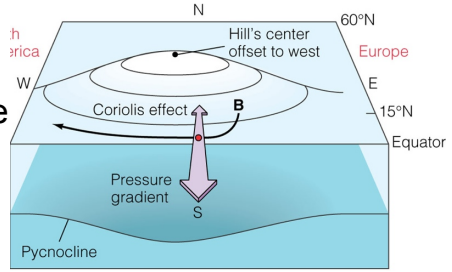
Geostrophic currents

- The pressure is opposite to the Coriolis Effect
  - Coriolis creates Ekman transport
  - Ekman transport created sea surface slope



Geostrophic currents

- Ekman transport creates hill of sea water
  - Until sea surface slope is too steep to push more water uphill
- Water flows "sidehill" instead of into center of basin
  - Elevation contours equivalent to isobars of pressure
  - Coriolis equal & opposite to pressure



Gyres

- Subtropical gyres correspond to mean high pressure centers
  - Flow in the same direction, clockwise (N. Hemisphere)
- Subpolar gyres correspond to mean low pressure centers
  - Flow in the same direction, counterclockwise (N. Hemisphere)

Alaska gyre

- Winter low pressure, counterclockwise winds
  - Outward Ekman transport
- Low sea level, divergence, upwelling at center of gyre
- High sea level, convergence, & downwelling, around the gyre
  - A "hole" of sea level