Wind-Driven Currents

- Dominated by the global wind patterns and the Coriolis Force
- Very shallow... typically not more than 100 m
- Inefficient transfer of energy... typically 2-3%
- Named for the Direction, as with winds, but \textit{inverted}
Boundary Currents

- Strong *Trade Winds* set up the Equatorial Currents
- At the Equator, there is no Coriolis Force, so the water moves from East to West
- Water to the North or South of the Equator is turned
- When the currents hit a *boundary*, they are turned poleward

Subtropical Gyres

- Most of the basin is filled by the gyres
- nutrient poor, warm waters
- Formed by Western and Eastern Boundary Currents
Ekman Transport

Ekman Layers...

[Diagram showing wind, surface currents, and the movement of objects such as ships and icebergs in relation to the wind.]
In the gyres, Ekman transport keeps pushing water towards the center of the gyre.

In the N. Atlantic, you get a “hill” 2 m tall!

The water is pulled by gravity down the hill, and turns to the right.

**Vorticity**

*Vorticity* is the tendency to spin.

At the North or South Pole, you spin once every 24 hours...at the Equator, you don’t spin at all.

As you move *Northward*, you gain more spin.
**Coriolis and Vorticity**

- Are not caused by winds...they are “earth turning” currents.
- Water flows downhill and turns to the right. The net balance is circular.
Intensification of Western Boundary Currents

Vorticity and Coriolis combine to form the Gulf Stream

Strong vorticity causes weak eastern boundary currents

Equatorial Counter Currents

- Trade Winds push water towards the western side of the basins
- This must be balanced by a return flow
Major Currents

• Dominated by:
  – Gyres
  – Wind Patterns
Monterey Bay Currents

Vertical Circulation

- Dominated by *Thermohaline flow*
- Upwelling/Downwelling are special cases
Upwelling...

- Winds form surface currents, deflected by Coriolis
- Near a coast, you form a vacuum

- When the winds reverse, you get downwelling

California Upwelling

- Temperature
- Chlorophyll
Thermohaline Circulation

- **Two sources:**
  - North Atlantic Deep Water
  - Antarctic Bottom Water

- Water moves from the Atlantic, through the Indian Ocean, and into the Pacific, with the Antarctic connecting them
- Oxygen decreases and nutrients increase along the way

Henry Stommel--The Conveyor Belt Model
**Vertical Profiles Revisited**

-Sarmiento et al. 2004 - Antarctic mode water controls the distribution of *almost all* nutrients in the world’s oceans!

-This can be tracked using a **conservative tracer** which tracks the ratio of silicate and nitrate

![Sarmiento et al., Figure 4](image-url)
Convergence Zones

- Although NADW and AABW are most important, **convergence zones** form intermediate water.
Antarctic Circulation

• Circles the Globe
• ACC=130 Sv !
(1 Sv = $1 \times 10^6$ m$^3$/s)
• West Wind Drift
• East Wind Drift

Atlantic Circulation

• Dominated by the Gyres in the surface
• NADW, AABW NAIW at depth

Pacific Circulation

• Similar to the Atlantic
• Bering Strait keeps deep water from entering the Pacific basin

Indian Ocean Circulation

• Dominated by Monsoons
Ocean Circulation--Review

Divided into Layers:
1) Surface Mixed Layer--warm, constant density, shallow
2) Clines--sharp change in density, temperature, and/or salinity
3) Intermediate Water--ca. 100-1500 m
4) Deep Water--1500-4000 m, not in contact with the bottom
5) Bottom Water--deeper than 4000 m
Summary

• Denser water masses sink
• It seeks its appropriate density level and then spreads laterally
• Water masses gain their particular characteristics (T, S, oxygen, nutrients) because of interaction with the surface during their development, and the following:

1. Different inputs of fresh water
2. Different patterns of precipitation/evaporation
3. Different temperature regimes at the surface