The Climate System

Ocean-Climate Processes
- Today: Intro. to Ocean Circ. And Chem. - main features
- Wed 3/30: Ocean Mixing
- Mon 4/4: Discussion of papers on ocean-climate change
- Wed 4/6: Ocean (Carbon) Chemistry
- Mon 4/11: Discussion of paper on ocean-carbon cycle

Ocean Effects on Climate
- Dampening effect on changes
- Responsible for some meridional heat transport
- Source of latent heat to atmosphere
- Ocean Carbon - the largest environmental reservoir of carbon
- Involved in feedbacks responsible for climate oscillations

Introduction to the Oceans
- first: ocean basics
  - ocean basins
  - temperature/salinity/density structure
  - currents and water masses
- then: role of ocean in climate, ocean as a reservoir of:
  - heat (covered in Climate Dynamics)
  - ecologically and climatically important chemical constituents

Ocean Basins

Typical Topography
Ocean Basins

Depth of Ocean Basins

Atlantic Ocean, Pacific Ocean, Indian Ocean

Age of Ocean Crust

Depth of Ocean Basins

Arctic Ocean
Ocean Basins

Southern Ocean

Temperature & Salinity

- **surface** T related to:
  - net heat flux
- **subsurface** T related to:
  - T of surface water where deep water leaves the surface
  - pressure effects - Potential Temperature (θ): temperature which a water parcel has when moved adiabatically to surface.

- **surface** S related to:
  - evaporation
  - precipitation
  - sea ice formation
- **subsurface** S related to:
  - S of surface water where deep water leaves the surface

Below surface, water masses are traced by conservative properties - Pot. Temp & Salinity

Seawater Properties - Density

- **Density** - related to salinity, temperature, pressure
  - Units (mass/volume, kg/m³, g/cm³)
  - **Equation of State** - empirical
    - Freshwater (@ 15°C): 999 kg/m³
    - Surface seawater (@ 15°C): 1020-1029 kg/m³
    - Total seawater range: 1020 - 1050 kg/m³

Potential Temp and Density

Figure 6.9 Profiles of Left in situ and potential temperature and Right sigma-t and sigma-theta in the Kermadec Trench in the Pacific measured by the R/V Eltanin during the Scorpio Expedition on 13 July 1967 at 175.825°E and 28.258°S. Data from Warren (1973).
The Oceans are well stratified

**Pycnocline** = layer of rapidly changing density

**Thermocline** = layer of rapidly changing temperature
- Not well developed in high latitudes
- Barrier to vertical mixing (upwelling and sinking) of water, carbon exchange with atm., migration of marine life

Figure 5.24

Seawater Properties

Seawater Properties
Ocean Circulation

- Wind-driven
  - Directly drives mixing and currents in upper 100 m
  - Indirectly drives geostrophic currents in upper 1000m by setting up strong pressure gradients
- Density or Pressure driven (mostly frictionless)
  - Geostrophic flow

FORMERLY: wind-driven versus “thermohaline” circulation

NOW: surface circulation, shallow and deep meridional overturning circulation
Ekman Spiral
Model of surface response to wind forcing

Ekman Transport
Net flow of surface layer when forced by wind

January Surface Air Pressure

July Surface Air Pressure

January winds

July winds

Heat Transport Via Ocean Currents

Surface Currents Resulting from Wind Drag


From Schmitz (1995)
Figure 6. Poleward heat transports by the atmosphere (large-dashed line), ocean (small-dashed line) and the two combined (solid line) in equatorials (from Tröltzsch and Casen 2001).
Surface Water Phosphate (major nutrient)

Ocean Productivity

Subduction of thermocline water

Fig. 5.3 Sketch of water mass formation by subduction in the Subtropical Convergence. The T-S diagram shows both the meridional variation of temperature and salinity between stations $A$ and $D$, and the vertical variation eastward of station $D$ from the surface down along the line $A-WCSP$. For more detail, see text.
Subduction of thermocline water (Harper, 2000)

Western boundary currents bring warm water poleward.
Ocean heat lost at high latitudes.

Balanced by ocean heat gain in cold upwelling regions (because thermocline is shallow).


Pacific - Sigma-theta (10m)
Net Circulation - Global Conveyor Belt

Rahmstorf, 2002
Global Conveyor Belt

Total turnover time of ocean = 1000 years

- **Surface Ocean**
  - Residence time = 100 years
  - Upwelling

- **Deep Cold Ocean**
  - Residence time = 900 years

Residence time is the average amount of time a substance (in this case water) spends in a reservoir.