Chapter 10: Global Wind Systems

Three-cell model of atmospheric circulation
Intertropical Convergence Zone (ITCZ)
Typical surface wind patterns
Upper-level pressure and winds
Climatological sea-level pressure and surface winds
Role of Bermuda High in American history
Jet streams
Dishpan experiments
Computer modeling of the atmospheric circulation
Ocean currents
Upwelling
El Niño

General Circulation (p. 256)

- "General circulation" refers to average, large-scale flow of the atmosphere.
- General circulation is summarized in figure on next slide. Lots of information there!
- Will be followed by 3 more slides that discuss
  - Average vertical motions
  - Intertropical Convergence Zone near equator
  - Average surface winds

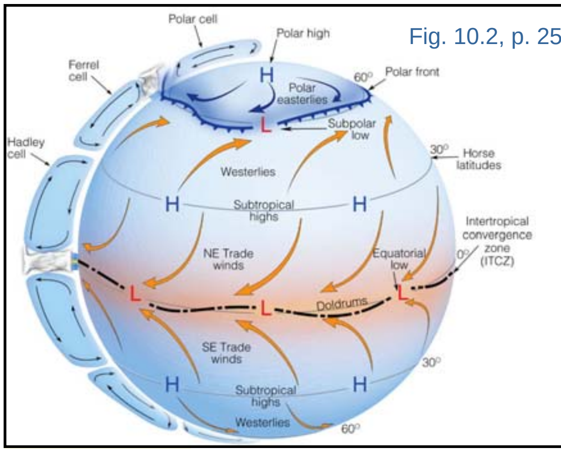


Fig. 10.2, p. 257

3-cell Model (pp. 257-258)

- 3 "cells" in each hemisphere; see next slide.
- Hadley cell: Hot air rises at equator, moves poleward in upper troposphere, and sinks at 30° latitude where it is cooler, then back to equator in lower troposphere.
- Polar cell: Very cold air sinks at poles, moves equatorward in lower troposphere, rises at 60° latitude where it is warmer, and then poleward in upper troposphere.
- Ferrel cell: Consistent with Hadley and Polar cells to its sides, air sinks near 30° latitude, moves poleward in lower troposphere in middle latitudes, rises near 60° latitude, and then equatorward in upper troposphere.

Intertropical Convergence Zone (ITCZ) p. 258

- The 2 Hadley cells meet at the intertropical convergence zone (ITCZ) near the equator. Region also called the doldrums.
- ITCZ is N of equator during July, S of equator during December
- Visible as line of thunderstorms in satellite pictures. Satellite picture below shows ITCZ west of the Americas (Picture from http://VisibleEarth.nasa.gov) What is the season?

ITCZ →

Typical surface wind patterns (fig. 10.2, p. 257)

- Weak winds where pressure gradient weak, at belt where circulation cells meet
  - the doldrums near equator where the 2 Hadley cells meet
  - Horse latitudes near 30° latitude where Hadley and Ferrel cells meet
- Low pressure to left/right of wind in N/S Hemisphere, so:
- Tropical easterlies and mid-latitude westerlies

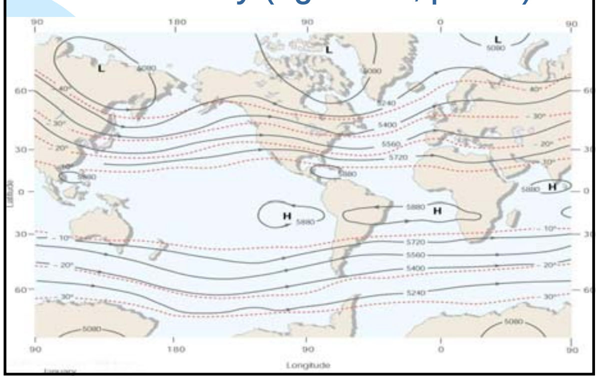
Upper-level Pressure & Winds (pp. 262-266)

- Upper-level pressure distribution is determined by temperature. (See fig. 8.2c, p. 193.)
  - Upper-level pressure is high where warm, low where cold.
- Wind is determined by pressure.
  - Low pressure to left of wind in Northern Hemisphere, with CCW flow around lows, CW around highs.
  - Low pressure to right in Southern Hemisphere, with CW flow around lows, CCW around highs.
  - Fast wind where isobars are close (large pressure gradient force).
  - Fastest winds – jet stream – lie between upper level high & upper level low, that is, above boundary between warm & cold air.

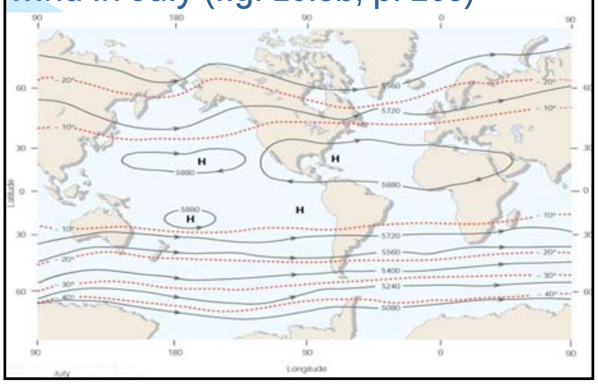
Application of preceding principles to understand maps of average upper-level pressure & wind: Figs. 10.8 on pp. 264-265

- Upper-level lows in cold areas: N & S Poles
- Upper-level highs in warm areas: tropics
- Large upper-level pressure gradient exists in mid-latitudes between high pressure over tropics and low pressure over poles. Stronger in winter hemisphere.
- Fast upper-level winds (jet streams) occur in mid-latitudes where pressure gradient force is large.
- Fastest winds occur in winter hemisphere because upper-level polar low has lower pressure in winter due to greater north-south temperature contrast.

Avg mid-tropospheric pressure & wind in January (fig. 10.8a, p. 264)



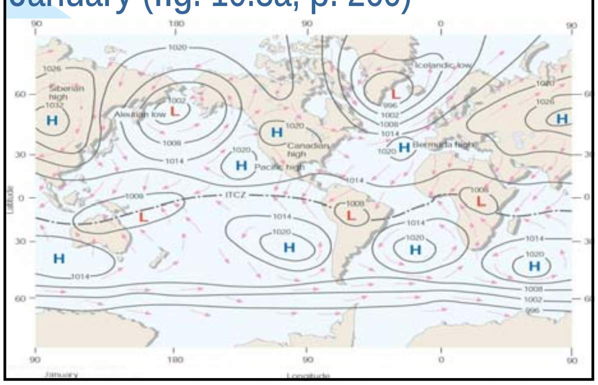
Avg mid-tropospheric pressure & wind in July (fig. 10.8b, p. 265)



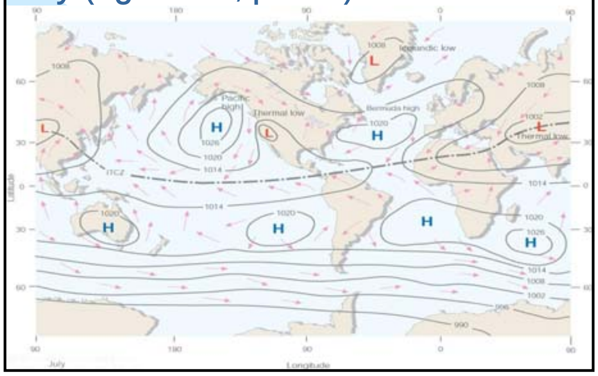
Climatological sea level pressure & surface winds (pp. 258-261)

- Averaged over time, sea level pressure tends to be low where it is warm and high where it is cold.
- The reason for these highs and lows is the same as for the surface low and high pressure for a sea breeze. See pp. 236-238, especially study fig. 9.20, p. 236.
- Speed and direction of surface-level wind governed by same rules as upper level wind
  - Faster where isobars are close
  - Low pressure to left of wind in N Hemisphere
- Friction against surface slows wind, causing air to spiral out of highs into lows.

Avg sea level pressure & wind in January (fig. 10.3a, p. 260)



Avg sea level pressure & wind in July (fig. 10.3b, p. 261)



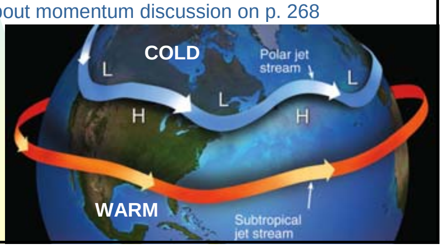
Role of Bermuda High in American History (not in book)

- Clockwise winds around Bermuda High (fig. 10.3, pp. 260-261)
- Sailing route on north side of Bermuda High used by Leif Ericson and Pilgrims was difficult: sailing against the wind.
- Sailing route on south side of Bermuda High carried Columbus from Spain to Caribbean with the wind
- CW flow around Bermuda High made possible the infamous slave-molasses-rum trading triangle.
  - Tropical easterlies carried slave ships from Africa to Caribbean
  - Southerly winds carried ships carrying molasses from Caribbean to Rhode Island
  - Rum made in Rhode Island from molasses was shipped to Africa and sold for slaves.

Jet streams (pp. 263-269)

- Jet stream: Region of fast wind 1000's of km long, a few 100 km wide, and a few km thick. Typically occurs near tropopause. Requires strong pressure gradient
- Because upper-level highs and lows form above warm and cold air, respectively, a jet will lie above the boundary between warm and cold air, i.e., above a "front."
- Don't worry about momentum discussion on p. 268

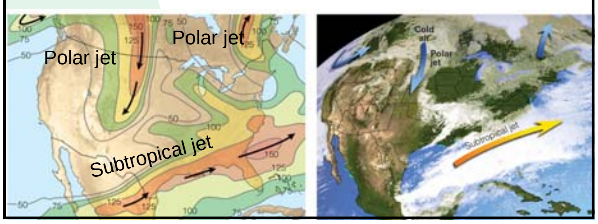
Fig. 10.10 p. 267



Polar and Subtropical Jets (pp. 267)

- Strong horizontal temperature contrasts (fronts) often exist at 2 latitudes
  - Polar jet to north
  - Subtropical jet to south

Fig. 10.11, p. 267: Jets over N America on 9 March 2005

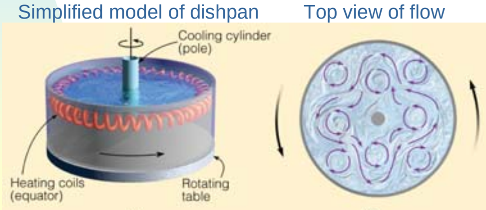


Dishpan Experiments (p. 266)

- Lab experiments can simulate atmospheric flow
- FSU is one of few places in the world where these experiments have been done. Geophysical Fluid Dynamics Lab is in basement of Keene Building.
- Lab experiments have a place, but they are less common now that computer modeling of the atmosphere has improved.

Simplified model of dishpan Top view of flow

Fig. 2, p. 266



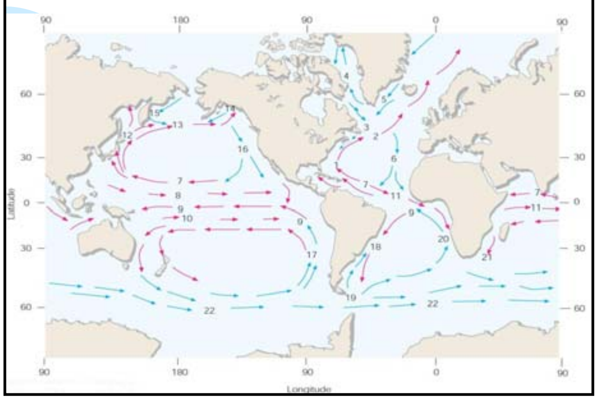
Computer models of the atmosphere and ocean

- Have largely replaced dishpan experiments
- Important for weather forecasting (chap 13, p. 338) and climate simulation (chap 16, pp. 448-451)
- Forecasting models often include just atmosphere and interaction with Earth's surface (heating, evaporation, friction)
- Climate models often include atmosphere and ocean circulation along with interaction with Earth's surface
- Equations that describe the atmosphere (and ocean) are written as a large computer program
- Program is run on a computer to solve the equations to estimate what the three-dimensional weather will be like
- Graphics, often fancy, are used to display results.
  Huge quantity of numbers from computer models.
- Development of a computer model requires many person-years of work.

Ocean Currents (pp. 271-272)

- Ocean currents are generally CW in the N Hemisphere and CCW in the S Hemisphere.
- Reason why: Ocean water is pushed by wind flowing around HIGH pressure over oceans in both hemispheres. See surface pressure maps on pp. 260-261.
- Coriolis force pushes surface currents about 45 degrees to the right of wind. (Will be important for EL Nino discussion.)

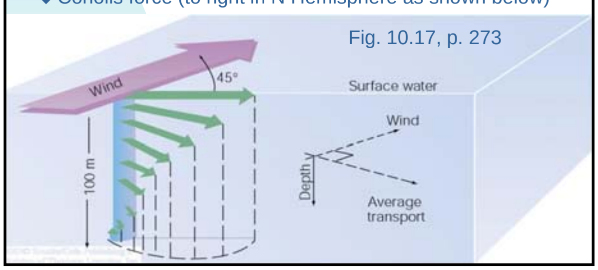
Major Ocean Currents (fig. 10.14, p. 271)



Ekman Spiral (p. 273)

- Arrows representing speed and direction of ocean current spiral with increasing depth. Named after Swedish graduate student studying in Norway who explained this in 1905.
- Forces on ocean:
  - Frictional drag from layers above and below
  - Coriolis force (to right in N Hemisphere as shown below)

Fig. 10.17, p. 273



Oceanic Upwelling (pp. 272-274): Water pushed away from land by Coriolis force brings up deeper, colder water

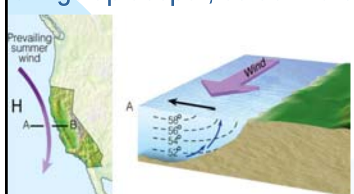


Fig. 10.16 (p. 273): Ocean surface temperature (deg F) in August

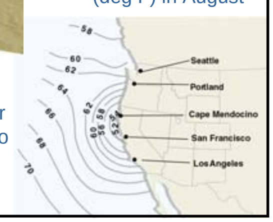
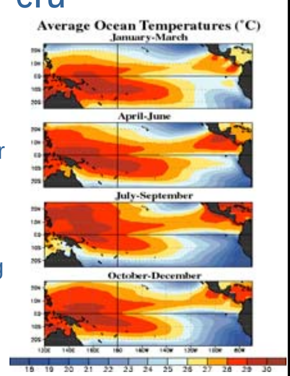


Fig. 10.18 (p. 274): Northerly wind in summer along coast pushes water south. Coriolis force pushes water to right, away from coast, bringing up cooler water from below.

Upwelling along west coast of South America by Peru

- Flow around high pressure over Pacific creates northerly wind along coast of Peru
- Coriolis force pushes water to left in S Hemisphere, away from coast.
- Cold water (shown in blue) rises from below: upwelling

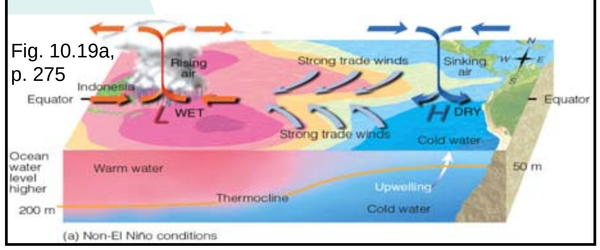
Figure from www.cpc.ncep.noaa.gov



Normal conditions in equatorial Pacific (pp. 274-278)

- Cold upwelling next to Peru. Ocean current toward west along equator, very warm by the time it reaches Indonesia.
- Air warmed in western Pacific, rises, and rains.
- Extreme case (very warm in west & cold in east) is called La Niña (also known as El Viejo).

Fig. 10.19a, p. 275



El Niño conditions (pp. 274-278)

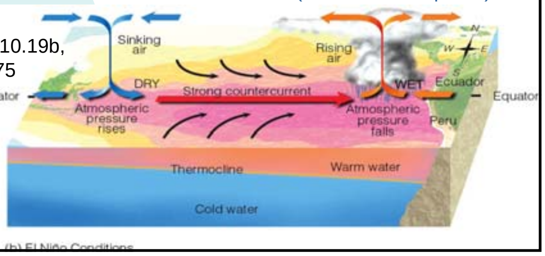
Equatorial easterlies weaken, allowing "hill" of water in western Pacific to slosh eastward along equator.

Warm ocean water shifts to E Pacific; W Pacific cools.

Air over E Pacific warmed; increased rain. Drought over W Pacific. Atmospheric fluctuations called Southern Oscillation.

ENSO = El Niño, Southern Oscillation (ocean & atmosphere)

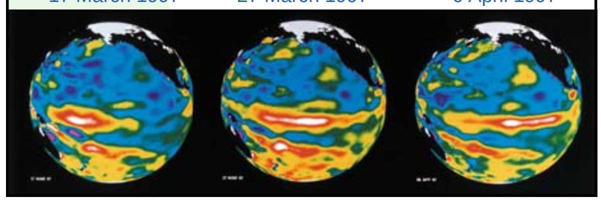
Fig. 10.19b, p. 275



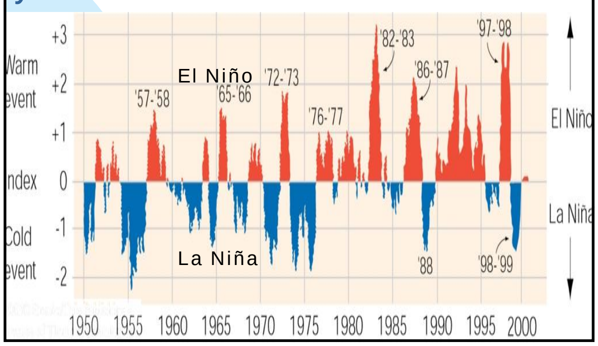
Onset of El Niño (p. 275)

- Equatorial easterly winds relax, allowing water from W Pacific to slosh eastward along equator toward South America.
- Fig. 10.20, p. 275: Red and white areas near equator denote sea level 4" and 8" above normal, respectively. Note white area (high sea level) moving eastward

17 March 1997 27 March 1997 6 April 1997



Duration of El Niño (fig. 10.22, p. 277): ½ to 2 years long, recurring every few years



Effects of El Niño (p. 277) in Winter

Don't memorize effects, but know that consequences extend far beyond Pacific Ocean

Fig. 10.23a, p. 277

(a) El Niño

Effects of La Niña (p. 277) in Winter

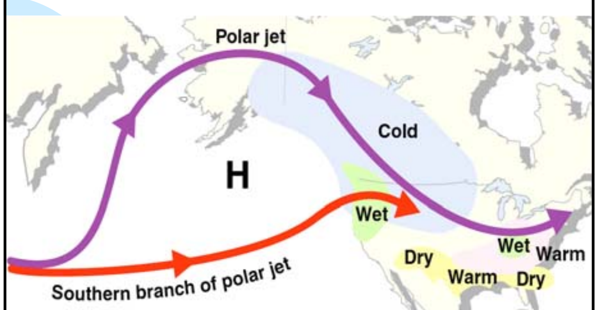


Fig. 10.23b, p. 277

(b) La Niña

El Niño / La Niña Effects on Southeast US including Florida

El Niño
- Cooler, wetter winters
- Fewer hurricanes in next summer

La Niña
- Warmer, drier winters
- More hurricanes in next summer

- For more info, see:
- www.ElNino.noaa.gov
- www.cpc.ncep.noaa.gov
- www.coaps.fsu.edu

For information on El Niño and climate prediction, see: http://www.atmos.washington.edu/gcg/RTN/rtnt.html