Wave clouds, called *billow clouds*, forming in a region of wind shear.

Scales of atmospheric motion. A) tiny *micro scale* motions
B) Are part of the larger *mesoscale* motions
C) which are part of the much larger *synoptic scale* motions
Smaller scale motions not visible at large scales

FIGURE 7.2 Under stable conditions, air flowing past a mountain range can create eddies many kilometers downwind from the mountain itself.

Formation of clear air turbulence (CAT) along a boundary of increasing wind speed shear.

Turbulent eddies downwind of a mountain chain produce *Kelvin Helmholtz* waves. The visible clouds that form are called *billow clouds*. 
Thermal Circulations - produced by the heating and cooling of the atmosphere near the ground.

H = high pressure
L = low pressure

Isobaric surfaces = surfaces of constant pressure.

Isobars all lie parallel here, so...

...no horizontal variation in P or T and no pressure gradient or wind

Air aloft moves to the north and “piles up”...which reduces surface air P to the south and raises it to the north...

PGF is established from N=>S, thus wind blows N=>S

Sea breeze and land breeze
(a) At the surface, a sea breeze blows from the water onto the land
(b) land breeze blows from land out over water

Note: pressure at the surface changes more rapidly with the sea breeze. (stronger pressure gradient force and higher winds)

FIGURE 7.5 Surface heating and lifting of air along a sea breeze combine to form thunderstorms almost daily during the summer in southern Florida.

FIGURE 7.6 Changing annual wind flow patterns associated with the winter and summer Asian monsoon. By defn, “monsoons” change direction seasonally.
Katabatic Winds

- drainage winds
- Katabatic winds are quite fierce in parts of Antarctica, with hurricane-force wind speeds.

Chinook (Foehn) Winds

- Chinook winds
- compressional heating
- chinook wall cloud

- In Boulder, Colorado, along the eastern flank of the Rocky Mountains, chinook winds are so common that many houses have sliding wooden shutters to protect their windows from windblown debris.
Cities near the warm air–cold air boundary can experience sharp temperature changes, if cold air should rock up and down like water in a bowl.

FIGURE 7.12 Surface weather map showing Santa Ana conditions in January in California.

Max temperatures for this particular day given in °F. Note down slope winds blowing into southern California raise temperatures into the upper 80s.

FIGURE 7.13 Formation of a dust devil. On a hot, dry day, the atmosphere next to the ground becomes unstable. As the heated air rises, wind blowing past an obstruction twists the rising air, forming a rotating column, or dust devil. Air from the sides rushes into the rising column, lifting sand, dust, leaves, or any other loose material from the surface.

FIGURE 7.14 A dust devil forming on a clear, hot summer day just south of Phoenix, Arizona.

FIGURE 7.15 Diagram (a) shows the general circulation of air on a non rotating earth uniformly covered with water and with the sun directly above the equator. (Vertical air motions are highly exaggerated in the vertical.) Diagram (b) shows the names that apply to the different regions of the world and their approximate latitudes.
FIGURE 7.16 Diagram (a) shows the idealized wind and surface-pressure distribution over a uniformly water-covered rotating earth. Diagram (b) gives the names of surface winds and pressure systems over a uniformly water-covered rotating earth.

Global Wind Patterns and the Oceans

FIGURE 7.17 Average sea-level pressure distribution and surface wind-flow patterns for January (a) and for July (b). The heavy dashed line represents the position of the ITCZ (Intertropical convergence zone).
The General Circulation and Precipitation Patterns

- major controls
- ITCZ, midlatitude storms, polar front

Most of the world’s thunderstorms are found along the ITCZ.

Westerly Winds and the Jet Stream

- jet streams
- subtropical jet stream
- polar front jet stream

FIGURE 7.22 Average position of the polar front jet stream and the subtropical jet stream, with respect to a model of the general circulation in winter. Both jet streams are flowing into the page, away from the viewer, which would be from west to east.
Position of the polar jet stream and the subtropical jet stream at the 300-mb level during the morning of March 10, 1998. Solid gray lines are lines of equal wind speed (isotachs) in knots. Heavy lines show the position of the jet streams. Heavy blue lines show where the jet stream directs cold air southward, while heavy red arrows show where the jet stream directs warm air northward.

FIGURE 7.25 Average sea surface temperatures (°F) along the west coast of the United States during August.

FIGURE 7.26 As winds blow parallel to the west coast of North America, surface water is transported to the right (out to sea). Cold water moves up from below (blue arrows) to replace the surface water.

Coriolis effect bends the northerly wind to the right and out to sea.

…the net effect is that a shallow layer of sfc water heads at right angles to the sfc wind and head seaward...

…thus allowing the cold water to rise!
usual: high $P$ over SE Pacific and low $P$ over Indonesia $\Rightarrow$ easterly trade winds...
=upwelling & cool $H_2O$ in E Pacific; warm $H_2O$ to west.
Strong trades $\Rightarrow$ La Nina
Atmos. $P$ dec over Pacific
...trades weaken...or reverse!
...countercurrent, warm $H_2O$ $\Rightarrow$ west
El Nino!

Note thermocline changes

FIGURE 7.28 (a) Average sea surface temperature departures from normal as measured by satellite. During El Niño conditions upwelling is greatly diminished and warmer than normal water (deep red color), extends from the coast of South America westward, across the Pacific.
(b) During La Niña conditions, strong trade winds promote upwelling, and cooler than normal water (dark blue color) extends over the eastern and central Pacific.
(NOAA/PHEL/TAO)
A strong ENSO event may trigger a response in nearly all areas shown; a weak event in only some areas. Note that the months in black type indicate months during ENSO; months in red type indicate the following year. (After NOAA Climatic Prediction Center.)

FIGURE 7.30 Typical winter sea surface temperature departure from normal in °C during the Pacific Decadal Oscillation’s warm phase (a) and cool phase (b). (Source: JISAO, University of Washington, obtained via the http://www.jisao.washington.edu/pdo/ Used with permission of N. Mantua.)

PDO-warm phase—warm surface water off west coast of NA—cooler than normal in central north Pacific

PDO-cold phase—cooler than average surface waters off west coast of NA; warmer than aver. in N. Cent. Pacific.

Winters cooler and wetter in NW N. Amer.; wetter in Great Lakes; warmer and drier in southern US.

Aleutian low strengthens—more Pacific storms into AK and Calif.

Drier in the Great Lakes; cooler and wetter in southern US.