Chapter 9: Wind: Small-scale & local systems

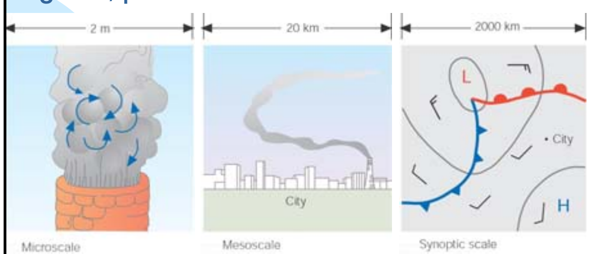
Scales of motion, turbulence
Microscale sculpts the Earth
Water waves excited by the wind
Measuring surface and upper level winds
Thermal circulations: sea breeze & monsoon
Air flow over a lake
Chinook
Radar winds
Monsoon and Santa Ana in SW United States
Dust devils
Wind power

Scales of motion (pp. 250-251)

- Atmospheric disturbances exist in all sizes
  Table 9. 1, p. 223: Bigger things last longer

What	Size	Life Span
Small eddies	cm to meters	Sec to min
Dust devils, tornadoes, thunderstorms	Meters to kilometers	Minutes to hours
Land/sea breeze, chinook, Santa Ana	10's of km to 100's of km	Hours
Tropical storms, hurricanes	100's of km	Days - week
H & L areas on TV weather	1000's of km	Days - week
"Long waves"	Planetary	Week or more

Names of Different Scales
Fig. 9.1, p. 222



Microscale (meters or less) | Mesoscale (1-100 km) | Synoptic scale (1000's km)

Turbulence (pp. 223-226)

- Irregular, 3D swirls, imperfectly predictable
- Most weather and many ocean disturbances involve turbulence
- **Mechanical turbulence** due to flow over or around rough objects (mountains, building, etc.) p. 223-224
- **Thermal turbulence** due to warm air rising and cold air sinking due to instability caused by surface heating and/or upper level cooling (infrared emission from cloud tops) p. 224
- **Clear Air Turbulence** (CAT) due to wind shear,i.e., change in wind speed &/or direction. p. 226
  (See story, p. 221. Wear safety belt on plane!)

Microscale sculpts Earth's surface (pp. 226-230)

- Wind can erode Earth's surface (see picture on p. 190) We've already mentioned clay dust in the air serves as ice nuclei.
- Creates ripples in sand as well as sand dunes (fig. 9.8, p. 228)
- Wind shapes snow on ground, e.g., snow drifts
  - Snow rollers: wind creates a roll of snow, just as a child might (fig. 9.9, p. 228)
- Wind can permanently bend trees (fig. 9.11)
- Windbreaks (shelterbelts): lines of trees to protect buildings or fields (fig. 9.12)

Water waves (p. 230)

- Most water waves are due to wind
- Wave activity depends on
  - wind speed
  - length of time wind blows over water
  - distance ("fetch") wind blows over water
- Extreme example: 50 kt wind blowing for 3 days over 1600 miles or more of ocean can generate waves 50 feet high
- Big waves rare in Gulf of Mexico: all three factors (wind speed, time, & fetch) are limited. Exception: Hurricane in Gulf of Mexico can generate large waves.

Measuring surface winds (pp. 233-234)

"Surface" winds are measured at 10 meters (~30 feet) above the surface. The most common tools are pictured below.

Cup anemometer & wind vane
Fig. 9.18, p. 233

Aerovane (speed & direction)
Fig. 9.19, p. 234

Measuring upper-level winds (p. 234)

Techniques:

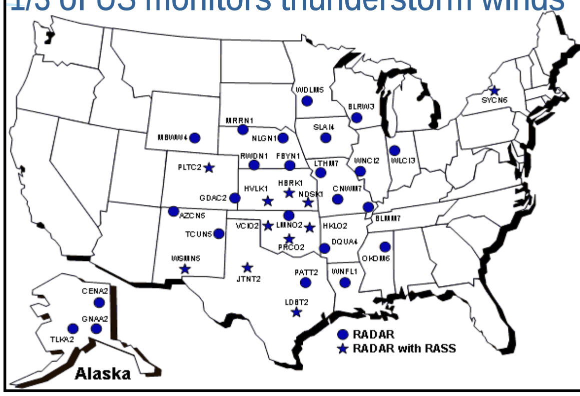
- Track radiosonde balloons or pilot balloons
- Track clouds in satellite pictures
- Get automated readings from equipment packages installed on many commercial aircraft (ACARS)
- **Profiler**: special continuously operating Doppler radar that gives speed & direction of wind at various levels from near surface up to 10 miles (16 km).

Profiler antenna at Haskell, OK

Profilers: www.profiler.noaa.gov

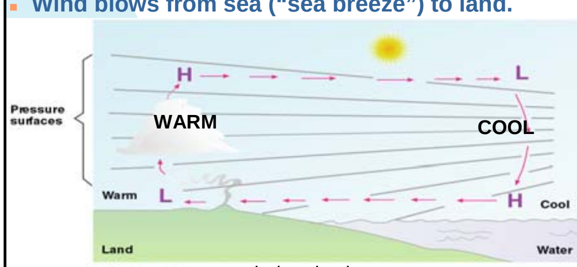
- National Weather Service "National Profiler Network" has 35 profilers. (Map on next slide.)
  - 32 in in middle third of US
  - 3 in Alaska
- Measure winds from 500 m to 16 km (10 miles) every 250 m continuously in time (reporting hourly).
- Particularly helpful in monitoring thunderstorms.
- In operation since 1988, continuously since 1992
- Other agencies operate profilers, too: Environmental Protection Agency (EPA), Federal Aviation Admin (FAA), Dept of Energy (DOE), Dept of Defense (DOD), etc.

National Profiler Network over central 1/3 of US monitors thunderstorm winds



Thermal Circulations: Sea and Land Breezes (pp. 236-240)

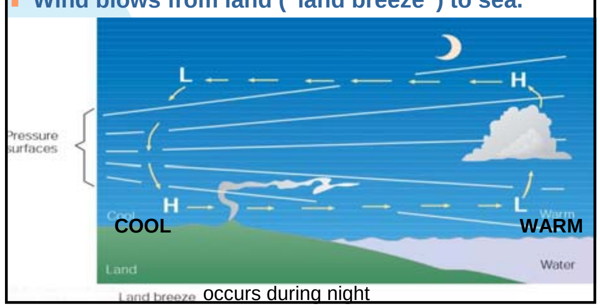
- **During daytime, land is warmer than water.**
- **Thunderstorms occur over land where air rises.**
- **Wind blows from sea ("sea breeze") to land.**



occurs during daytime

Land Breeze at Night (p. 237)

- **Land cools off more at night, so now water is warmer than land.**
- **Thunderstorms occur over water where air rises.**
- **Wind blows from land ("land breeze") to sea.**

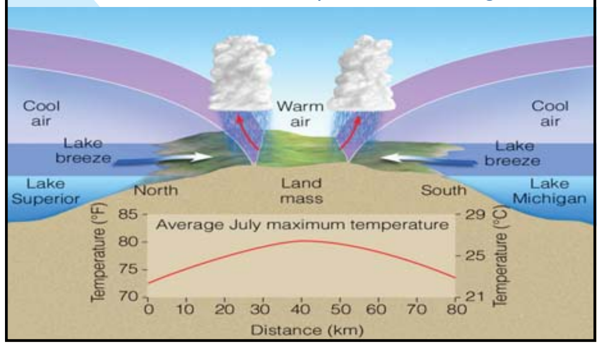


occurs during night

Florida sea breezes often converge from W & E over central FL (p. 240)

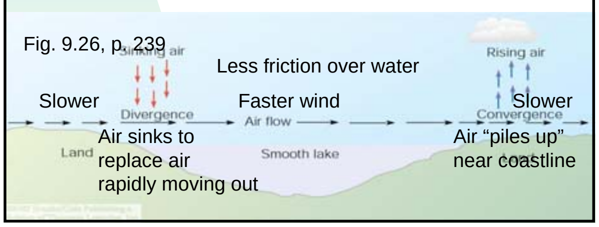
Sea breezes from 2 sides (fig. 9.24, p.239)

- Florida is not the only place to get sea breezes from two sides. This example is from Michigan.



Air Flow Over A Lake (pp. 239-240)

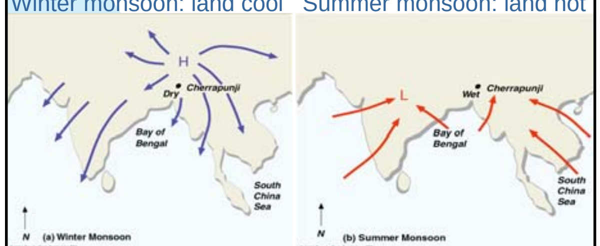
- Clearer sky where wind is leaving shore
- Cloudier & more precipitation where wind comes on shore
- More friction (slower wind) over land, less friction (faster wind) over water causes:
  - divergence and sinking where wind leaves shore
  - convergence and rising where wind reaches shore



Monsoon (pp. 240-242): Fig 9.27

- Like sea/land breeze but much larger & seasonal

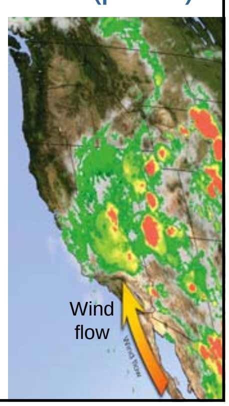
Winter monsoon: land cool Summer monsoon: land hot



Cherrapunji rainfall records: wettest year (87 FEET, Apr-Oct 1865) and wettest month (30.5 feet, July 1861)

Monsoon also in southwest US (p. 242)

- In summer, southwest US gets hot.
- "Thermal low" develops at surface, i.e., low pressure caused by same thermal process that causes low pressure over hot land in other contexts, like sea breeze. See fig. 9.22, p. 237.
- Air is pushed from higher pressure over the waters by Baja California toward the low pressure over the SW.
- Moist, warm air rises over SW US, creating rain, as seen in red in the enhanced satellite picture shown at right (fig. 9.29, p. 242).

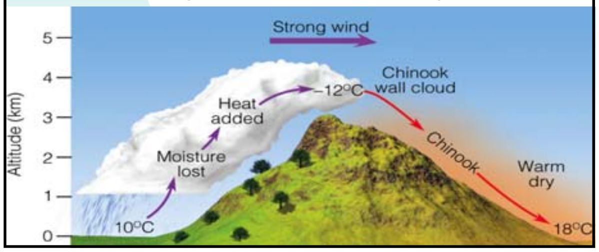


Chinook (pp. 244-245)

- Read these notes about the chinook before studying the text. The book mentions the two kinds of chinooks (with and without rain) but could do a better job distinguishing them.
- Chinook: warm, dry wind flowing down east side of Rockies. Named after Chinook Indian tribe in Pacific Northwest.
- Similar dry winds blowing down mountains exist elsewhere in the world and have their own regional names. Examples: two of the German names for chinook are "schneefresser" ("snow eater") and "foehn," also spelled föhn.
- Two kinds of chinooks: with and without rain

Chinook with rain (fig. 9.33, p. 244)

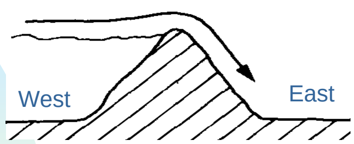
- Air flows up a mountain. The air expands as it moves up into lower pressure. Expansion involves work, which cools the air.
- The cooled air reaches saturation and condensation forms, releasing latent heat into air on uphill side.



Chinook with rain (cont.)

- The cooling experienced by the air as it goes up the mountain is reversed as the air is compressed going down the mountain.
- Net effect on the air after passing over the mountain:
  - air is fairly dry because moisture rained out on the upwind side.
  - air is warm (sometimes considerably warmer) because of release of latent heat from condensation on the upwind side.

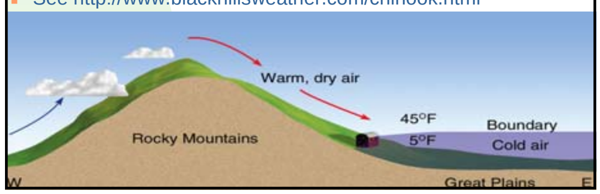
Chinook without rain (fig. not in book)



- Sometimes air to west of mountain only flows over mountain if it is above the mountain top; air below mountain top stays on west side.
- As upper-level air flows down mountain, it is compressed. Compression does work on air, heating it. Air is dry because it started cold, and cold air never has much moisture.

Chinooks can cause extreme temperature changes (p. 245)

- Extreme temperature fluctuations occur when boundary between warm chinook and cold air sloshes back and forth
- Extreme example: Morning of 22 January 1943 in S Dakota
  - Spearfish, SD: -4°F at 7:30 am, 45°F at 7:32 am, 54°F at 9:00 am, -4°F at 9:27 am
  - Rapid City: -4°F at 5:30 am, 54°F at 9:40 am, 11°F at 10:30 am, 55°F at 10:45 am
- See http://www.blackhillsweather.com/chinook.html



Santa Ana wind (pp. 245-247)

- Hot dry wind from E or NE in southern California.
- Funnels through valleys such as Santa Ana Canyon.
- Similar cause as chinook without rain: Air flows down elevated desert plateau and is warmed by compression as it descends.
- Especially in fall, these hot dry winds fan fires that threaten Los Angeles area.
- Santa Ana winds drove much of the wild fires in California in fall 2003: 13 dead, 650 homes burned

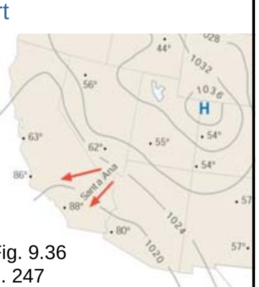


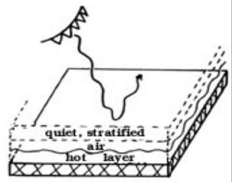
Fig. 9.36
p. 247

Dust Devil (pp. 248-249, fig. 9.39)

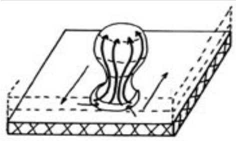
- Usually smaller, weaker, and shorter lived than a tornado. Rotation in either direction equally likely.
- Rises up from ground.
- Not a tornado, which descends from base of a thunderstorm
- Usually forms on a hot sunny day in desert (even on Mars, see p. 249) as unstable bubble of twisting air rises. (Details on next 2 slides.)
- For more information, see: text for fig. 9.39, p. 248 and http://newsletters.britannica.com/august_articles/whirlwind.htm

Dust Devil formation

- Overnight cooling creates stable layer of air near surface a couple meters thick; less stable air above.
- Heating of surface by sun makes layer right next to surface (1m or so thick) unstable. Thin layer of stable air still lies above.
- Unstable air near surface rises. If it rises fast enough, it can punch through the stable layer of air and continue to rise into the less stable air above.
- Same "punch through" principle on larger scale in moist conditions is how a severe thunderstorm can develop.

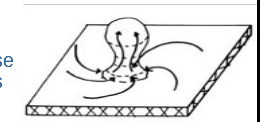


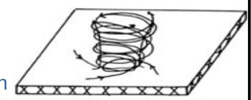
Sun heats air nearest ground


Wind or other disturbance causes hot air bubble to break through to stratified layer

Dust Devil: rotation

- Air is turbulent, meaning that there are usually swirls.
- The rate of any swirling will increase as the rising bubble of air contracts horizontally as the bubble is stretched vertically. Similar to tetherball spinning faster as rope length gets shorter or figure skater spinning faster as she pulls in her arms.
- Same principle of increased spin by vertical stretch helps storms grow on east side of Rocky Mountains.
- Drawings from: www.gi.alaska.edu/ScienceForum/ASF2/227.html


Hot, near surface air swirls into low pressure zone below bubble


Like a tether ball, the air moves faster as it approaches the center, then spirals rapidly upward to maintain the dust devil

Wind Power & Wind Mills (p. 235)

- Small wind mills pump water on farms.
- Large wind mills (“wind turbines”) in big groups (“wind farms”) generate electricity.
- Wind farms started in early 1970’s after Arab oil embargo greatly raised price of petroleum.
- Only practical where wind speeds are steady and moderately strong. Gusts that are too fast can damage the wind turbines. Winds that are too slow produce little to no power.
- For more info, search Web for “wind power”.

Wind Farms (p. 235)

- Wind farms utilize renewable energy BUT are expensive, noisy, ugly, and deadly to birds.
- Largest wind farm at Altamont Pass, CA (see below) near San Francisco kills 900-1300 birds of prey each year, including ~75 golden eagles/year.
- Not so romantic to people who live close to windmills.