Wind Energy

1. Wind Resource
2. Physics of extracting energy from the wind by using wind turbines
3. Wind turbine types and technologies, and their performance
4. Wind turbine systems and applications

1. Wind Resource
   Read §7.3

   A. Global Wind Patterns
      See Fig 7.8, p 273
      Main features of global winds:

      i. Warm air rises high into the atmosphere in the equatorial regions of the planet. The equator is a region of "permanent low pressure" at the surface.

      ii. The equatorial air that has risen high into the atmosphere flows north and south. Some of it "falls" to the ground at about 30°N and 30°S, creating "permanent high pressure" at the surface at those latitudes.

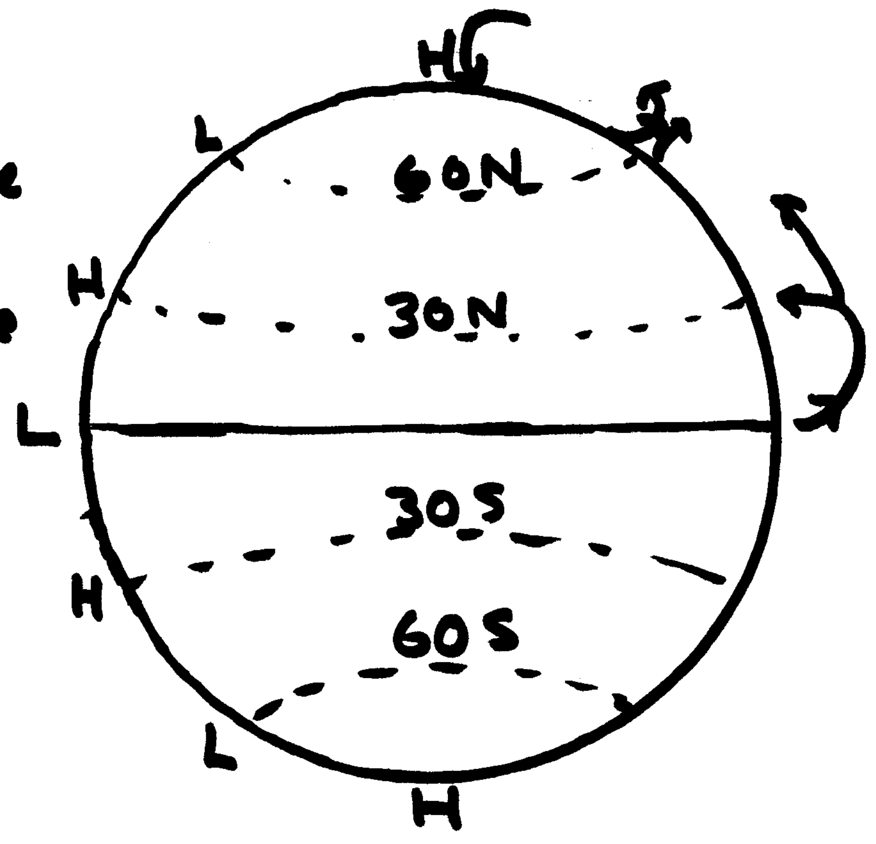
iii. The remainder of the air high in the atmosphere continues north and south.

iv. The poles are also regions of permanent high pressure. This occurs because the cold air is dense and "falls to" the ground.

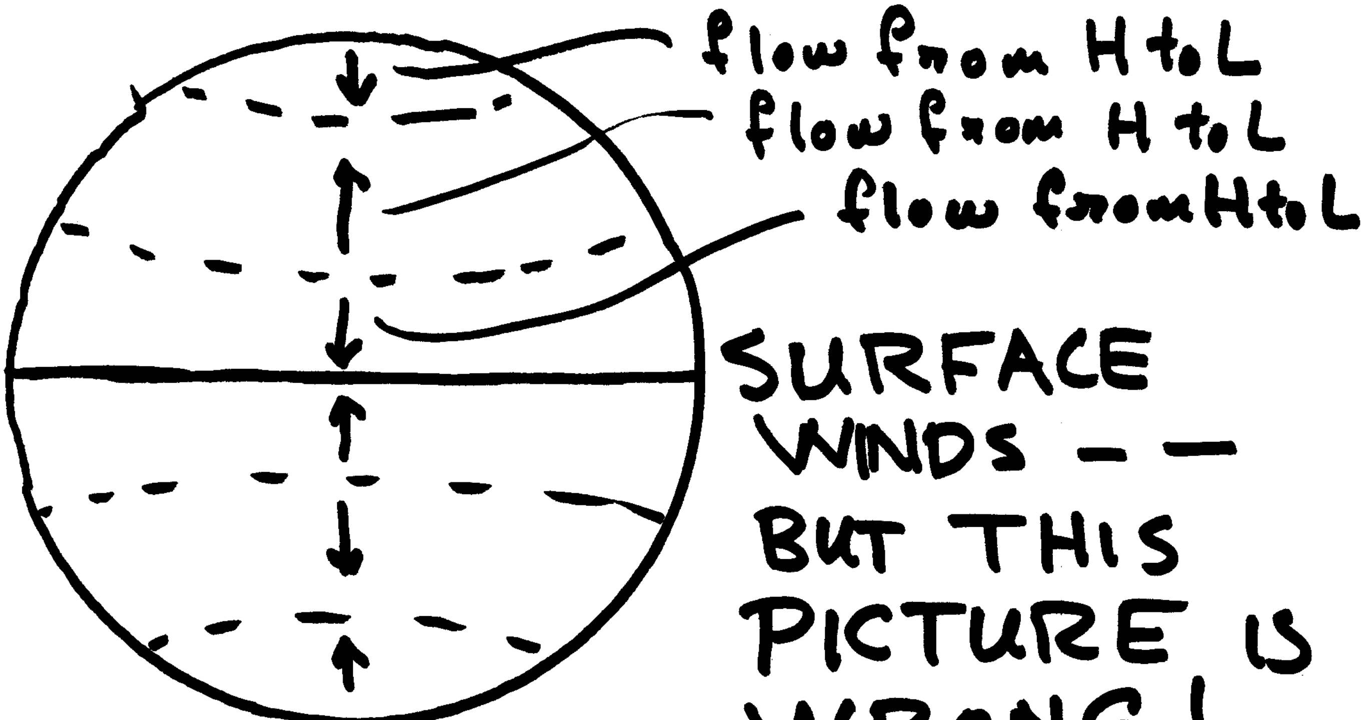
v. At about 60° N and 60° S air rises into the atmosphere, creating permanent low pressure.

L = low pressure = rising air

H = high pressure = falling air

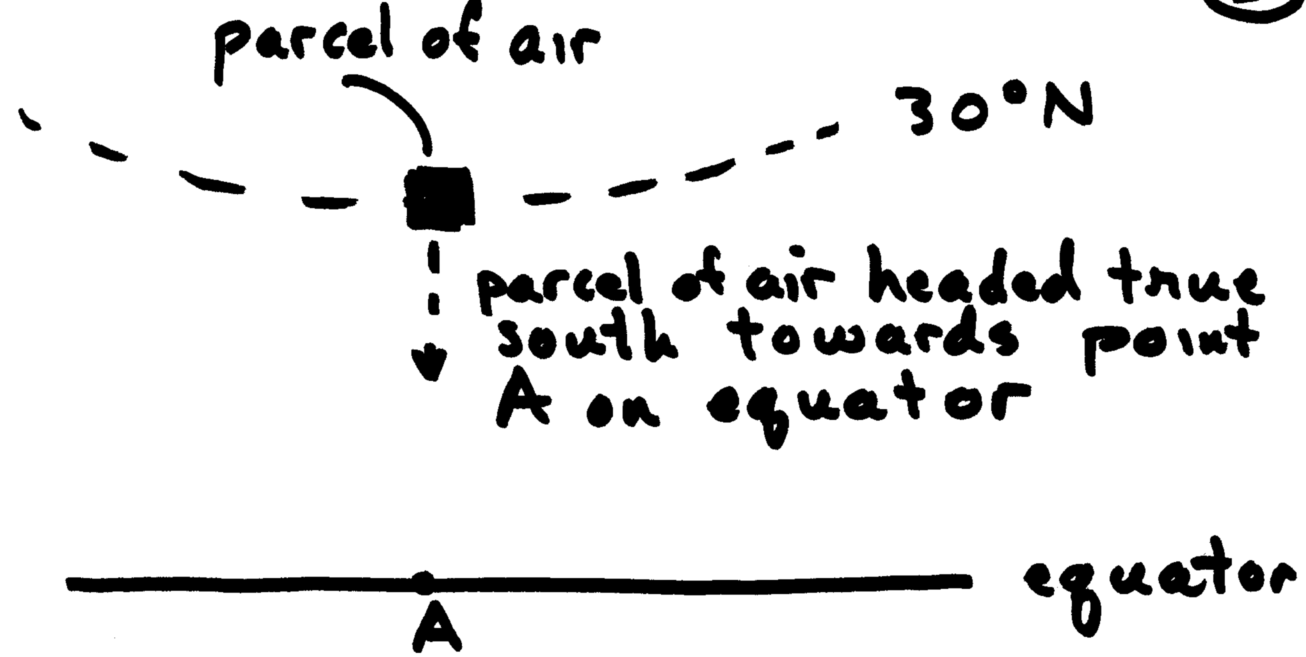


Because of permanent high and low pressure zones, one might expect the surface winds to look like the following:

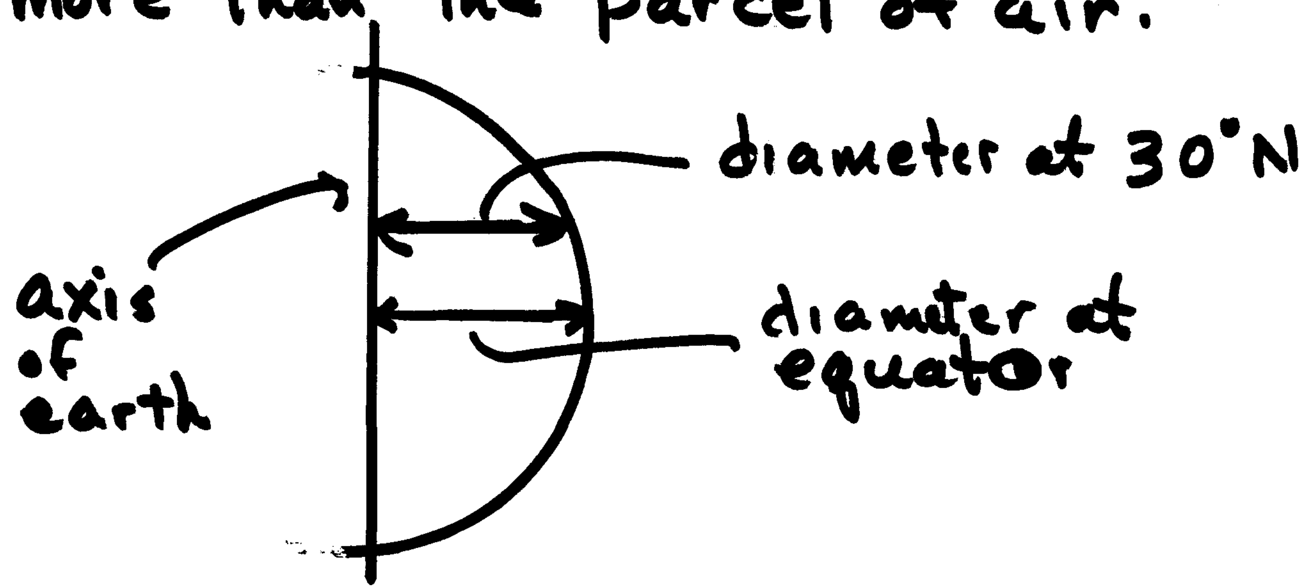


SURFACE WINDS -- BUT THIS PICTURE IS WRONG!

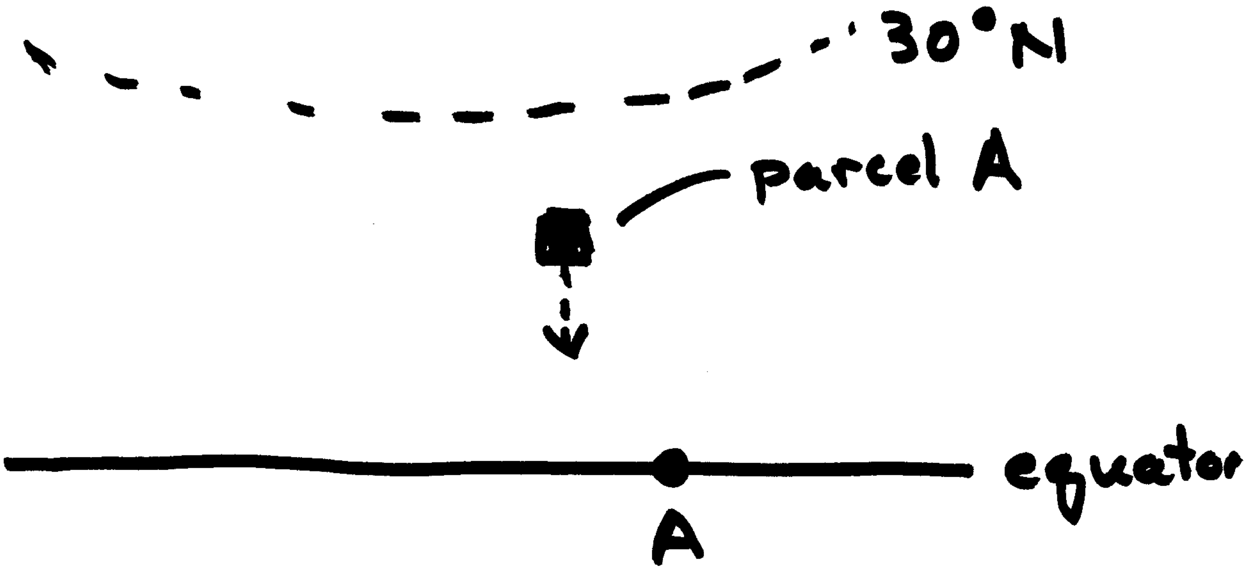
This picture is wrong because it doesn't consider the Coriolis force. The Coriolis force may be visualized by considering a parcel of air moving south from 30°N towards the equator:



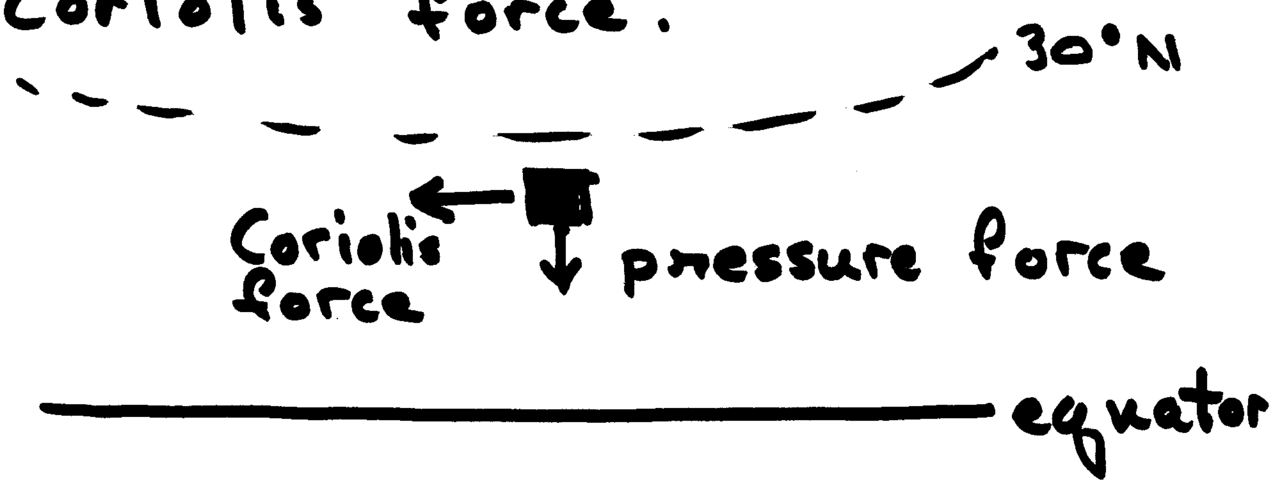
It takes considerable time for the parcel of air to flow to point A, and during this time the earth rotates about its axis. Because the diameter of the earth is greater at the equator than at 30°N, point A moves to the right (to the east) more than the parcel of air.



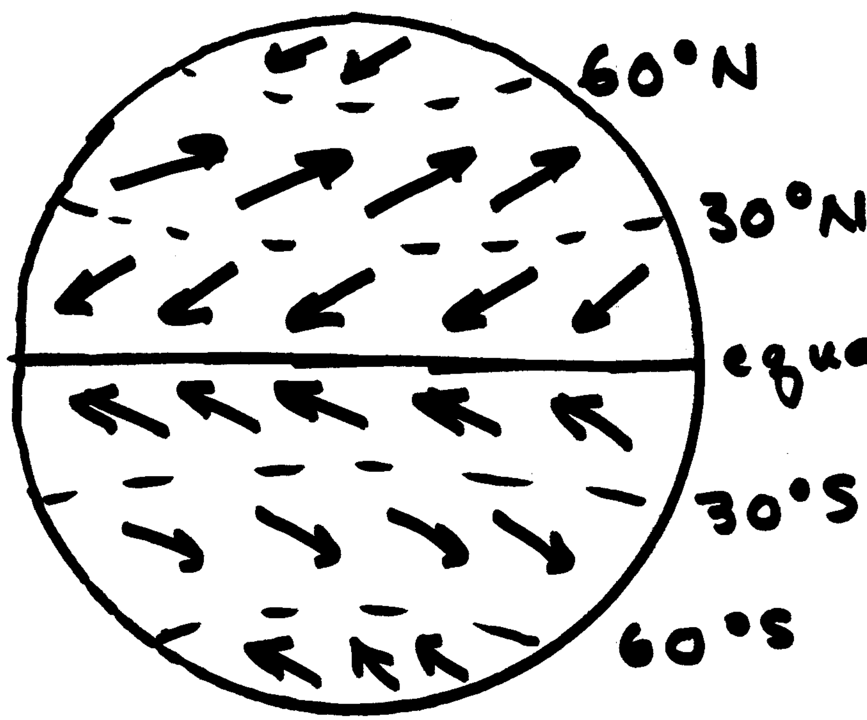
Thus, at a later time, our picture of the parcel of air is as follows:



Viewed from the surface of the earth, the parcel of air has a force on it acting to the left. This is the Coriolis force.



With the Coriolis force included, the global surface wind patterns appear as shown below (also, see Fig 7.8, p 273 of text).



This pattern of global winds is most strongly obtained over the oceans -- large masses of land tend to distort the global wind patterns.

The global wind patterns result in the following features:

1. Strong trade winds at about 20°N (northeastly trade winds) and 20°S (southeastly trade winds).
2. Strong westerlies as 60°N is approached from the south, and as 60°S is approached from the north. The 60°S winds are especially prominent since much of the southern hemisphere is ocean. The 60°N winds can be diminished over the large land masses of Siberia and Canada,

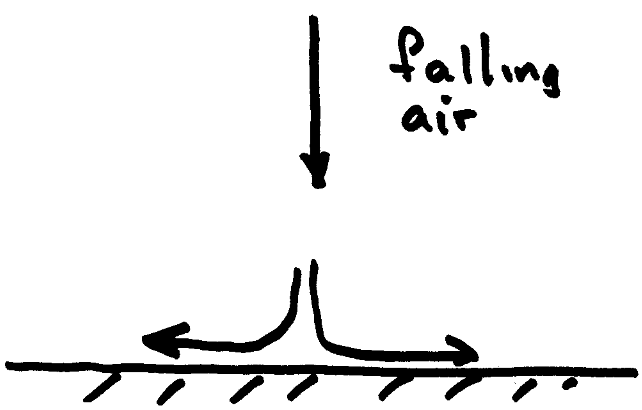
as cold, dense, slowly moving air from the artic moves in and takes over. The Pacific Northwest can experience this effect in the winter when clear, cold weather moves in from central Canada and blocks the westerly flow of air from the Pacific.

3. Because of the permanent high pressure at 30°N and 30°S, the deserts of the planet tend to be located at these latitudes. The global winds tend to be weak here. These regions are good for direct solar energy, but typically are not good for wind energy unless local effects (see below) create winds.

4. Low winds are also experienced at the equator -- the "doldrums".

We now turn to the regional high and low pressure patterns. For example, see the weather map on p 272 of text, Fig 7.7.

High pressure system - viewed from the side



K.E. + P.E. + T.E. = constant

K.E. = kinetic energy

P.E. = potential energy

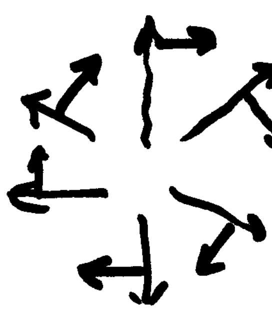
T.E. = thermal energy

As the parcel of air falls, it loses PE. As it approaches the ground, its KE (i.e. velocity) decreases. Thus, the PE & KE are converted to thermal energy, and the parcel of air heats up as it falls.

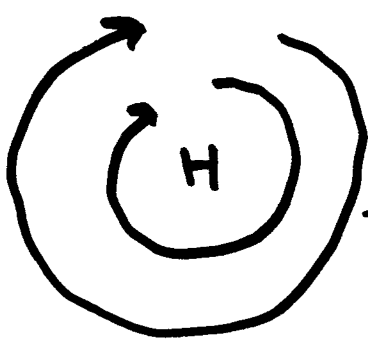
The water vapor in the parcel moves farther away from its due point. The sky becomes clear.

The surface winds in the northern hemisphere are clockwise

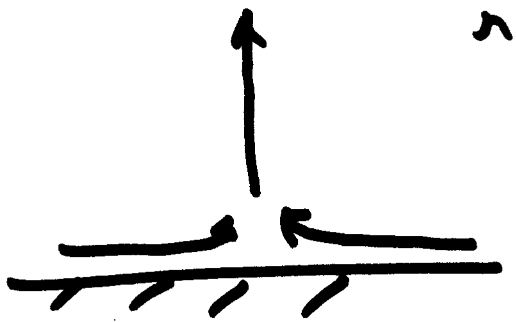
View from top:



result

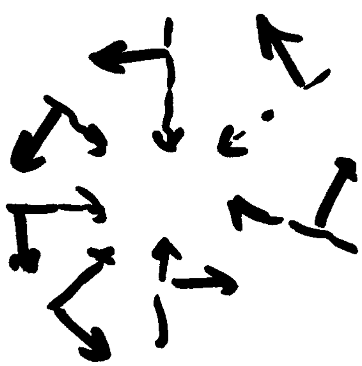


For a low pressure system:
View from side:

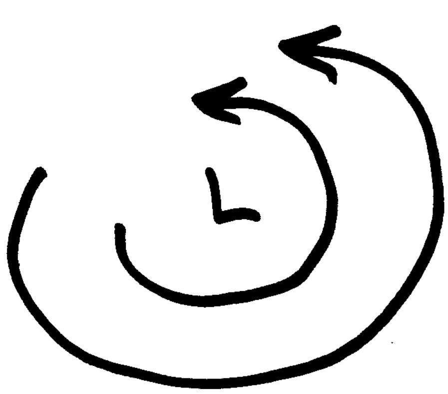


rising air:
KE ↑, PE ↑, TE ↓
air cools as it rises, reaches dew point, and precipitation occurs

top-view (Northern hemisphere):



Coriolis force (in southern hemisphere, force is in opposite direction - flow is clockwise)



flow around low pressure -
as move away center, pressure increases

These zones of high and low pressure, as they move across the surface of the earth, create alternating patterns of calm (H pressure) and wind (L pressure). The relative spacing of the H and L centers and their relative strengths affect the wind speed.

Topographic effects:

1. Sea-land interaction: During the day, the air over the sea tends to be cooler, and thus, denser than the air over the land. The denser sea air pushes inland, creating "on-shore" wind.

At night, a reverse flow is created, as the land cools more than the sea. Now the air over the land is denser than the air over the sea, and an "off-shore" wind is created. See Fig. 7.9.

2. Mountain-valley internation: During the day, due to the heating of the land, warm air is created. This warm air flows up-hill. At night a reverse flow is created, as cool air flows down-hill. See Fig. 7.10.