Atmospheric Pollution

Lecture 10

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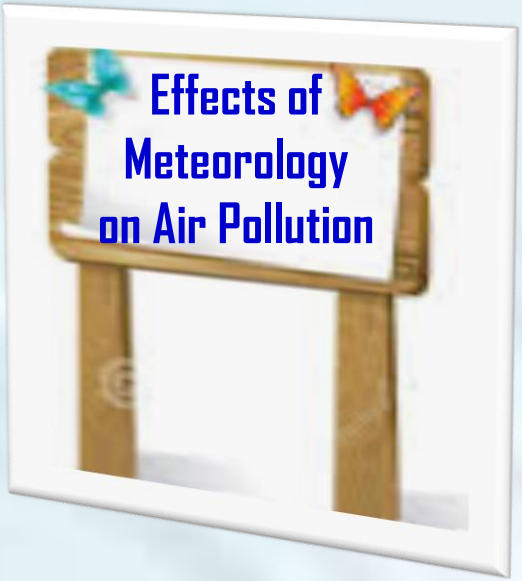


In this chapter, the effects of meteorology on air pollution are discussed.

The concentrations of gases and aerosol particles are affected by winds, temperatures, vertical temperature profiles, clouds, and the relative humidity.

These meteorological parameters are influenced by large-and small-scale weather systems.

Large-scale weather systems are controlled by large-scale regions of high and low pressure.

Small-scale weather systems are controlled by ground temperatures and small-scale variations in pressure.

The forces acting on air

how forces combine to form winds

how radiation, coupled with forces and the rotation of the Earth,generates the global circulation of the atmosphere.

The two major types of large-scale pressure systems

The effects of such pressure systems on air pollution

The effects of local meteorology on air pollution.

How the atmosphere moves

Winds arise due to forces acting on the air

Major Forces

$$\frac{dv}{dt} = \sum \mathrm{F}$$

The pressure gradient force (PGF)

The force is proportional to the difference in pressure divided by the distance between the two locations and always acts from high to low pressure.

Coriolis Force

We can apply Newton's second law of motion in a rotating coordinate system to an object at rest with respect to that rotating reference frame by including the centrifugal force, which is an apparent force.

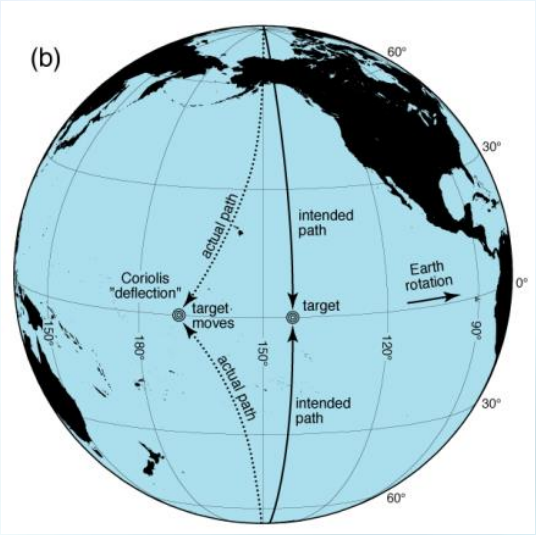
If the object is moving with respect to the rotating reference frame, an additional apparent force is required for Newton's second law to be valid. This is the Coriolis force.

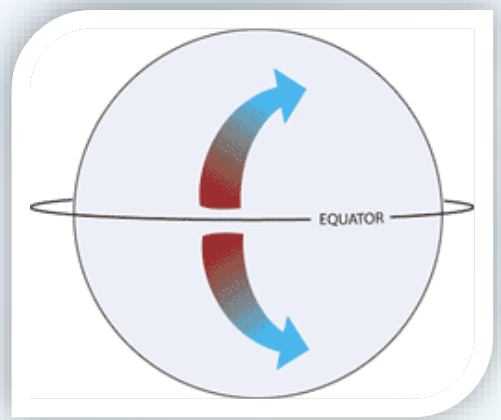
Coriolis Effect

Coriolis force only changes *direction*, not *speed* magnitude depends on *latitude*, and *wind speed*

Always acts to the right of the motion in Northern Hemisphere.

Always acts to the left of the motion in the Southern Hemisphere.

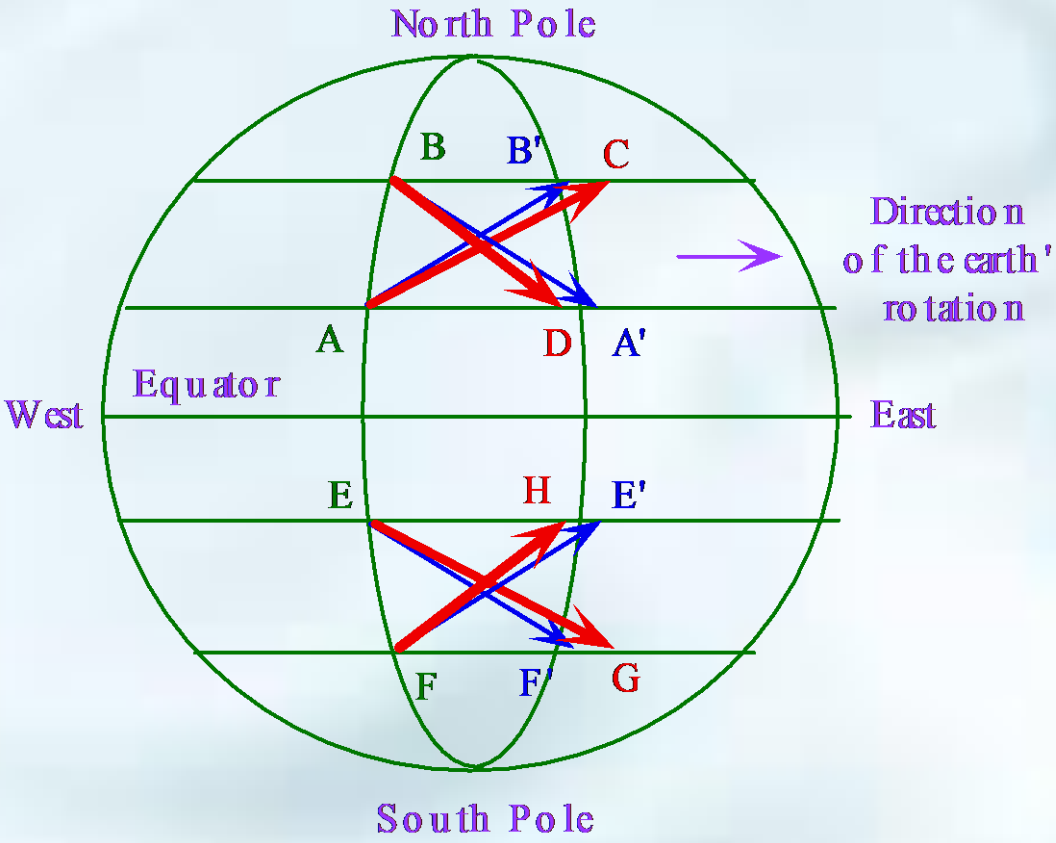


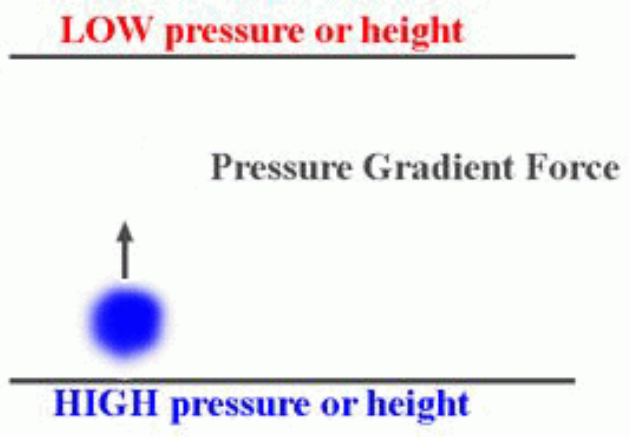


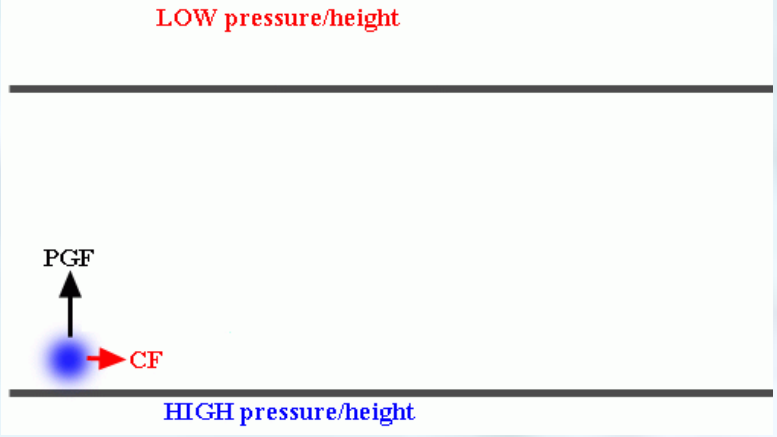
Apparent Coriolis Force (ACoF)

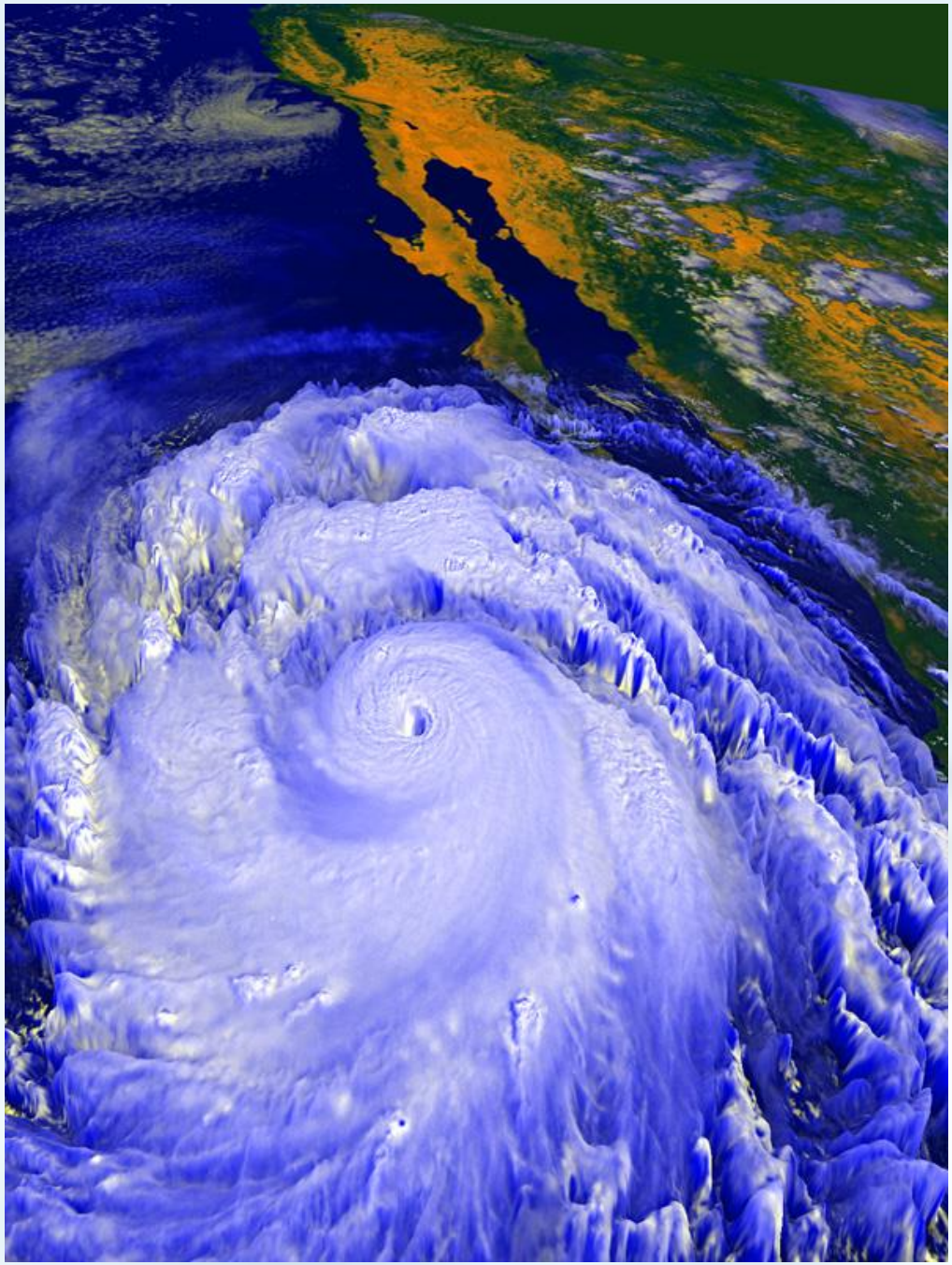
When air is in motion over a rotating Earth, it appears to an observer fixed in space to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere by the apparent Coriolis force (ACoF).

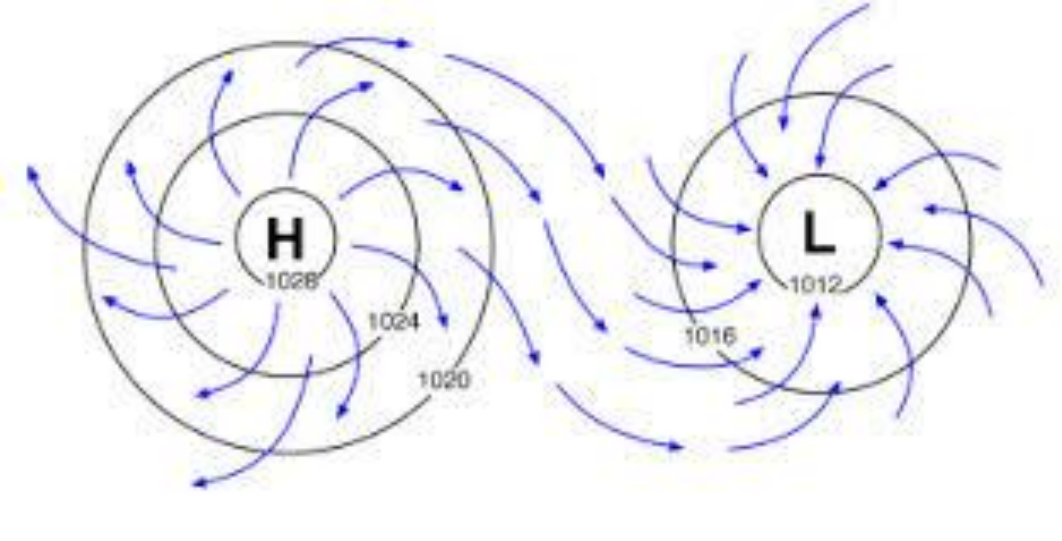
The ACoF is not a real force




LOW pressure or height
Pressure Gradient Force
HIGH pressure or height


LOW pressure/height
PGF
CF
HIGH pressure/height

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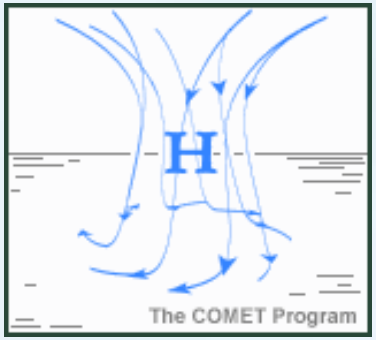
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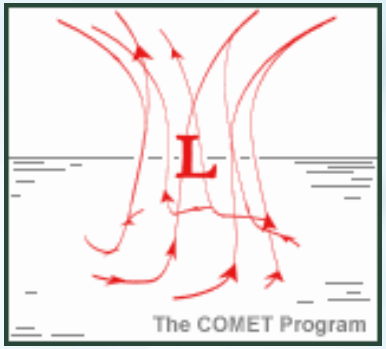
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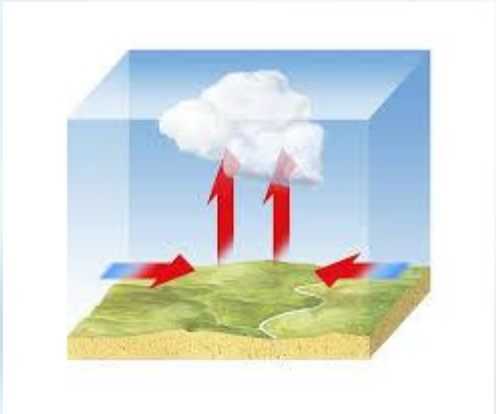
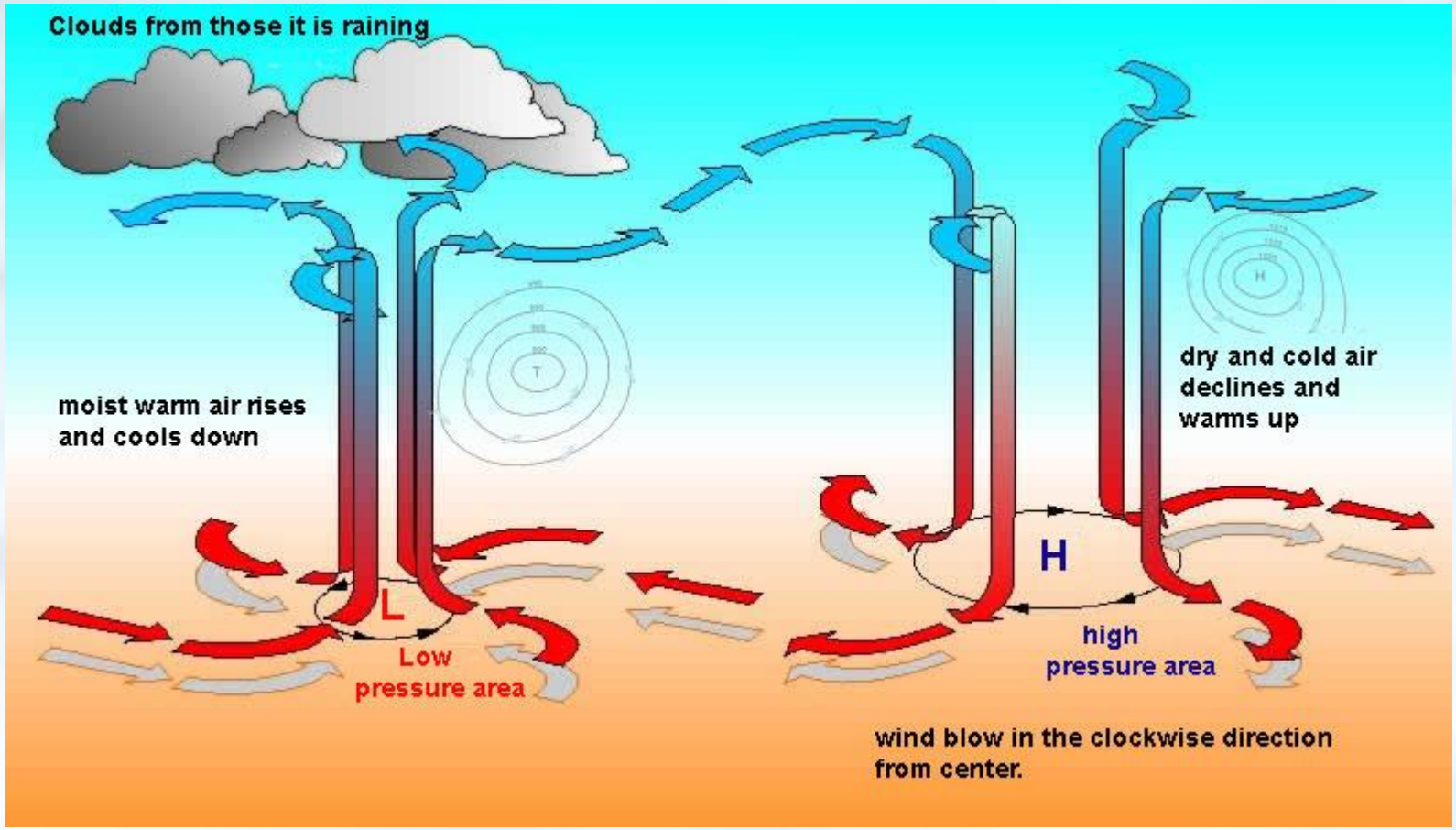



Clouds from those it is raining
moist warm air rises
and cools down
L
Low
pressure area
H
high
pressure area
dry and cold air
declines and
warms up
wind blow in the clockwise direction
from center.

Friction Force (FF)

A third force that acts on moving air is the friction force (FF).

This force is important near the surface only.

The FF slows the wind.

Its magnitude is proportional to the wind speed, and it acts in exactly the opposite direction from the wind.

The rougher the surface, the greater the FF.

The FF over oceans and deserts is small, whereas the FF over forests and buildings is large.

Apparent Centrifugal Force(ACfF)

A fourth force, which also acts on moving air,

The force arises when an object rotates around an axis

The apparent force is directed outward, away from the axis of rotation

When a passenger in a car rounds a curve, for example, a viewer travelling with the passenger sees the passenger being pulled outward, away from the axis of rotation, by this force. By contrast, a viewer fixed in space sees the passenger accelerating inward due to a centripetal acceleration, which is equal in magnitude to but opposite in direction from the apparent centrifugal force.

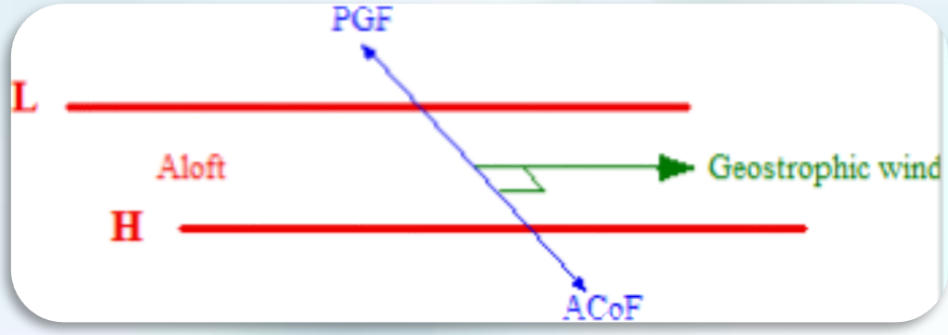
WINDS

The major forces acting on the air in the horizontal are the PGF, ACoF, FF, and ACfF.

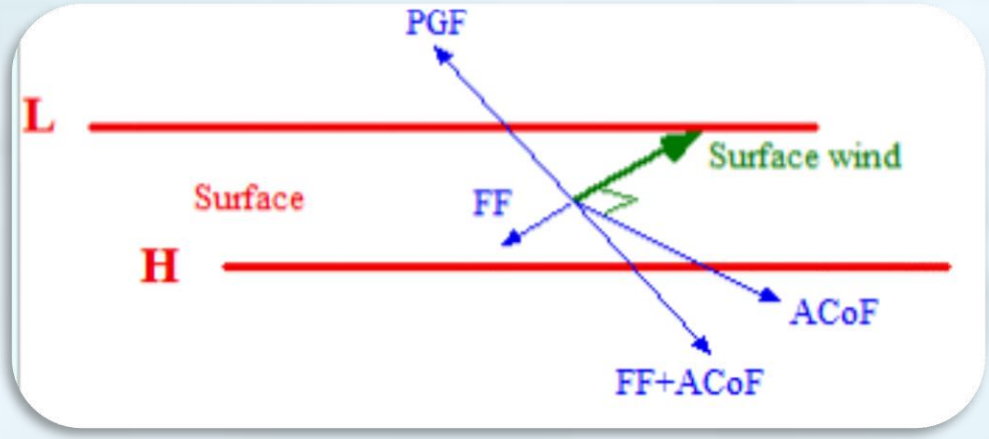
In the vertical, the major forces are the upward-directed vertical pressure-gradient force and the downward-directed force of gravity

These forces drive winds

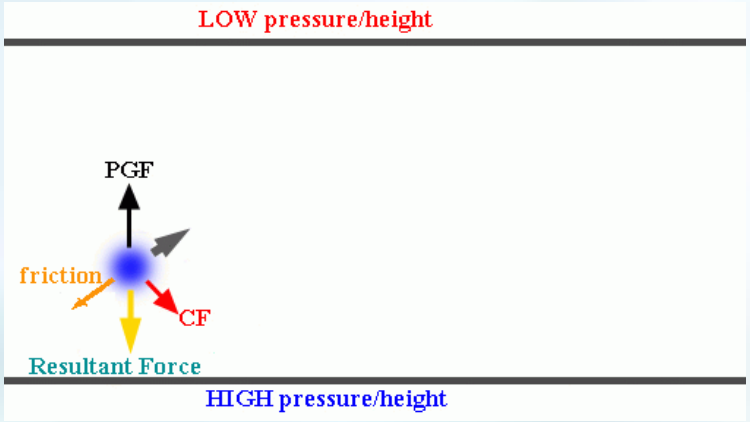
Geostrophic Wind



Surface Winds along Straight Isobars



On average, surface friction turns winds 15 to 45 toward low pressure, with lower values corresponding to smooth surfaces and higher values corresponding to rough surfaces.

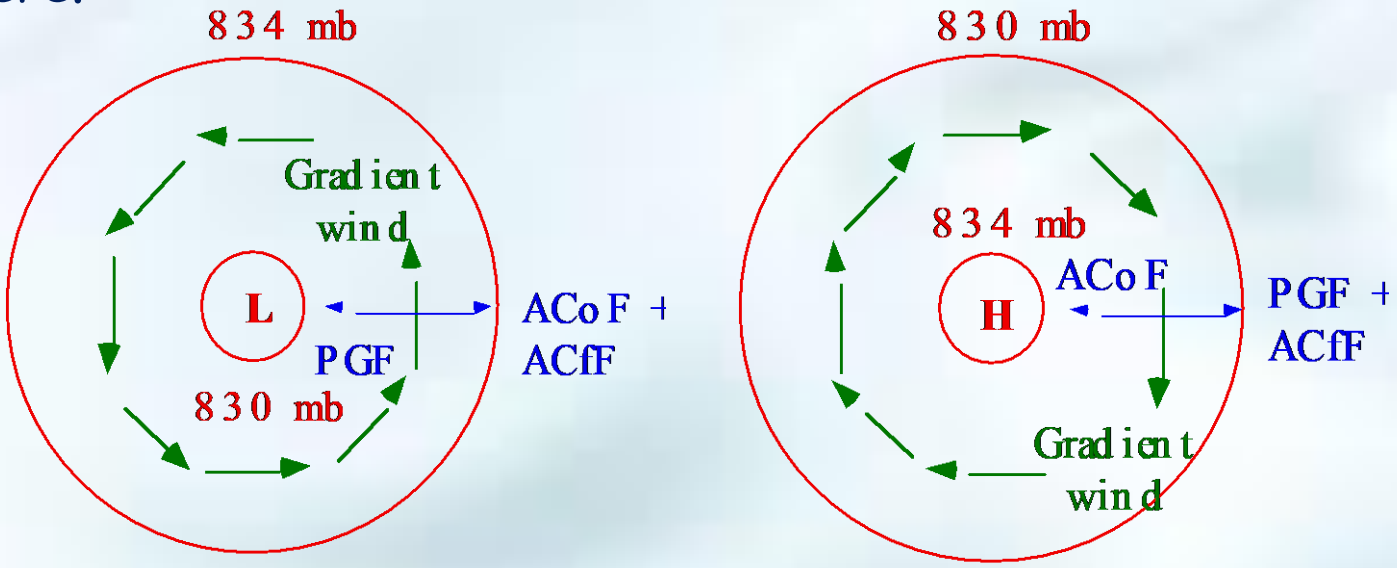


Gradient Wind

When centers of low and high pressure exist aloft, the wind is controlled by the PGF, ACoF, and ACfF. The resulting wind is the gradient wind

For a low-pressure center, the PGF acts toward and the ACfF acts away from the center of the low.

Balance requires that the ACoF also oppose the PGF. Figure shows the resulting counterclockwise (cyclonic) gradient wind in the Northern Hemisphere.



Surface Winds along Curved Isobars

Near the surface, the FF affects the flow around centers of low and high pressure.

A surface low-pressure center is a cyclone, and a surface high-pressure center is an anticyclone. Figure shows the force balances and resulting winds in the presence of a surface (a) low-pressure system and (b) high-pressure system in the Northern Hemisphere.