Lecture for Labs 7-8

GEOL 1147: Introduction To Meteorology Lab

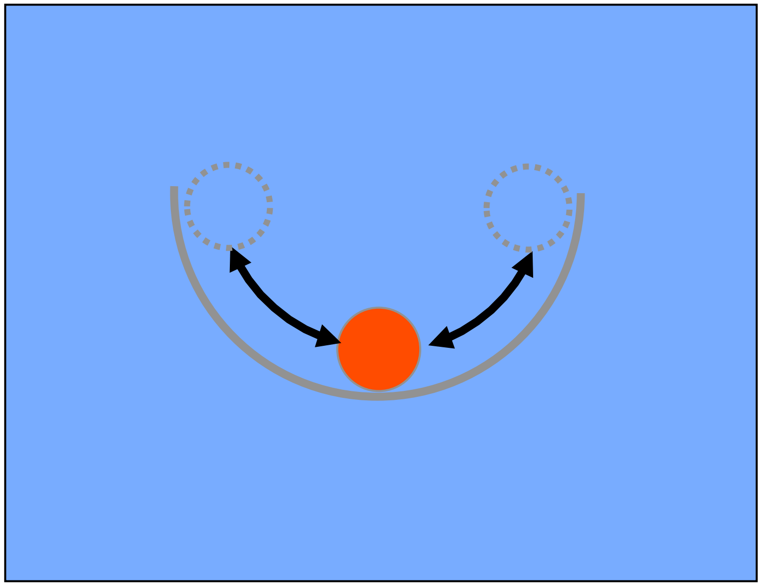
Lab 7

Stability of Atmosphere

- The ability of the air to return to its origin after displacement
- Depends on the thermal structure of the atmosphere
- Classified into three categories
  - Stable
  - Neutral
  - Unstable

Stable

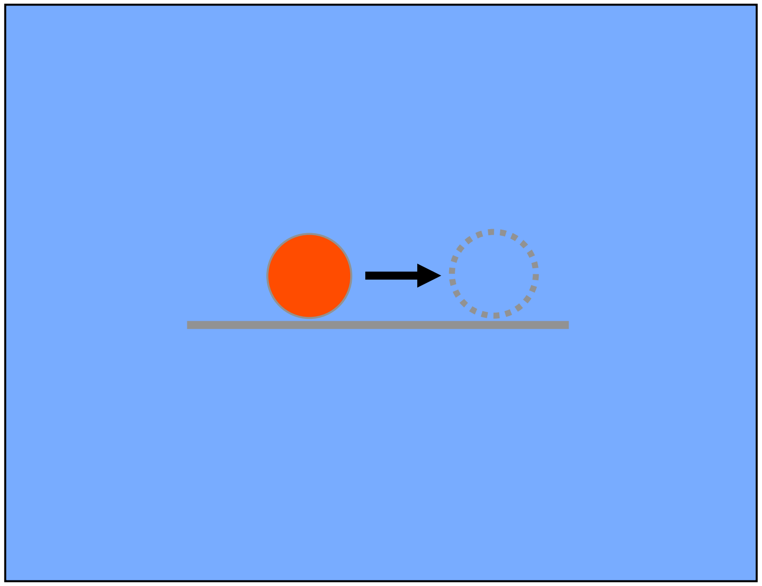
- Returns to original position after displacement



(courtesy F. Remer)

Neutral

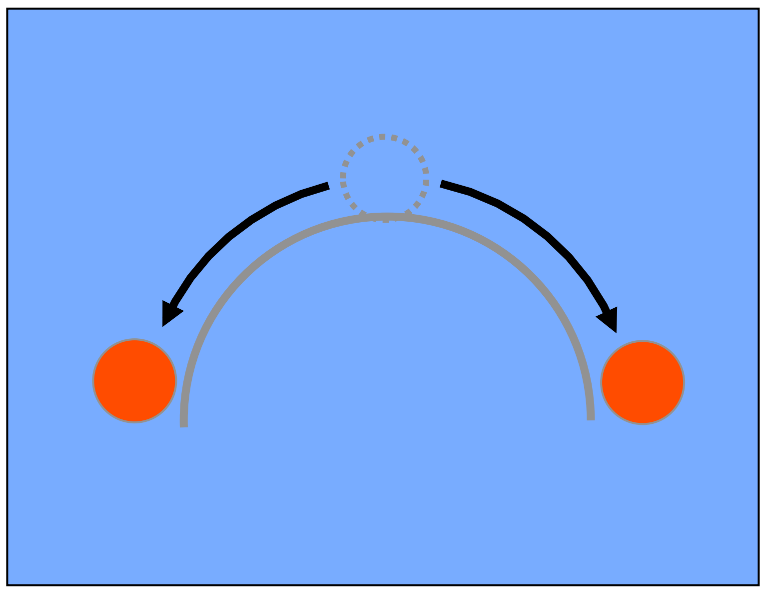
- Remains in new position after being displaced



(courtesy F. Remer)

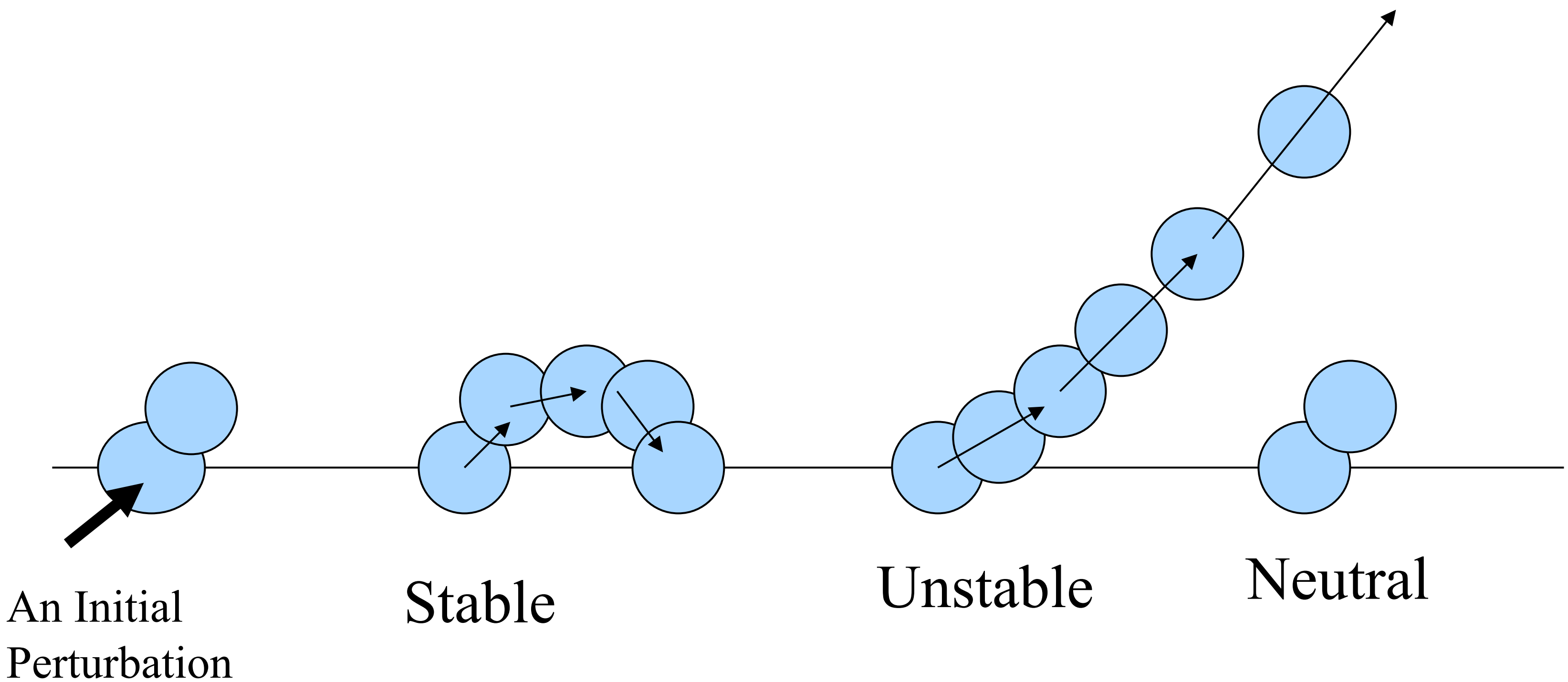
Unstable

- Moves farther away from its original position



(courtesy F. Remer)

Stability in the atmosphere



If an air parcel is displaced from its original height it can:

Return to its original height - Stable

Accelerate upward because it is buoyant - Unstable

Stay at the place to which it was displaced - Neutral

Stability of air parcel under the given environment

- A property of the environment
- *Stable* - displacement results in return to initial condition
- *Unstable* - displacement results in further displacement from initial condition

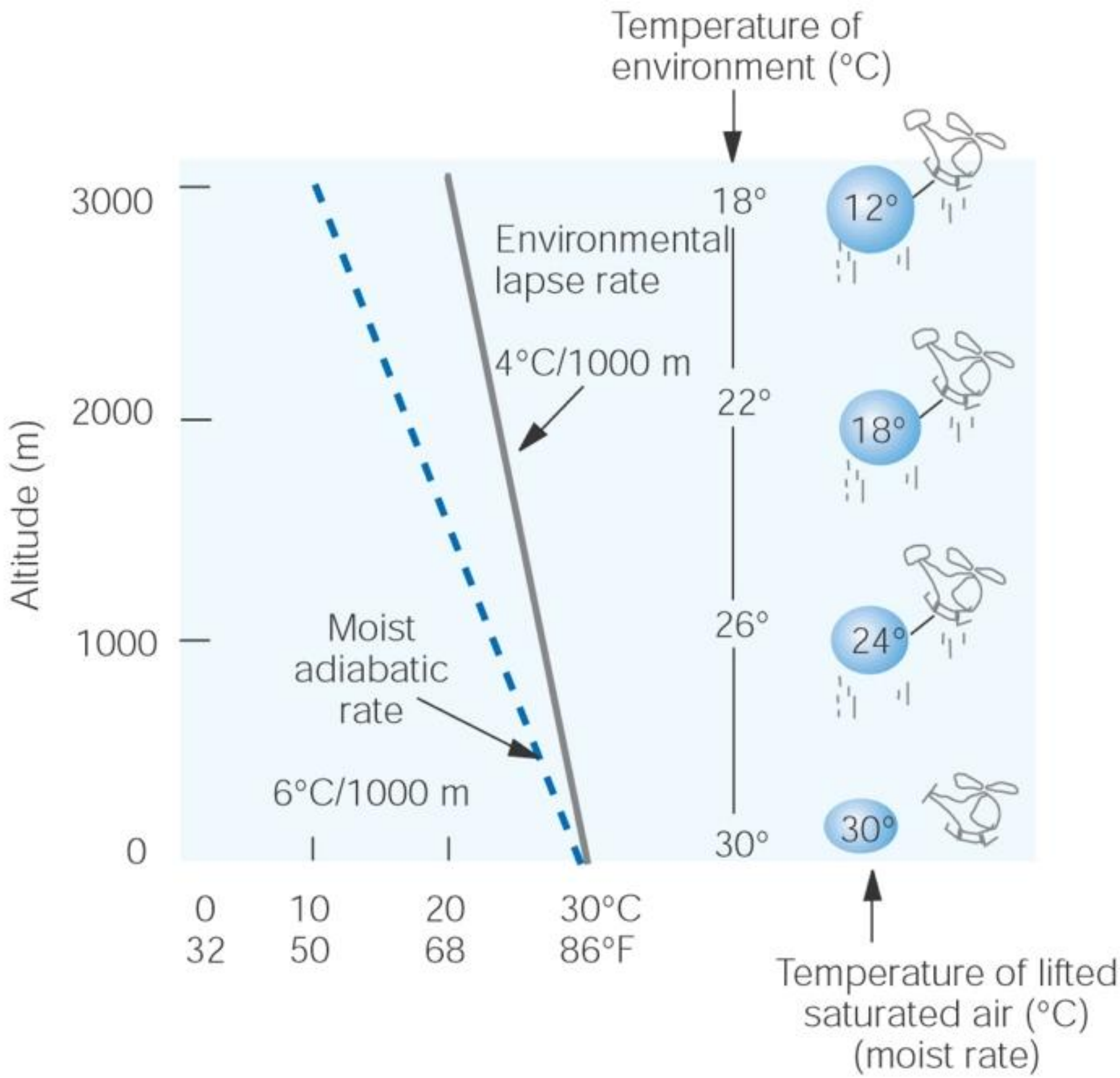
Stability is determined by comparing parcel's temperature with that of its environment

Simply speaking,

$T_{parcel} > T_{env}$ unstable

$T_{parcel} < T_{env}$ stable

$T_{parcel} = T_{env}$ neutral

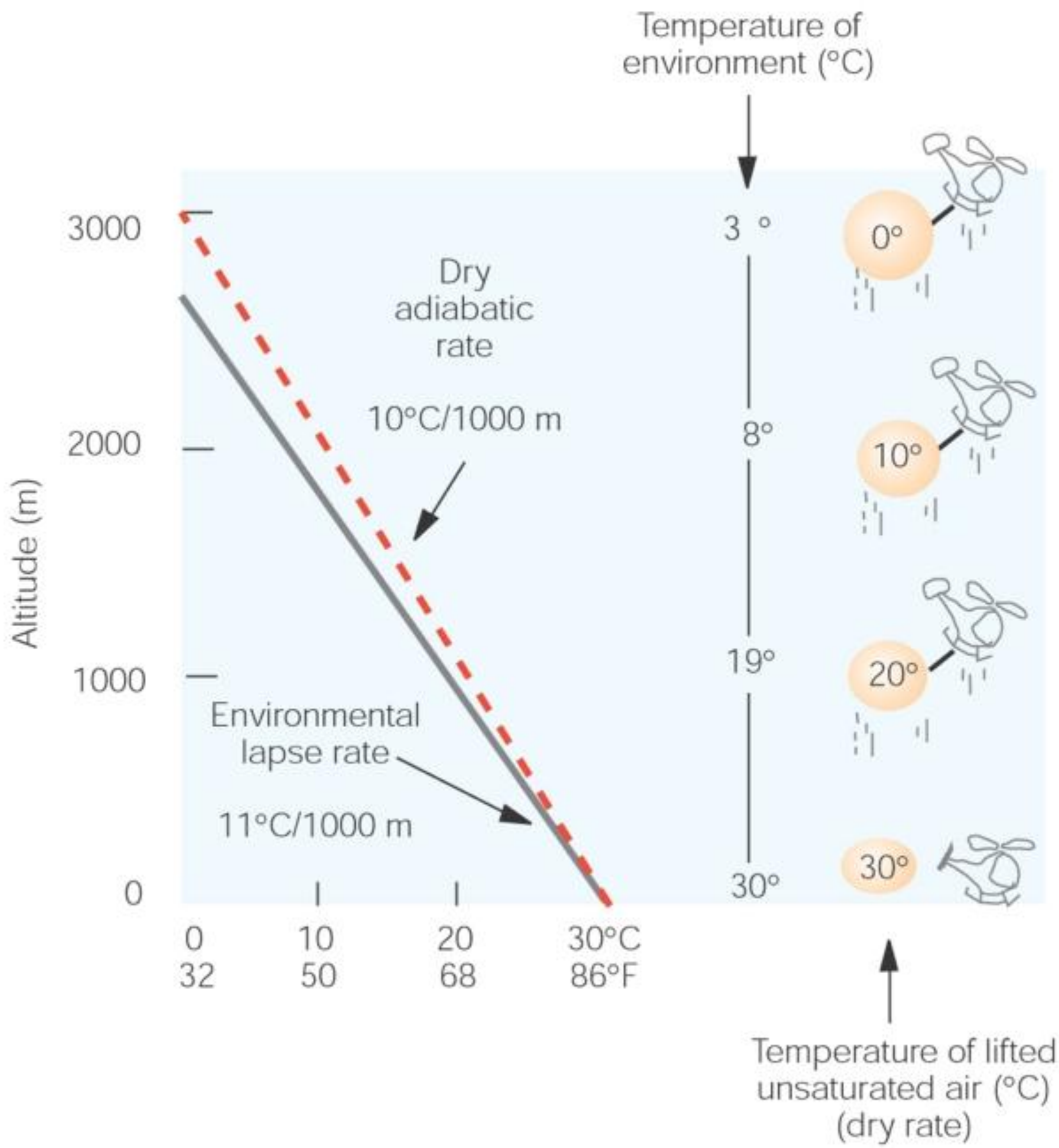


Lifted, saturated air at each position is colder and heavier than the air surrounding it. If released, the parcel would return to its original position.

Moist adiabatic lapse rate and stability

- –A rising saturated air parcel cools according to the moist adiabatic lapse rate
- –When the environmental lapse rate is smaller than the moist adiabatic lapse rate, the atmosphere is termed *absolutely stable.*
- – Recall that the dry adiabatic lapse rate is larger than the moist adiabatic lapse rate, so when the environmental lapse rate is less than the moist adiabatic lapse rate, it also smaller than the dry adiabatic lapse rate

Absolutely Unstable Atmosphere



The rising, unsaturated air parcel at each level is warmer and lighter than the air around it. If given the chance, the air parcel would accelerate away from its original position.

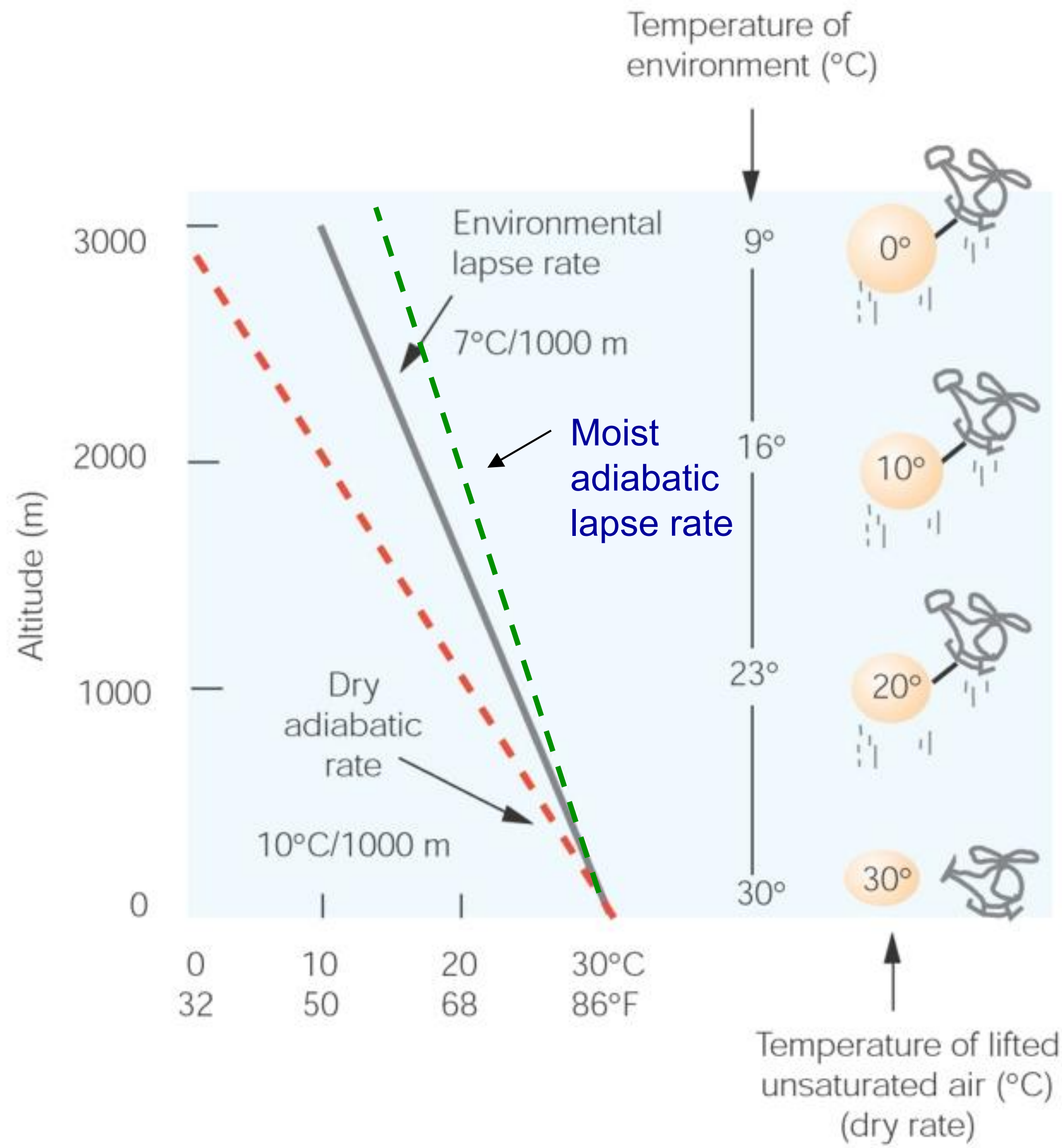
Absolutely unstable conditions indicate that a lifted parcel of air, whether dry or moist, will be warmer than the surrounding environmental air, and hence continue to rise.

Conditionally Unstable

The atmosphere is conditionally unstable when the environmental lapse rate is between the dry and moist adiabatic lapse rates.

$$\Gamma_s < \Gamma < \Gamma_d$$

The atmosphere is stable with respect to unsaturated air, but is unstable with respect to saturated air



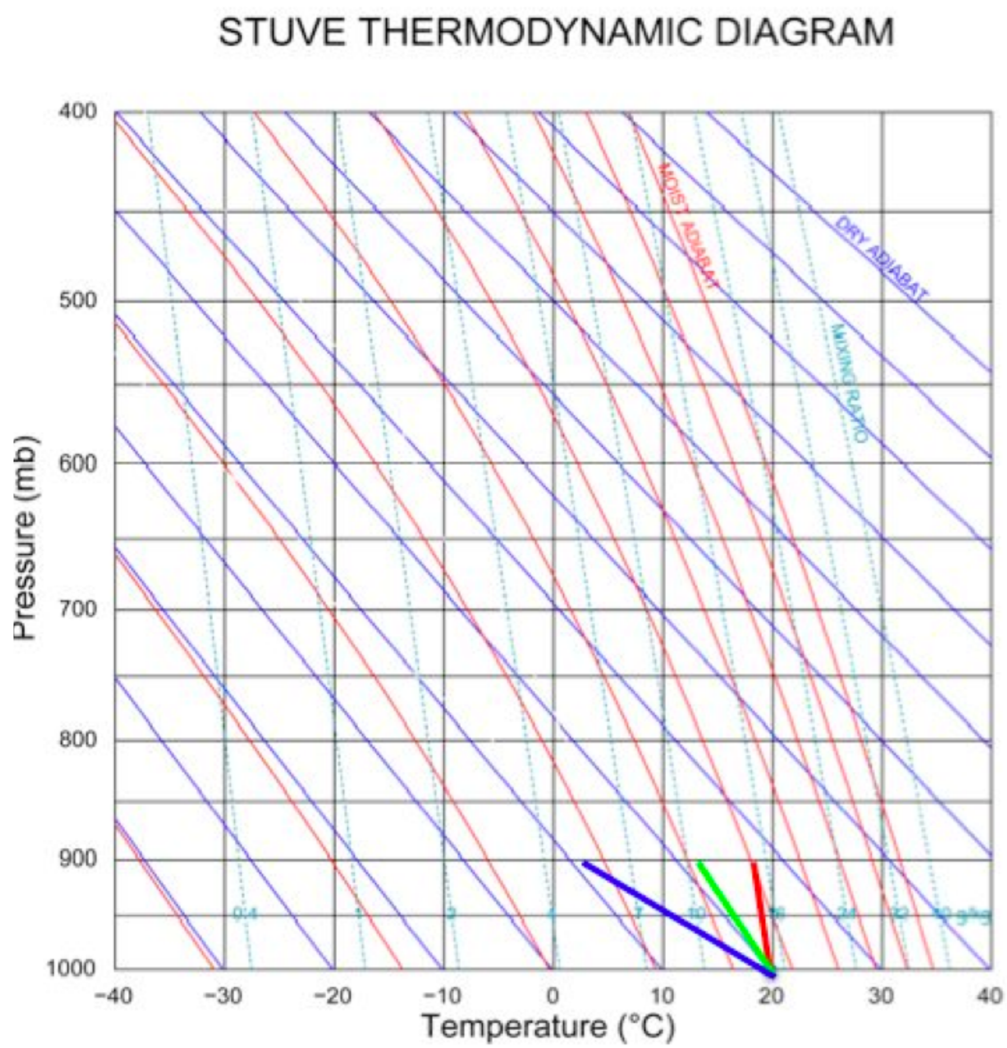
The unsaturated parcel of air at each elevation is colder than its surroundings. The atmosphere is stable with respect to unsaturated, rising air.

1. Starting at the point on your thermodynamic diagram that has a pressure of 1000 mb and a temperature of 20°C, draw and label an environmental temperature profile up to 900 mb for each of the following conditions:

1a. An absolutely unstable condition
Blue thick line in Figure 1.

1b. A conditionally unstable condition
Green thick line in Figure 1.

1c. An absolutely stable condition
Red thick line in Figure 1.

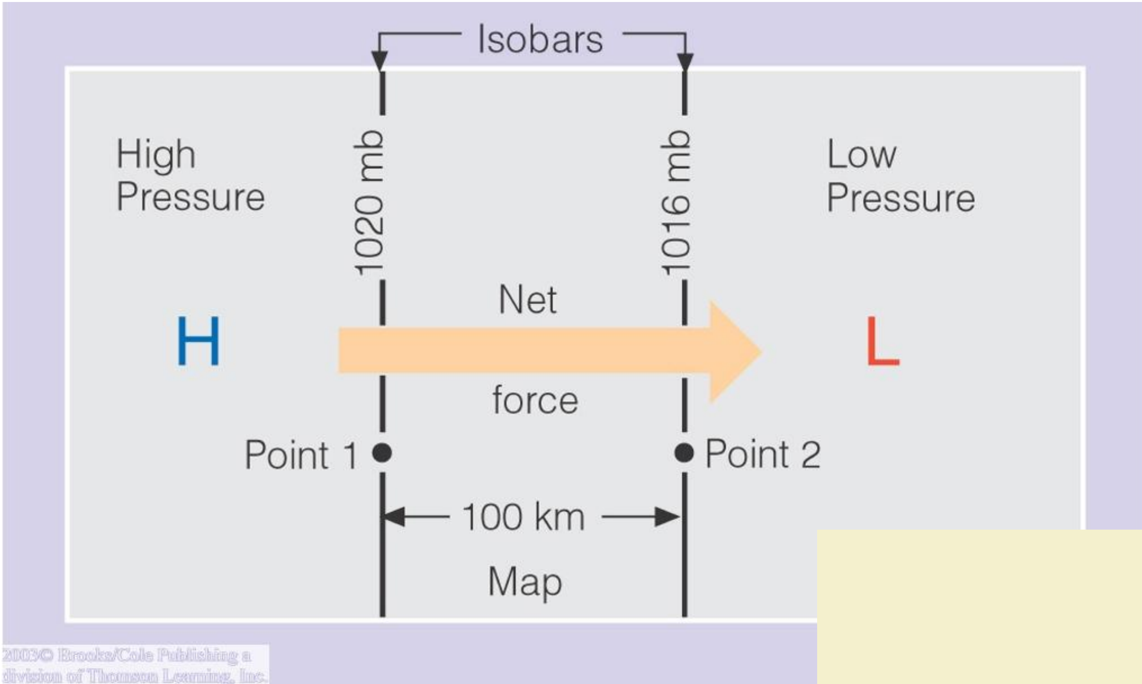


Lab 8

Forces that influence the winds

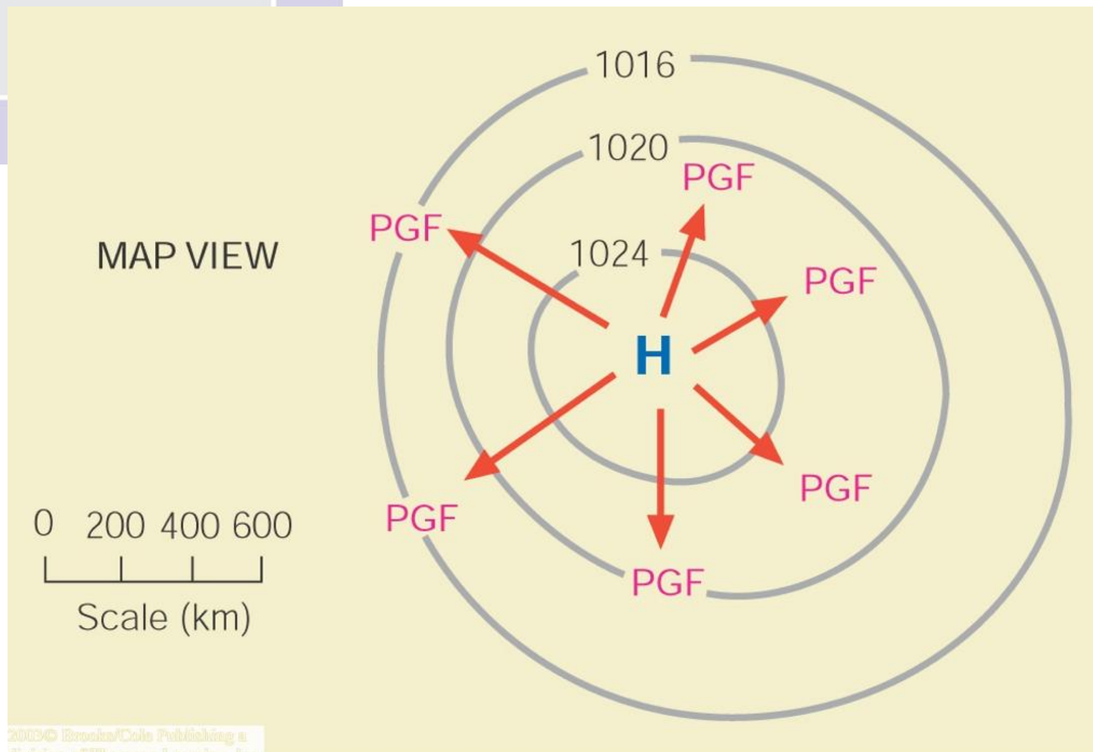
1. Pressure gradient force
2. Coriolis force
3. Centrifugal force
4. Frictional force

How to calculate pressure gradient force?



Pressure gradient force equals changes in pressure per changes in distance

PGF = $(1/\rho) \cdot (\Delta P / d)$



e.g., PGF = $1/(1 kg/m^3)$ (1020 mb-1016 mb) / 100 km = 4×10^{-3} N/kg

What determine the magnitude of Coriolis force ?

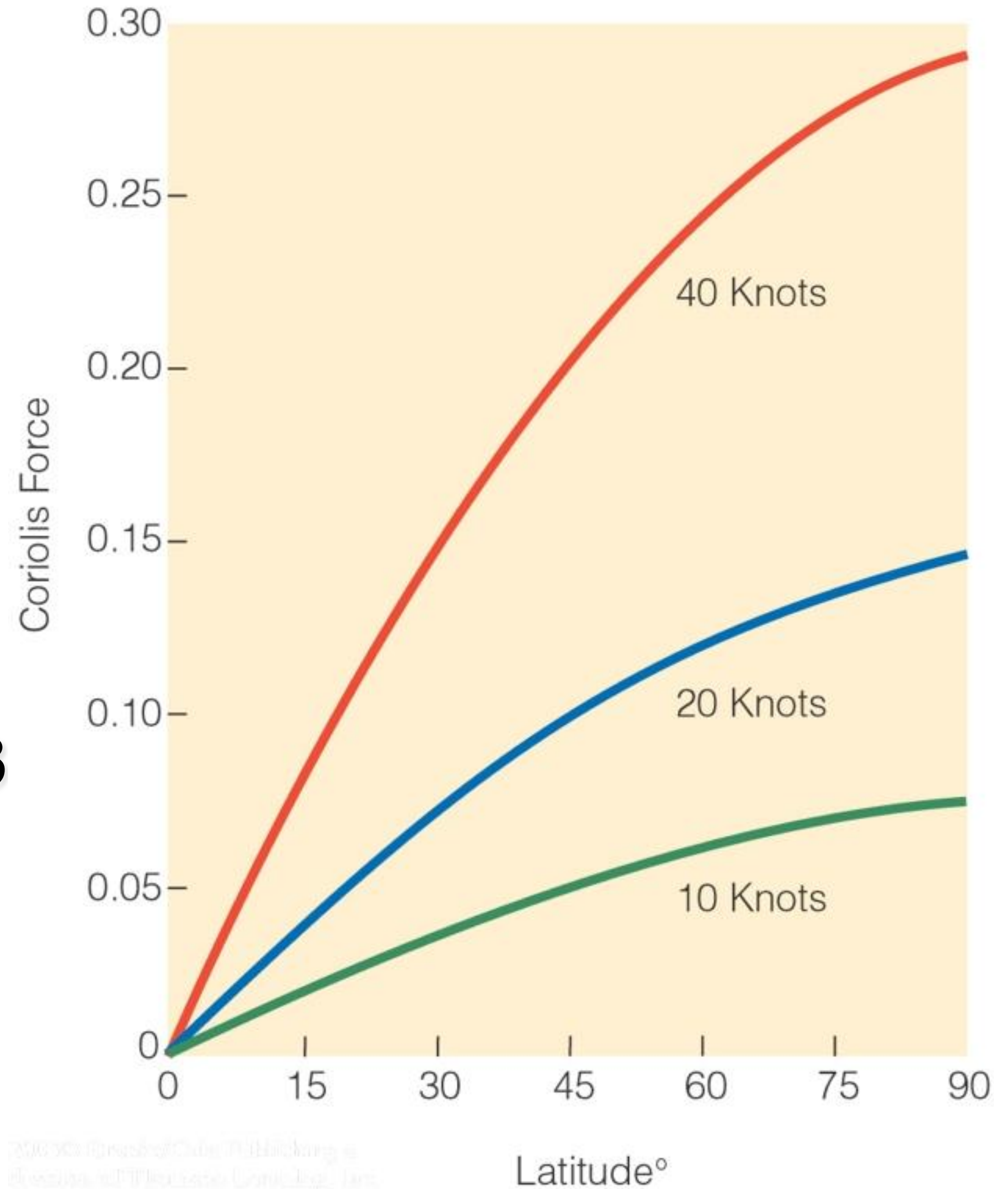
Coriolis force = $f \bullet V$

V is wind speed

f **is the *Coriolis parameter***

f = 2 × earth's rotational rate × sin of latitude

Earth's ratation rate (7.3 • 10^{-5} radian/s)



Coriolis Force (*CF*)

- **Apparent force due to the rotation of the earth**

- **Magnitude depends on latitude and the speed of the air parcel**

  The higher the latitude, the larger the Coriolis force

  Zero at the equator, and maximum at the poles

  The faster air moves, the larger the Coriolis force

- **Causes the parcel to deflect**

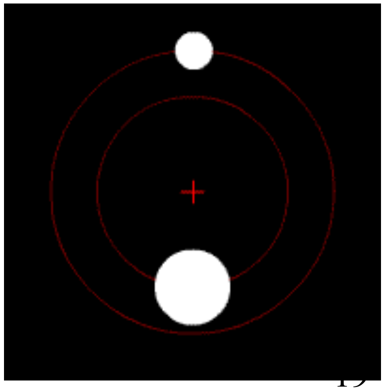
  to the right of its intended path in the northern hemisphere

  to the left of its intended path in the southern hemisphere.

Only influence wind direction, no effect on wind speed !

Centrifugal Force

- Magnitude   CENTF = mV^2/R
  - m is the mass
  - R the radius of curvature of the curved path
  - V is the speed of the air parcel
- Direction
  - Pointing away from the center of the curve
  - **The faster the speed and the tighter the curve of the path traveled (i.e., the smaller R), the larger the centrifugal force.**



Frictional Force

- **Frictional drag of the ground slows wind down.**

$$FF = -kV$$

  - **Magnitude**
    - **Depends upon the speed of the air parcel (V)**
    - **Depends upon the roughness of the earth's surface (k)**
  - **Direction**
    - **Always acts in the direction opposite to the movement of the air parcel (minus sign emphasizes this)**
  - **Important in the friction layer (planetary boundary layer)**
    - **~lowest 1000 m of the atmosphere**

Geostrophic Wind

When the pressure gradient force is balanced by the Coriolis force, the wind is called geostrophic wind.

Geostrophic wind blows in a straight line parallel to isobars (constant pressure lines)

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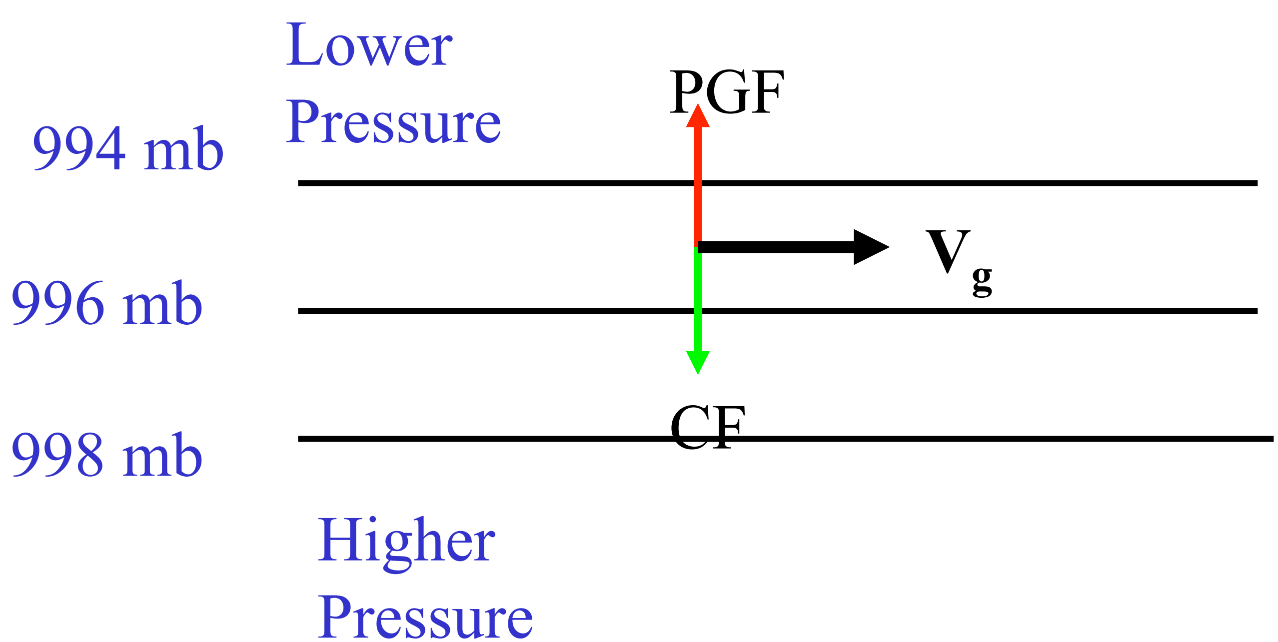


Gradient Balance – The Gradient Wind

- The Gradient Wind is flow around a curved path where there are three forces involved in the balance (gradient balance):
  - 1. Pressure Gradient Force
  - 2. Coriolis Force
  - 3. Centrifugal Force

  Gradient balance: PGF+CF+CENTF = 0
- Important near high or low pressure centers

Gradient Balance – The Gradient Wind

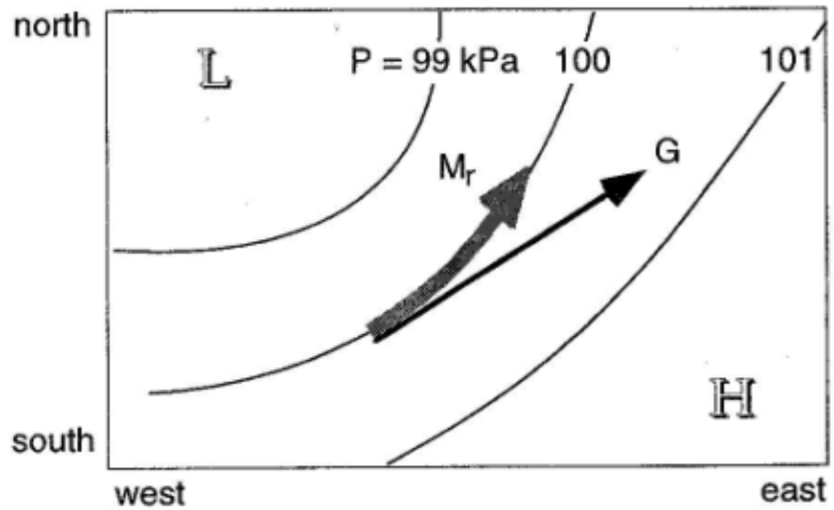
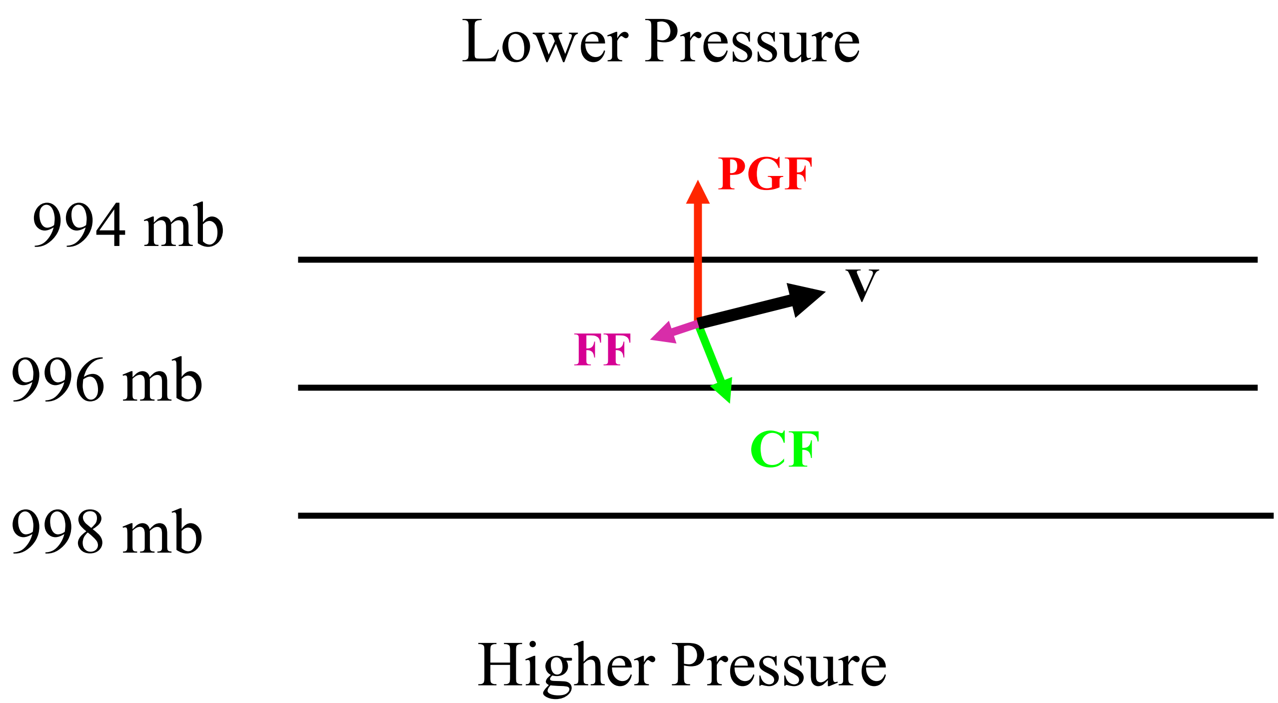


Figure 9.10
Geostrophic wind G and gradient wind M_r around a low pressure center in the Northern Hemisphere.

What happens when we add friction?

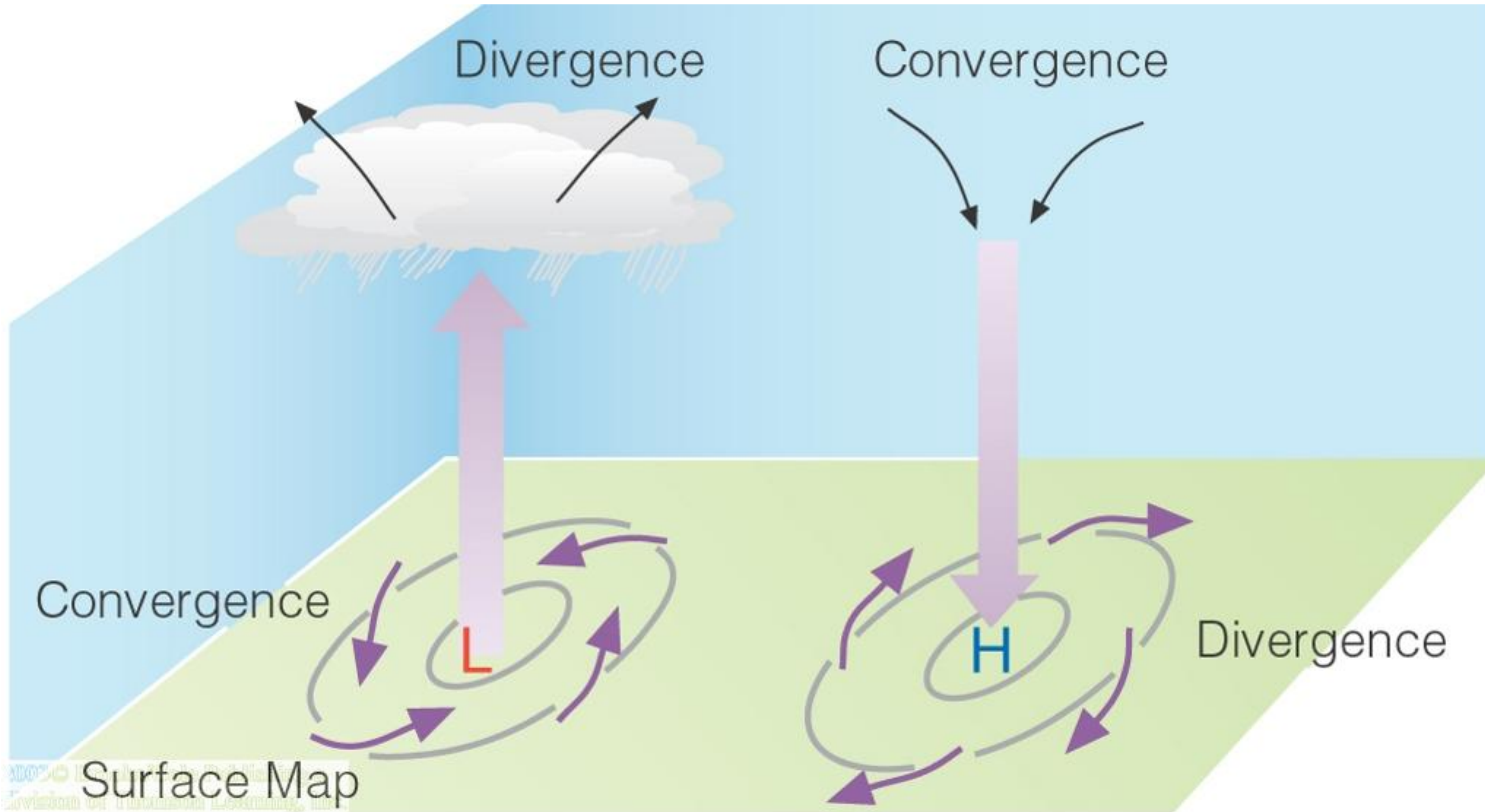
- Friction can only slow wind speed, not change wind direction
- Therefore, in the northern hemisphere, if the wind speed is decreased by friction, the Coriolis force (CF=fV) will be decreased and will not quite balance the pressure gradient force
  - Force imbalance (PGF > CF) pushes wind in toward low pressure center and outward away from high pressure center
  - Angle at which wind crosses isobars depends on surface roughness
    - Average ~ 30 degrees

PGF+CF+FF=0



The wind no longer blows parallel to the isobars, but is deflected toward lower pressure; this happens close to the ground where terrain and vegetation provide friction

Relationship between horizontal and vertical air Motion



Winds converging into a low pressure center generate upward winds that remove the accumulating air molecules. These updrafts may cause cloud formation.
Likewise, diverging air molecules from a high pressure area are replenished by downward winds.