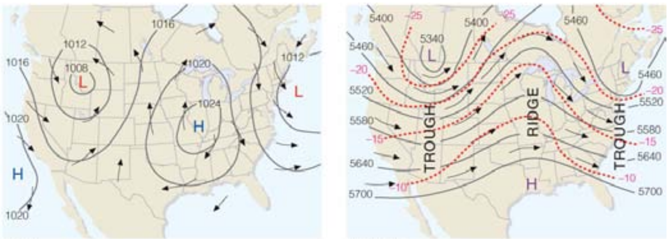
Horizontal Forces & Circulation

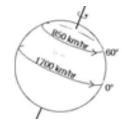


(a) Surface map (b) 500-millibar map

- If the *horizontal* pressure gradients last long enough (longer than several hours) or the air displacement is large enough (1000 of km)
  - The rotation of the earth greatly affects the motion (Coriolis Force)
  - The *horizontal* pressure gradients are balanced by Coriolis Force
    - The wind blows along a line of *constant* pressure and is said to be in geostrophic balance
  - E.g., hurricanes, mid-latitude cyclones, jet stream

Coriolis Effect

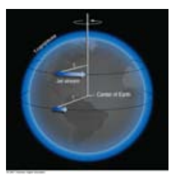
- If the *horizontal* pressure gradients last long enough (longer than several hours) or the air displacement is large enough (1000 of km) rotation of the earth greatly affects the motion
- In these cases, the are experiences the Coriolis Effect (or Force) which is a frame-of-reference effect: the combined effect of
  - Conservation of angular momentum
  - Gravity acting to keep air on the spherical Earth



In the net, air moving in the northern hemisphere experiences an *apparent force* to the right of motion

Coriolis Effect

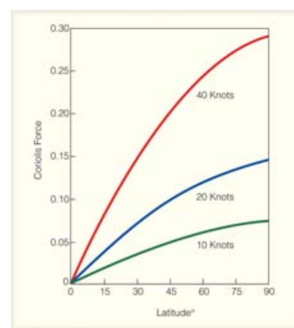
Think “Ice skater effect”



plus

the pull of gravity confining you to a rotating Earth

The Coriolis Force (CF) depends on latitude and wind speed



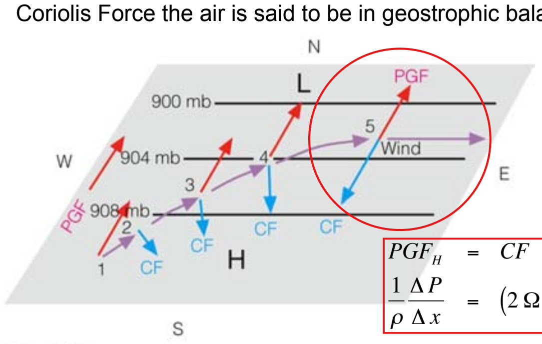
$$CF = \left(2\,\Omega \sin\theta\right) * V$$

where θ is latitude and Ω is a constant and *V* is the speed of the air relative to the rotating Earth (ie, as seen by an observer rotating with the earth)

Stronger wind => Stronger CF
Higher latitude => Stronger CF

Fig. 8-21, p. 205

When the horizontal pressure gradient balances the Coriolis Force the air is said to be in geostrophic balance

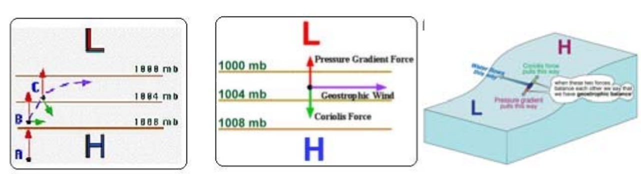


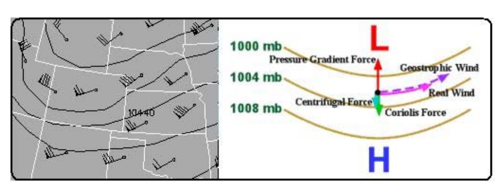
$$PGF_H = CF$$

$$\frac{1}{\rho}\frac{\Delta P}{\Delta x} = \left(2\,\Omega \sin\theta\right) * V$$

In geostrophic balance, the wind blows *along* a line of constant pressure (an isobar)

Geostrophic Wind and Gradient Wind

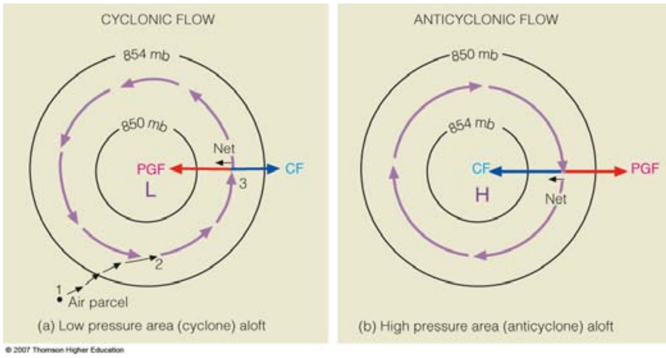




Nearly Geostrophic Flow (it is curved)

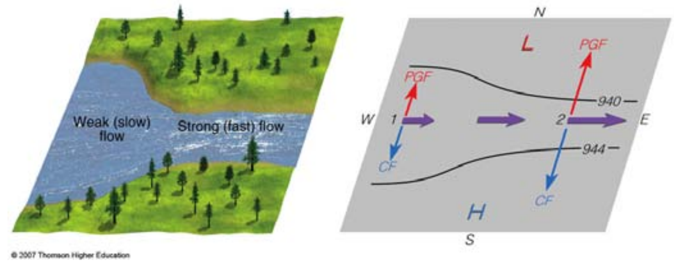
Northern Hemisphere

Gradient Flow (nearly Geostrophic)



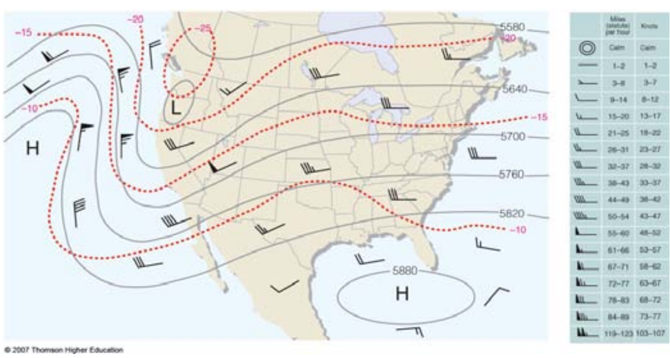
Northern Hemisphere

Geostrophic Wind

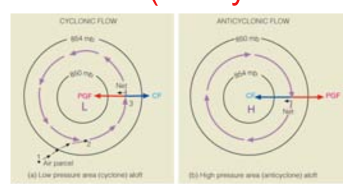


The stronger the PGF_V, the stronger the CF
(hence, the stronger the wind)

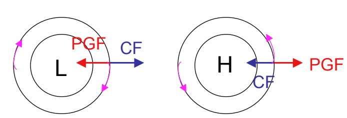
Gradient Flow (nearly Geostrophic)



Gradient Flow (nearly Geostrophic)



Northern Hemisphere



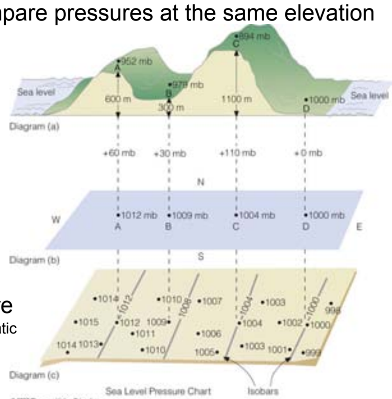
Southern Hemisphere

The CF acts to accelerate the air to the left of the motion in the Southern Hemisphere

Sea Level Pressure

To determine horizontal pressure gradients that drive winds, we need to compare pressures at the same elevation

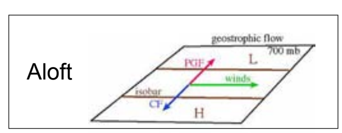
Surface Pressure

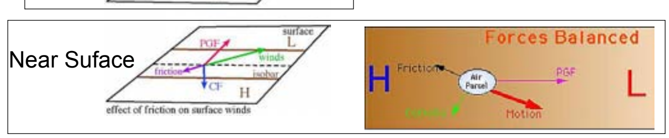


Sea Level Pressure
(adjusted using the hydrostatic equation)

Near Surface Winds

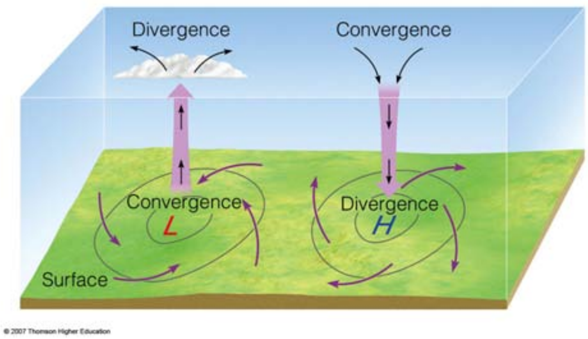
They feel PGF_H, CF and friction from the rough surface





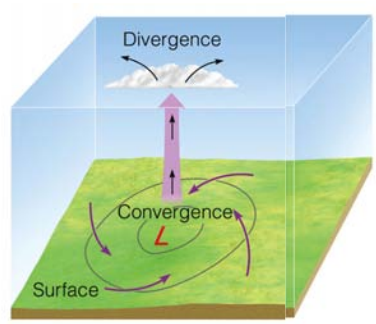
Averaged over many hours, the net force balance is zero and so at the surface there is a small component to the wind that blows toward the low pressure.

Hence, air tends to flow out of a surface high, causing sinking motion and convergence aloft (fair weather)



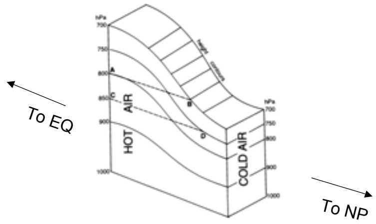
Conversely, air tends to flow into of a surface low, causing convergence and rising motions aloft (cloudy)

A very good analog for the Surface Low



Jets

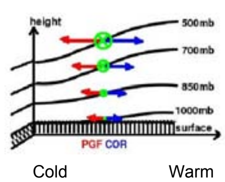
- The air column in the tropics is warmer than that at the poles. Hence, the density is less in the tropics so going up into the atmosphere, pressure drops more slowly in the tropics than in the polar regions

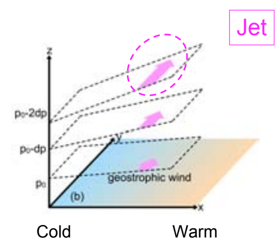


- Hence, a poleward pressure gradient develops as you go up from the surface

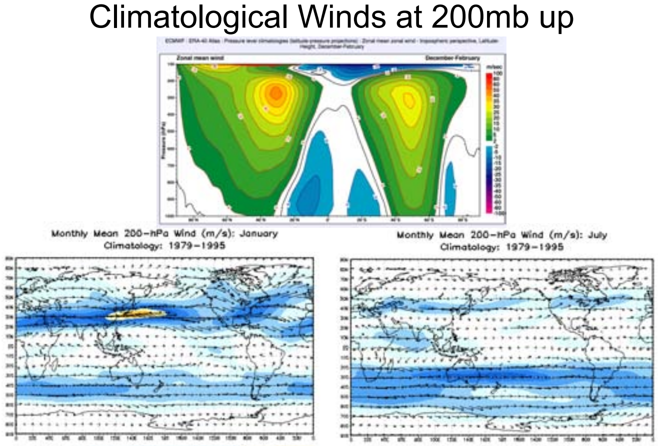
Jets

- A poleward pressure gradient develops and strengthens as you go up
- Air density decreases too, so the PGF_H becomes huge. Hence, the winds increase as you go up.





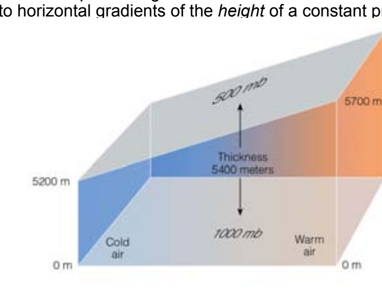
Climatological Winds at 200mb up



Movie http://www.cpc.ncep.noaa.gov/products/precip/CWlink/climatology/200wind/200windloop.gif

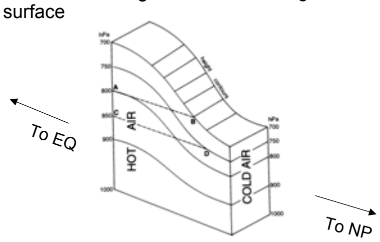
Mapping Pressure Gradients

- Horizontal pressure gradients that cause acceleration must be measured along a plane of constant elevation
- Horizontal pressure gradients on a constant elevation are proportional to horizontal gradients of the *height* of a constant pressure surface



Mapping Pressure Gradients

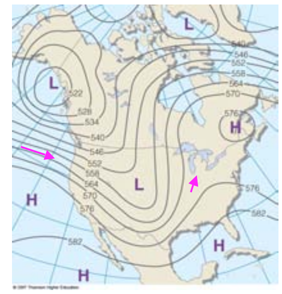
- Horizontal pressure gradients that cause acceleration must be measured along a plane of constant elevation
- Horizontal pressure gradients on a constant elevation are proportional to horizontal gradients of the *height* of a constant pressure surface



- Hence, we can infer/measure geostropic wind using gradients in the height of a constant pressure surface

Mapping Pressure Gradients

The height of the 500mb contour on this day



- Read this just like a pressure map on constant elevation:
  - flow is along a line of constant height
  - flow is strongest where the lines are closest together (stronger gradients = stronger CF ~ stronger wind)

Balanced Flow (nearly Geostrophic)