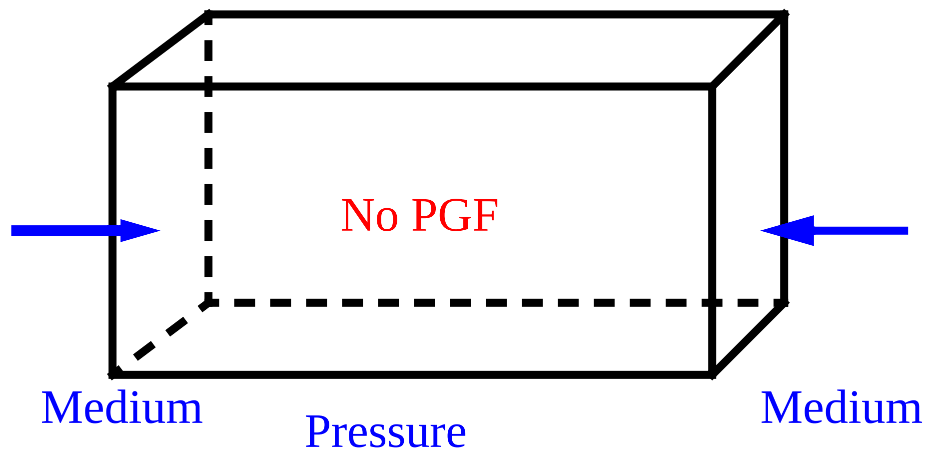
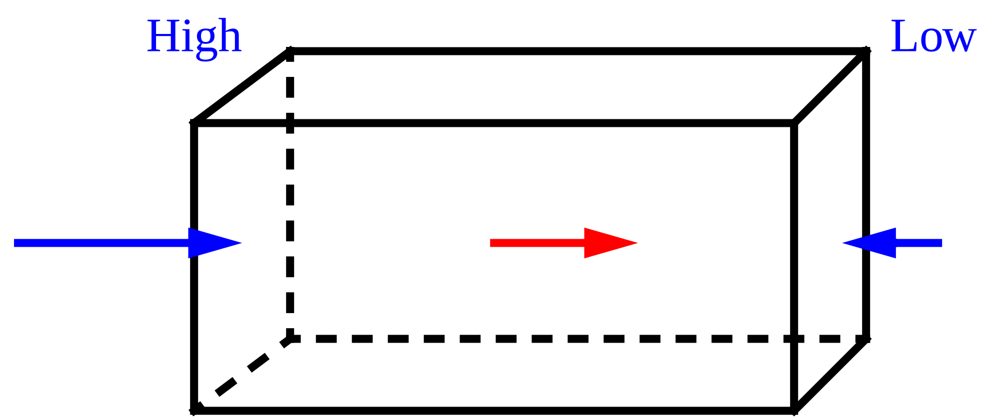
Lecture 8. Pressure Gradient Force

- Equal pressures on the left and right side of an air parcel (or any other object) cancel out to produce no net horizontal force on parcel.

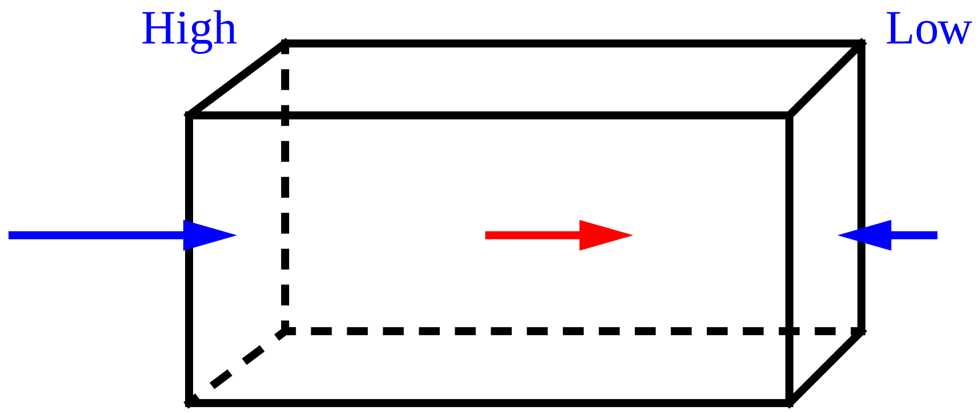


- Unequal pressures produce a horizontal force called the *Pressure Gradient Force* (PGF).

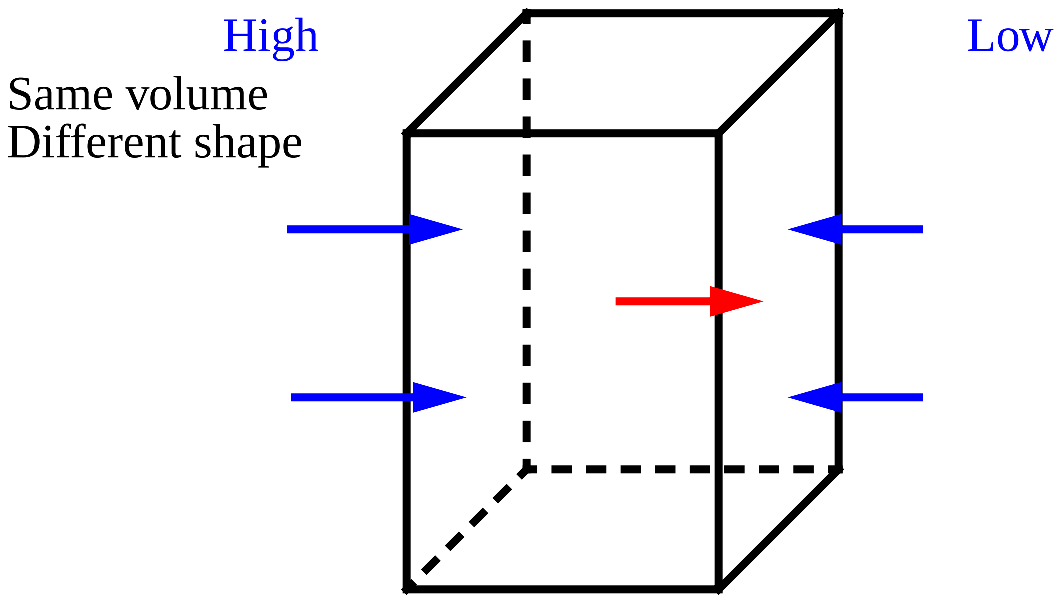


- PGF is stronger if pressure changes more rapidly between the two sides of the parcel

- PGF depends on the *volume* of the box, but not its *shape*.



Net PGF from high to low pressure



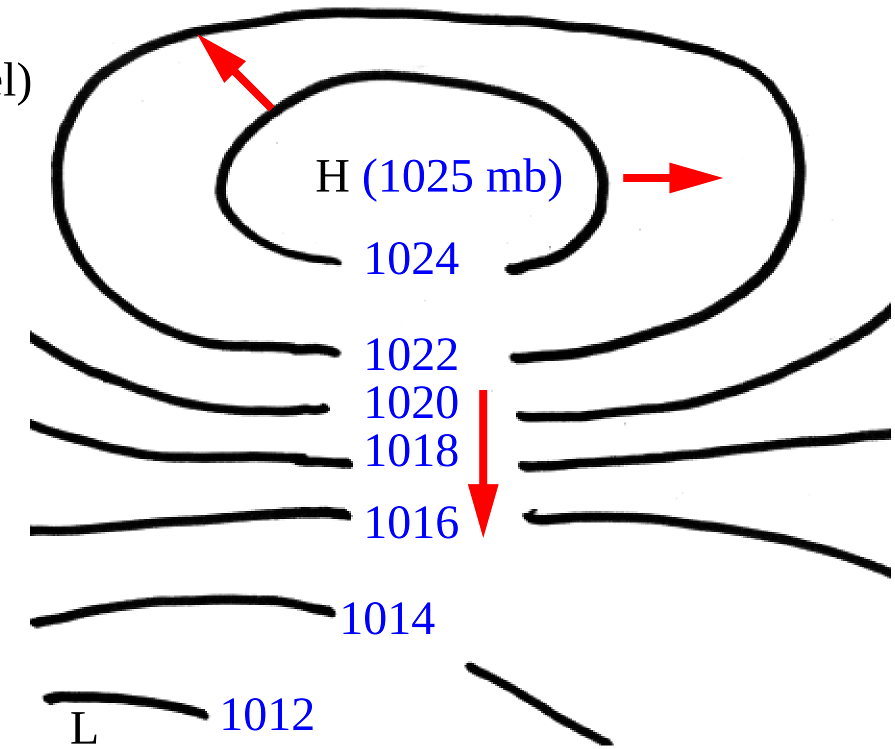
Less pressure difference
acting over more surface area
= <u>same</u> PGF

- Pressure varies with height too, creating vertical PGF. This balances weight of air in volume, so we normally discuss only PGF due to *horizontal* pressure variation, which is what makes winds.
- Pressure Gradient Force is expressed as force per unit volume, directed from high to low pressure:

$$PGF = \frac{\text{Pressure Change (mb)}}{\text{Distance (km)}}$$

On a contour map of pressure at a given altitude above sea level, PGF

- points from high to low pressure
- is largest where contours are closest.

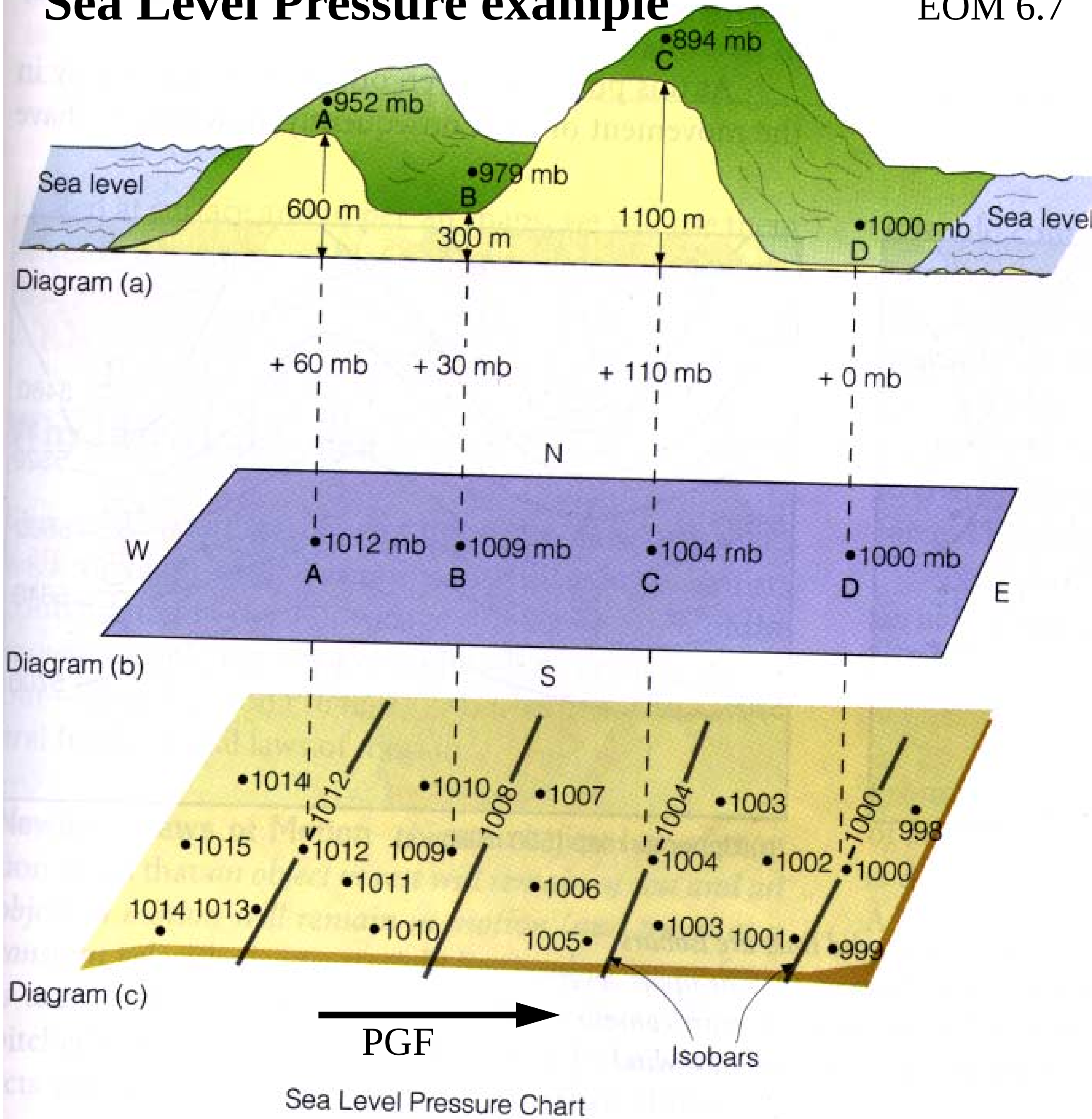


Surface Pressure Maps

- Surface pressure maps usually plot *sea-level pressure*, even though sea-level can be far below the ground! This is found by correcting the actual station pressure for altitude by adding about 1 mb per 10 m of altitude (exact formula depends on station temperature).
- By contouring sea-level pressure, we see horizontal pressure variations at sea-level from which we can deduce PGF.
- To draw a contour, e. g. 1008 mb, look for stations with pressure close to 1008 mb. The contour should be smoothly drawn to divide the stations with pressure less than 1008 mb from those with pressure more than 1008 mb. To keep the contour smooth, it is sometimes necessary to leave some stations slightly on the wrong side of the contour

Sea Level Pressure example

EOM 6.7



Upper air pressure maps contour *geopotential height*, the height of a surface of constant pressure (e.g. the 500 mb height surface) above sea-level.

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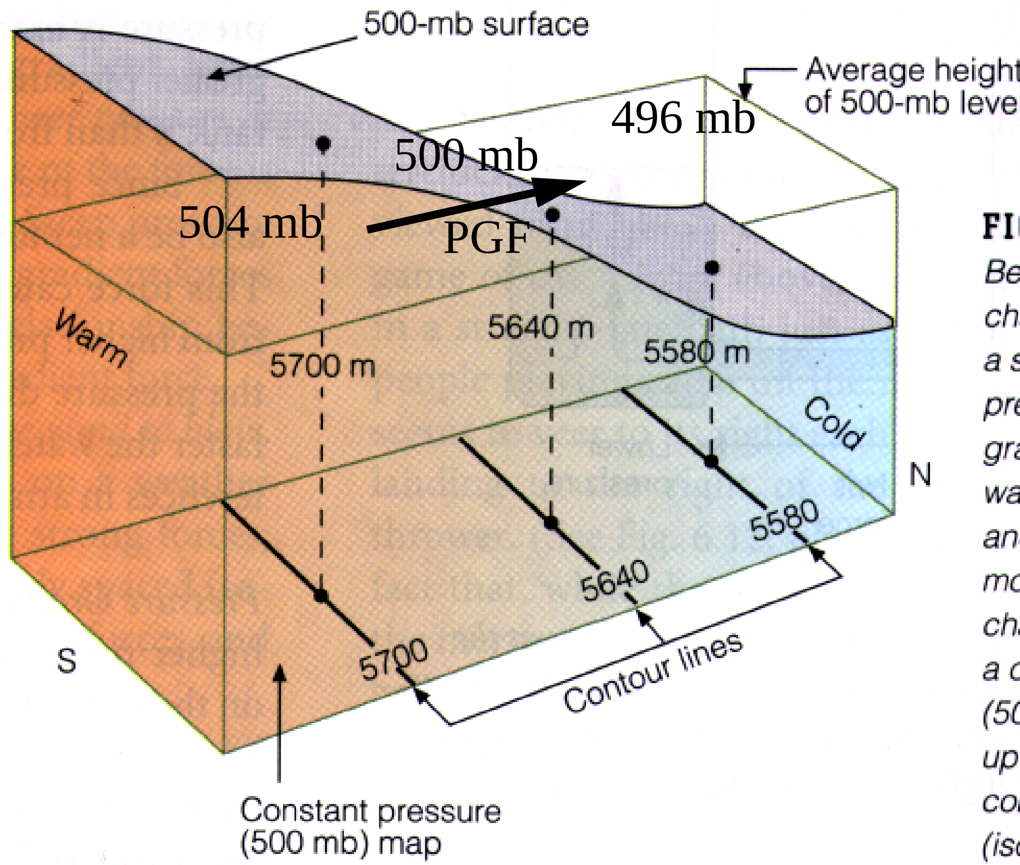
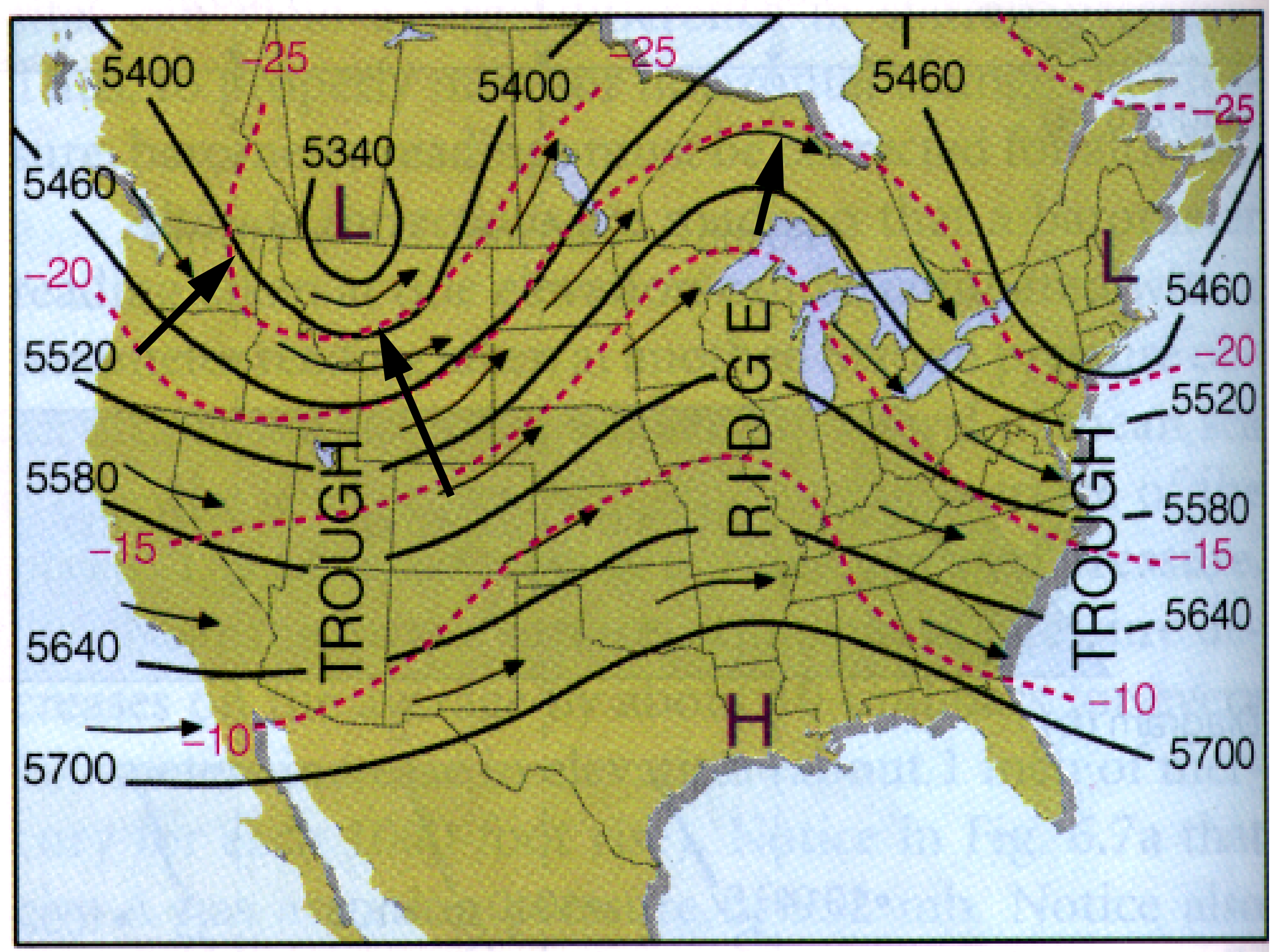


FIGURE 2 *Because of the changes in air density, a surface of constant pressure (the shaded gray area) rises in warm, less dense air and lowers in cold, more dense air. These changes in elevation of a constant pressure (500-mb) surface show up as contour lines on a constant pressure (isobaric) 500-mb map.*

- At a fixed elevation (e. g. 5640 m), pressure can be found by altitude correction - adding 1 mb for every 15 m the 500 mb height exceeds 5640 m.
- *High* 500 mb heights correspond to *high* pressure at the 5640 m level.
- PGF points from high to low heights, larger where height contours closer.

A typical wintertime 500 mb map

- Dotted lines show temperature (colder to north).
- Solid contours show 500 mb height.
- Thick arrows show PGF, pointing from high to low heights, and larger where contours are close.
- Thin arrows show wind direction.
- Why is wind direction *along* the contours when PGF is *down* the contours?



(b) Upper air map (500 millibars)

EOM 6.8b

Effect of Pressure Gradient Force on Wind

Newton's Laws:

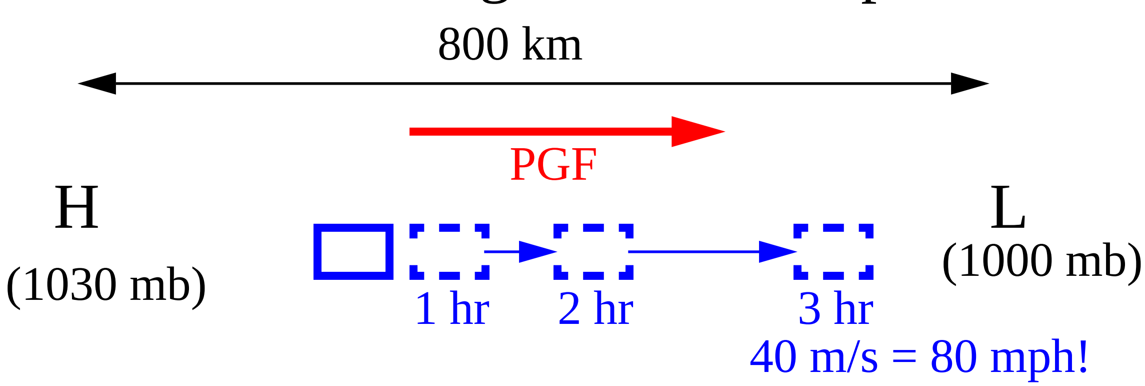
- 1. An object at rest remains at rest. An object in motion will remain in motion (travelling at constant velocity in a straight line) as long as no forces are exerted on the object

    (e. g. hockey puck)

2. Force = Mass × Acceleration

    (e. g. slapping hockey puck with a stick)

- The PGF produces a horizontal force which, acting alone, would rapidly accelerate air from high toward low pressure.



- But two other horizontal forces: **Coriolis 'force'** and (near ground) **friction**.