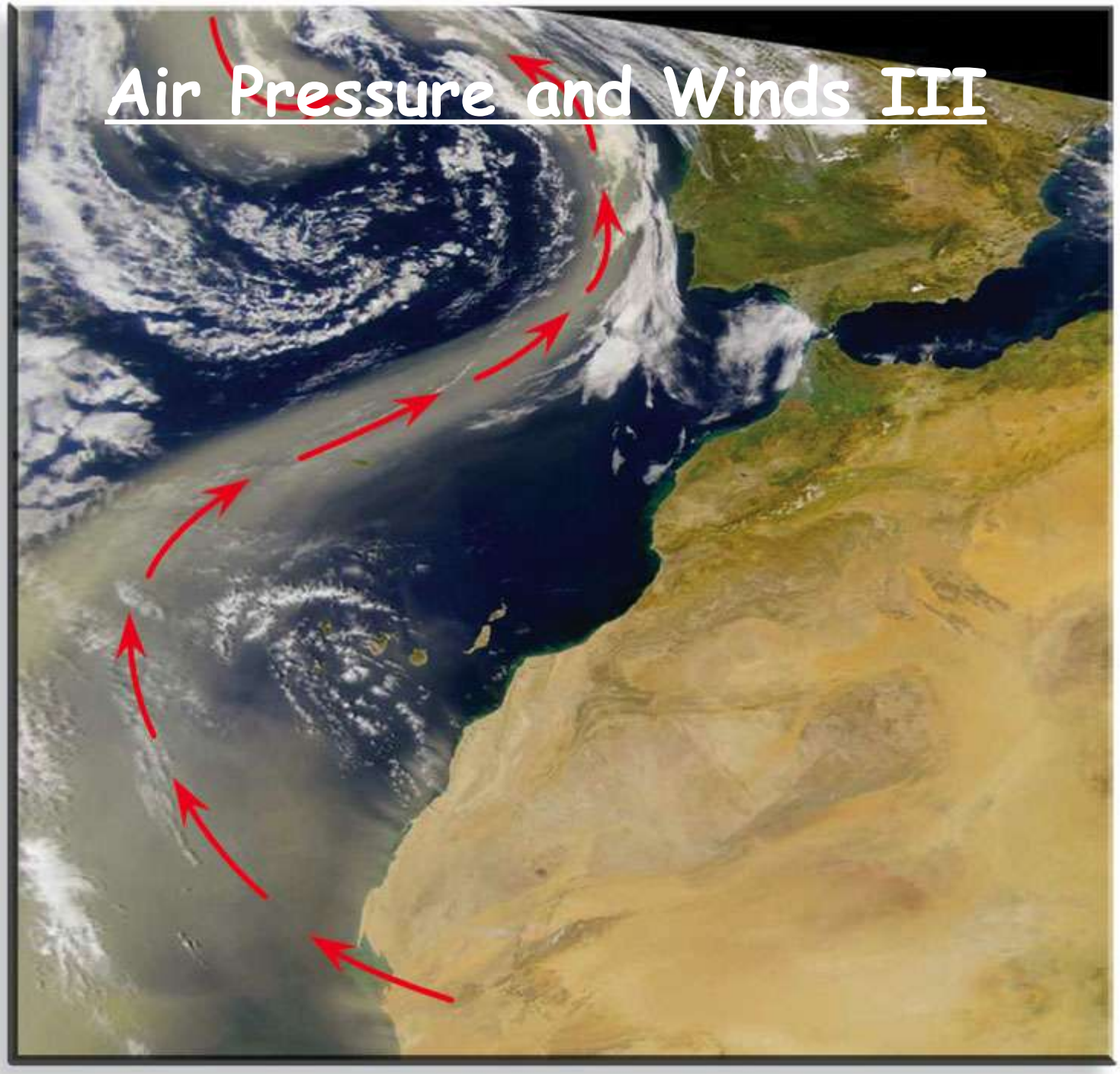
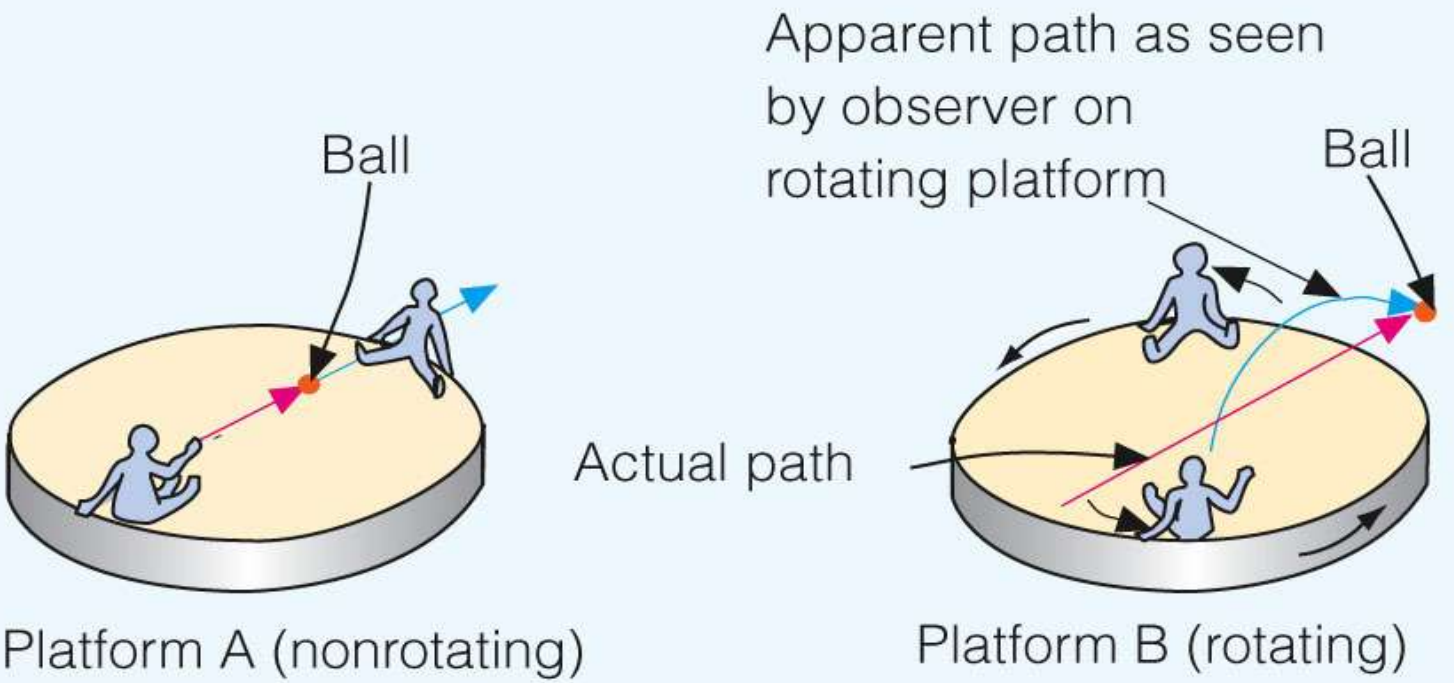
Air Pressure and Winds III

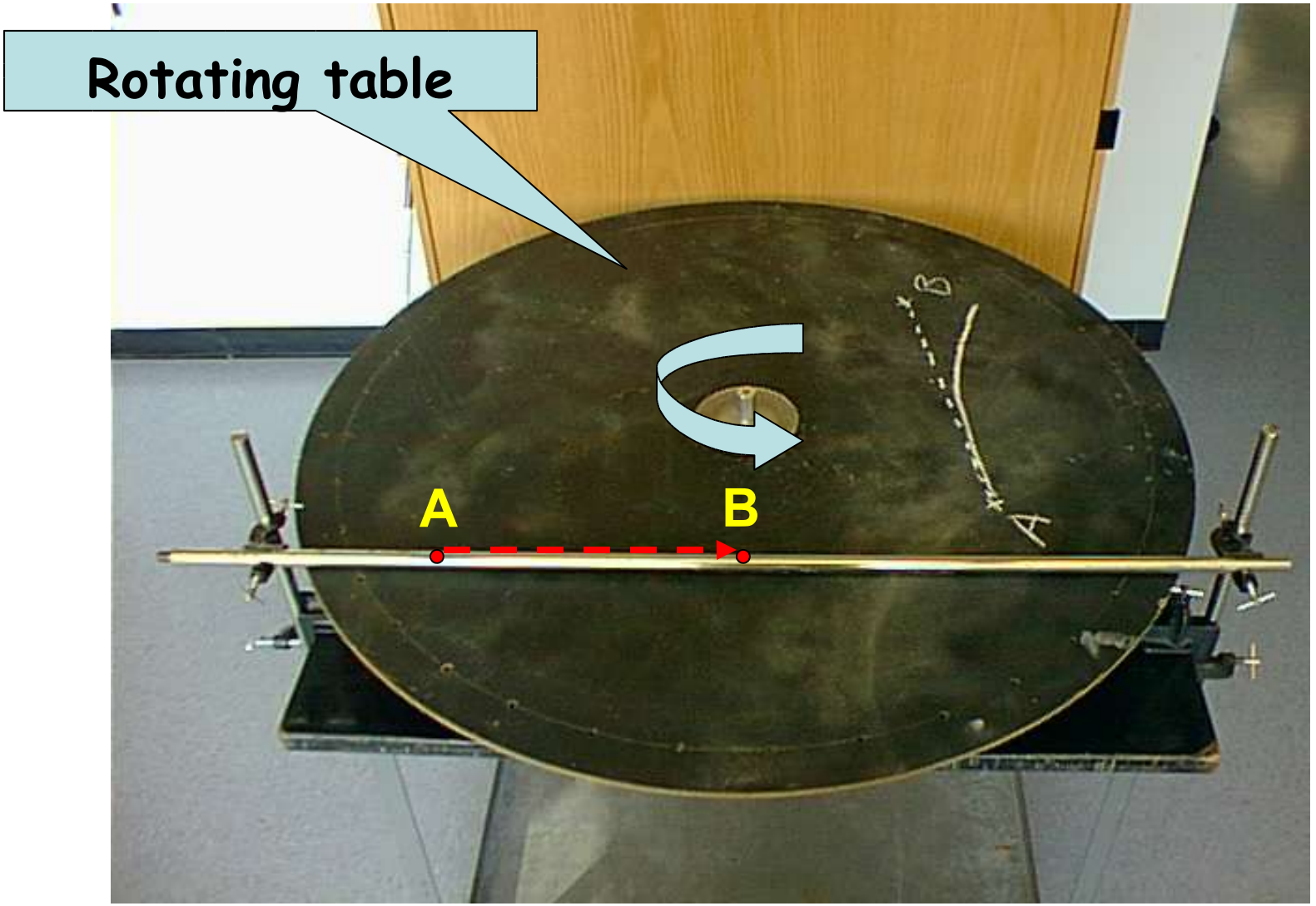


Coriolis Force (Effect)

- It is an apparent force;
- Due to the rotation of the coordinate system (Earth);
- It makes a moving object deflect from a straight line even in the absence of any forces acting on it.



Coriolis Force Demonstration

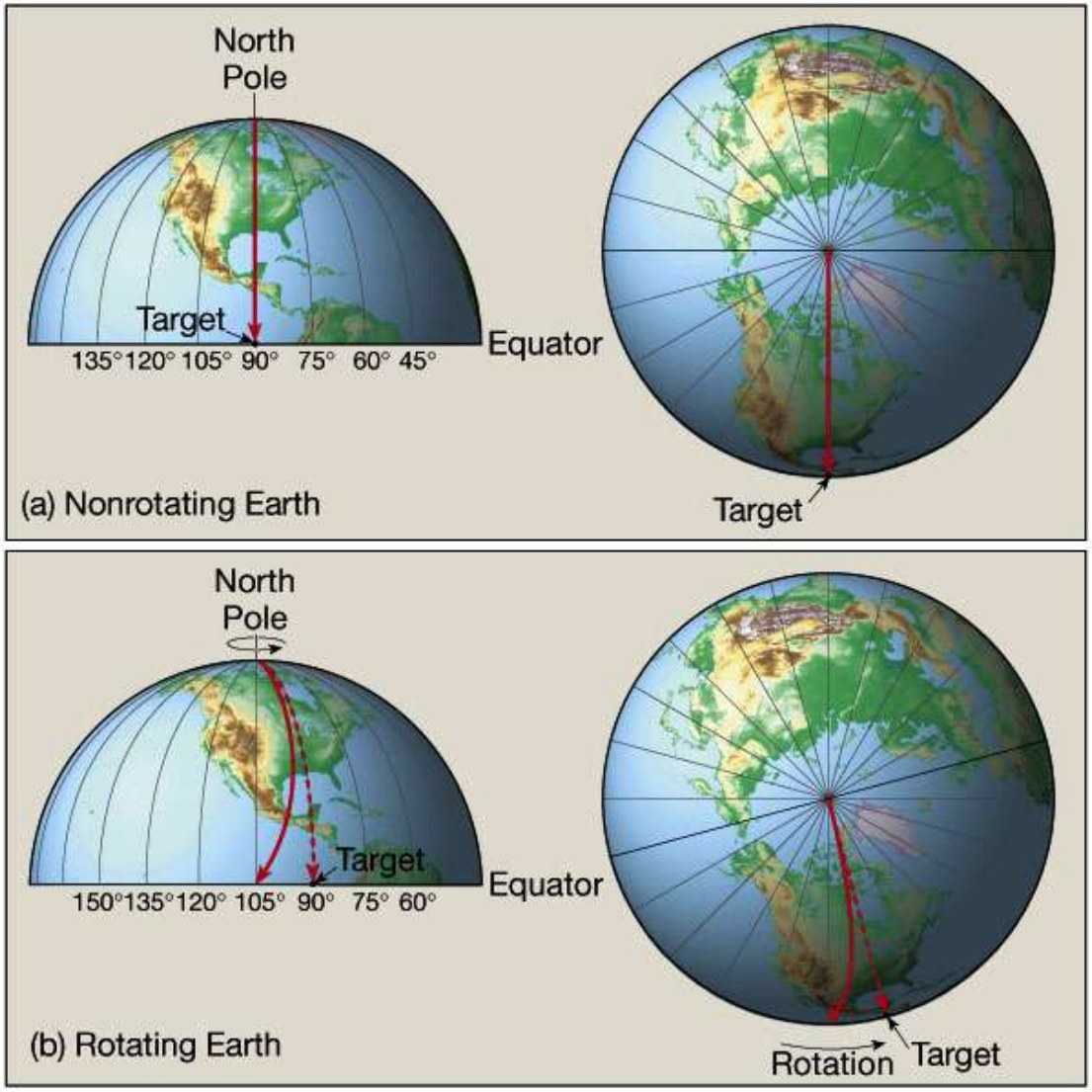


Dashed line - the trajectory of the chalk with respect to a non-rotating table.
Solid line - the trajectory of the chalk with respect to a rotating table.

The Magnitude of the Coriolis Force

- The rotation of the Earth
  - The faster the planet rotates the bigger the force
- The speed of the object
  - Bigger V -> bigger effect
- The latitude:
  - Min. at the equator
  - Max. at the poles

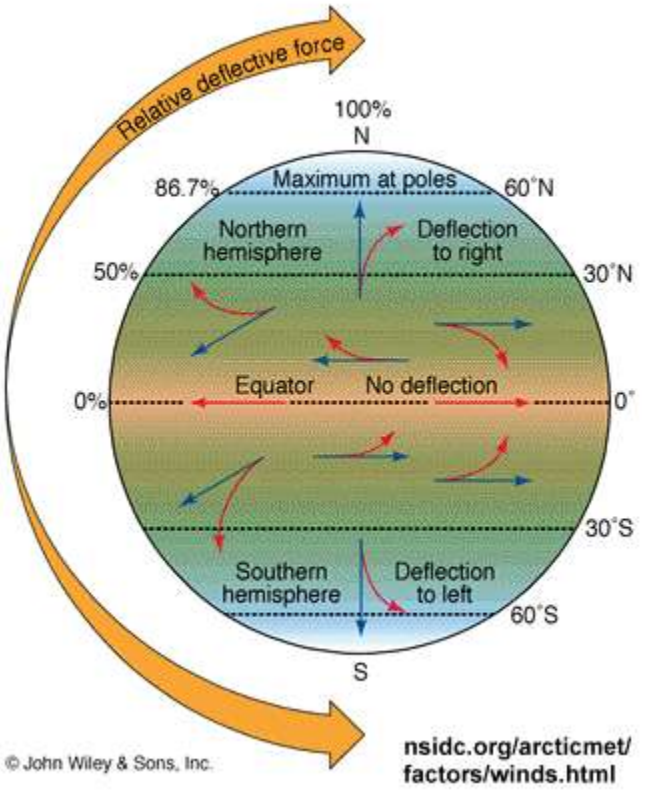
$$F_{co} = 2 m \Omega V \sin \varphi$$

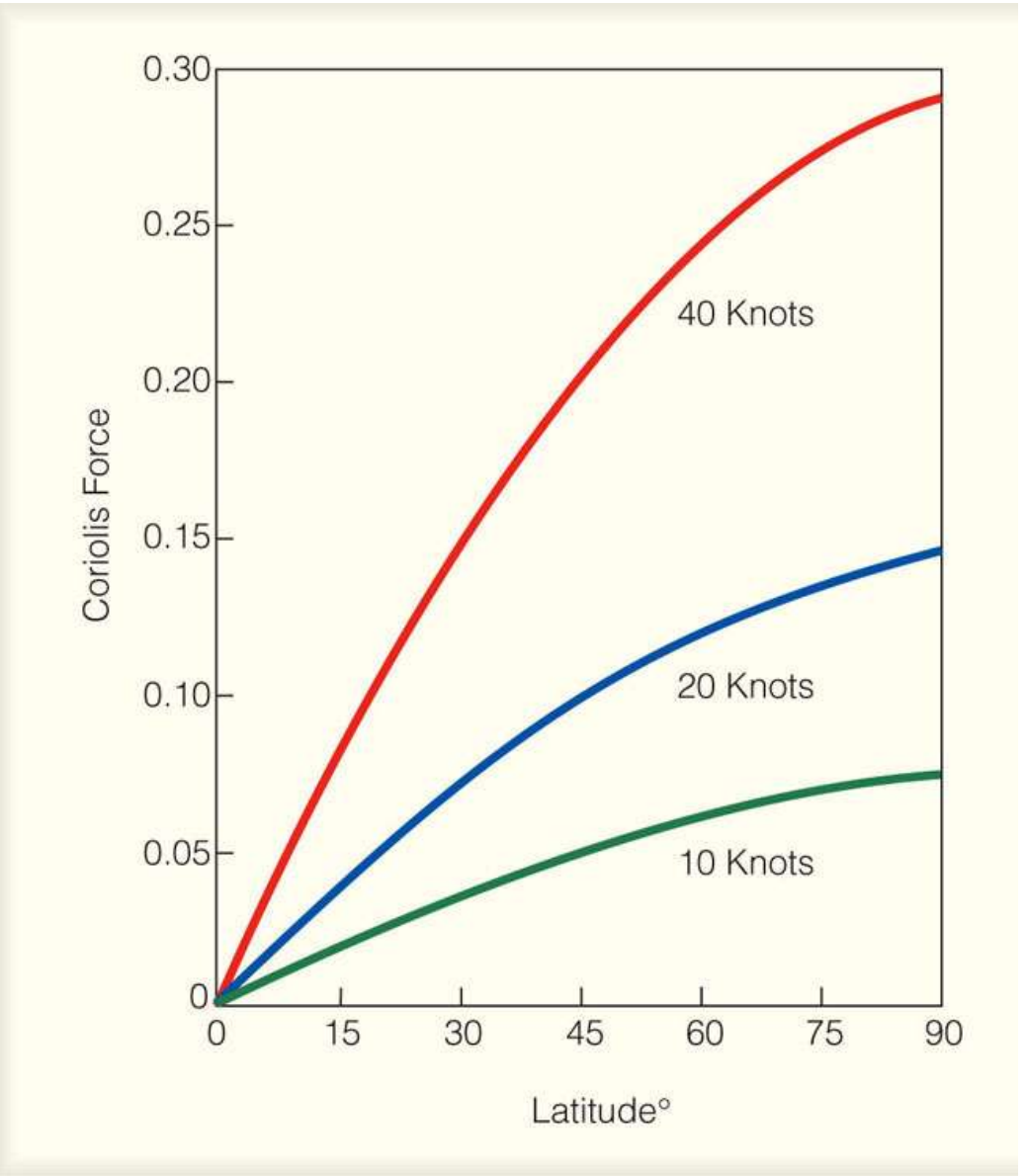


Coriolis force as a function of:

$$F_{co} = 2 m \Omega V \sin \varphi$$

- The speed of the object
- The latitude:
  - Min. at the equator
  - Max. at the poles



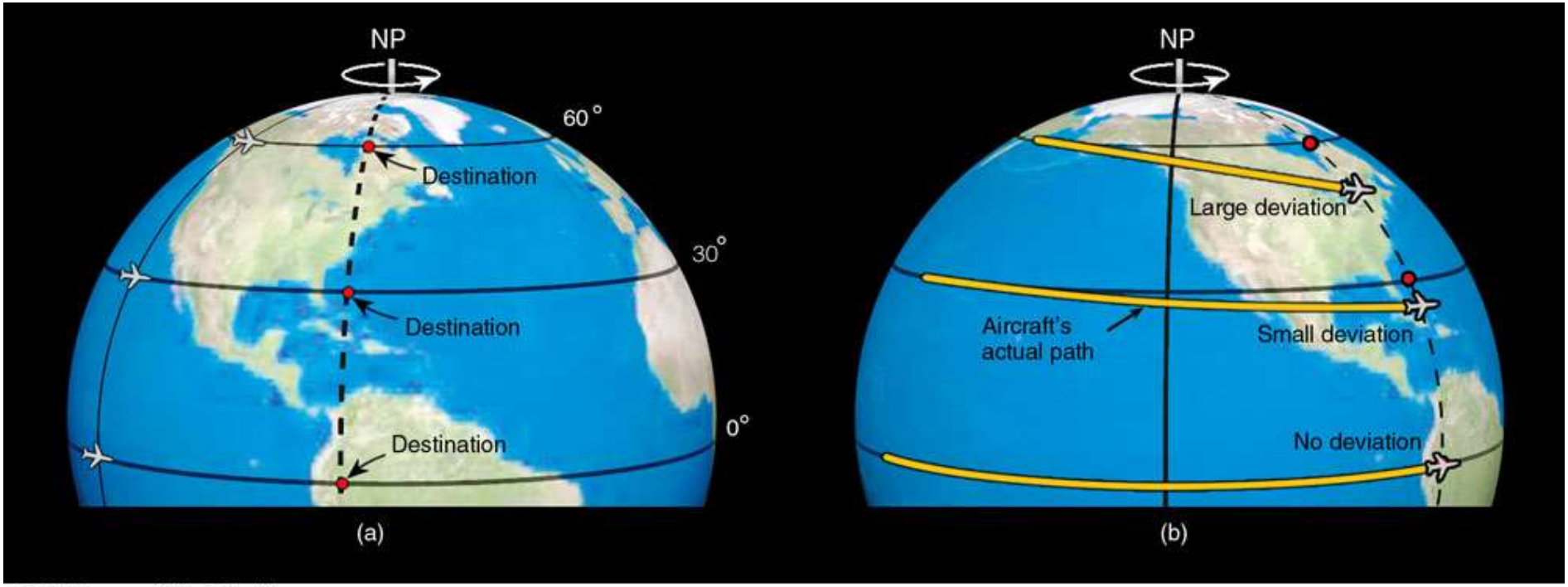


The Direction of the Coriolis Force

- In the Northern hemisphere the deflection is to the right of the direction of motion.
- In the Southern hemisphere the deflection is to the left of the direction of motion.
- The winds in the Northern hemisphere will be deflected to the right and in the Southern hemisphere they will be deflected to the left.
  - Hurricanes spin differently in the Northern and Southern hemisphere

The Coriolis Force and the Earth

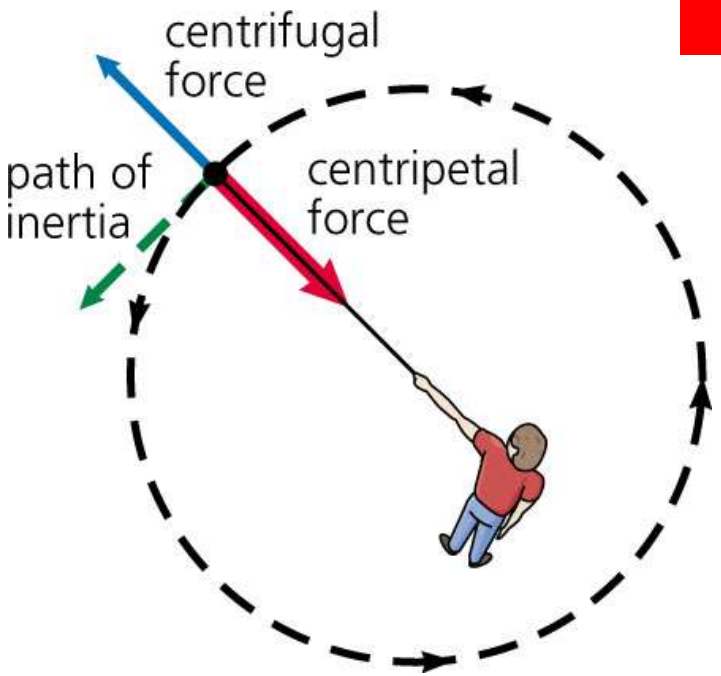
- The Coriolis effect is important when moving over LARGE distances (air plane travel), with large velocities, away from the equator.



Centripetal/Centrifugal Force

- Any motion in a curved path represents accelerated motion, and requires a force directed toward the center of curvature of the path. This force is called the centripetal force which means "center seeking" force.

$$F = ma = m\frac{V^2}{r}$$



Properties of the Centripetal Force (CF)

- The centripetal acceleration, and the centripetal force are perpendicular to the direction of motion.
- They only change the direction of motion.
- They do NOT change the magnitude of the velocity.
- The CF changes the direction of the wind but not the magnitude of the wind.

Recap: Forces in the Atmosphere

- Gravity force.
  - Vertical force in a downward direction

$$G = mg$$

- Atmospheric drag force (friction).
  - Acts against the motion
  - Proportional to velocity squared

$$F_{drag} = \frac{1}{2} C \rho_{air} A v^2$$

- Pressure gradient force
  - From high to low pressure regions
  - Perpendicular to the isobars
  - The bigger the pressure gradient (denser the isobars), the larger the pressure force

$$F_P \propto - \, pressure \;\; gradient$$

- Coriolis force: due to the Earth's rotation
  - Deflection to the right in the Northern hemisphere
  - Varies with latitude (absent at equator, max at the poles)
  - Proportional to the velocity of the object (wind)

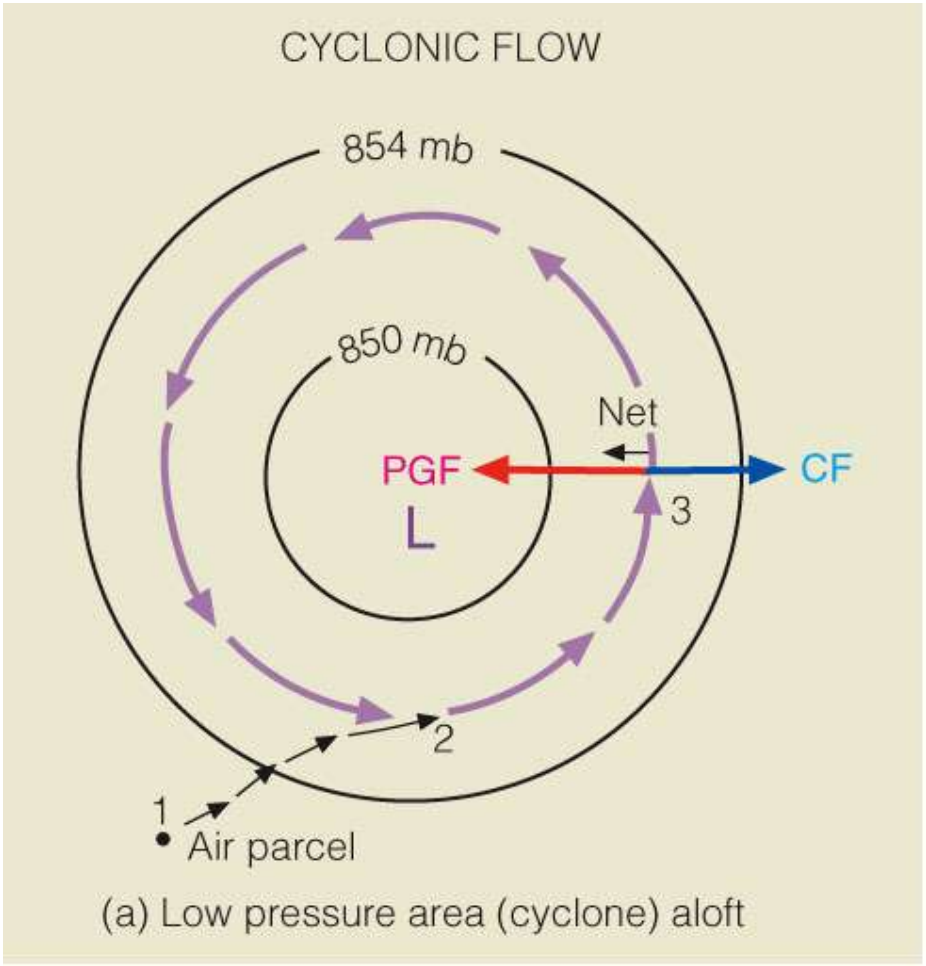
$$F_{co} = 2 m \Omega V \sin \varphi$$

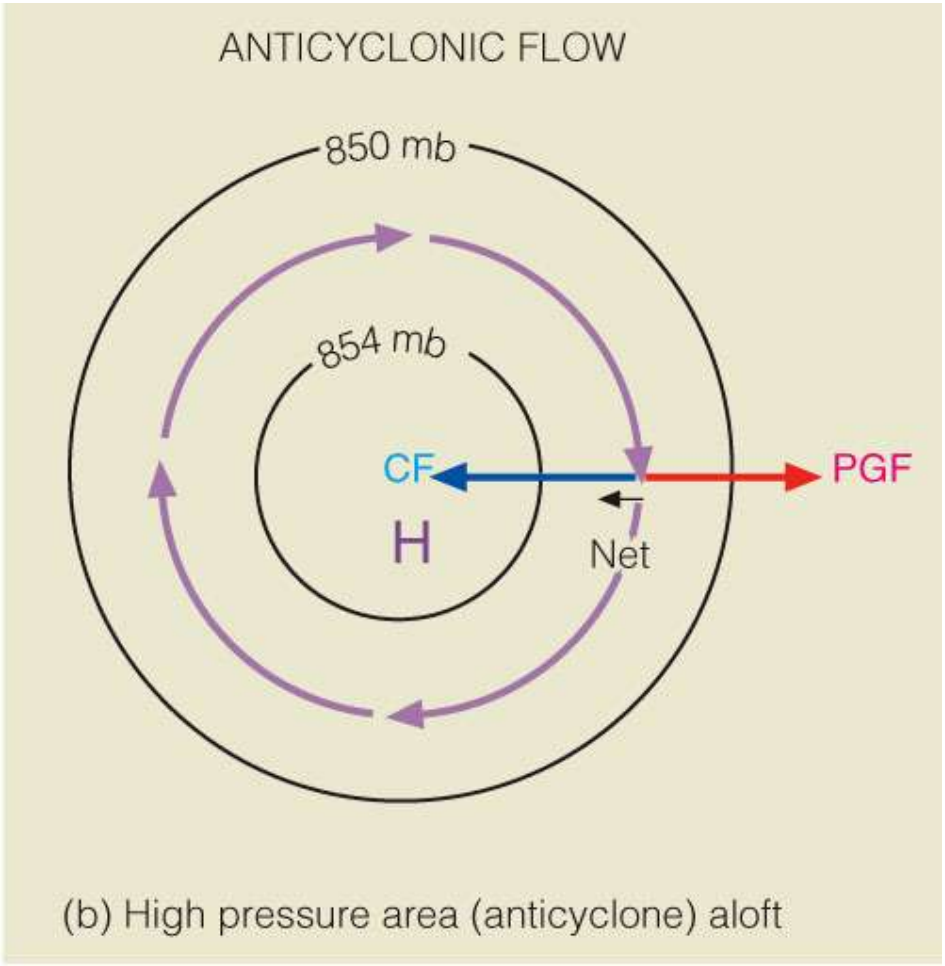
- Centripetal force:

$$F \propto \frac{V^2}{r}$$

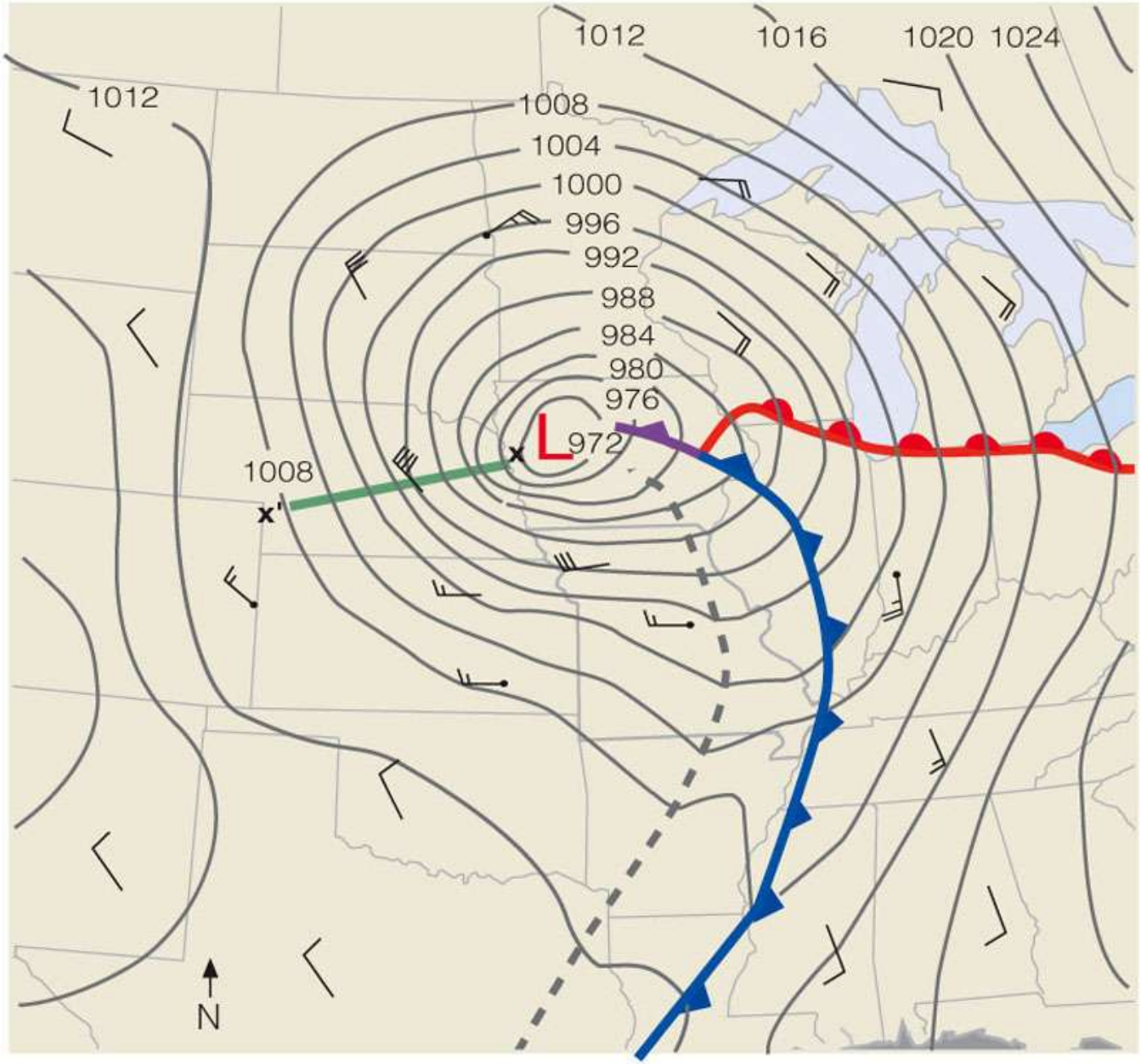
Origin of the Centripetal Force

- The centripetal force in the atmosphere is the net result of the pressure gradient force and the Coriolis force





Wind and Pressure Map



	Miles (statute) per hour	Knots
	Calm	Calm
	1–2	1–2
	3–8	3–7
	9–14	8–12
	15–20	13–17
	21–25	18–22
	26–31	23–27
	32–37	28–32
	38–43	33–37
	44–49	38–42
	50–54	43–47
	55–60	48–52
	61–66	53–57
	67–71	58–62
	72–77	63–67
	78–83	68–72
	84–89	73–77
	119–123	103–107

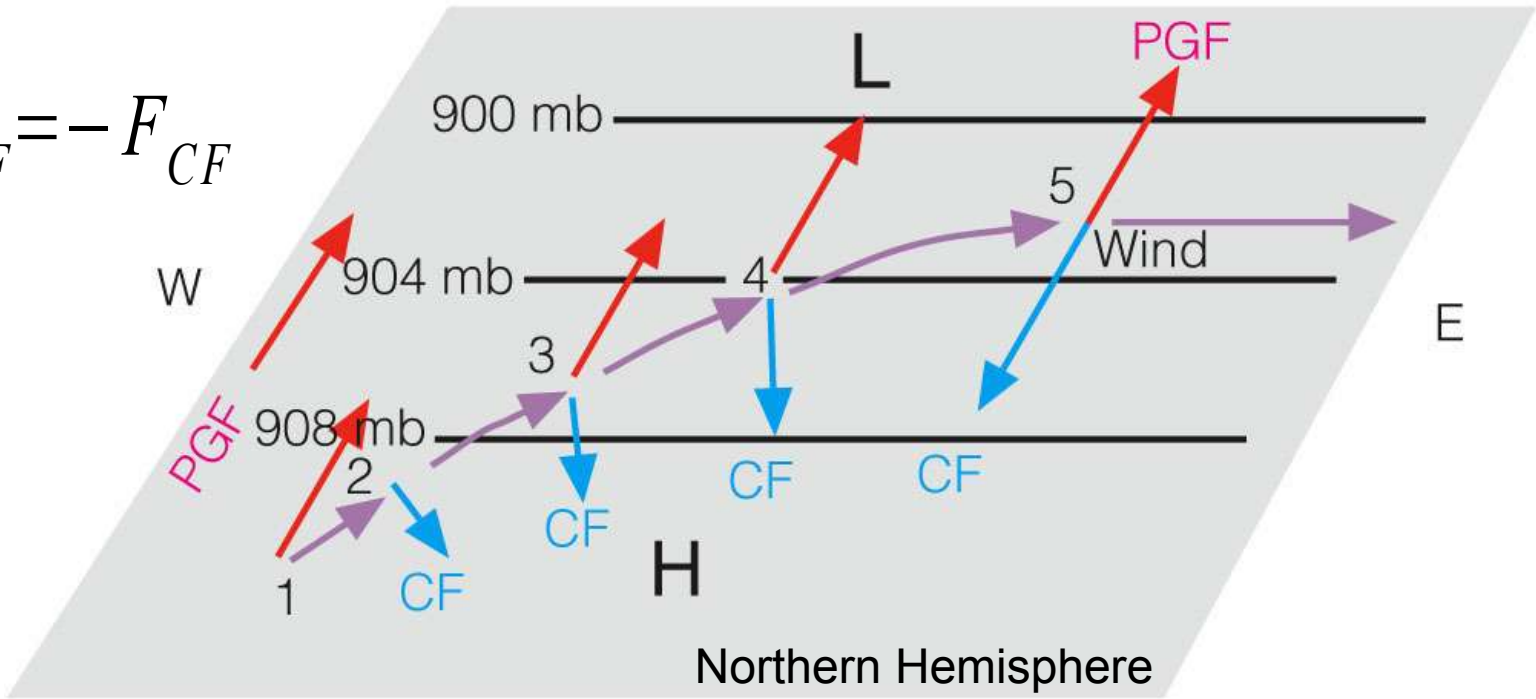
Winds in the Atmosphere

- Geostrophic winds
  - Pressure gradient force = Coriolis force
- Gradient winds
  - Pressure gradient force not equal to Coriolis force
  - Cyclones: PGF > CF
  - Anticyclones: PGF < CF
- Surface winds
  - Affected by ground friction
- Vertical air motion

Geostrophic Winds: direction

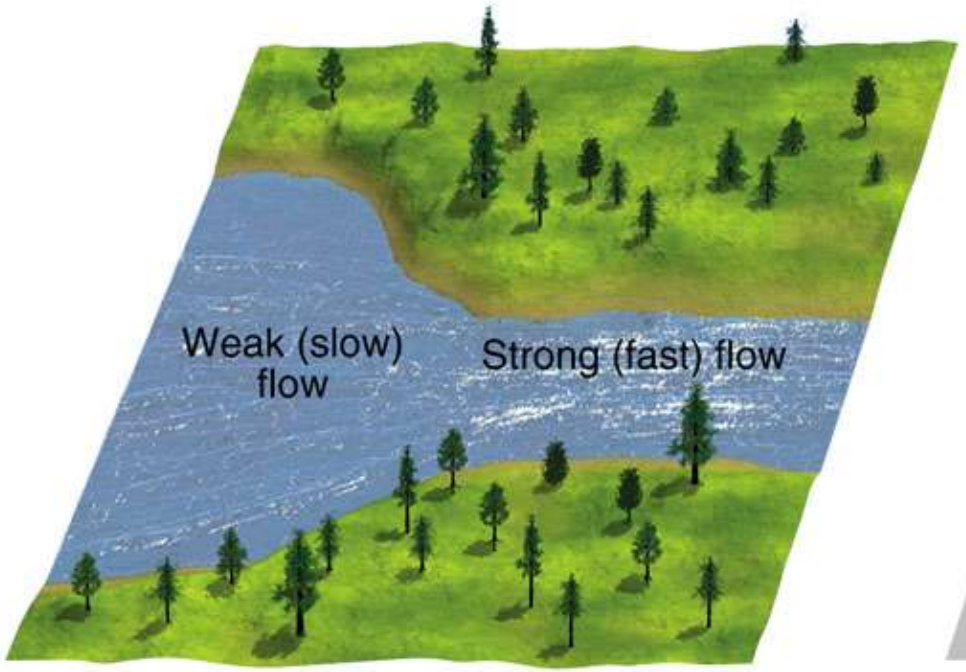
- The pressure gradient force balances the Coriolis force.
- Typically occur at higher altitudes (>1 km).
- The winds are parallel to the isobars.
- In the NH the low pressure is to the left of the wind direction and in the SH the low pressure is to the right.

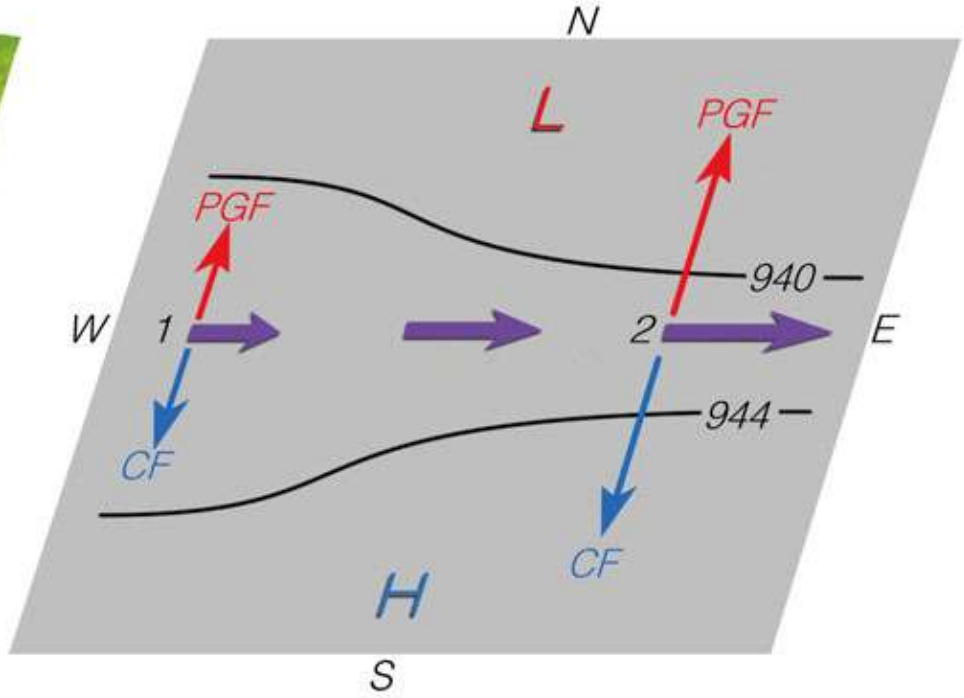
$$F_{PGF} = -F_{CF}$$



Geostrophic Winds: speed

- The wind speed is proportional to the density of the isobars – analogy to a water in a stream
  - Density of isobars increases -> PGF increases
  - Wind speed increases -> CF increases as well





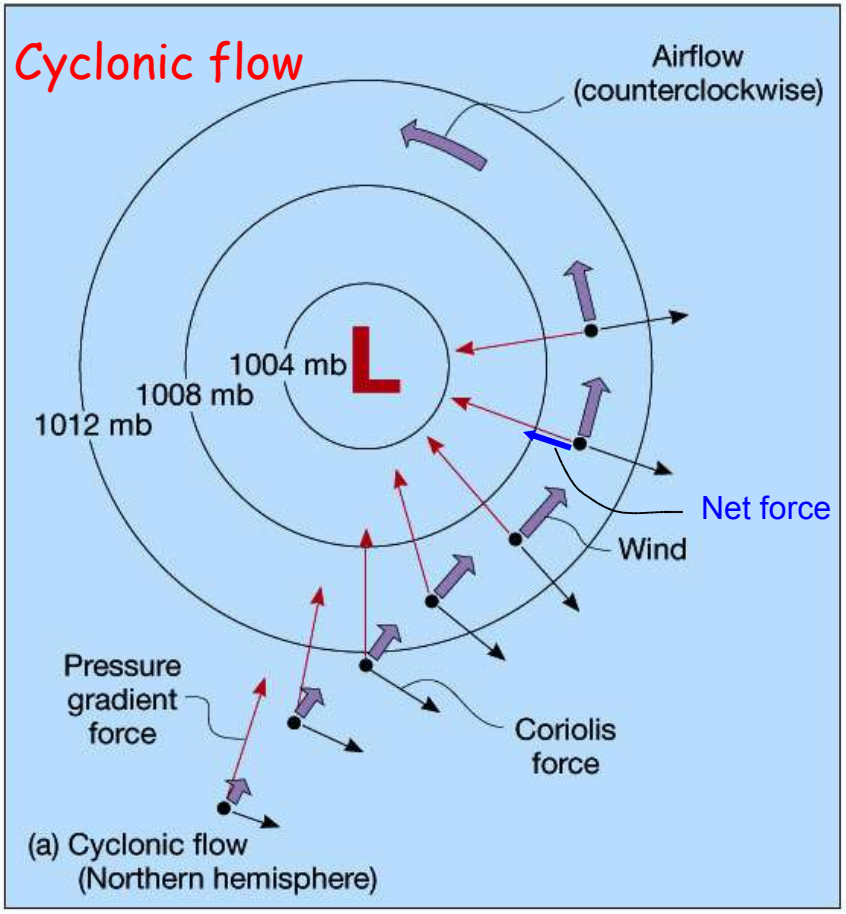
Gradient Winds (Northern Hemisphere)

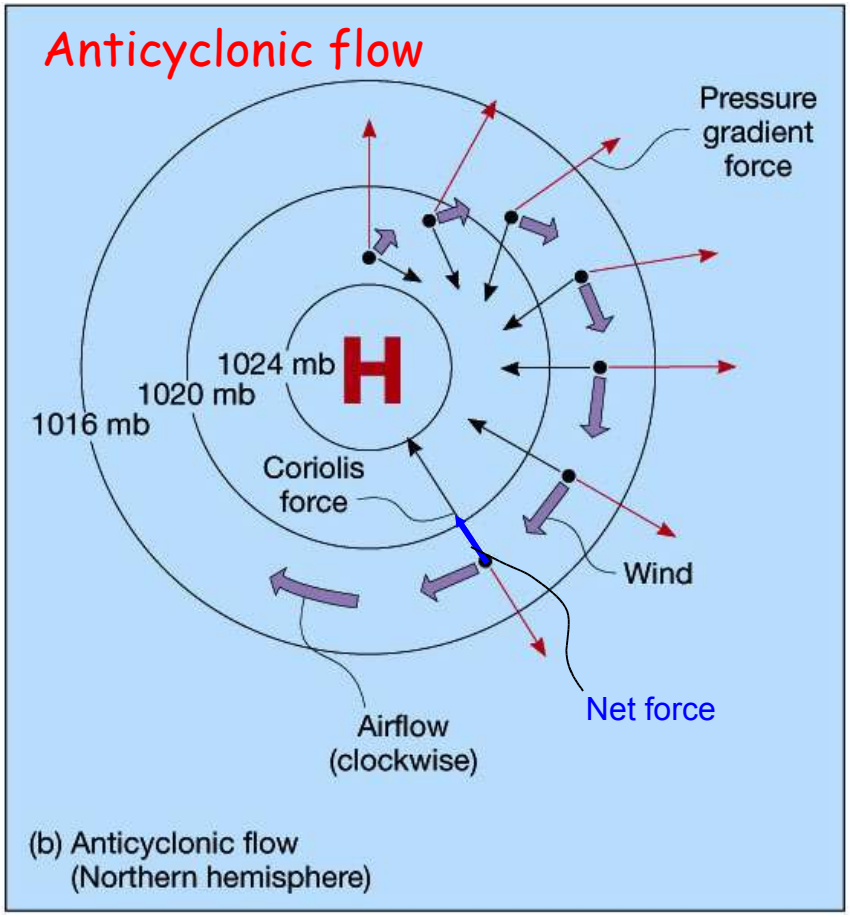
$$F_{pressure} > F_{coriolis}$$

$$F_{pressure} < F_{coriolis}$$

The net force acts as a centripetal force.

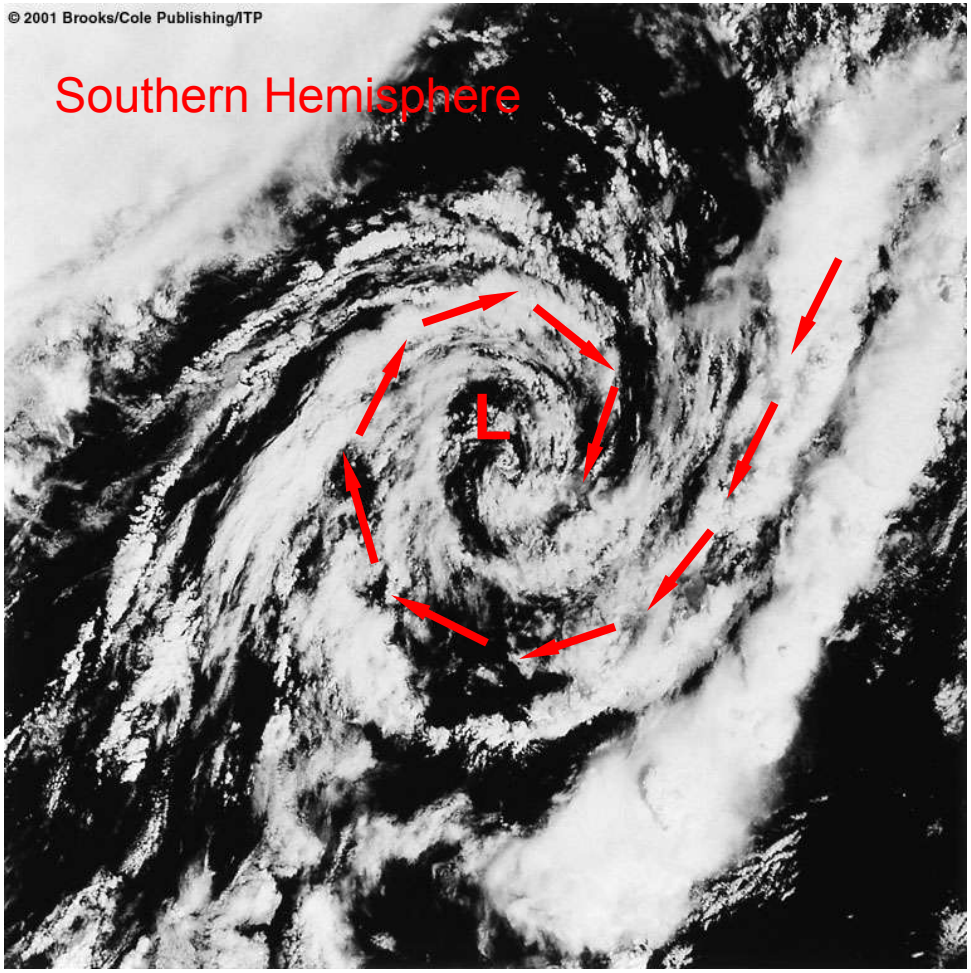
$$F_{net} = F_{pressure} - F_{coriolis}$$



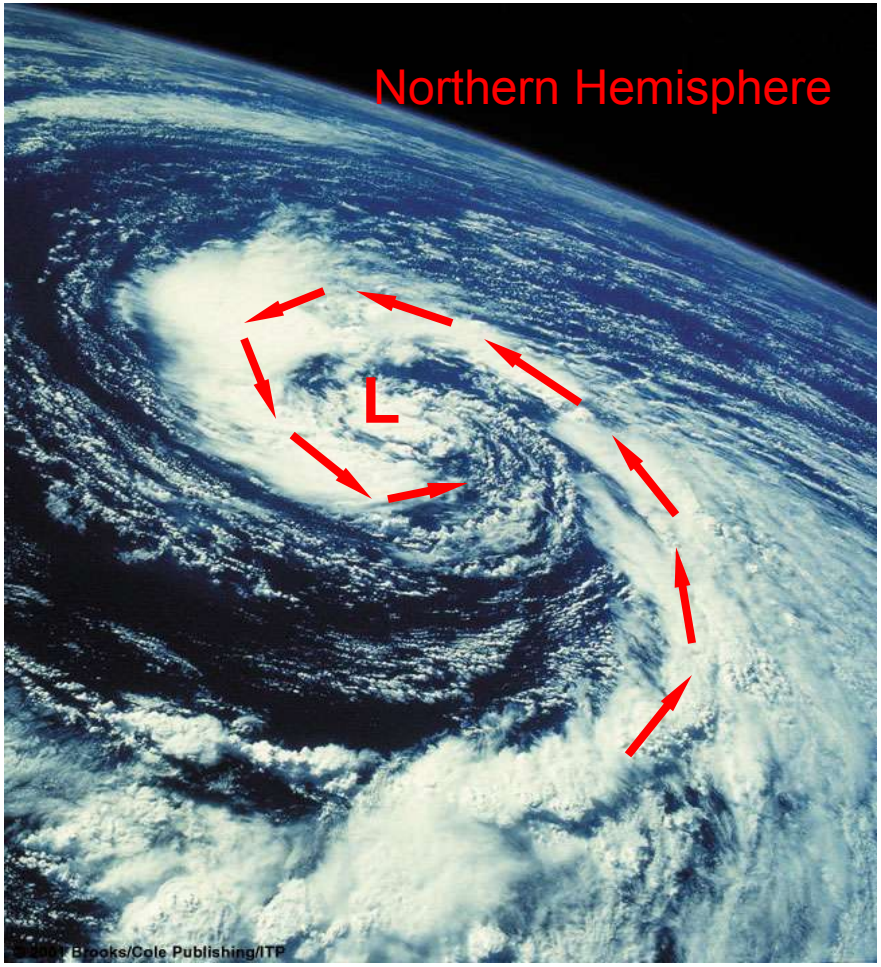


Cyclonic Flow (flow around a low pressure center)

- Clockwise in SH

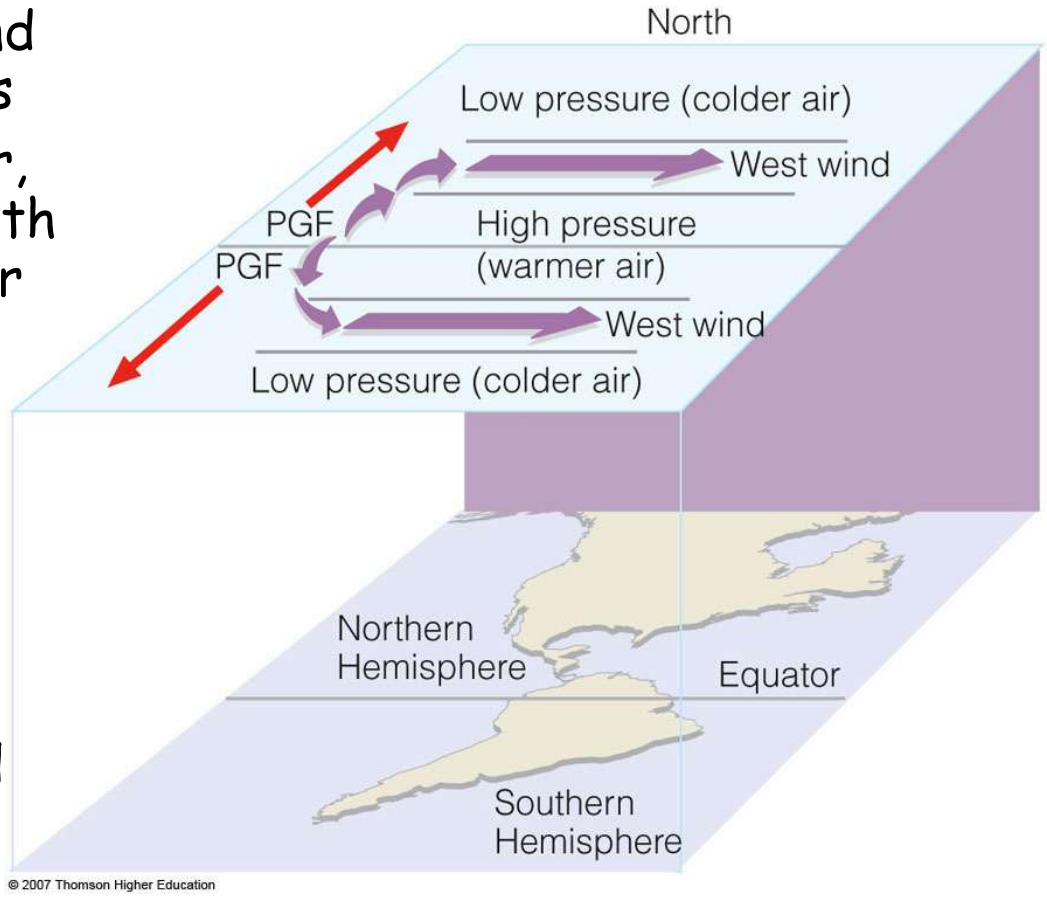


Counterclockwise in NH



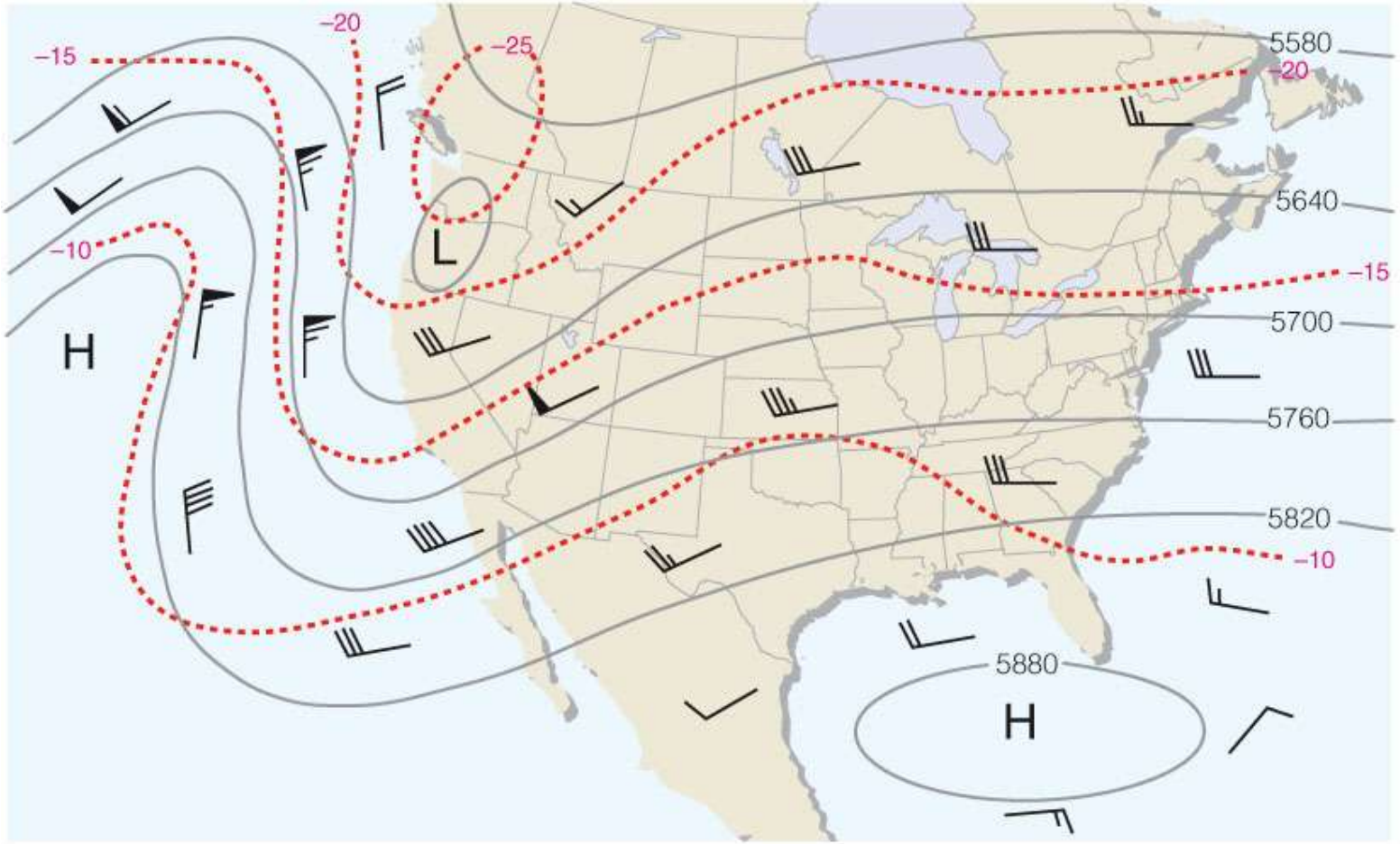
Winds Aloft in the Southern Hemisphere

- Warm air above the equator and cold air above the polar regions
- Higher pressure at the equator, lower pressure both to the north and to the south of the equator
- The pressure gradient force is towards the poles, sets the air in motion
- The Coriolis force
  - NH: to the right
  - SH: to the left
- The wind turns right in the NH and left in the SH, becomes parallel to the isobars
- Westerly winds in both the Northern and Southern Hemispheres.



Summary: prevailing winds at high altitudes

- Direction
  - Zonal: E-W
  - Meridional: N-S
- Balance of forces
  - Geostrophic: near straight isobars
  - Gradient: near curved isobars



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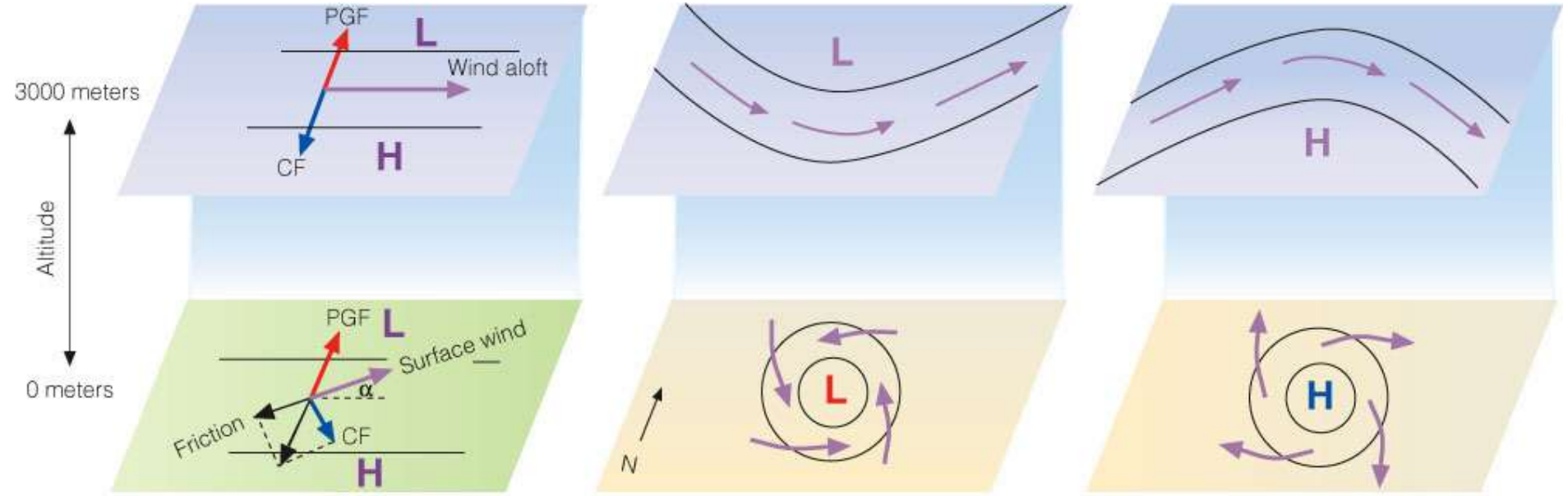
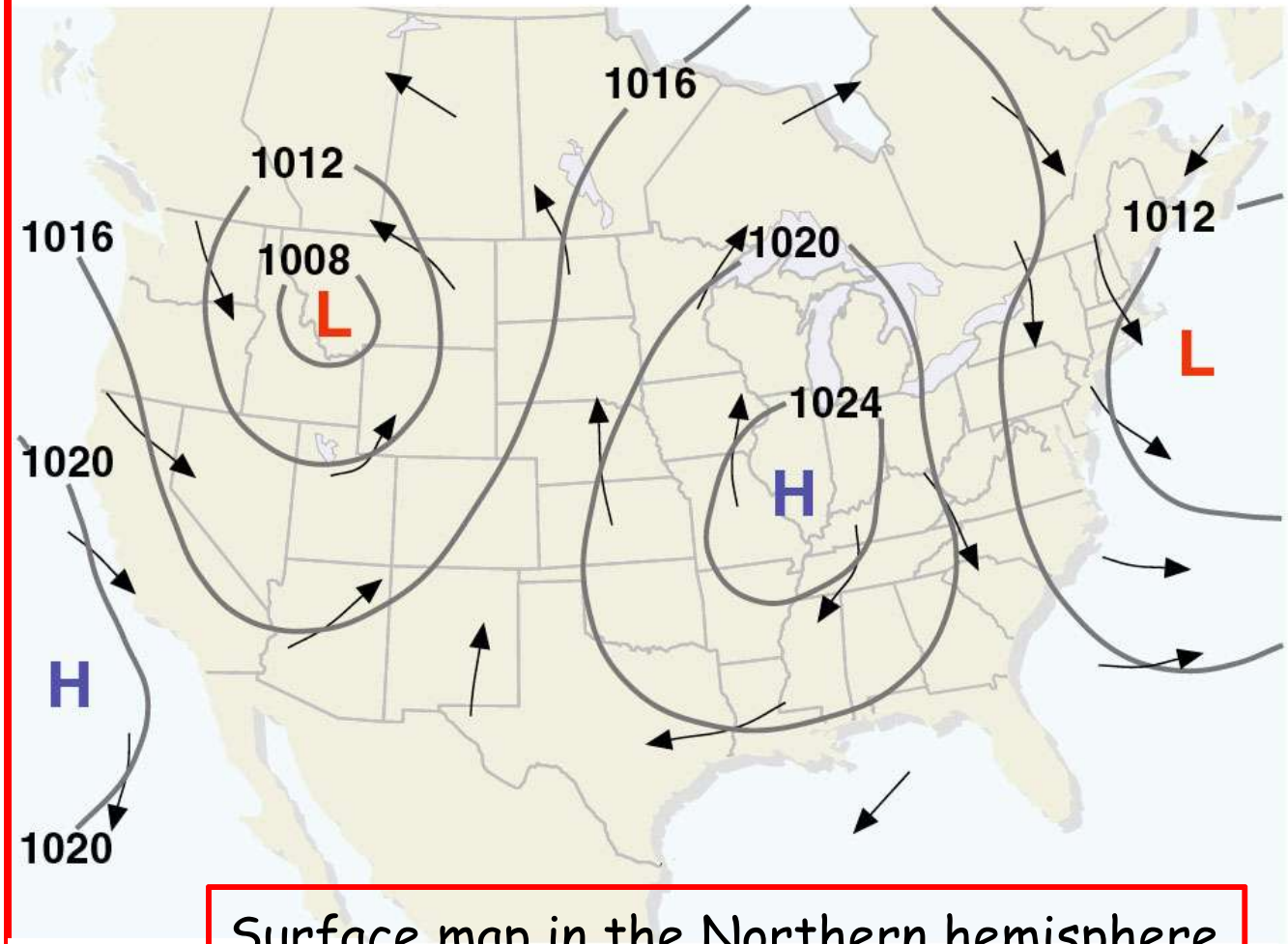
Surface Winds-a balance of three forces

- In the boundary layer (~1km thick) friction is important!
- Friction is acting opposite the direction of the velocity -> friction reduces the wind speed -> the Coriolis force becomes weaker -> it cannot balance the pressure force.
- The wind starts to blow across the isobars towards the low pressure
- The angle between the direction of the wind and the isobars is on average 30 deg. It depends on the topography.



Is this a surface or a high-altitude map?

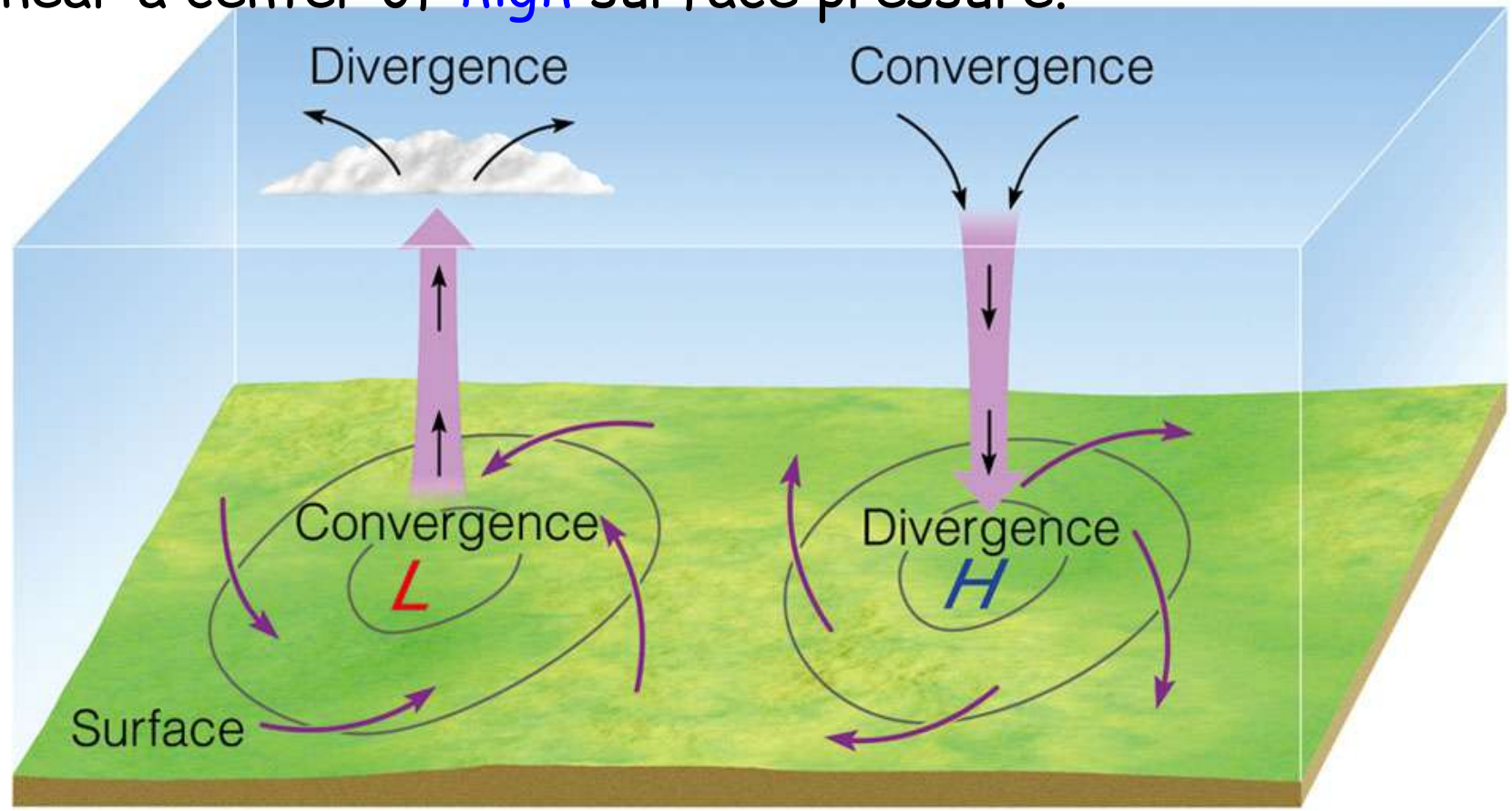
Which hemisphere is this?



Surface map in the Northern hemisphere

Vertical Air Motion: Convergences and Divergences

- Near a center of low surface pressure there is a convergence of air -> the air is forced to rise and then diverge at higher altitudes. The opposite takes place near a center of high surface pressure.



Hydrostatic Equilibrium

- On average gravity is balanced by the pressure gradient force -> hydrostatic equilibrium
- Small deviations from hydrostatic equilibrium result in small vertical winds (a few cm/s)