ATM 10 Severe and Unusual Weather

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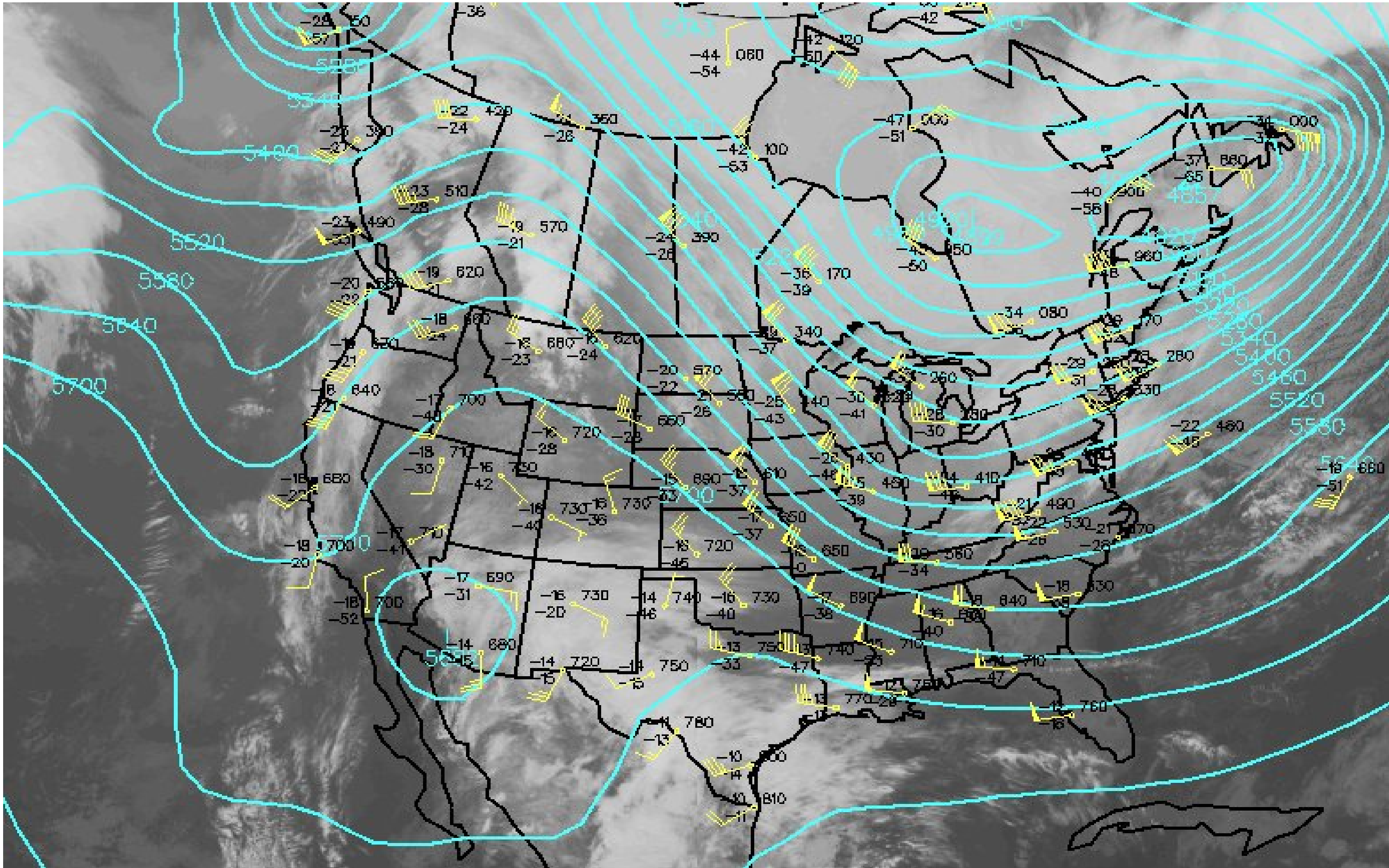
http://atm.ucdavis.edu/~grotjahn/course/atm10/index.html

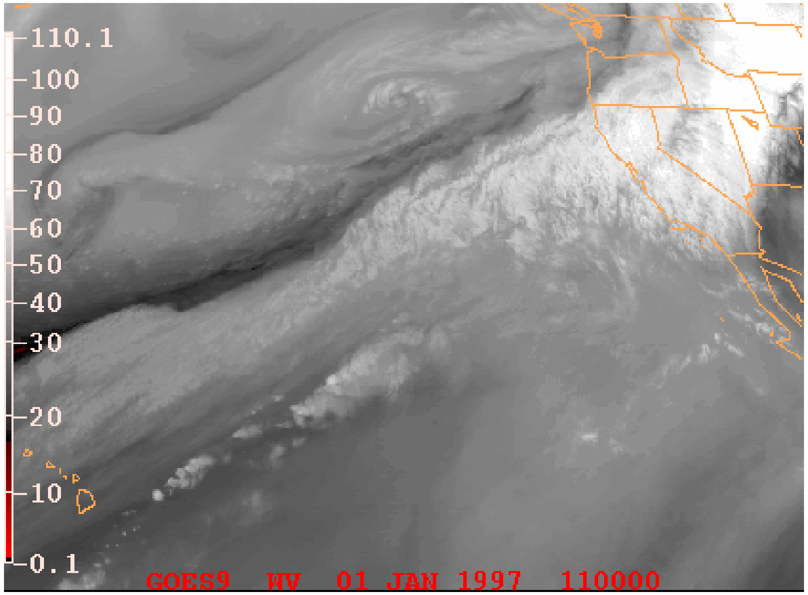


Lecture topics:

- Rotation and wind
  - Coriolis Force (CF)
  - Adding Vectors
- Geostrophic Winds (Vg)
- Centripetal Force (RF)
- Surface Winds

T, P, & Wind

- Recall: Why do clouds move like this?



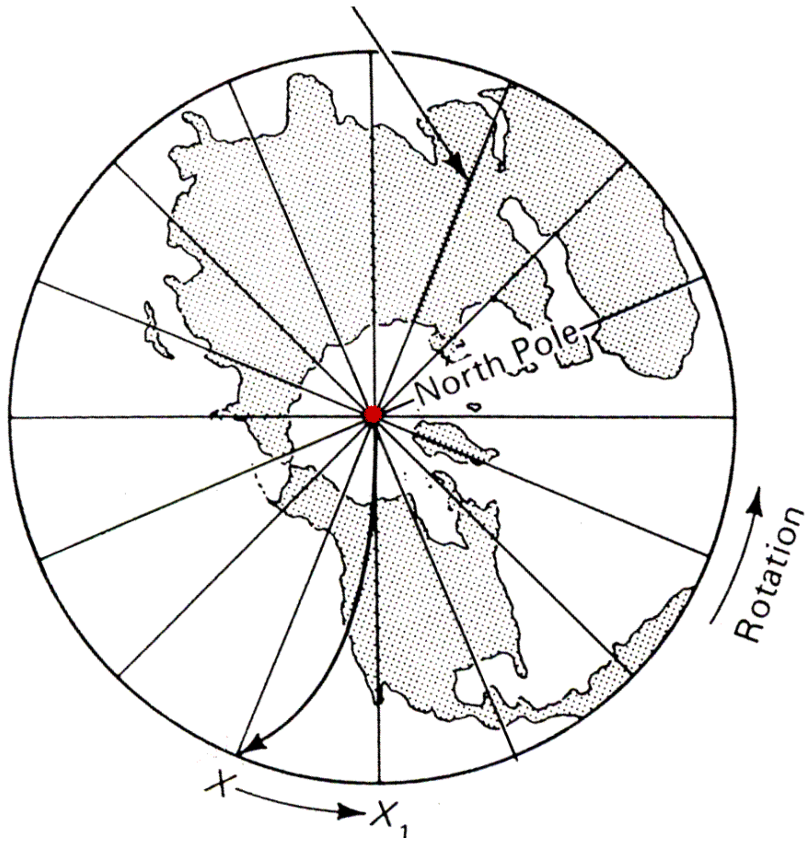
Recall: Forces

- 4 forces:
  - Pressure,
  - Coriolis,
  - Centripetal,
  - Friction
- Most motions a combination of 2 or more these 4

Coriolis Force (part 1)

- Newton's First Law: A body in motion will stay in motion unless acted upon by an external force

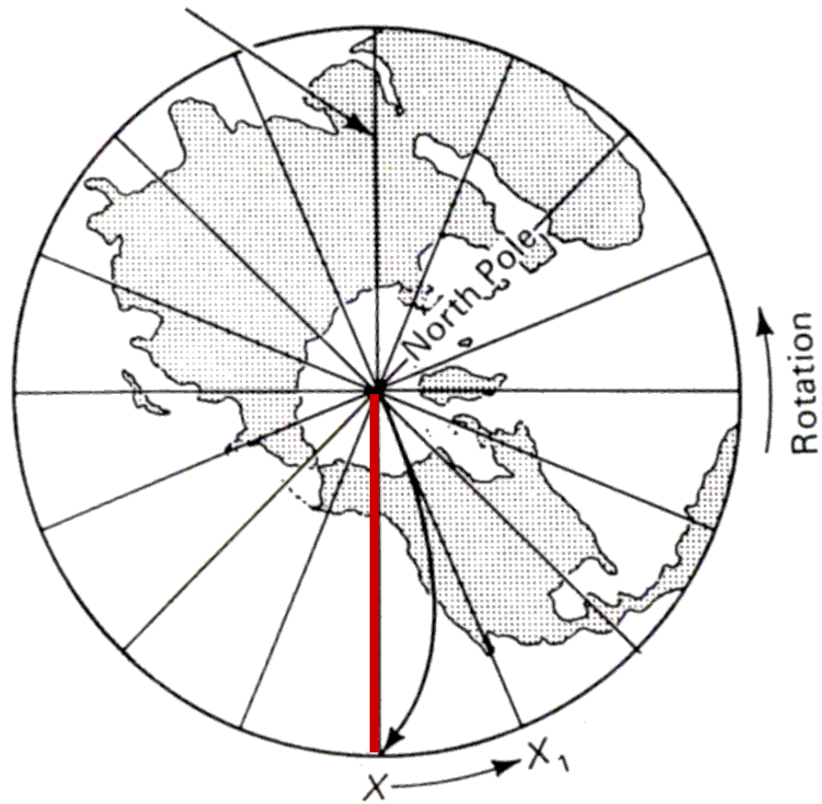
- Viewed from space (red line) path is straight.
- Viewed from the North Pole (black line) path appears defected to the right as you look from the starting point (N. Pole)



Coriolis Force (part 2)

- Newton's First Law: A body in motion will stay in motion unless acted upon by an external force

- Viewed from space (red line) path is straight.
- Viewed from ground (black line) path appears defected to the right
- The change of direction (viewed from earth) implies a force named the "Coriolis force"



Coriolis Force (part 3)

- Coriolis force is hard to understand because we describe things in terms of fixed points on the earth, but those fixed points are rotating
- Conceptual example: playground turntable

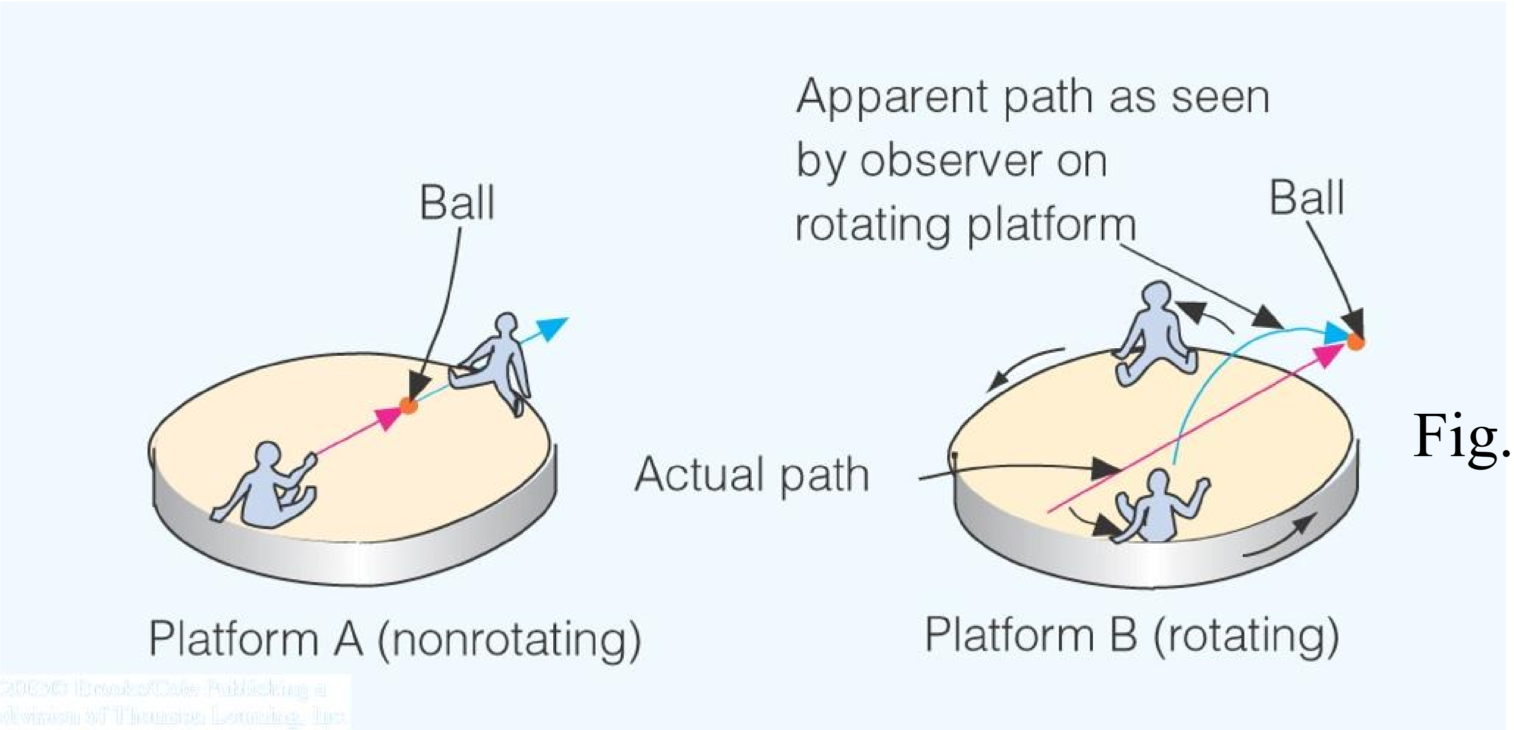
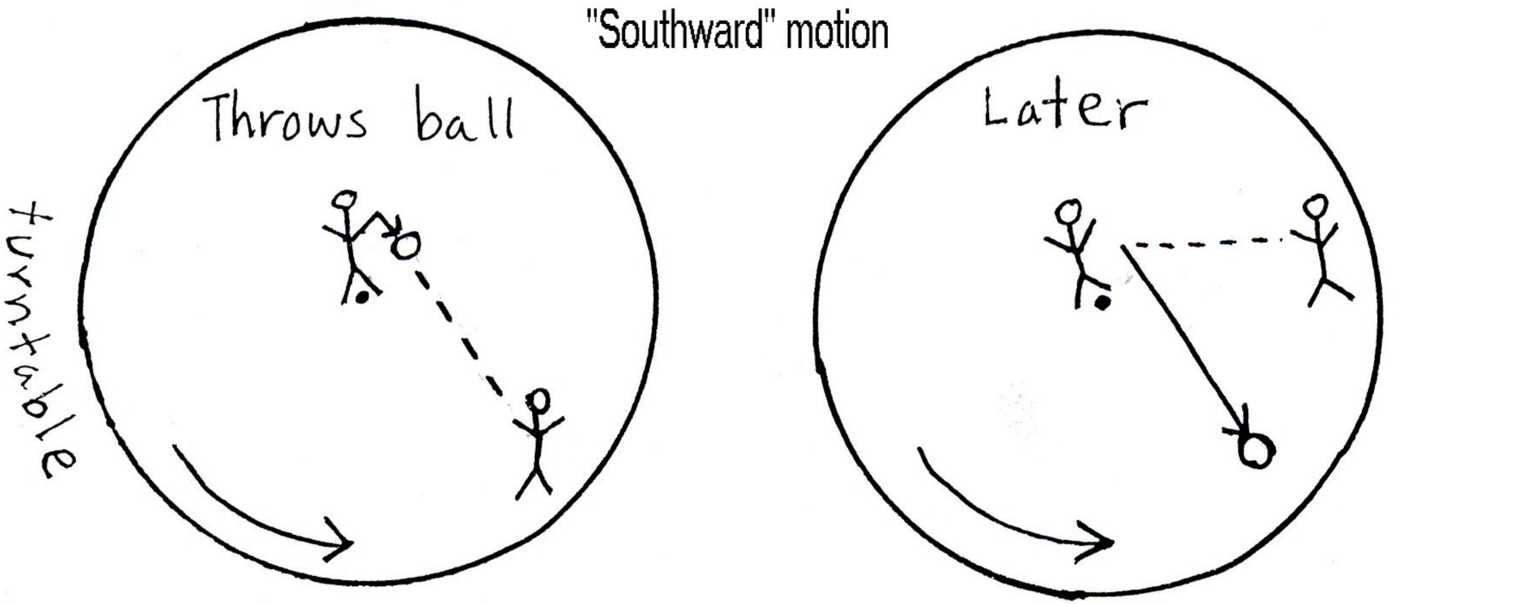


Fig. 9.20

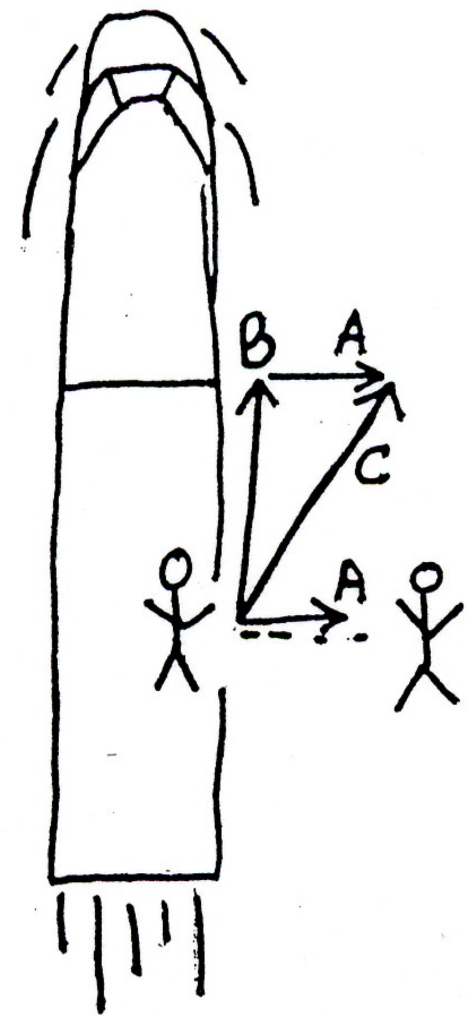
Coriolis Force (part 4) – Southward motion

- Example: toss ball from middle to edge. Similar to the rocket launched from the North Pole.
- Ball appears deflected to the right.



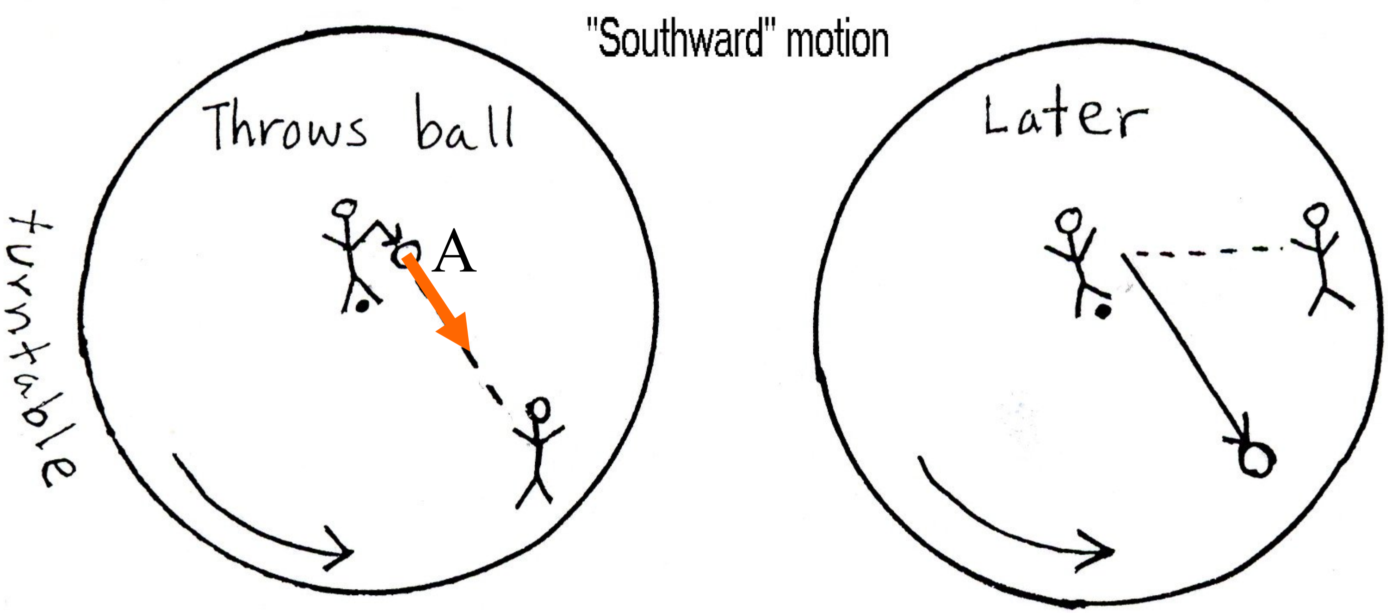
Coriolis Force (part 5) – adding vectors

- When adding 2 vectors, put the tail of one vector to the head of the other without changing direction of either vector.
- Vector A = motion from tossing item straight out.
- Vector B = motion of train.
- Vector A + vector B = vector C
- For rotating earth (or a rotating turn table) must add a vector for motion due to that rotation.



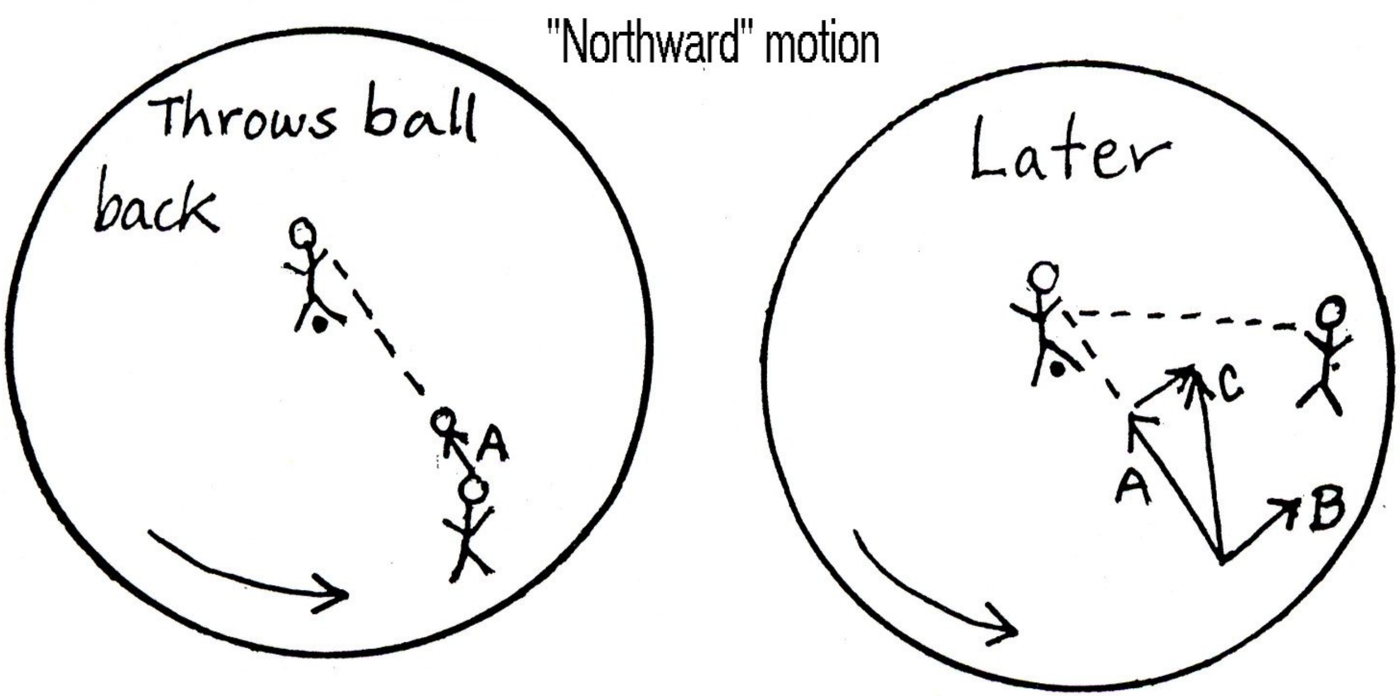
Coriolis Force (part 6) – Southward motion

- Example: toss ball from middle to edge. Similar to the rocket launched from the North Pole.
- Vector A = motion of the toss
- Vector B = 0 no speed of rotation at the middle
- Ball appears deflected to the right.



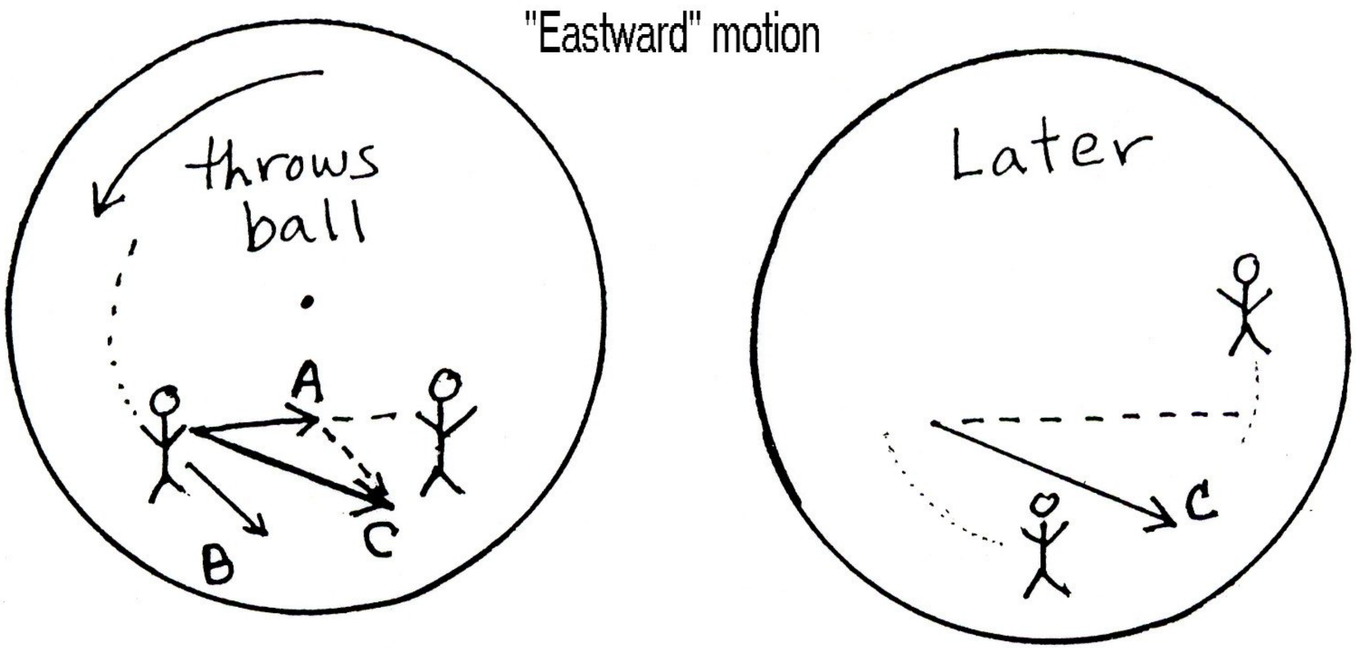
Coriolis Force (part 7) – Northward motion

- Example: toss ball from edge to middle.
- A = vector motion of toss.
- B = vector motion of turntable where toss was made
- A + B = C
- Ball appears deflected to the right.



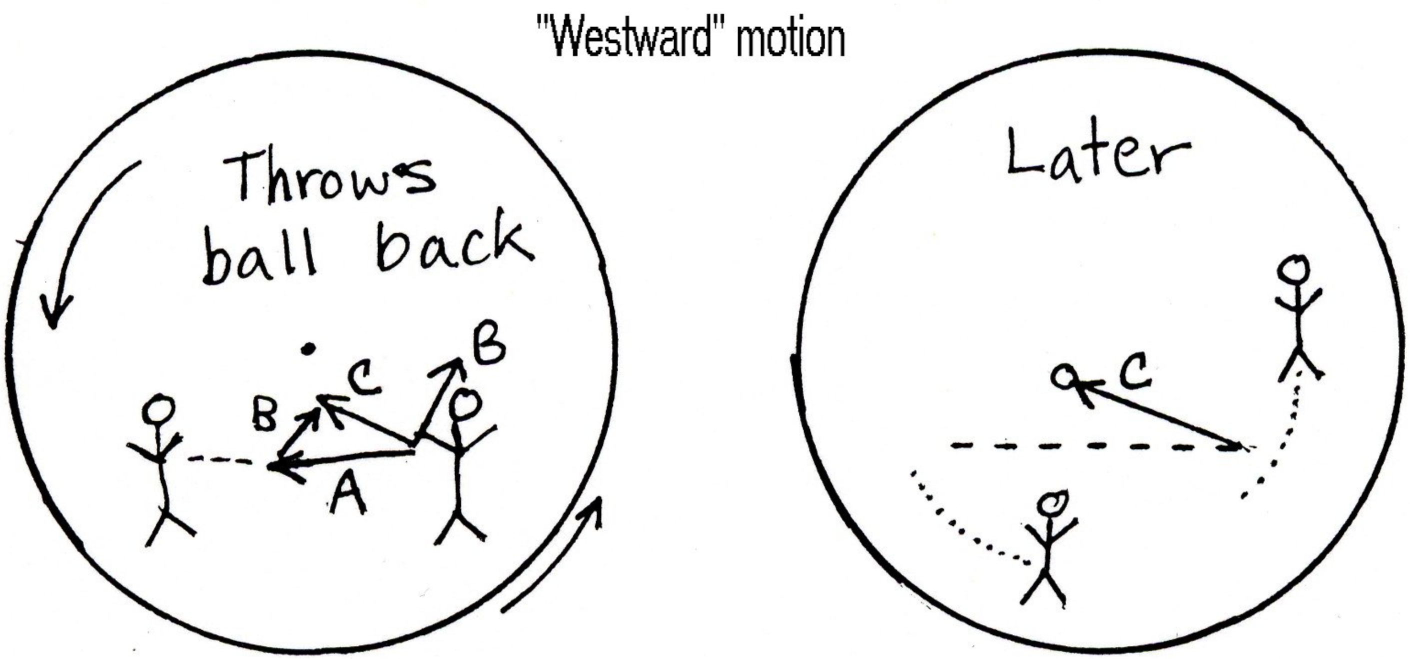
Coriolis Force (part 8) – Eastward motion

- Example: toss ball in direction of rotation.
- A = vector motion of toss.
- B = vector motion of turntable where toss was made
- A + B = C
- Ball appears deflected to the right.



Coriolis Force (part 9) – Westward motion

- Example: toss ball opposite to the direction of rotation.
- A = vector motion of toss.
- B = vector motion of turntable where toss was made
- A + B = C
- Ball appears deflected to the right.

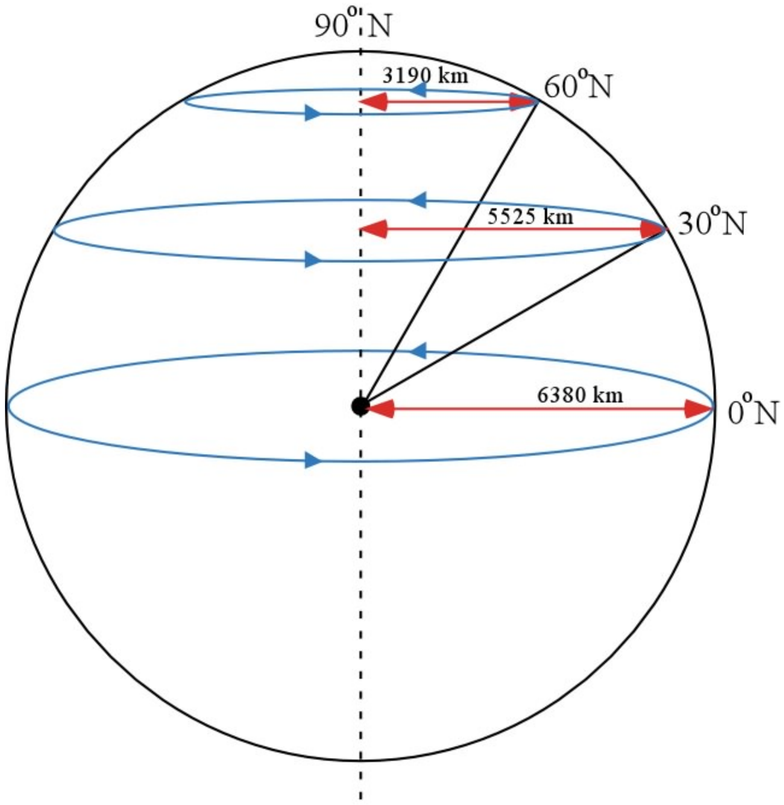


Coriolis Force (part 10)

1. when you view the motion in a rotating coordinate frame, **freely moving objects seem deflected**.
2. No matter which direction the objects move, they will be **deflected towards the RIGHT when the rotation is counter-clockwise**. This deflection is called the Coriolis force.

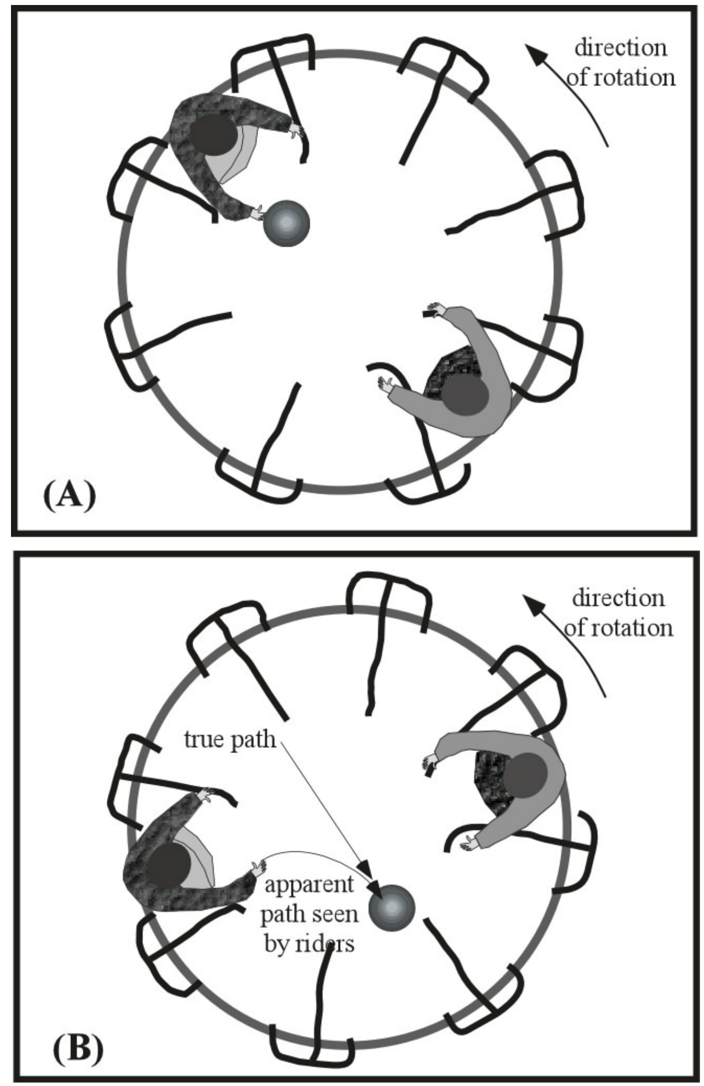
Coriolis Force (part 11)

- Coriolis force = CF
- CF depends on latitude.
- CF positive in Northern hemisphere (deflection to the right)
- CF negative in Southern Hemisphere (deflection to the left)
- CF = 0 at equator
- CF has maximum value at North Pole



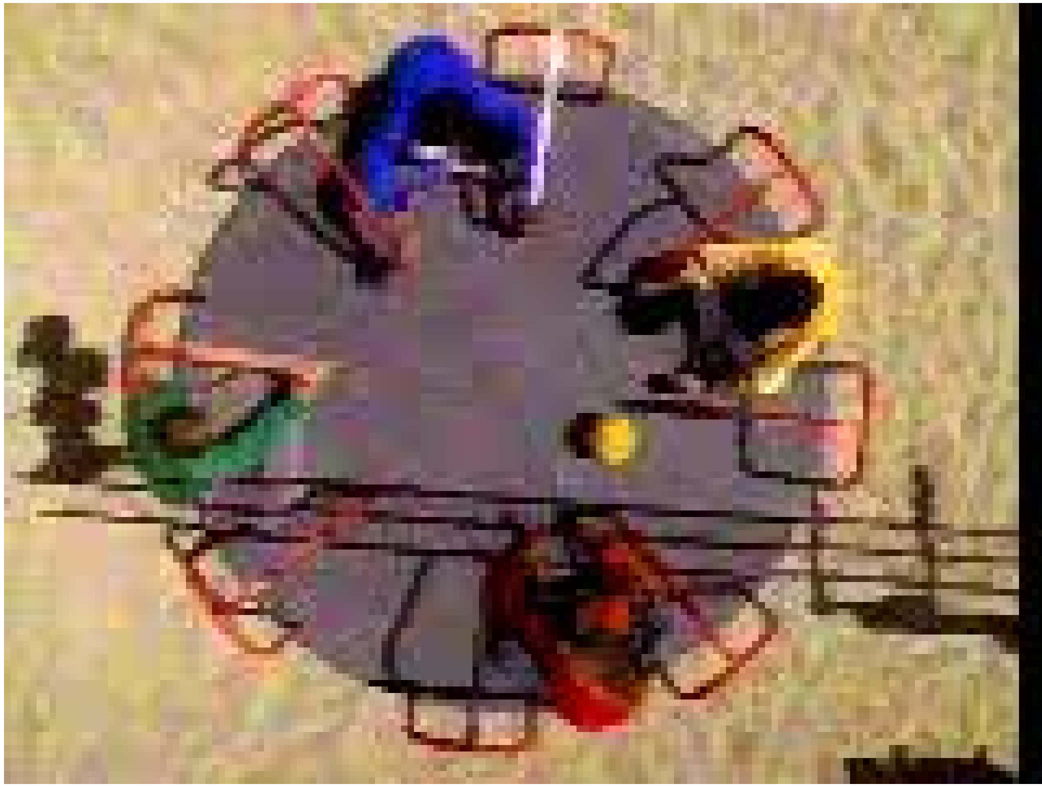
Coriolis Force (part 12)

- Video loop of turntable, similar to this figure, but **turntable in video rotates the other direction.**
- Drawing has deflection to right
- This rotation like looking down on North Pole



Coriolis Force (part 13)

- Video loop of turntable, similar to this figure, but turntable in video rotates the other direction. (Hence video has deflection to the left)
- This rotation like looking down on South Pole

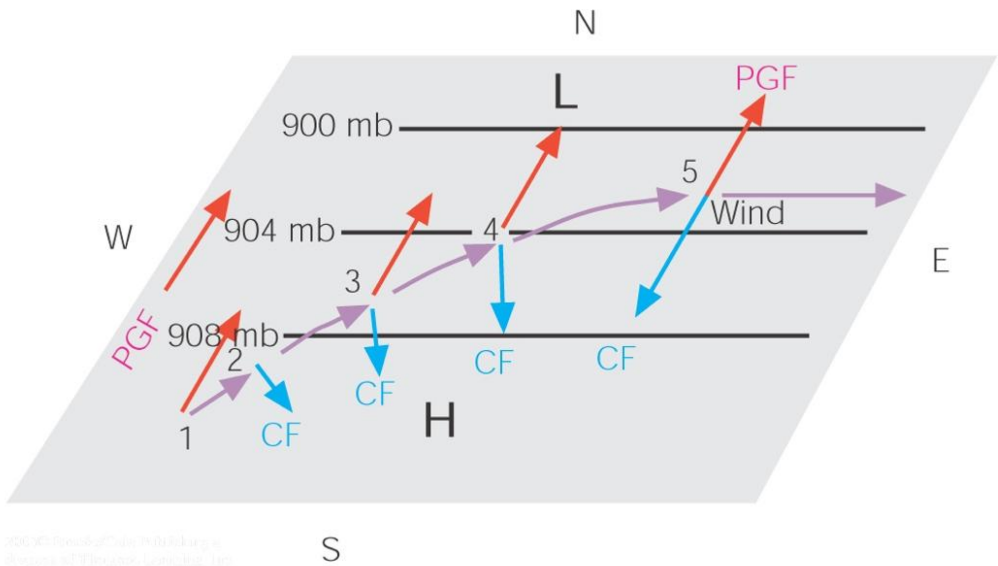


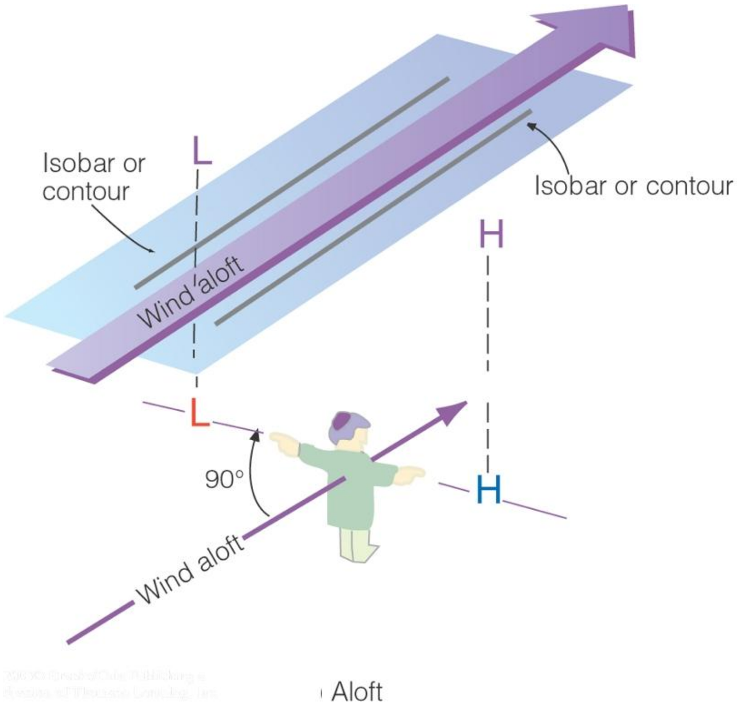
Coriolis Force (part 14) - Summary

- **CF depends on rotation rate of your reference frame (Earth’s rotation rate)**
- **CF depends on your distance from axis of rotation (a function of latitude)**
- **CF depends on your speed relative to the reference frame (speed of the air)**
- **CF is directed to your right (looking downwind in the Northern Hemisphere)**
- **CF in Southern Hemisphere directed to your left (turntable rotates other way).**

Geostrophic Winds (part 1)

- pressure gradient force (PGF) from H to L
- Coriolis force (CF) always to right
- PGF opposes CF for lower P on your left as look downwind.





Geostrophic Winds (part 2)

- $CF = 2 * \Omega * Vg * \sin \varphi$
- $PGF = \Delta P / \{d * \rho \}$

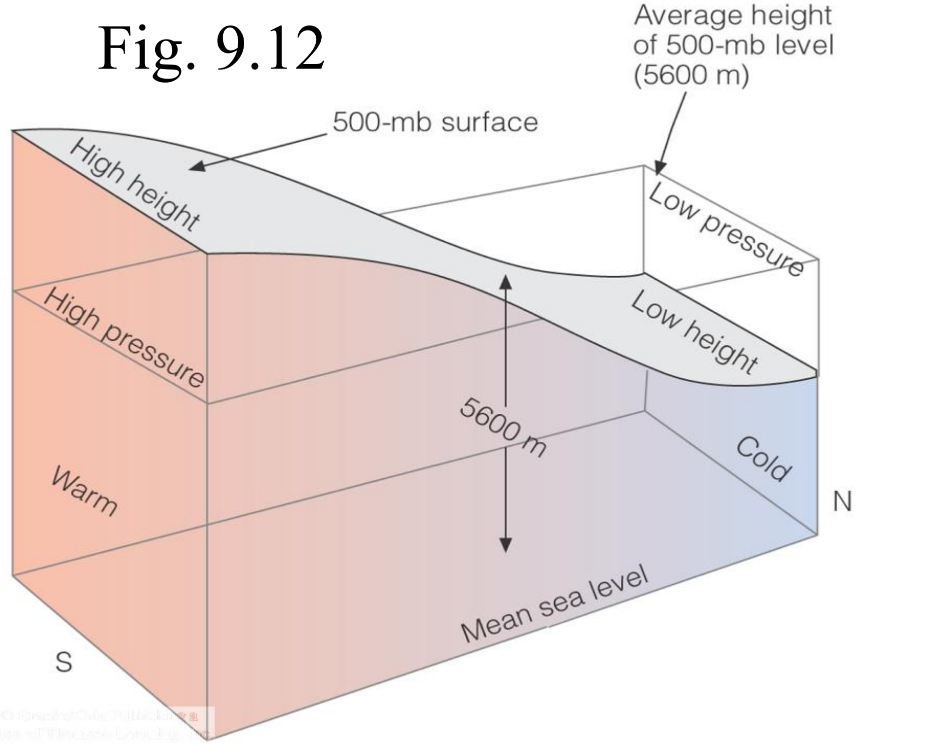
- Geostrophic wind formula:
- $CF = 2 * \Omega * Vg * \sin \varphi = \Delta P / \{d \rho \} = PGF$
- Rearranging for Vg:
- $Vg = \Delta P / \{d*\rho*2 * \Omega * \sin \varphi \}$

Geostrophic Winds (part 3)

- $Vg = \Delta P / \{d*\rho*2 * \Omega * \sin \varphi \}$

- Vg greater where the P slope is greater.
- Low to the left means flow is mainly westerly (from west)

Fig. 9.12



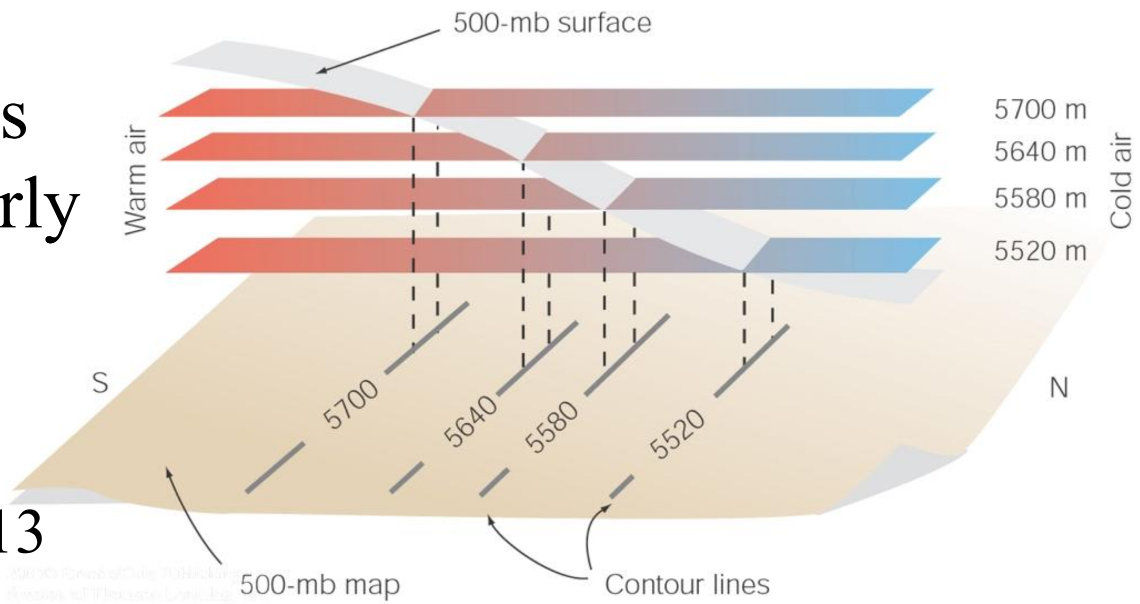


Fig. 9.13

Geostrophic Winds (part 4)

- $Vg = \Delta P / \{d*\rho*2 * \Omega * \sin \varphi \}$
- Vg greater where P contours more closely spaced

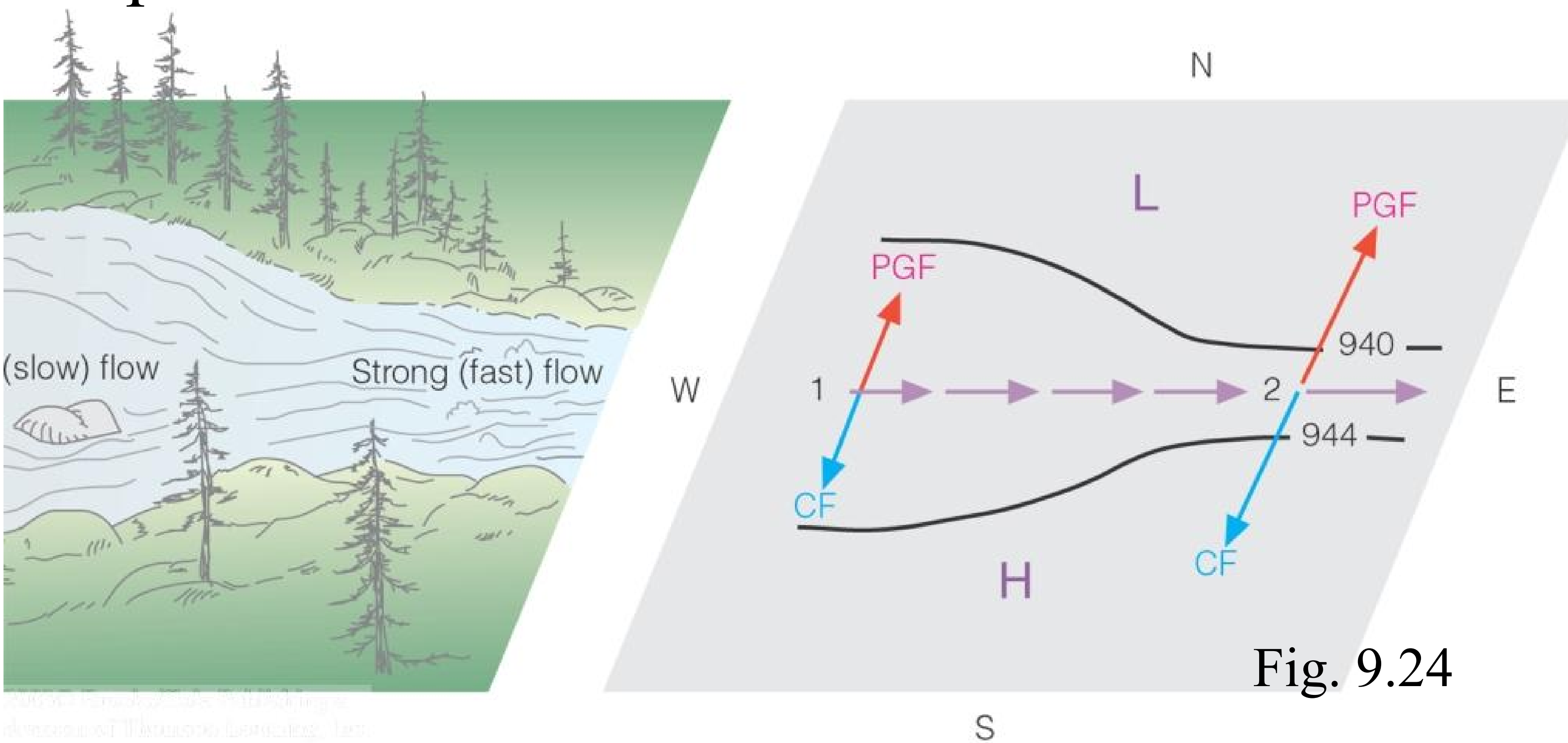


Fig. 9.24

Geostrophic wind (part 5) - summary

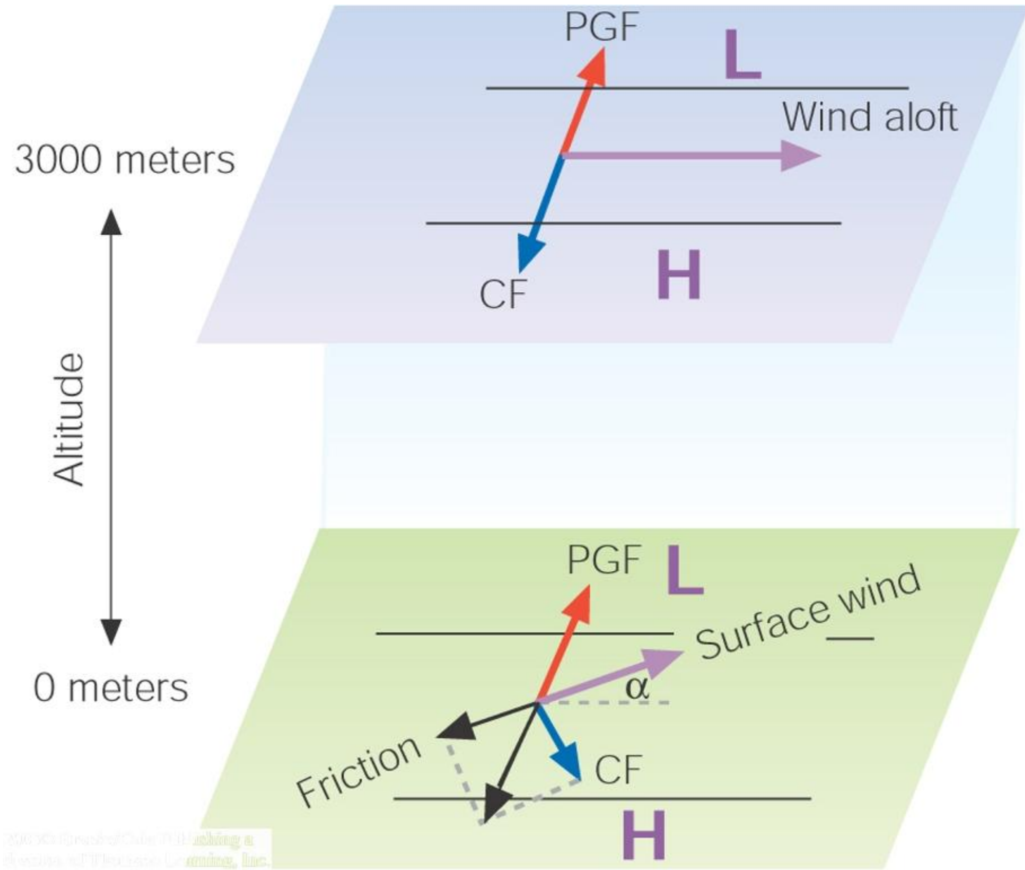
- **Balance between PGF & CF**
- **Blow parallel to the pressure contour lines**
- **In the Northern Hemisphere lower pressure is on your left as you look downwind**
- **In the Southern Hemisphere lower pressure is on your right as you look downwind.**
- **Good approximation for winds more than 1 km above the ground (outside tropics)**
- **Closer spacing of pressure contours means faster wind.**

Centripetal Force ("RF")

- When spin something around there is a force required to keep the object from flying off
- The force keeps the direction of the object changing (as it moves in a circle)
- Centripetal force (RF) is the term for the net force directing wind toward the center of a low or a high
- Formula: RF = V * V / r
- V is the velocity of the object
- r is the radius of the circle traveled by object
- Will use RF later for tornados

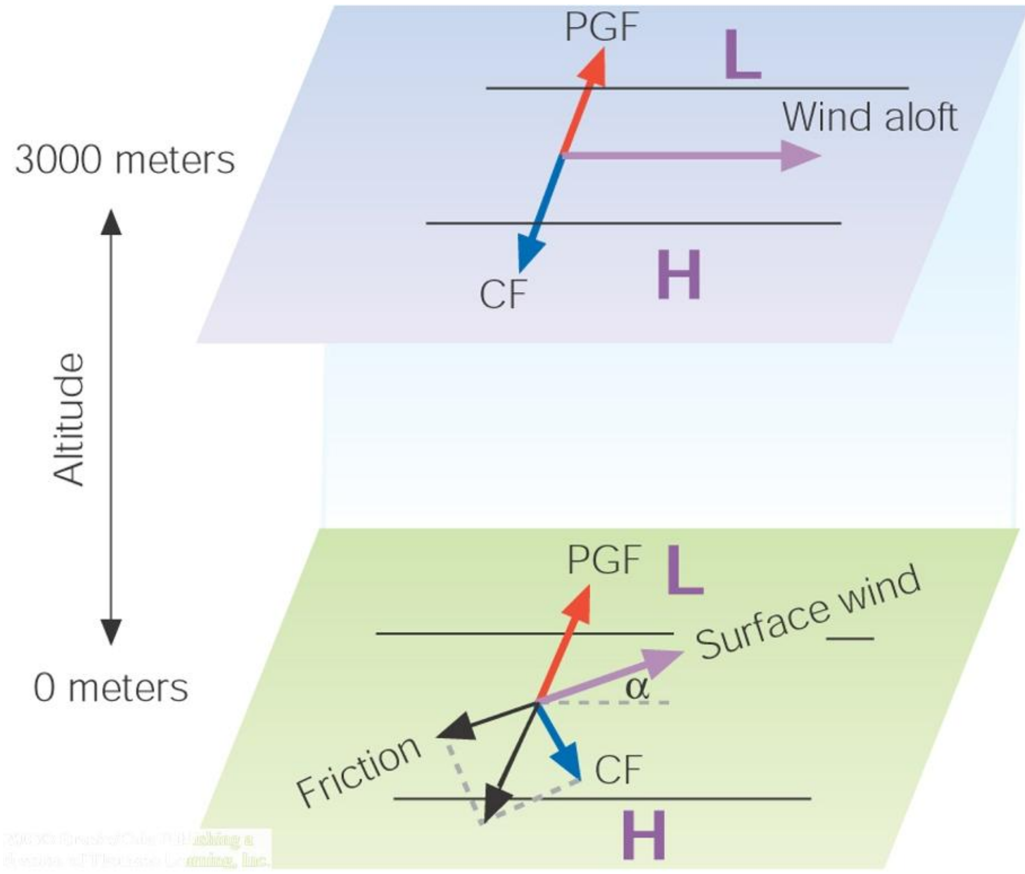
Surface Winds (part 1)

- Recall: Vg is balance of PGF & CF
- CF 90^o to right of wind
- PGF from H to L
- Friction always opposes the motion
- Friction force (FF) important near ground
- Surface winds Vs 3-way balance: PGF, CF, & FF



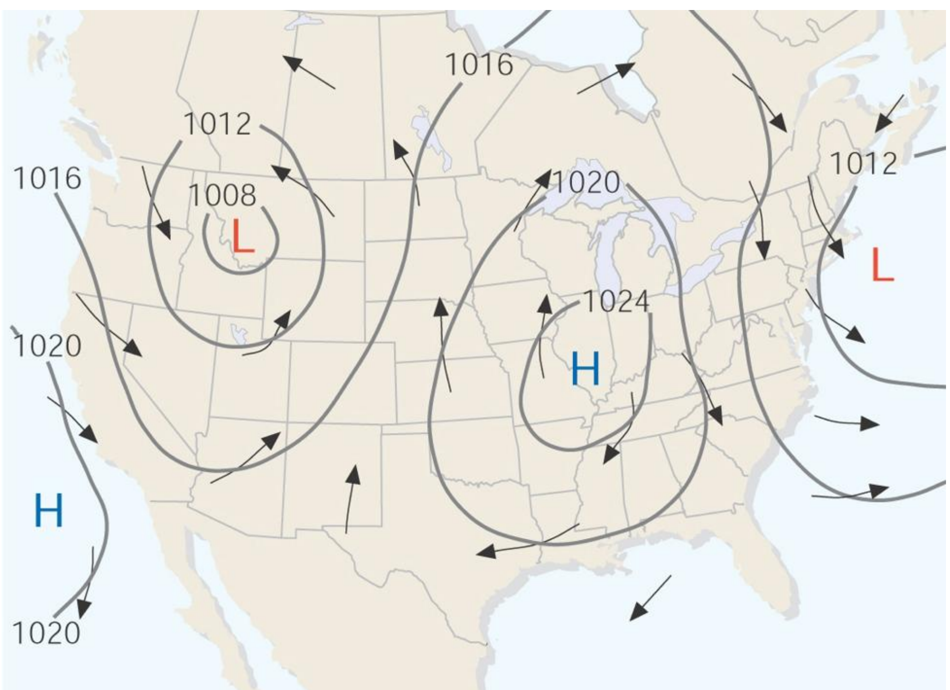
Surface Winds (part 2)

- FF = Friction force is largest near ground
- Surface winds 3-way balance: PGF, CF, & F
- Surface wind Vs has angle across pressure contours from H to L

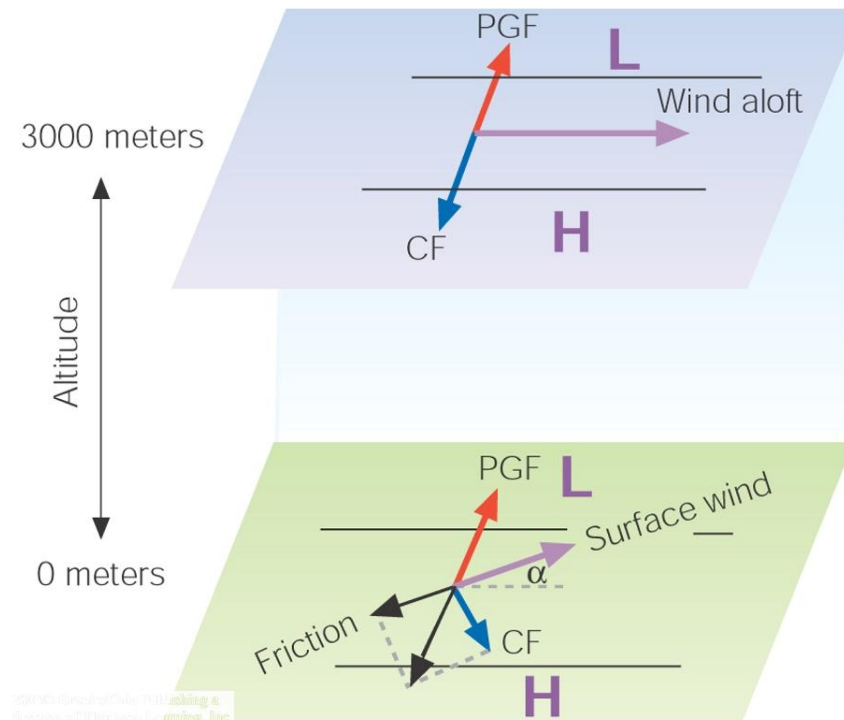


Surface Winds (part 3)

- FF largest near ground
- Surface winds Vs 3-way balance: PGF, CF, & F
- Vs has angle across pressure contours from H to L

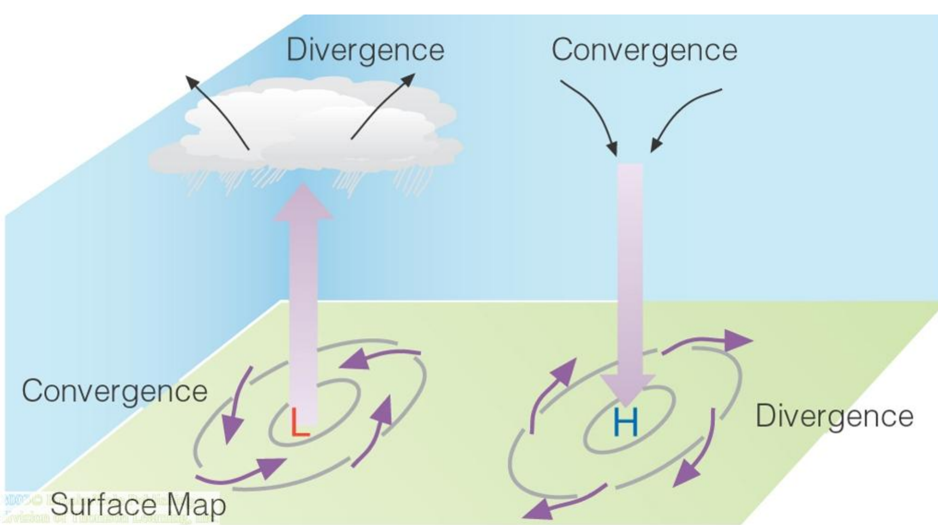


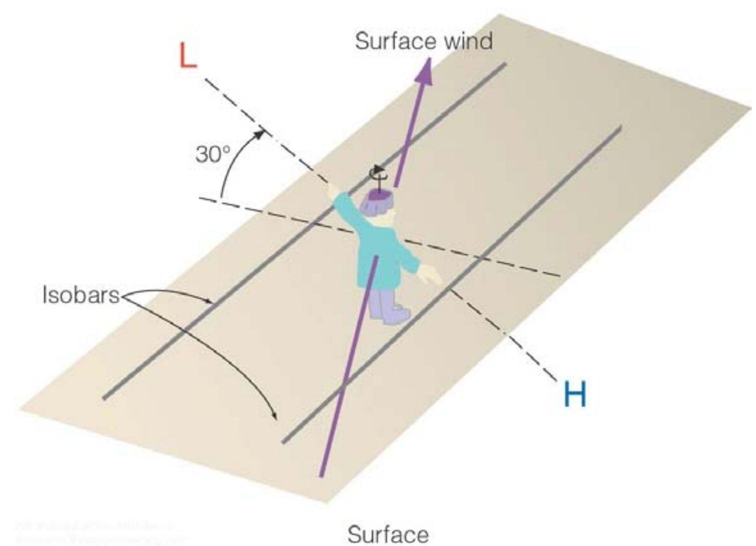
Surface map



Surface Winds (part 4)

- Vs has angle across pressure contours from H to L
- Convergence at low levels near a low → rising (clouds)
- Divergence near a high → sinking (clear skies)





Surface wind (part 5) - summary

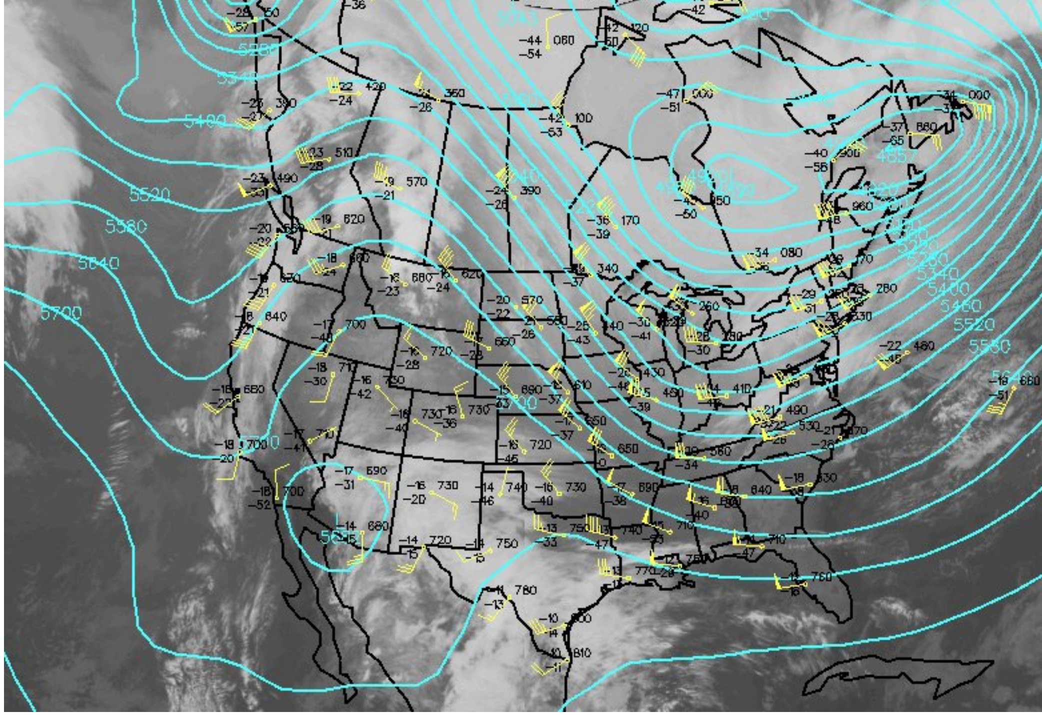
- **Good approximation is a 3-way balance between PGF, CF, & FF**
- **Blow somewhat parallel to pressure contours, but also across the pressure contours, from higher to lower pressure**
- **Lead to converging wind at a low, that causes rising, which aids precipitation**
- **Lead to diverging wind at a high, that causes sinking, which inhibits clouds**

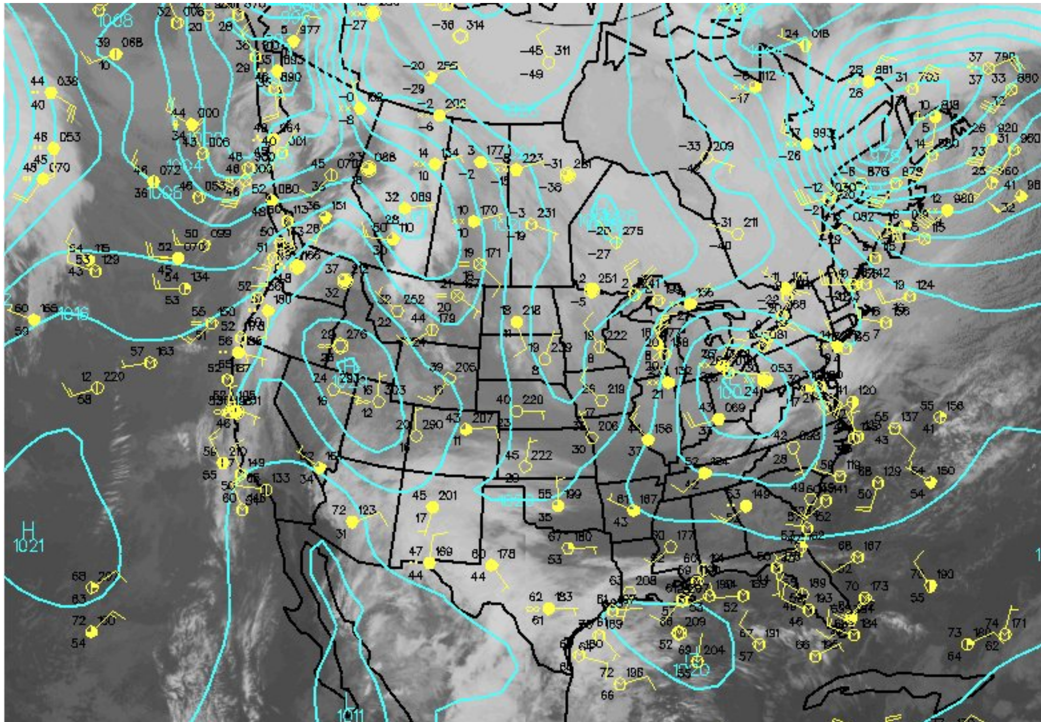
Example Weather Maps

Blue contours: 500 mb pressure & SLP contours

White areas: "clouds"

Yellow: Wind direction (barbs like arrow feathers) and wind speed (more barbs means faster). Wind clockwise around highs, counterclockwise around lows)





End of lecture 8

Current Weather Map

- Surface map for today: (pending)