General Meteorology

Lecture 13

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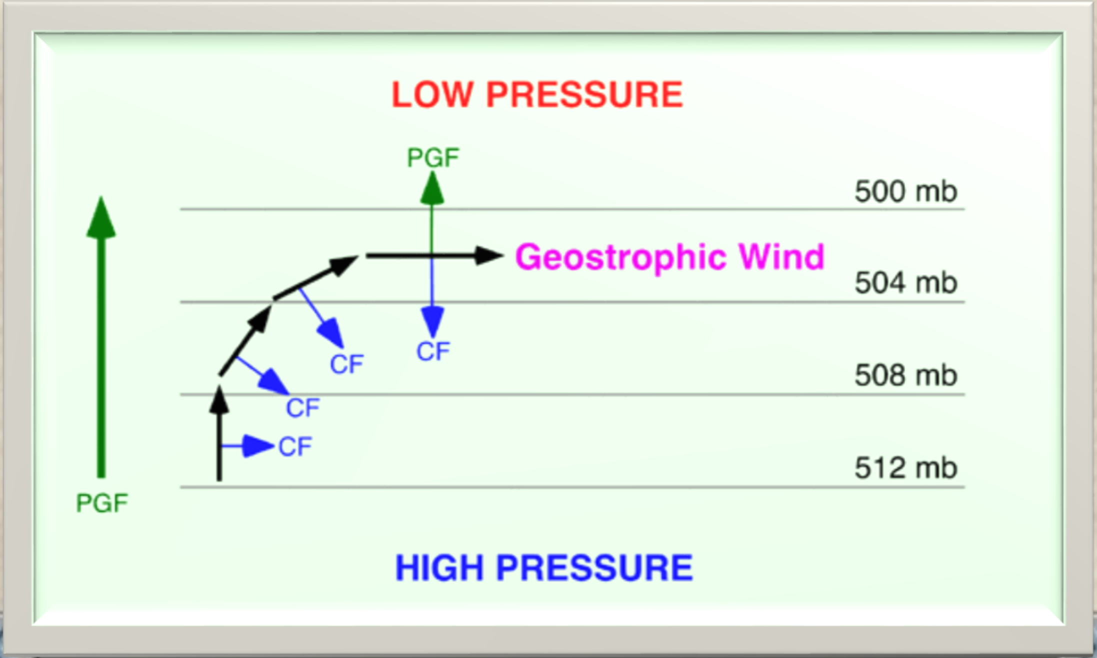
Geostrophic Wind

Winds aloft (above ~1000 m) flowing in a straight line, a balance between 2 forces:

- Pressure gradient force (PGF)
- Coriolis 'force' (CF)

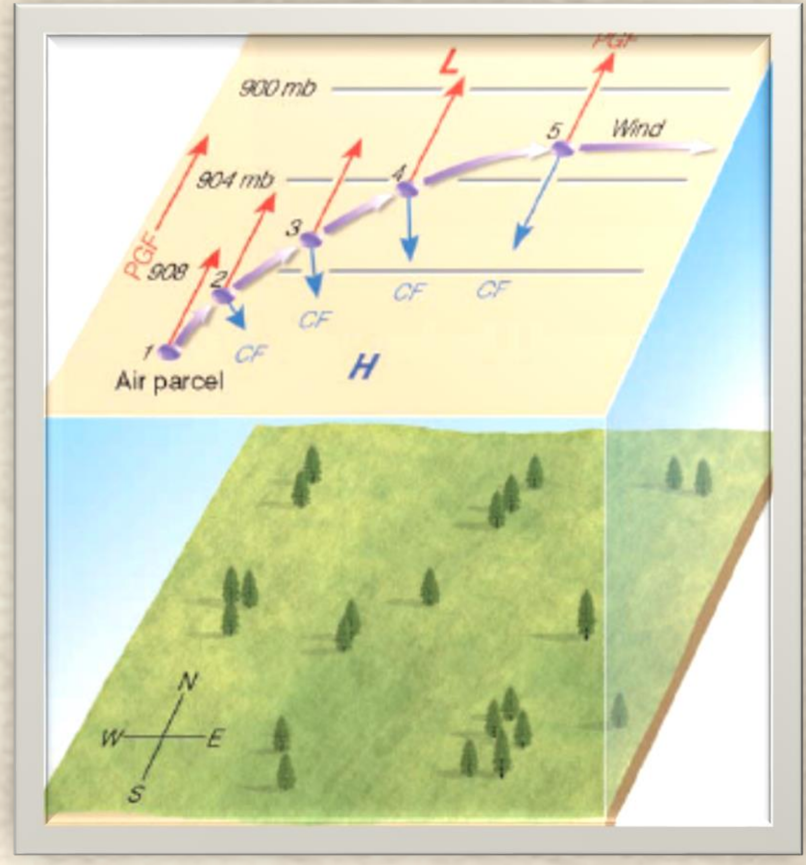
A wind that begins to blow across the isobars is turned by the Coriolis 'force' until Coriolis 'force' and PGF balance



geostrophic wind

Above the level of friction, air initially at rest will accelerate until it flows parallel to the isobars at a steady speed with the pressure gradient force (PGF) balanced by the Coriolis force (CF).

Wind blowing under these conditions is called geostrophic.



Strength of the geostrophic flow

So, if CF = PGF for geostropic flow, and:

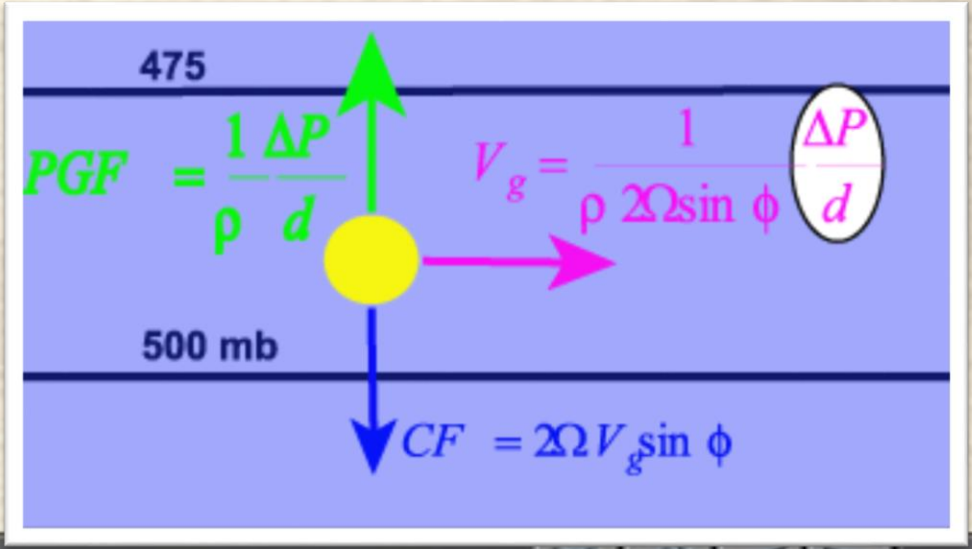
$$PGF = \frac{1}{\rho}\frac{\Delta P}{d} \qquad CF = 2\Omega V_g \sin\phi$$

$$\frac{1}{\rho}\frac{\Delta P}{d} = 2\Omega V_g \sin\phi \qquad V_g = \frac{1}{\rho 2\Omega \sin\phi}\frac{\Delta P}{d}$$

$$dp/dz = -\rho g$$

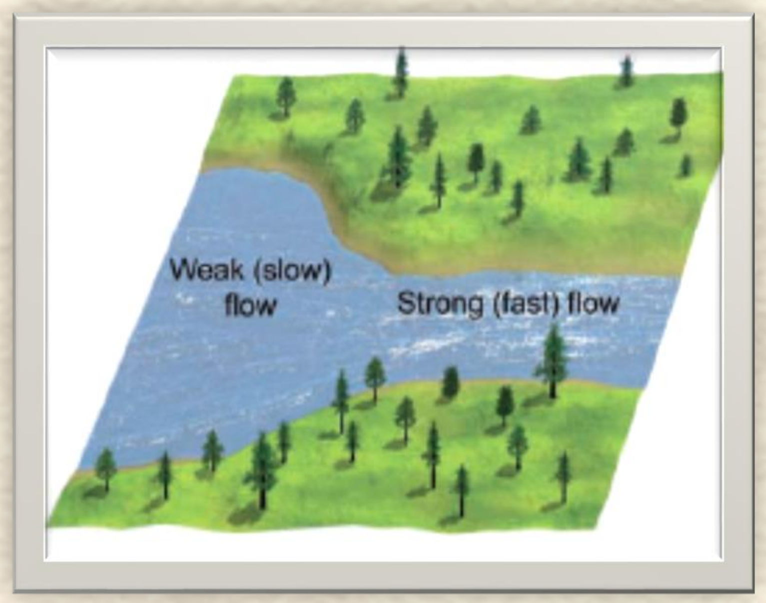
$$\nabla_z p = \rho g \nabla_p z$$

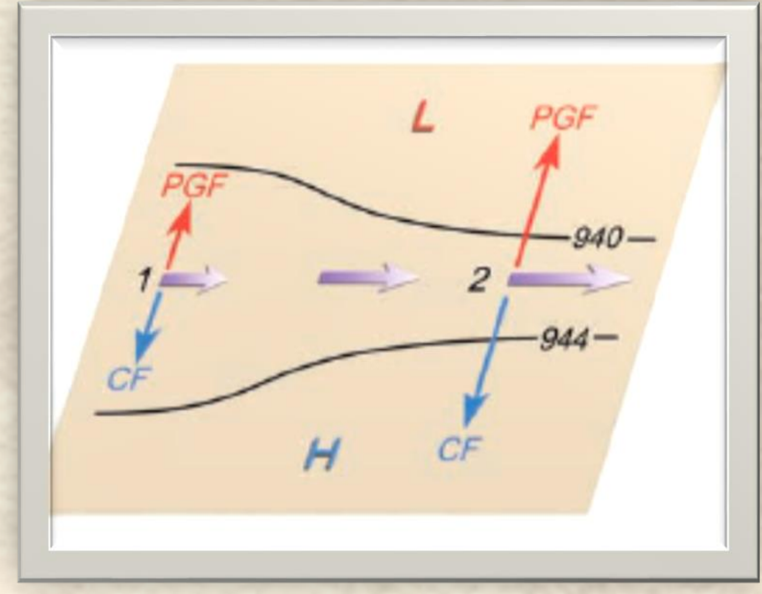
$$-\frac{1}{\rho}\nabla_z p = -g\nabla_p z = -\nabla_p \Phi$$



The isobars and contours on an upper-level chart are like the banks along a flowing stream. When they are widely spaced, the flow is weak; when they are narrowly spaced, the flow is stronger.

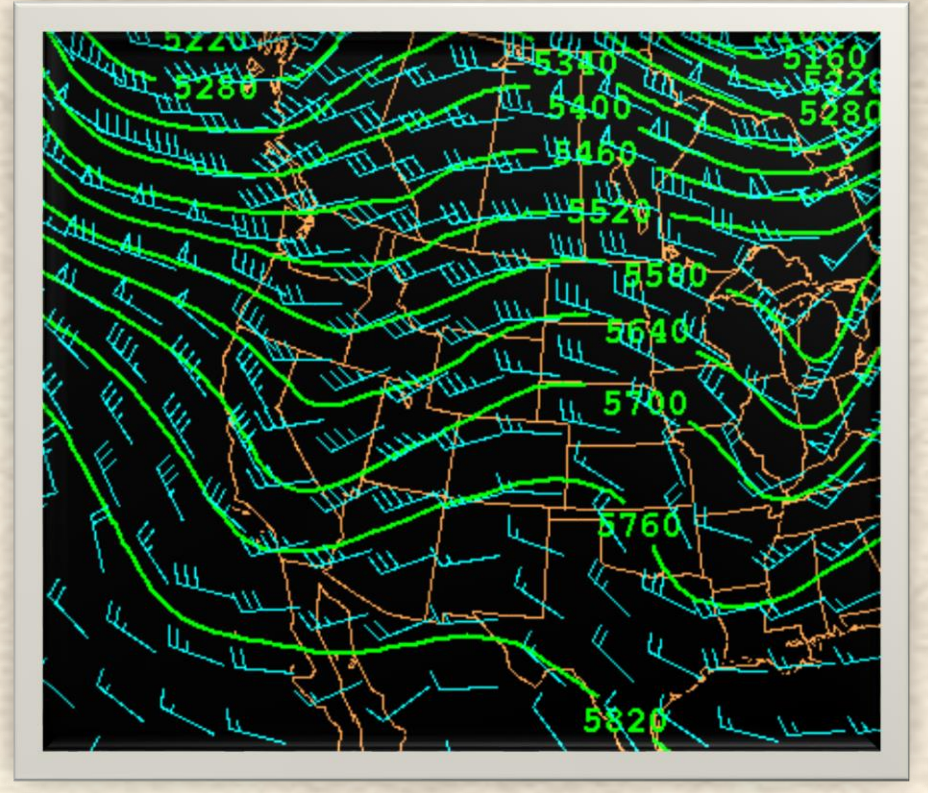
The increase in winds on the chart results in a stronger Coriolis force *(CF), which balances a larger pressure* gradient force *(PGF).*





Geostrophic Flow at 500 mb

When the flow is parallel to approximately straight height lines, the flow is geostrophic.

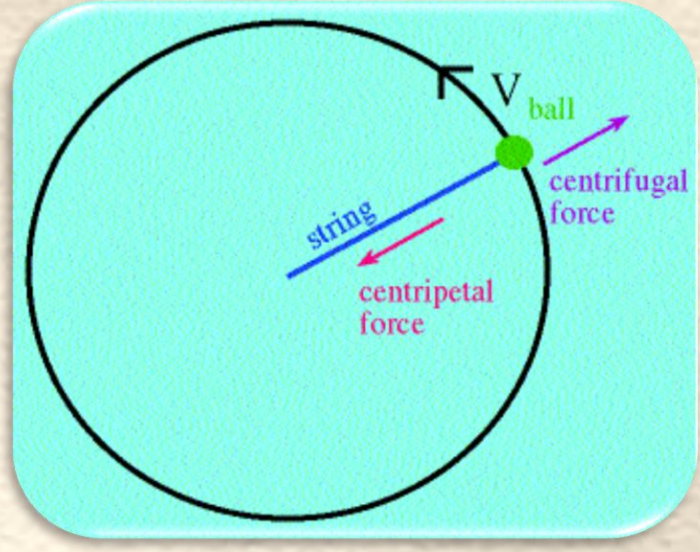


what determines the strength of the geostrophic flow?

The magnitudes **of The Pressure Gradient Force**

Centrifugal force (Ce)

recall from physics that if you attach a string to a ball and swing it in a circular manner, then the force that is required to keep the ball moving in the circular path is called the centripetal force.



the *centripetal force* is directed inward, towards the axis of rotation

$$\frac{1}{\rho}\frac{\Delta P}{d} + 2\Omega V_g \sin\phi + \frac{V^2}{r} = 0$$

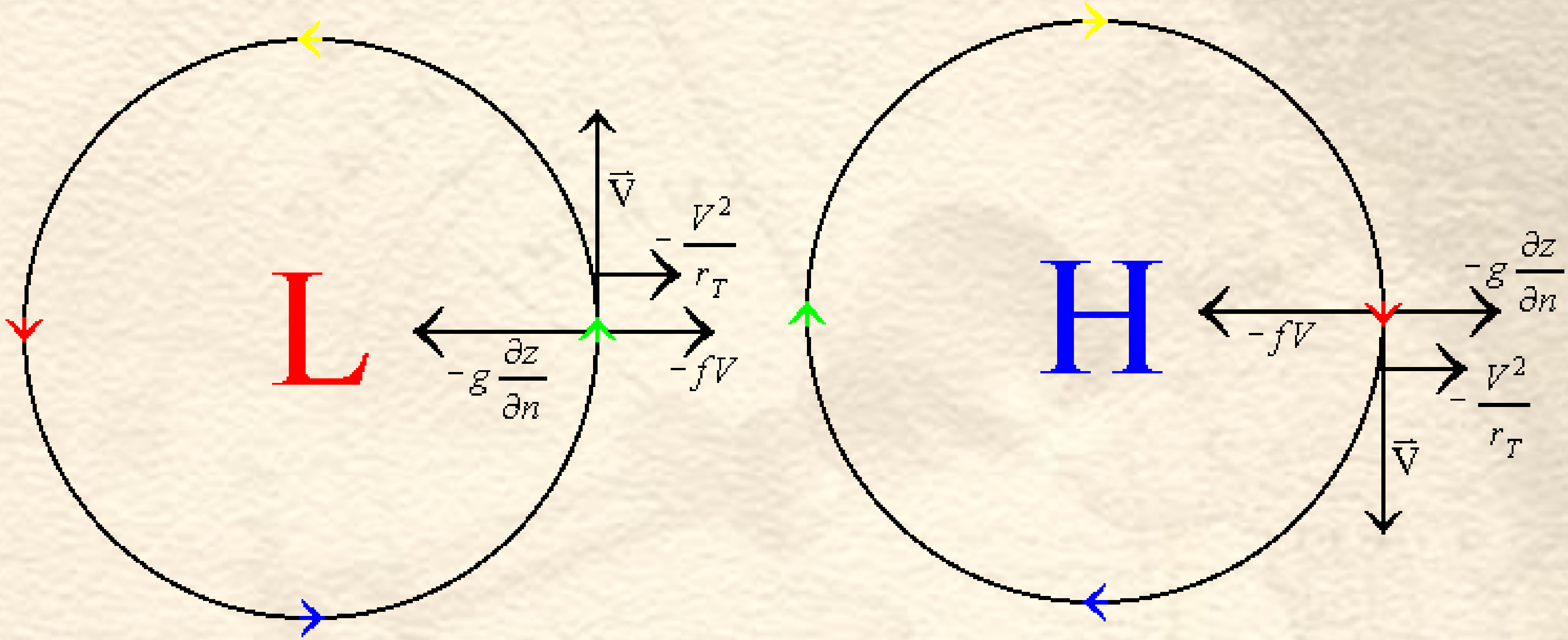
Gradient Wind

Winds aloft in rotation, a balance of 3 forces

Pressure gradient force (PGF)

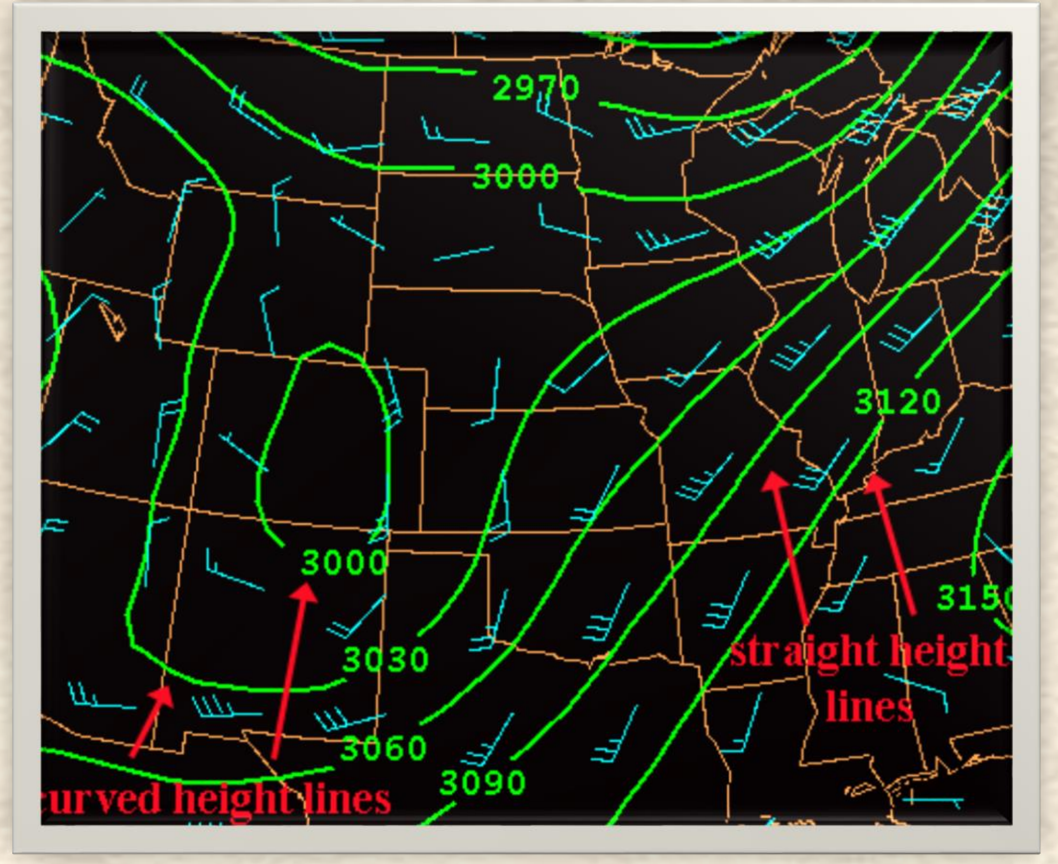
Coriolis 'force' (CF)

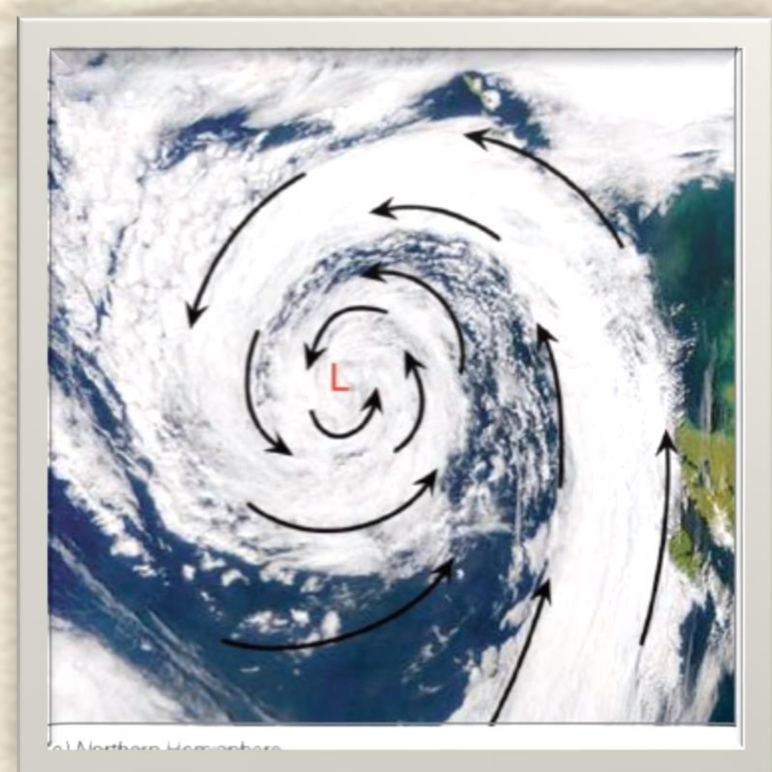
Centrifugal force (Ce)

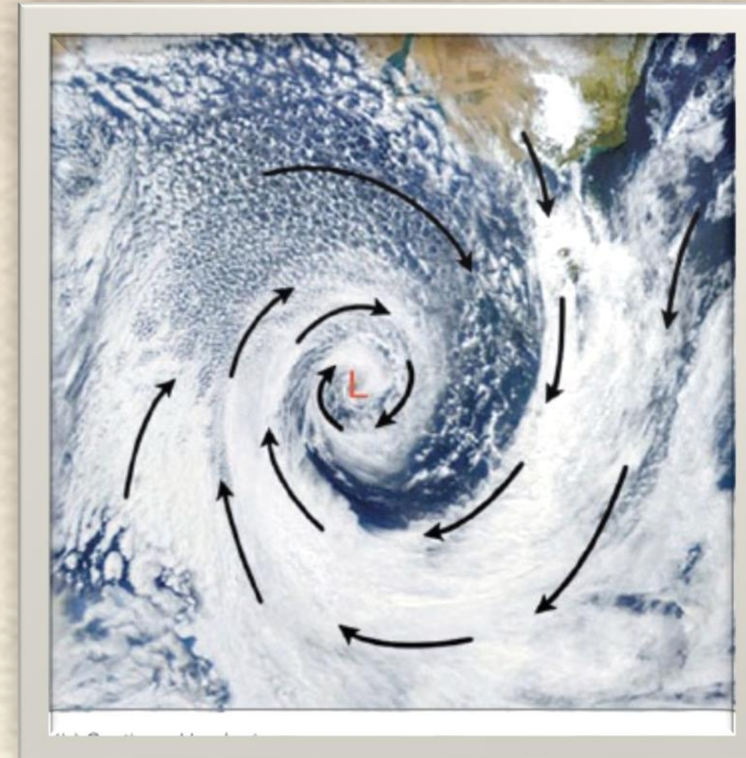


The Centrifugal Force

when there is curvature in the flow, we must also consider the *centripetal force* acting on a parcel.



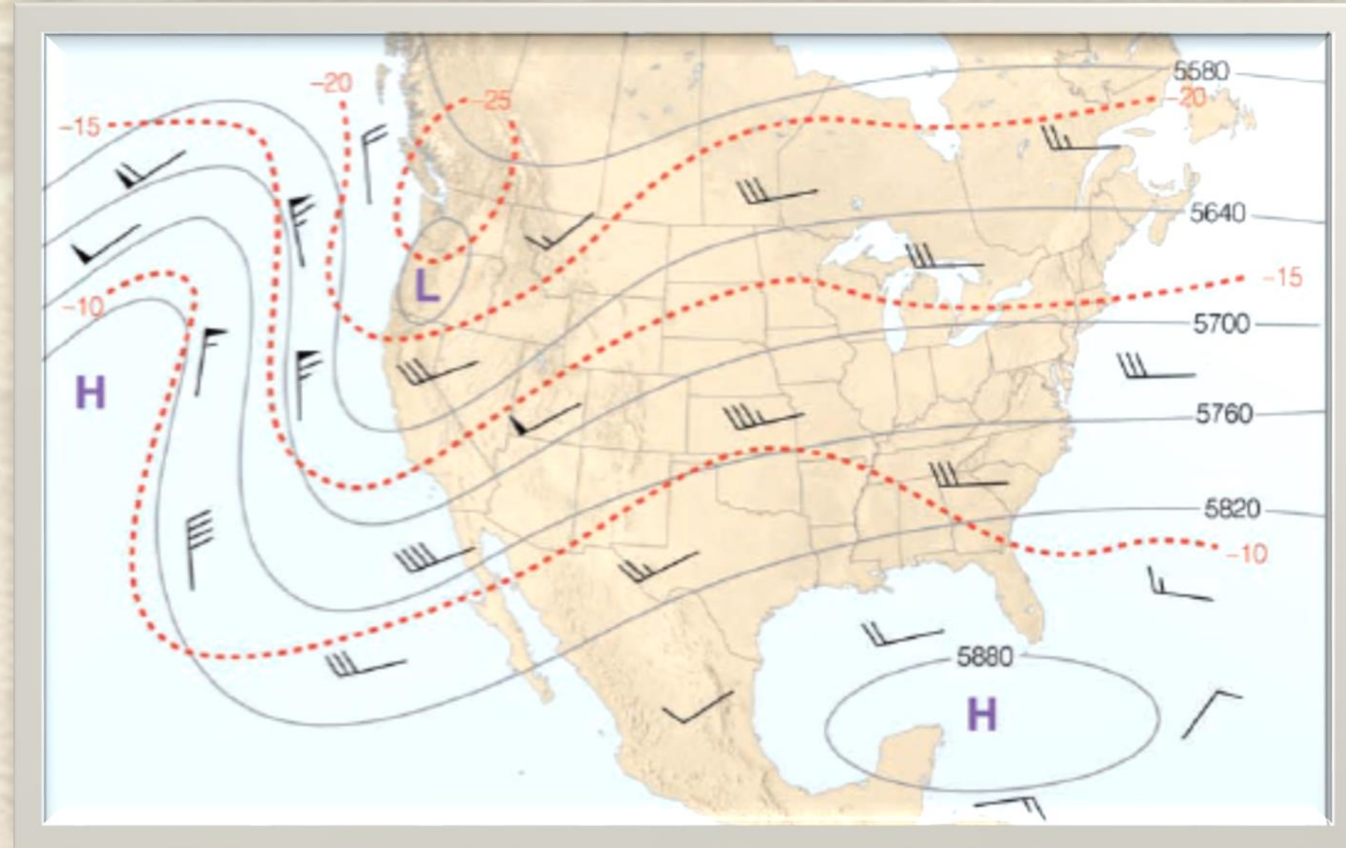


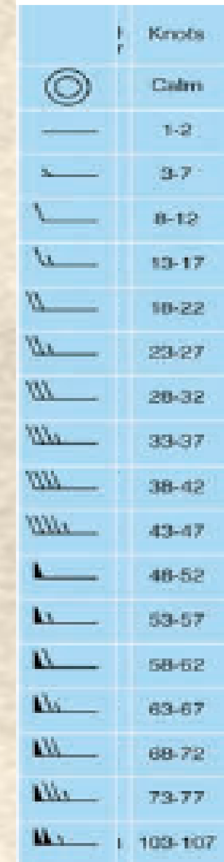


Clouds and related wind-flow patterns (black arrows) around low-pressure areas.

(a) In the Northern Hemisphere, winds blow counterclockwise around an area of low pressure.

(b) In the Southern Hemisphere, winds blow clockwise around an area of low pressure.





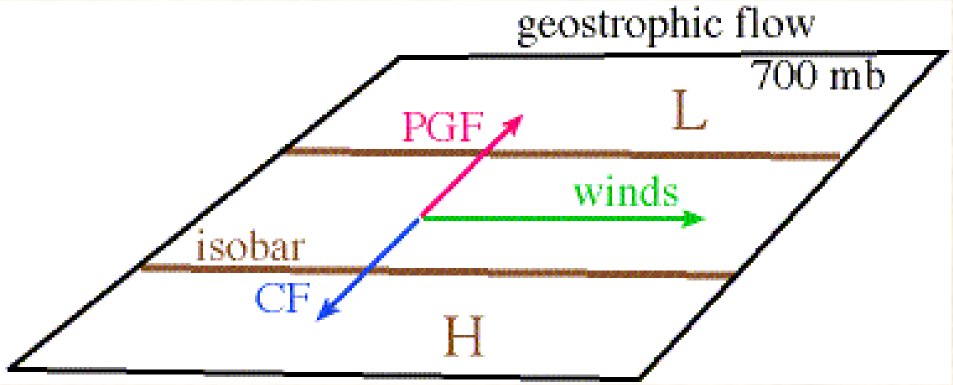
An upper-level 500-mb map showing wind direction, as indicated by lines that parallel the wind. Wind speeds are indicated by barbs and flags. (See the blue insert.)

Solid gray lines are contours in meters above sea level. Dashed red lines are isotherms in °C.

Effect of friction on winds

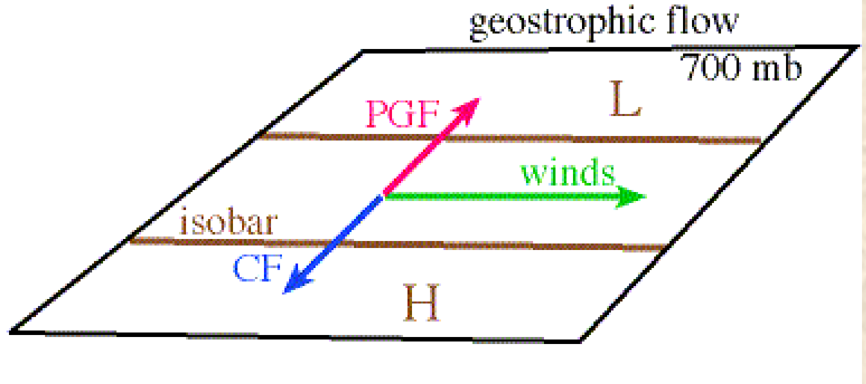
Where will friction have the greatest impact on the winds?

Hence, above approximately 850 mb, the flow is either in *geostrophic* or *gradient wind balance*



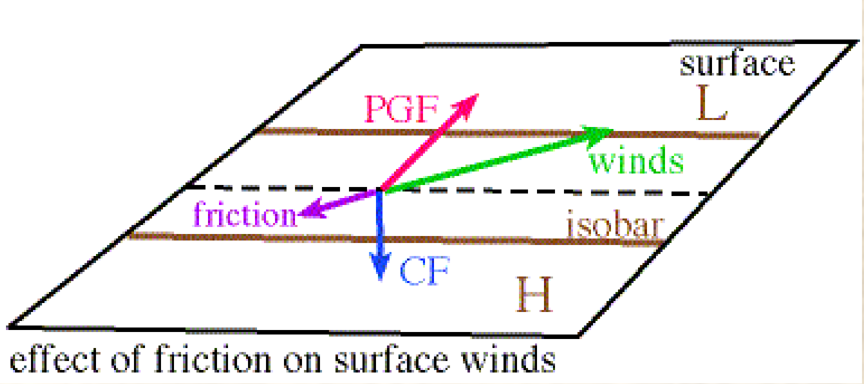
from the surface to about 1-1.5 km AG, we must include the effect of friction and therefore, *the flow is no longer in geostrophic or gradient wind balance.....*

as a result, which force becomes smaller, the PGF or the CF?



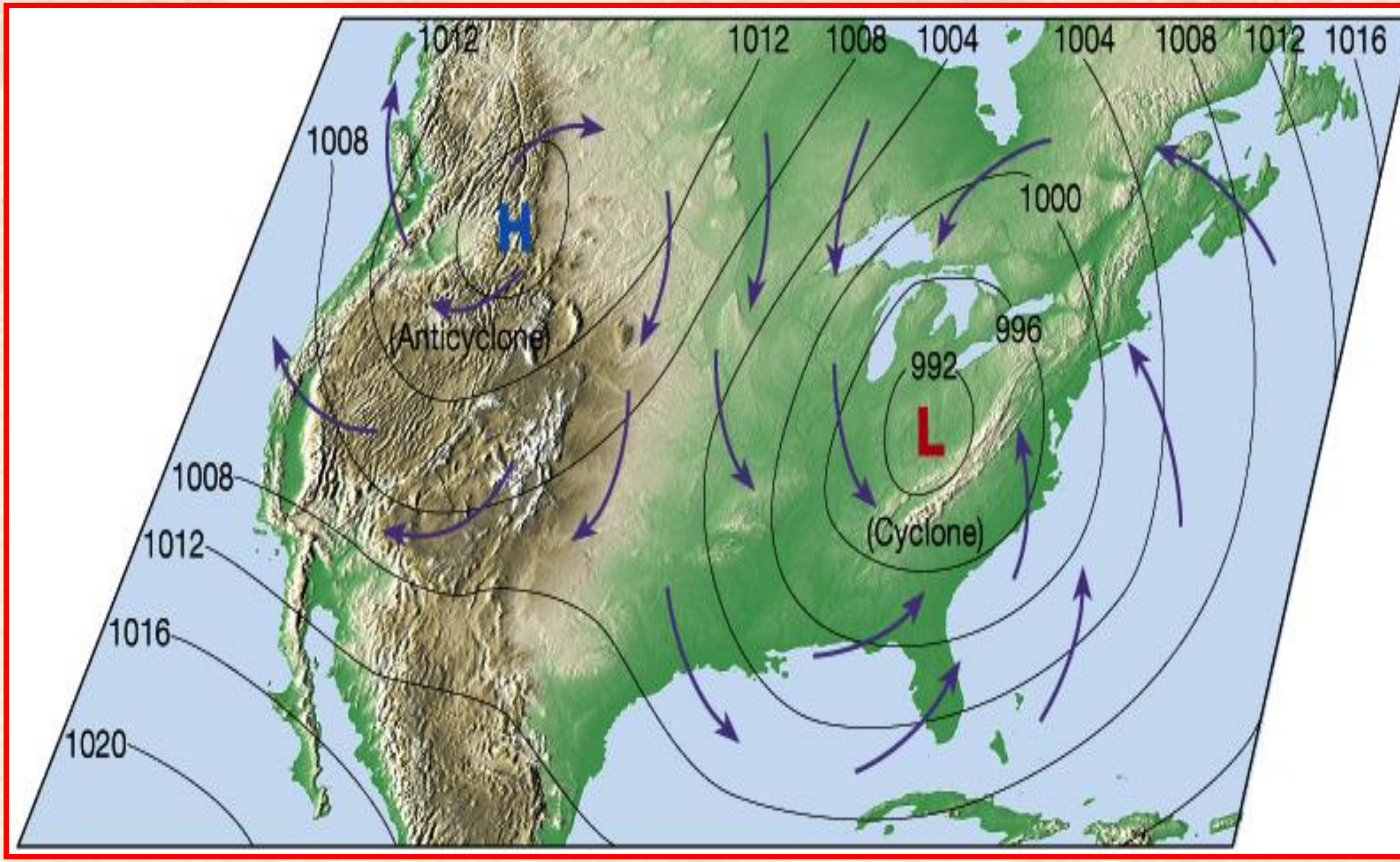
therefore, the winds cross the isobars, directed towards the lower pressure

friction + CF + PGF = 0

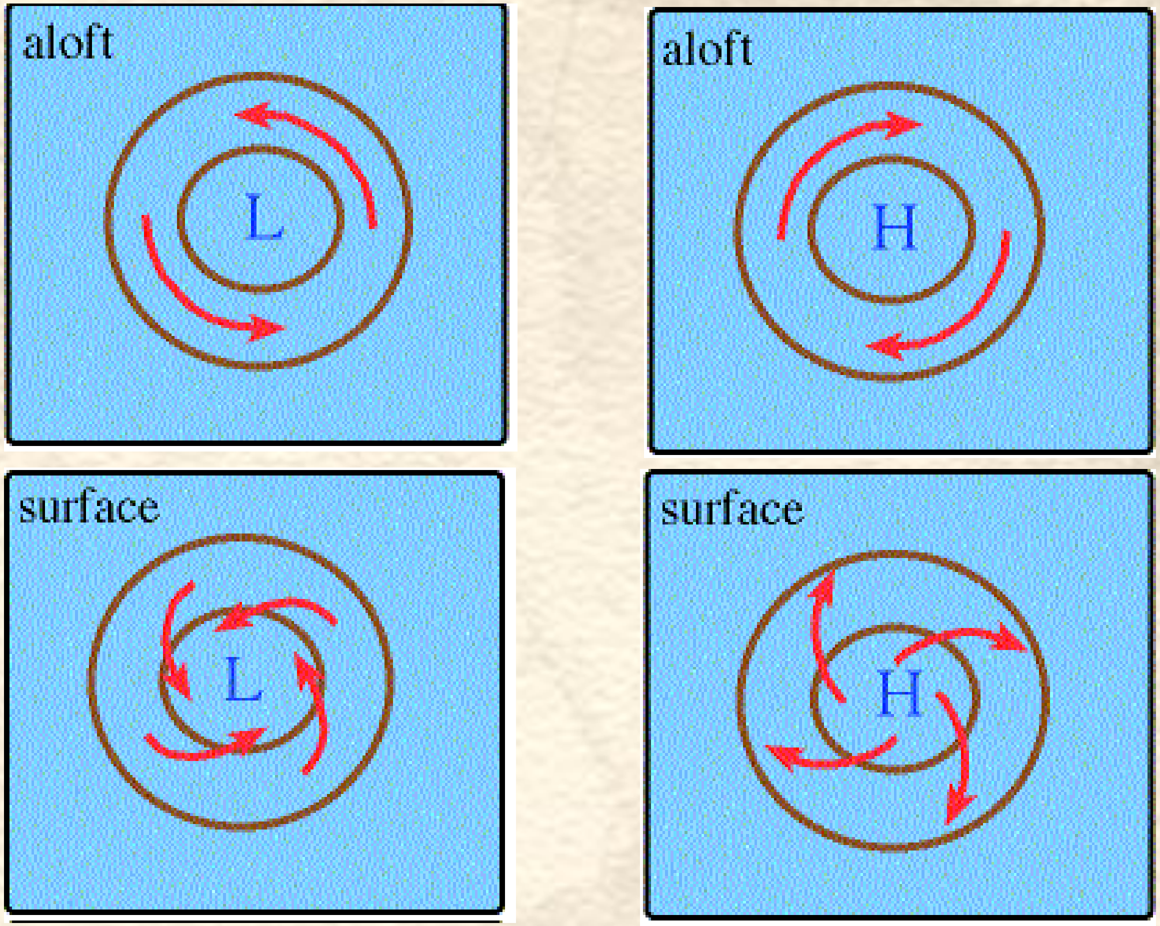


The effect of friction on wind is dominant near the surface, in the part of the atmosphere we call the *boundary layer*

The *boundary layer* extends from the surface to about 1-1.5 km AGL

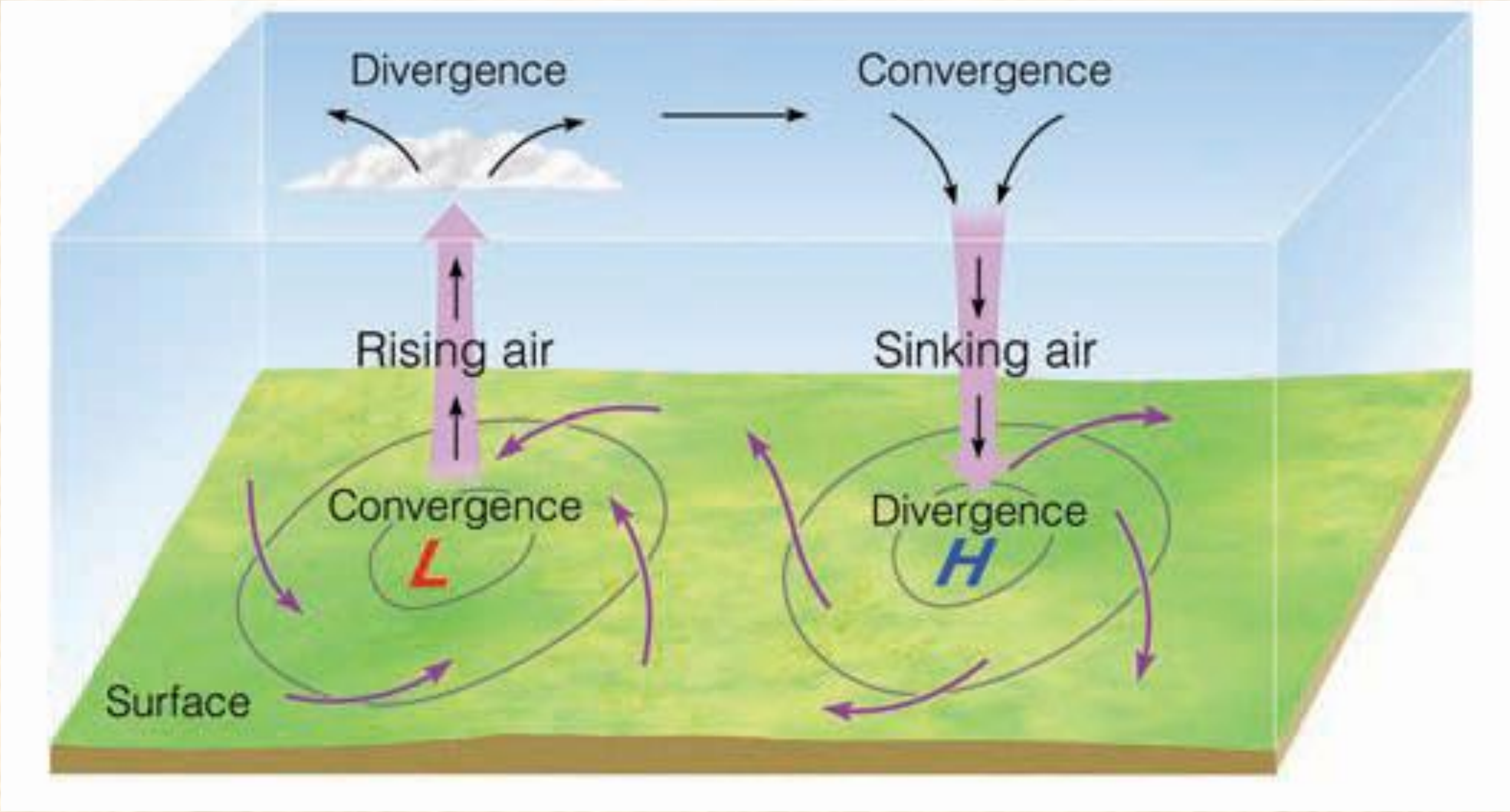

1012
1012
1008
1004
1004
1008
1012
1016
1008
H
(Anticyclone)
1000
996
992
L
(Cyclone)
1008
1012
1016
1020

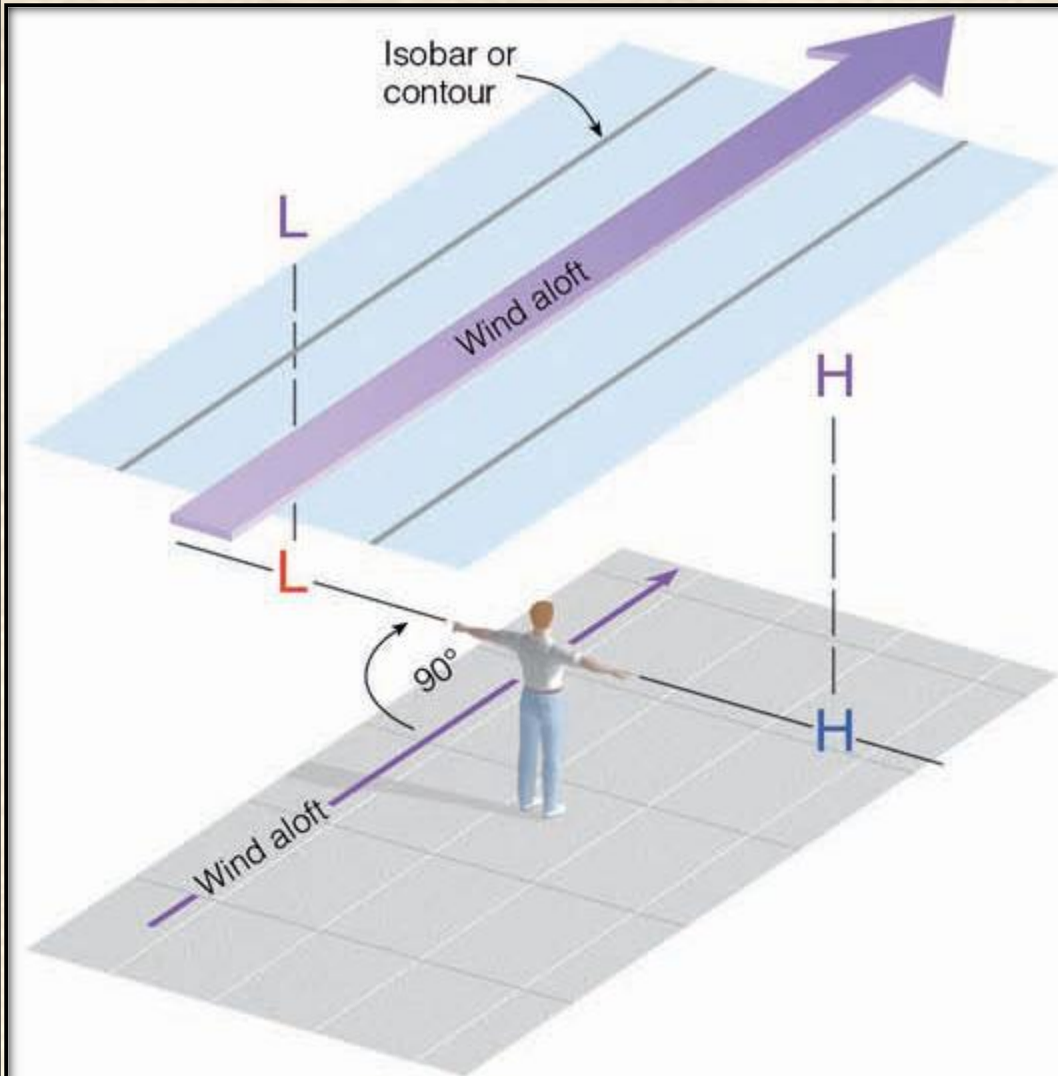
Effect of friction on flow around lows and highs



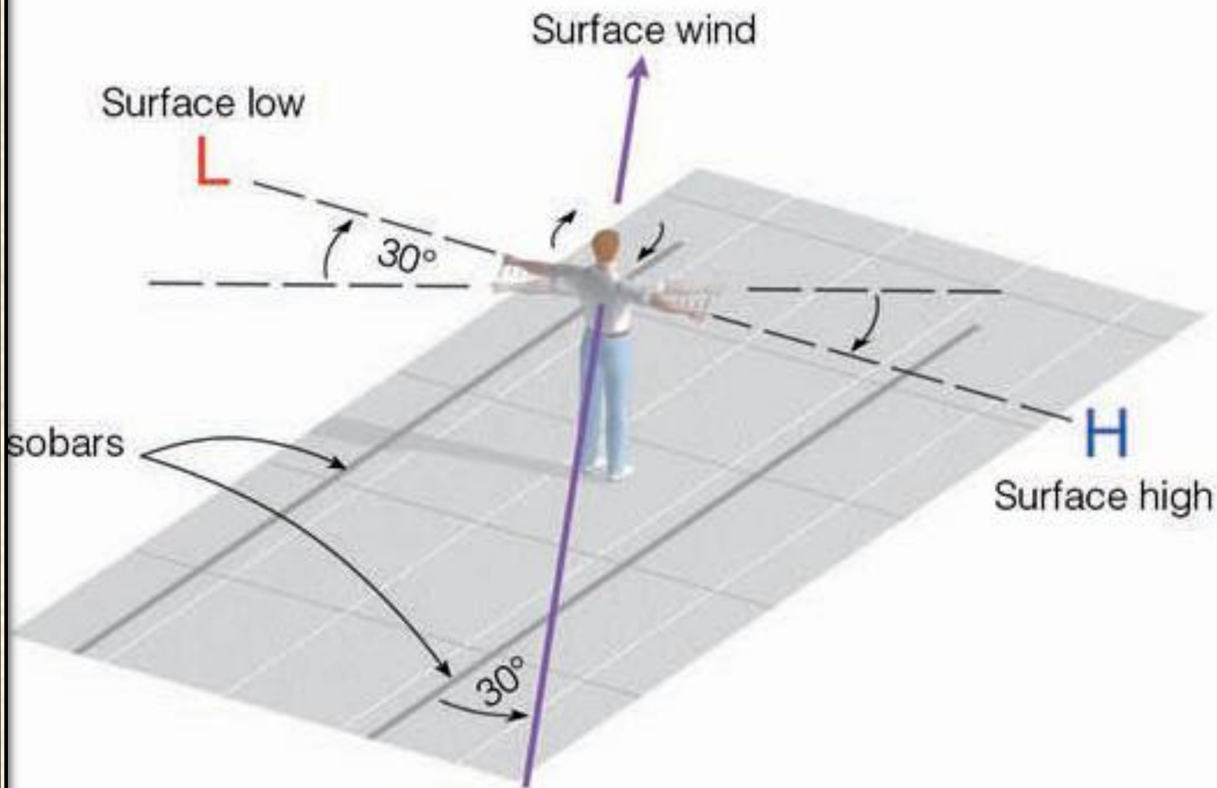
Due to the frictional turning of the wind such that it crosses the isobars, what can you infer about the vertical motions in the vicinity of a surface low, surface high at the center of a surface low, the air *converges*, and then must rise (Cyclonic Flow).

at the center of a surface high, the air is *diverging*, and must be coming from aloft due to sinking motion (Anticyclonic Flow)

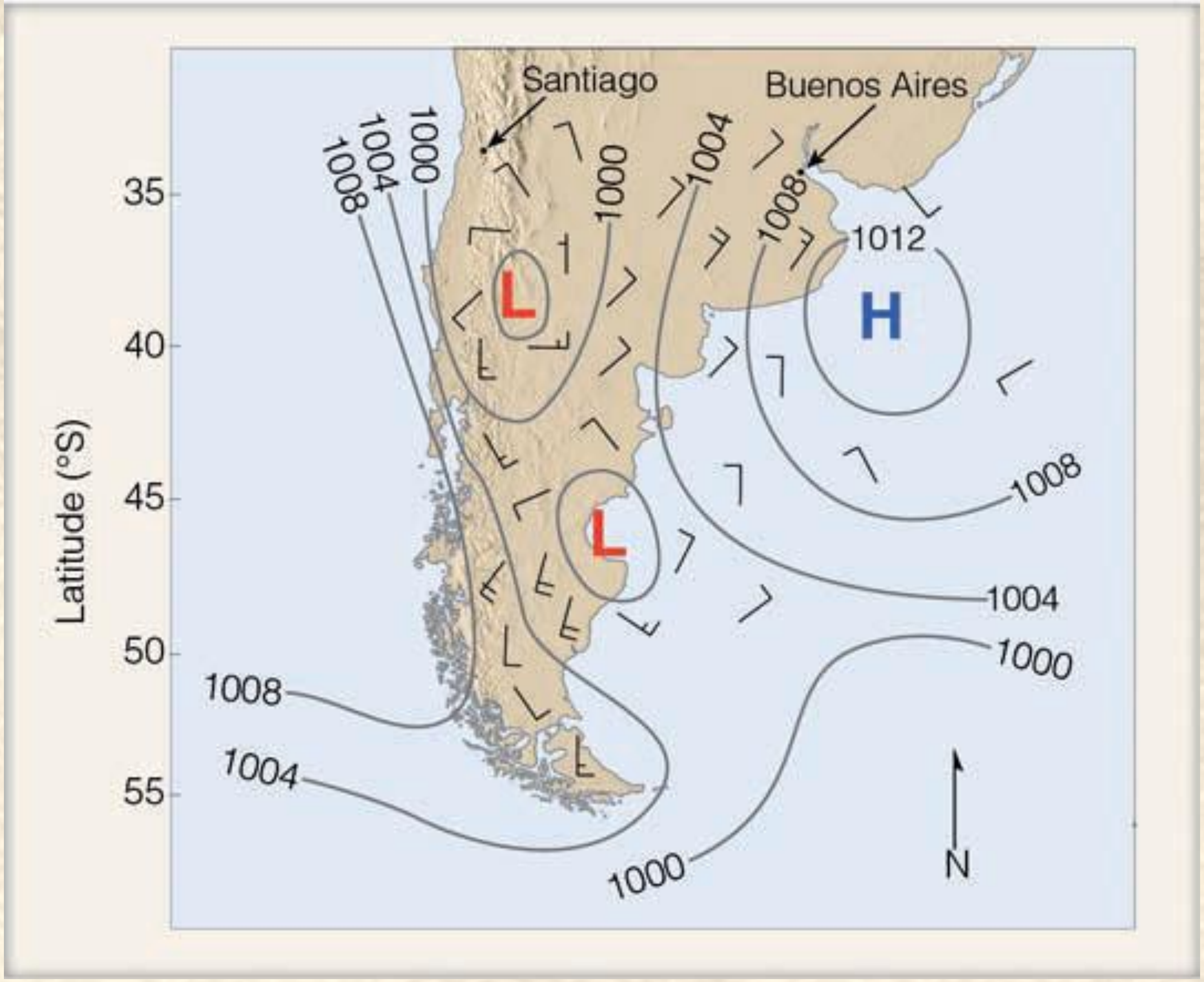


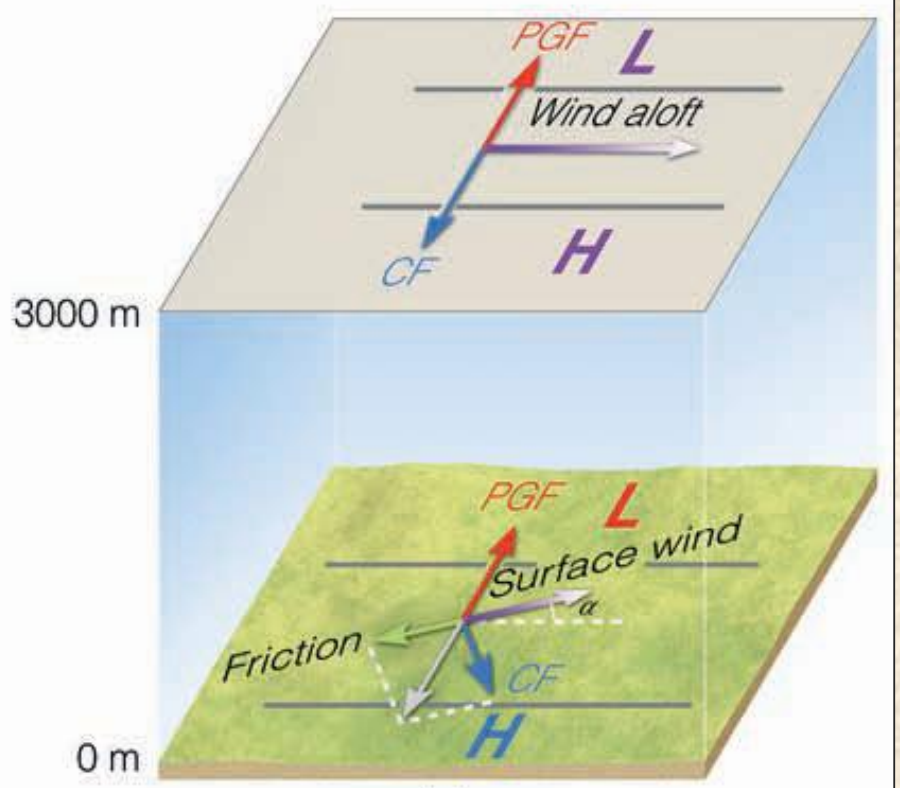


(a) Wind aloft

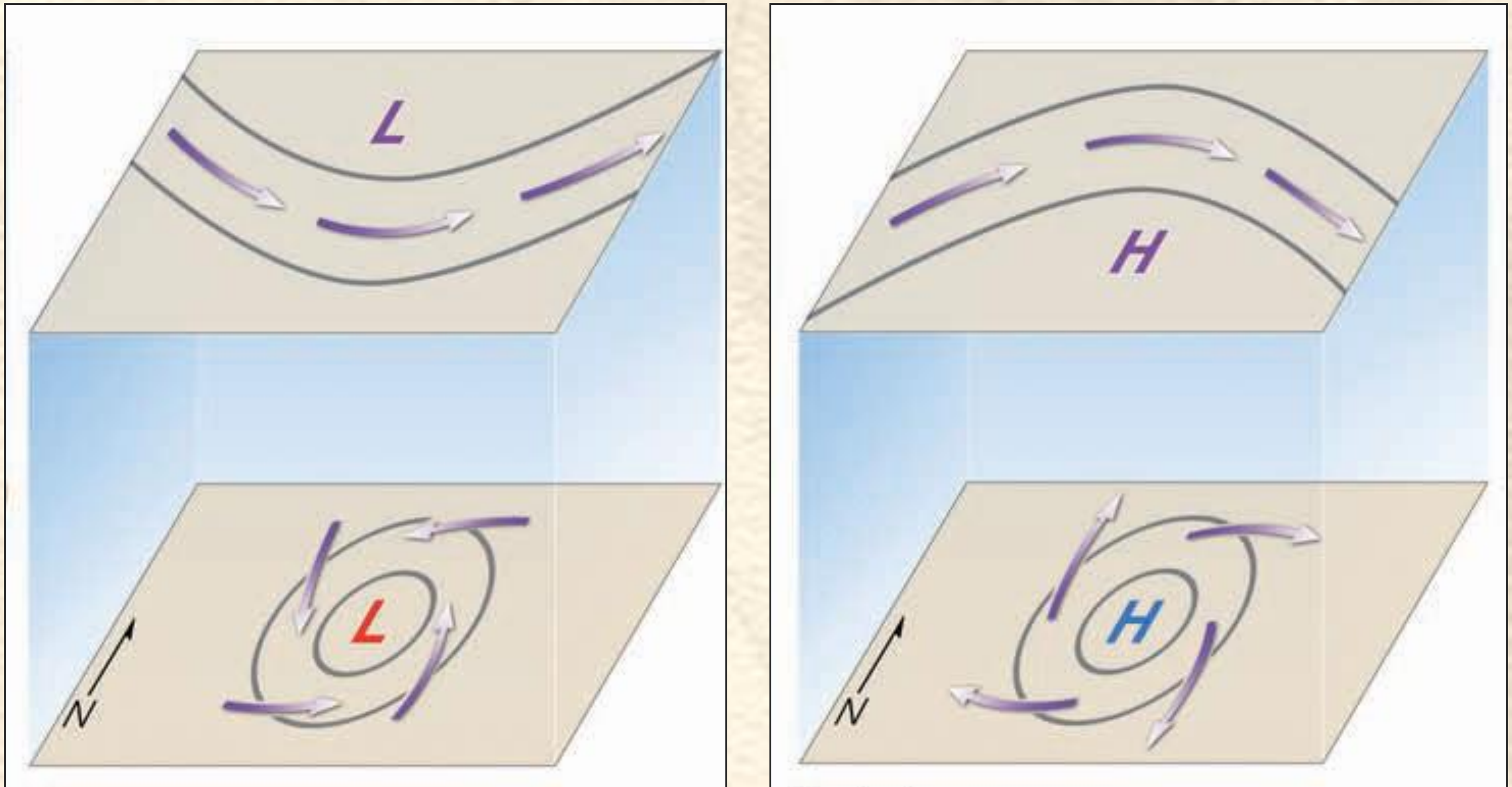


(b) Surface wind


Santiago
Buenos Aires
Latitude (°S)
35
40
45
50
55
1000
1004
1008
1012
H
L
L
1008
1004
1000
1008
1004
1000
N


PGF
L
Wind aloft
CF
H
3000 m
PGF
L
Surface wind
α
Friction
CF
H
0 m

(a)



(b) Northern Hemisphere

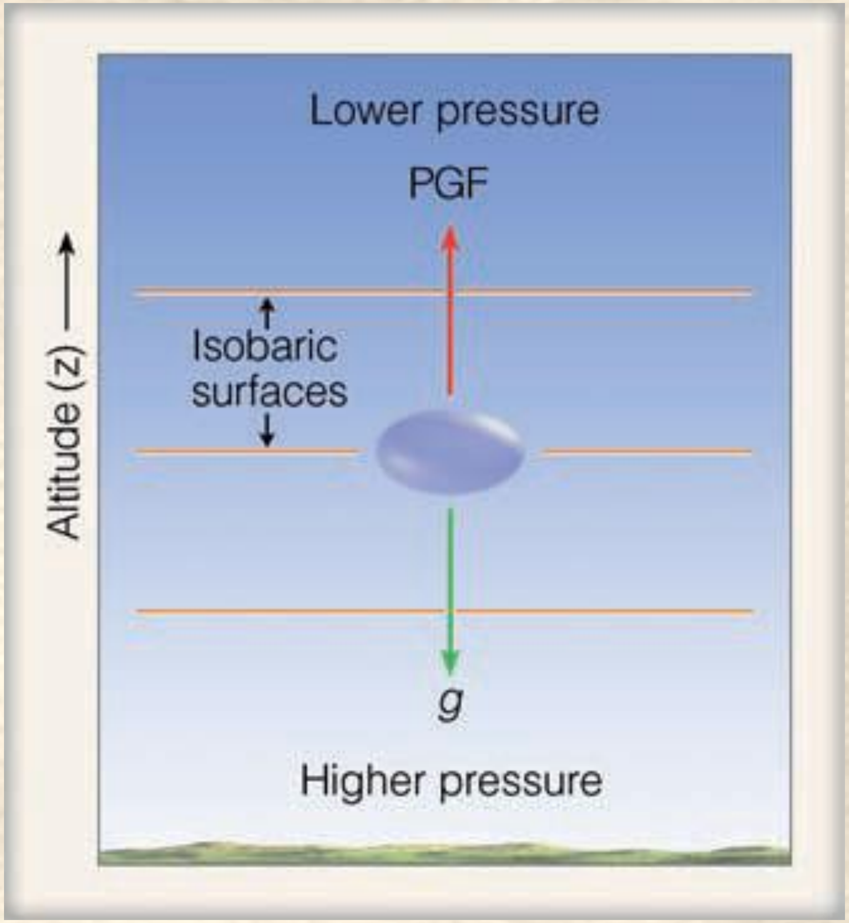
The Hydrostatic Equation

$$-\frac{1}{\rho}\frac{dp}{dz} = g$$

$$dp = -\rho g \, dz$$

$$p(z) = \int_z^{\infty} \rho g \, dz$$

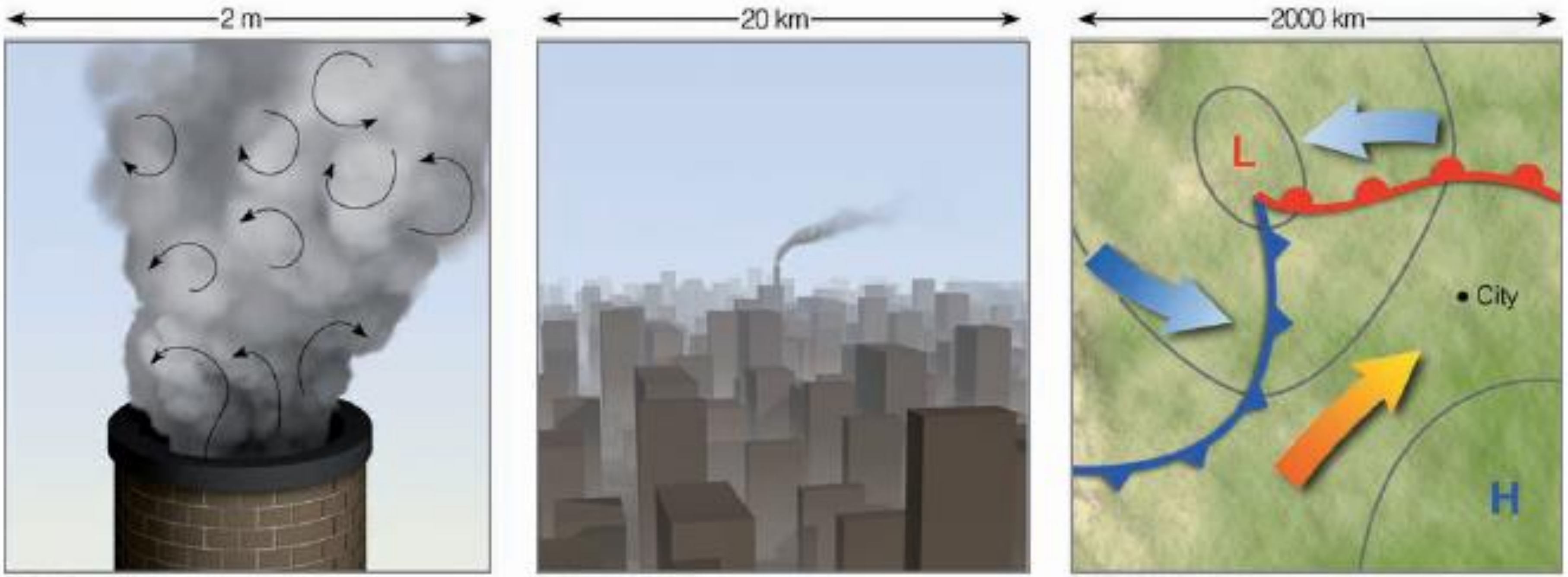
$$p(0) = \int_0^{\infty} \rho g \, dz = 101.325 \ kPa$$



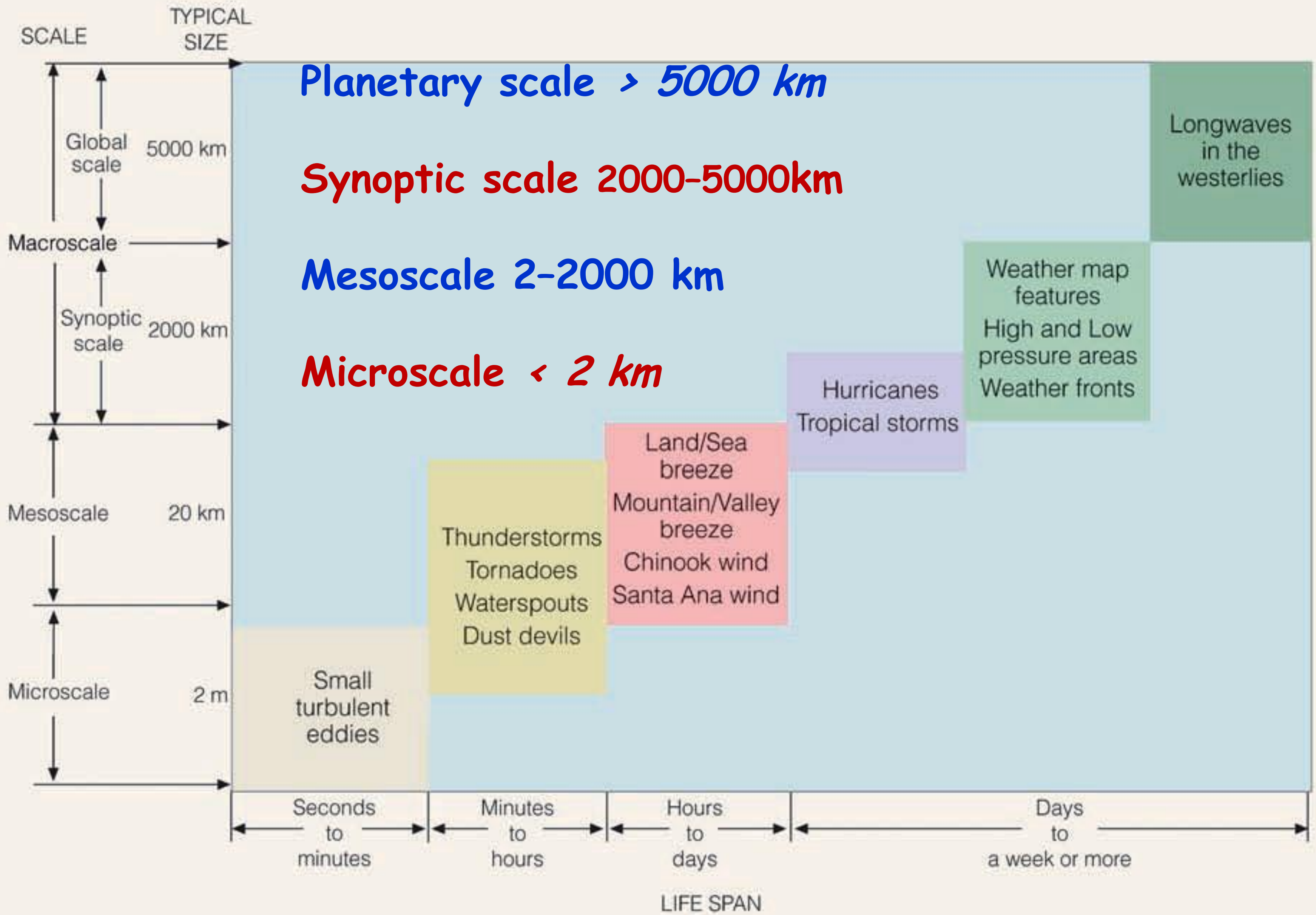
(one of the best approximations in meteorology)

Wind: Small Scale and Local Systems

Scales of atmospheric motion. The tiny microscale motions constitute a part of the larger mesoscale motions, which, in turn, are part of the much larger synoptic scale. Notice that as the scale becomes larger, motions observed at the smaller scale are no longer visible.



(a) Microscale (b) Mesoscale (c) Synoptic scale


Planetary scale > 5000 km
Synoptic scale 2000-5000km
Mesoscale 2-2000 km
Microscale < 2 km
SCALE
TYPICAL SIZE
Global scale
5000 km
Macroscale
Synoptic scale
2000 km
Mesoscale
20 km
Microscale
2 m
Small turbulent eddies
Thunderstorms
Tornadoes
Waterspouts
Dust devils
Land/Sea breeze
Mountain/Valley breeze
Chinook wind
Santa Ana wind
Hurricanes
Tropical storms
Weather map features
High and Low pressure areas
Weather fronts
Longwaves in the westerlies
Seconds to minutes
Minutes to hours
Hours to days
Days to a week or more
LIFE SPAN