

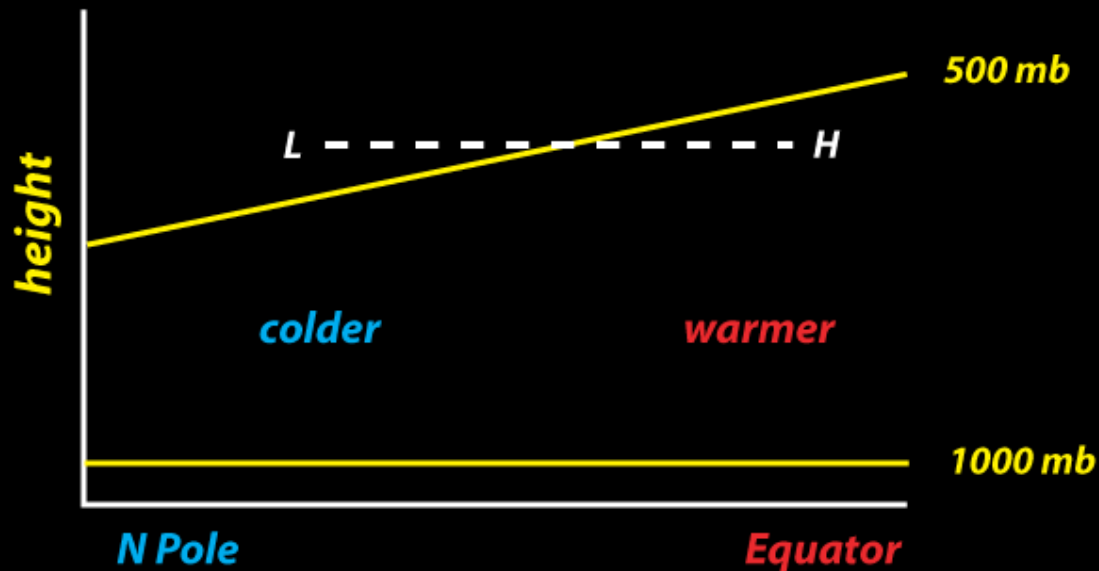
Meteorology – Lecture 15

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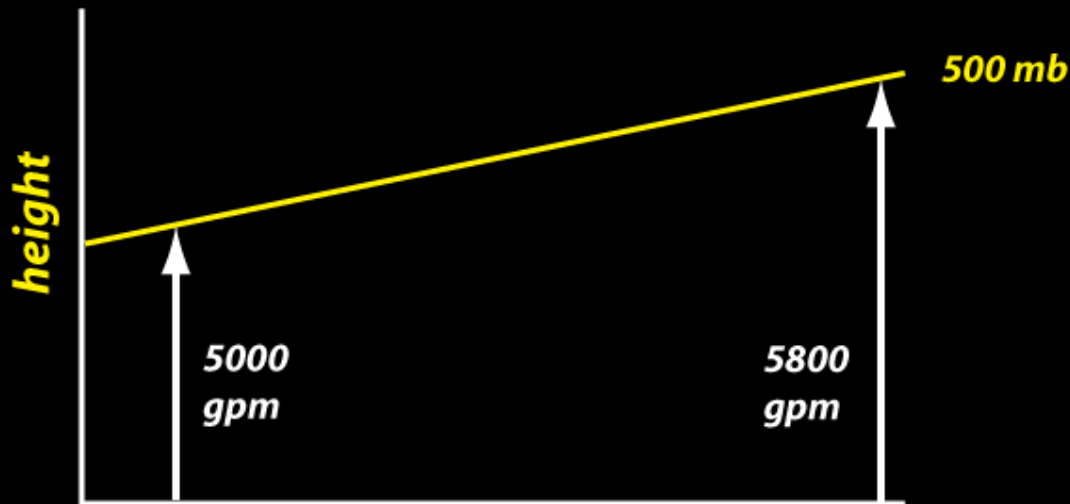
Important notes

- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his “Meteorology” course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but these were the figures I provided to TGC at the time the course was taped.
- These figures are intended to supplement the videos, in order to facilitate understanding of the concepts discussed in the course. *These slide shows cannot, and are not intended to, replace the course itself and are not expected to be understandable in isolation.*
- Accordingly, these presentations do not represent a summary of each lecture, and neither do they contain each lecture’s full content.

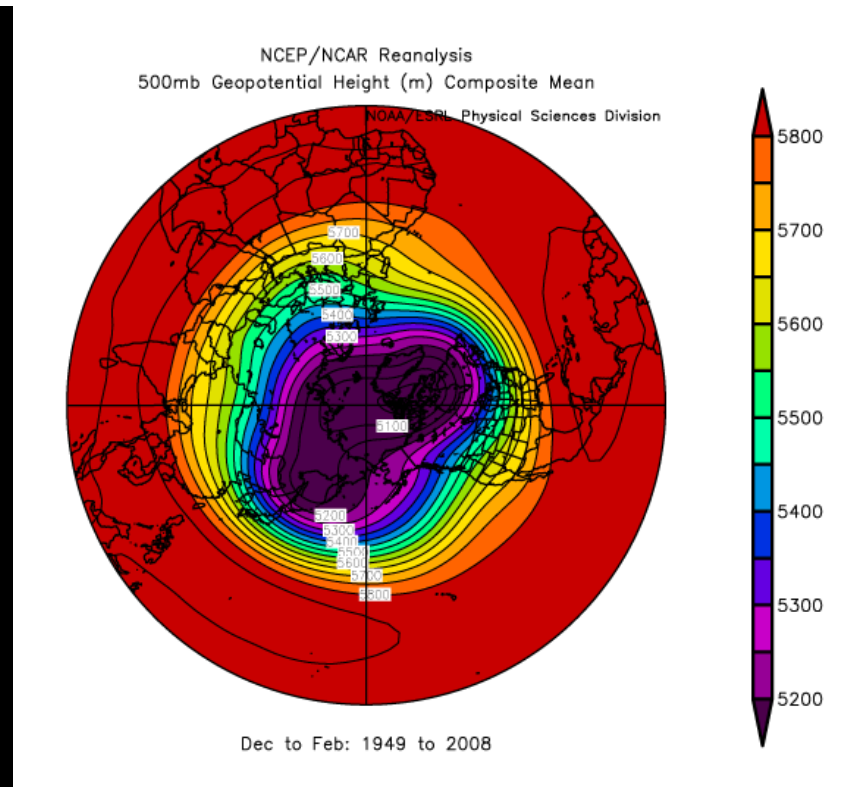
Isobaric charts



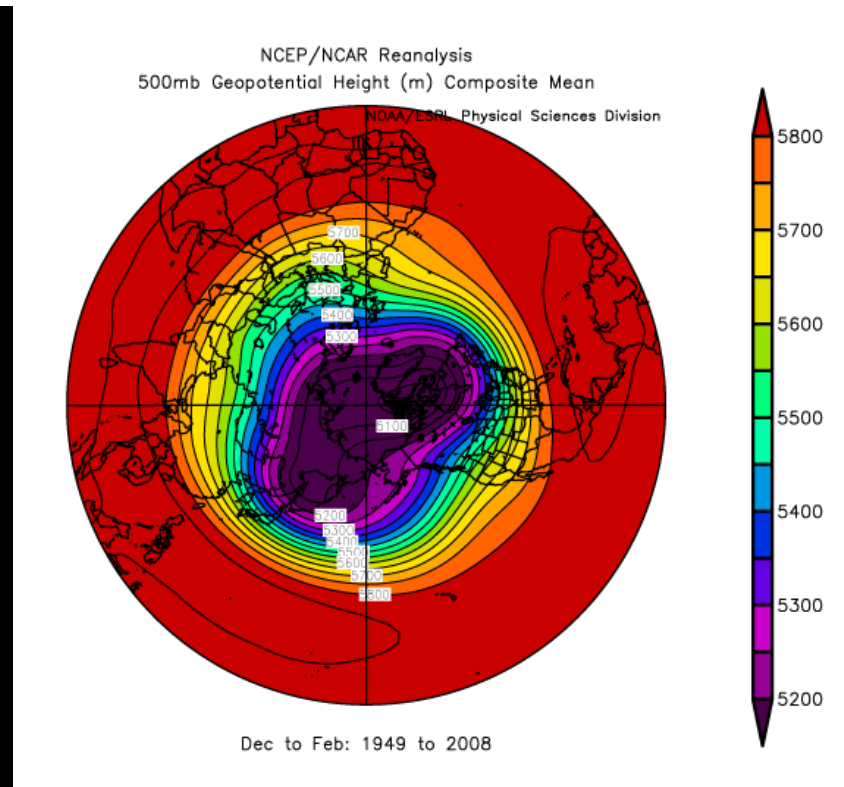
Consider again the N-S T difference between pole & equator. The 1000-500 mb layer is thinner at the pole than farther south. At 500m mb, the PGF points north, so the geostrophic wind is westerly, INTO the page.



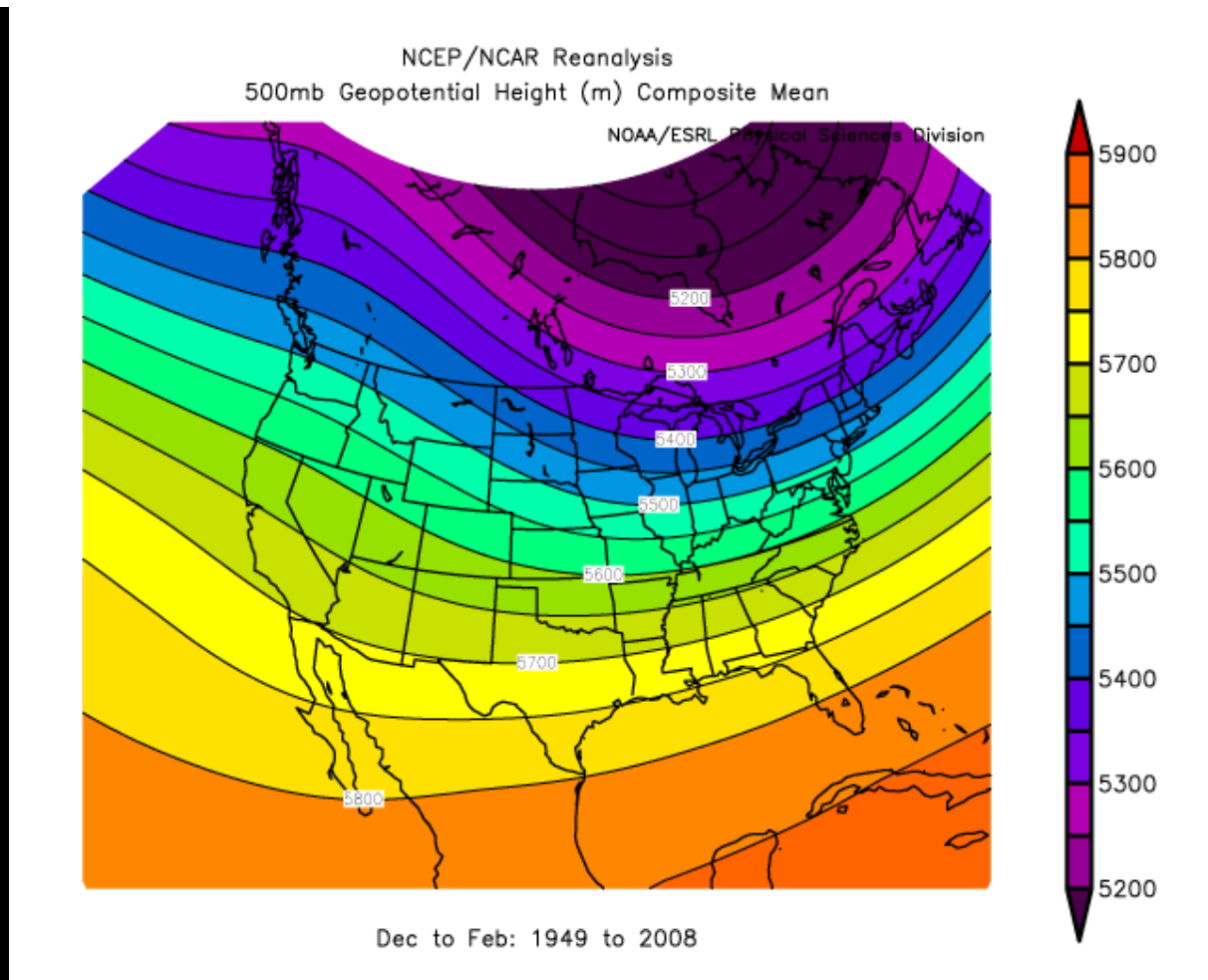
Now notice the 500 mb level slopes downward, towards the cold pole. We can also think about how far above sea-level the 500 mb level is and plot that as a function of space. Instead of plotting p variations on a constant height chart, such as sea-level, we will plot height on a constant p chart.



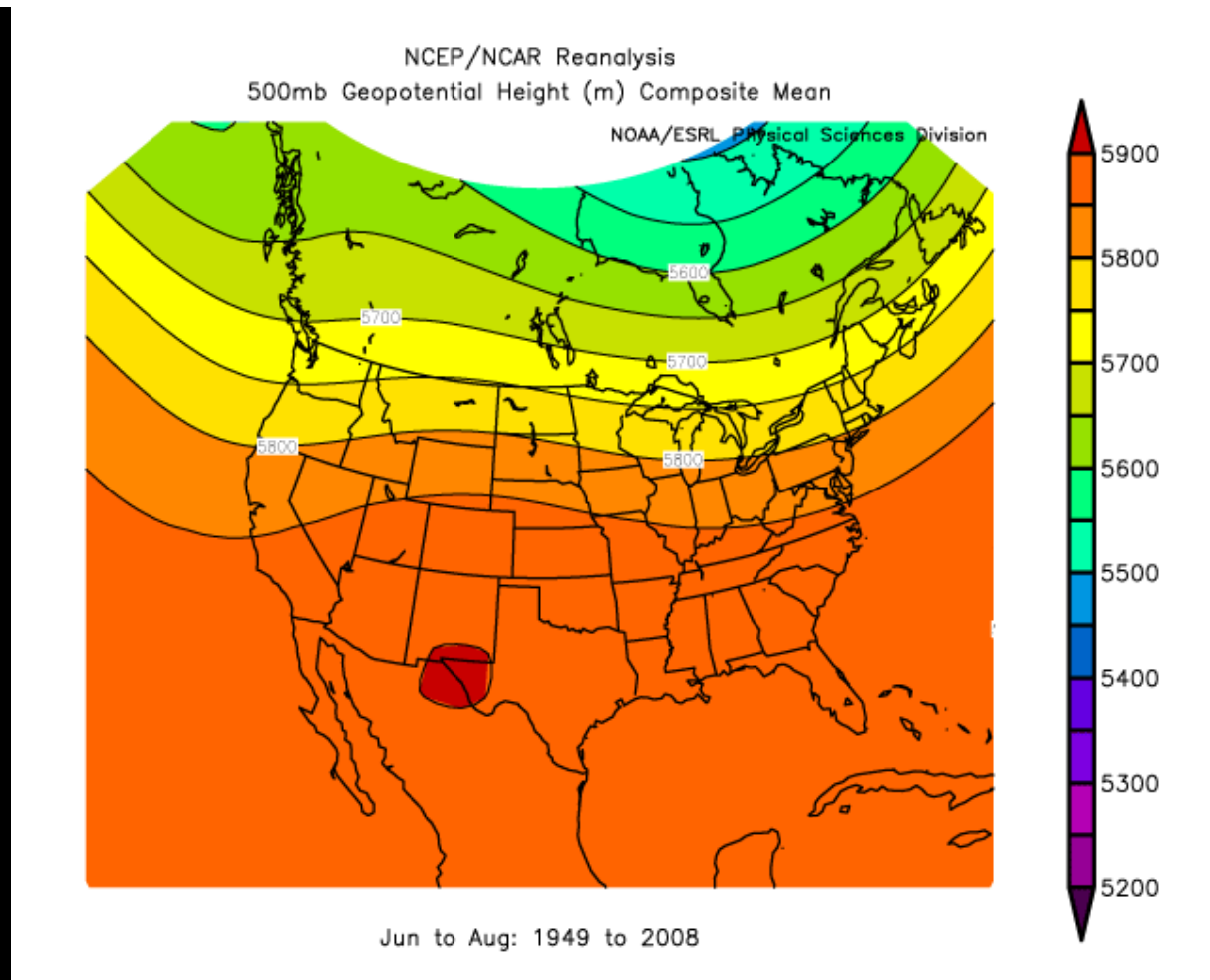
This is the average 500 mb isobaric chart for Dec-Feb, when the pole-equator T difference is largest. We see near the pole, the 500 mb height is only 5000 gpm (meters) above sea level. In the warmer tropics, it is over 5800 gpm. (A gpm is very, very close to a meter.)



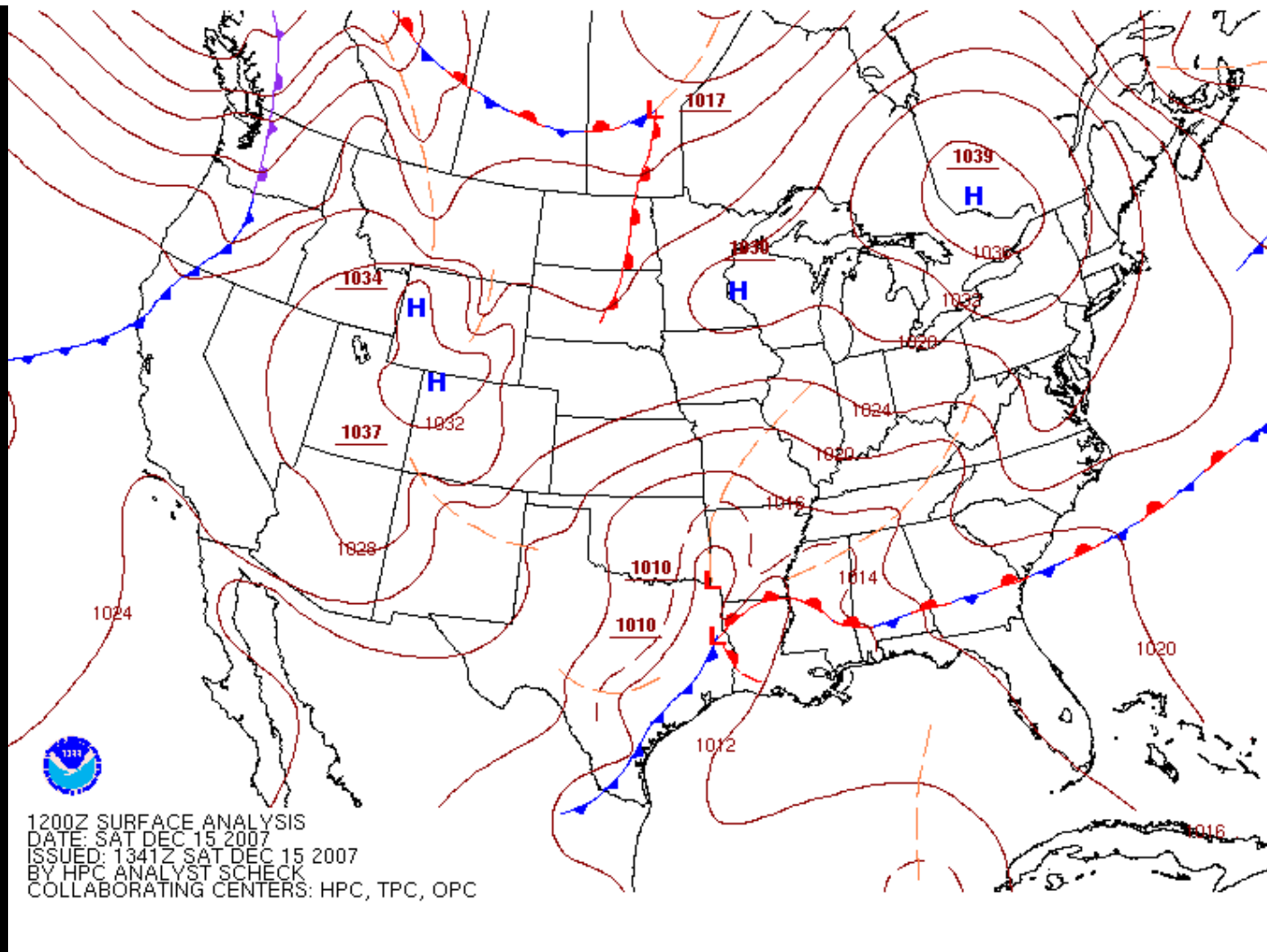
On our wintertime 500 mb chart, we can detect a belt of fast winds ringing the planet in midlatitudes, where the height contours are most packed. 500 mb winds are weak in the tropics, where height gradients are small.



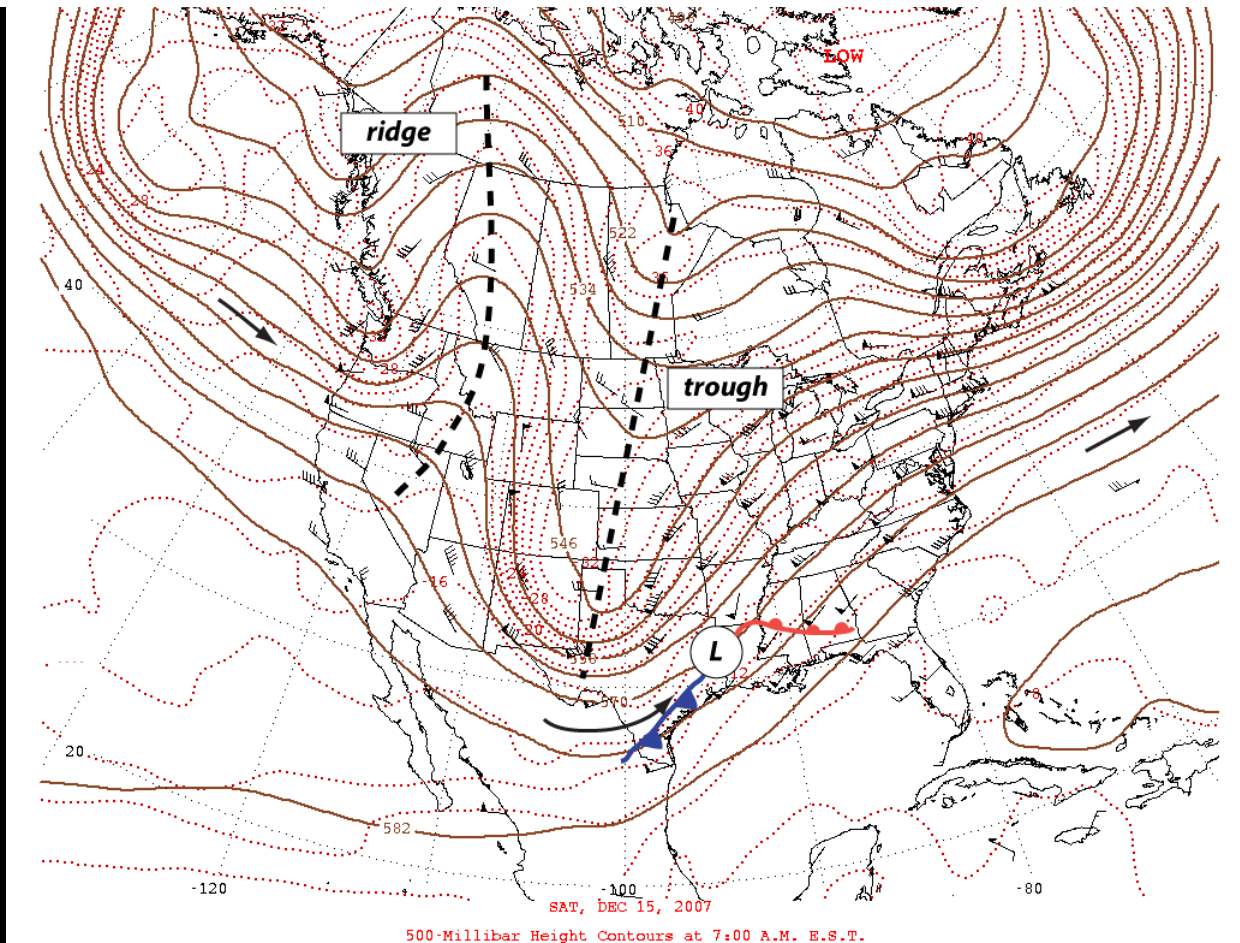
Focus on the United States.
We see 500 mb heights are generally lower over the land than over the ocean. This partly reflects the fact the land is colder in the winter.



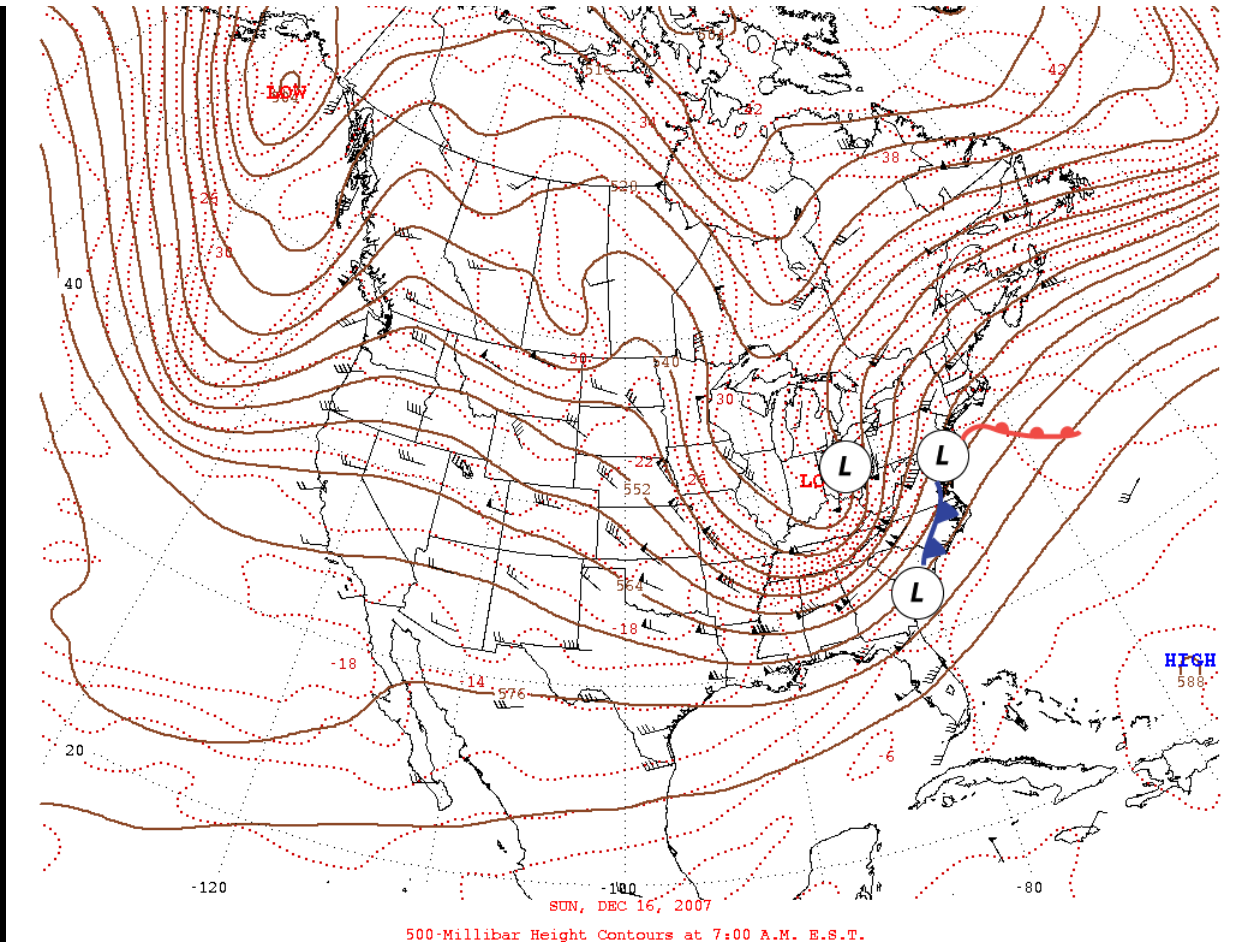
Here is our average 500 mb map for summer.
The heights are now higher over Canada
and the height contours are less packed,
indicating weaker winds.



Recall that an extratropical cyclone formed along a stationary front in Texas and subsequently moved to the NE.
This map shows surface conditions for 12Z Dec 15, which was
7AM EST or 6AM CST

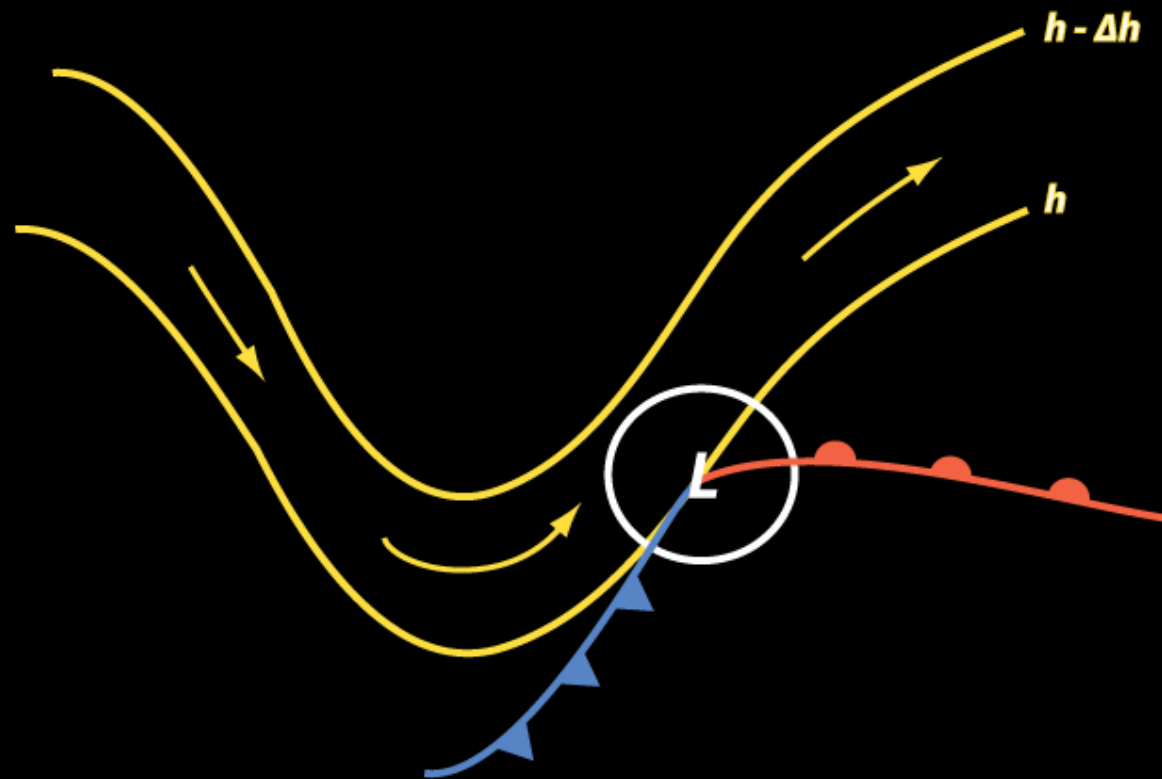


500 mb chart for the same time.
Lowest heights are at top of figure, in N Canada.
The winds are generally W-E everywhere.
Troughs and ridges are identified, and the surface cyclone location.

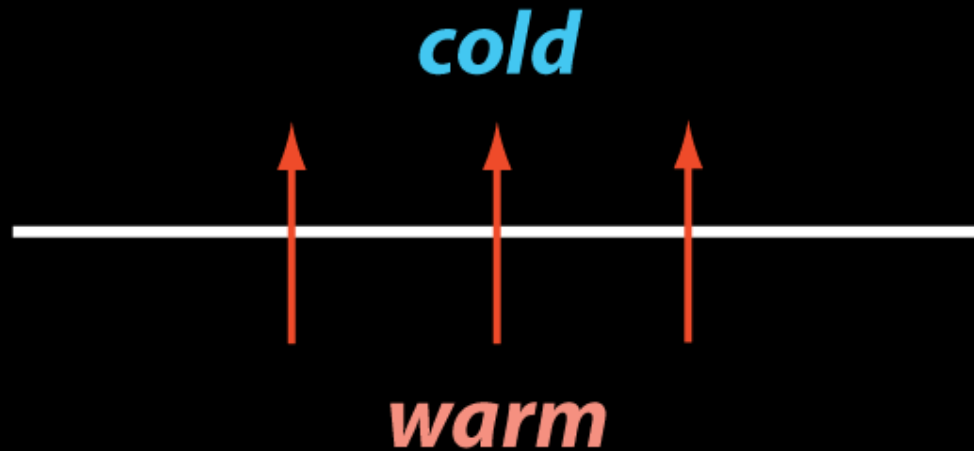


Not only do cyclones move, but also planetary waves do as well -- usually from west to east -- and grow or decay. Here is the 500 mb chart for 24 h later.

Establishing ascent:
warm advection

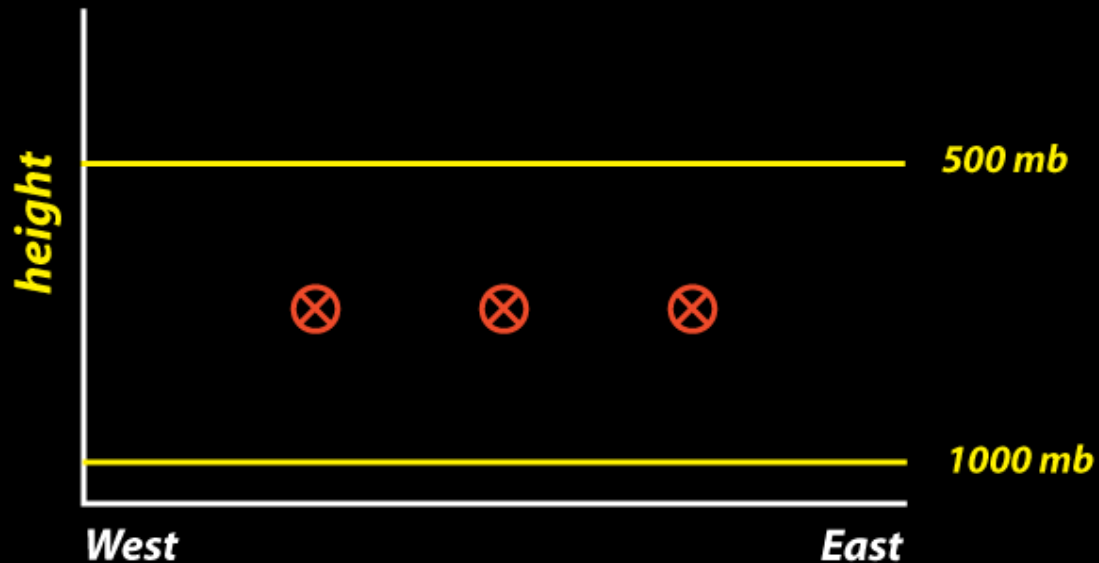


A surface cyclone position to the east of the 500 mb trough is a favorable one for the cyclone because rising motion is established above the surface L. Naturally, rising motion leads to saturation and storms, but in this case what the ascent does is create, maintain and increase the surface pressure drop.



Start with warm advection.

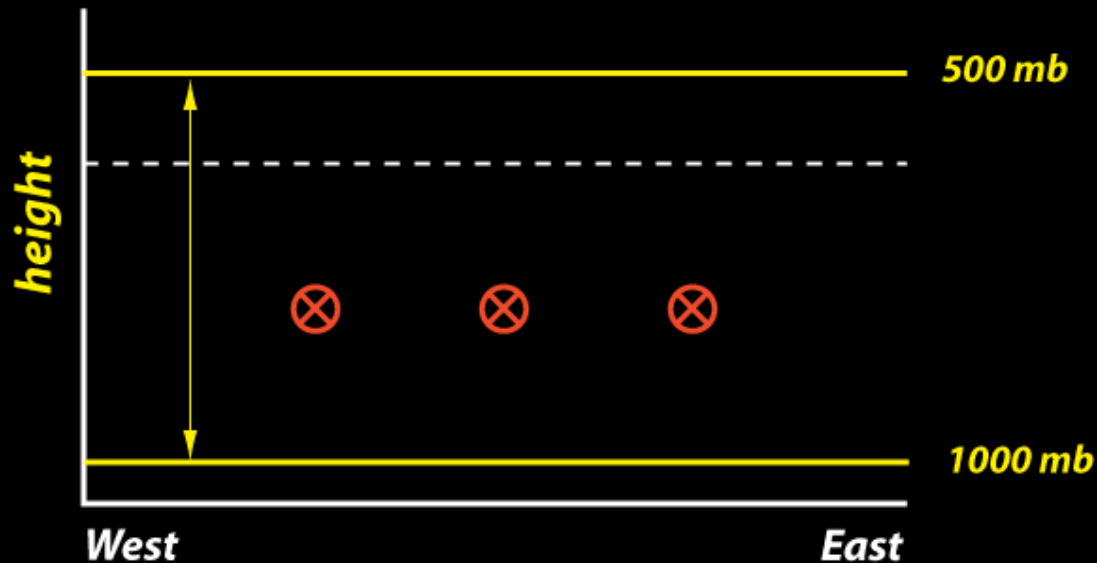
Suppose we have cold air to the N and warm air to the S. Further suppose we have a southerly wind. At the location indicated by the white line, warm advection is occurring.



Now look at a vertical plane along that white line.

Focus on the 1000-500 mb layer.

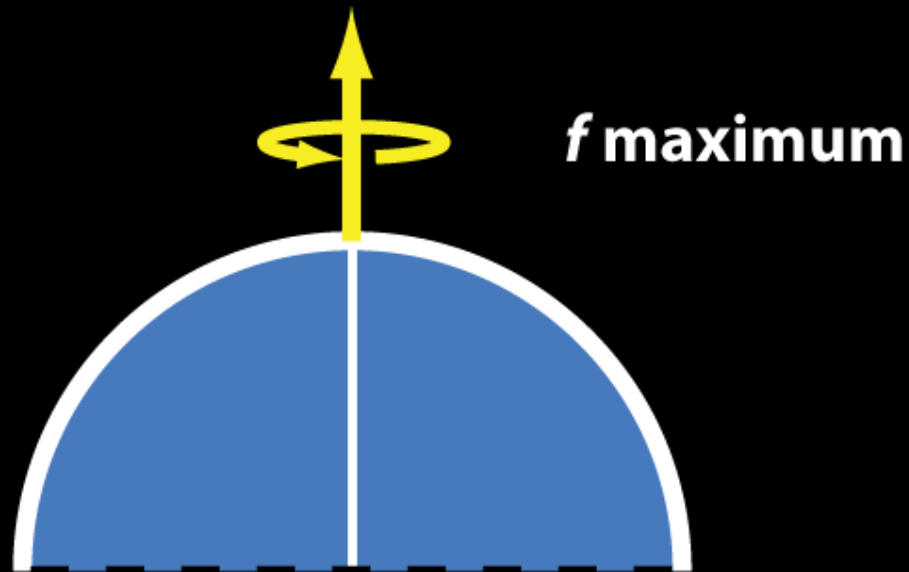
The symbols indicate warm air coming into this plane from the S. The warm wind is acting to increase the temperature of this layer.



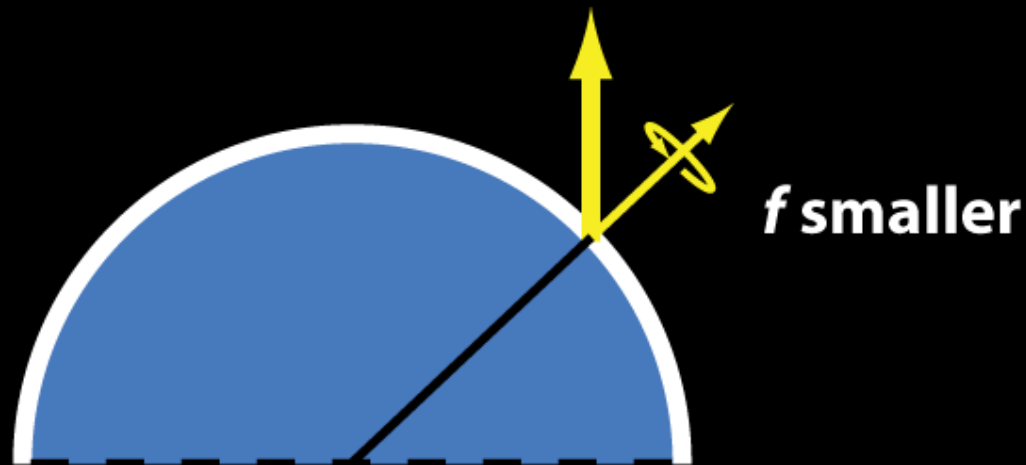
As a result of the T rise, the thickness of the layer will increase. Recall thickness is proportional to T . I didn't increase the T by heating the air from below or from causing latent heat release. I did it by pushing out colder air, replacing it with warmer air -- **warm advection**. The thickness increase implies the air must also be rising.

Establishing ascent:
positive vorticity advection

Vorticity = spin

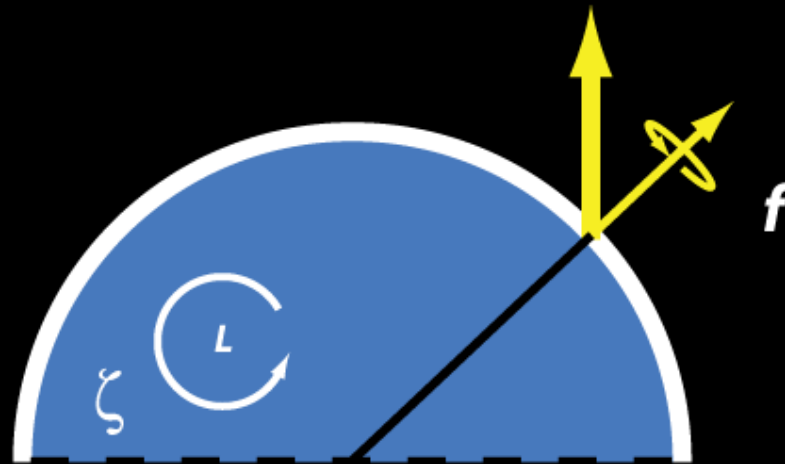


Earth's NH seen from above... it has CCW spin...
positive **planetary vorticity**.
We referred to this spin as f .



Recall only the component of Earth's spin in the local vertical matters -- so f is a function of latitude, decreasing to zero at the equator.

This is why Coriolis force vanished at the equator.



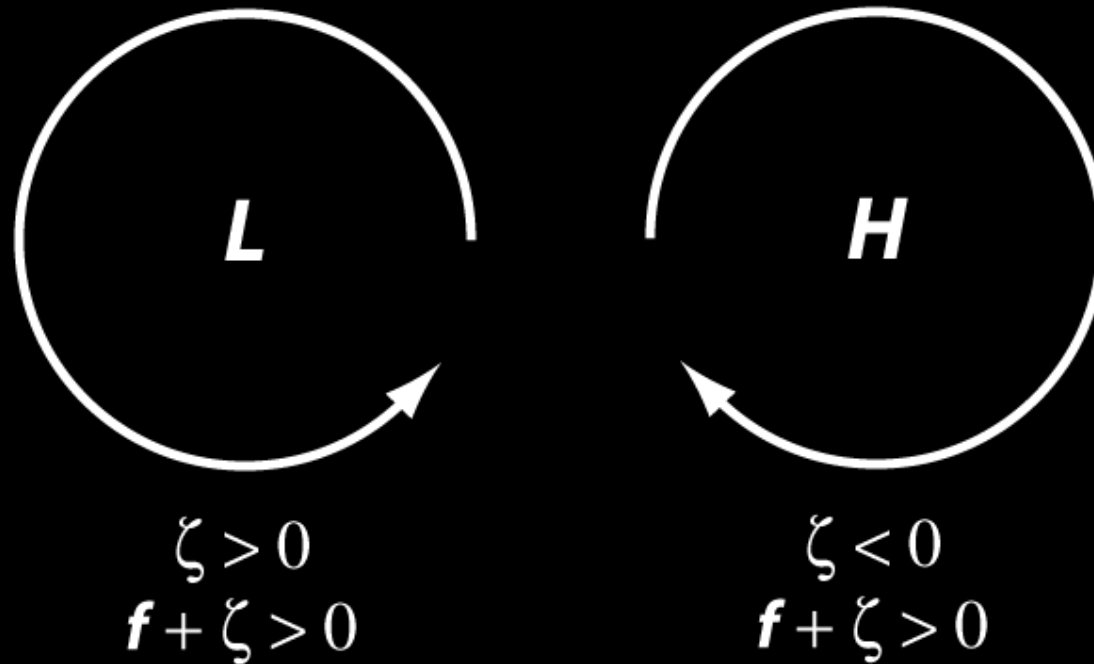
Relative vertical vorticity ζ is spin relative to the Earth.

Again, CCW is positive.

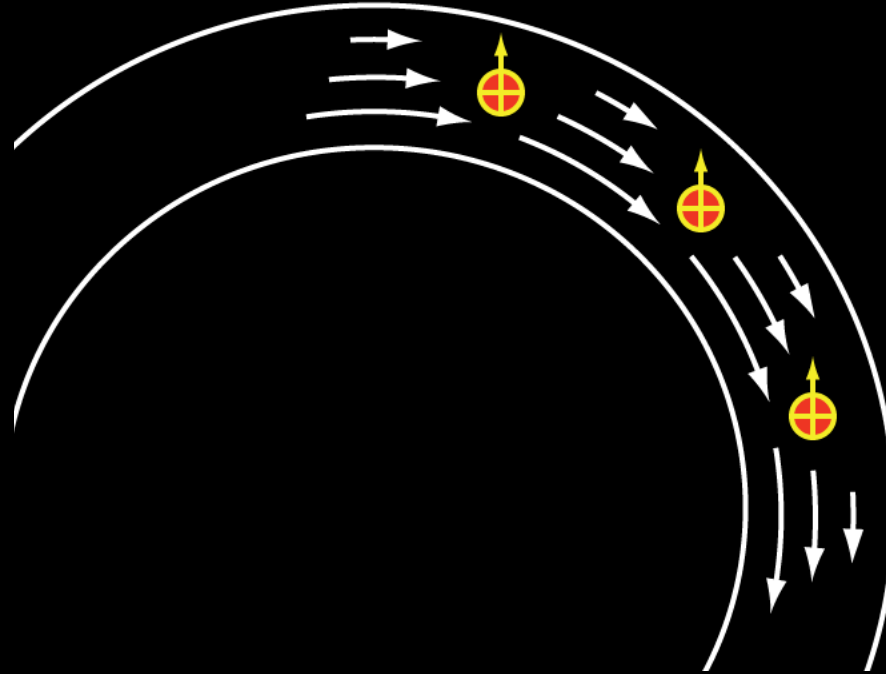
So consider a extratropical cyclone with its CCW flow.

It has positive relative vorticity ζ due to its spin,
AND positive planetary vorticity due to the Earth's spin.

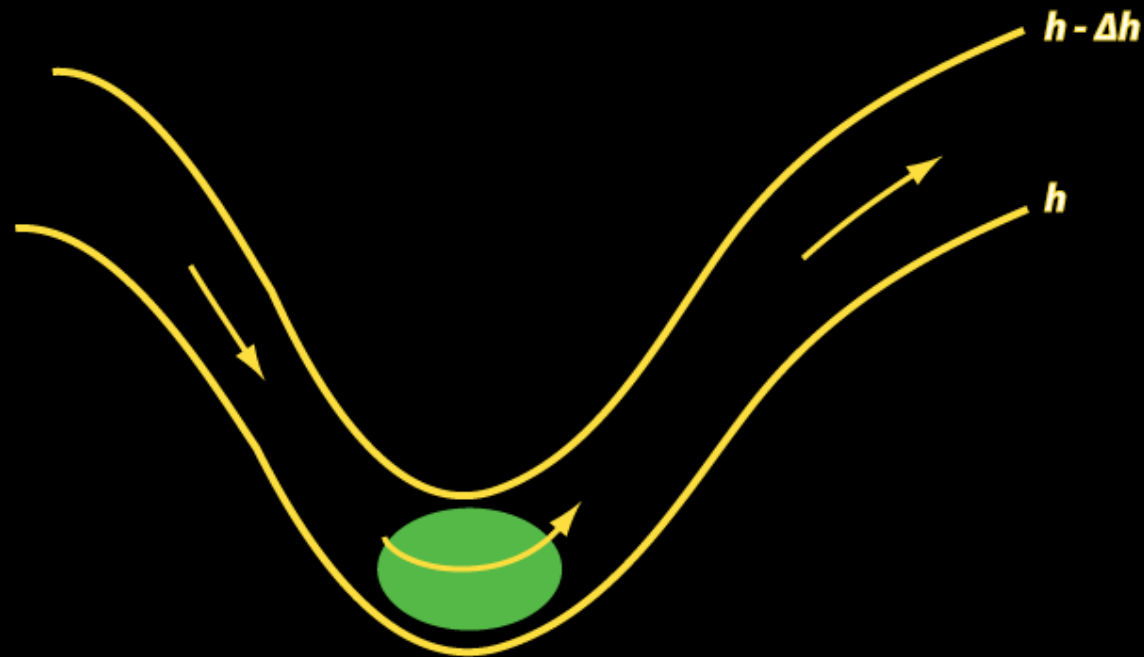
$$\text{Absolute vorticity} = f + \zeta$$



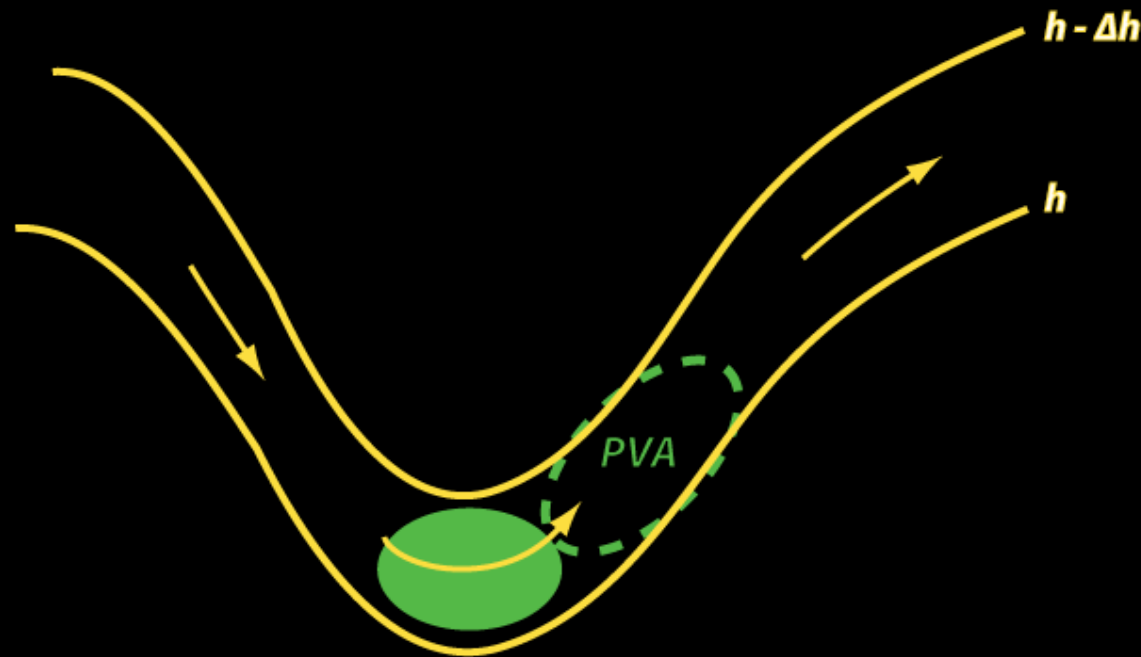
Here is an extratropical cyclone and anticyclone. For the anticyclone, its relative vorticity is negative, since the flow is CW. But f is positive and large, so absolute vorticity, $f + \zeta$, is still > 0 , though smaller than the absolute vorticity of the cyclone



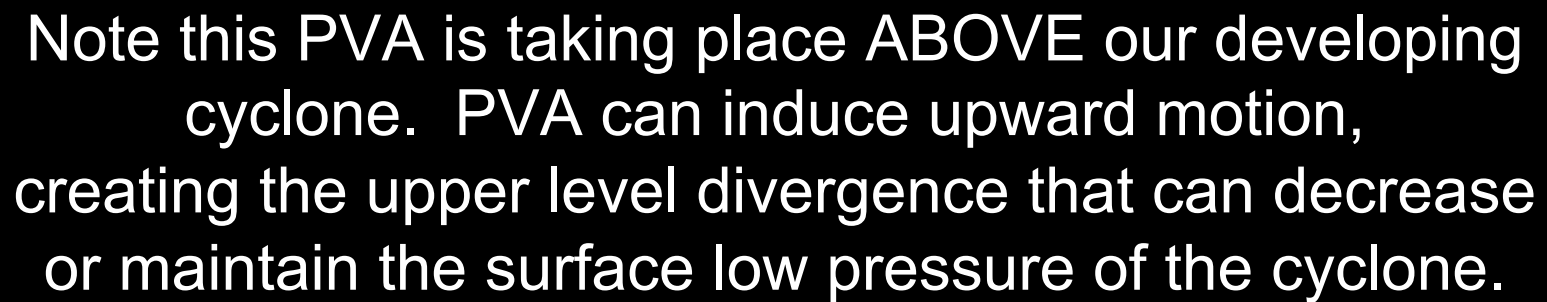
Relative vorticity has two components: due to **curvature** and **shear**. In this example, curvature and shear vorticity cancel, so the object does not rotate as it flows CW.

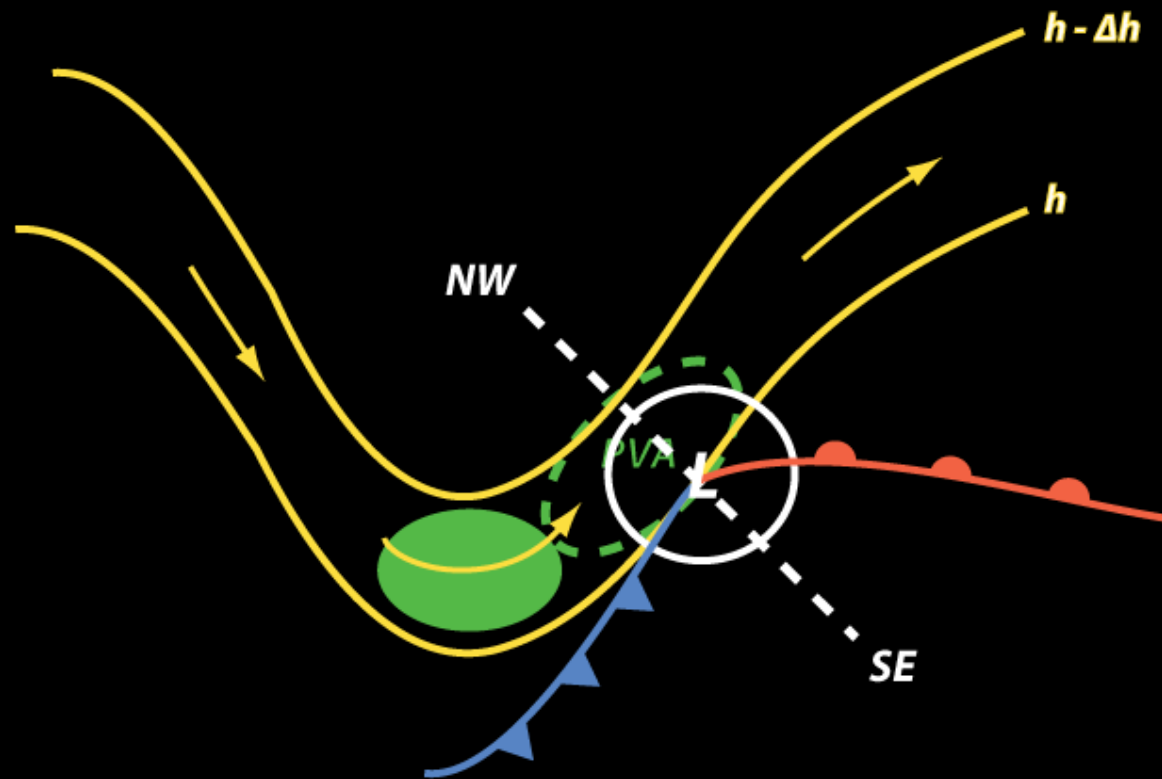


We're likely to find local maxima of absolute vorticity in troughs, in places where curvature and shear vorticity can constructively reinforce each other. We call this a vorticity maximum, or "vort max".

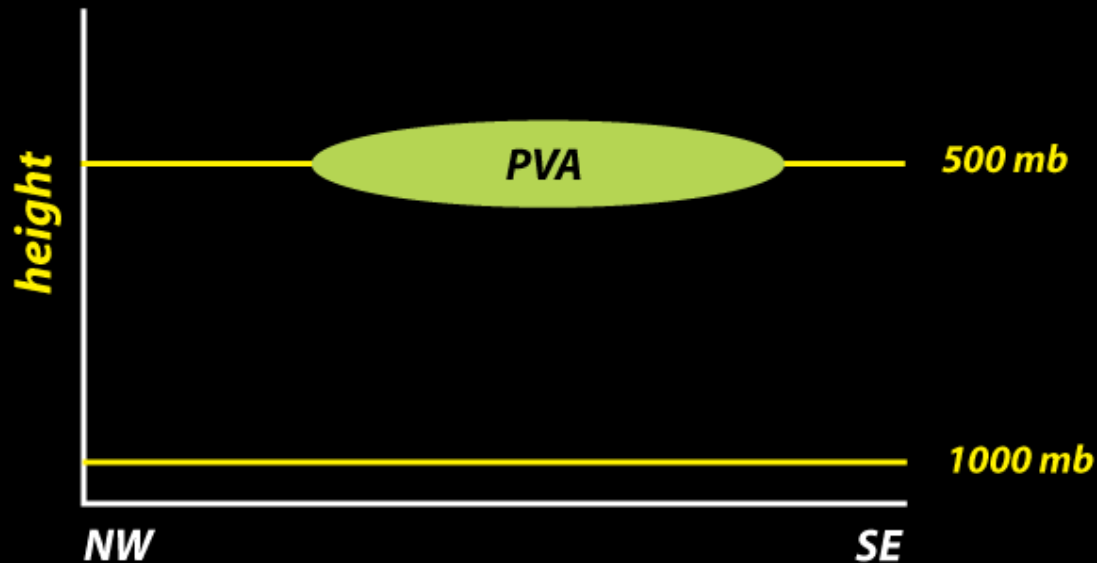


Absolute vorticity is a property of the flow that can be transported -- advected -- by the winds.
Positive vorticity advection will occur downwind of the vort max. We call this PVA.

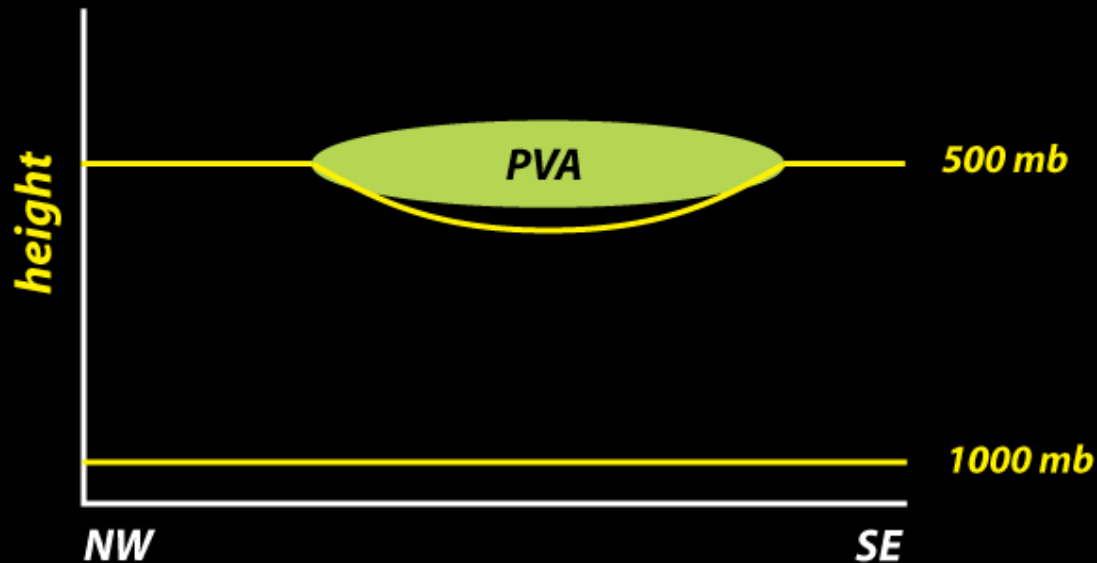




How and why does PVA induce ascent?
Let's take a look at a vertical cross section
across the cyclone, from NW to SE, in the
area where PVA is taking place

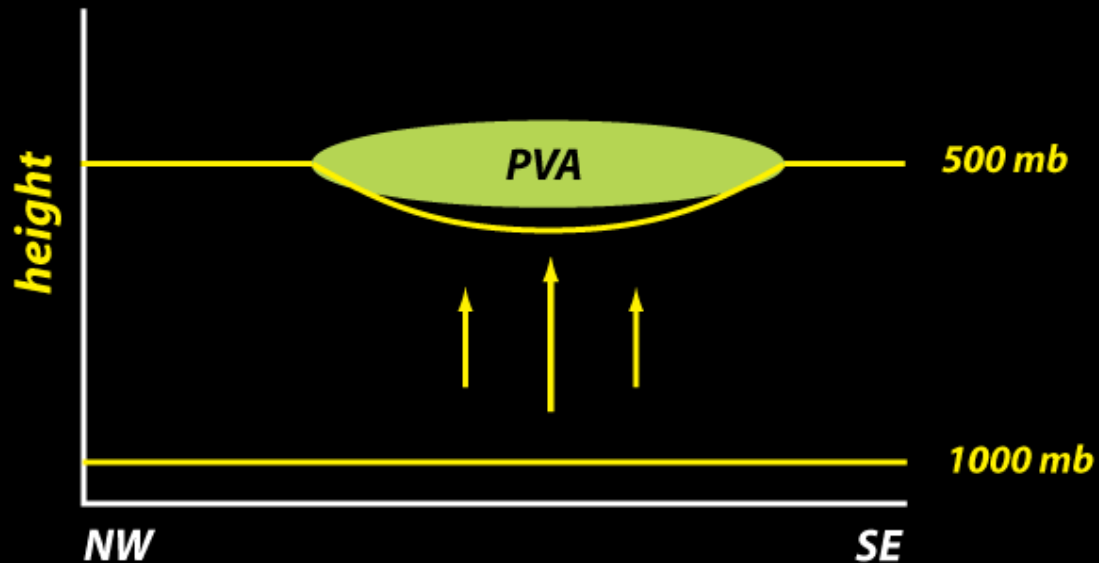


Let's start before the cyclone even formed.
Here's our PVA at 500 mb. Vorticity is spin, so PVA means that more spin, in a CCW direction is being transported into the plane at the 500 mb level.

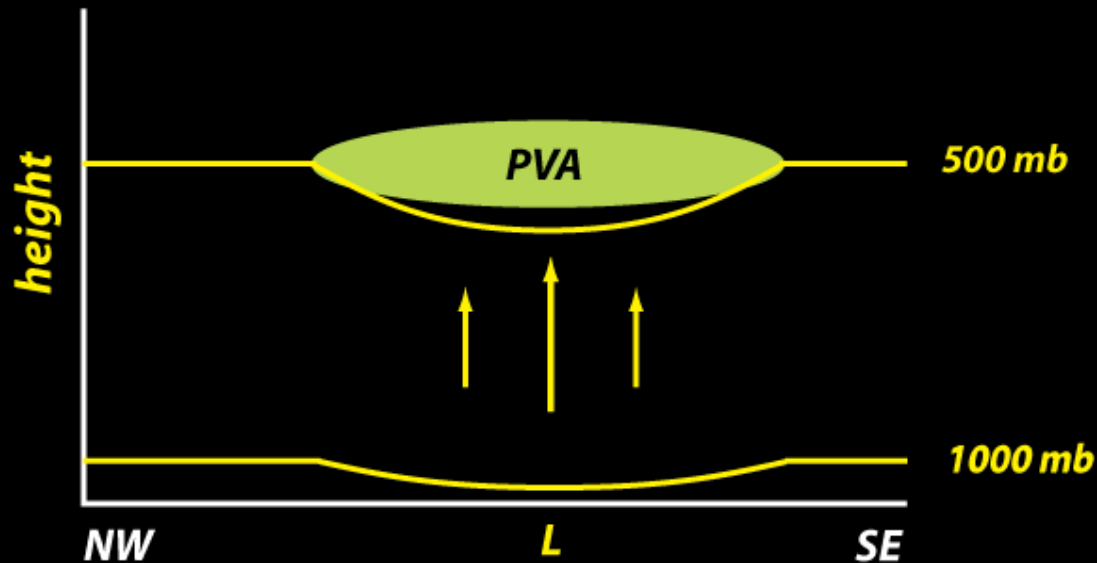


On the mesoscale, spin creates lower pressure -- the cyclostrophic effect. So, the pressure drops where the PVA occurs.

This makes the 500 mb level move downward to a lower altitude. Note this increases the vertical p gradient!

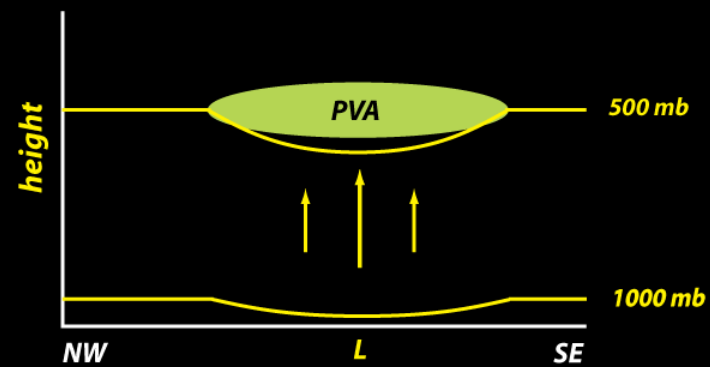
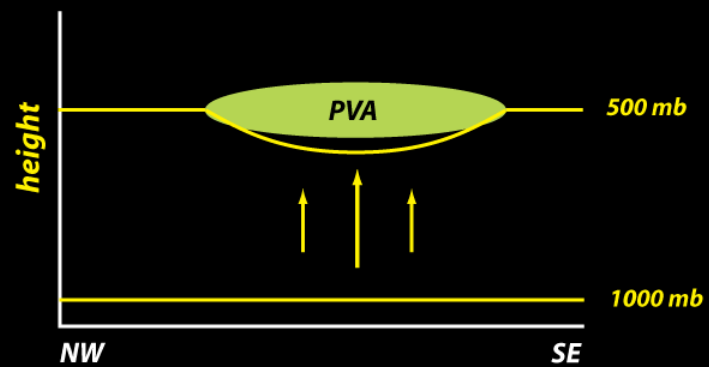
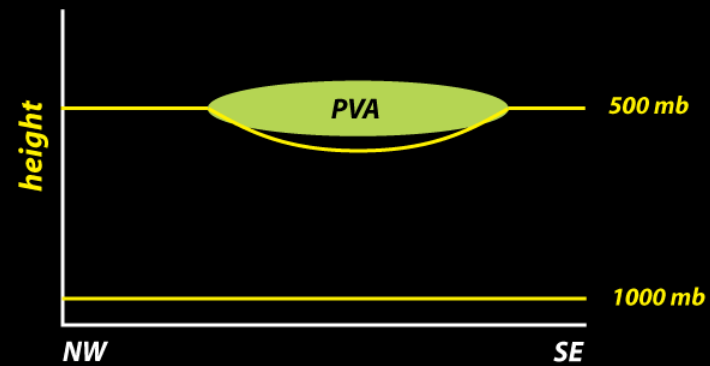
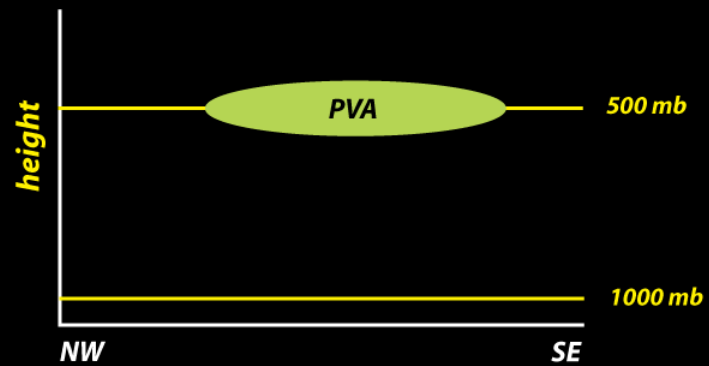


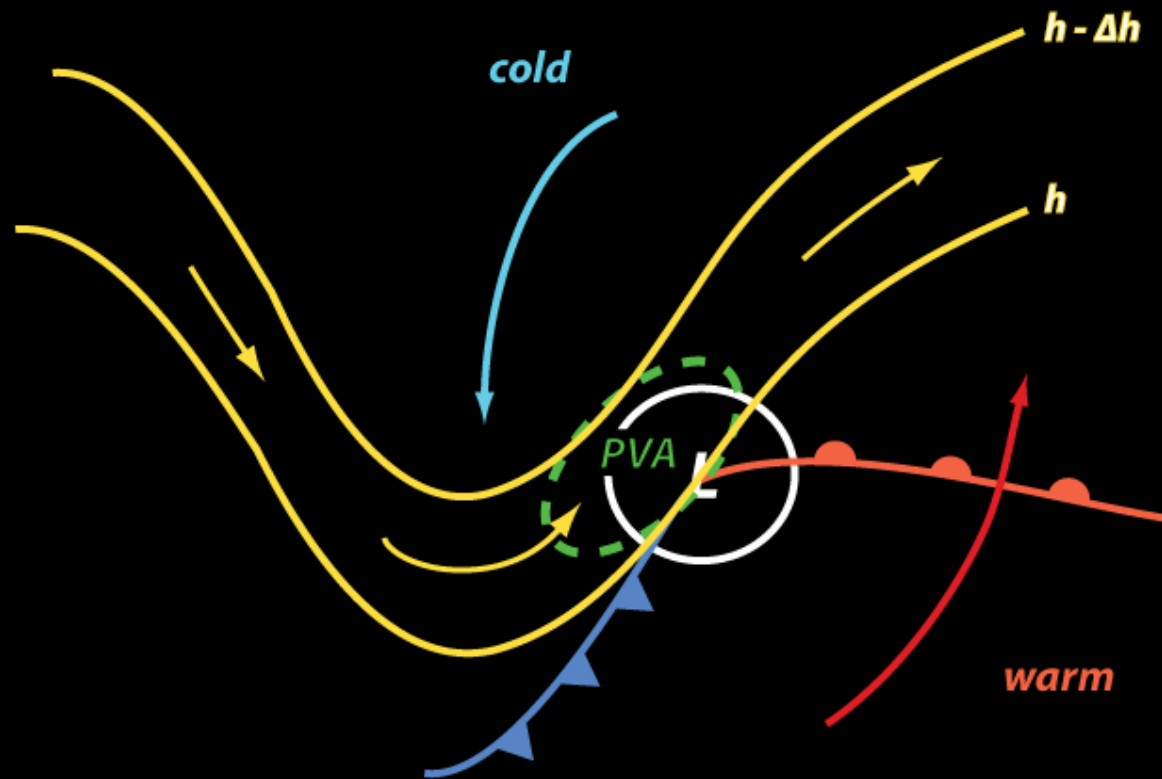
Note also this
DECREASES the thickness of the 1000-500 mb layer.
How to decrease the thickness? You need cooling.
Where does the cooling come from? How about
expansion cooling, owing to ascent?
There's our rising motion!



The ascent of mass in this column forces outflow above and causes the surface pressure to drop.

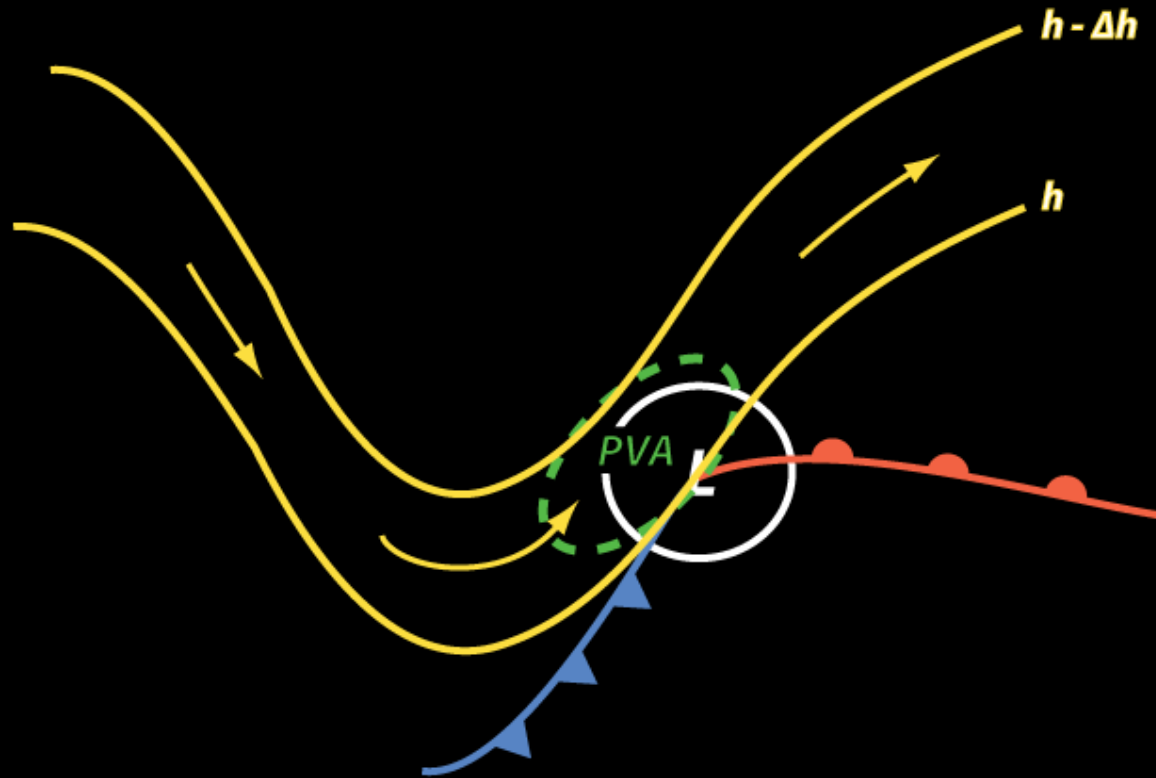
This process can create a cyclone that didn't already exist, or deepen an existing cyclone. Deepen = make stronger.



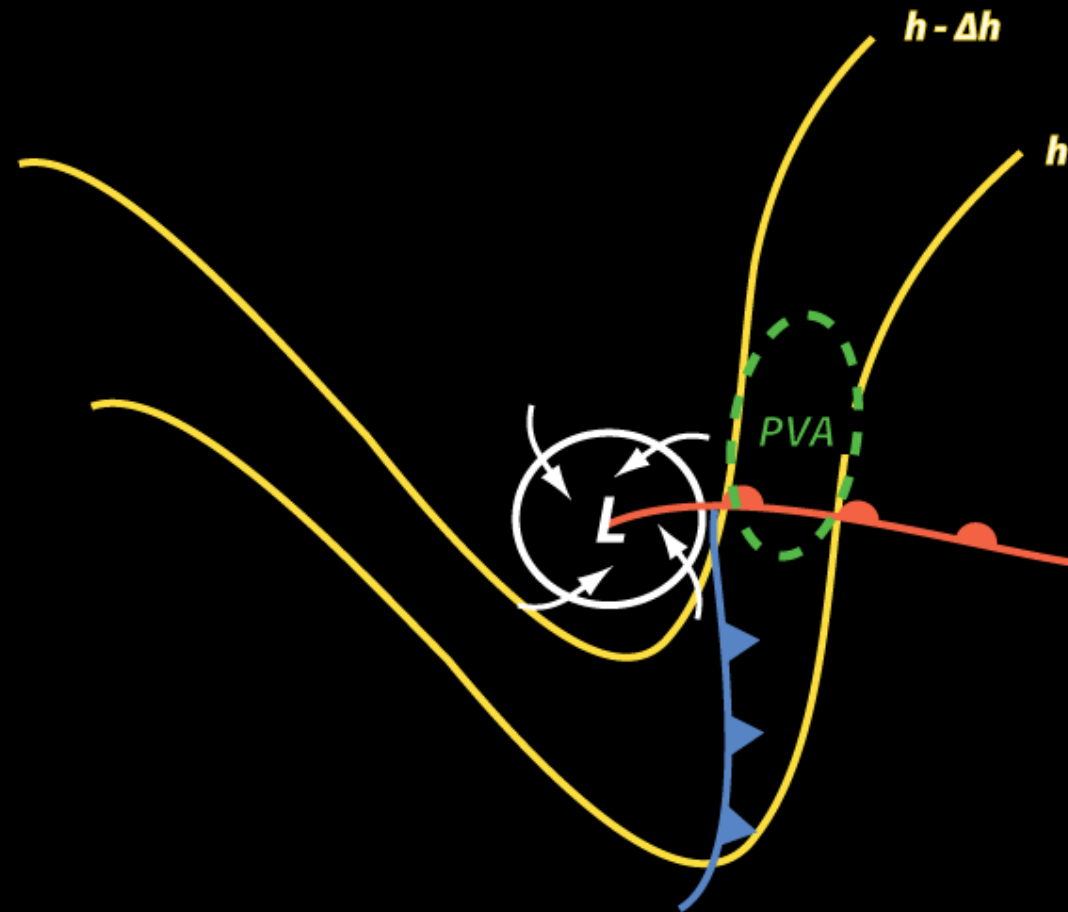


PVA and warm advection can cooperate or compete. In this case, PVA and warm advection are working cooperatively, to deepen the surface low and also increase the amplitude of the trough and ridge.

Trough motion and cyclone decay



Our cyclone system isn't just the surface low, but also the trough. Note that this system tilts WESTWARD with height. The spin associated with PVA is helping move the trough eastward.



If the trough winds up above the surface low, the system is “vertically stacked”. Note the PVA isn’t above the low anymore. The ascent that pushed air out of the column above the cyclone is absent. But friction is still at work.

[end]