Meteorology – Lecture 17

Robert Fovell

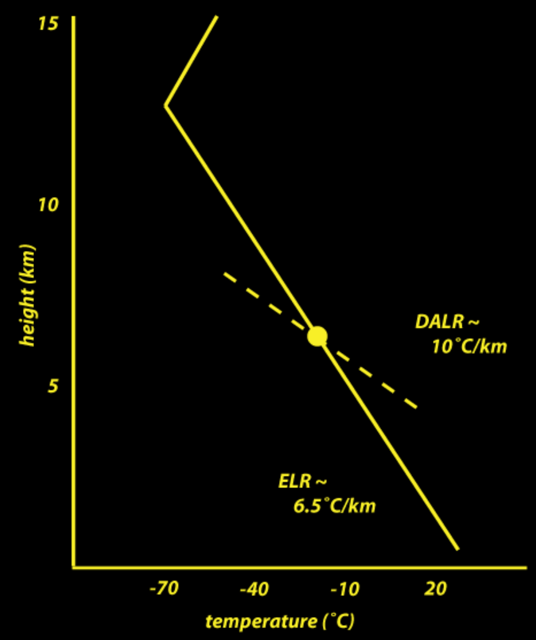
rfovell@albany.edu

Important notes

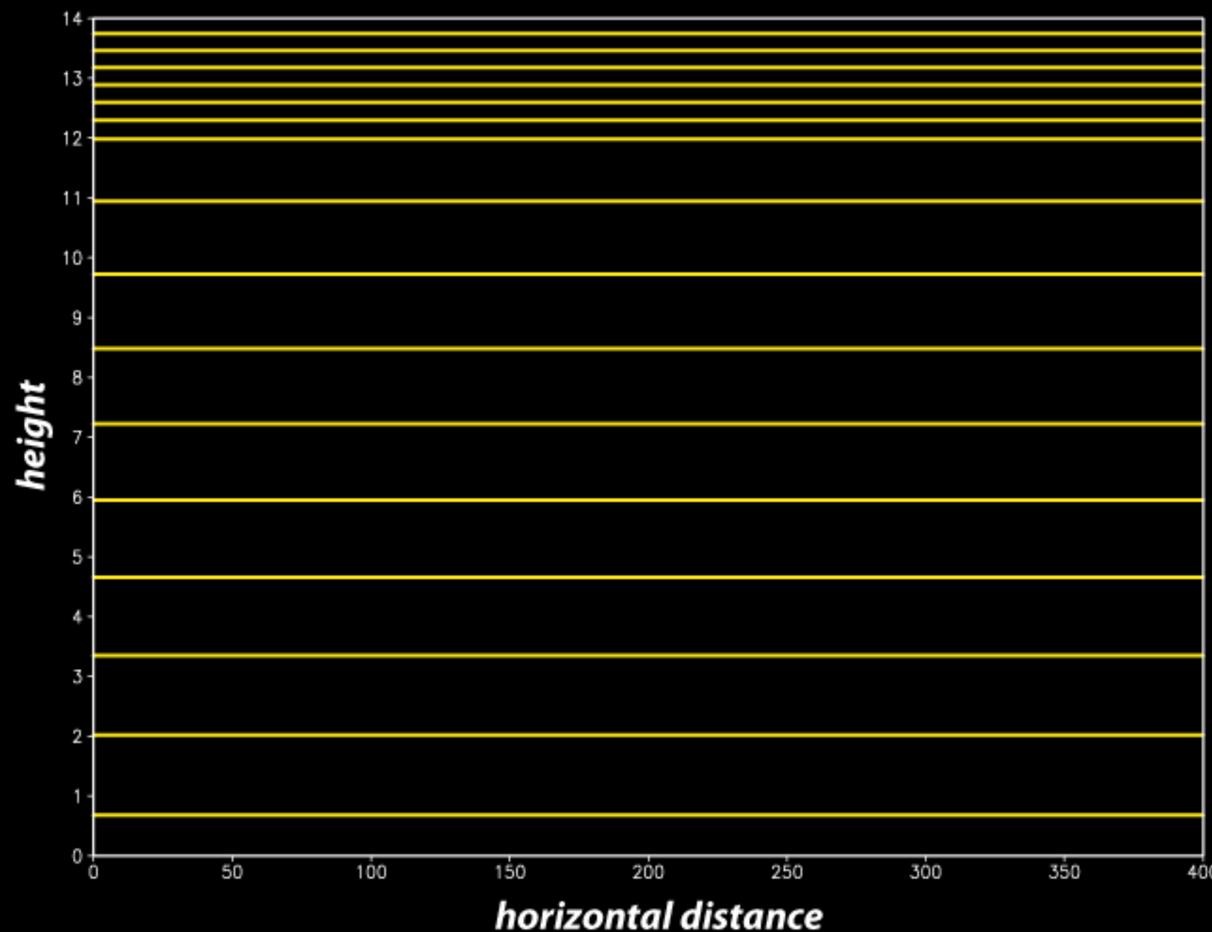
- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his "Meteorology" course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but 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.

Animations linked in the PowerPoint version of these slides may also be found here:

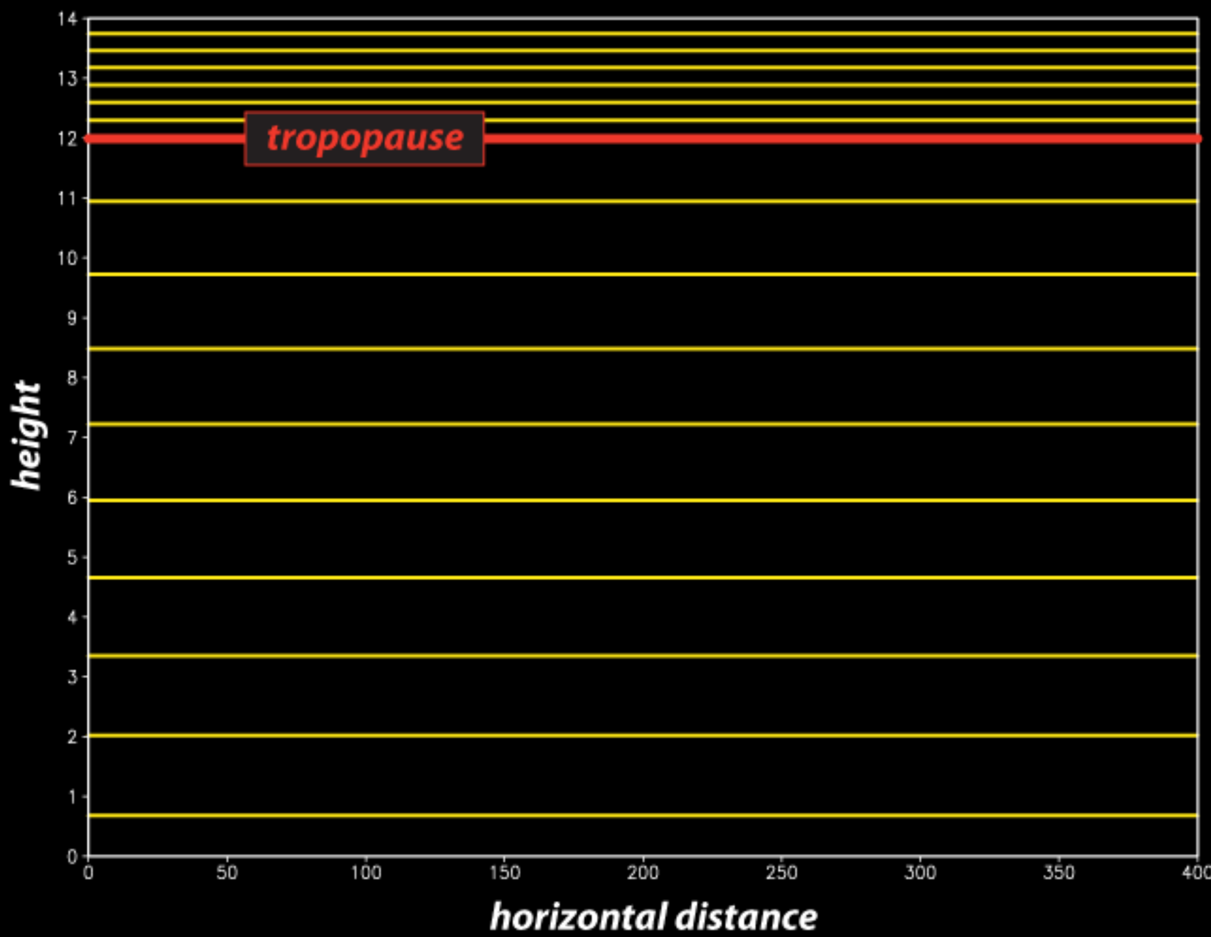
http://people.atmos.ucla.edu/fovell/meteo/



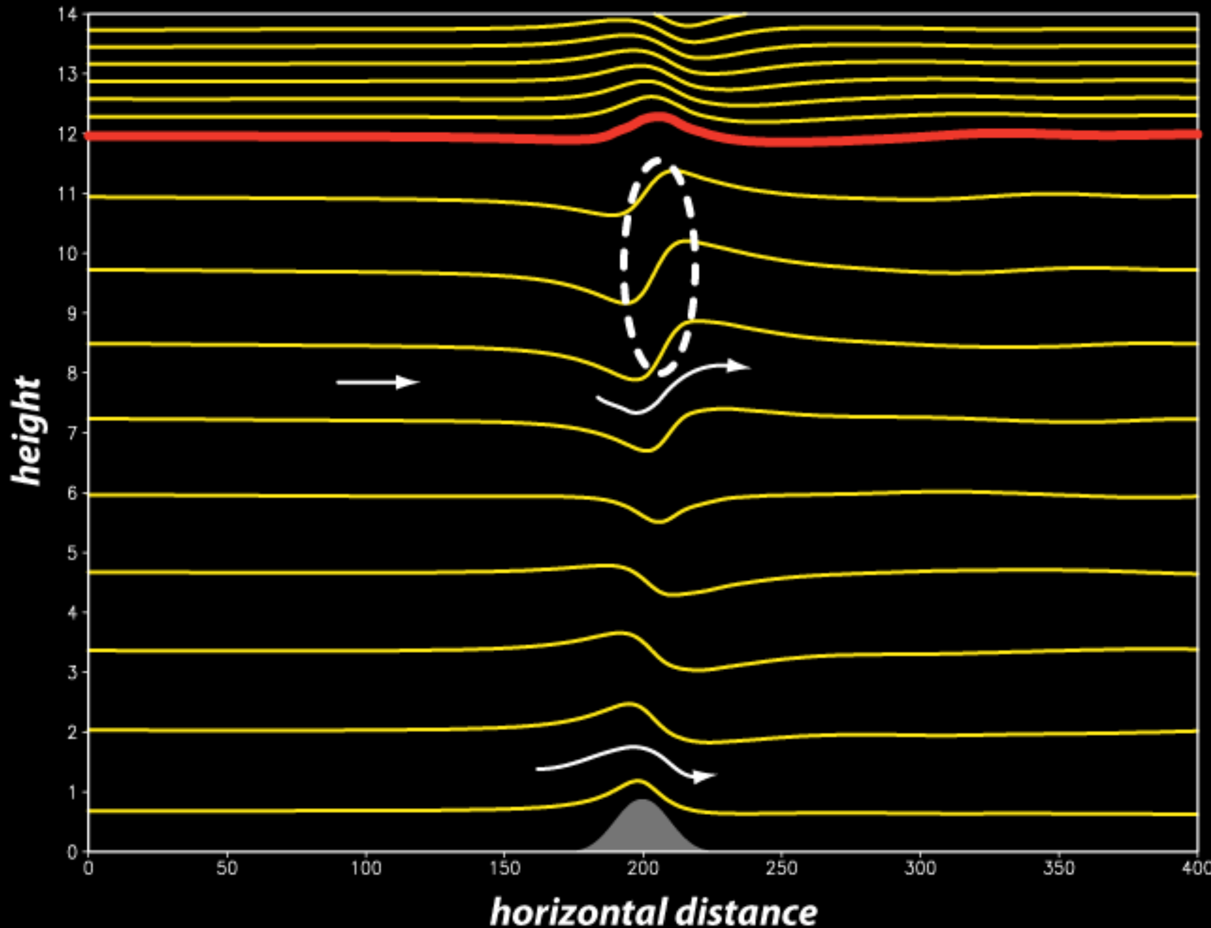
- Mountain waves form in a **stable** environment
- Recall a stable situation in one in which the environmental lapse rate (ELR) is less than the dry adiabatic lapse rate (DALR), as in the situation shown here



Now let's try to visualize a stable atmosphere in a somewhat different way. I've drawn a bunch of horizontal lines (called isentropes) I'll soon be using to indicate air parcel PATHS. Air is blowing from left to right.

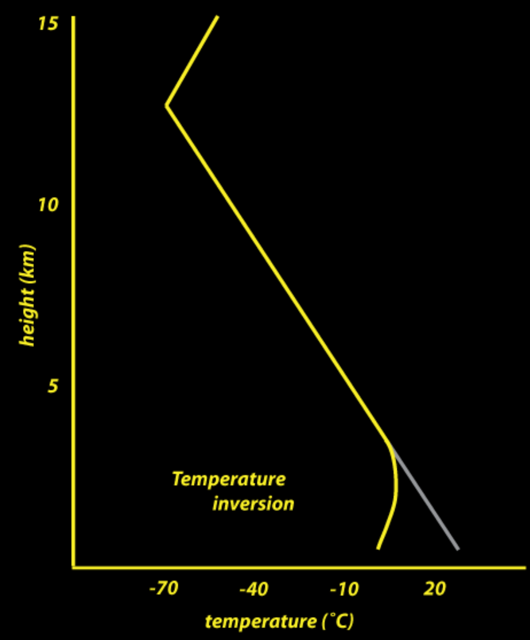


The initial spacing of these lines is a measure of how stable the environment is. More narrow = more stable. Note that spacing changes at the tropopause (about 12 km).



Pushing a mountain into the path of the westerly winds has created a disturbance. Down near ground level, we see air has been forced to rise up and over the mountain. The air is disturbed far above too.

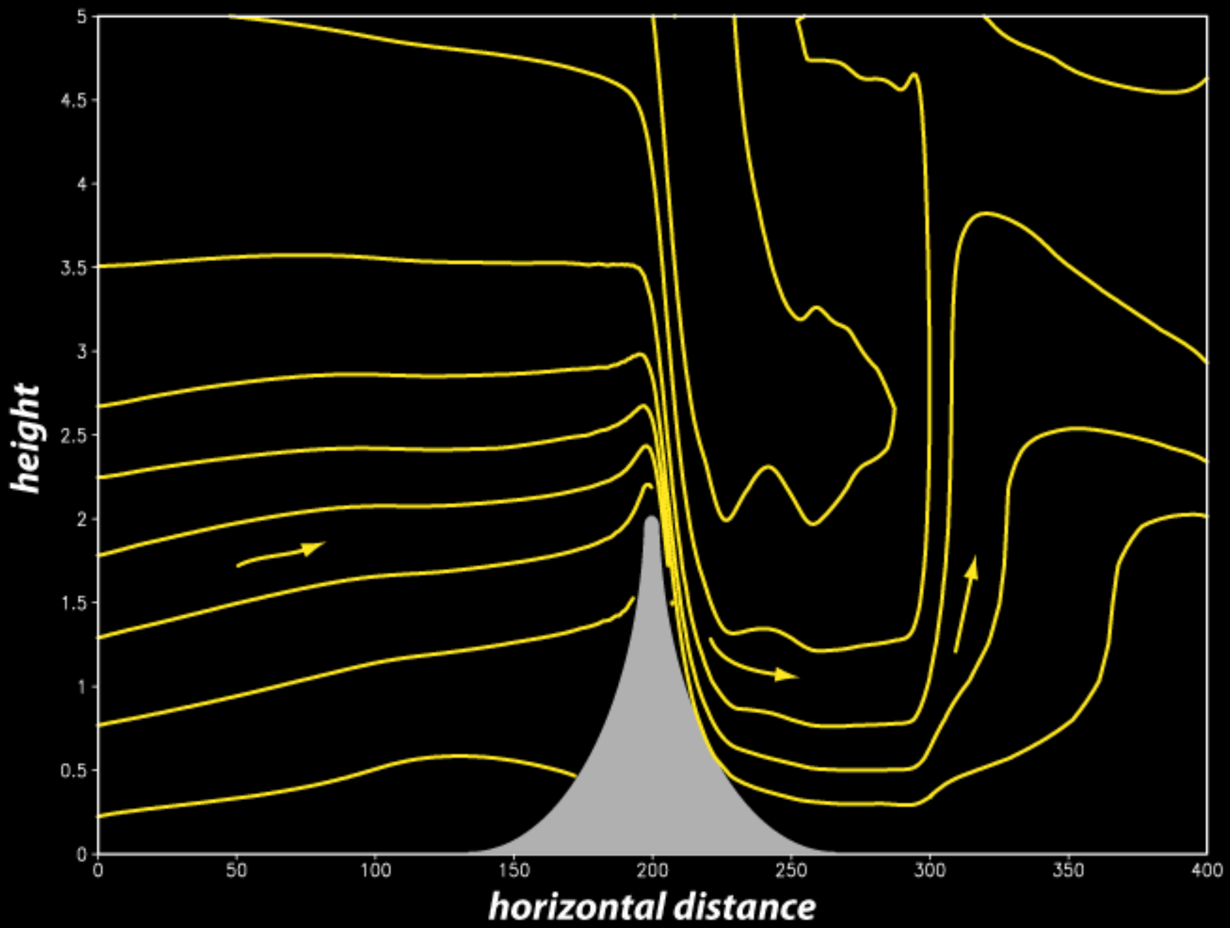
Downslope windstorms and hydraulic jumps



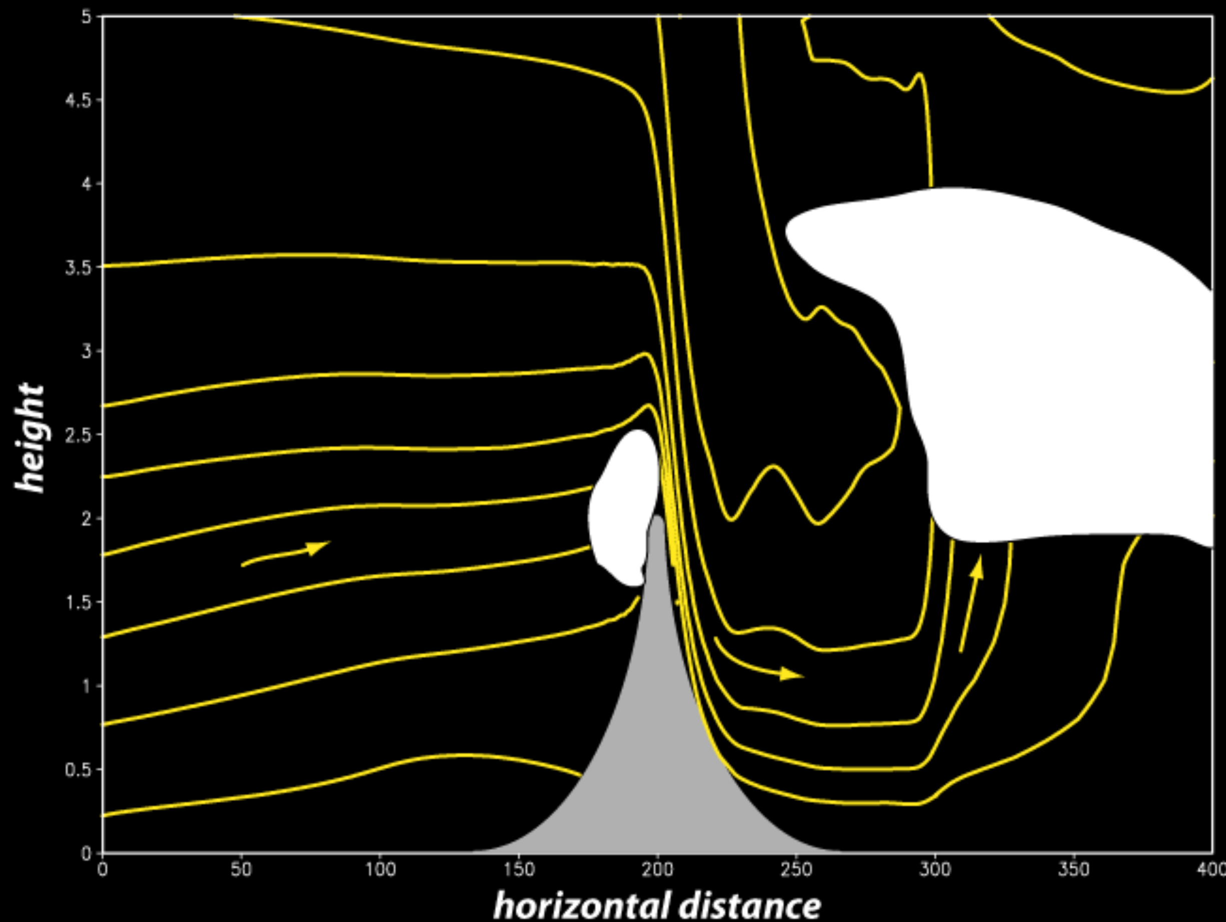
Recall the ELR is not a constant… It changes from place to place, day to day, and sometimes hour to hour

Here is a somewhat different T profile.

It has a **T inversion** near surface.



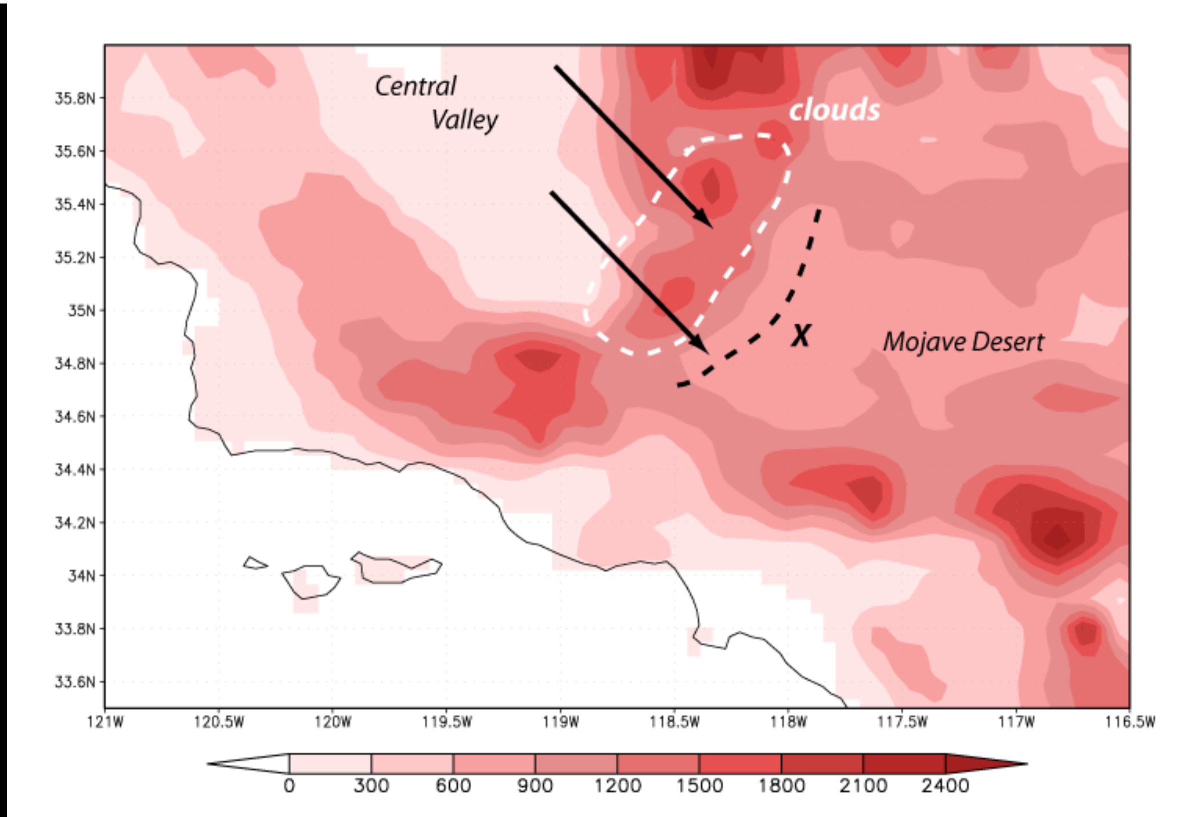
We' ve zoomed in on a 2 km tall mountain. The domain is now only 5 km deep. The wind's blowing L to R. Again, the yellow lines are isentropes, which we can use to deduce parcel paths.



Ascent on the windward side may produce a cloud. Note the tight contour spacing on the lee side: very fast winds. Then the sudden slowdown and ascent, which may also be cloud-topped: the hydraulic jump.

Compare to this photograph. In this case, the flow is right to left.

Animation



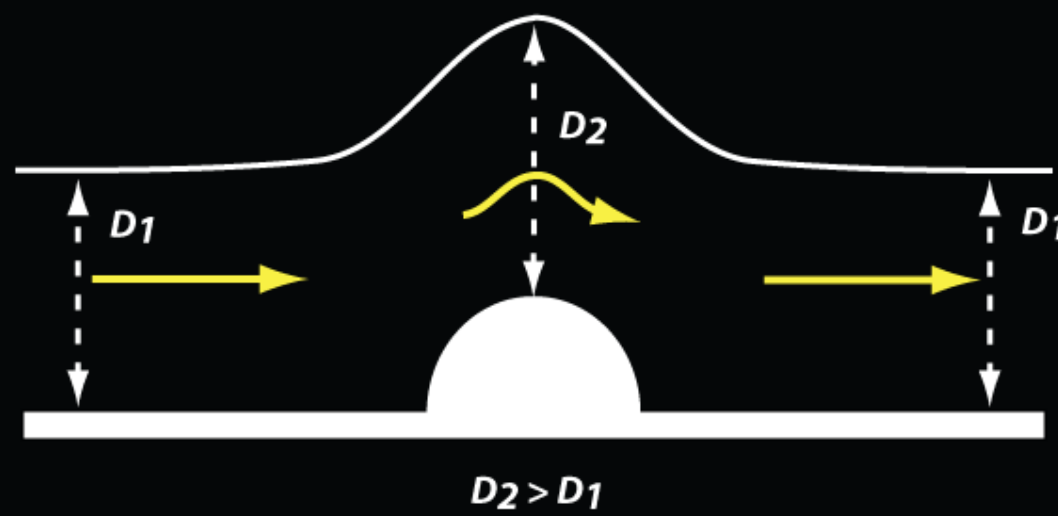
Here's a topographic map, with red indicating higher elevation. I was originally at the place marked "X", looking NW, into the wind. By my estimation, the jump was at the black dashed line. Astounding how the wind can change so much over such a short distance.

Hydraulic jump recipe

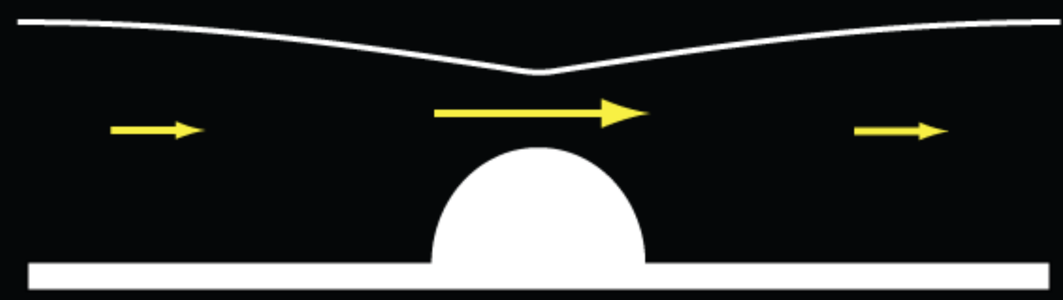
Picture a river flow in a situation in which there's no obstacle on the riverbed, which is the thick white line.

Flow L to R.

The thin white line at the top represents the river's free upper surface.

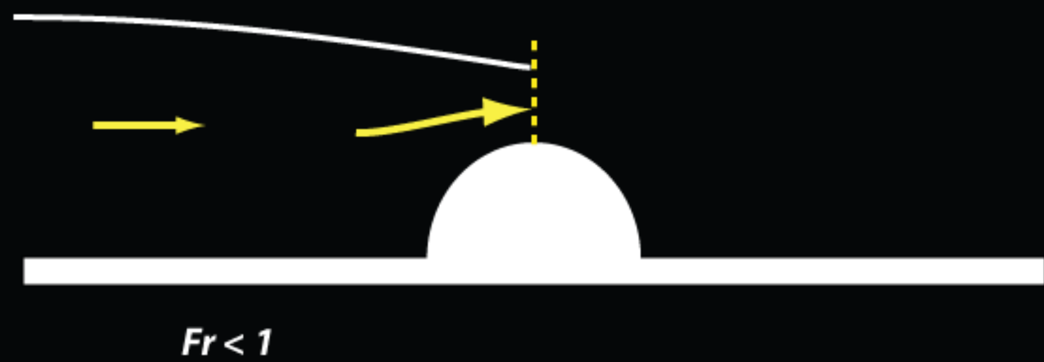


Consider fast oncoming flow approaching an obstacle. It turns out this flow will **slow down** as it rises over the obstacle, which makes the fluid thicker. Once past the crest, the flow will **speed up** again, returning to its original velocity downstream, as if the mountain had never existed. It slows uphill and speeds up downhill = **supercritical** flow.



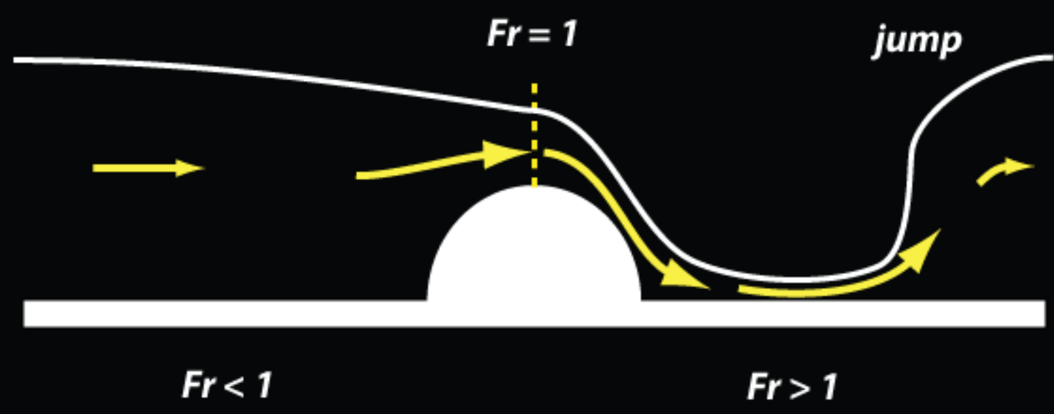
If the initial oncoming flow is somewhat slower, however, it CAN be very different. This situation is called **subcritical**. The flow actually **speeds up over the obstacle, and the fluid thins**.

$$Fr = \frac{u}{\sqrt{gD}}$$

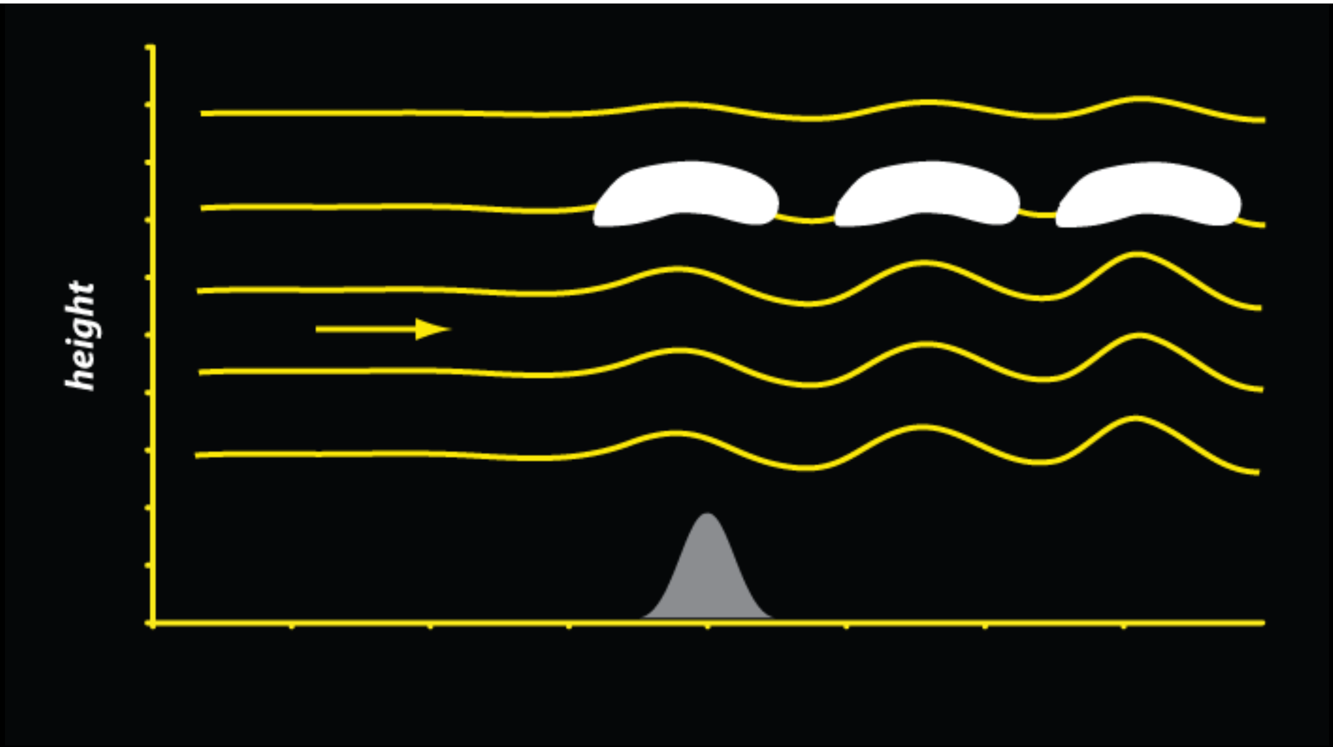


The flow can transition from subcritical to supercritical as it passes over the obstacle. If that happens, we can get acceleration UP and DOWN the hill, leading to very large wind speeds on the lee side. This phenomenon was explained with the simple Froude (Fr) number equation.

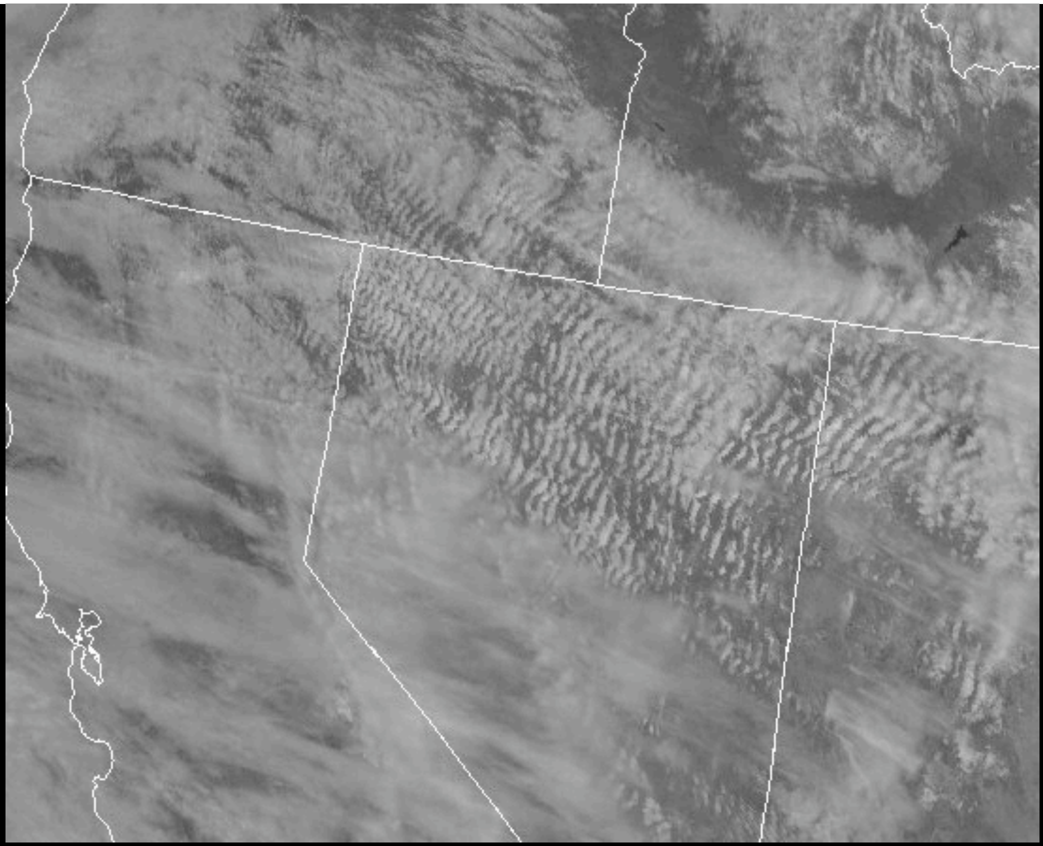
$$Fr = \frac{u}{\sqrt{gD}}$$



In this case, Fr starts < 1, the critical value. The flow speeds up over the obstacle. That increases Fr. If Fr reaches 1, the flow becomes supercritical, which means it also speeds up downhill. The very fast flow will abruptly slow own again at the hydraulic jump.

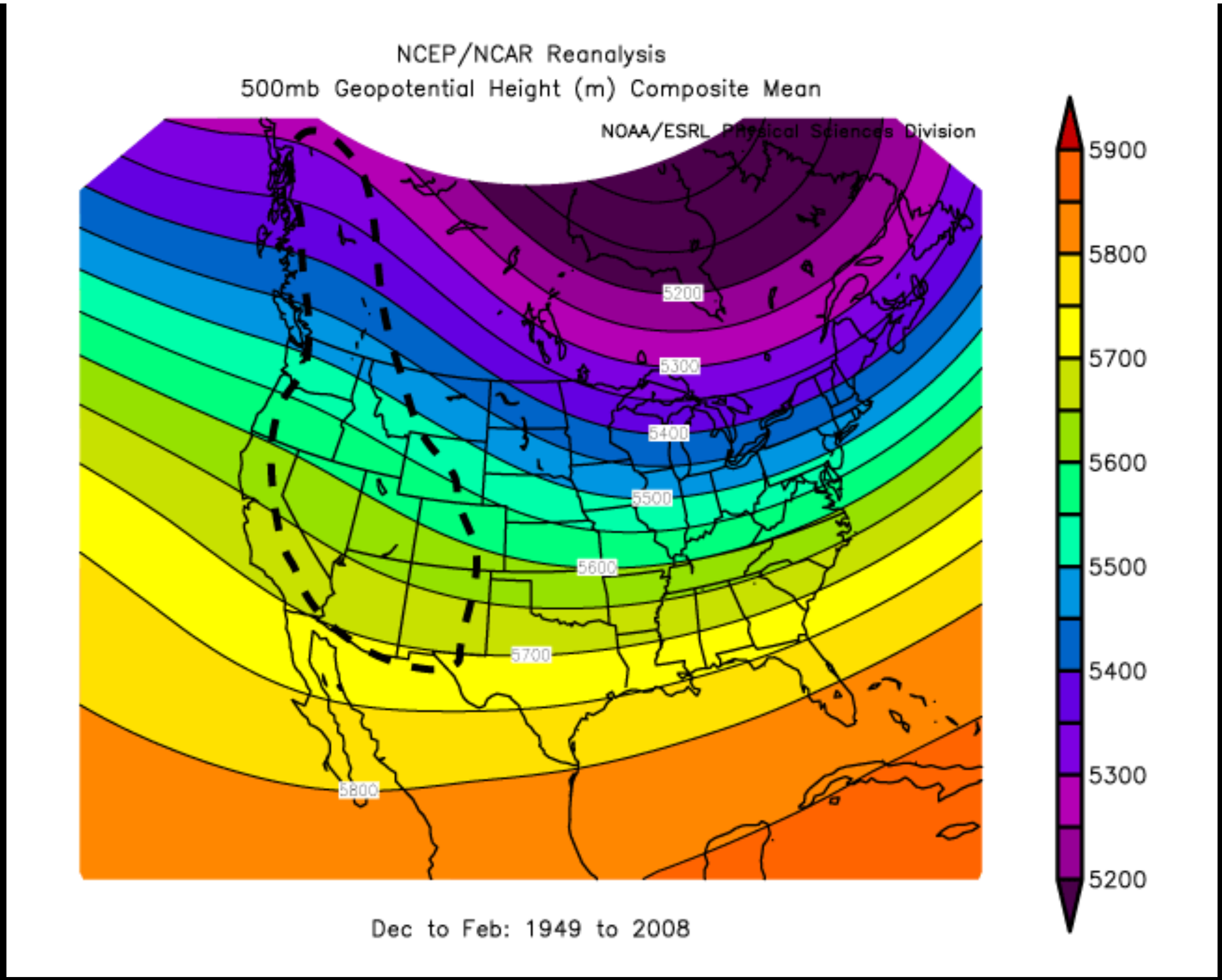


A less dramatic and more common example of trapped waves are LEE WAVES. The ascent portion of the bobbing up and down can create clouds.

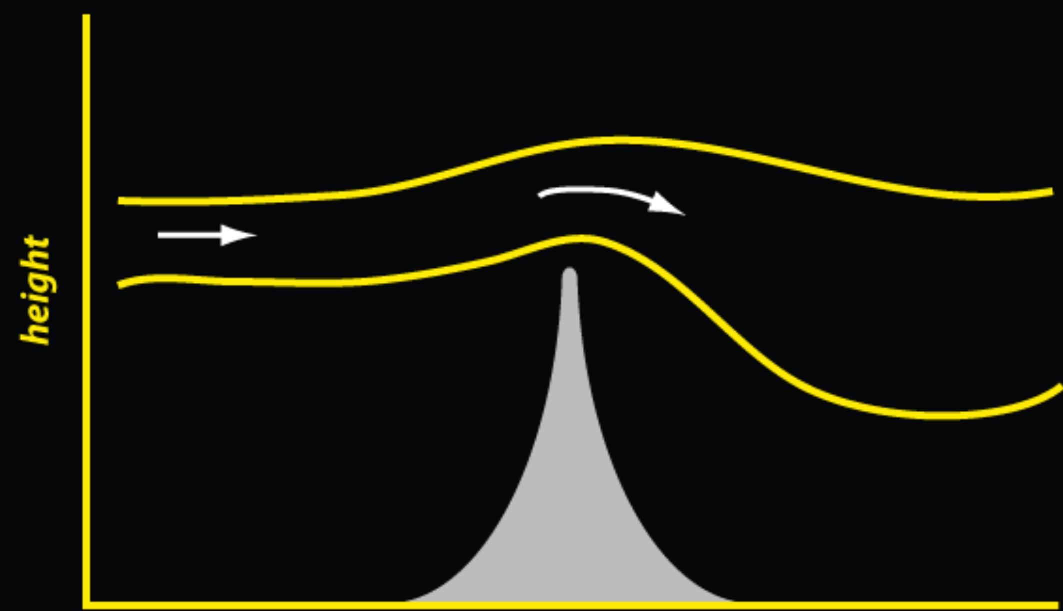


Beneath the high, wispy high cirrus are lee waves, oriented SSE to NNE, extending downstream from the Sierra and Cascades.

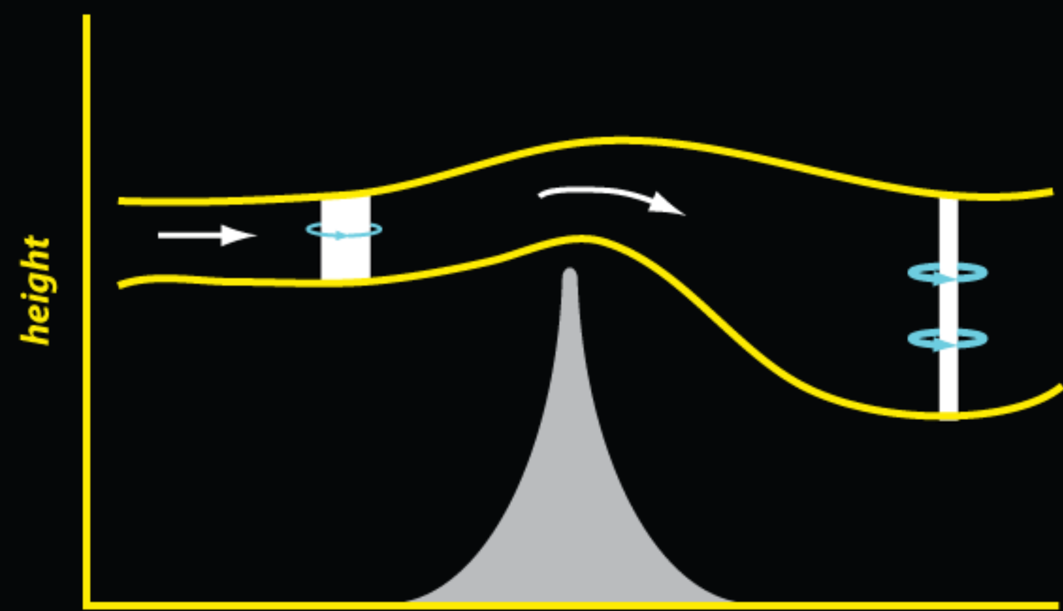
Large-scale influences of mountains



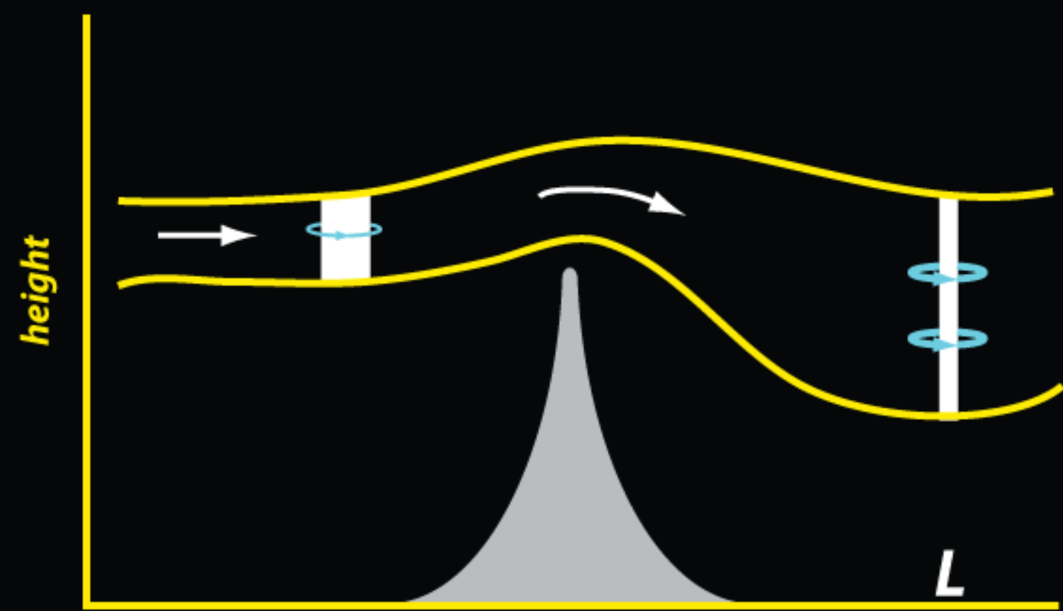
Mean 500 mb map for winter, seen earlier. Mountains help make troughs. They can also make extratropical cyclones.



Consider again westerly flow over a formidable topographic barrier. We've often seen subsidence on the lee side. Here are two isentropes. Remember, if our process is dry adiabatic, the mass between these isentropes is fixed.



Now picture a cylinder of air between the two curves approaching the mountain. The cylinder may not seem to be spinning, but it DOES have spin if only because of the rotating EARTH. Subsidence on the lee side can cause this cylinder to be STRETCHED vertically.

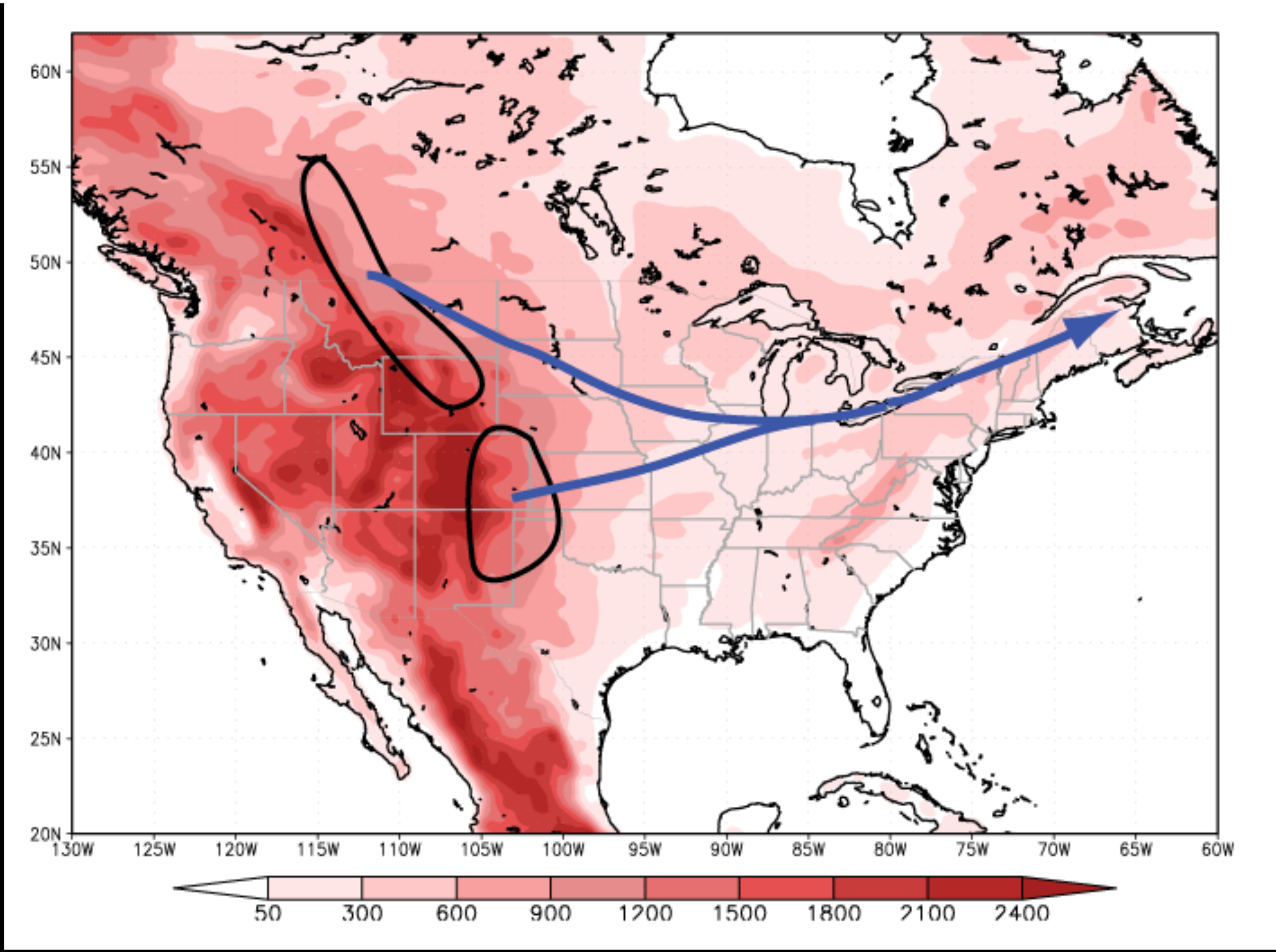


VERTICAL STRETCHING INCREASES SPIN.

Conservation of angular momentum.

The spin helps create the surface low.

Mountains can create troughs and extratropical cyclones



Hotspots of LEE-SIDE CYCLOGENESIS -- the formation of new cyclones owing to mountain effects -- and typical tracks taken by these storms. Northern track: "Alberta clippers" due to their location of origin and fast movement. Other favorable locations exist.

[end]