Meteorology – Lecture 12

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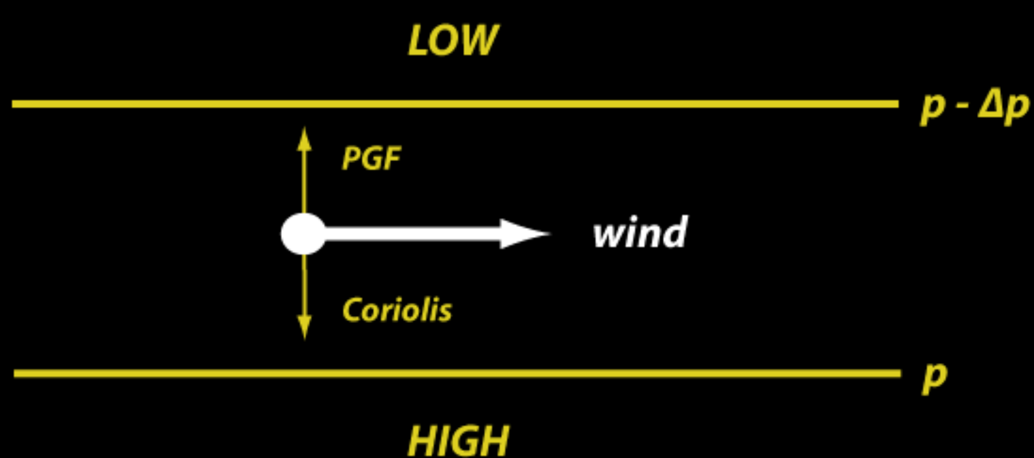
Important notes

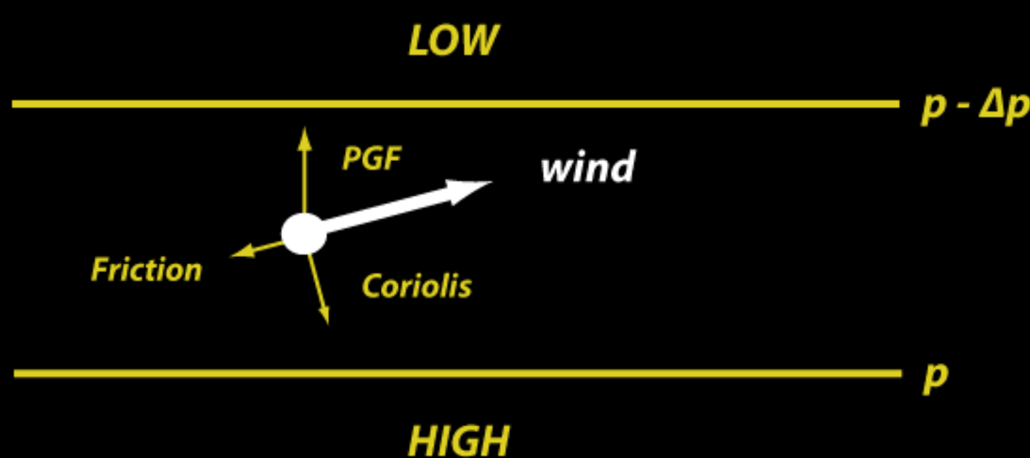
- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his "Meteorology" course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but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

Effect of surface friction

Let’s start with geostrophic balance.
The wind is blowing with low pressure to the left and Coriolis acting to the right of the motion.

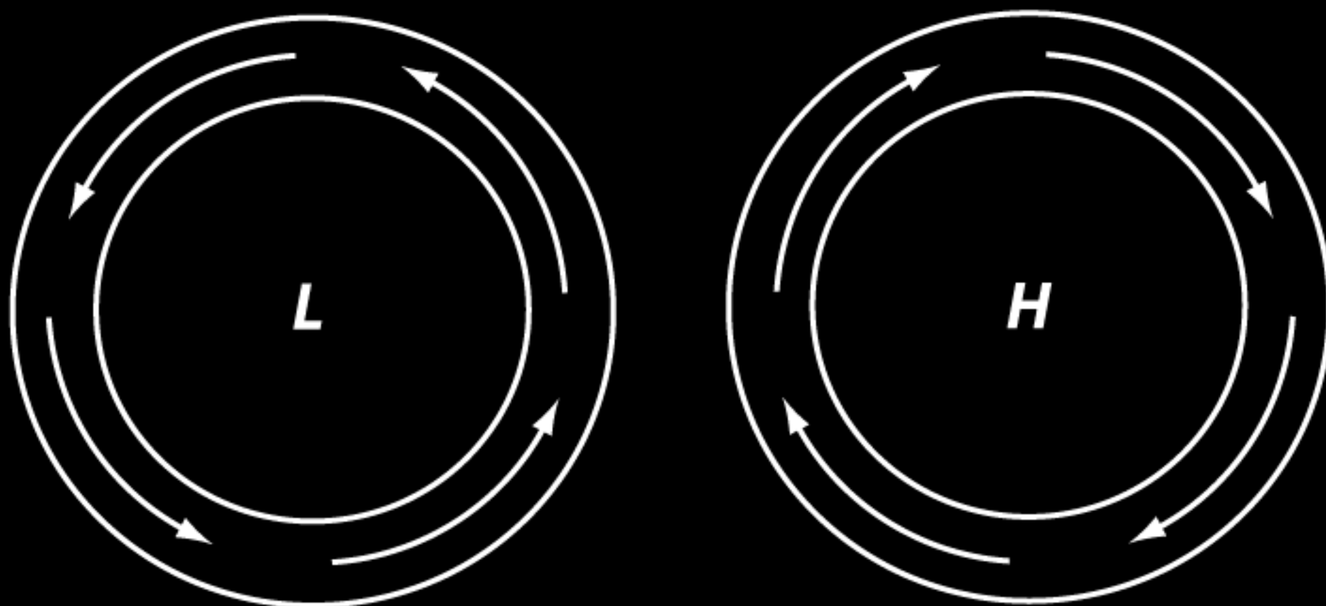


Friction opposes the motion, causing it to slow. Since Coriolis force is proportional to wind speed, it is weakened, but the PGF is not *directly* affected. This results in the wind developing a component towards L pressure.



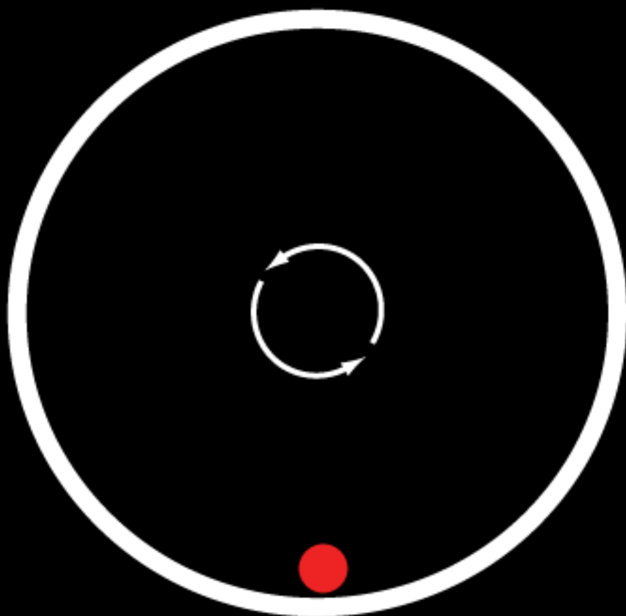
Large-scale lows and highs (cyclones and anticyclones)

The wind tends to curve CCW around large-scale regions of lower pressure (cyclones), and curve CW around larger-scale highs (anticyclones), in the NH.

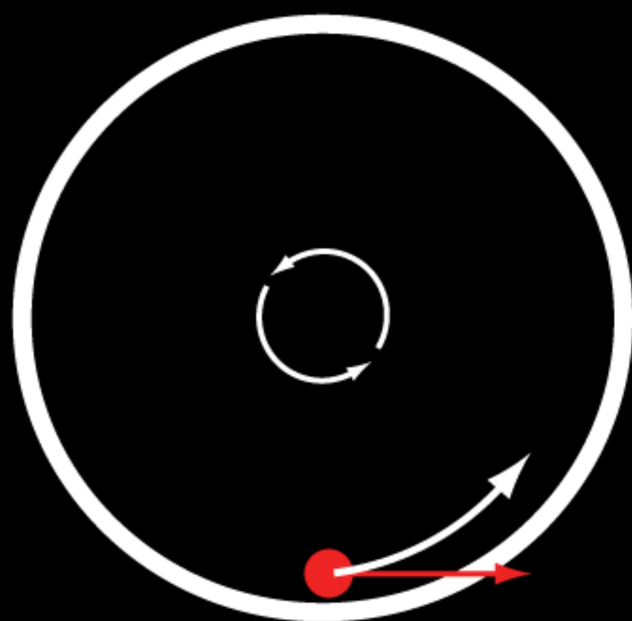


Centrifugal vs. centripetal accelerations

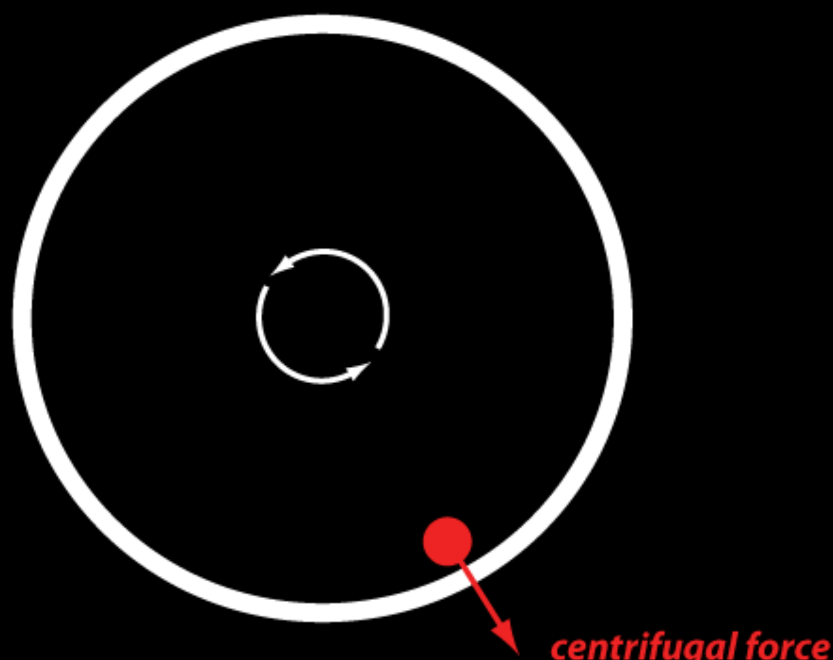
Here you are in the cylinder ride.
CCW or CW, no difference - same pain.



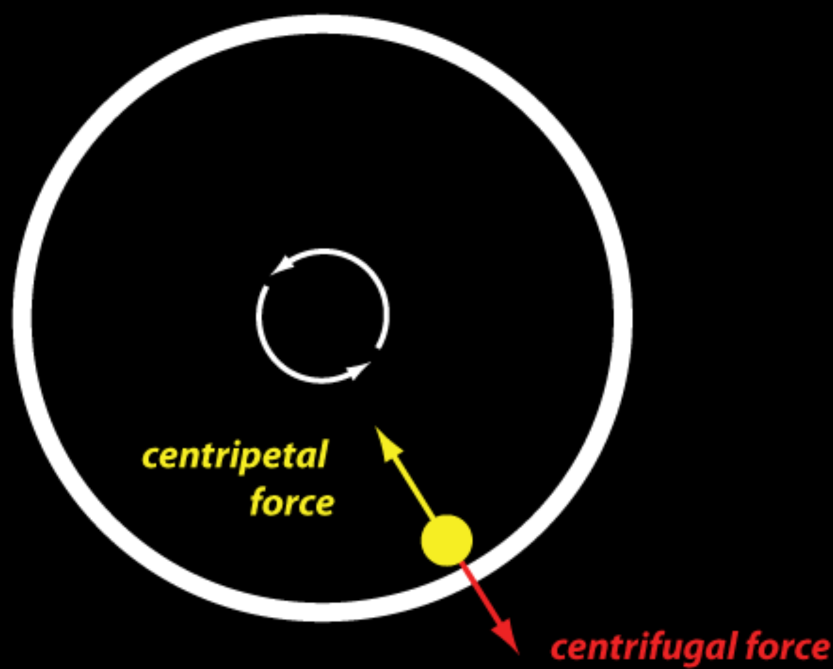
The key point to keep in mind is **inertia**.
Wherever you are, inertia is trying to make you move in a straight line. But the wall is preventing that. In this case, you're in a state of constantly crashing into the wall.



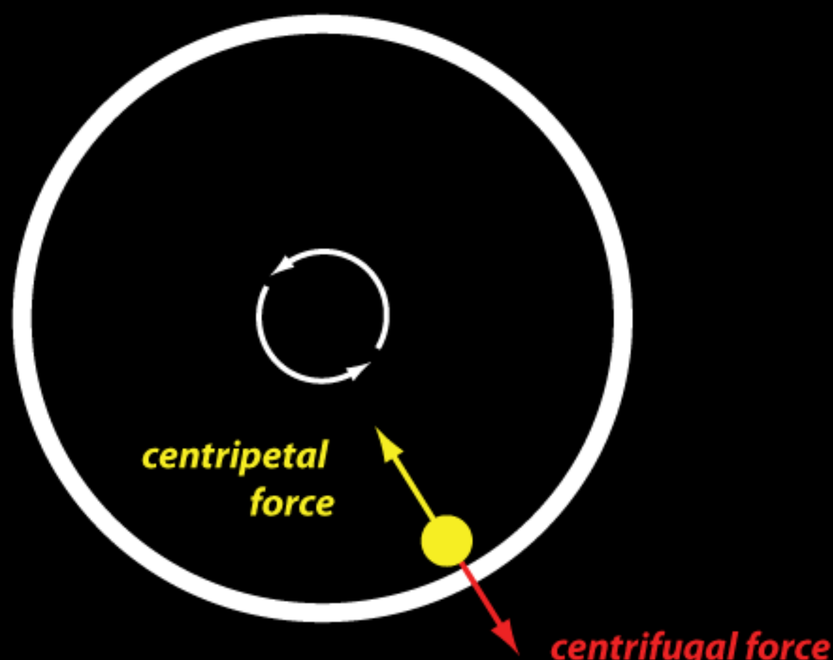
We INTERPRET this as the centrifugal force, acting outward like an unseen hand, pushing us up against the wall.



But we know the centrifugal force is not real because if the wall were to suddenly disappear, you wouldn't fly directly outward! Instead, you'd fly off at a tangent, as inertia predicts.

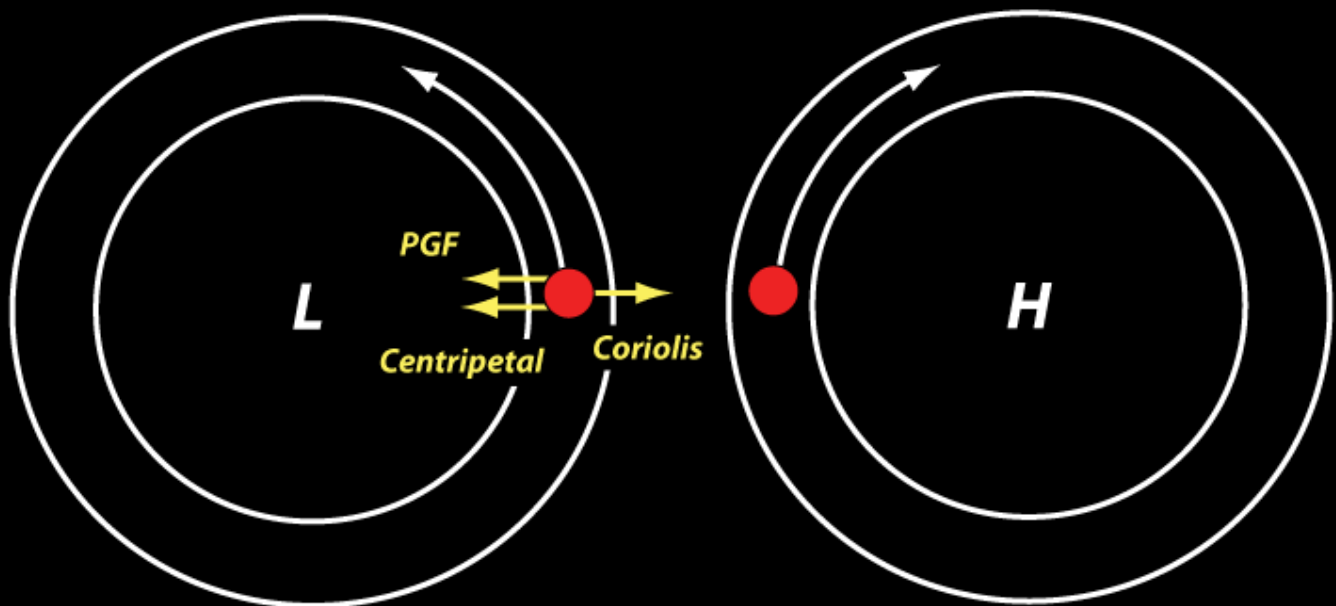


So the important force is provided by the WALL, and that's pushing directly inwards. The **centripetal force**.

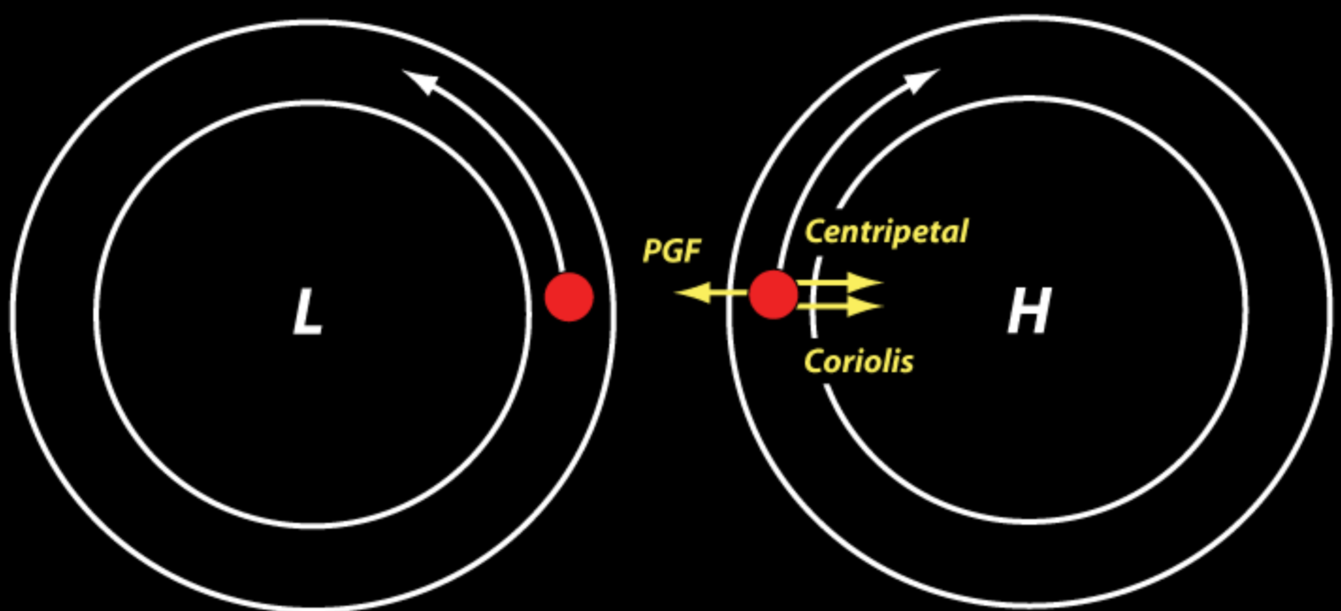


Gradient wind balance (textbook approach)

Again start with geostrophic balance (PGF vs. Coriolis). Add in centripetal force. Centripetal always points inward. If inward is in the direction of PGF, the combination, it helps guide the parcel CCW around the L



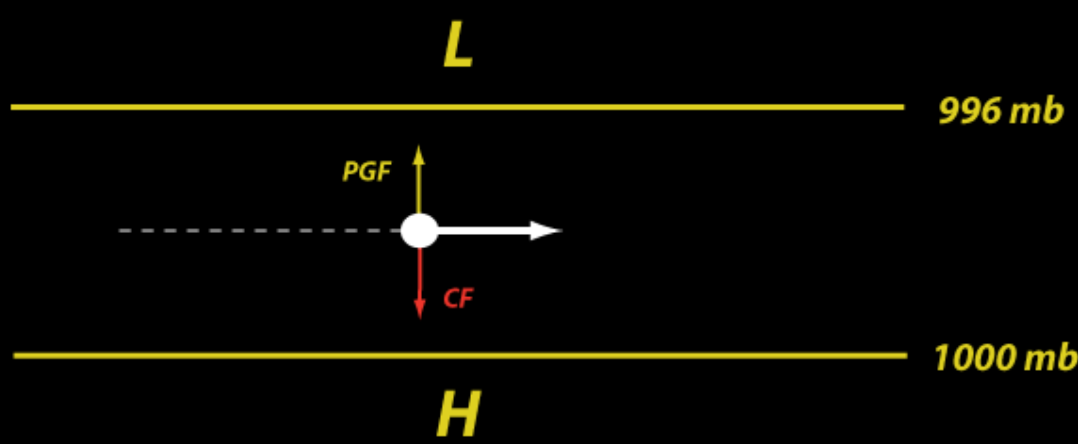
Around H pressure, inward-directed centripetal has joined forces with Coriolis, guiding parcel CW around the H.
(We could have done exactly the same explanation invoking outward-directed centrifugal force.)



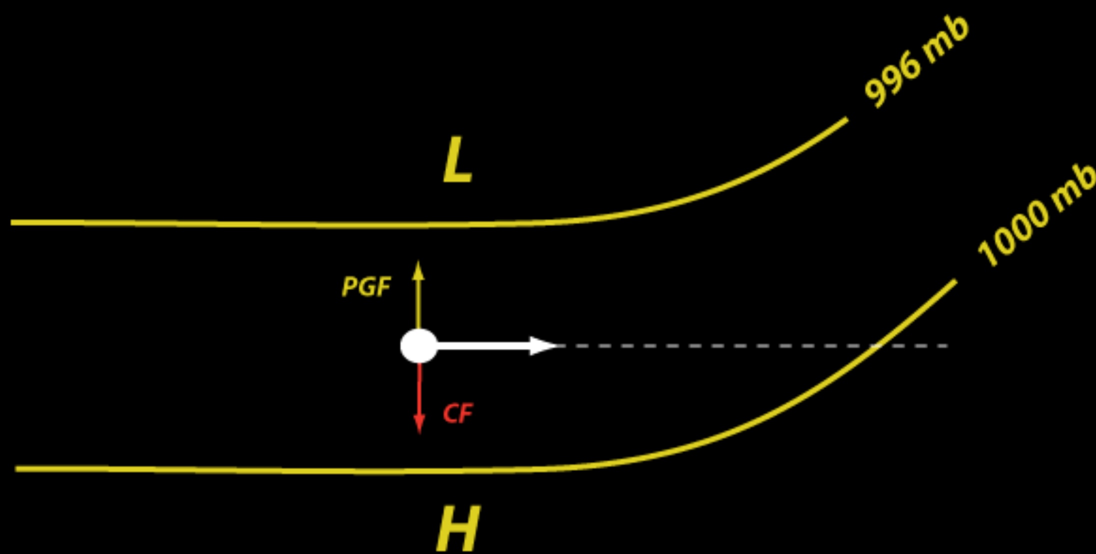
But where did the centripetal or centrifugal force come from?

Gradient wind balance (using inertia)

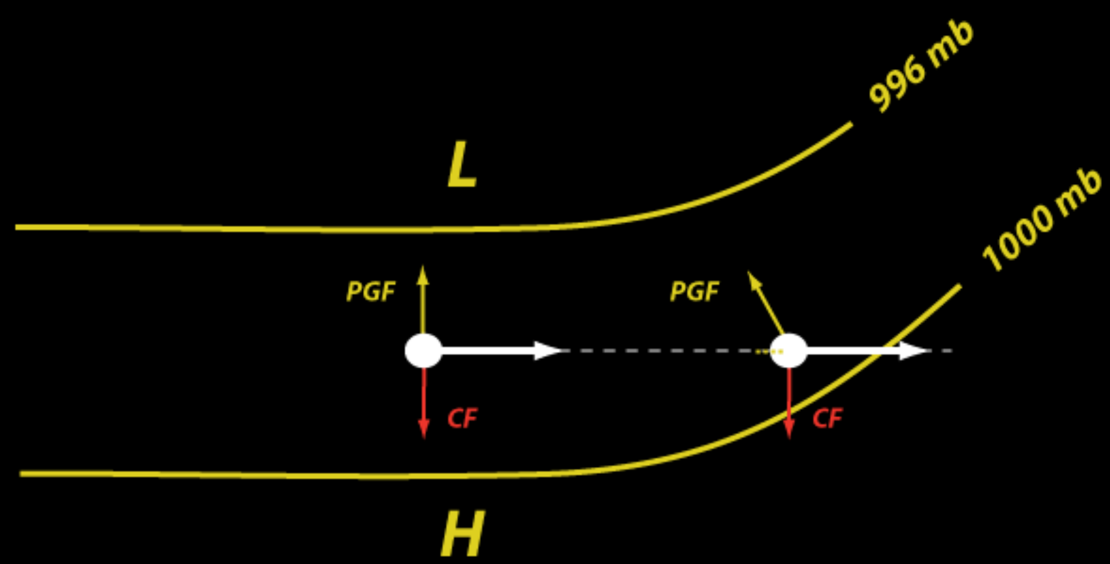
Start yet again with geostrophic balance --
The wind flowing with low pressure to the left.
I'll again presume the PGF is pointing North, but that's not necessary.



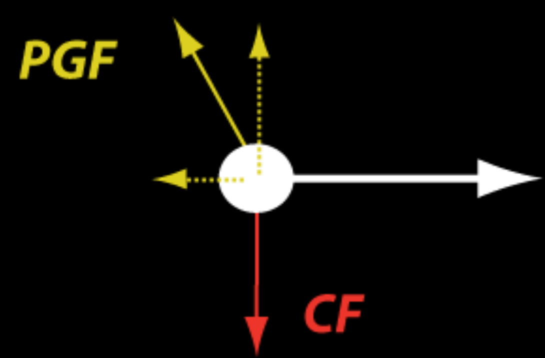
Now make the isobars curve CCW. Isobars can curve for many reasons. Inertia wants the air to continue moving STRAIGHT. But notice this would carry it across the 1000 mb isobar, toward higher pressure.



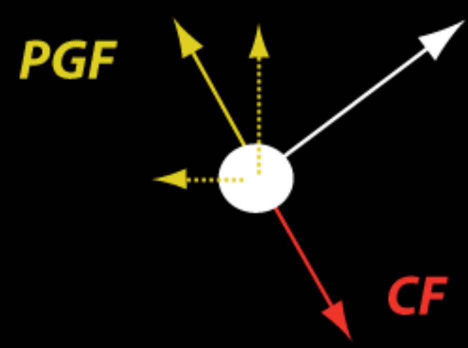
If inertia has its way and continued carrying the parcel straight, notice the PGF is now pointing NOT ONLY to the parcel's left BUT ALSO to its back



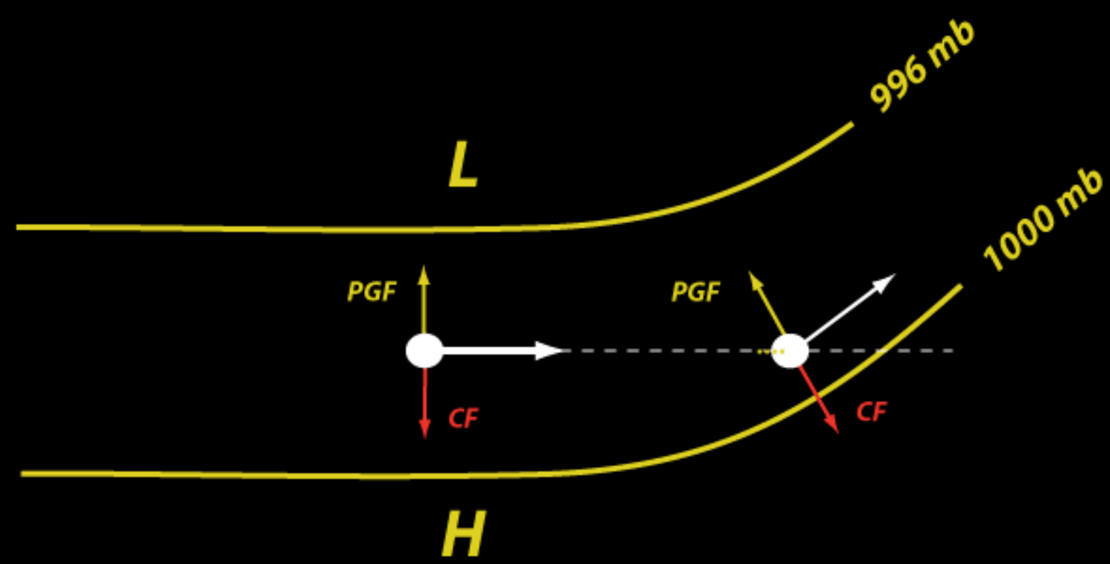
The component of PGF acting against the motion makes the parcel SLOW DOWN.



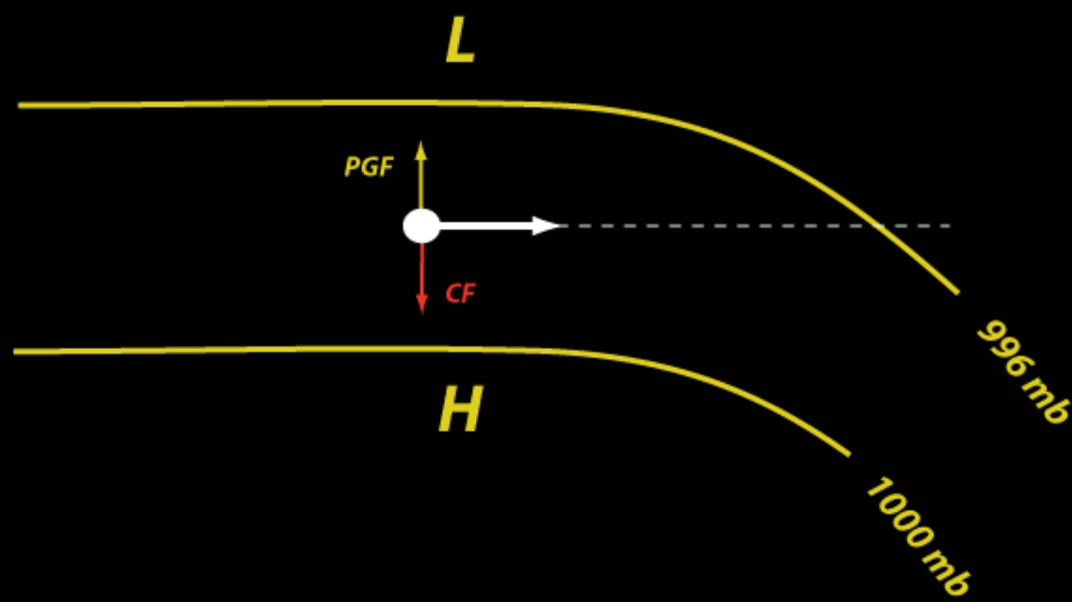
As the air slows, Coriolis is reduced, since it is proportional to wind speed. So here is another situation in which the Coriolis force is weakened, allowing PGF to gain the upper hand, permitting it to change the direction.



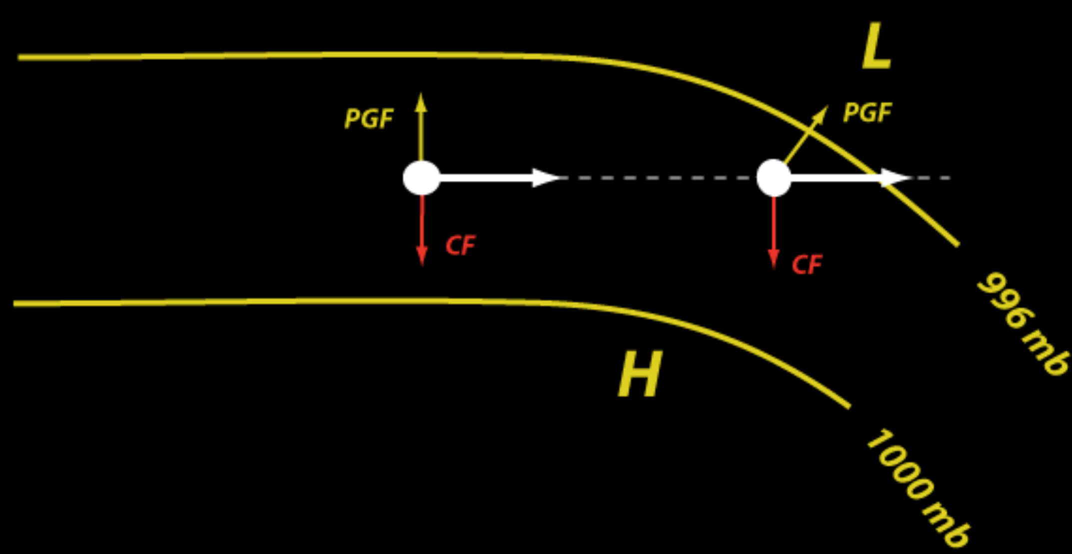
Except this time it doesn't result in cross-isobar flow. The parcel remains following the isobars as they curve, keeping low pressure to the left.
We have made a cyclone, with air curving CCW around low pressure.



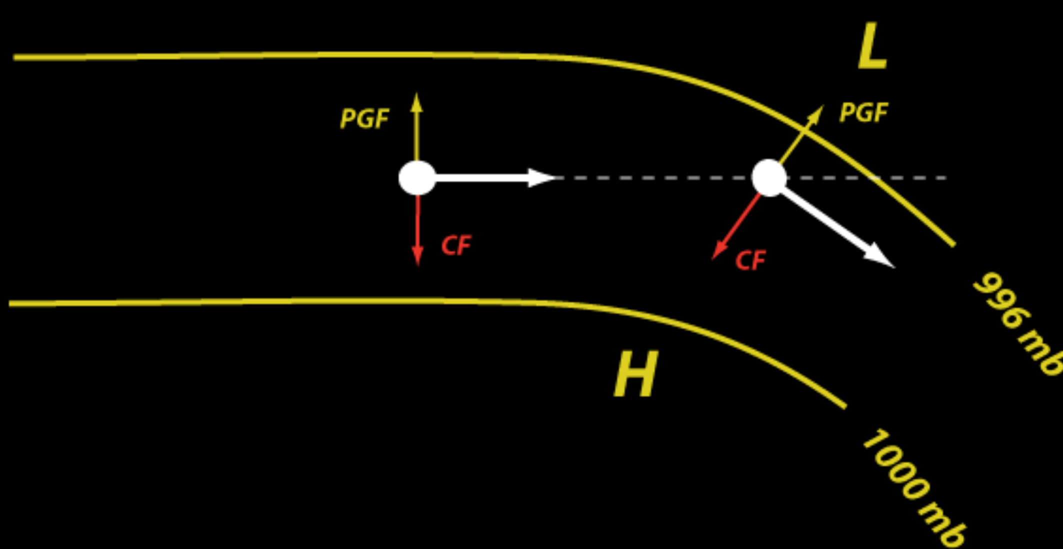
Now consider a parcel approaching CW curving isobars.
Again, inertia wants the parcel to continue straight.
This time, it would carry the air towards lower pressure.



The PGF turns so now it as a component in the direction of the parcel motion. This causes the parcel to SPEED UP. This will increase the Coriolis force.



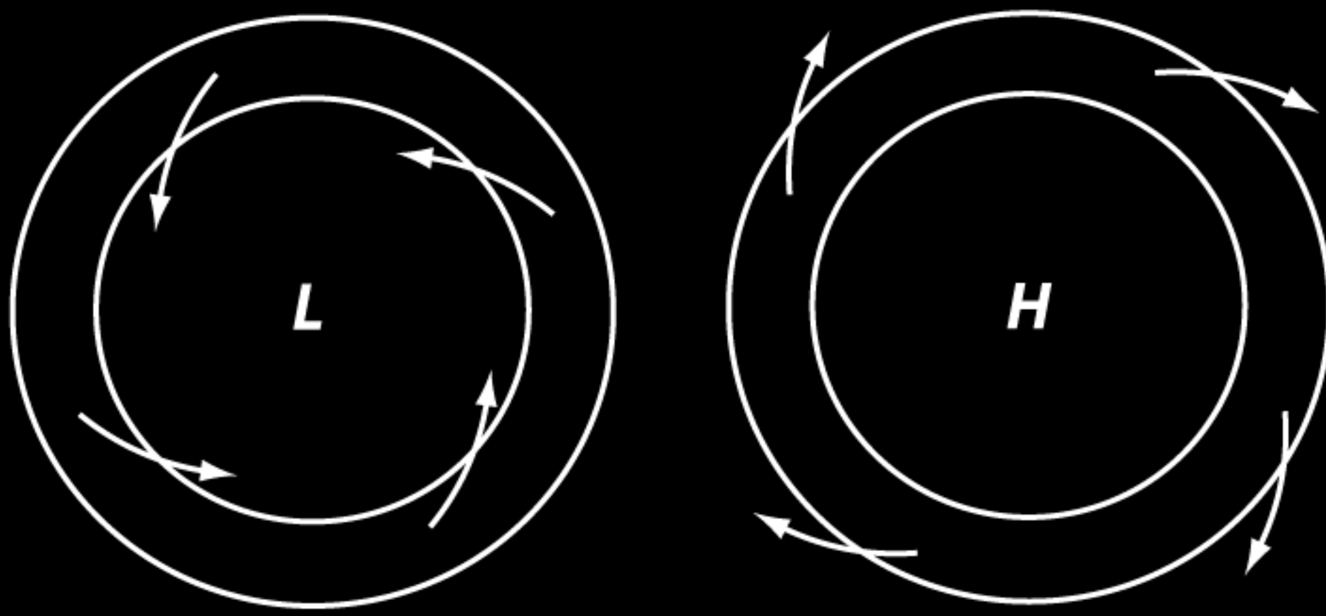
Coriolis wants to make air bend to the right. So, as it gets the upper hand on PGF, the air starts bending rightward. This keeps the air parallel to the isobars, but moving more QUICKLY than it did when the motion was geostrophic. To curve CW, it was necessary for the parcel to SPEED UP.



Combine these four forces: curved flow near the surface

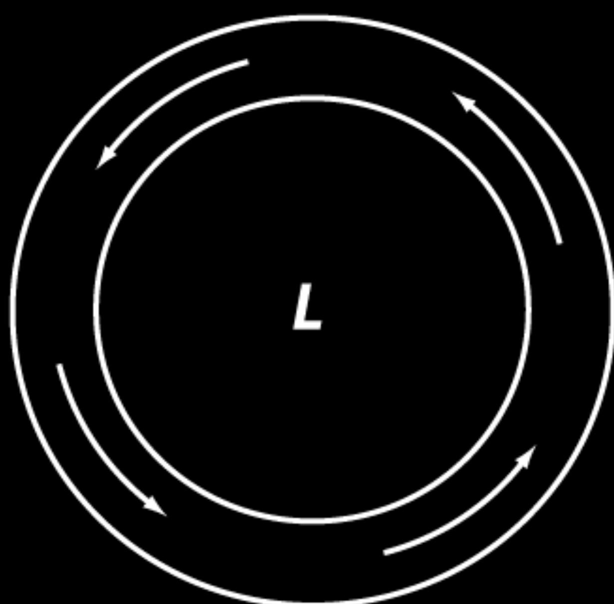
(PGF + Coriolis + Centripetal + Friction)

This is what the flow around large-scale Ls and Hs looks like near the surface, where friction is important. Owing to friction, the wind can across isobars. Note this means surface convergence into the L and divergence out of the H

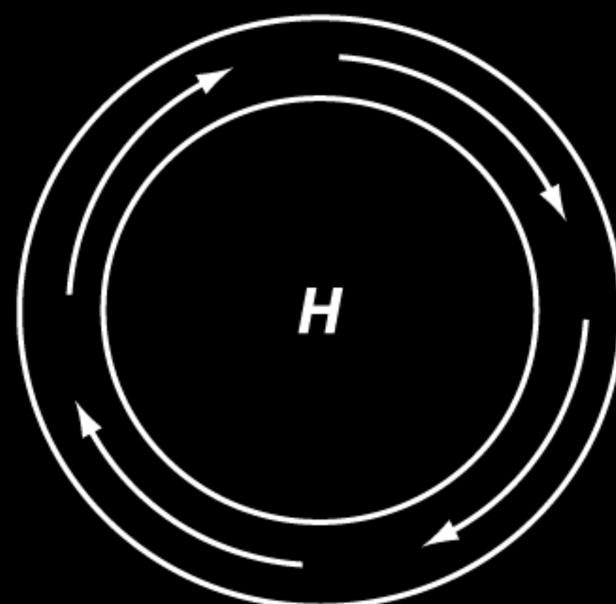


The cyclostrophic effect

Remember, we said isobar spacing indicates wind speed, because it reflects the magnitude of the PGF. But we have also seen isobar curvature also affects speed. For a given isobar spacing, air moves more slowly around CCW curved isobars, and more quickly when they're CW curved.

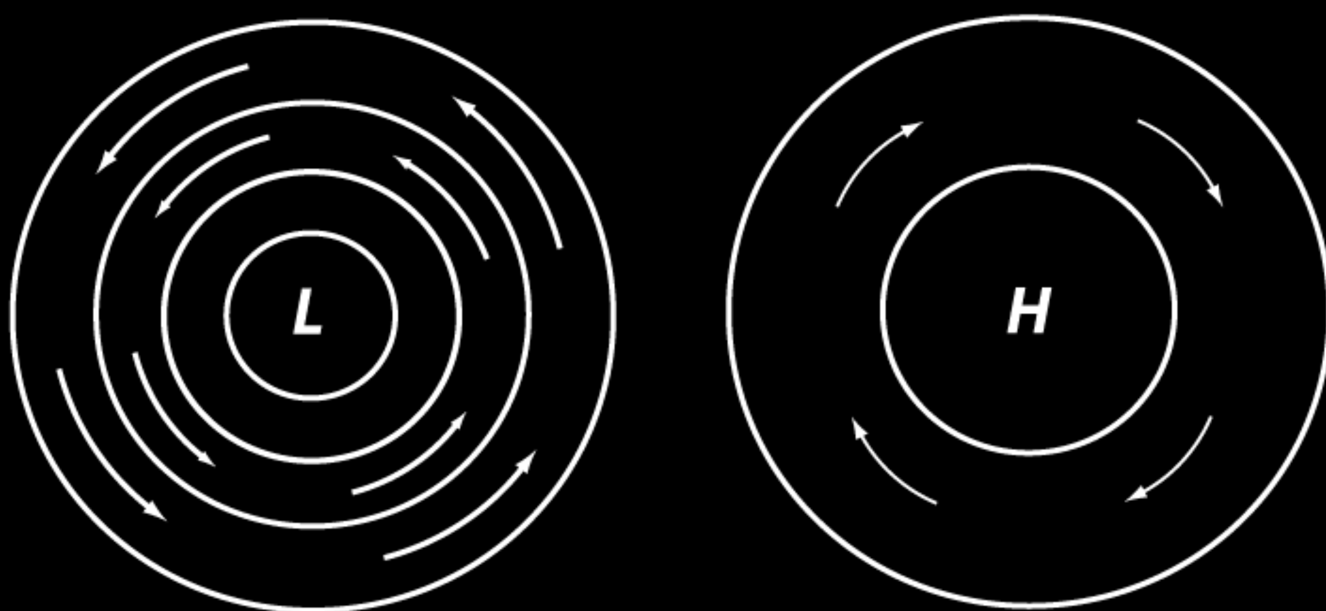


subgeostrophic



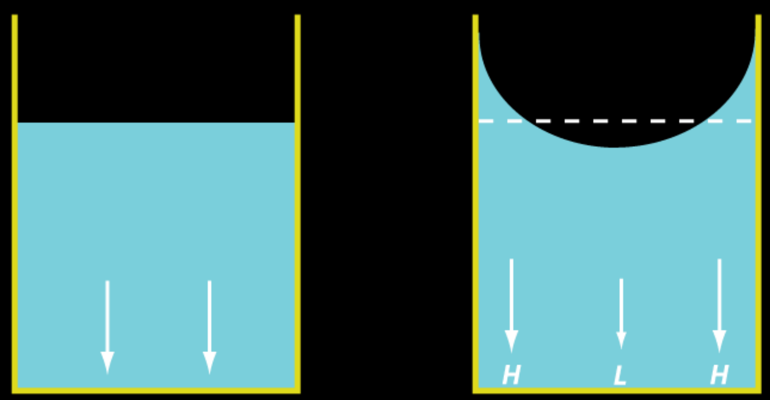
supergeostrophic

This is an apparent paradox because we often see strong winds around lows and weak winds associated with highs. In practice, isobar spacings can be much smaller around cyclones than anticyclones, leading to faster winds. Further, we don't usually see tight pressure gradients around highs.

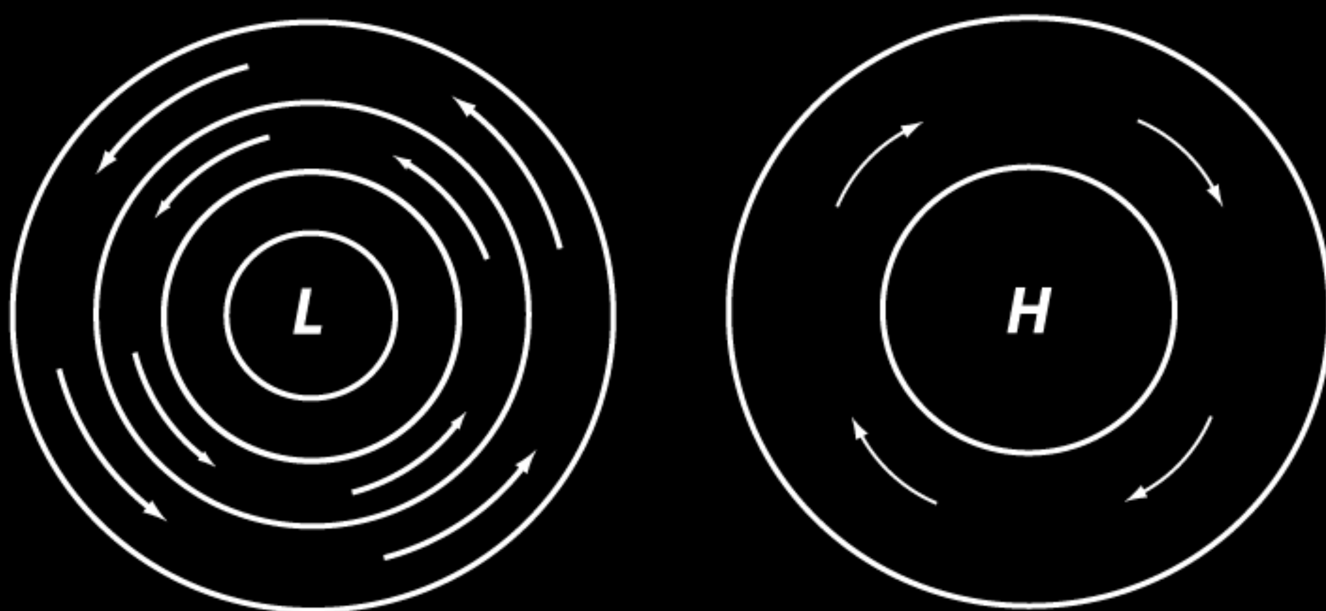


Spin has caused the fluid to pile up at the glass’ edge and dip down in the center.

The spin has resulted in low pressure in the center of the circulation.



Cyclostrophic balance applies to small-scale circulations, such a tea cups and tornadoes. However, it may help us understand why pressure gradients and wind speeds can be larger around large-scale lows and smaller around large-scale highs.



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