

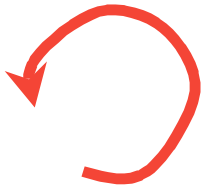
Vorticity

The measure of the rotation or spin of an air parcel. The spin can be in any direction but we are interested in the spin about the vertical axis.

Viewed from above:

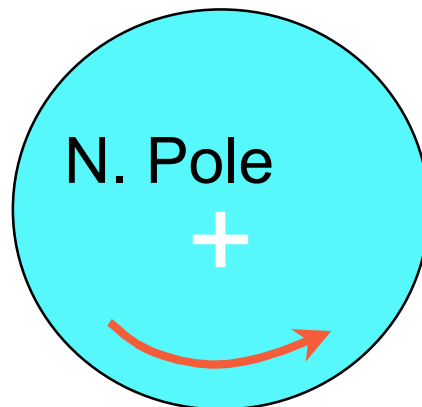


Anticyclonic Vorticity



Cyclonic Vorticity

Cyclonic vorticity is **positive** in the Northern Hemisphere and is in the same direction as the spin of the earth viewed from above the North Pole.



The earth spins cyclonically at the rate of one rotation per day. The

Earth's vorticity is a maximum at the poles and zero at the equator.

The earth's vorticity can be expressed as:

$$f = 2\Omega \sin \phi$$

That's the coriolis parameter!

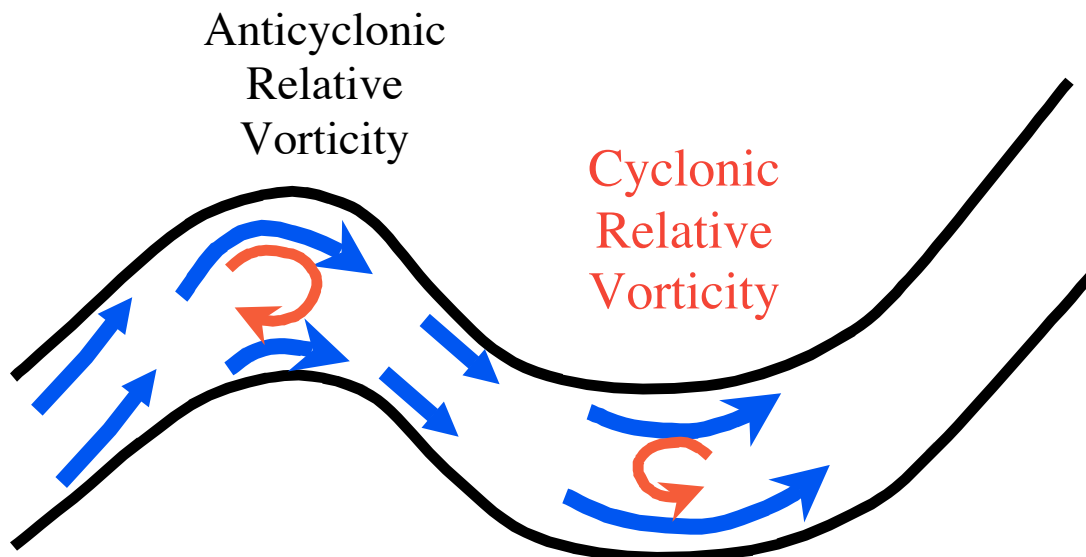
The combination of the earth's vorticity and relative vorticity is absolute vorticity.

Relative Vorticity:

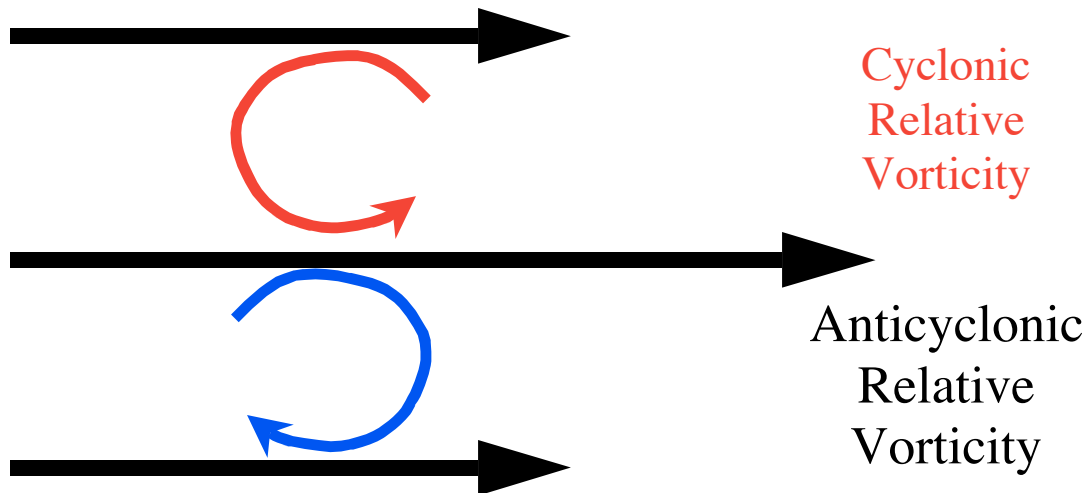
Relative vorticity can be expressed as:

$$\zeta = k \cdot \nabla \times \mathbf{V} = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Air moving relative to the earth's surface may have vorticity in addition to that of the earth. This is called relative vorticity. One type of relative vorticity is called **Curvature Vorticity**.



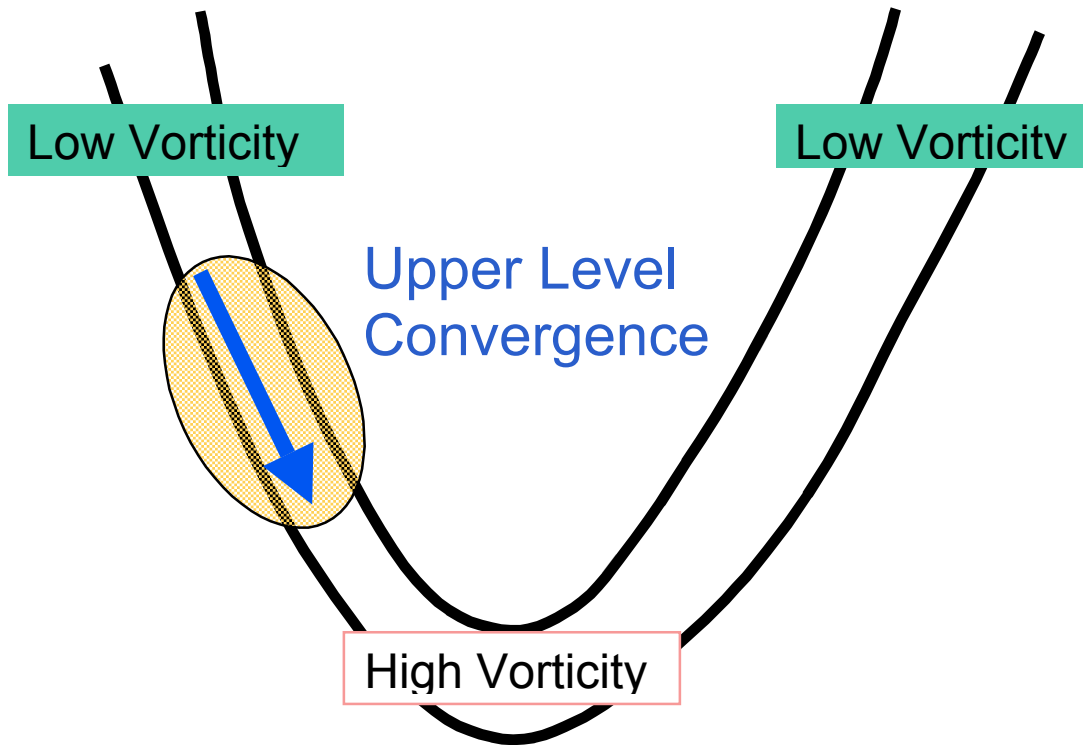
Another type of relative vorticity is called **Shear Vorticity**.



The advection of vorticity is very important. Why? Because:

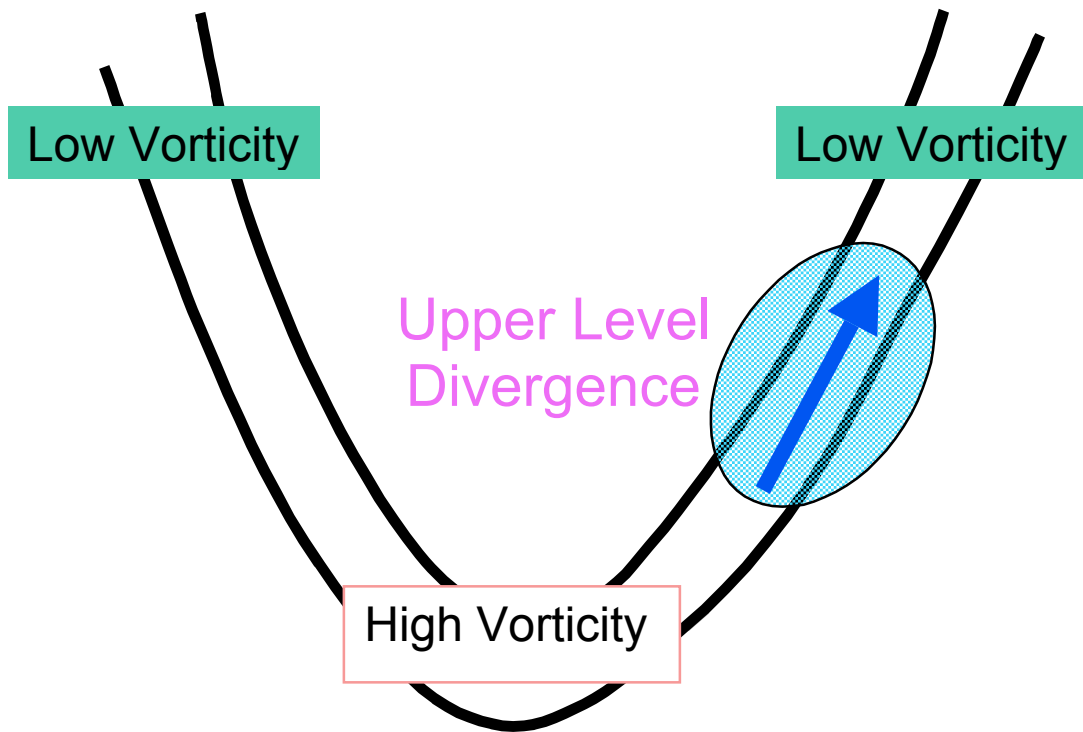
- The **advection of cyclonic vorticity** yields divergence aloft, rising motion in the atmosphere, surface convergence and surface pressure falls.
- The **advection of anticyclonic vorticity** yields convergence aloft, sinking motion in the atmosphere, surface divergence and surface pressure rises.

Let's take a closer look at this:



Anticyclonic Vorticity Advection

- Moving from low vorticity to high vorticity requires convergence aloft.
- An ice skater who wants to spin faster pulls in his or her arms -- a form of convergence.



Cyclonic Vorticity Advection

- Moving from high vorticity to low vorticity requires divergence aloft.
- An ice skater who wants to spin slower extends his or her arms -- a form of divergence.

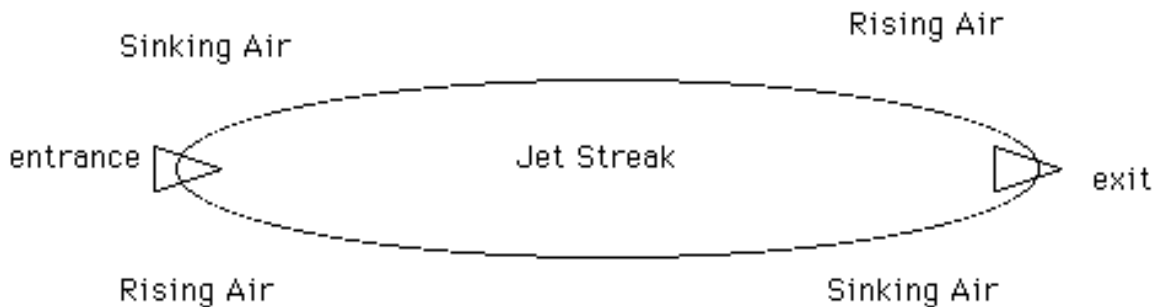
Absolute Vorticity:

So, absolute vorticity, which is the combination of relative vorticity and the earth's vorticity can be expressed as:

$$\zeta_a = \zeta_r + f$$

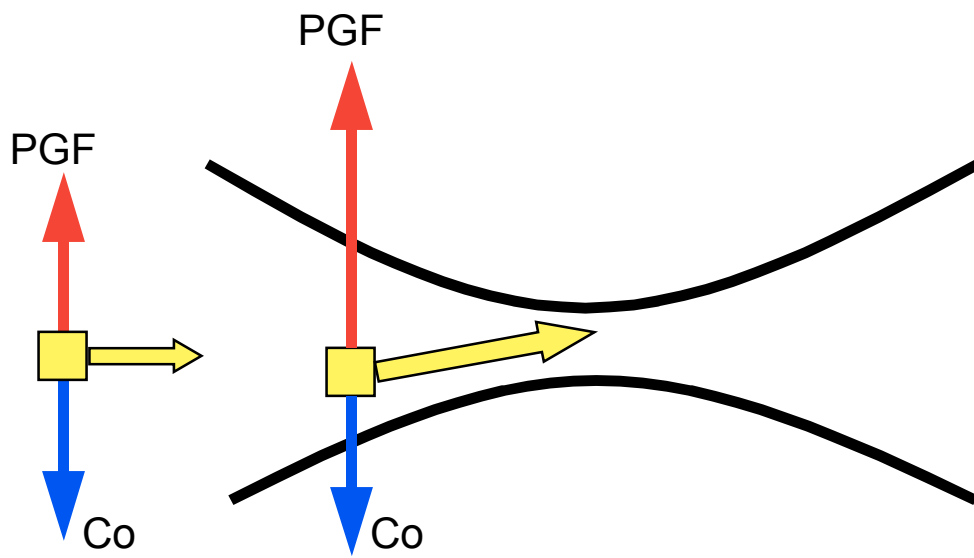
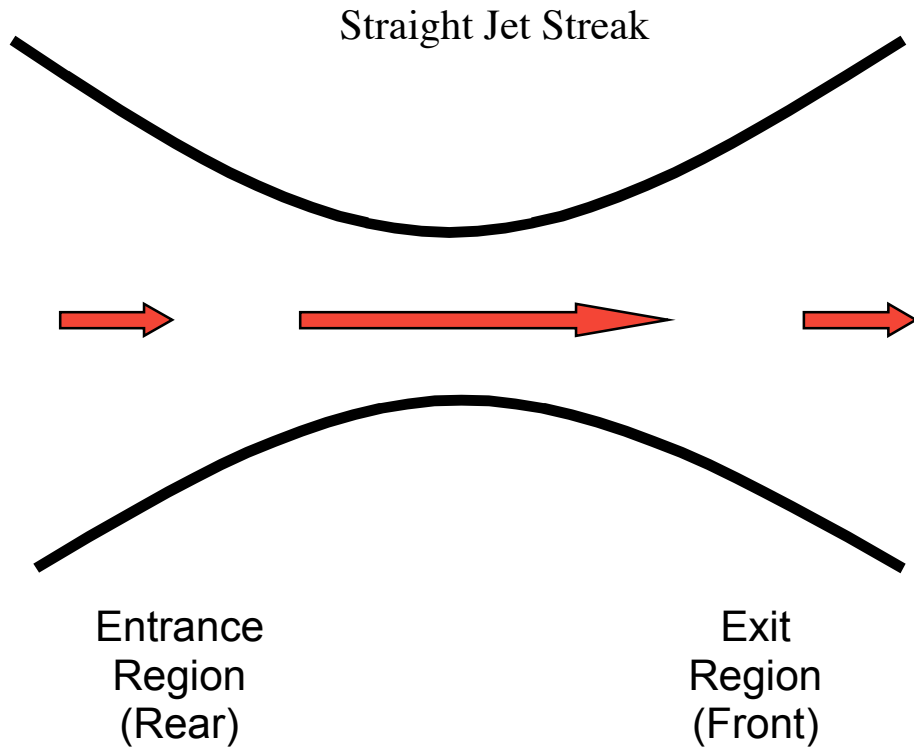
Jet Streaks

Jet streaks are localized regions of very fast winds embedded within the jet stream. Sometimes these local wind maxima reach speeds in excess of 160 knots. Jet streaks are important as they are indicative of rising motion/falling pressures at the surface. The figure below represents an idealized jet streak.



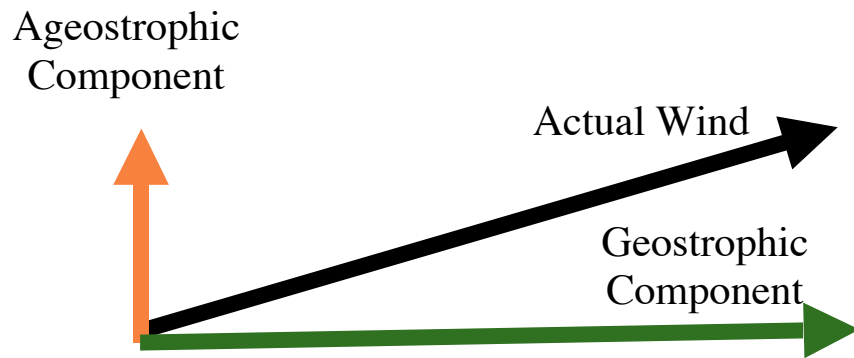
As air enters from the left, it must be accelerated. The force to do this is supplied by the Coriolis force as air flows from the south to the north near the jet entrance, leading to a force to the east (the right). This air motion results in a convergence to the north and a divergence to the south. As a result, air sinks in the northern 'quadrant', and rises in the southern quadrant, leading to pressure changes at the surface. In the jet exit region, the opposite happens, as air flows from north to south to create the force necessary to decelerate the air as it leave the jet streak. The vertical motion resulting from this leads to rising air in the north quadrant and sinking air in the south, also leading to surface pressure changes.

Let's take a closer look at this:



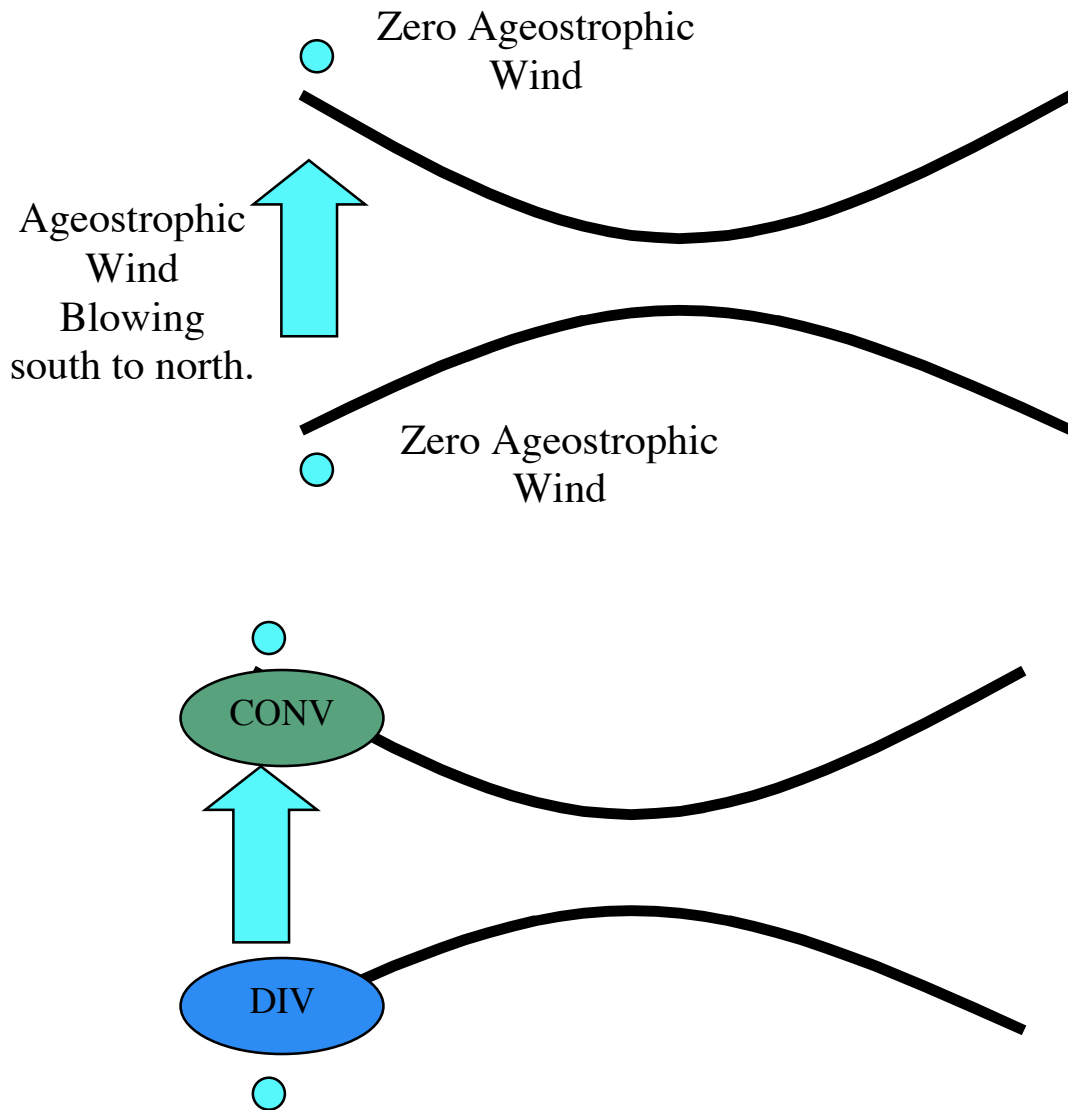
Entering the jet streak, the wind is in geostrophic balance. The parcel then moves into a region of a much stronger PGF. The Coriolis force does not have enough time to respond and the parcel will temporarily experience a force imbalance.

The force imbalance will cause the wind to deviate slightly toward low pressure. We can describe this deviation by splitting the actual wind into two components: a geostrophic part and an ageostrophic part:

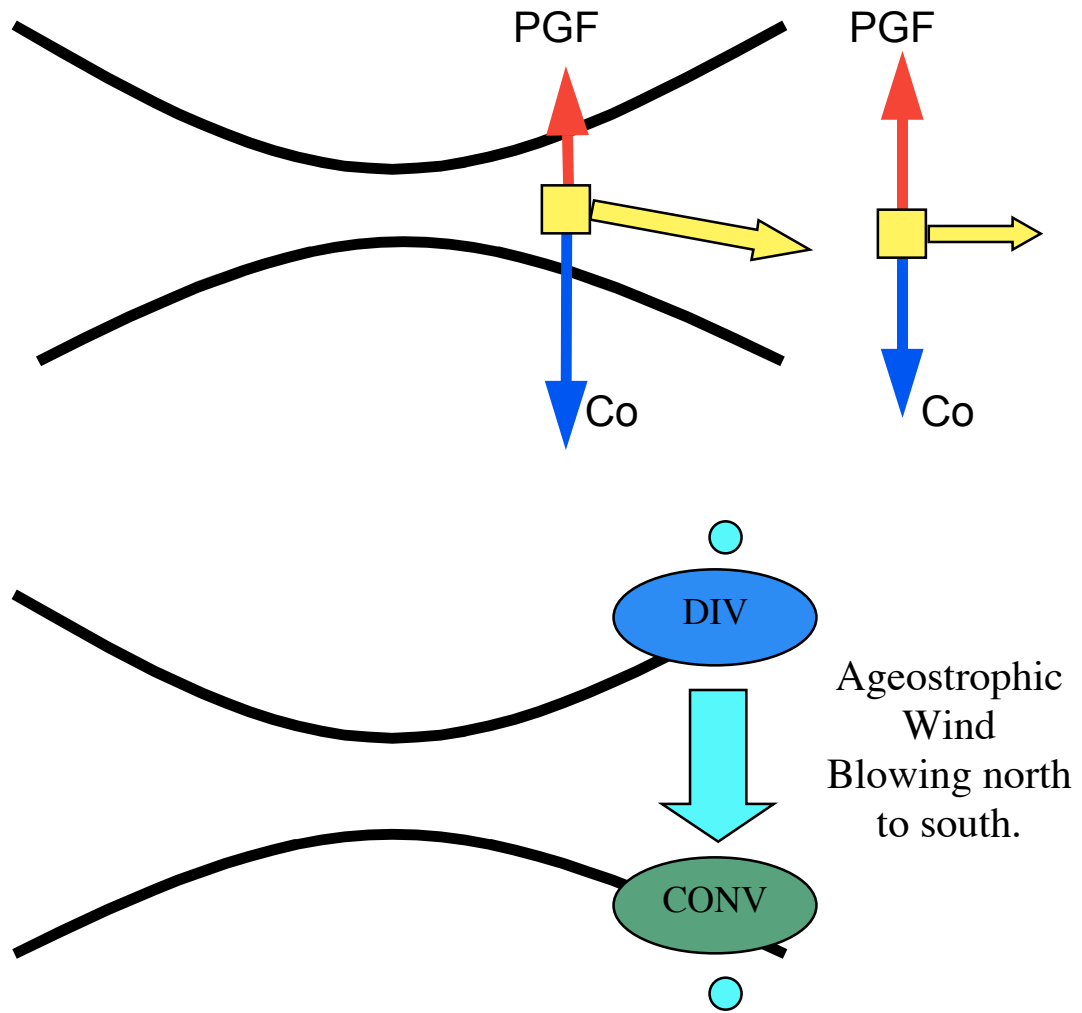


It's the ageostrophic component that contributes to divergence or convergence aloft.

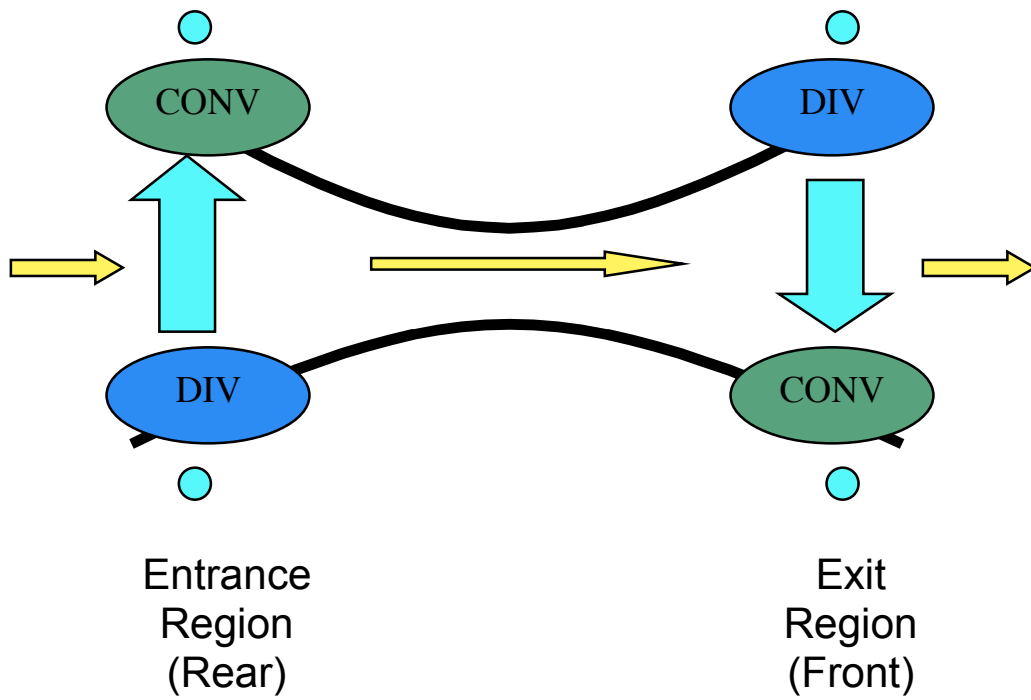
Let's look at that component alone.



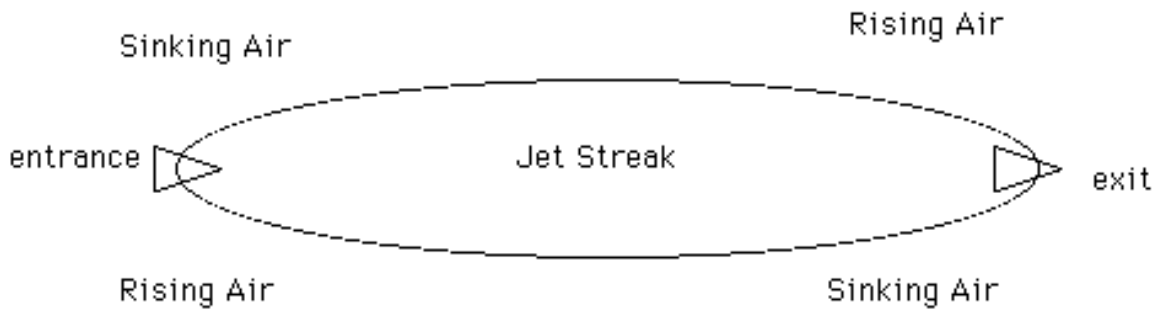
Exiting the jet streak, the wind is in geostrophic balance. The parcel then moves into a region of a much weaker PGF. The Coriolis force does not have enough time to respond and the parcel will temporarily experience a force imbalance.



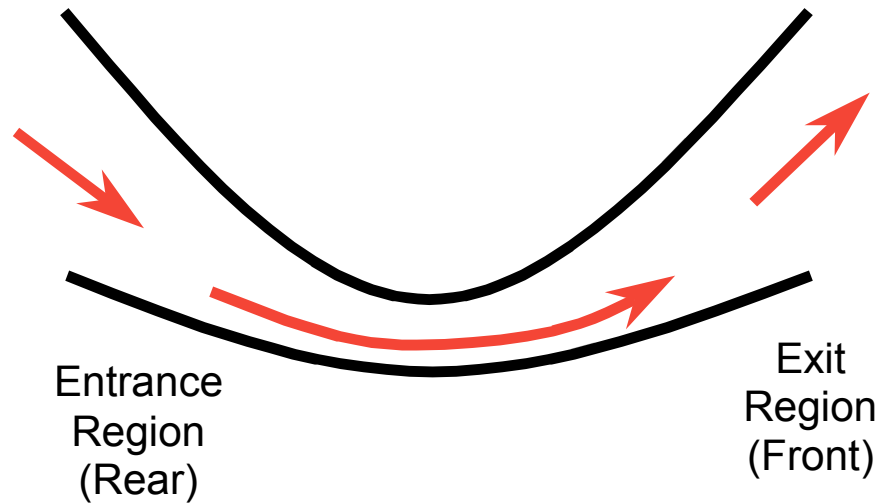
So, by putting it all together, we get a picture of how the jet streak influences divergence and convergence aloft.



Now, we are back to this figure:



However, not all jet streaks are straight. In fact, most are curved.



In the case shown above we have:

Left Entrance Region

Ageostrophic flow causes convergence.

Cyclonic vorticity advection causes convergence.

Right Entrance Region

Ageostrophic flow causes convergence.

Cyclonic vorticity advection causes divergence.

The effects tend to cancel.

Left Exit Region

Ageostrophic flow causes divergence.

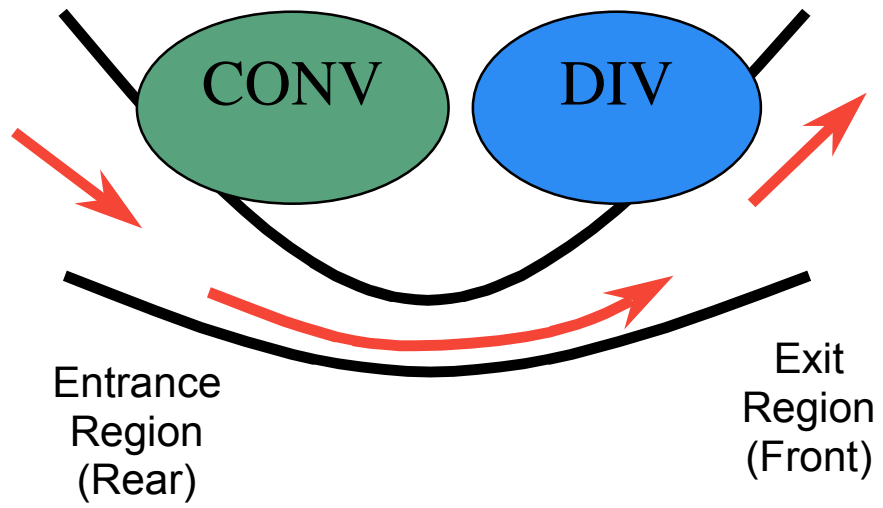
Cyclonic vorticity advection causes divergence.

Right Exit Region

Ageostrophic flow causes convergence.

Cyclonic vorticity advection causes divergence.

The effects tend to cancel.



Original graphics and text above courtesy of :

Univ. of Illinois WW2010 Project.
Frank Gallagher