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Three-dimensional generalization of the ageostrophic wind: How it changes our view on baroclinic waves.

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The geostrophic wind is usually defined with respect to a coordinate system, e. g. either p, z or θ system. However, we could also define a generalized geostrophic or inactive wind without any reference to a coordinate system as

$$\mathbf{v}_{ia} = \frac{\nabla\theta \times \nabla B}{\varrho P},$$

where θ is the potental temperature, B is the Bernoulli function, ϱ is the density and P is Ertel's potential vorticity (EPV). This wind follows isolines of the Bernoulli function on an isentrope. Knowing that an isentrope bends strongly up and down during a passage of a baroclinic wave, it is clear that this wind has a significant vertical component.

When now inspecting the active wind $\mathbf{v}_a = \mathbf{v} - \mathbf{v}_{ia}$ which is comparable to the ageostrophic wind, it contains likewise a vertical component. Only the active wind contributes to the advection of the potential temperature, because the advection with the inactive wind vanishes: $-\mathbf{v}_{ia} \cdot \nabla\theta = 0$. When considering the baroclinic development of an idealized cyclone, it is seen that the active vertical wind is upward in the cold sector and downward in the warm sector indicating that isentropes are moved upward in the cold sector (adiabatic cooling) and downward in the warm sector (adiabatic warming). This whole process makes the well-known effect of baroclinic wave development – namely the net erosion of the meridional tilt of isentropes – directly visible.

The horizontal components of the active wind are also of interest. They point polewards in the upper levels, indicating likewise a flattening of the isentropes.

In many aspects the active wind can be interpreted as a local and instantaneous representation of the residual wind, which can only be defined as a zonal or temporal average. Zonal means of the active wind resemble strongly the residual wind. The residual circulation is thus a net effect of three-dimensional ageostrophic motions.