Dynamic Instability

Recall the two realistic solutions

1. cyclonic flow, $R > 0$, $\frac{\partial \Phi}{\partial n} < 0$

$$|\vec{V}| = -\frac{fR}{2} + \sqrt{\left(\frac{fR}{2}\right)^2 - R\frac{\partial \Phi}{\partial n}}$$

2. anticyclonic flow, $R < 0$, $\frac{\partial \Phi}{\partial n} < 0$

$$|\vec{V}| = -\frac{fR}{2} - \sqrt{\left(\frac{fR}{2}\right)^2 - R\frac{\partial \Phi}{\partial n}}$$

Let's consider Eq 2, anticyclonic flow about a high pressure or a ridge of high pressure (the latter is not a "closed-off" high). The term $-R\frac{\partial \Phi}{\partial n} < 0$, hence $\left|\left(\frac{fR}{2}\right)^2\right| > \left|R\frac{\partial \Phi}{\partial n}\right|$ is necessary for $|\vec{V}|$ to be real.

Therefore:

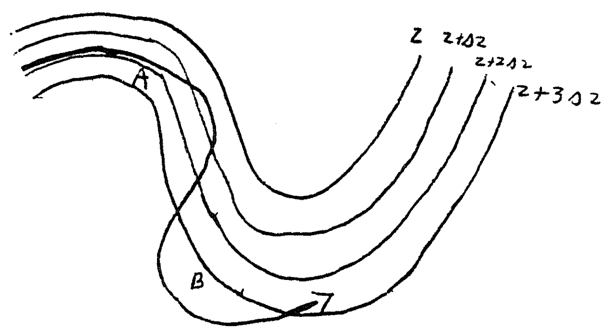
(3) $$\boxed{\left|\frac{\partial \Phi}{\partial n}\right| < \frac{|R| f^2}{4}}$$

This may be interpreted in two ways:

I. The pressure gradient in a high must approach zero as $|R| \to 0$. Typically near a high isobars spread far apart. In the center of highs, the wind is calm (usually).

In synoptic classes, we use this fact to locate the center of a high (calm wind).

II It may also be concluded that that, for a given pressure gradient, $|R|$ must not become too small (highly curved flow). If isobars in a ridge become too curved, an air parcel cannot move parallel to the isobars but must depart from gradient flow and cross isobars from high towards low pressure. This is depicted at point A:



At point A, air accelerates toward lower pressure, which increases the Coriolis force acting to the right of the parcel. This turns the air parcel back toward high pressure further downstream, decelerates it, and brings it back into gradient balance (Pt B).

These departures from gradient balance are called jet streaks, and are fundamentally linked to the development of troughs, and surface cyclones. As long as the jet streak is upwind (west) of a trough, the trough will grow. The chain of events begins when tightly packed isobars in a ridge have so small a radius that it is dynamically impossible for the air to conform to the sharp curvature! The assumption $\frac{D|\vec{V}|}{Dt} = 0$ breaks down, and accelerations (cross-isobaric flow) must occur to regain gradient wind balance.

How about troughs? Does dynamic instability occur in them? <u>No!</u> Note that $-R\frac{\partial\Phi}{\partial n} > 0$; hence the quantity in (1) under $\sqrt{}$ is always positive. Hence, the curvature in troughs can be very sharp. Furthermore, winds are often very fast near the center of lows.