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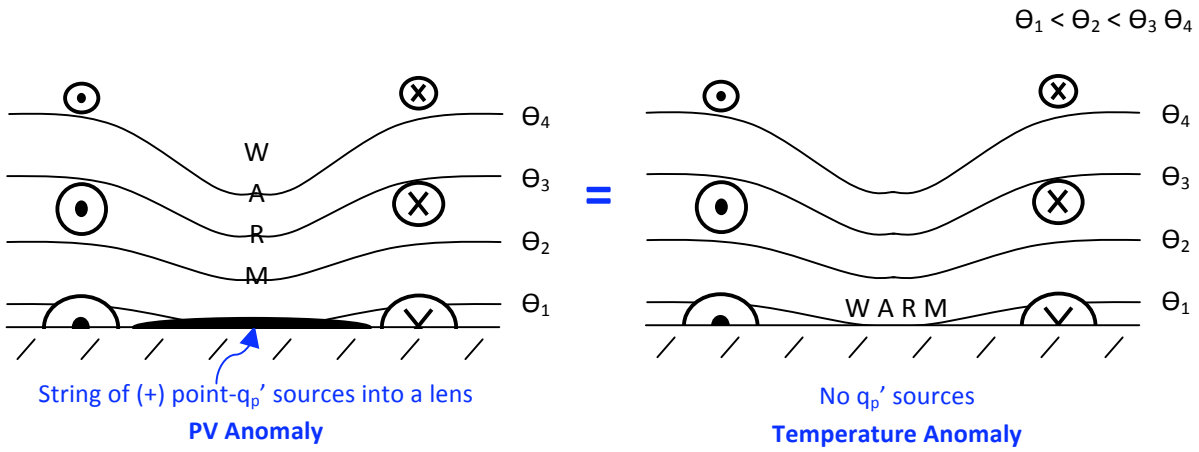
The goal of Monday's lecture was to realize the power of the notions of invertibility and "PV-Thinking" and to apply this logic to cyclogenesis.

Invertibility and PV-Thinking

First, invertibility is the notion that you can solve for the deviation of the geopotential from the horizontal average (Φ') given the deviation of pseudo-potential vorticity (QGPV) from the planetary vorticity ($q_p' = q_p - f$) and boundary conditions (BCs). The BCs along the lateral walls are specified by Φ' and/or the geostrophic wind along the walls. The BCs along the upper and lower boundaries are either T' or θ'. Kleinschmidt, and later Bretherton (1966) demonstrated that a warm (cold) temperature anomaly at the Earth's surface is dynamically



equivalent to a positive (negative) PV anomaly located just above the Earth's surface.
In the atmosphere and ocean, far removed from the lateral boundaries, knowledge of the anomalous distributions of potential temperature at upper and lower boundaries of a domain and the QGPV within that domain provides sufficient information to deduce the distributions of hydrostatically-balanced temperatures and geostrophic winds in the interior. Deduction of dynamical fields in this manner is called "PV-Thinking" (the same thinking we applied when discussing Rossby waves). This is very powerful because it can lead to understanding the dynamics of almost any atmospheric phenomena in geostrophic and hydrostatic balance.

Cyclogenesis

The diagram produced by Hoskins et al. in 1985 shows that positive feedback can amplify a disturbance caused by an upper-level PV anomaly arriving over a lower-level baroclinic region (although fronts are largely associated with baroclinicity, the existence of a front is not necessary for cyclogenesis). The cyclonic flow associated with the upper-level positive PV anomaly may extend to the surface. At the surface, this cyclonic flow would advect warm temperatures northward across the isentropes, leading to a thermal ridge just east of the original cyclonic rotation. Once created, the thermal ridge would be associated with a cyclonic circulation which

would decay upward but, if it extended to the tropopause, the winds associated with the surface thermal ridge would amplify the upper trough by advecting higher PV values from the north.