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A potential vorticity perspective on the motion of mid-latitude surface cyclones: the example of the winter storm Xynthia

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Mid-latitude surface cyclones are commonly observed to move across the mean flow from the equator to the pole and to undergo a strong and rapid deepening when they cross the axis of the large-scale jet stream. The purpose of the present study is to validate a recent theory that may explain this cross-jet motion which is a generalization of the so-called beta drift in the mid-latitude baroclinic context. According to this theory, the key parameter controlling the movement of a surface cyclone across the mean tropospheric jet is the vertical-average potential vorticity (PV) gradient associated with the jet. To test this theoretical result, numerical sensitivity experiments are performed using the Météo-France global operational forecast model ARPEGE-IFS for the particular case of the storm Xynthia (26–28 February 2010). The control forecast, starting from the operational analysis almost 2 days before the storm hit France, represents the trajectory of the storm quite well, together with the deepening during the crossing of the large-scale upper-level jet axis. A PV-inversion tool is used to modify the vertical-average PV gradient at the initial time. As expected from the theory, when the PV gradient is intensified, there is a quicker displacement of the surface cyclone toward the jet axis and the jet-crossing phase occurs earlier than in the control forecast. The opposite occurs for a reduced PV gradient. A dynamical interpretation is provided in terms of upper-levels PV anomalies generated by Rossby wave radiation.