# Synoptic Meteorology II: Q-Vector Examples

The below images, obtained from Tom Galarneau's QG Diagnostics webpage, depict Q-vectors that we can use to evaluate both forcing for vertical motion and for frontogenesis in the quasi-geostrophic framework. Here, we focus on the same two cases as we did in the QG Omega equation application example.

We first focus on a shortwave trough in the west-central United States at 1200 UTC 20 February 2019. Here, 700 hPa Q-vectors converge east of the trough axis, implying forcing for ascent there, and diverge along and south of the trough axis, implying forcing for descent there (Fig. 1). This is identical to the total forcing from the QG omega equation (Fig. 2), indicating the equivalency of the two frameworks for deducing forcing for vertical motion.

Unlike in the QG omega equation framework, however, we can also use the Q-vector analysis to diagnose two-dimensional frontogenesis following the flow. Here, the Q-vectors point in the same direction as the horizontal temperature gradient south of the trough axis as well as across much of the northeast United States, implying frontogenesis in these locations (Fig. 1).

We can confirm this analysis by using horizontal variations in geostrophic temperature advection as a proxy for the shearing and diffluence terms to the frontogenesis equation. South of the trough axis, we find cold advection maximized on the cold side of the baroclinic zone and weak advection on the warm side of the baroclinic zone (Fig. 3). This implies that horizontal motions are making it colder where it is already relatively cold and not changing the temperature where it is already relatively warm – a frontogenetic situation. Over the northeast United States, the Q-vectors point from cold advection over Maine and New Brunswick southwestward toward warm advection over the Ohio River valley (Fig. 1). Cold advection is making it colder where it is relatively cold and warm advection is making it warmer where it is relatively warm (Fig. 3) – also frontogenetic.

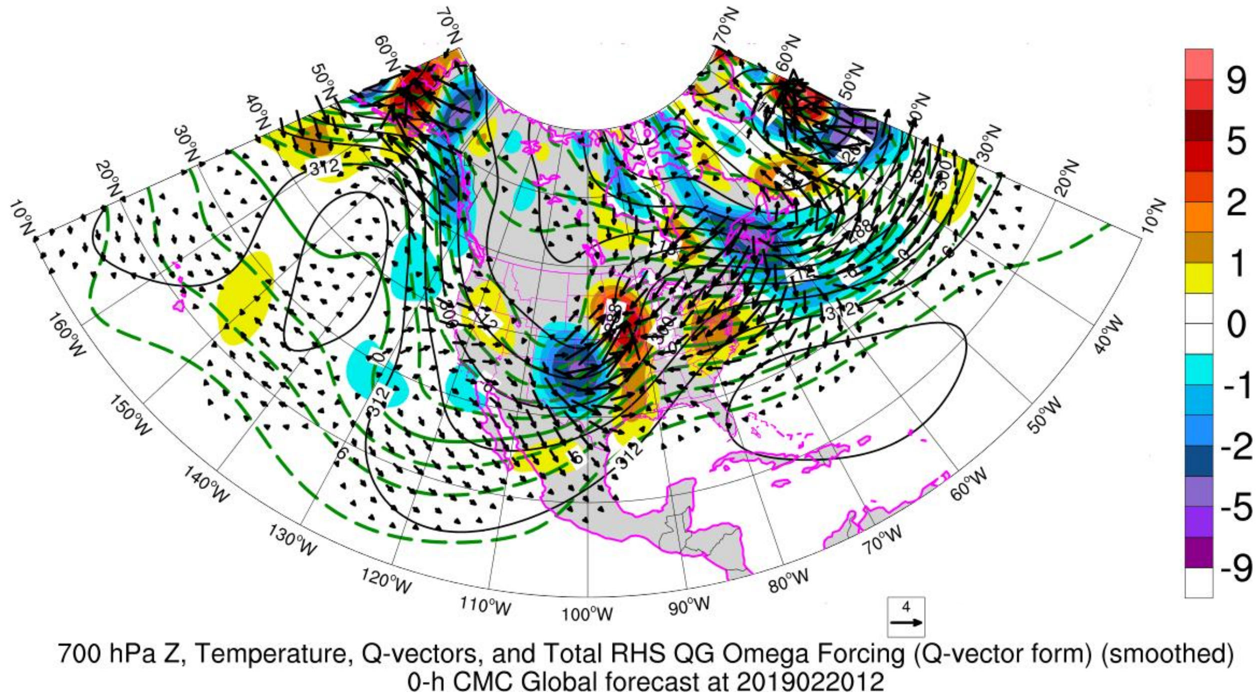


**Figure 1**. 700 hPa geopotential height (solid contours every 3 dam = 30 m), temperature (dashed contours every 3°C), Q-vectors (x$10^{-7}$ Pa $m^{-1}$ $s^{-1}$, reference vector at lower-center), and total forcing for ascent (x$10^{-12}$ Pa $m^{-2}$ $s^{-1}$, shaded per the color bar at right; functionally equivalent to Q-vector convergence) from the 0-h Canadian global model (CMC) analysis at 1200 UTC 20 February 2019.

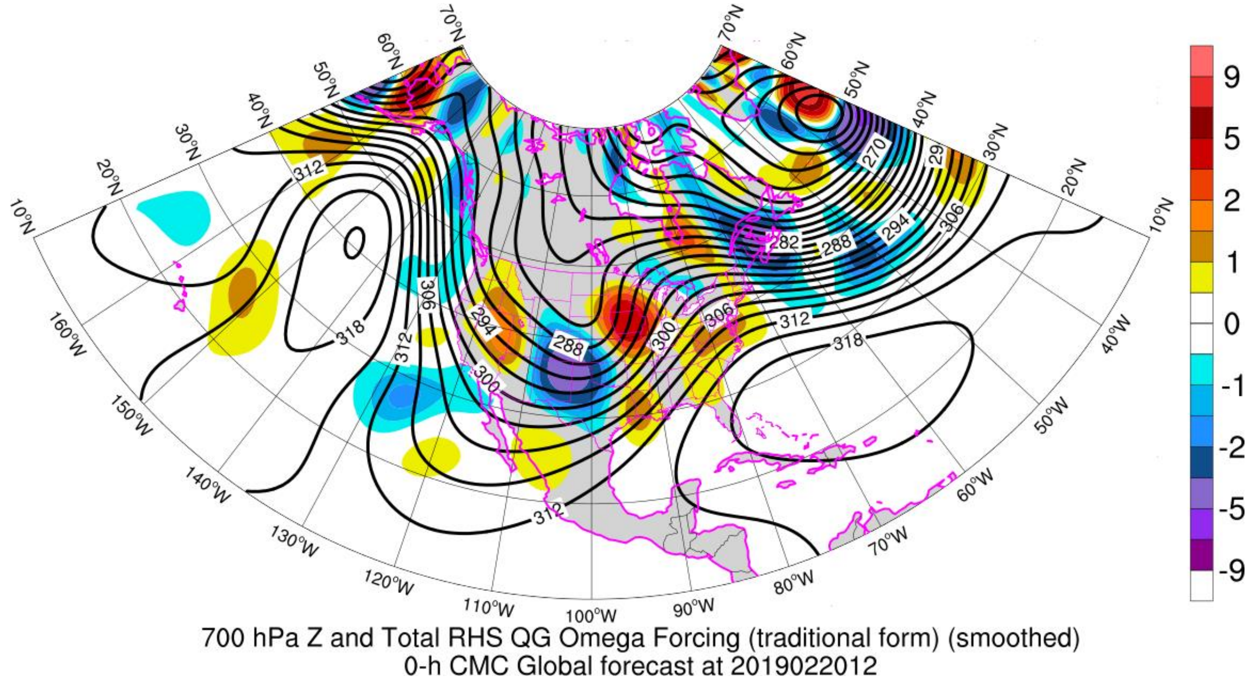


**Figure 2**. 700 hPa geopotential height (contours every 3 dam = 30 m) and the sum of the forcing terms depicted in Figs. 2 and 4 (x$10^{-12}$ Pa $m^{-2}$ $s^{-1}$, shaded per the color bar at right) from the 0-h CMC analysis at 1200 UTC 20 February 2019.

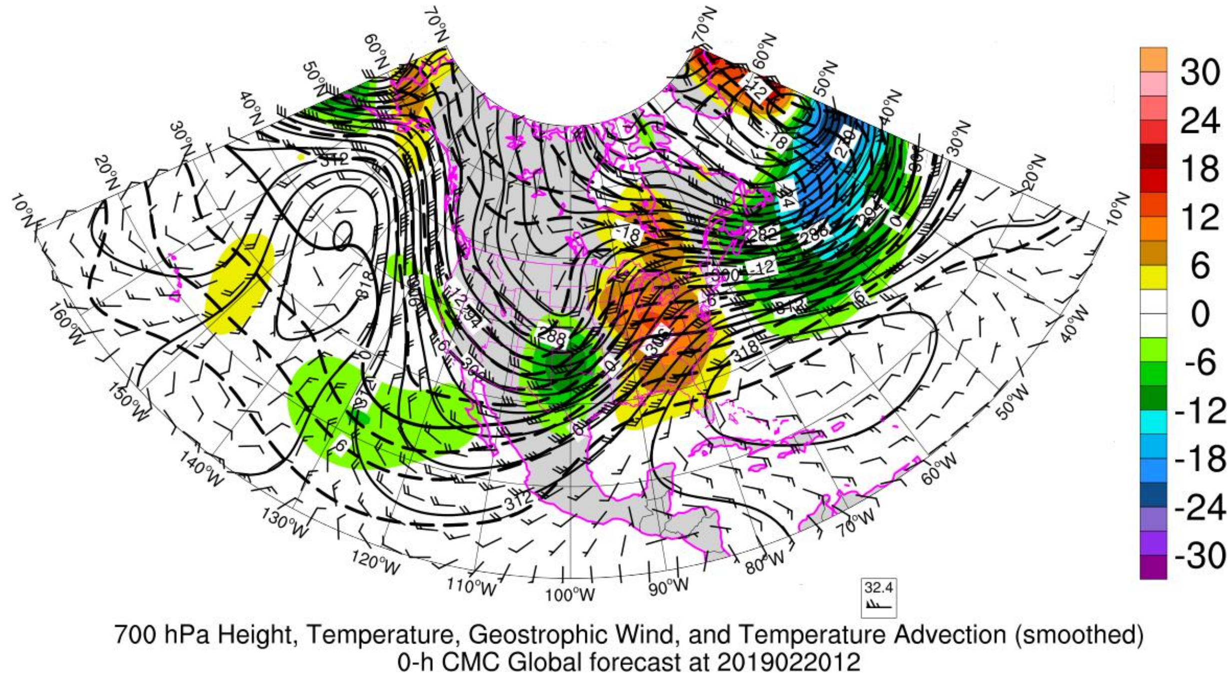


**Figure 3**. 700 hPa geopotential height (solid contours every 3 dam = 30 m), temperature (dashed contours every 3°C), geostrophic wind (barbs, kt; reference barb at lower-center), and temperature advection (K day$^{-1}$; shaded per the color bar at right) from the 0-h CMC analysis at 1200 UTC 20 February 2019.

We next focus on another trough in the central United States, this one from 1200 UTC 24 February 2019. Here, 700 hPa Q-vectors converge northeast of the trough axis and diverge southwest of the trough axis, implying forcing for ascent and descent, respectively (Fig. 4). This is again identical to the total forcing from the QG omega equation (Fig. 5), reaffirming the equivalency of the two frameworks for deducing forcing for vertical motion.

Further, the Q-vectors have a component parallel to the horizontal temperature gradient over the central Plains and southern Mississippi River valley, well behind the trough axis, and from Hudson Bay southward along 80°W toward Lake Ontario, ahead of the trough axis (Fig. 4). In the former, cold air advection is maximized behind the leading edge of an advancing cold front with weaker advection ahead of the cold front (Fig. 6). Thus, frontogenesis in this case is dominated by cold air advection making it colder where it is already relatively cold. In the latter, warm air advection is maximized along and on the warm side of an advancing warm front (Fig. 6). Thus, frontogenesis in this case is dominated by warm advection making it warmer where it is already relatively warm.

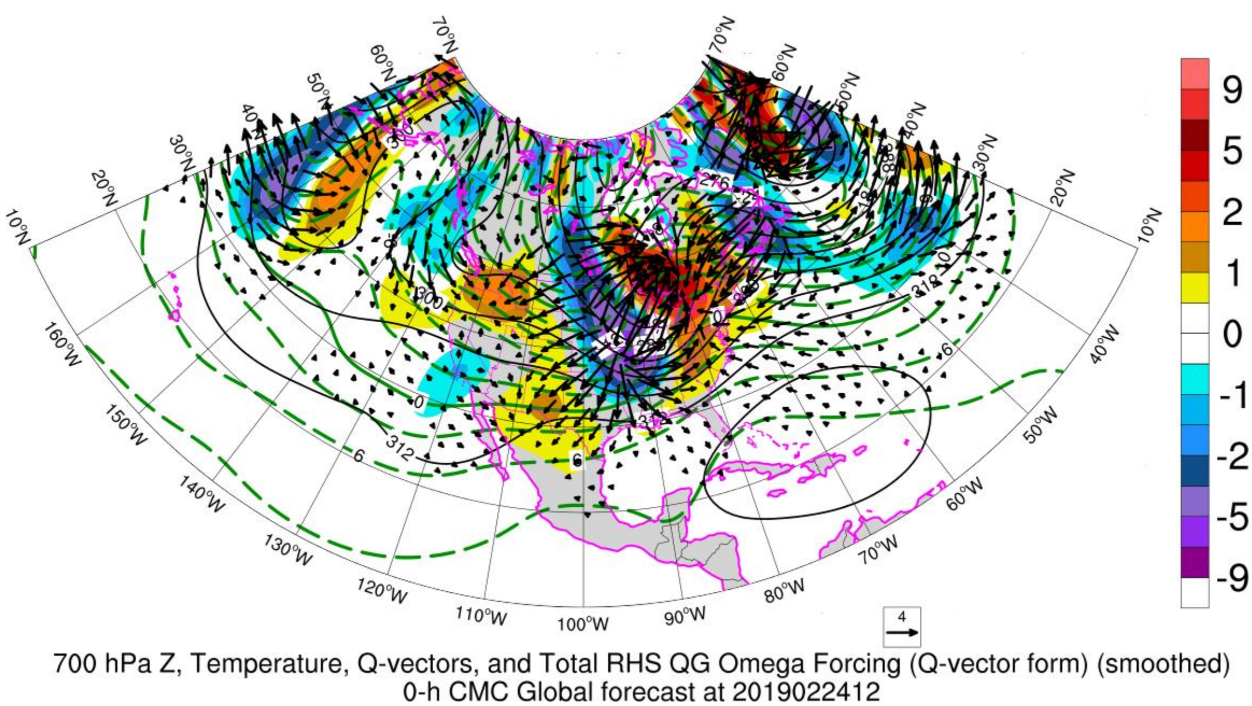


**Figure 4**. As in Fig. 1, except at 1200 UTC 24 February 2019.

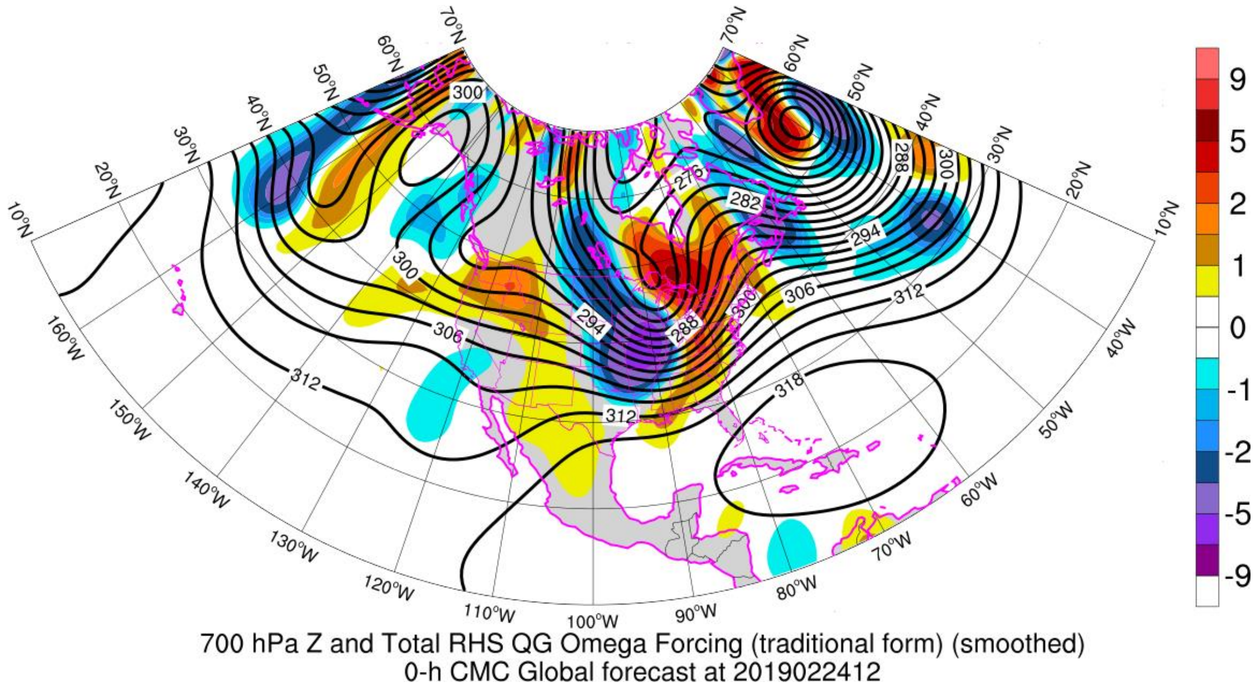


**Figure 5**. As in Fig. 2, except at 1200 UTC 24 February 2019.

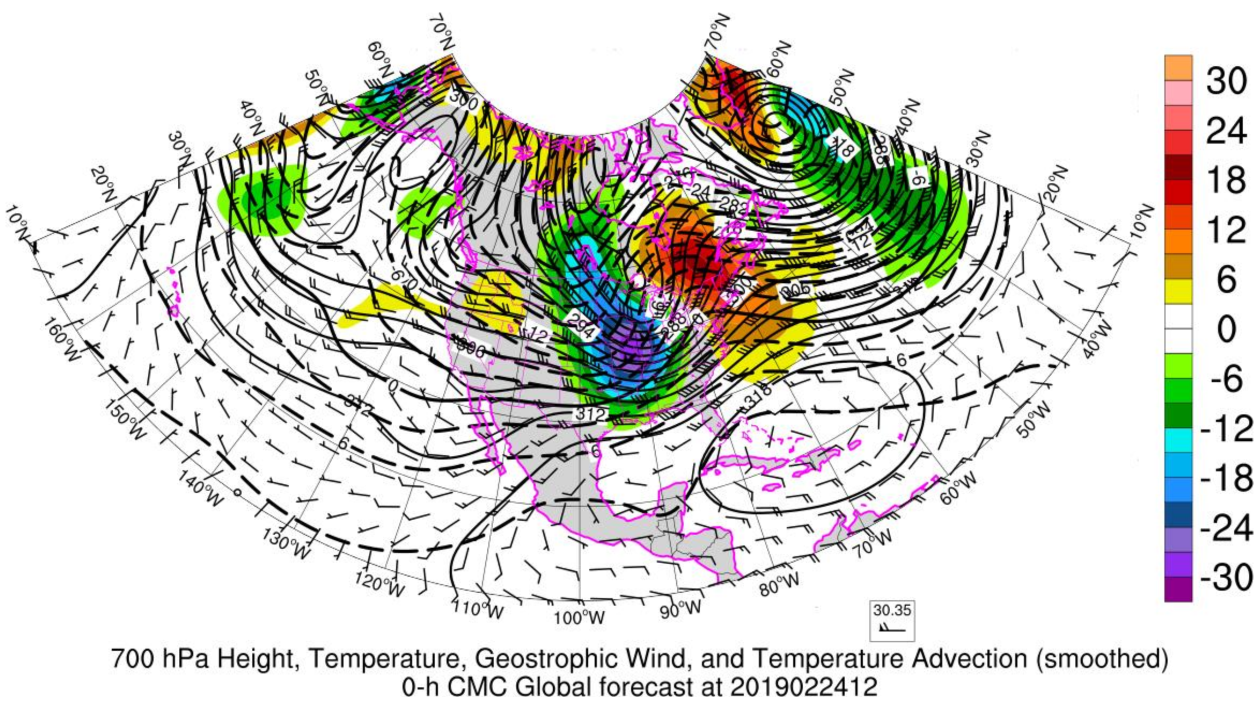


**Figure 6**. As in Fig. 3, except at 1200 UTC 24 February 2019.