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The Motion of Mesoscale Snowbands in Northeast U.S. Winter Storms

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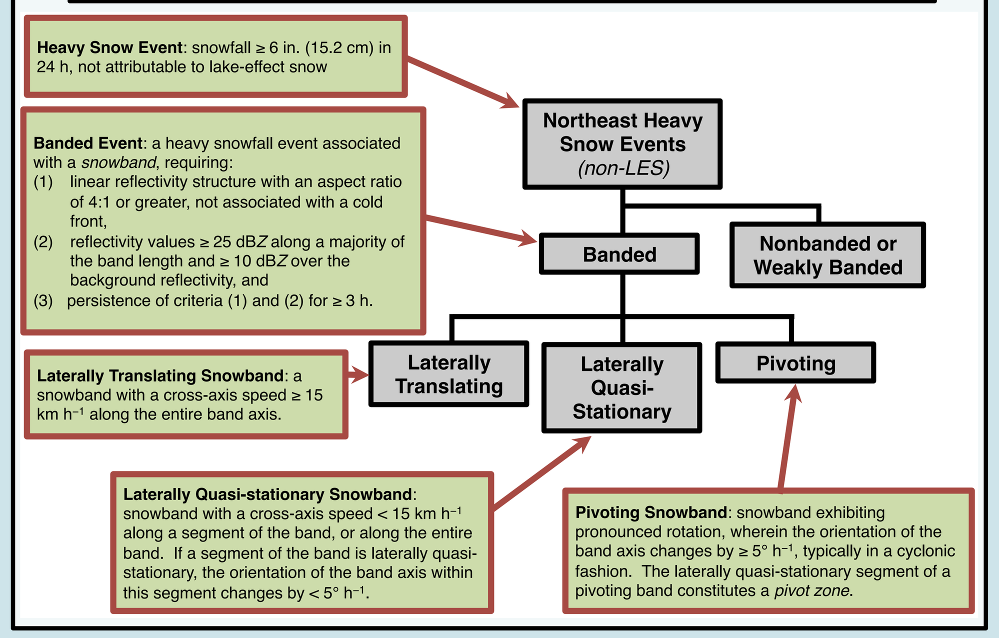
Motivation

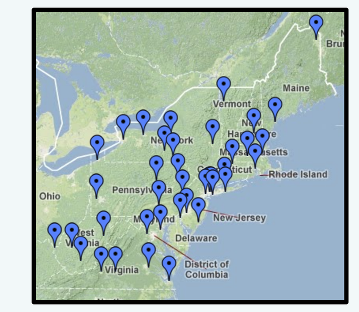
- Mesoscale snowbands are frequently observed in winter storms, and may contribute substantially to overall snowfall accumulation
- Motion characteristics of snowbands strongly modulate snowfall duration at a given location
- Snowband development is often signaled by NWP guidance at 24–36 h forecast ranges, but no conceptual models have been proposed to understand and anticipate band motion characteristics

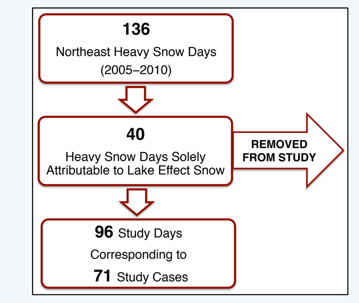
Snowband Motion Classification



Data and Methodology

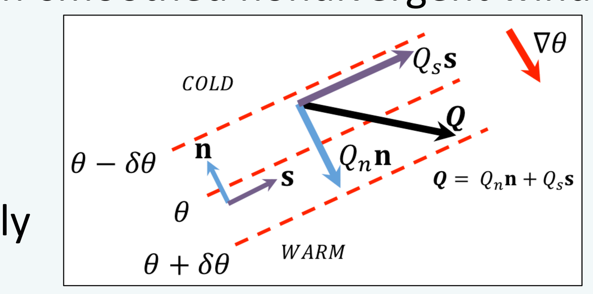
- 39 NWS first-order stations in the Northeast U.S. were queried for heavy snow occurrences during the period 2005–2010
  - Heavy snow: ≥ 6 in. (15.2 cm) in 24 h
- Of the 136 heavy snow days identified, 40 lake-effect snow (LES) days were subjectively identified and removed from study, leaving 71 non-LES study cases
- Diagnostics have been calculated using the 0.5° Climate Forecast System Reanalysis (CFSR) dataset
- For each study case, 0.5° radar reflectivity mosaics were constructed using archived WSR-88D data





Q-Vector Partitioning

- *Q*-vectors are calculated from Gaussian-smoothed nondivergent wind and potential temperature fields
- *Q*-vectors are then partitioned into along- and cross-isentrope vector contributions, $Q_s\mathbf{s}$ and $Q_n\mathbf{n}$, respectively (Keyser et al. 1988)
- Q_s is the rate of change of the *direction* of the horizontal potential temperature gradient due to relative vorticity and horizontal deformation
- Q_n is the rate of change of the *magnitude* of the horizontal potential temperature gradient due to horizontal deformation



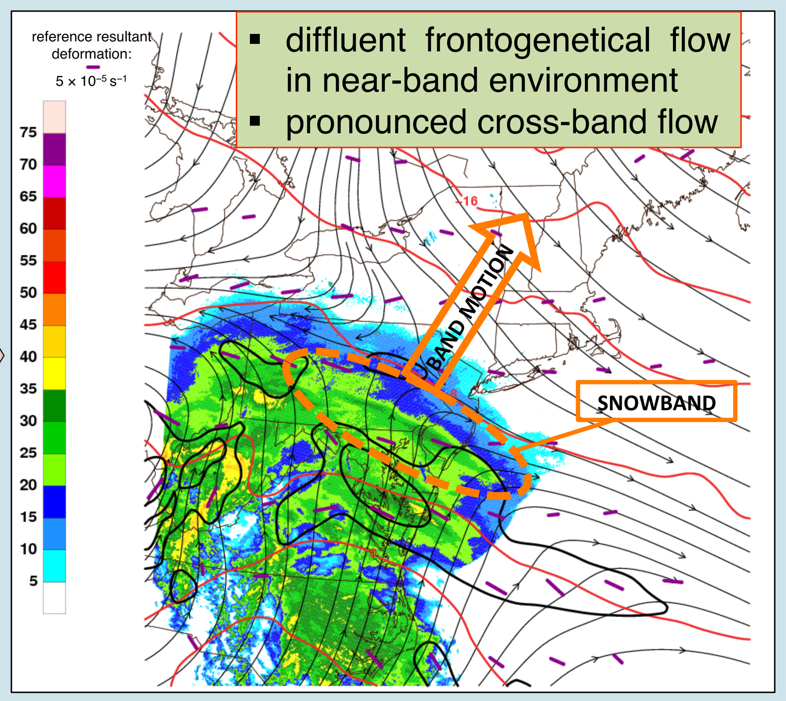
850–650-hPa layer-averaged streamlines (thin black), axes of dilatation (purple, plotted when resultant deformation ≥ 4 × 10^{-5} s^{-1}, scaled accordingly), temperature (red, every 4°C), frontogenesis (using the total horizontal wind) [heavy black, contoured at 1 and 3 K (100 km)$^{-1}$ (3 h)$^{-1}$], and 0.5° radar reflectivity (filled, dB*Z*).

700-hPa ***Q*** (left panels), $Q_s\mathbf{s}$ (center panels), and $Q_n\mathbf{n}$ (right panels) (magnitudes ≥ 2 × 10^{-10} K m^{-1} s^{-1} shown). All panels: 0.5° radar reflectivity (filled, dB*Z*), Gaussian-smoothed 700-hPa temperature (red, every 4°C), and 700-hPa *Q*-vector convergence and divergence (black and pink, respectively, every 3 × 10^{-15} K m^{-2} s^{-1}, starting at 1 × 10^{-15} K m^{-2} s^{-1}).

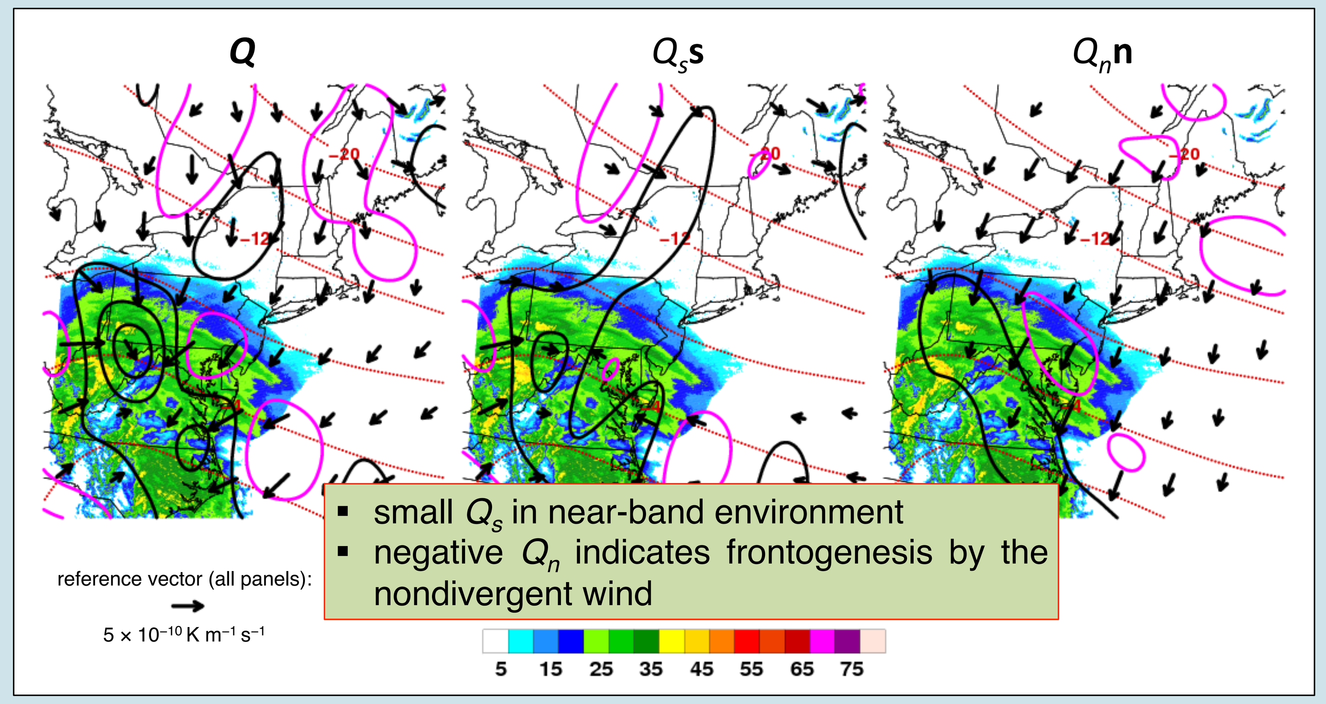
Left panels: 850–650-hPa layer-averaged temperature advection [filled, K (3 h)$^{-1}$], geopotential height (black, every 30 m), and temperature (dashed, every 4°C). Right panels: near-band vertical profiles for Wilmington, DE (KILG, top), Poughkeepsie, NY (KPOU, middle), and Windsor Locks, CT (KBDL, bottom), as indicated by arrows.

Snowfall accumulation maps for the periods indicated on each panel (courtesy of NOAA / NWS / NOHRSC, www.nohrsc.nws.gov)

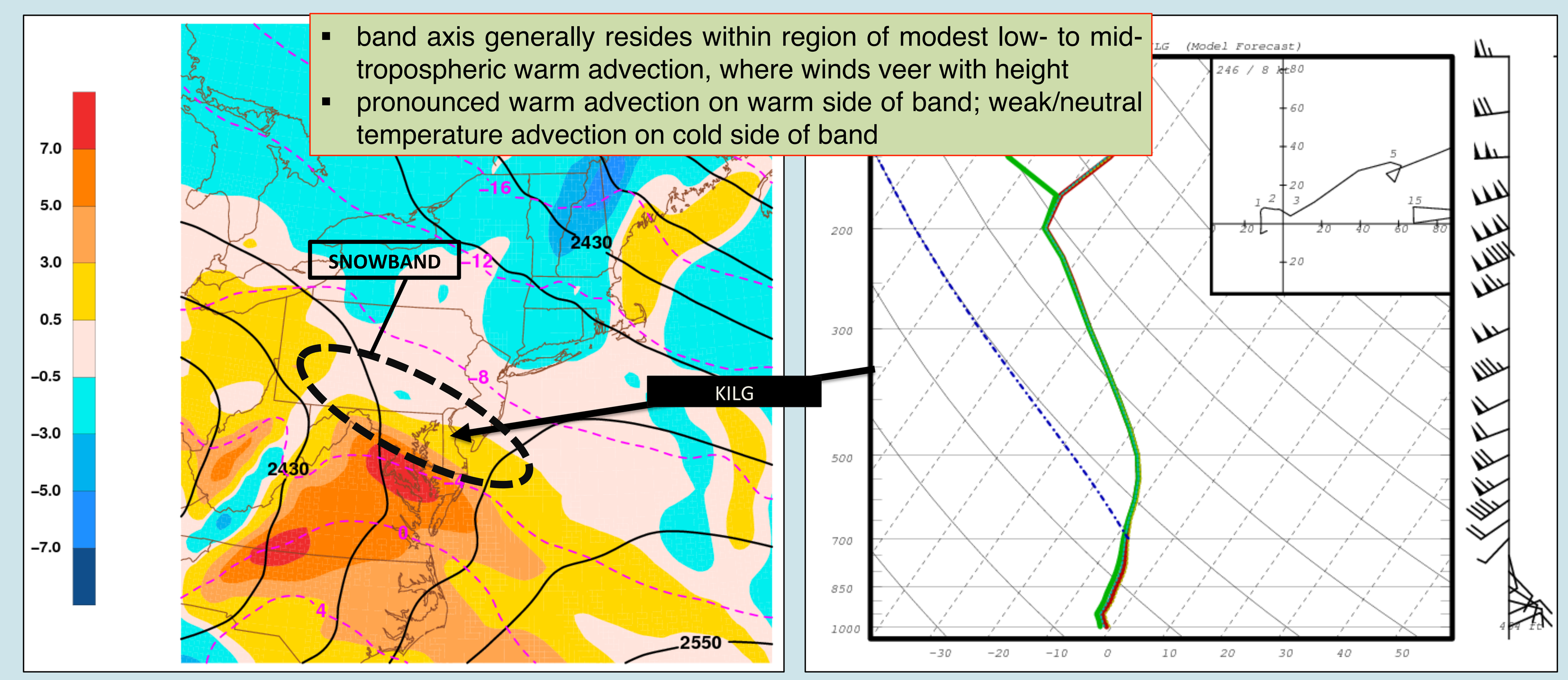
Example 1: ***Laterally translating*** snowband (0000 UTC 6 Feb 2010)



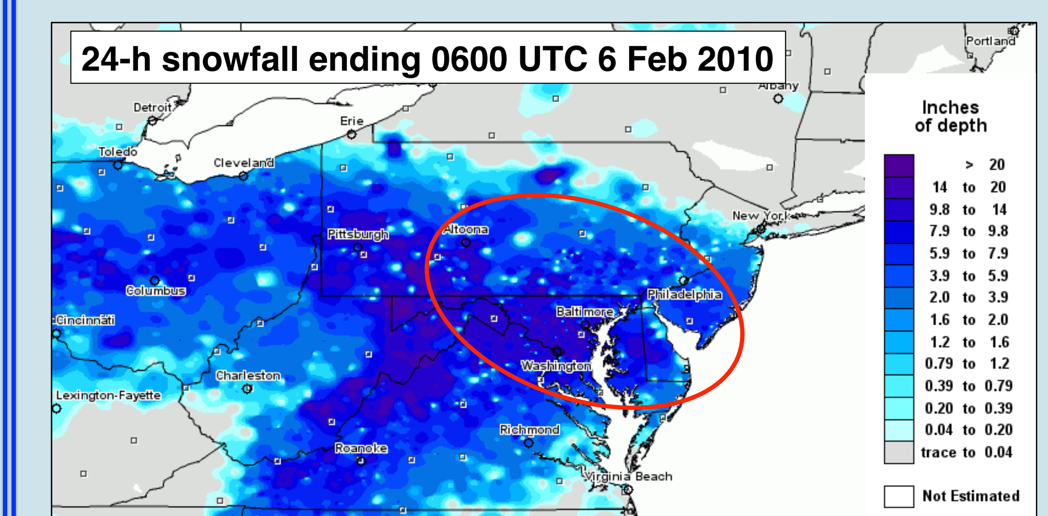
- diffluent frontogenetical flow in near-band environment
- pronounced cross-band flow



- small Q_s in near-band environment
- negative Q_n indicates frontogenesis by the nondivergent wind

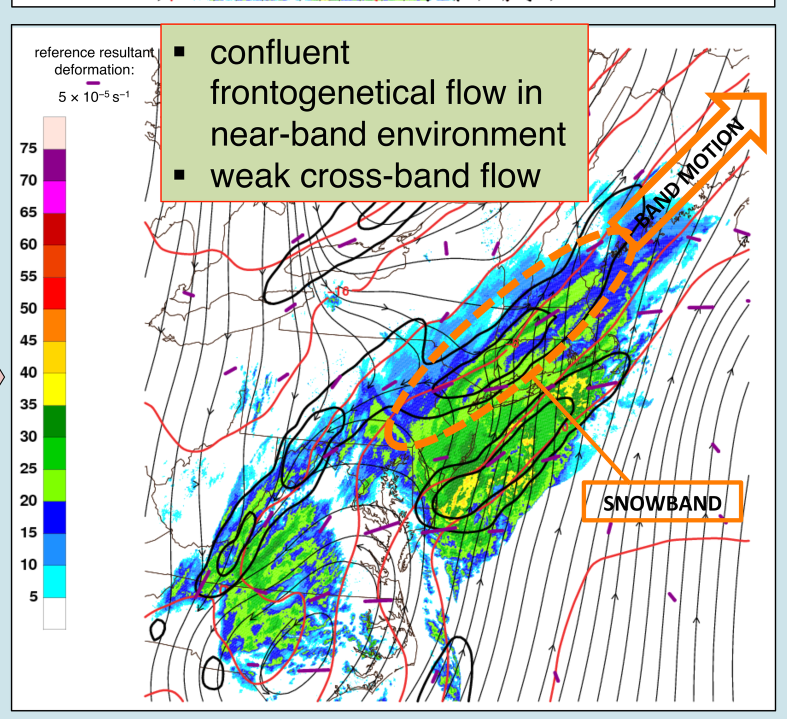


- band axis generally resides within region of modest low- to mid-tropospheric warm advection, where winds veer with height
- pronounced warm advection on warm side of band; weak/neutral temperature advection on cold side of band

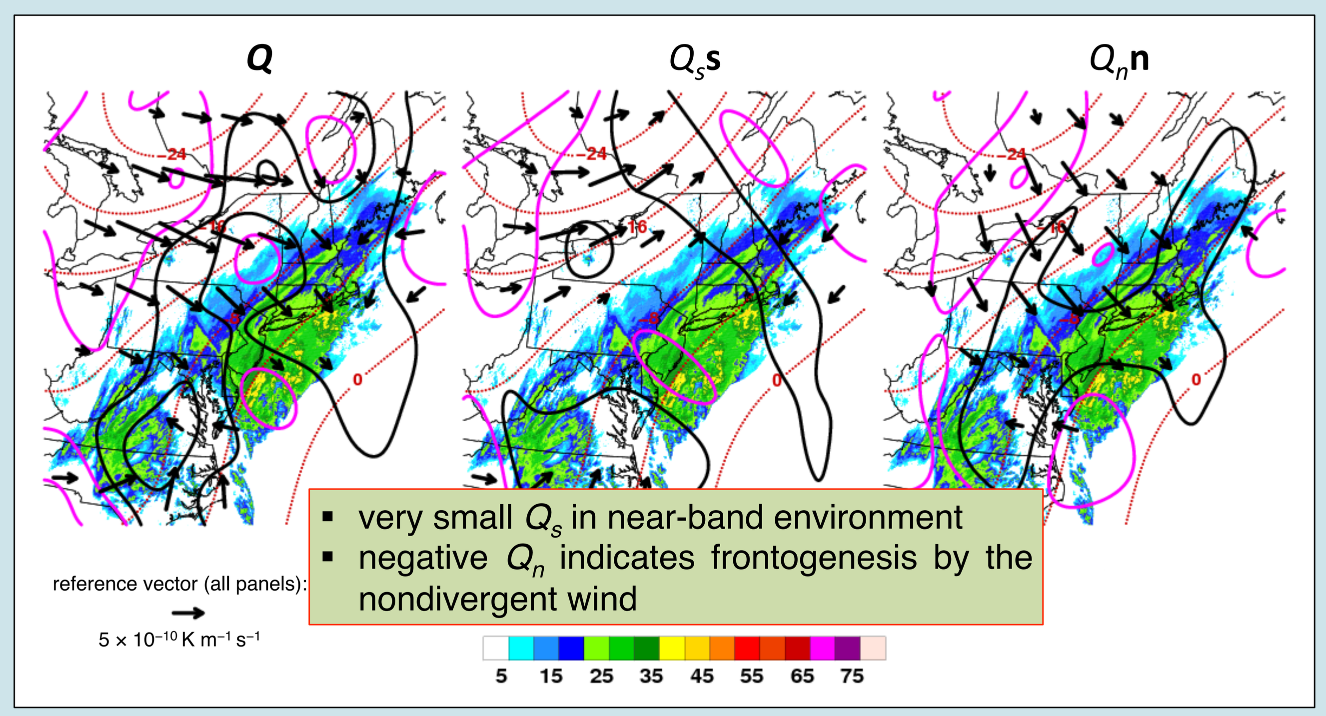


- snowband motion is progressive; heavy snowfall attending the laterally translating band is relatively brief at any location
- geographic distribution of snowfall is fairly uniform across snowband region

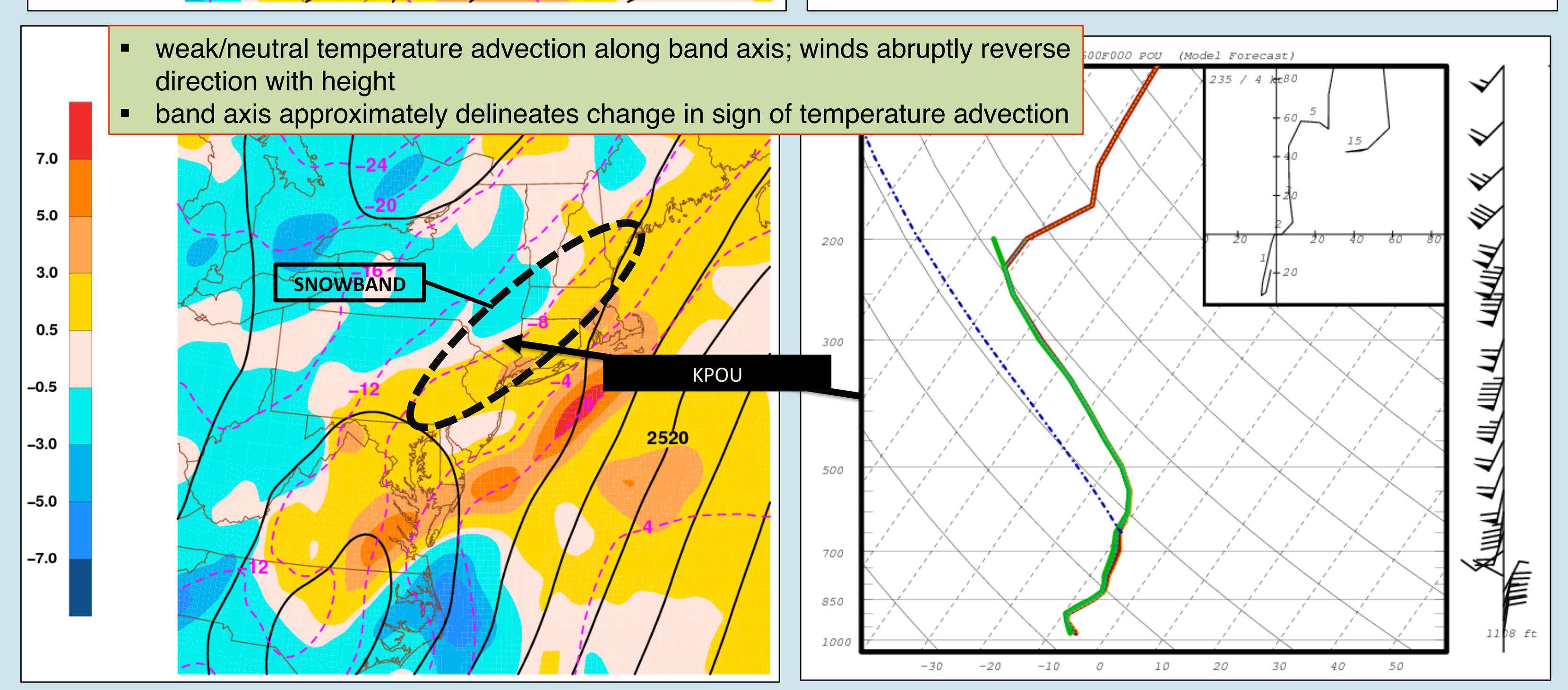
Example 2: ***Laterally quasi-stationary*** snowband (0600 UTC 1 Mar 2009)



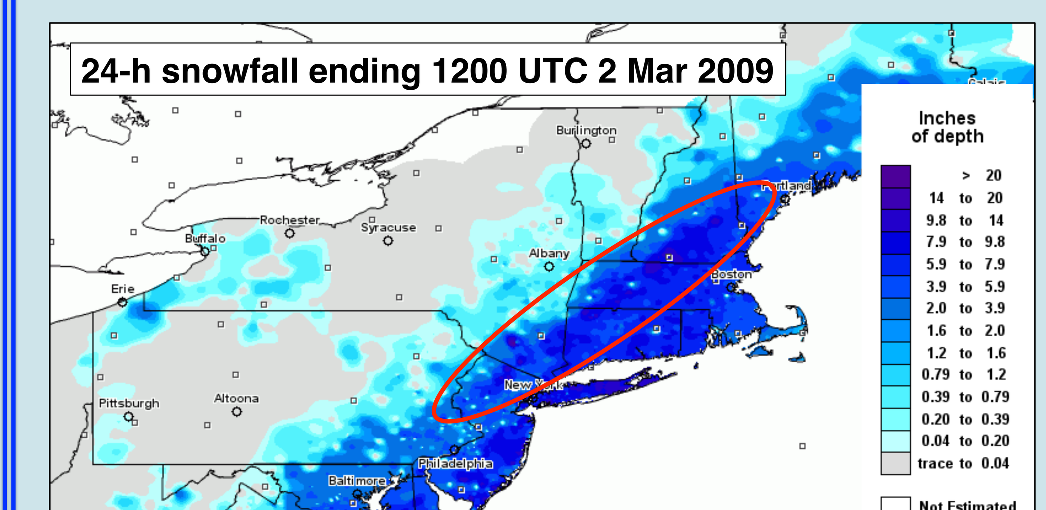
- confluent frontogenetical flow in near-band environment
- weak cross-band flow



- very small Q_s in near-band environment
- negative Q_n indicates frontogenesis by the nondivergent wind

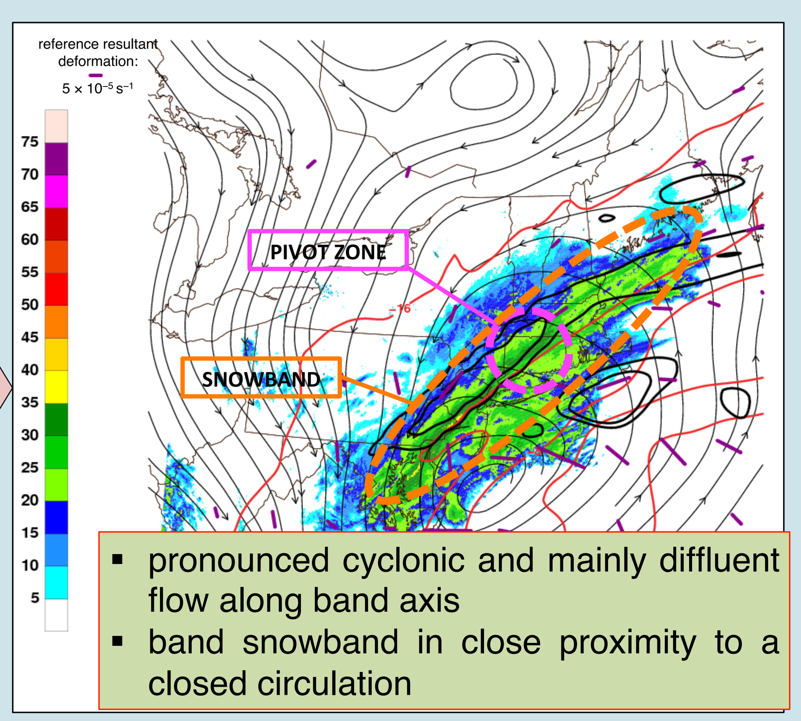


- weak/neutral temperature advection along band axis; winds abruptly reverse direction with height
- band axis approximately delineates change in sign of temperature advection

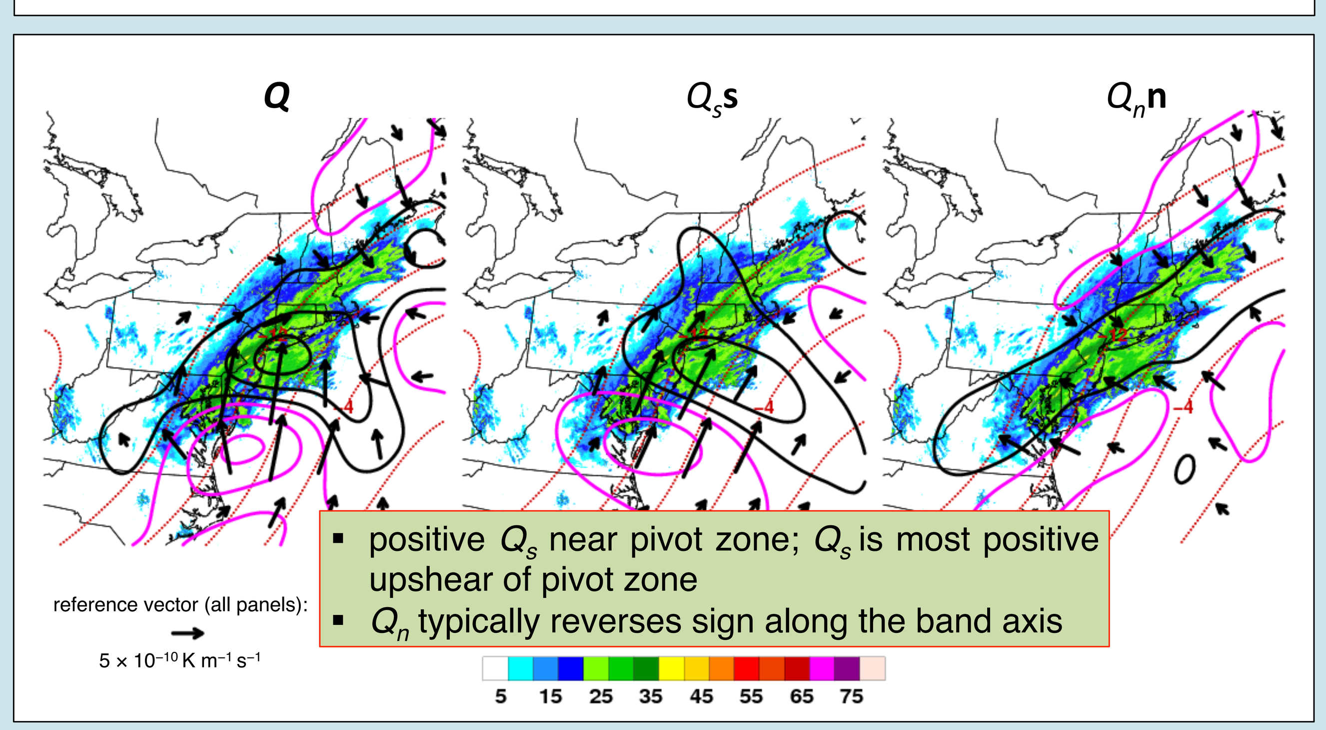


- snowband "training" occurs along laterally quasi-stationary band axis; heavy snowfall is prolonged at locations along axis
- pronounced tapering of snowfall on cold side of band

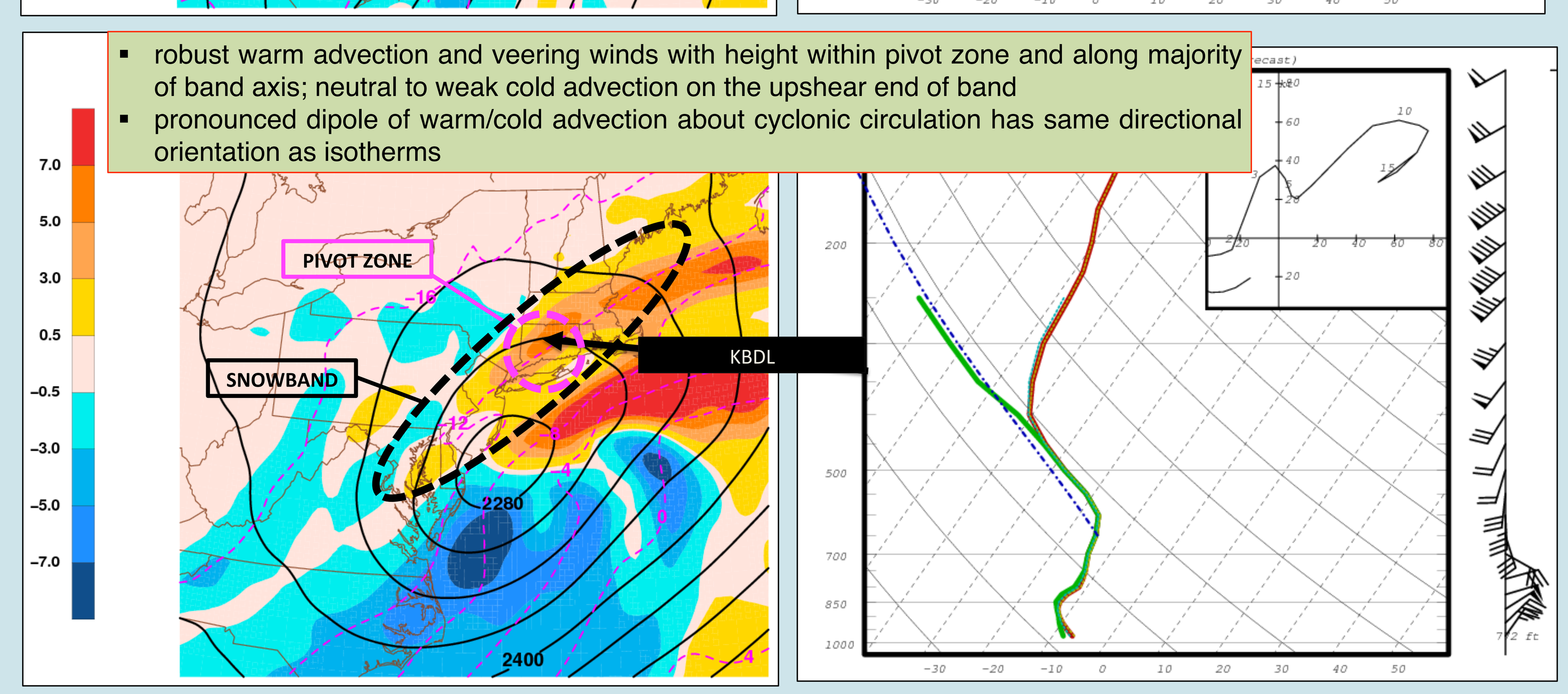
Example 3: ***Pivoting*** snowband (1200 UTC 12 Feb 2006)



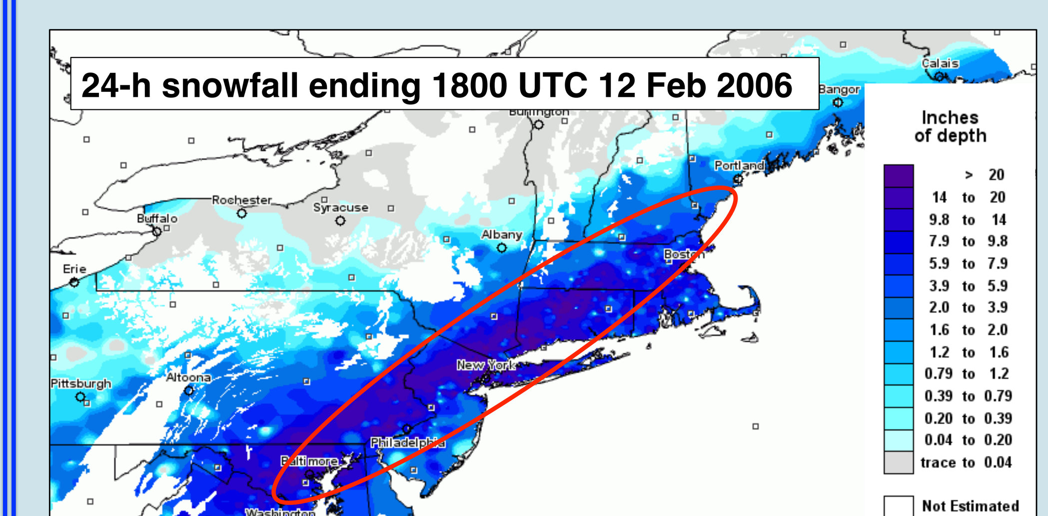
- pronounced cyclonic and mainly diffluent flow along band axis
- band snowband in close proximity to a closed circulation



- positive Q_s near pivot zone; Q_s is most positive upshear of pivot zone
- Q_n typically reverses sign along the band axis



- robust warm advection and veering winds with height within pivot zone and along majority of band axis; neutral to weak cold advection on the upshear end of band
- pronounced dipole of warm/cold advection about cyclonic circulation has same directional orientation as isotherms



- heavy snowfall in pivot zone where snowband is locally persistent
- snowfall tapers on cold side of pivoting snowband

Conclusions

- The mode of snowband motion can be anticipated by assessing the near-band environment:
  - laterally translating bands: favored by diffluent flow, small Q_s / negative Q_n, and modest warm advection (and veering wind profiles) along band axis.
  - laterally quasi-stationary bands: favored by confluent flow, very small Q_s / negative Q_n, and weak temperature advection along band axis.
  - pivoting bands: favored by pronounced cyclonic and mainly diffluent flow along band axis. Strongly positive Q_s is found upshear of pivot zone; Q_n reverses sign along band. Robust warm advection and veering wind profiles occur along a majority of the band axis.
- Snowband motion influences the geographic distribution of snowfall accumulation, and therefore has operational forecasting implications:
  - laterally translating bands: relatively uniform snowfall; accumulation forecasts are less sensitive to band location
  - laterally quasi-stationary and pivoting bands: pronounced snowfall tapering on cold side of bands; accumulation forecasts are more sensitive to band location

References and Acknowledgments

Keyser, D., M. J. Reeder, and R. J. Reed, 1988: A generalization of Petterssen's frontogenesis function and its relation to the forcing of vertical motion. *Mon. Wea. Rev.*, **116**, 762–780.

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