Snow Band Movement and Rain Occurrence in Northeast U.S. Winter Storms

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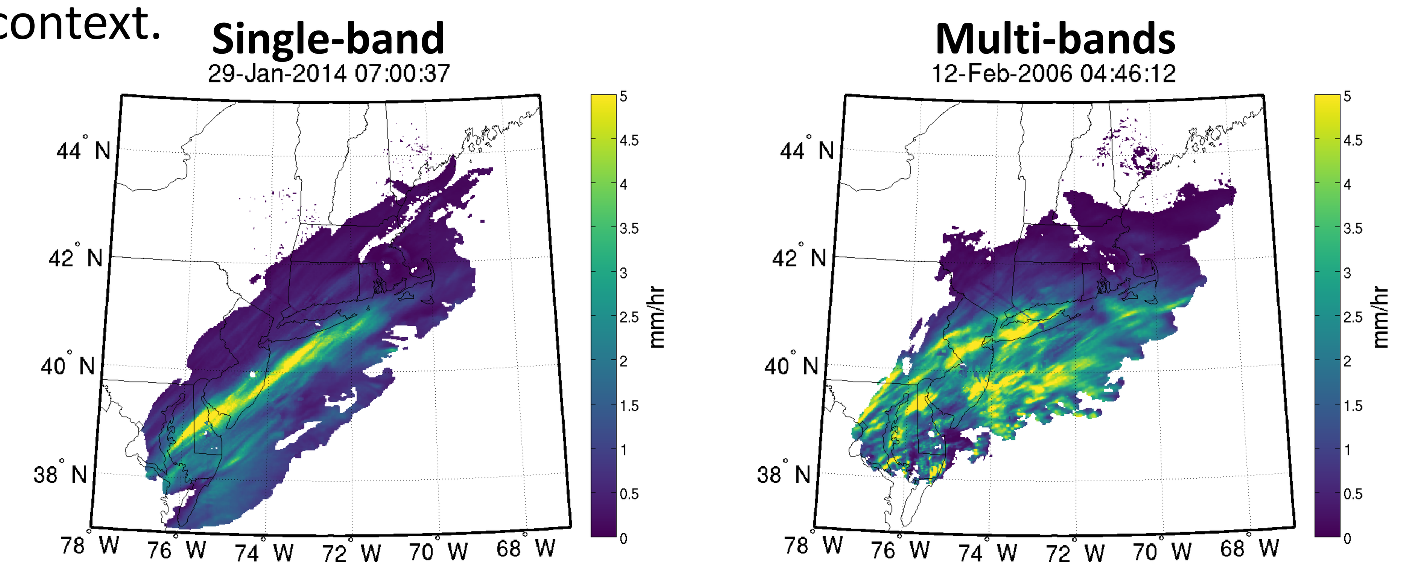
Background

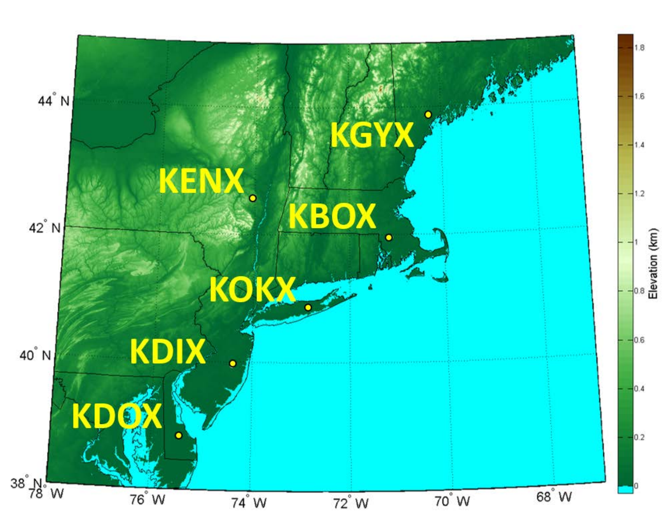
Accurate prediction of snow accumulation in storms impacting the northeastern U.S. coast can be a challenge. Coastal winter storms often contain time-varying 3D temperature structures yielding different precipitation types in different parts of the storm as well as mesoscale bands of locally enhanced precipitation. Single-bands are long (at least 200 km) and narrow, while multi-bands are smaller and generally exist in sets of 2 or more. These bands can move in a number of different ways. We examine multi-band motions in both a geographic framework and a Lagrangian framework relative to the low pressure center to better understand the reasons for band motion and their environmental context.



Estimated snow rate maps showing an example of a single-band on 29 Jan. 2014 (left) and multi-bands on 12 Feb. 2006 (right)

Data and Methods

111 storms between 1996 and 2016 were analyzed using data from six National Weather Service radars in the Northeast (shown right). Radar reflectivity was converted to estimated snow rate using the methods described in Hoban (2016). Bands can be identified from locally higher estimated snow rate values. Pressure, geopotential height, temperature, and wind data were used from the North American Regional Reanalysis (NARR).



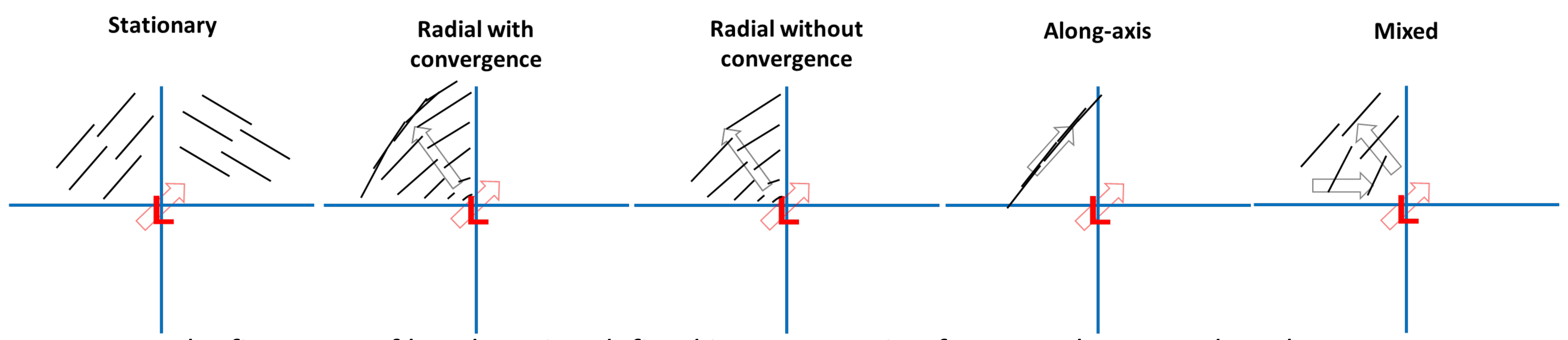
The low pressure center was found and tracked throughout the duration of each storm. The motion of snow bands can then be viewed in a Lagrangian framework (i.e. relative to the motion of the low).

The location and motion of bands were compared to the geopotential height and wind fields at the 700 hPa level.

The near surface temperature field during each storm period was assessed to find the percentage of times in which each NARR grid box in the domain had a 10-meter temperature above freezing.

Band Motion Types

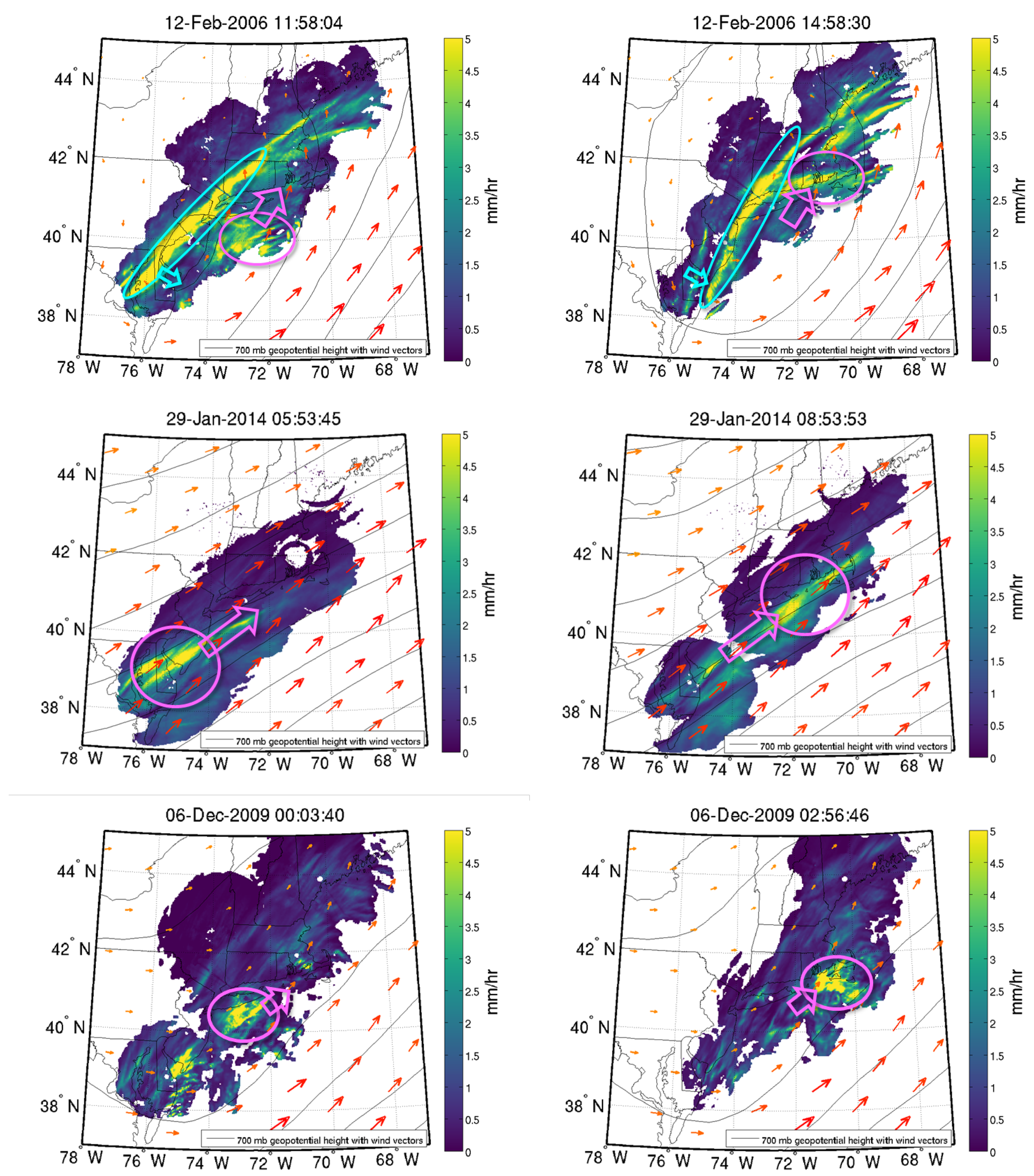
Bands were most prevalent in the northwest and northeast quadrants of cyclones. Five types of band motion relative to the low pressure center were observed and defined. These are: quasi-stationary band motion, radial motion with convergence, radial motion without convergence, motion along the band axis, and mixed motion.



The five types of band motion defined in a Lagrangian framework centered on the storm low pressure center. Note that along-axis motion can also occur with multi-bands, and quasi-stationary motion can occur with single-bands.

700 hPa Winds and Band Motion

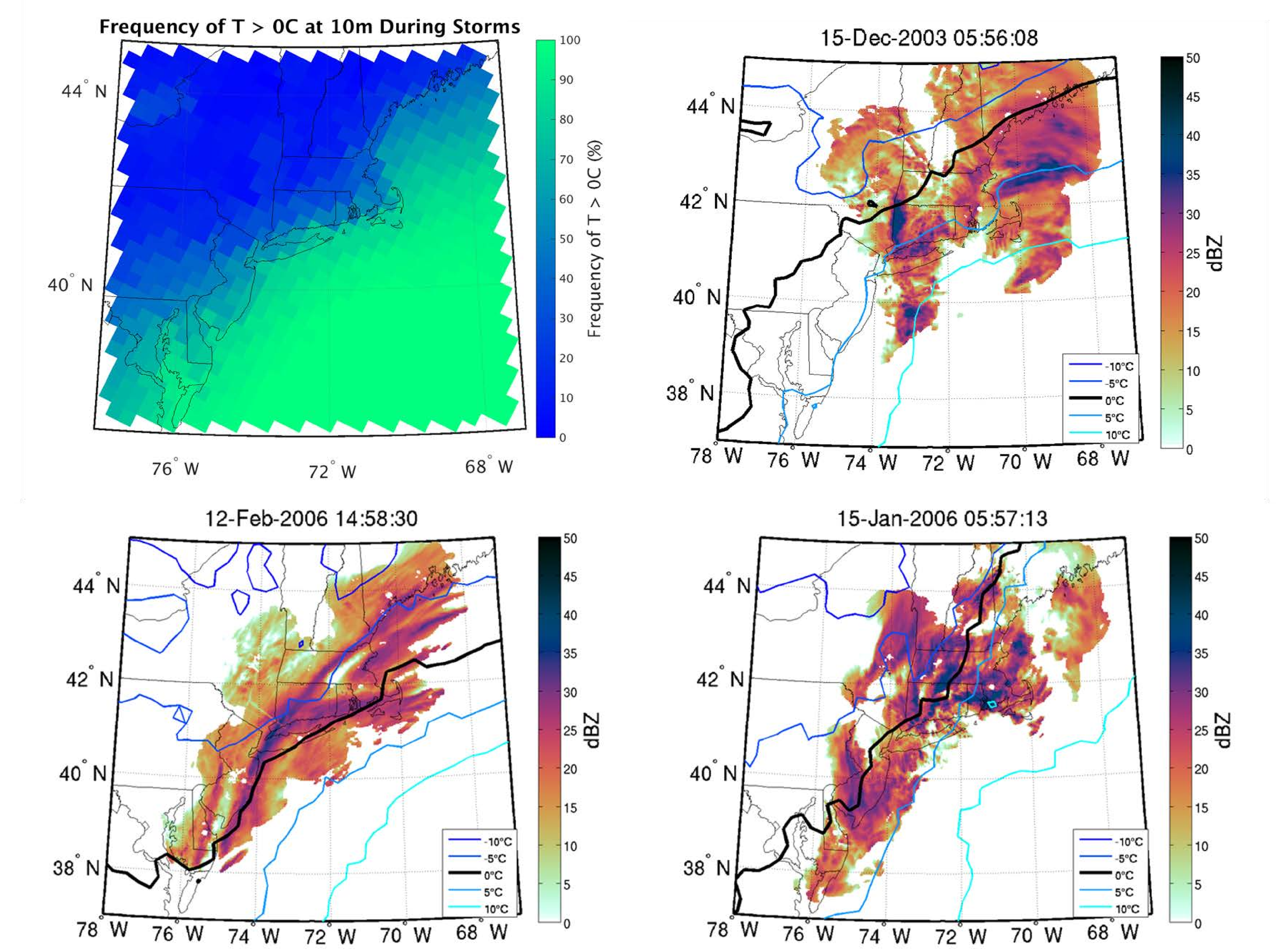
In several cases, the 700 hPa wind roughly indicated the motion of the overall area of precipitation, including sets of multi-bands, particularly when the 700 hPa flow was strong. However, individual bands within a set of multi-bands may or may not move in the same direction as the envelope of the set. In weak 700 hPa flow, the relationship between the 700 hPa flow and multi-band motion is less clear.



Three examples of 700 hPa heights (contours), 700 hPa winds (vector arrows), and estimated snow rate (shaded, mm/hr). The two images in each row are from the same storm and are roughly three hours apart. Areas of multi-bands and their motion are shown in pink. A single-band and its motion are shown in blue. Top: 12 Feb. 2006, radial band motion relative to the low with convergence. Middle: 29 Jan. 2014, along-axis band motion relative to the low. Bottom: 6 Dec. 2009, stationary band motion relative to the low.

Above and Below Freezing Occurrence

10-meter temperature contours were often found to be roughly parallel to the coastline, with warmer temperatures over the ocean. This implies that snow is more likely to fall over land, and rain is more likely to fall over the ocean.



Top-left: Percentage of NARR analyses in all storm periods with 10-meter temperature above 0°C. Top-right, bottom-left, bottom-right: reflectivity (shaded, dBZ) and 10-meter temperature contours (with 0°C contour bolded) from one time during 15 Dec. 2003, 12 Feb. 2006, and 15 Jan. 2006 cases respectively.

Conclusions

- The data suggest that sets of multi-bands often move roughly parallel to the mean flow at 700 hPa. However, some individual bands can move in different directions than others nearby and not necessarily with the mean flow.
- Near-surface temperatures are far more likely to be above 0°C and melting snow and rain are more likely to occur near coastlines than inland during these storms.

Future Work

Visualize the three-dimensional air mass boundary surfaces using reanalysis and compare the boundary locations and motions to those of the observed bands.

Use observed and reanalysis temperature data to determine which bands indicated by enhanced radar reflectivity correspond to partial melting.

Reference: Hoban, N.P., 2016: Observed Characteristics of Mesoscale Banding in Coastal Northeast U.S. Snow Storms, M.S. Thesis, Dept. of Marine, Earth, and Atmospheric Sciences, North Carolina State University.
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