**3. Warm MHC**

*a. Surface Analysis*

In the warm cases of MHC surface observations from various ASOS sites around Capital Region show the typical wind directions for these events. These wind observations can be seen in the wind roses of Figure 2a. The Utica and Rome stations, located in the western part of the Mohawk River Valley had various data outages during the cases. Utica and Rome typically saw winds from the W-NW or the W-SW, typically around a magnitude of 15 knots. Glens Falls, which is located north of the Capital Region typically saw Southerly winds with magnitudes that ranged from 6 to 12 knots. Poughkeepsie which is located to the south of the Capital Region typically saw winds from the South or Southwest. The Southerly winds were typically of stronger magnitude and ranged from 7 to 14 knots while the Southwesterly winds typically ranged between 5 to 10 knots. The Albany ASOS station which is located at Albany International Airport typically exhibited S-SW wind with magnitudes ranging from 6 to 12 knots.

*b. Composites*

Warm cases of MHC tend to form in environments just before the passage of cold fronts. In Figure 3a, composite mean, sea level pressure shows a generally weak surface cyclone located over southern Quebec during the time of peak reflectivity associated with warm MHC events. The position of this surface cyclone would induce weak southwesterly geostrophic flow over New York and New England. A pressure trough can be seen near eastern New York indicating a pre-frontal trough, though the pre-frontal trough in these cases did not directly initiate the convection.

 At 850-hPa, a trough can be seen sitting over the east coast of the United States and a ridge in the central United States. There is general composite west/southwesterly winds occurring over New York and New England. Weak warm air advection in the prefrontal environment occurs during the peaks of warm MHC events over extreme Eastern New York State (Fig. 4a). You can see cold air advection occurring in the wake of the cold front moving over central New York. Focusing on the eastern portion of New York, the composite shows weak warm air advection on the order of 0.4 *°*C h-1.

Weak advection of 500-hPa cyclonic relative vorticity occurs across eastern New York during warm MHC events (Fig. 5a). Weak cyclonic curvature is seen upstream of the Capital Region, indicative of possible shortwaves in the flow at 500-hPa. Investigation of individual cases revealed that there is significant spatial variability in the location of upstream shortwaves during warm MHC events.

 At 300-hPa (Fig. 6a), the flow is very zonal and a broad trough can be seen over the eastern United States a weak jet is located the northeast of New York State. The maximum of this jet is located over New Brunswick, Canada. The Capital Region is downstream of the trough axis and in the equatorward entrance region of the jet streak.

The composite sounding (Fig. 7a) for warm MHC cases shows a warm surface temperature around 28 *°*C and a surface dew points of 19 *°*C. With a warm, moist surface, the lack of any significant capping inversion, and steep mid-level lapse rates. Surface southwesterly winds around 5 kts veer with height, representative of warm air advection, which was seen in the 850-hPa composite map. Reviewing the cases generally surface based CAPE was between 1000 and 3000 J kg-1. In the individual cases the actual winds were more southerly in the valley due to the terrain channeled flow.

**4. Cold MHC**

*a. Surface Analysis*

 In the cold cases of MHC surface observations from various ASOS sites around Capital Region show the typical wind directions for these events. These wind observations can be seen in the wind roses of Figure 2b. The Utica and Rome stations, located in the western part of the Mohawk River Valley had various data outages during the cases. Utica and Rome typically saw winds from the N-NW or the W-NW, typically around a magnitude of 12 to 15 knots. Glens Falls, which is located north of the Capital Region typically saw Northwesterly winds with magnitudes that ranged from 6 to 9 knots. Poughkeepsie which is located to the south of the Capital Region typically saw winds from the North or W-NW. The winds typically ranged between 12 to 15 knots. The Albany ASOS station which is located at Albany International Airport typically exhibited Northerly wind with magnitudes ranging from 0 to 13 knots.

*b. Composites*

Cold cases of MHC typically occur after the passage of synoptically-forced precipitation. The cold case sea-level pressure composite (Fig. 2b) shows that during the peak of cold MHC events a surface cyclone is located just to the east of Cape Cod. Surface geostrophic winds are primarily northeasterly across New York State. The composite gradient in sea level pressure is much larger than that of the warm cases (Fig. 2a).

Cold air advection at 850-hPa dominates the region during cold MHC events (Fig. 4b). The cold air advection in western New York is stronger than that in the warm cases. Looking closely at the Capital Region (see inset), a noticeable minimum in the cold air advection is evident. This minimum is indicative of neutral or slightly warm air advection occurring in the lower levels. This could possibly be due to downslope warming in the lee of the Adirondacks. A positively tilted trough is in place over the eastern United States with general north/northwesterly flow in New York and New England.

At 500-hPa, a maximum in relative vorticity is located over the Capital Region (Fig. 5b), implying no advection of relative vorticity at the peak of the MHC event. The thermal wind is parallel to the thickness contours, showing anticyclonic vorticity advection by the thermal wind would soon be occurring in the Capital Region. By the Sutcliffe-Trenberth form of the quasi-geostrophic omega equation predicts that the Capital Region is in an area of downward vertical motion at 500-hPa.

In the 300-hPa composite (Fig. 6b), a more amplified flow is seen compared to the warm MHC cases. A trough is located over the eastern United States. A 100 kt jet maximum can be seen well to the south of the New York, pushing off the coast of North Carolina. This jet streak location would put the Capital Region on the central poleward side of the jet.

The cold MHC composite sounding (Fig. 7b) shows backing winds from the surface through the mid-troposphere, consistent with the presence of 850-hPa cold air advection (Fig. 4b). At the lowest levels, there is veering of the winds, which is associated with the friction and terrain channeled flow. Though the composite can smooth out detailed features of the individual events, a weak inversion can be seen around 900-hPa. The sounding is saturated from the surface to 800-hPa. The blue dashed lines on the sounding indicate the dendritic growth zone which includes all of the low to mid- levels allowing for a good environment for snow growth.

*c. Cold MHC case study: 2 January 2008*

The 2 January 2008 MHC event was particularly significant because of its duration, intensity, and low predictability in the Capital Region. Officially, an additional 0.8 cm of snow was reported at KALB, but weather observers reported more significant accumulation attributed to MHC in various parts of the region, with 12.7 cm of additional snow reported in Cohoes, NY, on top of the nearly 28 cm produced by the cyclone’s synoptically-forced precipitation. The evolution of the event is shown in the radar and surface observation data in Fig. 8. The event started as a broad swath of precipitation that ultimately organized into a more band-like feature with a north-northwest to south-south east orientation. The location of Cohoes, NY (red dot) coincides with where the highest reflectivity was reported. Outside of this narrow band, little or no additional snow accumulation were reported.

At the surface (Fig. 9), much like in the composite, there is an area of low pressure located off the New England coast over Nova Scotia with a central pressure of 986-hPa. The cyclone tracked slightly west of 40°N, 70°W, which allowed the synoptic-scale precipitation to impact the Capital Region. This cyclone location helped to induce northeasterly geostrophic flow.

On the back side of the storm, there was cold air advection at 850-hPa over most of New York State (Fig. 10). There was a small area of warm air advection located over the Capital Region on the order of 0.4 *°*C h-1.. This could be associated with downsloping winds off the eastern Adirondack Mountains or the veering of the winds due to friction and terrain channeling. Much like the cold MHC composite the trough was positively tilted inducing a north/northwesterly wind over New York.

 At 500-hPa, the most important cyclonic relative vorticity maximum was located over Nova Scotia with the surface cyclone (Fig. 11). A deep trough can be seen in the eastern United states with strong cyclonic relative vorticity in the base of the trough associated with the curvature. At this time, cyclonic vorticity advection was occurring in the Capital Region, shortly prior to the evolution of the MHC event from a broad area of precipitation to a single band (Fig. 8).

A 300-hPa jet maximum of over 165 kts (Fig. 12) was located southeast of eastern New York and western New England along the downstream side of a deep trough over the eastern United States. Like the cold composite the flow is very amplified with a large trough in the east coast. This trough is also positively tilted.

Figure 13 shows the observed sounding from KALB at 1200 UTC 2 January 2008, which is two hours prior to the MHC maximum in reflectivity. As in the composite for cold cases, the boundary layer is very moist with temperatures less than 0*°*C. The winds in the observed sounding veer in the lower layers from the surface to around 800-hPa, consistent with low-level warm air advection (Fig. 10). The winds above this level begin to back, which is consistent with the cold air advection through the remainder of the troposphere, very similar to the composite sounding.

**5. Summary and conclusions**

 The Mohawk and Hudson River valleys as well as the Catskill, Adirondack, Berkshire, and Southern Green Mountains play a pivotal role in altering wind flow in the Capital Region of New York State. Through composite analysis and a case study, an increased understanding of the synoptic-scale setup common to Mohawk–Hudson Convergence (MHC) events will improve forecasts.

 The synoptic setup for warm cases of MHC includes a broad trough at 300-hPa over the eastern United States. Also there is weak cyclonic vorticity advection associated with an upstream shortwave and weak warm air advection associated with the warm sector of a cyclone are typical of warm MHC cases. Most importantly, weak boundary layer geostrophic southwesterly winds are channeled westerly in the Mohawk valley and southerly in the Hudson valley supplying unstable air to the greater Capital Region. The winds are typically weak in the pre-frontal environment in the Capital Region and there is little upper-level forcing for ascent.

The synoptic setup for cold cases of MHC is a strong upper-tropospheric jet with a trough over the East Coast with the jet maximum off the coast of North Carolina. Strong cyclonic vorticity advection leads to the deepening of an area of low pressure off the New England coast, increasing the surface pressure gradient over eastern New York. This strengthening of the pressure gradient leads to moderate northerly flow in the Hudson valley and northwesterly flow in the Mohawk valley. Cold MHC events are also characterized by a moist boundary layer with weaker cold air advection in the low-levels and drier air with cold advection in the mid-levels. The low-level warm air advection suggests rising motion in the lower atmosphere being capped by mid-level descent as a cyclonic relative vorticity maximum moves past the Capital Region. The low level rising motion being capped by mid-level descent supports the fact that these cases seem to be bound to the lowest levels of the atmosphere.

 MHC events are hard to predict because of their seemingly innocuous conditions on the large-scale, though they can quickly turn into high-impact weather events. Slight ascent from convergence in the river valleys causing upward vertical motion can lead to thunderstorms and quick bursts of precipitation. Figure 14 shows a checklist for forecasters to help them determine if MHC is probable.

Future advances in surface observation such as the New York State Mesonet will significantly help the prediction of MHC events as often surface level winds can show convergence before the onset of precipitation. Observations from the New York State Mesonet showed such surface convergence before the onset of precipitation in a case of *enhanced* cold MHC on 9 February 2017. Figure 15 shows the surface observations and the derived surface convergence from the 109 stations in the New York State Mesonet. Surface convergence was seen before the onset of the enhanced precipitation in the Capital Region making this data great resource for forecasters.

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**References**

Anders, A. M., G. H. Roe, D. R. Durran, and J. R. Minder, 2007: Small-scale spatial gradients in climatological precipitation on the Olympic Peninsula. *J. Hydrometeor.*, **8**, 1068–1081.

Augustyniak, M., 2008: A multiscale examination of surface flow convergence in the Mohawk and Hudson valleys. http://cstar.cestm.albany.edu/CAP\_Projects/Project13/index.htm

Bosart, L. F., A. Seimon, K. D. LaPenta, and M. J. Dickinson, 2006: Supercell tornadogenesis over complex terrain: The Great Barrington, Massachusetts, tornado on 29 May 1995. *Wea. Forecasting*, **21**, 897–922.

Carrera, M. L., J. R. Gyakum, and C. A. Lin, 2009: Observational study of wind channeling within the St. Lawrence River valley. *J. Appl. Meteor. Climatol.*, **48**, 2341–2361.

Gross, G., and F. Wippermann, 1987: Channeling and countercurrent in the Upper Rhine valley: Numerical simulations. *J. Climate Appl. Meteor.*, **26**, 1293–1304.

Jeglum, M. E., and S. W. Hoch, 2016: Multiscale characteristics of surface winds in an area of complex terrain in Northwest Utah. . *J. Climate Appl. Meteor.*, **55**, 1549–1563.

LaPenta, K. D., L. F. Bosart, T. J. Galarneau, and M. J. Dickinson, 2005: A multiscale examination of the 31 May 1998 Mechanicsville, New York, tornado. *Wea. Forecasting*, **20**, 494–516.

Markowski, P., and N. Dotzek, 2011: A numerical study of the effects of orography on supercells. *Atmos. Res.*, **100**, 457–478.

Mass, C. F., 1981: Topographically forced convergence in western Washington State. *Mon. Wea. Rev.*, **109**, 1335–1347.

Milrad, S. M. , E. H. Atallah, and J. R. Gyakum, 2012: Precipitation modulation by the Saint Lawrence River Valley in association with transitioning tropical cyclones. *Wea. Forecasting*, **28**, 331–352.

Razy, A., S. M. Milrad, E. H. Atallah, and J. R. Gyakum, 2012: Synoptic-scale environments conducive to orographic impacts on cold-season surface wind regimes at Montreal, Quebec. *J. Appl. Meteor. Climatol.*, **51**, 598–616.

Saha, S., et al. 2010: NCEP Climate Forecast System Reanalysis (CFSR) Selected Hourly Time-Series Products, January 1979 to December 2010. Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory. <https://doi.org/10.5065/D6513W89>.

Tang, B., M. Vaughn, R.A. Lazear, K. L.Corbosiero, L. Bosart, T. Wasula, I. Lee, and K. Tipton, 2016: Topographic and boundary influences on the 22 May 2014 Duanesburg, New York, tornadic supercell. *Wea. Forecasting*, **31**, 107–127.

Wasula, A. C., L. F. Bosart, and K. D. LaPenta, 2002: The influence of terrain on the severe weather distribution across interior eastern New York and western New England. *Wea. Forecasting*, **17**,1277–1289.

Whiteman, C. D., and J. C. Doran, 1993: The relationship between overlying synoptic-scale flows and winds within a valley. J. Appl. Meteor., **32**, 1669–1682.

Zhong, S., J. Li, C. D. Whiteman, X. Bian, and W. Yao, 2008: Climatology of high wind events in the Owens Valley, California. *Mon. Wea. Rev.*, **136**,3536–3552.

[Stefano Serafin](http://journals.ametsoc.org/author/Serafin%2C%2BStefano), [Lukas Strauss](http://journals.ametsoc.org/author/Strauss%2C%2BLukas), and [Vanda Grubišić](http://journals.ametsoc.org/author/Grubi%C5%A1i%C4%87%2C%2BVanda), 2017: Climatology of Westerly Wind Events in the Lee of the Sierra Nevada. . *Journal of Applied Meteorology and Climatology* **56**:4, 1003-1023.

Weber, R. O., and P. Kaufmann, 1998: Relationship of synoptic winds and complex terrain flows during the MISTRAL field experiment. *J. Appl. Meteor.*, **37**, 1486–1496.

Kossmann, M., and A. P. Sturman, 2003: Pressure-driven channeling effects in bent valleys. *J. Appl. Meteor.*, **42**, 151–158.

Kossmann, M., and A. P. Sturman, 2003: Pressure-driven channeling effects in bent valleys. *J. Appl. Meteor.*, **42**, 151–158.

Corbosiero,L. K, R.A. Lazear, 2013: Verification of Thunderstorm Occurrence Using the National Lightning Detection Network. *Sixth Conf. on the Meteorological Applications of Lightning Data*.