**Precipitation events associated with terrain-generated convergence in the Mohawk and Hudson River valleys of New York**

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**ABSTRACT**

The unique terrain found in eastern New York State plays a pivotal role in both the warm- and cold-season weather of the region. The west to east Mohawk and north to south Hudson River valleys intersect in the Capital Region of New York, and can result in localized flow channeling and boundary layer convergence. Several previous case studies have documented the important role of Mohawk–Hudson convergence (MHC) in modulating the low-level wind profile in cases of warm-season severe weather. However, a comprehensive, composite and case study analysis of these events, which pose a significant challenge to local forecasters, has not been previously published.

 Composite analysis shows that warm-season MHC precipitation events are characterized by weak warm-air advection and geostrophic southwesterly flow that advects low-level, warm, moist air up the Hudson River valley and westerly flow down the Mohawk River valley, leading to increased instability. Cold-season MHC events are characterized by weak cold-air advection from the northwesterly geostrophic flow which allows for surface flow to be channeled westerly down the Mohawk Valley and northerly flow to be channeled down the Hudson Valley. As well as remnant boundary layer moisture in conjunction with cyclones departing off the coast of New England. On this no

While most MHC events do not produce significant sensible weather, they can occasionally be impactful if they occur with little warning and/or during peak travel times. Cold, MHC precipitation can result in persistent moderate to heavy snow in the wake of a departing low pressure, whereas warm MHC cases often initiate an unexpected thunderstorm close to Albany International Airport. The case of 2 January 2008 was a significant cold season event which caused heavy snow in the Capital District Region effecting travel at Albany International Airport.

**1. Introduction**

 Flow channeling occurs when orographic features, such as breaks in mountain barriers or valleys through hilly terrain, act to change the local wind direction and/or speed. Oftentimes, this phenomenon reveals itself as a recurring area of surface wind observations that differ systematically from surrounding observations and/or the geostrophic wind direction, and which occur only under certain specific synoptic conditions. As will be shown below, the flow in the Capital District of New York state, where the Mohawk and Hudson River valleys intersect (Fig 1), meets each of these qualifiers for channeled flow.

 Classically, there are four main mechanisms that have been identified as creating channeled flow. The first mechanism, thermal forcing, results from the diurnal cycle of heating in complex terrain, which causes up-valley winds during the day and down-valley winds during the night. The second mechanism is downward momentum transport caused by vertical turbulent mixing by gravity waves and/or friction. This process generates in-valley winds that are of a similar direction as the overlying, ambient flow. The third mechanism is forced channeling, in which the wind is channeled by the valley walls creating a flow up or down the valley axis depending on the direction of the geostrophic wind. Lastly, the fourth mechanism for channeled flow, pressure driven channeling, is driven by small differences in pressure along the valley’s length (Whiteman and Doran 1993).

 Pressure driven channeling has also been found to be the predominant forcing for other river valleys in eastern North America such as the St. Lawrence River Valley, which contributes significantly to the weather around Montreal, Canada (Razy 2011). The St. Lawrence River Valley in eastern Canada allows surface wind patterns and contribute to locally higher precipitation amounts. This sometimes occurs as transitioning tropical cyclones establish a synoptic-scale pressure gradient in the valley which can lead to pressure driven channeling (Milrad 2012). Most events in the Hudson and Mohawk valleys seem to be in a response to pressure driven channeling (Augustyniak 2008).

Topography also plays role in mesoscale events in river valley regions around the United States. In post-cold front environments in the Puget Sound, which are responsible for spatial variations in the precipitation climatology in the Seattle region associated with mesoscale convergence events (Mass and Clifford 1981). The important effects of topography were also investigated in Zhong (2008) where the presence of topography can lead to thermally and dynamically induced mesoscale wind fields in the Owens Valley of California. It is important that winds are directed through these valleys in order to induce low level flow regimes. Complex terrain can also influence the climatological surface winds due to channeling effects (Jeglum and Hoch 2016). River valleys can offer a mix of complex flow regimes and topographic layout leading to mesoscale forcing.

Channeled flow via the mechanisms above has been shown to occur even in very shallow river valleys. For example, Gross and Wippermann (1987) documented channeled flow in Germany’s Rhine Valley, where the valley walls only extended to 500 m in height, much like the depth of the Mohawk and Hudson River valley. The Hudson Valley is a broad and shallow river valley oriented north-south direction, stretching from near Glens Falls, New York to New York City. The Mohawk Valley is fairly narrow compared to the Hudson River valley and is oriented from west to east stretching from Rome, NY to Albany, NY. As shown in Figure 1, these two valleys intersect in the vicinity of Albany, NY. In the Capital District Region the valleys are approximately 500 m deep and approximately 60 km across, which fitting the . This intersection can alter the wind flow in such a way that leads to weak surface convergence (known as Mohawk–Hudson convergence (MHC)), unpredicted and significant precipitation events, and even severe weather.

MHC events often happen with very little warning and can have significant societal impacts. Cold MHC convergence can create moderate snowfall and additional accumulation of snow on the tail of nor’easters, prolonging the plowing and salting of roads. Often times, these isolated light to moderate snowfall events can extend periods of instrument flight rules (IFR), or even low instrument flight rules (LIFR), conditions at Albany International Airport. Warm MHC events can also quickly impact operations at Albany International Airport and affect the Capital District through the development of discrete convective cells. Channeled, southerly flow up the Hudson River Valley can add to the background instability and increase the vertical wind shear, which can rapidly turn discrete cells severe and even influence supercell and mesoscale convective system development (Markowski and Dotzek 2011). The channeled flow is also known to affect the formation of tornadic as topographic influences have been examined in cases such as the Duanesburg (Tang 2016), Mechanicville (LaPenta 2005), and Great Barrington (Bosat 2006) tornadoes.

MHC events only happen under stringent atmospheric conditions and often these events happen without warning as these events are difficult to predict by local forecasters. By preforming a composite analysis of past events we will be able to pinpoint synoptic scale precursors to these types of events.

**2. Data and methodology**

*a. Case selection*

All cases were chosen based on radar analysis of KENX base reflectivity to locate isolated precipitation events within a 16 km radius of Albany International Airport. Evidence for boundaries such as fronts, troughs, and/or cold pools from ongoing convection were identified from surface and upper air analyses, and radar. Cases in which precipitation was directly initiated by these features were discarded.

For the warm season MHC events, every event was analyzed in which lightning was reported in the Albany International Airport (KALB) METARs. These cases had to reach a minimum of 30 dBz. Cases were also verified by looking for a nose of increased, surface based convective available potential energy (SBCAPE) being advected northward up Hudson Valley. There was a subset of 17 warm-season events in which convection was initiated as the result of other mechanisms (e.g., prefrontal trough, cold pool dynamics, etc.), but were enhanced by MHC. As this paper seeks to analyze only clear MHC events, the “enhanced by MHC” events were excluded from study. In total, 19 pure warm cases were identified from July 2003 to August 2014.

For the cold season MHC events any case in which a low tracked west of 40N and 70W benchmark were analyzed. These events were examined to make sure no lake-effect, or lake-enhanced, snow took place. In total, 12 cold cases were identified from November 2002 to September 2013.

*b. Data*

 Surface observations were obtained from the Iowa State Archive and radar data was obtained from the National Centers for Environmental Information. Warm and cold-season MHC composites were created using 0.5° Climate Forecast Systems Reanalysis (CFSR) (Saha et al. 2010). Using the CFSR for the composites was justifiable to visualize the synoptic scale features in the composites as we were not using it to visualize the mesoscale phenomenon. The 2 January 2008 case study uses the 13-km resolution Rapid Update Cycle (RUC) model initialized at 1200 UTC 2 January 2008.

Acknowledgements. I would like to extend my thanks to two graduate students who have written work on MHC events that helped me prepare for this research, Mike Augustyniak and Christine Bloecker. I would also like to thank two faculty members at the University at Albany for their previous work on the topic of Mohawk-Hudson Convergence, Lance Bosart and . A special thanks to the National Weather Service Albany and the UAlbany DAES Internship Program at the National Weather Service Albany for helping to classify events of both cold and warm Mohawk-Hudson Convergence. Finally, I would like to thank Tomer Burg and Eric Bunker for providing some paliminary proof reading of this document.

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