1. INTRODUCTION

Substantial changes in the precipitation regime, particularly in heavy precipitation, have been observed in the northeastern United States (e.g., Groisman et al. 2005; Karl et al. 2009; Walsh et al. 2014; Douglas and Fairbank 2011). However, there has been little to no discussion regarding how the observed changes in precipitation in the eastern and northeastern United States (hereafter “the Northeast”) may be driven by changes in moisture source region or transport mechanism. In fact, a thorough understanding of water vapor fluxes in the Northeast does not currently exist. Because the Northeast is particularly sensitive to global climate change, both in the sense that it is a heavily populated region reliant on a multiplicity of climate-dependent economies, as well as in the sense that the regional weather patterns are greatly influenced by internal and external factors such as topography, land-ocean interactions, and transient cyclones, this shortcoming must be addressed to better understand changes in the regional hydroclimatic regime, ocean interactions, and transient cyclones, this internal and external factors such as topography, land-region is either very dry or advancing slowly (e.g., Fig. 1, Node 13) Some patterns reflect recognizable pressure patterns, such as an anticyclone centered over the East Coast in Nodes 14 and 15. A sum of IVT per pressure patterns, such as an anticyclone centered over the East Coast in Nodes 14 and 15. A sum of IVT per grid cell indicates that the nodes with strongest IVT stem from the top right (Node 4) along the edges of the SOM node array, and the nodes with the weakest IVT are clustered in the bottom left corner of the SOM node array.

3. RESULTS & DISCUSSION

The 16 IVT patterns show a wide range of water vapor fluxes influencing the study region. While some patterns depict broad systems IVT, other show confined corridors of enhanced water vapor fluxes (Fig. 1, Node 11 and Nodes 1–4, respectively). Other patterns show very little IVT, indicating that air moving through the region is either very dry or advancing slowly (e.g., Fig. 1, Node 13). Some patterns reflect recognizable pressure patterns, such as an anticyclone centered over the East Coast in Nodes 14 and 15. A sum of IVT per grid cell indicates that the nodes with strongest IVT stem from the top right (Node 4) along the edges of the SOM node array, and the nodes with the weakest IVT are clustered in the bottom left corner of the SOM node array.
The number of times each pattern occurred from 1979–2017 is indicated in Figure 2. Node 13 occurred most frequently, as any day with little IVT were likely sorted into this pattern. The nodes with extreme water vapor transport, located along the top row and left column of the SOM node array, each occur less frequently but still comprise nearly 25% of the study period, indicating that these patterns play a large role in the hydroclimatology of the Northeast. Node 4, showing the most intense water vapor fluxes over the Eastern Seaboard land area, influences the study area 8–9 times per year on average; given the extreme precipitation that likely is associated with IVT values in this range, the presence of this pattern may result in heavy precipitation and flooding if a lifting mechanism forces precipitation to occur.

The seasonality of each node is also distinct. Some nodes exhibit strong seasonality; others show little tendency to occur in one season over another (Fig. 3). Node 13, the most common pattern, dominates winter months in the study area. Conversely, Nodes 6 and 15 dominate the summer months. Other patterns show little seasonality; for example, Node 4 does not occur with any seasonality, indicating that this pattern of extreme IVT is equally likely to occur in any season.

The assessment of AR activity in these water vapor fluxes shows that ARs are an important component of the regional hydroclimatology. While most patterns contain levels of IVT above the AR threshold (Fig. 4), the long, narrow bands of enhanced moisture transport seen in the top row (Nodes 1–4) likely meet the spatial definitions of ARs as well, though we are unable to measure the fluxes outside the bounds of the study area. This finding suggests that ARs regularly influence the hydroclimatology of the Northeast. The frequency of AR water vapor transport through the study region challenges the definition of ARs and whether the definitions currently in practice are useful for the Northeast. We suggest that the AR definition be re-
examined while questioning if the foundation of the definition is the anomalous water vapor content, the shape and transport mechanism of enhanced water vapor, or the resulting precipitation. When historical daily IVT from ERA-20C were classified into the SOM-identified water vapor fluxes, many visible trends in the frequency of each node became apparent (Fig. 5).

Fourteen of the flux patterns showed significant trends. All but 2 of these trends show significant increases in node frequency; these increasing trends exist in the top 2 rows and left 2 columns of the node patterns. Decreasing frequency trends occurred in Nodes 13 and 14. These trends suggest that strong-IVT patterns have been increasing in frequency at the expense of weak- or
no-IVT patterns over the 20th century. While these results are logical given the increases in precipitation observed in the study area over the past century, caution should be exercised while interpreting results based on reanalysis products. Changes and additions to the data being assimilated into the reanalysis product may produce false trends. Additionally, the skill of the reanalysis product in representing the variable in question should also be considered when interpreting results.

4. CONCLUSIONS

In this research, a climatology of water vapor fluxes through the Northeast and surrounding areas is identified and characterized. Overall, 16 unique patterns of water vapor fluxes were found to be typical of the study area. These patterns occur with distinct seasonalities to form the foundations of the atmospheric component of the regional hydroclimatology. While not the most common patterns, extreme IVT patterns are an important part of this story. Some of these extreme IVT patterns by some definitions could be considered ARs; however, given the debates surrounding the definition of ARs as research into the phenomena expands from the US West Coast and Europe, we urge new discussion into the definition as it is applied elsewhere. Finally, we detect trends in the historical analysis of water vapor fluxes over the study area, with patterns representing high moisture transport significantly increasing in frequency at the expense of the patterns with low moisture transport. This aligns with observations in increases in precipitation and heavy precipitation in the Northeast.

Future work includes direct association of these water vapor flux patterns with observed precipitation, as the presence of water vapor fluxes alone does not necessarily indicate precipitation. Future work also includes examination of temporal flux variability within each pattern to determine if fluxes are becoming more or less saturated over time, and the effect of those changes on precipitation on the ground. We expect to find trends aligning with the Clausius-Clapeyron relationship, as well as changes in the characteristics of the water vapor fluxes which account for the dramatic increase in extreme precipitation observed in the Northeast.

![Graph of water vapor flux patterns](image)

**FIG 5.** Number of times each node occurs per year in ERA-20C daily IVT, 1900–2010. Red lines indicate significant trends at α<0.05 confidence level. Horizontal axes are identical in each subplot.
5. REFERENCES


