Application of Self Organizing Maps to Winter Precipitation on the Delmarva Peninsula

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Introduction

Self-organizing maps (SOMs) have been shown to be an effective use of machine learning tools for meteorological forecasting. Winter precipitation forecasting has been shown to be difficult on the Delmarva Peninsula due to numerous marine influences. In this study, we identify important features for winter weather on Delmarva, and trained the system to recognize winter precipitation conditions. This study utilizes data from the North American Regional Reanalysis product (NARR) using moisture and temperature variables at 21 levels in the low- to mid-troposphere from 1979 to 2017. The SOM was trained using only data from winter months and resulted in 15 common atmospheric modes. NARR is a long-term, consistent, high resolution climate dataset for the North American Domain, and was chosen for its gridded qualities. The days mapping to each SOM node are temporally aligned to winter precipitation data for multiple ASOS stations on the Delmarva Peninsula.

Methods

- NARR 3-hourly temperature and specific humidity data were acquired for every 25 hPa from 1000 hPa to 700 hPa, and every 50 hPa from 700 hPa to 500 hPa (Resulting in 17 pressure levels).
- Data were clipped to only include NARR gridpoints between 40–43°N and 74–77°W and data for December, January, and February from 1979–2017 were analyzed.
- 1-hourly ASOS data were acquired for all available stations on the Delmarva Peninsula for the period 1979–2017.
- SOMs were created by using the SOM Toolbox for MATLAB.
- A suite of 5x3 SOMs with 1000 training iterations , were trained using different input variables.
  - All 82 grid points, temperature and specific humidity (2925 dimensional vector).
  - Closest grid point to site being analyzed (e.g. Dover), temperature and specific humidity (34 dimensional vector).
- The output from the SOM gives a best-matching unit (BMU), which is the node closest to each NARR observation in the data space.
- MATLAB scripts were developed to query the ASOS data to find winter precipitation identifiers including 'SN', 'FZRA', 'PL' which correspond to snow, freezing rain, and ice pellets.
- Each NARR 3-hourly environment was compared to the three closest ASOS observations (i.e. the 3Z NARR environment was compared to ASOS observations at 2Z, 3Z, and 4Z.)
- If winter precipitation was observed during any of those ASOS observations, that NARR environment is marked as having winter precipitation.

Discussion

The output from the SOM with temperature and specific humidity as training input indicates increased weighting on the moisture variable. The single grid point SOM yielded improved results and better interpretability over the SOM trained with all 82 grid points. Nodes 3–5 are the freezing rain and sleet nodes as evidenced by the large increases in freezing rain and sleet observations mapping to these nodes compared to the expected frequency (e.g. the frequency on all winter days). At the Dover ASOS site, 50.3% of all freezing rain observations and 57.4% of all sleet observation occur during node 5. This node is nearly 12 times more likely to occur when sleet or freezing rain is observed compared to its normal expected frequency. This is likely due to these nodes have ample moisture throughout the profile coupled with sufficiently cold temperatures.

Results

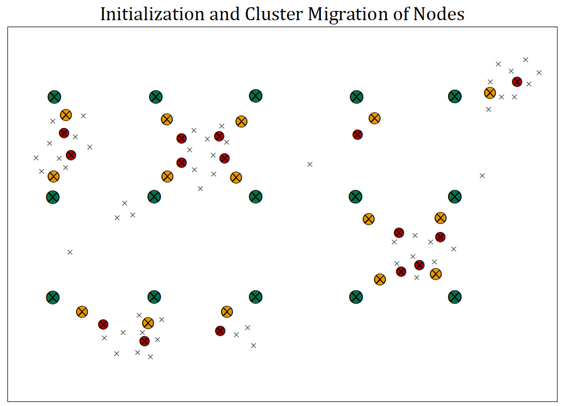


Figure 1. A 5x3 initialized grid SOM (Green) migrates to clusters of similar atmospheric composition data (Yellow) and settles in new positions (Red).

Figure 2. ASOS stations used in the study. The Delmarva Peninsula's atmospheric patterns are unique and relatively unstudied.

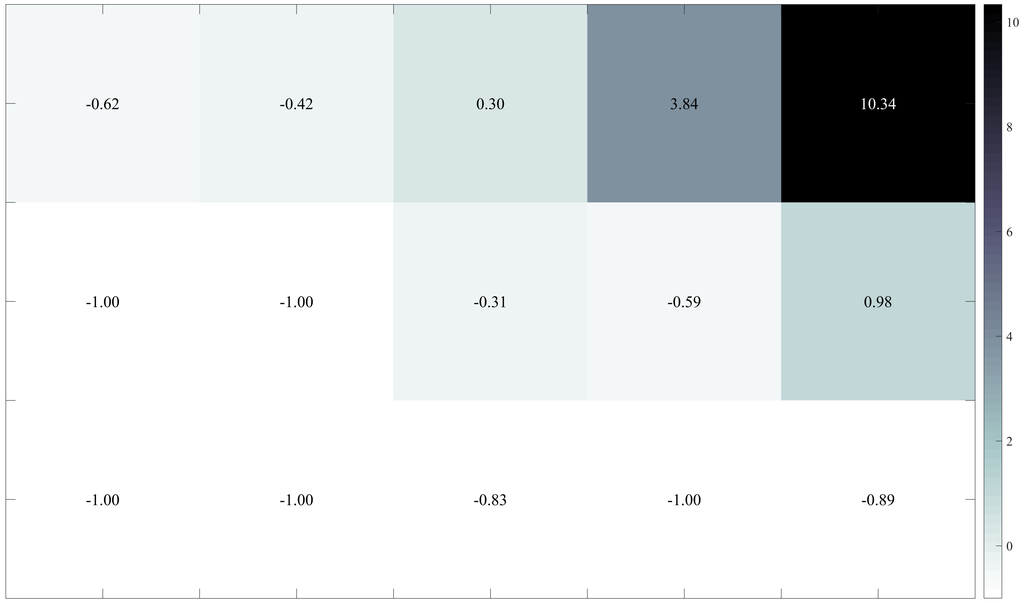
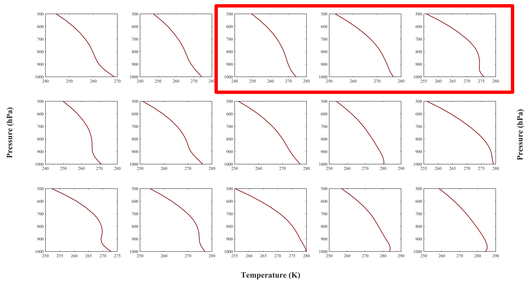


Figure 3. Departures in node frequency compared to expected frequencies during freezing rain observations. Negative (positive) values indicate those nodes are less (more) likely to occur when freezing rain is observed. Node 5 indicates that it is over ten times more likely to occur when freezing rain is observed compared to expected, climatological frequency.



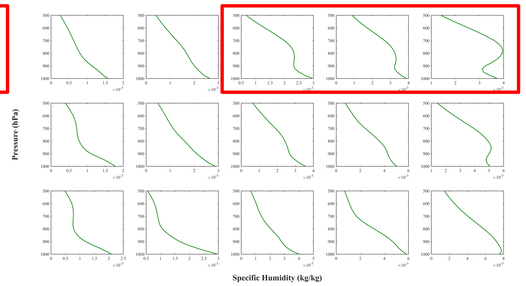


Figure 4. (Left) Temperature profiles of the atmosphere represented in the 15 nodes produced from the SOM. Notice that Node 1 is the coldest environment (upper right), but our winter precipitation is best represented in nodes 3-5.

Figure 5. (Right) Humidity profiles of the atmosphere are represented in these nodes where the most moisture is found in node 15 (lower right). Again, nodes 3-5 show a distinct atmospheric "set up" with a strong dry/wet division layer.

Conclusions

- Freezing rain and sleet seem to have higher predictive ability and tend to group to similar nodes (3–5).
- Nodes 1–5 are present in 70% of snow observations, however, there are still many observations mapping to nodes 12–15 which appear too warm to support snow.
- Future work will identify better predictor variables for snow that will be used to train the SOM and will focus on the snow growth region by identifying the most important moisture/temperature variables. More future work will train site-specific or localized SOMs as it appears that there is great variability in winter precipitation observations across the Delmarva Peninsula (and all sites can't be treated similarly).

References and Acknowledgements

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NARR Dataset from Fedor Mesinger et. al, submitted to BAMS 2004.