Relationships between Snow Depth and the Madden-Julian Oscillation using Self-Organizing Maps

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Introduction

Weather and climate are driven by the variability of the differing wind patterns of atmospheric circulation (Lutgens and Tarbuck 2013). Some planetary scale oscillations that impact weather include the El Niño Southern Oscillation, the North Atlantic Oscillation, the Arctic Oscillation, and the Madden-Julian Oscillation (MJO) (Henderson et al. 2013). Considering MJO's dominance in intraseasonal variability (Zhang, 2013), it is an integral oscillation for meteorologists to continue to track, analyze, and study in order to gain a better understanding of weather and climate on intraseasonal time scales in varying locations around the globe.

Additionally, snow cover is important to analyze and research because it is an essential part of both the water cycle and the heat balance of the earth due to albedo (Pavel et al. 1994). Considering snows impact on the water cycle, the heat balance and the ecological system, deviations in the normal amount of snow cover in a particular region can have lasting effects (Brown and Mote 2009). One way to analyze MJO in relation to snow depth change is through the use of self-organizing maps (SOMs). SOMs organize large data sets into a two-dimensional array that clusters the data set based off of similarities (Skific and Francis 2012). This method of clustering is instinctive to operational meteorologists because the clustering looks similar to synoptic charts in the way they are organized (Skific and Francis 2012).

Purpose

The main purpose of this research is to better understand changes in snow depth on the time scales of MJO. Self-organizing maps were used to explore patterns of snow variability across the Northern Hemisphere, and then these patterns were analyzed for connection to the MJO.

Data

* Snow depth data from North America and Eurasia was obtained from ERA-interim dataset from the European Centre for Medium-Range Weather Forecasts (ECMRWF 2009).
*The snow depth variable was compiled from 1980 to 2013 in the month of March.
*MJO index values from the real-time multivariate MJO index were used (Wheeler and Hendon 2004).

Methods

1. Filtered the data and created snow depth change anomalies based on averaging like calendar days
2. Ran the SOM program and created snow depth change anomaly figures
3. Created histograms of MJO by phase according to weight of SOM nodes
4. Through the use of SOMs, trained snow depth change anomalies and grouped into similar nodes through 600 iterations
5. Created [3,5], [5,5] and [5,7] arrays for North America and Eurasia
6. Through the use of the RMM, grouped significant nodes in relation to frequency of MJO by phase

Results: SOMs

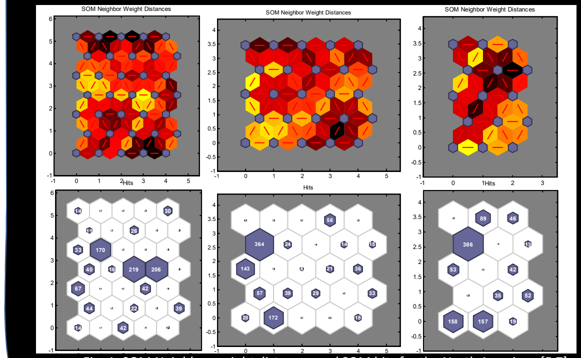

Fig. 1: SOM Neighbor weight distances and SOM hits for the North American [5,7], [5,5], and [3,5] arrays from left to right. In the first panel, the darker colors—maroon, brown, dark orange—represent greater neighbor node connections than the lighter colors—yellow, orange, light red. In the second panel, the most populated nodes have the highest numbers within that node; they have the highest number of hits.

Results: Snow depth change anomalies

[3,5] North American Array

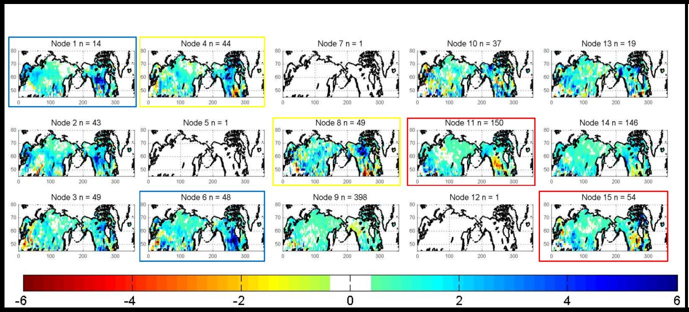

Fig. 2: [3,5] NA array showing snow depth change anomalies in mm. The boxed nodes display the most notable dipole (yellow), above normal (blue) or below normal (red) snow depth change anomaly characteristics.

[3,5] Eurasian Array

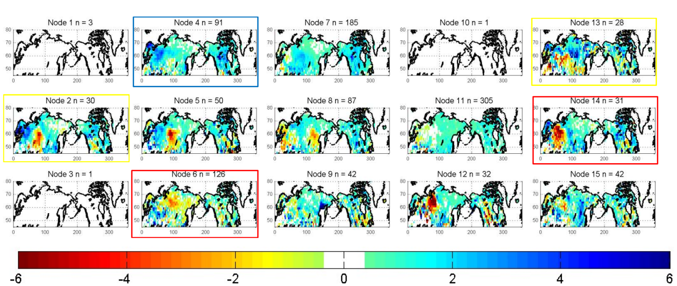

Fig. 3: Same as Fig. 2 but for the [3,5] Eurasian array.

Results: Relative frequency of MJO by phase

North America

Eurasia

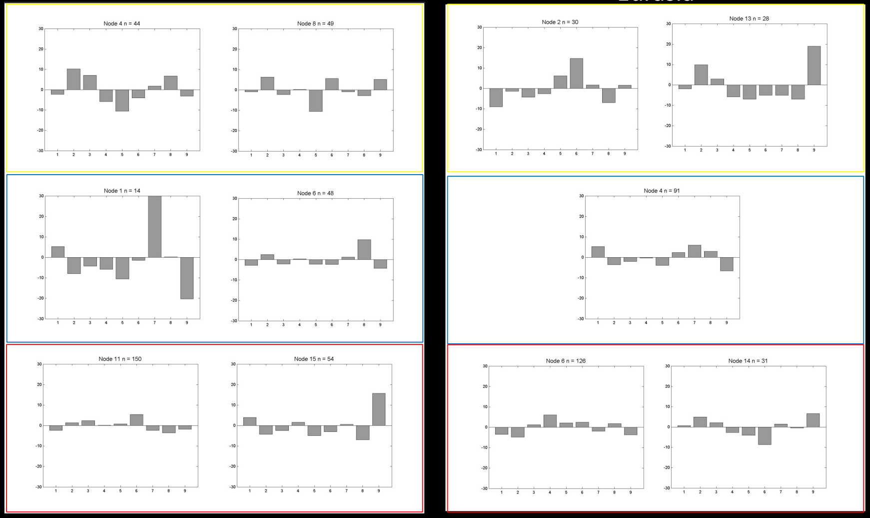

Fig. 4: The six nodes from the NA relative frequency histogram (left) and the five nodes from the Eurasian frequency histogram (right) that show dipole, above, and below snow depth change anomaly characteristics. The yellow box indicates dipole nodes, the blue box indicates above normal snow depth change anomalies, and the red box indicates below normal snow depth change anomalies. The y-axis shows MJO by phase and the x-axis shows the percent the significant days within that node deviate from normal .

Results

SOMs (Fig. 1):

1. Of the 15 nodes in the [3,5] array, 11 have more than 10 members: it is 73% populated.
2. Of the 25 nodes in the [5,5] array, 15 nodes have more than 10 members; it is 60% populated.
3. Of the 35 nodes in the [5,7 array, 17 nodes have more than 10 members; it is 49% populated.

* Taken together, these results suggest that the [3,5] array is the most appropriate to visualize snow depth change anomaly data

Snow depth change anomalies (Figs. 2-3):

1. For NA, nodes 4 and 8 show dipole characteristics (yellow boxes). For Eurasia, nodes 2 and 13 show dipole characteristics.
2. For NA, nodes 1 and 6 show above normal snow depth change anomalies (blue boxes). For Eurasia, only node 4 shows notable above normal characteristics.
3. For NA, nodes 11 and 15 show below normal snow depth change anomalies (red boxes). For Eurasia, node 6 and 14 show notable below normal characteristics.

* The NA array showed one more above normal snow depth change anomaly node than Eurasia. However, the Eurasian array showed more distinct dipole nodes.

Relative frequency of MJO by phase (Fig. 4):

1. Eight of the eleven significant nodes display a below normal occurrence of MJO phase 5.
2. MJO phase 6 displays an above normal occurrence for two of the NA dipoles and a below normal occurrence for one of the below normal snow depth change anomaly nodes.
3. MJO phase 8 displays an above normal occurrence for one above normal snow depth change anomaly node and fewer occurrences for two below normal nodes.

Conclusions

1. The SOM neighbor weight distances and number of populated nodes for North America and Eurasia show that of the three arrays chosen and analyzed, the [3,5] array is the best representation of the snow depth data.
2. SOMs are useful in organizing nodes into dipole (yellow), above normal (blue), and below normal (red) snow depth change anomalies when dealing with a snow depth variable.
3. There appears to be more above normal snow depth change in North America than in Eurasia.
4. There appear to be connections between snow depth change anomalies and occurrences of MJO by phase.

References

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Future Work

The usefulness of SOM methodology to the atmospheric sciences lends itself to much more research. This study would be made more complete if all of the months were analyzed and not just October. Also, though it was found that the [3,5] array was the best choice given two other array sizes—[5,5] and [5,7]—more research needs to be done on array sizes and which is most optimal for each type of atmospheric research. In addition, the number of iterations chosen for this study was arbitrary; thus, additional research on more than 600 and less than 600 iterations should be done in order to compare the resulting SOMs. Though the patterns should remain constant, it would be useful to note the slight nuances since more iterations means more fine-tuning. Finally, this research would be made better if more geographical locations were analyzed and compared to Eurasia and North America.