Constructing a Synoptic Climatology of Greenland Surface Ice-Melt Events using Self-Organizing Maps

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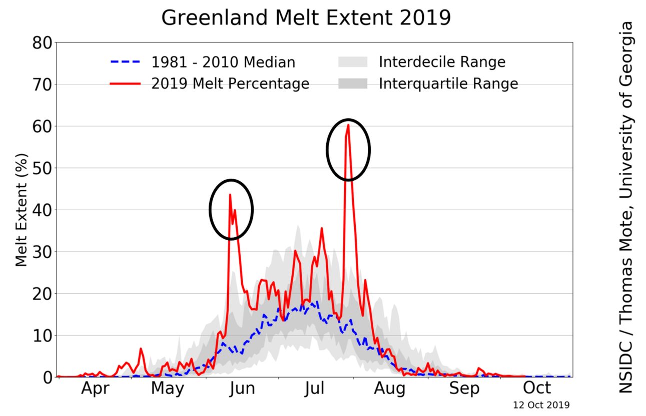
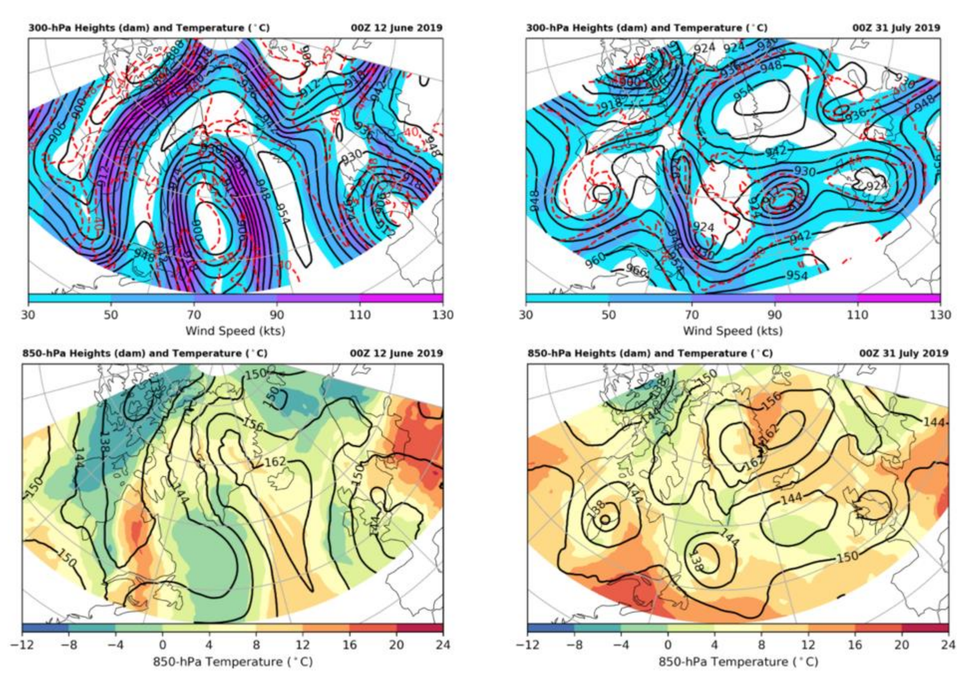
Introduction



The Synoptic Flow Patterns over Greenland During the Peak of the Two Major Greenland Ice-Melt Events of 2019



•On 12 June, two corridors of strong poleward warm air advection, one directed towards Baffin Bay and the other directed towards eastern Greenland, were associated with a deep trough over North America and a cutoff cyclone over the western North Atlantic

•On 31 July, very warm Saharan air was able to reach Greenland from the east in conjunction with a westward-moving Scandinavian blocking anticyclone

•Synoptic flow patterns conducive to Greenland surface ice-melt events, similar to the aforementioned events that occurred in 2019, are becoming increasingly more common as the Arctic warms (Mioduszewski et al. 2016)

•Intense, short-lived atmospheric rivers can advect high moisture poleward towards Greenland, resulting in Greenland surface ice melt by increasing downwelling longwave radiation (Mattingly et al. 2016)

Data and Methods

•This study utilizes self-organizing maps (SOMs), a type of artificial neural network that clusters data points into various nodes according to the similarity between the data points, in order to classify synoptic flow patterns that contribute to Greenland surface ice-melt events

•Use ERA5 data at 0.25° resolution (regridded to 1° resolution) for the April–October 1979–2019 time period

•Select days during the aforementioned time period where Greenland surface ice melt is at or above the 90th percentile compared to climatology according to the National Snow and Ice Data Center

•500-hPa geopotential height and sea level pressure (SLP) data are entered into the SOMs algorithm independently where the Greenland surface ice-melt event criterion is met to conduct one-variable SOM analyses

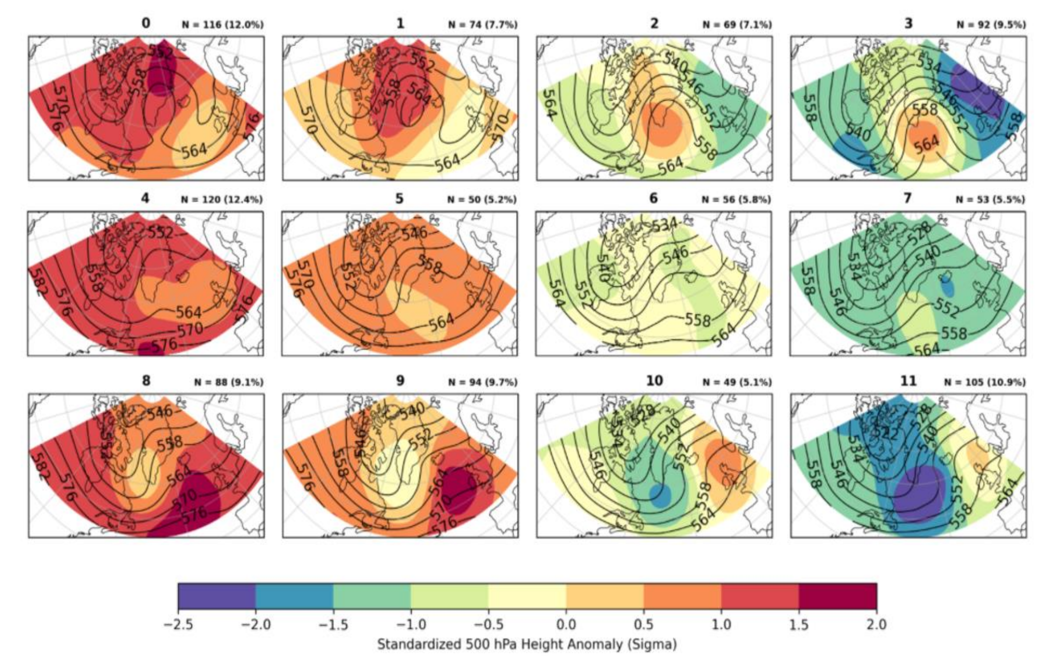
•700-hPa geopotential height and integrated water vapor transport (IVT), as well as SLP and 1000–500-hPa thickness data, are entered into the SOMs algorithm together where the Greenland surface ice-melt event criterion is met to conduct two-variable SOM analyses

•A 4 x 3 SOM size is chosen to display the full range of variability in the synoptic flow patterns

•The averages of the aforementioned variables are calculated for each node produced by the SOMs algorithm over a Greenland domain

One-Variable SOMs

500-hPa Geopotential Height (dam)

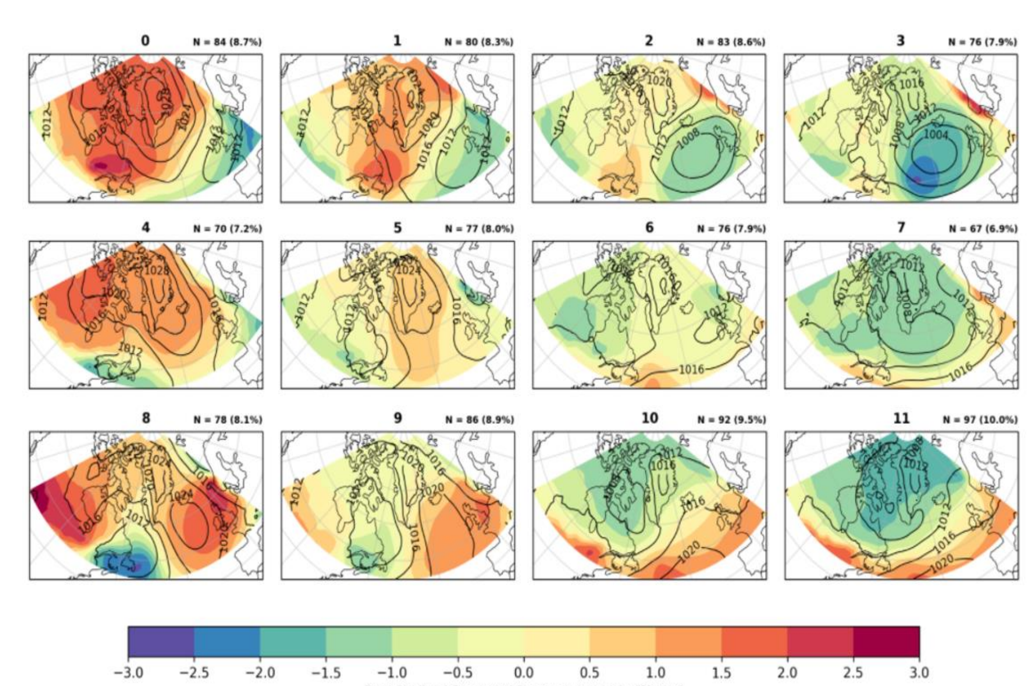


•The synoptic flow patterns transition from a strong ridge (positive 500-hPa geopotential height anomalies) in the top left corner, to a positively tilted trough upstream of Greenland in the second row, to a strong negatively tilted trough (negative 500-hPa geopotential height anomalies) upstream of Greenland in the bottom right corner

•Nodes 2 and 3 show a trough–ridge–trough pattern with a strong 500-hPa geopotential height gradient over Greenland

•The synoptic flow patterns tend to have the largest variability between rows, while the geopotential height anomalies tend to decrease between columns (from left to right) in each row, with only small changes in the synoptic flow patterns between columns in each row

SLP (hPa)



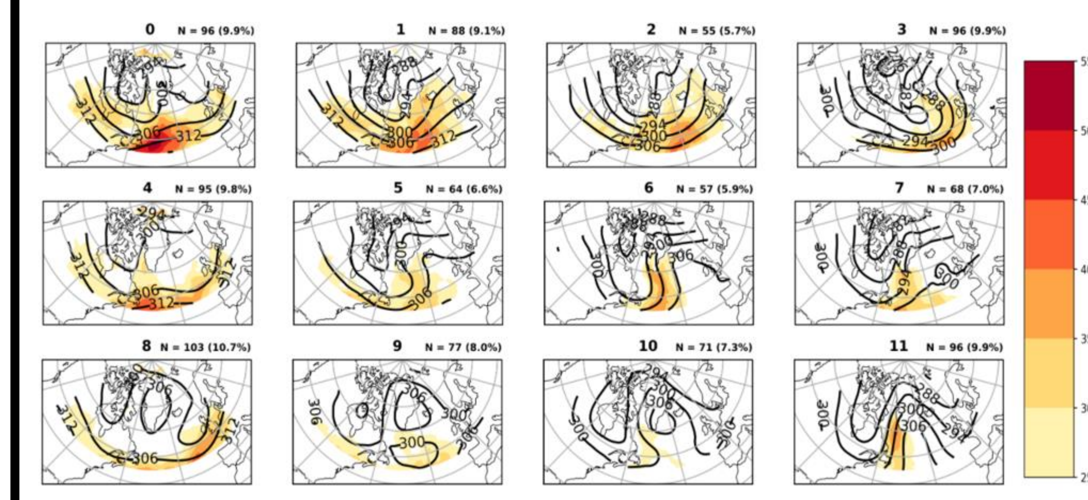
•The SLP transitions from high pressure (positive SLP anomalies) in the top left corner to low pressure (negative SLP anomalies) in the bottom right corner over Greenland

•Nodes 2 and 3 show strongly negative SLP anomalies near Iceland, which is indicative of the climatological Icelandic low

•Node 8 shows strongly negative SLP anomalies over far northeastern North America and strongly positive SLP anomalies over the north-central U.S. and eastern North Atlantic

Two-Variable SOMs

700-hPa Geopotential Height (dam) and IVT (kg m^{-1} s^{-1})



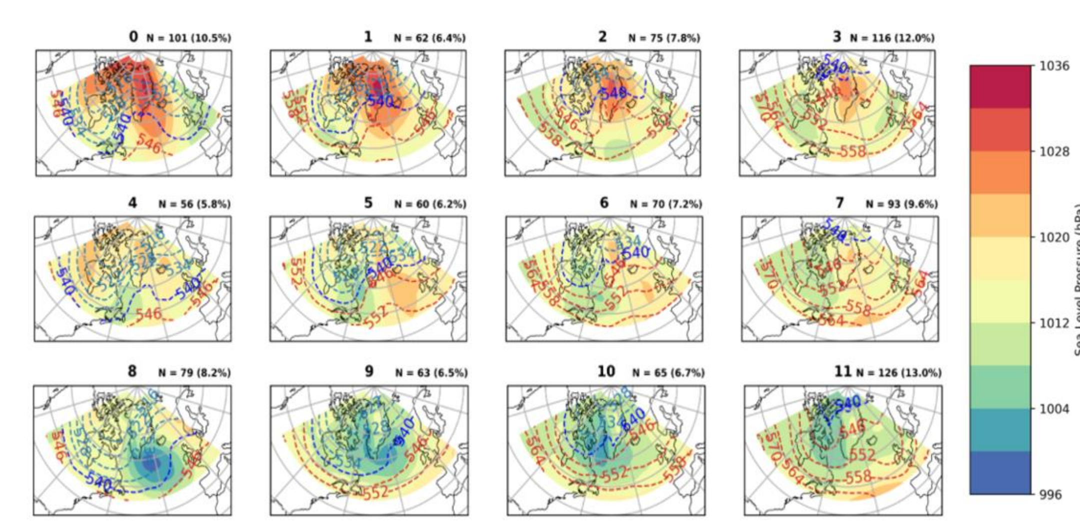
•Nodes 0–2 show a short-wave trough upstream of Greenland with highest IVT south and east of Greenland

•Node 3 shows a negatively tilted trough over the eastern Atlantic with highest IVT directed toward Europe

•Nodes 8, 9, and 10 show little poleward directed IVT, with a strong blocking pattern over Greenland

•Nodes 6, 7, and 11 show high poleward directed IVT, with a deep trough over eastern North America

SLP (hPa) and 1000–500-hPa Thickness (dam)



•The SLP transitions from higher SLP over Greenland in the first row to lower SLP over Greenland in the last row, with little variation in SLP between columns within a given row

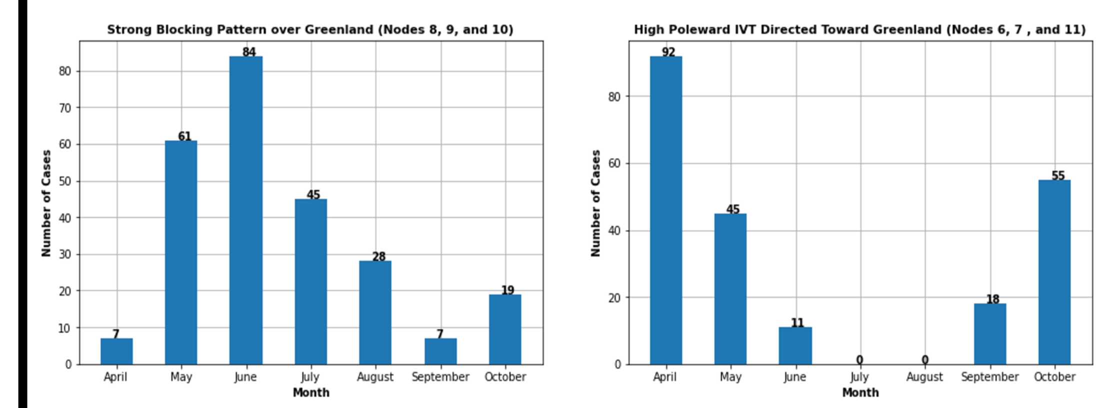
•The 1000–500-hPa thickness increases over Greenland from left to right within a given row indicating a warmer air mass for a similar SLP pattern

•The 540-dam thickness contour can be used to separate polar air from middle-latitude air

•The 540-dam thickness contour is located north of Greenland in the warmest nodes, while the 540-dam thickness contour is located over the northern U.S. in the coolest nodes

Seasonal Variations in Synoptic Flow Patterns

700-hPa Geopotential Height/IVT SOM Seasonal Analysis



•Cases where there is a strong blocking pattern over Greenland (nodes 8, 9, and 10) occur more frequently in summer than in spring and autumn

•Cases with high poleward IVT directed toward Greenland (nodes 6, 7, and 11) occur more frequently in spring and autumn than in summer

Conclusions

•The SOMs algorithm identifies three main types of synoptic flow patterns during Greenland surface ice-melt events:
- A strong ridge over Greenland
- A positively tilted trough upstream of Greenland
- A strong negatively tilted trough upstream of Greenland

•Greenland surface ice-melt events can occur in conjunction with both high SLP and low SLP over Greenland

•The warmest nodes tend to have higher SLP over Greenland with the 540-dam thickness contour located north of Greenland, while the coolest nodes tend to have lower SLP over Greenland with the 540-dam thickness contour located over the northern U.S.

•Nodes that show the highest poleward IVT directed toward Greenland tend to have a deep trough over eastern North America, while nodes that have little IVT directed toward Greenland tend to have a strong blocking pattern over Greenland

•Greenland summer ice-melt events tend to occur in conjunction with a strong blocking pattern over Greenland, while major Greenland spring and autumn ice-melt events tend to occur in conjunction with high poleward IVT directed toward Greenland

References

Mattingly, K. S., Ramseyer, C. A., Rosen, J. J., Mote, T. L., and Muthyala, R. (2016), Increasing water vapor transport to the Greenland Ice Sheet revealed using self-organizing maps, Geophys. Res. Lett., 43, 9250– 9258, doi:10.1002/2016GL070424.

Mioduszewski, J. R., Rennermalm, A. K., Hammann, A., Tedesco, M., Noble, E. U., Stroeve, J. C., and Mote, T. L. (2016), Atmospheric drivers of Greenland surface melt revealed by self-organizing maps, J. Geophys. Res. Atmos., 121, 5095– 5114, doi:10.1002/2015JD024550