EGU24-5669, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-5669
EGU General Assembly 2024

When winter is weird: Quantifying the change in winters across the Arctic

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Arctic winter climate is rapidly changing, with more variable snow depths, spring snowmelt timing, and more frequent midwinter thaw events. Less predictable conditions disrupt ecosystem balances and development in Arctic communities, and understanding winter variability across the Arctic and its influence on climate the whole year is needed to mitigate consequences of changing winters. However, access to *in situ* measured data has been extremely limited and scattered in local databases. Hence, cross-Arctic winter studies are few and based on remotely sensed data with larger spatial and temporal coverage, but less local sensitivity, and the winter contribution to annual average temperature change has not been investigated across the Arctic.

In this project, which runs January 2024-December 2025, we 1) obtain, clean and standardize *in situ* soil surface temperature, snow depth and soil moisture data from climate monitoring programs across the Arctic and create a unique database with cross-Arctic *in situ* winter climate data from the last appr. 30 years. We will use this dataset to 2a) estimate the accuracy of remotely sensed soil surface temperature, snow depth and soil moisture data using the regression model with the best fit, and quantify the bias, for each major Arctic region. We further 2b) construct an open access Winter Variability Index (WVI) for each major Arctic region based on the winter phenomena (average snow depth, snowmelt date, frequency of winter thaw events) that are most important drivers of a clustering analysis such as hierarchical clustering or autoencoders. Finally, we 3) use the change in WVI and in annual mean temperatures for each decade in a function-on-function regression analysis, which will quantify the contribution of winter variability change to annual average temperature changes in each Arctic region.

The project will produce a comprehensive dataset with potential for further research and will improve our region-specific understanding of remotely sensed data accuracy, and the WVI allows scientists or local communities to classify Arctic winter data within a quantitative framework of pan-Arctic winter variability also in the future, and to understand how important changes in winter variability is for Arctic climate changes the whole year.