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Self-organising maps and surface melt on East Antarctic ice shelves

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Surface melt occurs on most ice shelves in Antarctica each summer, with potential impacts on their strength and stability and thus on the ice sheet's contribution to global sea level rise. However, many questions remain regarding the spatiotemporal variability of surface melt and the processes driving it, particularly in East Antarctica where few in situ observations exist. Previous work in this field has largely relied on remote sensing observations to monitor the occurrence and extent of surface melt, often using metrics such as the onset and freeze-up dates of melt each summer, the number of melt days, or the cumulative melting area. Whilst such metrics are often necessary to handle the sheer volume of data produced by satellite observations, much of the information contained within the datasets is lost, hindering attempts to build a more complete picture of melt variability at different spatial and temporal scales, and thus of disentangling the different processes driving melt.

To help address this problem, we use the machine learning approach of a Self-Organising Map (SOM) and nearly two decades (2002/03–2020/21) of daily observations from the AMSR-E and AMSR-2 passive microwave sensors, gridded at a spatial resolution of 12.5 km. Here, we present results focused on the Shackleton Ice Shelf in East Antarctica, but our code, implemented in the R programming language, is openly available and can be applied to any Antarctic ice shelf, or adapted for use with other melt datasets.

Our results show that the daily distribution of surface melt on the Shackleton Ice Shelf can be described by nine representative spatial patterns of melt. These patterns demonstrate the potential for heterogeneous melt behaviour across the shelf, and thus provide insight into the influence of surface topography, katabatic winds, and surface albedo in driving surface melt. A sensitivity analysis of the SOM algorithm shows that the same general spatial patterns are returned repeatedly regardless of the parameter values used, strengthening confidence in our results and interpretation, and demonstrating the suitability of our approach. We further examine the temporal variability of the nine melt patterns, both within and across melt seasons, finding that there are no significant trends in any of the patterns. Instead, our analysis identifies a number of summers with unusual melt behaviour and also reveals correlations with shelf-wide, summer-averaged surface air temperatures, highlighting that both local and large-scale controls are

important for driving surface melt in Antarctica.