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North Atlantic sea-surface variability reflected in an array of Greenlandic methanesulfonic acid (MSA) records

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Marine processes, including rising sea-surface temperatures (SST) and the diminished stabilizing effects of sea ice extent (SIE) on marine-terminating outlet glaciers, are known to play a significant role in modulating Greenland Ice Sheet (GrIS) mass balance. However, observations of these processes are largely limited to the past few decades. If proxies can be developed, ice cores have the potential to extend our understanding of ocean-ice coupling well beyond the satellite era. In polar regions, atmospheric methanesulfonic acid (MSA) appears to be uniquely traced to summertime phytoplankton blooms occurring near the sea ice margin and has a relatively short lifetime (<7 days); hence, MSA may be uniquely suited for delineating past ocean-ice feedbacks local to Greenland. Here, we present a unique array of annually resolved MSA records from five GrIS ice cores (including two previously unpublished records) spanning the past two to three centuries, and covering a broad geographic area of the GrIS accumulation zone. We use long-term Lagrangian particle back-trajectories in order to derive probabilistic spatial-estimates of the maritime source regions of precipitating airmasses arriving at each site in our array. Across all sites we observe the most likely maritime source region to be the south-southeast Greenland coast, suggesting that a common MSA signal is embedded across our Greenlandic ice core sites. Our analyses of the MSA array reveals two distinct modes of variance common amongst all records. The first is a conspicuous 200-year decline in MSA concentrations into the present. This trend is similar to that observed in the anomalous, centennial-scale cooling of SST's within the south Irminger Sea region of the North Atlantic, where spatial correlations of the MSA array to historical SST reanalyses also show the highest significant correlations ($p < 0.001$; $n = 154$ years). The second mode of variability recorded within the MSA records emulates centennial-scale trends in previously published ocean-sediment SIC reconstructions from the Denmark Strait and Nordic Seas. These results indicate that the pan-Greenlandic MSA signal retains important information on both SIC and SST variability. As such, our records may have implications for novel, ice-core based delineations of past sea-surface variability and coupled ocean-ice feedbacks in the North Atlantic.