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Holocene Northern Hemisphere sea-ice distribution – proxy data reconstruction and modelling

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A strikingly fast decrease of Arctic sea-ice cover has been recorded for the instrumental period and attributed to anthropogenic climate change, but little is known about natural sea-ice variability. Hence, there is a need for longer sea-ice time series to establish a baseline for natural Arctic sea-ice variability.

We compiled 120 proxy-based sea-ice reconstructions from the Arctic Ocean and subarctic marginal seas to evaluate the stability/variability of sea-ice cover during the Holocene. The reconstructions are primarily based on published data combined with a few yet-unpublished records of biological (diatoms, dinoflagellate cysts, foraminifera, ostracods), sedimentological (IRD), and biogeochemical (IP25, PIP25, TOC) sea-ice indicators. Each indicator and record has been interpreted independently. We present all data as long-term annual means (months of sea ice per year). Sea-ice reconstructions are grouped into these classes: perennial (11-12 month/yr), dense (6-10 m/yr), common (1-6 m/yr), occasional (0.1-1 m/yr), rare (almost never) and absent (never). Further, reconstructions are made for the time slices 0-2 cal. ka (BP), 2-4 ka, 4-6 ka, 6±0.5 ka, 6-8 ka and 8-10 ka.

Our study shows that winter sea ice was present during the entire Holocene, but summer sea ice may have been somewhat reduced in some areas during the Holocene Climate Optimum (10-6 ka), with variations between basins. In the Nordic Seas and N Atlantic minimum sea-ice conditions are seen 10-6 ka, whereas in the eastern Labrador Sea minimum sea-ice occurred 6-4 ka. Since ∼4 ka sea-ice cover has increased, especially in the most recent millennia. Changes are subtle, however, but nonetheless consistent. The Pacific sector of the Arctic (Bering, Chukchi, Beaufort, Laptev, Okhotsk seas) shows less variability during the Holocene, though it is noted that these records have poorer age control and resolution than those from the Atlantic sector. It is noteworthy that, within the available temporal resolution, our data indicate that sea ice was present in the Arctic throughout the Holocene and that no longer periods of absence of sea ice occurred.

Our proxy data interpretations have been used to constrain model output using data assimilation in the LOVECLIM model, focusing on the period 6±0.5 ka. This period of warmer than present summer conditions can help to understand the dynamics of the system in a warmer world. As expected, data assimilation leads to an overall better agreement with the reconstructions, mainly because of changes in the simulated wind patterns. Overall, the model simulation suggests that during the Holocene Thermal Maximum sea ice distribution was controlled by a strong positive Northern Annular Mode.