Supplemental Material

Arctic Sea Ice Volume Variability over 1901–2010: A Model-Based Reconstruction

Axel J. Schweiger

University of Washington, Applied Physics Laboratory, Polar Science Center, Seattle, Washington

Kevin R. Wood

University of Washington, Joint Institute for Atmosphere and Ocean Studies, Seattle, Washington

Jinlun Zhang

University of Washington, Applied Physics Laboratory, Polar Science Center, Seattle, Washington

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Corresponding author: Axel Schweiger, schweig@uw.edu
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Text S1 Effect of assimilation and recalibration on ice volume and volume trends

In order to better understand the effect of our "ice-edge" data assimilation and tuning procedure on total ice volume and our conclusions about the magnitude of sea ice loss during the ETCW period relative to the period of more recent ice loss, we conducted two additional model integrations. The first experiment (denoted as No-Assim) used no data assimilation but the same model parameters as our PIOMAS-20C run. The second experiment (No-Assim-Recal) did not assimilate data either but was recalibrated using the procedure outlined in the main text to reduce model bias in ice thickness... The 1901-2010 mean volume difference between No-Assim and PIOMAS-20C is 5800 km^3 or about 19% of total volume. This means that model runs with and without assimilation require separate model calibration. This is why we conducted the second model experiment, the No-Assim-Recal run, where the model was recalibrated. Annually averaged time series of sea ice volume for the three runs examined here are shown in Fig S10. All time series track closely with fairly constant biases from 1901 through the mid 1960ies when runs without assimilation show significantly larger sea ice volume. Trends during the ETCW periods are hardly affected by data assimilation and calibration with trends varying from 526 km^3/decade for the recalibrated run to 574 km^3/decade. Because of the larger volume during the late 1970ies and early 1980ies in the runs without data assimilation, trends for the 1979-2010 period are much more strongly affected by the absence of assimilation. Ice volume loss during the 1979-2010 period increase from 3807 km^3 /decade to 5693 km^3/decade and 5363 km^3/decade for the runs without assimilation and recalibration respectively. This result shows that while assimilation can have a substantial effect on volume trends, recalibration only has a relative minor effect on anomalies. Surprisingly, differences between the runs with and without assimilation are largest during the early 1980ies when confidence in forcing and assimilation

data is substantially greater than during the earlier period. Future investigations should attempt to tease out error sources in both model physics and forcing to identify the source of the biases. Nevertheless, our fundamental conclusion that sea ice loss during the ETCW was substantially smaller than during the 1979-2010 period is robust in the runs without assimilation.

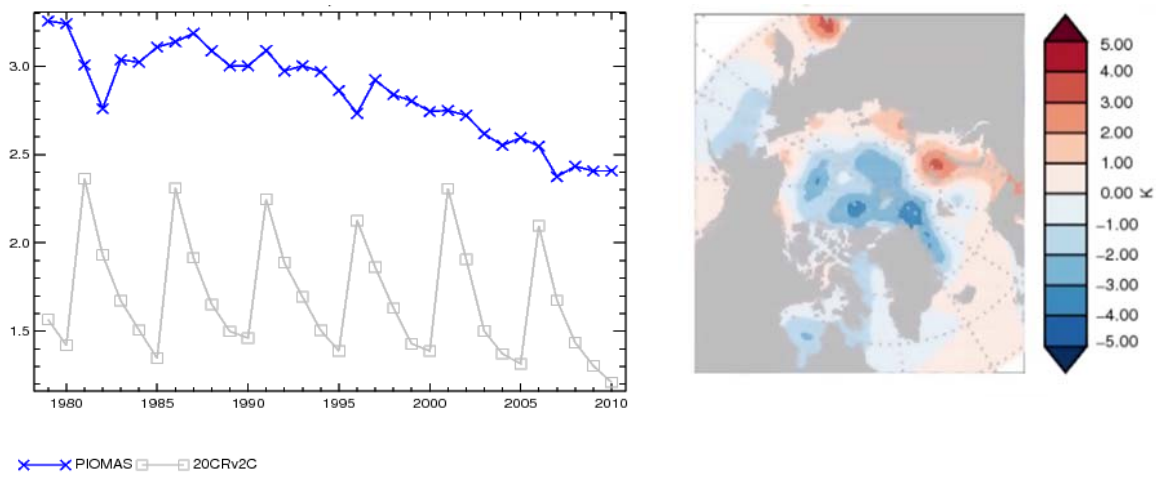


Fig. S1. a) Time series of spatially averaged April Ice thickness for 20CRv2c and PIOMAS, and b) surface air temperature difference between years with peak ice thickness and minimum ice thickness within each 5-year processing stream segment

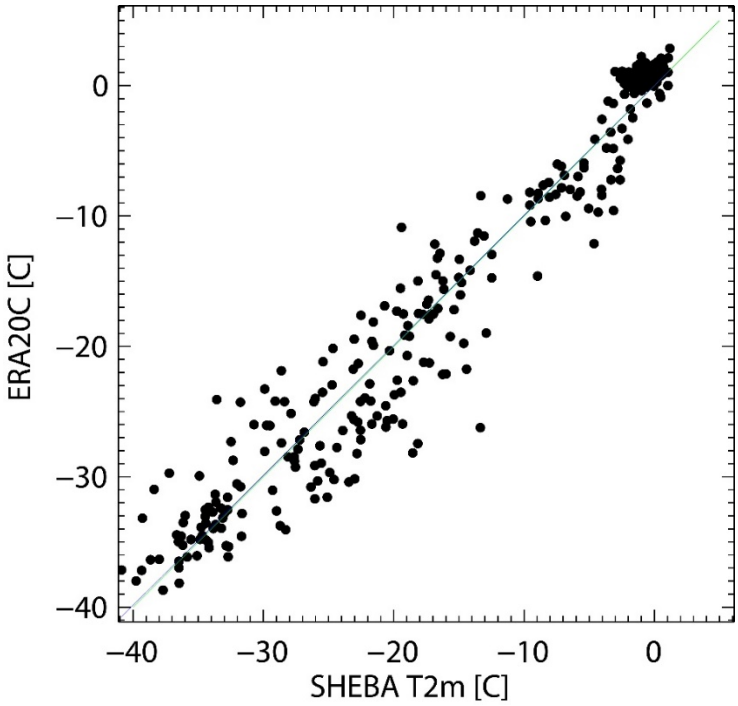


Fig. S2. Scatterplot of 2m Temperature measured at SHEBA and from ERA-20C reanalysis

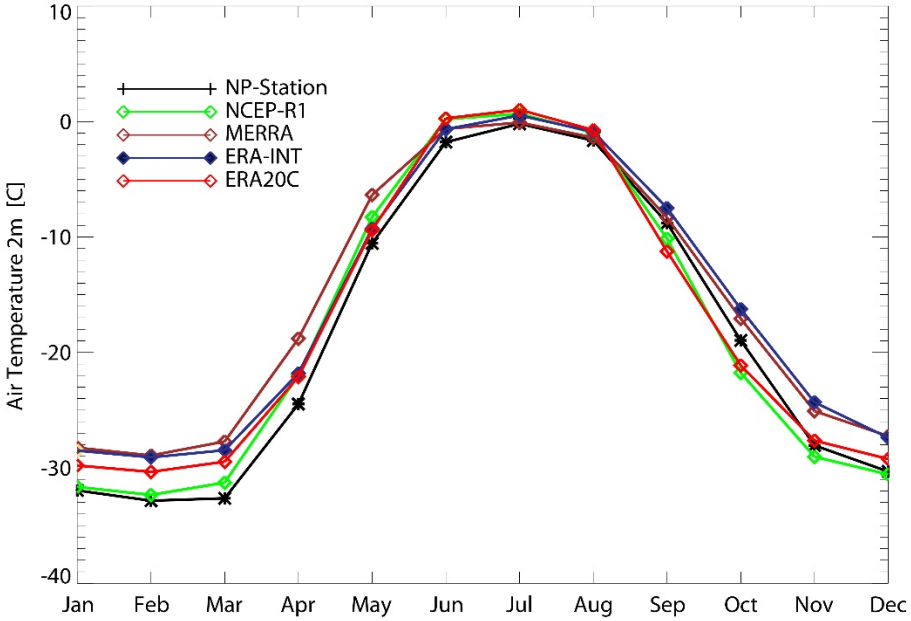


Fig. S3. Comparison of NP-Station 2m air temperatures and Reanalysis Data sets

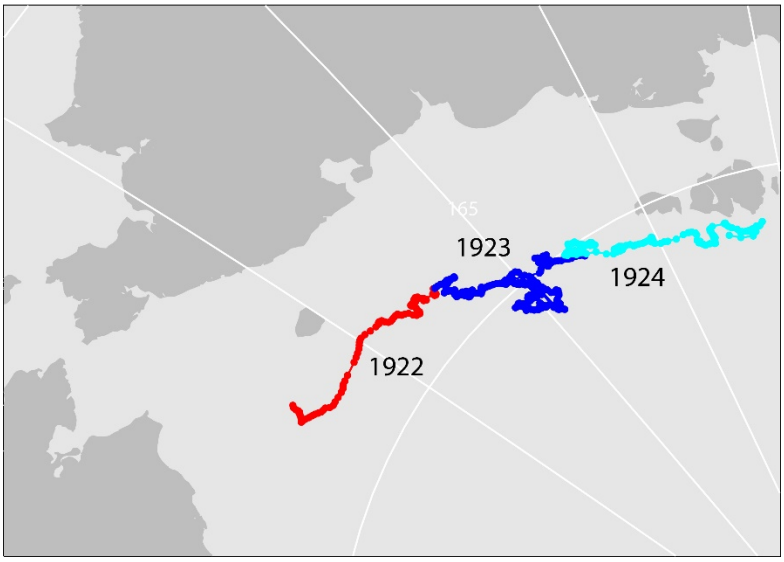


Fig. S4. Drift Track for Maud Expedition from 1922 through 1924. Different years are coded in colors with 1922, 1923, and 1924 given in red, blue, and cyan

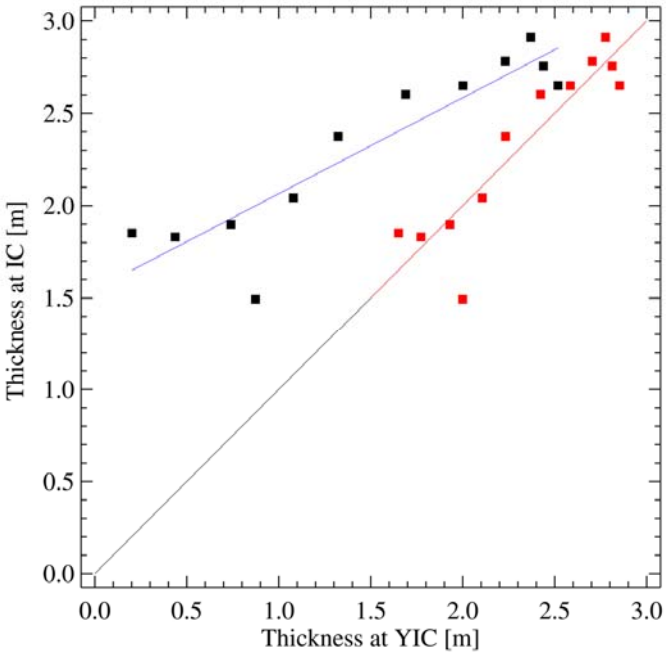
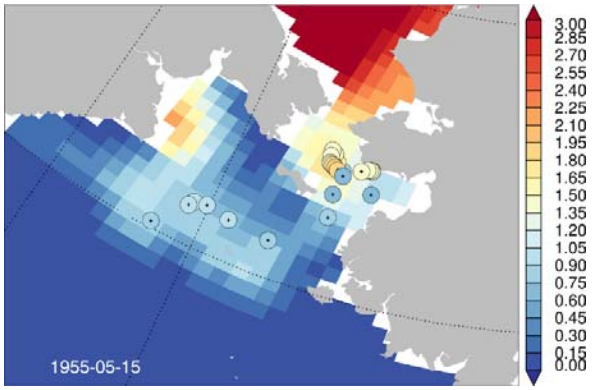
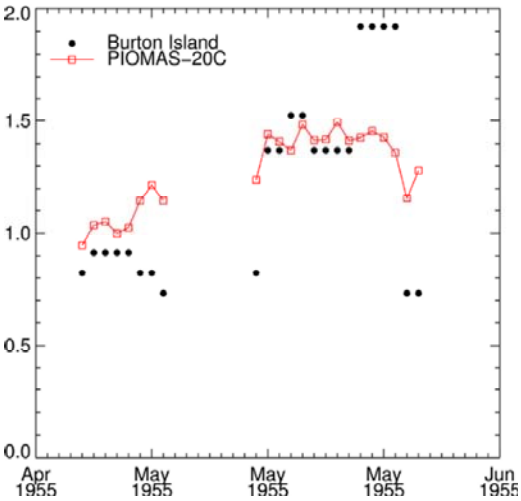


Fig. S5. Mean Monthly Sea Ice Thickness from two stations on Isachsen Island. Ice thickness is plotted for the overlapping periods from 1965-1973. The X –axis shows mean monthly ice thickness at the station designation of YIC, the Y-Axis shows data from the station designated by IC. YIC provides the longer record from 1948-1978, and IC provides data from 1965-1973. Black squares show the relationship between original time series, red squares show after recalibrating YIC data to IC. The recalibration equation is y^ = 1.54 + -0.519 x where x is the original YIC time series and y^ the recalibrated time series.

a)



b)



c)

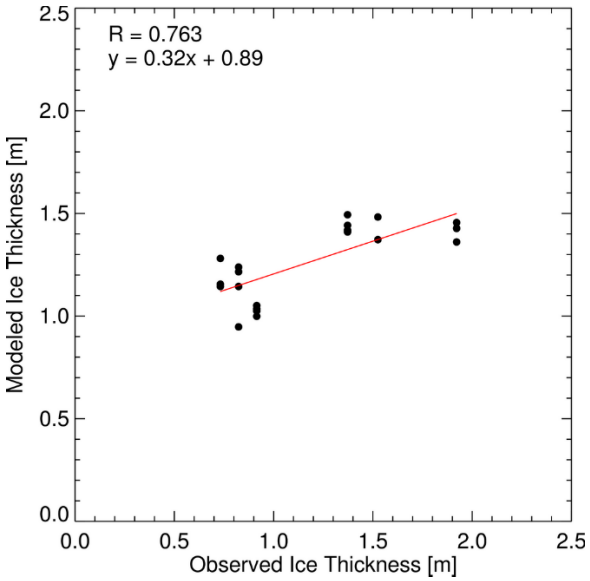


Fig. S6. Ice Thickness measurements from the Burton Island Cruise in 1955 (U.S. Navy Hydrographic Office (1958)) overlayed on PIOMAS-20C ice thickness from May 15 1955, Same data plotted as a time series b) and a scatter plot b)

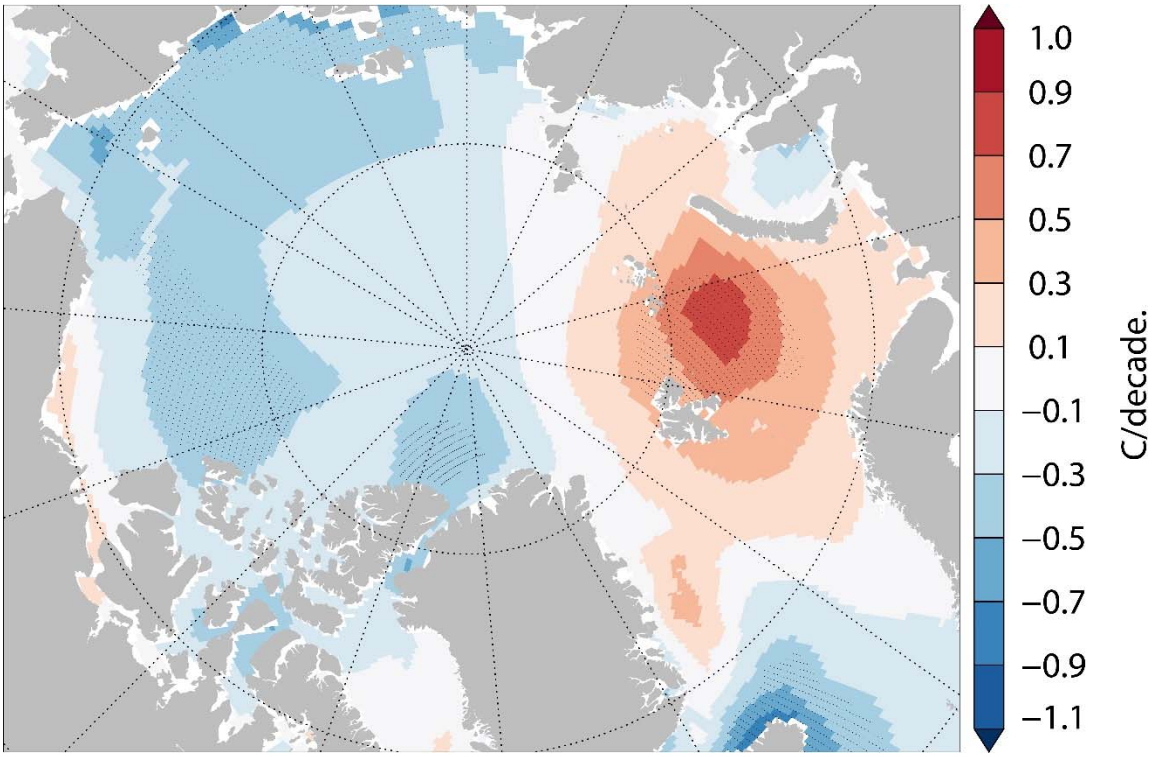


Fig. S7. September Surface Air Temperature Trend from 1901-1940 (C/decade) from the NOAA-20CRv2c reanalysis ensemble mean. Black stippling indicated 95% significance level.

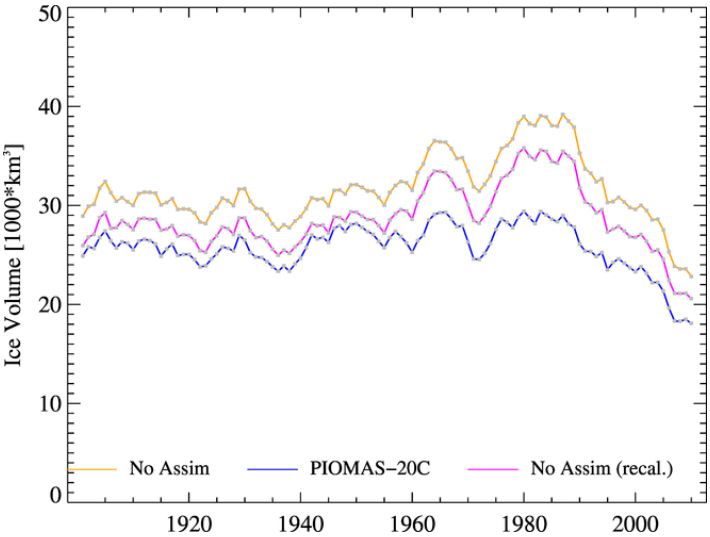


Fig. S8.Time series of annual averaged ice volume for runs without assimilation (No Assim), with assimilation (PIOMAS-20C) and without assimilation but with recalibration (No-Assim-Recal)

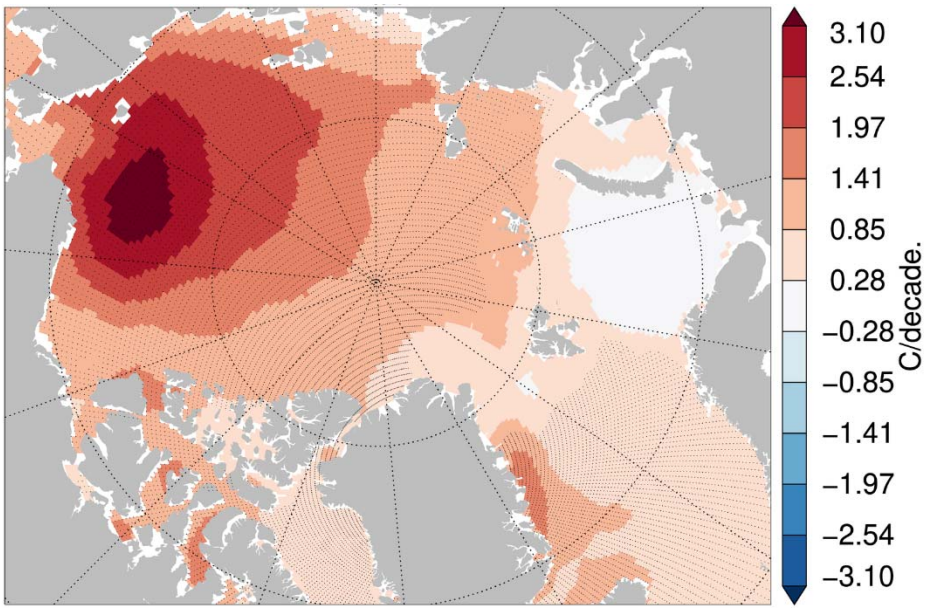


Fig. S9. ERA-20C temperature trend for the period 1979-2010. Note the different scale in comparison to **Fig. 15**.