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On the 2011 record low Arctic sea ice thickness: a combination of dynamic and thermodynamic anomalies

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Overview:

The authors investigate the 2011 Arctic record low sea ice thickness minimum by examining satellite-derived ice thickness, area and volume, CMST modeled sea ice thickness and drift, ice transport through the Fram Strait, and the thermodynamic and dynamic processes which contributed to the record minimum.

Utilizing AWI and ESA CryoSat-2 ice thickness data, coupled with ice age data to differentiate between FYI and MYI, they examine the Arctic sea ice area, extent, and volume during the period of 2010-2020. They note the ice thickness minimum in Oct 2011, the third lowest observed ice area minimum in Fall 2012, and the decline of MYI from 2010-2012.

The CMST dataset generated from the MITgcm model which assimilated SMOS ice thickness and SSMIS ice concentration is used to analyze ice transport through the Fram Strait for the period of Oct 2010-September 2016. They find that declining trends in MYI volume in October 2010, January 2011 and March 2011 were associated with dynamic processes.

Dynamical and thermodynamic processes are evaluated during the study period to examine the role of ice thickening, advection, convergence, and residual (melting/freezing). These fields are examined for two periods: October 2010-April 2011, and May-September 2011. Anomalies of these terms are made by subtracting the 6-year mean for each month. They found a strong thinning of the ice cover along the Canadian Archipelago and portions of the central Arctic with enhanced melting (compared to 6-year mean) during the period of May – September 2011.

The Arctic Oscillation (data provided by NCEP) analysis in conjunction with the ERA5 reanalysis is used to examine the monthly variability between the AO, positive ice export anomalies through the Fram Strait, surface air temperature anomaly, and surface net heat flux anomaly. They find a positive AO from Feb-April 2011, a maximum ice export through the Fram Strait in March 2011 which coincided with strong air surface temperature and surface net heat flux anomalies in March 2011.

SLP anomalies from the ERA5 reanalysis for the period of October 2010-January 2011 showed a peak positive anomaly over southern Greenland, and a gradual divergence of sea ice along the eastern Arctic toward the northern CAA. Enhanced transpolar advection (Fig. 5a) showed the transport of sea ice from the Beaufort Sea along the coast toward the Fram Strait.

Lastly, they examine the radiative fluxes for June, July, and August 2011 to investigate the impact of cloud cover, albedos and net surface longwave radiation anomalies on the enhanced melt of primarily FYI during this period.

This is a well written paper which investigates the contributing factors which led to the record 2011 Arctic sea ice thickness minimum. A combination of satellite-derived products, the MITgcm-based CMST and the ERA5 reanalysis are used in this study. Figures and table are clear and easy to understand. All references appear to be correct. I recommend a minor revision. See comments below.

General Comments:

Use consistent use of shortwave and longwave (not short-wave, long-wave) throughout the paper. For example see lines: 202, 205, 215. Figure 6 caption uses correct form.

Lines 86-88: Gate positions at 82°N between 12°W and 20°E and 20°E between 80.5 and 82°N are defined. Which position(s) are included in Table 1?

Although not a major contributor to Arctic ice export, please comment on the role of the absence of ice arches (or bridges) in 2008-2009 and 2009-2010 (Ryan and Munchow, 2017) on the potential impact of ice export through the Fram Strait in those years.

Technical Corrections:

Line 74: Should be CryoSat-2

Line 82: What is the source of the sea ice concentration used?

Line 130: Do you mean CAA instead of CA?

Line 145: Same comment as above

Line 170: Include years October **2011**-April **2012**

Line 233: I assume you mean "net surface shortwave"?

Line 380: Include years of 2010, 2011 in caption.

Line 385: Why not show 4-month averages for all 3 plots shown: Oct-Jan, Feb-May, June-Sep? Any particular reason why Fig. 5g, 5h, 5i encompass a larger area than the two panels above?

Table 1: Include 6-year mean in bottom of table

Ryan, P. A. and A. Munchow (2017), Sea ice draft observations in Nares Strait from 2003 to 2012, *J. Geophys. Res. Oceans*, 122, 3057–3080, doi:10.1002/2016JC011966.