Arctic Sea Ice Thickness Variability and Large-scale Atmospheric Circulation Using Satellite Observations, PIOMAS, and the CESM Large Ensemble

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PDF

The opportunity

Loss of sea ice concentration (SIC) and sea ice extent (SIE) are well documented over the satellite era (from 1979). However, a comprehensive overview of sea ice thickness (SIT) variability and therefore sea ice volume (SIV) remains challenging as a result of a lack of data and observational uncertainties.

Our approach

Here we evaluate SIT spatial and temporal variability using the Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS[2,4]) as reanalysis data and the CESM Large Ensemble Project (LENS) for future projections in SIT and SIV.

The conclusions

While total SIV has fallen over the satellite record (**Fig 1**), spatial trends and variability differ by season and region. Evaluating large-scale atmospheric circulation patterns (e.g., Arctic Dipole; AD) as drivers to these changes indicate SIT variability is largely driven by internal variability. However, further pan-Arctic losses in SIT and SIV are likely in response to 21st century climate warming.

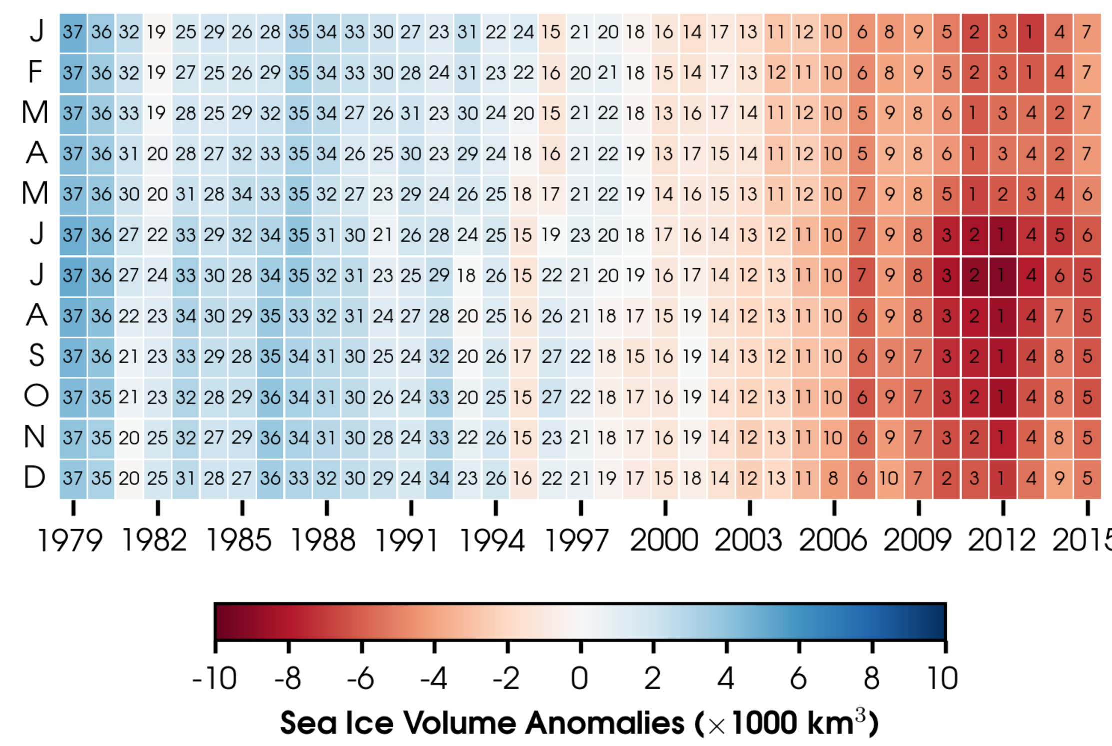
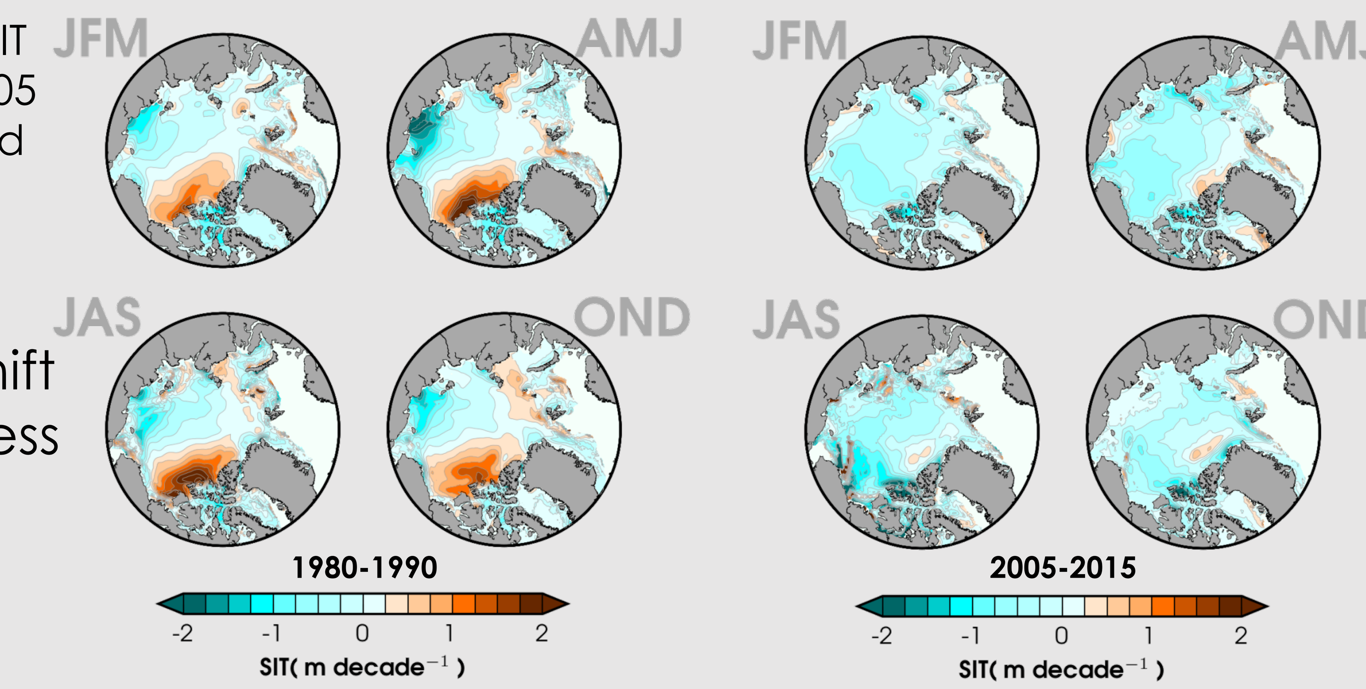


Fig 1. Monthly PIOMAS SIV anomalies (1981-2010 baseline) from 1979 to 2015 (color mesh). Rankings (numbers) are calculated per each month over the time series where 1=warmest

Sea ice variability and the Arctic dipole

Fig 3. Linear trends (slopes) in SIT over 1980 to 1990 (left) and 2005 to 2015 (right). Trends averaged for a seasonal mean



- Trends in PIOMAS SIT indicate significant shift to decreasing thickness in Beaufort Sea over the last couple of decades (**Fig 3**)

- AD Index calculated from normalized monthly sea level pressure (SLP) anomalies regressed onto EOF2 spatial pattern (**Fig 4**)
    - +AD defined as +SLP anomalies over Canadian archipelago

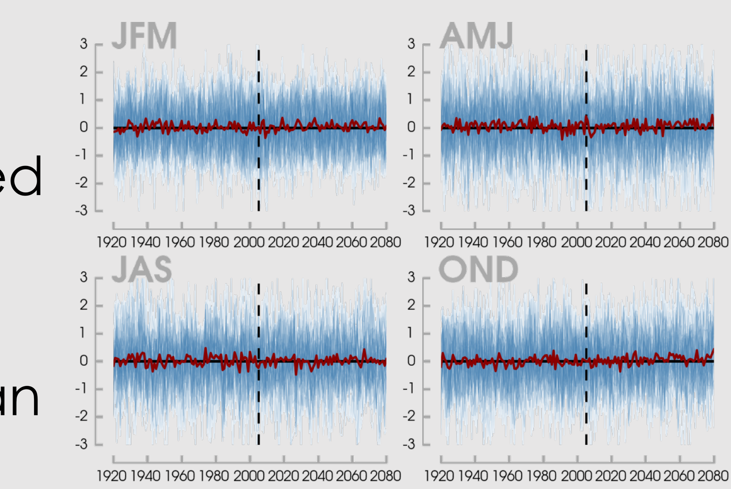


Fig 4. LENS AD Index seasonal means for each ensemble member from 1920 to 2080 (blue lines). Ensemble mean AD index calculated in red

Estimates of Arctic sea ice thickness

Table 1	Time	Spatial Domain
PIOMAS	1979 - present	pan-Arctic
Submarine Data	1986 - 1993	narrow sonar tracks
ICESat-J	2004 - 2009	ICESat domain
CryoSat-2	2011 - present	pan-Arctic
LENS	1920 - 2080	pan-Arctic

- PIOMAS, satellite, and submarine SIT data interpolated onto EASE 100 km grid[3] (**Table 1, Fig 2**)

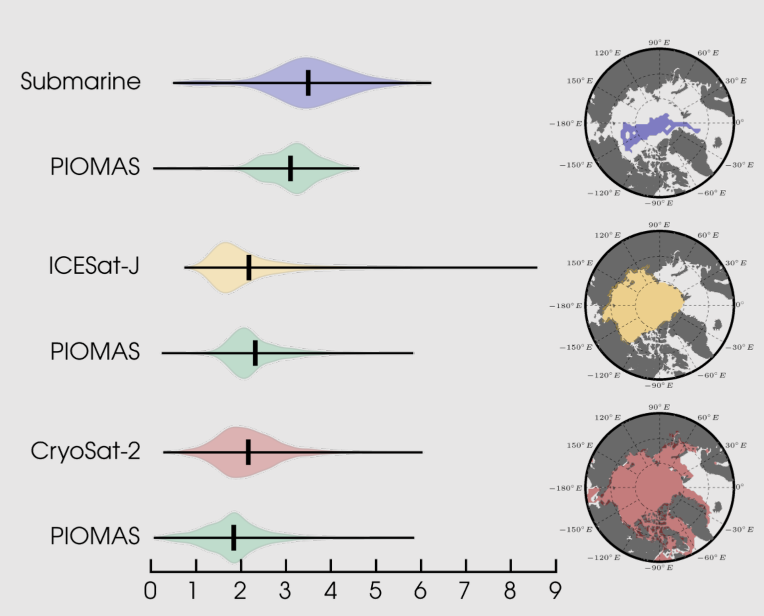


Fig 2. Violin plot of March PIOMAS, satellite, and submarine SIT data over listed time periods and spatial domains (**Table 1**)

- Interannual variability in satellite SIT data from CryoSat-2 and ICESat larger than the PIOMAS record
- PIOMAS *overestimates* thin ice and *underestimates* thick ice in comparison with satellite data
- Greatest differences in SIT between PIOMAS and observations along north and east coasts of Greenland

Future trends in sea ice thickness

- LENS trend in declining SIV comparable to PIOMAS over the 1979 to 2015 period (**Fig 5**)
- PIOMAS total SIV falls below the LENS mean during March and outside the ensemble envelope in September
- LENS composite analysis shows thicker sea ice off the eastern coast of Greenland and across the Beaufort and East Siberian Seas (**Fig 6**)
- Average September SIT falls below 1.0 m by the middle of the 21st century
- LENS SIV shows first September less than 1000 km³ mostly likely during the 2040s (**Fig 7**)

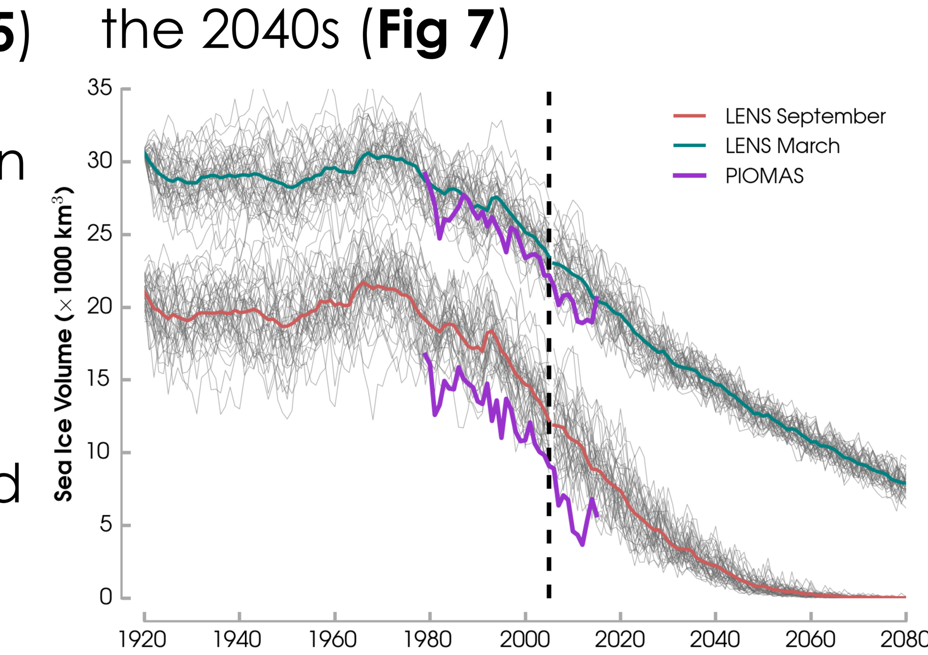


Fig 5. Time series of LENS SIV from 1920 to 2080 averaged for September (red) and March (blue) compared with PIOMAS SIV (purple) from 1979 to 2015

Fig 6. Spatial composites of September SIT. LENS historical from 1920 to 2005 and RCP8.5 from 2006 to 2080 averaged over three subsequently equal periods (1,2,3). PIOMAS composite SIT from 1980 to 2015 averaged into two equal periods

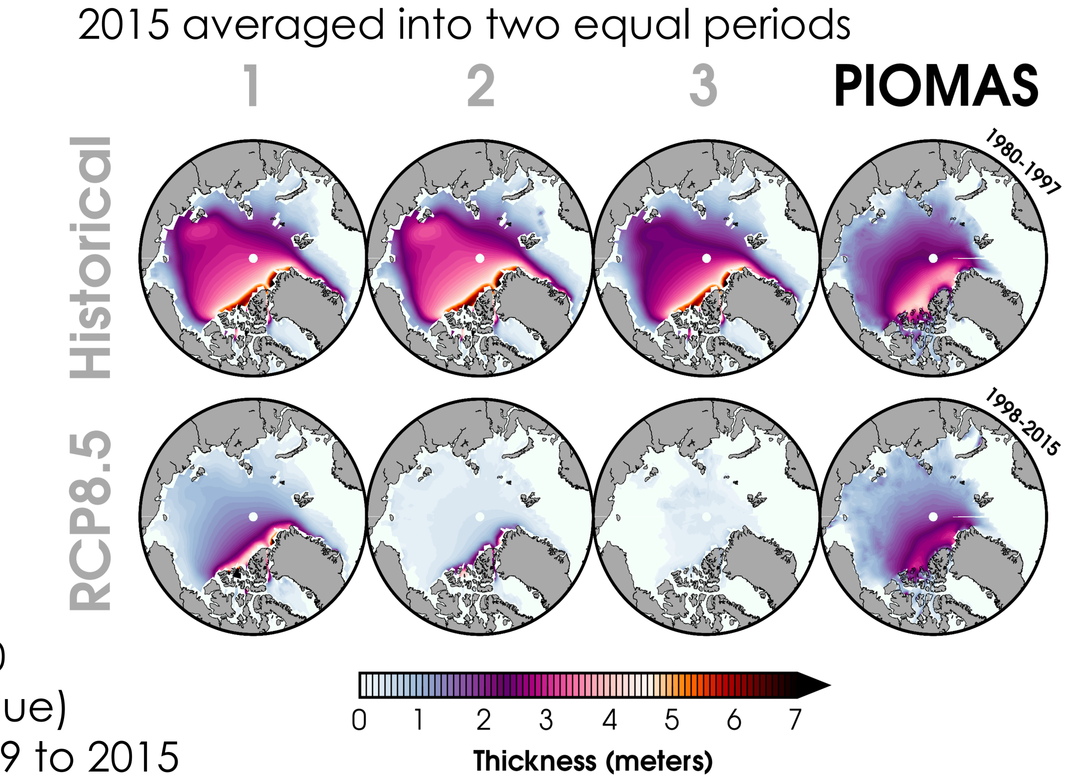
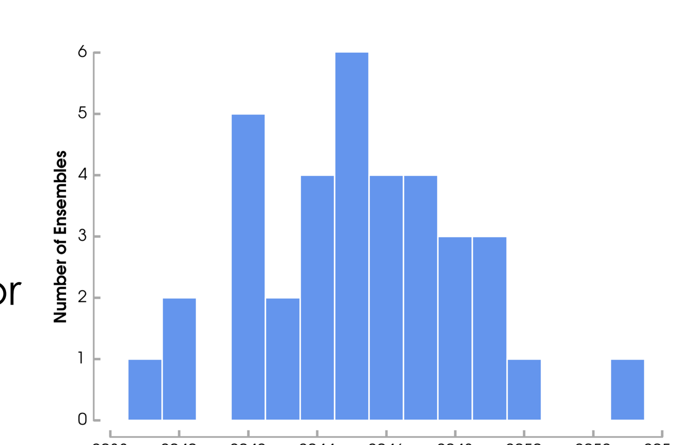


Fig 7. Histogram of the timing of the first September with less than 1000 km³ of SIV for all LENS members



References

[1] **Labe, Z.M.**, G. Magnusdottir, and H.S. Stern (2017), Internal variability of Arctic sea ice thickness using PIOMAS and the CESM Large Ensemble Project, in prep.

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