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) 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.

Estimates of Arctic sea ice thickness

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

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

Sea ice variability and the Arctic dipole

- 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

References


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

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

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

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