Making the most of Arctic sea ice thickness observations

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PDF

The opportunity

Arctic sea ice is an important component in Earth's climate system, contributing directly to the global energy balance. **The decrease in the extent of Arctic sea ice has been well observed by satellites since 1979 (Fig 1).** However, a satellite record of sea ice thickness (SIT) measurements remains limited to the last decade and is subject to a number of uncertainties including: snow depth on sea ice, age and density of sea ice, and satellite instrumental error.

Our approach

Here we use the **Pan-Arctic Ice Ocean Modeling and Assimilation System** (PIOMAS, *Zhang and Rothrock*, 2003) sea ice and ocean model in addition to satellite observations (**ICESat/CryoSat-2**) to analyze uncertainty and variability in SIT methods and data sets.

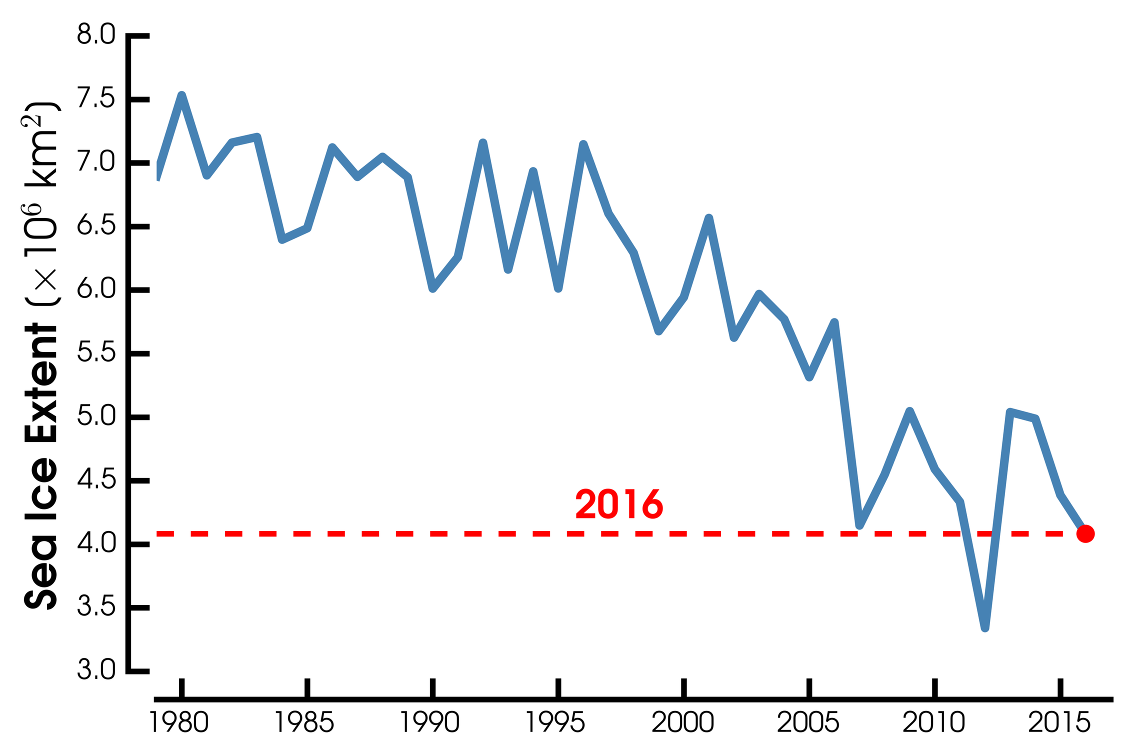


Fig 1. Minimum annual Arctic sea ice extents from 1979-2016 (NSIDC). A gridbox is ice covered if its sea-ice concentration is greater than or equal to 15%

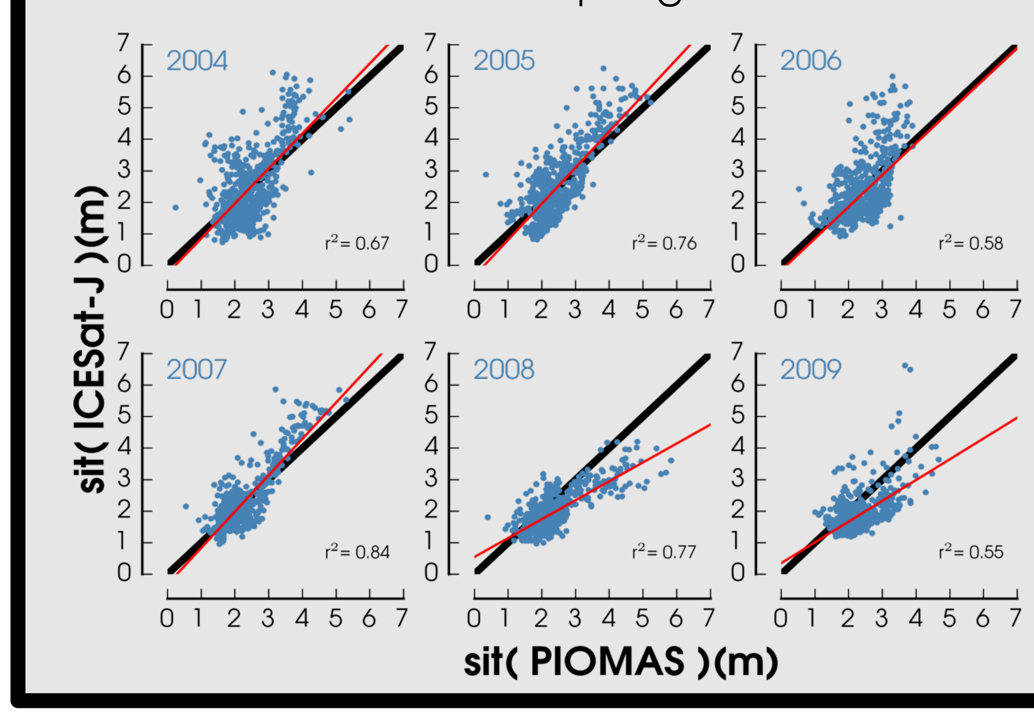
The conclusions

Comparisons between satellite observations and modeled SIT show **location and magnitude differences** over time. The short record of satellite observations combined with the numerous assumptions for retrieving SIT demonstrate that **PIOMAS is a more useful source for understanding long-term SIT variability than satellite observations.**

PIOMAS and long-term sea ice variability

- PIOMAS **overestimates thin ice** and **underestimates thick ice** in comparison with satellite data (Fig 5)
- PIOMAS significantly underestimates Fram Strait exported sea ice along the northeast coast of Greenland

Fig 5. March SIT relationships between PIOMAS and ICESat-J. One marker per grid cell



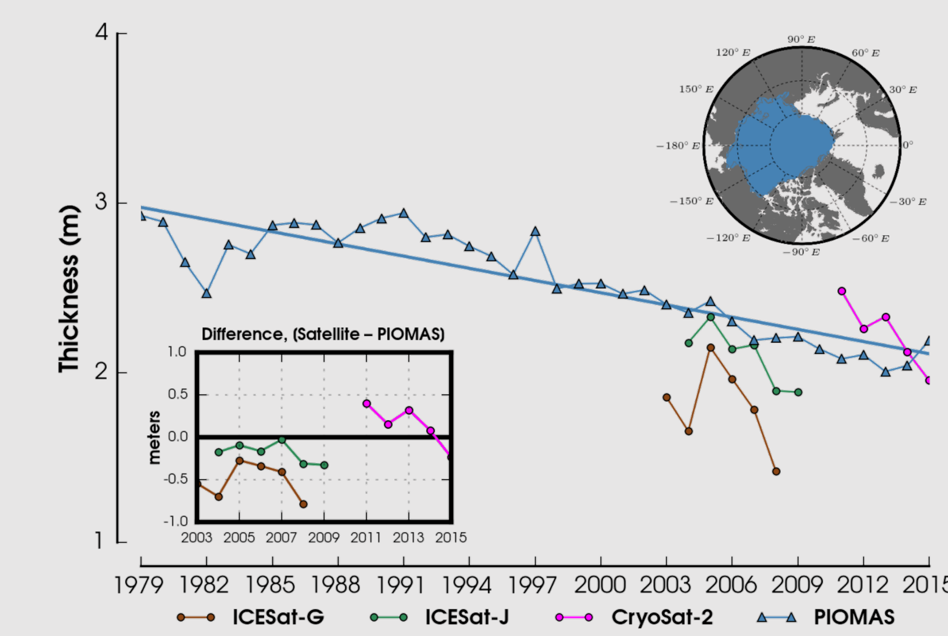


Fig 6. Comparison of March SIT averaged per year for all satellite observations (ICESat/CryoSat-2) and available PIOMAS data. SIT is averaged over a common grid as shown by the covered blue region. A linear regression line is calculated over the 1979-2015 PIOMAS data.

- Comparing average March SIT between PIOMAS and the satellites shows large interannual variability (Fig 6)

Observations and estimates of sea ice thickness

	Time	Spatial Domain
PIOMAS	1979 - present	pan-Arctic
Submarine Data	1986 - 1993	upward looking sonar
ICESat-J	2004 - 2009	ICESat domain
CryoSat-2	2011- present	pan-Arctic

Interpolated PIOMAS, satellite and submarine data on a common grid using the *Stroeve et al.,* [2014] EASE2.0 100 km product (Table)

Exploratory data analysis between PIOMAS and the observational SIT estimates for March (Fig 2,3,4)

Regional analysis by quadrants and 500 x 600 km grid cells to compare SIT smoothness over time in PIOMAS and satellites

Fig 2. Violin plot of March sea ice thickness data over each time period per SIT observation

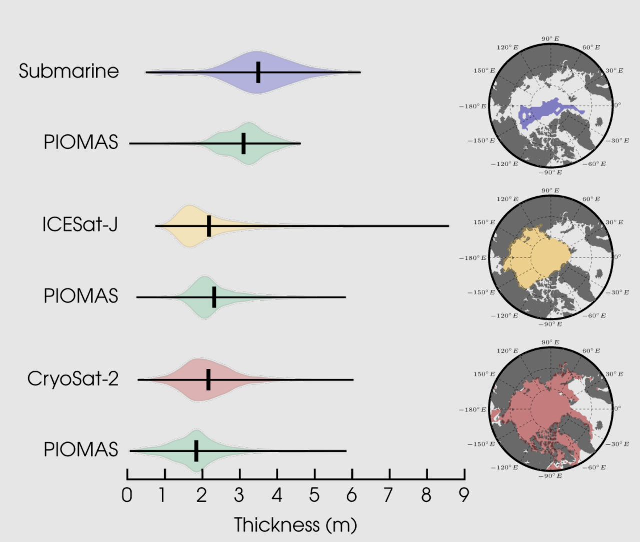
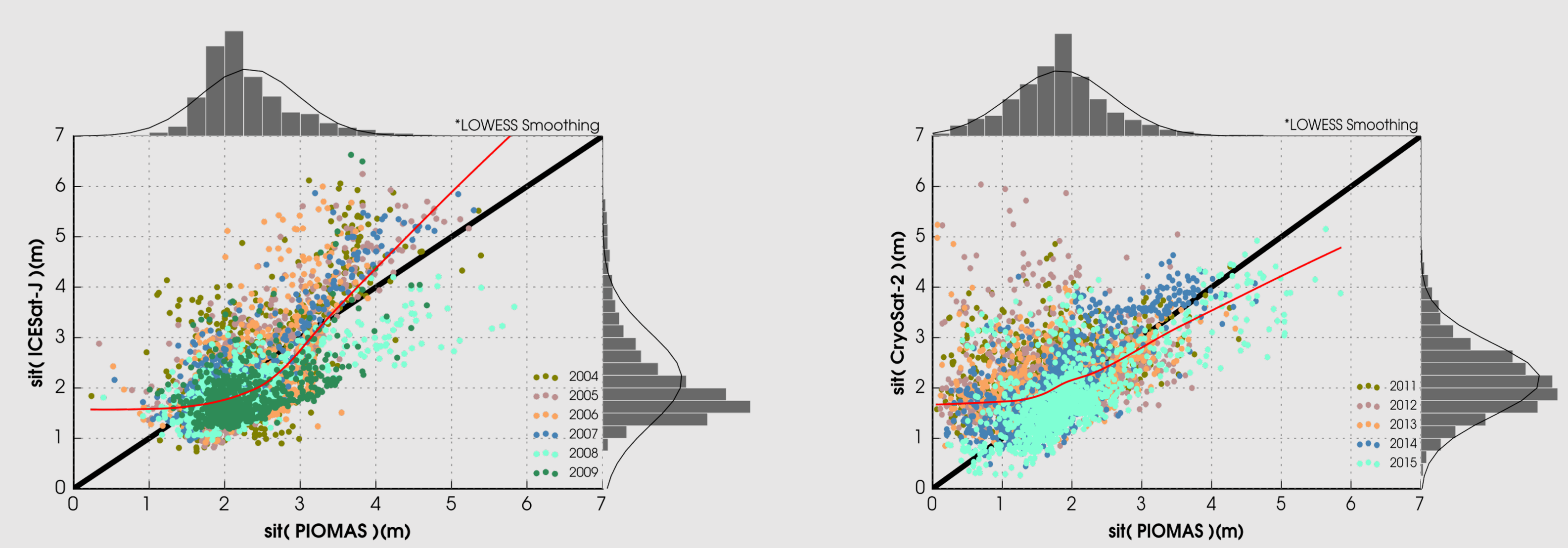


Fig 3,4. Scatter plots and histograms for PIOMAS vs. ICESat-J (left) and CryoSat-2 (right) over available data periods. Each marker is assigned for one grid cell. Finally, LOWESS shows the relationship between the two measures.



Historical trends in sea ice volume

- Decadal trends in sea ice volume (SIV) indicate spatial variability over the Arctic basin (Fig 7)
- Largest losses of SIV are located in the East Siberian, Chukchi, and Beaufort Seas (Fig 7)
- SIV anomalies are greatest during the early summer and coincide with the start of the sea ice melt season (Fig 8)
- Shift in spatial distribution of SIV coincides with +Arctic Dipole pattern

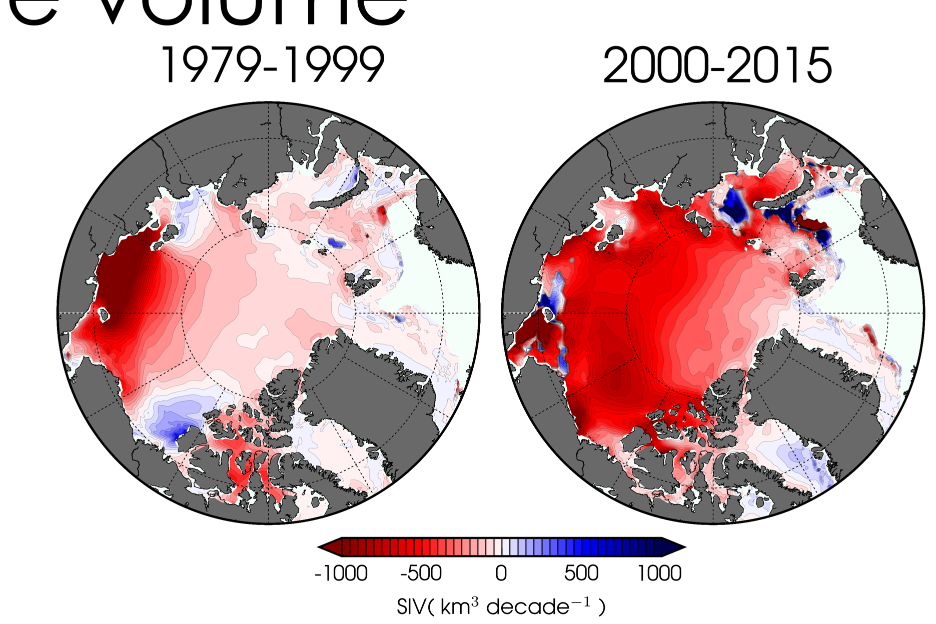


Fig 7. Trends in Arctic SIV (PIOMAS)

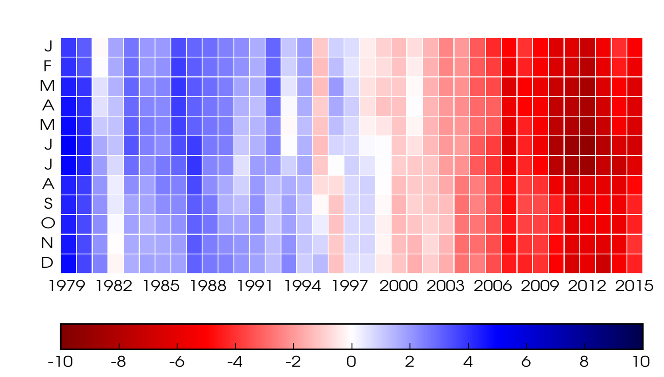


Fig 8. Monthly SIV anomalies from 1979 to 2015 using a 1981-2010 climatology

References

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Stroeve, J., A. Barrett, M. Serreze, and A. Schweiger (2014), Using records from submarine, aircraft and satellites to evaluate climate model simulations of Arctic sea ice thickness, The Cryosphere.

Zhang, J., and D. A. Rothrock (2003), Modeling Global Sea Ice with a Thickness and Enthalpy Distribution Model in Generalized Curvilinear Coordinates, Monthly Weather Review.