Seasonal dynamics of Totten Ice Shelf controlled by sea ice buttressing

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Abstract

Previous studies of Totten Ice Shelf have employed surface velocity measurements to estimate its mass balance and understand its sensitivities to interannual changes in climate forcing. However, displacement measurements acquired over timescales of days to weeks may not accurately characterize long-term flow rates where ice velocity fluctuates with the seasons. Quantifying annual mass budgets or analyzing interannual changes in ice velocity requires knowing when and where observations of glacier velocity could be aliased by subannual variability. Here, we analyze 16 years of velocity data for Totten Ice Shelf, which we generate at subannual resolution by applying feature tracking algorithms to several hundred satellite image pairs. We identify a seasonal cycle characterized by a spring to autumn speedup of more than 100 m yr^{-1} close to the ice front. The amplitude of the seasonal cycle diminishes with distance from the open ocean, suggesting the presence of a resistive backstress at the ice front that is strongest in winter. Springtime acceleration precedes summer surface melt and is not attributable to thinning from basal melt. We attribute the onset of ice shelf acceleration each spring to the loss of buttressing from the breakup of seasonal landfast sea ice.

Cryosphere Discussions paper

This work is currently in review as:
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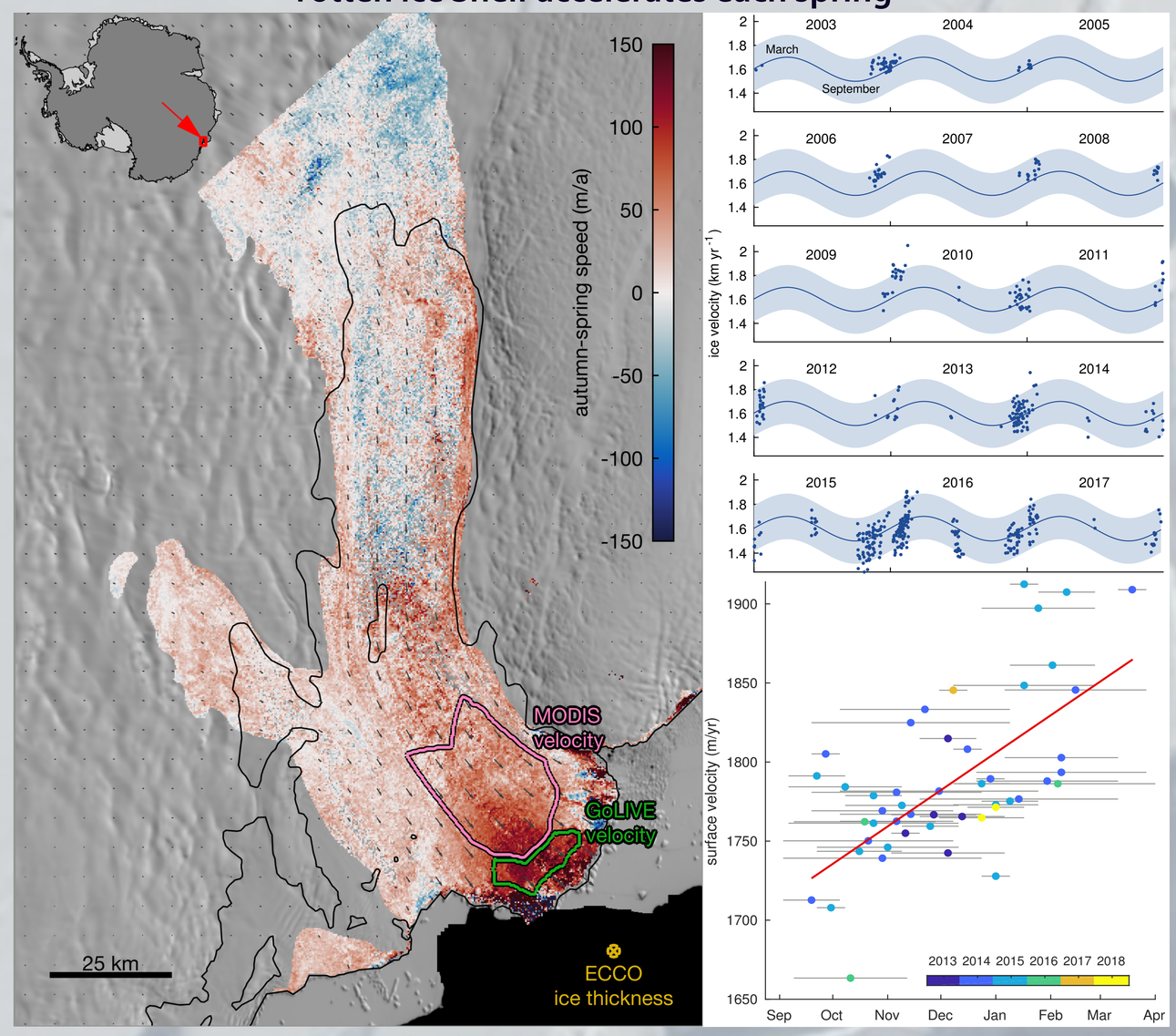
References

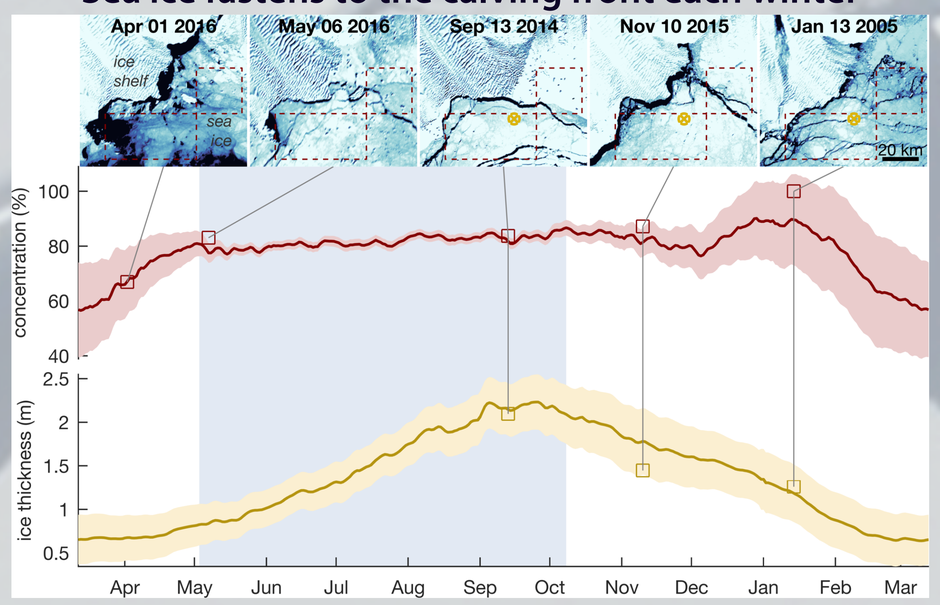
GoLIVE data: Scambos, T., M. Fahnestock, T. Moon, A. Gardner, and M. Klinger. 2016. Global Land Ice Velocity Extraction from Landsat 8 (GoLIVE), Version 1. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center.
Background images: Haran, T., J. Bohlander, T. Scambos, T. Painter, and M. Fahnestock. 2014. MODIS Mosaic of Antarctica 2008-2009 (MOA2009) Image
Sea ice thickness: Fukumori, I., Wang, O., Fenty, I., Forget, G., Heimbach, P., and Ponte, R. M.: ECCO Version 4 Release 3, 2017.
Sea ice concentration: Cavalieri, D., Parkinson, C., Gloersen, P., and Zwally, H. J.: Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data, Version 1.
Surface melt observations: Picard, G. and Fily, M.: Surface melting observations in Antarctica by microwave radiometers: Correcting 26-year time series from changes in acquisition hours, Remote Sensing of Environment, 104, 325–336, 2006.

Totten Ice Shelf accelerates each spring



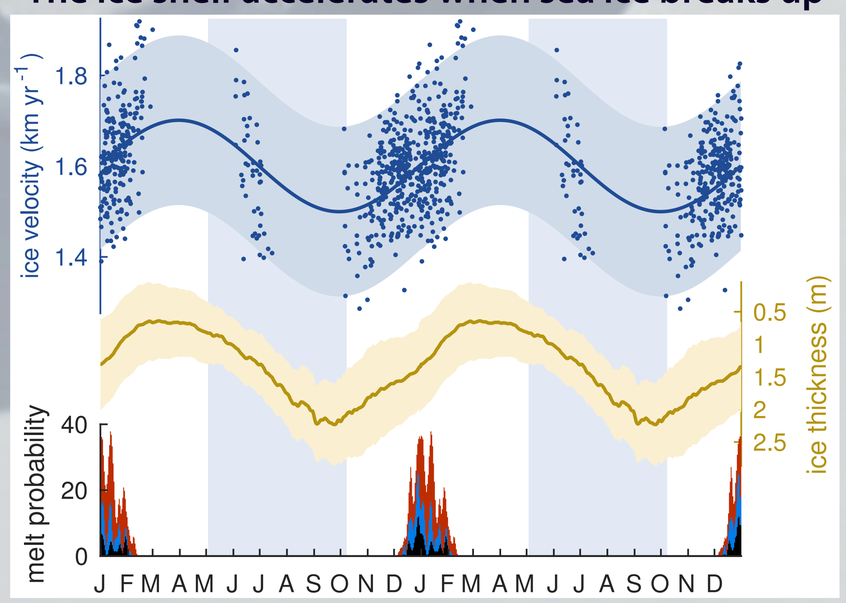
- Acceleration is most prominent near the calving front.
- Seasonality is apparent in the GoLIVE dataset (left and lower right) and in template matching applied to 672 MODIS image pairs (upper right).

Sea ice fastens to the calving front each winter



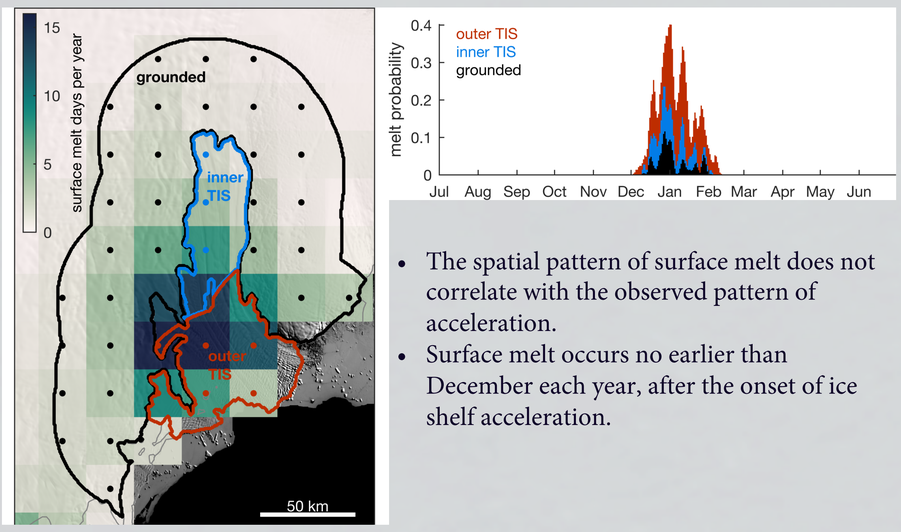
- Area-averaged sea ice concentration is constant from May to October.
- Modeled ice thickness is a better proxy for ice strength and level of consolidation

The ice shelf accelerates when sea ice breaks up



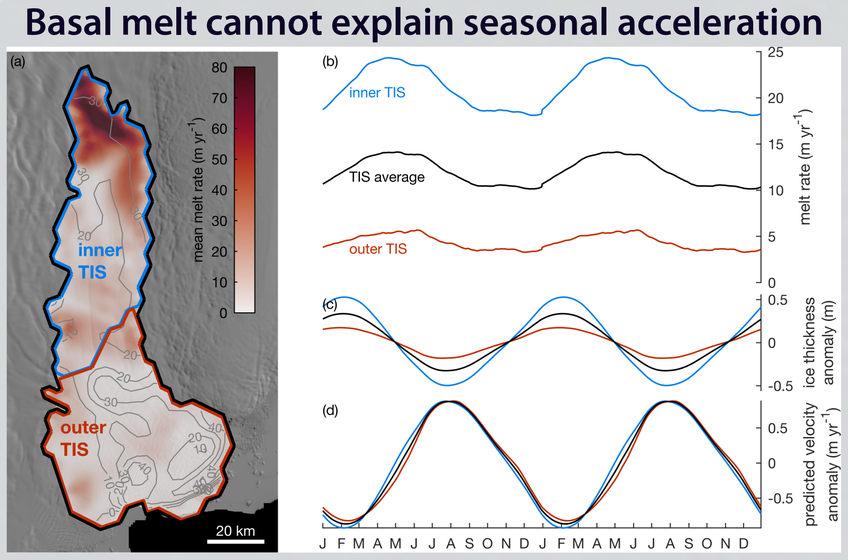
- Ice shelf acceleration coincides with the breakup of seasonal landfast ice at the calving front (note inverted ice thickness scale).
- Landfast sea ice likely inhibits calving over winter and preserves internal buttressing within the ice shelf.

Acceleration precedes surface melt



- The spatial pattern of surface melt does not correlate with the observed pattern of acceleration.
- Surface melt occurs no earlier than December each year, after the onset of ice shelf acceleration.

Basal melt cannot explain seasonal acceleration



- Ocean-forced melting varies seasonally, but the magnitude and timing of ice shelf thinning do not correspond to surface velocity observations.

Acknowledgments

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