National Aeronautics and Space Administration

Constraining model estimates of Antarctic surface mass balance, using satellite gravimetry and altimetry

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Program: R&TD Spontaneous Concept

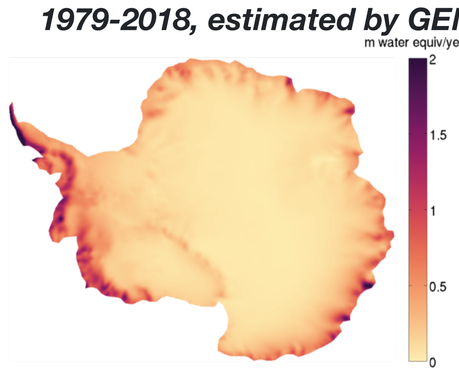
Project Objective:

Our first objective was to model daily Antarctic Ice Sheet surface mass balance (SMB, the sum of the snow accumulation, evaporation, and meltwater runoff at the surface of the ice sheet) and snow/firn air content (FAC, i.e. density) at unprecedented spatial resolutions (up to 5km), from 1979-2018, using the glacier and energy mass balance (GEMB) surface radiation model, integrated into JPL's Ice Sheet System Model (ISSM).

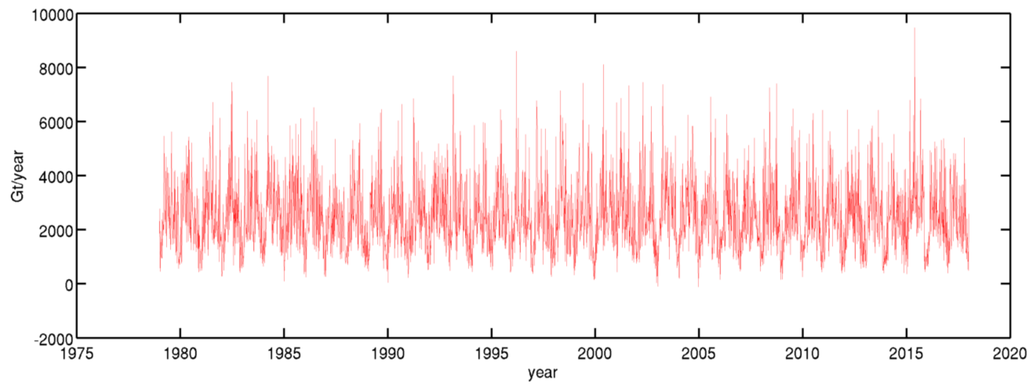
Our second objective was to assess the uncertainty of our product, specifically in trends and variability, using remote-sensing-derived FAC estimates. Monthly observed FAC, from 2002-2016, is derived from JPL gravimetry and altimetry products.

Results:

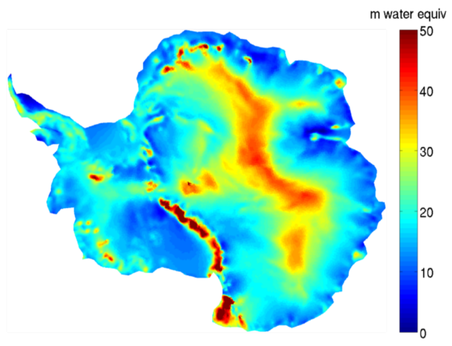
Mean Antarctica surface mass balance 1979-2018, estimated by GEMB



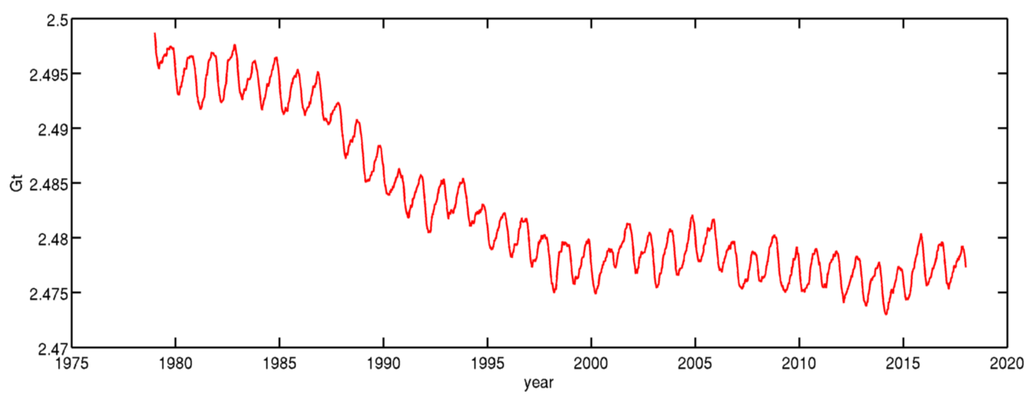
Total Antarctica surface mass balance, estimated by JPL's ISSM-GEMB forced with 3-hourly ERA-5 reanalysis



Mean Antarctica firn air content 1979-2018, estimated by GEMB

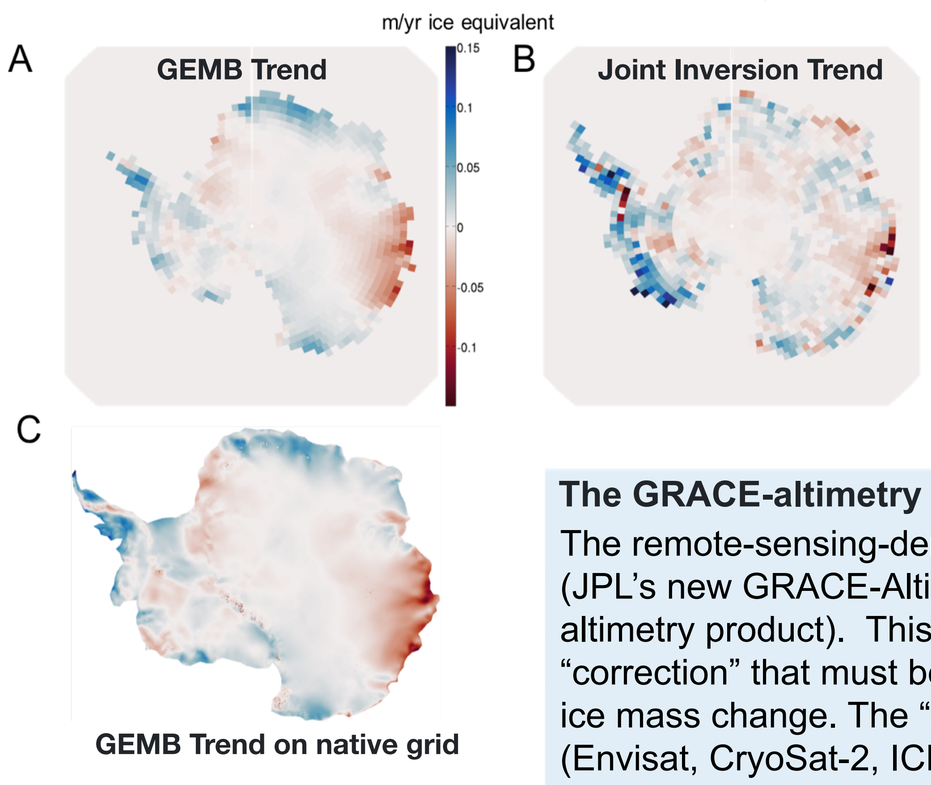


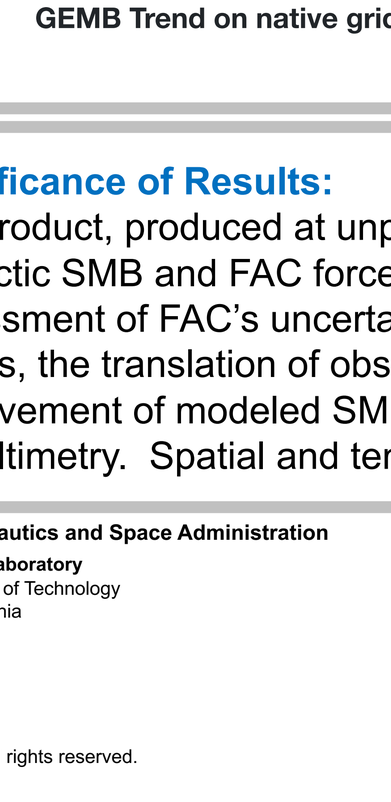
Total Antarctica firn air content, estimated by JPL's ISSM-GEMB forced with 3-hourly ERA-5 reanalysis



Evaluation of modeled Antarctic snow firn air content (FAC) using gravimetry and altimetry:

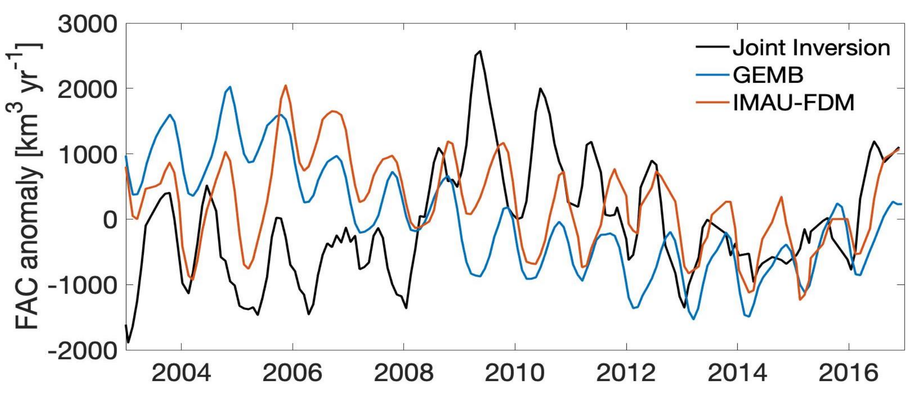
Evaluation of GEMB modeled trends in firn air content, 2010-2016





GEMB Trend on native grid

Evaluation of GEMB modeled variability in firn air content against the Joint Inversion and another FAC model (FDM)



The GRACE-altimetry *Joint Inversion* FAC product

The remote-sensing-derived firn air content product is derived from the difference between observed mass (JPL's new GRACE-Altimetry Joint Inversion) and observed surface height change (JPL's "uncorrected" altimetry product). This difference is dictated mostly by snow density change, and represents the "correction" that must be removed from "uncorrected" altimetry to convert it from surface height change to ice mass change. The "Joint Inversion" product is a combination of GRACE data with JPL's multi-mission (Envisat, CryoSat-2, ICESat) synthesized set of altimetry observations at the level of the normal equations. The combination allows for an order of magnitude improvement in the GRACE solution's spatial resolution.

Significance of Results:

Our product, produced at unprecedented spatial resolution (5km along the coast, 30km inland), is the first model estimate of daily Antarctic SMB and FAC forced by the newly released ERA-5 reanalysis. Robust estimates of density variations in snow/firn and assessment of FAC's uncertainty is essential to the interpretation of altimetry (e.g. ICESat-2) with regards to ice sheet mass balance. That is, the translation of observed surface height change into mass change requires information about snowpack density. To this end, improvement of modeled SMB and FAC can inform us about discrepancies between ice sheet mass changed derived from gravimetry and altimetry. Spatial and temporal FAC estimates are also key to the future assimilation of altimetry into JPL's Ice Sheet System Model.

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