National Aeronautics and Space Administration

From the Seasonal to the Decadal: Inferring Ice-Shelf Submarine Melting Changes from ICESat-2 Observations to Assess their Relationship to Ocean Variability

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Program: FY22 R&TD Topics
Strategic Focus Area: Ocean and ice

Objectives:
The overarching science goal is to investigate the crucial role of the interactions of Antarctic ice shelves with the ocean and consequent submarine melting in the stability and evolution of the ice sheet.The science objectives that we seek to implement to address the science goal are:

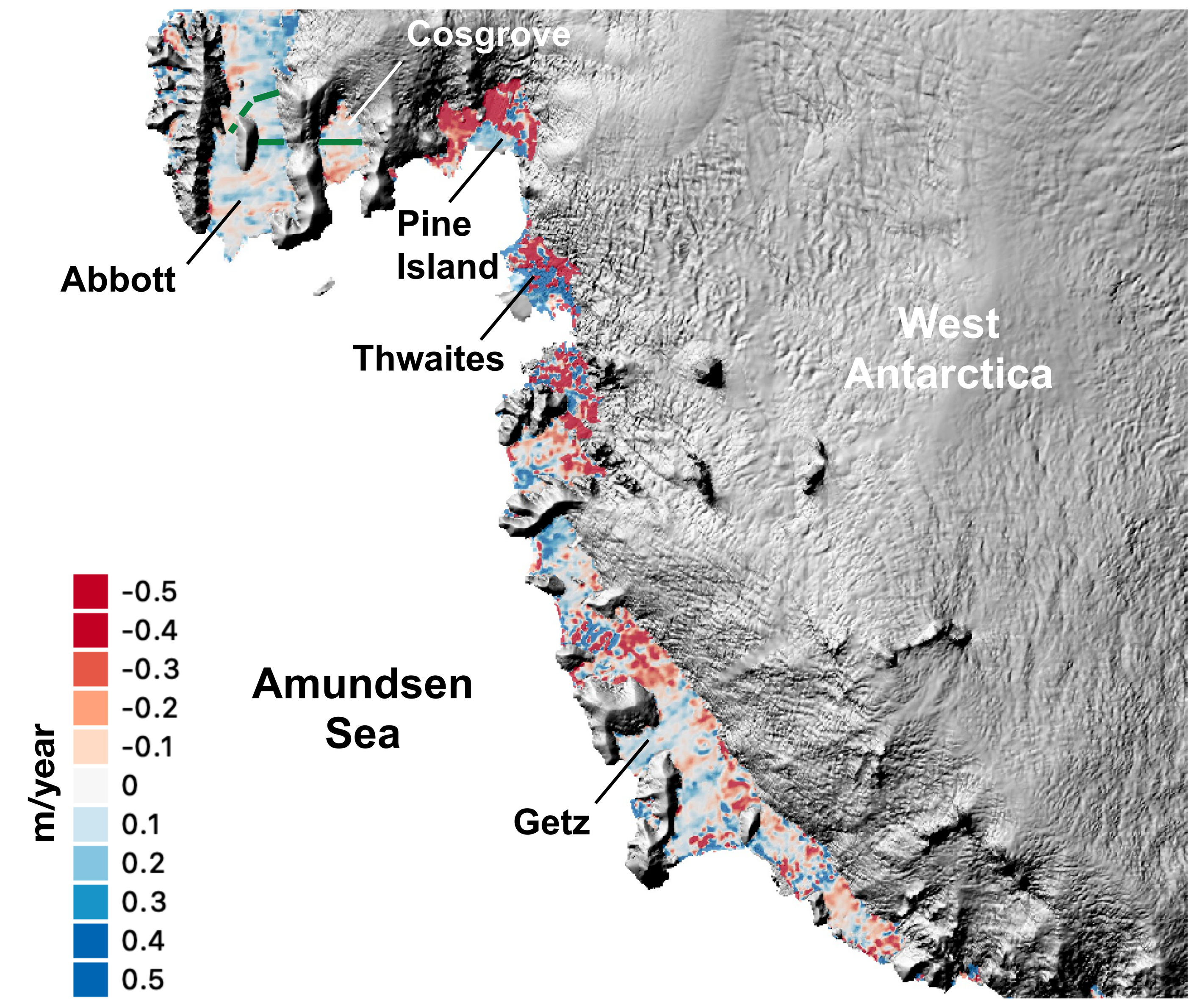
- Calculate ice-shelf basal melting rates at seasonal to annual timescales from altimetry measurements and ancillary data for ice shelves in the Amundsen and Bellingshausen seas of West Antarctica in the period 2010 to the present.
- Apply the adjoint mode of the Massachusetts Institute of Technology General Ocean Circulation Model (MITgcm), additionally constrained with submarine melting patterns inferred from observations, to simulate oceanographic variability on seasonal to annual time scales on the continental shelf during the study period.
- Determine if improved observational understanding of extrema in the sub-annual variability of ice-shelf submarine melting has decadal-scale consequences for ice-sheet model projections of sea-level contribution from Antarctica.

Approach and Results in Year 1:

a. Initial build of processing pipelines for altimetry data; process ICESat-2 and CroSat-2 data.
b. Apply to altimetry all necessary corrections, in particular, firn air content (FAC; see steps below).
c. Create time series and spatial fields of surface elevation from merged solution.
d. Analyze and iterate to improve solutions based on validation analyses with coincident ATM data.
e. Development and evaluation of ISSM's firn advection scheme.
f. GEMB model ~6000-years spin-up for the Amundsen Sea domain with advection.
g. Training of firn densification module for ERA5 Land forcing against firn cores, with advection.
h. ISSM ice-shelf model initialization, boundary conditions, stress balance regime/rheology.
i. Set up adjoint mode for model domain, and derive optimized turbulent exchange coefficients.
j. Start ocean control run (OCEAN-hist: run with ERA5 surface forcing, 1992-present, to derive ice-shelf submarine melting rates under historical forcing conditions).

Significance/Benefits to JPL and NASA: The steps completed (above and figures) put the project in a position to bring those threads together to infer submarine melting rates from observation, use them to constrain ocean models and investigate whether sub-annual variability of ice-shelf submarine melting has decadal-scale consequences for ice-sheet projections of Antarctica's sea-level contribution. These results helps JPL's future mission planning, such as the upcoming EVS-4 call.

Figure 1. The study area in the Amundsen Sea sector of West Antarctica showing our findings of the mean annual ice-shelf surface elevation change in the period 2010–2021. Reddish colors indicate surface lowering. The dark-green lines on the Abbott and Cosgrove ice shelves are the transects over which the validation comparisons shown in Figure 2 were made.



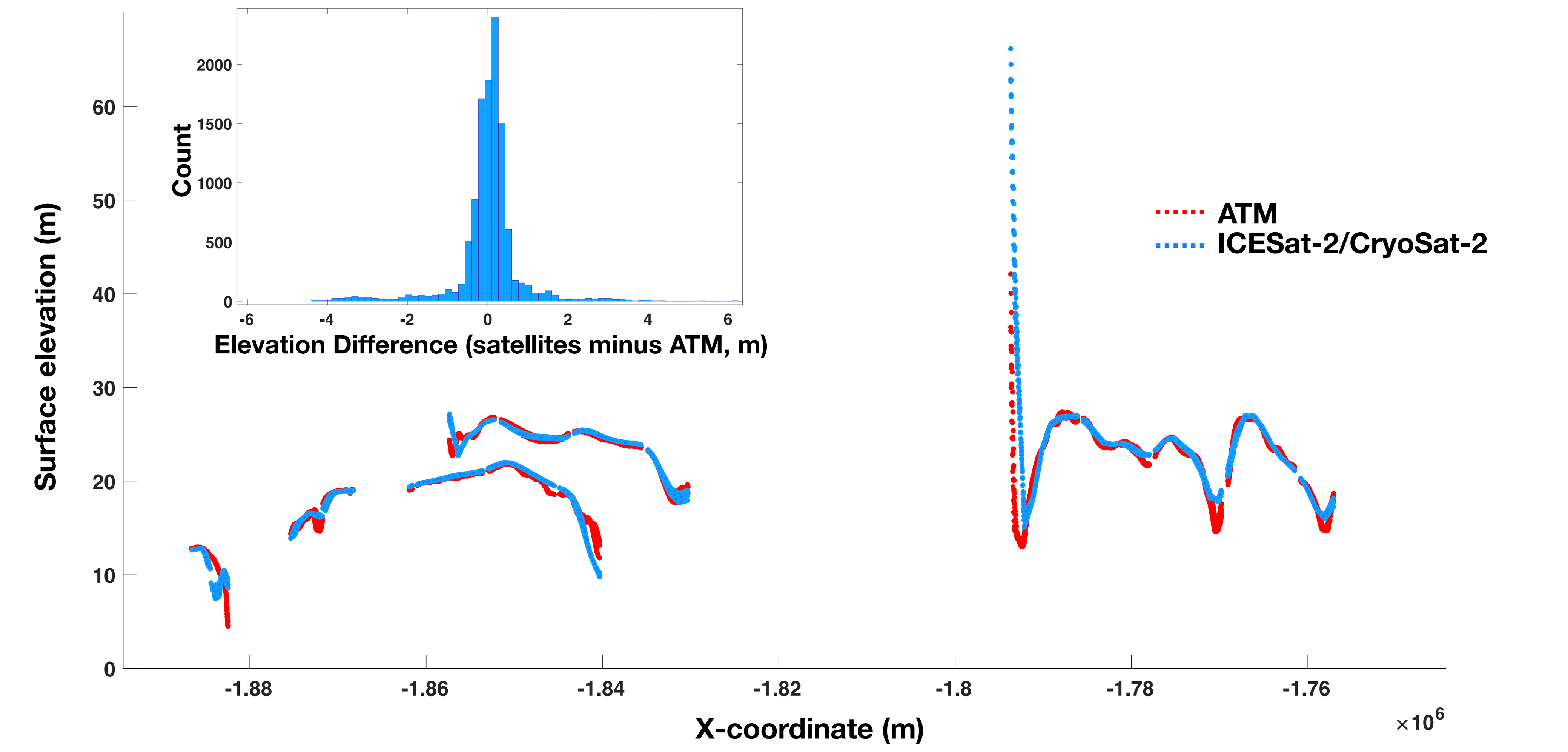


Figure 2. Validation comparisons over Abbott and Cosgrove ice shelves (Figure 1) between our altimetry inferred from ICESat-2/CryoSat-2 data and the laser altimetry of the Airborne Topographic Mapper (ATM), which flew as part of Operation IceBridge. Both sets of observations are from November 2018. Inset shows a histogram of the differences in measured elevations among the two data sets (11,521 points). The mean of the absolute value of the differences = 0.72 m (0.46 m when excluding the data from around x-coordinate -1.79 x 10^6 m, which is at the grounding line of Cosgrove Ice Shelf).

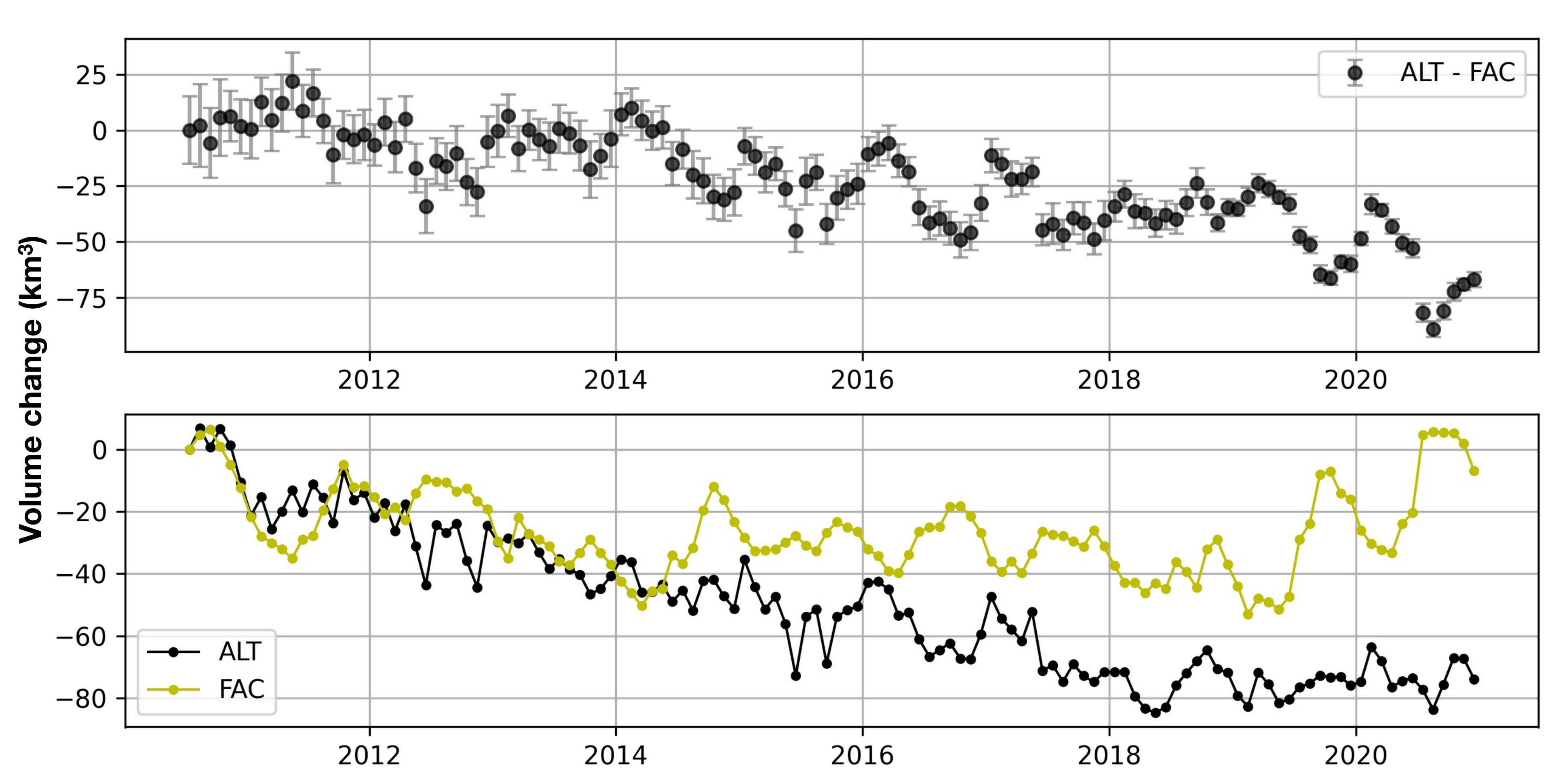


Figure 3. Top panel: Monthly time series of volume changes of the Getz Ice Shelf (Figure 1) relative to July 2010 inferred from firn-corrected altimetry. Time series is estimated by merging both CryoSat-2 (July 2010 to December 2020) and ICESat-2 (October 2018 to December 2020) data. Error bars represent the area-integrated relative error estimated from the RMS of the topographic residuals for each time series. **Bottom panel:** The two individual components that were combined to produce the time series in the top panel. These are the volume changes inferred from altimetry without correcting for firn, and volume changes due to firn air content variability. Top panel shows that by the end of this period Getz Ice Shelf shrank by ~65 km^3, which is equivalent to ~60 gigatons of ice, lost due to enhanced submarine melting.

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