Can Ocean Temperature Changes Around the Greenland Ice Sheet Be Inferred With Altimetry?

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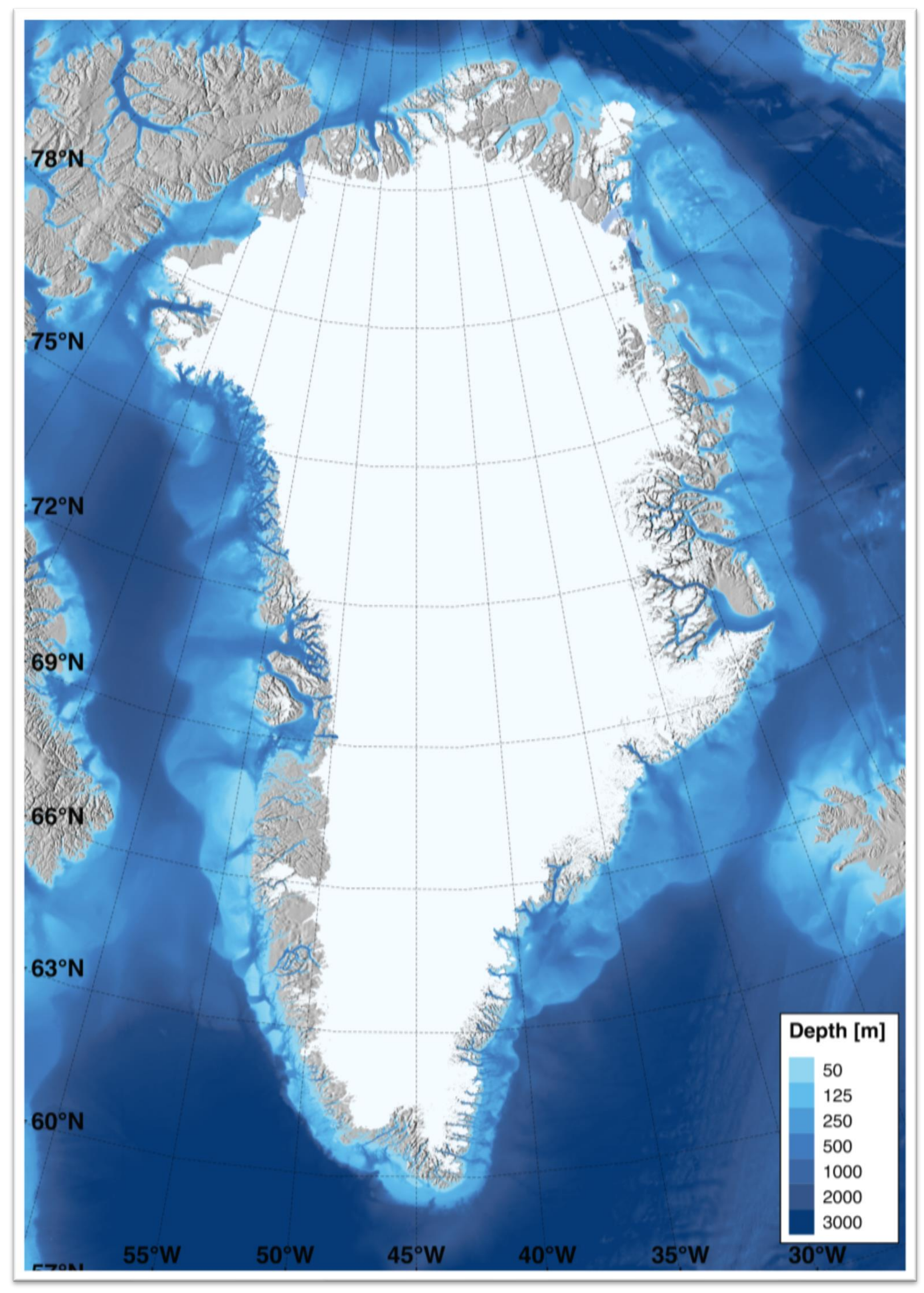
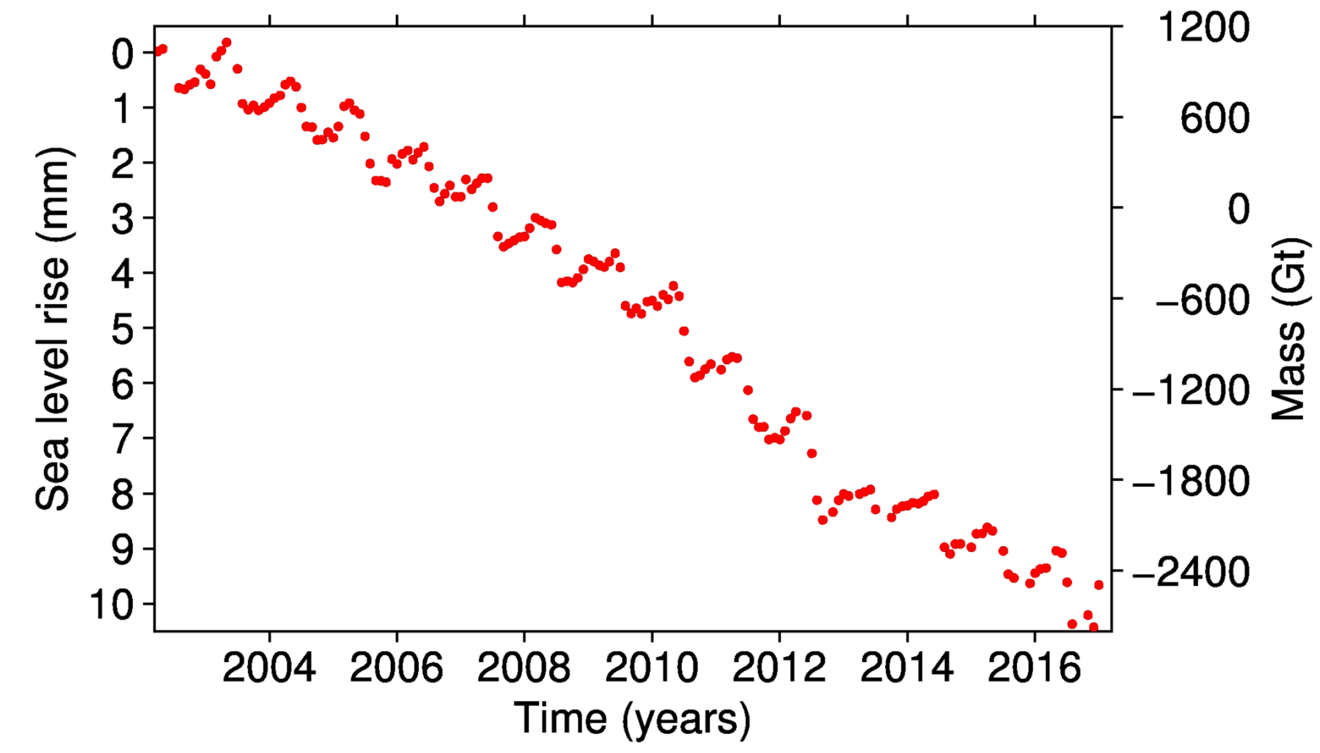
The recent acceleration of global mean sea level rise has been partly driven by Greenland Ice Sheet mass loss (~0.75 mm yr^{-1} of the total ~3.3 mm yr^{-1}). Starting in the mid-1990s, a warming North Atlantic Ocean was followed by increased ice mass loss principally along its southeast and northwest margins where the ice sheet is drained by numerous marine-terminating (tidewater) glaciers.

In this project we seek to ***establish a method for inferring changes in tidewater glacier melting caused by subsurface ocean temperature variability***. By exploiting the relationship between seawater warming and thermosteric expansion it may be possible to quantify ocean warming on Greenland's continental shelf using satellite altimetry data.

We will use ocean surface topography data and ocean and atmospheric data from *in situ* and remote-sensing sources in conjunction with numerical ocean models ***to reconstruct the three-dimensional time-varying ocean temperature and salinity state around Greenland from 1992-present***. Reconstructions of the ocean state will be made on a set of nested regional ocean models of increasing spatial resolution using the adjoint state estimation methodology developed as part of the Estimating the Circulation and Climate of the Ocean (ECCO) project.

Once the ocean state around Greenland is reconstructed, we will then ***relate the inferred ocean temperature variations to observed and estimated changes in ocean-induced glacier melt rates***. If successful, we expect that satellite altimetry will begin to be used to monitor ocean temperature variations in this traditionally highly under-sampled and difficult to access area that is vitally important area for the study of global sea level rise.





(left) Greenland has a shallow continental shelf 100-350 km wide except in the south (below 66N) where it narrows. A network of deep (> 500 m) troughs cut across the shelf and provide a pathway for warming subsurface offshore waters to reach Greenland's marine-terminating glaciers. (top) Greenland Ice Sheet mass change and equivalent mm of global mean sea level rise between 2003 and 2017 as observed by the NASA GRACE from the Danish Meteorological Institute Polar Portal)

Four Primary Activities of the Project

(1) Characterize SSH variability on Greenland's shelf in space and time using satellite altimetry data from all available instruments. Removal of the tidal signal from SSH will be performed using a new tide solution derived from an ocean model with an updated seafloor geometry using data collected as part of NASA's Ocean's Melting Greenland Mission.

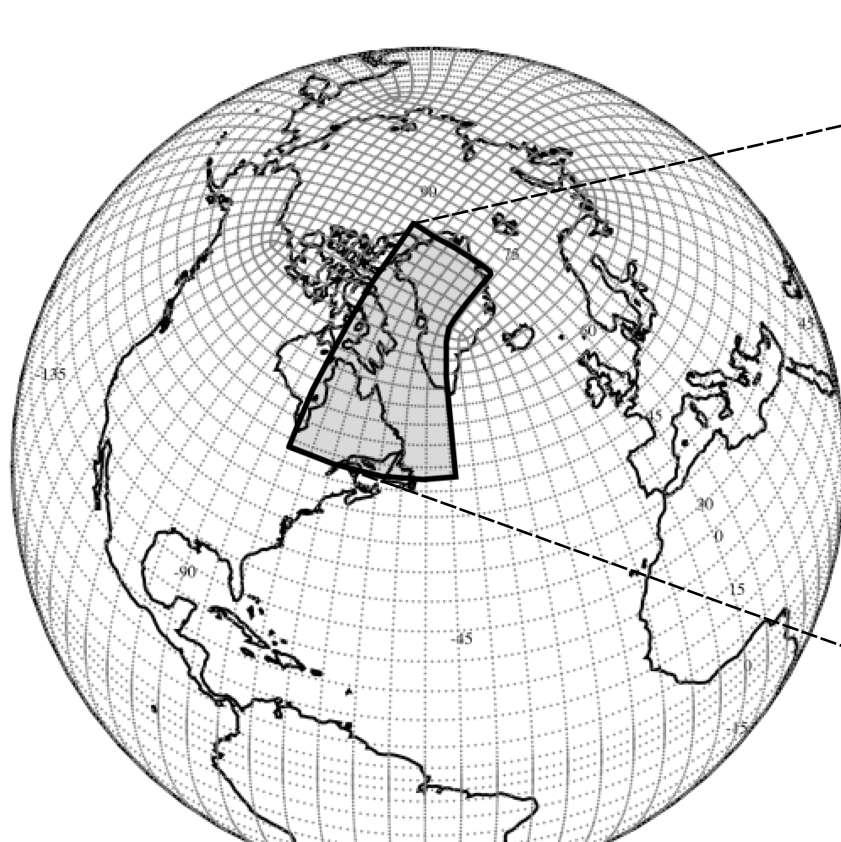
(2) Quantify the sensitivity of SSH on the shelf to ocean temperature variations and other contributing factors using the adjoint of our numerical ocean model. Use these calculated SSH sensitivities to determine the extent to which past SSH variations can be explained by observed atmosphere and ocean anomalies.

(3) Estimate the relative magnitudes and drivers of steric and non-steric SSH variations on the shelf from 1992-present using SSH and other ocean and sea ice data in conjunction with a set of nested high-resolution ocean models. Determine if past temperature variations on the shelf can be linked to ocean-melt induced glacier variations.

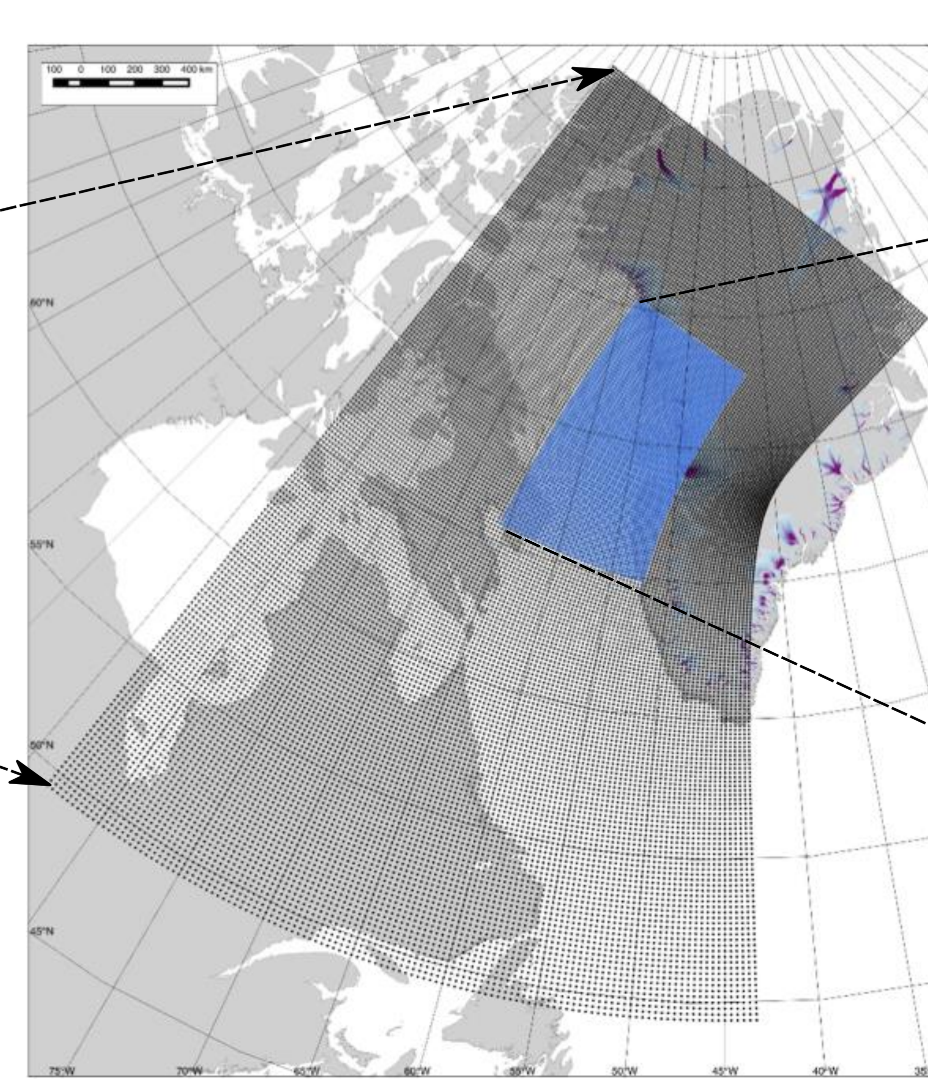
(4) Ascertain whether measurements from the current ocean observation system provide enough information to infer ocean temperature variations on Greenland's shelf and, if not, determine which additional observations would be necessary to achieve this objective.

(right) The global and a selection of regional nested ocean model grids used in this project. The Level 0 (not shown) and L1 domains are taken from the ECCO v4 Central Production state estimates. Regional domains are progressively downscaled subsets.

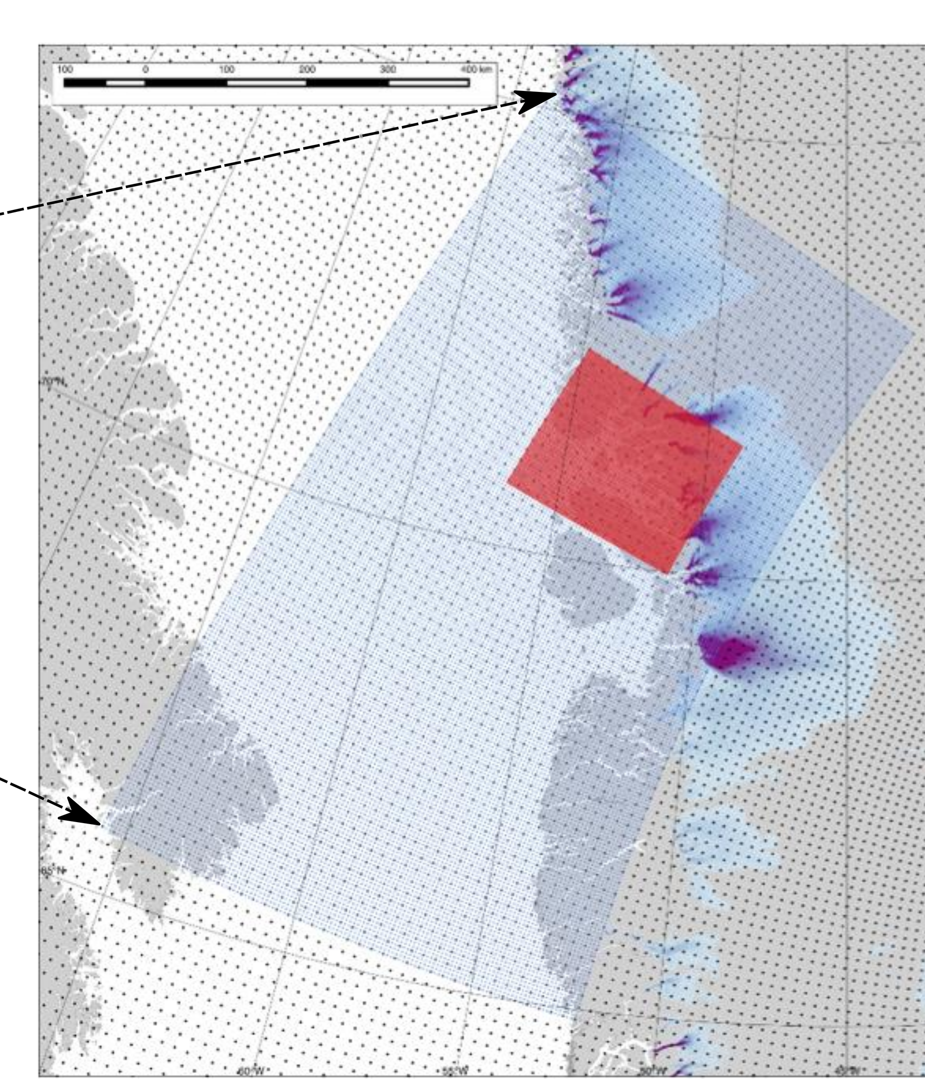
Shown is the "Labrador Sea-Baffin Bay" L2 grid (black), the "Davis-Baffin" L3 grid (blue) and the "Uummannaq Fjord" L4 grid (red). Between each level grid resolution is increased by a factor of 3.



level 1: global dx = 13.5 km
level 2: black dx = 4.5 km



level 2: black dx = 4.5 km
level 3: blue dx = 1.5 km



level 3: blue dx = 4.5 km
level 4: red dx = 0.5 km

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