

Consequences of a Deeper Bed for Marie Byrd Land Stability

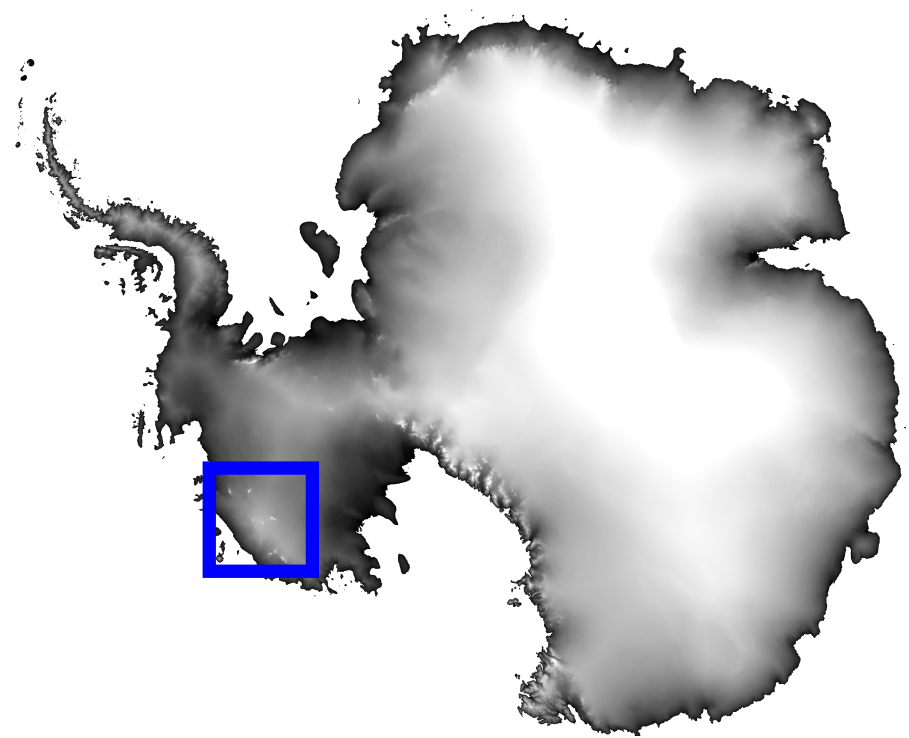
Nicholas Holschuh, David Pollard, Richard Alley, Sridhar Anandakrishnan - Pennsylvania State University

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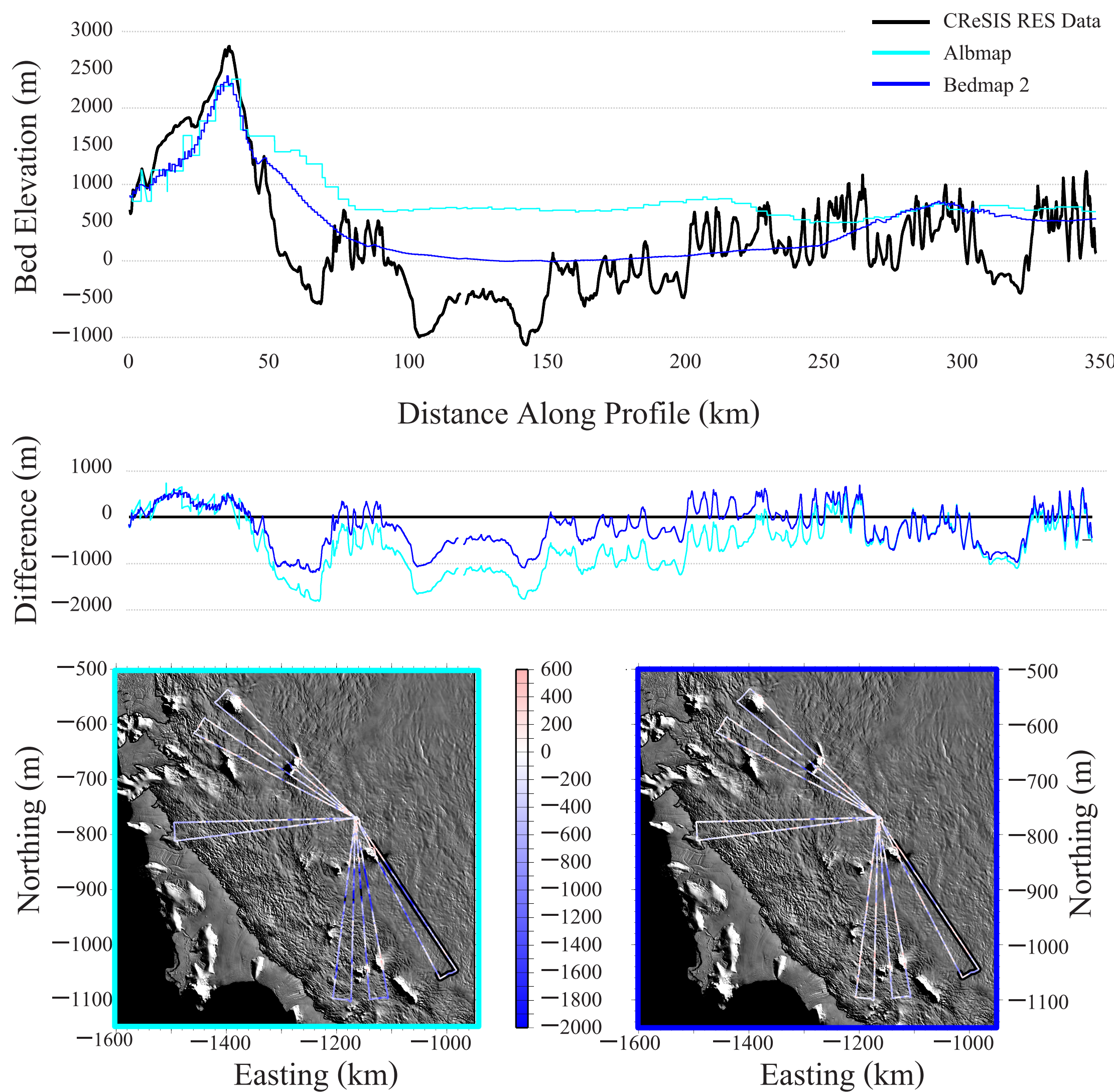
Introduction - MBL

Despite limited geophysical data for the region, bed topography for Marie Byrd Land (MBL) has been treated as a regional high in all major mapping efforts of Antarctica. The presence of a regional high reduces the glaciological significance of MBL; models using the currently prescribed bed topography show little change in ice volumes or its spatial distribution on MBL over the last 5 million years. This uncertain basal topography has also influenced other geophysical studies in West Antarctica; the accuracy of gravity and seismic inversions for the region rely heavily on knowing the bed elevation. Using airborne RES data collected in 2009, we have updated our understanding of the ice sheet geometry over Marie Byrd Land, in an effort to re-evaluate its potential impact on sea level rise in the case of West Antarctic collapse.



Basal Topography

This study was motivated by the discovery that Marie Byrd Land's bed is, in many places, much deeper than previously estimated. Albmap and Bedmap2, the leading topographic data sets for Antarctica, presented two different pictures of the bed (despite using the same radar and seismic data constraints for most of the region presented below). In many locations, new RES data shows the bed 1-2 km deeper than estimated.



2D and 3D look at topographic differences (Elevation Data - Grid). Selected profile boldened using black in map view.

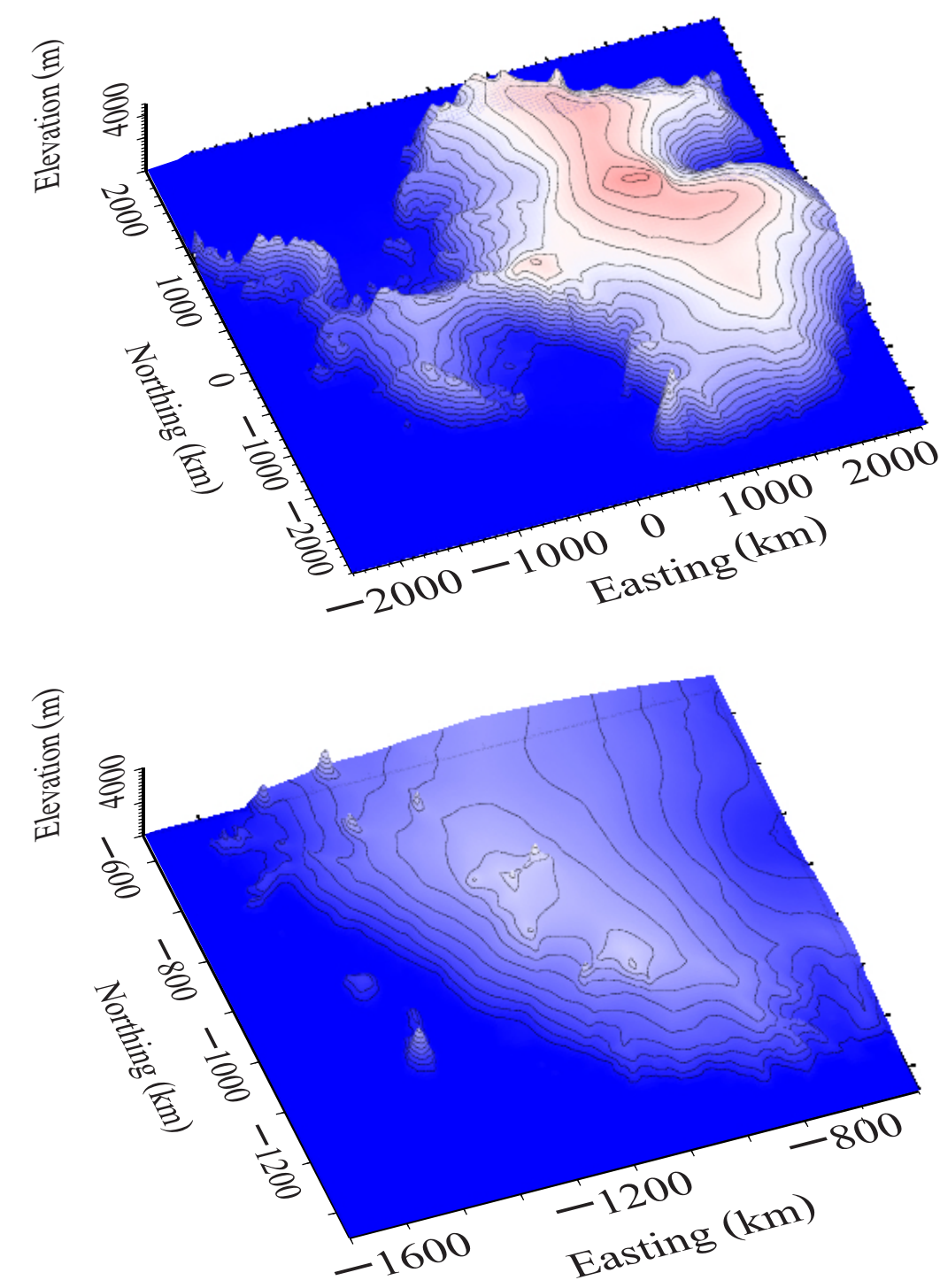
Modeling

The first step in modeling the impacts of a deeper bed was to produce a new 2D grid of bed topography. Data coverage is still quite poor; our grid was designed to be a maximum estimate of depth change, while still fitting all available sounding data.

Note: Ice volume was previously underestimated by ~19,000 km³ in MBL

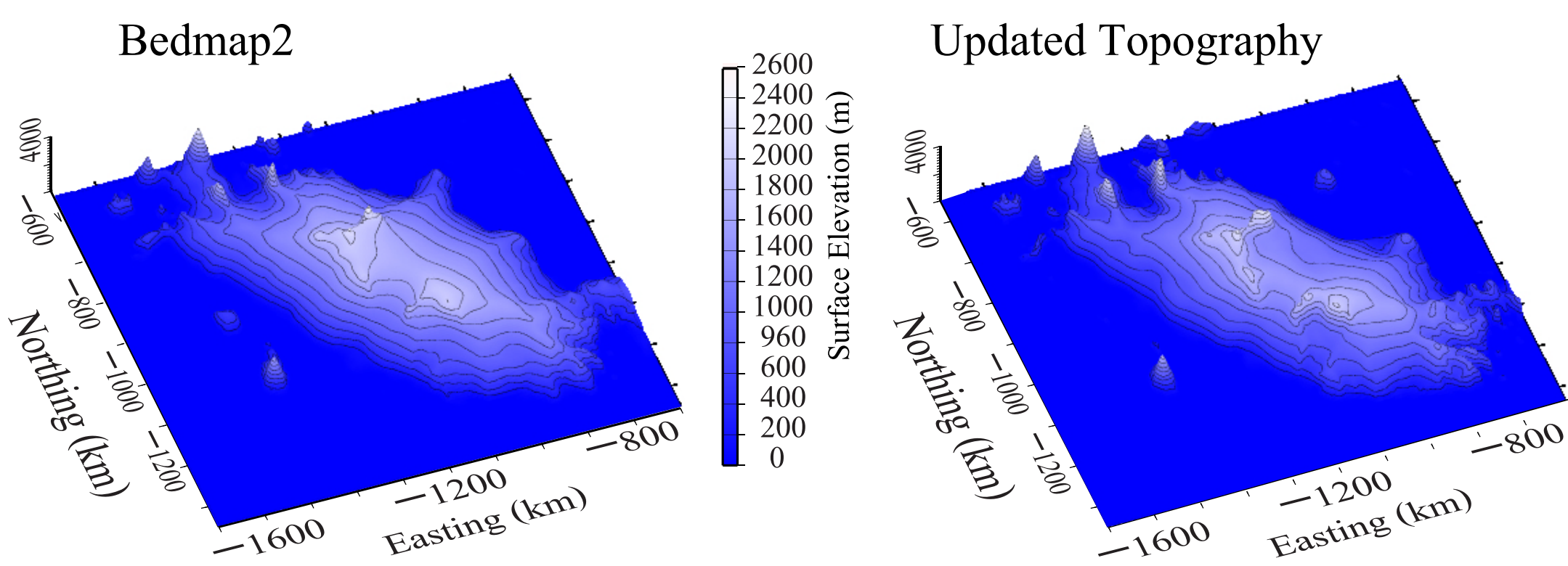
To determine whether or not deviations from previous bed elevation estimates impact the results of modeling, we use the hybrid Ice-Sheet/Ice-Shelf model of Pollard and DeConto to estimate values for sea-level rise in the event of West Antarctic collapse. The experiment was performed with the following steps:

- 1) Using Bedmap2 and an updated bed topography produced using the new CReSIS data, invert for basal sliding coefficients under Antarctica which reproduce the observed Ice Surface.
- 2) At 40km grid spacing, run the model for 100,000 years with modern climate to ensure both bed topographies produce the same stable result.
- 3) Using the results of the 40km run as boundary conditions, perform a nested run of just Marie Byrd Land with 5km spacing for higher resolution results in the region.
- 4) Repeat steps 2-3 for a warm climate, known to induce collapse of the West Antarctic Ice Sheet (WAIS), and determine to what extent the differences in topography yield differences in sea level rise.



Plots of the ice surface elevation during modern spin up for the global and regional domains. Contour intervals of 200m.

Simulating WAIS Collapse



Estimated ice surface elevations over Marie Byrd Land in the event of WAIS collapse. Contour interval of 200m.

WAIS collapse was driven in the model by increasing ocean temperatures 2°C over the modern ocean. Rapid retreat into the Amundsen Sea Embayment results in unstable migration of West Antarctic grounding lines, until almost 4m of SLE is added to the global oceans. As indicated by the ice cap that remains post WAIS collapse, the basal topography found under the ice of Marie Byrd Land controls how far ice will ultimately retreat. The deeper bed found in our updated grid is expected to result in additional ice surface draw-down, as it allows ocean-driven melt to penetrate deeper into the continent. The two figures above show the results of this modeling for MBL.

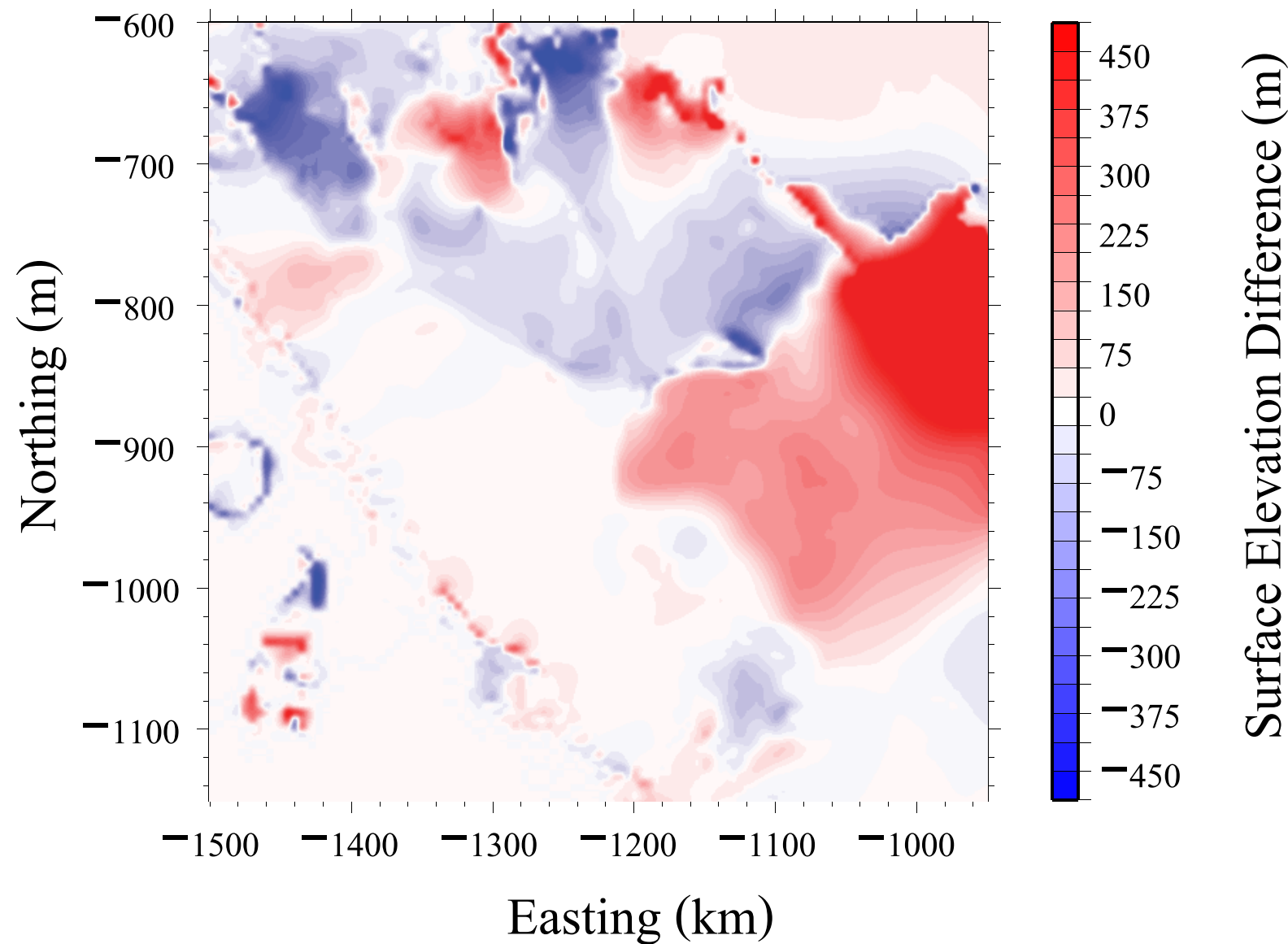
Results

Changes in bed topography have a profound impact on grounding line retreat, the primary driver for ice loss during WAIS collapse. We would expect changes in bed depth on the Eastern and Southern flanks of MBL to cause the greatest changes in dynamic thinning, since troughs in those locations define the grounding line retreat paths for Thwaites Glacier and the Siple Coast. The difference between the final ice surfaces, plotted below, shows increased dynamic thinning to the south (grid NE), consistent with the area of greatest adjustment to the basal topography. Despite localized changes to the bed, draw-down is enhanced over the entire region of interest.

Increase in SLR Contribution from MBL:

~3.5 cm

Plot of the difference in ice surfaces, post-collapse, using Bedmap2 and our updated topography as boundary conditions. Positive values represent regions where the ice surface was drawn down further using the deeper bed.



Conclusions

Previous estimates of basal topography and ice volume for Marie Byrd Land differ significantly from modern observations, but the impact of these incorrect assumptions on models of WAIS was not immediately apparent. We found that a deeper bed did result in additional ice loss in the event of WAIS collapse, so precise estimates of future sea level rise could be improved by additional geophysical data collection over the region. Ultimately, we believe it is possible to conclude the following:

- 1) **Evidence of a deeper bed in Marie Byrd Land results in small, but significant increases in sea level rise during WAIS collapse, both due to the presence of additional ice and from the dynamic effects from a different bed geometry.**
- 2) **Even with an extreme change in bed elevations, Marie Byrd Land still defines a stable region of West Antarctica in the face of rising temperatures.**