What Gravity Can Tell Us About West Antarctica:

A Close Look at Thwaites Glacier and a Plan for Future Holistic Studies

Theresa M. Diehl, Donald D. Blankenship, John W. Holt, Thomas G. Richter, and David L. Morse*

The University of Texas at Austin, Jackson School of Geosciences, Institute for Geophysics, Austin, TX

**Presenting author*

As the climate warms, the potential for rapid discharge of the West Antarctic Ice Sheet (WAIS) grows. Despite our recent activity towards understanding the WAIS' behavior, our community is currently unable to predict the magnitude or spatial extent of the WAIS' response to global warming. One of the reasons that we are unable to do so is that our current WAIS models- while improving rapidly- still fall short of accurately representing ice dynamics. The West Antarctic subglacial environment, for one, is fundamentally different than that of East Antarctica and yet ice sheet models use constants for lithospheric thickness, mantle rheology, and subglacial heat flux that are entirely appropriate for East Antarctica, but inappropriate for West Antarctica. The complicated tectonic history of West Antarctica causes these particular boundary conditions to be spatially heterogeneous. In order to better constrain these boundary conditions, we must stitch together our "up-close" subcontinental-sized surveys (that capture much of West Antarctica's small complexities, such as sediment and volcanics distributions) into a more holistic view that will be useful to WAIS modelers. Towards this end, we present here our most recent "up-close" airborne geophysical survey in West Antarctica and then we fold this survey into our holistic plan for examining West Antarctica's subglacial geology and lithosphere.

The threat of rapid WAIS collapse is stronger in the Amundsen Sea Embayment (ASE), which contains two of the fastest moving and highest discharge outlet glaciers in West Antarctica: Thwaites and Pine Island Glaciers. However, boundary conditions that affect the flow of these glaciers- such as sediment distribution and bedrock characteristics- have been previously unknown and, therefore, are inaccurate in current ice flow models of the catchments. In order to provide better constraints, the University of Texas (supported by NSF) conducted an airborne survey of the Thwaites Glacier catchment during the 2004-2005 austral summer. The British Antarctic Survey worked concurrently to complete an assay of the neighboring Pine Island Glacier catchment. Our surveys are the first and only large-scale geophysical surveys of this area. Over 43,500 line-km of data were collected by UT with an aerogeophysical platform that included ice-penetrating radar, gravity, magnetics, laser and pressure altimetry, and GPS.

With respect to gravity, this was a very atypical airborne survey. Planned altitude changes were necessary to keep the ice-penetrating radar within its optimal distance of ~500m from the steeply sloped ice surface. Airborne gravity meters, however, are notorious for being unable to recover quickly from the large accelerations induced by flight elevation changes, often resulting in greater than 30 min of irrecoverable data post-maneuvering. However, this survey was the first use of a LaCoste & Romberg Air/Sea II gravimeter in an airborne survey. The new Air/Sea II performed beyond expectation and data loss was limited to only the immediate area of the elevation change. Careful flight planning minimized the impact of this data loss on the final gravity products.

Here we present our primary results of free-air and 3-D Bouger gravity anomalies for the Thwaites Glacier survey. We assess the theoretical anomaly detection threshold, actual anomaly resolution, and data error. Upon comparison of the gravity anomalies with our airborne magnetics and subglacial topography results, we delineate West Antarctic crustal block boundaries and postulate their controls on the flow of the ice sheet through this area. Since the area of the Thwaites catchment (~800 x 600 km) is very large, we are able to compare the best extant satellite gravity anomalies to the long-wavelength airborne ones. This provides ground-truth for the Gravity Recovery and Climate Experiment (GRACE) satellite data and yields a feel for the inability of our community to use this satellite data at the limits of its resolution. In the end, this ground-truth comparison highlights the benefits using satellite and airborne gravity measurements in tandem to significantly improve satellite gravity measurements.

In a holistic sense, two different methods have already been used to provide modelers with constraints for lithospheric thickness and subglacial heat flux: surface wave tomography (Shapiro and Ritzwoller, 2004) and satellite magnetics (Fox Maule et al., 2005). However, these two models differ greatly and a third is needed to resolve their differences and improve on their coarse (~200km) spatial resolutions. The results presented here show that gravity can be used for such a task in West Antarctica where the spatial coverage is now available, especially since gravity can be constrained there by a suite of other geophysical measurements. It may be time to look past typical small-scale airborne gravity analysis and also consider gravity data holistically- on a continent scale; perhaps then we will be able to provide WAIS modelers with the spatially-dependent solid earth constraints that they need.