Accumulation Rates Over the Thwaites Glacier Catchment, West Antarctica, Using Radar Reflection Layers

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The scientific motivation for addressing the spatial and temporal distribution of snow accumulation rates in the catchment of the Thwaites Glacier (TG) is understanding the potential sea level contribution of the West Antarctic Ice Sheet (WAIS) over the next few centuries. TG lies in the Amundsen Sea Embayment (ASE) portion of the WAIS which is thought to be unstable both because its bed lies below sea level and because it's draining glaciers lack protective ice shelves. This instability is reflected in TG sensitivity to external forcing factors such as global climate, sea level rise, ocean temperature and accumulation rates, among others. These forcing factors affect the mass balance of the ice sheet. Given this general perspective, the present and past trends of spatial distribution of accumulation rates in the TG catchment serve as an essential boundary condition needed by the glaciology and climate communities to constrain models of WAIS evolution with the ultimate goal of describing its past and present behavior and forecasting its future evolution.

In this paper, we construct a map of snow accumulation rates over the catchment of TG using shallow internal layers traced from radio echo soundings. Based on these layer profiles, we compute a first order estimation of mass influx and compare it with published values of mass outflux over the grounding line and calculate an estimate of mass balance, a fundamental variable in ice flow and sea level rise models. The radar data was collected during the Airborne Geophysical Survey of the Amundsen Sea Embayment (AGASEA) in West Antarctica, performed by the University of Texas, Institute of Geophysics in the austral summer of 2004-05. In this survey, we collected 43,000 km of data that includes gravity, magnetics, laser altimetry and a 60 MHz coherent ice-penetrating radar.

The accumulation rate is calculated from observations of layer age and depth using Nye's methodology. For this purpose we traced two shallow radar-reflector horizons that are visible through most of the radar profiles and assume them to be isochrones. Since ice core dating for these reflectors is not currently available, we estimate their ages from a simple calculation of radar-layer thickness and accumulation rates from the ITASE ice cores that were close to the ice divide, where there is little lateral deformation of layers. This yields approximate ages of 863 ± 194 and 1092 ± 284 years for the two layers. To compute the accumulation rates we used Nye's methodology which takes into account vertical strain deformation under the assumption of steady state, uniform accumulation through time and no lateral variations of ice thickness. We computed a firn correction as a function of surface temperature and surface elevation and calibrated it with the ITASE ice cores as test points. We compare the resulting accumulation rates with those obtained by Arthern [2006] to assess the accuracy of our estimates and gain insight into accumulation patterns by analyzing the difference between the two methodologies. One potential drawback to our model is the deformation of layers in the ice stream trunk which are not accounted in the Nye's formulation.

The resulting average accumulation rate for the TG catchment was found to be 0.33 m/yr, with higher values close to the coast that gradually decrease inland as a function of surface temperature and surface elevation. This spatial distribution of accumulation rates agrees fairly well with that obtained by Arthern. The main difference between the two methods is that we were unable to track layers close to the coast and, therefore, could not resolve accumulation in that area. This is reflected in our overall estimation of mass volume, for which we obtain a total accumulation of 45.5 ± 10 Km^3/yr, while Rignot [2002] observes an accumulation of 57.6 Km^3/yr and outflow of 80.1 ± 8 Km^3/yr for a deficit in mass balance of -23 Km^3/yr , whereas for the same outflow we observe a deficit of -34.6 Km^3/yr. In order to improve our estimates, we need to include accurate ice core dating and a more comprehensive inversion of accumulation rates. The improved inversion, which is currently under development, will account for factors such as convergence and divergence of ice flow and high velocities over the ice trunk where Nye's model does not apply. In addition, we are working to track layers close to the coast, applying processing such as focused SAR that permit extended visibility of the layers.