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A comparison of the influence of topographic and mass balance uncertainties on modeled ice sheet extents and volumes

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Ice sheet models are an important source of estimates of the impact of future changes of global climate on, for example, sea level. Such models have multiple sources of uncertainty including inputs describing climate forcing, the topography on which this climate acts, and the modeled responses of ice sheets to such forcing. Up until the recent past, most ice sheet models at continental or regional scales have relied on a limited number of sources of elevation data such as those provided at resolutions of the order of kilometers by the USGS (i.e. GLOBE). Previous experiments demonstrated that quoted accuracies in such Digital Elevation Models (DEMs) of between 18m and 150m RMSE have significant impacts on modeled ice sheet extent and volume for a set of Monte Carlo simulations run on Scandinavian topography at a resolution of 20km.

The availability of high resolution elevation data at a near global scale provided by the Shuttle Radar Topography Mission (SRTM) provides an excellent opportunity to further explore such uncertainties. In this paper we explore the sensitivity of ice sheet model runs in southern South America to topographic uncertainty, by treating SRTM data as ground truth for comparison with GLOBE. A comparison of STRM with GLOBE data reveals that along the Andean ridge from the Pacific coast to the Amazon basin elevation values are highly biased with various sources of supposed error (for example, data sources of different quality, measurement, interpolation, and systematic errors). Importantly, while the average differences of GLOBE altitudes from corresponding SRTM means are around 30m over the whole area, large patches in the Andean Highlands, where ice sheet inception and growth is likely, show spatially auto-correlated differences of 80-300m. In order to examine the impact these inaccuracies have on ice sheet models, a suite of topographies was produced from the original GLOBE data by adding a random, spatially correlated error surface simulating the observed uncertainties. These modified topographies were then resampled to a resolution of 5km suitable for ice sheet modeling using a bilinear interpolator. This generalisation process is a further source of uncertainty in elevation values. To estimate the influence of this resampling in comparison to uncertainties present in elevation data, SRTM data was generalized to 5km resolution using a range of methods. The variance in suites of generalized DEMs is being used as input for simulation of the Patagonian ice sheet during the first 40k years of the Last Glacial Maximum through Monte Carlo Simulations.

Previous experiments have shown that the observed relative variation of modelled ice extent and volume depends on the absolute size of the ice mass and, in Patagonia, it is expected to be of the order of 10%. Variations caused by topographic uncertainty will be compared with the system's sensitivity to variation in mass balance through climate forcing, in order to assess the relative influence of these different terms on uncertainty.