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Influence of topographic uncertainty on modelled ice sheet extents in Patagonia

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Introduction and motivation

Ice sheet modelling seeks to improve our understanding of the behaviour of complex dynamic systems through the abstraction of key elements of the ice sheet system. One example where ice sheet models have been extensively used in this context is exploring the behaviour of **glacier fluctuations within Patagonia** during the Last Ice Age.

A key set of questions in any such modelling are, what uncertainties exist in our results and how do they contribute to overall **model uncertainty**? Typically these uncertainties are explored through sensitivity tests, where the susceptibility of a particular configuration to the climatic envelope is explored.

One source of uncertainty is introduced through the representation of topography. A means to assess the influence using a typical topographic base dataset - such as **GTOPO30/GLOBE** - has on modelled result, has recently become available through the advent of near global **SRTM90** coverage.

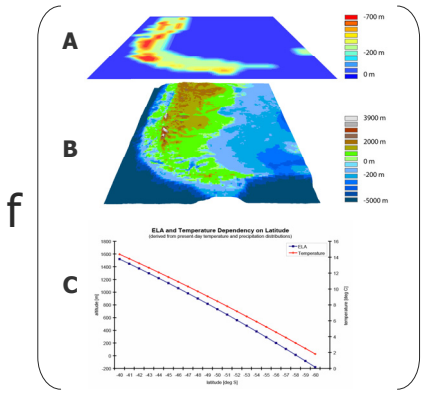


Fig.1: ELA/MB distribution adapted from present day precipitation patterns (A), topography at 10km resolution produced from GLOBE data (B) and latitude dependency of temperature and ELA derived from IPCC data.

GLIMMER

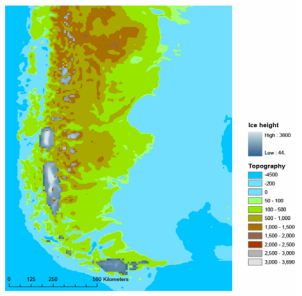


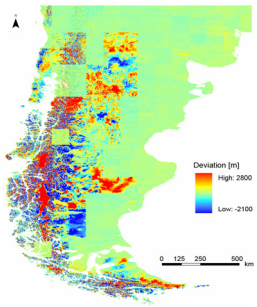
Fig.2: Ice extent and volume (blue) of the Patagonian ice caps modelled using the GLIMMER ice shield mode. Climate drivers approximating present day conditions with ELA lowered 200m after 300 model years. Maximum slope constrained to 16% to prevent instabilities.

Methods

A spatially variable ELA and temperature representation was developed based on current climatic conditions, and simulations constrained on past empirical ice sheet limits. These climatic drivers were then held constant during all model runs.

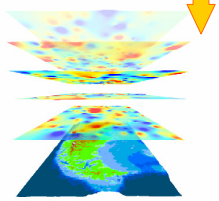
Using **SRTM90** data as ground truth, **uncertainty in GLOBE DEM** data can be assessed (Fig. 3). Deviations show various error sources, with an systematic area component of ~30m (STDEV 30m). Average deviation for the area -40° to -58°S show a STDEV of 130m around a mean of -2 due to large interpolation errors.

This values were used to generate random, normal distributed, spatially correlated error surfaces of mean 0 and STDEV 30 & 100m respectively, used as input for **Monte Carlo Simulations** using the **GLIMMER** ice sheet model, in order to explore the influence this topographic uncertainty has on modelled ice sheet extents and volumes.



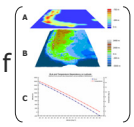
GLOBE DEM uncertainty

Fig.3: Deviation of GLOBE data at 1km resolution from mean SRTM90 elevation values (100m resolution), used as ground truth. Distribution of variation is used to create random error component for Monte Carlo Simulation.



Derived error surfaces

Fig.4: Spatially correlated, random error surfaces (mean 0, STDEV 30m and 100m, resp.) added to Patagonian topography as MCS input.



Monte Carlo Simulation using GLIMMER

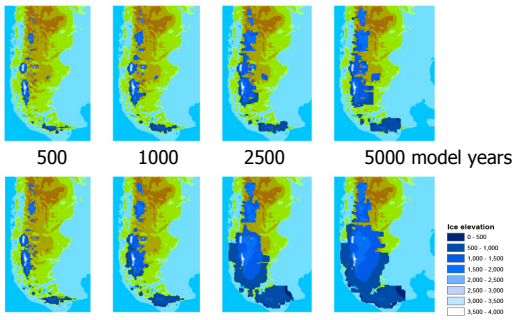
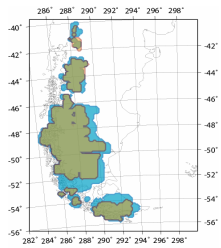


Fig.5: MCS model runs with minimum (top) and maximum (bottom) ice extent and volume for error of 100m STDev after 500, 1000, 2500 and 5000 years model time, respectively.

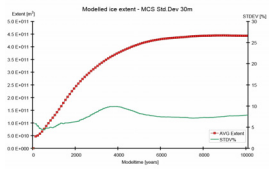
First Results

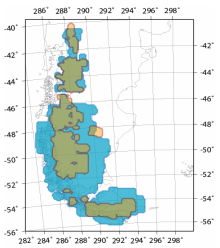
With small topographic uncertainties in the order of 30m STDEV introduced to the ISM, modelled extent and volume vary approx 8% and 12% across all runs, respectively, the equivalent being ~60m of ELA change. With larger errors of 100m STDEV, such as the deviations observed in GLOBE data, variations of up to 22% and 28% for modelled extent and volume can be observed, the euqivalent being 150m of ELA change.

Uncertainties in Ice shield model results



Model variations with topographic uncertainty of 30m STDEV





Model variations with topographic uncertainty of 100m STDEV

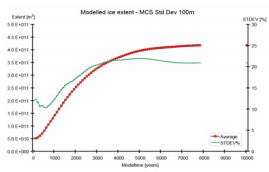


Fig.6: Results of MCS with errors of 30m STDEV (top) and 100m STDEV (bottom). Ice extent of minimum (beige) and maximum (blue) run after 3000 model years (left). Modelled average extent and volume across all runs are plotted against model time together with standard deviations.

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The GLIMMER project:
http://glimmer.forge.nesc.ac.uk/