Experiments on the sensitivity of modelled extent of Fennoscandian icesheets to representation of topography

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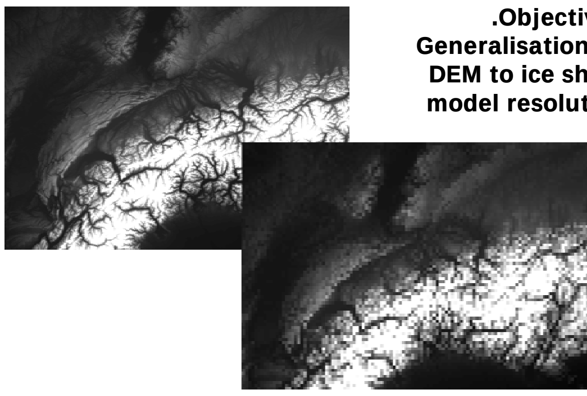
1. Motivation

Widespread availability of high resolution terrain data at a near global scale, allows quantification of likely uncertainties in low resolution terrain data commonly used to represent the bed and ice sheet initiation surface in ice sheet modelling (**ISM**). Spatial configuration and attributes like maximum and minimum altitude, slope or roughness of the target low resolution digital elevation model (DEM) strongly depend on factors such as the applied **generalisation method** and source **DEM quality**. Generation of low resolution (5-10km) surfaces from higher resolution (100m) data through a variety of algorithms shows a strong correlation between elevation and standard deviation in the generated surfaces. This correlation can be used to produce error surfaces that feature both a random and a correlated, spatial dependent component. Using these error surfaces as input for **Monte Carlo Simulations** (MCS) is a possible approach to testing ice sheet model sensitivity to terrain representation.

SRTM 90 data: ~77m resolution



.Objective: Generalisation of DEM to ice sheet model resolution

Model input: 10km resolution

2. Generating topographies

To derive standard deviation/altitude dependencies, **SRTM90** data of the central European Alps (44-50°N,4-14°E, altitude 0-4780m) was processed and generalised to 5 and 10km resolution using ESRI's ArcGIS 9 resampling methods (bilinear interpolation & cubic convolution) as well as total mean. For each method and target resolution, 40 DEMs were generated using **moving sampling origins**. Plotting target DEM altitude against standard deviation (STDV, Fig.1) of contributing cells, a general trend can be observed, that was fitted by a 4th order polynomial. To create input topographies for the MCS, altitudes at 250 random points were sampled from input Fennoscandian topography (20km resolution, 141x116 cells) and STDV was calculated using the derived trend polynomial. At each point, a random z value was drawn from a normal distribution of mean 0 and variance $STDV^2$. A continuous surface was interpolated from all 250 points using inverse distance weighting (**IDW**) (to minimize noise) and superimposed on the original DEM. Using this method, 150 topographies were produced with a mean maximum altitude of 1577m and a mean STDV of 890m (Original DEM: 1529m, 862m).

.Plot source STDV against target altitude

.Resample DEM with moving origin

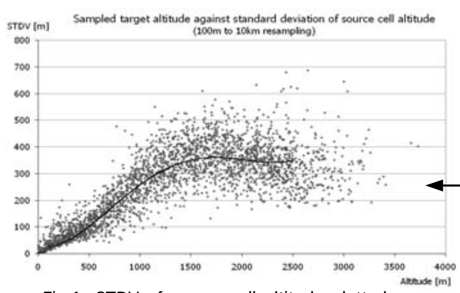
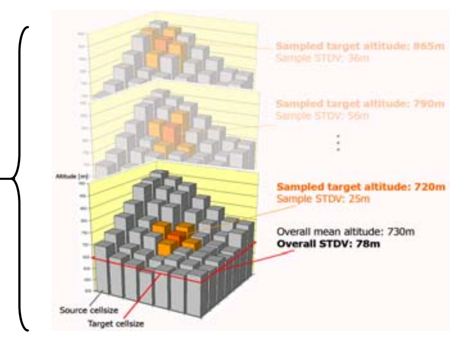


Fig.1: STDV of source cell altitude plotted against resampled target cell altitude.

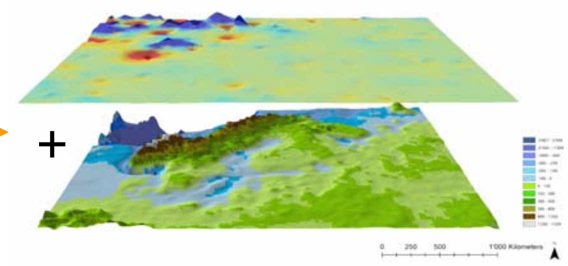


.Derive STDV-altitude dependency

[STDVterm]: $y = ax^n + bx^{n-1} + c$

.Generate spatially correlated error surface

```
for i = 1 to n:
   x,y = makeRandomCoordinates
   STDV_i = [STDVterm]*DEM.getZ(x,y)
   z_i,x,y = normal(mean=0;STDV_i)
DEM = DEM + IDW(z_1,... z_n-1, z_n)
```



.Create n topographies with altitude dependant spatially correlated error

3. Running the GLIMMER ice sheet model

With the generated suite of topographies as input for the MCS, GLIMMER was run 150 times to model the Fennoscandian ice sheet during the **Last Glacial Maximum** using the standard Edinburgh Ice Sheet model climate driver (EIS, based on GRIP S-10 proxy records for the LGM; Hagdorn 2003). The ice sheet is modelled from 120ka BP through its first retreat at ~72ka BP to 60ka BP. Ice height, temperature and velocities are output every 1000 model years and evaluated across all runs.

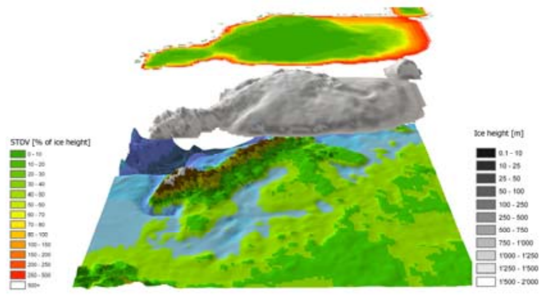
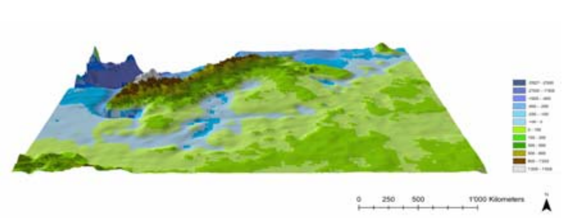


Fig.2: Modelled ice height (ih, middle layer) at 96ka BP with STDV as % of ih (top layer) over Fennoscandian topography (lower layer).



.Run ISM n times on suite of input topographies

4. Results

Input MCS error surfaces (mean=0±7.7m, STDV=70±9.4m, Kurt.=~30) resulted in variations of modelled ice volume and extent of an **average 5-10% STDV** with maxima of >20% during inception (Fig.4). A strong **negative correlation** of variation with absolute ice extent and volume can be observed (Fig. 5). Uncertainties introduced to the ISM by aspects of topographic representation influence model results significantly mainly during phases of **inception** and **ice retreat**. These results emphasize that careful consideration of uncertainty should be taken when using low resolution ISMs to ask questions about inception.

.Results:

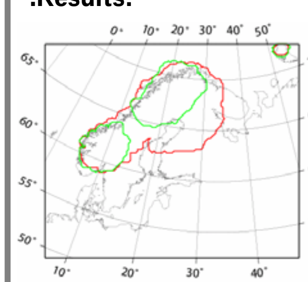


Fig.3 (above): Minimum (green) and maximum (red) modelled ice extent at 108ka BP over Fennoscandian coastlines.

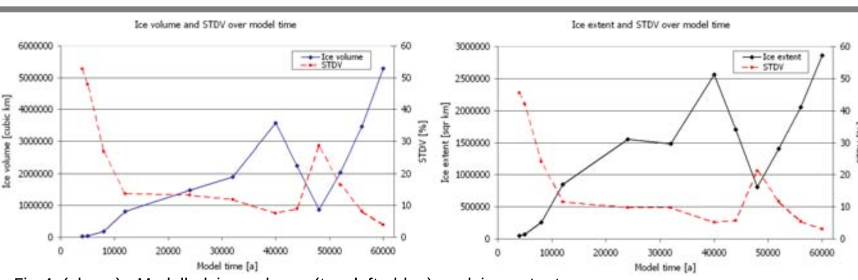


Fig.4 (above): Modelled ice volume (top left, blue) and ice extent (top right, black) with STDV [%] (red) over model time, starting at 120ka BP.

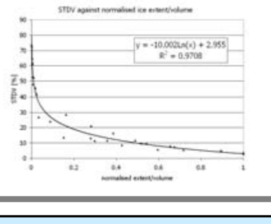


Fig.5 (right): STDV of ice extent and volume exhibits a negative logarithmic correlation (approx. -10ln(x)+3) with normalised extent and volume (R^2=0.97).

.Further information:

Hagdorn M, Hulton N, Payne AJ & Rutt I: Introducing GLIMMER - a 3D thermo-mechanical ice sheet model. EGU05-A-07312; CL11/CL32-1FR2P-0325; Friday, 29.4., Poster Area: Hall X

.The GLIMMER project:

http://glimmer.forge.nesc.ac.uk/

.References:

Hagdorn MKM, 2003: Reconstruction of the Past and Forecast of the Future European and British Ice Sheets and Associated Sea-Level Change. unpublished PhD thesis, University of Edinburgh

.Acknowledgements:

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