Constraining the minimum configuration of the Greenland ice sheet during the Last interglacial period

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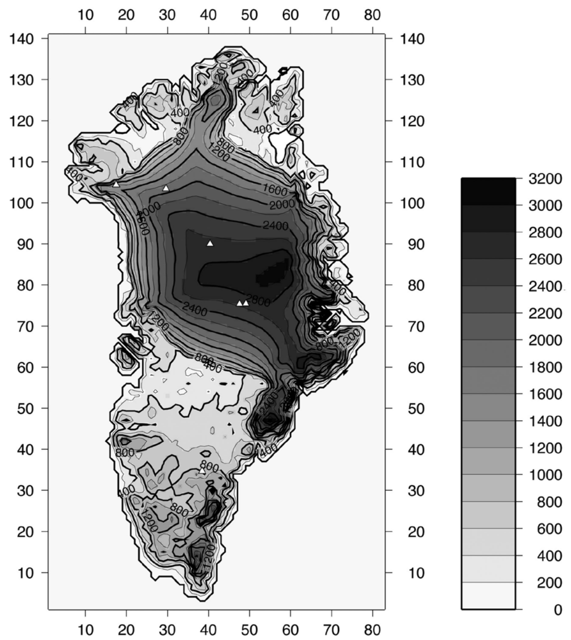
The Last Interglacial (LIG) between ca. 130 and 115 ky BP is probably the best analogue for future climate warming for which increasingly better proxy data are becoming available. The volume of the Greenland ice sheet (GIS) during this period is of particular interest to better assess how much and how fast sea-level can rise in a future Earth undergoing gradual climatic warming. Sea-level during the Last Interglacial is inferred to have been up to 8 meter higher than today and a substantial fraction of that must have come from melting of the Greenland ice sheet. Various ice-sheet modeling studies have come up with a very broad range of the LIG volume loss to between 1 and 6 m of equivalent sea-level rise. This wide range is mainly due to the sensitivity of GIS models to the imposed climatic conditions and to poor knowledge of the LIG climate itself, both in terms of the magnitude and precise timing of the maximum warming, as well as in terms of spatial and annual patterns.



Modeled surface elevation (m) of the GIS at 123 kyr BP. This configuration contributes 4 m to the global sea-level rise during the LIG. White triangles indicate deep ice core drilling sites

To circumvent the problem of our poor knowledge of the LIG climatic conditions, in our modeling study we take another approach to constrain the minimum LIG configuration of the GIS. Using a three-dimensional thermomechanical ice-sheet model, we produced an ensemble of 210 possible LIG configurations by varying only three key parameters for temperature, precipitation rate, and surface melting within realistic bounds. The result is a variety of glaciologically consistent GIS geometries corresponding to a wide range of possible "climates" thereby avoiding the complications of having to prescribe the details of the LIG climate itself. Forward numerical experiments were followed by a Lagrangian backtracing of ice particles in order to establish times and places of origin of ice particles from five Greenland ice-cores (GRIP, NGRIP, NEEM, Camp Century and Dye 3). This provides distances travelled by ice particles from an ice core to the place of deposition, latitudinal contrast and surface elevation histories. To constrain the ensemble of GIS geometries, we used data inferred from the above mentioned ice cores such as the presence or absence of LIG ice, borehole temperature and present to LIG δ18O contrast translated into surface elevation changes. Testing against ice-core data enabled us to bracket the mass loss of the Greenland Ice sheet during the LIG to between 3.4 and 5.0 m of sea-level rise with a preferred value of 4 m (see figure). The obtained results are justified for the specific assumptions of a uniform climate change, a constant isotopic-elevation and isotopic-latitudinal gradients, and a fixed precipitation pattern. It cannot be excluded that during the LIG precipitation changes were stronger in the south than in the north of Greenland. This would have led to a larger southern dome than in our runs, but would not entail an essential revision of the final conclusion about the sea level contribution because of pure geometrical restrictions on the size of the southern dome.