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Modeling the configuration of the Greenland ice sheet during the Last Interglacial constrained by ice core data

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The Last Interglacial (LIG or Eemian) 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 LIG is inferred to have been 6-9 meter higher than today, but the contribution of the GIS remains unclear. Various ice-sheet modeling studies have come up with a very broad range of the LIG volume loss by the GIS to between 1 and 6 m of equivalent sea-level rise. This wide range is explained by the sensitivity of GIS models to the imposed climatic conditions and to poor knowledge of the LIG climate itself in terms of the magnitude and precise timing of the maximum warming, as well as in terms of spatial and annual patterns.

Using a three-dimensional thermomechanical ice-sheet model, we produced an ensemble of possible LIG configurations by varying only three key parameters for temperature, precipitation rate, and surface melting within realistic bounds. The outcome of the numerical experiments 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. For instance, uncertainty in the magnitude of the warming (8 ± 4 ˚C) has a dramatic influence on the results.

To constrain the ensemble of GIS geometries, we used data inferred from 5 Greenland ice cores including NEEM, such as the presence or absence of LIG ice, borehole temperature and isotopic composition. Lagrangian backtracing of particles was used to establish ice-core chronologies and to take into account biases introduced by horizontal advection, systematic latitudinal contrast and local elevation changes. Comparison of model-generated ice-core characteristics with the observed data enabled to narrow down the ensemble to a bound on the GIS contribution to the LIG sea-level rise of between 2.7 and 3.1 m. This indicates that a substantial share of the LIG sea-level rise must have originated from the Antarctic ice sheet.