Geophysical Research Abstracts
Vol. 17, EGU2015-6838-1, 2015
EGU General Assembly 2015

Long-term future contribution of the Greenland ice sheet to sea level rise

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We investigate the impact of future cumulative anthropogenic emissions on the fate of the Greenland ice sheet. For this study, we use the polythermal ice sheet model SICOPOLIS, which is bi-directionally coupled with the regional climate model of intermediate complexity REMBO. We constrain our model parameters with simulations over two glacial cycles employing anomalies from the global CLIMBER-2 model. CLIMBER-2 treats the major components or the Earth system, including atmosphere, ocean, terrestrial vegetation and carbon cycle. As constraints we include the cumulative error in ice thickness, the surface mass balance partition (ratio between precipitation and ice discharge) and the ice elevation drop between Eemian and present-day at the NEEM ice core location. Our model includes a new ice discharge parameterization, which describes the ice loss via small-scale outlet glaciers in a heuristic statistical approach.

Using the large-ensemble of model versions consistent with our constraints, we estimate the range of the long-term future contribution of the Greenland ice sheet to sea-level rise under global warming. On the 100,000-year time scale, there is a visible modulation over the CO_2 signal in the simulated Greenland ice volume caused by the 20,000 years precessional cycle of insolation. In nearly all of our scenarios (500 to 5000 Gt carbon cumulative emissions), the Greenland is sheet fully decays in the future after at least 40,000 years. For the extreme scenario (5000 Gt), the Greenland ice sheet decays much faster – after about 5000 years, while there is still 80% of the ice sheet left after 40,000 years only for the model versions with a low temperature sensitivity and the low cumulative carbon emission scenario (500 Gt). Our results underline that without future negative CO_2 emissions, irreversible loss of Greenland ice sheet is essentially unavoidable.