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Wissenschaftliche Zusammenfassung der kumulativen Dissertationsschrift:

The Future Sea-Level Contribution from Antarctica - Projections of Solid Ice Discharge

Future sea level change has a strong impact on the livelihood of a large share of the world's population. Sea-level projections are thus of great importance with respect to an assessment of necessary mitigation and adaptation measures. The major uncertainty in state-of-the-art projections lies within the evolution of the solid ice discharge from Antarctica, the largest ice mass on Earth.

To understand the physical mechanisms underlying a change in solid ice discharge and to quantify the uncertainties in future projections of the sea-level contribution from Antarctica, we have developed the Potsdam Parallel Ice Sheet Model, PISM-PIK, which consistently represents the ice flow in sheet, shelves and the transition zone. In a dynamic equilibrium simulation of the Antarctic Ice Sheet under present-day boundary conditions the model is able to reproduce large-scale geometric properties and the full range of ice velocities observed in Antarctica, from almost zero near the ice divides to a few kilometers per year in ice streams.

With PISM-PIK, I investigate solid ice discharge for the years 1850 to 2500 under climate scenarios based on the Extended Concentration Pathways. I show that the uncertainties of the regional temperature projections and from unknown ice parameters used in PISM-PIK are of similar importance throughout the simulations. The maximum dynamic ice loss from Antarctica caused solely by surface warming within the time-period from 1850 to 2500 is 0.58 m. Additional ocean warming and the resulting increase in sub-shelf melting leads to almost a doubling of sea-level rise until year 2500. However, the largest contribution to solid ice discharge turns out to be caused by the projected increase in precipitation, tripling the overall ice loss. This is due to a precipitation-induced steepening of the surface gradients across the grounding line which results in an increase in driving stress along almost the entire coastline of Antarctica.

PISM-PIK is able to reproduce the recently observed rate of solid ice loss from Antarctica, but only in later years of the 21st century. The acceleration observed for the years 1992 to 2009 is first reached around year 2077 of the highest emission scenario. The states of the ice-sheet associated with these years are similar in their geometric properties, with a mean difference in ice thickness of only a few meters. However, while the solid ice discharge is maximally 0.07 m within the 21st century, it amounts up to 0.24 m within the century succeeding 2077. Future dynamic ice loss from Antarctica thus crucially depends on the history of the ice-sheet.

Following an alternative approach, I have derived a response function for solid ice discharge which also reflects this finding. This response function provides a relation between surface warming and the increase in outflow through softening of the ice. The resulting sea-level rise compares well with the model results from PISM-PIK on a centennial time-scale. The response function is of the form $R(t) \sim t^{\alpha}$, where the exponent α is positive because solid ice discharge increases with the amount of accumulated heat in the ice-sheet's interior. This is in contrast to the response functions which I derived for thermosteric sea-level rise and the dynamic ice loss from the Greenland Ice Sheet. While these are found to be of the same functional type, they yield negative exponents α, meaning that the influence of past climate changes on sea-level rise decreases with time.

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