Modeling the Effects of Greenland Ice Sheet Melting on AMOC Variability and Predictability

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Introduction

The evolution of the Atlantic meridional overturning circulation (AMOC) is one of the key uncertainties of future climate projections. State-of-art climate models that took part in the CMIP5 project show that over the 21st century the AMOC might reduce by 20-30% under the intermediate RCP4.5 scenario and by 36-44% under the high end RCP8.5 scenario relative to preindustrial values 1. On the centuries thereafter, most models project a slow AMOC recovery (Figure 1). However, a major uncertainty in these projections is the lack of enhanced meltwater input from the Greenland Ice Sheet (GIS) in the future scenarios. During the last decade a strong increase in mass loss of the GIS has been observed 2, a trend that is expected to continue into the future 3.

To improve AMOC projections, we have developed a future melt scenario of the GIS that is based on a relationship between 500 mbar temperature changes and runoff. This parameterization of future GIS melt will be used in a model intercomparison project of RCP4.5 and RCP8.5 simulations and will allow us to assess:

1) The potential impact of future GIS melt on the AMOC evolution over the course of the next 200-300 years.
2) The likelihood of an AMOC collapse in the next 200-300 years.
3) How a weakening of the AMOC could in turn influence future melt rates of the GIS.

Methodology

The high resolution regional climate model RACMO2 has shown to be able to produce a regional climate that compares favourably with in situ and satellite-based observations 4. In a simulation for the period 1960-2012 a high correlation is found in RACMO2 between summer (JJA) temperature changes at 500 mbar and annual mean runoff for 8 different basins (Figures 2 & 3).

A second order polynomial fit to the relation between 500 mbar summer temperature changes and annual mean runoff for the 8 basins, are used to translate CMIP5 multi-model-mean RCP4.5 and RCP8.5 temperature projections (Figure 4), into projections of Greenland runoff changes for the period 2006-2012 (Figure 5). The projections will be used to force state-of-the-art global climate models within a large AMOC-MIP setup. Moreover, the developed methodology enables the inclusion of GIS runoff changes in GCM climate change projections not only as a forcing, but also as a climate feedback through the coupling with upper air temperature changes.

GIS SMB projections

The parameterized runoff changes thus include projections of local changes in P-E, snow and ice melt based on high resolution regional climate modelling. Basin scale differences in the boundary conditions (most notably topography), and position with respect to the westerly storm tracks, result in considerable spatial differences in projected runoff changes.

AMOCMIP outline

In the coming years we will perform a model intercomparison (AMOCMIP) for several different experimental setups:

1) RCP4.5/8.5 + projected runoff changes
2) RCP4.5/8.5 + interactively calculated runoff changes
3) RCP4.5/8.5 + projected runoff changes + observed/RCM-based baseline runoff and calving fluxes

All modeling groups are more than welcome to participate, please feel free to contact us (pbakker@ceoas.oregonstate.edu).

References

5. How a weakening of the AMOC could in turn influence evolution over the course of the next 200-300 years.
6. The likelihood of an AMOC collapse in the next 200-300 years.
7. How a weakening of the AMOC could in turn influence future melt rates of the GIS.
8. The potential impact of future GIS melt on the AMOC evolution over the course of the next 200-300 years.
9. The likelihood of an AMOC collapse in the next 200-300 years.
10. How a weakening of the AMOC could in turn influence future melt rates of the GIS.