Impacts of Arctic climate change on sea level and atmospheric circulation in the Northern mid-latitudes

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Abstract

Global warming has been particularly pronounced in the Arctic, where observations show a temperature rise twice as high as the global mean. This Arctic amplification has led to accelerated melting of sea ice and the neighboring Greenland Ice Sheet (GrIS). Beyond the ice mass loss in the Arctic, the amplified warming has related global impacts:

The observed decrease in Arctic sea ice extent may be linked to changes in mid-latitude weather patterns, since the equator-to-pole temperature gradient and Earth's rotation control both the global and mid-latitude atmospheric circulation. While theory suggests a slowdown in the jet stream under global warming, which could lead to more frequent extreme weather, observations have yet to demonstrate a significant anomaly.

The Greenland Ice Sheet contains an ice equivalent of 7m global sea level rise and, due to the five-fold increase in ice loss in recent decades, the GrIS contributes now a quarter of the current rate of global sea level rise.

The accelerated mass loss of the GrIS was accompanied by the thinning, increasing velocity and rapid retreat of Greenland's marine-terminating outlet glaciers. These dynamical changes have potentially been triggered by enhanced submarine melting, modulated by a turbulent plume circulation that is, in turn, controlled by the subglacial discharge and fjord temperature. These plume dynamics have not been incorporated into ice sheet models yet, so the qualitative and quantitative impacts of submarine melting on Greenland's glaciers remain largely unknown.

This dissertation is divided into two topics. The first topic assesses how detected trends in the mid-latitude atmospheric circulation relate to a decline in the equator-to-pole temperature gradient.

The second topic aims to assess the importance of submarine melting in terms of its impact on future glacier dynamics and the associated global sea levels rise.

In the first section, in order to assess the atmospheric changes, I statistically analyze reanalysis datasets that provide reliable information on wind field observations in the time span since 1979, a time period for which satellite measurements are also available.

In the second section, I address the issue of submarine melting by adapting and further developing a line plume model, which I coupled to a 1D glacier model. With the combination of data sets from hybrid ice sheet-hydrology models, general circulation models, reanalysis data and in-situ measurements, I derived realistic projections of the forcing factors—surface mass balance, subglacial discharge and ocean temperature—that all affect the dynamics of outlet glaciers under global warming