How to give accurate SMB forcing to ice dynamic model for the 21st century projections?

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Abstract

Significant changes in atmospheric circulation occurred around Antarctica, due to the exceptional positive trend in the Southern Annular Mode and to the climate variability observed in the tropical pacific at the end of the 20th century. Even though climate over the East Antarctic Ice-Sheet (EAIS) remained quite stable, a warming and precipitation increase was observed over the West Antarctic Ice-Sheet (WAIS) and over the West Antarctic Peninsula (AP) during the 20th century. Nevertheless, the high regional climate variability still overwhelm climate changes associated to drivers of global temperature changes, as reflected by recent cooling of the Antarctic Peninsula. Climate and SMB models still fail to accurately reproduce these temporal SMB trends at a regional scale, mainly because complex processes are still insufficiently considered, such as: 1) atmospheric circulation changes related to complex ocean/ice/atmosphere interactions, 2) specific polar atmospheric features (cloud microphysics, wind scouring and impact on stable surface boundary layers), 3) surface firn physics involved in surface drag variations, or in firn air depletion and albedo feedbacks. As a consequence, reducing the uncertainty in projection of the future SMB of Antarctica will depend on our capability to remove biases in the future sea surface conditions and atmospheric general circulations proposed by the Atmosphere-Ocean General Circulation Models (AOGCM) and in considering specific Antarctic surface / atmosphere interactions.
Here, we account for this diagnosis and propose an approach based on 1) bias corrections of future sea surface conditions coming from AOGCM scenarios from CMIP5/CMIP6 models. These corrections are then used as boundary conditions for a modeling with a stretched grid atmospheric GCM (LMDZ4), whose systematic errors in atmospheric circulation are corrected using tendency errors from nudged simulations. These outputs are then used to force the regional atmospheric model (MAR) to assess future regional scale SMB variations in Antarctica. Here, the MAR is adapted to account for interactions between drifting snow and surface drag over sastrugi fields by introducing a specific formulation for the roughness length. This formulation accounts for the relationship existing between snow-surface temperature and microrelief erodibility caused by the sintering of surface crystals. This adaptation is necessary to reproduce the seasonal variations in drifting snow frequency and horizontal snow mass transport as evidenced from observations.

Keywords: Surface mass balance, regional atmospheric modelling, projection