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Three views of a secret: the grounding-line conundrum in marine ice-sheet models

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Understanding and attributing future sea-level changes demands serious efforts on the development of efficient ice sheet - ice shelf models that capture the essential physics and mechanics of grounding line behaviour. However, unlike atmospheric modeling, Antarctic continental-scale ice-sheet modelling only fully emerged at the beginning of the 1990s. Initially, such models were employed at rather coarse resolution to investigate ice-sheet changes during glacial-interglacial cycles or on longer time scales. At that time, ice sheets were believed to be a slow component of the climate system with a highly diffusive response to surface mass balance change. However, while the possibility of rapid continental change was advocated several decades before, ice sheet models were unable to deal with rapid changes, which was clearly identified as a limitation for Antarctic ice-sheet modelling.

Due to the increase of satellite data observations witnessing rapid mass loss, ice-sheet modelling needed a paradigm shift, which came through an improved insight into grounding-line (limit between the grounded ice sheet and the floating ice shelf) physics and the way to represent this in ice-sheet models.

Here, I will give an outline how gradually the modelling community views changed from 'ice meets ocean' towards 'ocean meets ice' through improved knowledge on how grounding lines control ice flux. These theoretical developments had a profound effect on model development, which required both verification and validation of numerical ice sheet models. Verification is initiated through several model intercomparisons, either based on simplified geometries or by focusing on isolated processes and forcings for real geometry cases. Model validation is harder to obtain, but the combination of geophysics (radar), model initialization, and ensemble modelling paves the way to models that are gradually capable of simulating rapid change and short-term effects.

While major international efforts are now focused on ice shelf processes and stability, the effect of ice shelf debuttressing leads to feedbacks that were hitherto hardly explored. These feedbacks, exacerbated by the interplay between ice sheet subglacial processes and grounding line flux lead to both a series of stabilizing as well as destabilizing effects. Hence, it also shifts the 'ocean meets ice' view to an 'ice meets ocean meets ice' view. Results of grounding-line destabilization and re-stabilization for the West Antarctic ice sheet are presented based on ensemble model runs, demonstrating, among others, the importance of Thwaites Glacier grounding line dynamics in the stability of the West-Antarctic ice sheet.