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Detecting high spatial variability of ice-shelf basal mass balance

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Ice shelves control the dynamic mass loss of ice sheets through buttressing and their integrity depends on the spatial variability of their basal mass balance (BMB), i.e. the difference between refreezing and melting. Here, we present an improved technique – based on satellite observations – to capture the small-scale variability in the BMB of ice shelves.

We use mass conservation in a Lagrangian framework based on high-resolution surface velocities, atmospheric-model surface mass balance and hydrostatic ice-thickness fields (derived from TanDEM-X surface elevation). Spatial derivatives are implemented using the total-variation differentiation, which preserves abrupt changes in flow velocities and their spatial gradients. Such changes may reflect a dynamic response to localized basal melting and should be included in the mass budget.

After testing our technique on the Roi Baudouin Ice Shelf, East Antarctica, we test our methodology on other ice shelves, with different flow regimes.
Whereas the detected large-scale pattern in the BMB is very similar to previous and coarser studies, we are nevertheless able detect small-scale features in the BMB with unprecedented detail (10 m gridding). Examples include elevated melting at an ice-shelf channel's flank and surface lowering of an elliptical surface depression.

Although the absolute, satellite-based BMB values remain uncertain, we have high confidence in the spatial variability on sub-kilometre scales. This work highlights expected challenges for a full coupling between ice and ocean models.