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Long- and Short-term Damage Changes on Antarctic Ice Shelves

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The contribution of the Antarctic ice sheet to sea level rise remains uncertain due to the potential instability of ice shelves. Damage areas in the shear zone of an ice shelf are a first sign of mechanical weakening, which can lead to speed-up of the ice and additional damage development. This damage feedback can precondition ice shelves for disintegration and enhanced grounding line retreat but remains one of the least understood processes, mainly since we lack a quantification of damage and its changes on large spatiotemporal domains.

Recent efforts have resulted in a new, automated approach to detect damage. The NormalisEd Radon Transform Damage (NeRD) detection method allows to robustly detect damage features from multi-source, high-resolution satellite imagery. We have made both long-term (25 years) and short-term (annual) assessments from SAR images, based on both RAMP Radarsat (1997) and Sentinel-1 datasets (2015-2021).

We produce, for the first stime, damage state and damage change maps of Antarctic ice shelves. Over the past two decades we detect a general damage increase on ice shelves, most evident on fast flowing ice shelves in the West Antarctic (Thwaites, Pine Island, Crosson) and the Peninsula (Wilkins). On short time scales the detected damage changes are governed by new damage development versus calving events, imposing fluctuations on its increase or decrease from year to year. A strong decrease in damage is observed on ice shelves that have retreated significantly, thereby removing all damaged parts. This gives attention to small, retreated ice shelves that are otherwise overlooked. We furthermore detect areas with stable damage states across the Antarctic. We detect this for both initially intact and initially damaged ice shelves, showing that the amount of damage itself is no indication for damage-induced instability.

Our results provide new insights in Antarctic wide damage change, identifying regions that are (not) sensitive to a potential damage feedback and/or are vulnerable to retreat in combination with other forcings such as ocean warming or surface melt. This large-scale damage change assessment is a first and important step in identifying ice shelf weakening and potential instability.