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Tipping of the Filchner-Ronne and other Antarctic ice shelf cavities

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Tipping of an ice shelf cavity from a cold to a warm state happens when a sustained inflow of warm Circumpolar Deep Water (CDW) or a modified variant of it replaces High Salinity Shelf Water (HSSW) and Ice Shelf Water (ISW) in a cold-water cavity. HSSW and ISW with temperatures close to or even below the surface freezing point provide little heat for melting glacial ice. CDW derivatives, however, can cause a substantial multiplication of the ice shelf basal melt rates. The increased melt water release may trigger a positive feedback loop that stabilizes the warm state. Therefore, if the outside circumstances turned back to previous conditions, a reversal from warm to cold would not occur under the same conditions as the switch from cold to warm.

A warm tipping has been found possible for the Filchner-Ronne Ice Shelf (FRIS) cavity in previous studies. In the framework of the EU project TiPACCs, we now reinforce our focus on the conditions which can cause a tipping for the Filchner Ronne and other Antarctic ice shelf cavities. We conducted a series of FESOM-1.4 simulations with different manipulations of the atmospheric forcing variables in order to analyse the common factors of tipping events, opposed to more stable results.

We found that for the Filchner Trough region in a warming world, the crucial balance is between the different rates of warming and freshening of (a) the continental shelf waters in front of the ice shelf and (b) the waters transported with the slope current. While other studies identified an uplift of the pycnocline at the continental shelf break as a necessary condition for warm onshore flow, we deem a tipping more likely to hinge on the density loss of the shelf waters. When density on the continental shelf decreases more rapidly than in the slope current at sill depth, the ice shelf cavity is prone to tip. Reversibility of the tipping is possible within three decades under ERA Interim atmospheric forcing (1979-2017), but our study also confirms that hysteresis effects can cause a bistability of warm and cold state in the FRIS cavity under the 20th century HadCM3 forcing.