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Drivers and reversibility of abrupt ocean cold-to-warm and warm-to-cold transitions in the Amundsen Sea, Antarctica

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Ocean warming around Antarctica has the potential to trigger marine ice-sheet instabilities. It has been suggested that abrupt and irreversible cold-to-warm ocean tipping points may exist, with possible domino effect from ocean to ice-sheet tipping points (Hellmer et al. 2017). Here we investigate the existence of drivers of ocean tipping points in the Amundsen Sea. This sector is currently relatively warm, but a cold-to-warm tipping point may have occurred in the past. The conditions for an hypothetic abrupt return to a cold state are also investigated. A 1/4° ocean model configuration of the Amundsen Sea, representing interactions with sea-ice and ice-shelves, is used to characterize warm-to-cold and cold-to-warm oceanic transitions induced by perturbations of the atmospheric forcing and their influence on ice-shelf basal melt. We apply idealized perturbations of heat, momentum and freshwater fluxes to identify the key physical processes at play. We find that the Amundsen Sea switches permanently to a cold state for an air cooling of 2.5°C and intermittently for either an air cooling of 0.5°C, precipitations decreased by 30% or a 2° northward shift of the winds. All simulated transitions are reversible, i.e. restoring the forcing to its state before the tipping point is sufficient to restore the ocean to its original state although the recovery time is correlated to the amplitude of the perturbations. Perturbations of the heat and freshwater fluxes modify the properties of the ocean by impacting the buoyancy flux, either through their impact on the sea-ice or, directly, to a lesser extent. Perturbations of the momentum flux involve more complex mechanisms as it combines both an Ekman effect and an indirect effect on the buoyancy flux related to changes in sea-ice advection.