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Changes in the coupled Southern Ocean ice–ocean system

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Sea ice in the Southern Ocean has been expanding for several decades, until a couple of years ago, when it suddenly declined to record low values that have persisted since. In this presentation, I will argue that this slow increase and abrupt loss of the sea ice arise from systematic, multi-decadal changes in the coupled ice-ocean system based on both a statistical and physical analysis. The statistical analysis provides evidence for an abrupt transition of the system from a high to a low ice extent regime that is reminiscent of abrupt transitions in complex dynamical systems and have been observed elsewhere in the climate system. This hypothesis is corroborated by the observed changes in the Southern Ocean subpolar water column and our understanding of ice-ocean feedbacks in this region. Changes in the seasonal formation and melting of sea ice have a profound influence on the Southern Ocean salinity and thereby the deep ocean circulation and ventilation, which in turn affect the ice. This relation arises from the unique role that salinity plays in setting the vertical density stratification in the cold polar oceans. I will discuss how the slowly expanding sea ice for several decades led to observed changes of the Southern Ocean subpolar waters, with a surface freshening and cooling and a subsurface warming due to an increased density stratification. Heat that was building up through this process at the subsurface was then suddenly released between 2015 and 2016, yielding the observed abrupt transition in the water column stratification and sea ice extent. Understanding these coupled changes in the subpolar Southern Ocean and their response to climate change is critical as they influence the unique local ecosystems, the melting Antarctic Ice Sheet, and the global climate through the heat and carbon cycle.