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The Fate of the Southern Weddell Sea Continental Shelf in a Warming Climate

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Abstract

Simulations using coupled ice-ocean models forced with the atmospheric output of the HadCM3 SRES-A1B scenario run show that the circulation in the southern Weddell Sea (Fig. 1) changes during the 21st century (Fig. 2 & 4). Derivatives of Circumpolar Deep Water are directed southward underneath the Filchner-Ronne Ice Shelf, warming the cavity and drastically increasing basal melting (Fig. 3). To find out whether the open ocean always will supply the 'fuel' for melting, we continue our simulations, applying 20th-century atmospheric forcing alone or together with prescribed basal mass flux at the end of (or during) the SRES-A1B scenario run (Fig. 3). **The results identify a tipping point in the southern Weddell Sea: Once warm water flushes the ice shelf cavity a positive melt water feedback enhances the shelf circulation and the onshore transport of open ocean heat. The process cannot be stopped solely by returning to 20th-century atmospheric forcing and needs a significant reduction to 20th-century basal melt rates (Fig. 2)**. This finding has implications for the future Antarctic Ice Sheet, because the prescribed small melt water input can only be achieved in reality by a significant loss of its floating portions.

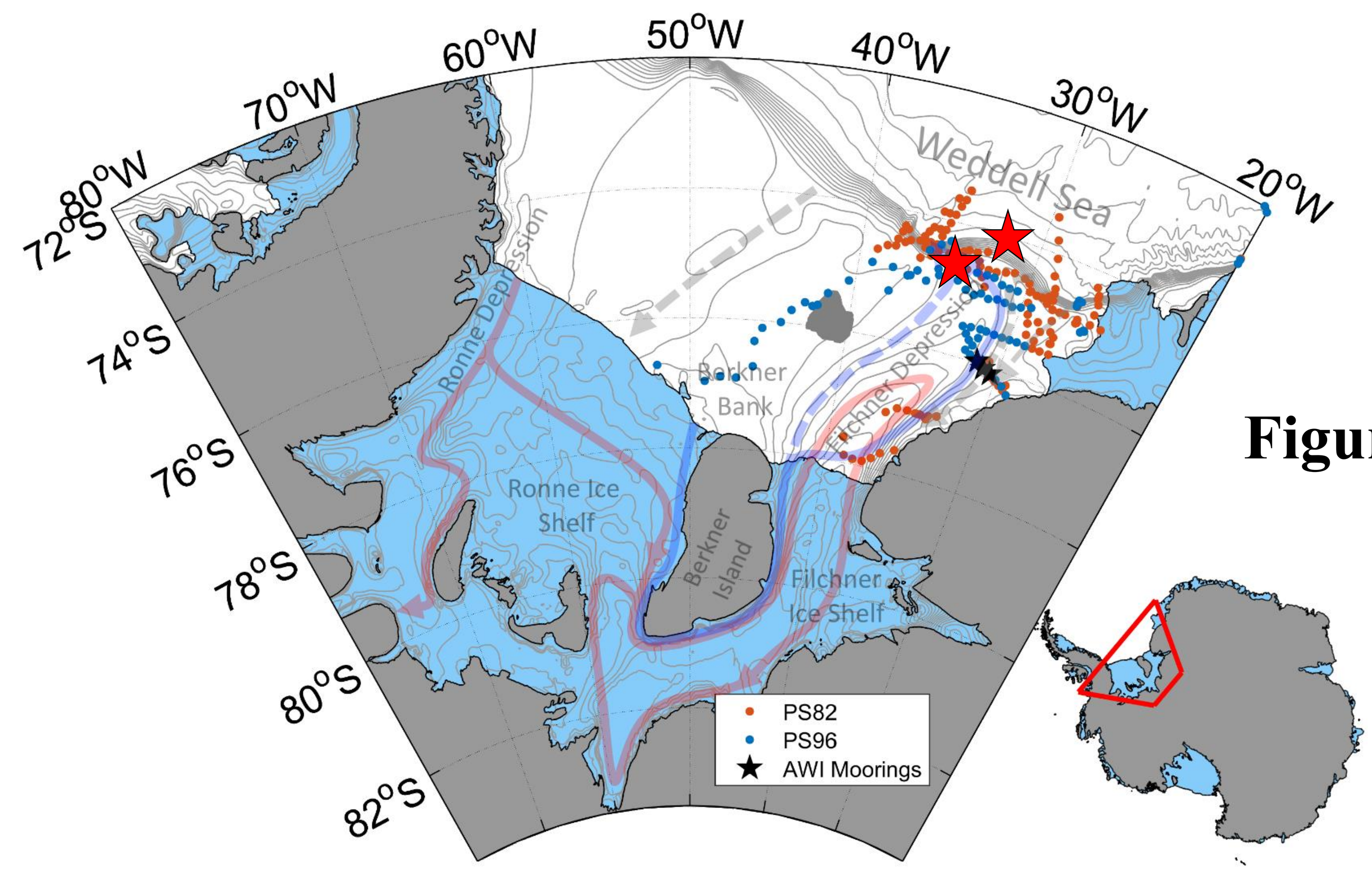
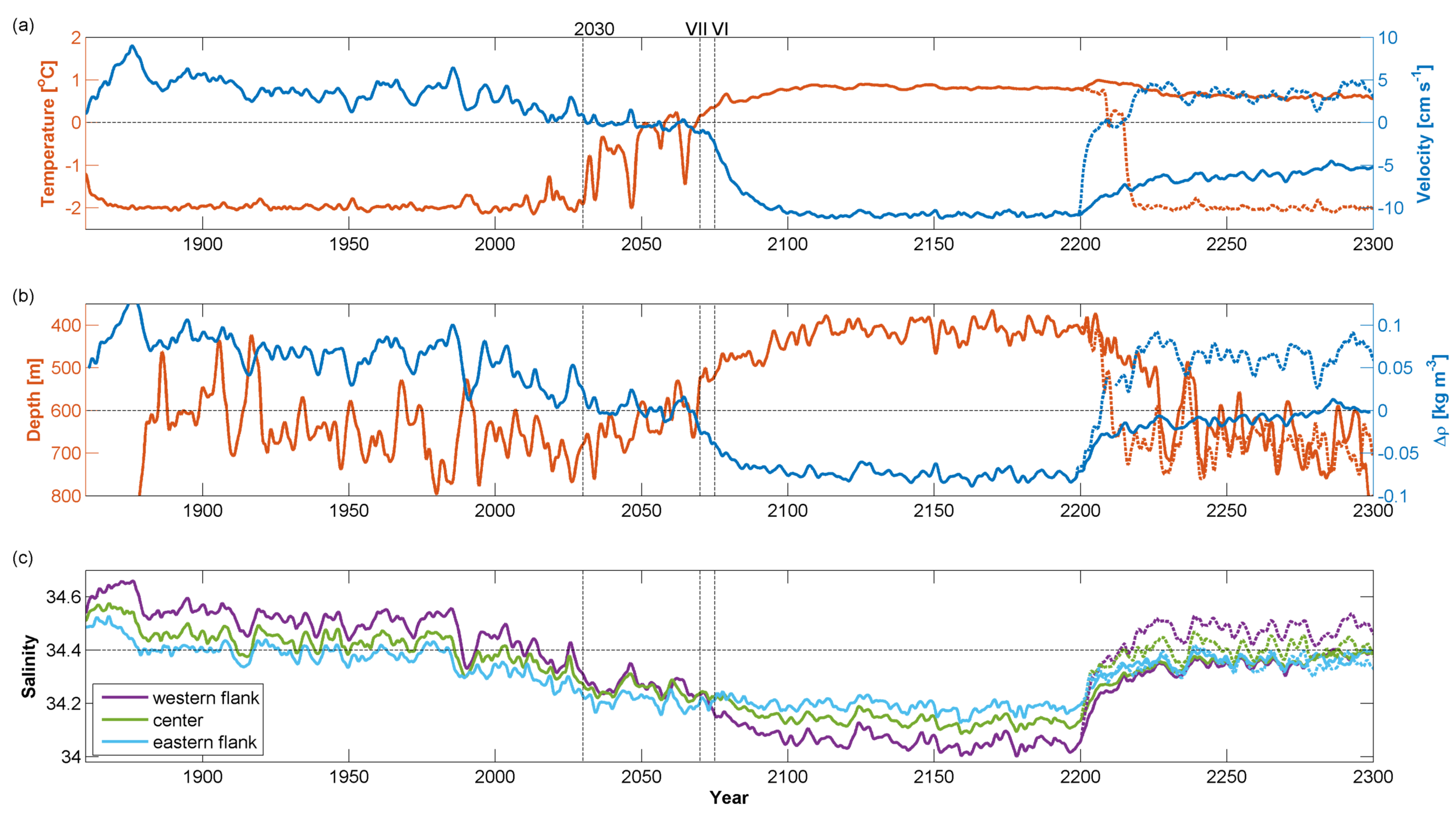


Figure 1

Ryan et al. (submitted, JGR-Oceans)

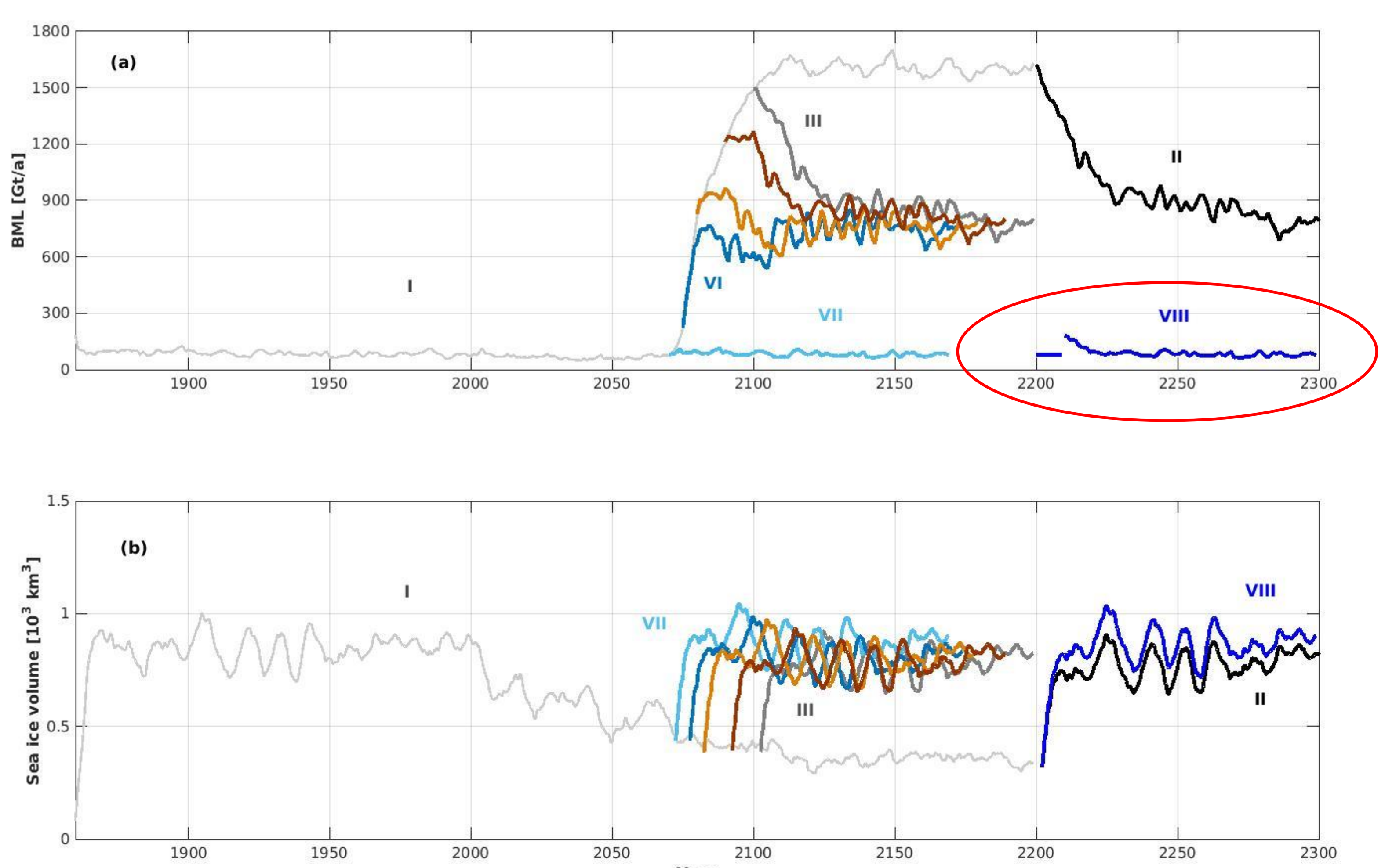
Figure 2



Time evolution of various parameters at/near the Filchner Trough sill (red stars in Fig. 1): (a) near bottom potential temperature and meridional velocity (positive represents northward flow), (b) zonal in-situ density gradient across the sill (west minus east), averaged below 250-m depth, complemented by depth of the WDW thermocline (defined as 0 °C isotherm) at the upstream continental slope, and (c) depth averaged salinity at three positions across the trough. Solid curves show the simulation period 1860–2199, continued with 100 years of the 20th-century atmosphere sensitivity experiment (II). Dashed curves represent the melt water sensitivity experiment (VIII). Vertical lines indicate onset of the warm pulses being concurrent with cease of the ISW outflow across the sill (2030), as well as the starting points of the sensitivity experiments VII (2070) and VI (2075), which frame the transition of the system into the melt water dominated 'warm-shelf phase'.

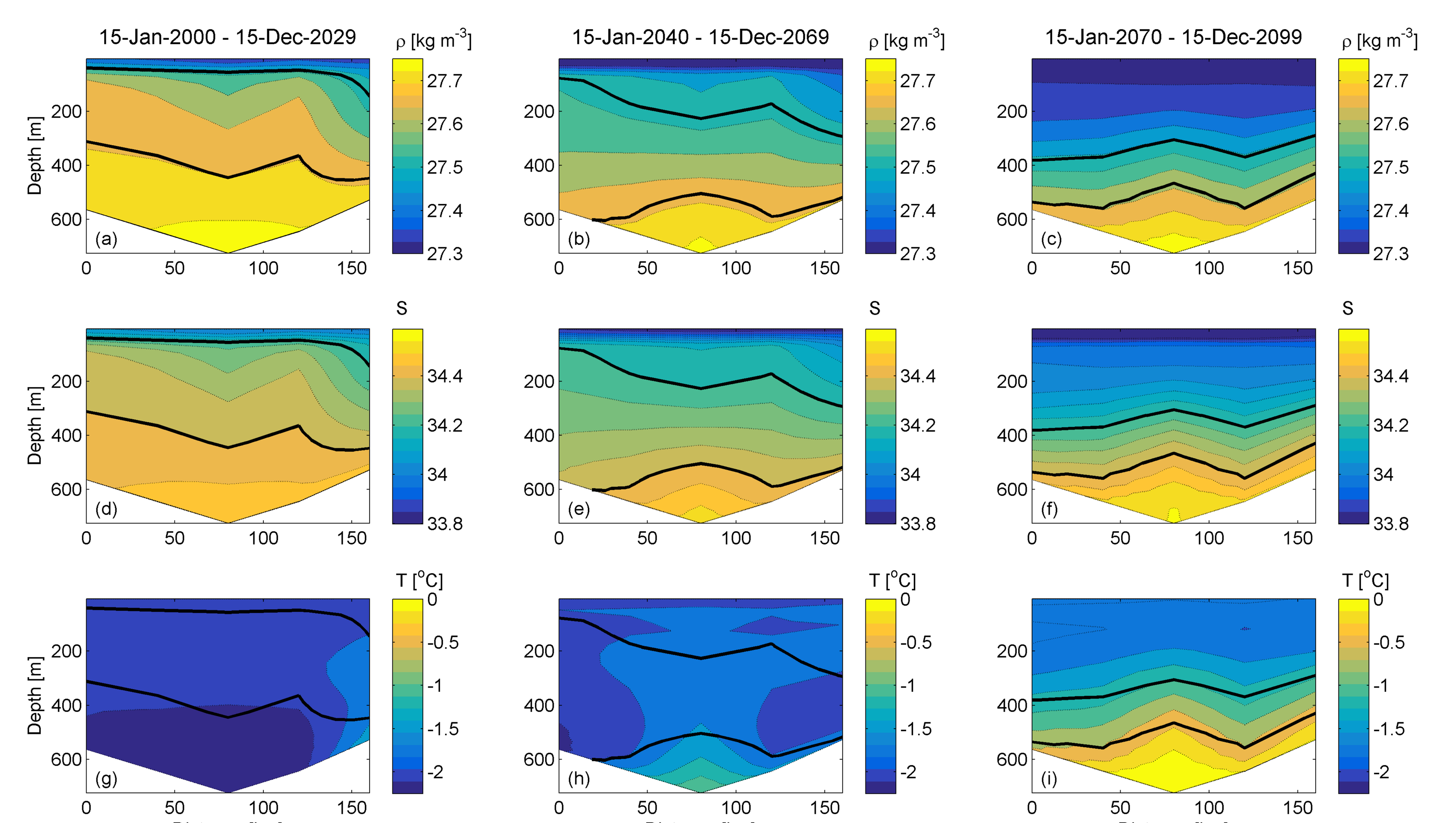
Notes

Figure 3



Spliced time series from year 1860 to 2300: (a) Basal mass loss (BML) of Filchner-Ronne Ice Shelf for the 20th century and SRES-A1B scenario extracted from the HadCM3 climate model (grey line), the perturbation experiments applying the 20th century atmosphere (1880-1979) during the 'warm phase' starting in year 2200 (II - black), 2100 (III - dark red), 2090 (IV - brown), 2080 (V - orange), 2075 (VI - blue), and 2070 (VII – light blue). For the starting point in year 2070, the onshore flow of warm open ocean water into the Filchner Trough and thus the increase in FRIS' BML does not occur. (b) Same as (a) but for sea ice volume on the southern Weddell Sea continental shelf (5-year running mean). In addition, climatological mean basal freshwater flux was applied for ten years only together with 100 years of atmospheric forcing of the period 1880–1979, starting in year 2200 (VIII - dark blue). Roman numbers indicate the simulation index.

Figure 4



Zonal section across the Filchner Trough sill (looking north) of (a-c) in-situ density, (d-f) salinity, and (g-i) potential temperature for time periods before, during, and after the transition into the 'warm-shelf-phase'. Black contours show the 34.2 and 34.4 isohalines, illustrating the reversal of the cross-trough density gradient, caused by the freshening of the ISW outflow.