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Control of the Agulhas leakage by the Antarctic Circumpolar Current: The role of the Weddell Sea sea-surface salinity

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The conventional view of the control of the Agulhas leakage is derived from processes that lead to interannual SST anomalies today, e.g., changes in the anticyclonic circulation and westerly wind belt (Cohen and Tyson 1995). Here we propose an additional mechanism based on the meridional density gradient in the ocean.

We used a global ocean model with coarse horizontal, but high vertical resolution, isopycnal mixing, meso-scale eddy parameterizations and Last Glacial Maximum (LGM) surface boundary conditions based on the GLAMAP 2000 project (Sarnthein et al. 2003). The surface wind forcing was simulated by an atmospheric general circulation model and kept constant in all glacial experiments. However, we used different values of the LGM Weddell Sea sea-surface salinity (SSS) anomaly (see Paul and Schäfer-Neth 2003 for details of the experimental set up).

From the enhancement and southward shift of westerly wind belt we expected a similar enhancement and southward shift of the Antarctic Circumpolar Current (ACC). The surprising result was a strenghtening of the ACC, accompanied by a northward shift of its northern boundary and a decrease of the leakage of Indian Ocean waters from the Agulhas Current into the Atlantic Ocean. The amplitude of these changes depended on the prescribed SSS of the Weddell Sea.

We hypothesize that the 'Agulhas leakage' is not only controlled by the strength of the westerlies in the atmosphere, but also by the meridional density gradient in the ocean. In a colder climate such as the LGM, more sea ice would be formed in the Weddell Sea, the SSS would rise and a positive density anomaly would be transported into the

deep ocean. The enhanced meridional density gradient would cause a stronger ACC. As its northern boundary would approach the Cape of Good Hope, the southward penetration of the Agulhas Current would be reduced, and the Agulhas leakage would diminish.

This hypothesis is supported by additional experiments with a coupled climate model that contains an ocean general circulation model, a comprehensive sea-ice model and an energy-moisture balance model of the atmosphere (Weaver et al. 2001). These experiments allowed us to directly study the impact of changes in sea-ice formation in the Weddell Sea on the Agulhas leakage.

We present further support from paleo-proxy data – which indicates the formation of cold and salty Antarctic Bottom Water (cf. Adkins et al., 2002), the upwelling of cold central water in the Benguela System (cf. Niebler et al., 2003) and enhanced Indian-Atlantic water exchange during interglacials (Peeters et al. 2004) – as well as from theory (Borowski et al. 2002). However, we also discuss conflicting evidence from observational studies by Pether (1994) and Cohen and Tyson (1995), and we try to resolve this conflict.

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