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Southern Boundaries in Global Ocean Models: Can We Do Better?

Motivation:

Global ocean circulation models do not usually take high latitude processes into account in an adequate form. Reasons include limited model domains or insufficient resolution. Without the processes in key areas contributing to the lower part of the global thermohaline circulation, the characteristics and flow of deep and bottom waters often remain unrealistic in these models.
In this study, section data from the dedicated Southern Ocean model BRIOS (Bremerhaven Regional Ice Ocean Simulation) are combined with a global inverse model by using temperature, salinity, and velocity constraints for the large-scale model (LSG). In a companion study BRIOS climatologies of hydrography and velocities serve as southern boundary restoring conditions in a global circulation model (MITgcm).

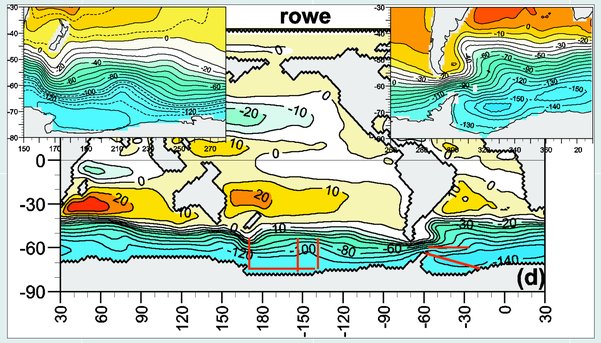

Fig. 1: Global barotropic stream function (LSG) as a temporal mean for the period 1993-2003 from the experiment with constraints in the Weddell and Ross seas. Contour interval is 20 Sv. The sections (red lines) in the Weddell and Ross seas represent the location of additional constraints in the experiments. Insets highlight the Weddell and Ross Sea circulation with a contour interval of 10 Sv.

Experiments with LSG and MITgcm:

- 2° resolution, 23 z-layers
- 11 yrs (LSG) vs 2000 yrs (MITgcm) integration

- Control run (cntr)
  Constraints/restoring applied in:
- Weddell Sea (wedd)
- Ross Sea (ross)
- Ross and Weddell Seas (rowe)

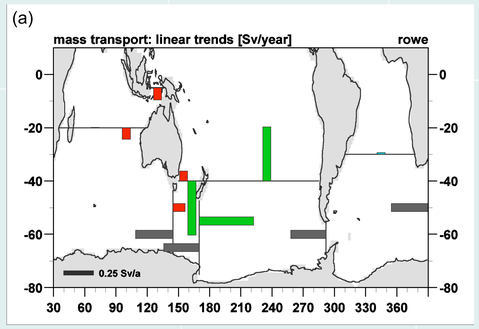

Fig. 3: LSG: Mass transport trends across selected sections in the case of decreasing (a - rowe) and increasing (b - wedd) ACC transports (black bars). With decreasing ACC transport the circum-Australian circulation (red bars) increases including an increased Indonesian Throughflow. While the Pacific Ocean circulation (green bars) also increased the Indian Ocean circulation (blue bars) remains almost the same.

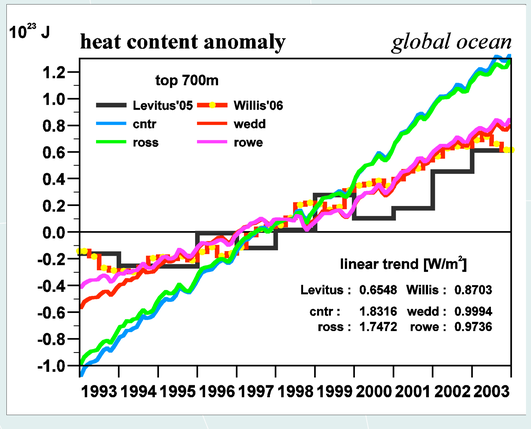

Fig. 2: LSG: Time series of the global heat content anomaly in the upper 700 m for the period 1993-2003 for all experiments in comparison to observations from Willis data (pers, comm., 2006, dashed red/yellow) and to Levitus climatology (black).

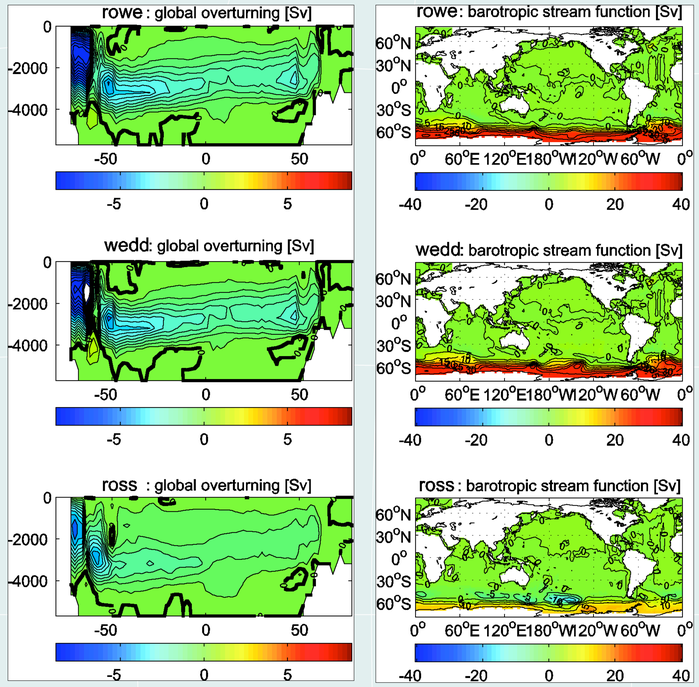

Fig. 4: MITgcm: Differences of meridional overturning (left) and barotropic stream function (right) between a control run of 2000 years of integration and experiments, in which temperature, salinity, and horizontal velocities are restored to BRIOS climatologies along the southern boundary.

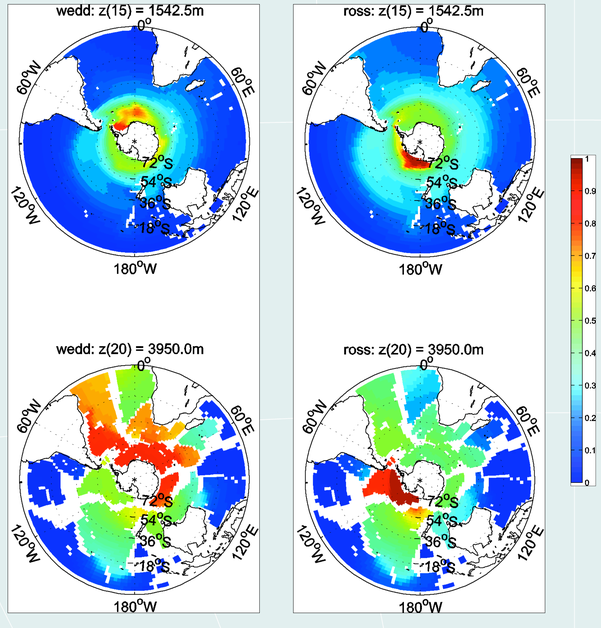

Fig. 5: MITgcm: Dye tracer distribution with arbitrary units normalised by the mean input in 1542.5 m (top) and 3950 m (bottom) depth at the end of a 2000 year integration. Dye is released in the Weddell Sea (a) or in the Ross Sea (b) following the temperature and salinity restoring method.

Conclusions

LSG - 11 year time scale:
- Weddell Sea water masses influence the global circulation while Ross Sea water masses only have a regional effect.
- While Weddell Sea constraints improve the heat content towards observed values Ross Sea constraints contribute less (Fig. 2).
- Increased (decreased) ACC transports are associated with decreased (increased) Indonesian Throughflows (Fig. 3).

MITgcm – 2000 year time scale:
- Weddell Sea water masses influence the global circulation while Ross Sea water masses only have a regional impact.
- Prescribing BRIOS climatology in the Weddell Sea has a larger effect on the overturning and the barotropic stream function than prescribing Ross Sea values (Fig. 4).
- Weddell Sea water spreads in to all basins, whereas Ross Sea water is restricted to adjacent deep sea basins (Fig. 5).

And … can we do better?
Yes. We can improve the global circulation of our ocean models by including the effects of unresolved Southern Ocean processes —such as shelf ice ocean interaction and deep and bottom water formation — with the help of data assimilation.

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Schodlok, M.P., H.H. Hellmer, and A. Beckmann, On the transport, variability and origion of dense water masses crossing the South Scotia Ridge, Deep-Sea Res., 49, 4808-4825, doi:10.1016/S0967-0645(02)00160-1

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