The response of the Mediterranean thermohaline circulation to changes in the ocean gateway

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1. Background

During the Cenozoic, the convergence of Africa and Eurasia gradually restricted the gateway(s) connecting the Mediterranean to the open ocean (Fig.1) which strongly affected the Mediterranean thermohaline circulation (MTHC) [Meijer et al. 2004].

Figure 1: Geologic records show major changes in the Atlantic-Mediterranean gateways during the Cenozoic (65-2 Ma) [Blakey: http://jan.ucc.nau.edu/rbc7].

In order to investigate the effects of the gateway geometry on the MTHC- expected to be of major importance on the basis of geological data- several experiments with different sill depths are performed.

2. Model setup

We used the Princeton Ocean Model [Blumberg and Mellor, 1987]. A simplified basin is used (Fig.2) with grid horizontal resolution of 1°x1°. A buffer zone and open boundary condition are applied in the Atlantic box. The Initial conditions for T-S are put to 20°C and 35 psu. The surface forcing is reduced to uniform net evaporation (1 m/yr) and relaxation of SST to a latitudinal profile of air temperature.

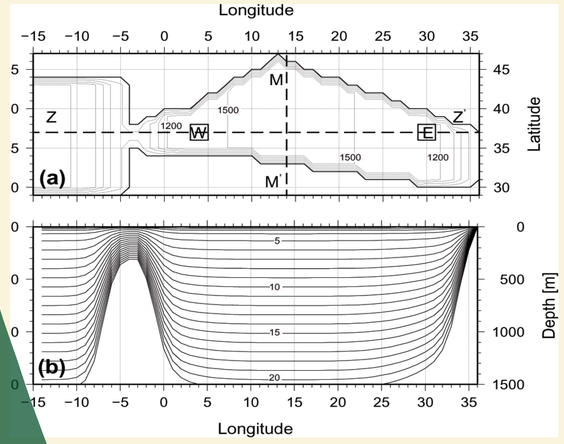


Fig.2: (a) Model grid and topography, dashed lines indicate the position of sections, (b) Vertical section at ZZ' of sigma levels.

3. Results

3.1. Model drift

These results are taken from three parallel sensitivity experiments (SD100, REF and SD500), where we only change the sill depth.

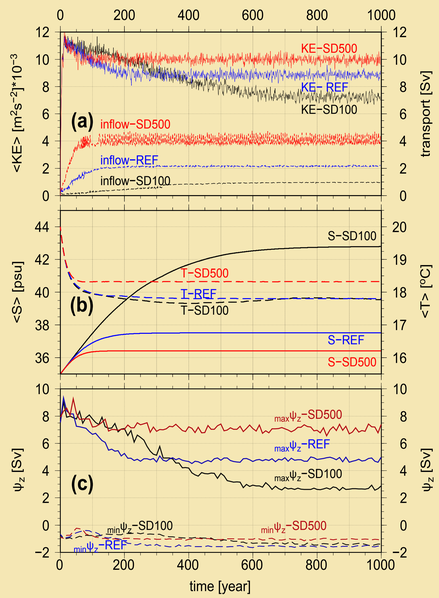


Fig.3: Time series for the different simulations of (a) Kinetic energy measure (solid line); volume transport through the gateway (in Sv; dashed line), (b) Basin-averaged salinity S (solid line) and temperature T (dashed line), (c) Decadal smoothed Mediterranean zonal overturning (in Sv); maximum value in the upper 1000 m (solid line); and minimum value in the lower 500 m (dashed line).

3.2. Impact of sill-depth changes

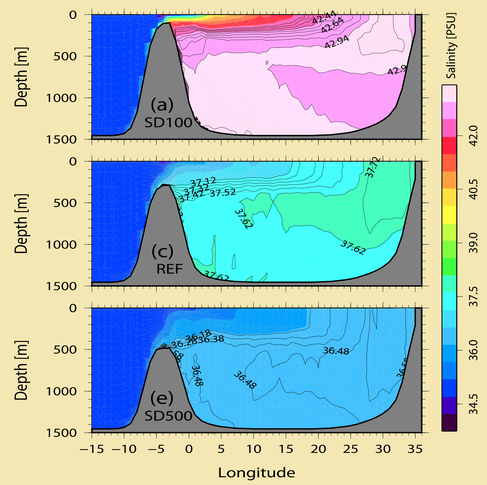


Fig.4: Zonal cross-sections (at ZZ' in Fig.1a); of the salinity fields averaged over the last 10 years of integration for the different experiments, (a) SD100, (c) REF, and (e) SD500.

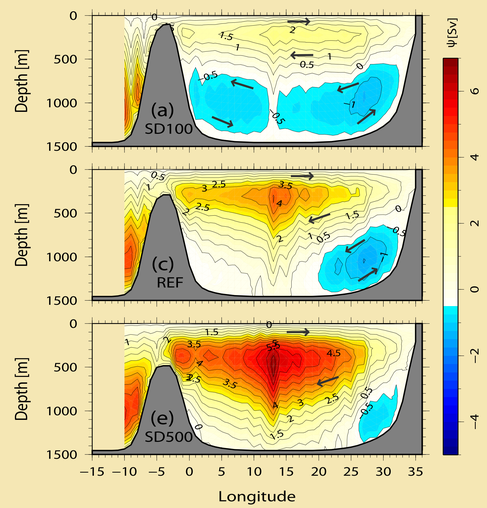
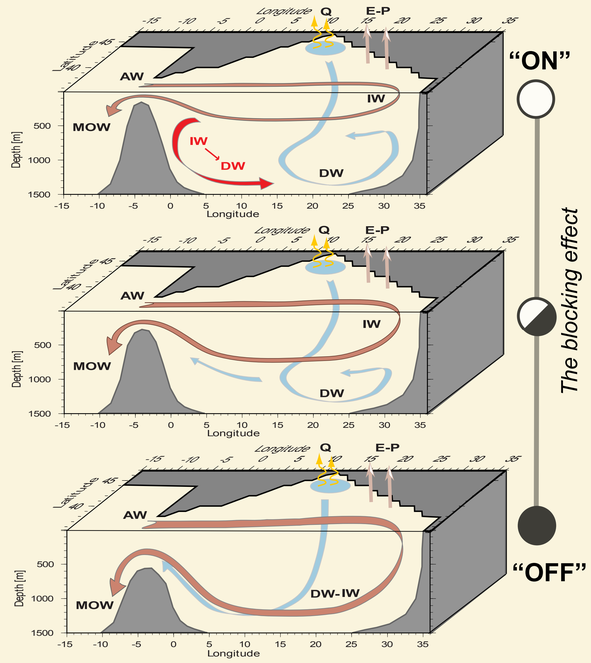


Fig.5: Same as Fig.4 but for the zonal overturning circulation, arrows indicate the sense of the flow, positive value corresponds the clockwise circulation.

4. Conclusion



The model reveals that shallow sills:

(1) lead to a "blocking effect": the intermediate water is partly prevented from flowing out and recirculates inside the basin.

(2) lead to a reduction in the strength of the upper overturning cell and reduced ventilation of the deep basin but not to a stagnation of the deep waters.

Thus, three deferent circulation modes are found: "ON", "OFF", and "Intermediate" blocking effect.

The generic quality of our experiment should be applicable to other basins or other time slices.

Acknowledgement

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References:

Blumberg, A.F., and G.L. Mellor (1987), A description of a three-dimensional coastal ocean circulation model, in Three-Dimensional Coastal Ocean Models, Coastal Estuarine Sci., Vol 4, ed: N.S. Heaps, 1-16, AGU, Washington, DC.

Meijer, P.Th., Slingerland, R. And Wortel, M.J.R. (2004). Tectonic control on past circulation of the Mediterranean Sea: A model study of the late Miocene. Paleoceanography, 19(1), PA1026.

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