

Interactive comment on “Model study of the circulation of the Miocene Mediterranean Sea and Paratethys: closure of the Indian Gateway” by A. de la Vara et al.

A. de la Vara et al.

delavarafernandez@uu.nl

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Perhaps we have been too brief about the relationship between our new work and that done previously in our team by the author of the comment. In a revised version we will describe this relation in more detail in the introduction. Also, we would use the discussion to elaborate on the reasons for differences and similarities in the results between our analysis and the regional ocean modelling of Karami (2011), wherever this indeed provides relevant additional insight. Following two analyses with a box model, the last chapter of the thesis of Karami (2011; note that this thesis is available open access) concerns what, to the best of our knowledge, was the first regional-scale

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implementation of an OGCM for the Miocene Mediterranean Sea. To stay close to the preceding box-model studies the bathymetry was strongly idealized, e.g., with most of the basin at a uniform depth of 1500 m. In terms of forcing the “minimal” setup explored by Meijer and Dijkstra (2009) was adopted. In one series of experiments, temperature forcing was not accounted for, again to stay close to the box-model studies. In a second series the required atmospheric fields and open-ocean conditions were derived from a global climate model simulation due to von der Heydt and Dijkstra (2006).

In the present study we return to the question of the role of the Indian gateway, reconsidering the entire model setup. The model bathymetry is derived from paleogeography following a new procedure and much more realistic than before. Temperature is forced by means of relaxation to a latitudinal profile and, in common with Karami (2011), a uniform net evaporation is imposed. The open-ocean conditions are redesigned, using simply a uniform salinity in combination with a new temperature profile. The role of differences in climate between present and Miocene is assessed by varying the related fields. No link to a Miocene climate experiment is attempted, yet. Importantly, the factor that is central to our study, the evolving geometry of the Indian gateway, is represented much less schematically than in Karami (2011).

In the following we reply to what appear to us to be the most relevant further comments. Aspects that were also addressed in the formal reviews are not repeated here. Minor points will be incorporated in a revised version.

Example mentioned in general comment: the role of differences in overturning. The anticlockwise cells referred to in the comment (blue in our Fig. 4) can be of two types. The first type is that related to the exchange with the Indian Ocean through a deep/intermediate-depth Indian gateway. These were also found by Karami (2011; “silled case”, see his Fig. 4.9 and 4.15), although much more schematically. The second type is that related to deep-water formation in the Mediterranean Sea and this dominates in our Figures 4c and 4d where the Indian gateway is either shallow or closed. It is this type of cell that does not exist in, what is the closest equivalent exper-

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iment in Karami (2011), the “with shelves”-case of his Fig. 4.19. Does this difference point to an important role for inflow into the Mediterranean through the connections with the Paratethys, as proposed in the comment? Close inspection of the experiments indicates that the many differences in model geometry and forcing do not make it easy to identify a single causal factor. The two connections to the Paratethys are present in both studies and we find the deep counterclockwise cells also in cases in which the arrangement of the strait flows is the same as in Karami (2011). In general our results indicate that deep-water formation depends on many factors, such as bathymetry, atmospheric temperature, net evaporation, conditions in the boxes, etc.

Page 4392, lines 20-26.: our justification for not using winds It is correct that we do use present-day values for the other forcings to drive our Miocene model. The problem with the wind pattern is that, winds being very different over land and sea, the present-day pattern is intrinsically related to the present coastline.

Page 4400, lines 5-12: two-level bathymetry We do not mention or mean that the addition of shallow shelves is necessary to capture the basic features of the present-day Mediterranean Sea circulation. The point of this paragraph is that we tried to assess the role of the uncertainty in the Miocene bathymetry by processing the present bathymetry in the same way and comparing the resultant model with a run with realistic bathymetry.

Page 4401, line 21-27: closed Atlantic gateway experiment In our experiments a shallow Indian Gateway can be considered effectively closed from an ocean-circulation perspective. Then, the reader may ask: how is it possible that with a gateway which is wider and has a similar depth to the present-day Strait of Gibraltar there is no water exchange between the Mediterranean and the Indian Ocean? To check that there is nothing wrong with our shallow gateway we decided to perform an extreme experiment closing the Atlantic connection. In this case, the Indian gateway certainly becomes effective and accommodates the exchange between basin and ocean.

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For reference list: Karami (2011) with link to on-line version spelled out: <http://igitur-archive.library.uu.nl/dissertations/2011-0331-200559/UUindex.html>

Interactive comment on Clim. Past Discuss., 9, 4385, 2013.

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