

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.

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De la Vara et al. use a regional ocean model aimed at investigating the regional impacts of the shoaling and closure of the Indian Ocean gateway on Paratethys and the Mediterranean Sea. There are only few regional model studies in which the Indian Ocean closure was studied as cited in this article. The authors perform a series of sensitivity experiment and gain interesting insights into the roles played by the gateway to the Indian Ocean and by the atmospheric forcing. As also mentioned by de la Vara et al., their study is mainly built on the last chapter of Karami (2011; PhD thesis) where the impacts of the Indian gateway closure was first investigated by using a regional

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model. I would like to make some remarks which require extra attention and to give some comments that may better place this article compared to the previous works.

General comments

In the introduction, a review of previous modelling works and their findings is not given. Oceanic box model studies of Karami et al. (2009, 2011) and ocean circulation model by Karami (2011) which are very relevant to the subject needs to be integrated into the introduction. Moreover, the related results obtained by the recent Miocene global climate models (e.g., Herold et al., 2012) and the need for a regional model could also be introduced.

Although the authors state that (page 4389, line 15-17) their work is built on Karami (2011) and two other box model studies, it is not really clear and is not discussed anywhere in the manuscript that what part of their model is built on the mentioned references. They can help the reader by elaborating more on this issue in section 2.

A comparison between the presented model results and those of for example Karami (2011), whether consistent or not, is not given. This makes it hard to follow the new findings of this manuscript compared to the previous relevant studies. I suggest starting the discussion with a short section that compares the insights gained by this study with the previous model studies, in particular with Karami (2011). This should stress the new findings in relation to the modified boundary conditions and bathymetries. Such a comparison provides a very valuable insight into understanding the Mediterranean paleocirculation. For instance, the patterns of the overturning cells shown in this study are different than in Karami (2011) where the anticlockwise overturning cells did not exist in some experiments. The authors do not specify whether the inflow from the eastern side of Paratethys into the Mediterranean is a contributing factor in driving the anticlockwise overturning cells. By comparing these results with Karami (2011), it could be suggested that inflow from both the east and the west side of Paratethys are important for the anticlockwise overturning cells. More importantly, the gateway

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depth between the Eastern and the western Mediterranean and between the Eastern Mediterranean and Eastern Paratethys can play an important role in controlling the anticlockwise cells.

The manuscript mainly focuses on the Mediterranean Sea and its overturning circulation. The reason for this approach is not explained. It is not also mentioned why, for instance, the overturning circulation was shown only for the Mediterranean Sea.

Section 4.3: most of the suggestions in this section has been already discussed and presented before in Karami (2011).

The global effect of closure on the development of the East Antarctic Ice Sheet is not direct result obtained from this model study. It is better to be kept in the discussion, and not to be included in the conclusions and abstract.

Specific comments

Page 4389, line 26: "... correctly ..." better to be changed to realistically

Page 4390, line 3-4: which part of the model set up follows the given reference? Not using wind? Then this sentence could be moved, for example, to page 4392, line 20-25.

Page 4390, line 6: did you check it for the Mediterranean and Paratethys separately?

Page 4390, line 13-16: citation to Karami (2011) is missing. I think this section will be a good place to explain the important differences between the bathymetry used in this study and that of the Karami (2011). For instance one of the main differences in the post-closure scenario is the presence of a gateway between the Eastern Mediterranean and the Eastern Paratethys which was not the case in Karami (2011).

Page 4391, line 17: Karami (2011) is also very relevant to be cited.

Page 4391, line 20-22: reference to Karami (2011)

Page 4392, line 14: Karami (2011) is also very relevant to be cited.

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Page 4392, line 20-26: This is confusing justification. For the other boundary conditions (e.g., sponges or surface temperature) an idealized or present-day condition was used, which could also be different in Miocene.

Page 4393, line 14: "... water sinks to great depth ..." is it possible to demonstrate this by showing the meridional cross section of temperature versus depth at 4° E and 9° E?

Page 4395, line 6-9: what about the magnitude of exchange flow? How does it change as a function of depth? what about the exchange flow between the Central and Eastern Paratethys? Is it also one-way exchange flow?

Page 4396, line 1-3: Does that mean a surface inflow from the Mediterranean into Paratethys through the western Mediterranean-Paratethys connection?

Page 4398, line 10-12: why not a negative net evaporation over Paratethys as the present-day Black Sea?

Page 4399, line 1-2: do you mean the response of thermohaline circulation in the Mediterranean Sea?

Page 4399, line 9: do climate models also suggest a reduced north-south temperature gradient?

Page 4400, line 3-4: consistent with Karami (2011)

Page 4400, line 5-12: Karami (2011) also showed that addition of shallow shelves is necessary to capture the basic features of the present-day Mediterranean Sea circulation.

Page 4400, line 17-20: help the reader by spelling out the difference between the two studies

Page 4401, line 21-27: I do not understand the point of this experiment. The Indian gateway dynamics are not same for open or closed Atlantic Ocean. The Indian gateway

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dynamics have nonlinear relation with the Atlantic gateway, and therefore, change by closing the Atlantic gateway.

Page 4402, line 12-13: Cold Paratethys inflow into the Mediterranean Sea from the east or the west?

Page 4402, line 13-15: how about the deep water formation in the Eastern Mediterranean sub-basin? I think it would be nice to include this figure in your results.

References

Herold, N., M. Huber, R. D. Müller, and M. Seton (2012), Modeling the Miocene climatic optimum: Ocean circulation, *Paleoceanography*, 27, PA1209, doi:10.1029/2010PA002041.

Karami, M. P., P.T. Meijer, H.A. Dijkstra, and M.J.R. Wortel (2009), An oceanic box model of the Miocene Mediterranean Sea with emphasis on the effects of closure of the eastern gateway. *Paleoceanography*, 24, PA4203, doi:10.1029/2008PA001679.

Karami, M. P., (2011), Palaeoceanography of the Miocene Mediterranean Sea and Paratethys: regional ocean modelling of the response to closure of the Tethys Seaway, Ph. D. thesis, supervised by Prof. M. J. R. Wortel and Dr. P.Th. Meijer, Utrecht University, the Netherlands.

Karami, M. P., A. de Leeuw, W. Krijgsman, P.Th. Meijer, and M.J.R. Wortel (2011), The role of gateways in the evolution of temperature and salinity of semi-enclosed basins: an oceanic box model for the Miocene Mediterranean Sea and Paratethys, *Global Planet. Change*, 79, 73–88.

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