

# Model study of the Miocene Mediterranean Sea and Paratethys: closure of the Indian Gateway

A. de la Vara<sup>1</sup>, P.Th. Meijer and M.J.R. Wortel, Faculty of Geosciences, Utrecht University  
<sup>1</sup>delavarafernandez@uu.nl

## 1. INTRODUCTION

The Early Mediterranean Sea and the Paratethys were both connected to the Indian Ocean until the Early-Middle Miocene, when the convergence of the Eurasian plate and African-Arabian plate caused the constriction and final closure of the Indian Gateway. Our objective is to gain model-based insight into the Mediterranean and Paratethys response to the closure of the Indian Gateway to obtain a background against which to interpret proxy data from the Mediterranean and globally.

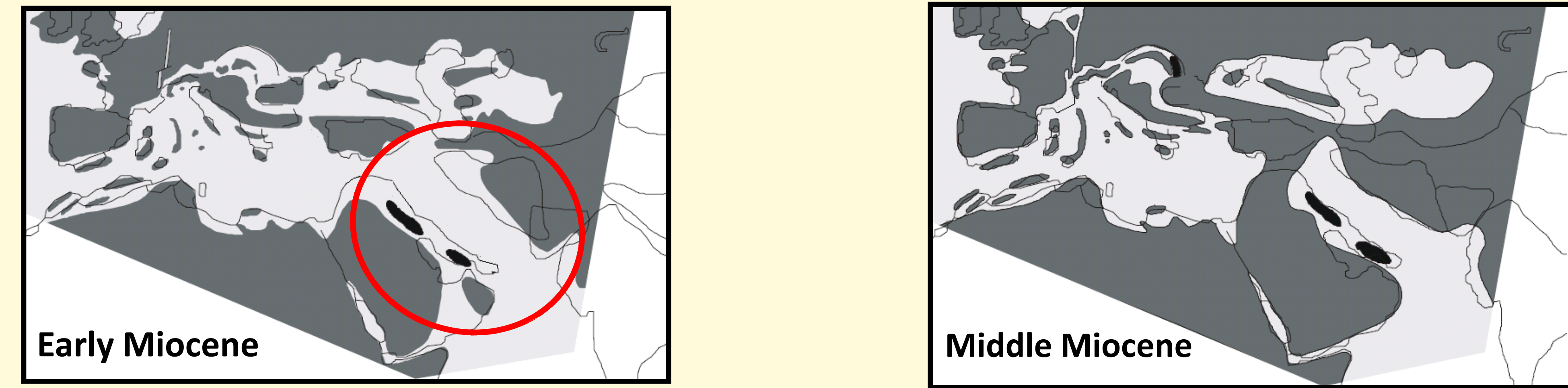


Fig.1. Reconstruction of the land-sea distribution from the Early to the Middle Miocene (modified from Rögl, 1999)

## 2. MODEL SETUP

- As a basis for our study we use the Modular Ocean Model Array (MOMA).
- In the west and in the east of the model domain we implement two “boxes” in which temperature and salinity are gradually restored to prescribed oceanic values.
- The heat exchange between the atmosphere and the ocean is defined by means of relaxation of the surface layer to the prescribed present-day sea surface temperature, which is shown in Figure 5a.
- Net evaporation is set to a constant and uniform value of 0.5 m/yr.

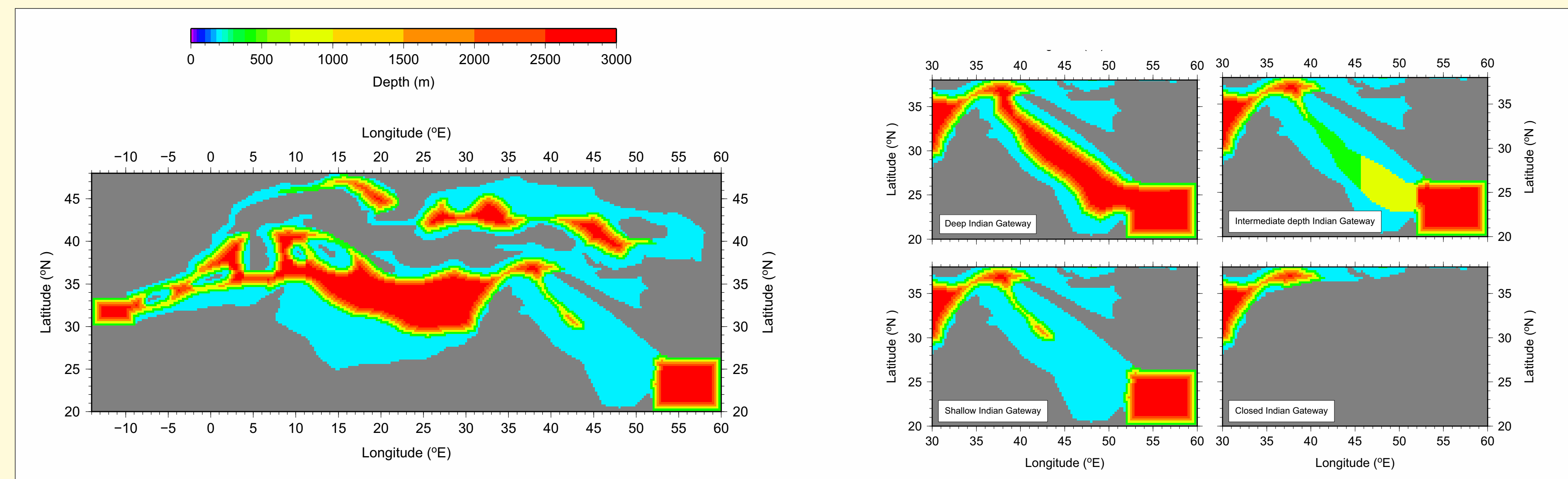


Fig.2. Left panel: simplified Burdigalian palaeobathymetry taking as a reference the Peri-Tethys Atlas. Right panel: set of idealized bathymetries: a) top left: 3000 meters deep Indian Gateway; b) top right: 1000 meters deep Indian Gateway; c) bottom left: 220 meters deep Indian Gateway and d) bottom right: closed Indian Gateway.

## 3. RESULTS

a) Set of basic experiments:

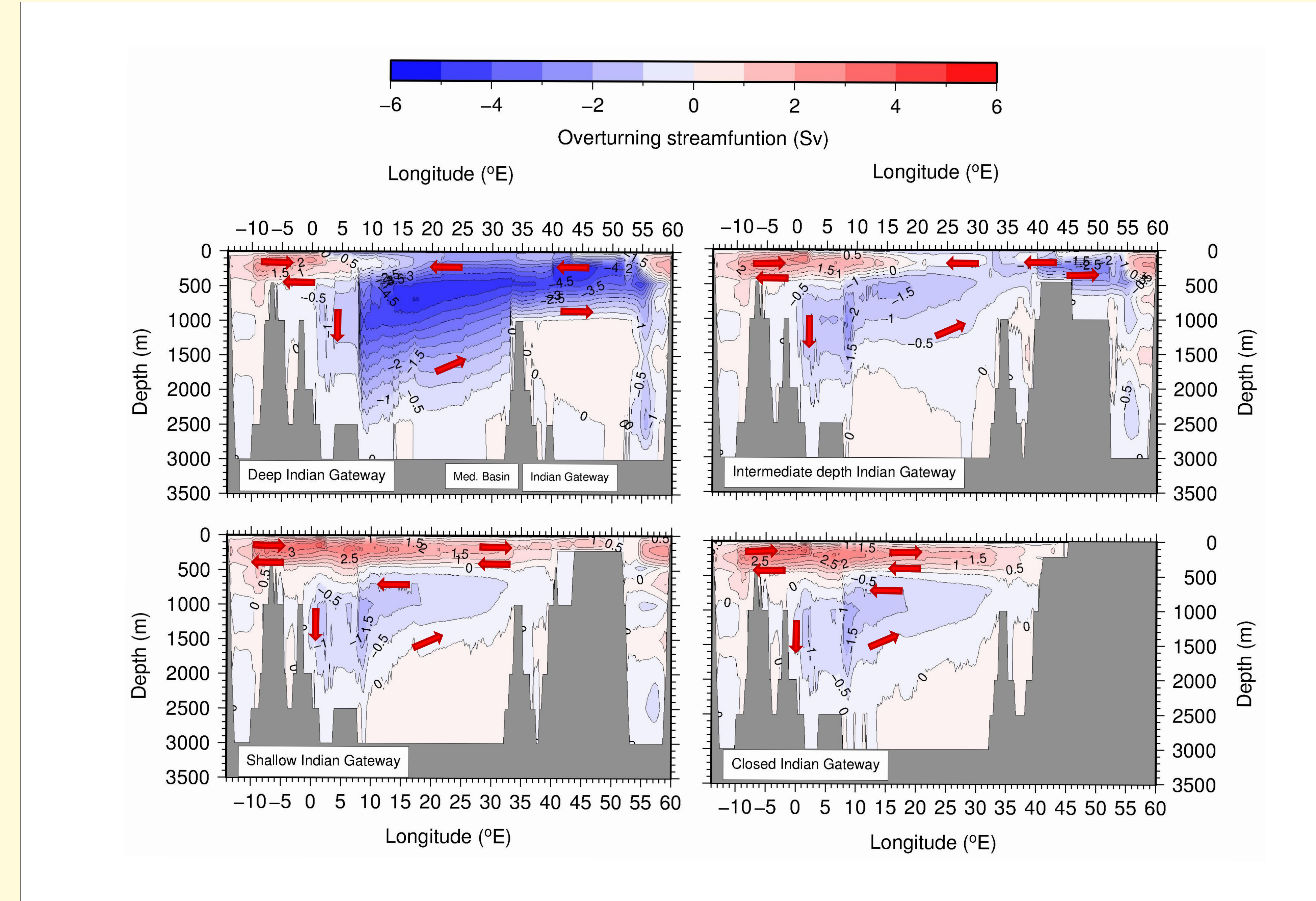


Fig.3. Mediterranean zonal overturning streamfunction for a: a) top left: deep; b) top right: intermediate depth; c) bottom left: shallow and d) bottom right: closed Indian Gateway. Contour interval: 0.5 Sv.

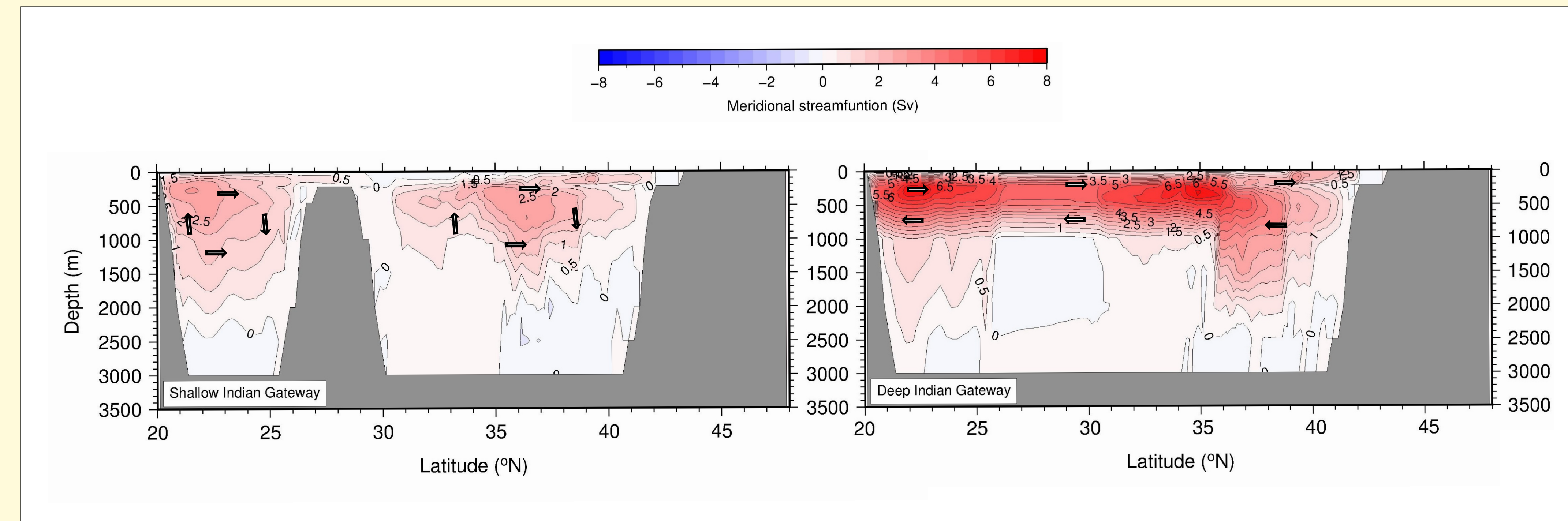


Fig.4. Mediterranean meridional overturning streamfunction for a: a) left: shallow and b) right: deep Indian Gateway. Contour interval: 0.5 Sv.

b) To assess the robustness of our results to the choices we made for the atmospheric forcing, some additional experiments were performed:

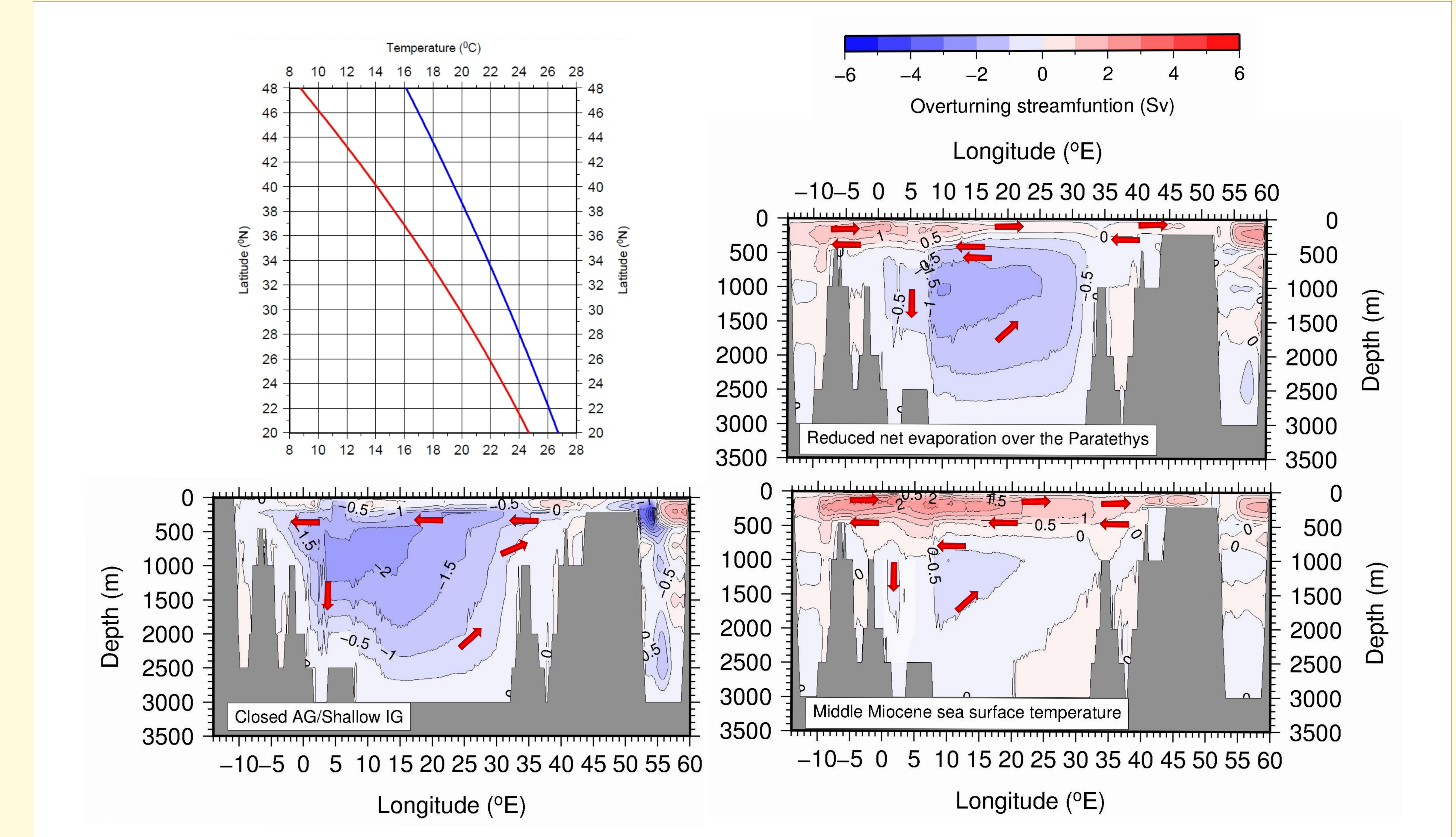


Fig.5. a) top left: present-day (red) and idealized Middle Miocene (blue) sea surface temperature; Mediterranean zonal overturning streamfunction for a shallow Indian Gateway: b) top right: forced with the Middle Miocene SST; c) bottom right: forced with a non-uniform net evaporation rate and d) bottom left: and a closed Atlantic Gateway. Contour interval: 0.5 Sv.

## 4. CONCLUSIONS

- The Mediterranean accommodates anti-estuarine exchange to the Indian and Atlantic Oceans.
- With a deep Indian Gateway the Indian Ocean dominates the circulation within the Mediterranean basin.
- Whereas with an intermediate-depth Indian Gateway the cell associated with the Indian does not extend spatially as much as before and has a lower magnitude compared to the previous case, the opposite occurs to the cell linked to the Atlantic Ocean. This reflects that, as the Indian Gateway shoals, the relative importance of the Indian with respect to the Atlantic Ocean decreases.
- At a depth of 200 meters the Indian Gateway can be considered effectively closed.
- The closure of this gateway, which is though to have entailed important consequences for the global climate, interrupted a source of outflow into the Indian Ocean.

A. de la Vara acknowledges financial support from NWO. Computational resources were provided by ISES.