Supplement of Unique ocean circulation pathways reshape the Indian Ocean oxygen minimum zone with warming

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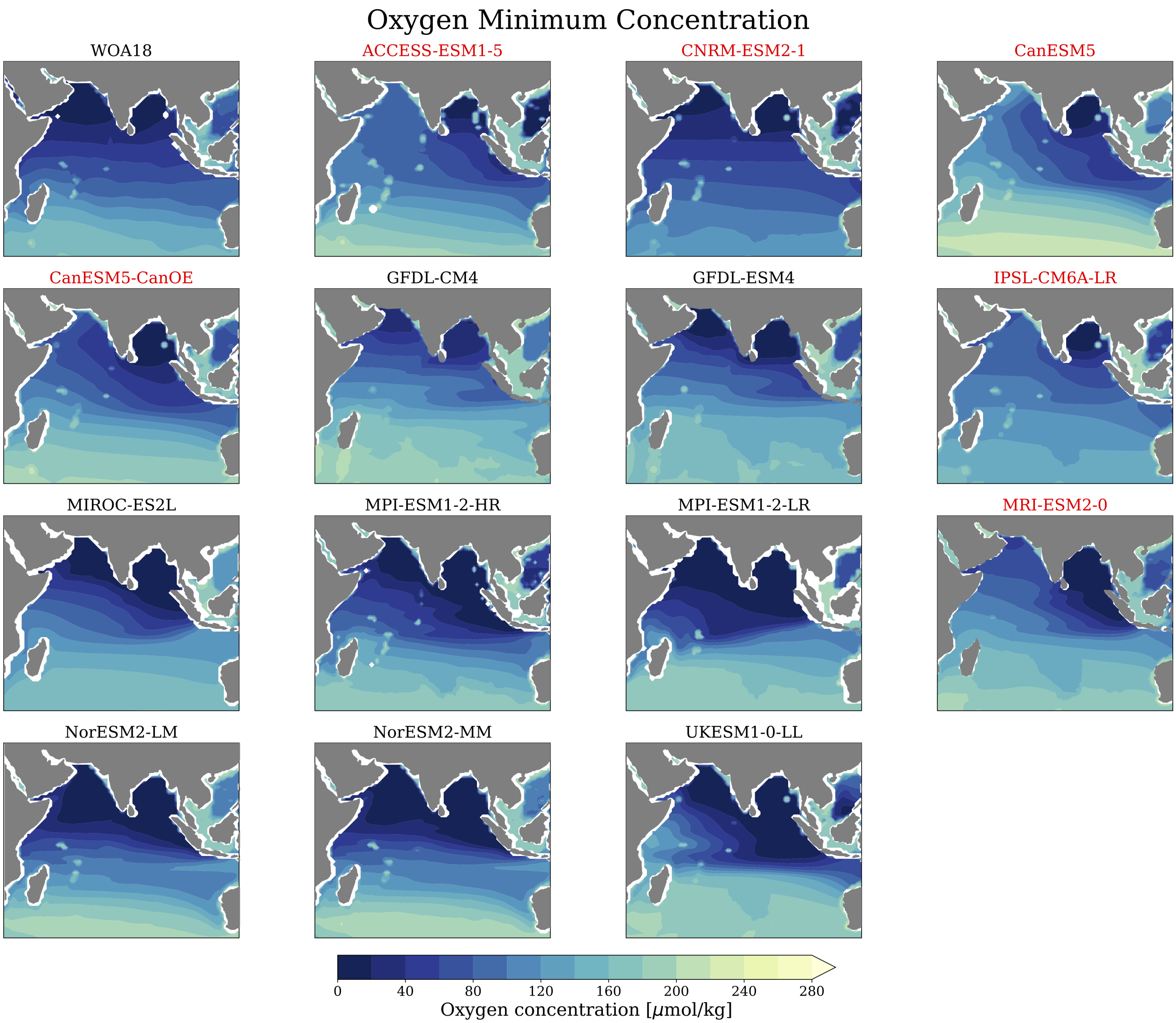

Figure S1. Maps of oxygen minimum concentration in the Indian Ocean for observed climatology (WOA18) and individual CMIP6 ESMs. Models labeled in black are used in the ESM ensemble, while models labeled in red have been omitted (see methods).

References

Sofianos, S. S. and Johns, W. E.: Observations of the summer Red Sea circulation, Journal of Geophysical Research: Oceans, 112, 2007.

Talley, L. D.: Descriptive physical oceanography: an introduction, Academic press, 2011.

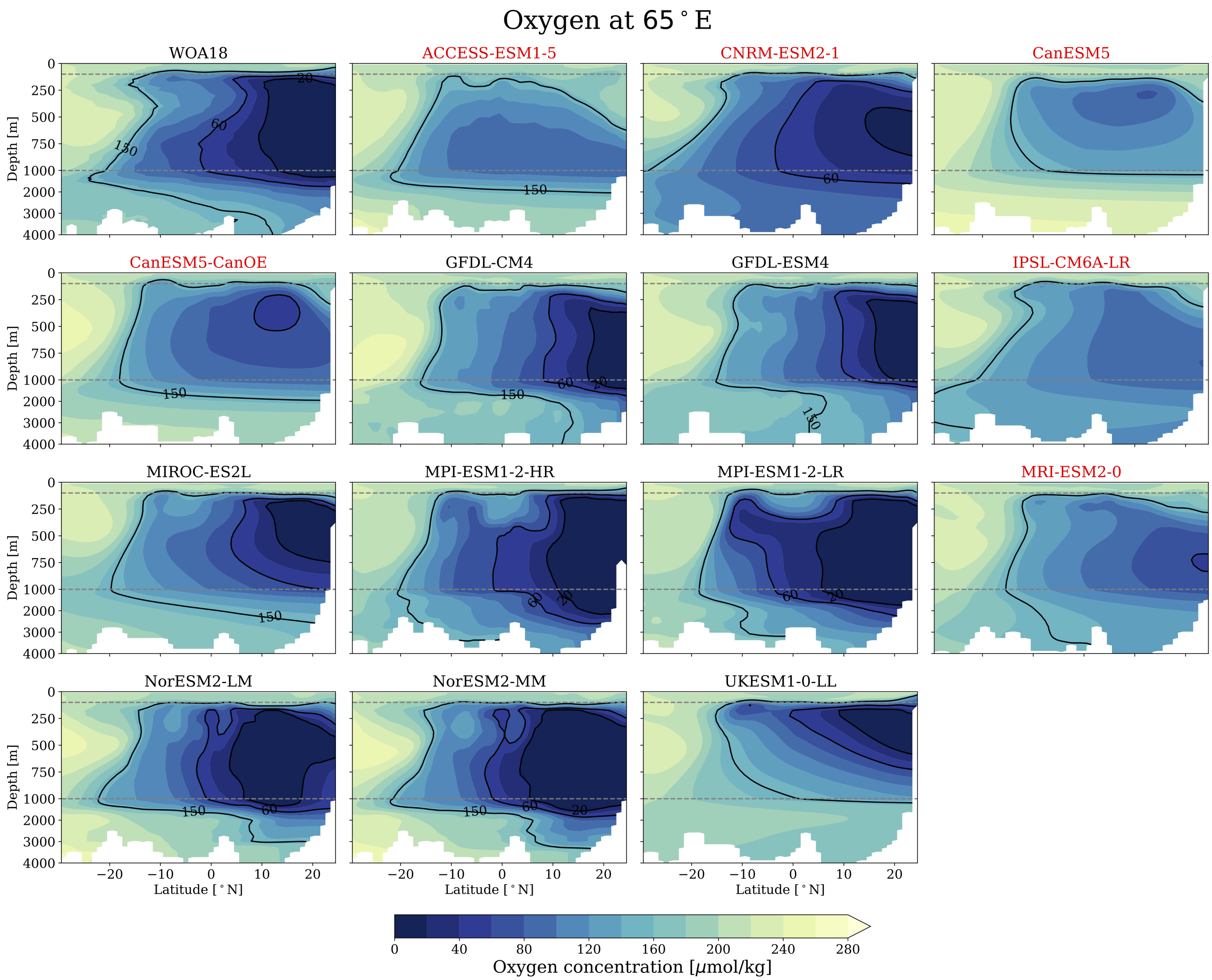

Figure S2. Sections of dissolved oxygen along 65° E in the Indian Ocean for observed climatology (WOA18) and individual CMIP6 ESMs. Contours show 20, 60, and 150 $\mu\mathrm{mol/kg}$ oxygen extent. Models labeled in black are used in the ESM ensemble, while models labeled in red have been omitted (see methods).

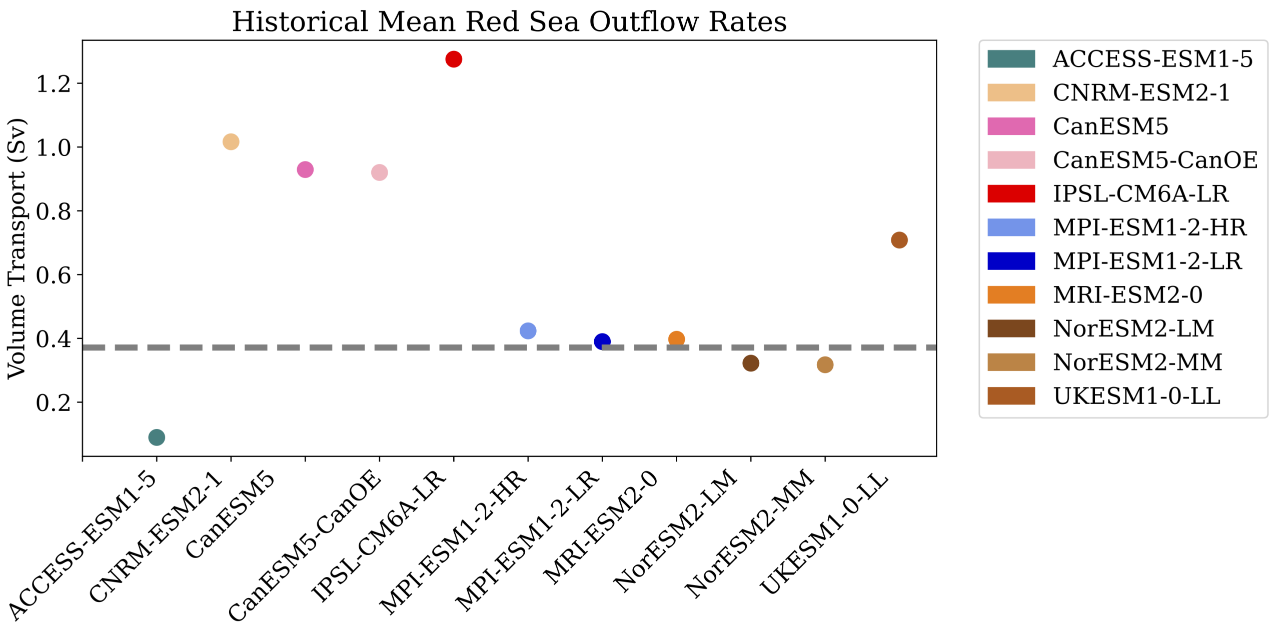

Figure S3. Mean volume transport out of the Red Sea over the historical period 1950-2015. Dashed gray line represents annual average observed outflow rate from Sofianos and Johns (2007). Red box around discarded ESMs. Transport fields for GFDL-CM4, GFDL-ESM4 and MIROC-ES2L unavailable.

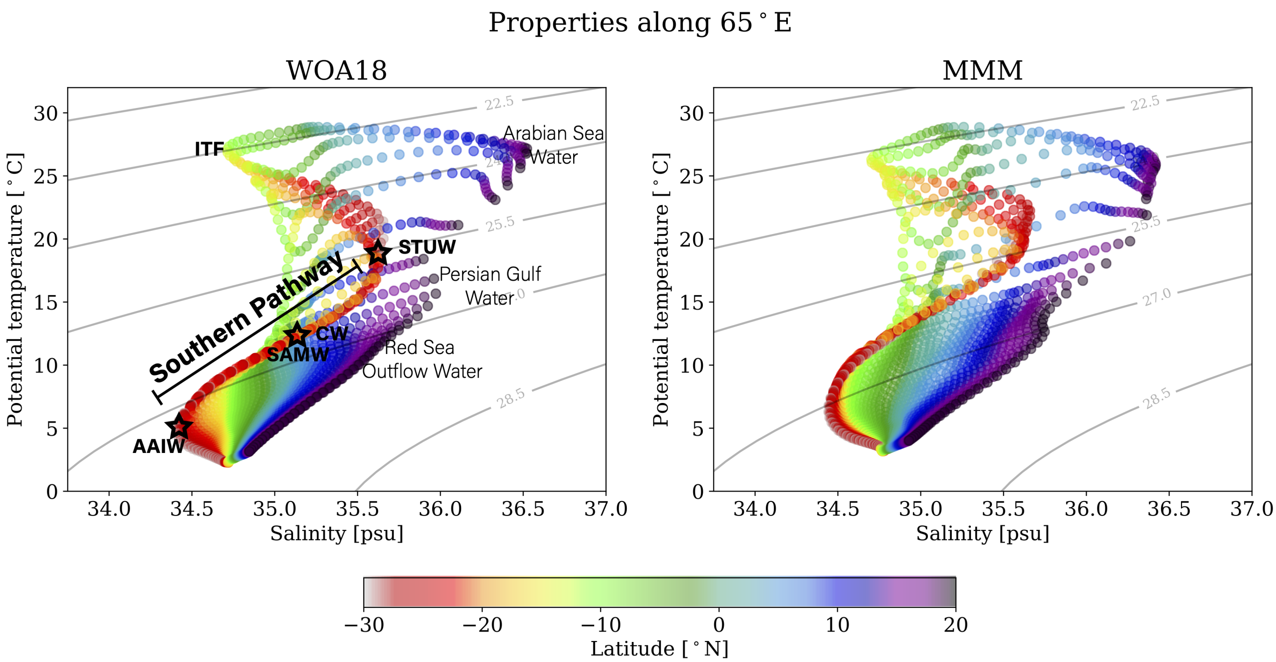

Figure S4. Temperature-Salinity relationship along 65°E between 30°S-20°N from 0-2000 m in World Ocean Atlas 2018 (WOA18) and 8-ESM multi-model mean (MMM). Water Mass Abreviations: Antarctic Intermediate Water (AAIW), Subantarctic Mode Water (SAMW), Central Water (CW), Subtropical Underwater (STUW), Indonesian Throughflow water (ITF). Potential density contours are referenced to surface pressure (σ_0). Similar to 11.18b from Talley (2011).

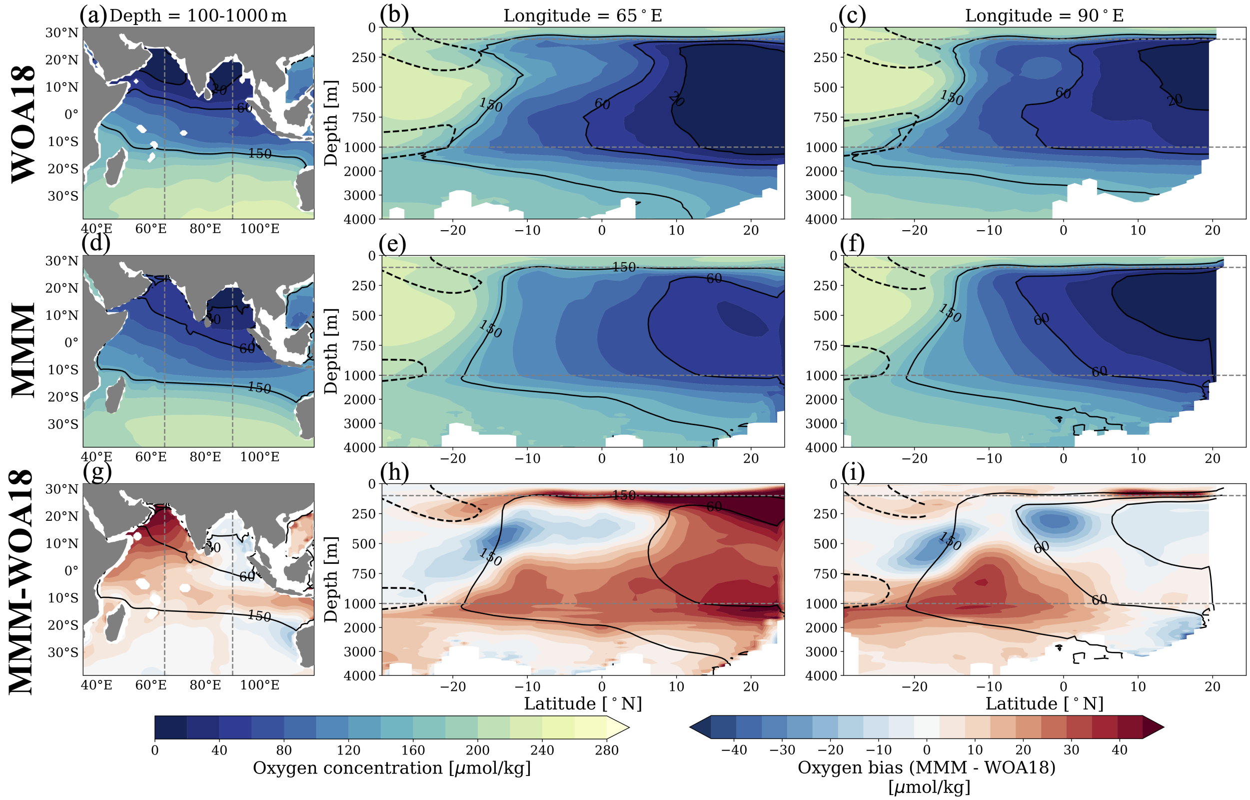

Figure S5. Same as figure 2, for all 14 CMIP6 ESMs with oxygen output. **(a-c)** Multi-Model Mean (MMM) dissolved oxygen in the Indian Ocean for historical period (1950-2015) **(a)** between 100 and 1000 m, **(b)** at 65°E, and **(c)** at 90°E. **(d-f)** Difference between MMM (1950-2015) and observed (WOA18) dissolved oxygen in the Indian Ocean **(d)** between 100 and 1000 m, **(e)** at 65°E, and **f)** at 90°E. **(a-f)** Thin solid black contours represent $150\,\mu\mathrm{mol/kg}$ in MMM, thick solid black contours represent $60\,\mu\mathrm{mol/kg}$. Dashed contours in **(b,c,e,f)** represent salinity signatures of Subtropical Underwater (STUW) and Intermediate Water (IW), with Central Water (CW) and Mode Water (MW) between the contours (water masses labeled in panel **(b)**). Dashed gray lines represent **(a,d)** represent 65°E and 90°E and **(b,c,d,f)** 100 and 1000 m.

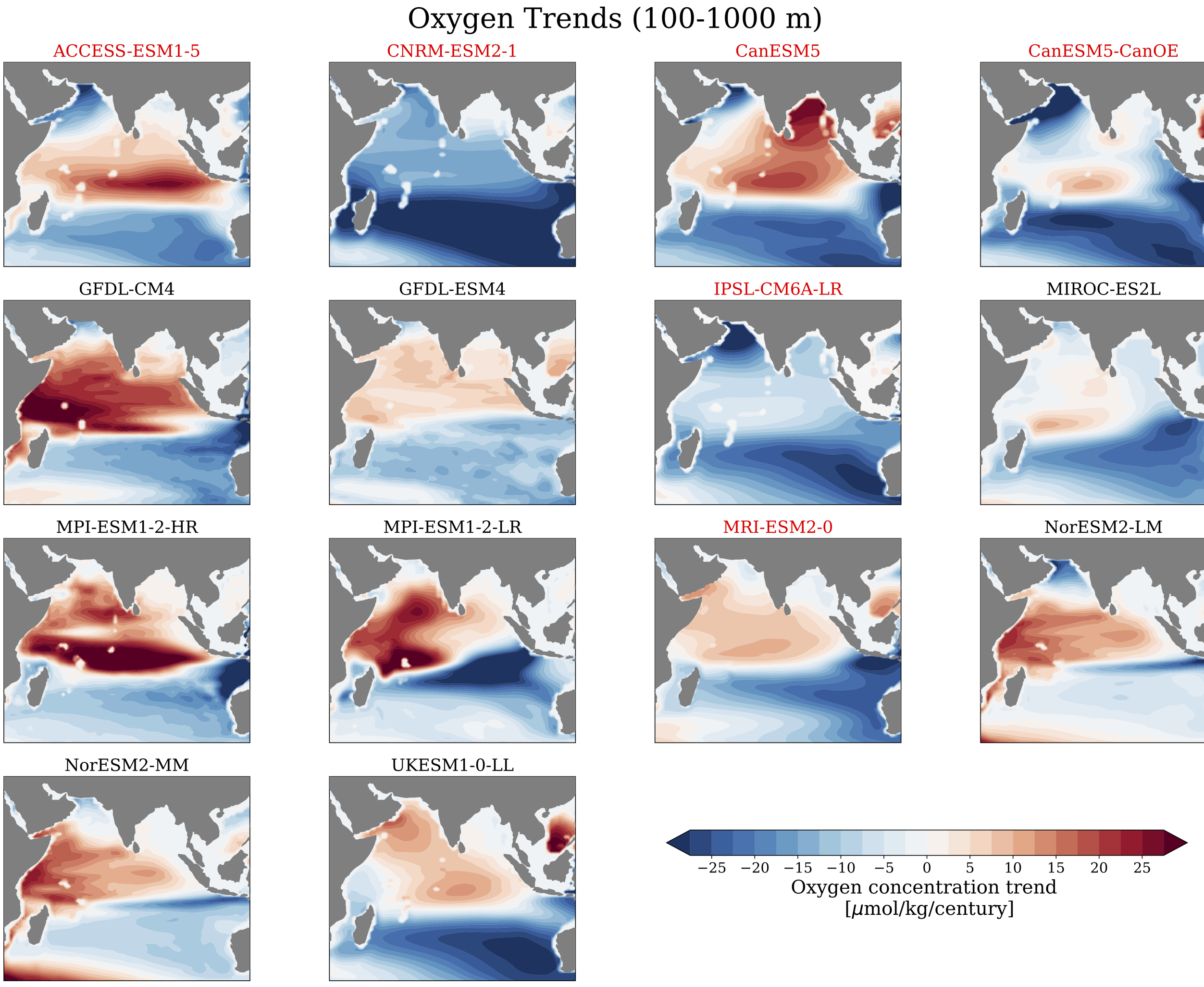

Figure S6. Maps of dissolved oxygen trends in the Indian Ocean averaged between 100 and 1000 m for individual CMIP6 ESMs. Models labeled in black are used in the ESM ensemble, while models labeled in red have been omitted (see methods).

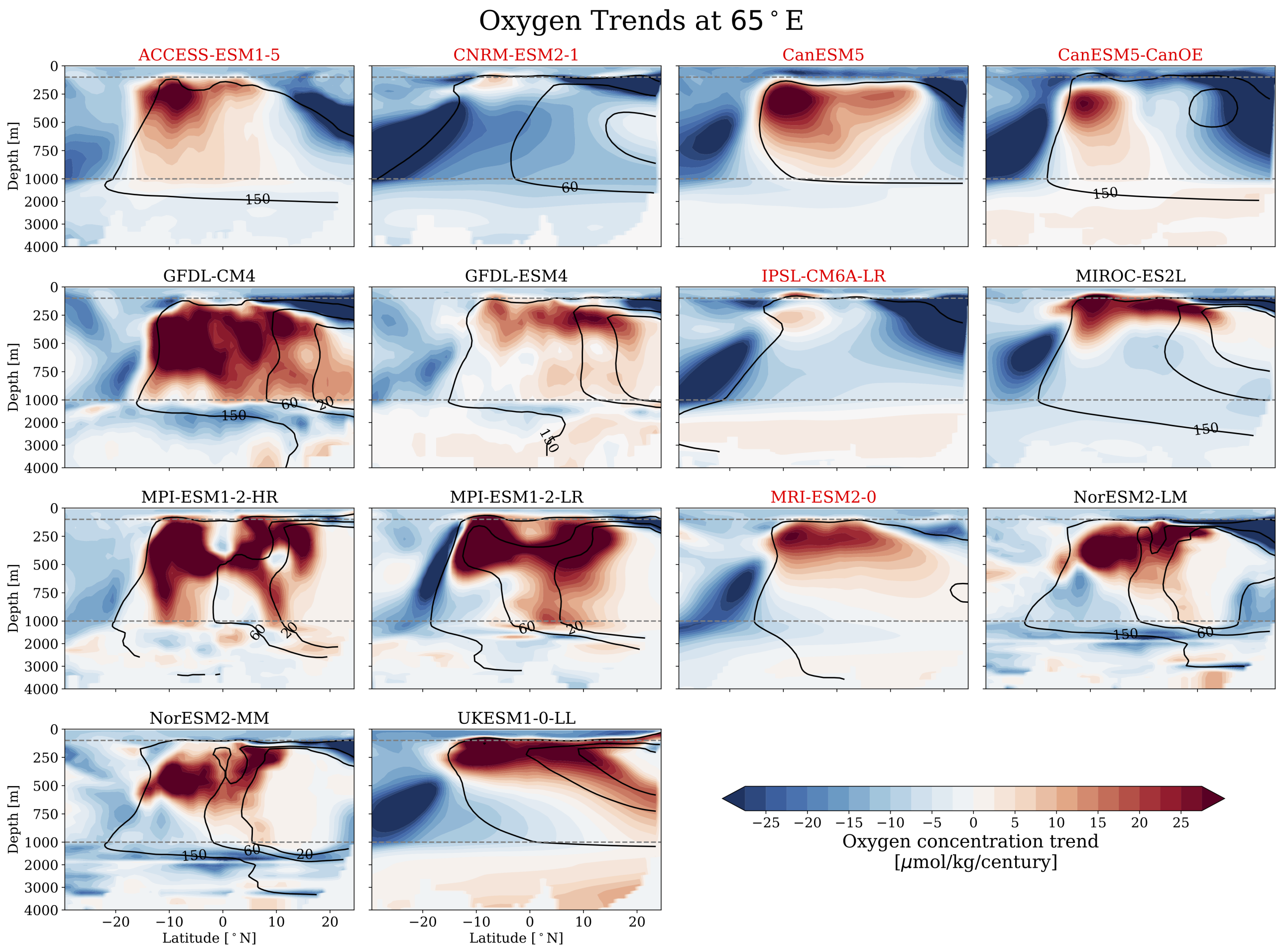

Figure S7. Sections of dissolved oxygen trends along 65° E in the Indian Ocean for observed climatology (WOA18) and individual CMIP6 ESMs. Contours show 20, 60, and 150 $\mu\mathrm{mol/kg}$ oxygen extent. Models labeled in black are used in the ESM ensemble, while models labeled in red have been omitted (see methods).

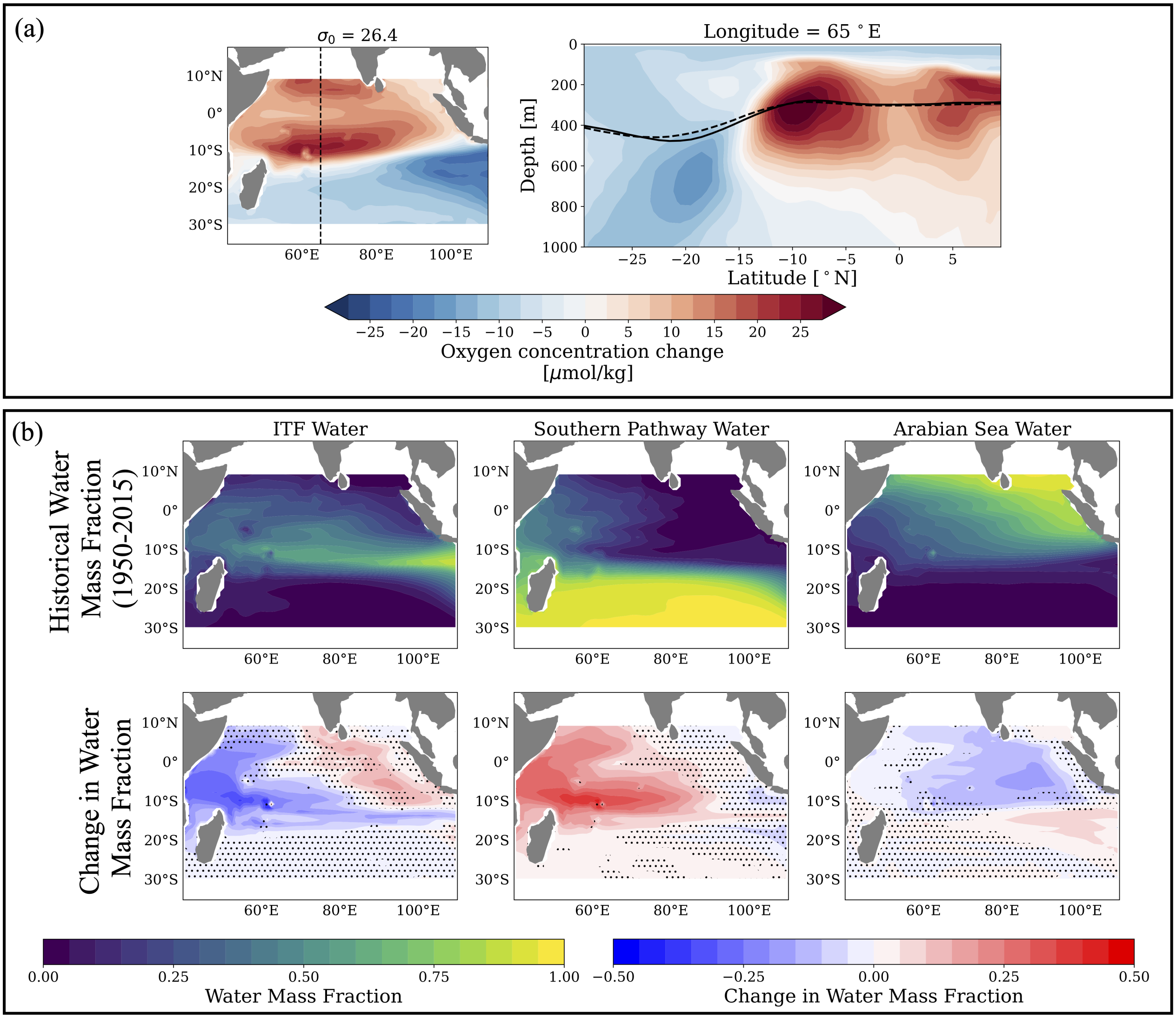

Figure S8. Alternative mixing model at thermocline ridge comparing historical and future density layers which occupy similar depths

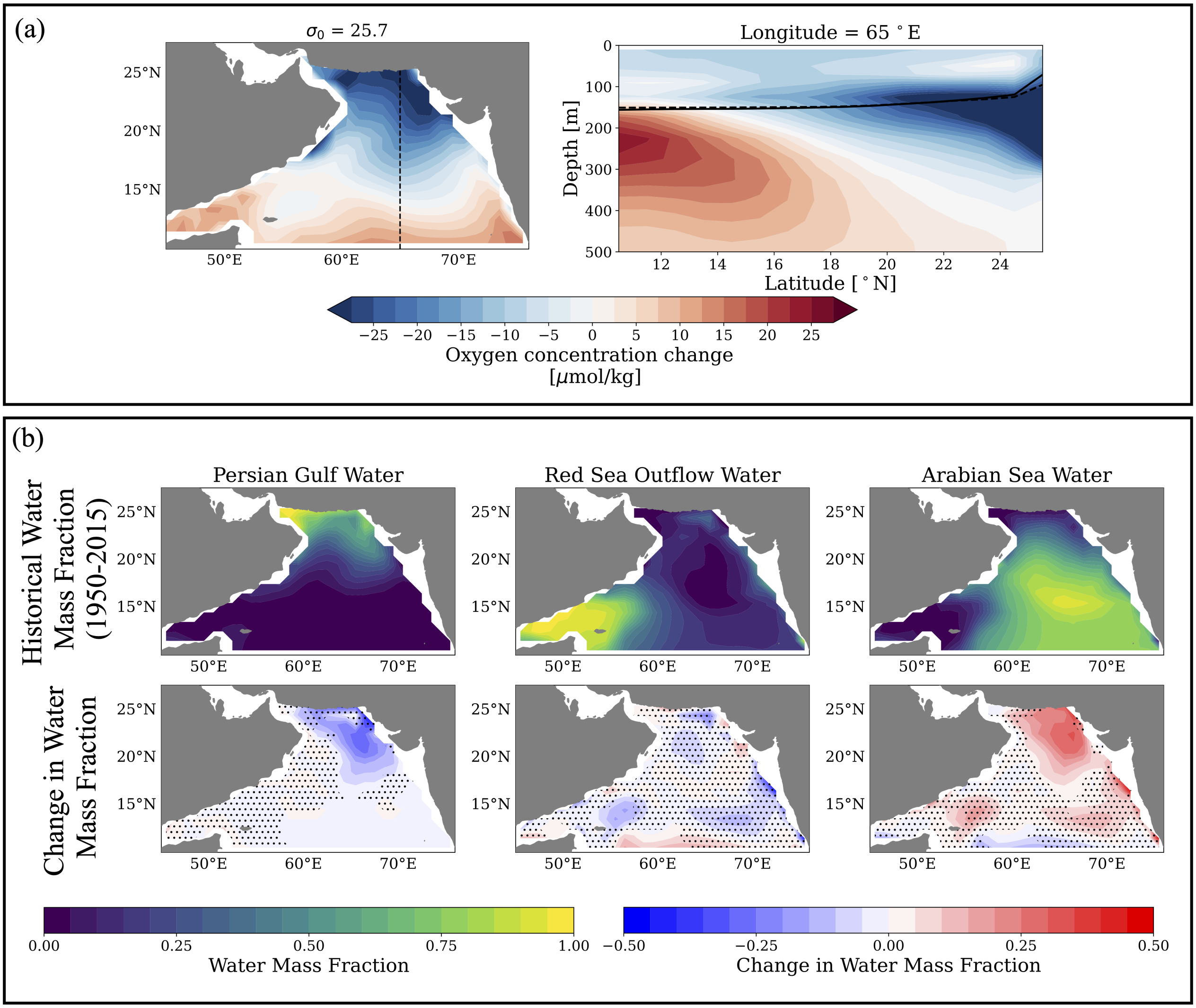

Figure S9. Alternative mixing model in Arabian Sea comparing historical and future density layers which occupy similar depths

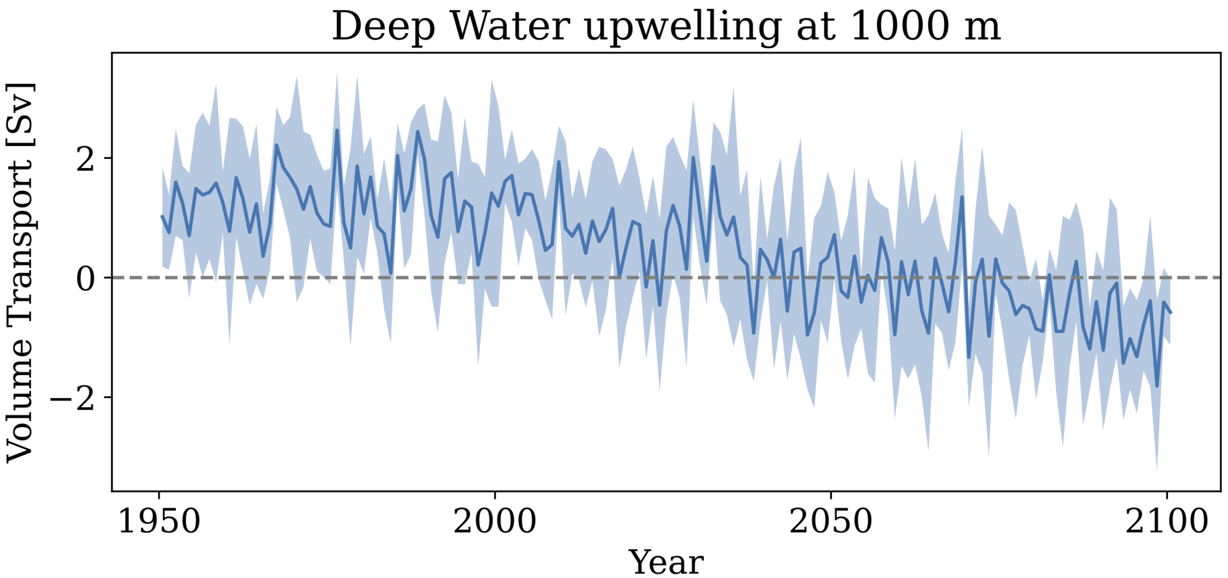

Figure S10. Volume transport of Deep Waters across 1000 m in the Indian Ocean derived from Deep Water fluxes in/out of via 30° S and Indonesian Throughflow. Solid curve represents multi-model mean and shading represents one standard deviation of the ensemble spread.