Surface and thermocline variability in the tropical eastern Indian Ocean since the Last Glacial Maximum

Henrik Sadatzki (1,*), Mahyar Mohtadi (1,2), Martina Hollstein (1), Andreas Lückge (3), Yusuke Yokoyama (4,5), Delia W. Oppo (6)

* hsadatzki@marum.de

(1) MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
(2) Faculty of Geosciences, University of Bremen, Bremen, Germany
(3) Federal Institute for Geosciences and Natural Resources, Hannover, Germany
(4) Atmosphere and Ocean Research Institute, University of Tokyo, Tokyo, Japan
(5) Department of Earth and Planetary Sciences, University of Tokyo, Tokyo, Japan
(6) Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, USA

LOW-LATITUDE CLIMATE VARIABILITY

OBJECTIVES

- Investigation of the surface ocean hydrographic evolution and variability in the tropical eastern Indian Ocean since the Last Glacial Maximum
- Resolving regional and basin-wide surface-thermocline temperature anomalies, changes in the Indian Ocean Dipole (IOD) pattern, and their linkages with global climate changes and sea level rise across the last deglaciation

MATERIALS & METHODS

- Centennial-scale planktic foraminiferal proxy records from well-dated tropical eastern Indian Ocean cores SO189-119KL, SO189-39KL and GeoB10035-5 (Fig. 1).
- $\delta^{18}O$ and Mg/Ca records of surface-dwelling *G. ruber* and deeper-dwelling *P. obliquiloculata* to reconstruct sea surface temperature (SST) and upper thermocline temperatures (TT), anomalies between them ($\Delta T_{SST\text{-}TT}$), and by extension thermocline/mixed layer depth

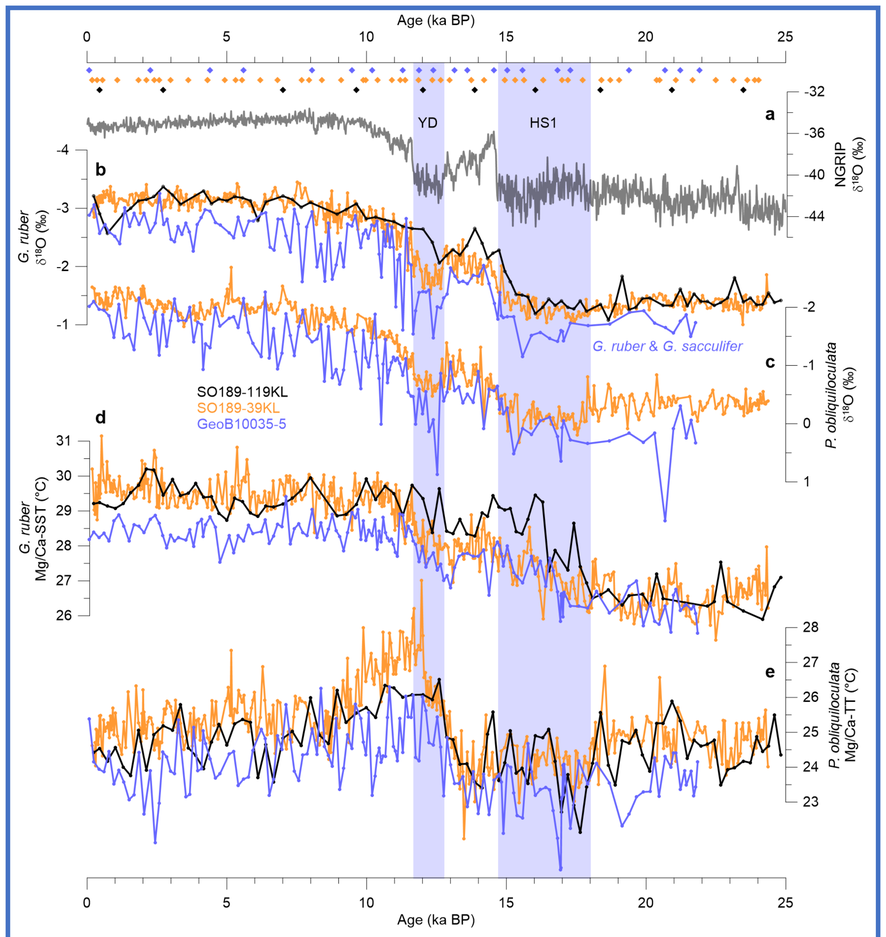

Fig. 2 Proxy records of cores SO189-119KL (black), SO189-39KL (orange) and GeoB10035-5 (blue) covering the last 25 thousand years. **a** NGRIP $\delta^{18}O$ (NGRIP members, 2004). **b** *G. ruber* $\delta^{18}O$. **c** *P. obliquiloculata* $\delta^{18}O$. **d** *G. ruber* Mg/Ca-based sea surface temperature (SST). **e** *P. obliquiloculata* Mg/Ca-based thermocline temperature (TT). Diamonds at the top mark planktic foraminiferal ^{14}C ages used for the age models. The $\delta^{18}O$ and Mg/Ca-SST of cores SO189-119KL and SO189-39KL are from Mohtadi et al. (2014).

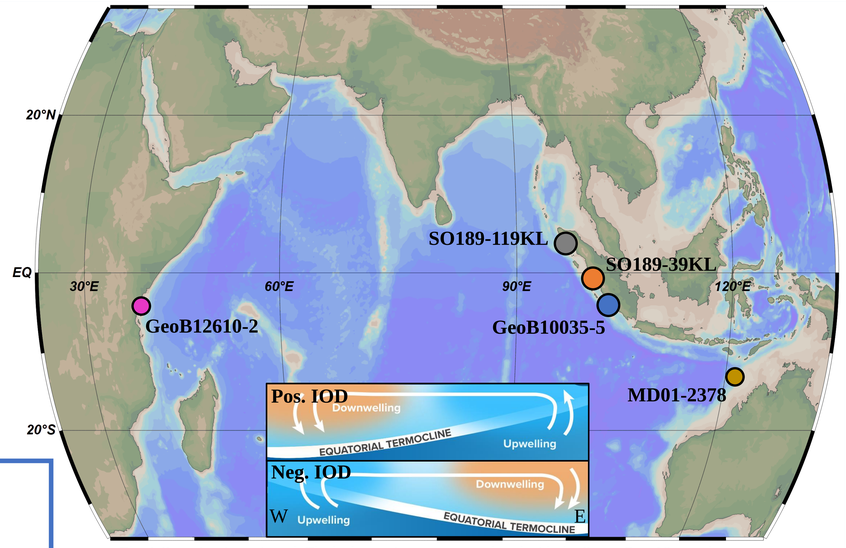

Fig. 1 Core sites investigated. The bathymetric map was produced with the Ocean Data View software (Schlitzer, 2023). Schematic West-East cross-sections at the bottom illustrate hydrographic features associated with a positive and negative mode of the Indian Ocean Dipole (https://www.weatherzone.com.au/news/indian-ocean-dipole-hits-highest-level-since-2019/1463010).

RESULTS

- Surface and thermocline $\delta^{18}O$ and Mg/Ca-temperatures show a consistent evolution at all three sites, but also some regional differences (Fig. 2)
- $\delta^{18}O$ reflects hydroclimatic variations linked to deglacial NH climate changes, while SST warming is concurrent with Antarctic warming and CO_2 rise
- TTs are decoupled from SSTs and reveal a temporary warming at 13-10 ka
- SSTs and TTs at upwelling site GeoB10035-5 are notably colder and more variable than those at the other sites, especially during the Holocene

DISCUSSION

- Smaller $\Delta T_{SST\text{-}TT}$ in the eastern Indian Ocean suggest a deeper thermocline during the glacial (and the YD) as compared to the Holocene (and early deglaciation) (Fig. 3)
- Increased zonal $\Delta T_{SST\text{-}TT}$ anomalies indicate a west-to-east downward tilt of the thermocline, corresponding to a negative IOD pattern during the glacial, early HS1, YD, and earliest Holocene
- Lowered or reversed zonal $\Delta T_{SST\text{-}TT}$ anomalies suggest that positive IOD patterns marked the Holocene as well as the B/A interstadial, pointing at complex underlying ocean-atmosphere dynamics acting on different time scales

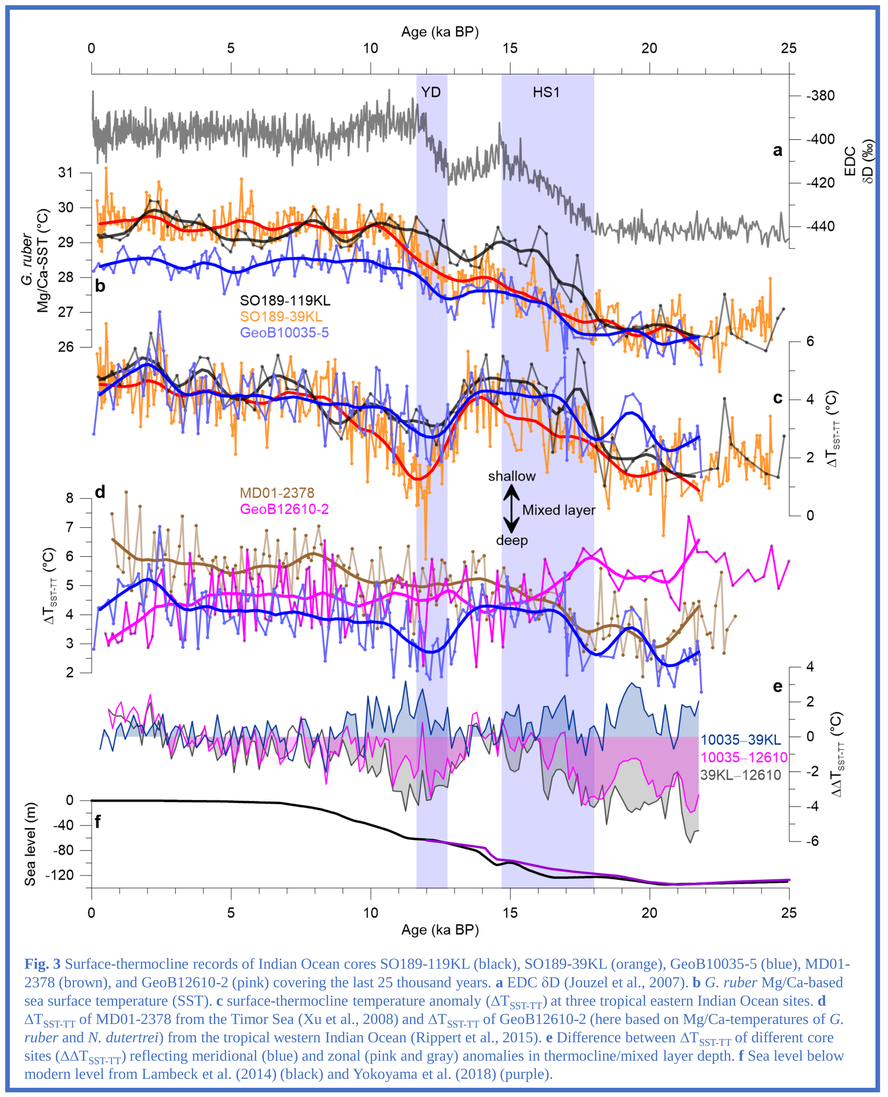

Fig. 3 Surface-thermocline records of Indian Ocean cores SO189-119KL (black), SO189-39KL (orange), GeoB10035-5 (blue), MD01-2378 (brown), and GeoB12610-2 (pink) covering the last 25 thousand years. **a** EDC δD (Jouzel et al., 2007). **b** *G. ruber* Mg/Ca-based sea surface temperature (SST). **c** surface-thermocline temperature anomaly ($\Delta T_{SST\text{-}TT}$) at three tropical eastern Indian Ocean sites. **d** $\Delta T_{SST\text{-}TT}$ of MD01-2378 from the Timor Sea (Xu et al., 2008) and $\Delta T_{SST\text{-}TT}$ of GeoB12610-2 (here based on Mg/Ca-temperatures of *G. ruber* and *N. dutertrei*) from the tropical western Indian Ocean (Rippert et al., 2015). **e** Difference between $\Delta T_{SST\text{-}TT}$ of different core sites ($\Delta\Delta T_{SST\text{-}TT}$) reflecting meridional (blue) and zonal (pink and gray) anomalies in thermocline/mixed layer depth. **f** Sea level below modern level from Lambeck et al. (2014) (black) and Yokoyama et al. (2018) (purple).

FUTURE WORK

- Generation of individual foraminifera Mg/Ca-temperatures for specific time intervals to reconstruct seasonal to inter-annual climate variability during different sea level and climate states
- Generation of plant wax δD and $\delta^{13}C$ records for the three sites to reconstruct rainfall and vegetation changes
- Proxy-model comparison to investigate the influence of deglacial sea level rise and climate change on IOD mode changes

REFERENCES:

Jouzel et al., 2007, Science 317, 793-796
Lambeck et al., 2014, PNAS 111 (43), 15296-15303
Mohtadi et al., 2014, Nature 509, 76-80, doi:10.1038/nature13196
NGRIP members, 2004, Nature 431, 147-151
Rippert et al., 2015, J. Quat. Sci. 30 (3), 201-210, doi:10.1002/jqs.2767
Schlitzer, R., 2023, Ocean Data View, https://odv.awi.de
Xu et al., 2008, EPSL 273, 152-162, doi:10.1016/j.epsl.2008.06.029
Yokoyama et al., 2018, Nature 559, 603-607, doi:10.1038/s41586-018-0335-4

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