SUNDA SHELF EXPOSURE SUPRESSES THE SEASONAL BARRIER LAYER IN THE WESTERN INDONESIA

Anggit Al Hafizh[1], Rima Rachmayani[2], Adnya Priscilla Prita Pratiwi[3], Vandikkar Silalahi[1], Mutiara R. Putri[2], Nurjanna Joko Trilaksono[4], Khoiril Anwar Maryunani[5], Nabilah S. M.[3]

[1] Study Program of Oceanography
[2]Environmental and Applied Oceanography Research Group
[3]Study Program of Earth Science
[4]Earth Science Research Group
[5]Paleontology and Quarternary Geology Research Group
Faculty of Earth Sciences and Technology

Abstract

The Southeastern Tropical Indian Ocean (SETIO) develops a seasonal barrier layer when surface salinity stratification separates the mixed layer from a deeper isothermal layer. Freshwater entering the Indonesian seas, including through the Karimata Strait, contributes to this stratification. This study uses time-slice experiments from the isotope-enabled Community Earth System Model version 1.2 (iCESM1.2) to compare a fully flooded reference configuration with an Exposed Sunda Shelf configuration representing Marine Isotope Stage 11 (MIS 11). Under the Exposed configuration, sea surface salinity increases across much of the SETIO, while both the mixed layer depth (MLD) and isothermal layer depth (ILD) become shallower. The stronger shoaling of ILD results in a regional barrier-layer thickness (BLT) reduction of approximately 5–15 m during December–February (DJF). At model location T1, BLT decreases by 1.8 m during DJF but increases slightly by 0.6 m during June–August (JJA). These results highlight the role of Sunda Shelf configuration in modulating seasonal upper-ocean stratification.

Keyword: Sunda Shelf, Marine Isotope Stage 11, Barrier Layer Thickness, iCESM1.2.

Introduction

The barrier layer forms when the mixed layer is shallower than the deeper isothermal layer due to differences in salinity and temperature stratification (Sprintall & Tomczak, 1992; de Boyer Montégut et al., 2004). In the SETIO, freshwater transported through the Indonesian seas and Karimata Strait contributes to its seasonal variability (Qu & Meyers, 2005; Sarr et al., 2019).

Quaternary paleogeographic changes can alter shallow ocean connections and freshwater distribution across the Maritime Continent. However, their effects on seasonal upper-ocean stratification remain less understood (Di Nezio et al., 2016; McGrath et al., 2023). This study investigates the effects of contrasting Flooded and Exposed configurations on surface salinity, MLD, ILD, and BLT. The study area, exposed Sunda Shelf, 5°S transect, and model location T1 are presented in Figure 1.

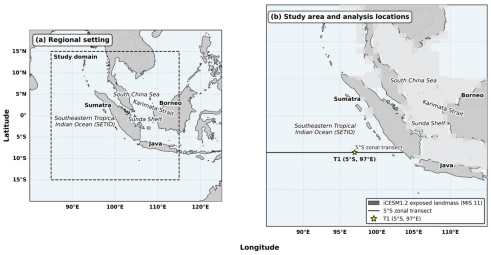


Figure 1. Study area and paleogeographic configuration, showing the SETIO domain, exposed Sunda Shelf, 5°S transect, and model location T1 (5°S, 97°E).

Research Method

Numerical output from the isotope-enabled Community Earth System Model version 1.2 (iCESM1.2) was used, with approximately 1° horizontal resolution and 60 ocean vertical levels (Brady et al., 2019). Two configurations were compared: Flooded, representing a fully inundated reference state, and Exposed, representing the prescribed MIS 11 paleogeography.

Ocean stratification was evaluated using TEOS-10 and the Gibbs SeaWater toolbox (McDougall et al., 2010; McDougall & Barker, 2011). Using a 5 m reference depth, ILD was identified at a temperature decrease of 0.2°C and MLD at a potential density increase of 0.03 kg m^{-3} (de Boyer Montégut et al., 2004, 2007). BLT was calculated as ILD − MLD. Monthly BLT values below 5 m were treated as undetected in the seasonal spatial analysis..

Discussion & Result

Under the Exposed configuration, BLT reaches approximately 15-25 m along western Sumatra during DJF and locally exceeds 25 m (Figure 2). BLT decreases during MAM and JJA before recovering in SON. This seasonal pattern is consistent with the influence of monsoon forcing and freshwater distribution (Qu & Meyers, 2005; Masson et al., 2002).

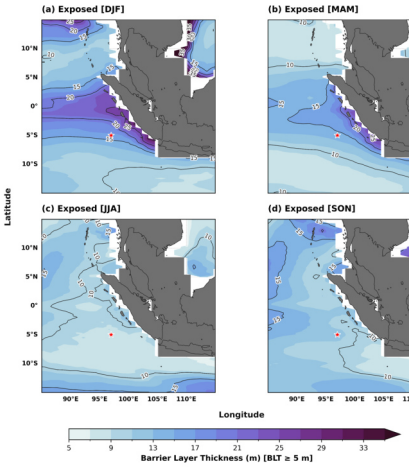


Figure 2. Seasonal BLT distribution under the Exposed configuration during DJF, MAM, JJA, and SON.

During DJF, BLT decreases by approximately 5-15 m across the core SETIO response region (Figure 3). Both MLD and ILD become shallower, but the stronger shoaling of ILD reduces the separation between the two layers.

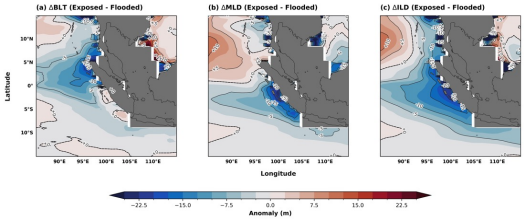


Figure 3. DJF anomalies of BLT, MLD, and ILD (Exposed minus Flooded).

The Exposed configuration produces positive SSS anomalies of approximately 0.3–0.6 PSU across much of the core SETIO response region (Figure 4). This reflects combined changes in freshwater forcing, runoff routing, and ocean circulation associated with the prescribed paleogeography (Sarr et al., 2019b; Zhang et al., 2022).

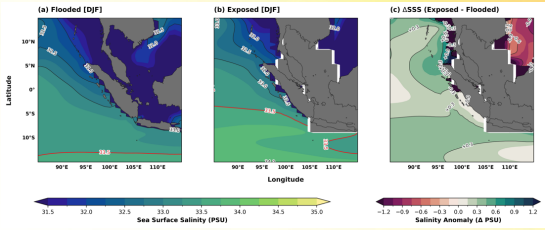


Figure 4. DJF sea surface salinity for Flooded and Exposed configurations and their anomaly.

Along the 5°S transect, the Flooded configuration exhibits a fresher surface layer, whereas higher salinity water reaches closer to the surface toward the eastern transect in the Exposed configuration (Figure 5).

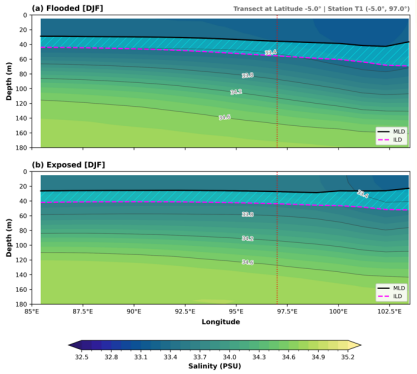


Figure 5. DJF zonal salinity cross-section along 5°S for Flooded and Exposed configurations. Solid and dashed lines indicate MLD and ILD, respectively; shading marks the interval between the two layers.

At model location T1 (5°S, 97°E), BLT decreases from 16.9 to 15.1 m during DJF (−1.8 m), as ILD shoals more strongly than MLD. During JJA, BLT increases slightly from 7.8 to 8.4 m (+0.6 m) (Figure 6). This local response highlights the seasonal differences in upper-ocean stratification.

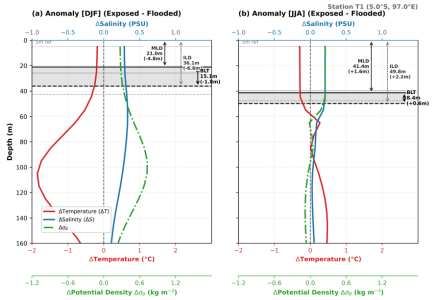


Figure 6 Vertical temperature, salinity, and potential density anomalies at T1 during DJF and JJA (Exposed minus Flooded). Horizontal lines and annotations indicate MLD, ILD, and BLT changes.

Conclusion

Sunda Shelf exposure is associated with increased surface salinity and reduced regional BLT during DJF. The stronger shoaling of ILD relative to MLD explains the reduced barrier-layer thickness. The opposite but small response at T1 during JJA demonstrates the seasonal and spatial variability of upper-ocean stratification.