Asian Hub (DOM)

Fri. Nov 13, 2026 9:00 AM - 10:30 AM JST | Fri. Nov 13, 2026 12:00 AM - 1:30 AM UTC | Room B (Kujaku) (2F)

Oral B4 - Asian Hub

Chair: Yushi Morioka

9:17 AM - 9:29 AM JST | 12:17 AM - 12:29 AM UTC

[hIaLijy4-03] Toward a Digital Twin of the Indonesian Throughflow: From Multiscale Ocean Dynamics to Predictive Intelligence

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The Indonesian Throughflow (ITF) is the world's only tropical ocean gateway connecting the Pacific and Indian Oceans and plays a fundamental role in global heat redistribution, climate variability, and marine ecosystem dynamics. Despite its importance, continuously observing and predicting ITF variability across multiple temporal and spatial scales remains challenging. We propose a Digital Twin of the Indonesian Throughflow (ITF-Digital Twin) as an integrated framework combining observations, ocean reanalysis, numerical modelling, artificial intelligence, and process-based understanding to represent and predict the evolving ITF system.

As a scientific foundation for this vision, we investigate the multiscale modulation of Makassar Strait ITF transport by the Madden–Julian Oscillation (MJO) under different El Nino-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) states. Using 17 years (2004-2020) of high-resolution GLORYS12 reanalysis evaluated against INSTANT mooring observations, we characterize intraseasonal, interannual, and vertical variations in ITF transport. Results demonstrate that MJO-related transport responses are strongly state-dependent, with systematic differences in amplitude, timing, and vertical structure across ENSO-IOD regimes. These responses reflect interactions between intraseasonal atmospheric forcing, wind-driven ocean adjustment, and large-scale pressure-gradient variability controlling Indonesian Seas circulation.

These findings highlight a key requirement for an ITF Digital Twin: the ability to dynamically represent interactions between fast atmospheric forcing and slowly varying ocean-climate states. We envision a multi-layer system integrating in situ moorings and acoustic observations for sensing, satellite and operational products for spatial coverage, high-resolution models and reanalyses for physical state estimation, and artificial intelligence for adaptive prediction. Makassar Strait provides a strategic natural laboratory and observation–modelling node for this architecture.

This work represents a step toward an Indonesian Ocean Digital Twin, with future expansion across the interconnected Indonesian Seas and coupling with the wider Indo-Pacific climate system, supporting climate services, marine ecosystem and fisheries management, and early-warning applications.

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