

Satellite Gravimetry for Monitoring Hydrological Dynamics in Indonesia

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Monitoring hydrological dynamics in Indonesia remains challenging due to its complex tropical maritime climate and the limited coverage of conventional observations, particularly for subsurface water storage. GRACE and GRACE-FO satellite gravimetry provide an alternative approach by measuring changes in Terrestrial Water Storage (TWS). However, their application is affected by mission-related data gaps and contamination from non-hydrological signals associated with major earthquakes. This study analyzes hydrological variability across Indonesia using CSR GRACE/GRACE-FO RL06.3 Mascon TWS anomalies from April 2002 to June 2025. Earthquake-induced signals in the Andaman–Sumatra region were corrected using Principal Component Analysis/Empirical Orthogonal Function decomposition. Missing observations were reconstructed using climate adjustment Singular Spectrum Analysis (climSSA) with precipitation and potential evaporation as covariates. The continuous TWS series was then analyzed using harmonic regression, water-budget closure, lag-correlation with ENSO, IOD, AUSMI, and IMI, GRACE Drought Severity Index (GRACE-DSI), and Groundwater Storage (GWS) estimation. The climSSA reconstruction achieved a correlation of 0.93 and an RMSE of 0.68 cm. Annual variability dominated most of Indonesia, whereas semiannual signals were concentrated in equatorial regions. ENSO exerted stronger influence over central and eastern Indonesia, while IOD effects were more pronounced toward western Indonesia. GRACE-DSI captured major drought events in 2015–2016 and 2019, with TWS responses lagging meteorological drought by approximately 5–12 months. GWS trends indicated depletion of about -0.08 cm/yr in Sumatra and Kalimantan peatlands, while positive trends occurred in Merauke and Pantura. Overall, the proposed processing framework improves the reliability of GRACE-based hydrological monitoring in Indonesia and supports drought assessment and water-resource management.

Keywords: hydrological, GRACE, Total Water Storage (TWS), data gaps, ENSO, drought, groundwater.