Aquarius surface salinity & Madden-Julian Oscillation: Salinity’s in surface layer density & potential energy

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The Madden-Julian Oscillation (MJO)

- The largest element of tropical intraseasonal variability (~ 30–90 days).
- Involving large-scale coupling between atmospheric circulation & deep convection.
- Propagating eastward from the Indian Ocean to western Pacific.
- Alternating wet (cold) phases with enhanced (suppressed) thunderstorms and precipitation.
- Important to Asian monsoon and El Niño-Southern Oscillation.
- Evidence that ocean-atmos. coupling enhances MJO.
Objectives of this study

- SSS signature of MJO.
- Controlling processes.
- Salinity’s role in surface density: implication to mixed layer depth.
- Salinity’s role in surface potential energy: implication to downward energy propagation.
Composite life cycle of MJO (8 phases)

Obtained from combined EOF for the 10-100 day filtered data ("Wheeler-Hendon Index", Wheeler & Hendon 2004)
Time series of MJO life cycle averaged over central-equatorial IO & W. Pacific

- $P$ explains $dS/dt$: $S$ lags $P$ by 2 phases during wet phase (quadrature relation between $P$ and $S$)

- $P$ cannot explain $dS/dt$: the lack of quadrature relation between $P$ & $S$ indicates the role of ocean dynamics.

Consistent with Matthew et al. (2010) based on Argo data, different from the interpretation by Grunseich et al. (2013) based on Aquarius.
Salinity’s role on density during MJO

Based on linear equation of state for sea water (surface – zero pressure), surface density anomaly is

\[ \rho' = (-\alpha T' + \beta S') \rho_0 \]

\( \alpha \) – thermal expansion coefficient
\( \beta \) – saline contraction coefficient

- Important contribution by \( S' \) (overall larger than \( T' \) effect); implication to mixed layer depth.
- Offset \( T' \) effect on density at times (esp. in the Indian Ocean)
- Pacific Ocean \( T' \) & \( S' \) effects tend to be more consistent, reflecting the role of ocean dynamics in advecting \( T' \) and \( S' \).
Salinity’s role on Perturbation Potential Energy (PPE)

\[ \text{PPE} = g \rho' / \rho_{0z} \]

(\(\rho'\) - surface density perturbation, \(\rho_{0z}\) – mean \(\rho\) gradient across mixed layer)

\[ \rho'^2 = \left[ (-\alpha T')^2 + (\beta S')^2 - 2\alpha\beta T'S' \right] \rho_0^2 \]

- Dominant role of \(S'\)
- Important implication to downward energy propagation
Summary

- Aquarius detects MJO signature in SSS (also detected by Matthew et al. 2010 using Argo & Grunseich et al. 2013 using Aquarius).

- Indian Ocean SSS changes are primarily forced by precipitation during wet phase; ocean dynamics plays important role in the western Pacific.

- Salinity has important contribution to surface density (thus mixed layer depth) anomaly.

- Salinity plays a dominant role in surface perturbation potential energy – important to downward energy propagation.
Time series of “MJO” life cycle for weak intraseasonal variability

Indian Ocean

Western Pacific