Interannual Variability of the Indonesian Throughflow Transport Estimated From Wind Stress and Adjoint Sensitivity

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1. Objectives

❶ Explore feasibility to estimate interannual transport of the Indonesian throughflow(ITF) using wind data.

❷ Investigate regional contribution of wind to ITF.

❸ Assess previous theories used to predict ITF transport.

2. Approach

❶ Use parallel MIT OGCM & its adjoint as dynamical platform (global, $1^\circ * 0.3^\circ$ tropics, $1^\circ * 1^\circ$ extratropics, 46 levels, 10 m above 150 m).

❷ Obtain sensitivity of annual mean ITF transport $\bar{V}$ to annual mean wind stress $\bar{\tau}(x,y)$ through the adjoint:

$$s(x,y) = \partial \bar{V} / \partial \bar{\tau}(x,y) \qquad (1)$$

❸ Compute annually averaged interannual anomalies of wind stress from NCEP reanalysis product:

$$\tau(x,y,t)' = \tau(x,y,t) - \bar{\tau}(x,y) \qquad (2)$$

❹ Derived geographical contribution of wind anomaly to ITF transport anomaly:

$$c(x,y,t)' = s(x,y) * \tau(x,y,t)' \qquad (3)$$

❺ Integrate $c(x,y,t)'$ spatially to estimate ITF transport anomaly due to regional or global wind anomaly:

$$V(t)' = \int c(x,y,t)' \, dx \, dy \qquad (4)$$

3. Highlight of Results

Sensitivity Function

Sensitivity of annual mean ITF transport to annual mean wind stress s(x,y) (Eqn.1, Fig.1), shows several areas of large sensitivity: (1) western to central tropical Pacific, (2) eastern tropical Indian Ocean, (3) coastal regions south and west of Java, South America, Australia, and New Zealand. The sensitivity can be explained by equatorial and coastal wave processes.

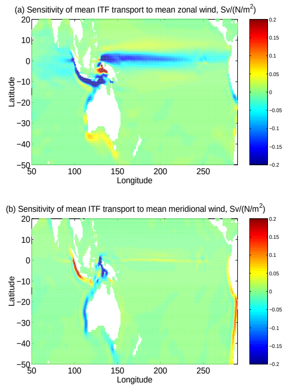

Fig. 1 Sensitivity of annual mean ITF transport to unit positive perturbation in annual mean zonal (a) & meridional (b) wind stress. Positive values indicate enhanced ITF.

Spatial Contribution

Spatial contribution of wind anomaly to ITF on interannual time scale c(x,y,t)' (Eqn.2) is computed. Its temporal rms map (Fig.2) shows regions of large contribution.

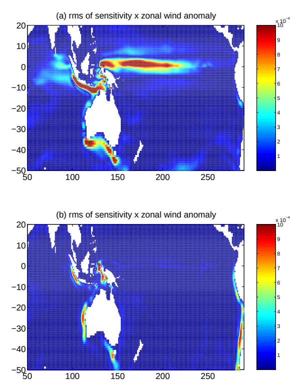

Fig. 2 r.m.s. map of the product of sensitivity and interannual wind anomaly: (a) zonal; (b) meridional.

Estimated interannual ITF transport

Interannual anomaly of ITF transport estimated from global wind (Eqn.4, Fig.3) resembles forward model simulations, and is qualitatively consistent with analysis of XBT data (Meyers 1996): ITF is stronger during La Nina and weaker during El Nino (Fig.4). This can be understood in terms of pressure difference between the Pacific and Indian Ocean.

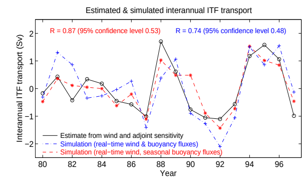

Fig. 3 Interannual anomaly of ITF transport estimated from sensitivity and interannual wind anomaly & those simulated by forward models.

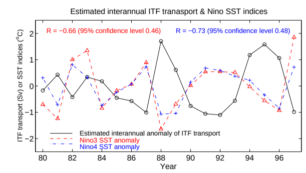

Fig. 4 Estimated interannual ITF transport is significantly correlated with SST anomalies in the central to eastern equatorial Pacific, and thus related to ENSO.

Effects of Regional Wind

Integrating c(x,y,t)' over various areas yields regional wind contribution to ITF. Fig.5 highlights the counteracting effect of Pacific & Indian Ocean wind. This is attributed to oscillation of Walker cells over the two oceans associated with ENSO.

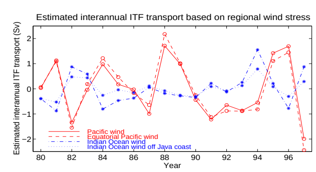

Fig. 5 Contribution of Indian and Pacific Ocean winds to interannual ITF transport. Counteracting effect is seen.

Assessment of the original "Island Rule"

Godfrey (1989) proposed using wind in the south Pacific and around Australia to infer ITF transport based on Sverdrup theory. Fig.6 shows that wind stress over such a domain tends to under−estimate the magnitude of interannual ITF transport, but predicts the phase reasonably well.

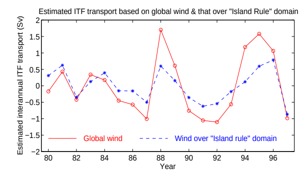

Fig. 6 Interannual ITF transports estimated from global wind and wind over the "Island Rule" domain (south Pacific and around Australia).

4. Summary

❶ Wind anomaly and adjoint sensitivity provide a reasonable mean to infer interannual ITF transport.

❷ ITF tends to be stronger during La Nina and weaker during El Nino (pressure difference).

❸ Indian Ocean wind counteracts Pacific wind in maintaining ITF (oscillation of Walker cells).

❹ South Pacific wind used by "Island Rule" under−estimates ITF transport (contribution by wind over north equatorial Pacific and Java coast missing).

References:

- *Godfrey, J.S., 1989: A Sverdrup model for the depth−integrated flow for the World Ocean, allowing for island circulations. Geophys. Astrophys. Fluid Dyn., 45, 89−112.*
- *Meyers, G., 1996: Variation of the Indonesian throughflow and the El Nino−Southern Oscillation. J. Geophys. Res., 101, 12255−12264.*