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# Three inflow pathways of the Indonesian throughflow as seen from the simple ocean data assimilation

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A B S T R A C T

The SODA product is used to investigate three Indonesian throughflow (ITF) branches: the flow through the Makassar Strait; through the South China Sea; and through the eastern Indonesian basins. The results reveal strong interannual variation in the Makassar Strait and the eastern Indonesian basins throughflow. Inspection of vertically integrated dynamic height (0–1000 db), a proxy of transport function, suggests that this interannual variation can be traced to the New Guinea Coastal Current, indicative of a strong influence of the South Pacific. The vertically integrated dynamic height along the south Java coast is related to variation in the North Pacific and in particular near the east coast of Mindanao Island, whereas the vertically integrated dynamic height along the coast of West Australia is related to variation in the South Pacific, and in particular near the coast of New Guinea. The integrated dynamic height difference between the Java and New Guinea coast appears to be a good proxy of ITF transport on the interannual time scale. Regression analysis shows a phase dependence of the three ITF pathways on the Nino3.4 index. Decoupling of current anomalies between the surface and subsurface layers is identified in the developing and mature phase of El Nino, reflecting different effects of local and remote forcing through oceanic pathways at the Makassar Strait and eastern Indonesian basins.



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## 1. Introduction

The Indonesian throughflow (ITF) is the only connection between two oceanic basins in the tropical region. The ITF features with high variability ranging from seasonal to interannual time scales. The annual and semi-annual variations are dynamically related to the monsoon forcing (Wyrtki, 1961; Meyers et al., 1995; Gordon et al., 2003). Originating from the Pacific, the ITF inherits a strong interannual variability associated with the El Nino and Southern Oscillation (ENSO) and is influenced by Kelvin waves generated in the Indian Ocean equatorial wave guide (Meyers, 1996; Wijffels and Meyers, 2004). In principal, the ITF is driven by the large scale wind in the Pacific (Godfrey and Golding, 1981; Godfrey, 1989) with the flow through the primary inflow pathway, Makassar Strait, being thermocline intensified (Gordon, 1986). As part of the global conveyor belt, the ITF is believed to play a role in the world's climate variability (Broecker, 1991; Godfrey, 1996; Murtugudde et al., 1998).

Direct measurement of the ITF has been difficult due to the complicated topography of the Indonesian Seas. Most of the existing ITF transport estimates were based on geostrophic calculation and/or heat, salinity, or tracer budget analysis, which have led to a wide range of estimates from nearly zero to >20 Sv (Sv = $10^6$ m$^3$/s) (see the review paper by Godfrey, 1996). As more direct measurements and repeated XBT samplings became available in the 1980s and 1990s (Murray and Arief, 1988; Fieux et al., 1994; Meyers et al., 1995; Gordon et al., 1999; Kashino et al., 1999; Luick and Cresswell, 2001), the mean ITF volume transport was set to be 10–12 Sv. The recent INSTANT project deployed multi-current meters in the Indonesian Seas, and the 3-year continuous observations suggested a mean ITF transport of ~15 Sv (Gordon et al., this issue; Van Aken et al., 2009; Sprintall et al., 2009).

Through Makassar Strait (Fig. 1) the thermocline and intermediate water of the North Pacific origin can be conveyed into the tropical Indian Ocean (Gordon and Fine, 1996; Gordon et al., 1999). Considerable recent effort has been made to investigate the pathway through the South China Sea (SCS). Among others, Qu et al. (2005, 2006) studied this throughflow using numerical models (see also Lebedev and Yaremchuk, 2000; Fang et al., 2005; Wang et al., 2006; Liu et al., 2006, 2010; Yu et al., 2007; Tozuka et al., 2007, 2009). They suggest that the flow through the SCS, involving the inflow of cold and salty

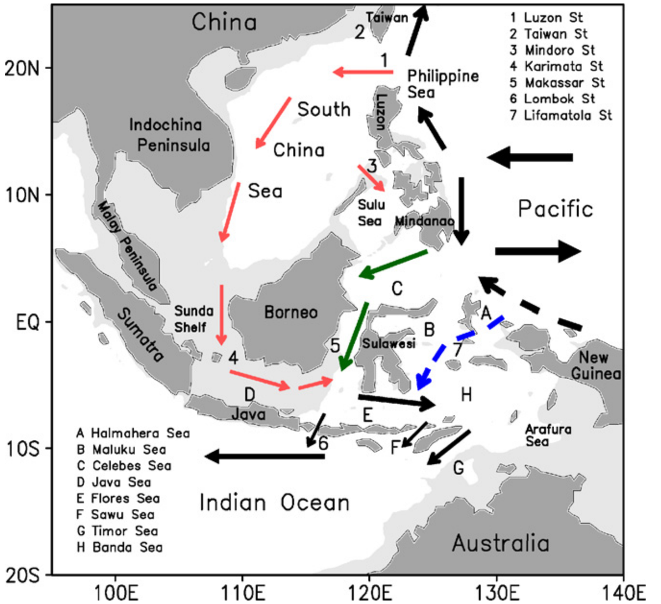


**Fig. 1.** Schematic diagram of the current system in the Indonesian throughflow region. Three inflow pathways of the Indonesian throughflow (ITF) are highlighted in different colors. Light shading indicates water shallower than 100 m. Topography is from ETOPO5 (http://www.microimages.com/downloads/etopo5.htm) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.).