Wind-Driven Cross-Equatorial Flow in the Indian Ocean

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INTRODUCTION

The influence of monsoons periods (summer and winter) in the Indian Ocean is a remarkable case of great seasonal variability. Besides transition lapses, both represent very different wind and ocean circulation conditions (Fig. 1). The winter monsoons occur during the months of December to March. In this interval, Northern trade winds cover the northern Indian Ocean, generating the wind–driven southward Somali Current. On the other hand, the summer monsoons prevail from June to September, characterized by strong southwesterly winds that occupy the whole Indian Ocean and flows northward. Two transitional periods occur between both monsoons (April – May and October – November respectively).

In order to check this pattern, a steady-state model based in NCEP wind stress data (National Oceanic and Atmospheric Administration, NOAA), temperature and salinity from the World Ocean Atlas 2005 (WOA05) and Argo database was developed. Results confirm previous studies, showing a Somali Current flowing to the south during winter monsoon carrying -11.5 ± 1.3 Sv (1 Sv = $10^6 m^3 s^{-1}$) and -12.3 ± 0.3 Sv from WOA05 and Argo, respectively. In the summer monsoon the Somali Current reverses to the north transporting 16.8 ± 1.2 Sv and 19.8 ± 0.6 Sv in the WOA05 and Argo results.

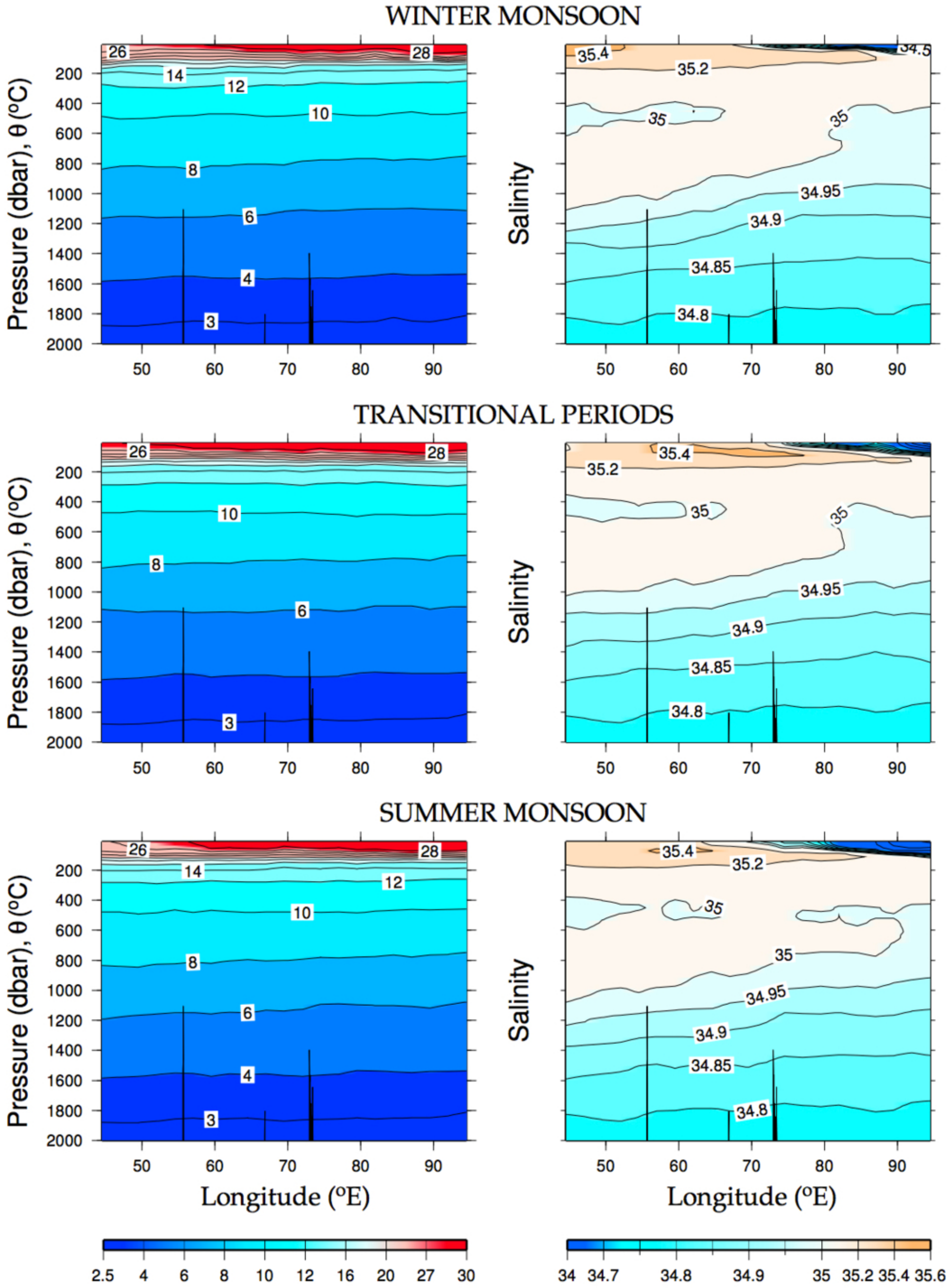

Figure 1 : *(left) Temperature and (right) salinity vertical sections in each season from the objective analyzed Argo data. © Pérez-Hernández et al, 2012*

DATA & METHOD

Wind and Argo data for a 7–year period (2003 – 2009) and climatological data from WOA05 were collected for the geographic area between 44.5° and 96°E (Fig. 2). The average of 7 years of wind velocity data (downloaded every 2.5° of latitude and longitude per month and year) avoids the strong interannual variability found in the Indian Ocean. Because of this, three different "seasons" were considered: winter monsoon, summer monsoon and transitional periods (both of them are considered together because there are not enough Argo profiles to consider them separately).

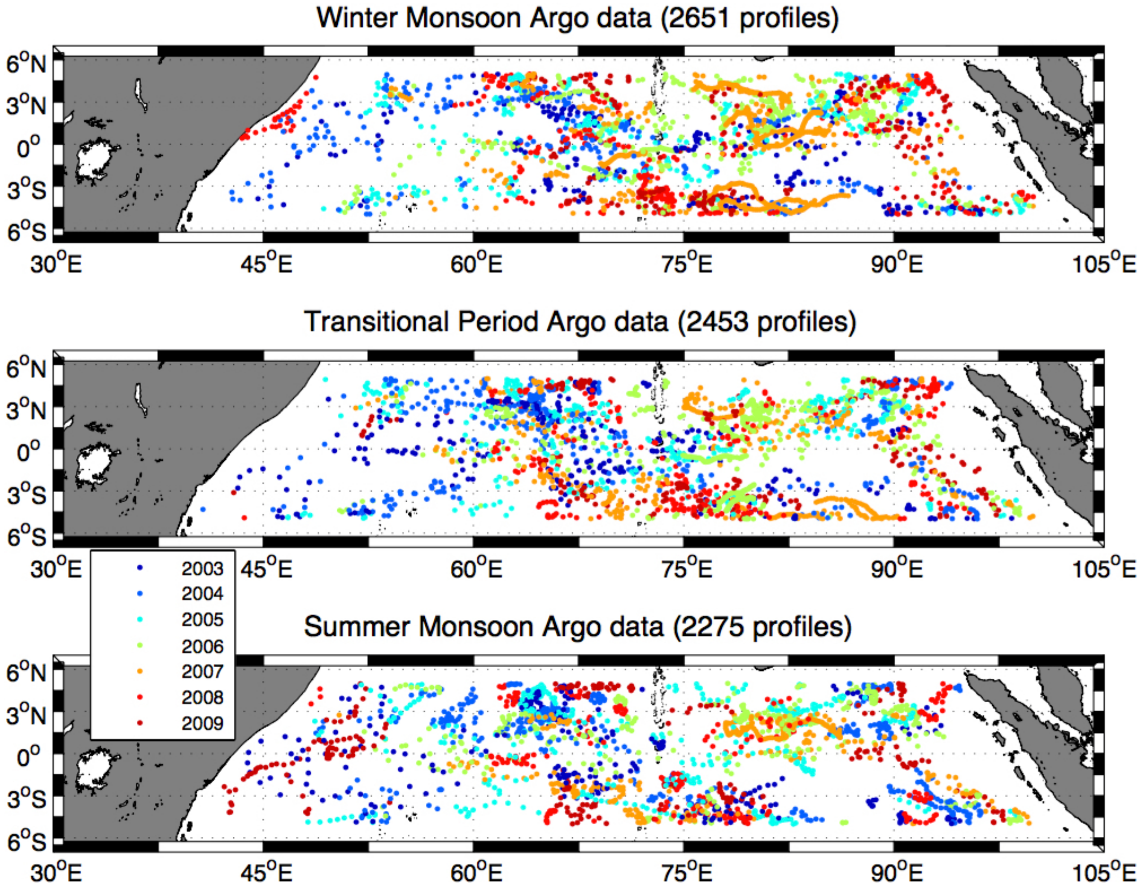

Figure 2 : *Distribution of Argo floats over the equatorial Indian Ocean in each season. Colors represent the year of each profile. © Pérez-Hernández et al, 2012*

RESULTS & PERSPECTIVES

In each season, the wind and the dynamic height present a dynamical balance. A reversal of the Somali Current between each monsoon has been found. The balanced meridional velocities in the Somali Current are higher during the summer monsoon that the winter monsoon, previously reported by Schott et al. (1990). The balanced volume transports for the Somali Current in the winter monsoon are -11.5 ± 1.3 Sv (WOA05) and -12.3 ± 0.3 Sv (Argo). The Somali Current balanced volume transport in the summer monsoon is of 16.8 ± 1.2 Sv and 19.8 ± 0.6 Sv in WOA05 and Argo, respectively. These results are close to the previously published by Schott et al. (1990), Swallow et al. (1991) and Donguy and Meyers (1995).

In both datasets a reversal of the surface flow between monsoons is observable. In the transitional periods positive volume transports are found in the upper ~800 dbar and negative volume transports below them (Fig. 3). When the monsoons are added to the integrated volume transport calculations, WOA05 presents two overturning cells, one shallow at 260 bar (1.2 ± 1.6 Sv), and one deep 1020 bar (-1.7 ± 0.9 Sv) while Argo only show one at 800 bar (3.7 ± 0.9 Sv). Our results agree with the Meridional Overturning Circulation (MOC) transports of 3.5 Sv obtained by Fu (1986) and 8.8 ± 4 Sv by Sultan et al. (2007) from inverse models carried out in the southern Indian Ocean.

The ocean interior annual heat transports (obtained as the mean of the three seasons) are -0.26 ± 0.13 PW (WOA05) and -0.11 ± 0.06 PW (Argo) to the south.

The meridional component of the wind stress has been neglected in Godfrey et al. (2001) and Godfrey et al. (2007), while the transport associated with the component τ_x^y is about half of the transport associated with τy^x for the ocean interior compared with our analysis. Compared with previous studies, our Somali Current and ocean interior heat fluxes have the same direction but a higher heat transport in each season, resulting in a stronger seasonal variation. However, the annual heat transport from both models presents similar heat transport for the Somali Current and for the ocean interior.

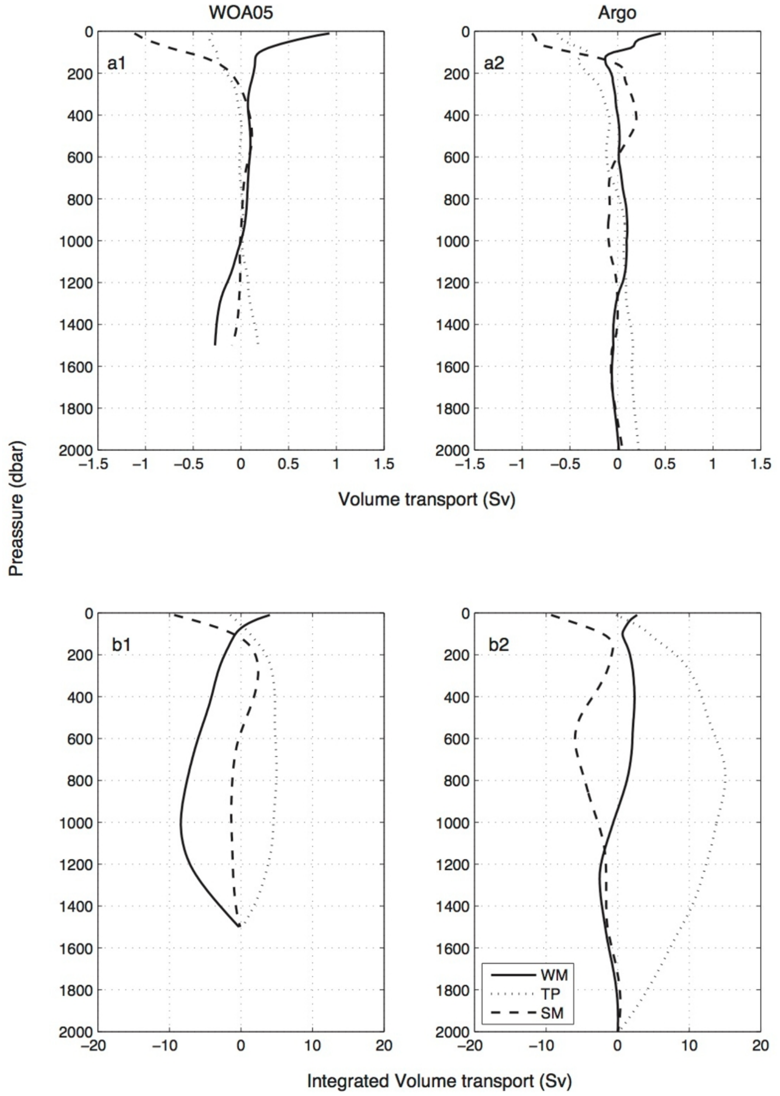

Figure 3: *Vertical structure of the volume transport for the ocean interior for (a1) WOA05 and (a2) Argo at each season, and the integrated, from the bottom, volume transport for (b1) WOA05 and (b2) Argo at each season. © Pérez-Hernández et al, 2012*

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