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Heat Transport through Indonesian throughflow

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ABSTRACT

Approximately 10.5 Sv (1 Sv=$10^6 m^3/s$) of water flows from Pacific Ocean into the Indian Ocean through the Indonesian archipelago region, which is composed of three major passages, Lombok (115° 50 E, 8° 30^{c} S), Savu (122°E, 9° 30^{c} S) and Timor (128°E, 11°S).The Indonesian seas provide a pathway for substantial transfer of Pacific Ocean waters to the Indian Ocean (Rochford, 1961; Wyrtki, 1961; Gordon, 1986; Wyrtki, 1987). The Indonesian Throughflow (ITF) heat transport is estimated on the basis of volume transport and surface temperature obtained from model output of one-year run of Princeton Ocean Model (POM) of 0.25X0.25 degree resolution. On the basis of model study the obtained heat transport is of the order of 1.087 PW (1 PW=10^{15}W), which shows dominant warm water transport.

INTRODUCTION

The ITF is the system of surface currents flowing from Pacific to Indian Ocean (IO) through the Indonesian Sea, it joins the South Equatorial Current (SEC) in the Indian Ocean between South of Java and Australia, Indonesian archepilago is composed of three major passages, Lombok (115° 50^{c} E, 8° 30^{c} S), Savu (122°E, 9° 30^{c} S) and Timor (128°E, 11°S) (Fig.1). It is one of the primary links of the global exchange of water and heat between ocean basins and is an essential element of global climate system (Gordon 1986; Toole 1987).

The ITF is considered to be central to the heat budget of the Pacific and IO. Temperature and ocean current time series obtained for this region for any duration can be utilized to calculate heat transport of ITF and consequently its influence on the Southern Indian Ocean (SIO) heat flux. There are results that support the model studies that the ITF heat, derived from the Pacific Ocean, is ultimately lost to the atmosphere in the SIO (Vranes, Gordon & Ffield 2002).

The ITF strongly influences the heat and freshwater budgets of these two oceans and therefore may be considered a key component in the El Nino and Southern Oscillation (ENSO) and monsoon climate phenomena (Webster et al., 1998). The meridional circulation stratification, sea surface temperature (SST) and sea level of the oceans would be altered if the ITF were zero (Verschell, Kindle & Brien 1995). Large scale observation based studies reveals significant Pacific export of freshwater and heat into IO. Increased oceanic heat and freshwater flux into the IO at the expense of Pacific affects atmosphere-ocean coupling with potential impacts on the ENSO and monsoon phenomena (Vranes, Gordon & Ffield 2002). Studies have shown that heat transport varies with ENSO as it is lower during El Nino and higher during La Nina (*Meyers 1996*)**.** The ITF heat transport remains a part of the Ocean dynamics to give overview of the ITF effect on the SIO.

As evidenced by the literature the heat transport of ITF and its effect on the Southern Indian Ocean is of paramount importance and therefore be studied. In the present study the main objective is to simulate the ITF heat transport and show its seasonal variation in year 1994.

In the following sections we will be providing brief description of the model configuration, properties and parameters used, different phase of model run, which will be followed by the results along with their physical interpretation.

Unlike previous observational studies the effort employs a relatively simple model run to get the output of volume transport and temperature of the region in order to calculate the average heat transport and monthly fluctuations in heat transport of ITF. This is done using three dimensional 14-layer sigma coordinate ocean circulation model POM developed by Princeton University, Princeton. Model is integrated over a period from January 1994 to December 1994 for Indonesian domain of 50°E –160°W and 40°S - 30°N, with an open Pacific and Indian Ocean (PACIO) region.

Model Configuration and Experiments

The numerical model used in this study is the 14 layer version of Princeton University (Blumberg & Mellor 1987) which is based on a three dimensional primitive equation, time dependent, sigma coordinate, free surface, estuarine and coastal ocean circulation model along with turbulence closure sub model (Mellor & Yamada 1982) that yields realistic Ekman surface and bottom layers .The model is formulated originally for estuarine and coastal studies and based on Arakawa C grid and now applied for basin scale and climate problems and is attractive for simulating processes associated with bottom topography, such as flow over sills, continental shelf flows, bottom boundary layer dynamics

Two different sets of numerical experiments are performed as follows: a) Model run with open channel without wind forcing. b) Model run with open channel and with wind forcing.

Model is initialized by Levitus 94 annual climatology of temperature and salinity. In the first experiment the model has been integrated with open channel of Indonesian throughflow for the domain 100°E-150°E and 40°S- 0°S for one year and complete flow field is generated. In the second experiment the model has been run for the same domain with same time period but forced by time-realistic time-varying wind field of da Silva SMD set for 1994. The model-produced fields were retained for every one-month interval for the analysis. Heat transport is calculated as volume transport multiplied by temperature with respect to reference temperature 4 °C, density and specific heat of the flowing water through the section.

RESULTS AND DISCUSSION

One-year time series of heat transports through Lombok, Savu and Timor Straits along with the combined heat transport through all three passages were calculated from the model run with open PACIO geometry. The maximum southward heat transport is 2.828 PW during January 1994 episode. Most of the transport values being between 0.424 PW and 1.414 PW. Transport through these three passages is highly correlated as expected.

The largest mean heat transport under open PACIO is through Savu Strait which is 1.104 PW closely followed by Timor Strait 1.086 PW. Also we observed that mean heat transport through Lombok strait is 1.072 PW. The average heat transport is almost similar for all the straits.

Heat transport values are smaller during months October to December with an average of 0.597 PW and largest during January to June 1994, with an average of 1.514 PW. Maximum heat transport occurs

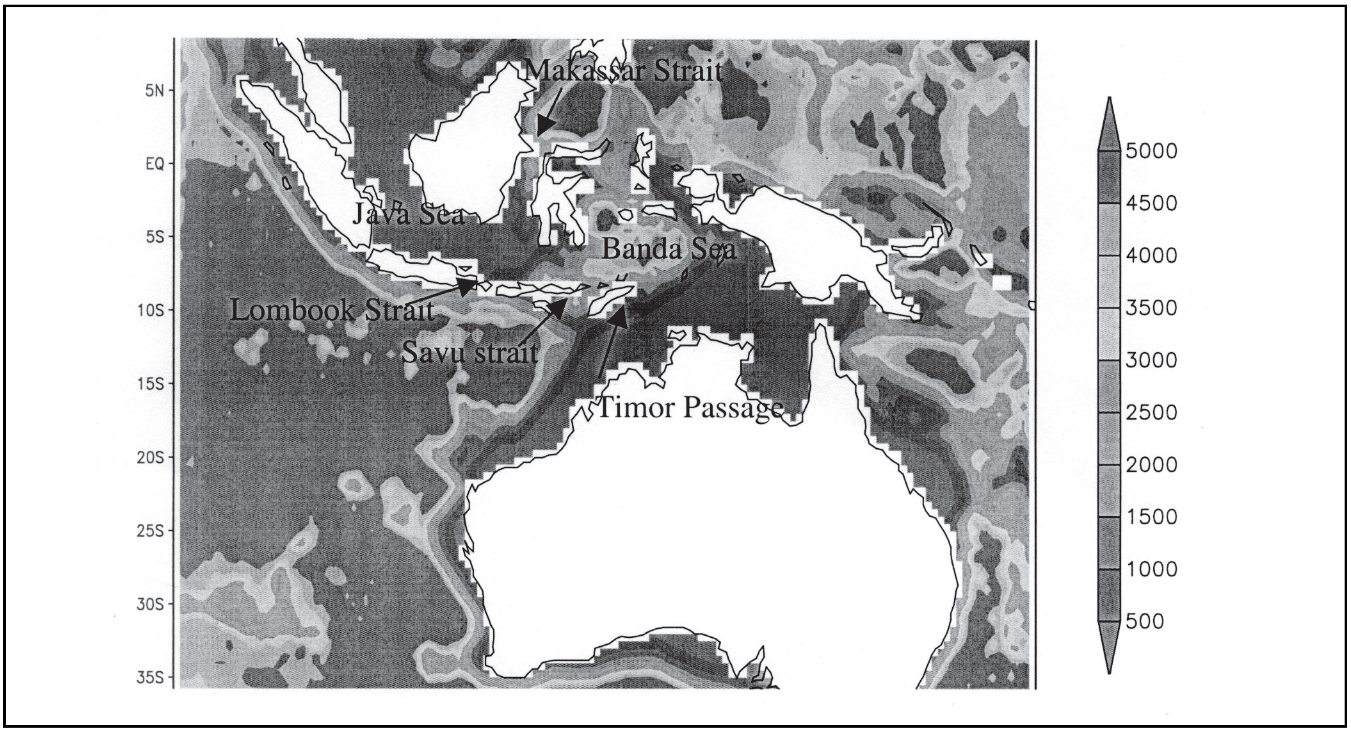

Figure 1. Lombok, Savu and Timor straits in Indonesian throughflow region

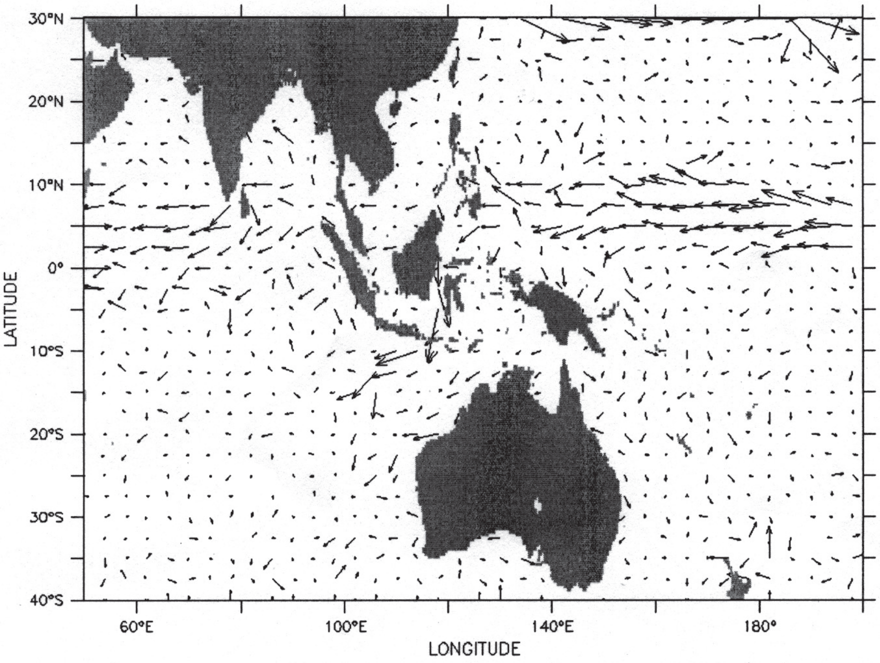

Figure 2. Sea Surface Current pattern in Indonesian throughflow region

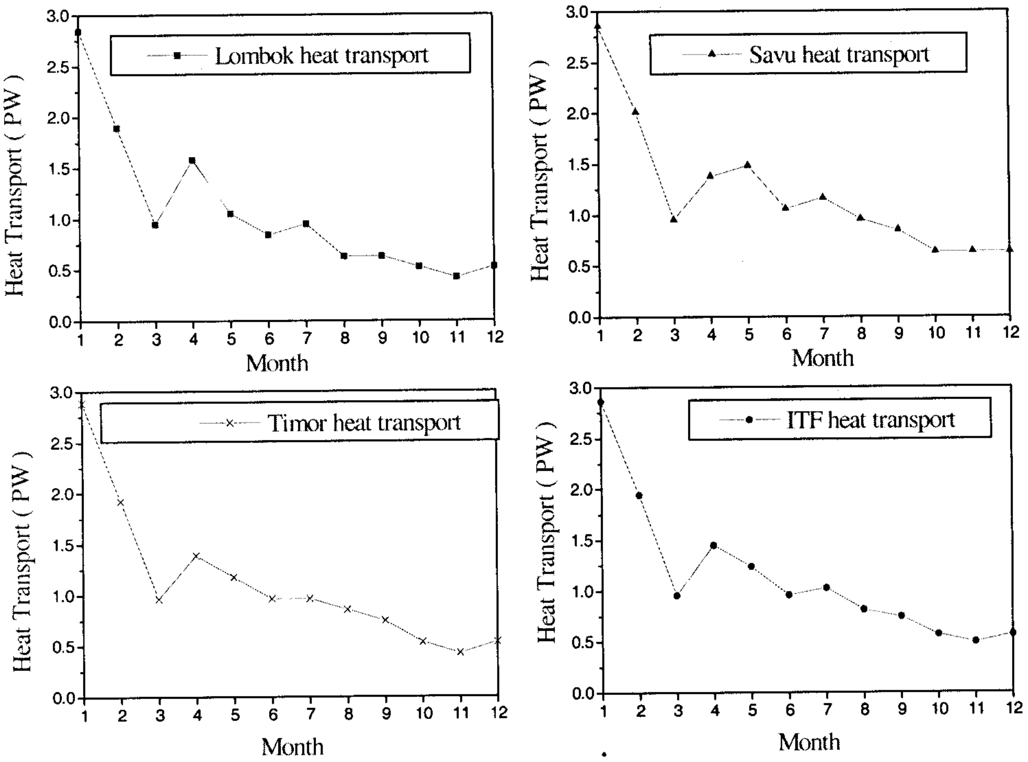

Figure 3. ITF Heat transport without wind forcing

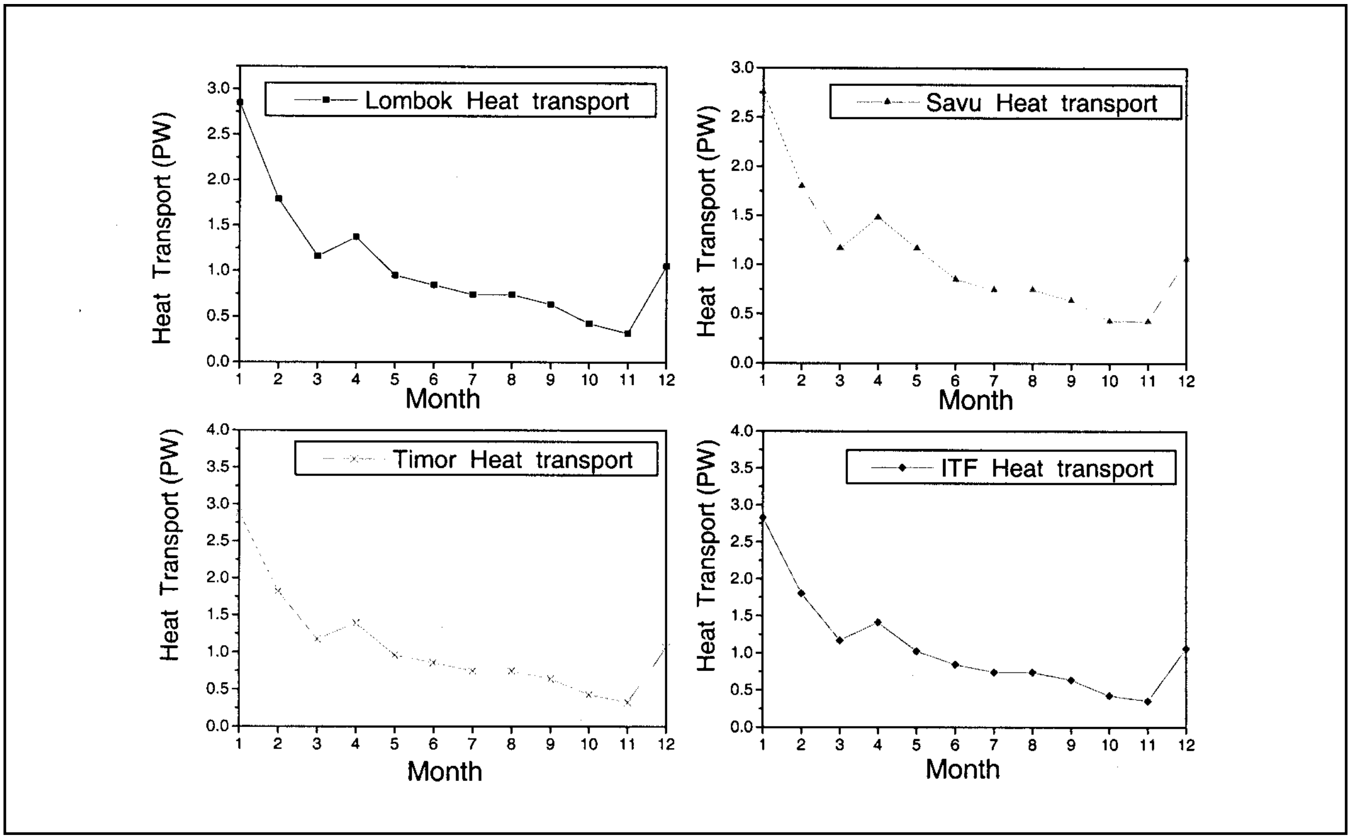

Figure 4. ITF Heat transport with wind forcing

from mid January to mid March, while the minimum heat transport is between October to November. The average heat transport in the Indian and Pacific Ocean basin between 50°E-160°W and 40°S –30 °N were calculated for open PACIO cases with and without wind forcing is 1.087 PW and 1.134 PWrespectively.

The topography and straits of the ITF region are shown in fig.1 and the sea surface currents are shown in Fig.2 . The seasonal variation in the heat transport in both the cases viz, without forcing and with forcing are shown in the figures 3 and 4.

In Fig. 3 it is seen that the heat transport value without wind forcing, is decreasing from first month to third month in all the three channel and then there is slight increment in fourth month followed by slight decrease up to last month. The heat transport of ITF is constructed from average value of these three channels. Heat transport value in first month shows abnormal transport followed by constant decrease.

From Fig. 4 it follows that with the wind forcing the heat transport decreases from first month to second month in all the three channels and then increases slightly in fourth month. The heat transport of ITF evaluated as previously for the first month also shows abnormal transport followed by some fluctuations in the last month. The seasonal variation in heat transport is an indication of change in heat-flux in the region that has direct impact on the climate of Indian and Pacific Ocean.

Comparing the results of both the experiments it is evident that the heat transport decreases with wind forcing, the average value being 1.134 PW and 1.087 PW respectively for without and with wind forcing.

SUMMARY AND CONCLUSIONS

POM has been used to investigate the regional effect of variation in the magnitude of the ITF on the IO upper layer heat content and SST. Consequent changes in SST (*Pandey et al. 2004*) associated with changes in the ITF transport shifts the position of deep atmosphere convection region of the western tropical Pacific and, due to changes of SST in the IO, the net evaporation within the Indian ocean is affected, which in turn governs the onset of monsoon.

The model results are showing abnormal behaviour due to Indian Ocean Dipole in this year. Model results are also being analysed for other comparisons and correlations, if any, for ENSO event and changes in net heat transport over a period of time. This will certainly reveal the tele-connection between heat transport and monsoon activity in the region.

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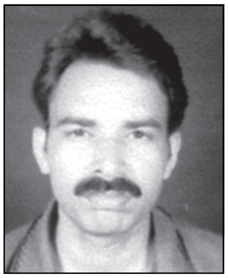

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