Seven Years of measuring the Makassar Strait throughflow, the primary component of the Indonesian Throughflow

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Abstract: Directly after the recovery of the NSF funded INSTANT western Makassar mooring in November 2006, a NOAA funded mooring was deployed at the same site (2°51' S; 118°28' E) on 22 November 2006. The NOAA-MAK was recovered on 31 May 2009 and re-deployed for another 2 years to continue to build the time series. We now have a 5.5-year continuous time series of the Makassar Throughflow, which represents ~80% of the total Indonesian Throughflow (ITF). The NOAA-MAK time series from late November 2006 to the end of May 2009 spans a predominately La Niña period, reaching a peak in strength in early 2008; a weak El Niño was present in the latter half of 2006. The Indian Ocean Dipole index (DMI) switched into a positive mode during 2006, remaining so throughout the NOAA-ITF time series. Three consecutive years with a positive IOD phase has not been detected in the historical SST records. The +DMI is likely related to the change in the along channel speed profile observed in 2006 and continued in the full record of the NOAA-MAK mooring: the thermocline flow was intensified and shallower, with a maximum speed near 75 m, rather than at 140 m as recorded during the INSTANT period.

1. Introduction:

The Indonesian Throughflow (ITF) transfers seawater, heat and freshwater from the western Pacific into the tropical Indian Ocean, at a rate of ~11 to 15 million m^3/sec [1] (see figure 2 of ref [2]). The strong monsoonal winds and tides amidst the complex sea floor morphology of the archipelago stretching from SE Asia to Australia, alter the temperature and salinity profiles of the ITF, which in combination with the velocity profile, link via an ocean route the Pacific and Indian Ocean climate systems. As the ITF region is at the nexus of ENSO (El Niño/La Niña) and the Asian monsoon phenomena, it is highly likely, as indicated by model studies, that the ITF serves as a key component of the larger scale climate system. Recording the ITF, and its connection to fluctuations in ENSO and the Asian monsoon, is an effective and cost effect way to monitor a component of the larger scale ocean and climate system, with the intent to enable a climate predictive capability.

As the ITF weaves through many passages of the Indonesian seas, from the Pacific inflow channels to the export channels to the Indian Ocean, a sustained observational array of mooring for measuring all of the pathways is not yet financially practical. However, a significant step towards this goal can be met by monitoring the throughflow with Makassar Strait, which carries ~80% (and >90% of the thermocline layer component) of the ITF [3]. This is presently underway with the NOAA/OCO funded current measuring mooring near 3°S in the Labani Channel constriction of Makassar Strait (Figure 1).

The observed transport in the Makassar Strait, from January 2004 through November 2006 is ~11.6 x10^6 m^3/sec, 27% larger than observed during 1997 when a strong El Niño suppressed the flow. As the ITF transport varies with ENSO, and likely other climate indices (e.g. Indian Ocean Dipole) a multi-year record is needed to fully appreciate its characteristics and links to the regional and larger scale climate system. Directly after the recovery of the NSF funded INSTANT western Makassar mooring in November 2006, a NOAA funded mooring was deployed at the same site (2°51' S; 118°28' E; 2147 m) on 22 November 2006. The NOAA-Mak was recovered on 31 May 2009, and re-deployed for another 2 years to continue to build the time series. We now have a 5.5-year continuous time series of Makassar throughflow (Figure 2); with the Arlindo data we have a full 7 years of Makassar throughflow recorded.

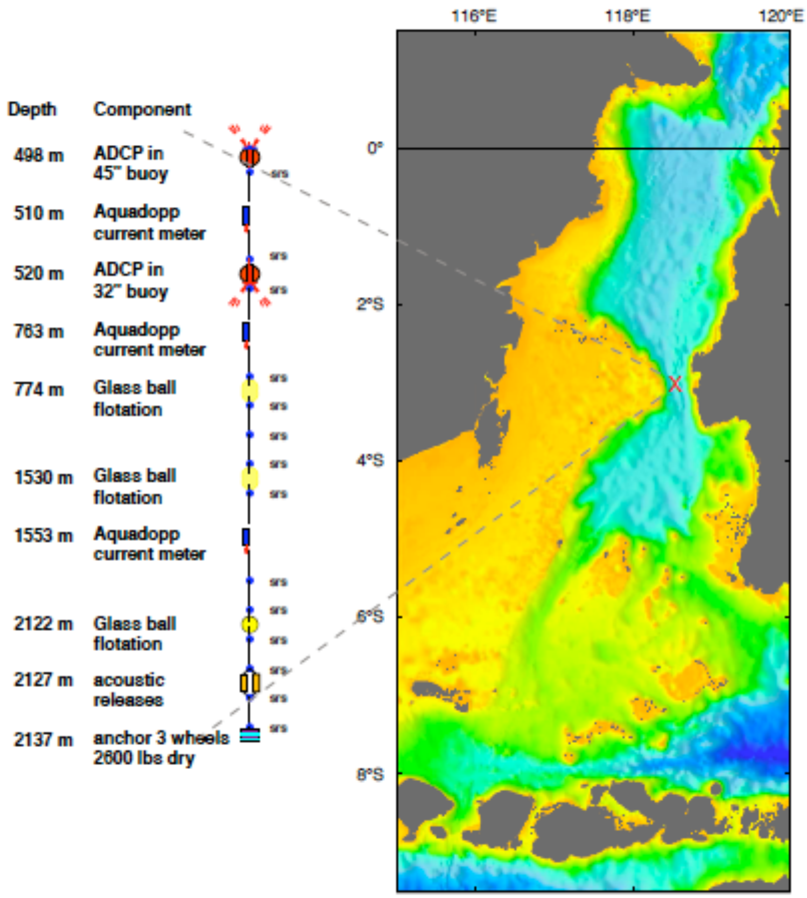
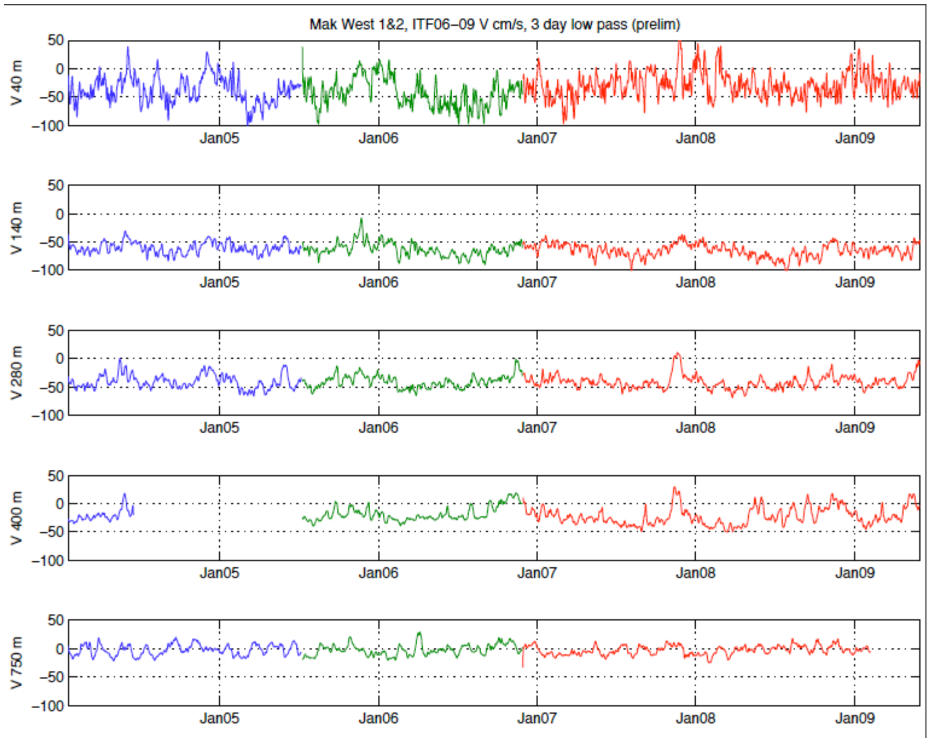


Figure 1 Configuration of the NOAA-ITF Makassar mooring deployed in November 2006 at the Red X (2°51'S; 118°28'E) in the bathymetry map of Makassar Strait.

During the INSTANT periods ENSO was in a weak El Niño state, with a brief La Niña phase occurring in early 2006. The NOAA mooring period from late November 2006 to the end of May 2009 spans a predominately La Niña period, reaching a peak in strength in early 2008; a weak El Niño was present in the latter half of 2006. The ITF is reduced during El Niño, elevated during La Niña phases, but this signal is rather weak in comparison to intraseasonal and seasonal events. The exception was during the Arlindo period when the ITF was substantially reduced during the strong El Niño event of 1997.

The December 2006 through May 2009 record displays many of the same attributes as earlier time series: 1. General southward surface layer flow interrupted by reversals in the December-March period corresponding to strong monsoonal eastward winds in the Java Sea; 2. The 2004-2009 record reveals a seasonal signal with maximum flow in August, with minimum flow in November. But there were also some unique events recorded: a particularly weak southward flow of November 2007 may be a consequence of a strong Kelvin Wave derived from the Indian Ocean; the persistent core of maximum southward flow within the thermocline, which began to shoal from 140 m to 75 m during the last 6 months of the INSTANT time series, continued throughout the NOAA-MAK period.



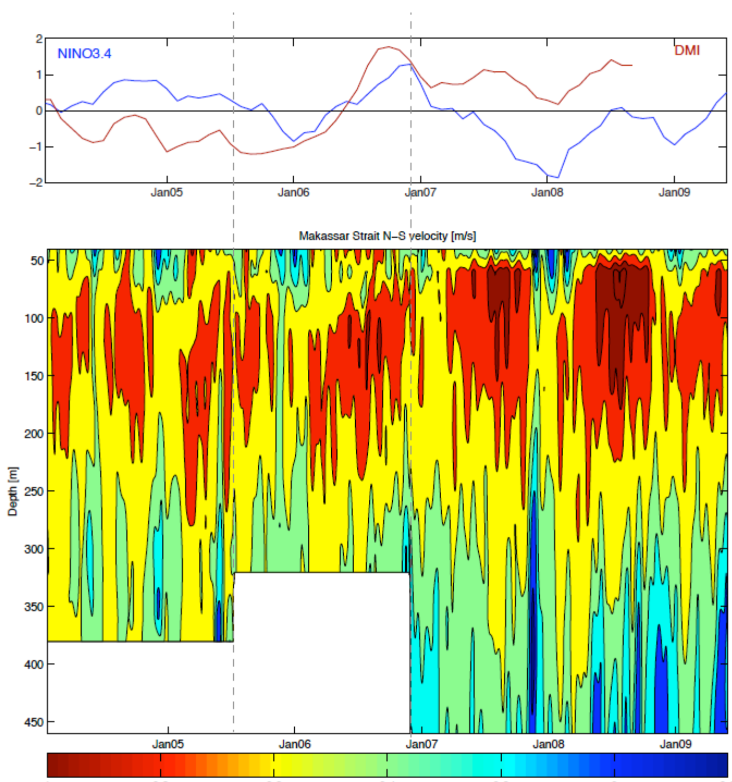


Figure 2 (top) A 5.5 year time series of the along channel flow at various depths from the INSTANT mooring [MAK-W; blue first deployment; green second deployment] 2°51' S; 118°28' E; 2147 m] and the NOAA-ITF mooring [red] at the same site. (middle) Nino3.4 and Indian Ocean Dipole Mode Index for the mooring deployment period. (lower) Time-depth contour plot of 30-day low passed N-S velocity in Makassar Strait, combining the upward-looking ADCP data from the INSTANT and 06-09 time series. The INSTANT MAK-W mooring was deployed on 18 January 2004, recovered and redeployed in July 2005, with the final recovery on 27 November 2006, at which time the NOAA-ITF mooring was deployed. It was recovered on 31May 2009, and redeployed, with planned rotation in two years.

The shoaling of the v-max feature to the upper thermocline is a significant and rather unexpected event. The Indian Ocean Dipole index (DMI) switched into a positive mode during 2006, remaining so throughout the NOAA-ITF time series. Three consecutive years with a positive IOD phase has not been detected in the historical SST records. The +DMI is likely related to the change in the along channel speed profile observed in 2006 and continued in the full record of the NOAA-MAK mooring, noted above. While the Makassar transport may have increased somewhat during 2007-2009, a more important factor may be the shallower depth of the thermocline maximum current, in that it marks a sustained increase in the heat transfer from the Pacific to the Indian Ocean via the ITF. The role of this change in the ITF profile to the coupled ocean-atmosphere climate system is now being considered.

The NOAA ITF mooring was redeployed on 1 June 2009, with a planned recovery in mid-2011.

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