INSIGHTS FROM THIRTY YEARS OF XBT OBSERVATIONS ACROSS THE INDONESIAN THROUGHFLOW

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Repeat XBT lines through the Indonesian Seas

- established by Stuart Godfrey and Gary Meyers, CSIRO
- contribution to the TOGA-WOCE XBT network
- all measurements are taken by merchant mariners on ships of opportunity – 4 hours/80nmi distance
- initially operated by CSIRO, but transferred to the Australian Bureau of Meteorology in the early 1990s.
- Contributions from RAN, SIO and NOAA.
- Largely operated continuously since 1983 though with some gaps
- IX1 is frequently repeated – roughly bi-weekly; others are monthly
The first 5 years: the mean and seasonal cycle

- Regional circulation documented
- 5 year average of the ITF 0/400dbar: 5.2Sv plus 2.1Sv (deep) ~ 7.3Sv

Meyers, Bailey and Worby, 1995
Two timescales revealed: ENSO in the south, something at higher frequencies in the northern part of the section.
Two dominant modes of variability

- Joint EOFs of SST, D20C, Dyn.Hgt.

The El Nino-Southern Oscillation Mode
The second mode? Northern Intensified
Impacts on transport?

Variance in total transport accounted for is quite low.
Clarke and Liu (1994) had already surmised wind-driven planetary waves were at work.
What does the wind-forcing look like?
Responses to remote wind changes? Eq Pacific

Response is largest off Australia, with lags of 0-2 months – agreed with linear coastally trapped and Rossby wave speeds.

Wijffels and Meyers, 2008
Responses to remote wind changes? Eq Indian

Response is largest off Java with zero lag – agreed with faster Kelvin wave speeds and short pathway.
Intersection of two waveguides
20 years of data – revisit the mean flow structure

- Complex flow in the S. Indian Ocean – multiple jets in the EGC
- Vertical structure of Ombai and Timor ITFs very different (as seen in short moored records, later confirmed by INSTANT)
- Two jets entering Timor Passage

Wijffels and Meyers, 2008
Regional flows: 0/750m transports (+Ekman)
Heat balance?

- IX1 XBT line + Makassar moorings => ITF warms by 2-3°C as it transits the region

Control volume used and NOC Air-Sea fluxes

Enhanced tidal mixing enhancing ocean heat uptake
Can the ENSO vs IOD transport responses be better identified and understood?
ENSO/IOD responses: wind correlations

8 El Ninos + 6 La Ninas

IOD impacts ITF transports with no lag, particularly if ENSO signal is removed. Agrees with the wave analysis

ENSO mostly impacts ITF transports ~6-8 months after peak of the event. Does not agree with the wave analysis!
Differing response from north to south

Composite 0/400m transport responses:
~ 1-3 Sv variations (our of a mean of ~5Sv)
~7-8 month lag (longer than wave response)

IOD winds opposing ENSO response
A series of long-lasting La Nina events without strong and intervening El Nino events has led to the increased ITF heat transport in the 2000s.

Transport trend = 1Sv/10 years
Caveats - impact of poorly resolved salinity fronts

(a) ITF: 2005–2013

(b) T–S relationship: CARS 2009

(c) 2005–2009: Diff between Argo and (b)

(d) 2010–2013: Diff between Argo and (b)
ITF role in Indo-Pacific decadal variability?

- Indian and Pacific Oceans are tightly linked due through modulations of the Walker Circulation
- Lee et al (2015) and others show that increased ITF heat transport associated with IPO shift brings a rapid Indian Ocean warming and global SST hiatus
- Associated freshwater/salinity changes are also large.

Du et al, 2015
Shedding light on tides and mixing

Ffield and Robertson, 2004
Internal wave tidal beams

Katsumata and Wijffels, 2006
Repeating internal tidal expression in sea level

M2 Mode 1: Coherent Internal Tide Amplitude (cm)

Zhou, 2018
The WOCE-TOGA XBT lines represent one of the longest records of ITF variability available.

As the record builds, we gain critical new insights into Indo-Pacific and regional dynamics.

Ongoing support and encouragement to continue these observations is needed.

Enhanced salinity observations near the boundaries would decrease errors.

Combined with a long-term moored campaign upstream, these lines comprise a strong ongoing ITF monitoring system.
Thanks to the many collaborators on this work including Stuart Godfrey, Gary Meyers, Ming Feng and others

Huge thanks to the CSIRO and Australian Bureau of Meteorology who work hard every year to fund and operate these lines, and make this data freely available

Thanks to the international XBT Science Team who aim to support and enhance these observations