Status and Plans for Research Related to Indonesian Throughflow

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Some inputs from

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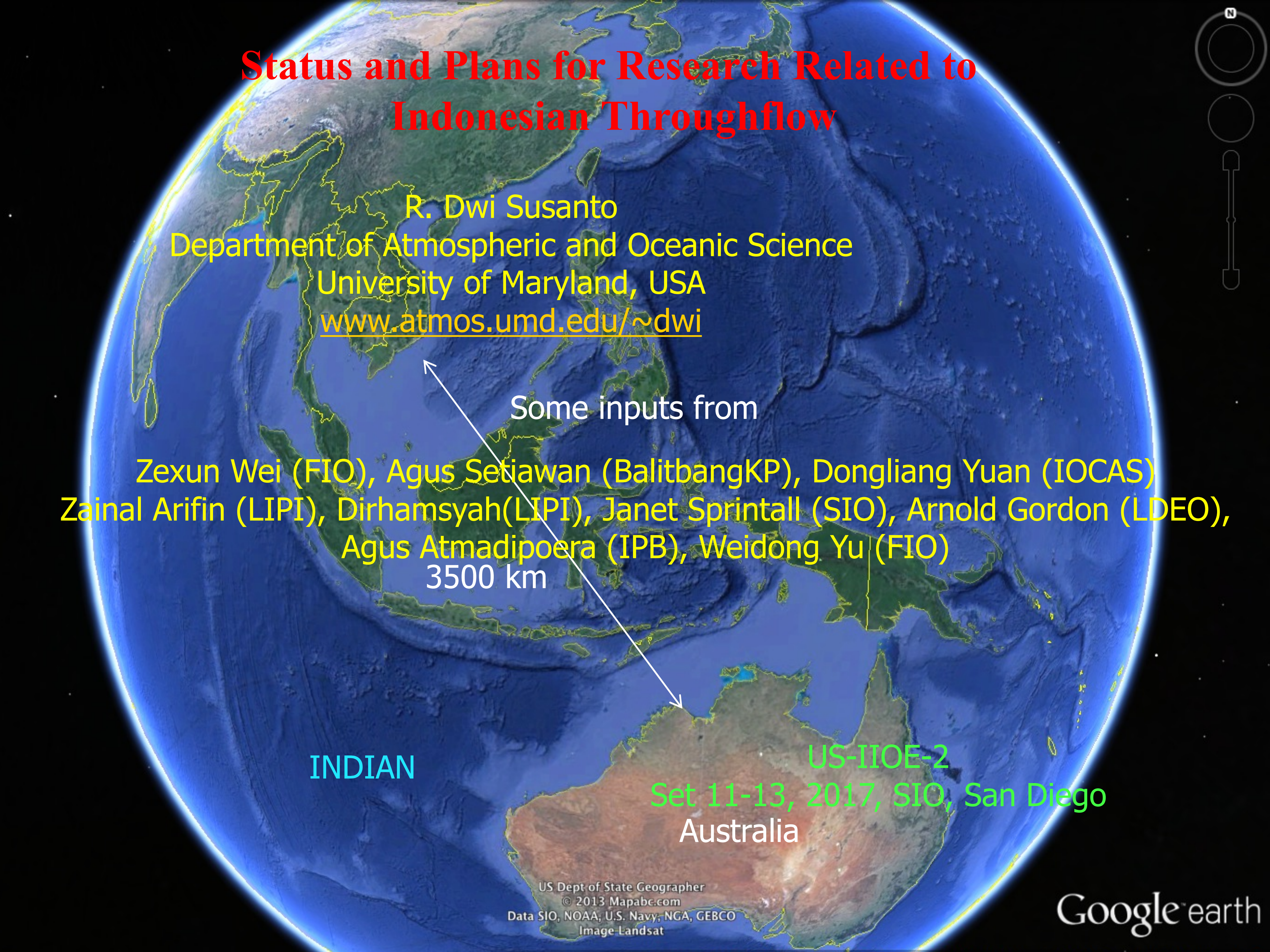
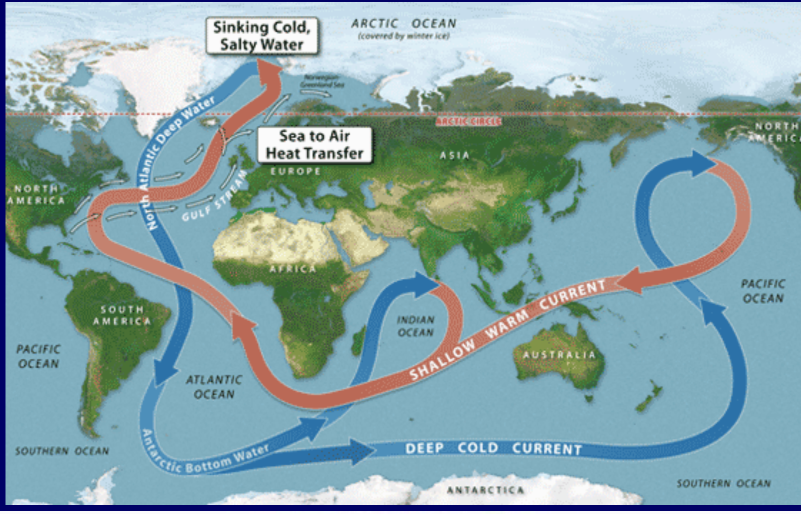
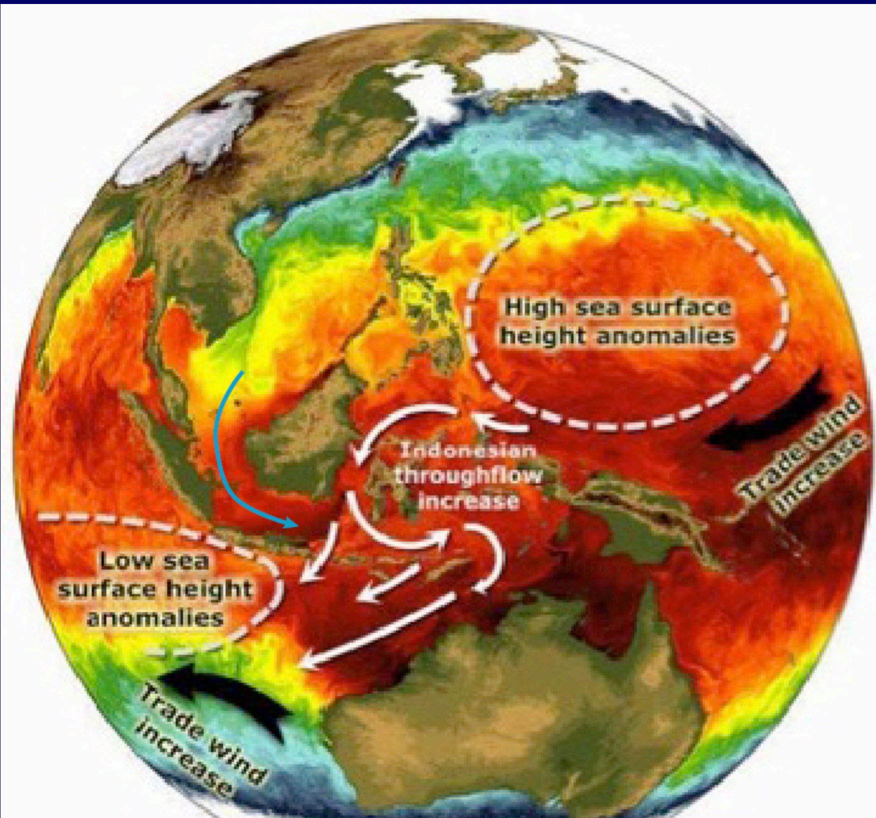
Zainal Arifin (LIPI), Dirhamsyah(LIPI), Janet Sprintall (SIO), Arnold Gordon (LDEO),
Agus Atmadipoera (IPB), Weidong Yu (FIO)



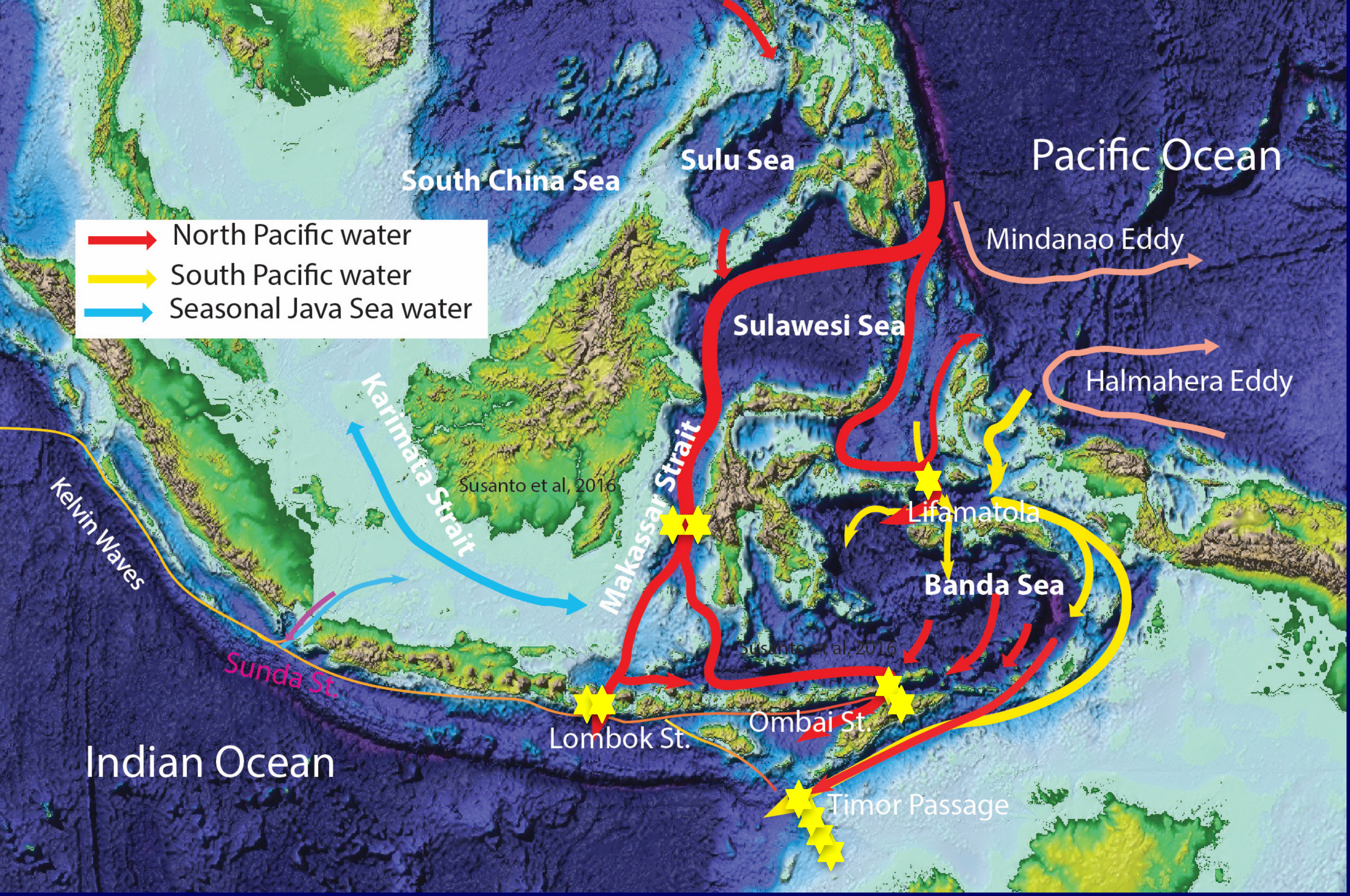
US-IIOE-2
Set 11-13, 2017, SIO, San Diego





Modified (Reid, EOS May 21,2015 Lee et al., 2015)

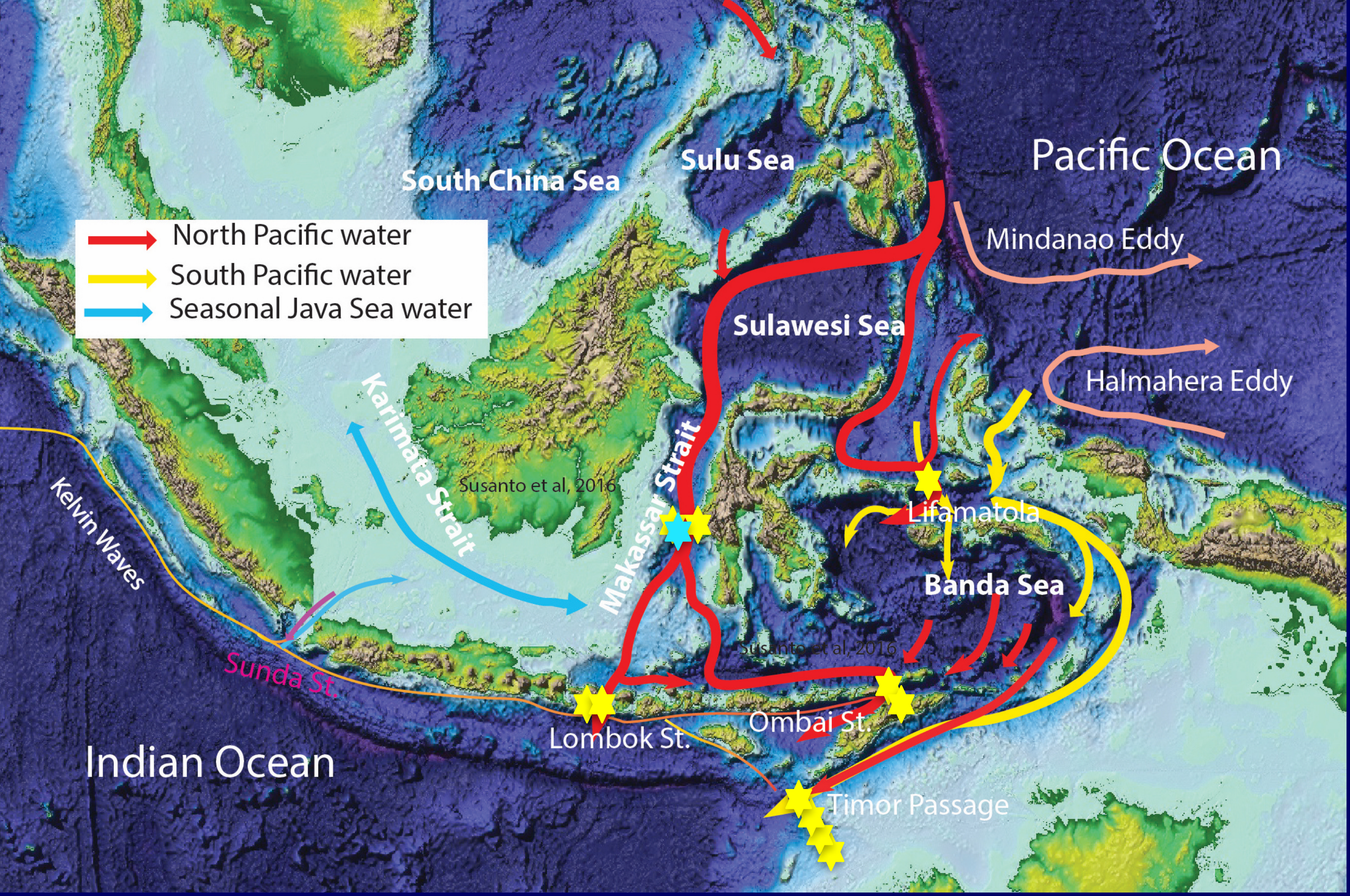
- ✓ITF strongly influences the heat and freshwater budgets of Indian and Pacific Oceans, and may couple with ENSO and monsoon phenomena, altering global ocean circulation and climate.
- ✓ Change in ITF magnitude is expected to alter the SST, and therefore altering the ocean-atmosphere fluxes.
- ✓~15 Sv of ITF water flushes the Indian Ocean thermocline waters, boosting transport of the Agulhas Current [by ~15%], increasing southward ocean heat flux across 20-30° S over the no-ITF condition, thus altering the meridional overturning of the Indian Ocean
- ✓ To get the ITF amplitude and variability right are challenge for numerical models.



INSTANT
2003-2006

Susanto et al., 2016

A. Gordon & R.D. Susanto (LDEO), A. Ffield (ESR)
J. Sprintall (Scripps)
S. Wijffels (CSIRO)
H. Van Aken (Royal Netherlands Institute for Sea Research)
R. Molcard (LODYC)



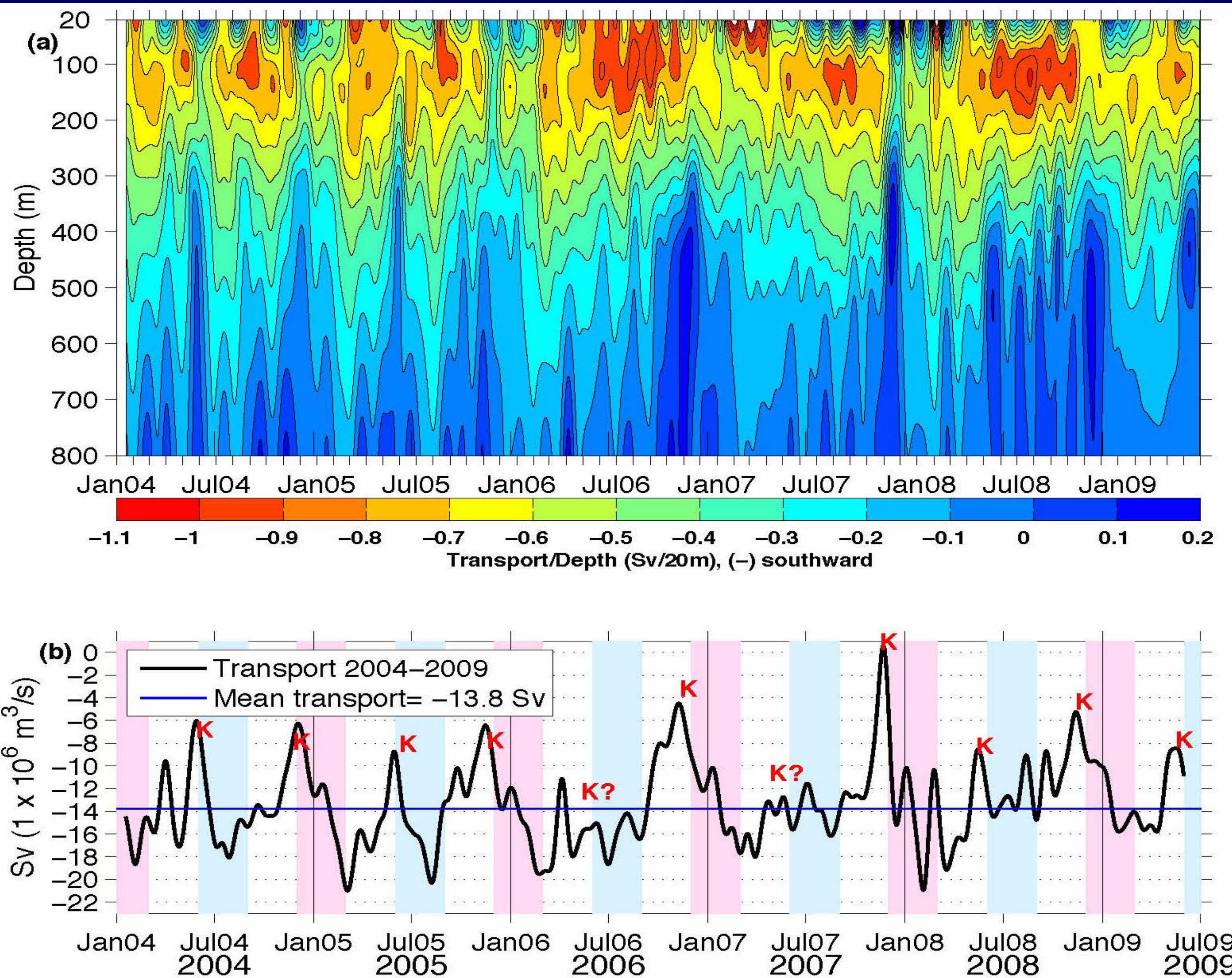
INSTANT
2003-2006

MITF
2004-2011
2013-2017

Susanto et al., 2016

ITF Transport in the Makassar Strait

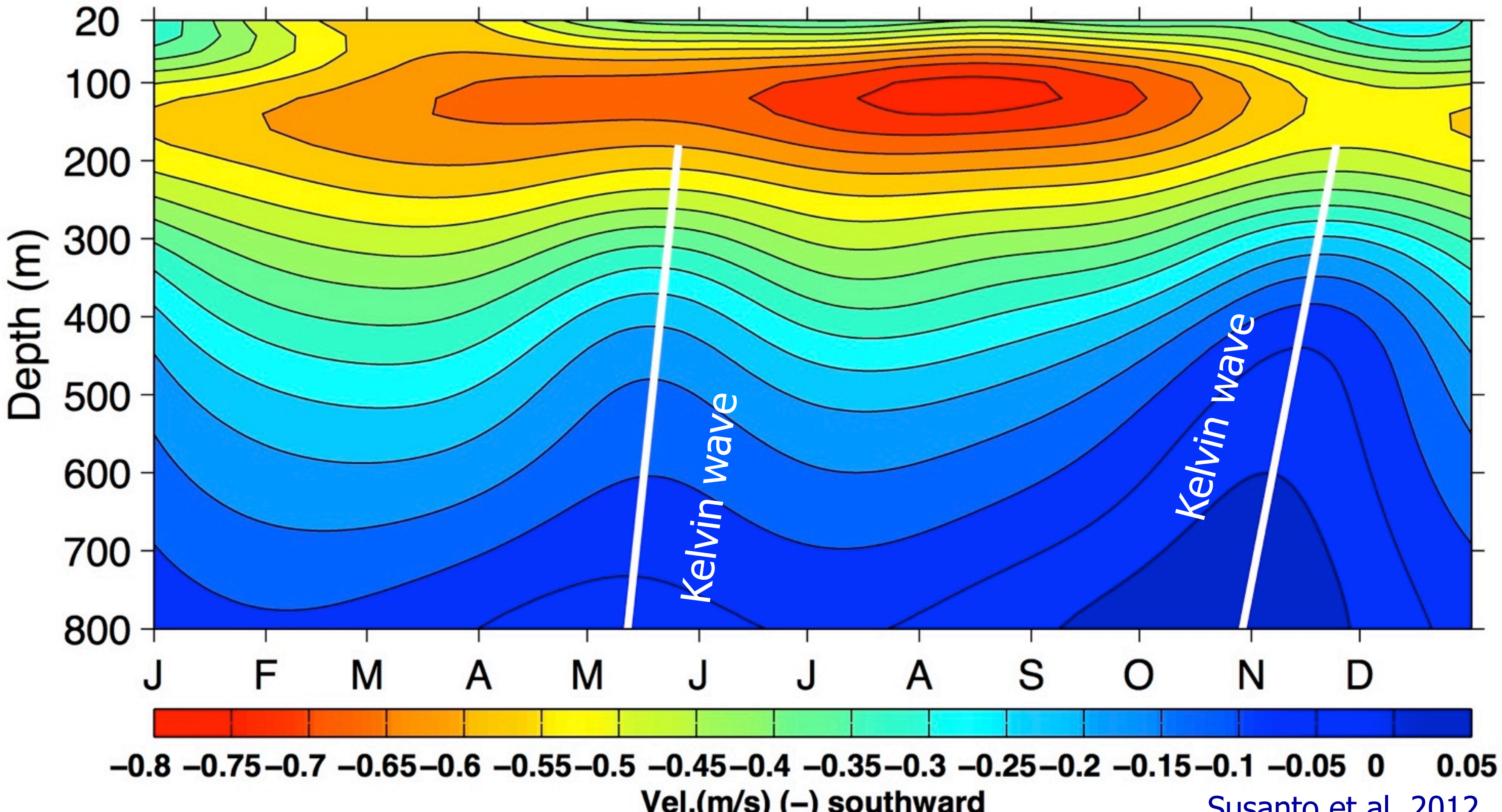
- Average volume transport: 13.3 Sv
- Thermocline intensified
- Instraseasonal-seasonal-interannual



Max: 120-150m

Susanto et al, 2012

Seasonal variability and intrusion of Kelvin waves from Indian Ocean



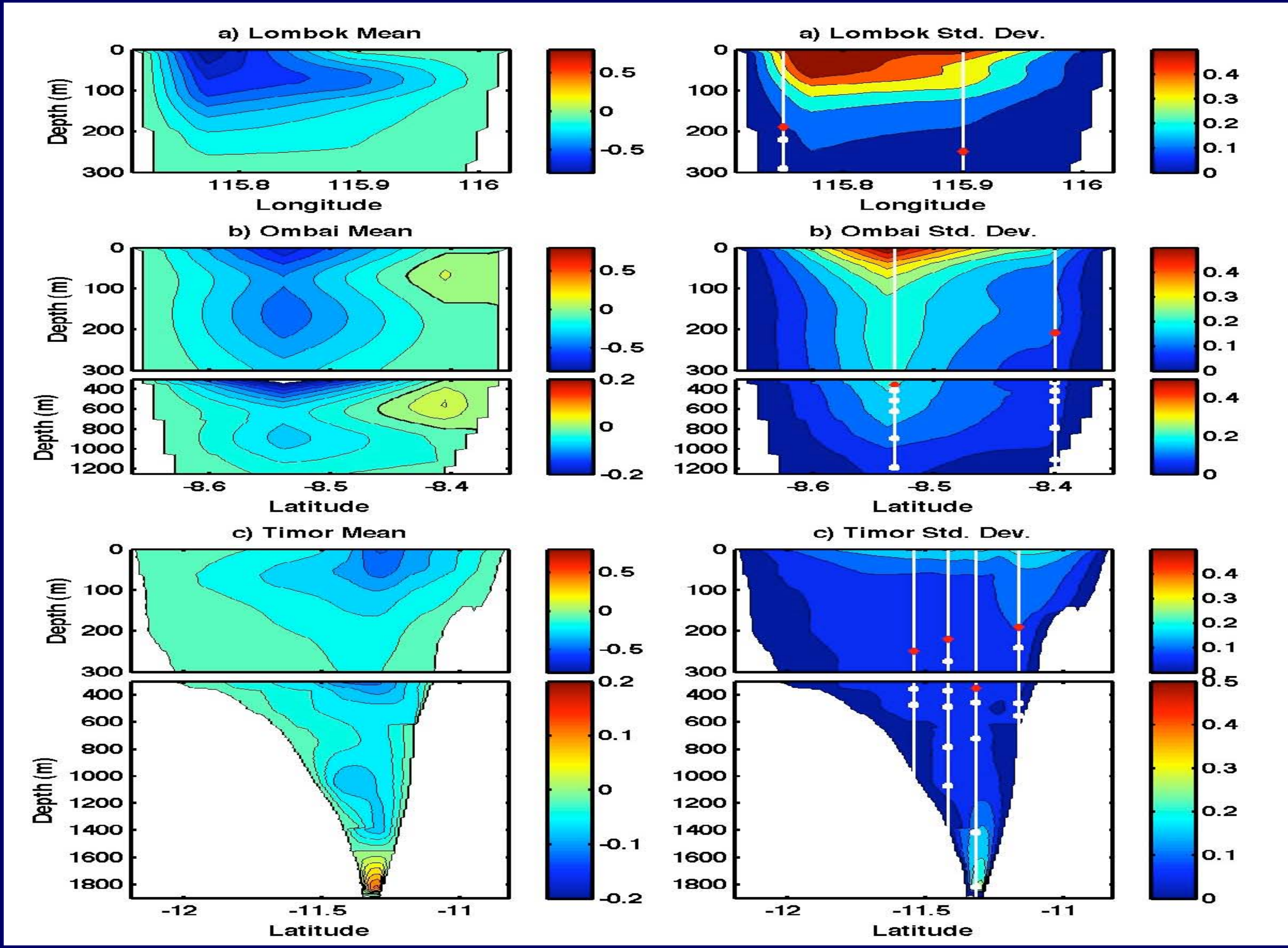
Susanto et al, 2012

ITF OUFLOW Profiles

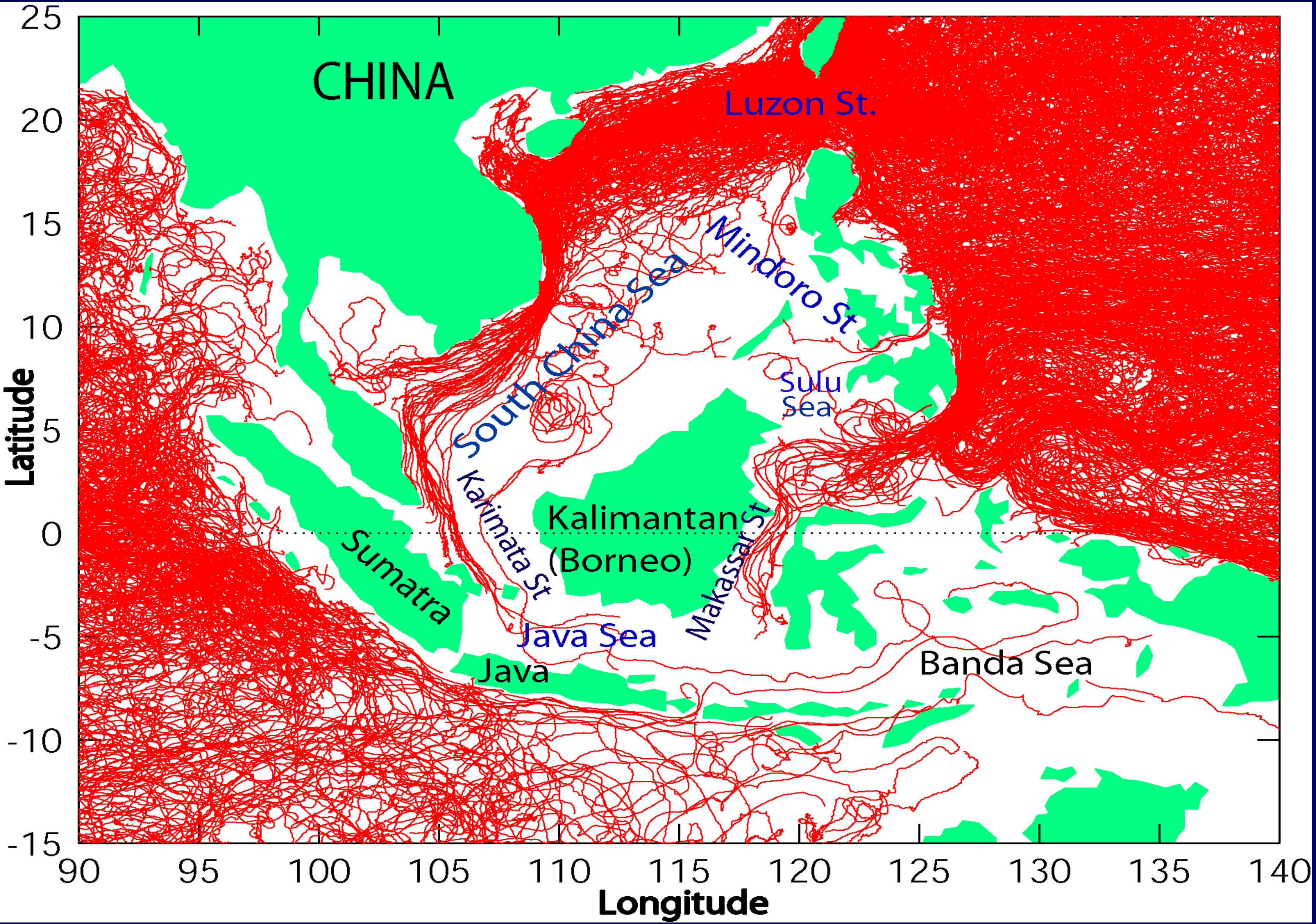
2.6 Sv

4.9 Sv

7.5 Sv



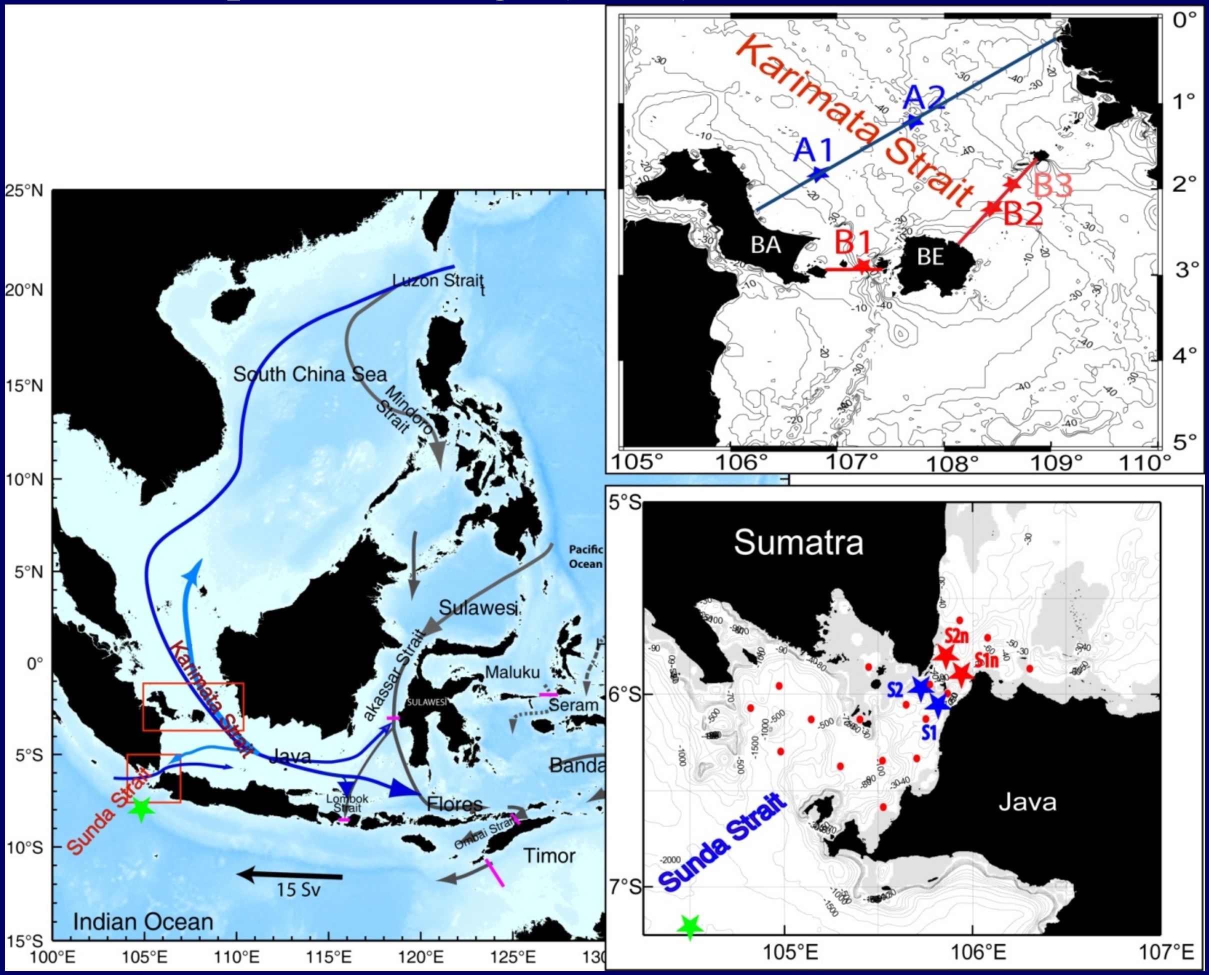
Sprintall et al, 2009



Trajectories satellite-track drift buoys from the Global Drifter Program (8/1988-6/2007) courtesy of Drifter Data Assembly Center at NOAA/AOML.

Susanto et al., 2010

South China – Indonesian Seas Transport/Exchange (SITE)



SITE PI' s

USA: Dwi Susanto

P.R. China:
Guohong Fang (FIO)

Indonesia
- Indroyono Soesilo
- Sugiarta Wirasantosa
- Budi Sulistyo

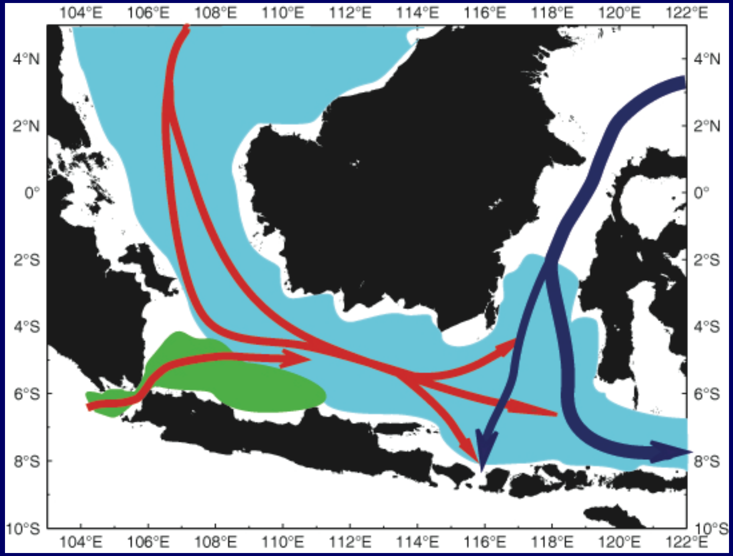
Questions:

✓ How does SCS/Java exchange affect air-sea interaction and ocean circulation within internal Indonesian Seas and the South China Sea?

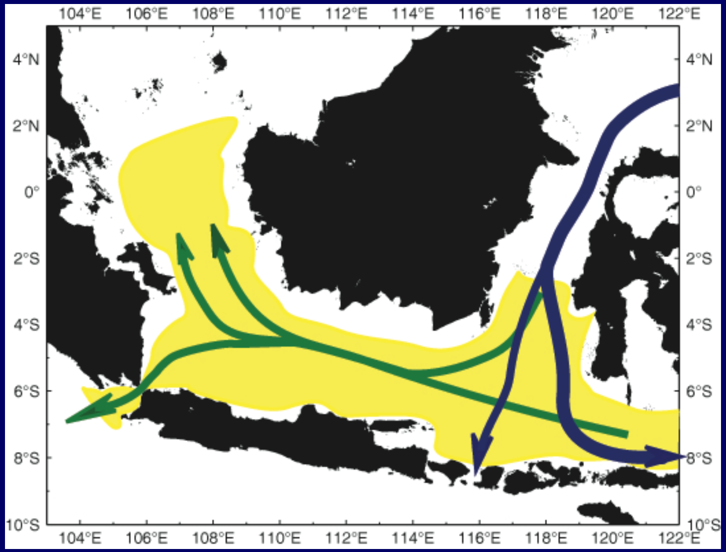
✓ How does this SCS/Java exchange affect the dynamics of the primary ITF?

CONCLUSIONS

NW monsoon



SE monsoon



- ✓ Even though the annual means of South China Sea throughflow & Sunda Strait flow are small, but their large seasonal variability play an important role and may control the thermocline intensified and seasonal flow in the Makassar Strait : enhancing southward flow ITF during Southeast monsoon and reducing ITF during northwest monsoon (boreal winter)

  Note: 2004-2009 Makassar throughflow -15.5Sv (JFM) and -9.6 Sv (OND)

- ✓ SITE Transport -2.5 Sv during northwest monsoon to + 1.0 Sv during northeast monsoon

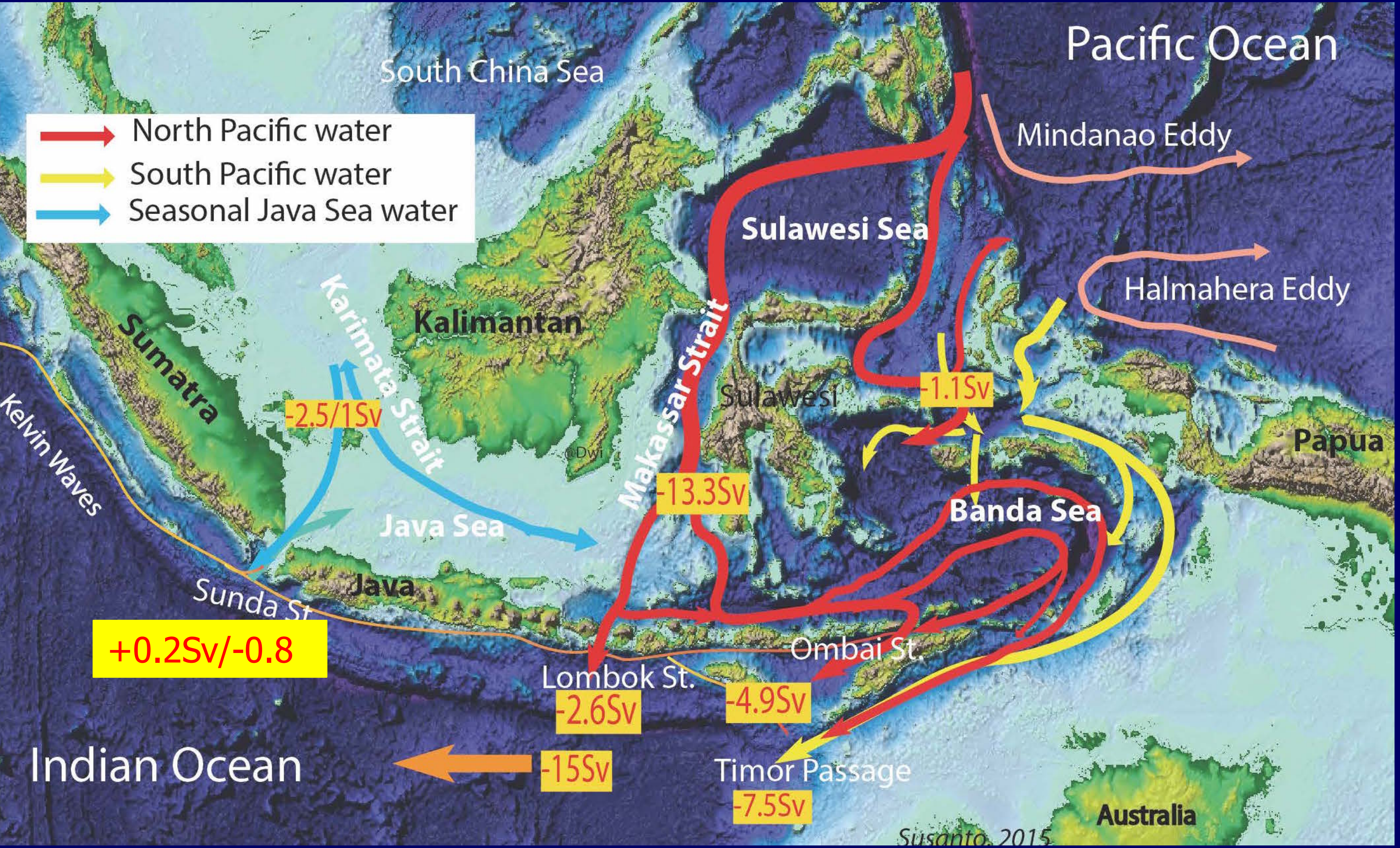
  Meanwhile for Sunda +0.24 Sv NW monsoon -0.83 Sv (NE) monsoon and

- ✓ Coastally trapped Kelvin waves from Indian Ocean probably enter the Sunda Strait

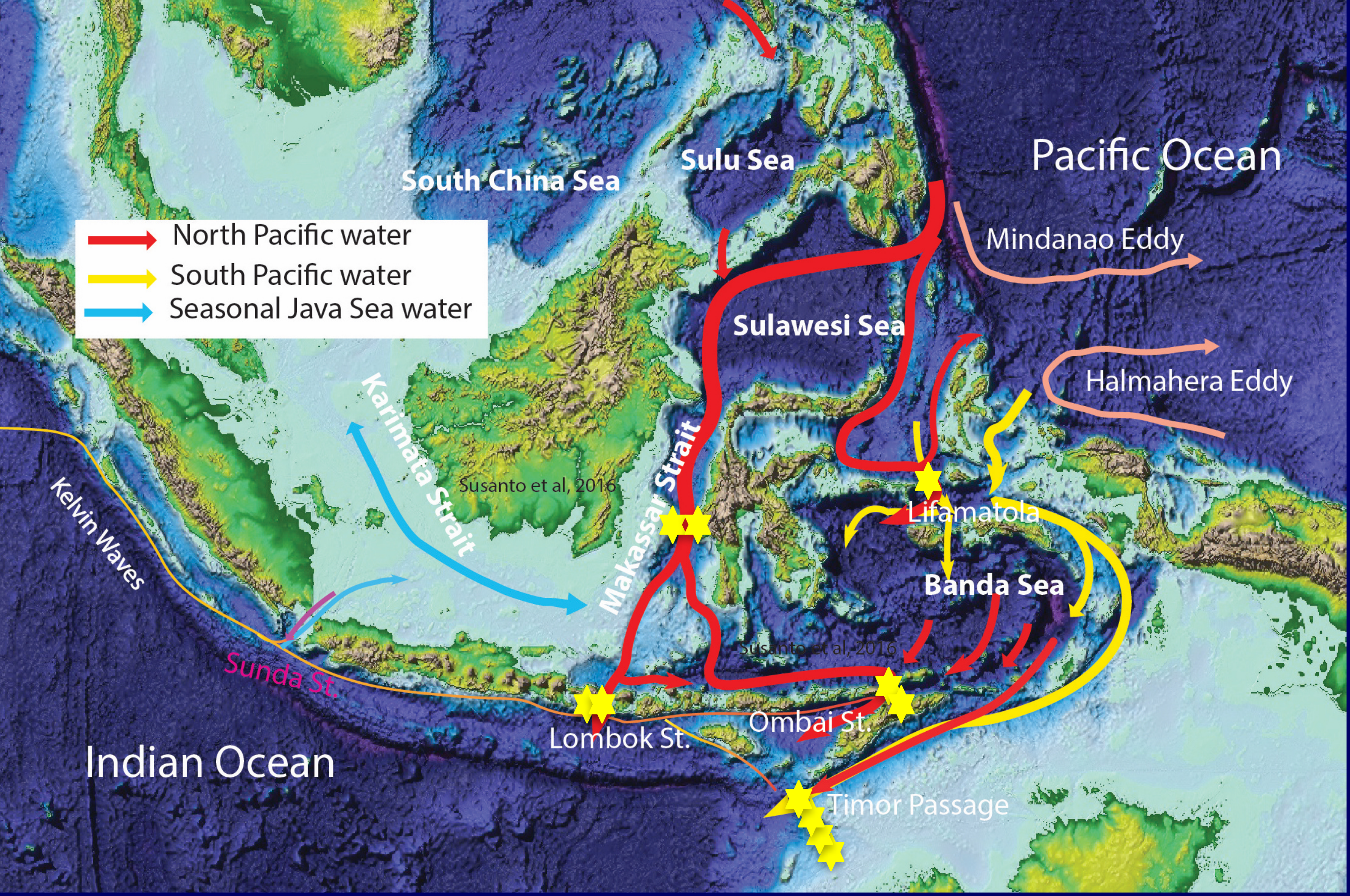
If main ITF is Coffee, the SCS and Sunda Strait throughflow is Creamer,
May be it is small but it is important

ITF Pathways and Transport

Susanto et al., 2016

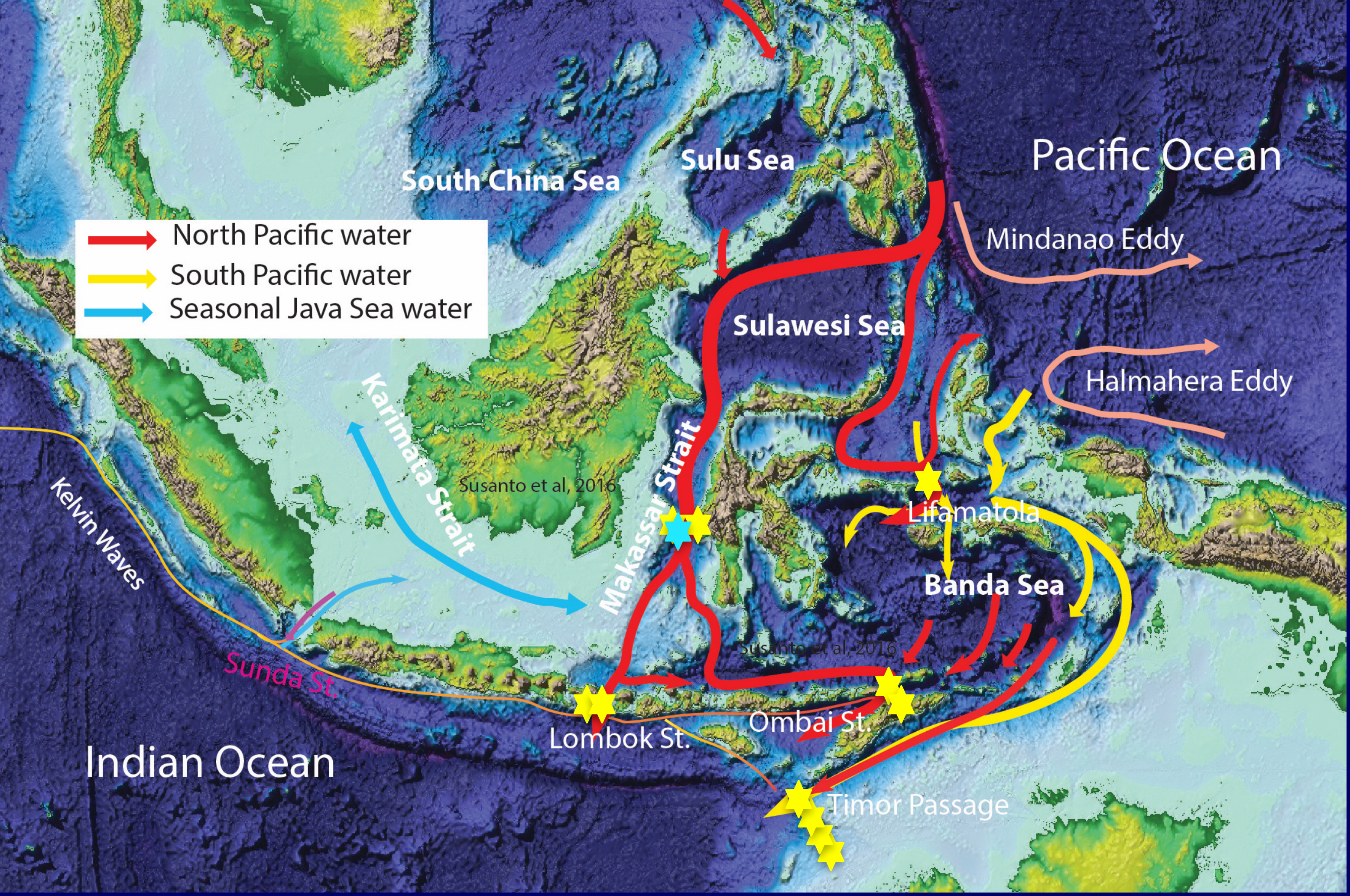


JADE (93-95), ARLINDO (96-98), INSTANT (03-06), MITF(07-11), & SITE (07-16)projects



INSTANT
2003-2006

Susanto et al., 2016



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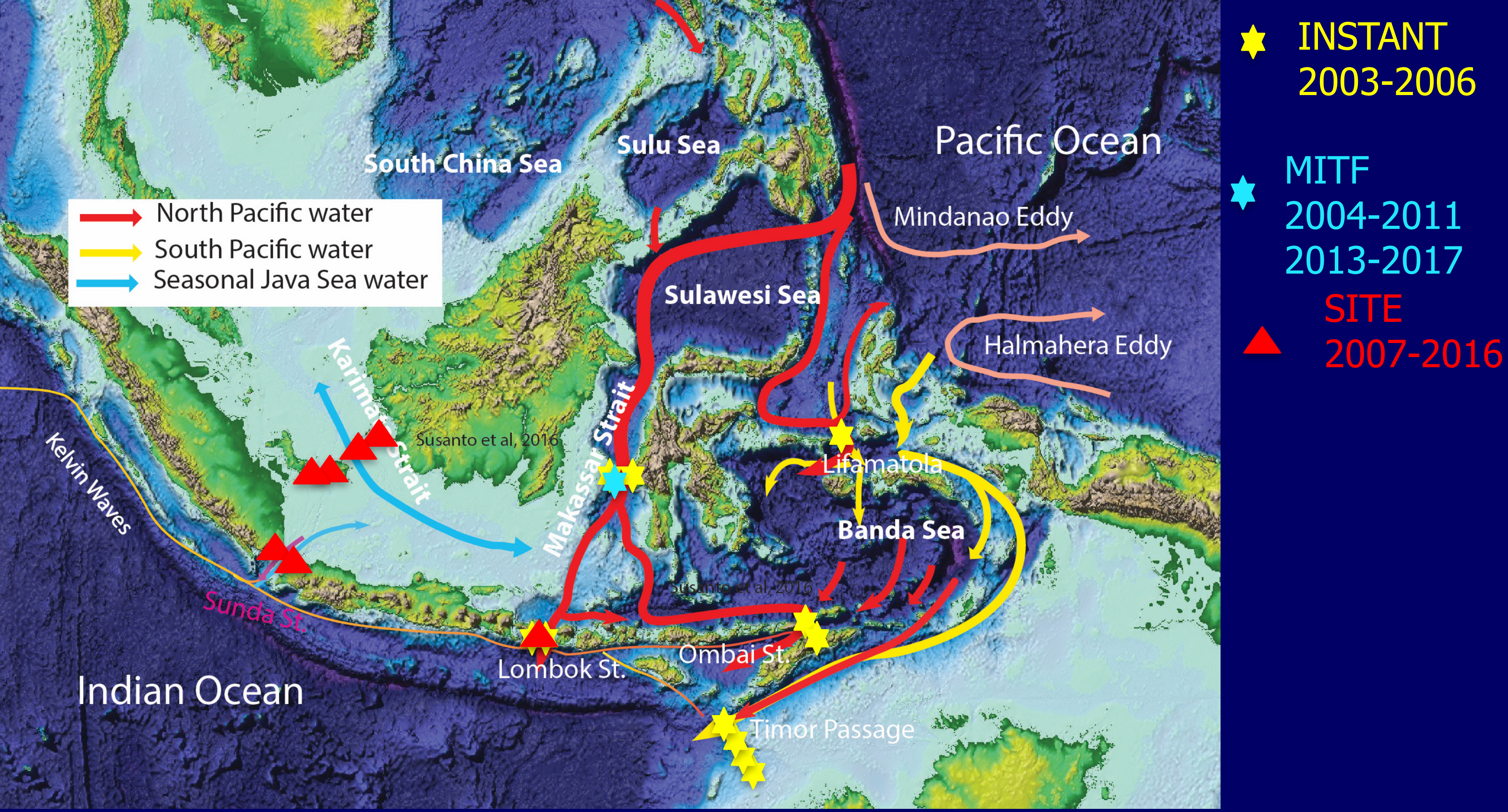
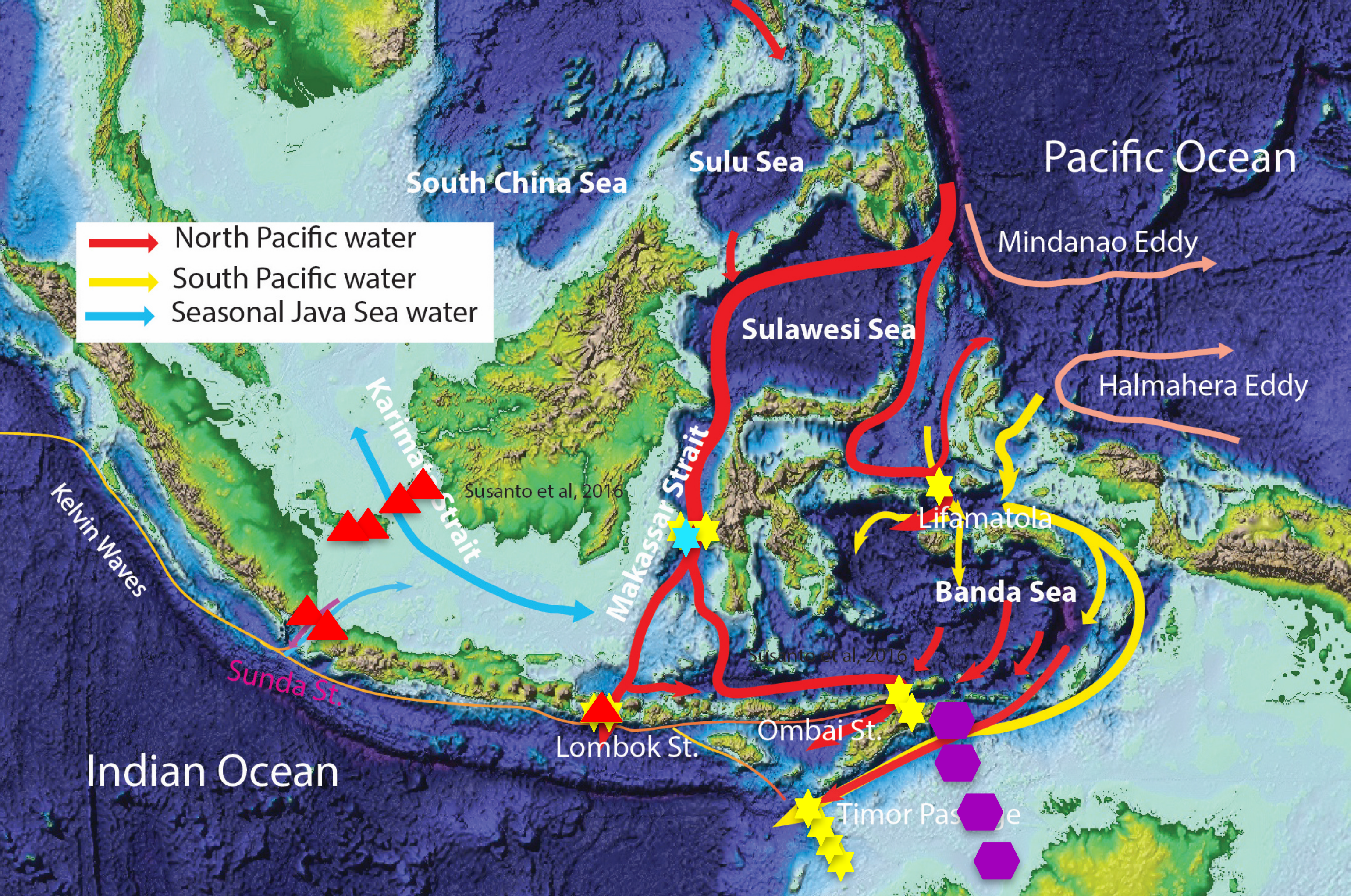


Susanto et al., 2016



INSTANT
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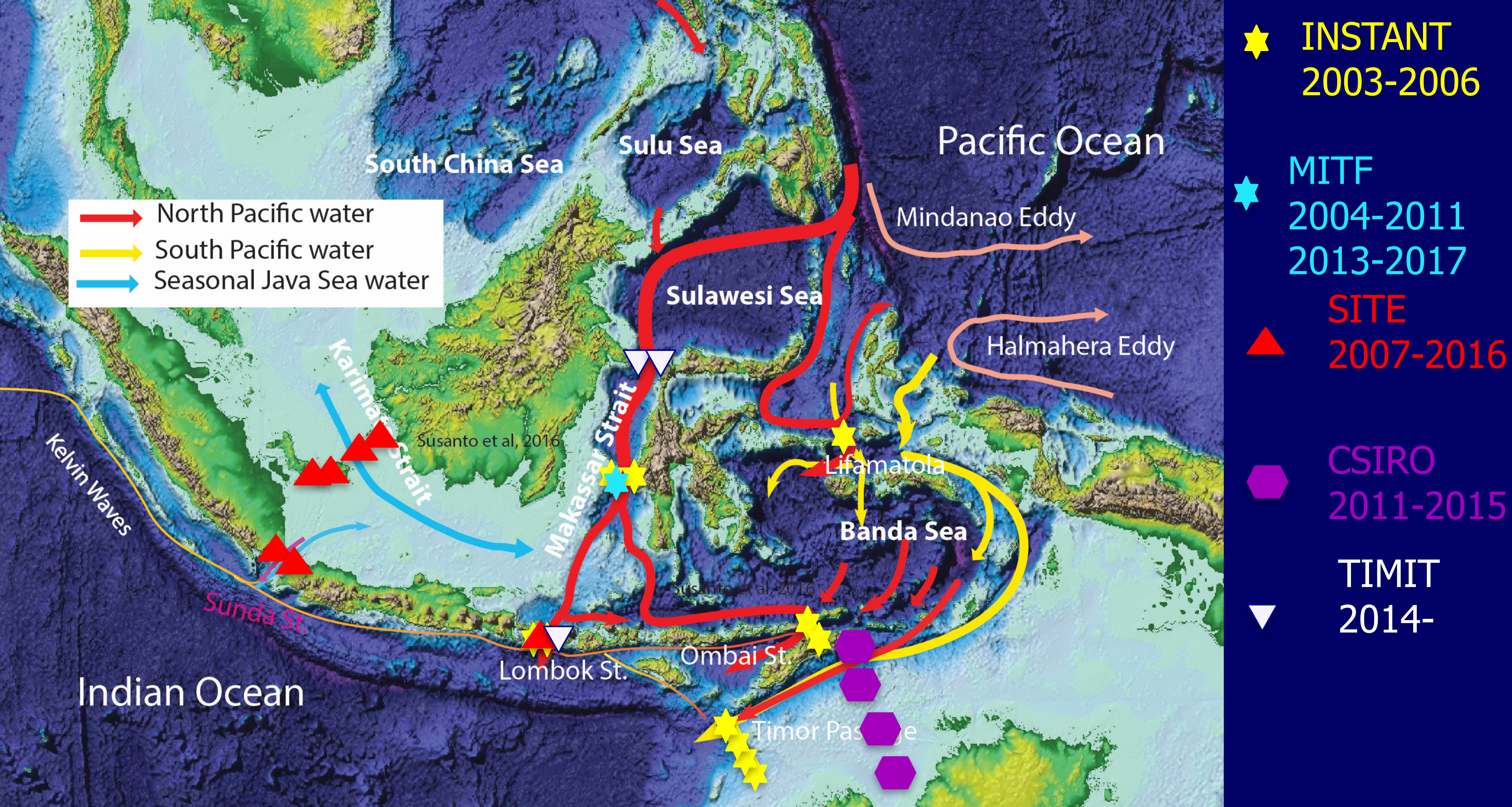
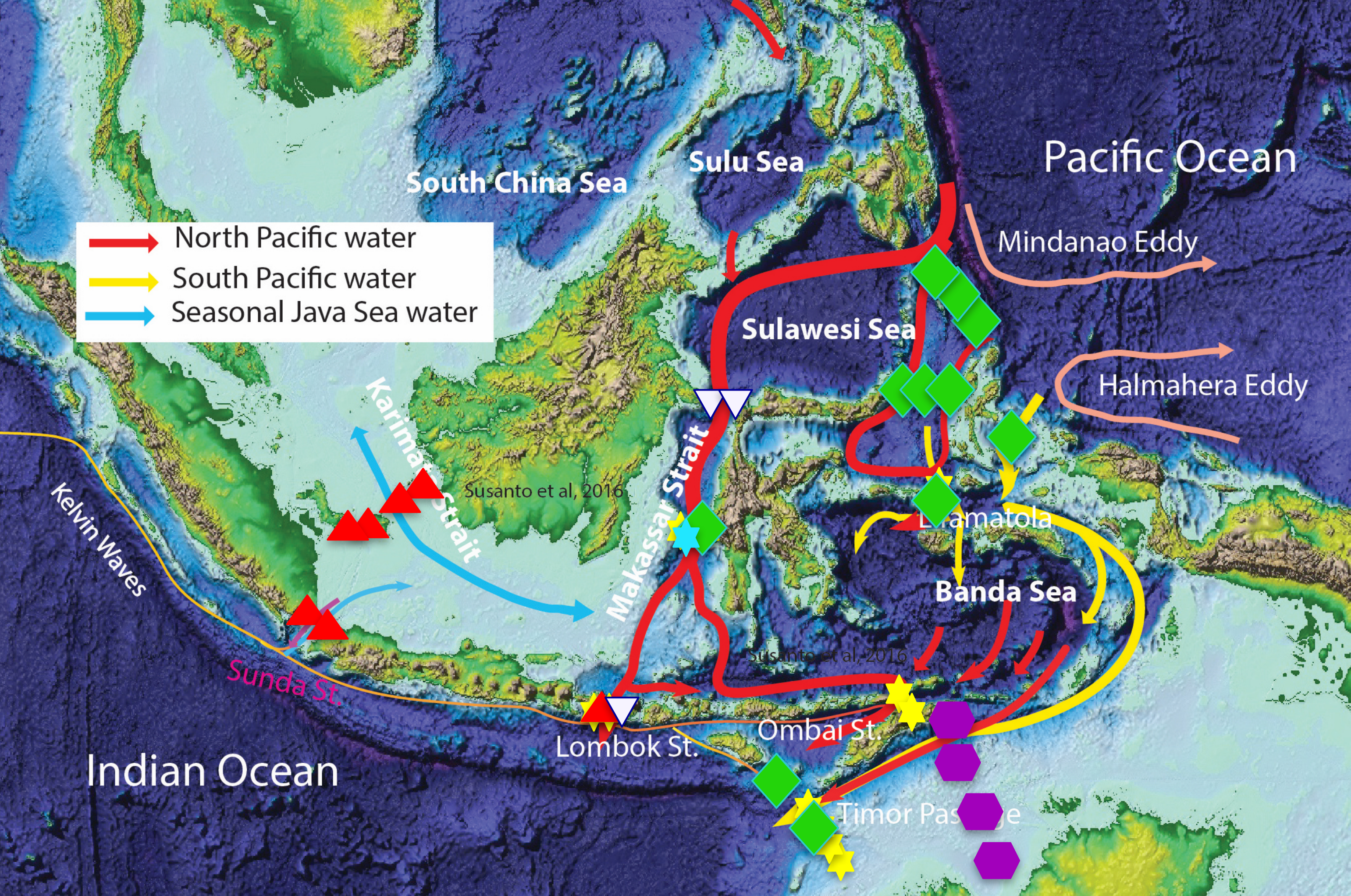
2007-2016

CSIRO
2011-2015

Susanto et al., 2016



Susanto et al., 2016



INSTANT 2003-2006

MITF 2004-2011 2013-2017

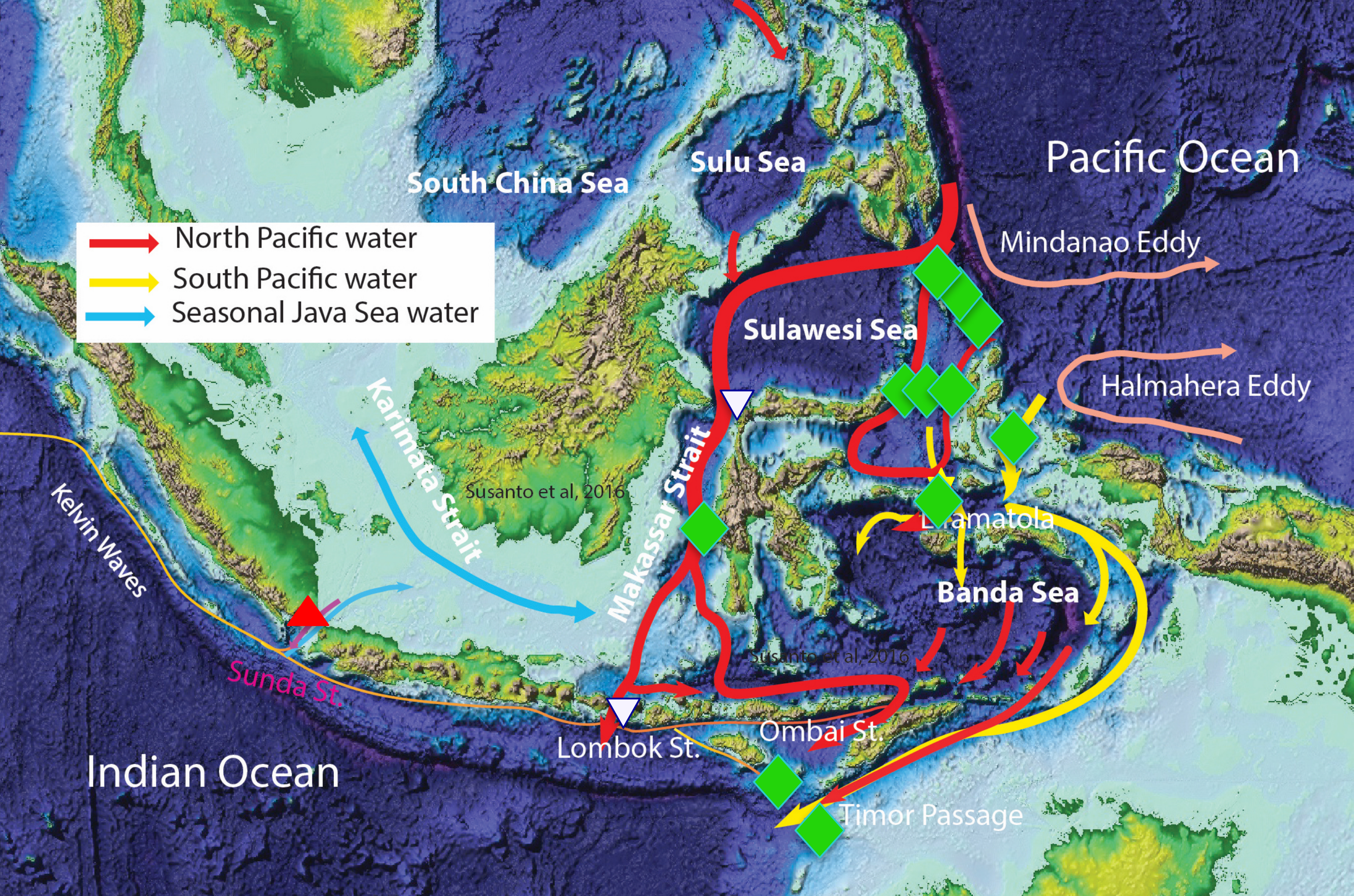
SITE 2007-2016

CSIRO 2011-2015

TIMIT 2014-

LIPI-IOCAS 2014-

Susanto et al., 2016



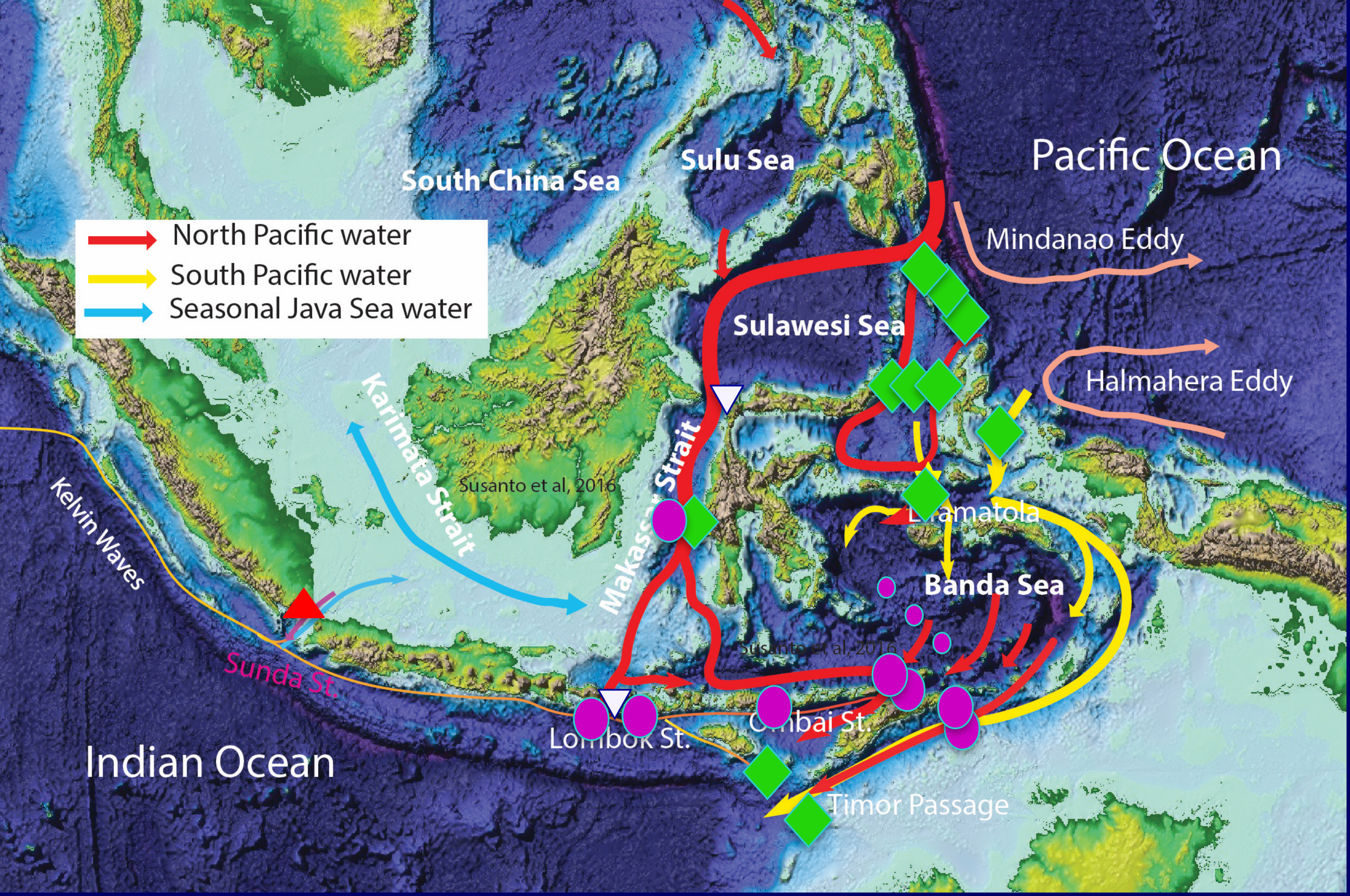
SITE
2007-2016

TIMIT
2014-

LIPI-IOCAS
2014-

Susanto et al., 2016

Current Available Moorings for ITF Observations



SITE 2007-2016

TIMIT 2014-

LIPI-IOCAS 2014-

Susanto et al., 2016

MINTIE : Proposal by Janet et al.

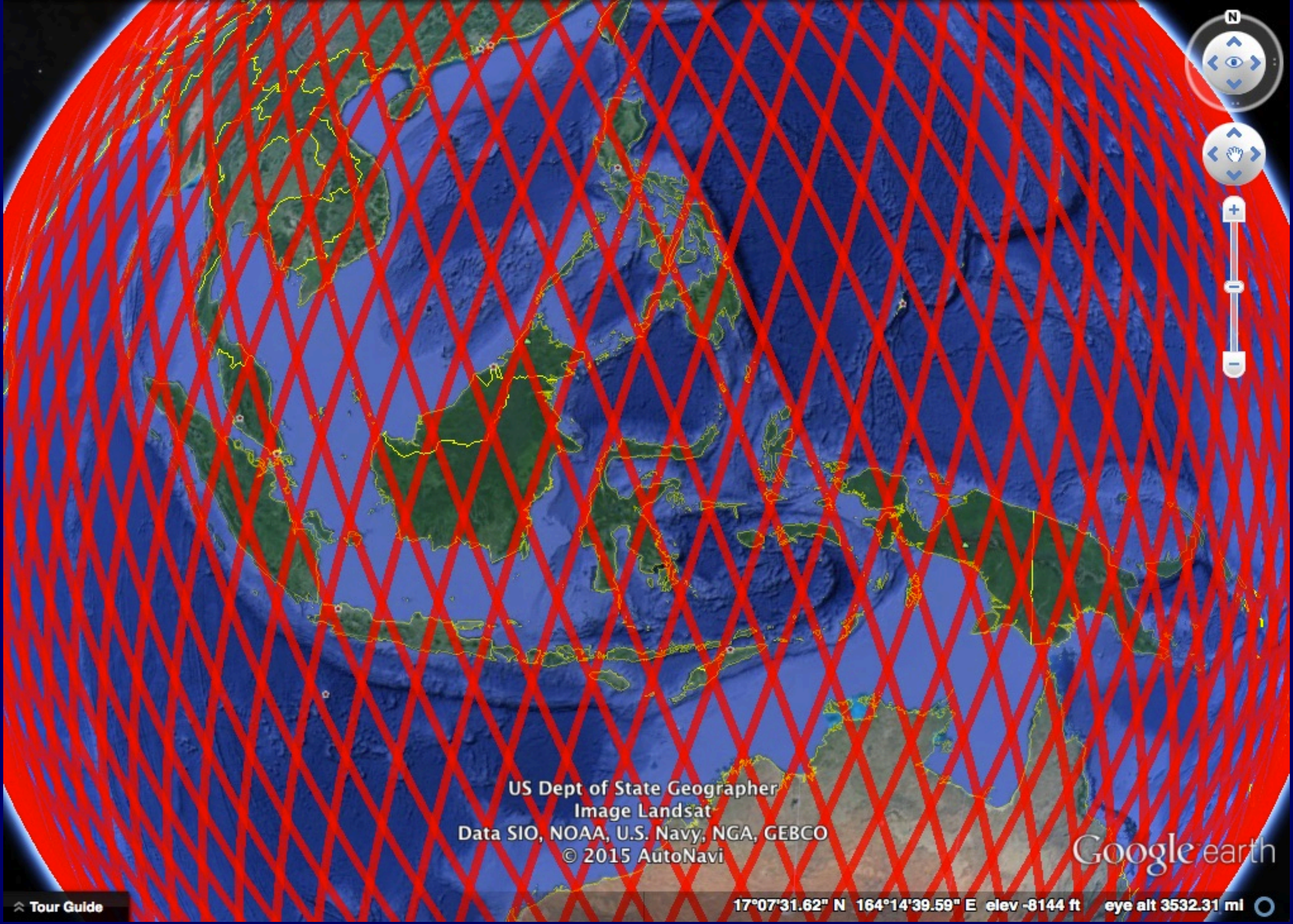
ITF PROXY

ITF plays important roles in global ocean circulation and climate.
Thus, it is desirable to not only quantify the ITF and its variability, but also monitor it for a longer period of time.

Yet, a sustainable in situ observation is expensive and challenging

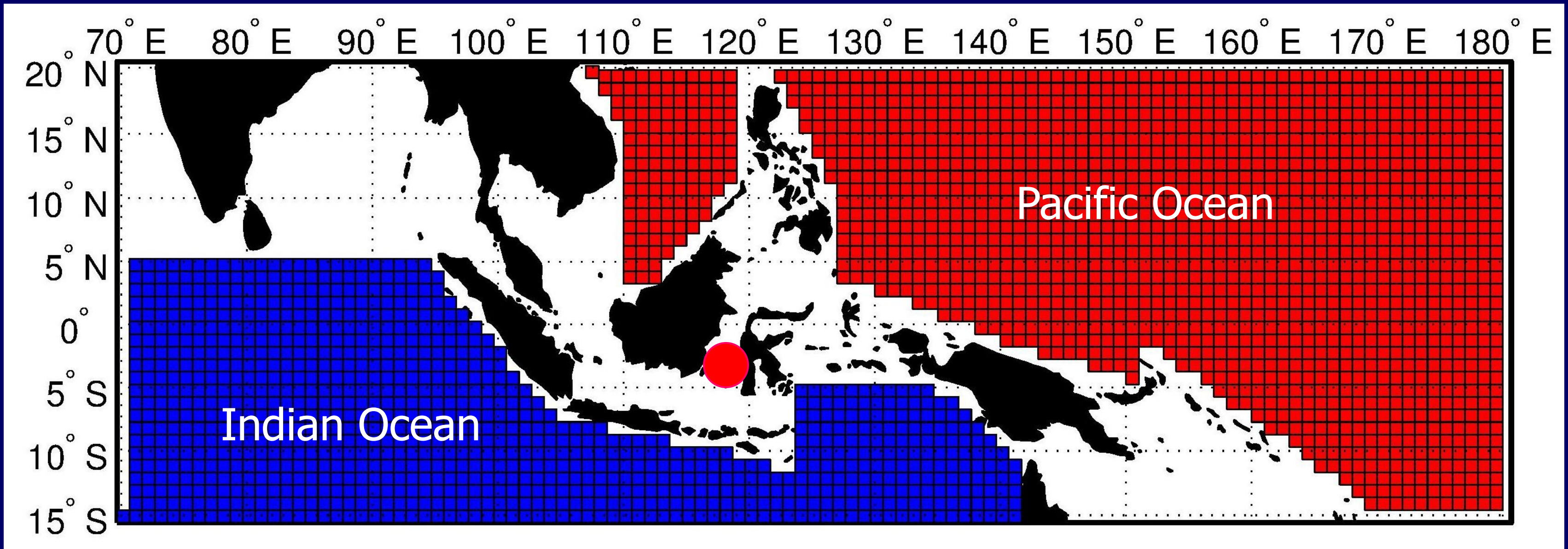
Example: comprehensive ITF INSTANT program last only for three years

Therefore, an alternative approach to gauge ITF transport or to develop a proxy is desirable.



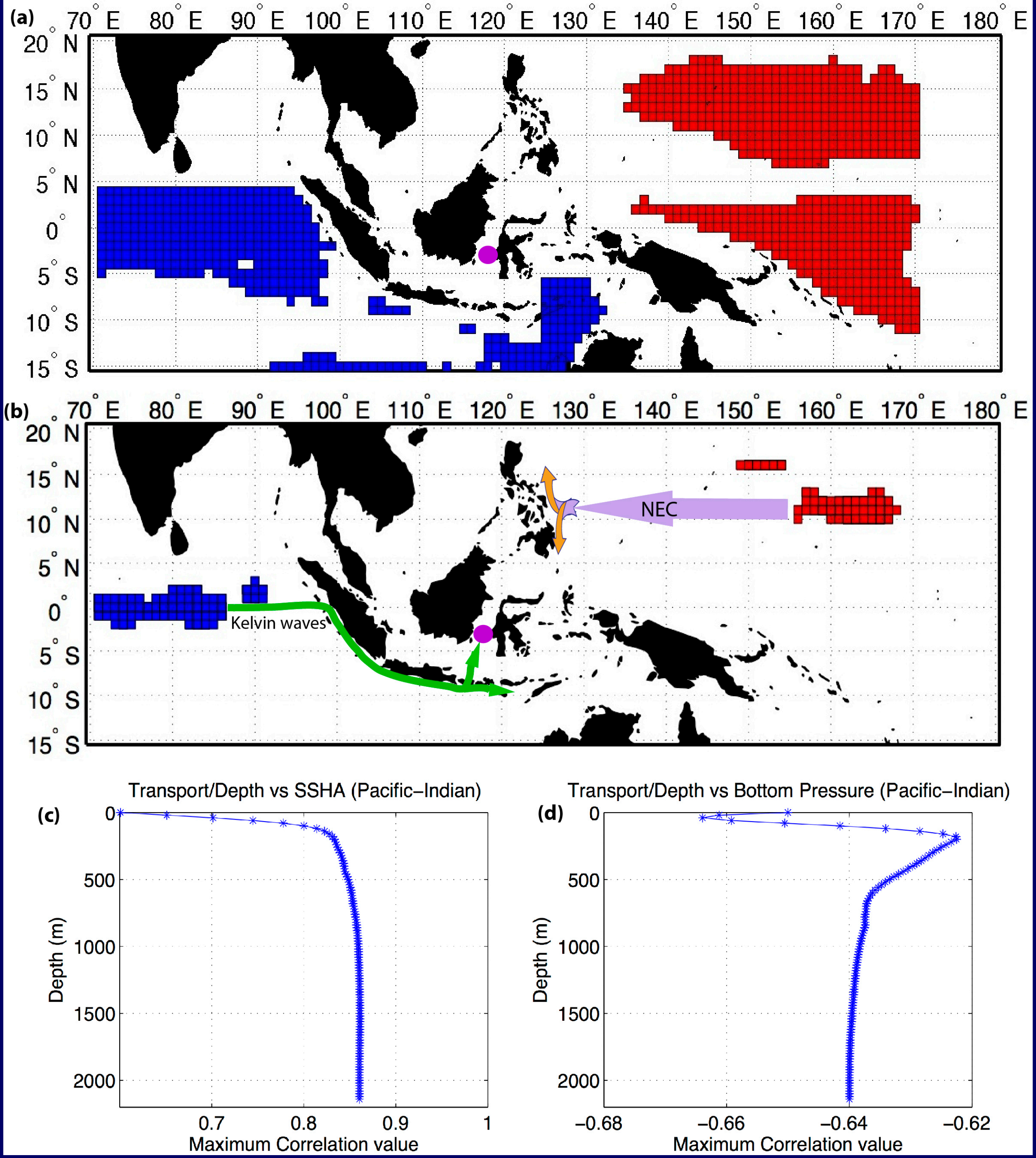
Using T/P-Jason ½ altimeters and gravimeters

Define grids (1° x 1°): Pacific Ocean (1134 grids) and Indian Ocean (968 grids)

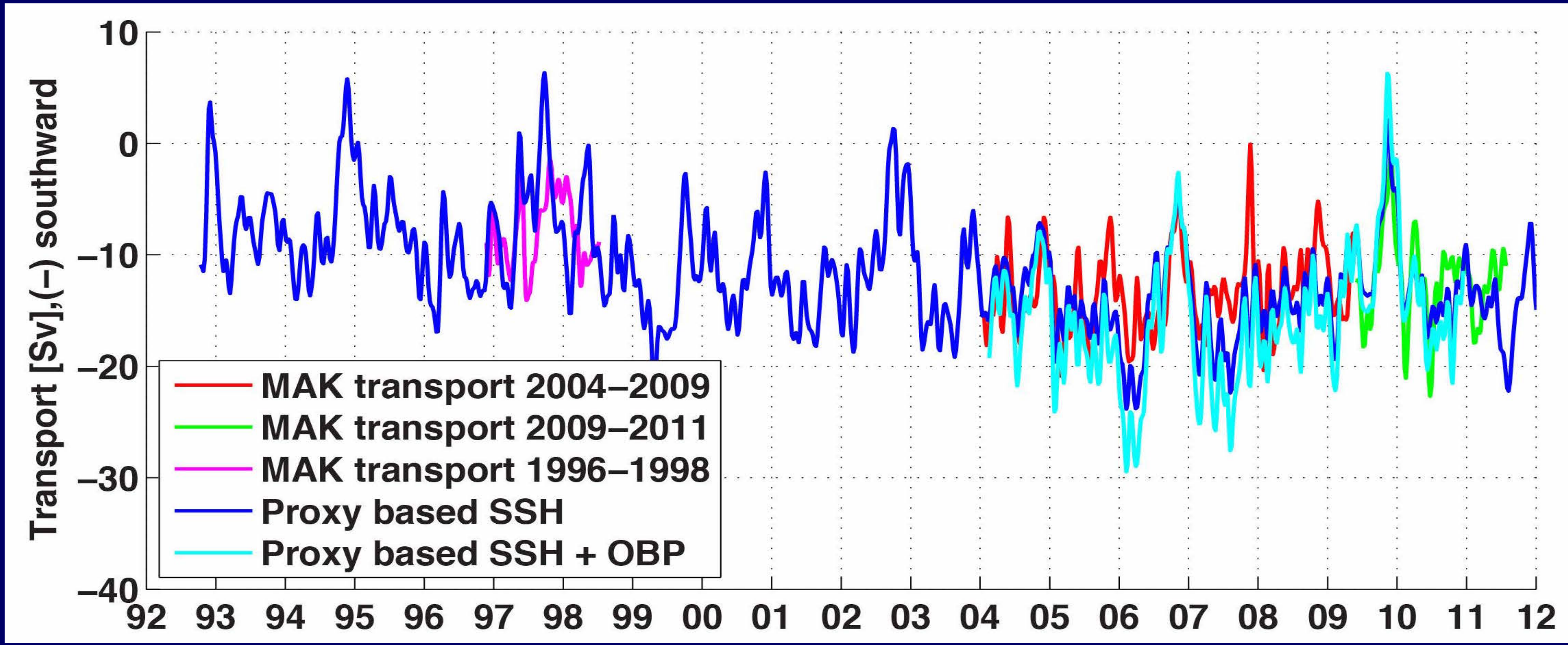


Susanto & Song, 2015

- In situ observation in the Makassar Strait 2004-2011: (2004-2009 as testing period and 2009-2011 as validation period)
- 20-years of sea surface height from satellite altimeters (1992-2012)
- 10-years of ocean bottom pressure from Gravity Recovery and Climate Exp. (GRACE)
- Theoretical transport formula for two layer model (Qu & Song, 2009)



Susanto & Song, 2015



Susanto & Song, 2015

ITF 2004-2009: testing period; 2009-2011 validation period
The proxy time series fits well with the observation from intraseasonal to interannual
The proxy during validation period 2009-2011 follows the observation quite well.

	Observation	Proxy
2004-2011	13.0 Sv	13.9 Sv (SSH) 15.8 Sv: SSH + OBP (2004-2010)
1993-2012		11.6 Sv

TIDAL MIXING

- ✓ Along the route within the Indonesian seas, the water undergoes strong tidal mixing, air-sea interaction, and other oceanic/atmospheric forcing processes associated with MJO, monsoon, ENSO and IOD.

- ✓ Tidal mixing in the Indonesian seas plays an important role in regulating the Pacific – Indian Ocean exchange, water. Where ?

Tidal Mixing Signatures in the Indonesian Seas*

AMY FFIELD

NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida

ARNOLD L. GORDON

Lamont-Doherty Earth Observatory of Columbia University and Department of Geological Sciences,

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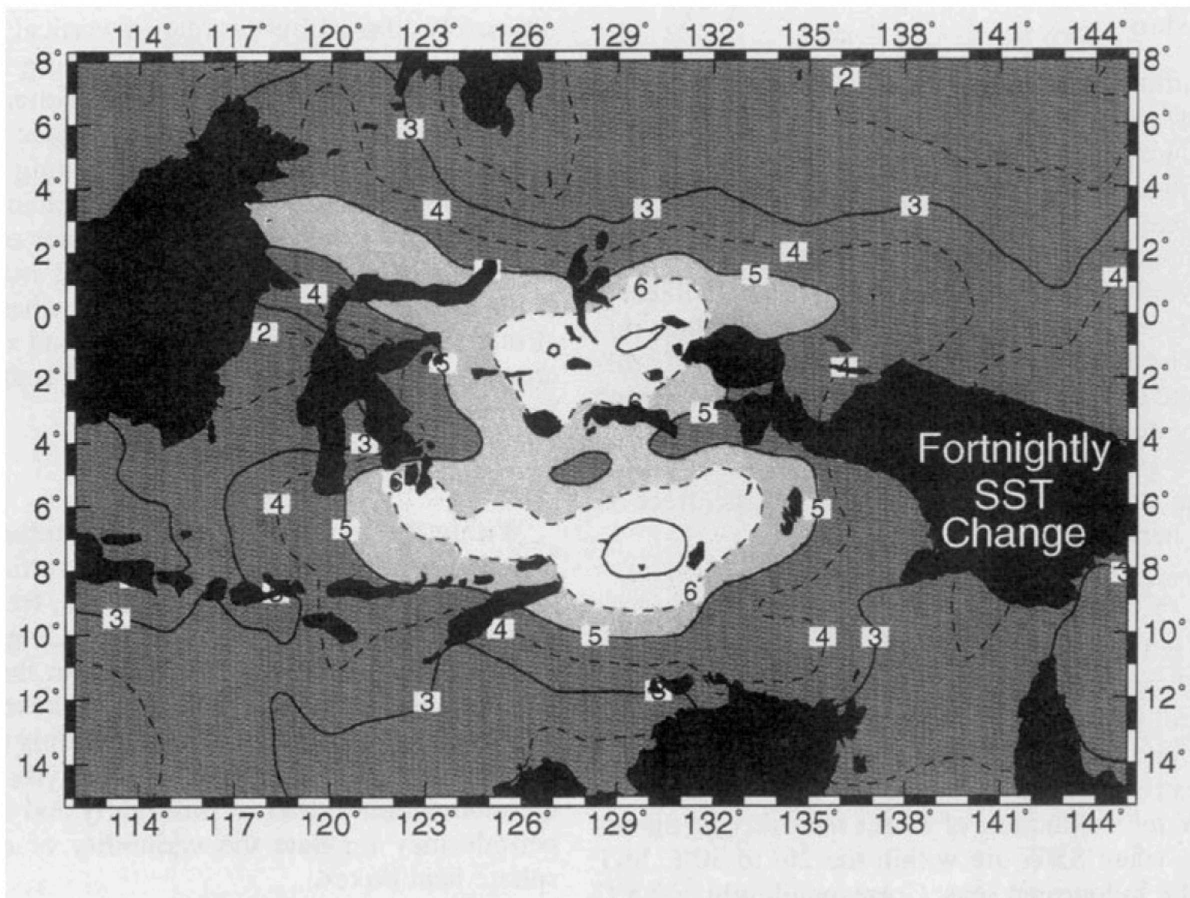


GEOPHYSICAL RESEARCH LETTERS, VOL. 26, NO. 17, PAGES 2741-2744 SEPTEMBER 1, 1999

Diapycnal Mixing in the Banda Sea: Results of the First Microstructure Measurements in the Indonesian Throughflow

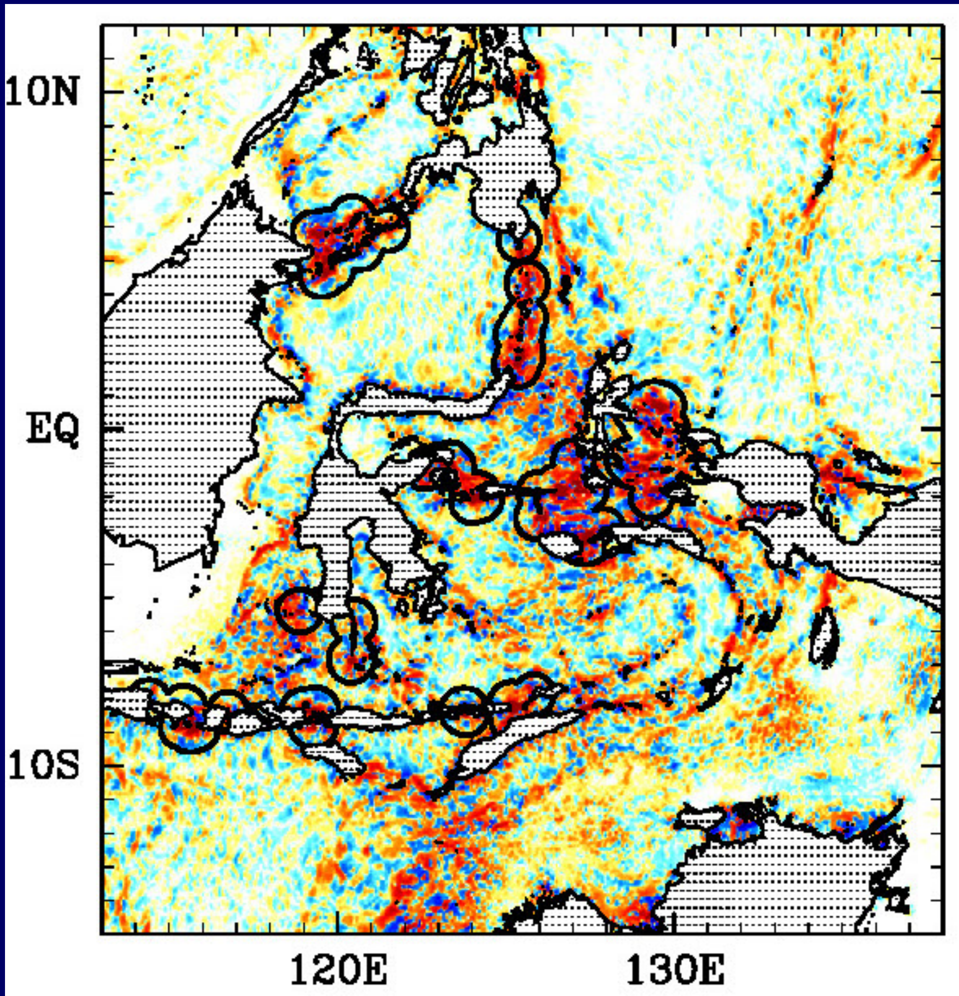
Matthew H. Alford and Michael C. Gregg

Applied Physics Laboratory and School of Oceanography, University of Washington, Seattle

Muhammed Ilyas

Agency for the Assessment and Application of Technology of the Republic of Indonesia (BPPT), Jakarta, Indonesia

Conclusion: Tidal mixing in the Banda Sea is Small, similar to the open ocean



Nagai & Hibiya, 2015

Depth integrated conversion rate from the M_2 barotropic to baroclinic tidal energy

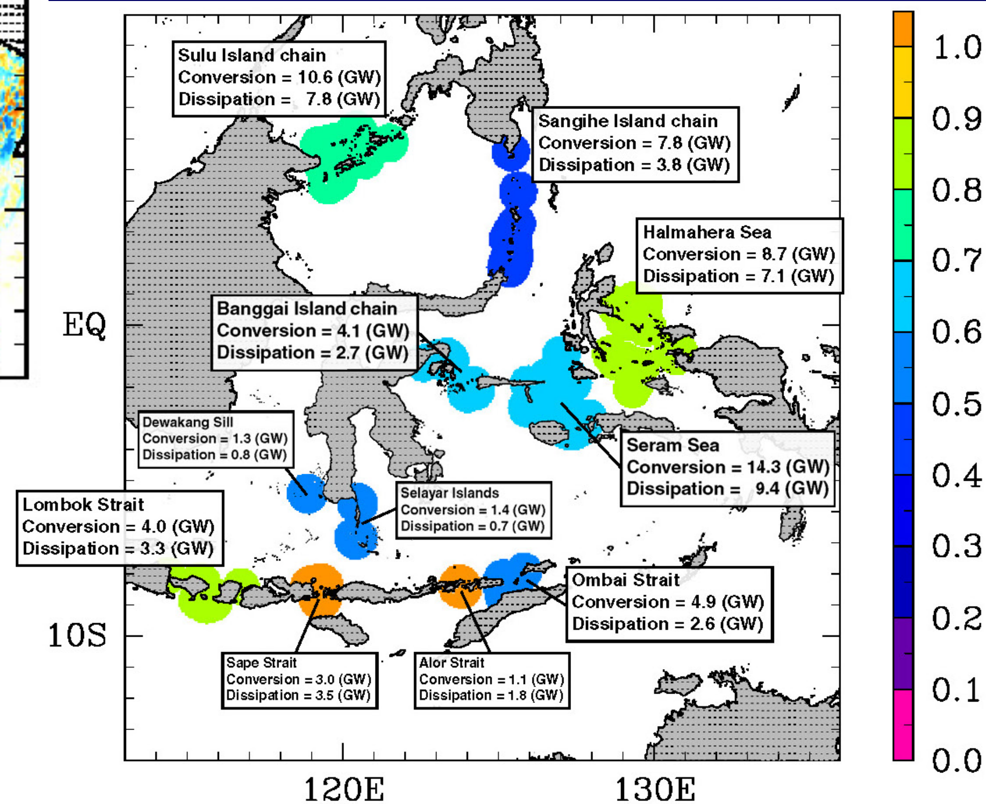


Figure 11. Model-predicted value of local dissipation efficiency *q* at each near-field site (color). Color saturates at 1 (orange). The values of barotropic to baroclinic energy conversion rate and baroclinic energy dissipation integrated over each near-field site are also shown.

PSD of fortnightly (top panel) and monthly (bottom panel)

1990-1995 (same period as FG96) 1981-1995 1981-2003

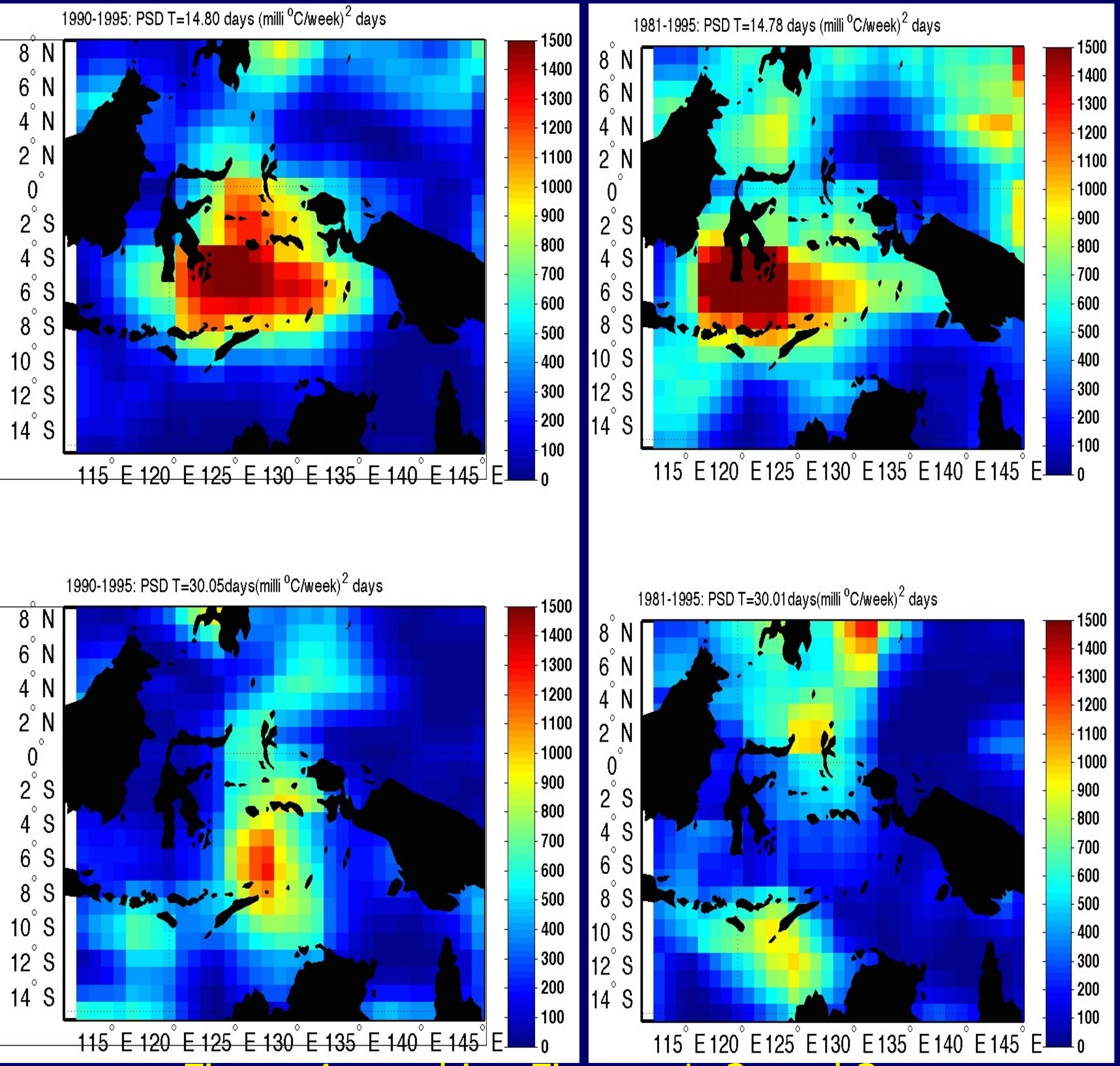
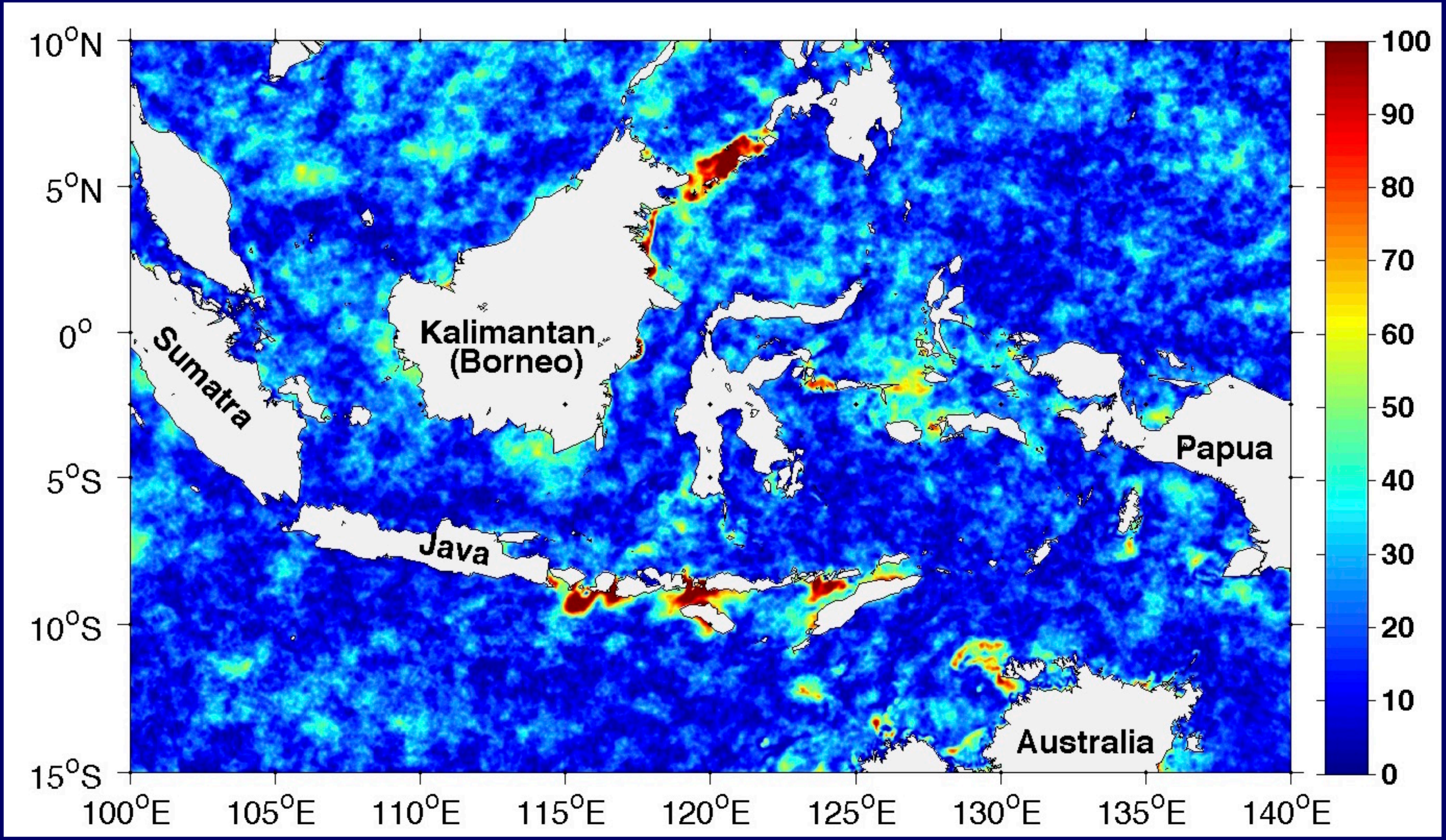
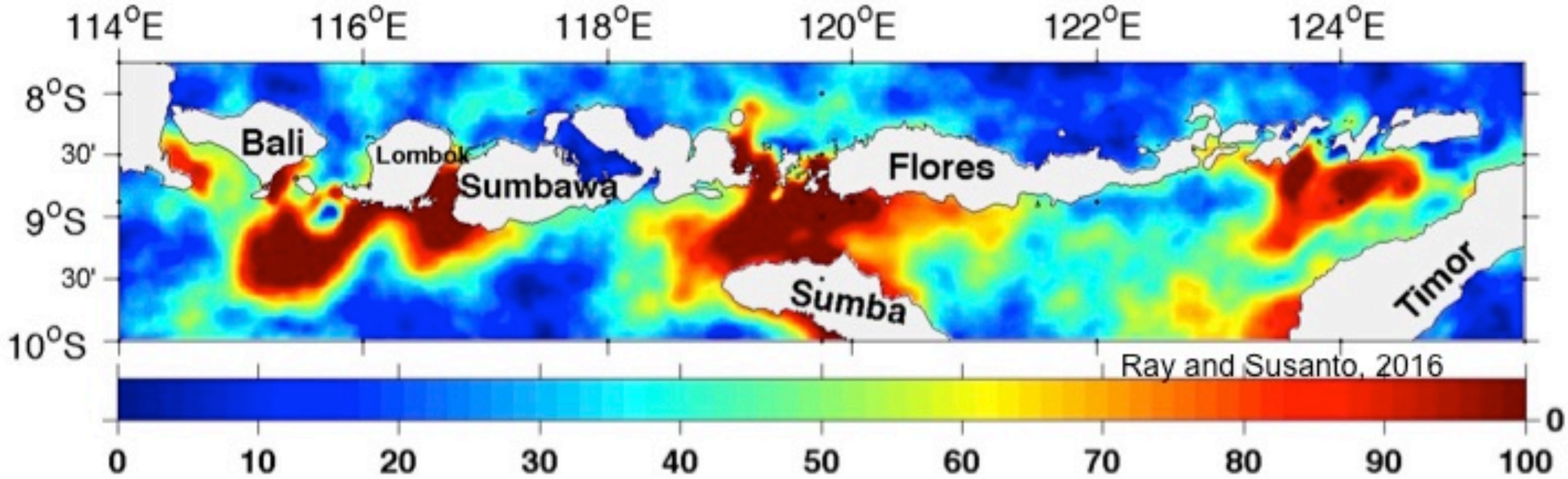


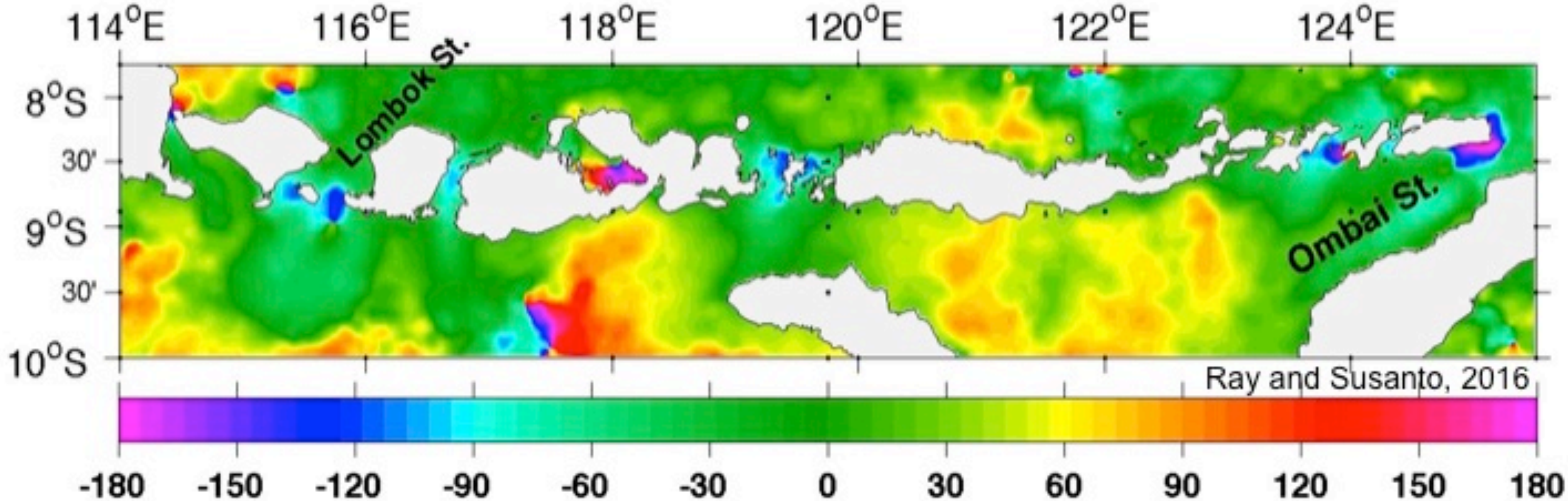
Figure 4: combine Figures 1, 2, and 3

Tidal Mixing in the Maritime Continent



Ray and Susanto, 2016


114°E
116°E
118°E
120°E
122°E
124°E
8°S
30'
9°S
30'
10°S
Bali
Lombok
Sumbawa
Flores
Sumba
Timor
Ray and Susanto, 2016
0
10
20
30
40
50
60
70
80
90
100


114°E
116°E
118°E
120°E
122°E
124°E
8°S
30'
9°S
30'
10°S
Lombok St.
Ombai St.
Ray and Susanto, 2016
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180

Conclusion

- ✓ Indonesian seas play important role in global ocean circulation and climate (especially the Indian Ocean) and may venerable to climate swings associated with ENSO and IOD. Long term observation of ITF is necessary.
- ✓ Direct observation of Indonesian throughflow is expensive and logistically challenging, therefore a proxy is needed (numerical model, remote sensing and paleoclimate)
- ✓ Tidal mixing in the Indonesian seas is more localized, it is not in the Banda Sea but in Sulu Sill, Lifamatola/Ceram sea, and along the lesser Sunda islands (Bali to Timor)
- ✓ To understand Indian Ocean variability (stratification and water mass properties, physics and dynamics, as well as biogeochemistry) we have to understand the ITF, stratifications, and mixing variability in the exit passage of Indonesian seas/entrance/gate into the Indian Ocean.

Thank You