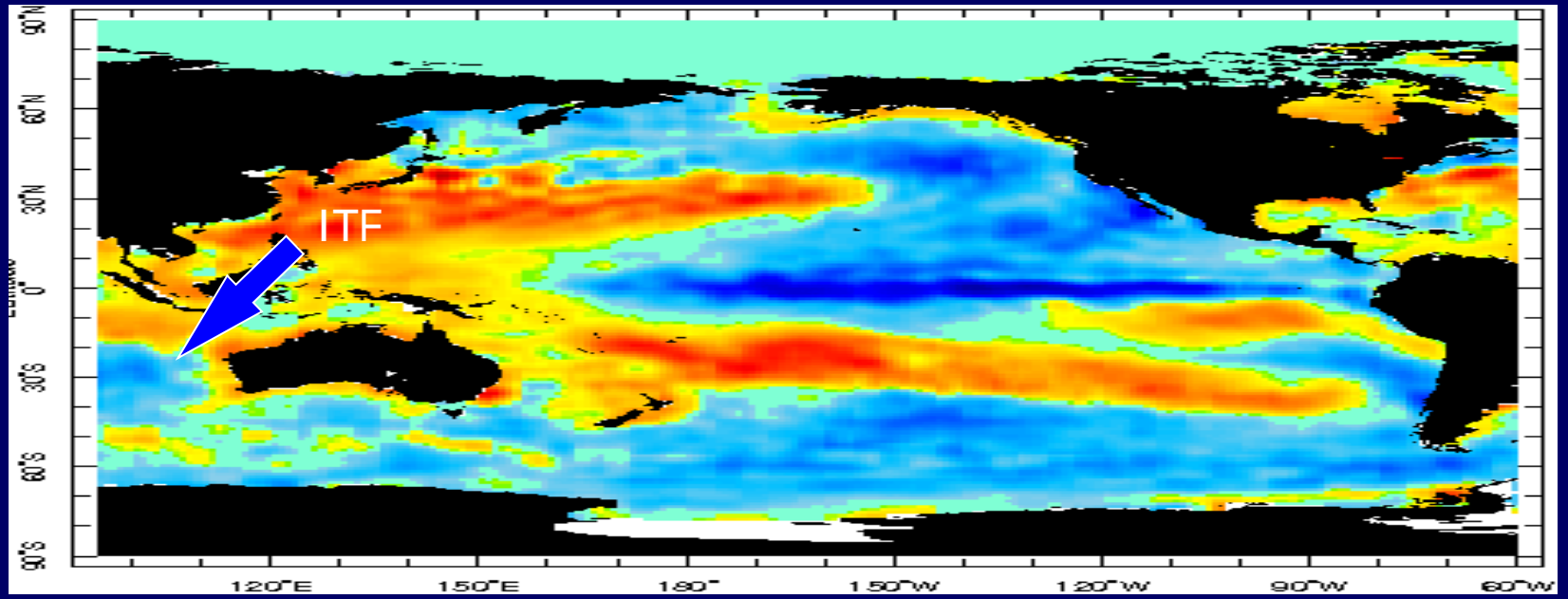
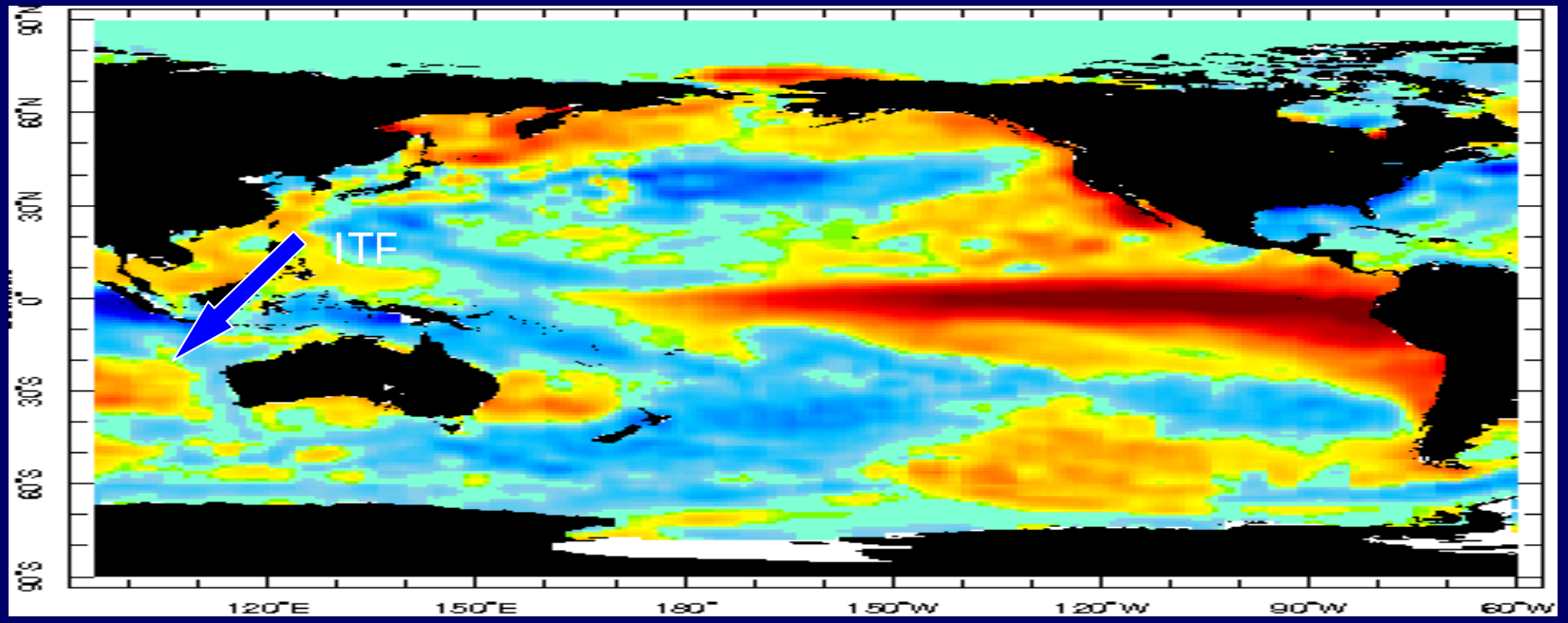
Indonesian Throughflow Proxy from Satellite Altimeters

Dwi Susanto[1] & Tony Song[2]

1. Lamont Doherty Earth Observatory of Columbia Univ., New York, USA
2. Jet Propulsion Laboratory, Pasadena, CA, USA

Lido-Venice, Italy
September 27, 2012


ITF
90°N
60°N
30°N
0°
30°S
60°S
90°S
120°E
150°E
180°
150°W
120°W
90°W
60°W


ITF
90°N
60°N
30°N
0°
30°S
60°S
90°S
120°E
150°E
180°
150°W
120°W
90°W
60°W


-4°C
-3°C
-2°C
-1°C
0°C
1°C
2°C
3°C
4°C

Motivations:

- Indonesian throughflow (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**

- Poorly observed and simulated in the ocean and coupled ocean-climate models. Accurately simulating the ITF is one of the challenges of ocean-climate prediction

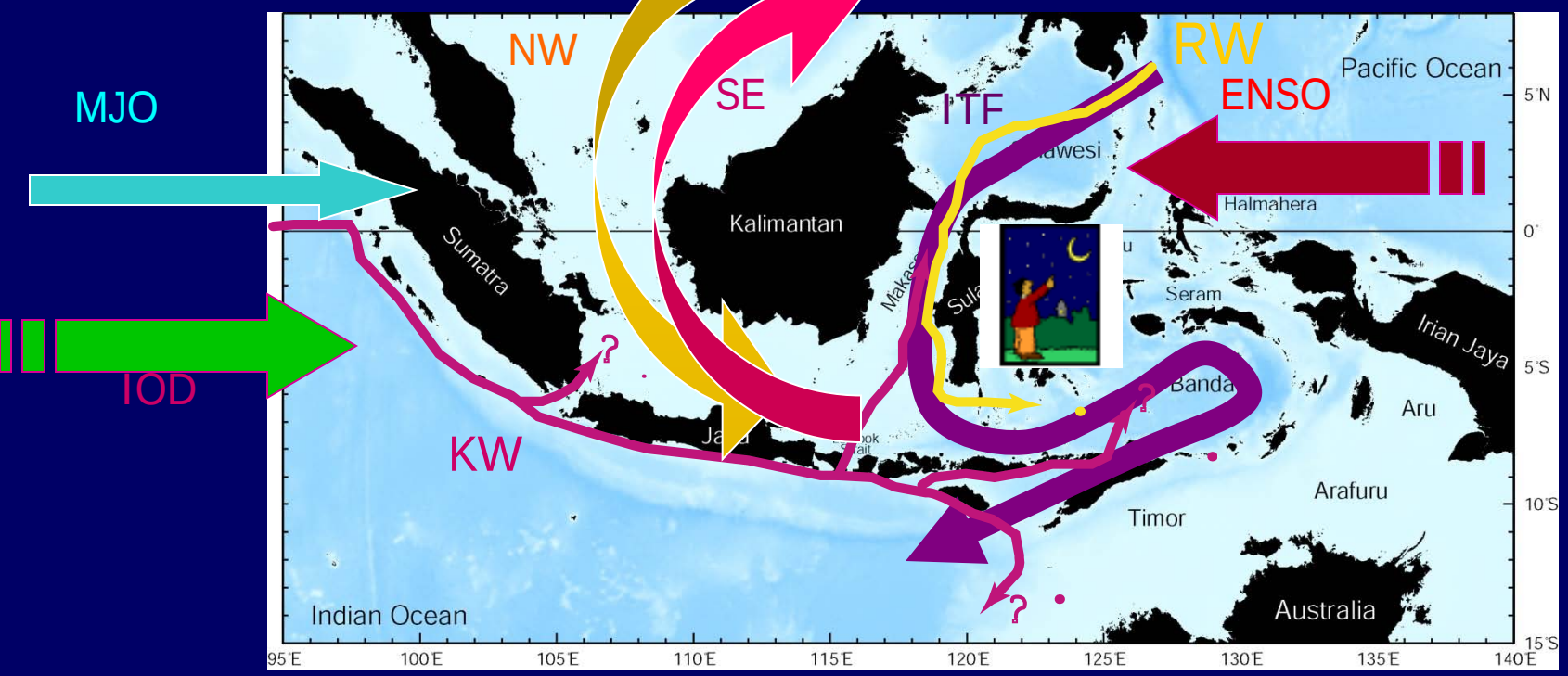
- Lack of concurrency in the time frames in which these observations were made makes it impossible to assemble a simultaneous picture of the multiple corridors of the ITF. A comprehensive measurement during INSTANT only last for 2004-2006

- Varies from tidal to interannual time scales. Observation: ITF transport from -1 Sv to 24 Sv. A consensus among numerical models has not been reached

- Direct field measurements is not sustainable: Logistically challenging and expensive.

➢ Need: Proxies of the ITF

Major oceanic & atmospheric forcings:



- ✓ ENSO+IOD+Monsoon → affects Ocean and atmospheric conditions

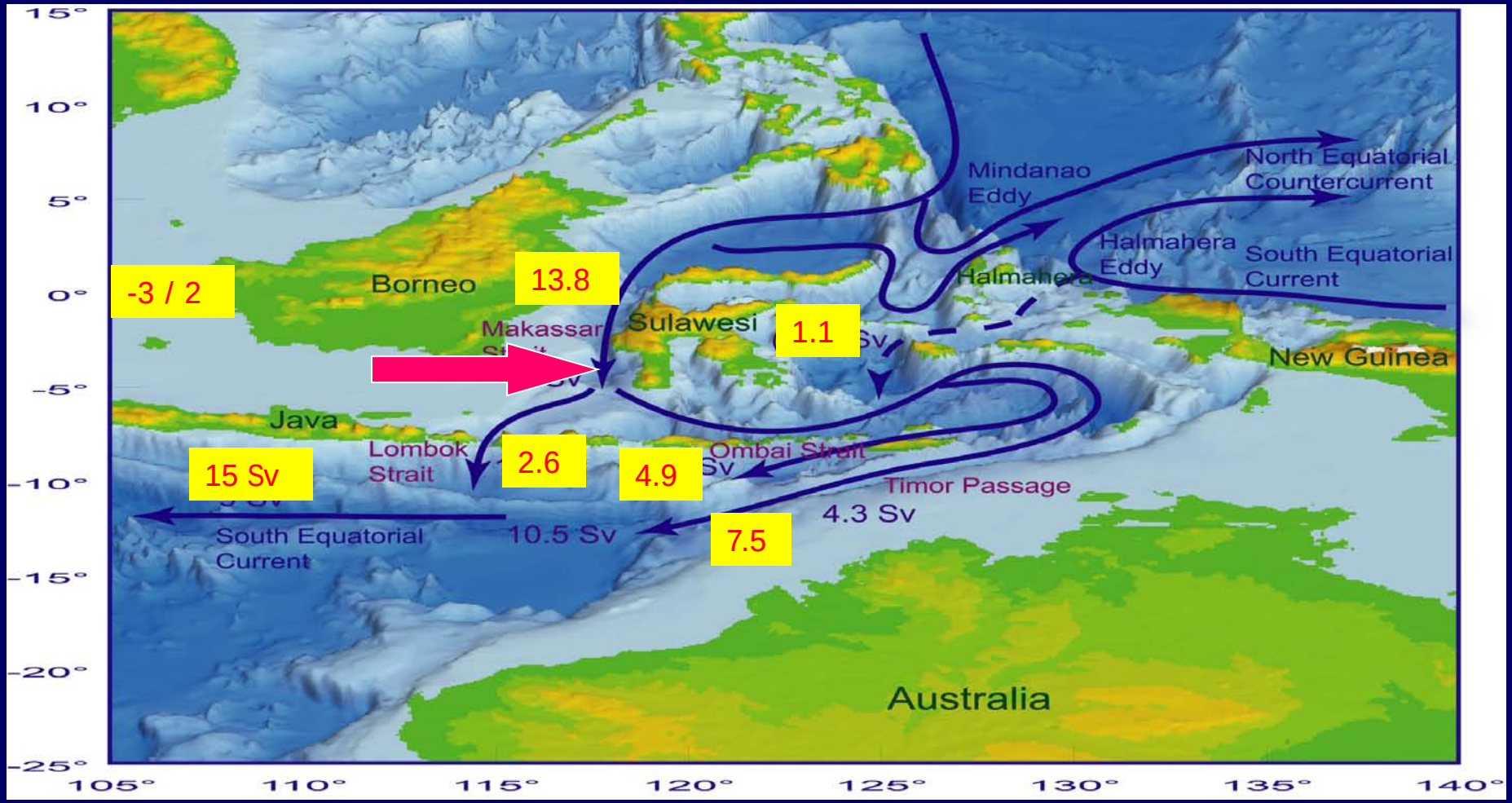
  Ocean: ITF, thermal structure, mixing, circulation, upwelling, fisheries

  (Susanto et al.,1999; 2000; 2001, Susanto and Gordon, 2005)

  Atmosphere: rainfall pattern (Aldrian and Susanto, 2003)
- ✓ Strong tide and rough topography → vigorous tidal mixing → internal waves

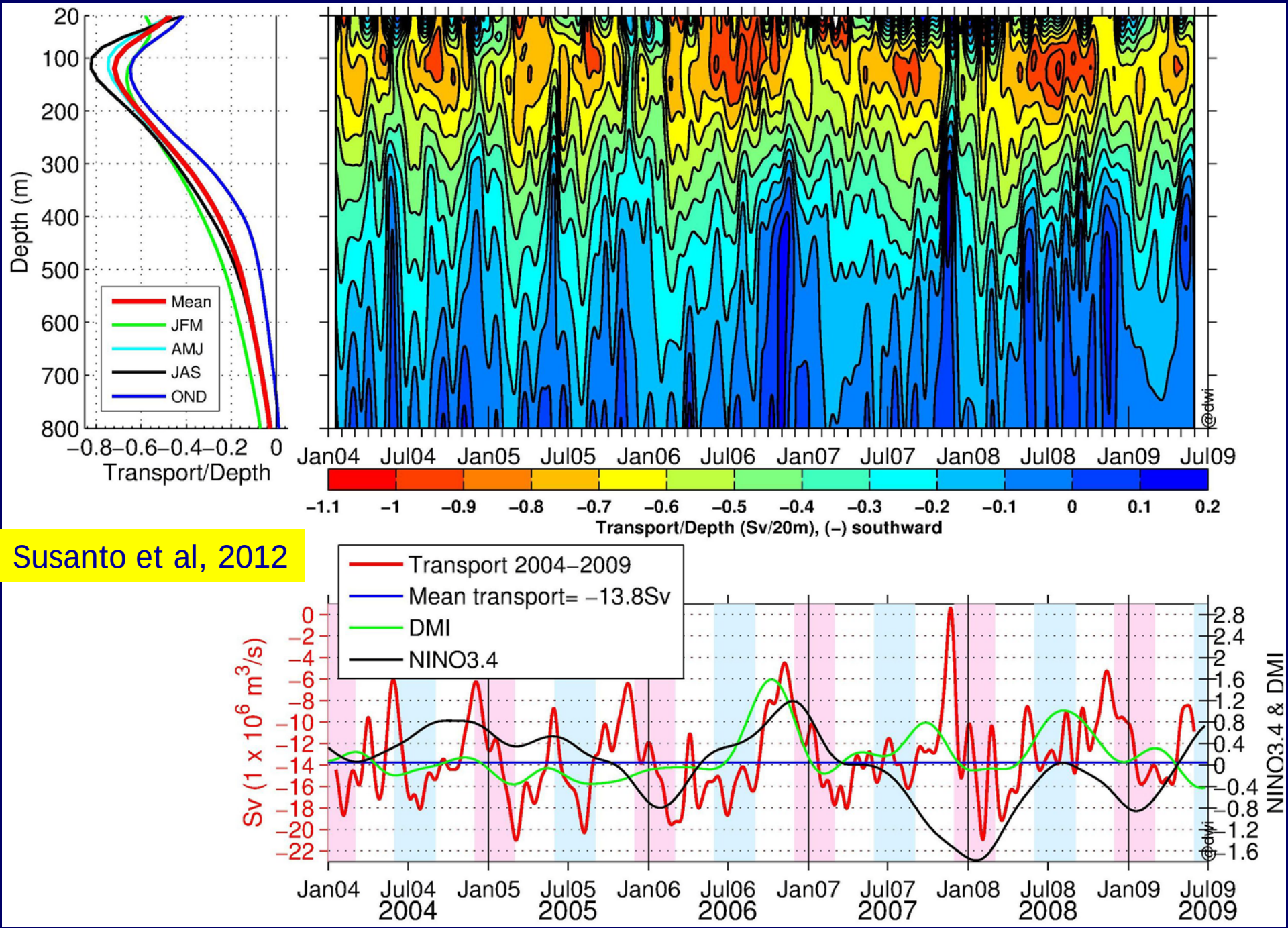
  (Susanto et al., 2005)

INSTANT + Makassar ITF – SITE programs



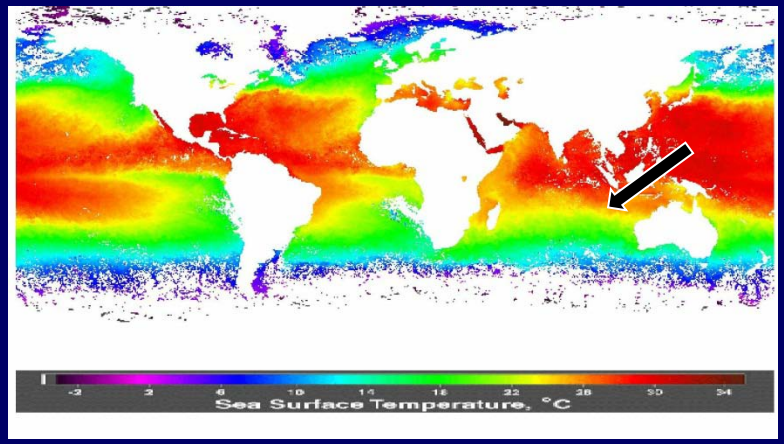
Fang et al., 2010; Gordon et al., 2010; Sprintall et al., 2009; Susanto et al., 2012
van Aken et al., 2009

1 Sv = 10^6 m^3/s

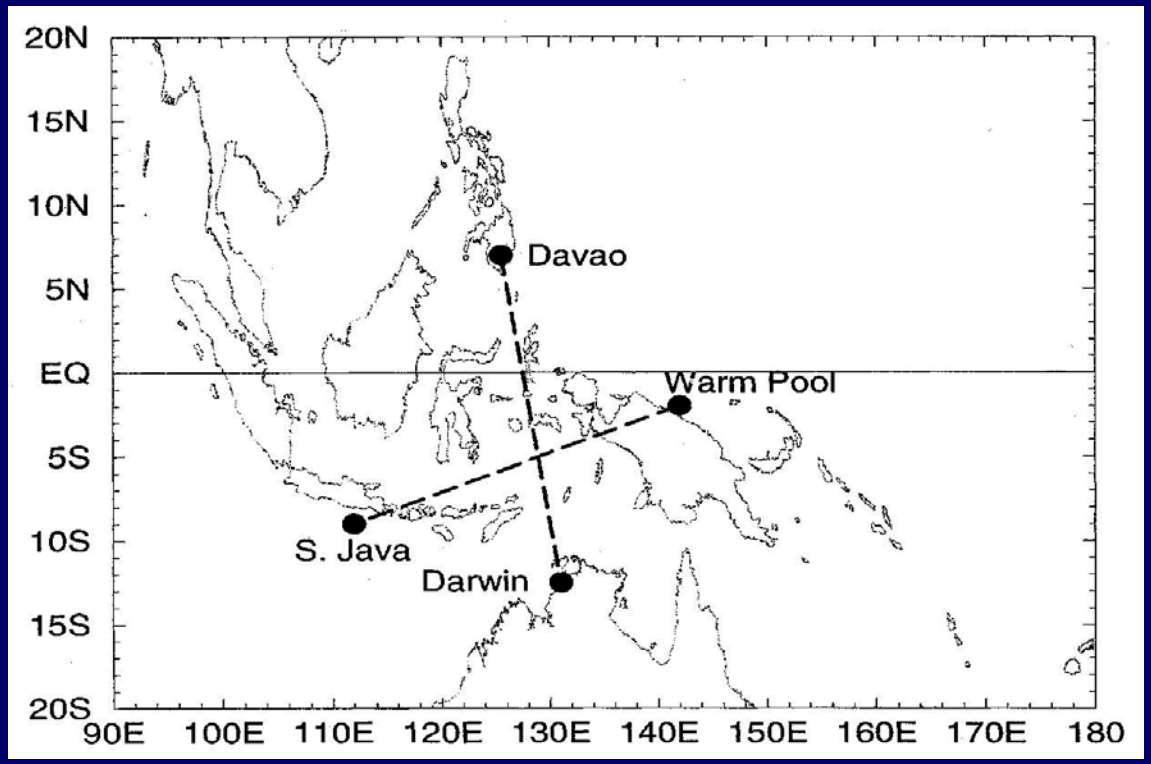


Susanto et al, 2012

Pressure gradient between Pacific and Indian Ocean



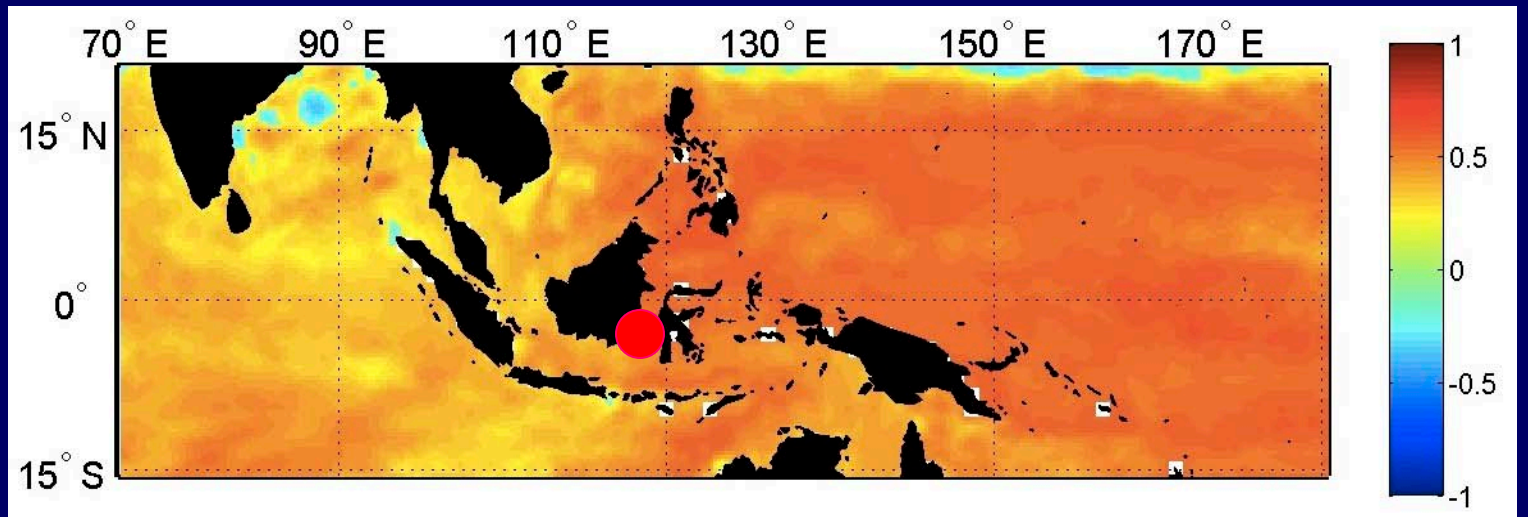
Wyrtki, 1987; Potemra et al., 1997; 2005; Wijffels and Meyers, 2003.



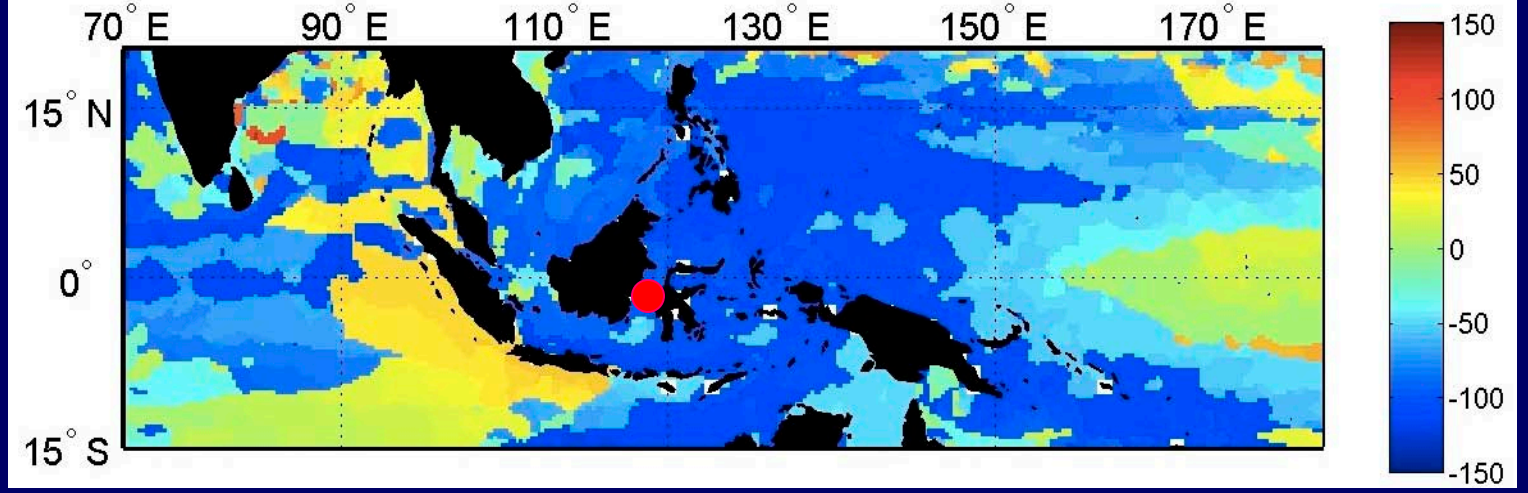
Correlation between Makassar transport (2004-2009) & Sea surface height

AVISO merged gridded SSHA 1/3 x 1/3 degree

Correlation Value

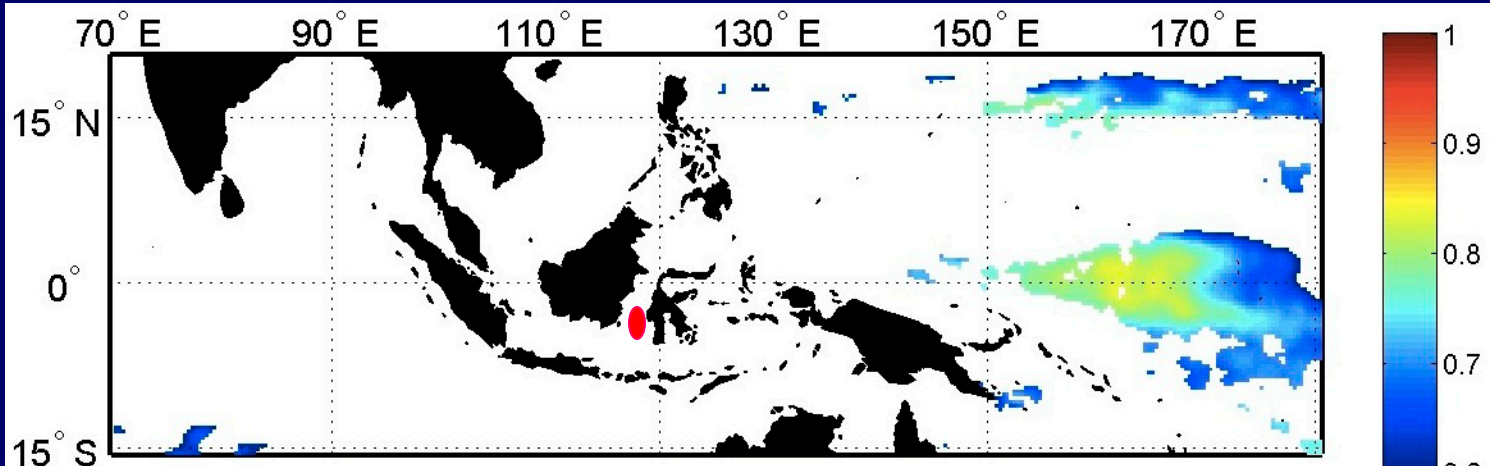


Time Lag (week)

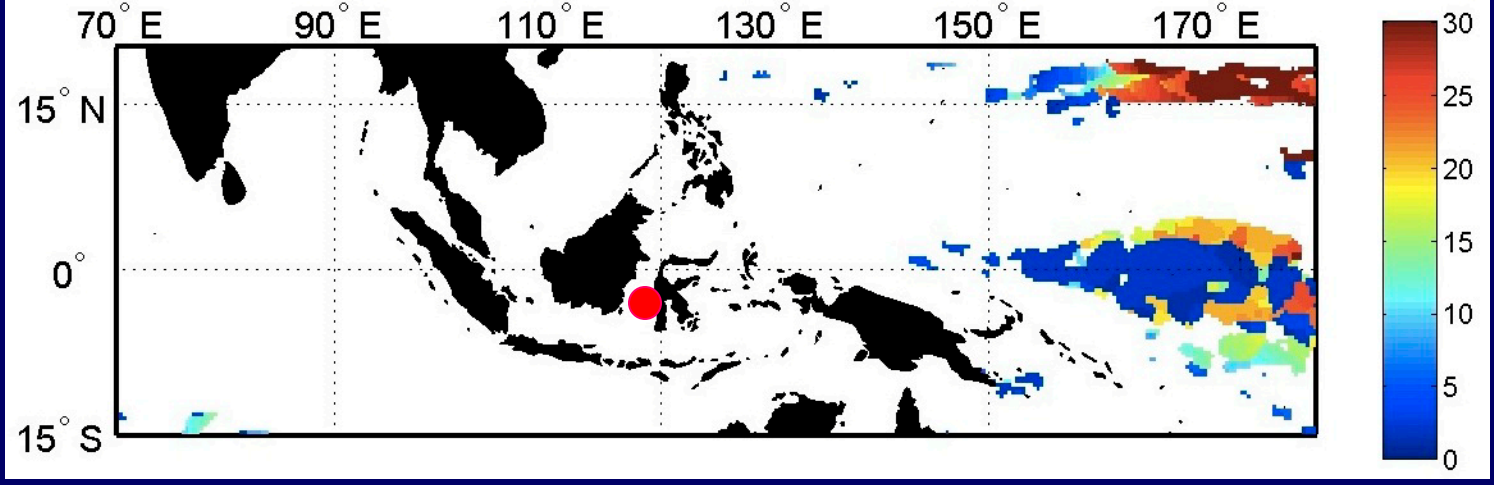


Correlation between Makassar transport & Sea surface height

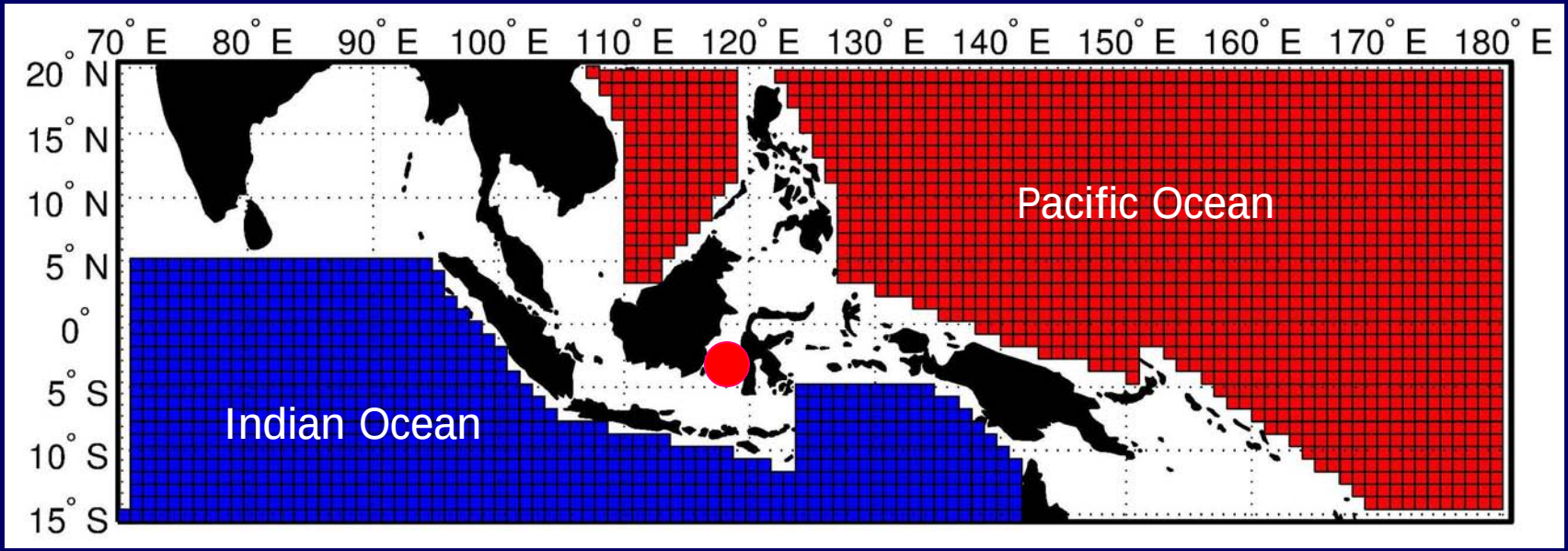
Correlation Value > 0.6



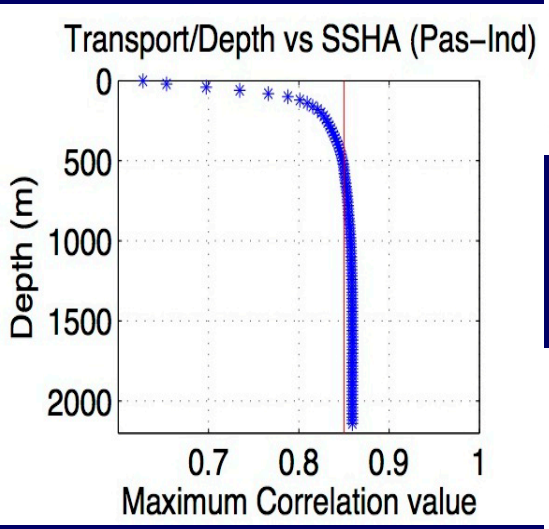
Time Lag (week)

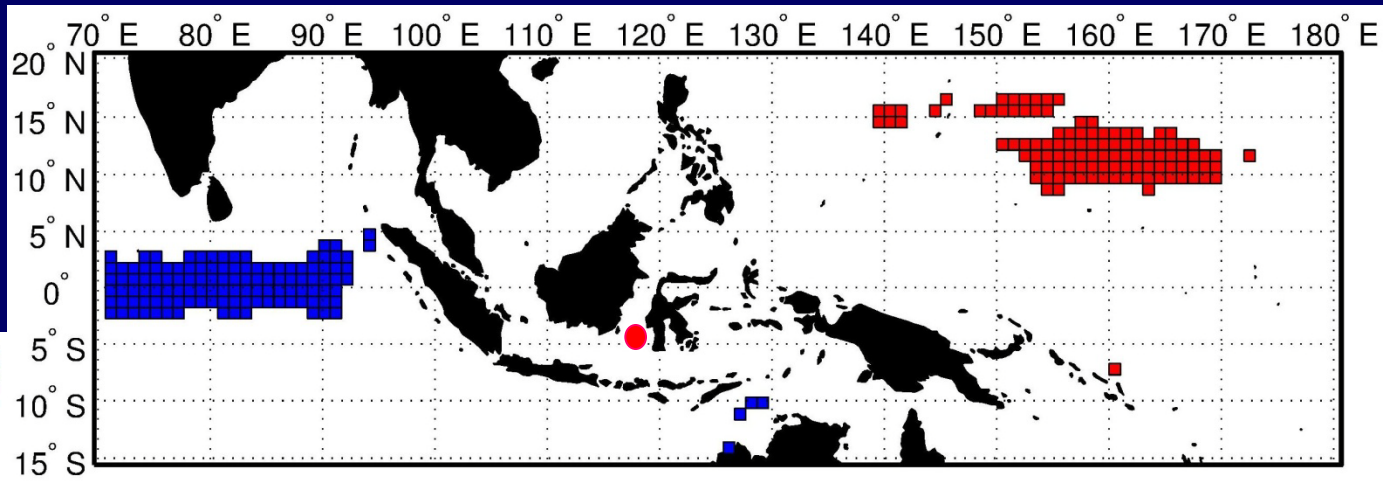


Define grids (1° x 1°): Pacific Ocean (1134 grids) and Indian Ocean (968 grids)

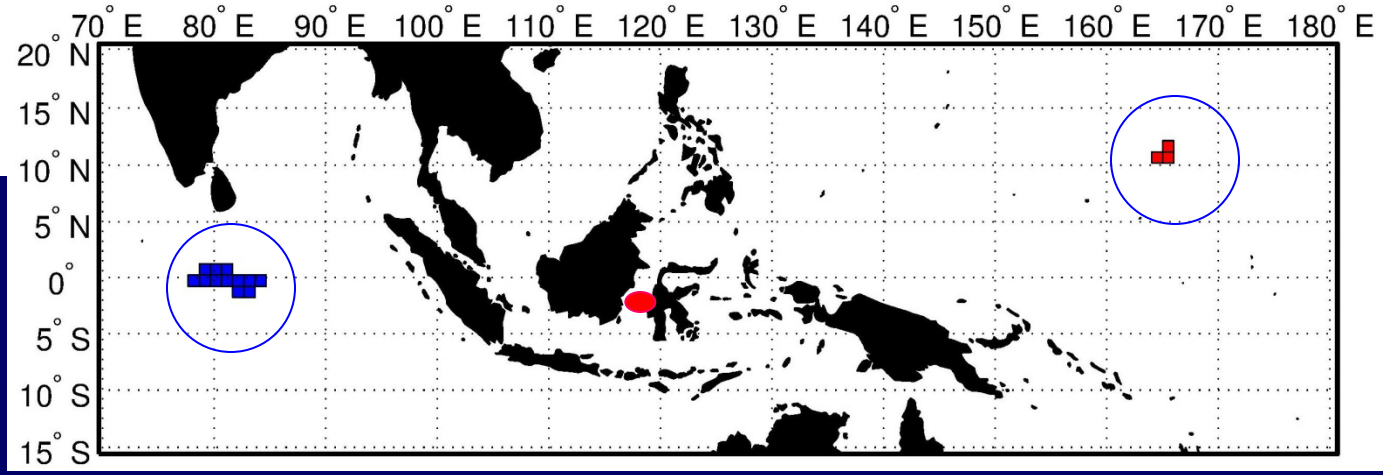


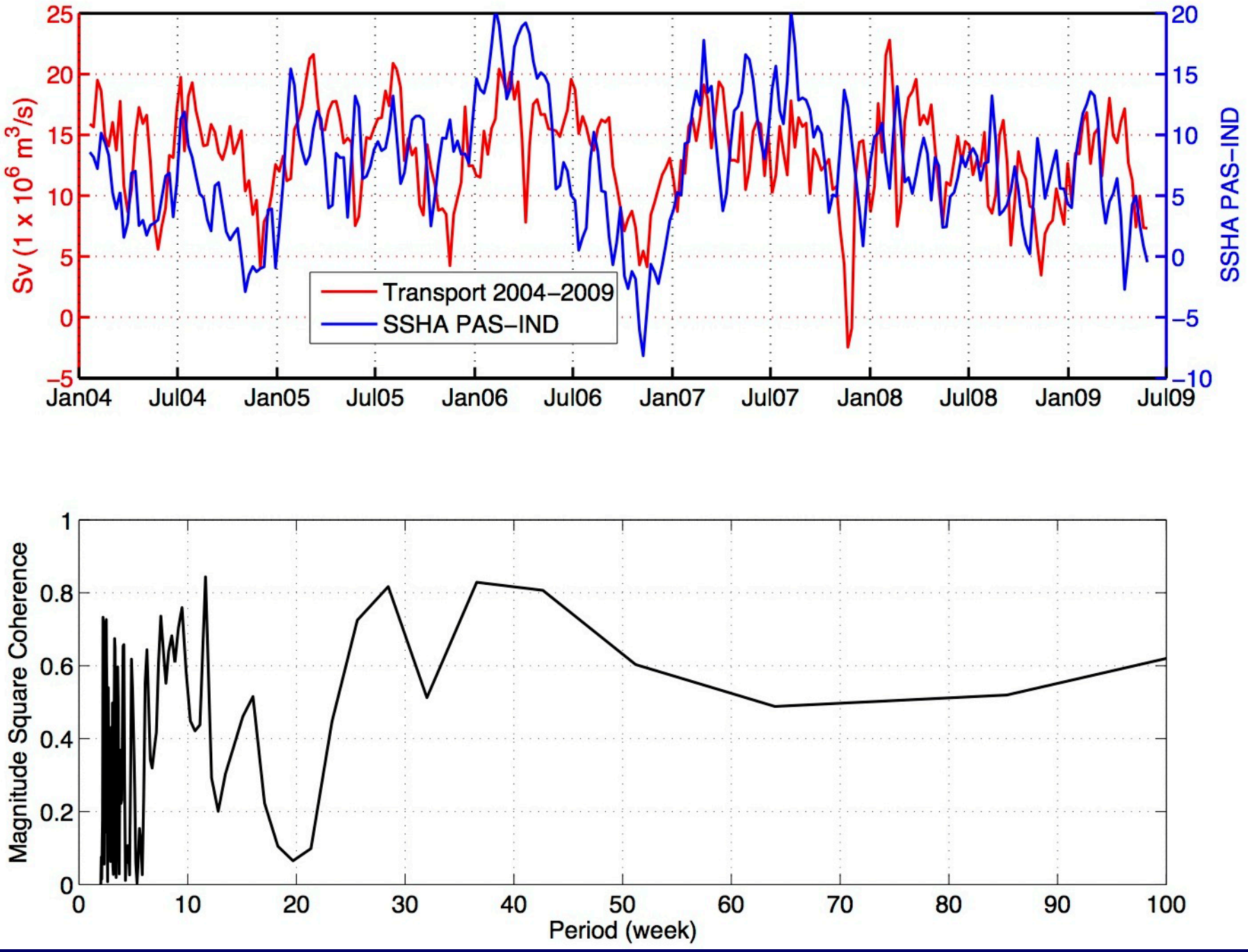
Correlation > 0.80 and time lag > 0

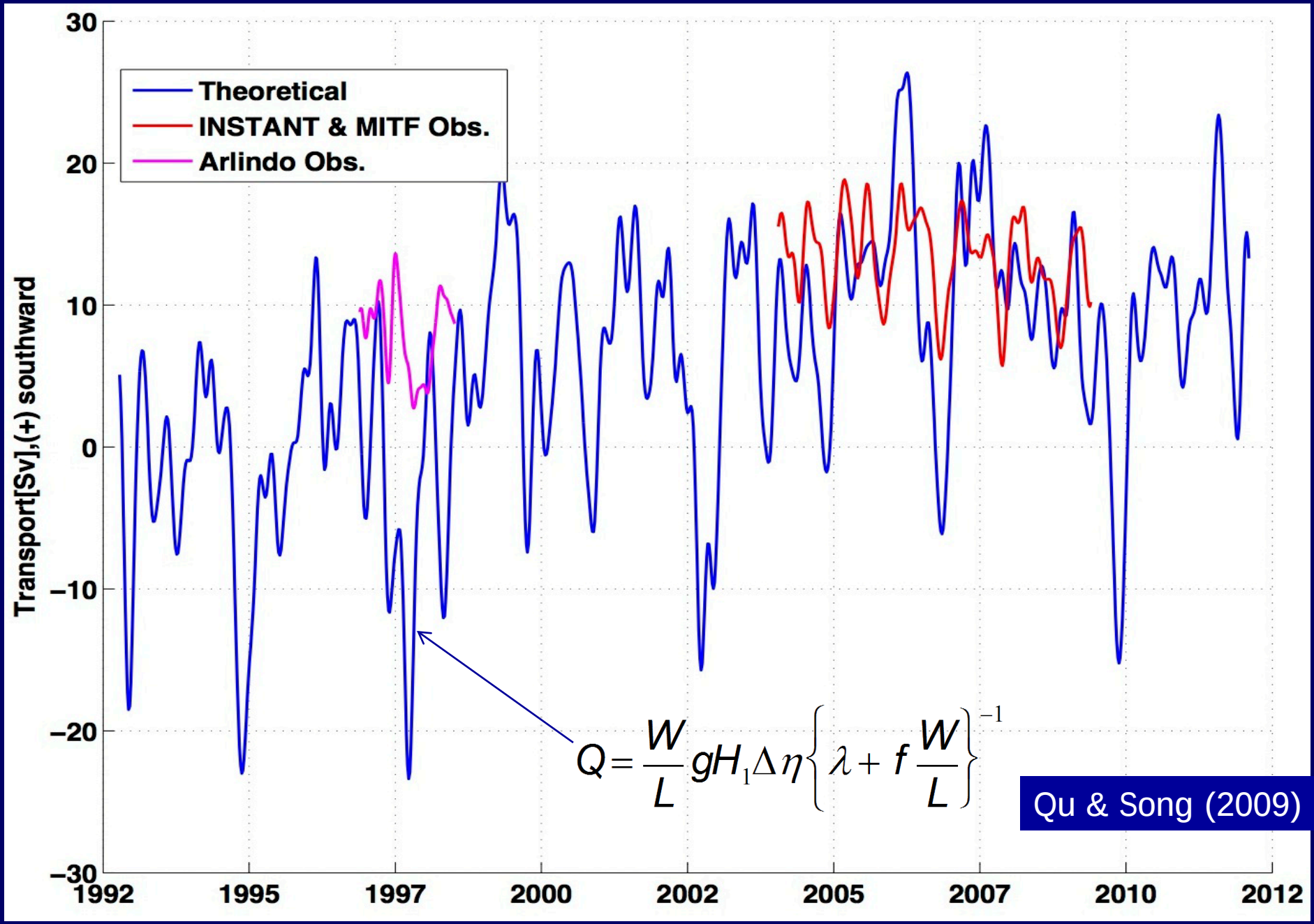




Correlation > 0.85 and time lag > 0

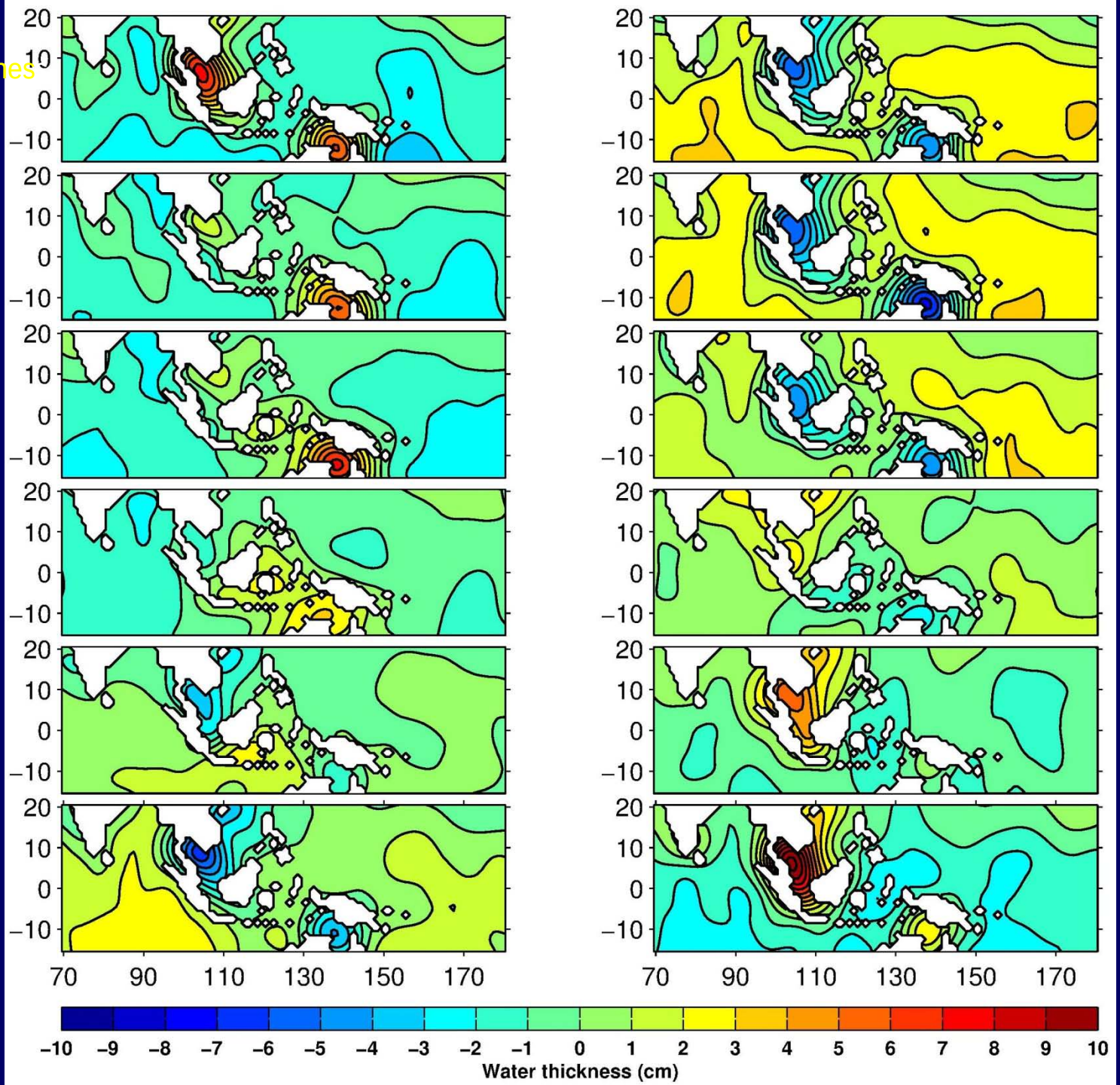



Sv (1 x 10^6 m^3/s)
SSHA PAS−IND
Transport 2004−2009
SSHA PAS−IND
Jan04
Jul04
Jan05
Jul05
Jan06
Jul06
Jan07
Jul07
Jan08
Jul08
Jan09
Jul09
Magnitude Square Coherence
Period (week)

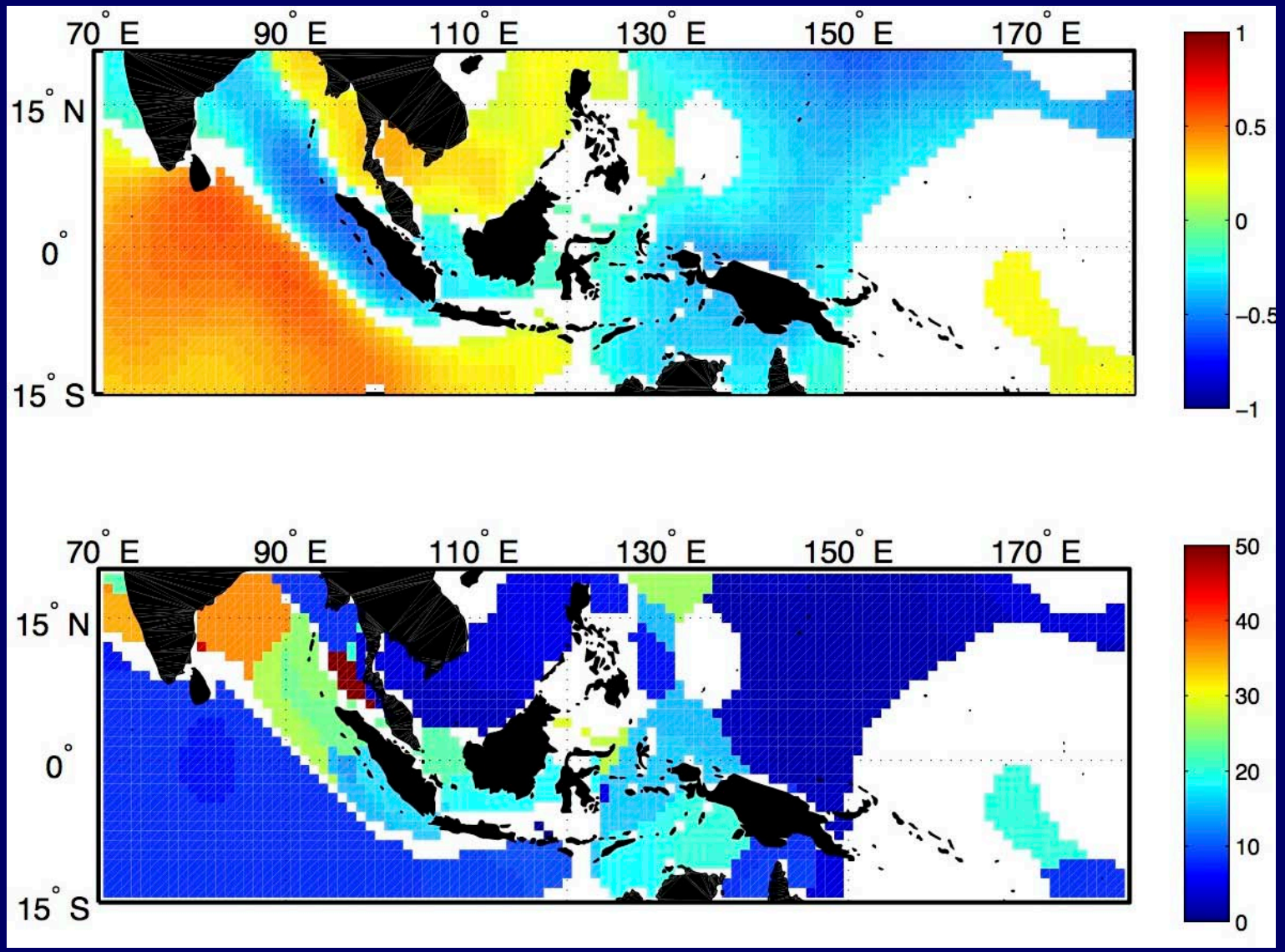

Theoretical
INSTANT & MITF Obs.
Arlindo Obs.
Transport[Sv],(+) southward
30
20
10
0
−10
−20
−30
1992
1995
1997
2000
2002
2005
2007
2010
2012
$Q = \frac{W}{L} g H_1 \Delta \eta \left\{ \lambda + f \frac{W}{L} \right\}^{-1}$
Qu & Song (2009)

GRACE

Water thickness



Correlation between ITF transport vs water thickness/ocean bottom pressure

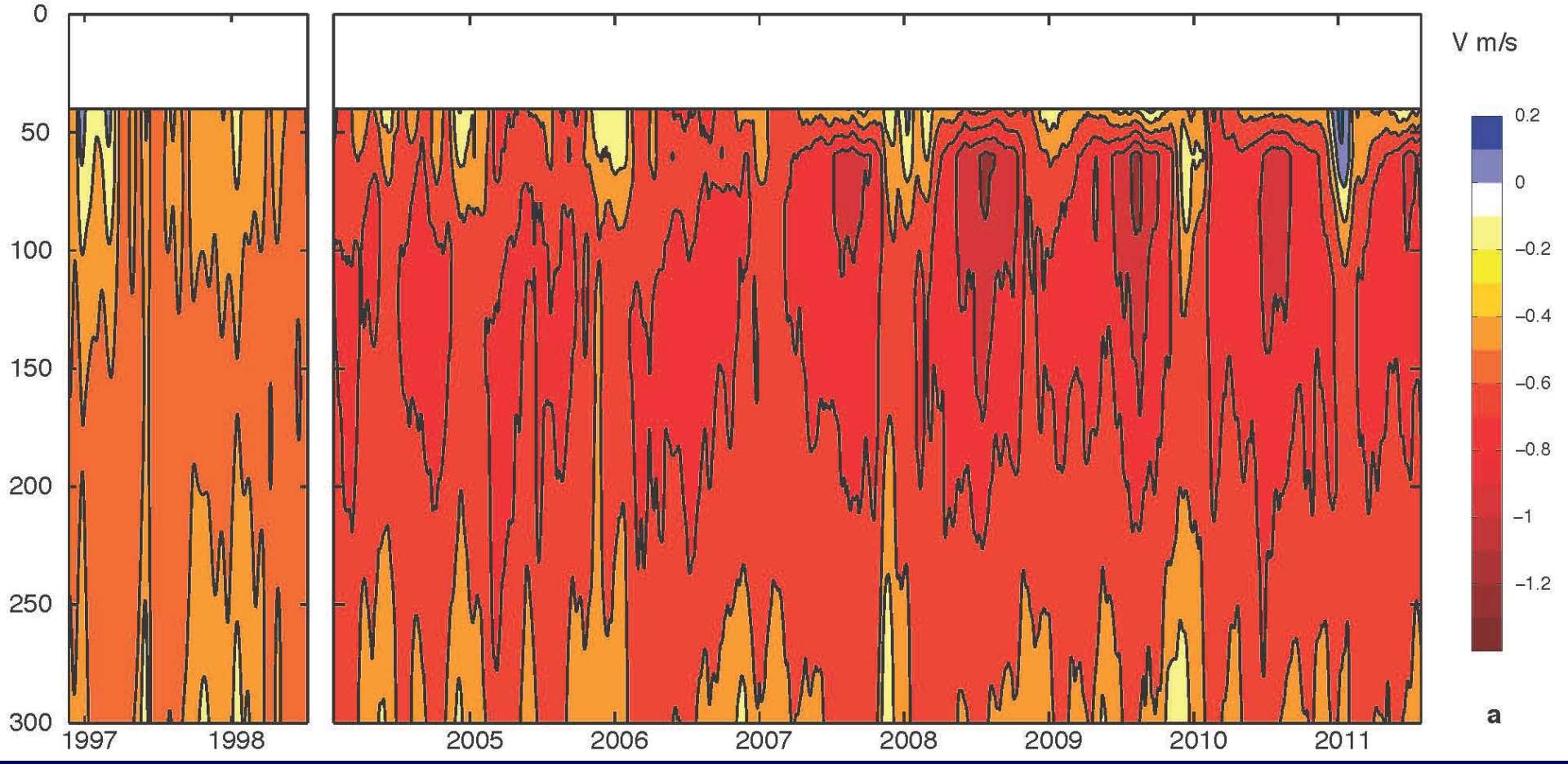


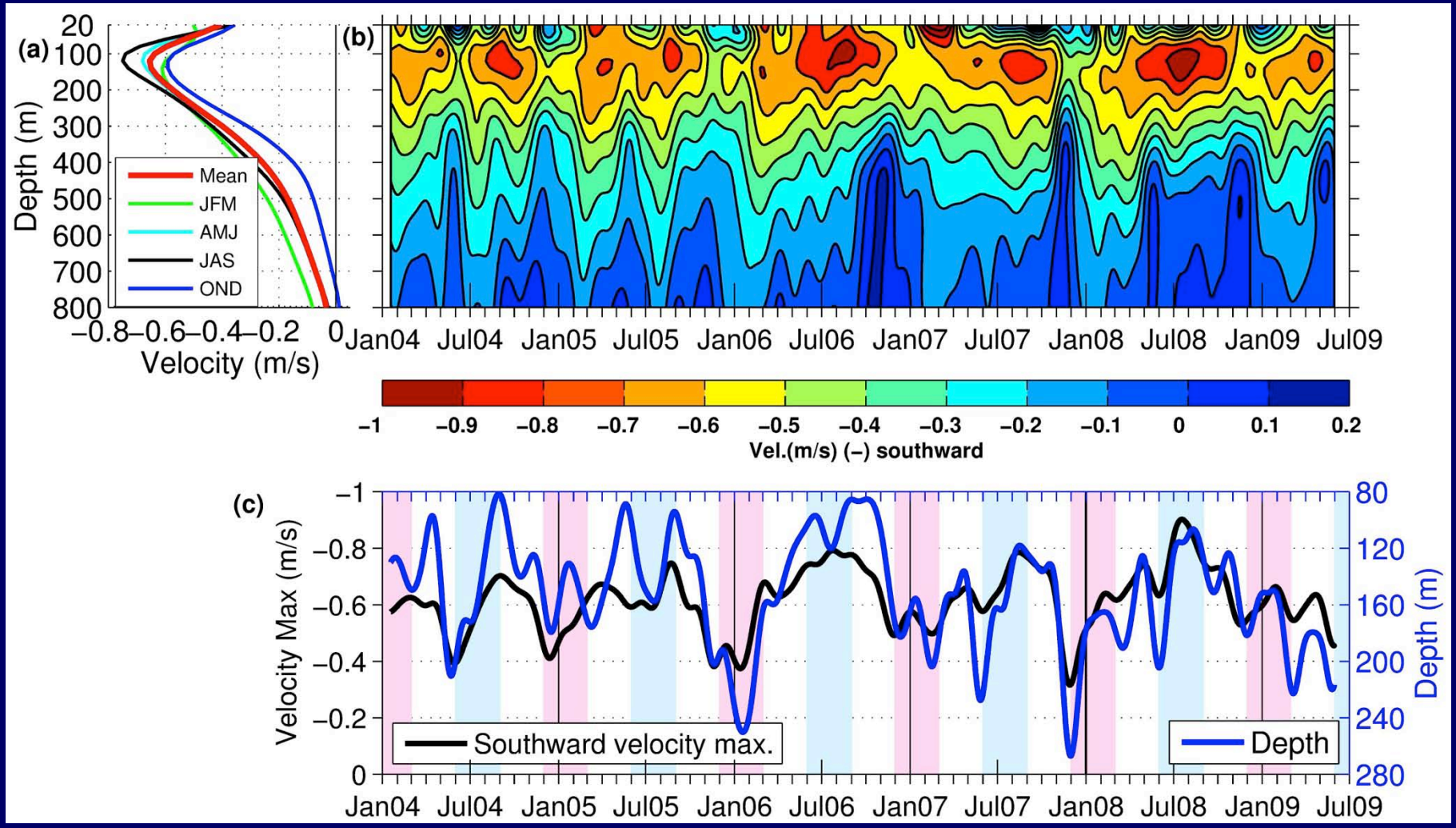
CONCLUSIONS:

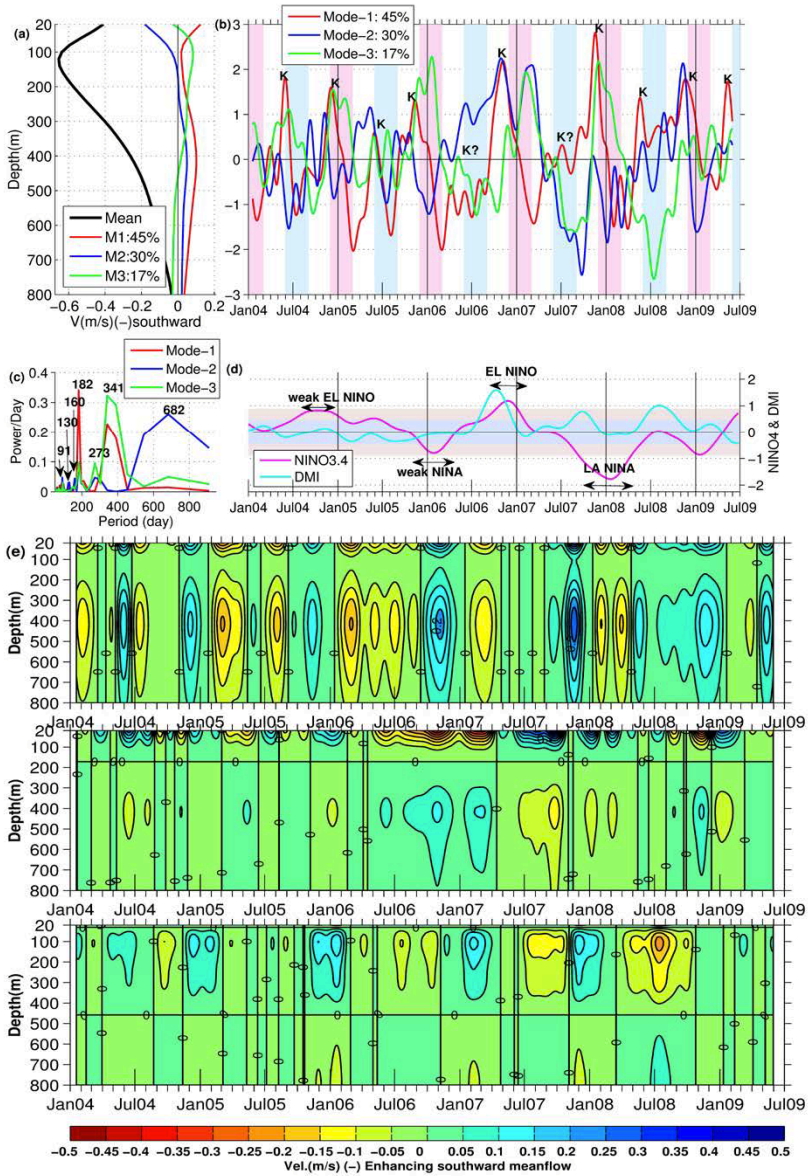
- ITF plays important roles in global ocean circulation and climate. Accurately simulating the ITF is a must for ocean-climate prediction
- ITF varies from daily to interannual time scales associated with tides, Kelvin/Rossby waves, monsoon, ENSO and IOD. ITF varies from -1 to 24 Sv, with annual mean of 15 Sv.
- Sustainable field measurement of the ITF is logistically challenging and expensive, therefore it needs ITF proxies.
- Sea surface height anomaly differences between Pacific (155 E to 170 E and 9 to 13 N) and (to 70 E to 90 E and -2 to 2 N) provide best prediction of the total volume ITF transport in the Makassar Strait (transport in the upper 120 m have no correlation with SSHA differences between Pacific and Indian Ocean).

THANKYOU

Makassar velocity profile 2004-2011 (Gordon et al., 2012)

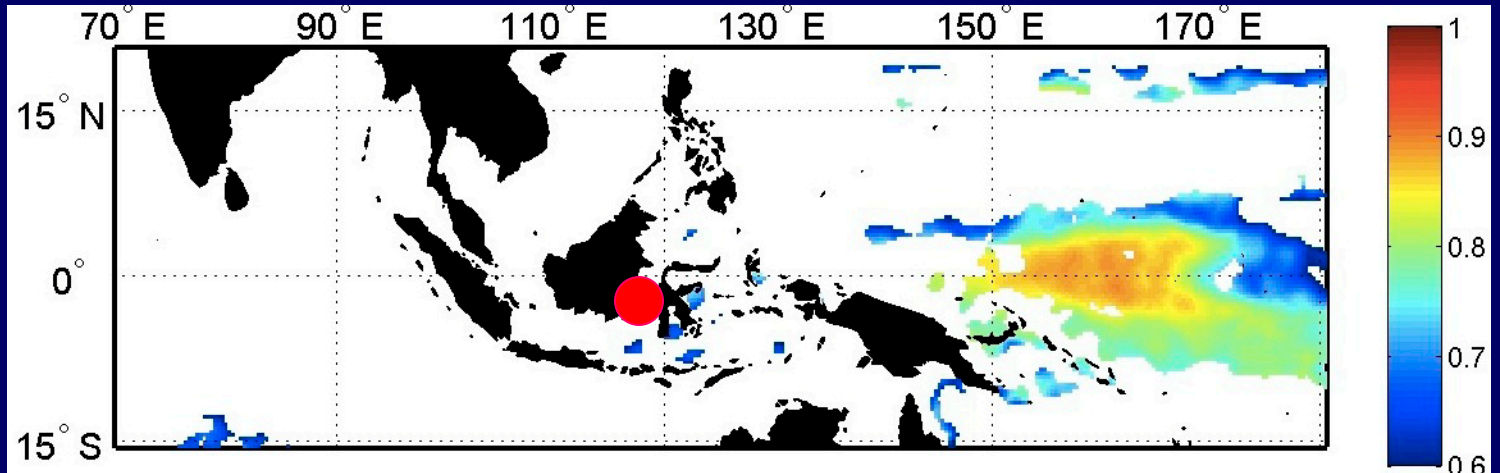



(a)
Depth (m)
20
100
200
300
400
500
600
700
800
Mean
JFM
AMJ
JAS
OND
−0.8 −0.6 −0.4 −0.2 0
Velocity (m/s)
(b)
Jan04 Jul04 Jan05 Jul05 Jan06 Jul06 Jan07 Jul07 Jan08 Jul08 Jan09 Jul09
−1 −0.9 −0.8 −0.7 −0.6 −0.5 −0.4 −0.3 −0.2 −0.1 0 0.1 0.2
Vel.(m/s) (−) southward
(c)
Velocity Max (m/s)
−1
−0.8
−0.6
−0.4
−0.2
0
Southward velocity max.
Depth
80
120
160
200
240
280
Depth (m)
Jan04 Jul04 Jan05 Jul05 Jan06 Jul06 Jan07 Jul07 Jan08 Jul08 Jan09 Jul09

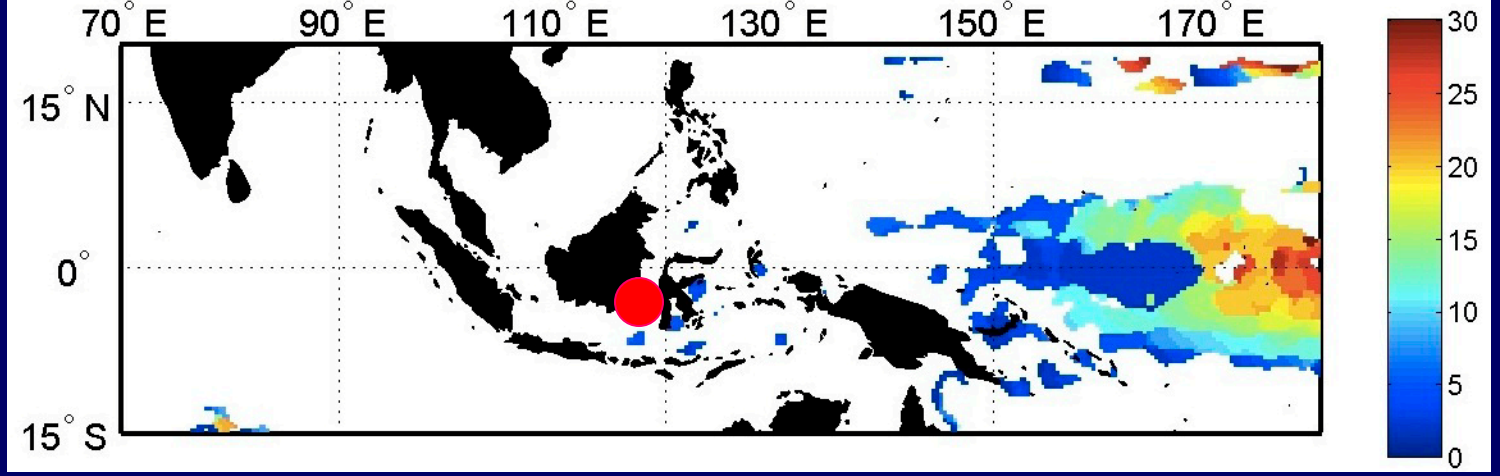

(a)
Depth(m)
Mean
M1:45%
M2:30%
M3:17%
V(m/s)(−)southward
(b)
Mode−1: 45%
Mode−2: 30%
Mode−3: 17%
K
K?
(c)
Power/Day
Period (day)
182
160
341
130
91
273
682
Mode−1
Mode−2
Mode−3
(d)
weak EL NINO
EL NINO
weak NINA
LA NINA
NINO3.4
DMI
NINO4 & DMI
(e)
Depth(m)
Jan04 Jul04 Jan05 Jul05 Jan06 Jul06 Jan07 Jul07 Jan08 Jul08 Jan09 Jul09
−0.5 −0.45 −0.4 −0.35 −0.3 −0.25 −0.2 −0.15 −0.1 −0.05 0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5
Vel.(m/s) (−) Enhancing southward meanflow

Top 100m MAK Transport vs Sea surface height derived from Altimeter Satellite

Corr > 0.6

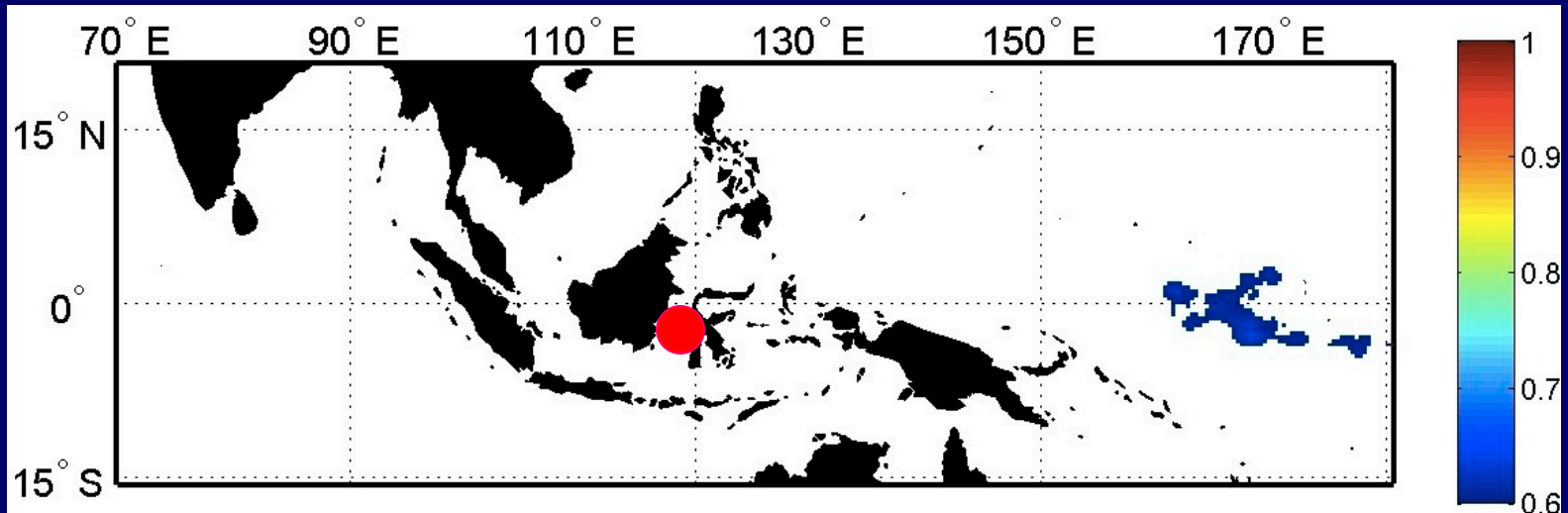


Time lag > 0

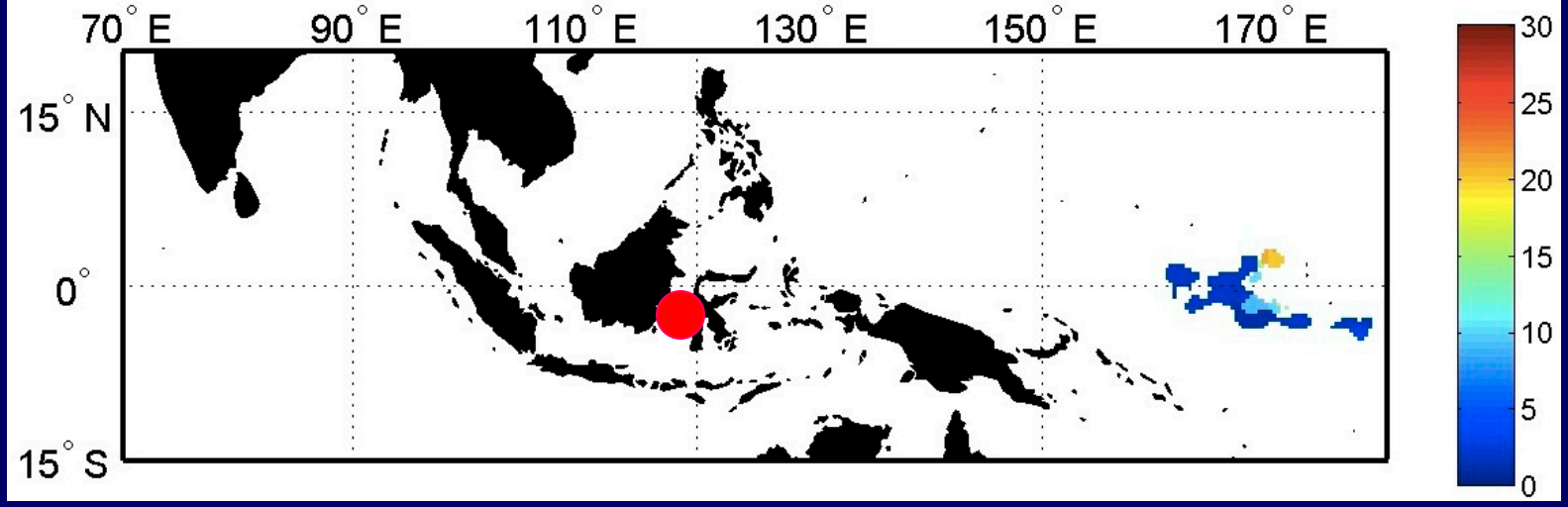


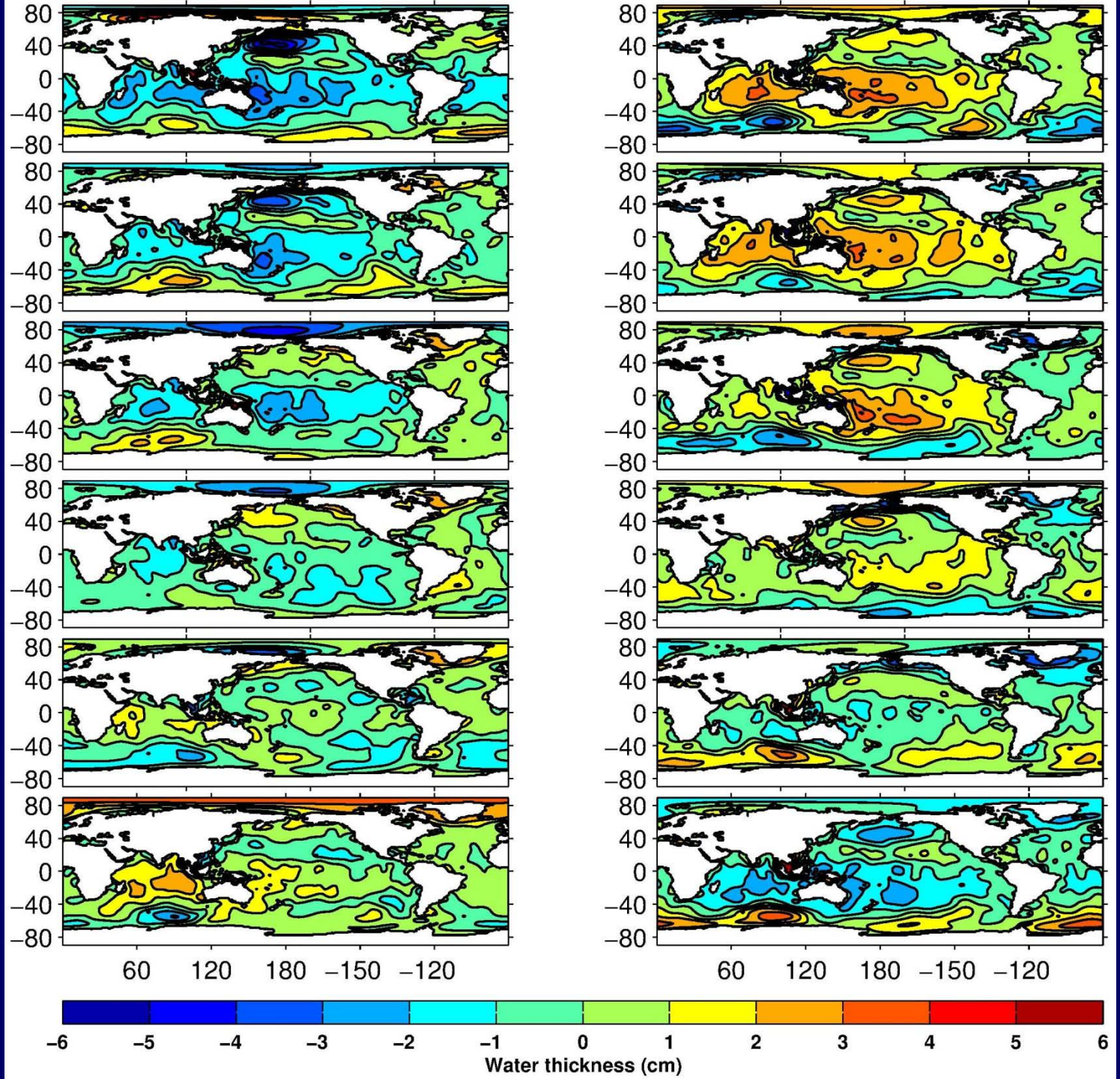
Surface MAK Transport vs Sea surface height derived from Altimeter Satellite

Corr > 0.6



Time lag > 0




80
40
0
−40
−80
60
120
180
−150
−120
−6
−5
−4
−3
−2
−1
0
1
2
3
4
5
6
Water thickness (cm)