Capturing the evolution of Indian Ocean Dipole using RAMA* buoy network

Iskhaq Iskandar[1,2] and Michael J. McPhaden[3]

[1] Dept. Physics, Fac. Mathematics and Natural Sciences, Sriwijaya University, South Sumatra, INDONESIA.

[2] Center for Geohazard and Climate Change Study, Fac. Mathematics and Natural Sciences, Sriwijaya University, South Sumatra, INDONESIA.

[3] NOAA/PMEL, Seattle, WA, USA.

*RAMA: ***R***esearch Moored ***A***rray for African – Asia – Australian – ***M***onsoon ***A***nalysis and Prediction

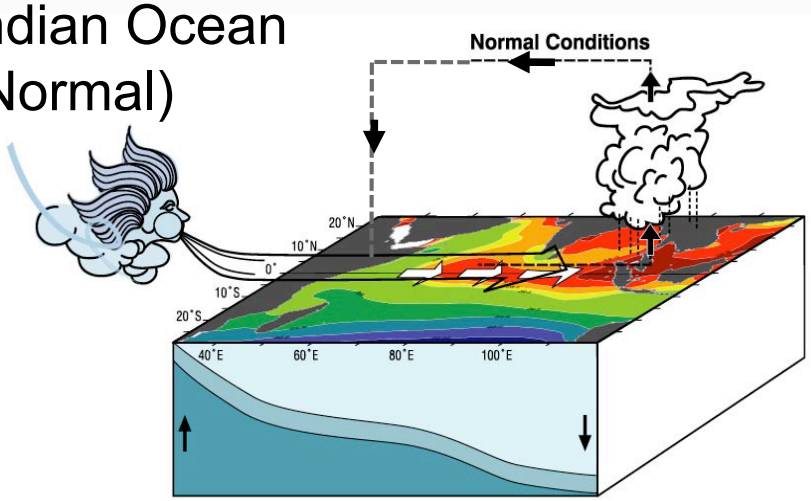
5th GEOSS-AP Symposium
Tokyo, 2-4 April 2012

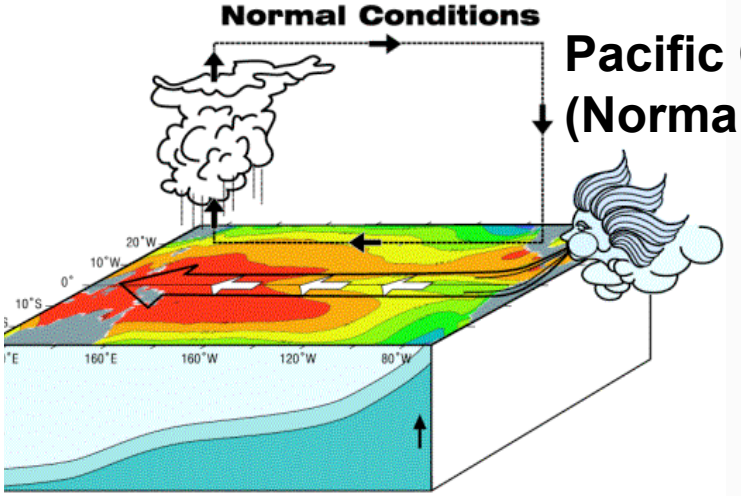
Why Indian Ocean?

- The Indian Ocean is unique among the three tropical ocean basins in that it is blocked by land in the north.
- It experiences a clear seasonal monsoonal wind and intense seasonal rains over Indian subcontinent, Southeast Asia, East Africa and Australia.
- The seasonal rains support agricultural productions that provides food for a third of the world's population → the rains show interannual variations (e.g. *deficit or excess*).

Coupled ocean-atmosphere phenomena in the Indo-Pacific sector: *IOD and ENSO*

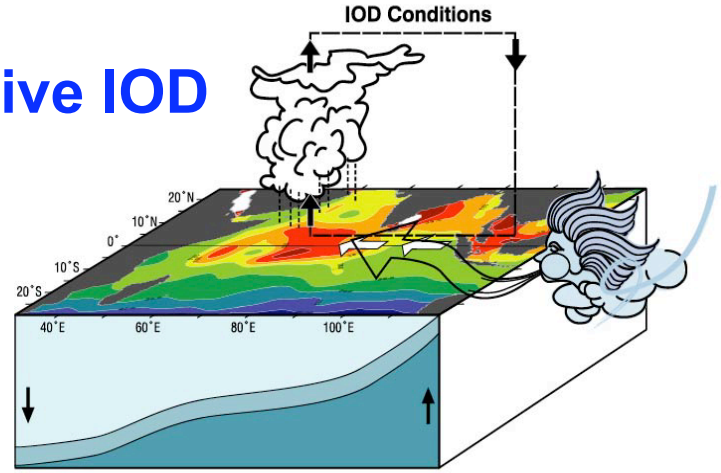
Indian Ocean (Normal)

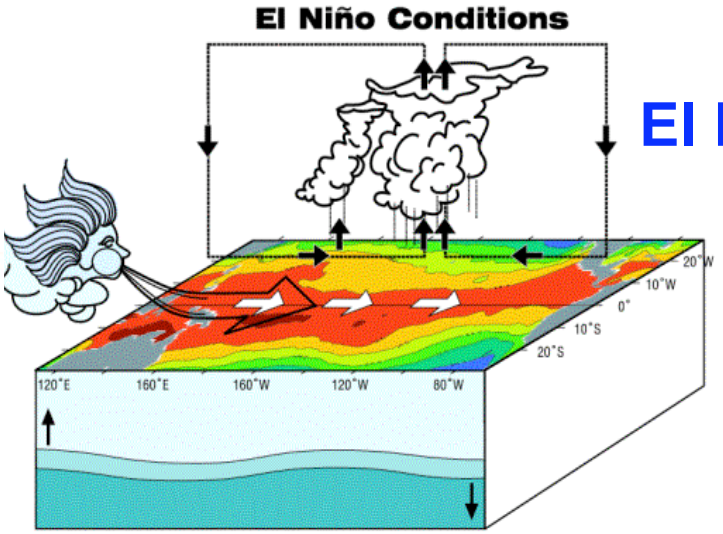




Pacific Ocean (Normal)

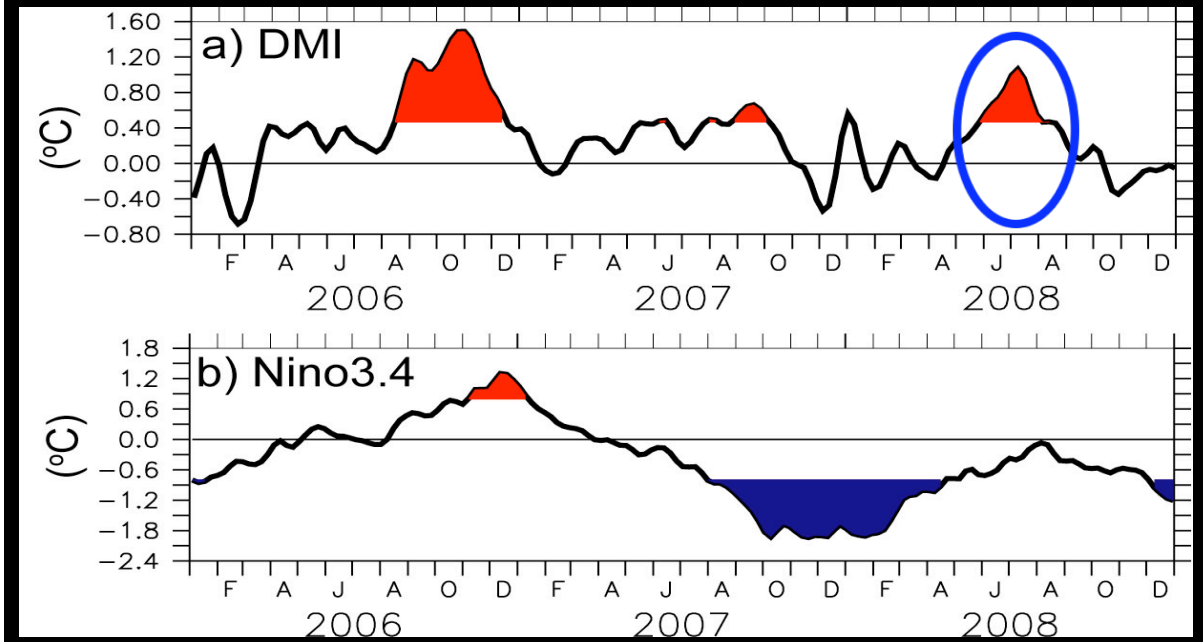
Positive IOD

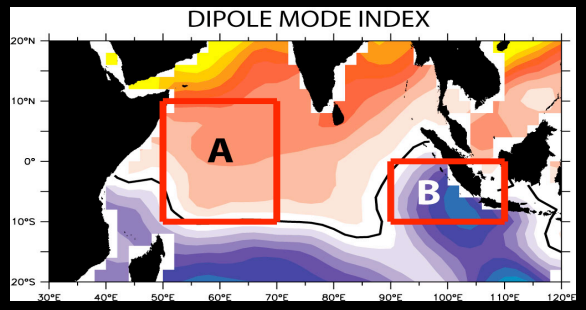


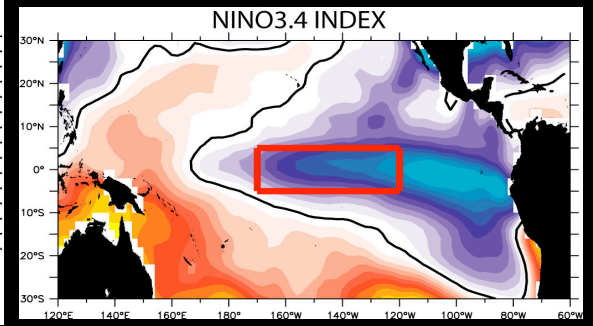


El Nino

Recent IOD and ENSO occurrences







- The 2006 IOD was a strong event, followed by a weaker El Niño.
- The 2007 IOD was a weaker and short-lived event which co-occurred with La Niña event in the Pacific.
- The 2008 IOD was an early matured and abruptly terminated event; *developed in April*, *matured in July, and terminated in September*.

Data

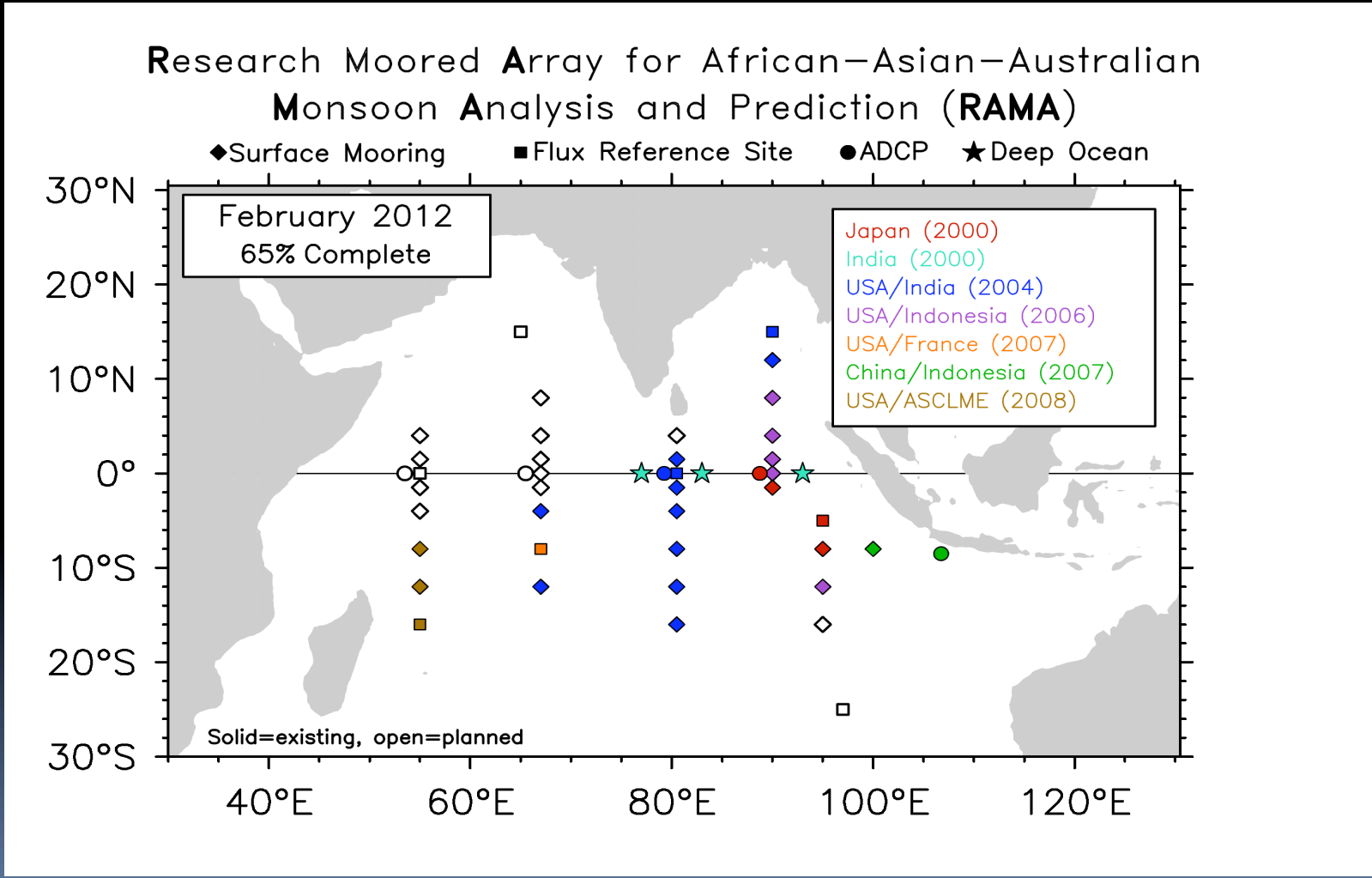
- **RAMA buoys**: m-TRITON (temperature), ATLAS (10m current), ADCP (subsurface currents)
- Weekly SSH from AVISO (Jan.1993 – Dec.2009).
- Weekly SST from TMI (Jan. 2000 – Dec.2009).
- Daily winds from QSCAT (Jan.1990 – Dec.2009).
- 5-day OSCAR surface currents (Jan.1993 – Dec.2009).

Model

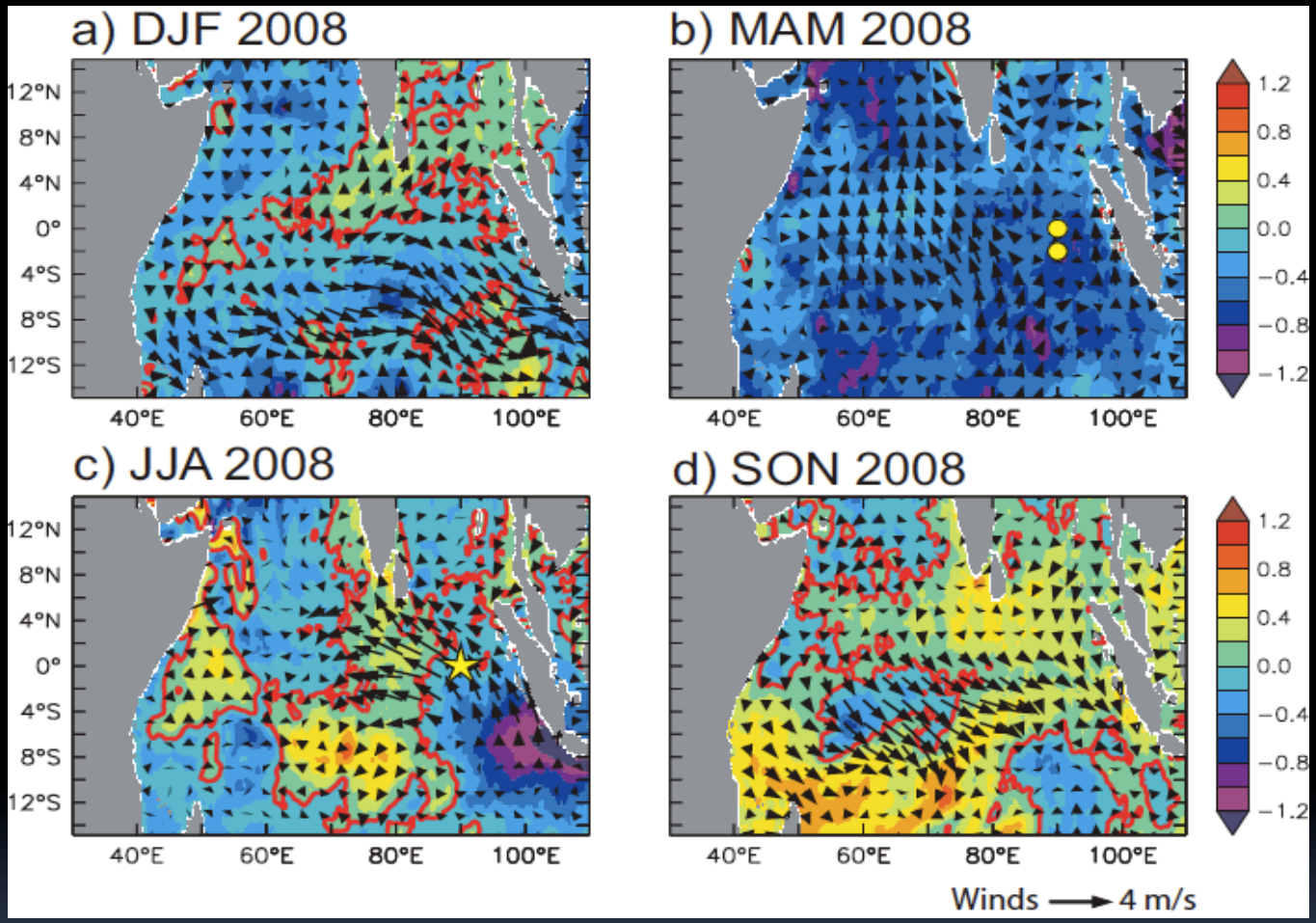
- A wind-driven, linear, continuously stratified long-wave ocean model forced by daily wind stress from ECMWF.

  [*Yu and McPhaden*, 1999-PO, *Nagura and McPhaden*, 2011-IO]

RAMA: *R*esearch Moored *A*rray for African – Asia – Australian – *M*onsoon *A*nalysis and Prediction

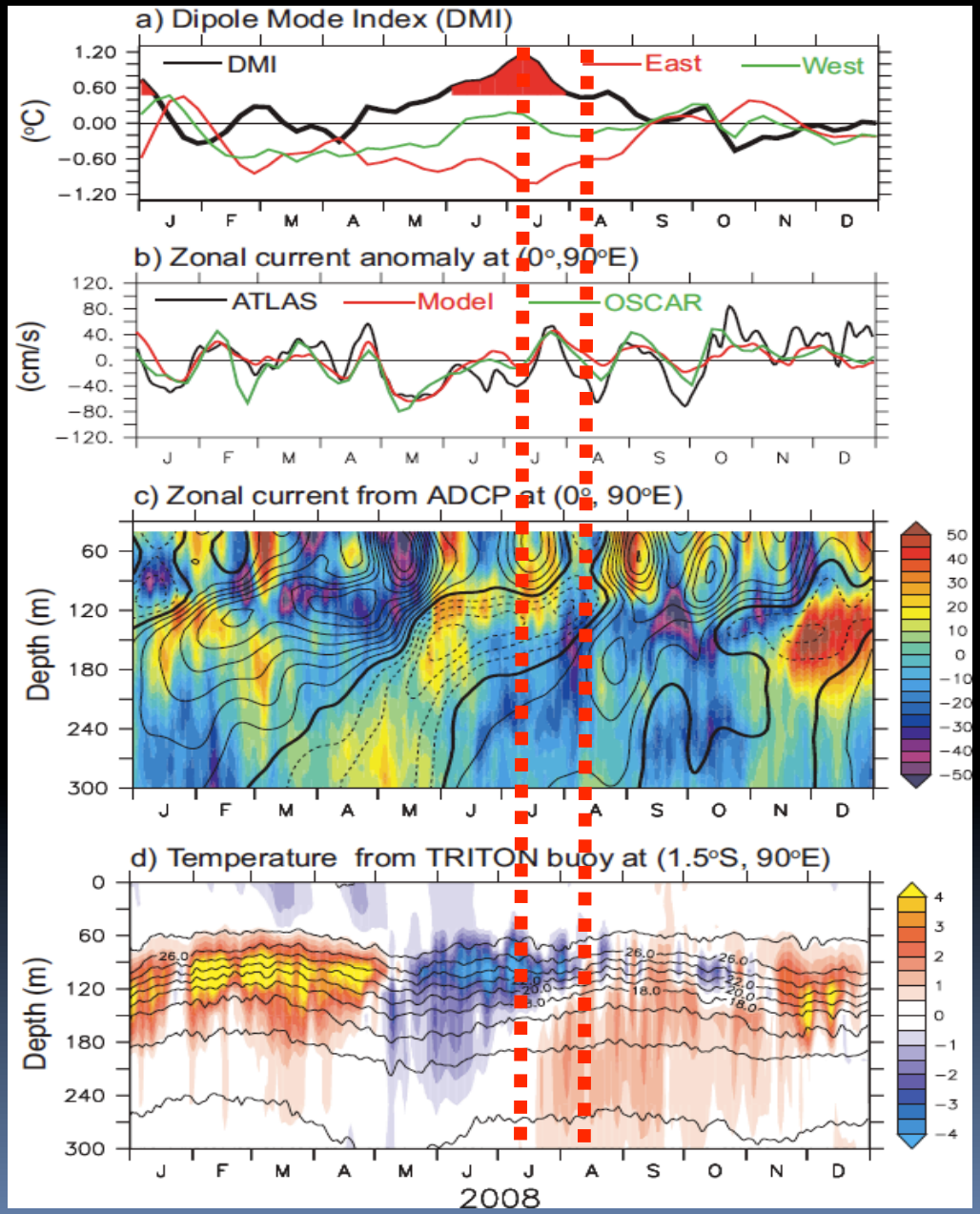


Basin-wide evolution of the 2008 IOD



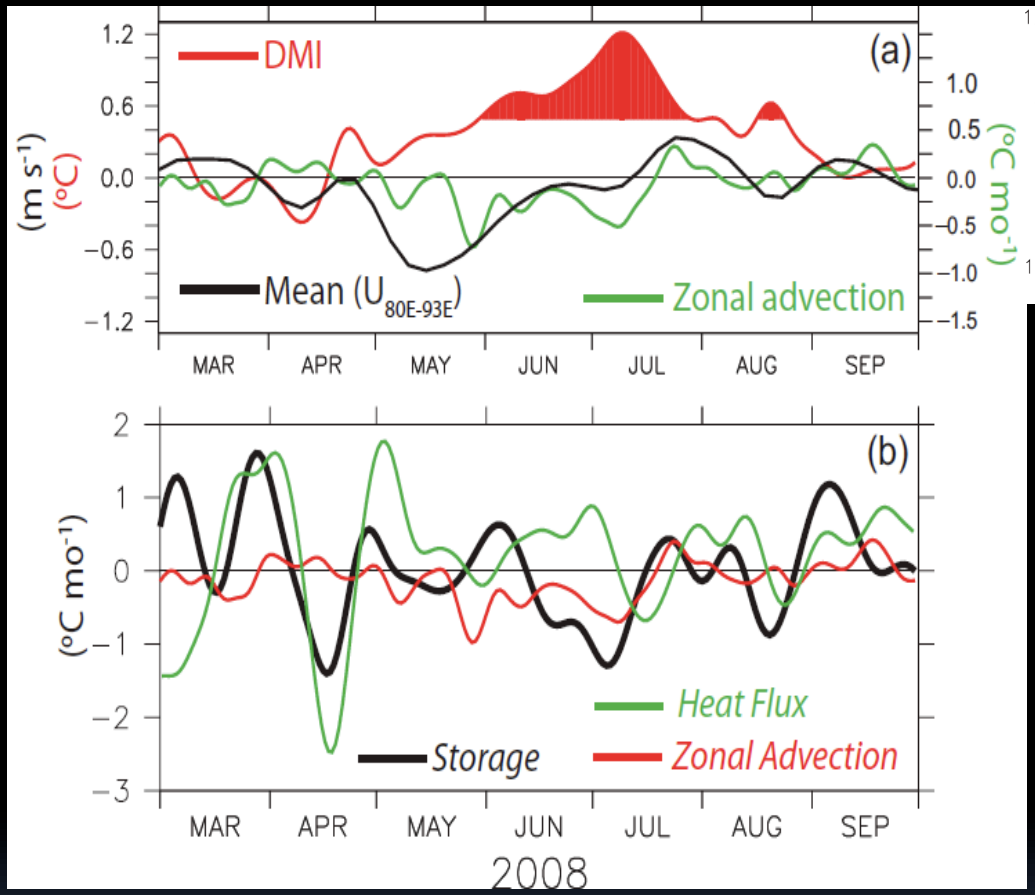
- It was preceded by a basin-wide cooling associated with the 2007/08 La Niña.
- It was developed in April, matured in July and terminated in September.

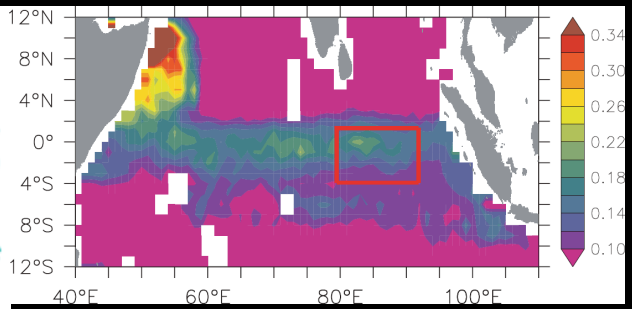
Subsurface oceanic variations



- Westward near-surface zonal current during the IOD event.
- There was a strong eastward zonal current during the decaying phase of the IOD.
- Negative temperature anomaly was observed from the development phase until the termination phase of the event.

Zonal temperature advection



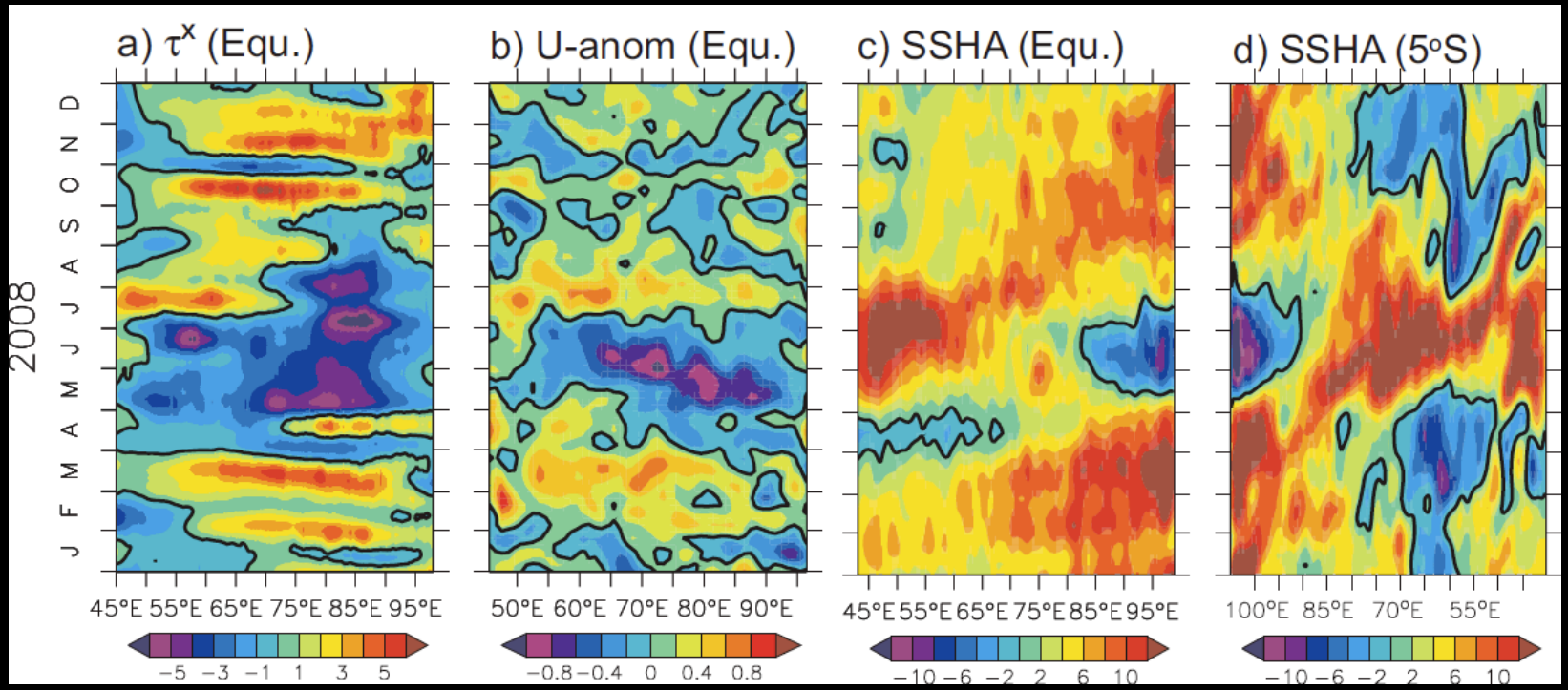


Heat balance:

$$\frac{\partial T}{\partial t} = \frac{Q_0}{\rho C_p H} - u\frac{\partial T}{\partial x} - v\frac{\partial T}{\partial y} + R$$

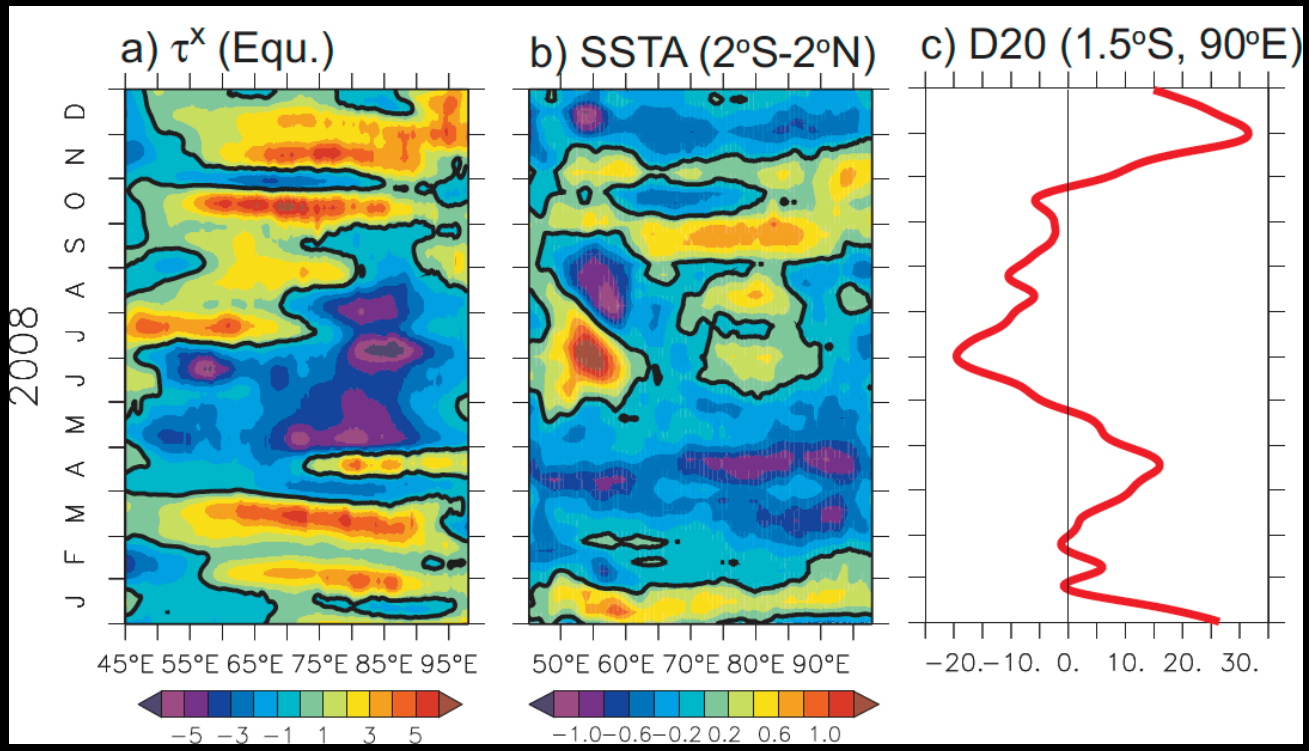
- The positive (warming) of *u*(dT)/dx in July shows the important of zonal advection on the surface temperature change (dT/dx) during the decaying phase of the IOD event.

Variability of surface fields (1)



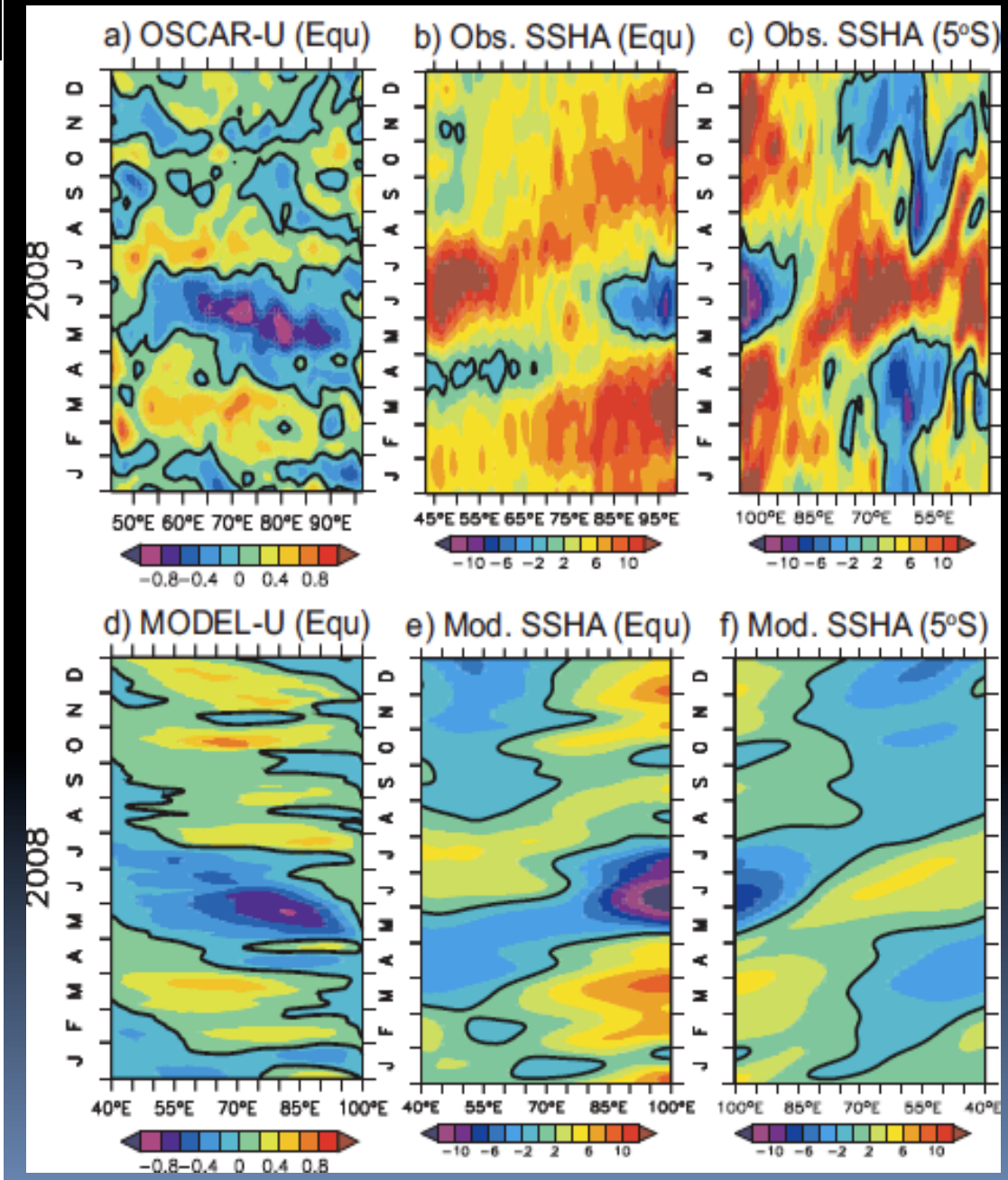
- Easterly wind anomalies excited westward surface currents (negative SSHA – upwelling Kelvin waves) along the equator and eastward currents (positive SSHA – *downwelling Rossby waves*) in the off-equatorial region.
- Strong eastward currents (large positive SSHA) were observed along the equator before and after the IOD event associated with strong westerly winds along the equator.

Variability of surface fields (2)



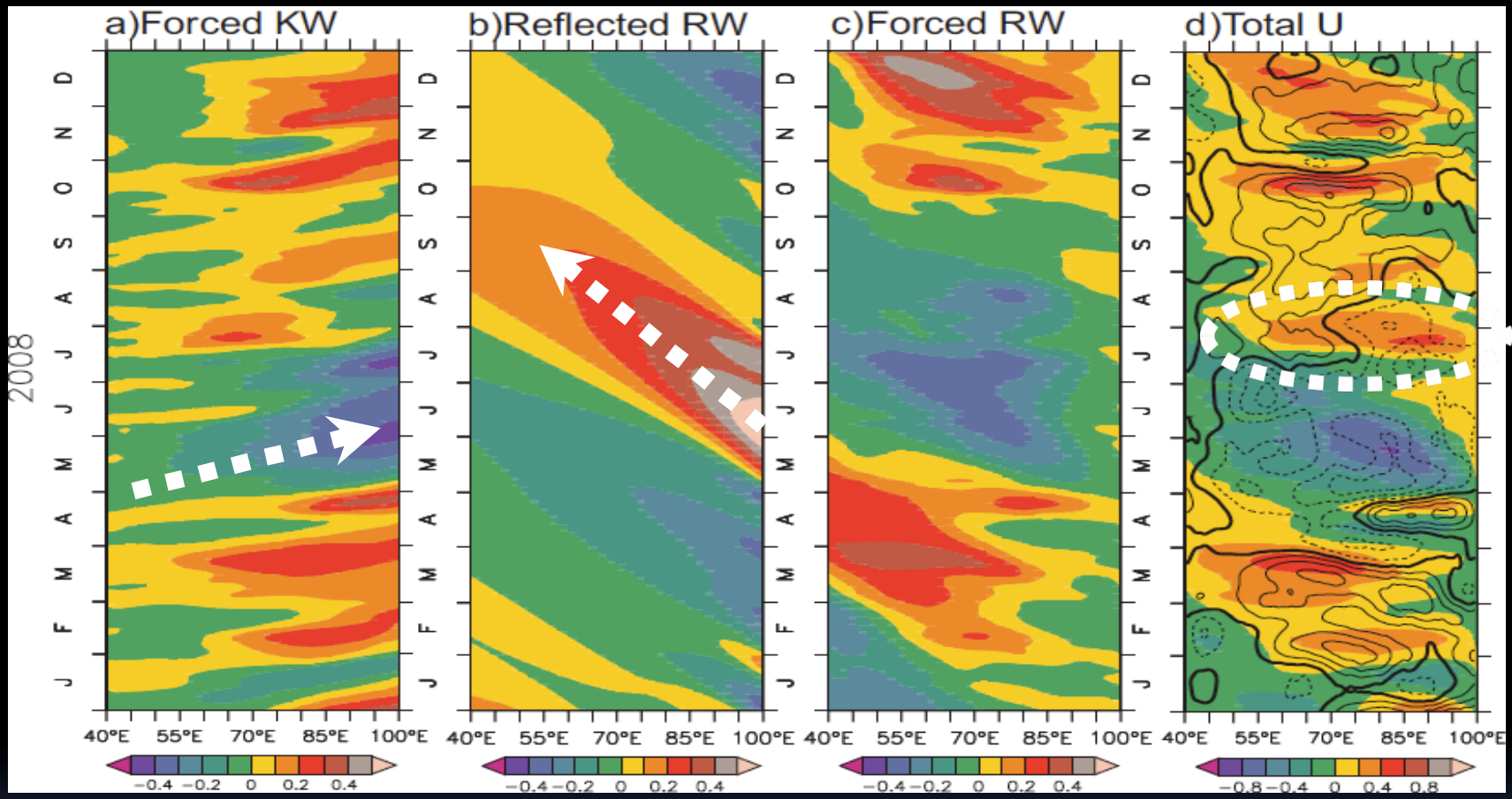
- SST along the equator showed negative temperature anomalies during Feb.-May (e.g. *basin-wide cooling associated with La Niña?)*
- The thermocline in the eastern equatorial Indian Ocean began to shoal in April, reached its negative maximum in late June/early July, and gradually deepen in August 2008.

Model results



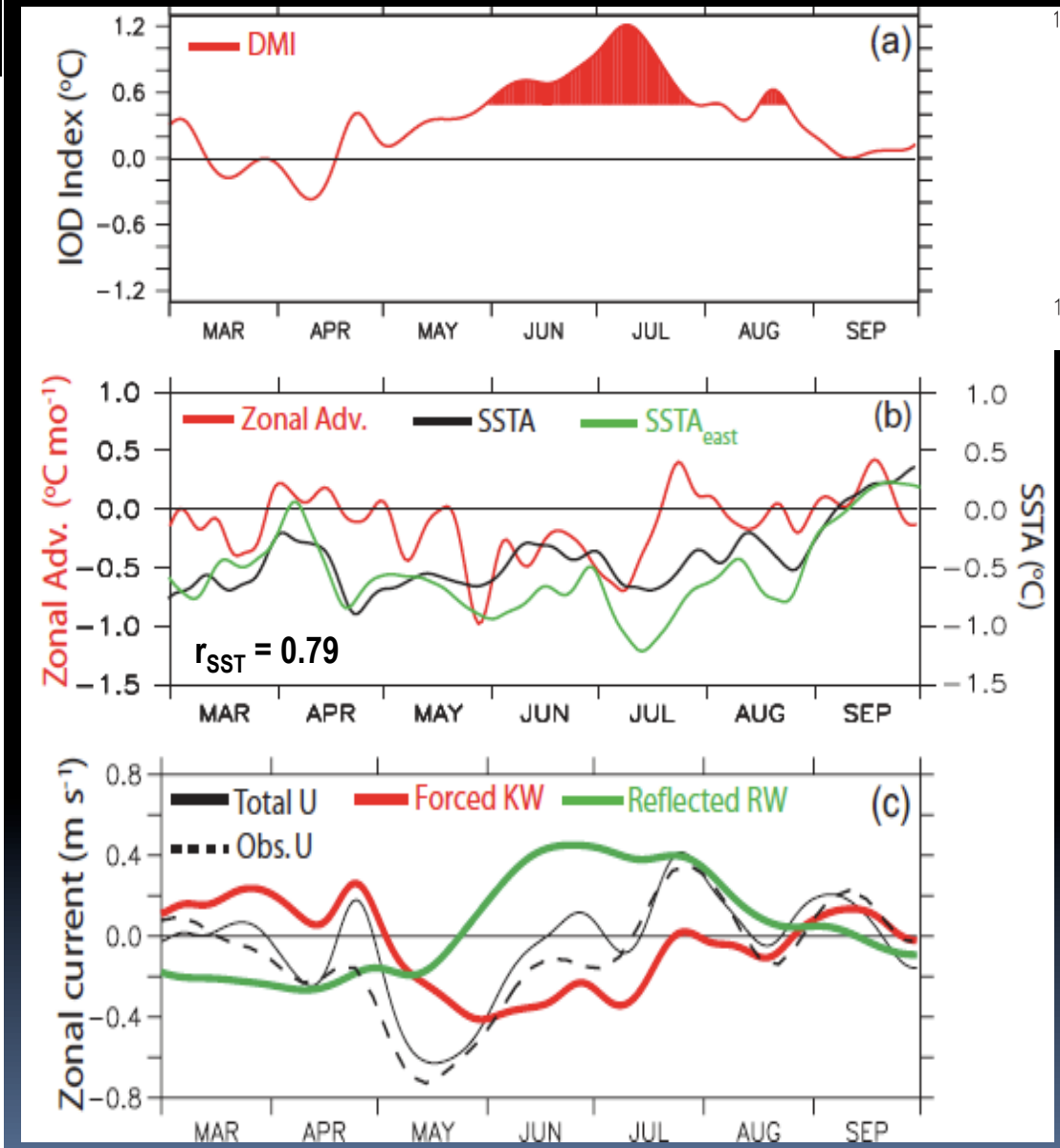
- The model simulated well the negative signals along the equator, and positive signals in the off-equatorial regions.
- Along the equator, the model simulation considerably overestimates negative SSHA signals.
- In the off-equatorial regions, the model underestimates the positive signals of both zonal currents anomaly and SSHA.

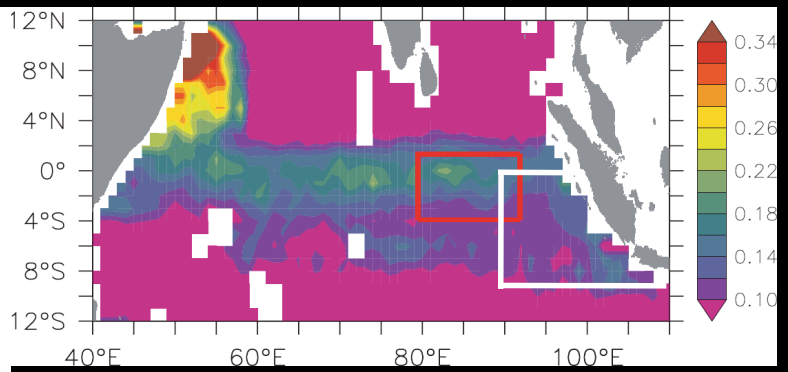
Variability of zonal currents



- Wind-forced upwelling Kelvin waves play a dominant role in generating westward surface currents during the development of the IOD event in April – May 2008.
- During the termination phase, the eastern-boundary-reflected upwelling Rossby waves contributed to the eastward zonal current in the eastern equatorial region in July 2008.

Decomposition of equatorial waves





During the termination phase in July 2008, the eastern-boundary-reflected upwelling Rossby waves play important role in generating the eastward zonal current in the eastern equatorial region.

Conclusion

1. Sustained RAMA buoy network is a key for a better observing understanding and predicting a climate anomaly originated in the tropical Indian Ocean.

2. There was a complex interplay of directly wind-forced and boundary-generated waves during the onset and termination of the 2008 IOD event.
   - During the onset of the IOD events, the wind-forced equatorial waves play significant role in cooling of the eastern pole.
   - During the termination of the IOD events, eastern boundary-generated Rossby waves significantly contribute to generation of eastward zonal current in the eastern equatorial region.

3. The cooling tendency in the eastern Indian Ocean induced by the wind-forced KW during the termination of the IOD events is terminated by the eastern-boundary-reflected RW.

4. Weakening of the zonal heat advection provided a favor condition for the surface heat flux to warm the SST in the eastern equatorial Indian Ocean.

Thank You

- Support from GEOSS Secretariat

- Dr. Keisuke Mizuno (JAMSTEC)

Dr. Iskhaq Iskandar
Jurusan Fisika, Fakultas MIPA, Universitas Sriwijaya
Jl. Palembang-Prabumulih Km. 32, Inderalaya, OI,
Sumatra Selatan, 30662 INDONESIA
Email: iskhaq.iskandar@gmail.com