Freshwater Dynamics in the Eastern Indonesia Sea:

Observation and Model Analysis

I Iskandar, A. Bahiyah & Y. Masumoto

LLDIKTI Wilayah 2

Training on Data Buoy Cooperation Panel

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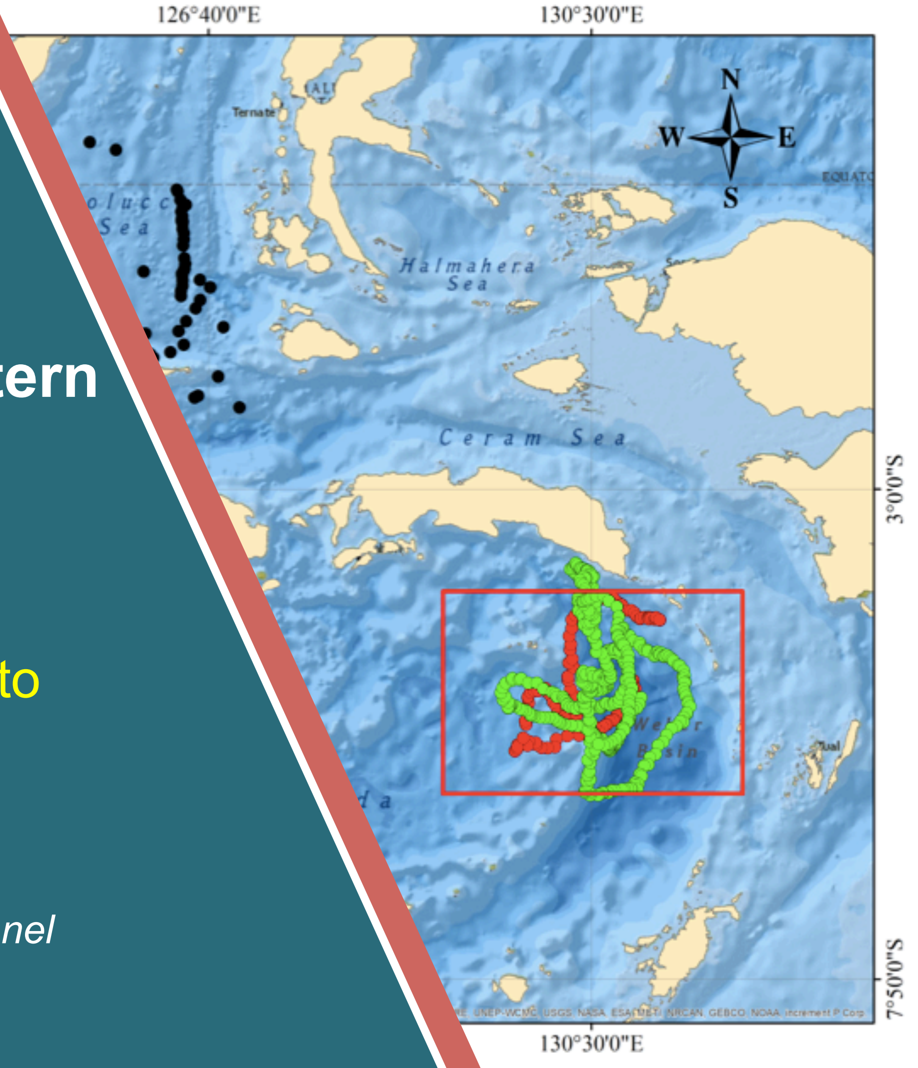
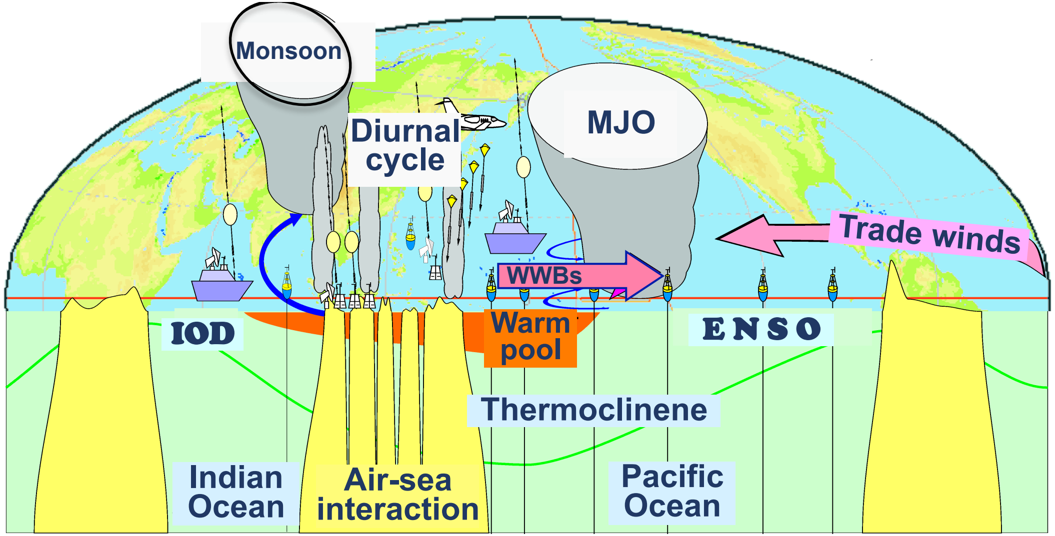


Background and Motivation

INDO-PACIFIC CLIMATE MODES

Air-sea Interaction in the Tropical Indo-Pacific



Courtesy: Ken Ando (JAMSTEC)

There are 5 (five) major climate drivers in Indonesia:

1. Diurnal cycle (*daily*)
2. Madden-Julian Oscillation (MJO) which varies from weekly to monthly timescale (*intra-seasonal*)
3. Monsoon (*seasonal*)
4. Indian Ocean Dipole - IOD (*biennial*)
5. EL Niño-Southern Oscillation - ENSO (*interannual*)

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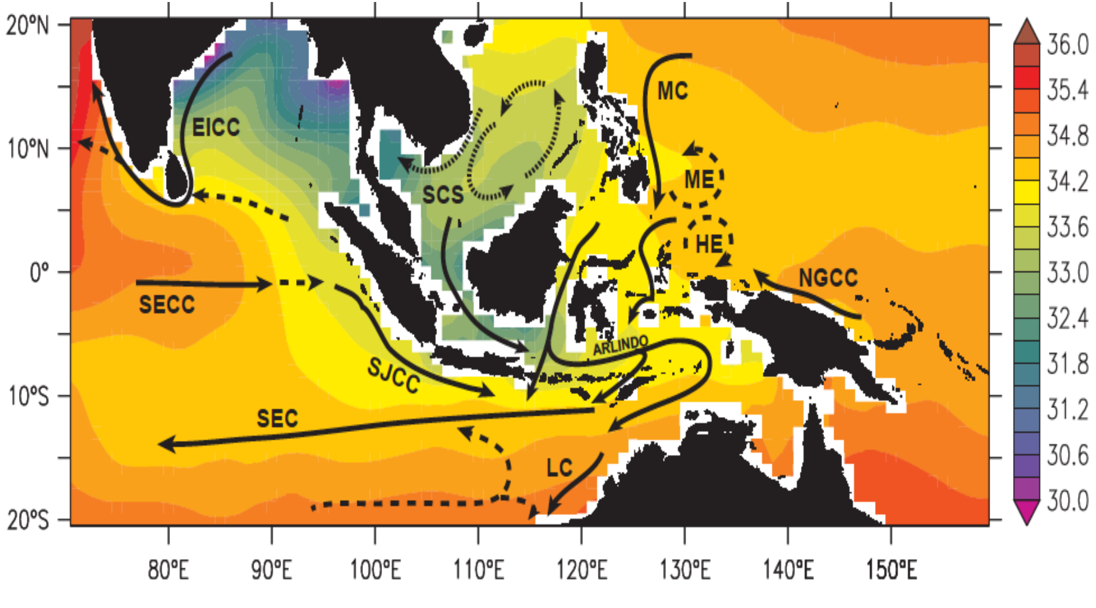
University of Sriwijaya

Background and Motivation

Circulation within Indonesian sea

Surface Currents in the Indonesian Sea



Iskandar et al. (2016)

The Indonesian seas is a cross-road of water masses from:

a. the Indian Ocean;
b. the Pacific Ocean; *and*
c. the South China Sea.

The Indonesian Archipelago provides the **only low-latitude connection** of the world tropical ocean, namely the Pacific and Indian Ocean → **the Indonesian Throughflow (ITF).**

SST within the Indonesian seas play important role in regulating global climate variations.

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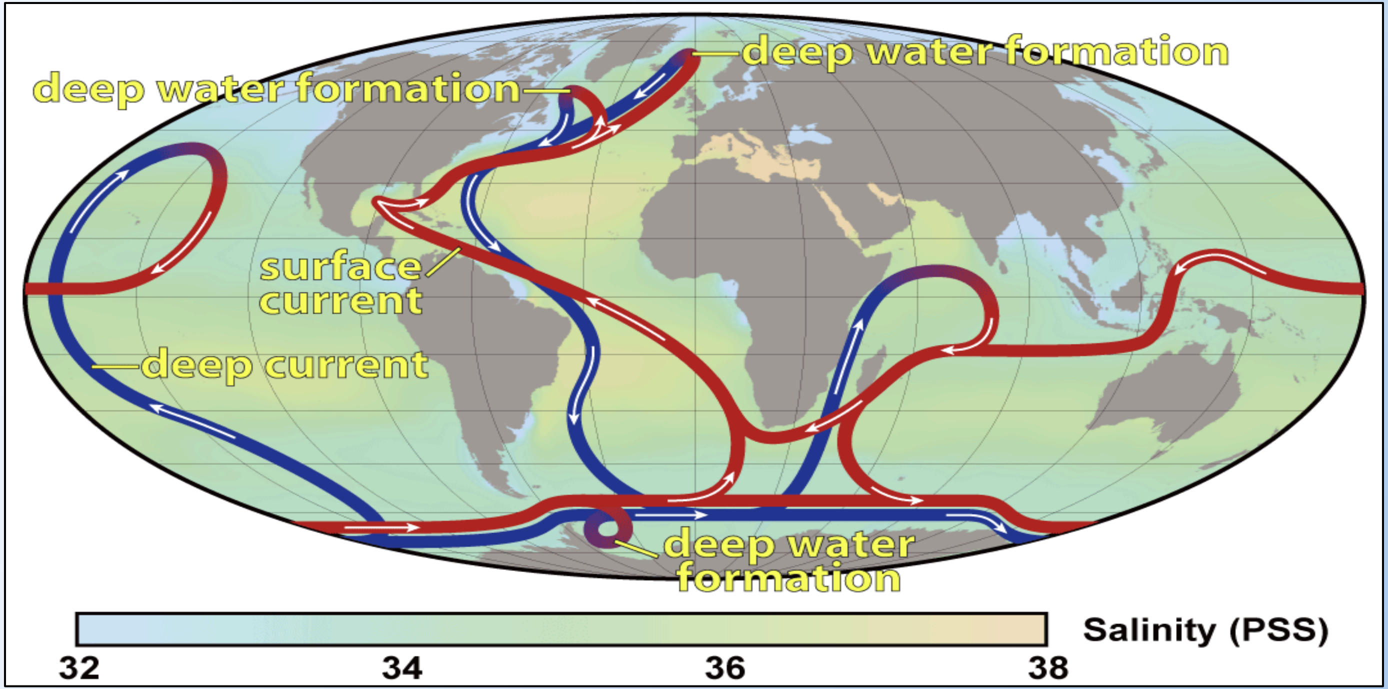
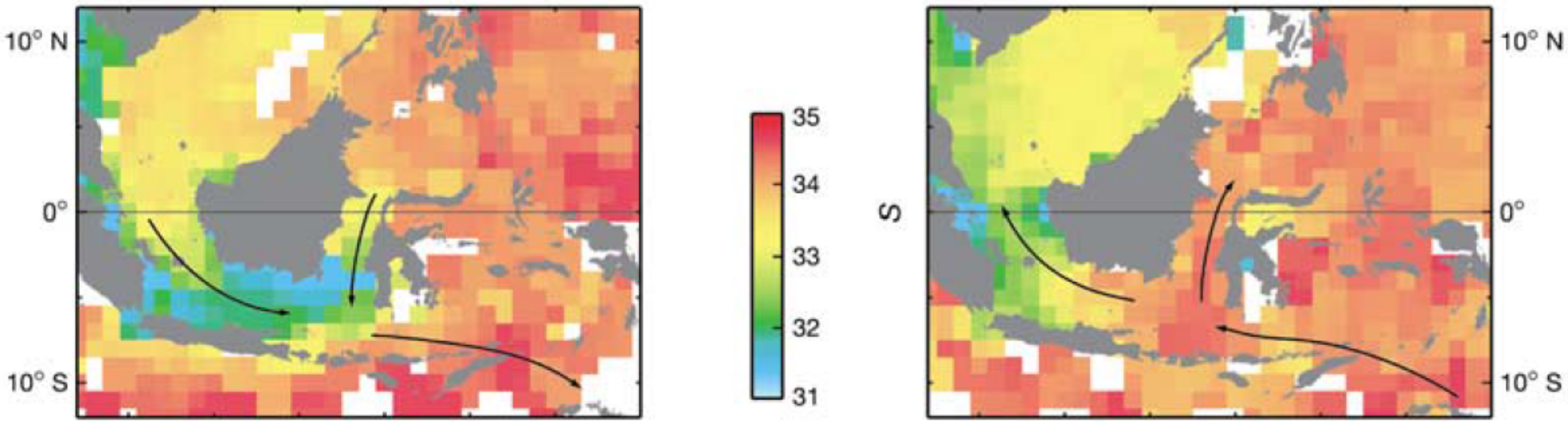
Background and Motivation

Thermohaline Circulation

The Maritime Continent (MC) is a low-latitude chokepoint of global ocean circulation, with the Indonesian throughflow (ITF) going through the MC, affecting ocean, climate, & BGC (e.g., Godfrey 1996, Lee et al. 2002, Gorgues et al. 2007, Sprintall et al. 2014)



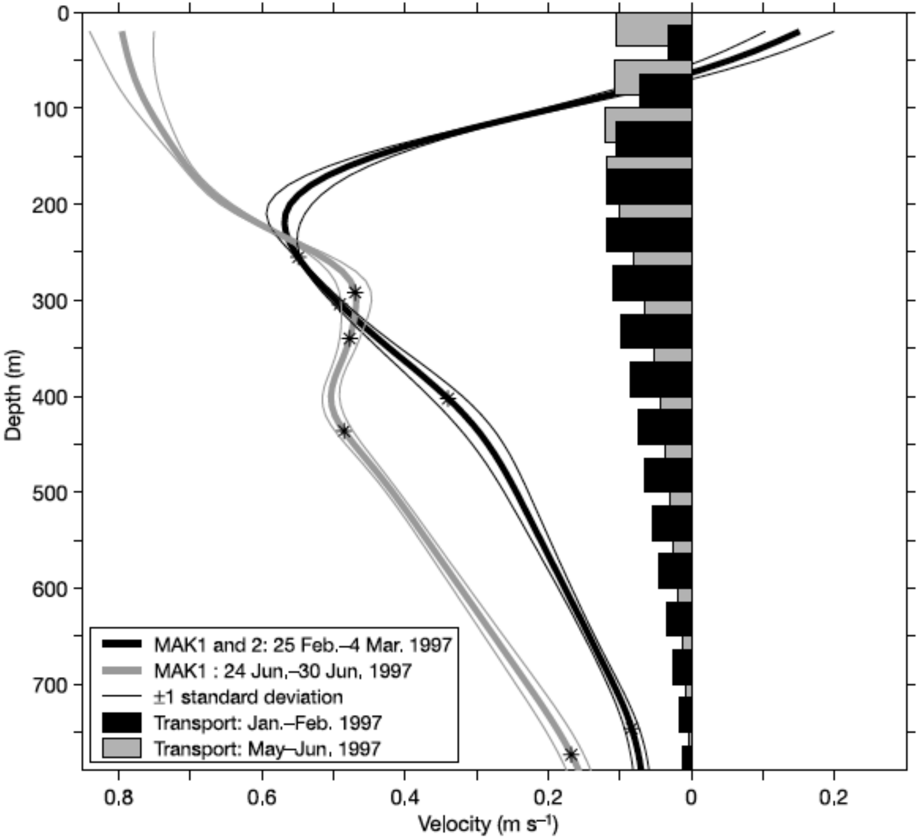
Freshwater Flux of the Southern Makassar Strait



(Gordon et al. 2003):

- During the northwest monsoon (JFM), the Java Sea low-salinity surface water shifts into the southern Makassar Strait. Meanwhile the southeasterly winds during the southeast monsoon (JAS) returned the low-salinity water into the Java Sea.
- The buoyant surface water of the southern Makassar Strait inhibits southward transport within the surface layer during the northwest monsoon, weakening the Indonesian Throughflow in the surface layer.

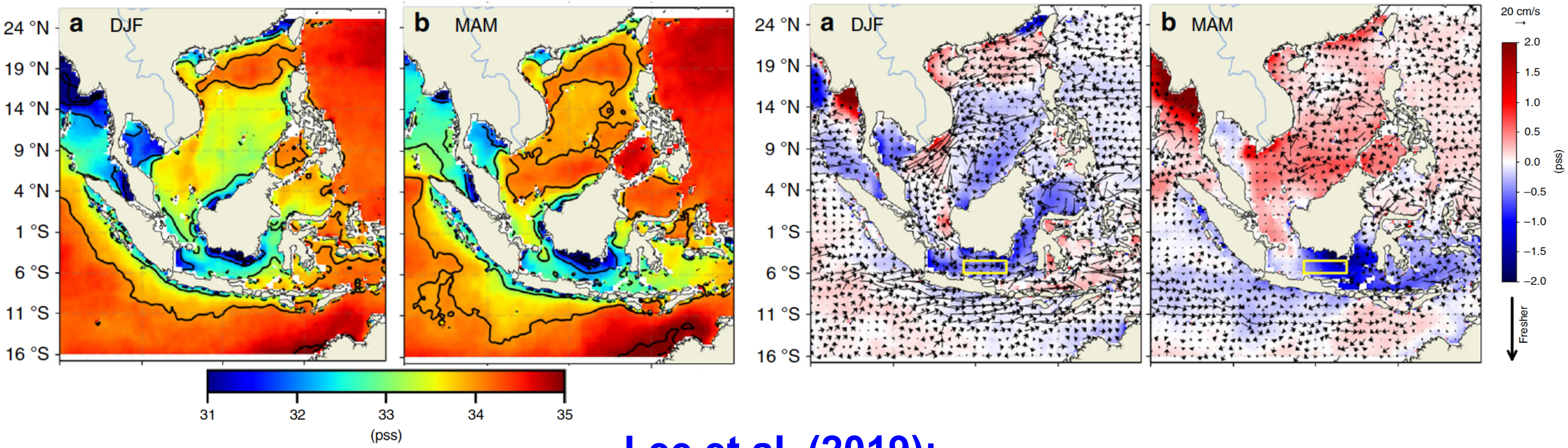
Vertical Profiles of Makassar Strait Throughflow



Seasonal variation of the vertical profile of ITF velocity in the Makassar Strait:

- much weaker upper-layer flow in boreal winter;
- caused by freshwater that increases the dynamic height, thereby reducing the N-to-S pressure gradient that drives the upper-layer flow (Gordon et al. 2003).

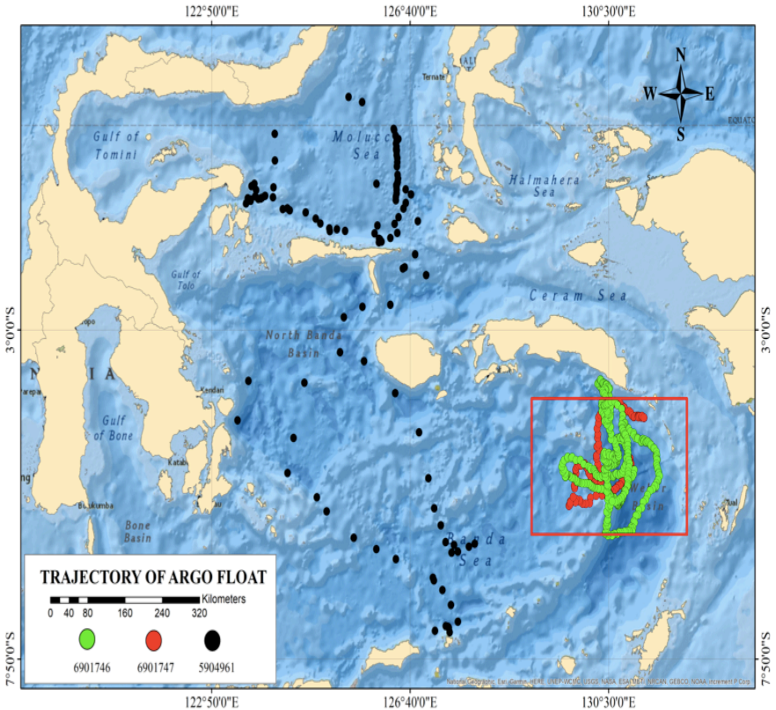
Freshwater Flux in the Indonesian Seas



Lee et al. (2019):

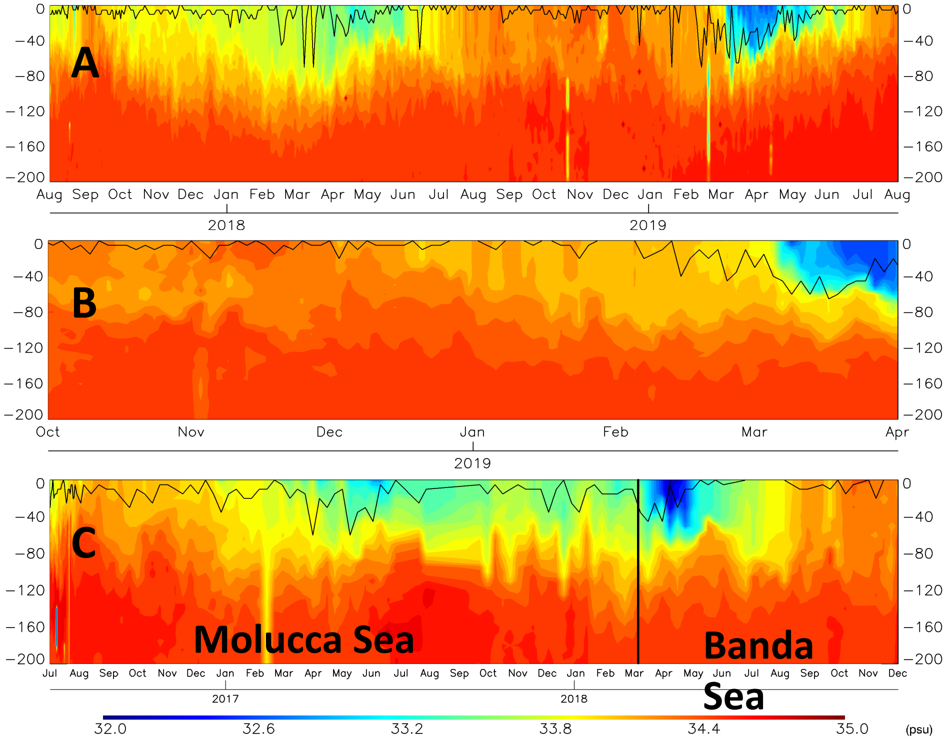
- During DJF and MAM, the SSS north of the Karimata Strait is higher than those in the Java Sea.
- The SCS waters cannot be the primary source of freshwater for the strong freshening in the Java Sea and Makassar Strait observed during DJF and MAM.
- Possible effects of Maritime Continent regional water cycle (local precipitation and runoff) on the freshening of the southern Makassar Strait

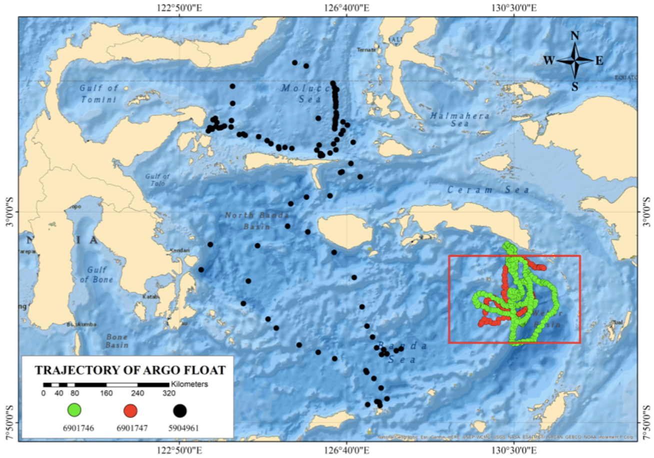
Observed Freshening in the Banda Sea



- **3 Argo floats** in the Banda Sea and Molucca Sea (2017 ≤ period ≤ 2019).
- Level 3 daily **SSS SMAP** with resolution 0.25° x 0.25° (Jan. 2017- Dec. 2019).
- Daily real-time **precipitation GSMaP** with resolution 0.1° x 0.1° (Jan. 2017- Dec. 2019).
- **Wind data** from **ASCAT** with resolution 0.25° x 0.25° (Jan. 2017- Dec. 2019)
- **Surface current & SLH data** from global reanalysis **Marine Copernicus** with resolution 1/12° x 1/12° (Jan. 2017- Dec. 2019)

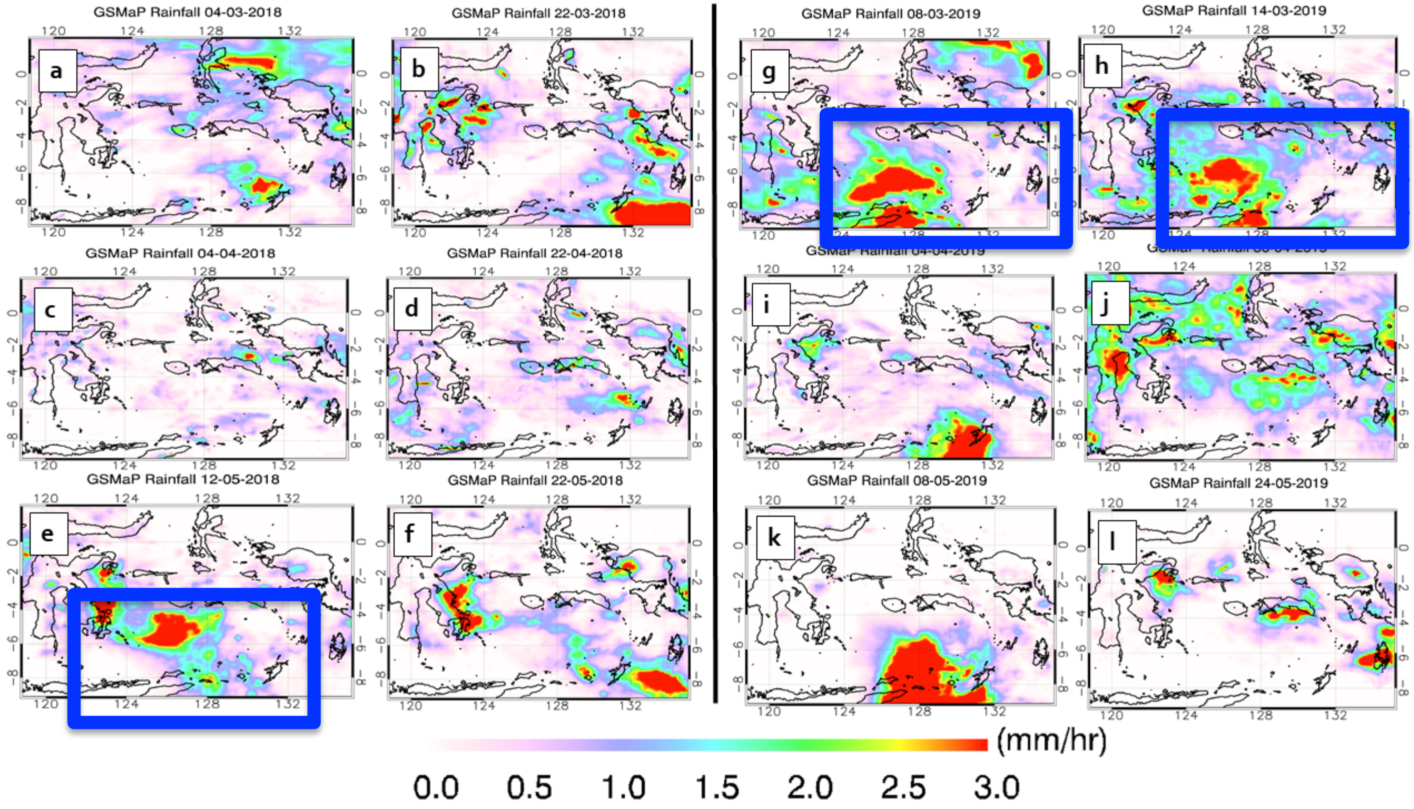
Time-Depth Profiles of Salinity





Vertical profile of observed salinity indicates a freshening of upper layer of the Banda Sea during boreal spring (MAM) of 2018 and 2019.

Precipitation over the Eastern Indonesian Seas

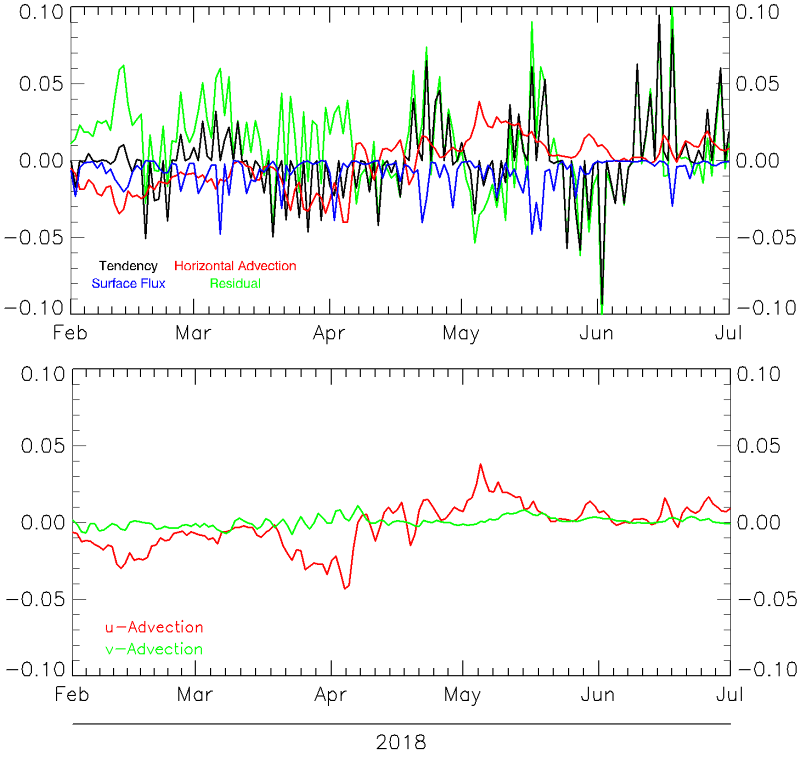


Heavy precipitation was observed during May 2018 and March 2019 in the Banda Sea.

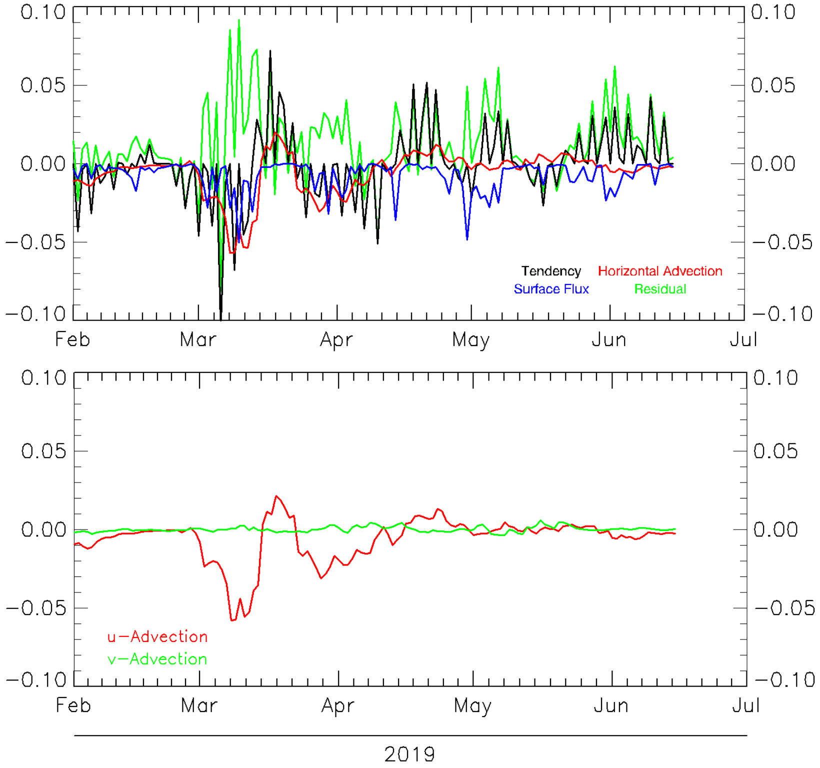
Salinity Budget in the Banda Sea

$$\frac{H}{\mathrm{Vol}} \times \iint \frac{\mathrm{d}S}{\mathrm{d}t}\,\mathrm{d}x\mathrm{d}y = \frac{S_0}{\mathrm{Vol}} \iint (-P)\,\mathrm{d}x\mathrm{d}y + \mathrm{Hadv} + \mathrm{RES},$$

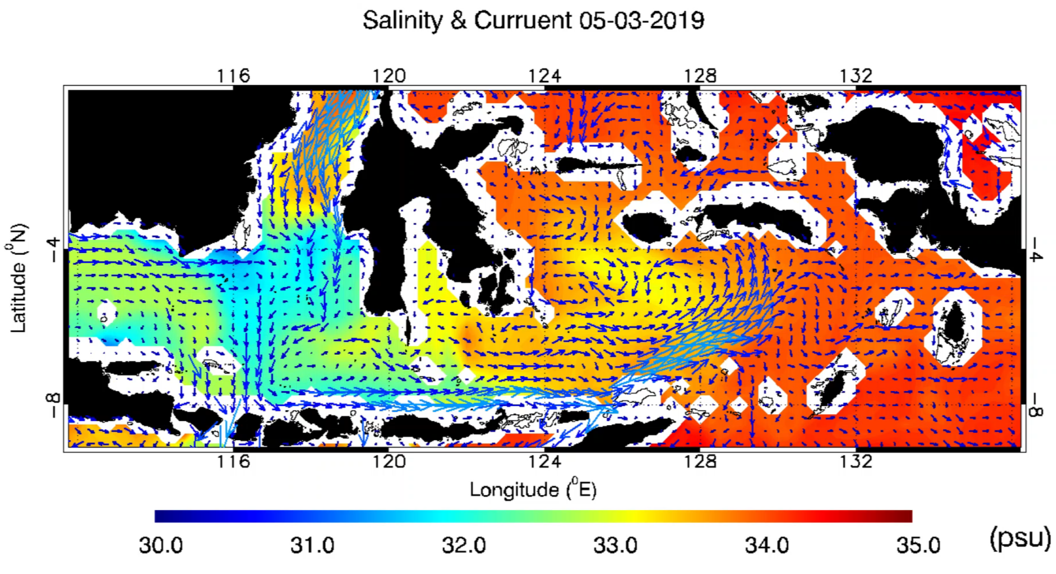
a) Spring 2018



b) Spring 2019



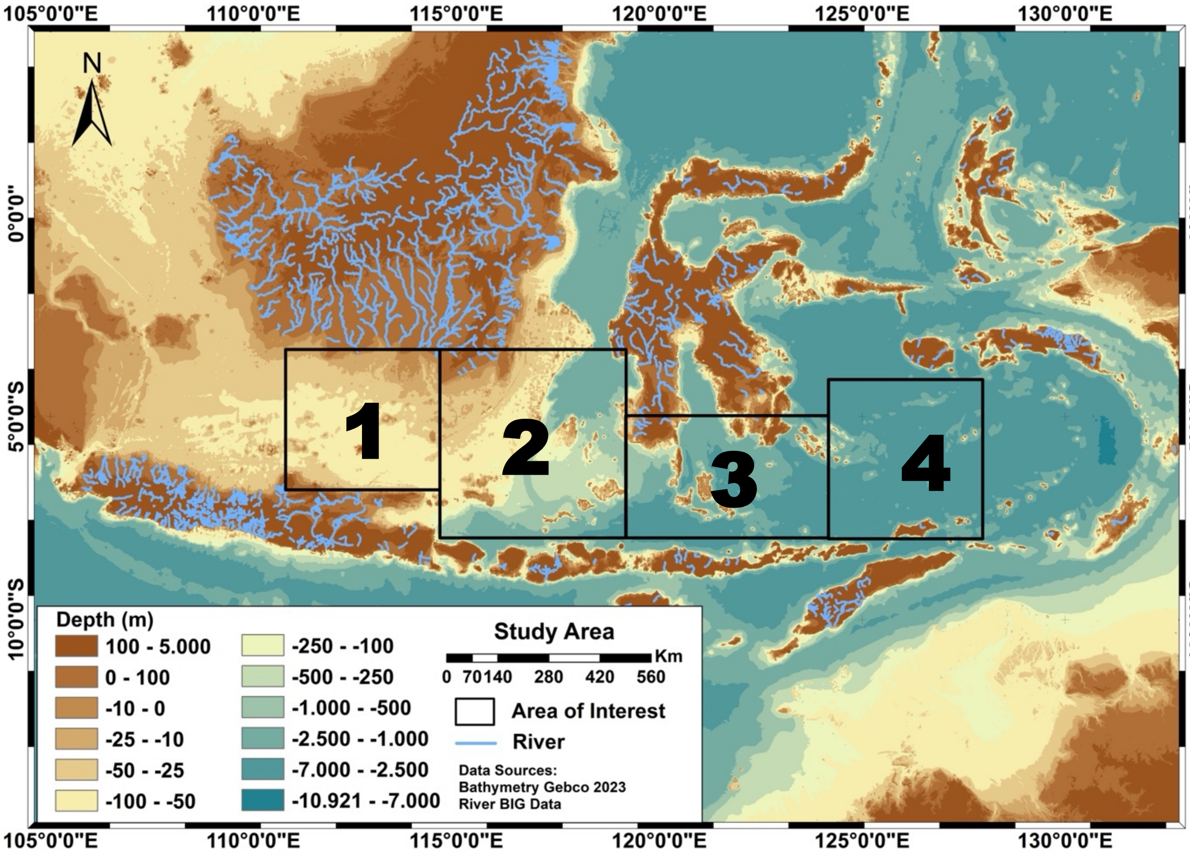
Surface Circulation in the Indonesian Seas



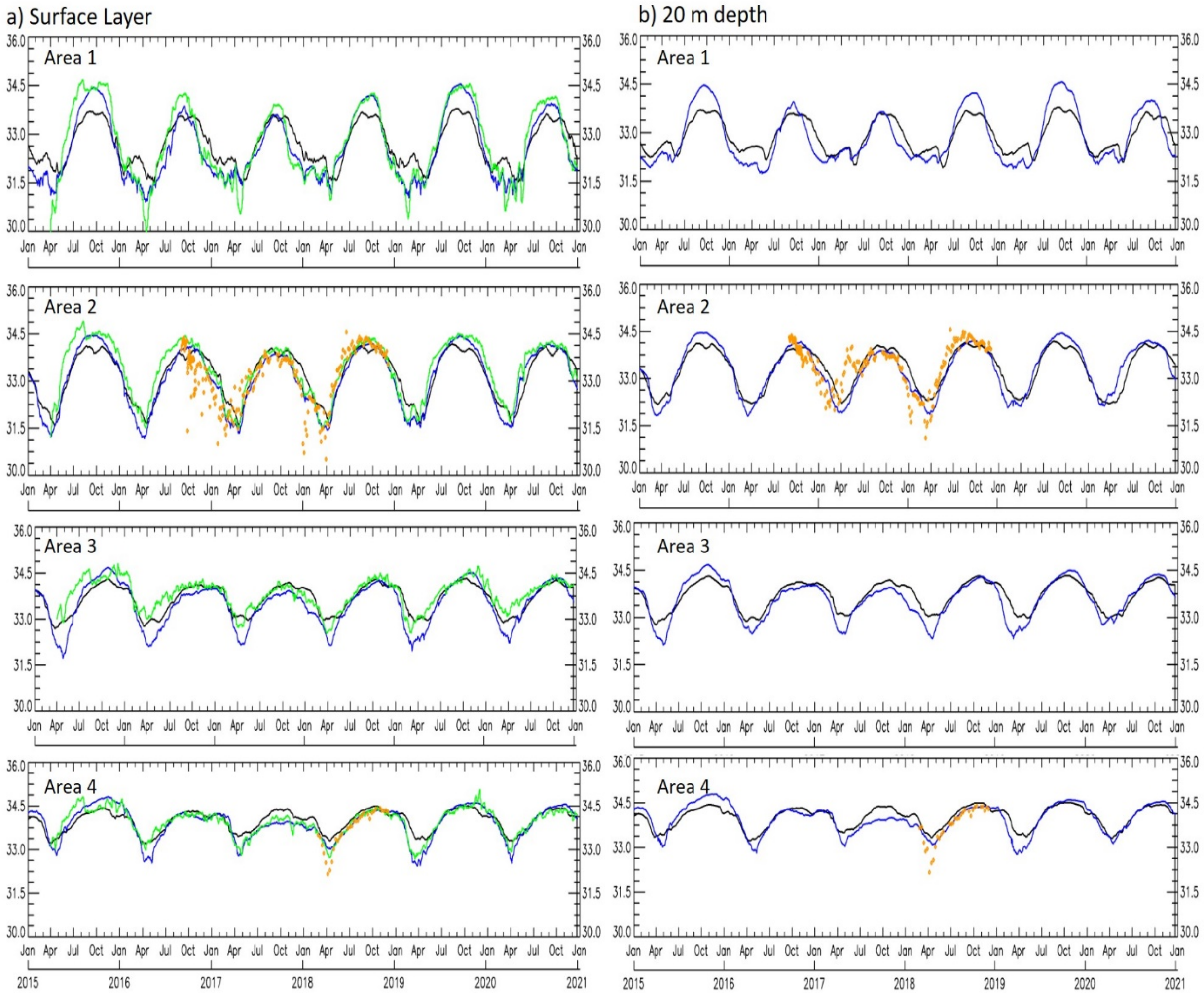
- Eastward flow of freshwater mass from the Java Sea to the Banda Sea via the south of Makassar Strait and the Flores Sea during boreal spring (MAM).
- The eastward Flores jet play important role for the eastward advection of the freshwater mass into the Banda Sea.

OGCM For the Earth Simulator (OFES) ver.2

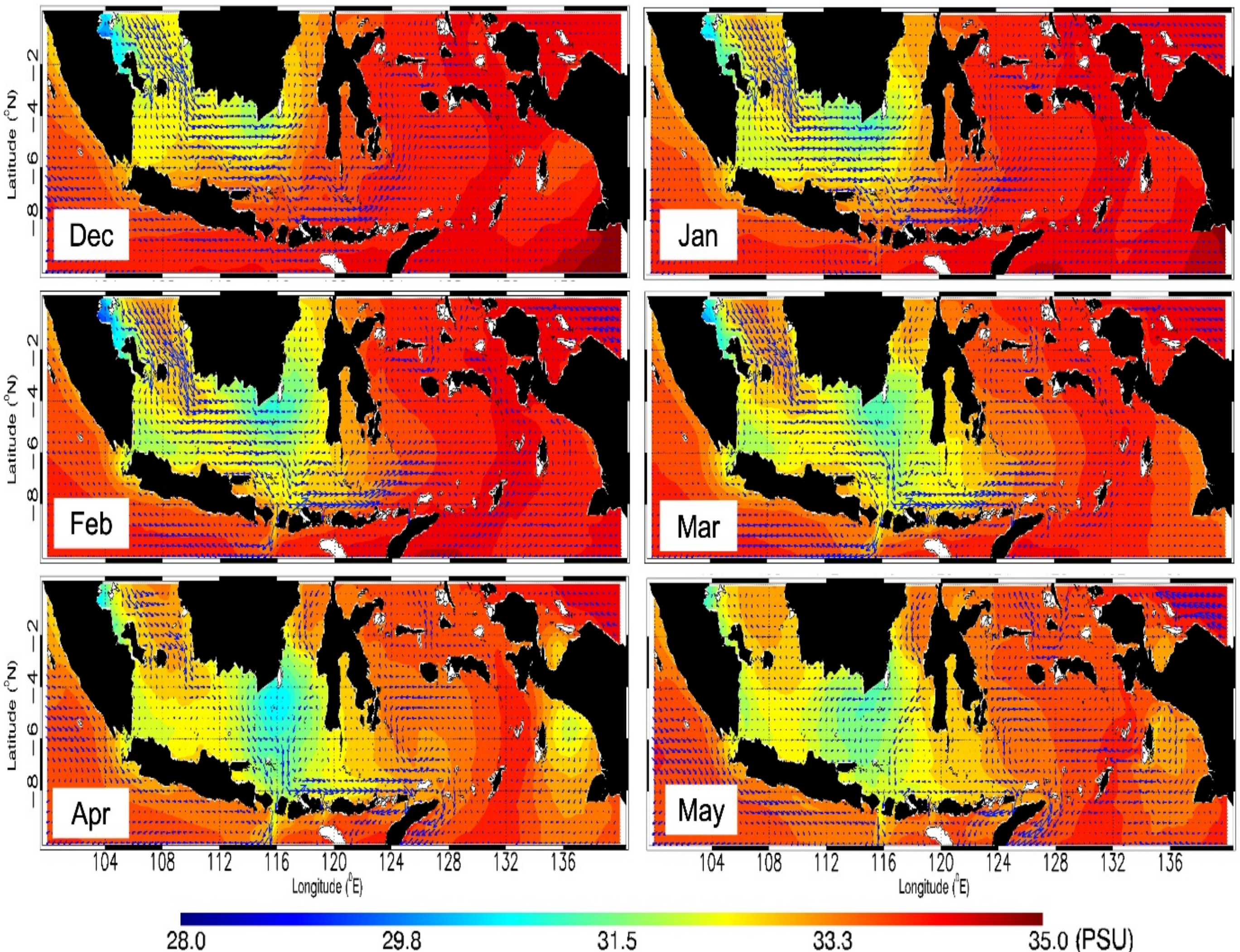
Domain	:	76°S - 76°N
Horizontal Resolution	:	0.1°
Number of Vertical Levels	:	105
Bathymetry Data	:	ETOPO1
Horizontal Mixing Scheme	:	Biharmonic
Vertical Mixing Scheme	:	Noh & Kim 1999
Tidal Mixing Scheme	:	St. Laurent et al., 2002
SSS Restoring	:	15 days to WOA13
Atmospheric Forcing	:	JRA55-do (3 hourly, 2.5° x 2.5°)
River Runoff	:	CORE 2 (daily climatology)
Initial Condition	:	T & S of OFES on January 1, 1958
Outputs	:	Daily mean every 3 days until 1989 Daily mean from 1990 Monthly mean



Area of Analysis



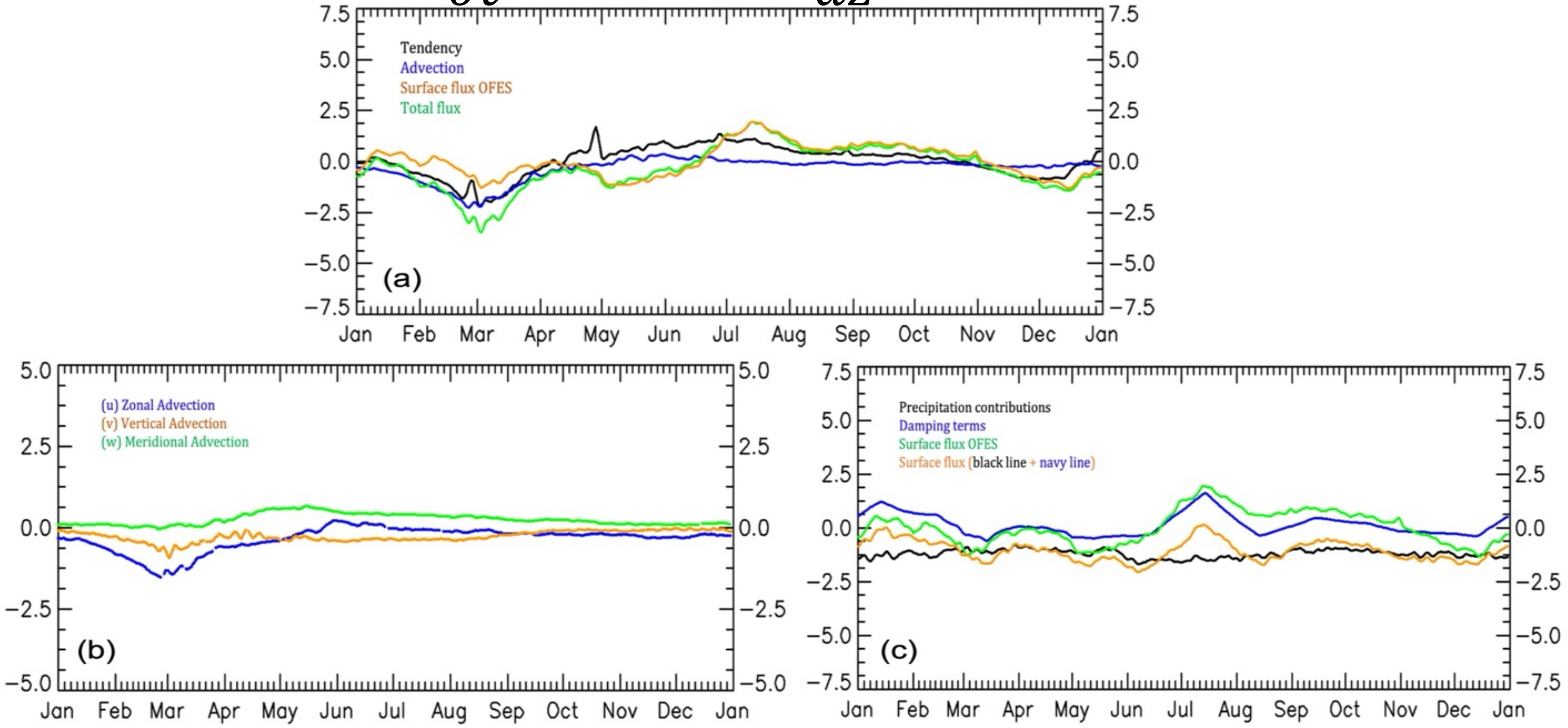
Observation vs Model Outputs



Climatology of SSS superimposed with surface currents (1990-2020)

Model Salinity Budget in the Banda Sea

$$\frac{\partial S}{\partial t} + \bar{u}.\nabla S = \left(\frac{-PS}{dz}\right) + \gamma(S_{obs} - S)$$



SUMMARY

- The ARGO floats clearly observed boreal-spring freshening in the Banda Sea.
- Both the zonal advection of freshwater mass from the Java Sea and precipitation contributed to the freshening of the Banda Sea during boreal spring (MAM) 2018 and 2019.
- OFES successfully simulates a boreal-spring freshening of the Banda Sea.
- OFES also shows that the freshening is mosly attributed to the zonal advection of freshwater from the Java Sea.

Thank You

Iskhaq Iskandar
LLDIKTI Wilayah II
Jl. Srijaya Nomor 883 KM 5,5 Palembang 30153
E-mail: iskhaq@mipa.unsri.ac.id