Projected sea-level trends and variability in the Southeast Asia region based on MPI-ESM-ER

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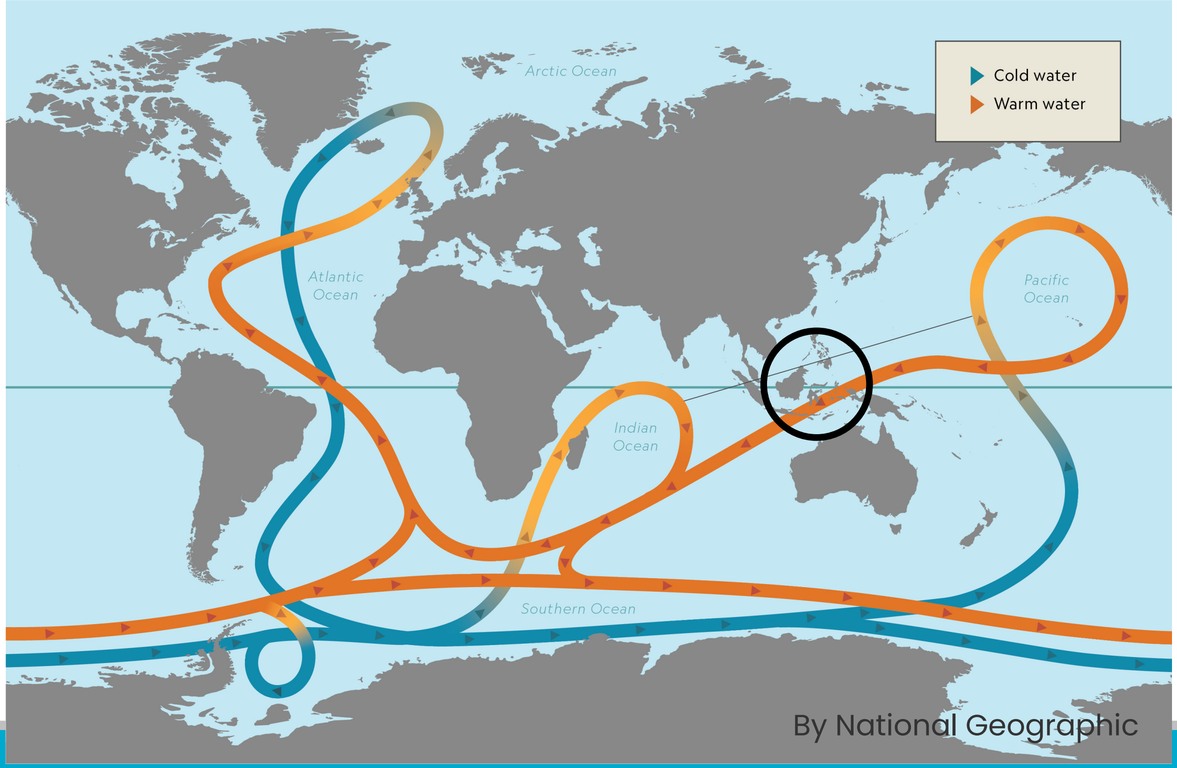
1. Introduction

- The **Southeast Asia (SEA)** region contains the largest archipelago globally and maintains one of the most diverse and active ecosystems in the world.

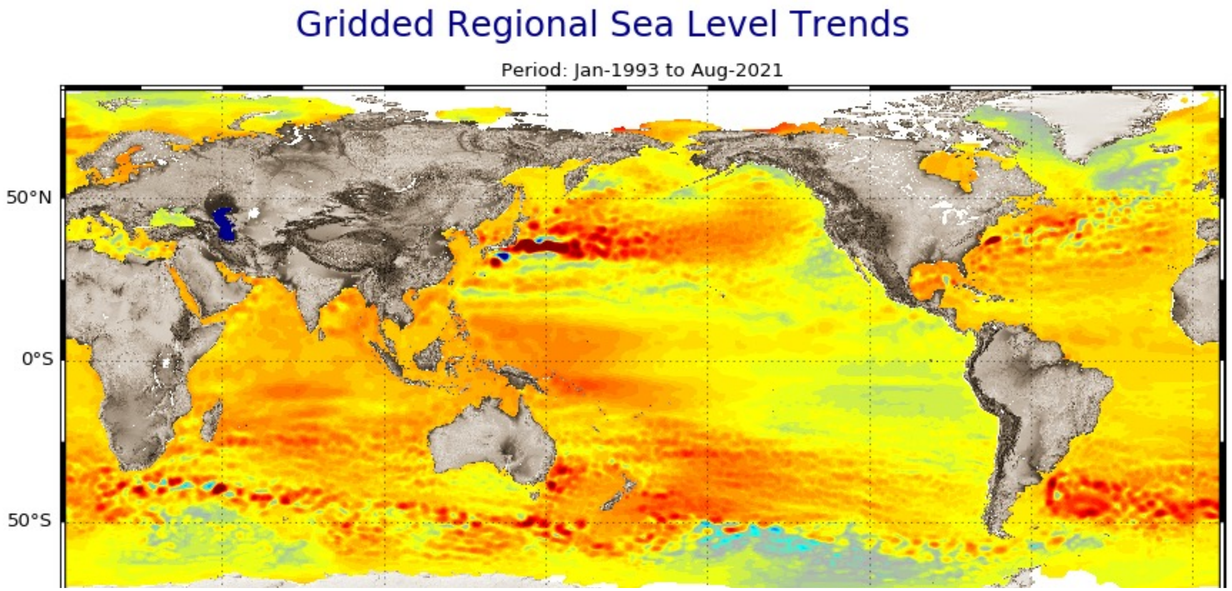
1. Introduction

- SEA region plays an important role in the **global climate system**. For example, the **Indonesian Throughflow (ITF)** is a key part of the **global ocean conveyor belt**, transporting a large volume of warm and fresh Pacific water into the Indian Ocean.



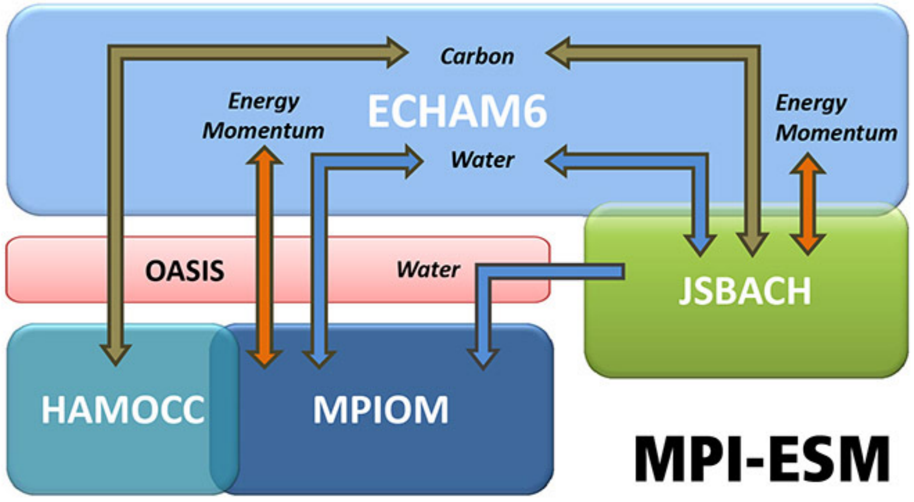
1. Introduction

- During the altimetry era (1993-2020), the observed linear trend of the SEA sea level rise is **3.8 ± 1.1 mm yr⁻¹**, which is higher than the linear trend of global mean sea level rise of **3.1 ± 0.4 mm yr⁻¹** over the same period (Ablain et al. 2019).



Aim to: investigate sea-level **trends and variability** in the SEA region based on the earth system model **MPI-ESM-ER**, by evaluating contributions from the **ocean transports** and the **air-sea fluxes**.

2. MPI-ESM-ER and Study Domain

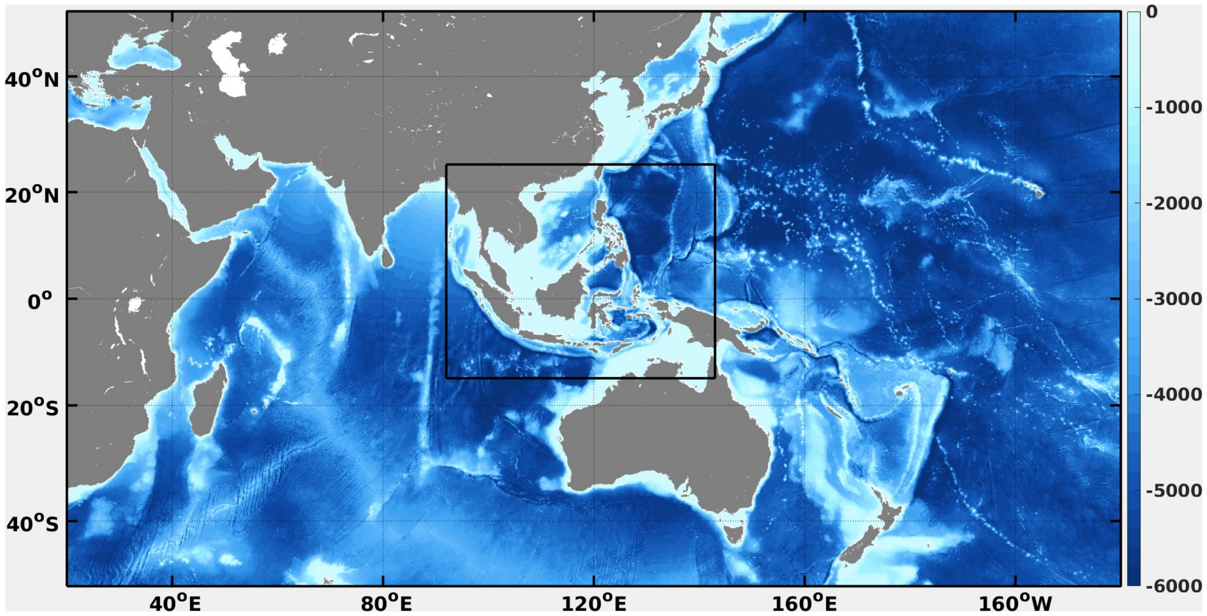


(DKRZ)

Name	Atmosphere resolution	Ocean resolution	Ocean mixing scheme	Description
HR	T127 (0.93° or ~ 103 km)	TP04 (0.4° or ~ 44 km)	PP, KPP	Reference, ocean mixing sensitivity
XR	T255 (0.46° or ~ 51 km)	TP04 (0.4° or ~ 44 km)	PP, KPP	Increased atmospheric resolution, ocean mixing sensitivity
ER	T127 (0.93° or ~ 103 km)	TP6M (0.1° or ~ 11 km)	PP	Increased ocean resolution

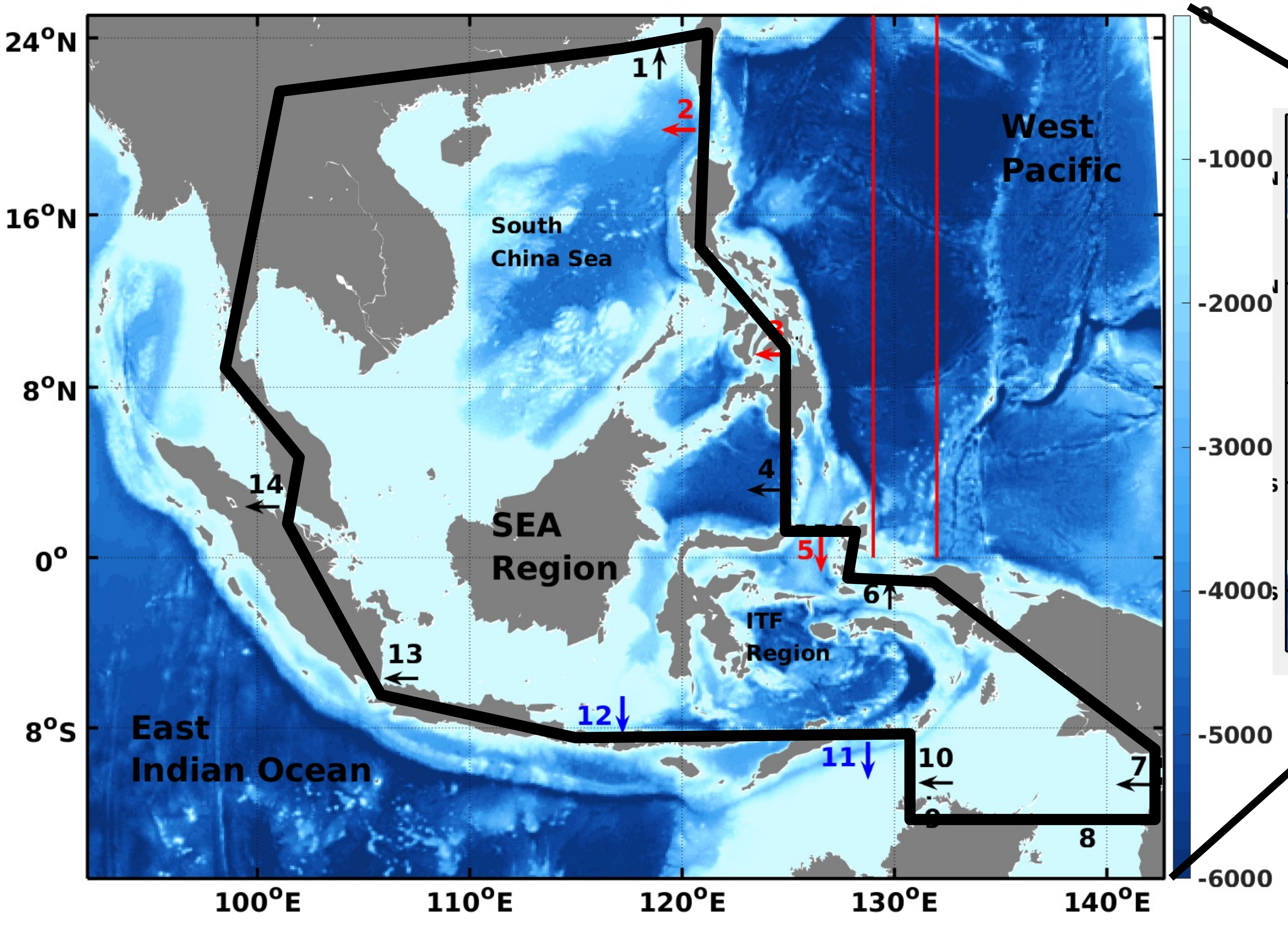
(Gutjahr et al. 2019)

MPI-ESM-ER study region

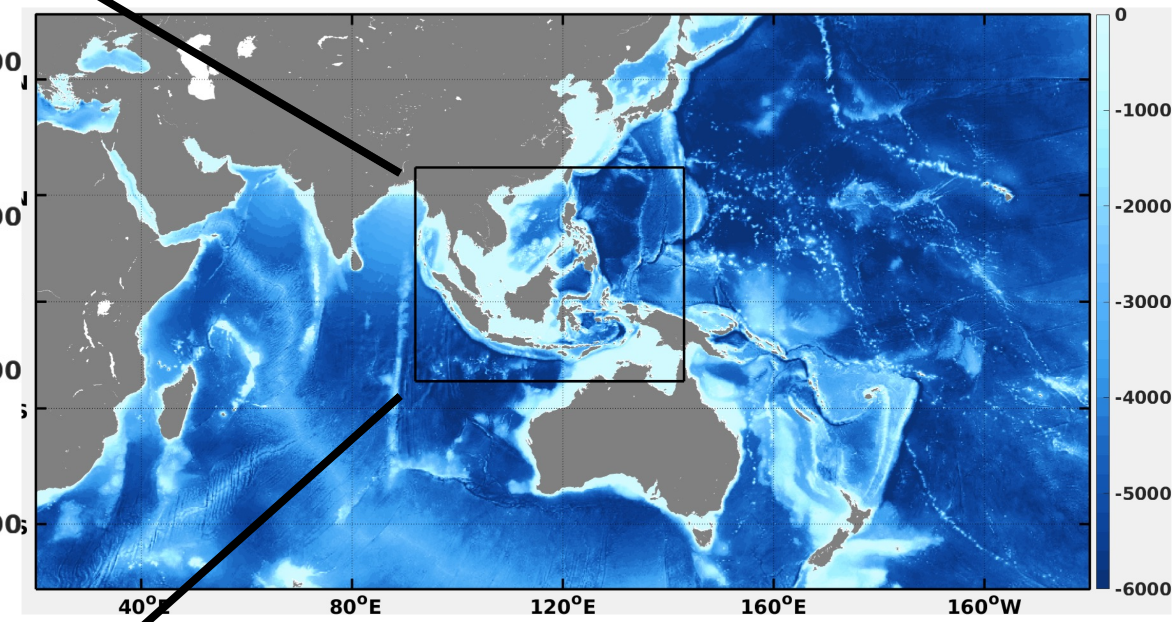


Historical period: 1950-2014
Future period (SSP5-8.5): 2015-2099

2. MPI-ESM-ER and Study Domain



MPI-ESM-ER study region

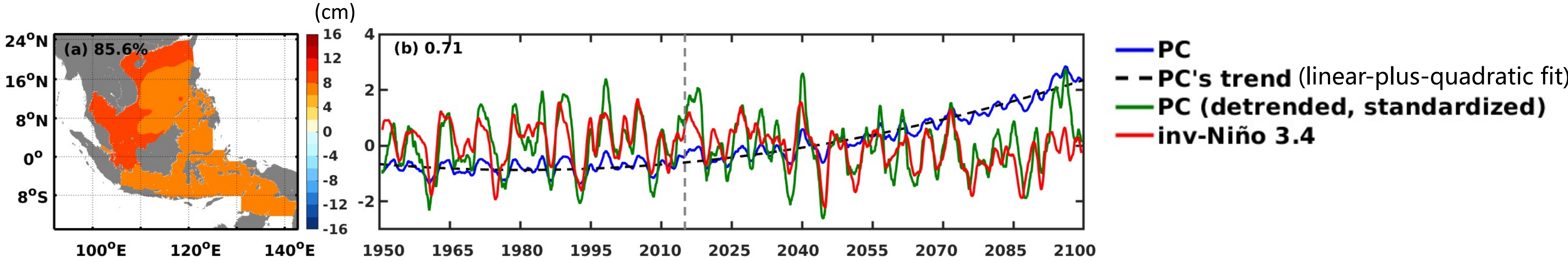


Historical period: 1950-2014
Future period (SSP5-8.5): 2015-2099

3. Sea-level trends and variability in the SEA region

Regional SDSL = Regional DSL + Global mean TSSL = Regional TSSL + Regional HSSL + Regional MMSL

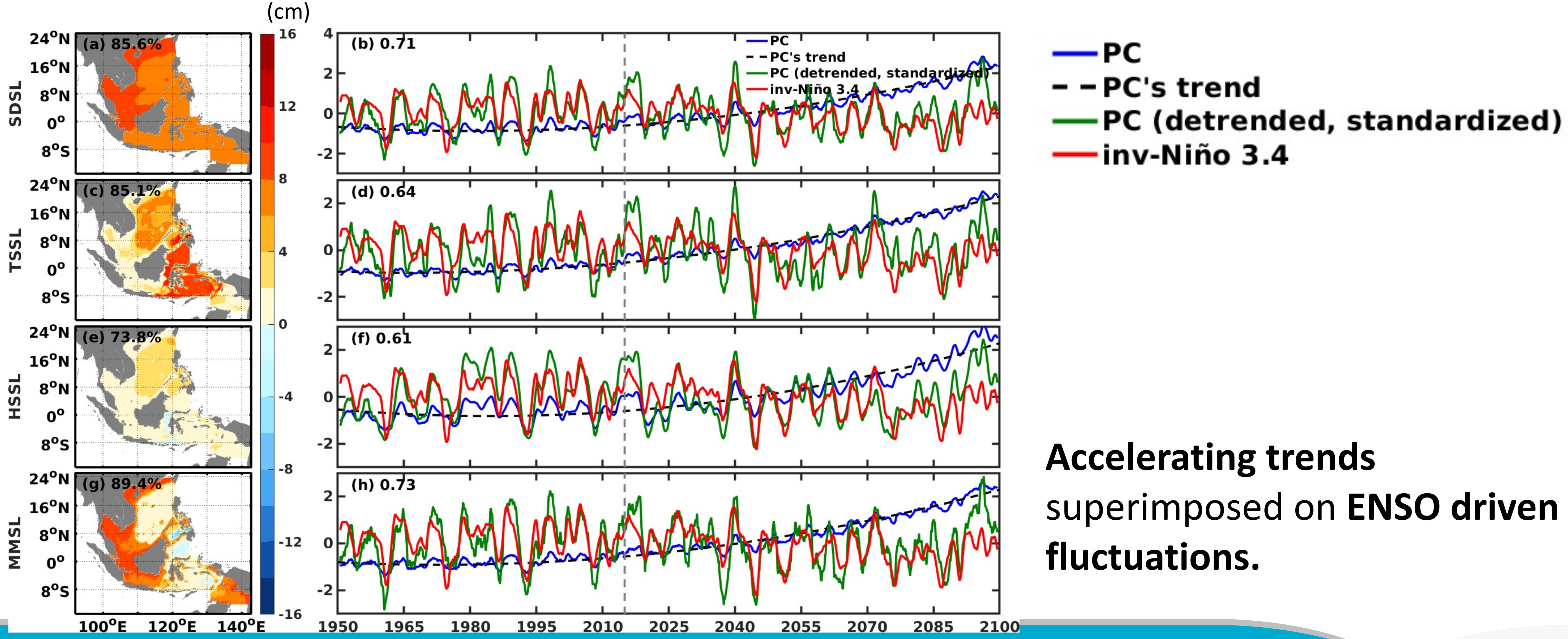
EOF1 of Sterodynamic Sea Level (SDSL)



3. Sea-level trends and variability in the SEA region

Regional SDSL $=$ Regional DSL $+$ Global mean TSSL $=$ Regional TSSL $+$ Regional HSSL $+$ Regional MMSL

EOF1 of SDSL, TSSL, HSSL and MMSL



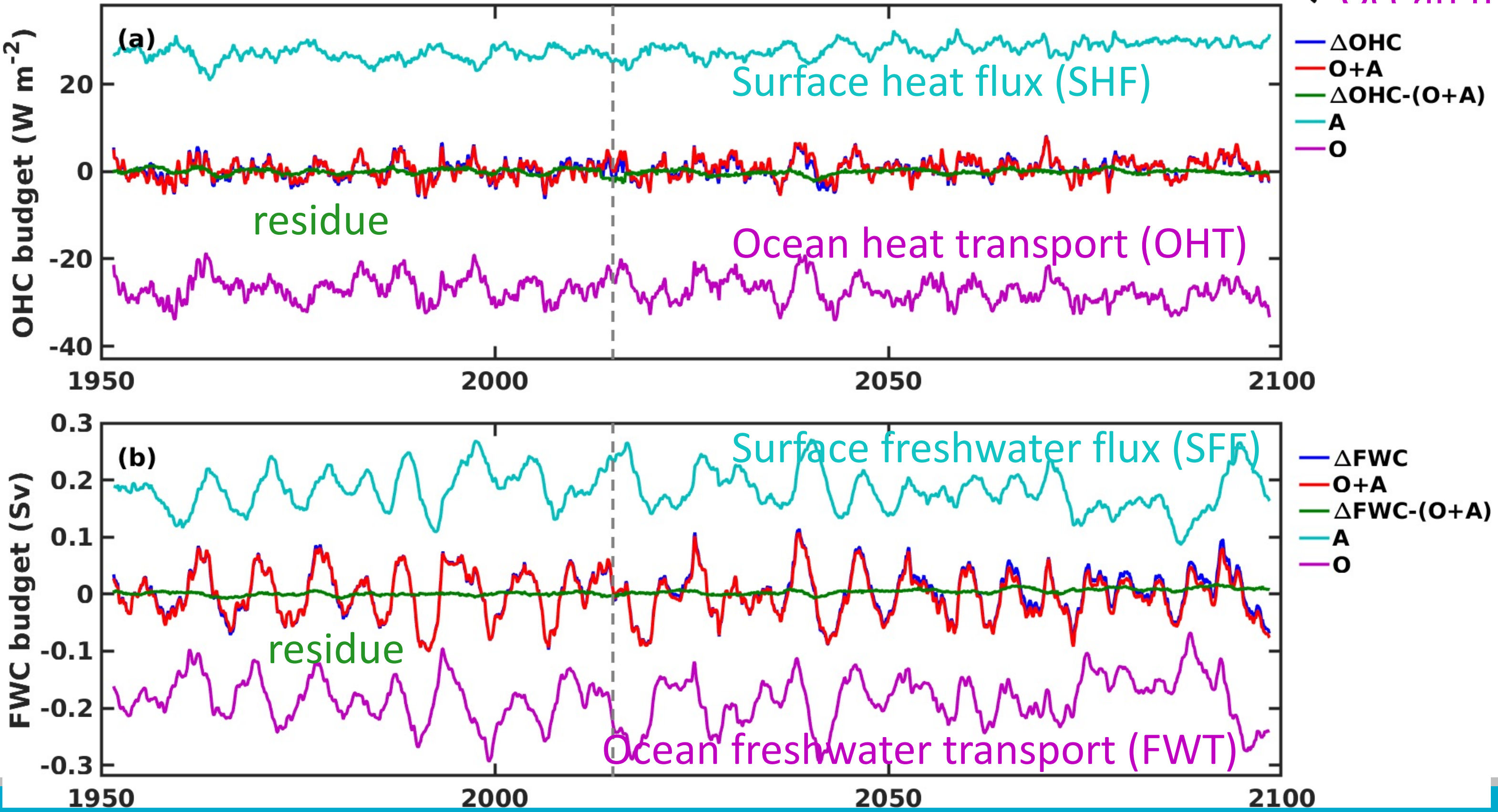
Accelerating trends superimposed on **ENSO driven fluctuations.**

4. Causes of sea-level trends and variability

4.1 Ocean heat and freshwater content budgets

ΔTSSL ⇄ ΔOHC (ocean heat content) ← Surface heat flux **(SHF)**, Ocean heat transport **(OHT)**

ΔHSSL ⇄ ΔFWC (freshwater content) ← Surface freshwater flux **(SFF)**, Ocean freshwater transport **(FWT)**



- Heat:
OHT leads SHF 6 months (-0.81)

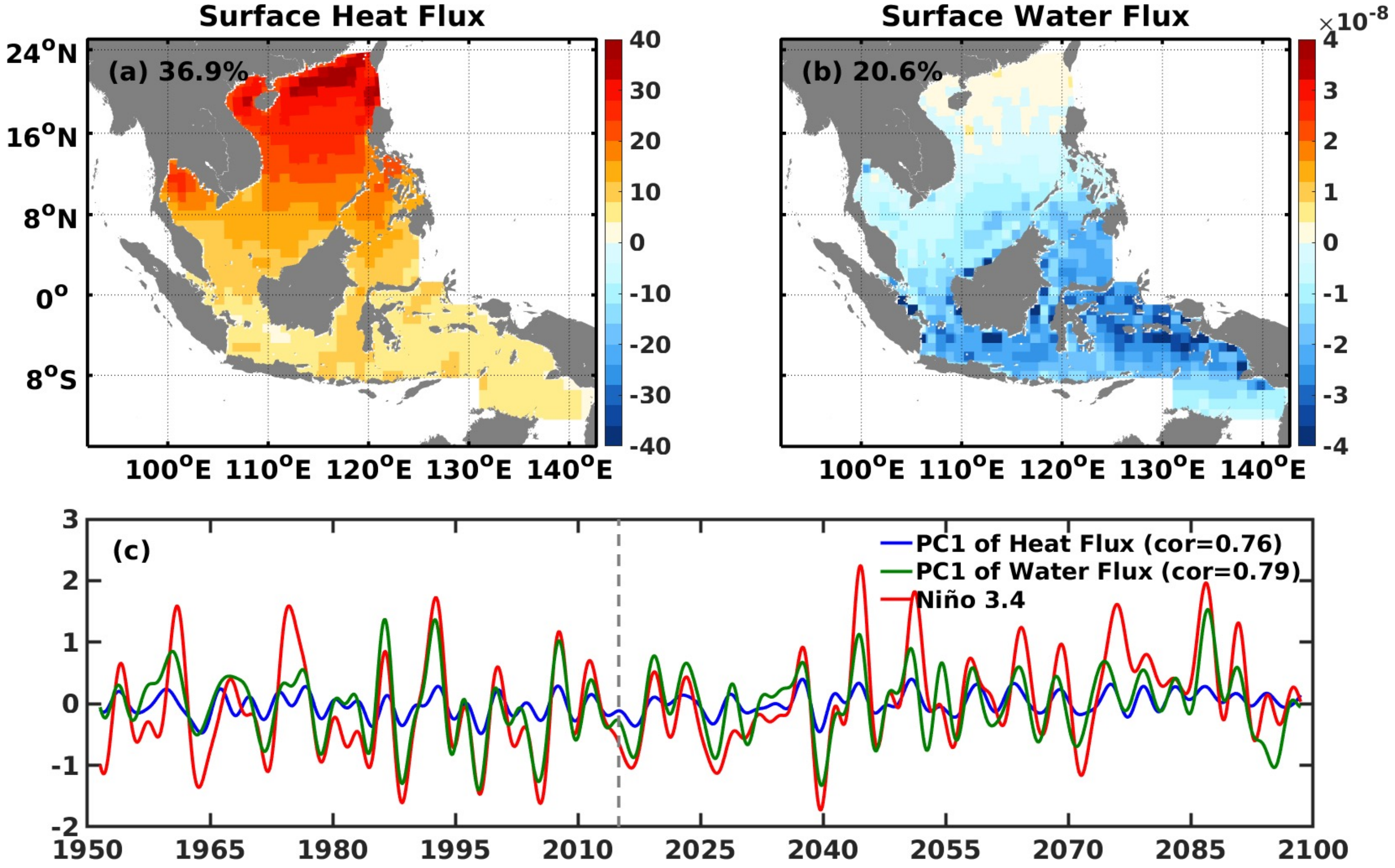
- Freshwater:
FWT lags SFF 19 months (-0.91)

OHC variability is mainly caused by **OHT**, while **FWC** variability is mainly induced by **SFF**.

4. Causes of sea-level trends and variability

4.2 ENSO-related variability caused by air-sea fluxes

EOF1 of SHF and SFF



Freshwater:

Cor(SFF, FWC) = 0.68

SFF $\xrightarrow[\text{ENSO}]{}$ FWC → HSSL

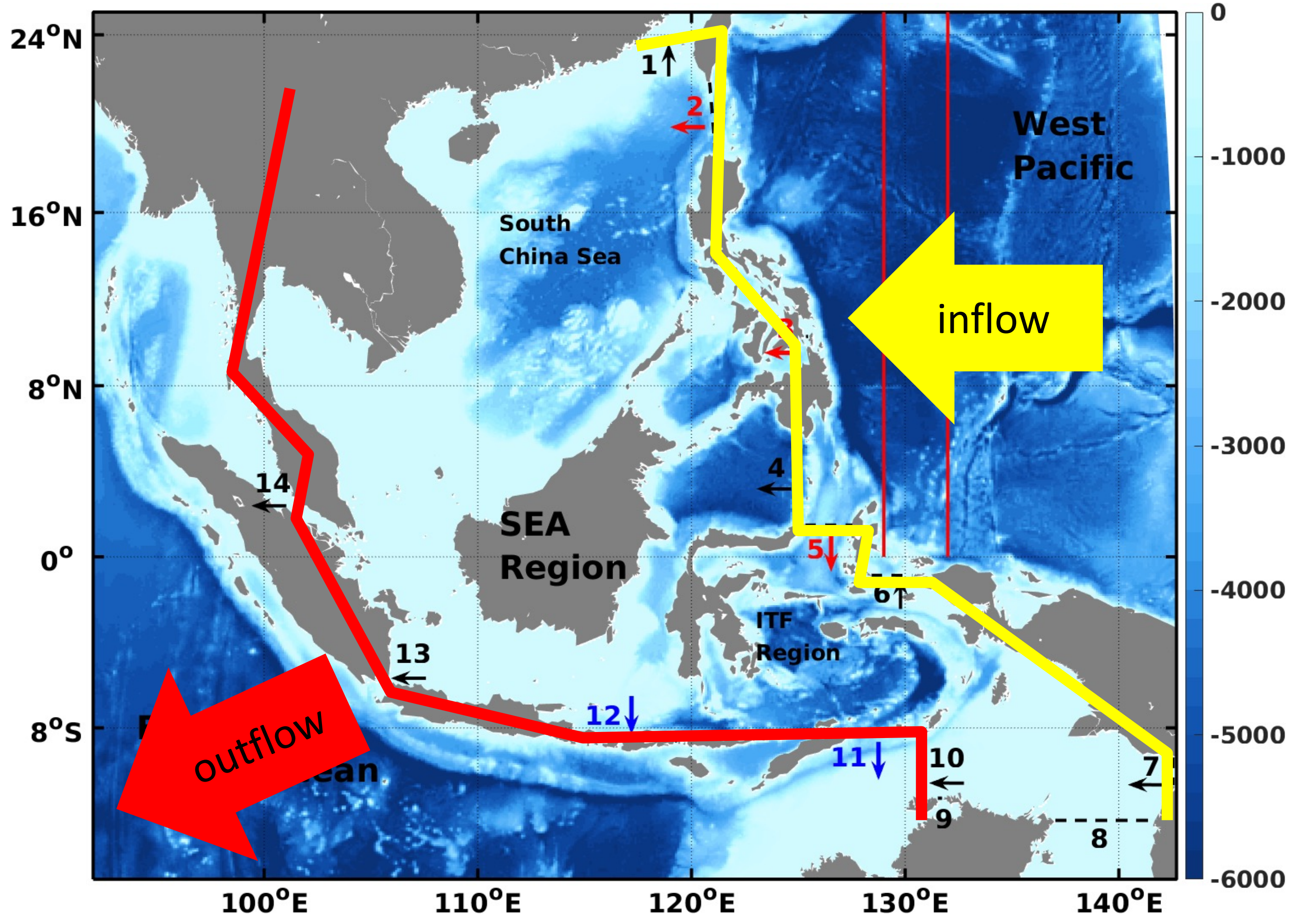
Heat:

Cor(SHF, OHC) = -0.65

SHF damps OHC anomaly

4. Causes of sea-level trends and variability

4.2 ENSO-related variability caused by ocean transports



Ocean heat transport:

$$OHT = \rho c_p \iint_0^H V \cdot (T - \boldsymbol{T_{mean}}) dzdx,$$

Ocean freshwater transport:

$$FWT = \iint_0^H V \cdot \frac{\boldsymbol{S_{mean}} - S}{S_{ref}} dzdx ,$$

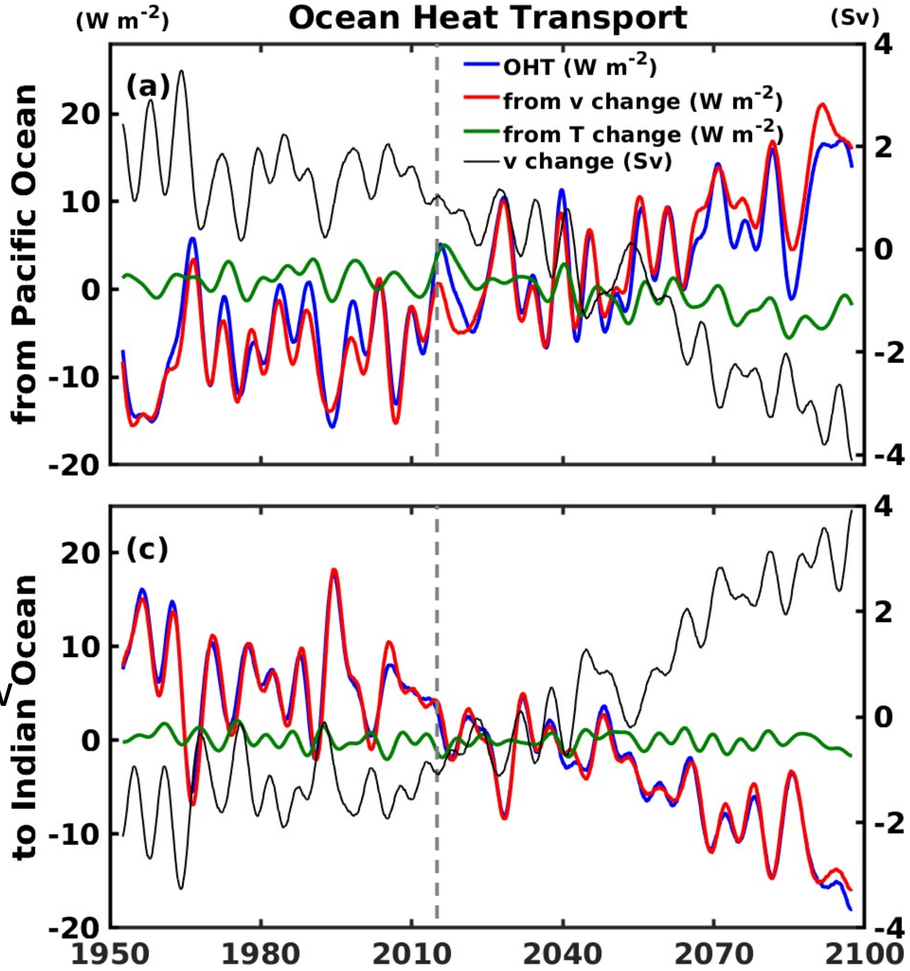
The **relative** heat/freshwater contribution to the study domain.

4. Causes of sea-level trends and variability

4.2 ENSO-related variability caused by ocean transports

inflow

outflow



OHT decomposition:

$$\boxed{OHT} = \iint_0^H tv\,dz\,dx = \iint_0^H (\bar{t}\bar{v} + \boxed{\bar{t}v'} + \boxed{t'\bar{v}} + t'v')\,dz\,dx$$

Velocity variability:

$$\boxed{F_v} = \iint_0^H v'\,dz\,dx$$

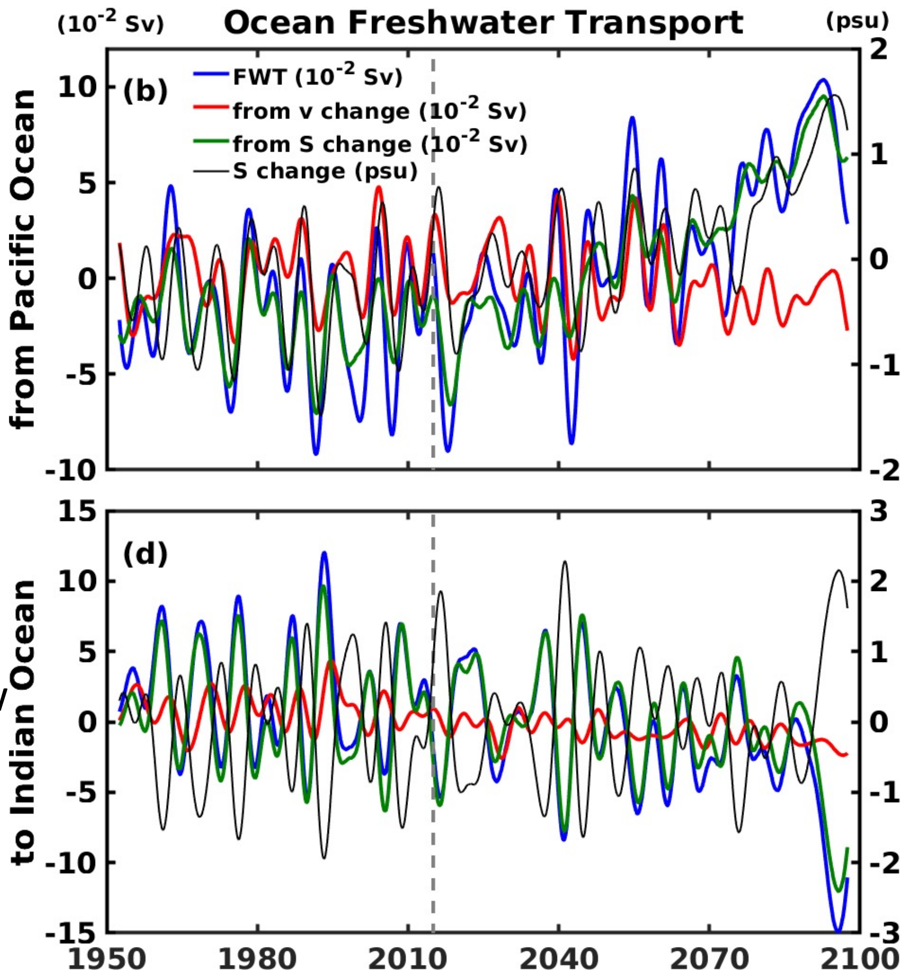
- The increasing trend and variability of the OHT is caused by the **decreasing volume transport** and the **variability of volume transport**, respectively.
- Inflow volume transport lags **Niño 3.4 index** 7 months (-0.76). OHT → OHC → TSSL

4. Causes of sea-level trends and variability

4.2 ENSO-related variability caused by ocean transports

inflow

outflow



FWT decomposition:

$$\boxed{FWT} = \iint_0^H fv\,dzdx = \iint_0^H \left(\bar{f}\bar{v} + \boxed{\bar{f}v'} + \boxed{f'\bar{v}} + f'v'\right)dzdx$$

Salinity variability:

$$\boxed{F_s} = \frac{\iint_0^H (S_{mean} - S)\,dzdx}{\iint_0^H dzdx}$$

The inflow-freshwater transport from the Pacific is enhanced with **fresher** water in the future.

4. Causes of sea-level trends and variability

4.2 ENSO-related variability caused by air-sea fluxes and ocean transports

El Niño

weaker westward volume transport

⬇

smaller OHT to the SEA region
eastward displaced warm pool

⬇

lower upper-layer ocean temperature in the SEA region

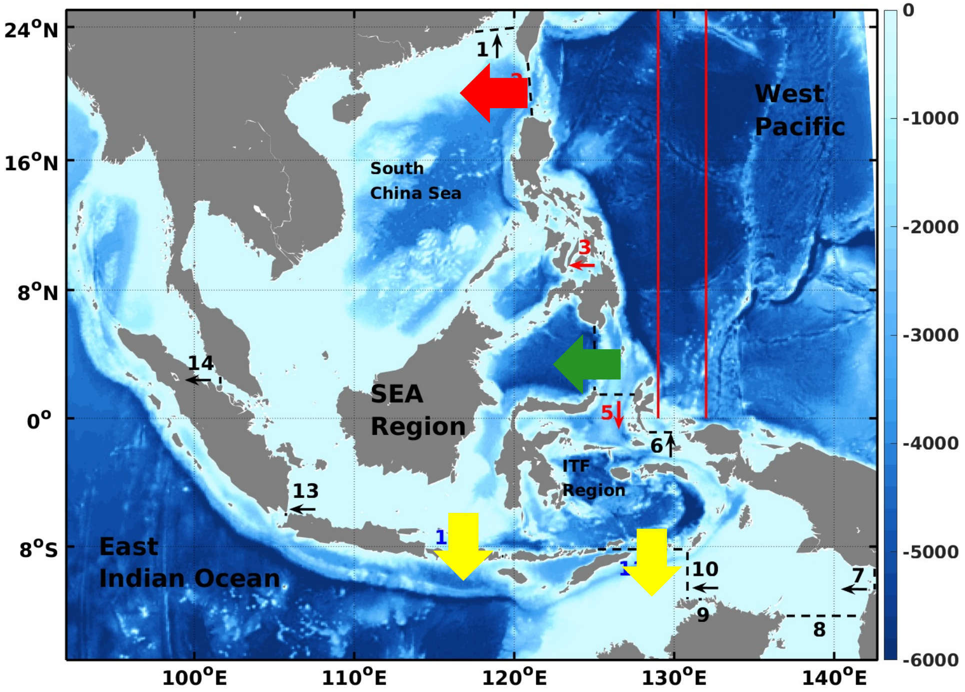
⬇

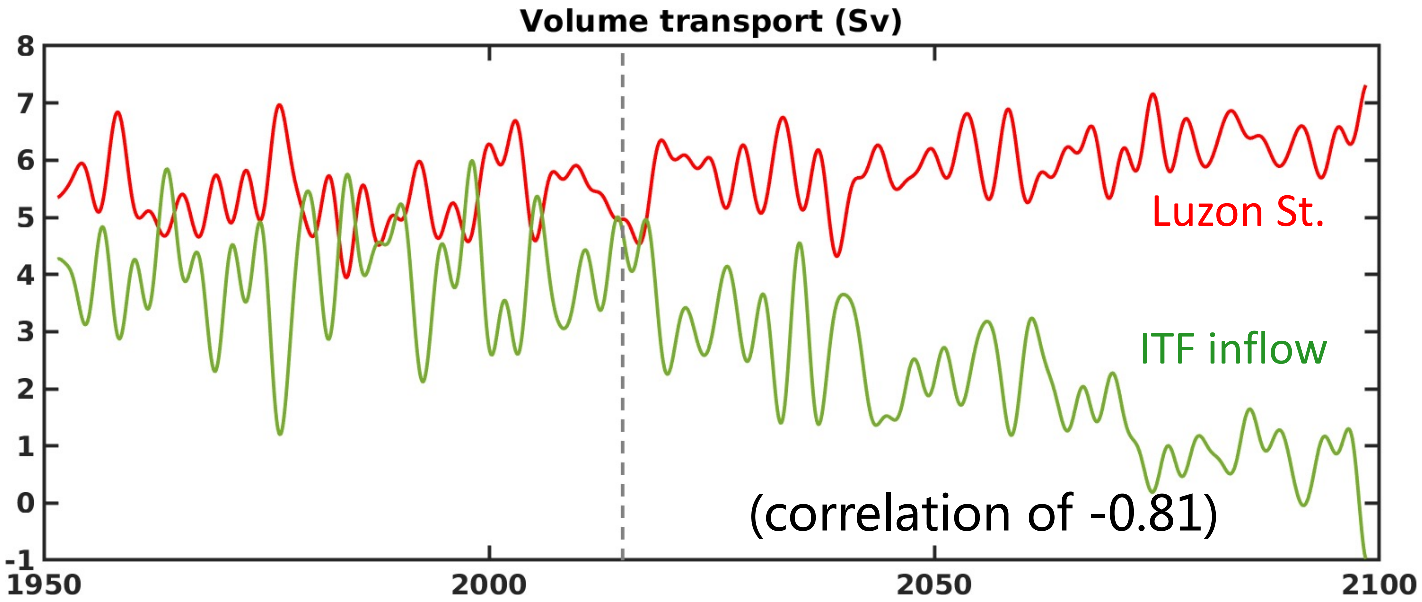
promotes the ocean obtaining additional heat from atmosphere (SHF)
suppresses rising air which leads to less precipitation (SFF)

$\Delta OHC \rightarrow \Delta TSSL$
$\Delta FWC \rightarrow \Delta HSSL$

4. Causes of sea-level trends and variability

4.3 Pathways changing in the western Pacific and SEA region





4. Causes of sea-level trends and variability

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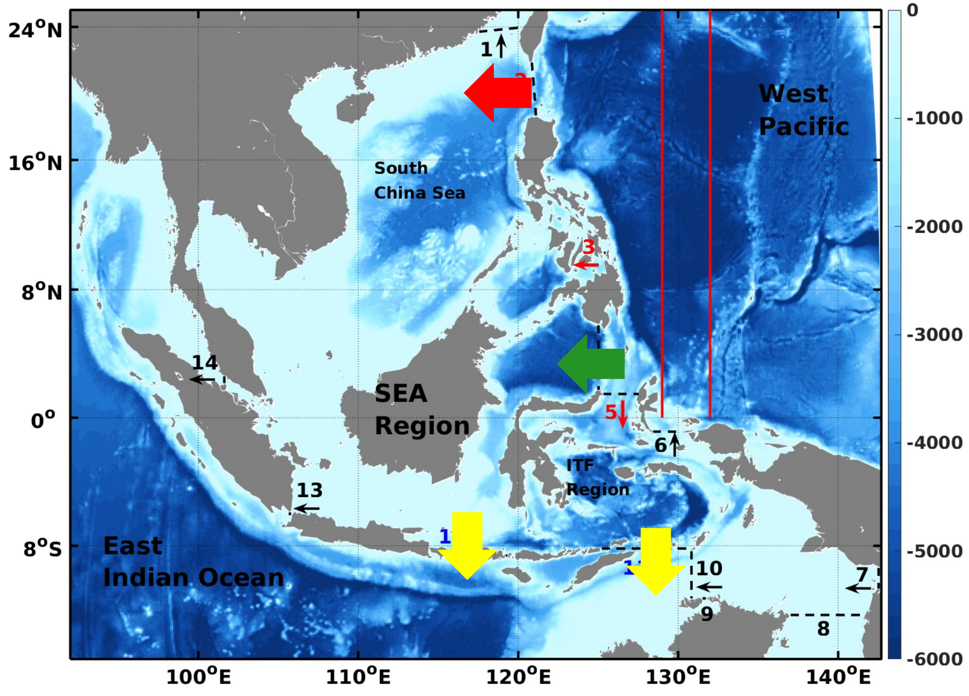
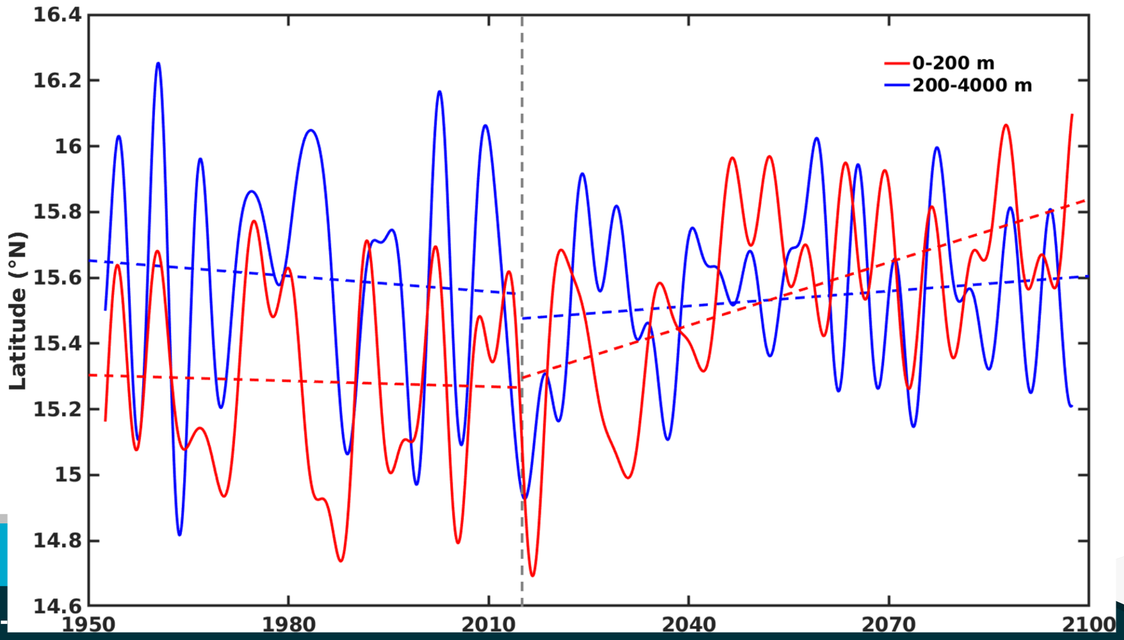


The latitude change of the averaged "center of zonal water velocity"

$$P = \frac{\int (u_{min} - u) \cdot lat}{\int (u_{min} - u)}$$

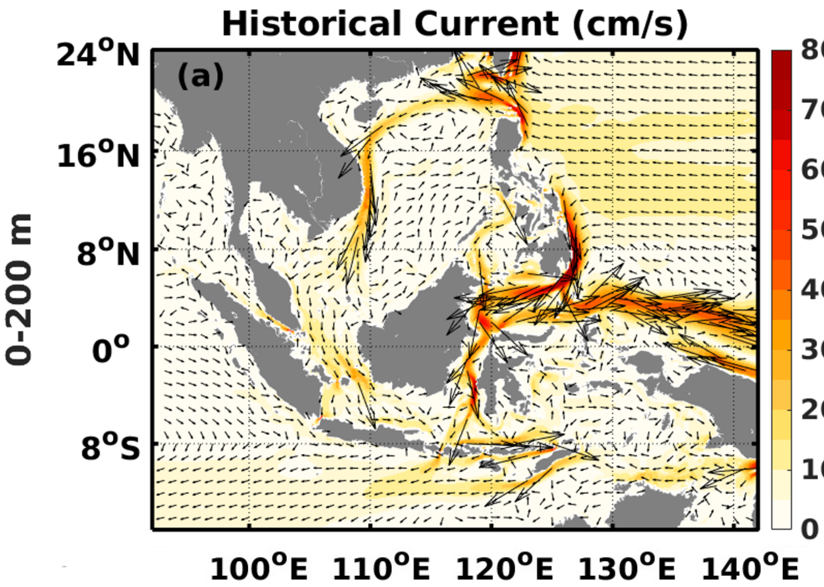
u_{min} is the minimum westward zonal water velocity
u is the averaged zonal water velocity corresponding to lat

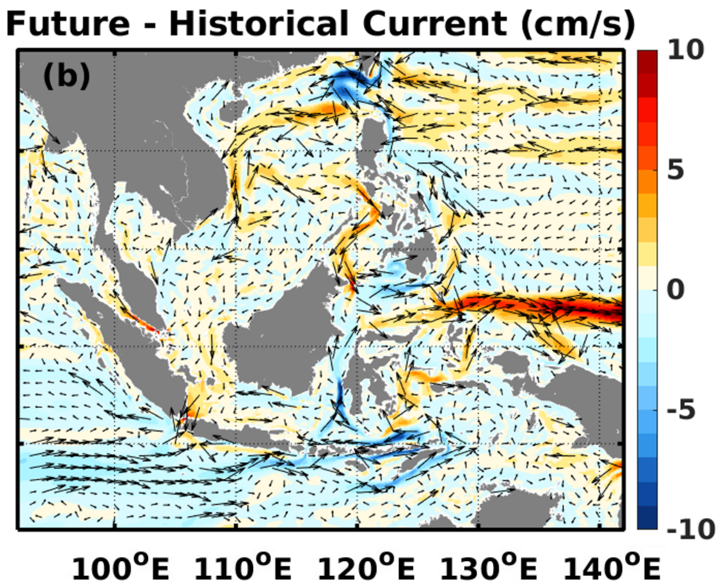


4. Causes of sea-level trends and variability

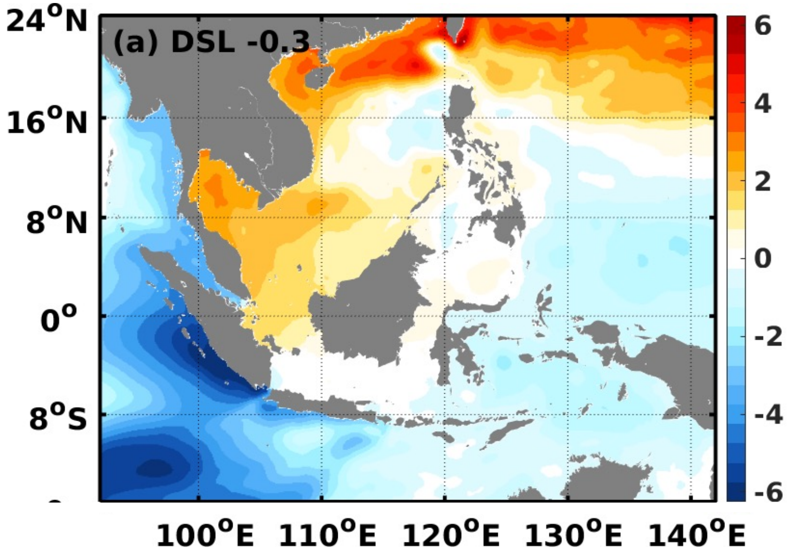
4.3 Pathways changing in the western Pacific and SEA region

Projected Change = Future (2080-2099) – History (1995-2014)





DSL change



5. Summary

- The SEA sea level is deeply influenced by **ENSO variability**. Specifically, ENSO affects **TSSL** mainly through **ocean transport**, while it impacts **HSSL** mainly through **air-sea flux**.
- Ocean transport impacts SEA **OHC** mainly through the **reduced volume transport**, but affects **FWC** by **freshening water**.
- The dominant zonal surface current from the Pacific to the SEA region is found to **move northward**, resulting in a **weakening ITF** and a **strengthening SCSTF**.

Thank you

Yi Jin

Projected Mean and Extreme Sea Level Changes in the China Marginal Seas based on Dynamical Downscaling

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