Sea level Extremes and compounding marine heatwaves in coastal Indonesia in recent decades

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- Kamp, W., W. Han, S. Kido, L. Zhang, J.P. McCreary: Atmospheric Intraseasonal Oscillations Leading to Sea Level Extremes Off the Indonesian Coasts Bordering the Indian Ocean in Recent Decades, J. Clim., (May 1, 2024).
- Han W., L. Zhang, G. Meehl, S. Kido, T. Tozuka, Y. Li, M. McPhaden, A. Hu, A. Cazenave, N. Rosenbloom, G. Strand, B.J. West, and W. Xing: Sea level extremes and compounding marine heatwaves in coastal Indonesia, Nat Commun **13**, 6410 (Oct 27, 2022).

Background

IPCC report: extreme sea level events will be 'once a year' by 2050

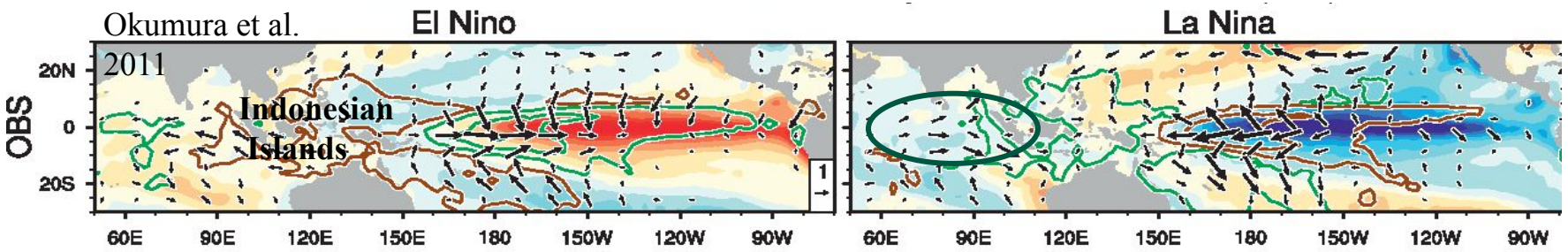
- **Global sea level rise (SLR) - magnified sea surface Height EXtremes (HEXs) & coastal flooding in recent decades;**

- **Most studies – storms & hightides on daily timescales; HEXs induced by climate modes of variability under anthropogenic warming – less attention**

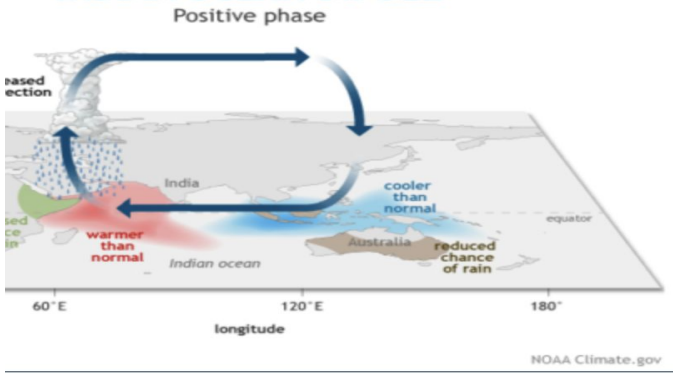
Indo-Pacific climate modes of variability

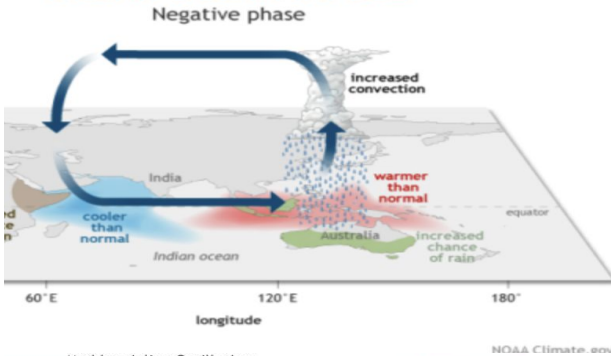
Interannual-decadal timescale:

- **El Nino – Southern Oscillation (ENSO): peak DJF**



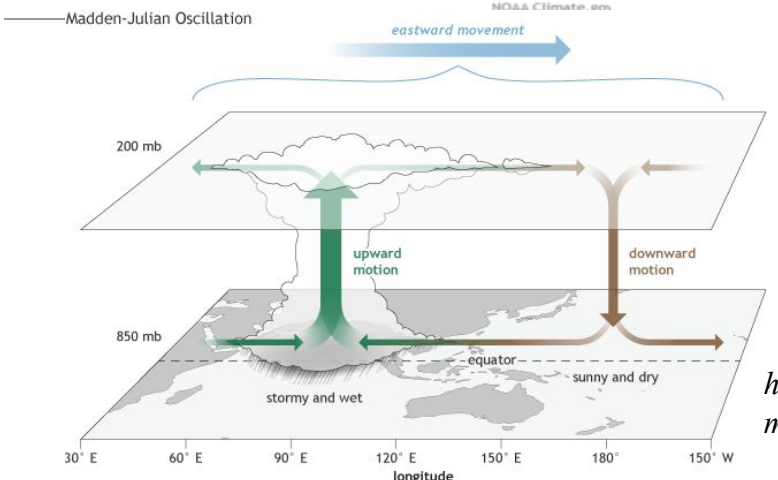
- **Indian Ocean Dipole (IOD): peak in SON**





Intraseasonal timescale:

- **Madden-Julian Oscillation (MJO)** – dominates Atmospheric Intraseasonal Oscilaltion (ISO; 10-90day period)



https://www.climate.gov/media/13488

Goal

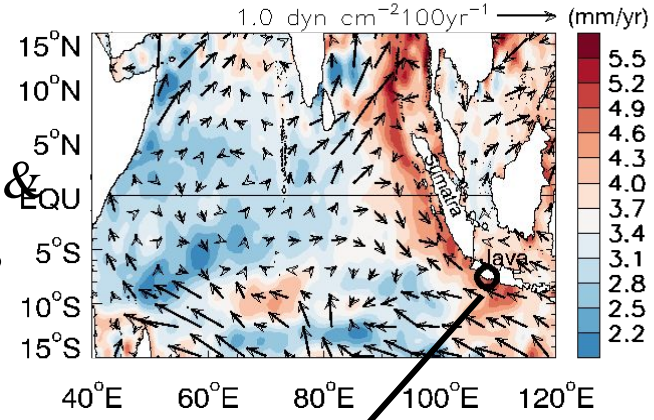
- **Detect climate-driven HEX events around Indonesian coasts of the Indian Ocean & understand their causes**

  - **This talk focuses on the ~30yr** satellite altimetry period (1993-pres)

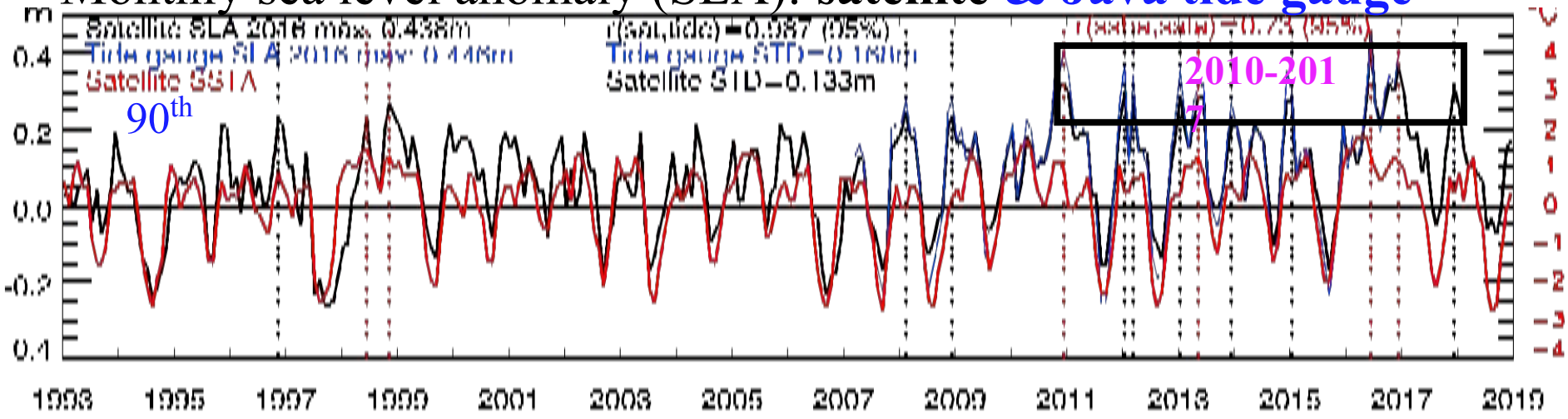
Results

a. HEX events w monthly data, ≥ interannual timescales

Linear trends: satellite sea level & wind 1993-2018; **> 5mm/yr**



Monthly sea level anomaly (SLA): **satellite & Java tide gauge**

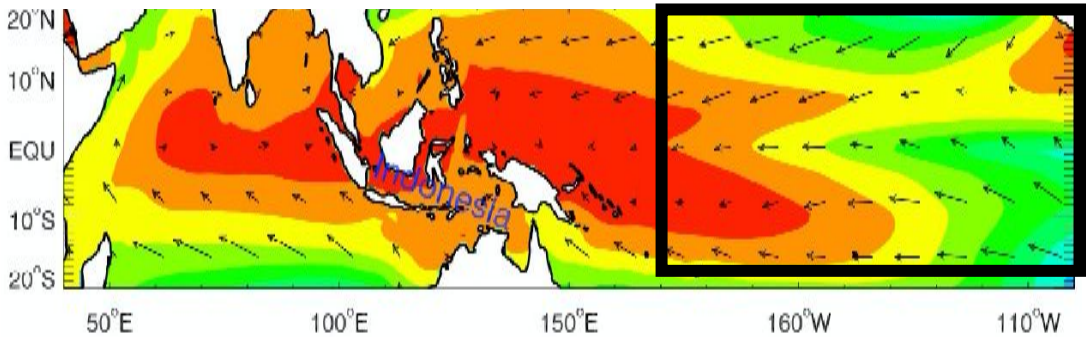


- **Max: monthly ~0.5m:** ~ 0.5-1m daily SLA due to storms & high tides (e.g., Muis et al. 2016)
- **15 HEXs are detected; with 10 concentrating in 2010-2017**

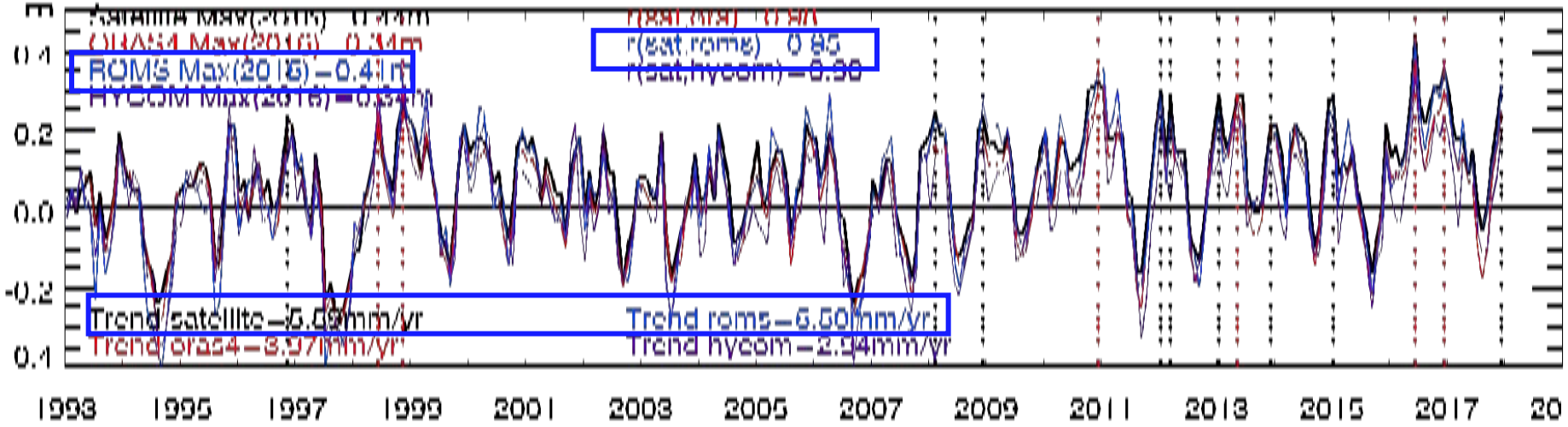
Approach:

- ***OGCM experiments:*** **ROMS & HYCOM** from 1958-present:
  - ***ROMS Main Run & ROMS Wind stress Run***

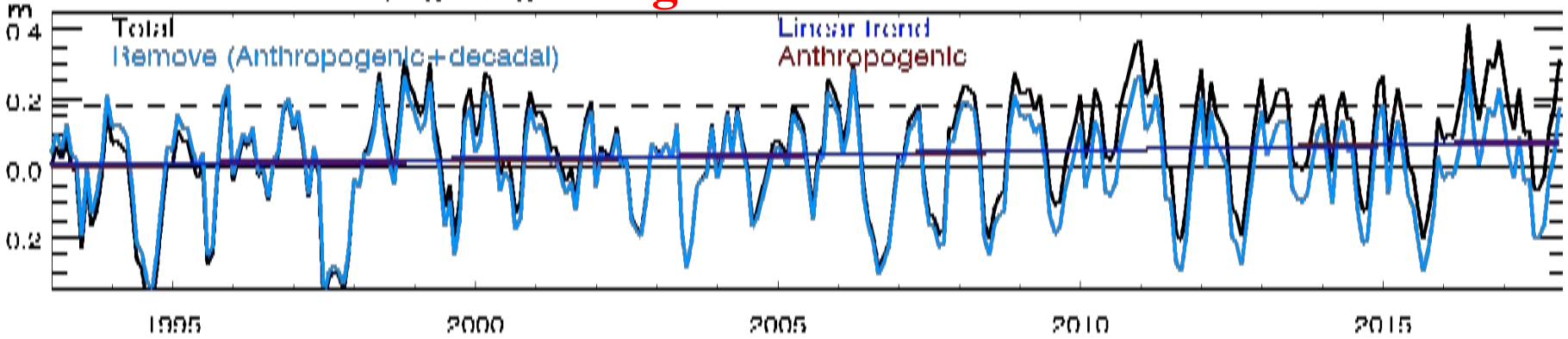
- **CESM1 Pacific Pacemaker Experiments: 10-member ensemble: 1920-present**



Model validation: Java sea level anomaly (SLA) 1993-2017

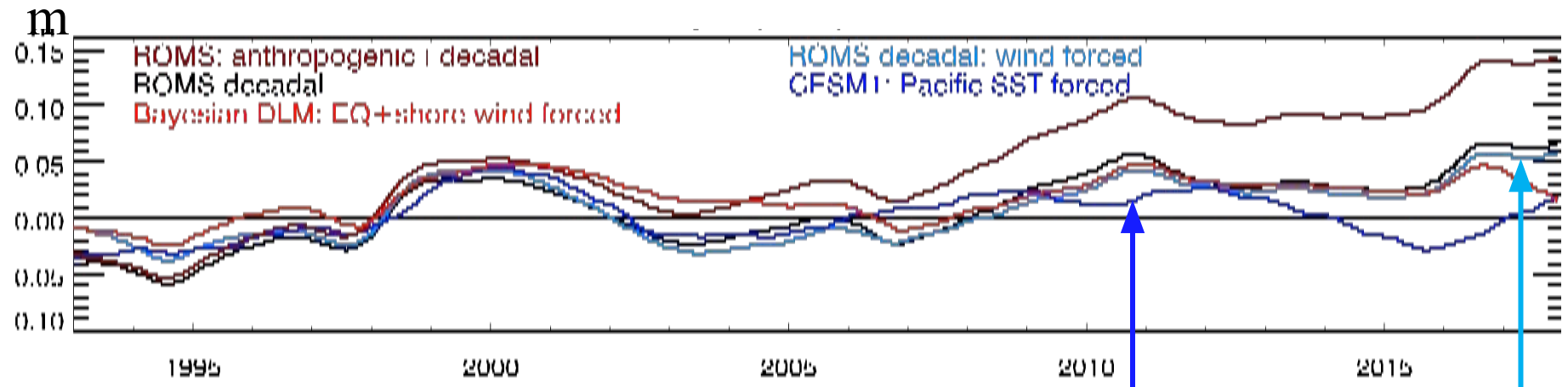


ROMS SLA & anthro global SLR for Java coastal mean

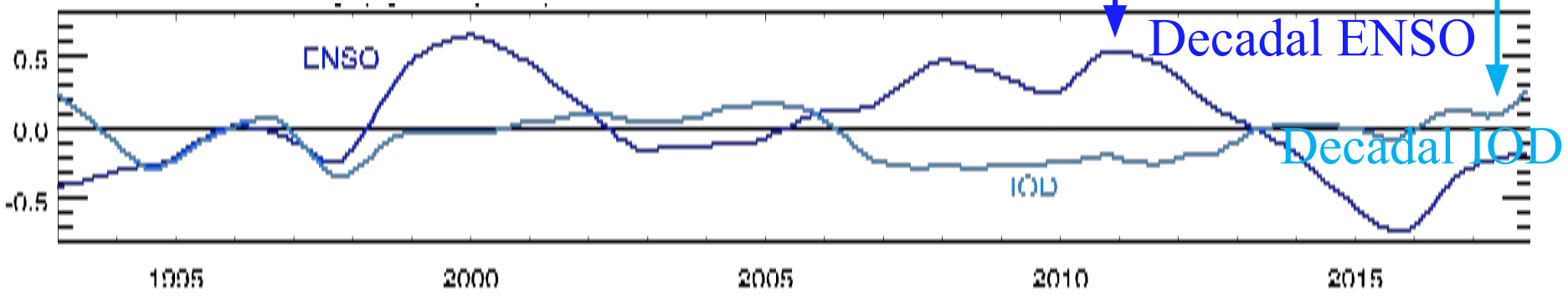


Suggesting that: Anthro. SLR + decadal SLA -> increased no. of HEXs during 2010-2017!

Java coast avg: Decadal SLA from ROMS &CESM1 experiments

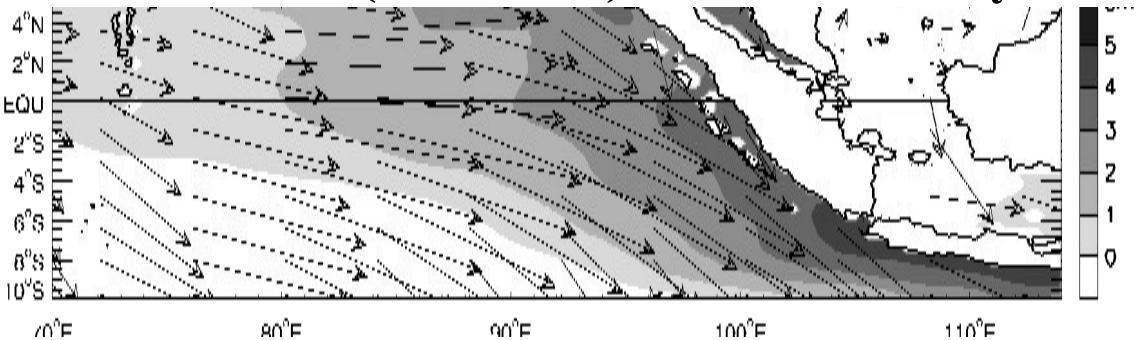


Decadal (8yr lowpassed) ENSO & Indian Ocean Dipole (IOD) indices



Wind & sea level anomalies (SLAs) associated with **decadal -IOD & -ENSO** (La Nina)

Decadal SLA (2010-2017) & wind anomaly



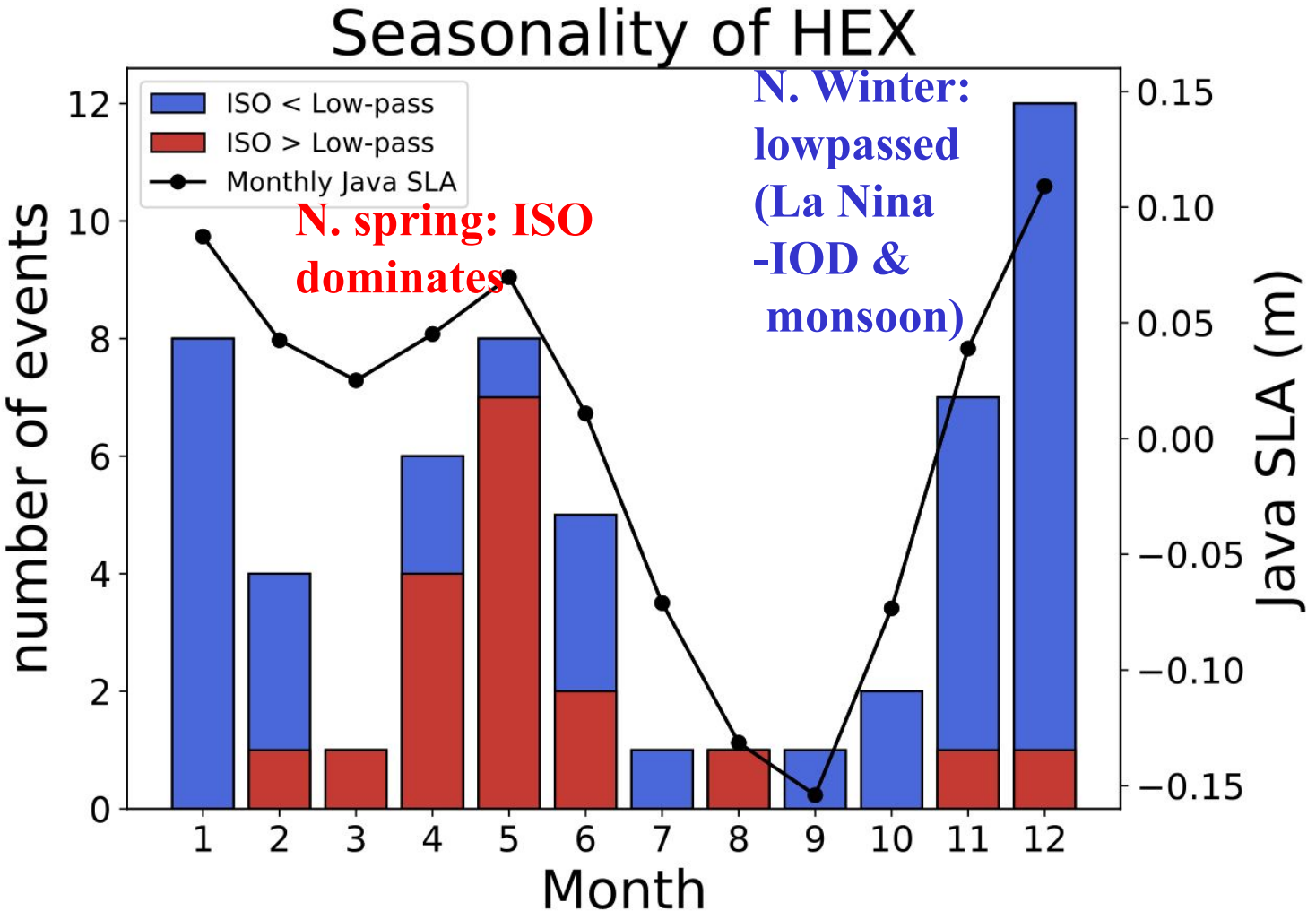
Summary 1

- **15 Height EXtreme (HEX) events are detected along the Indonesian coast since 1993; 2/3 concentrate in 2010-2017**

- **Anthro. global SLR combined with** EQ westerly and longshore northwesterly **surface wind anomalies associated with decadal negative ENSO & IOD raise sea level along Indonesia coast, increasing the no. of HEX events during 2010-2017**

b. Impacts of ISOs (dominated by MJO): daily data

- **ISOs contribute ~0.2m to HEX amplitude**

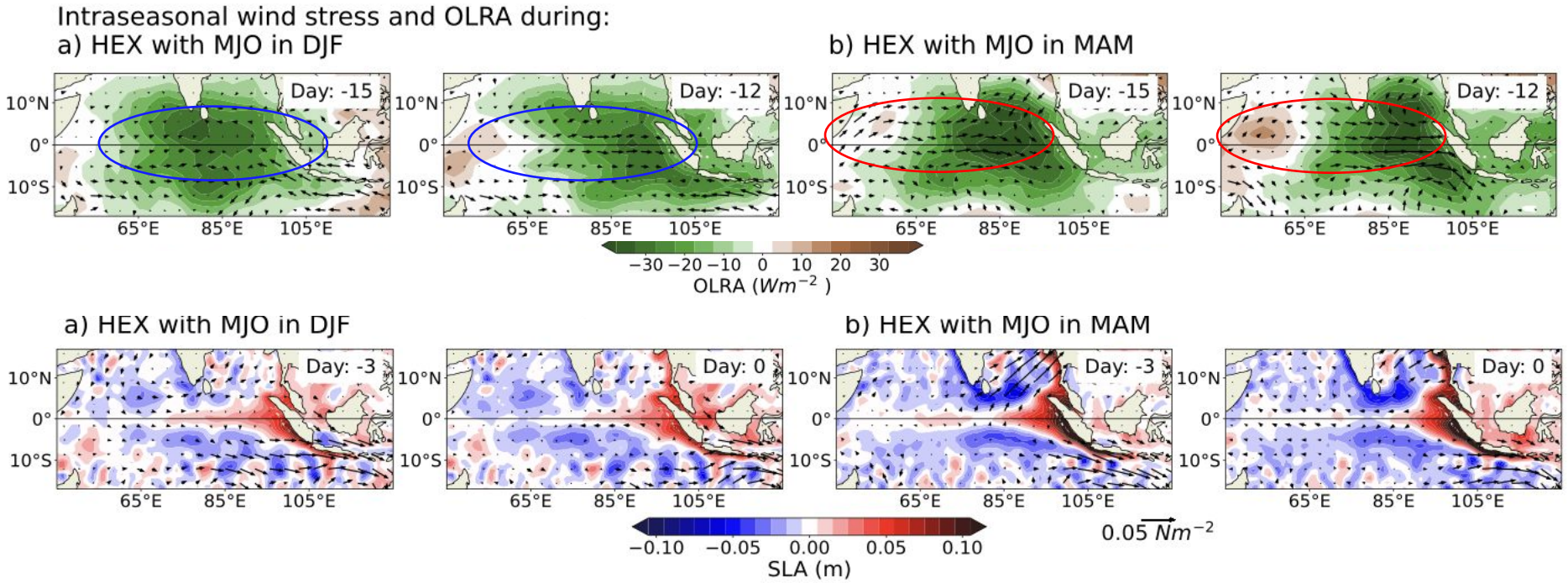


Why do MJOs contribute more to HEX in spring?

- ***Winter MJO:*** *convection shift south of EQ, weaker EQ westerlies*

- ***Spring MJO****:*

Convection more symmetric about equator, basin-scale stronger EQ westerlies



Summary 2

- **MJOs dominate interannual climate modes in causing HEXs along Indonesian coasts in boreal spring, contributing ~0.2m to HEX amplitude;**

- **The stronger zonal winds across the equatorial Indian Ocean for the spring MJOs drive strong SLAs, resulting in larger contributions to HEX events compared to winter.**

Thank you!

Acknowledgements

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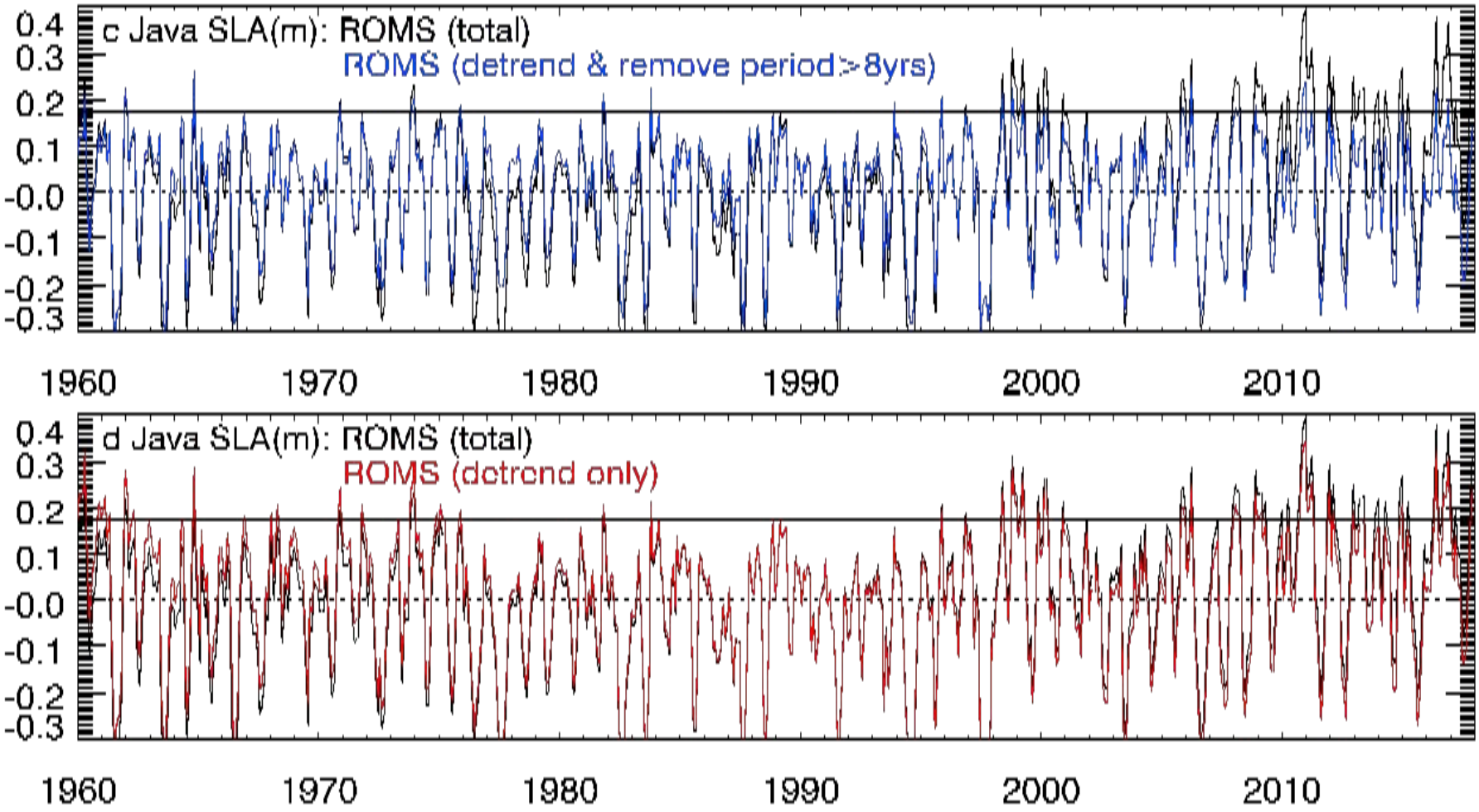
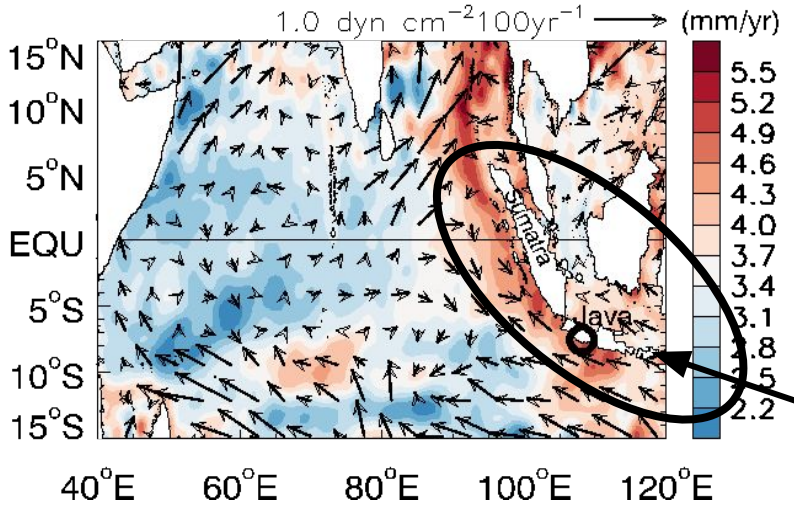
ROMS main run: sea level anomaly (SLA) avg Java coast



Anthro. SLR + decadal SLA -> increased no. of HEXs during 2010-2017!

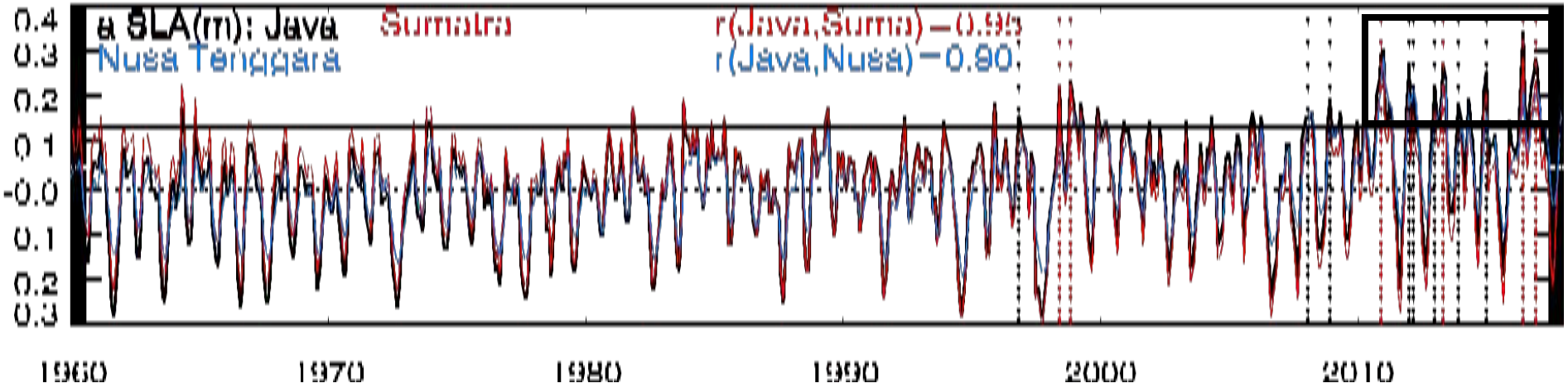


Coherent SLA along entire Indonesian coasts since 1960!

(ORAS4 reanalysis data);

rest - focus on Java coastal area

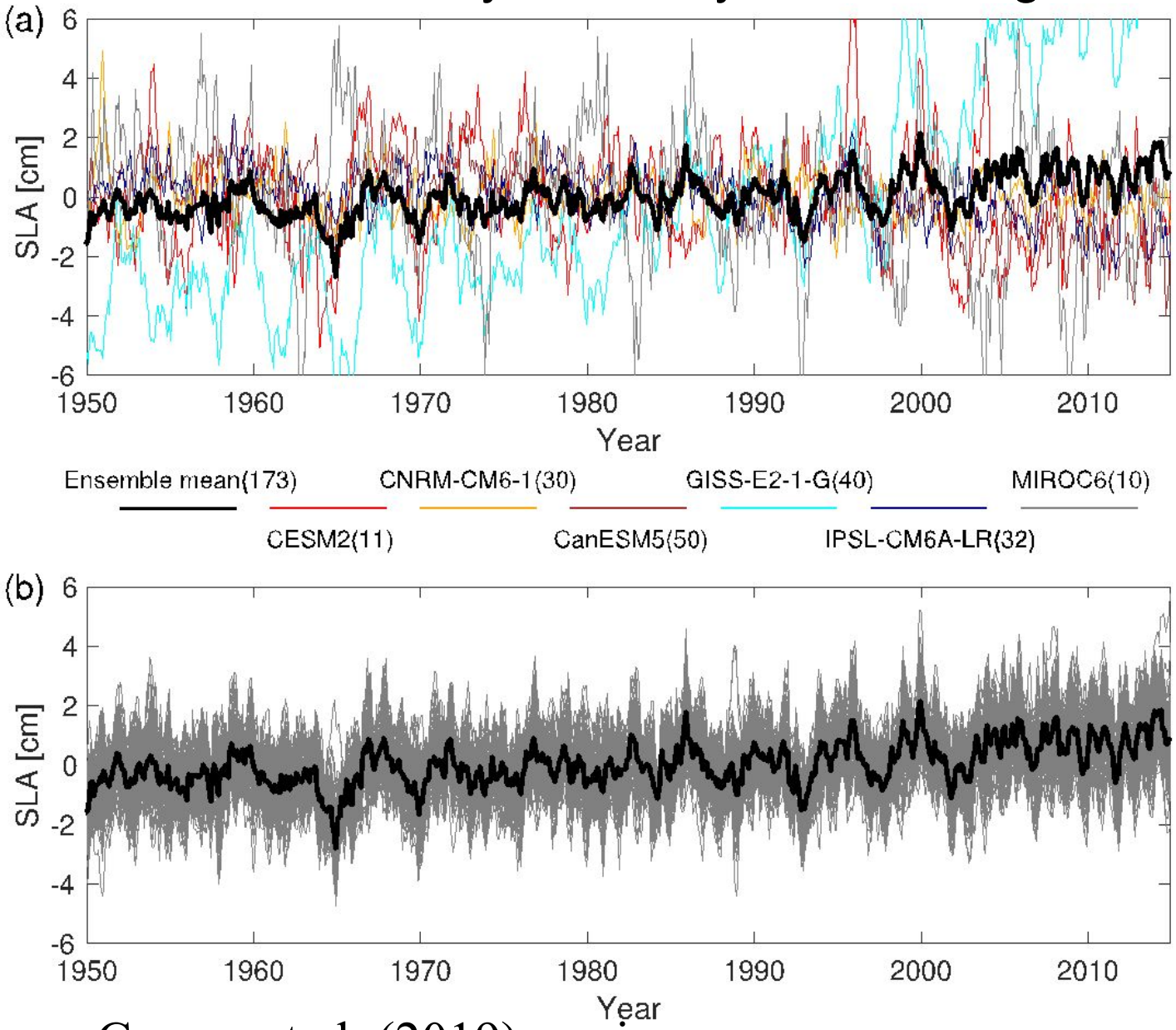
Nusa Tenggara



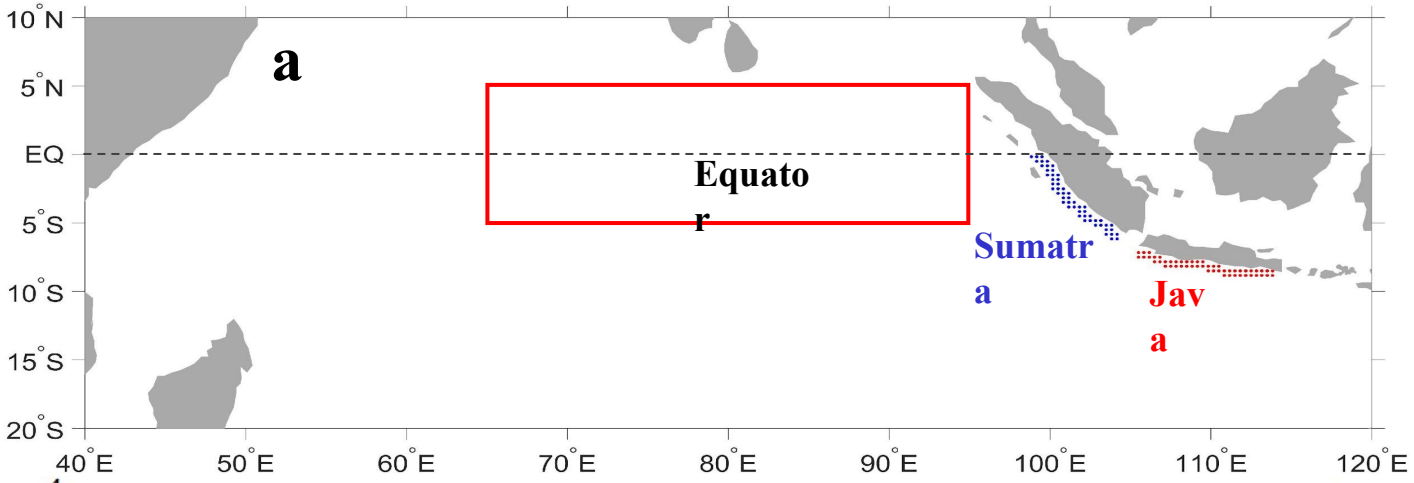
Question:

Why do the Height Extremes (HEXs) concentrate in the 8yr period of 2010-2017?

CMIP6 LENS: Externally forced dyn. SLA along Java coast



Carson et al. (2019): review paper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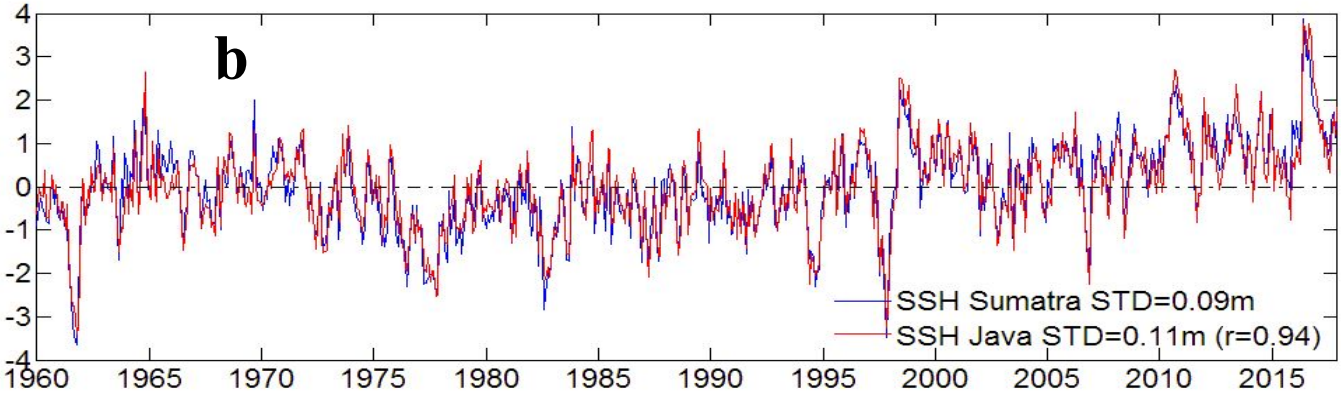
100°E
110°E
120°E
Equator
Sumatra
Java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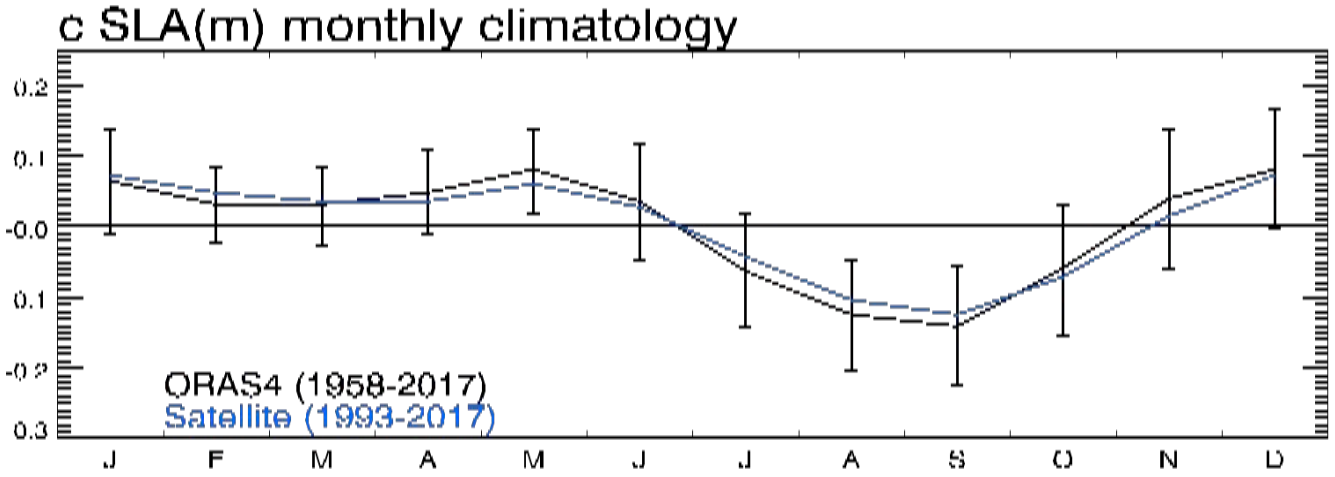
SSH Sumatra STD=0.09m
SSH Java STD=0.11m (r=0.94)


c SLA(m) monthly climatology
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ORAS4 (1958-2017)
Satellite (1993-2017)
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