

# Atmospheric Intraseasonal Oscillations Leading to Sea Level Extremes in Coastal Indonesia during Recent Decades

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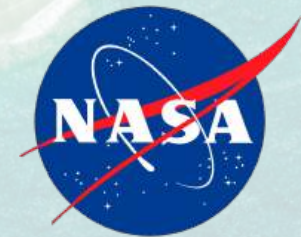
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## **Acknowledgements:**

NASA International Ocean Vector Wind Science Team award 80NSSC23K0982

NASA Ocean Surface Topography Science Team award 0NSSC21K1190



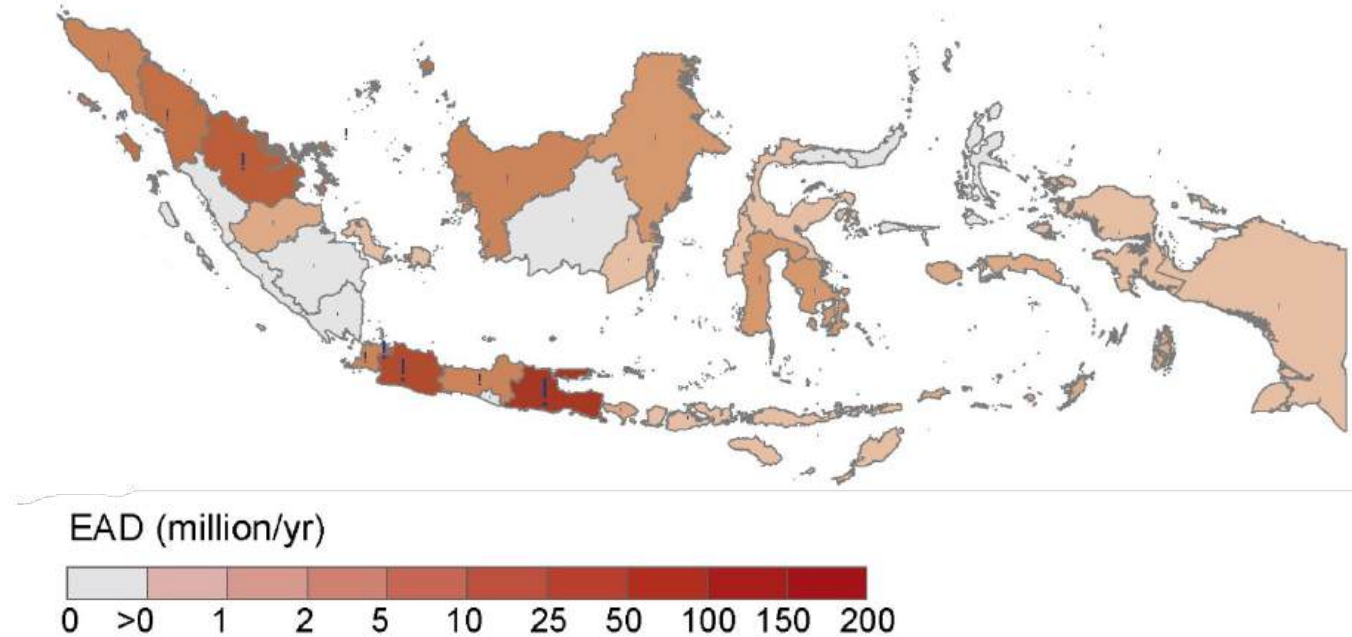
## Background:

High EXtreme (HEX) sea level events have large impacts on coastal communities, especially island nations

HEX events will be more damaging in the future due to:

- Anthropogenic sea level rise
- Urban expansion in coastal areas

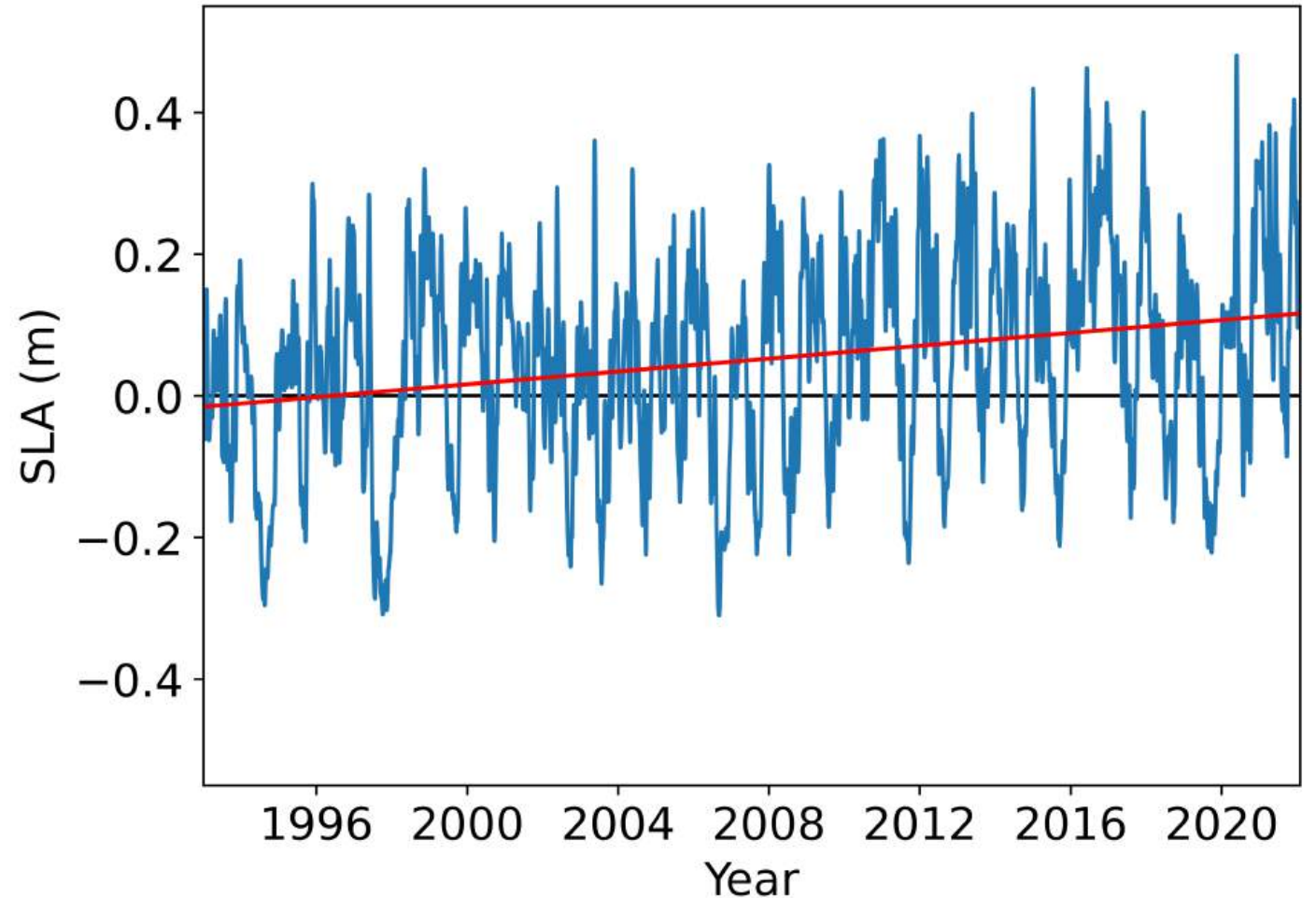
Coastal flood risk - 2030



## Background:

Java SLA internal variability exceeds the magnitude of anthropogenic sea level rise

**Our goal is to understand the role of intraseasonal variability on HEX along the Java coast bordering the Indian Ocean**



The satellite mean Java SLA (blue) and its linear trend (red) are shown from 1993-2021

# Madden-Julian Oscillation (MJO):

The MJO is the dominant mode of intraseasonal variability in the tropics

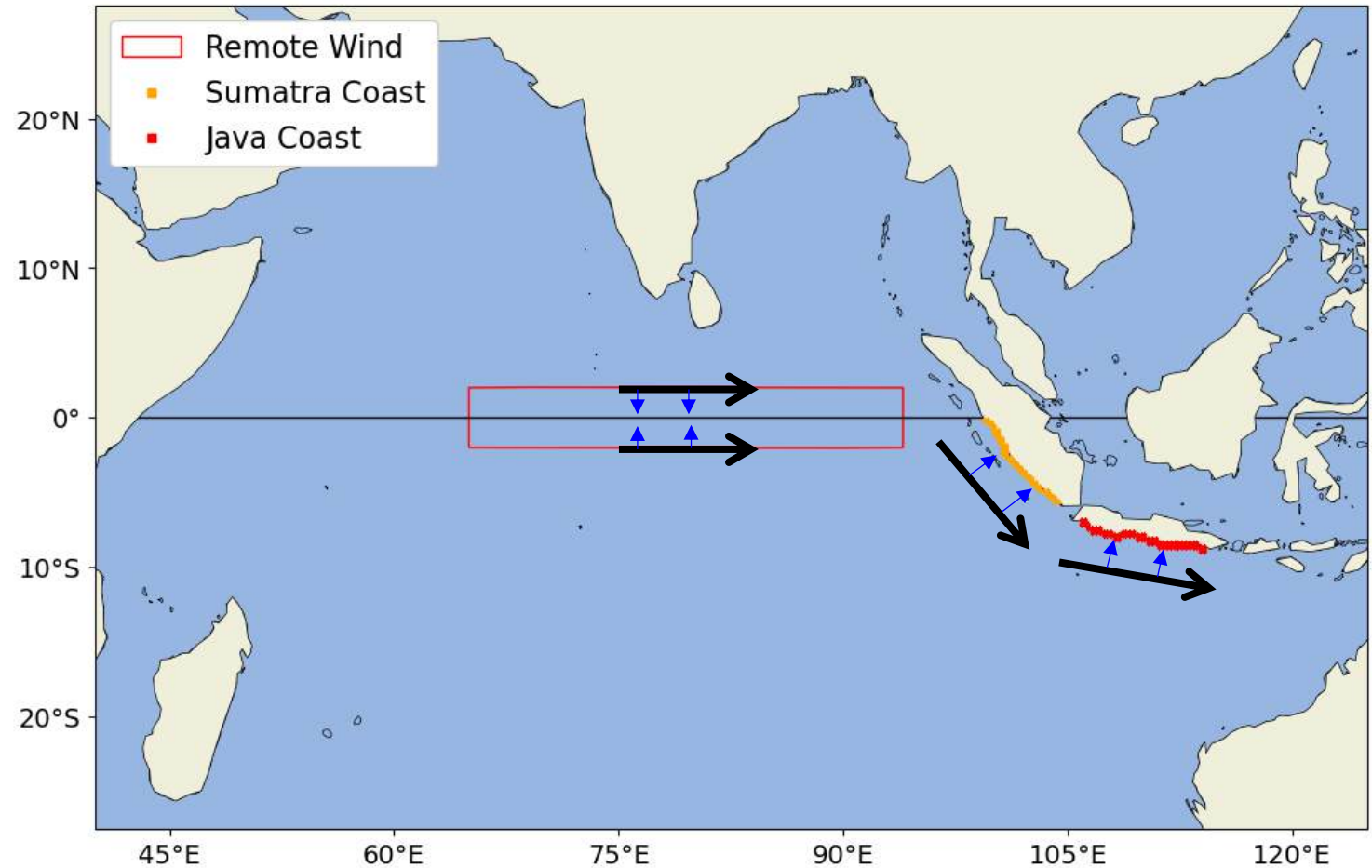
The MJO is associated with large scale convection and wind patterns over the Indian and Pacific Oceans



# How can the MJO influence Java sea level?

Remote westerly winds create equatorial Kelvin waves

Local longshore winds create and enhance coastal Kelvin waves

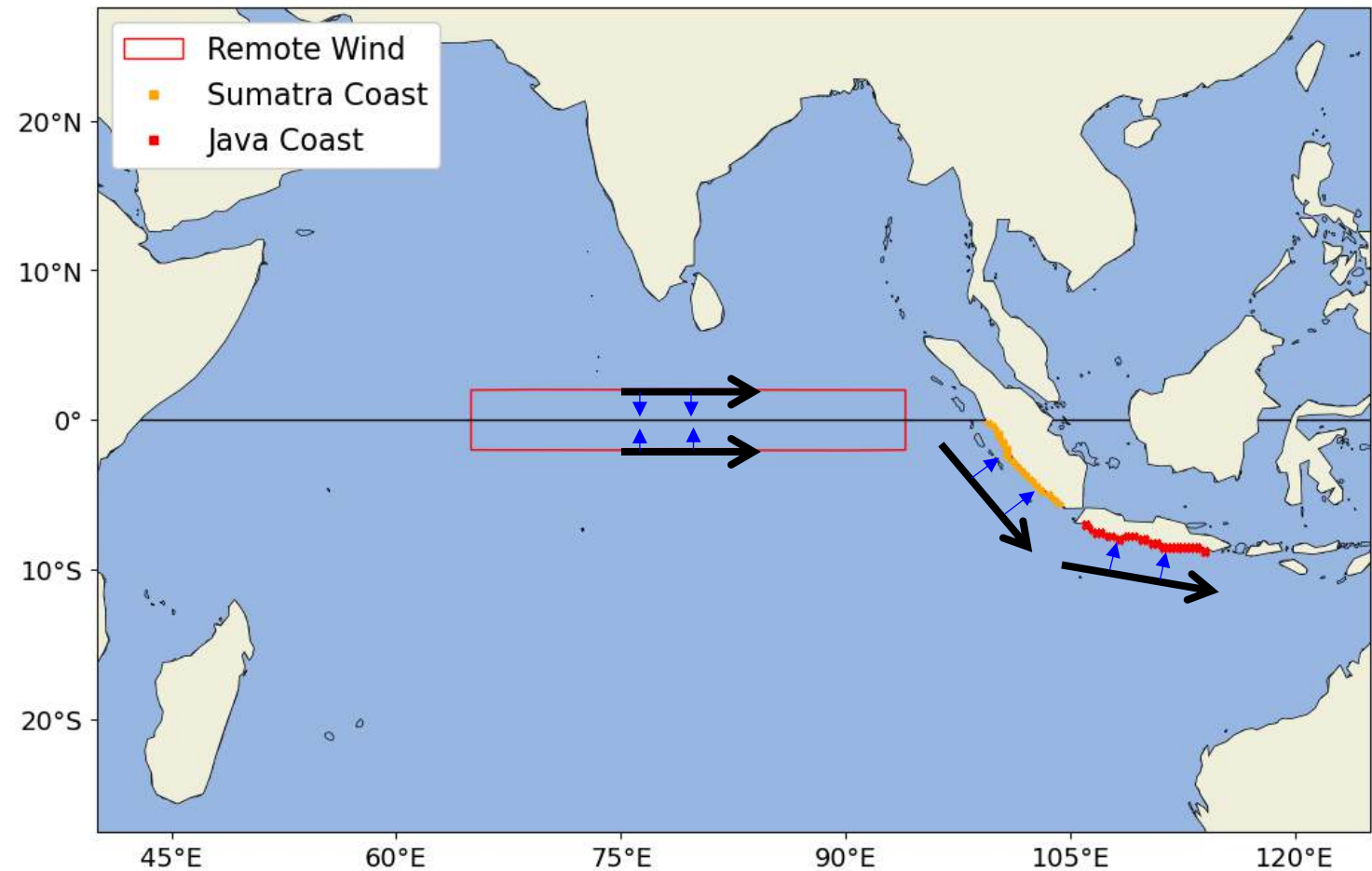


Black arrows indicate winds consistent with increasing Java SLA and blue arrows indicate the associated Ekman transport

## Research Questions:

1. How does the Madden-Julian Oscillation (MJO), drive HEX events along the coast of Java?

2. How does the seasonality of the MJO impact HEX events?



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## Approach:

Quantify impact of surface wind stress vs buoyancy flux with the Regional Ocean Modelling System (ROMS)

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## Approach:

Quantify impact of surface wind stress vs buoyancy flux with the Regional Ocean Modelling System (ROMS)

Determine role of equatorial wind and local longshore wind forcing on Java SLAs using

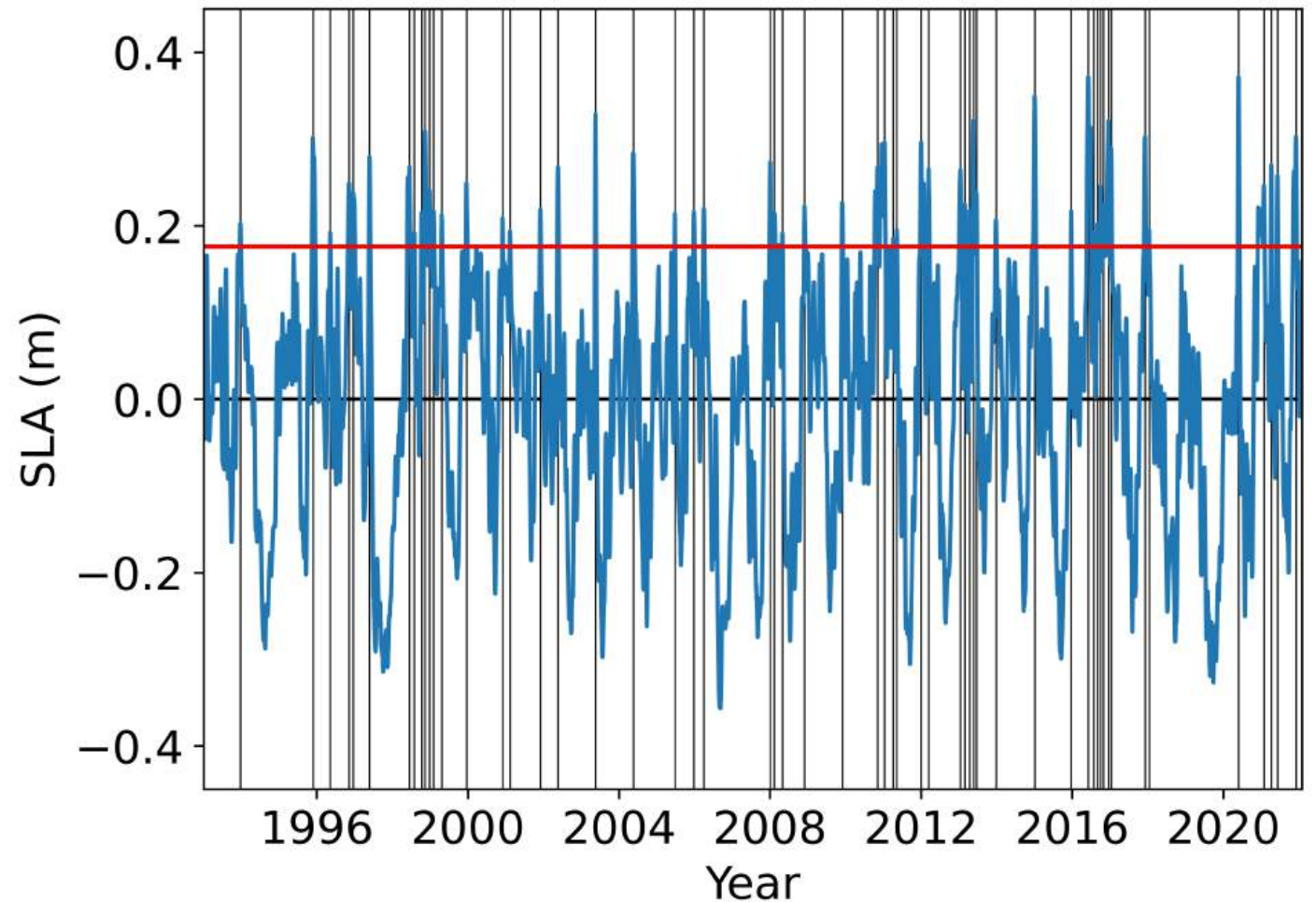
- Bayesian dynamic linear model
- Composite analysis

## Definition of HEX events:

Java SLA observed using satellite data from 1993-2022

HEX events were defined as detrended satellite Java SLA that exceeds the 90<sup>th</sup> percentile for at least 5 consecutive days.

56 HEX events from 1993-2022

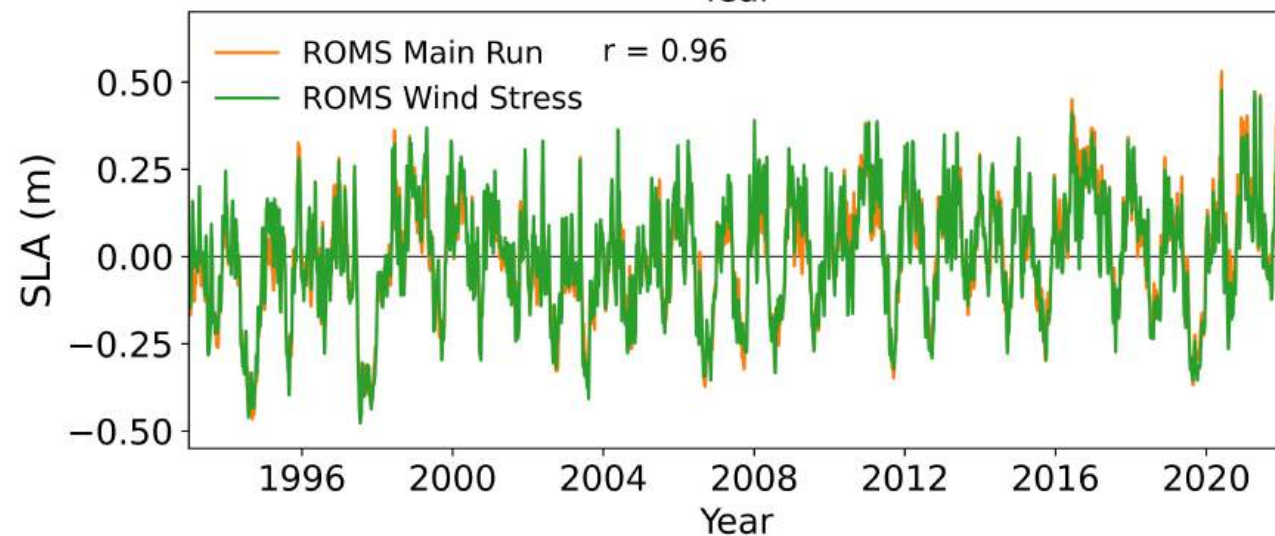
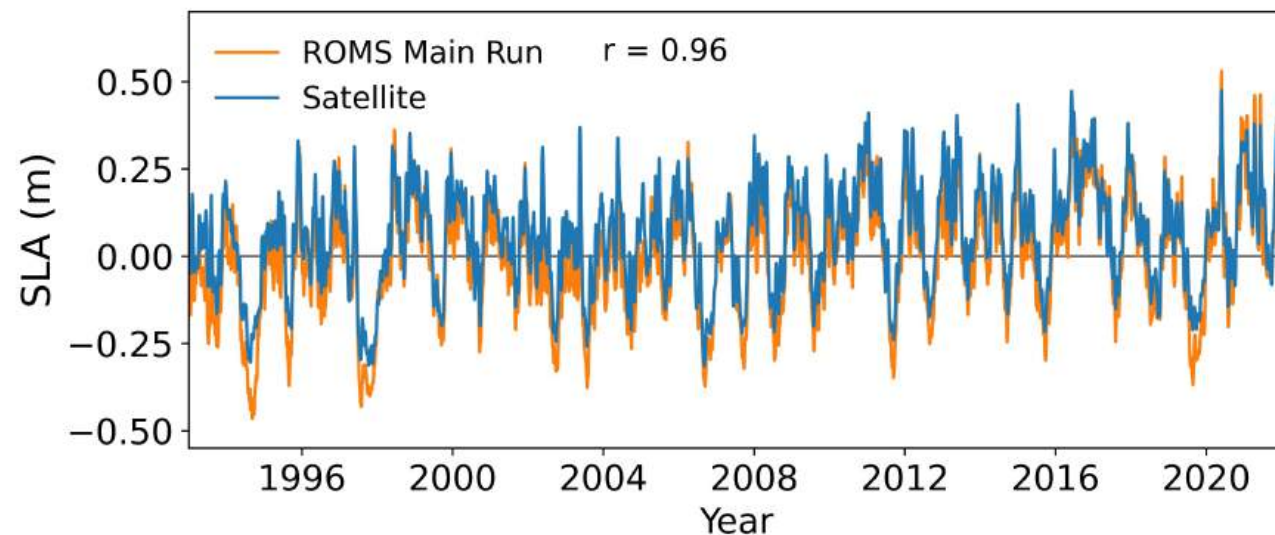


The satellite Java SLA (blue), its 90<sup>th</sup> percentile (red), and HEX (vertical black lines) are shown from 1993-2021

# Wind stress vs. buoyancy flux

Regional Ocean Modelling System (ROMS) main run validated successfully using satellite observations

ROMS Wind Stress run shows wind stress is the dominant physical process controlling Java SLAs



# Bayesian Dynamic Linear Model:

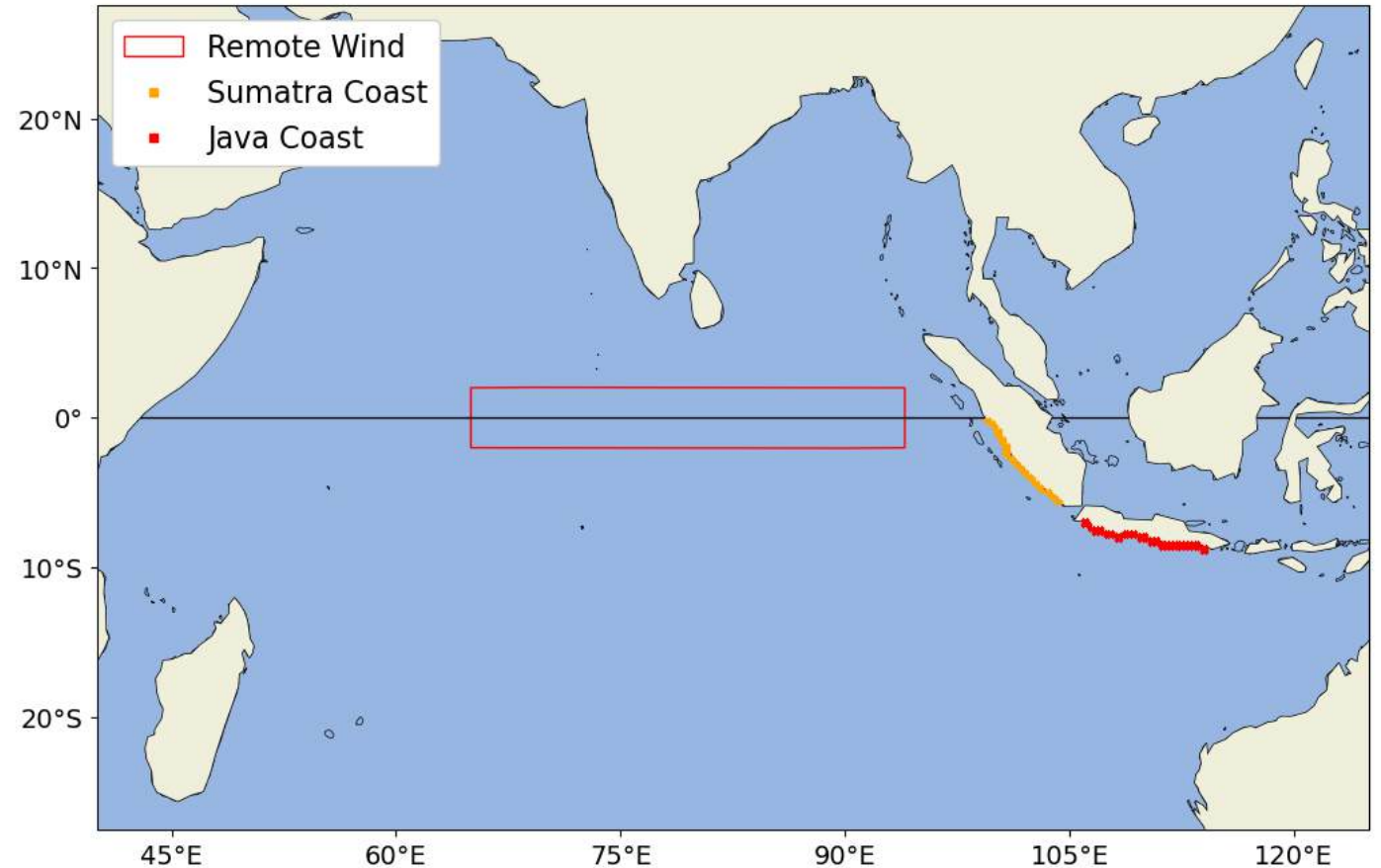
$$Y(t) = b_0(t) + b_1(t)X_1(t) + b_2(t)X_2(t) + b_3(t)X_3(t) + \varepsilon(t), \varepsilon(t) \sim N[0, V(t)] \quad (1)$$

$$b_i = b_i(t-1) + w_i, w_i \sim N[0, W_i(t)] \quad (2)$$

## Quantified wind stress forcing on Java SLAs at intraseasonal timescales

### Predictors:

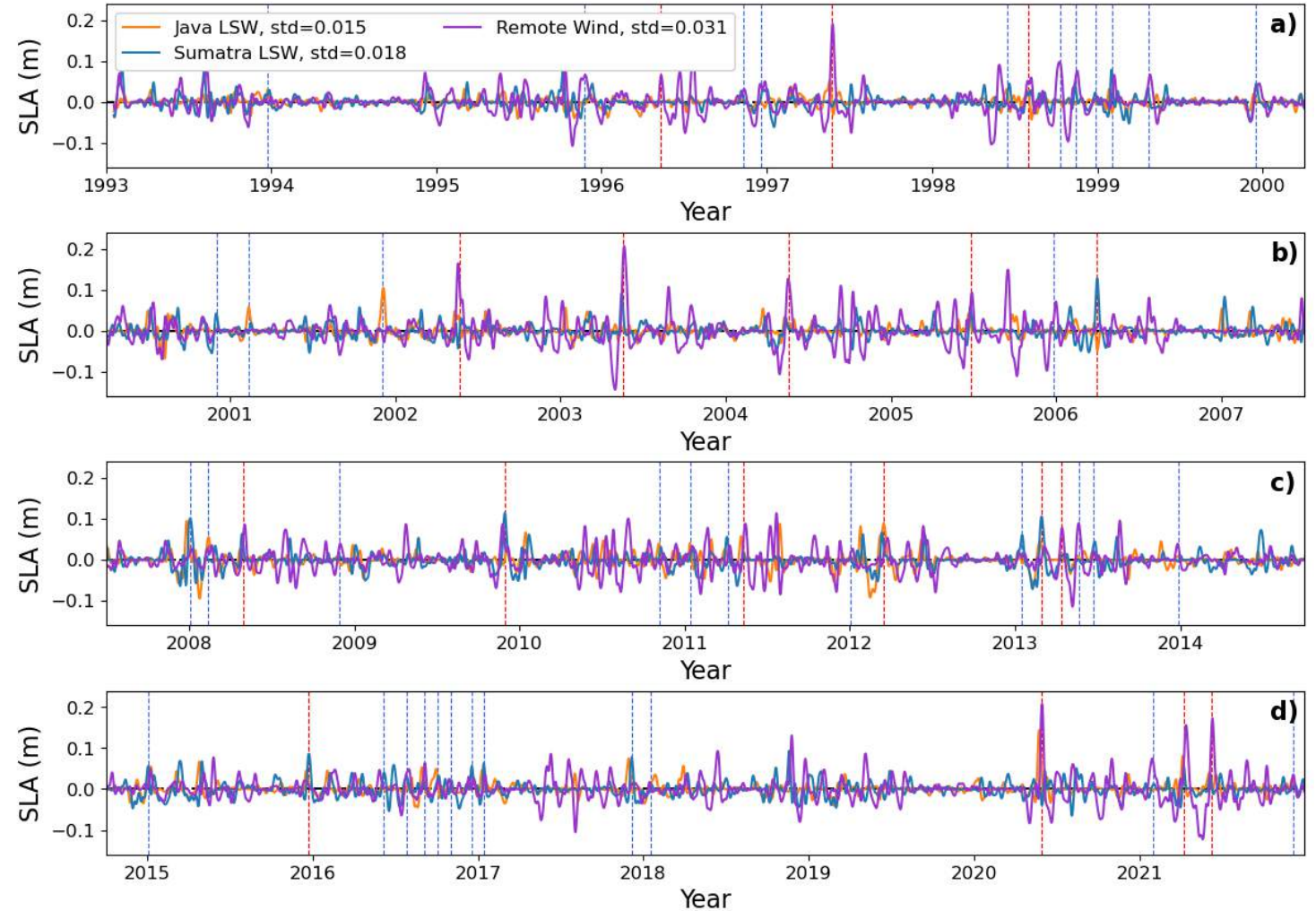
1. zonal wind stress from equatorial Indian Ocean (remote wind)
2. longshore wind stress along Sumatra
3. longshore wind stress along Java



# Bayesian Dynamic Linear Model Results:

Remote wind is most important for HEX events overall, but local longshore wind is important for some events

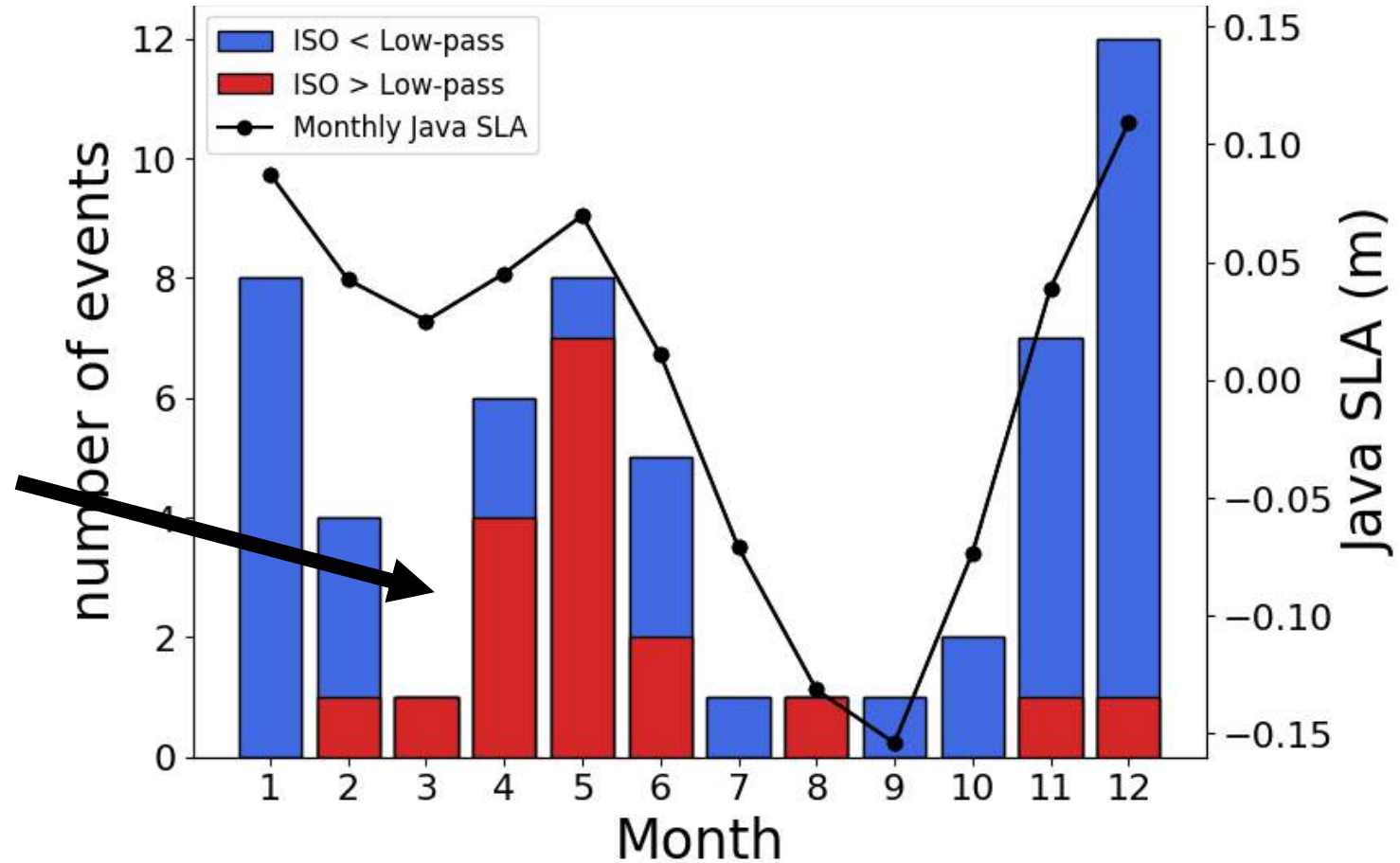
Remote wind forcing peaks during boreal spring



# Seasonality of HEX events

HEX events have a strong seasonal cycle peaking during winter and spring

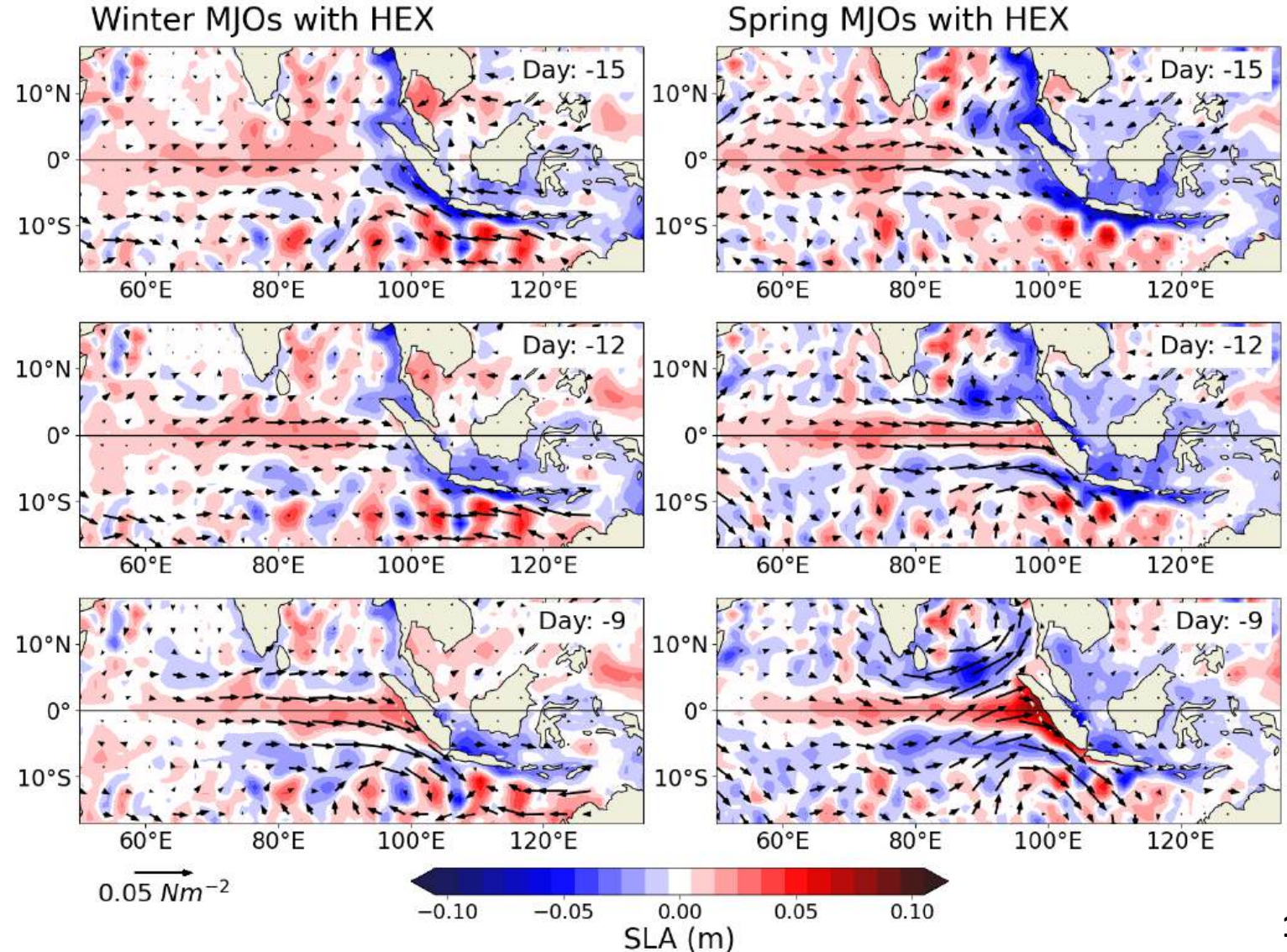
Intraseasonal SLAs are dominant during the spring peak



# Seasonality of MJOs related to HEX

Spring MJOs have greater OLRA (convection) over the equatorial Indian Ocean

Spring MJOs produce greater westerly wind stress over the equatorial Indian Ocean

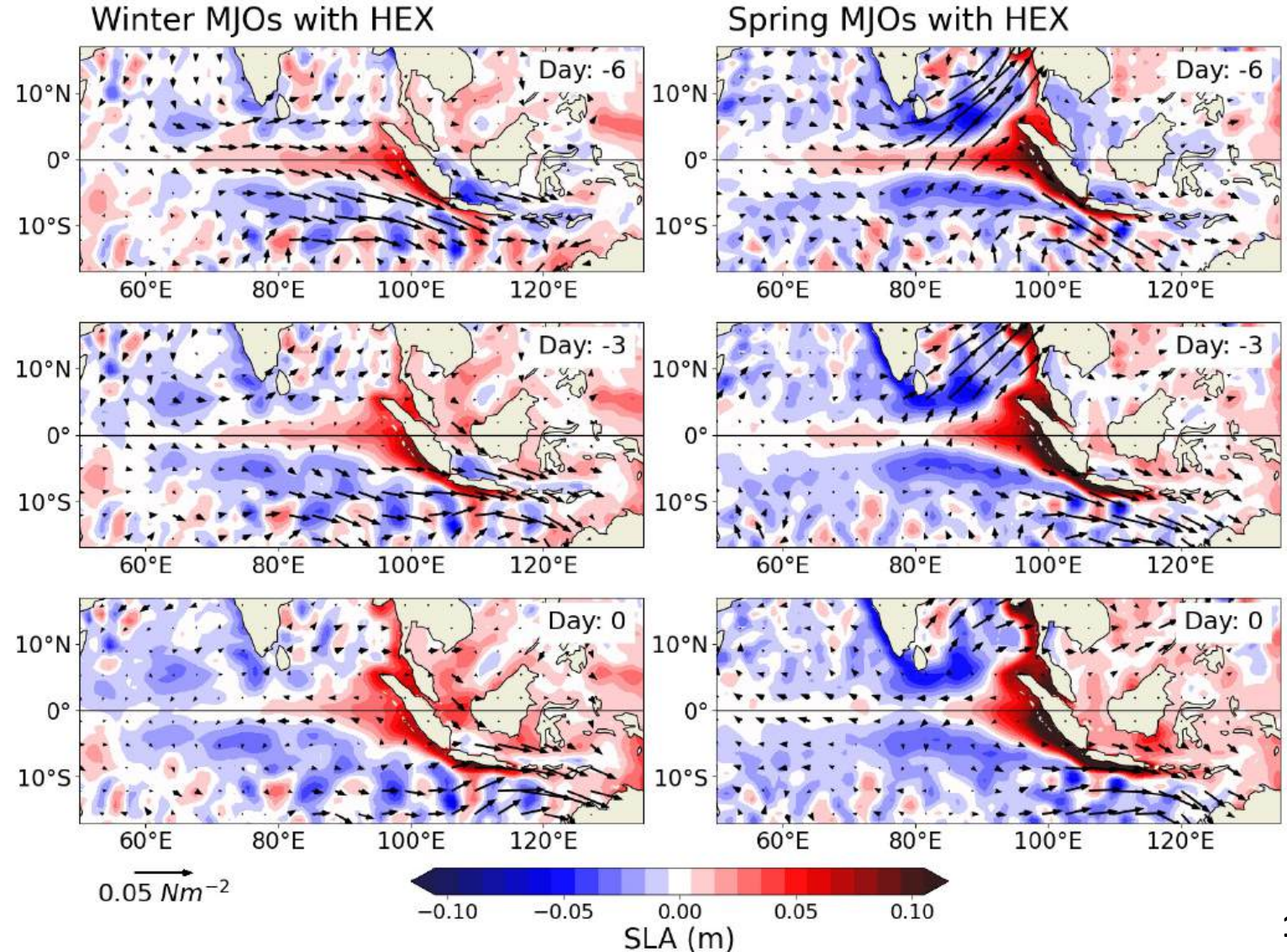


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Spring MJOs produce greater westerly wind stress over the equatorial Indian Ocean

Spring MJOs have greater SLAs along the southern coast of Java



## Summary:

1. The MJO forces Java SLAs during High EXtreme (HEX) sea level events primarily via westerly wind over the equatorial Indian Ocean
2. The MJO has the greatest impact on HEX during spring when convection and westerly wind anomalies peak over the equatorial Indian Ocean