The Madden-Julian Oscillation and Gulf of Thailand sea level and circulation variability

AMOS National Conference 2014
13 February 2014
Hobart TAS, Australia

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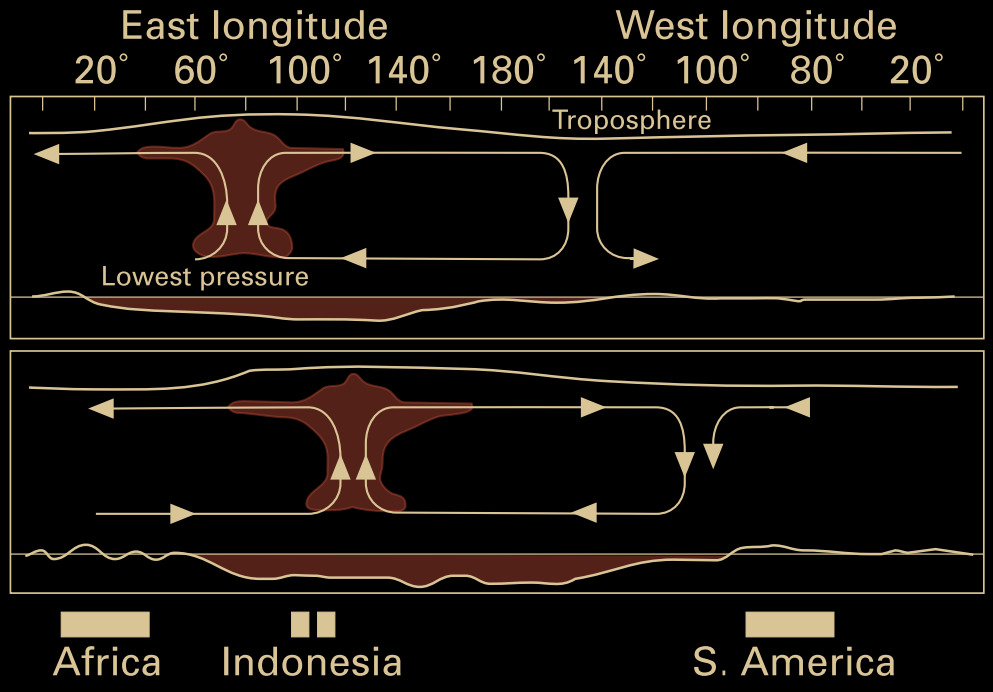
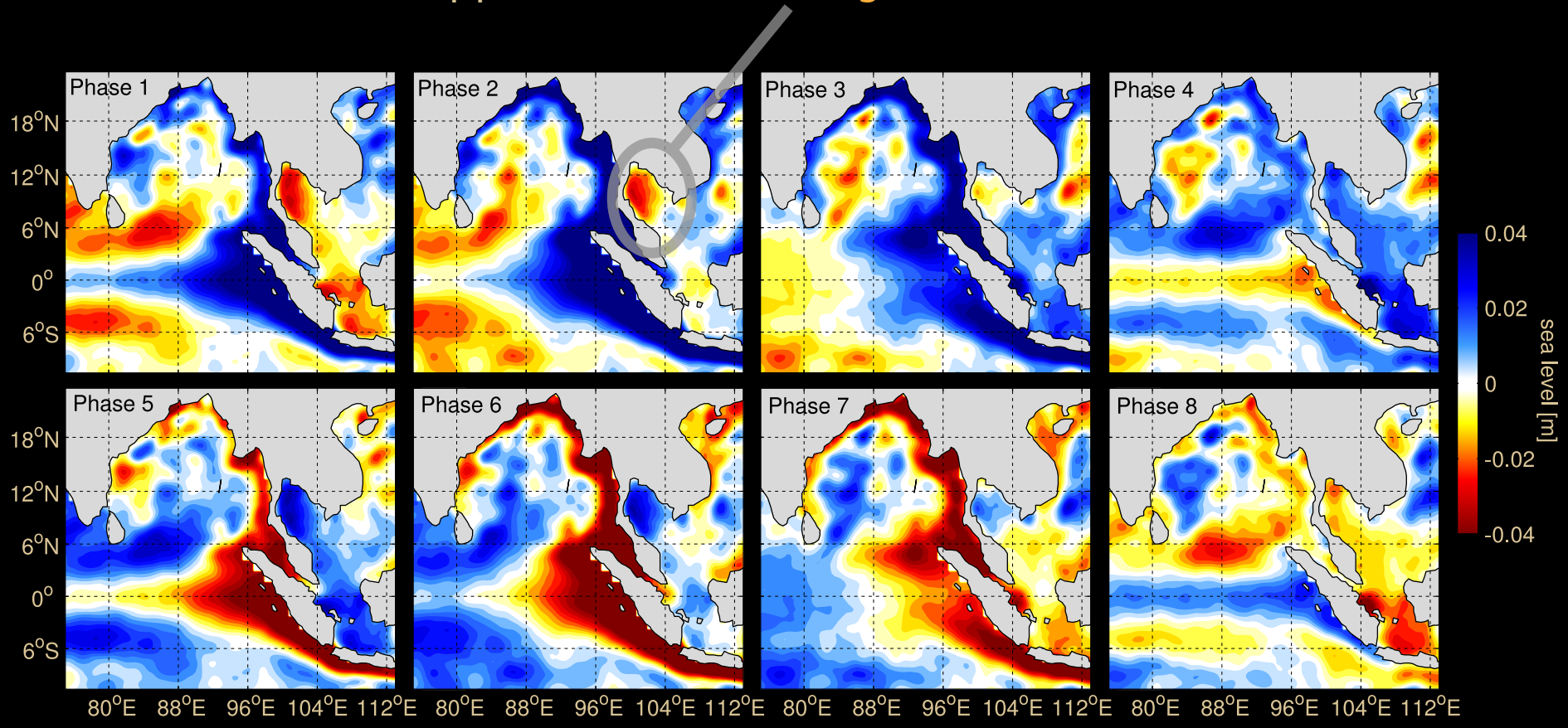
The Madden-Julian Oscillation

- The Madden-Julian Oscillation (MJO) is an intraseasonal (30-90 day period) phenomenon that originates over the equatorial Indian Ocean and propagates eastward
- Associated with deep convection and zonal wind anomalies at both low and high levels in the tropics
- Characterized by bivariate index [Wheeler and Hendon, 2004]



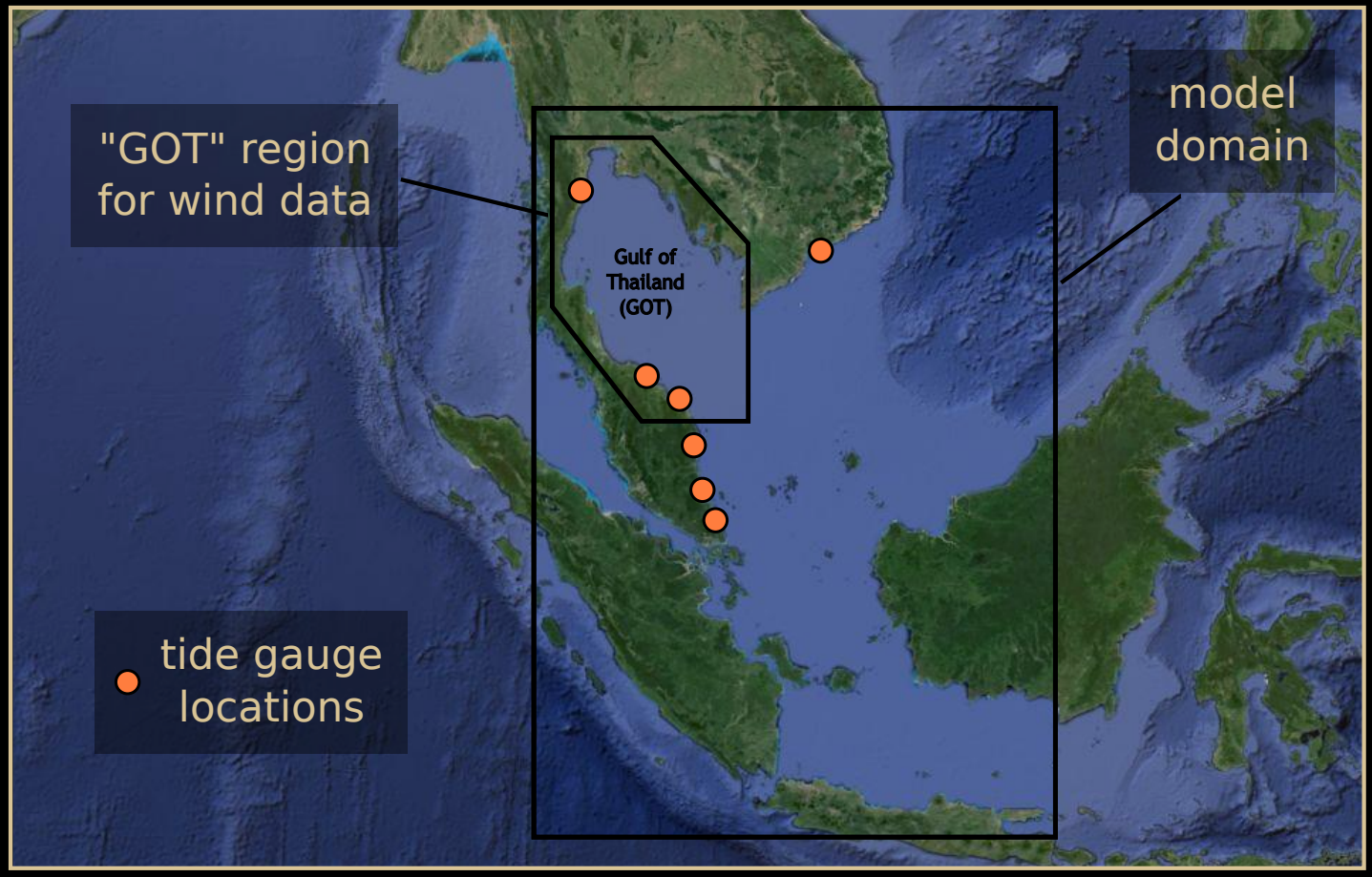
The MJO and Indo-Pacific Sea Level

- MJO composites of sea level in the northeastern Indian Ocean indicate the well-established system of Equatorial and coastal waves forced by MJO-related surface winds (Oliver and Thompson, 2010)
- However, also apparent is a standing mode in the Gulf of Thailand



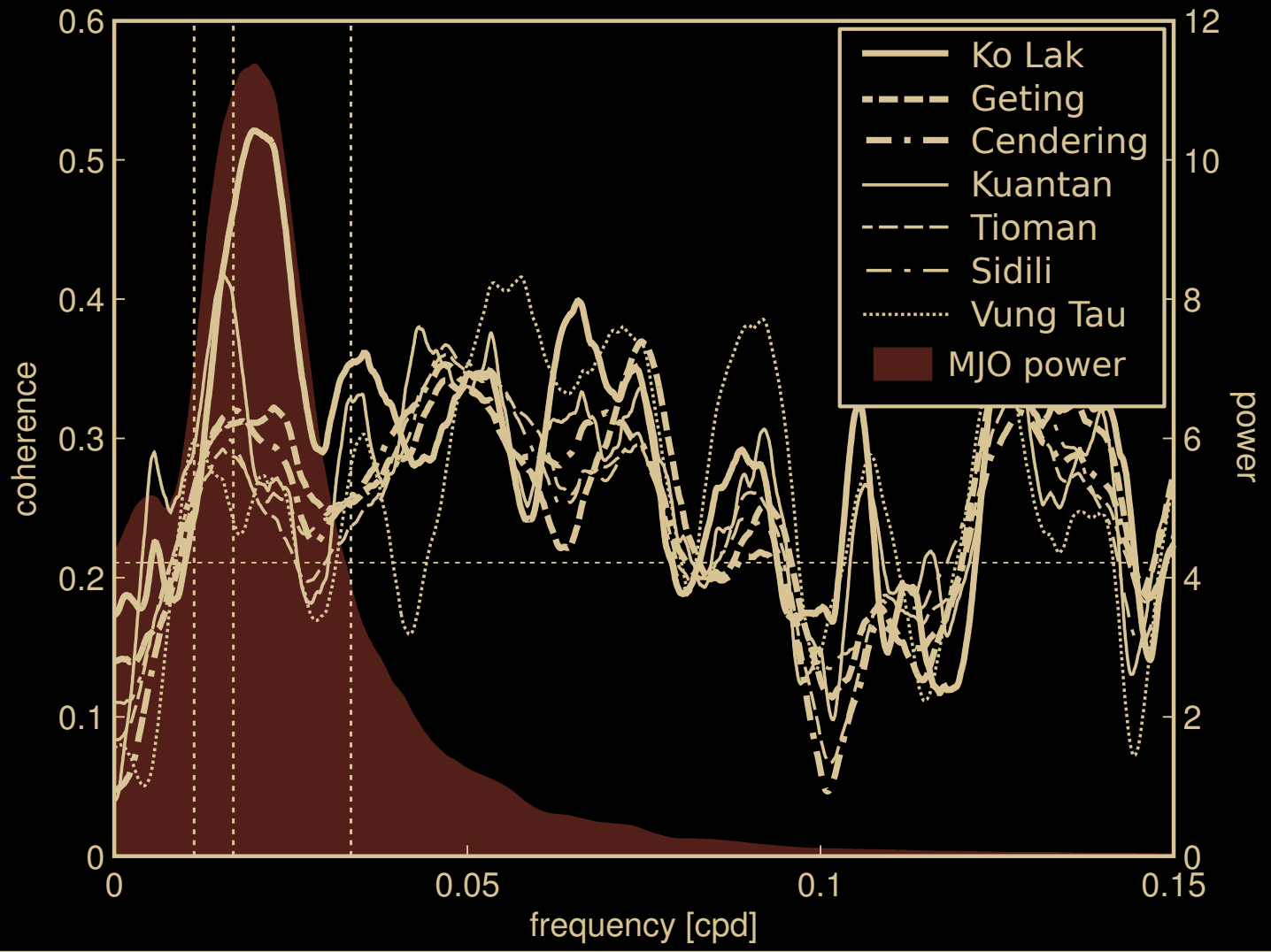
The Gulf of Thailand

- The Gulf of Thailand (GOT) is a shallow sea (~50 m avg.) in Southeast Asia. It, like the Gulf of Carpentaria which has been shown to have a strong connection to the MJO (Oliver and Thompson, 2011), lies within the tropical regions strongly influenced by the MJO.



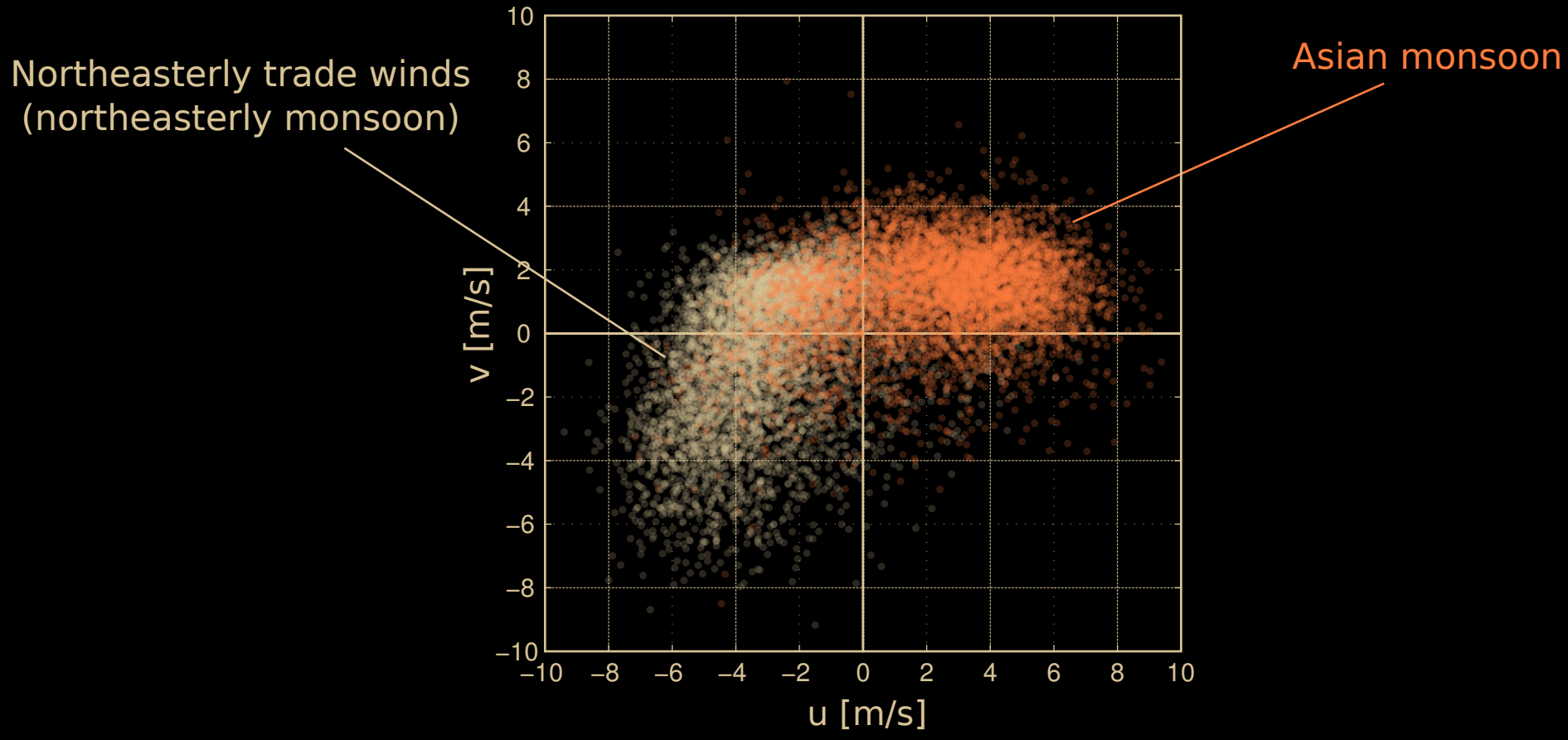
The MJO and Coastal Sea Level

- Sea level from tide gauges at the head of the Gulf also coherent with MJO over intraseasonal time scales:

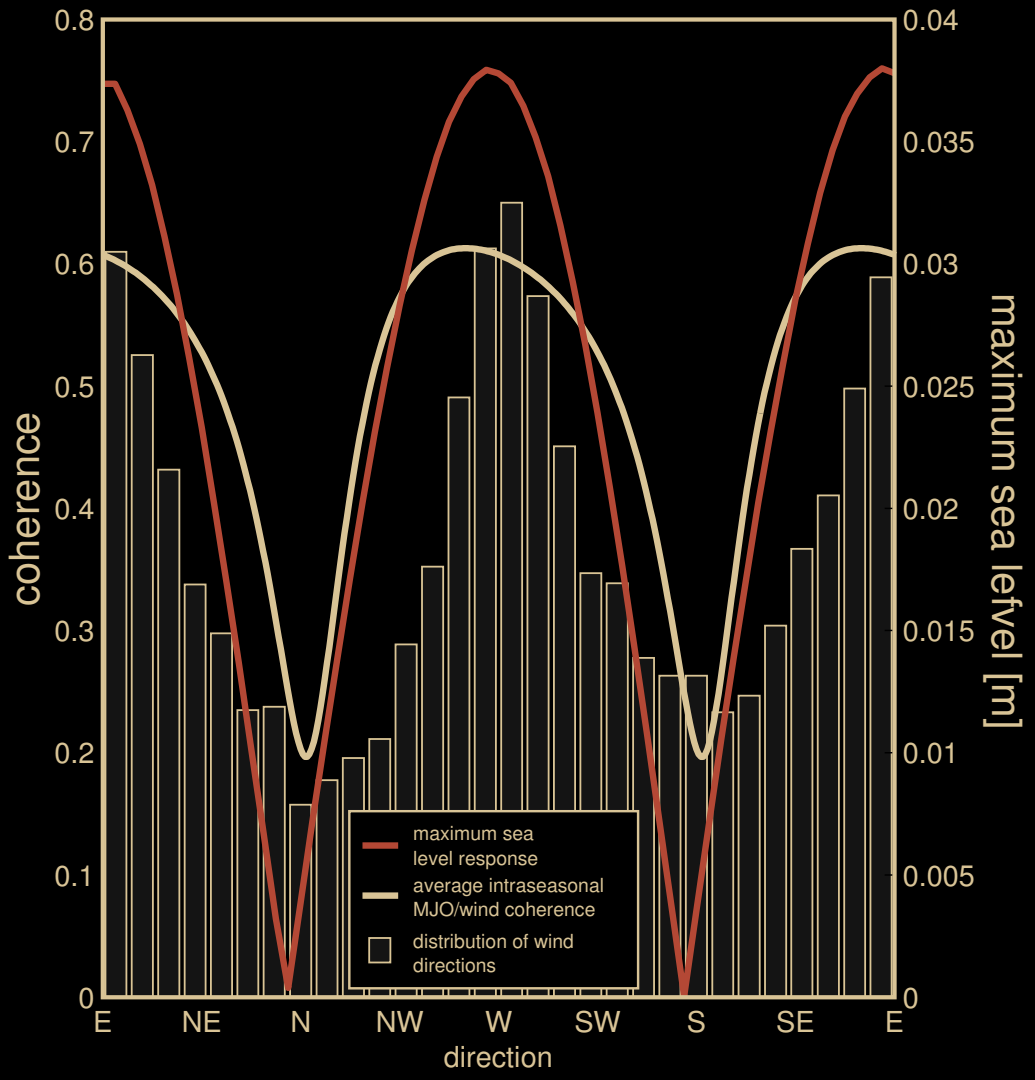


Observed Wind

- Surface wind (10m) over the GOT is predominantly northeasterly during the northeasterly monsoon (trade winds) from November to March and the predominantly westerly Asian monsoon peaks six months later (April to September)



Observed Wind

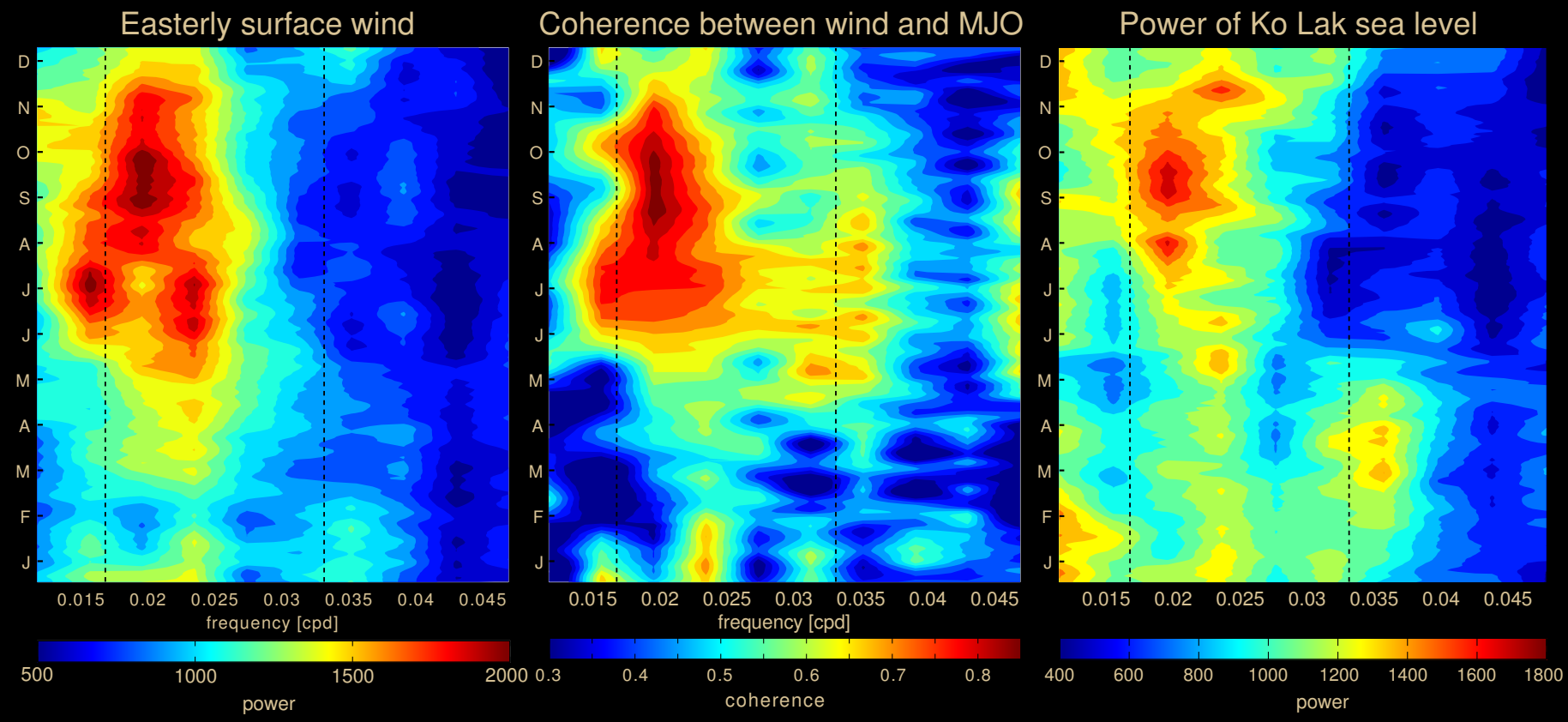


- Deseasoned wind over the Gulf is predominantly westerly or easterly (▯ histogram bars)
- The coherence between the MJO and surface wind is highest for WNW and ESE winds (— line)
- Sea level in the Gulf responds preferentially to WNW and ESE winds (— line)

These factors combine to make sea level in the Gulf particularly responsive to the MJO

Seasonality of ISV

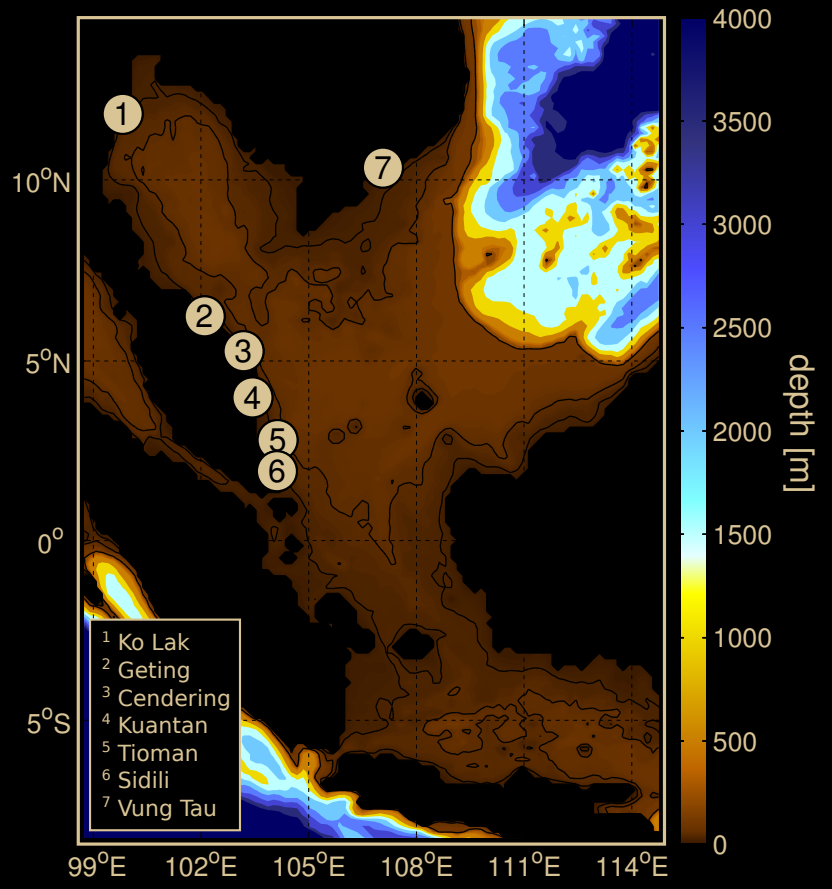
- Strong seasonality of wind, sea level, and MJO relationship over intraseasonal time scales.



Easterly surface wind is strongly coherent with the MJO predominantly during the Asian monsoon (April-September) and this corresponds to season of maximum intraseasonal sea level variability .

Numerical Model

- Princeton Ocean Model (POM) [Blumberg and Mellor, 1987]
- Non-linear, two-dimensional barotropic
- 1/6° spatial resolution (138 x 99 grid points)
- 12 s time step for CFL cond.
- Radiation conditions at open boundaries
- Sea level and both zonal and meridional currents output daily
- Bathymetry from General Bathymetric Chart of the Oceans



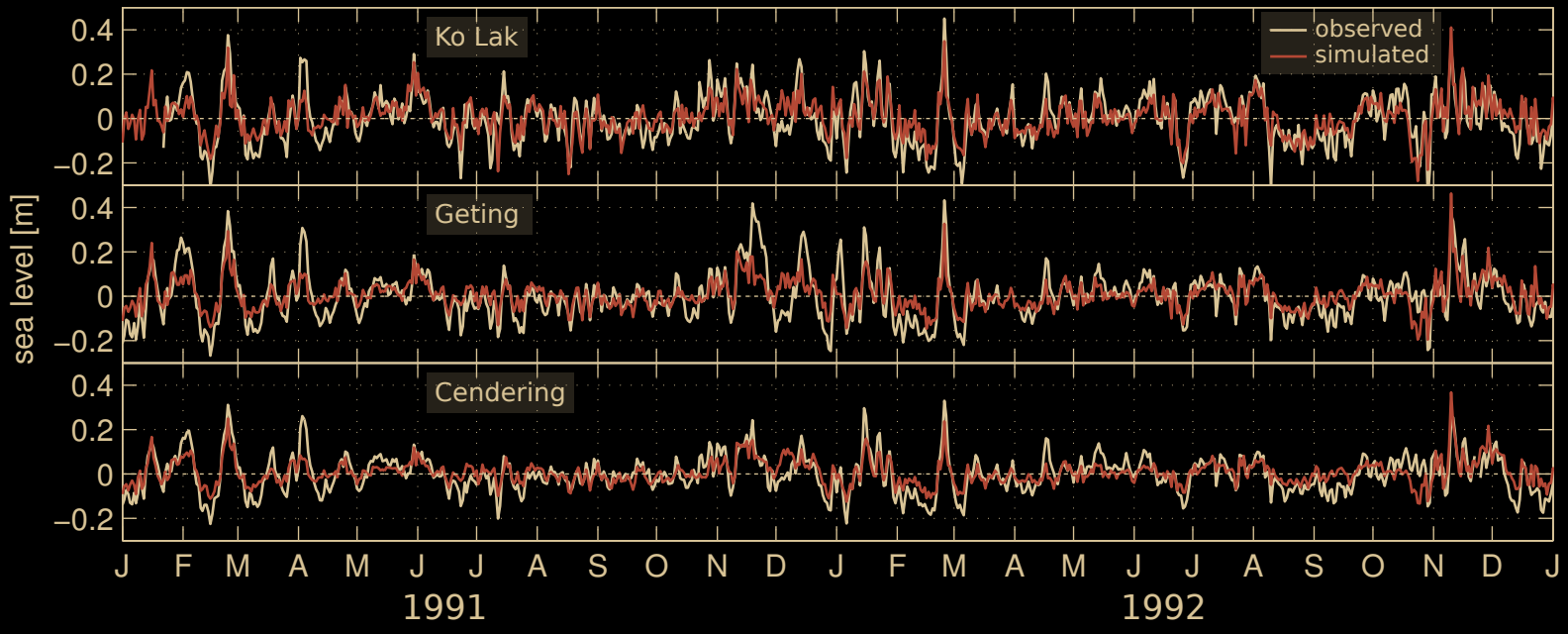
- Forced by NCEP CFSR and CFSv2 winds (6-hourly) over 1979-2011 and POM results are considered to be the wind-forced, barotropic component of sea level variability in the Gulf of Thailand

Predicted Sea Level

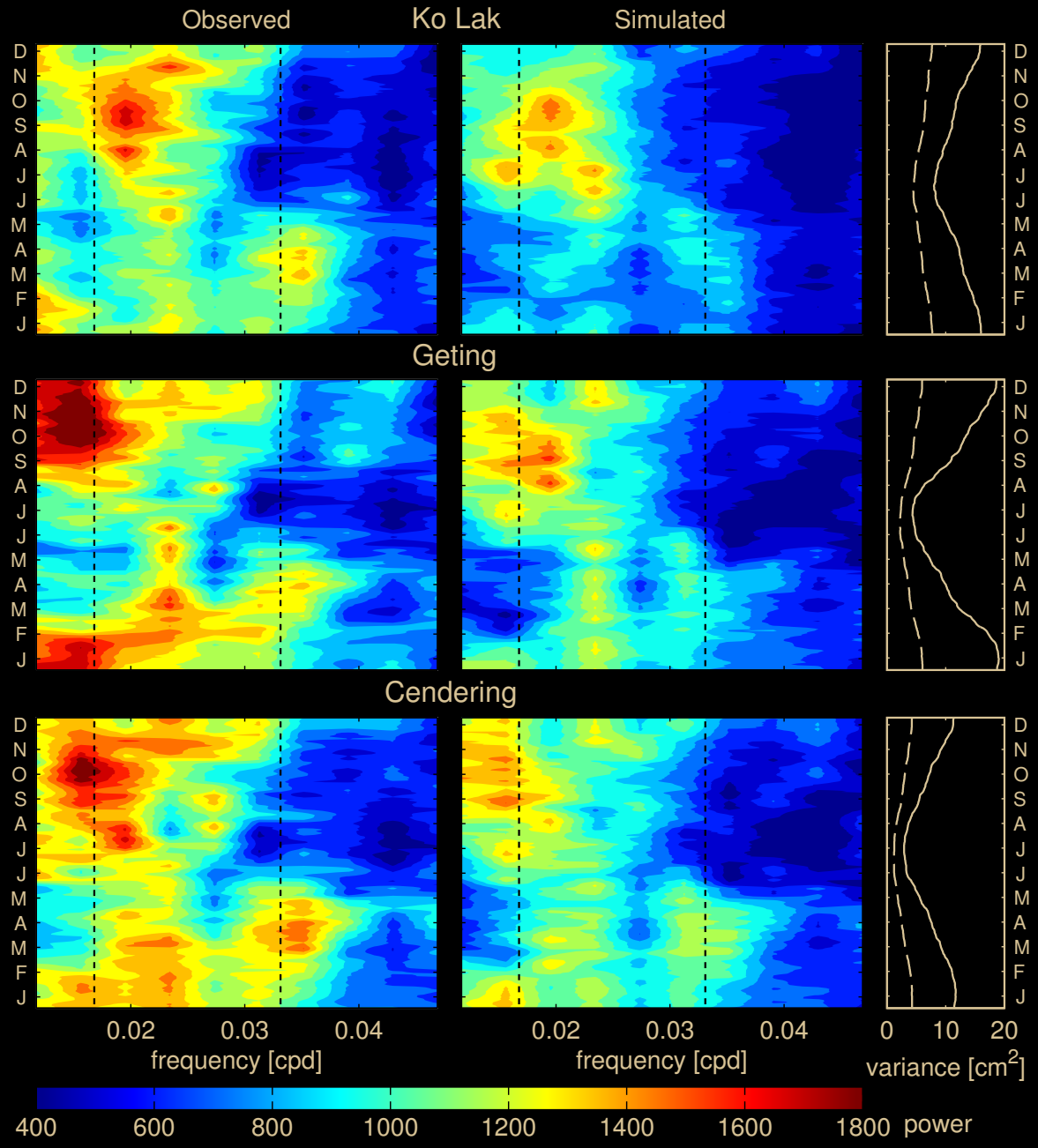
- Modeled sea level matches well with tide gauge records

	Ko Lak	Geting	Cendering	Kuantan	Tioman	Sidili	Vung Tau
Correlation:	0.75	0.76	0.79	0.78	0.76	0.77	0.63

- Coherence is high (0.7-0.9) on intraseasonal frequencies (20-100 days) but drops for longer periods (>100 days) - model does not capture low frequency variability



Predicted Seasonality of ISV

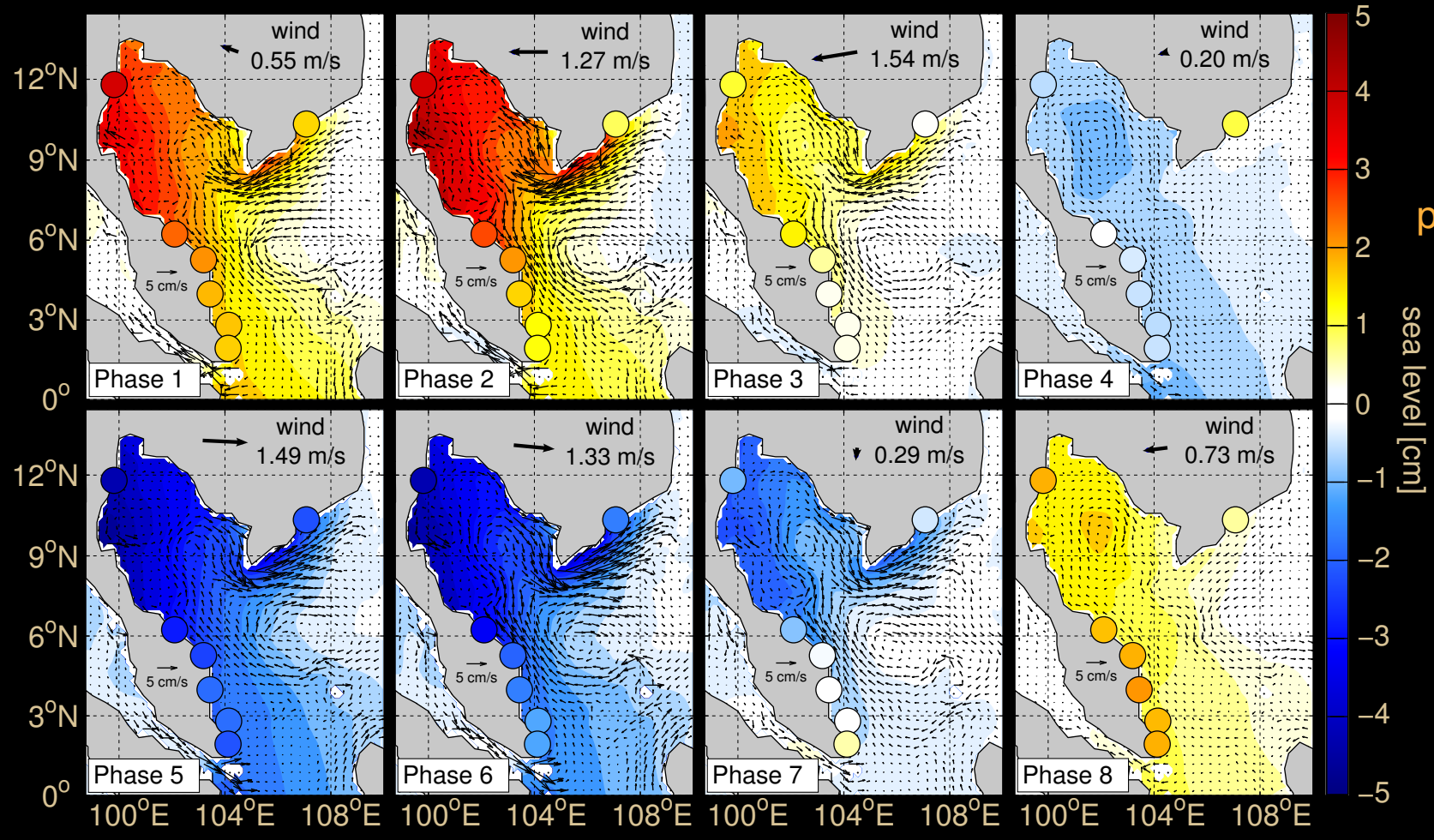


Numerical model reproduces the seasonal cycle of intraseasonal variability

although with reduced amplitude

Canonical Response to MJO

Composites of observed wind, modeled sea level and circulation with the MJO: canonical response of Gulf of Thailand to the MJO

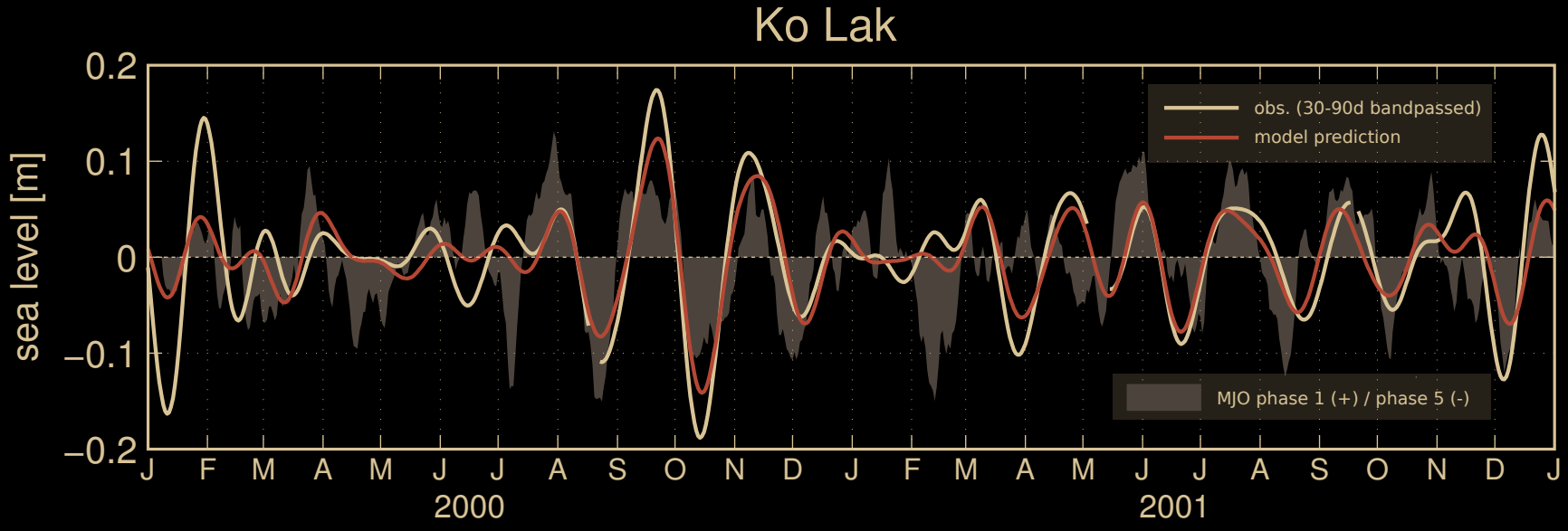


Set-up during phases 8, 1-3

Set-down during phases 4-7

Predictability: Role of the MJO

- The MJO index (projected on to phase 1/5 axis) shows remarkable correlation with intraseasonal sea level in the Gulf of Thailand



The MJO index can be used as an indicator for set-up or set-down favourable conditions . . . the MJO can give predictability to the system

Predictability

- Potential predictability of MJO-related sea level variability quantified using a simple statistical prediction model
- Statistical model is a lagged linear regression model of sea level onto the MJO index at lags from 0 to D days.

$$\eta_{t+k} = \sum_{d=0}^{D} \beta_{1,d} I_{1,t-d} + \beta_{2,d} I_{2,t-d} + \epsilon_t$$

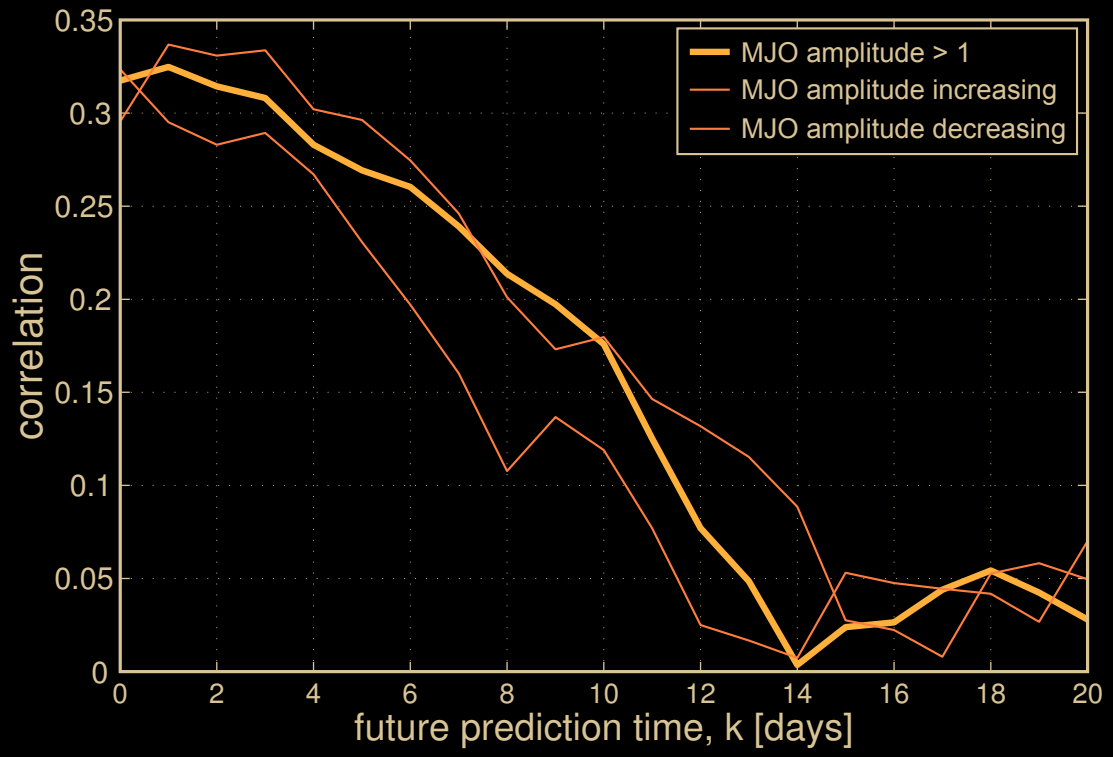
MJO index

regression coefficients

sea level at future time *k*

Predictability

- Model only includes lags 0, 15, and 31 days. Trained over July-January for 1985-1997 and validated for July-January 1998-2010:



- Variance accounted for by statistical model persists with lead times up to 20 days
- Can be supplemented with forecasts of the MJO index...

Conclusions

- Madden-Julian Oscillation is connected to global patterns of variability in sea level - notably in the NE Indian Ocean and the Gulf of Thailand
- Surface wind over the Gulf of Thailand is highly correlated to the MJO and is also well suited for setting up sea level.
- Numerical model confirms that observations are mainly wind-driven sea level set up, locked to the seasonal monsoon cycle
- Winds that lead to sea level set-up are part of a global system related to the MJO: there is potential for predictability and this is demonstrated using a simple real-time prediction model

Publications:

Oliver, 2014, *Climate Dynamics*, 42 (1-2)
Oliver and Thompson, 2011, *Journal of Geophysical Research*, 116 (C02019)
Oliver and Thomspon, 2010, *Journal of Geophysical Research*, 115 (C01003)

Thank you!

GOAPP

UTAS

DALHOUSIE UNIVERSITY

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

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The MJO and Global Sea Level

- Oliver and Thompson [JGR, 2010] calculated statistical connections between the MJO and global sea level using a coherence-based metric