Expressions of the Madden-Julian Oscillation in the Coastal Ocean: The Gulf of Carpentaria

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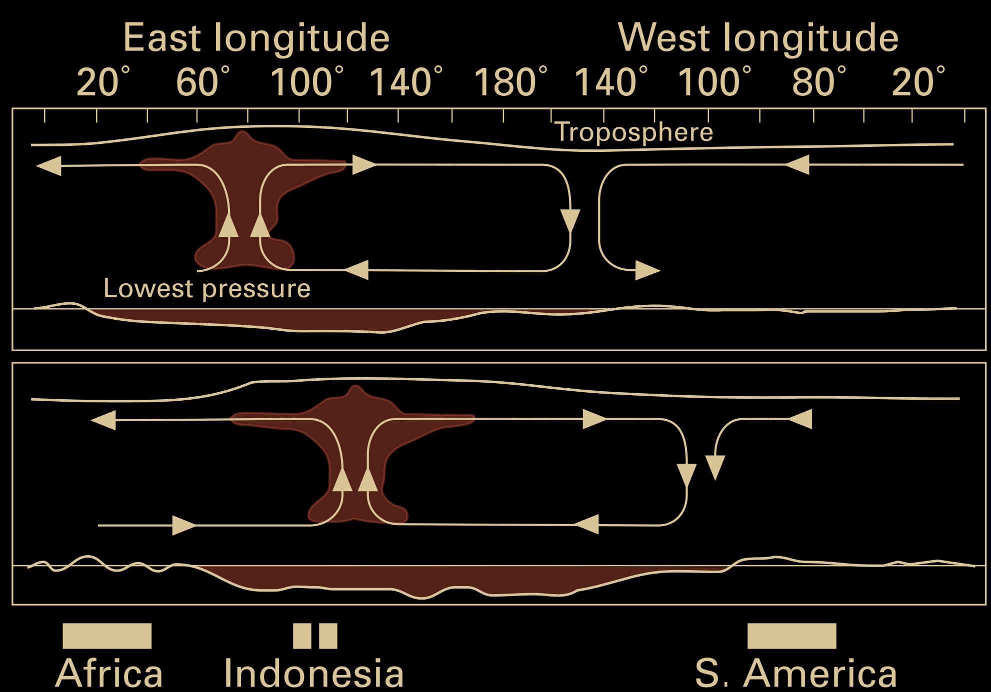
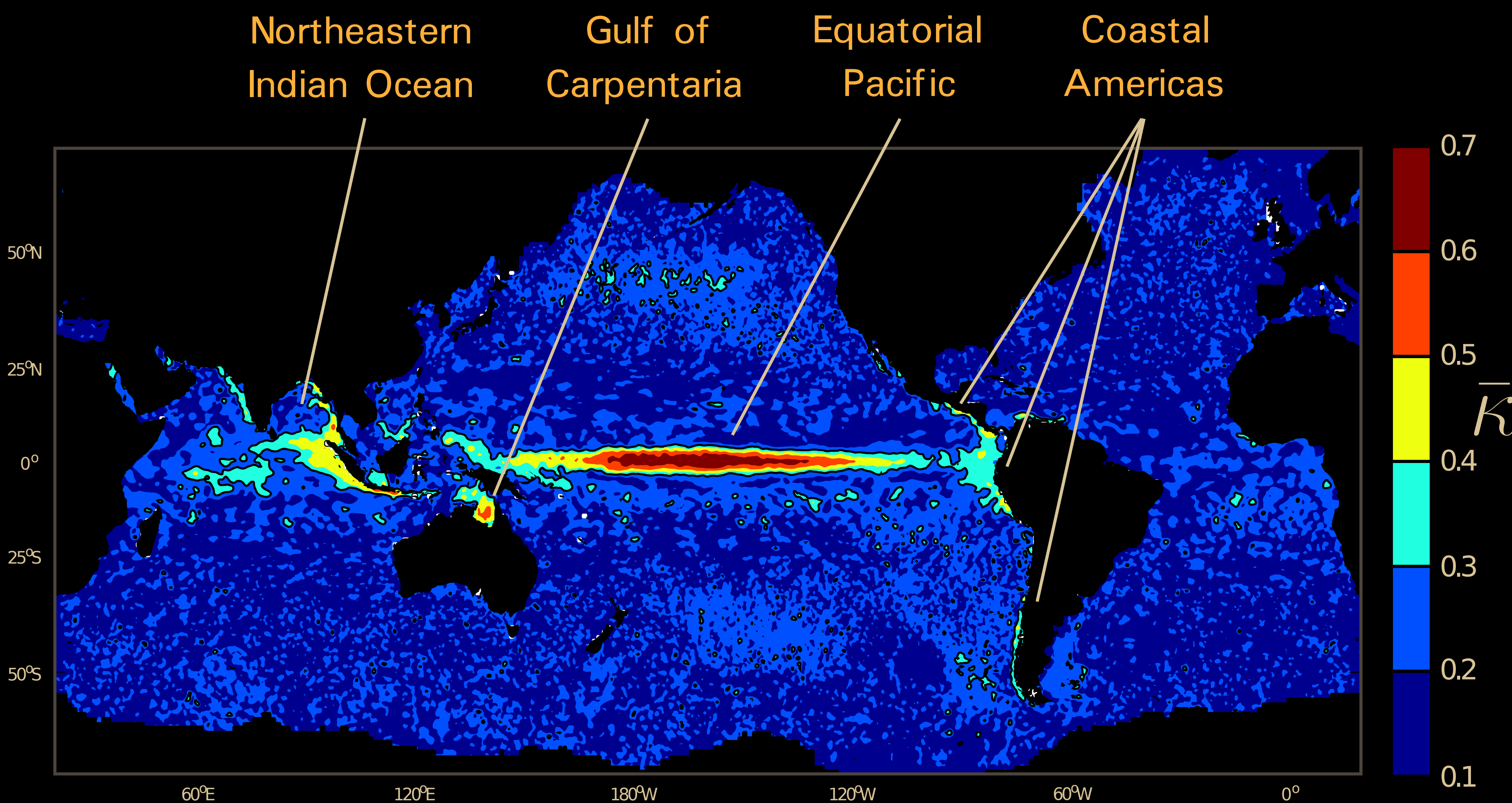
The Madden-Julian Oscillation

- 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]



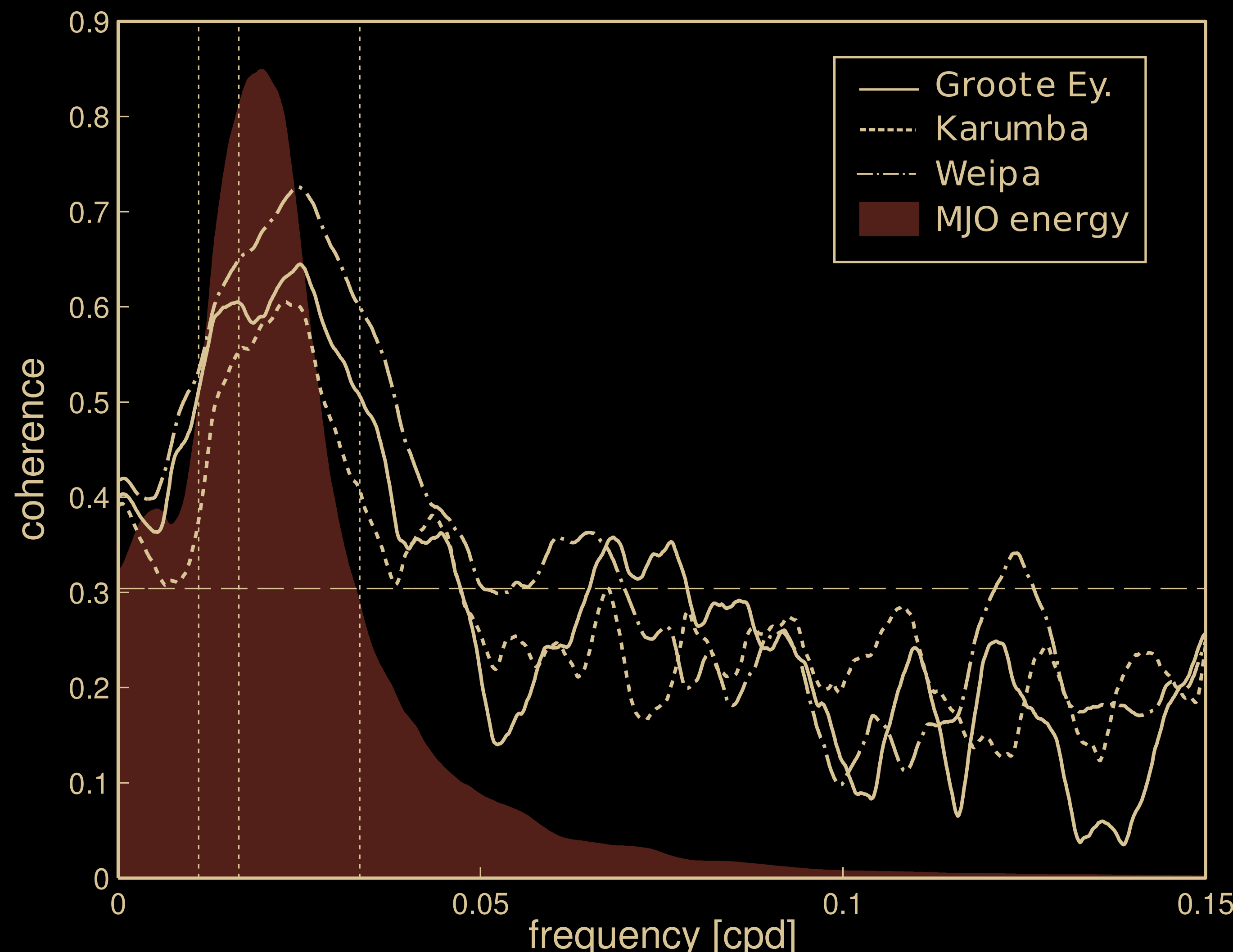
The MJO and Global Sea Level

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



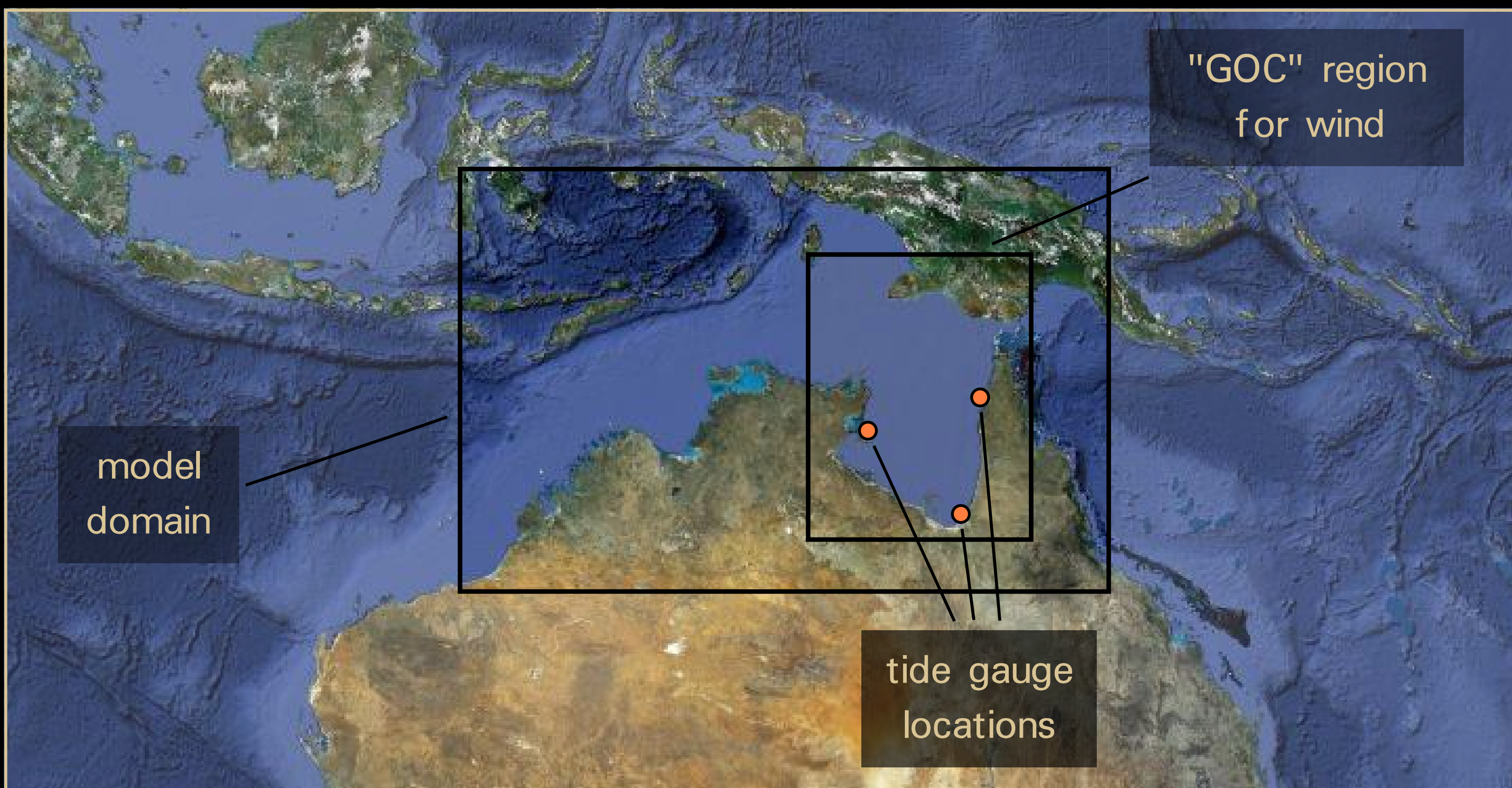
The MJO and Coastal Sea Level

- Sea level from tide gauges also coherent with MJO at intraseasonal time scales:



The Gulf of Carpentaria

- The Gulf of Carpentaria (GOC) is a shallow (~50 m avg.) sea north of Australia. It neighbours shallow Arafura and Timor Seas and the deep waters of the Indonesian Archipelago to the west as well as the deep waters of the Western Pacific to the East



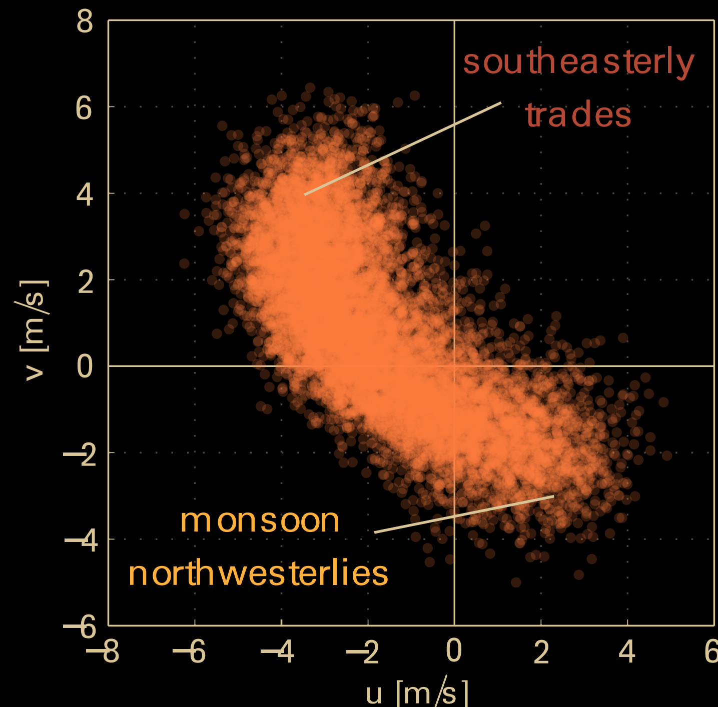
Observed Wind and the MJO

- Surface wind (10m) over the GOC is predominantly northwesterly during monsoon season (peak in January) and the predominantly southeasterly trade winds peak six months later, in July

- Sea level set up in the Gulf of Carpentaria responds strongest to northwesterly to northerly winds

- This surface wind is coherent with the MJO at intraseasonal timescales

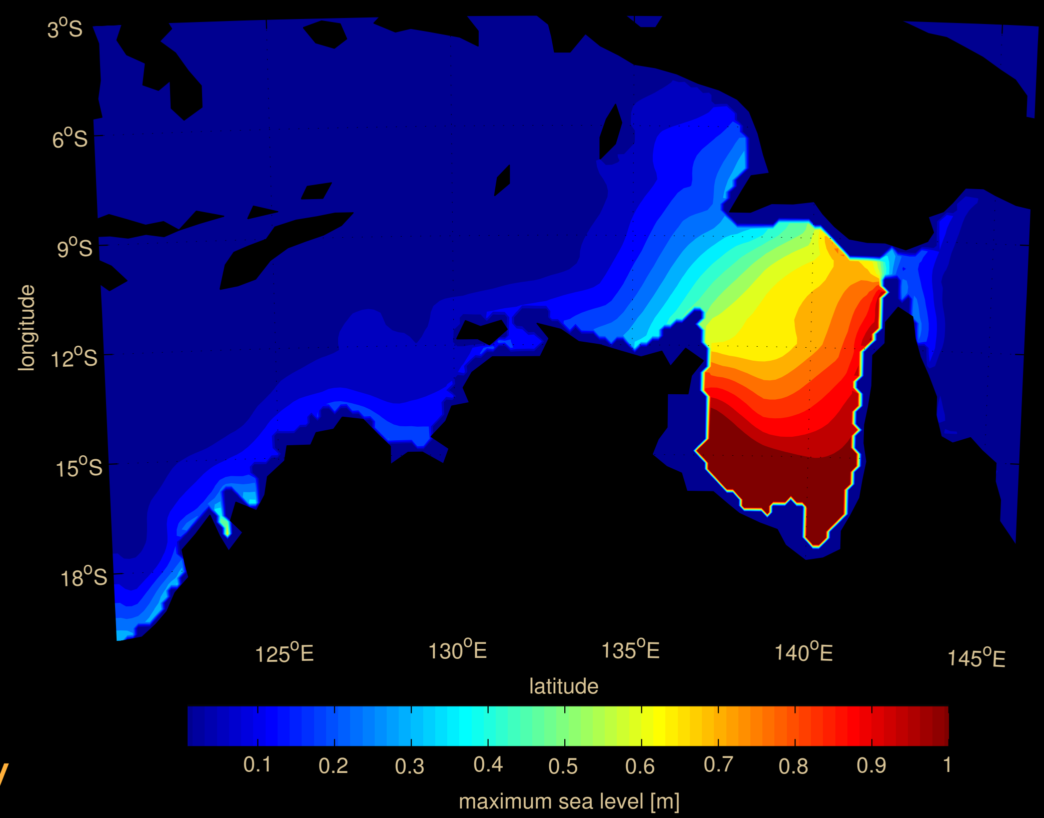
- MJO-Wind connection strongest for northwesterly to westerly winds



northwesterly winds ideal
for MJO-driven set-up

Numerical Model

- Princeton Ocean Model (POM) [Blumberg and Mellor, 1987]
- Non–linear, two–dimensional barotropic
- Ten–minute spatial resolution (157 x 103 grid points)
- 12 s time step for CFL cond.
- Radiation conditions at open boundaries
- Sea level and both zonal and meridional currents output daily



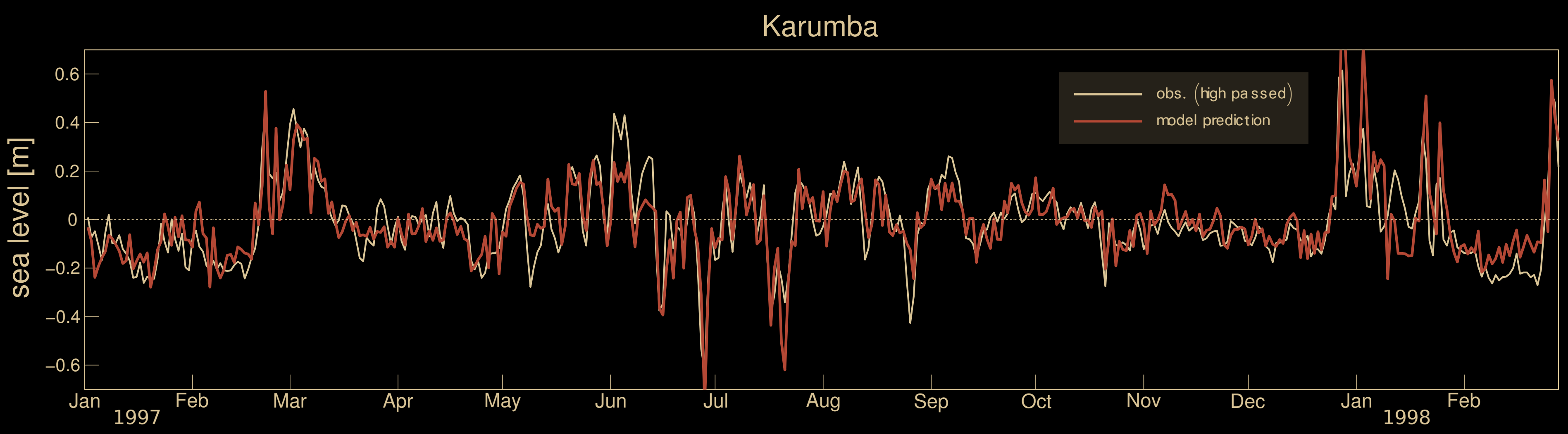
- Bathymetry from CSIRO, using Geoscience Australia (2009) data
- Forced by NCEP/NCAR winds (6 hourly) and we are considering the POM results to be the wind–forced, barotropic component of sea level variability in the Gulf of Carpentaria

Predicted Sea Level

- Modeled sea level matches well with tide gauge (tg) records

	Groote Eylandt	Karumba	Weipa
RMS error [cm]:	6.56	10.70	6.91
Correlation:	0.76	0.76	0.84
Gain	0.89	0.89	0.82

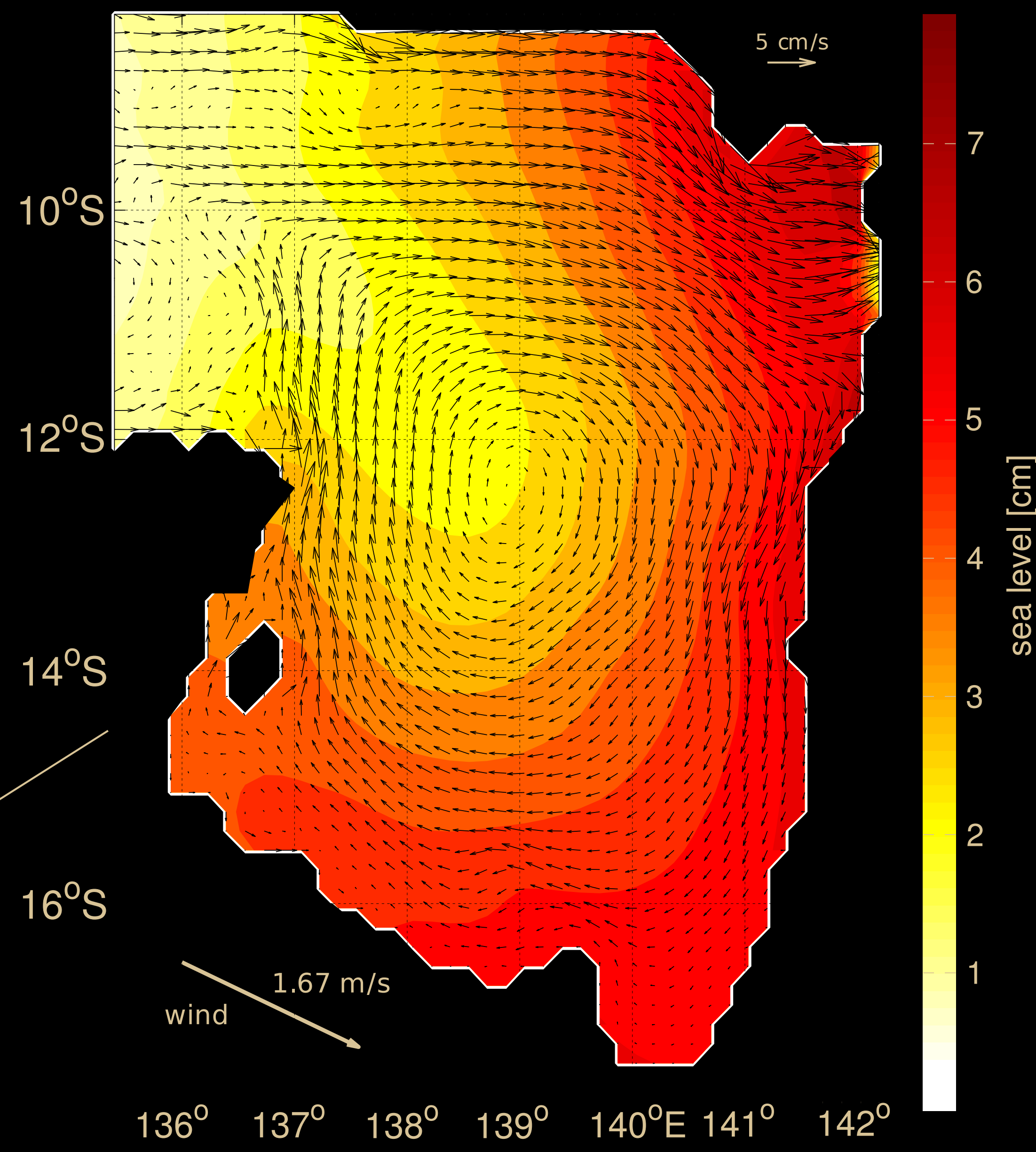
- Coherence is high (0.80–0.95) on intraseasonal frequencies (20–100 days) but drops for longer periods (>100 days) – model does not capture low frequency variability



Canonical Response to MJO

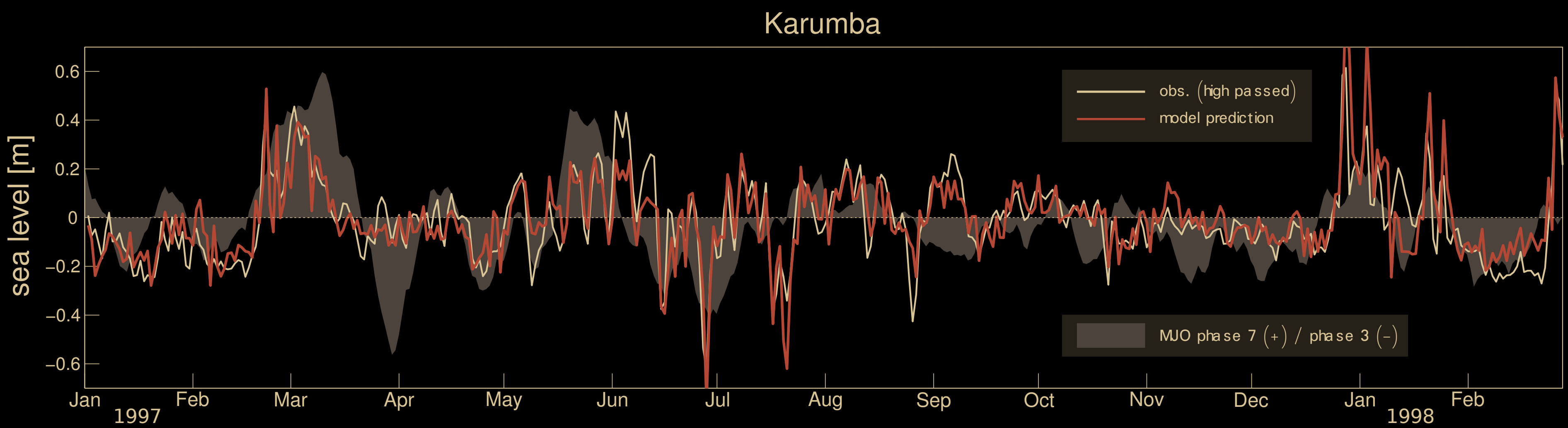
- MJO index can be characterized by phase (longitude of active MJO) and amplitude (strength of MJO)
- Composites of obs. wind, modeled sea level and circulation with the MJO: canonical response of GOC to MJO

Phase 7 (MJO active over W. Pac)



Predictability: Role of the MJO

- The MJO index (projected on to phase 7/3) shows remarkable correlation with intraseasonal sea level in the Gulf of Carpentaria.



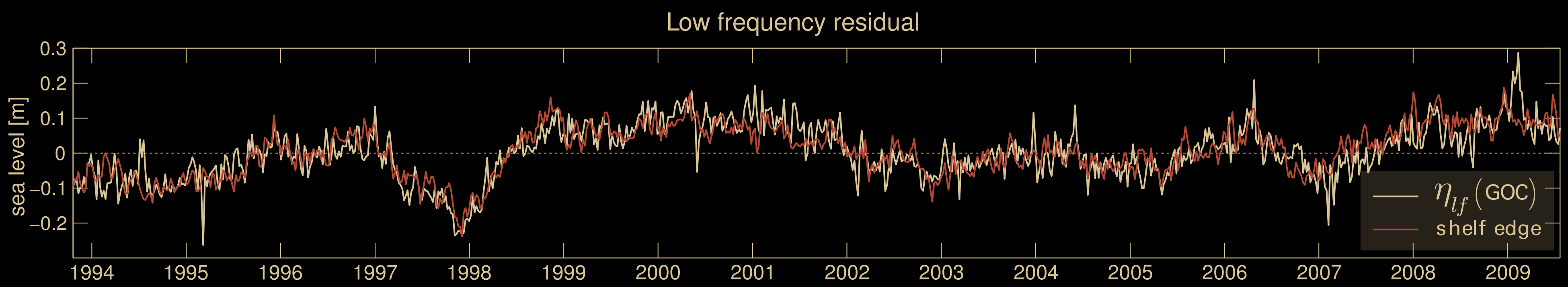
- The MJO index can be used as an indicator for set-up or set-down favourable conditions . . . the MJO can give predictability to the system

Interannual Variability

- Model prediction represents wind-driven component of sea level
- Tide gauges can be de-winded by subtracting the model prediction

$$\underbrace{\eta_{tot}}_{\text{tide gauge}} = \underbrace{\eta_{hf}}_{\text{POM}} + \underbrace{\eta_{lf}}_{\text{low freq. residual}}$$

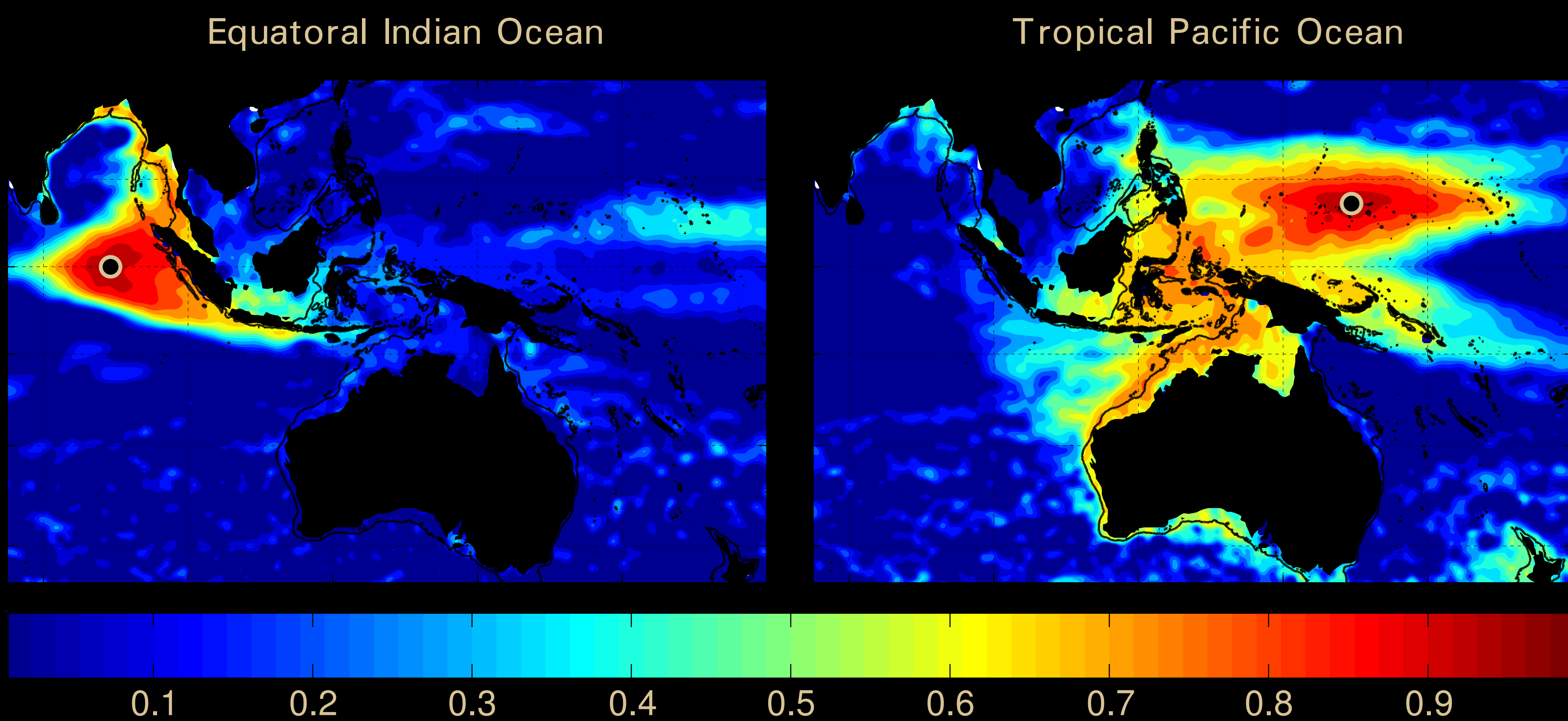
- Low frequency residual at each location is correlated with sea level at shelf edge



- Where does this variability come from? Does the Indian or Pacific dominate?

Indian or Pacific Forcing?

- Correlation maps suggest where energy propagates
- Partial correlations can be used to remove the effects one basin from the other . . . energy from the Pacific Ocean dominates in the GOC



Conclusions

- Madden-Julian Oscillation, an intraseasonal tropical phenomenon, is connected to global patterns of variability in sea level.
- Surface wind over the Gulf of Carpentaria 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 … at high frequencies.
- Winds that lead to sea level set-up are part of a global system related to the MJO: there is potential for predictability
- Residual low frequency signal is highly correlated with patterns in the regional deep waters that originate in the Pacific Ocean

Thank you!

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