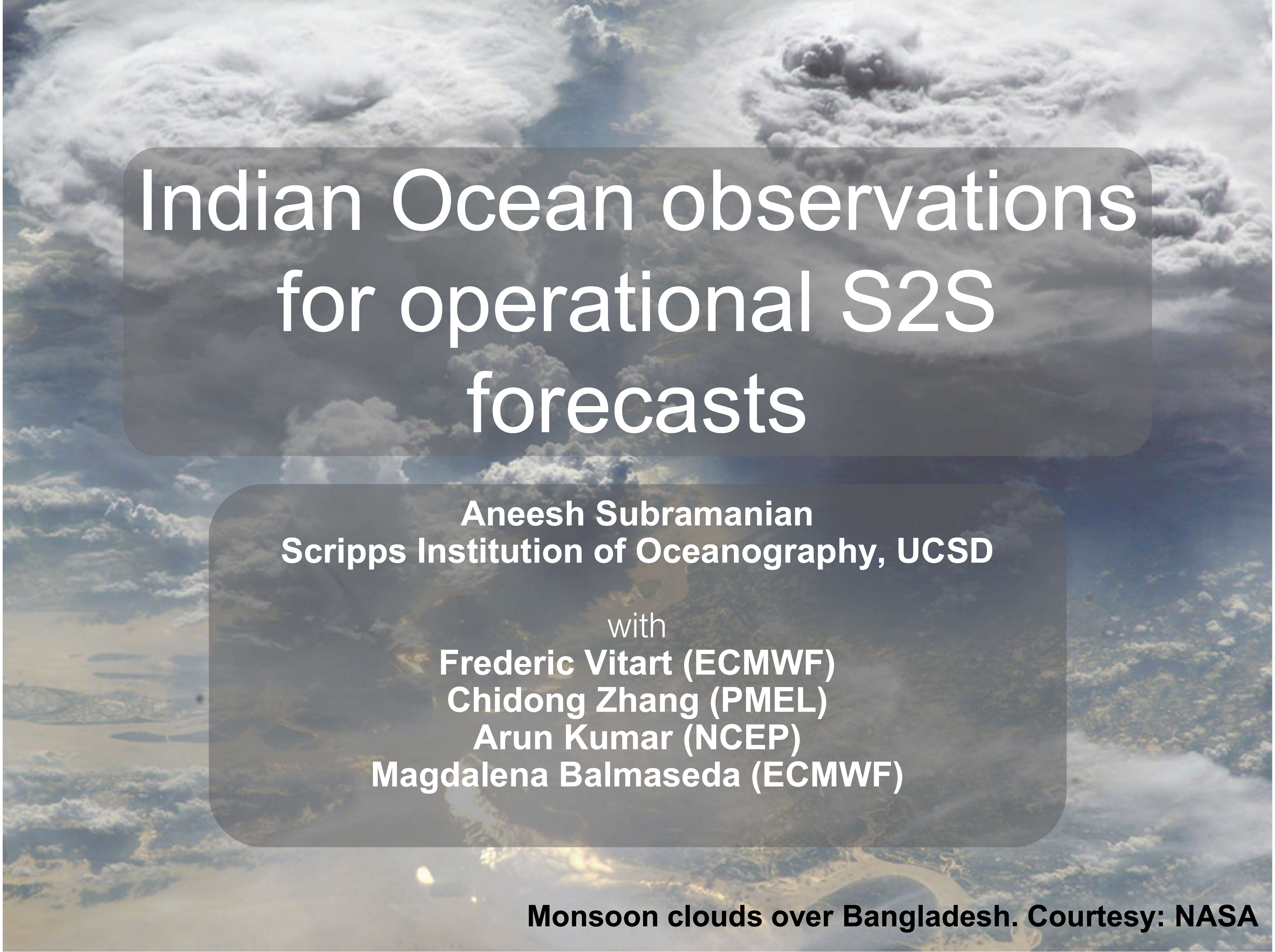
Indian Ocean observations for operational S2S forecasts

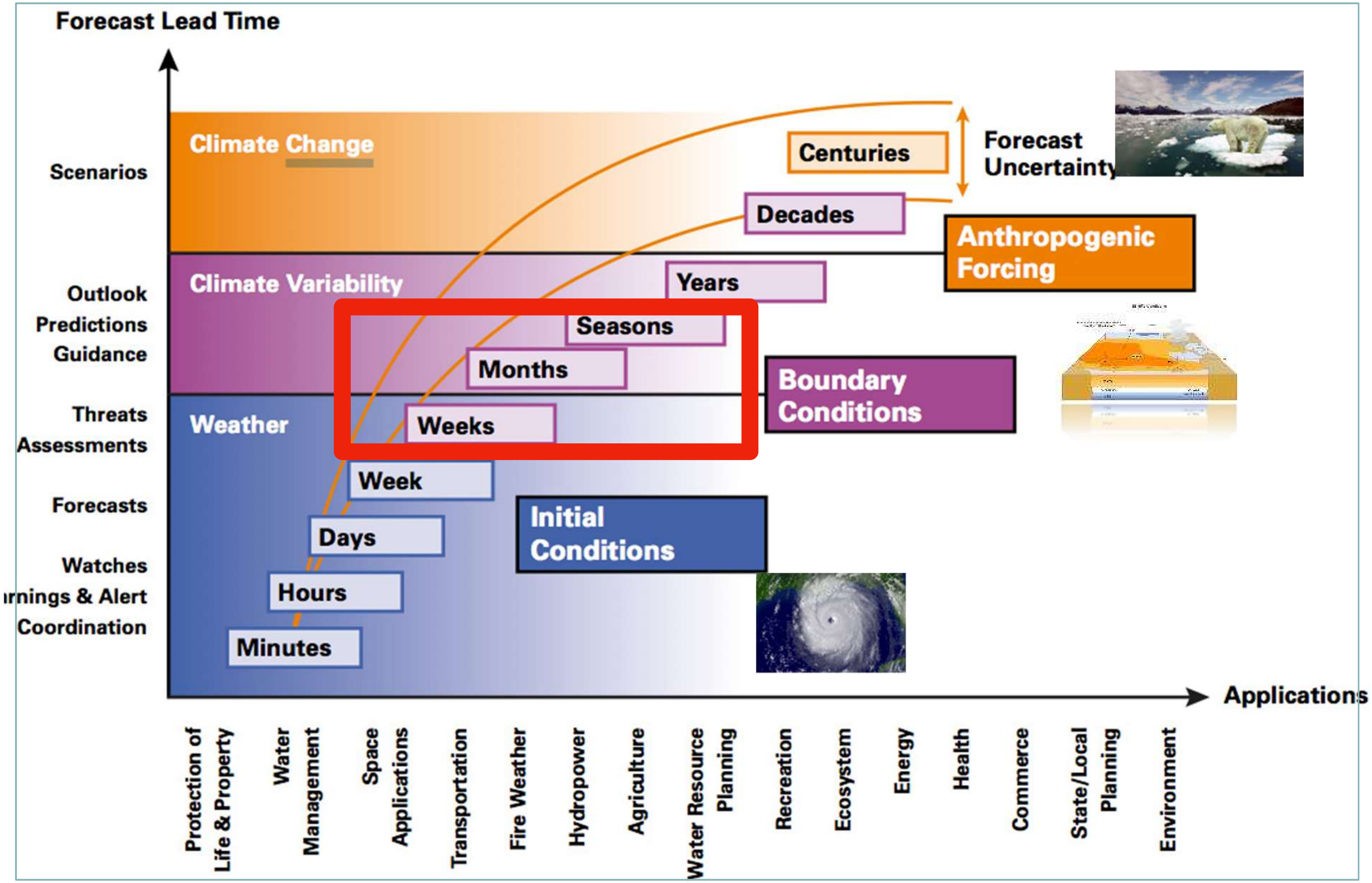
Aneesh Subramanian
Scripps Institution of Oceanography, UCSD

with
Frederic Vitart (ECMWF)
Chidong Zhang (PMEL)
Arun Kumar (NCEP)
Magdalena Balmaseda (ECMWF)



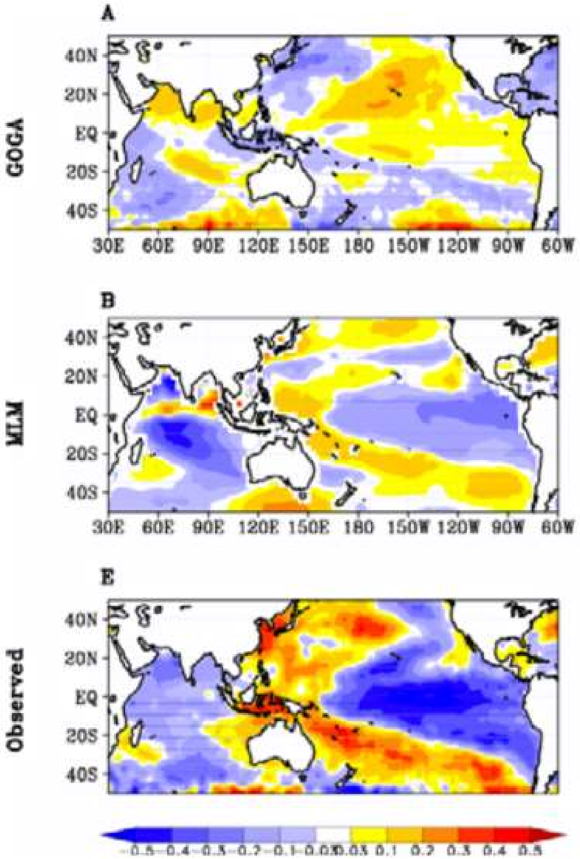
Monsoon clouds over Bangladesh. Courtesy: NASA

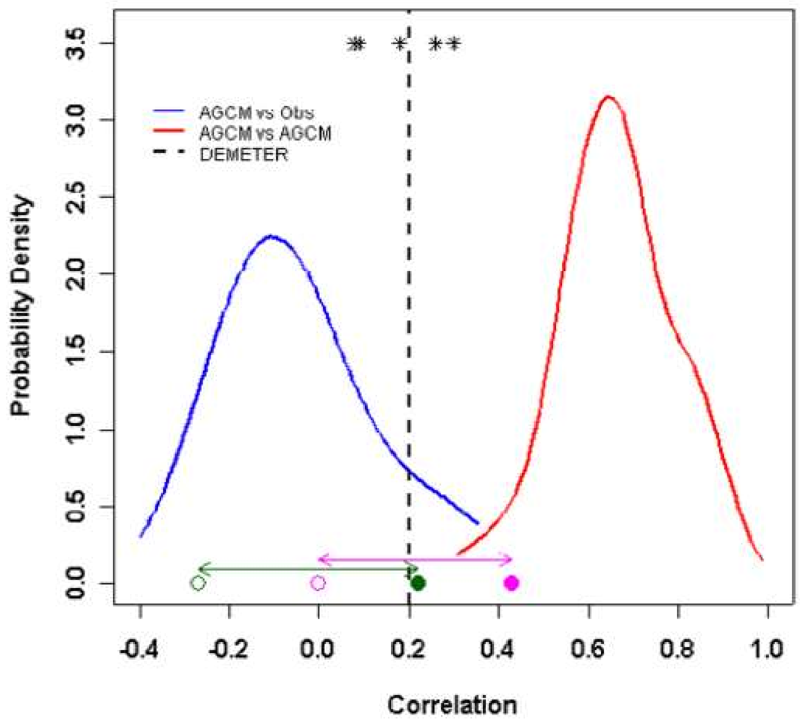
Subseasonal to Seasonal Forecasts



source: https://www.wmo.int/

Air-sea interaction and seasonal monsoon forecasts





Correlation maps of

(a) observed SSTs and monsoon rainfall simulated from uncoupled model,

(b) simulated SSTs and monsoon rainfall from the coupled model.

(c) observed SSTs and observed monsoon rainfall

PDFs of correlation skill of June – September Indian monsoon rainfall

(red) 'perfect model'

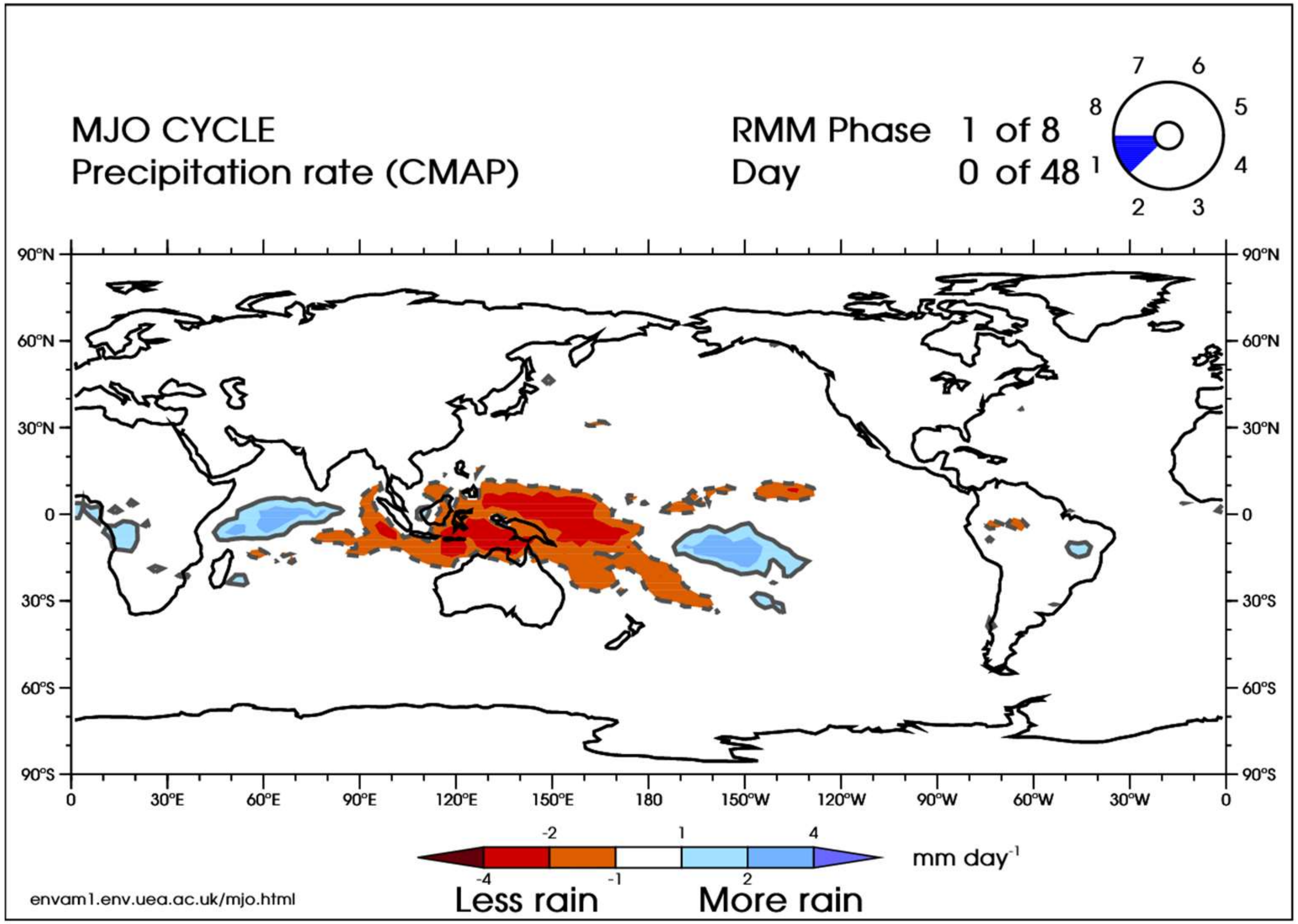
(blue) actual skill

Closed coloured circles - skill of two of AGCM coupled ML model.

Krishna Kumar et al., 2005

Madden-Julian Oscillation

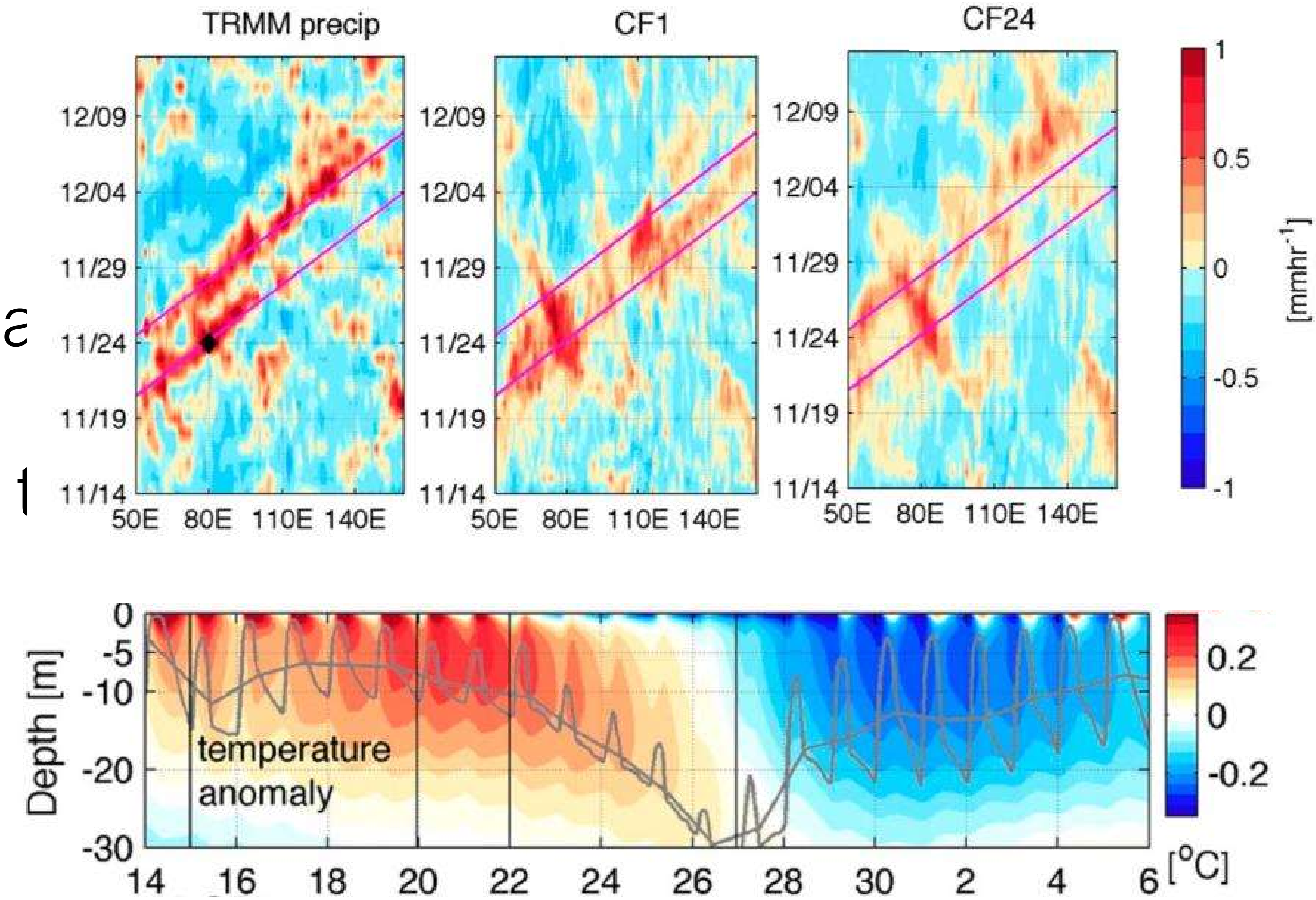
Largest signal in tropical precipitation on timescales shorter than a year



source: Prof. A. Matthews, Univ. of E. Anglia

Impact of high-frequency air-sea interactions on MJO

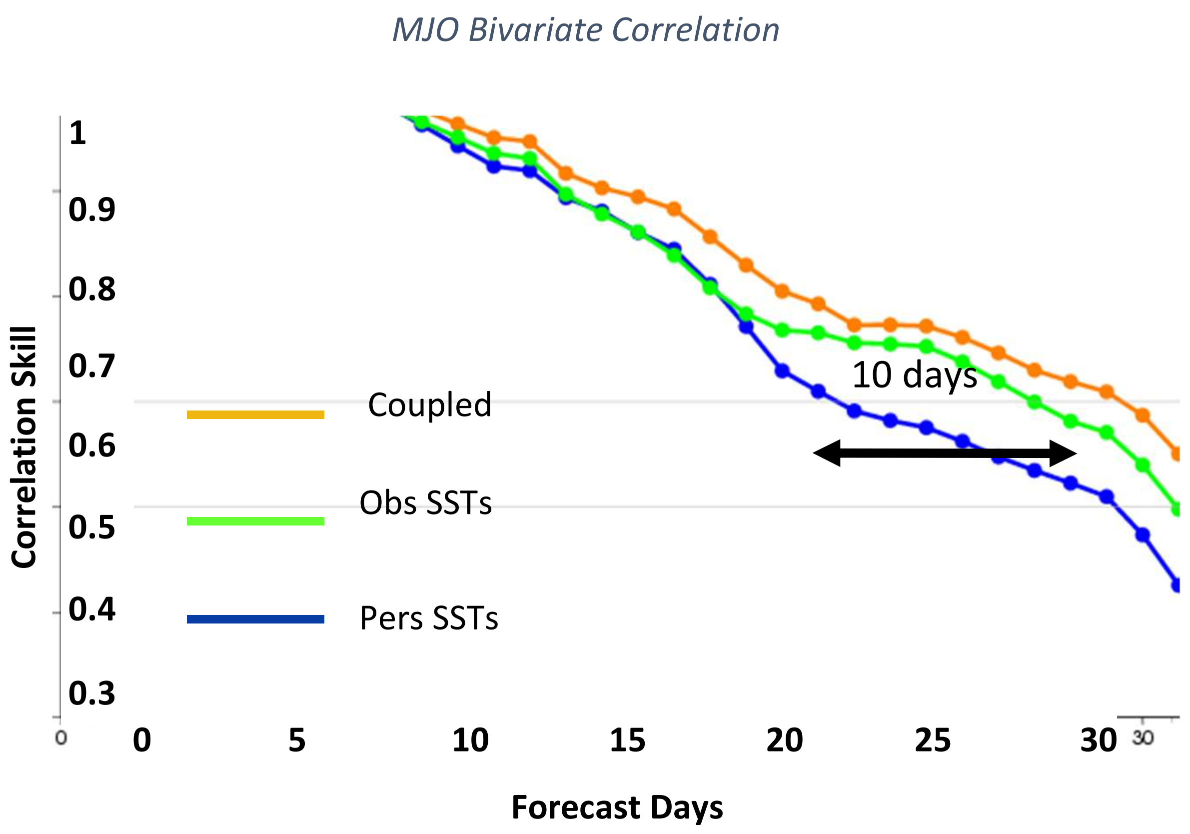
Diurnal coupling in a
regional model
improves MJO due t
rectification of
shallow moistening



Seo et al. 2014

Ocean coupling improves MJO predictability

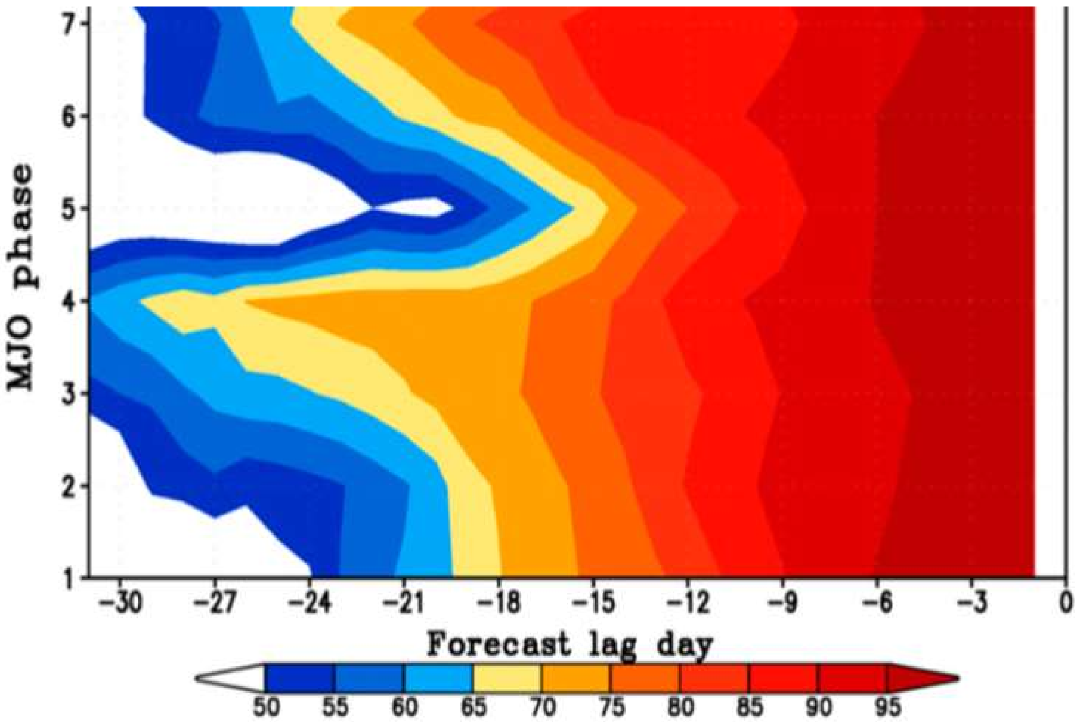
- Subseasonal forecasts of the MJO benefit significantly from coupling to the ocean (20 years of initialized forecasts)
- Ocean-atmosphere phase locking of anomalies and feedback act as a source of predictability on S2S timescales
- Understand coupled processes better to improve models and predictions on sub seasonal timescales



Subramanian et al. 2017 (sub judice)

MJO phases: forecast skill

- Prediction skill for forecasts targeting strong MJOs as a function of MJO phase and forecast lag day
- Low skill in initial and Maritime Continent phases



Kim et al. (2014)

MJO and the Maritime Continent

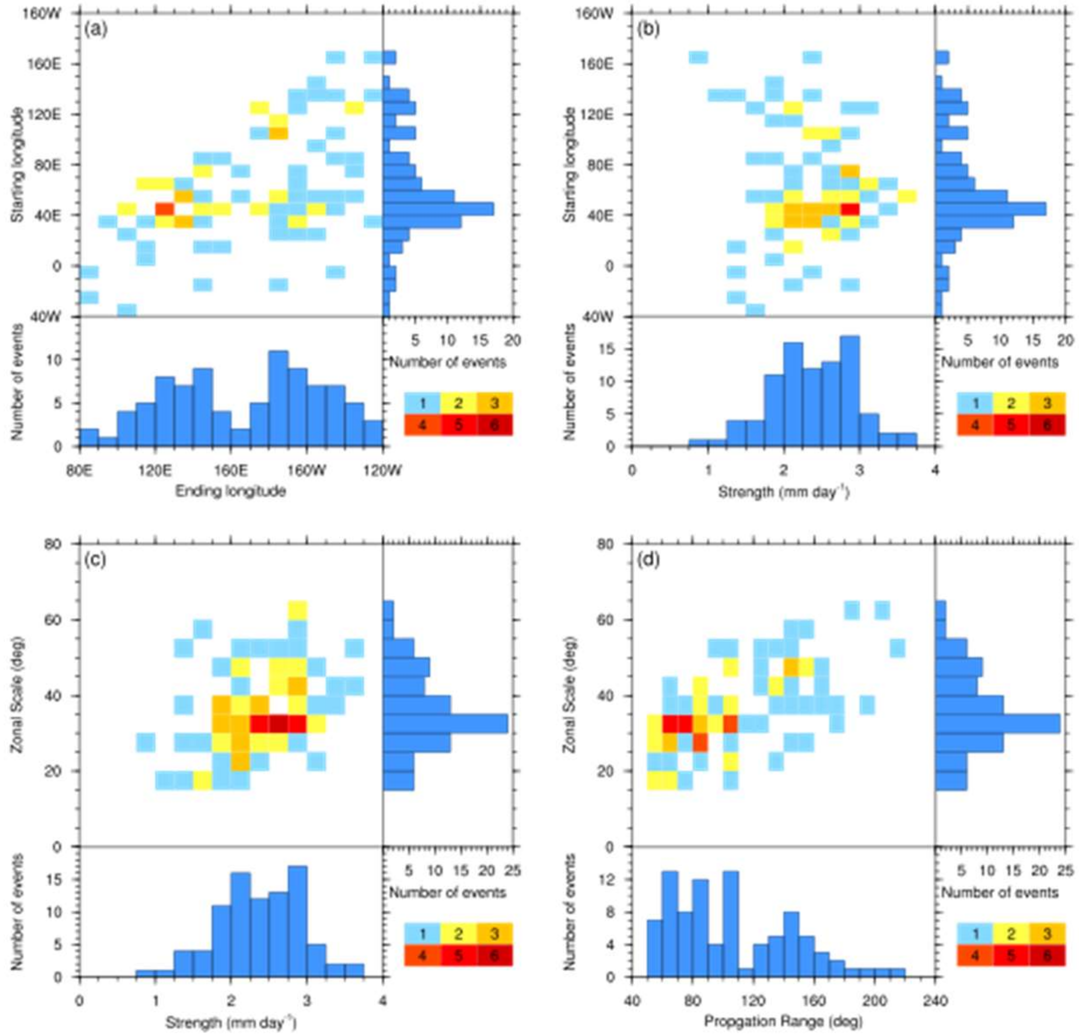
Individual and joint number distributions of

(a) starting vs ending longitudes

(b) starting longitudes vs mean strength

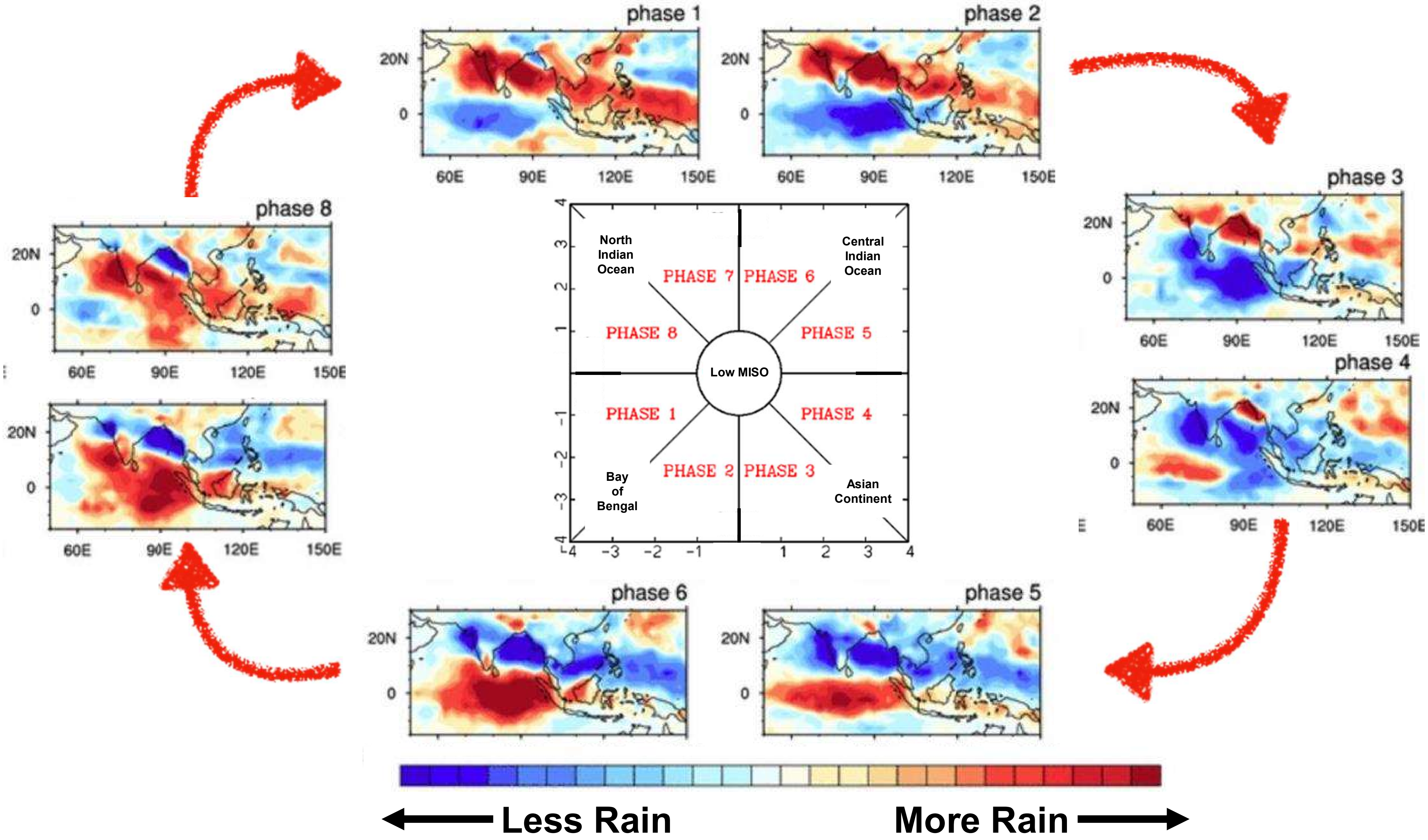
(c) mean zonal scales vs mean strength

(d) mean zonal scales vs propagation ranges of tracked MJO events using the TRMM precipitation data.



Zhang and Ling (2017)

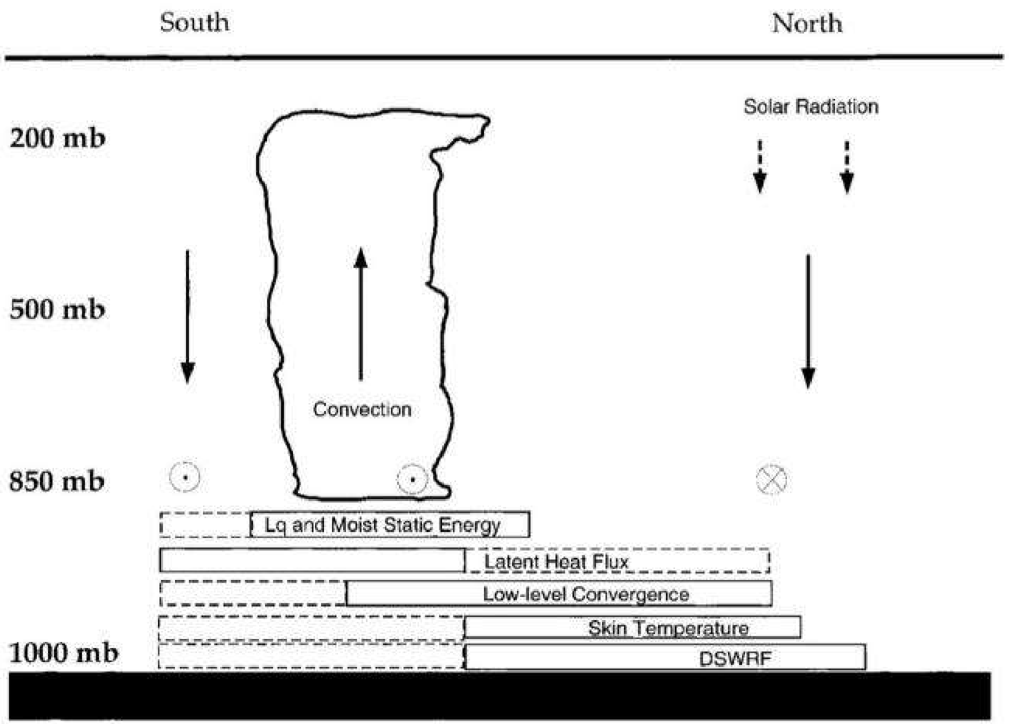
Monsoon Intraseasonal Oscillation



Based on an EEOF analysis of precipitation in the Tropics.

Neena et al., 2017

Air-sea interaction is key

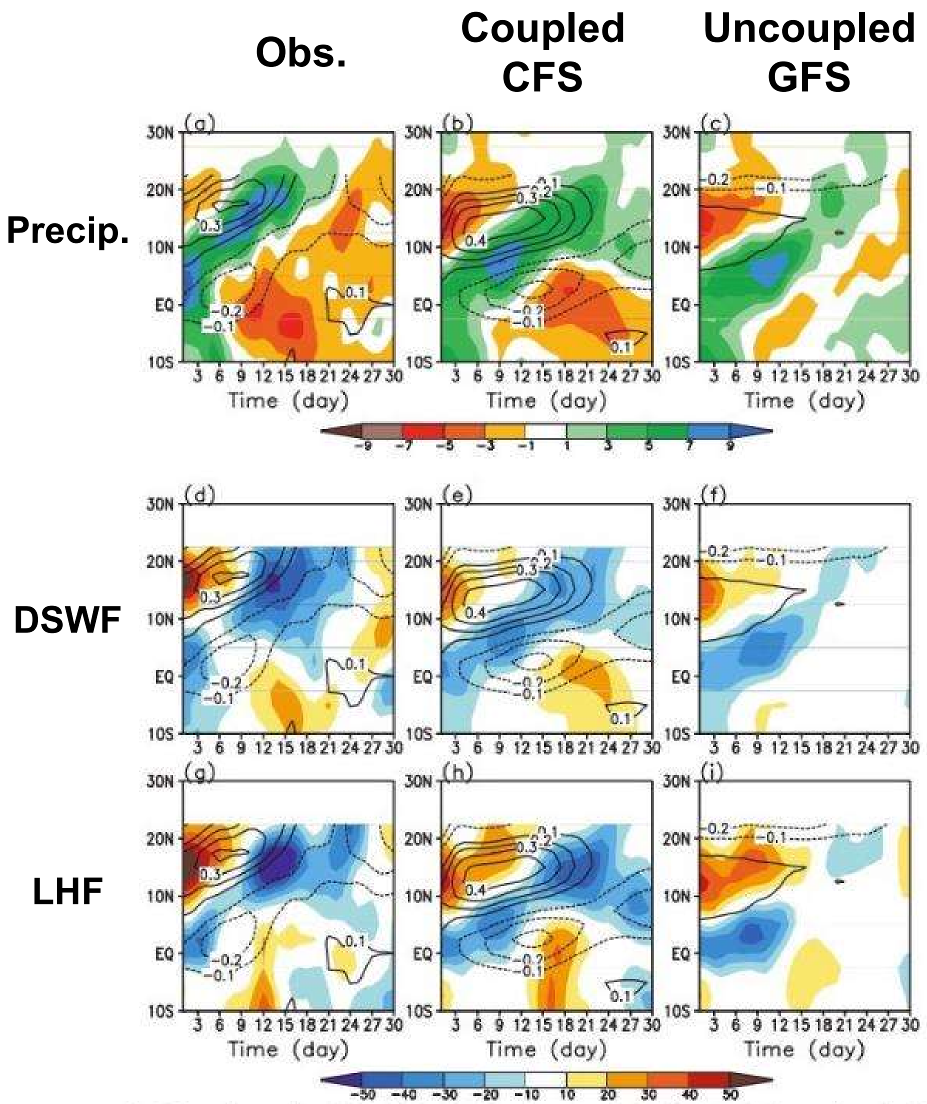


Schematic of air–sea interaction in the northward propagation of convective anomalies associated with the BSISO in the Indian and western Pacific Oceans. Dark vertical lines indicate the ω(500 mb) anomaly. The cloud indicates deep precipitating convection. The boxes represent the approximate locations of anomalies relative to the convection. Solid box indicates a positive anomaly, and dashed box indicates a negative anomaly. Circles indicate direction of 850-mb zonal wind anomaly with the ⊗ (⊙) representing easterlies (westerlies).

PBL convergence maximum north of the convection maximum leads to feedbacks that propagate the system poleward.
Kemball-Cook and Wang (2001)

Air-sea interaction for MISO forecasts

During MISO propagation, the observed phase relation between latent heat flux, SST and SW radiation is better represented in coupled NCEP forecasts compared to uncoupled forecasts.



Composite anomalies. (top) Precipitation (shaded starting at 1 mm day^{-1}, with a 2 mm day^{-1} contour interval) and SST (contours starting at ±0.1 K, with a 0.1-K contour interval, negative values dashed) averaged between 65° and 95°E. (middle) Same as the top row, except that the shading is for downward surface solar radiation (starting at ±10 W m^{-2}, with a 10 W m^{-2} contour interval). (bottom) Same as the middle row, except that shading is for downward latent heat flux. (left) Observation, (middle) CFS forecast, and (right) GFS forecast.

Wang et al. 2009

Ocean data assimilation impact: Precipitation in MISO predictions

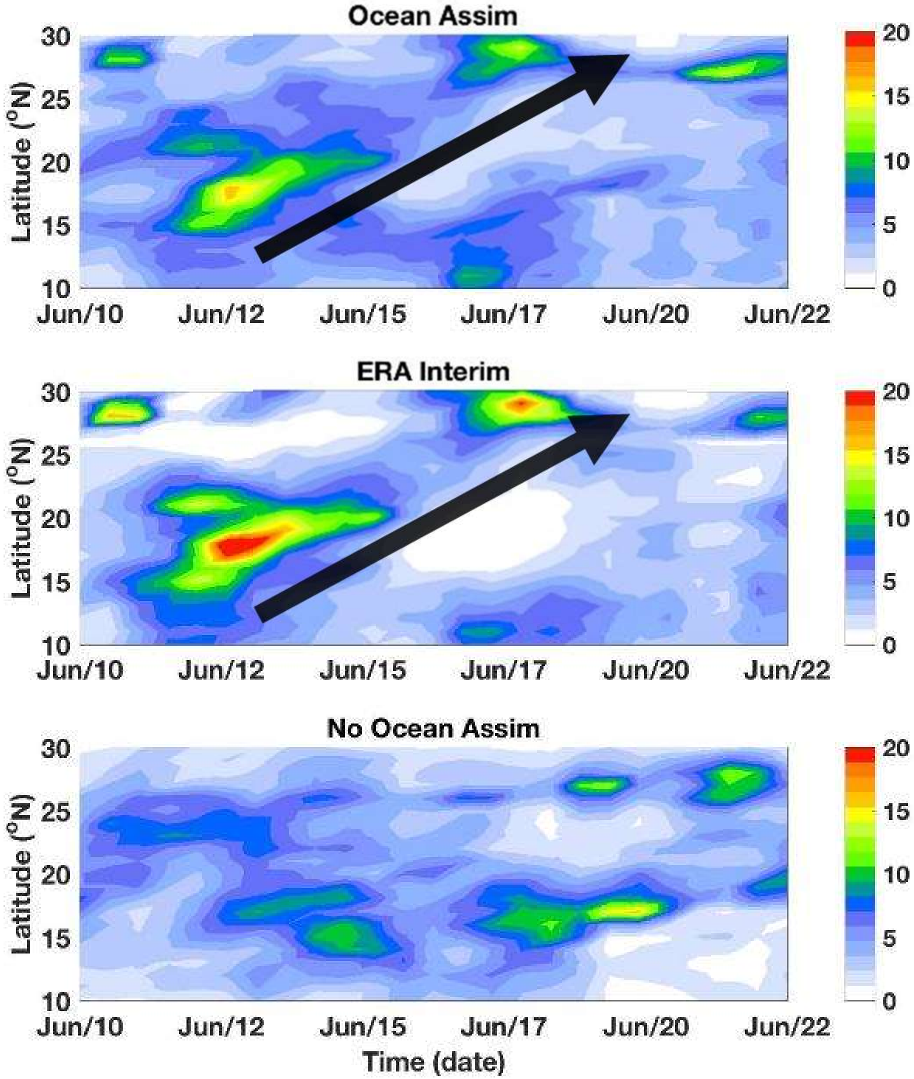
ECMWF sub seasonal forecast system

All ocean observations assimilated prior to hindcast initialization ⇒ **more coherent MISO propagation**

Reanalysis

Only surface SST was assimilated prior to hindcast initialization

2013 June: Precipitation Hovmöller



Subramanian et al. (2018, In Prep.)

Zonal mean precipitation [85 E - 90 E]

Ocean data assimilation impact: LH Flux anomalies in MISO predictions

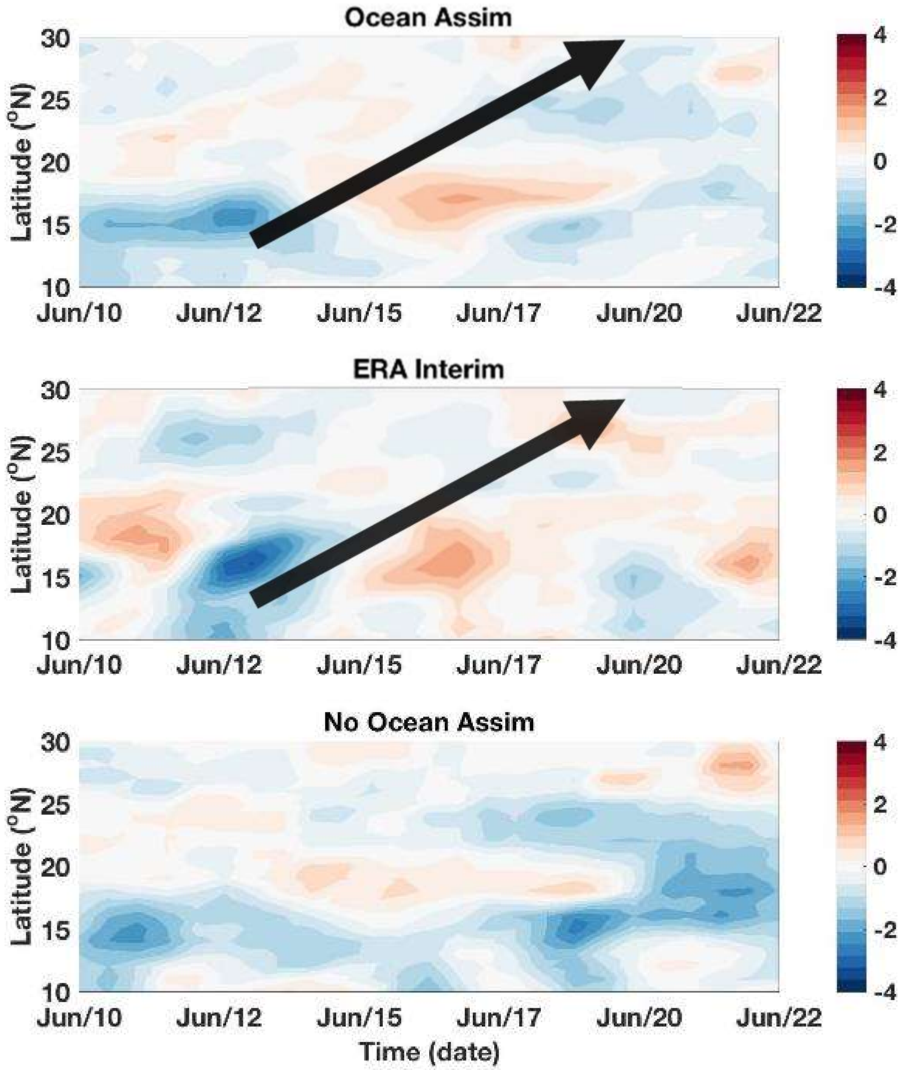
ECMWF sub seasonal forecast system

All ocean observations assimilated prior to hindcast initialization ⇒ **more consistent surface flux anomalies**

Reanalysis

Only surface SST was assimilated prior to hindcast initialization

2013 June: Latent Heat Flux (x10^3 kJ m^{-2})



Zonal mean LH Flux [85 E - 90 E]

Subramanian et al. (2018, In Prep.)

Process Studies

BoBBLE

ASIRI-OMM and MISO-BOB

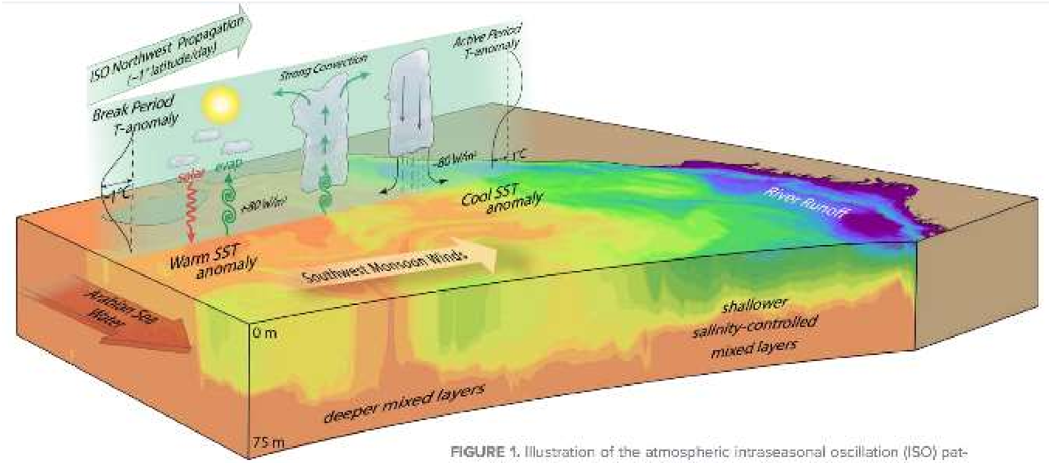
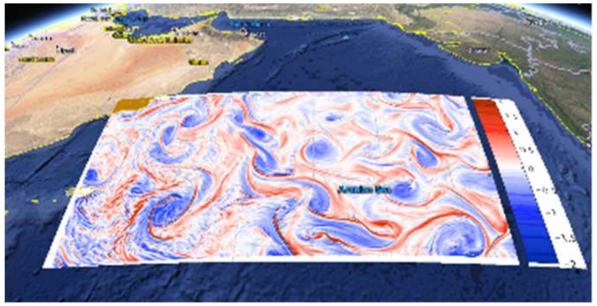


FIGURE 1. Illustration of the atmospheric intraseasonal oscillation (ISO) pattern that propagates over the Bay of Bengal during the southwesterly monsoon season. Color in the ocean represents salinity, and was produced using the HYbrid Coordinate Ocean Model, or HYCOM (Cummings and Smedstad, 2013, http://dx.doi.org/10.1007/978-3-642-35088-7_13). *Schematic drawing by Emily Shroyer and produced by David Reinert, Oregon State University.*

NASCar



Years of Maritime Continent

Recommendations

- **Resolve diurnal cycle : increase the vertical resolution in the upper 10 m of RAMA buoy.**

- **Add new sites of surface buoys in the eastern Indian Ocean and MC for upper ocean and air-sea fluxes**

- **Increase the surface flux buoy sites in western Indian Ocean (equatorial and Arabian Sea) while also maintaining the existing surface mooring sites in the revised RAMA-2.0 design**

- **Enhance some of the existing RAMA buoy measurements by augmenting the existing upper ocean measurements with concurrent high frequency meteorological measurements for the atmospheric state**

- **Increase observations in coastal regions especially near the Maritime Continent region (either through moorings or other platforms (saildrones?)).**

Summary

- Air-sea interaction plays a key role in MJO, MISO and monsoon dynamics

- Improved upper ocean representation in a coupled forecasting system can help improve model fidelity and predictions of MJO / MISO (data assimilation can help with coupled initialization)

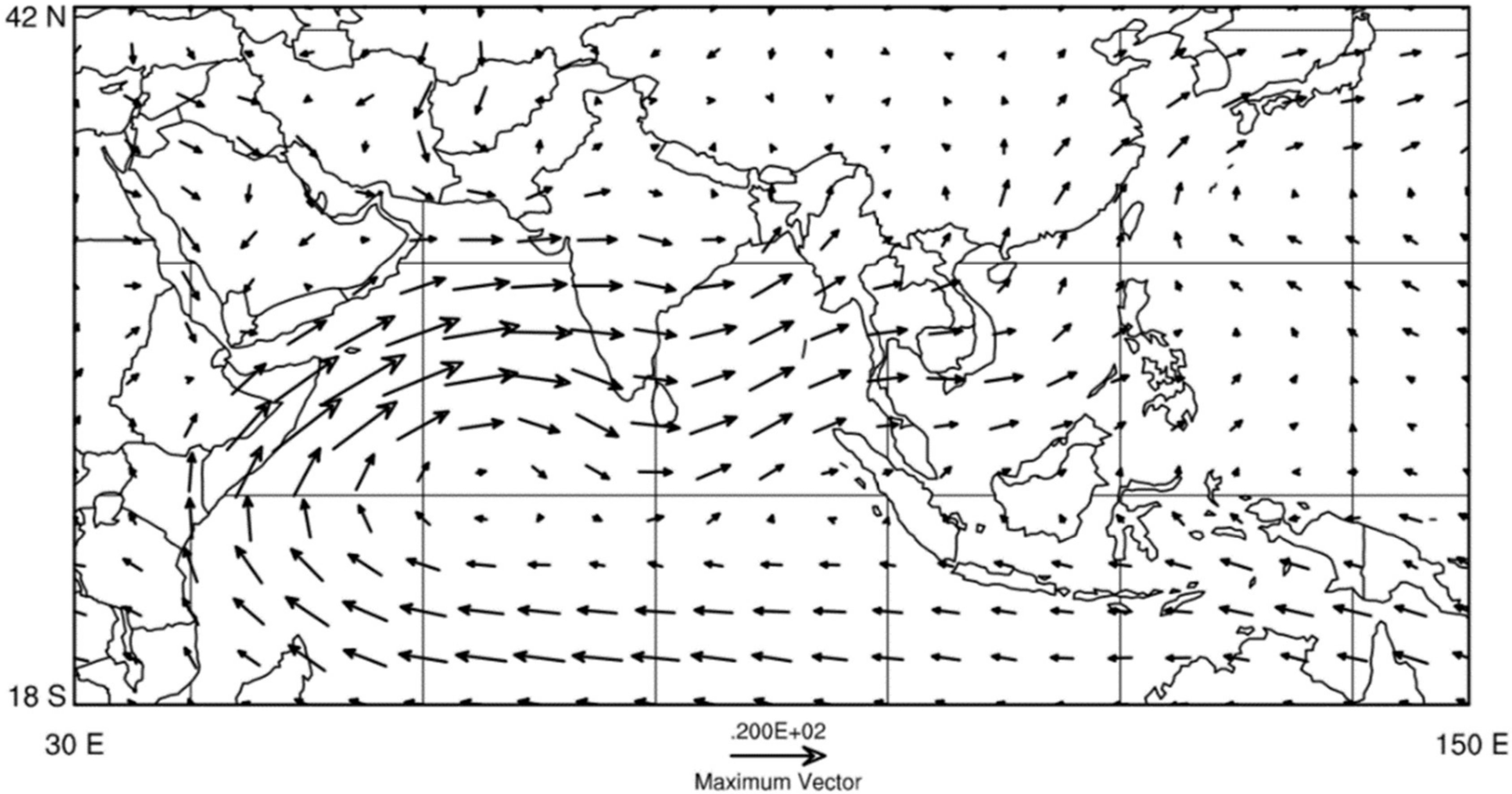
- Improved process understanding required for better parameterizations in the upper ocean

Thank you

Monsoon clouds over Bangladesh. Courtesy: NASA

Monsoons

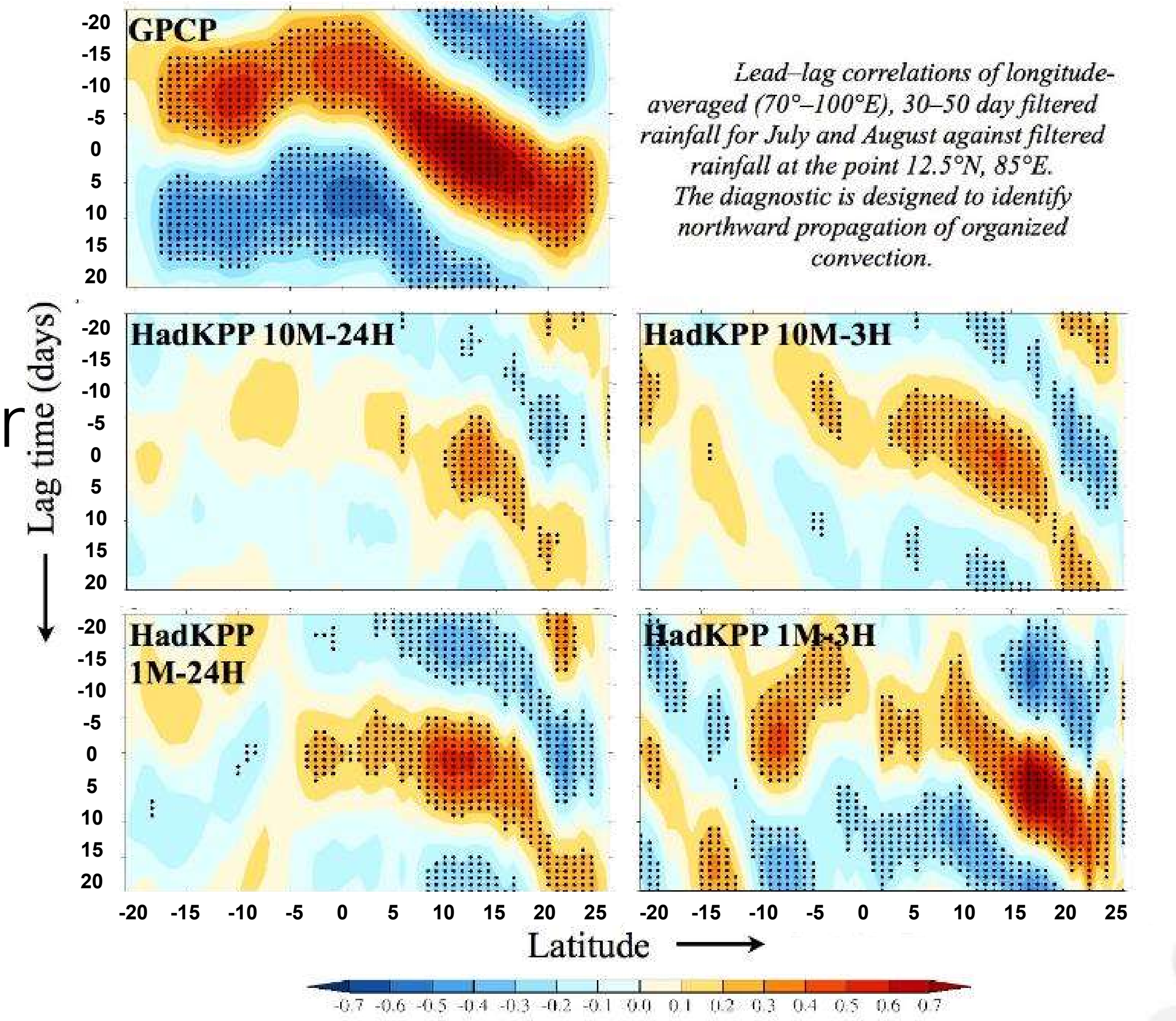
One of the largest seasonal reversals of winds and exchange of heat and freshwater between the ocean-land-atmosphere in one season



source: D. Randall (2012)

Impact of high-frequency air-sea interactions on MISO

Higher vertical resolution in the upper ocean and resolving the diurnal cycle ir coupling helps improve the representation of MISO.



Klingaman et al., 2010