The Madden Julian Oscillation

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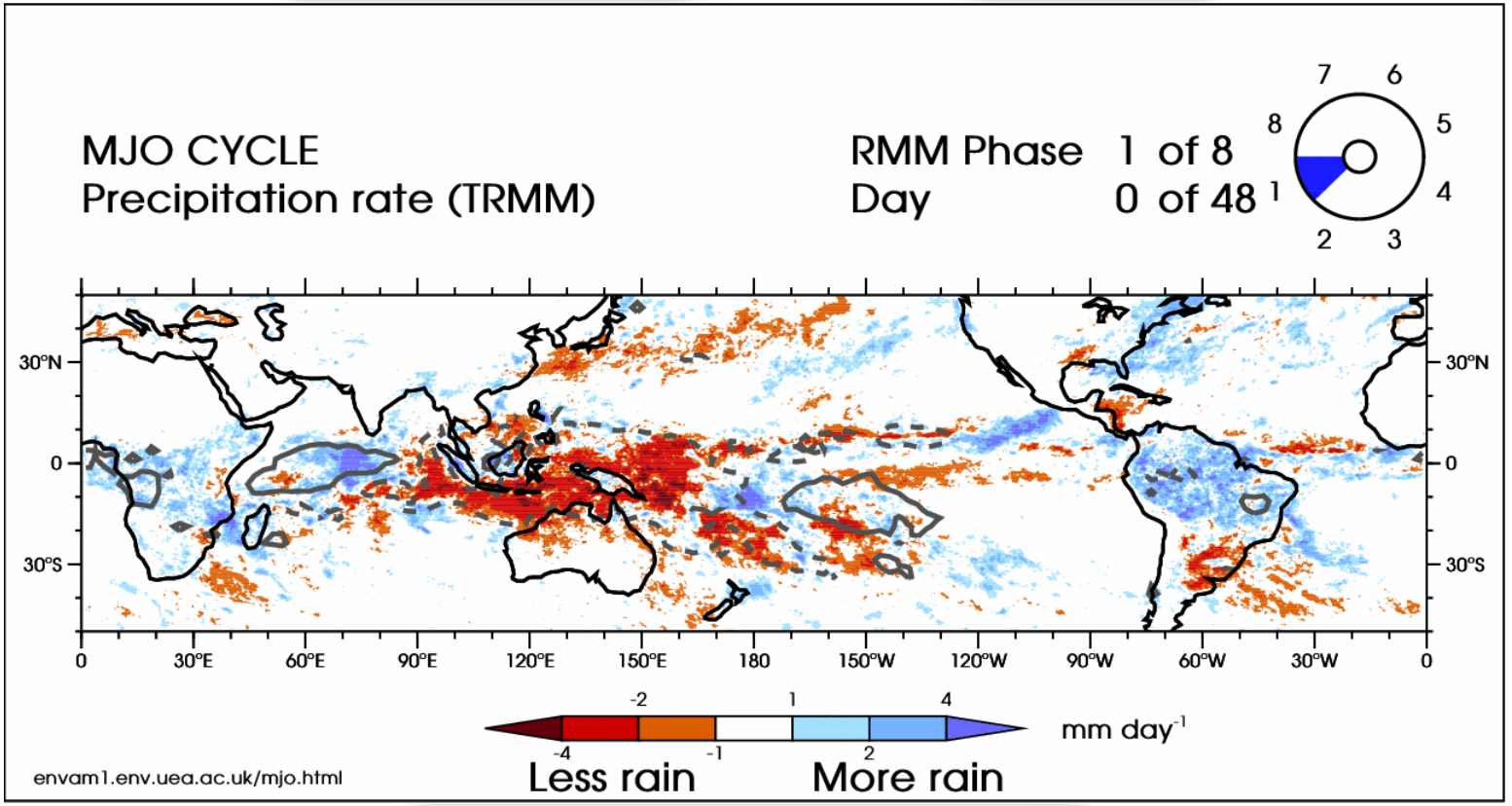
The Madden-Julian Oscillation (MJO)

- The MJO is the largest mode of subseasonal variability in the tropics



Animation courtesy of Adrian Matthewshttp://envam1.env.uea.ac.uk/mjo.html

The Madden-Julian Oscillation (MJO)

- The MJO is the largest mode of subseasonal variability in the tropic, with significant tropics-wide and global impacts on sub-seasonal timescales (*see Zhang, 2013 in BAMS, for a nice review)*
- Linked to sub-seasonal variability of the major monsoon systems
- Associated tropical heating anomalies act as Rossby wave-source and provide teleconnections to extra-tropics (troposphere and stratosphere)
- Modulates tropical cyclone activity
- Westerly Wind Bursts important in development of El Niño events

MJO Global Teleconnections

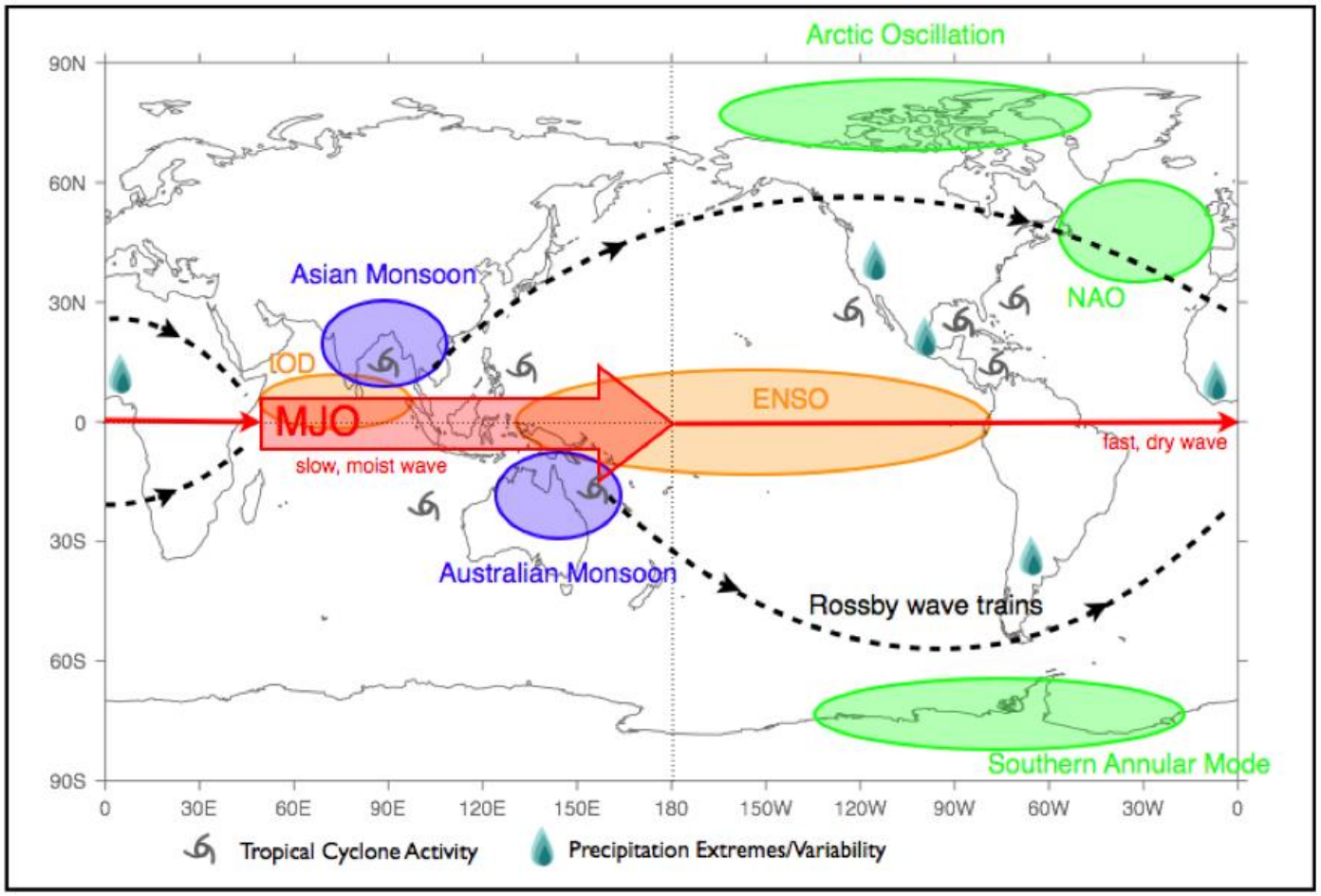
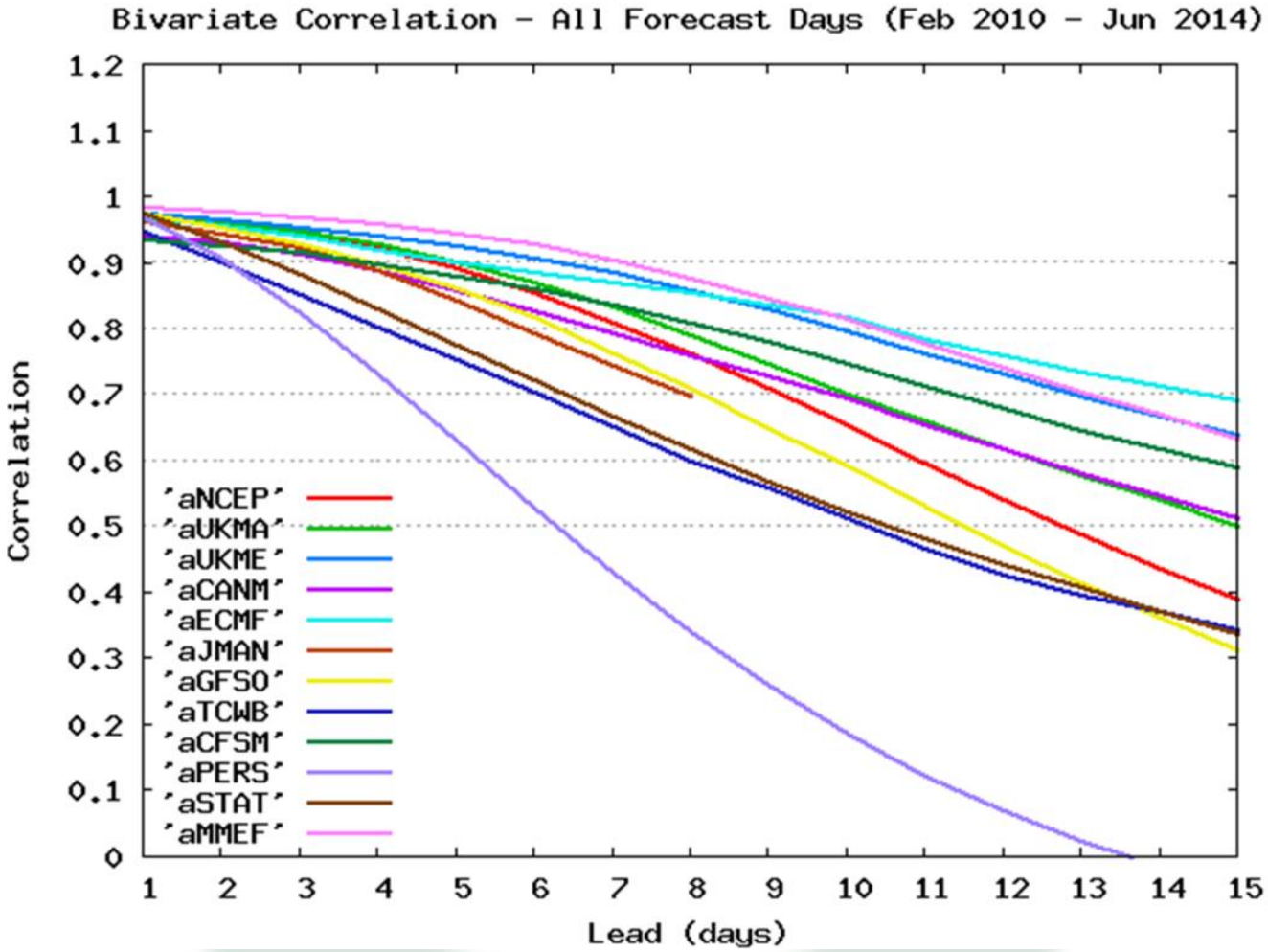


Figure 1.2 *Schematic representation of the global teleconnection patterns associated with the MJO. Adapted and extended from Lin* et al. *(2006).*

Courtesy of Linda Hirons

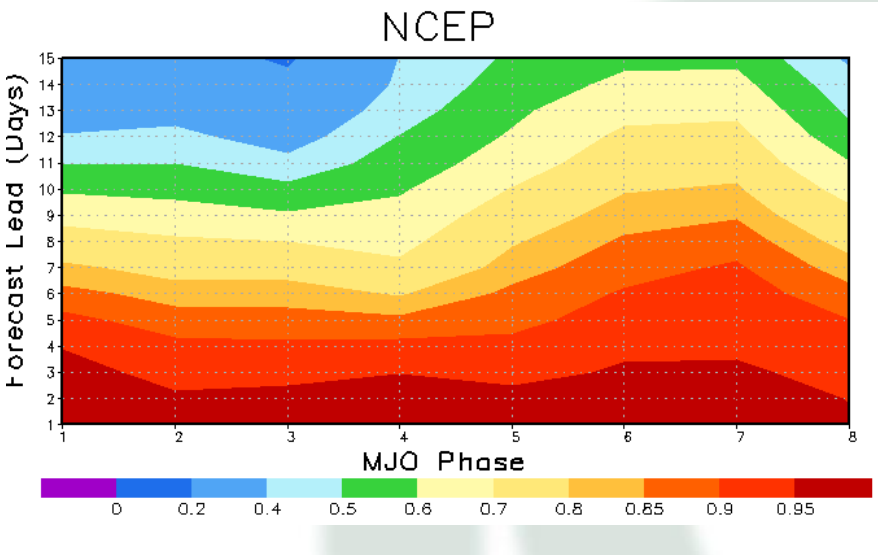
MJO Prediction skill

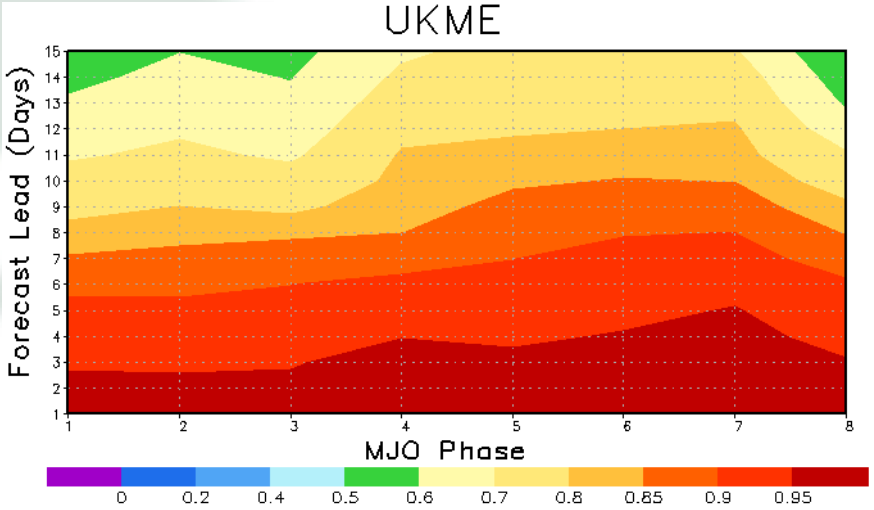


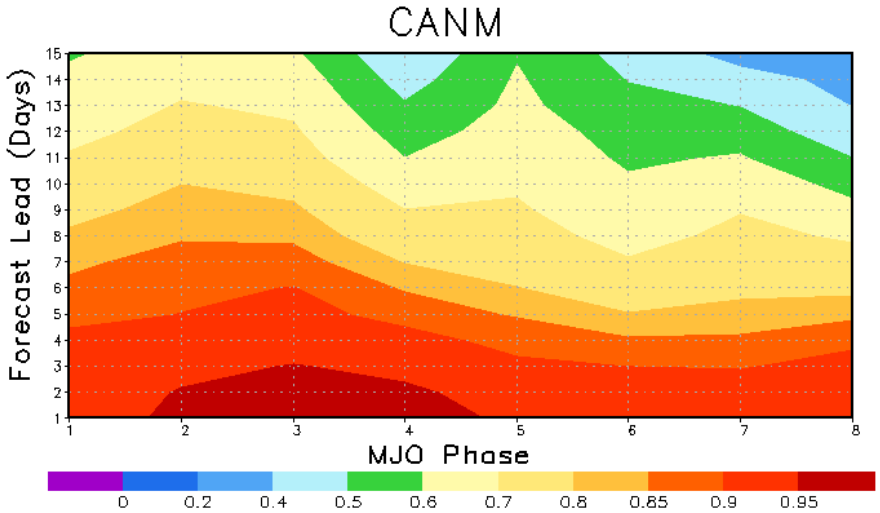
MJO bivariate correlation skill for models submitted to the MJOTF realtime MJO forecast monitoring activity at CPC

courtesy Jon Gottschalck

MJO Prediction skill



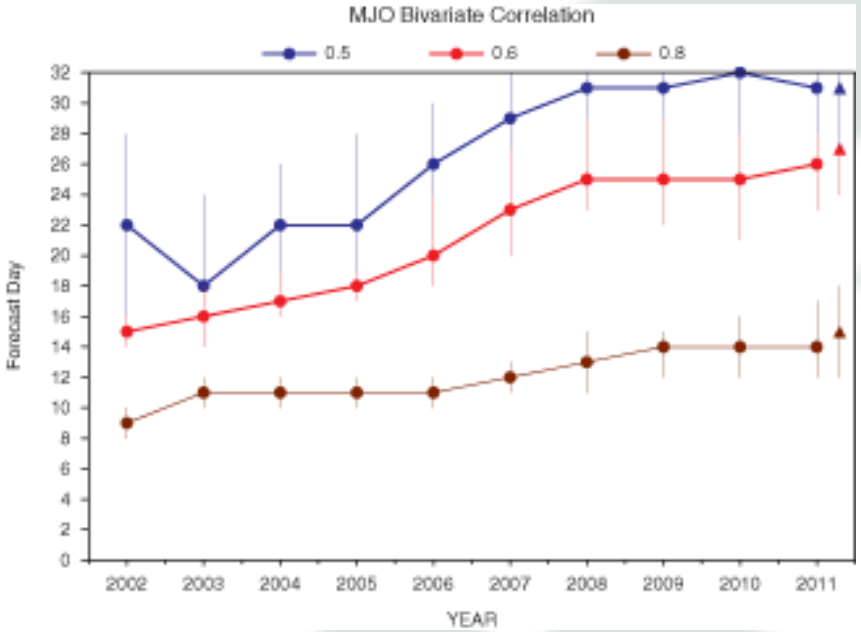


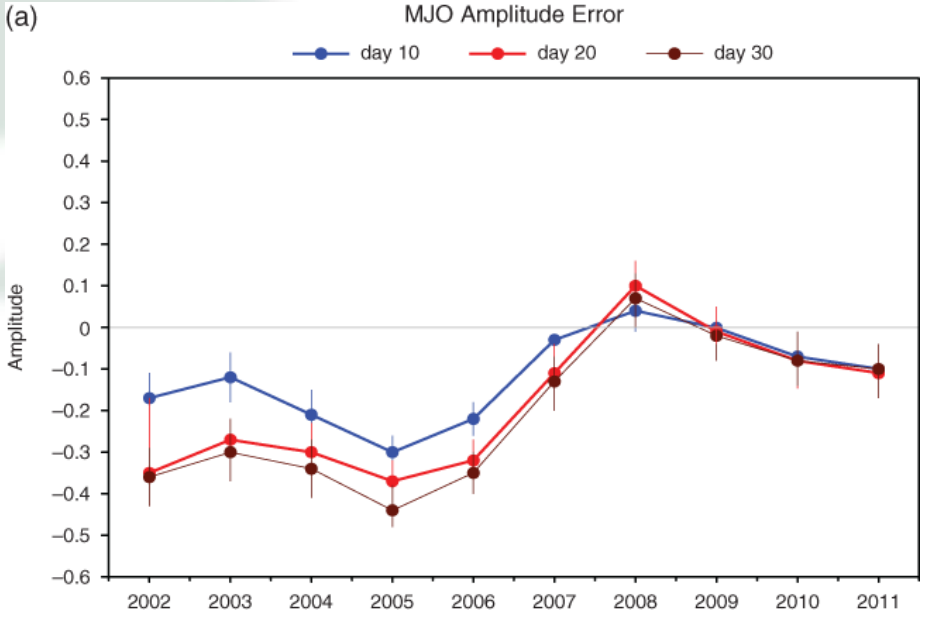


- Correlation skill varies as a function of initial MJO phase
- Different patterns between centres

courtesy Jon Gottschalck

MJO prediction skill at ECMWF

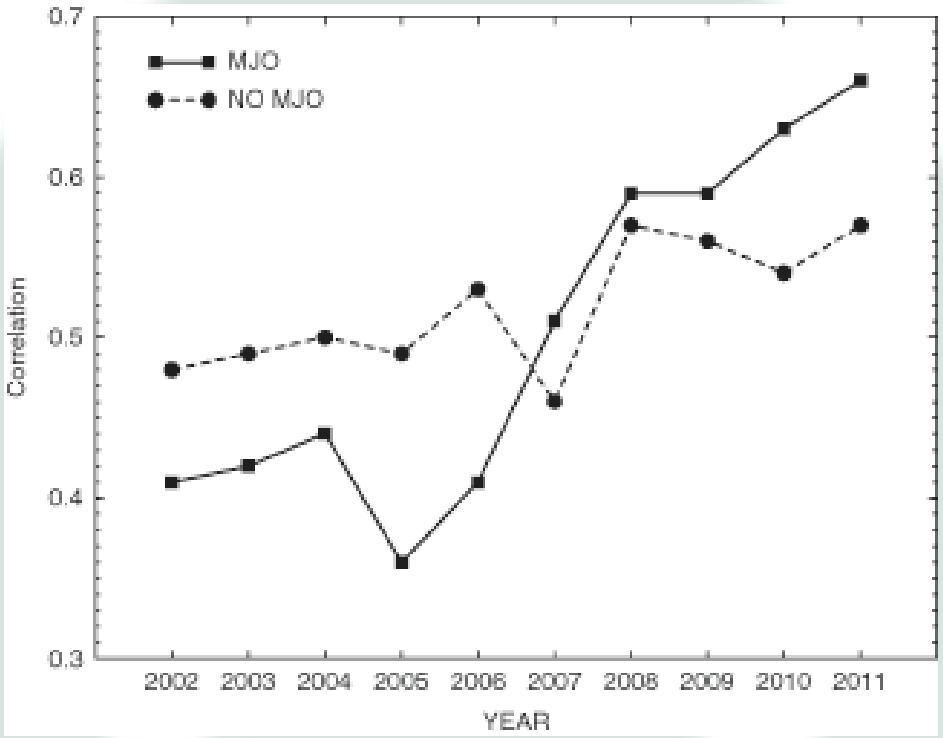




MJO bivariate correlation (lead time for correlation, 0.5,0.6,0.8) and amplitude error at days, 10,20,30

from Vitart (2014)

Impact of MJO on NAO skill



Improvement in NAO correlation score for days 19-25 in ECMWF monthly forecasting system for forecasts with or without an active MJO in the initial conditions

from Vitart (2014)

MJO maintenance and propagation

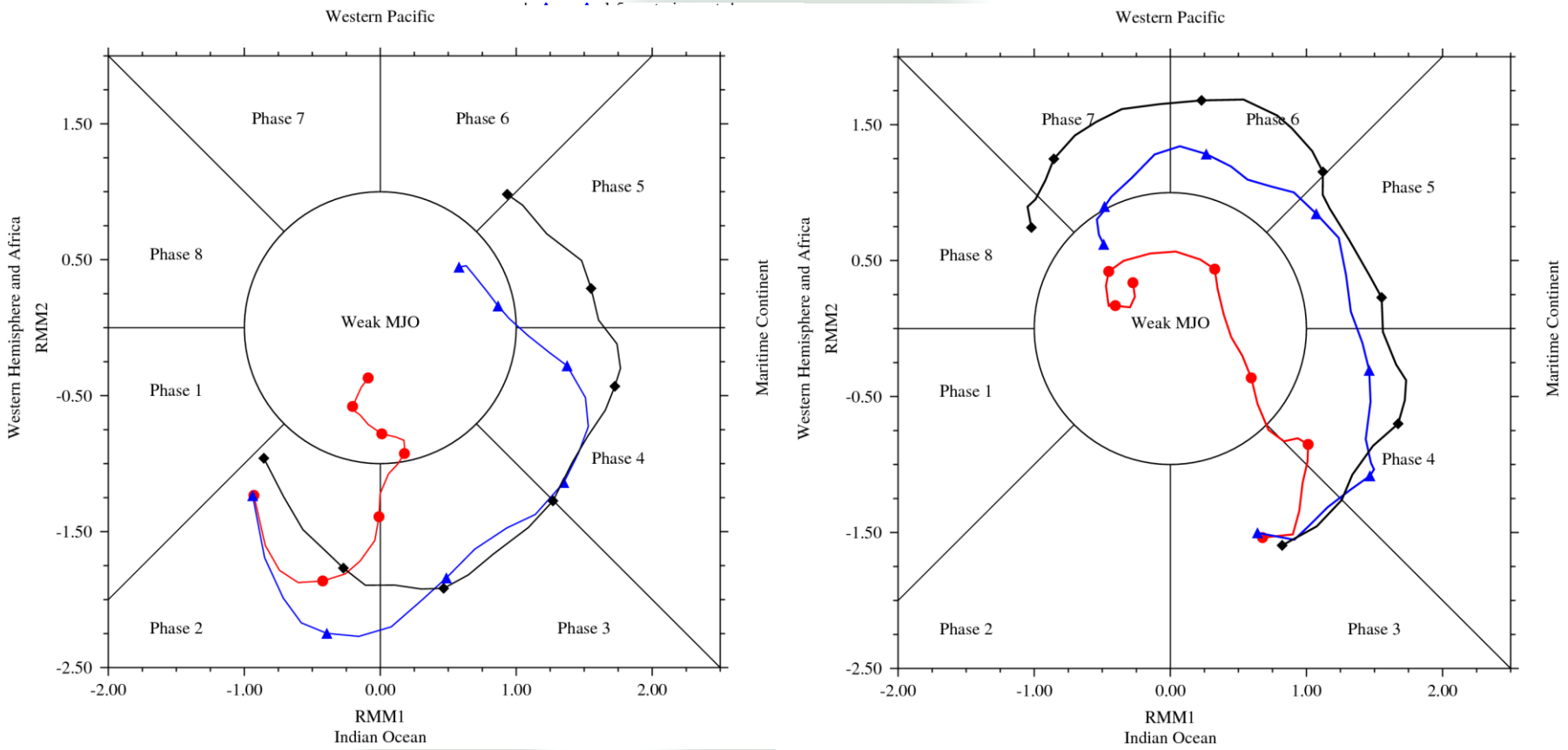
- A number of proposed mechanisms and theories for MJO maintenance and propagation, which are not necessarily mutual exclusive
  - Modification of linear equatorial waves, by convective heating
    - Wave-CISK, Frictional Wave-CISK
  - Moisture modes based around dynamical and diabatic processes influence on the moist static energy budget
    - Role of horizontal advection, longwave and surface heat fluxes, NGMS
  - Air-sea interaction
  - Scale interactions
    - Modulation of synoptic scale activity and their associated heat and momentum transports on the MJO scale flow

Underpinned by the interactions between convection and the large-scale circulation

Modelling the MJO: Representation of Convection

- MJO fidelity simulation in models very sensitive to the representation of convection
- Sensitivity of convection to environmental humidity
  - Effects of mixing entrainment on convective plumes
  - Changes in evaporation of precipitation
- Vertical profile of the heating
  - Projection onto different vertical modes
  - Impacts on the gross moist stability – maintenance of the moist static energy
  - Variations in the vertical profile during MJO cycle
  - Impact on Rossby Wave source and teleconnections

Modelling the MJO: sensitivity to convective entrainment



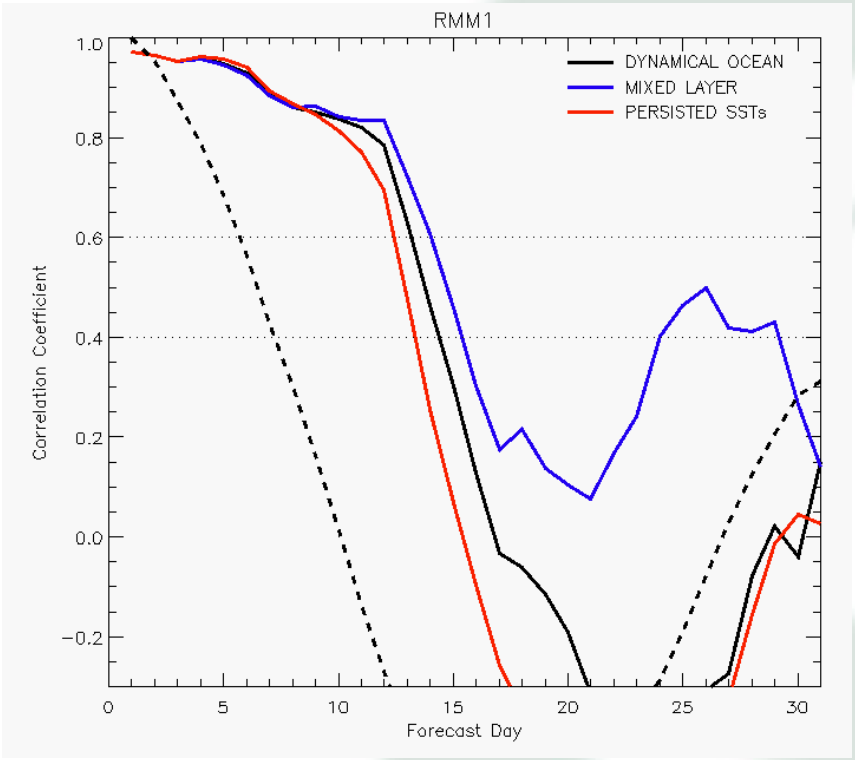
Composite RMM evolution of observations (black), control hindcasts (red) and 1.5x entrainment hindcasts (blue) for 14 strong MJO cases for initialization in phase 2 and 10 days later Dots spaced every five days.

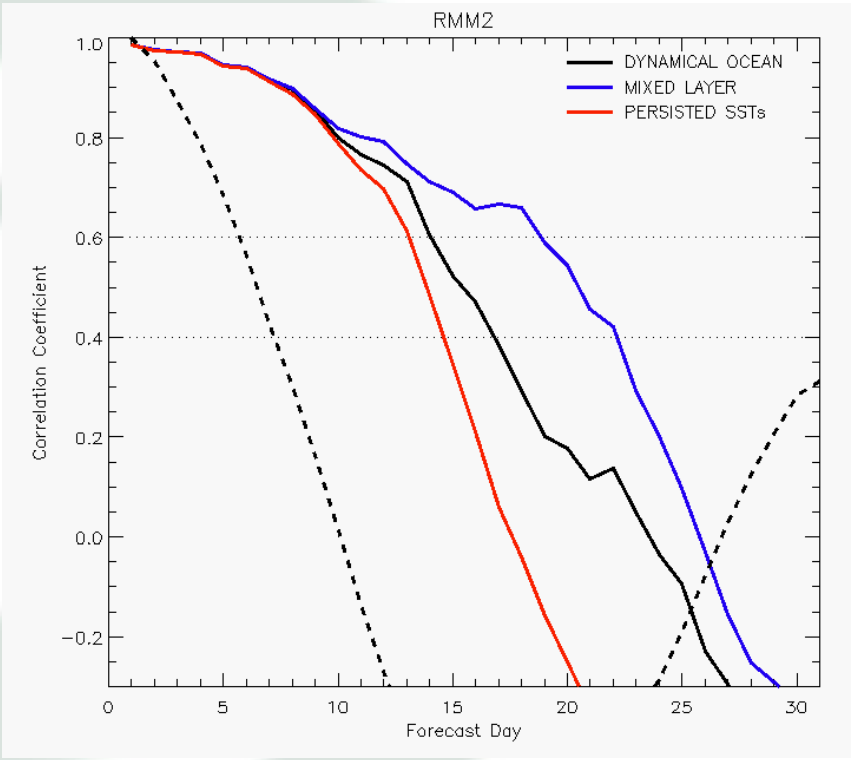
from Klingaman and Woolnough (2014)

Modelling the MJO: Air-sea interaction

- MJO modulates air-sea fluxes on intraseasonal timescales leading to intraseasonal variations in SST
- Representation of ocean mixed layer, important for capturing ocean response to air-sea fluxes
  - Capturing the intraseasonal variations in mixed layer depth
  - Ability to represent the enhanced diurnal cycle of SST during the MJO suppressed phase
- Modelling studies show MJO representation is improved in coupled simulations
  - Processes through which ocean feeds back on the MJO still not clear
  - Considerable variation in detail of GCM representation of important details in the relationship between atmospheric boundary layer and surface

Modelling the MJO: Air-sea interaction

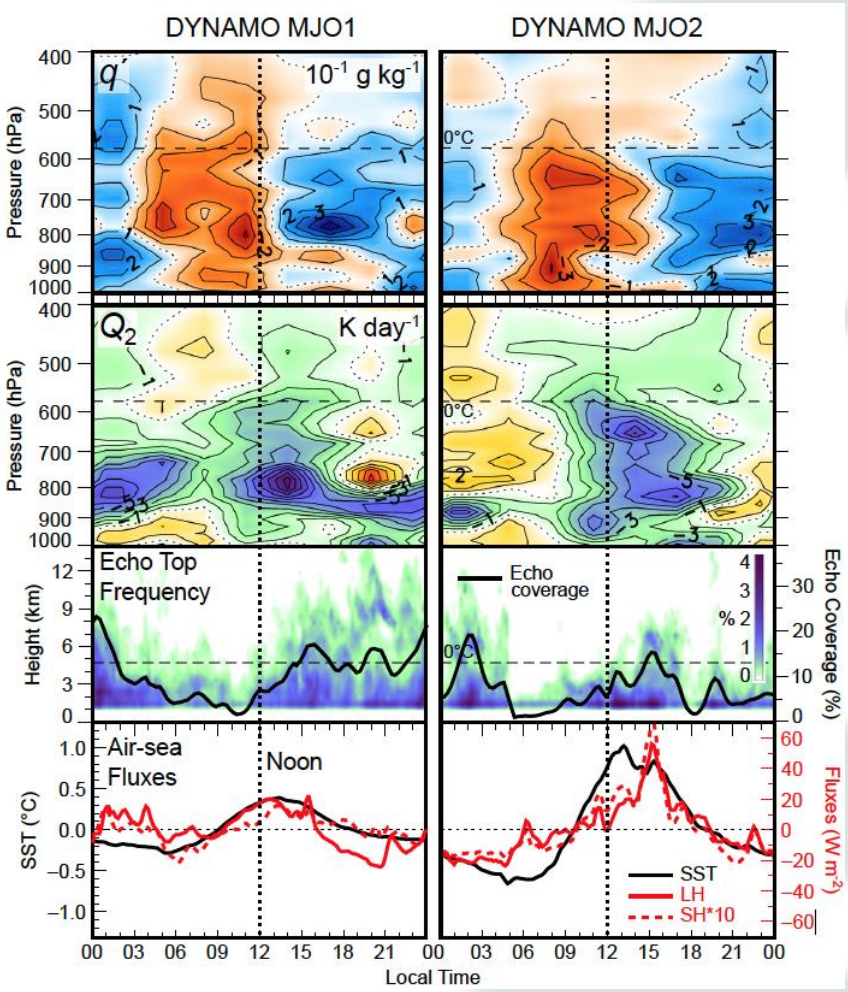




Sensitivity of MJO prediction skill to air-sea coupling, and representation of the ocean mixed-layer

from Woolnough et al. (2007)

Atmospheric Response to diurnal cycle of SST



- Diurnal Cycle during the suppressed phase of the MJO
- Observations from CINDY/DYNAMO
- diurnal cycle of SST
- diurnal cycle in convection
- diurnal cycle in convective moistening
- Role in MJO propagation?

from Ruppert and Johnson (2015)

The MJO and the Maritime Continent

- The synoptic weather within the Maritime Continent is strongly influenced by the MJO,
  - Modulation of cold-surges and Borneo vortex occurrence (e.g. Chang et al. 2005)
  - Modulation of the diurnal cycle of Maritime Continent (e.g. Peatman et al. 2013)

MJO and the diurnal cycle of Maritime Continent Convection

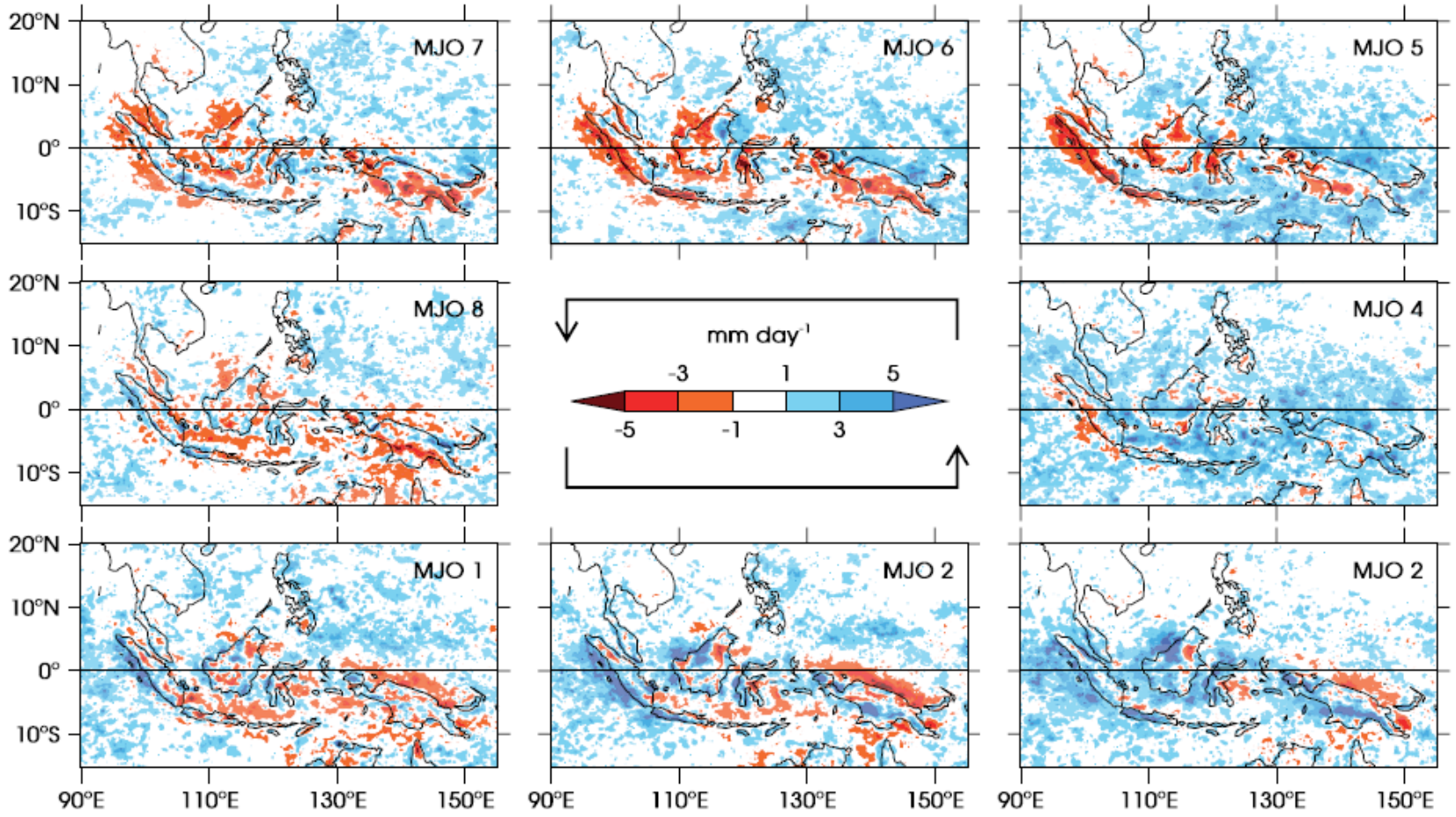


Figure 7. Anomaly of the amplitude r_d of the diurnal harmonic of precipitation from TRMM 3B42HQ in each phase of the MJO. This figure is available in colour online at wileyonlinelibrary.com/journal/qj

from Peatman et al, 2013)

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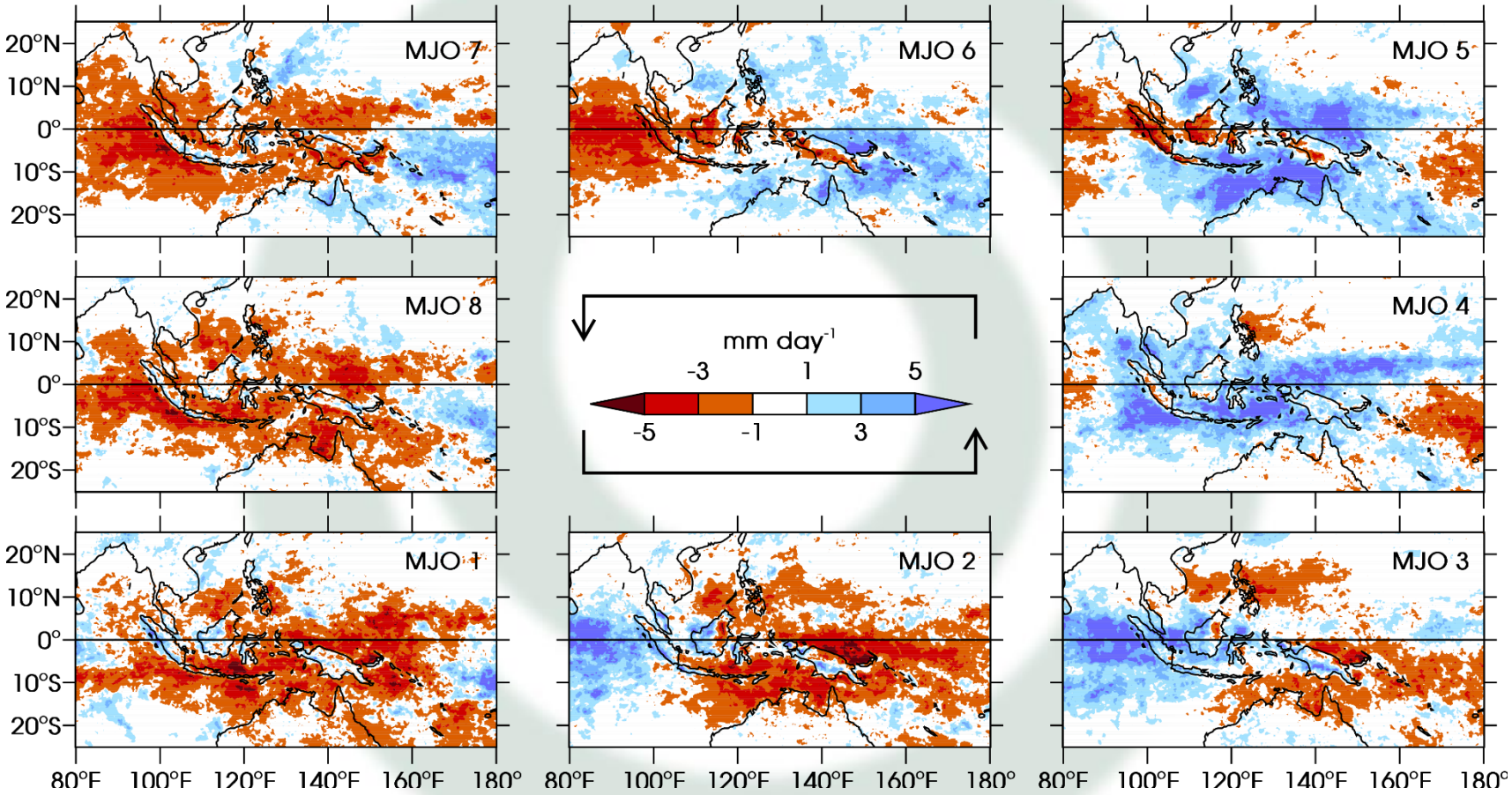
The MJO and the diurnal cycle in the Maritime Continent



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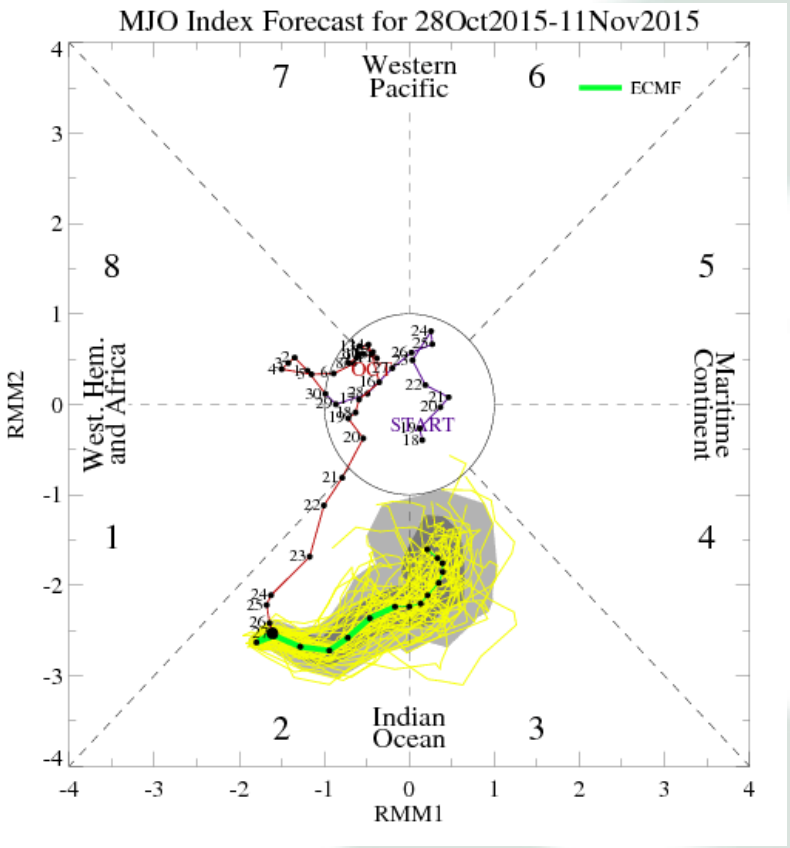
  - MJO modulation of convection over land is ahead of oceanic convection (Peatman et al, 2013)
- How well to models represent these variations in synoptic weather?
- How does the maintenance and propagation of the MJO through the MC depend on these processes?
- What other processes control propagation of the MJO through the Maritime Continent and into the West Pacific?

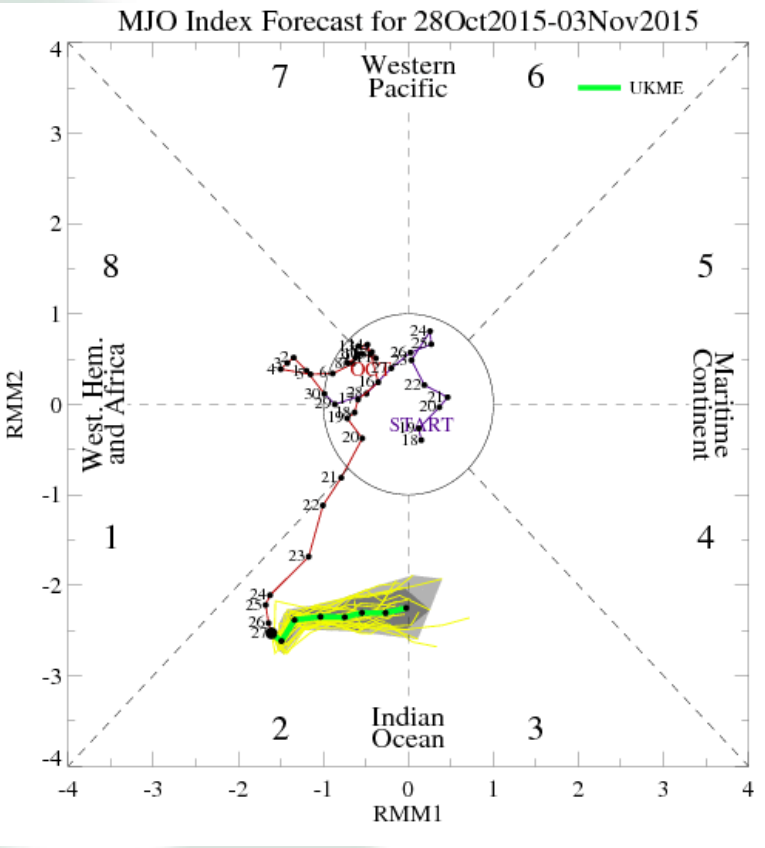
Summary

- MJO is a major source of predictability on sub-seasonal timescales
- Good skill in some operational prediction systems
- Model simulation of the MJO very dependent on the representation of convection
- Air-sea interaction improves simulation and prediction but details of feedback still uncertain
- We still have much to learn about the interaction of the MJO with the Maritime Continent

What's going on now

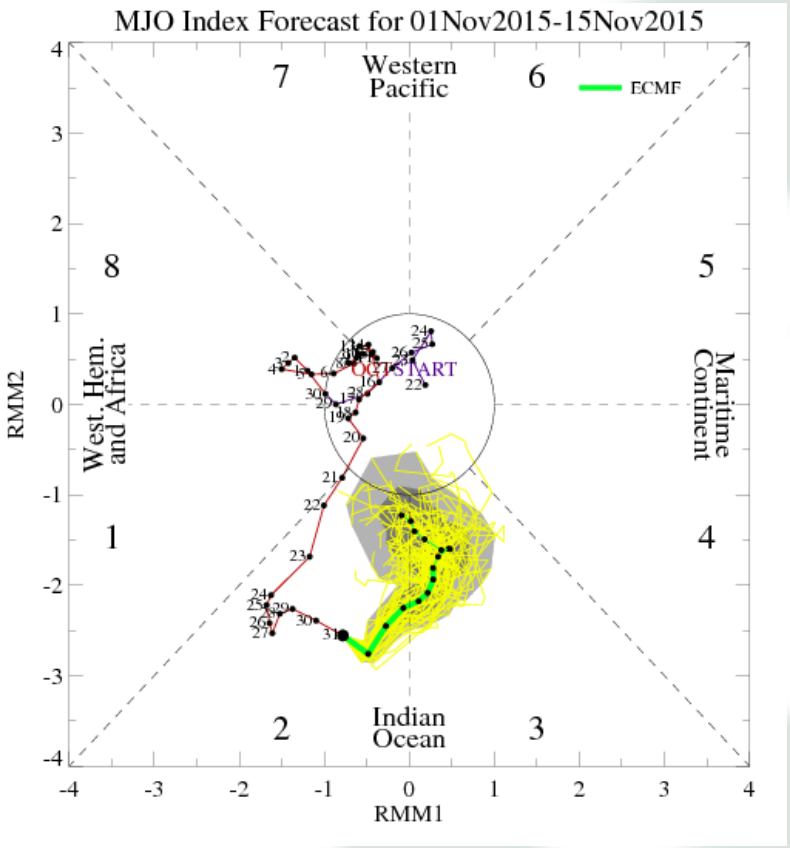


ECMWF



Met Office

What's going on now



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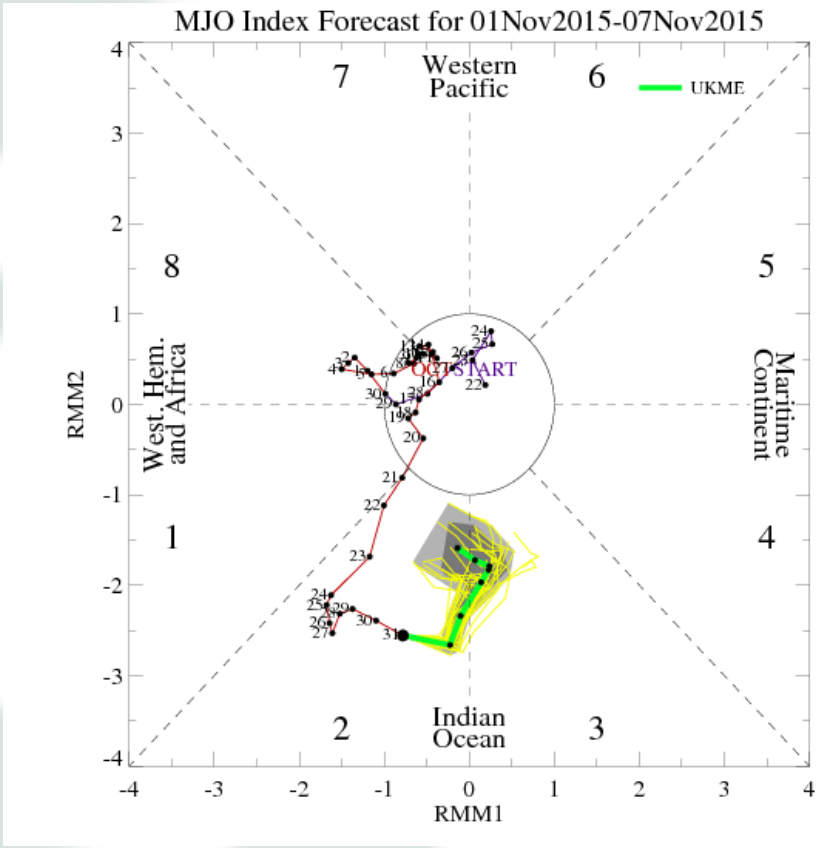

Met Office