NMME/SubX Science Meeting, Sep-14, 2017

Process-based evaluation of the MJO Prediction

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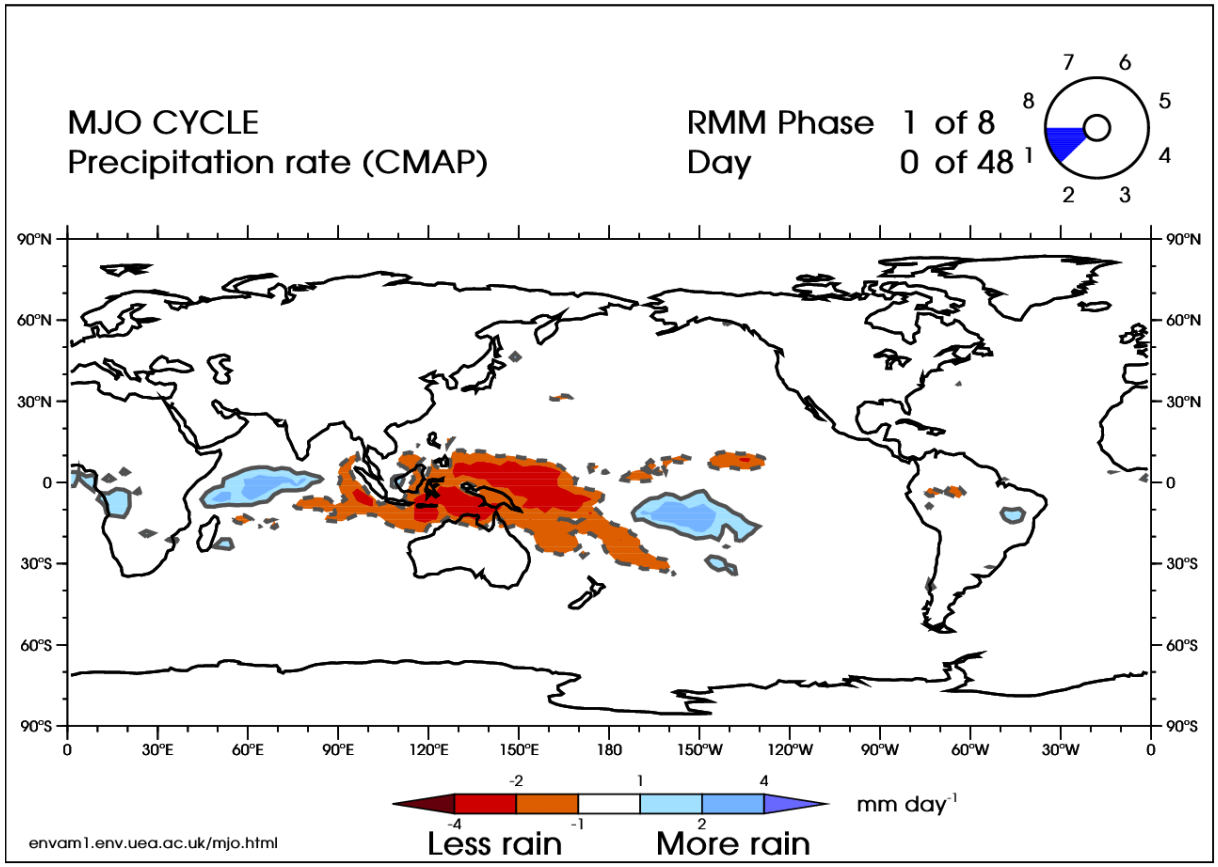
- Kim, H. M. 2017: The impact of the mean moisture bias on the key physics of MJO propagation in the ECMWF reforecast, *JGR-Atmos.*
- Kim, H. M., D. Kim, F. Vitart, V. Toma, J. Kug, and P. Webster, 2016: MJO Propagation across the Maritime Continent in the ECMWF Ensemble Prediction System. *J. Climate*.

MAPP
Modeling, Analysis, Predictions, and Projections

Madden Julian Oscillation (MJO)

- The dominant mode of intraseasonal variability in the tropics
- MJO tends to develop in the Indian Ocean and propagate eastward
- Major source of global subseasonal predictability

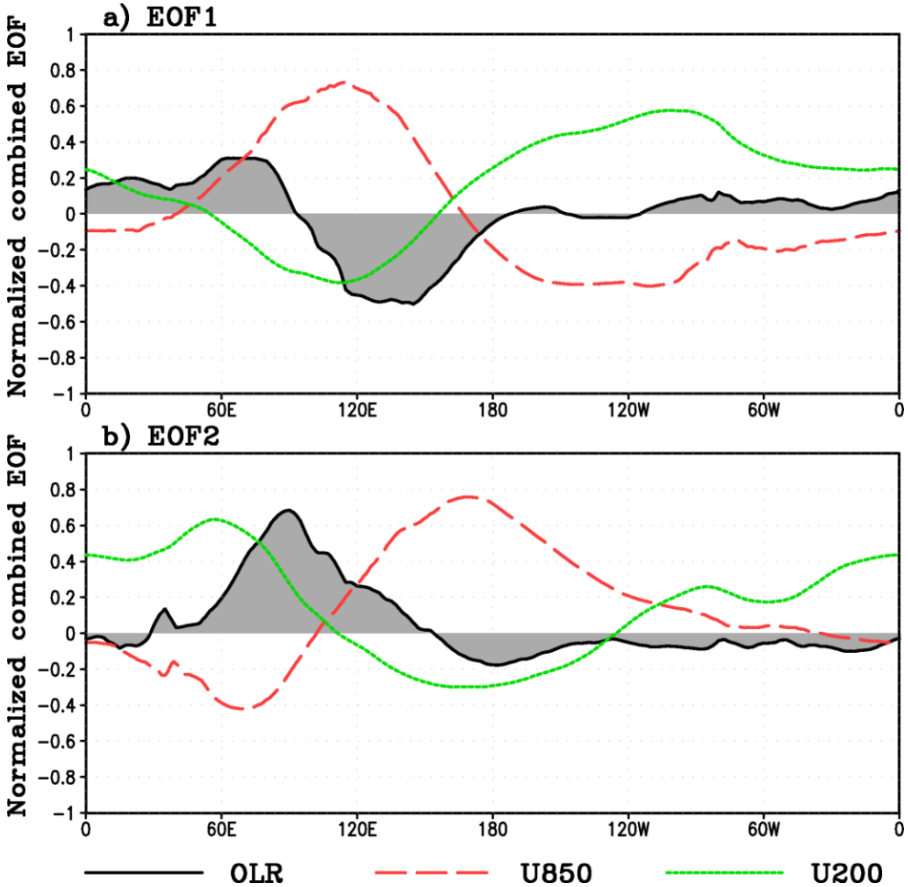


Source: http://envam1.env.uea.ac.uk/mjo.html

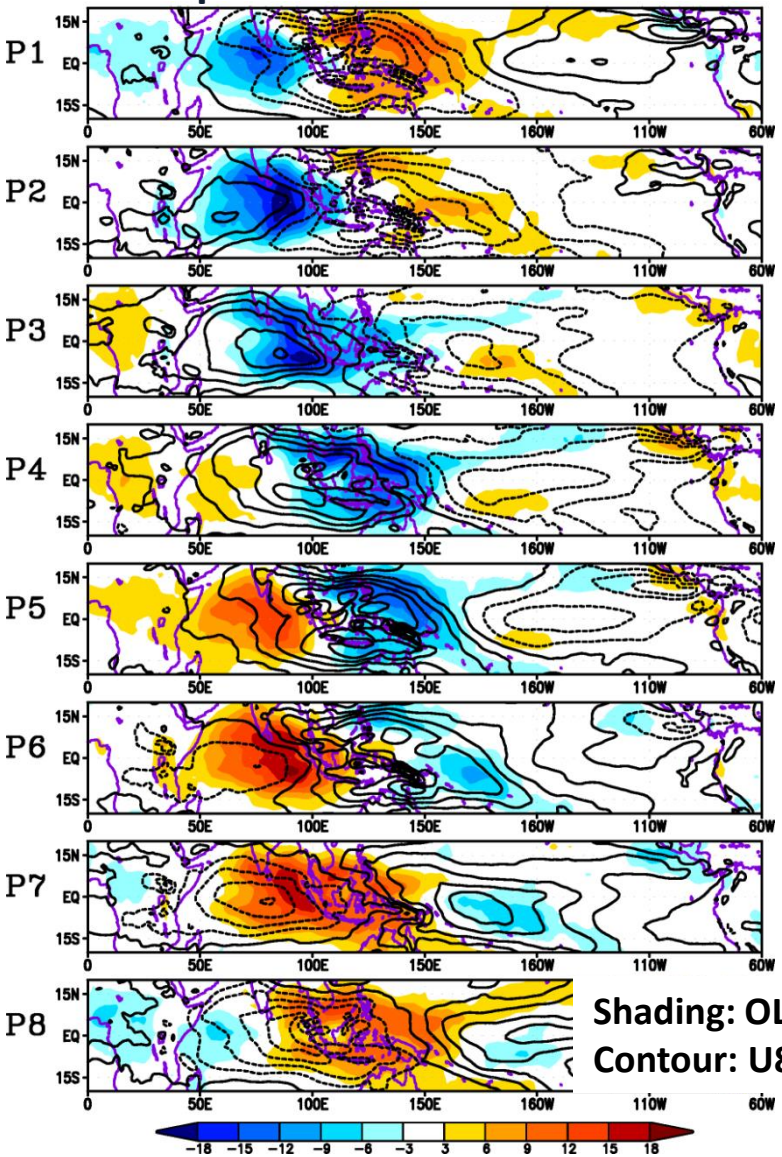
Real-time Multivariate MJO (RMM) index

Wheeler and Hendon (2004)

Eigenvector of 1st and 2nd EOF



Composite of OLRa and U850a



Shading: OLRa
Contour: U850a

RMM indices = PC time series

ECMWF Reforecast

	Reforecast (CY40R1)
Period, lead time	• 1994~2013 (20yr) • 32-day forecast lead
Initialization	• Once/week (Jan-Dec)
Ensembles	• 5 ensemble members
Resolution	• 32 km (64 km after day 10) • 91 levels (0.01 hPa)
Variables	• u, v, T, q, z (1000, 925, 850, 700, 500, 300, 200, 100 hPa)

→ 5,200 sets of 32-day forecasts

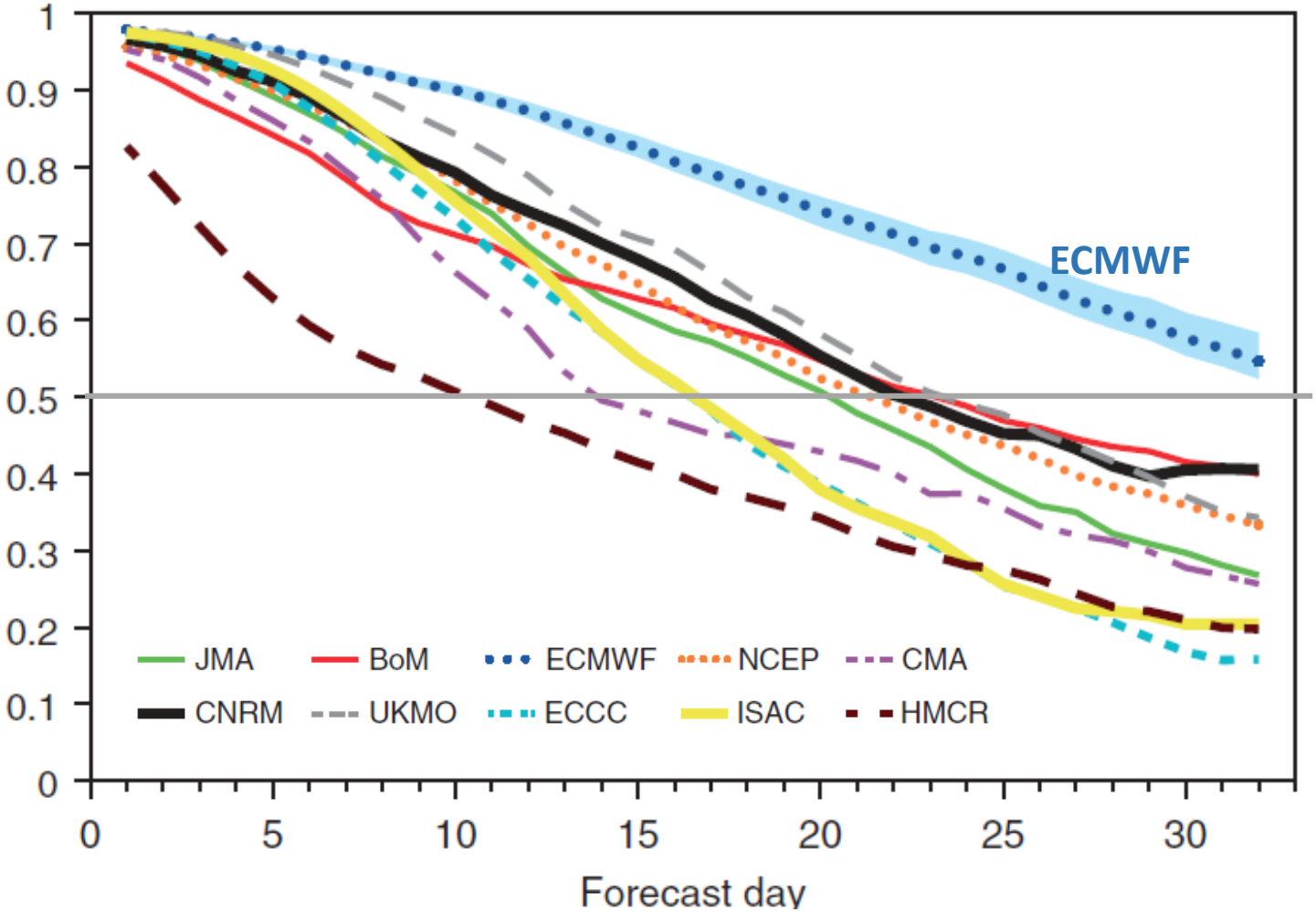
- ERA Interim

Details: https://software.ecmwf.int/wiki/display/S2S/ECMWF+Model+Description+CY40R1

MJO Prediction skill

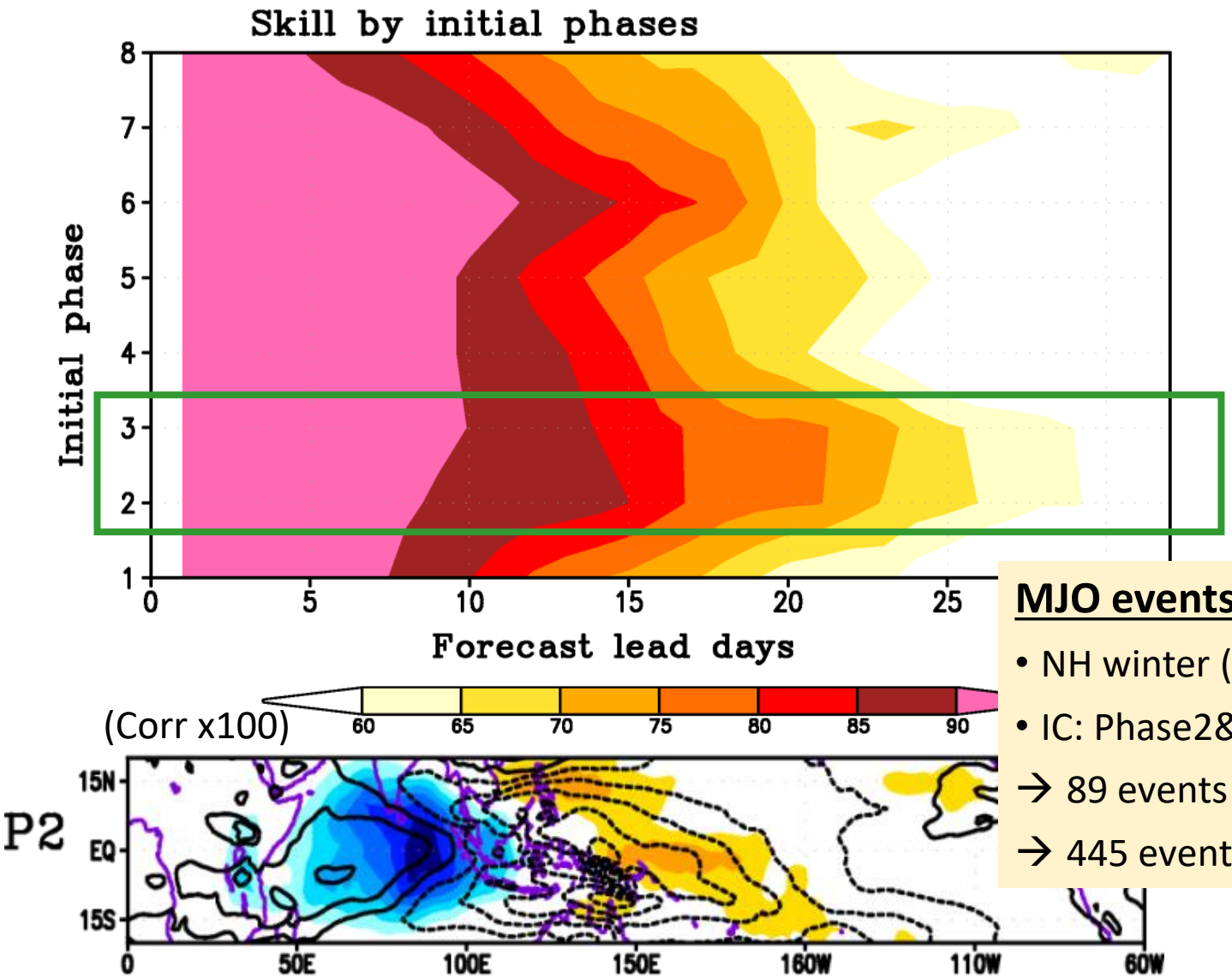
MJO Bivariate correlation (RMMs)
1999-2010 reforecasts

*** Vitart (2017)**
*** WWRP/WCRP S2S Database**



MJO Prediction skill (ECMWF)

* Kim (2017)



MJO events

- NH winter (Oct-Mar, 1994-2013)
- IC: Phase2&3, strong (>1.0)

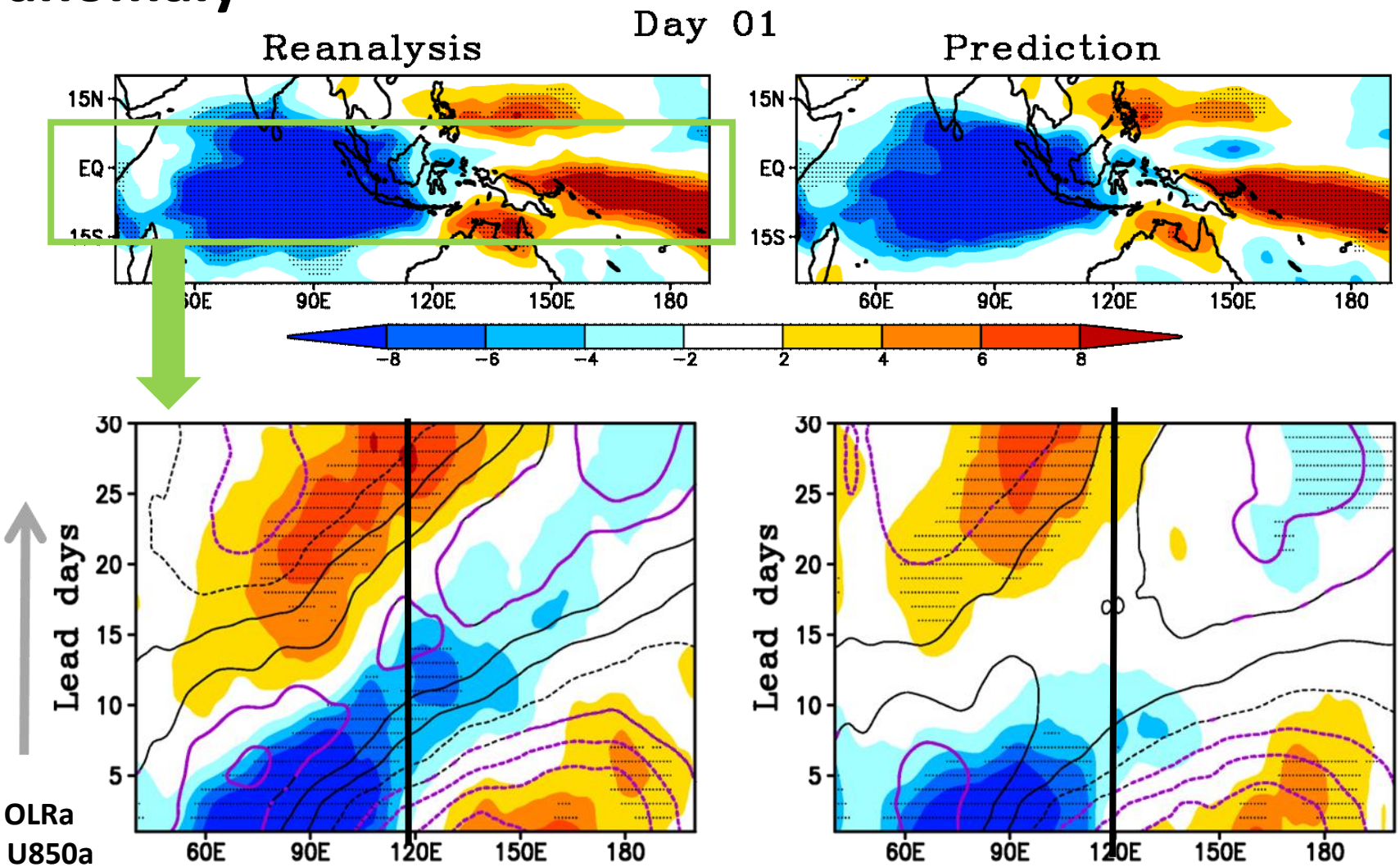
→ 89 events for ERA-I

→ 445 events for ECMWF (5 ens)

MJO eastward propagation

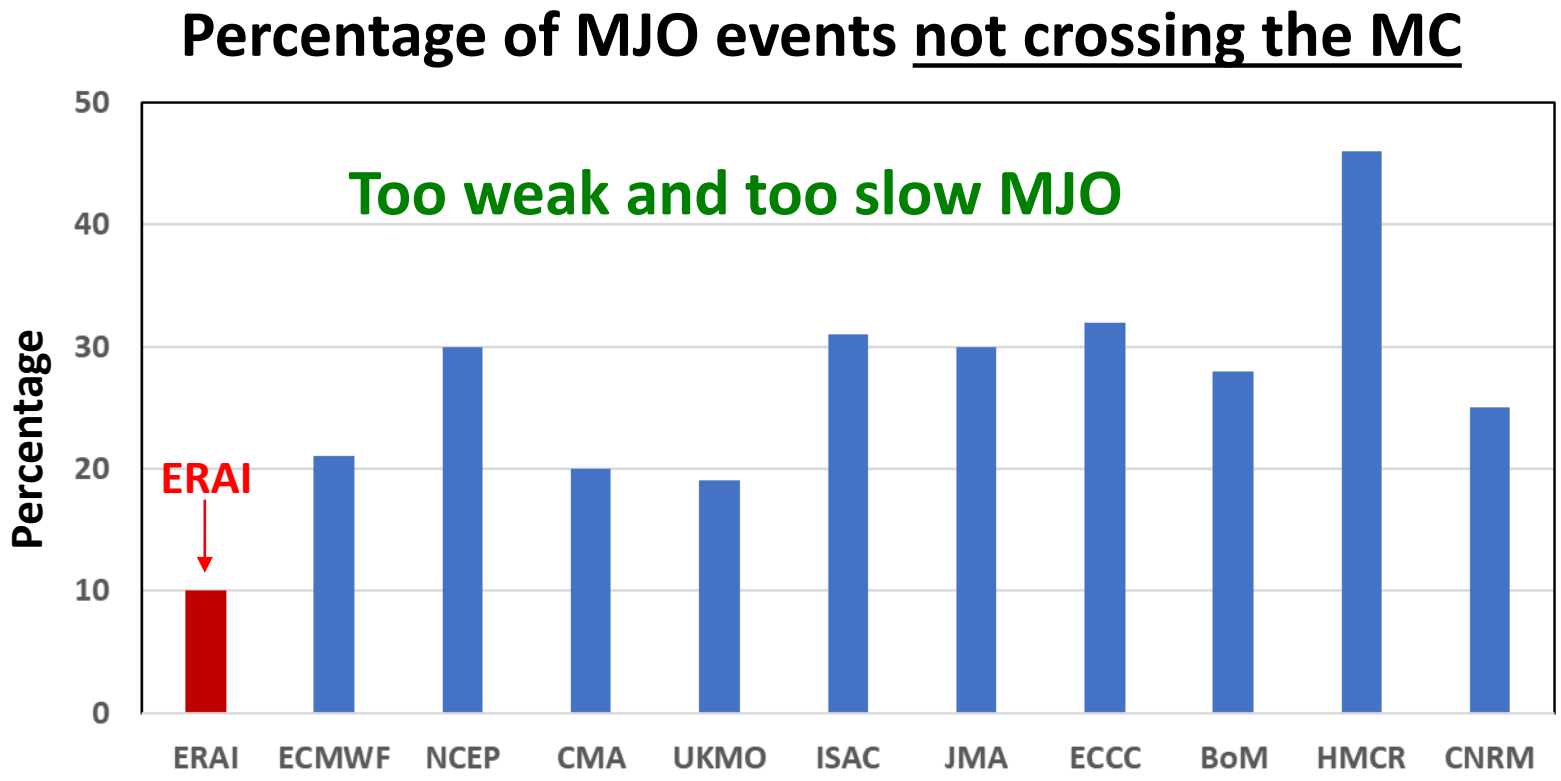
OLR anomaly

Quicker decay of the MJO signal



Shading: OLRa
Contour: U850a
Stippling, purple contours > 95% sig.

MC Prediction Barrier



Q: What processes impact the faster decay of the MJO propagation in predictions?

* Vitart (2017)

"Moisture mode" theory

- MJO physics is governed by feedbacks that regulate moisture anomalies
- MSE as a proxy for MJO convection

Moist static energy (MSE): $\boldsymbol{m} = c_p T + gz + Lq$

Colum-integrated MSE budget

$$\frac{\partial \langle \boldsymbol{m} \rangle}{\partial \boldsymbol{t}} = -\langle \boldsymbol{V} \cdot \boldsymbol{\nabla m} \rangle - \left\langle \omega \frac{\partial m}{\partial p} \right\rangle + Fsfc + \langle Qr \rangle$$

Tendency | **Horizontal advection** | **Vertical advection** | **Surface Fluxes** | **Radiative Fluxes**

* Yu and Neelin (1994), Raymond and Fuchs (2008), Raymond et al. (2009), Maloney (2009), Sobel and Maloney (2012, 2013), Jiang et al. (2015), Kim and Adames (2016), Jiang (2017)

MJO Propagation

$$\frac{\partial\langle m\rangle}{\partial t} = -\langle V\cdot\nabla m\rangle - \left\langle \omega\frac{\partial m}{\partial p}\right\rangle + Fsfc + \langle Qr\rangle$$

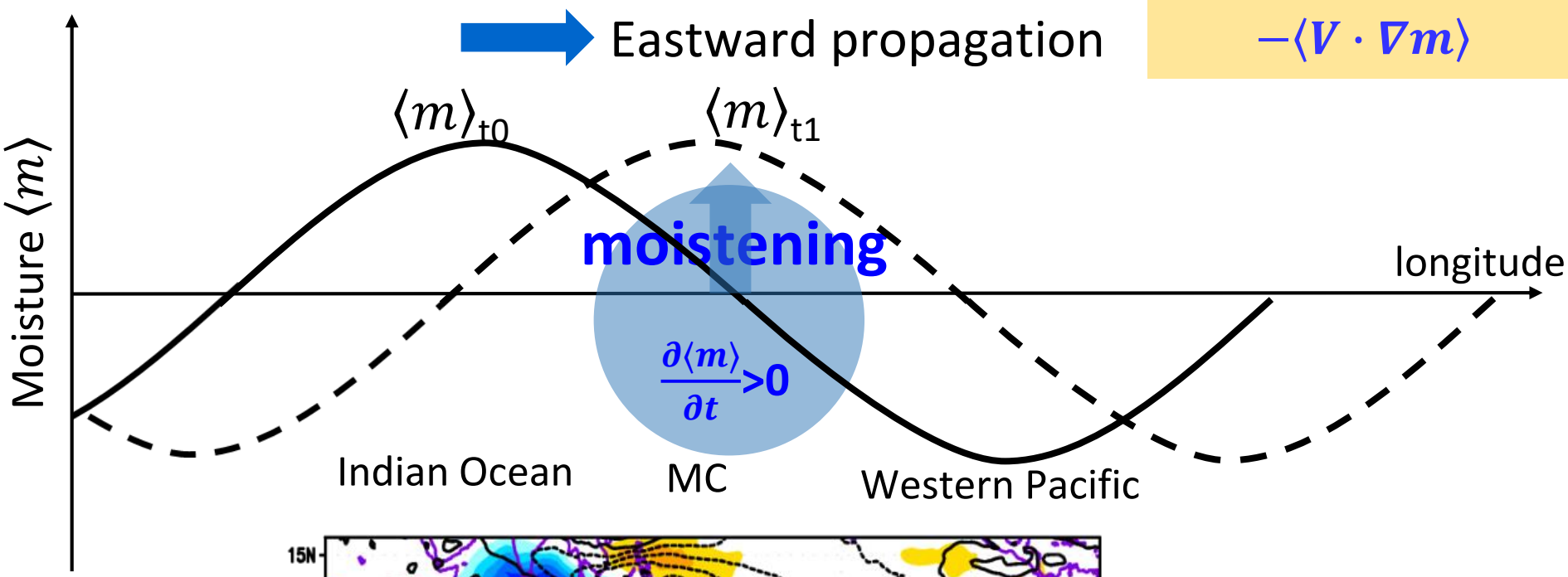
Tendency — **Horizontal advection**

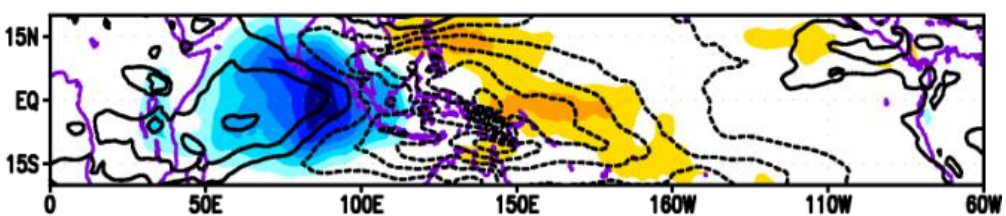
MJO eastward propagation

↑

Horizontal moisture advection

$-\langle V\cdot\nabla m\rangle$





MSE analysis in multi-models

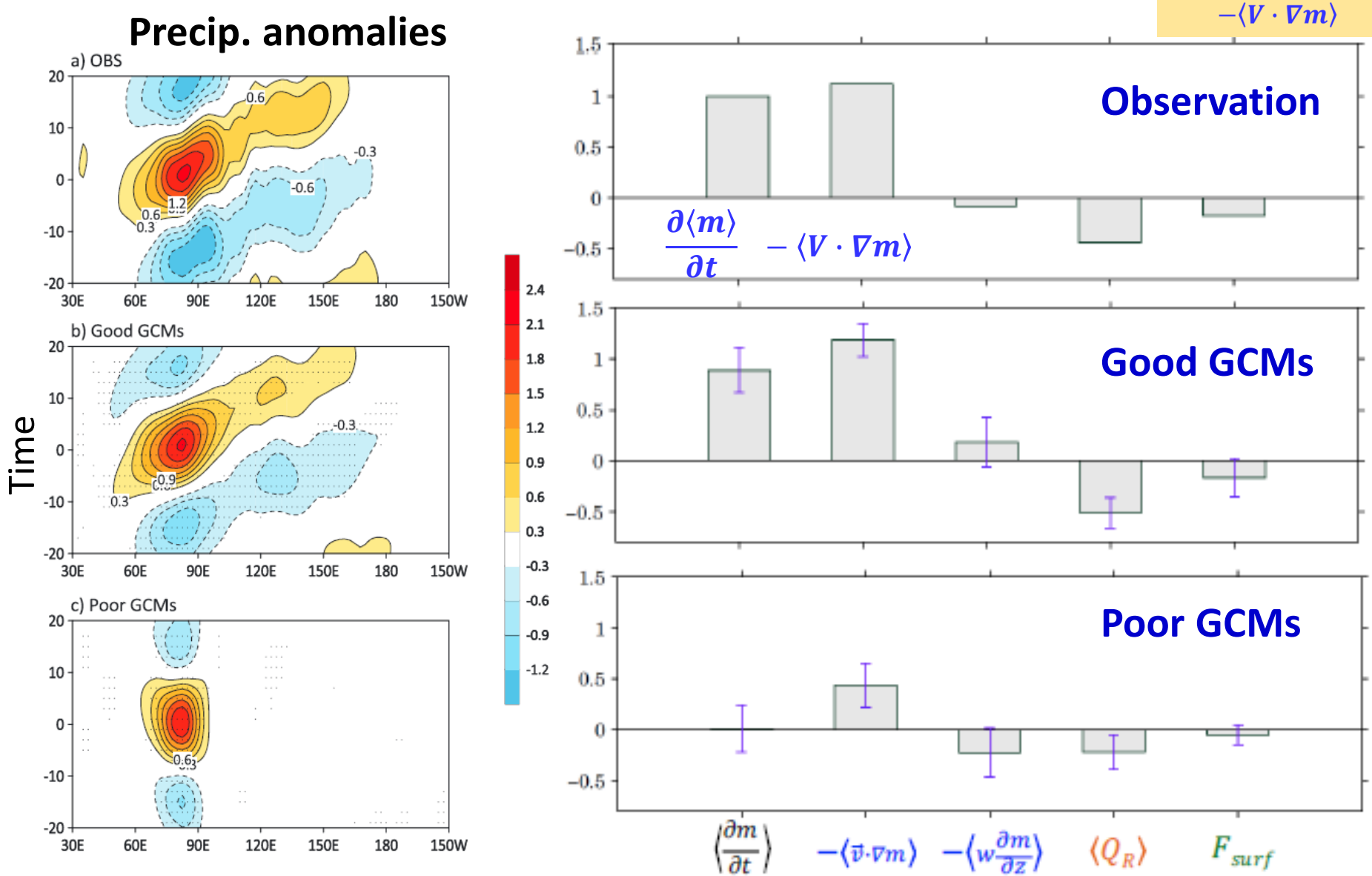
Jiang (2017): MJOTF/GASS MJO project

MJO eastward propagation

↑

Horizontal moisture advection

$-\langle V \cdot \nabla m \rangle$



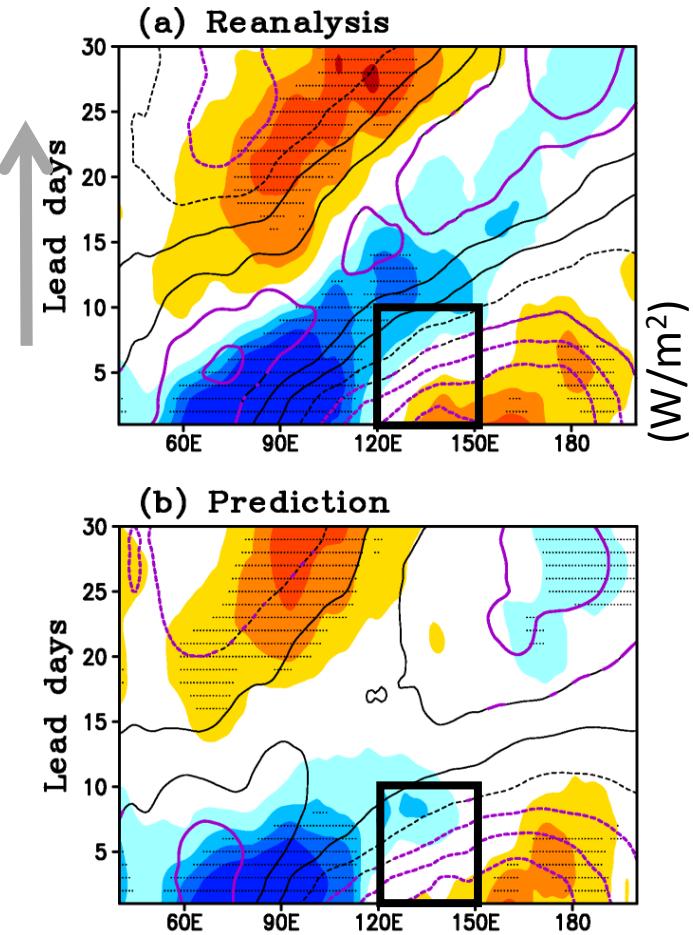
MSE analysis in ECMWF reforecast

MJO eastward propagation

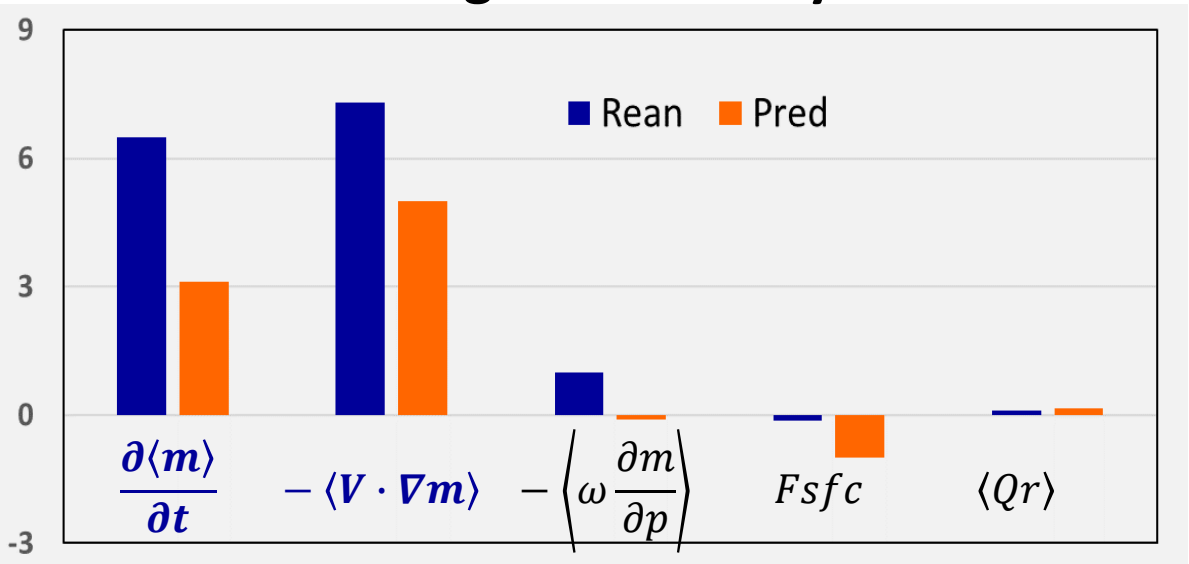
Horizontal moisture advection

$-\langle V \cdot \nabla m \rangle$

OLR and U850



MSE budget terms: Day 1~10



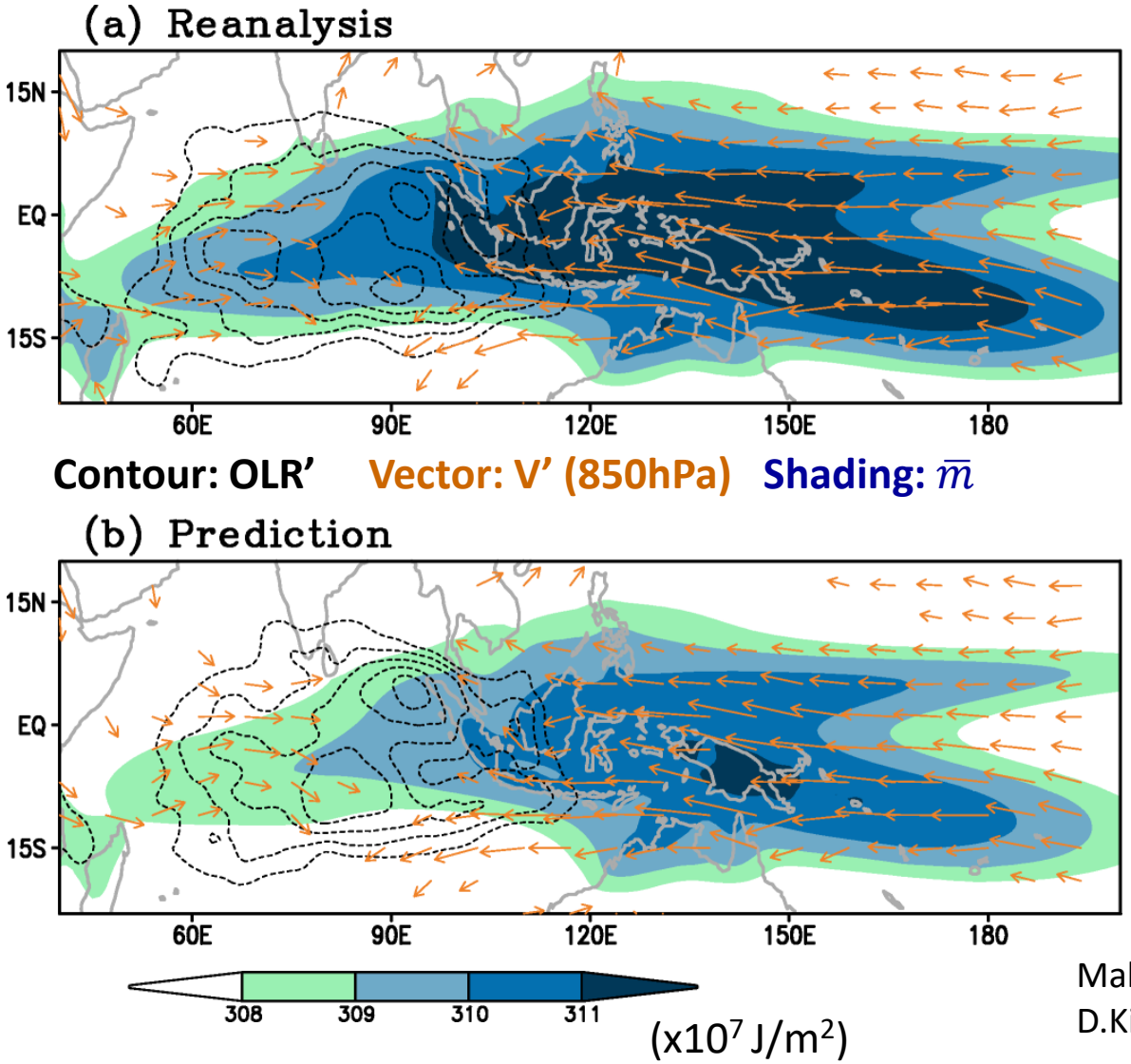
* Averaged area: 20°S-5°S, 120°-150°E

Prediction:

Weaker horizontal moisture advection

Mean Moisture Bias

Day 1~5



MJO eastward propagation

↑ Faster decay

Horizontal moisture advection

$-\langle V \cdot \nabla m \rangle$ Weaker

↑

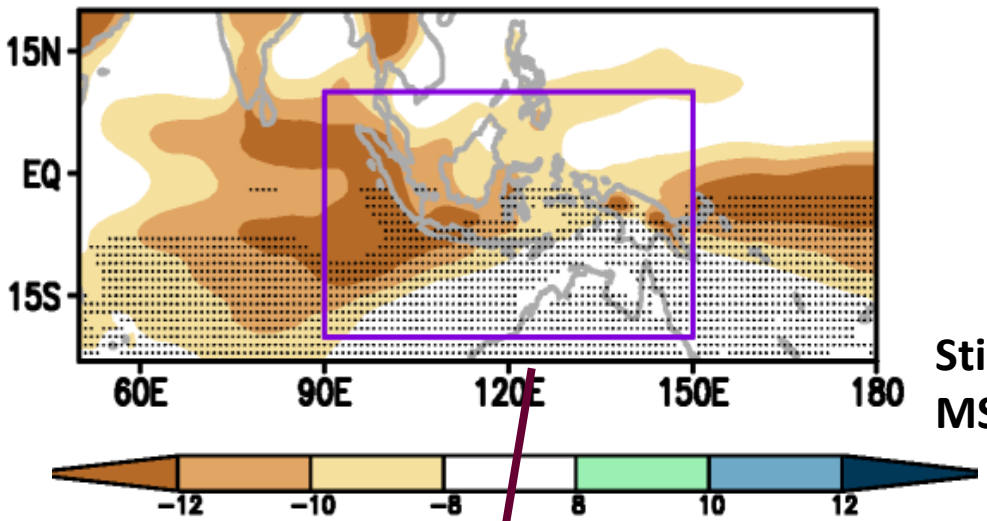
$-\langle V' \cdot \nabla \overline{m} \rangle$ Weaker

MJO wind **Mean MSE**

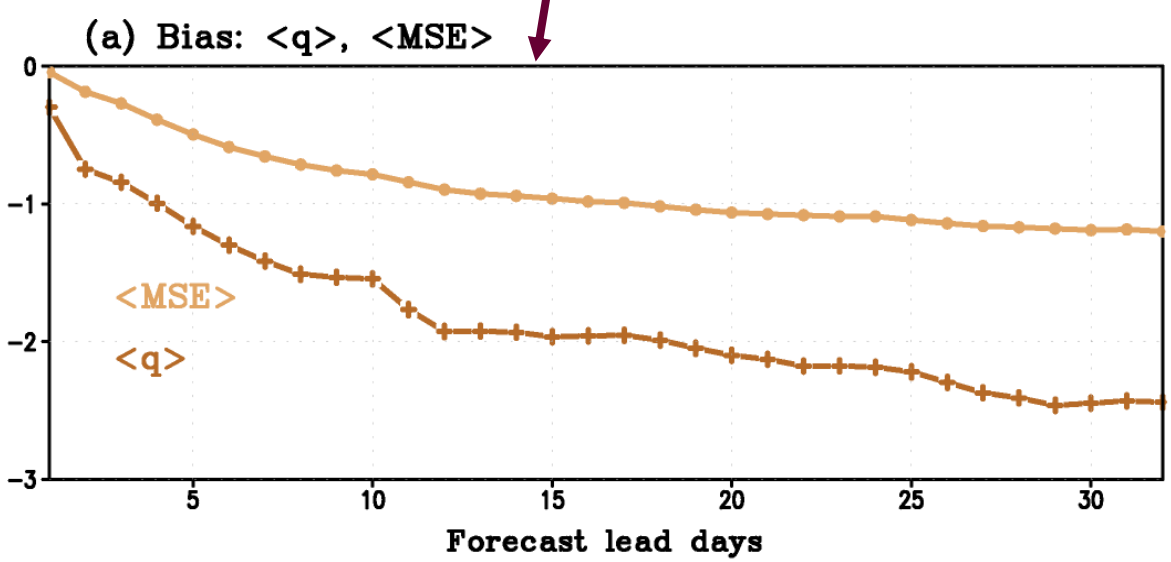
Maloney (2009), Andersen and Kuang(2012), D.Kim et al. (2014), Jiang (2017)

Mean Moisture Bias

Mean MSE Bias (Prediction-ERAI, 32days)



Stippling: Reduced MSE_y gradient



MJO eastward propagation

Faster decay

Horizontal moisture advection

$-\langle V \cdot \nabla m \rangle$ Weaker

$-\langle V' \cdot \nabla \overline{m} \rangle$ Weaker

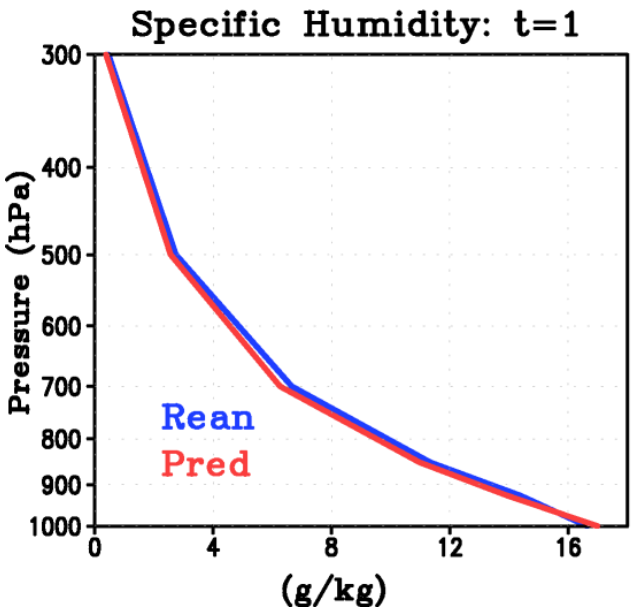
MJO wind Mean MSE

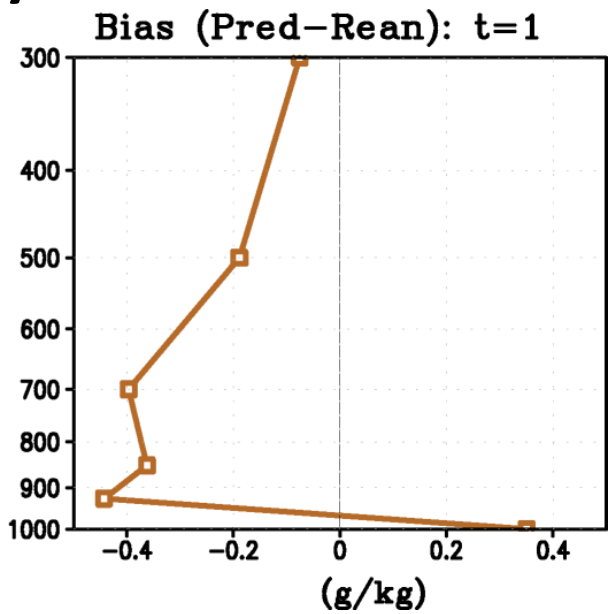
* Unit: <q> (kg/m^2), <MSE> ($\times 10^7$ J/m^2)

Mean Moisture Bias

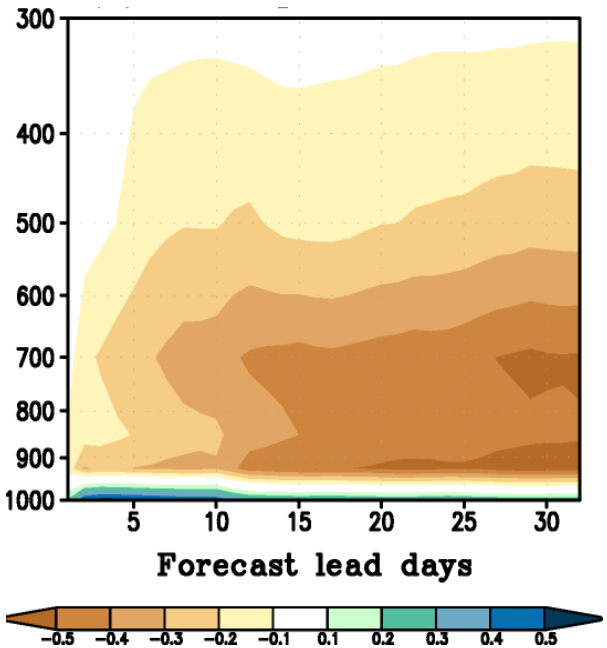
Specific Humidity (q)

Day 01





Bias: Day 1 to 32



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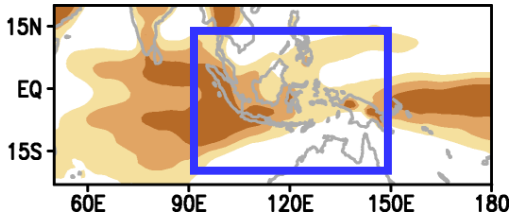
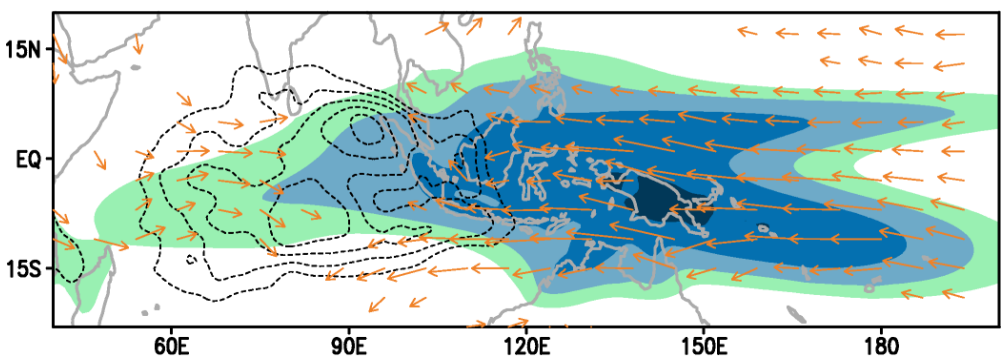
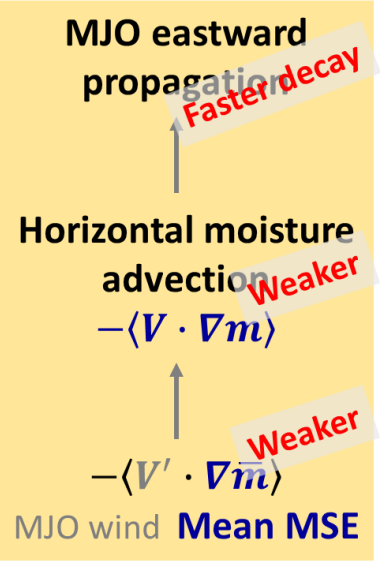


Summary

- The MJO is the main source of subseasonal predictability.
- Current operational models successfully predict the MJO up to 3-4 weeks but have **Maritime Continent MJO propagation/prediction barrier**.
- The weak predicted MSE tendency to the east of the MJO convection is due to the **weak horizontal MSE advection.**
- The **biases in seasonal mean tropospheric moisture field** is a key factor that weakens the horizontal MSE advection.





Kim, H. M. 2017: The impact of the mean moisture bias on the key physics of MJO propagation in the ECMWF reforecast, *JGR-Atmos.*