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The impact of the systematic mean bias on MJO prediction in the ECMWF ensemble prediction system

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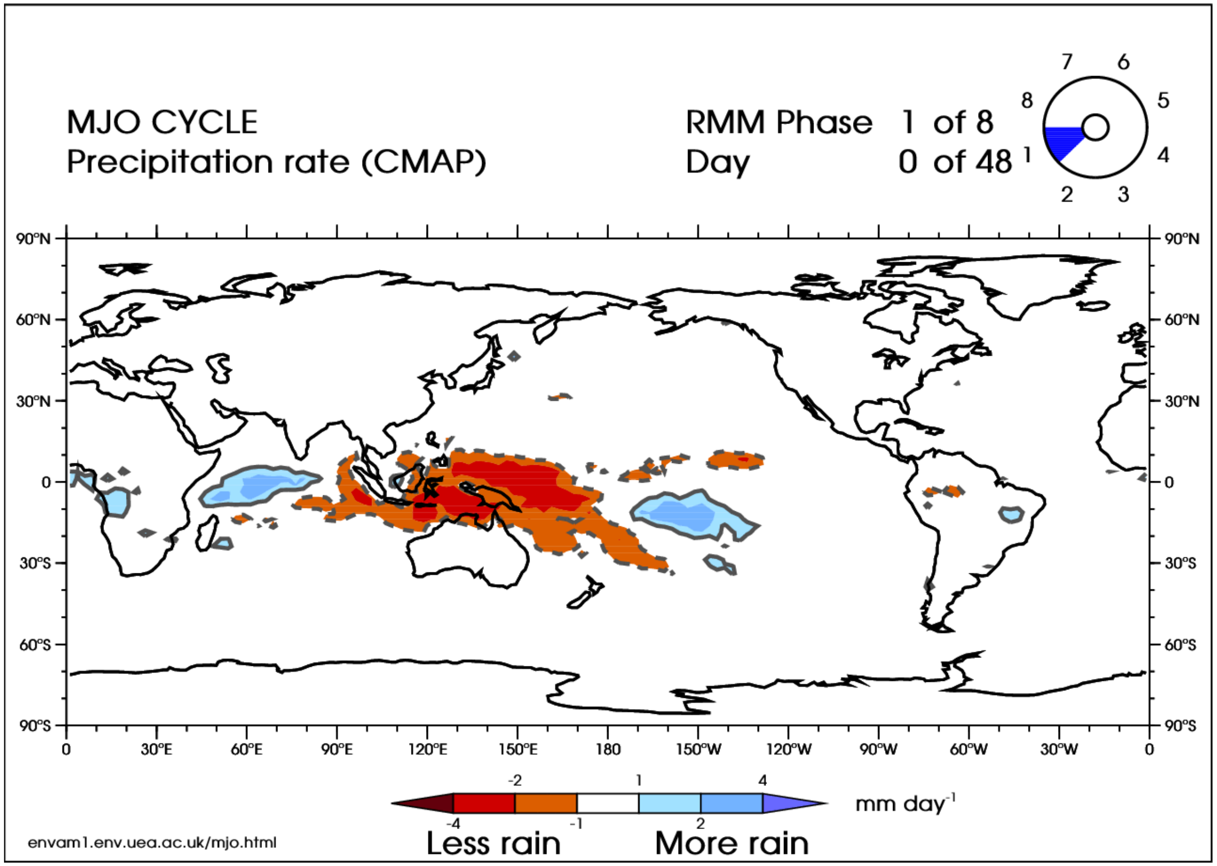
NSF

NOAA MAPP Modeling, Analysis, Predictions, and Projections

Madden Julian Oscillation (MJO)

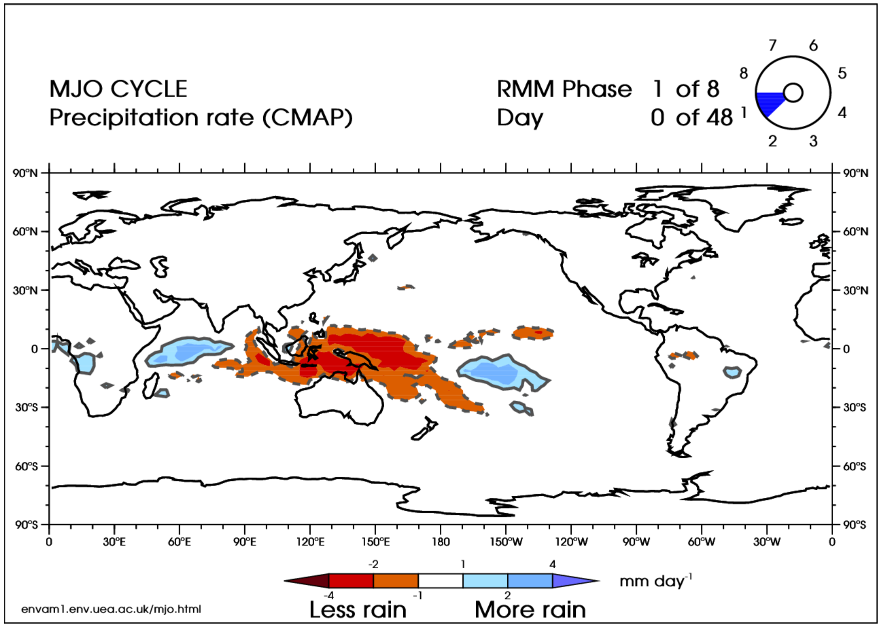
- The dominant mode of intraseasonal variability in the tropics
- MJO tends to develop in the Indian Ocean and propagate eastward
- Major source of global subseasonal predictability



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

Outline

- **MJO prediction skill in current models**
- **Prediction of the MJO propagation**
- **MJO propagation and the mean state bias**

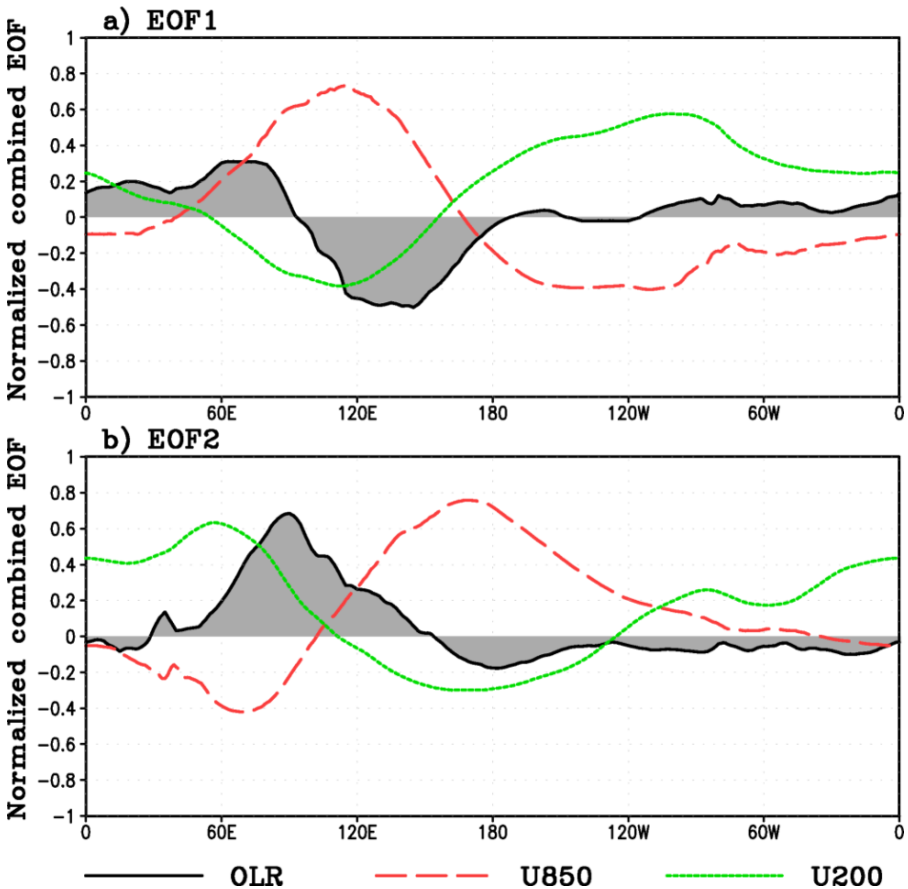


Source: http://envam1.env.uea.ac.uk/mjo.html

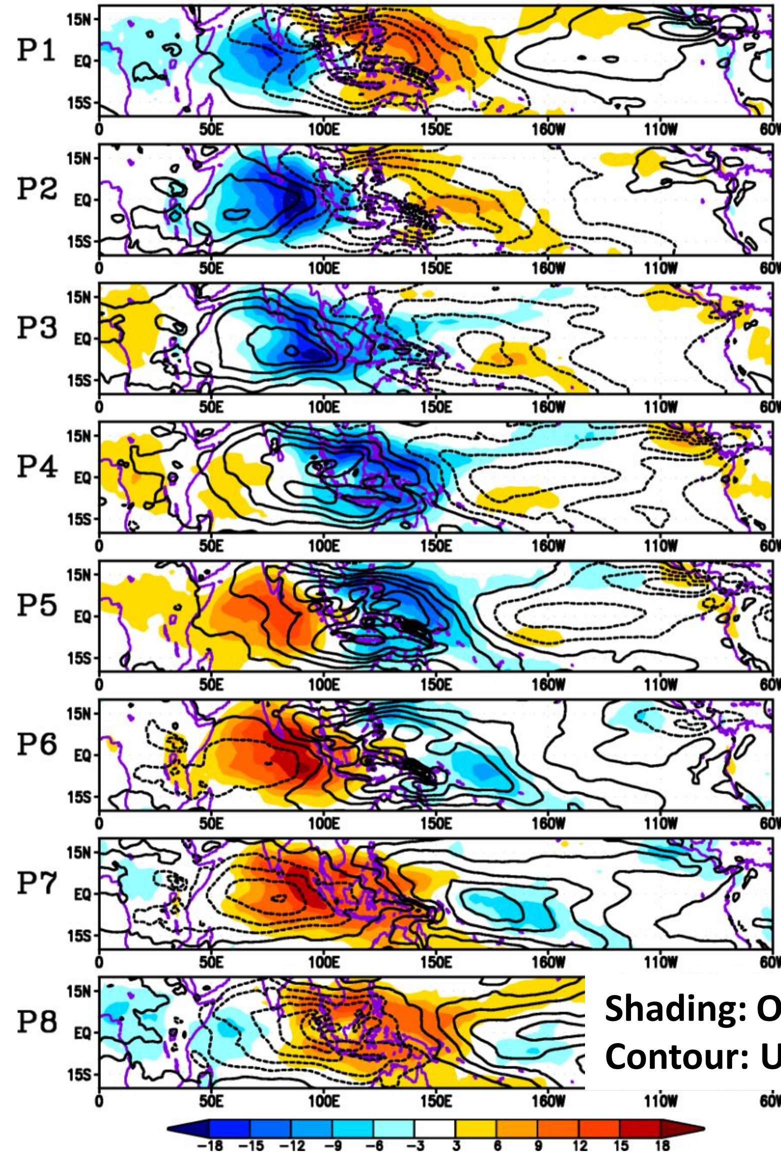
Real-time Multivariate MJO (RMM) index

Wheeler and Hendon (2004)

Eigenvector of 1st and 2nd EOF



Composite of OLRa and U850a

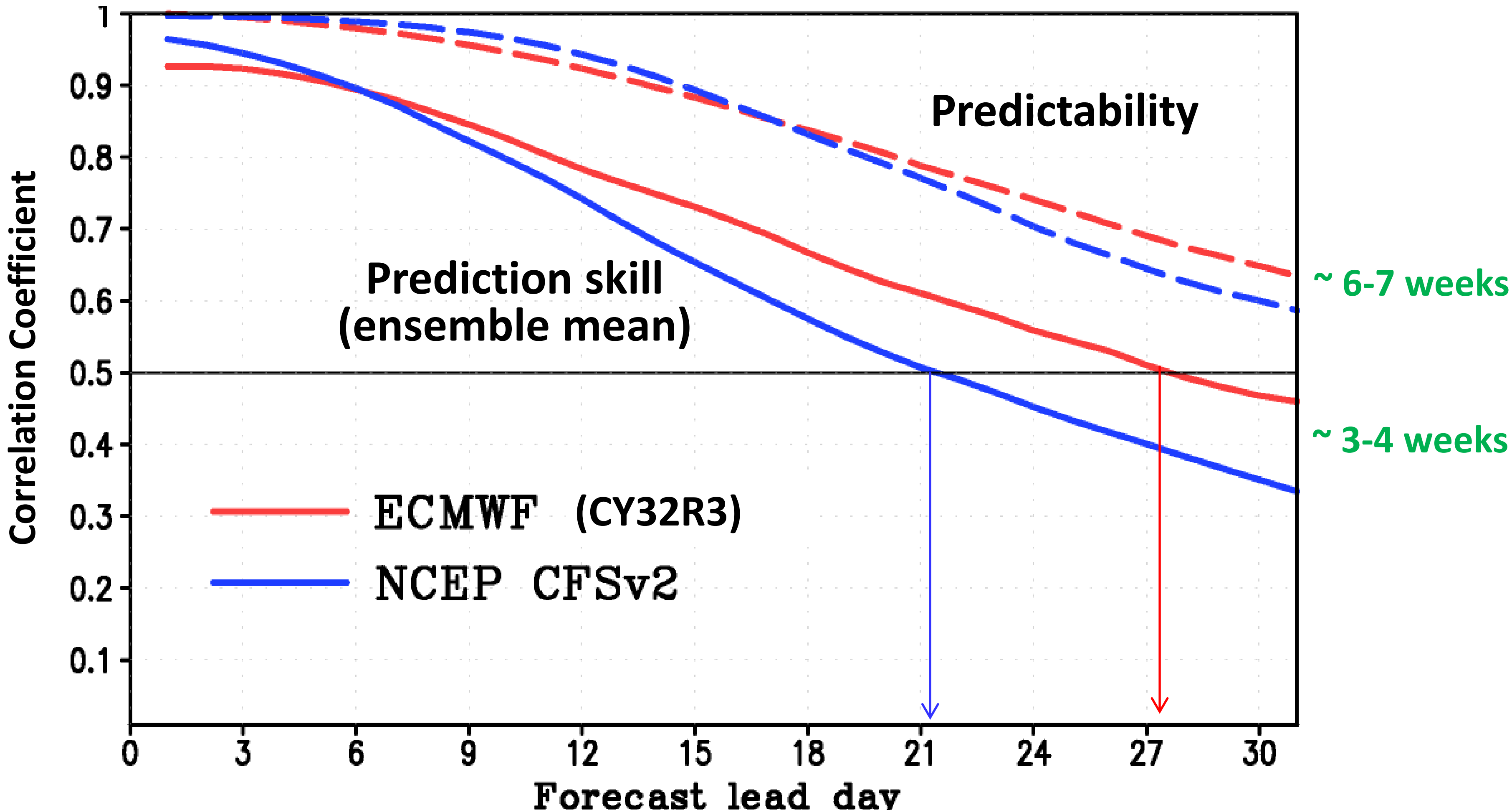


Shading: OLRa
Contour: U850a

RMM indices = PC time series

Capability of MJO forecast

MJO prediction skill (RMM index)

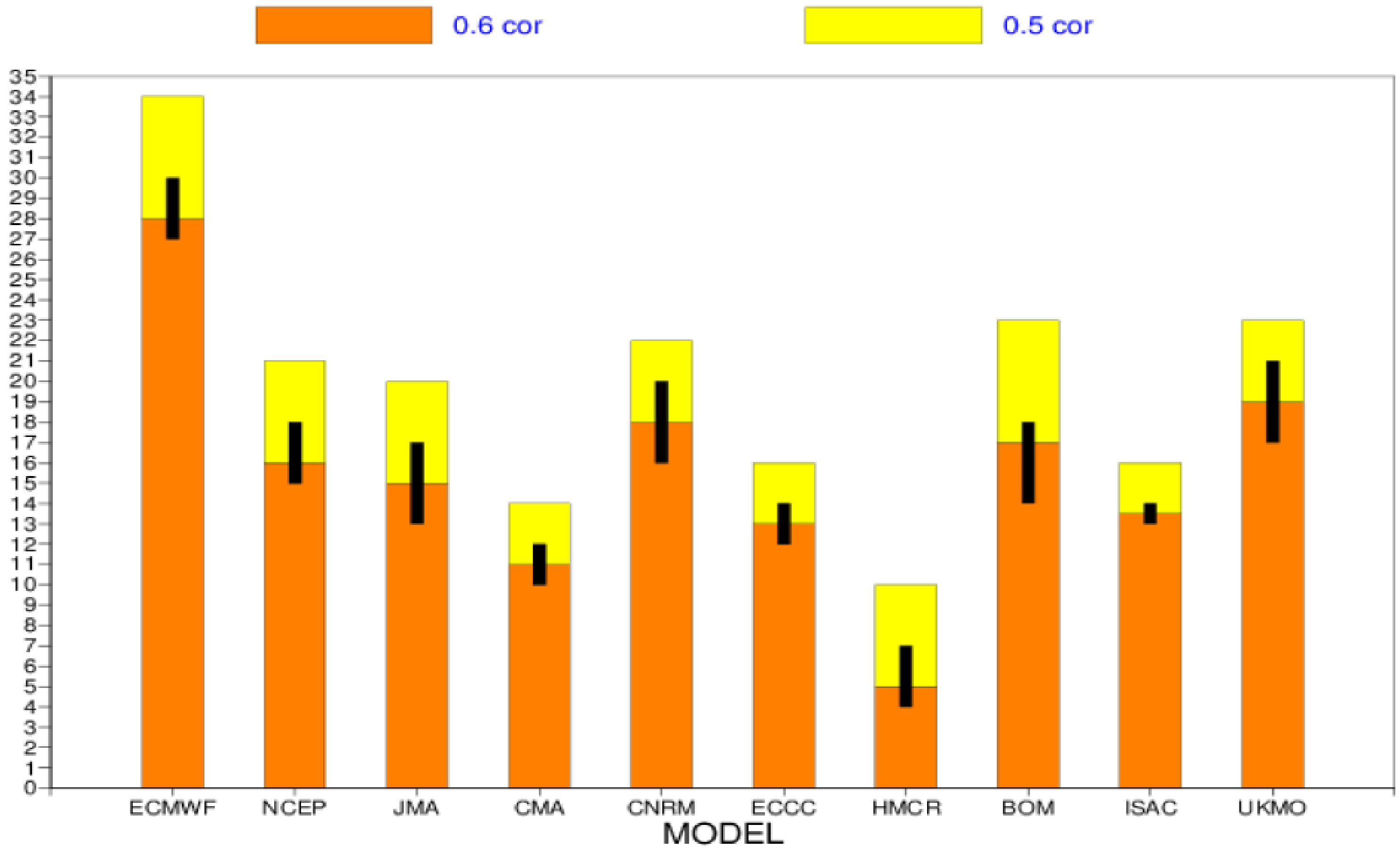


Kim et al. (2014)

Capability of MJO forecast

MJO prediction skill
(reforecasts: 1999-2010)

*** WWRP/WCRP S2S Database**



**** F. Vitart (NOAA Webinar, May 2017)***

Source: http://cpo.noaa.gov/sites/cpo/MAPP/Webinars/2017/05-24-17/Webinar_FV.pdf

Data

	Reforecast (CY40R1)
Period, lead time, ensembles	• 1994~2013 (20yr) • 32-day forecast lead • Five ensemble members
Initialization	• Once/week (Jan-Dec)
Resolution	• 32 km up to day 10 (64 km after day 10) • 91 levels (0.01 hPa)

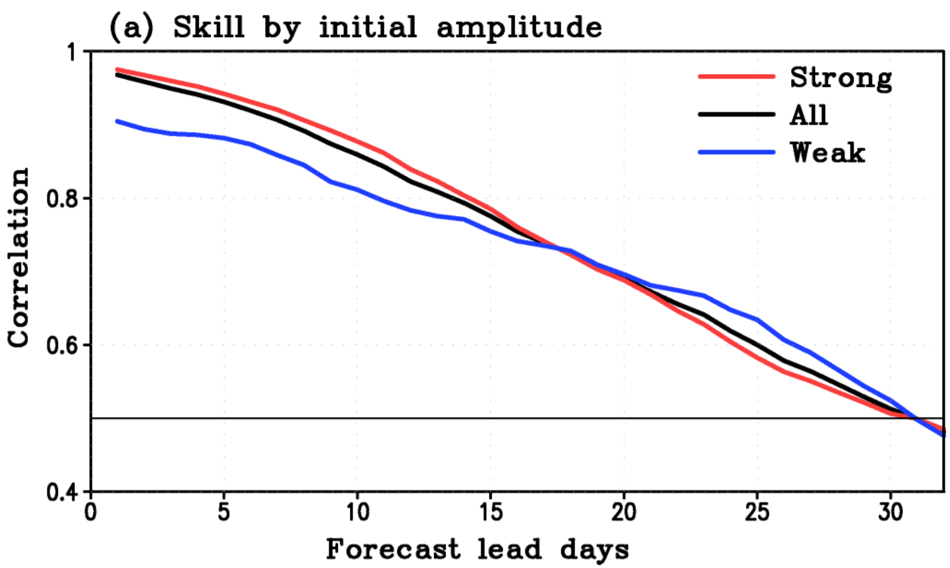
- ERA Interim

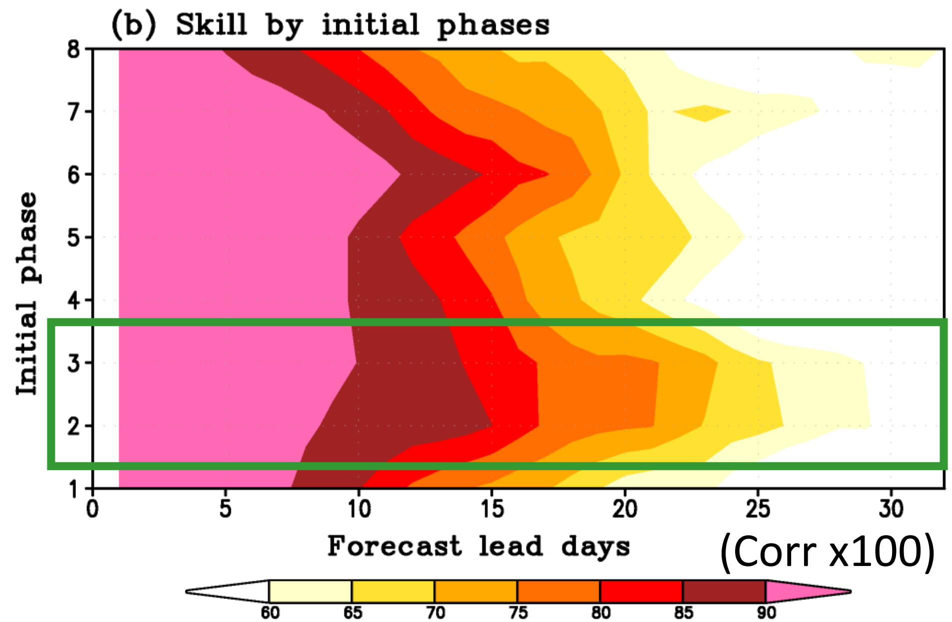
Details: https://software.ecmwf.int/wiki/display/S2S/ECMWF+Model+Description+CY40R1

ECMWF Reforecast

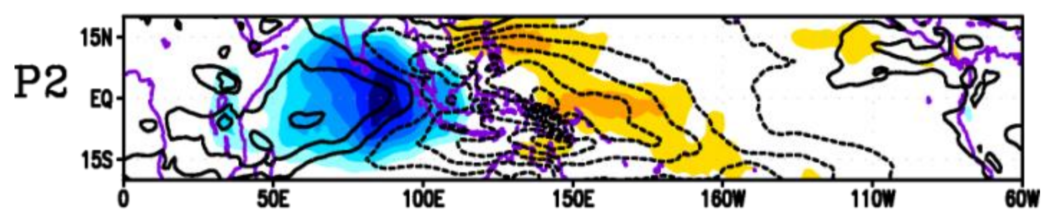
MJO Skill Dependency

- **Initial amplitude: Higher with initially strong MJO signal**
- **MJO Phase: Higher in Phase 2-3**





* Strong event: RMM amplitude > 1.0



MJO eastward propagation

MJO events

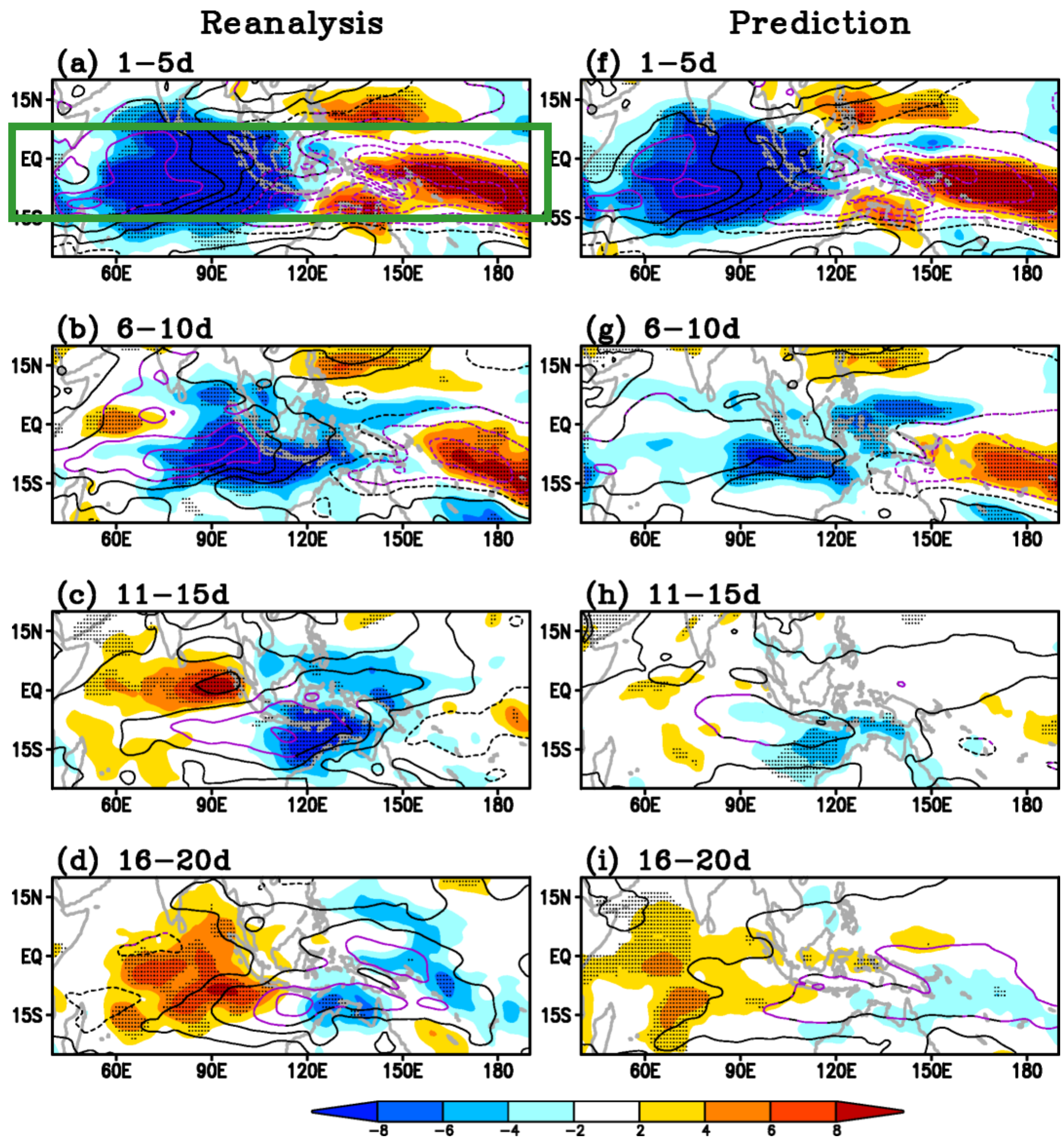
- NH winter (Oct-Mar, 1994-2013)
- IC: Phase2&3, strong (>1.0)

→ 89 events for ERA-I

→ 445 events for ECMWF (5 ens)

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

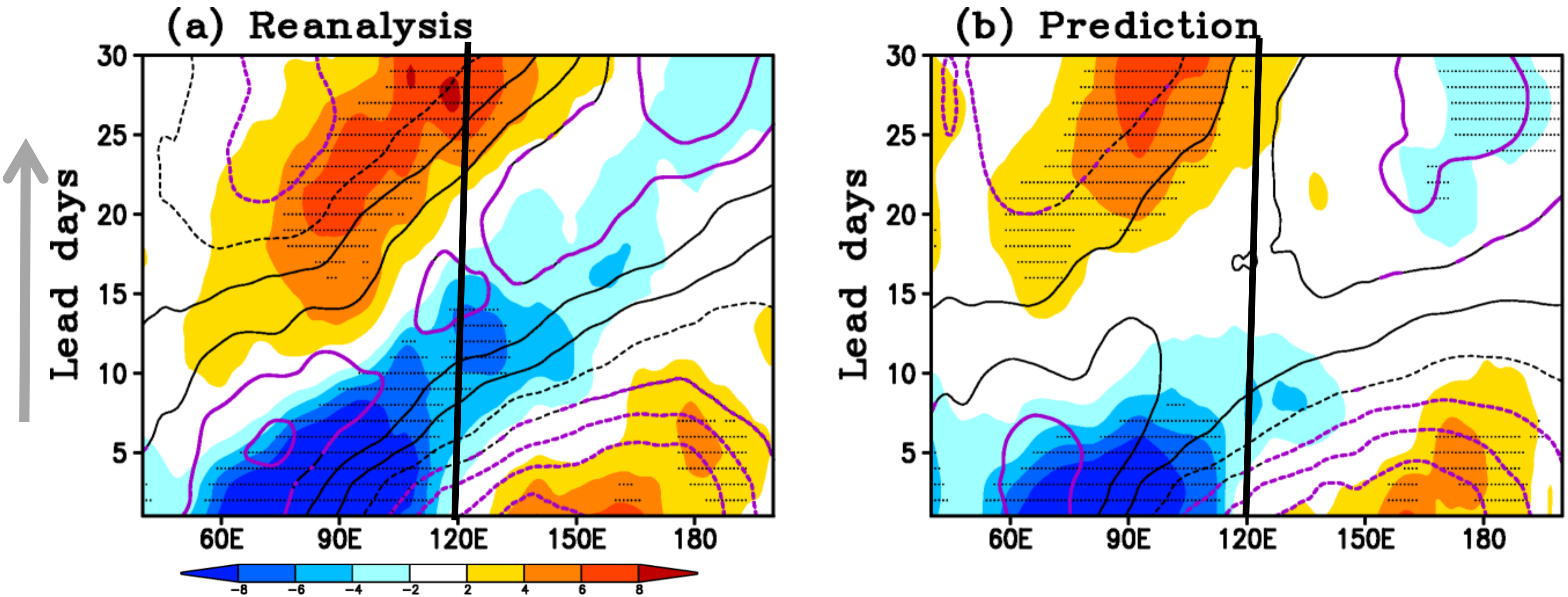
- **Quicker decay of MJO signal**

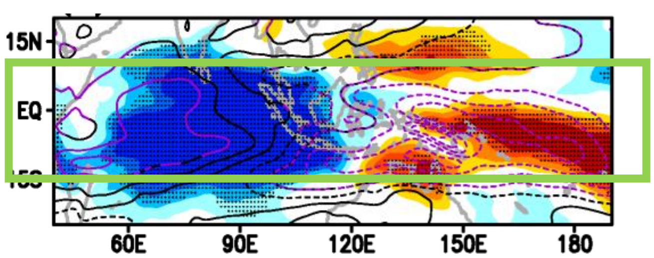


Kim (JGR, in review)

MJO eastward propagation

OLRa and U850a (15˚S-10˚N)



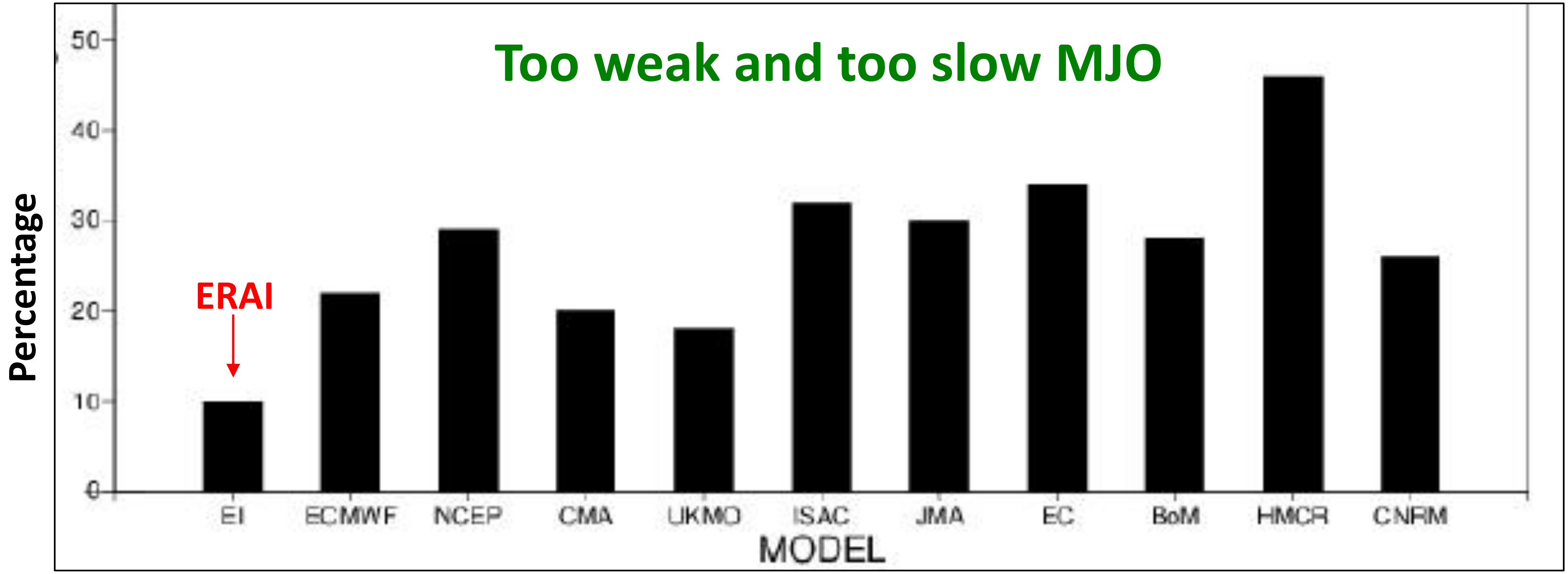


Maritime Continent (MC) MJO Propagation and Prediction Barrier

Kim (JGR, in review)

MC Prediction Barrier

Percentage of MJO events <u>not crossing the MC</u>
(S2S reforecasts, 1999-2010)



Q: How do mean state biases impact on MJO propagation?

**** F. Vitart (NOAA Webinar, May 2017)***

Source: http://cpo.noaa.gov/sites/cpo/MAPP/Webinars/2017/05-24-17/Webinar_FV.pdf

“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

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

Tendency | **Horizontal advection** | **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), many others

MJO Propagation

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

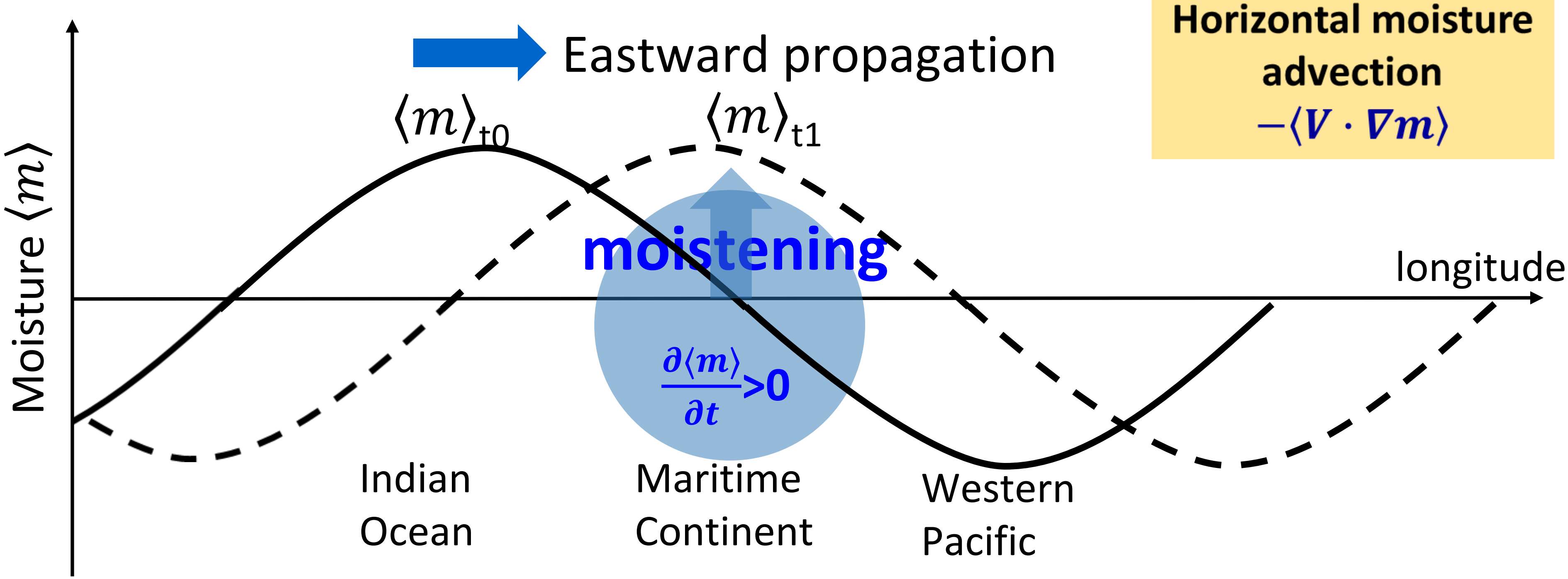
Tendency — **Horizontal advection**

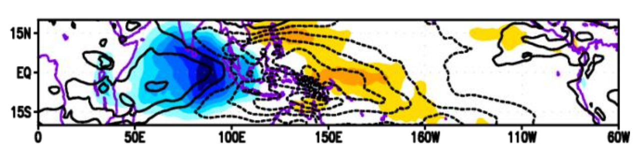
MJO eastward propagation

↑

Horizontal moisture advection

$-\langle \boldsymbol{V} \cdot \boldsymbol{\nabla} \boldsymbol{m} \rangle$

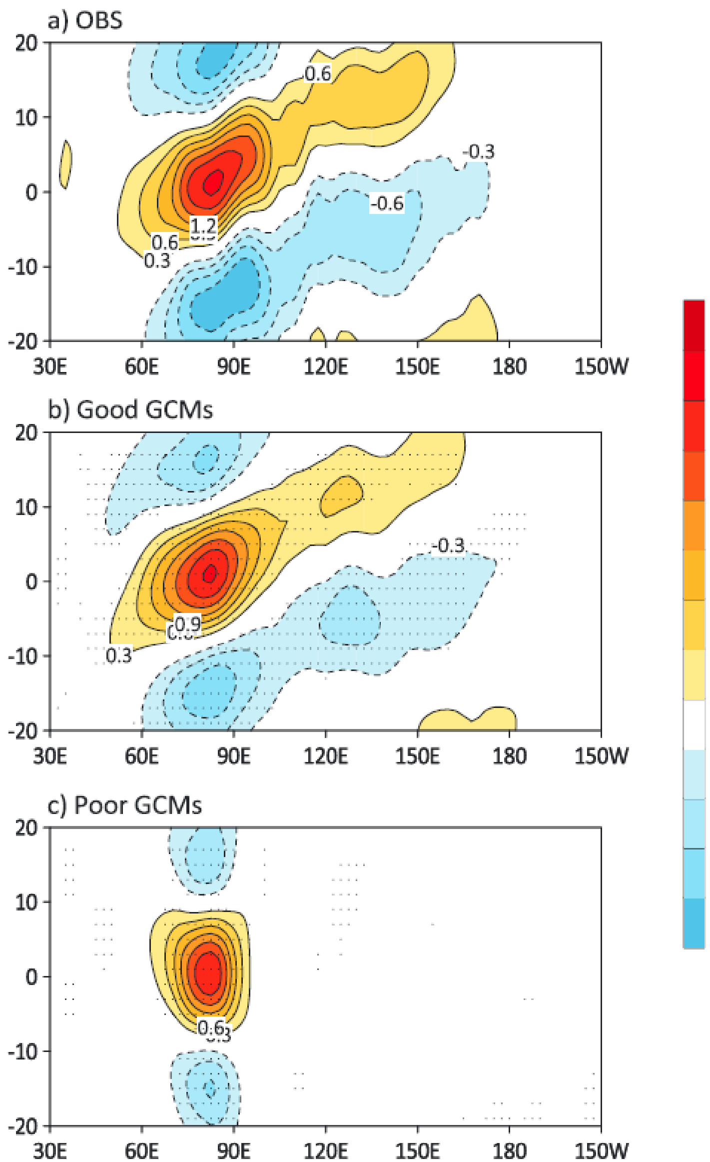


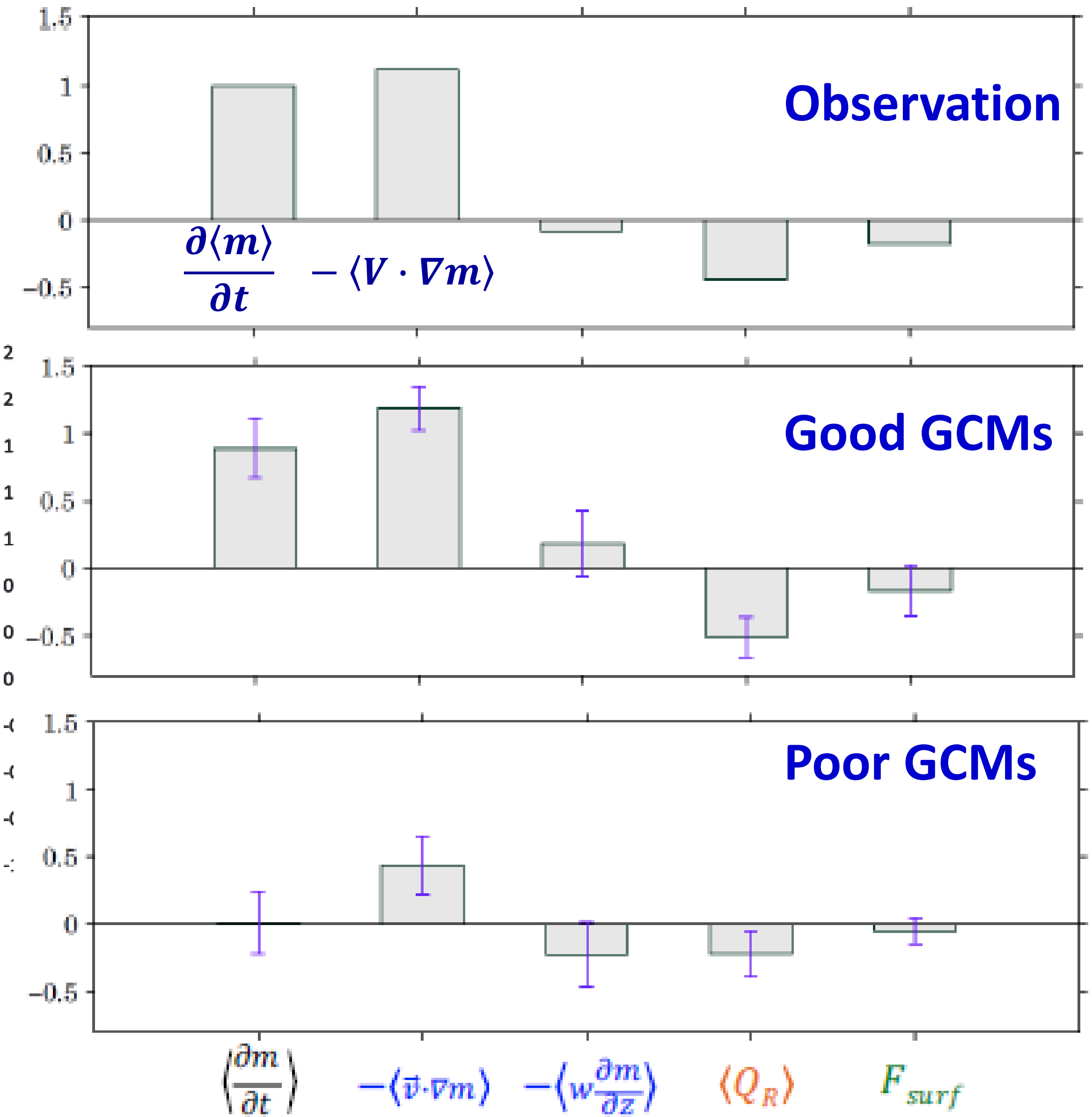


Maloney (2009), Kiranmayi and Maloney(2011), Andersen and Kuang(2012), Kim et al. (2014), Kim and Adames (2016), Jiang (2017)

MSE analysis in multi-models

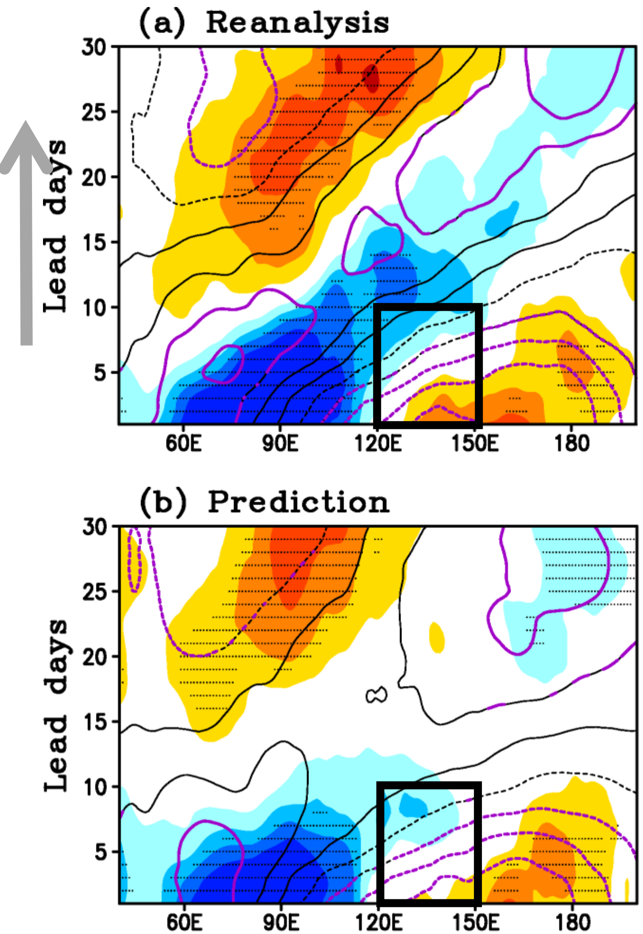
Jiang (2017): MJOTF/GASS MJO project



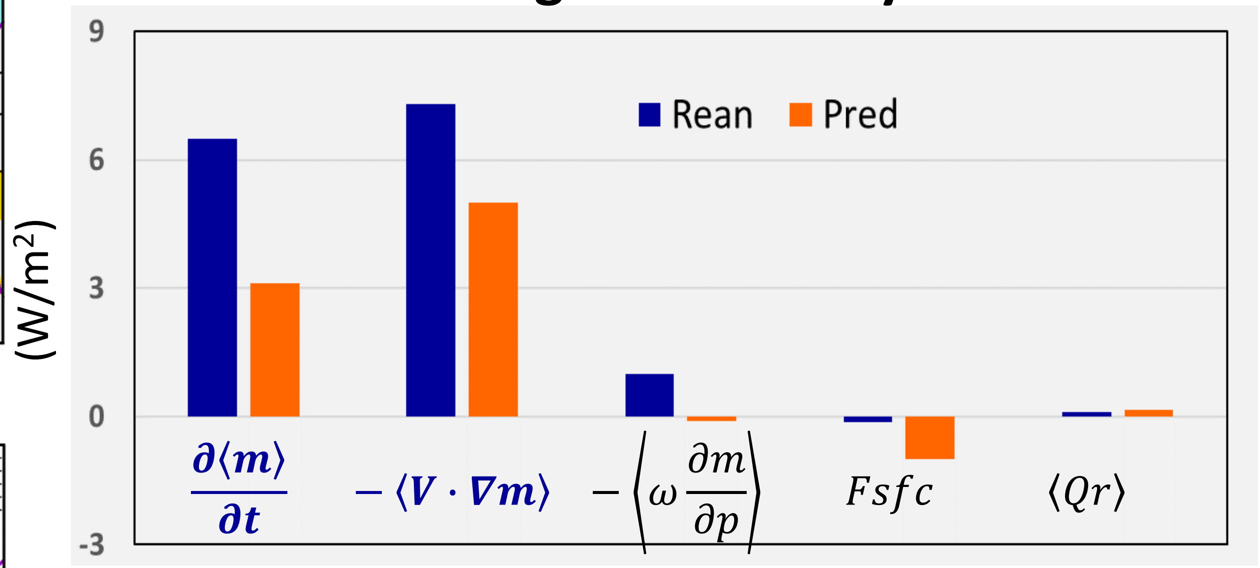


MSE analysis in ECMWF reforecast

OLR and U850



MSE budget terms: Day 1~10



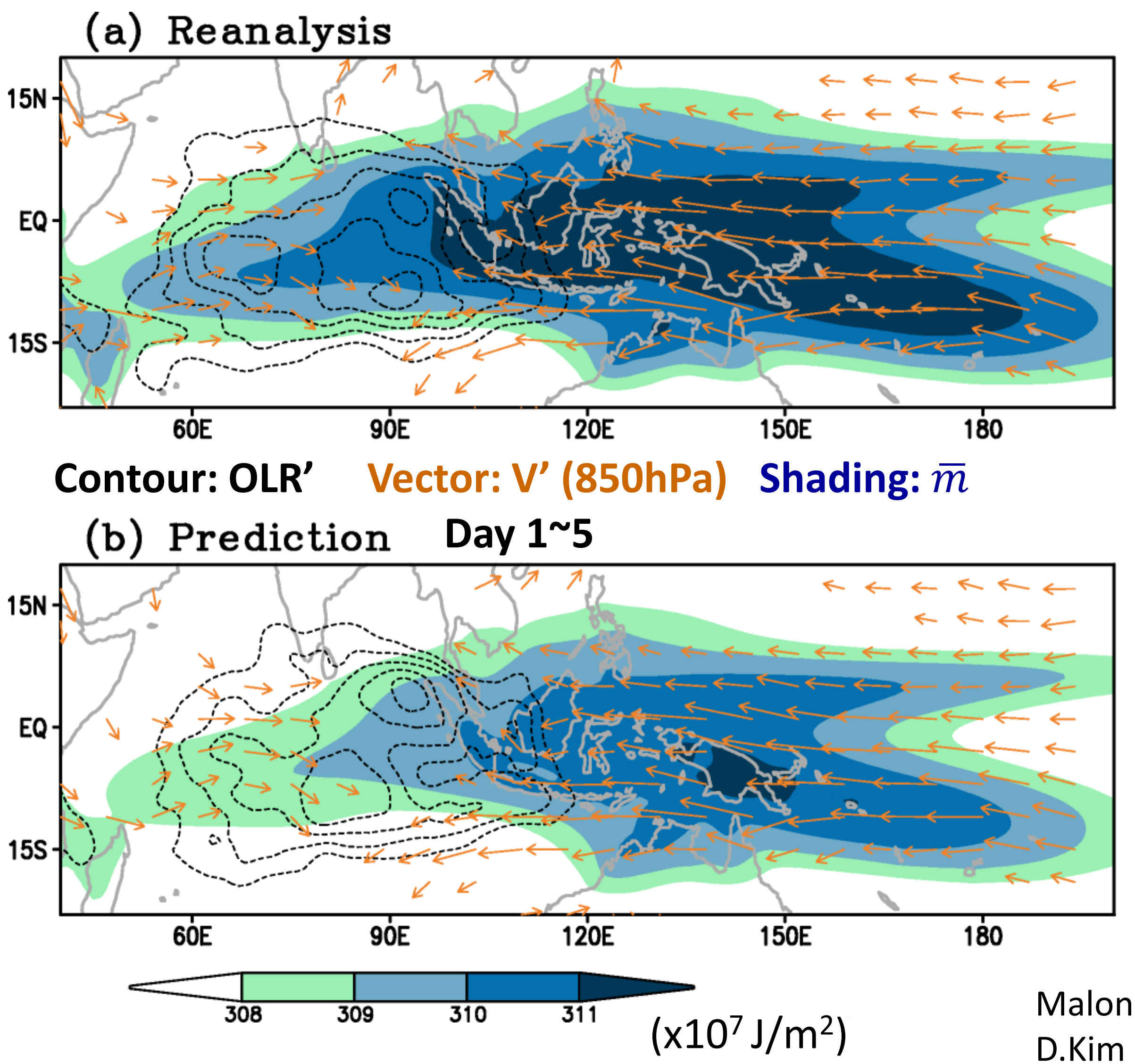
*** Averaged area: 20°S-5°S, 120°-150°E**

Prediction:

Weaker horizontal moisture advection

Kim (JGR, in review)

Mean Moisture Bias



MJO eastward propagation

Faster decay

↑

Horizontal moisture advection

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

Weaker

↑

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

Weaker

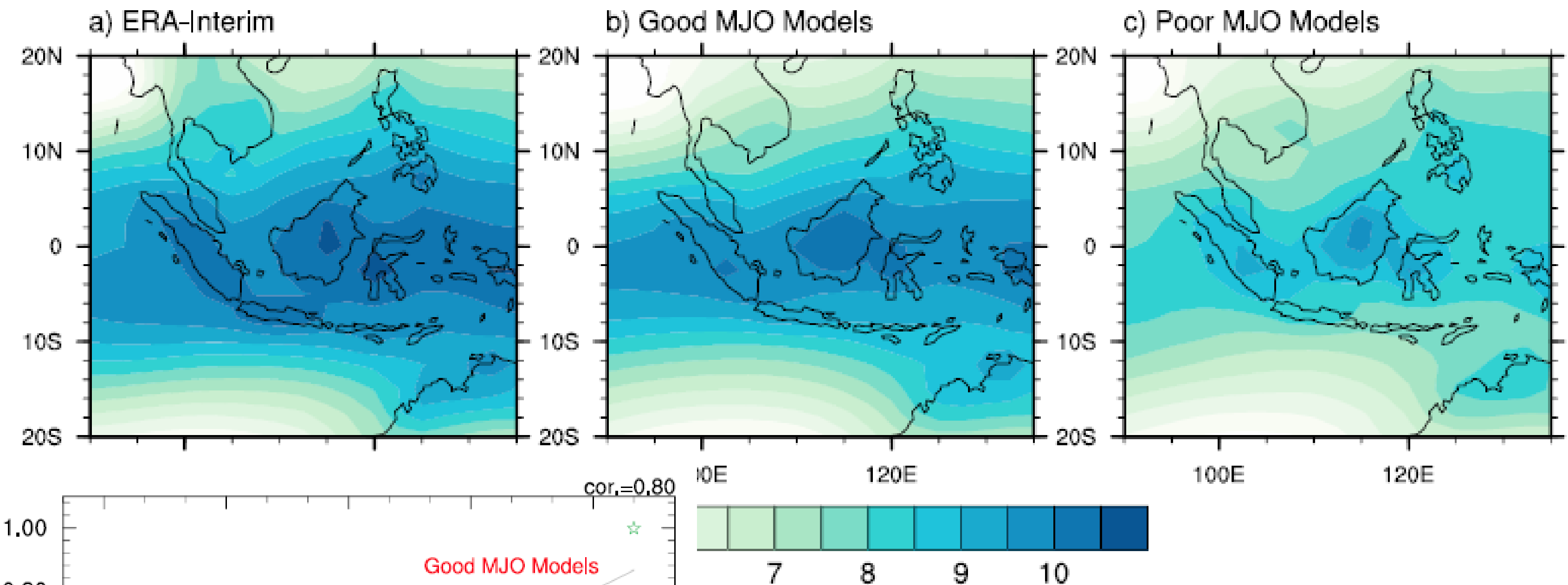
MJO wind **Mean MSE**

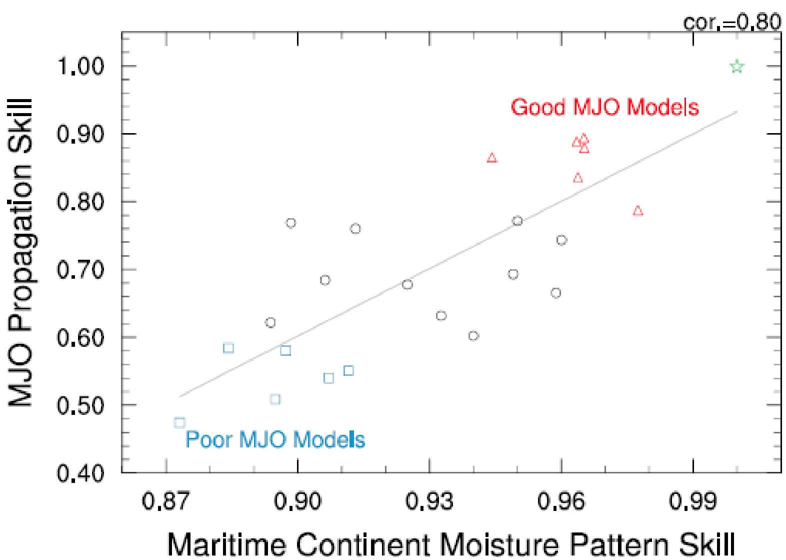
Maloney (2009), Andersen and Kuang(2012), D.Kim et al. (2014), Jiang (2017)

Mean Moisture Bias

Gonzalez and Jiang (2017)

Nov-April mean specific humidity (650-900 hPa)

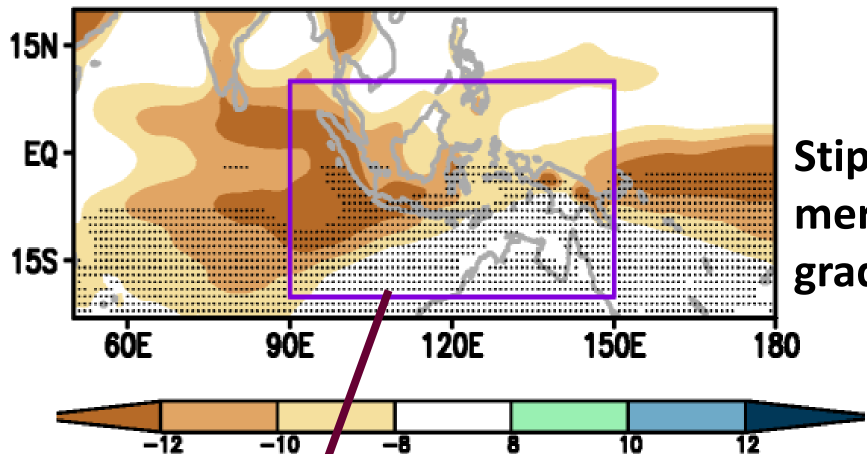




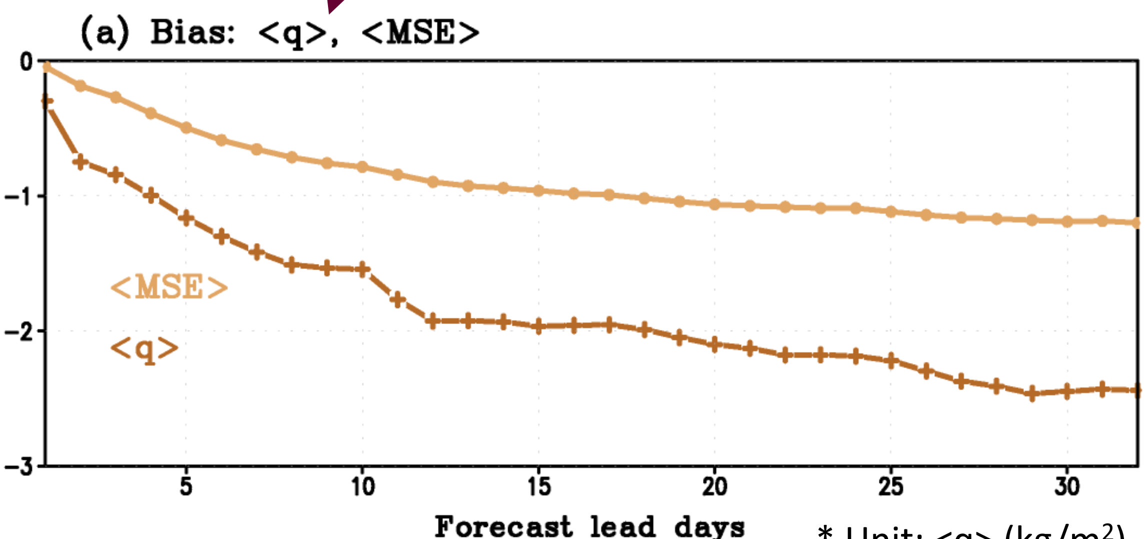
Mean state: Key for realistic simulation of MJO propagation

Mean Moisture Bias

Mean <MSE> Bias (Prediction-Rean)



Stippling: Reduced meridional MSE gradient



MJO eastward propagation — **Faster decay**

↑

Horizontal moisture advection — **Weaker**

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

↑

$$-\langle V' \cdot \nabla \bar{m} \rangle$$ — **Weaker**

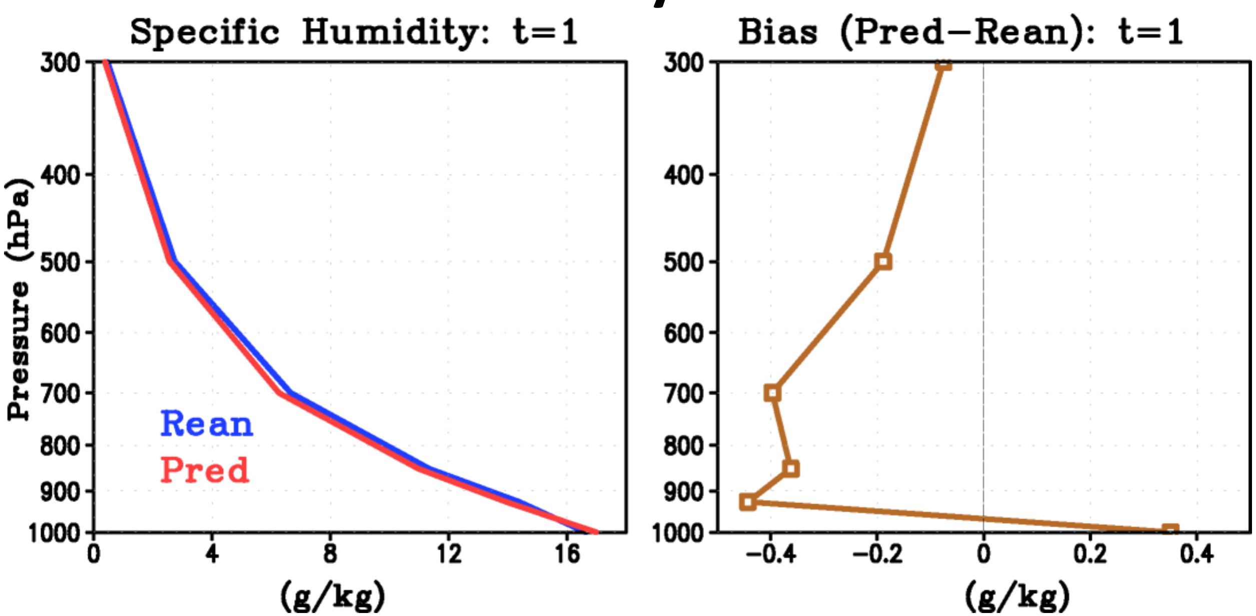
MJO wind **Mean MSE**

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

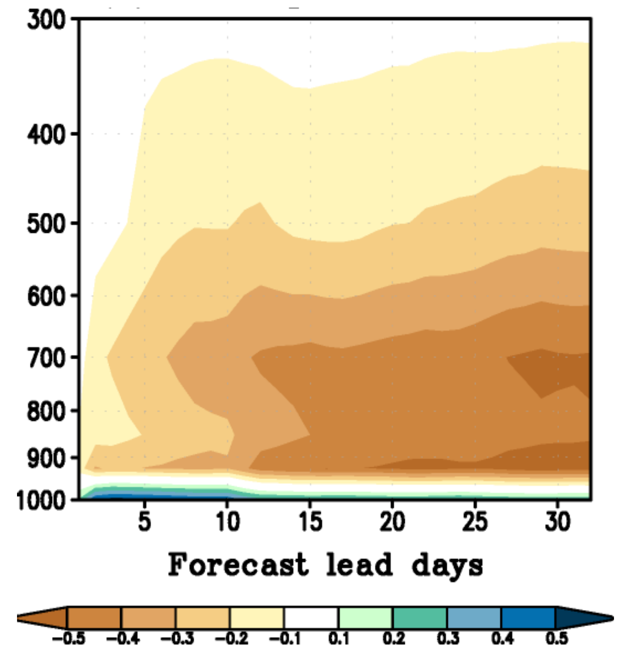
Mean Moisture Bias

Specific Humidity (q)

Day 01

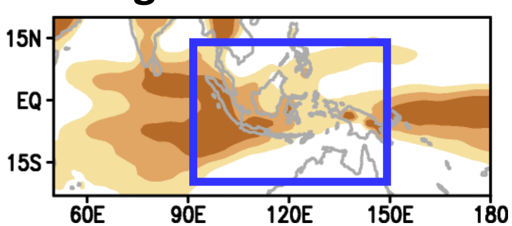


Bias: Day 1 to 32



(g kg^{-1})

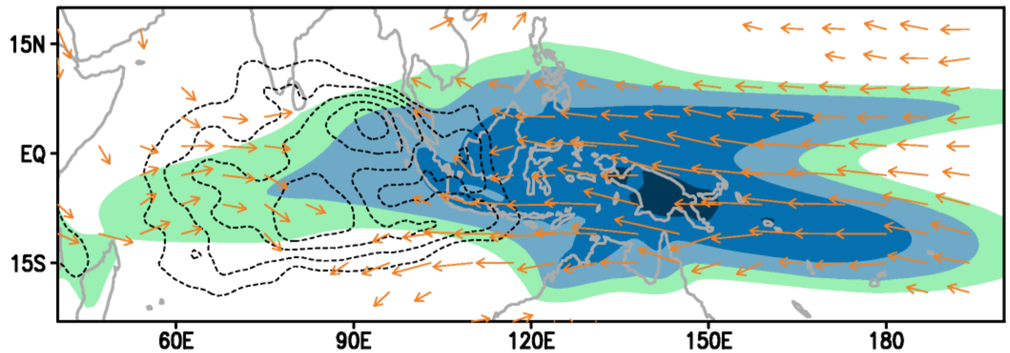
* Averaged area: 20°S-10°N, 90°E-150°E

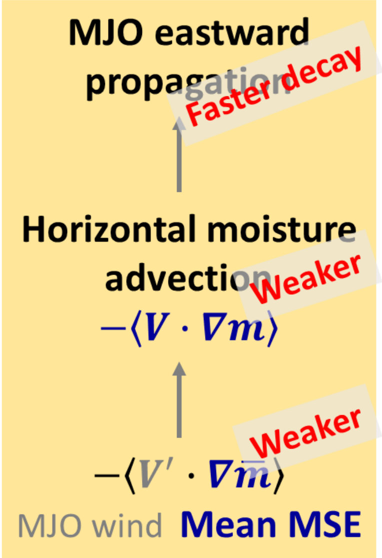


Kim (JGR, in review)

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.





Questions, comments?

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References

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- 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, 29, 3973–3988

- Kim, H. M., P. J. Webster, V. E. Toma, and D. Kim, 2014: **Predictability and prediction skill of the MJO** in two operational forecasting systems, *J. Climate*, 27, 5364-5378