

# MJO prediction skill of the S2S prediction models (S2S) prediction models

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1. Overall MJO prediction skill of S2S models
2. Influence of QBO on MJO prediction skills

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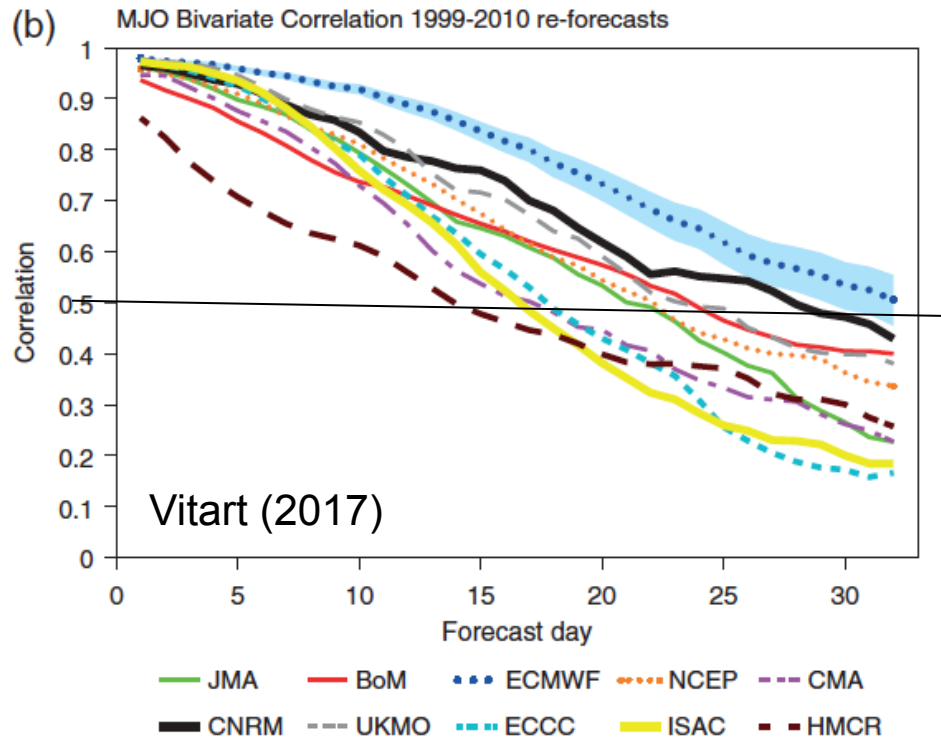
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1. Overall MJO prediction skill of S2S models
2. Influence of QBO on MJO prediction skills

# Background

MJO is predicted with a maximum lead time of about 2 to 4 weeks (e.g., Neena et al. 2014; Vitart 2017).

However, it is unclear what controls the MJO prediction limit.

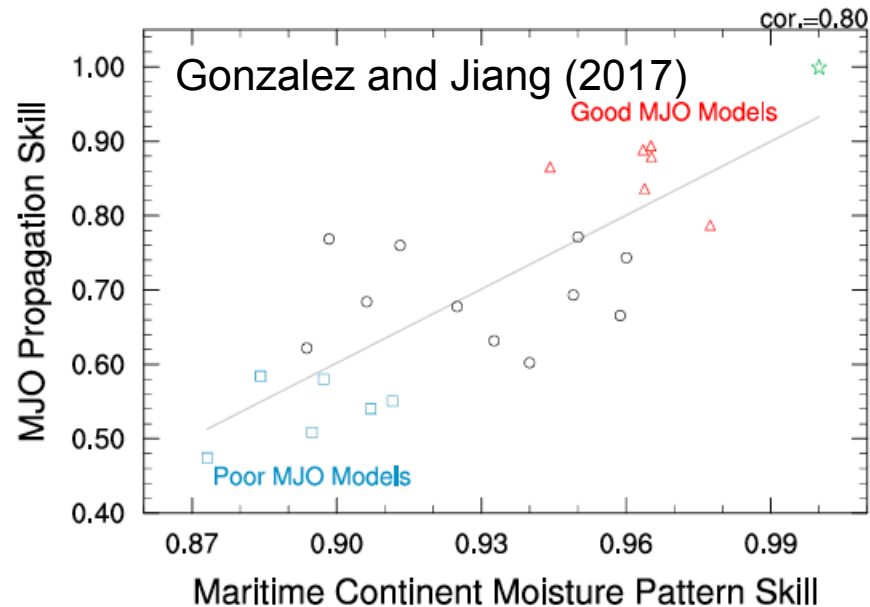


# Background

Horizontal moisture advection is the key process controlling the MJO propagation (Kiranmayi and Maloney 2011; Anderson and Kuang 2012; Adames and Wallace 2015)

Cloud-LongWave (CLW) radiation feedback is the key process for MJO maintenance.

$$\frac{\partial \langle q \rangle'}{\partial t} \approx - \left\langle u' \frac{\partial \bar{q}}{\partial x} \right\rangle' - \left\langle v' \frac{\partial \bar{q}}{\partial y} \right\rangle' - \left\langle \omega \frac{\partial q}{\partial p} \right\rangle' - P' + E'$$



# Purposes

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- To evaluate overall MJO prediction skill in the S2S models by extending Vitart (2017).
- To establish the relationship of the MJO prediction skills to model mean biases.

# Data: S2S models

- We examined all NDJFM reforecasts with MJO amplitude greater than 1.0 (based on RMM index).

Modeling center	Model resolution	Reforecast period	Reforecast frequency	Total number of reforecasts	Reforecast length	Ensemble size
BoM	T47 L17	1981-2013	six times/month	990	Days 0-60	33
CMA*	T106 L40	1994-2013	six times/month	600	Days 0-60	4
CNR-ISAC	0.75°x0.56° L54	1981-2010	every 5 days	900	Days 0-34	1
CNRM	T255 L91	1993-2013	twice/month	210	Days 0-61	15
ECCC	0.45°x0.45° L40	1995-2013	weekly	418	Days 0-32	4
ECMWF	T639/319 L91	1996-2013	twice/week	720	Days 0-31	11
HMCR	1.1°x1.4° L28	1985-2010	weekly	546	Days 0-46	10
JMA	T319 L60	1981-2010	three times/month	450	Days 0-61	5
NCEP*	T126 L64	1999-2010	six times/month	360	Days 0-44	4
UKMO	N216L85	1996-2009	four times/month	280	Days 0-60	3

# Evaluation metrics

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$O_1(t)$   $O_2(t)$

Observed RMM1, RMM2

$M_1(t, \tau)$   $M_2(t, \tau)$

Predicted RMM1, RMM2

$A_o(t)$   $\phi_o(t)$

Observed Amplitude, Phase

$A_M(t, \tau)$   $\phi_M(t, \tau)$

Predicted Amplitude, Phase

$$\text{BCOR}(\tau) = \frac{\sum_{t=1}^N C_{OM}(t, \tau)}{\sqrt{\sum_{t=1}^N A_o^2(t)} \sqrt{\sum_{t=1}^N A_M^2(t, \tau)}}$$

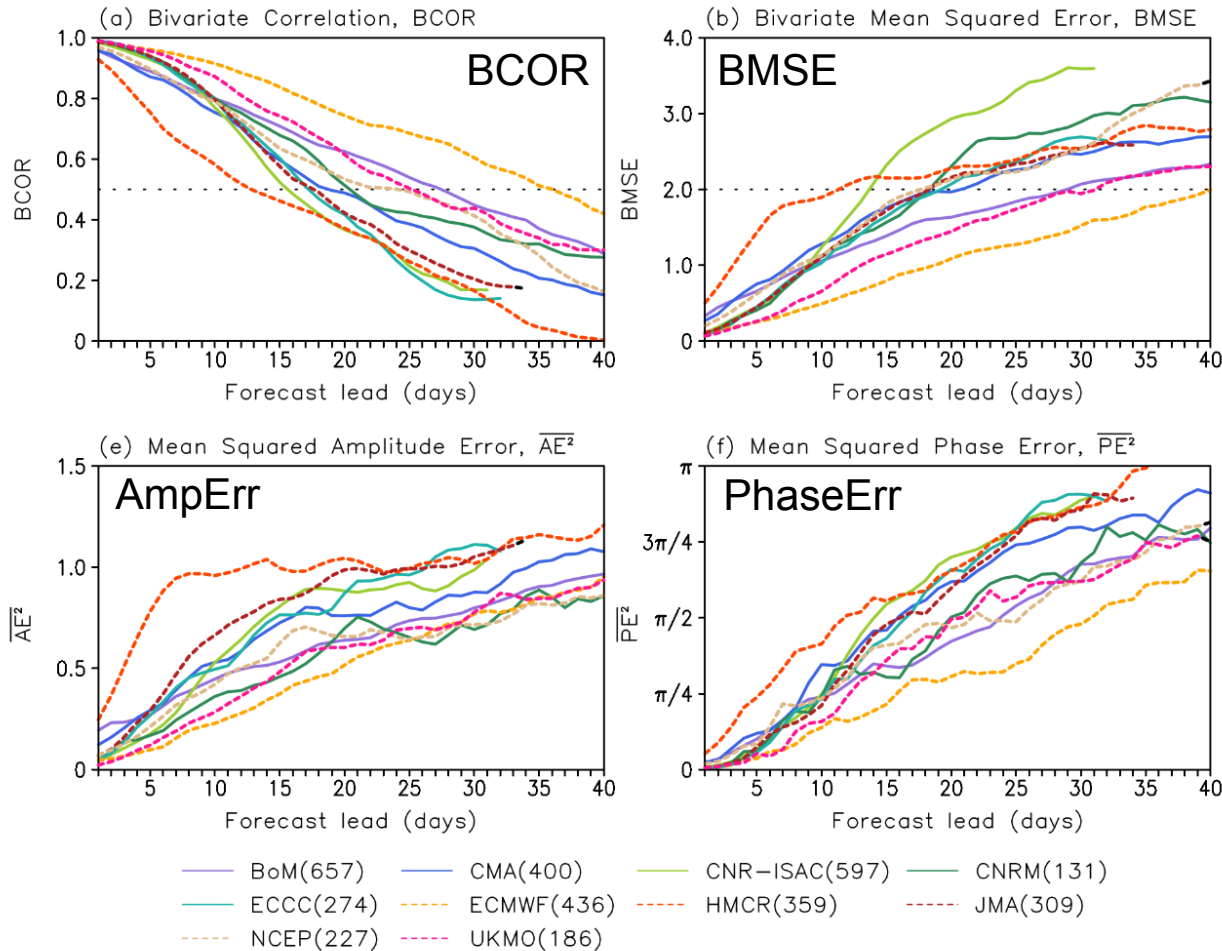
$$\text{BMSE}(\tau) = \frac{1}{N} \sum_{t=1}^N [(M_1(t, \tau) - O_1(t))^2 + (M_2(t, \tau) - O_2(t))^2]$$

$$= \text{BMSEa}(\tau) + \text{BMSEp}(\tau)$$

$$\text{BMSEa}(\tau) = \frac{1}{N} \sum_{t=1}^N [A_M(t, \tau) - A_o(t)]^2$$

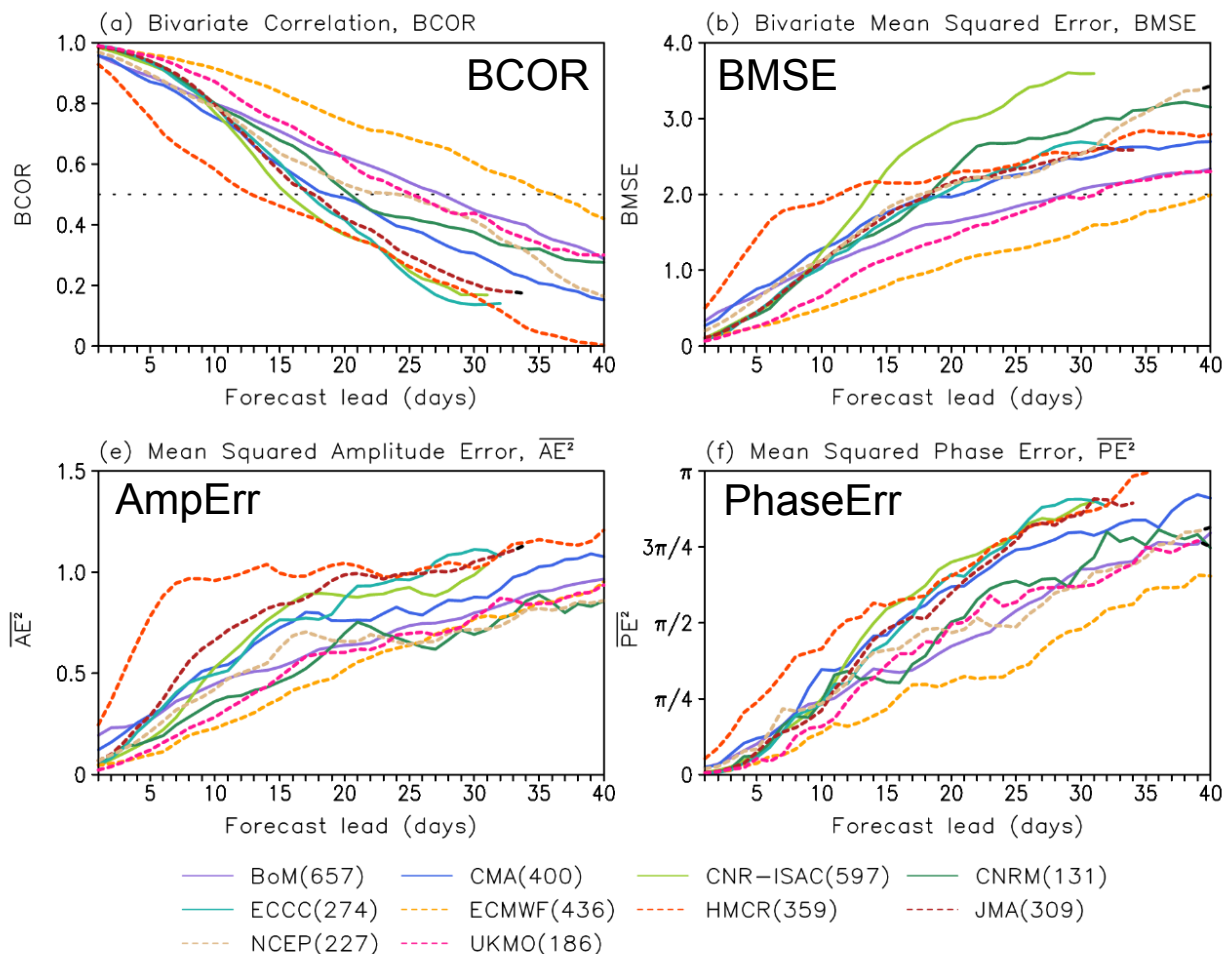
$$\text{BMSEp}(\tau) = \frac{1}{N} \sum_{t=1}^N 2A_M(t, \tau) A_o(t) \{1 - \cos(\phi_M(t, \tau) - \phi_o(t))\}$$

# MJO prediction skill



- MJO is qualitatively predicted with a maximum lead time of ~3 weeks.
- Amplitude errors become saturated.

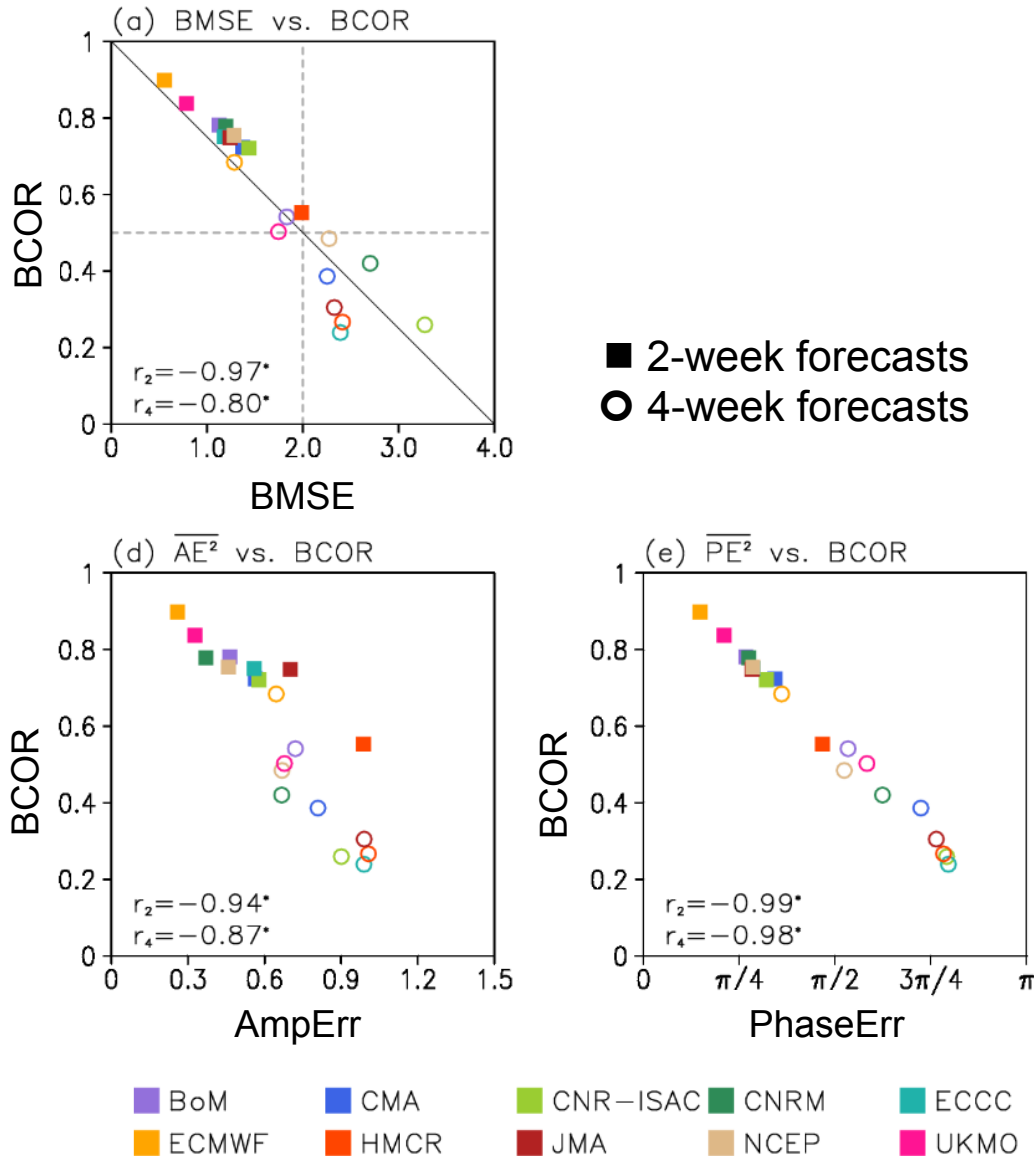
# MJO prediction skill



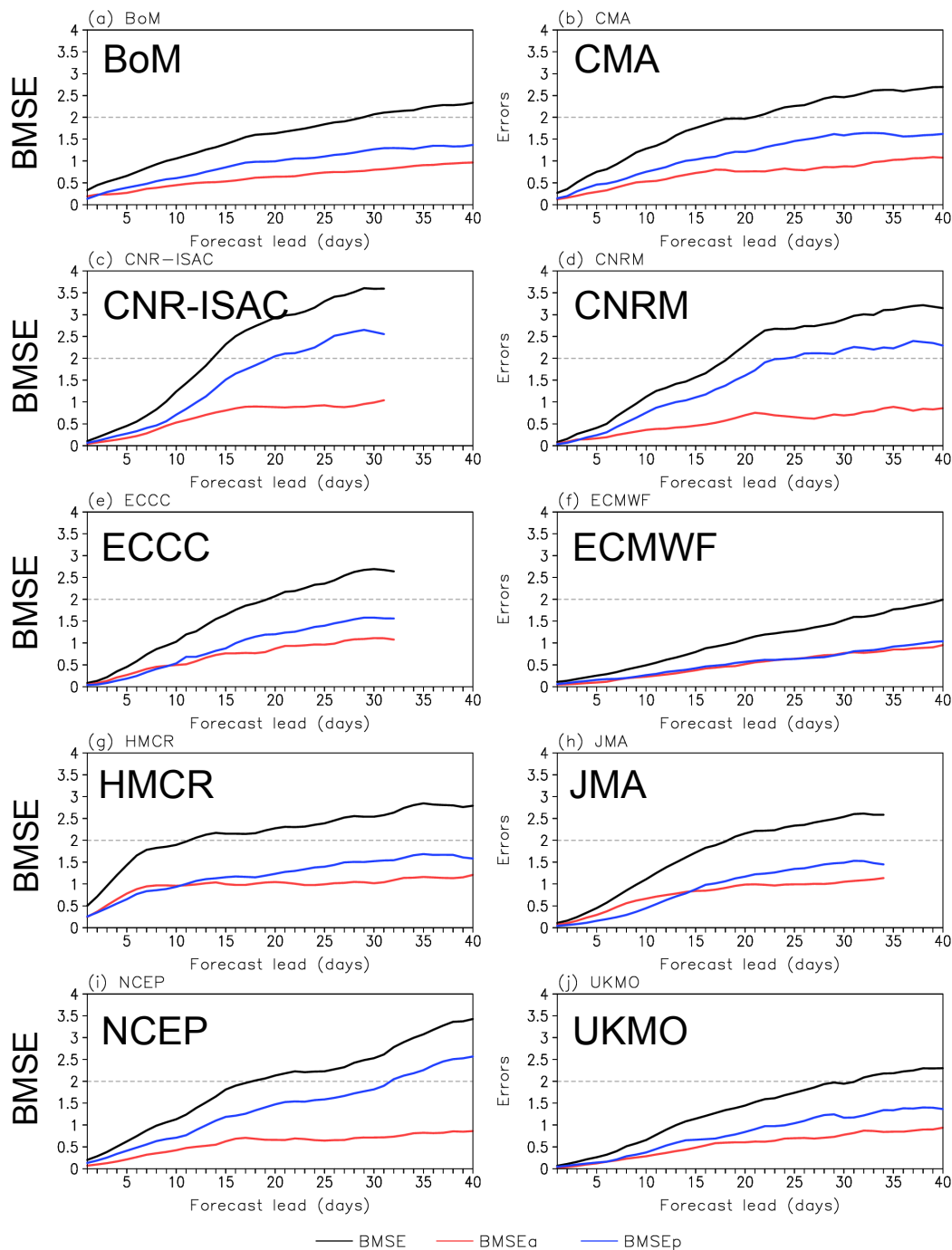
BCOR=0.5/ BMSE=2.0	
BoM	27/ 28
CMA	18/ 20
CNR-ISAC	15/ 13
CNRM	20/ 18
ECCC	17/ 19
ECMWF	36/ 40
HMCR	12/ 11
JMA	17/ 18
NCEP	24/ 17
UKMO	25/ 31
MMM	21.1±7.0 days 21.5±8.9 days

- MJO is qualitatively predicted with a maximum lead time of ~3 weeks.
- Amplitude errors become saturated.

# MJO prediction skill



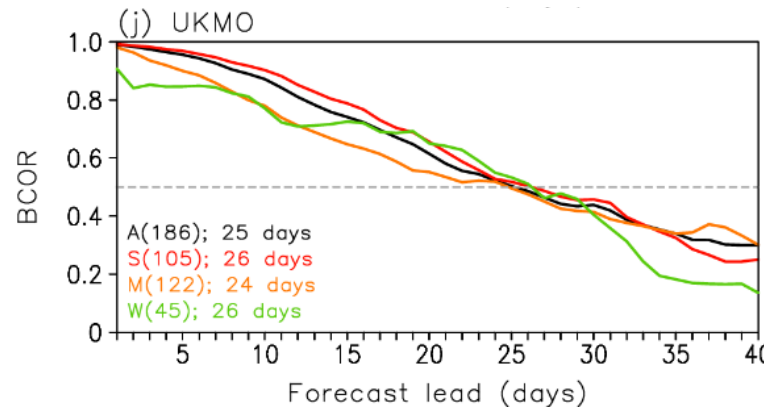
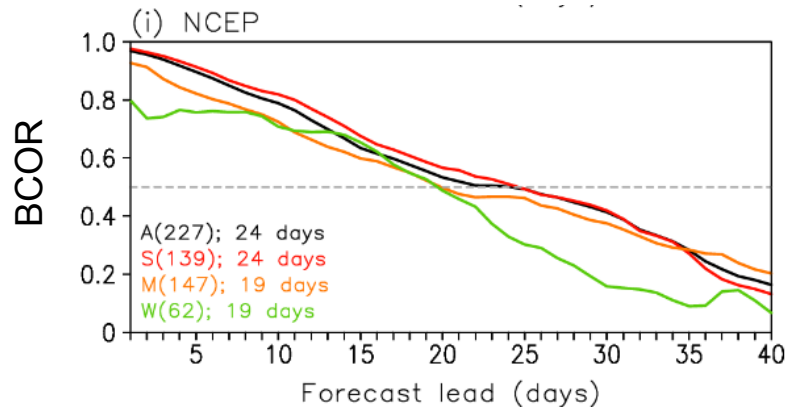
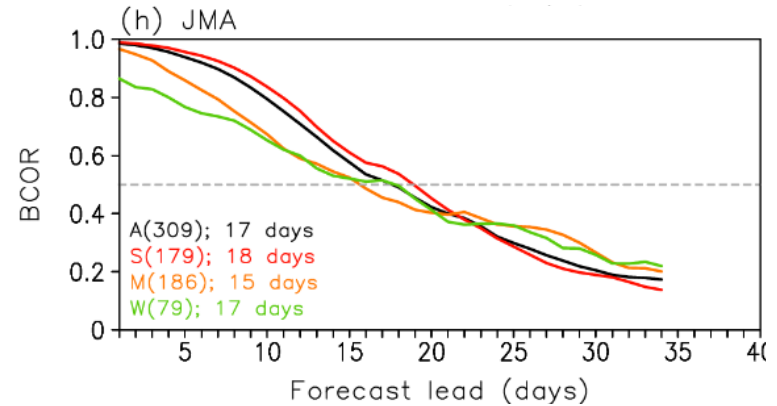
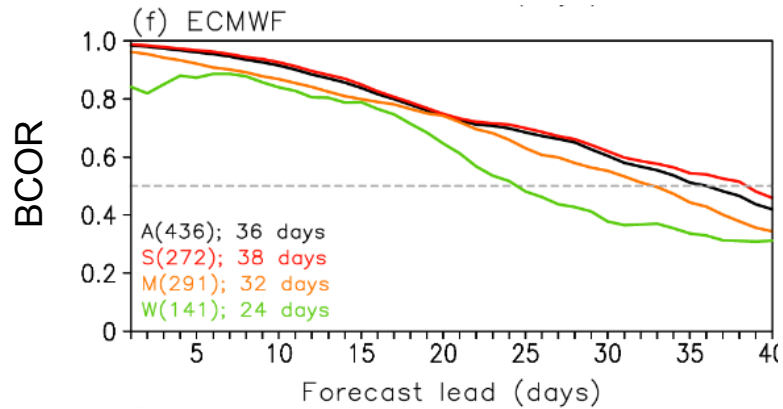
- BCOR and BMSE skills are highly correlated.
- BCOR skills are more closely related with phase errors than amplitude errors especially at a longer lead time.



-- BMSE  
 -- BMSEa (amplitude)  
 -- BMSEp (phase)

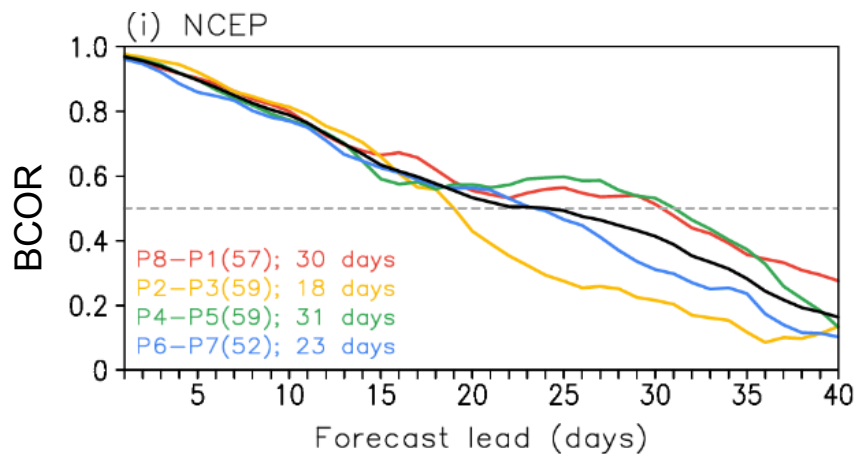
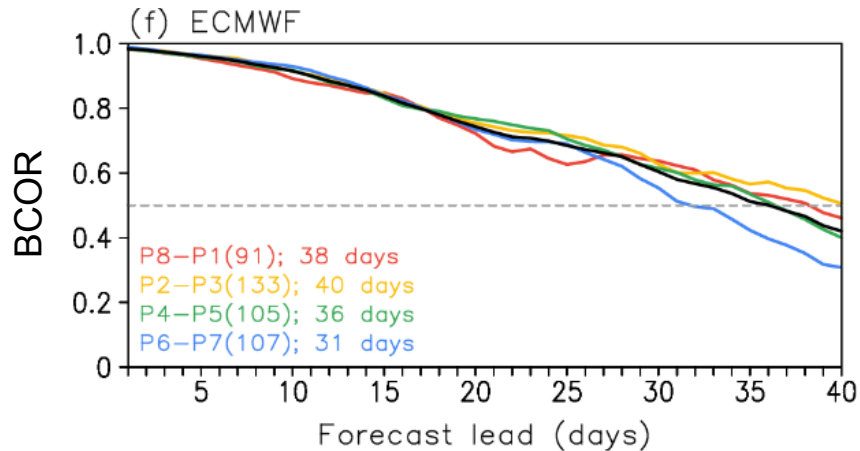
- BMSE skills is largely determined by phase errors except for ECMWF model.
- A higher MJO prediction skill of ECMWF model is partly due to a smaller phase error.

# Dependency to initial amplitude



- Strong MJO events are better predicted.

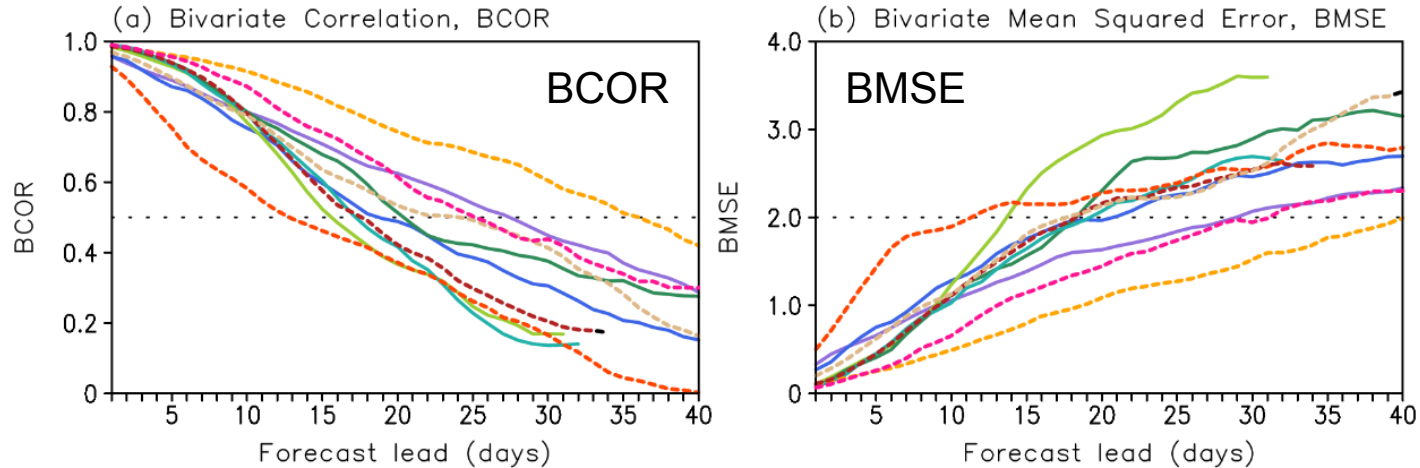
# Dependency to initial phase



	Phase 8-1	Phase 2-3	Phase 4-5	Phase 6-7
BoM	31/28	24/28	28/28	25/31
CMA	15/17	18/19	18/17	21/19
CNR-ISAC	14/13	17/14	14/13	15/13
CNRM	21/17	20/16	18/18	21/19
ECCC	19/20	16/22	15/15	17/18
ECMWF	38/40	40/41	36/39	31/37
HMCR	13/13	13/10	9/5	15/19
JMA	18/18	17/15	15/17	18/19
NCEP	30/18	18/19	31/15	23/15
UKMO	22/24	22/27	27/30	28/32
MMM	22.1±8.3	20.5±7.5	21.1±8.8	21.4±5.4
	20.8±8.1	21.1±9.0	19.7±9.8	22.2±8.1

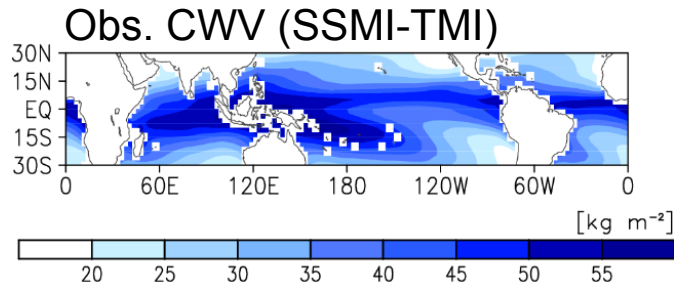
- MJO prediction skill is **not sensitive to initial MJO phase**. The Maritime Continent MJO prediction barrier is absent in most models.

# Dependency to model mean biases

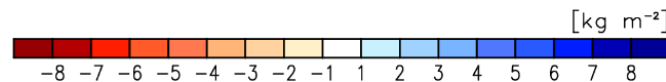
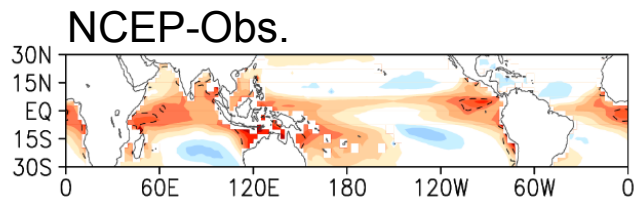
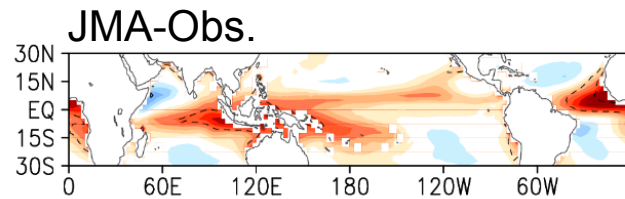
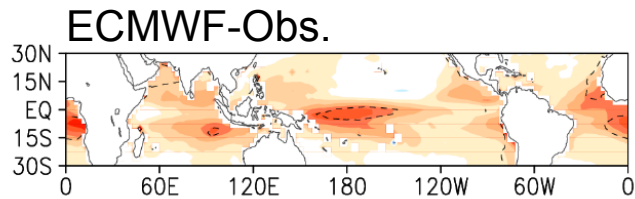
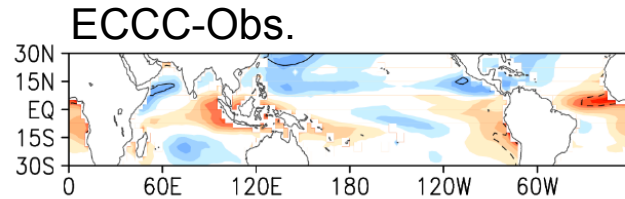
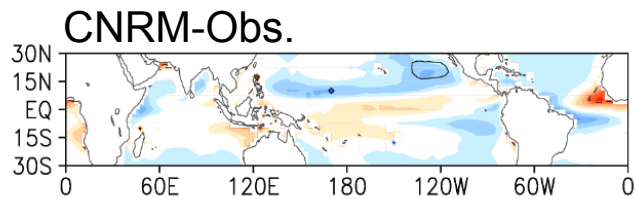
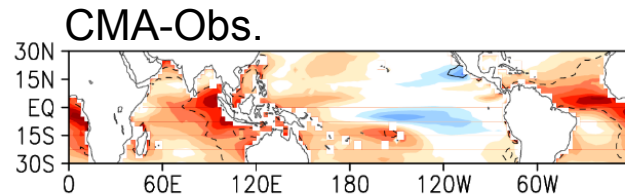
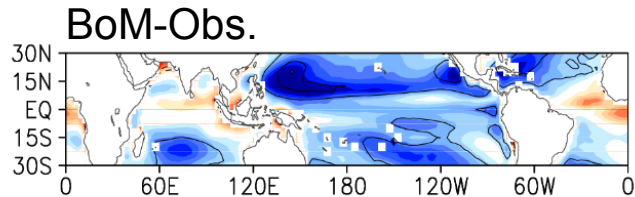


- The inter-model spread in MJO prediction skill is related with the model mean biases in [Column-integrated Water Vapor \(CWV\) gradient](#) and [Cloud-LW radiation \(CLW\) feedback](#).
- Here, the mean state is defined by first 30-day average. CLW feedback parameter is quantified by the regression coefficient between  $P' * Lv$  and  $-OLR'$  (Lin and Mapes 2004)

# a) Mean moisture bias

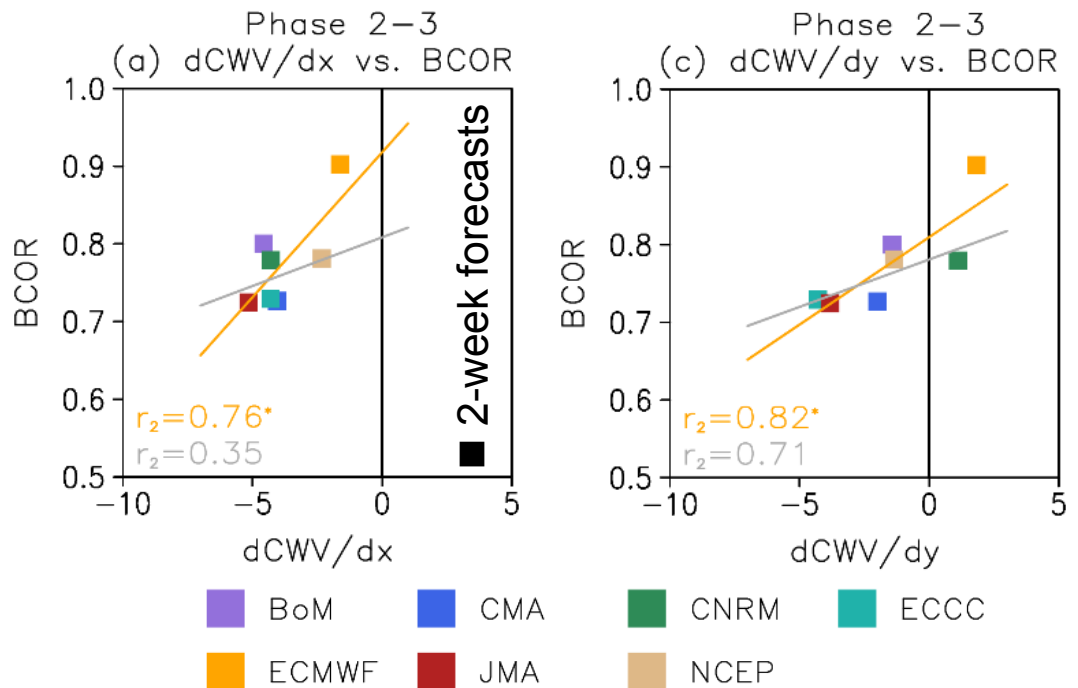
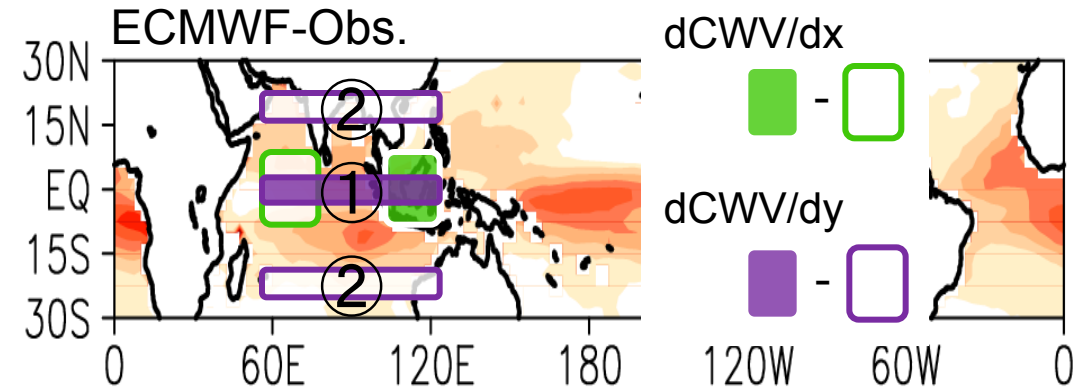


All models show **significant dry biases** over the Maritime Continent.

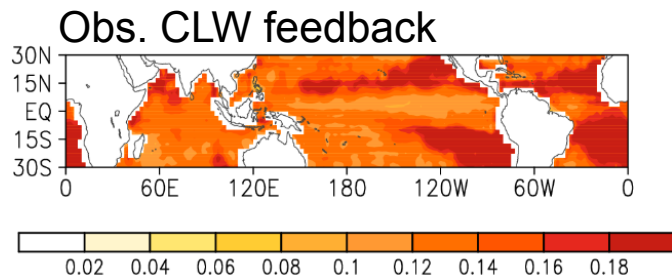


# a) Mean moisture bias

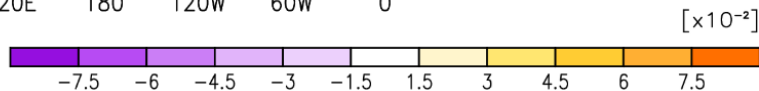
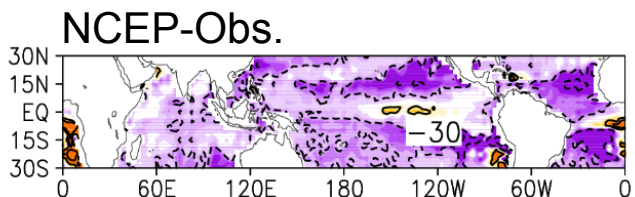
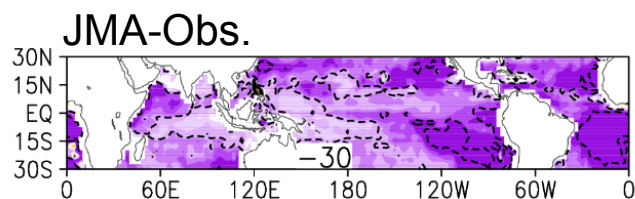
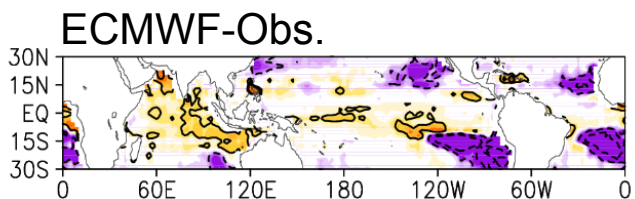
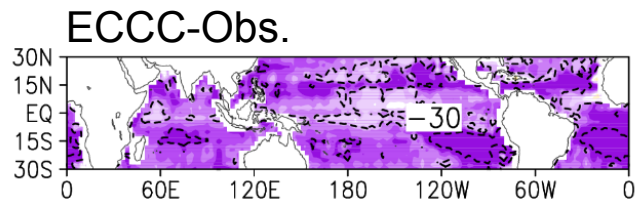
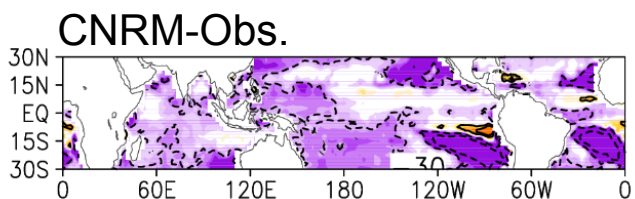
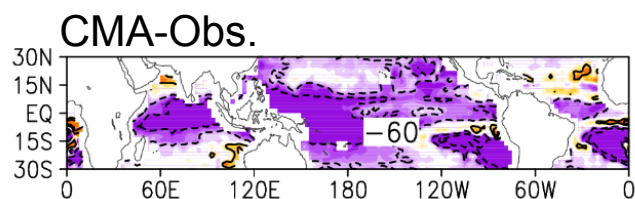
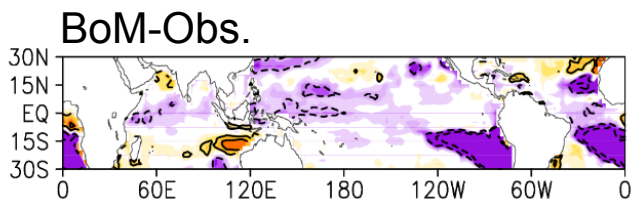
- BCOR skills are highly associated with mean moisture gradient biases & CLW feedback across the Maritime Continent.



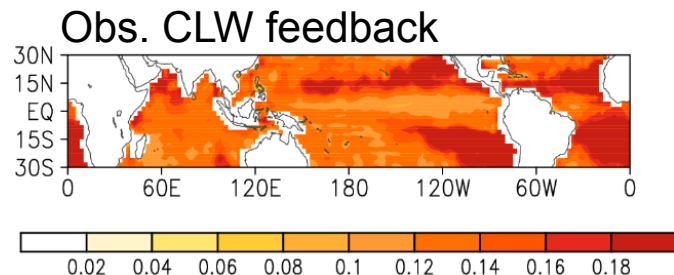
# b) Cloud-LW radiation (CLW) feedback bias



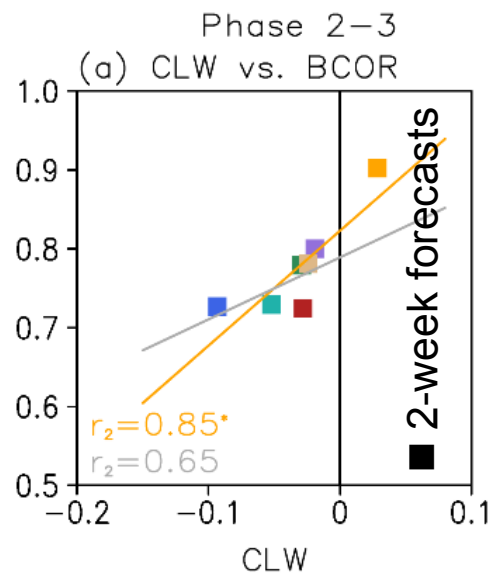
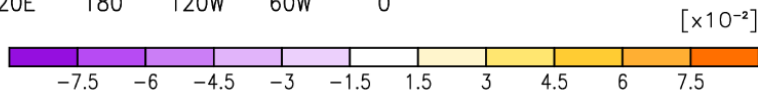
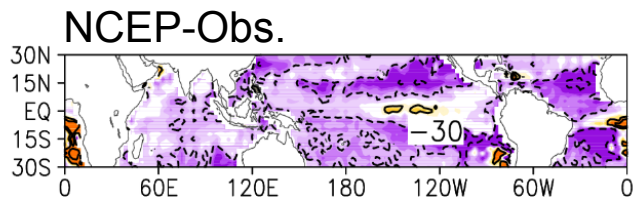
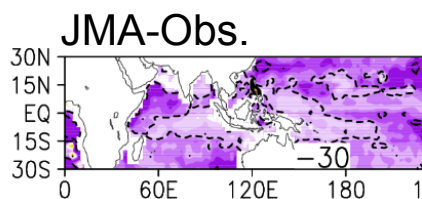
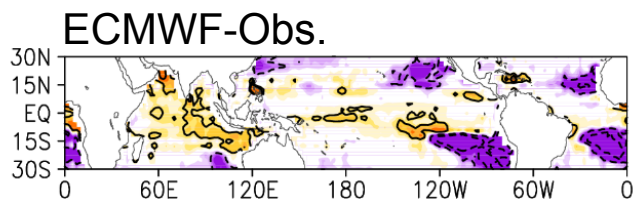
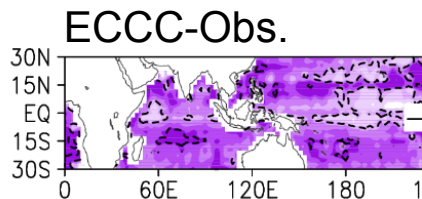
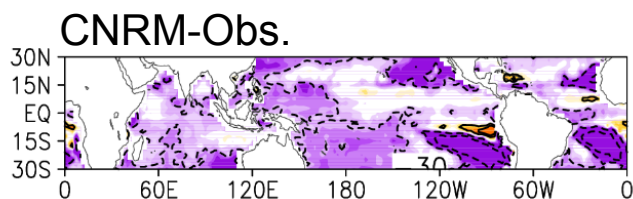
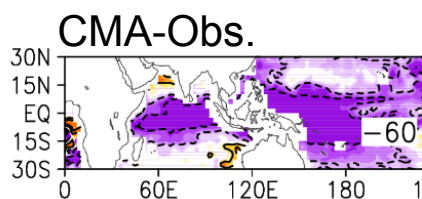
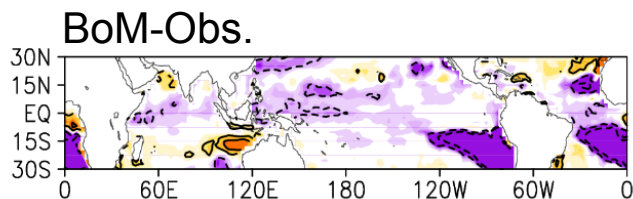
Most models, except ECMWF, show **negative biases in the Indo-Pacific regions.**



# b) Cloud-LW radiation (CLW) feedback bias



Most models, except ECMWF, show **negative biases in the Indo-Pacific regions.**



# Summary

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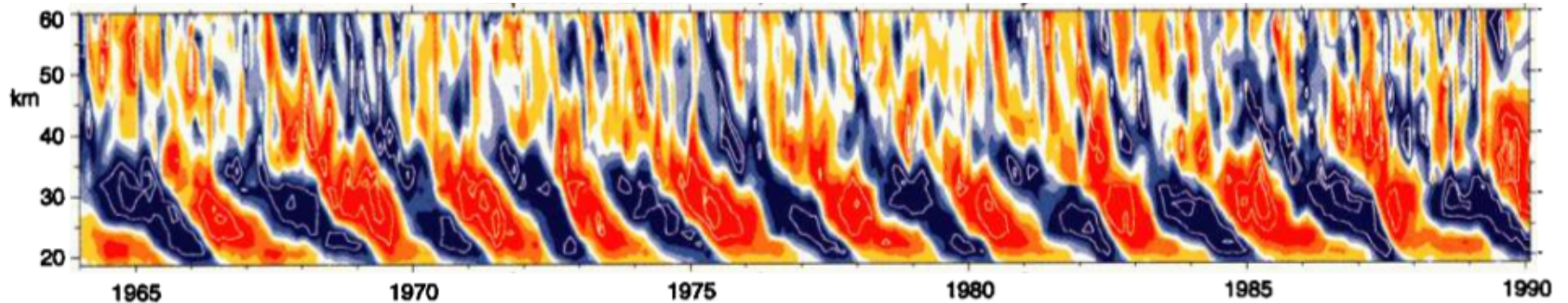
- S2S models predict the boreal-winter MJO with a maximum lead time of ~3 weeks (Neena et al. 2014; Vitart 2017)
- This prediction limit is more strongly influenced by the phase error than the amplitude error especially at a longer lead time.
- A large inter-model spread in MJO prediction skill is closely related with the model biases in moisture gradient and cloud-longwave radiation feedback. To confirm this finding, more datasets are required (Ahn et al. 2017; Gonzalez and Jiang 2017; H. Kim 2017).

Lim, Y., S.-W. Son, and D. Kim, 2018: MJO prediction skill of the subseasonal-to-seasonal (S2S) prediction models, J. Climate.

# Contents

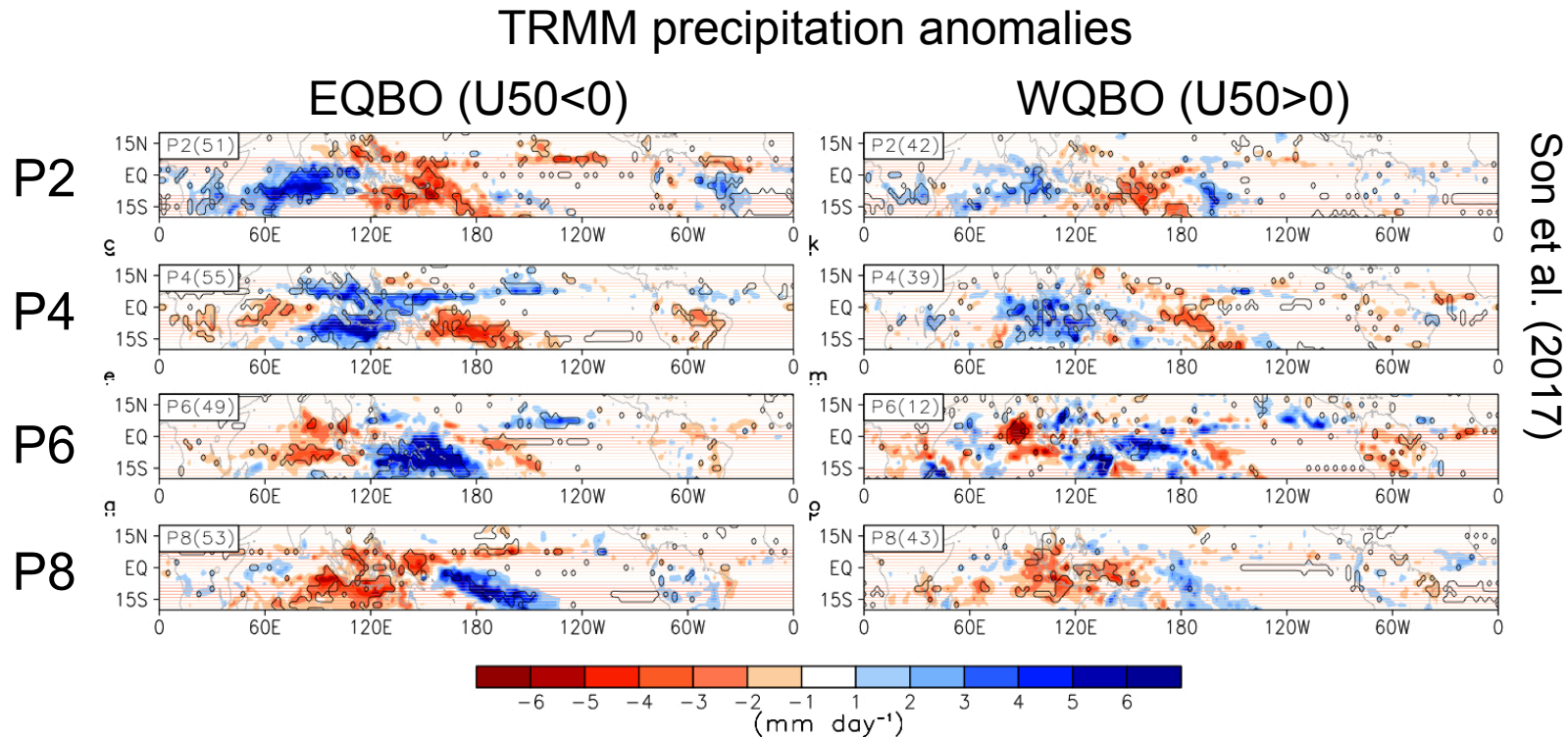
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1. Overall MJO prediction skill of S2S models
2. Influence of QBO on MJO prediction skills

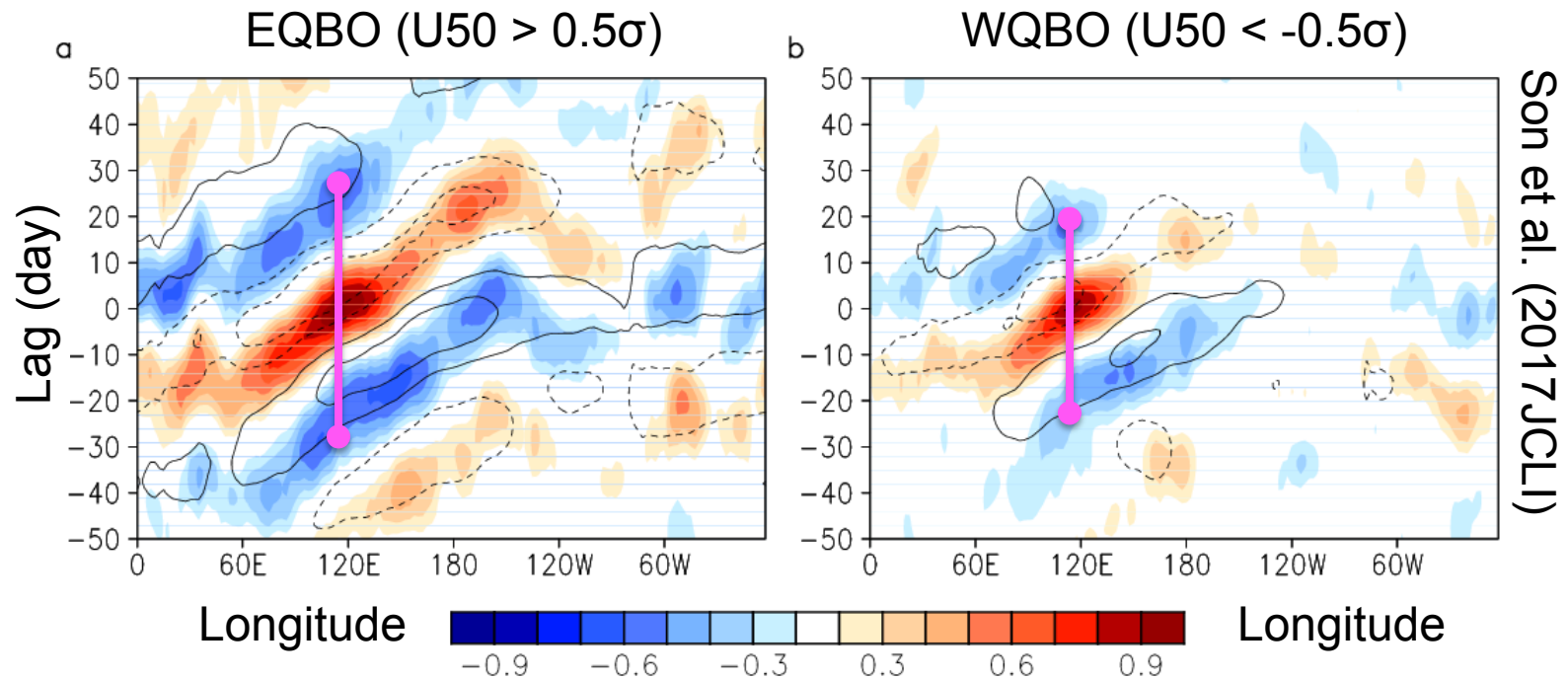


# Background

Stratospheric mean state could influence on overall MJO organization (Yoo and Son, 2016; Son et al. 2017; Marshall et al. 2017; Nishimoto and Yoden, 2017; Zhang and Zhang 2018).



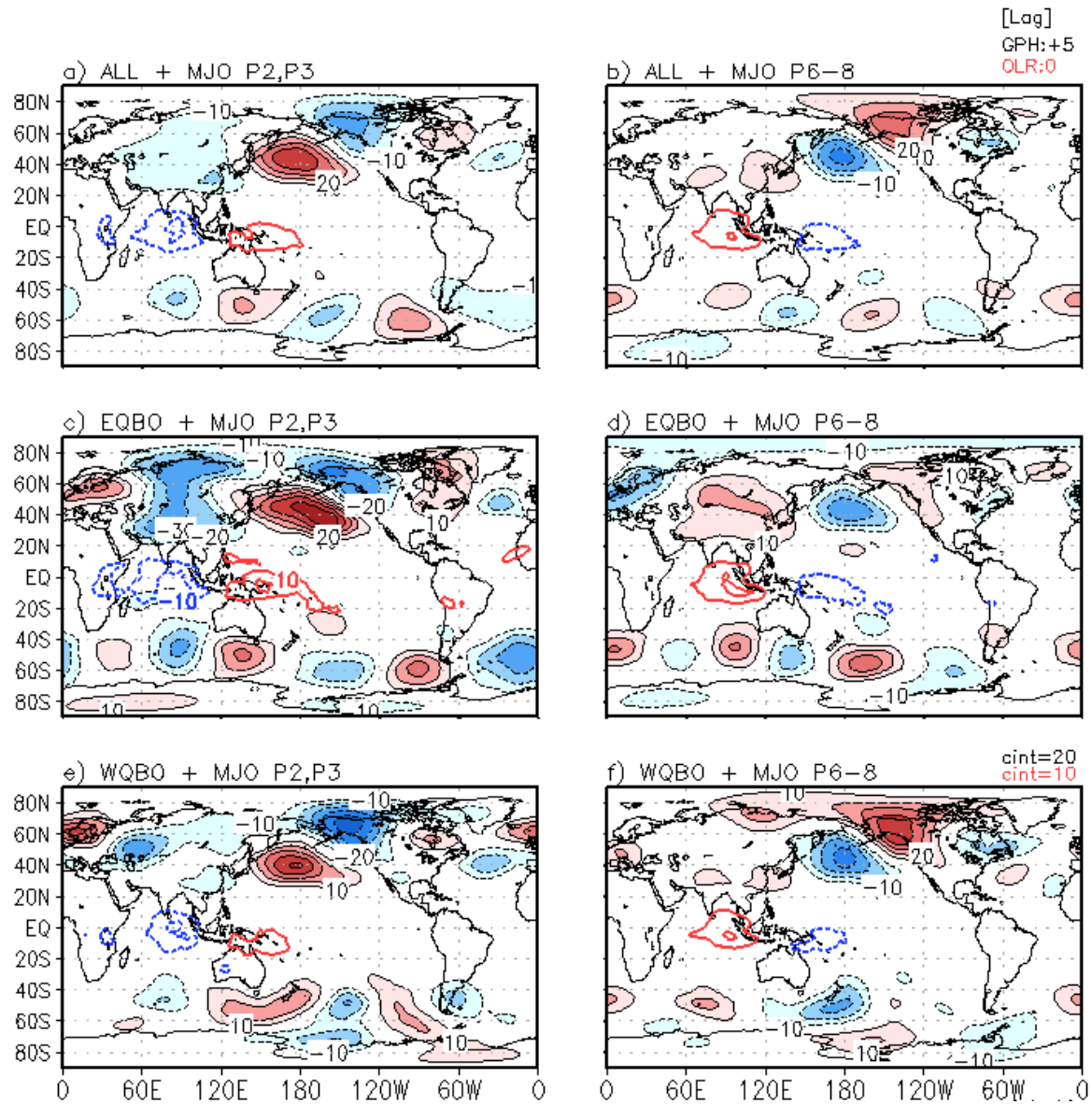
# Background



OLR(shading) and U850(contour) correlation w.r.t.  
maritime continent OLRa (100-130°E; 15°S-5°N)

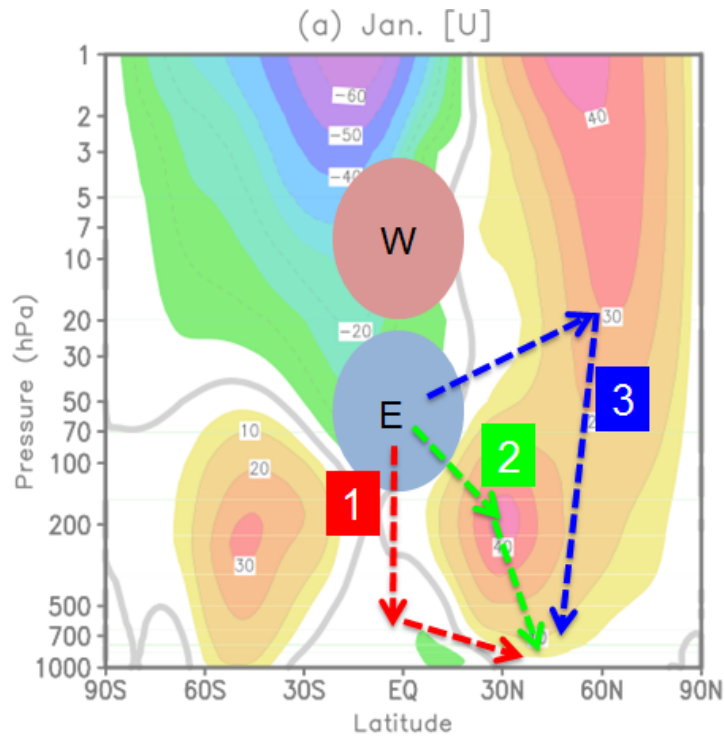
Stronger amplitude, slightly slower (and farther eastward crossing the dateline) propagation, and longer period of MJO are observed during EQBO (U50) winter.

# Background



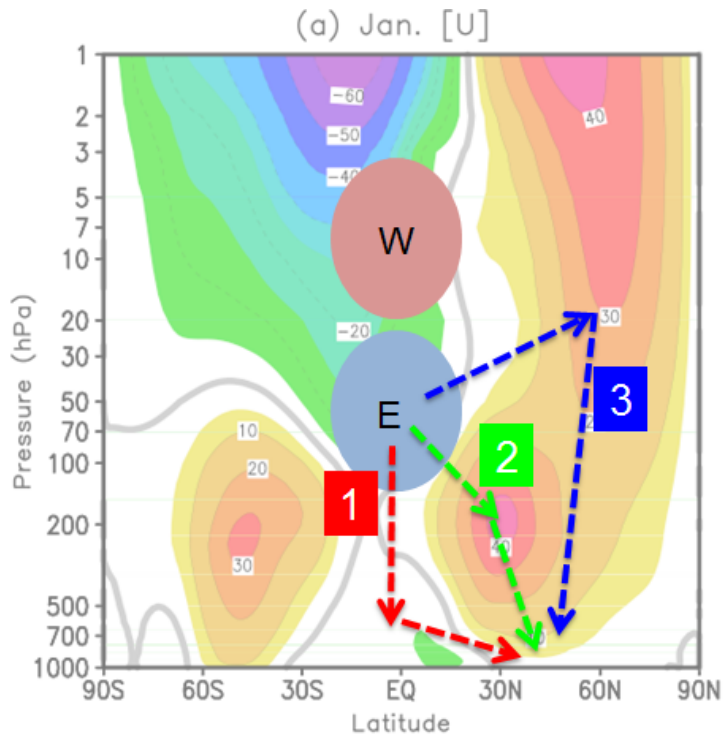
# Purpose

- To explore the possible impact of QBO on the MJO prediction skills.

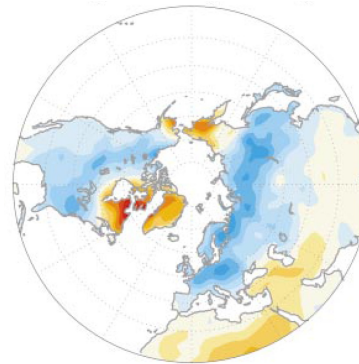


# Purpose

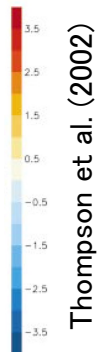
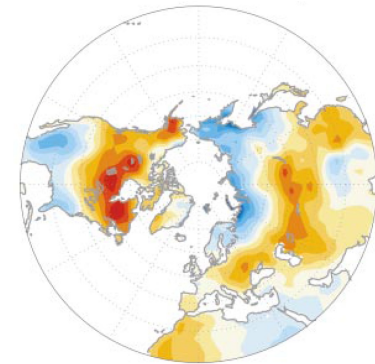
- To explore the possible impact of QBO on the MJO prediction skills.



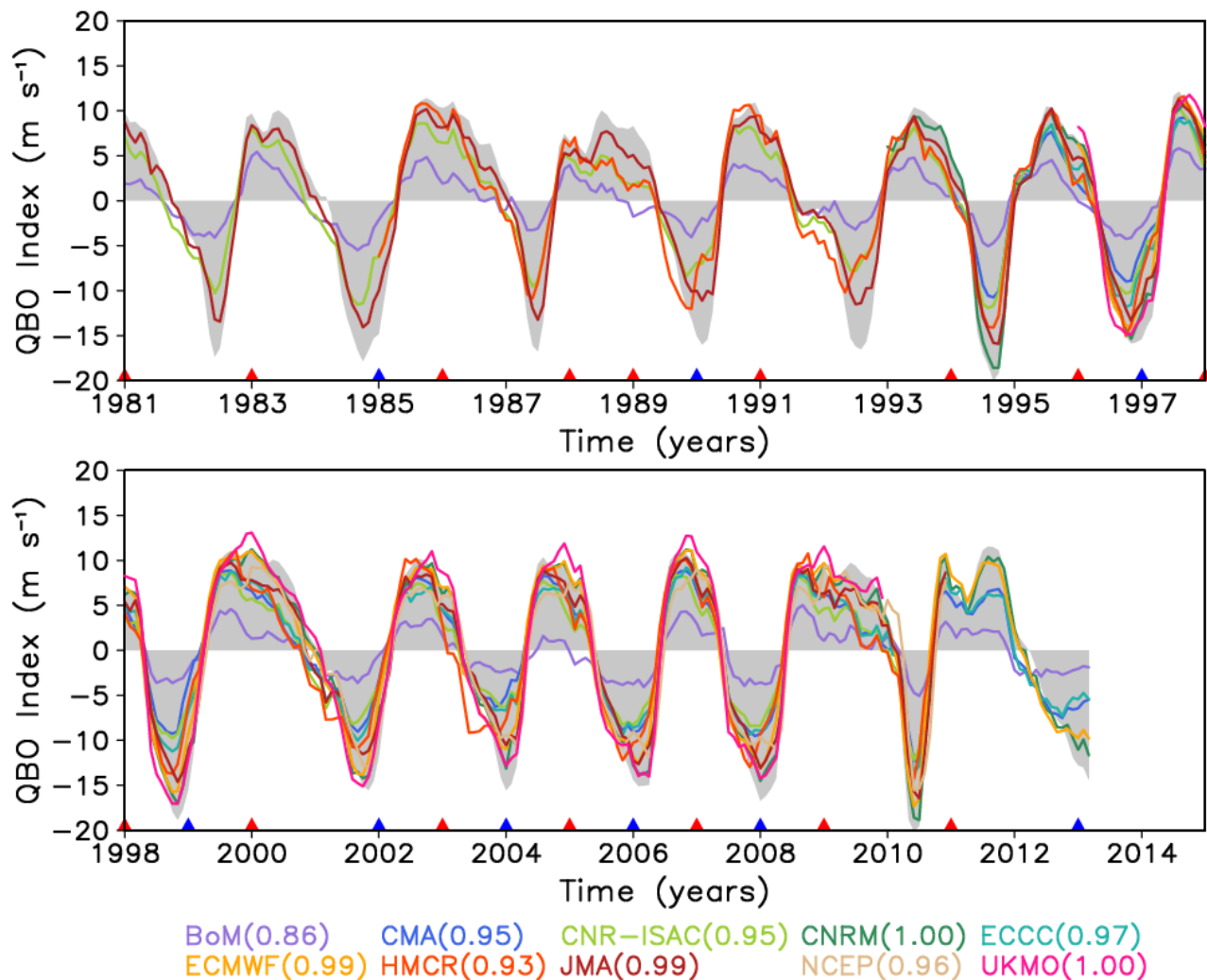
EQBO-WQBO



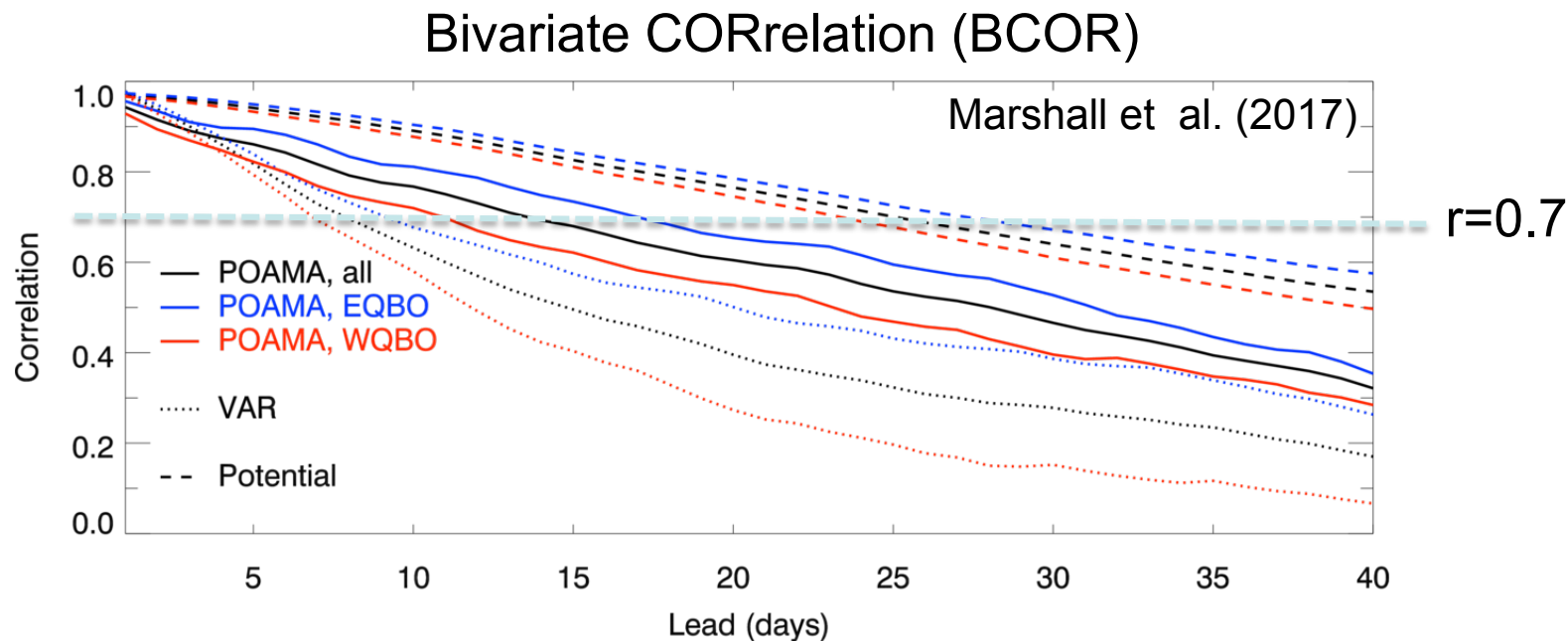
El Niño-La Niña



# QBO prediction (U50)



# QBO modulation of MJO prediction skill



- MJO is better predicted during EQBO winters than during WQBO winters in BoM model.

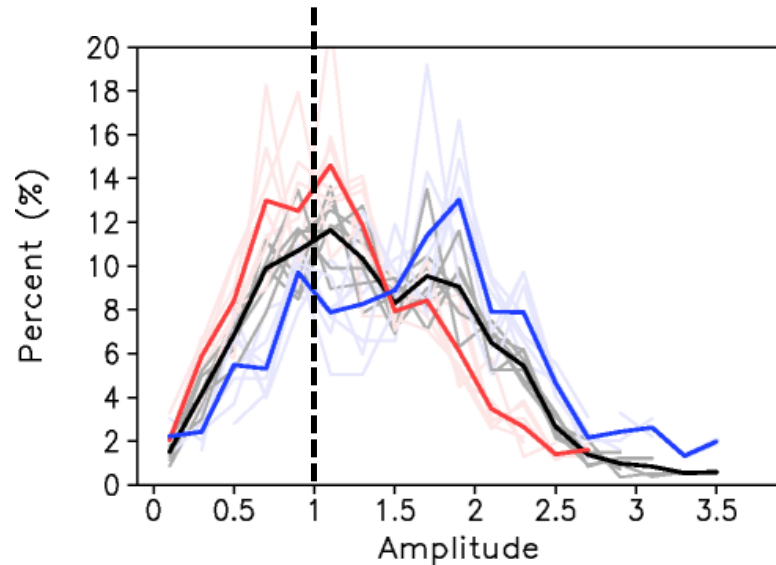
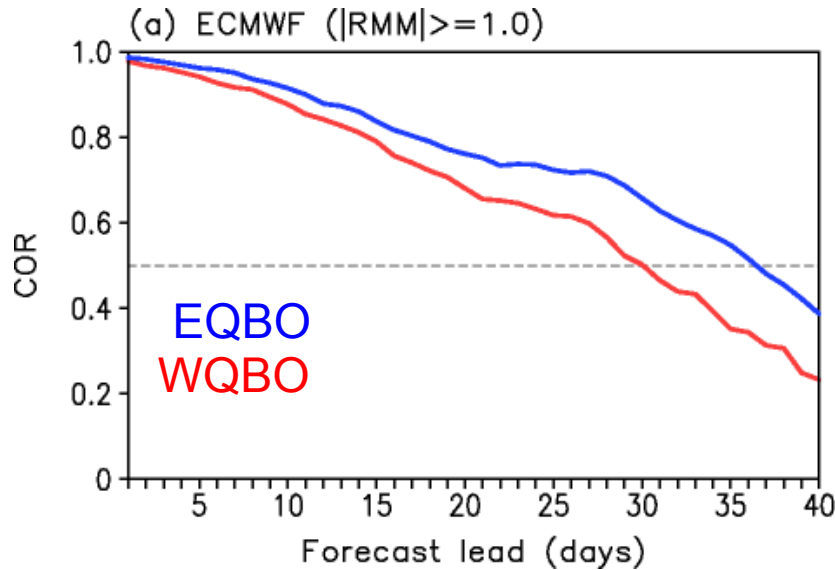
# QBO modulation of MJO prediction skill

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BCOR=0.5(0.7)	All	EQBO	WQBO
BoM	28 (15)	31 (17)	24 (12)
CMA	17 (11)	20 (13)	13 (9)
CNR-ISAC	15 (11)	18 (13)	14 (11)
CNRM	20 (13)	26 (17)	16 (12)
ECCC	16 (12)	19 (12)	14 (10)
ECMWF	36 (25)	36 (28)	30 (19)
HMCR	13 (6)	18 (9)	10 (5)
JMA	16 (12)	23 (15)	14 (10)
NCEP	25 (13)	19 (13)	18 (11)
UKMO	27 (17)	28 (18)	27 (13)
MMM	<b>21.3±7.4</b> (13.5±4.9)	<b>23.8±6.3</b> (15.5±5.2)	<b>18.9±6.4</b> (11.2±3.5)

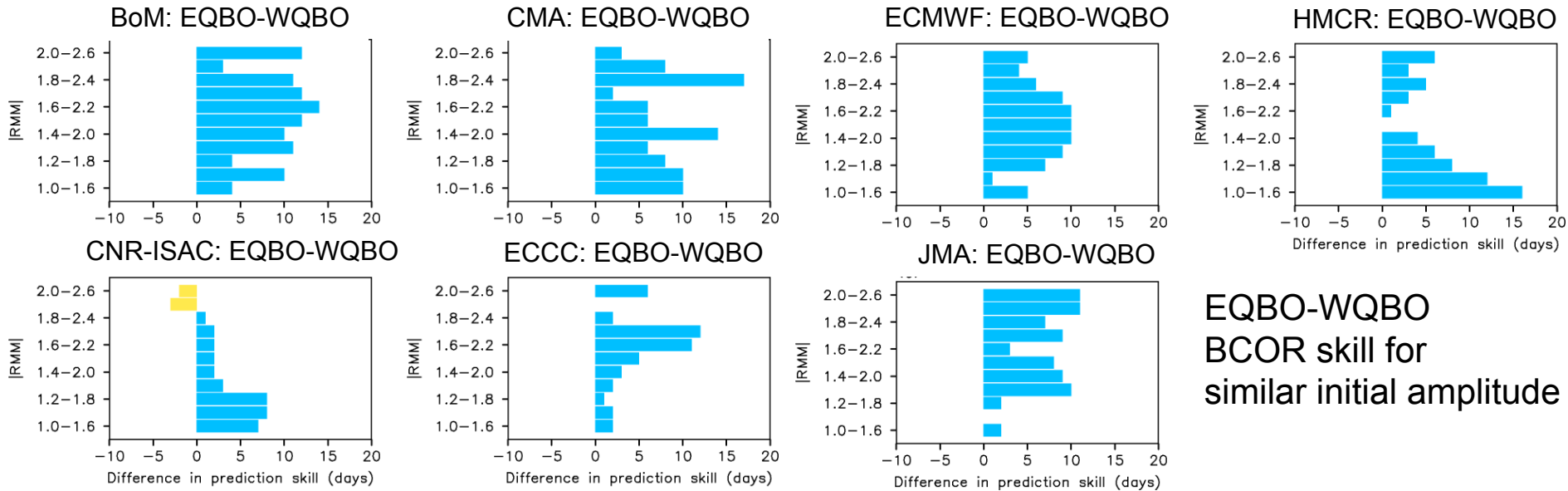
- MJO is better predicted during EQBO winters up to ~5 days.

# Dependence to initial amplitude



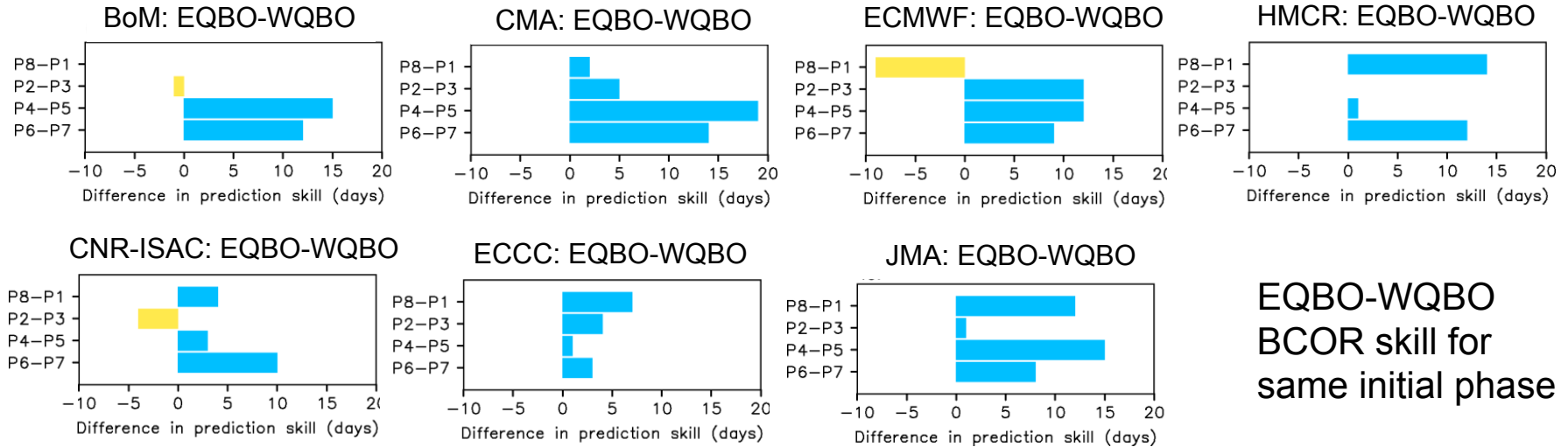
- ECMWF model shows a higher MJO prediction skill during EQBO winters. This is partly because EQBO-MJO is stronger than WQBO-MJO.

# Dependence to initial amplitude



- For all amplitudes, MJO is better predicted during EQBO winters. This result indicates that an enhanced MJO prediction skill during EQBO winters is **not simply due to stronger MJO amplitude during EQBO winters.**

# Dependence to initial phase

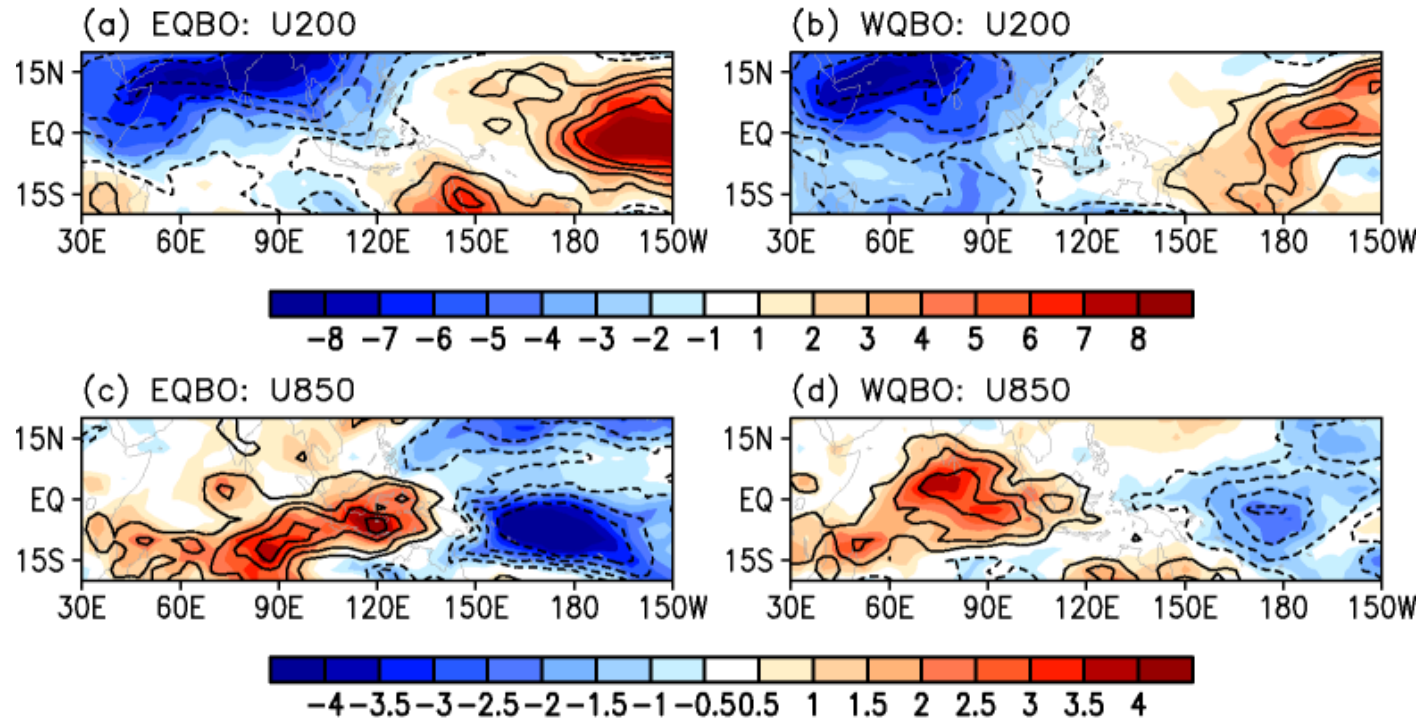


EQBO-WQBO  
BCOR skill for  
same initial phase

- For most phases (especially MJO phases 4-7), MJO is better predicted during EQBO winters than during WQBO winters.

# Dependence to background flow

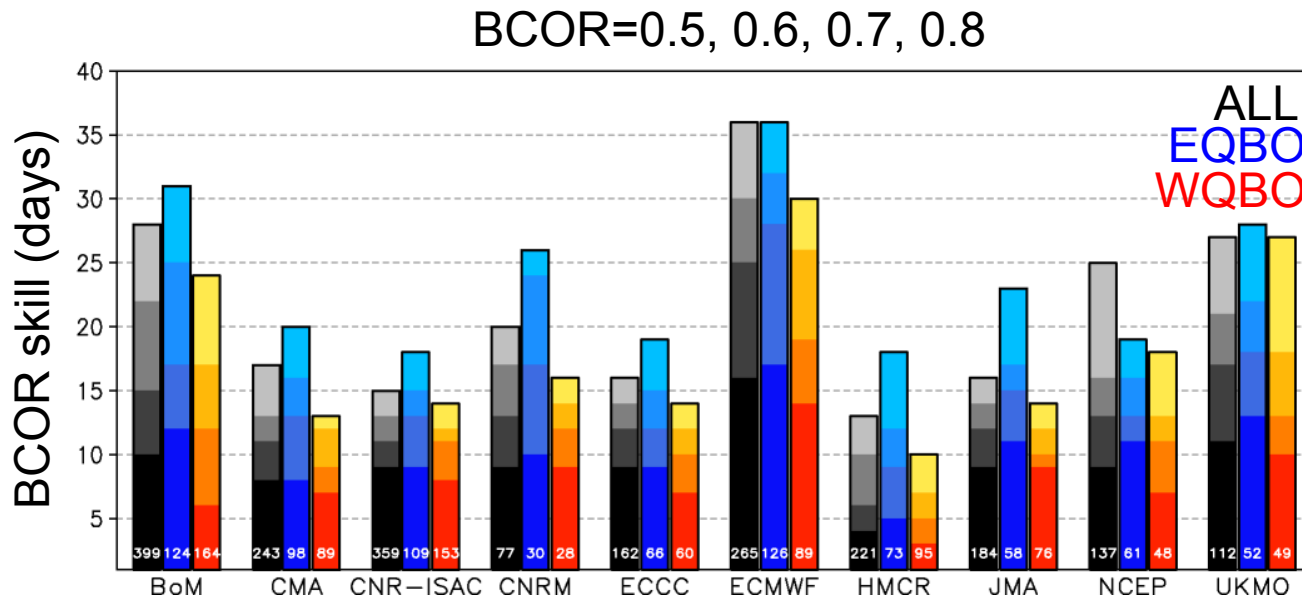
## ECMWF: MJO phase 4-5



- Large-scale circulation is **better organized during EQBO winters**. This is especially true in front of MJO convection center.

# Summary

- MJO is better predicted during EQBO winters (up to ~5 days compared with WQBO winters), regardless of initial amplitude.

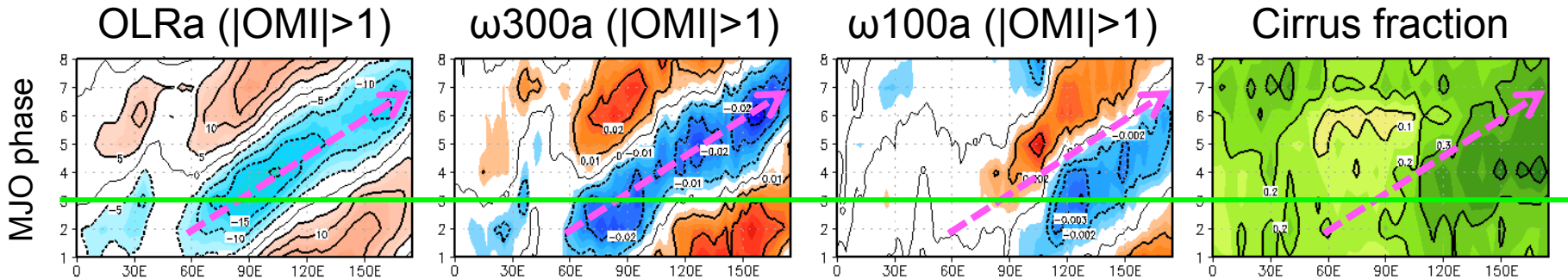


Lim, Y., S.-W. Son, A. Marshall, H. Hendon, and K.-H. Seo, 2018: Influence of the QBO on MJO prediction skill in the subseasonal-to-seasonal prediction models, submitted.



# Discussion: Mechanism?

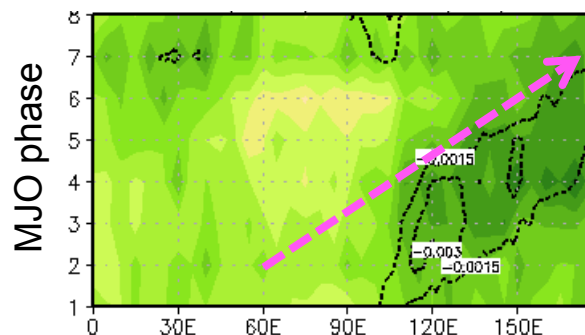
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- Analysis for 2006/07–2015/16 when CALISO datasets are available.
- $\omega_{100a}$  leads OLRa about  $30^\circ$  longitude.  $\omega_{100a}$  matches cirrus fraction rather than OLRa!

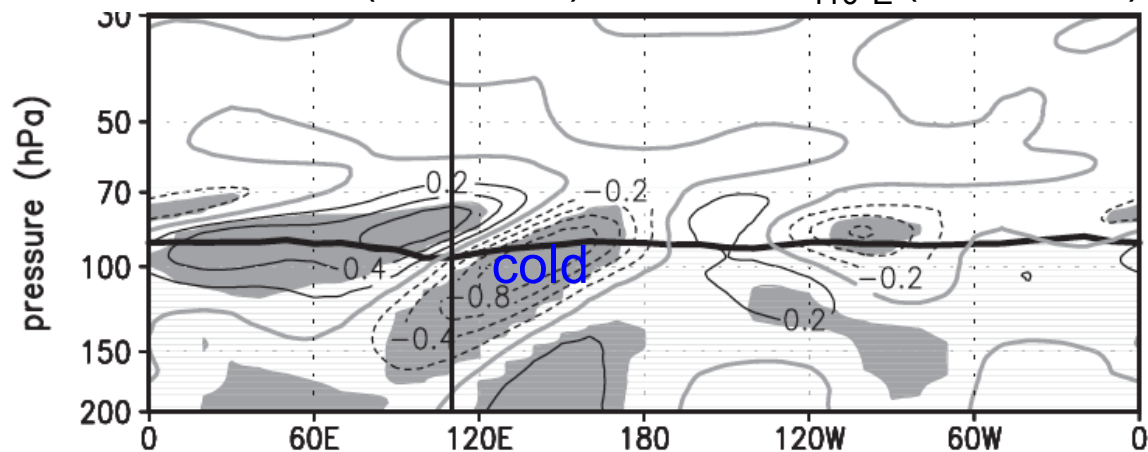
# Discussion: Mechanism?

Cirrus fraction (shading) &  $\omega_{100a}$  (contour-only upward)



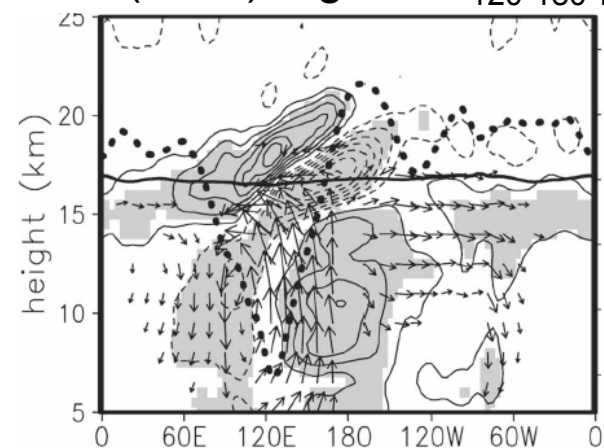
Cirrus and  $\omega_{100a}$  are maximum on the east of MJO convection. This is largely due to TTL temperature response to deep convection.

MJO-fil. Ta (COSMIC) w.r.t.  $OLR_{110^{\circ}E}$  (18 events)



Kim and Son (2012JCLI)

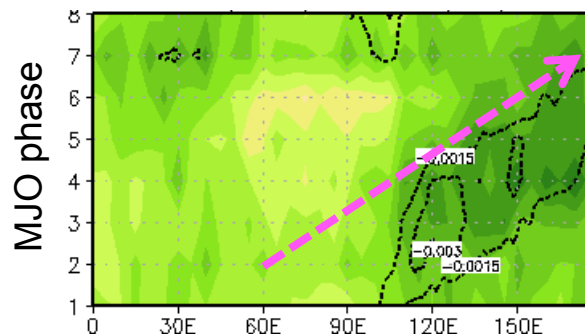
Ta (NNR) reg.  $OLR_{120-180^{\circ}E}$



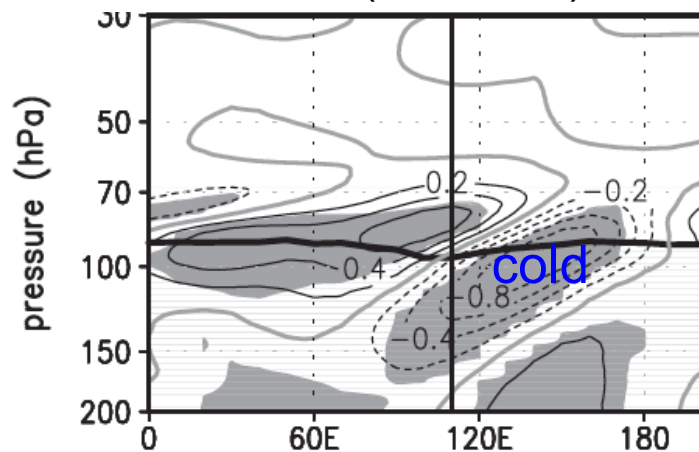
Ryu, Lee, Son (2008JAS)

# Discussion: Mechanism?

Cirrus fraction (shading) &  $\omega_{100a}$  (contour-only upward)



MJO-fil. Ta (COSMIC)



Kim and Son (2012JCLI)

Proposed hypothesis:

Adiabatic cooling on the east of MJO convection

-> more cirrus

-> weak diurnal cycle across the Maritime continent

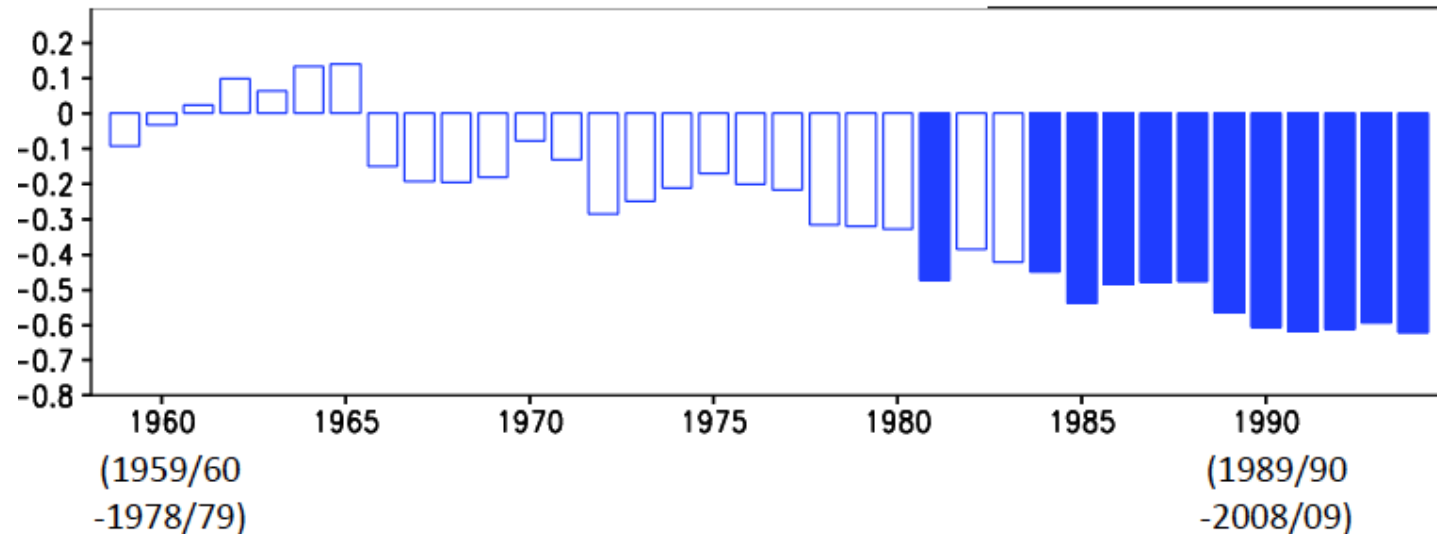
-> weak Maritime continent barrier?

EQBO, causing a colder tropopause, may enhance the above processes.

# Discussion: QBO-MJO link trend?

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- Need to establish the mechanism(s) of QBO-MJO link
- Need to understand possible changes in future.



20-yr moving correlation between QBO and MJO. MJO amplitude is estimated from velocity potential of NNR (Ventrice et al. 2013).