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Assessing the Impact of Ocean In-situ Observations on MJO Propagation across the Maritime Continent in ECMWF Subseasonal Forecasts

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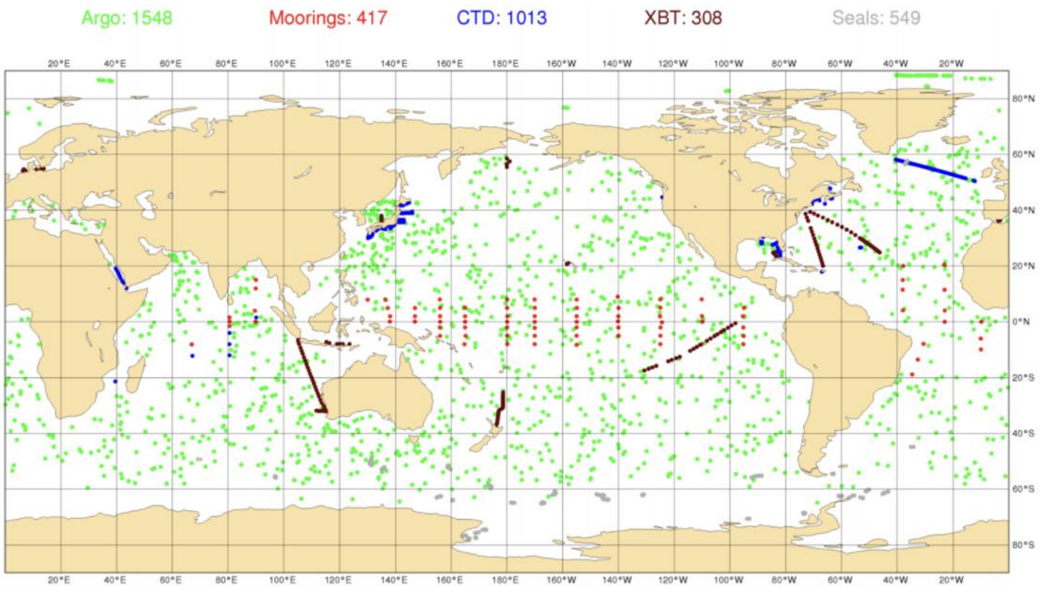
Ocean observing system experiments (OSE) and subseasonal forecasts in ECMWF model

InSitu observations assimilated in ORAS5: July 2-6, 2010



Zuo et al., ECMWF Tech Memo., 2015

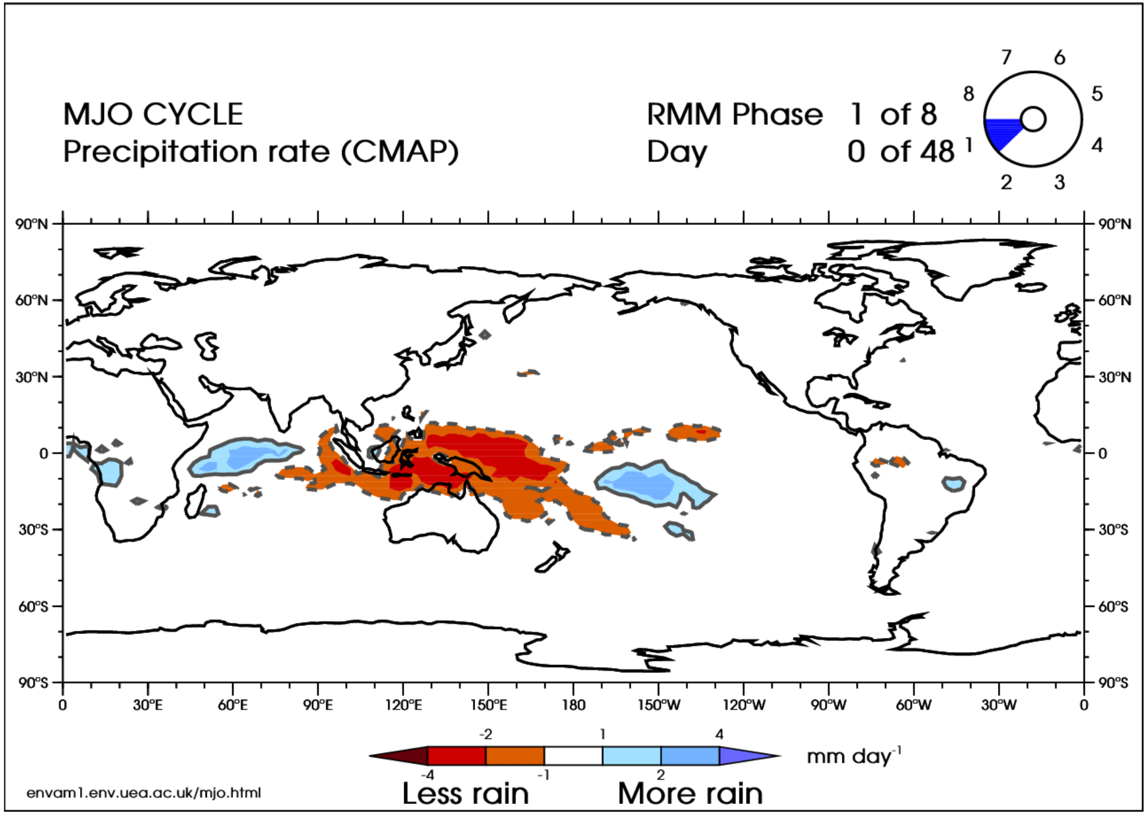
OSEs are used to examine the value of different types of observations (O5-LR).

Subseasonal forecasts (model cycle 47R1)
32-day coupled forecast
Initialized from the first day of each month
From 1993 to 2015 (23 years)

all_obs is initialized from the OSE with all subsurface observations assimilated (5 ensemble members).

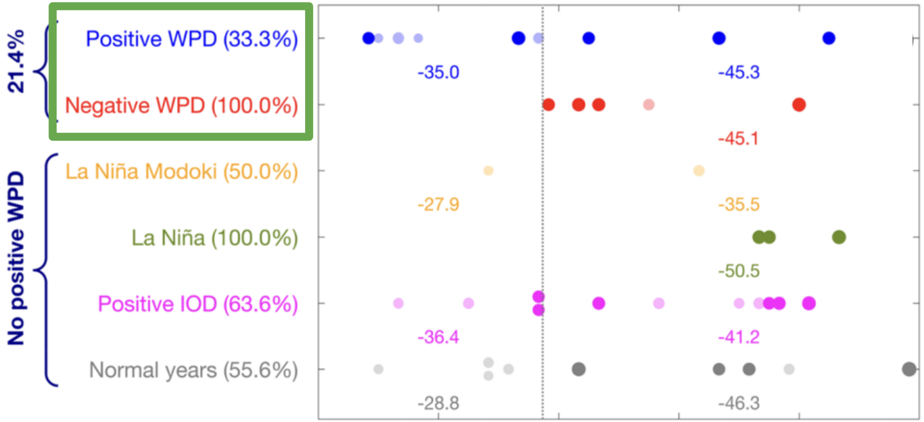
no_insitu is initialized from the OSE without any subsurface data assimilation (5 ensemble members).

What is the Madden-Julian Oscillation (MJO)?

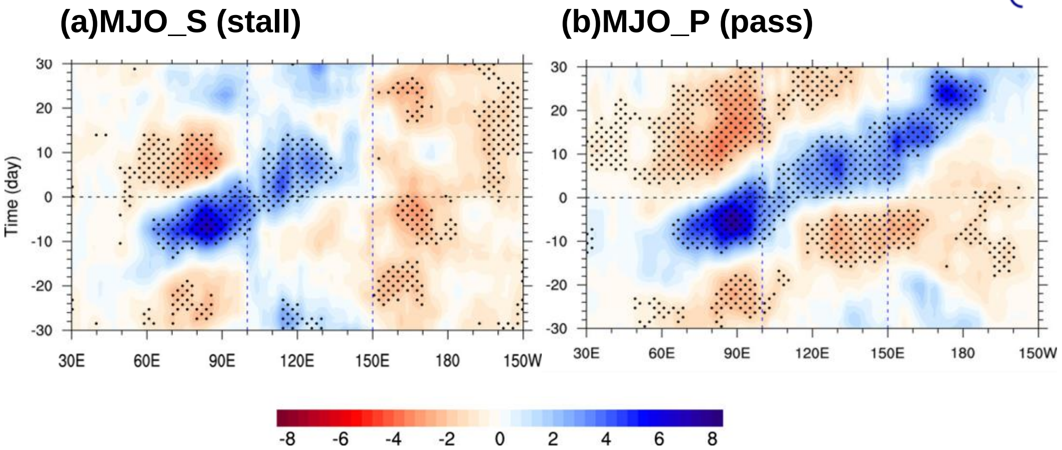


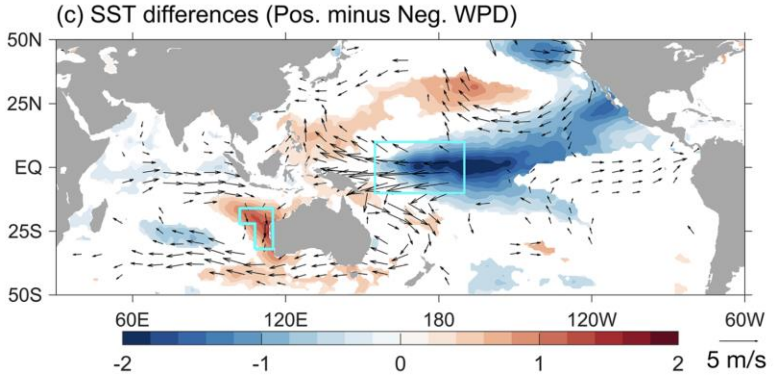
MJO propagation across the Maritime Continent (MC)

MC barrier effect:
As MJO propagates from the Indian ocean to the Western Pacific, it tends to decay and sometimes stall over MC.



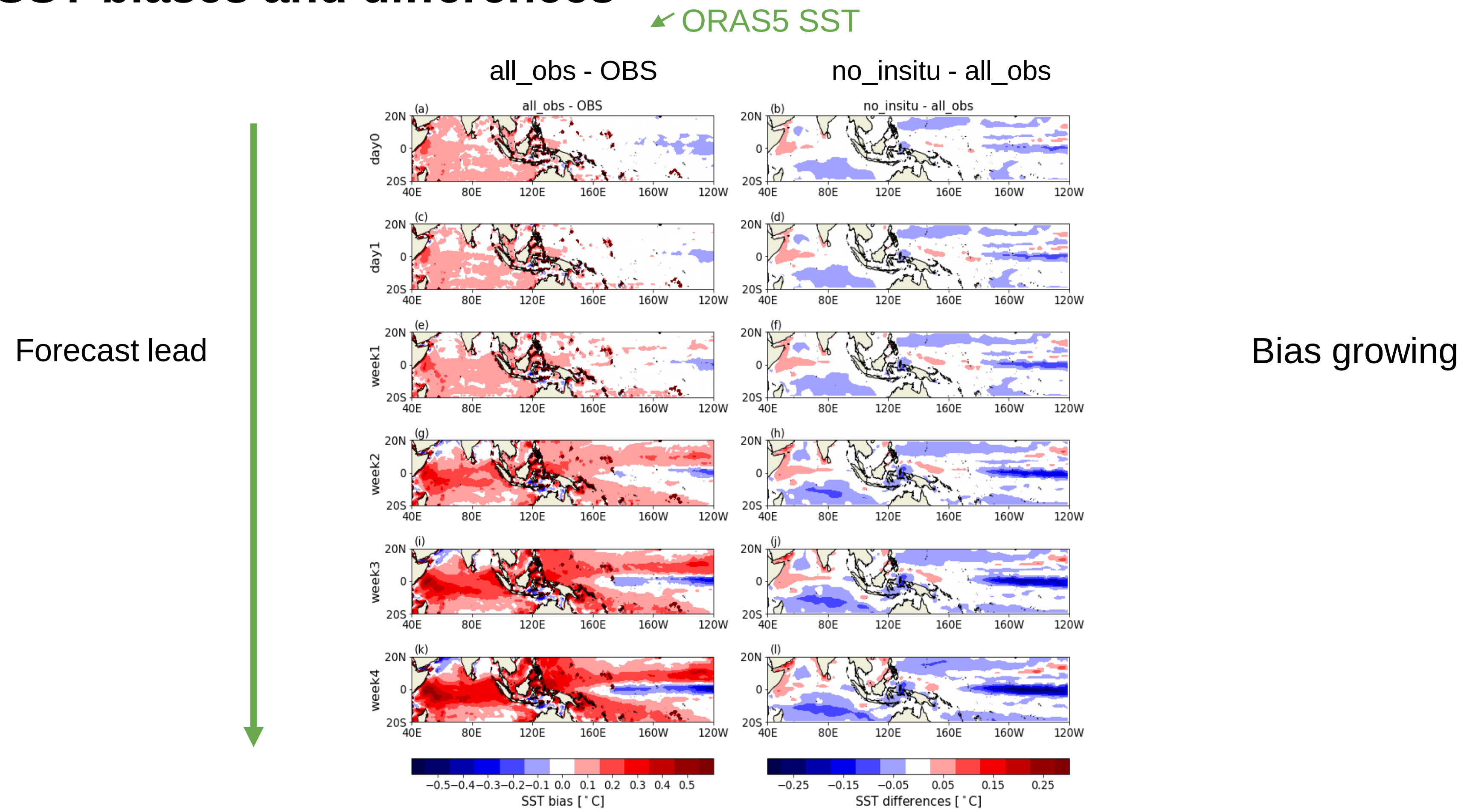
(C. Zhang & Lin 2017) precip





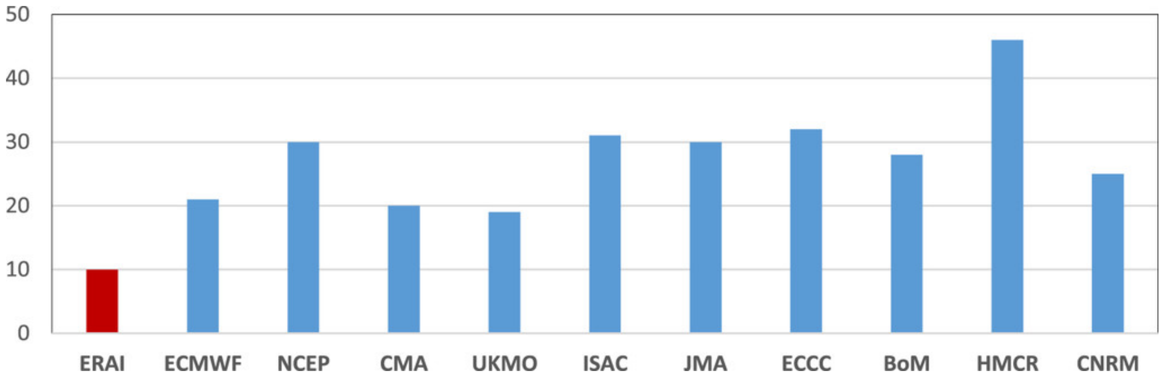
(L. Zhang & Han 2020) Warm Pool Dipole

SST biases and differences



MJO propagation across the Maritime Continent (MC)

MC prediction barrier:
Models exaggerate the MC barrier effect, allowing much fewer MJO events to cross the MC.



Percentage of MJO_S events (Kim et al., 2018)

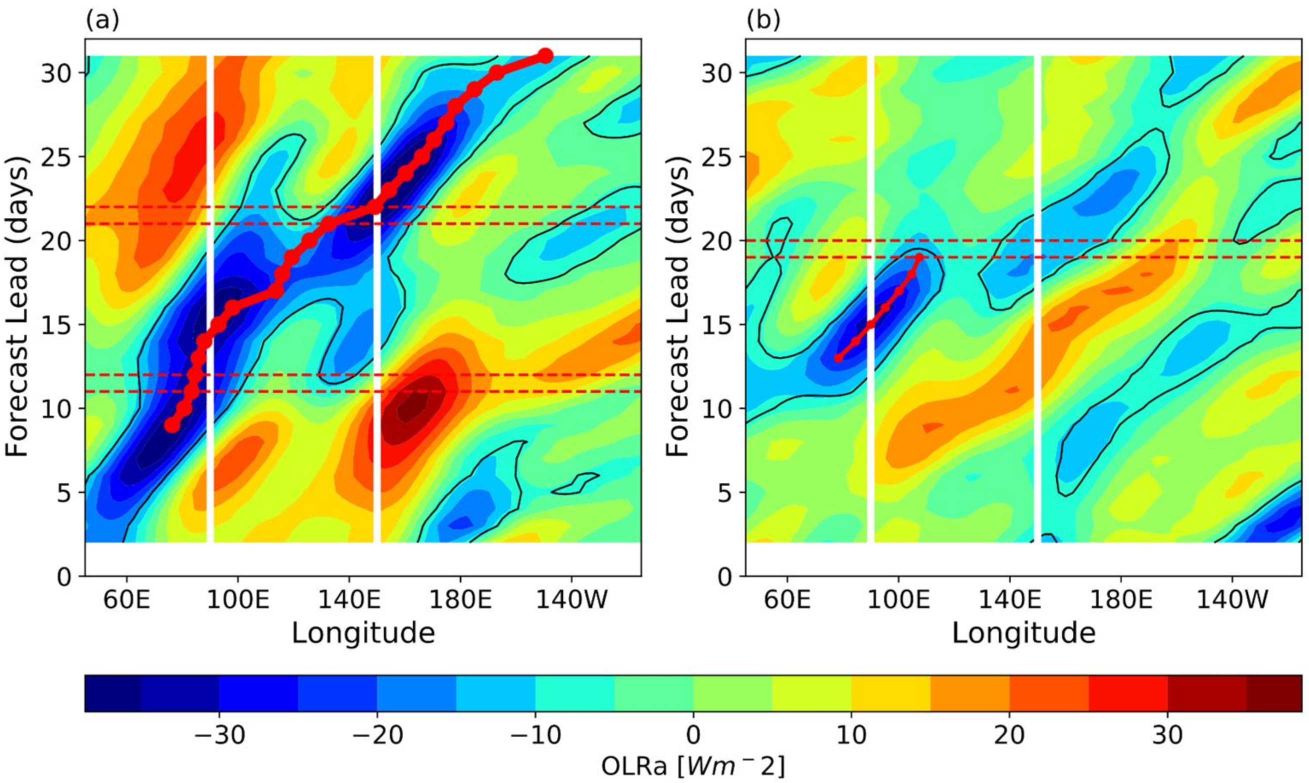
Evaluation metric

The # of successfully forecasted MJO_P events in the subseasonal forecast

OLRa-based MJO_P identification

MJO_P:
An MJO event whose track
- Starts from the west of 90E,
- And propagates to the east of 150E

within the 32 days.



OLRa-based forecast evaluation

No differences between all_obs and no_insitu;
RMMI-based evaluation shows the same result.

	MJO_P	MJO_P in OBS	MJO_IO (RMMI-based)	MJO_IO_P	Passing rate
OBS	**79**	79	44	22	**0.50**
all_obs	**70**	**35**	45	12	**0.27**
	[70,65,65,69,68]	[30,25,33,27,29]	[45,45,45,44,45]	[15,7,11,10,14]	[0.25]
no_insitu	**68**	**37**	45	13	**0.29**
	[76,69,58,75,62]	[35,26,21,32,32]	[45,45,45,44,45]	[13,10,8,16,13]	[0.27]

- numbers in the bracket are for the individual ensemble members.

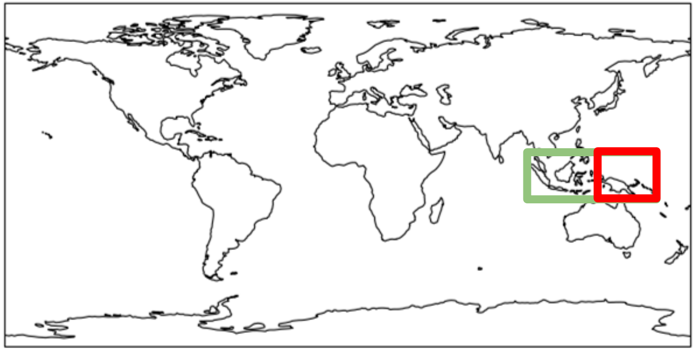
Process diagnostics: Moist Static Energy (MSE) budget analysis

$$\left\{\frac{\partial m}{\partial t}\right\}' = -\left\{u\frac{\partial m}{\partial x}\right\}' - \left\{v\frac{\partial m}{\partial y}\right\}' - \left\{\omega\frac{\partial m}{\partial p}\right\}' + LH' + SH' + \{LW\}' + \{SW\}'$$

MSE tendency — advection — Heat fluxes — radiation fluxes

$$m = C_pT + gZ + L_vq$$

Moisture mode theory: the growth, decay and the eastward propagation of the MJO convection is governed by the intraseasonal moisture anomalies

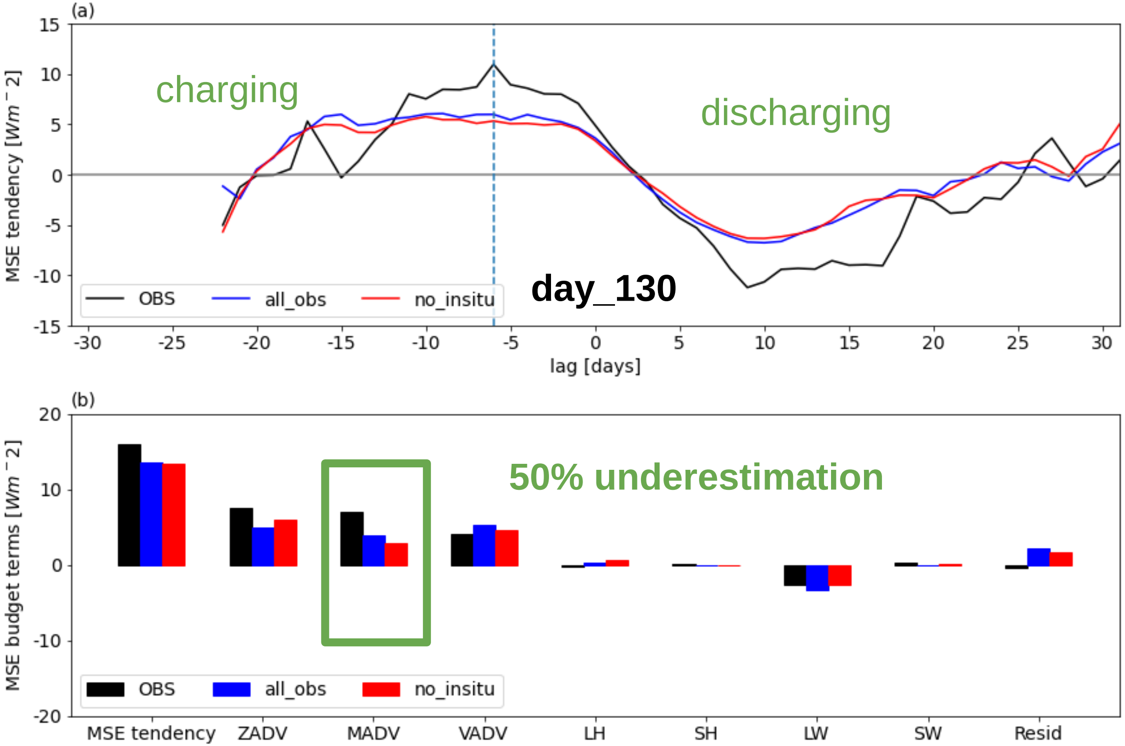


Region of interest:
The eastern part of MC

130E to 150E
15N to 15S

- Remove the 23 year daily climatology
- Average over a 10-day window

MSE analysis: underestimated meridional advection



The MSE tendency is positive before the arrival and is negative after the arrival.

Composite of MJO_P events in OBS, all_obs and no_insitu

underestimated meridional advection: robust or not?

Multiple linear regression on MSE tendency with MSE budget terms

Coefficient of the MADV:

OBS: **0.67**

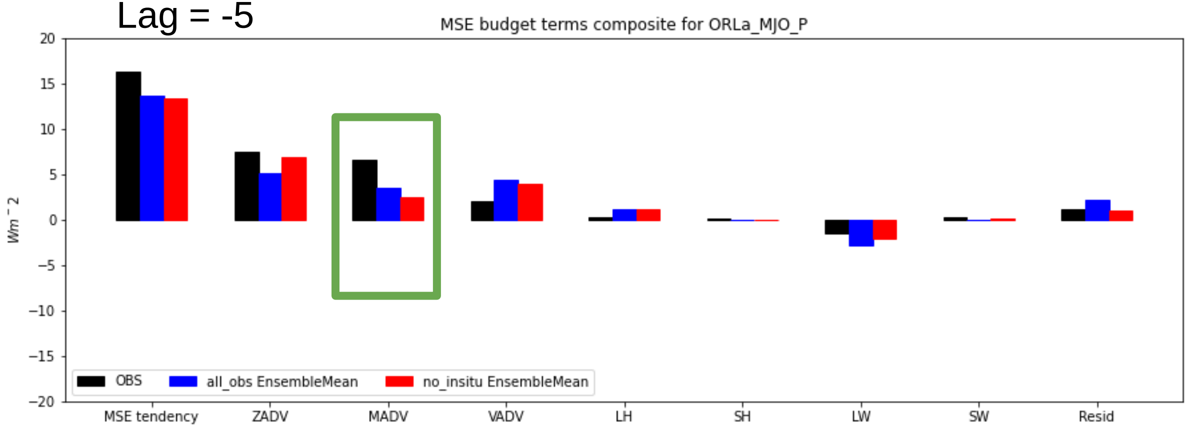
All_obs: **0.35**

No_insitu: **0.37**

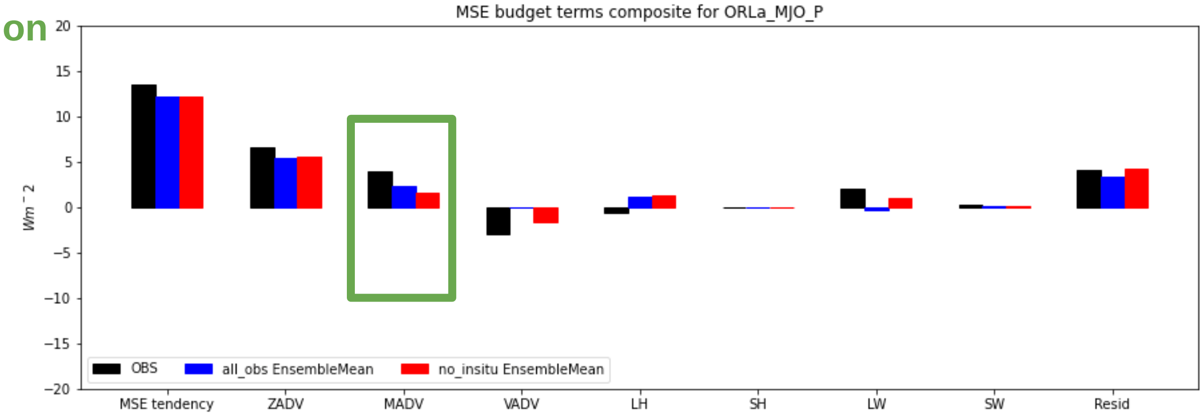
underestimation

The underestimation is robust.

Lag = -5



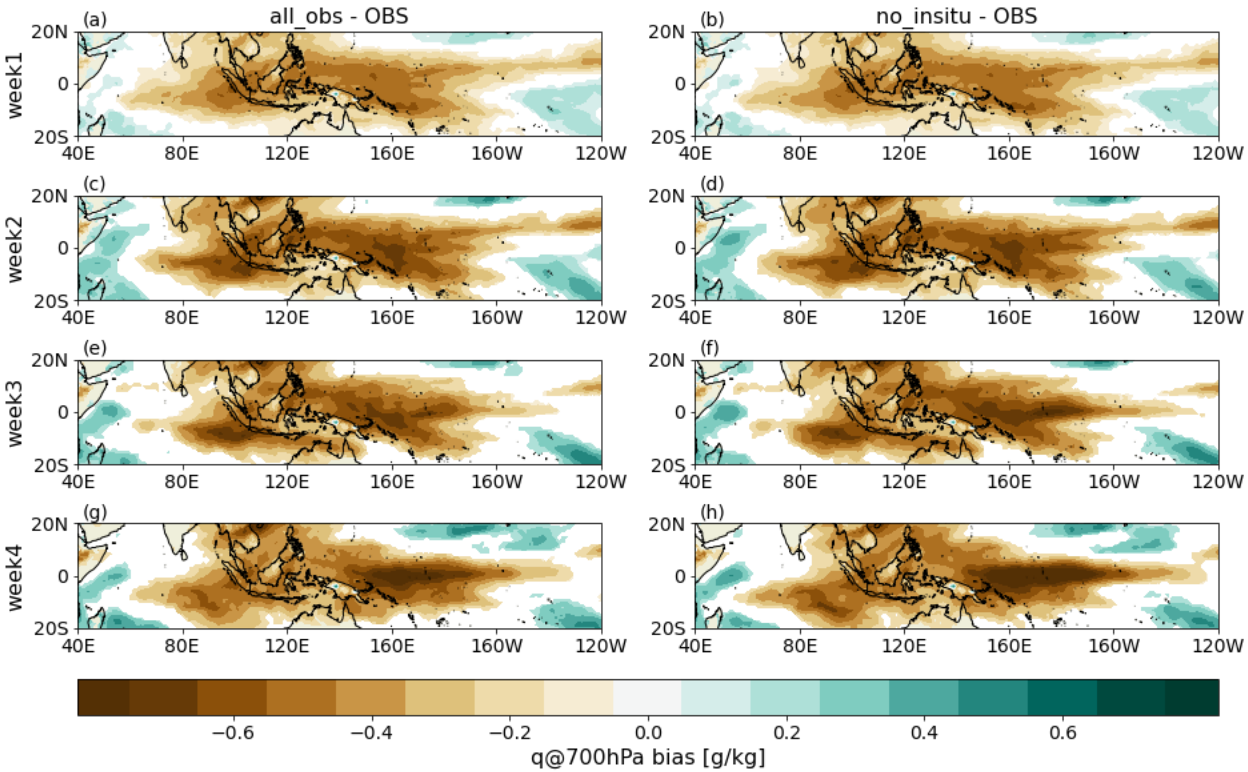
Lag = -2



underestimated meridional advection: dry biases

The seasonal mean moisture gradient advected by the intraseasonal wind dominates the intraseasonal horizontal moisture advection.

Many studies argue that the model tends to underestimate the MJO due to a systematic dry bias.



underestimated meridional advection: T1, T2 and T3

Composite advecting composite; v: intraseasonal wind; Q: climatological moisture

$$-v_i \frac{\partial Q_i}{\partial y} = -(v_{obs} + v_i^*) \frac{\partial (Q_{obs} + Q_i^*)}{\partial y} = -v_{obs} \frac{\partial Q_{obs}}{\partial y} - v_{obs} \frac{\partial Q_i^*}{\partial y} - v_i^* \frac{\partial Q_{obs}}{\partial y} - v_i^* \frac{\partial Q_i^*}{\partial y}$$

The differences between the model forecast and the observation are rooted in these 3 terms

$$T_{1i} = -v_{obs} \frac{\partial Q_i^*}{\partial y}$$

Observed winds advecting the moisture biases

$$T_{2i} = -v_i^* \frac{\partial Q_{obs}}{\partial y}$$

Wind biases advecting the observed moisture

$$T_{3i} = -v_i^* \frac{\partial Q_i^*}{\partial y}$$

Wind biases advecting the moisture biases

underestimated meridional advection: T1, T2 and T3

Observed winds advecting the moisture biases

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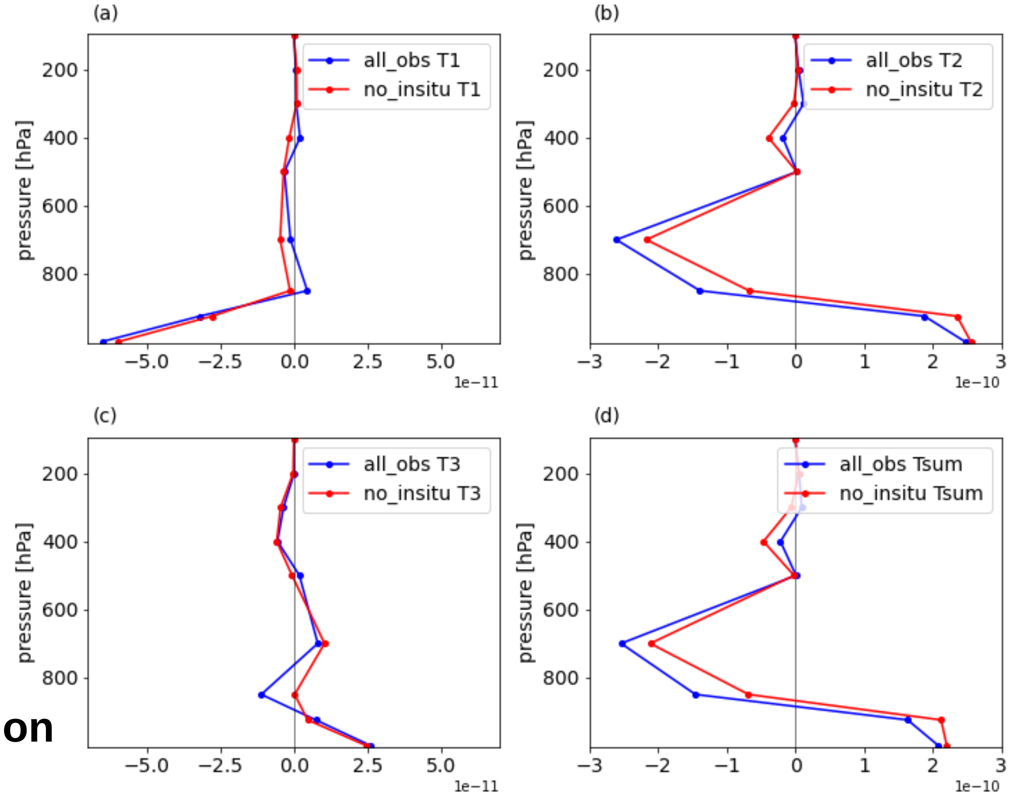
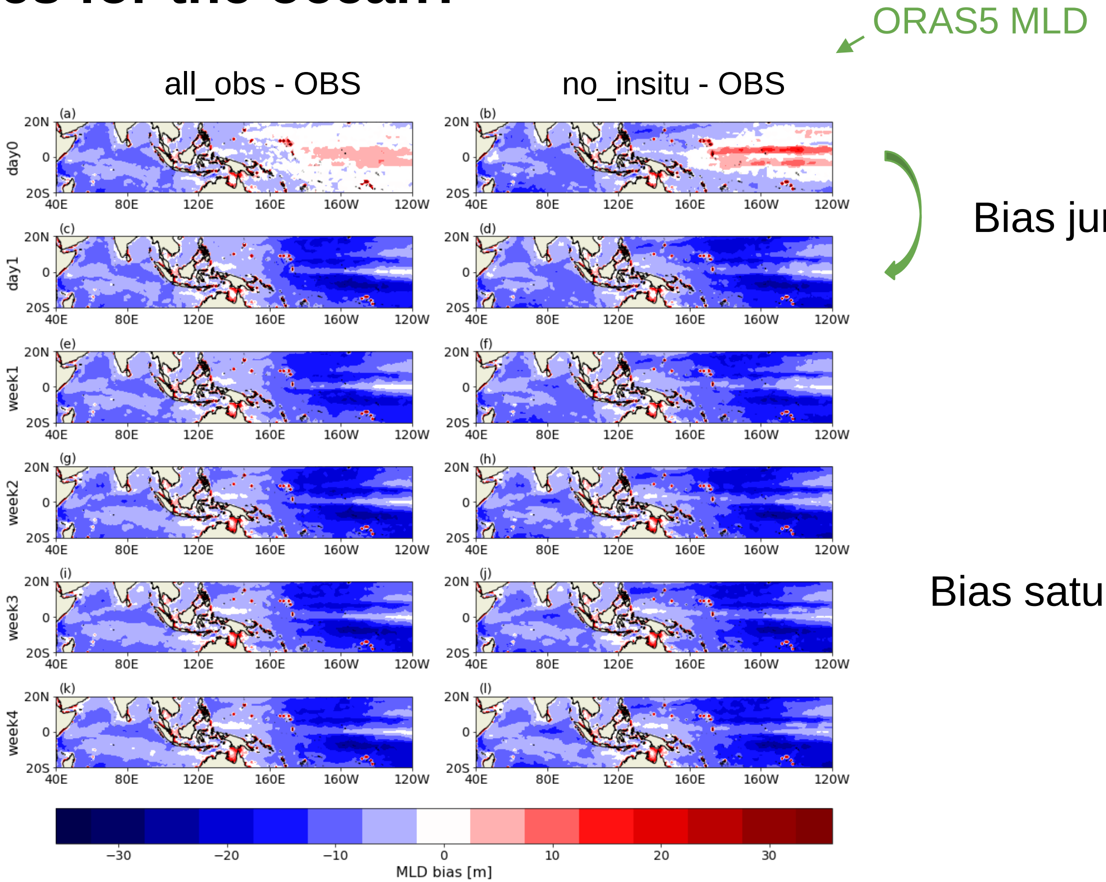


Wind biases dominate the underestimation of meridional moisture advection.

Note that the scale of (b) and (d) are one order of magnitude greater than that of (a) and (c).

Atmospheric biases dominate the error growth. Any opportunities for the ocean?

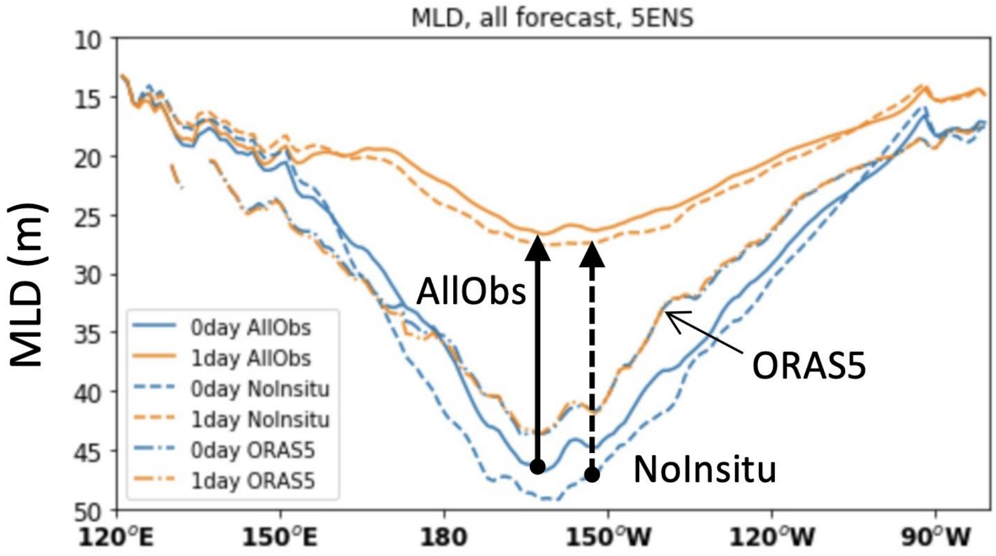
Forecast lead



Bias jump

Bias saturated

Ocean Mixed Layer Depth biases



Wei et al., 2022 (submitted)

Initialization shock

Uncoupled data assimilation for coupled forecast initialization

Takeaways

- Ocean initialization with subsurface observation assimilation has an impact on the S2S forecasts of SST
- Yet, ocean initialization does not have an impact on predicting the MJO propagation across the MC in the ECMWF subseasonal forecast.
- The large atmospheric biases in the model likely cause the insensitivity of the model forecasts to the SST differences.

Discussion

- Reducing the intraseasonal wind biases could help overcome the MJO prediction barrier in ECMWF subseasonal forecast model.
- Coupled data assimilation for initializing subseasonal forecasts might help reduce the initialization shock.

Thanks!