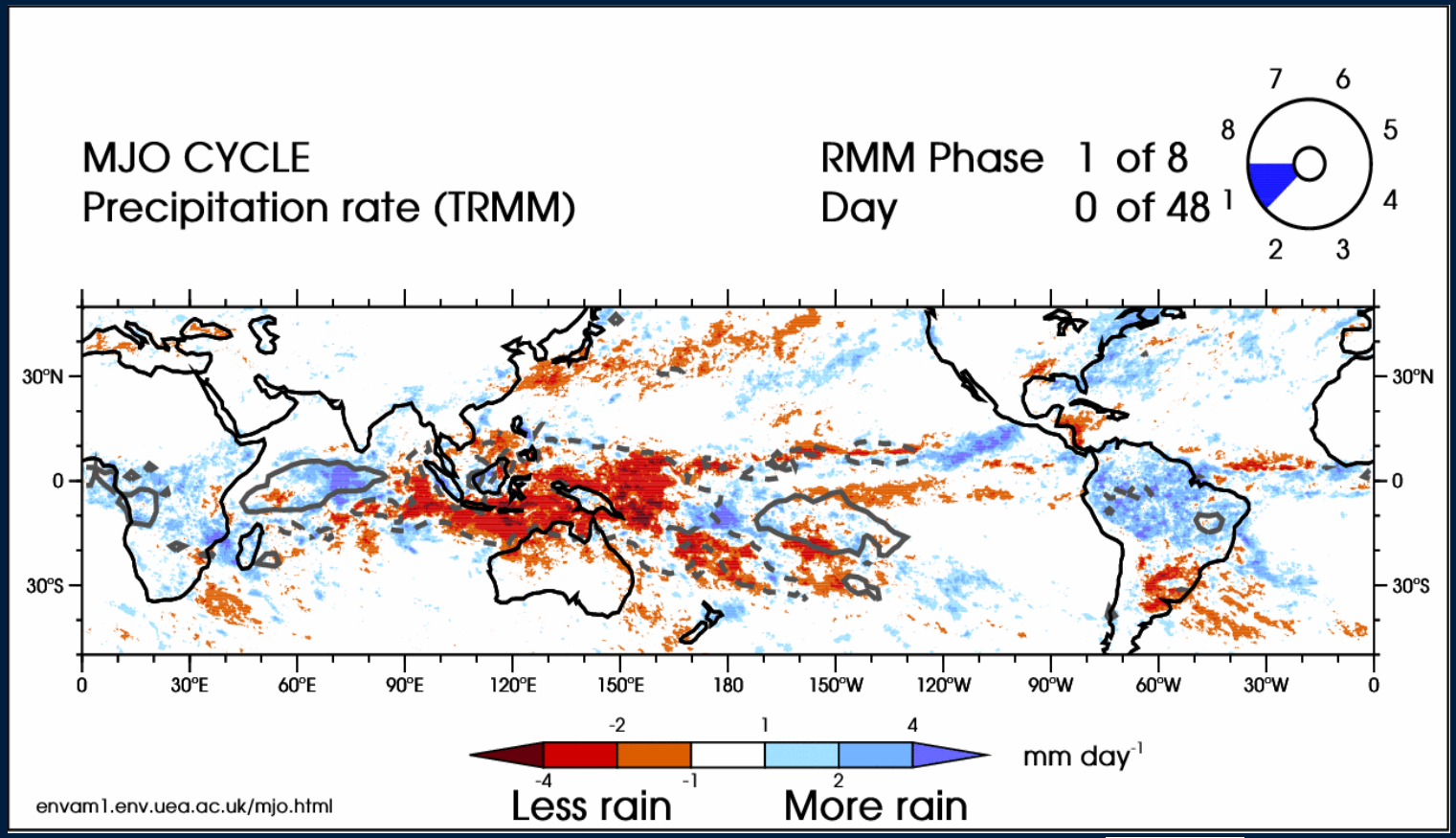
The Maritime Continent barrier effect on MJO predictability

Hyemi Kim[1,2]

[1]*Ewha Womans Univ., Seoul, S. Korea*

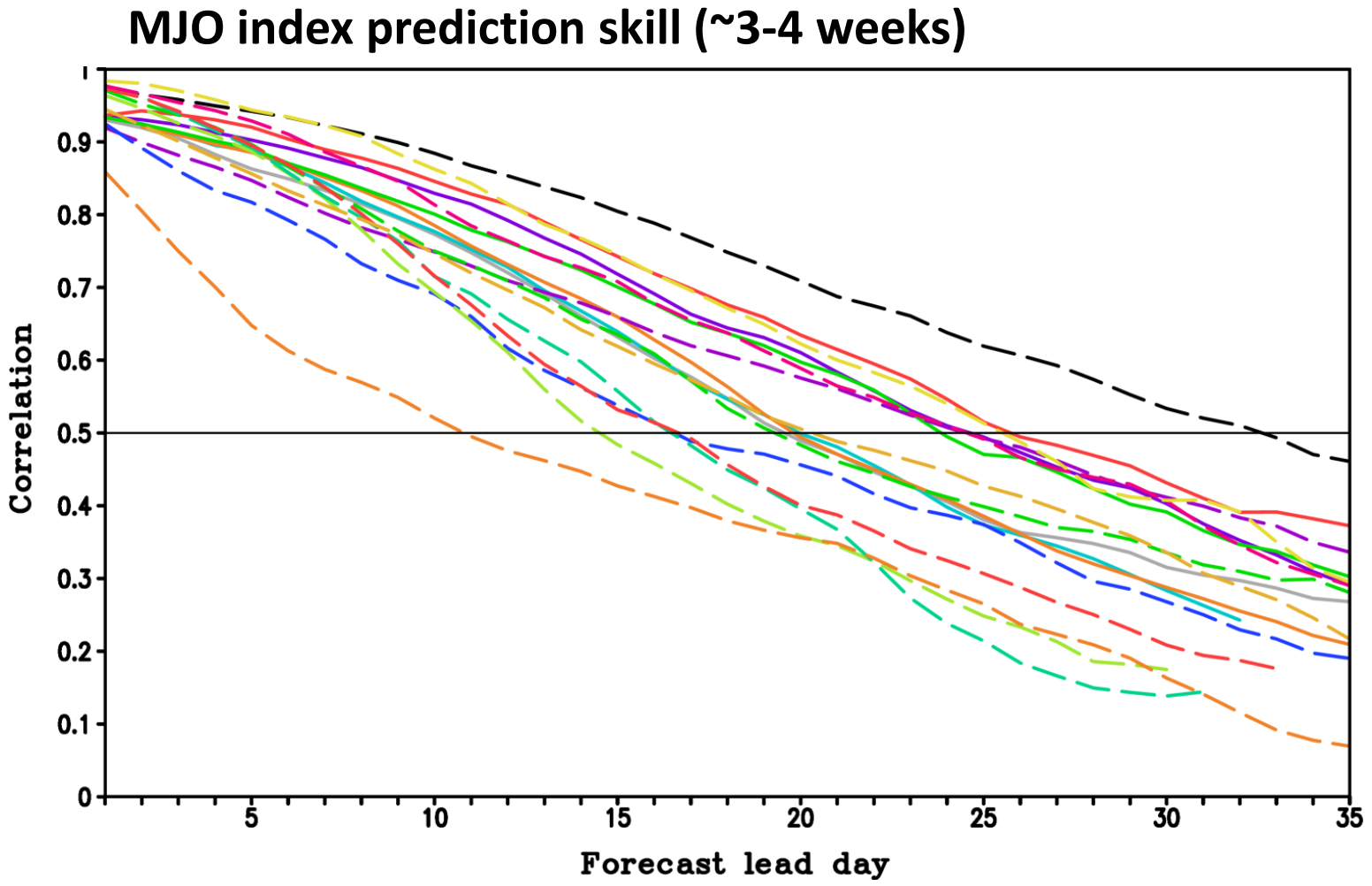
[2]*Stony Brook Univ., NY, USA*



hyemi.kim@ewha.ac.kr

https://sites.google.com/site/climatekim/

MJO prediction: S2S & SubX models



- Kim et al. (2019)
- Lim et al. (2019)
- Jiang et al. (2020)

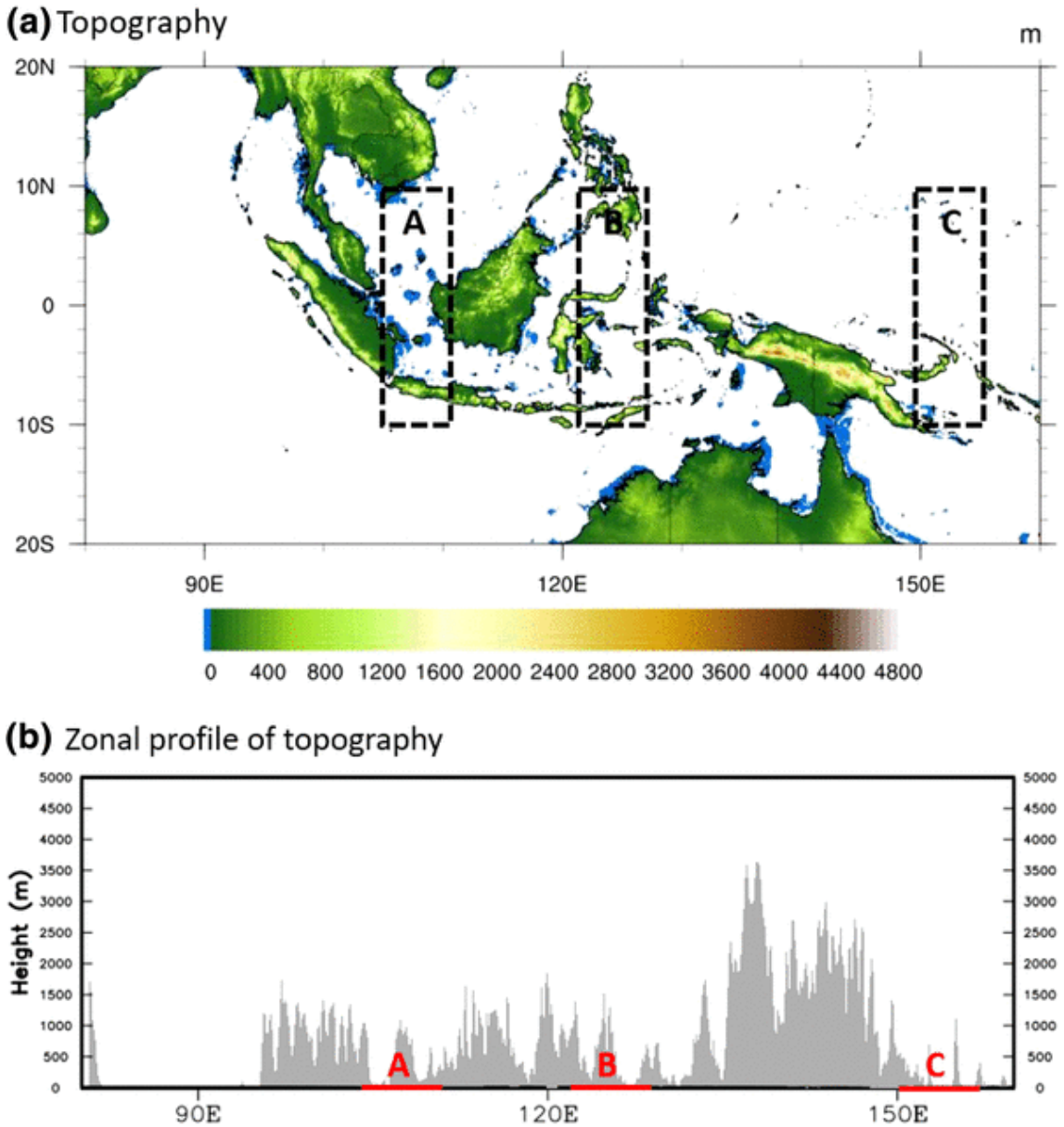
Common Issues in MJO prediction

- Lack of ensemble spread (under-dispersive)
- Quick decay of MJO signal
- Weaker convection-moisture coupling
- Missing interaction with other sources of predictability (e.g., QBO)
- **MJO Maritime Continent prediction/propagation barrier**

among many others…

H. Kim, F. Vitart, D. Waliser, 2018: Prediction of the Madden-Julian Oscillation: A Review (*J. Climate*)

Maritime Continent prediction barrier

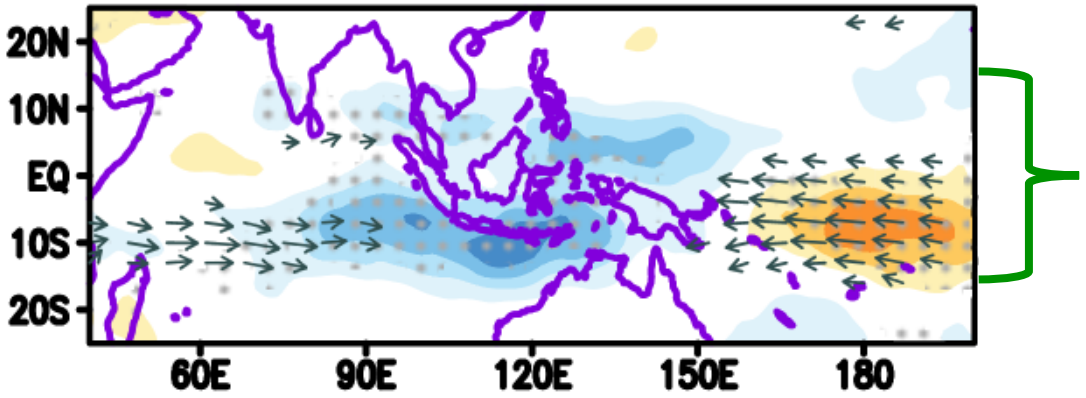


Maritime Continent prediction barrier

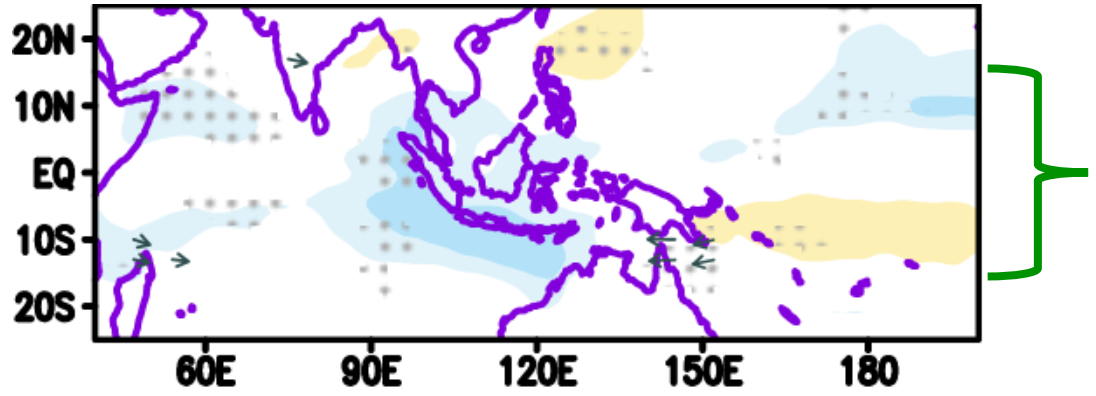
Forecast DAY **10**

OLR & 850hPa wind anomaly

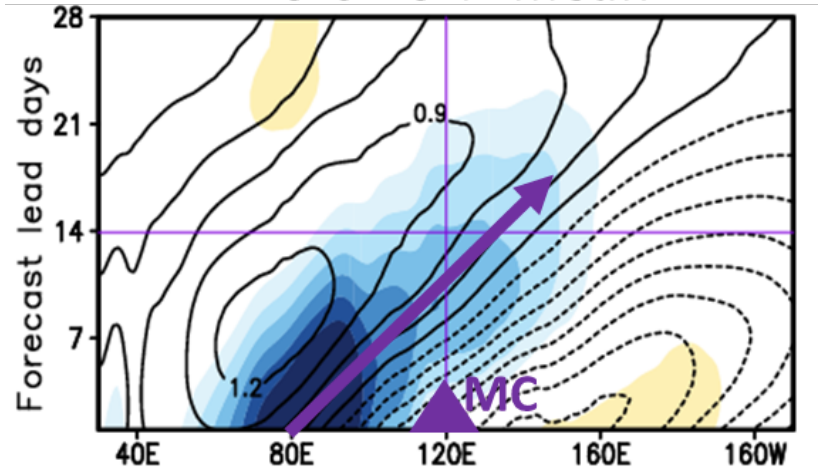
OBS (NOAA OLR/ERAI)



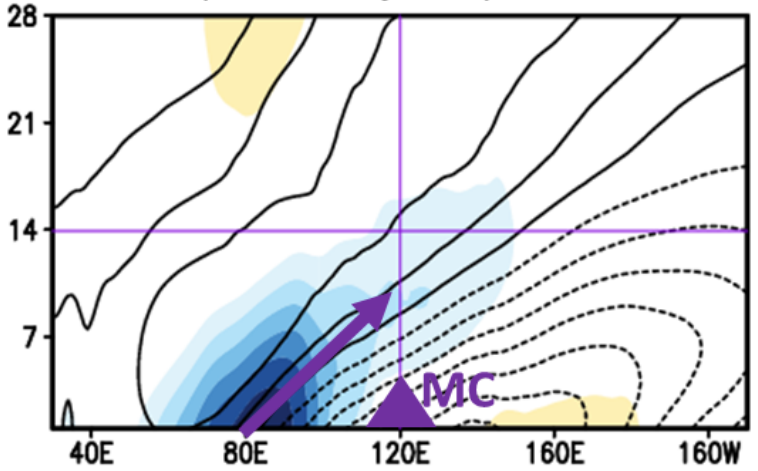
ECMWF (S2S)

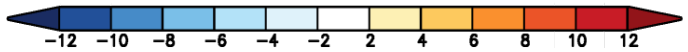


15°S-15°N mean



b. S2S (ECMWF−Cy43r3)



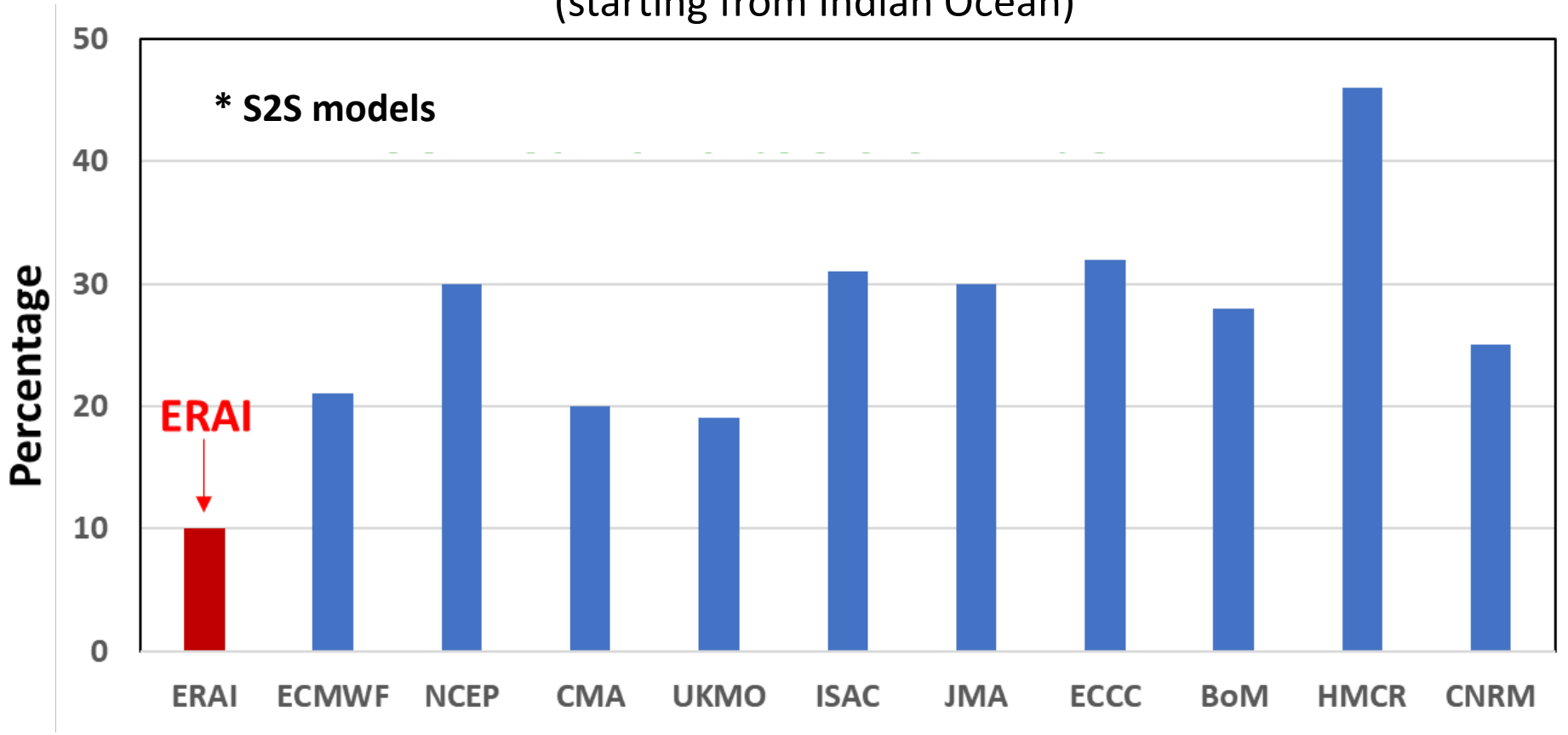


Shading: OLRa
Contour: U850a

* Kim et al. (2019)

Maritime Continent prediction barrier

% of MJO events **NOT crossing the Maritime Continent**
(starting from Indian Ocean)



Kim et al. (2018, modified Table 1 from Vitart 2017)

MJO eastward propagation process (moisture mode theory)

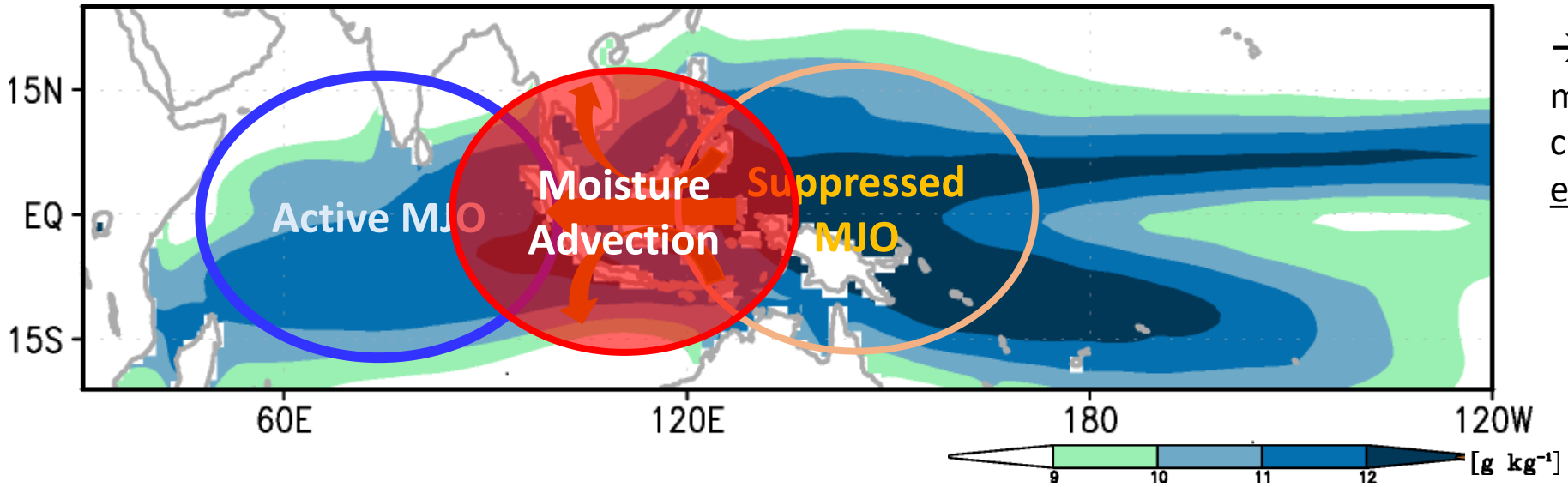
Observation (ERAI, NOAA OLR)

$$-\langle V' \cdot \nabla \bar{Q} \rangle$$

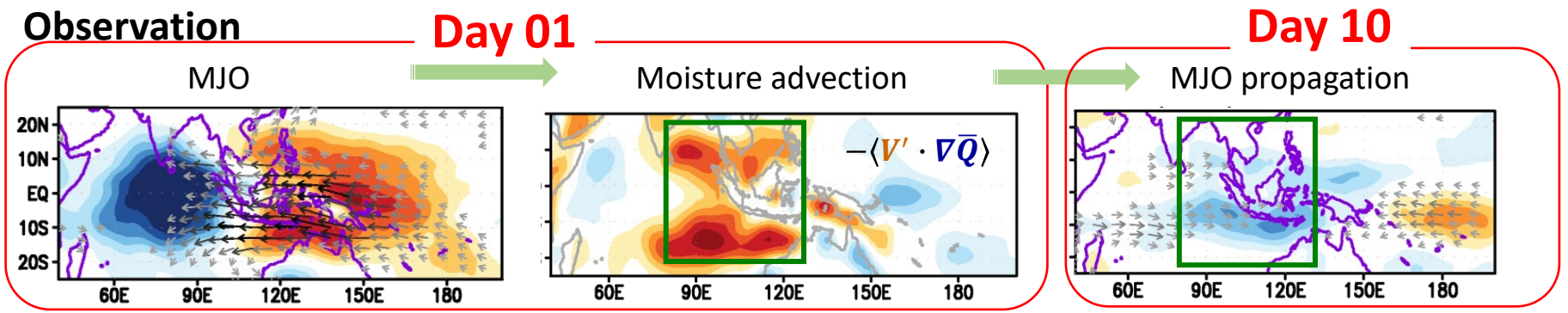
MJO wind Mean Q

→ Advection of seasonal mean moisture ($\bar{Q}$) by anomalous MJO circulation (**V'**) controls the MJO eastward propagation

Winter mean moisture (Q850)



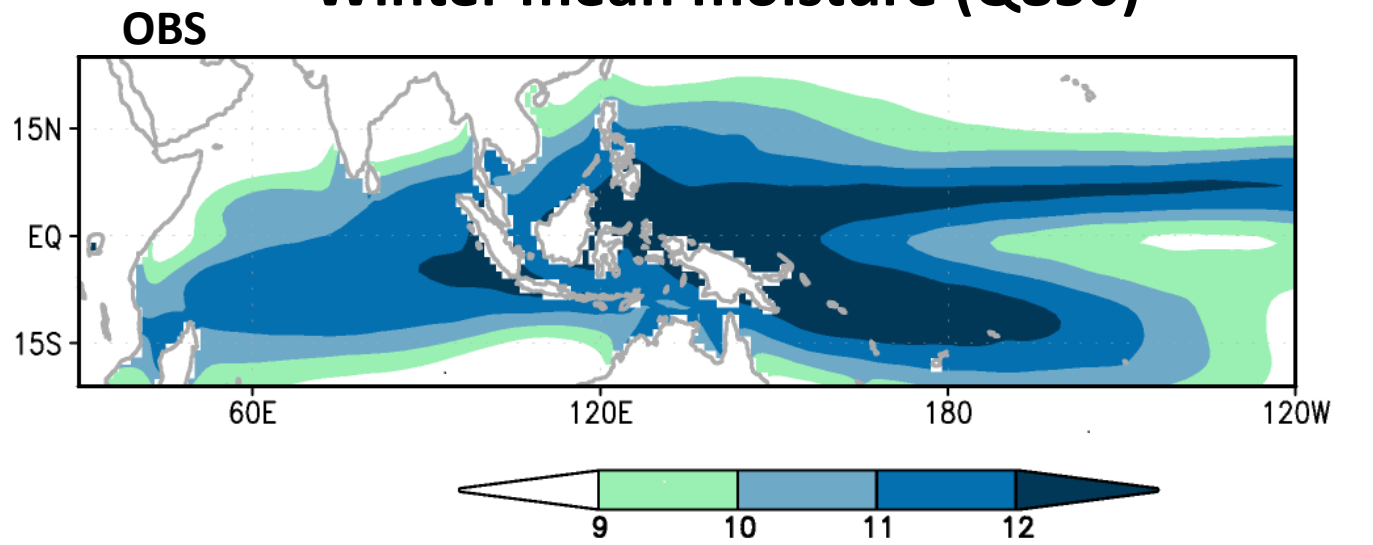
Observation

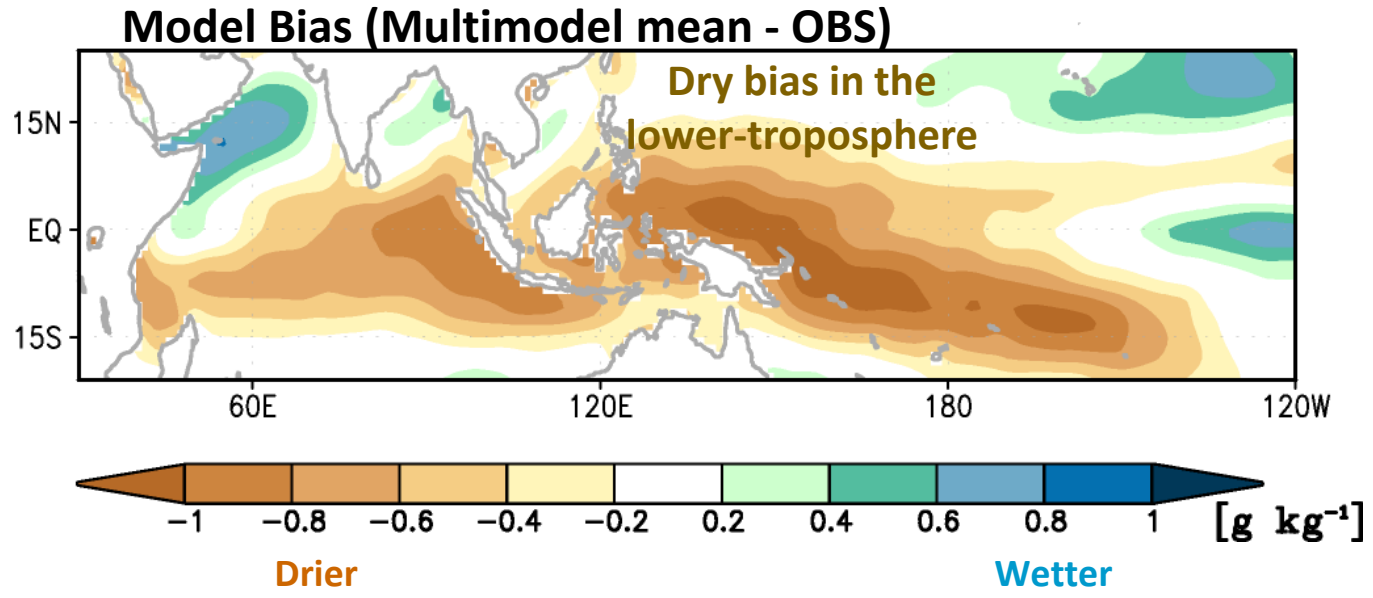


Kim et al. (2019)

Mean State Bias

Winter mean moisture (Q850)

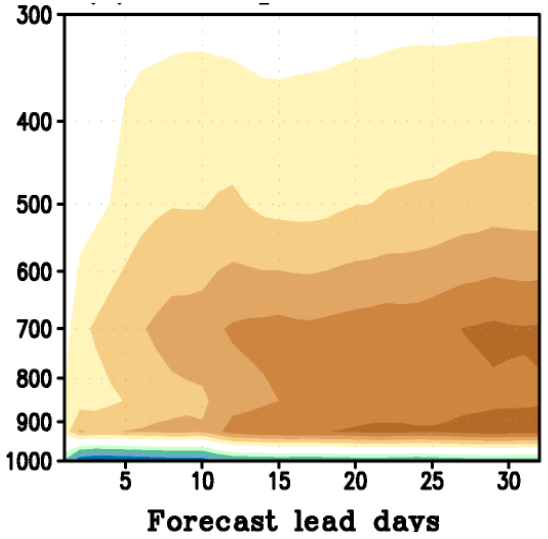




$$-\langle V' \cdot \nabla \bar{Q} \rangle$$

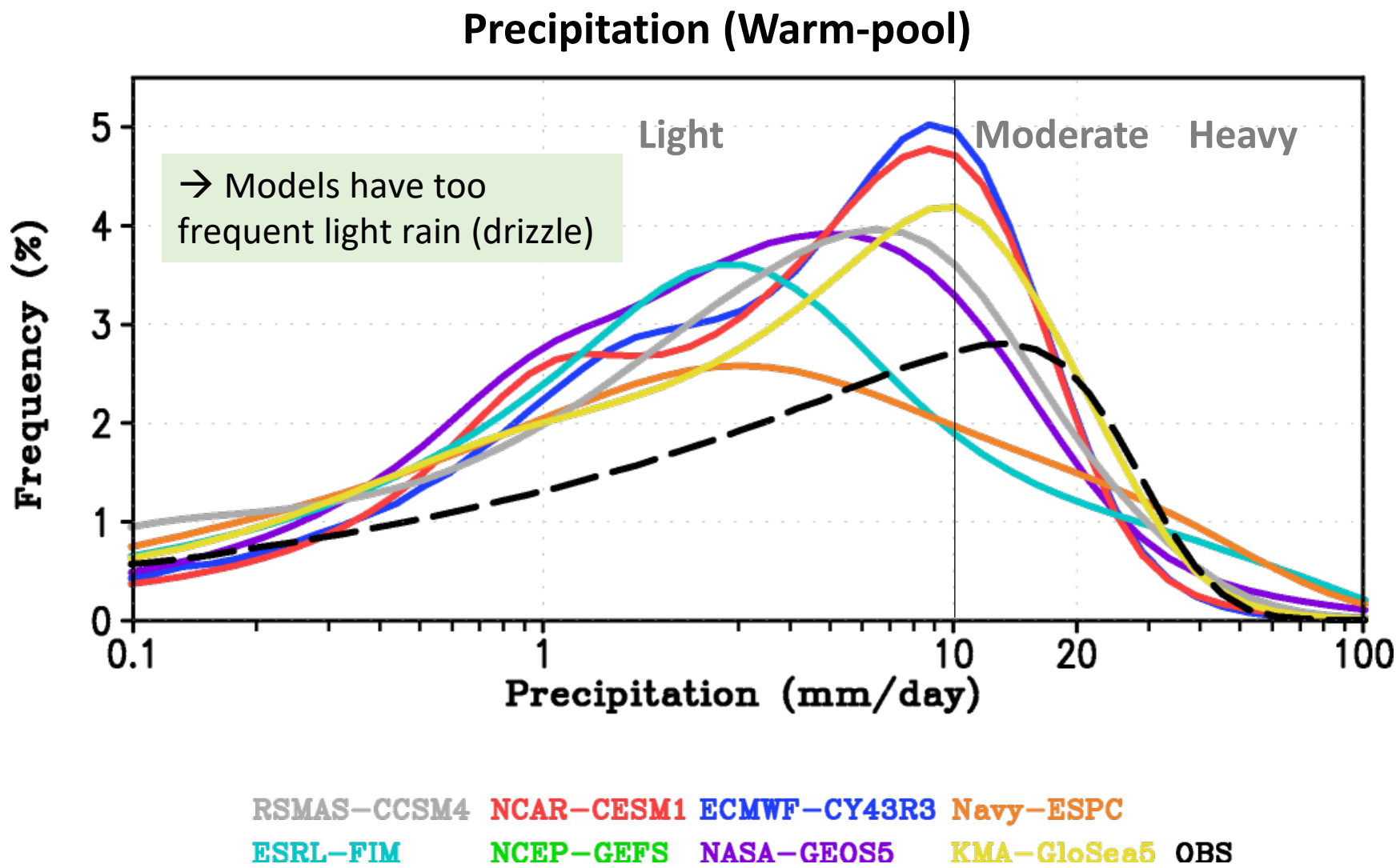
MJO wind Mean Q

Bias: IFS (Q)



Kim et al. (2019, 2017)

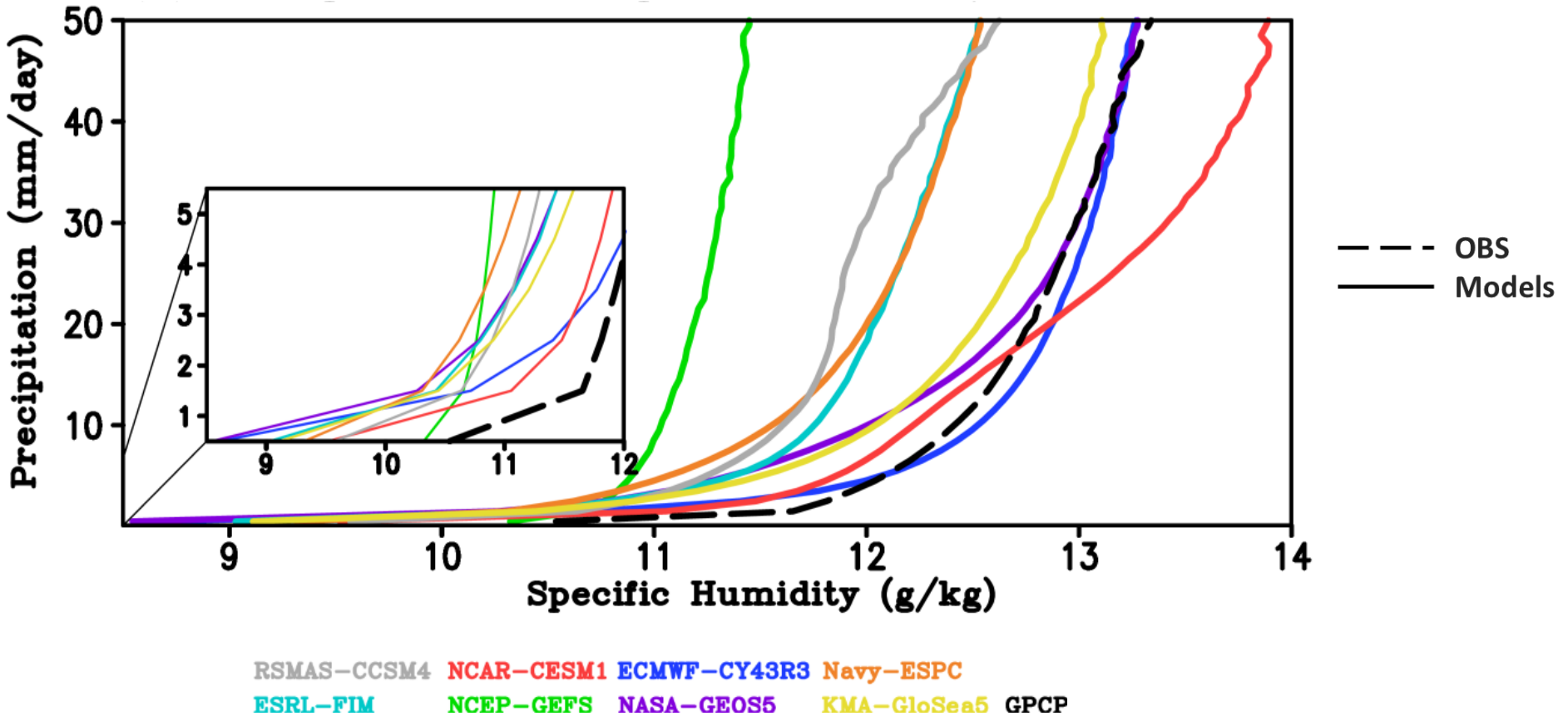
Precipitation distribution



- Precip. days/Total days
- 4-weeks average
- [60E-180E, 15S-15N]
- Control simulation
- Land area excluded

Kim et al. (2019)

Moisture-Precipitation coupling

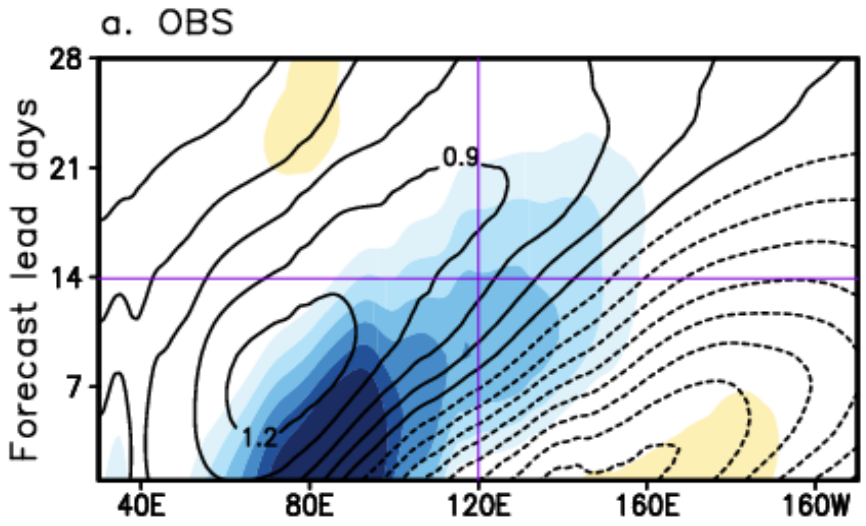


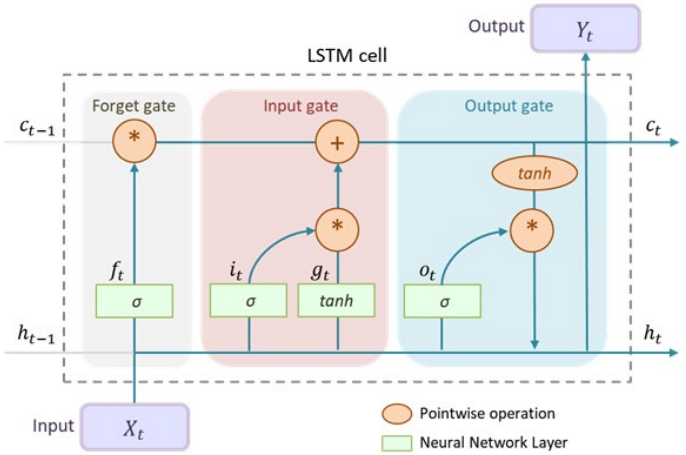
- Convection starts **too early** and occurs **too frequently** in the **low moisture regime**
- Deep convection is not sufficiently inhibited when tropospheric moisture is low
- This is likely due to the representation of entrainment

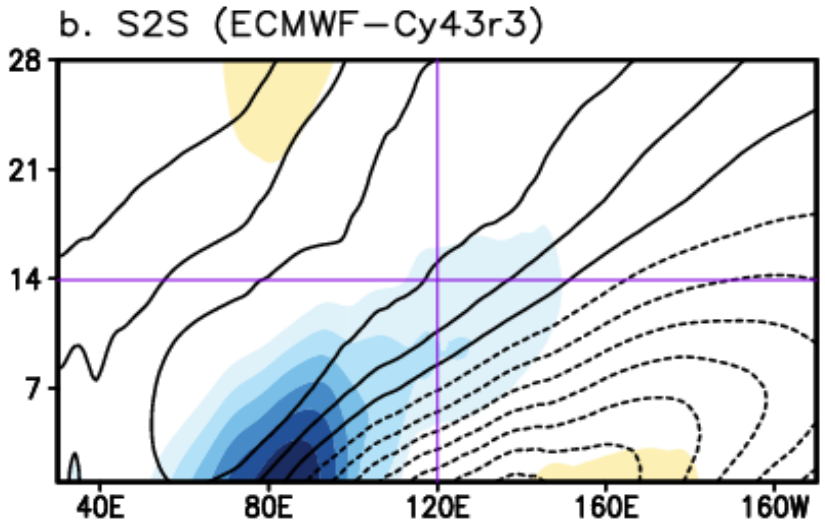
→ **Moisture-depleted atmosphere (dry bias)**

Kim et al. (2019)

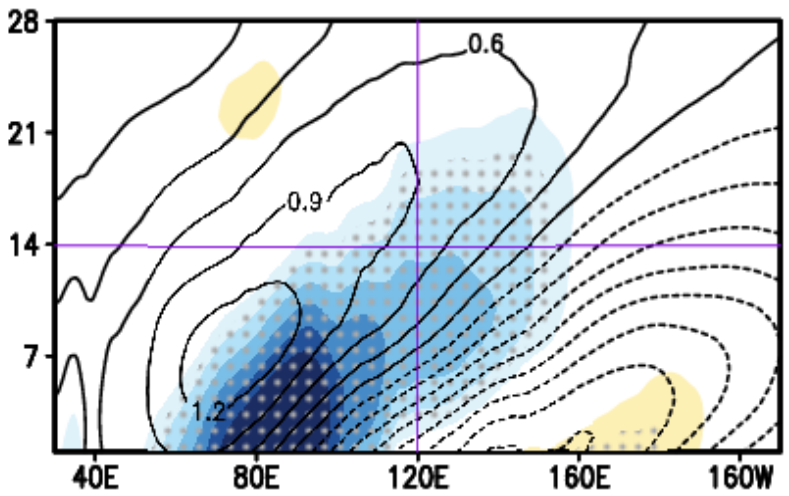
Deep Learning for MJO bias correction







Bias correction with Machine Learning



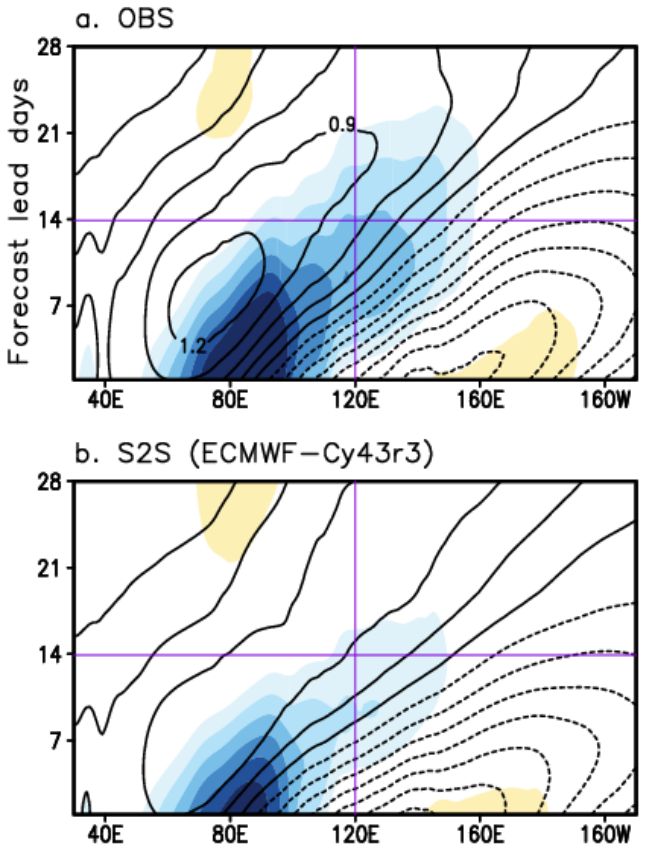
Kim et al. (2021, Nature Comms)

Summary of Part I

- One of the main hurdles that plague the modeling and forecasting communities is the exaggerated MJO Maritime Continent (MC) barrier effect in models.
- This limits the global subseasonal predictability.
- S2S models have common biases in the mean state: Drier lower troposphere weakens the moisture advection process and MJO propagation signal

→ This limits the MJO prediction skill and global subseasonal predictability.

→ Deep learning bias correction may help to improve the prediction.



CESM2 Aquaplanet (0.9°×1.25°resolution, 32 vertical levels, 10yr)

- Earth is completely covered by water.
- Prescribed SST, no topography, no sea-ice.

"WarmPool" run

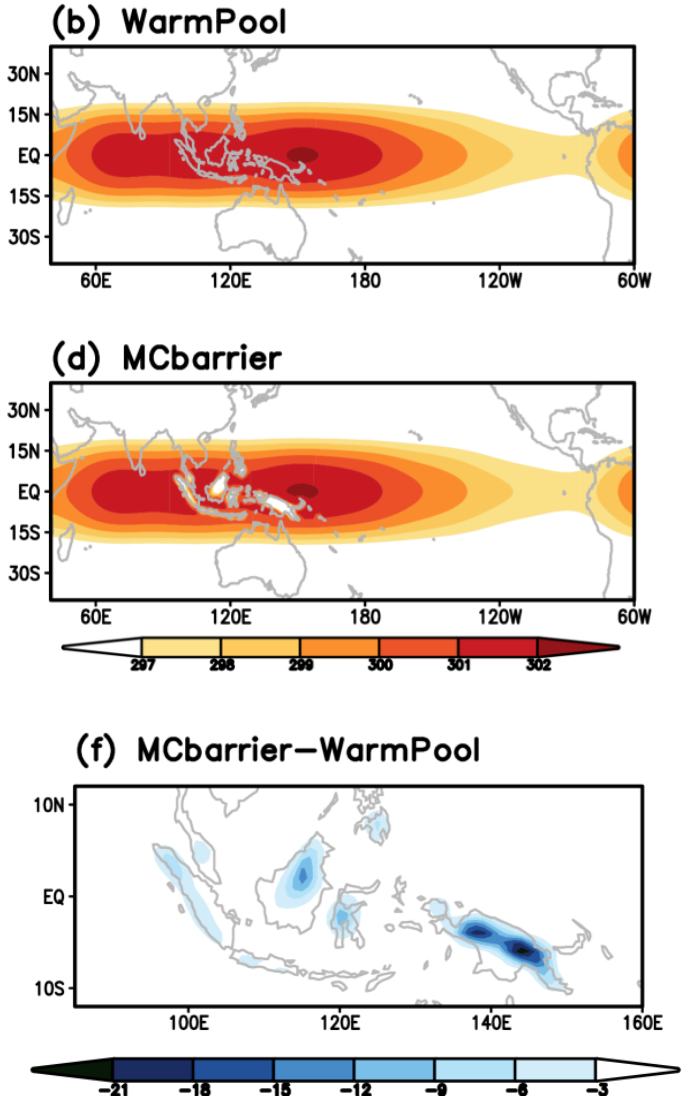
Reasonable tropical intraseasonal variability

"MCbarrier" run

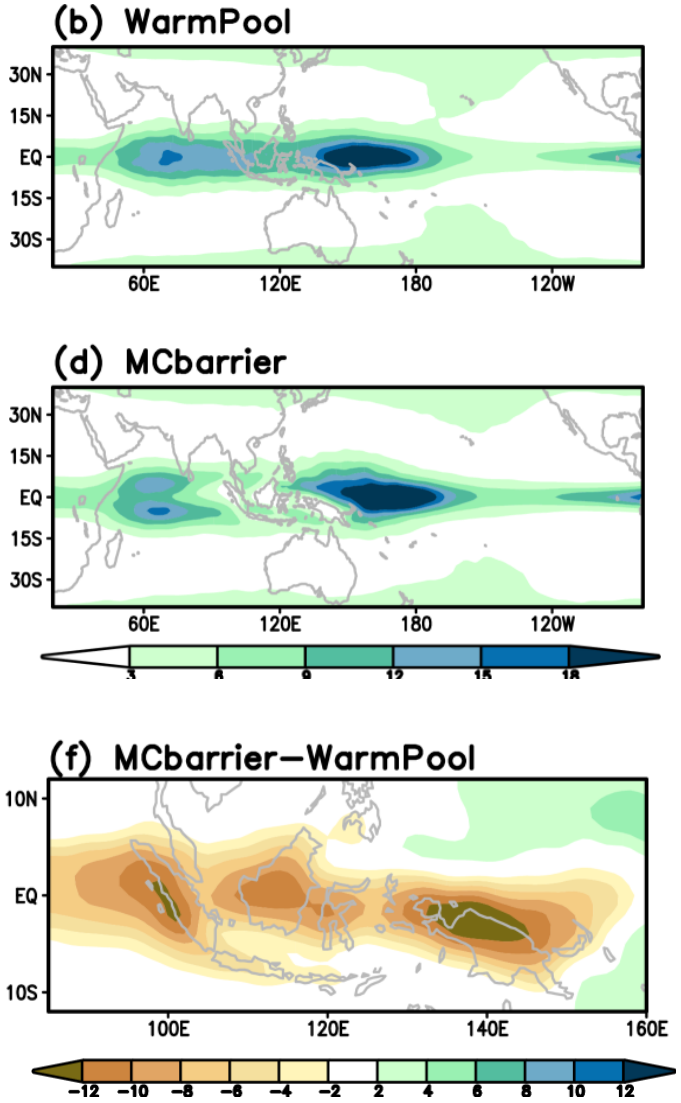
"Aqua-mountains": SST decreases with 6.5K/km lapse rate over the MC.

MCbarrier run: Colder and Drier

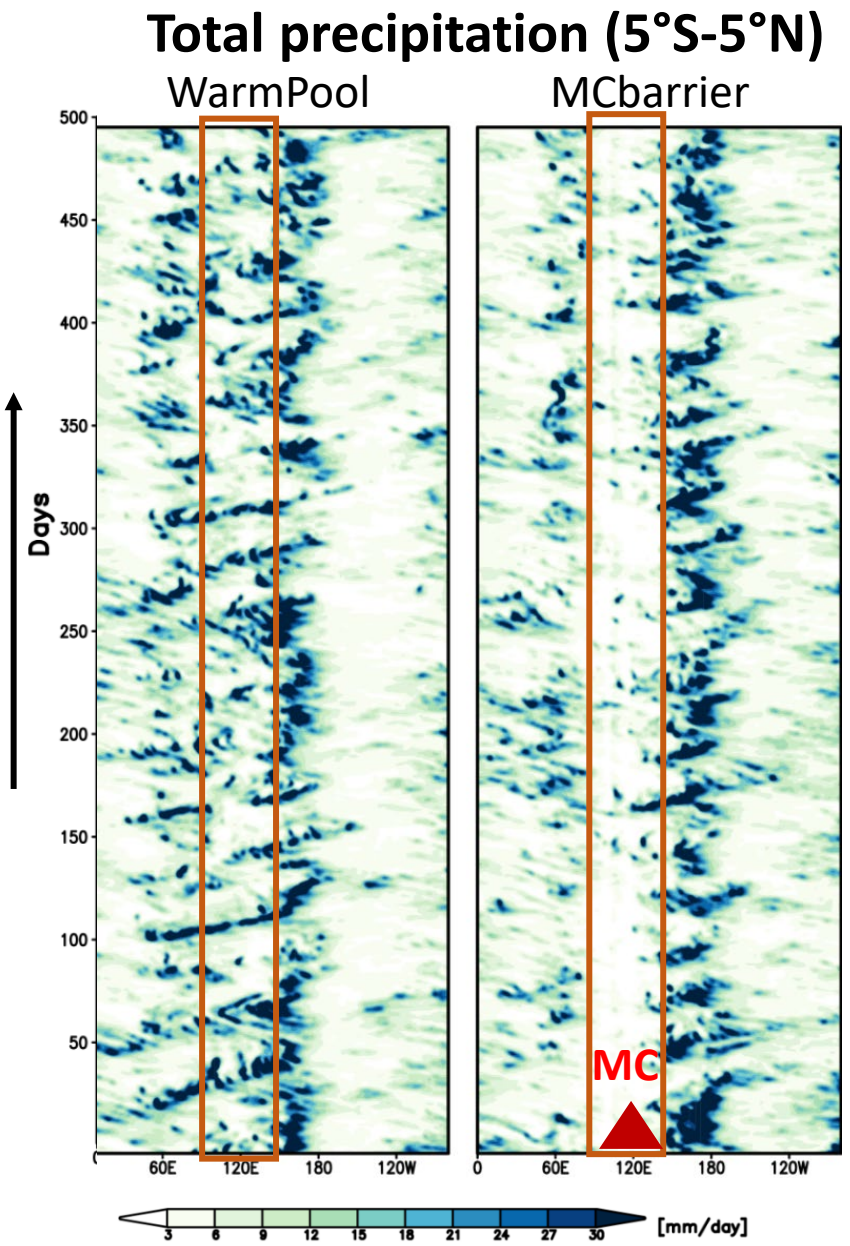
SST [K]

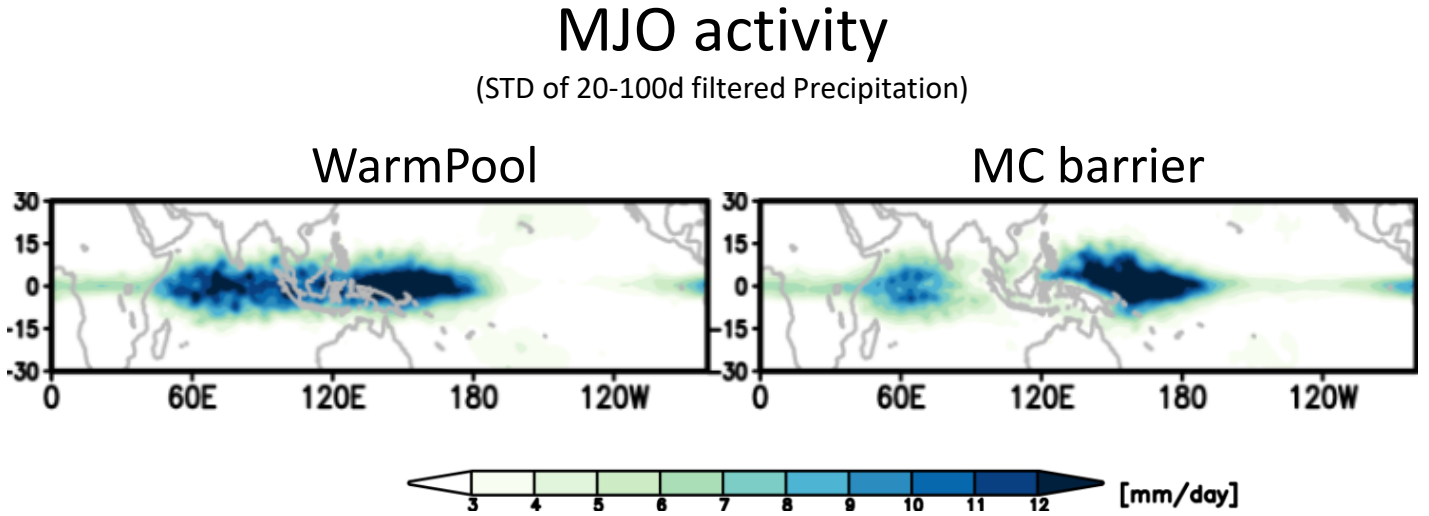


Precipitation [mm/d]



MJO activity

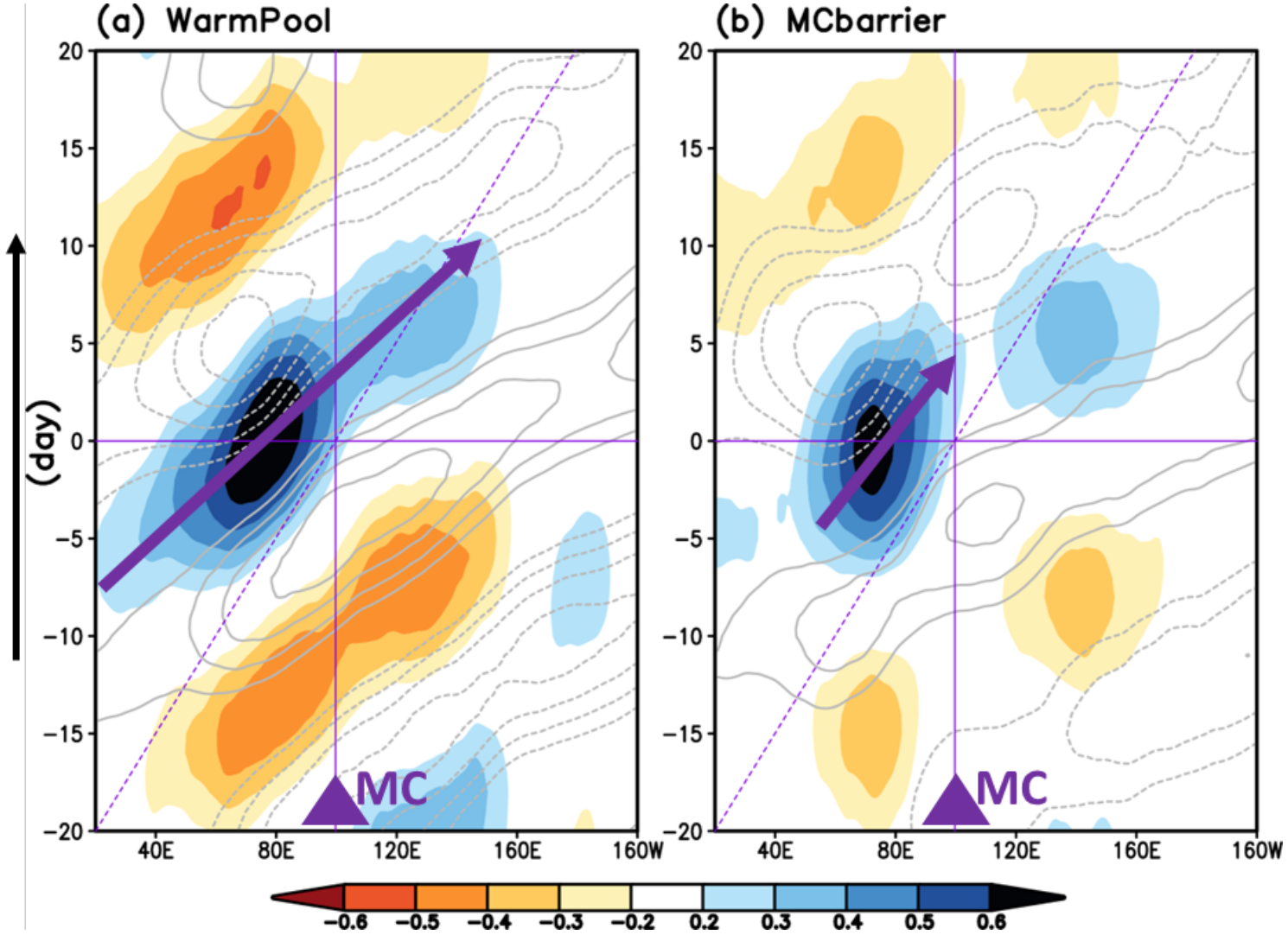




- MC barrier run: Weaker MJO activity near the MC

MJO propagation

Lag correlation
(filtered OLR and U850, 10°S-10°N)



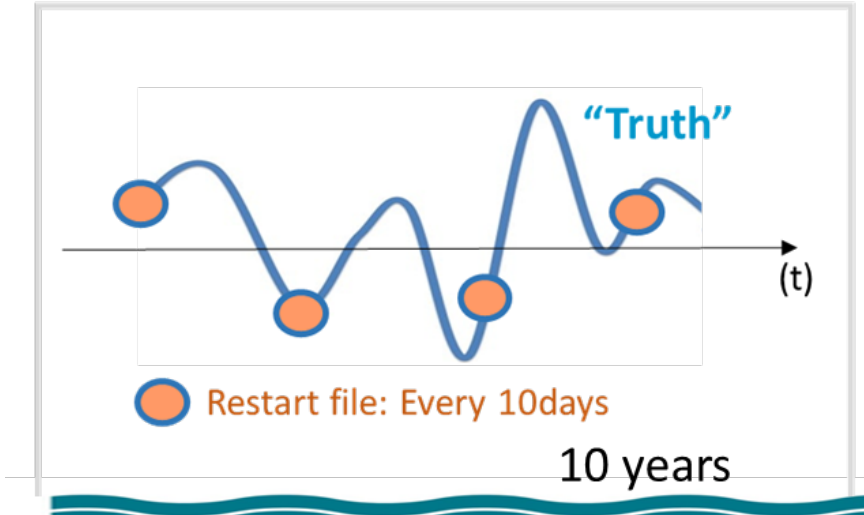
- MCbarrier: MJO propagation is disturbed by the MC

→ mimics the S2S models.

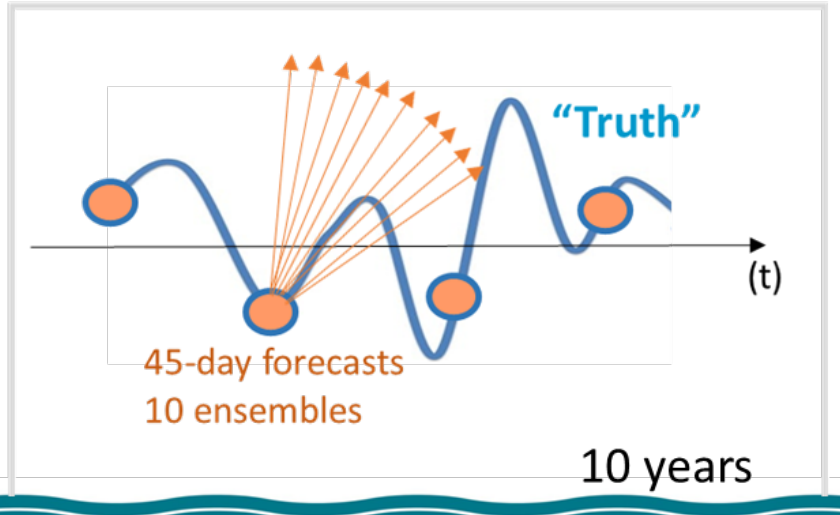
- OLRa (shading), U850a (contour)
- Reference: filtered OLR over IO (60°-90°E, 10°S-10°N)
- Dashed lines: 5m/s phase speed.

Perfect-model ensemble forecast experiment

Step (1): Perpetual run ("Truth")

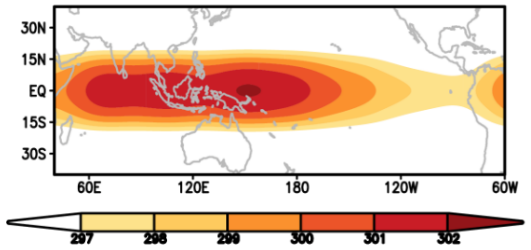


Step (2): Perfect-model forecast



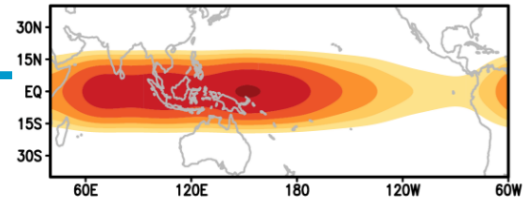
Prescribed SST

WarmPool SST



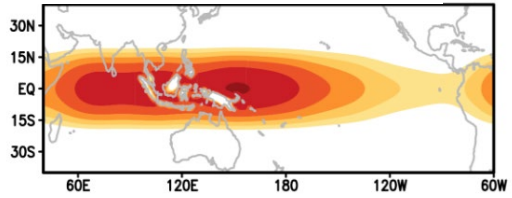
MJO predictability

WarmPool SST

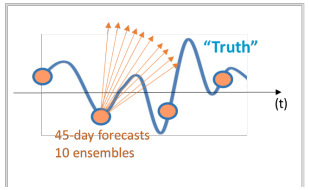


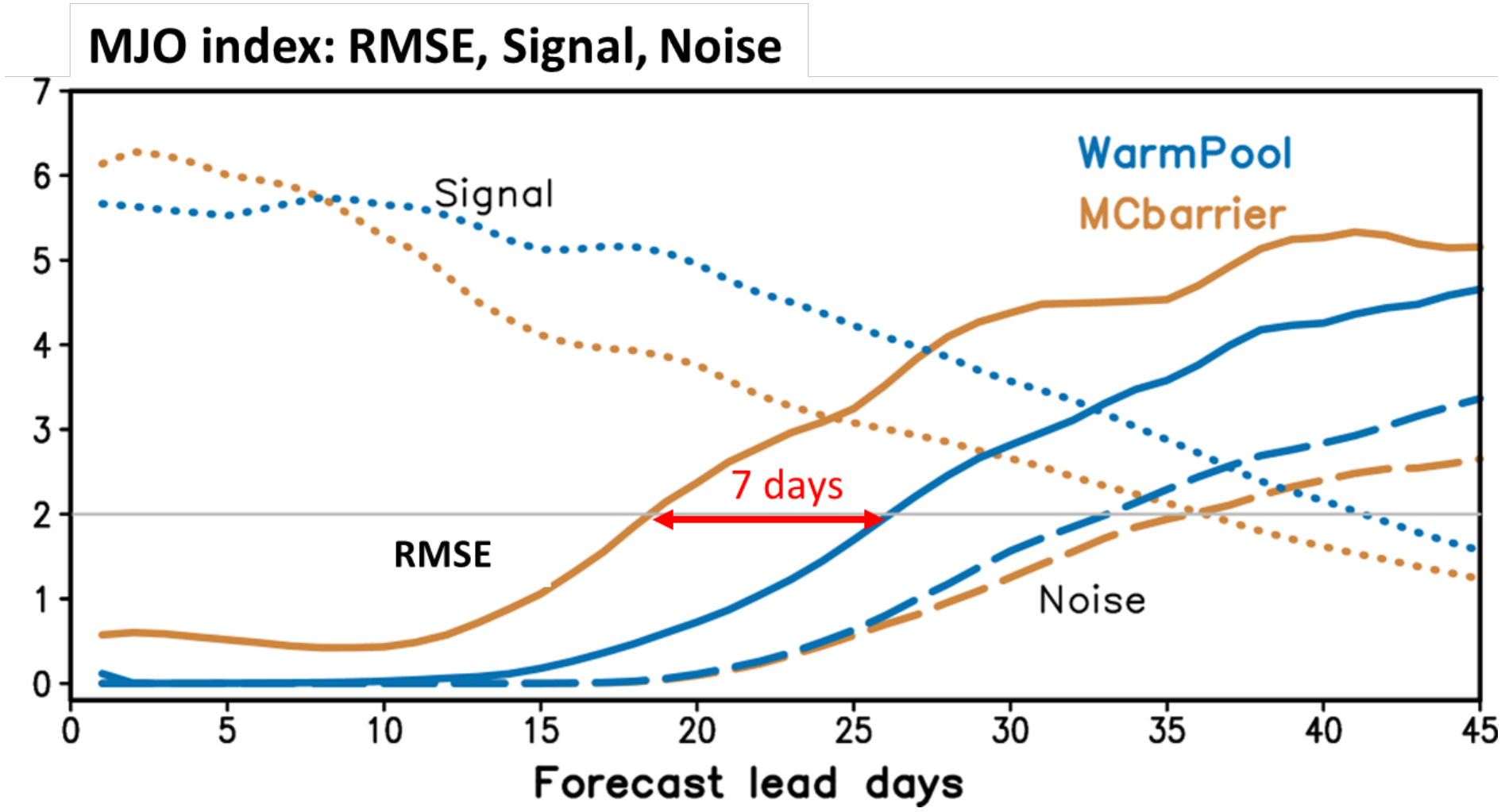
MJO predictability loss by the MC barrier

MC barrier SST

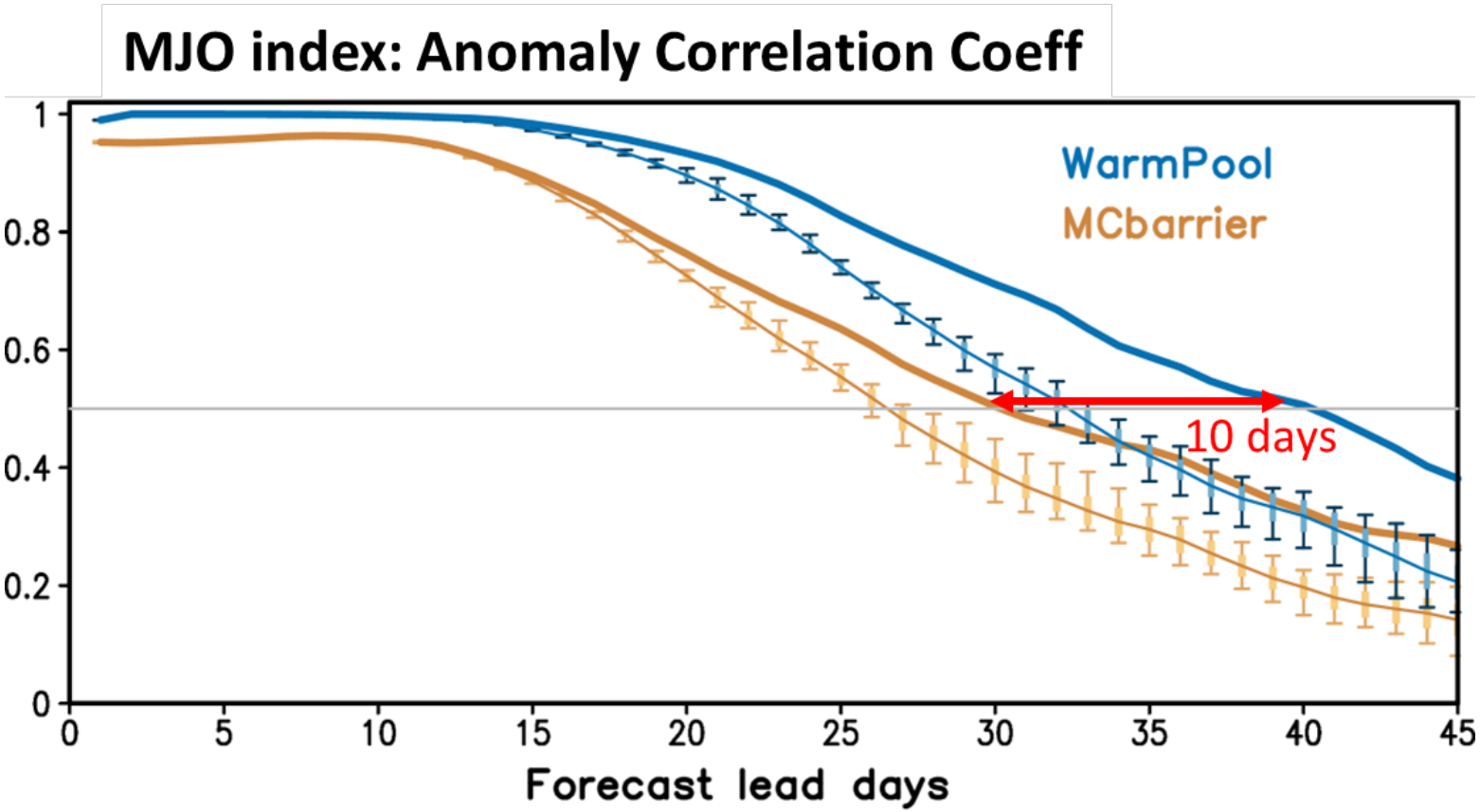


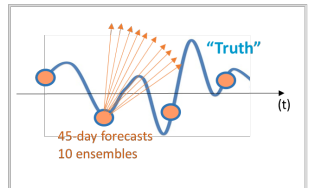
MJO Predictability





MJO Predictability





- Bold lines: ensemble mean
- Thin lines: mean of ensembles
- Bar: ± 1.0 STD of skill by ensembles
- Whiskers: min and max values.

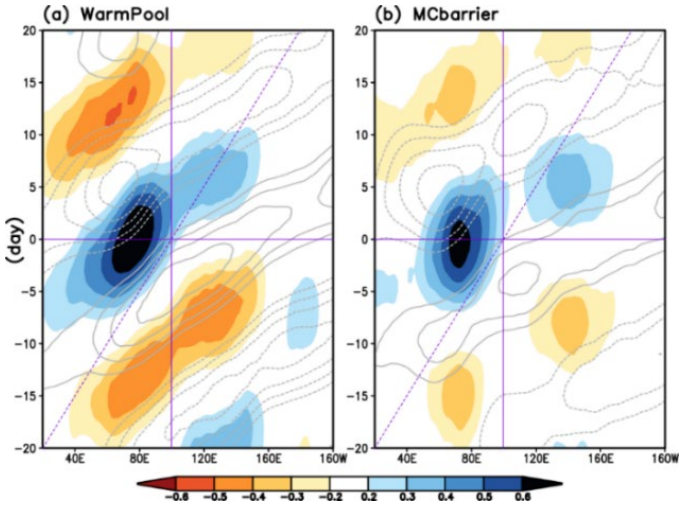
Q: What is the upper limit of the MJO prediction? ~ 6 weeks if the model is perfect.

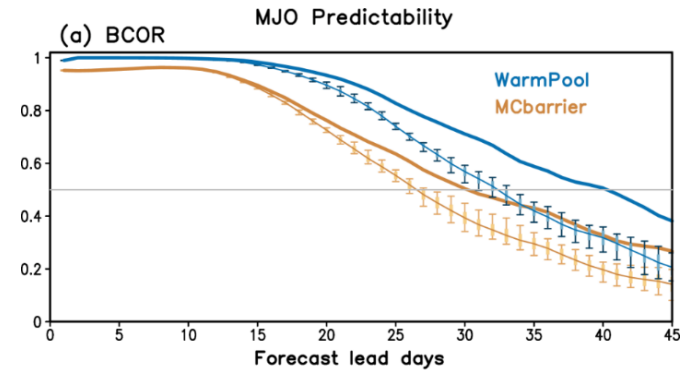
(S2S/SubX model forecast skill: 3-4 weeks)

Q: How much skill is reduced by the Maritime Continent barrier? ~ 10 days

Summary of Part II

- We address the sole MC barrier effect on MJO predictability with a reduced-complexity model (CESM2 Aquaplanet with WarmPool SST).
- The intrinsic MJO predictability is approximately **6 weeks,** and skill reduces to about **4.5 weeks when the MJO is impeded by the MC barrier**.
- Given that the recent operational forecasts (S2S, SubX) show an average of 3-4 weeks of MJO skill, improving the MJO propagation could improve the MJO skill to 4.5-5.5 weeks, close to its potential predictability (6 weeks).





* Kim, H., and J. J. Benedict, 2023: The idealized aqua-planet Maritime Continent barrier effect on the MJO predictability. J. Climate.

hyemi.kim@ewha.ac.kr
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