CAFE
Climate Advanced Forecasting of sub-seasonal Extremes

Ensemble forecast of the Madden Julian Oscillation using a stochastic weather generator based on analogs of Z500

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Machine Learning Workshop

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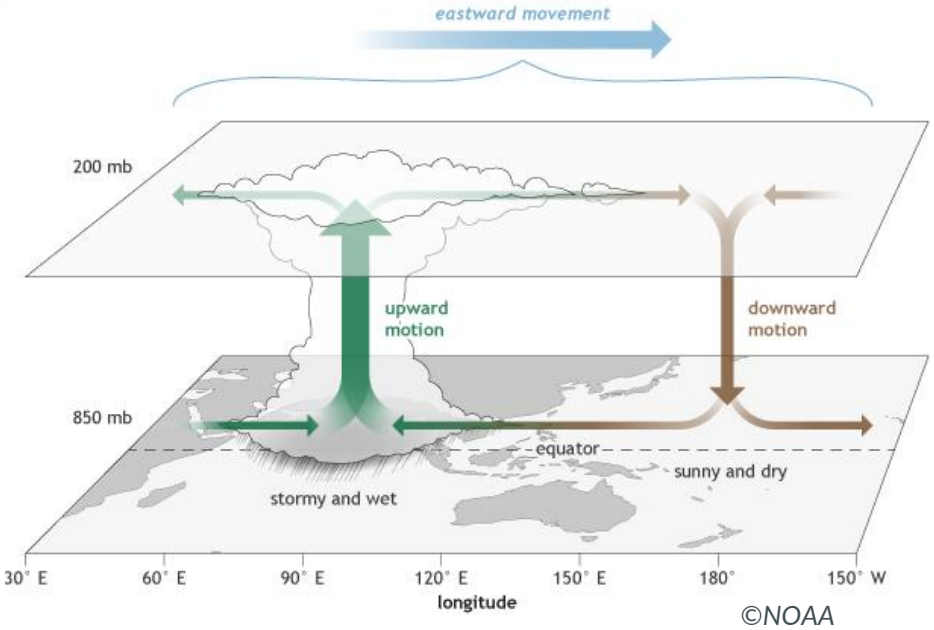
Motivation

Madden Julian Oscillation

- Major sub-seasonal fluctuation in tropical weather,
- Source of intra-seasonal fluctuations in the Indian monsoon,
- Impacts the tropical & extra-tropical weather.



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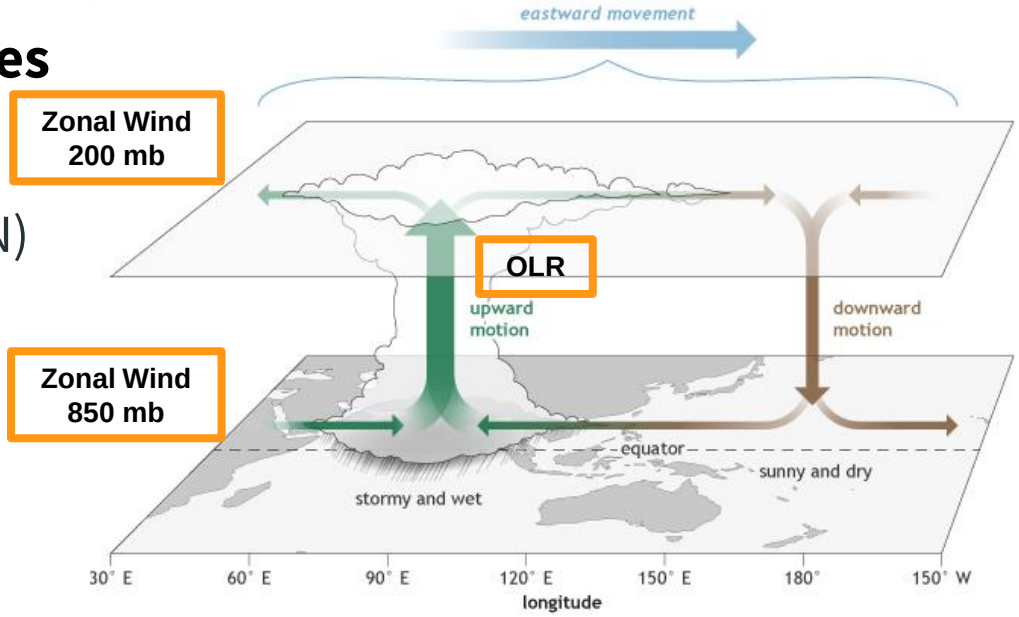
Motivation

Madden Julian Oscillation indices

RMM1 & **RMM2** (between 15°S – 15°N)

EOF
- Zonal Wind at 850 mb
- Zonal Wind 200 mb
- OLR

➔ Amplitude & phase



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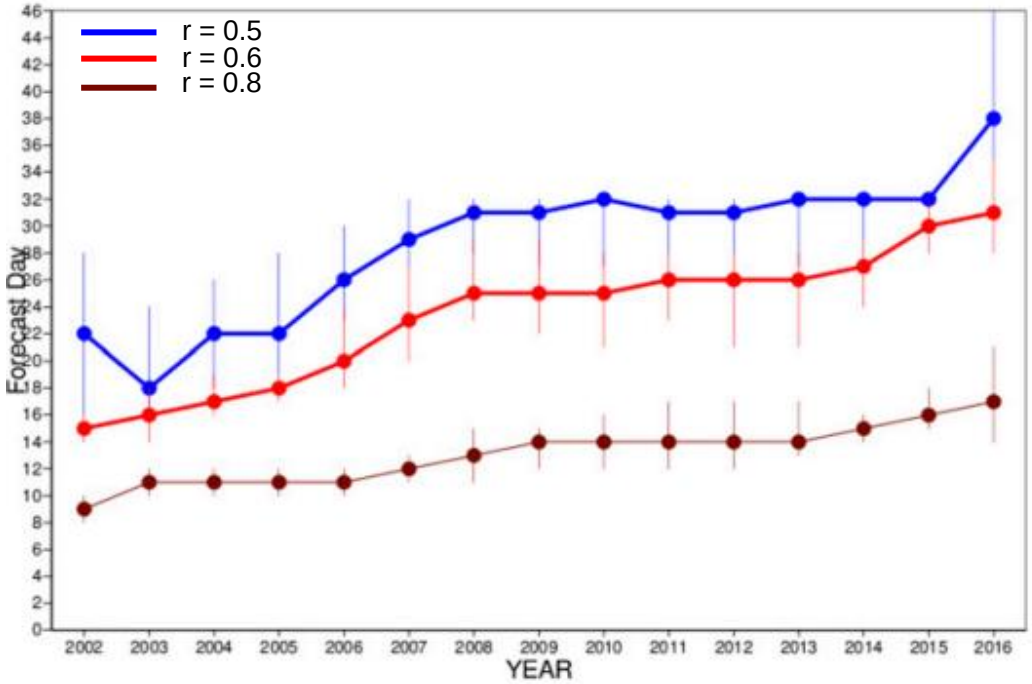
Current state of Art

Evolution of the MJO skill scores



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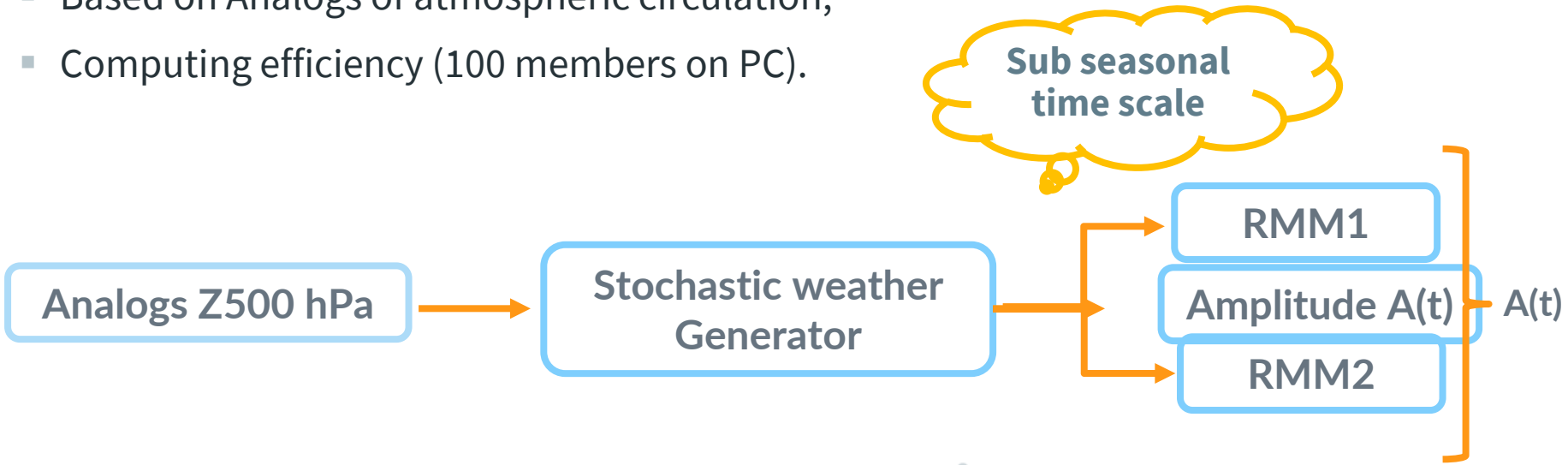
- MJO indices (RMM1 & RMM2)
- **Forecast of MJO ≈ 46 days**

Scientific challenge

Would it be possible to forecast the MJO using a probabilistic approach? for a sub seasonal lead time?

Our forecast approach

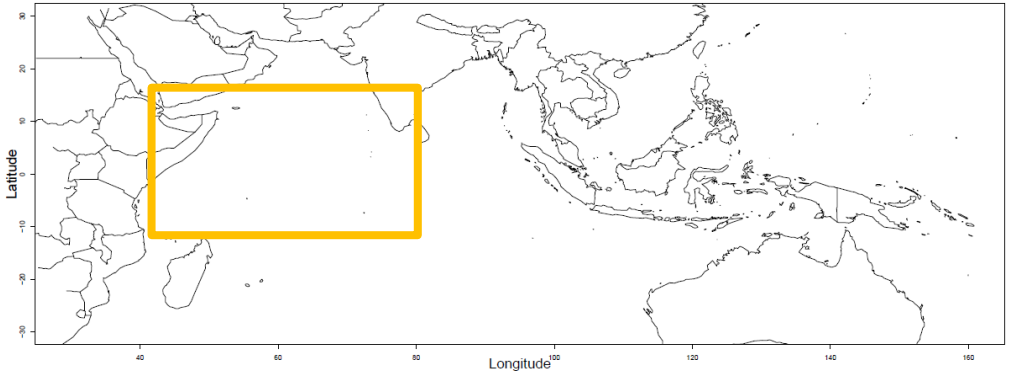
- Analog weather generator developed by P. Yiou (2013) ,
- Tested on **NAO** (Yiou and Déandreis, 2019), **precipitation** (Krouma et al.,2021)
- Based on Analogs of atmospheric circulation,
- Computing efficiency (100 members on PC).



Step 1. Compute Analogs of Geopotential Hight 500 mb

Data.

- **Z 500** (NCEP) 1979 to 2020
- resolution 2.5°x 2.5°



Analog.

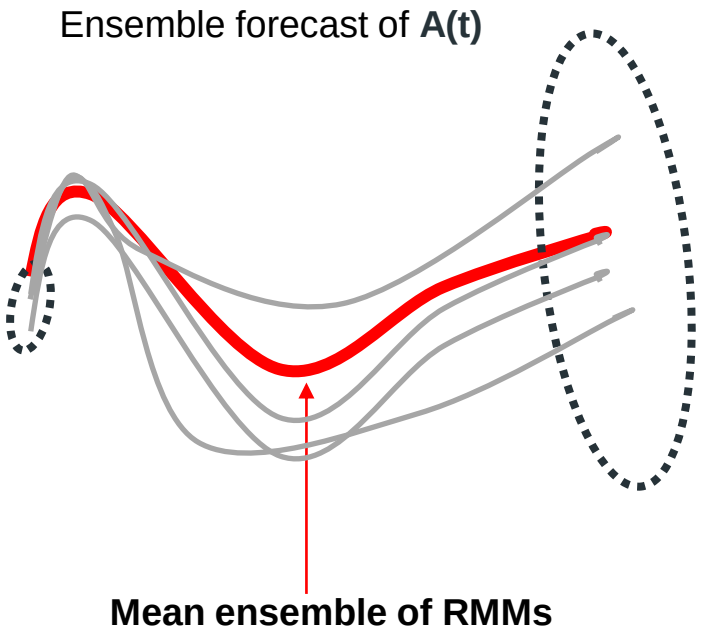
- Calendar distance between (d,d′) ≤ 30
- $y_d \neq y_{d'}$
- $Min\ (D_{(d,d')} = [\sum_X [Z500(x,d) - Z500(x,d')]^2]^{\frac{1}{2}})$

Amplitude A(t)
RMM1 & RMM2

Step 2. Stochastic weather generator (SWG)

- Generate $n_{trajectories} = 100$ random trajectories,
- Simulate Amplitude from trajectories of Z500 for lead times **T= 1 to 90** days.

Assess of the Forecast skill



1. Probabilistic score.

Continuous Rank Probabilistic score

$$CRPS(P, x_a) = \frac{1}{n}\sum_{t=1}^{n}\int_{-\infty}^{+\infty}\left(P(x) - P_a(x)\right)^2 dx$$

$$\mathrm{CRPSS} = 1 - \frac{\mathrm{CRPS}}{\mathrm{CRPS_{Ref}}}$$

CRPSS =1 ➔ Perfect forecast

©Zamo and Naveau, 2018 (Mathematical Geosciences)

2. Scalar score.

Bivariate Correlation & RMSE

$$COR(\tau) = \frac{\sum_{t=1}^{t=N}[a_1(t)b_1(t,\tau) + a_2(t)b_2(t,\tau)]}{\sqrt{\sum_{t=1}^{N}[a^2{}_1(t) + a^2{}_2(t)]}\sqrt{\sum_{t=1}^{N}[b^2{}_1(t) + b^2{}_2(t)]}}$$

$$RMSE(\tau) = \sqrt{\frac{\sum_{t=1}^{N}[|a_1(t) - b_1(t,\tau)|^2 + |a_2(t) - b_2(t,\tau)|^2]}{N}}$$

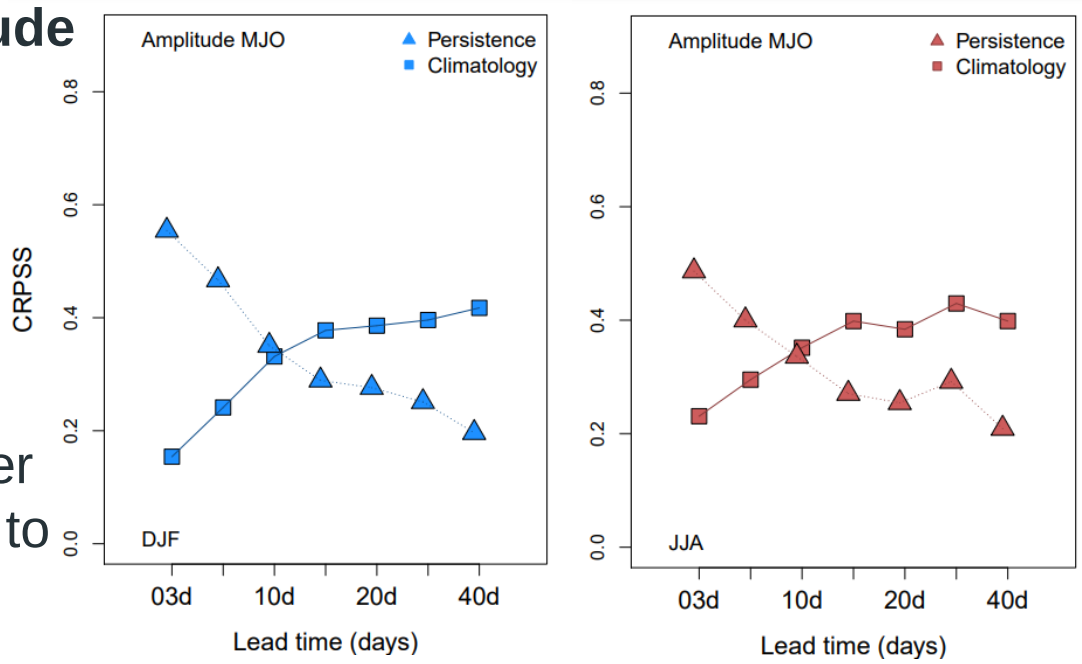
➔ RMSE = $\sqrt{2}$ **&** COR = 0.5

©Kim et al, 2018 (J. Climat) & Rashid et al., 2011 (Clim Dyn)

Evaluation of the ensemble forecast

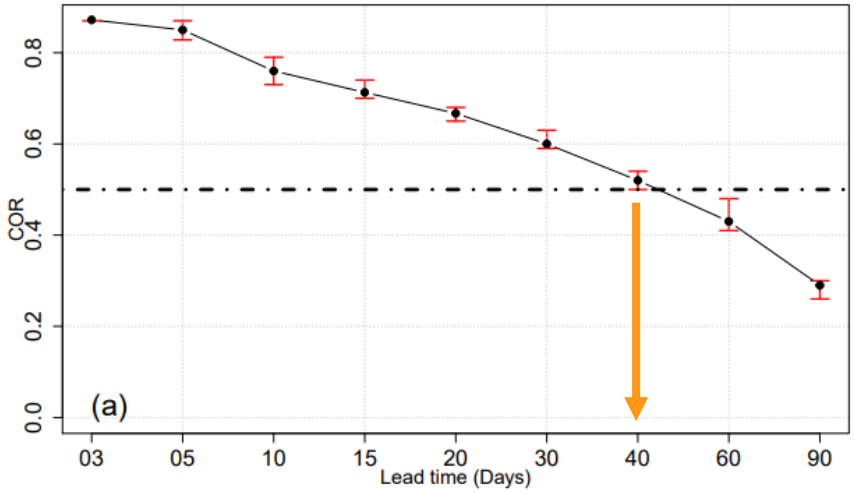
Skill score for the MJO Amplitude

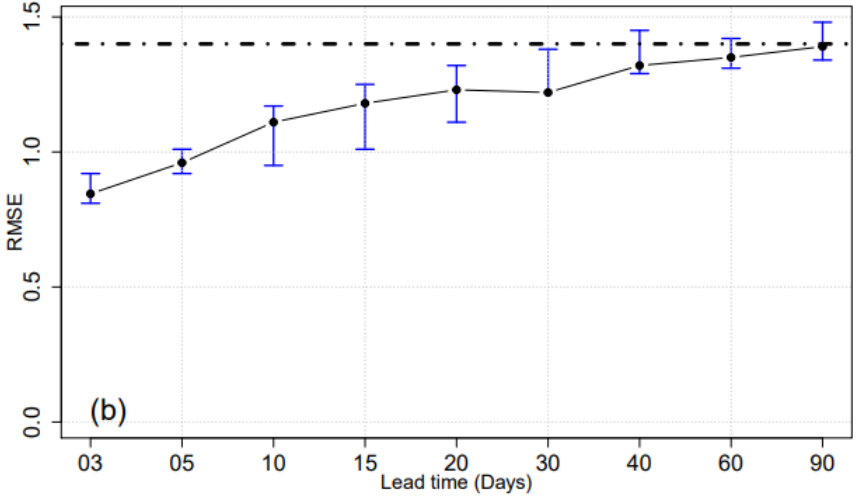
- CRPSS shows a positive improvement until 40 days for DJF and JJA.
- The correlations indicate the spread across the 100-member ensemble forecasts are equal to **0.62**.



Evaluation of the ensemble mean forecast

Skill score for the RMMs

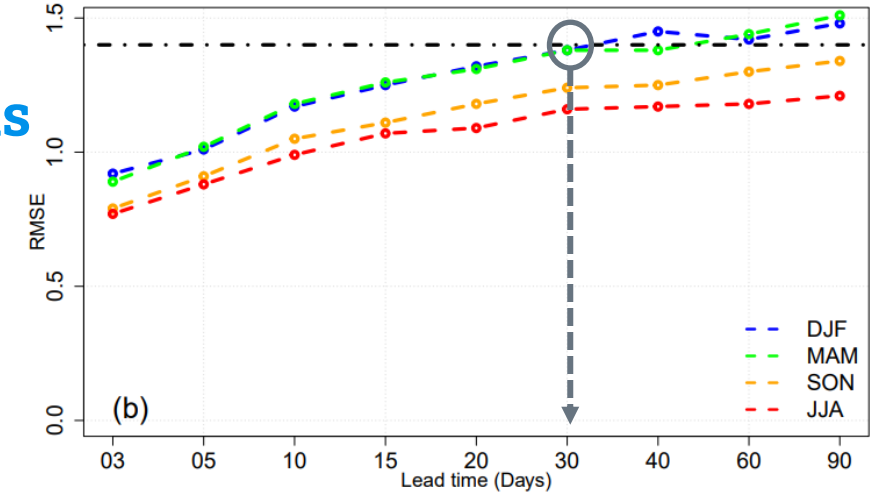


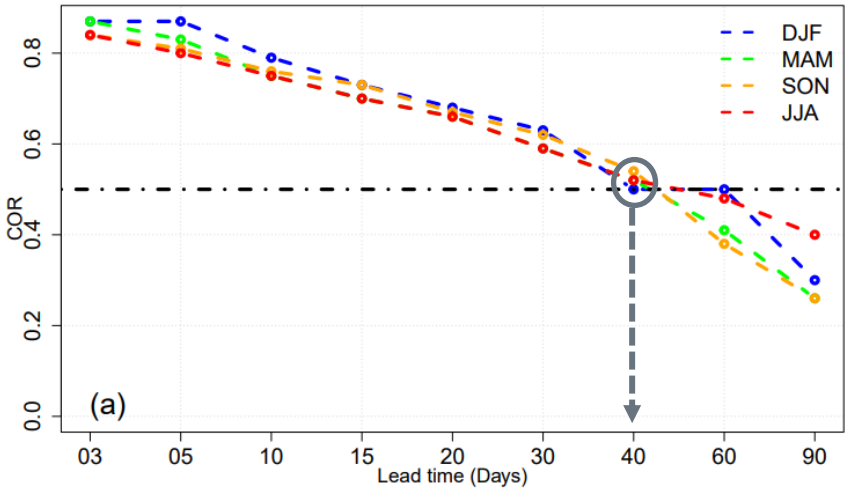


➔ The SWG forecast of the RMMs shows good skill until 40 days.

Sensitivity of the forecast to seasons

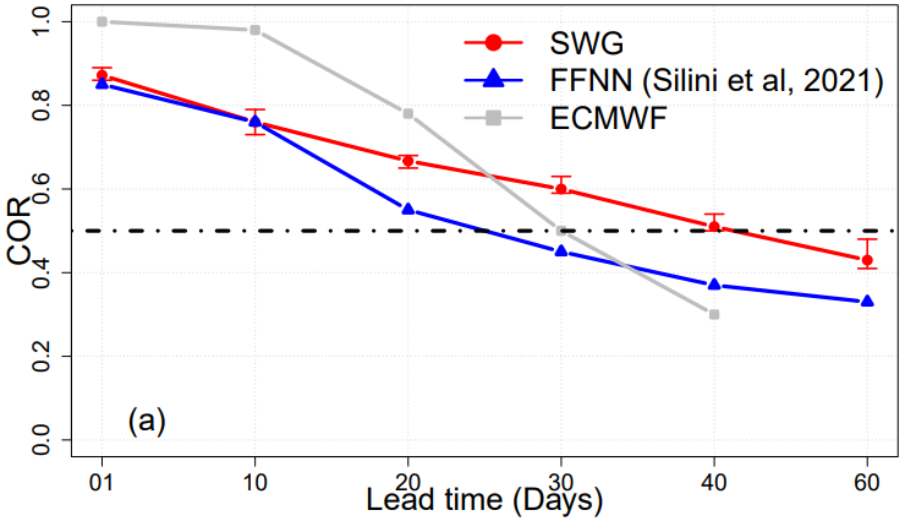
- The forecast for DJF and MAM has a good skill until 30 days,
- The forecast for SON and JJA could reach 40 days.

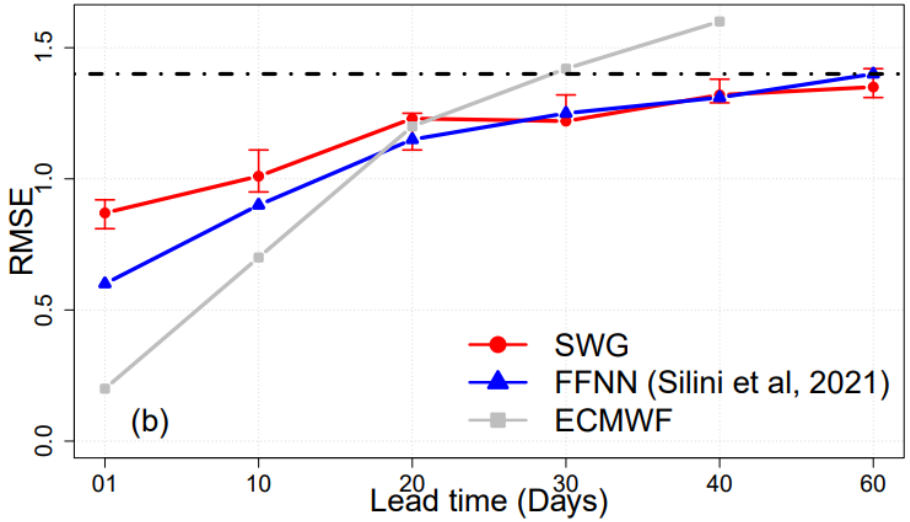




SWG forecast Vs other forecasts

- ECMWF Forecast is more reliable for small lead time (≈10 days).
- Silini et al. (2021) forecast has the same skill until 10 days.
- SWG forecast could reach 40 days.





Conclusions

- The performance of analogs weather generator shows skill to forecast the MJO indices from analogs of Z 500 mb.
- Atmospheric circulation is useful for forecasting MJO.
- The comparison with ECMWF forecast confirmed the good performance of SWG quantitatively and qualitatively.

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