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

Meriem Krouma, Pascal Yiou & Riccardo Silini

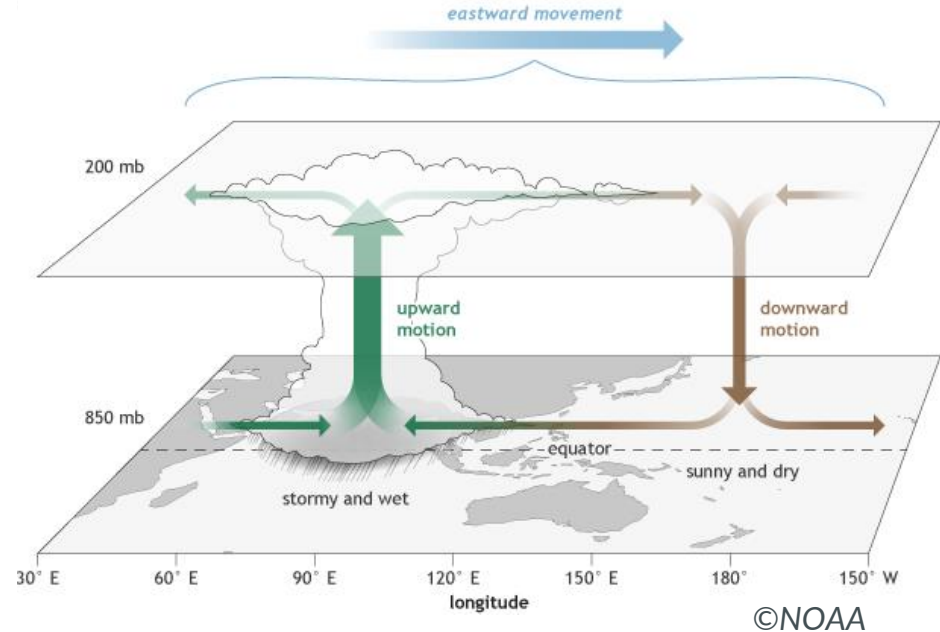*Session AS1.3 – Forecasting the weather*
EGU General Assembly 2022
Mai 23rd, 2022, Vienna

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.
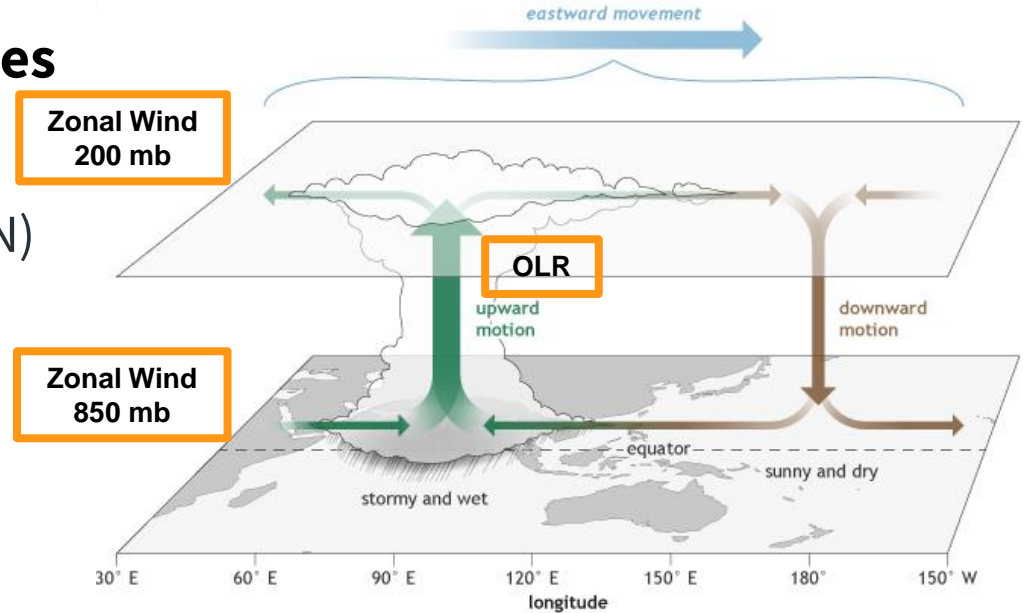

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Motivation

Madden Julian Oscillation indices

RMM1 & **RMM2** (between 15°S – 15°N)
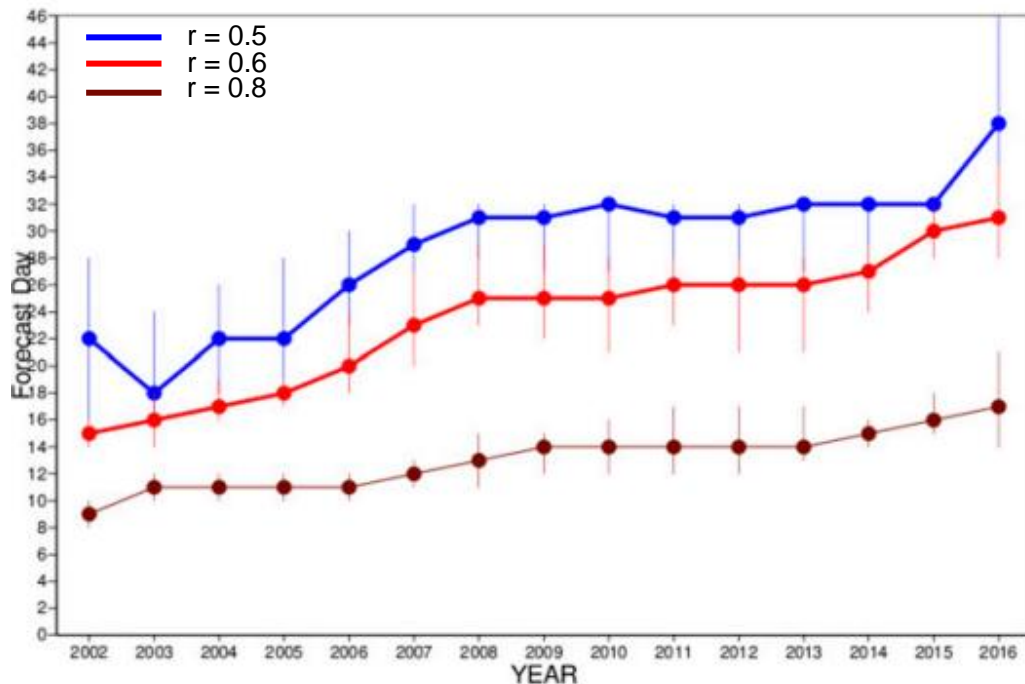
EOF
- Zonal Wind at 850 mb
- Zonal Wind 200 mb
- OLR

➔ Amplitude & phase

eastward movement

Zonal Wind 200 mb

OLR

upward motion

downward motion

Zonal Wind 850 mb

equator

stormy and wet

sunny and dry

30° E   60° E   90° E   120° E   150° E   180°   150° W

longitude

©Wheeler and Hendon, 2004 (Monthly Weather Review)

Current state of Art

Evolution of the MJO skill scores

©Kim et al, 2018 (J. Climat) & Vitart 2014

- 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

- Stochastic weather generator developed by P. Yiou (2013) ,

- Tested on **NAO** (Yiou and Déandreis, 2019. GMD), **precipitation** (Krouma et al.,2021. GMD)

- Based on Analogs of atmospheric circulation,

- Computing efficiency (100 members on PC).
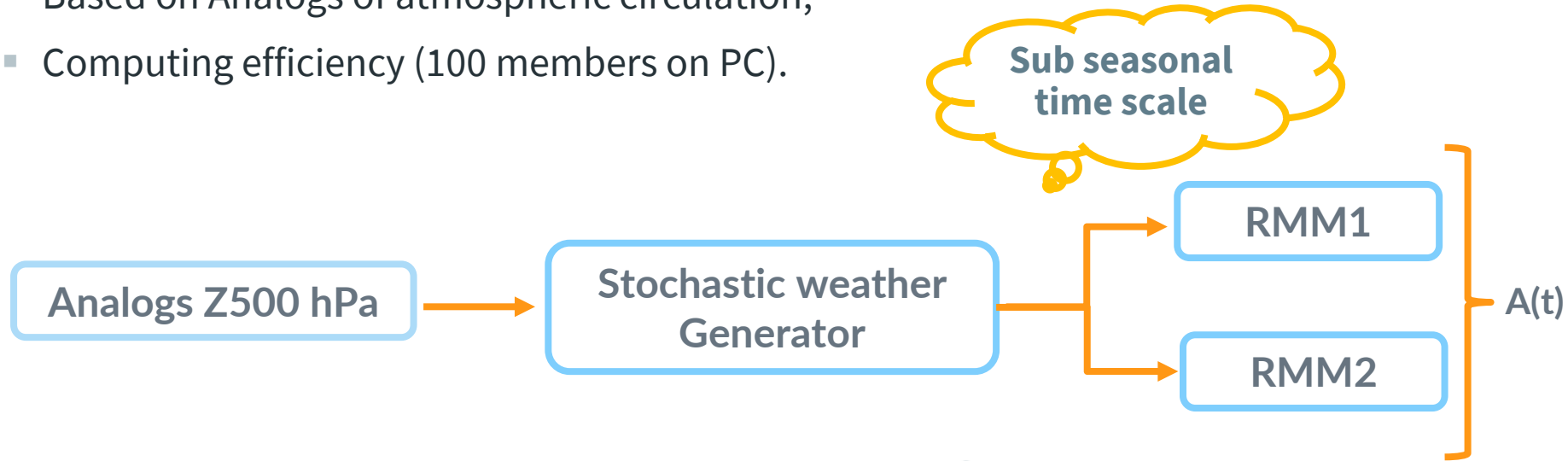
Sub seasonal time scale

Analogs Z500 hPa → Stochastic weather Generator → Amplitude A(t)

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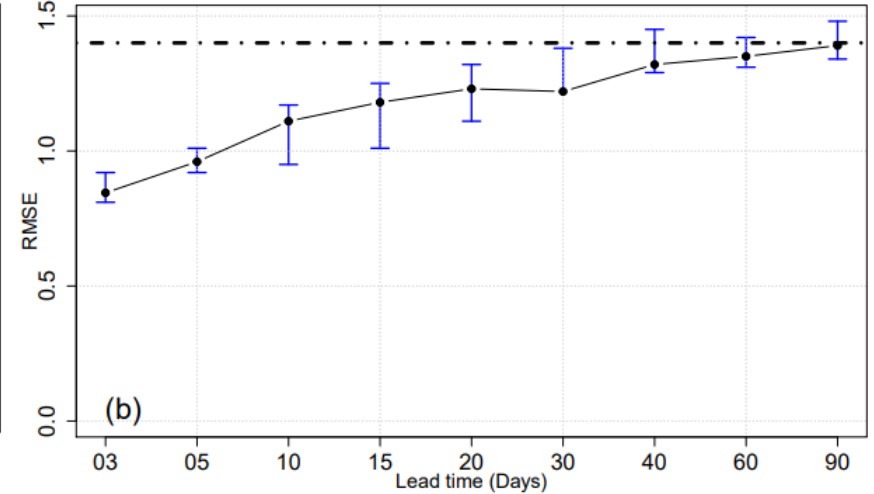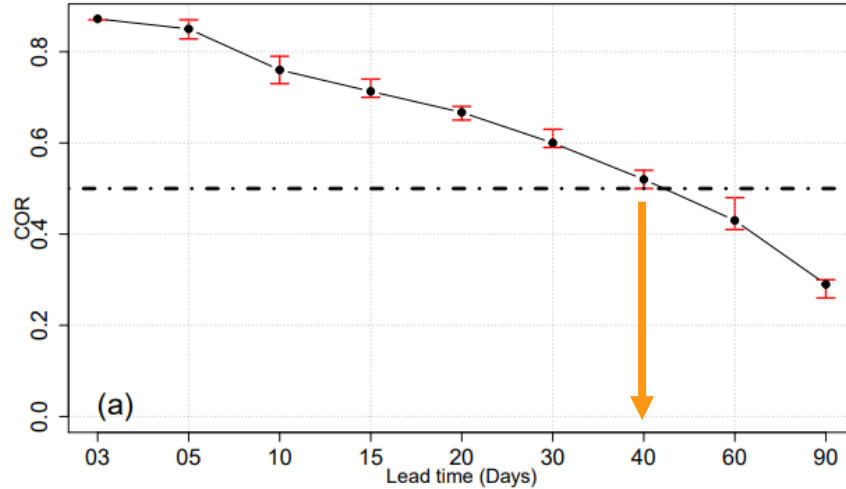
Evaluation of the ensemble forecast

Skill score for the MJO Amplitude

◎ CRPSS shows a positive improvement until 40 days for DJF and JJA.
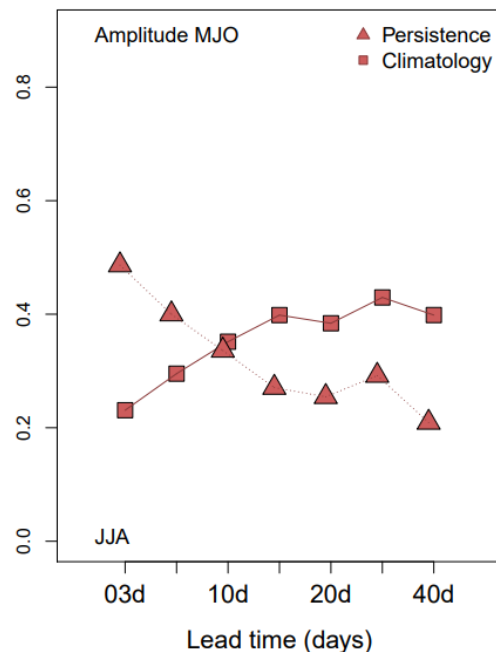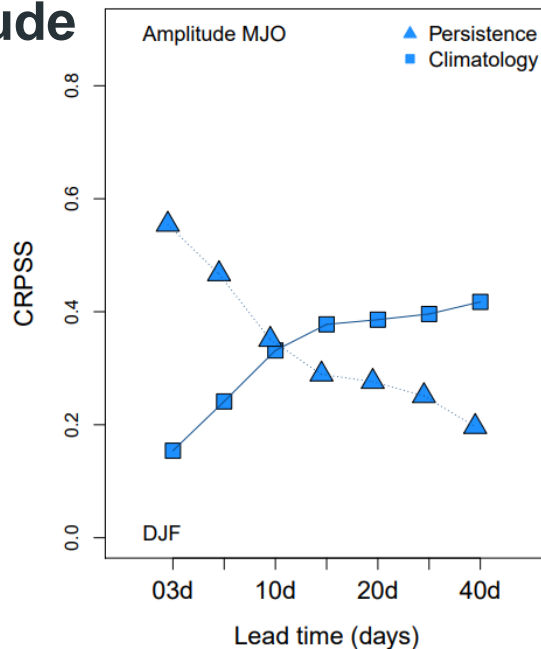
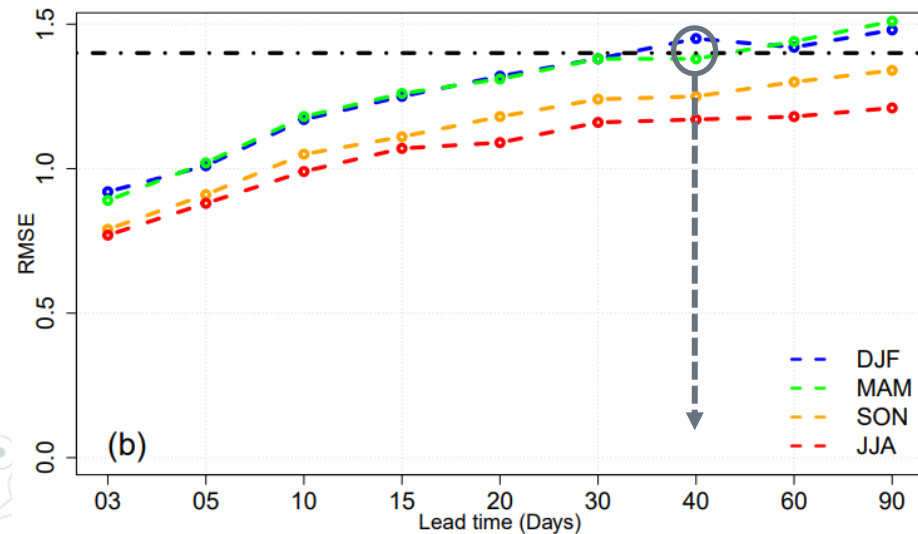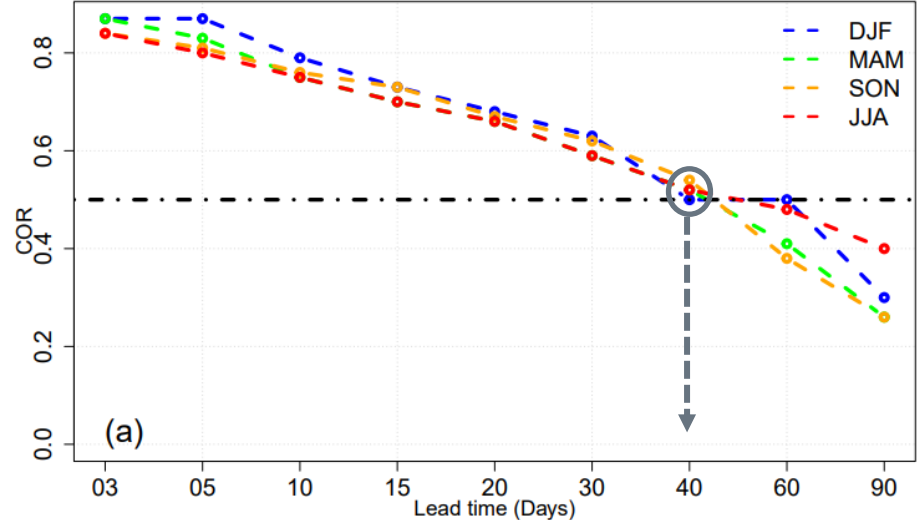# Evaluation of the ensemble mean forecast

Skill score for the RMMs

➜ The SWG forecast of the RMMs shows good skill until 40 days.
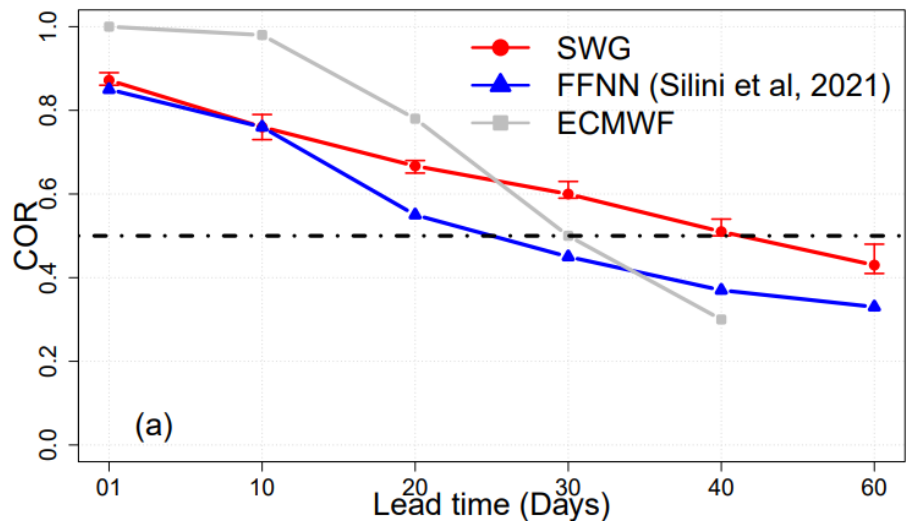
Sensitivity of the forecast to seasons

◎ 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.
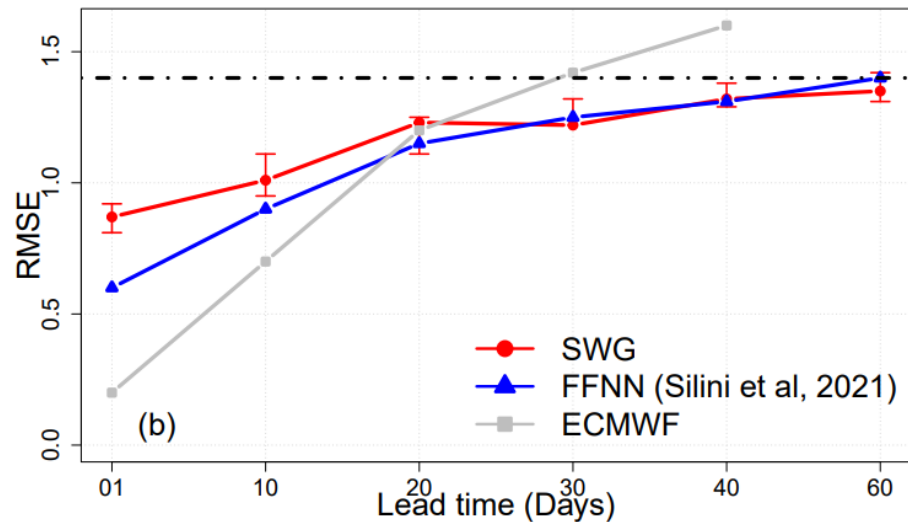
Conclusions

◎ 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 & machine learning forecasts confirmed the good performance of SWG quantitatively and qualitatively.
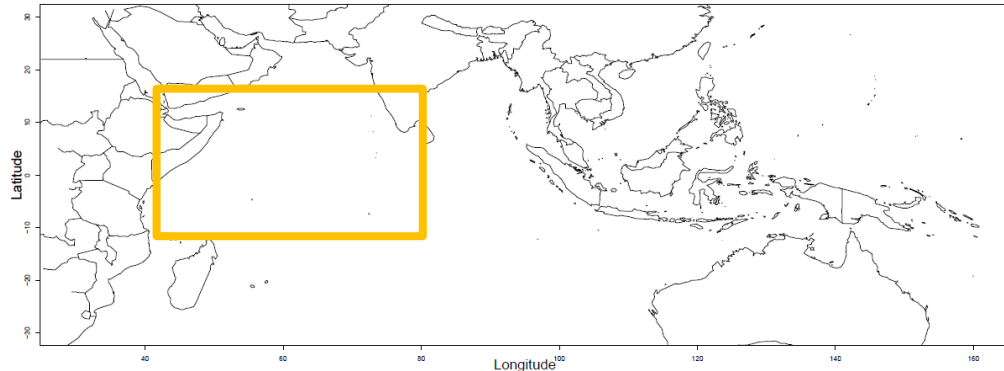
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@MeriemKrouma

Supplemantary

Step 1. Compute Analogs of Geopotential Hight 500 mb

Data.
- **Z 500** (NCEP) 1979 to 2020,
- resolution 2.5°x 2.5° (200 points), daily.

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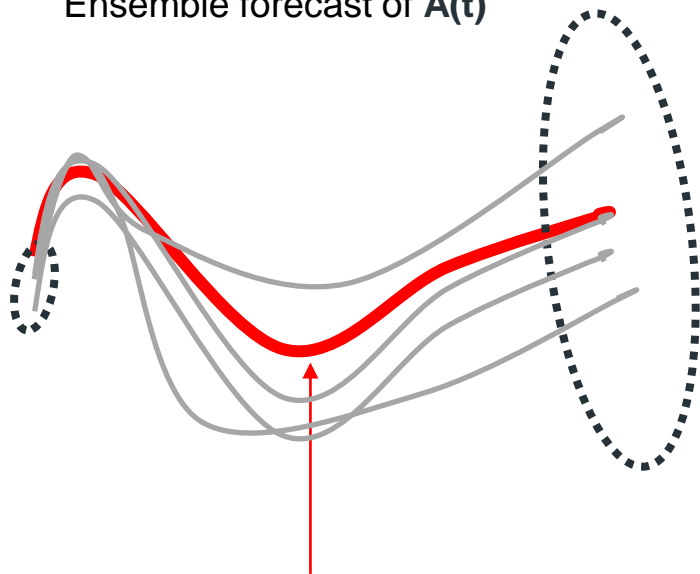- $Min\ (D_{(d,d\prime)} = [\sum_X [Z500(x,d) - Z500(x,d\prime)]^2]^{\frac{1}{2}})$

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.

Amplitude A(t)
RMM1 & RMM2

Assess of the Forecast skill

1. **Probabilistic score.**

Continuous Rank Probabilistic score

Ensemble forecast of **A(t)**

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

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

$$CRPSS =]0,1] \rightarrow \text{Good forecast skill}$$

©Zamo and Naveau, 2018 (Mathematical Geosciences)
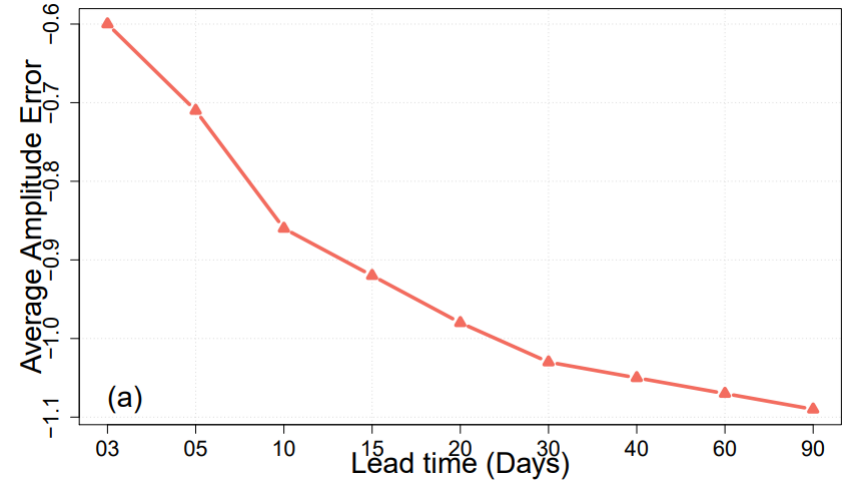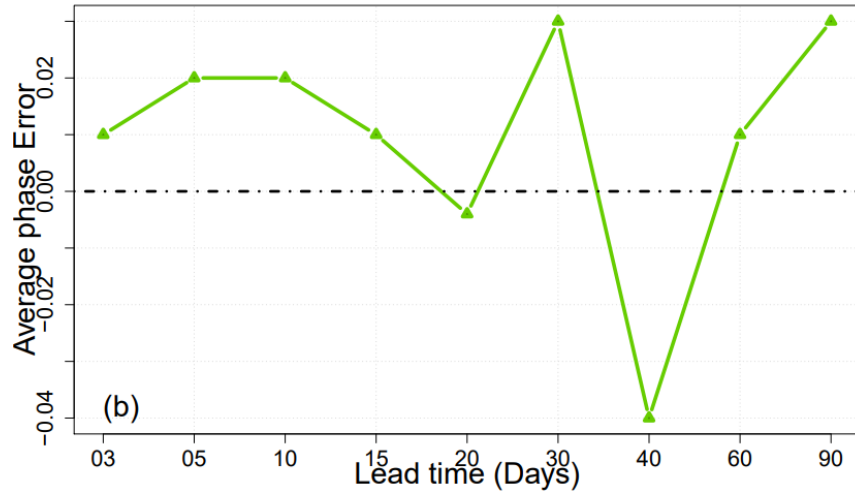
2. **Scalar score.**

Bivariate Correlation & RMSE

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

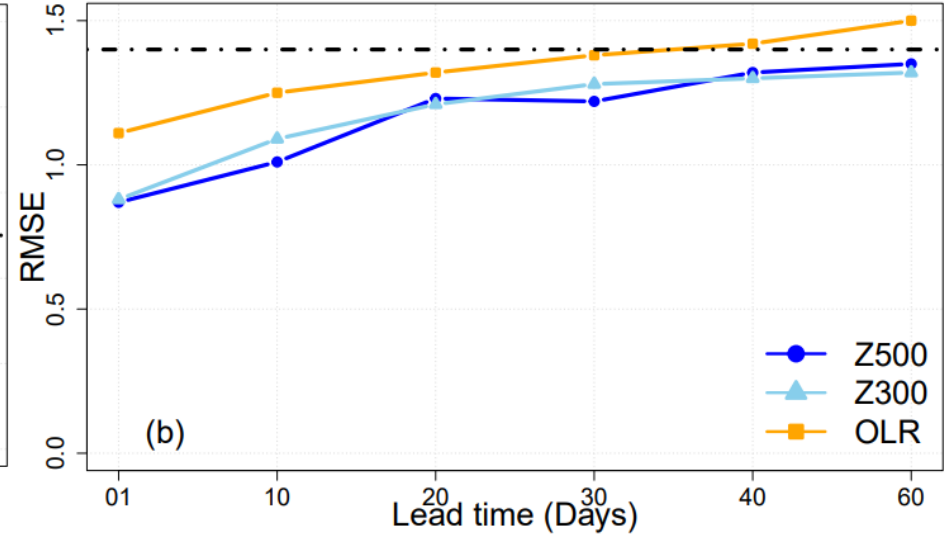$$RMSE(\tau) = \sqrt{\frac{\sum_{t=1}^{N}[|a_1(t) - b_1(t,\tau)|^2 + |a_2(t) - b_2(t,\tau)|^2]}{N}}$$
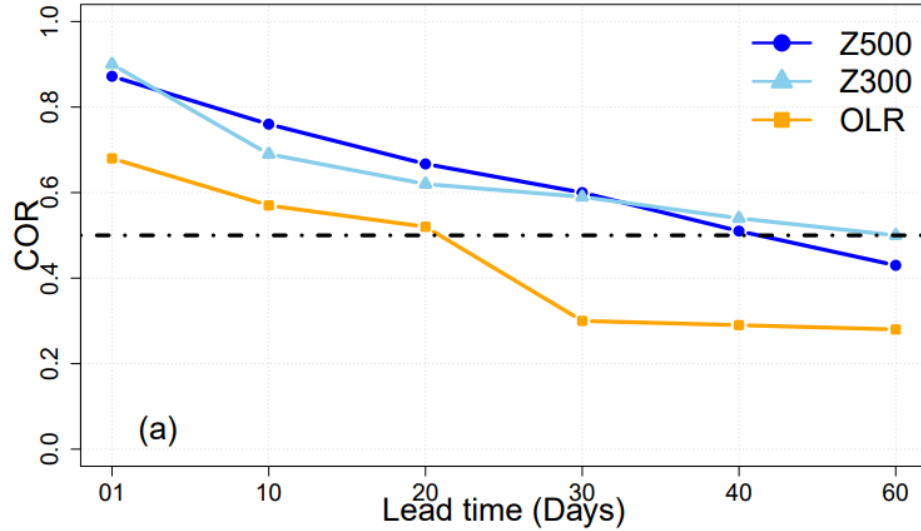
$$\rightarrow RMSE \leq \sqrt{2} \ \& \ COR \geq 0.5$$

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

Mean ensemble of RMMs

Error for amplitude & phase
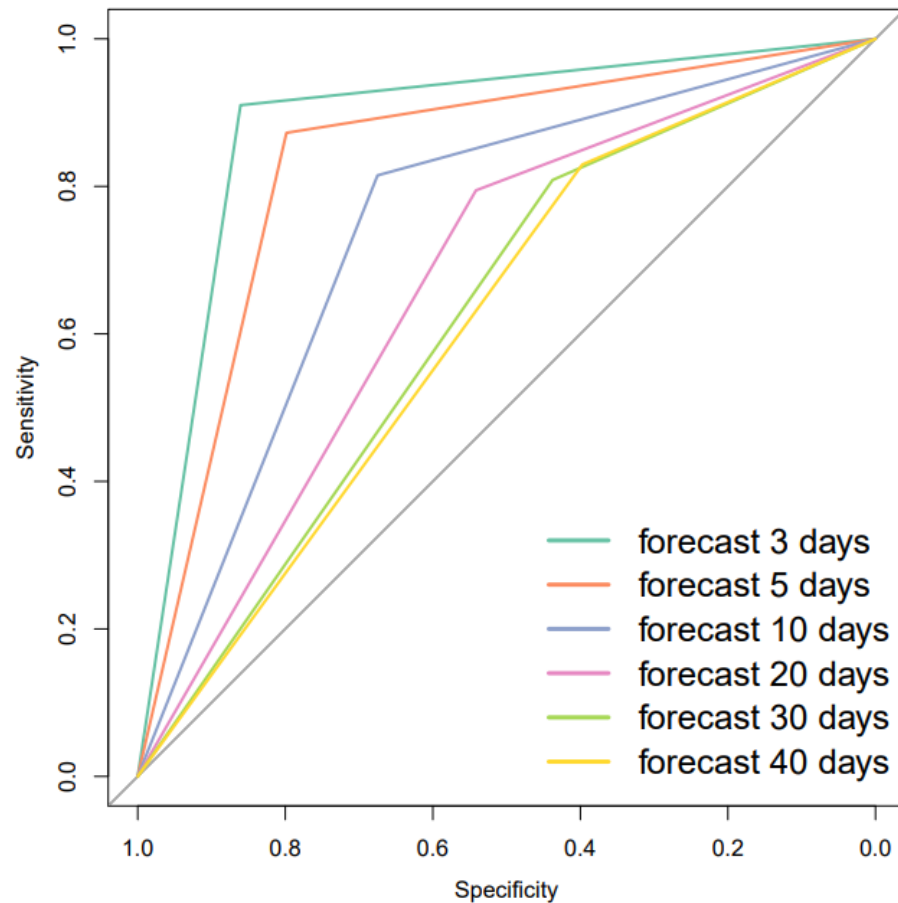
What if we use other atmospheric circulation?

Evaluation of the ensemble forecast

ROC curve

- Good discrimination skill of the SWG forecast ➔ to distinguish between events and nonevents until 40 days

References

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