Evaluation of AROME NWP model in forecasting extreme weather events in Morocco

Bari .D , **Alaoui .B**, Sbii.S, Sahlaoui.Z, Hdiddou.F, Ouardi.M et al.

CNRM/SMN, National Weather Department (DGM), Casablanca, Morocco

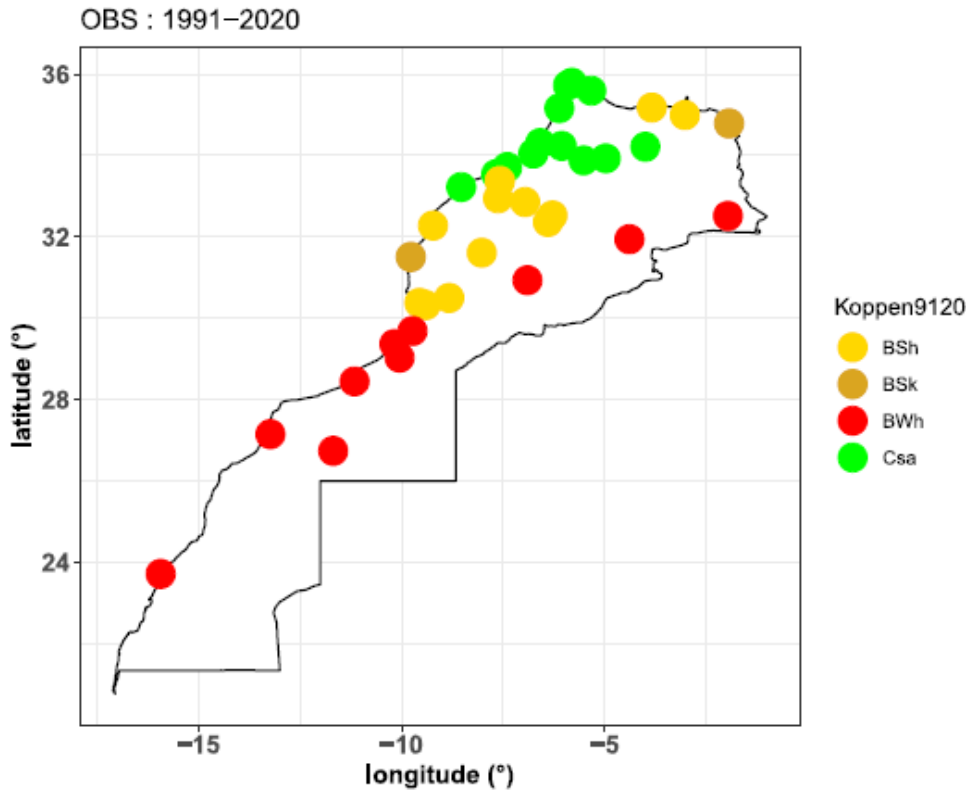
EWGLAM/SRNWP-2025, SMHI, Norrköping, Sweden, 22-25 September 2025

Context

- Heatwave: Fires Burned Over 1,200 Hectares of Moroccan Forest in July 2021
- Extreme climate events cost Morocco over $575 million per year (World Bank)
- Extreme Weather Events are more frequent and intense

Dataset & Study Domain

- **Archive of Observations from SYNOP from 2016-2024**
- **Archive of Hourly Forecasts of AROME Cycle 43 2.5 km from 2016-2024**
- **Max Lead-time 72h**
- **44 Weather Station**
- **Surface Weather Parameters (T2m, RH, MSLP, WS, RR, FFX)**
- **Diversity of Micro-Climates**



Csa = Hot−summer Mediterranean climate
BSh = Hot semi−arid climates
BWh = Hot desert climates
BSk = Cold semi−arid climates

Definition of Extreme Events

- RR -> Total RR from 18h (J) to 18h (J+1)
- TM -> Min T2m from 6h(J) to 6h (J+1)
- TX -> Max (T2m) from 18h (J) to 18h (J+1)
- FFX -> Max (WS10m) for 24h
- Probability that the Variable > Q95,Q96, Q97, Q98

Verification Scores

Continuous Verification

$$Bias = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$$

$$EHI = \frac{(T_i + T_{i-1} + T_{i-2})}{3} - \frac{(T_{i-3} + ... + T_{i-32})}{30}$$

Probabilistic Verification

	Observed Event	No Event
Forecasted Event	Hits (H)	False Alarms (F)
No Forecasted Event	Misses (M)	Correct Negatives (C)

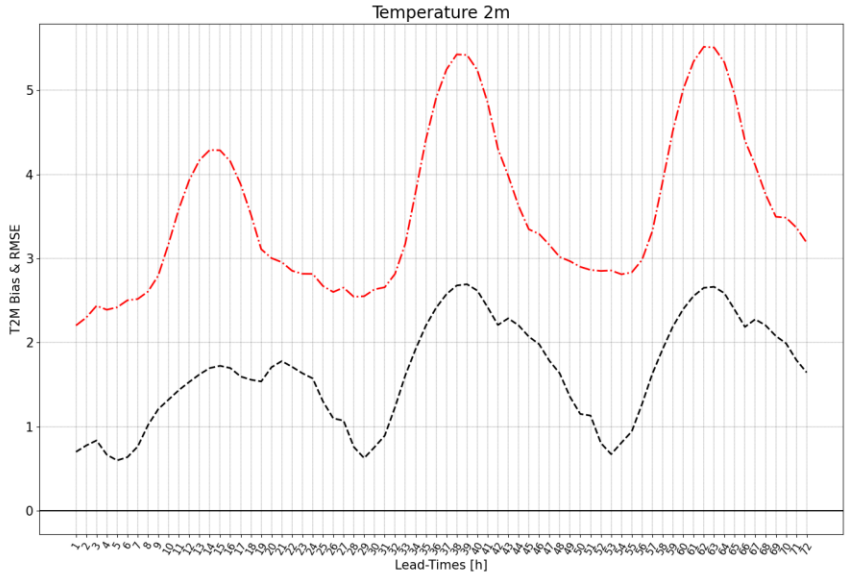
$$FAR = \frac{F}{H+F} \qquad POD = \frac{H}{H+M}$$

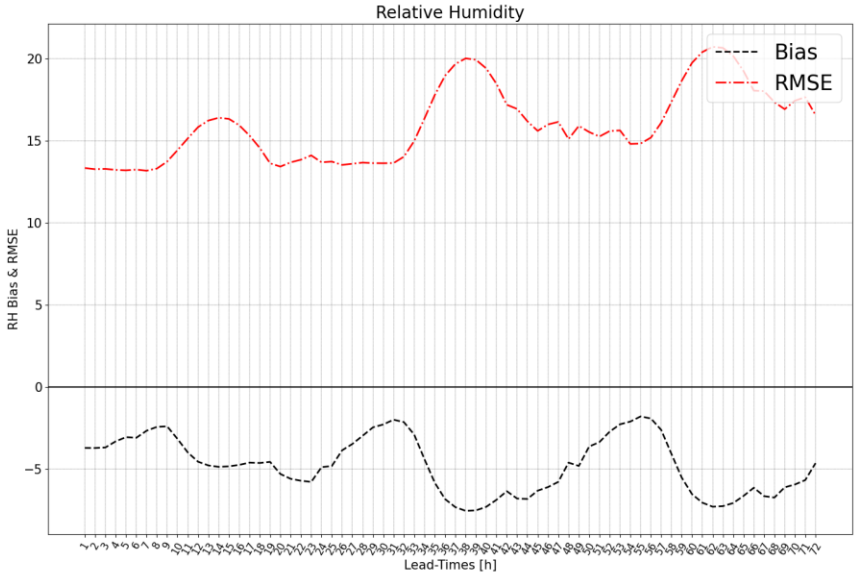
$$EDI = \frac{log(H) - log(M)}{log(H) + log(M)}$$

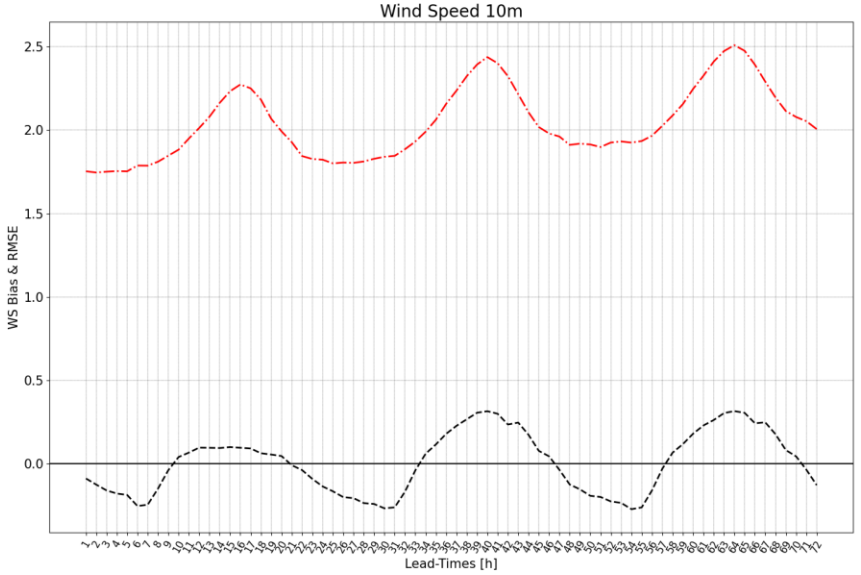
$$SEDI = \frac{log(FAR) - log(POD) + log(1-POD) - log(1-FAR)}{log(FAR) + log(POD) + log(1-POD) + log(1-FAR)}$$

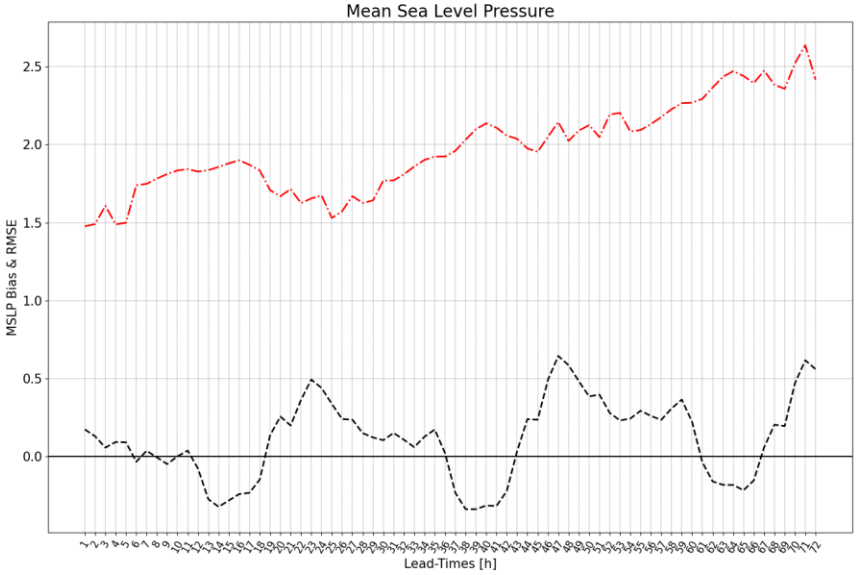
$$ETS = \frac{H - H_r}{H + M + F - H_r} \qquad H_r = (H+M)(H+F)/N$$

Hourly Bias and RMSE



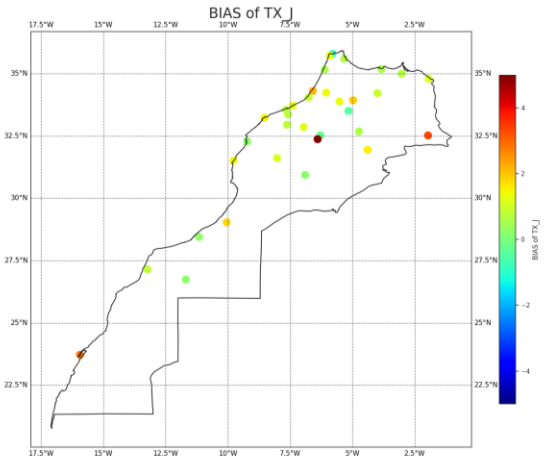


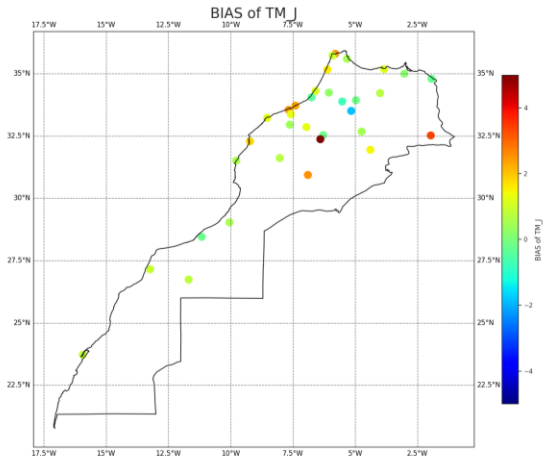


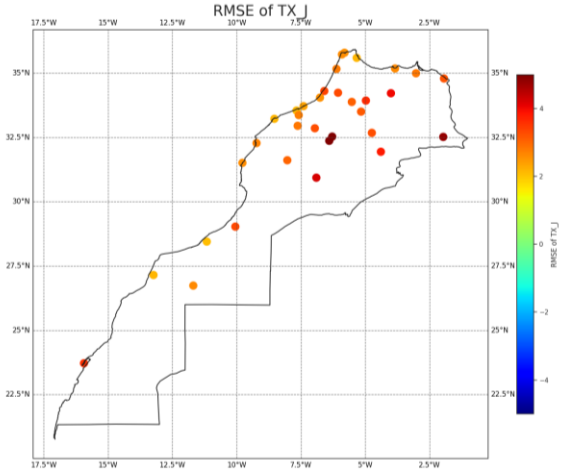


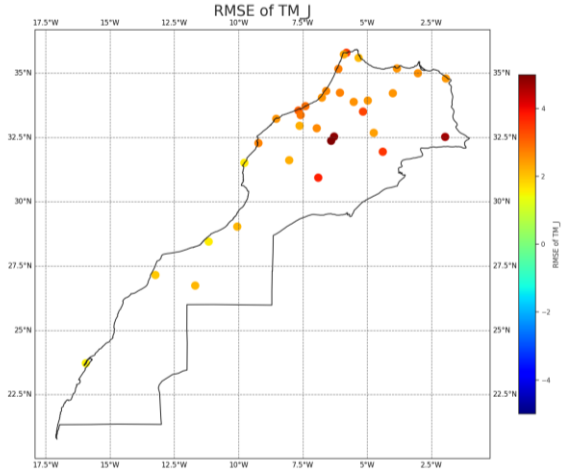
- Max Bias of T2m ~2 °C and RMSE ~ 5 °C
- RH Bias ~ -5 % and RMSE ~ 15%
- WS10m Bias ~ 0 m/s and RMSE ~ 2 m/s
- MSLP Bias ~ 0 hPa and RMSE ~ 1.5 hPa
- Scores getting bad with greater leadtimes -> Predictability

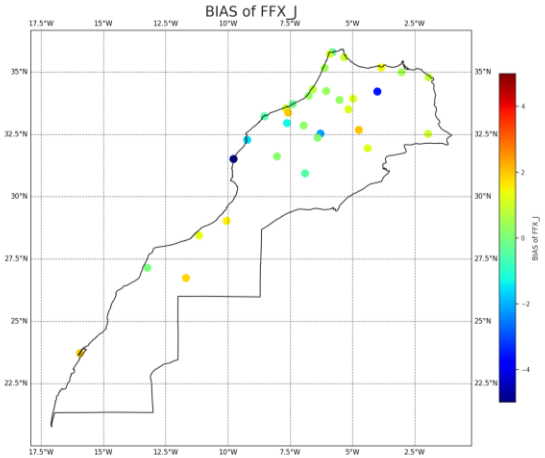
Bias and RMSE at J Extreme

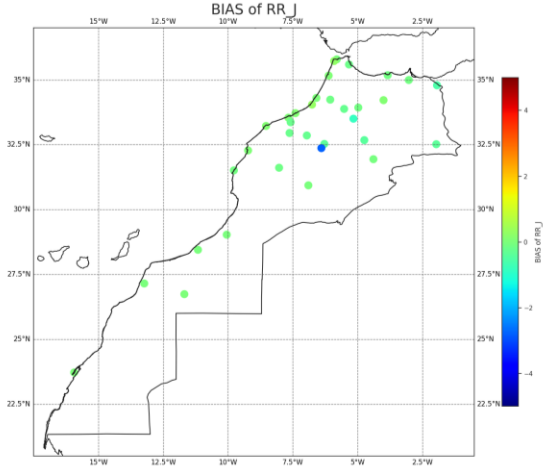


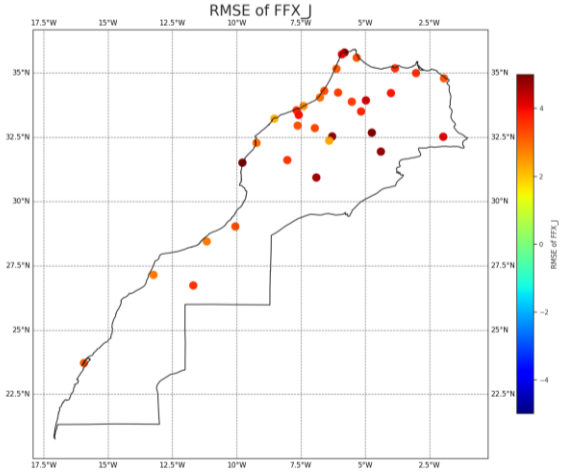


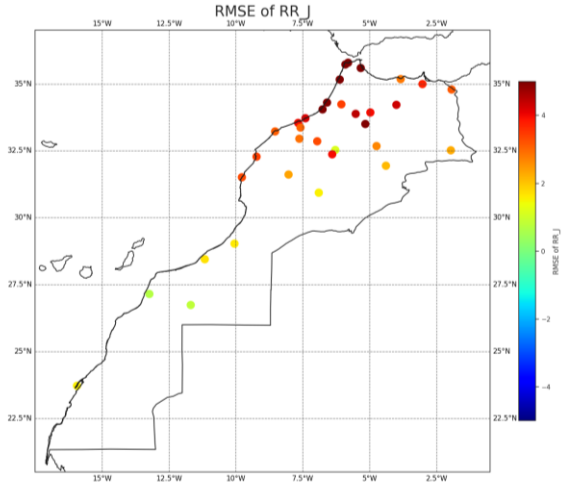






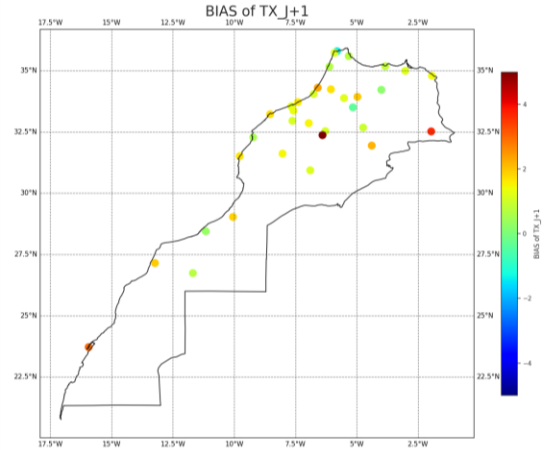


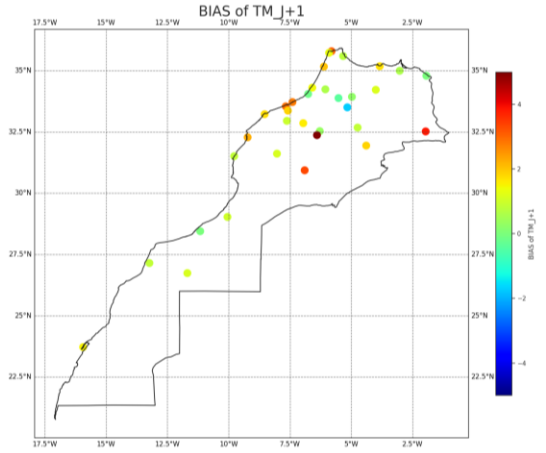


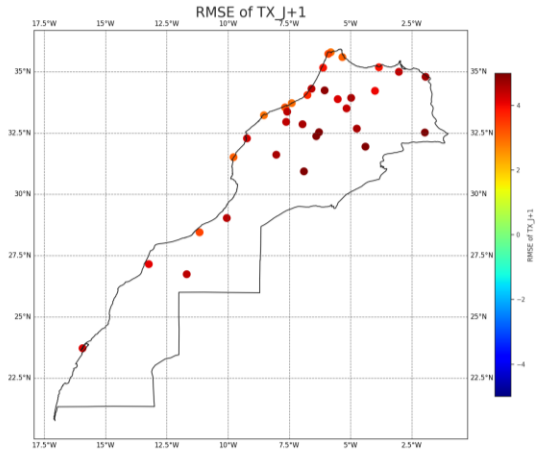


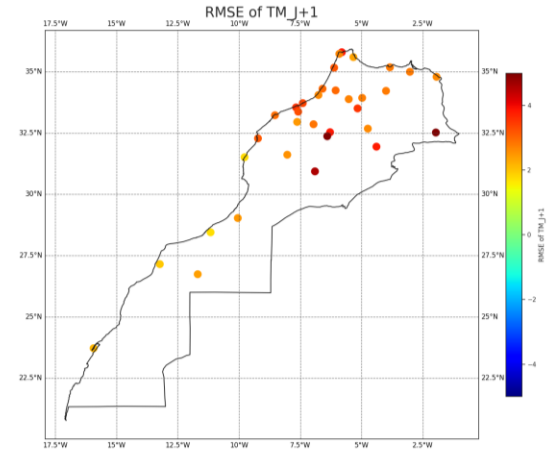
- Weak Bias for All the parameters except for some locations (TX and TM <2°C, FFX>1.5 m/s , RR ~ 0mm)
- RMSE superior to 2 in magnitude for all the parameters (except for some locations (desert for RR))

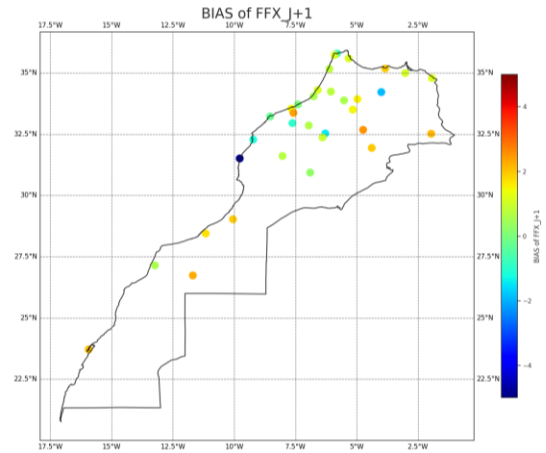
Bias and RMSE at J+1 Extreme

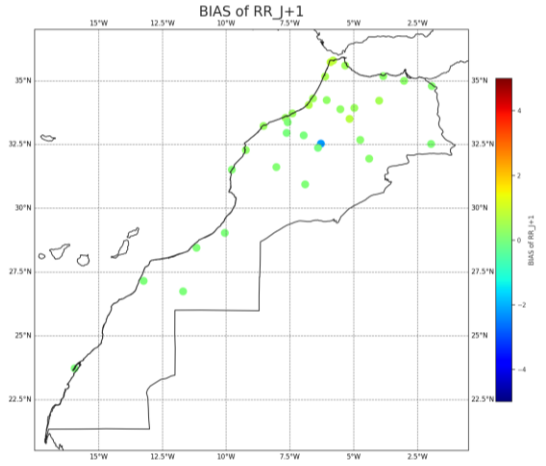


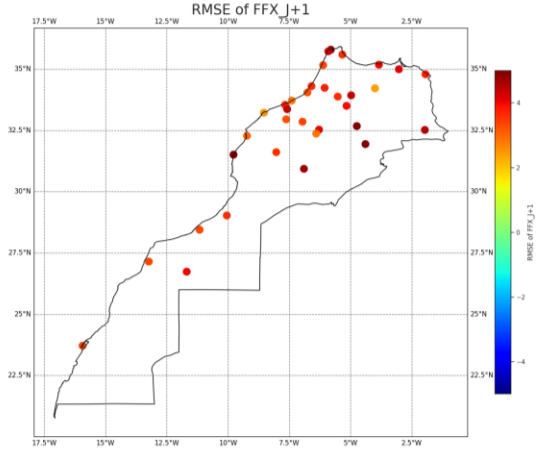


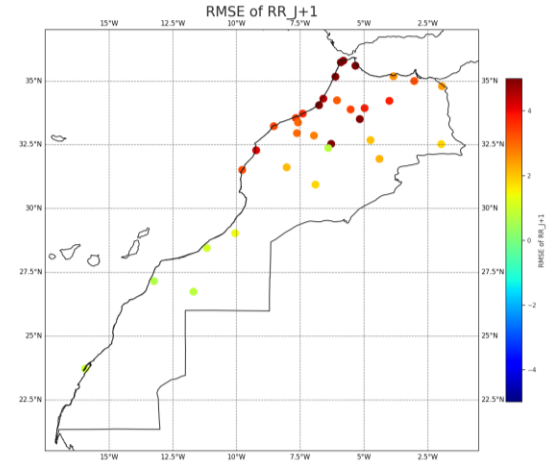






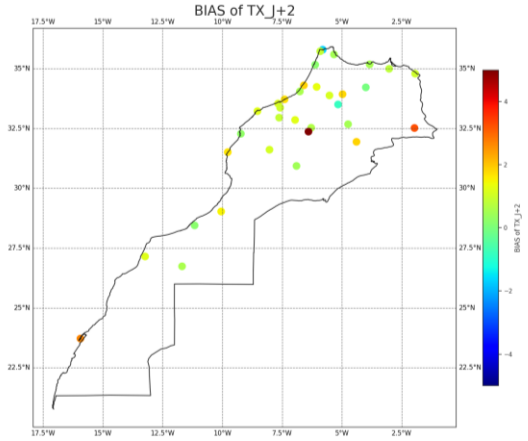


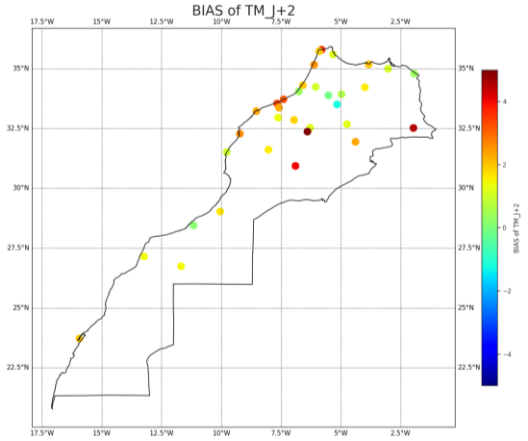


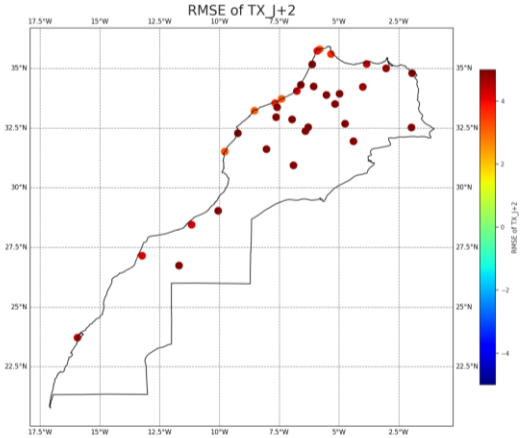


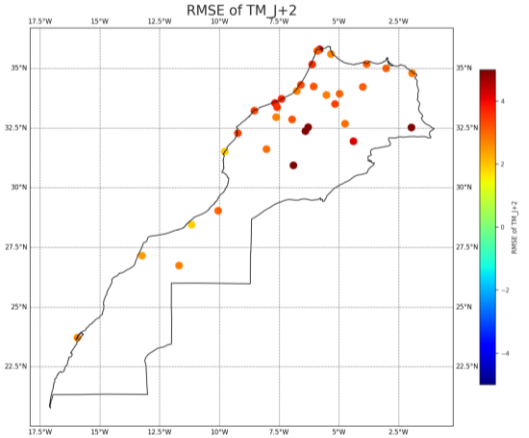
- Weak Bias for All the parameters except for some locations (TX and TM <3°C, FFX> 2 m/s , RR ~ 0mm)
- RMSE superior to 3 in magnitude for all the parameters (except for some locations (desert for RR))
- Bias and RMSE in J+1 is larger than in J

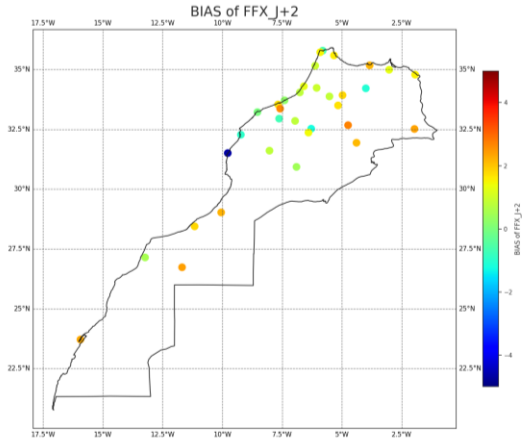
Bias and RMSE Extreme J+2

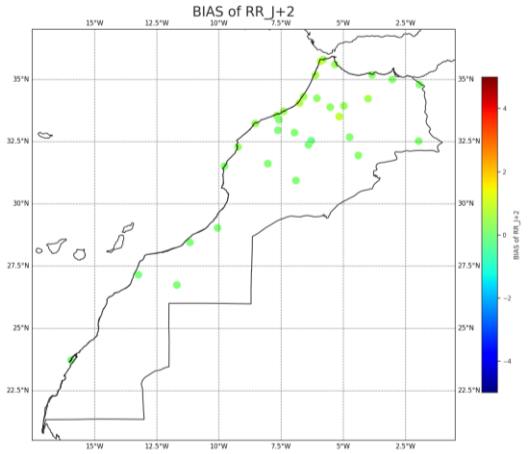


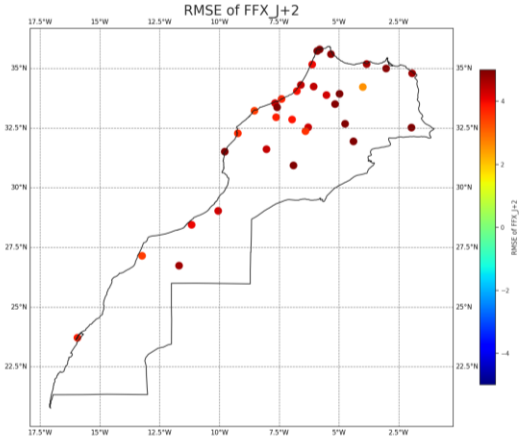


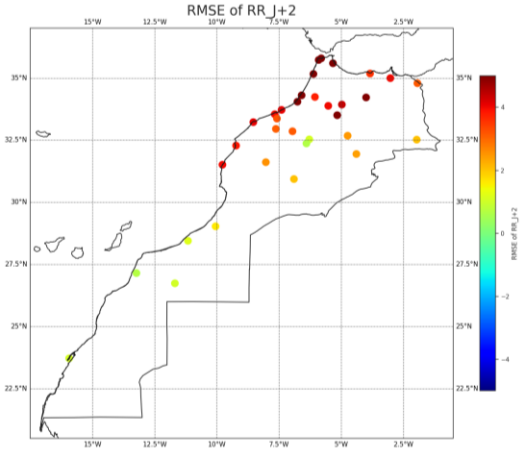






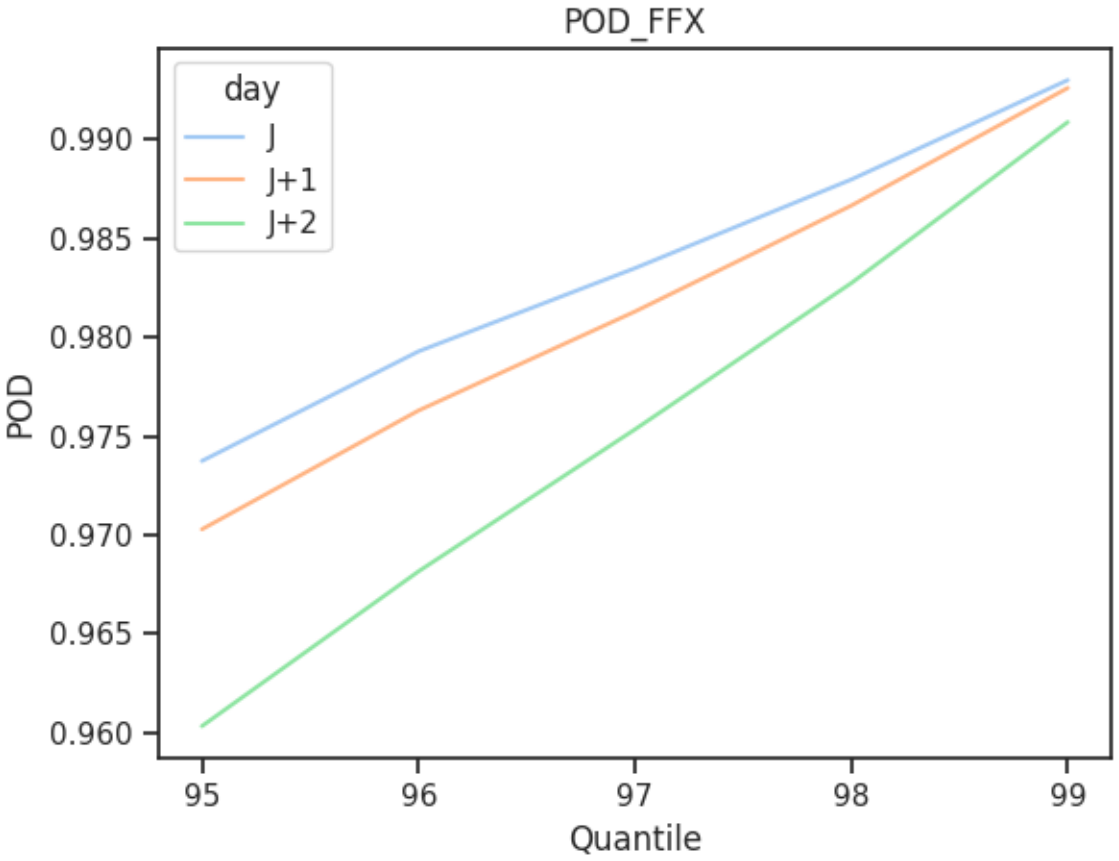


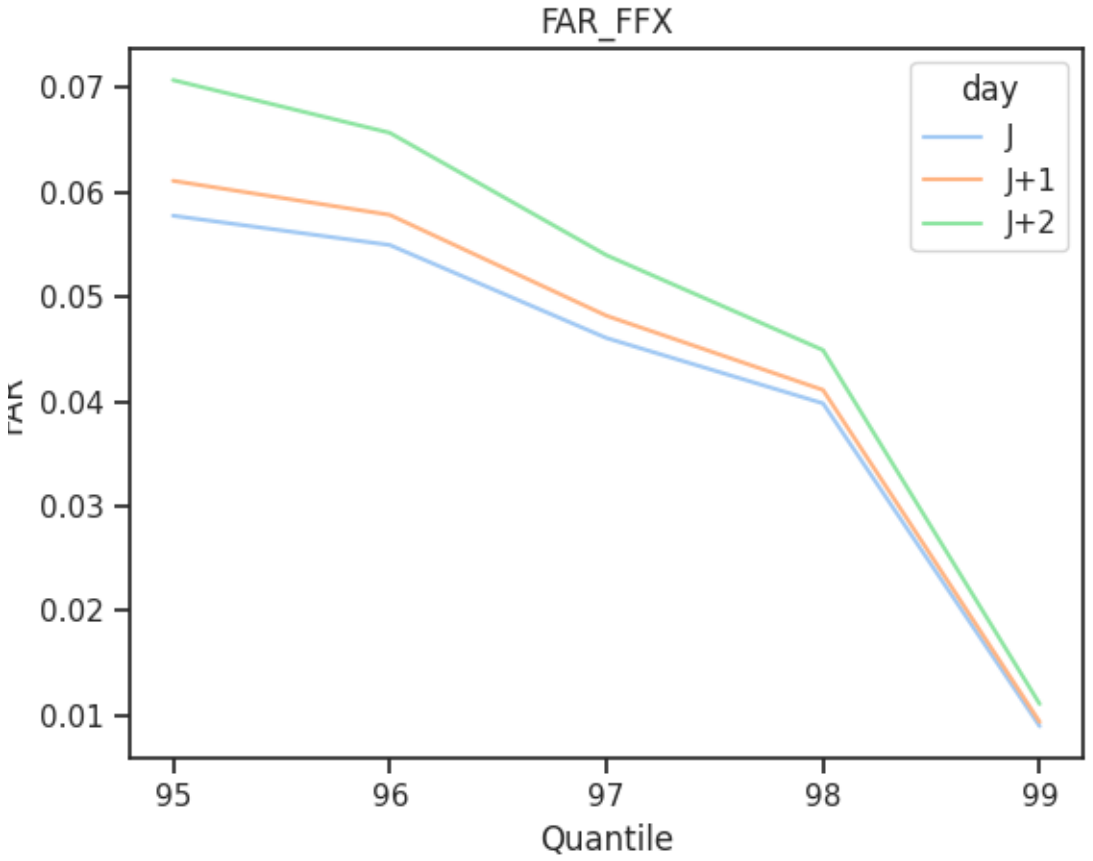




- Weak Bias for All the parameters except for some locations (TX and TM <3°C, FFX> 2 m/s , RR ~ 0mm)
- RMSE superior to 4 in magnitude for all the parameters (except for some locations (desert for RR))
- Bias and RMSE in J+2 is larger than in J and J+1 (Predictability)

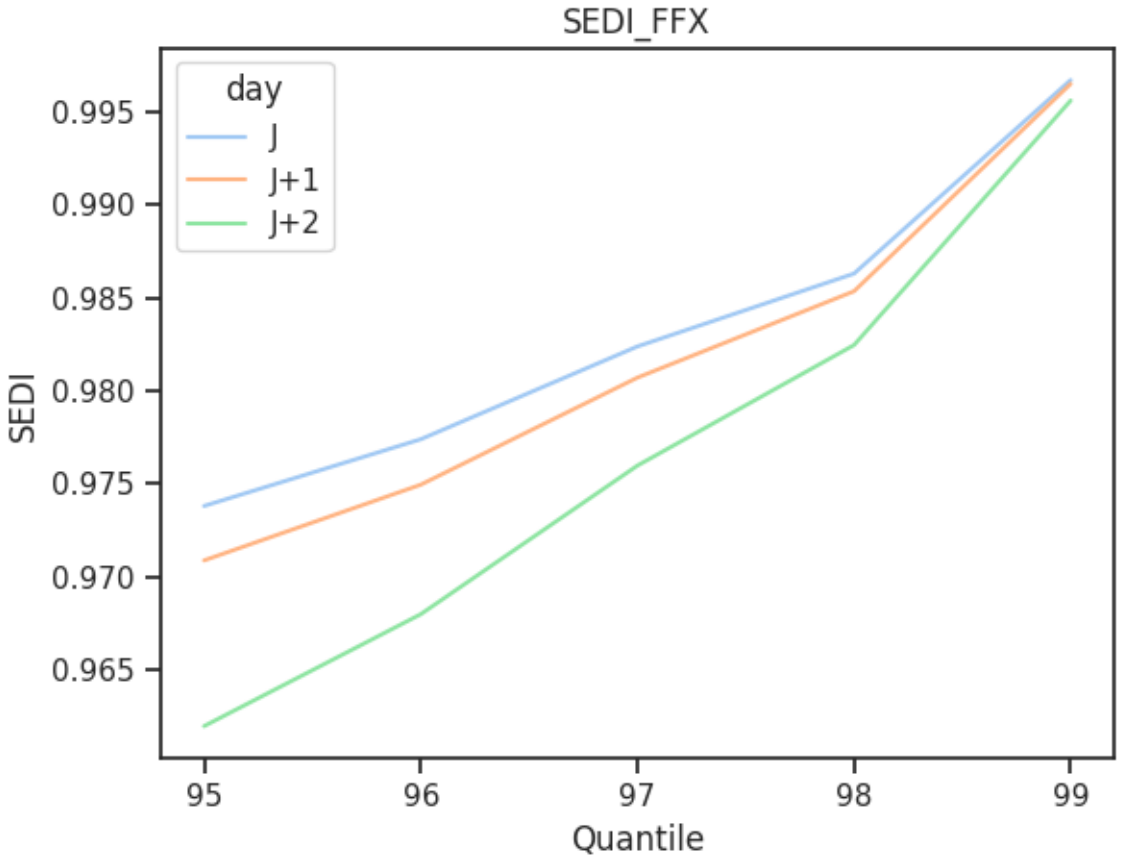
Wind Gust (FFX)

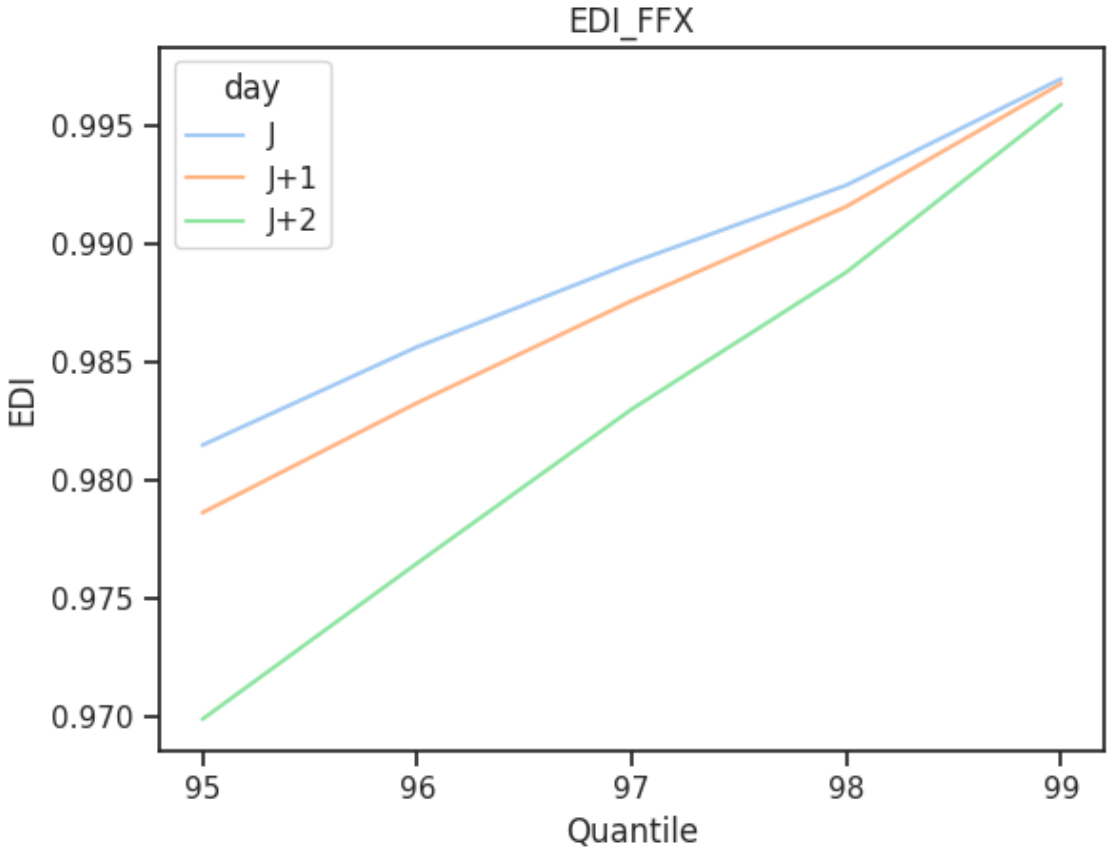




- POD > 0,96 for all quantiles
- FAR < 0,07 for all quantiles
- Better scores for high quantiles
- Better scores for most recent days

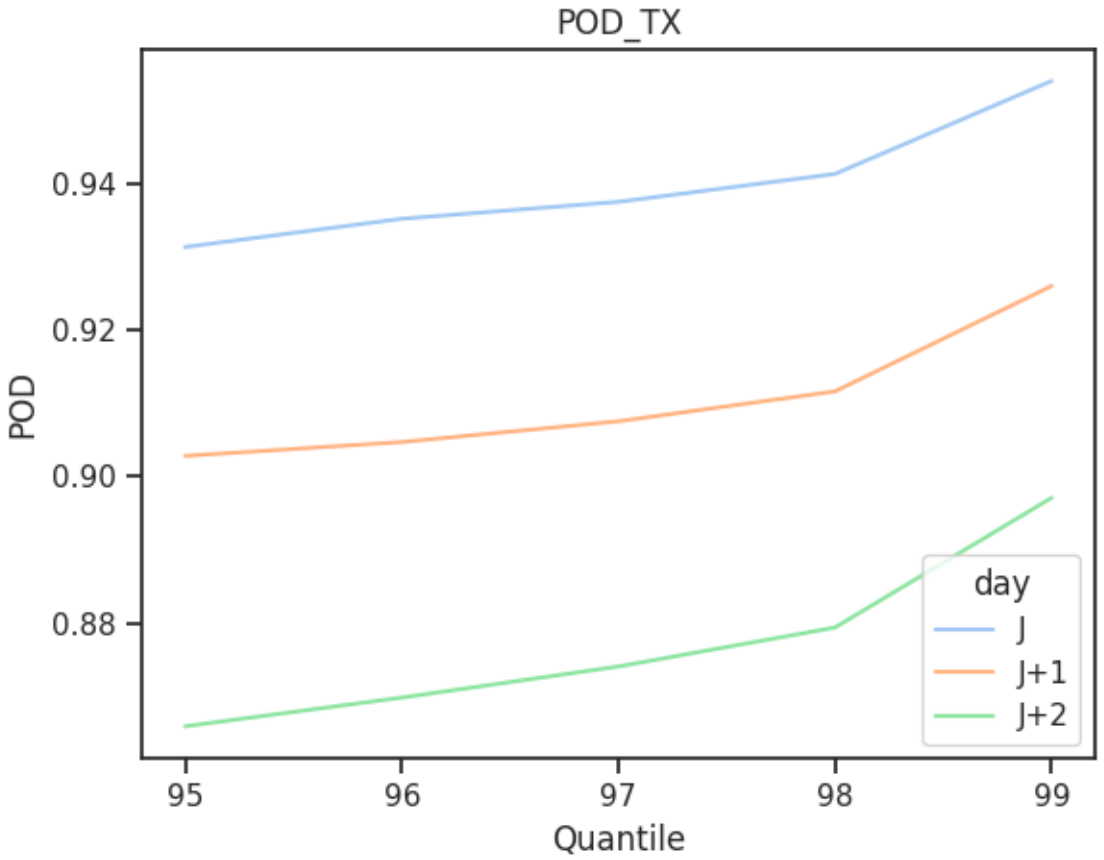
Wind Gust (FFX)

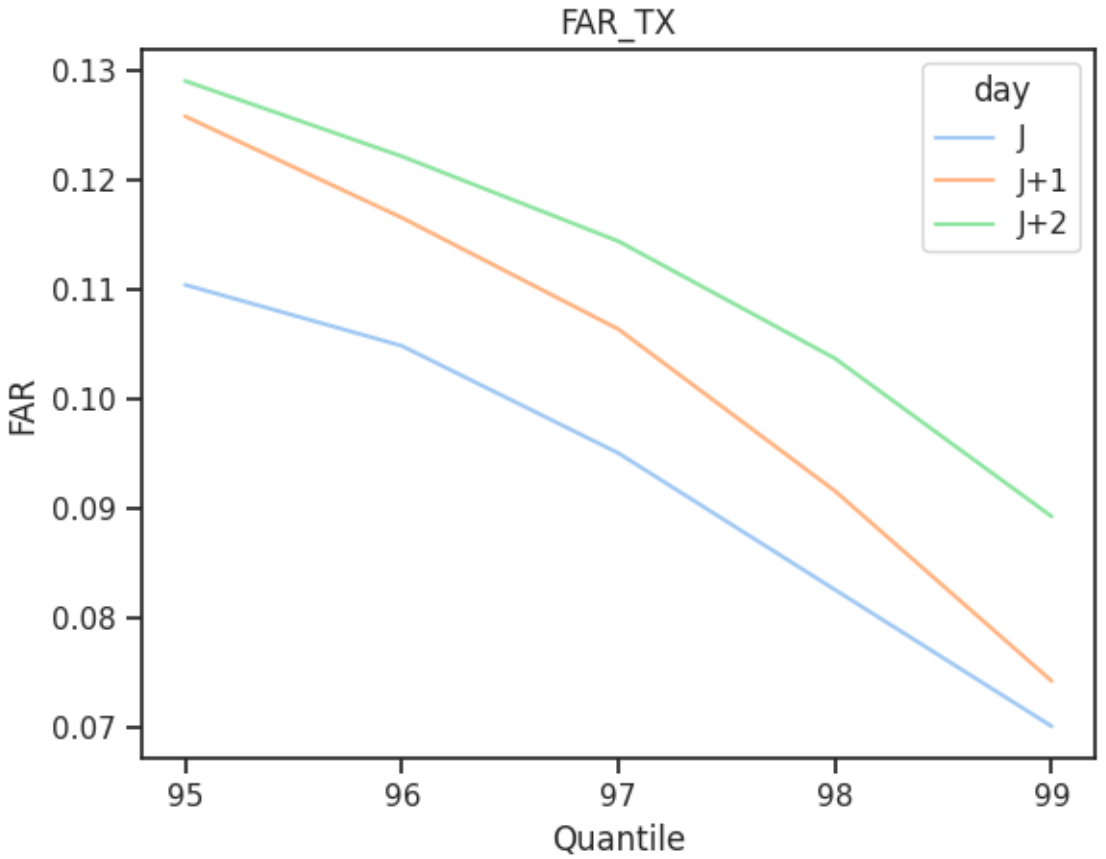




- SEDI > 0,96 for all quantiles
- EDI > 0,97 for all quantiles
- Better scores for high quantiles
- Better scores for most recent days

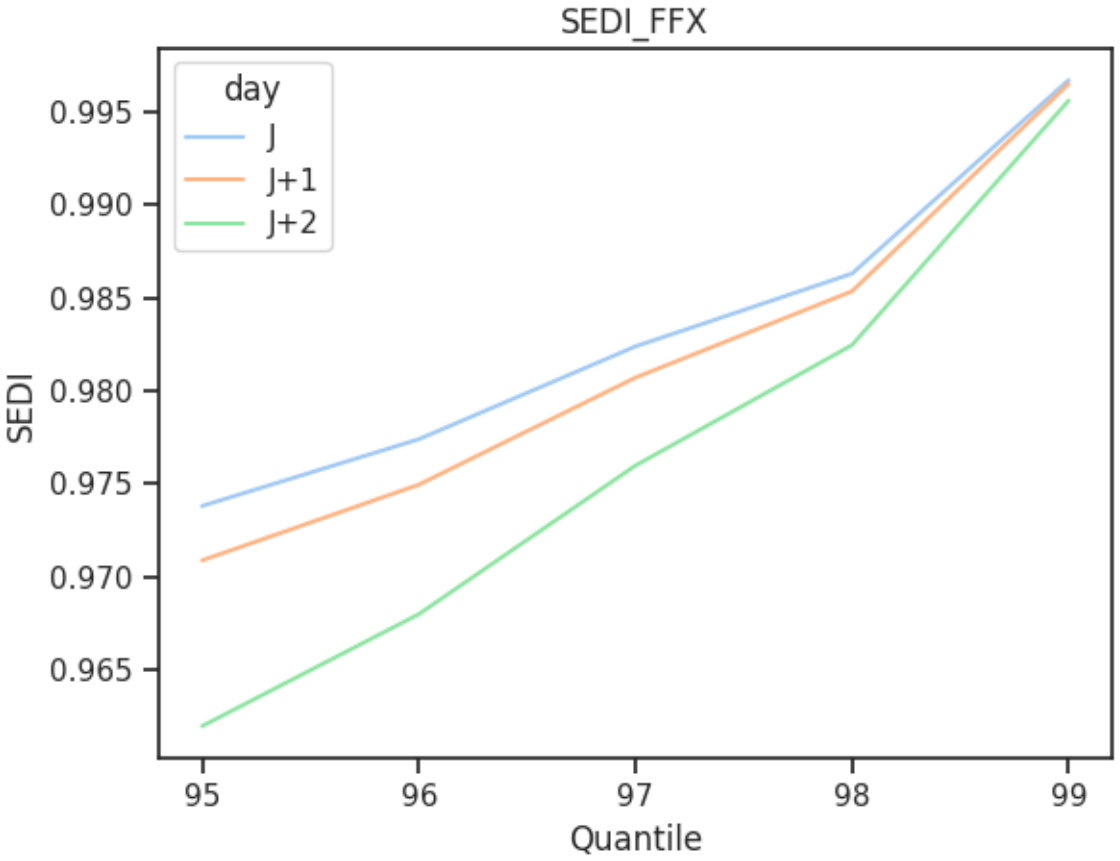
Max Temperature (TX)

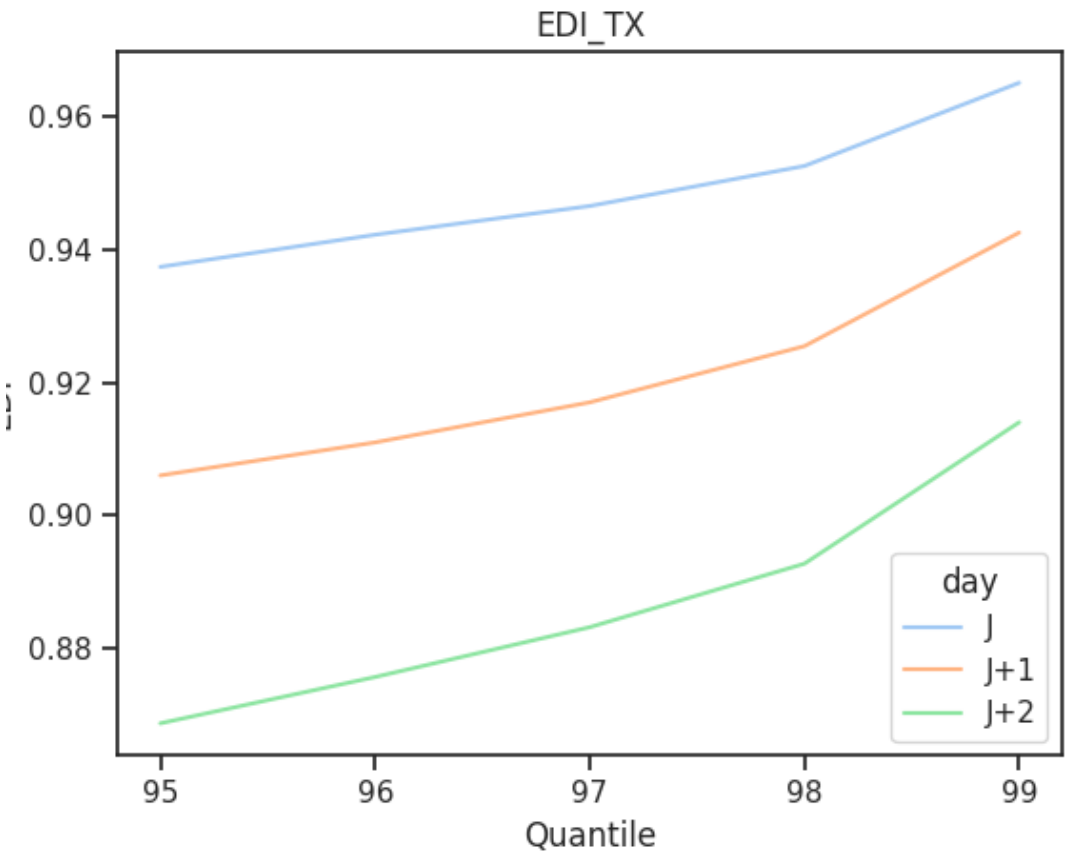




- POD > 0,86 for all quantiles
- FAR < 0,13 for all quantiles
- Better scores for high quantiles
- Better scores for most recent days

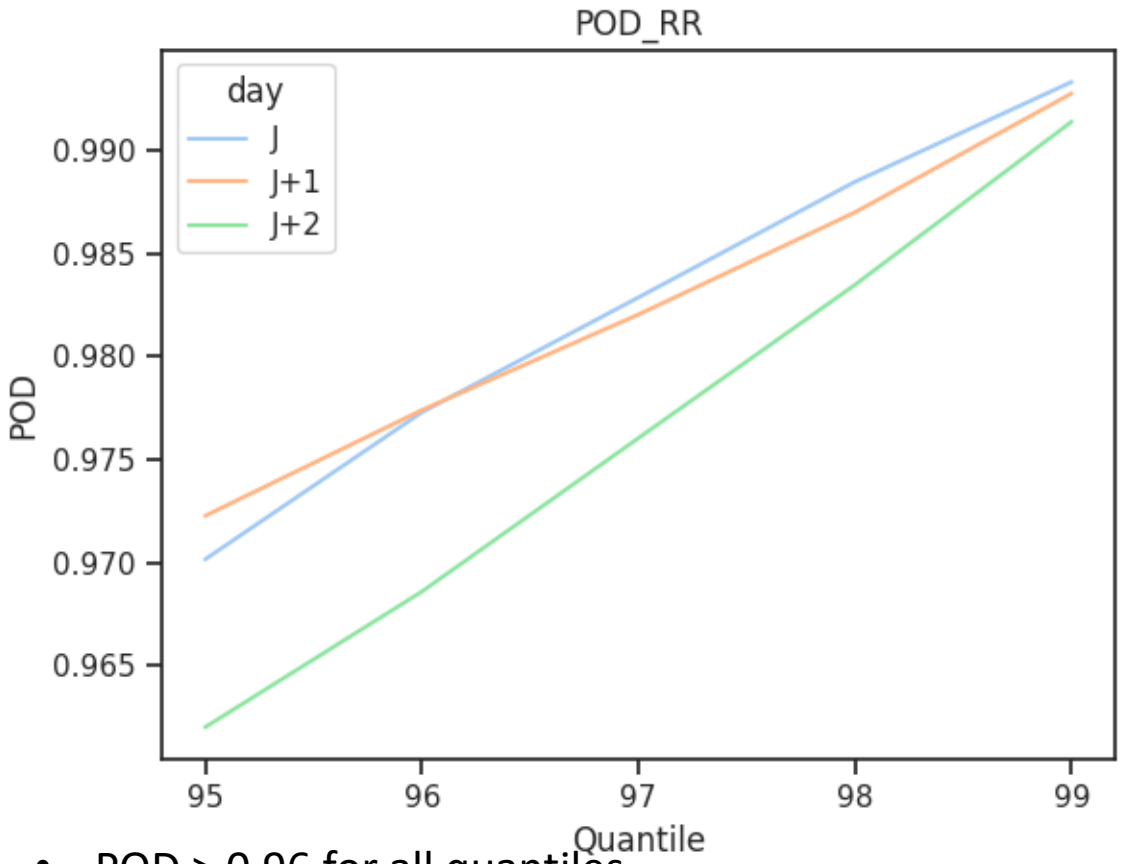
Max Temperature (TX)

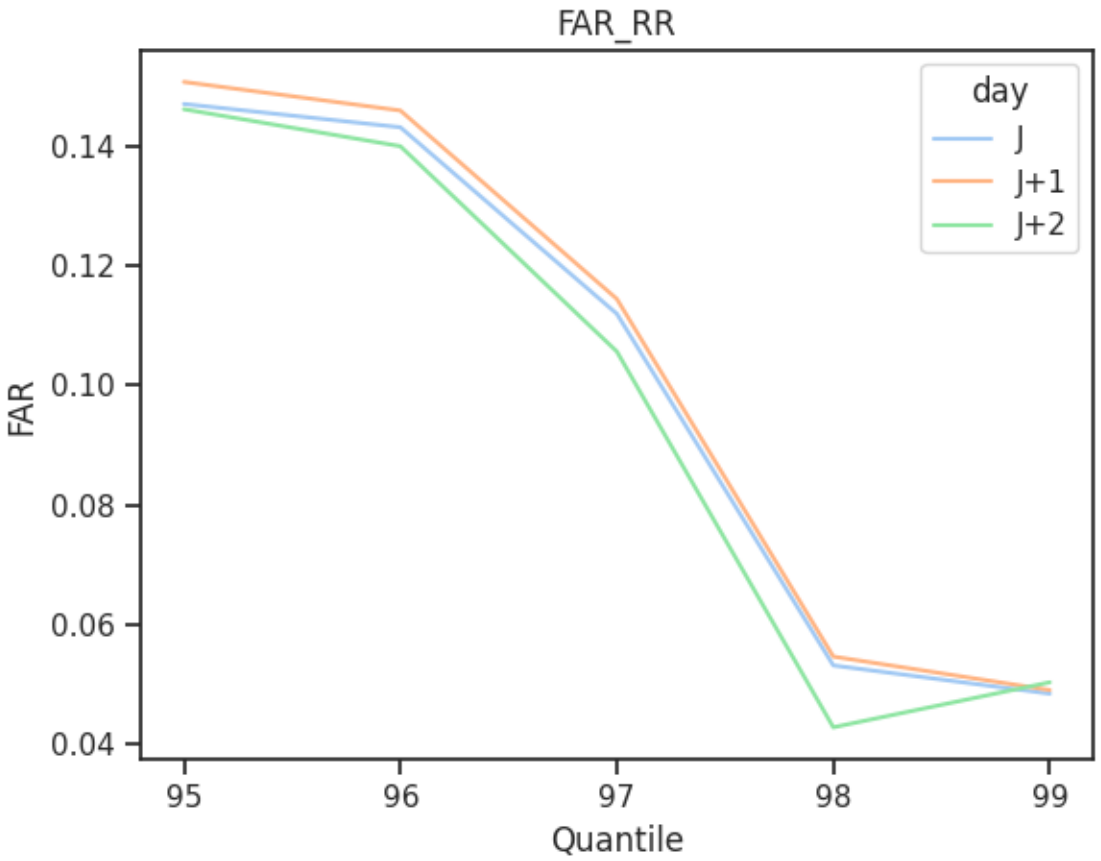




- SEDI > 0,96 for all quantiles
- EDI > 0,86 for all quantiles
- Better scores for high quantiles
- Better scores for most recent days

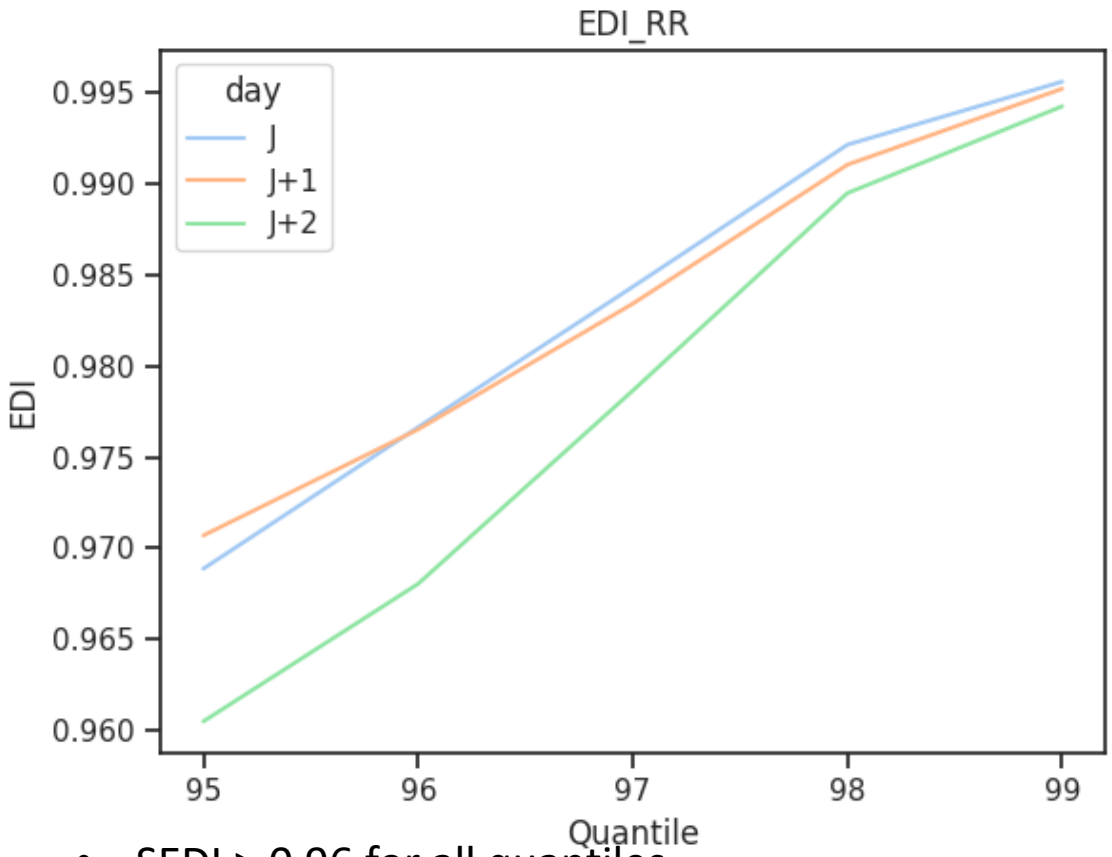
Precipitations (RR)

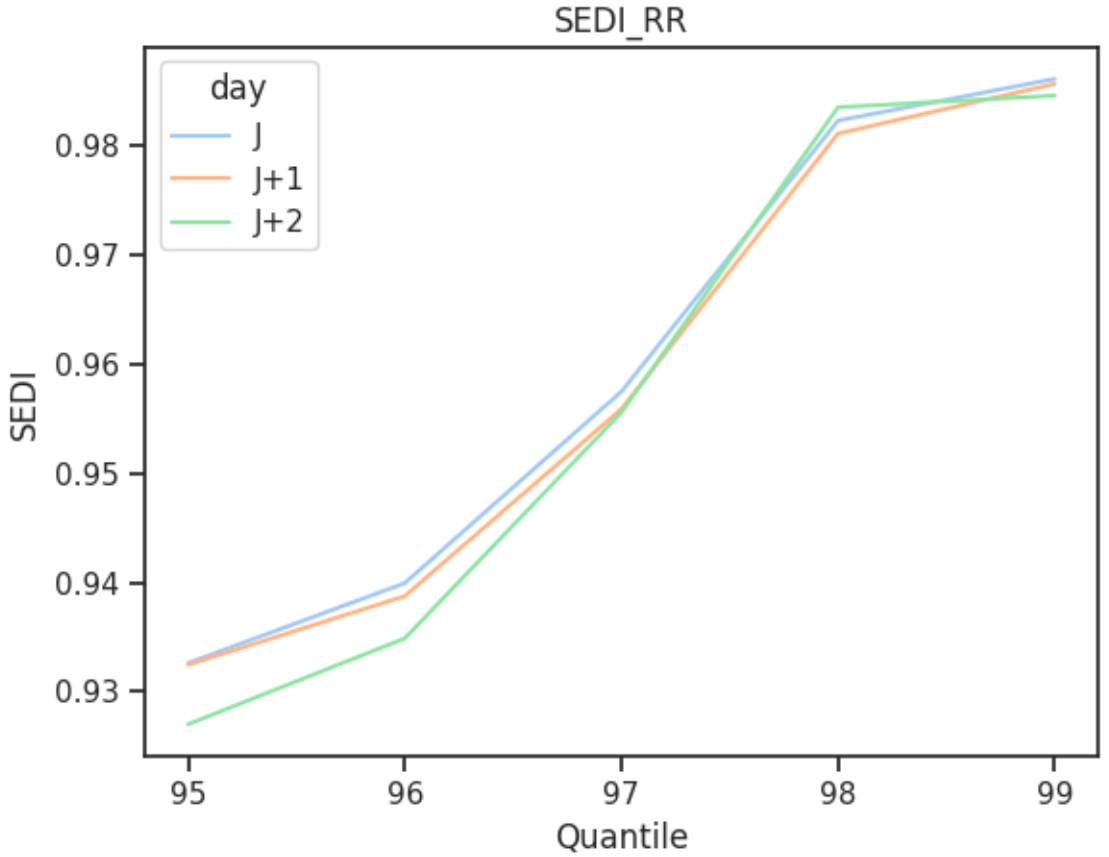




- POD > 0,96 for all quantiles
- FAR < 0,14 for all quantiles
- Better scores for high quantiles
- Better scores for most recent days

Precipitations (RR)





- SEDI > 0,96 for all quantiles
- EDI > 0,93 for all quantiles
- Better scores for high quantiles
- Better scores for most recent days

Conclusion

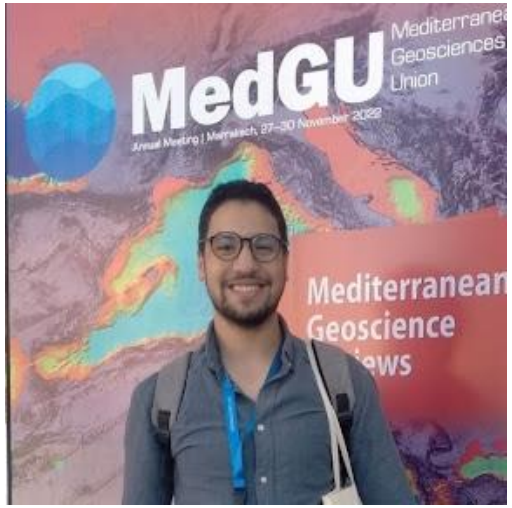
- AROME shows weak bias and RMSE for continuous verification for most parameters (except RH)
- Regarding probabilistic verification AROME shows high scores > 96%
- Scores depends on locations
- Degradation of scores with high predictability

Perspectives

- Verification of AROME relatively to seasons and climate types
- Probabilistic verification of AROME-EPS
- Investigating Calibration methods using AI algorithms

Thank you!

Badreddine Alaoui
alaoui.badreddine.abe@gmail.com
alaoui.badreddine@marocmeteo.ma



References

- Amodei, M., Sanchez, I., & Stein, J. (2015). Verification of the French operational high-resolution model AROME with the regional Brier probability score. *Meteorological Applications*, *22*(4), 731-745.
- Luitel, B., Villarini, G., & Vecchi, G. A. (2018). Verification of the skill of numerical weather prediction models in forecasting rainfall from US landfalling tropical cyclones. *Journal of hydrology*, *556*, 1026-1037.
- Raynaud, L., Touzé, B., & Arbogast, P. (2018). Detection of severe weather events in a high-resolution ensemble prediction system using the extreme forecast index (EFI) and shift of tails (SOT). *Weather and Forecasting*, *33*(4), 901-908.
- Stoop, F., & Stein, J. (2020). Application of neighborhood-based contingency scores to AROME verification.
- Sass, B. H. (2021). A scheme for verifying the spatial structure of extremes in numerical weather prediction: Exemplified for precipitation. *Meteorological Applications*, *28*(4), e2015.
- El Khalki, E. M., Tramblay, Y., Amengual, A., Homar, V., Romero, R., Saidi, M. E. M., & Alaouri, M. (2020). Validation of the AROME, ALADIN and WRF meteorological models for flood forecasting in Morocco. *Water*, *12*(2), 437.
- Roff, G., Bermous, I., Dietachmayer, G., Fernon, J., Fraser, J., Lu, W., ... & Xiao, Y. (2022). APS2-ACCESS-C2: the first Australian operational NWP convection-permitting model. *Journal of Southern Hemisphere Earth Systems Science*, *72*(1), 1-18.