Project: **1478**

Project title: **Mediterranean and pan-European forecast and Early Warning System against natural hazards - MedEWSa**

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1. Overview of the project results acquired until now

The MedEWSa project aims to establish an Early Warning System (EWS) for major climate hazards—floods, droughts, and heatwaves—across Europe, the Mediterranean, and Africa. Within this framework, JLU contributes to the Decision Support Dissemination System (DSDS) by generating high-resolution, bias-corrected seasonal forecasts and supporting the detection and forecasting of extreme events. Major progress has been achieved in the development of the AI/ML-based post-processing system, including: 1) Completion of data preprocessing, regional division, and model training across the pan-European–Mediterranean–African domain 2) Successful downscaling and bias correction for the period 1993–2015, using 1993–2014 for model training and 2015 for independent testing and 3) Integration of European Meteorological Observations (EMO-1) as reference datasets for evaluation.

2. Preprocessing Phase

Due to the data spatial resolution (1 arcminute) and wide geographical coverage (−12° to 45°E, latitude 30° to 72°N), a regionalization approach was necessary to optimize computational performance and ensure model stability. The study domain was divided into: Five zones for maximum (TX) and minimum (TN) temperature and Six zones for precipitation.

For temperature, regionalization was performed using annual mean monthly temperature as input for Principal Component Analysis (PCA) with varimax rotation. The first six principal components, explaining 81.4% of total variance, were retained. A 0.75 loading threshold was applied, defining five overlapping temperature zones to maintain smooth spatial transitions and reduce boundary effects.

For precipitation, regionalization was based on annual monthly sums and followed the same PCA–varimax procedure. The first sixteen principal components explained 68.1% of total variance, with the 0.75 loading threshold producing six precipitation zones. This preprocessing ensured that the model effectively represented both large-scale climatic gradients and local-scale variability, enabling stable, efficient, and scalable model training and evaluation across the full MedEWSa domain.

3. Downscaling and bias correction

This study employed a two-stage process encompassing statistical downscaling followed by bias correction. The primary dataset, the European Meteorological Observations at 1 arcmin (EMO-1) daily dataset (1990–2015) (Thiemig et al., 2022) acting as the predictand (observational) data.

For the statistical downscaling, an enhanced Deep Residual Neural Network–Convolutional Neural Network (DRNN–CNN) framework was implemented (Díaz Esteban et al. 2024, Lin et al. 2024).

The model architecture integrated Channel Attention Blocks (CAB) and Spatial Attention Blocks (SAB) (Woo et al, 2018) to improve spatial generalization, feature prioritization, and sensitivity to regional variability. Topography was introduced as an early input to the model to retain terrain-driven effects, while controlled resizing operations were substituted for heavy upsampling to maintain structural consistency.

Following the downscaling procedure, two distinct bias correction approaches were evaluated. The first was an AI-based method utilizing a deep CNN with a weighted Mean Absolute Error (MAE) loss, specifically designed to address skewed precipitation data. The second was Quantile Mapping (QM). Comparative analysis demonstrated that QM provided superior stability and distributional accuracy across regions. Consequently, the Quantile Delta Mapping (QDM) method (Cannon et al., 2015), a specific variant of QM that corrects systematic deviations while preserving projected climate trends, was selected for bias correction implementation. This QDM method was applied to all temperature and precipitation zones.

The performance of the post-processed model was validated using 2015 as an independent test year for 25 ensembles. The results showed close agreement with the reference datasets and significantly reduced biases across all variables. The final post-processed simulations were produced at a daily temporal resolution as shown in Figure 1.

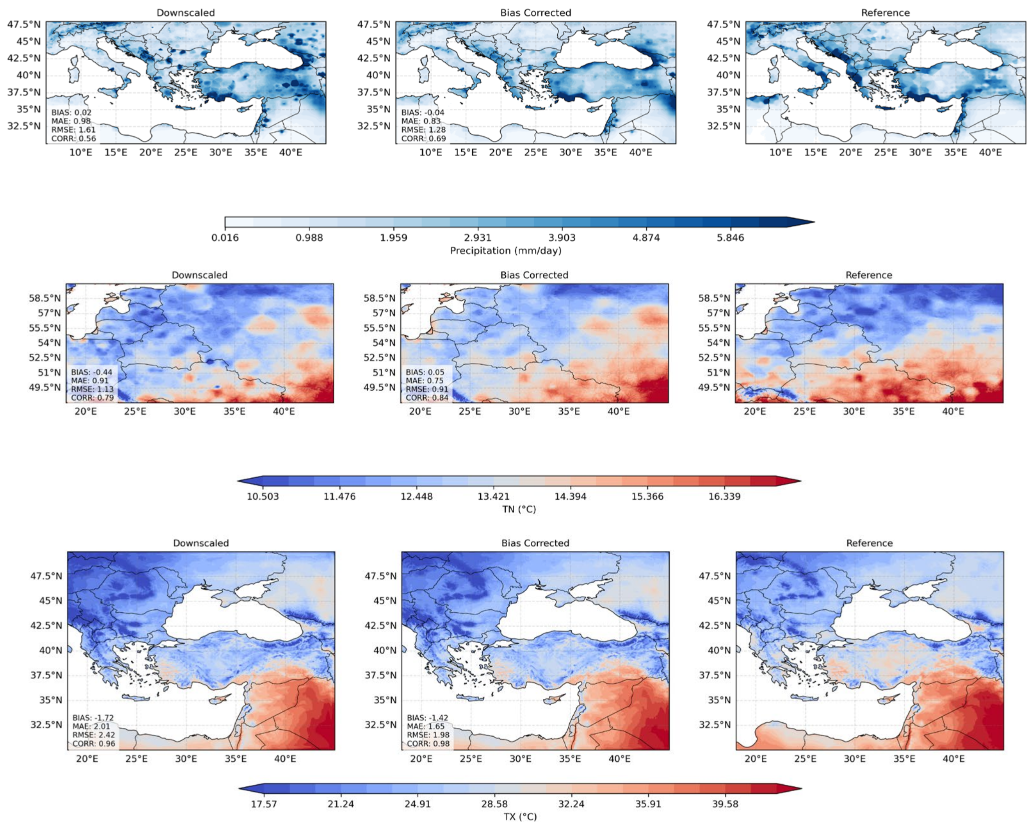

Figure 1. Comparison of downscaled, bias-corrected, and reference datasets for (top) Precipitation (mm/day, Zone 2, Ensemble 02, 01/2015), (middle) Minimum Temperature (Zone 1, Ensemble 01, 09/2015), and (bottom) Maximum Temperature (Zone 2, Ensemble 03, 09/2015).

4. Summary

The MedEWSa project is developing an Early Warning System for climate hazards across Europe, the Mediterranean, and Africa, with a key contribution being the generation of high-resolution, bias-corrected seasonal forecasts. To manage the large and high-resolution (1 arcminute) domain, the study area was first regionalized into five temperature and six precipitation zones using Principal Component Analysis. Following this preprocessing, an enhanced Deep Residual Neural Network (DRNN–CNN) with attention blocks was used for statistical downscaling, and the Quantile Delta Mapping (QDM) method was selected for bias correction due to its superior stability over an AI-based CNN approach. The final post-processed daily simulations, which used EMO-1 observational data as a reference, were successfully validated using 2015 as an independent test year, showing close agreement with observations and significantly reduced biases.

5. References

Woo et al. (2018). https://arxiv.org/abs/1807.06521

Díaz Esteban et al. (2024). https://doi.org/10.5194/egusphere-egu24- 19311.

Lin et al. (2024). https://doi.org/10.5194/egusphere-egu24-12988, 2024.

Cannon et al. (2015). https://doi.org/10.1175/JCLI-D-14-00754.1

Thiemig et al. (2022). https://doi.org/10.5194/essd-14-3249-2022