Enhancing Spatial Consistency in downscaled Fire Weather Index (FWI) Projections for Improved Wildfire Risk Management: A multi-site multi-gaussian CNN approach

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Overview

In this study we describe different **CNN-based regression models** for multi-site extreme fire danger assessment under climate change conditions, based on the **Canadian Fire Weather Index** (FWI) records on 29 locations.
We deploy three alternative CNN topologies based on the PP-WG approach, that estimate either daily uni-variate or multi-variate Gaussian distributions. The validation is undertaken using specific measures of extreme reproducibility and spatial coherence, and are put in the context of other benchmarking classical **SD methods** (analogs and GLMs).

Objectives

Study CNNs for understanding FWI spatial patterns across diverse areas, emphasizing:

- Reproducibility of extreme events
- Ensuring the spatial consistency
- Extrapolation capacity

CNN Architectures

These architectures are trained on a 64 GB NVIDIA T100 for 100 epochs using early stopping to prevent network overfitting.

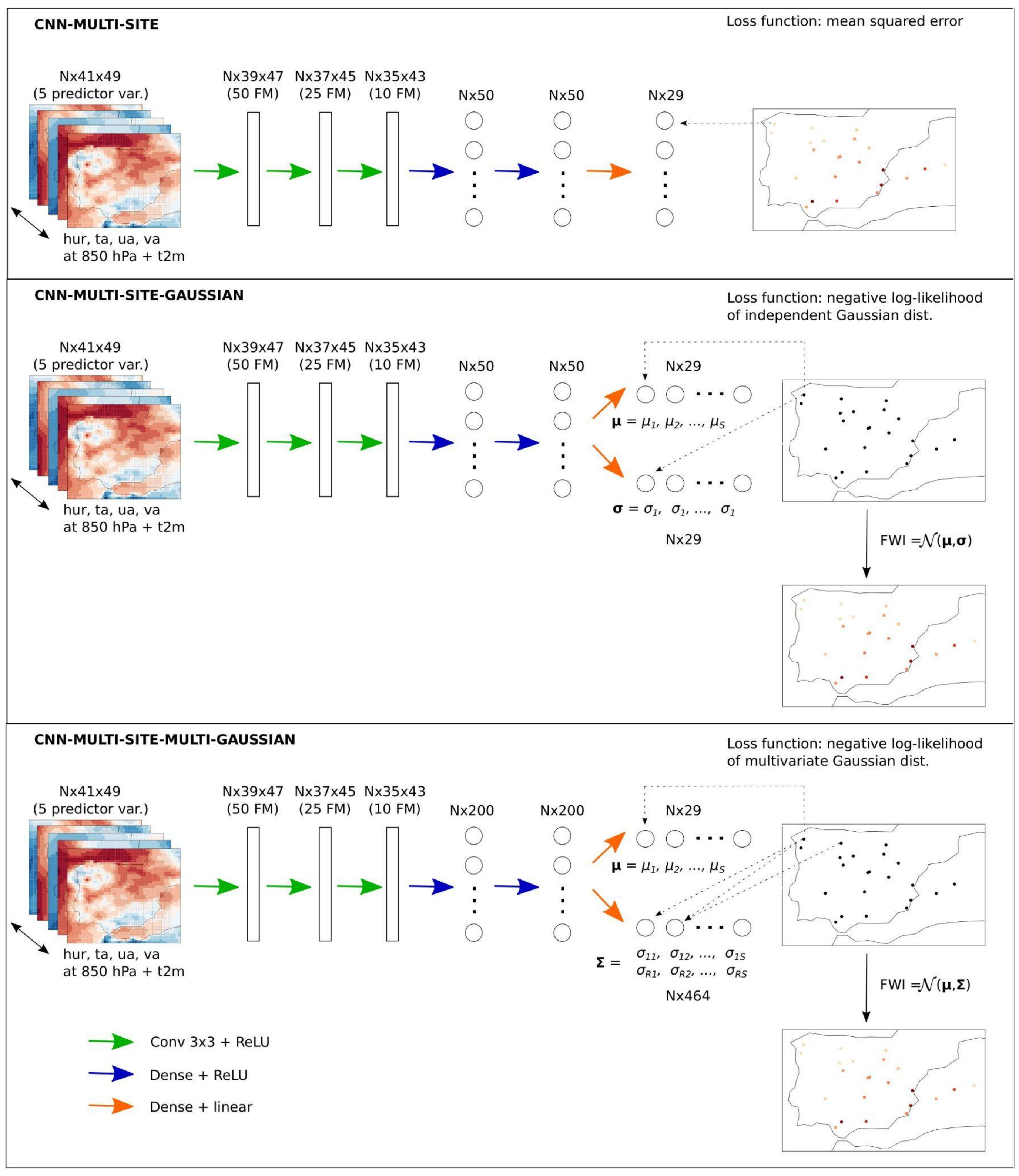

Figure 1: CNN architectures in this study

Data

- 29 stations selected from **AEMET** spanish network.
- **ERA5** 0.25º x 0.25º daily predictors (see Table 1) from 1985 to 2011 for computing the FWI.
- Use of cross-validation 4 chronological folds: 1985-1991, 1992-1998, 1999-2004, 2005-2011

Code	Name	units
T2M	Air Temperature at surface	K
T850	Air Temperature at 850 hPa	K
HUS850	Specific humidity at 850 hPa	$g\,kg^{-1}$
UA850	U-wind at 850 hPa	$m\,s^{-1}$
VA850	V-wind at 850 hPa	$m\,s^{-1}$

Table 1: Predictor variables used in this study, selected from the predictor combination proposed for statistical downscaling of FWI in [1].

Validation: FWI Correlation & FWI90 Mutual Information

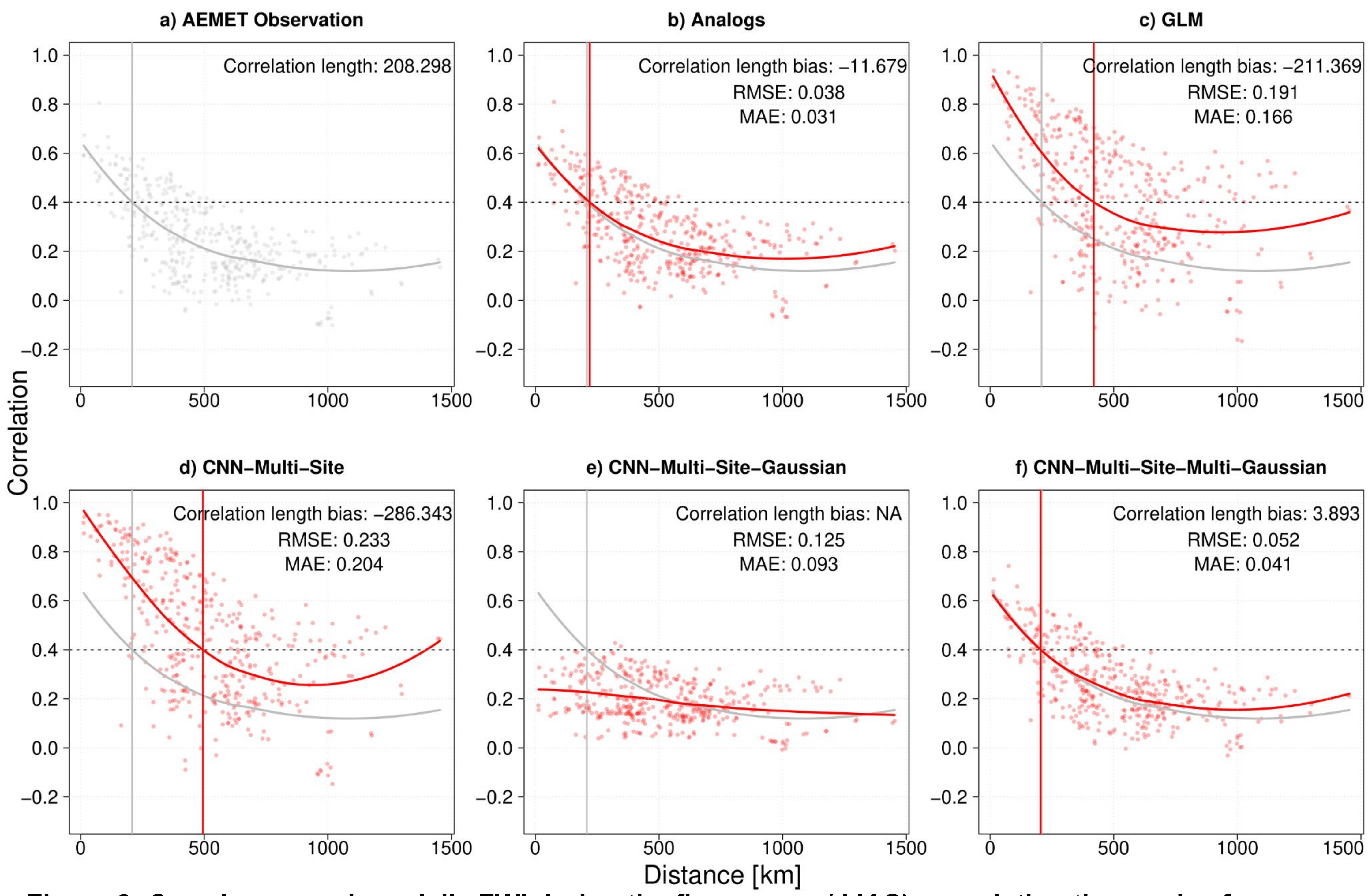

Figure 2: Correlograms show daily FWI during the fire season (JJAS), correlating time series for station pairs based on geographical distances.

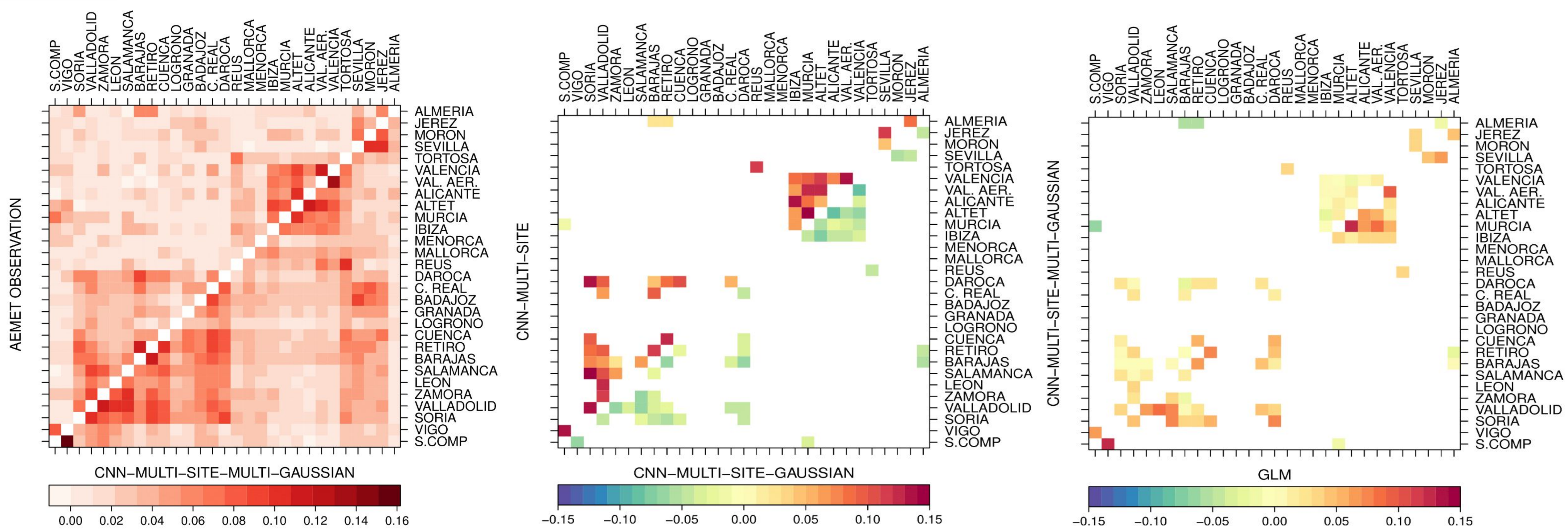

Figure 3: MI matrices for FWI90 in the JJAS fire season. Top matrix displays MI for observation references and best-performing model. Bottom left and right matrices depict MI bias relative to observations, showing pairs with MI ≥ 0.05.

Conclusions

- **CNN-MSMG** balances the **extrapolation ability** with adequate **extreme event reproducibility** and **spatial consistency.**
- These findings provide a methodological basis for the development of more robust, spatially coherent regional future FWI SD scenarios, as effective instruments in building resilience to wildfires.
- **Tuning** CNNs is vital for enhancing FWI spatial downscaling, boosting accuracy and applicability in predicting fire weather conditions.

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[2] Van Wagner, C.; Forest, P. In Development and structure of the Canadian forest fireweather index system, Can. For. Serv., Forestry Tech. Rep, Citeseer: 1987.