



Calibration of solar radiation ensemble forecasts using convolutional neural network

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Context and objective

We want to calibrate the PEARP ensemble forecast of global horizontal irradiation (GHI)

Traditional methods used to calibrate ensemble forecasts, like EMOS, are not explicitly designed to take advantage of spatio-temporal correlations

Convolutional neural networks (CNNs) are designed to process gridded data making them a suitable tool to work with numerical weather prediction data

⇒ **Objective: quantile regression using CNNs**

Data

CAMS - ground truth

- global horizontal irradiation (GHI) at 0.2° resolution
- over Europe
- derived from satellite observations (cloud cover) and model outputs (chemistry, aerosols, ...)

<http://www.soda-pro.com/fr/web-services/radiation/cams-radiation-service>

PEARP - 35 members ensemble forecast

- 3-h mean GHI
- forecasts starting at 18h UTC, lead times from 3 to 48h

ARPEGE - deterministic forecast

- 19 parameters

Predictors

Post-processing specifications

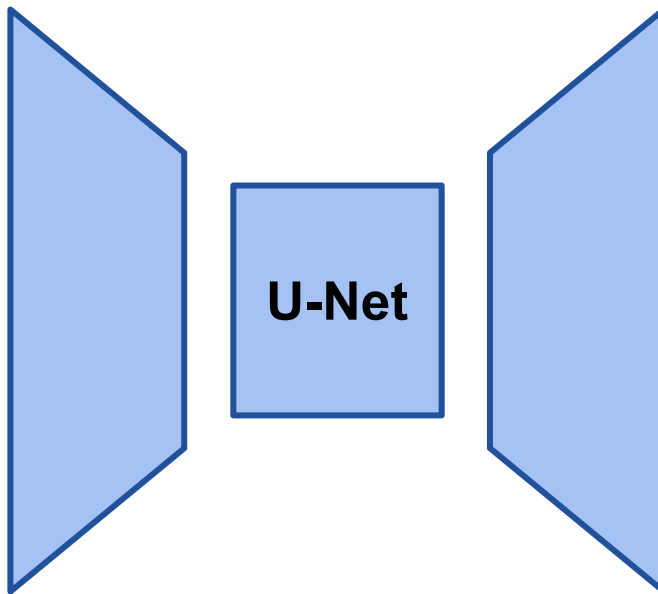
Predictors

PEARP

- GHI: min, max, median, quantiles 0.2 and 0.8

ARPEGE

- cloud cover: low level, med level, high level, convective cloud cover and TCC
- 3-h accumulated net fluxes: latent, sensible, solar
- wind components at 10 m
- classic weather parameters: temperature and relative humidity at 2 m, MSLP
- CAPE
- latitude and longitude



Outputs

35 quantiles

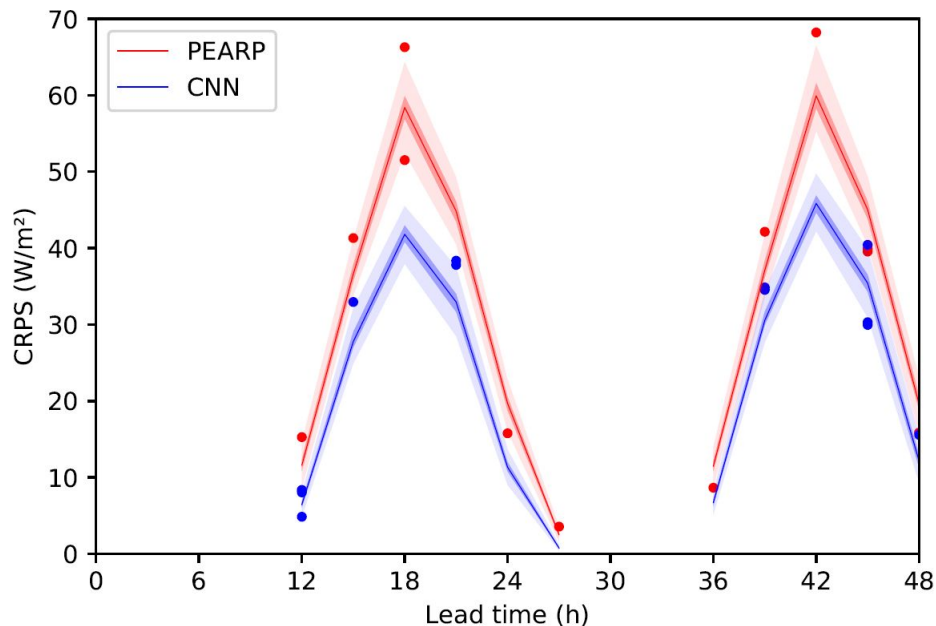
Loss function

Pinball function

$$L_{\tau}(y, z) = \begin{cases} (y - z)\tau & \text{if } y \geq z \\ (z - y)(1 - \tau) & \text{if } z > y \end{cases}$$

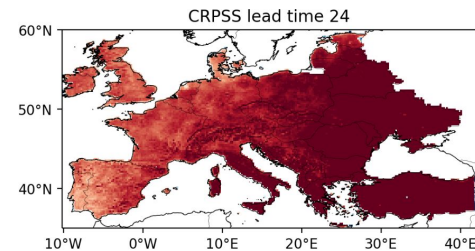
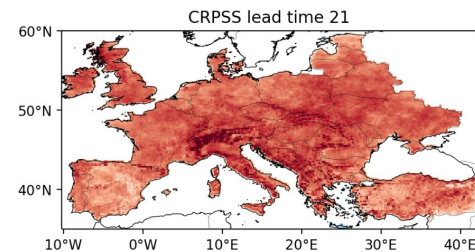
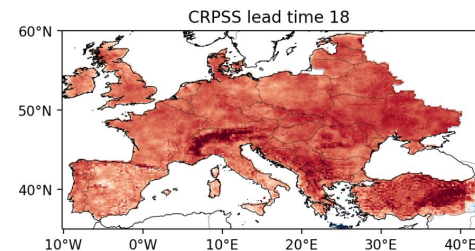
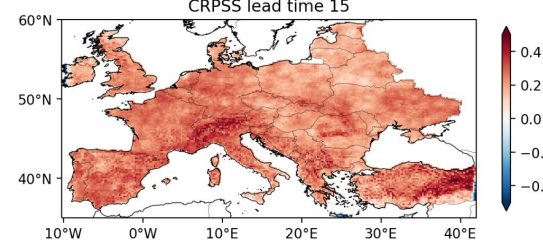
One new training for each lead time

Results - CRPS



↑ Comparison of mean CRPS per lead time, for PEARP (red) and the CNN (blue). A distribution of values was created by bootstrap. The thick lines represent the median values, the darker areas represent the 25%-75% interval, the lighter areas represent the whiskers of a boxplot and the dots represent the outliers.

CRPS skill scores for lead times 15, 18, 21 and 24 →
(9h UTC, 12h UTC, 15h UTC and 18h UTC)



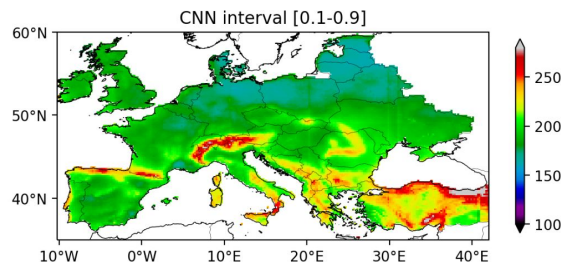
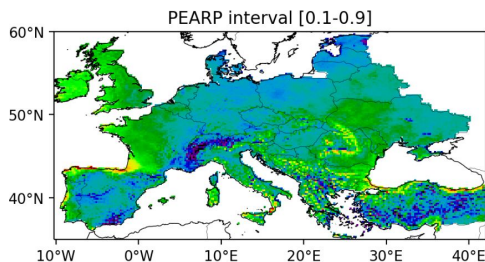
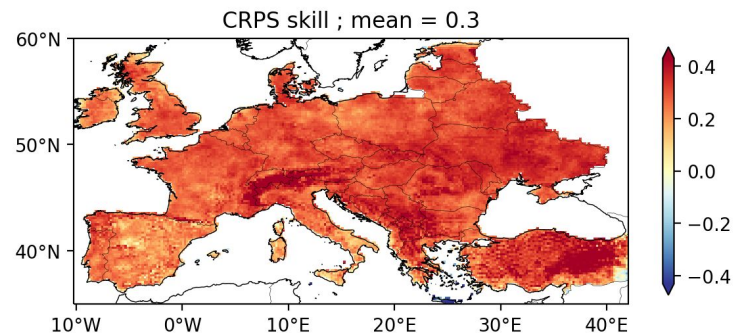
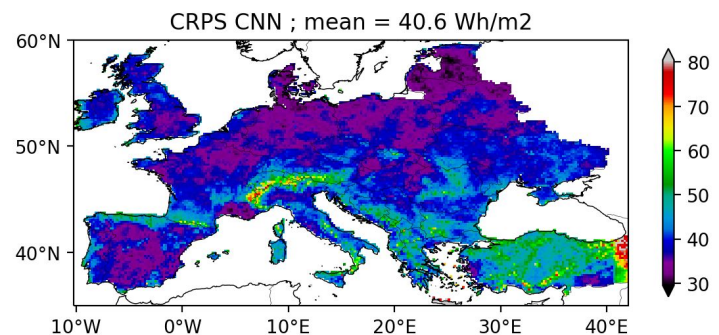
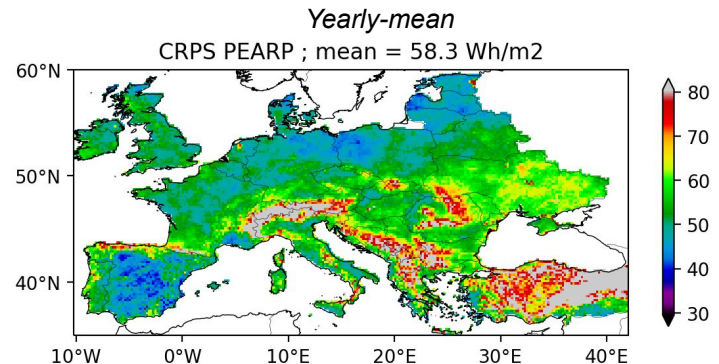
Results - lead time 18 (12UTC)

PEARP

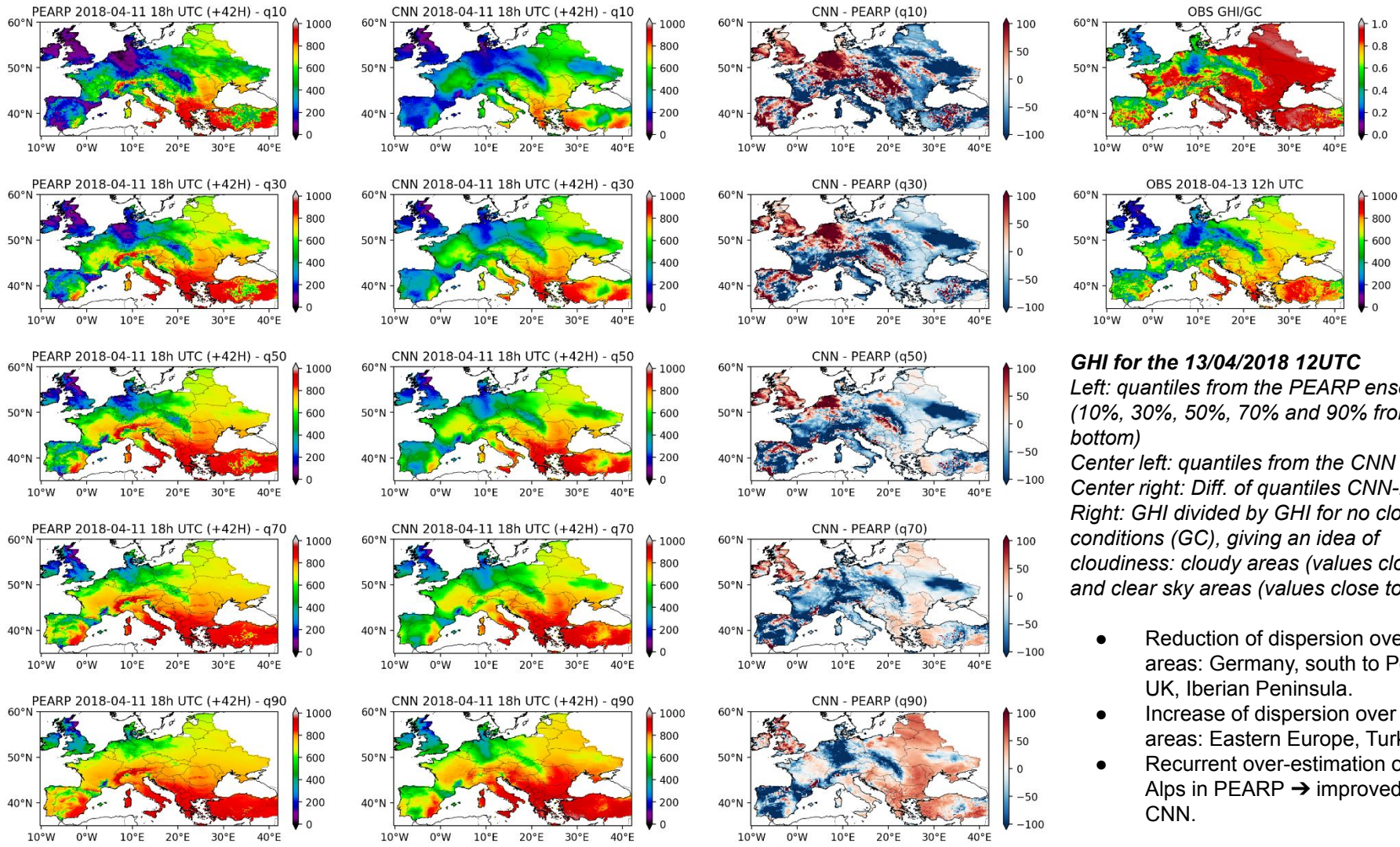
- Local **maximums** of CRPS sometimes correspond to local **minimums** of dispersion in the forecast

CNN

- Local **maximums** of CRPS always correspond to local **maximums** of dispersion in the forecast

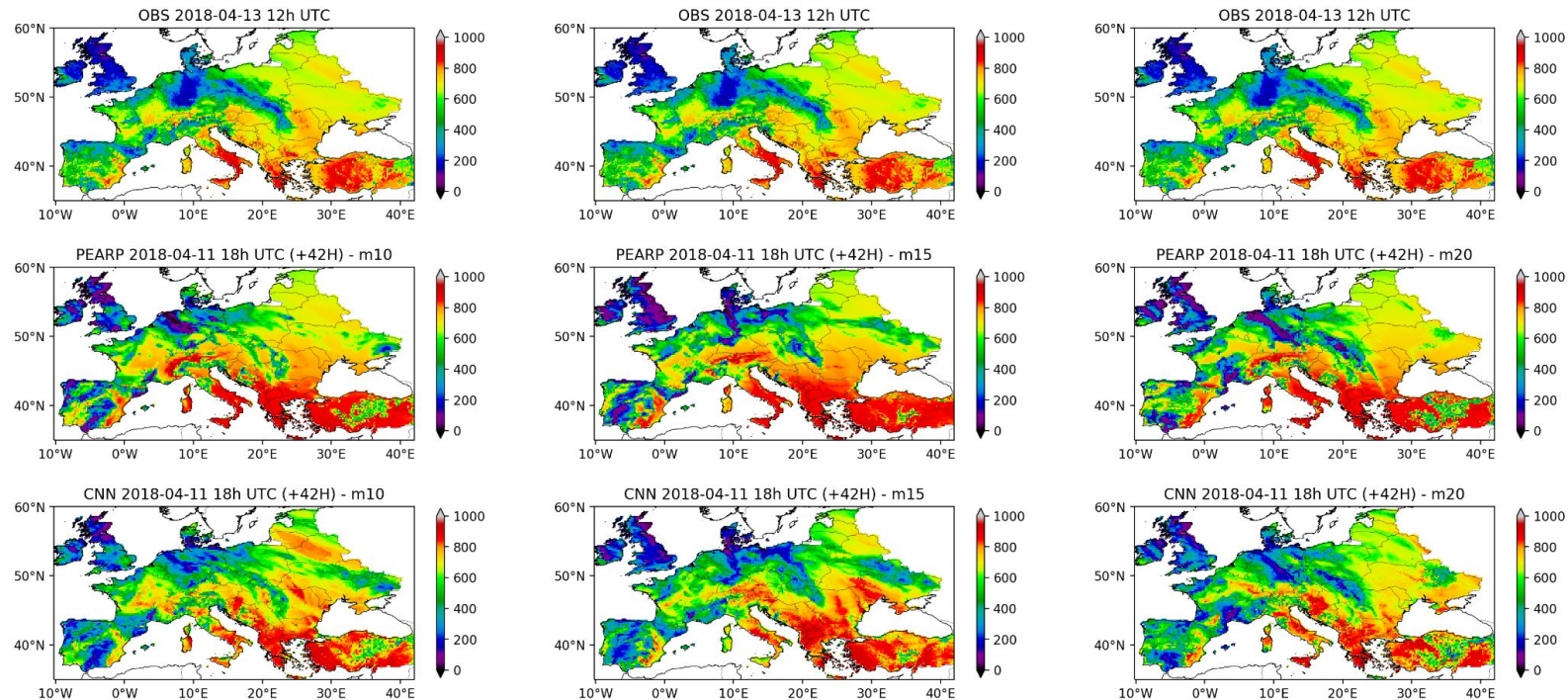


Yearly-mean of 0.1-0.9 quantiles intervalle for PEARP and the CNN



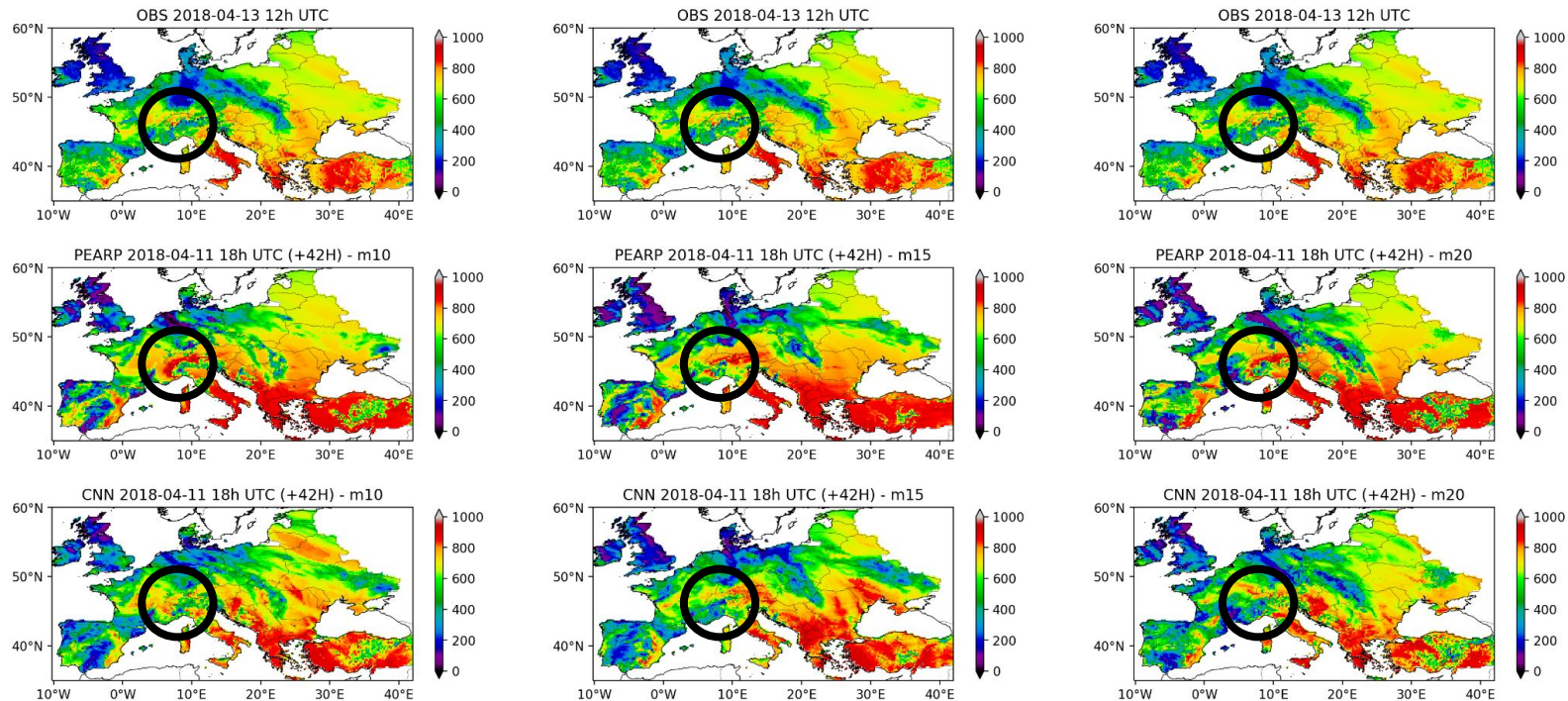
- Reduction of dispersion over cloudy areas: Germany, south to Poland, UK, Iberian Peninsula.
- Increase of dispersion over clear sky areas: Eastern Europe, Turkey.
- Recurrent over-estimation over the Alps in PEARP → improved by the CNN.

Example of 13/04/2018 12h UTC (lead time 18)



Comparison of GHI forecasts for the 13/04/2018 12h UTC. Top line: ground truth. Center line: PEARP forecasts for members 10 (left), 15 (center) and 20 (right). Bottom line: CNN ECC forecasts for members 10 (left), 15 (center) and 20 (right).

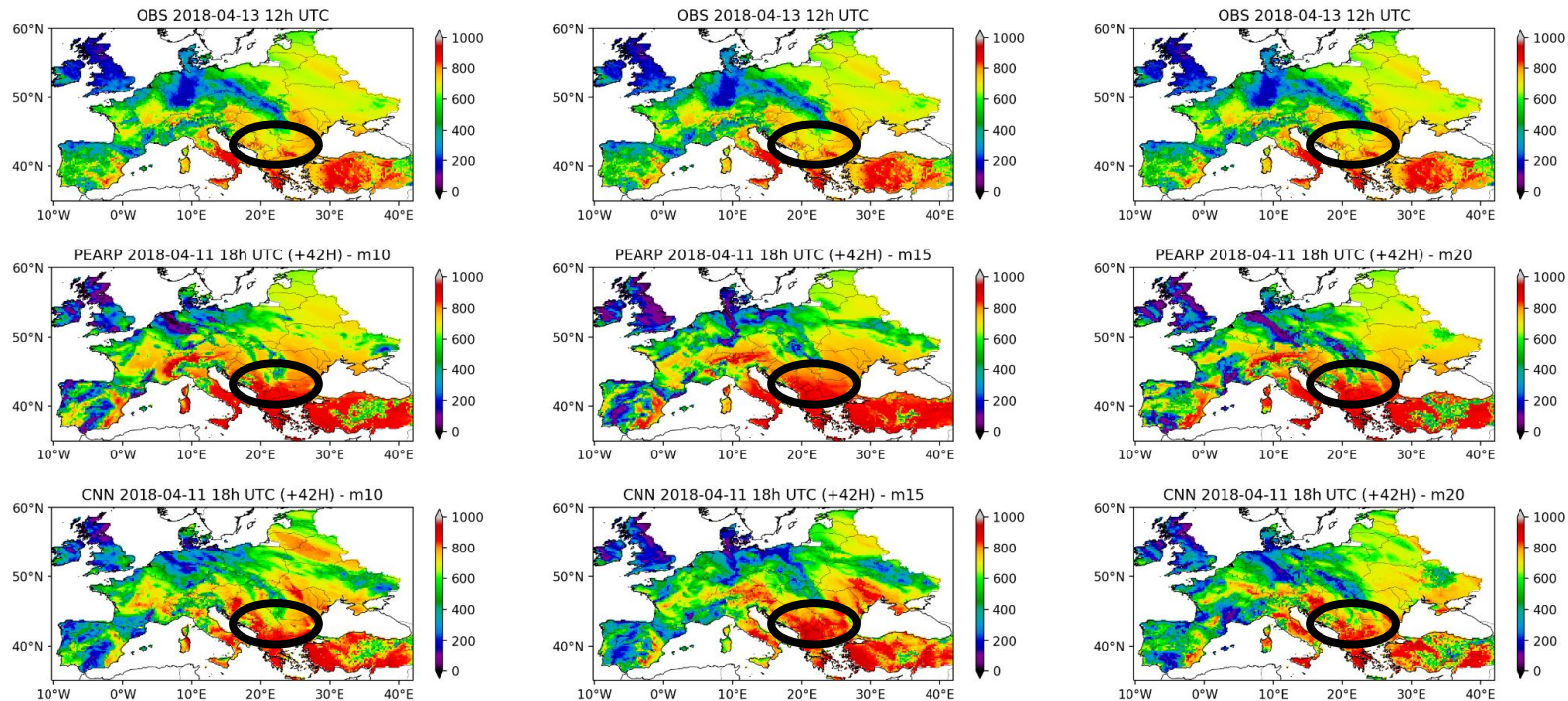
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- Correction of the recurrent bias over the Alps

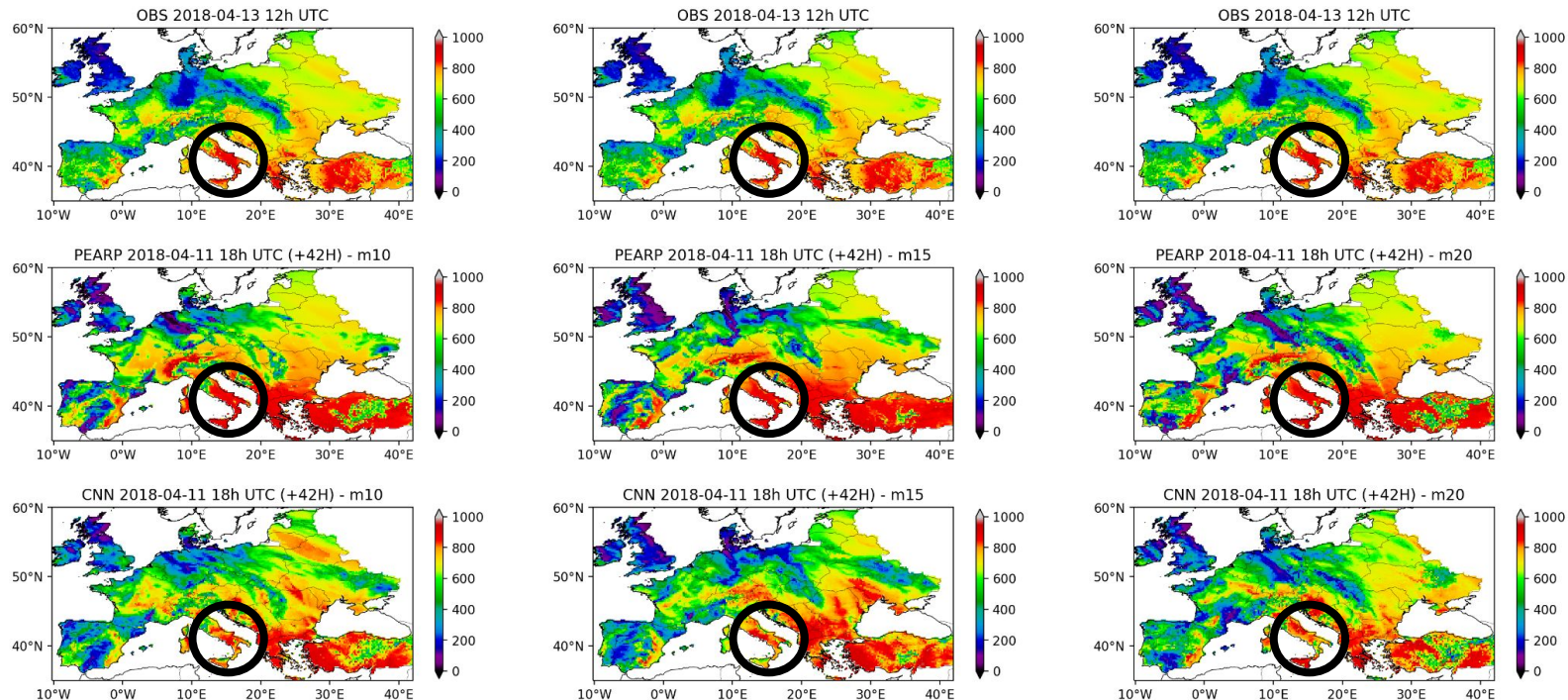
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- Correction of the recurrent bias over the Alps
- Improvement over south-eastern Europe

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- Correction of the recurrent bias over the Alps
- Improvement over south-eastern Europe
- Deterioration over southern Italy

Conclusion

Results

- The GHI PEARP forecast is calibrated using a convolutional neural network
- High dispersion in the CNN outputs corresponds to high errors (high CRPS values), which is not always the case in PEARP.

⇒ example of the Alps

Perspectives

- CNN results must be compared to other calibration methods to appreciate the results (EMOS)
- Calculate (1) the theoretical clear sky GHI and (2) the factor of attenuation of GHI due to clouds, then derive the GHI (1)×(2) instead of directly calculate the GHI (Lauret et al, 2017)