Calibration of DNI ensemble forecasts with quantile regression

Jose Luis Casado (jcasador@aemet.es)

Applications Area, AEMET

International Conference Energy & Meteorology, Copenhague, Jun 2019

Outline

- Description of PreFlexMS Project
- Results for raw forecasts
- Algorithm
- Results for calibrated forecasts
- Related issues

General framework

GOBIERNO DE ESPAÑA MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA AEMet Agencia Estatal de Meteorología

PreFlexMS
PREDICTABLE&FLEXIBLE SOLAR POWER WITH MOLTEN SALT ENERGY STORAGE

Direct Normal Irradiance (DNI) is the key parameter to predict the output from a Concentrated Solar Power (CSP) plant.

CSP plants with molten salts storage can adapt their output to the demand, storing energy during the day and dispatching it during the night.

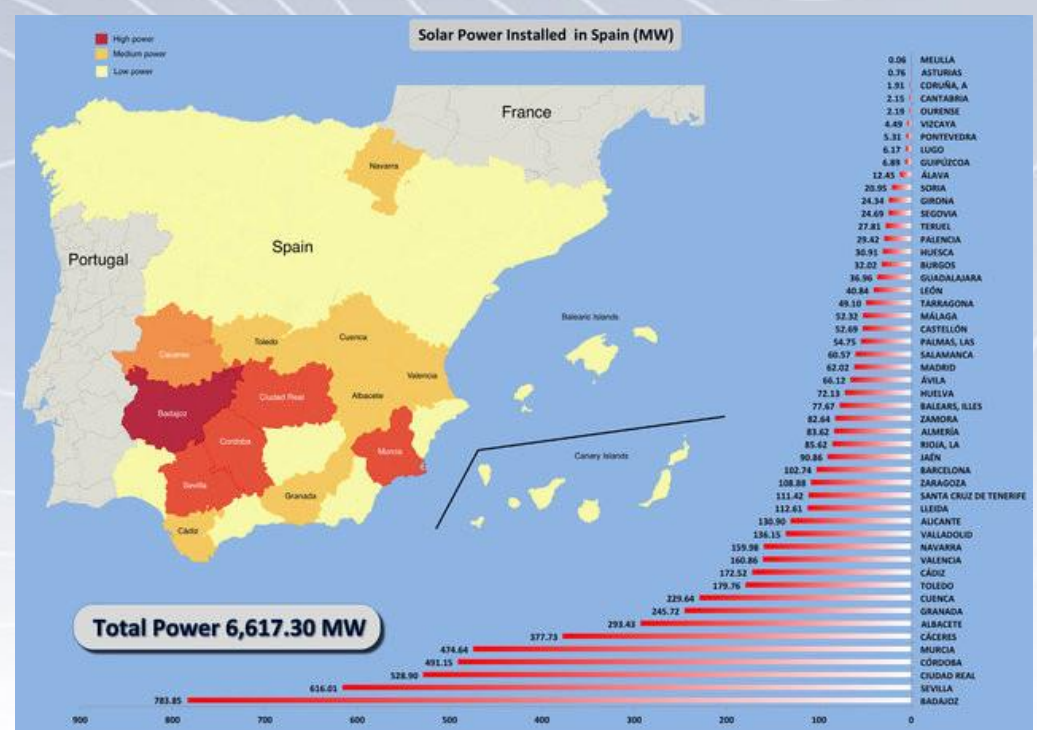
One of the objectives of the project is to take into account DNI meteorological forecasts in the operation of CSP plants to get predictable solar power outputs, which can be modulated according to both meteorological conditions and economical constraints to optimize output and profit.

This would help to avoid the problem of intermittency, omnipresent in many renewable sources of energy.

General framework

Badajoz AEMET station was selected as the site to test the accuracy of the meteorological models.

It has very high values of sunshine, and is the region with the most solar power installed in Spain (data from 2014)

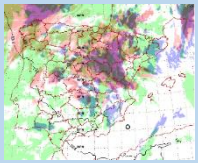


Source: Montoya et al (2014). *Renewable energy production in Spain: A review. Renew. Sustain. Energy Rev.,33, 509-531*

General framework

Data flows:

Meteorological models
(AEMET)



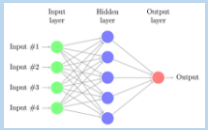
ECMWF High Res
3-hourly

ECMWF EPS
3-hourly, 50 members

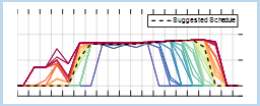
HARMONIE - AROME
every 15 min

gSREPS
3-hourly, 20 members

Machine learning (post-processing)
(CENER)



Dispatch Optimizer
(DLR)

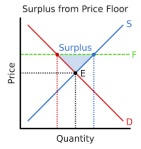


Optimal dispatch trajectory

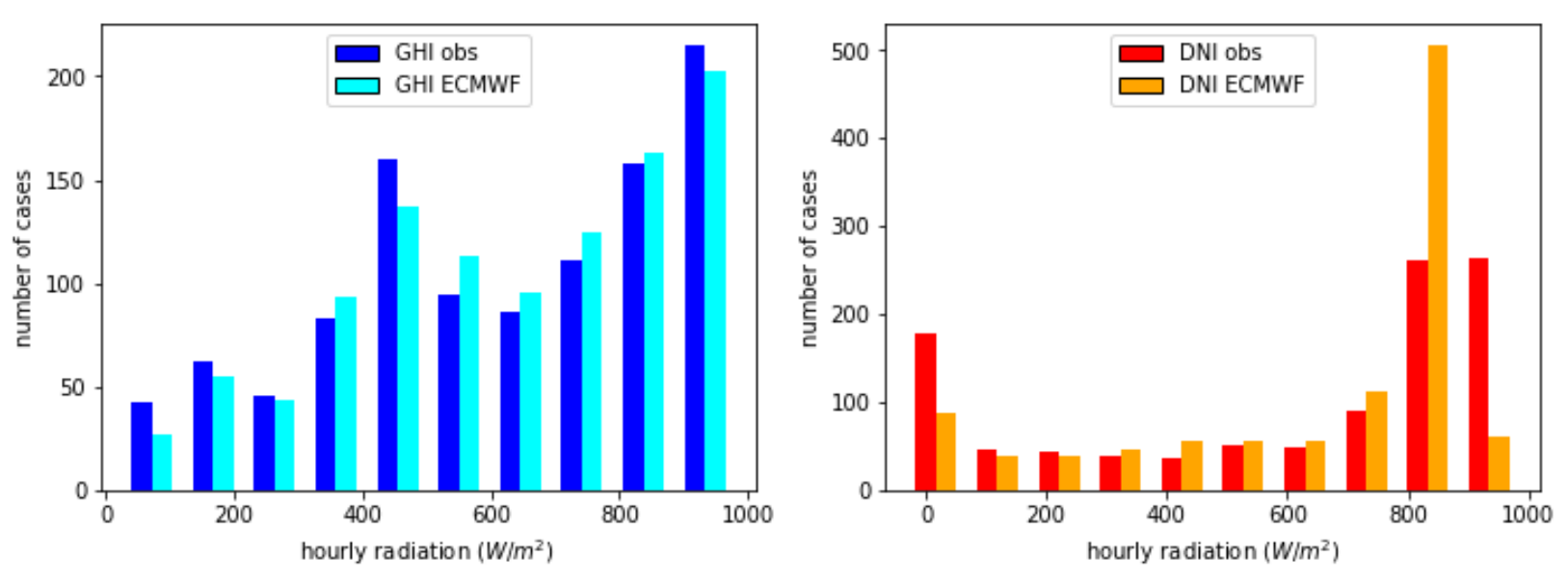
Past observations

CSP Plant variables

Market price



GHI vs. DNI distributions

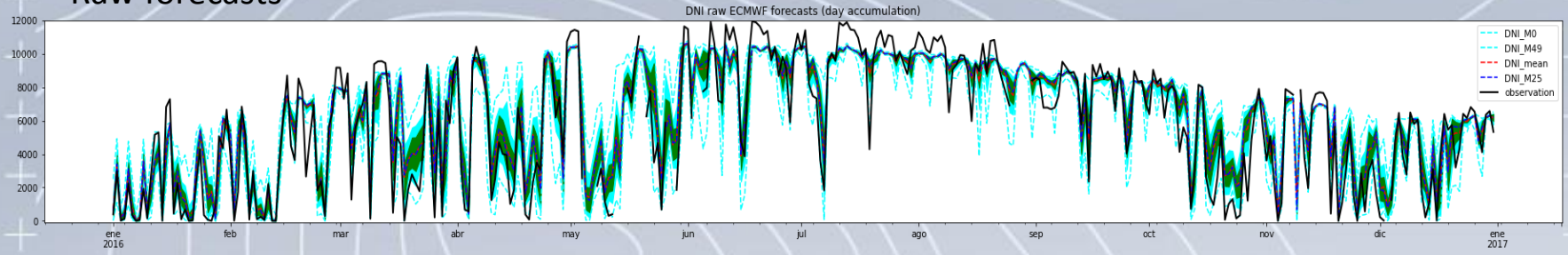


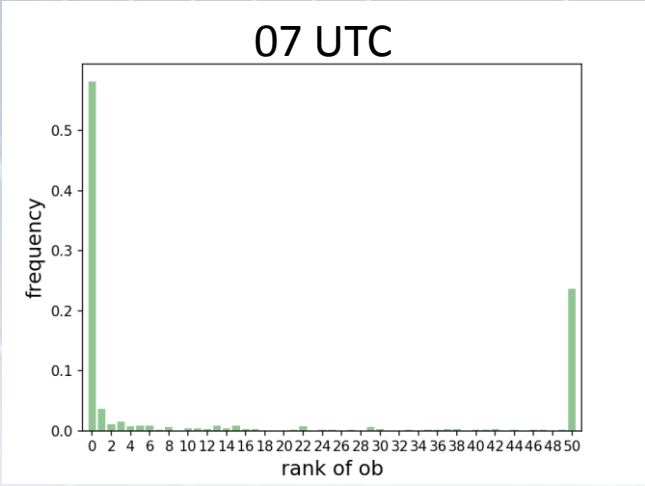
➡ DNI does not follow a normal distribution

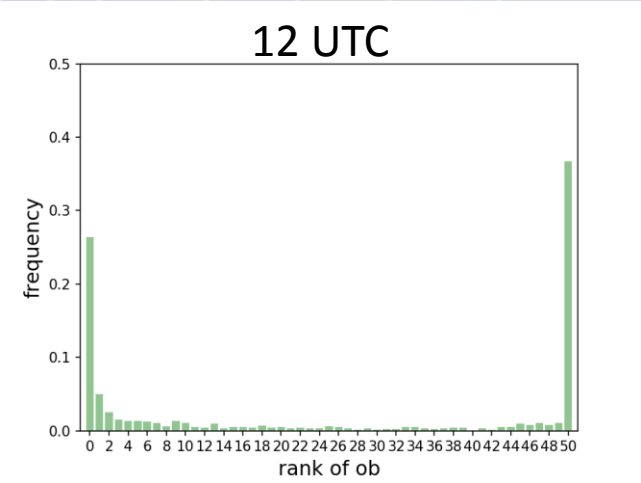
➡ Its behaviour can vary a lot for different locations

Results for raw ECMWF forecasts

Raw forecasts

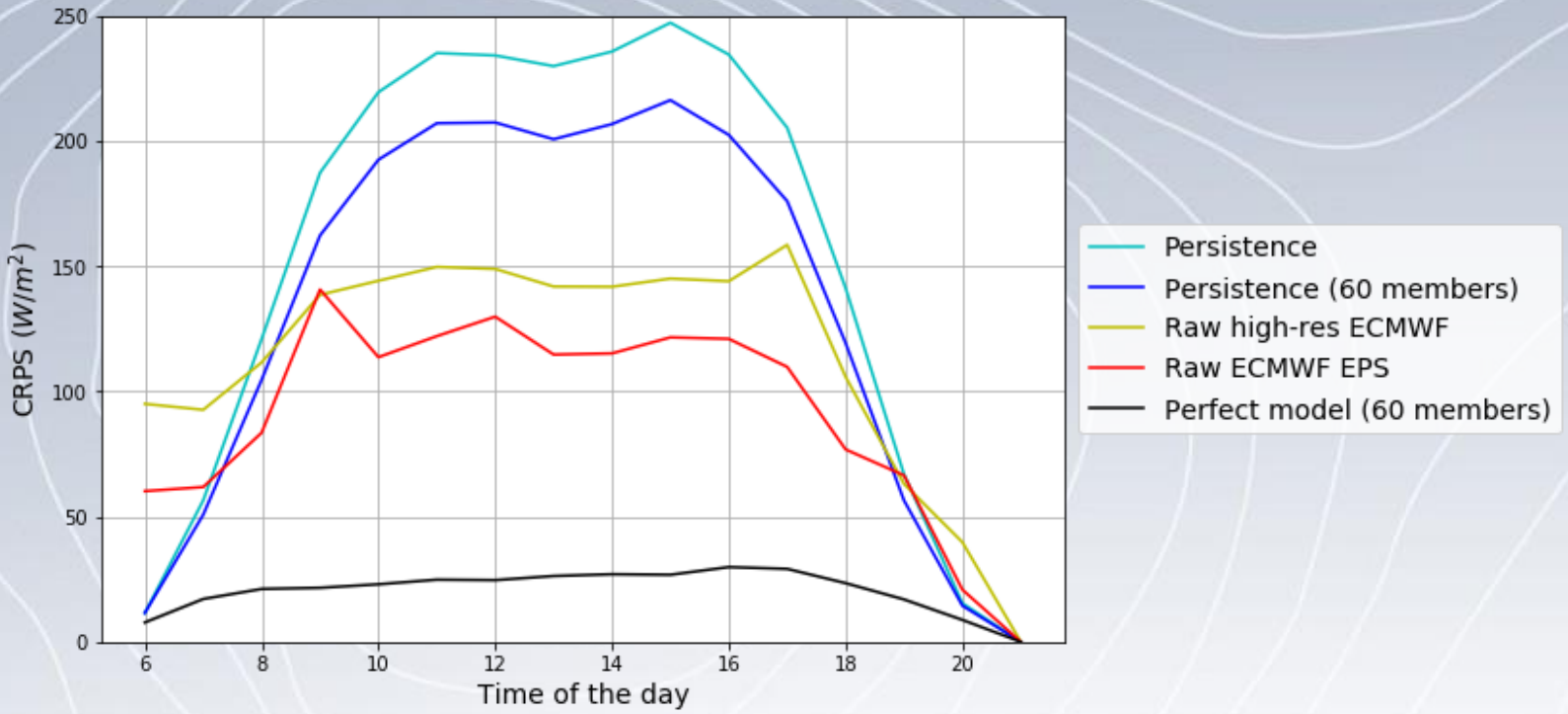






➡ Strong underdispersion of the DNI ensemble

Results for raw ECMWF forecasts



CRPS = ~120 W/m² for the ECMWF EPS model

Quantile regression algorithm

- Quantile regression is the algorithm chosen to calibrate the EPS
- It is a non-parametric method, appropiate for the DNI. It was already selected by Bouallegue (2017) to calibrate the GHI for the Cosmo model.
- Period of study: 1 Jun 2015 – 31 May 2018 (3 years)
  (for gSREPS: 1 Jun 2017 – 31 May 2018)
- Forecasts used: ECMWF EPS 00Z run, 0-24 hours ahead
  (24-48 and 48-72h forecasts have also been studied, obtaining similar results)
- Two training periods: 30 and 60 days before the forecasts. Better results using 60 days.

➡ Crossing quantile problem: quantiles need to be reordered in some situations. quantreg R-package reordering algorithm has been used for that.

Bouallegue, Z. (2017). *Statistical postprocessing of ensemble global radiation forecasts with penalized quantile regression. Meteorologische Zeitschrift, 26(3), 253-264*

Quantile regression algorithm

Every quantile τ is adjusted as:

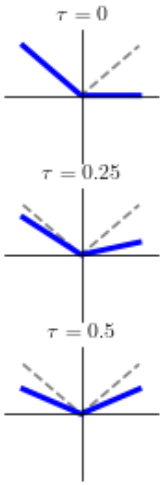
$$q_\tau(y|x) = \beta_0 + \beta x$$

β coefficients are calculated minimizing:

$$argmin_{\beta_0,\beta} \sum_{i=1}^{n} \rho_\tau(y_i - \beta_0 - \beta x_i)$$

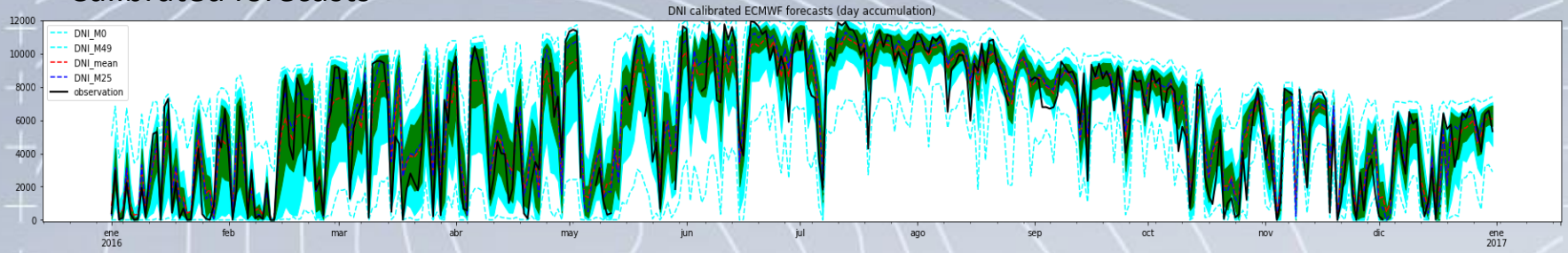
being ρ the check function:

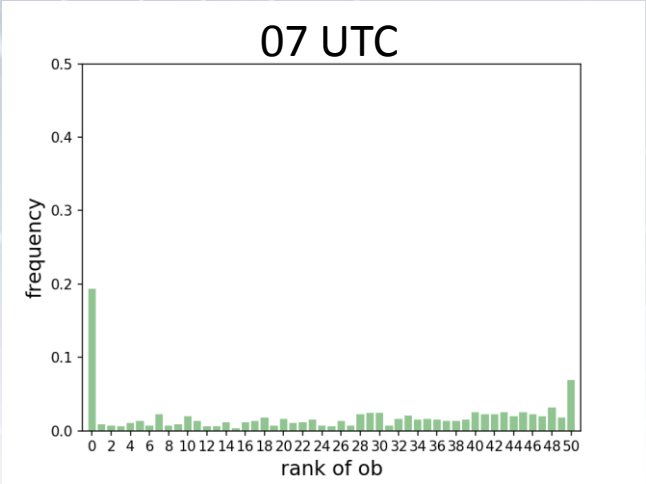
$$\rho_\tau(u) = u[\tau - I(u < 0)] = \begin{cases} \tau u & if\ u \geq 0 \\ (\tau - 1)u & if\ u < 0 \end{cases}$$

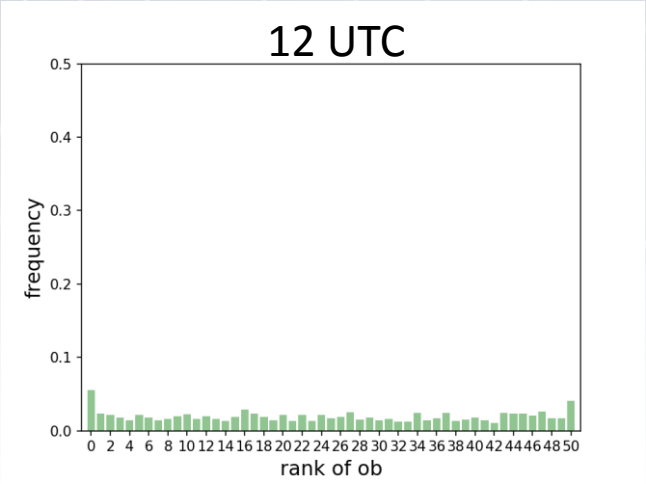


Results for postprocessed ECMWF forecasts

Calibrated forecasts

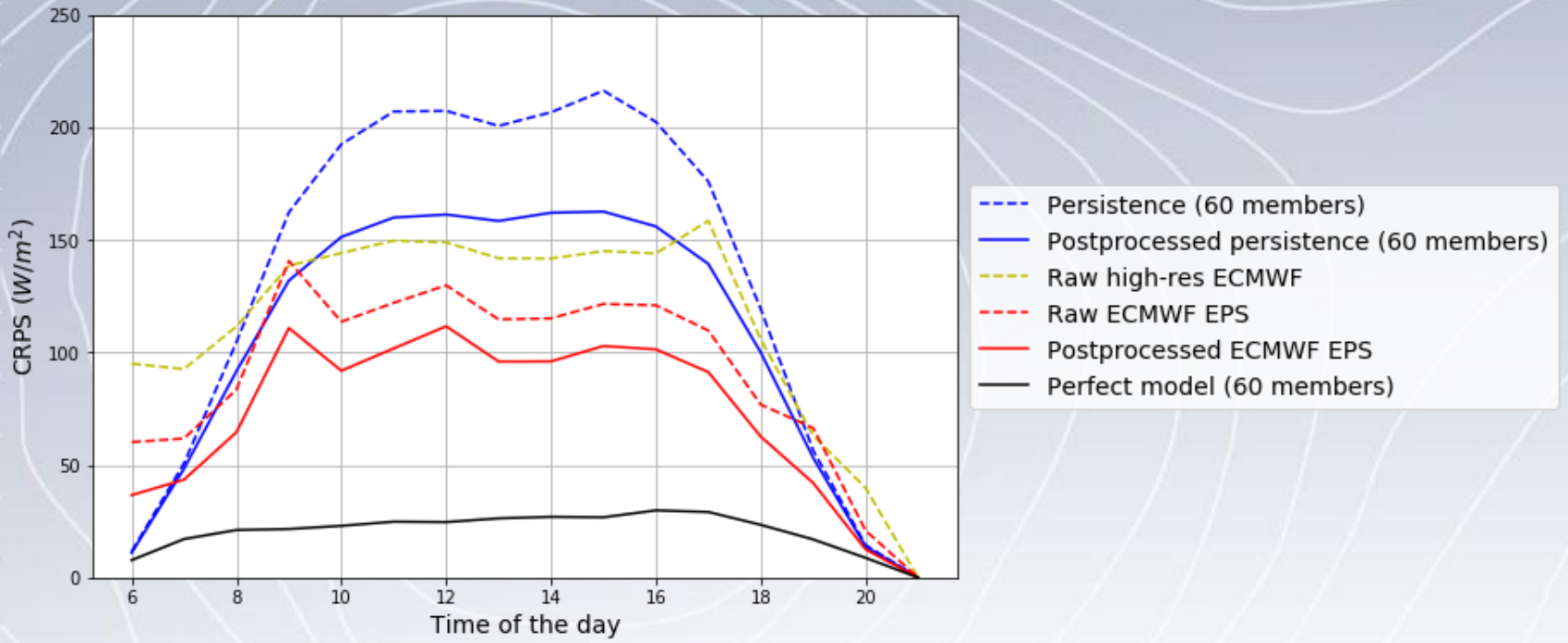






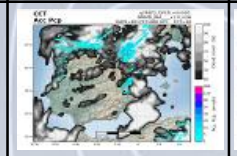
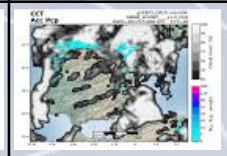
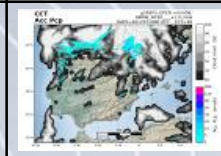
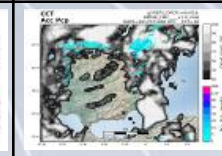
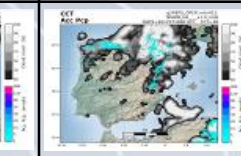
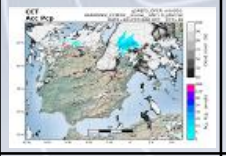
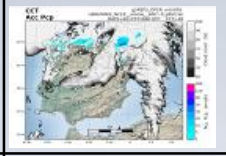
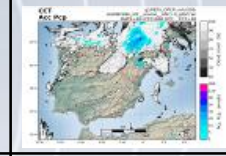
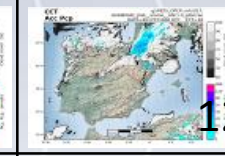
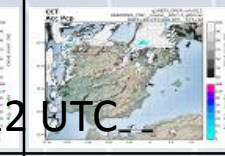
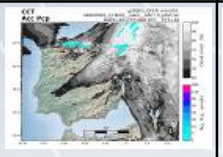
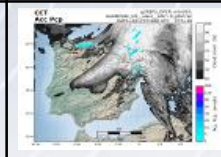
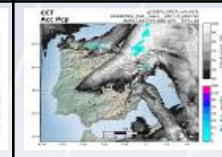
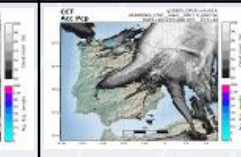
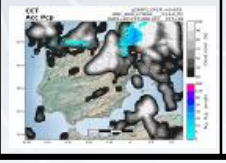
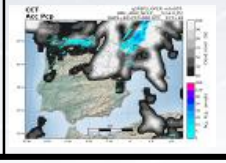
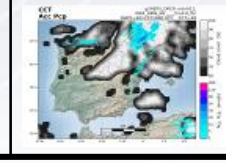
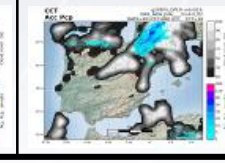
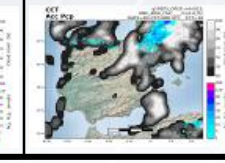
➡ Underdispersion corrected (not completely at dawn or dusk)

Results for postprocessed ECMWF forecasts



➡ CRPS improves from ~120 to ~100 W/m²

And gSREPS?

Multi-BCs / Multi-NWP	ECMWF / IFS	NCEP / GFS	MF / ARPÈGE	JMA / GSM	CMC / GEM
HARMONIE-AROME					
HARMONIE-ALARO					
WRF ARW					
NMMB					

12 UTC

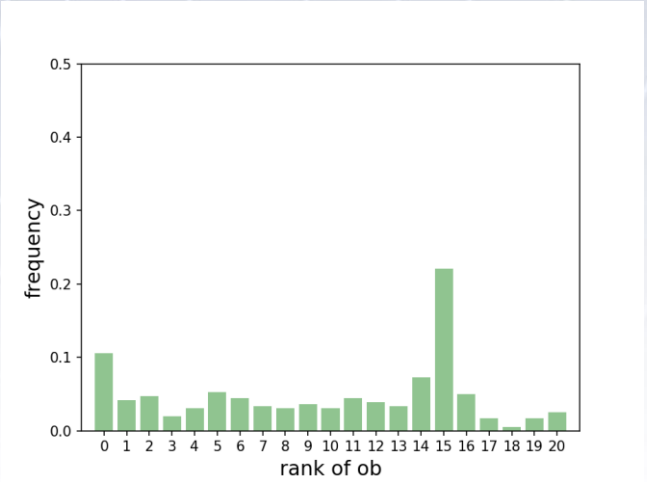
Multimodel ensemble, using 4 models x 5 boundary conditions = 20 ensemble members

Results for gSREPS

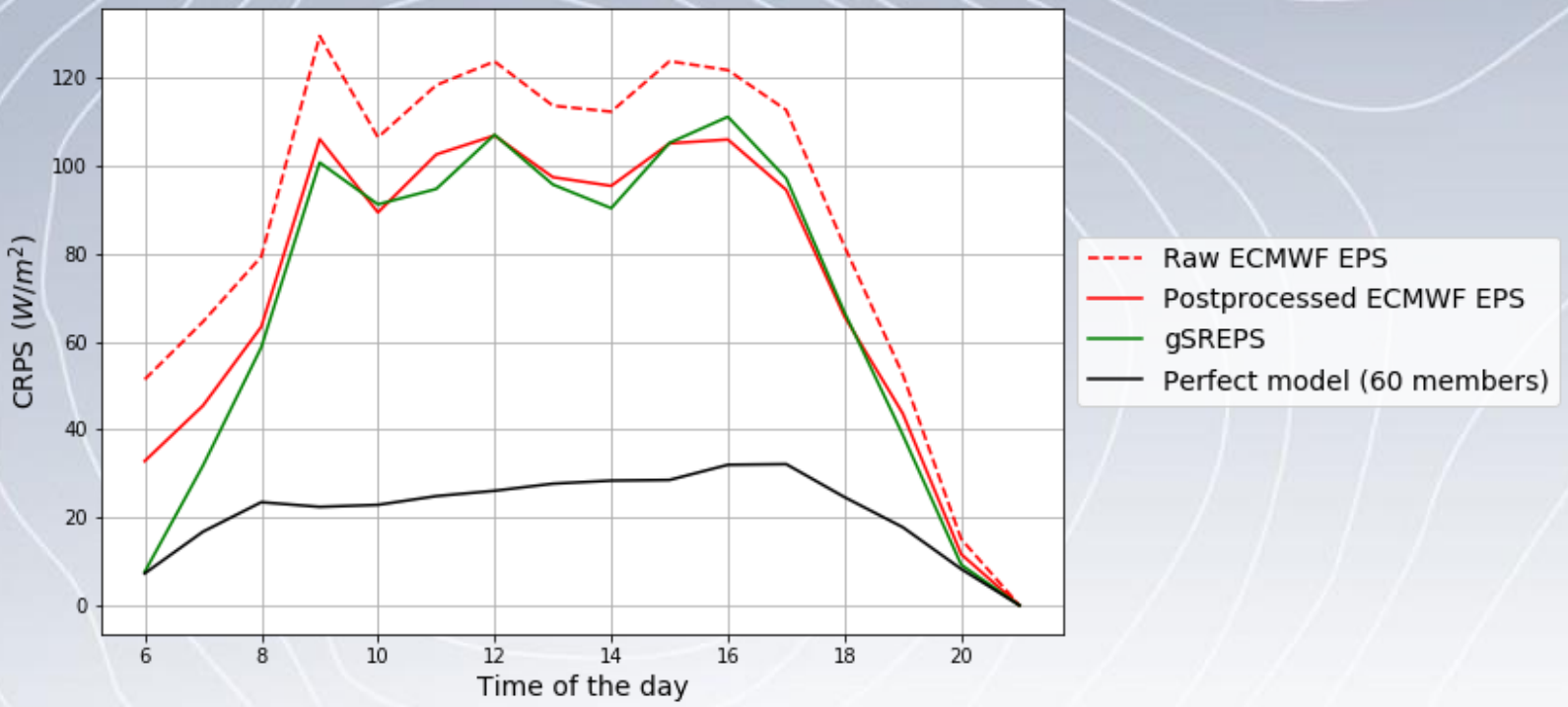
The ensemble members are distinguishable, so their systematic errors can be corrected individually.

(For this work not postprocessing of the ensemble has been done)

Quite good spread for gSREPS
(no underdispersion):



Results for gSREPS



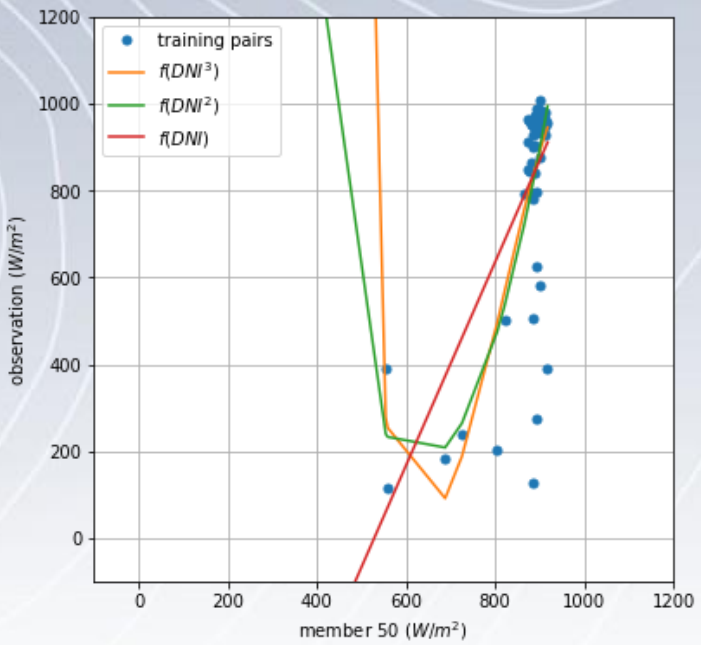
➡ gSREPS CRPS similar to the values obtained for the calibrated ECMWF EPS

Training data issue

A normal case (27th Jun 2016):

Linear regression is ok, but using higher powers can be dangerous.

In general, regularization techniques will decrease the weight of high power terms, but… will it be happen always?



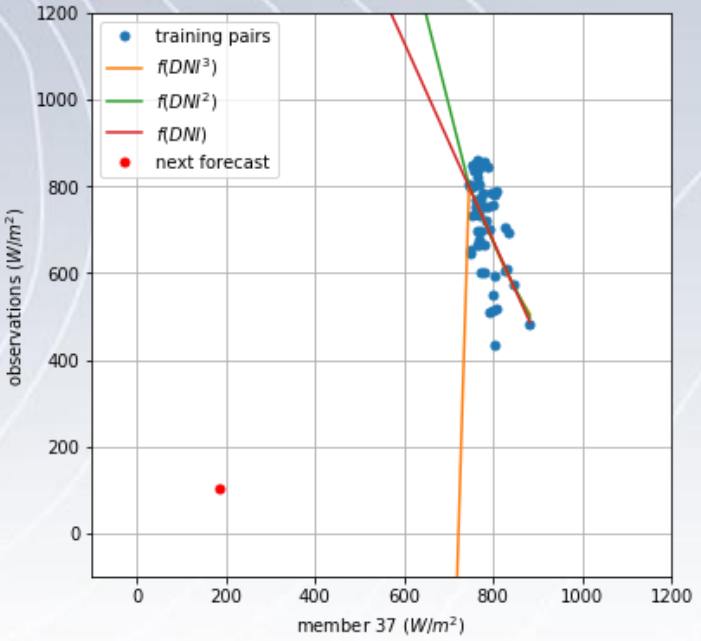
Training data issue

An anomalous case (13th Sep 2016):

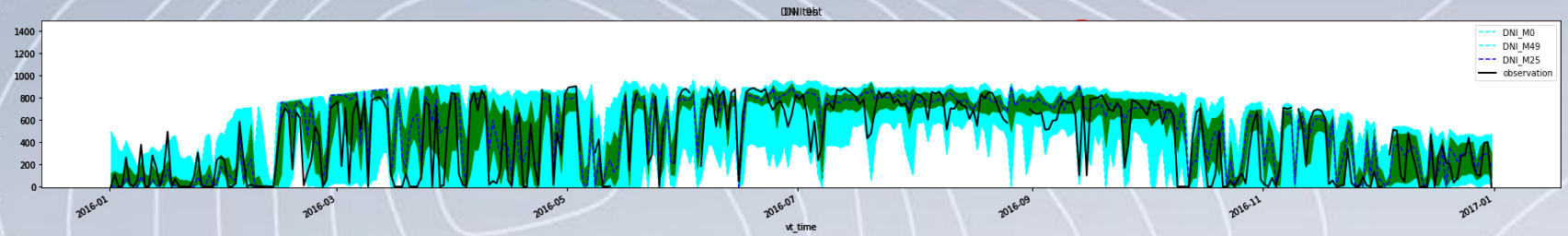
There is not enough variability in the training period.

This problem is more acute when the weather regime changes.

Even linear regression produces a nonsense calibration in this case.



Training data issue



Calibrated forecasts need to be “capped”.

But many other not so blatant cases will be missed, and will produce bad calibrations.

This problem might be aggravated if more input parameters are used (for example, if regularization schemes are used).

Summary

- Using the full ensemble is more valuable than a deterministic forecast (or the mean or median of the ensemble). It gives extra information about the uncertainty of the prediction.

- Quantile regression is a good method to calibrate DNI ensemble forecasts for the short range, improving the CRPS score for the ECMWF EPS by 20% approximately. It is a flexible method, and can be used in very different locations.

- Abnormal behaviour can happen when the weather regime changes, if the training data is not varied enough. This is not guaranteed for the DNI, and the data available for training is not unlimited.

- Raw gSREPS model, specially appropiate for the short range, gives a very good performance, similar to the calibrated ECMWF EPS. It could be improved further through postprocessing to eliminate systematic errors.