GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología

Indirect verification of 100m winds through measurements of electric power in wind farms

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(thanks to Javier Calvo and Gema Morales)

Outline

- Project background
- Qualitative methods
- Quantitative methods
- Summary

Project background

Wind accounted for the 20.3% of the electricity generated in mainland Spain in 2014 (REE, 2014). It is important to have good wind forecasts, to predict the energy that wind can provide in the next hours or days.

There are almost no observations at 100 m (the height of most wind turbines), so it is difficult to assess the accuracy of meteorological models.

From a user-oriented perspective, it is more interesting to verify electric power forecasts directly, not wind speeds.

AEMET and Red Electrica de España (REE), the Spanish TSO, are cooperating to improve REE wind and solar energy predictions, using their expertise in their respective fields.

Project background

In particular, a study has been conducted to verify the skill of several models to predict wind energy production, using BRISA, a REE post-process system to convert 100m wind forecasts into electric power. It is based on the older SIPREOLICO system (Sanchez, 2006).

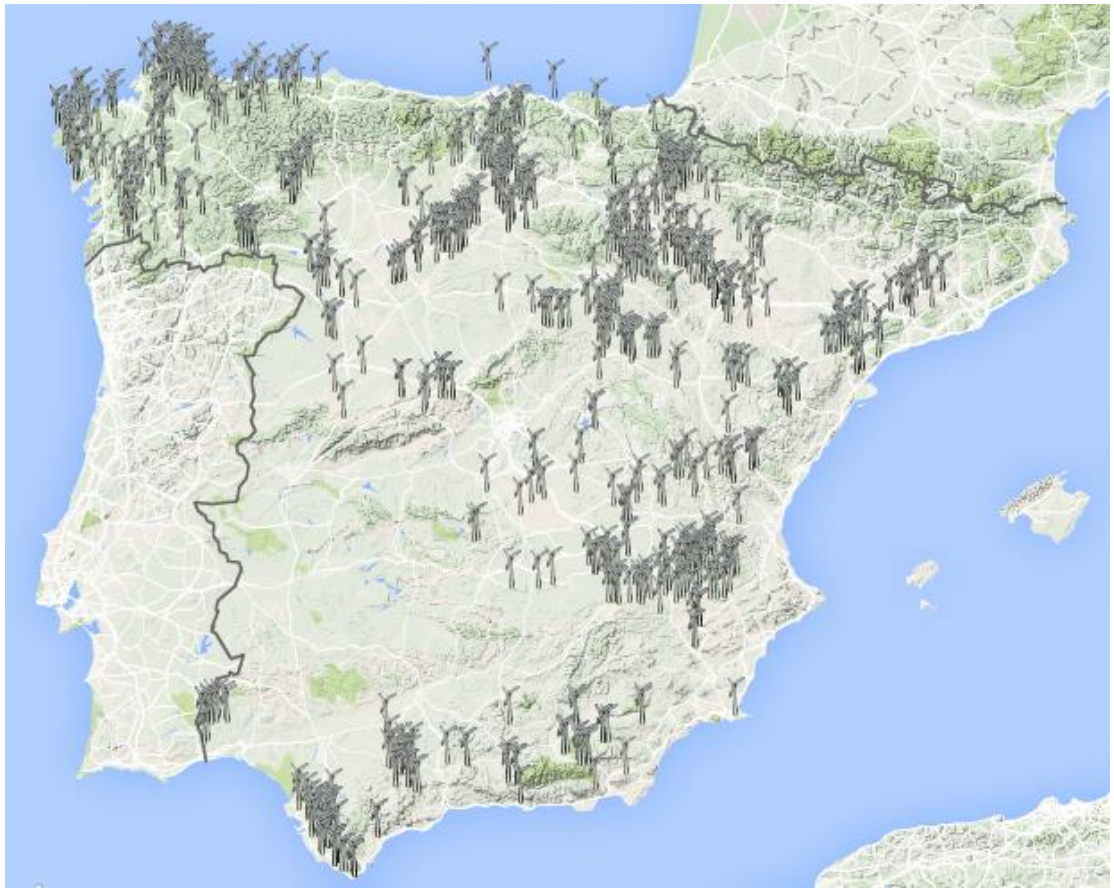
BRISA uses the last meteorological and non-meteorological available data to generate its forecasts.

Models compared:

- 3-hourly ECMWF model, interpolated in time to get forecasts every hour.
- 1-hourly Arome/Harmonie model, running cycle 37 from January 2013 to September 2014, and cycle 38 from October 2014.
- A “reference” model used by REE before (not shown here).

I will focus on the T+24 forecasts, though the results can be extended to other ranges.

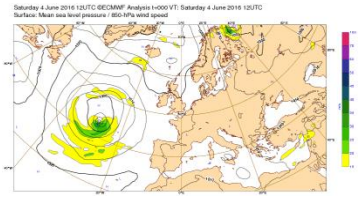
Project background



Data available for 739 wind farms over mainland Spain for years 2013 and 2014.

Project background

ECMWF model

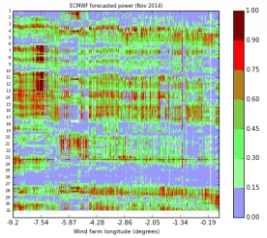


ECMWF weather fcst 2013: training

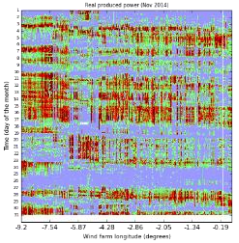
ECMWF weather fcst 2014: verification

BRISA (REE postprocess)

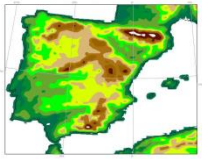
ECMWF power fcst 2014



Real produced power



Arome/Harmonie model

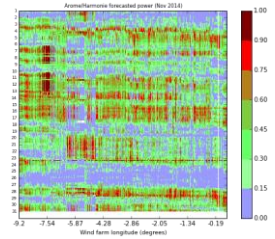


Harmonie weather fcst 2013: training

Harmonie weather fcst 2014: verification

BRISA (REE postprocess)

Harmonie power fcst 2014

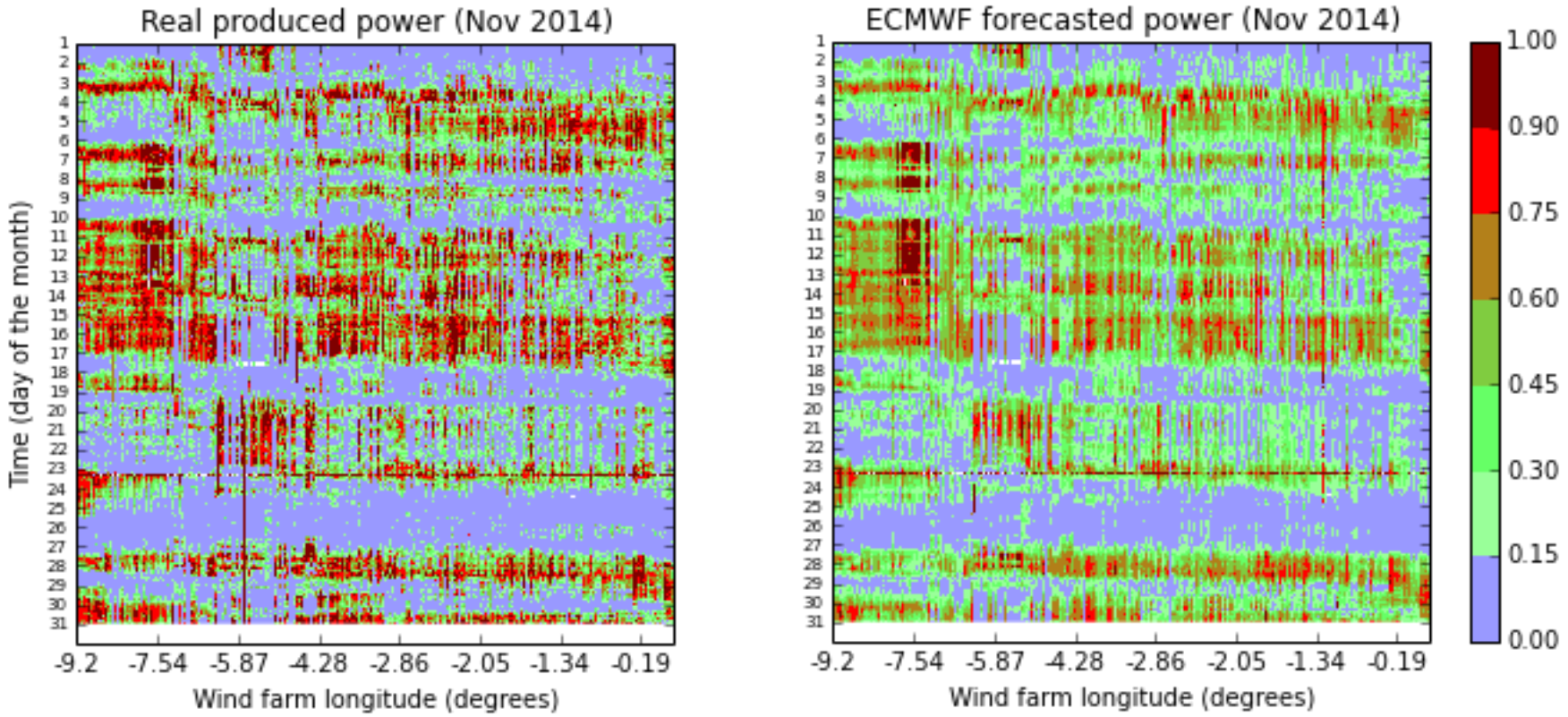


Problems found

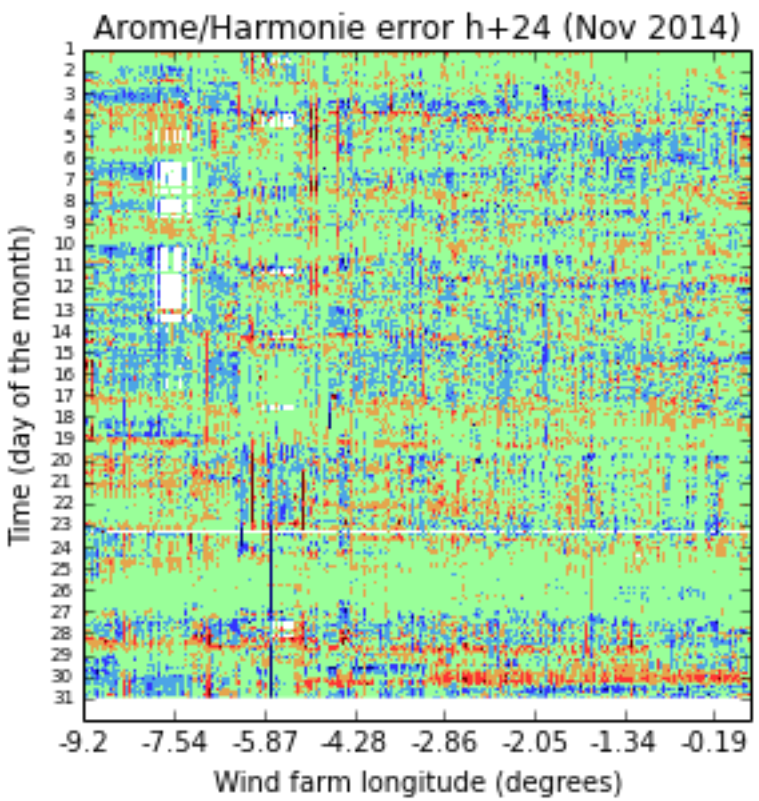
- There is not much information about the post-process system (BRISA). It is not known how it affects model output.
- Lack of metadata: scarce information about the specifications of the wind turbines.
- There are observations from more than 700 wind farms. It is difficult to get manageable results and not to lose valuable information in the process.
- REE was particularly interested in events which might affect the stability of the grid. But to analyze them, they need to be found first.
- It is necessary to find a method to separate meteorological errors from others not related to models (problems from the post-process, or from reality).

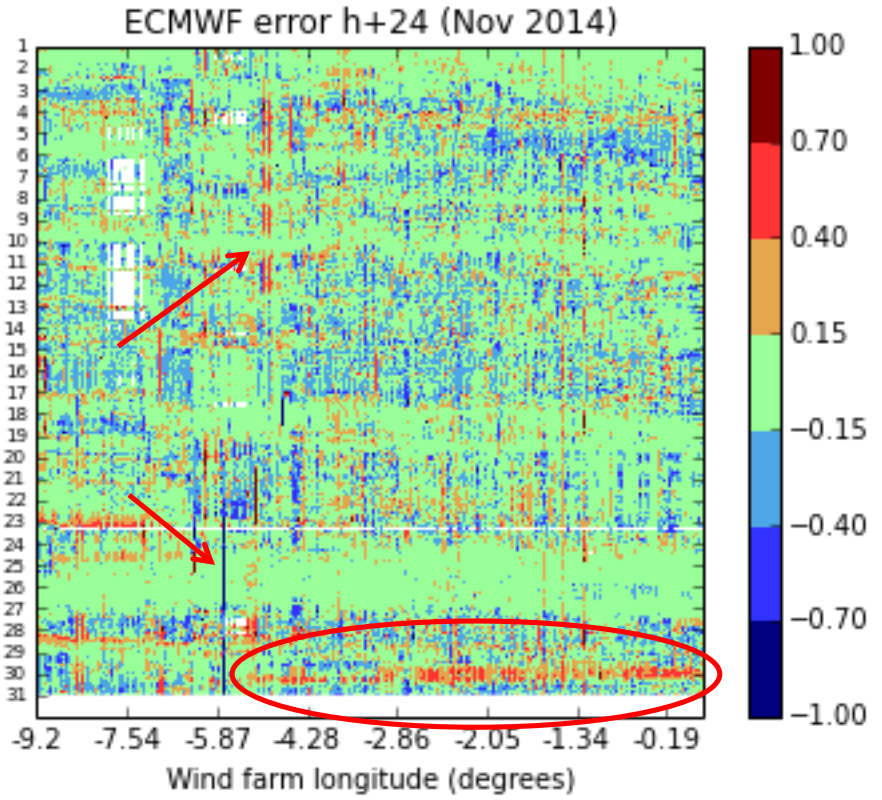
Qualitative methods

Pseudo-Höwmoller diagrams are specially suitable to study huge amounts of data

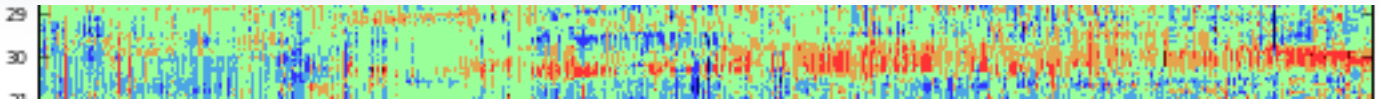


Qualitative methods

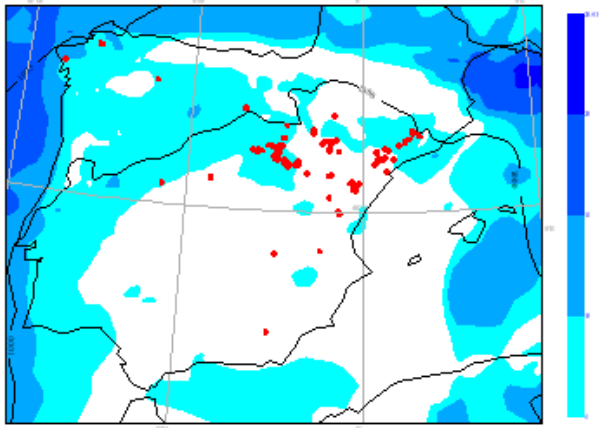




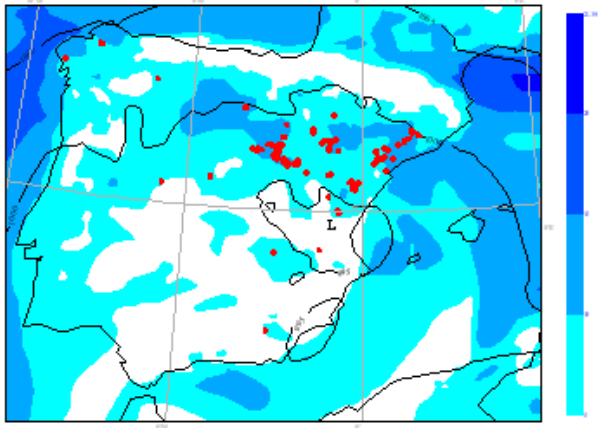
Qualitative methods



Analysis (30 Nov)

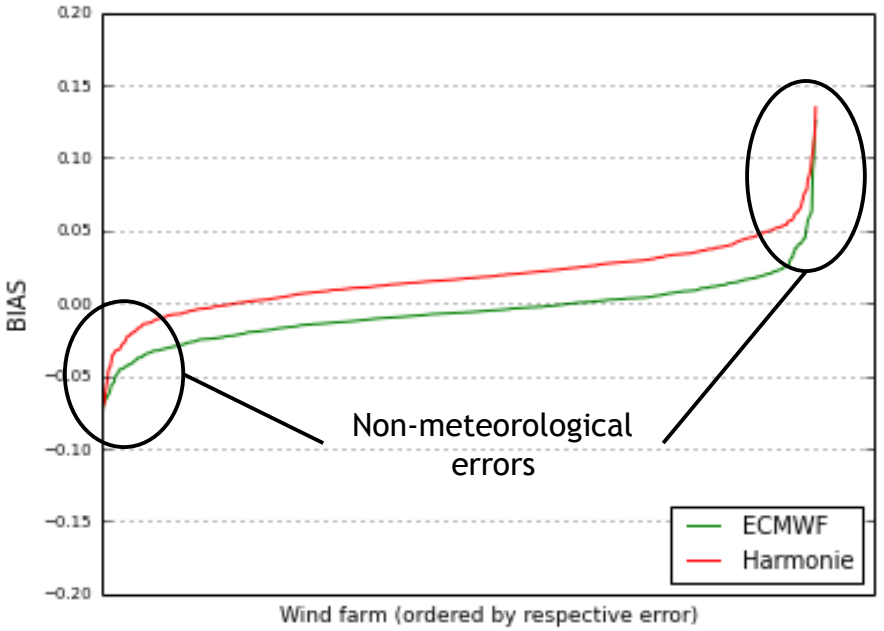


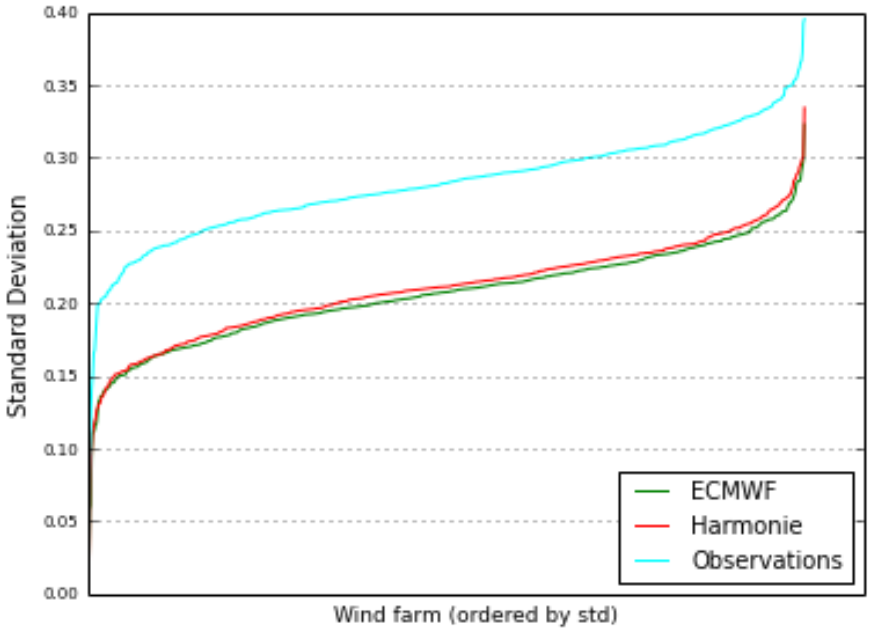
Forecast T+24 (30 Nov)



Correlation of cyclones with large errors (Steiner, 2015)

Systematic errors



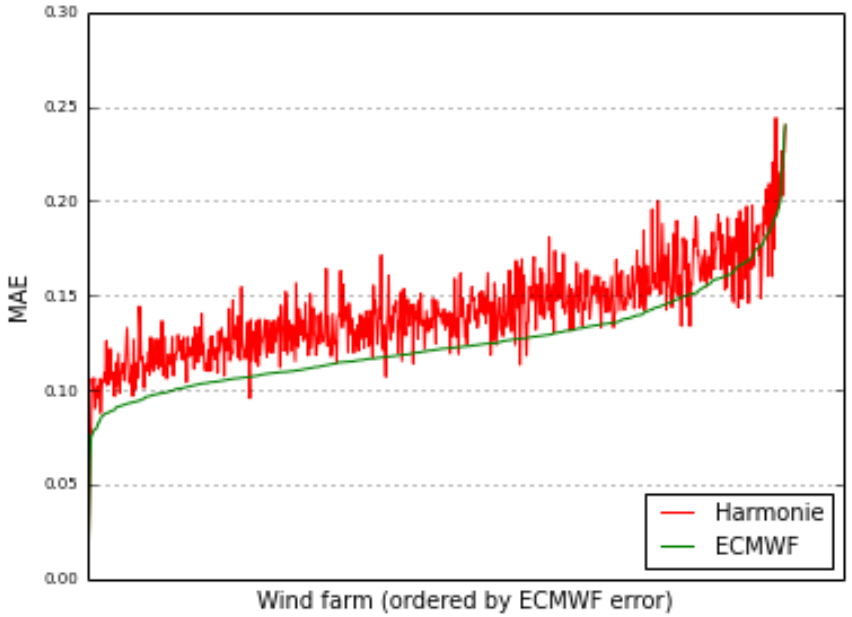


bias ECMWF = -0.006
bias Harmonie = 0.015

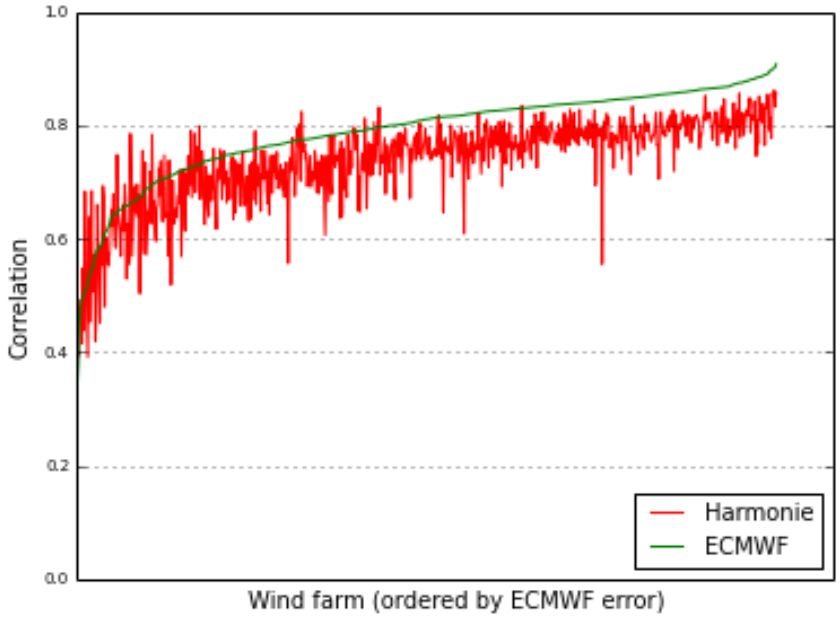
It gives information about the post-process, not about the models

The conditional bias is practically zero

MAE



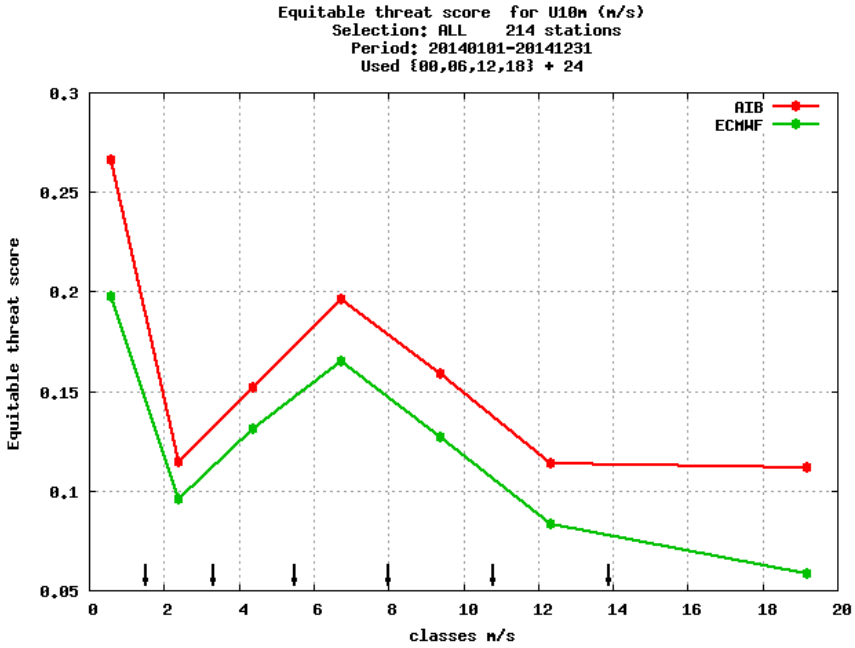
Correlation



ECMWF model gives a smaller MAE in 641 wind farms (out of 739).

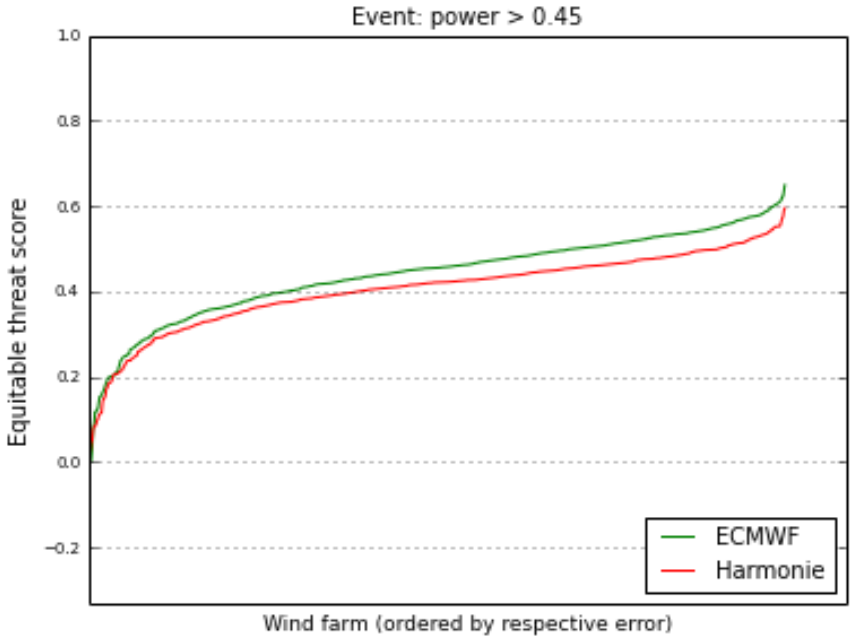
Equitable threat score

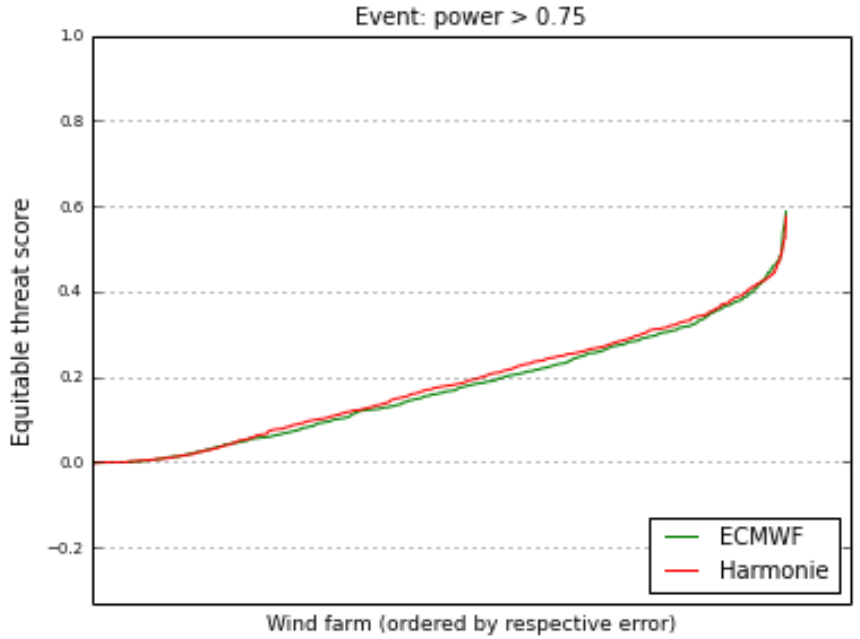
Arome/Harmonie gives better ETS for 10m winds, specially for high wind speed classes.



(AIB: Harmonie for mainland Spain)

Equitable threat score

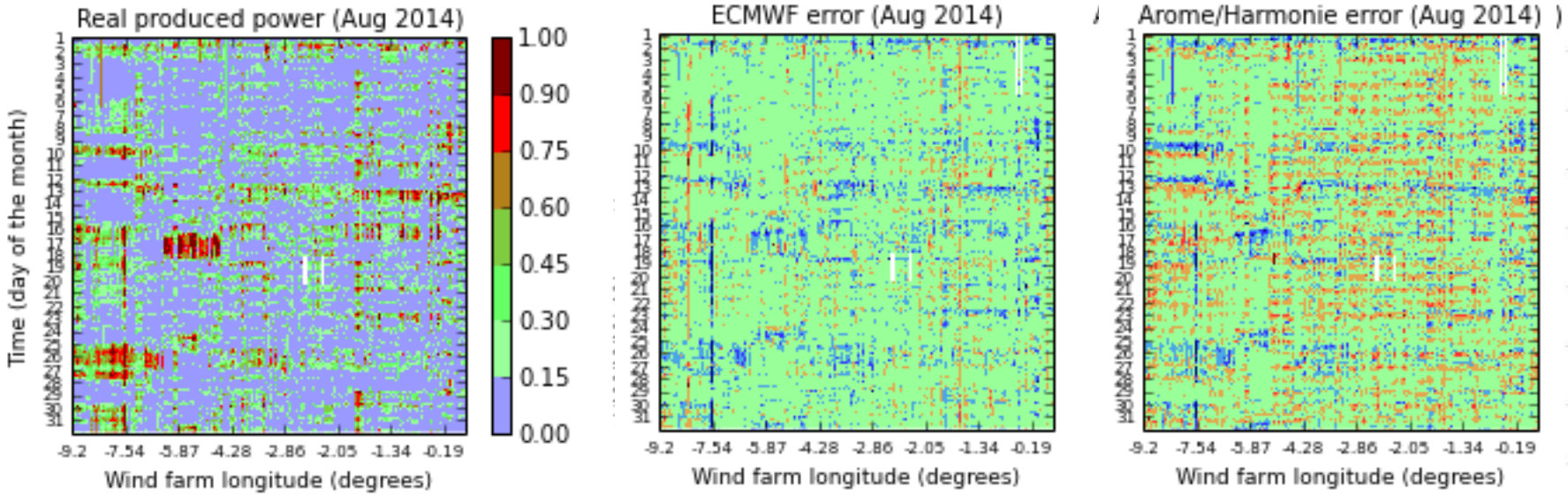




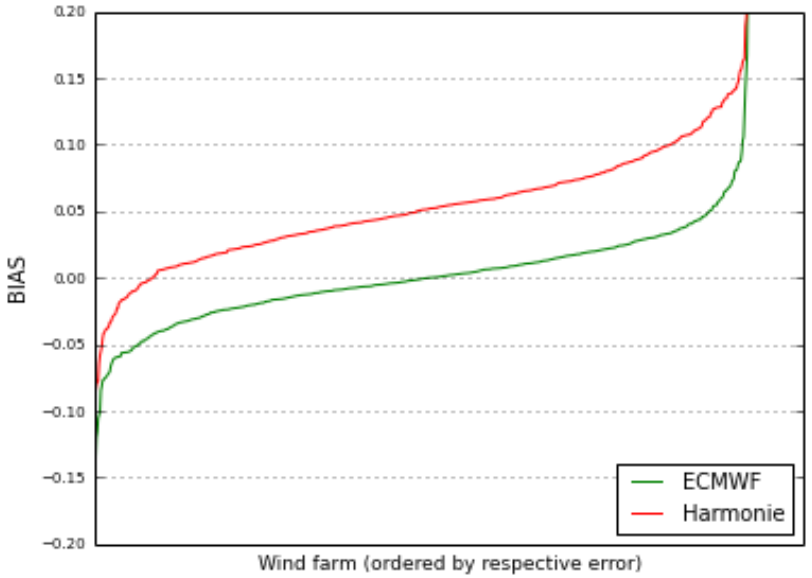
But ECMWF is better for electric power, specially for medium wind speeds.

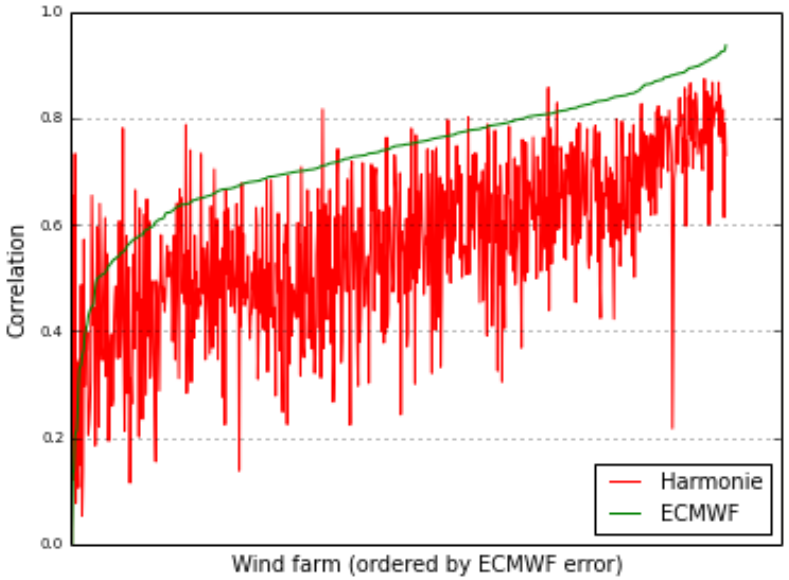
BRISA is not designed to optimize ETS: number of misses is 9 times the number of false alarms (for the event “power > 0.75”).

BRISA overestimates the energy produced in July, August and September, when it is fed with Arome/Harmonie forecasts:

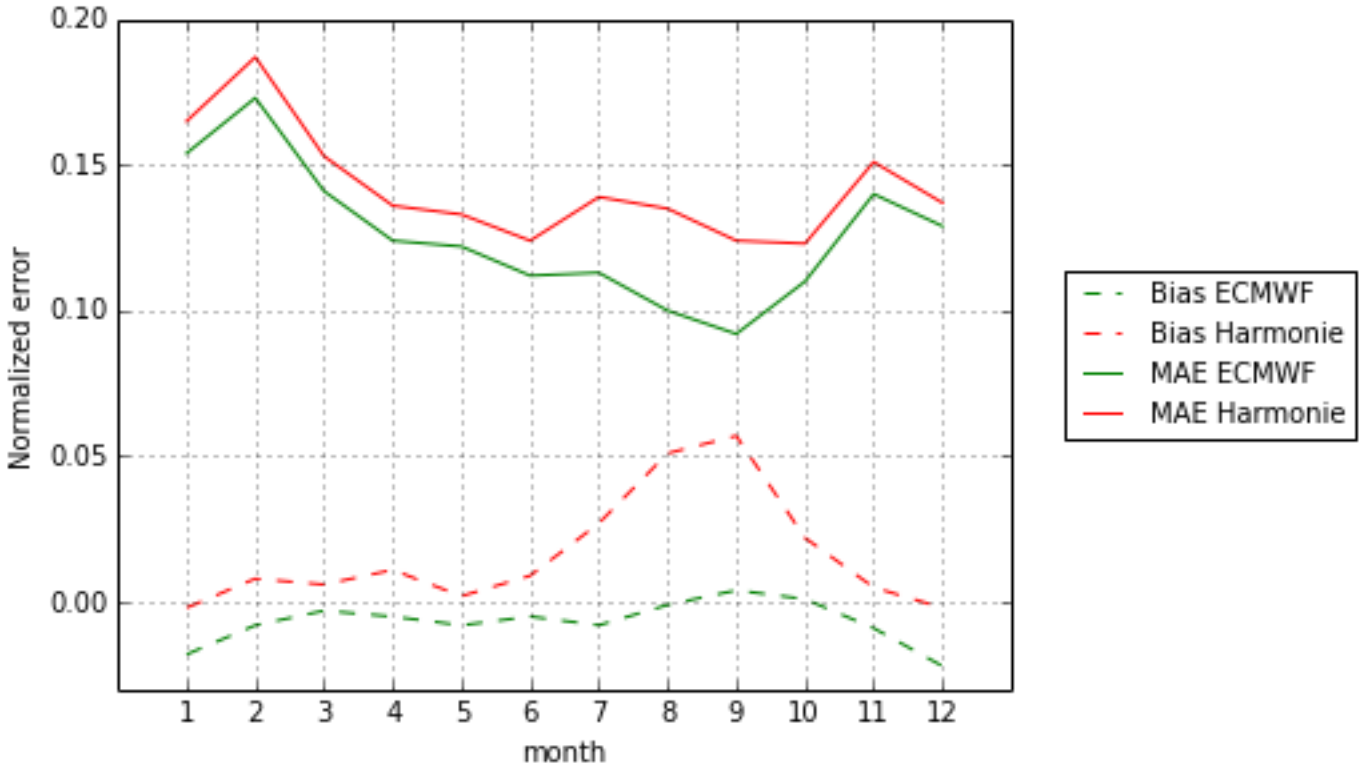


Bias and correlation for August 2014:

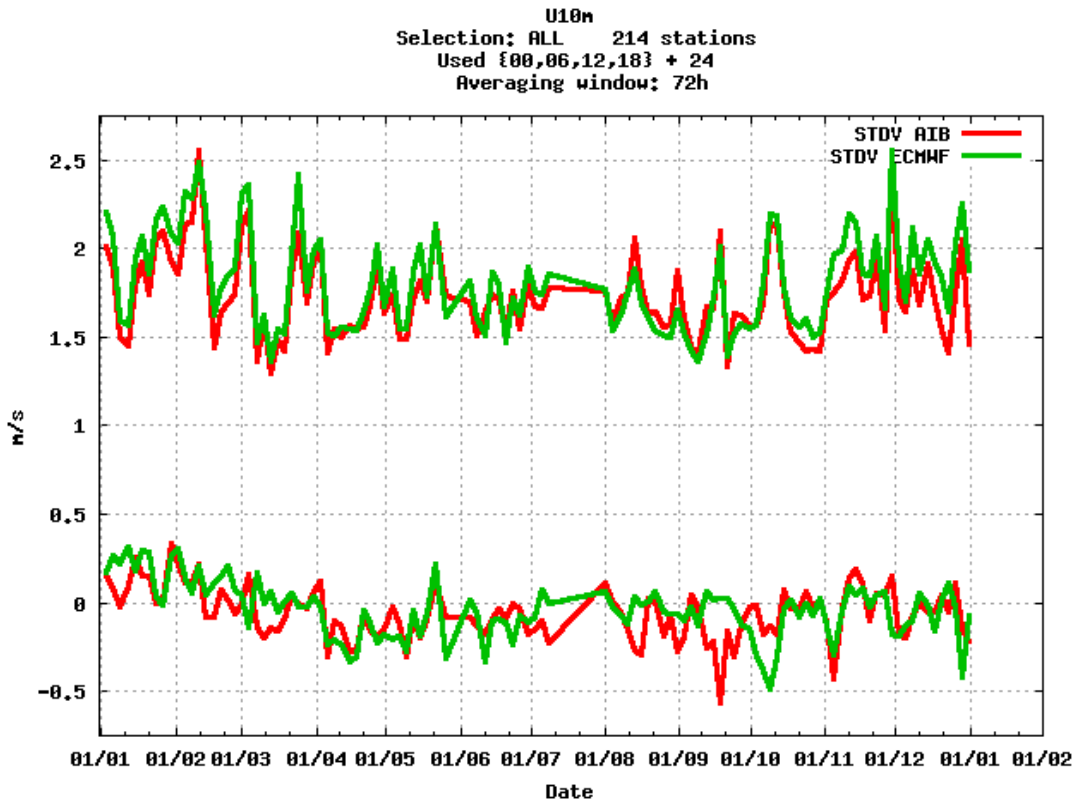




There is clearly a problem in summer when forecasting power with Harmonie



But not for 10m winds:



Summary

- Verification of electric power forecasts allows to reach some conclusions about the skill of meteorological models valuable to users.
- Meteorological and non-meteorological errors can be distinguished at least partially even with limited external information.
- Phase errors are the main contributors to error, but specific events can be more relevant to users. Höwmoller diagrams are a useful tool to detect them.
- ECMWF model seems to have slightly more skill to forecast 100 m winds, though the post-process system can distort results => More research is needed.

Thank you for your attention!

Literature

- Red Electrica de España: The Spanish Electricity System 2014 (http://www.ree.es/sites/default/files/downloadable/the_spanish_electricity_system_2014_0.pdf)

- I. Sanchez: Short-term prediction of wind energy production, International Journal of Forecasting (2006), 22, 43-56

- Giebel G., Brownsword R., Kariniotakis G., Denhard M., Draxl C.: The State-Of-The-Art in Short-Term Prediction of Wind Power A Literature Overview, 2nd Edition. Project report for the Anemos.plus and SafeWind projects. 110 pp. Risø, Roskilde, Denmark, 2011

- A. Steiner and C. Köhler: "Objective Identification of Critical Weather Events for Ensuring Net Stability", International Conference Energy & Meteorology 2015, Boulder, USA.