Renewable Energy Production Forecast

PROJ0016 - Big Data Project

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Photovoltaic production

Improvements

- Maximum power bounding
- Temperature influence
- Sine scaling
- (timezone fixing)

Resulting Model

$$P_{out} = \min\left(\frac{\eta I \cos(\theta) A}{\sin(alt)}, \texttt{MAX\_POW}\right)$$

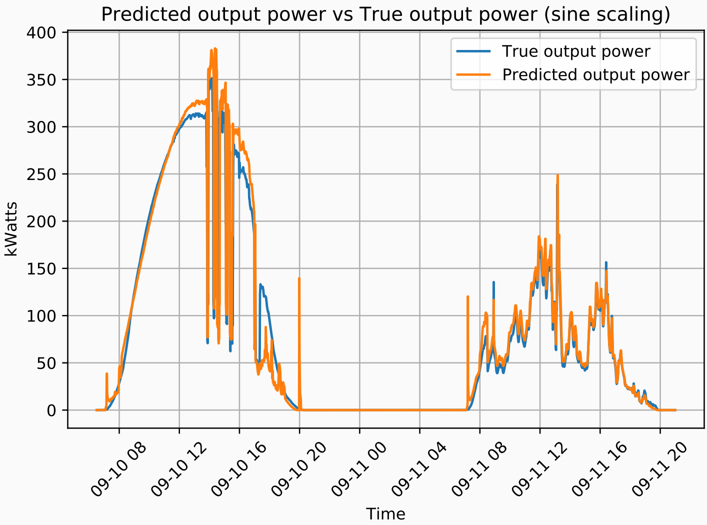
where

$$\texttt{MAX\_POW} = \min\left(P_{max}, P_{max} - 0.004(T - 25)\right)$$

Updated Model Example

Using the thermodynamics laboratory data, the following model is obtained for a period ranging from September 10th to September 12th.

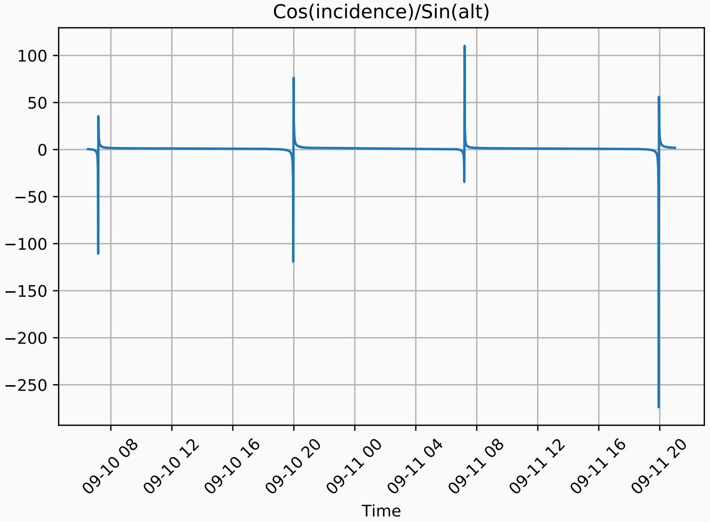
Updated Model Example



Issue

There seems to be peaks at regular periods of the day. By looking at the ratio between the sine and cosine, we notice the existence of peaks as well.

Issue

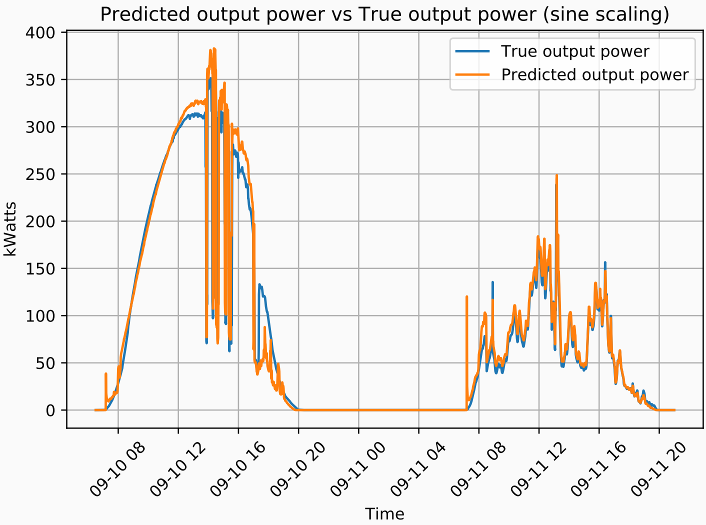


Cos(incidence)/Sin(alt)
100
50
0
−50
−100
−150
−200
−250
09-10 08
09-10 12
09-10 16
09-10 20
09-11 00
09-11 04
09-11 08
09-11 12
09-11 16
09-11 20
Time

Issue

To fix the issue, we decided to force the output power to be equal to zero whenever both quantities are negative: it means the sun is “behind” the panels and has set.

Final model



Predicted output power vs True output power (sine scaling)
True output power
Predicted output power
kWatts
400
350
300
250
200
150
100
50
0
09-10 08
09-10 12
09-10 16
09-10 20
09-11 00
09-11 04
09-11 08
09-11 12
09-11 16
09-11 20
Time

Alternative model

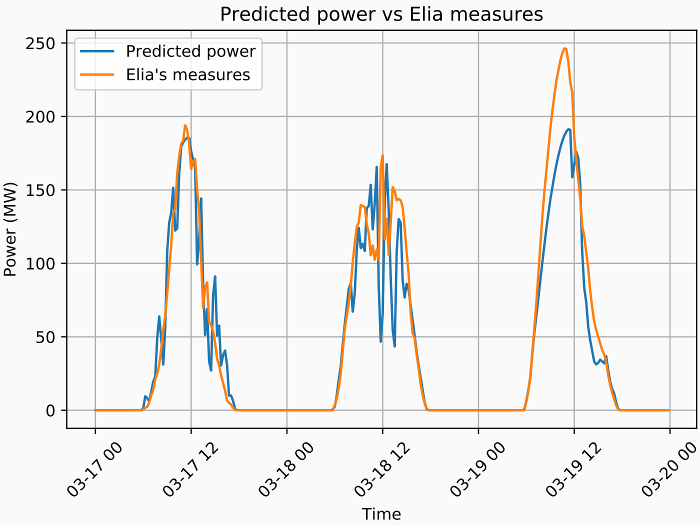
We have access to old (2017-2018) solar statistics data, containing among others the kVA (maximum solar power) of photovoltaic panels installed in the municipalities of Liège.

Alternative model

Using this, as well as some measure of area of photovoltaic panels per kWPeak (~ 7), we obtained a rough measure of the average area of photovoltaic panels installed in the province of Liège.

Setting the efficiency η to some fixed arbitrary value (0.15), we obtain the following model (for a period of 3 days).

Alternative model



Alternative model

- Use PyStan to fit sensitive parameters to posterior measures made by Elia.
- Potentially use Elia's measure of monitored capacity as starting point

Next objectives

- Deal with uncertainty on parameters (η, peak area, etc.)
- Find relevant irradiance forecast data

Photovoltaic panels enumeration

Test set – Google Maps

In the previous review, we talked about using the Google Maps satellite imagery for detection (not training) because of its high resolution.

Unfortunately, the Google Maps API isn't free. Actually, it is probably reserved to commercial use (cannot remove Google watermark).

Test set – Google Earth Engine

Afterwards, we found the Google Earth Engine API [1]. It combines a multi-petabyte catalog of satellite imagery and geospatial datasets, like Landsat (Nasa) [2] and Sentinel (Esa) [3].

The API is primarily available in JavaScript and secondarily in Pyhton.

The access to this API is restricted, but we obtained the rights.

Test set

Unfortunately, the available satellite imagery had an insufficient resolution for Belgium.

WalOnMap is still our best choice.

Learning set

Last review, we proposed a few way to investigate in order to find a learning set.

- Asking to a university/repository owner.
- OpenStreetMap solar panel coordinates dataset for England.
- Keep searching for a dataset.

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Learning set

Last review, we proposed a few way to investigate in order to find a learning set.

- Asking to a university/repository owner. We sent multiple mails, none were answered.
- OpenStreetMap solar panel coordinates dataset for England. Gives only (very) approximate location, not surface nor shape.
- Keep searching for a dataset. We found one comming from Duke University ! [4]

Learning set

This dataset contains the geospatial coordinates and border vertices for over 19 000 solar panels across 601 high resolution (5000×5000) images from four cities in California (Fresno, Modesto, Oxnard, Stockton).

Learning set

Figure 1: Modesto city, picture 1, zoomed 10 times

Learning set

The solar panel geospatial coordinates are very precise and provided as polygon vertices in either a `csv` or a `json`.


```json
{
 "polygons": [
  {
   "polygon_id": 1,
   "centroid_latitude": 36.926310139710594,
   "centroid_longitude": -119.84055537864529,
   "centroid_latitude_pixels": 107.6184581,
   "centroid_longitude_pixels": 3286.151487,
   "city": "Fresno",
   "area_pixels": 136.192872,
   "area_meters": 1513.254134,
   "image_name": "11ska460890",
   "nw_corner_of_image_latitude": 36.92633611,
   "nw_corner_of_image_longitude": -119.8516222,
   "se_corner_of_image_latitude": 36.91323333,
   "se_corner_of_image_longitude": -119.8343,
   "datum": "NAD83",
   "projection_zone": "11",
   "resolution": 0.3,
   "jaccard_index": 0.914019659,
   "polygon_vertices_lat_lon": [
    [
     -119.84030285285368,
     36.92625126752494
    ],
    [
     -119.84068167074253,
     36.92636019465177
    ],
```


Figure 2: `SolarArrayPolygons.json`

Learning set

These coordinates are not useful *as-is* for training.

We have written (using mainly `OpenCV` [5]) a code `learning_set.py` to

1. transform the polygons into black and white classification images.
2. slice the images into smaller (256×256) images.
3. produce (X, Y) image pairs.

Learning set

Figure 3: Example of (X, Y) image pair.

Learning set – Data augmentation

We plan to rotate and translate these (X, Y) image pairs in order to increase the quantity of available training data.

Next objectives

Now that we have suitable learning and testing sets, we are ready to build our first detection model(s).

Wind production

Data

New data has been retrieved:

- Wind speed measures from February 2012 to now (one single location in Wallonia for now)
- Physical model output using the wind speed measures and the wind turbines data collected for last review, from 2012 to now
- Elia's wind power measures from February 2012 to now

Models

For now, only four types of models have been investigated.

- A Gaussian Process based on a Rational Quadratic Kernel predicting the power from the wind speed (at a unique location)
- A Gaussian Process based on a Rational Quadratic Kernel predicting residuals between the measures of Elia and the physical model
- A Random Forest predicting the power from the wind speed, physical model, and timestamp.
- Extra-Trees predicting the power from the wind speed, physical model and timestamp.

Results - Gaussian Process

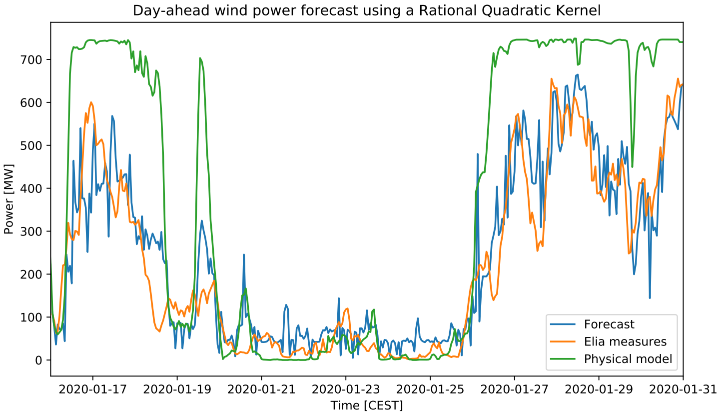

Figure 4: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Results - Gaussian Process

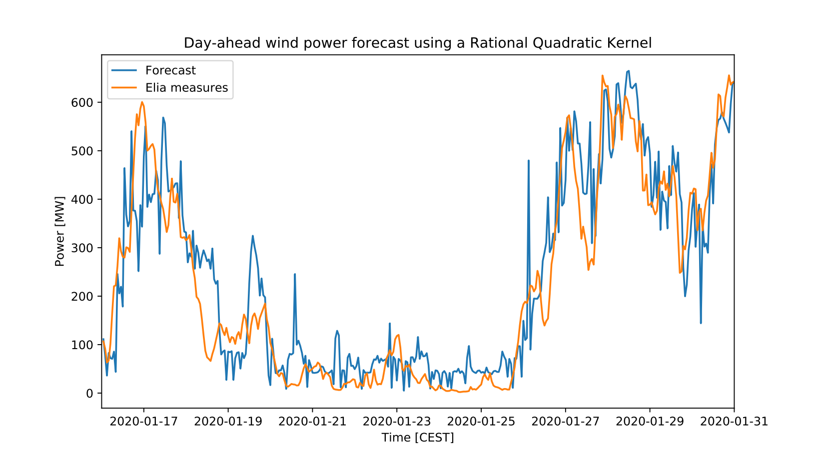

Figure 5: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Results - Gaussian Process

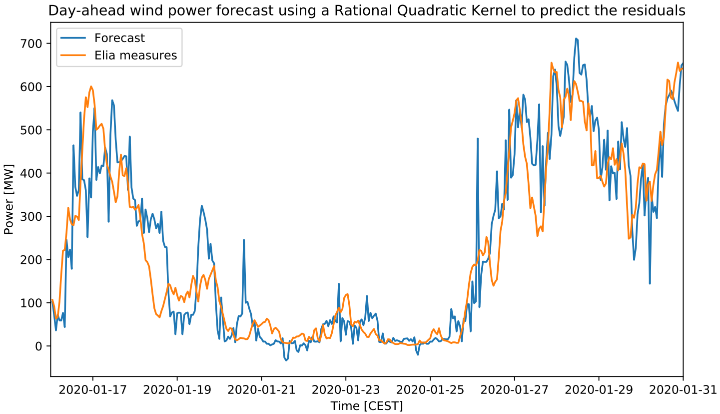

Figure 6: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Results - Gaussian Process

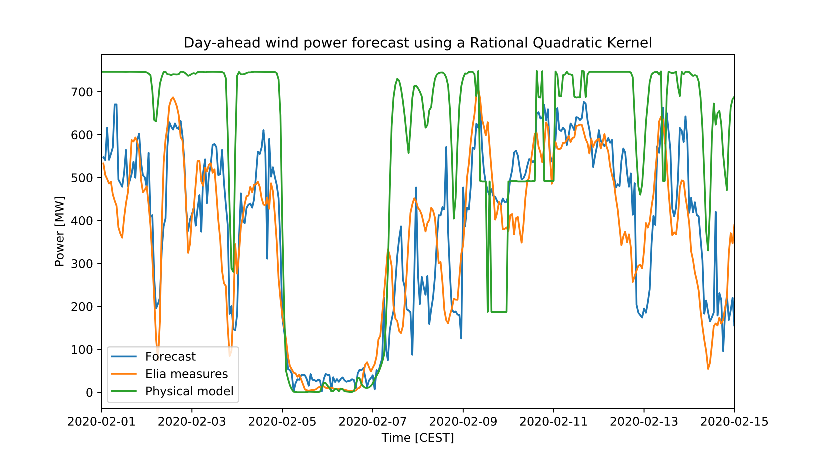

Figure 7: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Results - Gaussian Process

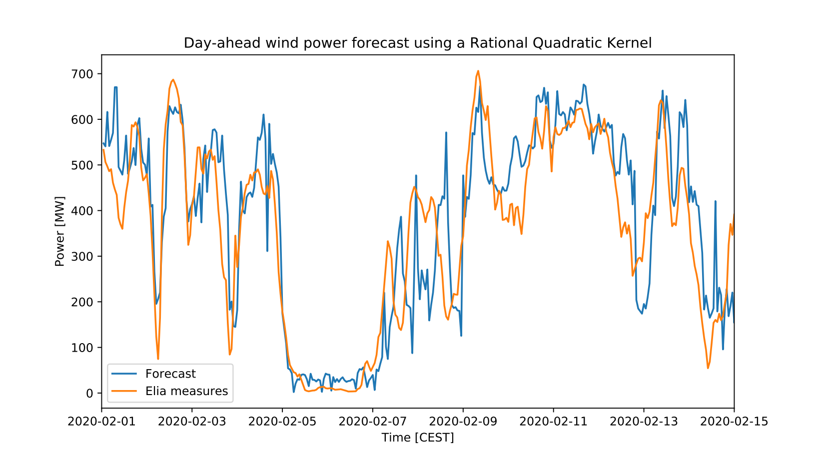

Figure 8: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Results - Gaussian Process

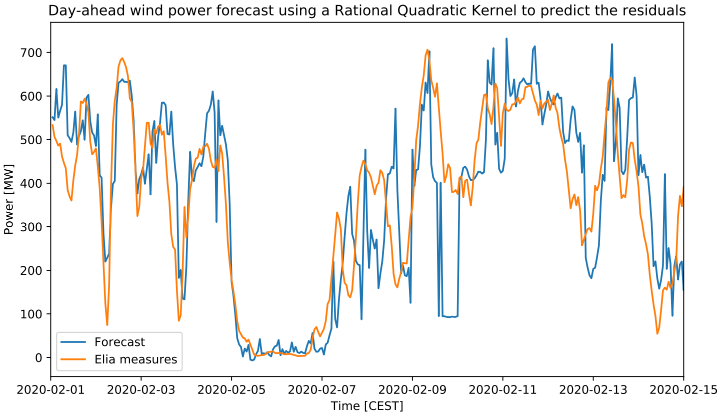

Figure 9: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Results - Gaussian Process - Issues

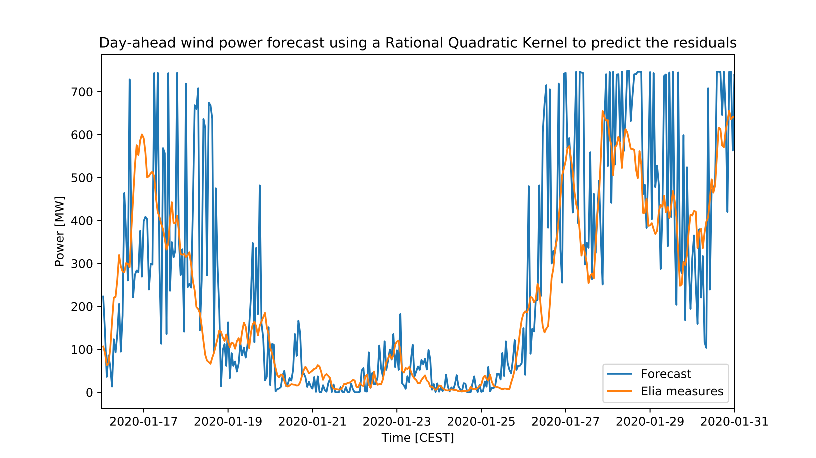

Figure 10: Gaussian Process with Rational Quadratic Kernel - 3 months of training data

Results - Gaussian Process - Issues

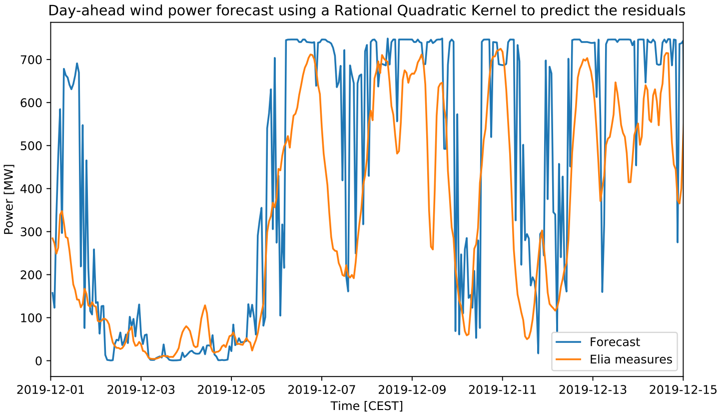

Figure 11: Gaussian Process with Rational Quadratic Kernel - 1 month of training data

Result - Random Forest

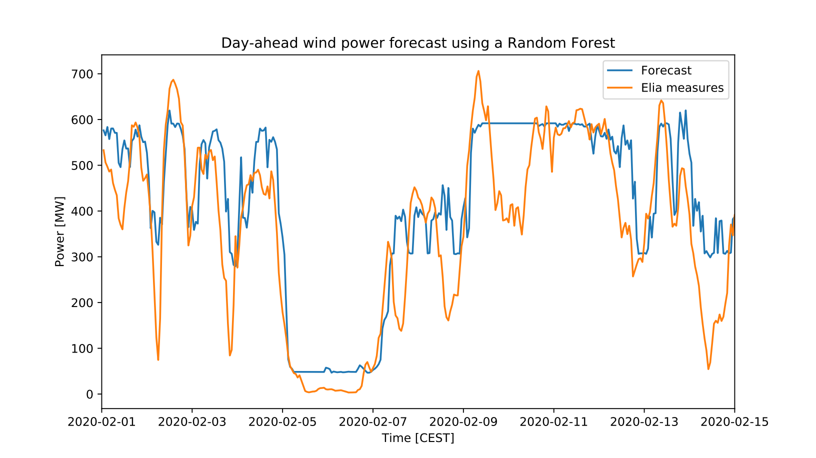

Figure 12: Random Forest - 1 month of training data

Result - Random Forest

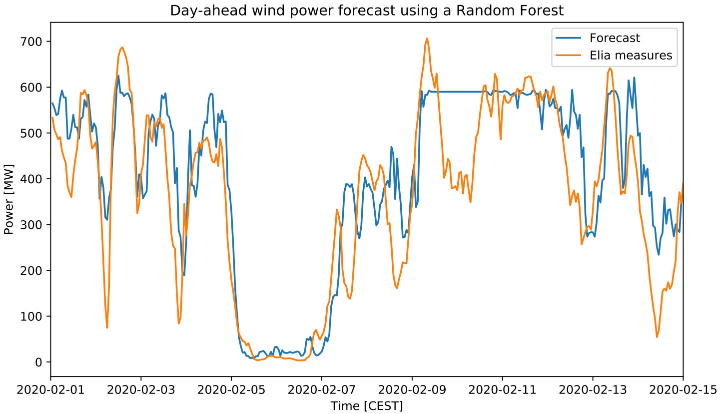

Figure 13: Random Forest - 1 year of training data

Result - Random Forest

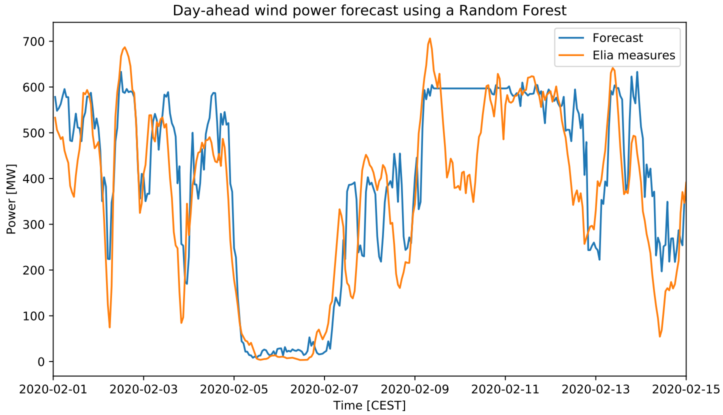

Figure 14: Random Forest - 8 years of training data

Result - Extras Trees

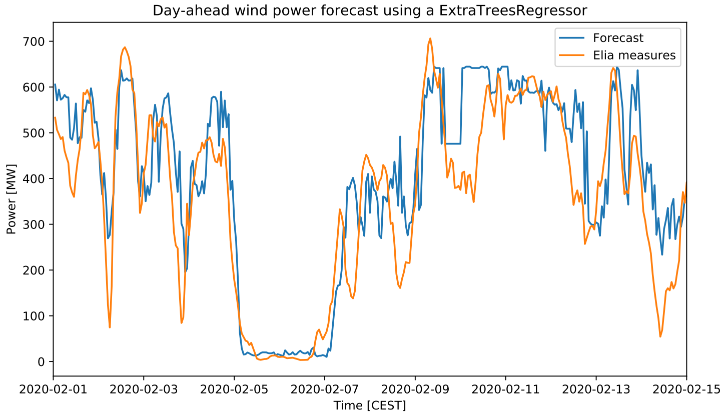

Figure 15: Extra Tree - 1 month of training data

Result - Extras Trees

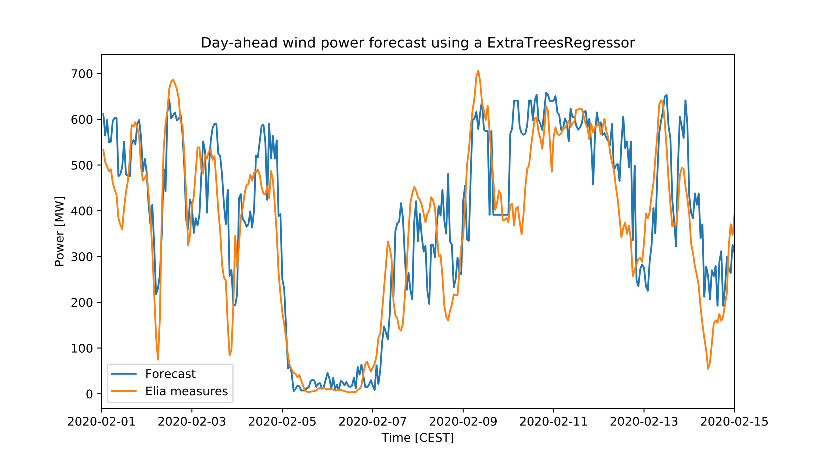

Figure 16: Extra Tree - 1 year of training data

Result - Extras Trees

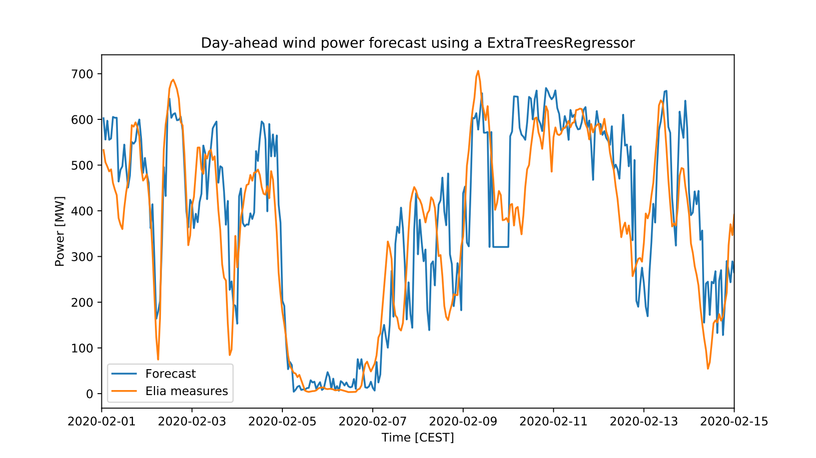

Figure 17: Extra Tree - 8 years of training data

Questions ?

References

Google. *Google Earth Engine*. 2020. URL: https://earthengine.google.com/.

Nasa. *Landsat*. URL: https://landsat.gsfc.nasa.gov/.

Esa. *Sentinel*. URL: https://sentinel.esa.int/web/sentinel/home.

Kyle Bradbury. *Distributed Solar Photovoltaic Array Location and Extent Data Set for Remote Sensing Object Identification*. 2016. URL: https://figshare.com/collections/Full_Collection_Distributed_Solar_Photovoltaic_Array_Location_and_Extent_Data_Set_for_Remote_Sensing_Object_Identification/3255643.

OpenCV. URL: https://opencv.org/.