Towards a seamless approach for photovoltaic forecasting

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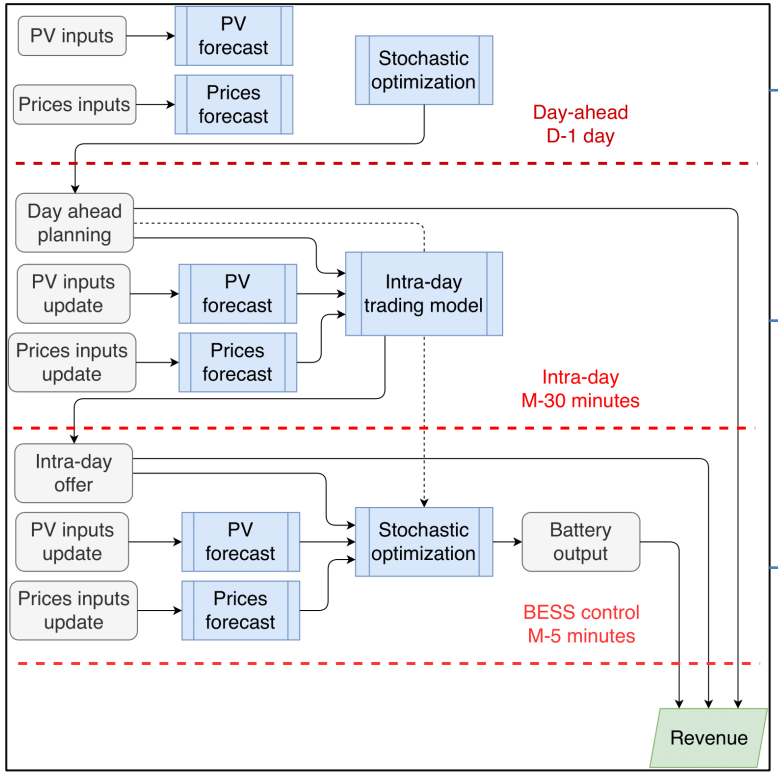
Motivation

- Large variety of forecasting products required for electricity markets:



Day-ahead schedule:
Horizon +12 to +36 hours
Resolution ~1 hour

Intra-day market:
Horizon +30 minutes
Resolution ~30 minutes

Storage planning:
Horizon as close to real-time as possible
Resolution as high as possible

Motivation

- PV power forecasting models are often designed for one specific horizon/resolution

- In this work we propose a **single model** to cover all PV forecasting products

- This effectively simplifies the usage of PV power forecasts in several decision-making processes

Motivation

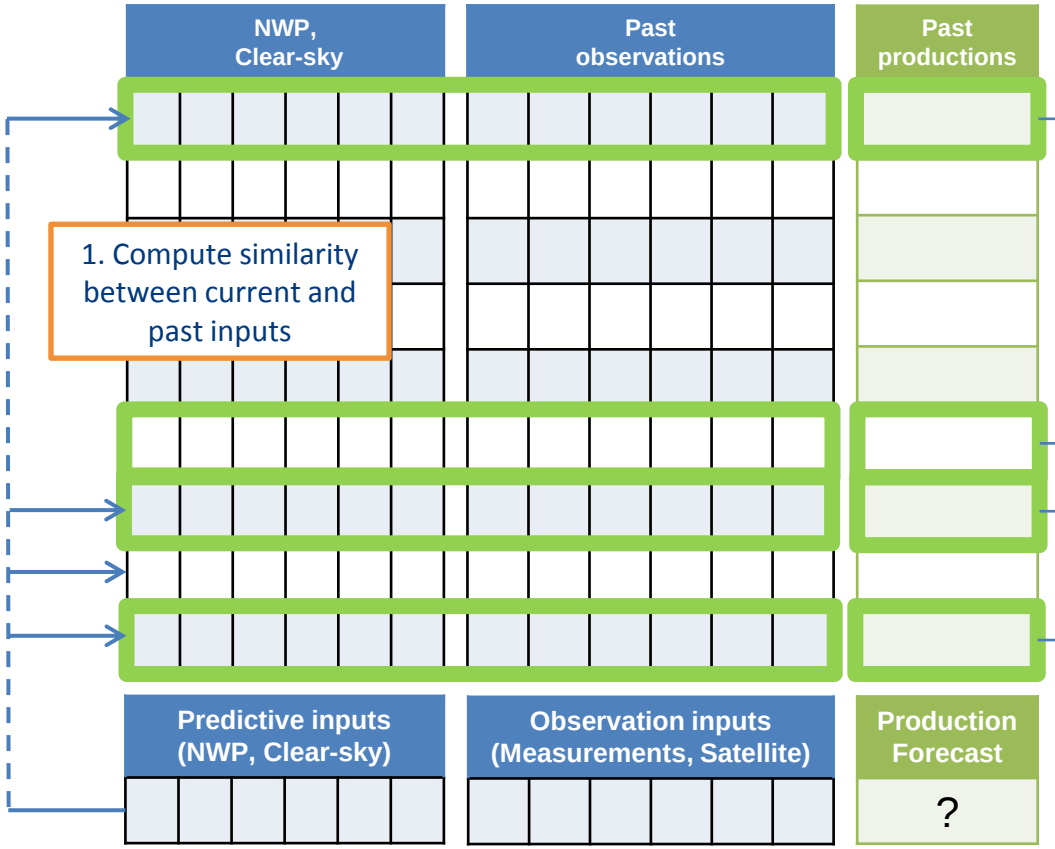
- Proposition based on the Analog Ensemble (AnEn) method
  - Combine **heterogenous** sources of input
  - Forecasts adapted to market time frames:
    - Provide both **intra-day** and **day-ahead** accurate forecasts
    - Provide forecasts with **both high (i.e. 5 minutes) and low (i.e. 30 minutes) temporal resolutions**
    - Provide forecasts starting at **any time of the day**
  - As **fast** as possible
  - **Probabilistic forecasts** for decision under uncertainty

Already present in the state-of-the-art

To implement

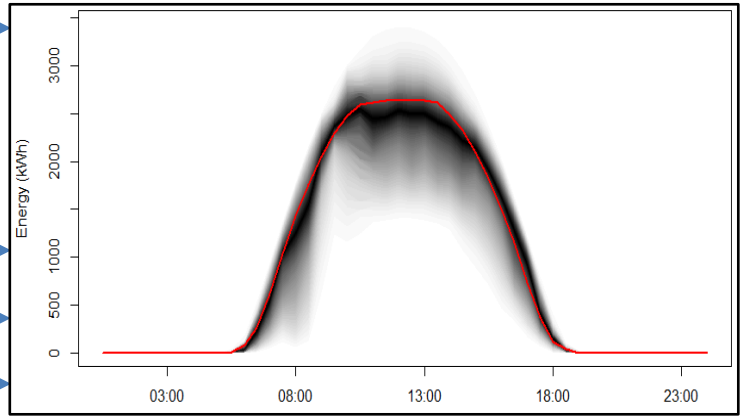
To check after implementation

Methodology



2. Select k most similar past inputs

3. Obtain the k corresponding past productions = **Analog Ensemble**



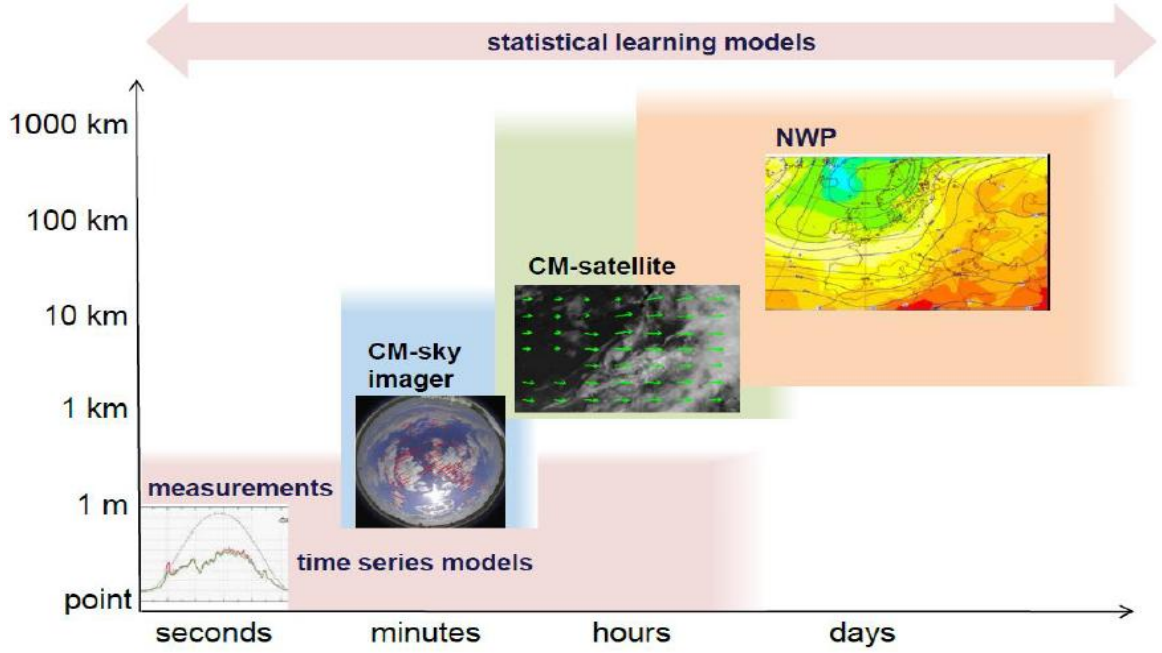
4. Derive PDF from the Analog Ensemble using a KDE approach

$$f(p) = \frac{1}{\sum_{i=1}^{N_{A_n}} s_i} \sum_{i=1}^{N_{A_n}} \frac{s_i}{bw} \left[K\left(\frac{p - e_i}{bw}\right) + K\left(\frac{p + e_i}{bw}\right) + K\left(\frac{p + e_i - 2E_n}{bw}\right) \right]$$

Methodology

- To achieve short-term forecasts:

  - Measurements for very short-term
  - Satellite data for short-term



Source: Solar Training 2016, OIE- Transvalor

Methodology

- Standard AnEn model:

- The weights w_i are optimized on a training set ("wrapper")
  - ➢ We propose a "filter" approach to compute the weights directly from the history without an optimization loop

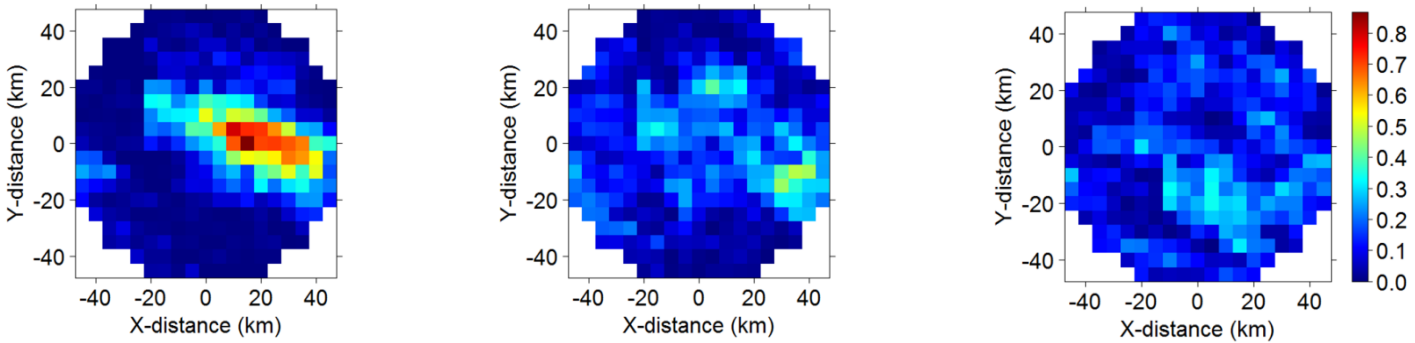
Methodology

- When h is the forecast horizon:

- The weights w_i^h are dependent on the forecast horizon.

Methodology

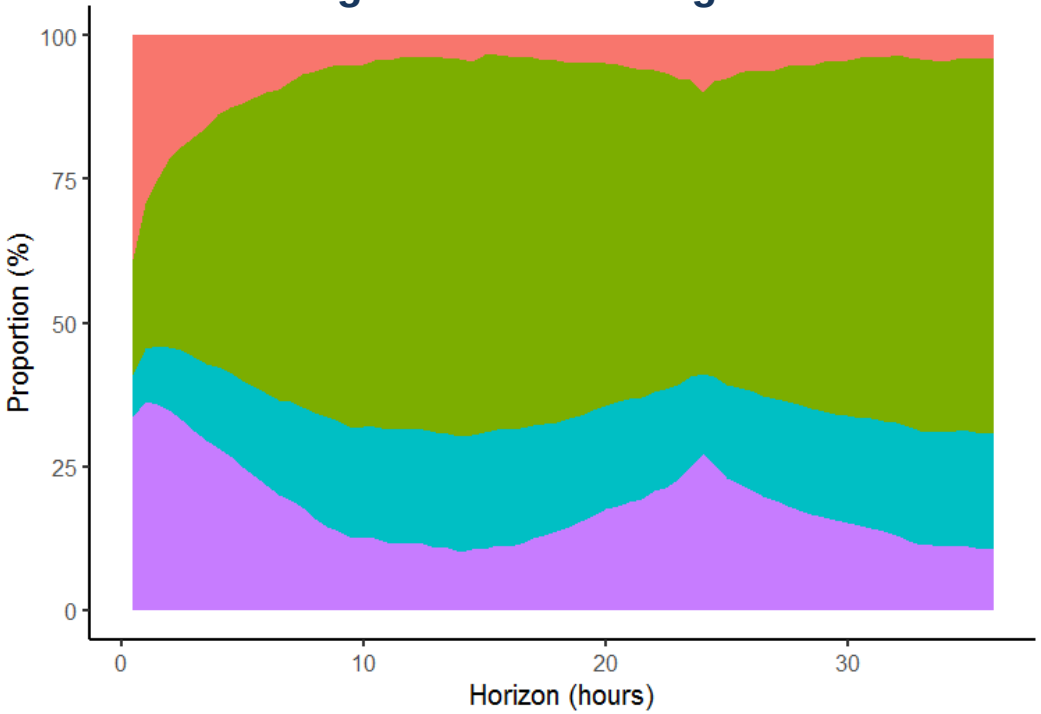
- Satellite data: Estimation of GHI time series for each pixel from geostationary satellite images following *[Blanc2011]*
  - ➢ Very large number of redundant features
  - ➢ Selection of representative pixels based on MI with the measurements

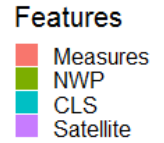


T + 30 minutes | T + 90 minutes | T + 250 minutes

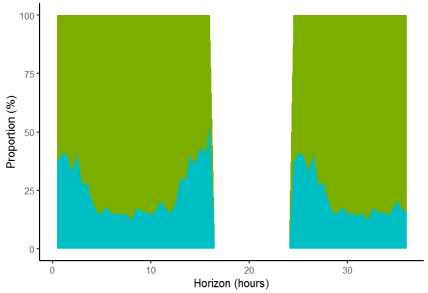
[Blanc2011]: Philippe Blanc et al., *The HelioClim project : Surface solar irradiance data for climate applications*, In: Remote Sensing 3.2 (2011)

Methodology

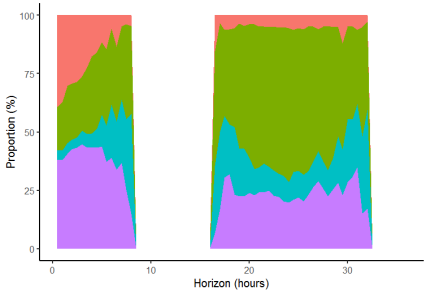




3 AM



12 AM



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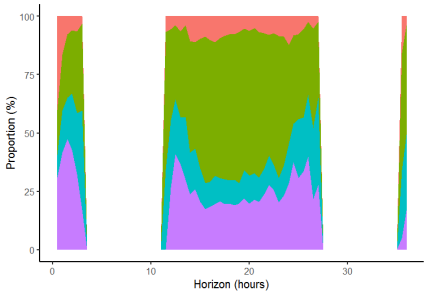


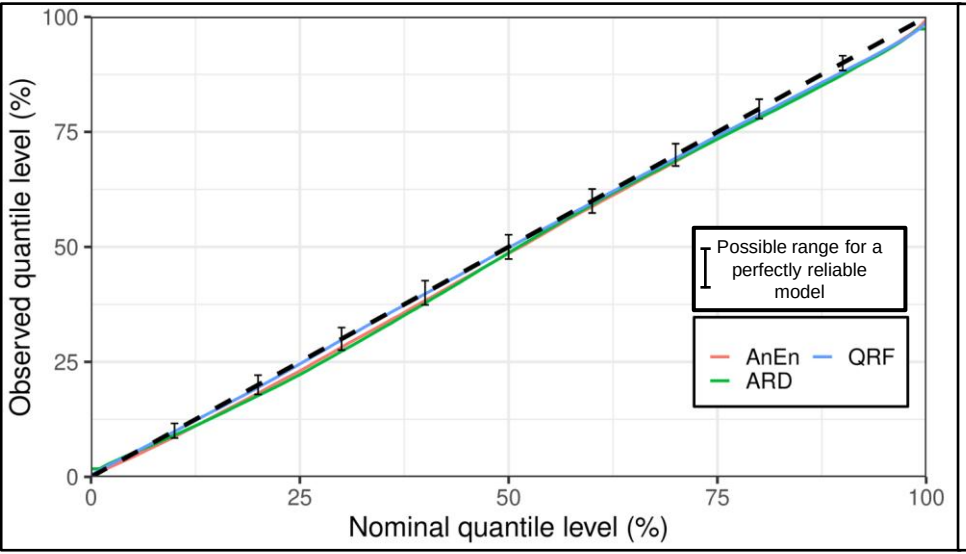
Evaluation of the AnEn model

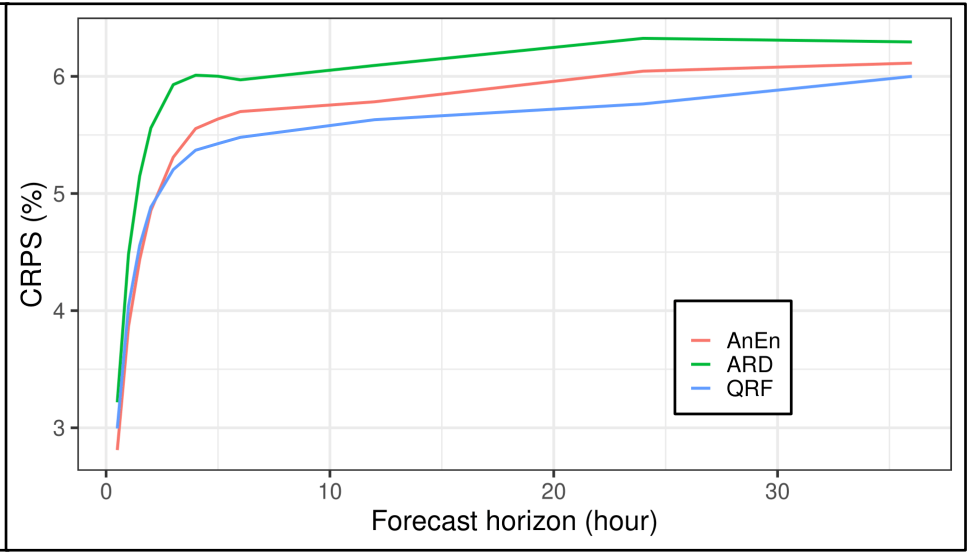
- Evaluation of the AnEn model on a portfolio composed of 12 PV plants ranging from 2 to 10 MW.
- Measurements with 5- and 30-minute resolutions are used

- Benchmark models are implemented:
  - **Day-ahead forecasts:** Quantile Random Forest (QRF) and Bayesian Automatic Relevance Determination (ARD)
  - **Intra-day forecasts:** Clear-sky index persistence and integrated auto-regressive (ARIMA) model

Result – 30 minute resolution

- Forecast performance for day-ahead forecasts (30-minute resolution, plant n°4):



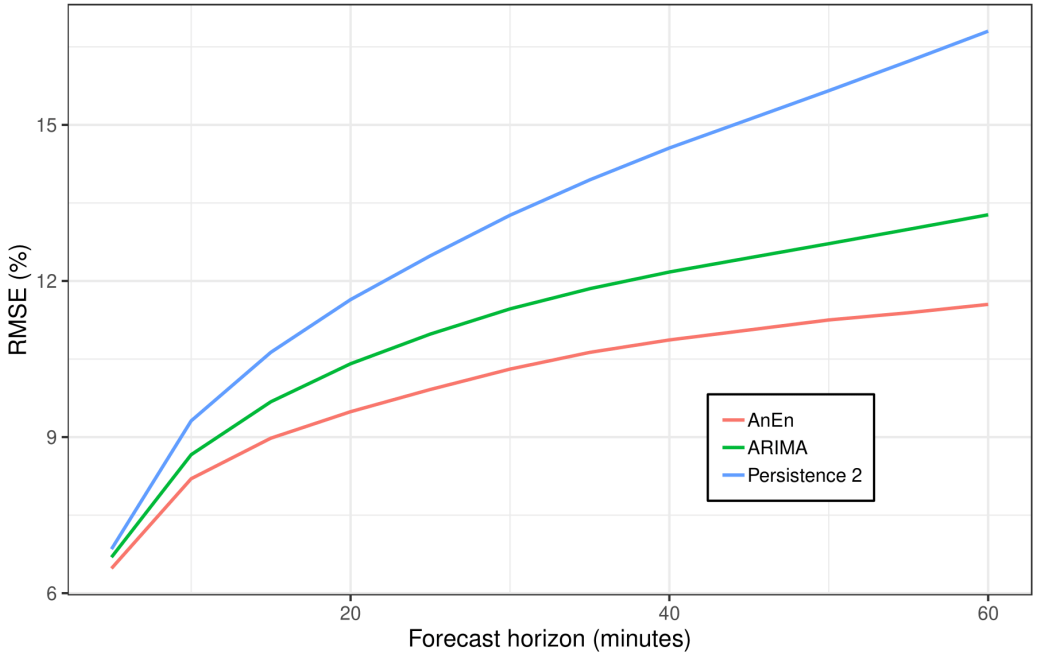


Reliability diagram: nominal vs. observed quantiles

CRPS: Continuous Ranked Probability Score, normalized by installed PV capacity

Result – 5 minute resolution

- Forecast performance for intra-day 5-minute forecasts. QRF and ARD models are discarded due to computational cost:



RMSE: Root Mean Square Error, normalized by installed power

Computing time

- Computing time required for providing a forecast for a given horizon in seconds

	30-minute resolution		**5-minute resolution**	
	Training	*Forecasting*	*Training*	*Forecasting*
AnEn	-	1.87	-	8.77
Persistence 1	-	5e-3	-	6e-3
Persistence 2	-	5e-3	-	6e-3
ARIMA	9.2e-2	2.5e-7	10e-2	3.7e-3
QRF	4.26	1.3e-2	68.0	4e-2
ARD	10.75	10e-3	154	1e-3

Conclusions and perspectives

- A single forecasting model that can quickly provide accurate forecast for temporal resolutions from 5-minute to 1-hour, and horizon from 5 minutes to 3 hours
- Additional types of data could be used:
  - All-sky imagers
  - Neighboring plants or weather stations
  - Infra-red satellite data
  - Commercial forecasts from third entities

- **More details in:** T. Carriere, C. Vernay, S. Pitaval, F.P. Neirac, G. Kariniotakis, *A Novel Approach for Probabilistic Photovoltaic Power Forecasting Covering Multiple Time Frames*, IEEE Transactions on Smart Grid