Direct Normal Irradiance Nowcasting methods for optimized operation of concentrating solar technologies
DNICast

Optimizing DNI forecast using combinations of nowcasting models from the DNICast project

Dublin, Sep 2017

CIEMAT - PSA L. Ramírez, L.F. Zarzalejo, J.M. Vindel
DLR – ISF N. Hanrieder, S. Wilbert
CENER M. Gastón

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1. Introduction

- This presentation describes some examples of methods for combining nowcasting data sets.
- The combination methodologies have been applied to nowcasting models created in the DNICast project.
- The data sets are prepared for their validation and their application in CST (Concentrating Solar Technology) models.

First a short summary of the combination methods and the input data sets is presented. Then three implemented combination methods are described in more detail as well as their results in comparison with the input models.

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2. General overview

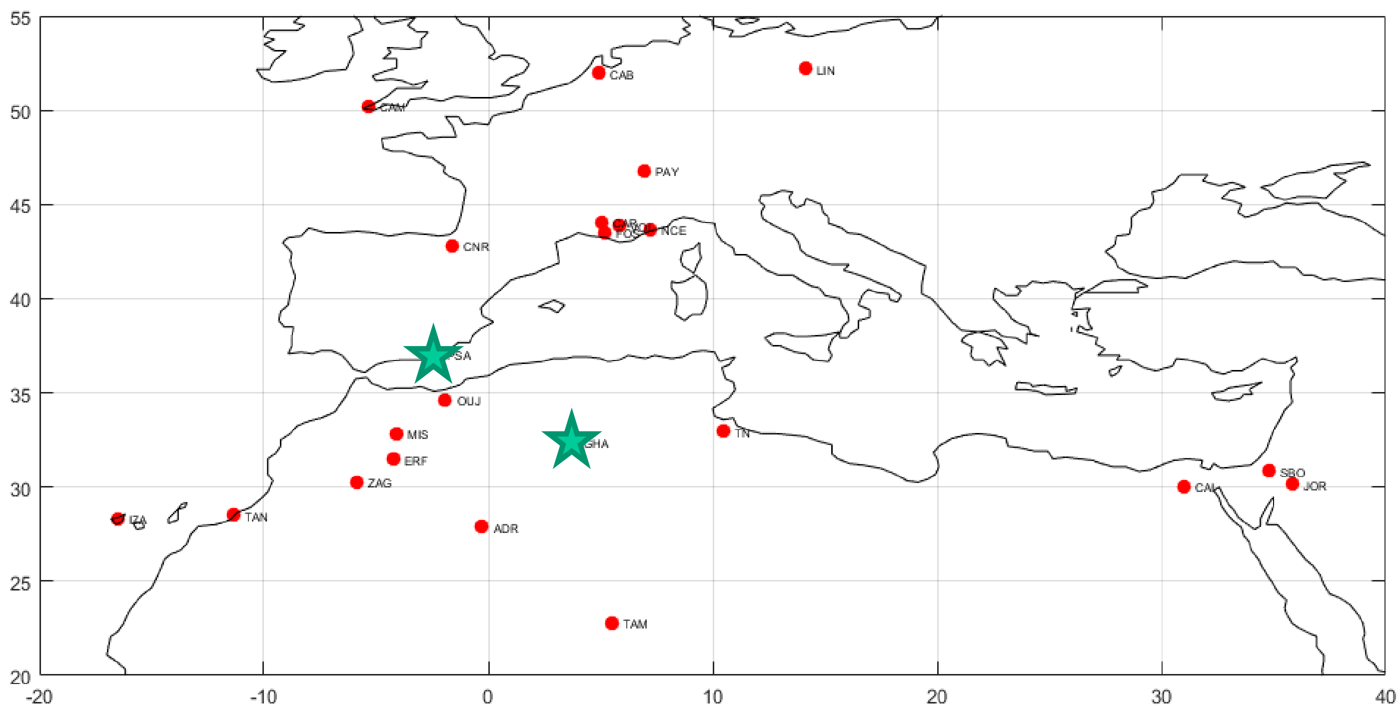
Characteristics of nowcasting inputs for the combination

- Selected data sets have different formats, refresh time, resolution and forecasted horizon

Method	Partner	Refresh frequency (min)	Nowcast resolution (min)	Nowcast horizon (hour)
SATELLITE	DLR-DFD	15	1	8
SATELLITE	DLR-IPA	15	5	6
SATELLITE	Meteotest	15	5	4
NWPM	SMHI	180	15	9

Testing sites and time periods

2 selected sites for testing the combination



4 Time periods*

Jan Feb Mar 2010
Mar Apr May 2013
Jun Jul Aug 2014
Sep Oct Nov 2015

* **Depending on the availability of models and local measurements**

Methods overview

Uncertainty weighted based approach (UWA)	Multi-regressive approach (MRA)	Distance weighted based approach (DWA)
Makes use of the uncertainty of each input nowcasting data set.	Uses a time-dependent multi-regressive model.	Makes use of the distances to the previous measurements.
Only available data sets are included in the combination.	An adaptive linear merging model is applied.	Similar to the UWA, only available sets can be used for the combination.
Combine several nowcasts using a quality weighting to enhance nowcast performance	Input variables are those DNI values predicted in previous forecast events.	Weights are based on the Euclidean distance and CoV comparisons.
(Applied by DLR ISF)	*(Applied by CIEMAT)*	*(Applied by CIEMAT)*

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3.1 Uncertainty weighted Combination Method

Combination of *n* nowcasts

Quality-weighted average is produced depending on the individual uncertainties of each data set

$$DNI_{combined} = \left(\frac{1}{\sum_{i=1}^{n} \frac{1}{\Delta i}}\right) \cdot \left(\sum_{i=1}^{n} \frac{DNI_i}{\Delta i}\right)$$

(Meyer et al. 2008)

nowcast DNI_i with absolute uncertainty Δi

Uncertainties have to be known

→ are provided with DNICast data sets

Main findings of Meyer et al. (2008):

1. If various input data of comparable quality are combined, combined data lead to better results
2. If one data set is of limited quality, the resulting combination can be worse than each single data set

Meyer, R., Geuder, N., Lorenz, E., Hammer, A., Beyer, H.G., 2008. Combining solar irradiance measurements and various satellite-derived products to a site-specific best estimate, in: SolarPaces Conference. pp. 1–8.

3.1 Uncertainty weighted Combination Method

Define used nowcasts of DNICast project

- DLR-PA Satellite based (WP 3.2)
- Meteotest clim postprocessed Satellite based (WP 3.2)
- Meteotest climdirect postprocessed Satellite based (WP 3.2)
- Meteotest maccdirect postprocessed Satellite based (WP 3.2)
- DLR-DFD Satellite based (WP 3.2)
- SMHI NWP Harmonie based (WP 3.3)
- SMHI NWP Harmonie based (5x5 neighboring points) (WP 3.3)

- **Additional DLR-ISF Persistence**:

→ calculate Linke turbidity for last 15 timestamps

→ determine last reliable Linke turbitidy

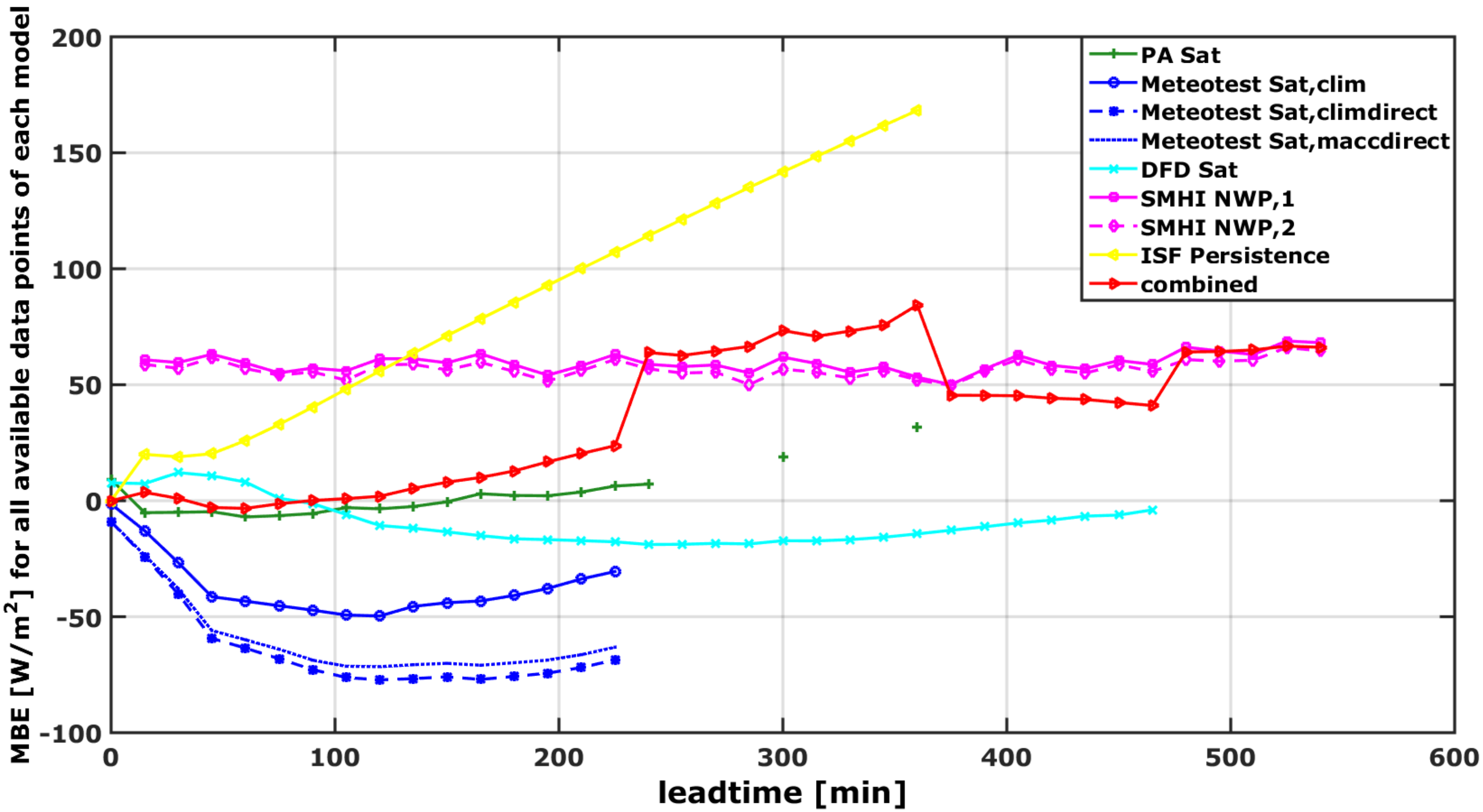
→ Perform Nowcast with the help of a clear sky forecast and the variation of the sun's position

3.1 Uncertainty weighted Combination Method

Mean bias error (PSA)

For all data points for each nowcast individually (different leadtimes by model)

Including selected periods of 2010, 2013, 2014 and 2015



3.1 Uncertainty weighted Combination Method

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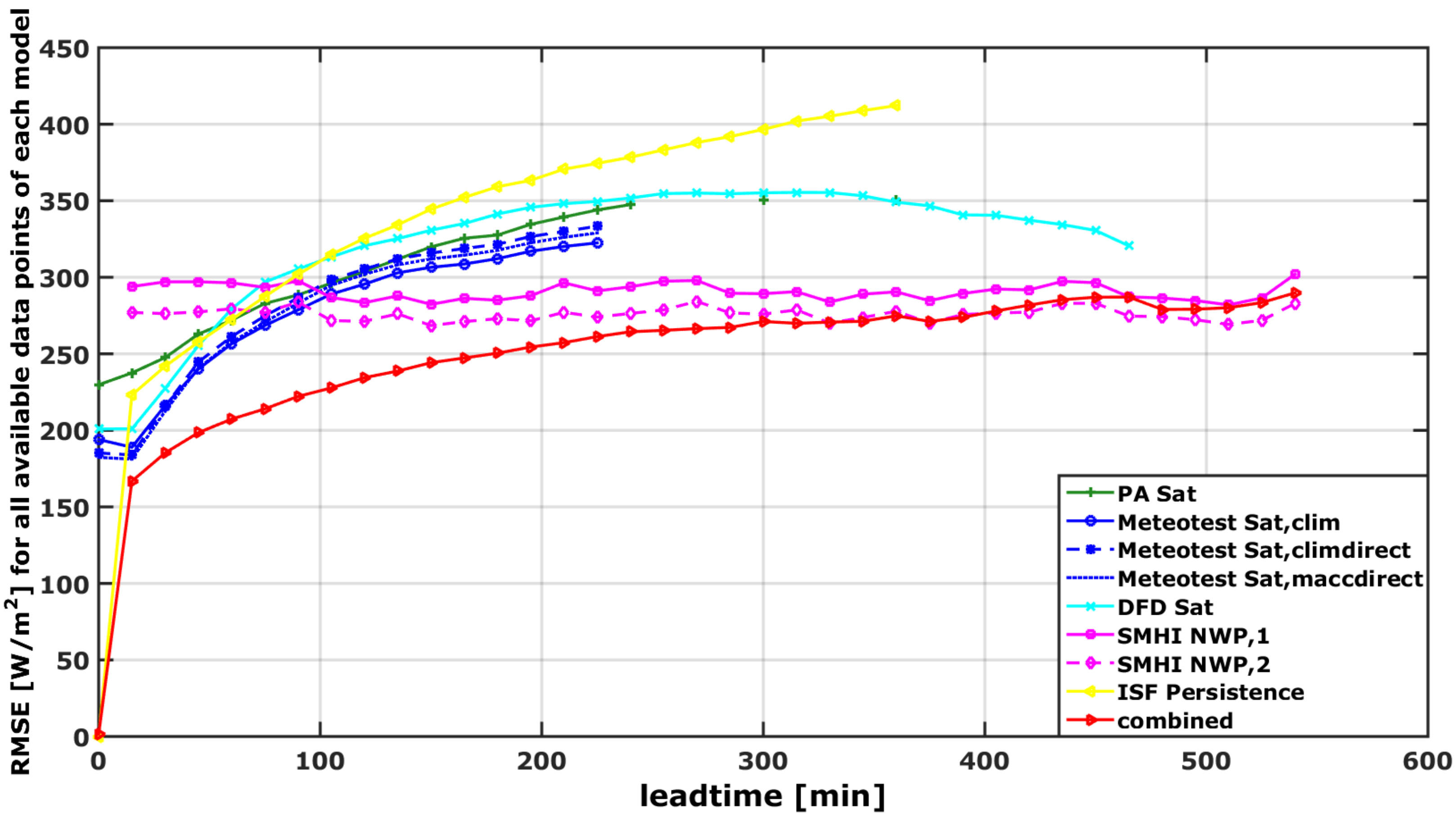
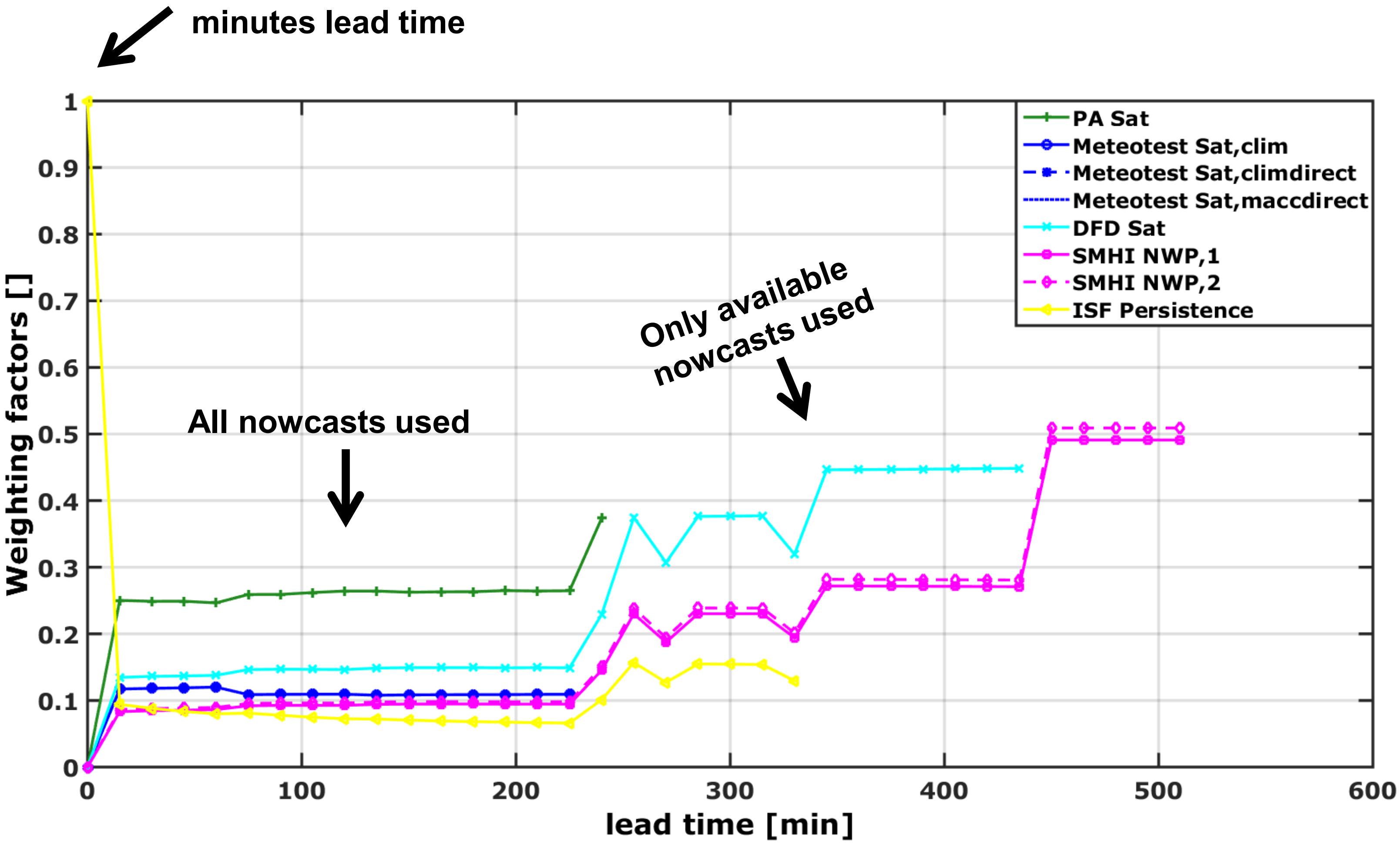


3.1 Uncertainty weighted Combination Method

Weighting Factors (PSA)

Only Persistence used for 0 minutes lead time



3.2 Multi-regressive approach

Pretreatment

- All DNI values predicted in previous forecast events are included as inputs.

Model characteristics

- Dynamic fitting
- A moving window of 5 days is set.
- Use Stepwise regression for reducing the number of inputs.
- Regression outputs have to be smoothed and filtered with physical limits

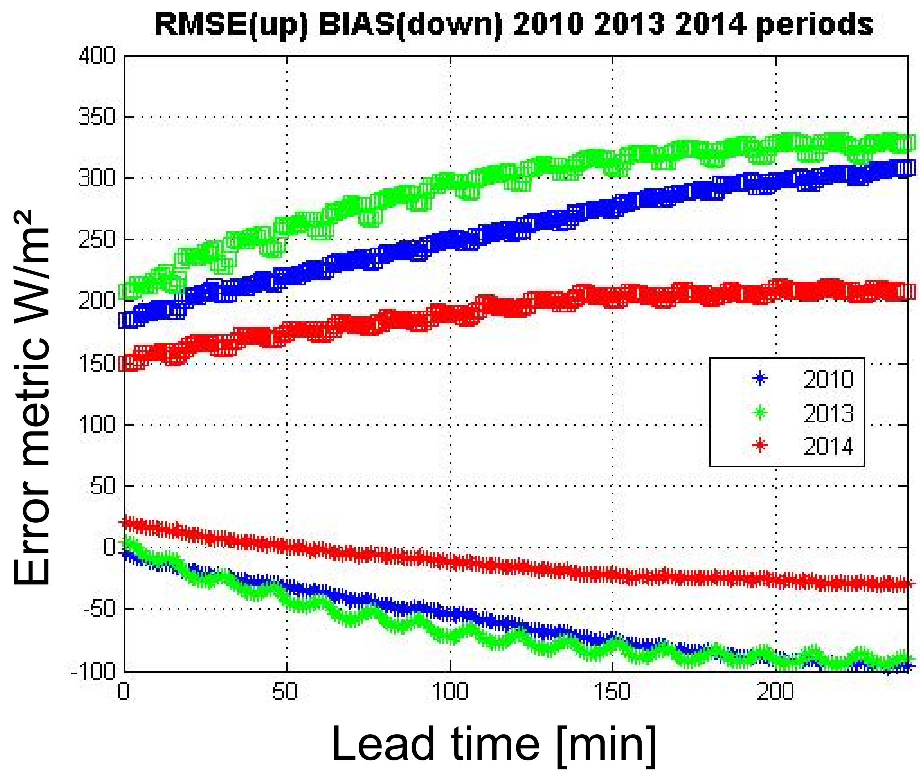
3.2 Multi-regressive approach

Results at PSA:

Including selected periods of 2010, 2013, 2014

2010: winter time
2013: spring time
2014: summer time

- <u>RMSE decreases in uncloudy periods</u>
- <u>Results similar to UWA in mean values</u>
- Small artificial waves from the artificial concatenation of different refresh times



3.3 Distance weighted combination method

Pretreatment

- ❑ All data sets are interpolated to minutely data and to the same refresh time.
- ❑ DLR - ISF Clear Sky Persistence is used as additional input.

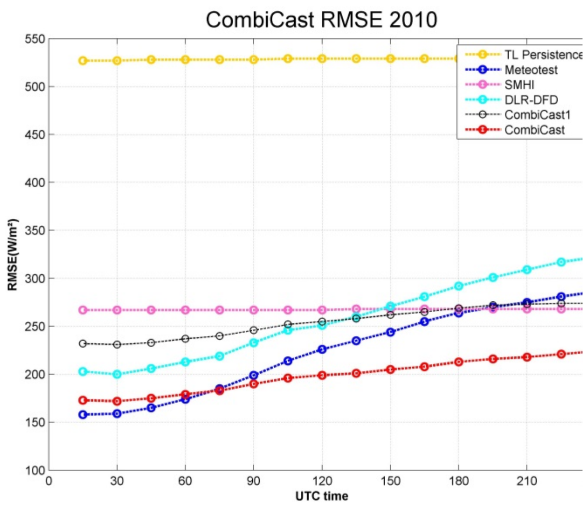
Model characteristics

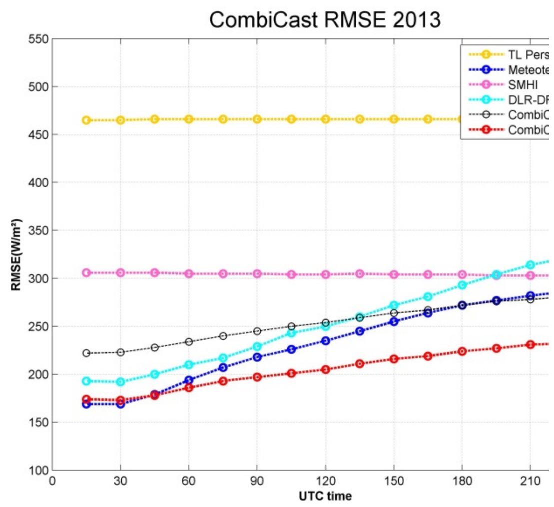
- ❑ Dynamic fitting in two steps
- ❑ Refresh times are used as a whole = same weight all lead-times
- ❑ Step1: - A moving window of 1 day.
  - Weights calculated by each refresh time using:
    - Euclidean distance of each model nowcast to the measurements.
    - COV distances among models and measurements.
- ❑ Step 2: Output from Step1 and persistence are weighted based in the Euclidean distance in the last 15 minutes.

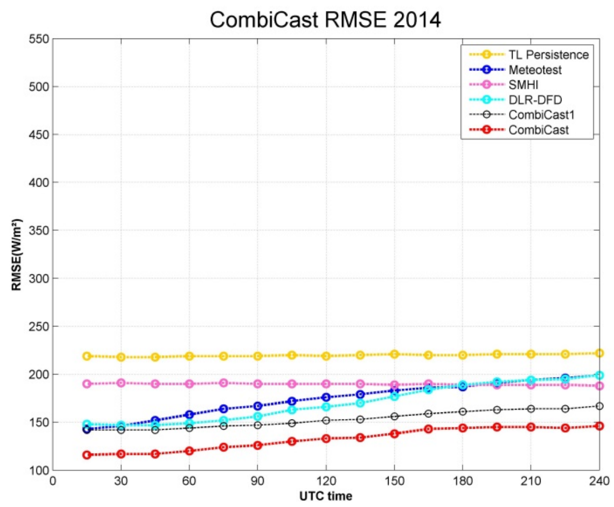
3.3 Distance weighted combination method

Results at PSA:

Selected periods of 2010, 2013, 2014







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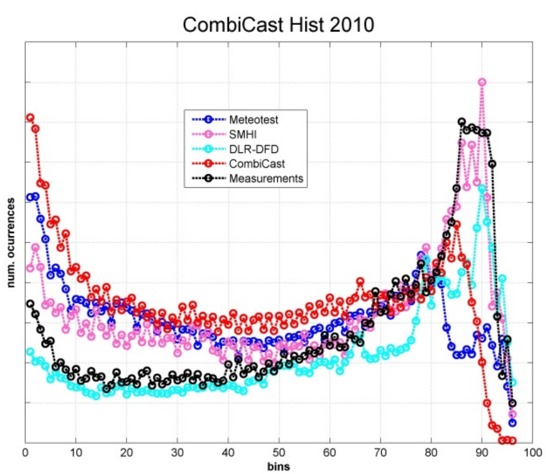
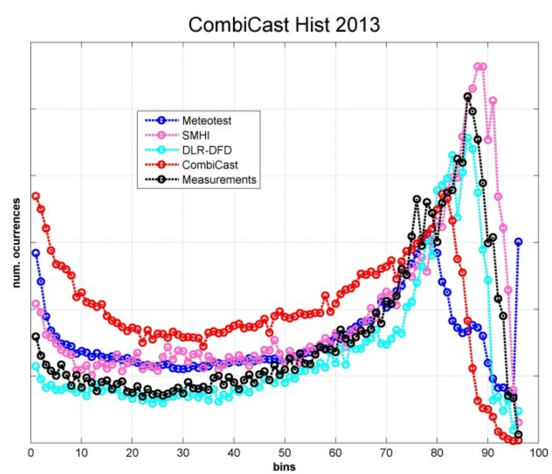
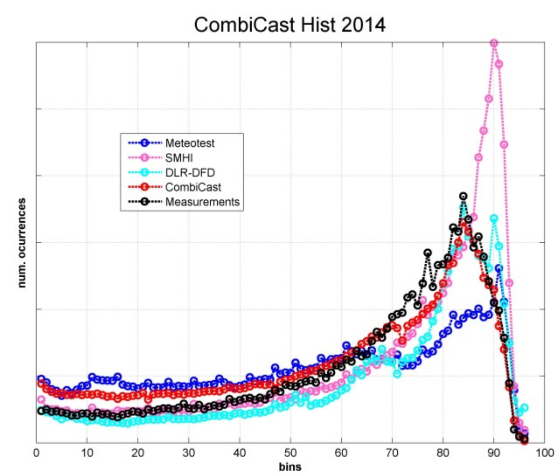
- **<u>Main objective</u>** of the combination use to be <u>minimizing errors</u>.
- But methods that are good for minimizing errors <u>sometimes change the variable range and distribution</u>.
- The **<u>nowcasting application have to be considered</u>** in order to select a combination method not only assessing the errors results.
- In the case of nowcasting <u>for CST plant operation</u>, the <u>range and variability</u> of the forecasts are in fact <u>more important than the right time forecast</u>.

Probability density functions evaluation - like using the KSI error - should be considered for CSP systems applications







Conclusions

Different combination models have been tested using nowcasting outputs from DNICast Project

- **Combined nowcast** in almost all cases lower errors than single nowcasts
- **Summer months** show better results due to less clouds and better coincidence of persistence with measurements
- **UWA model** seems to be the most simple and effective method for combination among tested
- Probability density functions considerations like KSI error should to be considered for CSP systems.
- **Combined nowcasts** is used to evaluate benefits of power plant operation using nowcasting systems (DNICast WP 4)

Thank you