Inter-System Time Lag due to Clouds in an Urban PV Ensemble

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CONTEXT

- In situ determination of cloud transit **time lag** on reconstructed Global Horizontal Irradiance (GHI) and the use of this time lag for short-term irradiance **forecasting**.

- Part of project: Solar Forecasting & Smart Grids: aimed at improving the **hosting capacity** for PV in the Dutch LV/MV grid.

SET UP

- **177** small residential Rooftop PV-systems (< 5 kWp) in and around the city of Utrecht (The Netherlands) covering approx. **1600 km²**.

- High resolution Energy and Power measurements with Wi-Fi link (AC side).

- Power Output measurements of **0,7 W** and **2 sec** resolution; 5 sec. interpolation used for **GHI** reconstruction.

METHOD

- Relative **shift** (δt) of GHI(t) (or ΔGHI(t)) time series of two PV-system locations.

- Calculation of overlap Y(δt) of time series within a fixed **observation window** (e.g. 15 min.).

- Minimization of **overlap** gives **time lag** τ of passing cloud for these two locations.
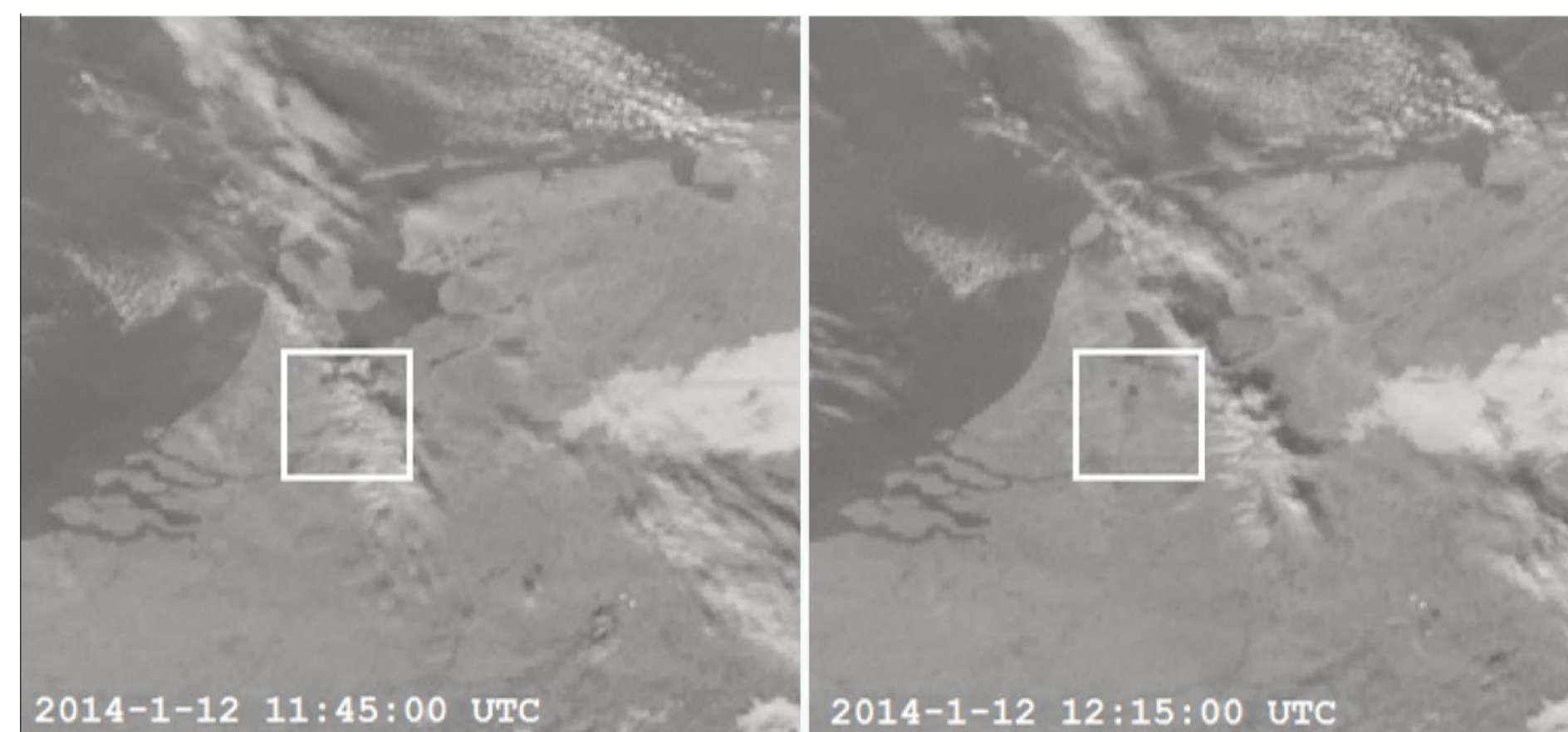
FORECASTING ALGORITHM

- Data from **several** peripheral PV-system locations j combined, are shifted by their respective time lag to **forecast** the GHI and thus Power at a location i.
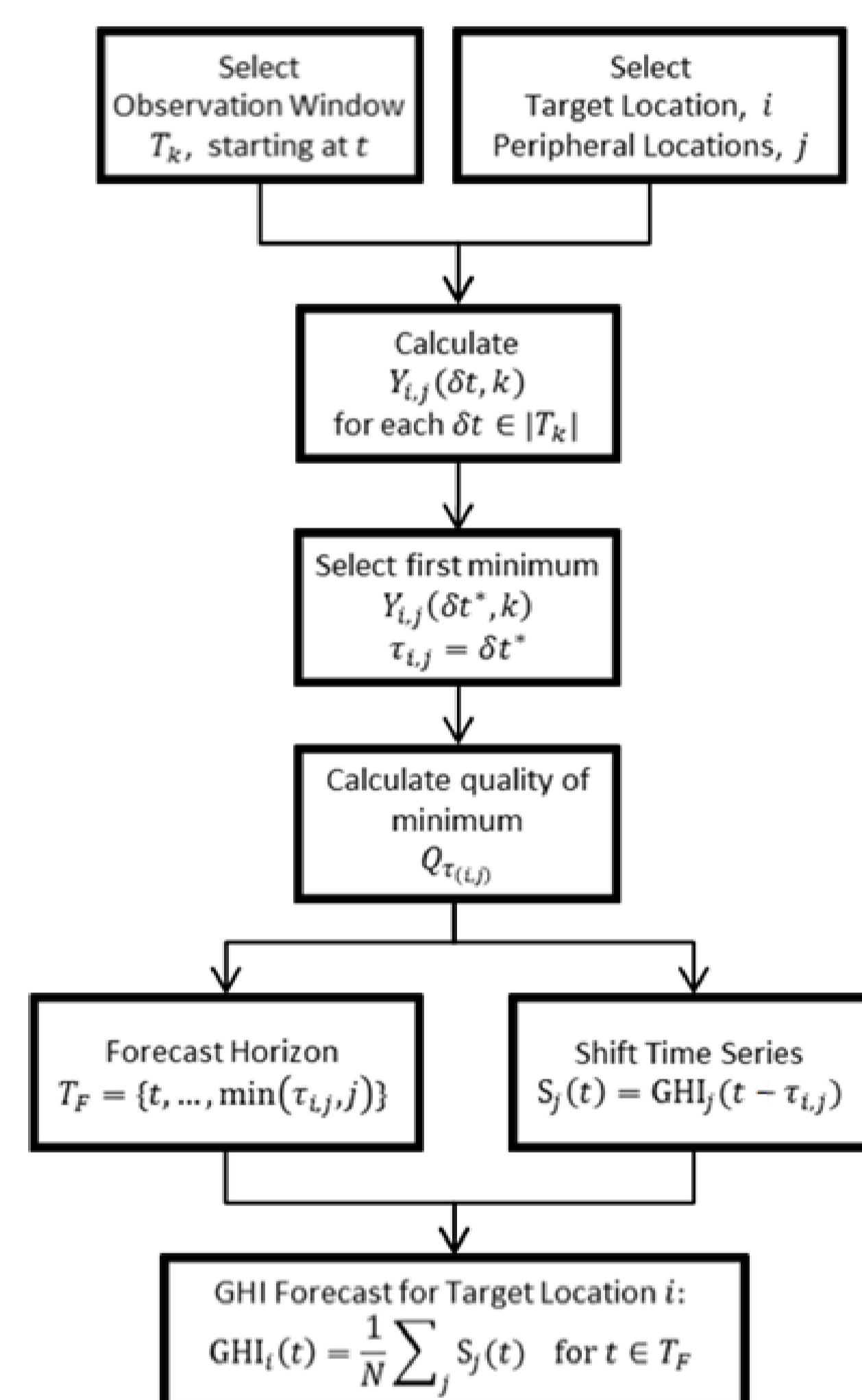
RESULTS

- GHI(t) time series of four peripheral PV-system locations (red, dashed) shifted by their respective time lag combined, produce the forecast (solid **thick** line) for the target location (solid blue line). This forecast can be compared with the actual development of the GHI(t) of the target location. Two examples are presented below:

Ex#1: Forecast based on 4 **peripheral** locations

Ex#2: Forecast based on 4 **peripheral** locations
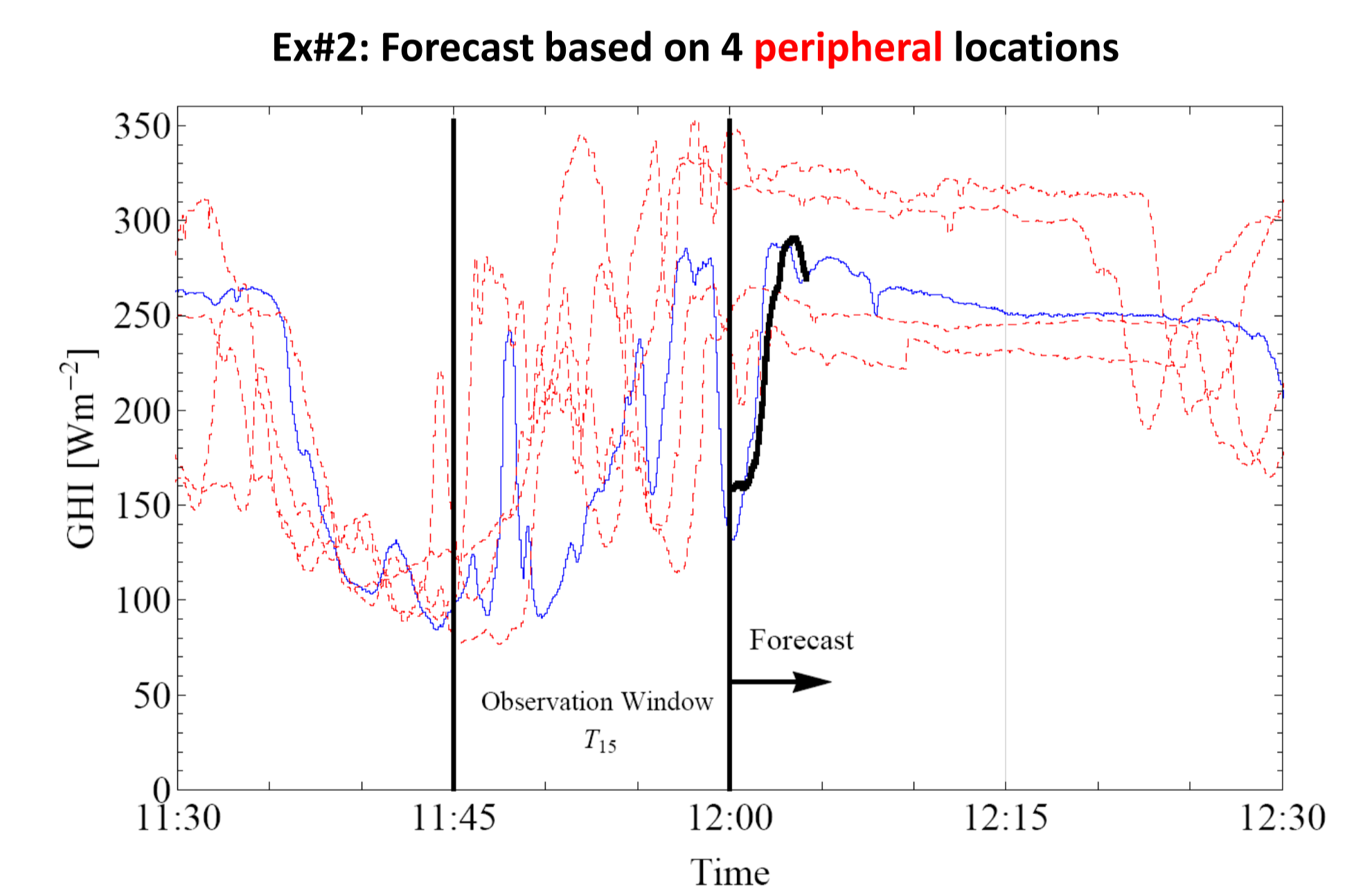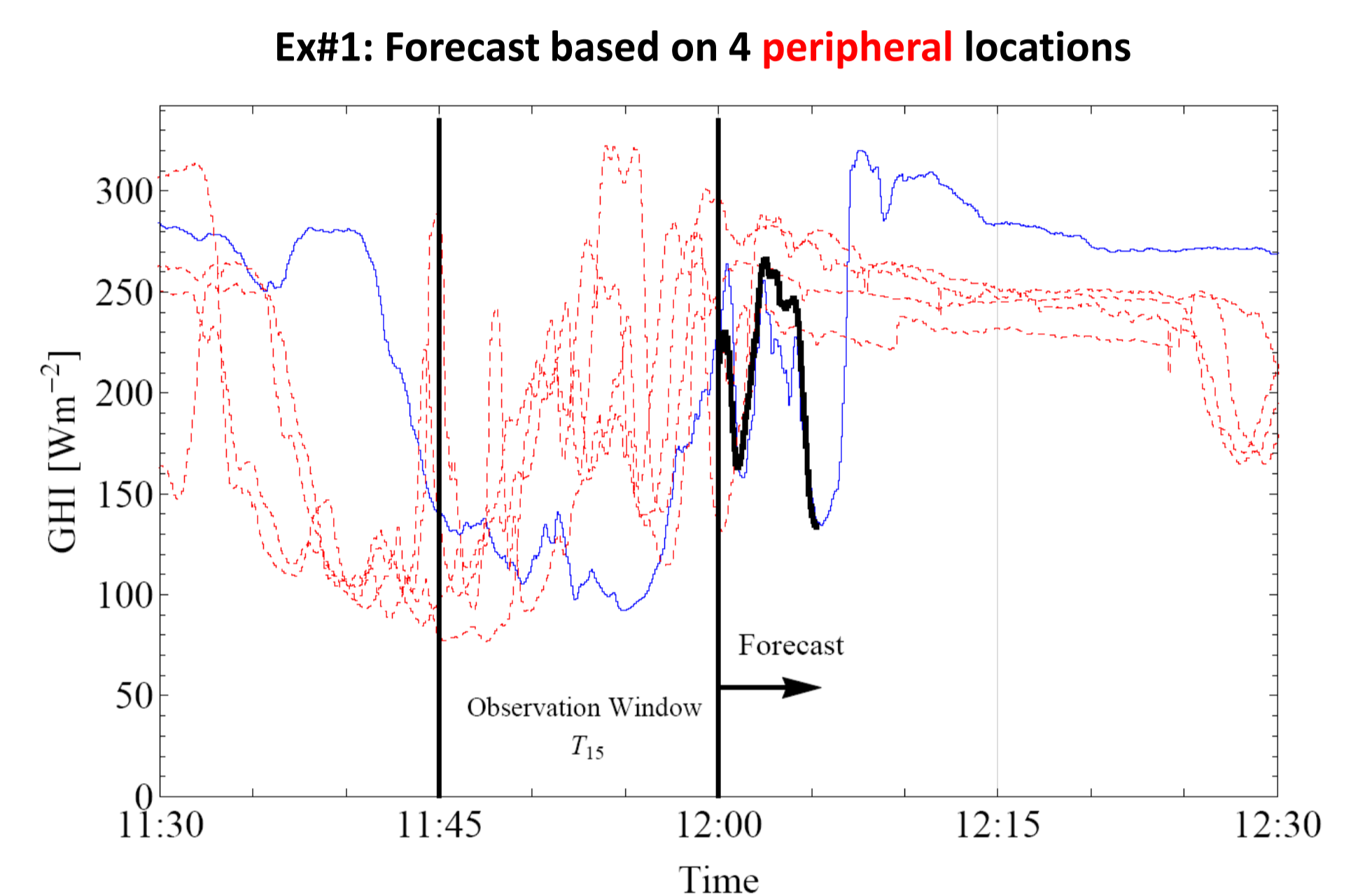
FURTHER RESEARCH

- Numerical **validation** of the forecast

- Optimize selection of peripheral locations

- **Updating** forecast every minute (moving observation window) and using e.g. Kalman Filtering.

- Determination of time lag itself not very sensitive to relative normalization, but forecast of GHI(t) requires reliable meta data of PV systems.

SUMMARY / CONCLUSION

- Reliable determination of time lag

- No external meteorological data needed.

- Straight forward forecasting method: no "Black box" methods as e.g. Artificial Neural Networks.

Figure shows GHI(t) time series (a) and shifted overlap function (b). Similarly ΔGHI(t) time series (c) and corresponding overlap function (d). The two locations of interest are separated approximately 3.2 km and both methods produce the same time lag of 2:20 min. Noteworthy, the ΔGHI(t) method (c and d) produces a much more distinctive minimum.

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