Faculty of Geosciences
IMEW - Energy & Resources

Universiteit Utrecht

Short-term Horizontal Irradiance forecasting with PV network

Boudewijn Elsinga[1]*, Ruut Brandsma[2], Lou A.M. Ramaekers[2],
Bas Vet[3], Santiago Peñate Vera[3], Paul H. Raats[3], Wilfried G.J.H.M van Sark[1]

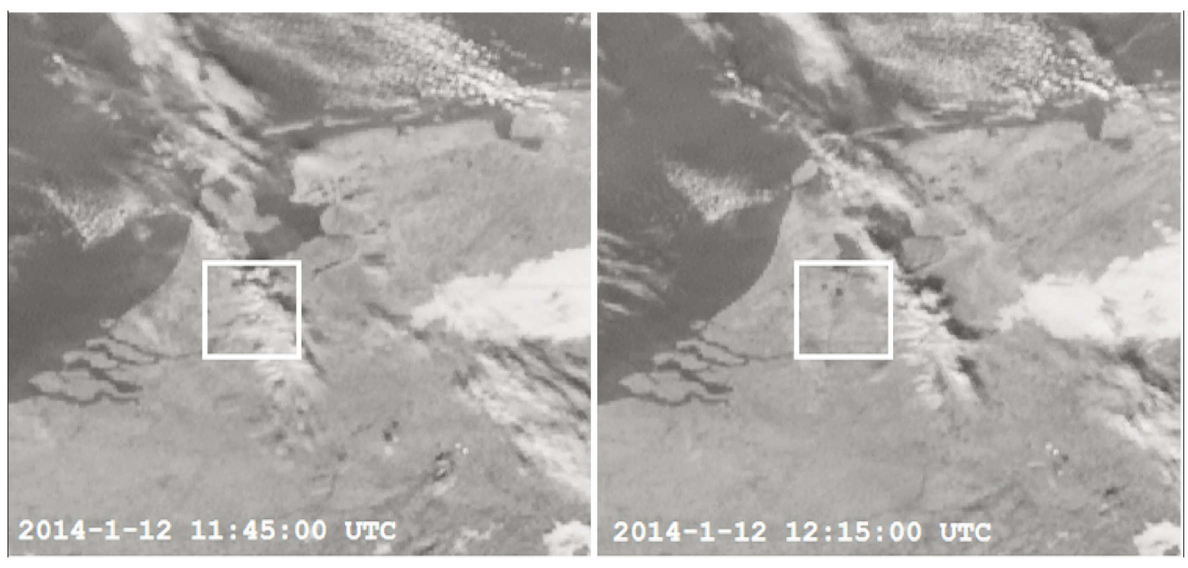
[1]Copernicus Institute of Sustainable Development – www.uu.nl/geo/copernicus
[2]Ecofys – www.ecofys.com
[3]DNV GL - Energy – www.dnvgl.com/energy
Solar Forecasting & Smart Grids - www.solarforecasting.nl

Objective

- *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**.
- Forecast horizon **0 ~ 15 min**. at resolution of input data: **15 sec.**

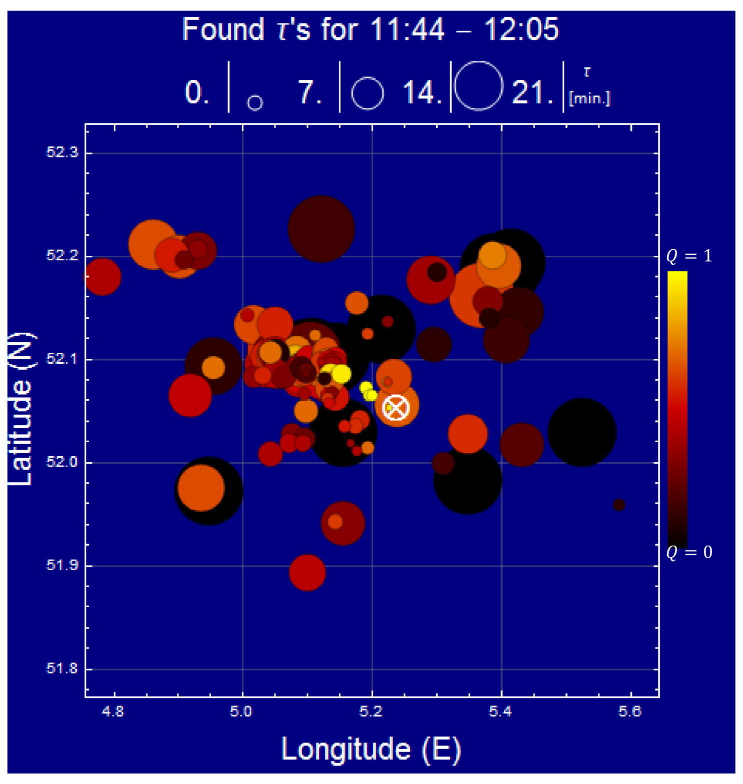
Set up

- **169** Rooftop PV-systems (< 5 kW_p) covering approx. **1600 km²**.
- AC Power Output measurements of **0.7 W** and **2 sec** resolution; 15 sec. interpolation used for **GHI** reconstruction (inverse PV-model).

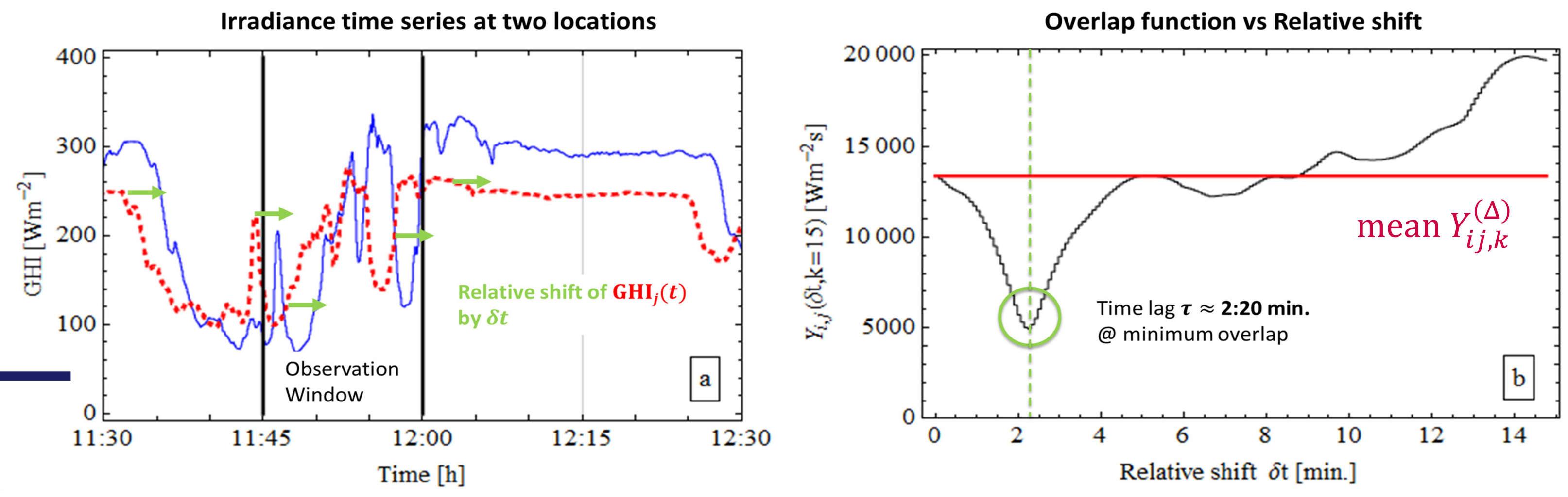


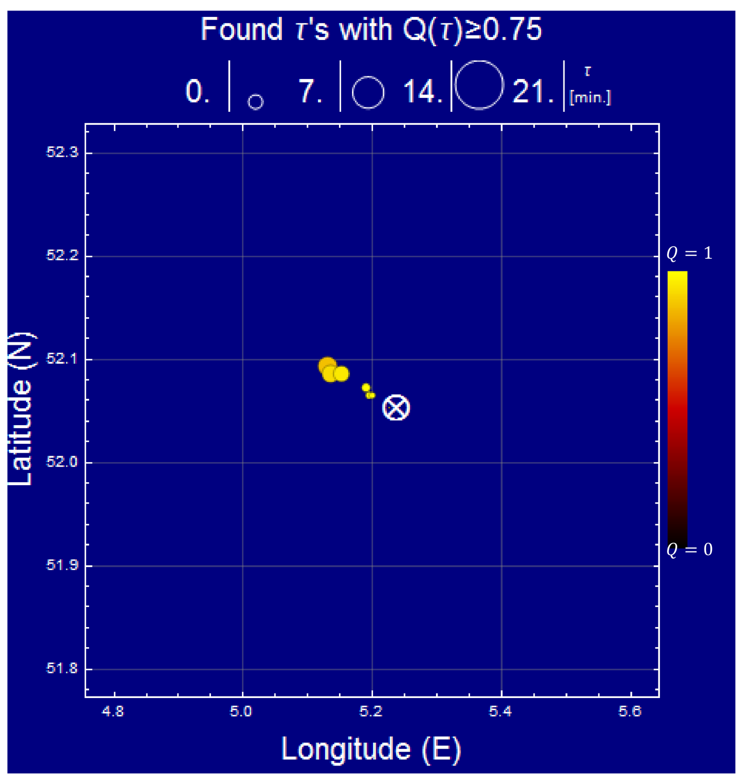
Selection

- Example data from a distinct cloud system moving over Utrecht on **12-01-2014**.
- For a target location, the **time lag** is determined with respect to **all** the other locations.
- Selection of τ's with high **quality factor**, e.g. $Q \geq 0.75$
- 3D plot *staircase graph* shows **wind direction.** Wind speed can be deduced from this as well.

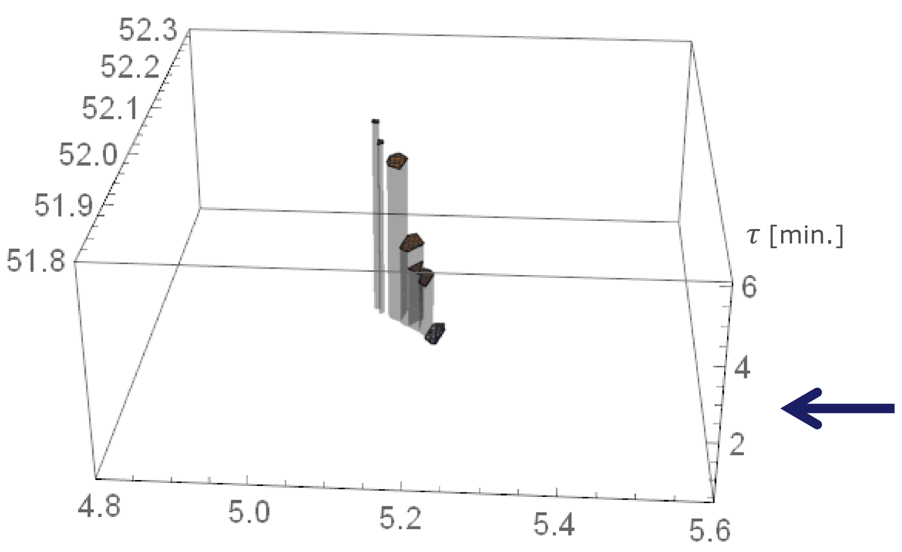


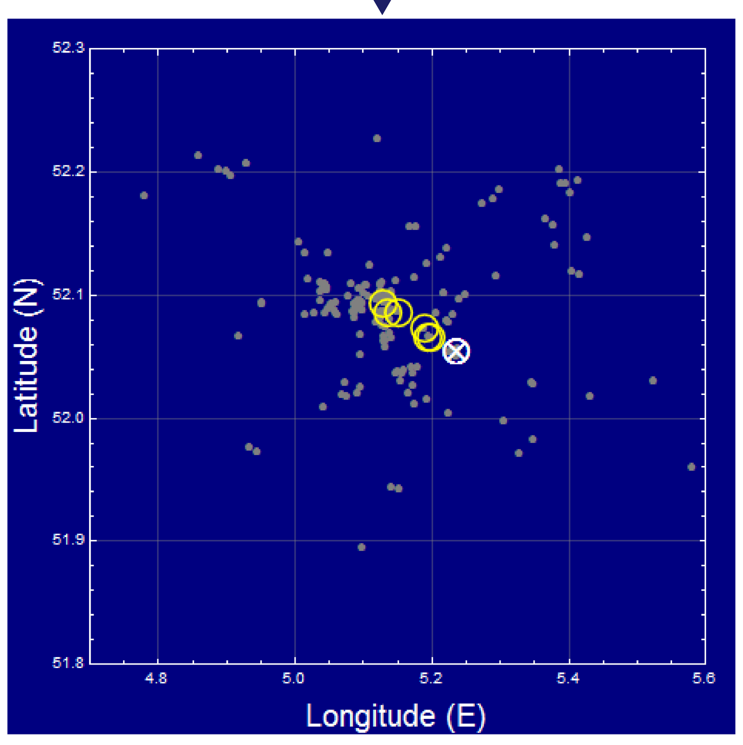
Size of the disk indicates the time lag of that location with respect to the target location (yellow cross). The color indicates the quality. GHI time series method was used here.





Only locations with a sufficient quality factor are used. In the final selection round, systems too close (e.g. 900 m) to the target location are dismissed.





Time series for the found locations are used for the forecast of the target location (yellow)

Method

Determination of Time Lag τ

The **minimum** of the absolute overlap between two GHI or ΔGHI time series, dependent on relative temporal shift δt in observation window T_k, see [1]:

$$Y_{ij}^{(\Delta)}(\delta t, k) \propto \sum_{t \in T_k} \left| (\Delta)\mathrm{GHI}_i(t) - (\Delta)\mathrm{GHI}_j(t - \delta t) \right|$$

$$\boldsymbol{\tau_{ij,k}^{(\Delta)} = \min\left(Y_{ij}^{(\Delta)}(\delta t, k), \delta t\right)}$$

Robustness

Similarity of time series of locations i and j does not need to be perfect: this method allows for changing cloud structure or velocity, albeit modestly. The minimum of the overlap determines the time lag. Other characterization functions Y_{ij} may be used, e.g. covariance [2].

Quality factor

A found **time lag** τ has a quality factor $0 \leq Q \leq 1$, determined by the **relative depth** of the found minimum:

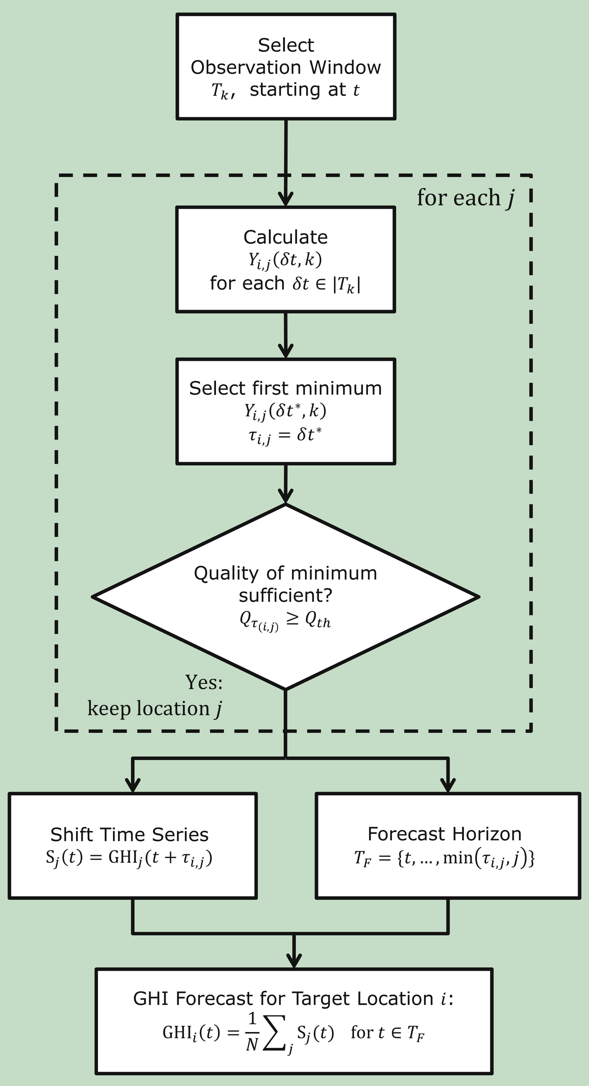
$$Q_{(ij,k)}^{(\Delta)} = \left| \frac{\min Y_{ij,k}^{(\Delta)}}{\text{mean } Y_{ij,k}^{(\Delta)}} - 1 \right|$$

Forecasting

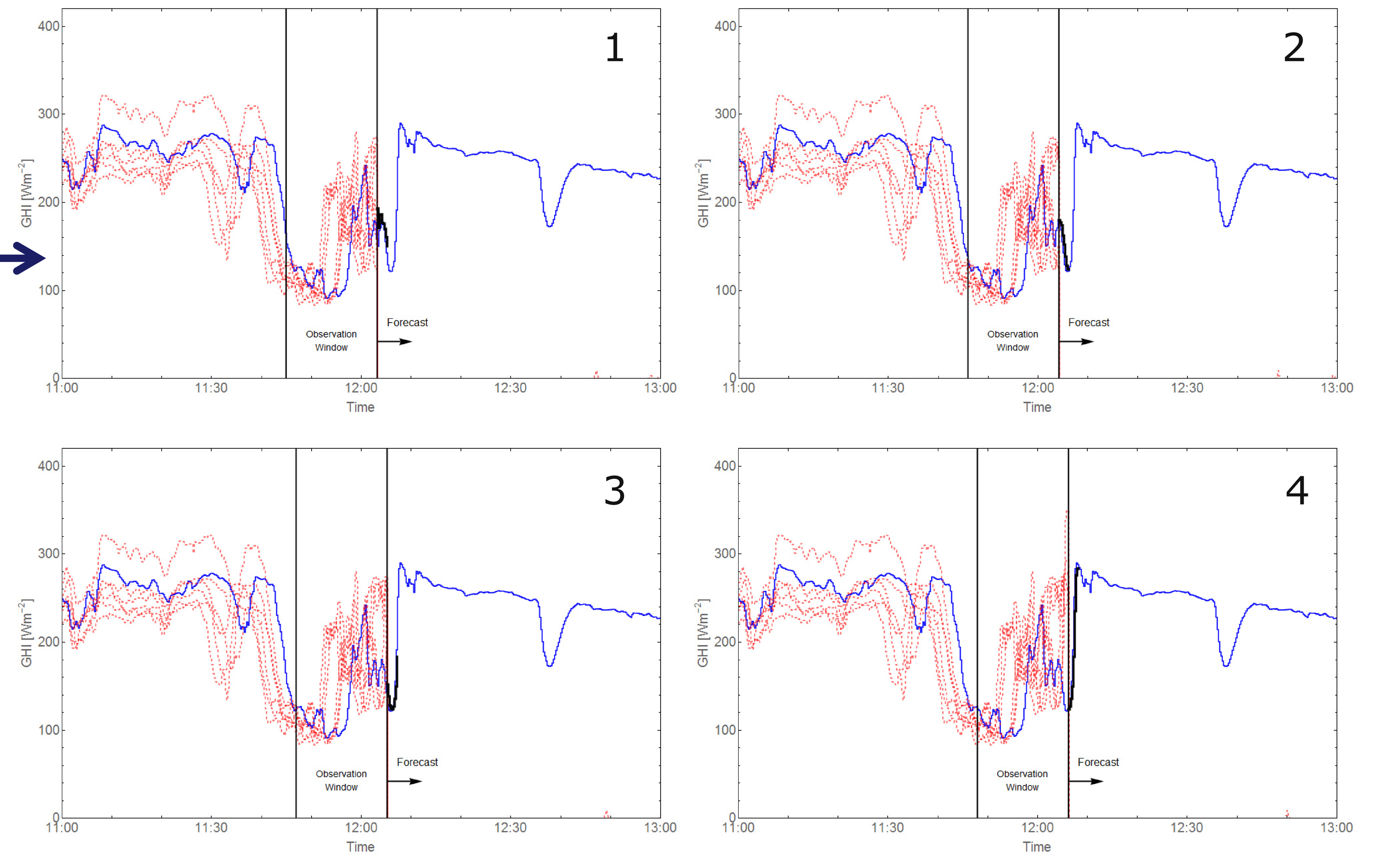
(Δ)GHI time series of peripheral locations with sufficient high quality factors (Q) are then **shifted** by their respective time lag (τ) with respect to the target location. The sum of the shifted time series is then the **forecast** for the target location, assuming constant cloud speed and direction.

This method can also be applied to spatially **interpolated** data to forecast for PV-systems that are not monitored.

Forecasting Algorithm



Four successive **forecasts** shown. GHI time series of target location is shown in the future for reference.



References

[1] B. Elsinga, W.G.J.H.M. van Sark, *Inter-system time lag due to clouds in an urban PV ensemble*, Conference proceedings of the 40th IEEE PVSEC, Denver (CO) USA June 2014.

[2] B. Elsinga, W.G.J.H.M. van Sark, *Spatial power fluctuation correlations in urban rooftop photovoltaic systems*, Progress in Photovoltaics (Accepted: June 2014), DOI: 10.1002/pip.2539

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*Corresponding Author: b.elsinga@uu.nl

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