High resolution solar irradiance forecasting using All Sky Imagers and machine learning

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IEA - Methods for Minute Scale Forecasting and their Uncertainty
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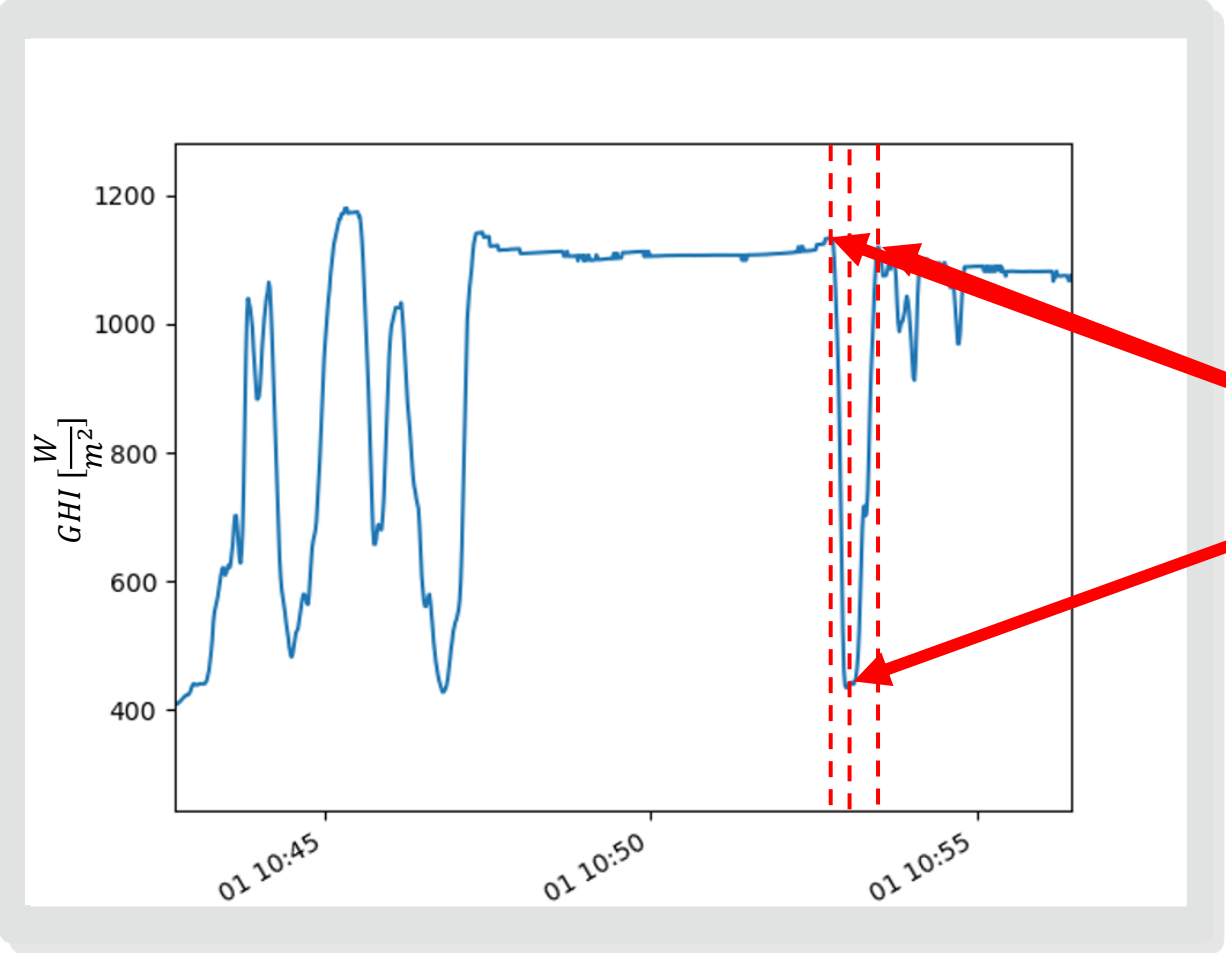
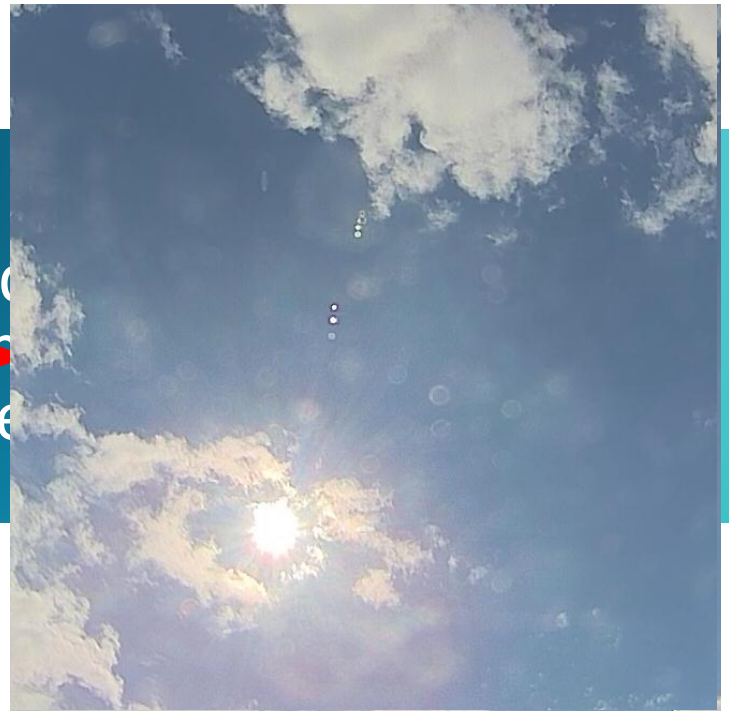
www.ise.fraunhofer.de

Motivation

Short-term irradiance forecasting





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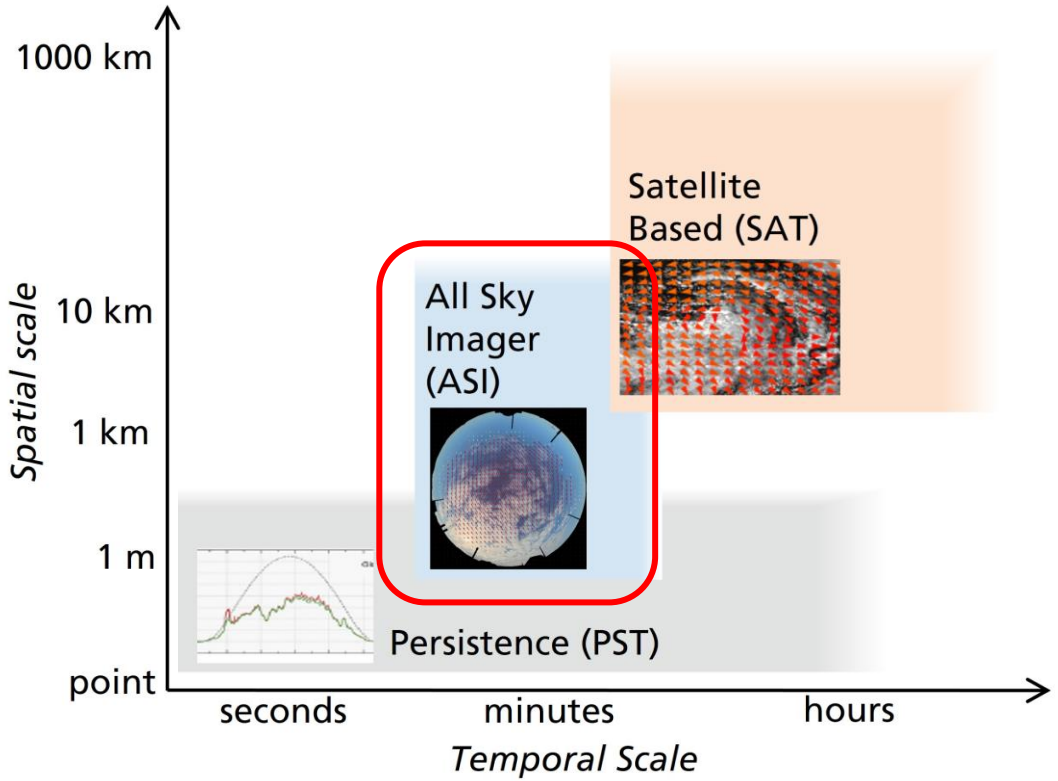
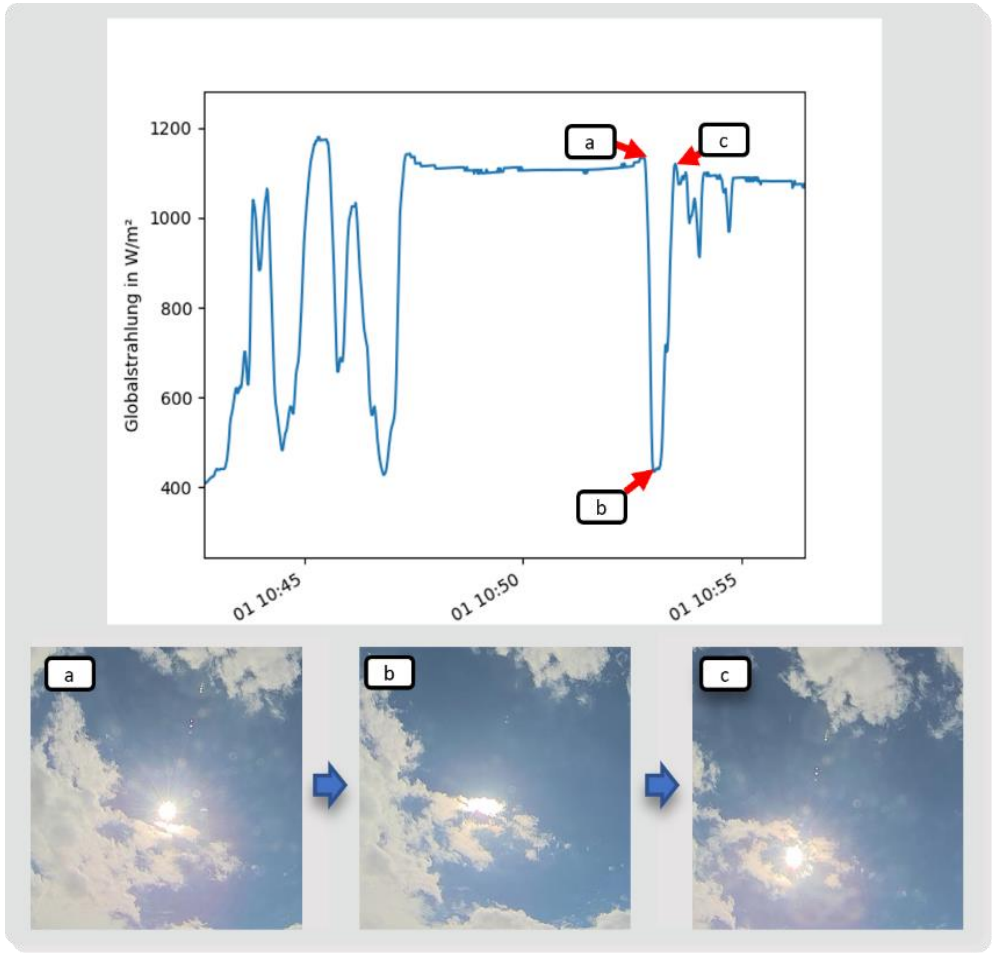
Aim and approach

Minute resolution irradiance nowcasting

Irradiance nowcasts from different sources





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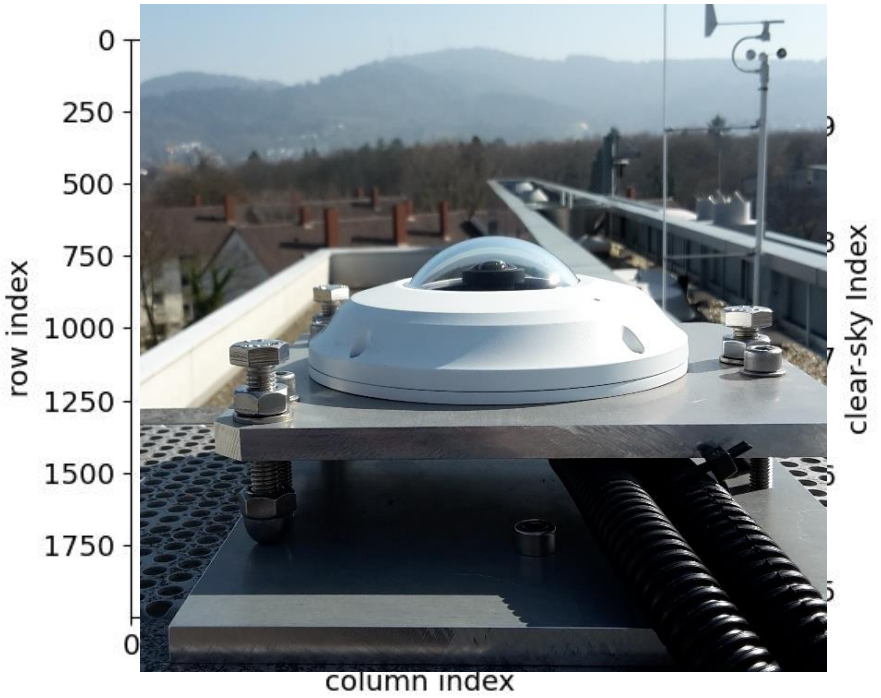
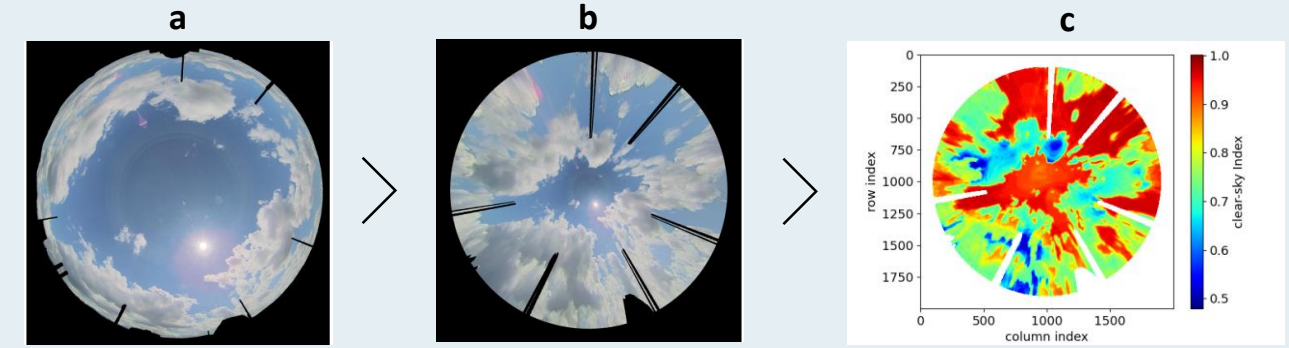
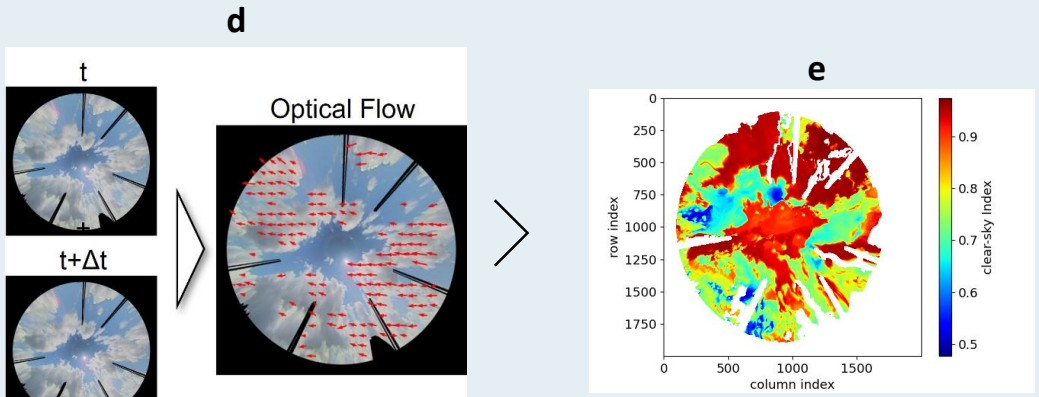
Methodology

ASI Overview

e) Apply optical flow







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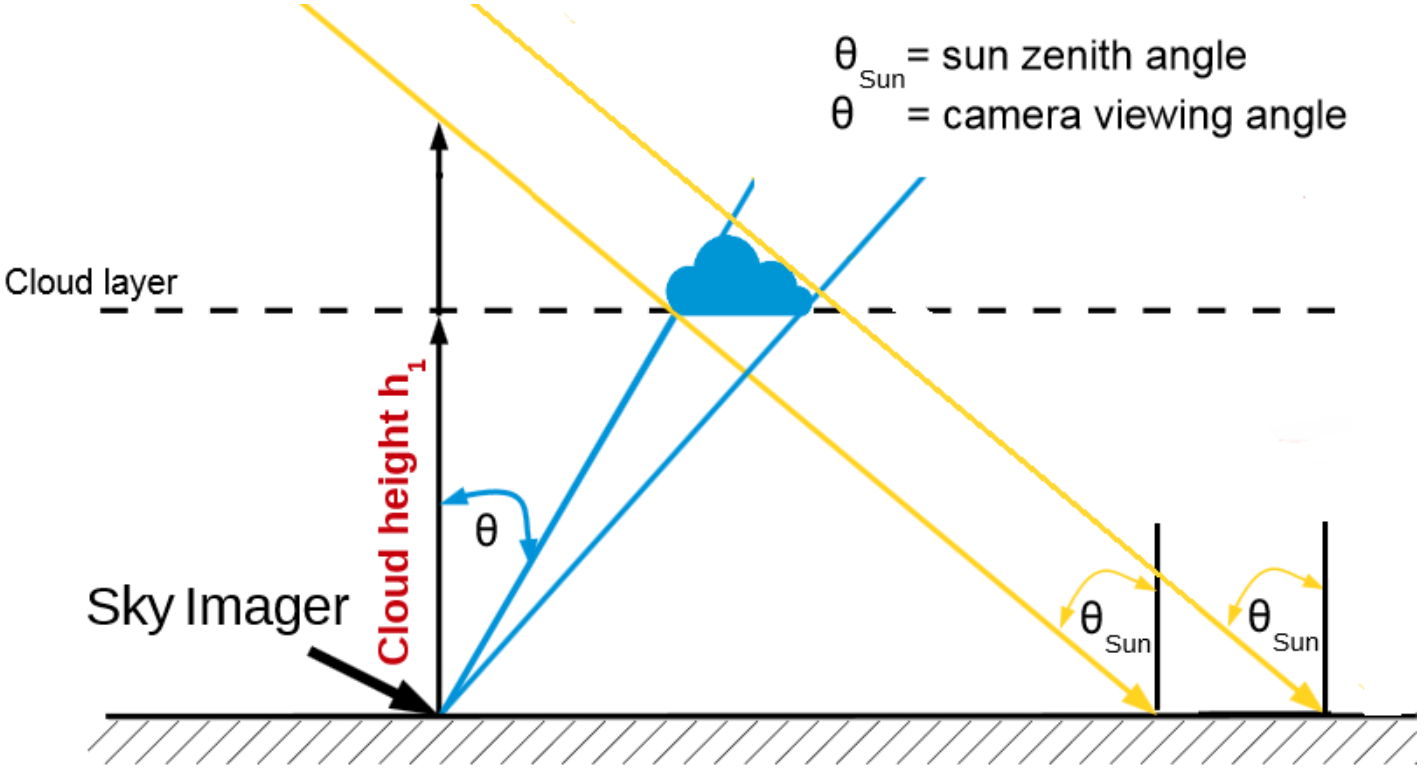
Methodology
Step C & F

Cloud Projection

- Cloud height
  - Nearby Ceilometer
- Camera Projection parameters
  - Pair of incidence Angles for each pixel
- Geolocate Clouds
- Project to real-world position
  - Sun position



Source: T. Schmidt “High resolution solar irradiance forecasts based on skyimages.”, 2017, edited

Methodology

Step C

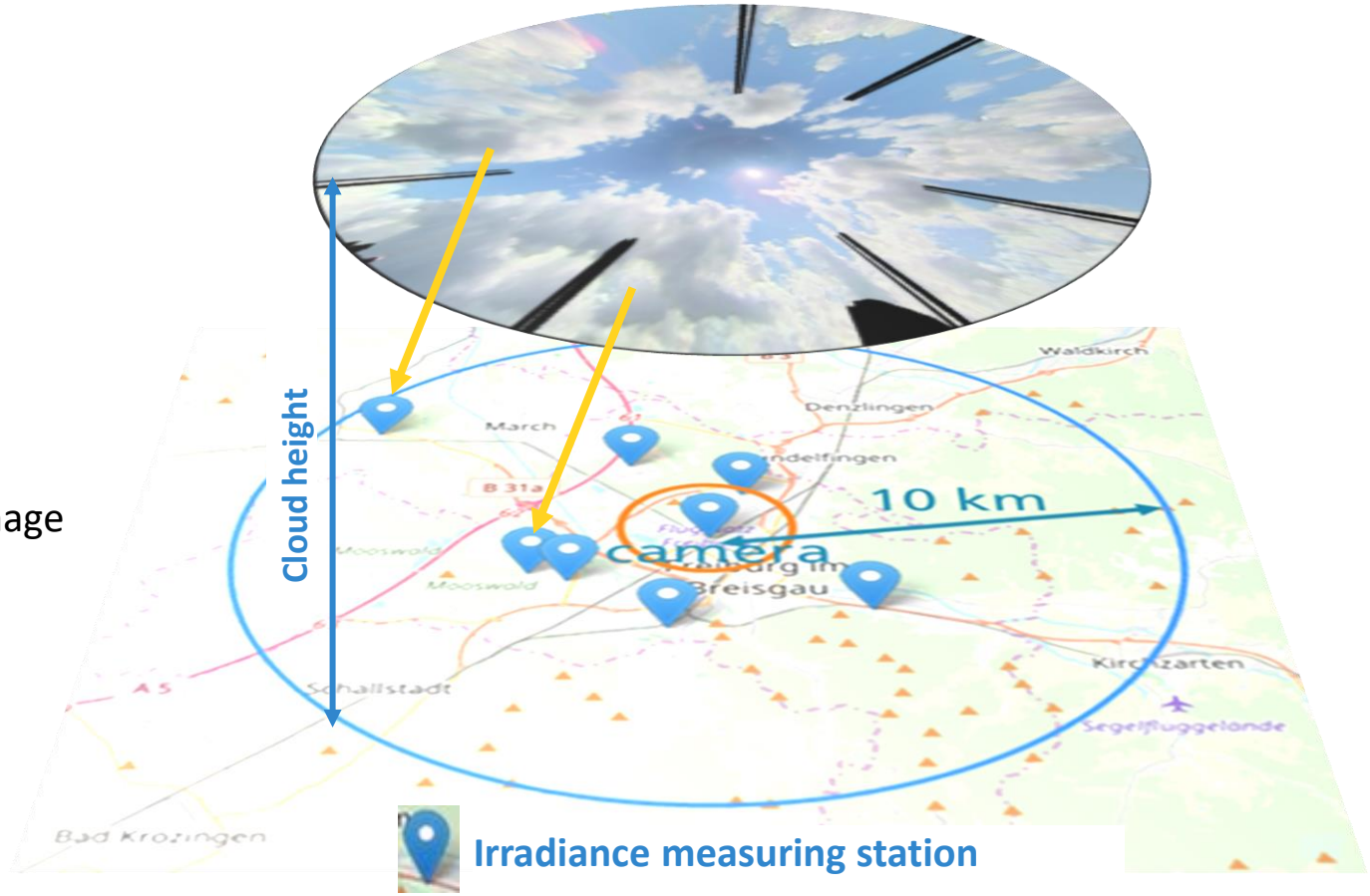
Irradiance retrieval

- Geolocate clouds in image
- Map Pixel values to irradiance measuring stations
  - Network of irradiance measuring stations

Machine learning algorithm

- Gradient Boosting Regression
- Training
  - Learn relation between pixel values (and other image features) and irradiance level (clearsky index)

- Application
  - Convert skyimage into clearsky index map



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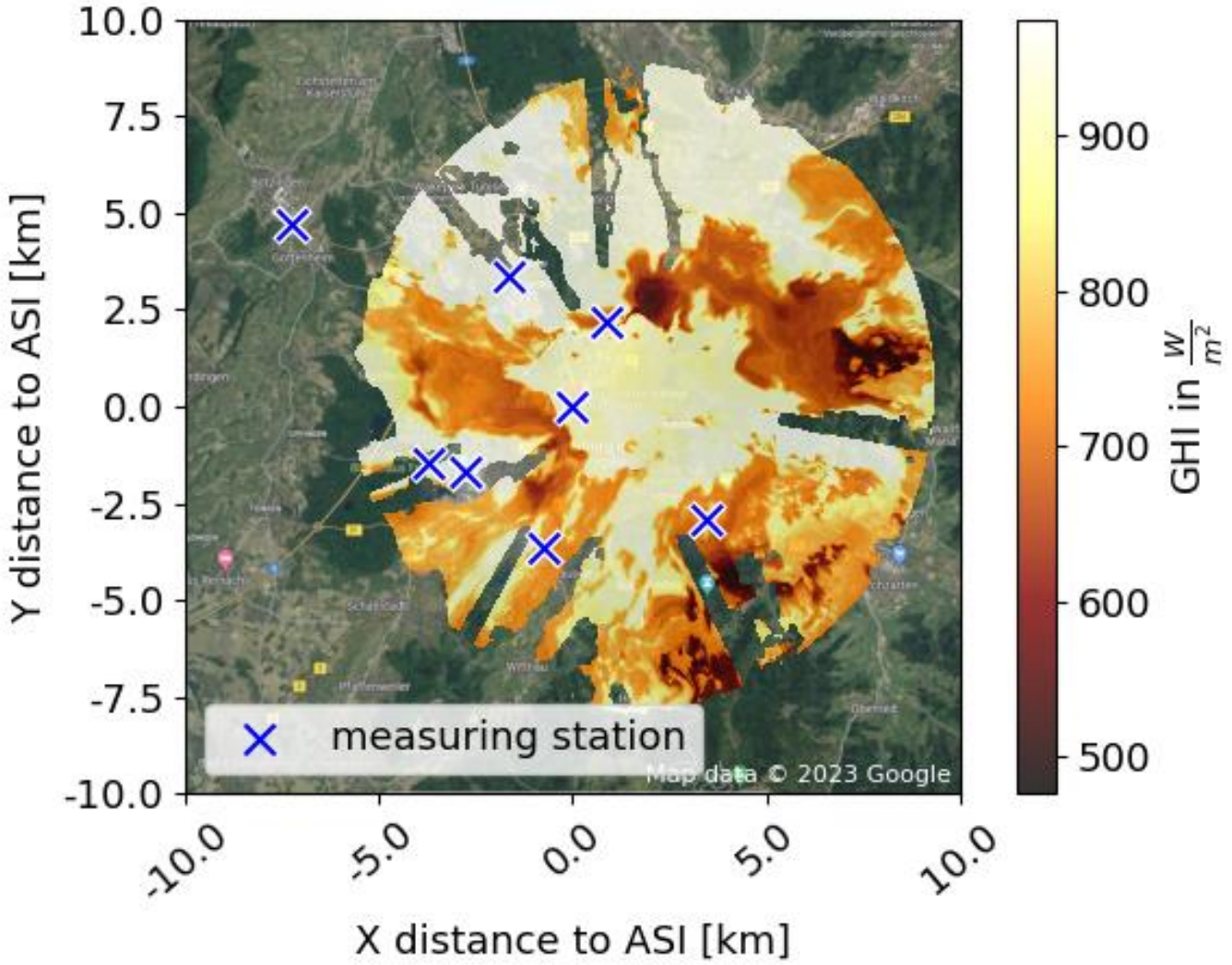
Methodology

Step F

Projection of irradiance levels

- Convert Image into clear-sky index map
- Apply optical flow
- Apply cloud projection to each pixel
- Areal irradiance forecast



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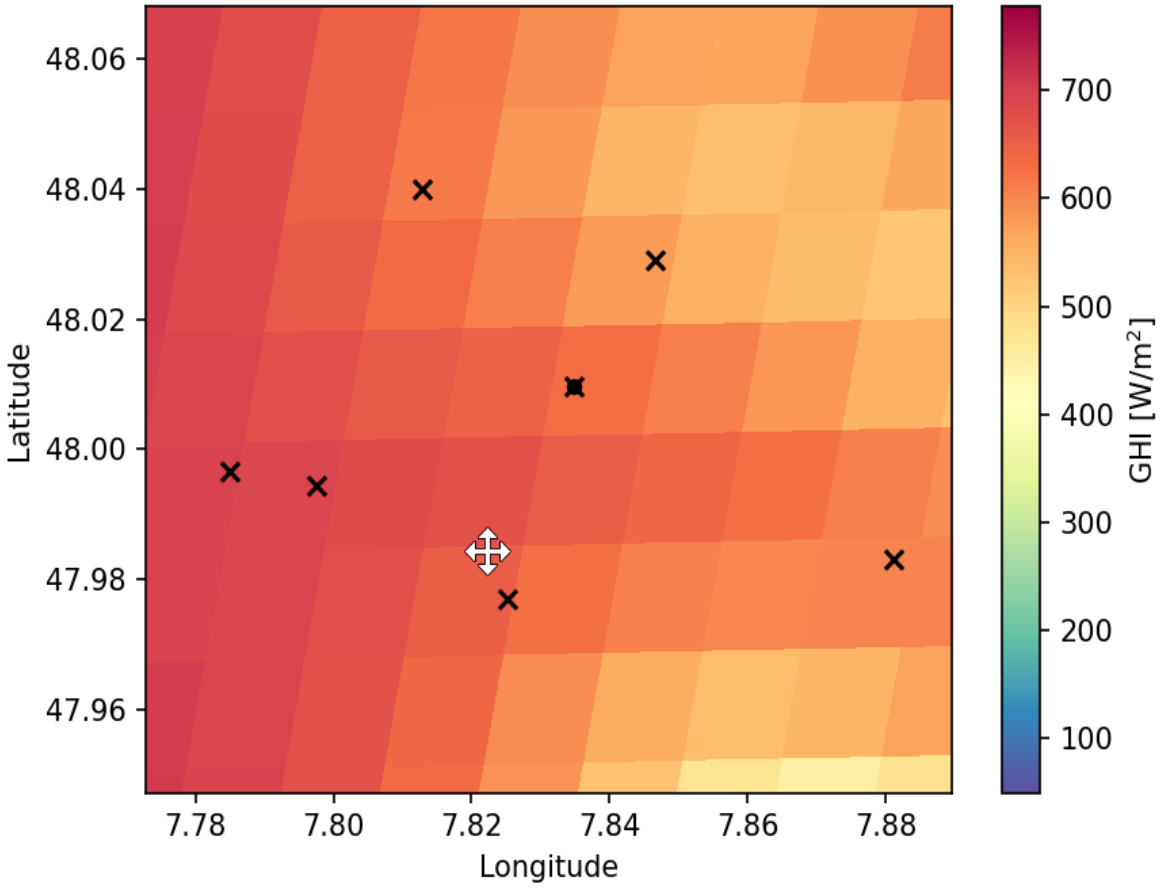
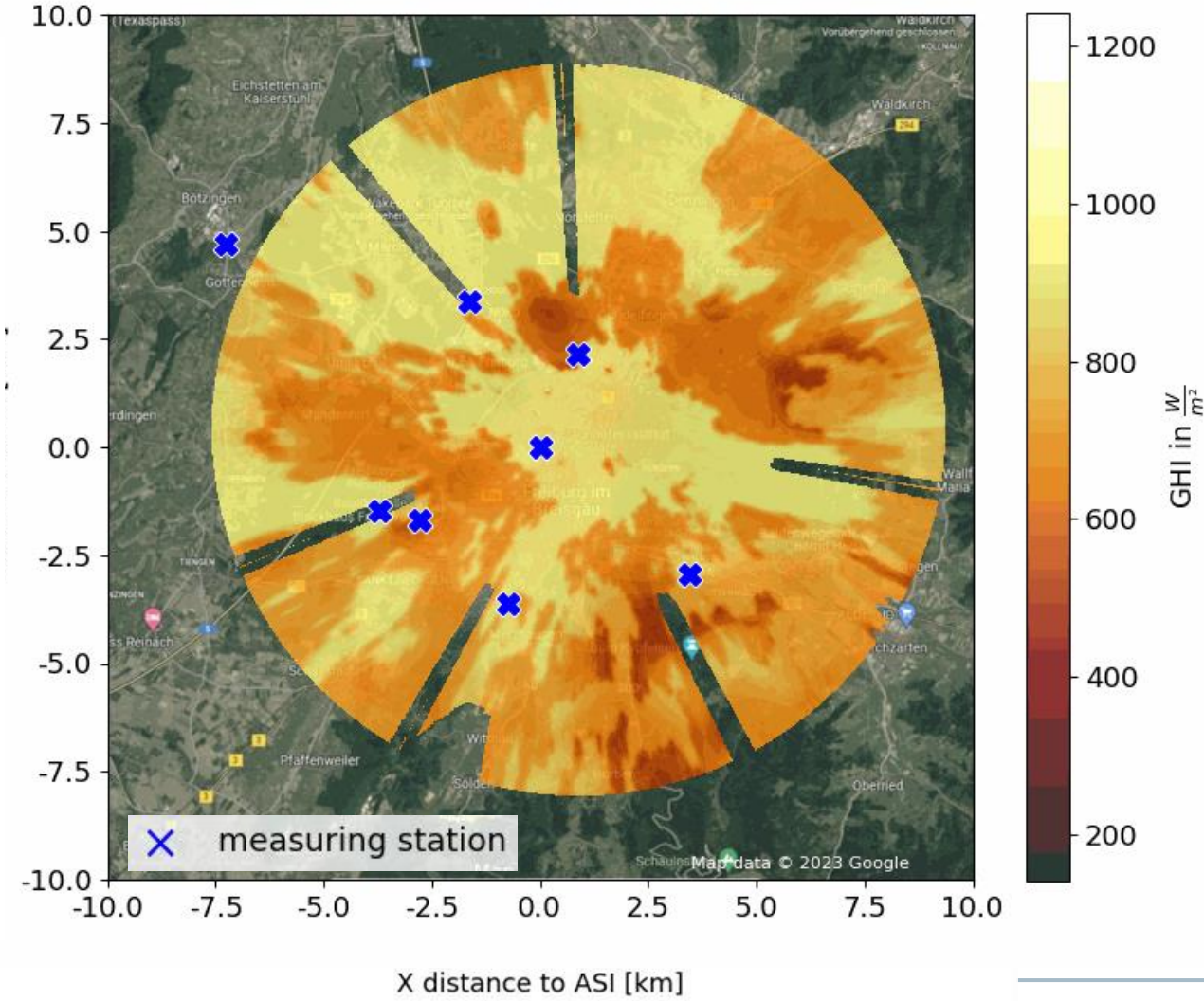
Forecast visualization

ASI and Satellite – 15 Minutes ahead

Satellite based forecast – same area





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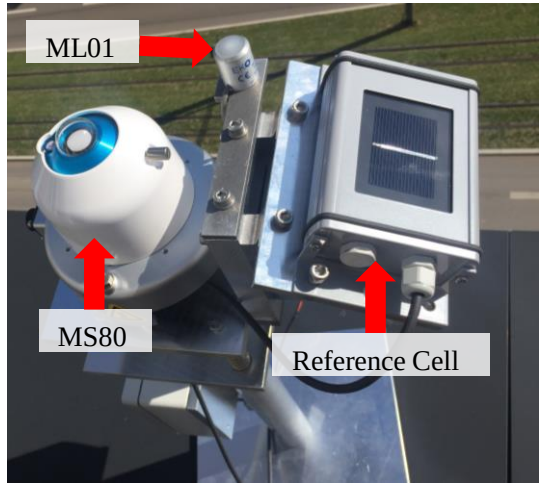
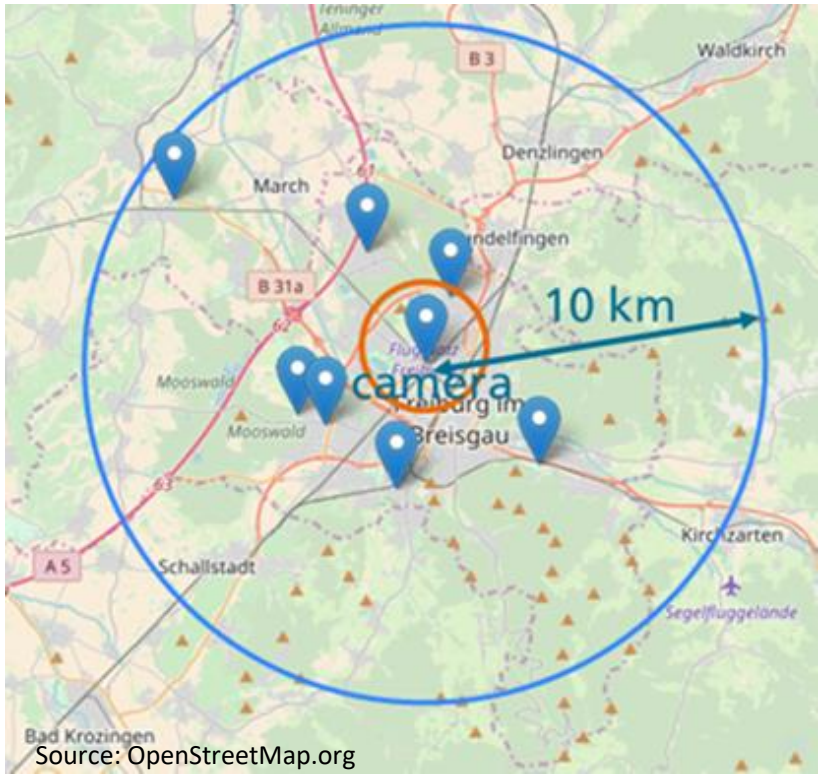
Evaluation

Benchmark ASI against Satellite and Persistence forecasts

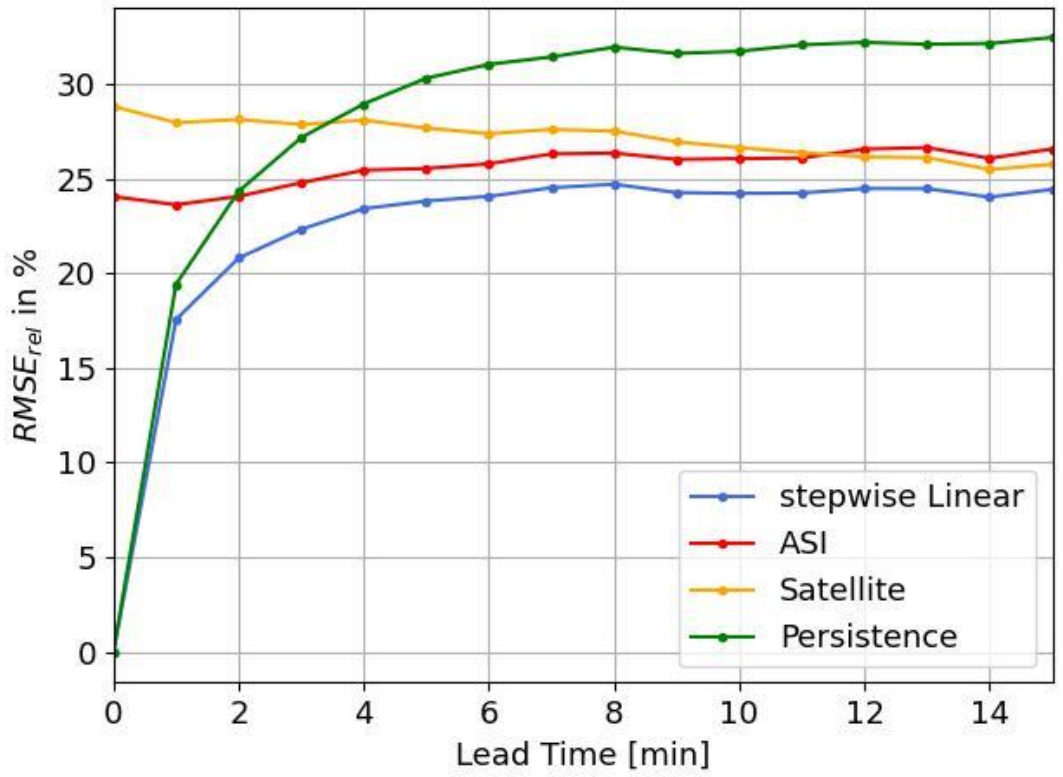
- GHI measurements from measuring network
  - Period: May 2021 – April 2022
    - 8 stations, $r \approx 10\ km$
- Train test split
  - Evaluation on independent dataset
- Specifications
  - 15 Minutes ahead
  - 1 Minute resolution
    - Interpolate Satellite forecasts



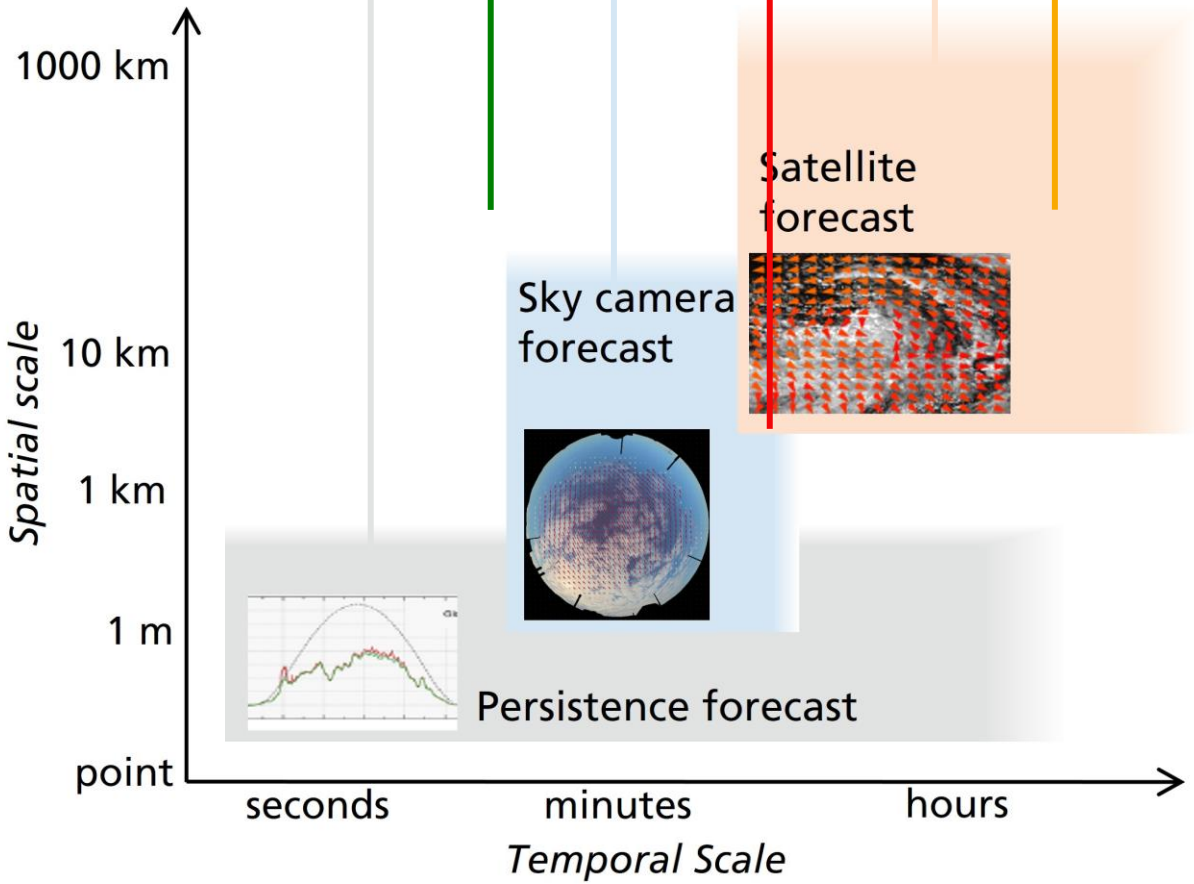


Results

Individual nowcasts and linear blending



$$FC_{hybrid} = FC_{PST} \cdot c_1 + FC_{ASI} \cdot c_2 + FC_{SAT} \cdot c_3$$



Significant improvement over optimal individual method!

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Summary and conclusion

Novel All Sky Imager based method

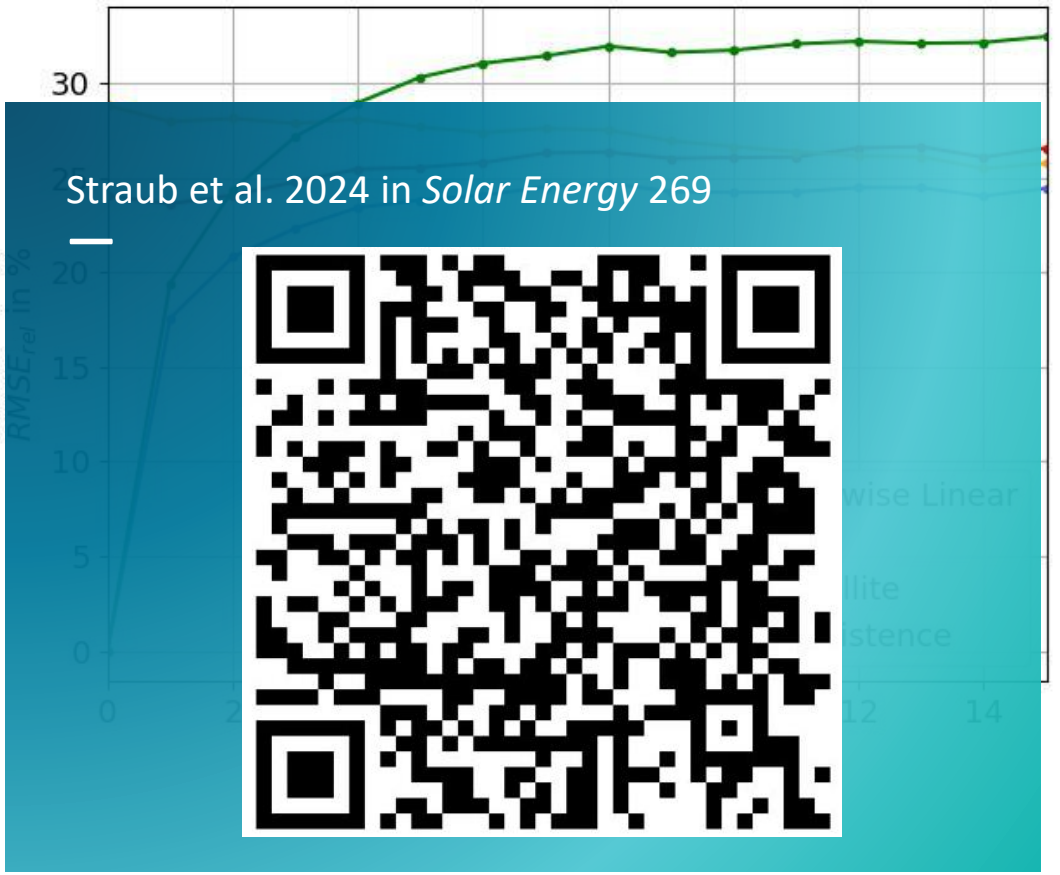
- Sub-minute resolution
- ML-based
- Trained on spatially distributed measurements

Comparison of three individual methods

- ASI, Satellite and Persistence
- Different optimal method within different LT intervals

Linear blending

- RMSE Improvement over optimal individual method for all LT
- $S_{RMSE} \approx 5 - 13\%$



Thanks for your attention!

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