COMPARISON OF SHORT-TERM SOLAR IRRADIANCE FORECASTS FROM ALL SKY IMAGERS AND SATELLITE IMAGES

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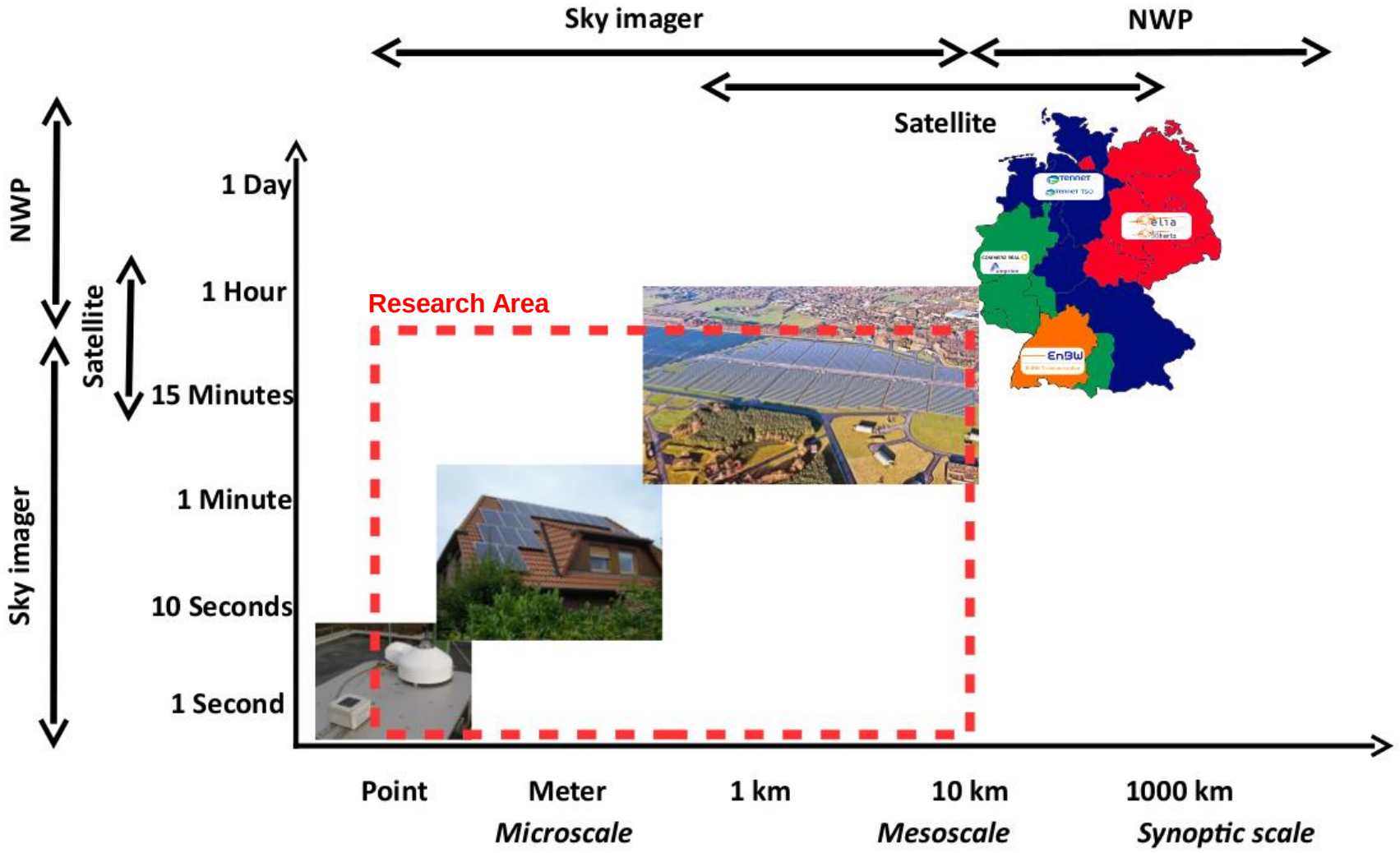
DLR

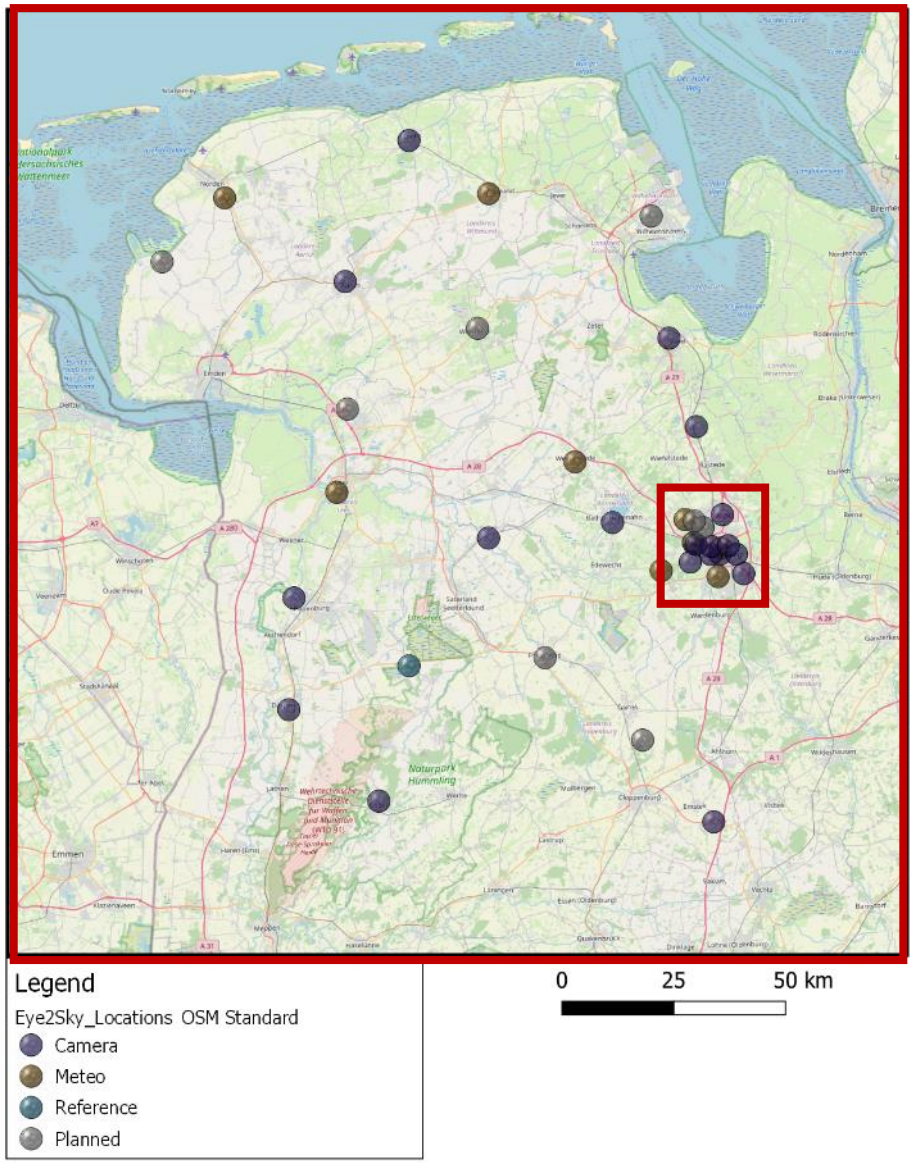
Solar irradiance forecasts

Towards increasing spatial and temporal resolution



Cloud camera and meteorological network

- 30 All-Sky Imager (ASI) installed in north-west Germany
  - With 12 stations equipped with meteorological equipment
- covering ~110km x 100km area in north-western Germany
- Low density in rural area covering low voltage distribution grid
- High station density in city of Oldenburg



Instrumentation

Meteorological sensors

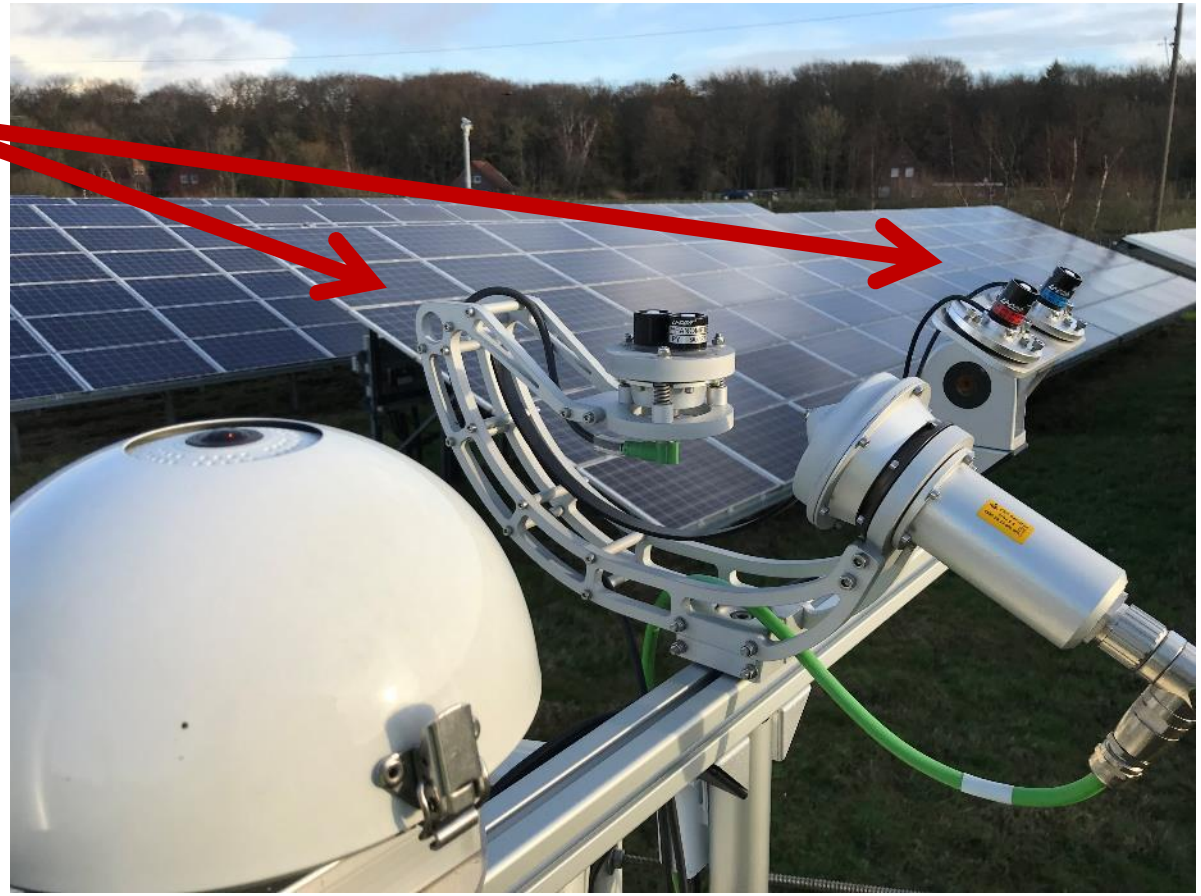
- Solar irradiance sensors (GHI, DHI, DNI, GTI)
- Air temperature and humidity

All-sky imagers

- Commercial surveillance camera used
- Fish eye lenses with 180° field of view
- Recording images every 30s

Ceilometers

- 6 atmospheric lidars (ceilometer) measuring cloud height



Photography of Eye2Sky station PVNOR

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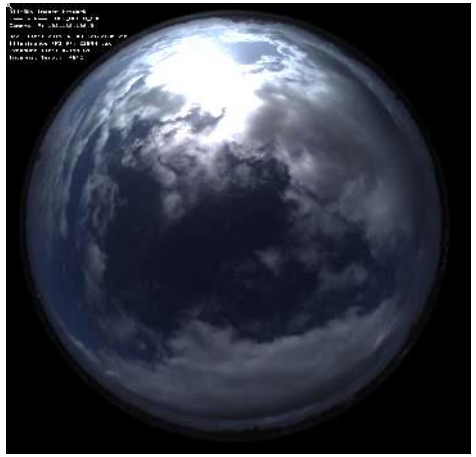
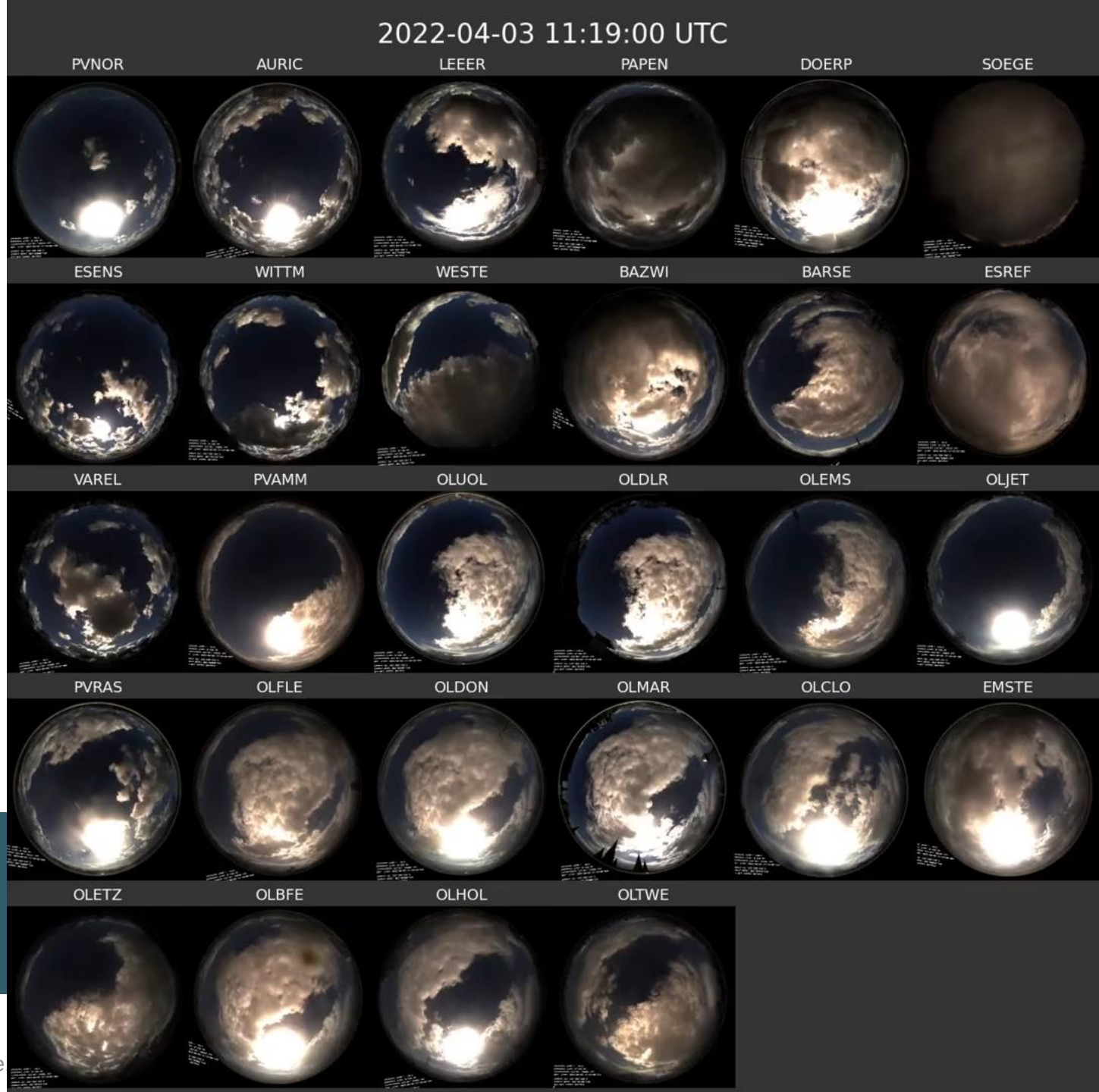
Photography of Eye2Sky station PVNOR

2 hours of weather seen by multiple fish eye cameras

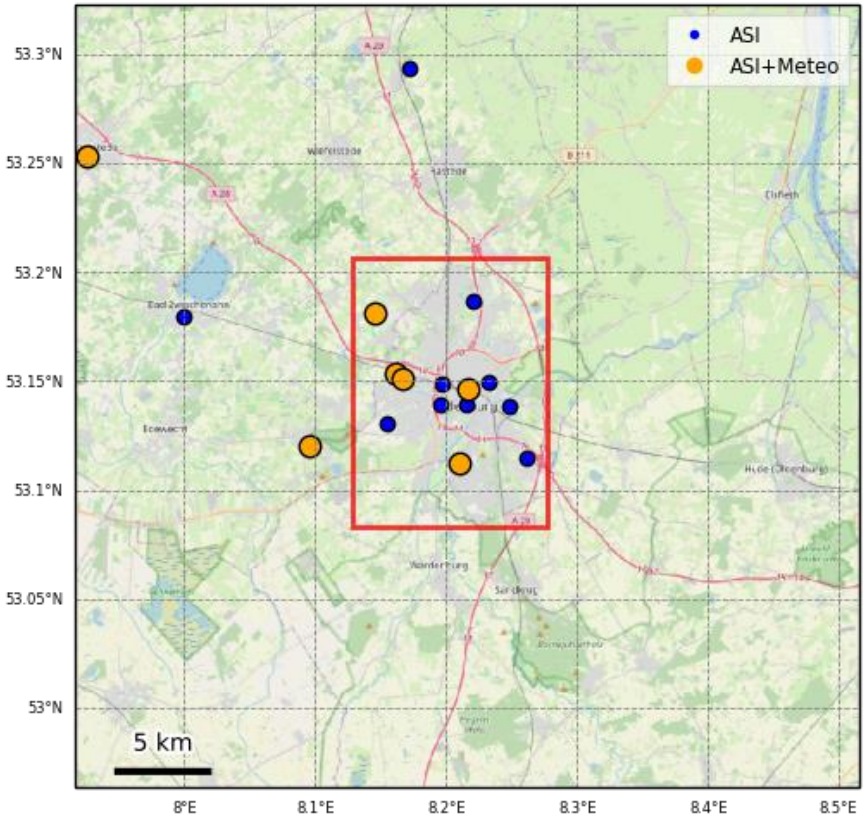


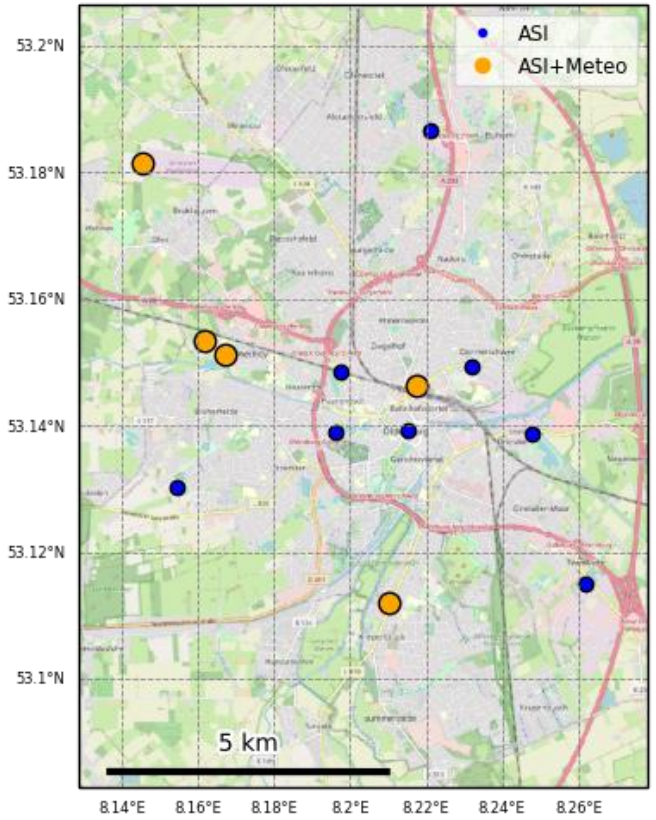


Why cameras?

Solar irradiance nowcast based on ASI-Network

- Nowcasts for 2022 on 40 x 40 km domain (left)
- 17 ASI used
- Evaluation for city of Oldenburg (10 x 12 km, right)
- Grid resolution: 50m

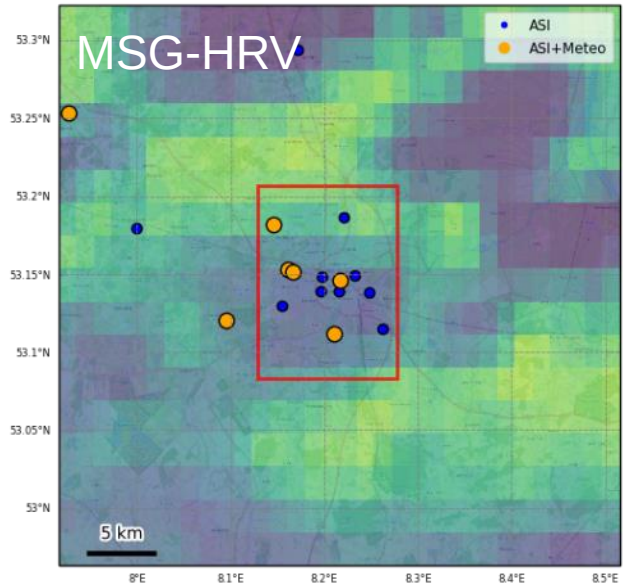


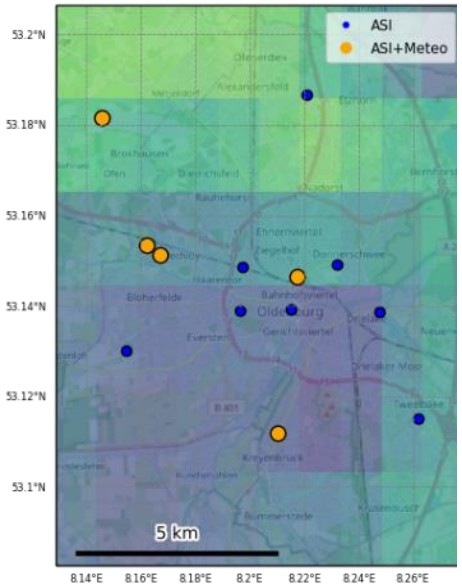


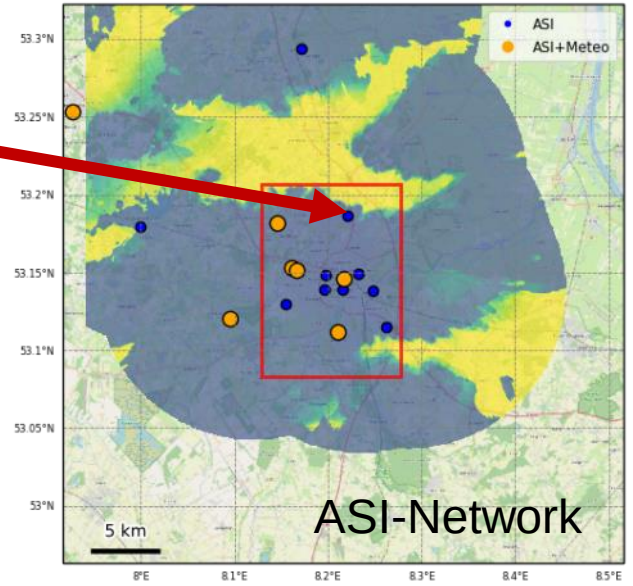
Nowcasting model for a network of ASI:

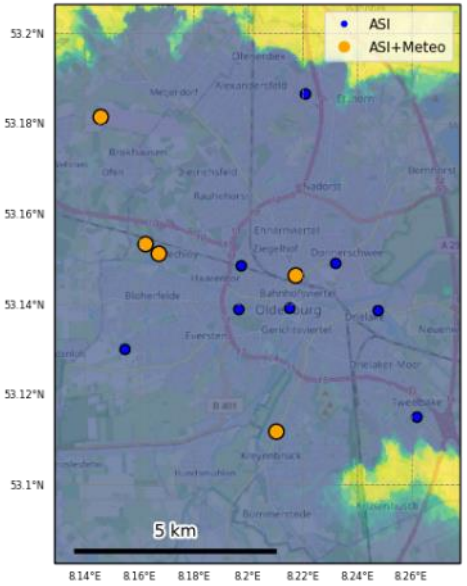
- Blum, Niklas (2022): *Nowcasting of Solar Irradiance and Photovoltaic Production Using a Network of All-Sky Imagers*. Dissertation, RWTH Aachen
- Blum, Niklas et al. (2022): *Analyzing Spatial Variations of Cloud Attenuation by a Network of All-Sky Imagers.* Remote Sensing, 14 (22), Seite 5685.

Domain comparison with satellite derived irradiance information





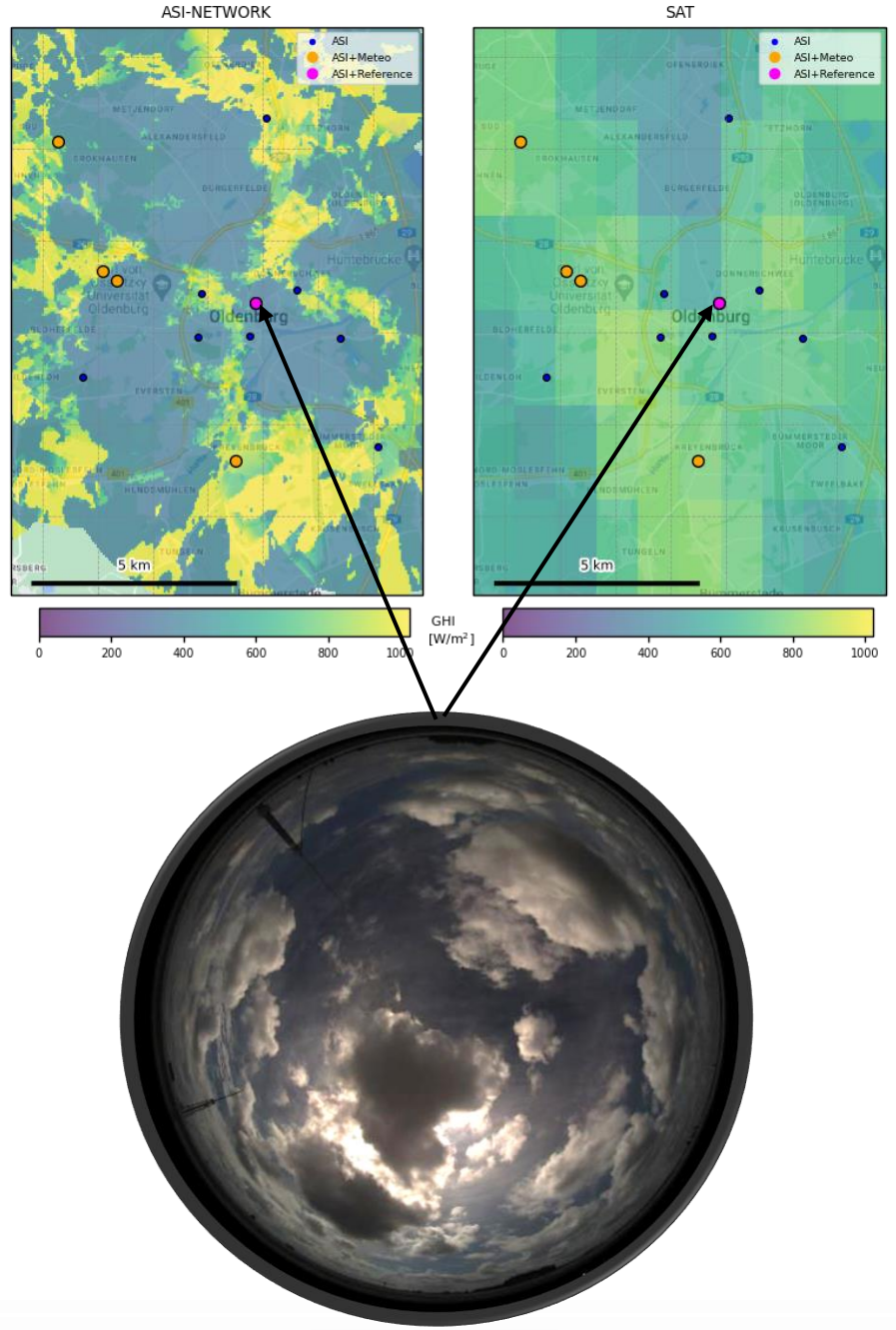




Solar irradiance estimations

Example of small scale cloud conditions

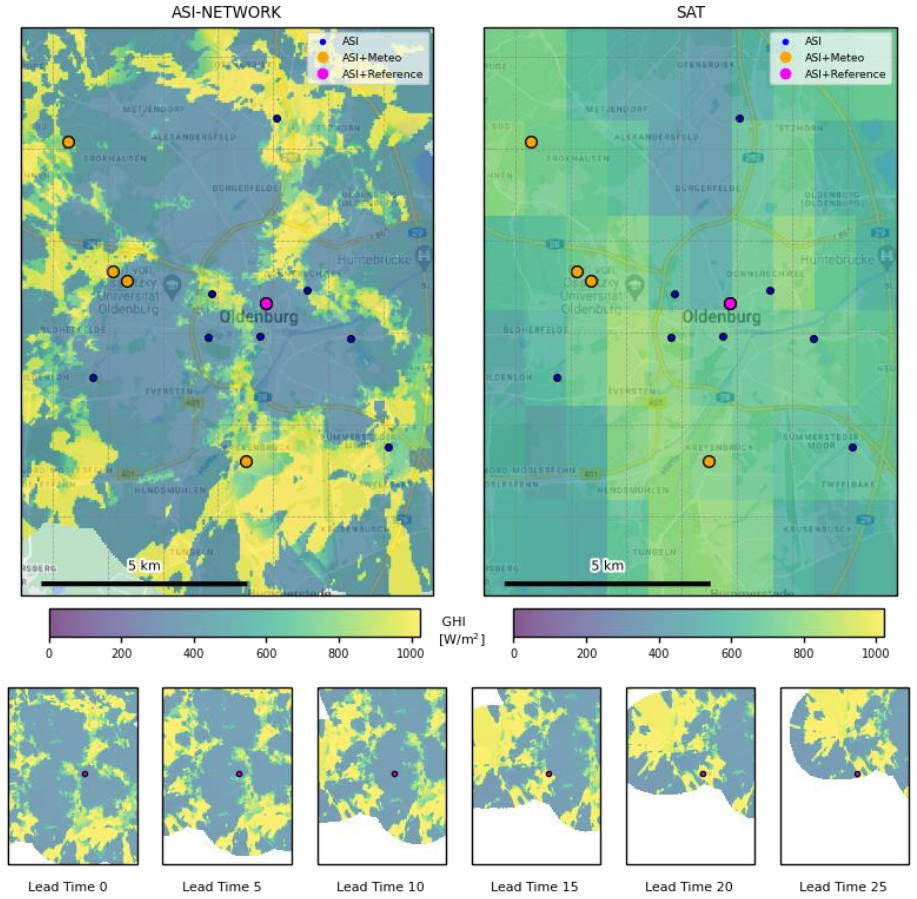
- Large differences in cloud/irradiance resolutions between camera and satellite
- Cloud (shadow) projection has large uncertainties -> Difficult to match both scenes / timing and location errors
- Satellite (here MSG-HRV with Heliosat3 method) and other coarse resolution data sources smooth fields and timeseries



Solar irradiance estimations

Example of small scale cloud conditions

- Nowcast is result of cloud tracking / motion
- Forecast horizon is limited depending on cloud motion (and height)



Cloud direction

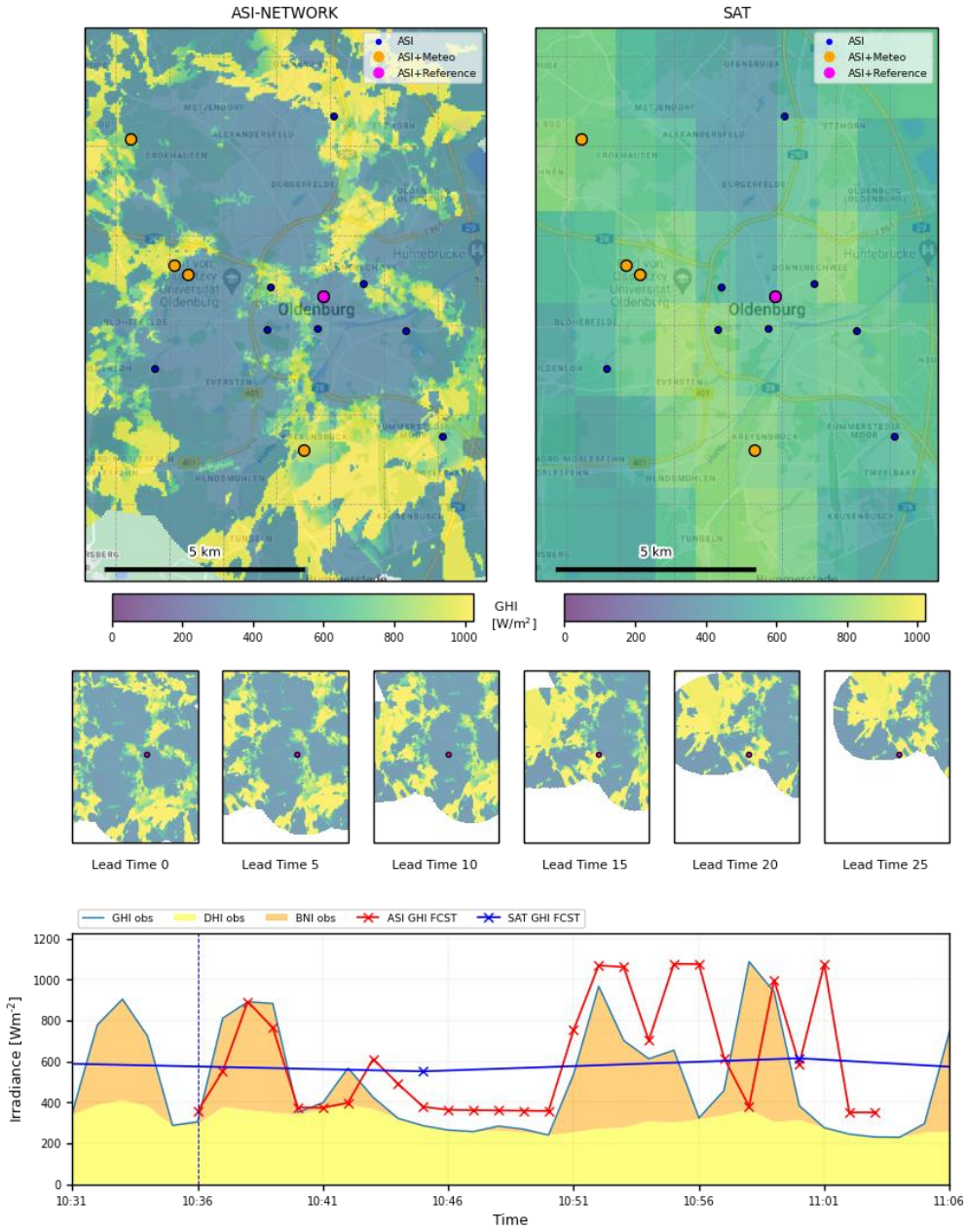
Solar irradiance estimations

Example of small scale cloud conditions

- Nowcast validated for measurement sites show good representation of local cloud induced solar variability, but timing and amplitude errors occur
- Satellited based nowcast (15 minute resolution) predicts smooth timeseries

On one-minute timescale, which nowcast shows lower error metrics at single sites?

What about a hybrid multi data source model?



Camera vs/with Satellite
Nowcast validation

Setup:

- Validation on minute level
- Validation against measurements at two distinct independent sites in the domain
- Satellite nowcasts have been interpolated to minute level

Findings:

- nowcasts based on the ASI-network show better performance for 8/13 minutes ahead (RMSE/MAE)
- A linear combination of both nowcasts can reduce nowcast error

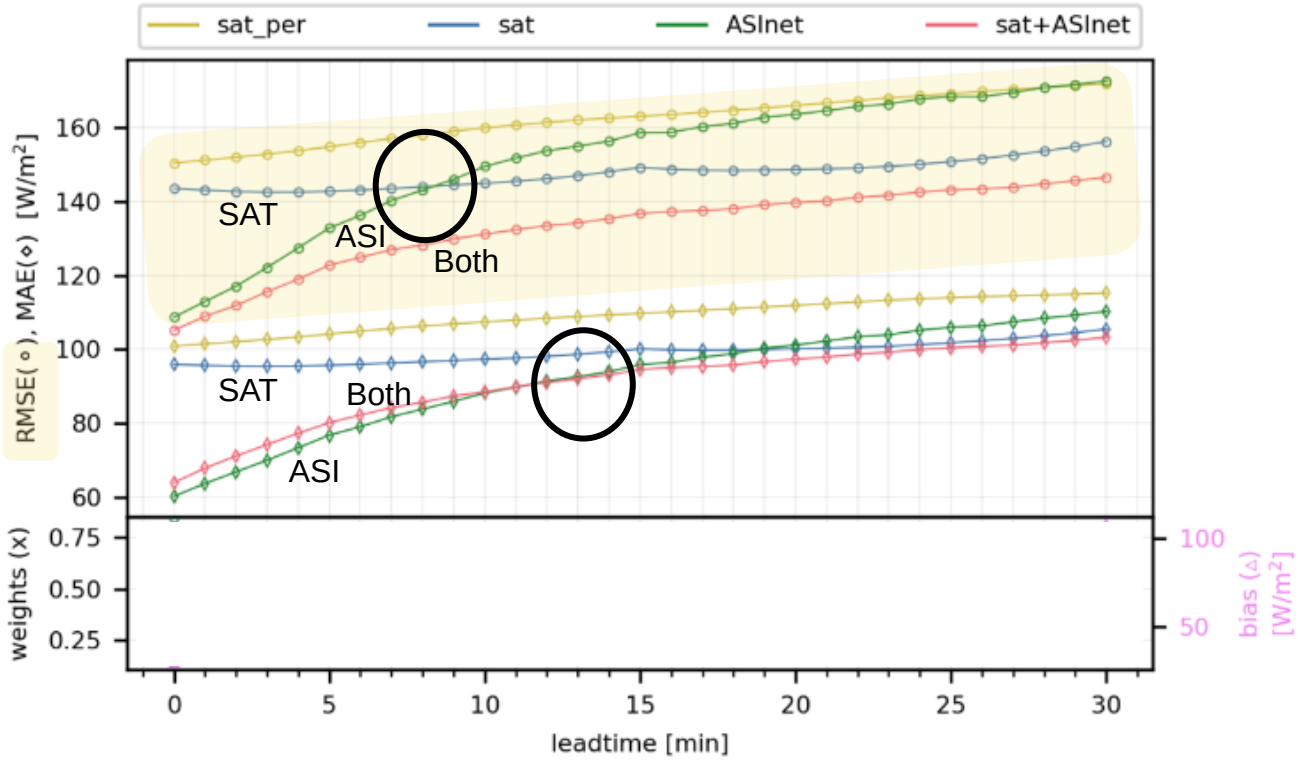


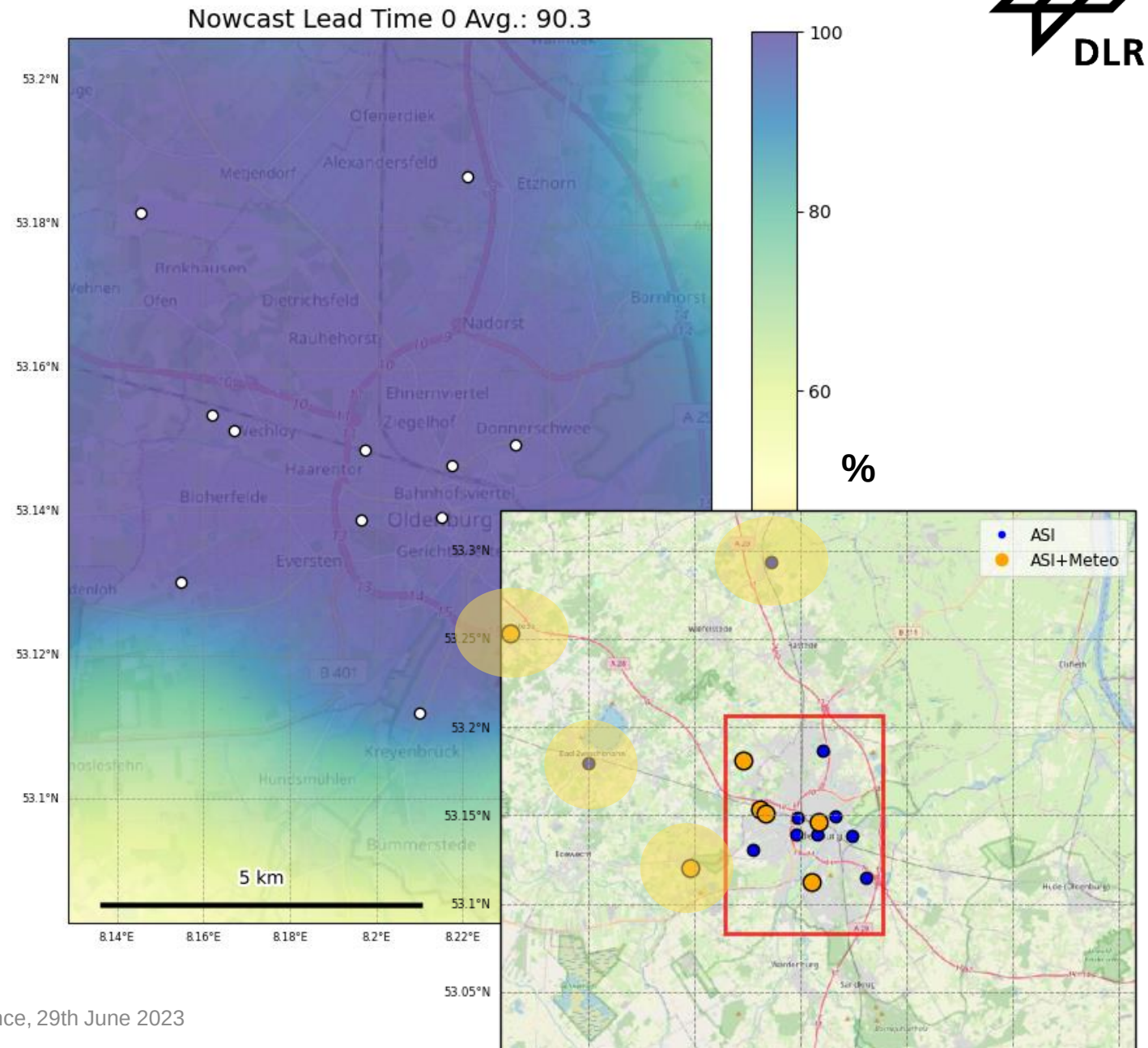
Figure 15. Benchmark for the combined forecast on the nominal synchronization case. ***Top****: Error metrics RMSE(○) and MAE(◇).* ***Bottom****: average optimized combination weights(x) and optimized combination bias term (△) in the secondary axis.*

- *Lezaca, Jorge et al. (2022): High resolution hybrid forecast based on the combination of satellite and an all sky imager network forecasts. EMS Annual Meeting 2022, 04-09 Sept 2022, Bonn, Germany.* https://elib.dlr.de/190483/
- *Lezaca, Jorge et al. (2022):* Methodologies for short-term solar resource forecasting by merging various inputs, Smart4RES Project, https://www.smart4res.eu/wp-content/uploads/2023/01/Smart4RES_Deliverable_D2.3.pdf

Spatial coverage of ASI-Network

Analysis of 1 year of nowcast runs and the occurence of available information

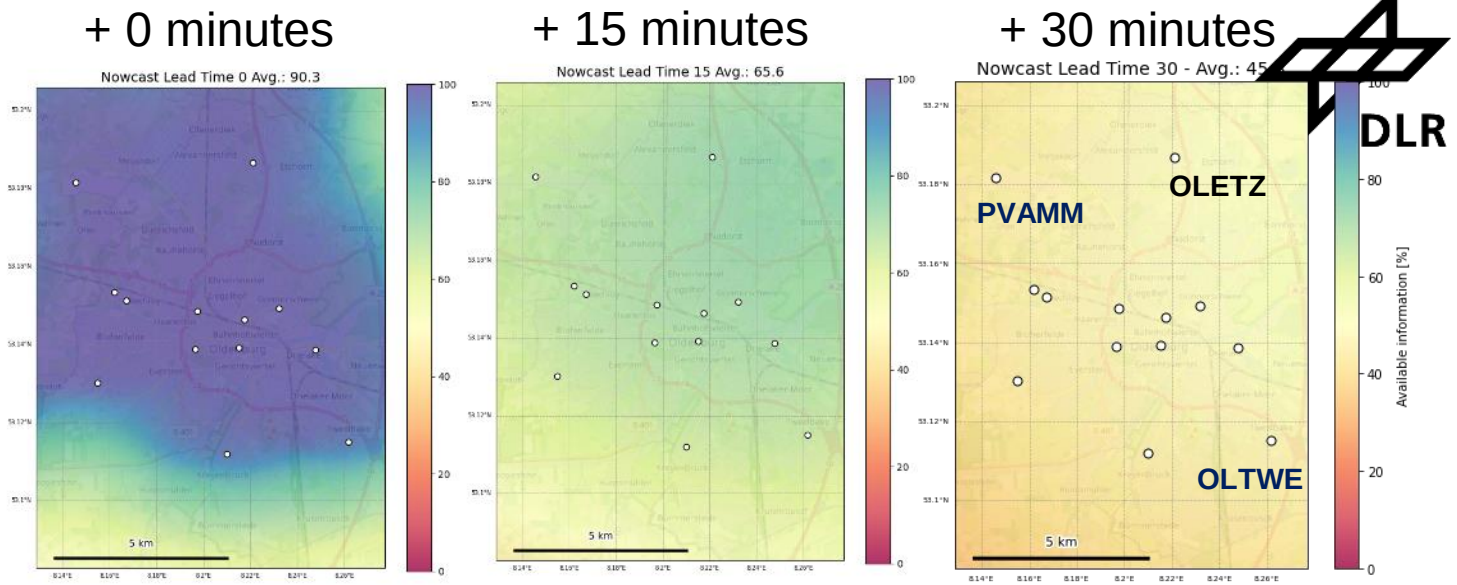
- Spatial distribution of cameras determines the coverage
- Additional ASI in northwest part out of this domain add information to Oldenburg domain

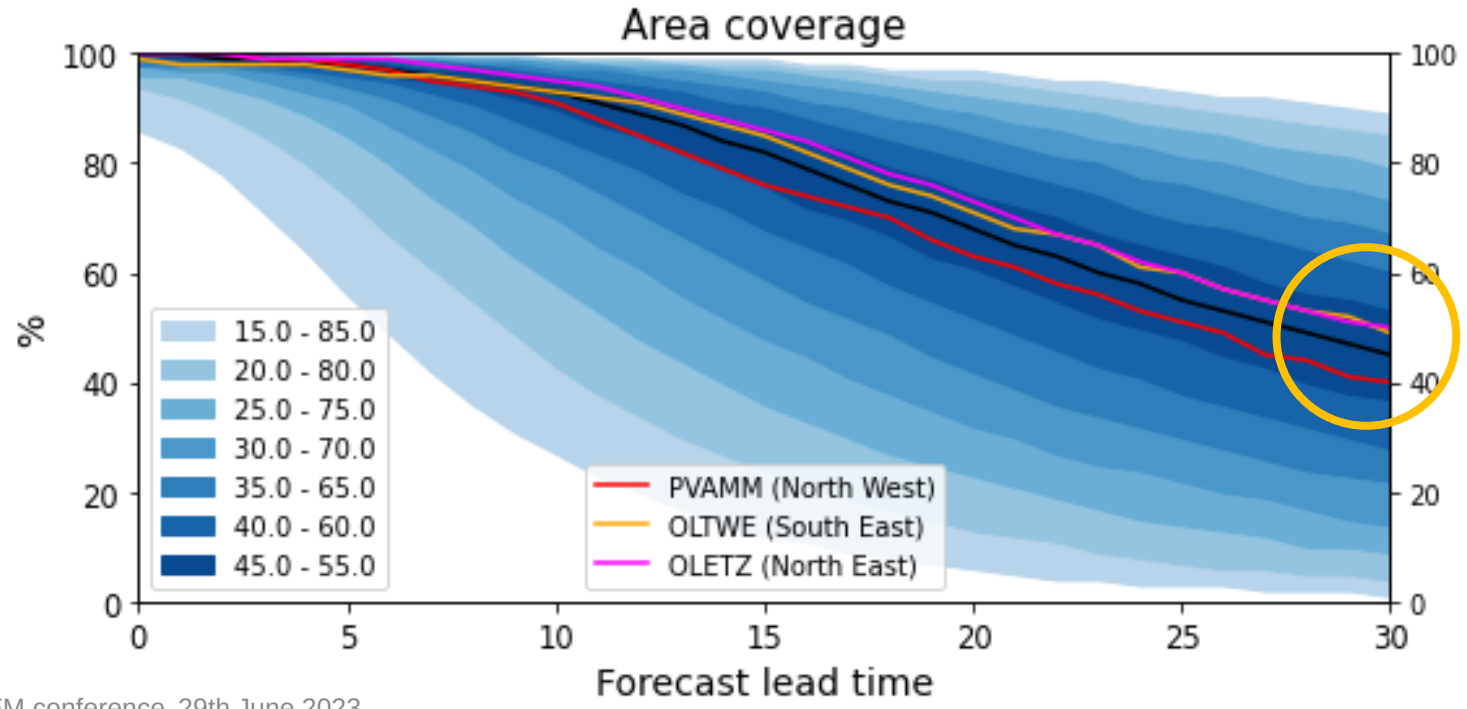


Spatial coverage

- Large variations in cloud conditions lead to large variations in spatial coverage for all lead times

„A 30 minutes forecast horizon with 50% coverage of the city is reached in about 50% of the time“

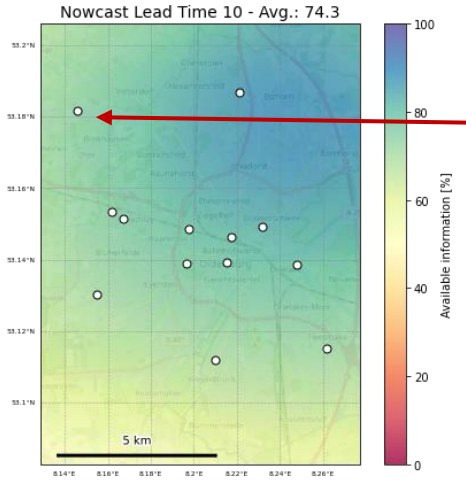


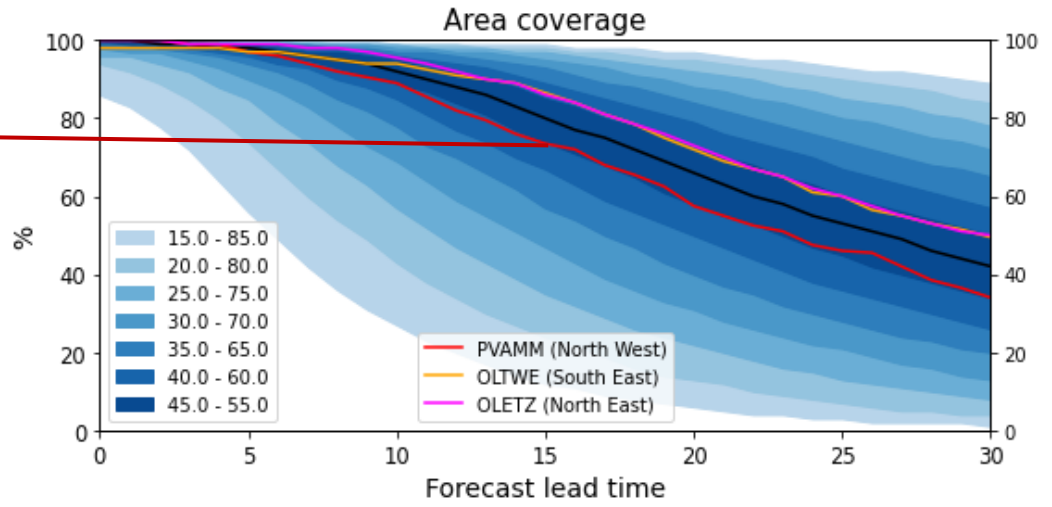


Network coverage depending on cloud motion

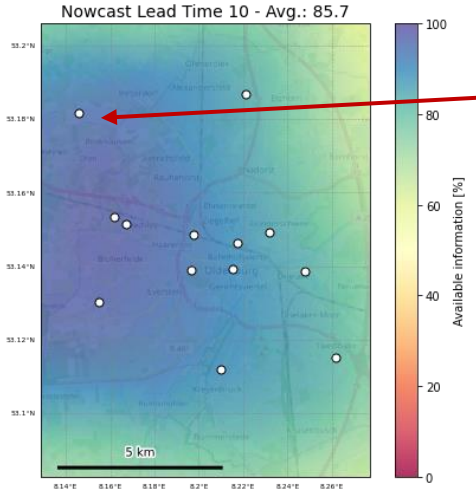
10 minutes ahead nowcast

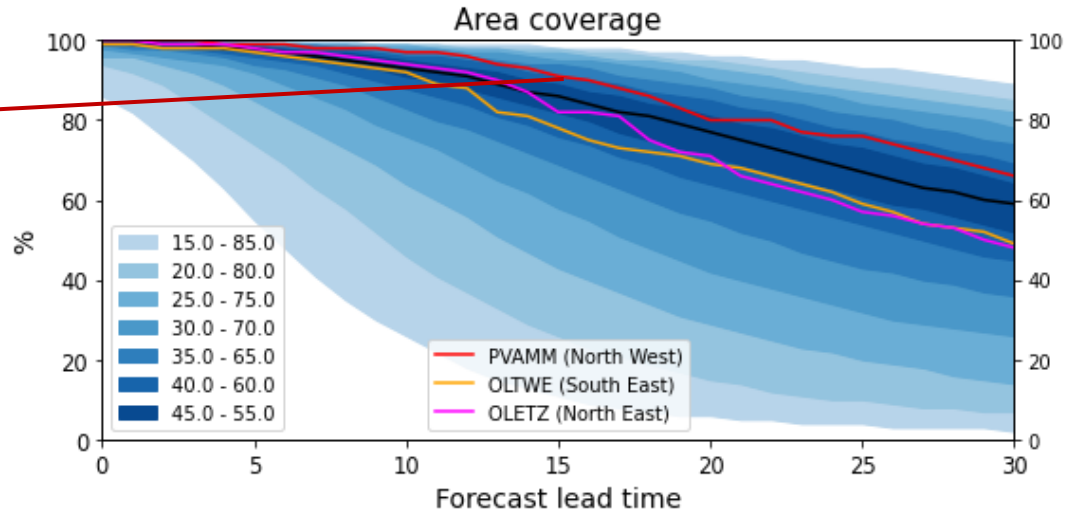
Clouds from west





Clouds from east





Conclusions

Summary

- High resolution and frequently updated solar irradiance nowcasts for an urban area based on a network of cameras have been processed and demonstrated
- A comparison against „low-resolution“ satellite based information show the value of high resolution but also weakness in terms of standard error metrics.

Outlook

- Investigate further the value of high temporal and spatial variability information
- Add high-resolution NWP evaluation
- Develop hybrid models for seamless forecasting
- Integrate in Energy System Applications (Distribution Grid, large-scale PV)

Thank you for listening…

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Website:

https://www.dlr.de/ve/en/eye2sky

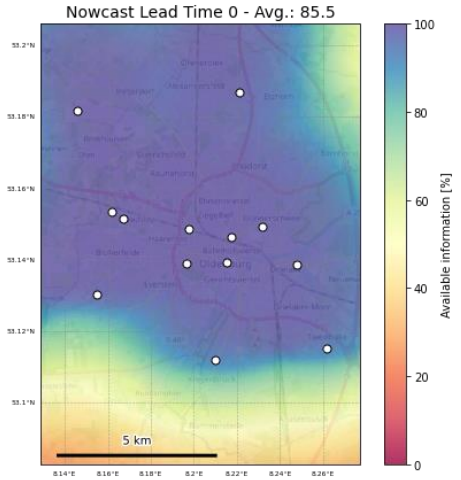
Video:

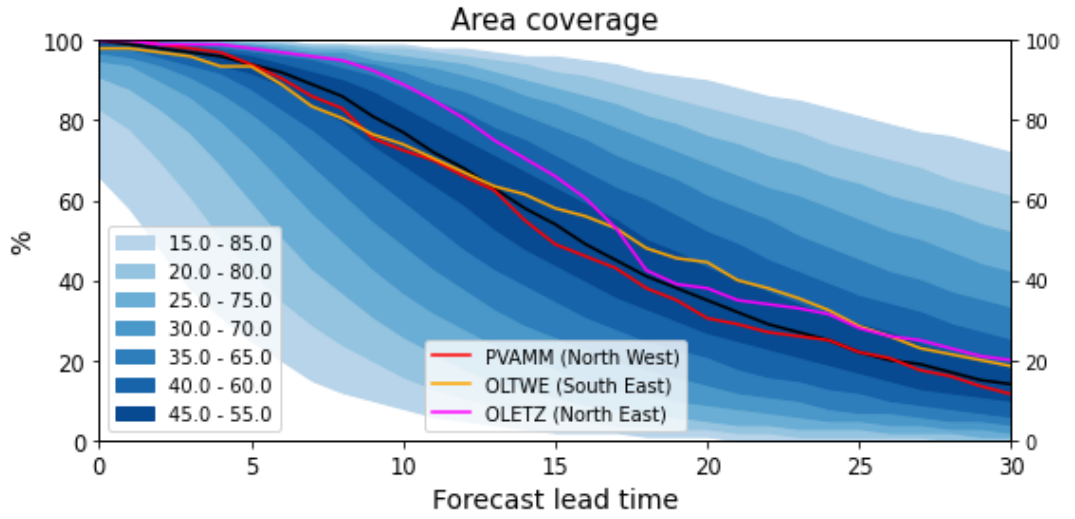
Portrait of Eye2Sky in 5 Min Video

Network coverage depending on cloud base height

Cloud height < 2000m

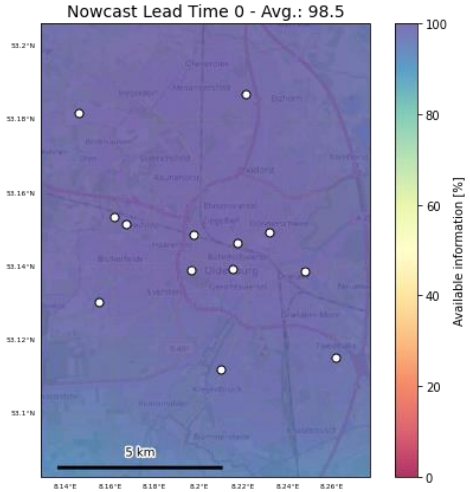
Reduced forecast horizon in low cloud conditions

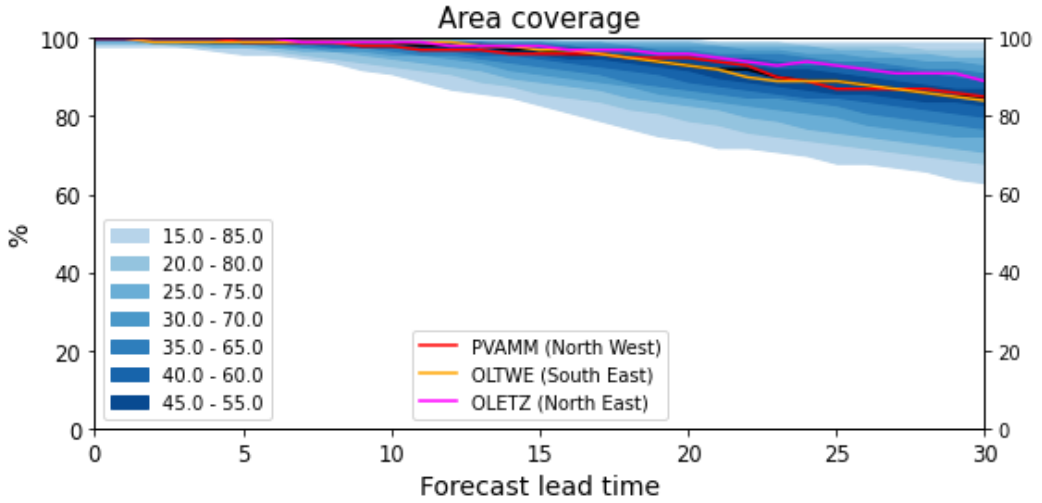




Cloud height > 4000m

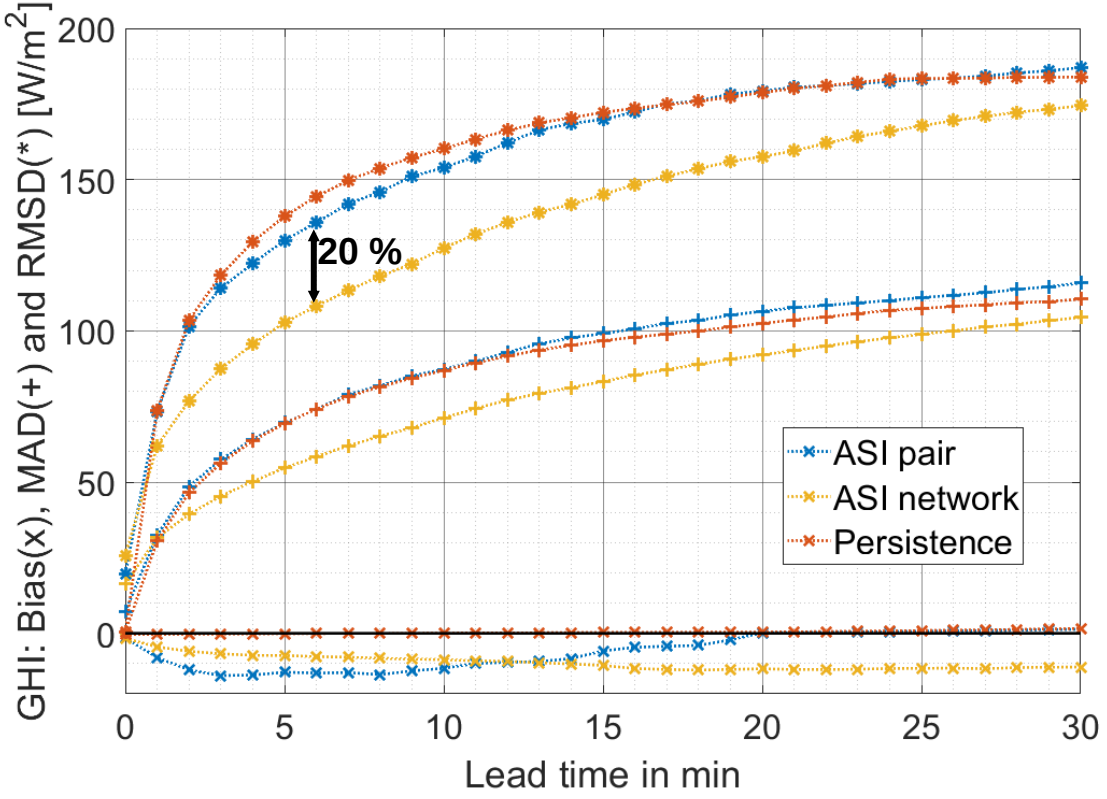
Increased forecast horizon in high cloud conditions





Validation ASI net vs ASI pair forecast

E.g. for GHI at OLDON:

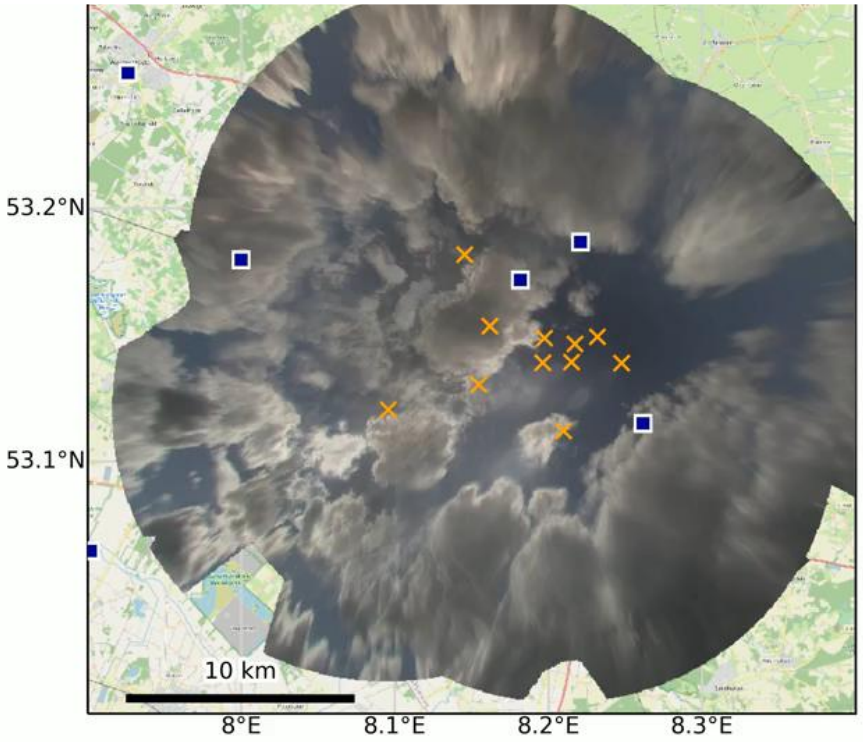


- ASI network forecast presents a relative improvement on RMSD of around 20% between the leadtimes 2 min to 15 min.
- Advantage of the ASI network over the ASI pair and persistence remains for large lead times
- As expected the ASI network outperforms an ASI pair even more clearly at locations farer from the ASI pairs location (not shown here)

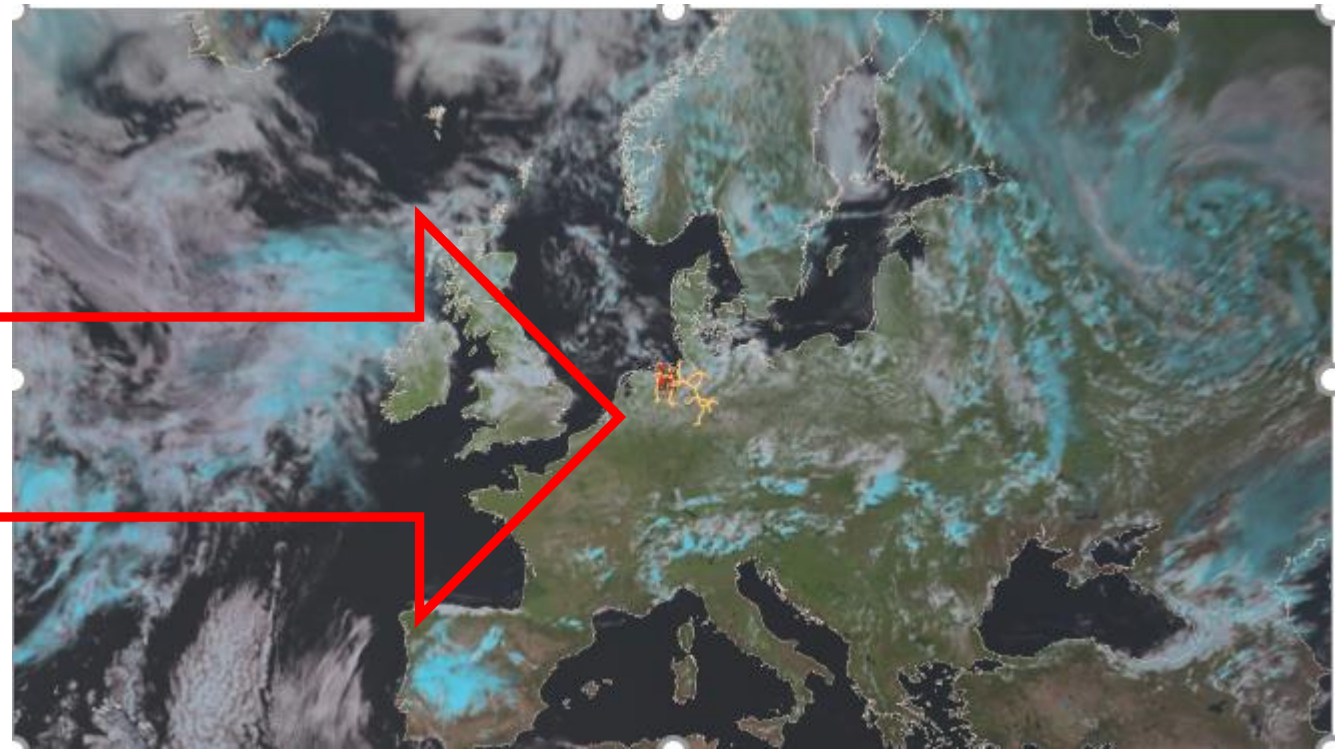
[2] Blum, N. B., et al., (2021). Cloud height measurement by a network of all-sky imagers. Atmospheric Measurement Techniques, 14(7), 5199-5224.

Clouds - observed from ground and space

ASI Network

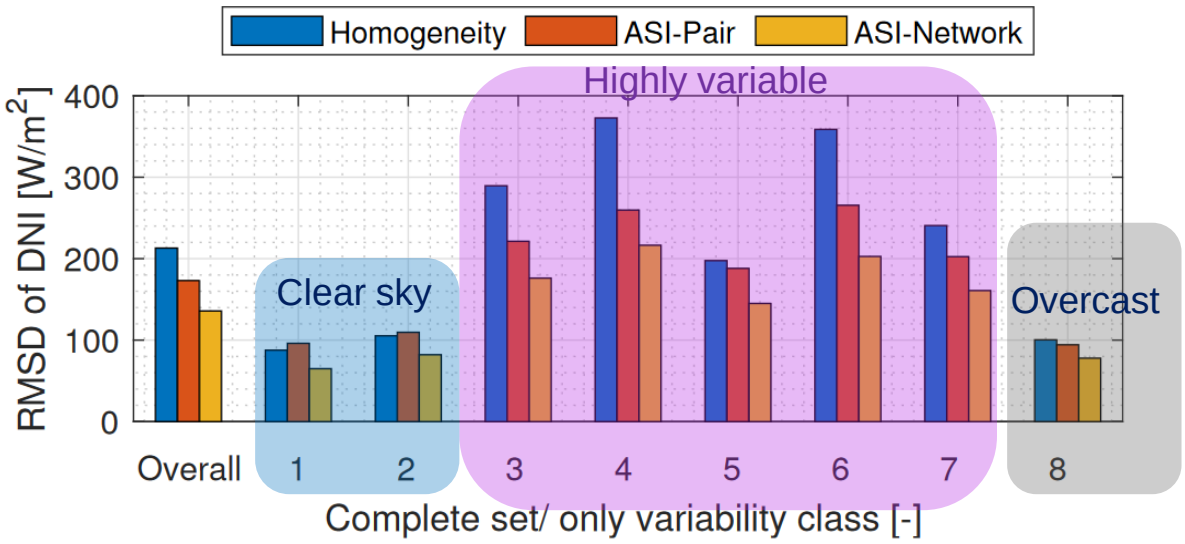


Meteosat Second Generation – Geostationary satellite



- Temporal resolution: (ASI-Network – 30 seconds, MSG-Satellite – 15 minutes)
- Spatial resolution: (ASI-Network – 50 meters, MSG-HRV - ~1.5 kilometres

Validation at OLUOL on DNI using variability classes



- ASI pair predicts DNI at OLUOL more accurately compared to homogeneity under most conditions
- ASI network has clear advantage over homogeneity & ASI pair under all conditions
- Improvements related to combination of perspectives and also to method to assign transmittance