SOLAR IRRADIANCE NOWCASTING BASED ON A NETWORK OF ALL-SKY IMAGERS: THE VALUE OF HIGH-RESOLUTION DATA ON VARIABILITY INFORMATION

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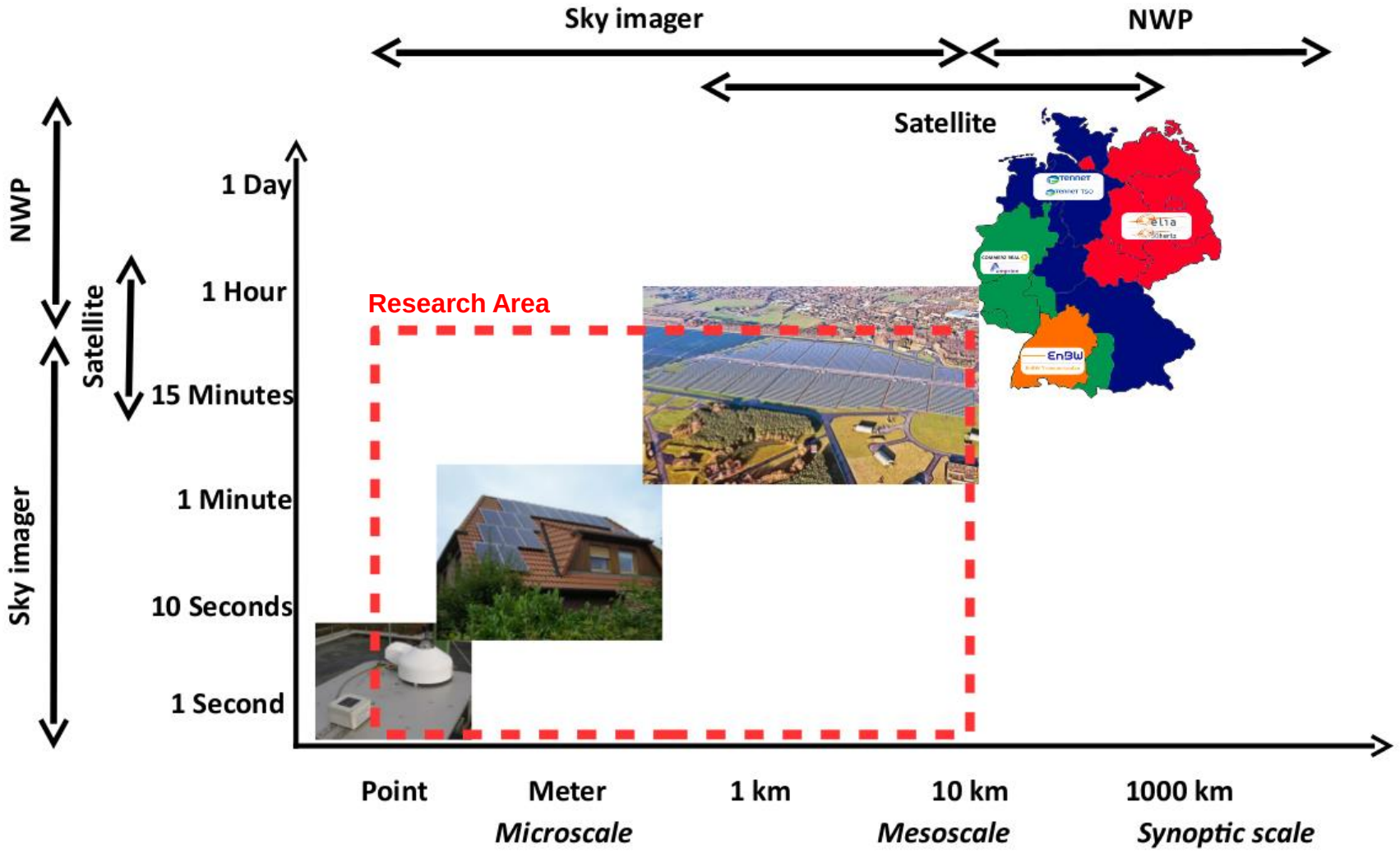
DLR Institute of Networked Energy Systems (* and Institute of Solar Research)

DLR

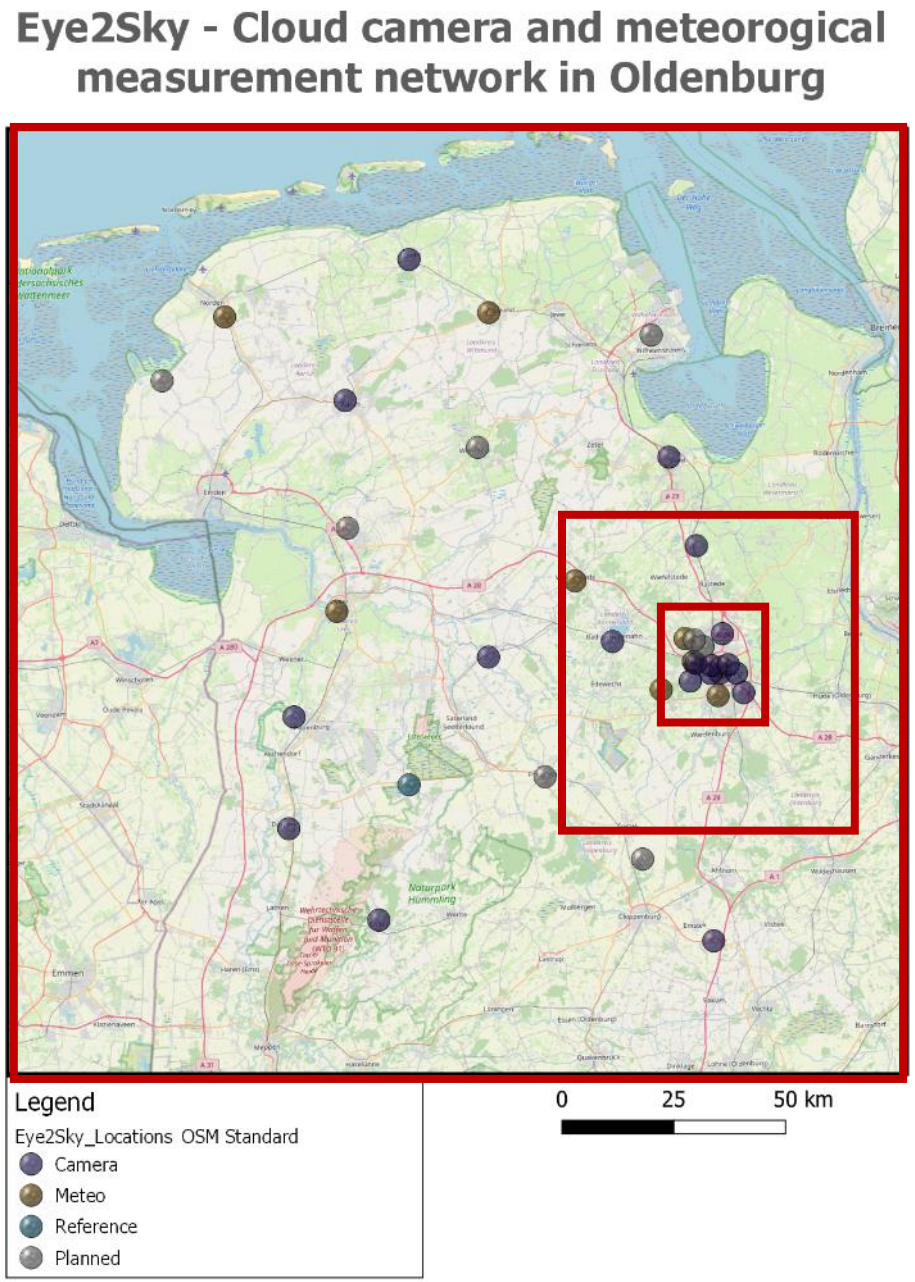
Solar irradiance forecasts

Towards increasing spatial and temporal resolution



Eye2Sky 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

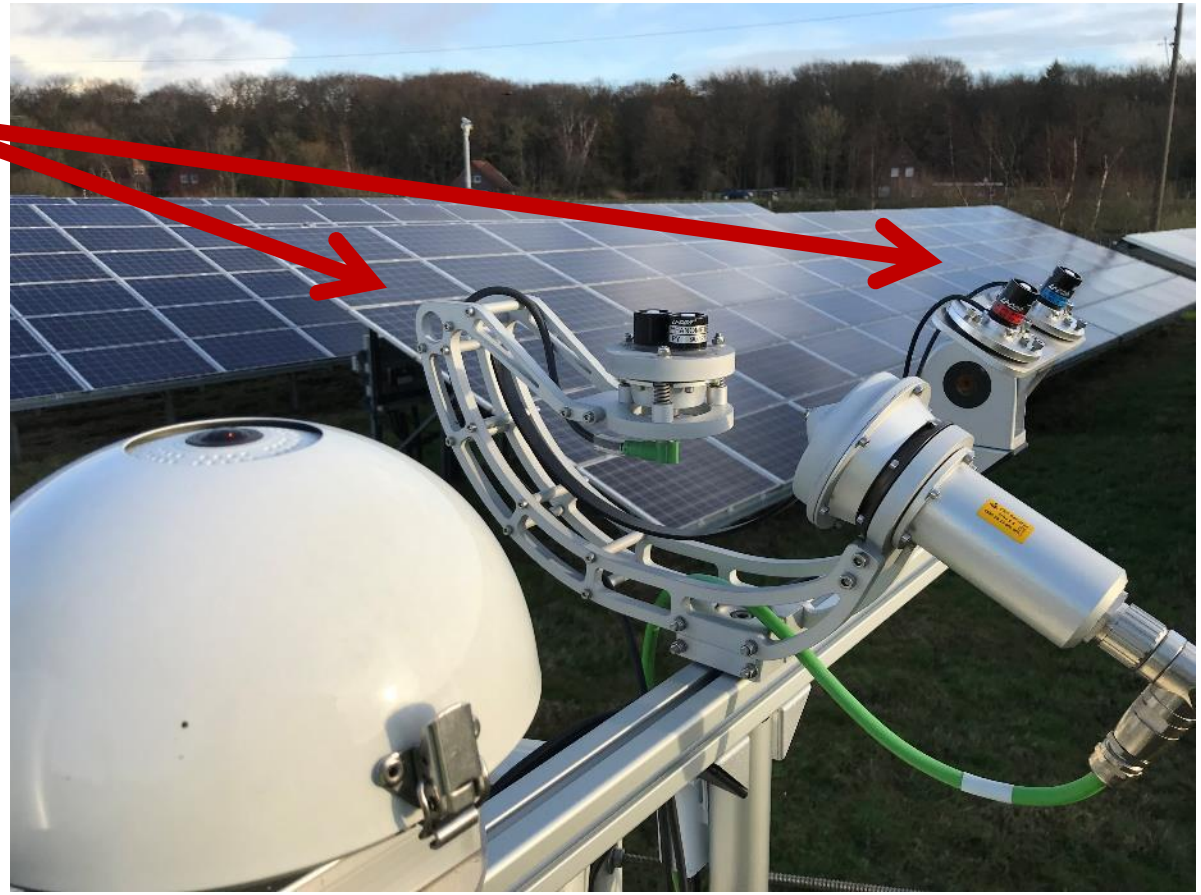
- Solar irradiance sensors (GHI, DHI, DNI, GTI)
- Air temperature and humidity

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

Instrumentation

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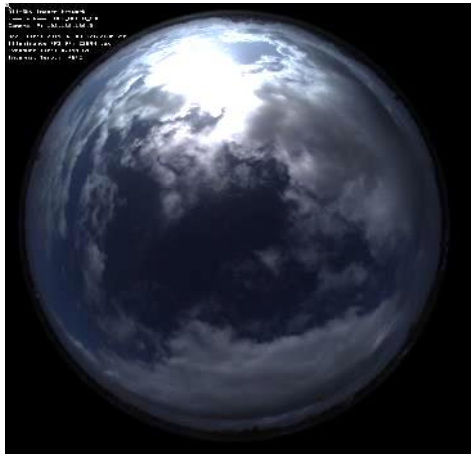
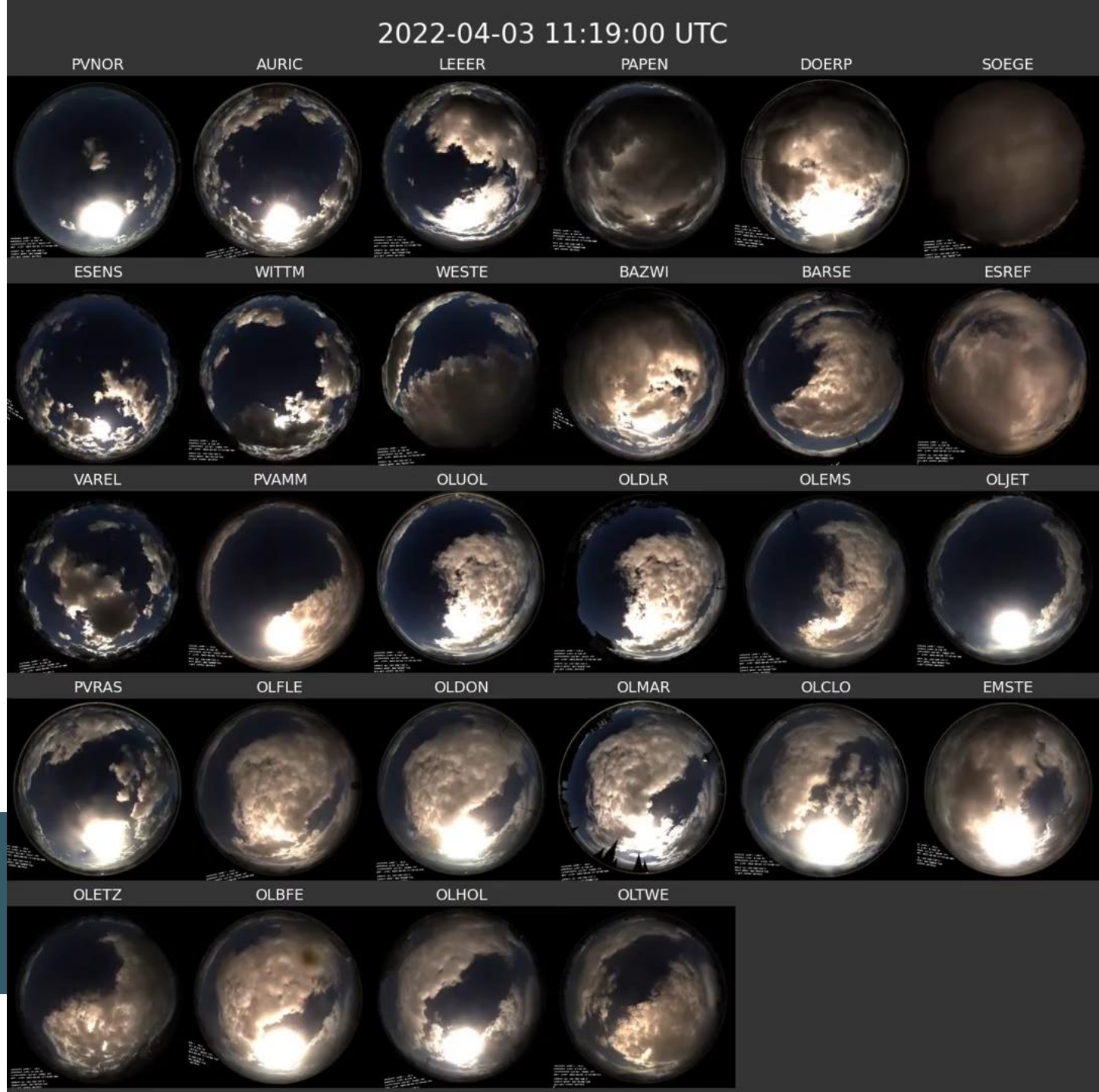
Photography of Eye2Sky station PVNOR

2 hours of weather seen by multiple fish eye cameras

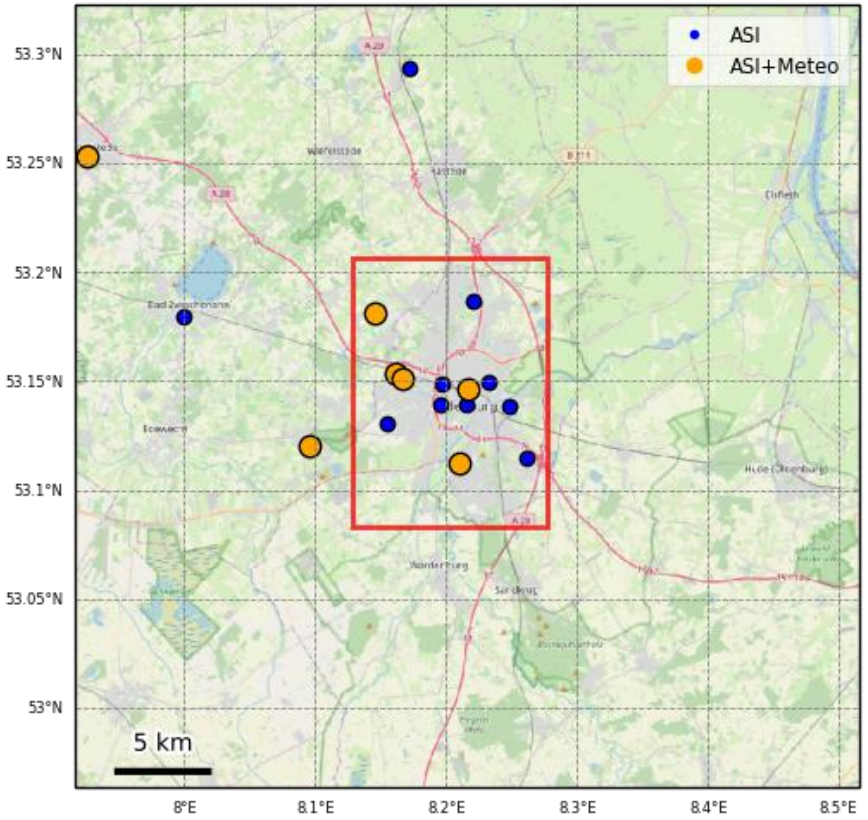


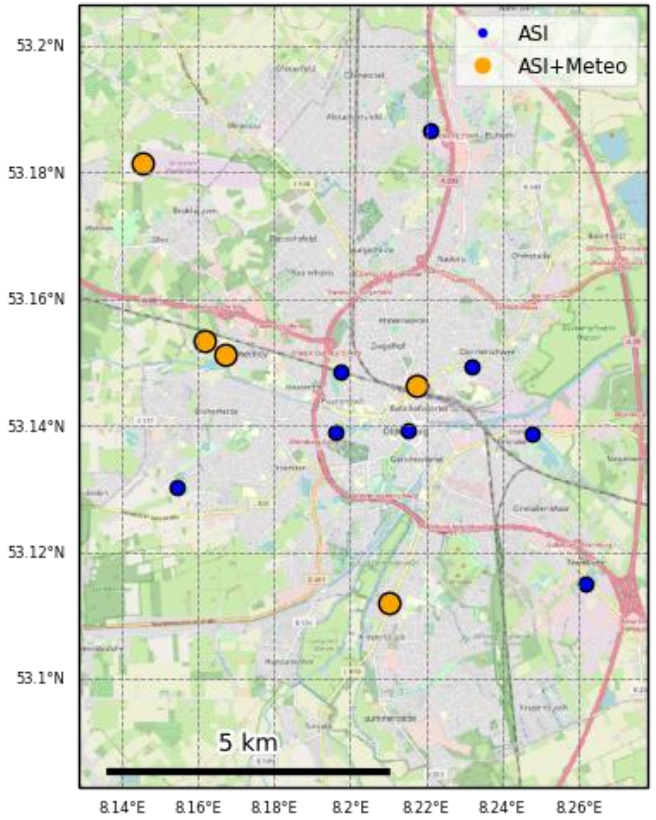


Why cameras?

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 13.75 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.

Comparison of camera, satellite and weather model based data sets

Parameter:
GHI
Period:
06/2022 – 12/2022

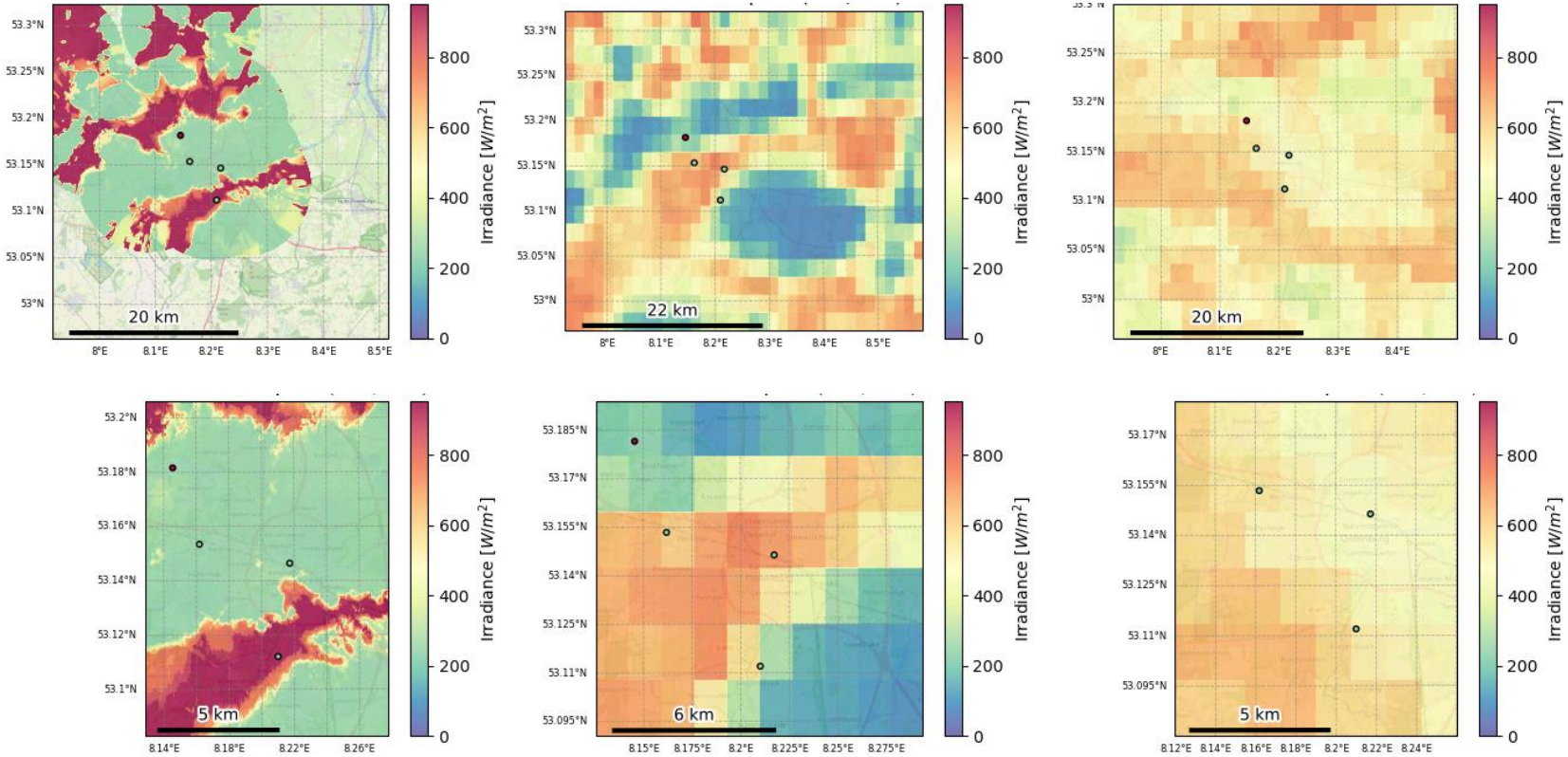
Domain Oldenburg+
40 km x 40 km

Domain Oldenburg
13.27 km x 10 km

ASI Network
Δx = 50m
Δt = 1 min

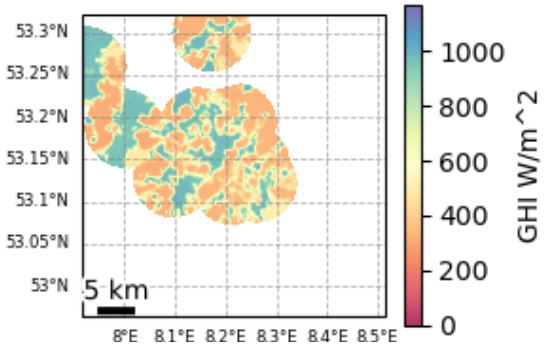
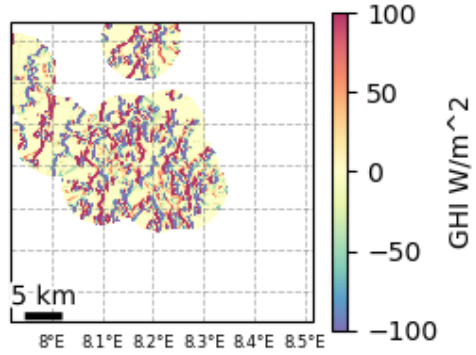
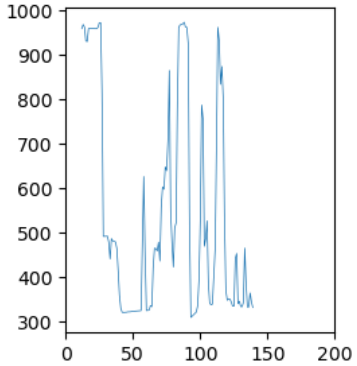
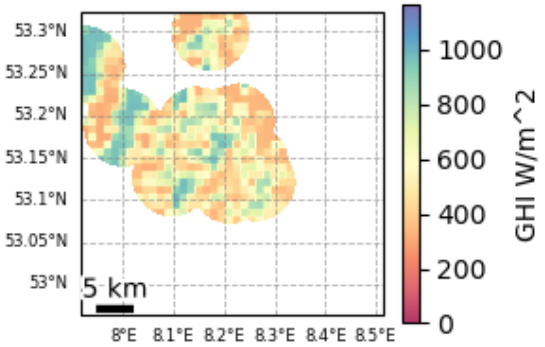
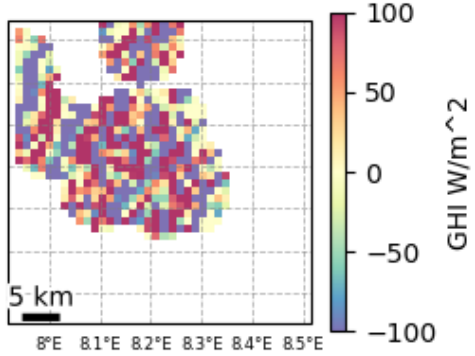
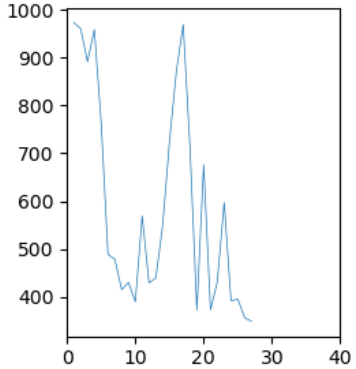
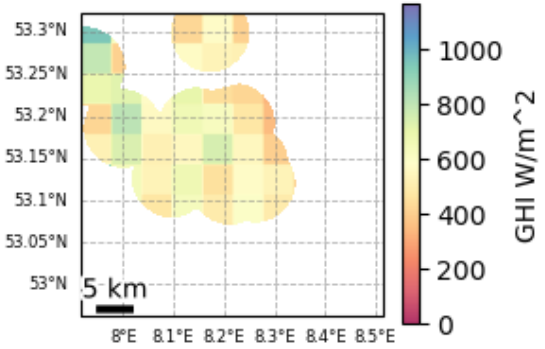
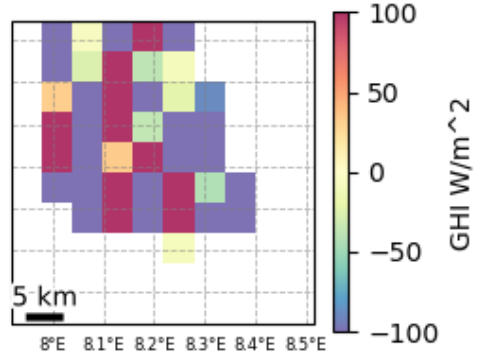
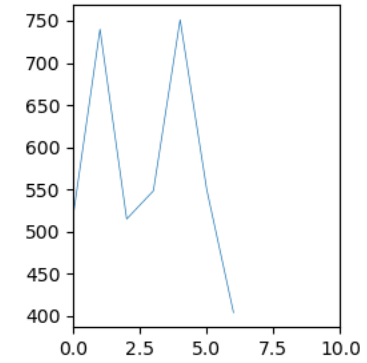
MSG-SAT
Δx ~ 2km
Δt = 15 min

NWP ICON-D2
Δx ~ 2.2 km
Δt = 15 min
Run: 3 UTC



Impact of reducing spatial resolution
of ASI data

- Reduction in spatial resolution leads to smoothing of cloud edges
- Depending on the size of cloud patterns and grade of smoothing, spatial and temporal patterns are affected

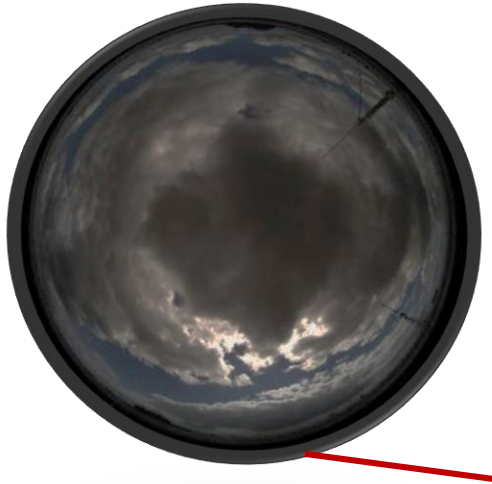
	GHI map	GHI Gradients	Cross-Section
200m			
1000m			
4000m			

Evaluation of spatial variability

- Applying temporal variability indizes from literature on solar irradiance maps
- Indizes used here:
  - $V = \sigma(\Delta k_c(t))$ (Marquez & Coimbra, 2013)
    - Applied on maps the clear sky index increment is $\Delta \mathrm{k}_c = (\mathrm{k_c}(\mathrm{x_i}) - \mathrm{k_c}(\mathrm{x_i} - 1))$ along the x-axis of the map (iterating all rows)
  - $STD = \sigma(k_c)$
    - Applied on maps it measures the overall standard deviation of the solar irradiance map

- *Marquez, Ricardo; Coimbra, Carlos F. M. (2013): Proposed Metric for Evaluation of Solar Forecasting Models. In: J. Sol. Energy Eng 135 (1), Artikel 011016. DOI: 10.1115/1.4007496*

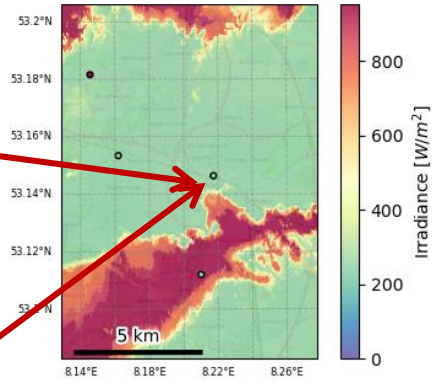
Spatial Variability Index (broken cloud conditions)



Domain Oldenburg
13.3 km x 10 km

ASI Network
(Analysis)
Δx = 50m
Δt = 1 min (snapshot)

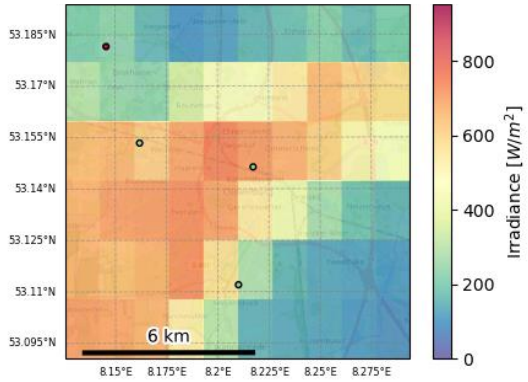
V = 0.07
STD = 0.34



275 x 200

MSG-SAT
(Analysis, corrected for scan time)
Δx ~ 2km
Δt = 15 min (snapshot)

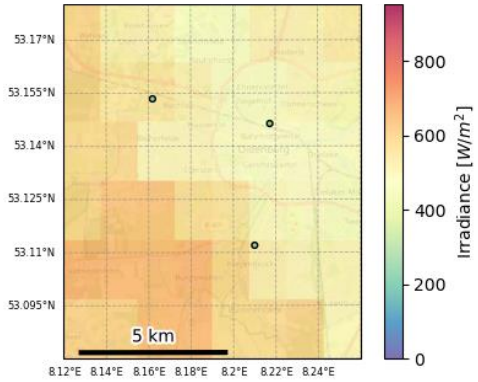
V = 0.20
STD = 0.29



6 x 10

NWP ICON-D2
(Forecast run 3 UTC)
Δx ~ 2.2 km
Δt = 15 min (average)

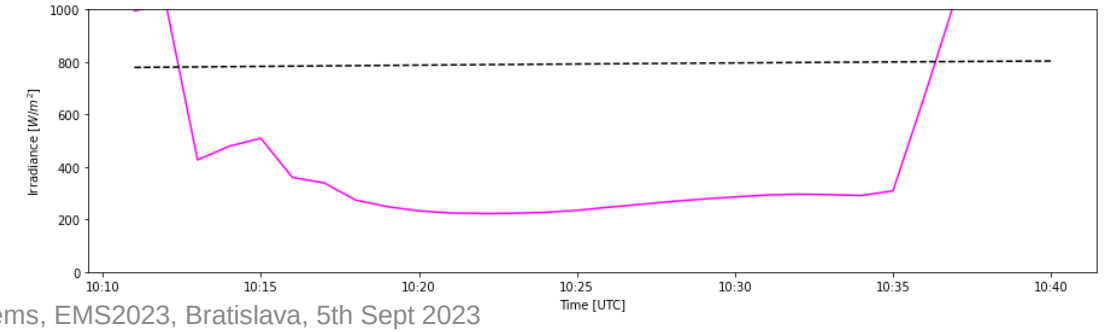
V = 0.07
STD = 0.08



6 x 8

In-situ data
Δt = 1 min

V = 0.19
STD = 0.25



Data from 2022-07-27 10:26 UTC

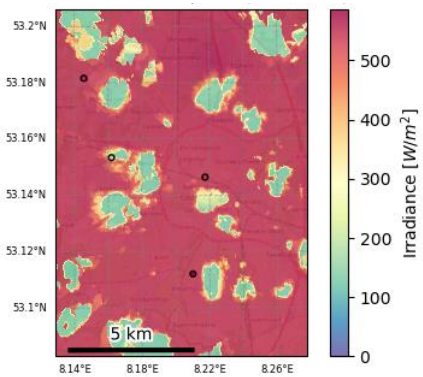
Spatial Variability Index (small scale cloud conditions)

Domain Oldenburg
13.3 km x 10 km

ASI Network

Δx = 50m
Δt = 1 min

V = 0.12
STD = 0.28

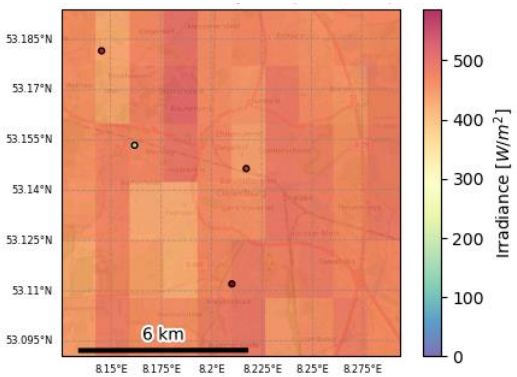


275 x 200

MSG-SAT

Δx ~ 2km
Δt = 15 min

V = 0.05
STD = 0.04

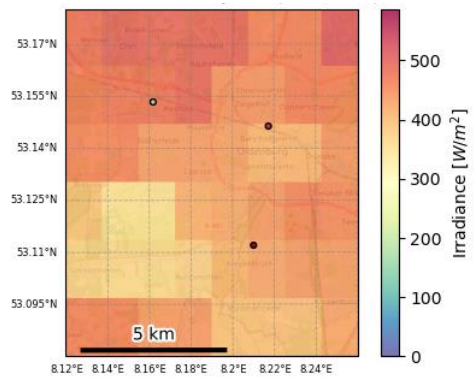


6 x 10

NWP ICON-D2

Δx ~ 2.2 km
Δt = 15 min
Run: 3 UTC

V = 0.05
STD = 0.08

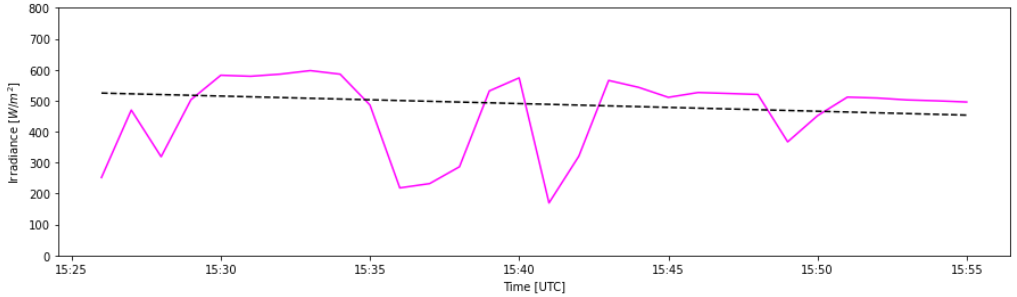


6 x 8

In-situ data

Δt = 1 min

V = 0.27
STD = 0.24



Data from 2022-07-23 15:41 UTC

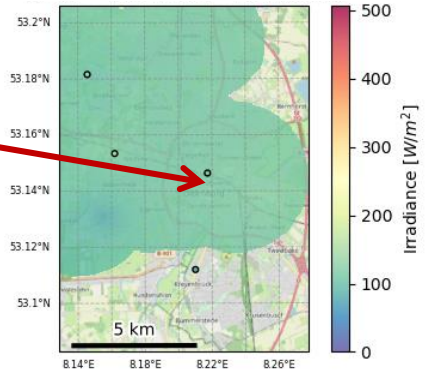
Spatial Variability Index (Overcast conditions)

Domain Oldenburg
13.3 km x 10 km

ASI Network

Δx = 50m
Δt = 1 min

V = 0.0
STD = 0.02

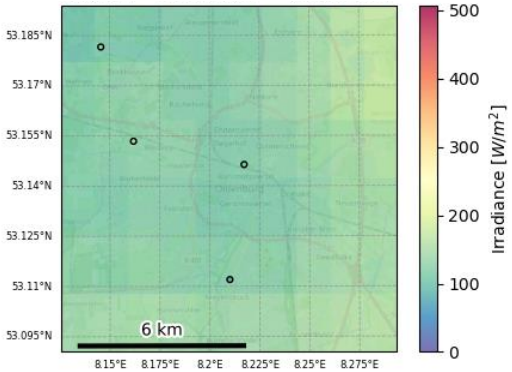


275 x 200

MSG-SAT

Δx ~ 2km
Δt = 15 min

V = 0.03
STD = 0.04

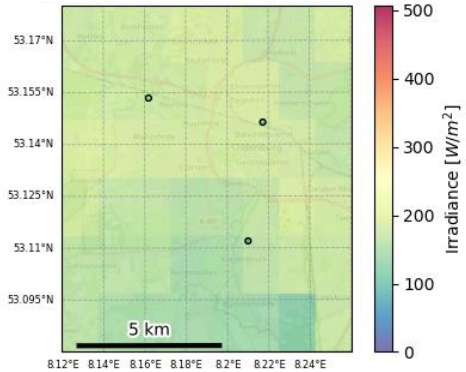


6 x 10

NWP ICON-D2

Δx ~ 2.2 km
Δt = 15 min
Run: 3 UTC

V = 0.03
STD = 0.04

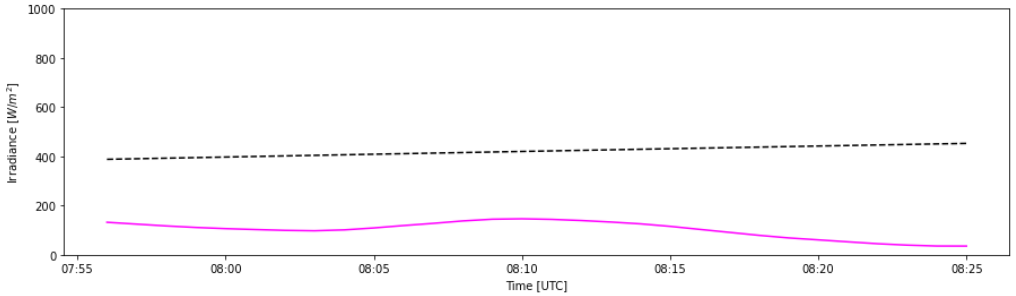


6 x 8

In-situ data

Δt = 1 min

V = 0.02
STD = 0.03



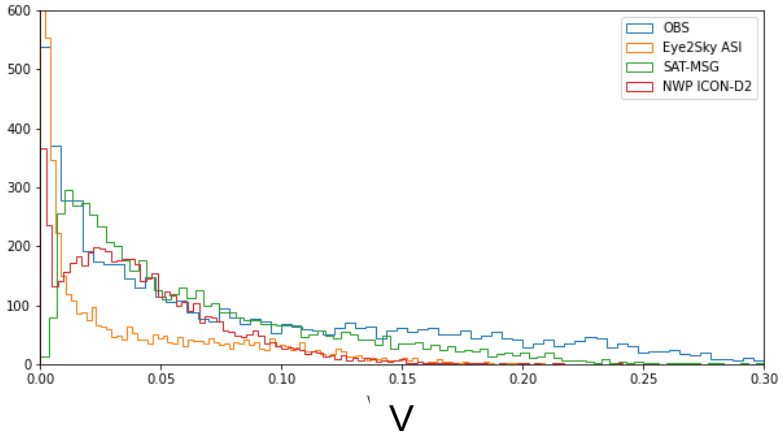
Data from 2022-09-10 08:11 UTC

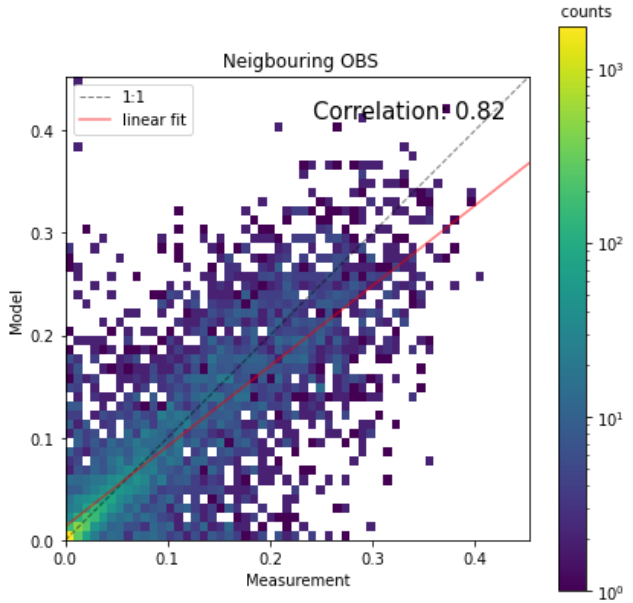
Comparison with temporal variability of in-situ measurements

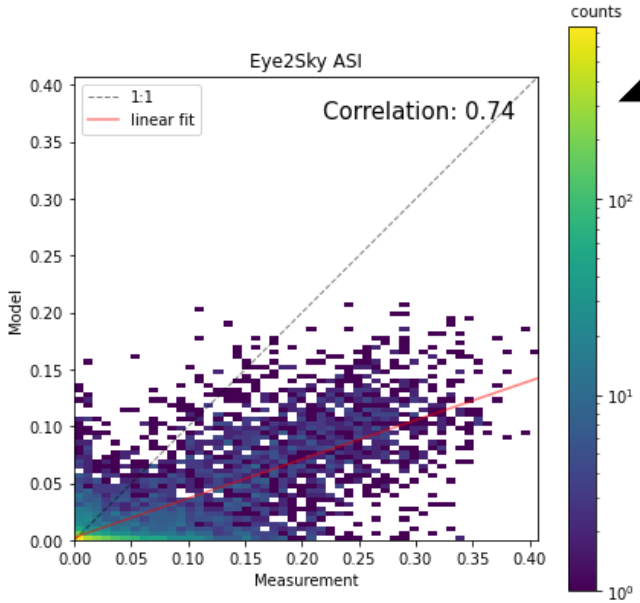
$$V = \sigma(\Delta k_c))$$

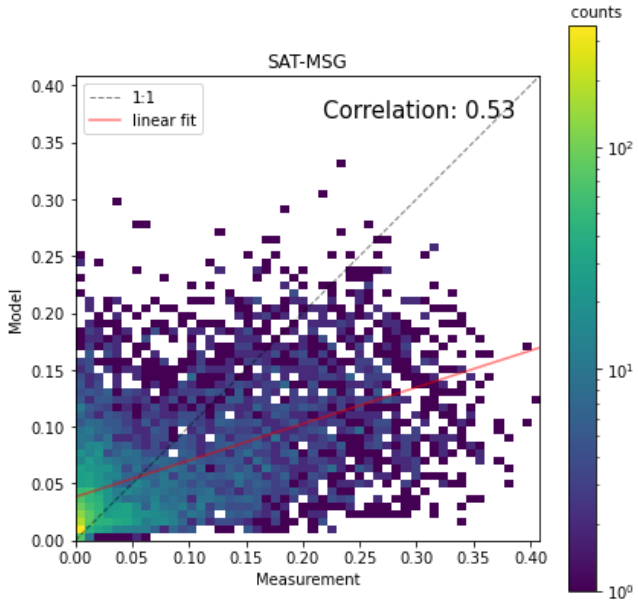
- ASI data shows higher correlation than SAT/NWP *(attention: NWP is forecast)*
- The distribution shows better agreement of SAT data with measured timeseries

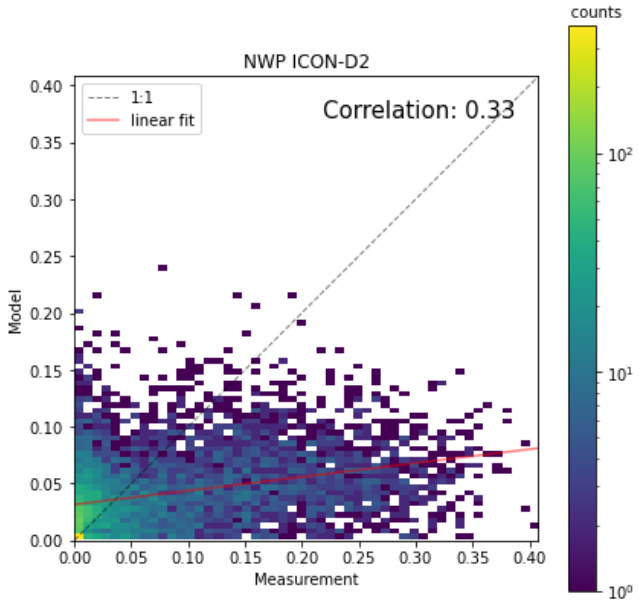
Histogram of the variability index









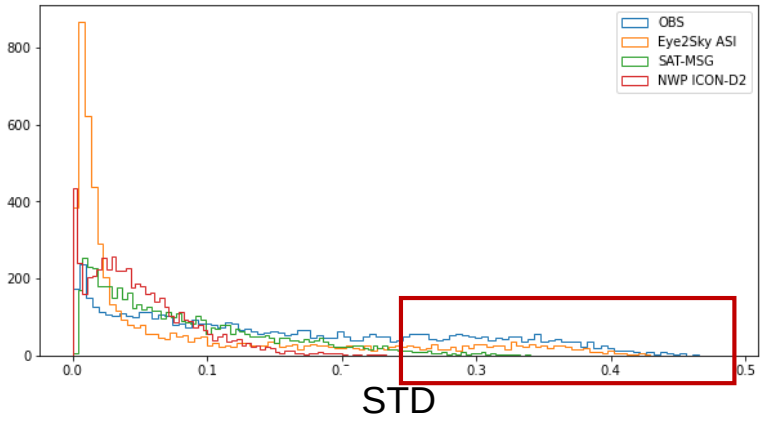


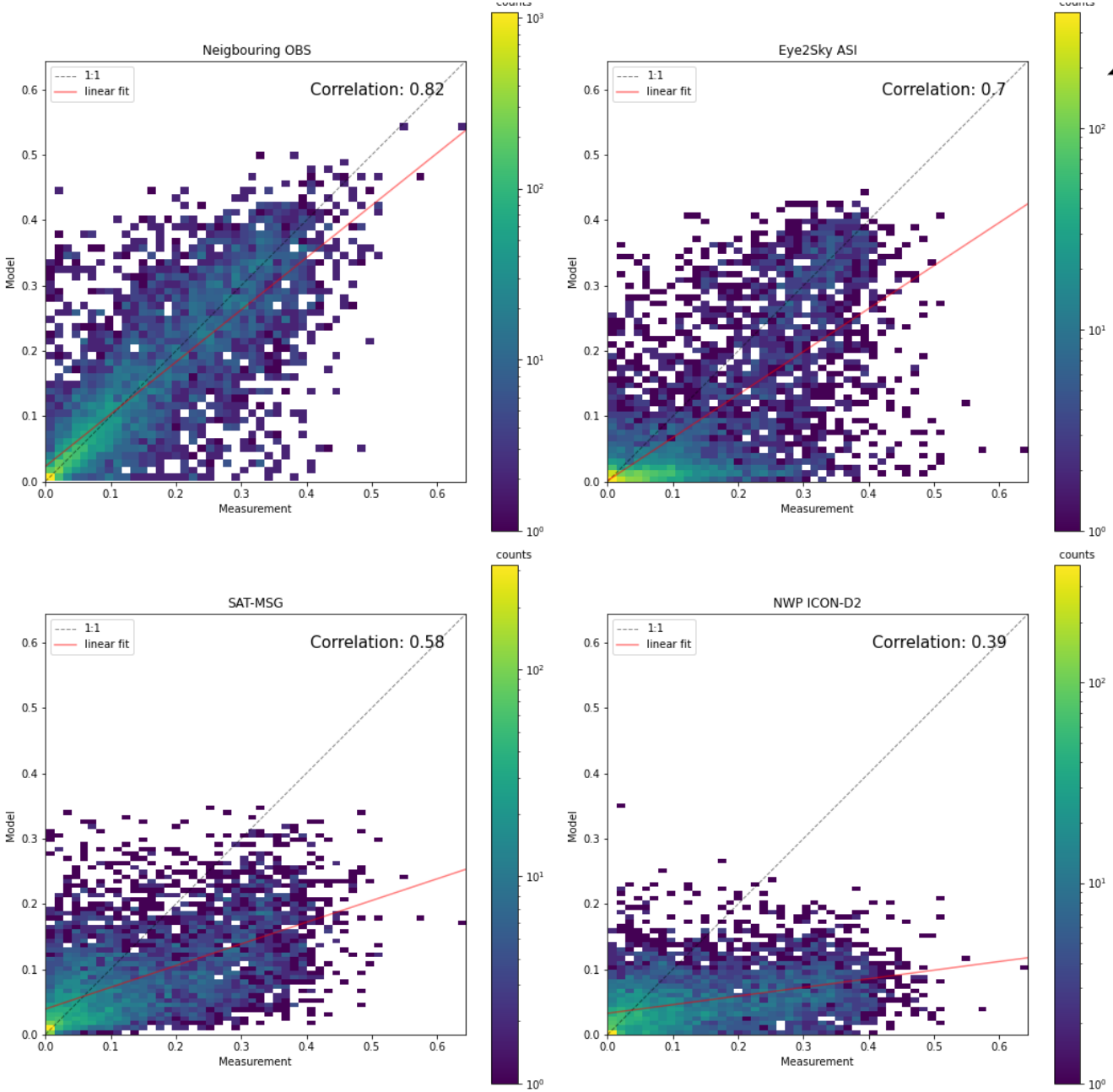
Comparison with temporal variability of in-situ measurements

$$\mathrm{STD} = \sigma(k_c))$$

- Similar results with even better agreement of ASI with timeseries.
- Distribution shows also better agreement, especially in high variability conditions

Histogram of the variability index





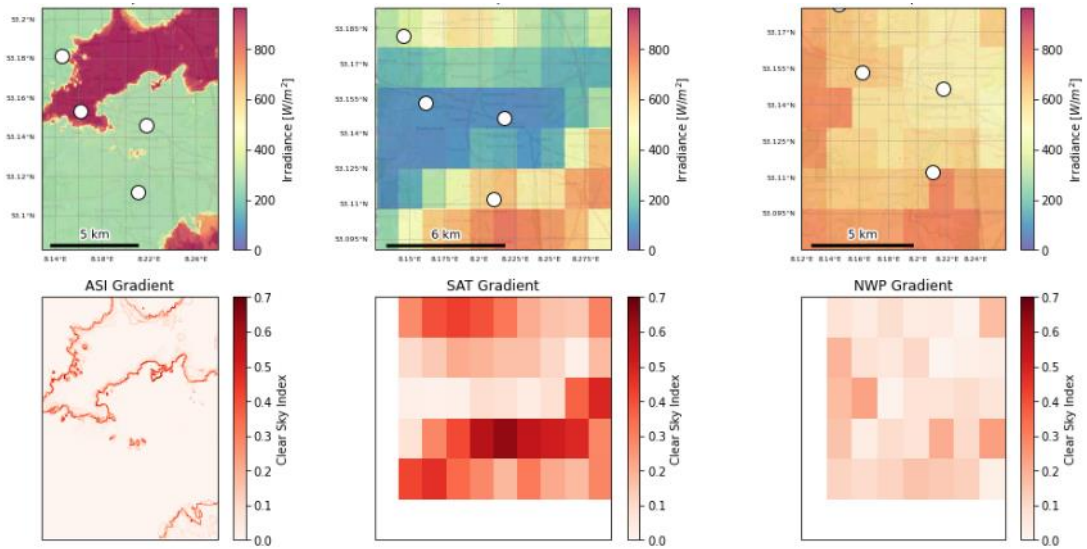
Summary

Conclusions

- ASI-based GHI data provides more details and sharper cloud edges compared to satellite and NWP data
- ASI data is able to resolve small scale cloud patterns
- Simple variability indizes used for timeseries show higher correlations with in-situ measurements but cannot show the full potential of the high resolution data sets

Outlook

- Investigate the relation between temporal and spatial domain, especially with regards to resolution
- Account for cloud motion (speed/direction)
- Apply analysis on forecast data
- Apply analysis on climate model data (EU DestinE project: UseCase Energy Systems)



Thank you for listening…

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Website:

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

Video:

Portrait of Eye2Sky in 5 Min Video