Observing clouds from above and below – a chance for Redispatch 2.0?

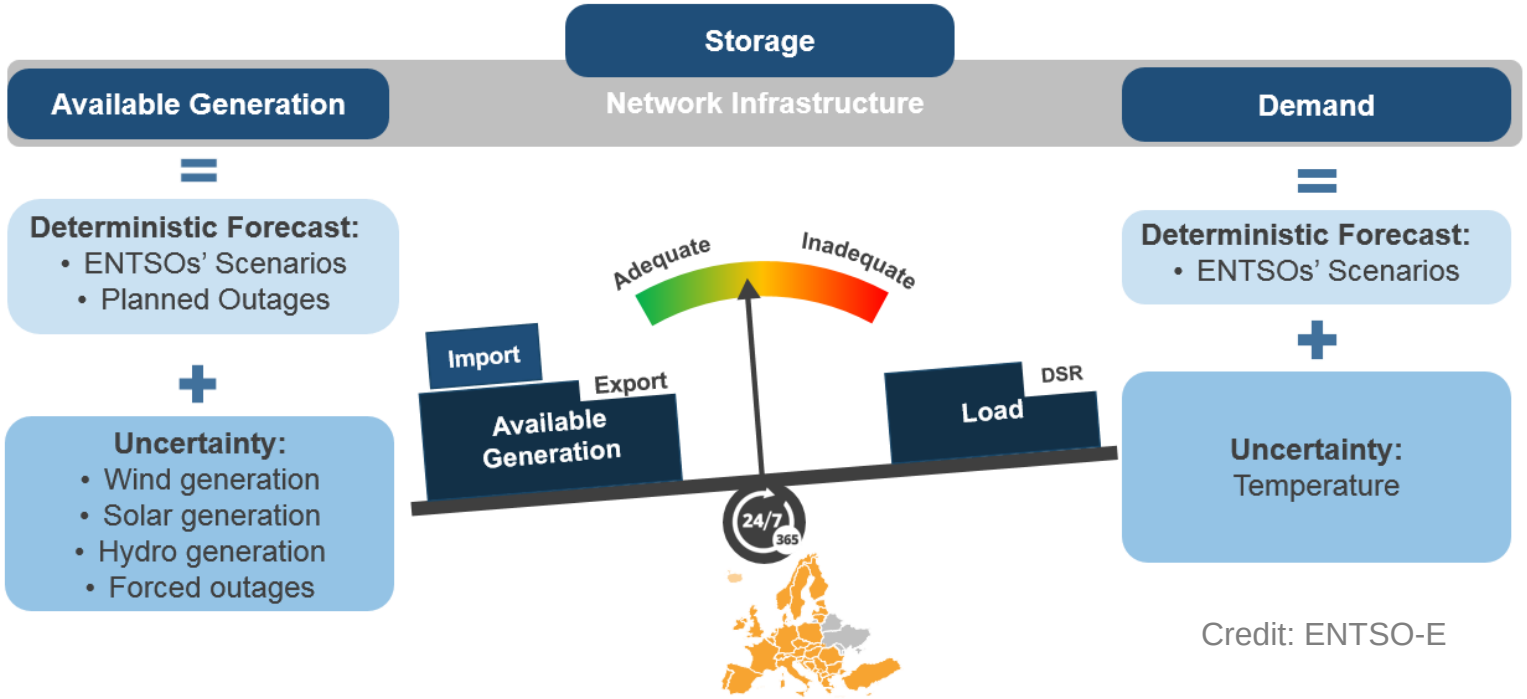
EUMETSAT Meteorological Satellite Conference, Malmö, Sweden, 11 to 15 September 2023

Marion Schroedter-Homscheidt, Thomas Schmidt, Jonas Stührenberg, Jorge Lezaca,
Bijan Nouri*, Niklas Blum*, Maximilian Schellhorn, Arindam Roy, Annette Hammer, Thomas Vogt

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

DLR

Balancing electricity generation & demand



Credit: ENTSO-E

Task in grid planning,
but also in daily operations
based on day ahead,
intraday and short term
information

Redispatch = ramping up/down production to solve a congestion

Generation is getting more regional, wind and especially solar
Additional need for monitoring & nowcasting

Redispatch gets more regional
case of Germany

Trasmission grid control zones
Source: www.netzentwicklungsplan.de

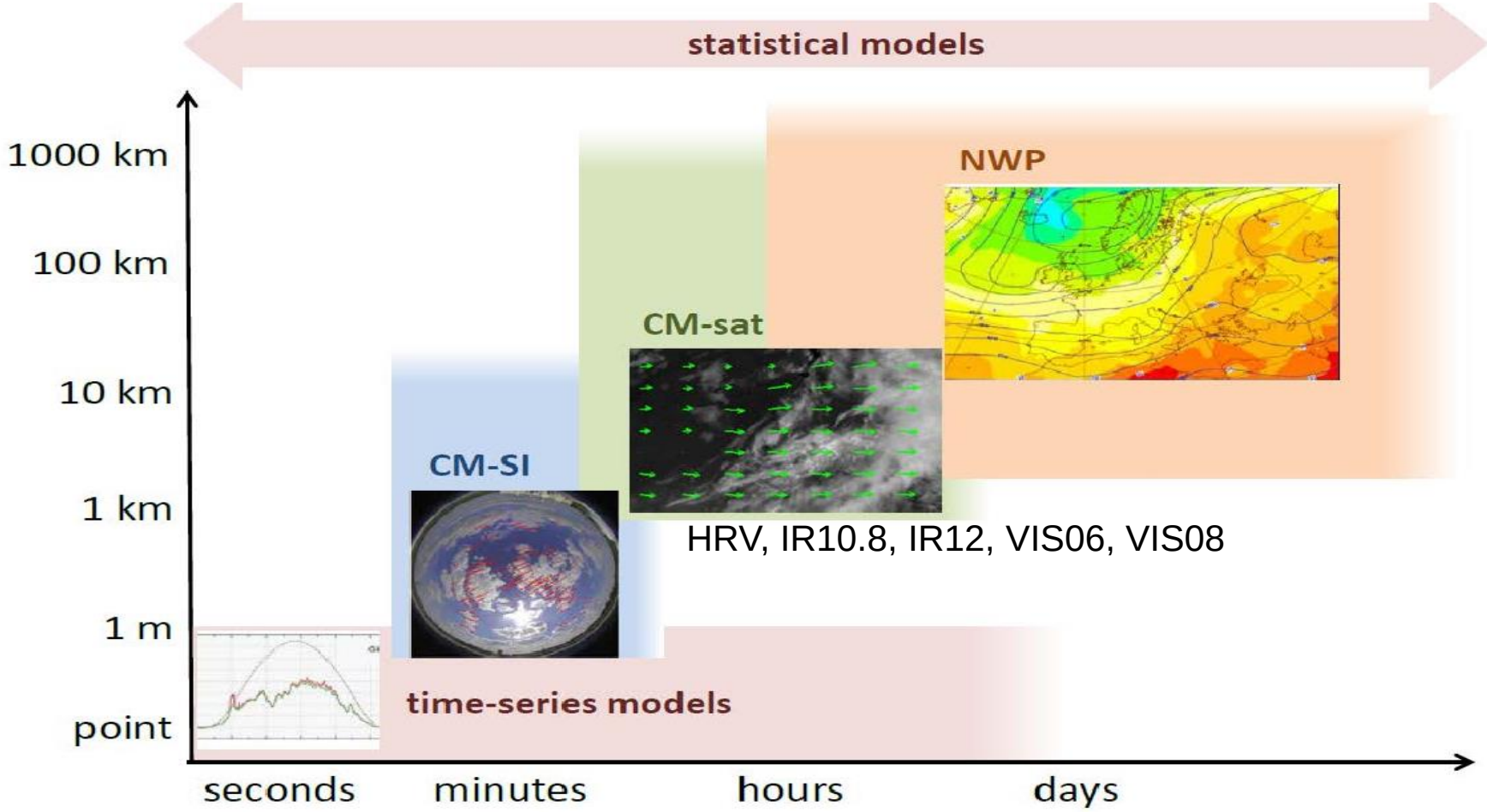
Redispatch 2.0:
Many distribution grid operators now included in redispatch process

Conventional & Renewables
> 100 kW

Old:
only plants
> 10 MW were included in Redispatch 1.0

Distribution grid operators
Source: https://www.enet.eu/portfolio/analysen/karten

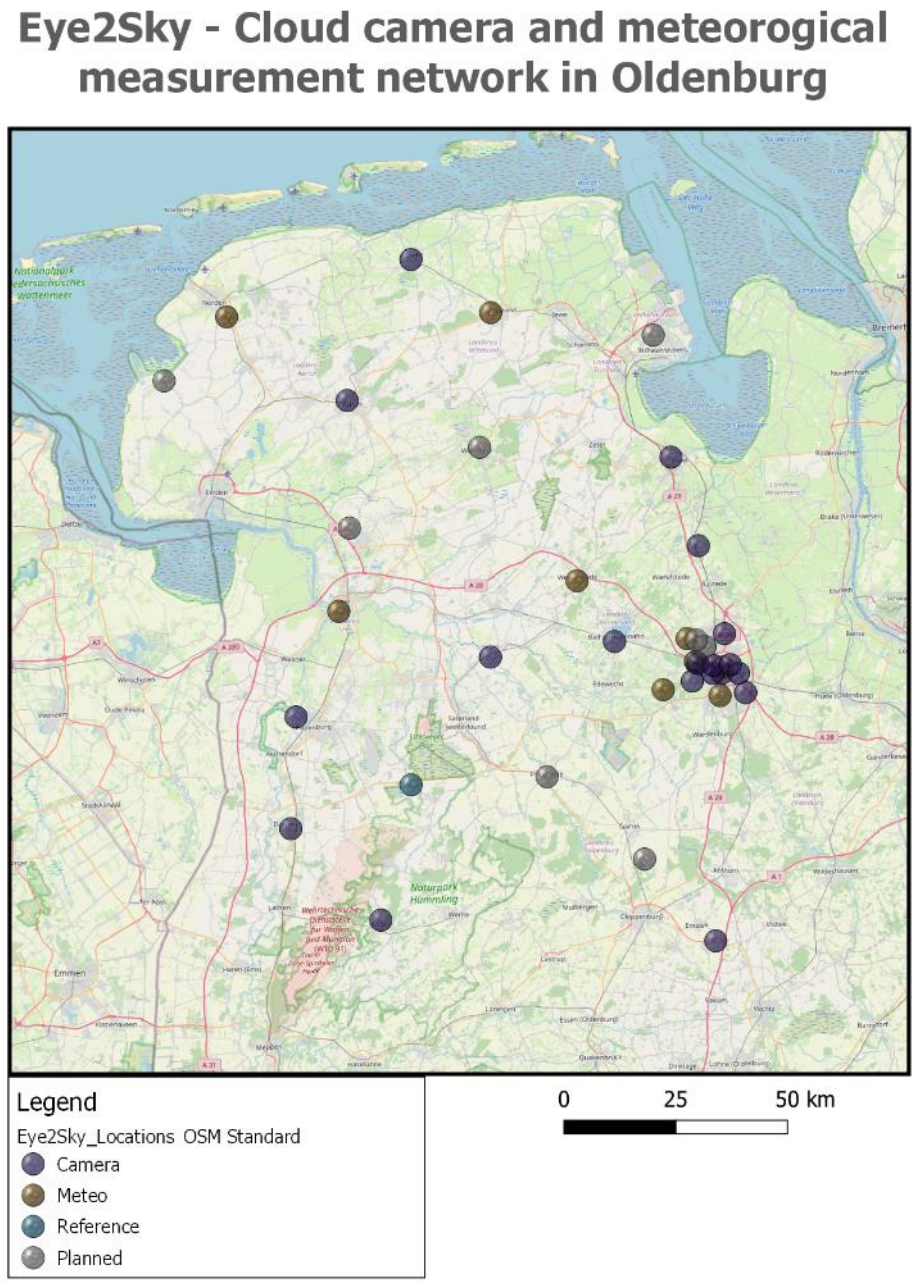
State-of-the-Art - Solar Power Forecasts



Sengupta et al.: Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications, Technical Report NREL/TP-5D00-63112, Denver, 236pp, 2015

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 the city of Oldenburg



Instrumentation

Meteorological sensors

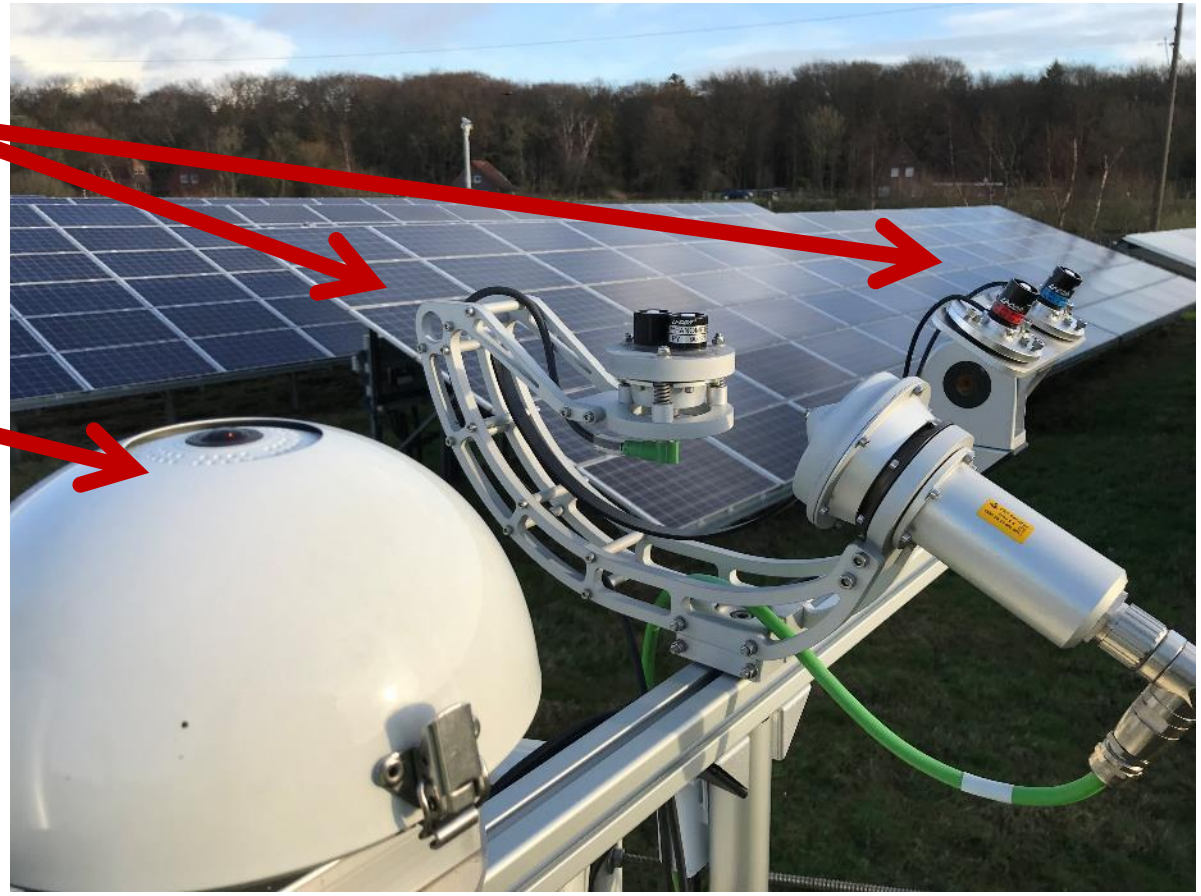
- Solar irradiance sensors (GHI, DHI, DNI, GTI)
- Air temperature and humidity

All-sky imagers

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

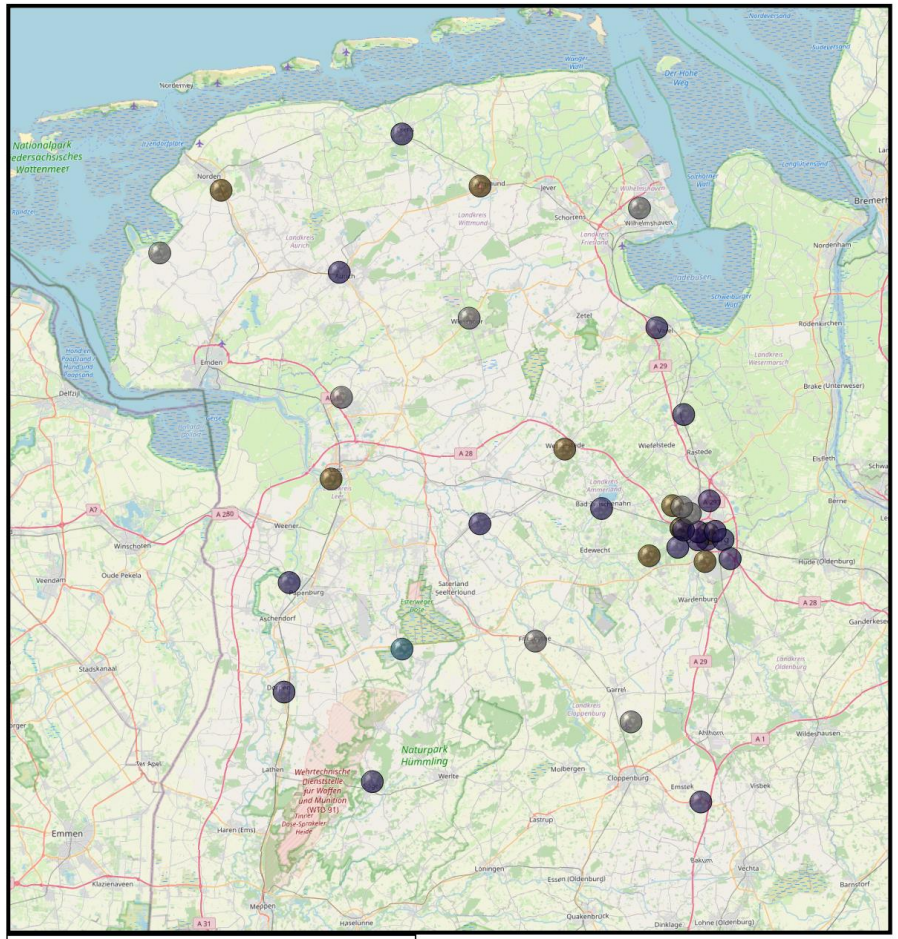
Ceilometers

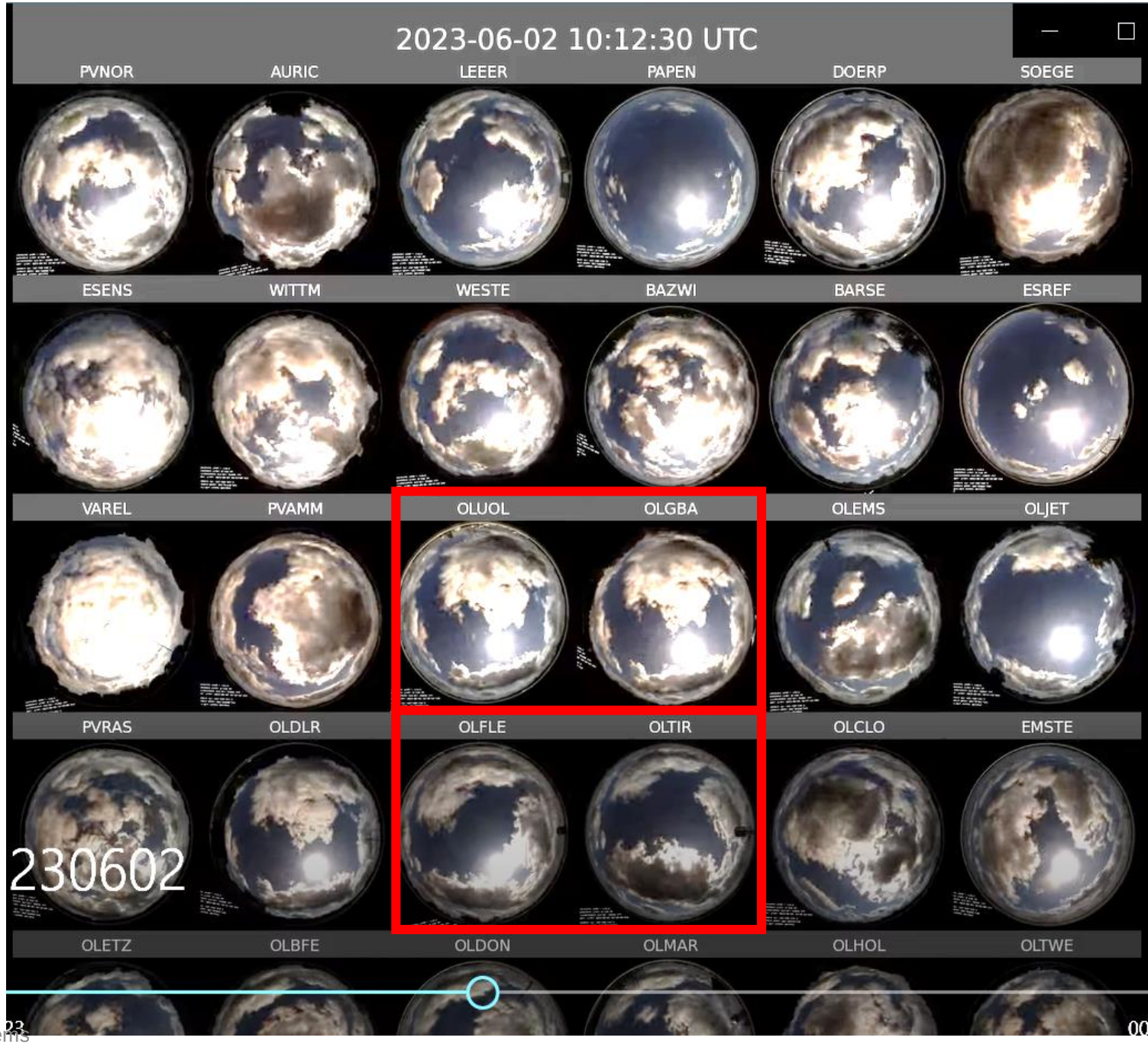
- 6 atmospheric lidars (ceilometer) measuring cloud height



Photography of Eye2Sky station PVNOR

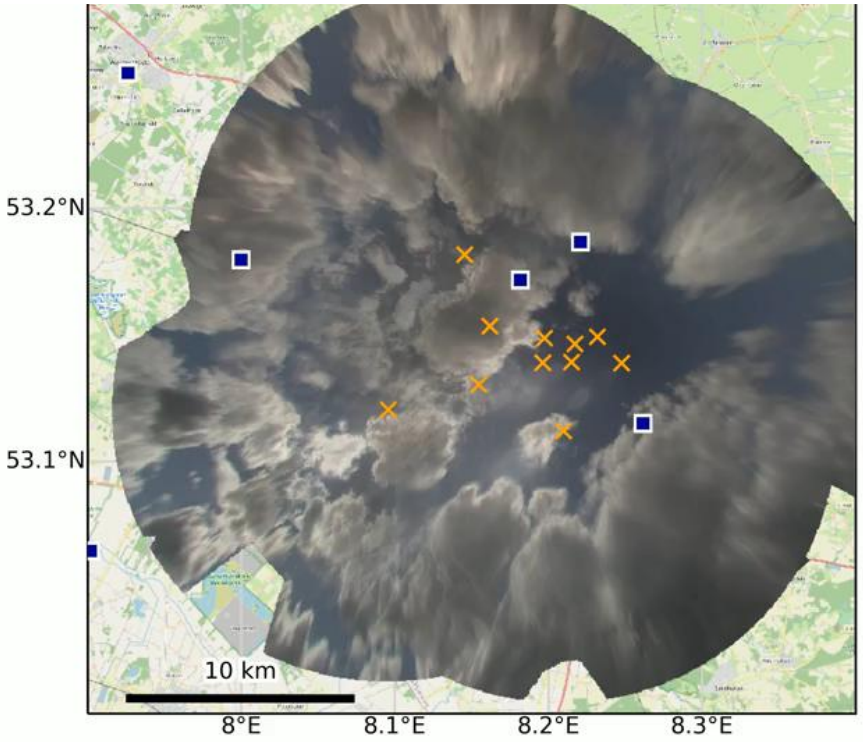
Eye2Sky - Cloud camera and meteorogical measurement network in Oldenburg



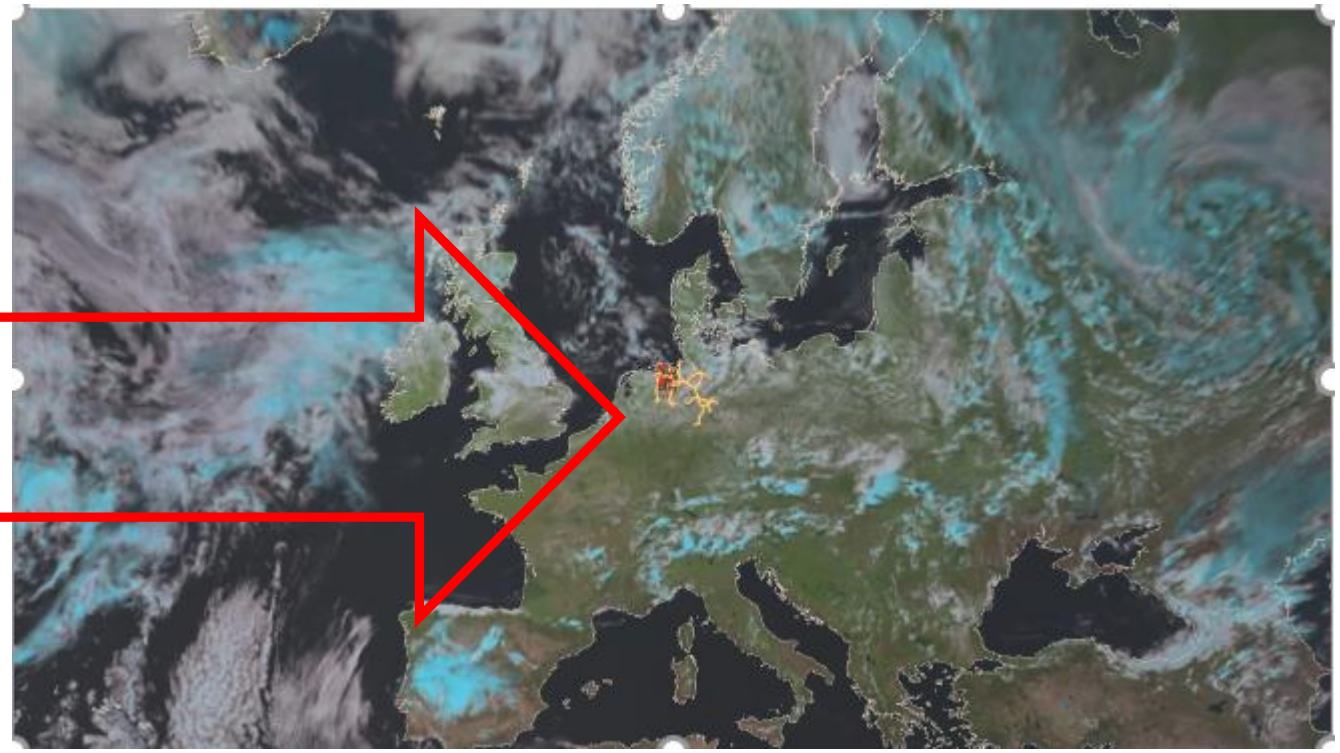


Clouds – as seen from below and above

ASI Network

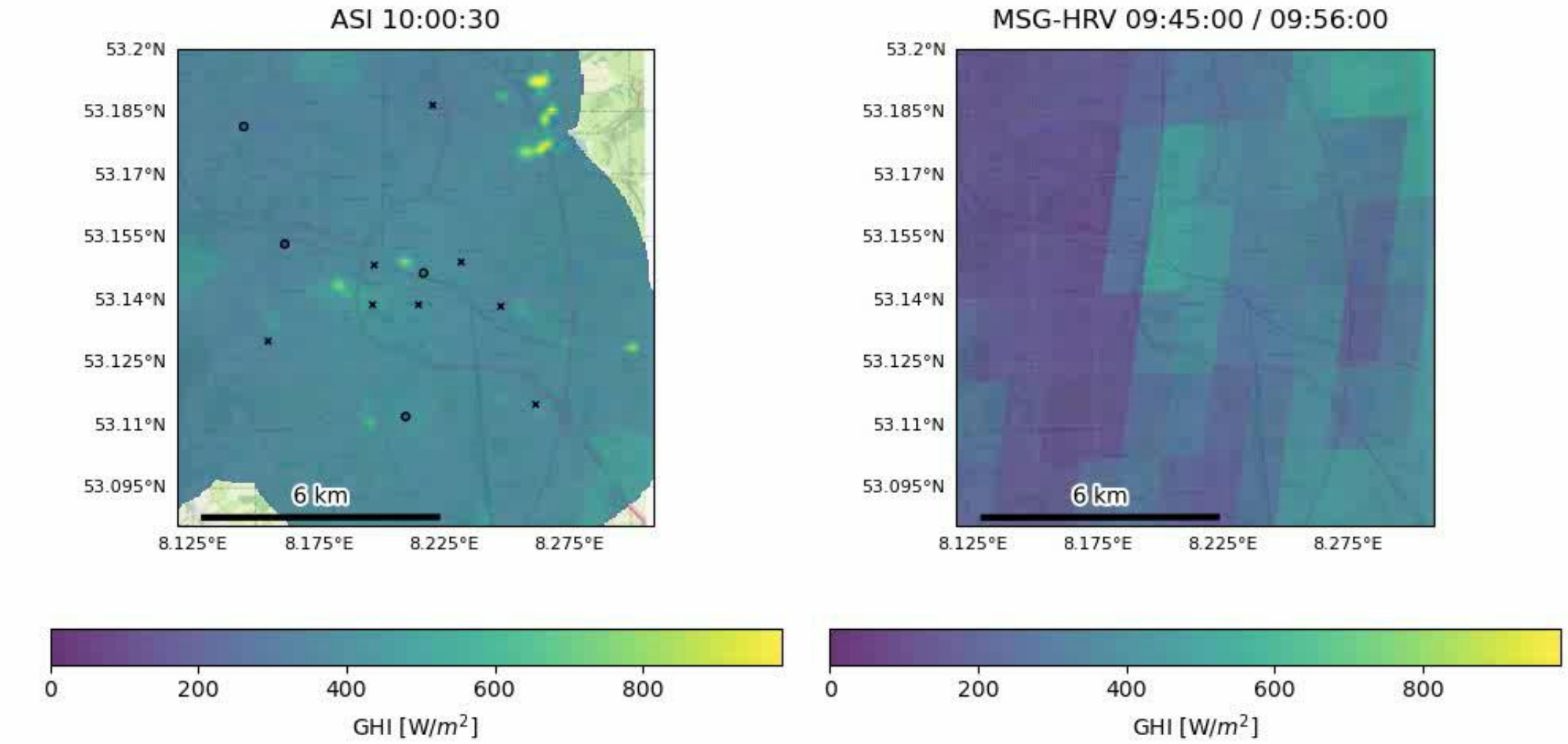


Meteosat Second Generation – Geostationary satellite



Temporal resolution: (ASI-Network – 30 seconds, MSG-Satellite – 15 minutes)

GHI map, 26.6. 2020, 10 to 11:50 UTC
ASI 30 sec, MSG 15 min, approx. 12.8 km window



SPATIAL RESOLUTION MATTERS?

Comparison of camera, satellite and weather model based data sets

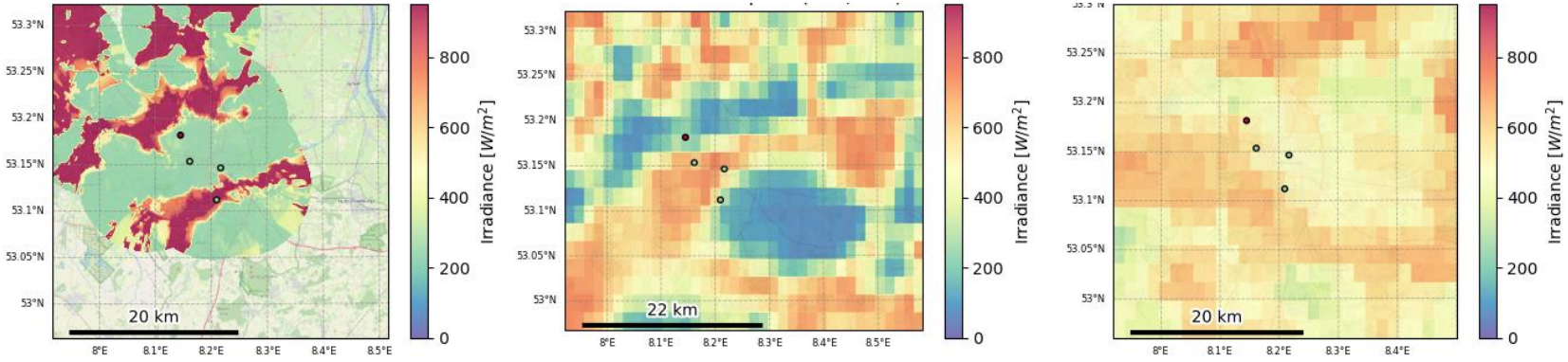
Parameter:
GHI

ASI Network
Δx = 50m
Δt = 1 min

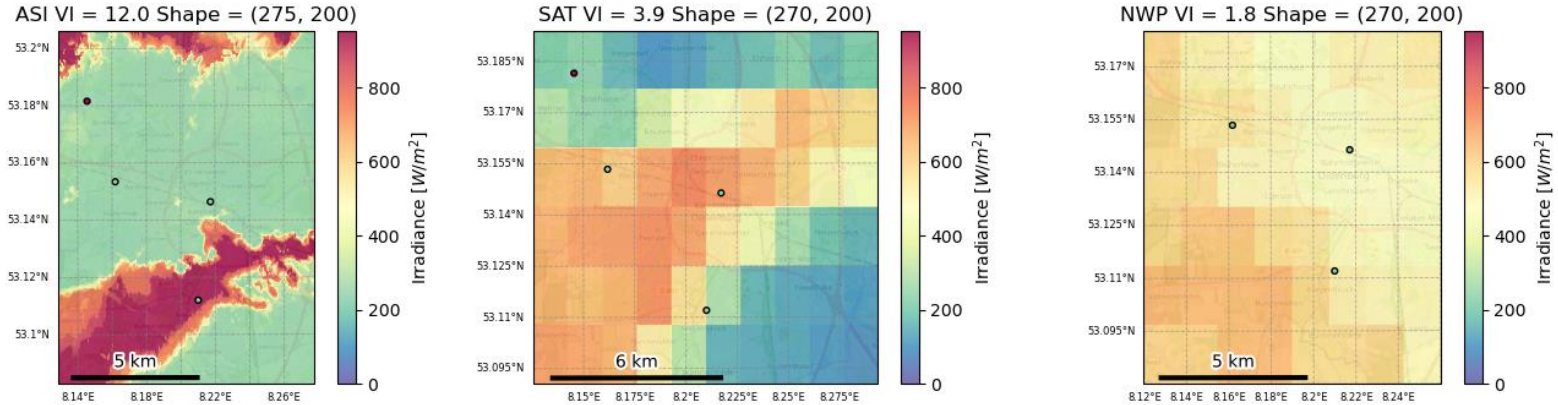
MSG-SAT
Δx ~ 2km
Δt = 15 min

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

Domain Oldenburg+
40 km x 40 km



Domain Oldenburg
13.27 km x 10 km

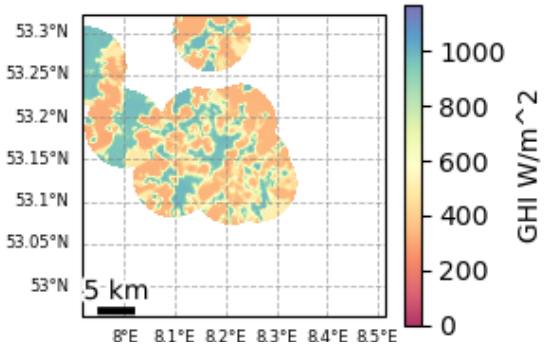


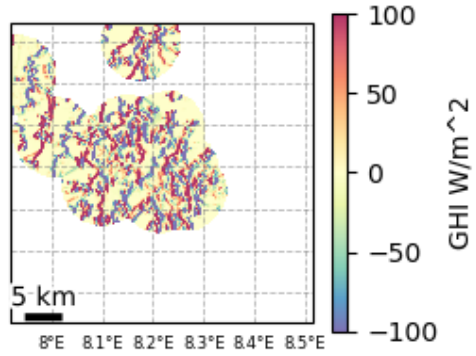
Impact of reducing spatial resolution
of ASI data

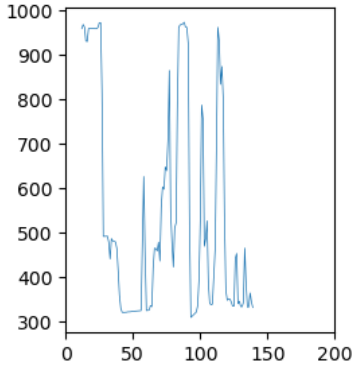
- Reduction in spatial resolution leads to smoothing of cloud edges
- Depending on the size of cloud patterns and grade of smoothing, spatial and temporal patterns are affected

GHI map | **GHI Gradients**

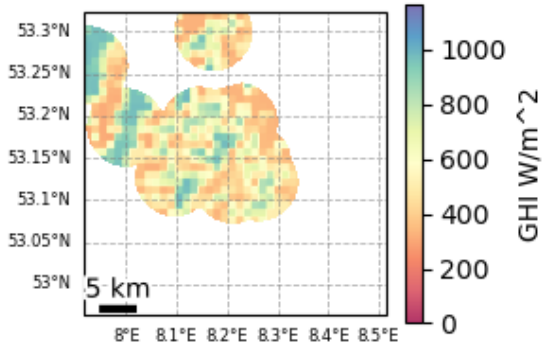
200m

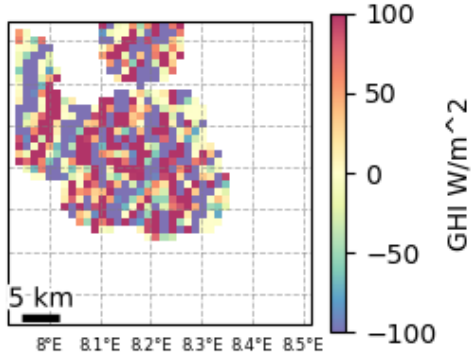


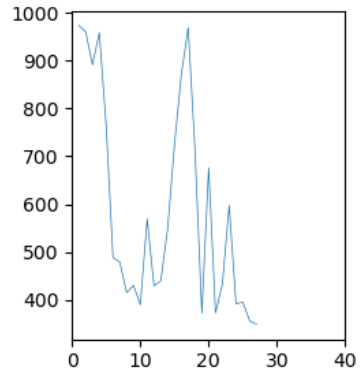




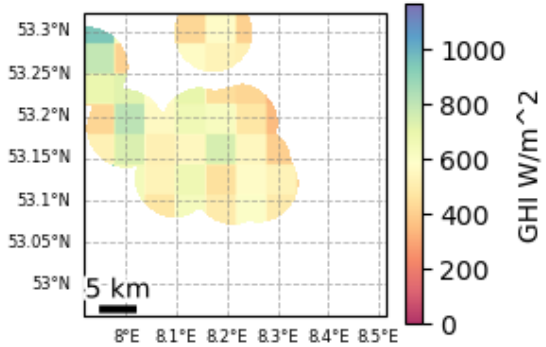
1000m

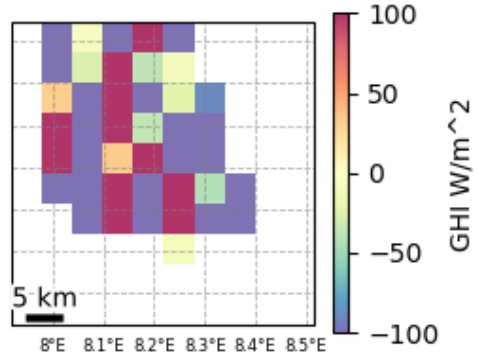


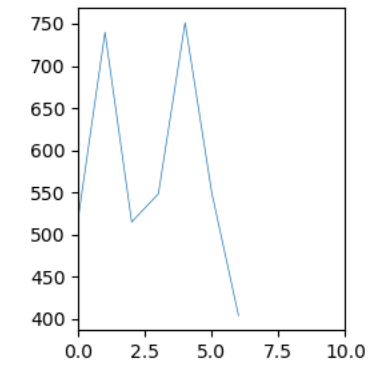




4000m







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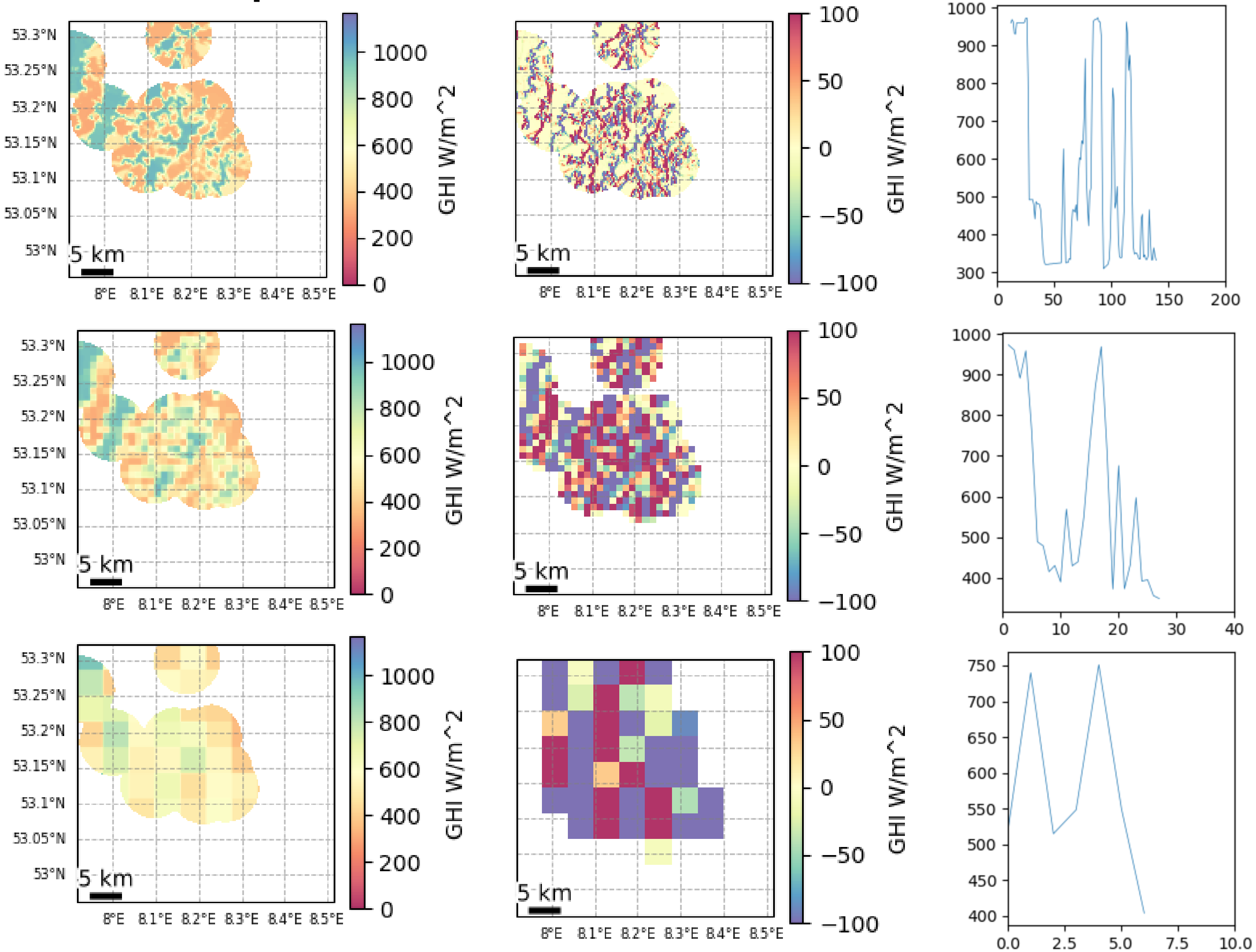
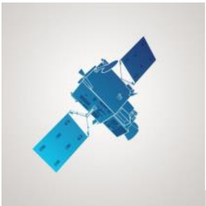
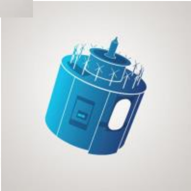
200m



MSG, MTG





1000m

4000m

Destination Earth

ICON – D2

SOLAR IRRADIANCE FORECASTING

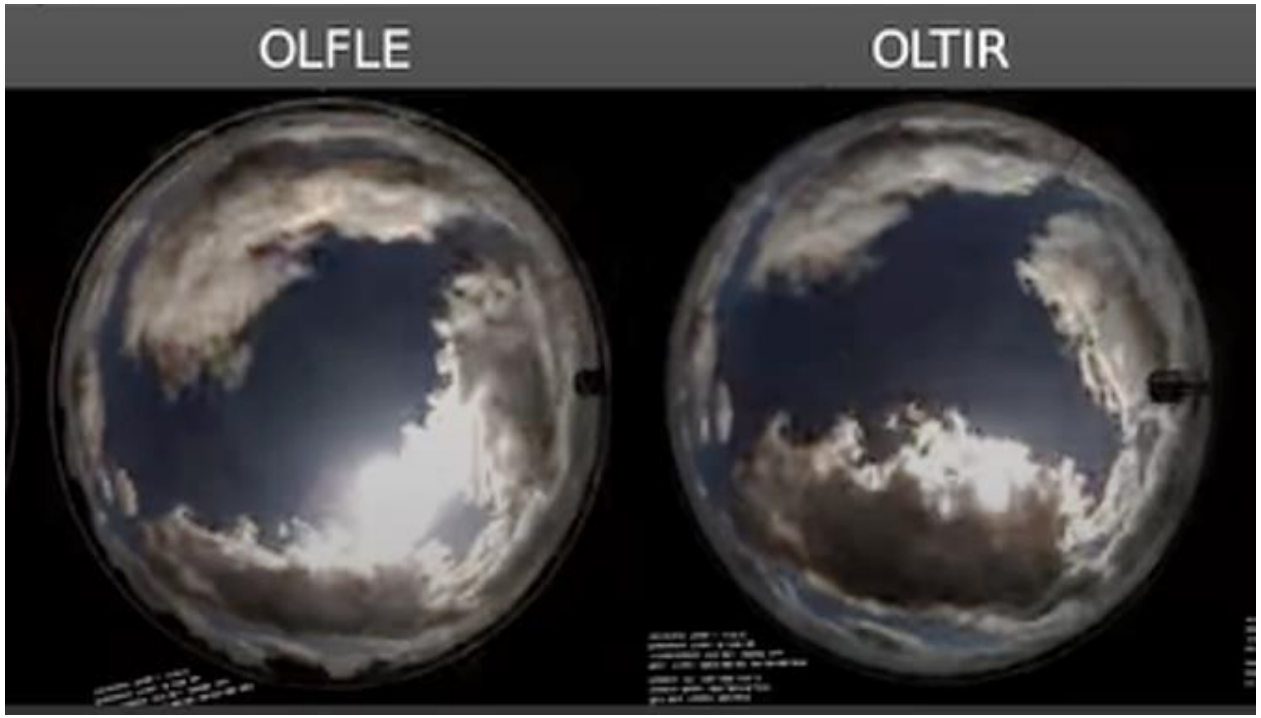
What do we need to know for deterministic forecasting?

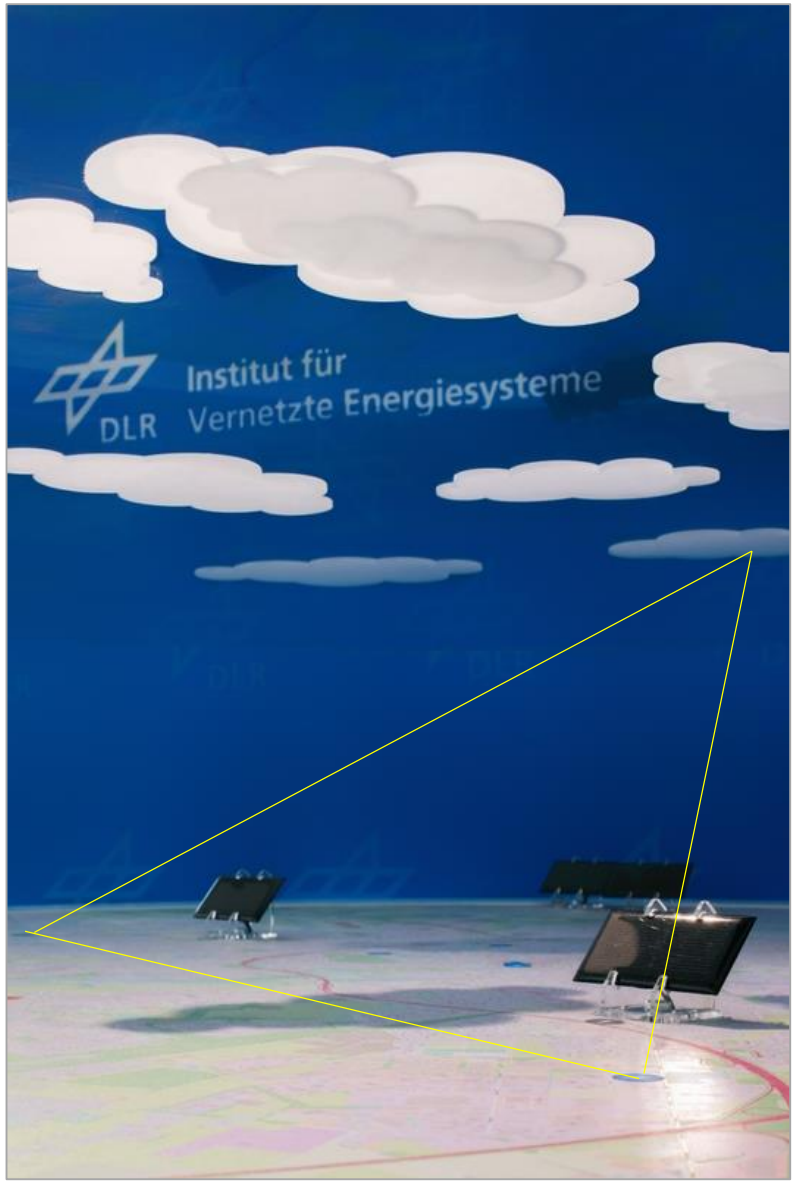
- Clear sky model
- Optical thickness of clouds / transmission

- Future positions of clouds (and sun)
- Cloud Motion Vectors

What do we need to know for deterministic forecasting?

- Use two cameras for cloud height detection





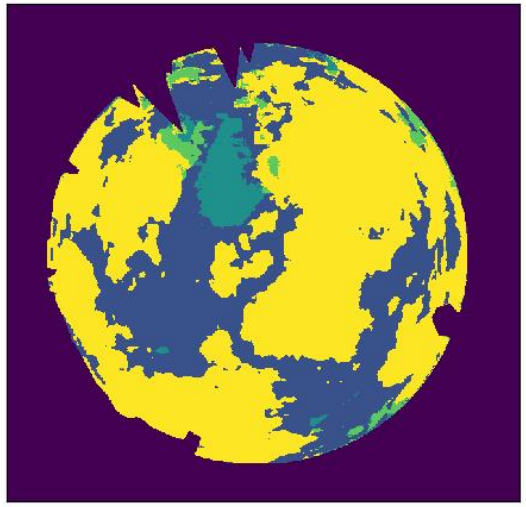
Cloud Detection – Semantic Segmentation

clear sky

low layer clouds

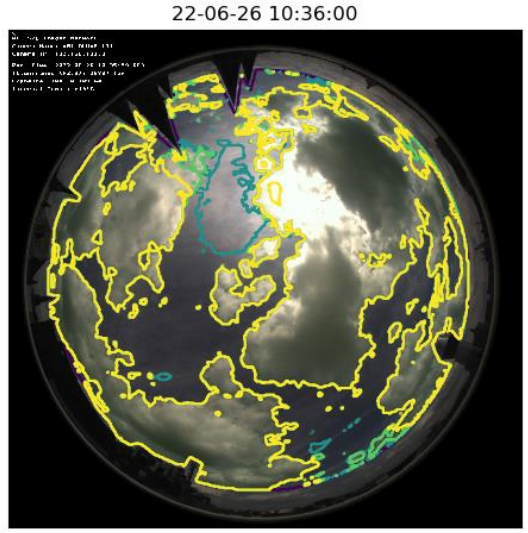
mid layer clouds

high layer clouds

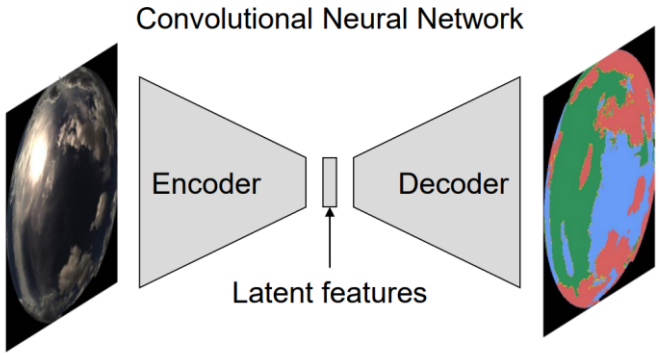


Cloud classes

original RGB image



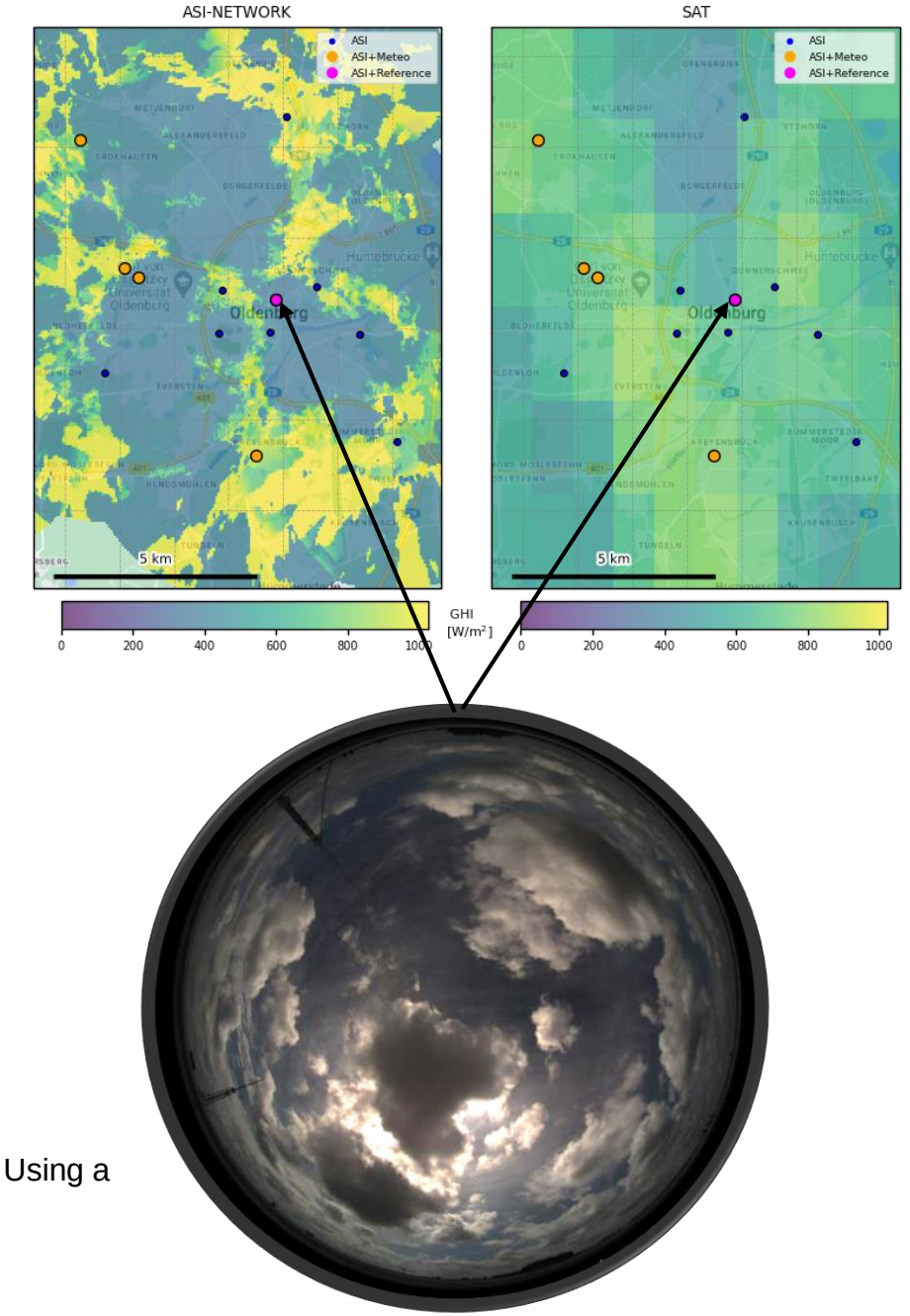
cloud edges



Fabel, Y.; Nouri, B.; Wilbert, S.; Blum, N.; Triebel, R.; Hasenbalg, M.; Kuhn, P.; Zarzalejo, L.F.; Pitz-Paal, R.
Applying self-supervised learning for semantic cloud segmentation of all-sky images.
Atmos. Meas. Tech. **2022**, *15*, 797–809.

30min ahead forecasting for domain Oldenburg

- Large differences in cloud/irradiance resolutions between camera and satellite
- Satellite (here MSG-HRV with Heliosat3 method) and other coarse resolution data sources smooth fields and timeseries



Blum, Niklas, 2022: Nowcasting of Solar Irradiance and Photovoltaic Production Using a Network of All-Sky Imagers. Dissertation, RWTH Aachen

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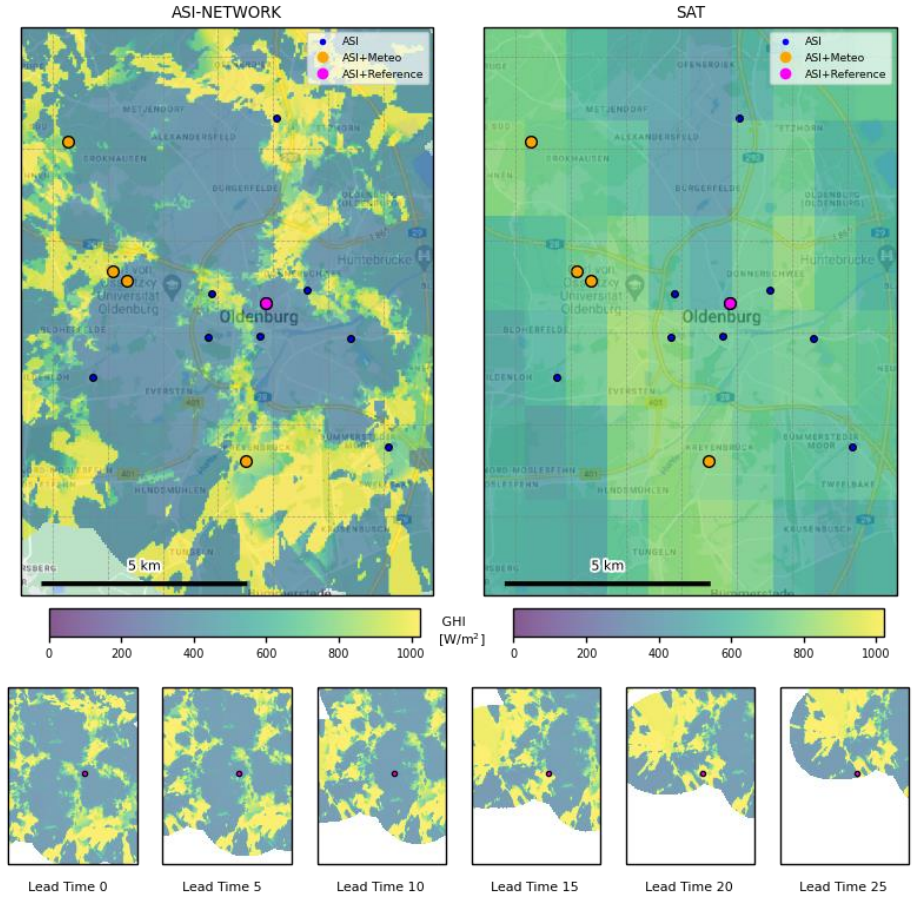

Cloud direction

Blum, Niklas, 2022: Nowcasting of Solar Irradiance and Photovoltaic Production Using a Network of All-Sky Imagers. Dissertation, RWTH Aachen

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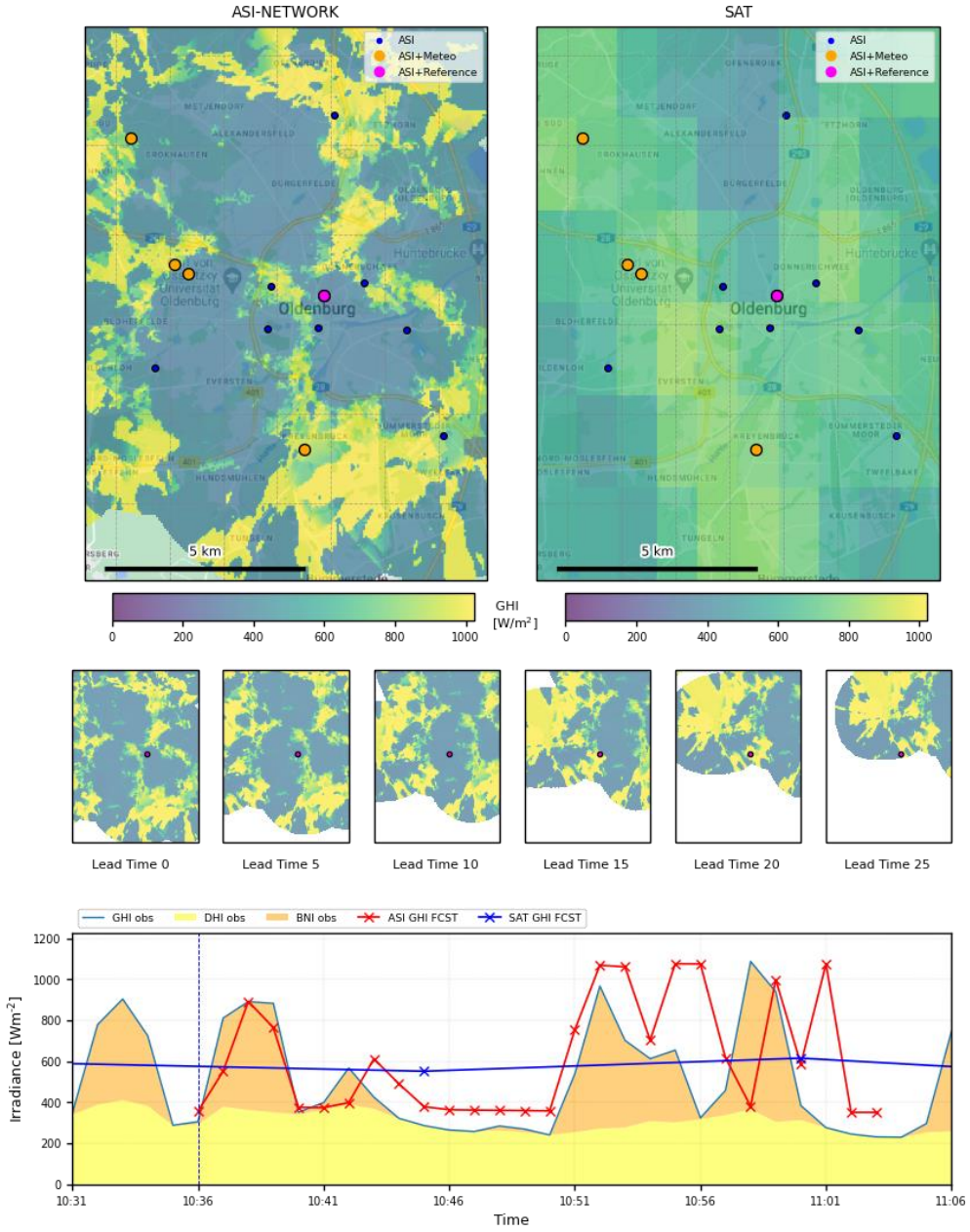
- One-minute timescale – validation at single sites?



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

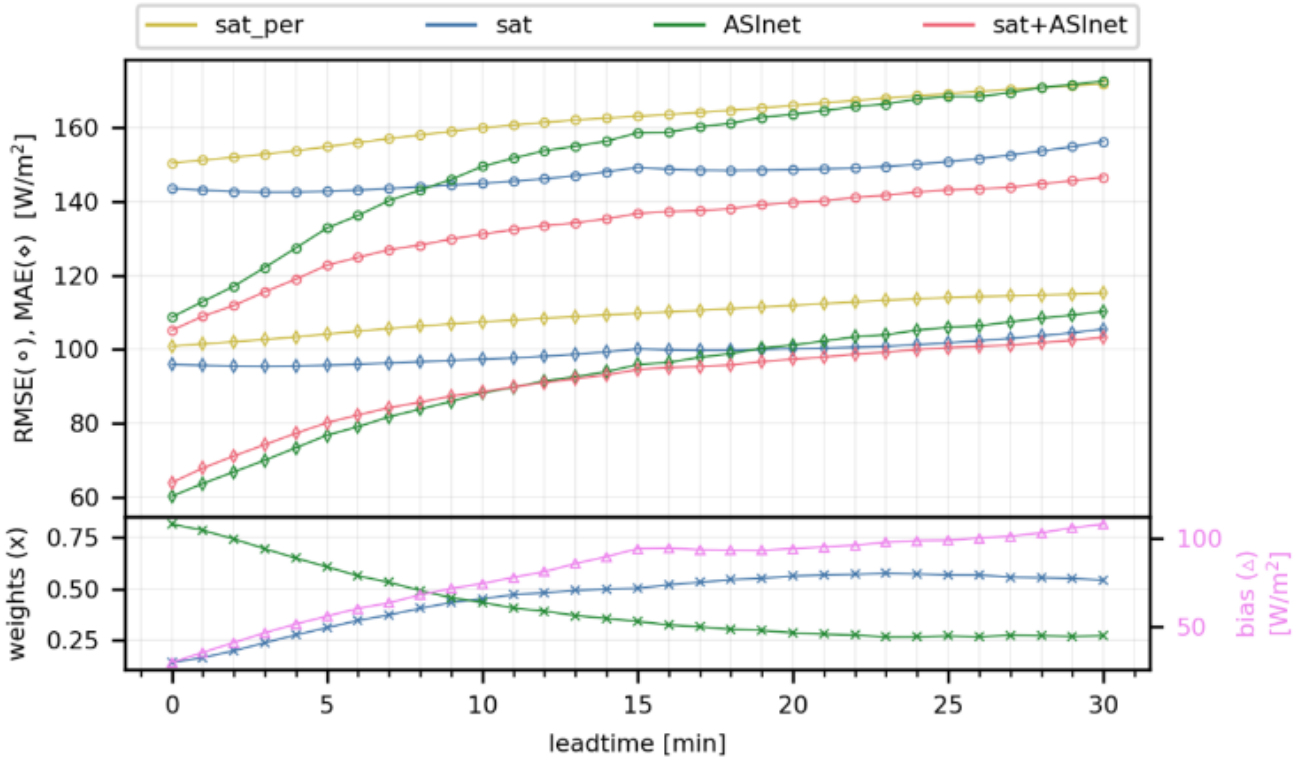


Figure 15. Benchmark for the combined forecast on the nominal synchronization case. ***Top****: Error metrics RMSE(○) and MAE(◊).* ***Bottom****: average optimized combination weights(x) and optimized combination bias term (△) in the secondary axis.*

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

Conclusion

High resolution cloud observations from above and below were shown.

The network is operational – now we are preparing for grid integration studies.

Used as a testbed to assess NWP and climate scenario data

Do NWP and DestinE digital twins include suitable weather patterns for infrastructure planning?

Spatial resolution matters

But which spatial resolution do we need for which application?

Redispatch of a larger PV park, management of many small systems, management in an energy neighbourhood?

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- DLR-Project DESYS (Design and operation of networked energy systems)