A hybrid solar irradiance nowcasting approach: combining all sky imager systems and persistence irradiance models for increased accuracy

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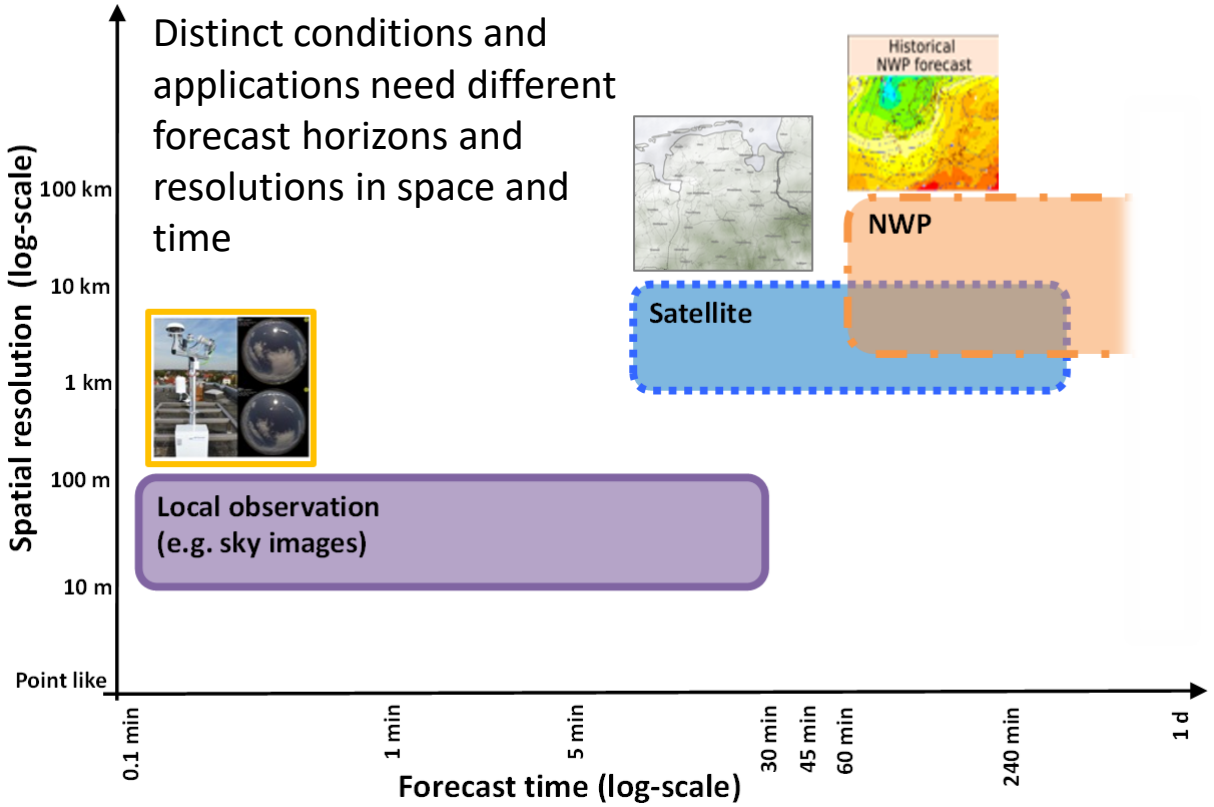
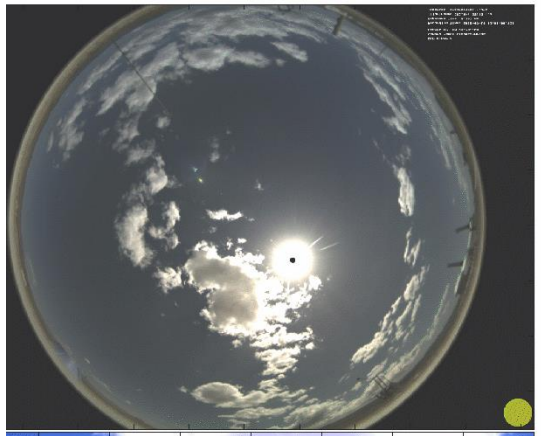
Overview

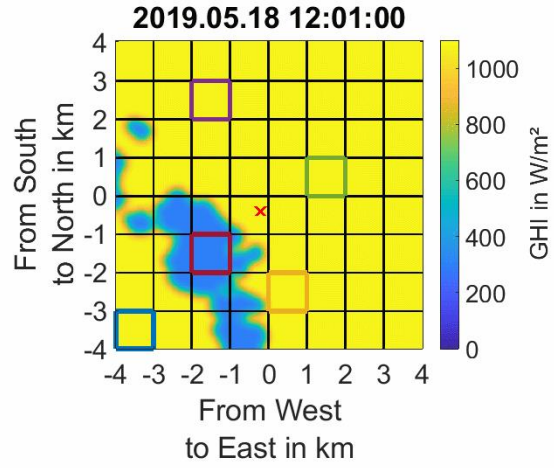
- Motivation
- Nowcasting systems
  - Persistence approach
  - All sky imager approach
  - Hybrid approach
- Validation
- Conclusion

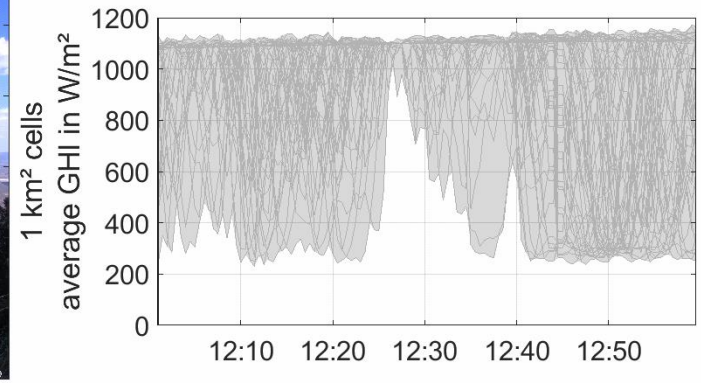
Motivation

Distinct conditions and applications need different forecast horizons and resolutions in space and time







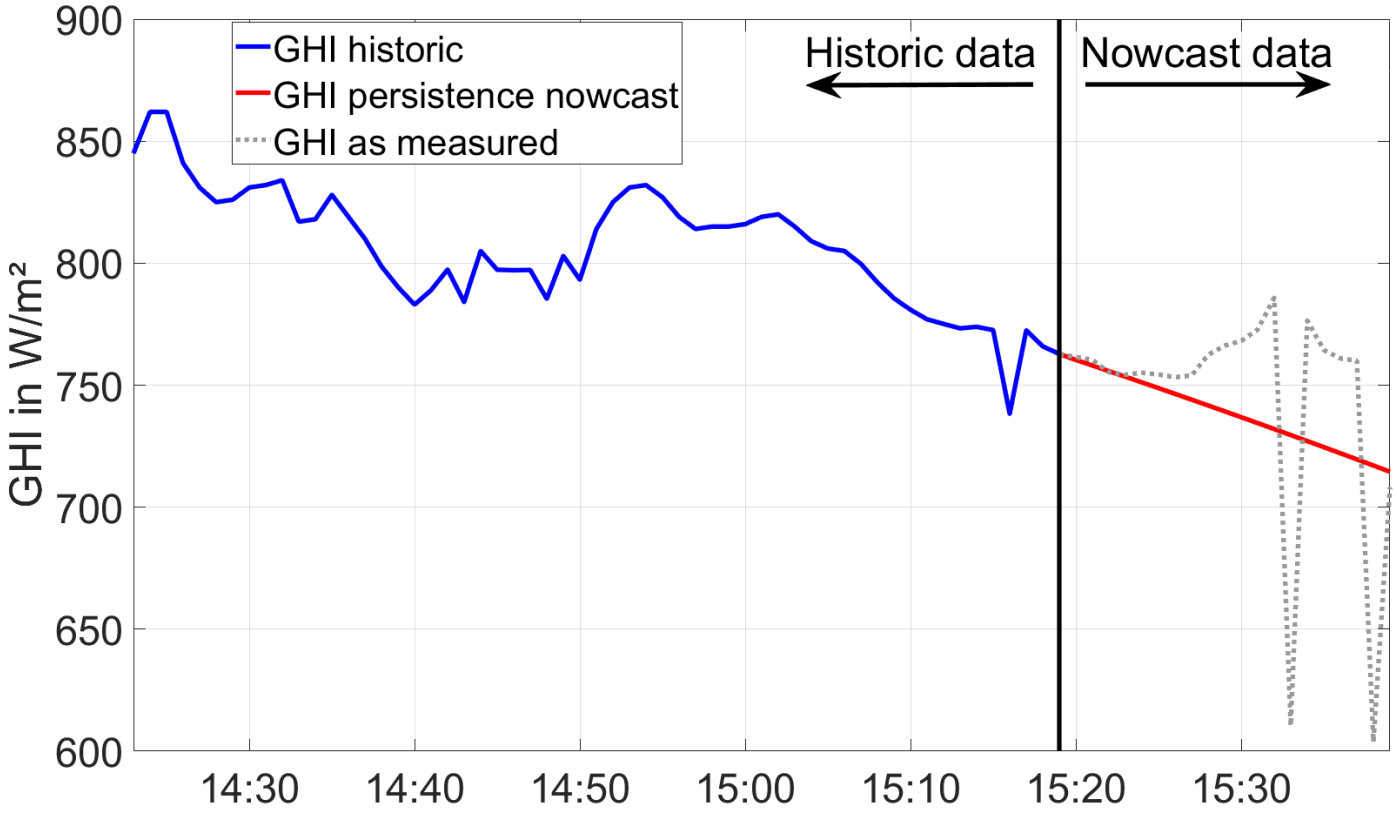


- Strong solar irradiance variabilities in space and time on the local scale occur due to cloud passing
- Derive nowcasts from local observations which are suitable to describe variabilities induced by clouds
- Improved situational awareness → better local grid and power plant management under error prone variable conditions (e.g. less curtailment, cheaper balancing, extended battery life,…)
- Nowcasts accuracy is decisive → **objective reduce nowcast uncertainties**

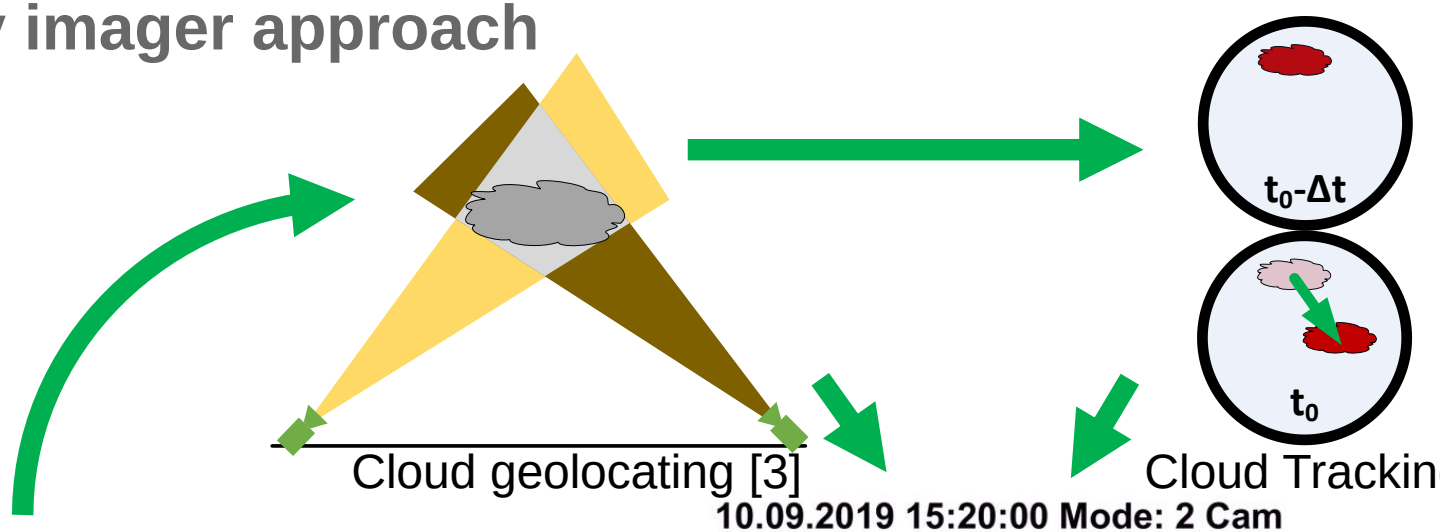
Nowcasting systems
Persistence approach

Persistence nowcast is based on the work from Ineichen & Perez (2002) [1]

- Linke turbidity factor (TL) is calculated using the GHI
- For GHI nowcasts the TL is kept constant while considering future solar positions



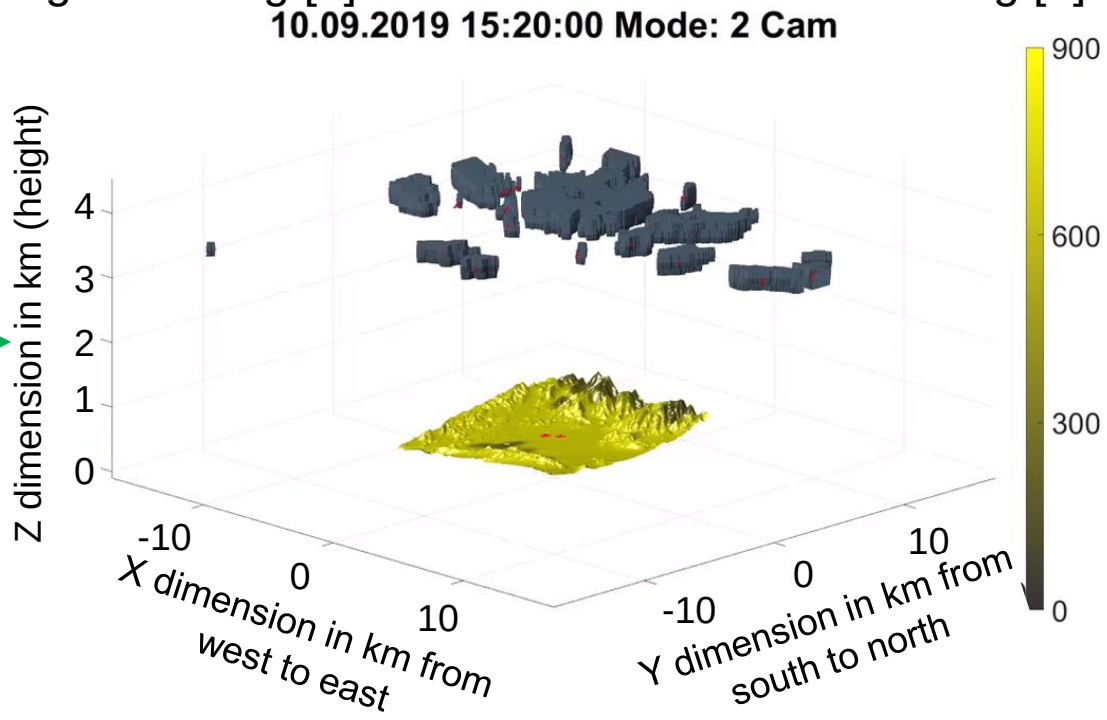
Nowcasting systems
All sky imager approach



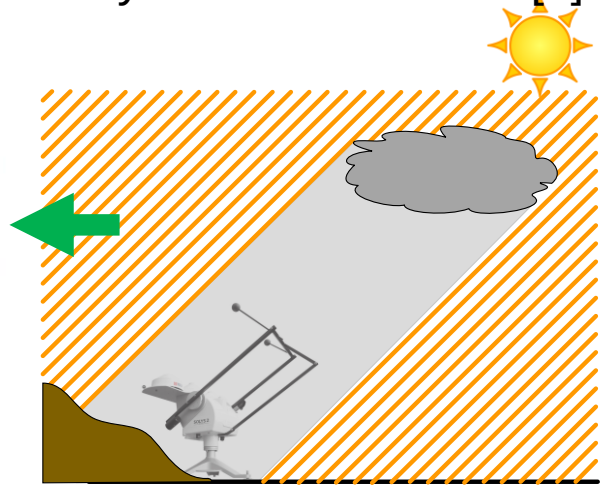
Cloud geolocating [3]

Cloud Tracking [3]

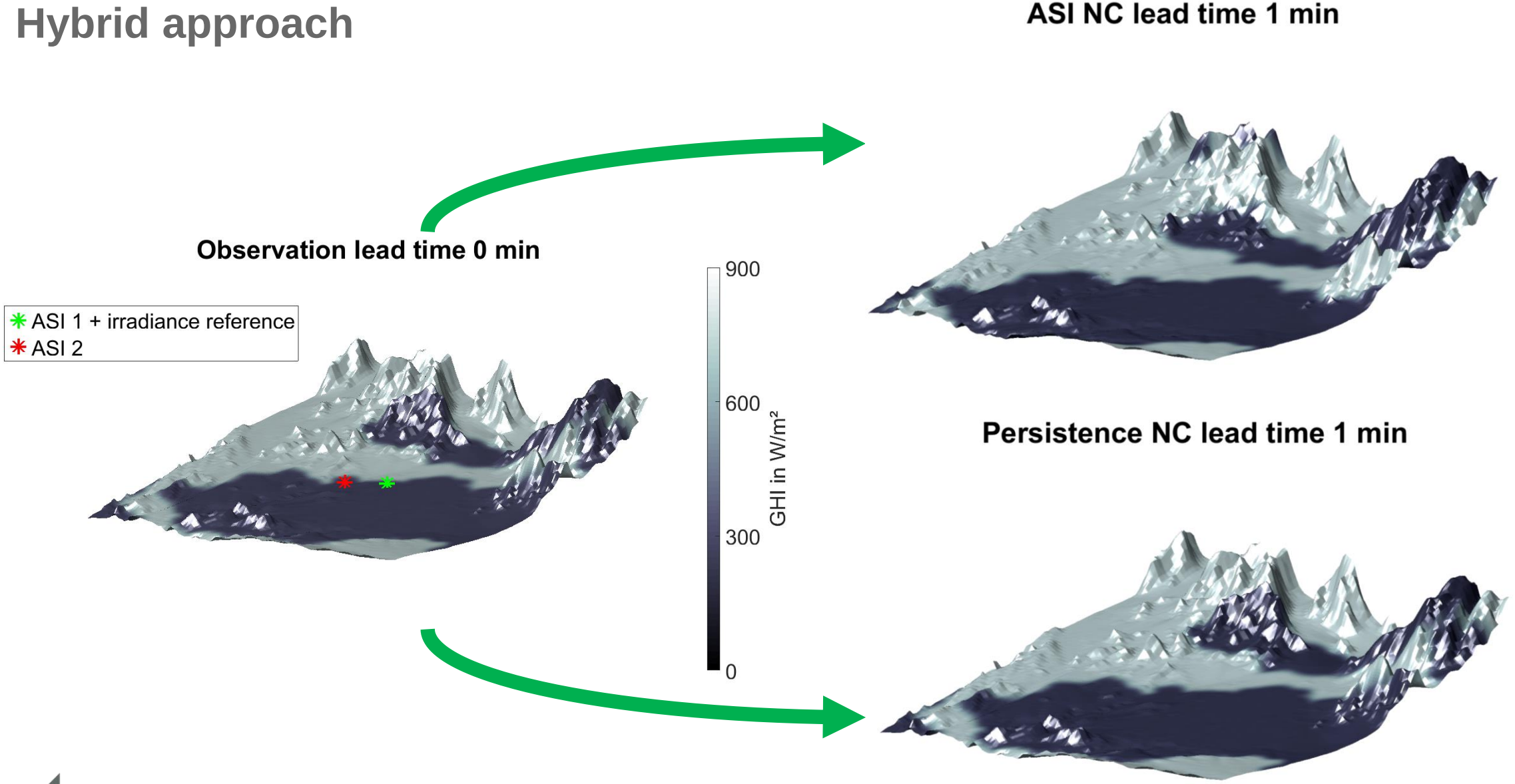
Cloud detection & classification [2]



Cloud shadow projection & analyze radiative effect [4]

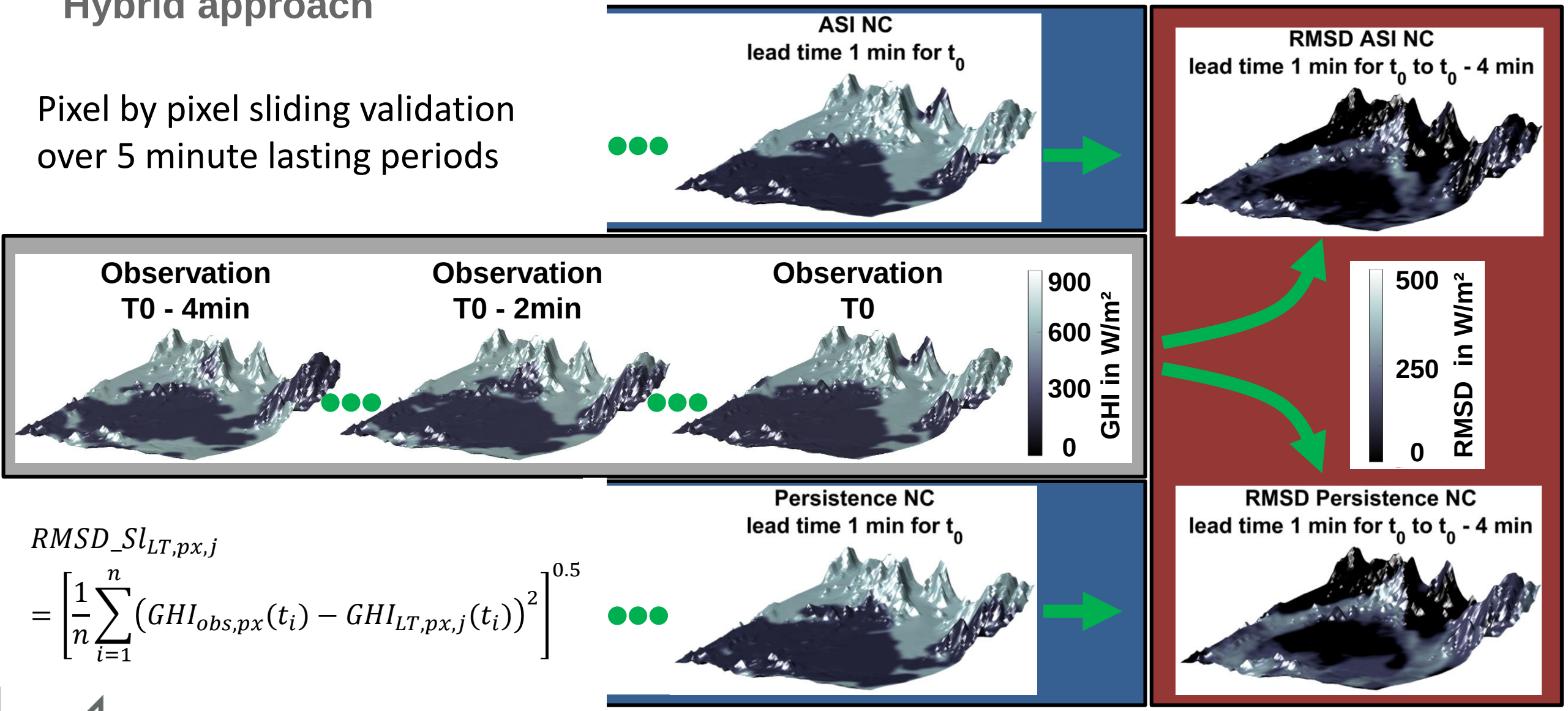


Hybrid approach



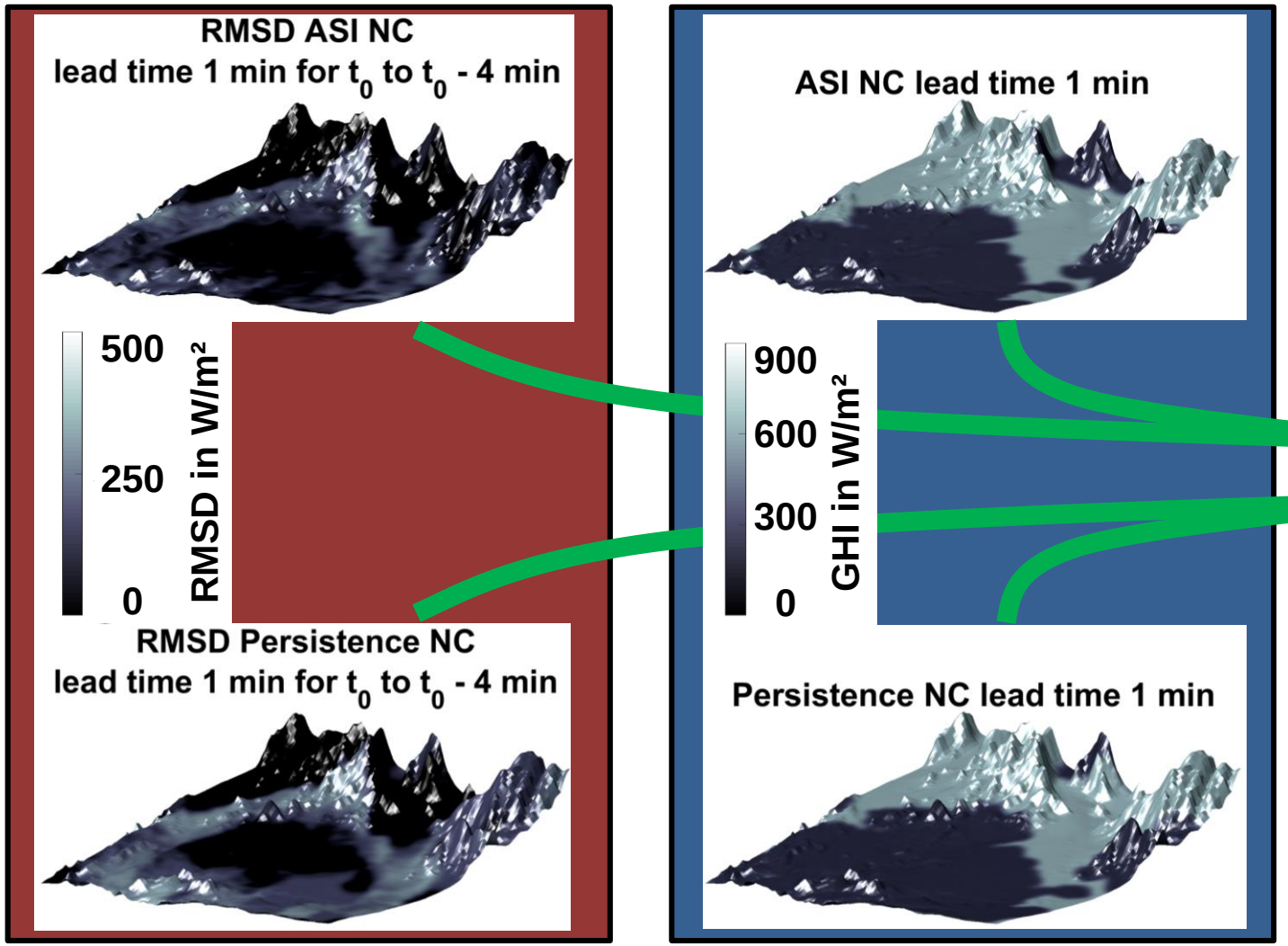
Hybrid approach

Pixel by pixel sliding validation over 5 minute lasting periods



$$RMSD\_Sl_{LT,px,j} = \left[\frac{1}{n}\sum_{i=1}^{n}\left(GHI_{obs,px}(t_i) - GHI_{LT,px,j}(t_i)\right)^2\right]^{0.5}$$

Hybrid approach

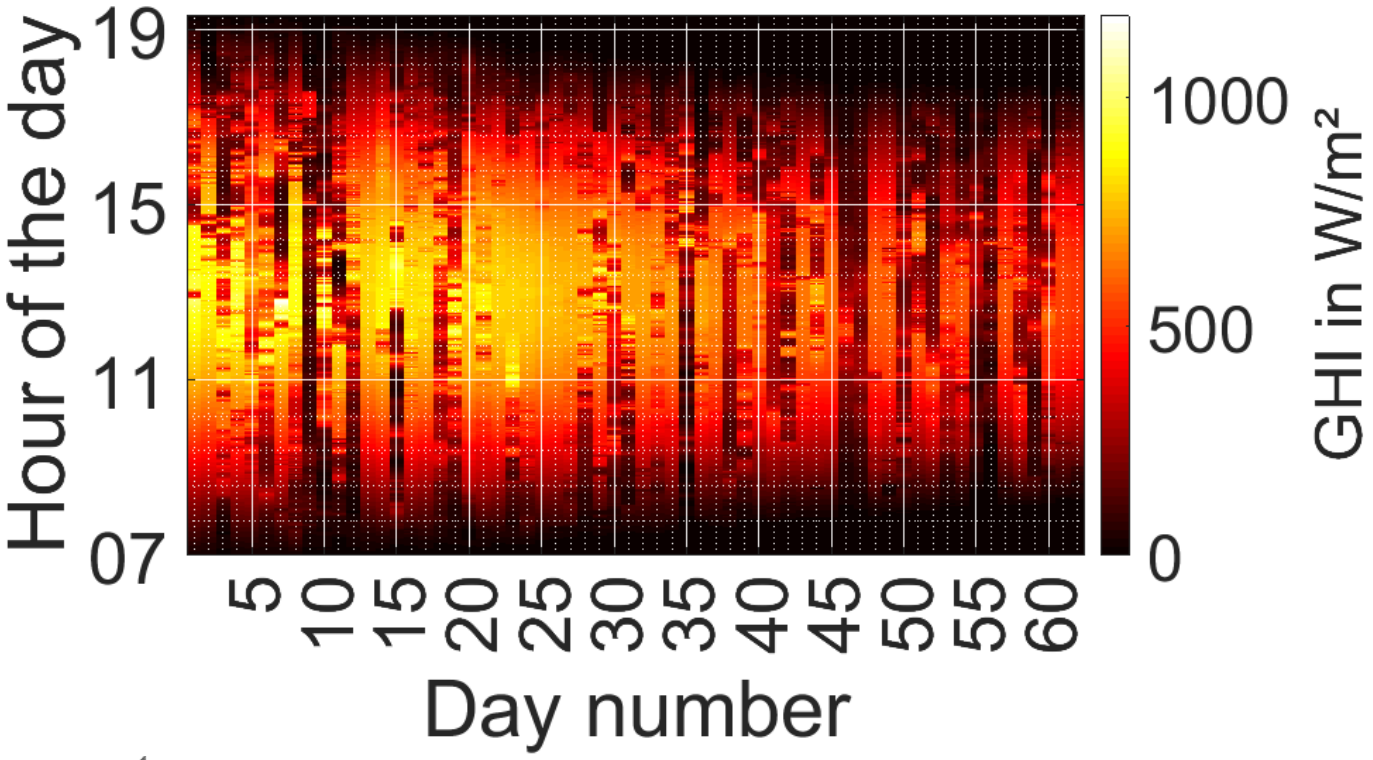


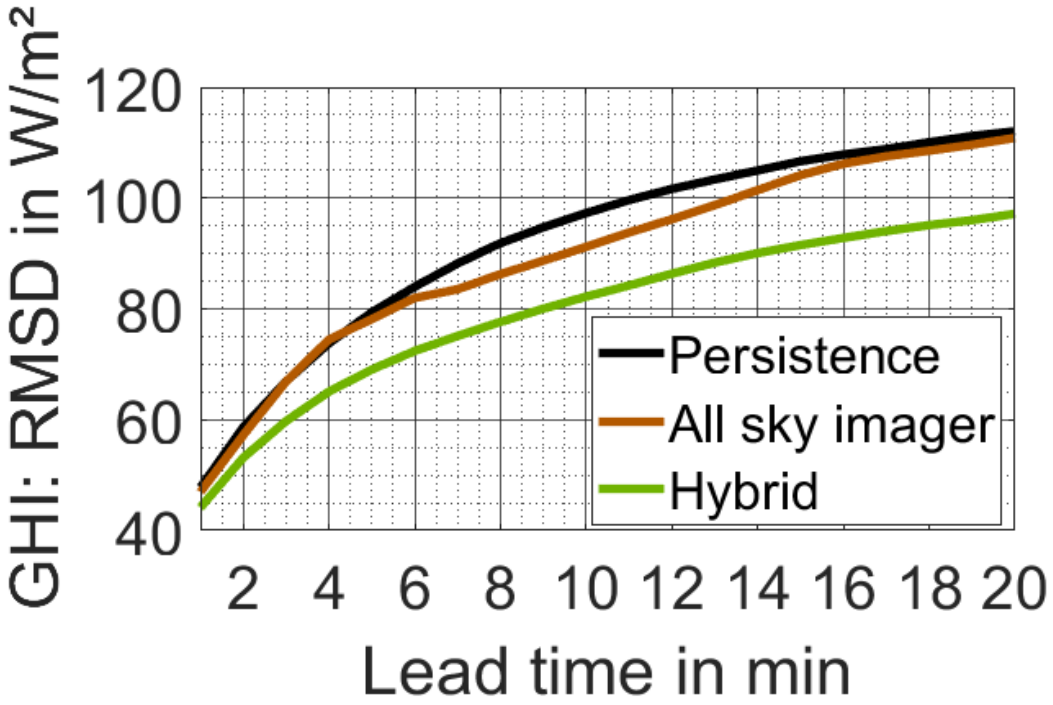
- RMSD derived from previous nowcasts
- Current nowcasts which describe future conditions
- Combined hybrid nowcasts using accuracy weighting approach [5]

$$GHI_{LT,px} = \frac{1}{\sum_{j=1}^{2} \frac{1}{RMSD\_Sl_{LT,px,j}}} \cdot \sum_{j=1}^{2} \frac{GHI_{LT,px,j}}{RMSD\_Sl_{LT,px,j}}$$

Validation

- Validation period: 62 days at CIEMAT's Plataforma Solar de Almería (Spain)
- Reference systems: eight pyranometers spatially distributed over ≈1 km²

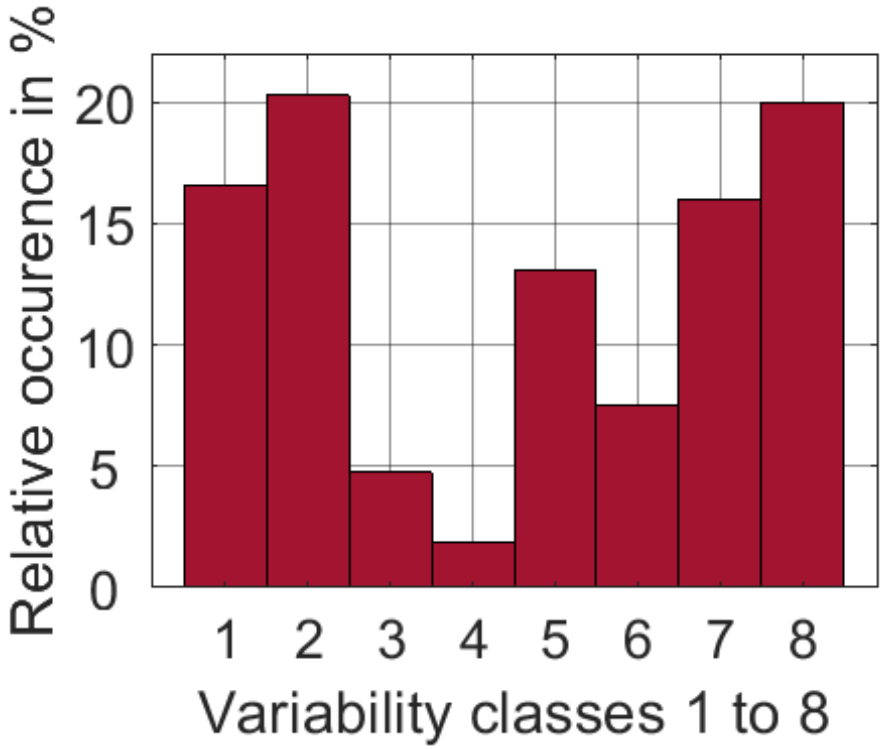




Validation

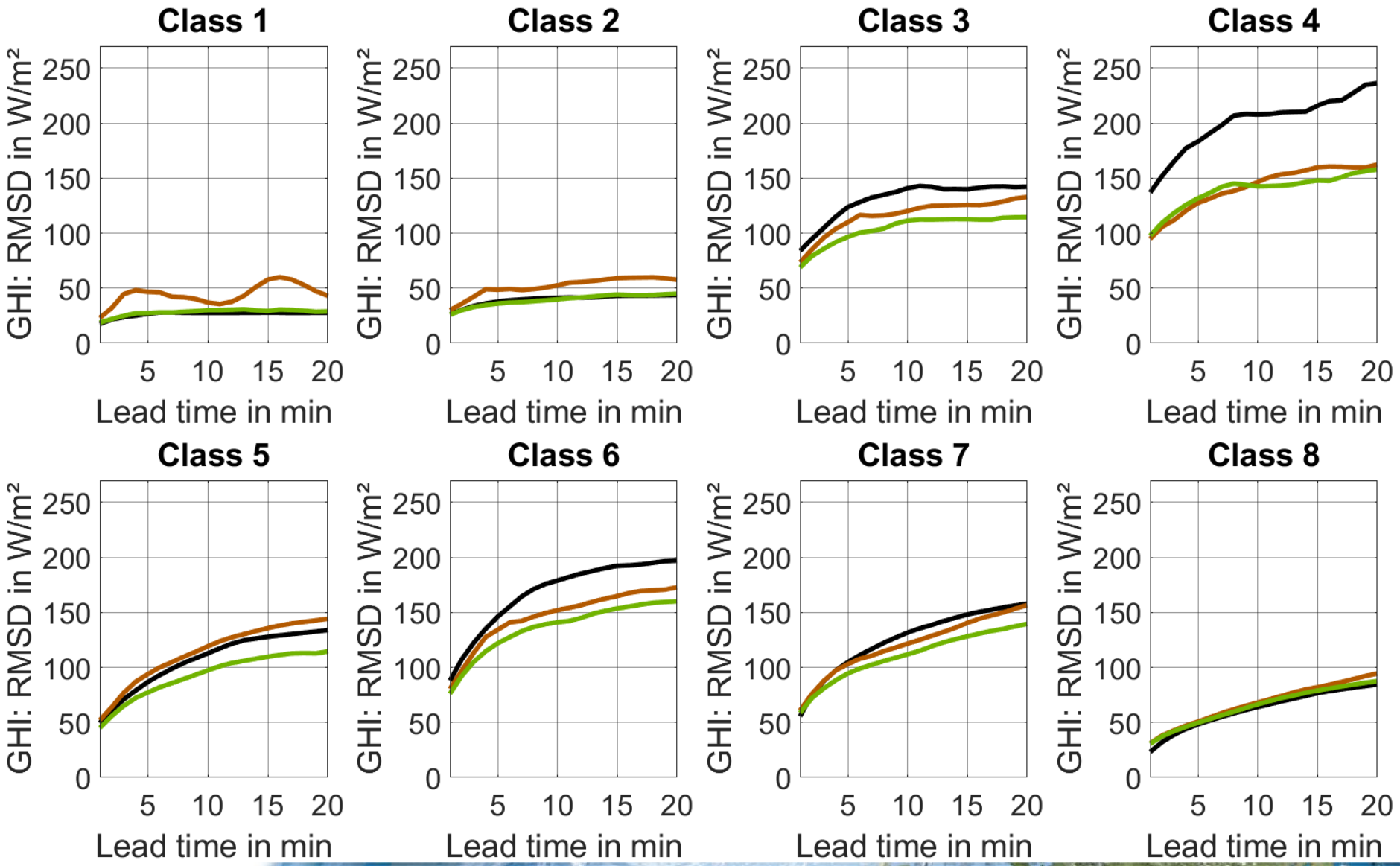
- Nowcasting uncertainties are highly dependent on the prevailing ambient conditions
  - Overall errors metrics might not be meaningful (depending on the chosen data set)
  - Discretization of validation data set in eight distinct variability conditions [6]

Class	Sky conditions	Clear sky index	Variability
1	Mostly clear sky	Very high	Low
2	Almost clear sky	High	Low
3	Almost clear sky	High/intermediate	Intermediate
4	Partly cloudy	Intermediate	High
5	Partly cloudy	Intermediate	Intermediate
6	Partly cloudy	Intermediate/low	High
7	Almost overcast	Low	Intermediate
8	Mostly overcast	Very low	Low



Validation

Persistence
All sky imager
Hybrid



Conclusion

- Highly resolved irradiance nowcasts with considerable spatial coverage can be derived from all sky images in real time
- Performance of persistence nowcasts for the next minutes ahead are competitive during low variability conditions
- **The newly developed all sky imager and persistence hybrid nowcasting approach outperforms under almost all conditions the former approaches [7]**

Thank you!
Questions?

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[1] P. Ineichen, R. Perez, A new airmass independent formulation for the Linke turbidity coefficient. Solar Energy. 2002, 73(3), 151-157.

[2] Y. Fabel, et al., Applying self-supervised learning for semantic cloud segmentation of all-sky images. Atmospheric Measurement Techniques Discussions. 2021, 1-20.

[3] B. Nouri , et al., Cloud height and tracking accuracy of three all sky imager systems for individual clouds. Solar Energy. 2019, 177, 213-228.

[4] B. Nouri, et al., Determination of cloud transmittance for all sky imager based solar nowcasting. Solar Energy. 2019, 181, 251-263.

[5] R. Meyer, et al., Combining solar irradiance measurements and various satellite-derived products to a site specific best estimate. 2018, in: SolarPACES Conference. pp. 1–8

[6] M. Schroedter-Homscheidt, et al., Classifying ground measured 1 minute temporal variability within hourly intervals for direct normal irradiances. 2018 Meteorol. Z. 2018.

[7] B.Nouri, et al., A hybrid solar irradiance nowcasting approach: combining all sky imager systems and persistence irradiance models for increased accuracy. 2021, Solar RRL, 2100442