Solar irradiance and ramp events forecasting with ASIs

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The overreaching goal of this benchmarking exercise

1) to qualify the current state-of-the-art of ASI-based solar nowcasting

2) to identify the strengths and the weaknesses of the implemented algorithms

3) to evaluate the effect of various cloud conditions and time horizons on ASI-based nowcast performance

4) to investigate the performance of the ASI-based GHI nowcasts against typical reference forecast models

5) To investigate the role of ASI-based solar irradiance nowcasts in ramp event detection

Publications

Paper 1

Benchmarking of solar irradiance nowcast performance derived from all-sky imagers

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Paper 2

Solar irradiance ramp forecasting based on all-sky imagers

energies
MDPI

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Details of the campaign days and measurements

GHI nowcast systems

1) All Sky Imagers (ASI):
   4 camera setups, 5 nowcasting methods.
2) Persistence Model and Physical-based Smart Persistence for Intra-hour forecasting of solar radiation (PSPI) model

❖ Time horizon = Forecasts up to 20 min

Experimental setup at METAS at CIEMAT's PSA

Cloud clustering of campaign days

All campaign days were flagged in the following **6 cloud** classes:

1: Cloud-free (or almost cloud-free)

Scattered/broken cloudiness with:

2L: Low clouds | **2M:** Multiple clouds | **2H:** High/Middle clouds

3H: Scattered/broken cloudiness with High/Middle clouds during half of the day, cloud-free during the other half.

4A: Overcast cloud conditions during half of the day, scattered/broken cloudiness during the other half

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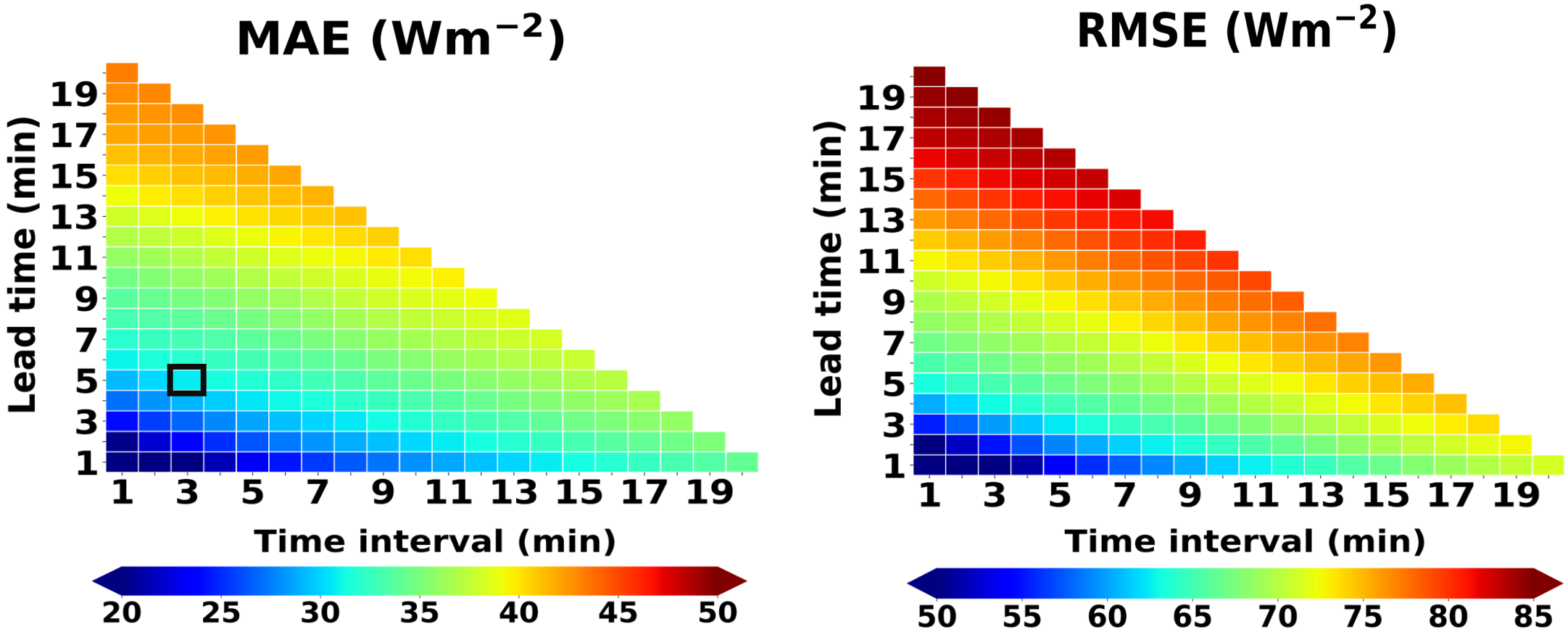
Paper 1: Results (1)

- ASI2 algorithm performance under different time horizons and intervals



The **vertical axis** shows **starting forecast minute (lead time).**
The **horizontal axis** shows the **number of minutes included (time interval)**.

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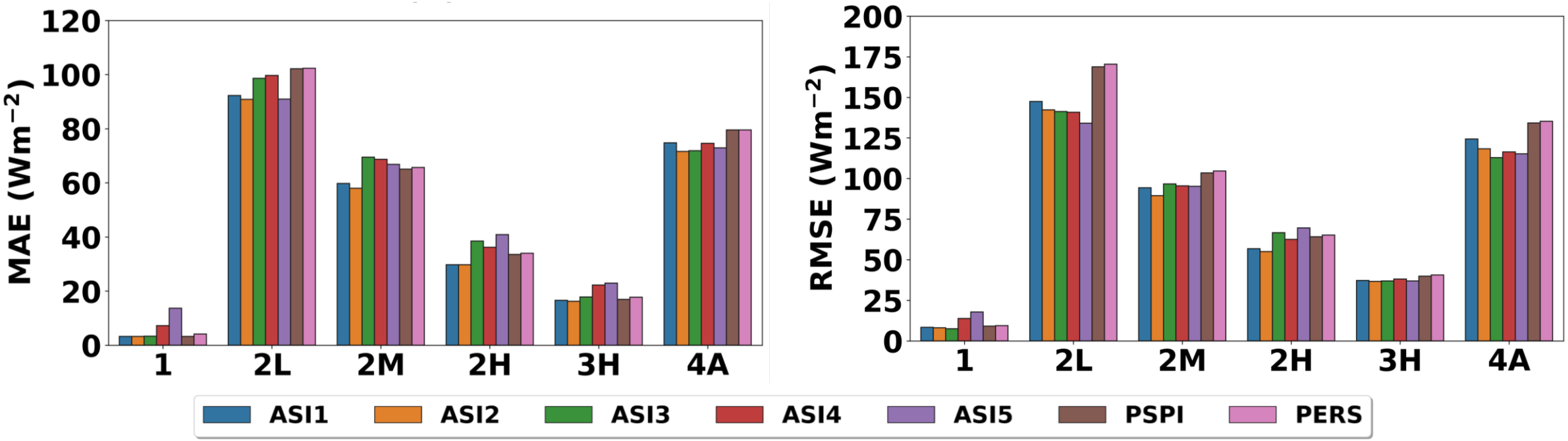
Paper 1: Results (2)

- **Bar plots showing the overall MAE and RMSE for each ASI algorithm under the 6 different cloud clusters.**



Summary of the algorithms with the **best performance** for each cloud cluster.

	Cloud Cluster					
	1	2L	2M	2H	3H	4A
Metric						
MAE	PSPI	ASI2	ASI2	ASI1	ASI2	ASI2
RMSE	ASI2	ASI5	ASI2	ASI2	ASI2	ASI3

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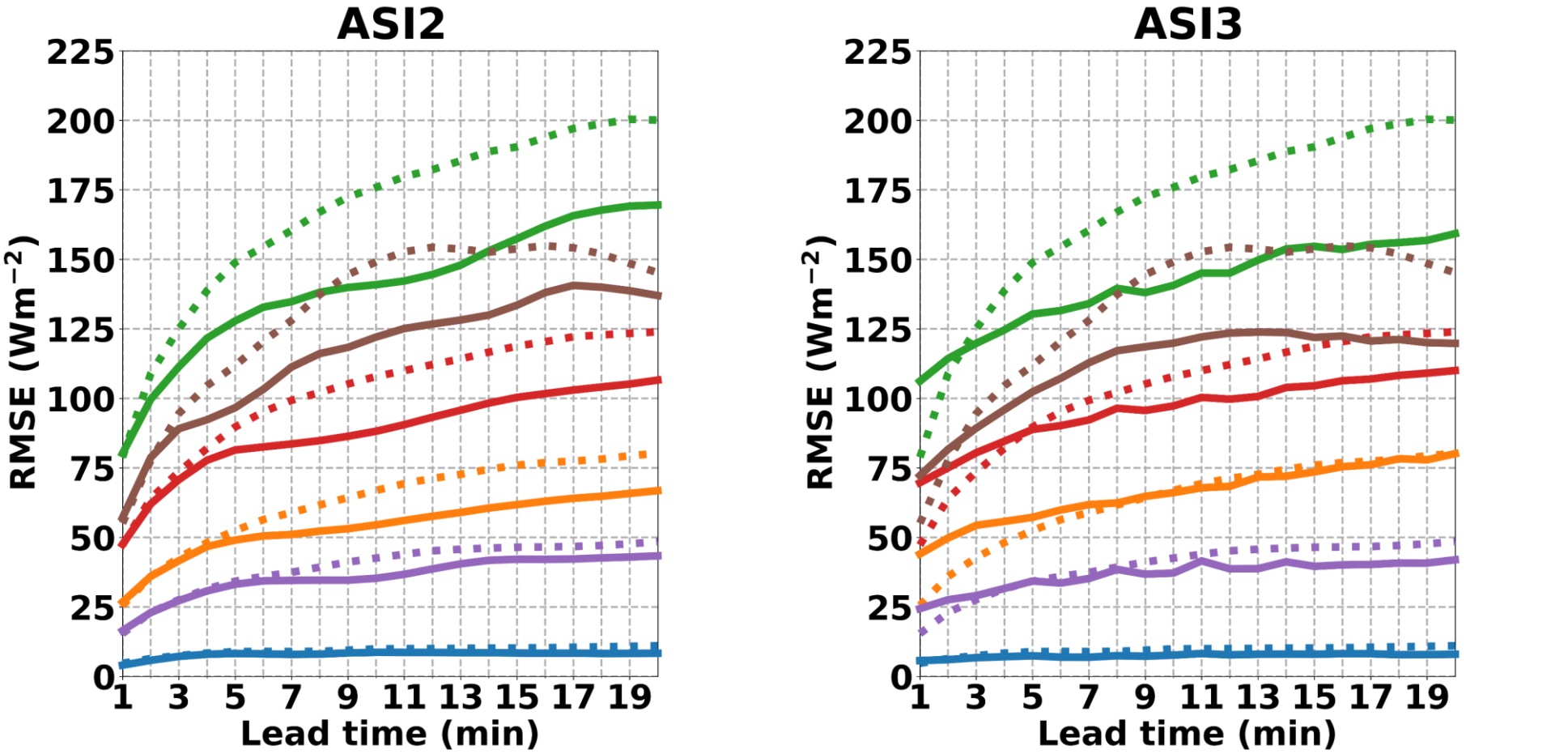
Paper 1: Results (3)

- RMSE under the 6 different cloud clusters and forecast lead time.



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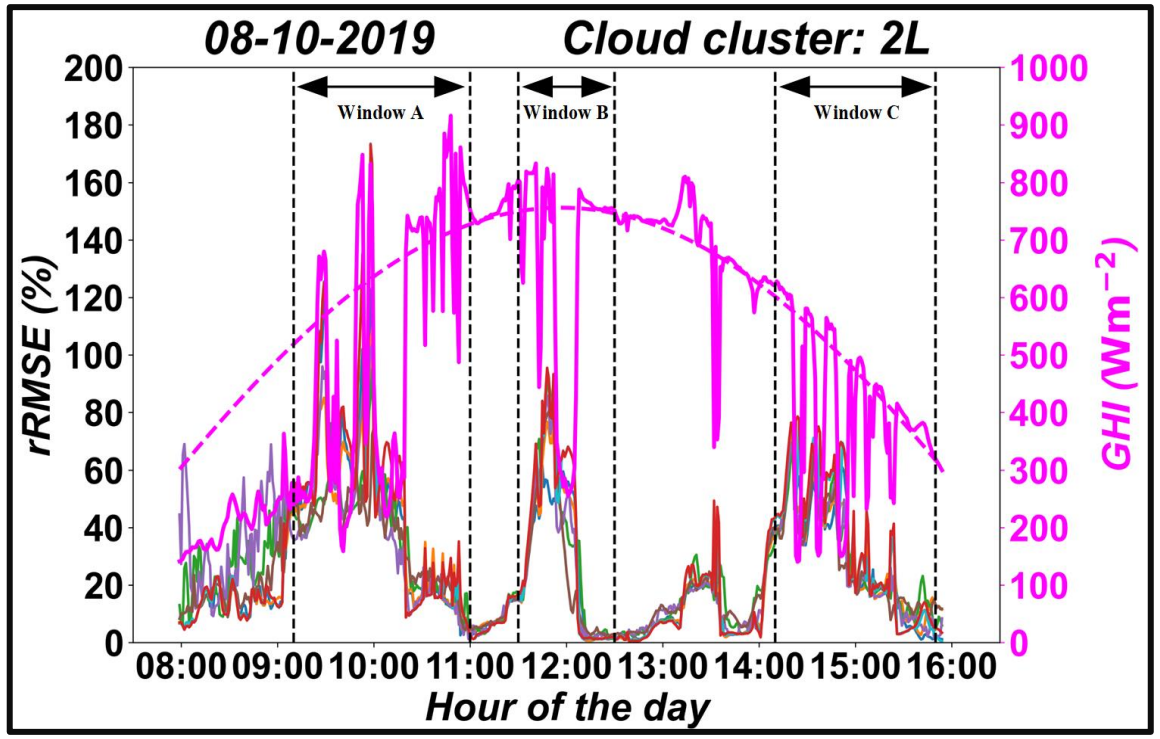
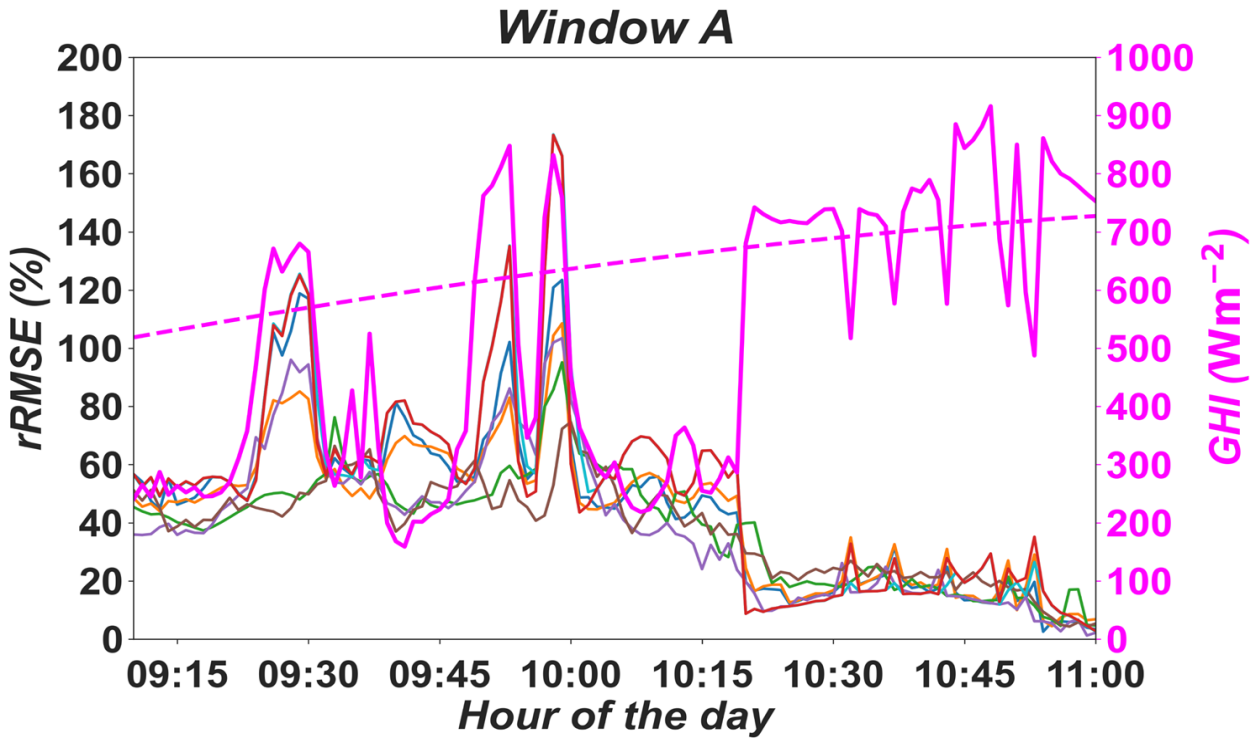
Paper 1: Results (4)

- **Diurnal variability for the performance of ASIs at a typical 2L day.**





Observations Clear sky

ASI1 ASI2 ASI3 ASI4 ASI5 PSPI PERS

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Paper 2: Metrics

- **Possible cases**

Predicted Ramp Events \ Observed Ramp Events	Ramp	No-Ramp
Ramp	True Ramp (TR)	False Ramp (FR)
No-Ramp	False No-Ramp (FNR)	True No-Ramp (TNR)

- **Temporal analysis of ramp event detection**

1) At each specific time horizon (from 1 to 20 min)
2) Over the whole 20-min time horizon (Time window, TW, analysis)

- **Metrics**

$$\text{Total Accuracy} = \frac{\text{True cases}}{\text{Total cases}} = \frac{\text{TR} + \text{TNR}}{\text{TR} + \text{FR} + \text{FNR} + \text{TNR}}$$

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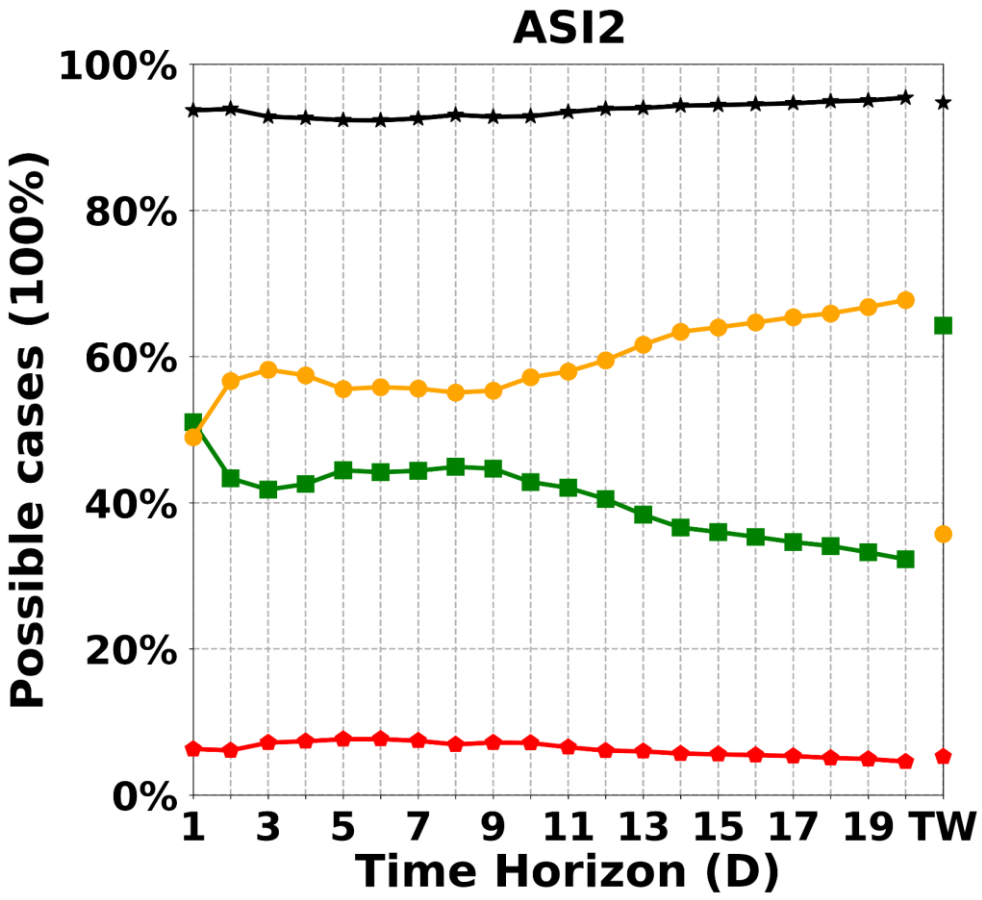
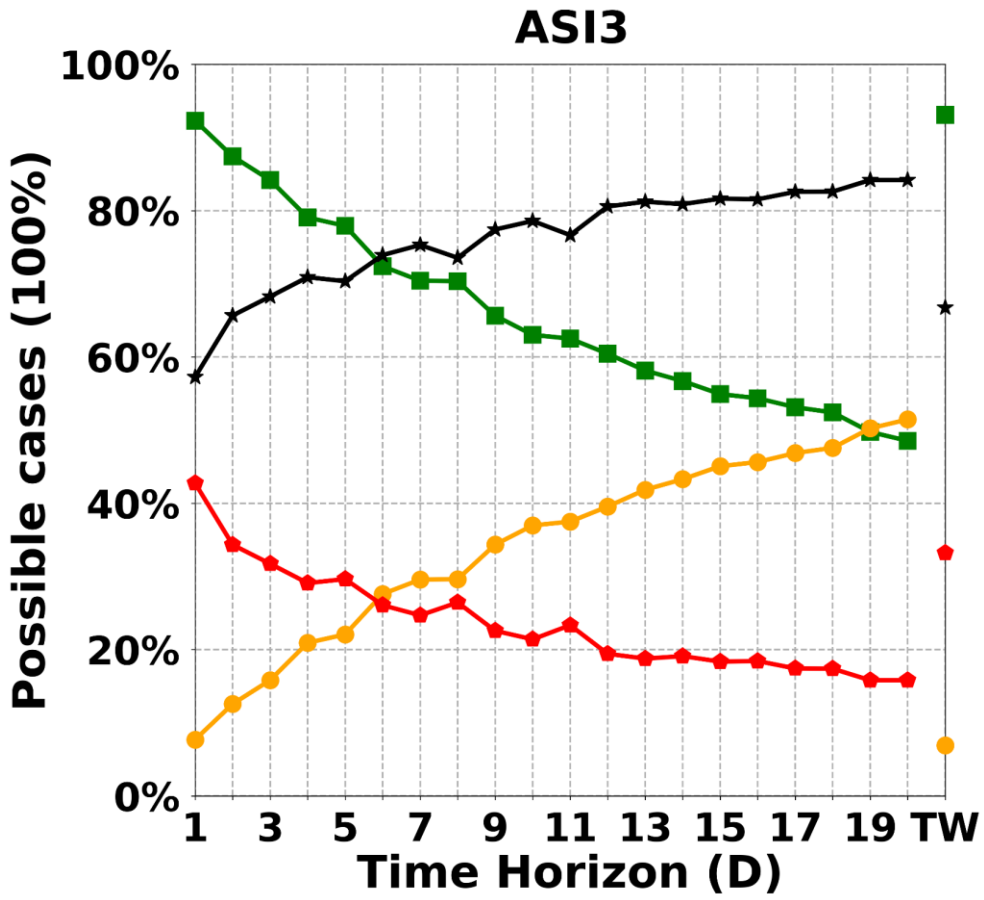
Paper 2: Results (2)

- ASIs performance at each time horizon D



TW Accuracy=78.6%



TW Accuracy=80.7%

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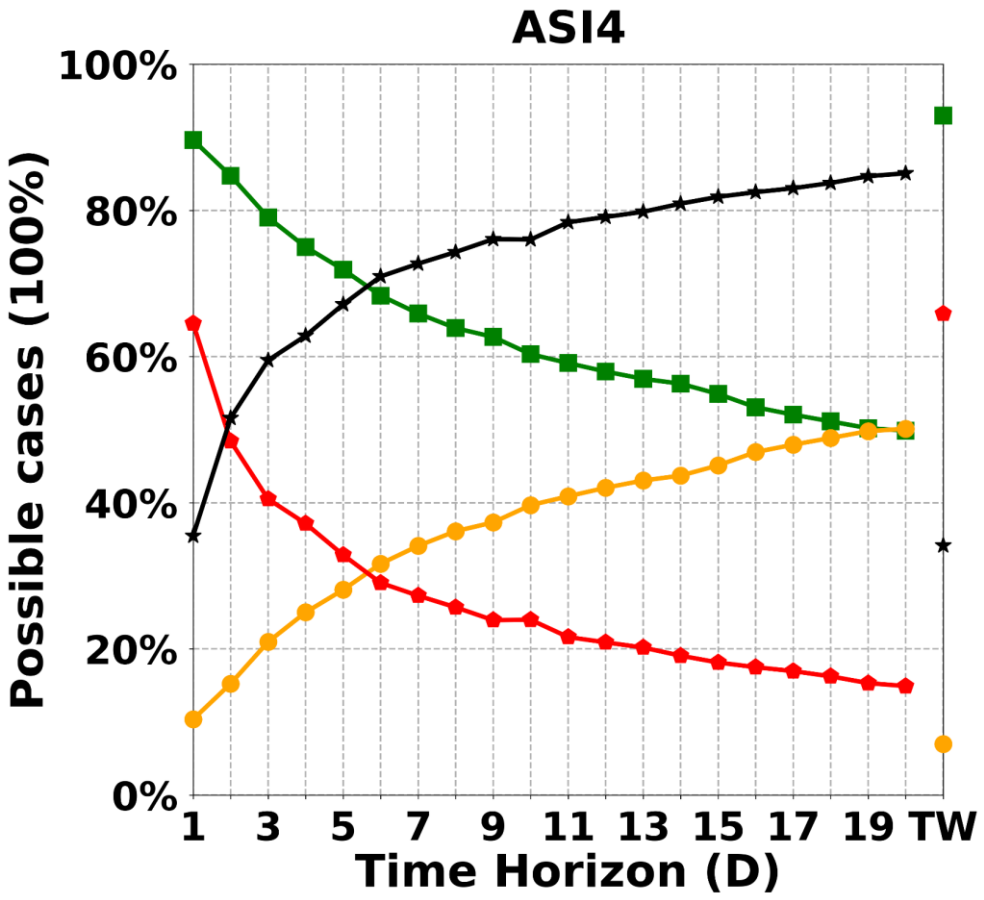
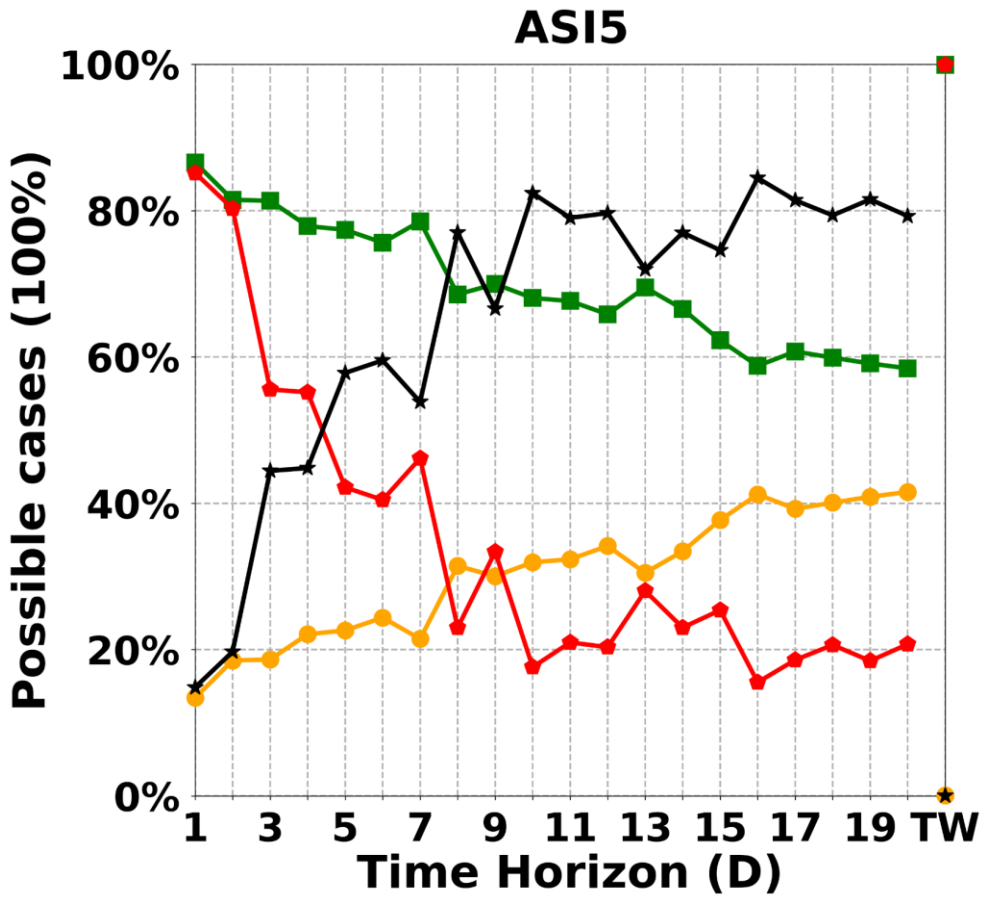
Paper 2: Results (3)

- ASIs performance at each time horizon D



TW Accuracy=65.3%



TW Accuracy=52.9%

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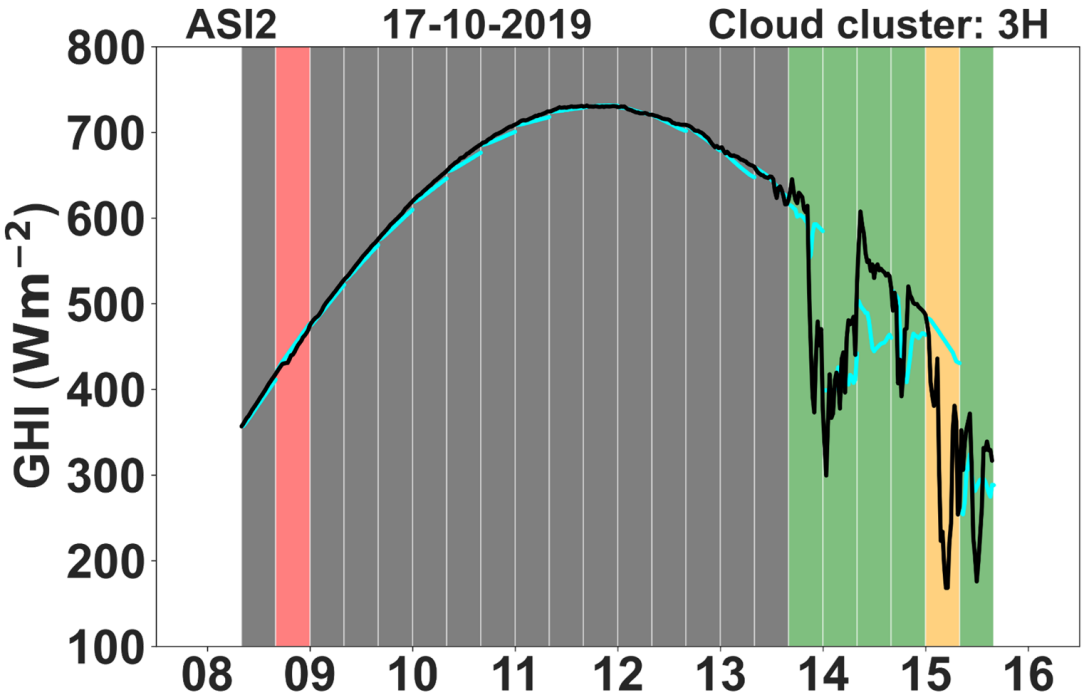
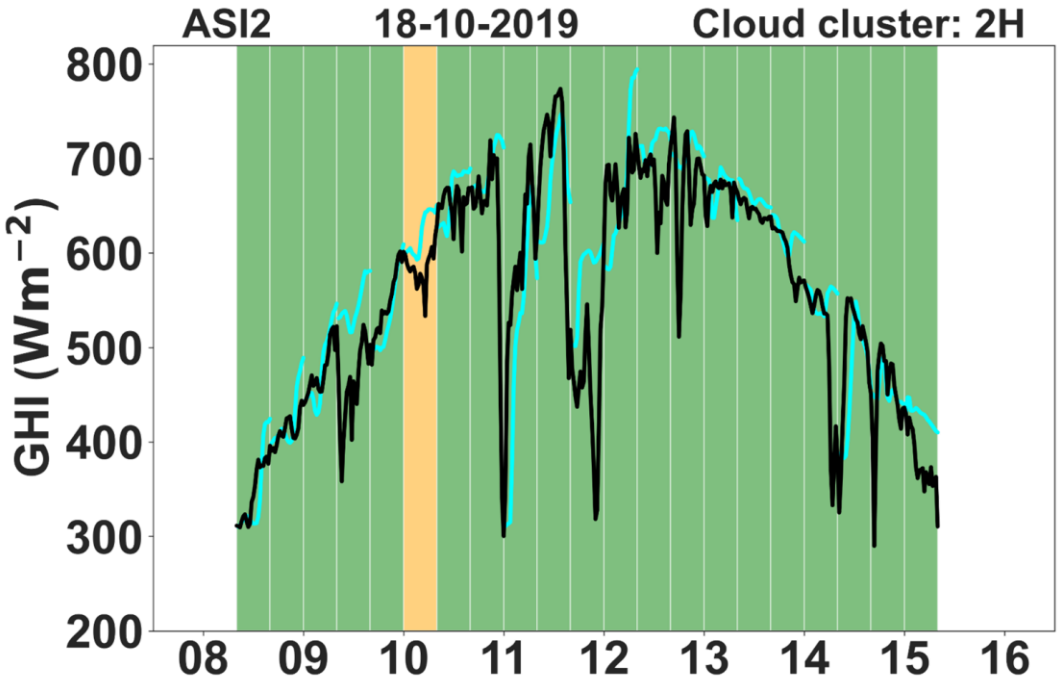
Paper 2: Results (4)

- **ASIs performance at specific cloud conditions for the TW analysis**





15/16 TNR predictions | **5/6 TR predictions** | **20/21 TR predictions**

Forecasts — Measurements

TR — FNR — FR — TNR

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Conclusions: Paper 1

Within the whole validation period:

- ASIs 1-2 reported the **lowest** deviations among the ASIs (from −0.39% to 0.95%).
- In general, ASIs deviations follow an **increasing trend** as the **time horizon increases**, with ASI1 and 2 revealing the highest forecast accuracy either at low (<5 min) or at distant (>15 min) lead times.

Under specific cloud conditions:

- ASI1 and 2 **outperform** the persistence models at **all** cloud clusters and lead times.
- For time horizons longer than 5 min, the other 3 ASIs (3-5) are also efficient to **outperform** the persistence model **under cloudy skies**.

Under cloud-free conditions:

- Three ASIs (1-3) proved to be capable of providing **better** results than persistence.

Overall conclusion

- Specific ASIs **outperform** the persistence models even under clear, scattered, and overcast skies.

Conclusions: Paper 2

The performance of the detected ramp event is connected to the applied forecast algorithms.

- The true predicted ramp event cases for all ASIs decrease as the time horizon increases.
- The ASI1 and ASI2, tend to wrongly record no-ramp events more often than ASI 3-5 systems.
- The ASI 3-5 show the tendency to wrongly predict ramp events which happens less often for ASI1 and ASI2.
- They can predict ramp events accurately from 30% to 95% of the cases.

Overall conclusion

- The selection of the most suitable ASI system for solar irradiance ramp event nowcasting depends on the application.

Thank you for your attention!

For more details, please check our published papers

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Paper 2	Solar irradiance ramp forecasting based on all-sky imagers energies MDPI

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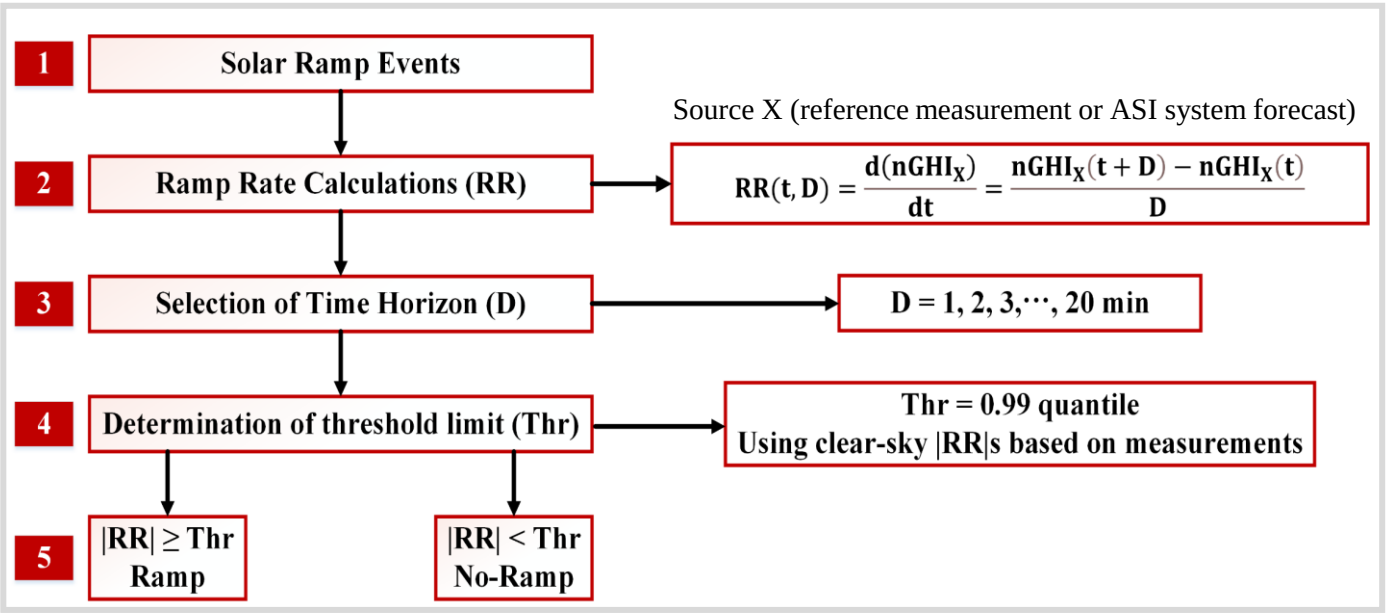
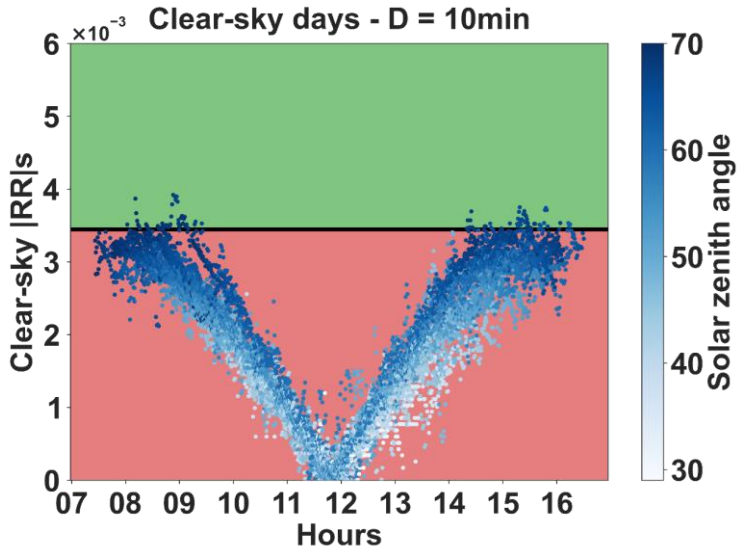
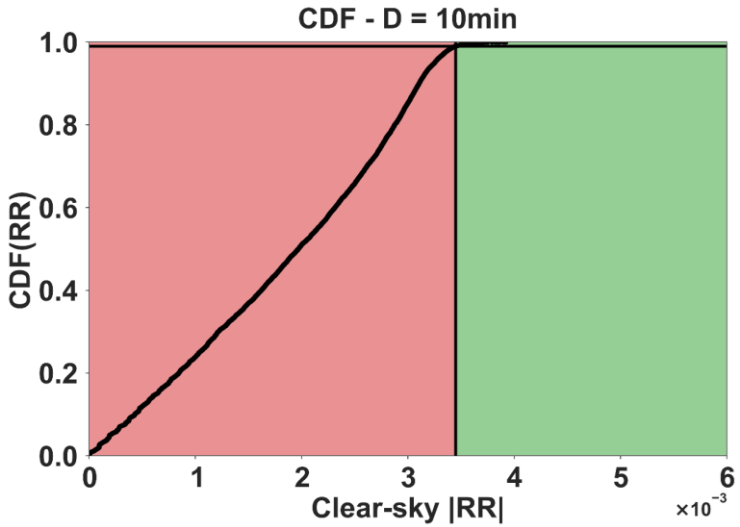
Paper 2: Methodology

- **Flowchart of the applied methodology**







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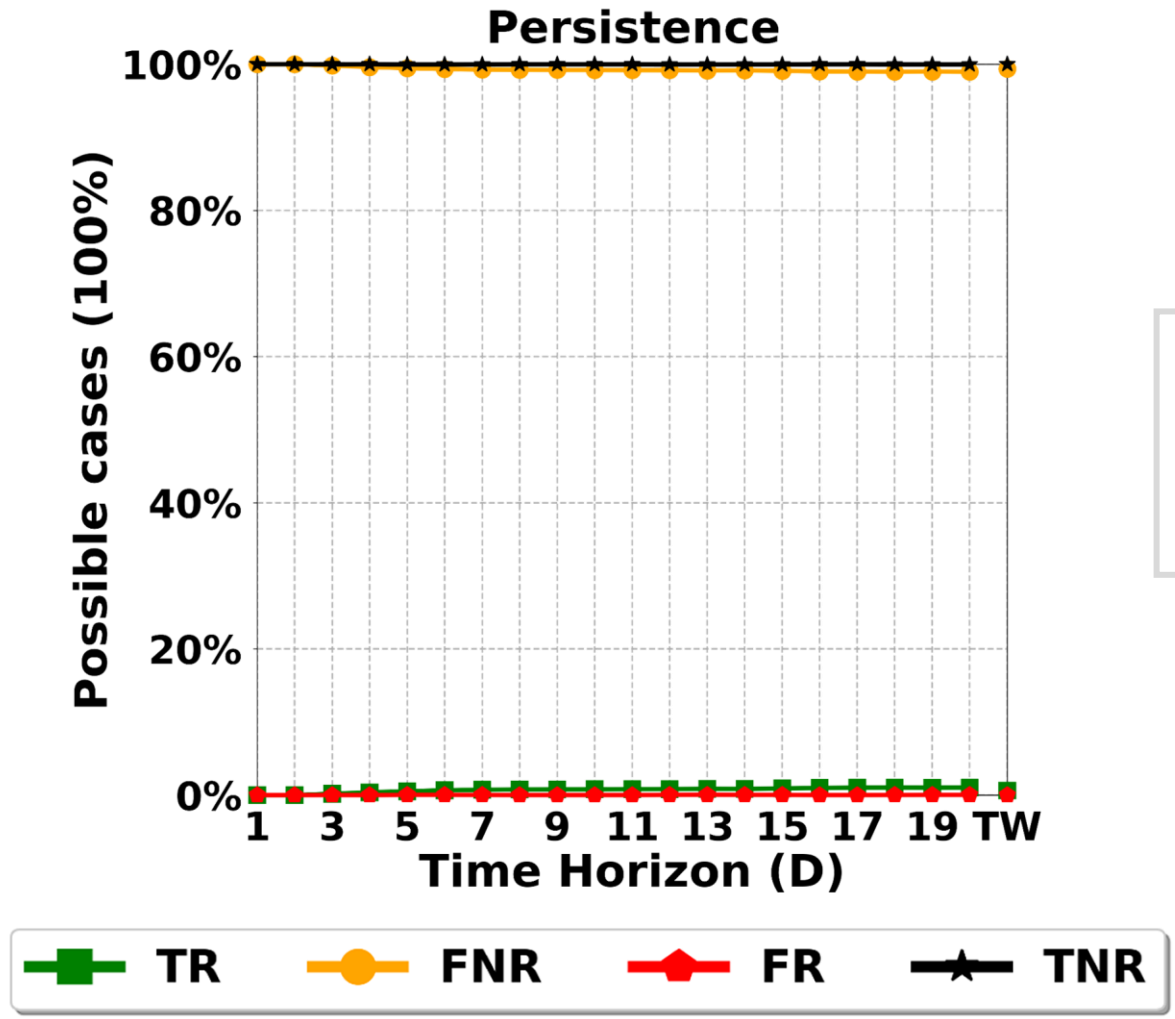
Paper 2: Results (1)

- **ASIs performance at each time horizon D**



Note: Typical reference forecast model (Persistence) cannot predict any ramp event

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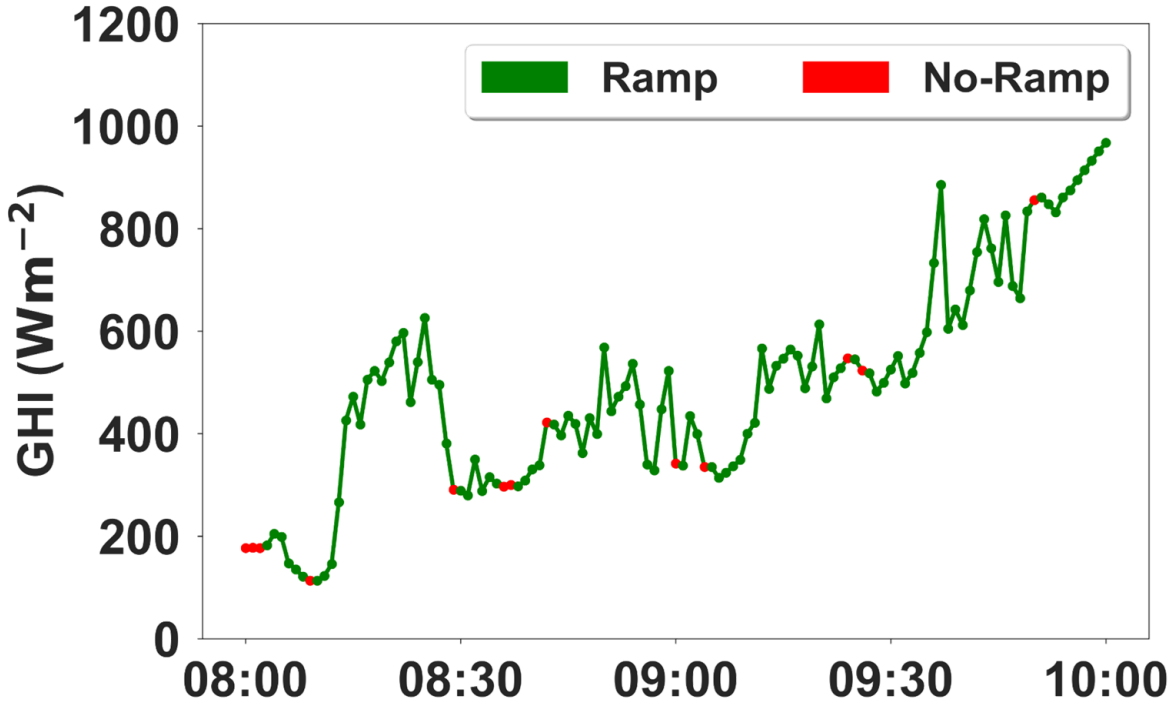
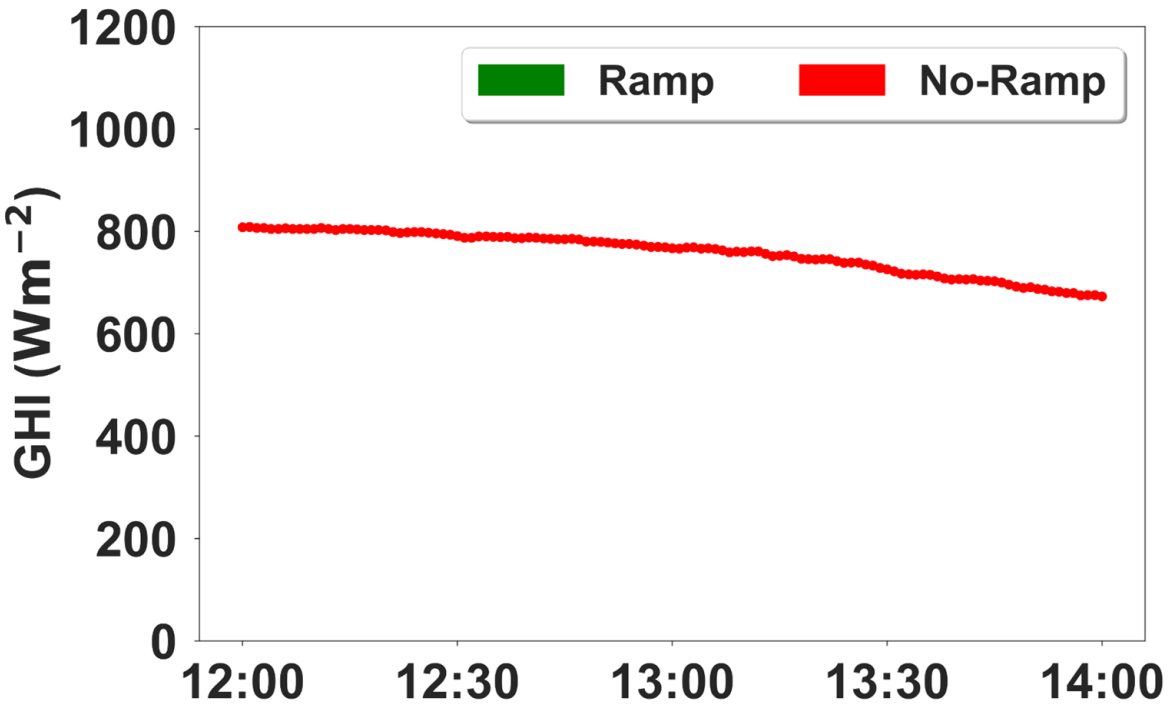
Paper 2: Verification

- Verification of the applied methodology at a specific time horizon.





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