All Sky Imager (ASI) benchmark

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Team des IEA PVPS Task 16

50 organisations
20 countries

Research organisations

Met Services / utilities

Service providers

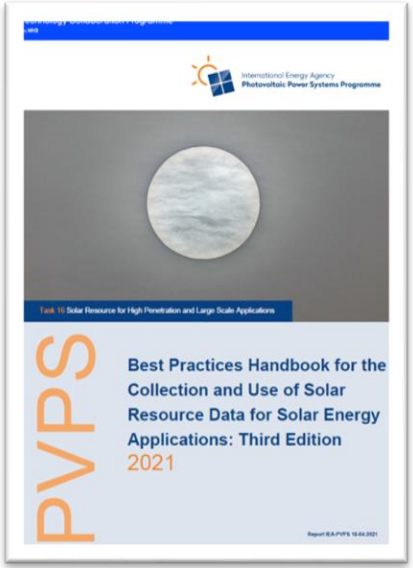
PVPS

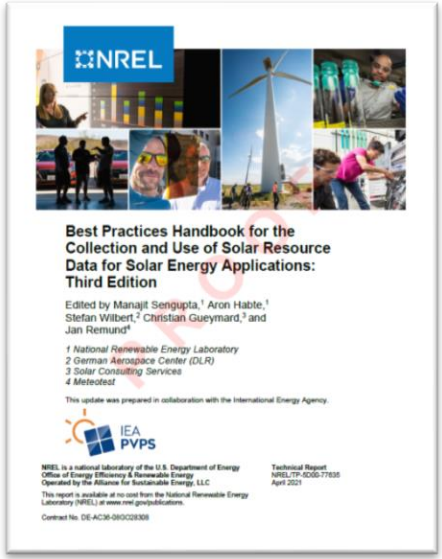
Solar resource bible v3.0

All you ever wanted to know about solar data and forecasts

What data and methods are trustful?

You don’t need always the best … but the most suited





PVPS: https://iea-pvps.org

https://iea-pvps.org/key-topics/best-practices-handbook-for-the-collection-and-use-of-solar-resource-data-for-solar-energy-applications-third-edition/

Which data for which use case?

- Needs depend strongly on system size and phase of project

System Size

Phase

	Small	Medium	Large
1. Pre-feasibility & Planning	• Long-term averages • Monthly data • Solar cadastres / maps • Simple shading analysis	• TMY • Hourly data • Shading analysis	• Long-term satellite data • Hourly data
2. Feasibility			• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Shading analysis • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)
3. Due diligence & Finance		• Satellite data • Time series (>10 y) • Minute data • Shading • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)	• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Minute data • Shading analysis • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)
4. Operation & Maintenance	• Simple monitoring	• Local measurements Forecasts	• Local measurements Forecasts

Forecasts→

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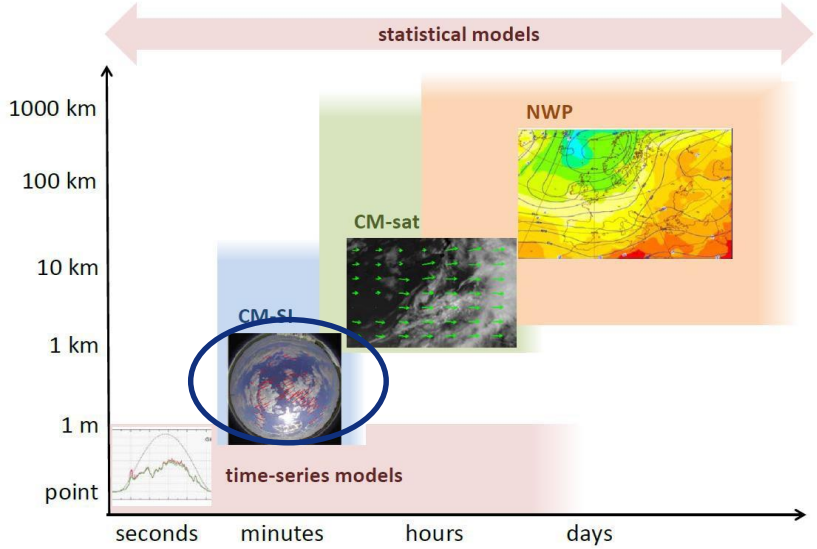
Solar forecasts

- Updated chapters in “**Solar Res. Handbook**”:
  - Machine learning (ML) based systems
  - Probabilistic forecasts
  - All sky imagers / cloud cameras
- Machine Learning is coming
  - Scientific studies show, that ML can enhance forecasts (but doesn’t provide wonders)

Depending on space and time different methods are optimal



All Sky Imagers (ASI) / cloud cams

- All Sky Imager (ASIs) provide high temporal and spatial resolution data (10 seconds – 1 minute / 10 – 100 m)
- Nowcasting for the next 15-20 min
  - Calculation of cloud speed, extrapolation of future position of clouds
  - Calculation of cloud cover
- Useful for:
  - Forecast of ramps of ramps / Conservation of batteries / Reduction of size of batteries
  - Regulation of electricity production (Redispatch 2.0)
  - Regulation of PV Hybrid power plants (PV + Diesel, PV + hydro power, …)

ASI / Motivation for Benchmark

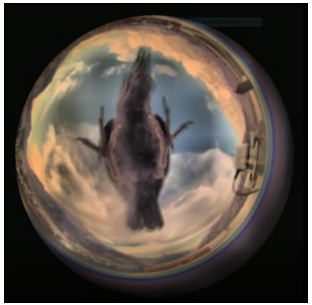
- Many ASI systems are described in literature
  - Different cameras, different analysis methods, different climates

    → Comparison of ASI uncertainty wasn‘t possible up to now
  - Up to now, not clear, which method is best
- → Comparison of different ASI systems at one place at the same time within IEA PVPS Task 16
- Test in July – October 2019

ASI / CSEM & Meteotest System

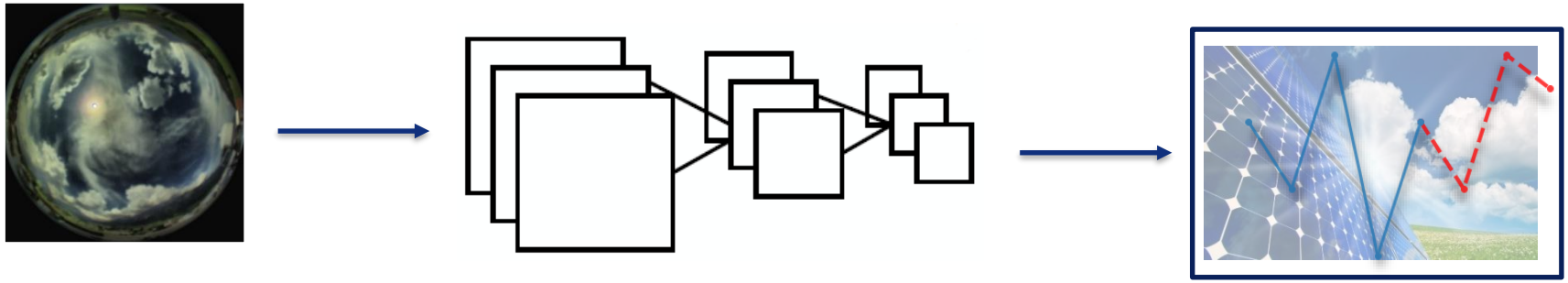
- Camera system developed by CSEM / Meteotest (MT) was part of test
- Measurements of whole year 2018 were published in 2021:
- https://arxiv.org/abs/2105.02922

- Camera didn't only see the sky:



ASI / CSEM & Meteotest System

- Method (extreme): “Deep Learning only”
- 1. Analyse of HRD images of current situation:



HDR Images

Trained neuronal net

Forecast of global irradiance [W/m^2]

2. Analysis of forecasts: (1-minute time resolution)

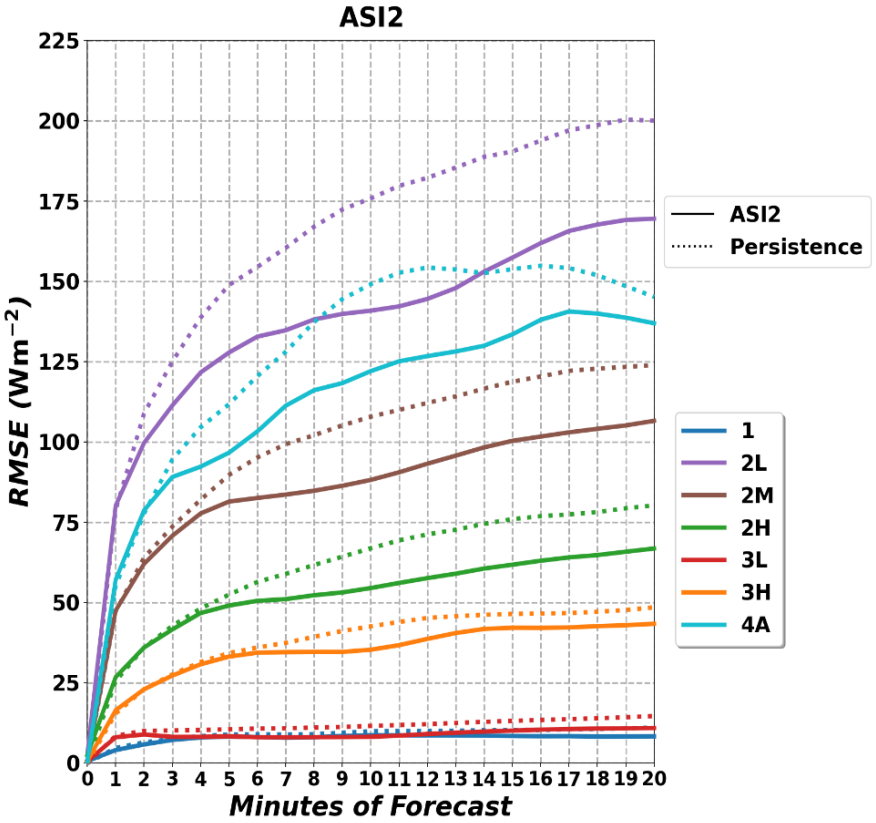
See also: https://www.aramis.admin.ch/Texte/?ProjectID=40172

ASI / Benchmark in Almeria

Different ASI systems and measured GHI as input for the forecasts

Results of ASI Benchmark for camera “ASI2”

- for all cloud classes better results than persistence
- Advantage especially in cloud classes with high cloud influence (2L, 4A, 2M)
- Up to approx. 1 min to 5 min depending on class ASI2 and persistence similarly accurate
- Similar form for MAE, lower values
- Bias rel. small, not relevant



1 (almost) clear sky
2L Broken cloud cover with low clouds
2M Broken cloud cover with high, medium and low clouds
2H Broken cloud cover with (medium) high clouds
3L Broken cloud cover with low clouds approx. half of the day, cloudless otherwise
3H broken clouds with high or medium clouds approx. half of the day, cloudless otherwise
4A completely cloudy approx. half of the day, otherwise broken clouds

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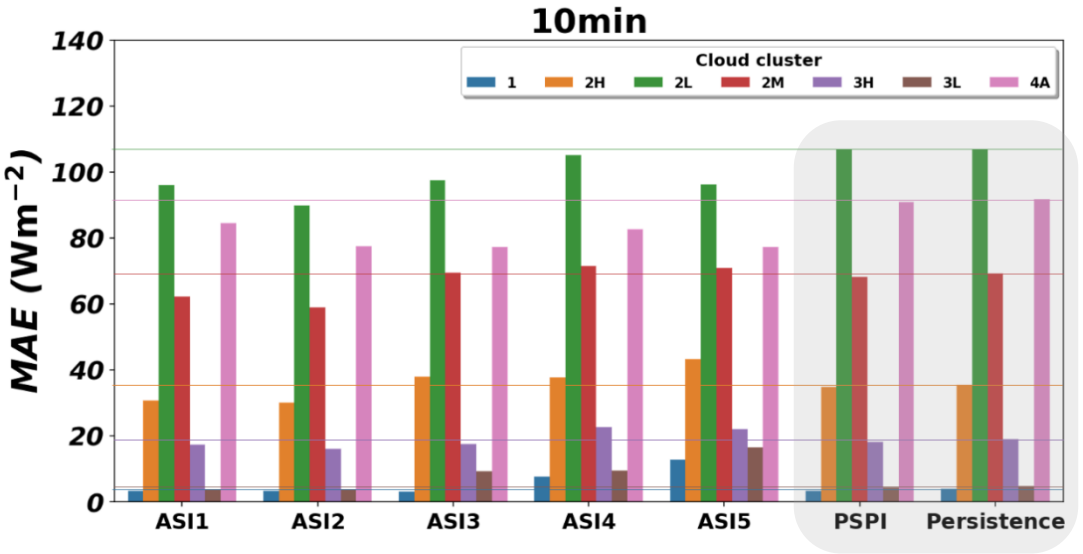
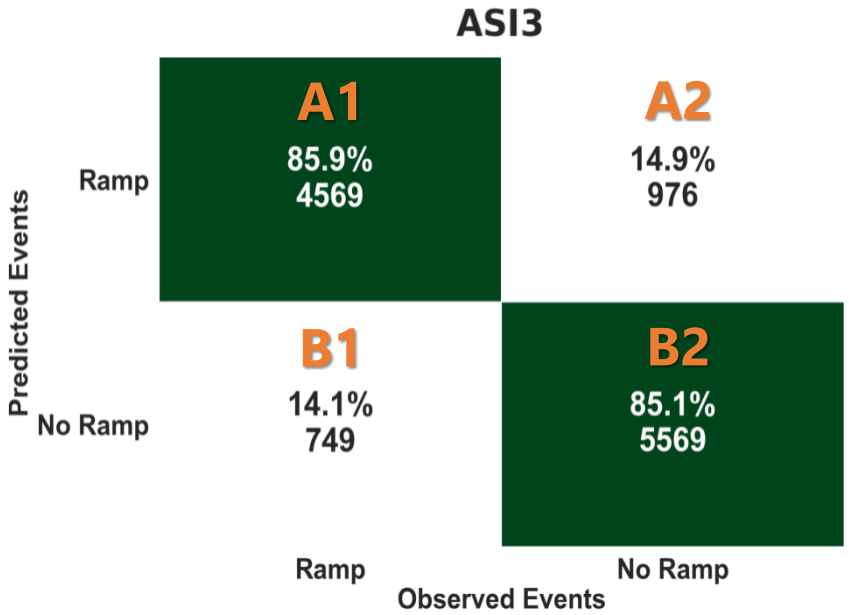
Benchmark of all cameras – 10 minutes forec.

- Two ASI systems beat persistence in all cloud classes
- All ASI systems beat persistence in at least two classes with high shares of clouds (2L and 4A)
- In stable situations deviations are small (1, 3L)
- Advantage compared to persistence: forecast of ramps are possible



Ramp rate dection (preliminary for ASI3)

- **A1**: any detected ramp event for ASIs and observations.
- **A2**: at least 1 recorded ramp event for ASIs but none for observations.
- **B1**: none recorded ramp event for ASIs but at least 1 observed ramp event.
- **B2**: none recorded ramp event for ASIs and observations



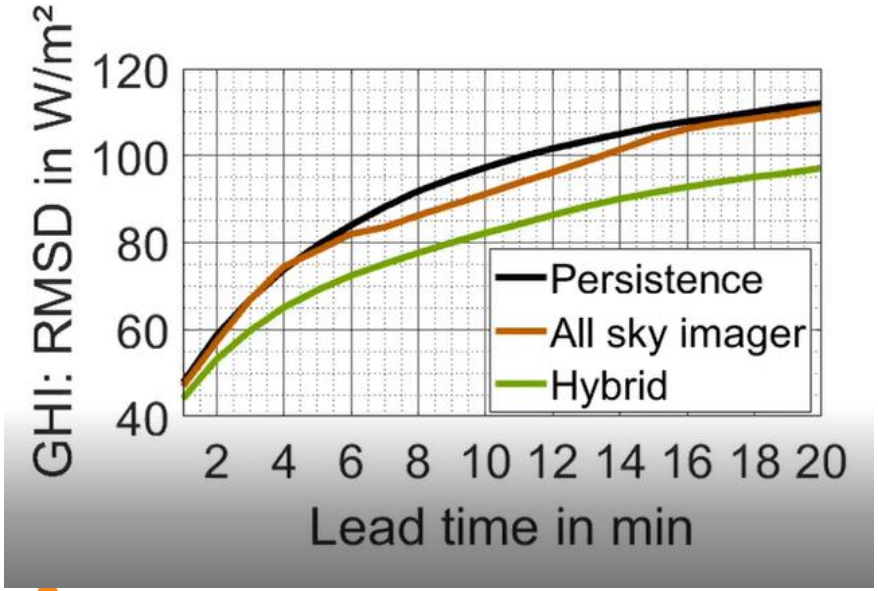
From all ramp events, the 85.9% are correctly detected. In addition,
ASI3 can avoid the false forecast of ramp event in 85.1% of the cases.
https://doi.org/10.5194/ems2021-75

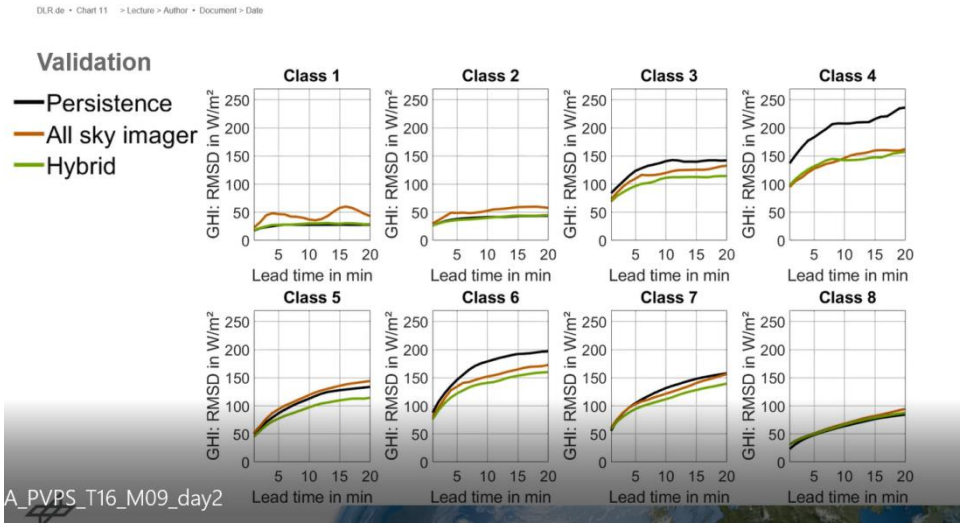
Outlook

- Combination of persistence model and satellite based Cloud Motion Vectors (CMV) enhances the quality:
- Two presentation at IEA PVPS Task meeting in September 2021:
  - DLR Almeria / Bijan Nouri
  - Univ. Jaen / David Pozo
- Next publication on benchmark is in preparation (beginning of 2022)

Outlook / DLR Almeria

- Combination of **persistence model and ASI CMV based forecast**





Source: B. Nouri, DLR, 9th Task 16 expert meeting Rome

Outlook / Univ Jaen

- Combination of **persistence model and satellite based CMV**: paper: https://doi.org/10.1016/j.apenergy.2021.116838
- By blending different short term solar radiation forecasting models an important improvement on the accuracy can be attained
- Machine Learning approaches outperforms other more simple blending methods.
  - Best Machine Learning tool seems to be Random Forest.
- The improvement can reach 15% for GHI and 25% for DNI, in terms of rRMSE
- The importance of the satellite based models and data driven models seems to be greater than ASI based models regarding the final blended model

Conclusions

- Most important concepts, basics and state of the art are concluded in the **Solar Resource Handbook**
  - Chapter 8 shows the overview over forecasting
  - Heavily enhanced: “Machine Learning” and probabilistic forecasts
  - Inclusion in applications makes sense
- ASI Benchmark isn’t included in Handbook
  - Systems are useful – however to be enhanced
  - CSEM / MT camera is “deep learning only” – works well with clouds – less effective in case without clouds
    - Blending with persistence enhances forecasts

Thank you

On behalf of IEA PVPS Task 16

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