Evaluating remote sensing methods of solar irradiance methods under the consideration of cloud variability.

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IEA PVPS Task 16 Meeting September 2021

IEA PVPS

DLR Institute of Networked Energy Systems

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag
Copernicus Europe's eyes on Earth
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Content

- Introduction: new generation of satellites and cloud variability
- Background on CAMS Radiation scheme
- Evaluating improvements in CAMS scheme in traditional manner
- Evaluating with variability classes
- Evaluation with ground based COD and cloud duration
- Conclusions and Outlook

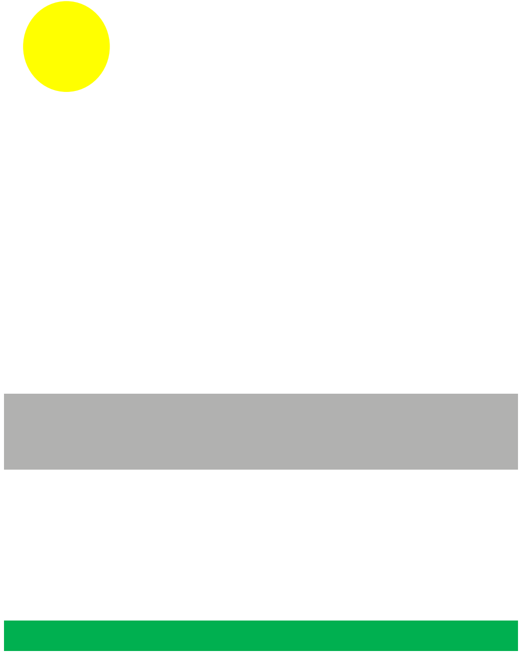
New Capabilities Satellite MTG satellite (fulldisk)

	MSG	MTG
Temporal resolution	15 min.	10 mim.
Spatial resolution nadir full disk	3 km x 3 km	0.5 km x 0.5 km/ 1 km x 1km

Similar or better resolutions for Himwari and GOES

Steps forward with MTG

Clouds in most remote sensing models:

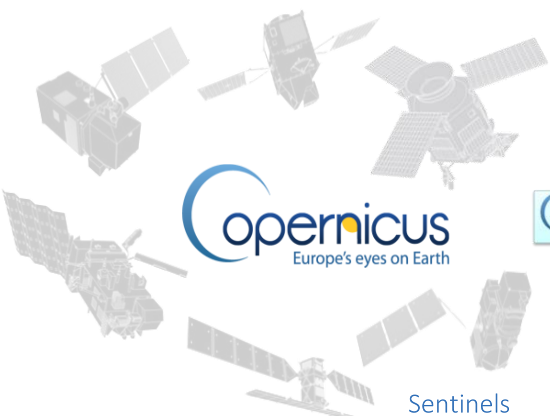


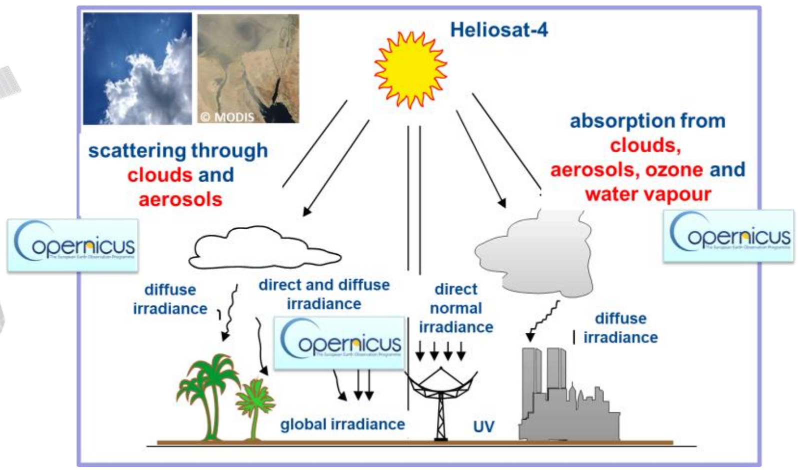
Real clouds:

→ Even with improved temporal and spatial resolution it will not be possible to give an accurate detailed description of individual clouds. Identifying cloud states by variability is the next best thing

Case study: Method Development for EU`s Solar Radiation Services

CAMS is the EU's **C**opernicus **A**tmospheric **M**onitoring **S**ervice Programme

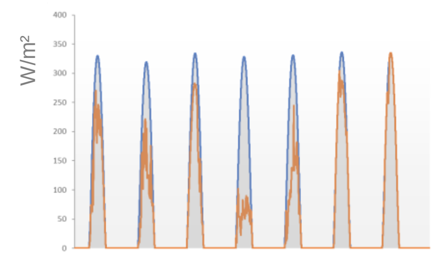




clouds from satellite

aerosols, H_2O, O_3 from model

New: APOLLO_NG & circumsolar treatment



The **CAMS Radiation Service** is provided by

DLR with ARMINES, TRANSVALOR, FINNISH METEOROLOGICAL INSTITUTE

Qu et al., Contrib. Atm. Phys, 2017; Lefèvre et al., AMT, 2013;
Gschwind et al., Contrib. Atm. Phys., 2019;
Schroedter-Homscheidt et al., Contrib. Atm. Phys. In prep.

Changes in CAMS cloud scheme

CAMS 3.2	CAMS 4.0
Uses reflectance values as given by EUMETSAT	Variable calibration correction based on Meirink et al. 2013
Deterministic cloud mask based on Kriebel et al. 1988/1989	Probabilistic cloud mask from Klüser et al. 2015
COD from Stephens scheme, 0< COD< 0.5 clipped at 0.5	Stephens scheme extrapolated down to zero
Single COD value	Empirical apparent COD modification factor for DNI calculations: • 0.41 for optical thin ice clouds • 0.20 for water/mixed phase clouds Implicitly corrects for circumsolar irradiance and broken clouds
Bias correction of irradiance with empirical multiplication factor (uncorrected irradiance available in expert mode)	Retrained Bias correction (uncorrected irradiance available in expert mode)

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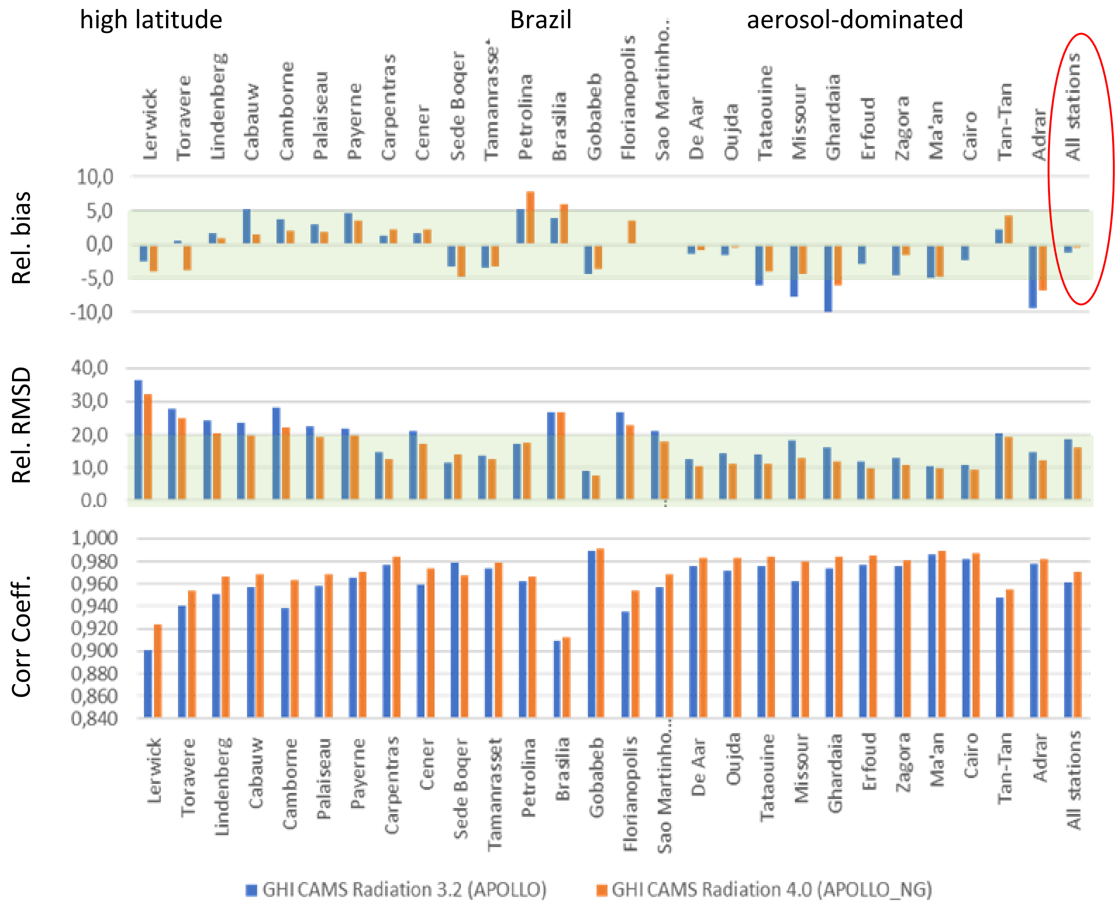
General validation of improvements: GHI

Study design:
GHI (Global horizontal irradiation)
hourly evaluation; 2004 to 2020
CAMS operational v3.2 (old)
CAMS operational v4.0 (online)

Note: Bias correction method as originally developed for v3.2 was updated for v4.0, but is now nearly passive for GHI.

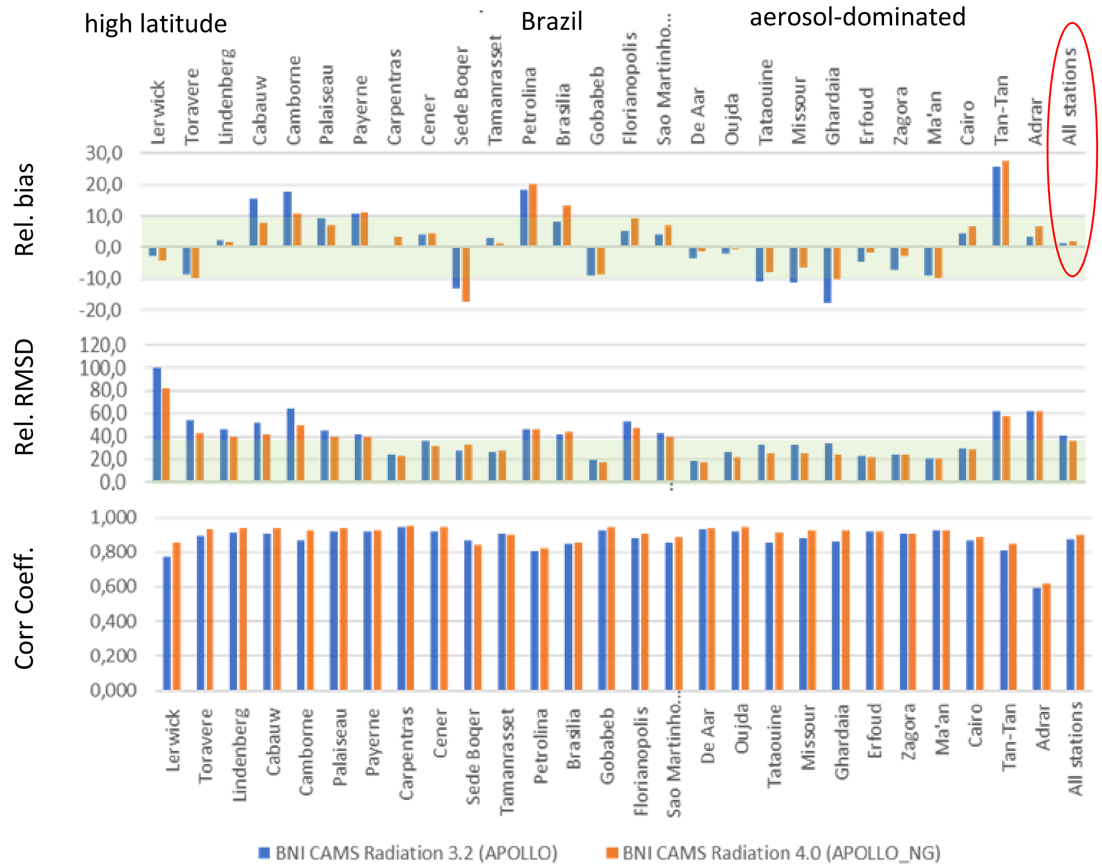
Thanks to BSRN & EnerMENA station teams for providing their data.



Hourly GHI – rel. bias, rel. RMSE and correlation coefficient change from CRS 3.2 to CRS 4.0

General validation of improvements: DNI

Study design:
BNI (beam normal irradiation)
hourly evaluation; 2004 to 2020
CAMS operational v3.2 (old)
CAMS operational v4.0 (online)



Hourly BNI – rel. bias, rel. RMSE and correlation coefficient change from CRS 3.2 to CRS 4.0

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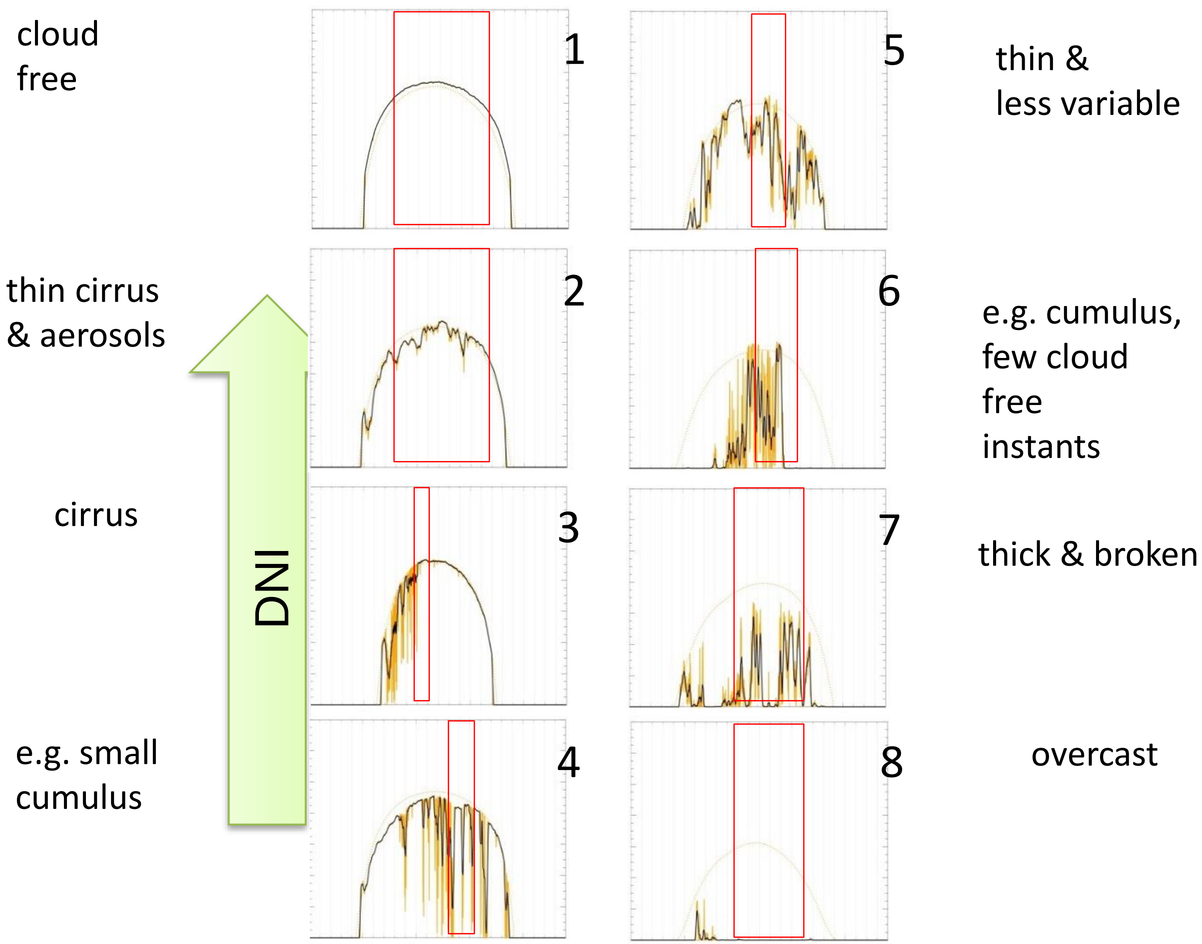
Ground based variability classes



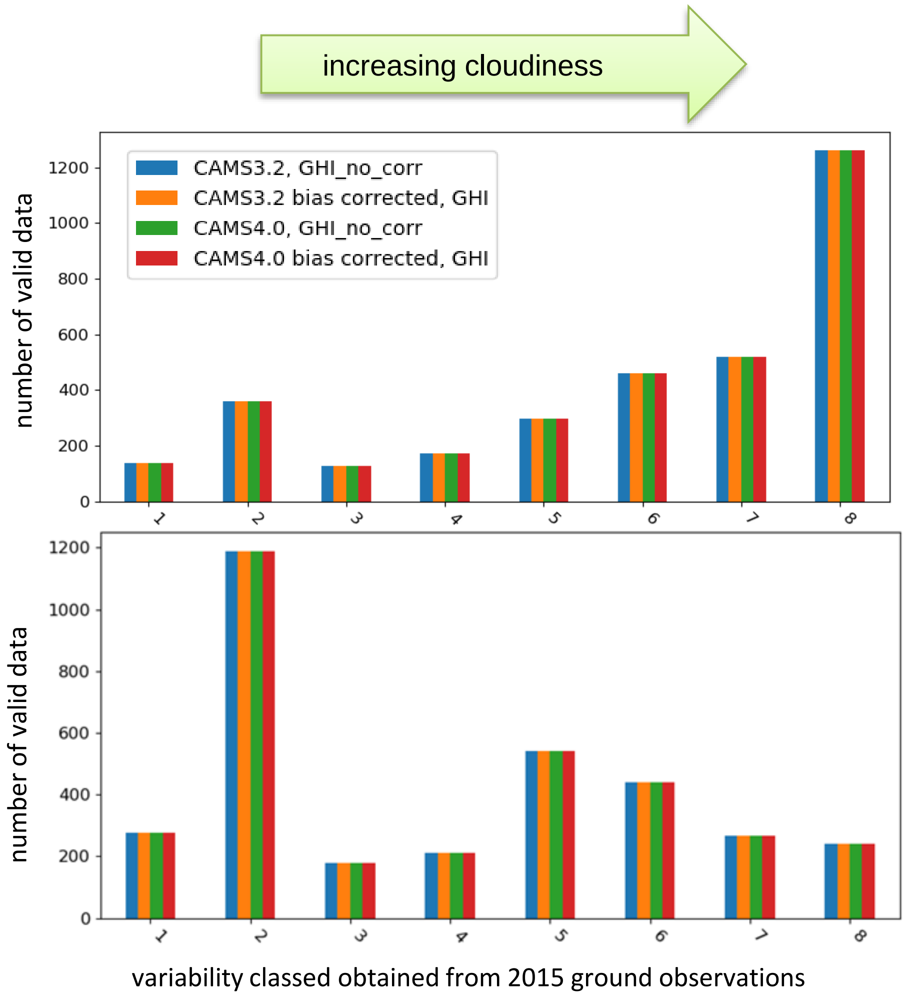
- 8 variability classes defined by typical direct irradiance patterns
- Automatic classification possible from ground-based direct irradiance time series, sky cameras, and SEVIRI cloud mask structure parameters

Schroedter-Homscheidt, et al., Meteorol. Z., DOI:10.1127/metz/2018/0875

Typical distribution of classes for two climate zones

Cabauw, Netherlands
BSRN station

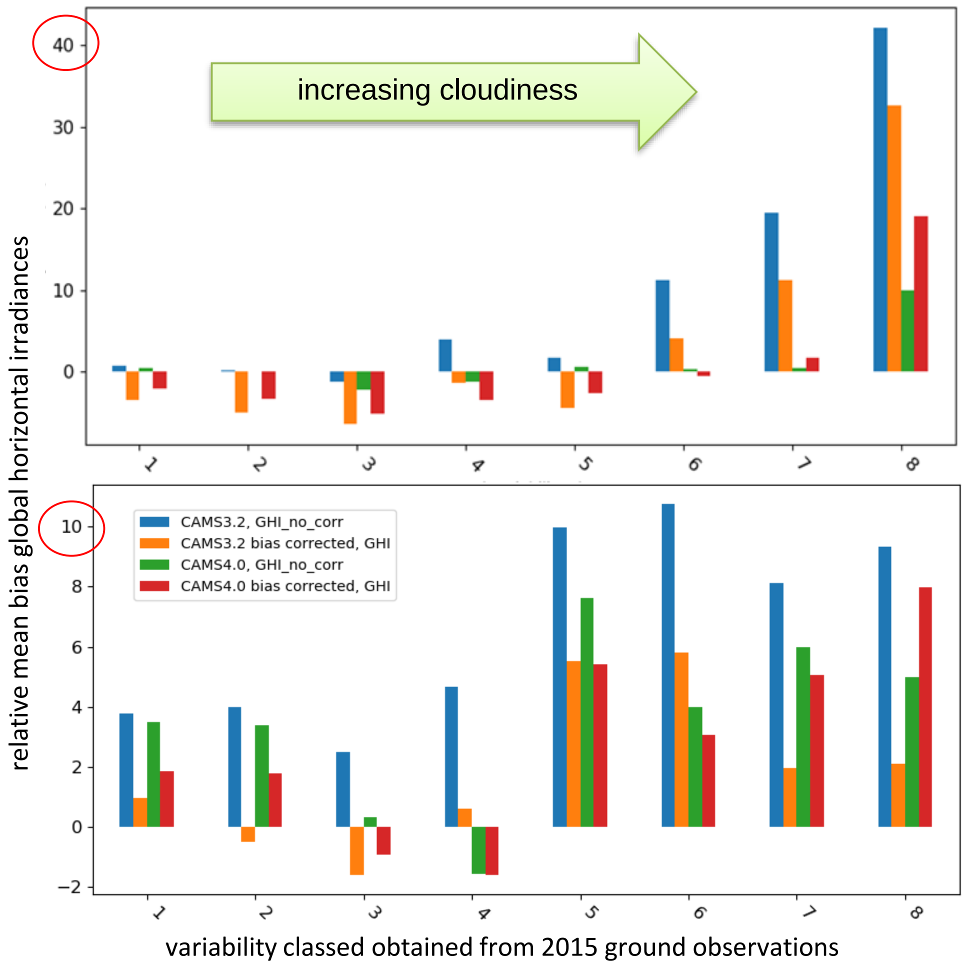
Cairo, Egypt
EnerMENA station



Variability dependent validation – relative mean biases

Cabauw, Netherlands BSRN station

Cairo, Egypt EnerMENA station



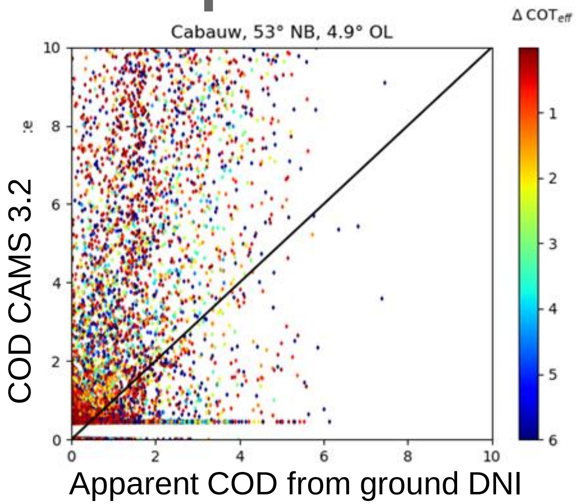
- 8 variability classes detected from ground-based 1 min direct irradiance observations
- Rel. biases CAMS v3.2 and v4.0 global horizontal irradiance
- With and without operational CAMS bias correction – trained globally with all data 2004-2020
- Bias correction V3.2: correcting cloudy cases & SEVIRI calibration; negative impact in clearer conditions in Cabauw
- Bias correction V4.0: correcting variable cloud conditions, less successful in clear & overcast conditions

Directly assessing the COD using ground measured DNI

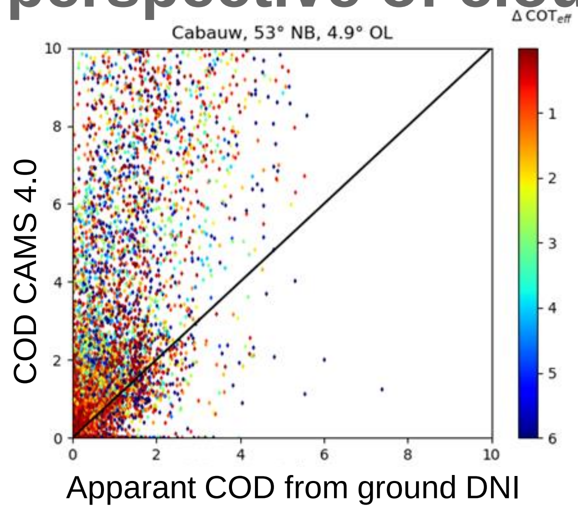
- $\mathrm{COD}^{eff} = -\log\cos(\mu)\left(\frac{DNI^{meas}}{DNI^{model}_{clear}}\right)$ with μ : Solar zenith angle

- Limitations: only possible for COD < 5 to 8 (depending on SZA)
- Less suitable for cases of high atmospheric aerosol content
- Some interference by circumsolar radiation
- Temporal averaging mixes up clear sky, cloud interruptions and cloudy states
  → Need to identify total overcast states
  → Determining cloud duration from min and max values of minute DNI values, assuming binary states within the minute.

COD Improvements from perspective of cloud duration

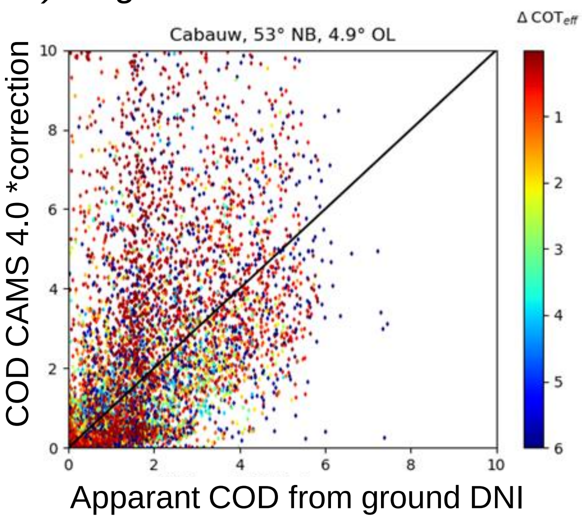


a) Original APOLLO Scheme

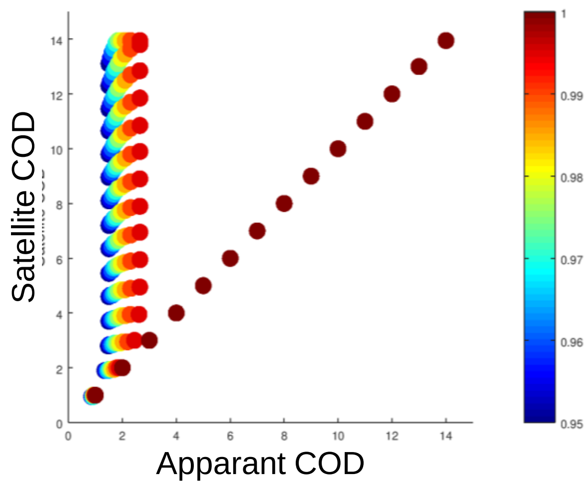


b) APOLLO NG Scheme

15 minute resolution



*c) APOLLO NG Scheme * Apparent COD correction*



c) RTM calculation for interrupted clouds (courtesy Antti Arola, FMI)

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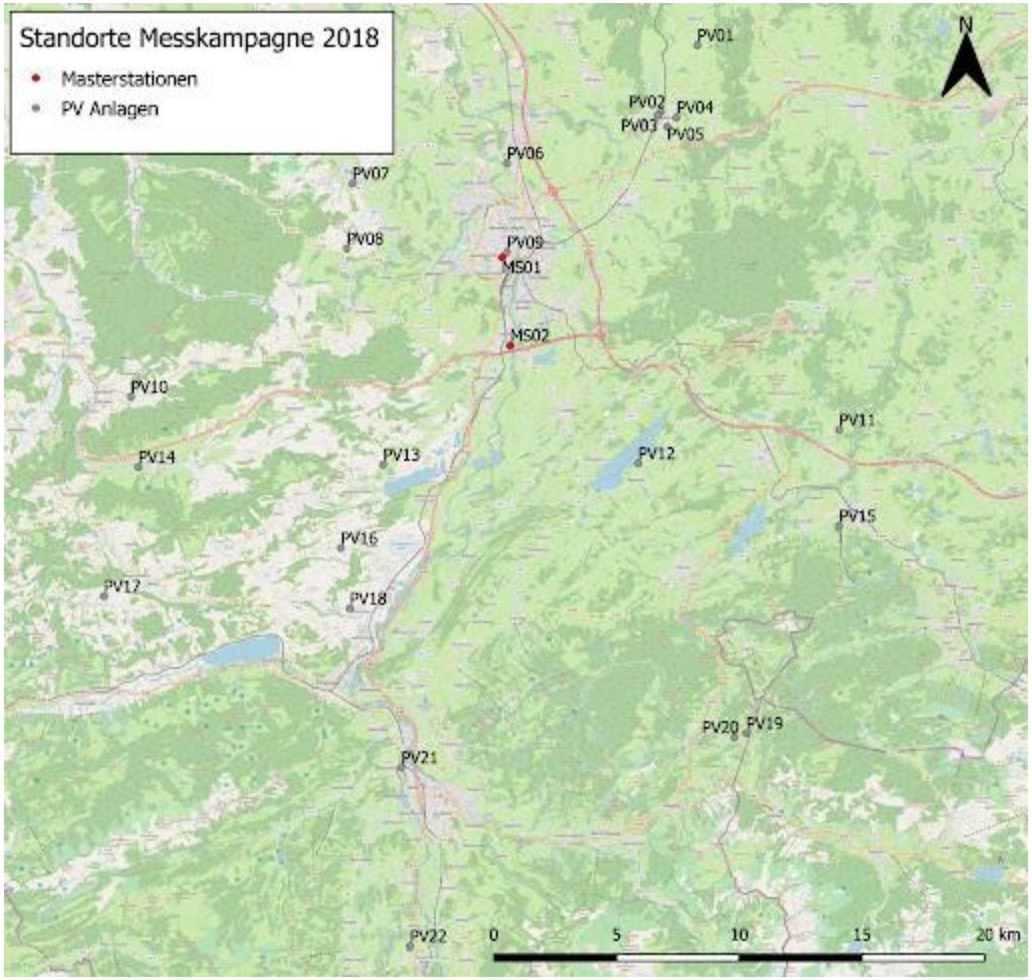
MetPVNet Measurement Network

MetPVNet

- 24 Measurement stations for GHI measurement
- Located in South of Germany near town of Kempten
- Area covers 4x4 satellite pixels
- Month long measurement campaigns in 2018 and 2019
- Data provided courtesy of TROPOS and Hochschule Bonn-Rhein-Sieg

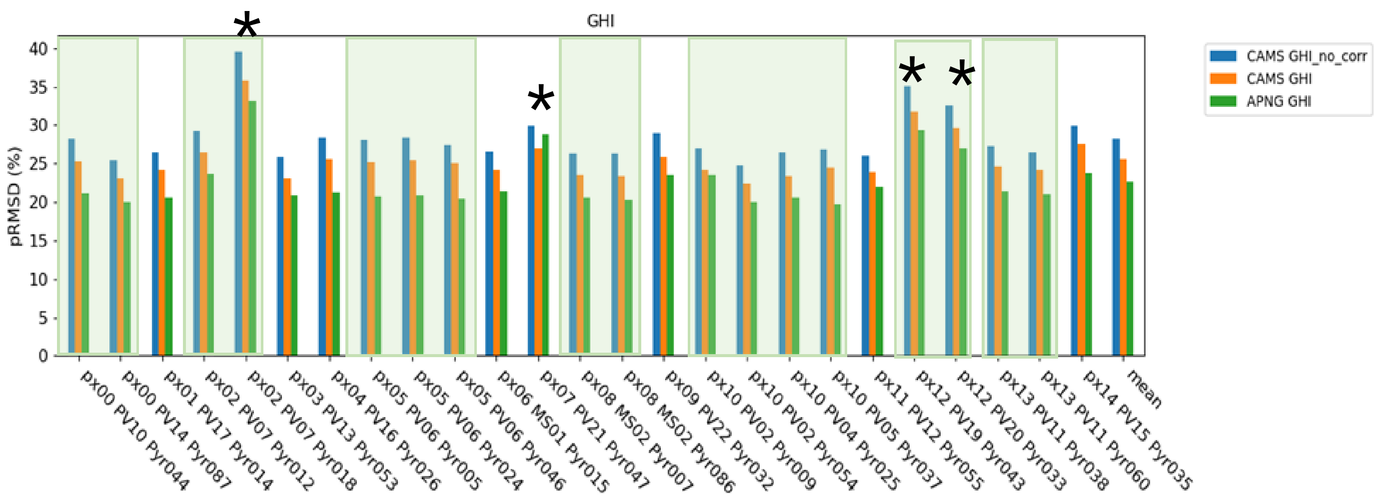
TROPOS
Leibniz Institute for Tropospheric Research

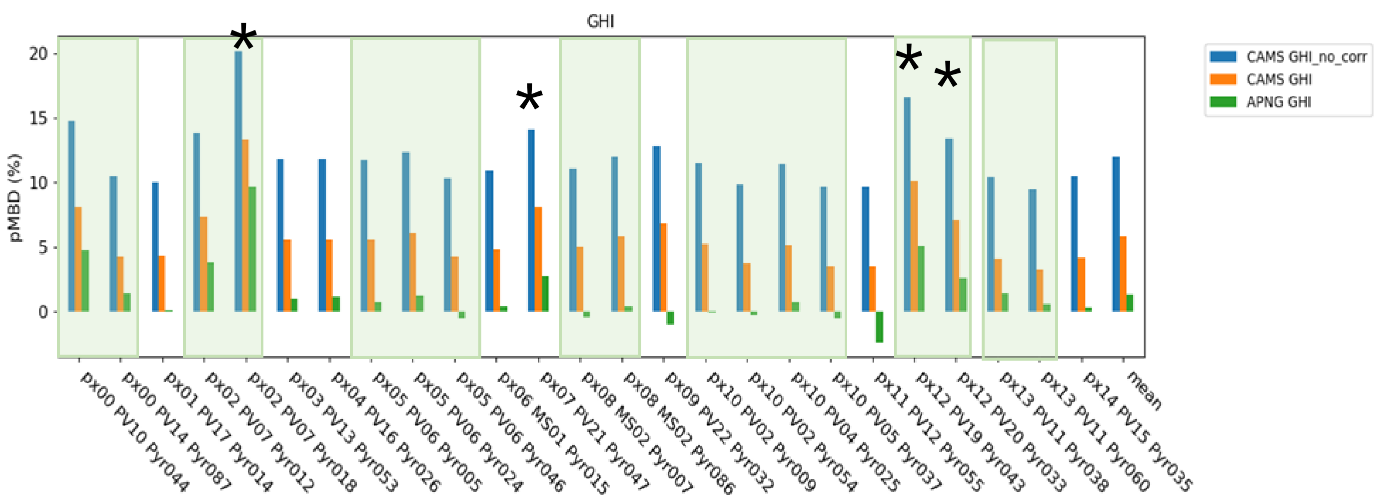
Hochschule Bonn-Rhein-Sieg
University of Applied Sciences



Spatial evaluation

* reduced data availability





- 35 days in June-Juli 2019
- Temporal resolution 15 minutes
- Differences in accuracy between pixels, but also within pixels:

  → shows limits to comparison of point measurement and spatial average

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Conclusions and outlook

- The quality of the irradiance data of the CAMS-Rad service has improved significantly due to recent methodological changes.
- Analysing satellite based irradiance by means of variability classes, cloud duration and spatial distribution gives additional information on the performance of the satellite method under different cloud state conditions.
- It is expected that these analysis method will be useful in further development of satellite based remote sensing of irradiance

Acknowledgements

This work was supported by:

- the EU Copernicus program
- the sixth Energy Research Framework Program of the German Federal ministry for economic Affairs and Energy

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Special thanks to:

- The colleagues of Transvalors and ARMINES for providing the operational CAMS-RAD data
- The colleagues of TROPOS and Hochschule Bonn-Rheinland-Sieg for providing the METPVNET measurements
- Annti Arola of FMI for the RTM calculations