CAMS RADIATION SERVICE FOR SOLAR ENERGY, EVALUATION OF RECENT IMPROVEMENTS AND SERVICE EVOLUTION

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EuroSun2024, 29.08.2024, Limassol, Cyprus

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CAMS radiation service (CRS)

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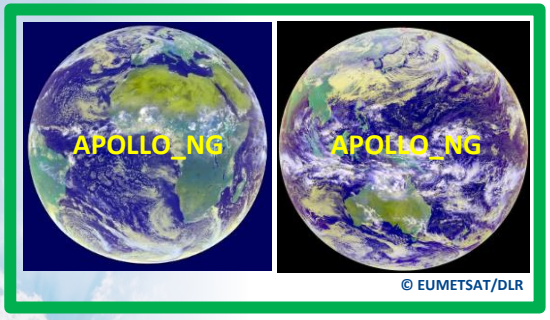
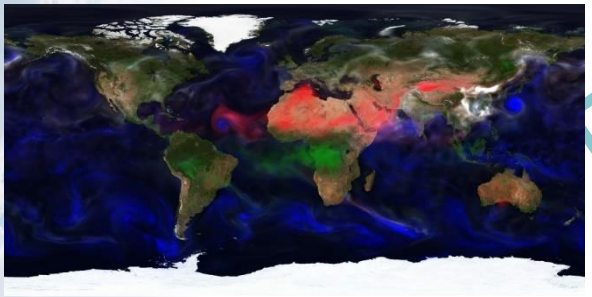


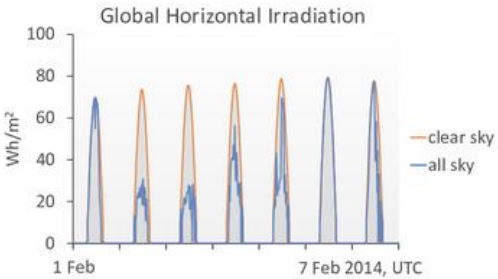
clouds from satellite



aerosol H_2O, O_3 from model

Heliosat-4 and McClear physical approaches, fast radiative transfer

Example Surface Solar Irradiance (SSI)



method papers

Gschwind et al., Contrib. Atm. Phys., 2019
Lefèvre et al., Atm. Meas. Tech., 2013
Qu et al., Contrib. Atm. Phys., 2017
Schroedter-Homscheidt et al., Contrib. Atm. Phys., 2022

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CRS time series to gridded data – generation principle

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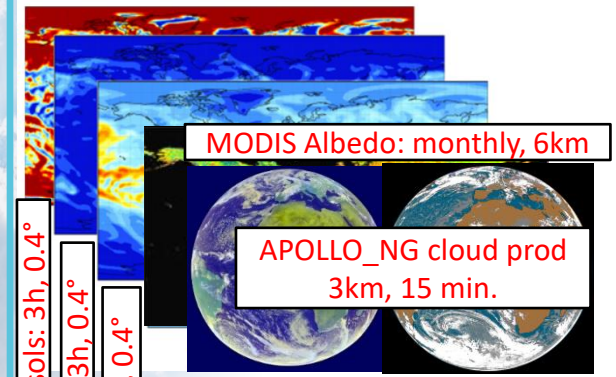
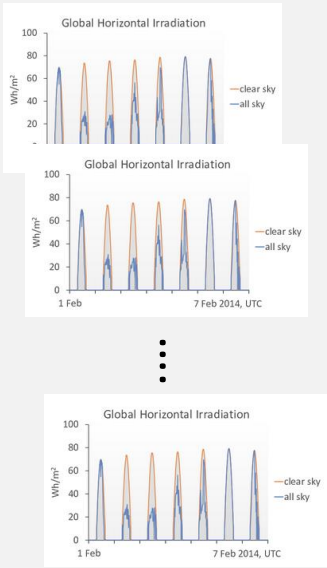
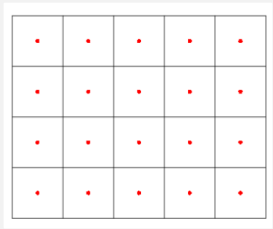
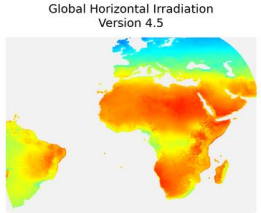


Primary product: CRS irradiation timeseries at specific lat/lon, 1 min temporal time step, aggregated to 15 or 60 min, 1 day, 1 year



Derived product: Collection of irradiation timeseries in 0.1° spatial grid in 15 min temporal aggregation





Global, direct, diffuse, direct normal components, cloud-free as well as all-sky irradiation

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Time series and gridded data service

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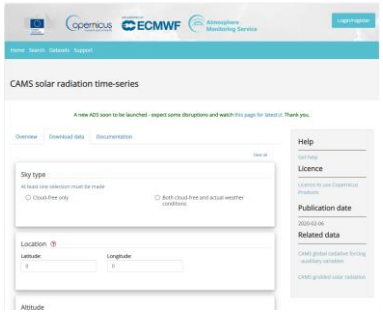
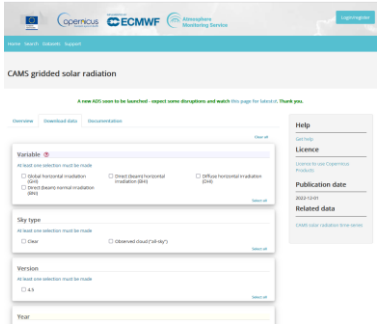
Primary product: On-the-fly processing of time series

- global, diffuse, direct and direct normal irradiation
- 2004 onwards in MSG FOV and 2016 onwards for HIMAWARI FOV
  1 min, 15 min, 1 hour, 1 day, 1 month temporal resolution
- any point within satellite field of view
- interactive access on CAMS ADS and user portal
- OGC script access possible or via open source library
- transparent access to all input data in expert mode (1 min)

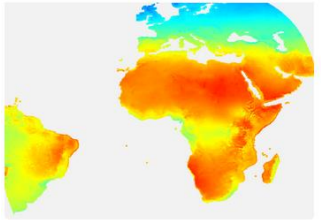
Pre-calculated gridded data

- global, diffuse, direct and direct normal irradiation
- 15 min temporal resolution selected
- 2005-2022 in MSG FOV
- **interactive access on CAMS ADS**
- **0.1° spatial grid selected**





Global Horizontal Irradiation
Version 4.5



Implemented by

https://www.soda-pro.com/web-services/radiation/cams-mcclear
https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-solar-radiation-timeseries?tab=overview

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Ground measurement database and Quality Control

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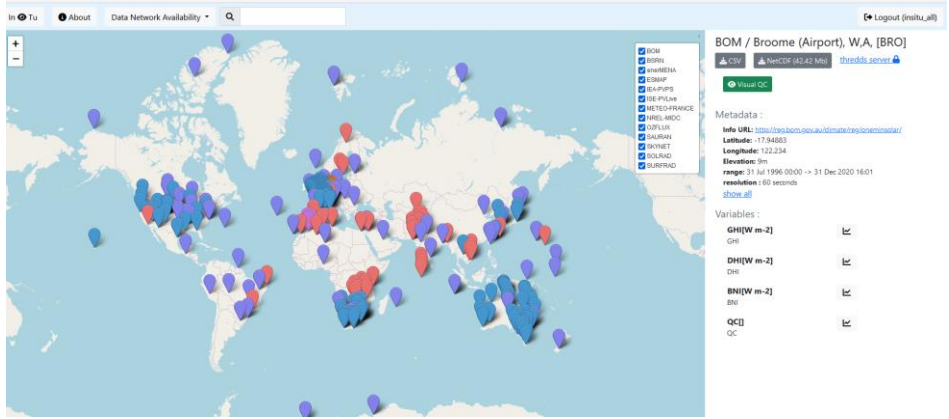
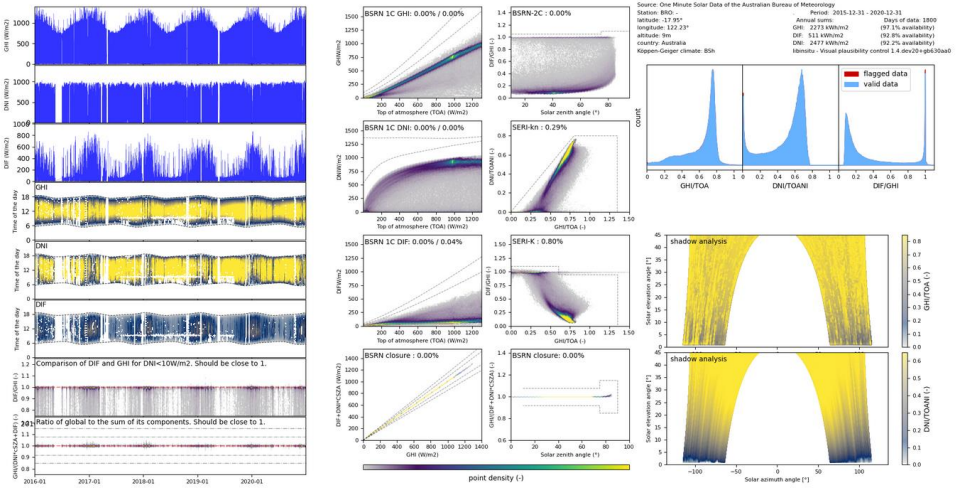
- Obtaining ground based SSI measurements on global scale – **continuous data base additions**
- harmonized netCDF structure, Climate and Forecast (CF) conventions and the FAIR (Findable, Accessible, Interoperable, Reproducible) principle
- Automatized visual Quality Control (QC)
- Python library libinsitu for data processing
- Data access through THREDDs data server
  https://viewer.webservice-energy.org/in-situ/



Quality check for station BOM / Broome (Airport), W.A. [BRO]



ECMWF

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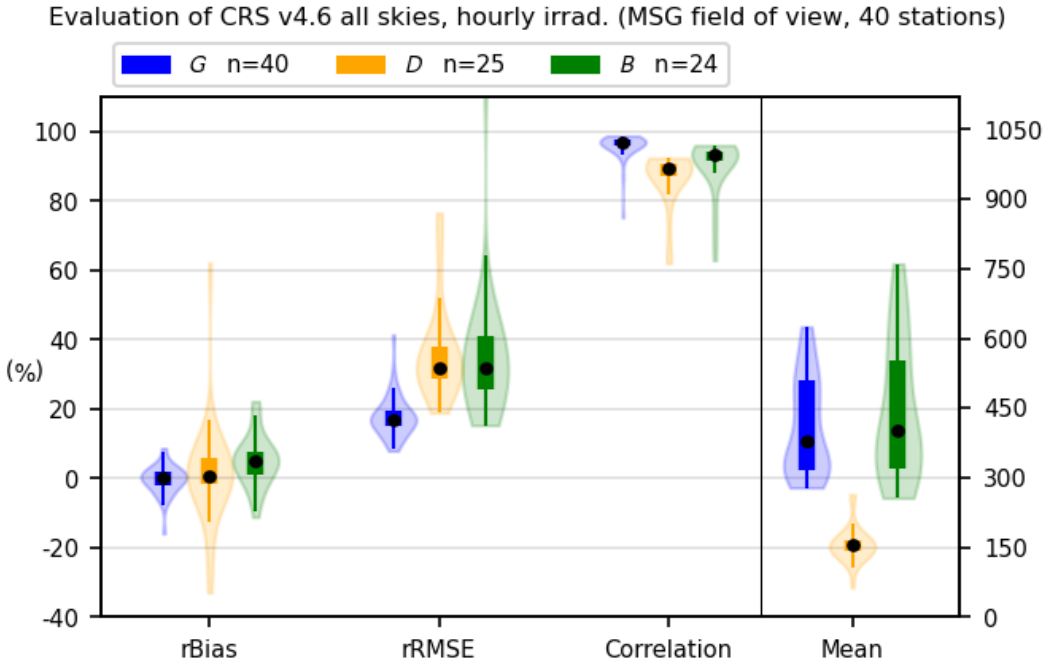
CRS recent version 4.6 evaluation

Summary of performances for stations for GHI (G), DHI (D) and BNI (B), hourly irradiance, year 2023



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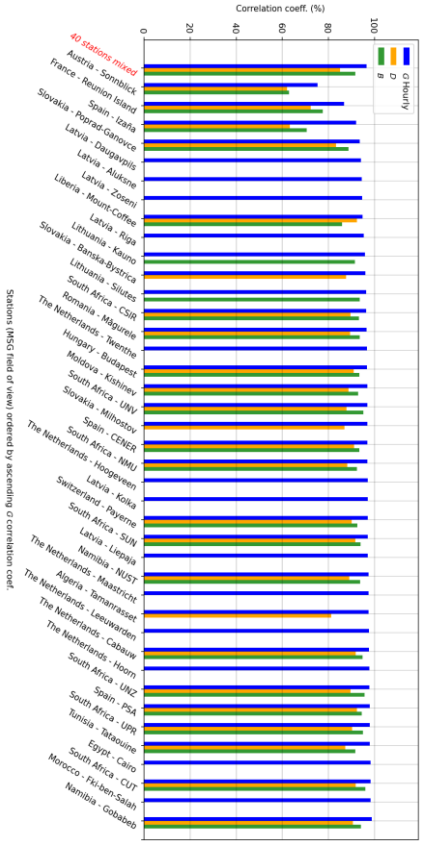

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CRS 4.6 evaluation

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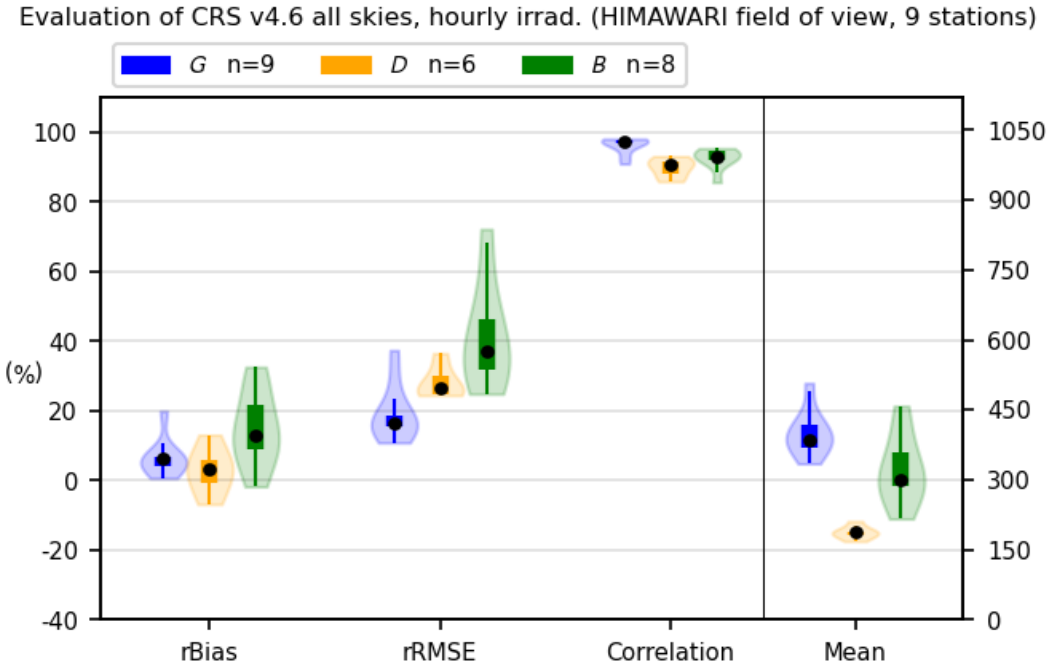

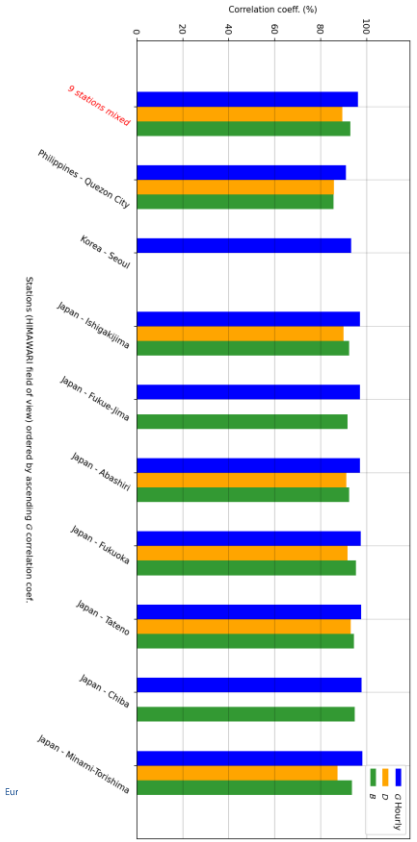

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CRS: Recent improvements

	CAMS 3.2 (until 05/2021)	CAMS 4.0 (until 09/2022)	CAMS 4.5 (until 06/2023)	CAMS 4.6 (current)
Calibration	Reflectances provided by EUMETSAT	Time-dependent updated calibration coefficients (Meirink et al. 2013 & updates)	same	same
Cloud retrieval	APOLLO, binary cloud mask (Kriebel et al. 1988 and 1989)	APOLLO-NG, probabilistic cloud mask (Klüser et al. 2015)	same	same
	Cloud optical thickness (COT) using Stephens et al. 1984 with clipping at COT < 0.5	COT using Stephens et al. 1984 with COT LUTs extended to 0.001	same	same
Cloudy/Clear in Heliosat-4	based on a binary mask	Cloud probability threshold 1%	same	same
Circumsolar correction	Single COT value	Empirical apparent COT factor for direct normal iradiance (DNI) : • 0.41 for thin ice clouds • 0.20 for water/mixed phase clouds	same	same
Aerosol/ TWC/O3	MACC reanalysis & CAMS NRT, various versions	MACC reanalysis & CAMS NRT, various versions	CAMS reanalysis*	CAMS reanalysis until 2020, update to IFS NWP (Cy 48r1) in McClear v3.6
Bias correction	Empirical multiplication factor	Re-trained bias correction	No bias correction	same
Coverage	MSG FOV	MSG FOV	MSG FOV	MSG/HIMAWARI FOV

- For CAMS v4.5, CAMS reanalysis is used for times series within 2004 and 2020. After 2020, McClear v3.5 or v3.6 with different IFS inputs are used

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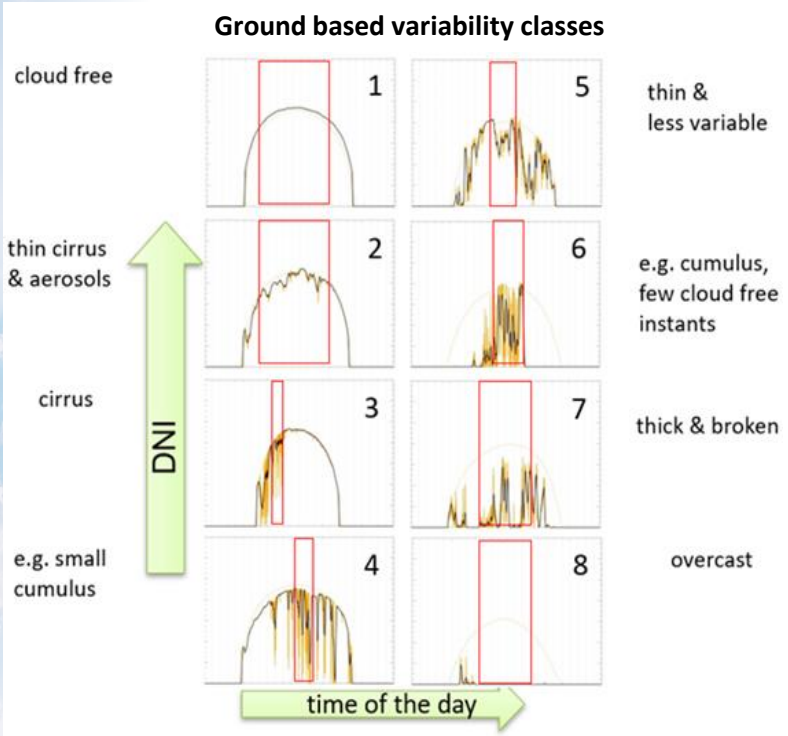
CRS version updates - evaluation based on radiation variability classes



Example variability classes 1-8

Hours being classified, 1-min resolved data, 10 min moving average

- 8 classes defined by ground based direct irradiance patterns
  - Classes 1 & 2: clear and nearly clear sky
  - Classes 3-5: large number of optically thin clouds
  - Classes 6-7: optically thick scattered or broken clouds
  - Class 8: overcast
- Schroedter-Homscheidt, et al., Meteorol. Z., DOI:10.1127/metz/2018/0875

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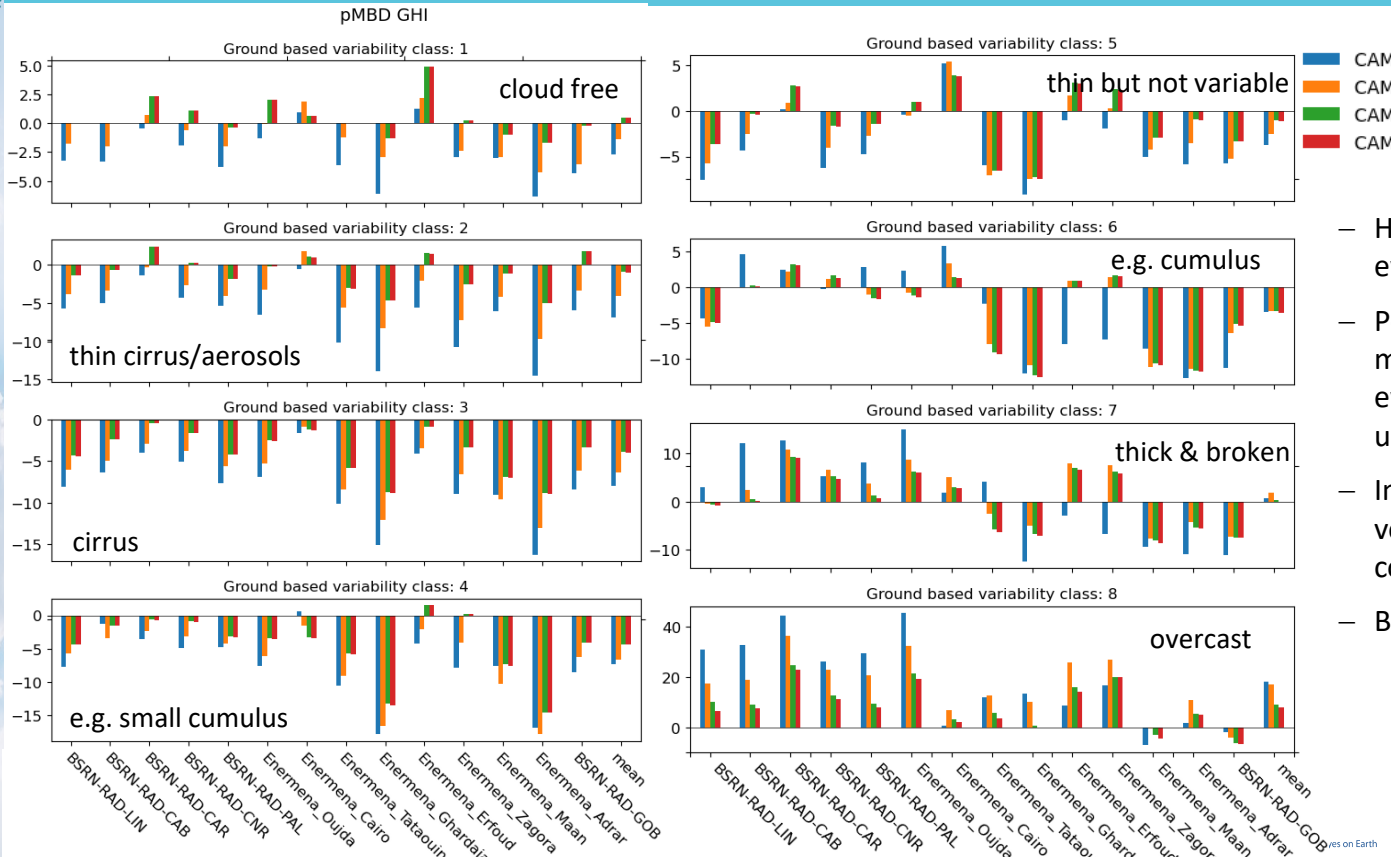
CRS version updates evaluation: based on DNI variability



- Hourly GHI. Year evaluated 2015
- Percental relative mean bias (pMBD) evolution in version updates
- Improvement over versions in all cloud conditions
- Balancing biases

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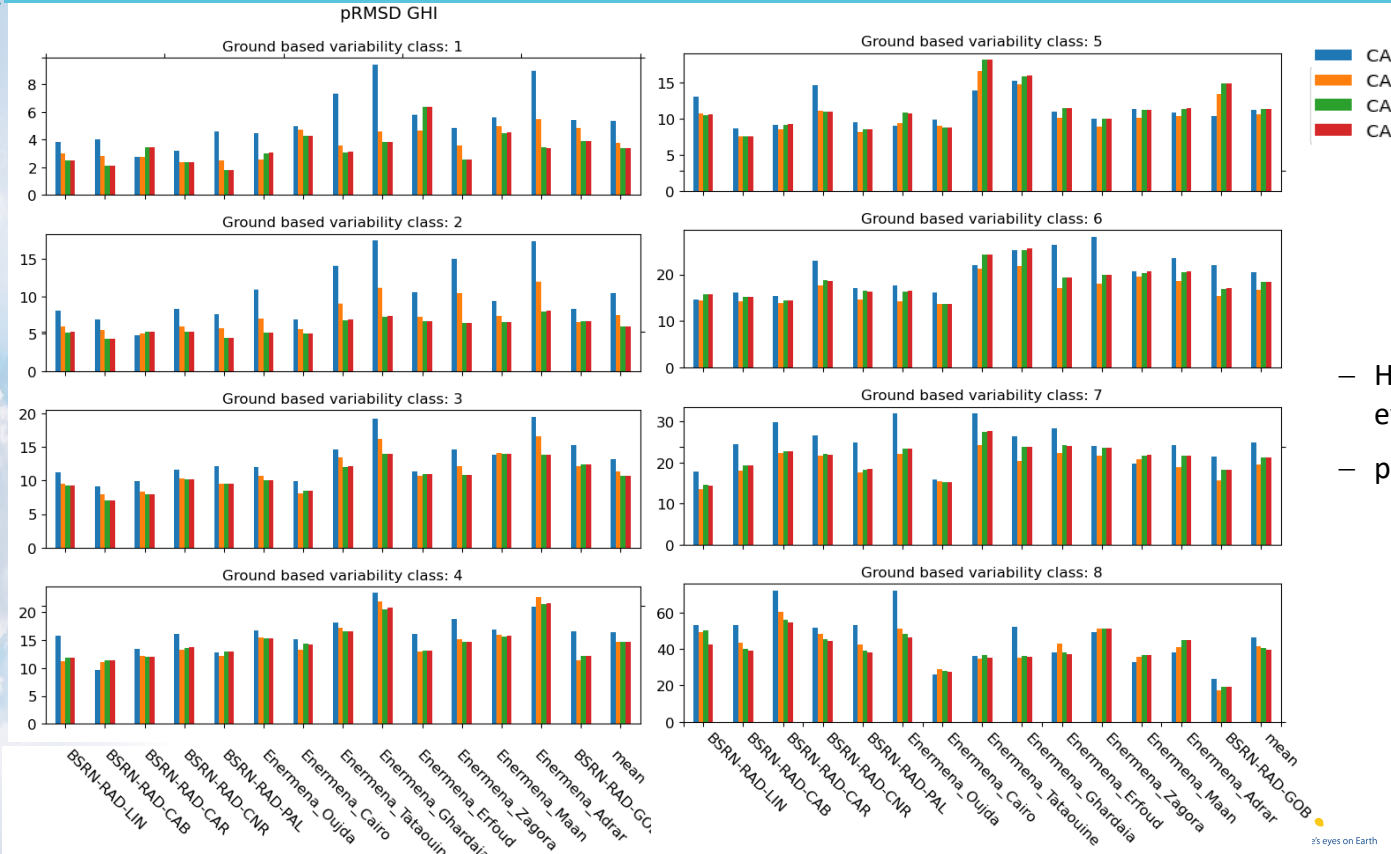
CRS version updates evaluation: based on DNI variability



- Hourly GHI. Year evaluated 2015
- pRMSD

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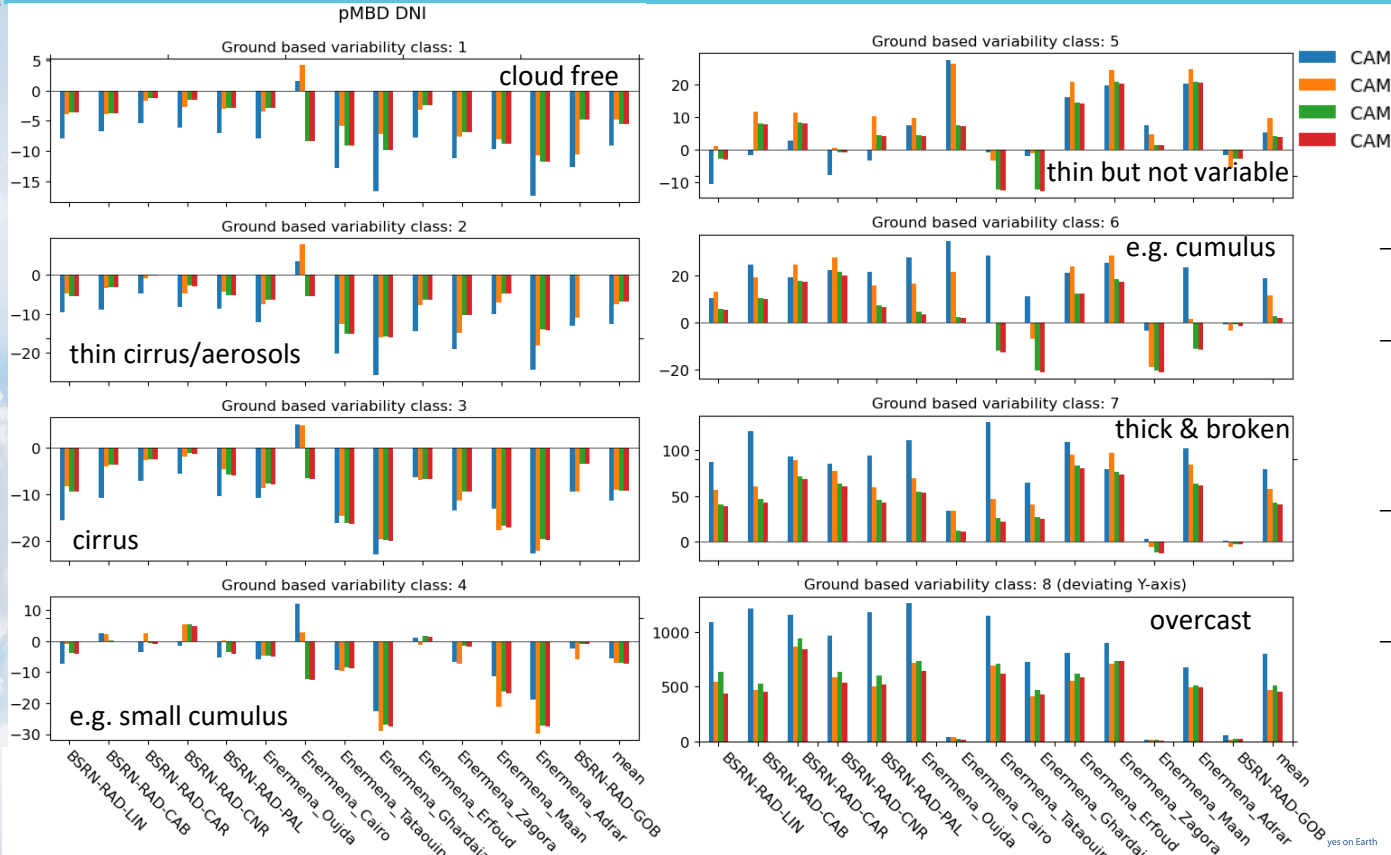
CRS version updates evaluation: based on DNI variability



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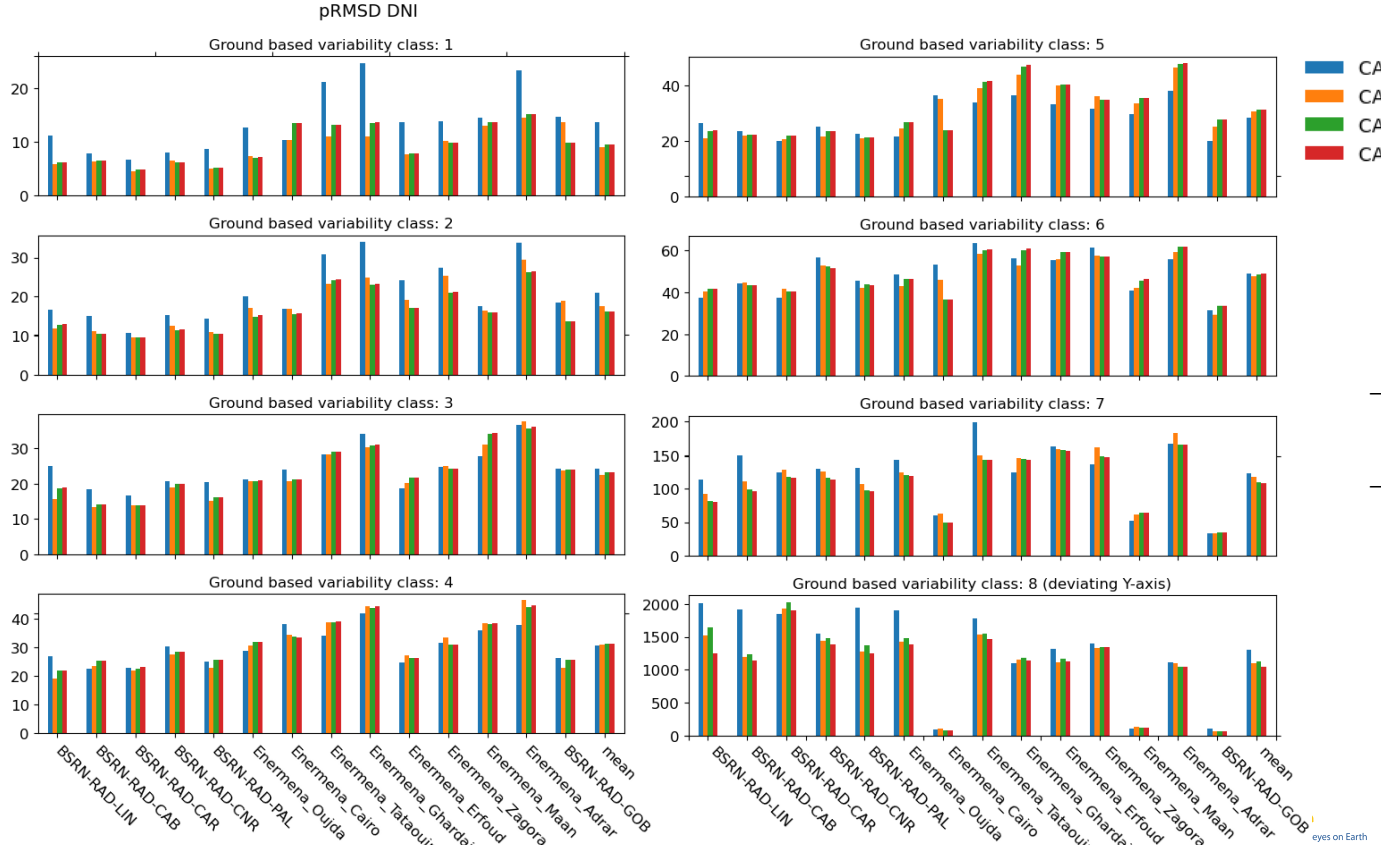

- Hourly DNI. Year evaluated 2015
- pRMSD

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Preparing for McClear V4 – principle of using aerosols more flexible

	McClear v1 & v2 (n_{dim}=10)	***McClear v3*** (n_{dim}=9)	***McClear v4*** (n_{dim}=12)
Site information	• Site elevation above mean sea level (8) • Elevation above ground level (5) • albedo(3)	• Site elevation above mean sea level (8) • Elevation above ground level (5) • albedo(3)	• Site elevation above mean sea level (8) • Elevation above ground level (5) • albedo(3)
Sun position	• Solar zenith angle (6)	• Solar zenith angle (9)	• Solar zenith angle (9)
Atmosphere	• Vertical profile of temperature, pressure, density and volume mixing ratio for gases (5) • Total column content in ozone (4) • Total column in in water vapour (12)	• Vertical profile of temperature, pressure, density and volume mixing ratio for gases (5) • Total column content in ozone (4) • Total column in in water vapour (12)	• Vertical profile of temperature, pressure, density and volume mixing ratio for gases (5) • Total column content in ozone (4) • Total column in water vapour (11)
Aerosol	• Aerosol optical depth at 550 nm (10) • Aerosol Angstrom coefficient (9) • Aerosol mixture (9)	• Aerosol optical depth at 550 nm (10) • Aerosol species (5)	• Aerosol optical depth at 550 nm (10) • Aerosol Angstrom coefficient (5) • **Asymetry factor g (5)** • **Single scattering albedo ssa (4)** • **Absorption Angstrom exponent AAE (4)**

McClear V4 acceptance procedure - evaluation

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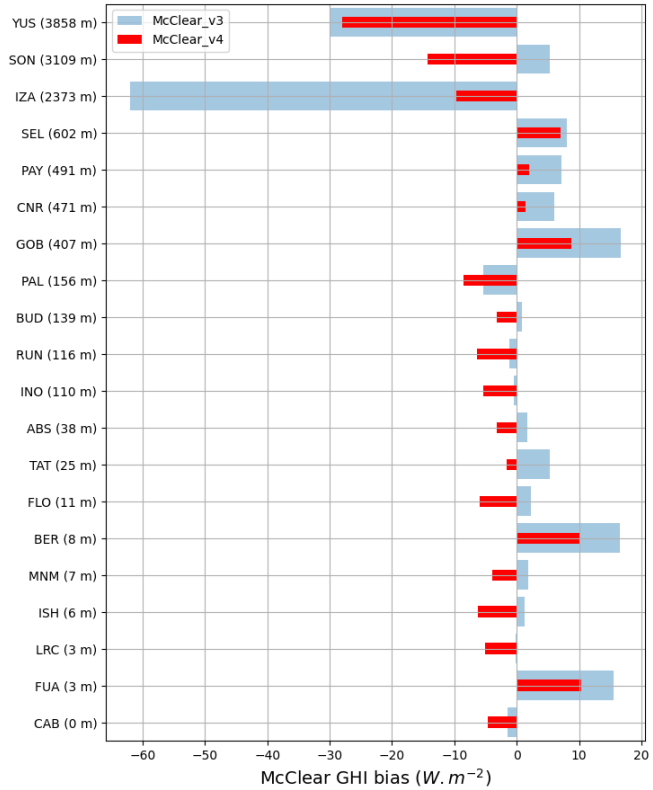
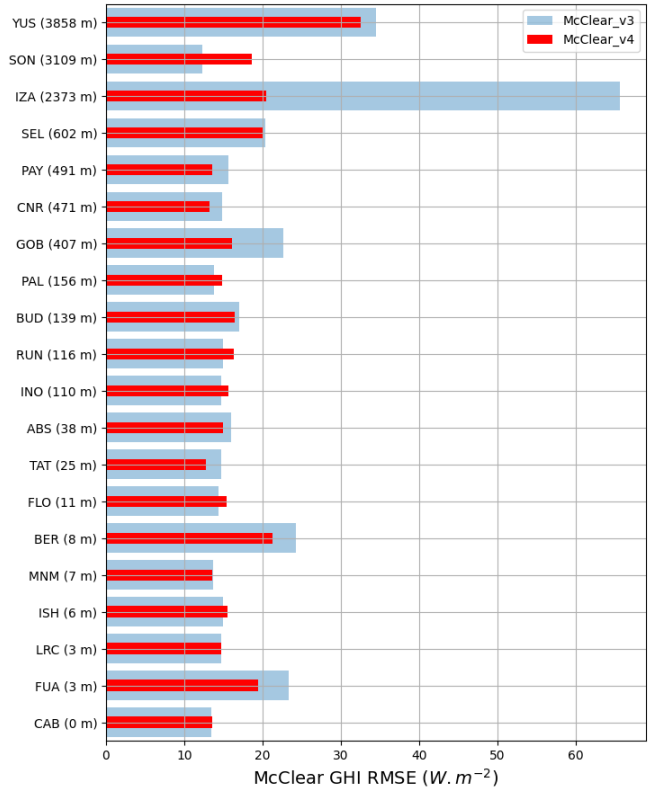
- Bias and RMSE for McClear GHI
- Positive impact of v4 shown
- LUT generation ongoing to generate operational code





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Conclusion & Current + future work

Conclusions:

- The evaluation of the CAMS recent version 4.6 shows that the trend of metrics is similar for both MSG and HIMAWARI FOV
- Variability classes based evaluation of CAMS v3.2 – CAMS 4.6 show improvement over versions in all cloud conditions

Current and future work:

- McClear V4 implementation to replace mapping to OPAC aerosol types
- Gridded data in HIMAWARI FOV in preparation
- Preparations for MTG ongoing
- Investigating reasons for balancing biases

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Contact point & references

- general inquiries and user requests: ADS Support page at https://ads.atmosphere.copernicus.eu/cdsapp#!/usersupport
- specific for the Solar Radiation Service team: marion.schroedter-homscheidt@dlr.de
- User's Guide at http://atmosphere.copernicus.eu/documentation
- Heliosat-4 method
  - Qu et al., Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method, MetZet, 2017
  - Schroedter-Homscheidt et al., Surface solar irradiation retrieval from MSG/SEVIRI based on APOLLO Next Generation and HELIOSAT-4 methods, Contr. Atm. Phys., Vol. 31 No. 6 (2022), p. 455 – 476, DOI: 10.1127/metz/2022/1132
- McClear method
  - Lefèvre et al., McClear: a new model estimating downwelling solar radiation at ground level in clear-sky conditions, AMT, 2013
  - Gschwind et al., Improving the McClear model estimating the downwelling solar radiation at ground level in cloud-free conditions – McClear-v3, Contrib. Atm. Phys./Meteorol. Z., 2019
- Broadband irradiation evaluation: Quarterly validation reports at https://atmosphere.copernicus.eu/supplementary-services