The new CAMS Radiation Service v4.6 :

method improvements and service evolution with a special focus on solar energy

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[3]Vaisala, France
[4]MINES Paris, PSL University, France

Atmosphere Monitoring

EUPVSEC 2024, Vienna, 23 – 27 September

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DLR with MINES PARIS | PSL VAISALA

What is the CAMS Radiation Service ?

Atmosphere Monitoring

Copernicus Atmosphere Monitoring Service (CAMS)

CAMS provides consistent and quality-controlled information related to air pollution, solar energy and greenhouse gases worldwide.

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CAMS Radiation Service (CRS)

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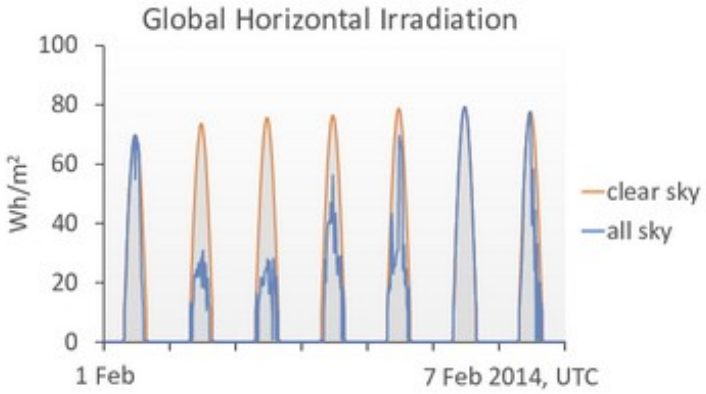
CAMS colected data



From CRS you get for **free and fore any use** time series :

- **normal mode:** clear and all sky irradiance time serries
- **expert mode :** AODs, cloud type, cloud optical depth
  Albedo, O3, water vapor, solar zenith angles ...

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CRS in a nutshell

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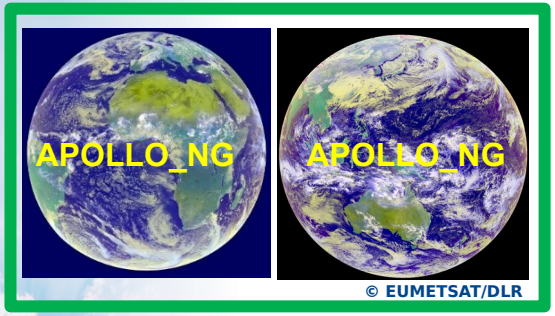
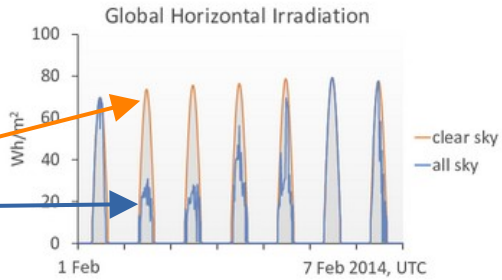
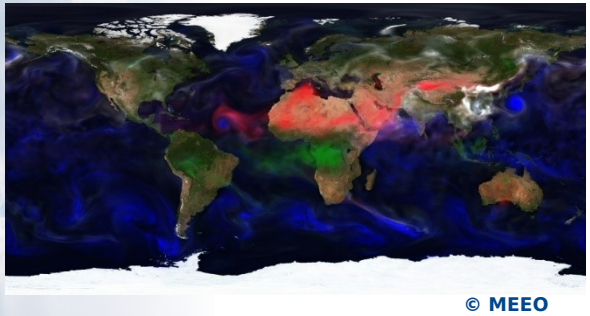


clouds from satellite

Fast radiative transfer pysical approachoes: **McClear** and **Heliosat-4**



aerosol H_2O, O_3 from model



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 inputs and products

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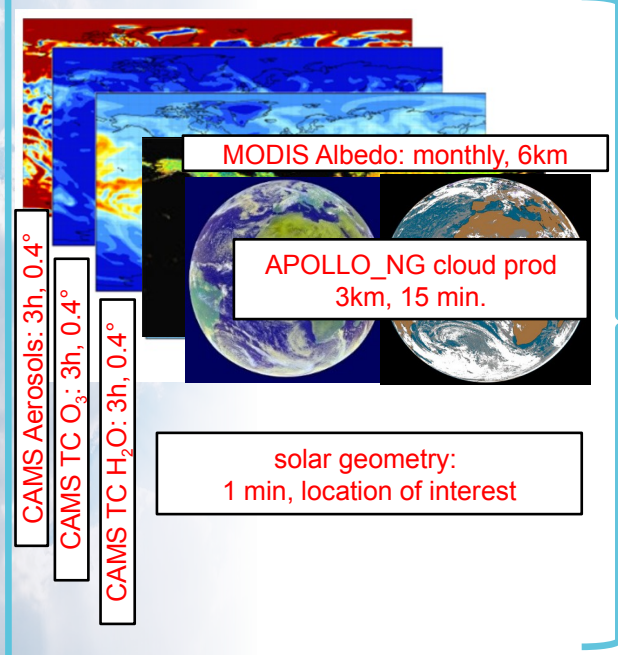
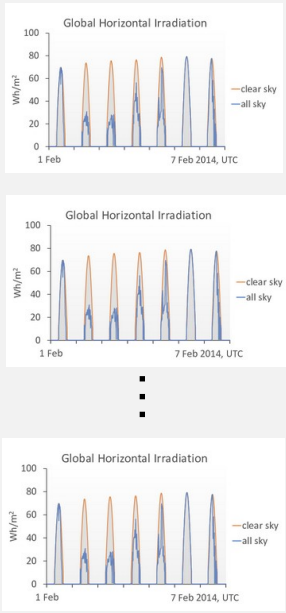
Input data



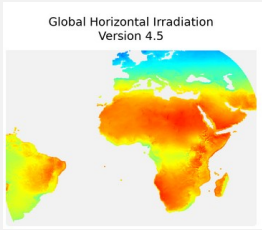
Primary product

Irradiation timeseries:
Specific lat/lon



Derived product

Irradiation gridded data:
Collection of irradiation timeseries



Global, direct, diffuse :
- **cloud-free as well**
- **all-sky irradiation**

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Time series and gridded product description

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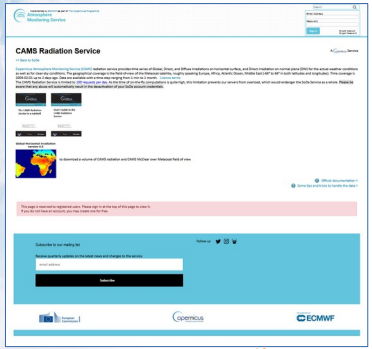
Primary product: on-the-fly processing of time series

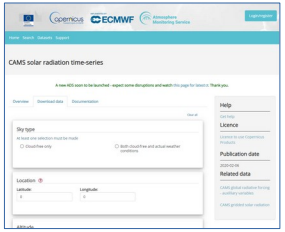
- **global, diffuse** and **direct normal** irradiation
- Since **2004** (MSG FOV) and **2016** (HIMAWARI FOV)
- **1 min, 15 min, 1 hour, 1 day, 1 month** temporal resolution
- interactive access on **CAMS ADS** [1] and **user portal** SoDa Solar radiation Data [2]
- OGC script access possible or via **open source library** pvlib [3]
- expert mode (AODs, Cloud classificaiton, …)
- registration necesary (statistical purposes)

Derived product: pre-calculated gridded data

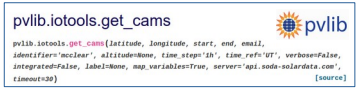
- **global, diffuse** and **direct normal** irradiation
- **15 min** temporal resolution selected
- **2005-2023 in MSG FOV**
- interactive access on **CAMS ADS [4]**
- **0.1°** spatial grid selected

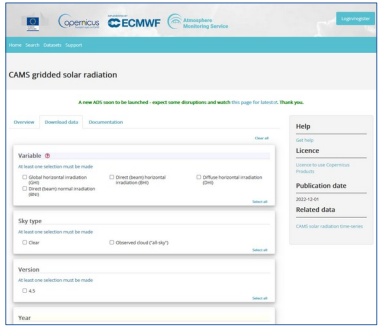


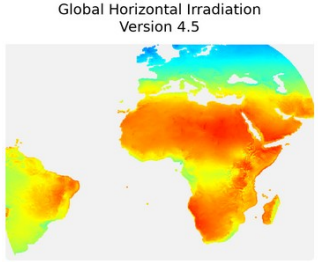
Implemented by SoDa Solar radiation Data



ADS







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[1] https://ads-beta.atmosphere.copernicus.eu/datasets/cams-solar-radiation-timeseries?tab=overview
[2] https://www.soda-pro.com/web-services/radiation/cams-radiation-service
[3] https://pvlib-python.readthedocs.io/en/stable/reference/generated/pvlib.iotools.get_cams.html

[4] https://ads-beta.atmosphere.copernicus.eu/datasets/cams-gridded-solar-radiation?tab=download

CRS v3.6 evaluation

Ground measurement database and Quality Control

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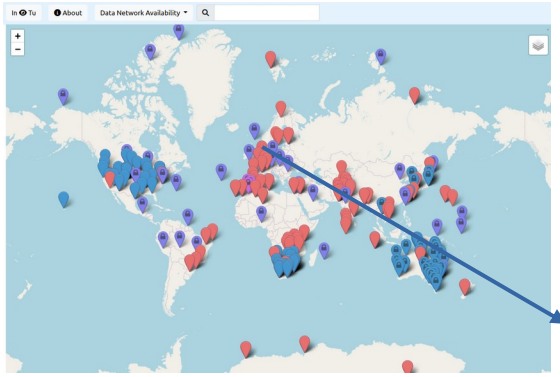
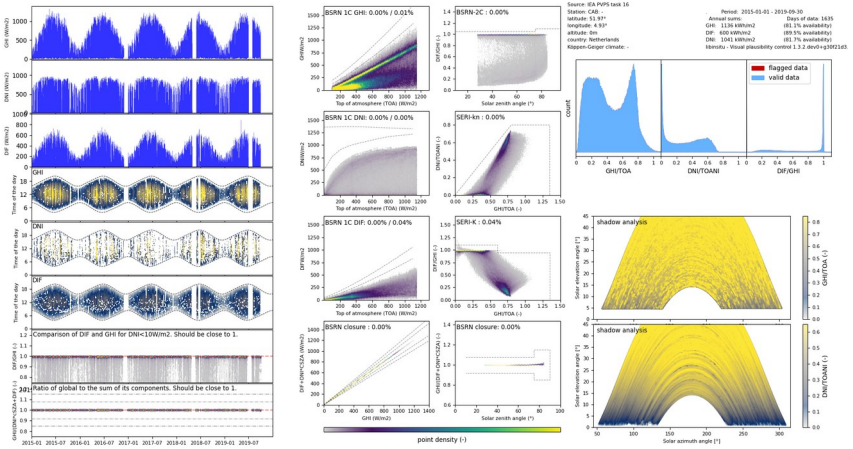
Database

- ground observations on high quality networks
  - harmonized netCDF structure
  - Climate and Forecast (CF) conventions
  - FAIR principle (Findable, Accessible, Interoperable, Reproducible)
- Data access through THREDDs data server [1]





Quality checks

- Automatized visual Quality Control (QC)
- Python library libinsitu for data processing and QC [2]

[1] https://viewer.webservice-energy.org/in-situ/
[2] https://libinsitu.readthedocs.io/en/latest/

CRS recent version 4.6 evaluation (MSG)

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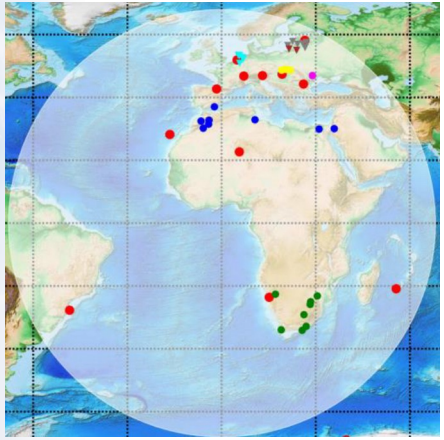
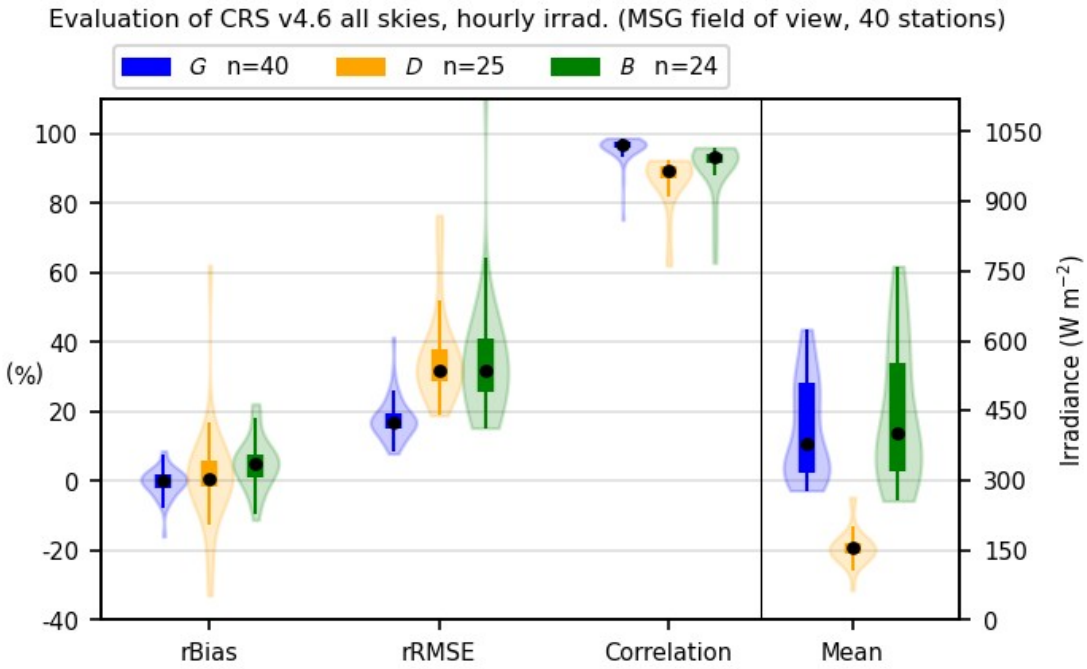
Error metrics for CRS for :

- GHI (**G**), DHI (**D**), BNI (**B**)
- **40 locations in** MSG field of view
- **year 2023**





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CRS recent version 4.6 evaluation (HIMAWARI)

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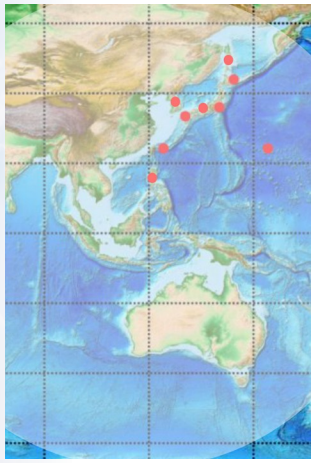
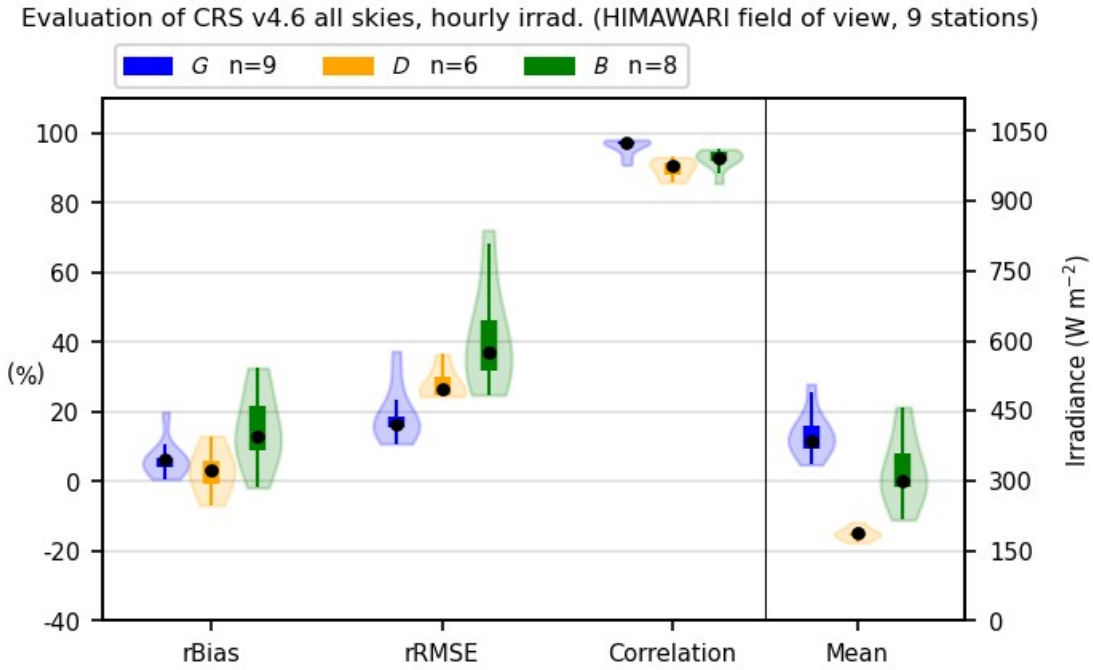
Error metrics for CRS for :

- GHI (**G**), DHI (**D**), BNI (**B**)
- 9 **locations in** HIMAWARI field of view
- **year 2023**





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CRS evolution evaluation

CRS: version updates

	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 detection	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**
Radiative model	Heliosat 4	Heliosat 4	Heliosat 4	**Heliosat 4**
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)**
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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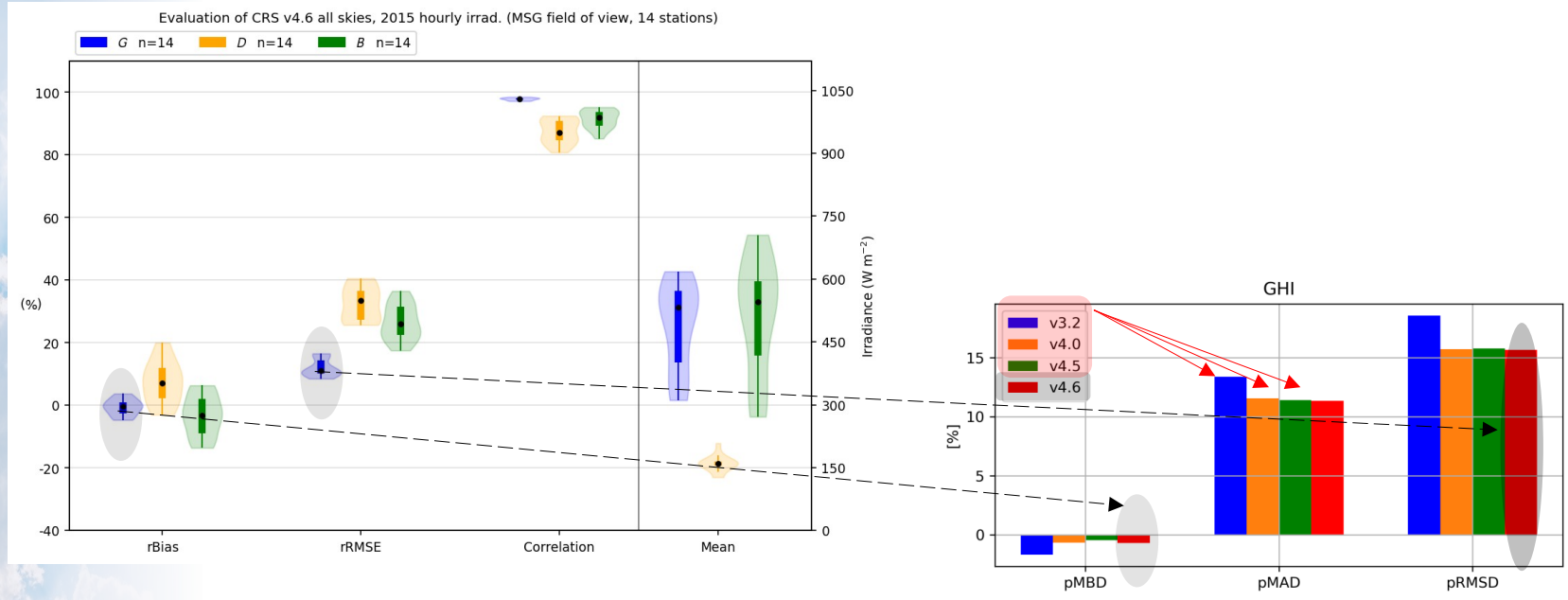
CRS version updates evaluation : Benchmark year 2015



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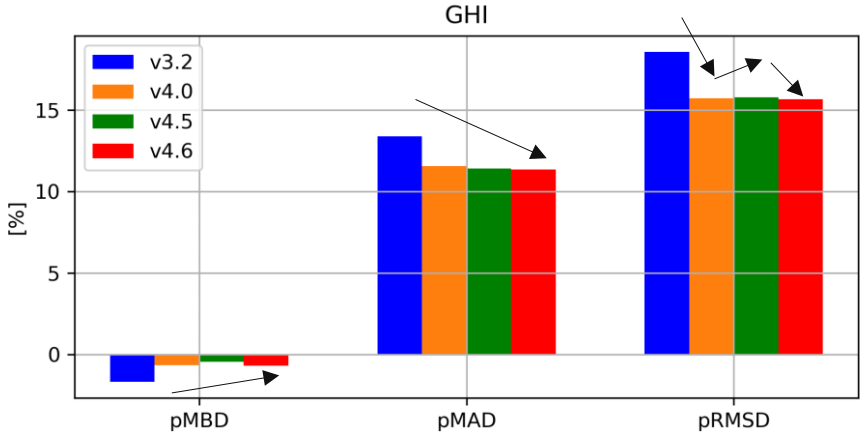
CRS version updates evaluation

Evaluation :

- CRS versions evaluated in the
  - **year 2015** : variability classes benchmark
  - components : **GHI**
  - Metrics : **rMBD, rMAD, rRMSD**
  - **14 locations in** MSG FoV (BSRN, enerMENA)



Results :

- **BIAS, MAD** improvement with each version
- **RMSE:** deterioration on v4.5 and improvement in 4.6

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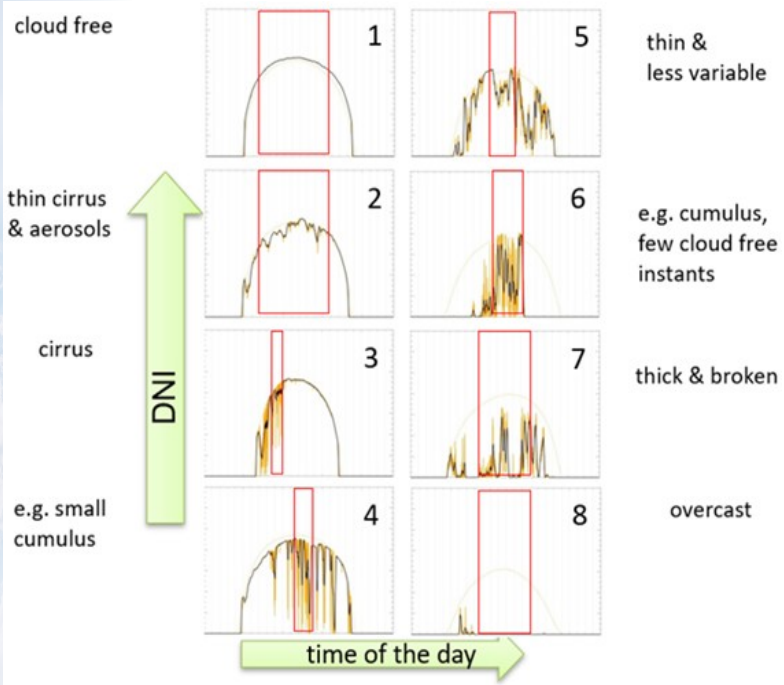
CRS version updates - evaluation based on radiation variability classes

DNI based variabilitiy classes



- 8 classes defined by DNI 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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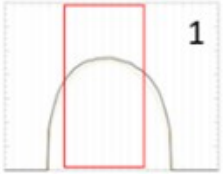
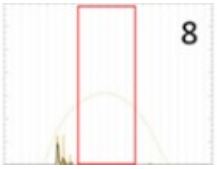
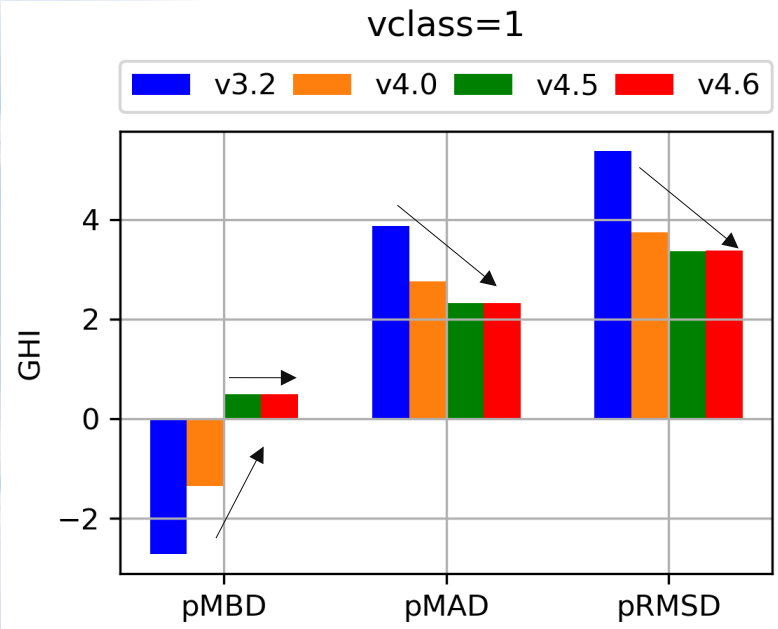
CRS version updates evaluation: based on DNI variability

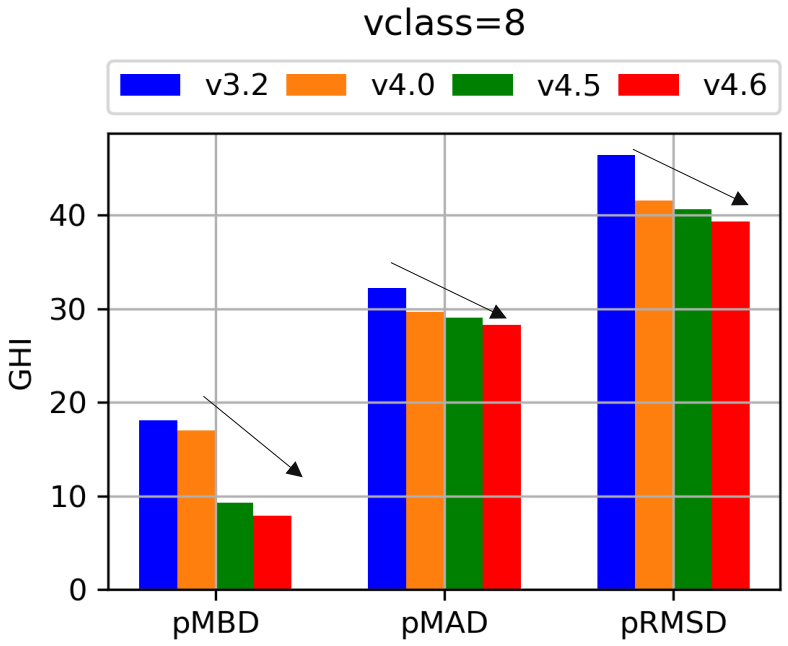


Cloud free



Overcasted





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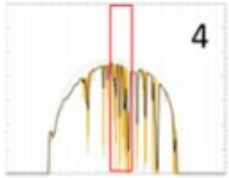
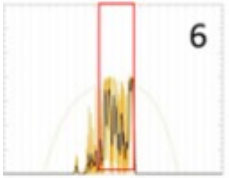
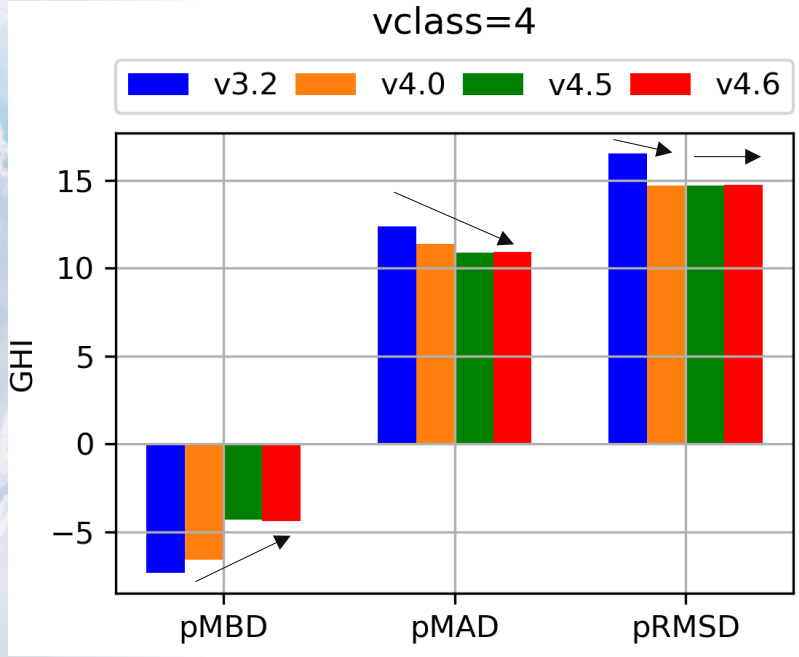
CRS version updates evaluation: based on DNI variability

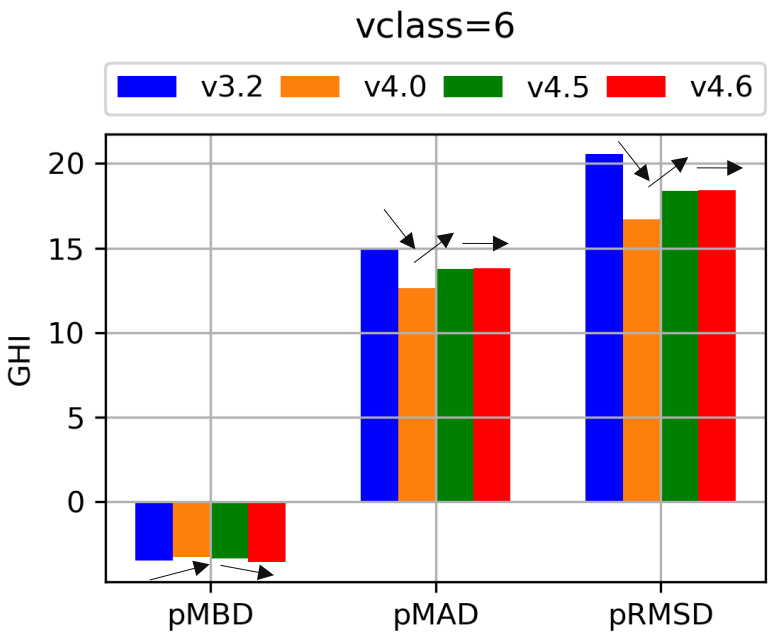


Small cumulus



Cumulus,
few cloud free





Preparing for McClear V4 – principle of using aerosols more flexible

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	McClear v1 & v2 (n_{dim}=10)	***McClear v3*** (n_{dim}=9)	***McClear v4*** (n_{dim}=9)
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 treated in variable preprocessing) • 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)	• Pressure (3) • Total column content in ozone (4) • Total column in water vapour (14)
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 (14) • Aerosol Angstrom coefficient (7) • **Asymmetry parameter g (3)** • **Single scattering albedo ssa (3)**
	139 968 000 (~139 M)	12 960 000 (~13 M)	4 000 752 (~4 M)

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McClear V4 acceptance procedure - evaluation

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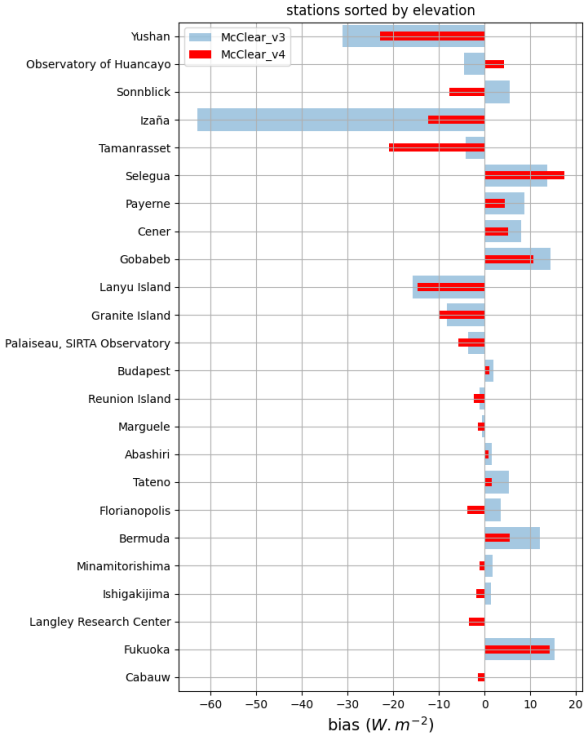
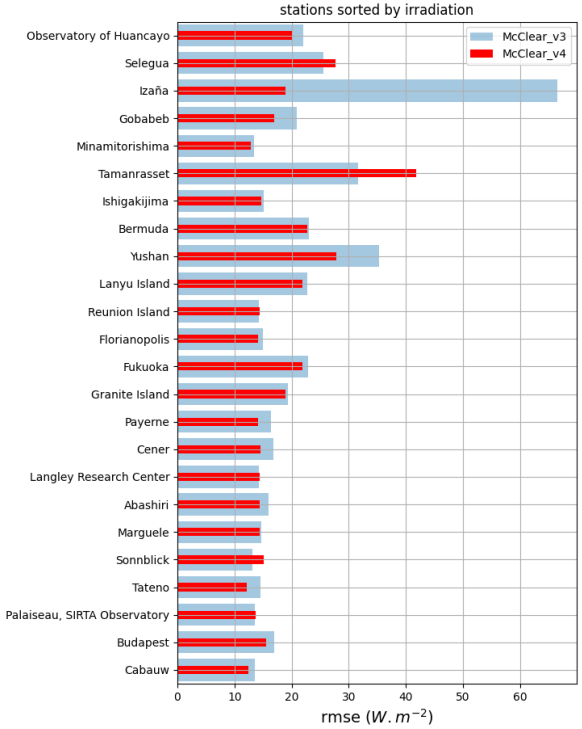
- Bias and RMSE for McC
- Positive impact of v4 shown
- LUT generation ongoing operational code





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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 time for the different versions
  - Highly variable classes to be studies further

Current and future work:

- McClear V4 implementation to replace mapping to OPAC aerosol types (prototype ready)
- 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

Thank you for your attention

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Exrtra slides

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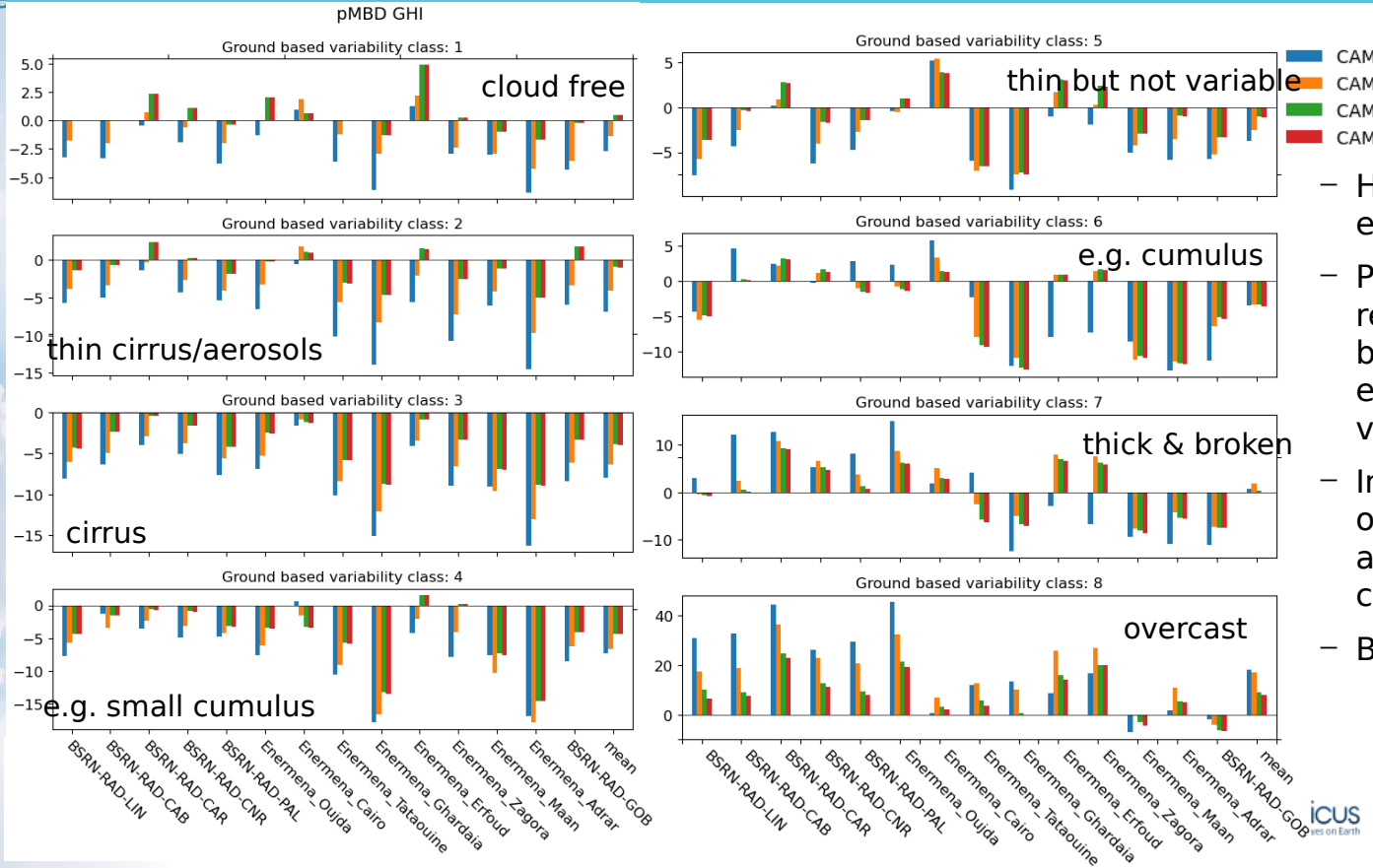
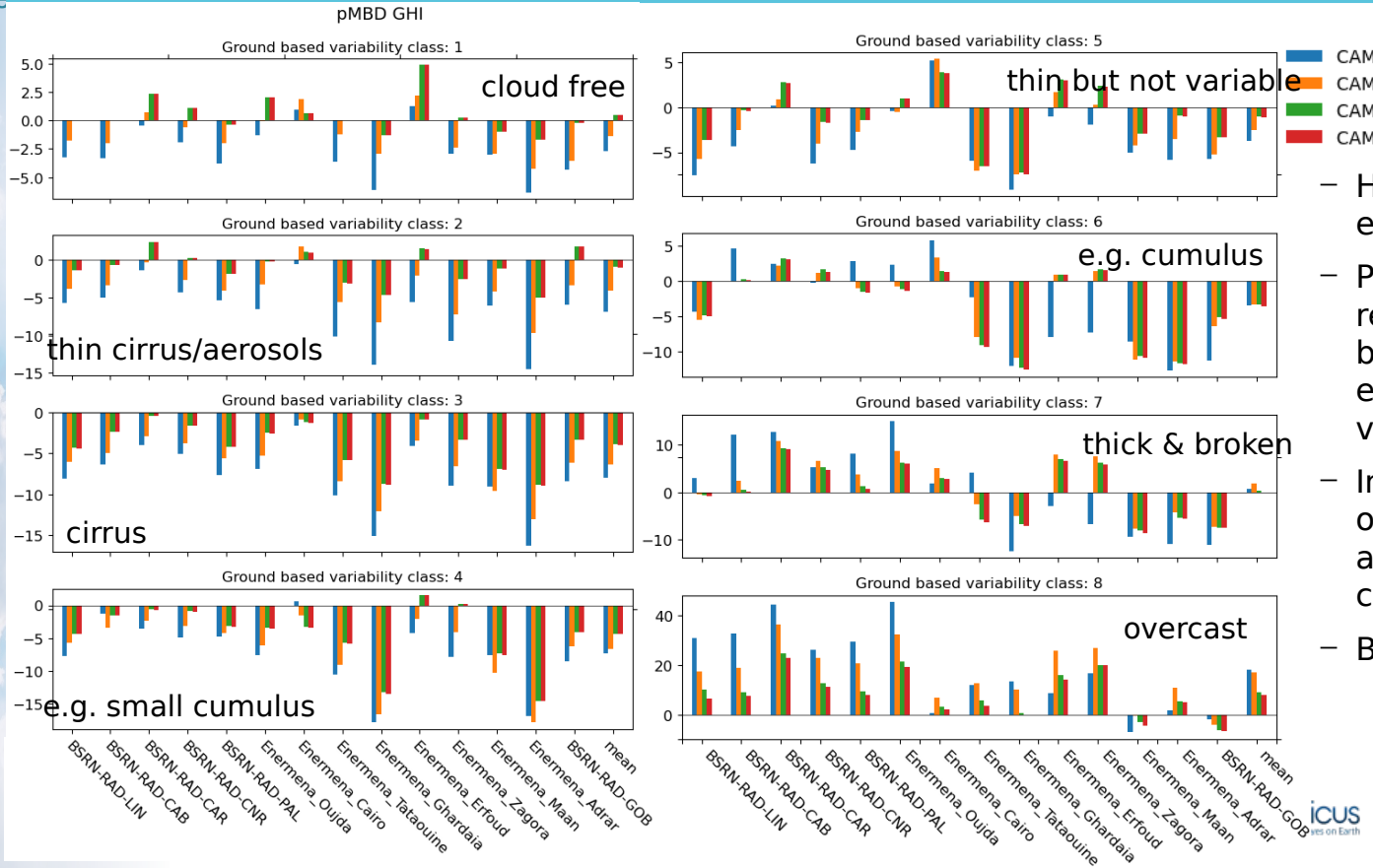
CRS version updates evaluation: based on DNI variability



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

CRS version updates evaluation: based on DNI variability



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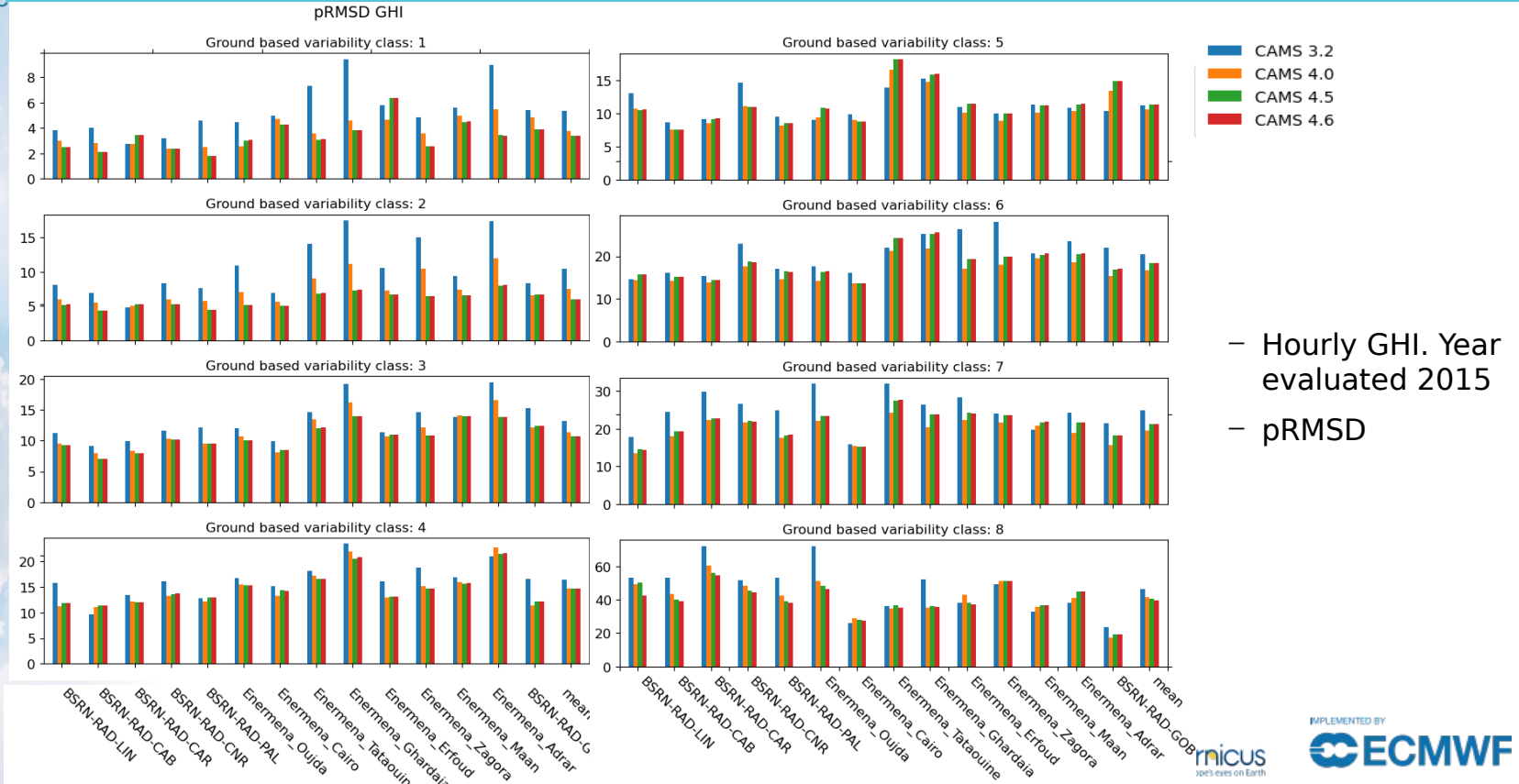
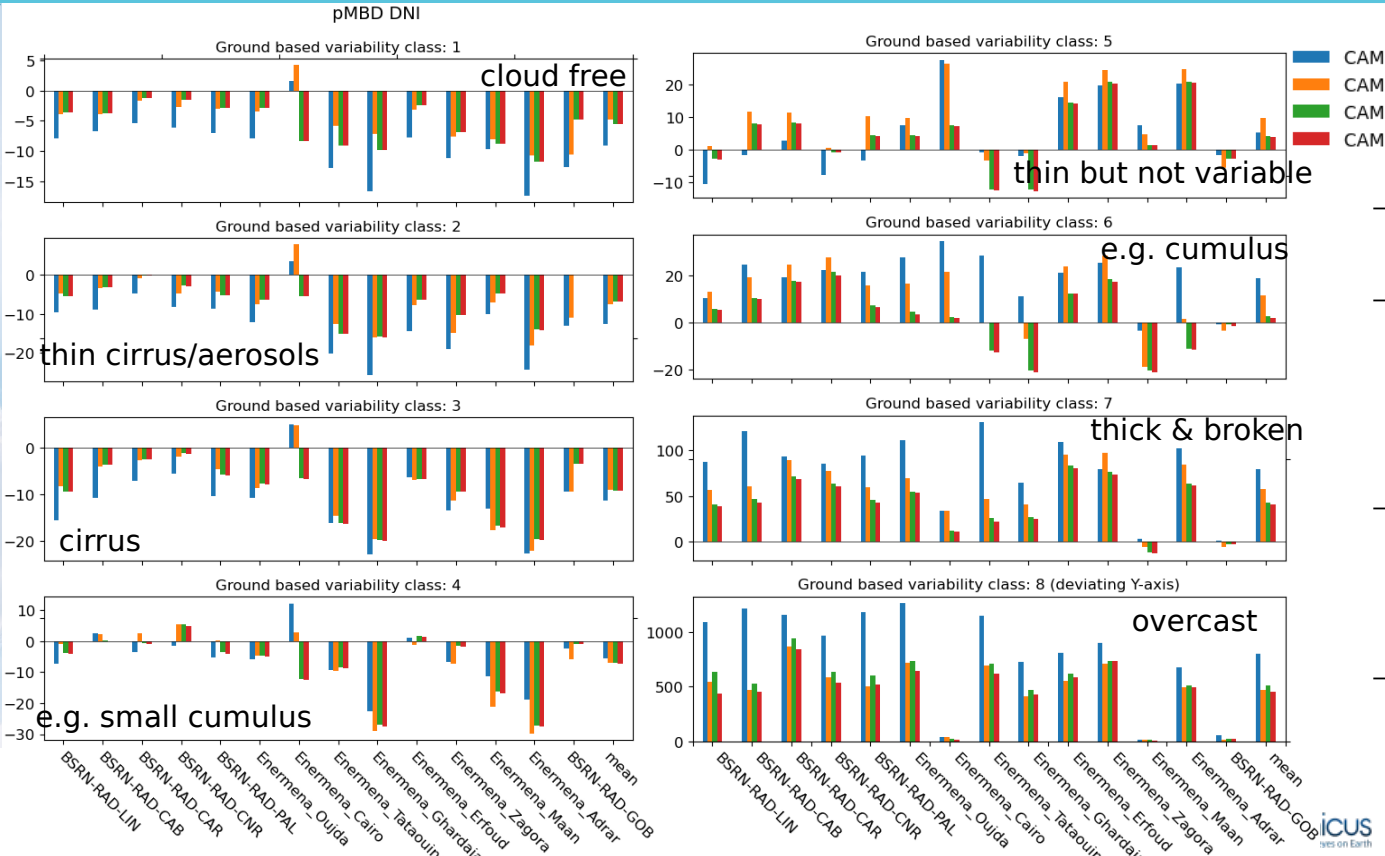


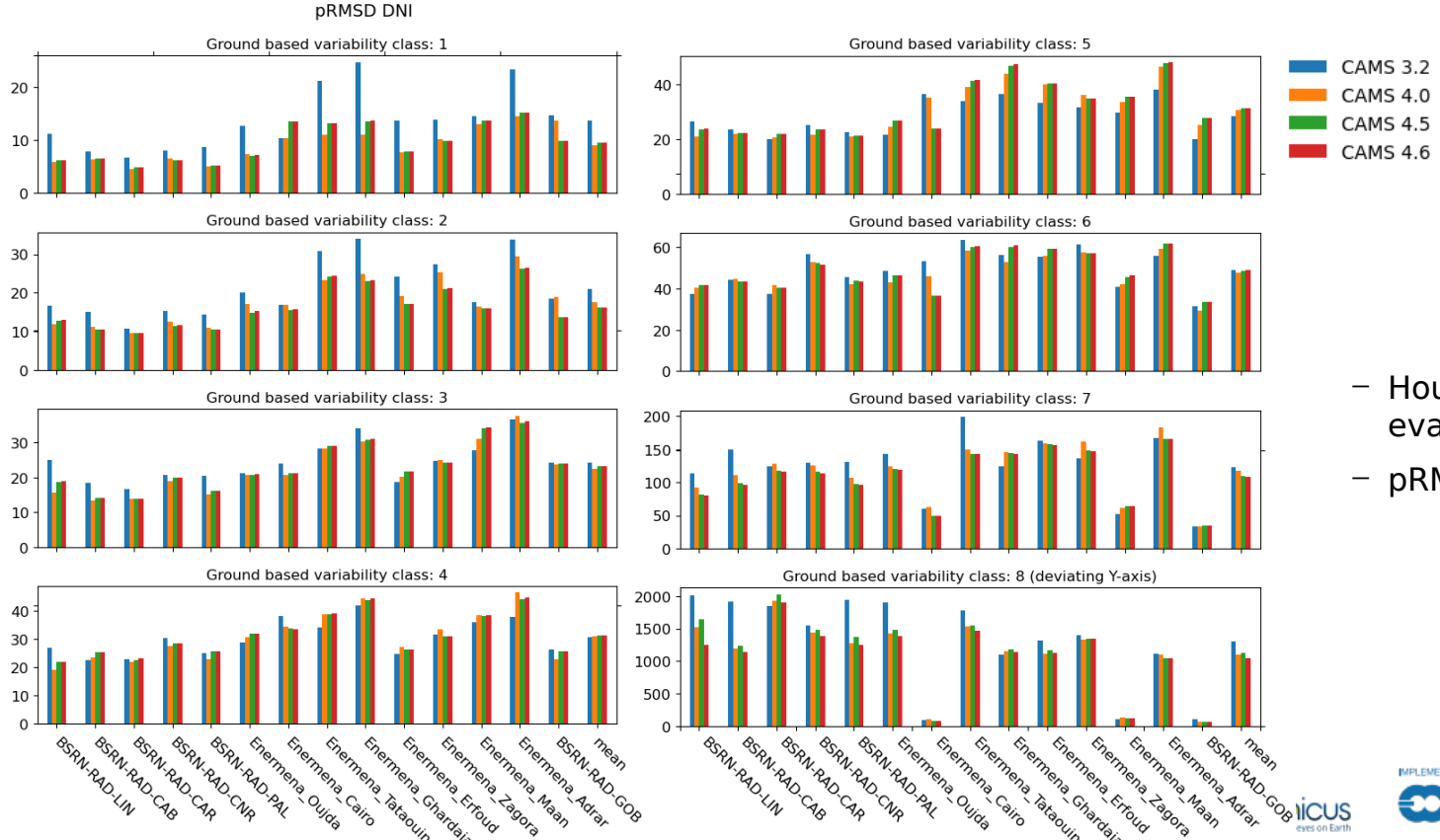
- Hourly GHI. Year evaluated 2015
- pRMSD

CRS version updates evaluation: based on DNI variability



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

CRS version updates evaluation: based on DNI variability



- Hourly DNI. Year evaluated 2015
- pRMSD