CAMS radiation service:
- **Recent improvements**
- **Analyzing the performance of standard cloud retrieval schemes**

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Faiza Azam[1], Jorge Lezaca[1], Marion Schroedter-Homscheidt[1], Mireille Lefevre[2], Laurent Saboret[3], Yves-Marie Saint-Drenan[2]

[1]German Aerospace Center (DLR), Institute of Networked Energy Systems, Oldenburg, Germany

[2]MINES Paris, PSL University, France

[3]Vaisala, France

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The CAMS radiation service (CRS)

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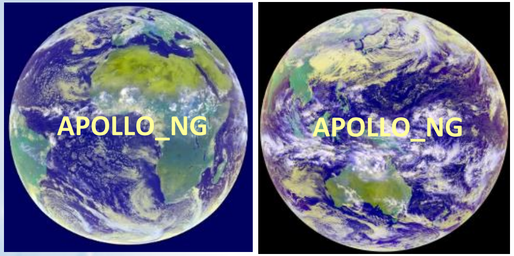

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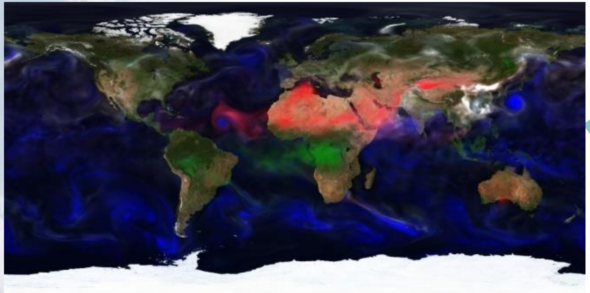
clouds from satellite

Heliosat-4 (physical approach, fast radiative transfer)

aerosol H_2O, O_3 from model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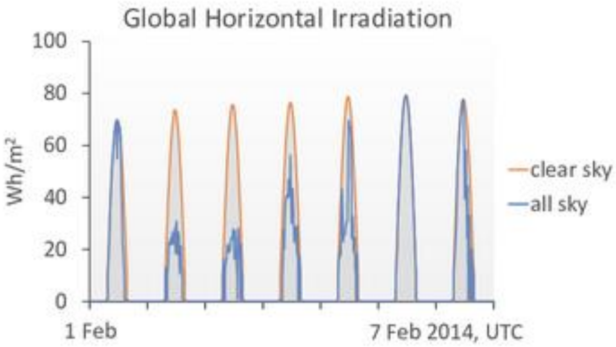
Example Surface Solar Irradiance (SSI)



method papers:

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

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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 irradiance (DNI) : • 0.41 for thin ice clouds • 0.20 for water/mixed phase clouds	same	Improved parametrization
Aerosol/ TWC/O3	MACC reanalysis & CAMS NRT, various versions	MACC reanalysis & CAMS NRT, various versions	CAMS reanalysis*	CAMS IFS NWP (version 48r1) in McClear v3.6
Bias correction	Empirical multiplication factor	Re-trained bias correction	No bias correction	No bias correction
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

Variability classes used for CRS version updates evaluation

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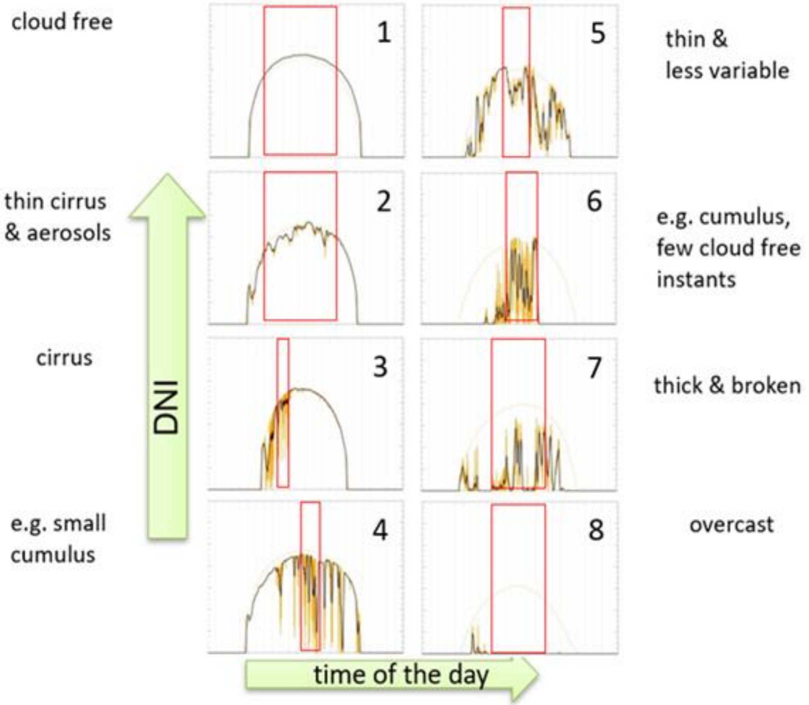
Ground based variability classes



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
- Class 1 is cloud free and class 8 is overcast
- Classes 2-5: cloudy cases with large number of optically thin clouds
- Classes 6-7: optically thick, scattered or broken clouds
- Automatic classification possible from ground-based direct irradiance time series, sky cameras and using cloud mask from satellite
- Method paper ground based: Schroedter-Homscheidt, et al., Meteorol. Z., DOI:10.1127/metz/2018/0875

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CRS – Variability classes dependend evaluation

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Evaluation of CAMS radiation services based on variability classes

Data used in the evaluation:

- Year evaluated = 2015
  - Ground based variability classes time series
  - CAMS Global horizontal irradiance (GHI) and Direct normal irradiance (DNI), versions 3.2, 4.0, 4.5 and 4.6
  - BSRN & Enermena stations GHI and DNI as reference, 2015

CRS – Variability classes dependend evaluation

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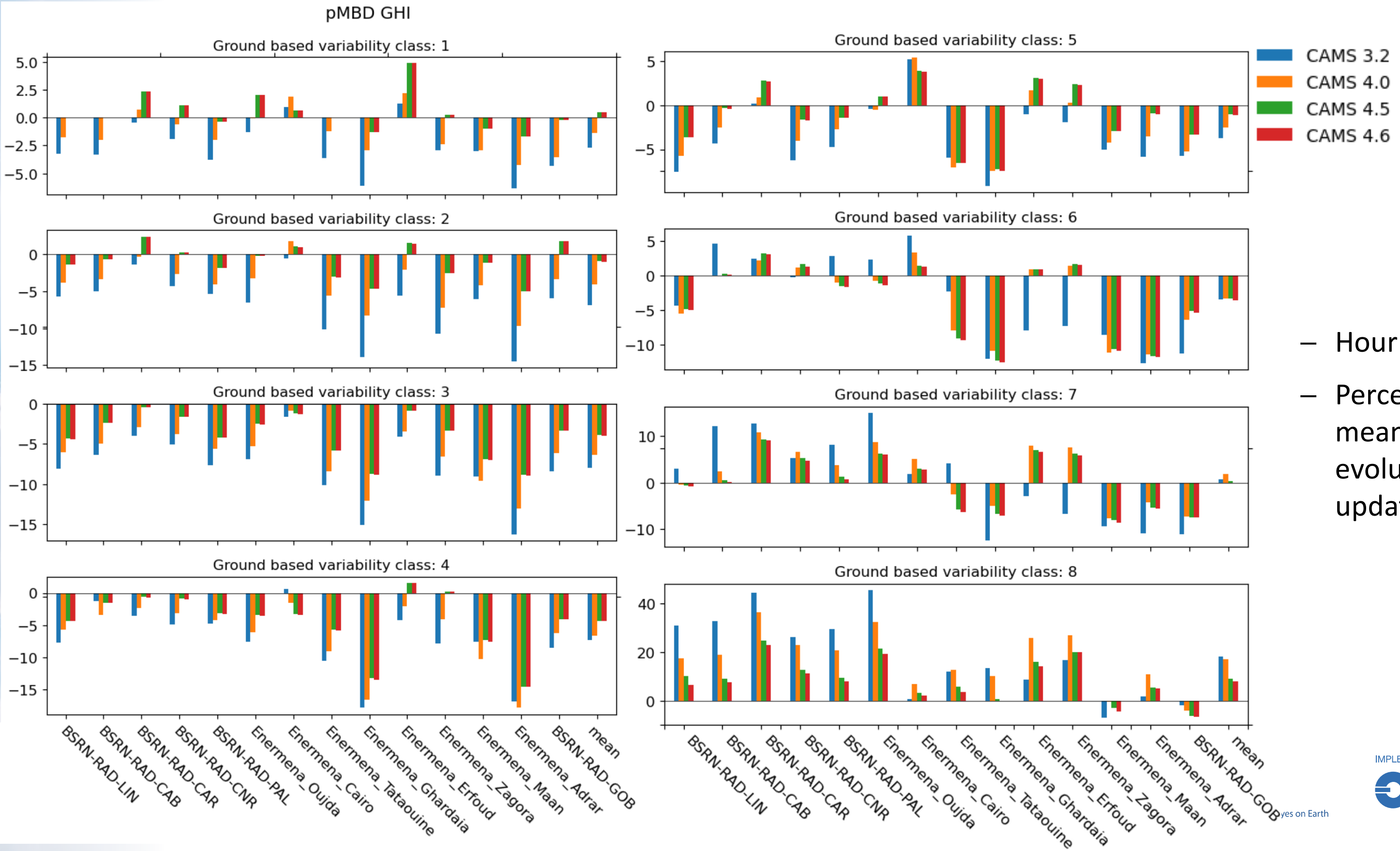

- Hourly GHI
- Percental relative mean bias (pMBD) evolution in version updates

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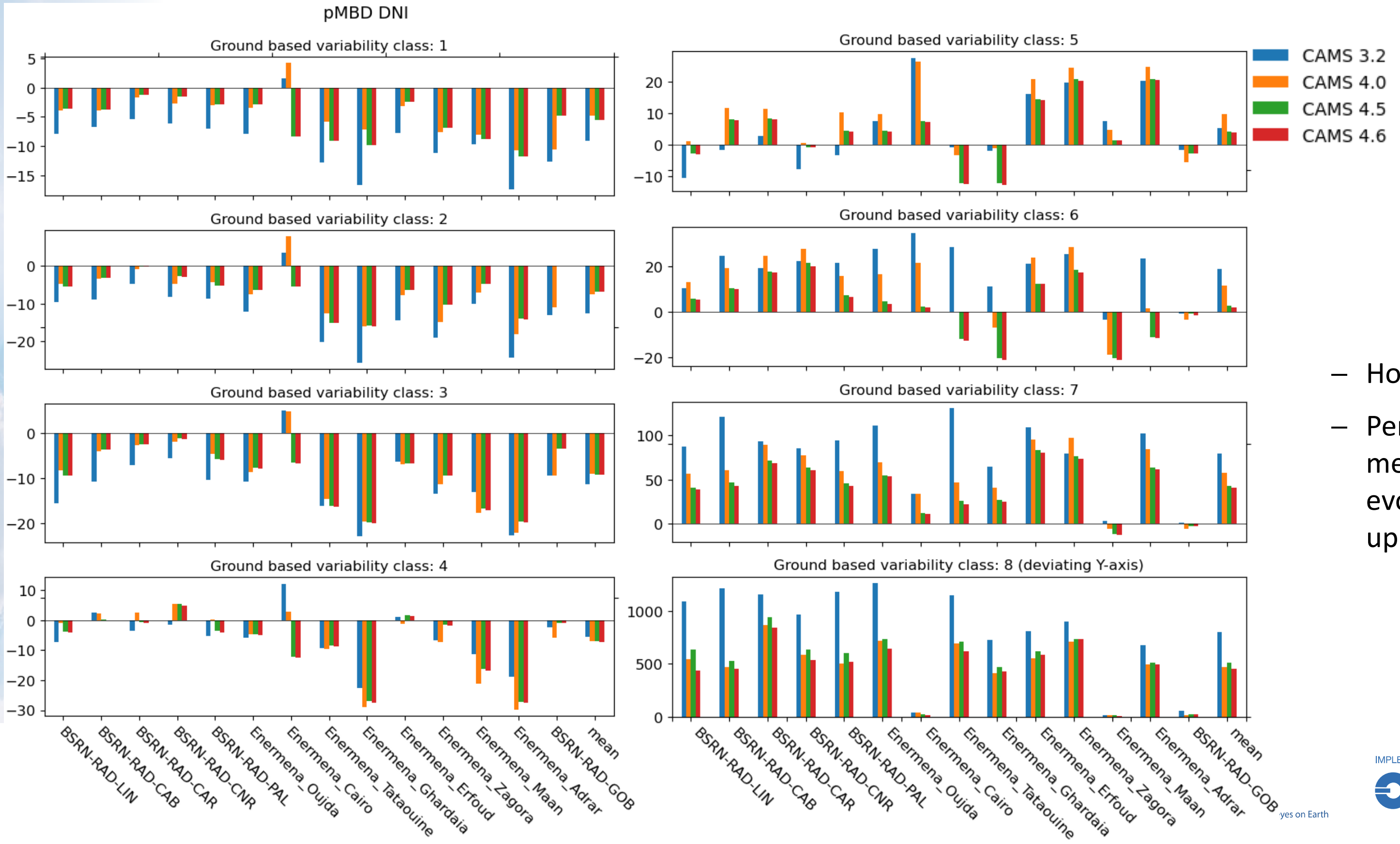
CRS– variability class dependend evaluation



- Hourly DNI
- Percental relative mean bias (pMBD) evolution in version updates

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Analyzing the performance of standard cloud retrieval schemes

Motivation

- For the radiative transfer we need to know
  - A) Where are clouds? -> Cloud mask
  - B) How thick are clouds? -> Cloud optical depth/Cloud optical thickness (COT)
- There are other methods to derive cloud masks and COT

  EUMETSAT CM-SAF

  EUMETSAT Nowcasting-SAF

  Can other cloud retrieval methods be used in the CAMS Radiation Service?

  Question: Do other methods perform better as input to our Heliosat-4 radiation scheme?

Data used

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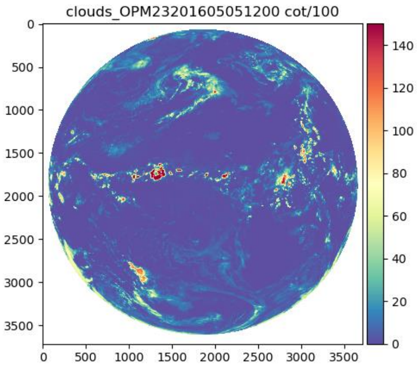
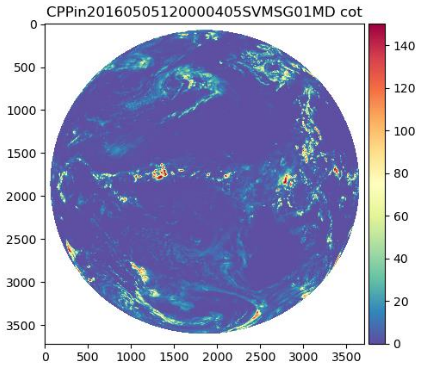
- Year analysed: 2016
- Cloud Products:
  - CAMS 4.5 APOLLO_NG COT
  - CLAAS-3 CPP COT from CM-SAF (CLoud property dAtAset using SEVIRI (CLAAS-3) Cloud Physical Properties (CPP); and Nowcasting-SAF based cloud masks)
- SSI Products:
  - SSI time series resulting from usage of above cloud products in Heliosat-4





Locations analyzed

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BSRN, Enermena & KNMI stations locations in MSG field of view

Cloud retrieval schemes : CAMS/APOLLO NG vs CLAAS-3/CPP

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	CAMS 4.5	CLAAS-3 CPP
Calibration	Time-dependent updated calibration coefficients from KNMI based on Meirink et al., 2013 & updates	Time-dependent updated calibration coefficients from KNMI based on Meirink et al. 2013 & updates
Cloud algorithm	APOLLO_NG REL1.1	NWC/PPS version v2018 patch5 + CmsafPpsSeviri 0.5.0 and CPP v6
Cloud masking	Probabilistic cloud mask, uses 5 threshold tests in VIS and IR (Klüser et al., 2015).	Probabilistic cloud mask, trained on collocated cloud observations from CALIOP onboard CALIPSO satellite (Karlsson et al., 2020).
Cloud threshold	1% cloud probability	50% cloud probability

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Cloud retrieval schemes : CAMS/APOLLO NG vs CLAAS-3/CPP

	CAMS 4.5	CLAAS-3 CPP
COD/COT retrieval	Single channel approach, VIS 0.6 µm (Stephens et al. 1984)	Two channel approach, VIS/NIR 0.6/1.6 or 0.6/3.8 µm (Nakajima and King, 1990 & Roebling et al., 2006)
Cloud type	low (5), medium (6) and high clouds (7), and thin clouds (8)	Not available in CPP
Cloud phase	water (1) and ice (2)	water (1) and ice (2). Extended cloud phase : water (3), supercooled (4), opaque_ice (6), cirrus (7), overlap (8), overshooting_convection (9)

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Significant deviations in COT

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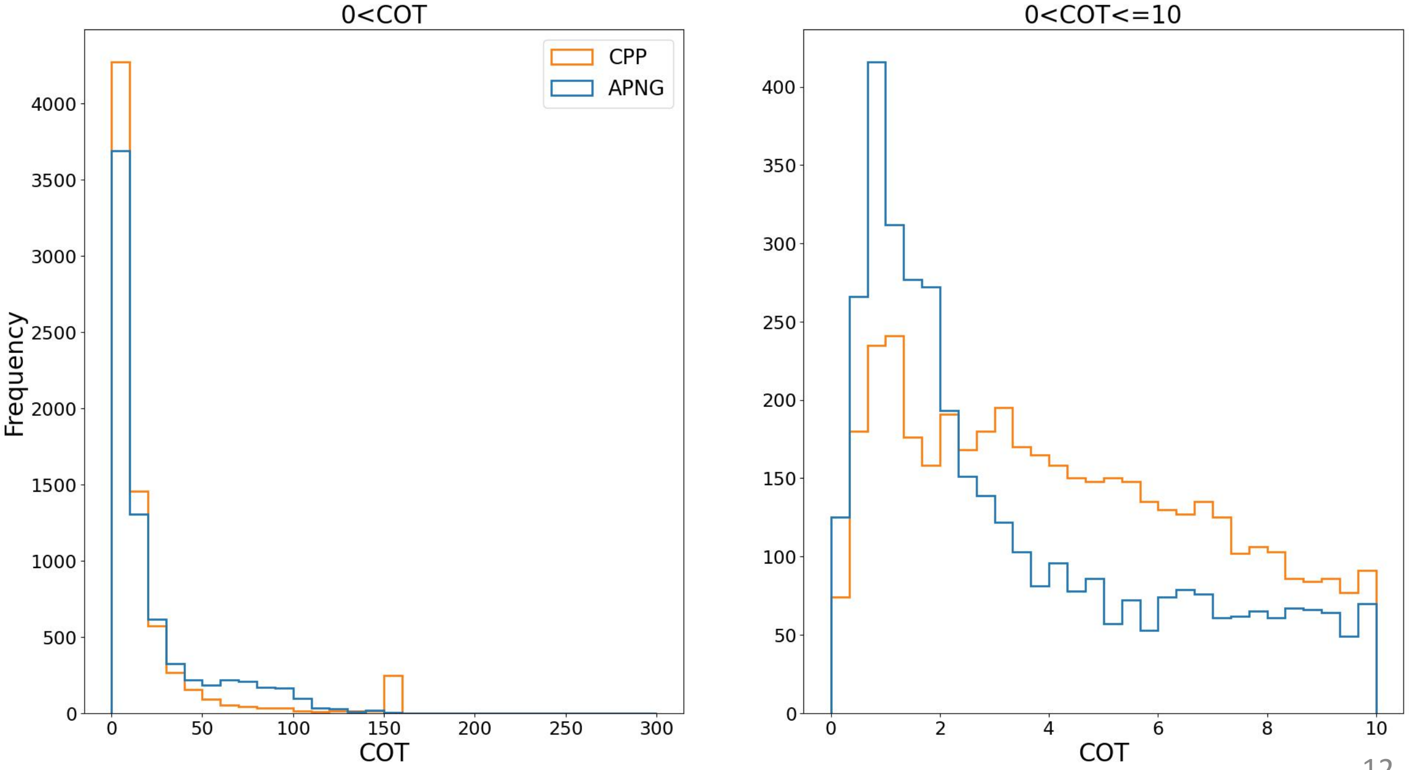
– COT maximum at 150 for CLAAS3-CPP

– APOLLO_NG detects more optically thin clouds for COT<=2

Example: BSRN location Cener, 2016

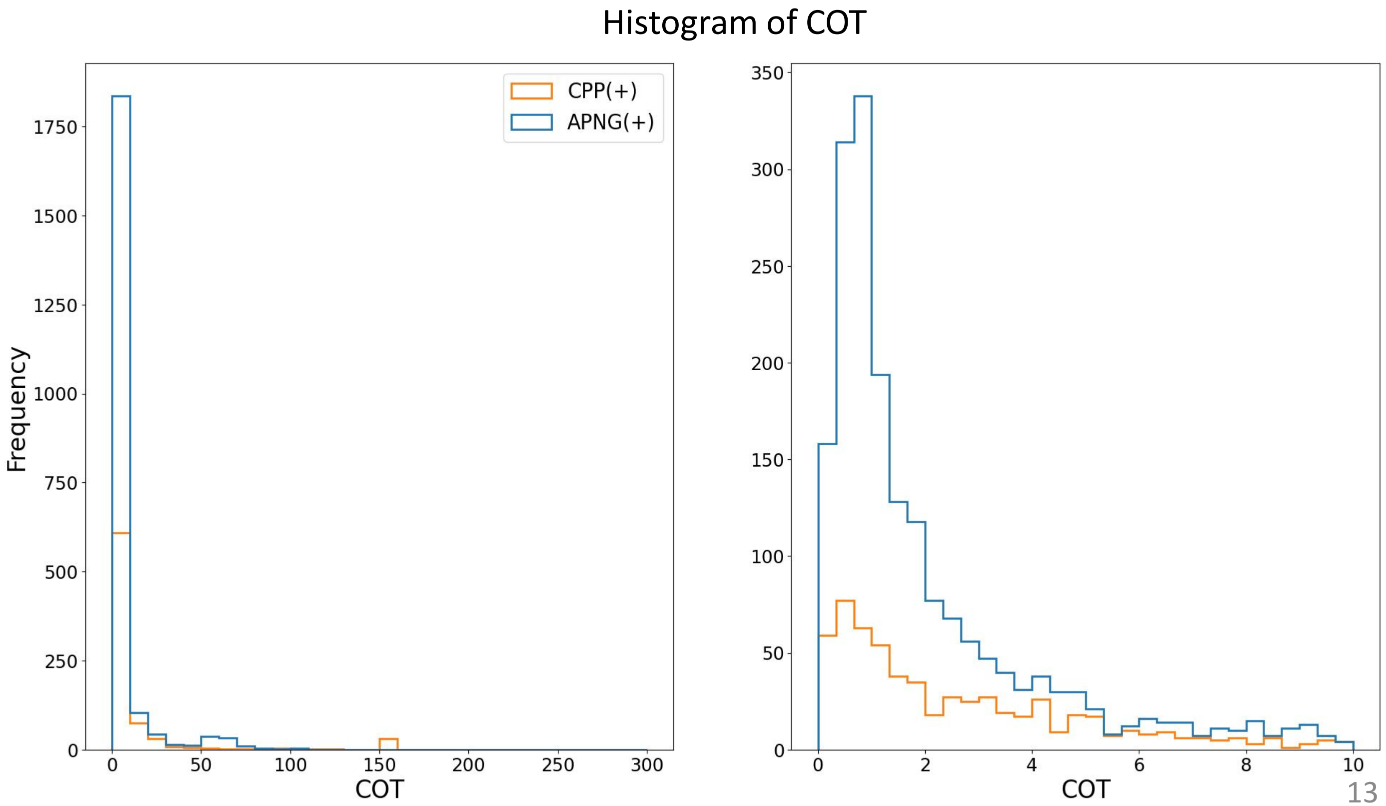
Histogram of COT, cloudy in both methods



Cloud masks also disagree

Example: BSRN location Cener, 2016

- (+) with a method indicates cloudy in that method and clear in the other
- More cases where APOLLO_NG detects clouds and CLAAS3-CPP does not see clouds



SSI Assessment vs ground observations

- Heliosat-4 offers the possibility to use cloud properties from different sources
- Cloud parameters required for Heliosat-4:
  - COT and Cloud type
- CLAAS-3 CPP Cloud phase is mapped to APOLLO_NG Cloud type:
  - water and supercooled classes to low clouds
  - opaque_ice, overlap and overshooting _convection to high clouds
  - cirrus to thin clouds
- Hourly estimates of all-sky GHI and DNI compared to BSRN, Enermena and KNMI stations classifying the locations as urban, rural and desert

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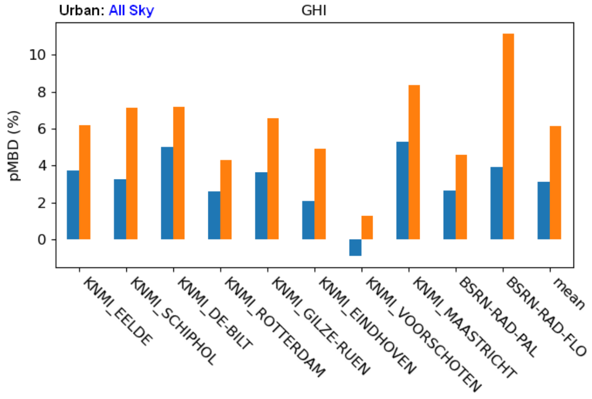
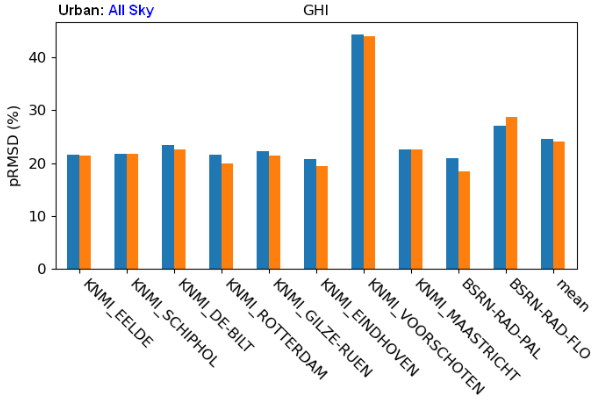
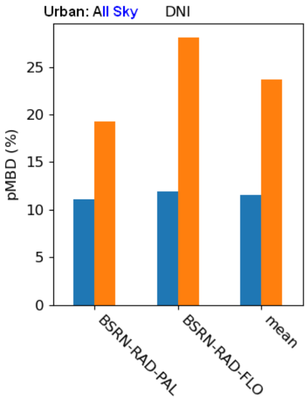
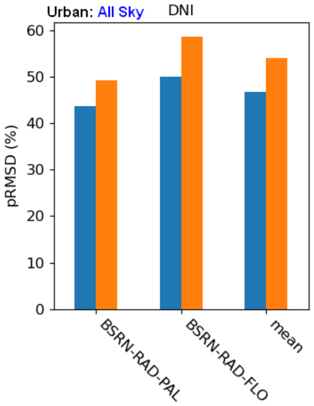
SSI Assessment vs ground observations

Urban region

pMBD: CAMS4.5 has lower bias compared to CLAAS-3 CPP

pRMSD: CAMS4.5 slightly more for GHI and less for DNI

CAMS4.5
CMSAF-CPP

	pMBD(%)	pRMSD(%)
GHI		
DNI		

SSI Assessment vs ground observations

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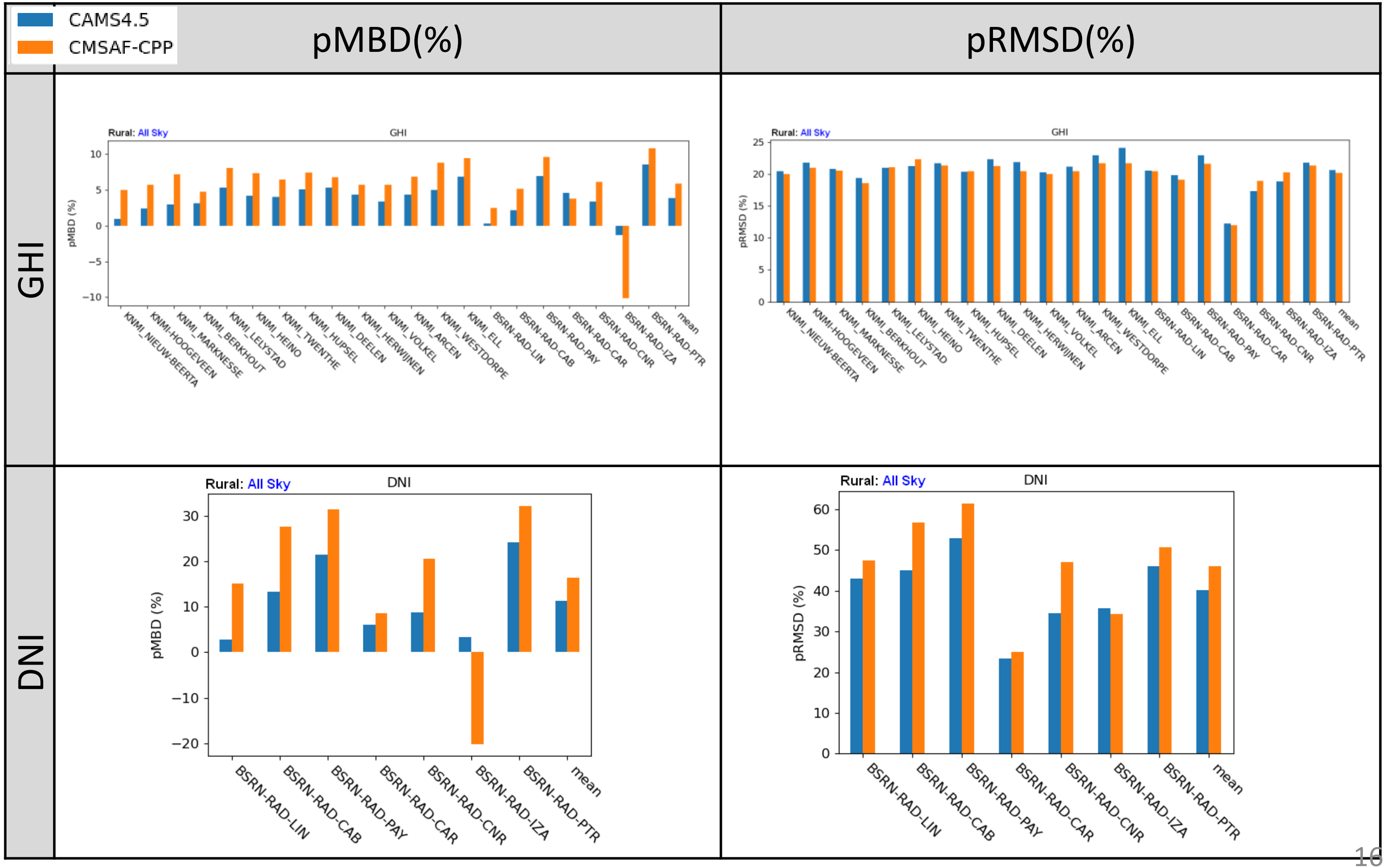
Rural region

pMBD: CAMS4.5 has lower bias compared to CLAAS-3 CPP

pRMSD: CAMS4.5 slightly more for GHI and less for DNI



SSI Assessment vs ground observations

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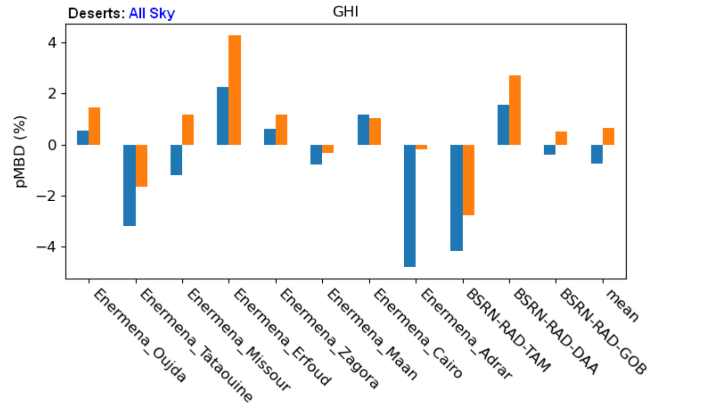
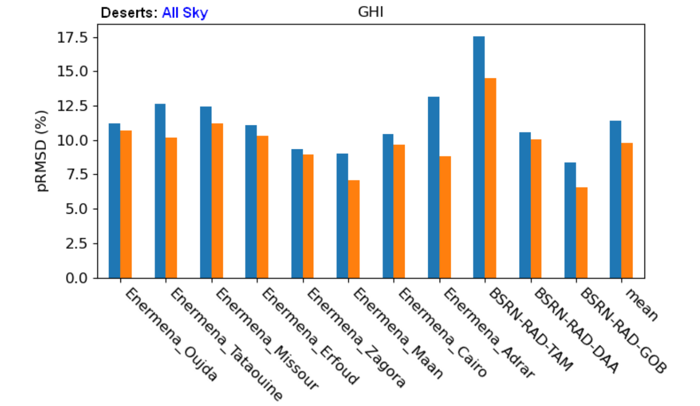
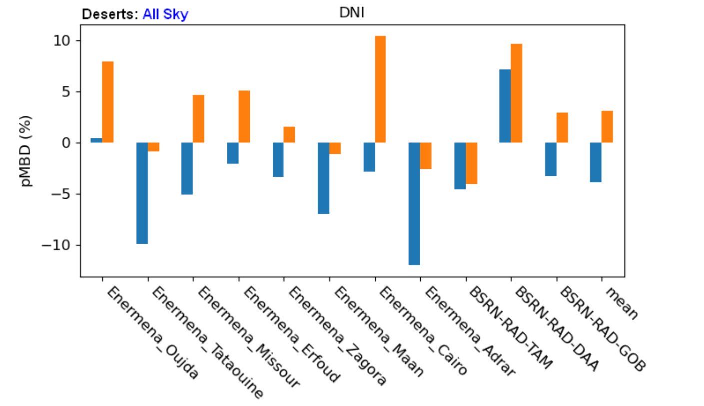
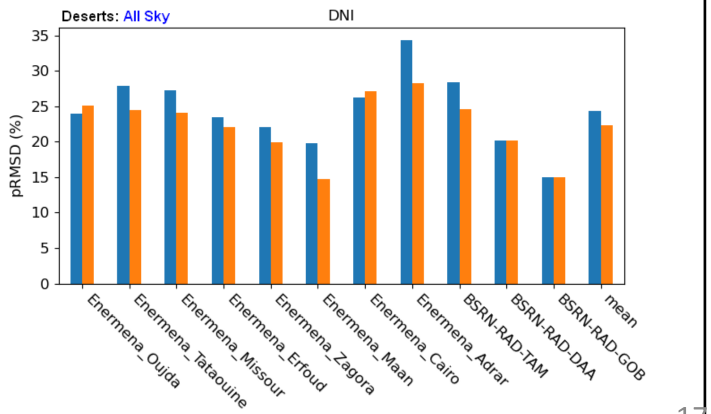
Desert region

pMBD: different results for different locations

pRMSD: CAMS4.5 slightly more for GHI and DNI

CAMS4.5
CMSAF-CPP

	pMBD(%)	pRMSD(%)
GHI		
DNI		

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References

- Kriebel et al., 1989: Optical Properties of Clouds Derived from Fully Cloudy AVHRR Pixels. Beiträge zur Physik der Atmosphäre, Vol. 62, No. 3, pp. 165-171, August 1989
- Klüser et al., 2015: APOLLO_NG – a probabilistic interpretation of the APOLLO legacy for AVHRR heritage channels, Atmos. Meas. Tech., 8, 4155-4170
- Lefèvre et al., 2013: McClear: a new model estimating downwelling solar radiation at ground level in clear-sky conditions, AMT, 2013
- Gschwind et al., 2019: Improving the McClear model estimating the downwelling solar radiation at ground level in cloud-free conditions – McClear-v3, Contrib. Atm. Phys./Meteorol. Z., 2019
- Stephens et al., 1984: A Shortwave Parameterization Revised to Improve Cloud Absorption, Journ. Atm. Scienc., Vol 41, no 4, 687-690
- Schroedter-Homscheidt, M., et al., 2018: Classifying ground-measured 1 minute temporal variability within hourly intervals for direct normal irradiances. – Meteorol. Z. 27, 2, 160–179. DOI:10.1127/metz/2018/0875
- Schroedter-Homscheidt, M.; Azam, F.; Betcke, J.; Hanrieder, N.; Lefèvre, M.; Saboret, L.; Saint-Drenan, Y.-M., Surface solar irradiation retrieval from MSG/SEVIRI based on APOLLO Next Generation and HELIOSAT-4 methods, Meteorologische Zeitschrift Vol. 31 No. 6 (2022), p. 455 – 476, DOI: 10.1127/metz/2022/1132
- Meirink, J.F., et al., 2013: Inter-calibration of polar imager solar channels using SEVIRI, Atmos. Meas. Tech., 6, 2495-2508.
- Qu et al., 2017: Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method, Contrib. Atm. Phys./ Meteorol. Z., 2017
- User's Guide at http://atmosphere.copernicus.eu/documentation

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Extra slides