The new CAMS Radiation Service v4.5 – method improvements and variability class-dependent validation

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The CAMS radiation service principle

Atmosphere Monitoring

Heliosat-4 and McClear physical approaches, fast radiative transfer

Clouds from satellite

Aerosol H₂O, O₃ from model

Cloud free irradiance

All sky irradiance

Surface solar irradiation retrieval from MSG/SEVIRI based on APOLLO Next Generation and HELIOSAT-4 methods

Schroeder-Homscheidt, Lefèvre, Gschwind et al., Contrib. Atm. Sci., 2019
on-the-fly processing of time series

- global, diffuse, direct and direct normal irradiation
- time series 2004 onwards
  - 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 used if 1 min is selected

pre-calculated gridded data

- 15 min temporal resolution
- 2005-2022
- 0.2° gridded data
- update foreseen 0.1° gridded

https://www.soda-pro.com/web-services/radiation/cams-mcclure
## Recent improvements

<table>
<thead>
<tr>
<th></th>
<th>CAMS 3.2 (until 05/2021)</th>
<th>CAMS 4.0 (until 09/2022)</th>
<th>CAMS 4.5 (from 09/2022)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>Reflectances as provided by EUMETSAT</td>
<td>Time-dependent updated calibration coefficients from KNMI based on Meirink et al. 2013 &amp; updates</td>
<td>same</td>
</tr>
<tr>
<td>Cloud retrieval</td>
<td>APOLLO, binary cloud mask based on Kriebel et al. 1988 and 1989</td>
<td>APOLLO-NG, probabilistic cloud mask from Klüser et al. 2015 (cloud confidence level)</td>
<td>same</td>
</tr>
<tr>
<td></td>
<td>Cloud optical thickness (COT) using Stephens et al. 1984 scheme with clipping at COT &lt; 0.5</td>
<td>COT using Stephens et al. 1984 scheme with COT LUTs extended to 0.001</td>
<td>same</td>
</tr>
<tr>
<td>Cloudy/Clear decision Heliosat-4</td>
<td>based on a binary mask</td>
<td>Cloud probability threshold 1%</td>
<td>same</td>
</tr>
<tr>
<td>Circumsolar correction</td>
<td>Single COT value</td>
<td>Empirical apparent COT modification factor for direct normal irradiance (DNI) calculation:</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• 0.41 for optical thin ice clouds</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• 0.20 for water/mixed phase clouds</td>
<td></td>
</tr>
<tr>
<td>Aerosol/TWC/O3</td>
<td>MACC reanalysis &amp; CAMS NRT, various versions</td>
<td>MACC reanalysis &amp; CAMS NRT, various versions</td>
<td>CAMS reanalysis</td>
</tr>
<tr>
<td>Bias correction</td>
<td>Empirical multiplication factor</td>
<td>Re-trained bias correction</td>
<td>No bias correction</td>
</tr>
</tbody>
</table>
Bias correction scheme removed

- Clear improvement from v3.2 to v4 in cloudy situations

- Bias correction
  
  V3.2: compensating errors in aerosol- and cloud dominated situations
  
  V4.0: bias correction worse in most situations

  -> switched off in v4.5

Example: BSRN Cabauw, 2015
Further results v3.2 vs. pre-version 4

IEA PVPS Task 16 - Solar Resource for High Penetration and Large Scale Applications

Worldwide benchmark of modelled solar irradiance data
IEA PVPS Task 16, Report IEA-PVPS T16-05:2023
ISBN 978-3-907281-44-4


Replacing consecutive updates with the CAMS reanalysis -> used in v4.5
Minor changes in GHI, but positive impact for DNI and DIF

Abs. Bias
STDV
RMSE

better

Gain of abs(bias) in %
STDE gain in %
RMSE gain in %
V3.2 -> v4 (new clouds) -> v4.5 (new AER/TWC/O3)

Example: Carpentras, 2017, 1 min data

Note: This is 1 min data == developer view

For users more relevant is hourly validation which overcomes the point/area mismatch.

This is done in regular quarterly validation reports (see CAMS web page)

Example: Carpentras, 2017, 1 min data
Extension to Himawari-8 FOV ongoing

- Clouds from satellite
- Heliosat-4 and McClear physical approaches, fast radiative transfer
- Aerosol, H₂O, O₃ from model

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I’m not a cloud...

Well, plane-parallel assumption is used...

Clouds as seen in DLR’s sky camera network

From Karlsruher Wolkenatlas

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I’m not a cloud...

Well, plane-parallel assumption is used...

Deeper insights into quality

Study set-up

- Himawari field of view; 2018; Baseline Surface Radiation Network (BSRN) and Bureau of Meteorology (BOM) stations GHI and DNI
- CAMS pre-operational (HIMAWARI FOV) version 4.5, download from sandbox
- Conditional evaluation:
  Ground based variability classes time series
  Variability class dependent analysis can help in assessment of all sky irradiance under different cloudy conditions without directly using the cloud parameters
- Conditional evaluation:
  Satellite-based cloud type classification
Ground based variability classes dependent evaluation

8 classes defined by ground based direct irradiance patterns

Reference:
Ground based variability classes dependent evaluation - biases

- CAMS v4.5 GHI MBD
- Largest positive biases in variable cloud conditions
- Same result for RMSD (see backup slides)
Ground based variability classes dependent evaluation

- CAMS v4.5 DNI MBD
- Largest positive biases in variable cloud conditions
- Same result for RMSD (see backup slides)
**Cloud types**

- Thin cirrus (type 8)
- Optically thick, low level (type 5)
- Optically thick, medium level (type 6)
- Thin cirrus (type 8)
- Optically thick, high level (type 7)

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Cloud type based evaluation

- CAMS 4.5 GHI MBD, 1-minute resolved data
- Bias is positive for clear sky and thin ice clouds and negative in most of the regions for low, medium clouds.
- Bias is negative for high level clouds in all regions
Cloud type based evaluation

- CAMS 4.5 DNI MBD, 1-minute resolved data
- Bias is positive for clear, thin and medium clouds
- Different biases at different locations for low and high clouds
Conclusions

- Significant method changes from v3.2 to v4 and v4.5
  - New SEVIRI calibration
  - New cloud scheme
  - New aerosols

- Next generation of method improvements in preparation
  - Looking closer at sub-pixel/variable/multi layer clouds
  - Especially in cases where cloud retrievals are known to be inaccurate
    - Solar energy users need to use all cases
    - No choice to omit such non-valid cloud retrievals as the cloud community can do
  - Preparing a more flexible use of CAMS aerosols and their optical properties (not shown, but in preparation ...)

Conditional assessment will be done deeper in
https://www.cameo-project.eu/
Contact point & references

• general inquiries and user requests: copernicus-support@ecmwf.int
• specific for the Solar Radiation Service team: marion.schroedter-homscheidt@dlr.de
• Heliosat-4 method
  • Qu et al., Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method, Contr. Atm. Sci., 2017
• 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. Sci., 2019
• Broadband irradiation evaluation: Quarterly validation reports at https://atmosphere.copernicus.eu/supplementary-services
Ground based variability classes dependent evaluation

- CAMS 4.5 GHI RMSD
- Largest value in optically thick, but variable cloud conditions
Ground based variability classes dependent evaluation

- CAMS 4.5 DNI RMSD
- Largest value in optically thick, but variable cloud conditions
CAMS Cloud type based evaluation

- CAMS 4.5 GHI RMSD, 1-min resolved data
CAMS Cloud type based evaluation

- CAMS 4.5 DNI RMSD, 1-min resolved