Validation of EarthCARE surface irradiance products using ground-based observations and CAMS estimates

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CERTAINTY CLOUD-AEROSOL INTERACTIONS & THEIR IMPACTS IN THE EARTH SYSTEM

HARMONIA International network for harmonization of atmospheric aerosol retrievals from ground based photometers

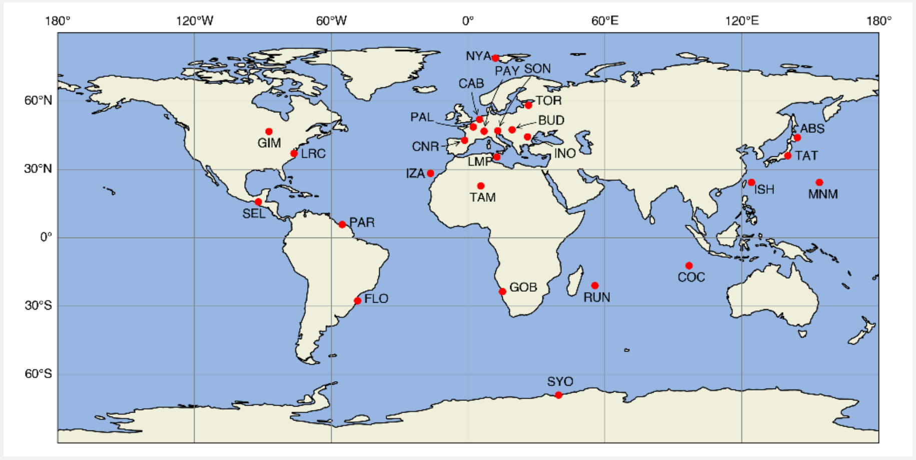
1 Introduction

The EarthCARE (ECA) satellite is currently in its second year in orbit, collecting new data every day that could play a crucial role in advancing climate science. However, due to the advanced technologies and retrieval approaches used in EarthCARE, the credibility of each instrument and of their synergistic products must be verified. Significant effort has been devoted to this topic both currently and in the past. Nevertheless, a substantial amount of publicly available data that could improve validation has not yet been utilized. In this study, we use ground-based global horizontal irradiance (GHI) observations from the Baseline Surface Radiation Network (BSRN) to validate along-track 1D/3D surface solar radiation estimates from the EarthCARE ACM-RT product [1]. In addition, across-track GHI values are assessed using EarthCARE's Scene Construction Algorithm (SCA) in the ACMB-3D product [2]. To evaluate discrepancies under different cloud regimes, the cloud modification factor (CMF) is utilized. Furthermore, an intercomparison with Copernicus Atmospheric Monitoring Service (CAMS) gridded solar radiation dataset was conducted, which infers high-resolution cloud information from geostationary satellites. For all EarthCARE products, baseline BA was used.

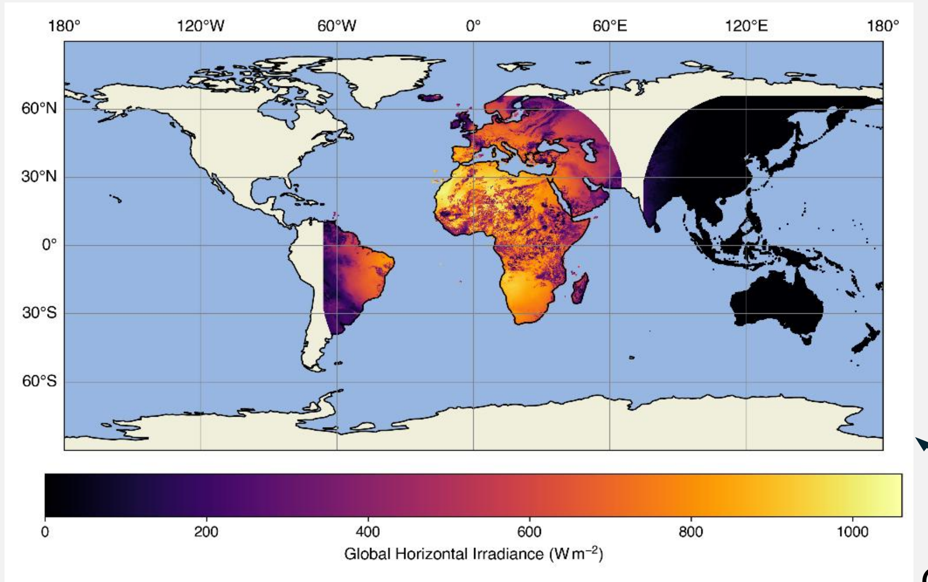
2 Methods

Dataset

BSRN

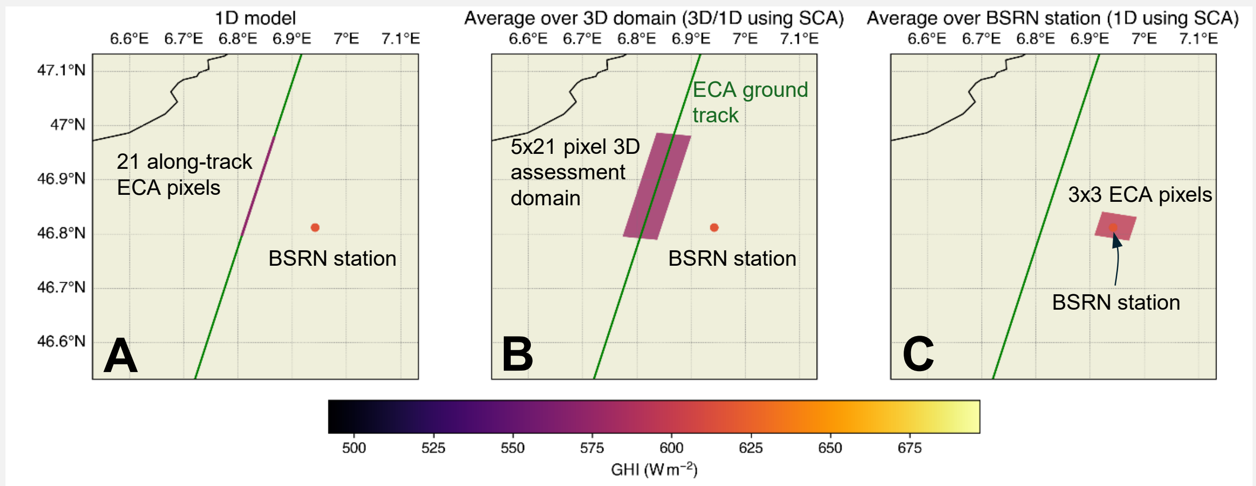


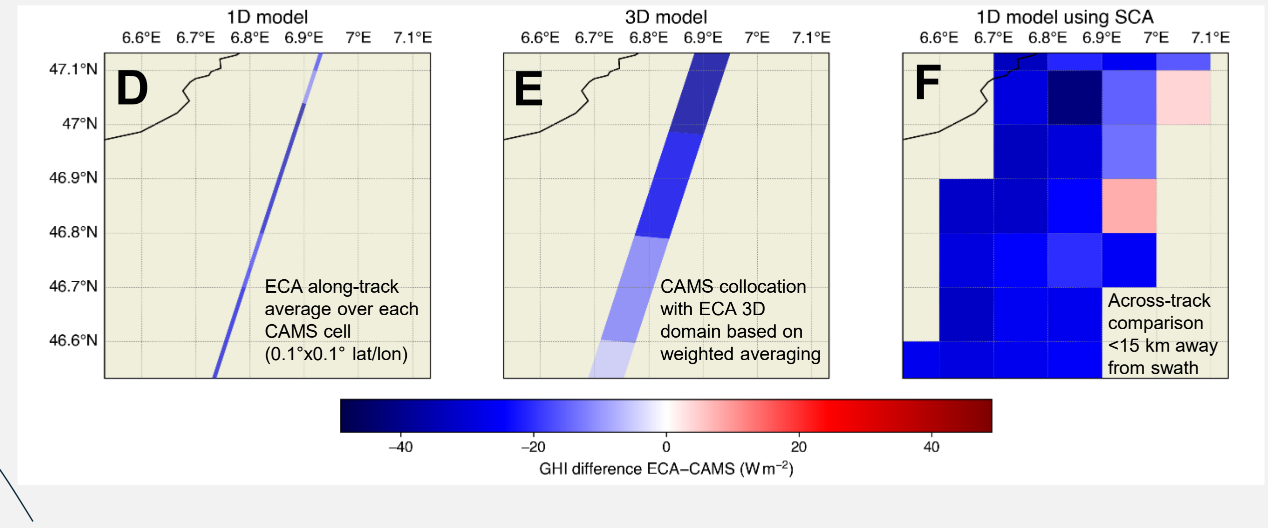
CAMS



Currently only available for 2024

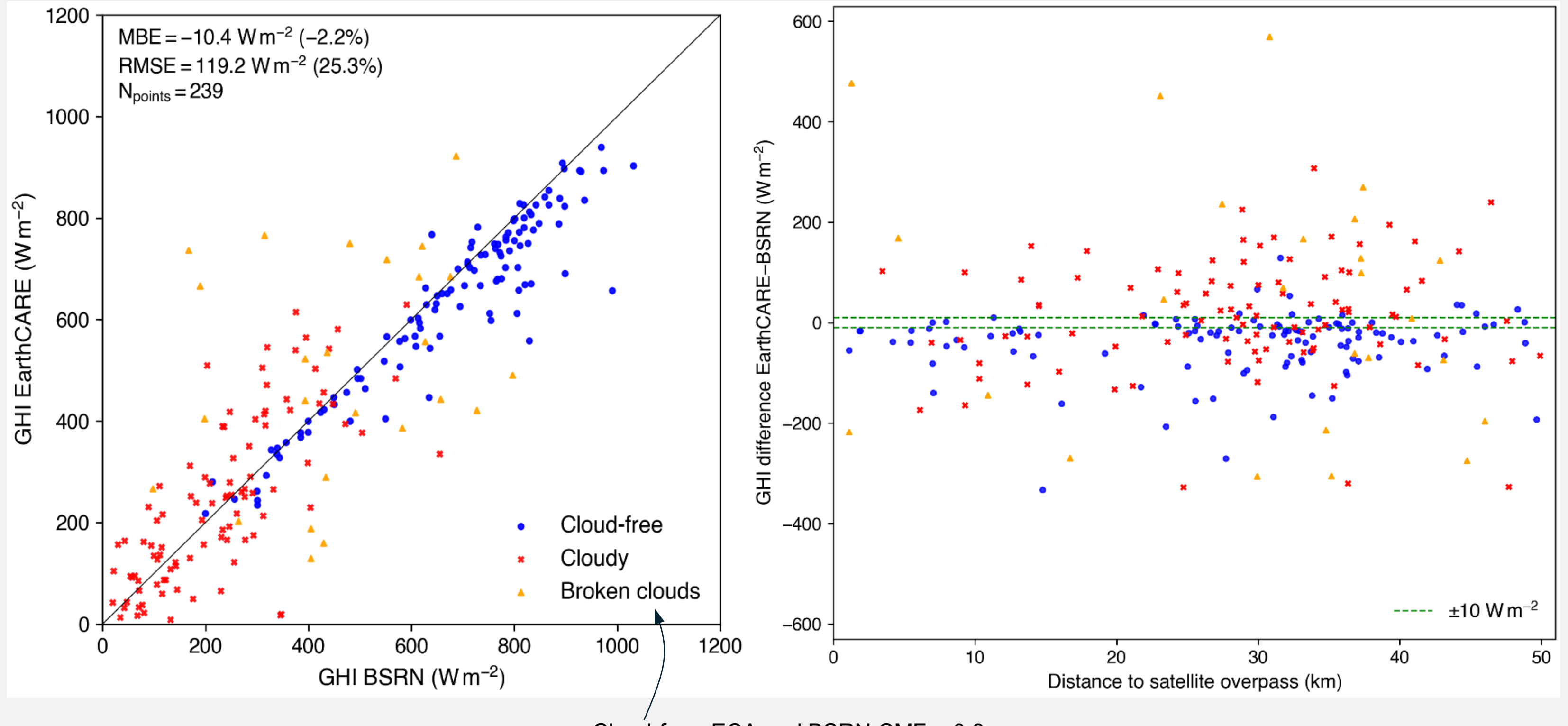
Collocation approach with EarthCARE





3 Validation against BSRN

Results for ECA average over BSRN station (Method C)



Cloud-free: ECA and BSRN CMF > 0.8
Cloudy: ECA and BSRN CMF < 0.8
Broken clouds: Either ECA or BSRN CMF > 0.8

- Under cloud-free conditions, BSRN GHI consistently exceeds ECA GHI (MBE = – 41 W m^{-2})
- For cloudy cases, bias remains negative (MBE = – 14 W m^{-2}) and rMBE (6%) is similar to cloud-free observations.
- The presence of broken clouds complicates comparisons due to the pronounced spatiotemporal variability of the radiation field
- Discrepancies the lowest for ECA overpasses close to the BSRN station, though broken clouds again challenging
- In the comparison of EarthCARE models, 1D model exhibits the lowest RMSE, although values remain relatively high across all iterations
- 3D model bias close to zero, while other two are negative

EarthCARE models comparison

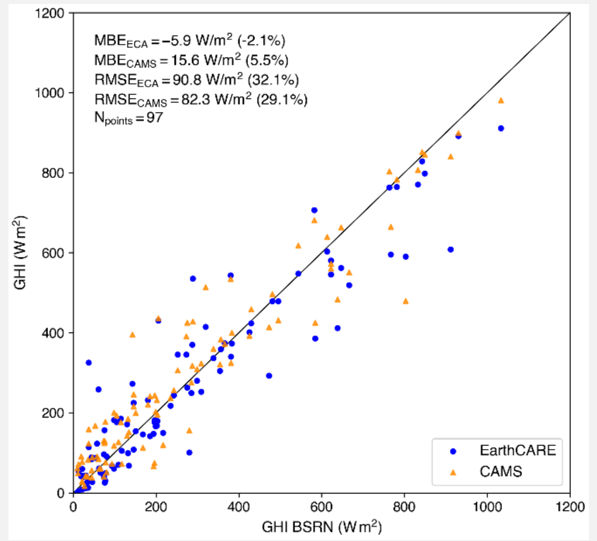
N_{points} = 291

Averaging domain	Along-track (Method A)	3D assessment domain (Method B)	
Model	1D	3D	1D (SCA algorithm)
MBE (W m^{-2})	–19.6	–1.1	–18.9
rMBE (%)	–4.0	–5.5	–3.8
RMSE (W m^{-2})	162.1	170.0	163.9
rRMSE (%)	32.7	34.3	33.1

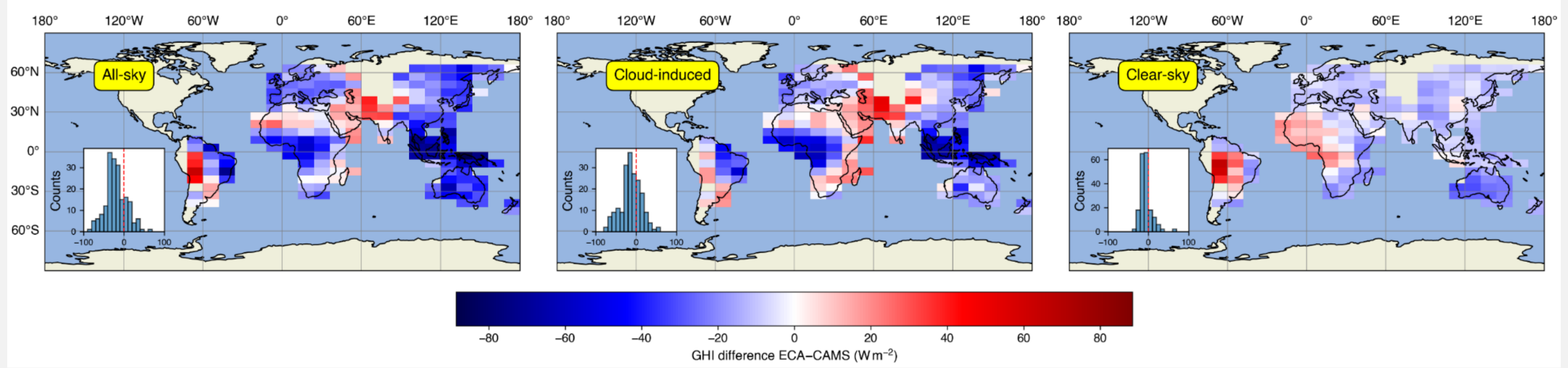
4 Intercomparison with CAMS

- EarthCARE's 3D model achieved the lowest rRMSE, likely due to the larger along-track averaging window
- When accounting the known positive bias of CAMS during this period (8 W m^{-2}) [3], the 3D model operates with near-zero bias
- Collocation with SCA algorithm demonstrates enhanced reliability, exhibiting the lowest RMSE while having the highest number of points

Method	MBE (W m^{-2})	rMBE (%)	RMSE (W m^{-2})	rRMSE (%)	N_{points}
1D model (D)	–21.5	–3.9	102.8	18.7	378'352
3D model (E)	–8.1	–1.5	91.0	16.5	147'335
1D model using SCA (F)	–20.1	–3.9	88.4	17.0	805'439



Validation with BSRN confirms that EarthCARE tends to underestimate GHI, while CAMS tends to overestimate



- Cloud-induced GHI residuals closely mirror those observed under all-sky conditions, showcasing that cloud estimation is a dominant source of the discrepancies between the datasets
- Tropical regions mostly blue, hence EarthCARE's high-resolution sensors likely provide more realistic characterization of deep ITCZ cloud structures
- Negative all-sky GHI biases in Oceania are primarily attributed to known overestimations in CAMS Himawari-8 retrievals [3]
- Clear-sky map suggests that EarthCARE underestimates AOD attenuation in South America, likely due to the under-detection of Amazonian deforestation and wildfire events

5 Conclusions

- Ground-based BSRN stations observe slightly higher irradiance than EarthCARE
- Especially under cloud-free conditions, the bias is significant
- 3D model achieves the lowest MBE relative to both BSRN and CAMS
- Direct collocation with the datasets using the SCA algorithm provides superior comparison quality
- Against CAMS, ~65% of the GHI bias is related to differences in cloud estimation, while ~35% can be attributed to clear-sky irradiance discrepancies

6 Outlook

Expanding the scope and statistical robustness of this analysis depends heavily on the availability of the BSRN/CAMS datasets. While 66 BSRN stations are currently active, only 26 have released data since September 2024. Therefore, a significant amount of data has yet to be released. Similar goes for the CAMS dataset, with its 2025 version being expected by next month. This will help evaluate EarthCARE irradiance across all seasons. In addition, the subsequent ACM-RT baseline BC can be analyzed (released November 2025), which made significant changes specifically regarding its aerosol input

Acknowledgments

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References

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[3] Lefèvre M., CAMS Solar Radiation Validation Report (SON 2024), https://bit.ly/3OGZPMk, 2024

Abstract: