Validation of EarthCARE Surface Irradiance Products Using Observations from BSRN Stations and Modelled Values from CAMS

Yannis Gschwind[1,2], Kyriakoula Papachristopoulou[1,*], Jason N.S. Cole[2], Stelios Kazadzis[1]

[1]Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center 7260 Davos Dorf, Switzerland

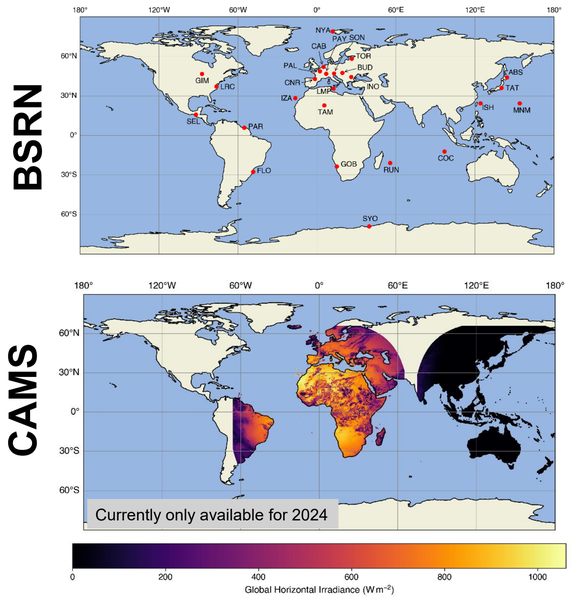
[2] 2Environment and Climate Change Canada, Toronto, ON, Canada

Introduction

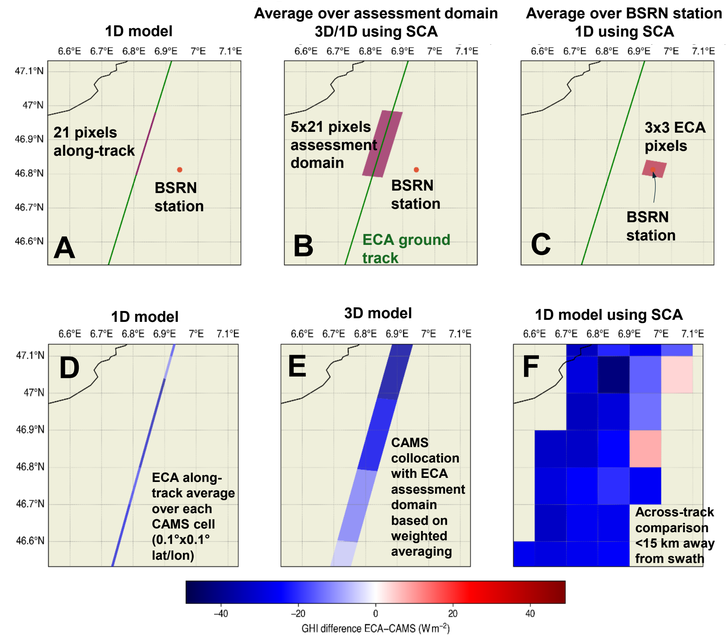
The **EarthCARE (ECA)** satellite is currently in its second year in orbit, collecting new data every day that could play a crucial role in advancing climate science. However, due to the advanced technologies and retrieval approaches used in EarthCARE, the credibility of each instrument and of their 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]. 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.

Methods

Dataset

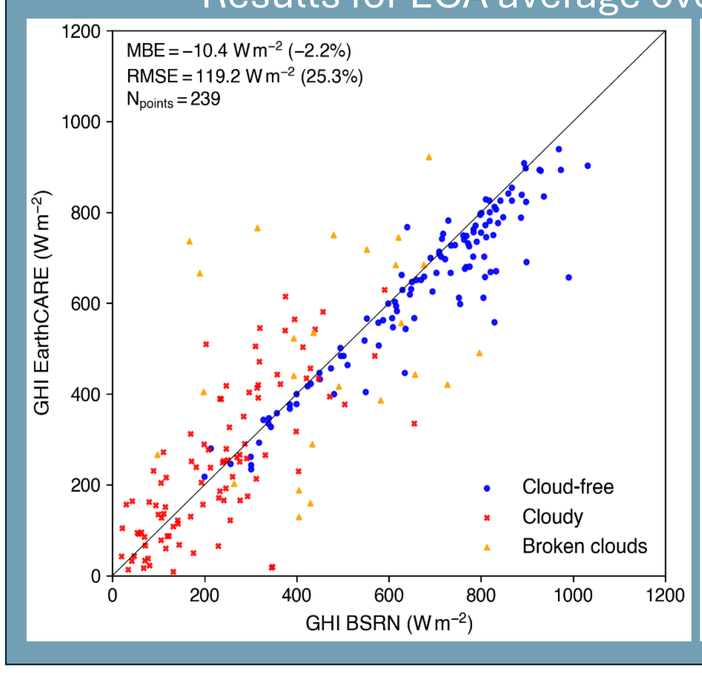


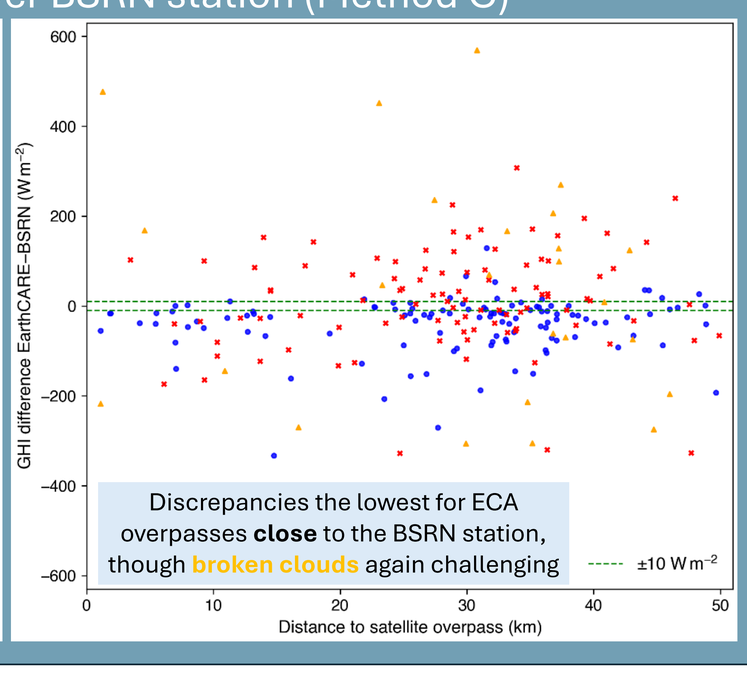
Collocation approach with EarthCARE



Validation against BSRN

Results for ECA average over BSRN station (Method C)





EarthCARE models comparison (N_{points} = 291)

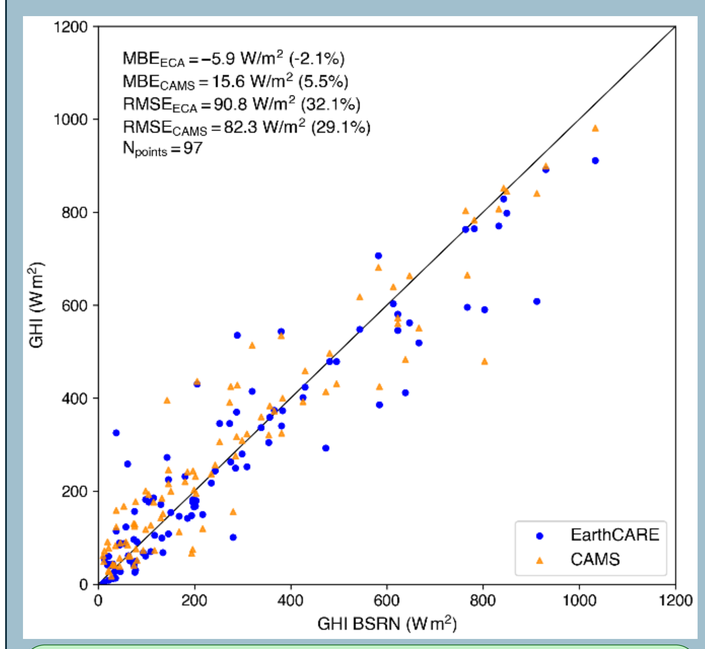
Averaging domain	**Along-track (Method A)**	**assessment domain (Method B)**	
Model	**1D**	**3D**	**1D (SCA algorithm)**
MBE (W m^{-2})	–19.6	–1.1	–18.9
rMBE (%)	–4.0	–5.5	–3.8
RMSE (W m^{-2})	162.1	170.0	163.9
rRMSE (%)	32.7	34.3	33.1

cloud-free cases : **BSRN GHI consistently exceeds ECA GHI (MBE = – 41W m^{-2})**

cloudy cases : **bias remains negative (MBE = – 14W m^{-2}) and rMBE (6%) is similar to cloud-free observations.**

broken clouds cases : **complicates comparisons due to the pronounced spatiotemporal variability of the radiation field**

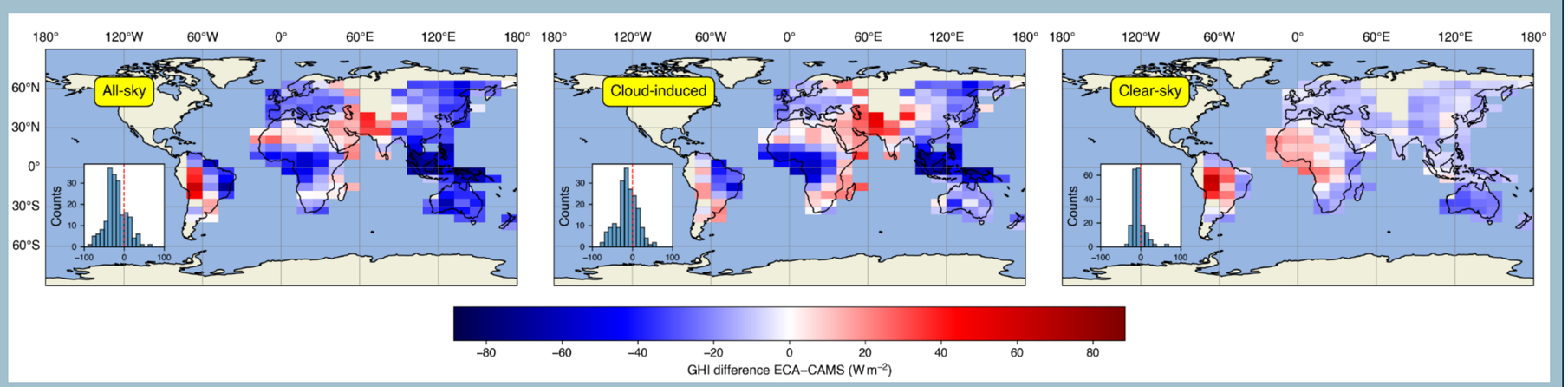
Intercomparison with CAMS



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

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

- **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**



- **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]**

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

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 this 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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Corresponding author e-mail: kyriaki.papachr@pmodwrc.ch

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