Spatial resolved and localized uncertainty analysis of the irradiance product from the CAMS Radiation Service v4

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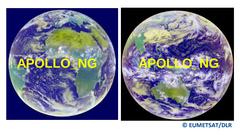
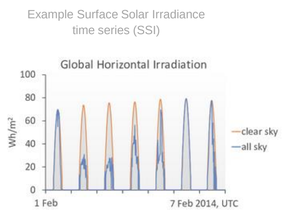
1. CAMS Radiation Service (CRS)

Atmosphere Monitoring Service → Solar Radiation Service

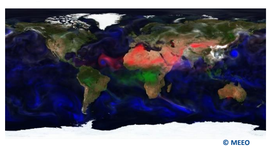
Cloud info :



clouds from satellite → **Heliosat-4 and McClear physical approaches, fast radiative transfer**



Clear sky info :



aerosol H_2O, O_3 from CAMS model

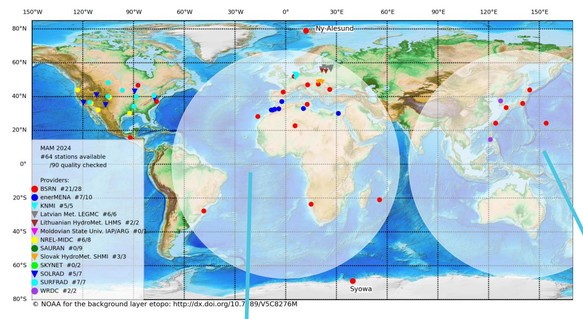
method papers
Gschwind et al., Contrib. Atm. Phys., 2019
Lefèvre et al., Atm. Meas. Tech., 2013
Qu et al., Contrib. Atm. Phys., 2017
Schroedter-Homscheidt et al., Contrib. Atm. Phys., 2022

CRS output : Expert mode

Irradiance : clear sky GHI, clear sky BHI, clear sky DHI, clear sky, BNI, GHI, BHI, DHI
Atmos. : tco3, tcwv, AOD BC, AOD DU, AOD SS, AOD OR, AOD SU, AOD NI, AOD AM, AOD SO
Clouds : cloud optical depth, cloud coverage (probability), cloud type
Albedo : fiso, fvol, fgeo, albedo
Other : reliability, sza, summer/winter split, alpha, Snow probability

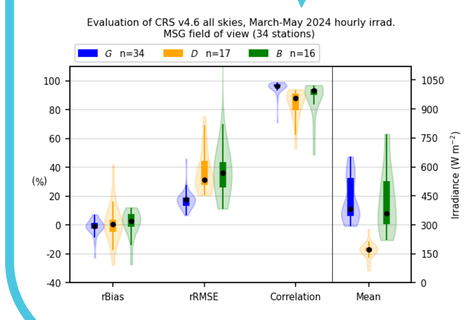
2. CRS regular evaluation and quality control (EQC)

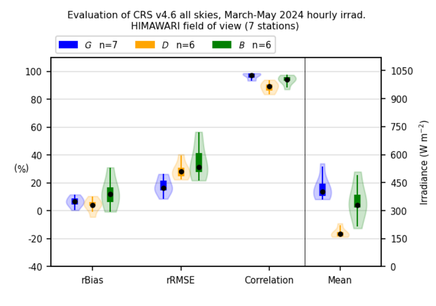
Ground observations :



Methodology :

- CRS irradiance vs ground observations : high quality radiation networks
- Additional CAMS expert QC on ground observations
- Standardize error metrics (Bias, RMSE, …) on cloudless / cloudy skies : per station and aggregated
- Quarterly updates (3 months evaluation with 6 months delay)
- Publicly available *https://atmosphere.copernicus.eu/supplementary-services*



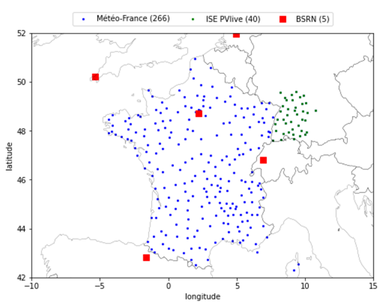


Questions to be addressed in CAMEO :

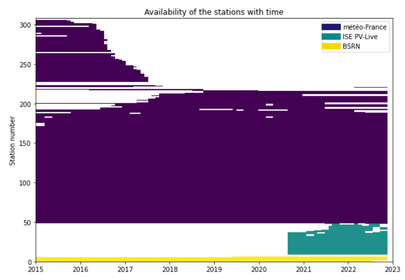
- Are thess aggregated **error metrics sufficient** for expert applications ?
- Can we assess the **main error sources** of these irradiance estimates ?
- Could we give more pixel-wise (non aggregated) uncertainty indicators for irradiance estimations to the users?

3. Analysis of the CRS spatial uncertainty

Ground database :

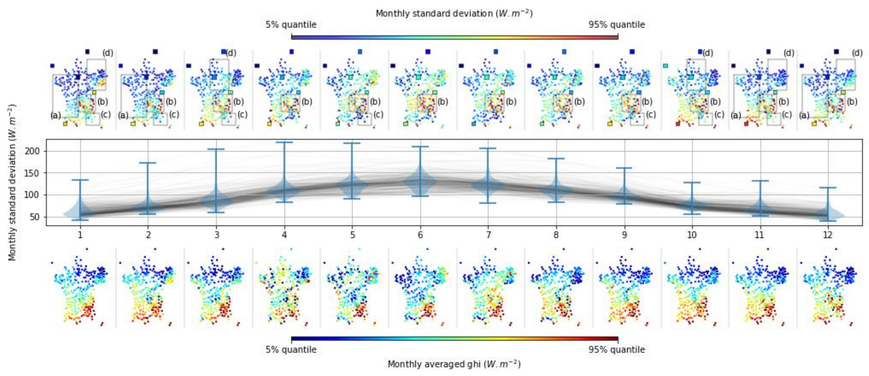


Dense pyranometric network (GHI)



Data availability

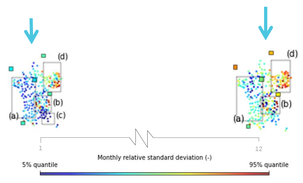
Seasonal analysis :



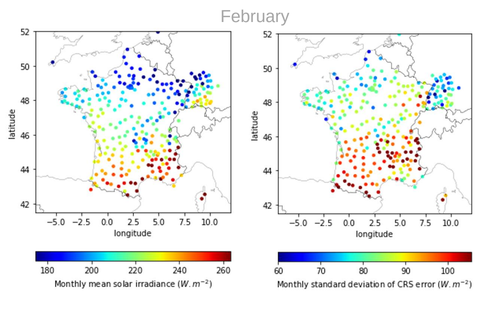
a) Spatial gradient due to mean solar irradiance (not visible in relative)
b) Orography related deviation

c) Low relative standard deviation not seen on absolute values

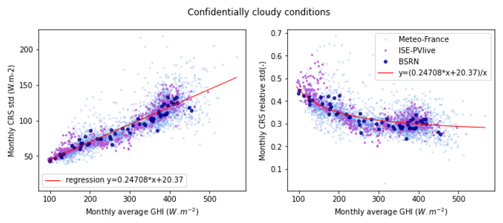
d) High relative standard deviation not seen on absolute values



Correlation to mean irradiance :

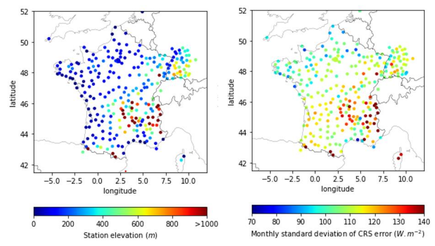


- Spatial and seasonal analysis depend on the mean solar radiation
- Common practice to remove dependency using relative error metrics



- linear relationship between the standard deviation of the error and the average irradiance with an offset **of 20.37 W.m^{-2}** → the hypothesis of proportionality does not holds (zero-expected value).
- Non-linear Increase of the relative standard deviation of the error with low mean irradiance

Correlation to elevation :



- Clear dependence of the standard deviation of the error of the CRS error with the station elevation

4. Analysis of the CRS temporal uncertainty

SHAP analysis :

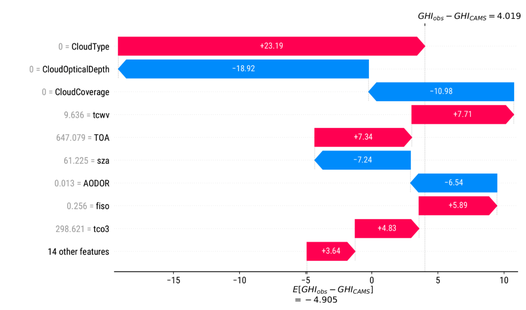
Method (game theory) to understand the contributions of single model parameters/features on the total error of the CRS irradiance estimates

$$f(X) = GHI_{cams}$$
$$e(X) = GHI_{obs} - f(X)$$

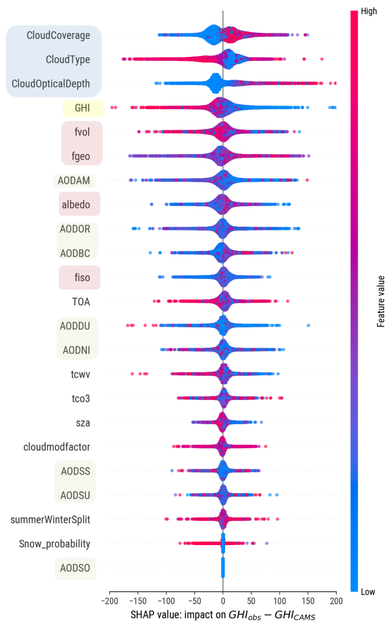
X → $XGboost$ (overfitted) → $e(X)$

SHAP value :

Contribution of the feature to the deviation of the average estimate

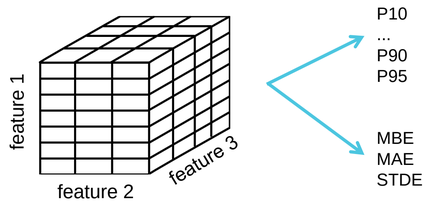


Ranking : Beeswarm plot



5. Pixel-wise error model Development

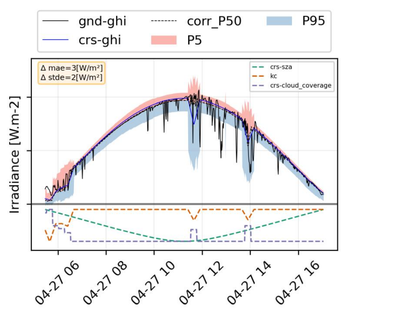
Model based on LUT / NN:



- Find a probability distribution for every bin in our multidimensional feature space (56 internal cams parameters)
- Estimate the uncertainty of a specific combination of features (time dependent)
- LUT approach / NN approach based on tensor.probability with a mutli-moment distribution

Experiment with 3 parameters :

cloud_prob = [0, 20, 40, 60, 80, 100]
Kc = GHI/GHIcs = [0, 0.1, 0.3, 0.5, 0.7, 1.0, 1.3]
crs-sza = [0, 10, 20, 30, 40, 50, 60, 70, 80]



6. References

- **Qu et al.,** Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method, Contrib. Atm. Sci., 2017
- **Schroedter-Homscheidt et al.,** Surface solar irradiation retrieval from MSG/SEVIRI based on APOLLO Next Generation and HELIOSAT-4 methods,Contrib. Atm. Sci.,/Meteorol. Z. Vol. 31 No. 6 (2022), p. 455 – 476, DOI: 10.1127/metz/2022/1132
- **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./Meteorol. Z., 2019

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