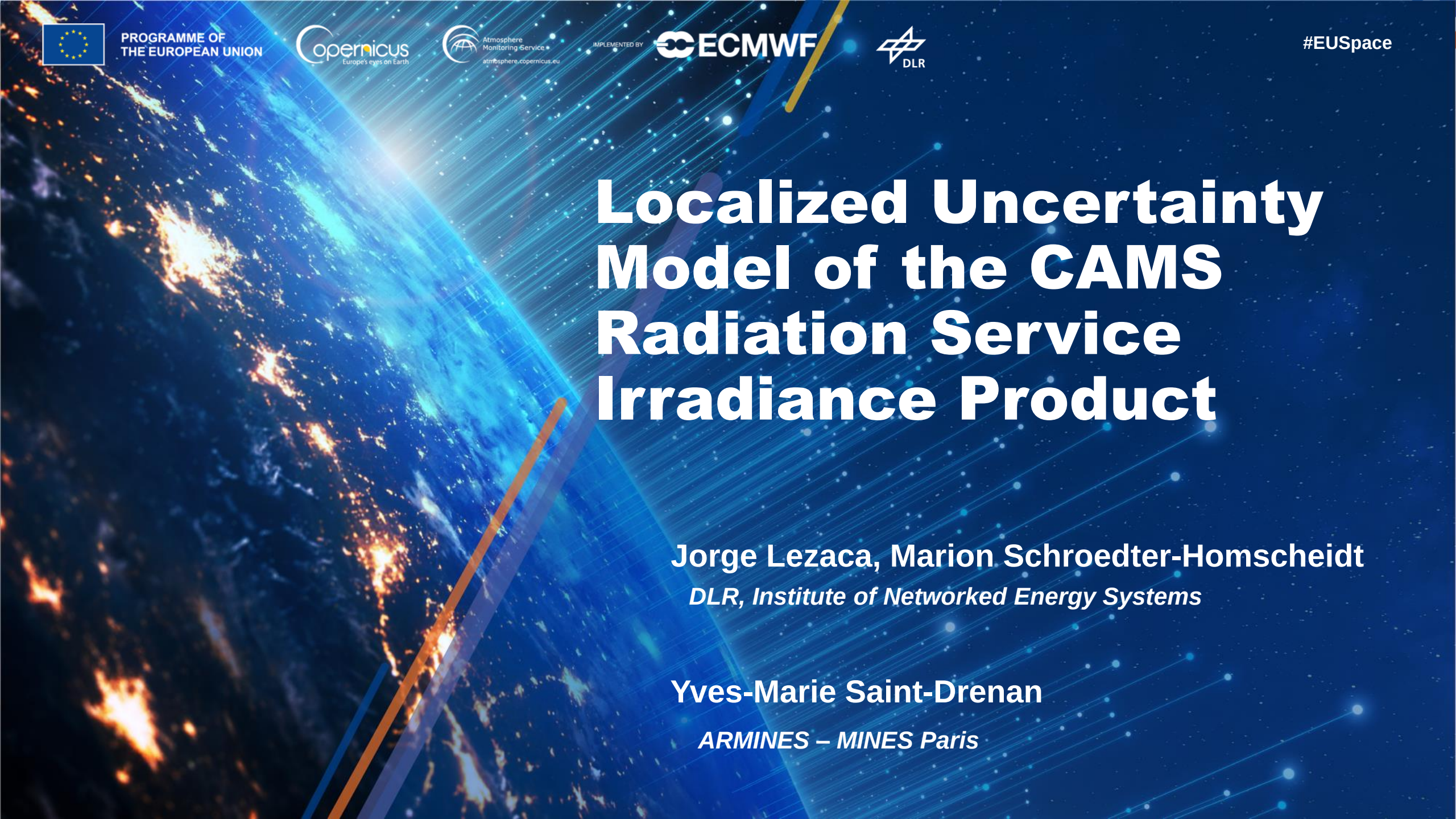


Localized Uncertainty Model of the CAMS Radiation Service Irradiance Product

Jorge Lezaca, Marion Schroedter-Homscheidt

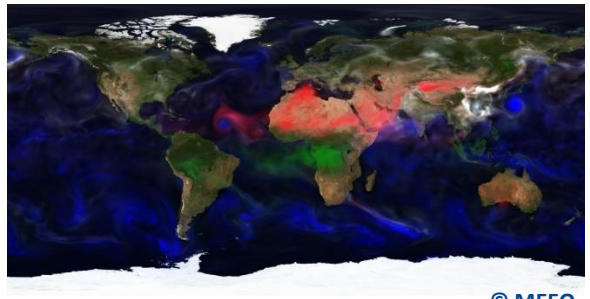
DLR, Institute of Networked Energy Systems

Yves-Marie Saint-Drenan

ARMINES – MINES Paris

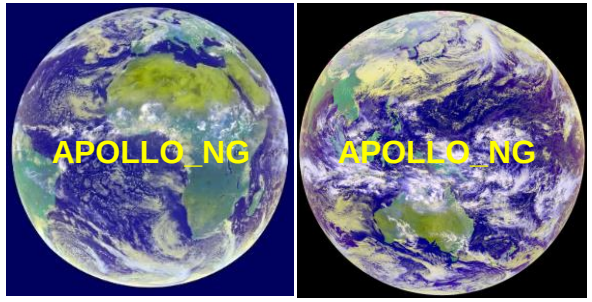
CAMS radiation service (CRS) : method

Worldwide
(2004 - yesterday)



© MEEO

MSG **HIMAWARI**
(2004 - yesterday) **(2016 - yesterday)**



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Aerosol H_2O, O_3 from CAMS models

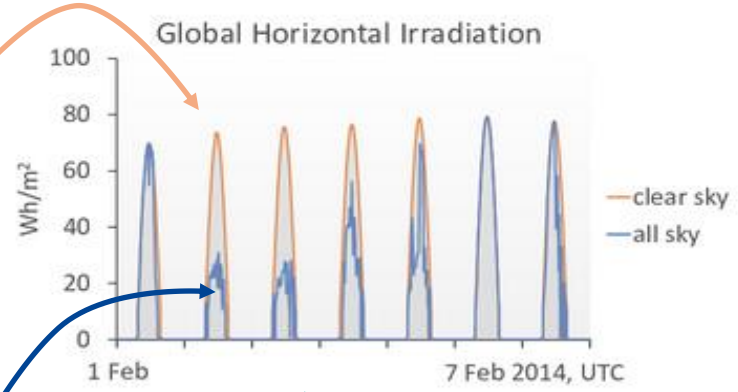
clouds from satellite

McClear

Fast radiative transfer

Heliosat-4

MSG / HIMAWARI



pvlib

ADS-TS

Method papers

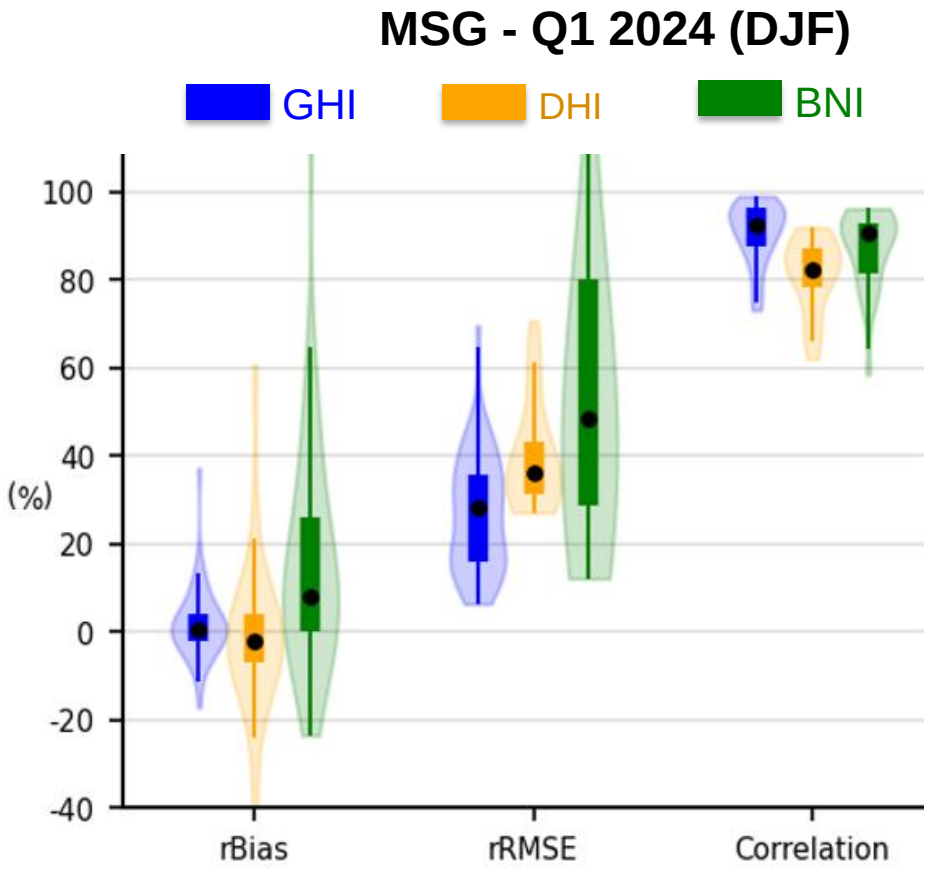
Lefèvre et al., Atm. Meas. Tech., 2013
Qu et al., Contrib. Atm. Phys., 2017
Gschwind et al., Contrib. Atm. Phys., 2019
Schroedter-Homscheidt et al., Contrib. Atm. Phys., 2022

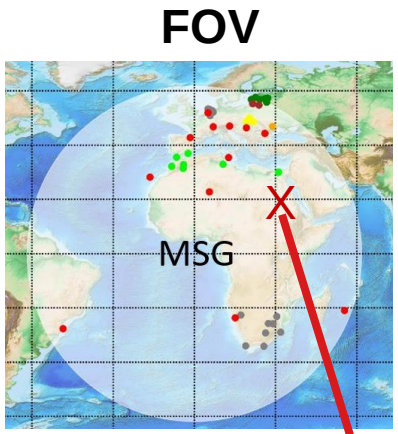
Localized uncertainty model

Motivation

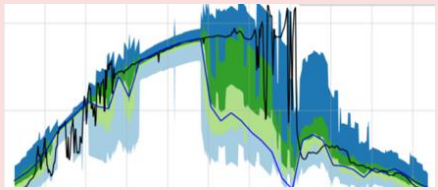
Motivation for a localized uncertainty model

- **CRS estimations** widely used : Steady increase (commercial, scientific, policy)
- **Today CRS performance evaluation** : EQC validation reports





- Statistical deviation metrics for a site (or aggregation for multiple sites)
- Quarterly/Yearly statistics
- Limited for estimating local uncertainty



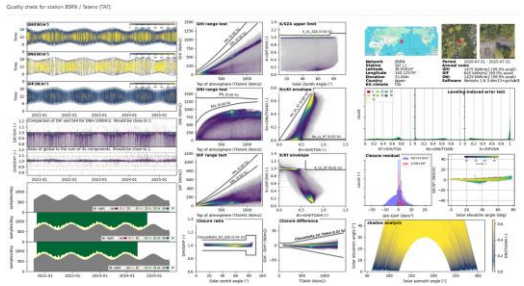
<?> : localized uncertainty specific to the CRS user query (space and time)

Localized uncertainty model

Method

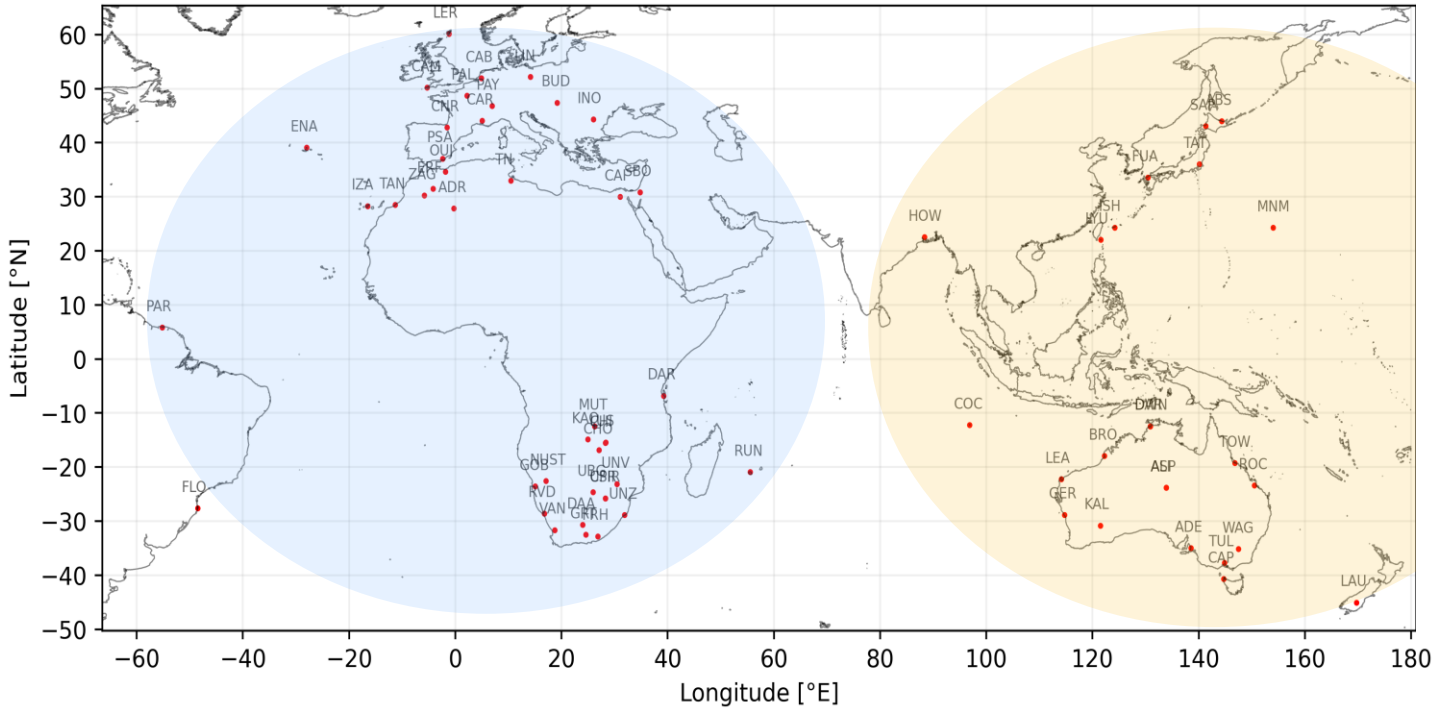
Deviations from ground observations

- CRS operational database : **300** stations available worldwide in **1 min resolution** (inseetu)
- For this study : **very selective quality checks**
  - Only stations with 3 components
  - Highly selective QC tests:



  - Acceptance on 6 months batches

66 stations retained for the study



Total of 67×10^6 data points

Development conditions

1) **Data driven** : Well populated ground observations
   - Spatial extent : 66 locations
   - Temporal extent

2) **Rationale** : exploit information of **deviations** between CRS estimates and ground observations to estimate the localized uncertainty

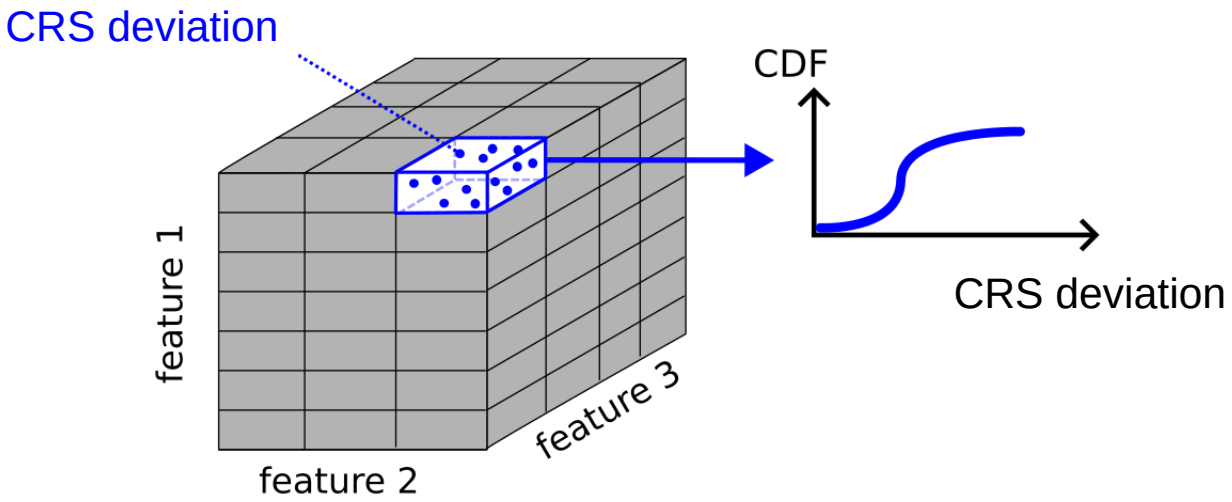
Note: CRS deviations account for:

- Physical model assumptions (McClear, APOLLO_NG, Heliosat-4)
- Mismatch between spatial average CRS irradiance (satellite/NWP) and ground observations (point measurements)

3) **Objective** : Obtain a first approach to the spatial and temporal generalization of the uncertainty of the CRS estimate

Localized uncertainty model

CDF* of deviations conditioned to the CRS inputs



a) Characterization (historic data)

*CDF : cumulative distribution function

Localized uncertainty model

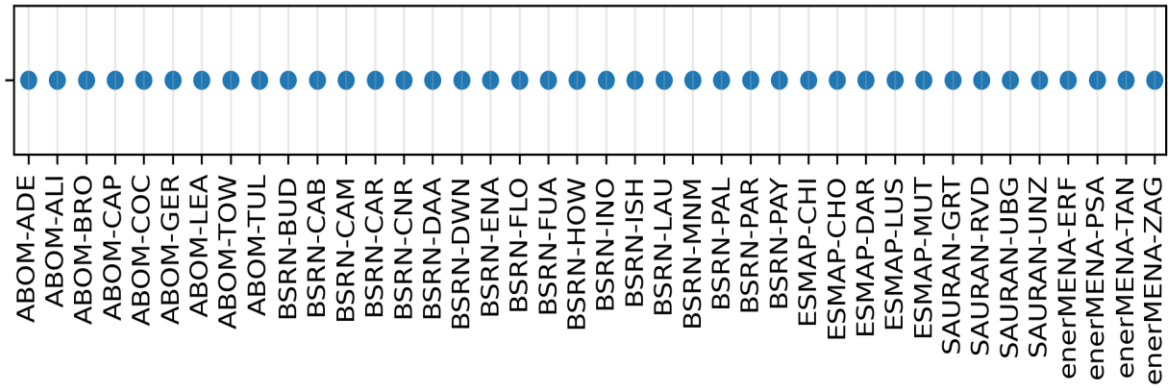
Run 0

Localized uncertainty model

Model Run 0

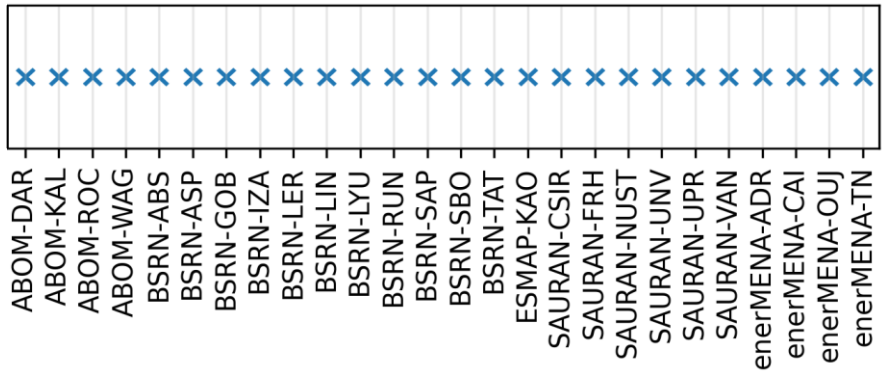
Characterization phase

- 40 randomly selected locations :



Inference phase

- 26 Locations :



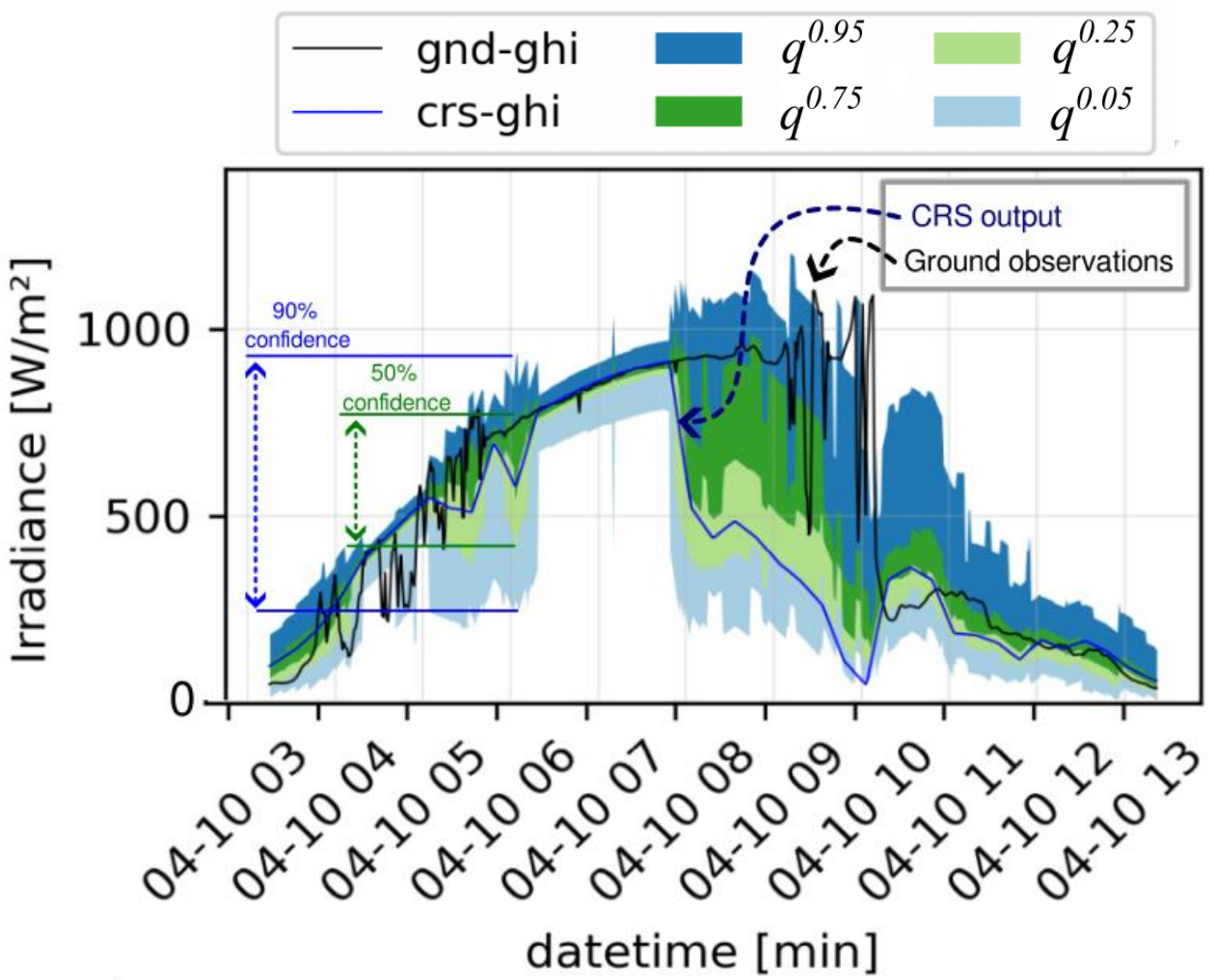
- Feature space chosen: 3 dimensions following SHAP results

1) - **SZA** = from 0° to 80° every 2° (40 bins)
2) - **Kc** = from 0 to 1.4 every 0.1 (15 bins)
3) - **Cloud probability** = from 0% to 100% every 5% (20 bins)

Localized uncertainty model

Run0 – Inference on cloudy conditions

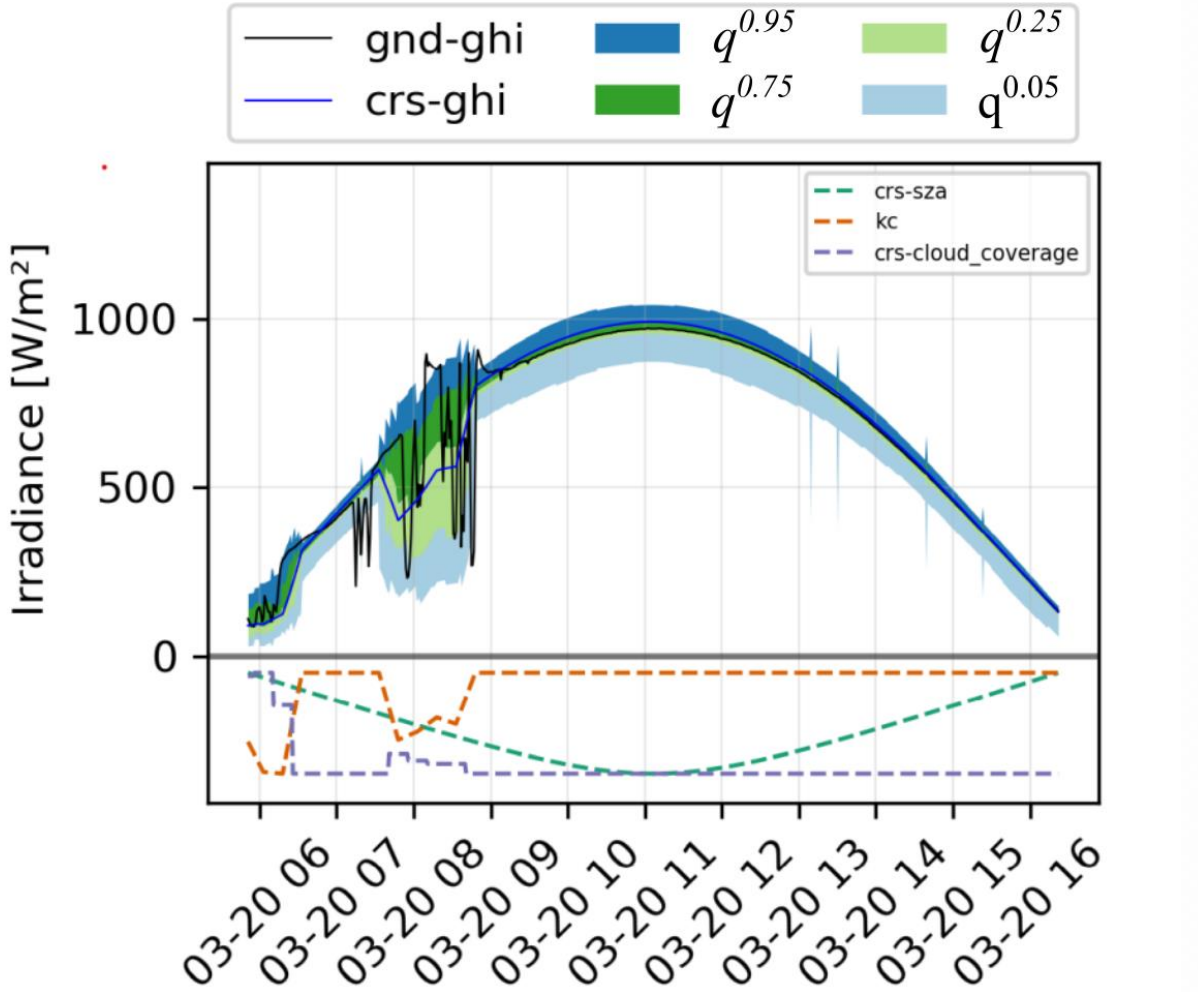
- Location : **BSRN–RUN**
- Date**: 2022-04-10**
- Site characteristics : **island, mountainous terrain** (Difficult site for CRS)



Localized uncertainty model

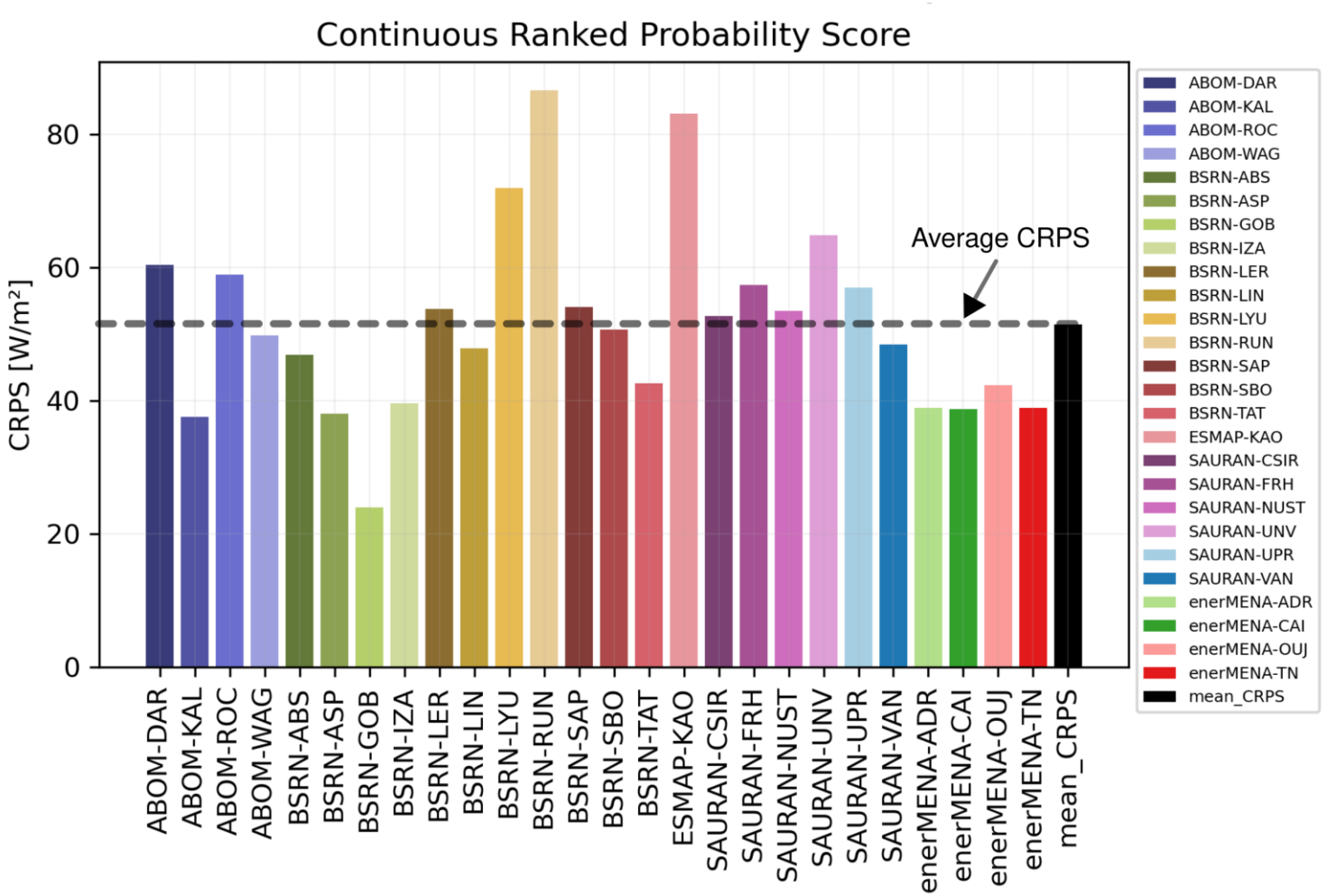
Run0 – inference in clear sky conditions

- Location : **BSRN–GOB**
- Date**: 2022-04-10**
- Site characteristics : **Desert**



Localized uncertainty model

Run0 – method calibration

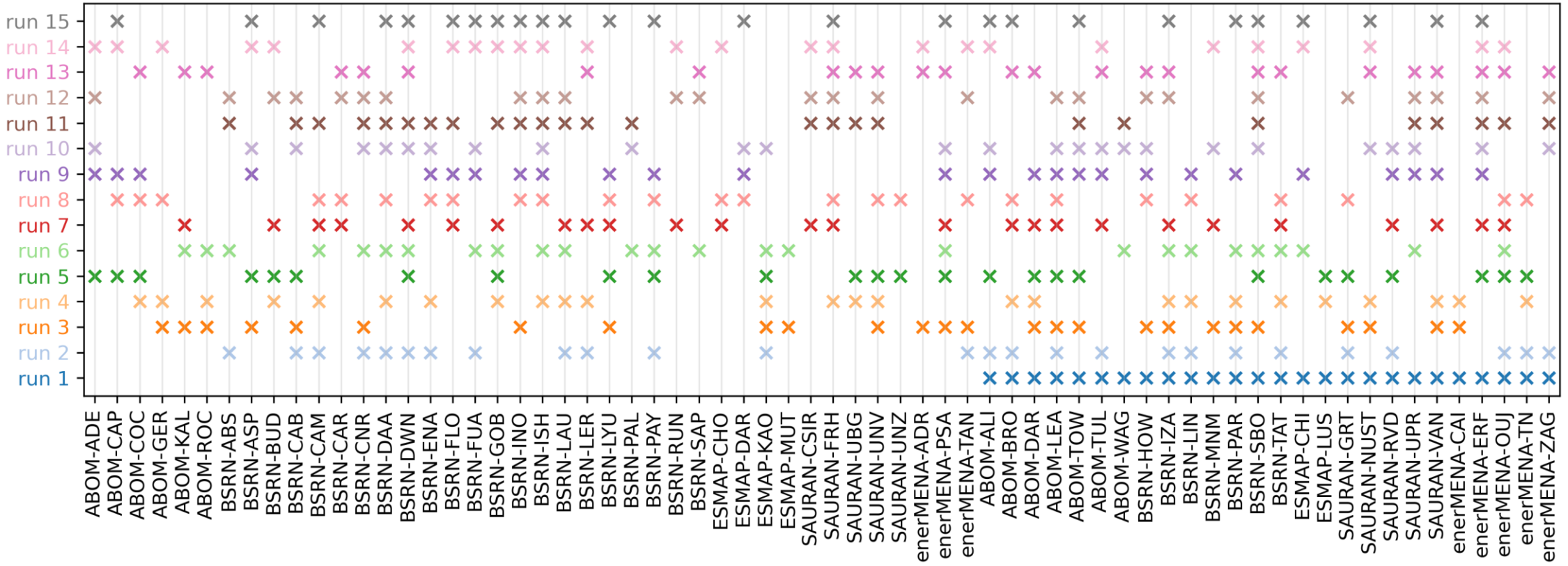


Localized uncertainty model
Runs 1-15

Localized uncertainty model

Model robustness: Runs 1-15

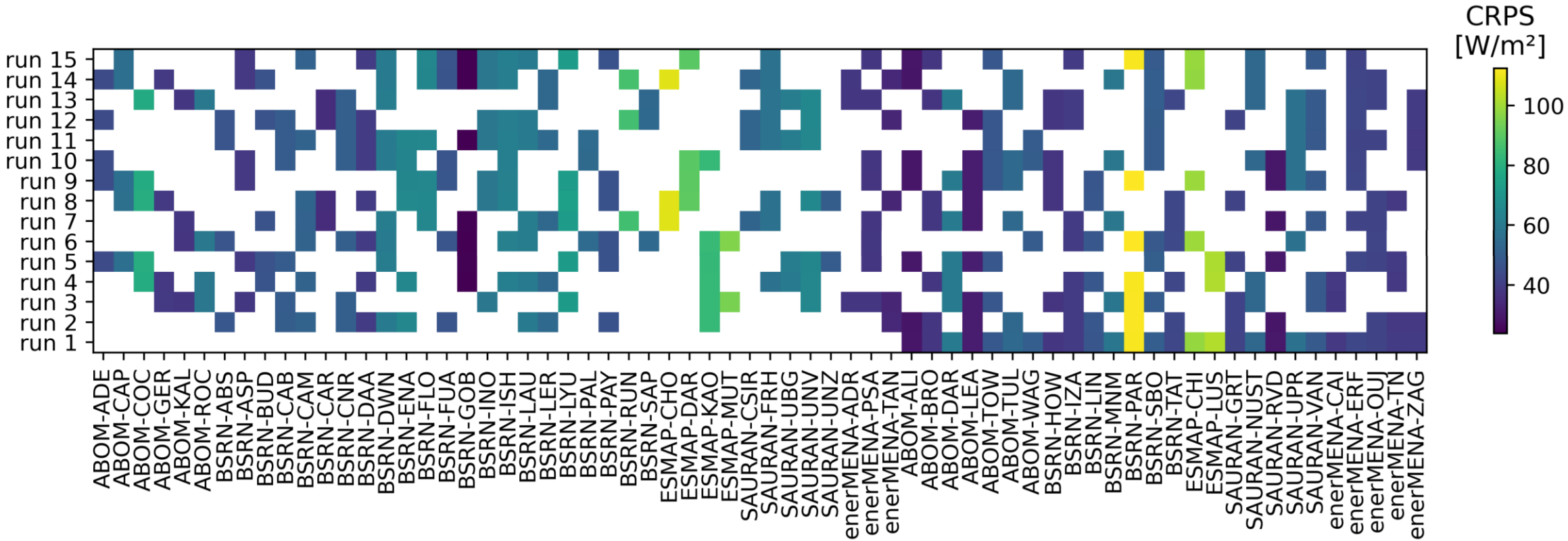
15 runs with different randomly locations splits :



Localized uncertainty model

Run 1-15 CRSP

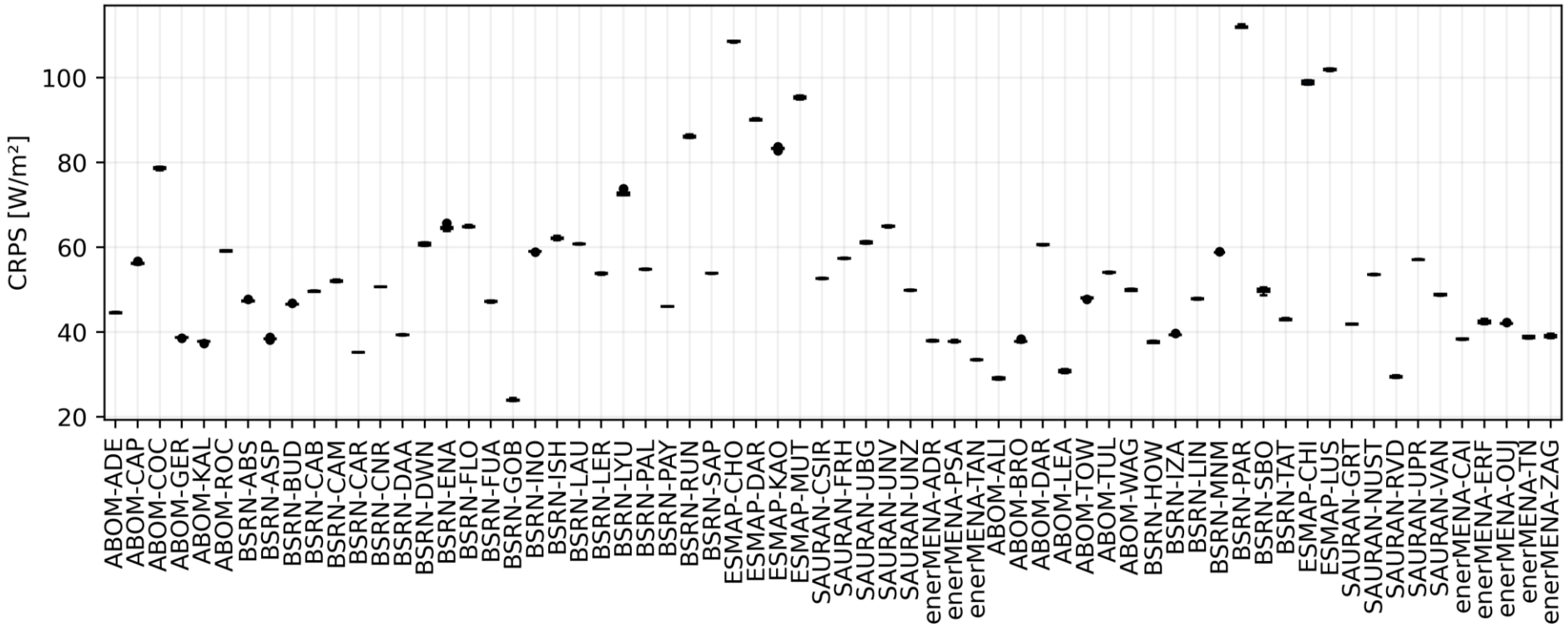
CRPS per station per run :



Localized uncertainty model 1

Run 1-15 CRSP box plots

Box plots of CRPS values in the 15 runs :

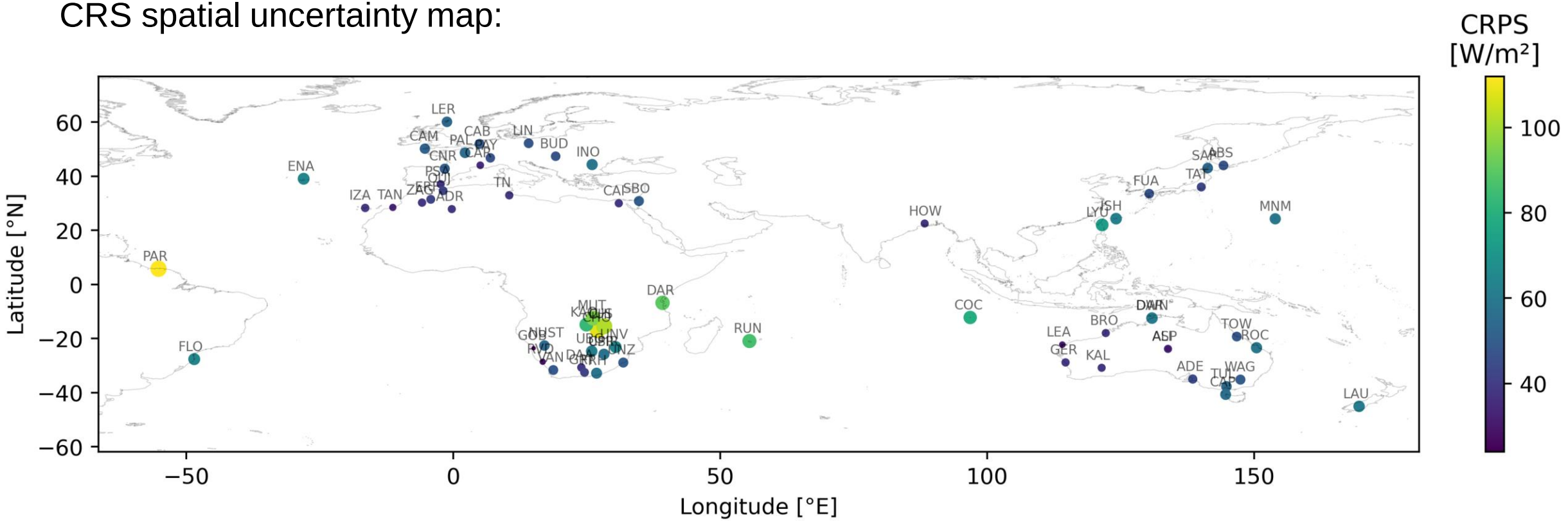


- Consistent CRPS independent of the locations choosen for characterization

Localized uncertainty model 1

Parametric binning : Run1-15 (robustness)

CRS spatial uncertainty map:



Benchmark for future development

Conclusion
Open questions

Conclusions

- Developed a first approach to localized (spatial-temporal) uncertainty of the CRS estimate
- Model shows a low and consistent CRPS within the different locations
- Model is very robust against training stations selected

Outlook

- Define uncertainty metric meet user expectations (full CDF too overwhelming for typical user)
- Increase the number of features and data (*curse of dimensionality !*)
- Neural Network to optimized moments of parametrical PDF to describe the CRS estimate
    - Includes by desing automatic binning + dimension reduction

References CRS

•Heliosat-4 method

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

•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./Meteorol. Z., 2019

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CAMS Radiation Service (CRS)

opernicus
Europe's eyes on Earth

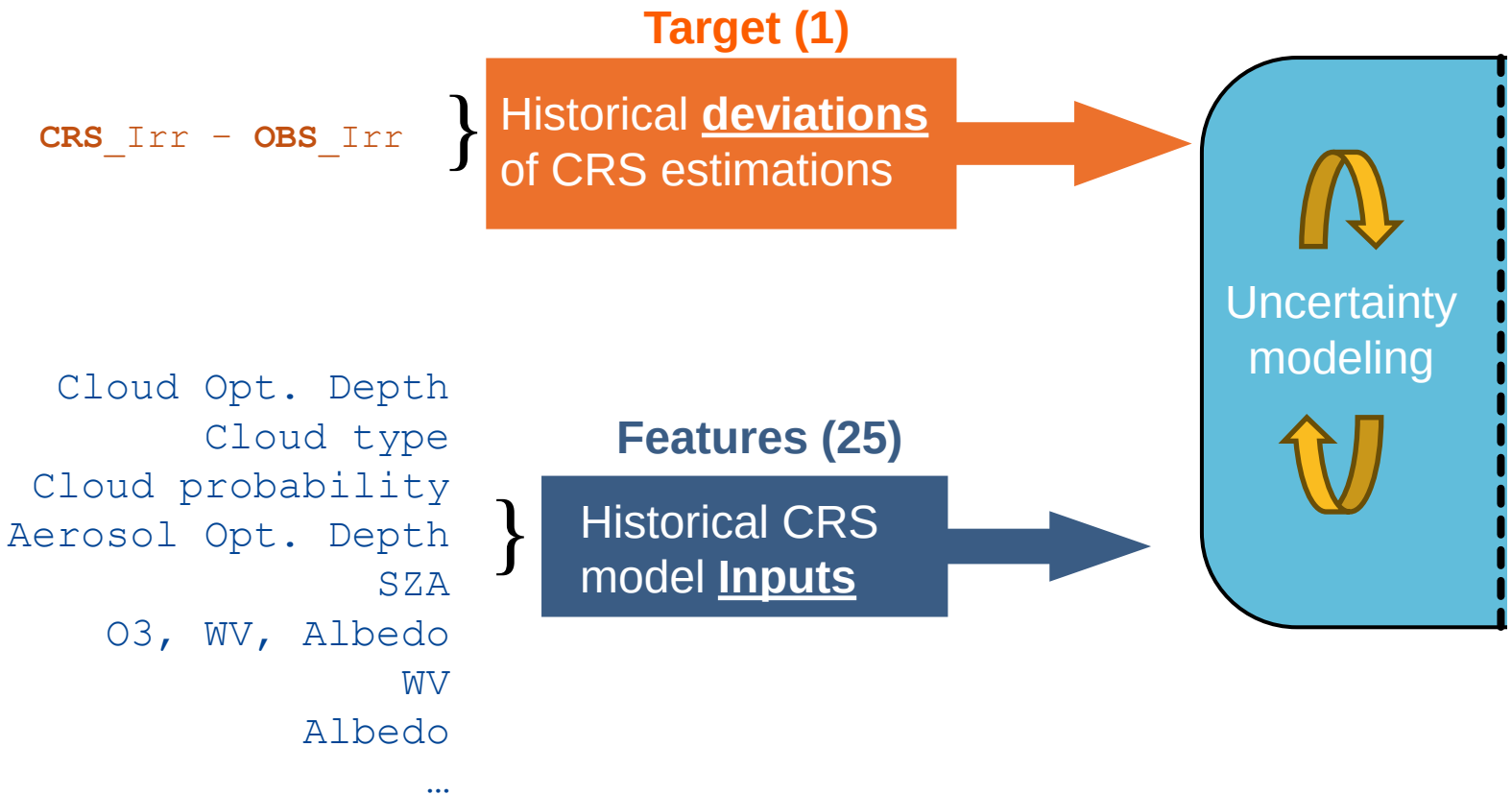
Earth observation Program

AMS → provides consistent and quality-controlled information related to air pollution, and greenhouse gases **solar energy** worldwide.

Cams Radiation Service

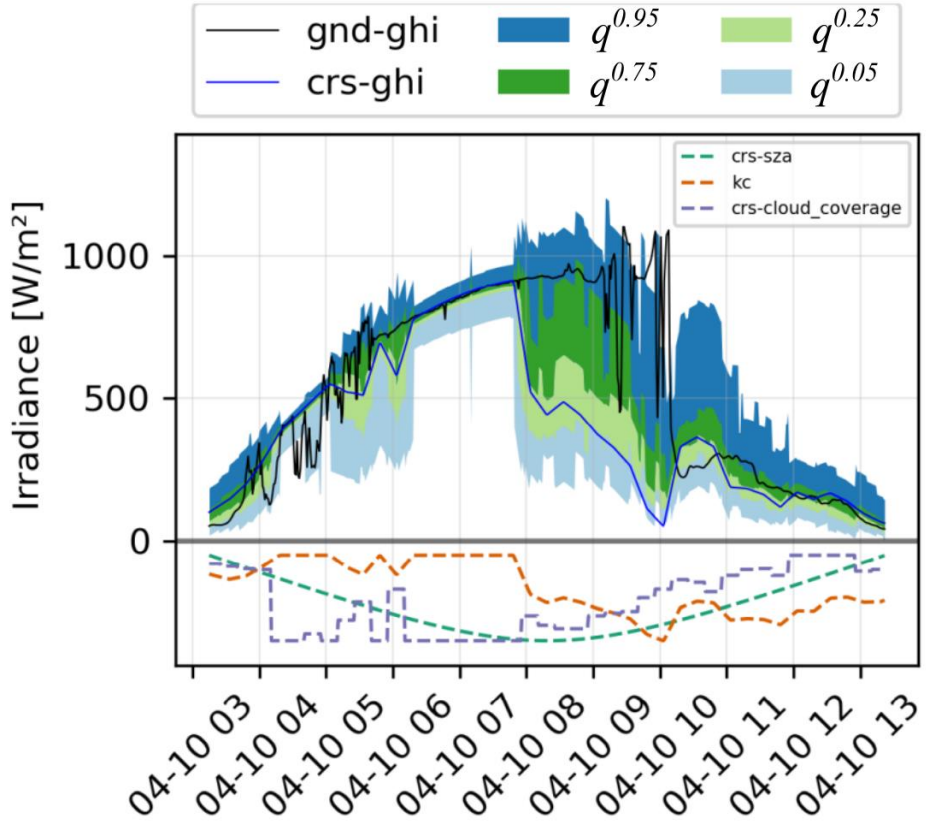
Uncertainty model concept

Data : $ts(k,t)\Big|_{\text{site } k\ (lon_k, lat_k),\ \text{time } t}$

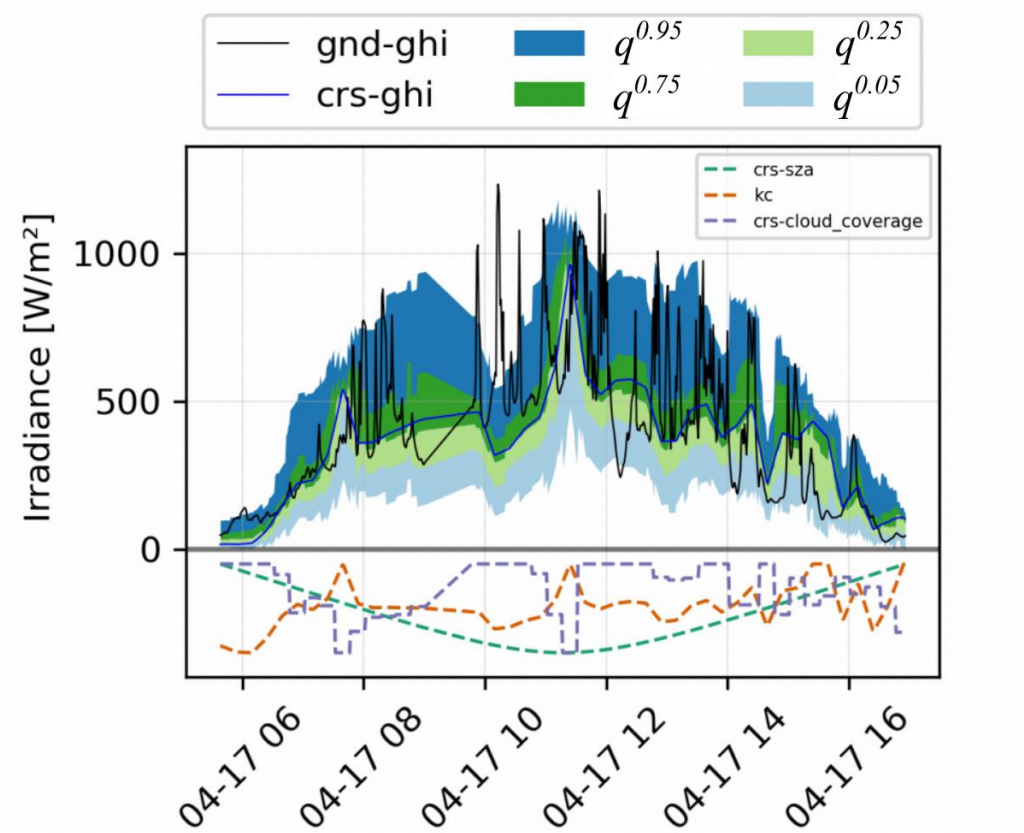


Localized uncertainty model 1

Parametric binning : Run1 – inference in cloudy conditions



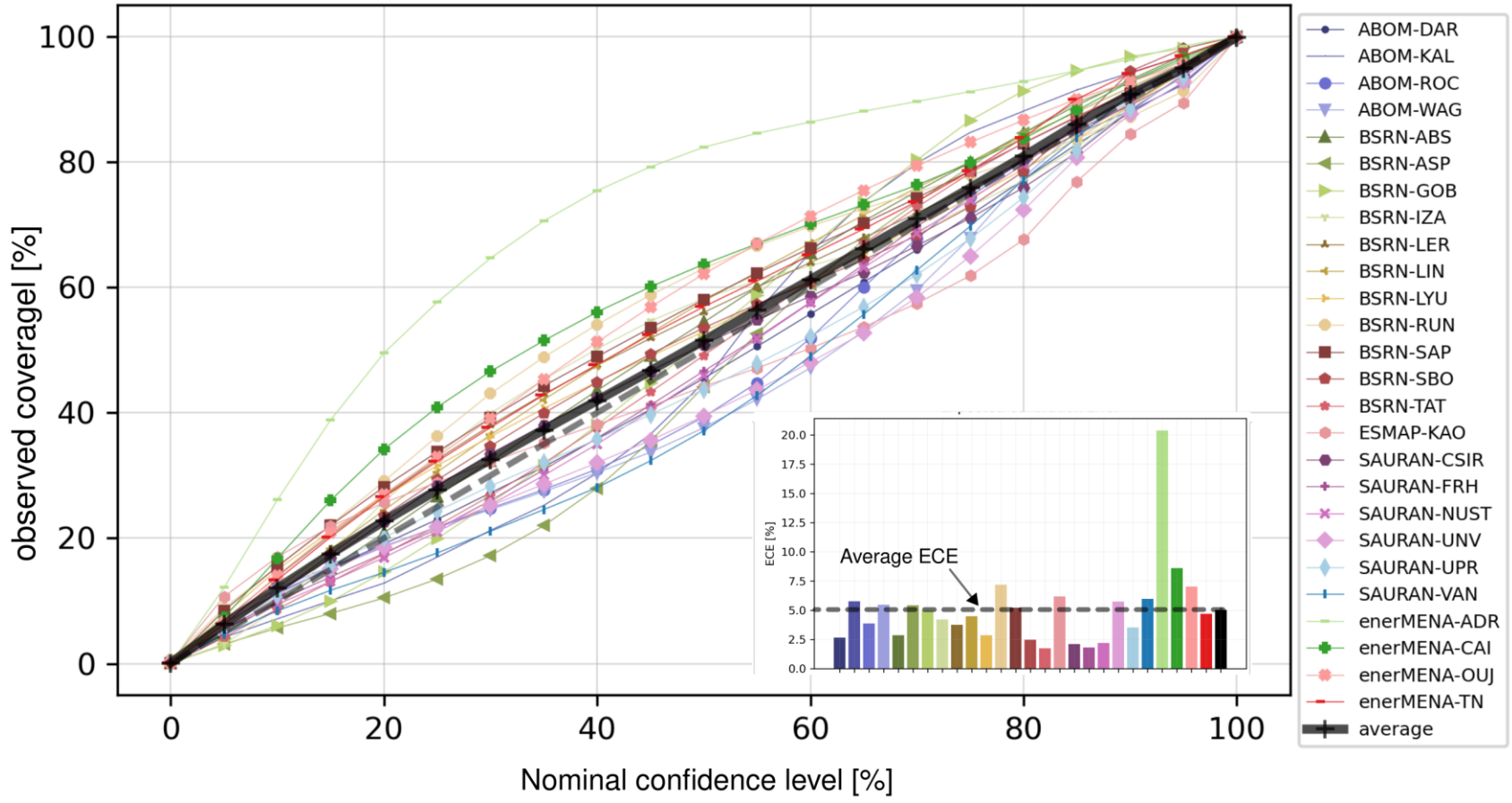
c) BSRN-RUN - 2022-04-10



d) enerMENA-TN - 2021-04-17

Localized uncertainty model

Run0 – probabilistic calibration



Localized uncertainty model 2

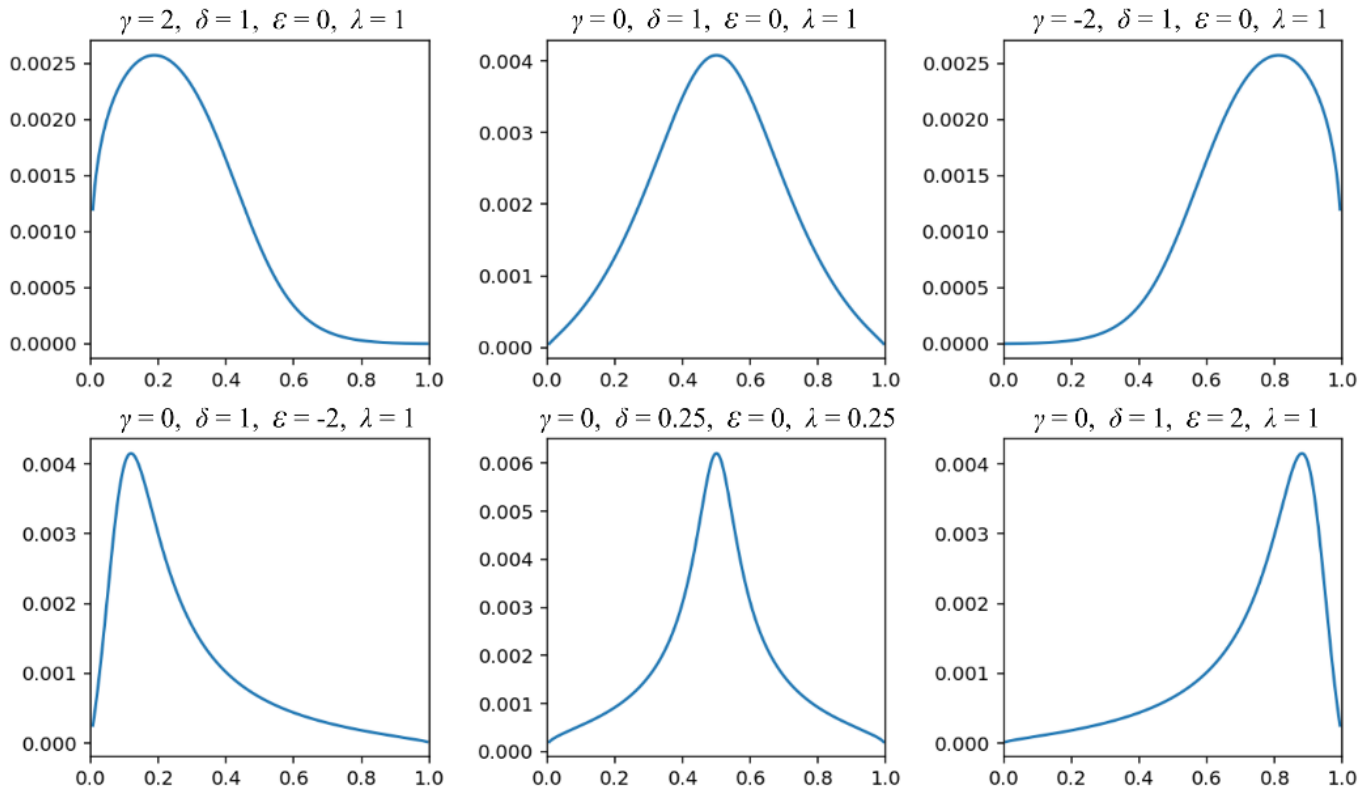
ML based : proof of concept

Localized uncertainty model 2

ML based : basic concept

Use the SU-Jonshon parametric distribution (4 parameters) to model the CRS deviations distributions

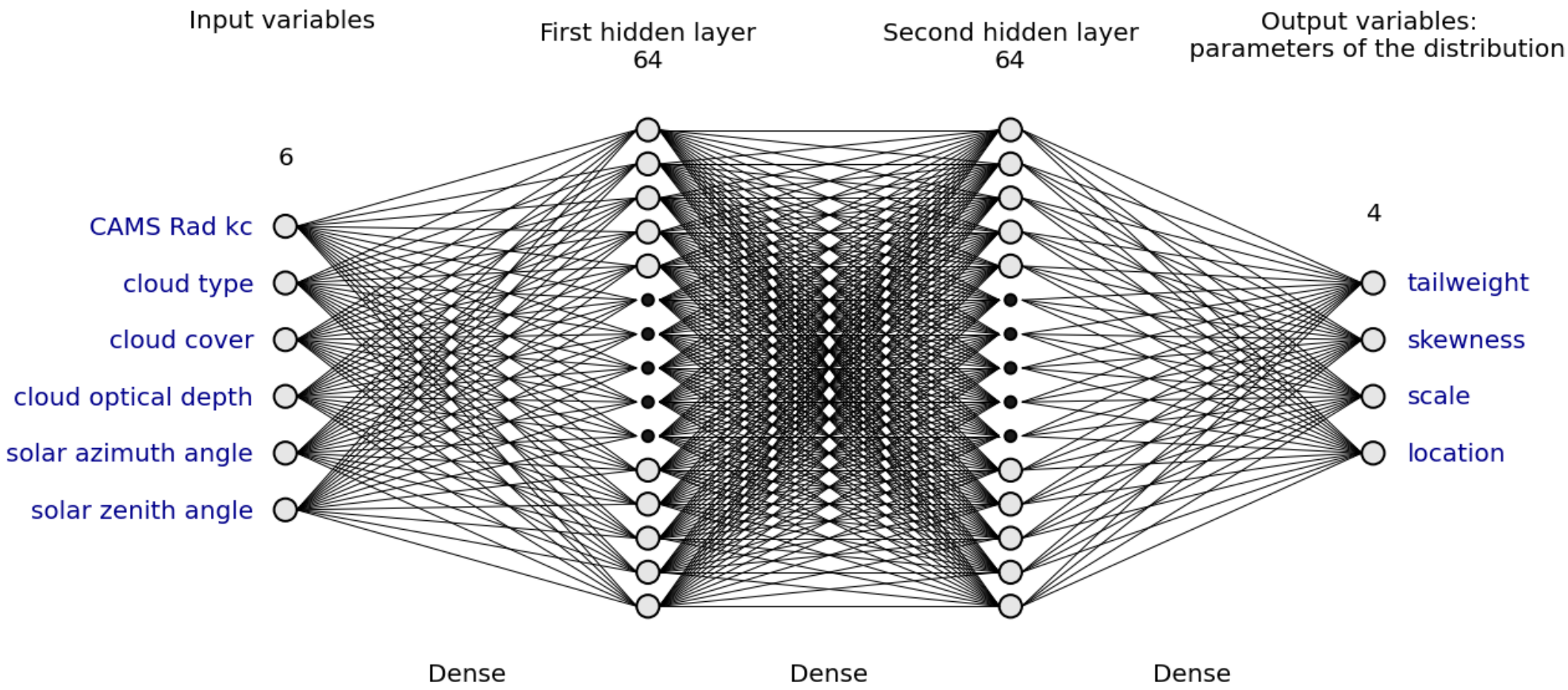
$$(x|\eta,\gamma,\lambda,\varepsilon)=\frac{\delta}{\lambda\sqrt{2\pi}}\frac{\eta}{\sqrt{1+\left(\frac{x-\varepsilon}{\lambda}\right)^2}}\exp\left(\frac{-1}{2}\left(\gamma+\delta\,asinh\left(\frac{x-\varepsilon}{\lambda}\right)\right)^2\right)$$



The parameters of a parametric distribution are predicted as a function of the CRS inputs using a neural network

Localized uncertainty model 2

ML based : ML architecture

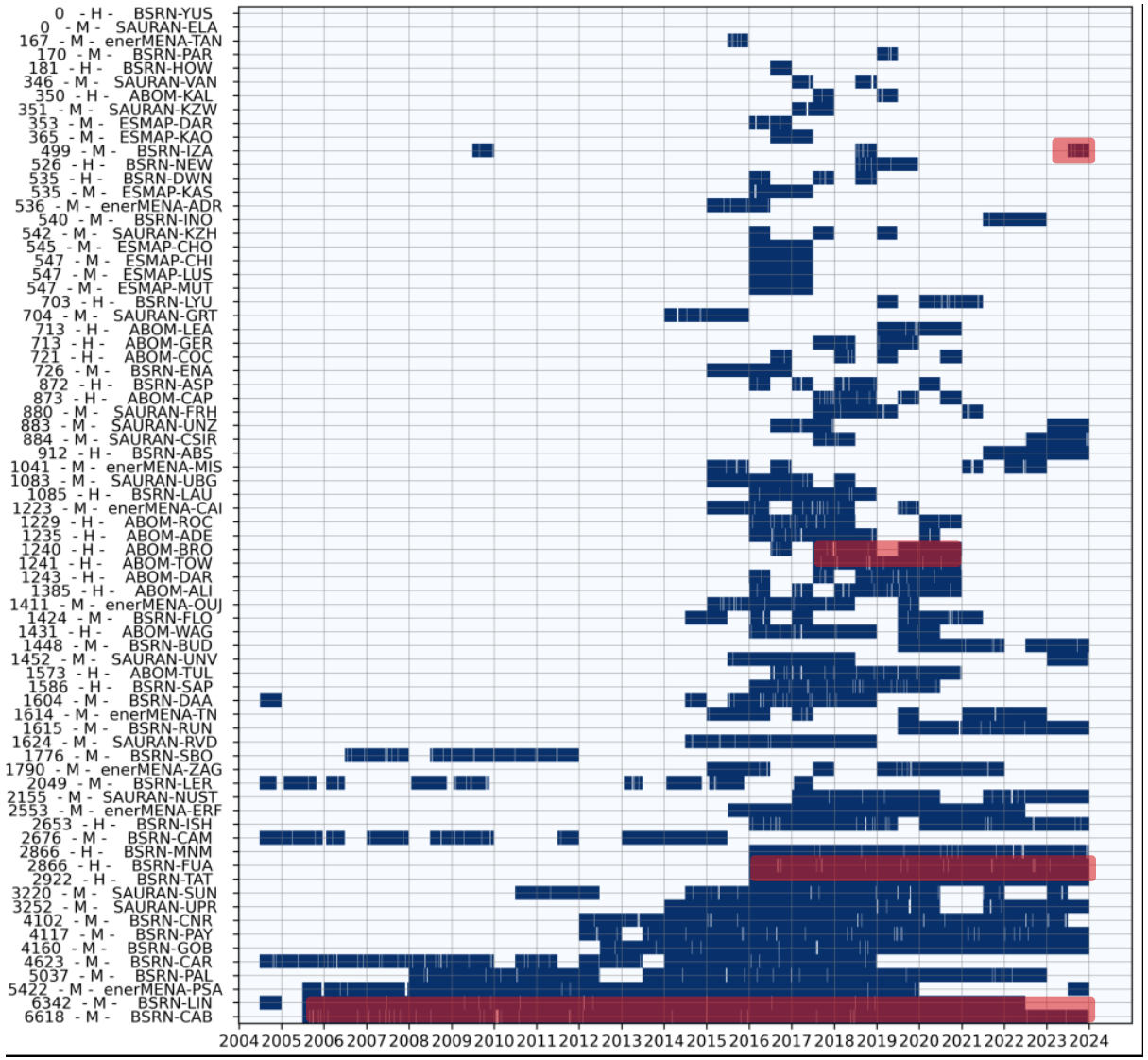


Data : ground observations

Availability :

- 66 Station
- 1 min resolution
- From 6 months to 20 years

Total of 67×10^6 data points



6 months

5 years

8 years

20 years

Uncertainty model concept