EMS Annual Meeting 2022

In Situ Based Performance of Satellite- and Reanalysis-derived Hourly Global Horizontal Irradiance Products over West Africa

Dr. Windmanagda Sawadogo

Prof. Dr. Harald Kunstmann

Dr.-Ing. Jan Bliefernicht

Dr. Benjamin Fersch

Dr. Seyni Salack

Samuel Guug

Dr. Belko Diallo

Prof. Kehinde.O. Ogunjobi

Guillaume Nacoulma

Dr Michael Tanu

Prof. Stefanie Meilinger

9 September 2022, Bonn, Germany

WASCAL West African Science Service Centre on Climate Change and Adapted Land Use

Universität Augsburg University

Introduction

➢ Background & motivation

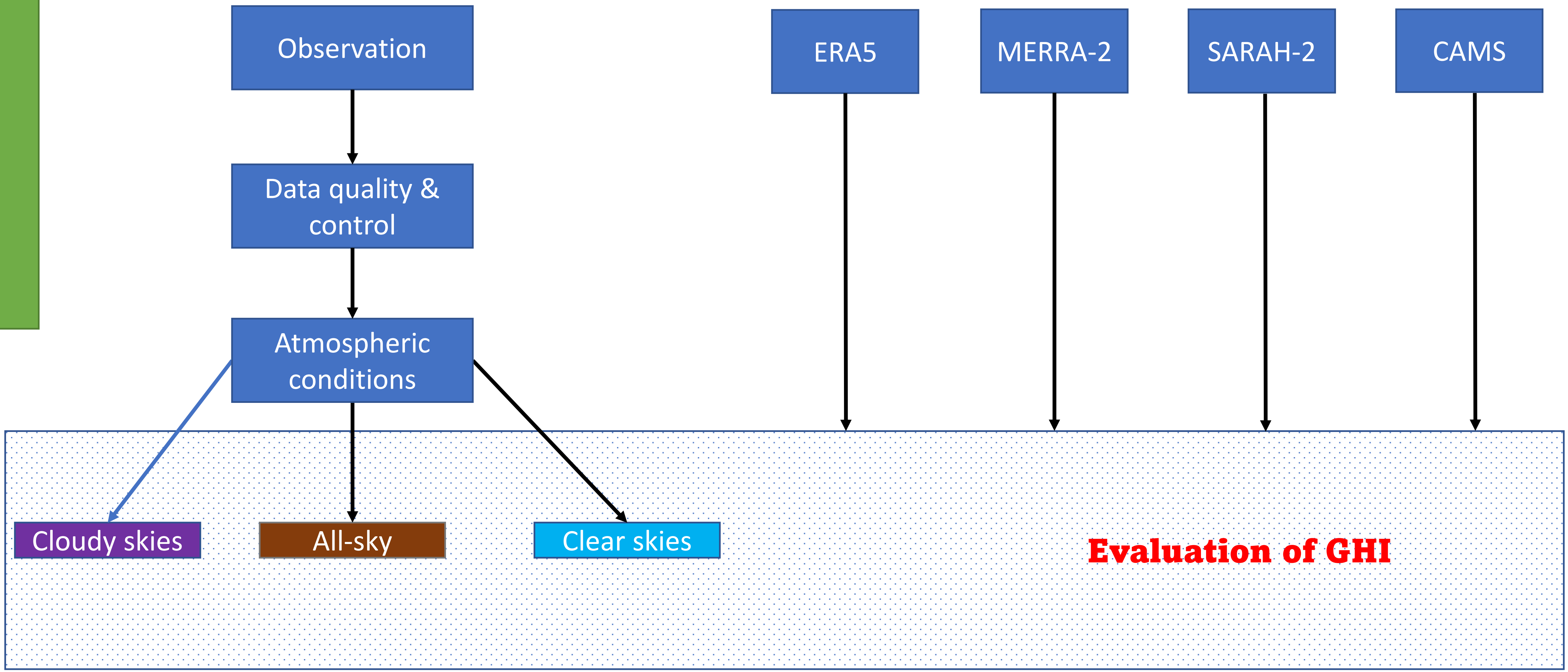
- ➢ Knowledge of GHI is crucial for solar PV assessment.
- ➢ There is boom in using solar PV technology in West Africa in the recent years.
- ➢ Pyranometers are the standard way to record GHI values.
- ➢ However, data are not available or contain missing data and most of the stations are sparely distributed.
- ➢ Most of the assessment use satellite or reanalysis data.
- ➢ These sources require an evaluation with in-situ data.

Introduction

➢ Aim

Evaluate the performance of hourly GHI derived from MERRA-2, ERA5, SARAH -2 and CAMS data with in-situ data for the year 2020.

Methodology

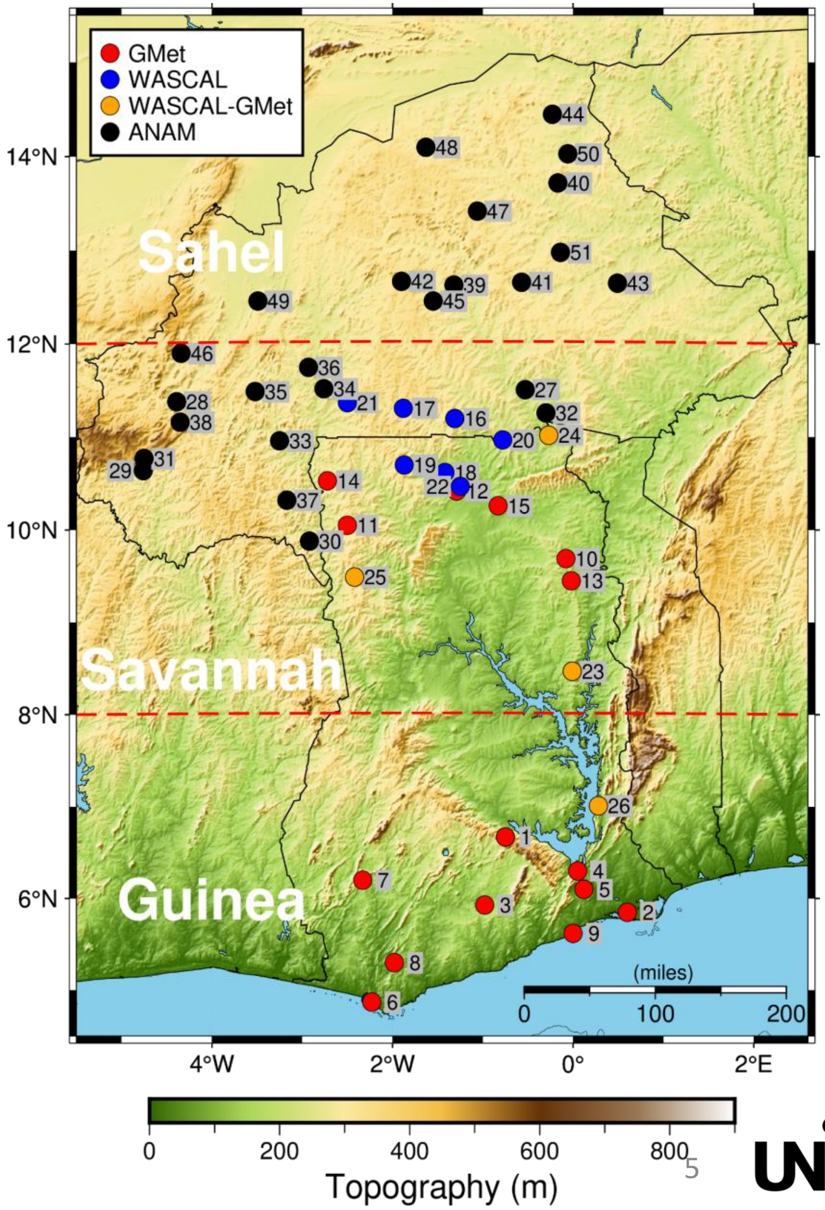


Flow chart of the methodology

Methodology

➢ Study area & data

- The study focuses in the West Africa region: Burkina Faso and Ghana.
- The region is divided in 3 climatic zones
  - •Sahel (12˚N–16˚N)
  - •Savannah (8˚N–12˚N)
  - •Guinea (4˚N–8˚N)
- 51 automatic weather station (AWS):
  - 25 AWS from ANAM (15 minutes time-step);
  - 7 AWS from WASCAL (5 minutes time-step);
  - 15 AWS from GMet (15 minutes time-step);
  - 4 AWS from WASCAL-GMet (5 minutes time-step).



Methodology

➢ Quality control

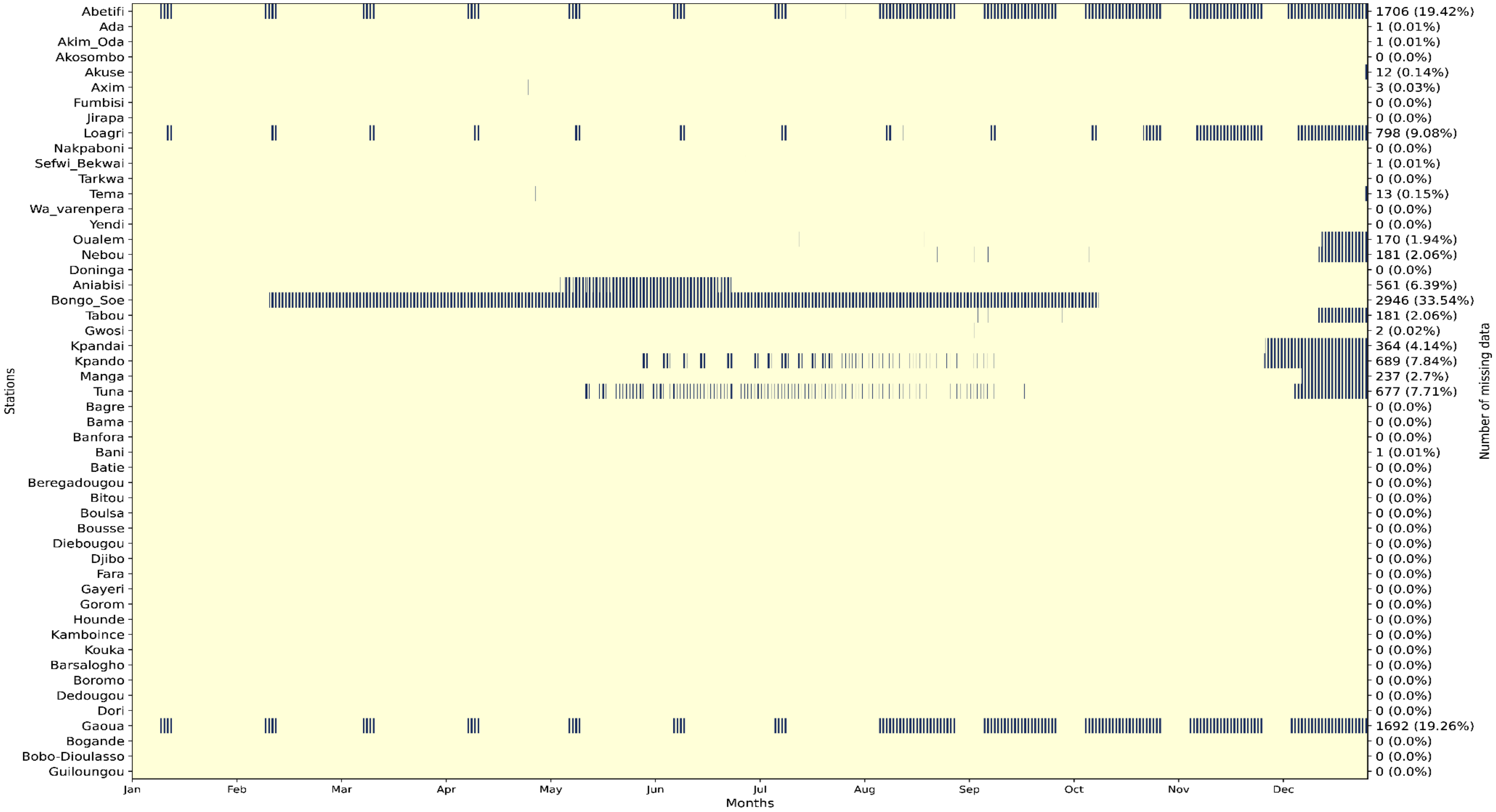


Fig.2: Missing data for the year 2020 from different AWS

Methodology

➢ Quality control

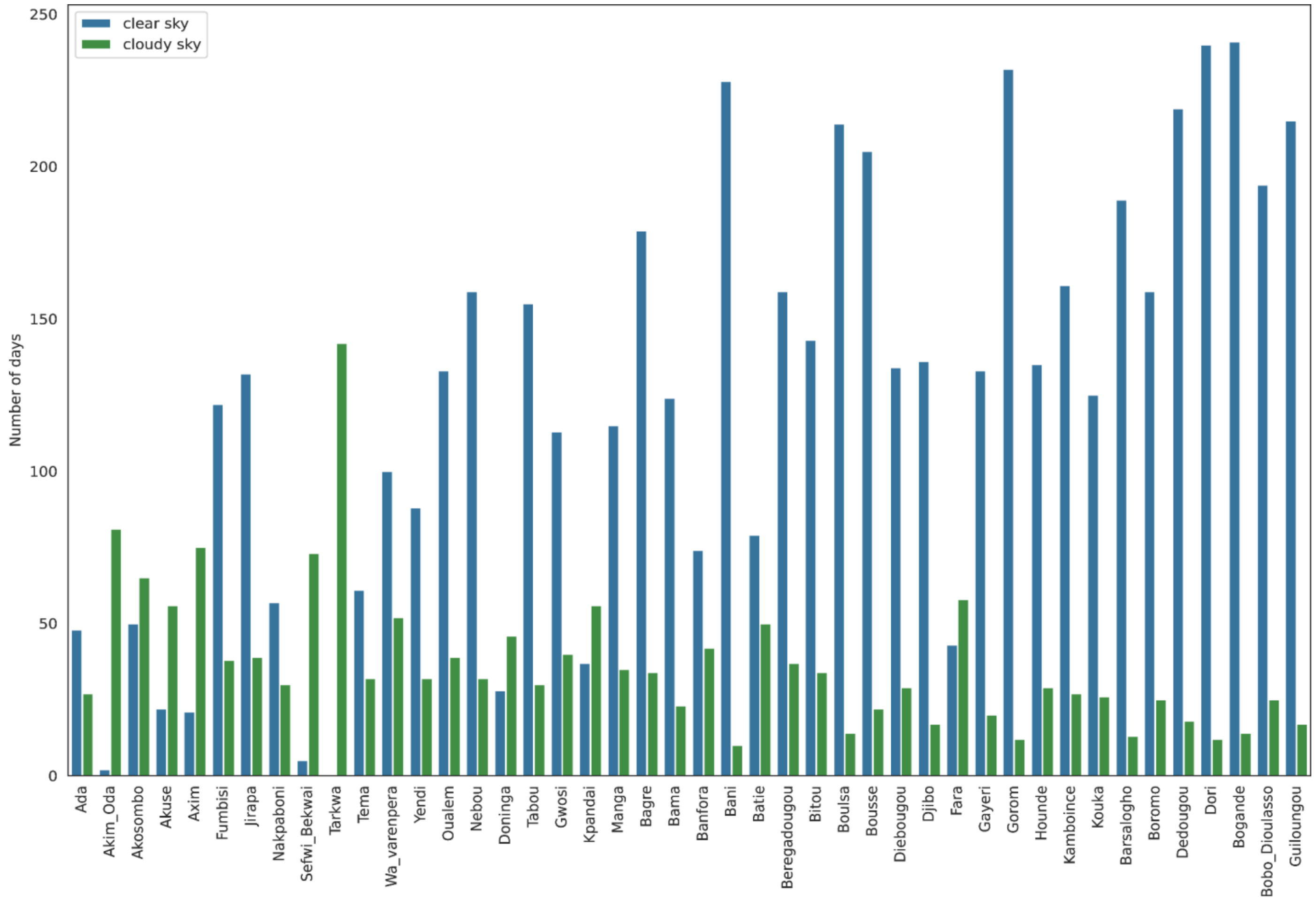


Fig.3: Number of clear and cloudy sky days composite

- Number of clear and cloudy sky days composite

Methodology

➢ Quality control

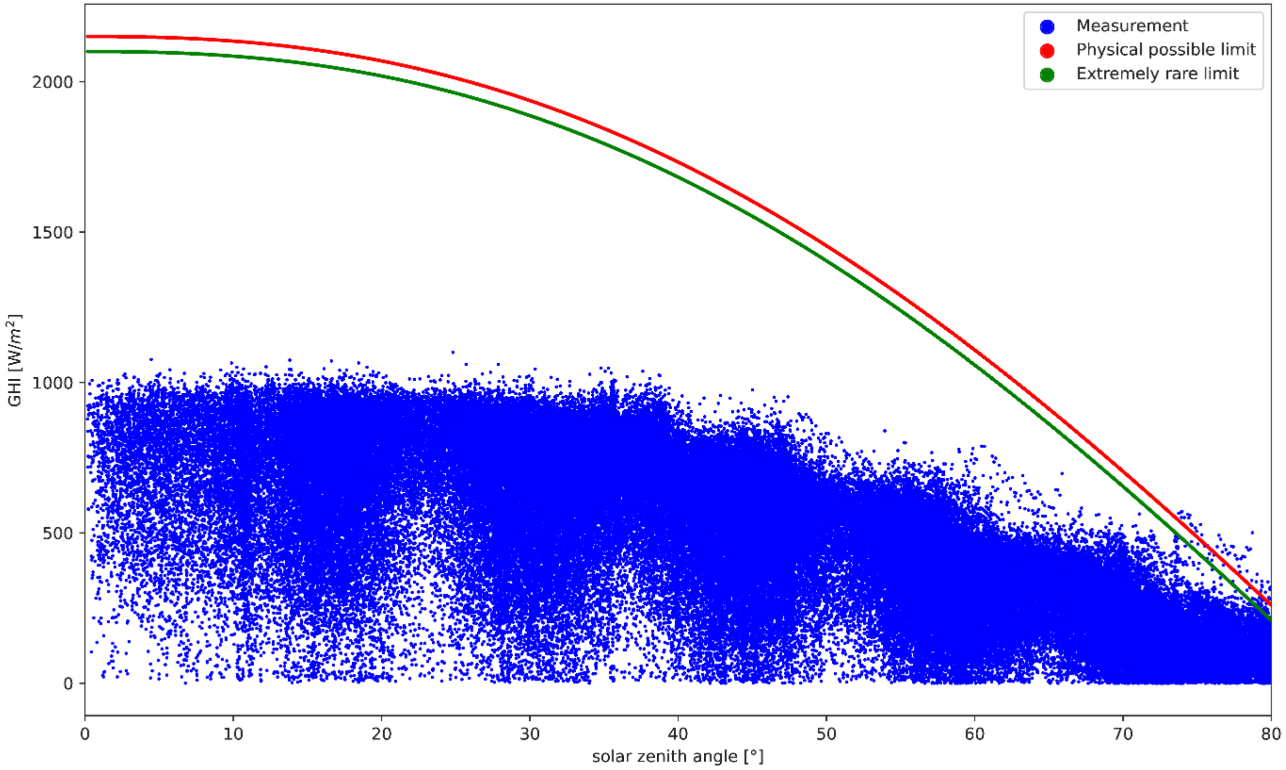


Fig.4: Quality control using BSRN guidelines

- SZA <80 °
- Quality control based on the Baseline Surface Radiation Network (BSRN) guidelines

$-4\ W/m^2 < GHI < I_0 * 1.5 * cos\ (SZA)^{1.2} + 100\ W/m^2$

$-2\ W/m^2 < GHI < I_0 * 1.5 * cos\ (SZA)^{1.2} + 50\ W/m^2$

0.59% data points were flagged and removed from the analysis.

Methodology

➢ Analysis

➢ 3 atmospheric conditions:

- Clear sky days composite when $K_t \geq 0.6$
- Cloudy-sky days composite $0.12 \leq K_t < 0.35$
- All-sky

➢ Statistical metrics:

- RMSE
- MAE
- IOA
- R

A new overall performance is introduced to select the best product over the region.

$$OP = 1 - \left[\frac{nRMSE}{100} + (1 - R) + (1 - IOA)\right]$$

+1: the data is perfectly close to the observation,

-1: the data is far from the observation

Results

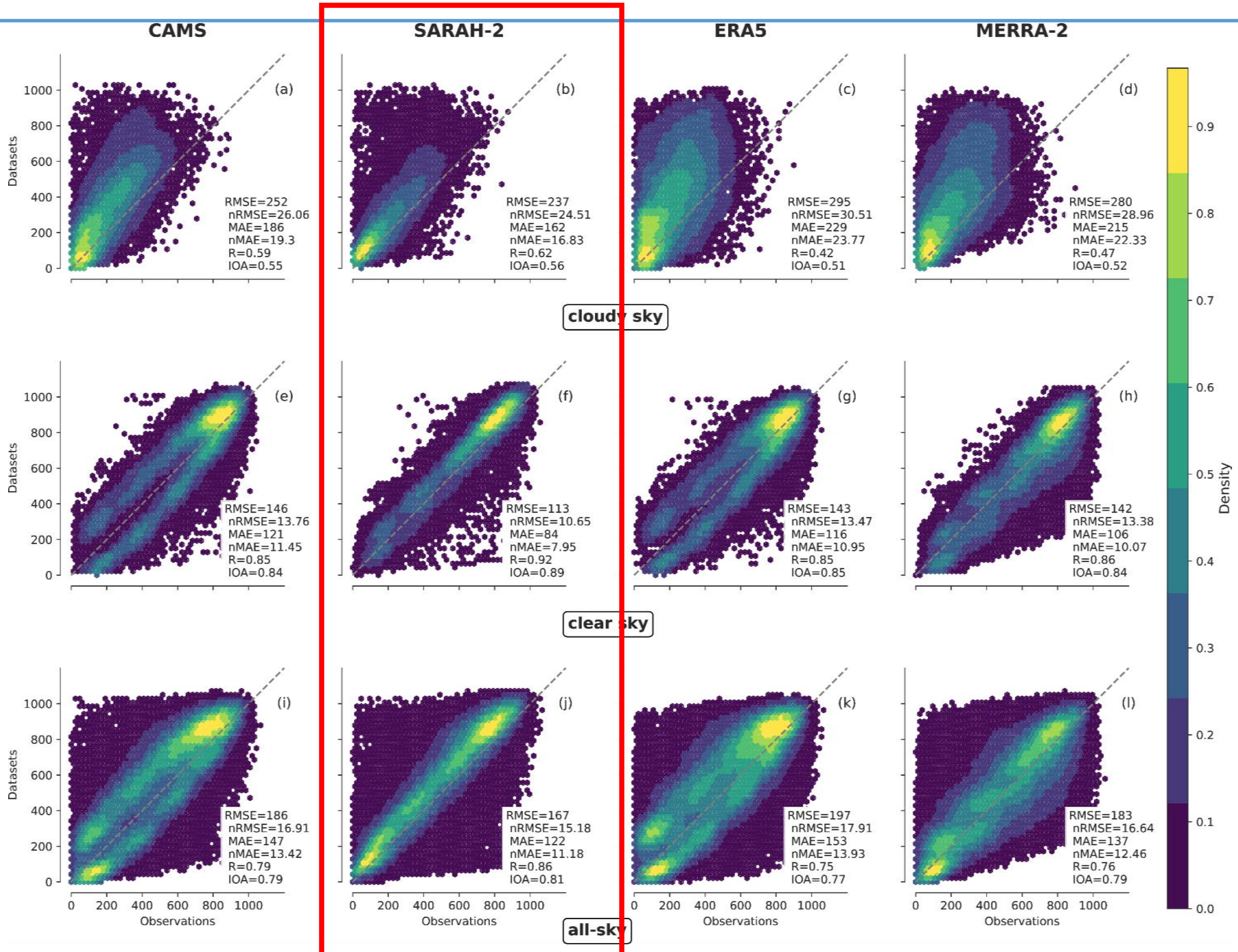
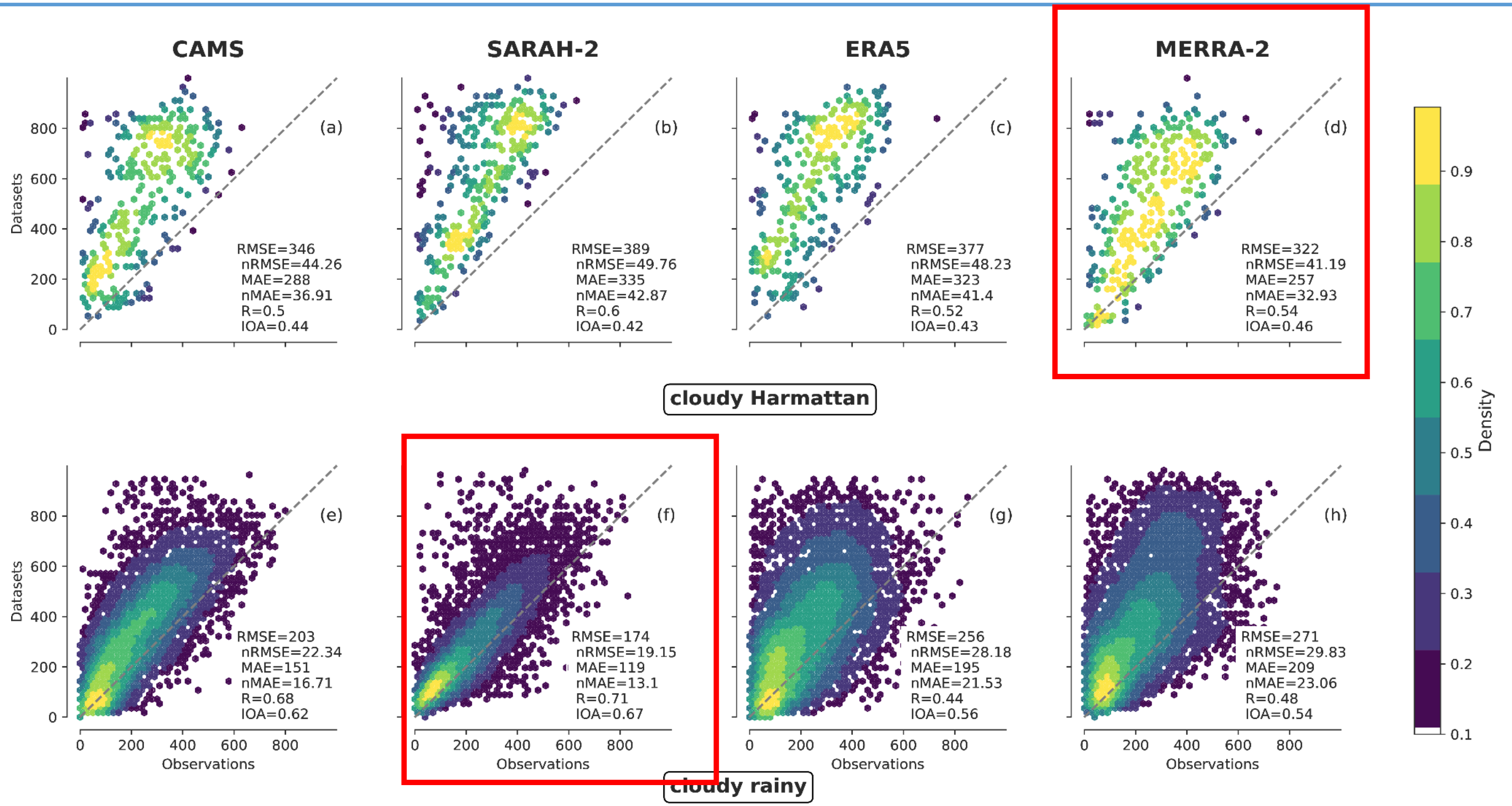


Fig.5: Density plot of hourly values of GHI from different datasets (CAMS, ERA5, SARAH-2, and MERRA-2) against observation for 43 stations.

- SARAH-2 performs better under different atmospheric conditions.
- Satellite data are better than the reanalysis data.
- ERA5 performs poorly.
- High bias occur under cloudy conditions.

Results



- MERRA-2 performs well during Hartman period under cloudy days composite.
- SARAH-2 has better score during the rainy season.

Fig.6: Density plot of hourly values of GHI from different datasets (CAMS, ERA5, SARAH-2, and MERRA-2) against observation for 43 stations.

Results

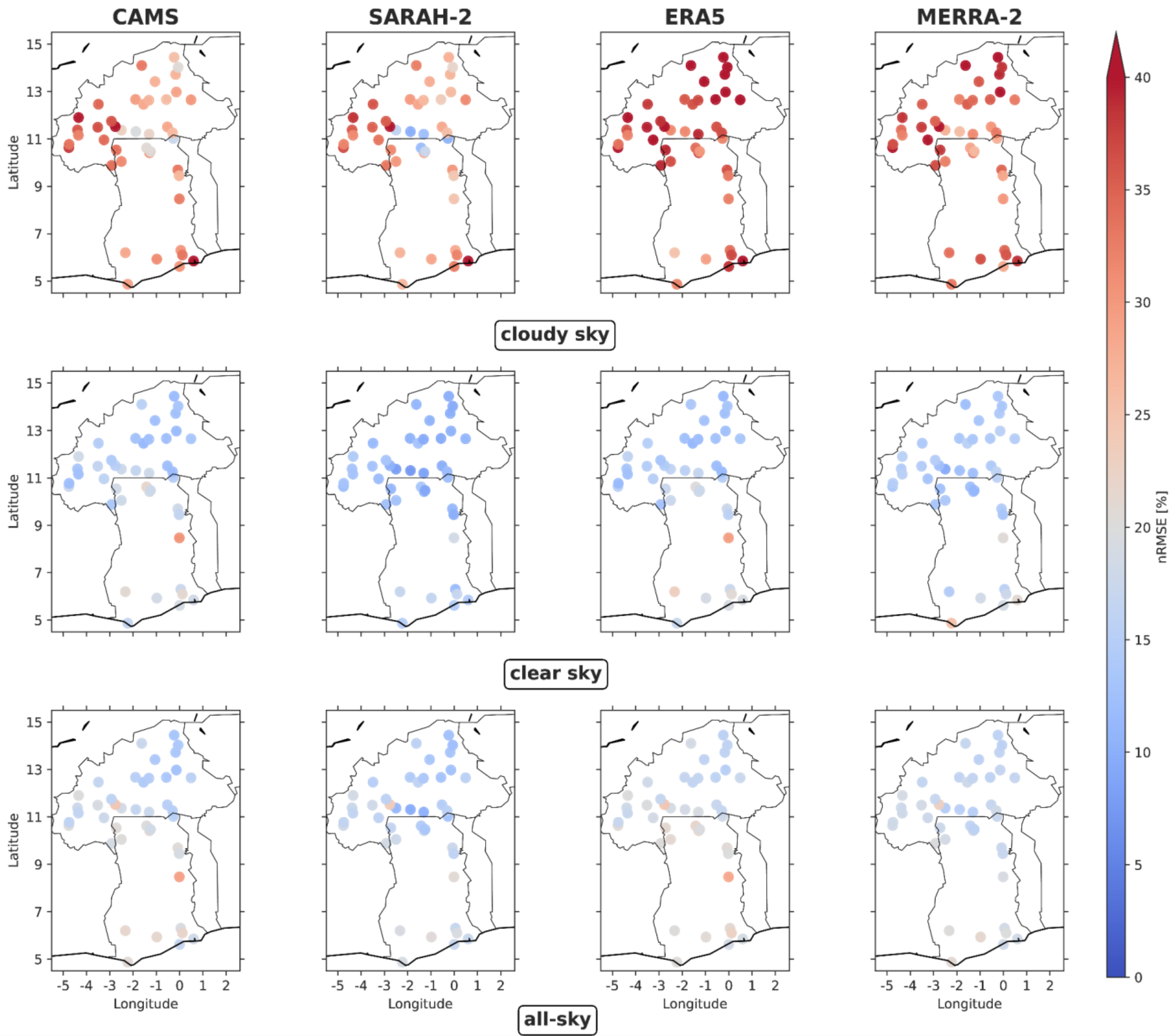


Fig.7: Spatial nRMSE under different atmospheric conditions.

- ➢ High nRMSE are in the Guinea zone (cloudy region)
- ➢ Low nRMSE are in the cloudless region (Savannah and Sahel zones).
- ➢ High nRMSE occur under cloudy skies.
- ➢ SARAH-2 exhibits a low nRMSE compared to ERA5, CAMS and MERRA-2 datasets.

Results

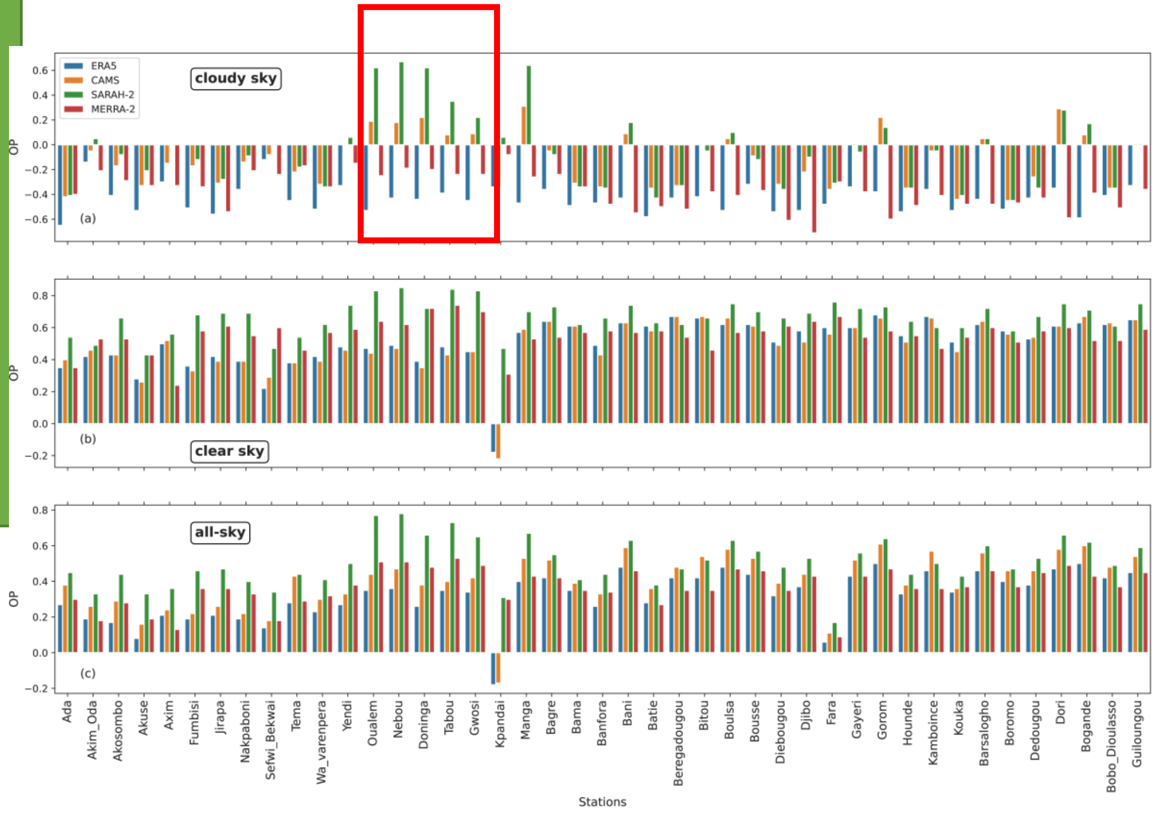


Fig.8: : Overall performance of hourly GHI for different automatic weather stations under cloud-sky (a), clear-sky (b) and all-sky (c) conditions.

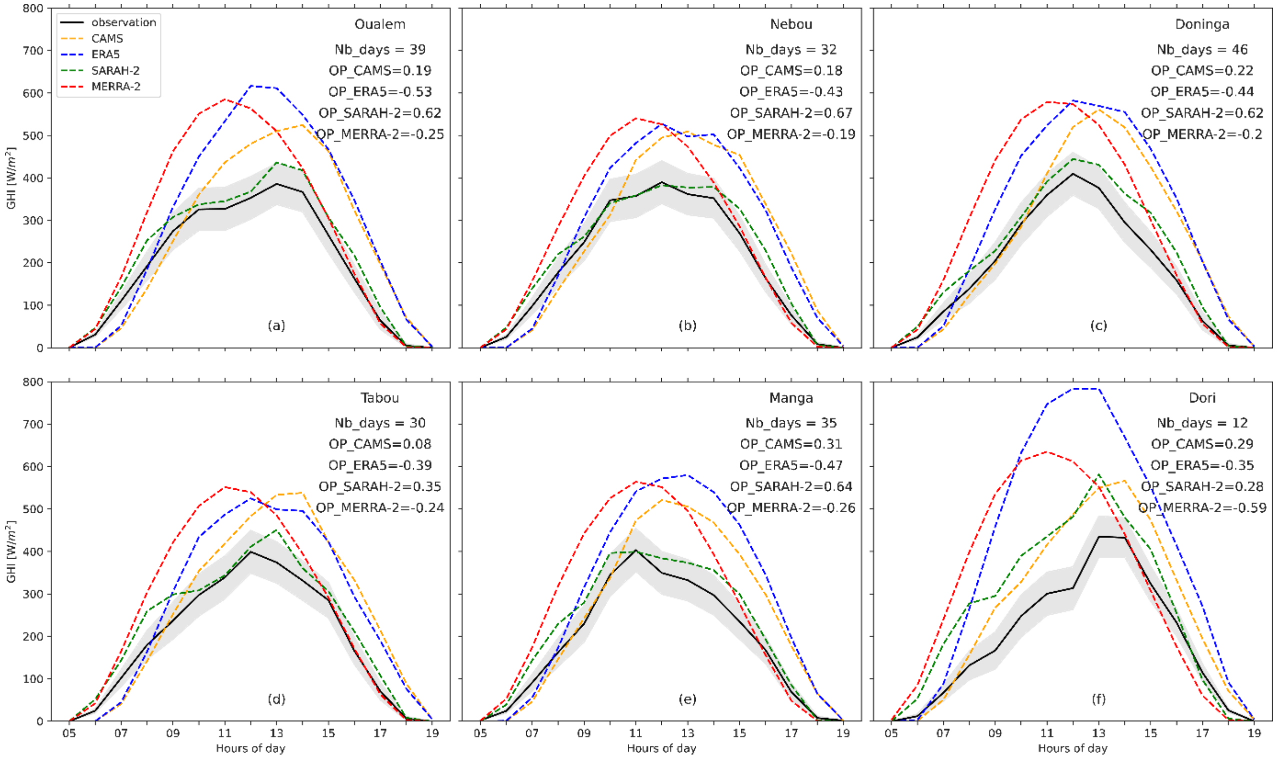


Fig.9: Average diurnal variation of the observed GHI compared with CAMS, ERA5, SARAH-2, MERRA-2 dataset with high positive overall performance (OP) under cloudy skies.

Results

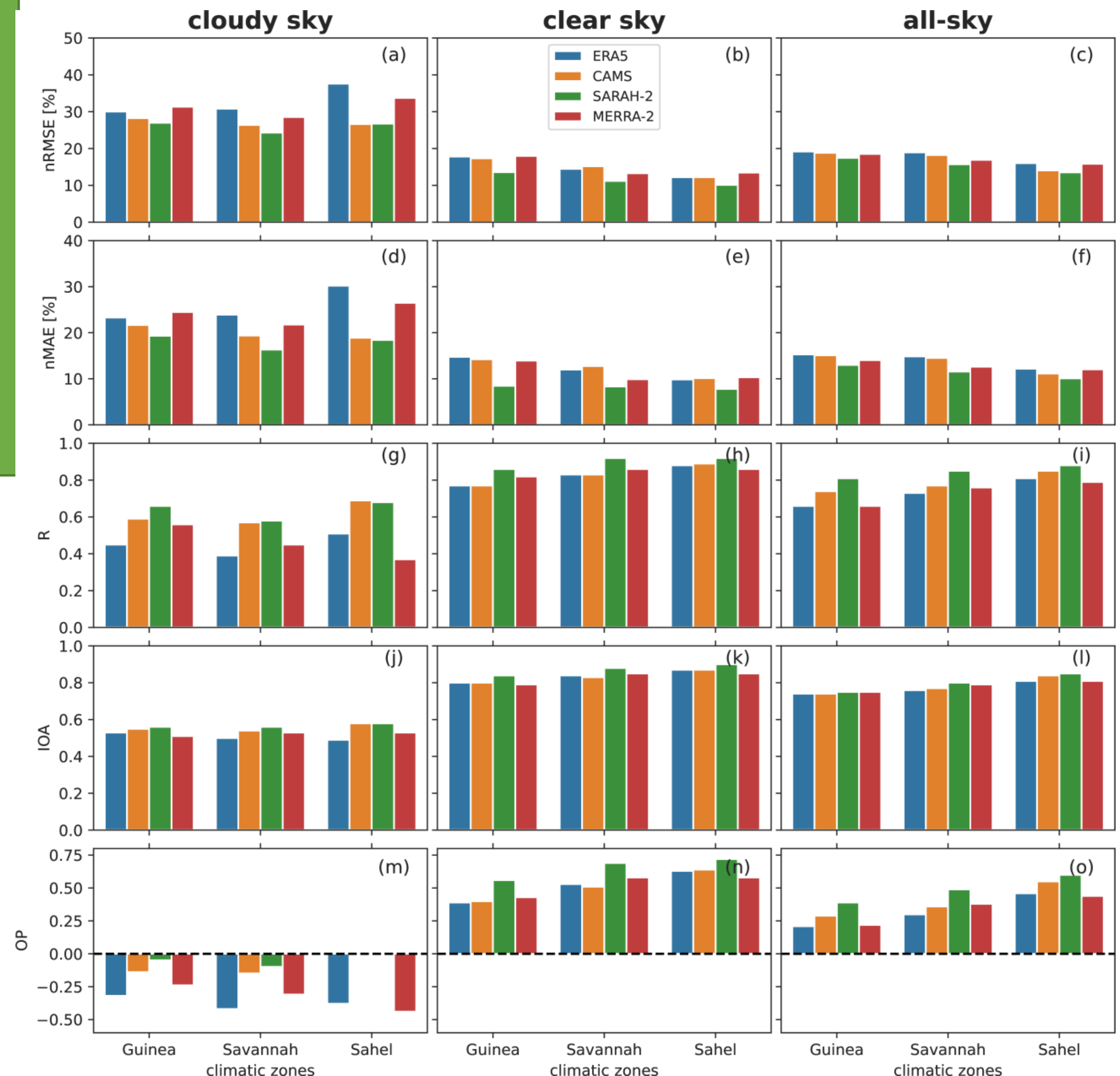


Fig.10: Performance metrics showing the normalized root-mean-square-error (nRMSE), normalized mean absolute error (nMAE), correlation (R), index of agreement (IOA) and the overall performance (OP)

- A negative OP values under cloudy conditions for all the datasets.
- SARAH-2 has a lower OP under clear, cloudy and all skies.

Conclusion

- For the combined 43 stations, the data derived from satellite and reanalysis data from GHI perform better in an area with cloud-free conditions than in a cloudy region in terms of RMSE and MAE.
- Both satellite-based hourly GHI estimates perform well in cloudy conditions compared to the reanalysis data.
- MERRA-2 outperforms SARAH-2, ERA5 and CAMS in estimating hourly GHI during the Harmattan period (DJF), while SARAH -2 performs best during the rainy season (JJA) under cloudy skies.
- SARAH-2 could be used as an alternative for solar energy assessment in West Africa.

Thank you