Comparison of satellite precipitation products in Burkina Faso for operational hydrology

Case Study

Anna D'Andrilli[1,4], Andrea Libertino[1], Anna Mapelli[1], Simone Gabellani[1], Nicoletta Roberto[3], Silvia Puca[3], Tania Gascoin[2]

1 CIMA Research Foundation-H SAF partner

2 World Meteorological Organization

3 National Department of Civil Protection - H SAF partner

4 Polytechnic of Tourin

27 March 2025

1 Short Introduction/Abstract

Date & Time	*01 January 2019 –31 January 2023*
Region	Burkina Faso
Satellites	*MSG 0 deg. GPM. METOP,*
Instruments	*SEVIRI, GMI.*
Channels/Products	*NASA IMERG Late (12 hours latency – if combined with Early 6 hours latency) (https://gpm.nasa.gov/data/directory)* *NASA IMERG Final (3 months latency) (https://gpm.nasa.gov/data/directory)* *JAXA GSMap (6 hours latency) (https://sharaku.eorc.jaxa.jp/GSMaP/)* - *HSAF H61B (15 minutes latency) (https://hsaf.meteoam.it/Products/Detail?prod=H61B)*
Latitude/Longitude	*-1 11 / 35 47*

In this case study, we assess the performance of multiple satellite precipitation products by comparing them with ground-based data and ERA5 reanalysis in Burkina Faso. The objective is to identify the satellite product best suited for hydrological modeling at the national scale. The evaluated products include NASA IMERG Late, NASA IMERG Final, JAXA GSMaP, and HSAF H61B. These datasets are compared against ERA5 reanalysis, ground-based precipitation measurements, and observed discharge data.

2 Description

In this case study we compare multiple satellite precipitation products with ground data and ERA5 reanalysis to evaluate their performance in Burkina Faso (Figure 2). The objective is to determine which satellite product performs best for use in hydrological modeling at the national scale. The satellite products considered are NASA IMERG Late, NASA IMERG Final, JAXA GSMap, HSAF H61B. ERA5 reanalysis have been considered too.

Product	Spatial Resolution	Temporal resolution	Latency
IMERG Late	10 km	0.5 h	14 hours
IMERG Final	10 km	0.5 h	3 months
GSMaP	10 km	1 h	6 hours
HSAF H61B	MSG-SEVIRI grid	1 h	30 minutes
ERA5	31 km	1 h	5 days

The first benchmark for the assessment of the quality of the product is a set of 108 meteorological stations provided by Agence Nationale de la Météorologie du Burkina Faso (ANAM-BF). The gauge stations provide daily data; their location is shown in Figure 2.

The second benchmark for the assessment of the satellite products is a set of 32 hydrological stations that provide daily streamflow values provided by the Direction Générale des Ressources en Eau du Burkina Faso (DGRE). Figure 3 shows hydrological gauging stations' location.

The data have been shared by ANAM-BF and DGRE within the collaboration between the World Meteorological Organization and CIMA in the project titled “Technical Assistance to Burkina Faso for the implementation of hydrological component of the HYDROMET Burkina Faso (TA Burkina Faso)”.

The period of the analysis is January 2019 - January 2023 except for HSAF H61B that is available from January 2020.

It is worth mentioning that the HSAF H61B is, among the satellite products considered, the only one without bias correction; this should be considered in the evaluation of the results.

HSAF H61B also has the lowest latency that is an important parameter in application for early warning.

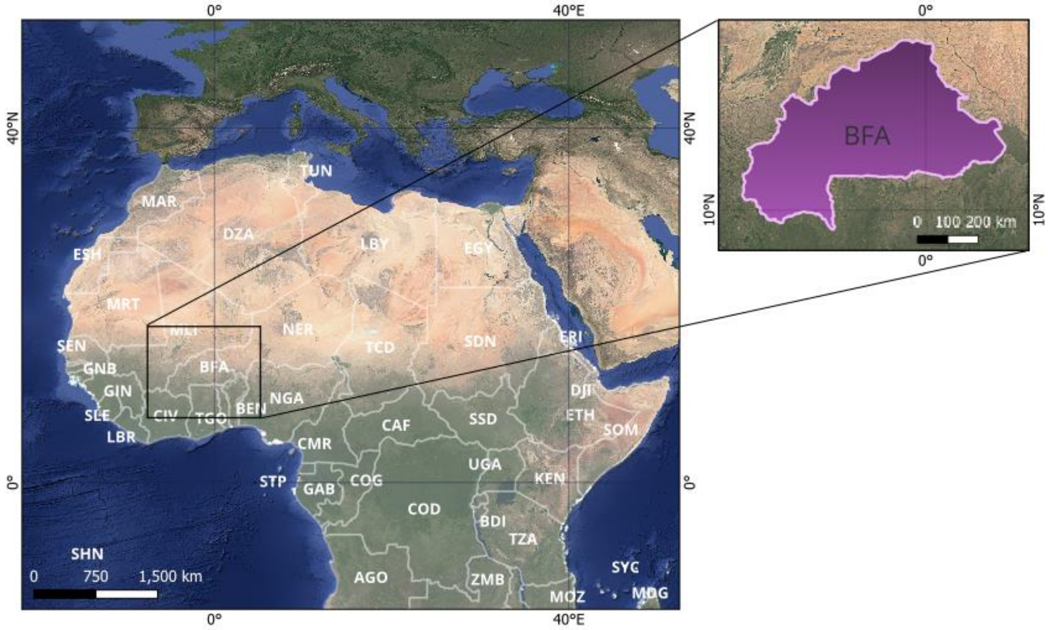

Figure 1 The Geographic setting and location of Burkina Faso.

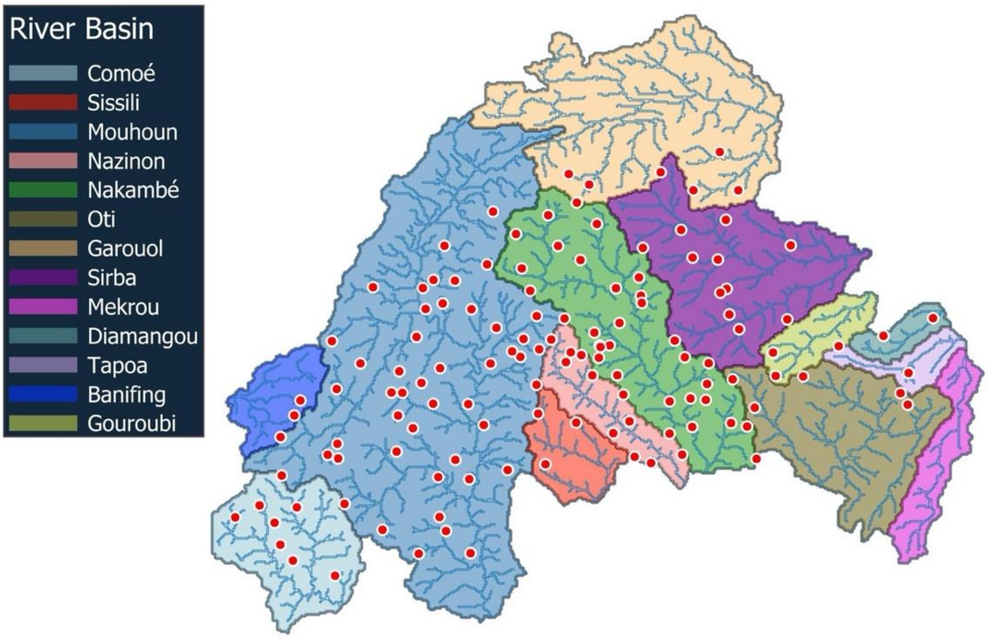

Figure 2: Rain gauges location provided by ANAM and used for the validation of satellite products.

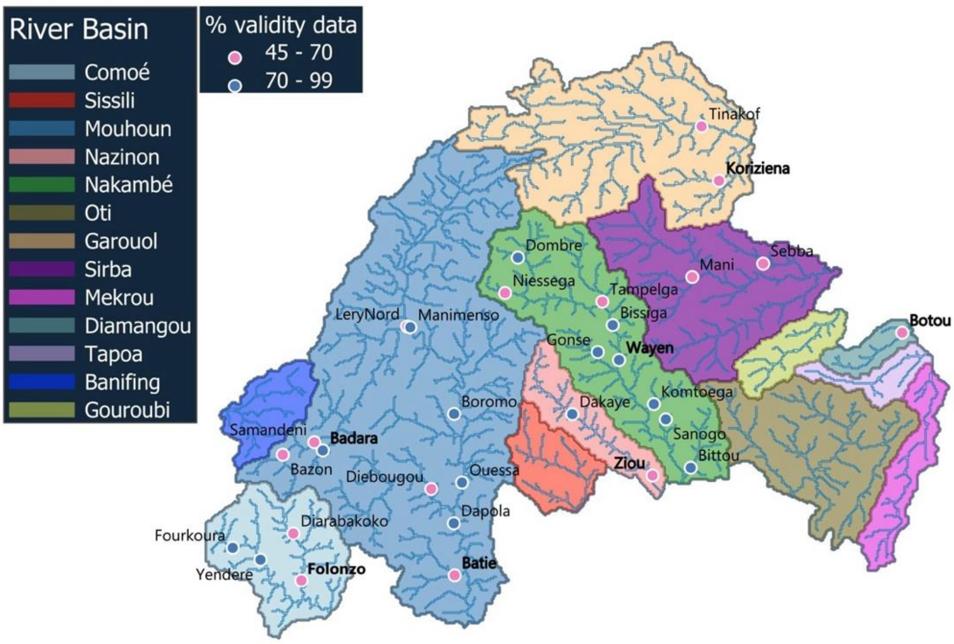

Figure 3: Hydrometric station's location provided by DGRE. The markers represent the percentage of valid data for each station.

2.1 Comparison between satellite products and raingauge data

As a first analysis, we compare daily rain gauge measurements with satellite precipitation data aggregated to a daily scale. The comparison is made considering the precipitation value of the pixel that contain the raingauge. Figure 4 presents two box plots illustrating the performance of different satellite products (IMERG Final, IMERG Late, GSMaP, HSAF, and ERA5) in terms of the correlation coefficient (left panel) and relative error (right panel).

The distribution of correlation coefficients suggests that HSAF exhibits lower median correlations compared to the other satellite products. However, as mentioned, the other products include bias correction based on ground data. Notably, HSAF H61B shows a higher correlation than ERA5 reanalysis. Outliers are present in all products, indicating spatial or temporal inconsistencies in performance.

Satellite products exhibit higher relative errors compared to ERA5. While HSAF H61B shows greater relative errors, its distribution is slightly less spread than that of other satellite products. The presence of numerous positive outliers suggests a tendency for overestimation in some products.

The comparison suggests that IMERG Final and IMERG Late generally outperform the other products in terms of both correlation and error, making them more suitable for hydrological modeling applications in Burkina Faso.

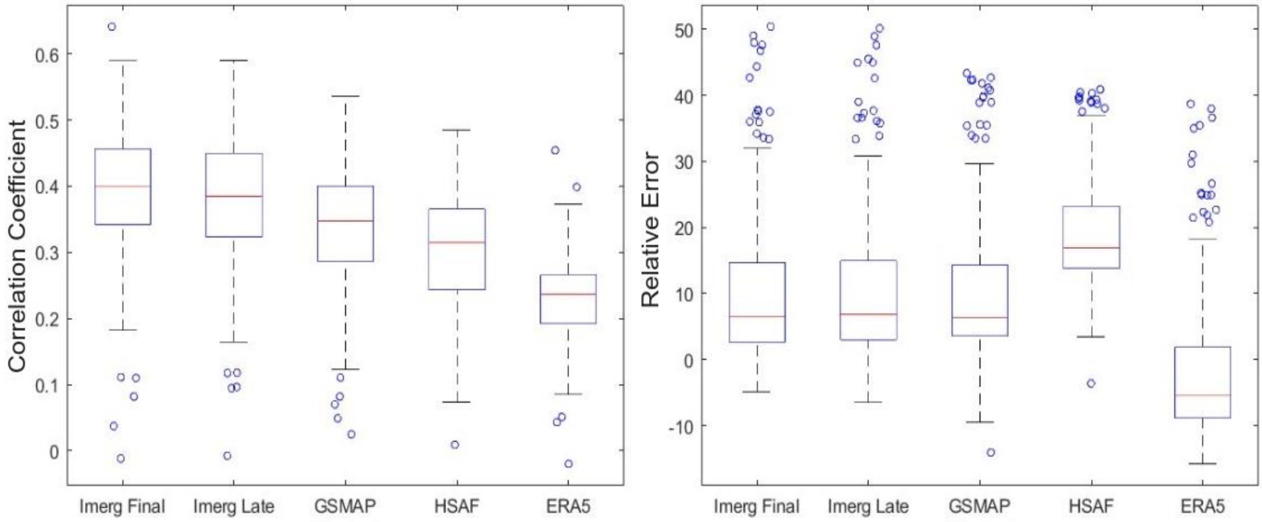

Figure 4: Results of the comparison between the considered products and gauge data.

As a second analysis, the satellite products and ERA5 were compared with interpolated gauge data. The interpolation was performed using the Inverse Distance Weighting (IDW) algorithm and Ordinary Kriging, the comparison was performed using both IDW and Kriging, since the results are very similar the results of the comparison with Ordinary Kriging are reported here. Figure 5 presents the total average annual rainfall for each product for a qualitative comparison, as a general comment H61B overestimate the precipitation amount while ERA5 underestimate it.

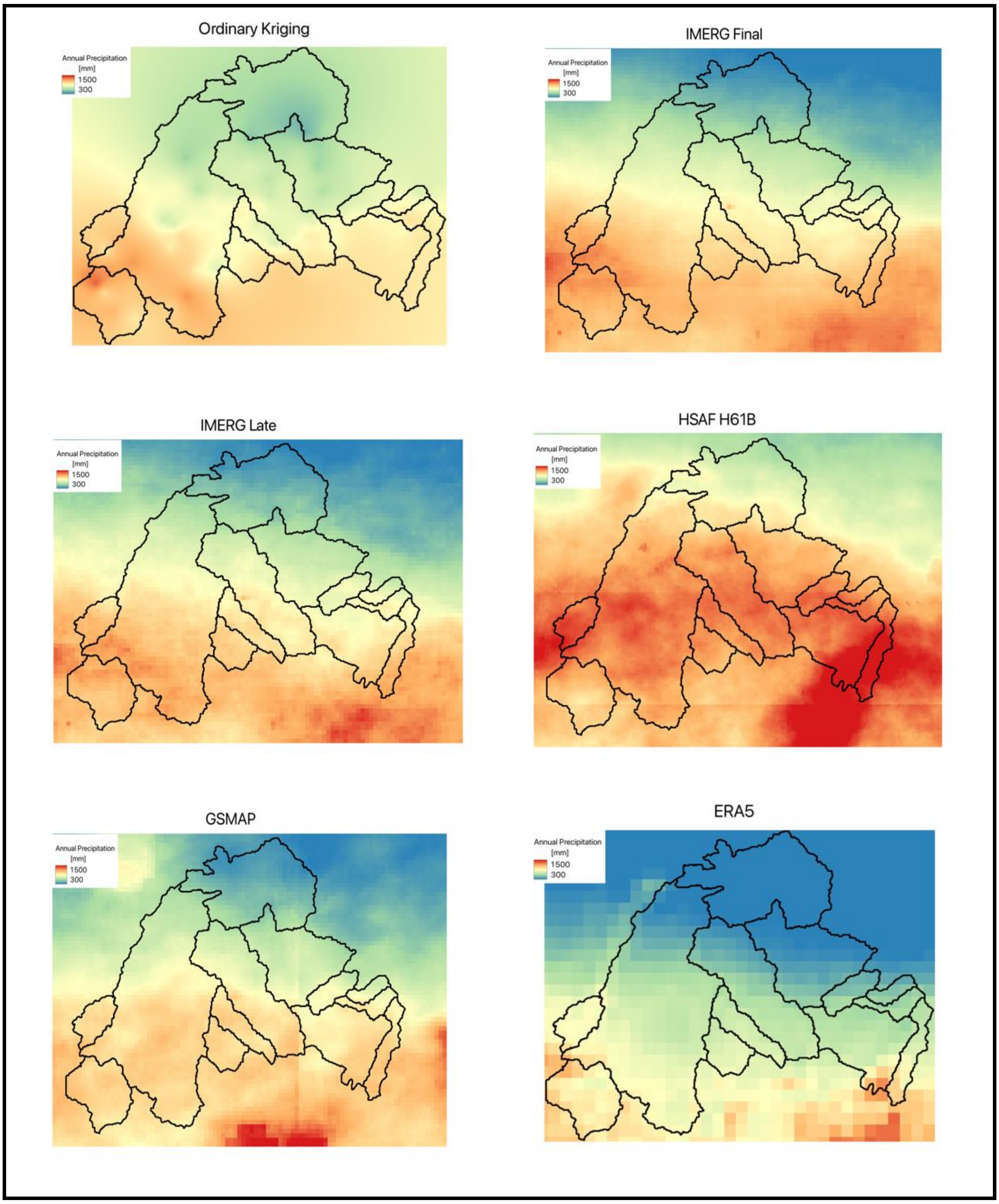

Figure 5 : Maps of average annual cumulative precipitation in [mm] the average is computed in the study period January 2019 - January 2023.

2.2 Basin scale analysis

A basin-scale analysis was conducted by comparing runoff coefficients computed using both interpolated and satellite-derived precipitation data. The runoff coefficient, defined as the ratio between runoff and precipitation, was calculated using different datasets.

The results show that runoff coefficient estimates based on rain gauge data interpolated with IDW and Ordinary Kriging are nearly identical, indicating that the choice of interpolation method does not significantly affect the computation. The runoff coefficient derived from Ordinary Kriging interpolation is used as a benchmark to evaluate satellite products and ERA5. Figure 6 presents the relative error between the runoff coefficients for all the sections considered; Figure 7 shows the relative error between the runoff coefficients grouped for basins.

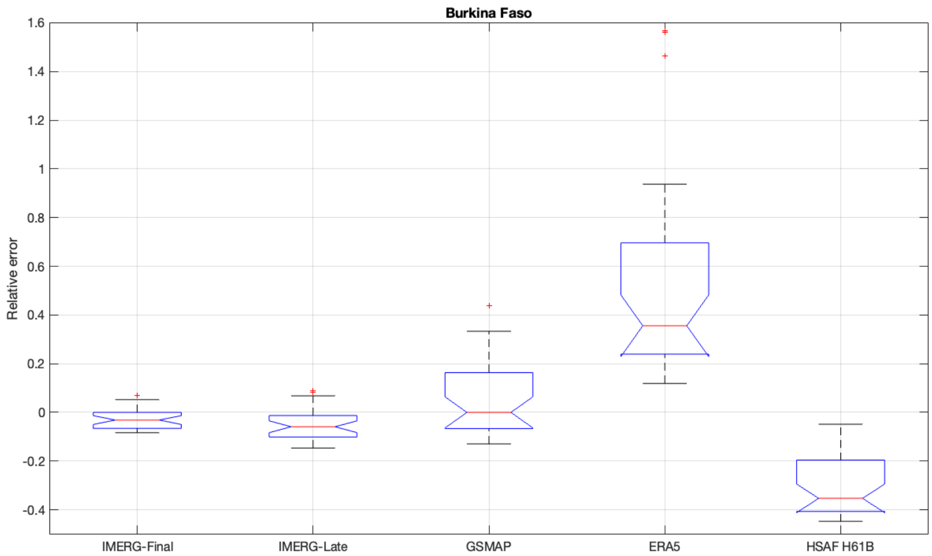

Figure 6 Relative error between the runoff coefficient computed with interpolated gauge data and gridded products.

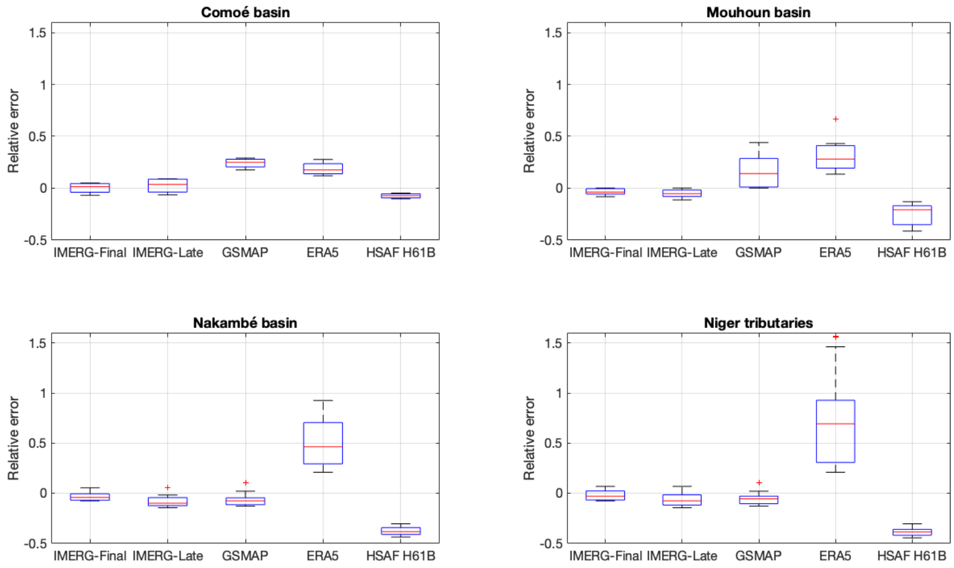

Figure 7 Relative error between the runoff coefficient computed with interpolated gauge data and gridded products for some basins.

The IMERG products provide the best results in terms of runoff coefficients, exhibiting a small relative error and lower variability. While GSMaP shows the lowest median value, it has a greater spread. ERA5 is the dataset that has greater errors on the runoff coefficient.

Nevertheless, it is worth noting that the results of the analysis of runoff coefficients may be influenced by the uneven distribution of rain gauges (e.g. tributary of the Niger and Oti has very few rain gauges). This could lead to border effects and artifacts in the interpolated maps that make the runoff coefficients computation more uncertain.

Figure 8, Figure 9, Figure 10, Figure 11 show the runoff coefficients for the river sections grouped for basin. The values of the runoff coefficients can be seen in Table 1.

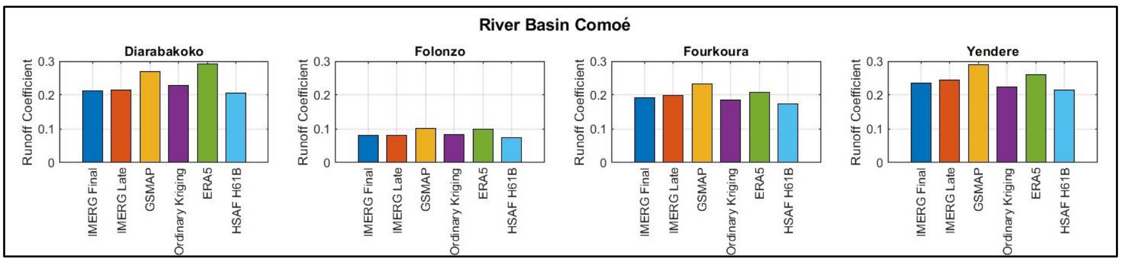

Figure 8 Runoff coefficient for the stations in the Comoé basin (2020-2022).

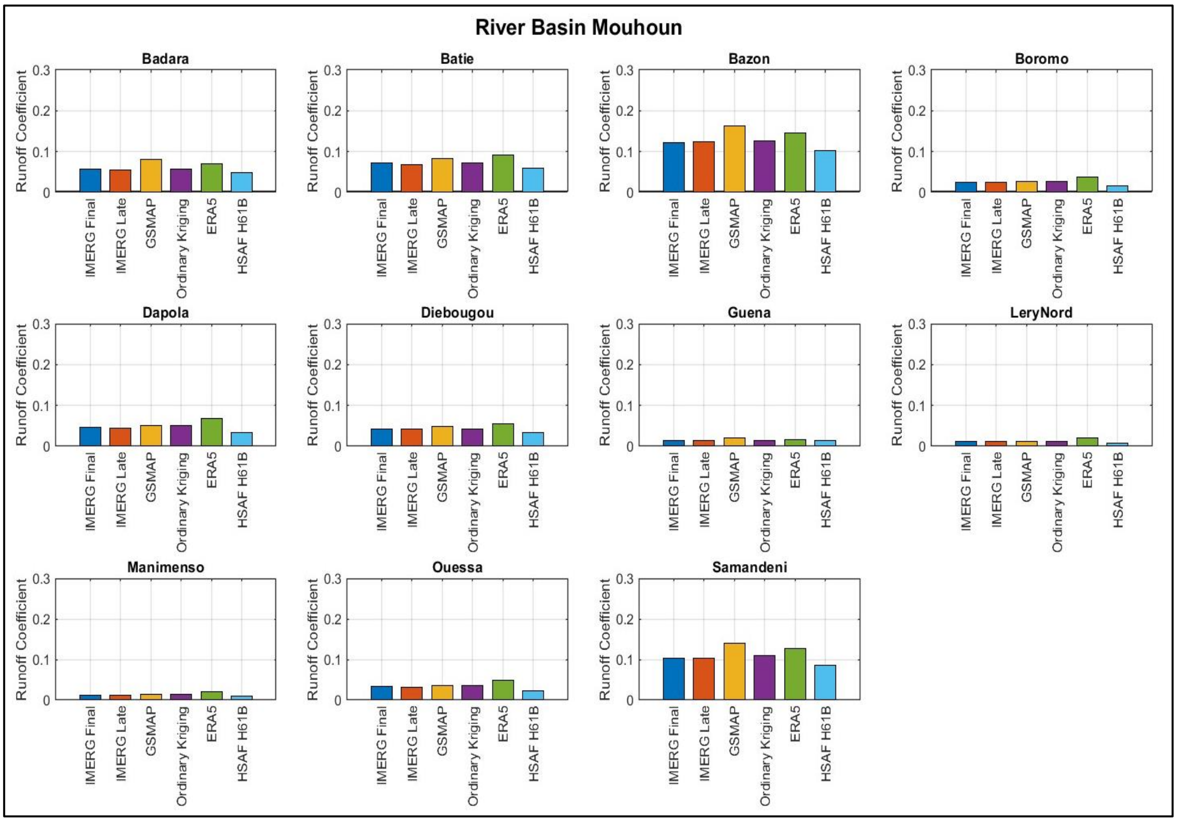

Figure 9 Runoff coefficient for the stations in the Mouhoun basin (2020-2022).

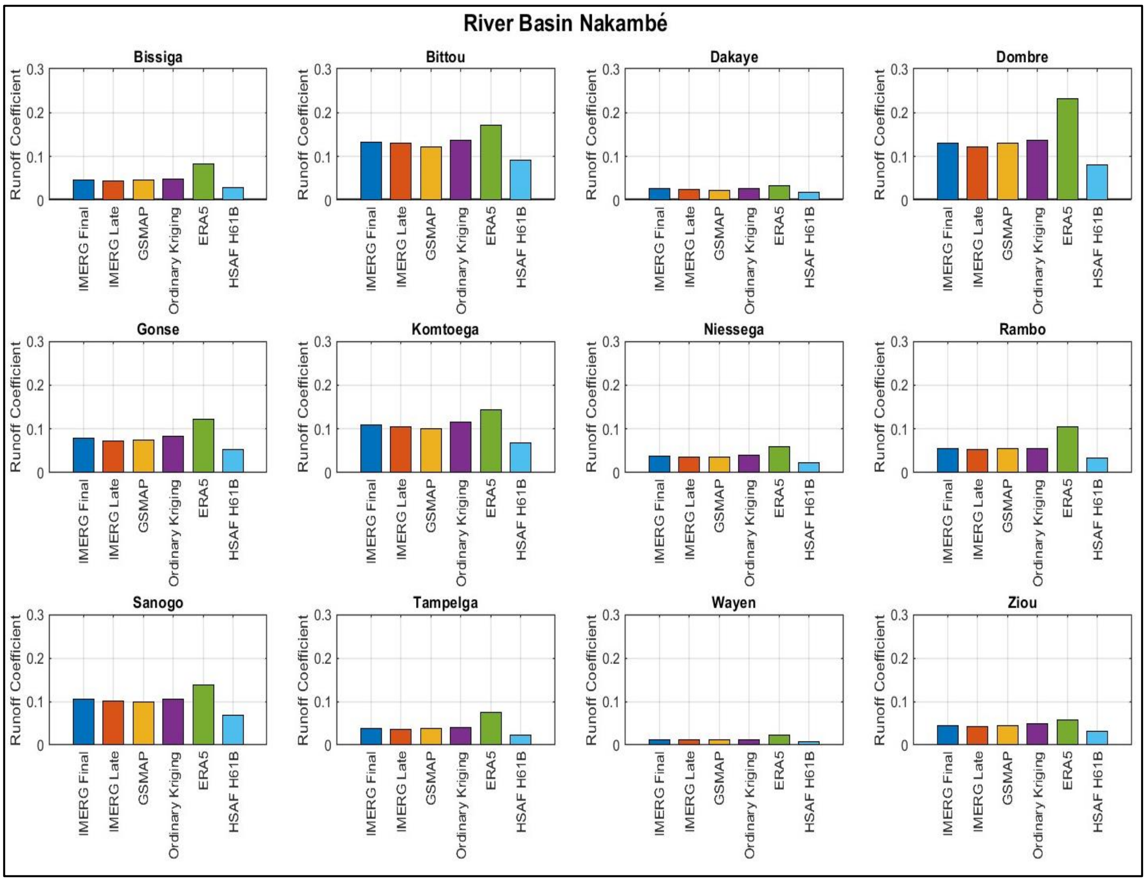

Figure 10 Runoff coefficient for the stations in the Nakambé basin (2020-2022).

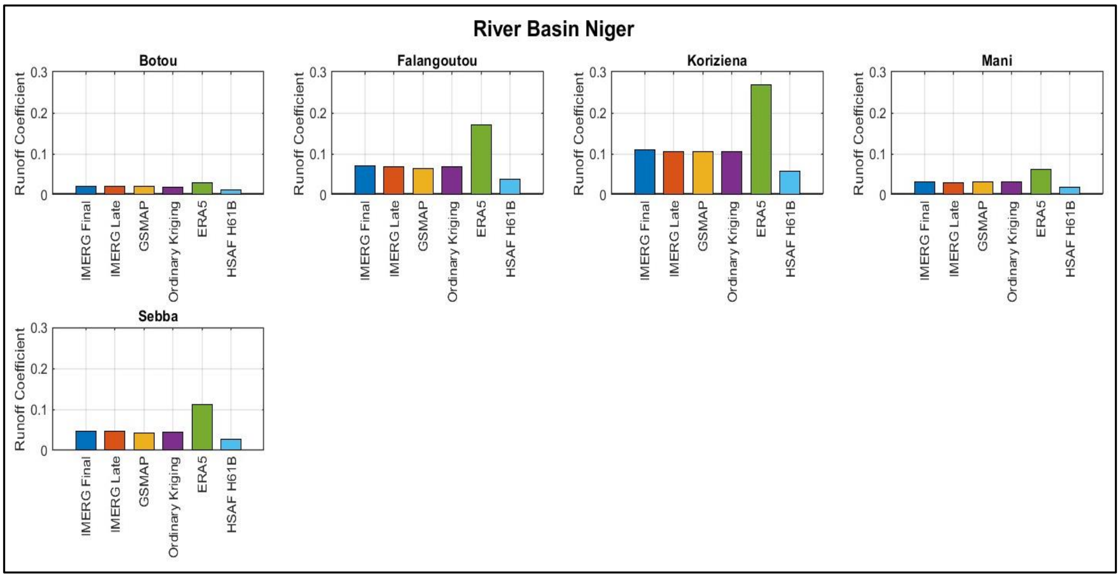

Figure 11 Runoff coefficient for the stations in the tributary of Niger basin (2020-2022).

3 Conclusion

This study evaluated multiple satellite precipitation products for Burkina Faso, comparing them with ground-based data and ERA5 reanalysis. The objective was to identify the most suitable dataset for hydrological modeling and water resource management at the national scale.

The analysis of satellite rainfall estimates against gauge data revealed that IMERG Final and IMERG Late generally exhibit the highest correlation and the lowest relative errors, making them the most reliable choices for hydrological applications. GSMaP also showed promising performance, although with higher variability. HSAF H61B, despite its lower correlation and larger errors, remains the only product without bias correction, and its high spatial and temporal resolution and low latency make it valuable for real-time applications.

At the basin scale, runoff coefficient estimates derived from IMERG products closely matched those based on interpolated gauge data, further confirming their reliability. ERA5, on the other hand, exhibited the largest discrepancies, suggesting limitations in its applicability for detailed hydrological modeling in Burkina Faso. HSAF H61B, while not the most accurate, still performed better than ERA5 in some cases, highlighting its potential for flood forecasting when timeliness is a priority.

It is important to note that the performance of satellite products is influenced by the spatial distribution of rain gauges, which can introduce uncertainties in interpolated benchmark datasets. The relatively sparse coverage of ground stations, particularly in certain basins, may affect the accuracy of the validation process.

Future work will be focused on integrating these satellite datasets into operational hydrological model to assess the impact of those datasets on the calibration of the model.

-

4 Supplemental material

Station name	*Basin*	*% Data Validity*	*IMERG Final*	*IMERG Late*	*GSMAP*	*ERA5*	*HSAF (H61B)*	*Ground sensors (Ordinary Kriging)*
Diarabakoko	*Comoé*	*59*	*0.213*	*0.214*	*0.269*	*0.292*	*0.205*	*0.229*
Folonzo	*Comoé*	*52*	*0.081*	*0.081*	*0.101*	*0.098*	*0.075*	*0.082*
Fourkoura	*Comoé*	*74*	*0.192*	*0.2*	*0.234*	*0.207*	*0.173*	*0.185*
Yendere	*Comoé*	*88*	*0.236*	*0.245*	*0.29*	*0.26*	*0.214*	*0.225*
Badara	*Mouhoun*	*73*	*0.057*	*0.056*	*0.082*	*0.071*	*0.049*	*0.057*
Batie	*Mouhoun*	*50*	*0.072*	*0.068*	*0.083*	*0.091*	*0.06*	*0.072*
Bazon	*Mouhoun*	*46*	*0.122*	*0.125*	*0.162*	*0.146*	*0.103*	*0.126*
Boromo	*Mouhoun*	*85*	*0.025*	*0.024*	*0.027*	*0.037*	*0.017*	*0.026*
Dapola	*Mouhoun*	*84*	*0.047*	*0.045*	*0.05*	*0.067*	*0.033*	*0.05*
Diebougou	*Mouhoun*	*61*	*0.042*	*0.042*	*0.049*	*0.055*	*0.034*	*0.043*
Guena	*Mouhoun*	*35*	*0.015*	*0.015*	*0.02*	*0.017*	*0.013*	*0.015*
LeryNord	*Mouhoun*	*58*	*0.011*	*0.011*	*0.012*	*0.02*	*0.007*	*0.012*
Manimenso	*Mouhoun*	*74*	*0.013*	*0.013*	*0.015*	*0.02*	*0.009*	*0.014*
Ouessa	*Mouhoun*	*83*	*0.033*	*0.031*	*0.035*	*0.048*	*0.022*	*0.035*
Samandeni	*Mouhoun*	*54*	*0.103*	*0.104*	*0.14*	*0.128*	*0.086*	*0.109*
Bissiga	*Nakambé*	*91*	*0.047*	*0.044*	*0.047*	*0.084*	*0.029*	*0.049*
Bittou	*Nakambé*	*74*	*0.132*	*0.13*	*0.122*	*0.172*	*0.091*	*0.136*
Dakaye	*Nakambe*	*73*	*0.026*	*0.024*	*0.023*	*0.034*	*0.018*	*0.026*
Dombre	*Nakambé*	*89*	*0.131*	*0.121*	*0.13*	*0.233*	*0.08*	*0.137*
Gonse	*Nakambé*	*73*	*0.078*	*0.073*	*0.074*	*0.121*	*0.052*	*0.084*
Komtoega	*Nakambé*	*93*	*0.108*	*0.104*	*0.101*	*0.143*	*0.068*	*0.116*
Niessega	*Nakambé*	*48*	*0.038*	*0.035*	*0.036*	*0.06*	*0.023*	*0.041*
Rambo	*Nakambé*	*28*	*0.055*	*0.053*	*0.055*	*0.104*	*0.033*	*0.054*
Sanogo	*Nakambé*	*99*	*0.105*	*0.101*	*0.098*	*0.138*	*0.069*	*0.106*
Tampelga	*Nakambé*	*66*	*0.038*	*0.035*	*0.039*	*0.075*	*0.023*	*0.041*
Wayen	*Nakambé*	*75*	*0.012*	*0.012*	*0.012*	*0.022*	*0.008*	*0.013*
Ziou	*Nakambé*	*58*	*0.045*	*0.042*	*0.044*	*0.058*	*0.032*	*0.048*
Botou	*Niger*	*54*	*0.02*	*0.02*	*0.021*	*0.029*	*0.012*	*0.019*
Falangoutou	*Niger*	*33*	*0.071*	*0.068*	*0.065*	*0.17*	*0.039*	*0.069*
Koriziena	*Niger*	*56*	*0.11*	*0.105*	*0.105*	*0.269*	*0.058*	*0.105*
Mani	*Niger*	*54*	*0.031*	*0.03*	*0.032*	*0.062*	*0.019*	*0.032*
Sebba	*Niger*	*69*	*0.047*	*0.047*	*0.042*	*0.113*	*0.027*	*0.044*

Table 1 Runoff coefficients for the outlet sections for the products.