ICEM 2023 - Energy Operations & Maintenance

West African solar forecast errors and their link with meteorological conditions: case study of the Zagtouli solar farm (Burkina-Faso)

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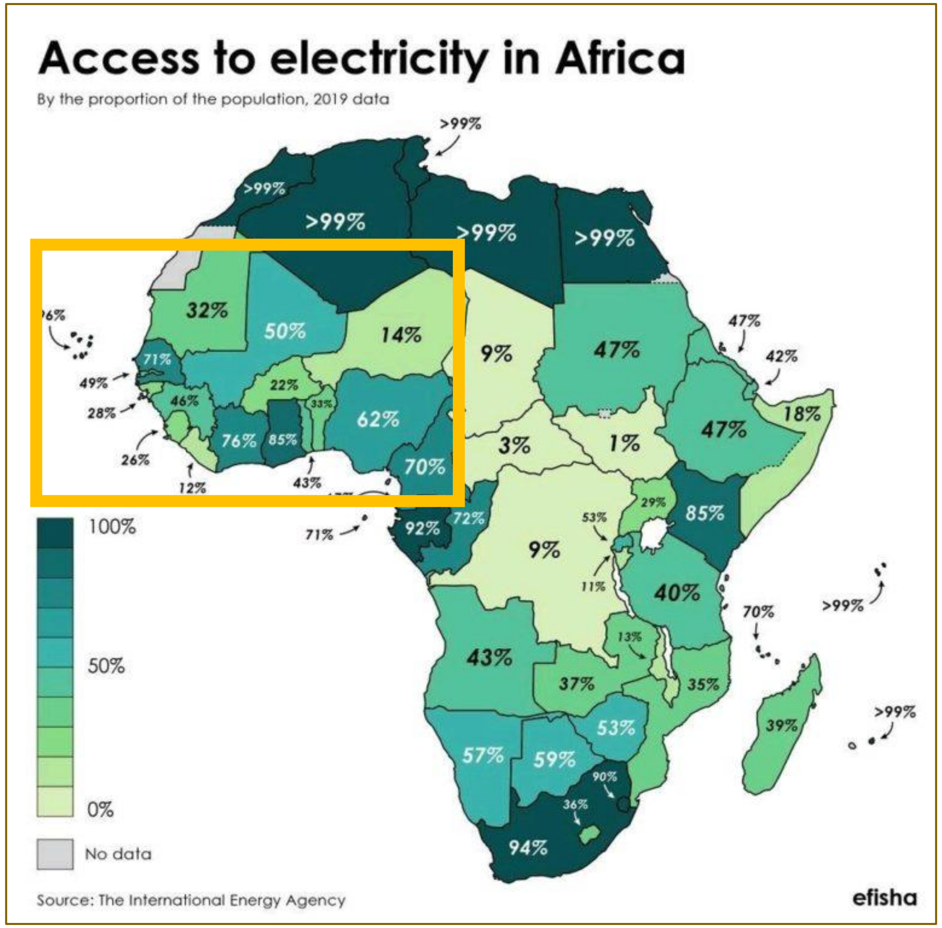
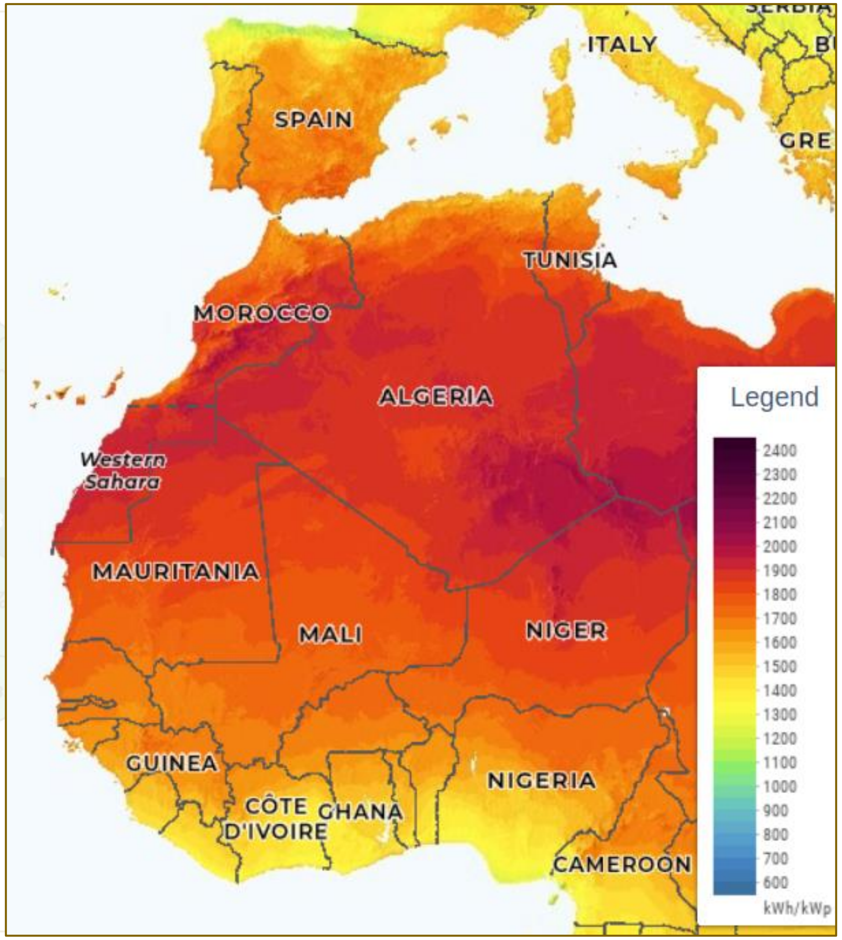


➢ Access to electricity is a key challenge in West African development



- Access to electricity is a key challenge in West African development
- Solar PV is a good candidate for answering the West African stakes

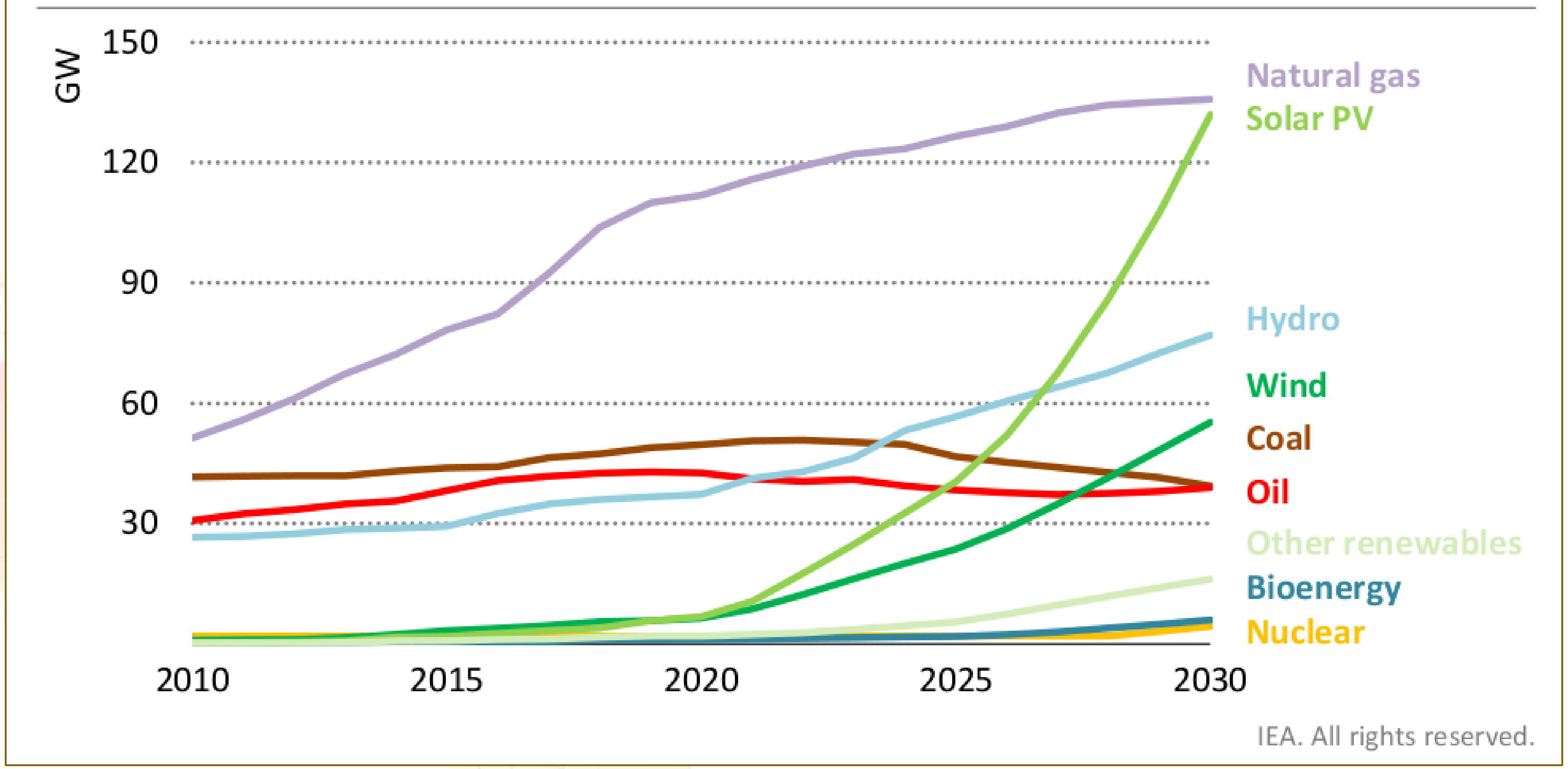
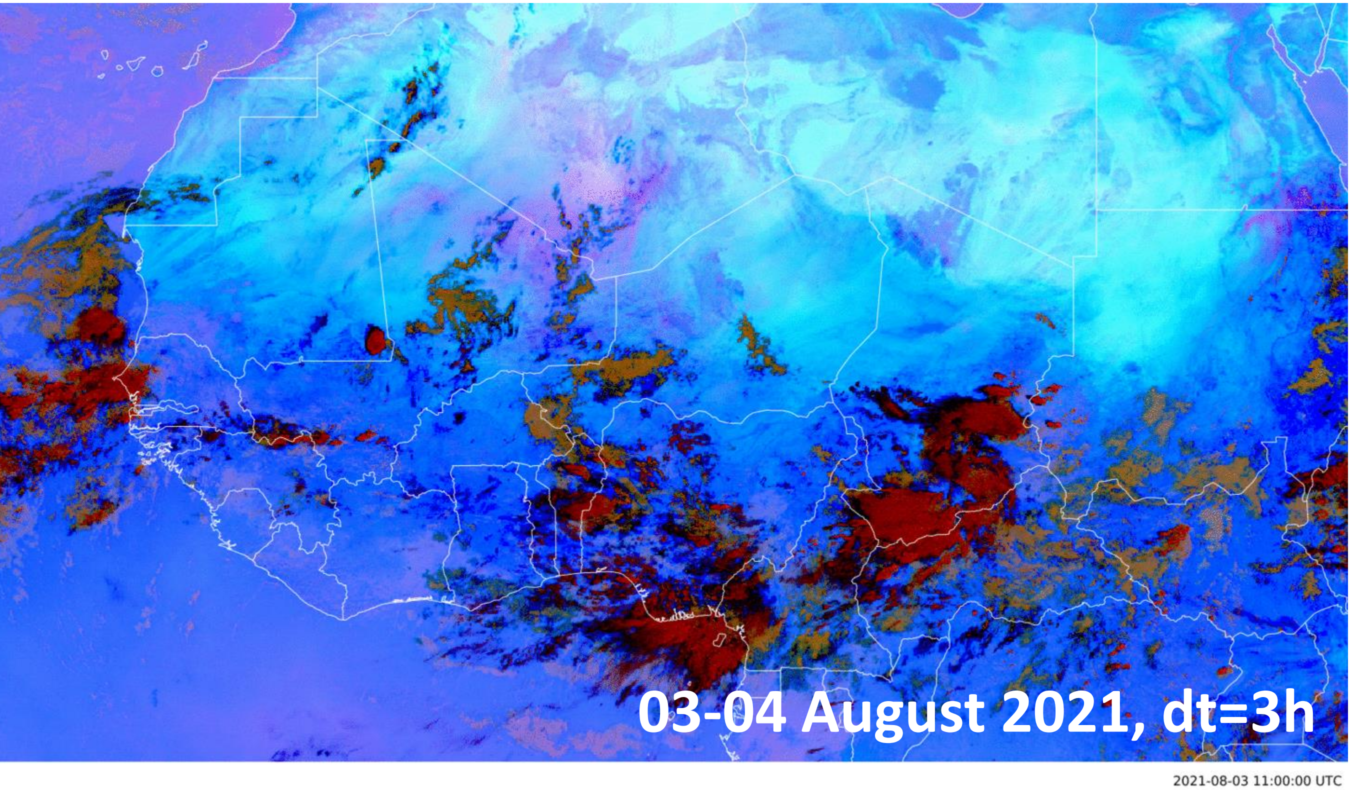


Figure 2.20 ▹ Installed power generation capacity by source in the SAS

- Access to electricity is a key challenge in West African development
- Solar PV is a good candidate for answering the West African stakes
- Solar PV bring new constraints on the network => need for high-performance forecasting

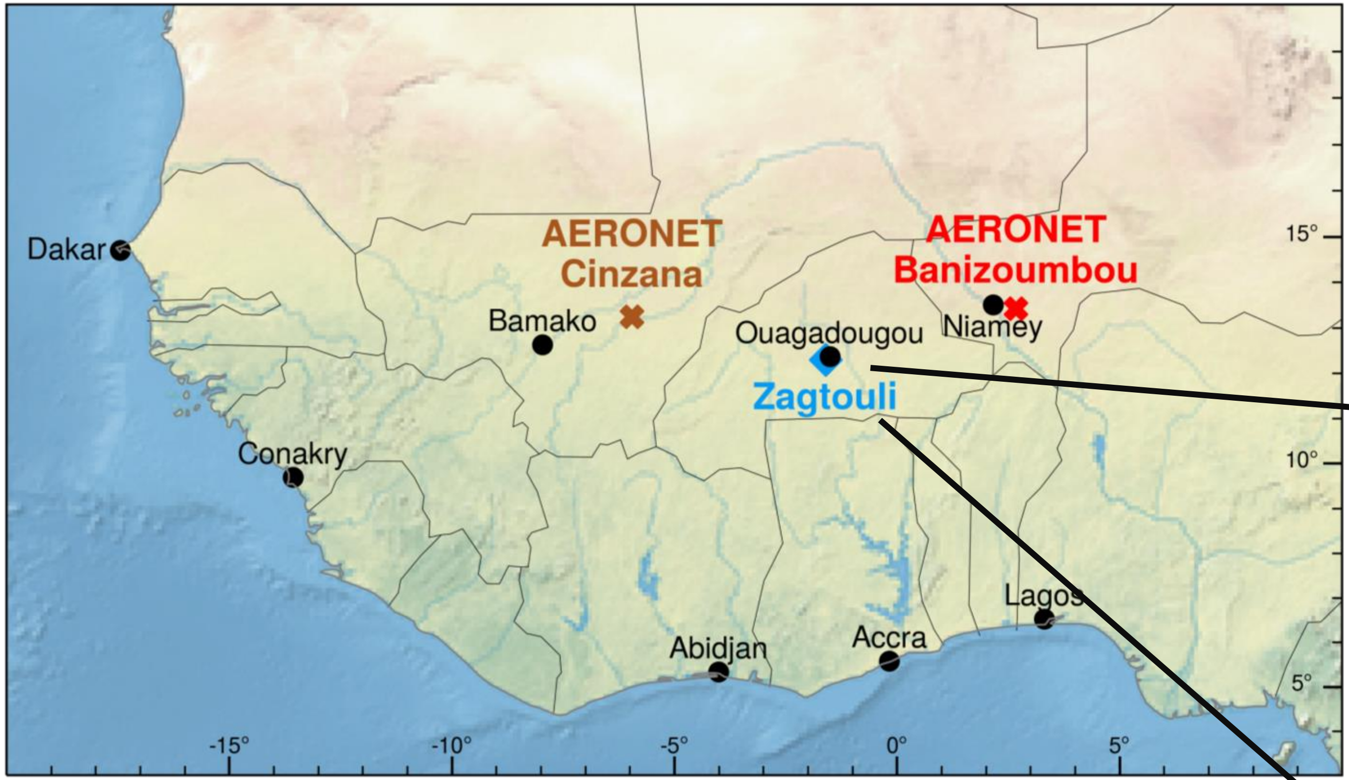
Meteorological constraints on solar radiation availability



RGB composite, MeteoSat Second Generation

Dust deposit, INDAAF Network (Marticorena et al., 2017)

- Specific cloud dynamic (Mesoscale Convective System, ...)
- High dust load in the region



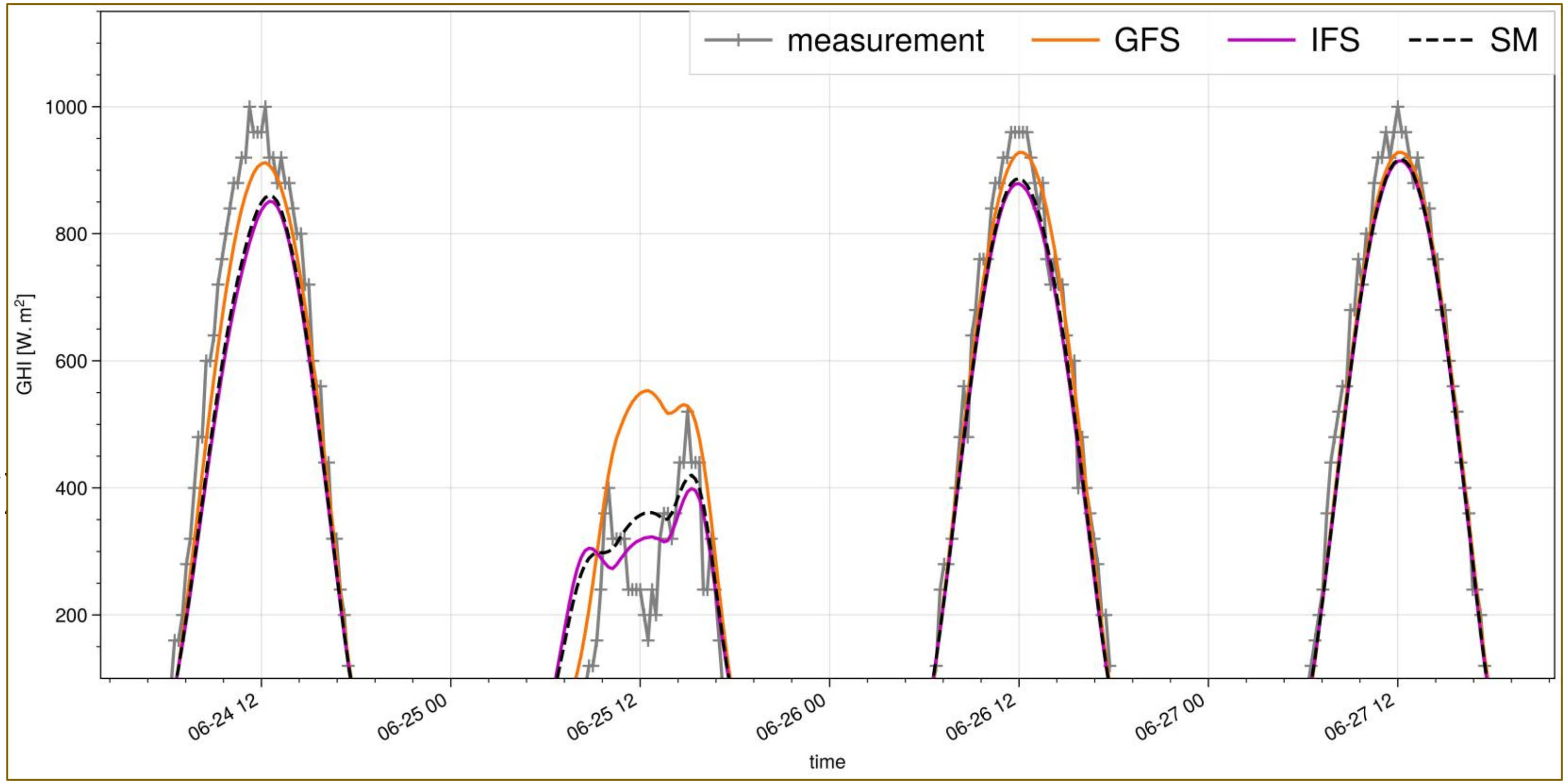
Zagtouli solar farm (Burkina Faso)

- 34MWp
- 56GWh/year since 2018
- 4% of national electric production
- SONABEL (national electricity company)

Available data :

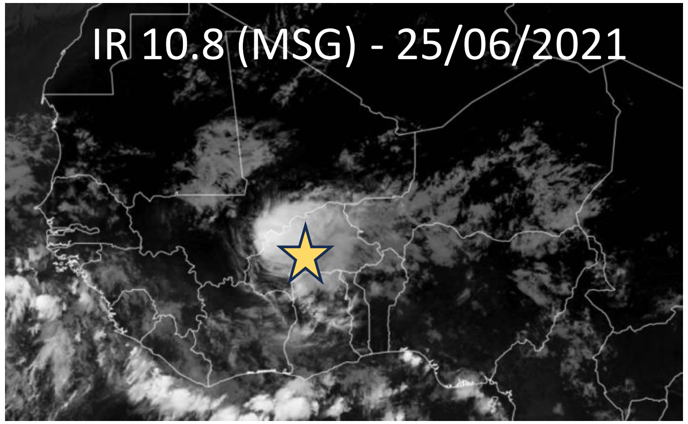
- **Pyranometer GHI measurements :**
  15min – local
- **Global Forecast System** (GFS, NCEP) :
  3h – 25km
- **Integrated Forecast System** (IFS, ECMWF) :
  1h – 9km
- **SteadyMet** (SM, Steadysun) :
  Aggregation

==> Study period = 2021-2022



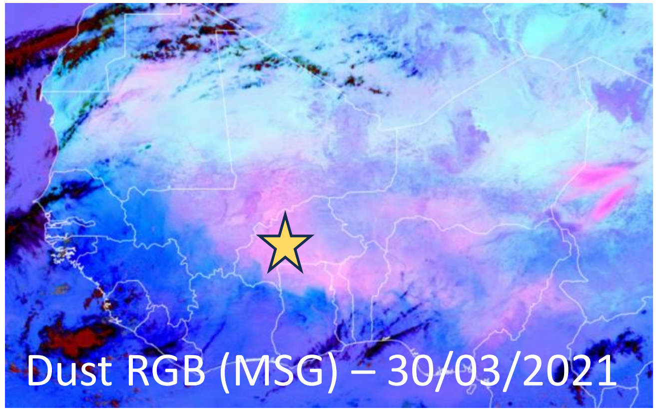
Zagtouli GHI day-ahead forecasts and measurement – 24 to 27 June 2021

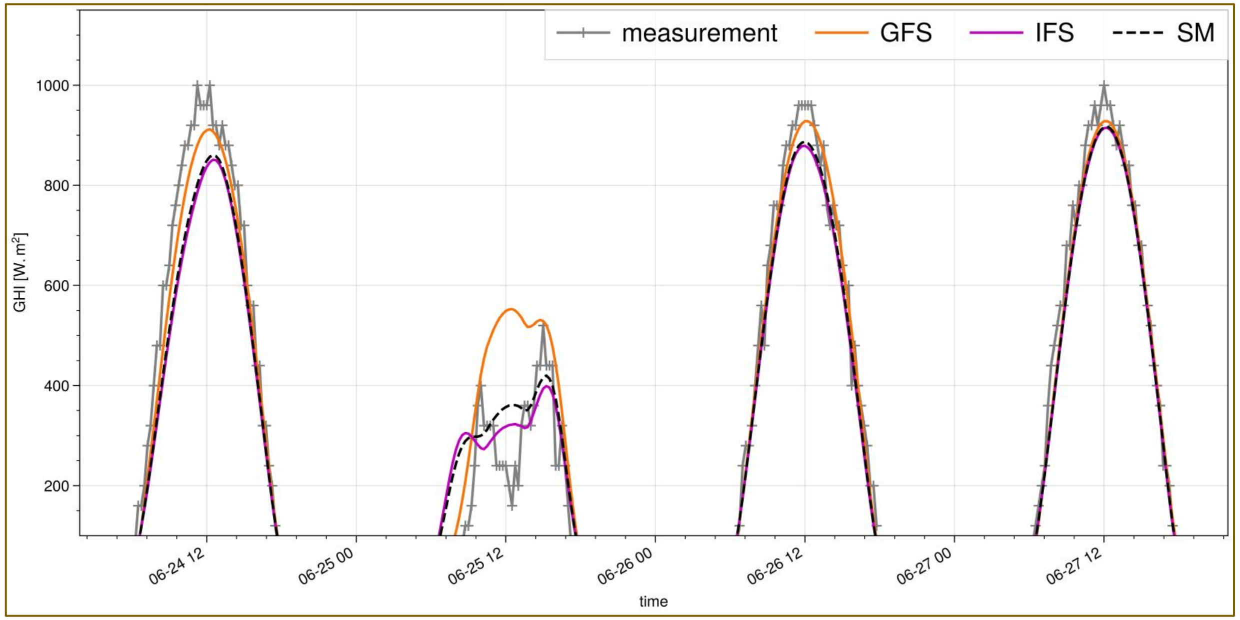
Example of solar forecast defects and associated meteorological conditions

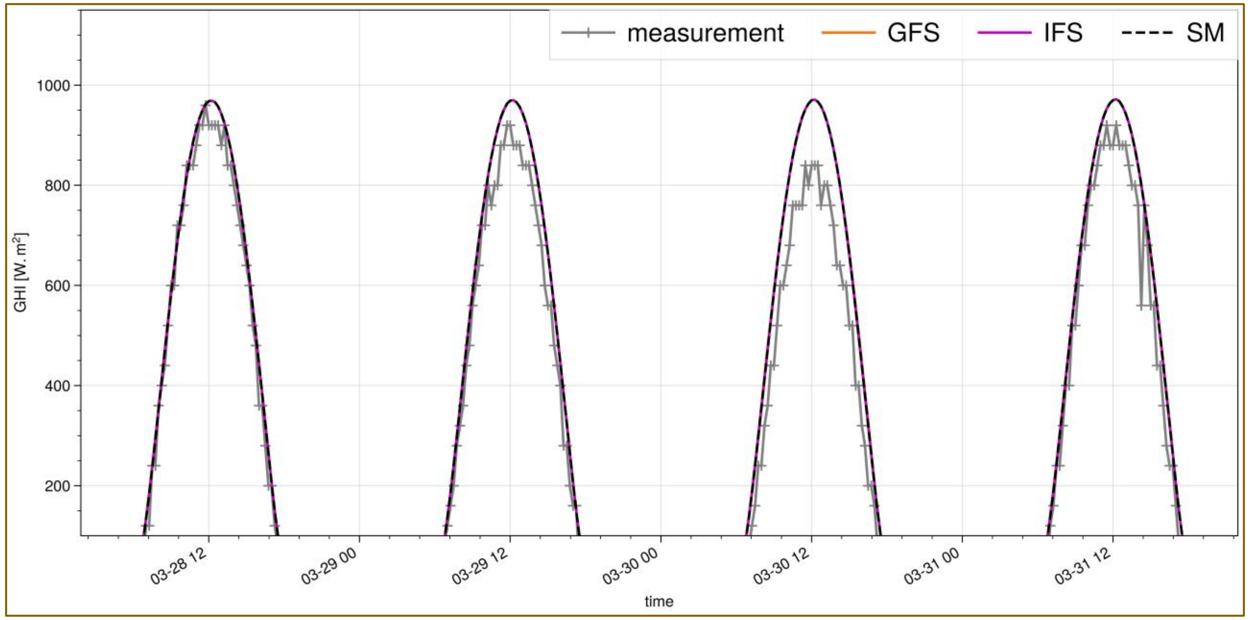


Case 1 :
- Cloud event
- Mesoscale Convective System

Case 2 :
- Dust event
- Emission from Bodele depression







What are the main causes of the solar radiation forecast defect ?

2 mains objectives :

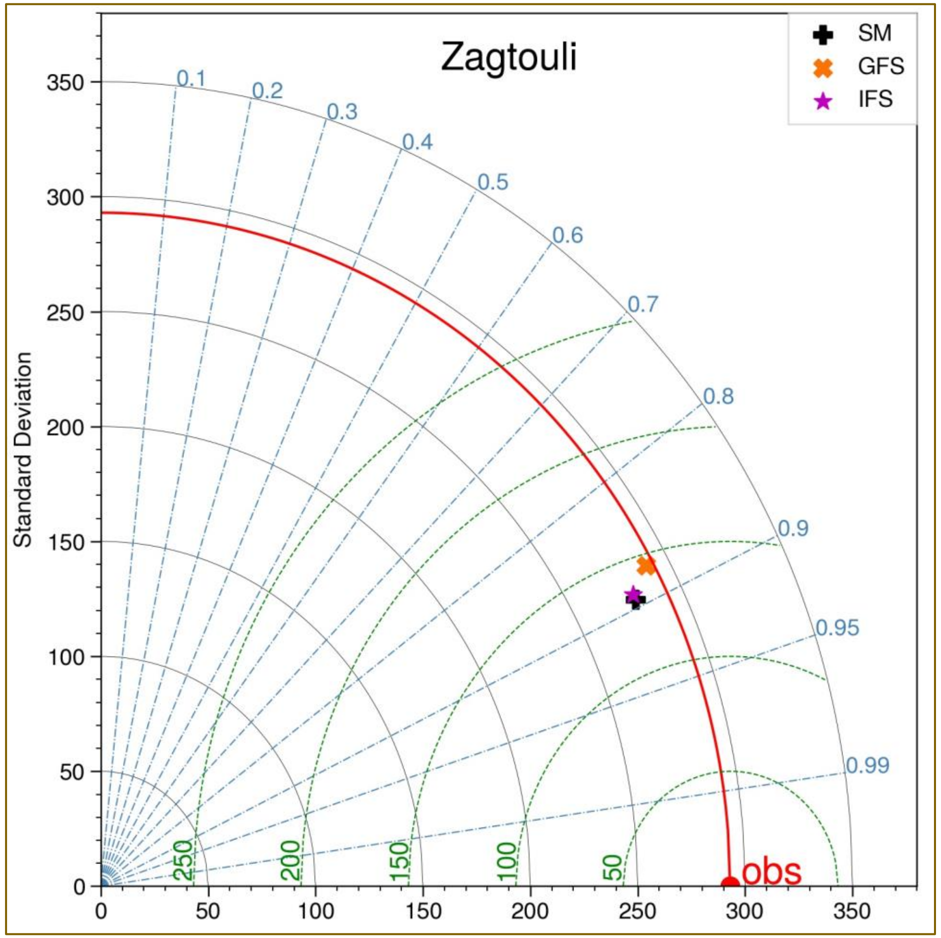
- ❖ **Characterization of the errors**
- ❖ **Determine link with meteorological conditions**

1. Characterization of the errors

General statistics: comparison of 3 models

- GFS has the highest errors and lowest correlation
- SteadyMet performs slightly better than IFS
- GFS, IFS and SM have comparable performances

==> Advantage of aggregation (multi-model, multi-member, multi-mesh)



Taylor diagram showing the evaluation of SteadyMet, GFS and IFS with ground GHI measurement

	MAE [W.m²]
GFS	90.9
IFS	88.2
SM	86.8

Mean daily MAE

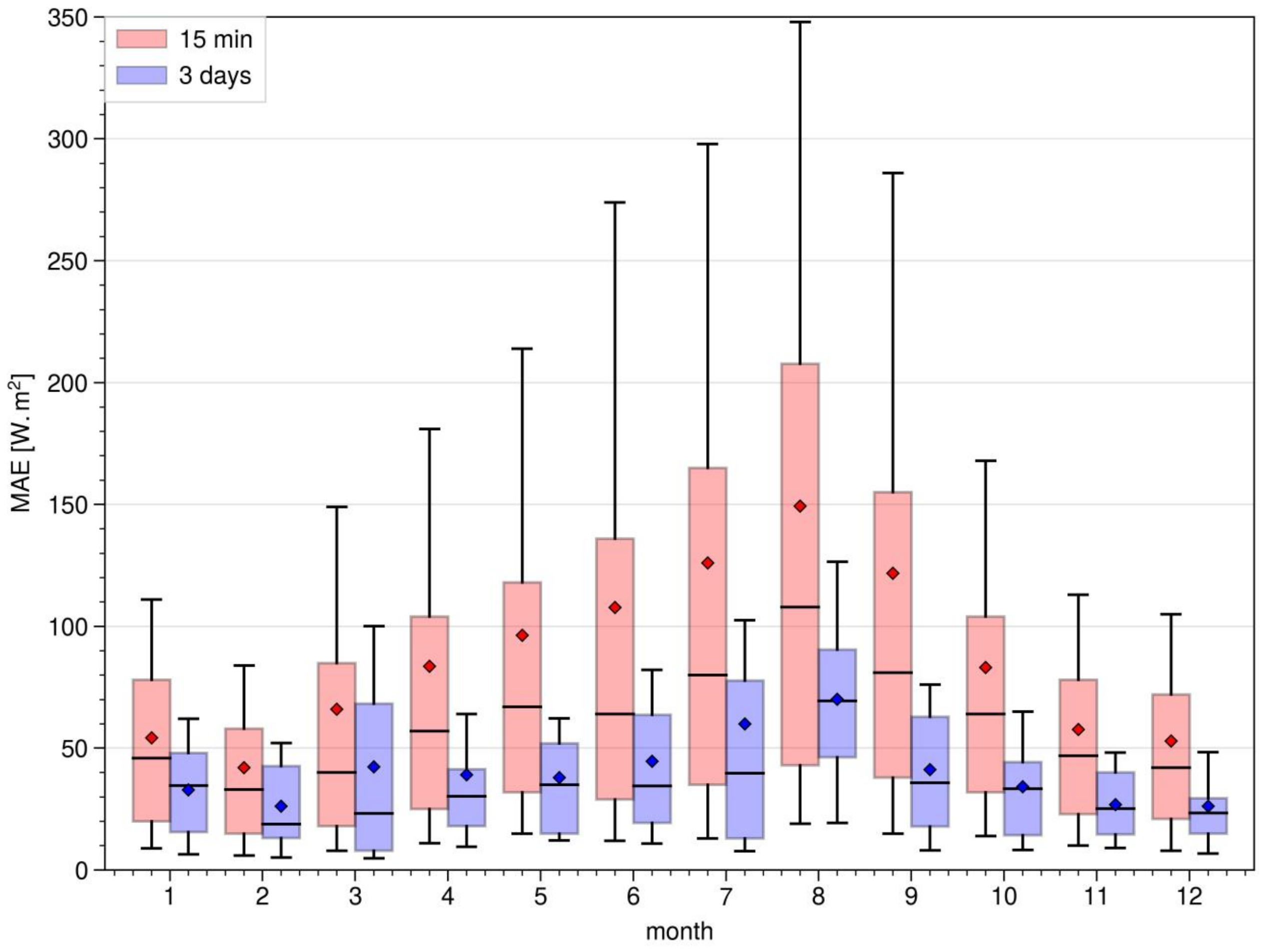
1. Characterization of the errors

Error in function of the season

$$MAE_{dt} = \left| \left(\overline{measurement}\right)_{dt} - \left(\overline{forecast}\right)_{dt} \right|$$

- 15min-MAE : pic of mean value and dispersion in August (wet season)

- 3days-MAE :
  - ❑ Biggest pic of mean value in August and of dispersion in July (wet season)
  - ❑ Second pic of mean value and dispersion in March (dry season)



Monthly boxplot for MAE integrated on different time scale.

2. Link with meteorological conditions

Meteorological data :

A) Aerosol indicators

- **AERONET AOD** = ground measurement, local, dt=5min (clear sky)
- **MODIS AOD** = satellite observation, dx=1°, dt=daily (clear sky)
- **CAMS Dust OD** = atmospheric reanalysis, dx=0.75°, dt=3h (all time)

=> **validation of CAMS** with AERONET and MODIS

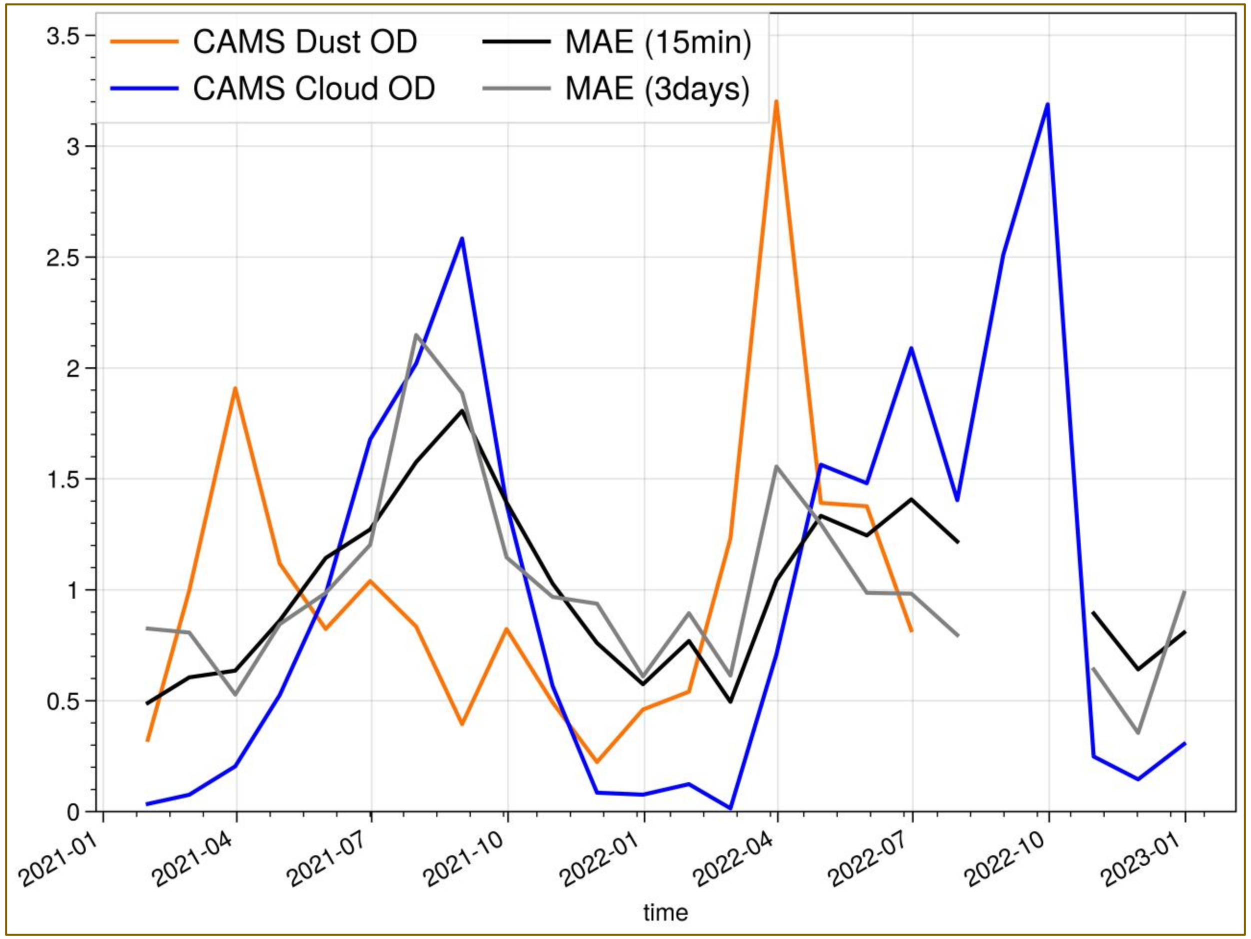
=> CAMS advantage : consistency, day and night, cloudy and clear sky days

B) Cloud indicators

CAMS solar radiation time-series :

- derived from Meteosat Second Generation satellite observation
- Cloud Optical Depth, dx=5km, dt=15min

2. Link with meteorological conditions



Normalized monthly mean of errors and meteorological indicators

<u>Seasonality comparison</u>

- 15min-MAE and Clouds both pic during the wet season (July-October)
- Dust pics in the late dry season (April)
- 3days-MAE shows a pic in the wet season (2021) and a pic in April 2022

=> Cloud may be the major cause of defect in solar forecast model

=> Depending on the time scale, dust may have a significant impact

2. Link with meteorological conditions

		Cloud Optical Depth (COD)	Dust Optical Depth (DOD)
MAE	3 hours	0.55	0.01
	1 day	0.61	0.04
	3 days	0.50	0.13

Table 1. Pearson correlation coefficient between MAE integrated for different timesteps with Dust and Clouds indicators

- Correlations are significantly higher for COD than for DOD
- Correlations are higher for 1day-MAE with COD and for 3days-MAE with DOD
  - ➢ Forecast errors are linked with clouds event

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Table 1. Pearson correlation coefficient between MAE integrated for different timesteps with Dust and Clouds indicators

		Cloud Optical Depth (COD)	Dust Optical Depth (DOD)	COD & DOD
MAE	3 hours	52%	28%	11%
	1 day	61%	27%	17%
	3 days	50%	31%	16%

Table 2. Co-occurrence between the 30% most critical errors and the 30% highest values of Cloud and Dust indicators, for different integration timesteps.

- Correlations are significantly higher for COD than for DOD
- Correlations are higher for 1day-MAE with COD and for 3days-MAE with DOD
  - ➢ Forecast errors are linked with clouds event

- Co-occurrences with Clouds are higher than with Dust
- Co-occurrences with Dust are not negligible, especially with 3days-MAE
- Above 10% of major errors occurred with Dust and Clouds
  - ➢ The Dust impact should not be underestimated (Aerosol-Cloud Interaction)

Main conclusions :

i. The three models have similar overall performances, SteadyMet is slightly better (contribution of aggregation)

ii. Errors are highest **during the wet season**, but when integrated over several days we also see a **secondary peak during the late dry season**

iii. Correlations suggest that the presence of **clouds explains the most critical errors**, but co-occurrences show that the presence of **aerosols has a secondary impact**

Perspectives :

1. Improving the knowledge on the **impact of meteorological condition** :
   ==> Strengthen the measurement networks on site (AOD, cloud mask) to have a better view on the local conditions

2. Taking into account **dust deposition impact** on the solar PV production
   ==> Reduce the dust deposition impact by determining an optimize cleaning strategy

3. Improving the **solar forecast performances**
   ==> Development of a high-resolution forecast model that takes into account dust particles (WRF-CHIMERE)

WRF-ARW Chimere

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NETWAT project :

See poster 48 : *West African Mineral Dust: a key in the NExus ClimaTe – WATer – Energy* (Sandrine Anquetin, Guillaume Tremoy), presented on Tuesday

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