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.
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**Context**

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.

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Generation Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>150</td>
</tr>
<tr>
<td>Solar PV</td>
<td>120</td>
</tr>
<tr>
<td>Hydro</td>
<td>90</td>
</tr>
<tr>
<td>Wind</td>
<td>60</td>
</tr>
<tr>
<td>Coal</td>
<td>30</td>
</tr>
<tr>
<td>Oil</td>
<td>50</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>10</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
</tr>
<tr>
<td>Other renewables</td>
<td>0</td>
</tr>
</tbody>
</table>

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**Study sites**

**Objective**

**Results**

**Conclusion**

**Perspectives**
Context – Study sites – Objective – Results – Conclusion - Perspectives

Meteorological constraints on solar radiation availability

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

RGB composite, MeteoSat Second Generation

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

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ICEM 2023 – Energy Operation and Maintenance - Léo Clauzel
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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

**West African solar forecast errors and their link with meteorological conditions**

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Example of solar forecast defects and associated meteorological conditions

Case 1:
- Cloud event
- Mesoscale Convective System

Case 2:
- Dust event
- Emission from Bodele depression

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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)

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

**Context – Study sites – Objective – Results – Conclusion - Perspectives**

<table>
<thead>
<tr>
<th>MAE [W.m²]</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>GFS</td>
<td>90.9</td>
</tr>
<tr>
<td>IFS</td>
<td>88.2</td>
</tr>
<tr>
<td>SM</td>
<td>86.8</td>
</tr>
</tbody>
</table>

*Mean daily MAE*
1. Characterization of the errors

**Error in function of the season**

\[
MAE_{dt} = | (\text{measurement})_{dt} - (\text{forecast})_{dt} |
\]

- 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

**Seasonality comparison**

- 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

<table>
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<tr>
<th>MAE</th>
<th>Cloud Optical Depth (COD)</th>
<th>Dust Optical Depth (DOD)</th>
</tr>
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<tbody>
<tr>
<td>3 hours</td>
<td>0.55</td>
<td>0.01</td>
</tr>
<tr>
<td>1 day</td>
<td>0.61</td>
<td>0.04</td>
</tr>
<tr>
<td>3 days</td>
<td>0.50</td>
<td>0.13</td>
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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
2. Link with meteorological conditions

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<th>Dust Optical Depth (DOD)</th>
<th>COD &amp; DOD</th>
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</thead>
<tbody>
<tr>
<td>3 hours</td>
<td>52%</td>
<td>28%</td>
<td>11%</td>
</tr>
<tr>
<td>1 day</td>
<td>61%</td>
<td>27%</td>
<td>17%</td>
</tr>
<tr>
<td>3 days</td>
<td>50%</td>
<td>31%</td>
<td>16%</td>
</tr>
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Table 2. Co-occurrence between the 30% most critical errors and the 30% highest values of Cloud and Dust indicators, for different integration timesteps.

- 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)

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

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