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Long-term variability of solar irradiance and its implications for photovoltaic power in West Africa

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1 Solar power for West Africa

- Solar power can serve the rising global energy demand with low environmental impact.
- West Africa is rich in global horizontal irradiance (GHI) and power generation is lacking.
- Satellite data for GHI can serve as input for a linear photovoltaic (PV) power model, processed with measured data (see Fig. 1).

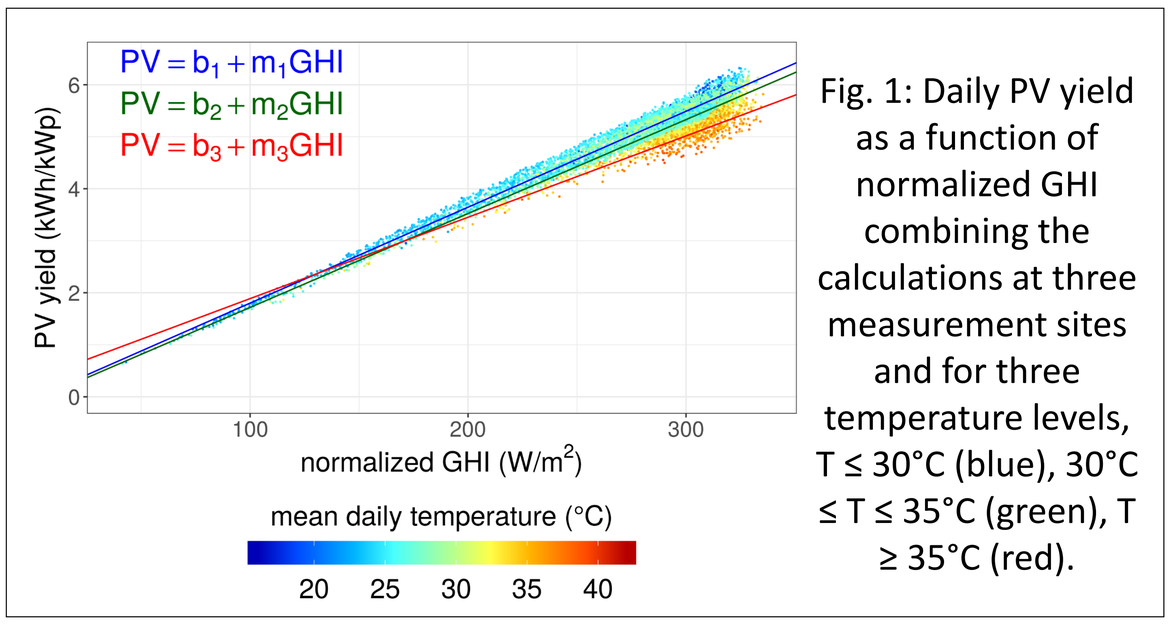

Fig. 1: Daily PV yield as a function of normalized GHI combining the calculations at three measurement sites and for three temperature levels, T ≤ 30°C (blue), 30°C ≤ T ≤ 35°C (green), T ≥ 35°C (red).

2 Surface Solar Radiation Data Set - SARAH-2.1

- Satellite retrieval of GHI in a daily resolution between 1983 and 2017.
- Comparison of satellite data to measurements in Agoufou (Mali), Banizoumbou (Niger) and Djougou (Benin) (Fig. 2, AMMA dataset).
- RMSE: 20 - 34 W/m²; better agreement in Agoufou and Banizoumbou than in Djougou.
- Normalization of GHI with minimal daily zenith to model PV power.

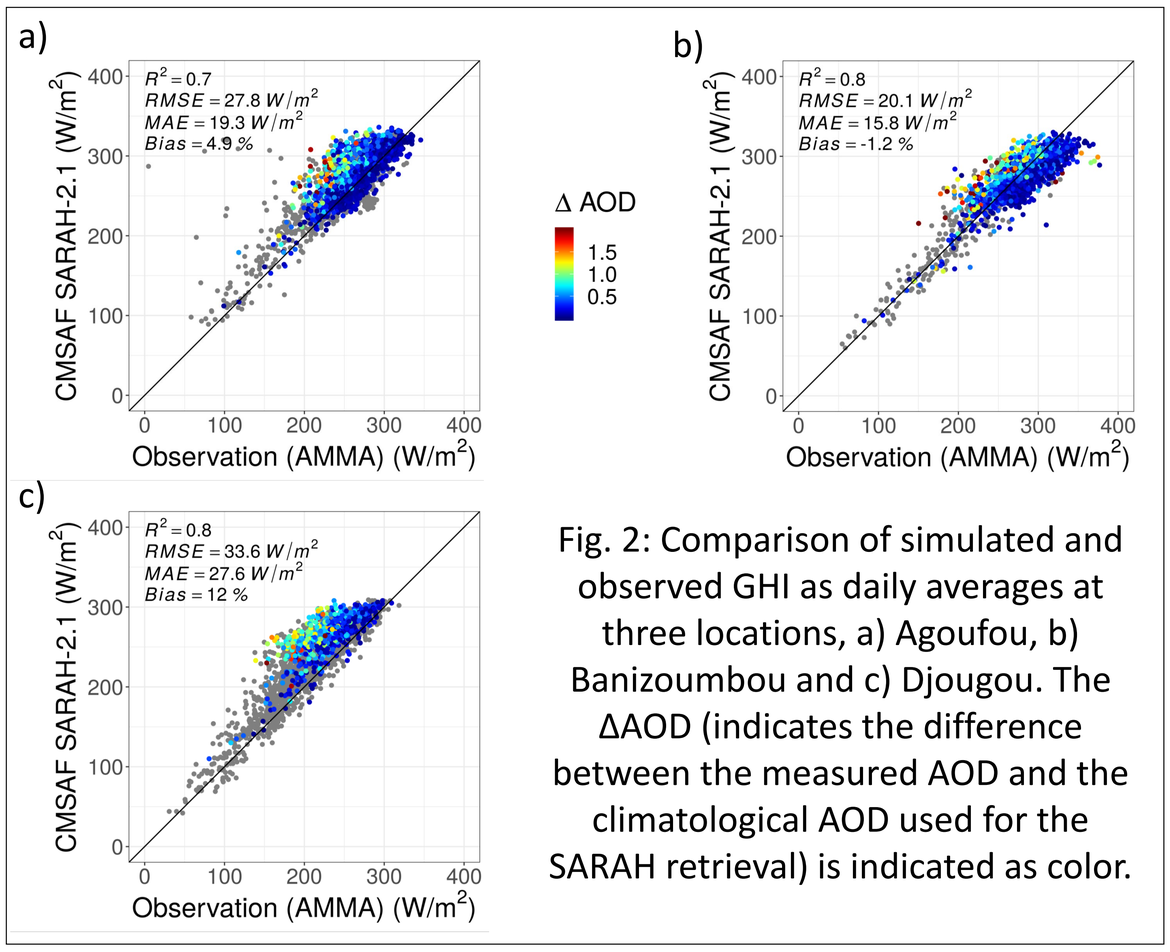

Fig. 2: Comparison of simulated and observed GHI as daily averages at three locations, a) Agoufou, b) Banizoumbou and c) Djougou. The ΔAOD (indicates the difference between the measured AOD and the climatological AOD used for the SARAH retrieval) is indicated as color.

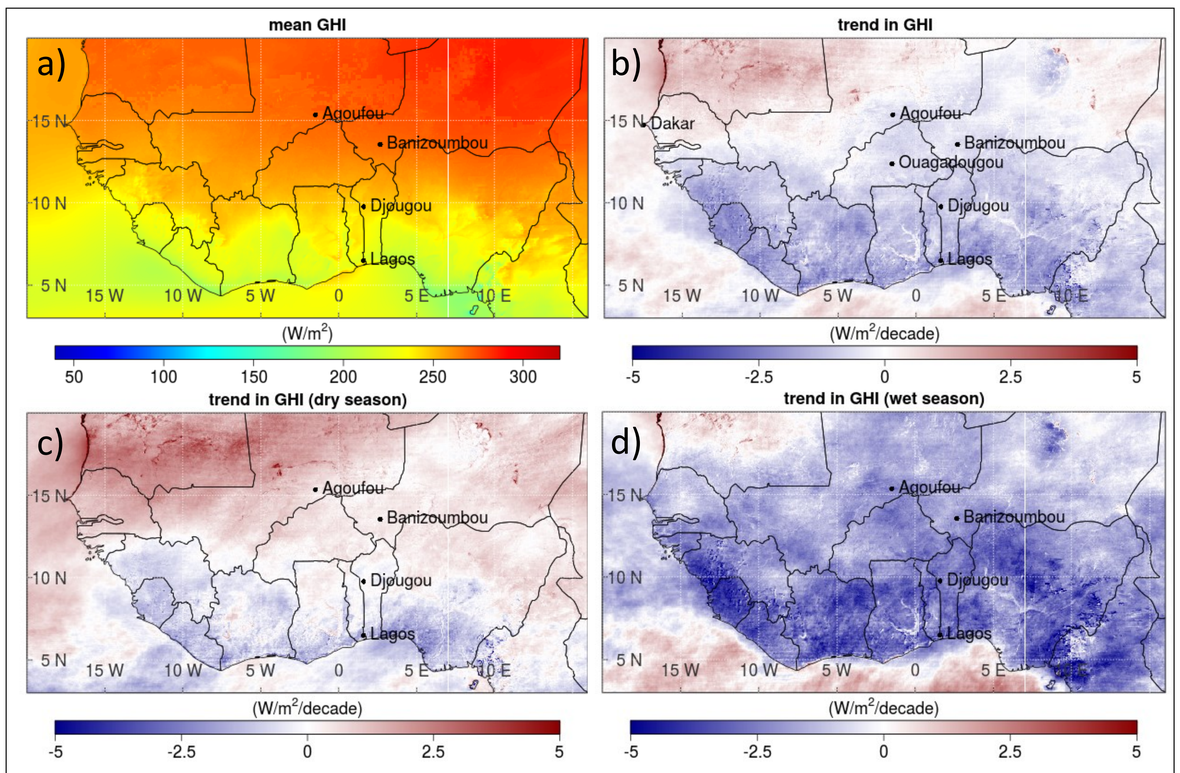

Fig. 3: Mean GHI (a) and linear trend for all seasons (b), the wet (c) and the dry season (d) between 1983 and 2015.

3 PV potential between 1983 and 2017 and trends

- High potential in Sahel region and Sahara (GHI > 250 W/m², Fig. 3 a); PV yield > 5 kWh/kWp, Fig. 4 a).
- Positive trend of GHI in the Sahara, marginal trend in Sahel zone and negative trend in Southern West Africa (Fig. 3 b).
- Positive trend of GHI mainly during dry season (October to April, Fig. 3 c).
- Negative trend of GHI mainly during wet season (Mai to September, Fig. 3 d).

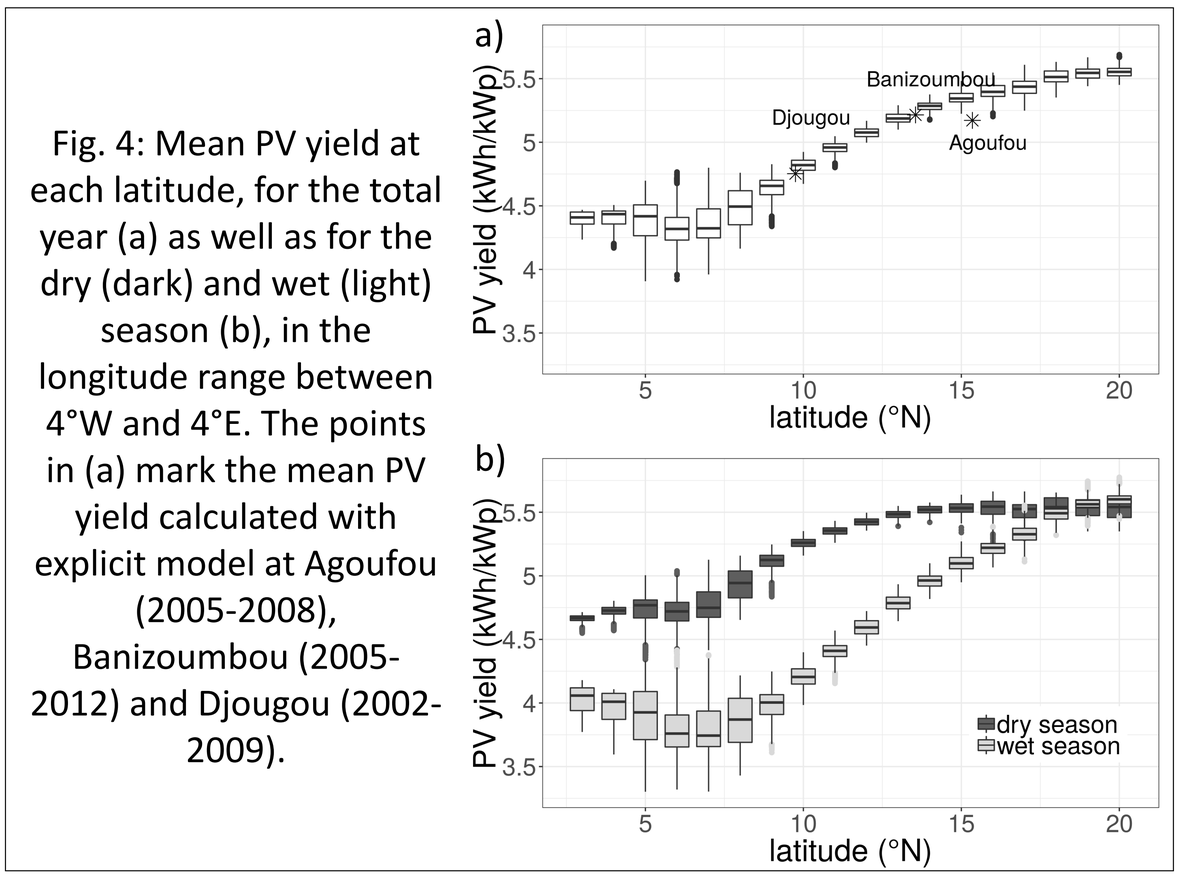

Fig. 4: Mean PV yield at each latitude, for the total year (a) as well as for the dry (dark) and wet (light) season (b), in the longitude range between 4°W and 4°E. The points in (a) mark the mean PV yield calculated with explicit model at Agoufou (2005-2008), Banizoumbou (2005-2012) and Djougou (2002-2009).

4 Conclusion

- Decrease of GHI during wet seasons (likely due to the increase of cloud cover) and increase during dry season (likely due to lower dust movement and clouds).
- PV potential increased over time in regions with low urban density and decreased in regions with high urban density.
- For a solar based electricity system in West Africa, North-South grid and seasonal storage capacities are needed.