Effect of a seasonal demand and the optimal tilt angle on the sizing of 100% solar microgrids power systems in Africa

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Context

- 1.2 billion people lack access to electricity in the world today, of which 80% live in rural areas and 600 millions in Sub-Saharan Africa
- In remote rural areas, the development of solar power electric microgrids (MG) is expected to partly fulfill this electricity access challenge [1]
- The diffusion of 100% solar microgrids (without diesel generator) can be limited by the multiscale variability and intermittency of the solar resource, its seasonality or the occurrence of low resource periods

Data

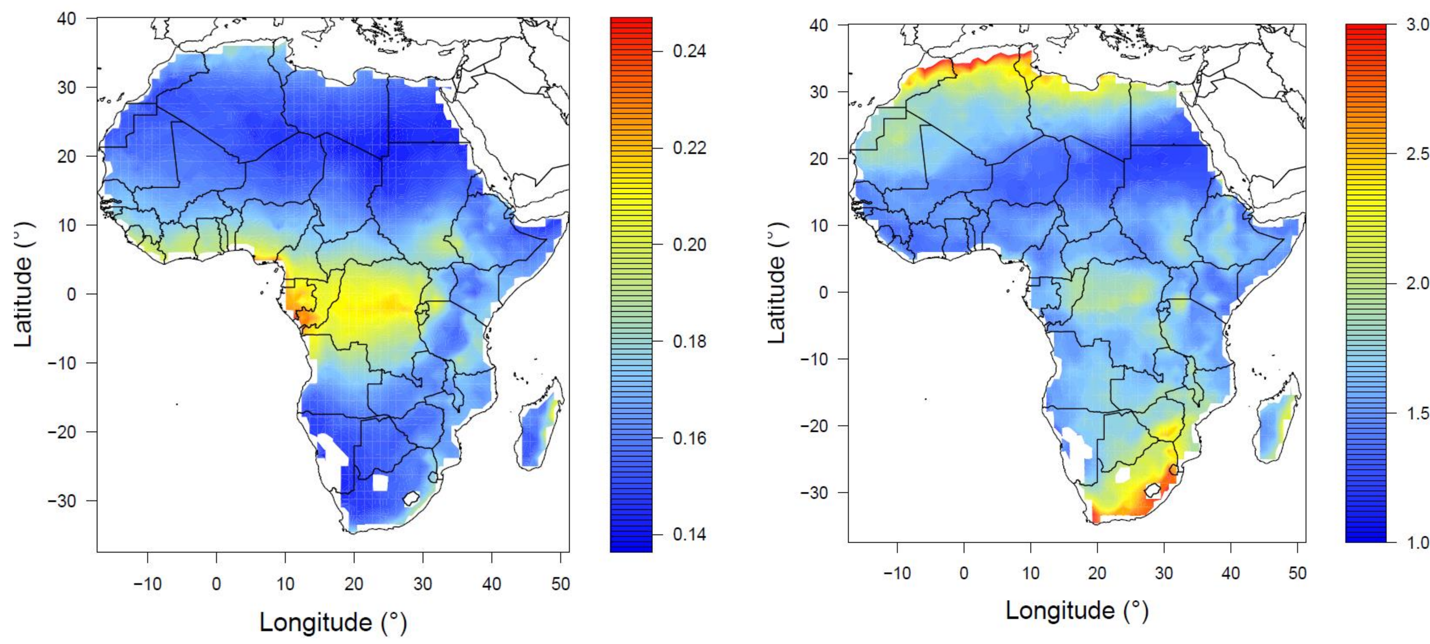
- "CAMS radiation service dataset "JADE" over Africa computed with McClear version 3 and CAMS radiation bias correction - CAMS project - Dec. 2017" [2].
- Period : 2005 – 2016
- Spatial resolution : 0.05° x 0.05°

Notation & Method

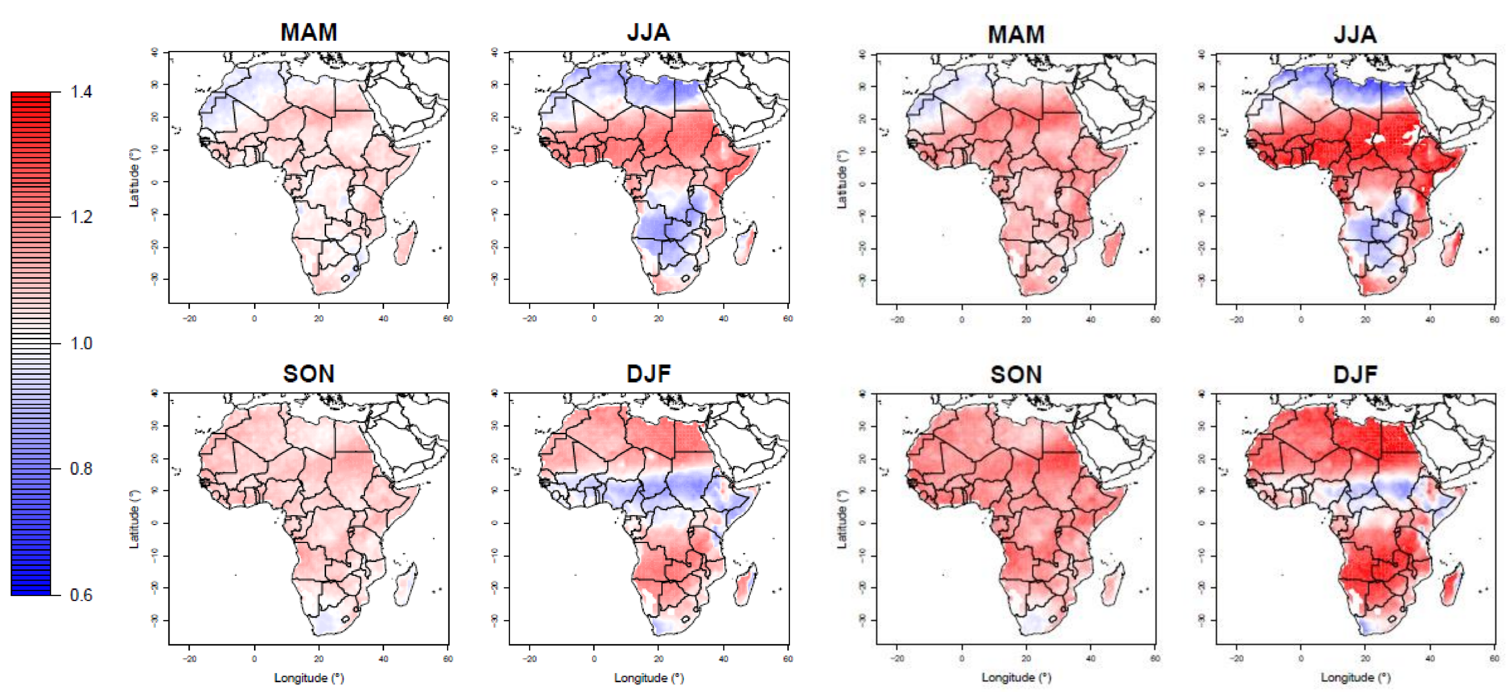
- We consider the variability of Global Tilted Irradiation (GTI) that is the main driver of PV production. A key issue with 100% solar production is the sub-daily temporal mismatch between the resource and the demand. In our work, we disregard this issue and focus on the day-to-day and low-frequency variability of the resource
- For the sake of simplicity, the seasonal pattern of the demand is sinusoidal with a peak demand occurring either in spring, summer, falls or winter. An amplitude of seasonality equal to 30% corresponds to a variation of demand between 0.7 and 1.3 times the mean daily demand
- We evaluate here the impact of the seasonality for the daily demand on the sizing of the MG, and to what extent the optimization of the tilt angle can mitigate the impact of demand seasonality on the sizing of the MG
- $ORL95_{lat}^{cst}$, $\mathrm{ORL95}_{\mathrm{lat}}^{\mathrm{sea}}$, $ORL95_{opt}^{unk}$: Oversizing required level to have 95% of Days satisfied for a constant (resp. seasonal and unknown seasonality) daily demand and a tilt angle equal to the latitude (resp. optimal)
- The oversizing required level is the ratio between the size of the MG when it is designed to meet the demand 95% of the days and the size of the MG when it is designed so that the mean production is equal to the mean demand over the considered period (2005-2016).

I. Cost of the seasonality of the demand

Peak power of solar PV panels in kWp needed to satisfy 1 kWh per day in average Tilt angle = Latitude



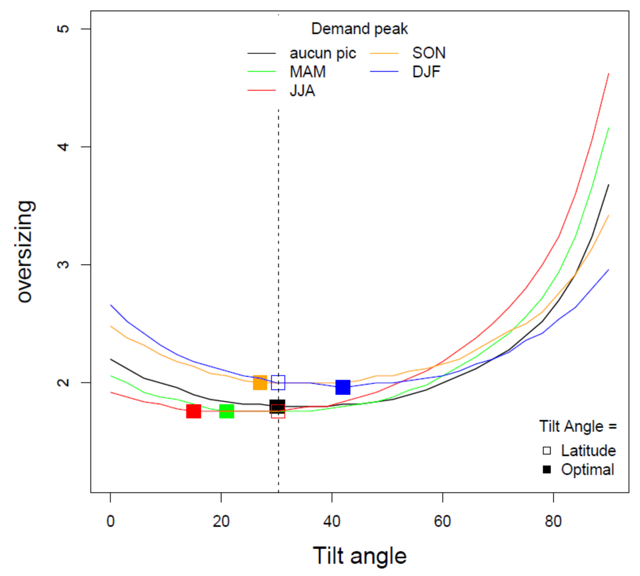
$ORL95_{lat}^{cst}$



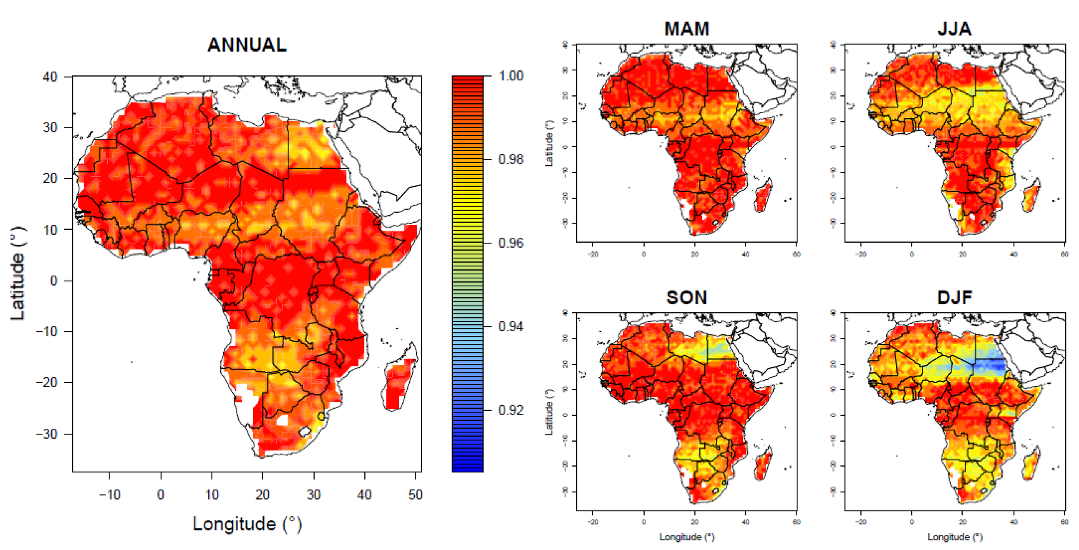
$\mathrm{ORL95}_{\mathrm{lat}}^{\mathrm{sea}}$ / $\mathrm{ORL95}_{\mathrm{lat}}^{\mathrm{cst}}$ *Amplitude of seasonality of the demand equal to 30% (on the left) and 50% (on the right).*

1 For an amplitude of seasonality equal to 30% (resp. 50%), for a peak demand in JJA, the $\mathrm{ORL95}_{\mathrm{lat}}^{\mathrm{sea}}$ is 20% (resp. 40%) larger than $\mathrm{ORL95}_{\mathrm{lat}}^{\mathrm{cst}}$ in latitudes between 0° and +20°, in the extreme East and South, and up to 25% (resp. 40%) lower in Northern Africa and in the central part of Southern Africa

II. Tilt angle effects



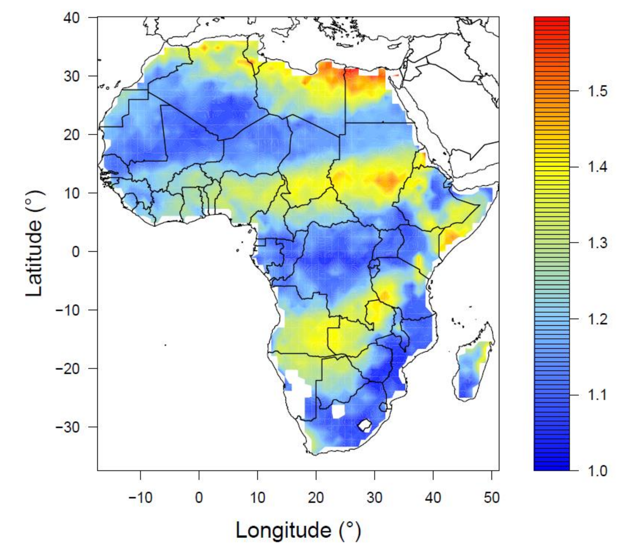
ORL95 as a function of PV panel tilt angle for a grid point in North-Est Africa. Empty squares: $ORL95_{lat}$. Full squares: $ORL95_{opt}$.



$ORL95_{opt}$ / $ORL95_{lat}$. *Left: in the case of a demand with no seasonality and right: when the seasonality occurs in one of the 4 seasons. . Amplitude of seasonality equal to 30%.*

2 Overall the optimal tilt angle can be rather different from the absolute value of the latitude. For a non-seasonal demand, the oversizing gain induced by the optimal tilt angle is at most 4%. In this case, the empirical rule of "inclination equal to latitude" therefore also appears relevant even when the objective is not to maximize production but to reach the 95DS level. Results slightly change when considering a seasonal demand. For specific areas and seasonality, the optimal tilt can lead to oversizing gain up to 9% when the amplitude of seasonality is 30%. This is especially the case in north-east Africa for a peak demand occurring in DJF season

III. Benefits of identifying seasonality



$ORL95_{opt}^{unk}$ / $ORL95_{opt}^{sea}$ *(when the peak demand occurs in the most favorable season) (amplitude of seasonality equal to 30%).*

3 In addition to the amplitude of seasonality, identifying the time of year for peak demand could reduce the size of the required MG by more than 60% (mainly in north-east and east part of Africa) compared to the case where it is not known at which time this peak demand occurs (for a 30% amplitude of seasonality)

References

- [1]: Outlook, A. E. (2014). A focus on energy prospects in Sub-Saharan Africa. International Energy Agency IEA.
- [2] : "Cams radiation service dataset "jade" over africa computed with mcclear version 3 and cams radiation bias correction - cams project," 2017.

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