Temporal variability of the solar resource in Africa for off-grid power systems

Plain, N.[1,2,3], Hingray,B.[1], Mathy, S.[2]
[1] Univ. Grenoble Alpes, CNRS, Institut des Géosciences de l'Environnement (IGE), F-38000 Grenoble, France
[2] CNRS, Grenoble INP, INRA, Univ. Grenoble-Alpes, Laboratoire d'Economie Appliquée de Grenoble (GAEL), F-38000 Grenoble, France
[3] Schneider Electric, Strategy and Innovation, F-38000 Grenoble, France

Context

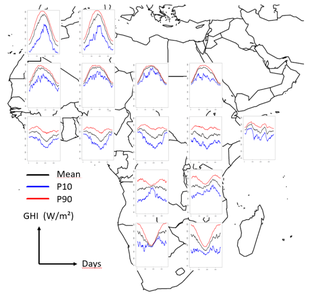
- 1.2 billion people lack access to electricity in the world today, of which 80% live in rural areas and 600 millions in Sub-Saharan Africa
- In remote rural areas, the development of solar power electric microgrids is expected to partly fulfill this electricity access challenge [1]
- The diffusion of 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

- Data base (daily) : Global Horizontal Irradiance (GHI) from the Surface Solar Radiation Data Set - Heliosat (SARAH) - Edition 2 [2]
- Period : 1995 – 2015
- Spatial resolution : 0.05° x 0.05°

GHI for 15 grid points

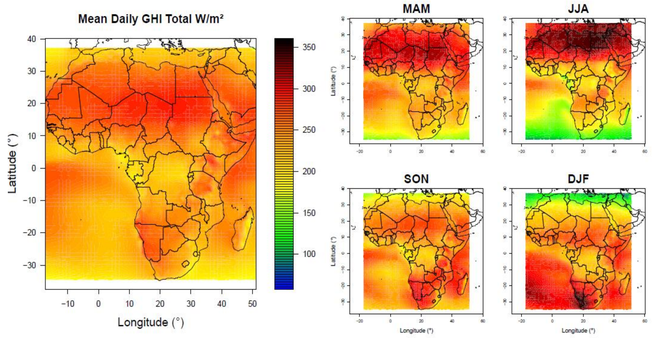
Average year of the mean daily GHI and the P10 and P90 computed for the 21 years of data



Method

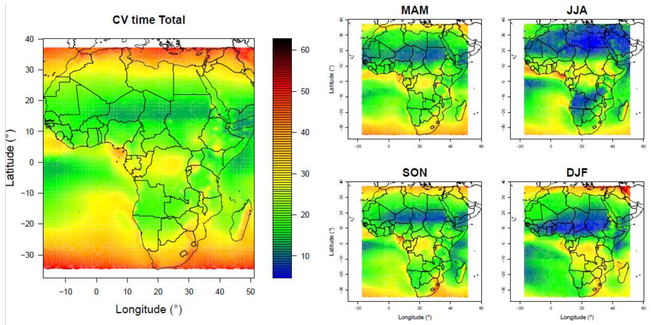
- We consider the variability of Global Horizontal Irradiation (GHI) that is the main driver of PV production
- A key issue with 100% solar production is the sub-daily temporal mismatch between the resource and the demand. In our work, we disregard this issue and focus on the day-to-day and low-frequency variability of the resource
- We first present the GHI and its variability. Then characterize the low resource daily values, directly related to level of power service quality to be achieved somewhere. Finally we give some insight on the characteristics of low solar resource periods.

Mean GHI and its variability



Annual average of daily GHI (Total and for the 4 seasons)

- The mean annual GHI is on average globally higher for areas of medium latitude compare to the ones near equator. It also presents high value in desert areas and tends to decrease for high latitude

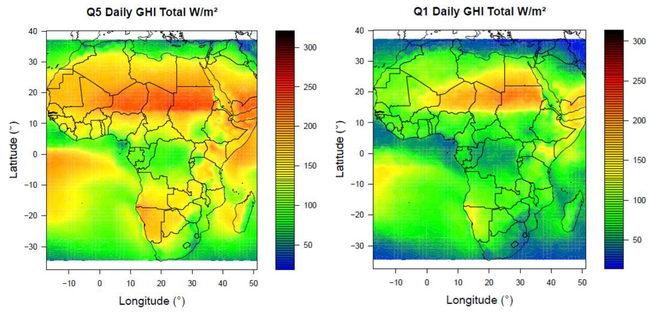


Variation coefficient of daily GHI (Total and for the 4 seasons)

- At the annual scale, the variability mainly depends on the latitude. It roughly increases northward and southward with basically two main exceptions: near the equator where the variability is relatively high and in the southern part of the Sahara region where the variability is much lower than elsewhere.

Low solar resource percentile

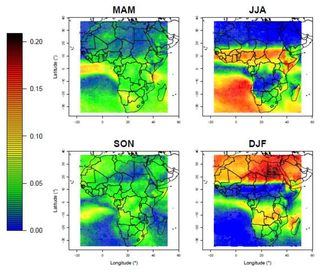
- The Xth percentile value for a given exceedance probability is a very robust indicator of the resource value to be considered for the design of a 100% solar minigrid allowing to have (100-X)% of days where the electricity demand is satisfied.



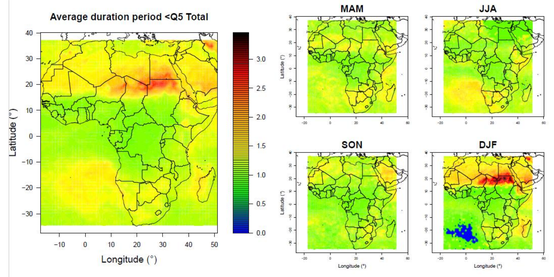
P5 and P1 of the daily GHI for the 21 years of data

Low solar resources sequences

- In the context of 100% solar microgrids, low solar resource sequences must be characterize since they are directly linked to the quality of service providing by these off-grid systems.



Percentage of days < P5 for the whole period 1995-2015



Average duration period (in days) of consecutive days < P5

Conclusion & Perspectives

- Surface of PV panels required when the MGS is sized with this 5% percentile is 2 to 3 times compare to the surface estimated based on the mean annual GHI resource.
- Targeting the 99% DSL would additionally require increasing the surface by a factor of 2.
- For a number of regions, days where the resource is lower than the design percentile are clustered in a given season, making the level of service quality variable in time. On the other hand, the low resource days mostly occur individually, a rather convenient configuration, as soon as a part of the not-satisfied demand can be postponed to some following day when some extra resource is available.
- The quality the SARAH 2 satellite radiation data for the African continent is roughly unknown since as they are only few ground measurements station
- Considering the full cost of the storage/PV panel fleet system would allow to identify the best compromizing storage / oversizing configuration and this latter may be rather different from that estimated here

References

- [1]: Outlook, A. E. (2014). A focus on energy prospects in Sub-Saharan Africa. International Energy Agency IEA.
- [2] : Pfeifroth, Uwe; Kothe, Steffen; Müller, Richard; Trentmann, Jörg; Hollmann, Rainer; Fuchs, Petra; Werscheck, Martin (2017): Surface Radiation Data Set - Heliosat (SARAH) - Edition 2, Satellite Application Facility on Climate Monitoring, DOI:10.5676/EUM_SAF_CM/SARAH/V002,

nicolas.plain@univ-grenoble-alpes.fr