National Aeronautics and Space Administration

Quantifying the Effect of Dust on Solar Energy Generation in Burkina Faso

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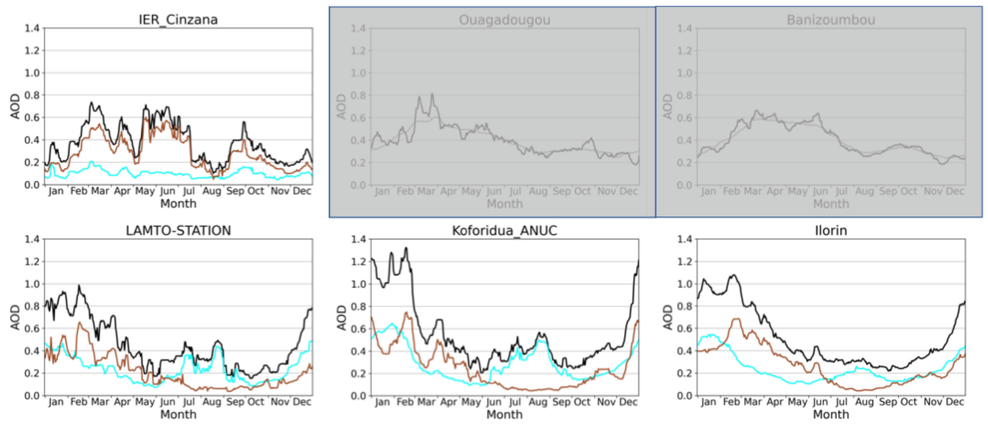
Program: FY21 SURP **Strategic Focus Area: Atmospheric composition and dynamics**

(Left panel) Location of the town of Koupela in respect to AERONET stations in Nigerand Burkina Faso; (Right panel) Boureima Kabre, local leader in solar energy systems in Koupelá, Burkina Faso shows a dust-covered non-operational solar system during a visit in January 2018. Credit to Stewart Isaacs, MIT graduate student.

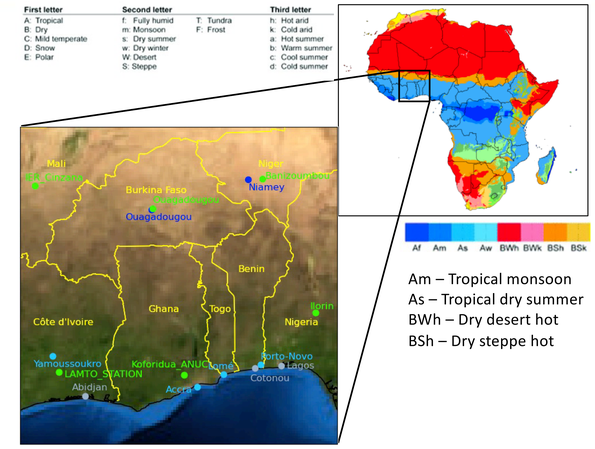
- **Project is focused on understanding aerosol impacts on productive energy generation in West Africa**
- **Satellite and ground-based aerosol optical depth (AOD) datasets are used to understand effects of aerosols on solar extinction**
- **Ground-based and satellite-derived boundary layer $PM_{2.5}$ datasets are used to understand effects of dust deposition on solar panels**
- **We have ongoing collaborations with decision makers in West Africa**

Our specific objectives are to:

1) Quantify the sensitivity of solar energy system sizing to changing AOD values;
2) Produce a multi-year climatology of dust events and dust deposition patterns using satellite observations;
3) Calculate the contribution of dust, biomass burning, and anthopogenic aerosols to the total regional aerosol load and the near-surface contribution of different aerosol types;
4) Develop an integrated PSGIM modeling tool using existing methods for quantifying the relationship between near-surface aerosols, aerosols deposited on photo-voltaic and photo-voltaic cell efficiency;
5) Determine efficient locations for the deployment of solar energy systems in Burkina Faso.



AOD for total (black), fine (cyan), and coarse (brown) mode at 500 nm from the spectral deconvolution algorithm (SDA) for each available AERONET smoothed using a ±5 day (centered) running median. Fine and course mode aerosols are associated with anthropogenic and natural aerosol sources respectively, suggesting the Harmattan AOD loading is due to human activity adding to a naturally occurring peak in aerosols.



Am – Tropical monsoon
As – Tropical dry summer
BWh – Dry desert hot
BSh – Dry steppe hot

The region of West Africa receives a lot of solar insolation, but sits just below the Sahara Desert, a location well known as the largest source of dust aerosols in the world. Shown is Present-day Koppen-Geiger Map of Africa.

Designing solar energy systems for productive-use solar applications has a different set of considerations than utility scale solar developments. Unlike utility scale developments where capital can be easily procured, small and medium scale business owners in sub-Saharan Africa often have limited access to capital. This means that panels should be no bigger than what is required to meet an application's energy requirement in an effort to limit extra cost. We developed an approach of estimating solar panel sizing accounting for aerosol extinction of solar energy.

AOD	Solar Irradiance [W/m^2]	Solar Capacity [W]	Solar System Cost [USD]
0.5	835	462	1600
1.0	763	521	1790
1.5	697	581	1980
2.0	635	648	2170

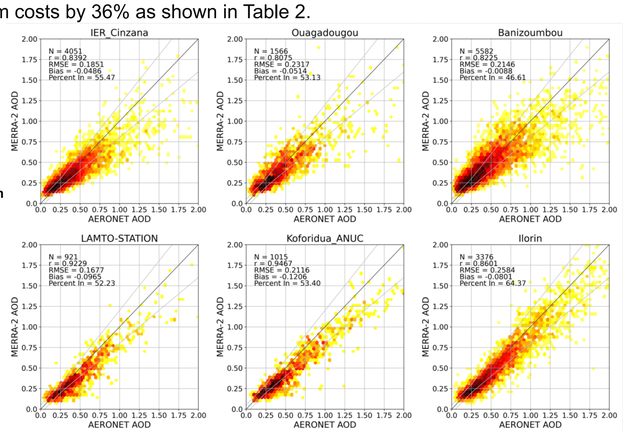
Table1: AOD Value vs Solar System Size and Cost

	AERONET		MERRA-2		% Δ
	Capacity [W]	Threshold AOD	Capacity [W]	Threshold AOD	
Koupela	1302	2.60	1156	2.02	-11%
Tamale	1315	2.99	1542	3.87	+15%

Table2: Solar powered freezer capacity in Watts sized using the 2-consecutive day threshold AOD value in Koupela, Burkina Faso and Tamale, Ghana

Sizing a PV system to power a poultry egg incubator working with an AOD value of 2 compared to 0.5 reduces the maximum solar irradiance available in a day by 24%, increases the PV panel capacity by 40%, and increases the total system costs by 36% as shown in Table 2.

When considering the freezer and milling productive-use scenarios as well, an AOD value increase of 1 led to a 19-24% increase in solar system costs for the system.

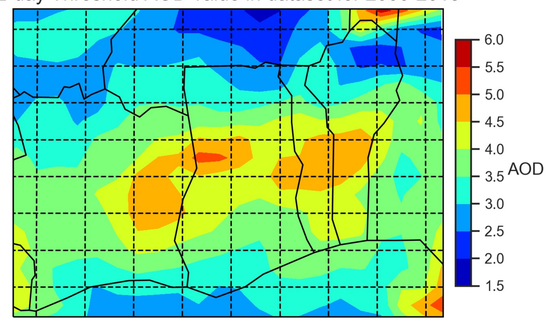


Point Density
High
Low

AOD measurements from MERRA-2 compared to co-located AERONET sites in West Africa. Good agreement can be seen for the dataset, but MERRA-2 becomes less accurate for AOD values above 1.

Result1: We found that aerosol impacts vary by region and season, and while dust is prevalent in the dry desert hot zone through the year, biomass burning is affecting the tropical monsoon region in the summer, and dust is present in the winter through Harmattan winds.

2-day Threshold AOD value in dataset for 2000-2018



The threshold AOD derived from MERRA-2 AOD climatology below which there is at least one 2-consecutive day event within the aerosol MERRA-2 dataset. The threshold AOD indicates the appropriate sizing of the solar panels in the region.

Result 2: We established requirements on temporal and spatial coverage of various ground-based, satellite, and model (MERRA-2) datasets for productive energy use.

Significance/Benefits to JPL and NASA:

Our SURP effort makes possible an innovative infusion of remote sensing aerosol speciation data into solar energy research, and will constitute the first application of MISR's new high-resolution aerosol product in regions of the world where dust impacts are serious for both solar energy and health applications, yet in situ monitoring is poor. Among current satellite instruments, MISR is uniquely capable of assessing AOD size and type information over land, including over bright desert-like areas where other satellite aerosol information is limited. The novel approach and analysis framework to be developed has the potential for establishing breakthrough methodologies for characterizing the effect of dust on solar energy generation, providing critical knowledge to support policy decisions on renewable energy use in underserved regions like Western Africa. In addition, the project will quantify capabilities and limitations in existing satellite observations for characterizing and monitoring near-surface aerosols from space and formulate requirements for future missions with a specific emphasis on AOS Decadal Surface mission requirements.

Publications: *Isaacs S., O. V Kalashnikova, M. J. Garay, and D. Wood, Assessment of variability of aerosol properties in West Africa for productive-use solar energy applications, Remote Sensing, in review, 2021*

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