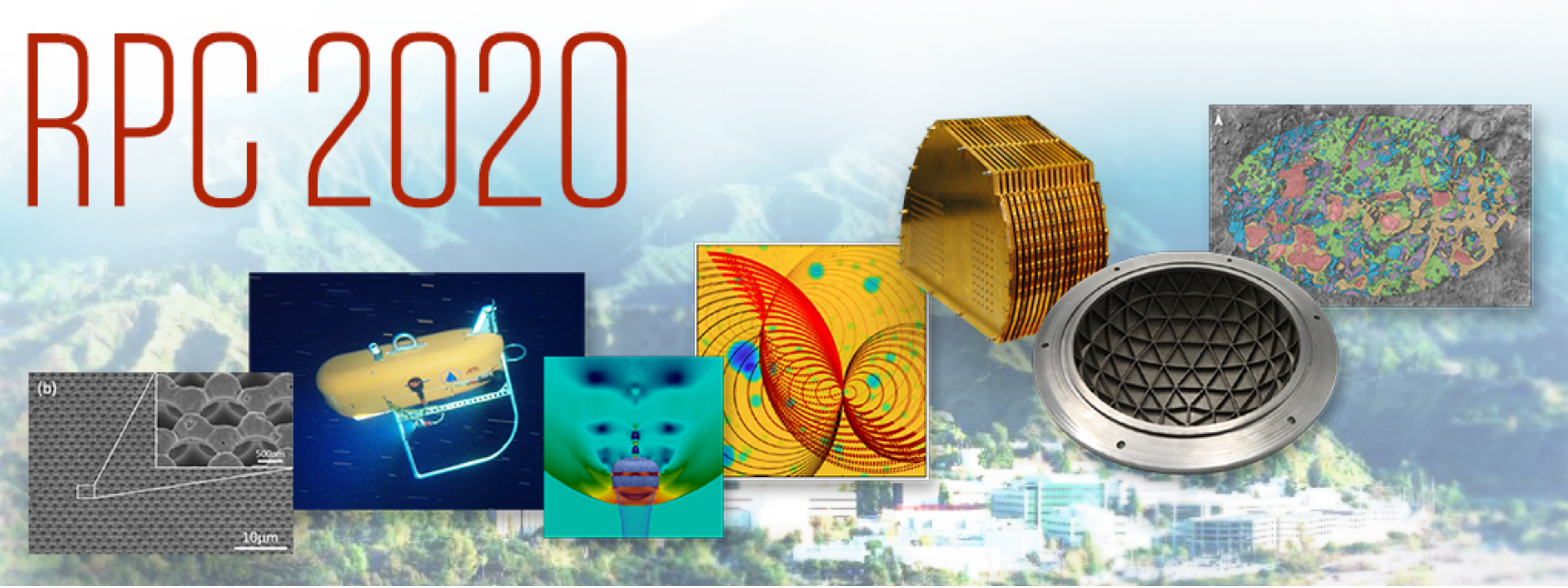



# Virtual Research Presentation Conference

## QUANTIFYING THE EFFECT OF DUST ON SOLAR ENERGY GENERATION IN BURKINA FASO

**Principal Investigator: Olga Kalashnikova (PI), Earth Science Section (329)**
**Co-Is: Alyssa M. Deardorff (312), Michael J. Garay (329), Stewart Isaacs (Aeronautics and Astronautics, MIT), Danielle Wood (MIT Media Lab, MIT)**
**Program: (Lew Allen, Strategic Initiative, Topic, Spontaneous Concept, or SURP)**

**Jet Propulsion Laboratory**
California Institute of Technology

Assigned Presentation # RPC-040

# Tutorial Introduction


**Abstract**

Nominally, west Africa receives a relatively large amount solar insolation, giving it good potential for solar energy projects. However, this region is positioned below the Sahara Desert, a location well known as the largest source of dust aerosols in the world. Currently, the impact of environmental barriers, including atmospheric aerosol loading, on solar energy adoption is not well understood.

Our work utilizes JPL's MISR instrument aerosol data to support a doctoral student project developing an innovative, integrated Earth-system model called the Particulate-matter Solar Generation Impact Model (PSGIM) that will be used to predict the impact of dust events on future solar power generation in the Burkina Faso region of west Africa.


## *Solar Generation Model:*

Photovoltaic (PV) electricity generation depends on solar irradiance, and other atmospheric variables affecting panel efficiency such as surface air temperature and surface wind velocity. The effects of aerosols are currently not accounted for.

- **Context**

"Productive use" solar energy for devices like refrigerators can provide valuable services in a region without access to reliable electricity. These devices are gaining attention in sub-Saharan Africa as a method for advancing development.

High aerosol optical depth (AOD) values are common during the dry season (Harmattan) and are known to significantly reduce solar irradiance


- **Advancement over current state-of-the-art**

Current solar modeling methods rely on AOD values from model assimilations with limited spatial resolution in their outputs. Additionally, the impact of high AOD values (AOD > 0.5) on solar energy production has not been explored in detail.

- **Relevance to NASA and JPL**

NASA JPL's satellite measurements could be used to improve spatiotemporal resolution to meet solar modeling criteria for productive-use applications. Additionally, this work bridges the link between air quality and renewable energy production – offering a new vector of research for future programs.

# Methodology: Stakeholder Analysis for Productive-Use Solar Modeling

- We use the method of stakeholder analysis from Systems Architecture methodology to define system objectives for productive-use solar modeling (Pfotenhauer et al. 2016, Joseph and Wood).
- There are key differences between sizing utility-scale (power plant) and productive-use (community) solar energy systems

| Parameter | Productive-Use | Utility Scale |
|---|---|---|
| Capacity | 400-10,000W | 1-25 MW |
| Sizing relevant Timescale | 24 hours | 10-25 years |
| Objective | System Reliability | Financial Returns |
| Access to Capital | Limited Access | Highly Accessible |
| Location | Fixed | Variable |

## Identify Stakeholder Needs, Desired Outcomes and Objectives for the System

*Stakeholder Need*
- What problems or desires are stakeholders facing?

*Desired Outcomes*
- What do stakeholders want the world to be like in the future?

*System Objectives*
- What activities will a system do to contribute to the desired outcomes?

# Three Productive-Use Applications Considered

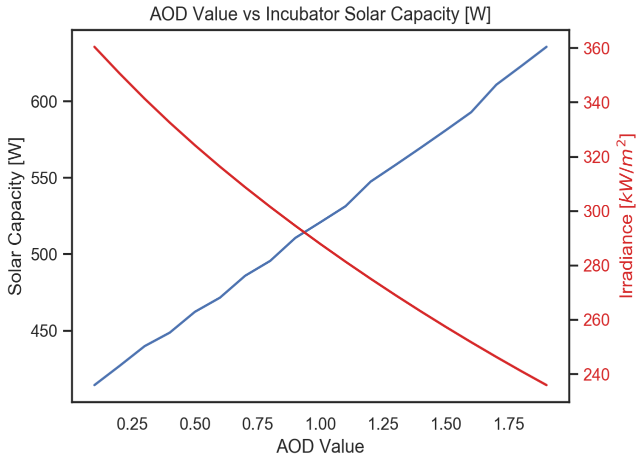
- Key device parameters are sourced from Booth et al. 2018, and supplemented with information from discussions with Boureima Kabre, a Burkinabe solar entrepreneur.

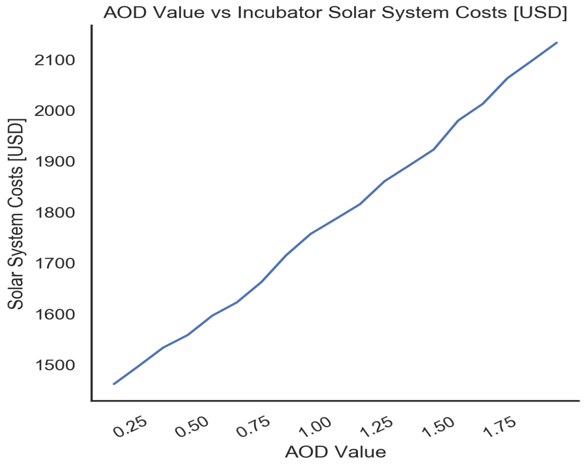
- Solar modeling is done using Pvlib, maintained by Sandia National Labs, with the clear sky simplified Solis module (Inechien, 2018)
- Solar system is sized to meet the daily energy requirements from a device based on its power consumption and daily hours of operation

Photo courtesy of Samuel Booth, NREL

| Productive-Use Service | Power Requirement [W] | Daily Hours of Operation [hrs] |
|---|---|---|
| Poultry Egg Incubator | 100 | 24 |
| Medicine or Food Freezer | 180 | 24 |
| Grain Milling | 10,000 | 2 |

# Initial Results: Required Solar Panel Capacity and Cost are Sensitive to AOD Value

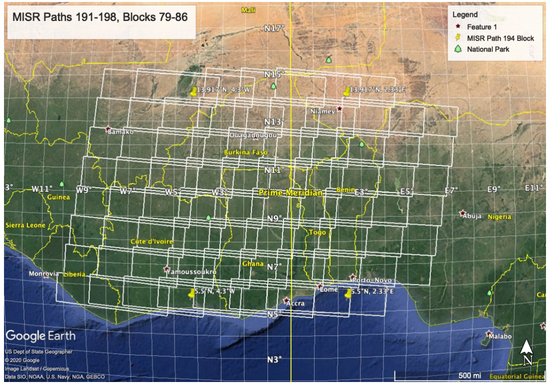


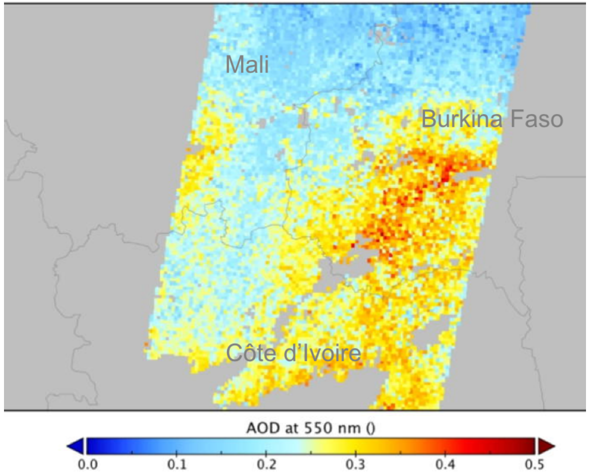

- An AOD increase of 0.25 leads to an increase of $1,000 in solar system cost
- In West African countries, many individuals have limited access to capital

- Aerosol loads (expressed as AOD) reduce irradiance and require greater solar panel capacity to meet energy requirements
- Energy-intense devices increase solar panel capacity as a function of AOD at a faster rate due to higher energy requirements

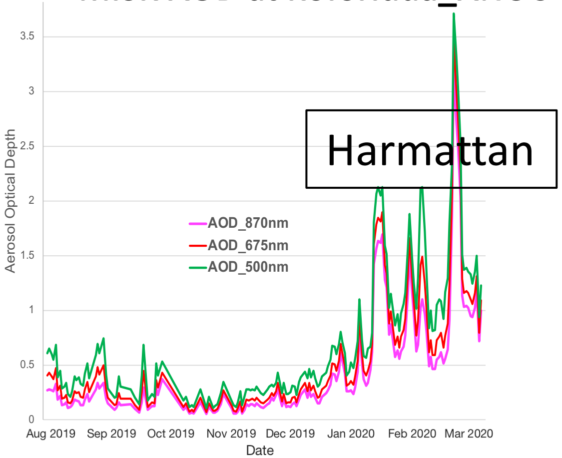
## MISR coverage



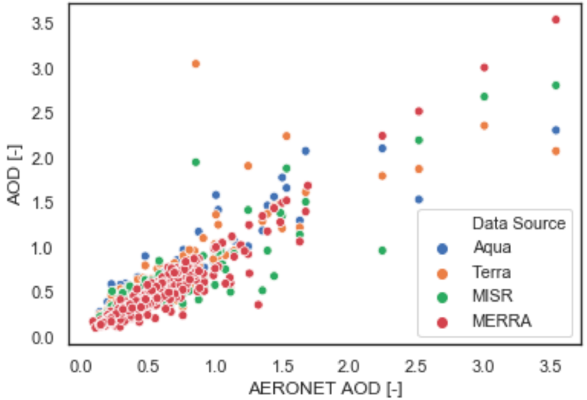

## MISR AOD



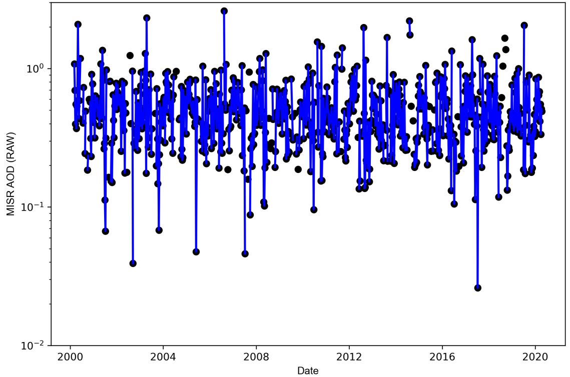

## MISR AOD at Koforidua_ANUC



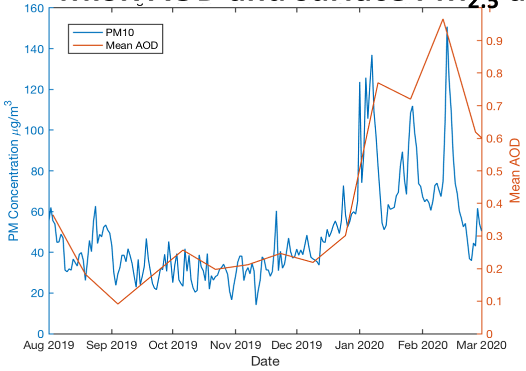

## Satellite and MERRA2 AOD vs. AERONET



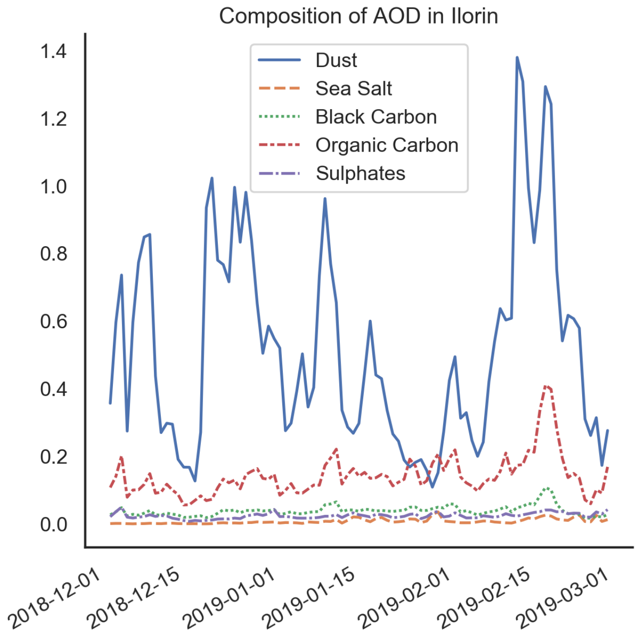

## MISR AOD timeseries

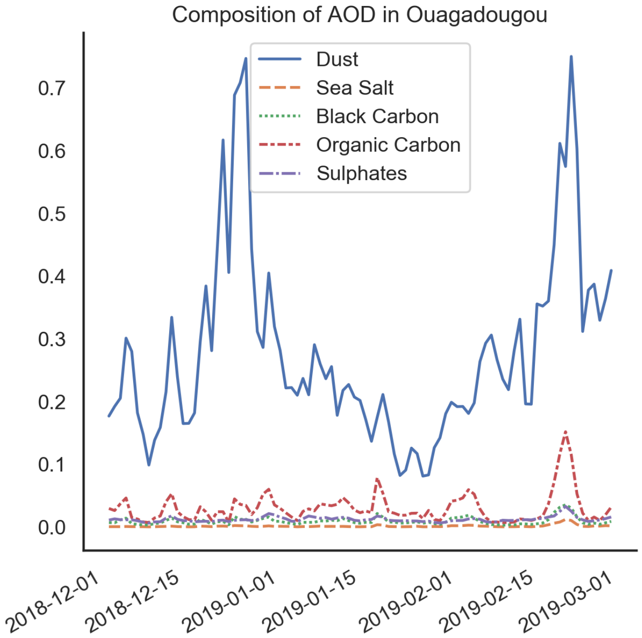



## MISR AOD and surface $PM_{2.5}$ at Accra



# Initial Results: Composition of AOD is Primarily Dust

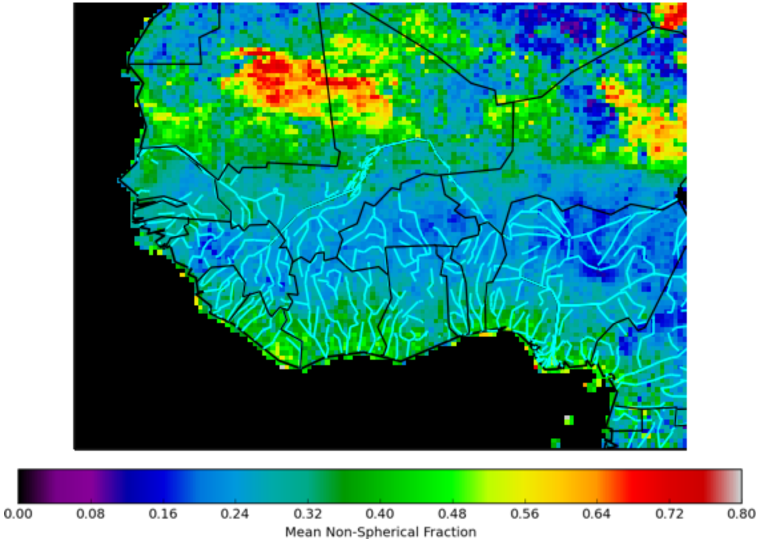


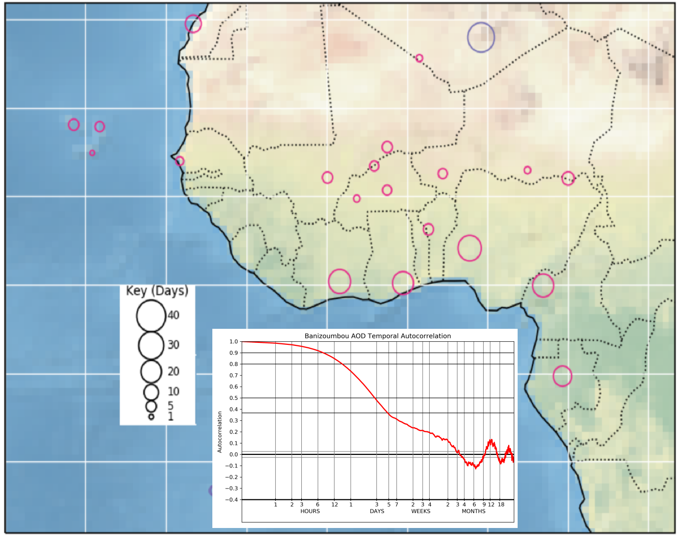

- During the Harmattan season, AOD in the region primarily comes from dust particles
- Greater composition of AOD from organic carbon for locations farther south from the Sahel Desert (Ilorin is farther south than Ouagadougou)

# Initial Results: Temporal Variability of Dust AOD

Mean MISR Non-Spherical Fraction




AERONET Autocorrelation Time




- Non-spherical fraction from multi-year MISR satellite observations, the northern part of Burkina Faso is more affected by dust transport from the Sahara
- Temporal autocorrelation time scale for AOD based on ground-based AERONET data – note that the autocorrelation time is shorter in Burkina Faso compared to the more coastal regions indicating the effects of dust

# Next steps:

- AOD climatology assembled in Year 1, together with MIT-collected ground-based measurements of surface dust accumulation on PV panels will be used to develop the PSGIM tool.
- The PSGIM tool will be used to determine the net impact of different factors on regional PV solar energy generation in Burkina Faso.
- The difference between traditional estimates for solar insolation in the region will be contrasted with our estimates that adequately account for regional dust deposition on deployed panels.

**Danielle Wood:** Director of the Space Enabled Research Group and Assistant Professor, MIT Media Lab; Assistant Professor, MIT Department of Aeronautics and Astronautics; previously served as the Applied Sciences Manager in the Earth Science Division of GSFC; has expertise in designing complex systems models to quantify properties of satellite systems.

**Stewart Isaacs***:* graduate student pursuing a PhD in Aeronautics and Astronautics at MIT; voice of African-American Students expressing concerns regarding solar energy utilization in the developing countries of Africa; works with colleagues in Burkina Faso who operate PV solar energy systems, and will leverage the MIT-Africa program to perform field work in Burkina Faso.

***Value of collaboration:*** *The JPL-MIT collaboration provides a unique opportunity to apply JPL's satellite aerosol datasets to support policy, and allow technology creators to design effective interventions towards increasing energy access in northern and western Africa.*

Locations of minimal aerosol interference will be identified for policymakers.

# Publications and References

Booth, S., Li, X., Baring-Gould, I., Kollanyi, D., Bharadwaj, A., & Weston, P. (2018). *Productive Use of Energy in African Micro-Grids: Technical and Business Considerations* (NREL/TP-7A40-71663, 1465661; p. NREL/TP-7A40-71663, 1465661). https://doi.org/10.2172/1465661

Ineichen, P. (2018). High Turbidity Solis Clear Sky Model: Development and Validation. *Remote Sensing*, *10*(3), 435. https://doi.org/10.3390/rs10030435

Joseph, C., & Wood, D. (2019). Understanding Socio-Technical Issues Affecting the Current Microgravity Research Marketplace. 2019 IEEE Aerospace Conference, 1–10. https://doi.org/10.1109/AERO.2019.8742202

Pfotenhauer, S. M., Wood, D., Roos, D., & Newman, D. (2016). Architecting complex international science, technology and innovation partnerships (CISTIPs): A study of four global MIT collaborations. Technological Forecasting and Social Change, 104, 38–56. https://doi.org/10.1016/j.techfore.2015.12.006

In preparation: Stewart Isaacs, Olga.V Kalashnikova, Michael J. Garay, and Danielle Wood, “Assessing aerosol measurements from MISR and MERRA-2 for modeling productive-use of solar energy in West Africa”, to be submitted Remote Sensing