Westervelt group at LDEO and UM6P: activities on air quality and climate in Africa

Prof. Daniel M. Westervelt[1,2]

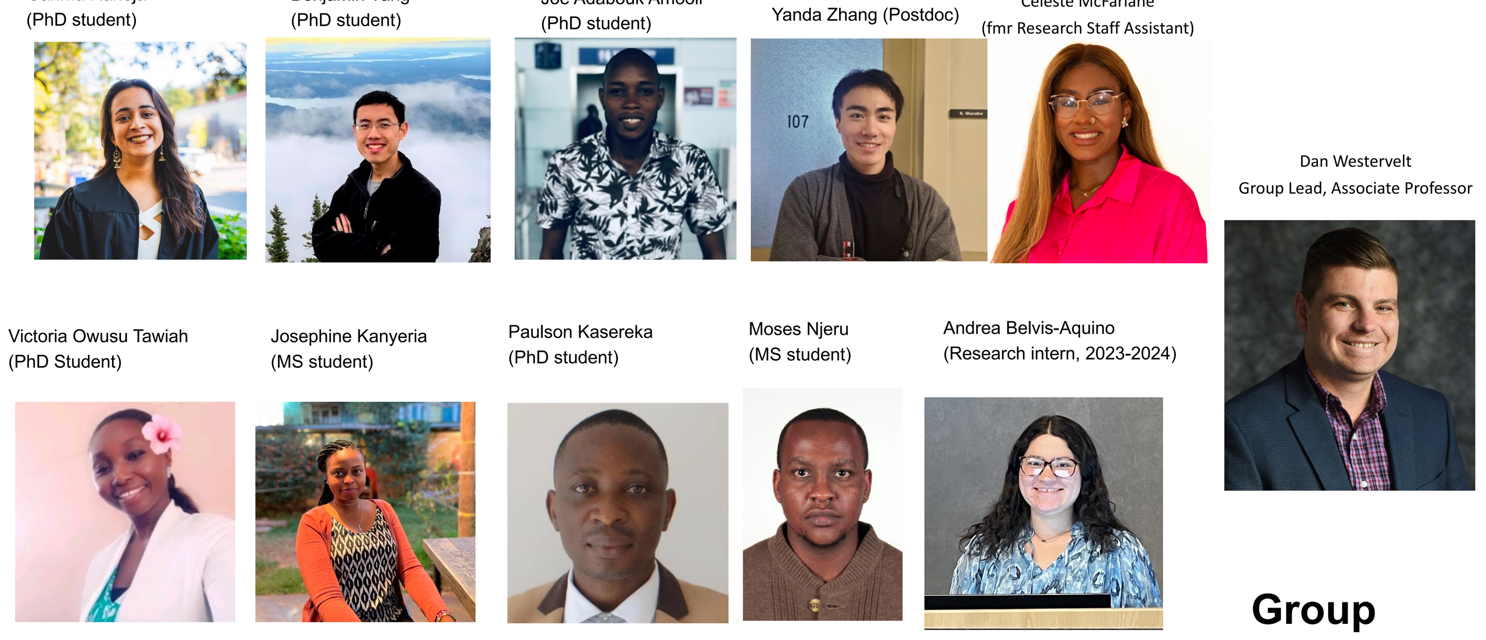
[1]Lamont-Doherty Earth Observatory, Columbia University, New York, USA (Associate Professor)

2. University of Mohammed VI Polytechnic, Benguerir, Morocco (Affiliate Professor)

UM6P University Mohammed VI Polytechnic

1. Introduction to our group

PEOPLE



Group Website

FUNDING SOURCES

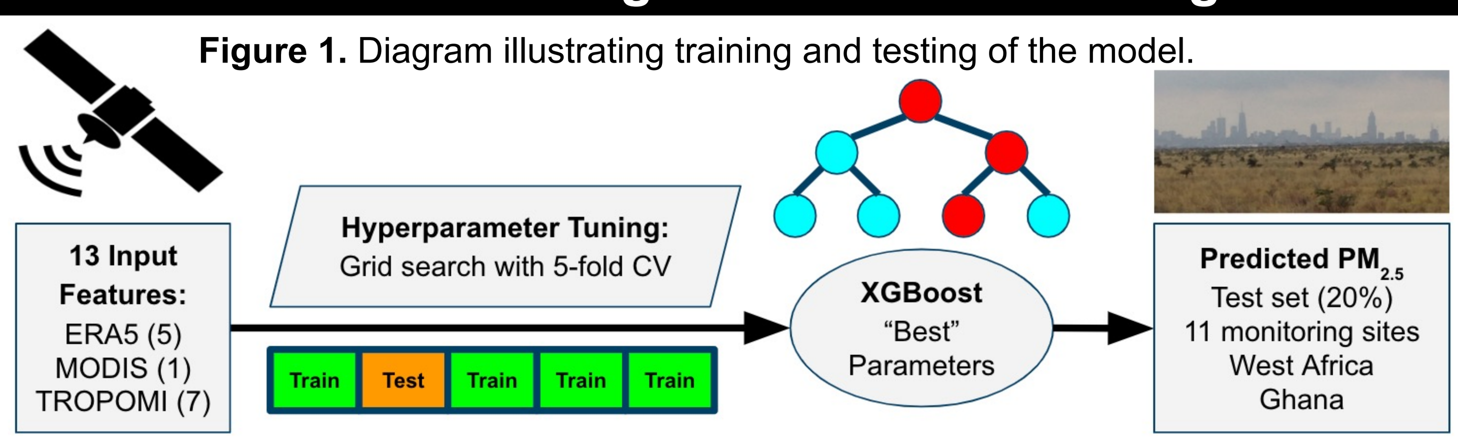
NSF · CLEAN AIR FUND · Columbia University Data Science Institute

MAJOR RESEARCH FOCUSES

- Air pollution, low-cost sensors, research-grade instrumentation, chemical transport modeling, climate modeling, remote sensing, atmospheric chemistry

2. High resolution estimates of PM2.5 in Africa using remote sening and machine learning

Figure 1. Diagram illustrating training and testing of the model.



- Used **13 input features from satellite** to predict daily mean $PM_{2.5}$ by training an XGBoost model with surface observations in Africa
- Incorporating trace gas columns improved $PM_{2.5}$ model estimates here as it did in Zheng et al. (2023) which focused on India.

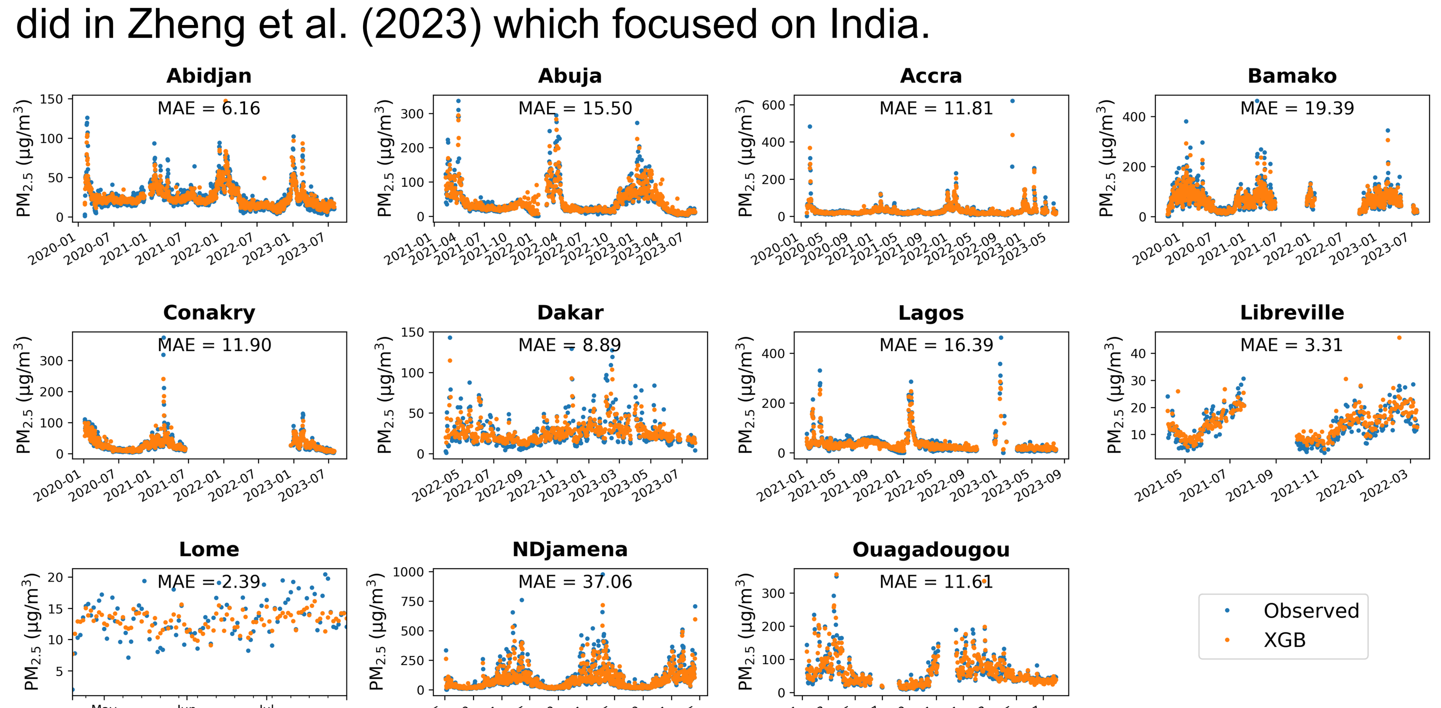


Figure 2. Comparing modeled (orange) and observed (blue) daily mean $PM_{2.5}$ at each reference-grade monitoring site (R^2 ~ 0.8)

- We are leveraging calibrated air sensors for a Ghana-specific model which are expected to improve $PM_{2.5}$ estimates and help us to conduct epidemiological, policy, and environmental justice studies.

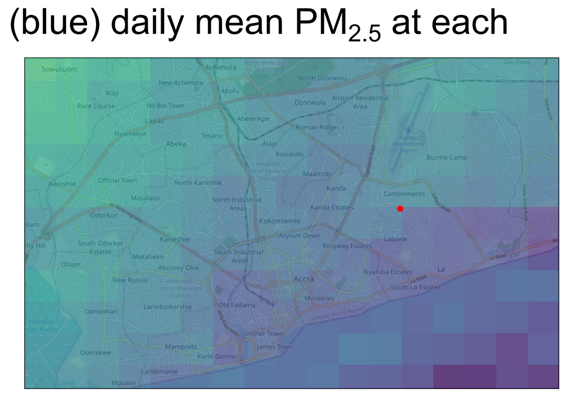


Figure 3. Maps of annual mean $PM_{2.5}$ **(Accra)**

3. Surface air quality monitoring in Africa

- We have pioneered efforts at using hybrid networks of air sensors and reference monitors for PM2.5 and other pollutants for applications such as:
  - Correction factor development
  - Source attribution
  - WHO or National guidelines exceedances
  - Program evaluation of clean air interventions

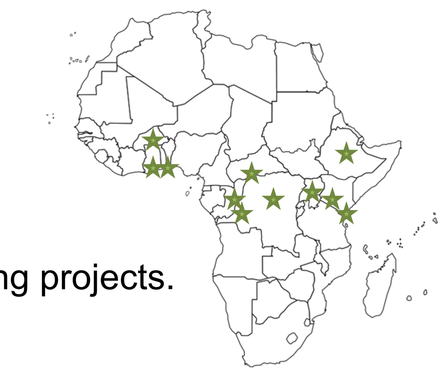
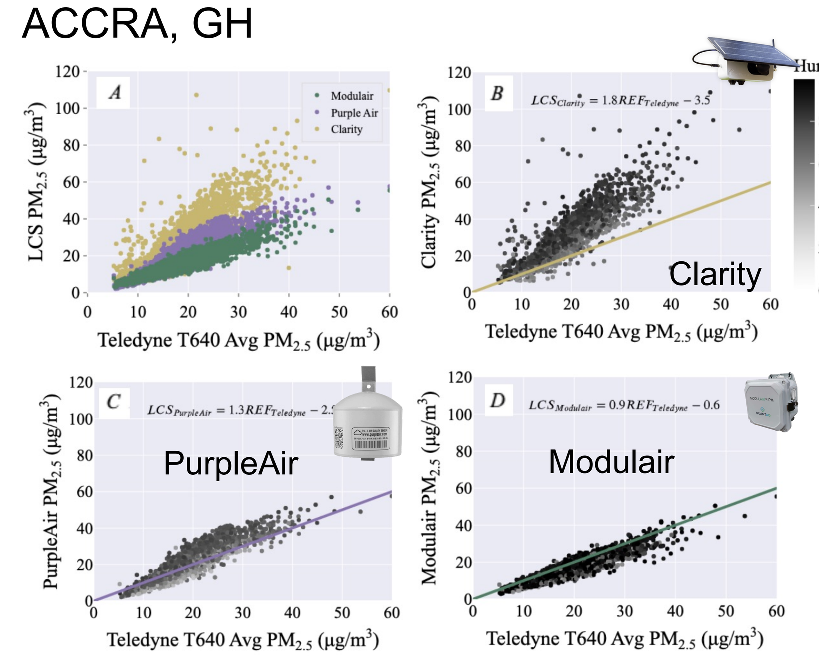


Figure 4. Active air monitoring projects.

ACCRA, GH



Low-Cost Sensor Performance Intercomparison, Correction Factor Development, and 2+ Years of Ambient $PM_{2.5}$ Monitoring in Accra, Ghana

Garima Raheja*, James Nimo, Emmanuel K.-E. Appoh, Benjamin Essien, Maxwell Sunu, John Nyante, Mawuli Amegah, Reginald Quansah, Raphael E. Arku, Stefani L. Penn, Michael R. Giordano, Zhonghua Zheng, Darby Jack, Steven Chillrud, Kofi Amegah, R. Subramanian, Robert Pinder, Ebenezer Appah-Sampong, Esi Nerquaye Tetteh, Mathias A. Borketey, Allison Felix Hughes, and Daniel M. Westervelt*

AFRI-SET

- Performance of sensors and development of correction factors in Accra

Figure 5. Clarity, PurpleAir, and QuantAQ air sensors versus Reference Teledyne T640 in Accra.

KINSHASA, DRC – SOURCE ATTRIBUTION USING PARTICLE AND GAS SENSORS AND NMF

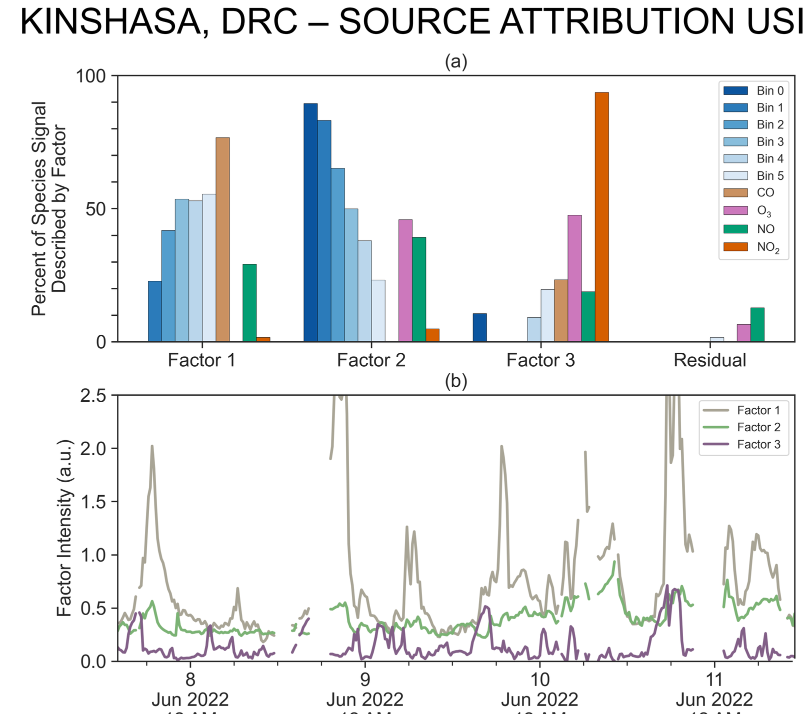


Figure 6. Non-negative matrix factorization decomposition for source attribution in Kinshasa

- Factor 1
  - CO-dominated, with some influence from larger particles
  - Diurnal cycle with peaks 6am and 6pm
  - Influence from larger particles suggests some aging
  - **Local combustion secondary particles (vehicles, cooking)**
- Factor 2
  - Particle-dominated (especially accumulation mode)
  - **Local combustion primary particles (e.g. BC from small fires, cooking)**
- Factor 3
  - NO_2 dominated, unique diurnal cycle
  - **Regional sources, biomass burning**

Low-Cost Investigation into Sources of $PM_{2.5}$ in Kinshasa, Democratic Republic of the Congo

Daniel M. Westervelt*, Paulson Kasereka Isevulambire, Rodriguez Yombo Phaka, Laura H. Yang, Garima Raheja, George Milly, Jean-Luc Balogije Selenge, Jean Pierre Mfuamba Mulumba, Dimitrios Bousiotis, Buenimio Lomami Djibi, V. Faye McNeill, Nga L. Ng, Francis Pope, Guillaume Kiyombo Mbela, and Joel Nkiama Konde

First Measurements of Ambient PM2.5 in Kinshasa, Democratic Republic of Congo and Brazzaville, Republic of Congo Using Field-calibrated Low-cost Sensors

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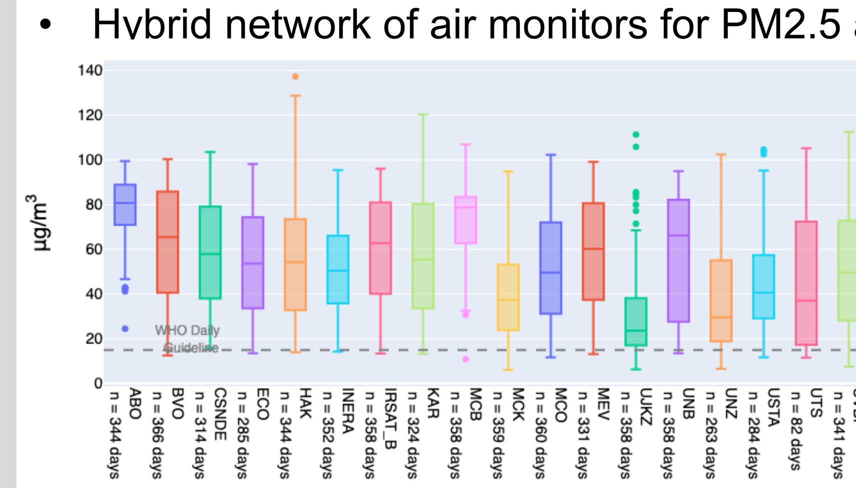
OUAGADOUGOU, BURKINA FASO:

- Hybrid network of air monitors for PM2.5 and comparison against WHO guidelines



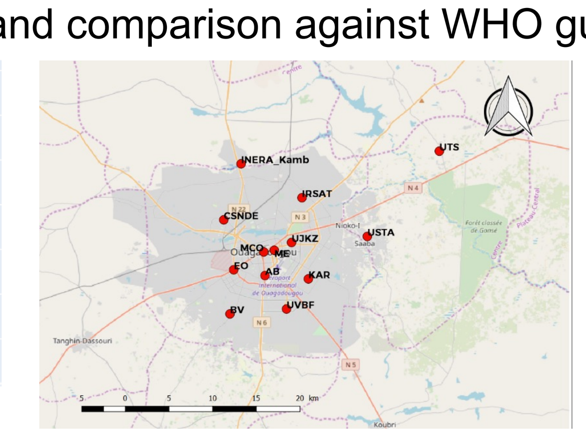


Figure 7: Ouagadougou air quality monitoring network

NAIROBI, KENYA: NOx, O3, and PM monitoring in a traffic-impacted urban area (**Nairobi AQ Supersite**)

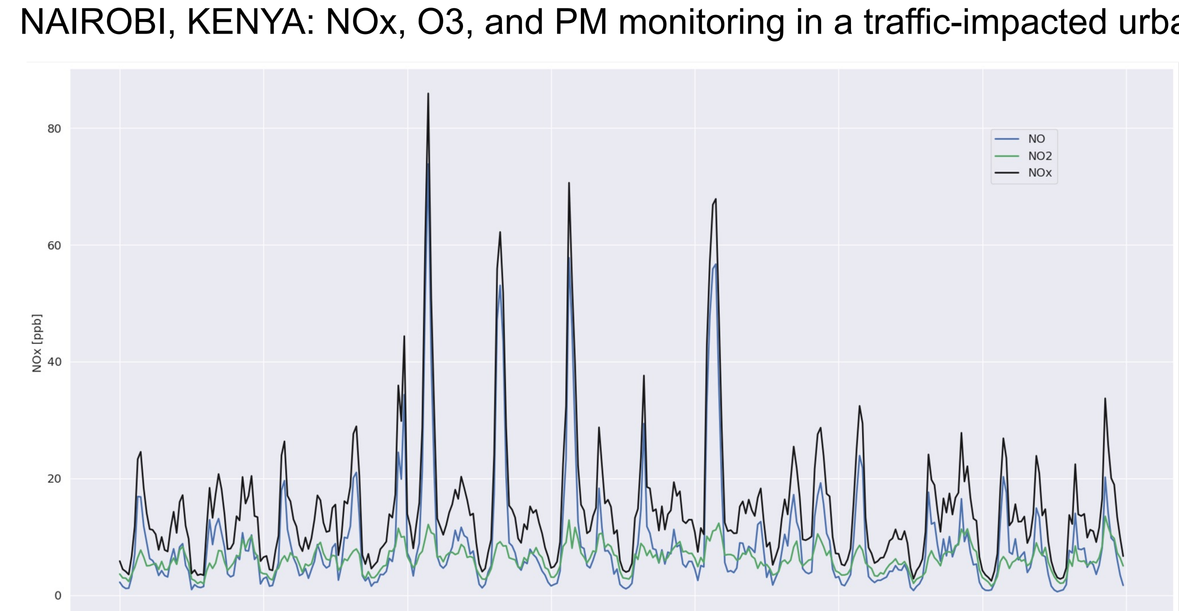


Figure 8: NOx monitoring with chemilumisence NOx analyzer in CBD, Nairobi, Kenya

5. Climate and air quality modeling

- Climate and air quality response to rapidly changing African anthropogenic aerosol emissions

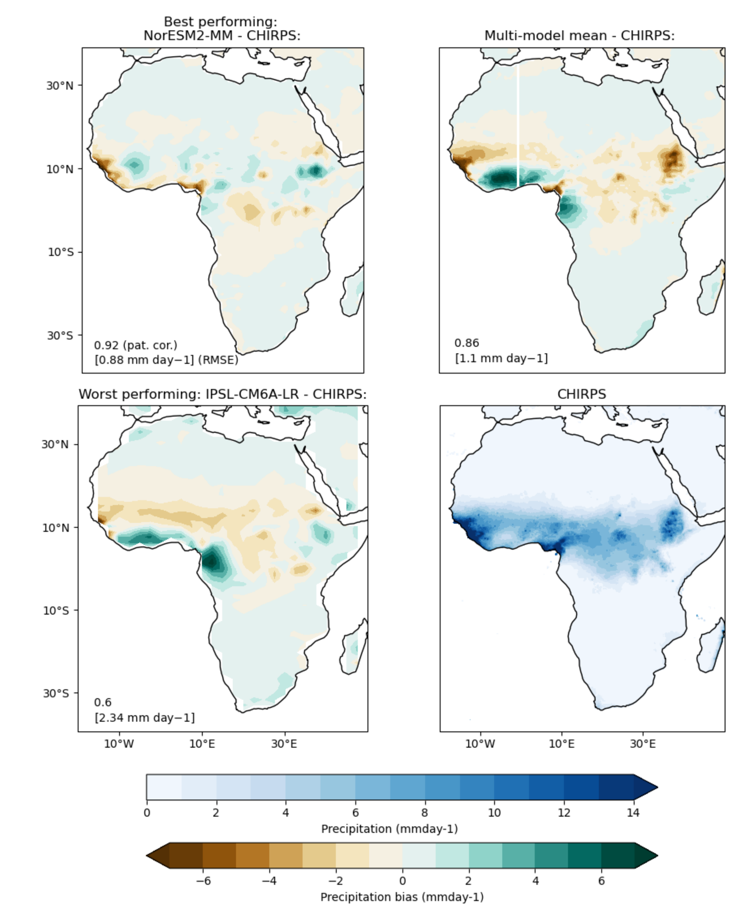
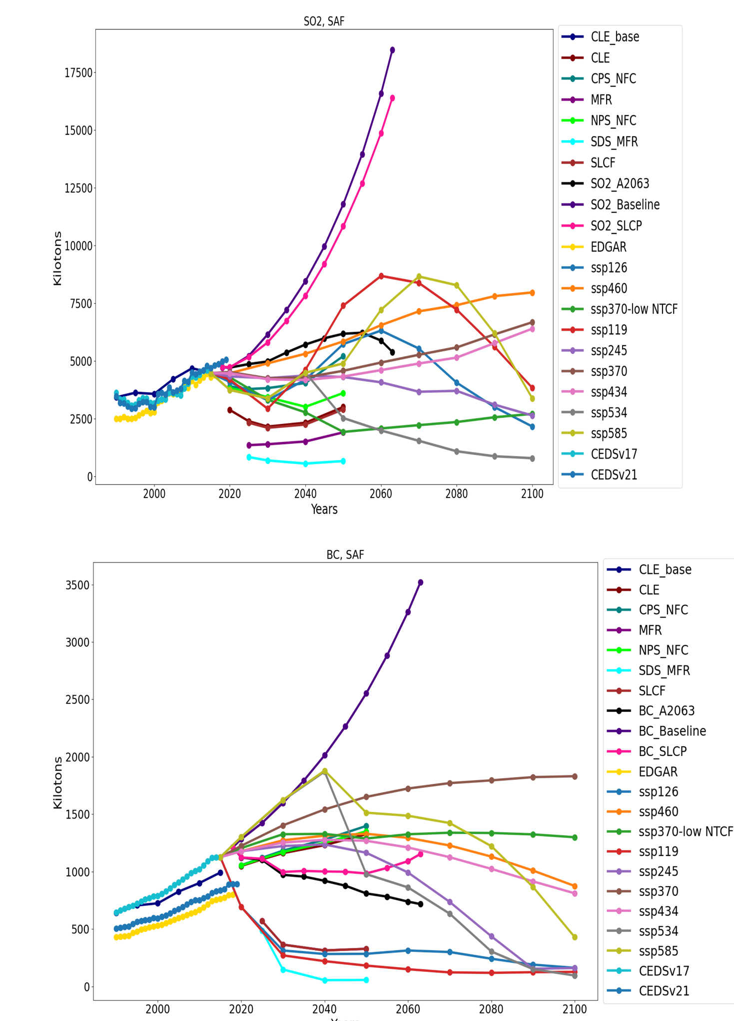


Figure 9 (left): Precipitation model bias in CMIP6 models (from Toolan et al., 2024, in progress)

Figure 10 (right): Emissions inventories used in global climate models for BC and SO2 over Africa



The Regional Aerosol Model Intercomparison Project (RAMIP)

Laura J. Wilcox, Robert J. Allen, Bjørn H. Samset, Massimo A. Bollasina, Paul T. Griffiths, James Keeble, Marianne T. Lund, Risto Makkonen, Joonas Merikanto, Declan O'Donnell, David J. Paynter, Geeta G. Persad, Steven T. Rumbold, Toshihiko Takemura, Kostas Tsigaridis, Sabine Undorf, and Daniel M. Westervelt

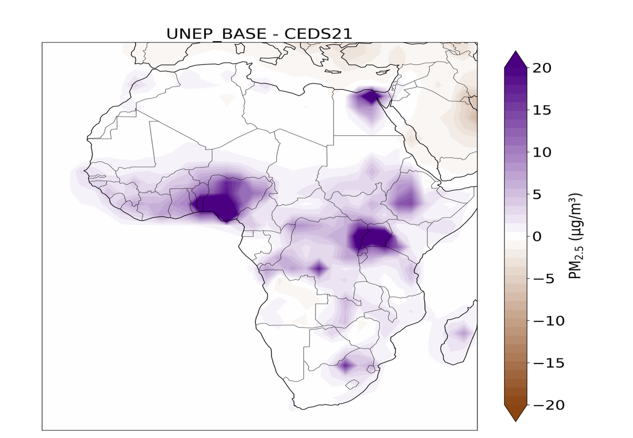


Figure 11: 2050 minus 2010 PM2.5 concentrations in Africa from a high emissions scenario (UNEP)

Perturbation = ssp370-126aer – ssp370 (low aerosol – high aerosol) Aerosols changing globally

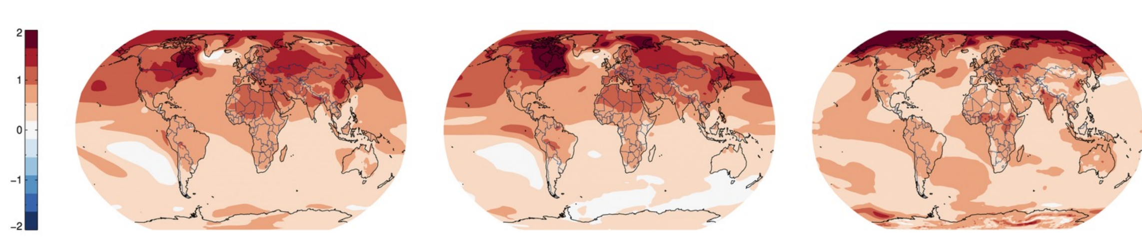


Figure 12: CESM2 (left), NorESM2 (middle), and UKESM (right) surface temperature response to a low future aerosol emissions case versus a high emissions case

6. Capacity Building and Knowledge Sharing

- Certificate programs, seminars, scholar exchanges, air quality management plan development

Project Lead, Kenya Dr. Godwin Opinde Kenyatta University, local champion

"US DOS funded air quality project that has led to increased awareness in air quality management and caused research interest/conversations in this subject area among Academia, policy makers, regulators, Non Governmental Organizations and students in East Africa."

"The project has enhanced collaboration between Kenyatta University and its partners such as Nairobi County City Government, National Environmental Authority, Jomo Kenyatta University of agriculture and Technology, the University of Nairobi and Makerere University AirQo".