Air quality in Africa research at Columbia University

Prof. Dan Westervelt, Celeste McFarlane
Congo-Kinshasa: Paulson Kasereka Isevulambire, Dr. Raymond Sinsi Lumbuenamo
Congo-Brazzaville: Arnold Murphy Elouma Ndinga
Kampala: AirQo Team
Lomé: Prof. Sabi Kokou
Accra: Prof Alison Hughes, Dr. Emmanuel Appoh
Nairobi: Prof. Michael Gatari, Prof. Godwin Opinde, Prof. Paul Njogu
USA: R Subramanian, Mike Giordano, V. Faye McNeill, Albert Presto, Randall Martin
Many others…

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Westervelt group

Celeste McFarlane (CU undergrad)

Garima Raheja (PhD student)

Funding:
US Dept of State
National Science Foundation
Columbia University Center for Climate and Life
USAID

https://www.nsf.gov/awardsearch/showAward?AWD_ID=2020677&HistoricalAwards=false

Accelerating Research through International Network-to-Network Collaborations (AccelNet)

A global network for getting useful, actionable data out of low cost sensors

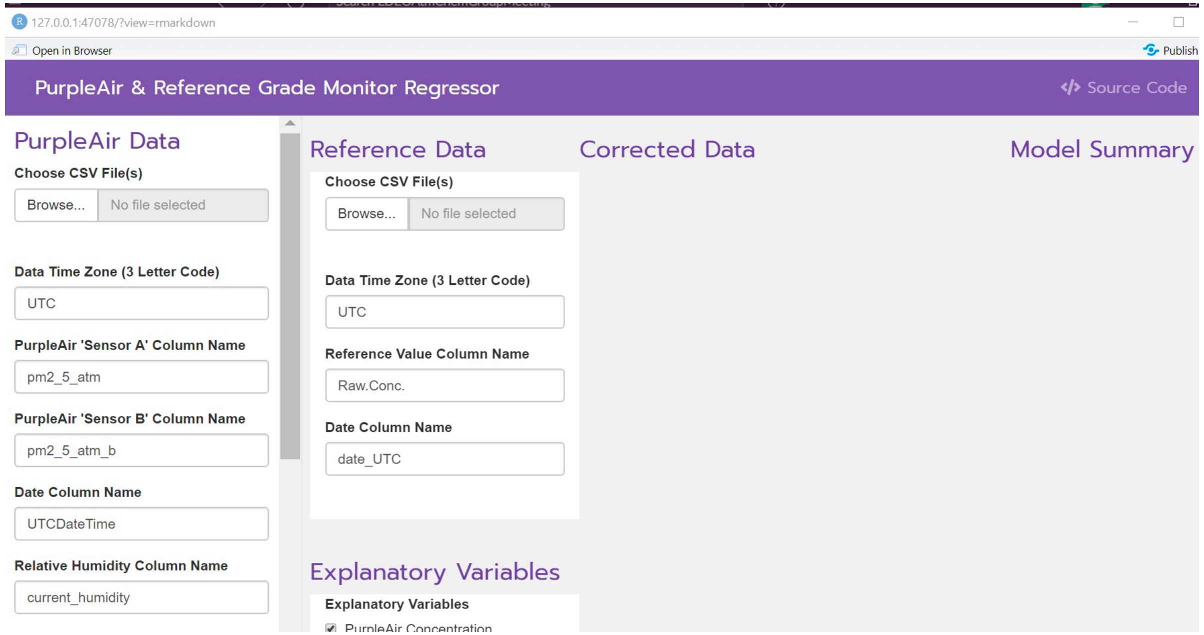
- Clean Air Monitoring and Solutions network (CAMS-Net)

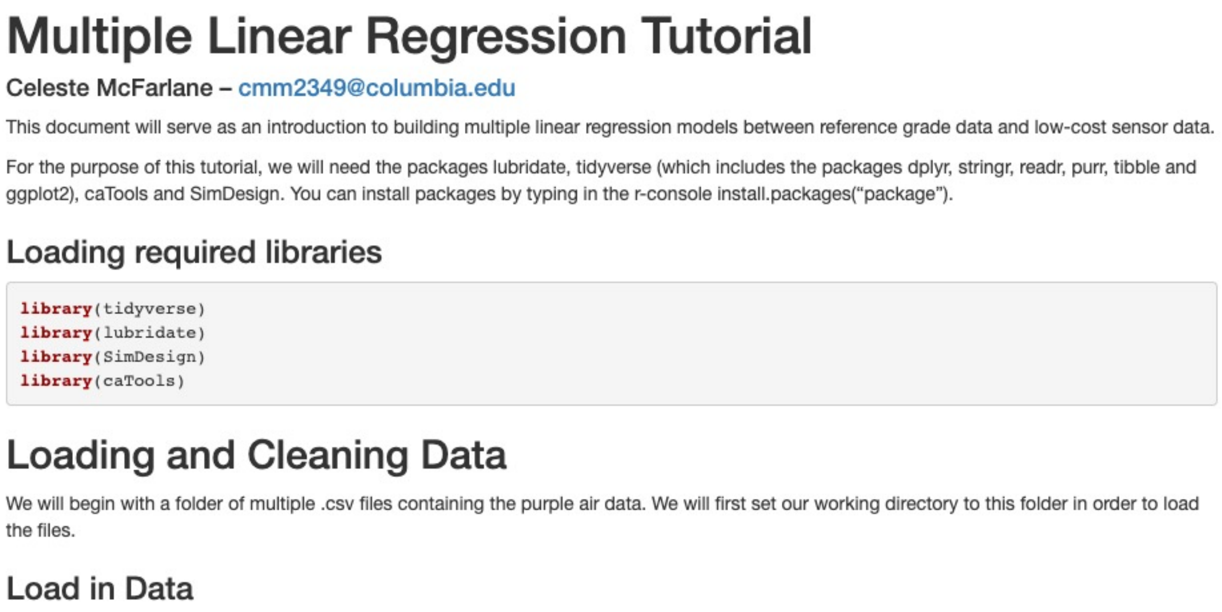
- Create an international network of networks that provides a forum for exchange of knowledge, ideas, and data among scientists, decision-makers, citizen groups, the private sector, and other stakeholders towards the goal of improved usage and application of low-cost sensor (LCS) data for air quality

- Getting useful, actionable data out of LCS and exploring uses of this data for air quality modeling, satellite observations, policy recommendations, and health studies

Clean Air Monitoring and Solutions Network (CAMS-Net)

- Website: www.camsnet.org
- To get involved, reach out to danielmw@ldeo.columbia.edu
- Example outputs from project: Tutorial on Multiple Linear Regression for air quality colocation study in R



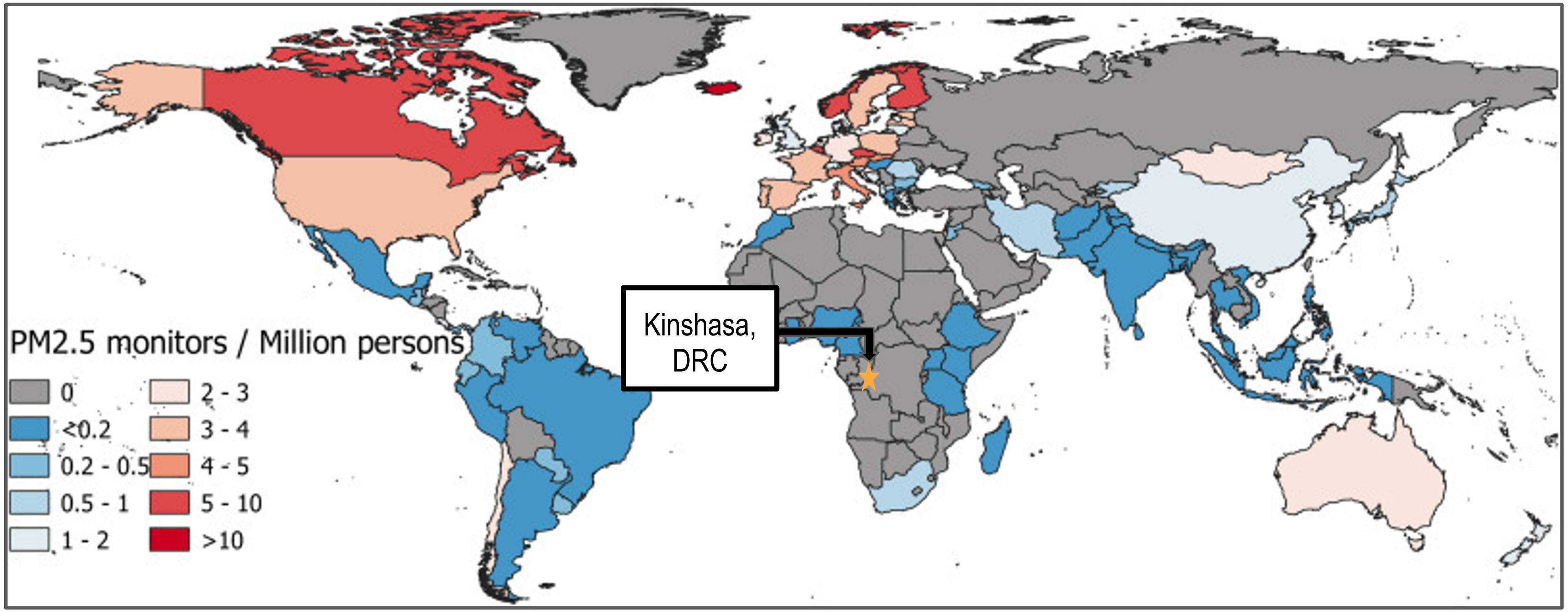


International Networking, Knowledge Sharing, and Capacity Building for Improved Air Quality in East Africa

- Scope of project is East Africa
  - Kenya, Uganda, Rwanda, Ethiopia
- Co-develop and co-implement an air quality management certificate program in at least one local university in each country
  - University of Nairobi, Kenyatta University, JKUAT, CMU-Africa, Addis Ababa University, Makerere University, others
  - Online in July 2021, in person soon after
  - Register here: https://camsnet.org/air-quality-in-east-africa-certificate-program/
- Co-develop and co-implement an air quality management plan
  - City governments and environmental protection agencies are involved in the project
- A locally owned air monitoring network for Mombasa, Kenya
  - LCS deployments in July 2021
  - BAM-1022 in Fall 2021
- With Prof. Solomon Bililign at NCAT

ECOTECH NOx analyzer

Air pollution data is sparse globally

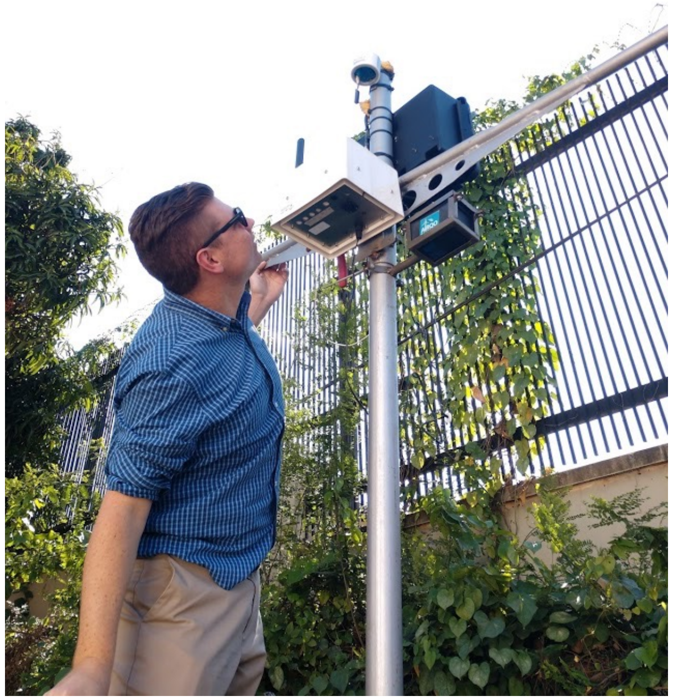


Martin et al. (2019)

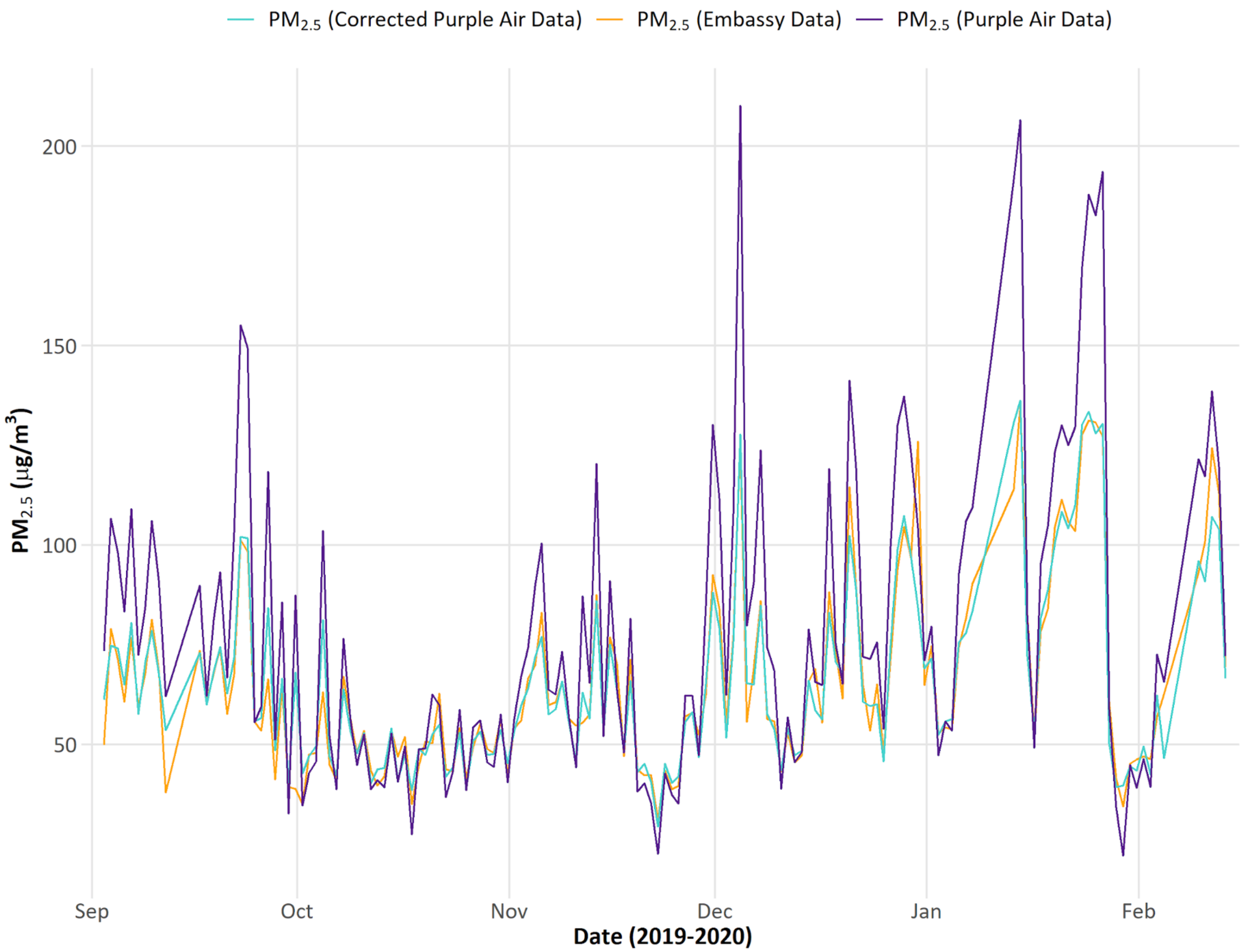
- Kinshasa: population 14.3 million; Brazzaville: population 2.4 million
- No ambient air quality monitoring to date
- We deployed and calibrated a small network of 5 low cost air quality sensors starting in 2018, covering both cities

Kampala, Uganda

- Co-location of a PurpleAir at US Embassy starting in September 2019
- Several other sensor groups also co-located



Co-located Sensors Produce High Accuracy Model



- Multiple Linear Regression following the method of Malings et al. (2019)
- 75/25 training/test data split

$$PM_{2.5} = \beta_0 + \beta_1 \times purpleairPM_{2.5} + \beta_2 \times T(°C) + \beta_3 \times RH(\%)$$

$$PM_{2.5} = 64.7 + 0.52*[PurpleAirPM_{2.5}] - 0.234*[T] - 0.59*[RH]$$

McFarlane et al. (2021)

Kampala colocation (Sep 2019 – Mar 2020)

$PM_{2.5}^* = 64.7 + 0.52*purpleairPM_{2.5} - 0.234*T(°C) - 0.59*RH(\%)$

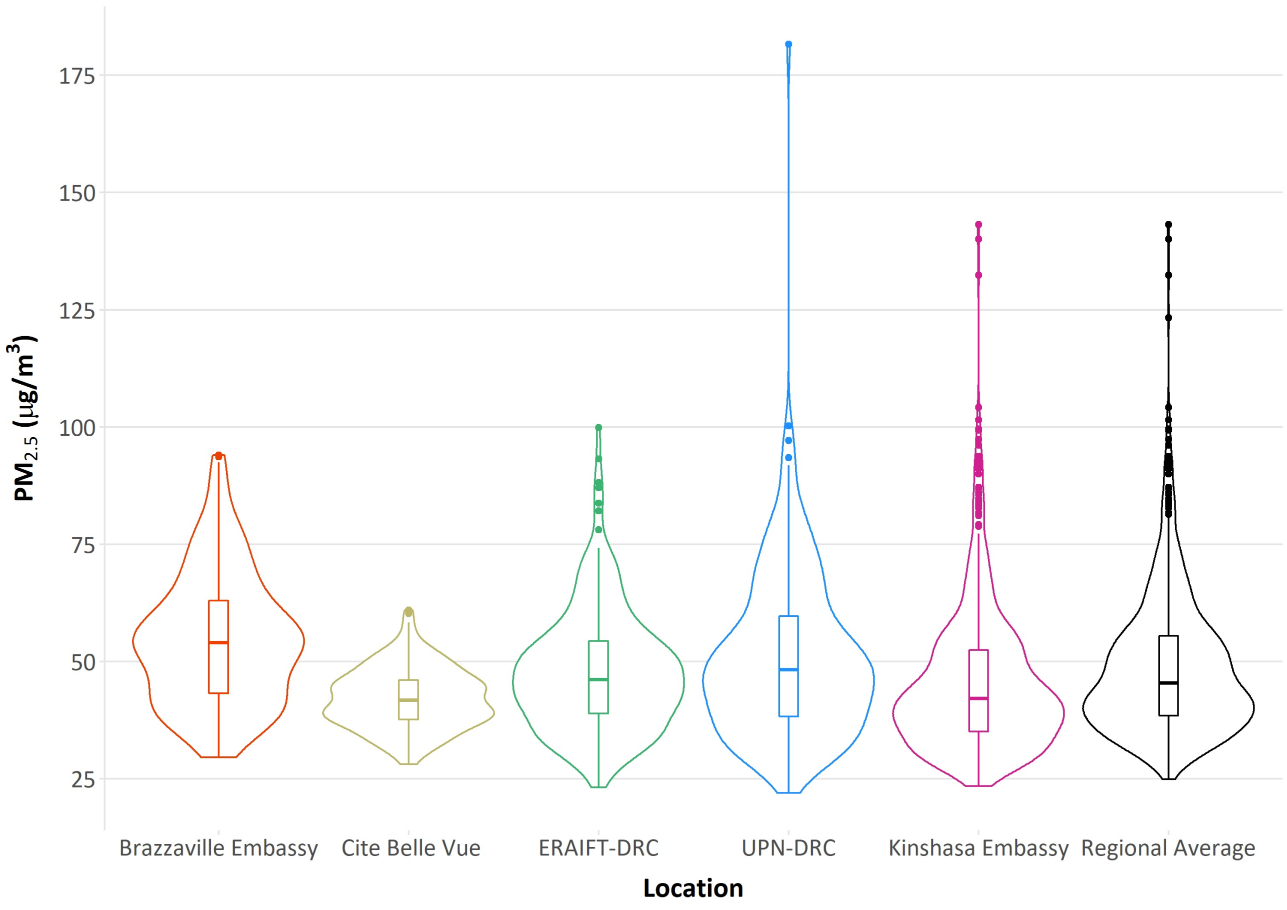
Model	**Averaging time period**	**R^2**	**MAE ($\mu g/m^3$)**
Raw PurpleAir Data	Daily	0.88	14.8
	Hourly	0.88	20.3
Multiple Linear Regression*	Daily	0.96	3.4
	Hourly	0.90	7.3
Random Forest	Daily	0.86	5.8
	Hourly	0.91	7.2

Five Low-Cost Sensors Deployed in Kinshasa, DRC and Brazzaville ROC

1. Kinshasa US Embassy, March 2018
2. Cite Belle Vue Compound, November 2019
3. Brazzaville US Embassy, February 2020
4. L'Ecole Régionale Postuniversitaire d'Aménagement et de Gestion intégrés des Forêts et Territoires tropicaux (ERAIFT), November 2019
5. L'université Pédagogique Nationale, November 2019

McFarlane et al. (2021)

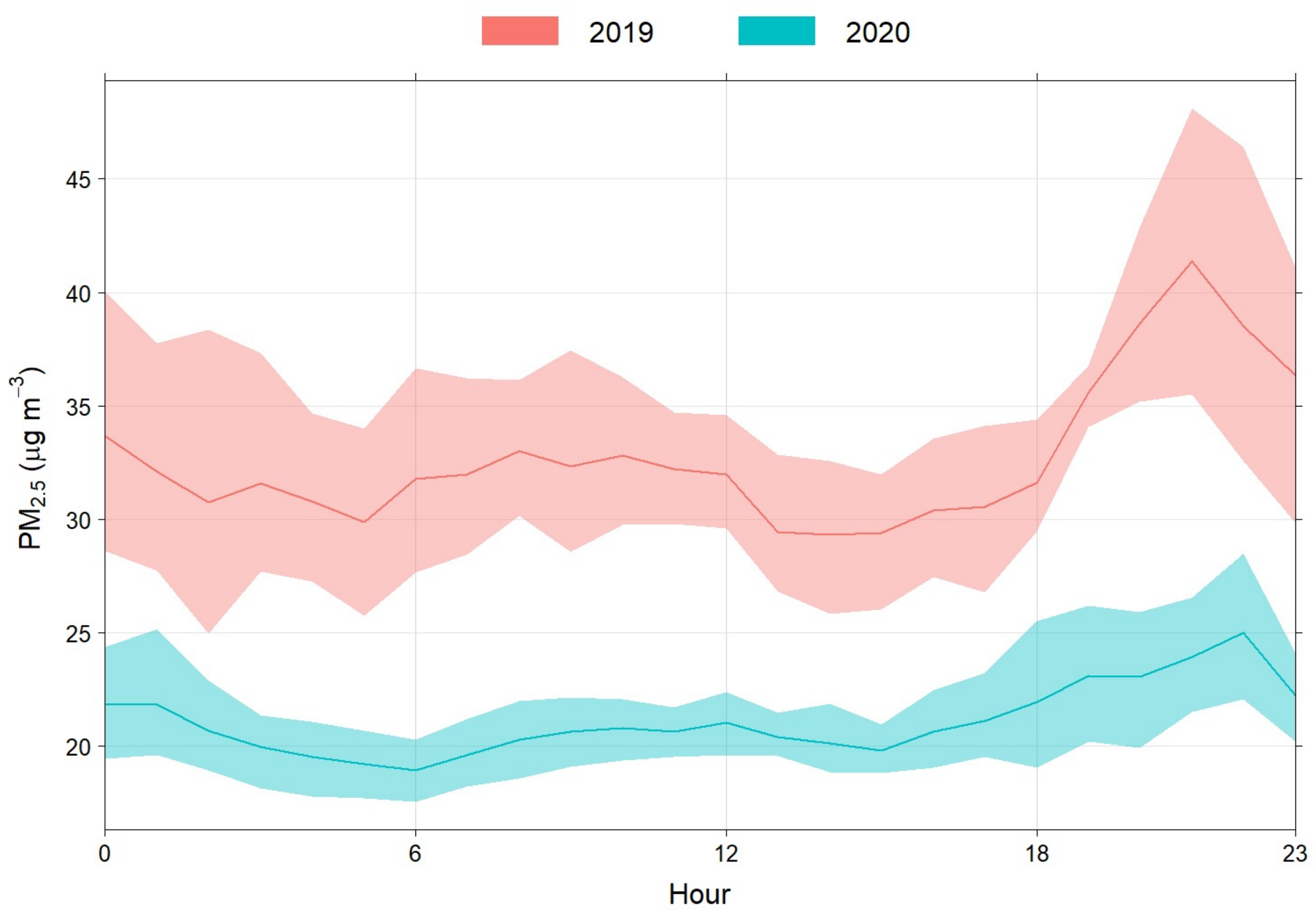
Median Daily $PM_{2.5}$ Values are Quadruple the WHO Annual Mean Guideline



- 5-site average median daily $PM_{2.5}$ value is 42 µg m^{-3}
- Highest median and quartile ranges located at UPN-DRC and Brazzaville Embassy
- Excluding CBV, "long tails" with nonzero density near 100 µg m^{-3}, indicate a high frequency of poor air quality
- Discrepancies can be described by variation in location type (residential vs educational vs diplomatic)

McFarlane et al. (2021)

COVID19 Lockdown Lowers Mean Hourly $PM_{2.5}$ By 15 µg m^{-3}



- Evening $PM_{2.5}$ peak from 2019 flattened in 2020
- Average and maximum hourly $PM_{2.5}$ increased between April 2018 & 2019
  - 32.18 vs 36 µg m^{-3} & 98.42 vs 103.5 µg m^{-3}
- Average and maximum hourly $PM_{2.5}$ decreased between April 2019 & 2020
  - 36 vs 21.28 µg m^{-3} & 98.42 vs 40.02 µg m^{-3}
- Similar decrease observed in 1-km aerosol optical depth data over the region

McFarlane et al. (2021)

Summary

- Air pollution data is sparse in Africa, though air quality seems to be poor. Several new projects involving capacity building and new research on LCS will aim to improve data quality and spur innovative solutions

- Deployed a 5 node LCS network in Kinshasa and Brazzaville, the first ever ambient air quality data in these cities

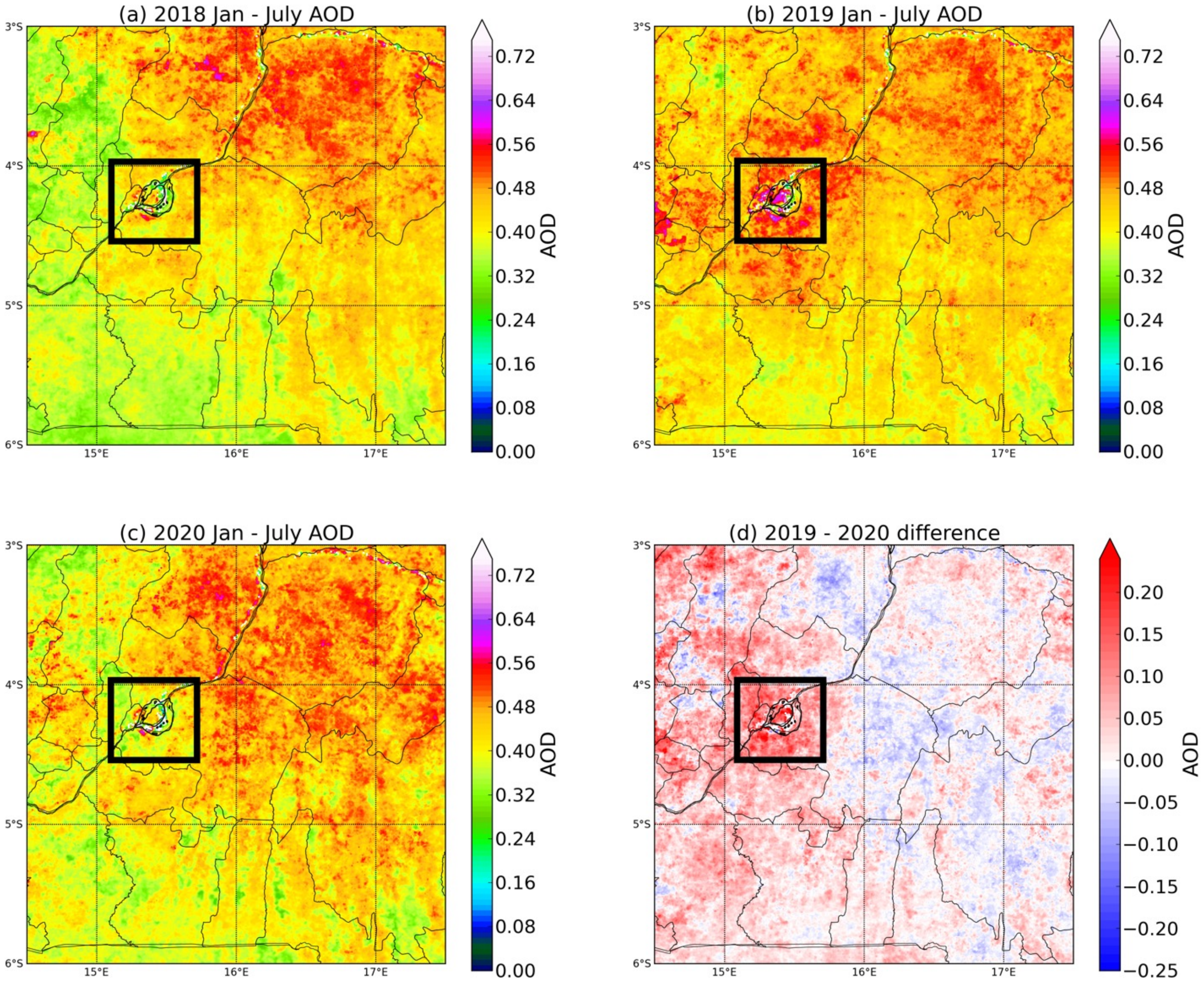
- Corrected towards FEM using surface-based calibrations from a collocation in Kampala using MLR
  - MAE reduced from 12 μg m^{-3} to close to zero

- PM2.5 in the Kinshasa area exceeds WHO guidelines by a factor of 4
  - Network wide mean of 45 μg m^{-3}

- COVID-19 restrictions lowered PM2.5 by about 15 μg m^{-3}

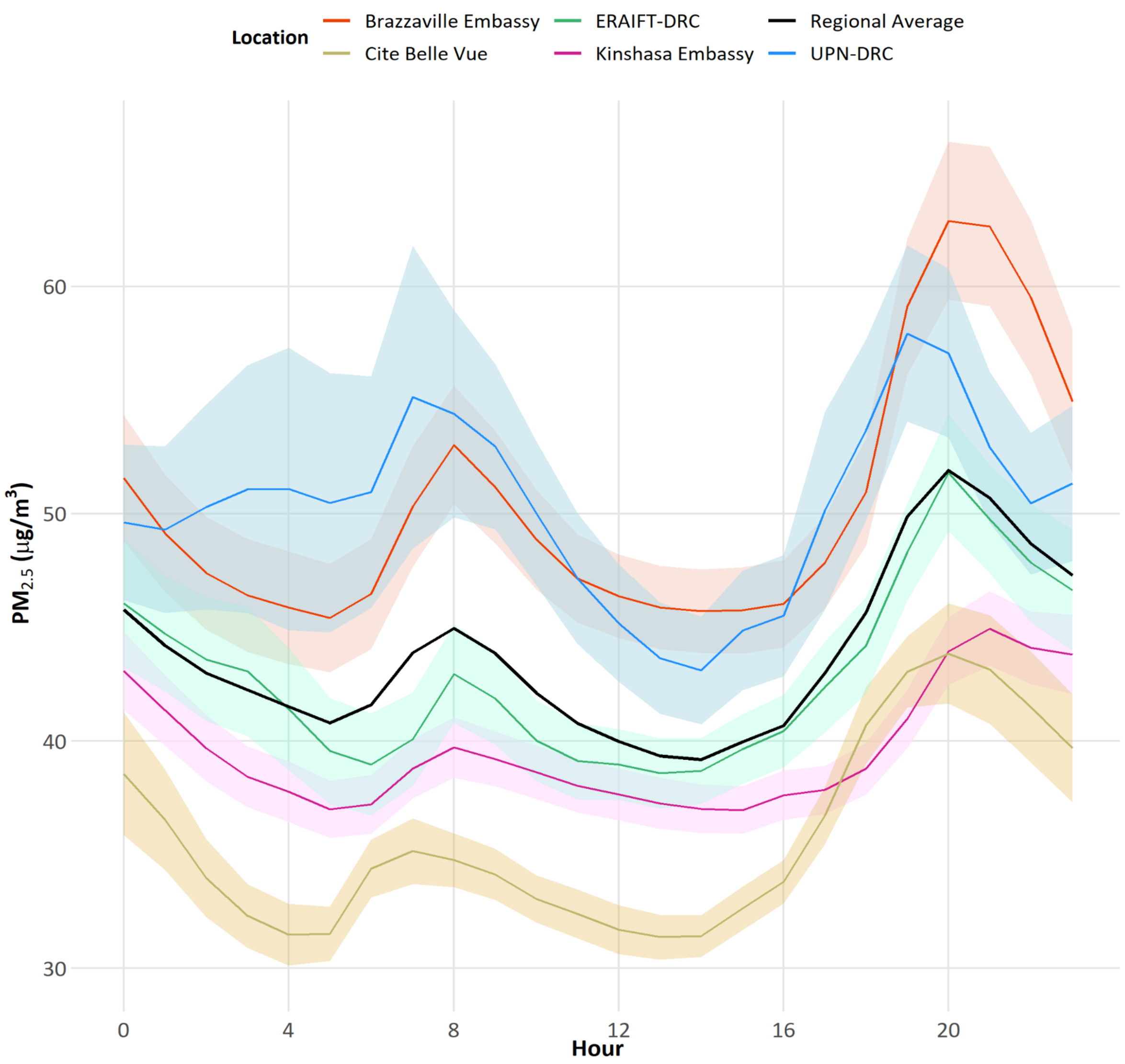
Extra slides

1-km Level 2 MAIAC AOD retrievals over Kinshasa



McFarlane et al. (2021)

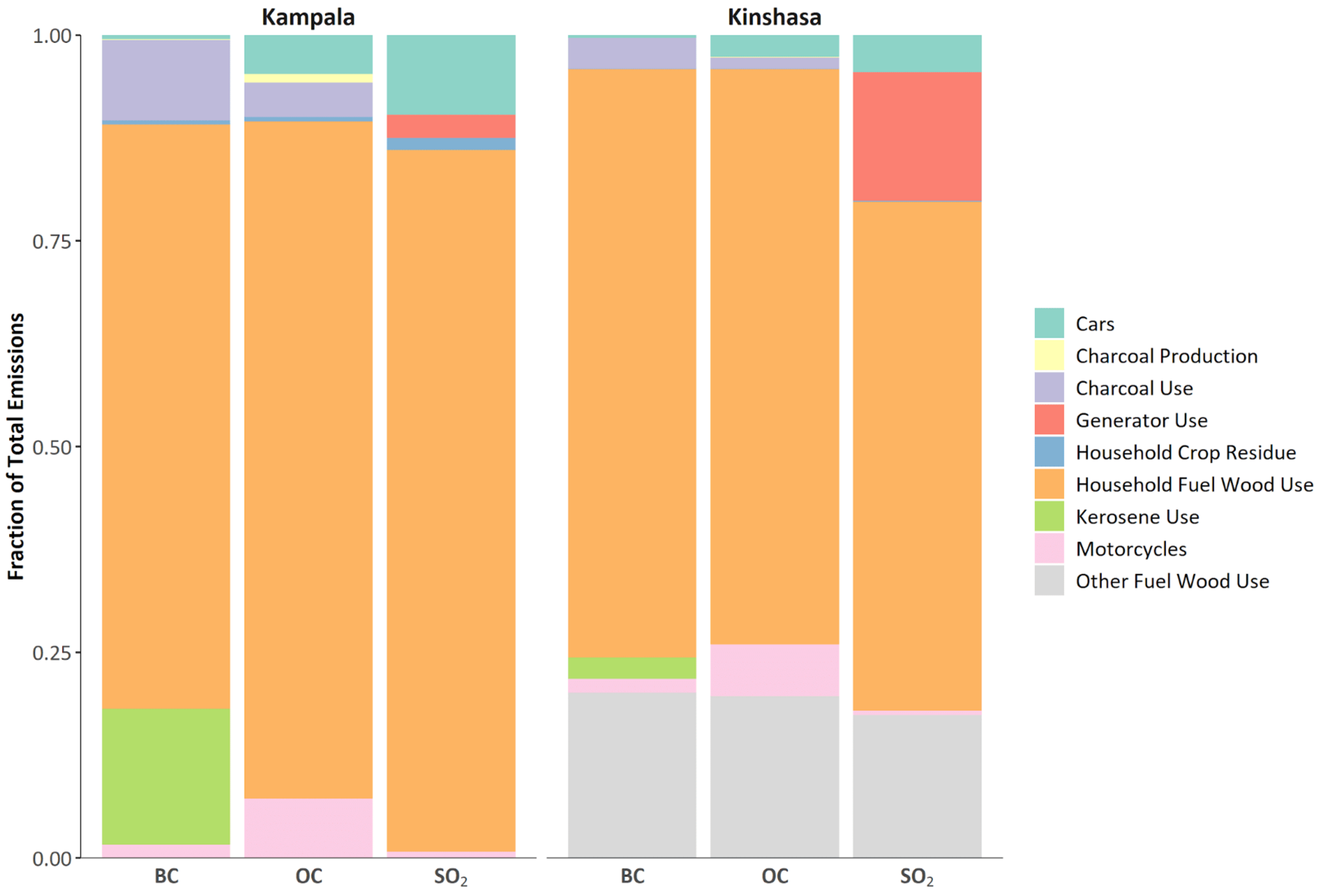
Diurnal Peaks Coincide With Evening Vehicle Traffic and Cooking



- Sites have similar diurnal $PM_{2.5}$ variability with varying $PM_{2.5}$ magnitude
- Morning and Evening peaks likely correlated with increase in traffic and also increased fire activity for cooking, waste burning, etc
- Highest $PM_{2.5}$ values occur at Brazzaville Embassy and UPN-DRC (≅ 60 µg m^{-3} peak in the evening)

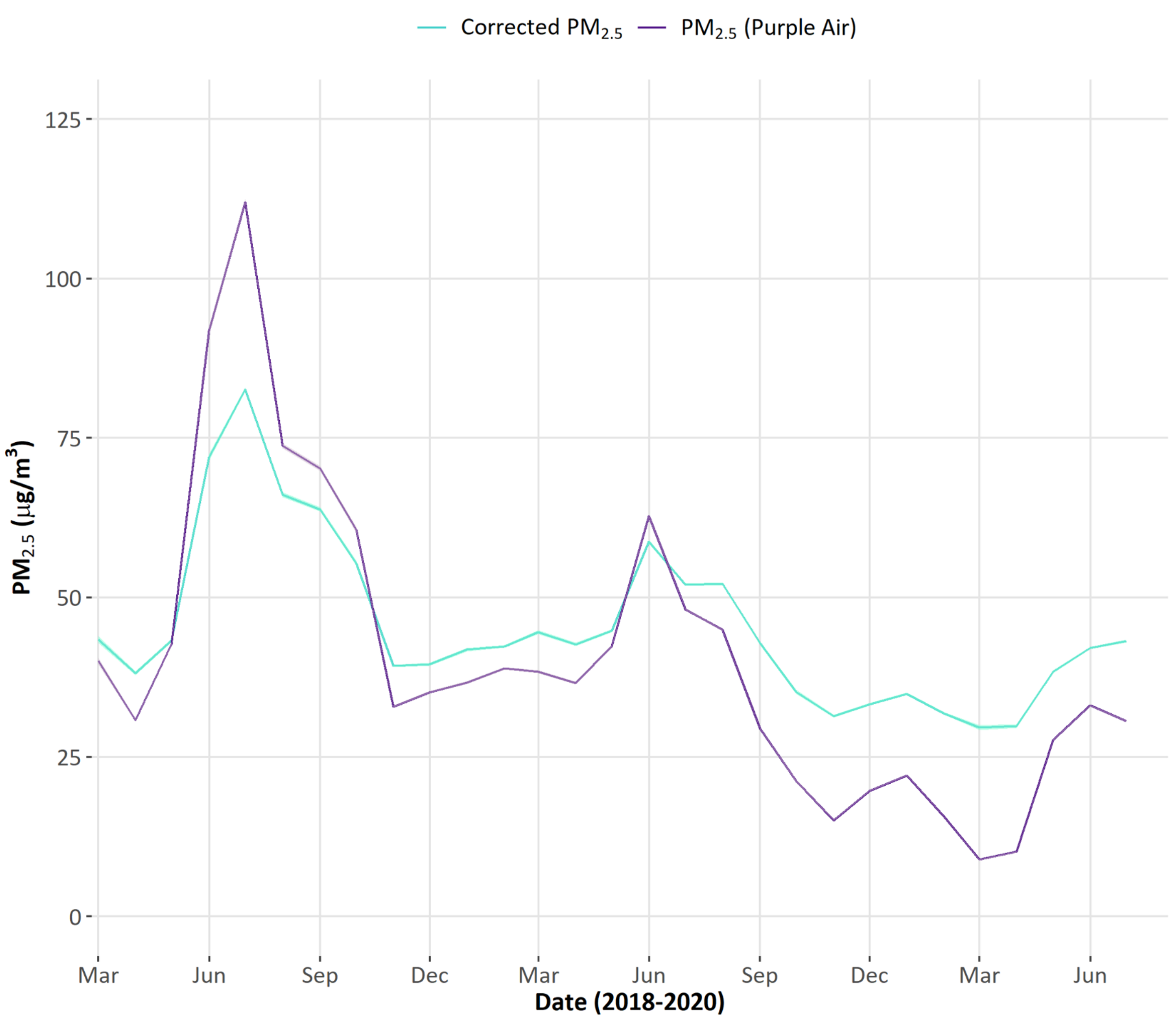
McFarlane et al. (2020)

Kampala and Kinshasa Have Similar Combustion Emission Profiles and are also similar climatologically



McFarlane et al. (2020)

Kinshasa Dry Season $PM_{2.5}$ Peaks are Decreasing Annually



- ≅10 μg m^{-3} difference in calibrated and raw data for $PM_{2.5}$ values between 25 μg m^{-3} and 100 μg m^{-3}
- Annual means of daily $PM_{2.5}$ decrease from 54.4 μg m^{-3} (2018) to 43.5 μg m^{-3} (2019) to 35.7 μg m^{-3} (through July 2020)
  - Meteorological differences do not explain decreases in $PM_{2.5}$
  - No known $PM_{2.5}$ emissions control measures in the last 3 years
  - Decreasing $PM_{2.5}$ values from 2019 to 2020 can be partially attributed to COVID19

McFarlane et al. (2020)