Estimation of hourly BC from BAM tapes using image reflectance-based method

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Objectives

- To develop a model to estimate BC from BAM tape spots.
- Define the method detection limit suitable to use in countries in the Global South.

What is black carbon (BC)!

- A dark carbonaceous substance with light absorbing property.
- Formed by incomplete combustion of fossil fuels, biofuel, or biomass
- Tracer for combustion sources.

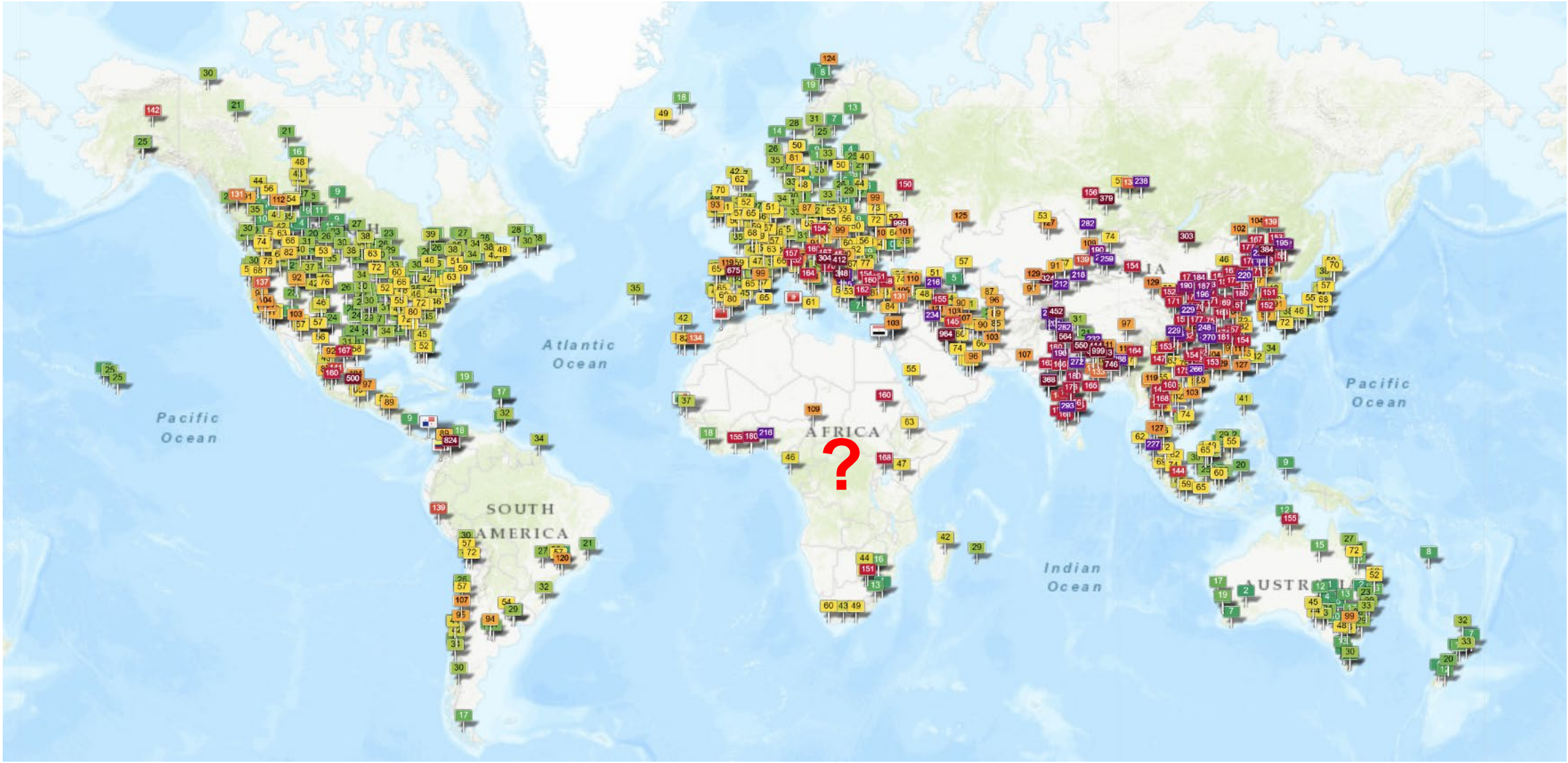
Concerns

- Health effects: pulmonary, cardiovascular, and a suspected carcinogen

BC: Black Carbon

(EPA, 2011)

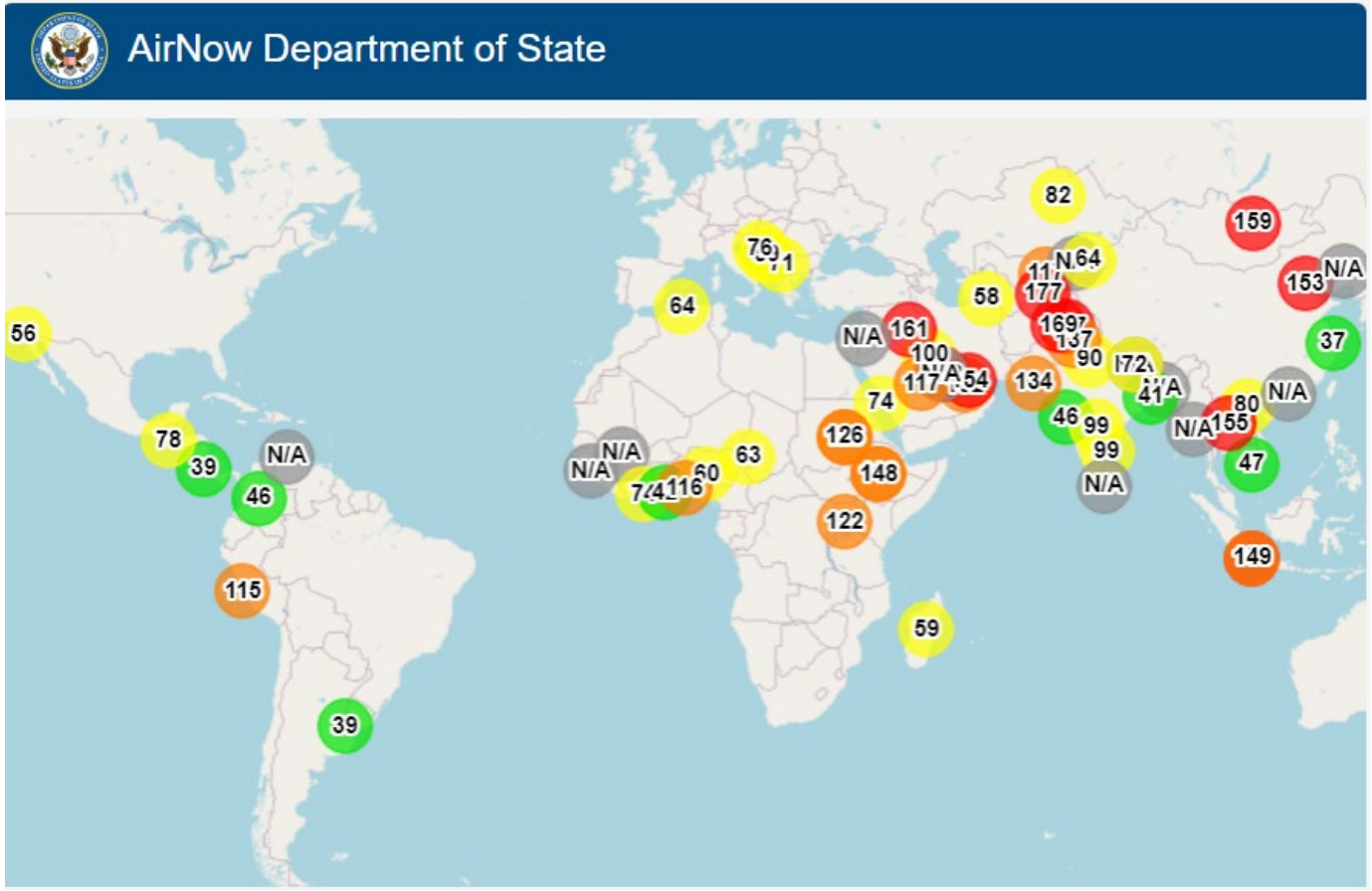
Disparity in ground-based monitors



https://waqi.info/

Our approach

- A cost-effective way to measure BC
- Leverage existing monitors
- US DOS collects air pollutant data at US Embassies around the world
- BAM is used to measure $PM_{2.5}$

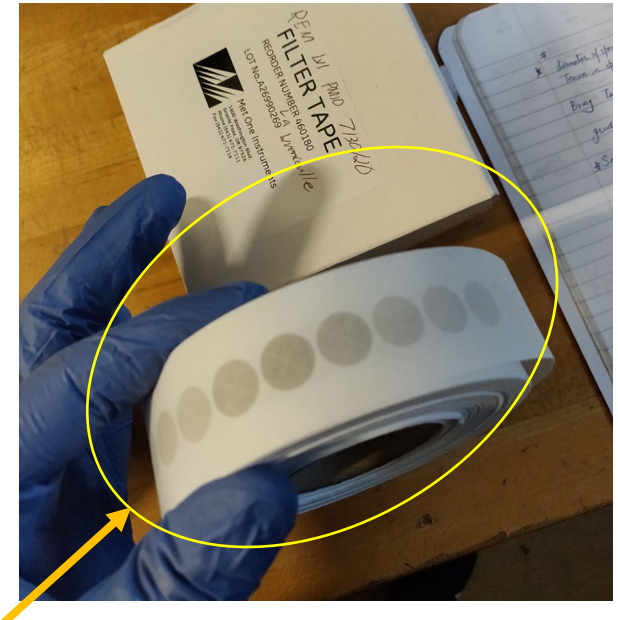


BAM: Beta Attenuation Monitor; DOS: Department of State

What is a BAM?

- Continuous **hourly** ambient measurement
- Glass-fiber filter tapes
- Target pollutants: $PM_{2.5}$, PM_{10}
- Flow rate: **1 m^3 h^{-1} or 16.67 LPM**

BAM 1020
Met one Instruments



How does BC data from BAM helps?

Measures hourly **$PM_{2.5}$** data

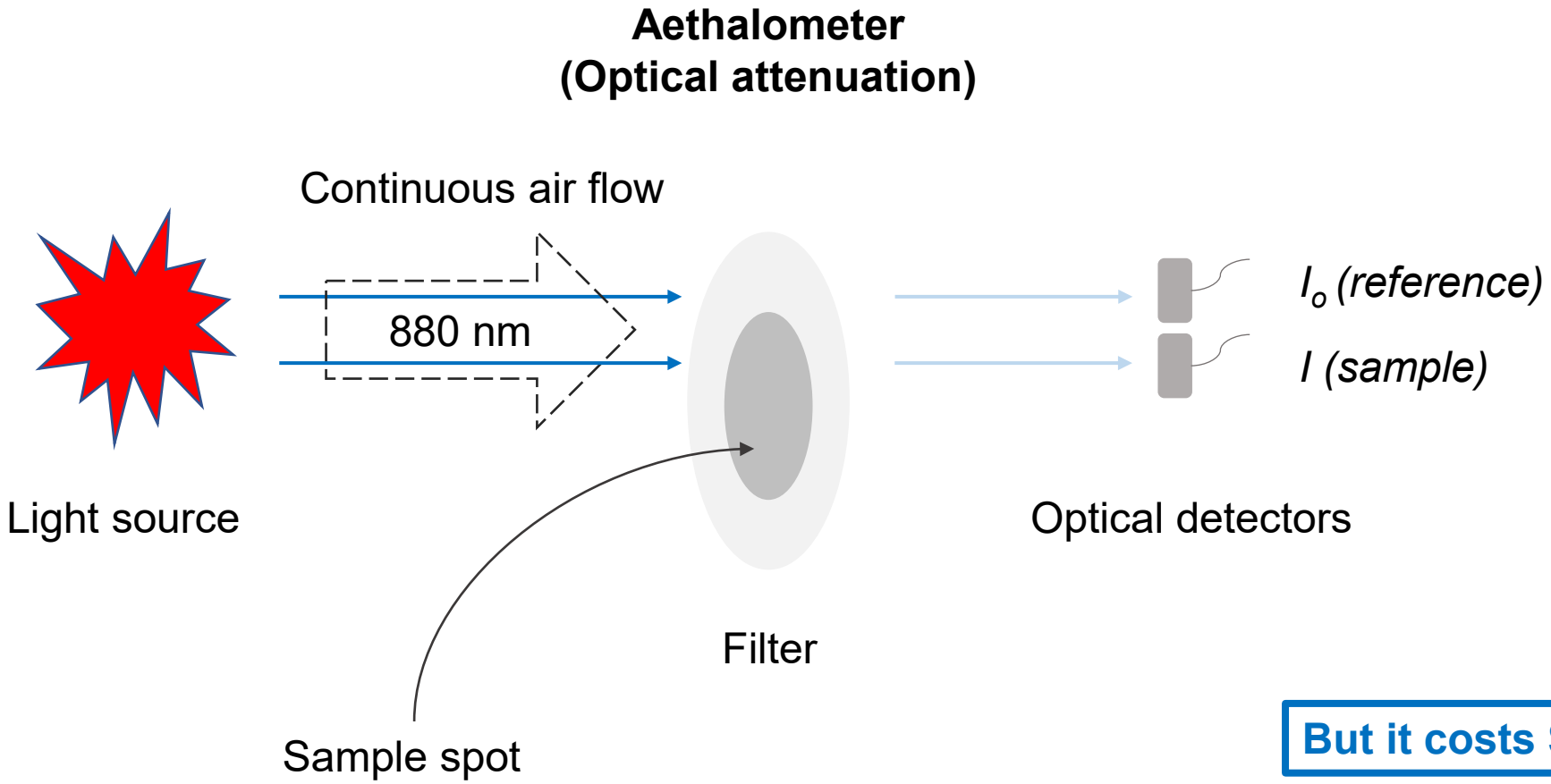
+

Estimate hourly **BC** from tape spots

=

Hourly **$PM_{2.5}$ + BC** helps understand combustion sources

Working principle of BC measurement

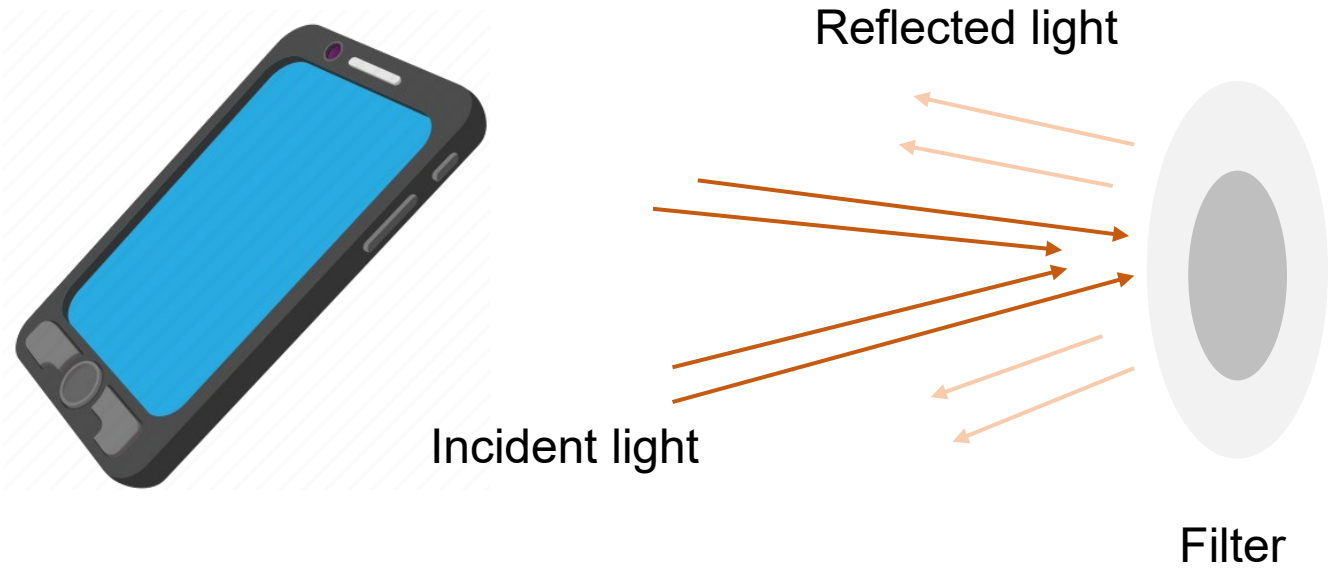


But it costs $25,000!

$$ATN = 100 * \ln (I_0 / I)$$

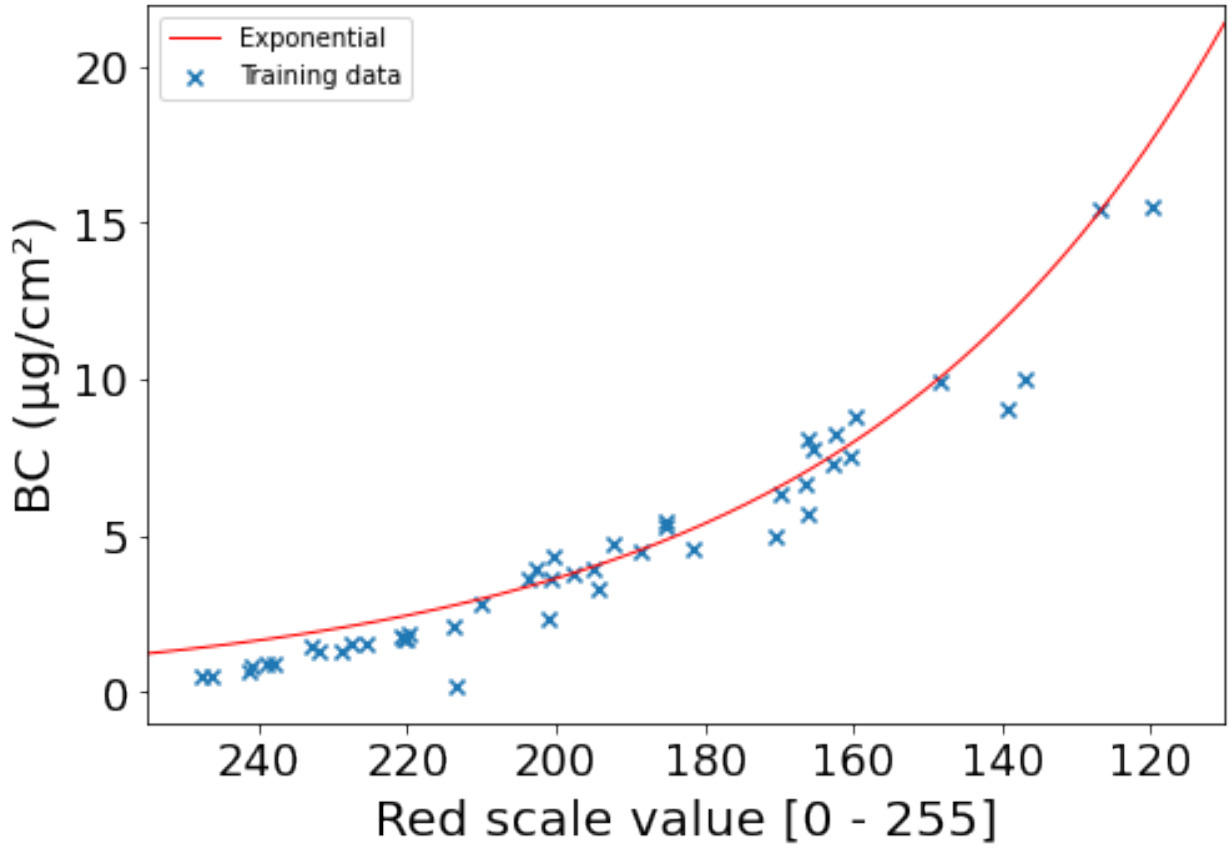
Image reflectance-based method

BC is correlated to intensity of reflected red light



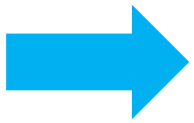
Only need
Existing filters + cellphone!

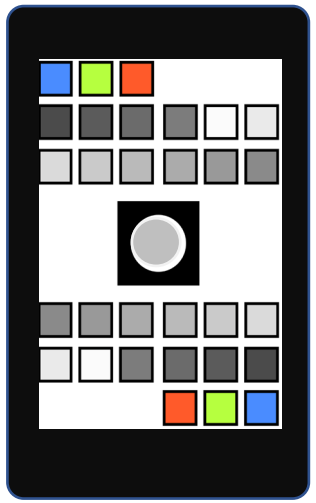
BC loading is correlated to red scale values

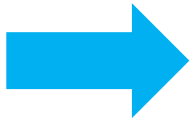


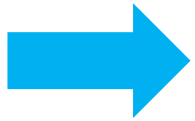
Exponential relationship!

Workflow









Sampled particulates on quartz and glass filters

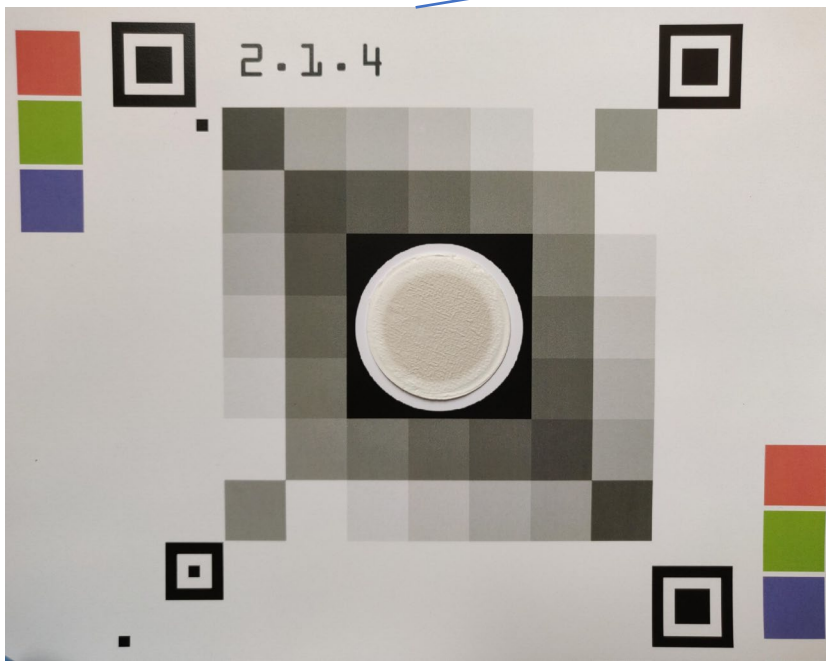
Images captured (filter + reference card)

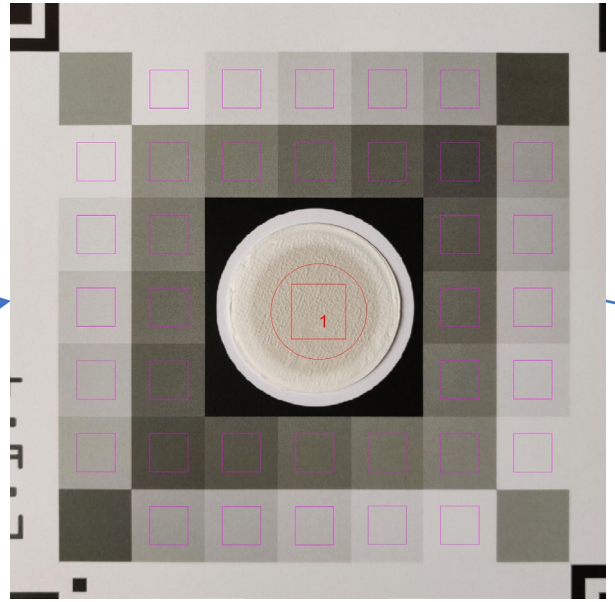
Image processing to estimate optical BC

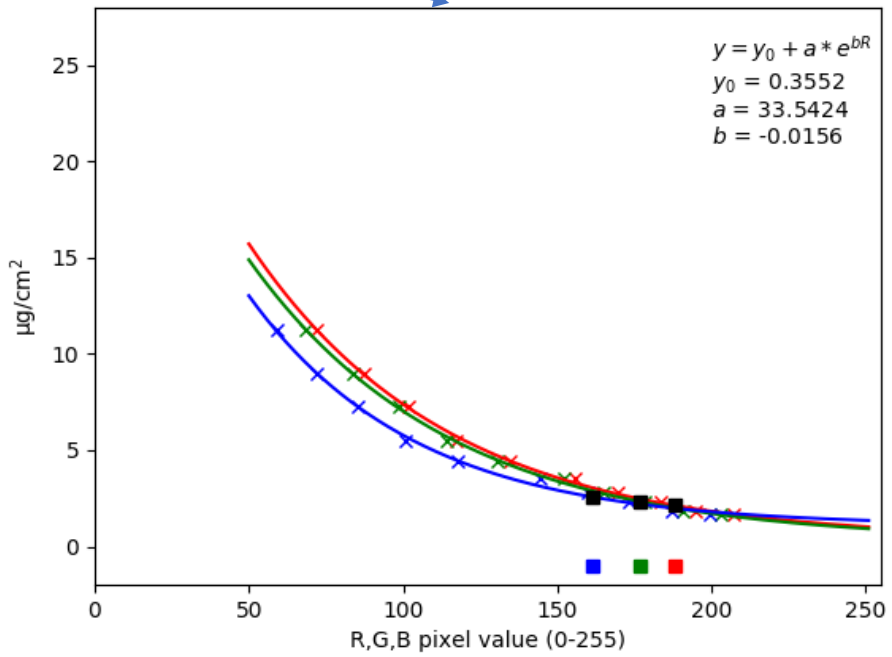
Comparison with references (BC & EC)

Step 1 **Step 2** **Step 3** **Step 4**

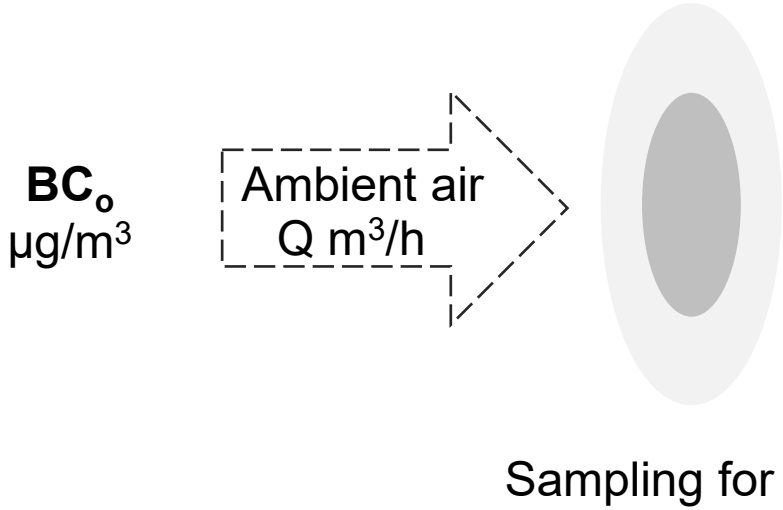
Image processing steps







The method measures area concentration

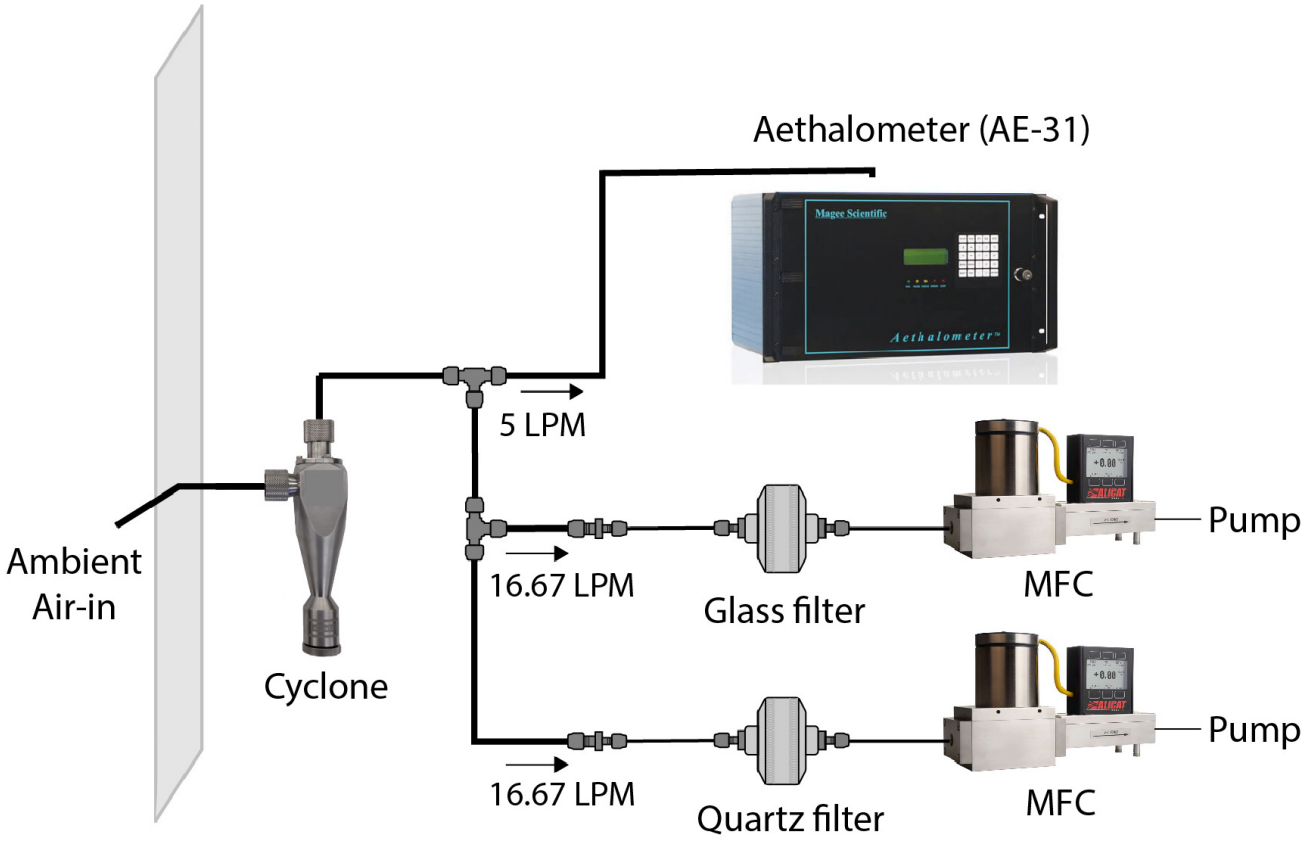


$$\mathbf{BC}\ (\mu \boldsymbol{g/cm^2}) = \frac{\mathbf{BCo}(\mu \boldsymbol{g/m^3}) * \boldsymbol{Qm^3/h}\ * \mathbf{T}\boldsymbol{hr}}{\mathbf{A}(\boldsymbol{cm^2})}$$

Note: Q is 1 m³/h &T is 1 hr for BAMs

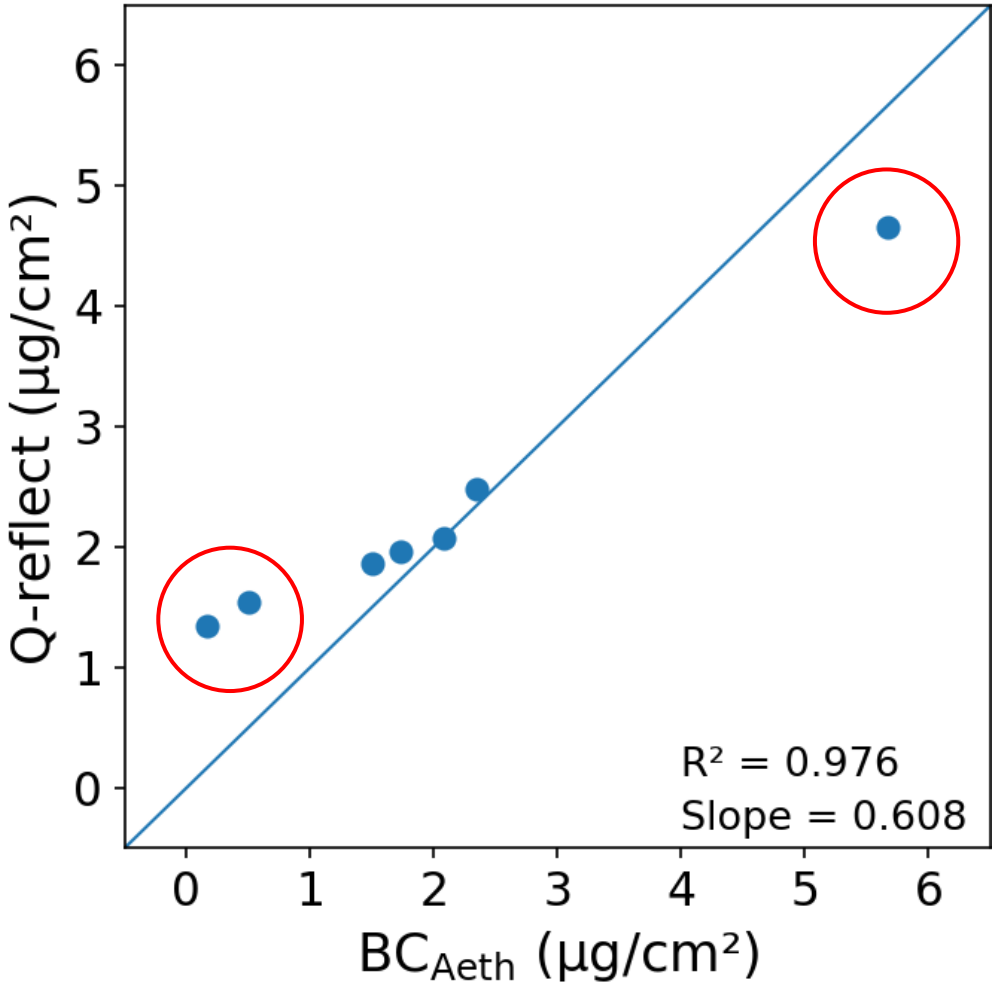
Filter sampling set-up

- Sampling on quartz- and glass fiber filters
- Parallel sampling ensures same BC loadings
- AE-31 used as a reference
- Sampling duration varied for different BC loadings



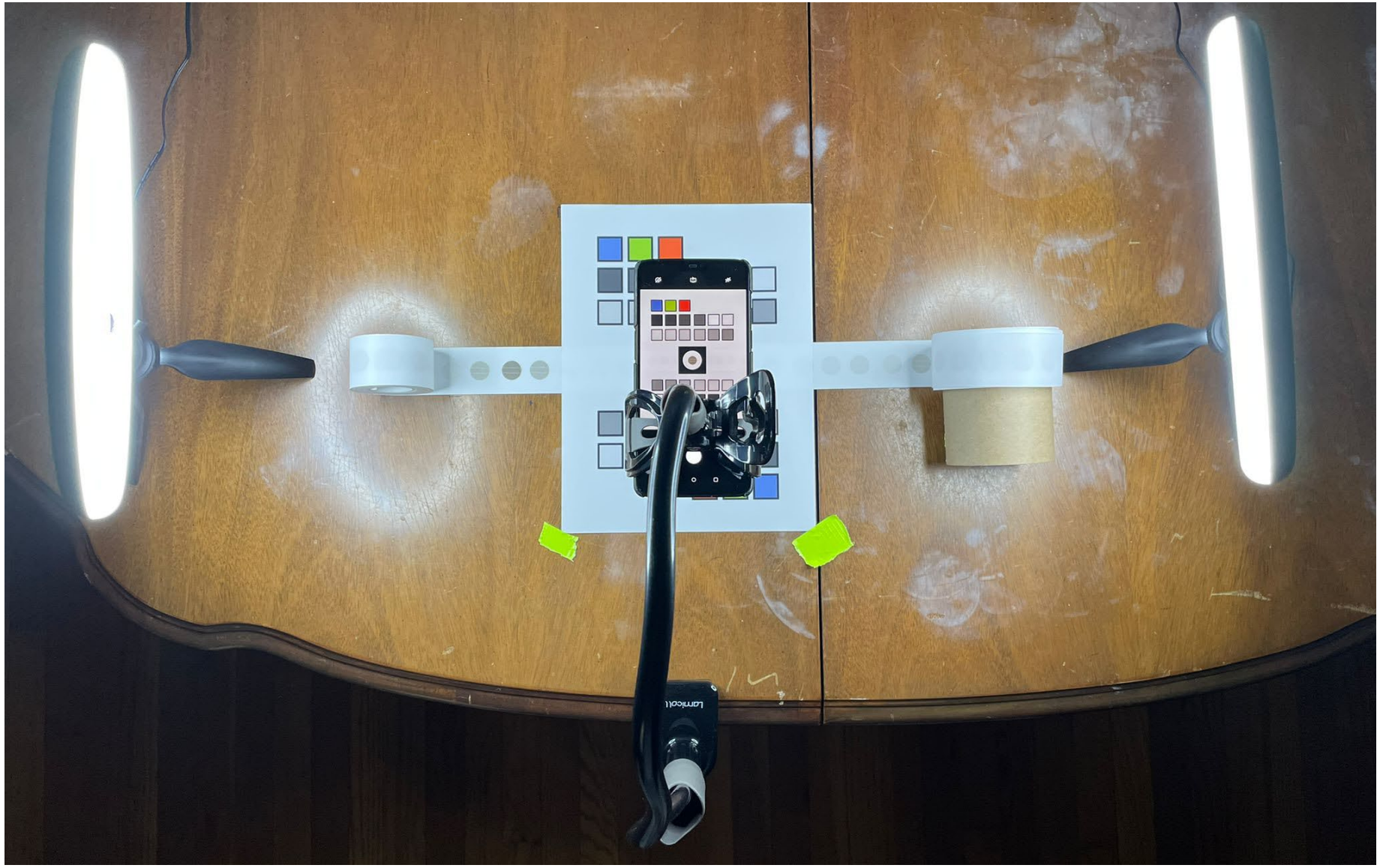
Estimation errors at low and high BC levels

- Overestimation for low BC levels
- Underestimation for high BC levels



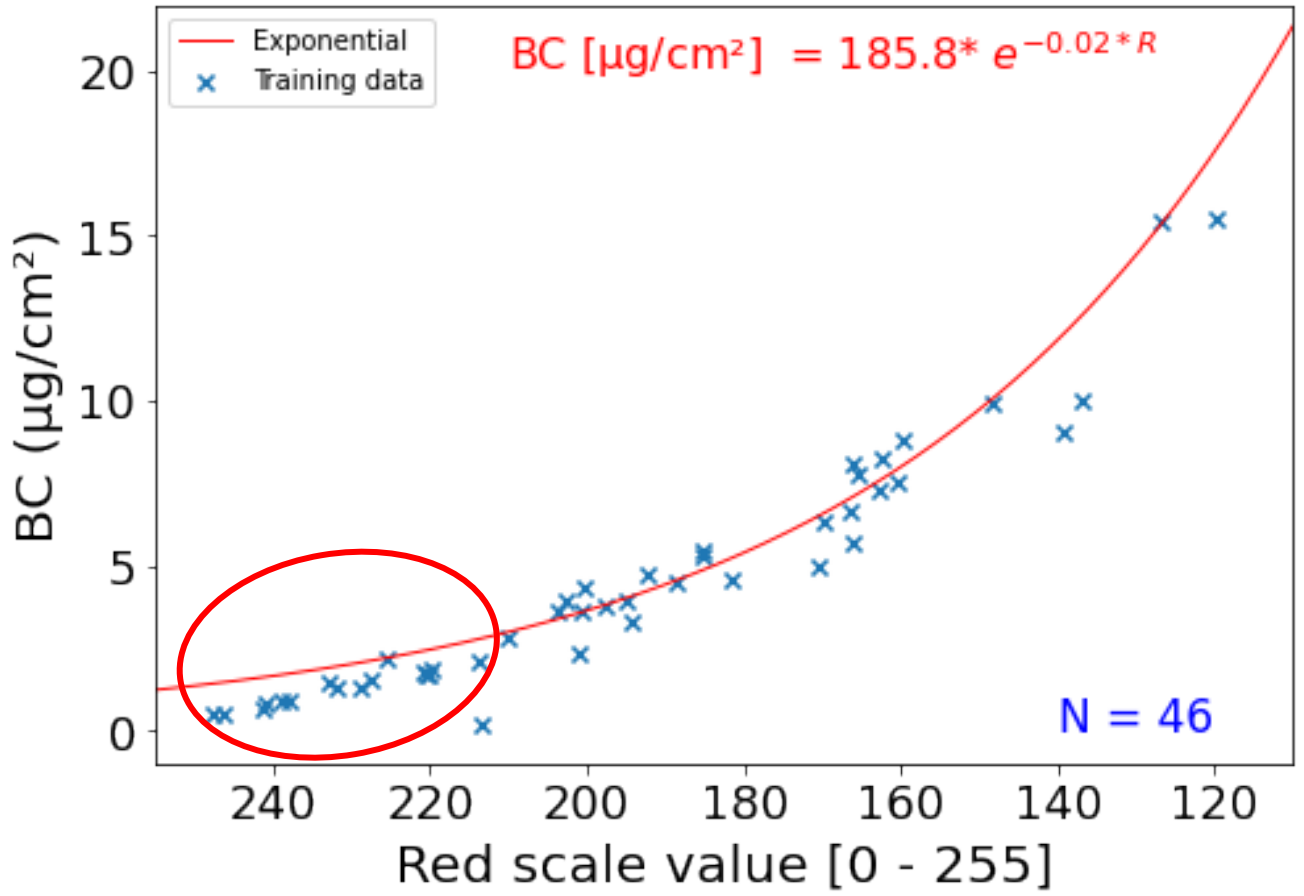
(Nexleaf Analytics Inc.)

Developing our own calibration model



Exponential model – overestimates low BC

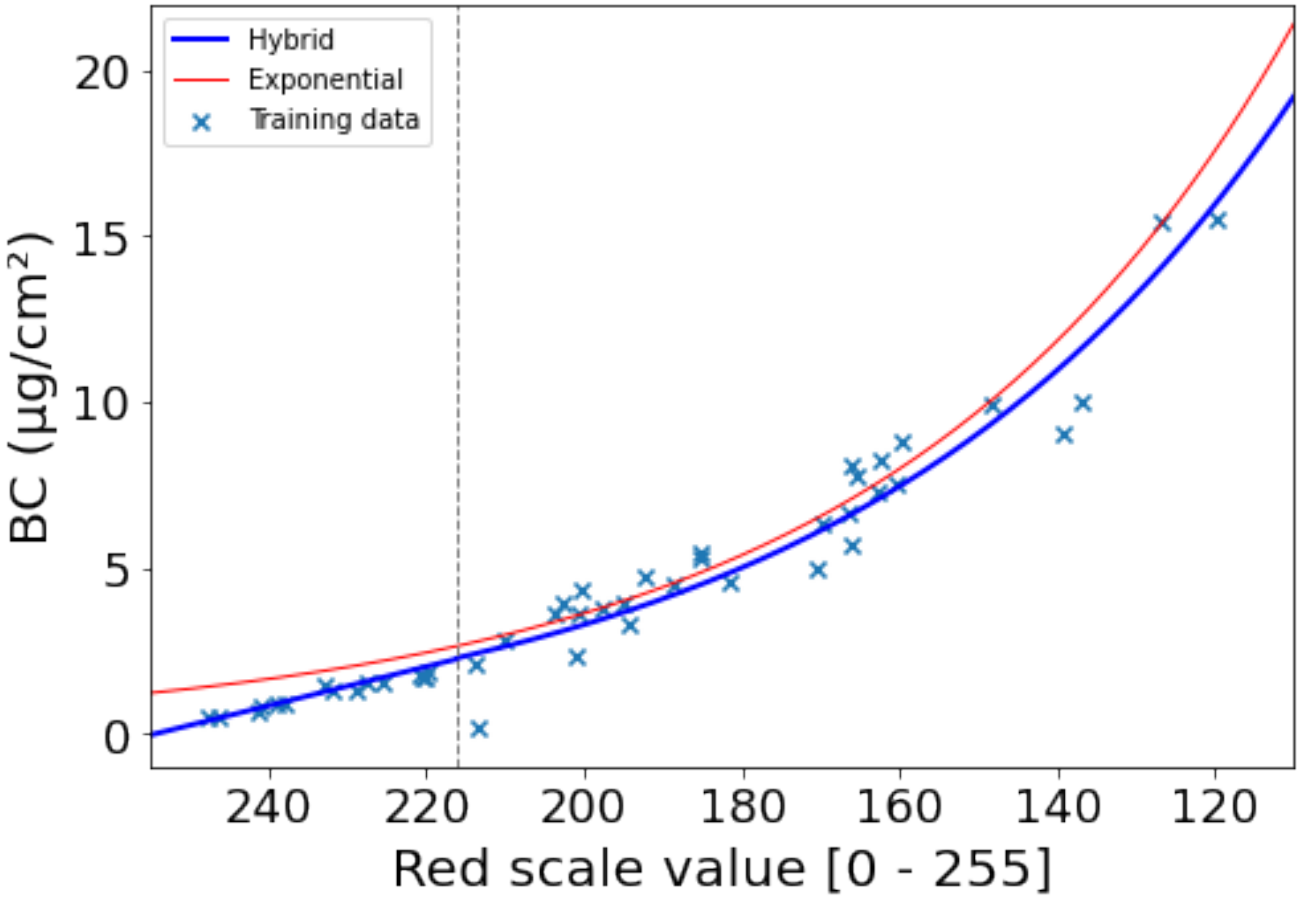
- R^2 ~ 0.944
- RMSE ~ 0.857



Hybrid model works better!

- Exponential + Linear
- Threshold R = 216

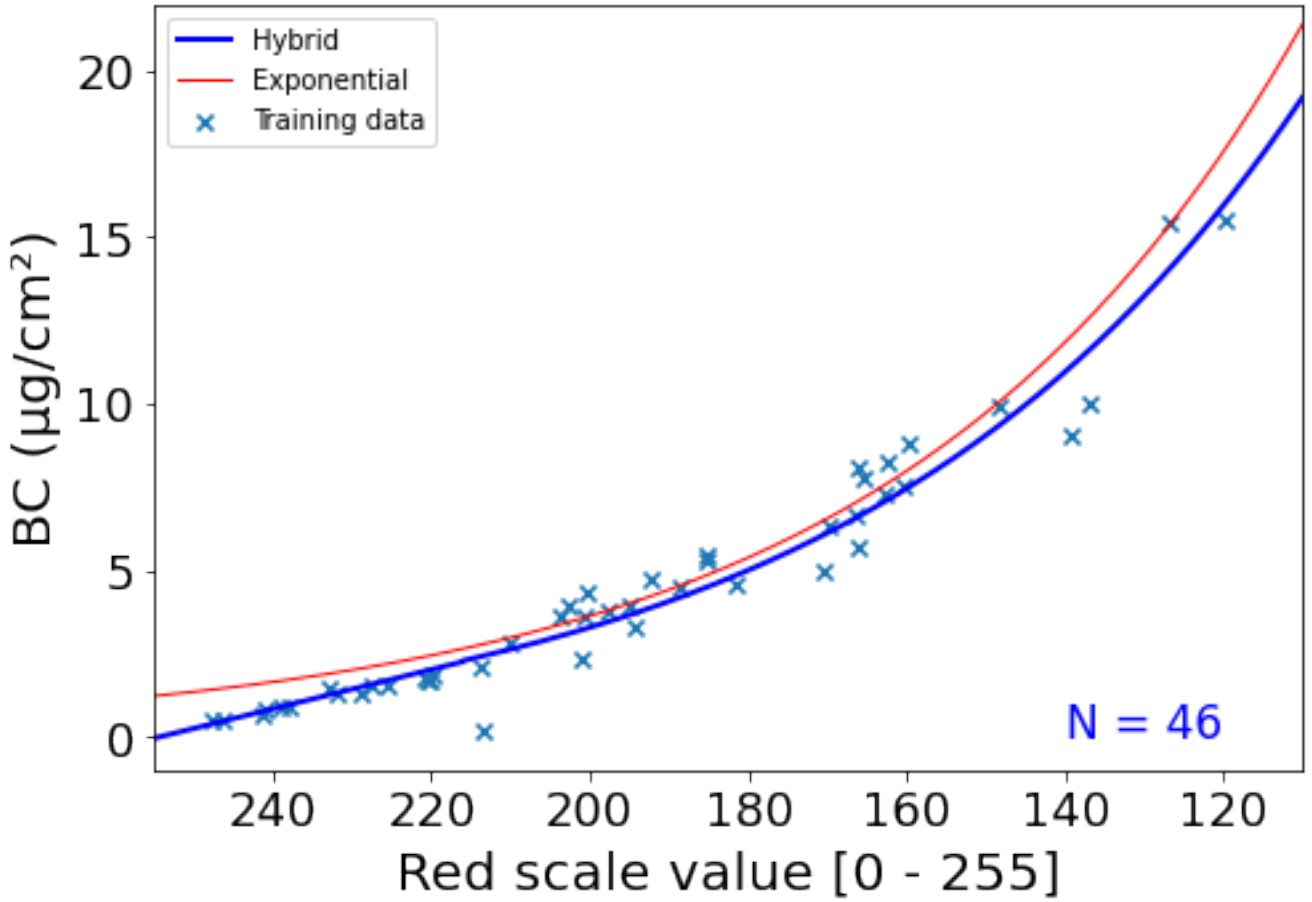
- Linear, $R^2 = 0.966$
- **RMSE = 0.672**



Effective Detection Limit (EDL)

BC (R=254) ~ 0.22 µg cm^{-2}

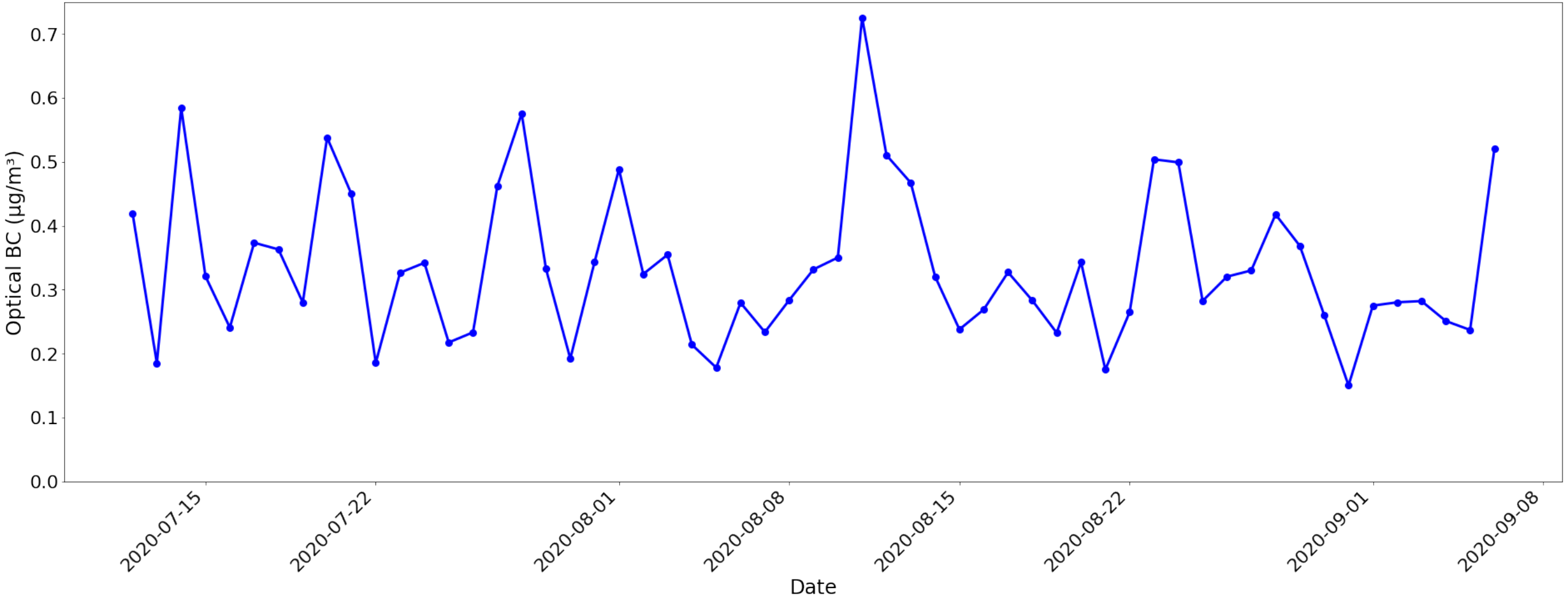
Ambient BC **~ 0.21 µg m^{-3}**



BAM tape from Lawrenceville monitoring station

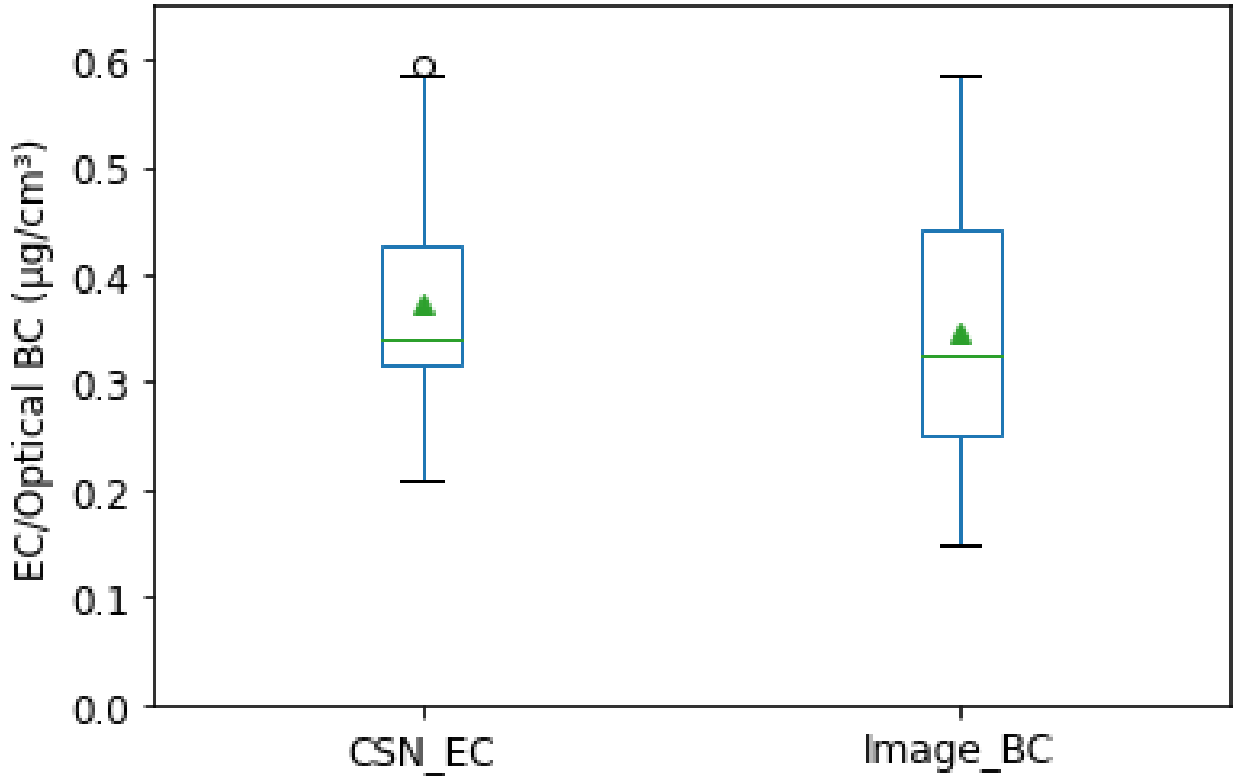
- ACHD monitoring station
- US EPA Chemical Speciation Network

Optical BC - Lawrenceville ACHD station

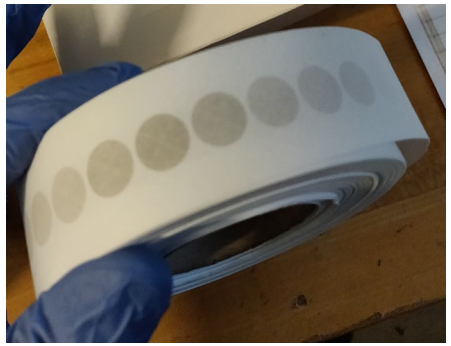


Optical BC vs CSN EC (Lawrenceville)

Sampling Period	Optical BC (μg m^{-3})	CSN_EC (μg m^{-3})
07/12/2020 – 09/06/2020	0.345	0.374



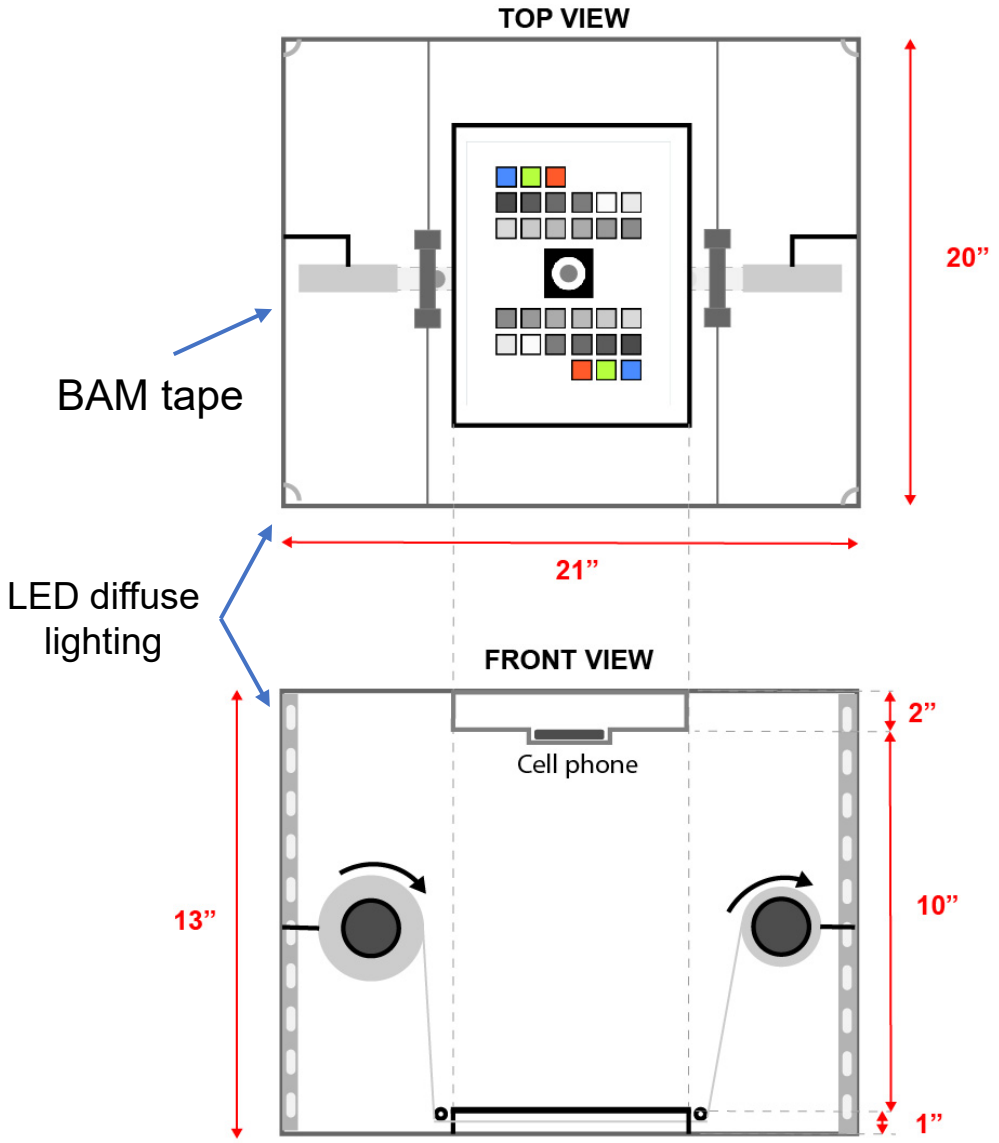
High throughput system



1 BAM tape runs for 3 months

3*30*24

2160 spots in 1 roll



Controlled spool movement

⇩

BAM tape spot adjusted across RC

⇩

Image captured

⇩

Sent to cloud/laptop

⇩

Hourly BC result available on cloud

Let’s summarize

- The method is suited for use in most developing nations.
- Next step is to analyze BAM tapes from countries in Sub-Saharan Africa.

We are looking for collaboration!

- More BAM tapes to analyze

Thank you…

- Prof. Albert Presto
- Our collaborators: Suryaprakash and Eniola (CMU Africa)
- Presto group
- CAPS