

# Cellphones as a Distributed Platform for Black Carbon Monitoring

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## The need for monitoring Black Carbon (BC)

Credit: Adam Ferguson



### Major contributor to global warming

Black carbon, following carbon dioxide, is the second largest contributor to global warming. However it exists in the atmosphere for a shorter period of time therefore any changes will bring quicker results.

### Major component of indoor air pollution, which is linked with 1.5 to 2 million deaths a year

Black carbon, a chief component of soot and a part of diesel emissions, is linked with respiratory illnesses.

### Highly localized sources, requiring measurement at scale of individual household

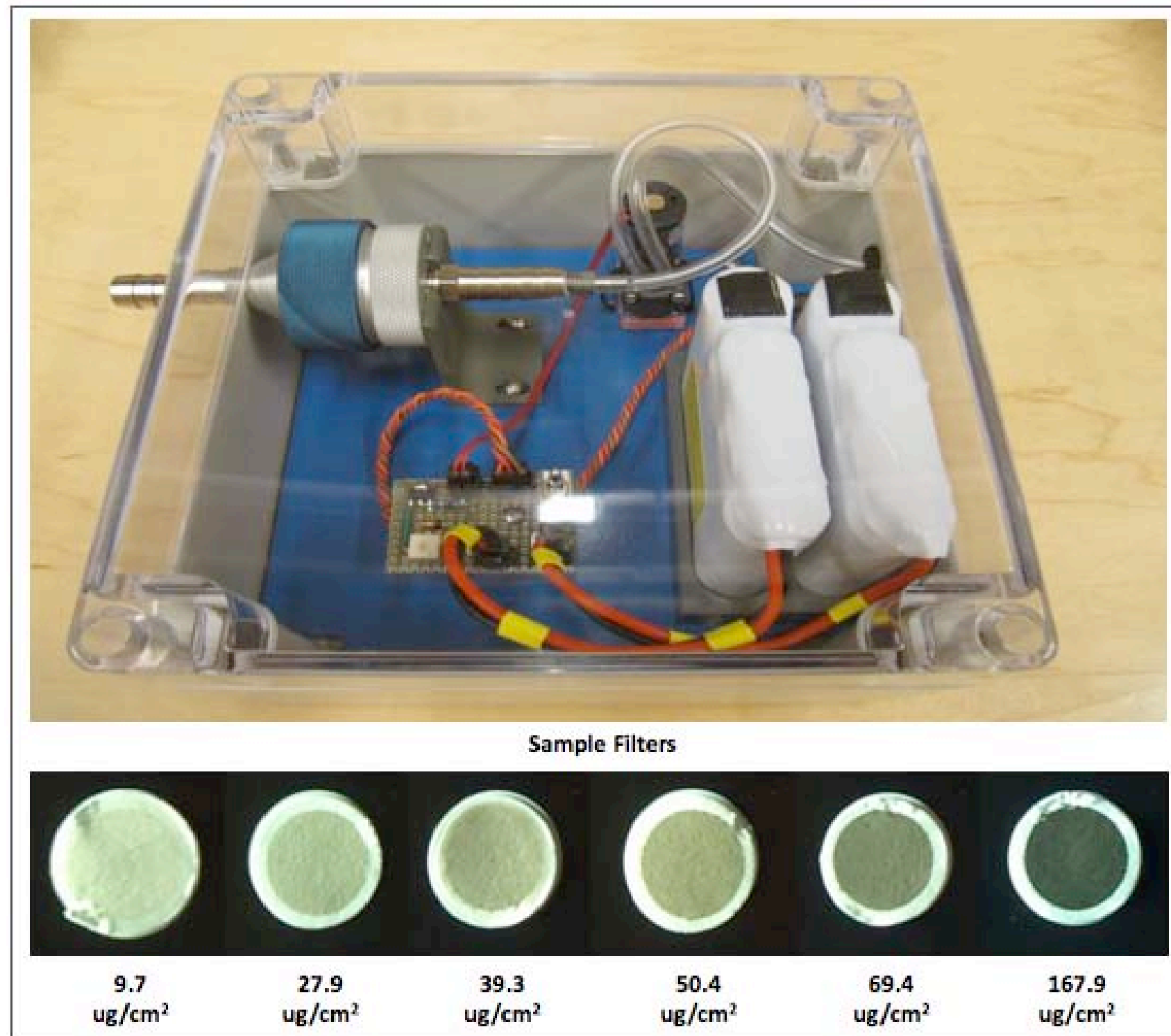
Primary sources include diesel emissions, industry, and burning of biomass.

Reliable and cost-effective solutions to measure black carbon globally are necessary to validate air pollution, health, and climate models and to evaluate the effectiveness of black carbon mitigation actions.

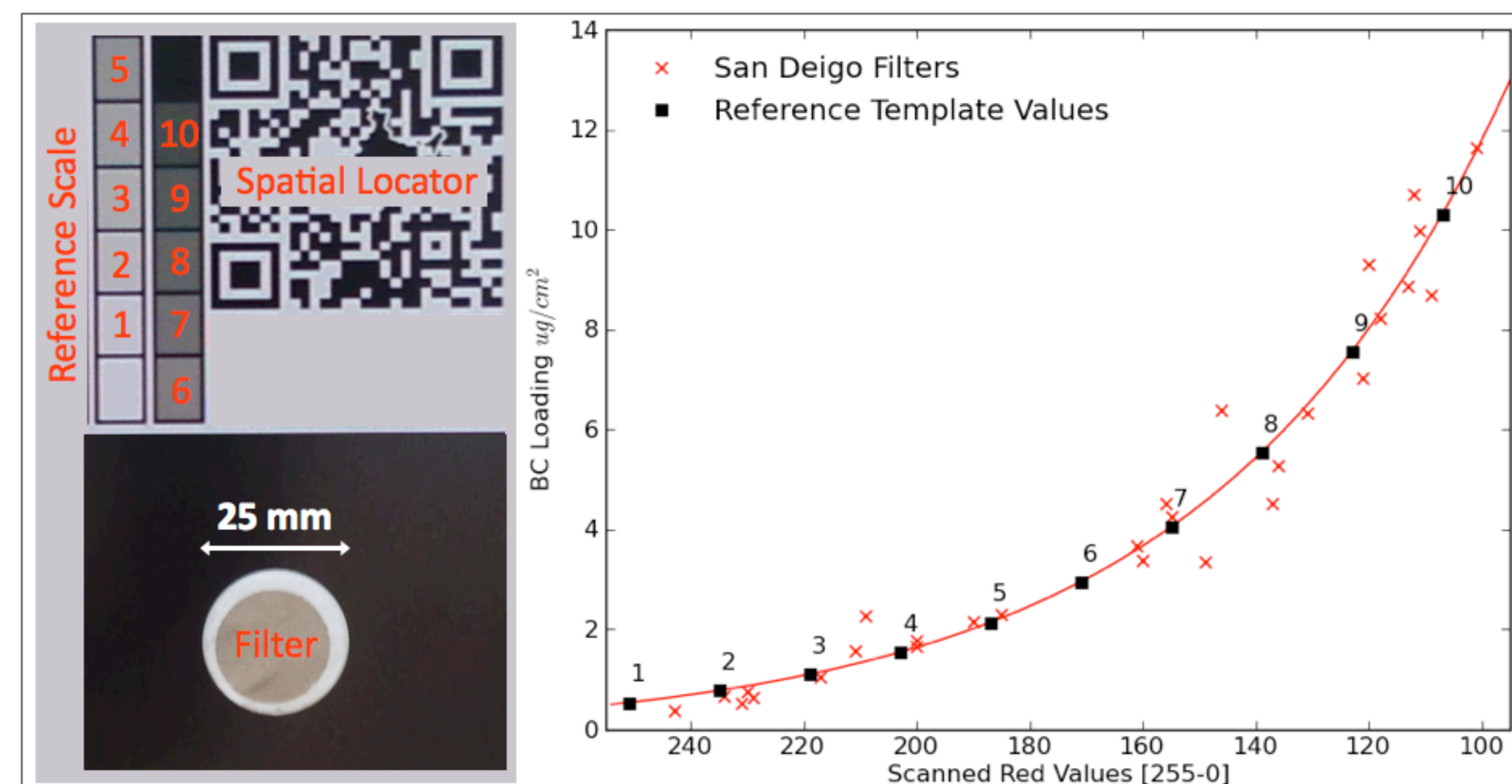


Credit: Adam Ferguson

## Method

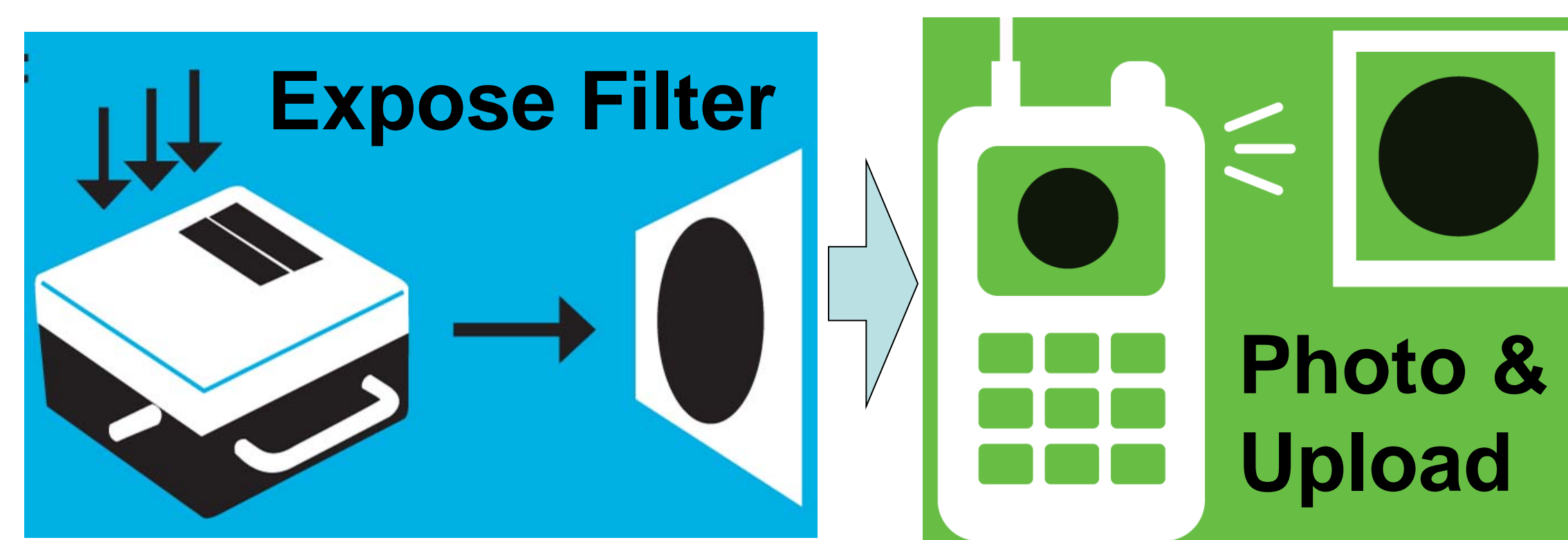


The primary insight resulting from our work is that the total loading of BC accumulated on the filters is directly related to the color expressed by that accumulation. Specifically measure the BC particles' absorption of the red wavelength (650 nm) by extracting the red chromaticity of the filter from the image.



A plot of red chromaticity versus BC loading creates a calibration curve. The curve is used to create a calibrated reference scale.

The Miniaturized Aerosol filter Sampler (MAS) system and filters. The MAS includes: (i) ultra-low power micro air pump (ii) filter holder (iii) battery (iv) control electronics.



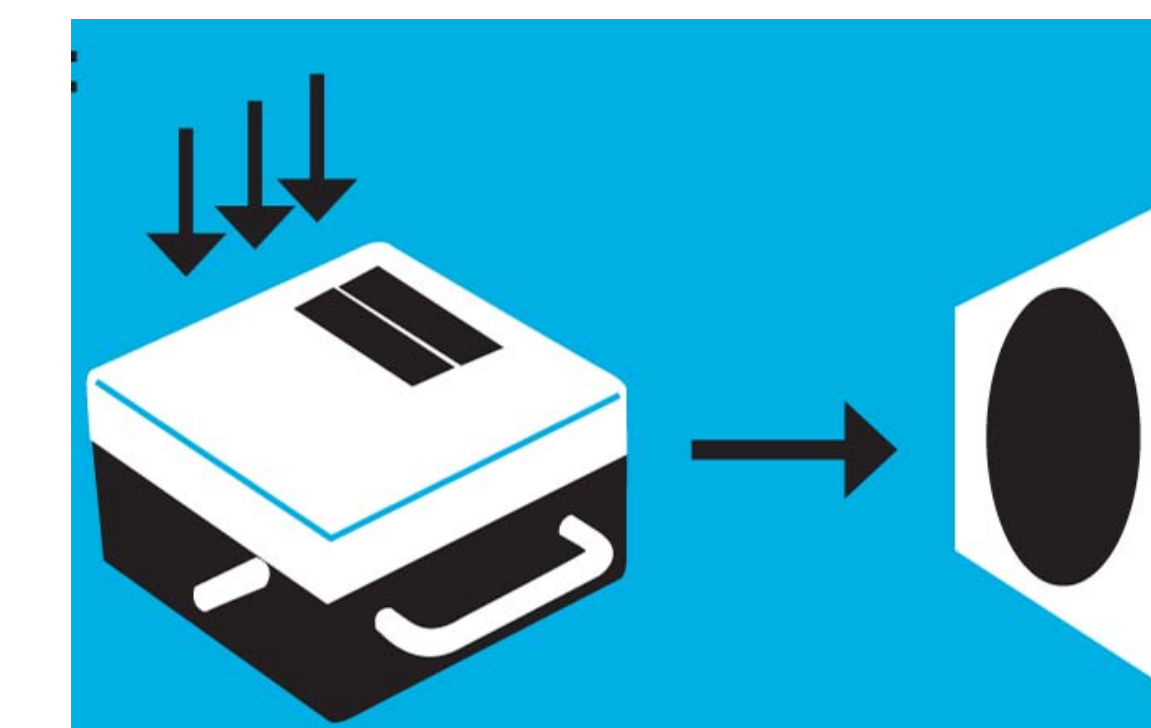
Convert color to BC Loading using reference scale  
Convert BC Loading to BC Concentration

$$BC_{conc} [ug/m^3] = \frac{BC_L [ug/cm^2] * A [cm^2]}{F [m^3/min] * D [min]}$$

## Ultra low-power, cellphone based instruments

### Project Surya distributes clean cookstoves

Project Surya, is deploying clean cookstoves and rigorously evaluating their impact on BC emissions, using a combination of cellphone sensors, instrument towers, and satellite measurements. See <http://www.projectsurya.org>



### Black Carbon Sensor

An air pump placed within the kitchen collects black carbon particles onto a quartz filter that can be photographed with a standard mobile phone camera.

The image is emailed to a receiving server, where it is analyzed to determine the black carbon concentration in real-time.



### Cookstove Temperature Sensor

Using a standard headset jack allows the cookstove temperature sensor to be connected to a mobile phone without the use of batteries. Software on the phone reads the sensor data and uploads it automatically in real-time.

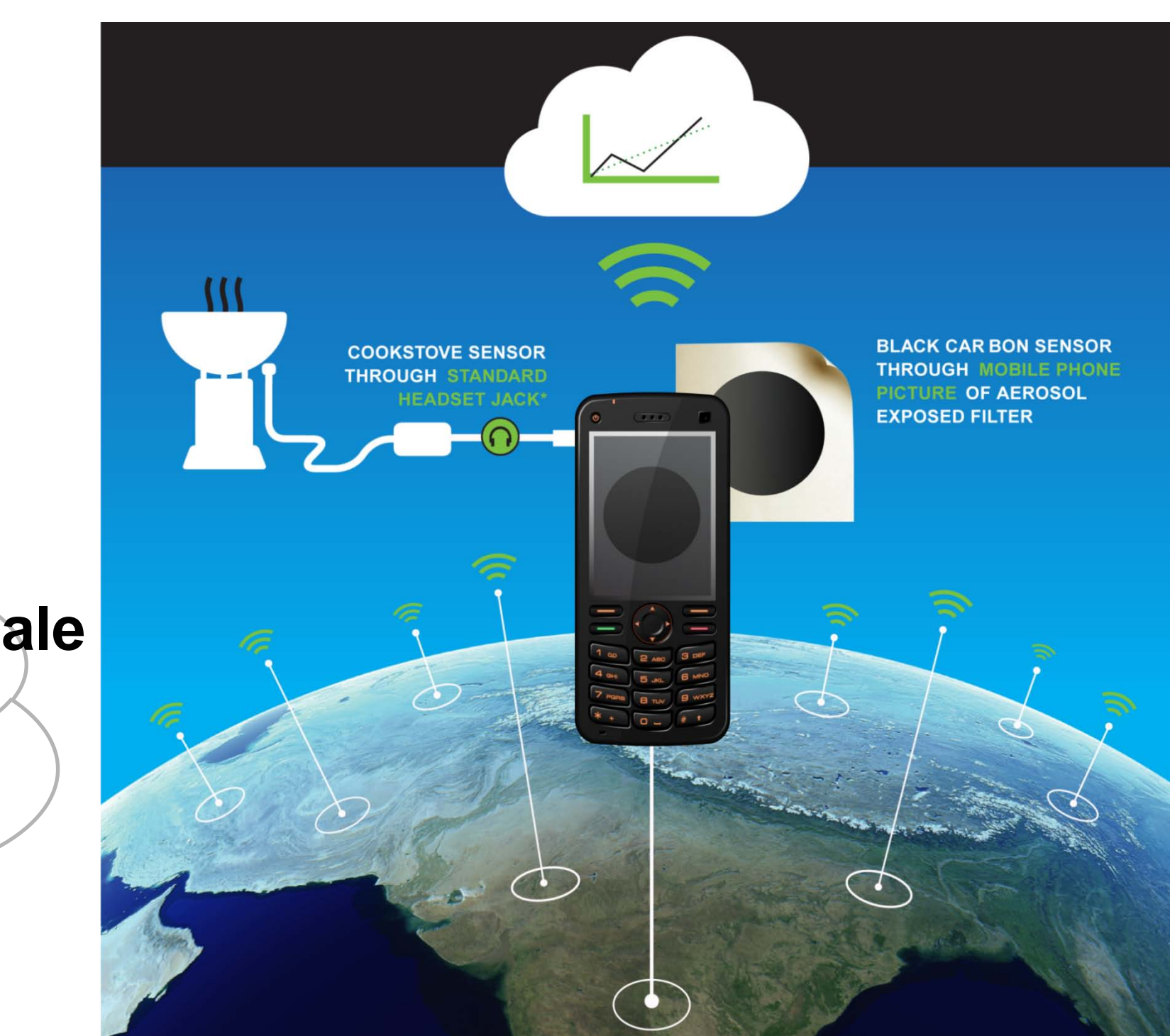
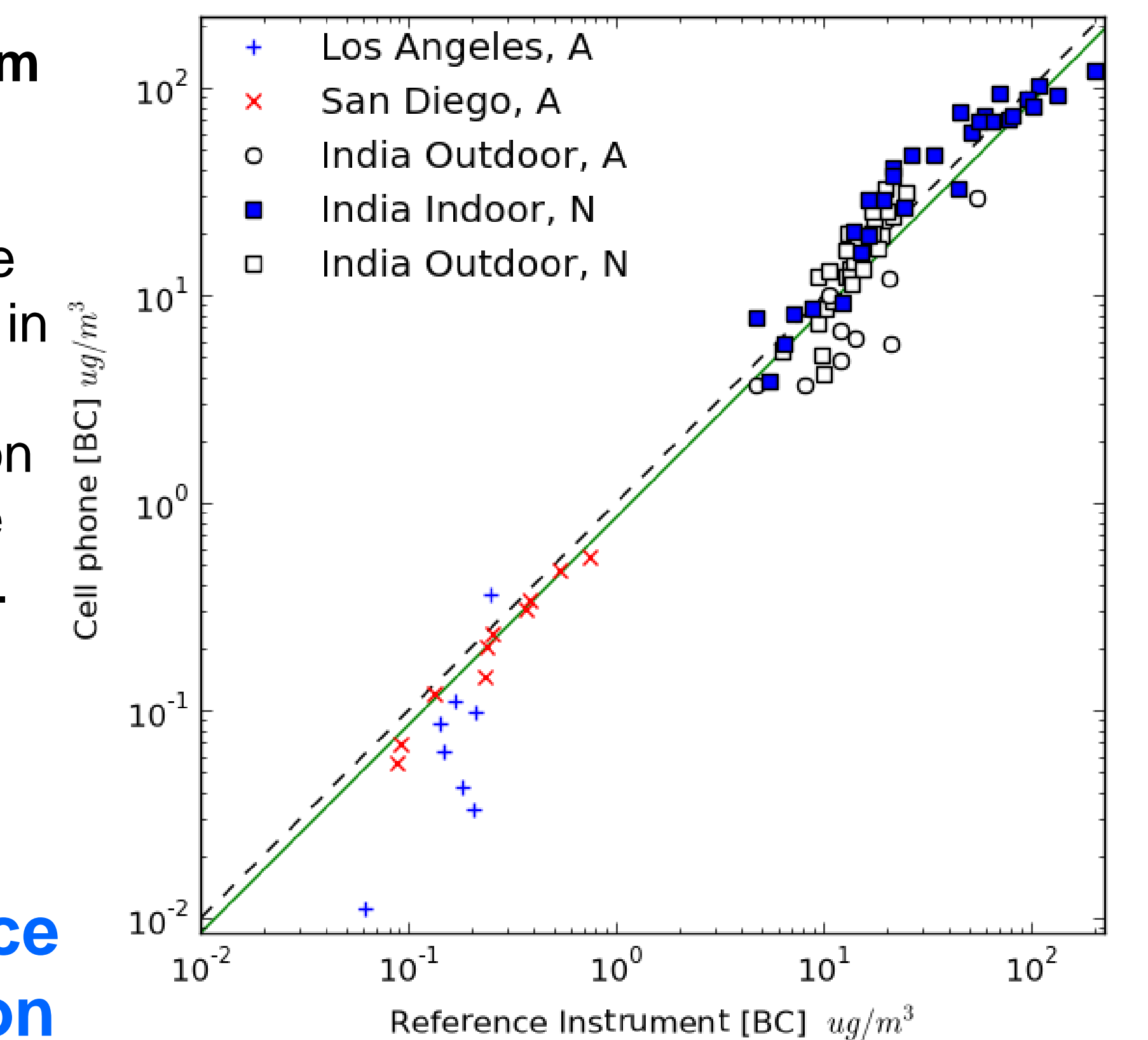


Credit: Adam Ferguson

## Results and Citizen Science data collection

- The cell phone based [BC] agrees with the reference system [BC] with a root mean squared (rms) error of less than 10%
- The rms error in the cellphone based measurements is similar across all of the sampling locations. BC aerosols in California are primarily sourced by burning of fossil fuel, while the BC aerosols in Indian are dominated by biomass-fuel cooking.
- The rms error is independent of the [BC] levels, regional location and the source of BC in spite of using the same calibration curve to reduce the color from the cell phone filter photographs to [BC].

- These results show promise for cellphones as distributed platforms for global black carbon monitoring.



### Citizen Science Data Collection

We are working with three community groups in Los Angeles, and will recruit three groups in the San Francisco Bay Area, to enable 40 citizens to be actively engaged in monitoring BC across California. We are working with The Energy Resources Institute, an international NGO based in India, to deploy this instrument with 60 people in conjunction with Project Surya.

The use of cellphones for data collection permits monitoring of BC on a greater, more comprehensive scale not previously possible, and serves as a means of instituting more precise, variation-sensitive evaluations of emissions. By storing the data in a publicly available repository, our system will provide real-time access to mass-scale BC measurements to researchers and the public.