Title:
Data set associated with "A low-cost monitor for simultaneous measurement of fine particulate matter and aerosol optical depth – Part 3: Automation and design improvements"

Abstract:
Atmospheric particulate matter smaller than 2.5 microns in diameter (PM2.5) impacts public health, the environment, and the climate. Consequently, a need exists for accurate, distributed measurements of surface-level PM2.5 concentrations at a global scale. Remote sensing observations of aerosol optical depth (AOD) have been used to estimate surface-level PM2.5 for studies on human health and the Earth system. However, these estimates are uncertain due to a lack of measurements available to validate the derived PM2.5 products, which rely on the ratio of surface PM2.5 to AOD. Traditional monitoring of these two air quality metrics is costly and cumbersome, leading to a lack of surface monitoring networks with high spatial density. In part 1 of this series we described the development and validation of a first-generation device for low-cost measurement of AOD and PM2.5: The Aerosol Mass and Optical Depth (AMODv1) sampler. Part 2 of the series describes a citizen-science field deployment of the AMODv1 device. Here in part 3, we present an autonomous version of the AMOD, known as AMODv2, capable of unsupervised measurement of AOD and PM2.5 at 20-minute time intervals. The AMOD includes a set of four optically filtered photodiodes for multi-wavelength (current version at 440, 500, 675, and 870 nm) AOD, a Plantower PMS5003 sensor for time-resolved optical PM2.5 measurements, and a pump and cyclone system for time-integrated gravimetric filter measurements of particle mass and composition. The AMODv2 uses low-cost motors and sensor data for autonomous sun alignment to provide the semi-continuous AOD measurements. Operators can connect to the AMODv2 over Bluetooth® and configure a sample using a smartphone application. A Wi-Fi module enables real-time data streaming and visualization on our website (csu-ceams.com). We present a sample deployment of 10 AMODv2s during a wildfire smoke event and demonstrate the ability of the instrument to capture changes in air quality at sub-hourly time resolution. We also present the results of an AOD validation campaign where AMODv2s were co-located with AERONET (Aerosol Robotics Network) instruments as the reference method at AOD levels ranging from 0.016-1.59. We observed close agreement between AMODv2s and the reference instrument with mean absolute errors of 0.046, 0.057, 0.026, and 0.033 AOD units at 440 nm, 500 nm, 675 nm, and 870 nm, respectively. We identified individual unit bias as the primary source of error between AMODv2s and reference units and propose re-calibration to mitigate these biases. The AMODv2 is well suited for citizen-science and other high-spatial-density deployments due to its low cost, compact form, user-friendly interface, and high measurement frequency of AOD and PM2.5. These deployments could provide a rich air pollution data set for evaluating remote sensing observations, atmospheric modeling simulations, and provide communities with the information they need to implement effective public health and environmental interventions.

Contact:
John Volckens (john.volckens@colostate.edu)

Associated article:
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Format of data files:
.csv

Locations where data were collected:
amod_v2_test_deployment.csv:
CSU Powerhouse Energy Campus (430 N College Ave, Fort Collins, CO 80524)

amod_v2_validation.csv:
NEON-CVALLA (N 40º09'39", W 105º10'01")

File information:
amod_v2_test_deployment.csv: This file includes all data taken by 10 AMODv2 units in a sample deployment in Fort Collins, Colorado from October 16th-October 18th 2020.

amod_aod_co-locations.csv: This file includes AOD and other relevant AMODv2 and AERONET data from the AOD co-location experiments. AMOD and AERONET measurements were filtered to ensure all AMODv2 measurements retained were taken within 120 seconds of an AERONET measurement.

Variable definitions:
amod_v2_test_deployment.csv:
amod_id: AMODv2 id (AD#####)
date: The date and time of the measurement (yyyy-MM-ddThh-mm-ssZ)
pm: $PM_{2.5}$ concentration ($\mu g \cdot m^{-3}$)
a500: AOD measured at 500nm (dimensionless)

pm_aod: $PM_{2.5}$ to AOD ratio ($\mu g \cdot m^{-3}$)

amod_v2_validation.csv:
amod_id: AMODv2 id (AD#####)
datetime_am: The date and time of an AMODv2 measurement (yyyy-MM-ddThh-mm-ssZ)
datetime_ae: The date and time of an AERONET measurement (yyyy-MM-ddThh-mm-ssZ)
latitude_am: Longitude (°)
longitude_am: Latitude (°)
altitude_am: Altitude (m)
pressure_am: Pressure (hPa)
zenith_am: Solar zenith angle (°)
r_am: Earth-sun distance (Astronomical Units)
v_440nm_am: Voltage from AMODv2 440nm optically filtered photodiode (V)
v_500nm_am: Voltage from AMODv2 500nm optically filtered photodiode (V)
v_675nm_am: Voltage from AMODv2 675nm optically filtered photodiode (V)
v_870nm_am: Voltage from AMODv2 870nm optically filtered photodiode (V)
aod_440nm_am: AMODv2 440nm AOD (dimensionless)
aod_440nm_ae: AERONET 440nm AOD (dimensionless)
aod_500nm_am: AMODv2 500nm AOD (dimensionless)
aod_500nm_ae: AERONET 500nm AOD (dimensionless)
aod_675nm_am: AMODv2 675nm AOD (dimensionless)
aod_675nm_ae: AERONET 675nm AOD (dimensionless)
aod_870nm_am: AMODv2 870nm AOD (dimensionless)
aod_870nm_ae: AERONET 870nm AOD (dimensionless)