Development and Evaluation of the Raindrop Size Distribution Parameters Provides Vital Ground-Truth for the NASA Global Precipitation Measurement Mission

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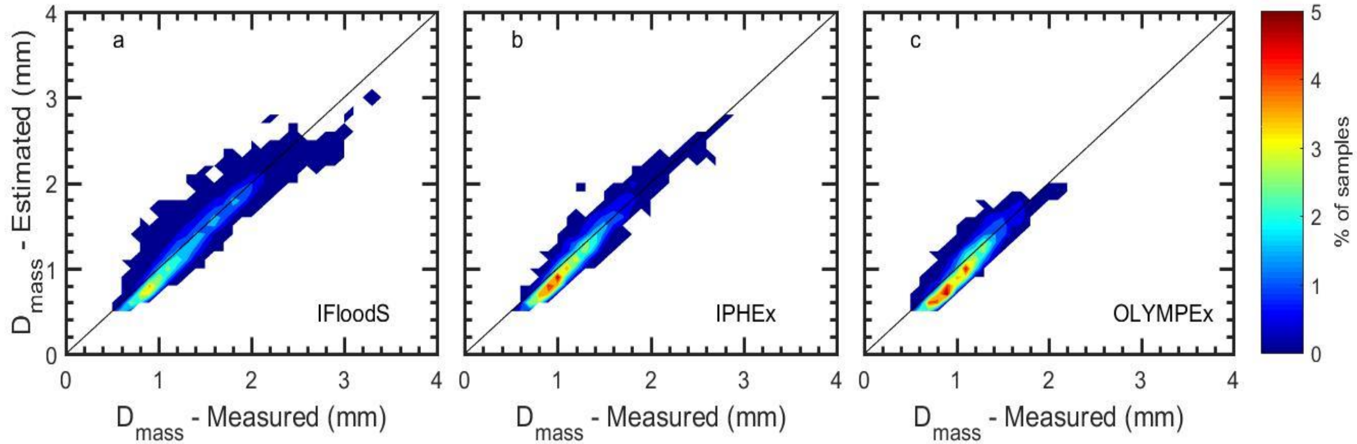

One of the Level-1 Science Requirements specified by the National Aeronautics and Space Administration (NASA) Global Precipitation Measurement (GPM) program states that measurements from the GPM Core observatory shall estimate the mass weighted mean drop diameter (D_{mass}) of precipitation particle size distribution to within ± 0.5 mm. This study focuses exclusively on the development of parametric relationships for D_{mass} and normalized intercept parameter (N_W, not shown) based on disdrometer-calculated radar observables Z_{DR} and Z_H. These relationships are used in the radar-based validation network software architecture.

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References:

Tokay, A., L.P. D'Adderio, D.B. Wolff, and W.A. Petersen, 2020: Development and Evaluation of the Raindrop Size Distribution Parameters for the NASA Global Precipitation Measurement Mission Ground Validation Program. *J. Atmos. Oceanic Technol.,* **37**, 115–128, https://doi.org/10.1175/JTECH-D-18-0071.1

Data Sources: The two-dimensional video disdrometer (2DVD) and PARSIVEL^2 (PARticle SIze VELocity) disdrometer database collected at six differentfield campaigns and three direct data collection sites funded by the Global Precipitation Measurement (GPM) mission ground validation program are used to derive and evaluate the raindrop size distribution (DSD) parameters and generate synthetic polarimetric radar observables (Z_H and Z_{DR}). Data may be found through https://ghrc.nsstc.nasa.gov/home/field-campaigns/XXX, where XXX refers to field campaign (see text below for campaign names).

Technical Description of Figures:

Graphic: Two-dimensional density plot of measured D_{mass} and estimated D_{mass} (derived from the synthetic polarimetric radar observables) based on 2DVD database during a) Iowa Flooding Studies (IFloodS), b) Integrated Precipitation and Hydrology Experiment (IPVEx) , and c) Olympic Mountain Experiment (OLYMPEx). The 2DVD-calculated differential reflectivity (Z_{DR}) is used to estimate D_{mass}.

Scientific significance, societal relevance, and relationships to future missions: This study presents the methodology and evaluation used by the GPM ground-validation team to develop $D_{mass}(Z_{DR})$ and $N_W(Z_{H,} D_{mass})$ relationships. The methodology relies on the use of polarimetric radar-based retrievals developed from disdrometer datasets collected at six mid-latitude sites and one tropical site. More emphasis was given to the retrieval of D_{mass} because its accuracy is tied to the level-1 requirements of the GPM mission. The sensitivity of the $D_{mass}(Z_{DR})$ relationships to climate regime and disdrometer type was also presented. The uncertainty of the empirical relationships relies on the two-dimensional distribution of the retrieved and observed variables. The empirical fits perform better for narrow and unskewed distributions of the retrieved variable for a given value of observed variable. Considering a $D_{mass}(Z_{DR})$ relationship, the Sequential Frequency Intensity Technique (SIFT) method using a third order polynomial performed well with an absolute bias of 0.12-0.13 mm in D_{mass} during IFloodS, IPHEx, and OLYMPEx. The absolute bias was also low for $\log(N_W)$ in the $N_W(Z_H, D_{mass})$ relationship. Orographic enhancement played a key role on the presence of abundant small drops and low concentrations of large drops resulting in lower D_{mass} at high Z_{DR} during OLYMPEx in contrast to the other five sites. A few large drops resulted in large Z_{DR} due its sensitivity to the drop shape, while D_{mass} remained relatively low due to its sensitivity to the mass of the drop. Considering a tropical oceanic site, large concentrations of small drops were also present but large drops were rare. The maximum Z_{DR} interval was therefore considerably lower at KWAJ than the two mid-latitude sites. A PARSIVEL^2 (P2) based comparison of $D_{mass}(Z_{DR})$ relationships between KWAJ, IFloodS, and OLYMPEx reveal that the use of the OLYMPEx-based relationship for the KWAJ database resulted in the highest absolute bias, 0.15 mm in D_{mass}. Considering differences between 2DVD and P2 measurements, the absolute bias in D_{mass} was relatively high, 0.12-0.13 mm, when P2 based Dmass(Z_{DR}) relationships were applied 2DVD databases during OLYMPEx and IFloodS. *Overall, The validation of $D_{mass}(Z_{DR})$ satisfies the level-1 requirement of the GPM mission.* The follow-up study of comparison of disdrometer calculated and radar estimate D_{mass} will provide further evidence on the uncertainty of the D_{mass} as a ground-based reference. Accurate estimates of precipitation provide vital information for hazard prediction and identification and resource management, and this calibration and validation reference for GPM ensures high quality products. Beyond GPM, this study is relevant to the Aerosols, Clouds, Convection, and Precipitation (ACCP) Decadal Survey Designated Observable, which is currently under study.

MODIS Observing Distinct Trends of Combustion Aerosol

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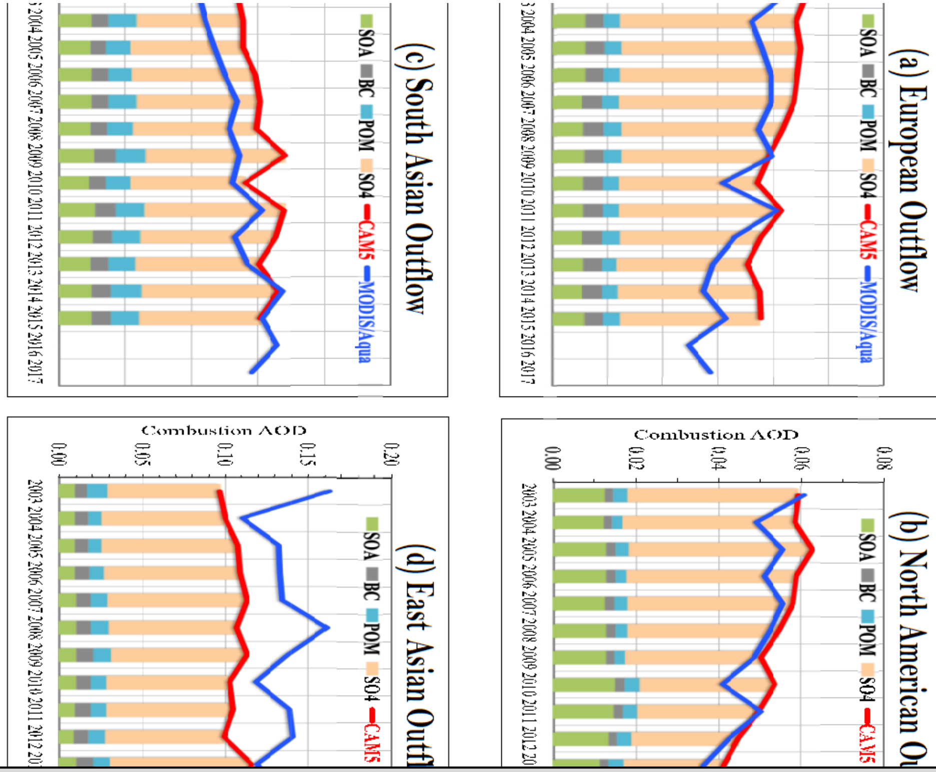

MODIS – Moderate resolution Imaging Spectrometer

CAM5 – Community Atmospheric Model version 5

SO4 – Sulfate

POM – Primary Organic Matter

BC – Black Carbon

SOA – Secondary Organic Aerosol

A novel analysis of Aqua MODIS observations (2003-2017) shows distinct trends of combustion aerosol (e.g., industrial/urban pollution, biomass burning) in the four major continental outflow regions: *declining* in Europe and North America (a & b), *increasing* in South Asia (c), and *declining after 2008* in East Asia (d). The observed trends are consistent with how pollution emissions have changed in different regions because of economic growth and implementation of environmental policies. The CAM5 model largely captures the trends except for the East Asian outflow.

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References:

Yu, H., Y. Yang, H. Wang, Q. Tan, M. Chin, R. Levy, L.A. Remer, S. Smith, T. Yuan, Y. Shi, Interannual variability and trends of combustion aerosol and dust in major continental outflows revealed by MODIS retrievals and CMA5 simulations during 2003-2017, *Atmospheric Chemistry and Physics, 20,* 139-161, 2020.

Data Sources: NASA GSFC MODIS/Aqua dark-target aerosol retrievals (Collection 6) over ocean are used to separate combustion aerosol (e.g., industrial/urban pollution, biomass burning) from mineral dust and marine aerosol. We are grateful to all MODIS team members for their dedicated efforts in producing the high-quality data. The Community Atmospheric Model version 5.3 (CAM5) with source tagging technique was run from 2003 to 2015 by PNNL collaborators (Y. Yang, H. Wang, S. Smith) to obtain aerosol species from distinctive source regions. The CAM5 simulations were performed at the DOE National Energy Research Scientific Computing Center. The PNNL is operated for the DOE by the Battelle Memorial Institute. The work was supported by the NASA ACMAP, CCST, and TASNPP programs.

Technical Description of Figures:

The four panels show the annual mean combustion aerosol optical depth (AOD) derived from MODIS/Aqua observation (blue lines) and CAM5 model (red lines) in major continental outflow regions: (a) European outflow over the Mediterranean Sea, (b) North American outflow over the North Atlantic Ocean, (c) South Asian outflow over the tropical Indian Ocean and Bay of Bengal, and (d) East Asian outflow over the northwestern Pacific Ocean. Blue and red dotted line denotes the regressed trend for MODIS and CAM5, respectively. The stacked bar shows CAM5 components of sulfate or SO4 (excluding those produced from DMS chemistry), primary organic matter (POM), black carbon (BC), and secondary organic aerosol (SOA). CAM5 simulations also tag aerosol from 14 source regions, and sulfate from volcanic and oceanic sources (not shown).

The highlight shows distinct trends of combustion aerosol optical depth in the four outflow regions dominated by industrial/urban pollution. The MODIS retrievals and CAM5 simulations consistently yield a declining trend of -0.017 to -0.020 per decade for the European and North American outflow. On the other hand, pollution aerosol from South Asia show an increasing trend of +0.036 (MODIS) and +0.020 (CAM5) per decade, respectively. In East Asian outflow, MODIS shows a declining trend after 2008, which is consistent with observed SO_2 decreases associated with China's enforcement of more stringent pollution control policies. However, the CAM5 model has limited skill in capturing the MODIS-observed trajectory of East Asian pollution trend, suggesting possible uncertainties in regional emission inventories used by the model.

Similar analysis was performed in other major continental outflow regions for both combustion aerosol and dust. We did not find significant trends from MODIS observations in biomass burning dominated regions. For MODIS dust observations, only Asian dust in the northwestern Pacific Ocean shows a decreasing trend of -0.012 per decade from 2003 to 2017. The CAM5 model lacks skill in capturing the interannual variations of biomass burning smoke and dust, highlighting the difficulty in quantifying episodic dust and smoke emissions and their evolution.

Scientific significance, societal relevance, and relationships to future missions: The method we developed to distinguish combustion aerosol from dust from MODIS retrievals allows us to examine aerosol trends pertinent to man-made and natural sources separately. The MODIS observations complemented by CAM5 source-tagging simulations further trace the change to individual sources. Future satellite missions, such as the A-CCP mission recommended by the 2017 Decadal Survey, should develop more advanced satellite sensors with enhanced capabilities of deciphering aerosol properties to better distinguish combustion aerosol from dust. An integration of such new observations with MODIS data could allow to monitor any meaningful trends in episodic emissions of biomass burning smoke and dust.

Reductions in Nitrogen Dioxide Air Pollution Presumably Associated with Reductions in Fossil Fuel Use

Joanna Joiner (614), Bryan Duncan (614) + GSFC Aura Ozone Monitoring Instrument (OMI) Team

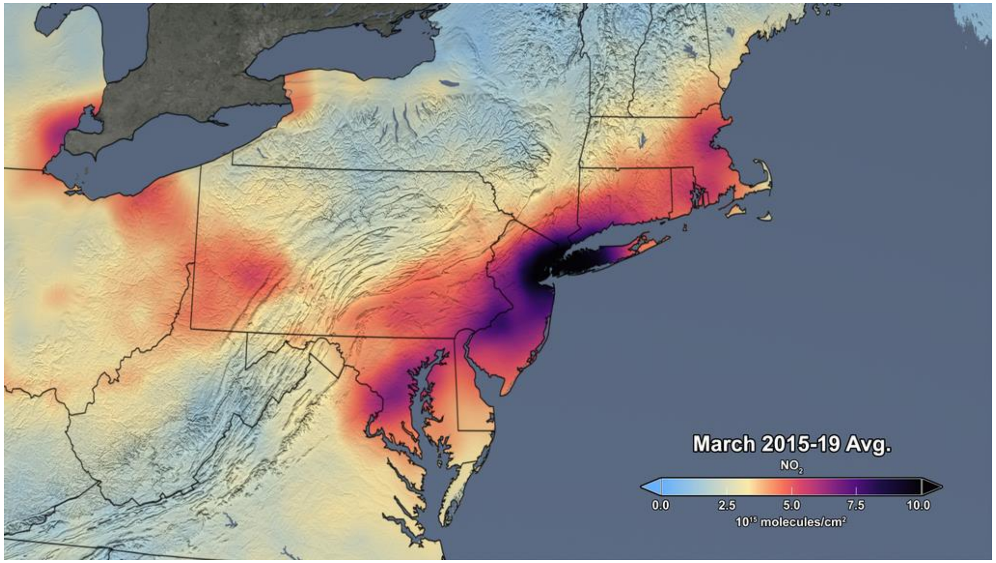
Over the past several weeks, the Northeast US has seen significant reductions in air pollution over its major metropolitan areas. These recent improvements in air quality have come at a high cost, as communities grapple with widespread lockdowns and shelter-in-place orders as a result of the spread of COVID-19.

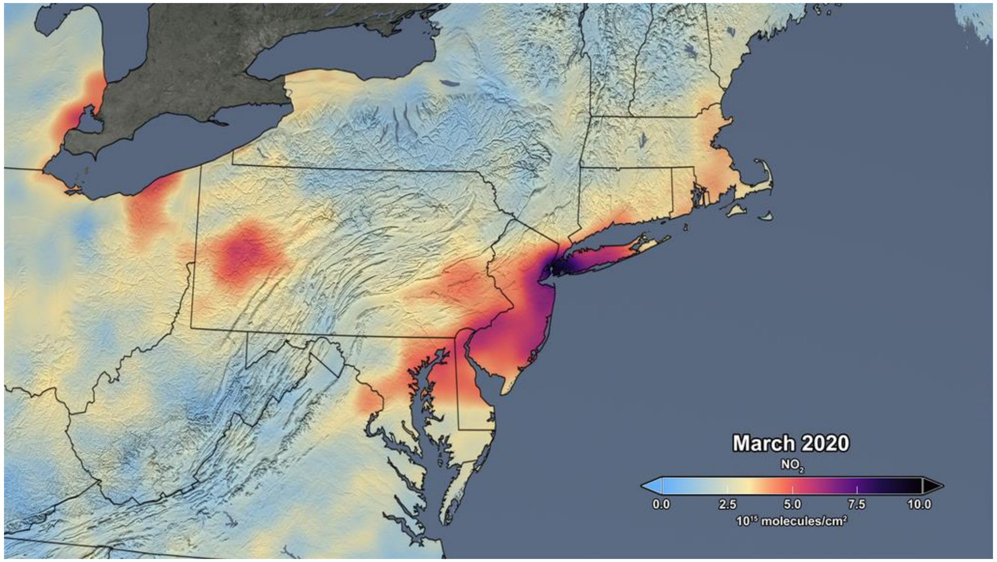
One air pollutant, nitrogen dioxide (NO_2), is primarily emitted from burning fossil fuels (diesel, gasoline, coal). If processed and interpreted carefully, NO_2 levels observed from space serve as an effective proxy for NO_2 levels at Earth's surface.

The images show satellite data of NO_2 from the Aura Ozone Monitoring Instrument (OMI) over the Northeast US in March. The **top image** shows the mean of the period from 2015 through 2019, while the **bottom image** on the right shows the mean for 2020.

Though variations in weather from year to year cause variations in the monthly means for individual years, March 2020 shows the lowest values as compared to any of the monthly values for March during the OMI data record, which spans 2005 to present. In fact, the data indicate that the NO_2 levels in March 2020 are about 30% lower on average across the region of the I-95 corridor from Washington, DC to Boston than when compared to the mean of 2015 to 2019. The images are free and publicly-available and may be downloaded.

Caution: Further analysis is required to rigorously quantify the amount of the change in NO_2 levels associated with changes in pollutant emissions versus natural variations in weather.





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Data Sources:
Satellite-derived emission estimates are based on NO_2 measurements from the Aura Ozone Monitoring Instrument (OMI). OMI is a Dutch–Finnish contribution to the NASA Aura mission.

Technical Description of Figure:
The slider above shows satellite data of NO_2 from the Aura Ozone Monitoring Instrument (OMI) over the Northeast United States in March. The image on the left shows the mean of the period from 2015 through 2019, while the image on the right shows the mean for 2020. Though variations in weather from year to year cause variations in the monthly means for individual years, March 2020 shows the lowest values as compared to any of the monthly values for March during the OMI data record, which spans 2005 to present. In fact, the data indicate that the NO_2 levels in March 2020 are about 30% lower on average across the region of the I-95 corridor from Washington, DC to Boston than when compared to the mean of 2015 to 2019. ***Caution:*** Further analysis is required to rigorously quantify the amount of the change in NO_2 levels associated with changes in pollutant emissions versus natural variations in weather. The images are free and publicly-available and may be downloaded.

Scientific significance, societal relevance, and relationships to future missions:
The OMI NO_2 data will enable scientific and applied research. The following are a few examples:

- *Air Quality:* While air pollution is decreasing around the world due to lockdown orders, the US government has relaxed pollution emission restrictions on some industrial sectors (e.g., power plants). Therefore, the changes in air pollution associated with the pandemic will serve as a natural experiment in how the atmosphere responds to changes in pollutant emissions from various sources.
- *Climate:* Several recent studies by the proposers have shown that NO_2 emissions inferred from satellite data serve as an effective proxy for co-emitted CO_2 emissions from cities and power plants. Therefore, researchers may be able to assess the impact of the pandemic on climate gas emissions.
- *Economics:* Given that most world economies are driven by fossil fuels, economists may use NO_2 data, a non-traditional source of data for this community, to assess the impact of the pandemic on economic activity around the world, including in countries without reliable economic data.
- *Intelligence Agencies:* The global intelligence community will likely find interesting uses of the NO_2 data for assessing the impact of the pandemic on world countries, including with world governments that purposely misrepresent or withhold the true extent of the pandemic's impact.
- *Health Professionals:* The NO_2 data may be used to gauge the effectiveness (e.g., reduction in emissions from traffic and industry) of lockdown efforts to contain or slow the pandemic in a given area.