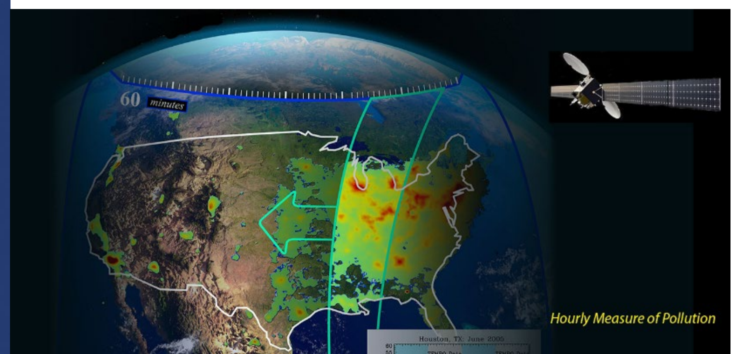
August 2022 MAIA-TEMPO Environmental Justice Workshop Report
Virtual workshop, August 5, 2022



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1. Introduction

The Multi-Angle Imager for Aerosols (MAIA) and the Tropospheric Emissions: Monitoring of POllution (TEMPO) projects are two competitively selected NASA instrument investigations focused on the study of air quality and societal benefit. Both projects are part of NASA's Earth Venture Instrument program and will be hosted by spacecraft provided by commercial or international partners, with TEMPO's launch in April 2023 and MAIA planned for launch in late 2024. MAIA and TEMPO are complementary missions, with MAIA focusing on particulate air pollution and TEMPO on trace gas pollutants including ozone and nitrogen dioxide. MAIA's host, the Italian Space Agency (ASI)-provided PLATiNO-2 spacecraft, will be launched into a polar, sun-synchronous low-Earth orbit, while TEMPO's host will be in geostationary Earth orbit (GEO) stationed at 91° West above the equator to focus on North America. MAIA's data products will have slightly higher spatial resolution and will be generated over discrete locations distributed around the globe, while TEMPO's data products will have higher temporal resolution - every hour during the daytime - with coverage over North America.

On August 5, 2022, the MAIA and TEMPO Applications Programs hosted an Environmental Justice Workshop in a virtual format. The objectives of this workshop were to:

1. Raise awareness about MAIA/TEMPO to environmental justice (EJ) advocacy groups, and provide background information on the missions.
2. Improve understanding of the TEMPO and MAIA EVI project teams about the EJ user community's needs: Do they need certain data formats/compatibility/tools? What capacity building resources do they need and desire?
3. Participate in collaborative brainstorming regarding how MAIA/TEMPO data could be useful to EJ work.

The full agenda for the workshop is included here in Appendix A. 297 people registered for the workshop, of which 185 attended live and the remainder received the workshop recording for asynchronous viewing. The registrants included representatives of twenty environmental justice advocacy organizations, as well as epidemiologists, environmental health researchers, air quality managers, and others. The full list of attendees at the live workshop is included in Appendix B.

The coordinators decided to hold this workshop virtually to ensure it was accessible to all interested participants, by eliminating travel costs and accommodating various home time zones through distribution of the workshop recording. To reduce teleconference fatigue, the agenda was compressed to five and a half hours and introductory material about the projects was migrated to slides made available to participants in advance of the workshop.

The workshop was presented via Microsoft Teams teleconference, and an online tool called Mentimeter (https://www.mentimeter.com) was employed to allow all participants to ask questions and provide feedback in real time. Activities included some initial questions before the workshop began to gauge the attendees' areas of interest, as well as an interactive discussion during the workshop to gather input and feedback.

1.1 Introduction to the NASA Multi-Angle Imager for Aerosols (MAIA) Early Adopters Program

MAIA's primary science objective is to study the effects of various compositional makeups of particulate matter (PM) air pollution on human health. Exposure to PM air pollution is recognized as the largest worldwide environmental risk factor, as opposed to personal risk factors like heredity and behavior, for premature death. MAIA will use a combination of spaceborne technologies to collect multispectral, multi-angle, and polarimetric observations, which provide information about the size, shape, and composition of the particles that comprise PM air pollution. The data collected from the instrument will be combined with measurements from air pollution monitors on the ground and outputs from a chemical transport model to calculate the concentrations of various PM types over a globally distributed set of Primary Target Areas. Epidemiologists on the MAIA team will conduct studies on the health impacts of the derived PM compositions.

From the beginning, the MAIA EVI science team has included a diverse team of co-investigators along with collaborators from the National Institutes of Health (NIH), the Centers for Disease Control and Prevention (CDC), and the National Oceanic and Atmospheric Administration (NOAA). This unique team will help ensure that MAIA data products and science advancements are able to make a material impact on those managing public health air quality issues. More recently, collaborations with the US Agency for International Development (USAID), the US Department of State, and the Italian Space Agency have been established, and a cadre of collaborators who will assist in surface monitor operations and epidemiological studies in the target areas has been identified. In addition, the NASA Applied Sciences Program (ASP) is committed to developing and implementing a broad-reaching applications program to reach additional potential users of the MAIA data. Lawrence Friedl, the NASA ASP Director, and John Haynes, ASP Health and Air Quality Program Manager, oversee the applications efforts associated with various missions. ASP funds the MAIA Deputy Program Applications (DPA) Lead, who acts on behalf of the ASP specifically for MAIA.

The primary goal of the MAIA Applications Program is to maximize the benefit of the NASA Earth Science Directorate (ESD) investment by enhancing the applications value and overall societal benefits of the project. The keystone of the MAIA applications effort is the Early Adopters Program, through which interested potential users will have the opportunity to avail themselves of regular updates from the MAIA EVI science team, take advantage of resources including simulated data products prior to launch, and offer feedback to the project on potential product improvements. The Early Adopters program is intended to entrain potential users outside the MAIA EVI science team prior to launch and provide resources to ensure MAIA is meeting their individual needs to the greatest possible extent. MAIA Early Adopters, who numbered 209 individuals at the time of this writing, have the opportunity to offer feedback on MAIA's planned data products through workshops, experiment with test versions of the products pre-launch, and can take advantage of the expertise of the MAIA EVI science team. More details about the Early Adopters program and other MAIA activities related to reaching data users, including a link to sign up for the MAIA Early Adopters mailing list and apply to receive the MAIA Simulated Data, are available on the applications page of the MAIA website (https://maia.jpl.nasa.gov/resources/data-and-applications/).

1.2 Introduction to the NASA Tropospheric Emissions: Monitoring Of POllution (TEMPO) Early Adopters Program

TEMPO will measure hourly daytime pollution at high spatial resolution over North America from GEO orbit, which will significantly improve our capabilities to monitor the spatial and temporal variations of emissions of gases and aerosols and understand their influence on air quality and climate, a key science objective of the mission. The TEMPO spectrometer is specifically designed for measuring trace gases in the atmosphere, including U.S. EPA criteria (policy-relevant) pollutants of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3). TEMPO will also measure formaldehyde (HCHO) and glyoxal (CHOCHO), which are major proxies for air pollution and will enable a better understanding of O_3 sensitivity to precursor gases of HCHO and NO_2. Altogether, the revolutionary capabilities of TEMPO will provide new knowledge for understanding and addressing air pollution issues from sub-urban to continental scales.

The TEMPO Early Adopters program aims to broaden and enhance air quality and health applications of future TEMPO data, with special attention on applications that directly benefit society. The three main objectives of the Early Adopters program are as follows: (1) Engage new and existing stakeholders and end users, particularly in the applied air quality and health communities, to expand the use of future TEMPO data and understand user needs; (2) demonstrate and enhance TEMPO applications through use of pre-launch proxy data and relevant observations from currently available sensors; (3) align the TEMPO observing time, products, and data interfaces to user needs and applications.

The overarching goal of the program is to accelerate and maximize the use of TEMPO data for societal benefit. As a user-centric program, participation from early adopters during workshops, meetings, and tutorials, is key to achieving the defined objectives and goals. In addition to providing important prelaunch input on TEMPO data products, early adopters can govern use of the special scan operations of TEMPO by contributing experiment ideas to the TEMPO Green Paper, receive access to proxy data along with product information and support tools, and develop new collaborations within the applied science community. TEMPO proxy data products can be downloaded from the NASA Earthdata website, enabling the user community to develop tools to effectively prepare for the real mission data after launch. The only requirement to access the TEMPO proxy data is to sign up for the TEMPO Early Adopters Program, which currently has nearly 340 members (as of September 2022) from numerous federal, state, and local air quality agencies, health organizations, private companies, and

NGOs. A link to sign up for the program is available on the Early Adopters website (https://weather.msfc.nasa.gov/tempo/).

The living TEMPO Green Paper is specifying fundamental and applied science experiments for the TEMPO mission, with particular attention on coordinating experiments requesting the special operations of TEMPO to maximize the value and societal impact of the higher frequency data products. Details on the TEMPO Green Paper and request document can be found here: https://weather.msfc.nasa.gov/tempo/green_paper.html. Early Adopters are encouraged to submit requests for impactful experiment opportunities of TEMPO.

2. Summary of workshop proceedings

A summary of the material presented in the workshop is provided here for the benefit of those who were not able to attend and other interested parties.

2.1 Introductions

The workshop began with a welcome from John Haynes, NASA ASP Health and Air Quality Program Manager. The Health and Air Quality Program's objective is to support the use of Earth observations in air quality management and public health, particularly regarding infectious disease and environmental health issues. The funded activities of the program include the Health and Air Quality Applied Science Team (HAQAST), now in its third generation; a portfolio of competed projects that fall within the program's topic areas; and support for applications programs for applicable NASA missions, including MAIA and TEMPO.

Afterwards, Dr. Nancy Searby, the NASA ASP Capacity Building Program Manager, gave a brief summary of NASA's current activities in the area of equity and environmental justice. The 2022 NASA Equity Mission Plan added "equity in climate data accessibility and environmental justice" as a fourth foundational area. The NASA Earth Science Division (ESD) has set five goals in its equity and environmental justice strategy: 1) Assess ongoing environmental justice engagements, barriers, gaps and opportunities; 2) Engage with organizations involved with environmental justice and harvest lessons and potential partnerships for the strategy; 3) Host data accessibility and utility sessions; 4) Enable transdisciplinary science and applications that integrate physical and social science using NASA datasets; and 5) Incorporate equity and environmental/climate justice themes across ESD programs. The FY22 NASA omnibus funding solicitation included the first ever call specific to environmental justice projects; it requested EJ proposals on landscape analyses, feasibility and data integration topics. 39 proposals were accepted under the call, of which twenty fall under the Health and Air Quality program area. Dr. Searby also summarized several other NASA activities related to environmental justice and provided links for more information.

Finally, the two workshop coordinators Aaron Naeger and Abbey Nastan covered the logistical introduction to the workshop. This included the land acknowledgement, the objectives, and the schedule.

2.2 Mission updates

The first section of MAIA and TEMPO presentations consisted of a brief mission update from both projects. Much more extensive background information was distributed prior to the meeting for those attending a MAIA or TEMPO event for the first time, so these presentations were limited to the current progress of the missions and immediate future plans.

2.2.1 MAIA project and launch update (presenters: Abbey Nastan and Sina Hasheminassab, JPL)

Figure 1. *The MAIA instrument (shown without its cover).*

As the MAIA-EVI principal investigator David Diner was unable to attend the workshop, the MAIA mission status update was presented by Abbey Nastan, the MAIA Deputy Program Applications Lead, and Dr. Sina Hasheminassab, a member of the MAIA EVI Science Team at JPL. The update covered the current status of the instrument build and hosting services, surface monitor deployments, target areas, and data products. The MAIA instrument is nearing completion and delivery is expected in Fall 2022[1] after environmental testing is completed. The project also announced that NASA and the Italian Space Agency (ASI) are currently working on an agreement for ASI to provide the hosting services for MAIA[2]. Under this plan, MAIA would be installed on one of the PLATiNO series of ASI satellites, and launch will be targeted for 2024. More details will be forthcoming once the agreement is finalized.

For brevity, the full technical description of the instrument is omitted here. For more details, consult the MAIA website https://maia.jpl.nasa.gov and the publications listed therein. The instrument will collect multi-angular views of each target (see Figure 2) and produce radiance and polarization information, from which aerosol optical properties will be retrieved. The approach to produce speciated PM concentrations is geostatistical regression modeling, which will take the MAIA aerosol product and geospatial and spatiotemporal predictors, including PM surface monitor data, as inputs. A daily-averaged, gap-filled PM concentration product will be produced using a chemical transport model as input to cover areas and days that have no MAIA aerosol retrievals. The full details of the MAIA aerosol and PM retrieval approach and validation will be detailed in several Algorithm Theoretical Basis Documents and a Science Validation Plan, which will be available online and accessible from the MAIA website once published.

[1]The MAIA instrument was subsequently delivered on October 31, 2022.
[2]The hosting agreement between NASA and ASI was signed in January 2023. Please see this link for more info.

The current list of candidate MAIA target areas (Figure 2) was also presented. The MAIA Primary Target Areas, wherein epidemiologists on the MAIA Science Team will conduct health studies, consist of 11 identified targets. The MAIA Secondary Target Areas include cities with major PM pollution, aerosol source regions, climatically important cloud regimes, or other locations of scientific interest. As of August 2022, the MAIA team has identified 27 potential Secondary Target Areas based on team and Early Adopter input, with San Juan, Puerto Rico and Yakutsk, Russia being the most recently added. Calibration/Validation Target areas will be primarily used for instrument radiometric, polarimetric, and geometric calibration while in flight.

***Figure 2**. The MAIA candidate target areas as they were presented at the workshop. A more recent version with additional target areas in Italy can be viewed on the MAIA website.*

Where available, MAIA project collects data from existing ground-based PM monitoring networks managed by government agencies, research groups, and other sources. In several PTAs, the MAIA project is capitalizing on the existing Surface PARTiculate mAtter Network (SPARTAN) for $PM_{2.5}$ speciation and expanding this network with additional filter samplers; deploying Aerosol Mass and Optical Depth (AMOD) to complement $PM_{2.5}$ speciation networks; and installing AethLabs microAeth MA350 monitors for black carbon measurements in heavily polluted regions. Over the past year, 5 SPARTAN stations and 4 aethalometers have been shipped and installed in different PTAs. In Ethiopia, where only a few total PM2.5 monitors have historically been operating, a set of cost-effective PurpleAir sensors has been deployed to enhance the spatial coverage of ground-based $PM_{2.5}$ measurements. One additional SPARTAN and 9 Aerosol Mass and Optical Depth (AMOD) filter-based samplers are in the process of being shipped and installed as of this writing. Dr. Hasheminassab showed some preliminary data from the instruments installed thus far, including data from the PurpleAirs and aethalometers in Addis Ababa, Ethiopia, that highlight the very high PM loading experienced in that city. In addition to the monitor deployments, the MAIA science data system team has also completed work to obtain, reformat, and quality screen the data from the existing and newly installed surface monitor networks in the PTAs.

Overall, the team has made excellent progress towards launch readiness and the instrument and data software are expected to be completed well in time for a prospective launch in 2024.

2.2.2 Update on the TEMPO project and launch (presenters: Kelly Chance and Xiong Liu)

***Figure 3**. TEMPO instrument (image courtesy of Maxar Technologies)*

The Deputy Principal Investigator of the TEMPO mission, Dr. Xiong Liu, led the presentation on the TEMPO mission updates. The integration of the TEMPO sensor with its host satellite Intelsat 40e was recently completed in June 2022 (Figure 3), which was a major step towards the satellite launch date set for April 2023. Upcoming milestones for the mission include preparation of the TEMPO ground systems by the end of September 2022 and the Operations/Mission Readiness Review in December.

TEMPO is an imaging grating spectrometer that will measure solar backscattered radiances in two channels from 293-494 and 538-741 nm over a Field of Regard (FoR) covering Greater North America from Mexico City to the Canadian Tar Sands (Figure 4). The nominal TEMPO operations will consist of hourly East-West scans composed of 10 different granules across the full FoR. Optimized scans with sub-hourly temporal frequency will be conducted in the early morning and late afternoon over the East and West U.S., respectively. The TEMPO mission will also commit up to 25% of its observing time to special operations over selected portions of the FoR at higher temporal resolution (e.g., < 10 minutes). The baseline mission length of TEMPO is 20 months.

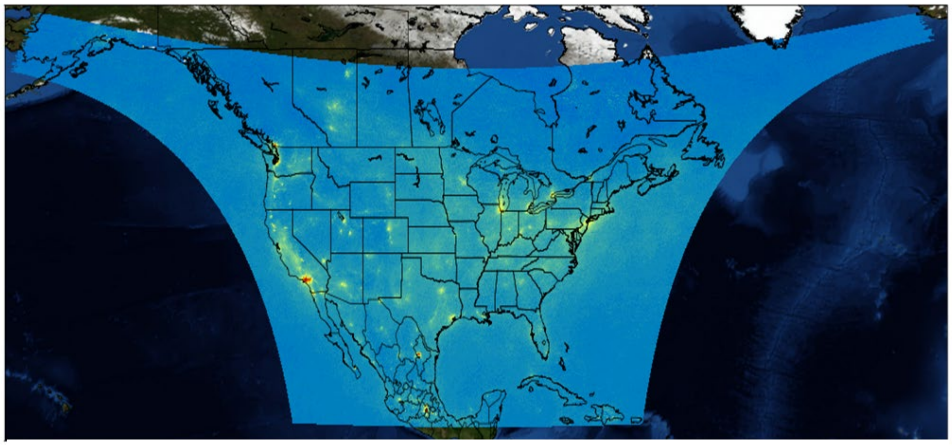

***Figure 4**. Coverage of TEMPO's nominal (hourly) scans across the Field of Regard shown by remapping NO_2 data from the TROPOspheric Monitoring Instrument (TROPOMI).*

The TEMPO instrument capabilities will enable a suite of baseline level 2 and 3 products consisting of 0-2 km O_3, total O_3, and tropospheric O_3, along with tropospheric NO_2 and HCHO. Level 3 products will be the same as level 2 except on a regular grid across the FoR. Aerosols, SO_2, and CHOCHO were removed from the baseline list, but have been proposed to be brought back along with additional products and near real-time and offline products for some species. Additional products include bromine (BrO), water vapor (H_2O), and a TEMPO/GOES-R synergistic product, which will provide aerosol retrievals for UV and VIS aerosol optical depth (AOD), absorbing aerosol index (AAI), and aerosol optical centroid height (AOCH). The proposed near real-time products with expected data latency (i.e., time between TEMPO observations across each granule and when data are distributed to public) less than 2 hours are NO_2, SO_2, HCHO, and aerosols. Efforts continue with improving products during the pre-launch phase of the mission using TEMPO proxy data and Geostationary Environment Monitoring Spectrometer data. Further algorithm refinements and optimizations will be implemented during the commissioning (July - Oct 2023) and nominal operation phases of the mission. The Atmospheric Science Data Center (ASDC) will provide a number of tools and services for archiving and distributing TEMPO data after launch, including NASA Earthdata Search, NASA Worldview, Harmony, and OPeNDAP capabilities. TEMPO data will also be served directly through the EPA RSIG3D Gateway.

With TEMPO launch planned for April 2023, the commissioning phase will occur from July into October 2023 with nominal operations commencing about 6 months after launch. The public release of level 1b radiance data is expected in February 2024, followed by level 2 and 3 products in April 2024. TEMPO has an extensive validation plan to ensure high-quality data products are provided to the user community. Current satellite observations will be used for cross validation of TEMPO data. The Pandora and Pandonia Global Network will be used to validate TEMPO NO_2, HCHO, and total O_3 retrievals from the ground up. TOLNet will provide 8 lidar ground-based instruments for validating tropospheric and 0-2 km O_3. Pandora and TOLNet will also aid in validating the diurnal variability of the TEMPO data products. Airborne instruments and planned flight campaigns, including the Synergistic TEMPO Air Quality Science (STAQS) mission in summer 2023, will provide critical validation of TEMPO products as well.

2.2 Introduction to MAIA and TEMPO Data

The second portion of the workshop consisted of background about the MAIA Simulated Data and TEMPO Proxy Data, which was intended to ensure that the environmental justice groups and other attendees would have an understanding of the capabilities of the instruments and data products going into the panel discussion.

2.2.1 MAIA Capabilities for EJ and Panoply introduction (presenter: Abbey Nastan, JPL)

Since the introduction to MAIA data was presented first, MAIA Deputy Program Applications Lead Abbey Nastan covered a brief introduction to NASA Earth science data products. The standard modern format of NASA Earth data is called NetCDF, which is an array-based, self-describing data format also used by NOAA and USGS, among other organizations. There are many software tools and programming language packages available that work with NetCDF files; one tool useful for those new to the format is the free NASA Panoply software, which allows one to easily explore the content of a NetCDF file and make plots and maps of the scientific data inside it. NASA Earth science data are available from various portals: NASA Earthdata Search is a central repository. Access is free to all datasets stored in Earthdata, though new users need to create a free account. Another thing to note is that NASA Earth science data products are assigned "levels" according to how much processing on the data was performed for that product. So, raw data from the spacecraft is Level 0; the core measurement of the instrument is Level 1; Level 2 data refers to per-observation derived science products; Level 3 data are science products that have been regridded and sometimes temporally averaged; and Level 4 data refers to gridded products that combine satellite data and model results.

MAIA data will be distributed in NetCDF format, but the team is working to ensure that the files are GIS compatible and that export to CSV will be readily available, as these two compatibilities were identified as highly important by MAIA Early Adopters. MAIA will have four core data products: Level 1 imagery and polarization data, Level 2 aerosol data, and Level 2/4 PM concentration data.

- The Level 1 imagery product will allow users to construct various true and false color images from MAIA's radiance measurements at various angles in 14 spectral bands and 3 polarimetric bands at 250 meter resolution per pixel. The Level 1 data will also be useful to those who want to construct their own science products derived from MAIA data; as one example, one could use MAIA Level 1 data to derive smoke plume height measurements using an algorithm that calculates the parallax between different angular views.
- The Level 2 aerosol data product* will contain parameters similar to other NASA satellite-derived aerosol data, such as aerosol optical depth (AOD), single scattering albedo (SSA), and various parameters describing the microphysical properties of the observed aerosol. Two main future uses have been identified for this product: aerosol researchers can use it to extend their work from other satellite instruments with aerosol products, and PM exposure modelers can use it

to derive their own PM concentration models to compare with or supplement MAIA's PM concentration products. The MAIA Level 2 aerosol data will be produced at 1 kilometer resolution per pixel.

- The Level 2 PM concentration product* will contain daily averaged concentrations of total PM2.5 and PM10, as well as sulfate, nitrate, organic carbon, elemental carbon and dust PM2.5. These parameters will originate from geostatistical regression models trained on surface monitor data to predict PM concentrations using the MAIA aerosol product as input (along with several ancillary datasets and chemical transport modeling). The Level 2 PM product will also be produced at 1 kilometer resolution per pixel. This data product will be available on days that MAIA overpasses that particular target; coverage will be limited by any cloud cover, shallow water, mountainous terrain, and other factors that prevent retrieval of aerosol properties for that particular pixel.
- The Level 4 PM concentration product* will have identical format and parameters to the Level 2 PM product. The main differences of the Level 4 compared to the Level 2 product are: that it will be produced every day, regardless of the availability of MAIA observations for that day, and that it will be gap-filled to achieve complete spatial coverage of the target area in question. This additional spatial and temporal coverage is possible by using MAIA's specialized chemical transport models as predictor where MAIA aerosol product results are not available; however, it is important to note that data quality will not be as high where MAIA observations are not available.

*The MAIA project is committed to producing these data in the Primary Target Areas (see Figure 2 above for the target list current as of this writing). The project's ability to produce them in Secondary Target Areas depends on the needed compute and team personnel resources, and is still being evaluated at this time.

With the caveat that MAIA would like to hear from the EJ community about their thoughts on the use of MAIA data for EJ purposes, Nastan shared some initial ideas about the applicability of MAIA data to EJ. The major strength of satellite-derived data, in contrast to surface monitors, is the ability to provide contiguous spatial coverage over an area. The major advance of MAIA is to provide satellite-derived concentrations of PM species, but it will also provide ongoing, ground-level PM concentration data at high spatial resolution, which hasn't been widely available to date. This means that MAIA data should provide substantial value-added information for determining species of concern, local hotspots for total PM and PM species, and tracking trends over time. This information could be used by EJ groups for source apportionment to determine effective mitigation strategies, to site sensors for a local measurement campaign, or to request additional regulatory monitor coverage for hot spot areas.

At the same time, MAIA does have some limitations that users should keep in mind. The project foresees a delay of roughly one to two days between MAIA observations of a target and when the data will be available to the public (in other words, 24-48 hour data latency), which will limit the use of MAIA data for forecasting or real-time monitoring. The latency will be known with more certainty once hosting and ground station details are confirmed. Additionally, since MAIA PM data will be daily averaged, it won't be able to provide insights into the diurnal cycle of air pollution. Finally, and probably most importantly, MAIA data will be limited to discrete target areas around the globe, and the project is not able to guarantee that the PM data will be provided in the Secondary Target Areas. While this limitation is an inherent consequence of the MAIA instrument design, it does emphasize the importance of synergy work with other instruments like TEMPO and future satellite missions to enhance the value of MAIA by extending coverage.

While the actual MAIA data products won't be available until after launch, the MAIA team has made some Simulated Data available to help potential users decide whether the products will be of use. The simulated data that were available at the time of the workshop, for the L2 aerosol and L2 PM product, are the result of basic software tests and the parameter contents are NOT meant to be a good representation of reality. However, they are useful for understanding the data format and contents. The Simulated Data are available through NASA Box (a tool similar to Dropbox) by submitting the data access agreement to Abbey Nastan via email. The team is currently preparing a more advanced simulated PM dataset for release to Early Adopters. This dataset, provided by MAIA science team member Dr. Yang Liu of Emory University and his colleagues, includes a full year of simulated PM concentrations for MAIA's Northeast United States Primary Target Area (which includes both Boston and New York City) for 2019. These data will be made available via NASA Earthdata, so potential users can test the system for acquiring MAIA data at the same time.

2.2.2 TEMPO Proxy Data and EJ Applications (presenter: Aaron Naeger, UAH)

The baseline requirements for the TEMPO mission is to provide a suite of level 1, 2, and 3 science data products to the user community. TEMPO will measure backscattered solar radiances at the top-of-atmosphere every 0.2 nm throughout its two spectral bands from 293-494 and 528-741 nm. After applying geolocation and calibration procedures, the radiances will be provided in a level 1b data product. The level 1b radiance data will be fed into the TEMPO retrieval algorithms based on known absorption signatures of trace gases in the atmosphere and auxiliary information to generate the level 2 data products, including the baseline products of cloud, O_3 profile, total O_3, NO_2, and HCHO. Additional level 2 products proposed for the mission are SO_2, aerosol, H_2O, BrO, CHOCHO, and aerosol products.

For the level 2 trace gases (O_3, NO_2, HCHO, SO_2, BrO, CHOCHO, H_2O), TEMPO will retrieve the total number of molecules of a specific gas along the light path from each TEMPO footprint at Earth's surface to the satellite location, termed the slant column density (SCD). The SCD is then converted to a vertical column density (VCD), which provides the total number of molecules of the specific gas right above each TEMPO footprint. The VCD variable for each trace gas product will have units of molecules per cm^2, except for O_3 where molecules per cm^2 is converted to Dobson units (DU) as the variable unit. One DU is equivalent of 2.69×10^{16} molecules of O_3 per cm^2. The aerosol product includes unitless variables of AOD and AAI and AOCH in units of meters. All level 2 products are provided every daytime hour at the TEMPO footprint resolution ($2 \times 4.75\ km^2$) in 10 different granules across the FoR, except the O_3 profile and aerosol product. The O_3 profile will have a coarser spatial resolution of either 8 x 4.75 km^2 or 8 x 9.5 km^2 (still under evaluation) to reduce the noise level and decrease the uncertainties in the product. Level 3 products are also planned for the mission, which will be the same as the level 2 products but on a regular grid, likely 2 km, across the FoR.

A brief overview of how the TEMPO proxy products are produced was presented to workshop participants. Since TEMPO is not yet launched and making observations, we use model output fields from the Goddard Earth Observing System Model (GEOS-5) Nature Run simulations from July 2013 - June 2014 to represent the atmospheric conditions including trace gas concentrations and clouds in the proxy product methodology. Known information on TEMPO instrument sensitivities and trace gas absorption spectra are applied in the methodology to derive the SCDs and VCDs for a specific trace gas based on the model concentrations. To date, NO_2, HCHO, O_3 profile, SO_2, H_2O, and aerosol proxy products have been generated for the early adopters community. The level 2 NO_2, HCHO, and O_3 profile products are available in the NASA Earthdata system (https://www.earthdata.nasa.gov/) for early adopters to download, which will be the same system used to distribute real TEMPO data after launch. The proxy products are provided in the same NetCDF file format as planned for the real TEMPO products. However, some differences exist with the variables in the NetCDF files, such as using fill values or zeros to represent a few variables that require information on simulated radiances, which is not done in the proxy methodology. The proxy files also include a “true quantities” group consisting of several variables with values directly from the GEOS-5 Nature Run model. Nevertheless, the structure and variables in proxy files are very similar to the TEMPO products that will be available after launch, enabling early adopters to gain an early understanding of the files and prepare applications for real TEMPO data.

The second part of this presentation focused on providing a proxy product demonstration with emphasis on EJ applications. Images of the proxy tropospheric NO_2, total HCHO, tropospheric O_3, and 0-2 km O_3 products over the entire TEMPO FoR were shared with the workshop participants. Some distinct enhancements in tropospheric NO_2 and total HCHO VCDs due to wildfire smoke across the western U.S. on August 14, 2013 were highlighted (see Figure 5), along with an additional enhancement in HCHO VCDs over the southern U.S. associated with biogenic sources. A more in-depth demonstration was shown for a wildfire event on August 23, 2013, where proxy NO_2 and HCHO images were shown for every daytime hour from morning to evening over California. This example highlighted the capability of TEMPO to observe the rapidly varying NO_2 and HCHO within wildfire smoke plumes and NO_2 across urban areas and traffic corridors throughout the day, a major advancement over current low-earth orbiting instruments [e.g., Ozone Monitoring Instrument (OMI)], which are limited to midday observations of NO_2 and HCHO. TEMPO will be able to monitor wildfires during the later afternoon when peak fire intensity and smoke production usually occurs, helping to improve smoke monitoring and better understand disparities in wildfire smoke exposure that can contribute to EJ issues. TEMPO will also observe fine gradients in NO_2 throughout the day, enabling analyses on how within-day variability and peak exposures in pollutants affects health. By averaging hourly TEMPO data over longer time periods (i.e., oversampling), TEMPO will resolve pollutants at higher resolution than the nominal footprint size (2 x 4.75 km^2) with the potential of generating ~1 km resolution monthly maps for characterizing disparities in air pollution at the community level. EJ studies will

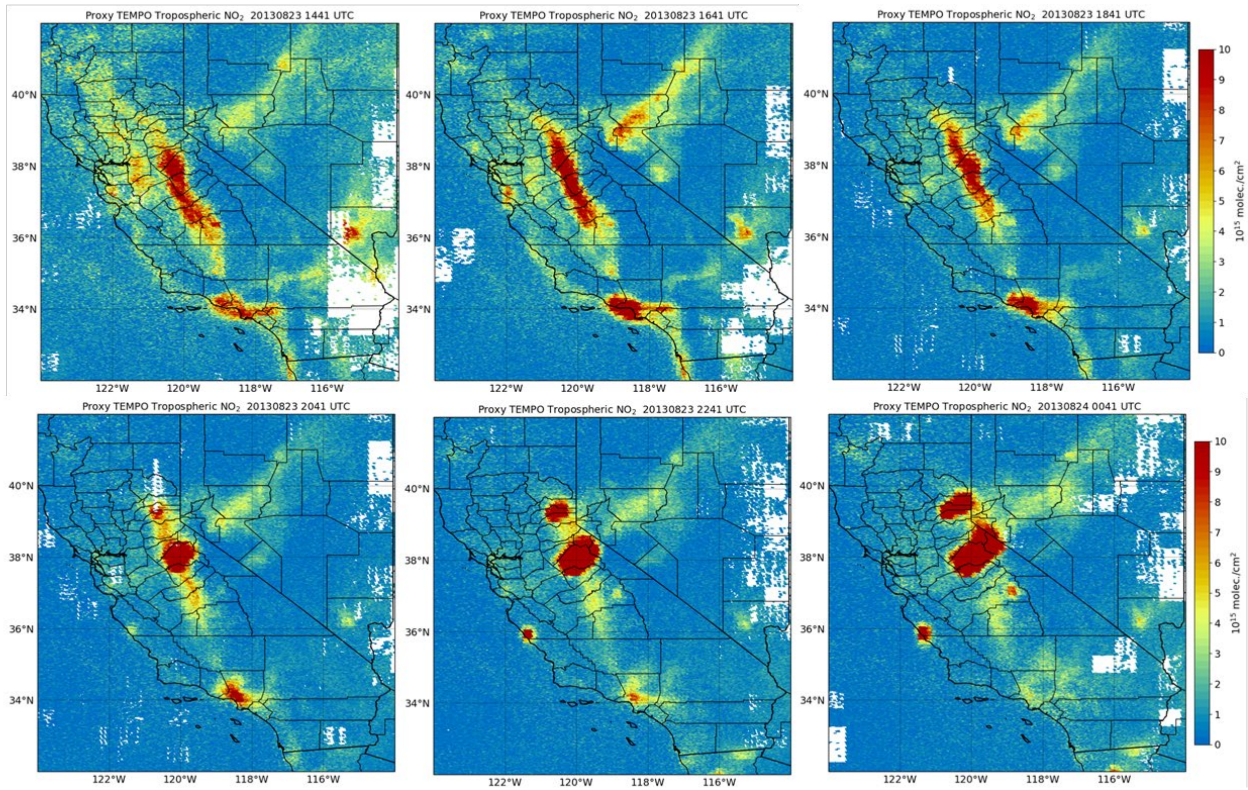

***Figure 5**. Pre-launch proxy TEMPO NO_2 data showing strongly varying and high NO_2 VCDs over California and Nevada associated with urban emissions, vehicles, and wildfire smoke.*

also benefit from using the O_3 profile product from TEMPO to discern O_3 pollution in the boundary layer where people live and breathe throughout the day. Altogether, the high resolution, multi-pollutant products from TEMPO will enable new and improved EJ studies in the future.

Community members interested in downloading and using the TEMPO proxy data must first join the TEMPO Early Adopters Program mailing list to receive access to the data. A button link to join the mailing list is available on the TEMPO Early Adopters website (https://weather.msfc.nasa.gov/tempo/). Intended uses of the proxy data include understanding TEMPO file structure and content, preparing methods and decision support systems for application of TEMPO data, and conducting qualitative assessments on how TEMPO data will enhance applications. Workshop participants were informed that the proxy data are not intended for supporting operational and management decisions and quantitative research studies. Finally, a demo on how to download the TEMPO proxy data from NASA Earthdata concluded the presentation.

2.3 EJ Panel and Discussion

The third portion of the workshop consisted of a panel discussion with representatives of three organizations working in environmental justice: Denise Bruce of CleanAIRE NC, Janice Archuleta and Arlyssia Sells of Ute Mountain Ute Tribe, and Jane Williams of California Communities Against Toxics. The panelists gave presentations on their organizations' work, followed by a discussion session. Following this, the discussion was opened to all workshop participants with several guided questions, facilitated with the use of Mentimeter.

2.3.1 CleanAIRE NC (presenter: Denise Bruce, CleanAIRE NC Citizen Science Manager)

CleanAIRE NC focuses on Charlotte's Historic West End, Sampson County, and Wilmington in North Carolina. Cluster networks of 15-20 low-cost PM2.5 sensors are being deployed near pollution sources affecting EJ communities in these counties, which face a number of challenges. In particular, in the Historic West End of Mecklenburg County, less educated and poverty-stricken communities have less access to hospitals and health care. Active swine and poultry production dominantly in areas with higher demographic index (higher percentages of low income and minority population) in Sampson County contributes to higher ambient levels of particulate matter, ammonia, and hydrogen sulfide (Figure 6). These concentrated animal feeding operation (CAFO) pollutants are associated with low birth weight, shorter life expectancy, diabetes, and kidney disease. The CleanAIRE NC Citizen Science program engages North Carolinians in EJ communities to fight for cleaner air by deploying and maintaining a PM2.5 monitoring network and involving sensor hosts (e.g., AirKeepers) in the process. The AirKeepers Monitoring Program started in the Historic West End in fall 2016 to address health inequalities caused by air pollution in EJ communities. The AirKeepers use PurpleAir sensors to collect PM2.5 data and help track and interpret the air quality data. A major outcome from the Citizen Science program was the approval of a regulatory-grade EPA monitor in the Historic West End. Several goals of CleanAIRE NC in the Historic West End include:

- Increase strategic tree planting and monitoring along highway corridors
- Installation of green roofs, green walls, and other green infrastructure to filter pollution and cool the area
- Advocate for electric vehicle charging stations and more walking, biking, and clean transit
- Increase education around health impacts of air pollution and provide air quality advocacy training to residents

CleanAIRE NC uses a number of tools in their EJ work consisting of the real-time PurpleAir PM2.5 maps, EJScreen, interactive maps of air quality on the AirNow website, information on the U.S Department of Agriculture website, GreenLink Equity Mapping, Esri, and data and tools on the USGS website. They plan to incorporate new data through a Science Advisory Team, Easter Research Group for dashboard creation and reporting, and collaboration with the Research Triangle Institute.

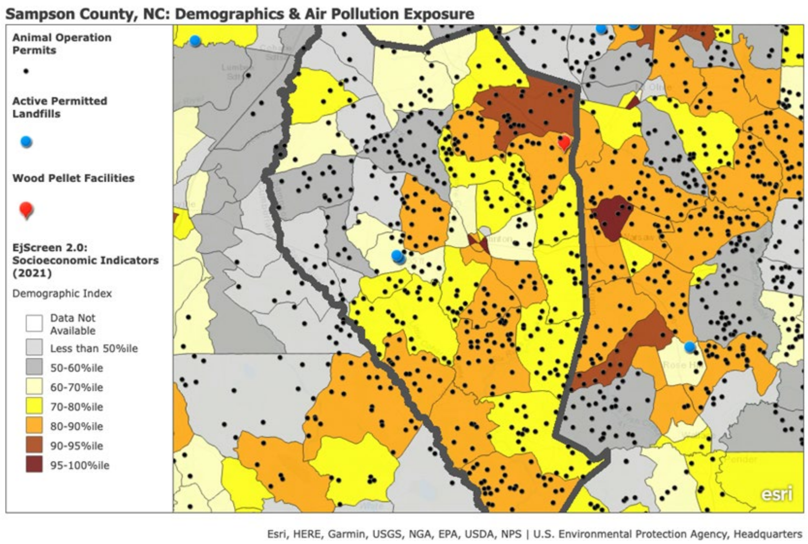

***Figure 6**. Emissions sources and socioeconomic indicators in Sampson County.*

2.3.2 Ute Mountain Ute Tribe (presenter: Janice Archuleta, Ute Mountain Ute Tribe Air Quality Program Manager, and Arlyssia Sells, Air Quality Technician)

The Ute Mountain Ute Tribe (UMUT) focuses on the homeland of the Weeminuche Band with 2,200 members located in extreme southwestern Colorado with portions extending into southeastern Utah and northwestern New Mexico. The UMUT is a U.S. recognized Native American Indian Tribe, which faces a number of socio-economic hardships including poverty. Higher incidences of asthma, diabetes, heart disease, and chronic obstructive pulmonary disorder impact the indigenous / tribal populations than non-American Indian / Alaskan Native populations. This area includes trust land covering 933 square miles and fee land (cattle ranching) covering 43 square miles. The mission of the Air Quality Program of the Environmental Programs Department of the UMUT is to protect air quality for the Ute Mountain community and lands. The Air Quality Program is funded by the U.S. EPA dating back to 2011 with the 2011 - 2022 Clean Air Act Grant 103. Recently, the UMUT was awarded an EPA EJ Grant in 2022.

Major pollutant sources and air quality concerns in the UMUT region are associated with the oil and gas industry, White Mesa Uranium Mill and area mines, and coal burning electrical generating power plants (Figure 7). UMUT maintains a network of surface monitors and sensors including regulatory-grade monitors for measuring ozone and PM2.5 in Towaoc, CO and White Mesa, UT along with low-cost PurpleAir sensors for additional PM2.5 measurements in these areas. There is a plan to deploy more low-cost sensors as part of a Citizen Science effort under the EJ grant at White Mesa. One focus area of the EJ grant are the concerns with the emissions from the uranium mill in the White Mesa community. UMUT noted several TEMPO products that could aid in their air quality work and EJ efforts such as O_3, SO_2, HCHO, and CHOCHO for monitoring the oil and gas and industrial sources in the region and NO_2 and a derived level 4 PM2.5 product for monitoring the White Mesa Mill, industry, and vehicle emissions. Current data and tools used by UMUT include surface monitor data for pollutants and meteorology, QREST (Tribal Air Database), neighboring datasets (i.e., Southern Ute Indian Tribe / Mesa Verde National Park), GIS, TEISS (Tribal Emissions Inventory Program), EPA codes and data, AirNow Fire and Smoke map, and the Active Fire

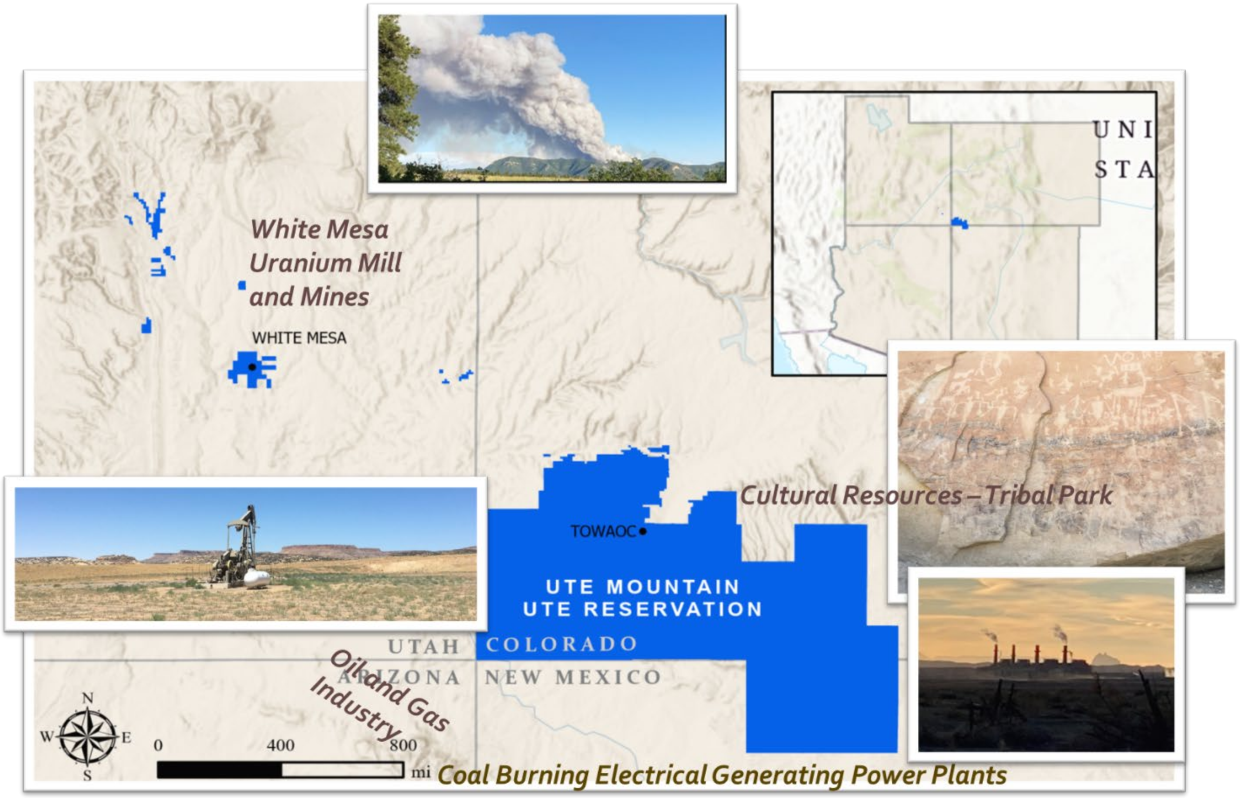

***Figure 7**. Major pollutant sources in the UMUT region.*

Mapping Program from the National Forest Service. The process of incorporating new data into the UMUT operations is usually made by the program manager with guidance from the Tribal leaders and upper management. UMUT is most familiar with CSV files and GIS compatible formats (shapefiles) with data processing usually performed using R code and OpenRefine. Training may needed to help UMUT integrate new satellite products into their operations and understand products of most importance in the region.

2.3.3 California Communities Against Toxics (presenter: Jane Williams, California Communities Against Toxics Executive Director)

California Communities Against Toxics (CCAT) focuses on reducing and preventing pollution and advocating for peace and environmental justice. CCAT tackles issues at the state, national, and international level, with special attention on air pollution issues in California. The Alameda industrial corridor in the Greater Los Angeles region is a major focus area of CCAT, which will benefit from both TEMPO and MAIA observations (primary target area of MAIA). Public health impacts from air pollution in this industrial corridor are very significant with high asthma mortality and COPD rates. CCAT recently worked on the Public Health Air Quality Management Act which would mandate the U.S EPA to use satellite data to better regulate high pollution areas across the nation. In addition to working with communities affected by air pollution in high impact areas across California, CCAT provides technical expertise to communities across the country on air pollution monitoring with community based monitors, NCORE (National Core

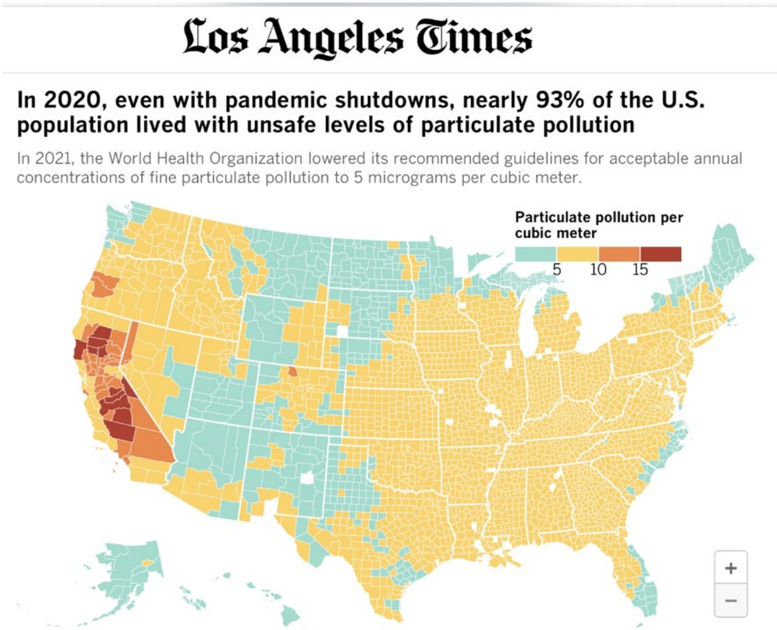

Figure 8*. Map of fine particulate pollution showing unsafe levels of pollution even during the pandemic shutdowns in 2020.*

Monitoring Stations), SLAMS (State and Local Air Monitoring Stations), and fenceline monitoring for air toxics. CCAT also works to reduce air pollution and criteria pollutants from the petrochemical sector, mining sector, energy sector, and large stationary sources of air pollution with environmental justice partners across the country. A number of facilities have been assessed by CCAT including chrome platers, lead and copper smelters, refineries, chemical manufacturing facilities, storage tanks for petrochemicals, oil and gas infrastructure, and power plants.

The critical use of satellite data for monitoring the spatial distribution of air pollutants was emphasized throughout the presentation, as surface networks lack the coverage needed for fully characterizing air pollutants and their health impacts. CCAT has a strong desire to use the NO_2, SO_2, and O_3 products from TEMPO and PM2.5 products from MAIA in their work, and stressed the importance of making satellite data more user friendly for the public and the advocacy community. They strongly advocate for the use of satellite data to identify areas of the country that are not in compliance with the National Ambient Air Quality Standards (NAAQS) and have a high-level of interest in using future TEMPO and MAIA data in their own NAAQS compliance work. Air toxics (e.g., ethylene oxide, benzene, lead, chloroprene, hexavalent chromium) from fenceline monitoring operations are another major focus area of CCAT. The presentation concluded with a statement that promoted an air pollution monitoring approach in the U.S. that better integrates satellite data with surface and fenceline monitoring data.

2.3.4 Panel discussion

Four discussion questions were presented to the panel during this session. Responses from each panel member are summarized below.

Question 1: What are the biggest data barriers to your work?

UMUT - Need for more open source data and access to software such as GIS for effective and efficient data analysis. Limited funding levels was also noted as a data barrier.

CleanAIRE NC - Data on government websites are geared for academic researchers. When registering for data access, community organizations are usually not listed as an option, which can discourage the community members from using the data. Bandwidth issues and limited personnel to access and analyze the data were noted.

CCAT - All science data should be disseminated along with some tools for translating the data. Science translation is a major data barrier that needs further improvement.

Question 2: How could hourly, daytime (morning to evening), ~3km resolution data on NO_2, SO_2, O_3, HCHO, AOD, and aerosol layer height be used in your work? Is there value in near real-time data on these pollutants?

CCAT - Overall, there is high value in using satellite data as a supplement to ground-based measurements for monitoring pollutants. In particular, high-resolution satellite data can help resolve SO_2 concentrations from industrial facilities in the CCAT interest area. You should never trade latency for accuracy.

UMUT - Potential to explore NOx and VOCs from mill operations in the region. Tribe is a member of the western regional air partnership which deals with regional haze, NOx, and SOx. Wind speed and direction within TEMPO data products could aid in analysis of emissions from industrial operations.

CleanAIRE NC - NOx, SOx, and ozone data would be good for monitoring the urban environment over NC. Data with higher accuracy is more important.

Question 3: How could daily averaged 1 km resolution data on PM2.5, PM10, and sulfate, nitrate, organic carbon, dust, and PM25 concentrations from MAIA data be used in your work?

CCAT – There will be benefits from having MAIA data in large portions of California as two target areas exist in the state. MAIA data on PM2.5 and PM10 will significantly benefit public policy making on the ground. People are burning at the worst times in the agricultural areas of the Central Valley and MAIA data will help further understand this issue and the health burden associated with the burning. Overall, MAIA data will provide key support to epidemiological studies, which aim to influence public policy on the ground. It is critical to make MAIA data easily accessible and translatable for public policy applications.

UMUT – MAIA has a target area in Colorado but does not cover the Utah tribe region. However, there are tribal lands in southern Ute within the MAIA target over Colorado. Ute people share recreational spots so having MAIA data outside of the Utah tribe region will still benefit regional air quality monitoring and help protect the health of the tribal community. The MAIA targets of opportunity where the mission can adjust to observe a target outside of the permanent targets could provide valuable for UMUT.

Question 4: How do we best incorporate community feedback to solve EJ related air quality issues?

CleanAIRE NC - It is important to listen to EJ communities, reach out to communities, and conduct regular surveys and polls to determine how to better enable the EJ community to use satellite data for their applications.

UMUT – Engaging the community, getting feedback on data products, and establishing partnerships with organizations involved with EJ work will help solve EJ related AQ issues.

CCAT – EJ issues with air quality are hyperlocal, regional, and international, which is why we need a robust air quality monitoring network with transparent data for EJ applications. Satellite data must be as transparent as possible to be useful in regulatory applications that can help mitigate EJ related air quality issues.

2.3.5 Whole group discussion and participant input

All workshop participants were invited to contribute input in three ways: the pre-workshop survey, a whole group discussion held after the panel portion of the workshop, and the post-workshop survey. (The results of the post-workshop survey will be discussed in section 3.)

The pre-workshop survey was intended to provide information on the workshop audience that would allow the organizers to communicate more effectively. Participants were asked to self-identify with their field(s) of work: the majority of participants worked in air quality and atmospheric research (48.6%), air quality management (37.6%), and environmental justice or citizen science (18.34%). The other participants worked in epidemiology and health research (11.9%) or worked at NASA or JPL (8.3%), with a few participants identifying that they worked in renewable energy, computer/data science, education, civil engineering or air quality technology development. (Note: these percentages add up to over 100% because participants could select more than one field.) As the organizers anticipated, the workshop was of interest to many people not directly involved in environmental justice work. The organizers believed this would be compatible with the workshop objectives, as long as precautions were taken to ensure that environmental justice advocates had their voices heard and organizers were able to break out participant input to identify responses from workers in EJ.

Table 1. Responses to the question: Which of the following “pain points” would concern you about using satellite data from MAIA, TEMPO, or other instruments? 0 = not at all concerned 10 = very concerned

	Everyone	EJ/ citizen science	AQ Management	AQ/aerosol research	Epidemiology/ health research	I work at NASA/JPL	Other/ unspecified
Finding the products online	3.3	9.5	4.1	1.3	5	2	0.7
Adequate internet speeds for download	1.5	0.5	3.3	0.2	0.5	0.5	0
Compatibility with software/process/system	4.2	4.5	5.6	2.7	2	7.5	1.7
Time to learn new software/tools	4.8	8	5.3	3.1	8.5	9	0
Finding resources to learn about the products	4.2	5	5.1	2	7	6.5	2.3
Time to process into needed information	5.9	9.5	5.6	6.1	8	5.5	8

Workshop participants provided responses to a list of EJ-focused questions on TEMPO and MAIA data during the whole group discussion using the Mentimeter tool. A summary of the participant responses are documented below.

Question 1: What do you think is the future for satellite data in EJ work?

New data availability in locations without ground-based instruments will paint a more realistic picture of the air quality conditions and ensure our monitoring of pollution is equitable. The improved resolution of the new satellite instruments will enable trend analyses at the neighborhood-scale for better characterization of local EJ issues and aid in identifying hot spots in EJ areas. Unknown sources of pollutants will be realized by the new satellite data for advancing EJ research. The potential in developing a warning system at the local scale for EJ issues and protecting public health was noted. Several participants also commented that the future is great for using satellite data in EJ work as long as the accuracy can meet user expectations and data are easily accessible.

Question 2: Which of the following "pain points" would concern you about using satellite data from MAIA, TEMPO, or other instruments?

Responses are summarized in Table 1. Not surprisingly, the EJ / citizen science community has the highest level of pain points, particularly with finding products online and time required to process into needed information. At the same time, every user community noted that "time to process [satellite data] into needed information" was a significant concern. The least concerning pain point to all user groups was "adequate internet speeds for download." This factor should, in theory, become even less of a concern as NASA moves more of its Earth science data into the cloud, where processing can be done without having to download all the individual files.

Question 3: Assuming TEMPO data met all your accessibility / compatibility needs, how might you use it in your work?

Use of TEMPO data for informing the placement of ground-based monitors was noted in the participant responses, in addition to improving emission inventories and aiding source appointment analyses. Overall, the application of TEMPO data in air quality management activities such as supporting exceptional event documentation and policy evaluations will be important. Monitoring and quantifying the diurnal trends in ozone precursors including formation and production regimes will be enabled by TEMPO data. Support in air quality forecasting activities will be another critical application of TEMPO. One participant noted that TEMPO should lead to improved analyses of ozone formation around Lake Michigan and additional support for state-level rulemaking. Lastly, participants also noted the use of TEMPO data for better quantifying the impacts of different pollutants in epidemiological studies.

Question 4: Assuming MAIA data met all your accessibility / compatibility needs, how might you use it in your work?

Participants shared several environmental justice focused ideas, including tracking emissions related to supply trains, dust control (Owens Lake, CA was the noted location), monitoring outcomes of zero emission trucking policies, comparing MAIA data products to EPA and other surface monitor data, and, very importantly, expanding access to air pollution data trends to areas globally that have less surface monitor data. Several attendees also expressed intentions to use MAIA data for health studies, one in particular noting that MAIA can be used to develop exposure-response curves (how people's health changes as a function of exposure to various concentrations of air pollution) for species of PM. Other noted possible uses included analysis for the US EPA's Regional Haze Rule, submission of exceptional event reports by state air quality agencies, and wildfire smoke forecasting and/or modeling.

Question 5: What are we getting wrong? Are we forgetting anything? How can NASA help increase the use of satellite data in EJ applications?

Several participants made comments regarding the need for more active EJ-community outreach and story sharing on use of satellite data in EJ-relevant matters. Production and dissemination of level 4 data products aggregated to social scales (i.e., census tract) would facilitate the use of satellite data in EJ applications. Web-based dashboards would also help in terms of improving data access, analysis, and visualization capabilities for the EJ community, and finding partners to develop locally-focused dashboards would further enable EJ applications. Lastly, always making sure to be clear on what the data can and cannot tell the EJ community is important. For example, noting the difference between the true surface concentration data versus satellite-retrieved values of measured compounds.

3. Conclusions and recommendations

Attendees rated the workshop with moderately high satisfaction in the post-workshop survey, giving a response of 3.8 out of 5 to the statement "I learned what I wanted to get out of the workshop." Additionally, attendees rated the statement "I enjoyed participating in the workshop" at 3.9. Overall, the workshop was effective at increasing participant's level of knowledge about the missions; attendees' average rating of the statement "I know a lot about MAIA" increased from 2.1 out of 5 before the workshop to 3.4 afterward and "I know a lot about TEMPO" increased from 2.4 to 3.7. The EJ panel presentation was the highest rated portion of the workshop, with participants rating the statement "The panel presentation was useful and interesting" at 4.3 out of 5. This indicates that, while some aspects of the workshop could no doubt be improved, the workshop was an overall success and did accomplish the objectives stated in the introduction of this report. Participants provided positive feedback about the panel, the data product demos, the discussions of needs and benefits, and the diversity of perspectives that were presented.

Based on the participant feedback provided, the NASA MAIA and TEMPO investigations should consider working with NASA Earthdata and the Atmospheric Sciences Data Center – in partnership with EJ groups and other interested potential users – to implement data dashboards and other means of serving critical *information*, as opposed to just data products. This information also needs to include usability and accuracy guidance. The teams should also continue to engage the EJ community in conversations as the projects and data get closer to launch.

In regards to opportunities for improvement in workshop design, participants suggested that the panel and group discussion portions of the workshop were more instrumental to EJ groups than the technical presentations. More demos were requested, including demonstrations of the capabilities of MAIA and TEMPO in comparison to those of previous satellite-derived air quality data. Future EJ-focused events could increase the proportion of time dedicated to demonstration, discussion, and interaction - though this would probably necessitate holding a multi-day event or separate pre-workshop orientation, or alternately, envisioning a new way to efficiently provide background technical knowledge to participants who haven’t previously attended Early Adopter events.

Environmental justice is an increasing focus at NASA, and a continued focus of the MAIA and TEMPO projects. Engagement with those working in EJ is critical to forming relationships and establishing trust. Importantly, this engagement should not solely occur during events like this workshop - rather, events should be co-designed with EJ representatives, while respecting (and ideally, compensating) the time these experts provide. Aaron Naeger and Abbey Nastan would like to thank Denise Bruce, Janice Archuleta, Arlyssia Sells, Jane Williams, and the larger organizations of CleanAIRE NC, the Ute Mountain Ute Tribe, and California Communities Against Toxics who made this workshop possible. We would also like to propose that the larger NASA community hold a conversation about providing funds to EJ representatives to participate in events such as these, in the interests of furthering equitable access to NASA resources.

Appendix A: Agenda

UTC offset of your local time zone | -5.00 | hours

Friday, August 5, 2022

Local time	UTC time			Duration
Welcome and introductions				
10:40 AM	15:40	Webex setup and icebreaker questions	All	20
11:00 AM	16:00	Introduction from NASA Applied Sciences Program	John Haynes	5
11:05 AM	16:05	NASA Equity and Environmental Justice Activities	Nancy Searby	5
11:10 AM	16:10	Introduction from workshop organizers	Aaron Naeger and Abbey Nastan	10
Background: MAIA and TEMPO				
11:20 AM	16:20	Update on the MAIA project and target areas	Abbey Nastan and Sina Hasheminassab	15
11:35 AM	16:35	Update on the TEMPO project and launch	Kelly Chance and Xiong Liu	15
11:50 AM	16:50	Questions and discussion	All	10
12:00 PM	17:00	Break		10
Introduction to MAIA and TEMPO Data				
12:10 PM	17:10	MAIA Capabilities for EJ and Panoply introduction	Abbey Nastan	20
12:30 PM	17:30	TEMPO Proxy Data and EJ Applications	Aaron Naeger	20
12:50 PM	17:50	Break	All	30
EJ Panel and Discussion				
1:20 PM	18:20	Panelist introductions	Abbey/Aaron	5
1:25 PM	18:25	Panel presentations: Ute Mountain Ute Tribe CleanAIRE NC California Communities Against Toxics	Panelists	30
1:55 PM	18:55	Panel discussion questions	Panelists	45
2:40 PM	19:40	Panel Q and A	All	15
2:55 PM	19:55	Whole group: Discussion questions	All	35
3:30 PM	20:30	Adjourn		

Appendix B: Attendees

Note: This list only includes those who attended the workshop live.

Name	Affiliation
Aaron Naeger	University of Alabama Huntsville
Abbey Nastan	NASA Jet Propulsion Laboratory
Abdullah Mahmud	California Air Resources Board
Abhishek Dhiman	California Air Resources Board
Abi Roberts	Clemson University
Adam Ross	Arizona Department of Environmental Quality
Adriana Palleni	Association of the Independent Citizens Committees Citta Del Tricolore
Aislinn Johns	Idaho Department of Environmental Quality
Alberto Ayala	Sacramento Metropolitan Air Quality Management District
Alejandra Cervantes	California Air Resources Board
Alex C Oser	Wisconsin Department of Natural Resources
Alex Weaver	California Air Resources Board
Alexandra Chudnovsky	Tel Aviv University
Allison Patton	Health Effects Institute
Amadou Thierno Gaye	Université Cheikh Anta Diop de Dakar
Amanda Brimmer	US Environmental Protection Agency
Amanda L. Clayton	NASA Langley Research Center
Ann Schneider	
Arlyssia Sells	Ute Mountain Ute Tribe
Armando Paz	New Mexico Environment Department
Ashlee M. Autore	NASA Langley Research Center
Barbara E Trost	Alaska Department of Environmental Conservation
Behzad Heibati	University of Oulu
Beiming	
Betsy Farris	Ball Aerospace
Bob Carp	University of Wisconsin Space Science and Engineering Center
Brandon McGuire	Montana Department of Environmental Quality
Brian E. Tisdale	NASA Langley Research Center
Brian Magi	University of North Carolina Charlotte
Brian McDonald	US National Oceanic and Atmospheric Administration
Brian Schath	New Mexico Environment Department
Byeong Kim	Georgia Department of Natural Resources
Caitlin Cannon	Washington State Department of Ecology
Carl A. Malings	NASA Goddard Space Flight Center
Carol Pride	Savannah State University
Carolyn M Kelly	Northern Arizona University

Catherine Fischer	
Charanya Varadarajan	California Air Resources Board
Cheryl Winfield	California Air Resources Board
Chia-Hua Hsu (來賓)	University of Colorado Boulder
Chola Regmi	Texas Commission on Environmental Quality
Chris Smith	
Christian Saravia	AMBENTE
Christina D Moats-Xavier	NASA Langley Research Center
CJ DiMaggio	Maricopa County Air Quality Department
Clayton Bean	US Environmental Protection Agency
Cody M Converse	Wisconsin Department of Natural Resources
Colleen Williams	Maryland Department of the Environment
Daisha Williams	CleanAireNC
David Edgar	California Air Resources Board
Demba Ndao Niang	Université Cheikh Anta Diop de Dakar
Denise Bruce	CleanAireNC
Desalegn Tarekegn	National Meteorology Agency
Elise G. Elliott	Health Effects Institute
Ellen Considine	Harvard University
Emma H Cleveland	Wisconsin Department of Natural Resources
Erin Torrone	Washington State Department of Ecology
Filo Gómez	NASA SERVIR
Forrest Lacey	National Center for Atmospheric Research
Frederic Chagnon	Environment and Climate Change Canada
Garima Raheja	Columbia University
Georgina Hayes-Crepps	NASA Langley Research Center
Gil Grodzinsky	Georgia Department of Natural Resources
Gill-Ran Jeong	George Mason University
Gonzalo Gonzalez Abad	Center for Astrophysics, Harvard and Smithsonian
Greg DeAngelo	Southeastern Air Pollution Control Agencies
Hazem A. Mahmoud	NASA Langley Research Center
Heather Holmes	University of Utah
Heesung Chong	Center for Astrophysics, Harvard and Smithsonian
Helena Chapman	NASA Headquarters
Hyundeok Choi	NASA Langley Research Center
James Boyle	Maryland Department of the Environment
Jane Williams	California Communities Against Toxics
Janice Archuleta	Ute Mountain Ute Tribe
Janice Lam Snyder	Sacramento Metropolitan Air Quality Management District
Jay Baker	Western States Air Resources Council
Jennifer Ofodile	University of California, Berkeley
Jeremy Avise	California Air Resources Board
Jesse Marquez	Coalition for a Safe Environment

Jessie Zhang	University of Iowa
Joel Scott	NASA Headquarters
Johanna Kuspert	Maricopa County Air Quality Department
John A. Haynes	NASA Headquarters
Joseph Mangino	US Enivronmental Protection Agency
Joshua Uebelherr	Maricopa County Air Quality Department
Judy Lai-Norling	Carbon Mapper
Karl O'Sharkey	University of Southern California
Kate O'Dell	George Washington University
Katie Swanson	United States Agency for International Development
Kazuhiko Ito	New York City Department of Health and Mental Hygiene
Keita Ebisu	California Office of Environmental Health Hazard Assessment
Kelley M. Murphy	University of Alabama Huntsville
Kelly Chance	Smithsonian Astrophysical Observatory
Kelly Crawford	US Deparment of Energy
Kelvin Fong	Dalhousie University
Kenton W. Ross	NASA Langley Research Center
Kimberly Butler	Maricopa County Air Quality Department
Kirsten Hall	Center for Astrophysics, Harvard and Smithsonian
Komalpreet Singh	University of Florida
Laurie Hulse-Moyer	Washington State Department of Ecology
Leah Schwizer	NASA Langley Research Center
Lindsay Dayton	US Environmental Protection Agency
Liz Ulrich	Montana Department of Environmental Quality
Lotta Mayana	South African Air Quality Information System
Madankui Tao	Columbia University
Majiong Jiang	California Air Resources Board
Manzhu Yu	Pennsylvania State University
Marcus Trail	BreezoMeter, Inc.
Margee Chambers	Spokane Regional Clean Air Agency
Mary Uhl	Western States Air Resources Council
Mary Zakrasek	Community Organizer
Masha Pitiranggon	New York City Department of Health and Mental Hygiene
Matthew Densberger	California Air Resources Board
Matthew S. Tisdale	NASA Langley Research Center
Maura Palacios Mejia	Mt. San Antonio College
Mayank Gangwar	University of Florida
Melissa Maestas	South Coast Air Quality Management District
Melissa Venecek	California Air Resources Board
Michael Ketcham	Oklahoma Department of Environmental Quality
Michelle Horn	Oklahoma Department of Environmental Quality
Mike Glenn	Retired from United States Department of Agriculture
Mike Sundblom	Pinal County Air Quality Control
Monika Kopacz	US National Oceanic and Atmospheric Administration

Morgan D Frank	Alaska Department of Environmental Conservation
Morgan Schafer	Oregon Department of Environmental Quality
Nancy D. Searby	NASA Headquarters
Natalie Shepp	Pima County Environmental Quality
Natasha R. Johnson-Griffin	NASA Langley Research Center
Nellie Elguindi	US Bureau of Ocean Energy Management
Nga Lee (Sally) Ng	Georgia Institute of Technology
Nga Nguyen	Air Sciences, Inc.
Nicholas Witcraft	Minnesota Pollution Control Agency
Paul J Goodfellow	Alaska Department of Environmental Conservation
Peterson Peter	Whittier College
Pingkuan Di	California Air Resources Board
Prithviraj Pramanik	Discovery Partners Institute, University of Illinois
Priyanka deSouza	University of Colorado Denver
Ratha (He/Him)	
Rebekka Fine	California Air Resources Board
Regan Patterson	University of California Los Angeles
Rei Zhang	Ramboll
Ren Garity	Clemson University
Riyang Liu	Yale University
Robina Suwol	California Safe Schools
Ron Pope	Maricopa County Air Quality Department
Rosalie Preston	Community Organizer, Redondo Alondra
Rose Scott	MobiCycle
Ryan Templeton	Arizona Department of Environmental Quality
Sarah Inskeep	National Renewable Energy Laboratory
Sean M Raffuse	University of California, Davis
Sean Nolan	Pennsylvania Department of Environmental Protection
Seyi	
Shailaja Kim	US Department of State
Sina Hasheminassab	NASA Jet Propulsion Laboratory
Siya	
Stefano Scippa Palleni	
Steve Moran	BreezoMeter, Inc
Susannah Abbate	Snug Harbor Cultural Center
Talat Odman	Georgia Institute of Technology
Tamar Klein	Israel Institute of Technology
Teresa Sikorski	Oklahoma Department of Environmental Quality
Tesfamichael Ghidey	Washington State Department of Ecology
Theral	
Thomas Frey	Maryland Department of the Environment
Timothy "Seph" Allen	NASA Langley Research Center
Ting-Yu Dai	Unviersity of Texas at Austin

Toby Coombes	C40 Cities
Venkatesh Rao	US Environmental Protection Agency
Victoria Breeze	US National Oceanic and Atmospheric Administration
Virginia Gewin	Science Journalist
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