

EARTH SCIENCE
APPLIED SCIENCES

2019 ANNUAL SUMMARY

NASA Earth Science Applied Sciences Program

HEALTH & AIR QUALITY



Health & Air Quality: 2019 Annual Summary

Table of Contents

I.	Introduction	3
II.	Overview of 2019	3
III.	Major Accomplishments	4
IV.	Health and Air Quality Applied Sciences Team	6
V.	Assessment	10
VI.	Project Portfolio	11
VII.	Program Management	11
VIII.	Community Leadership	11
IX.	International Activities	17
X.	Looking Ahead	21
XI.	Appendix	22
	A. Abbreviations and Acronyms	22
	B. Contacts	23

I. Introduction

The Earth Science Division's (ESD) Applied Sciences Program promotes efforts to discover and demonstrate innovative and practical uses of Earth observations. The Program funds applied science research and applications projects to enable near-term uses of Earth observations, formulate new applications, integrate Earth observations and related products into practitioners' decision-making, and transfer the applications. The projects are carried out in partnership with public- and private-sector organizations to achieve sustained use and benefits from Earth observations.

The Applied Sciences Program's applications themes are currently focused on five of the eight Societal Benefit Areas (SBAs) of the Group on Earth Observations (GEO): Health (including Air Quality), Disasters, Ecological Forecasting, Agriculture/Food Security, and Water Resources.¹ The Program includes weather and climate-related influences and impacts within each of these themes.

The Health and Air Quality (HAQ) Applications program encourages the use of Earth observations in air quality management and public health, particularly involving environmental health and infectious diseases. The program also addresses the effects of climate change on air quality and public health to support managers and, ultimately, decision makers of health-related issues.

II. Overview of 2019

The past year was a very productive one for HAQ Applications, with numerous projects concluding or achieving significant milestones. Projects addressed public health issues such as air quality, infectious diseases, vector-borne diseases, environmental health, and harmful algal blooms (HABs). Current projects in the portfolio met or exceeded expectations regarding technical performance. In addition, projects received media coverage or substantial praise from stakeholders on the value of the respective applied science.

The HAQ Applications program continued to support online resources to disseminate important information and data covering health surveillance, the effects of global climate

¹ The eight GEO SBAs are Agriculture, Ecosystems/Biodiversity, Disasters, Energy/Minerals, Health, Infrastructure/Transportation, Urban Development, and Water Resources.

change on public health, and air quality management. In 2019, the program continued monthly Health and Air Quality newsletters that were circulated online and via mailing list. The program expanded a website focusing on the GEO Health Community of Practice and the new GEO Earth Observations for Health (EO4HEALTH) Initiative and showcased results across NASA web platforms. The applications program distributed applied research results and representatives led or participated in meetings across the health/air quality and Earth-science community, at both the national and international levels.

The following report summarizes a few challenges and many achievements that occurred during 2019. HAQ Applications looks forward to coming activities and milestones, including future solicitations, continued support for airborne field campaigns, as well as the support of, and applications planning for, relevant satellite missions.

III. Major Accomplishments

Some of the notable programmatic achievements this past year include:

- In the United States, the Northern Great Plains is a high-risk geographic region for West Nile Virus (WNV) transmission. Of the 50 states, South Dakota has a long-term record of the highest reported incidence of WNV, including WNV neuroinvasive disease. Michael Wimberly (University of Oklahoma) and his team developed a WNV early-warning system in South Dakota. Forecasts produced by the [Arbovirus Monitoring and Prediction \(ArboMAP\) system](#) are driven by a combination of mosquito infection data and environmental monitoring data (including the North American Land Data Assimilation System, NLDAS) and are calibrated with historical human case data. An automated Google Earth Engine script accesses and processes NASA environmental data for assimilation into ArboMAP. Released in January 2019, this code is freely available via [GitHub](#) to allow potential expansion of ArboMAP to other states. This project successfully built capacity on ArboMAP capabilities with South Dakota Department of Health (SDDOH) epidemiologists to allow integration of ArboMAP into SDDOH operational WNV surveillance activities in 2018 and 2019. The ArboMAP team is now working with the Louisiana Department of Health to determine the feasibility of ArboMAP implementation in Louisiana, as the Deep South is another high-risk geographic region for WNV.
- In 2019, public health officials in Utah, New Jersey, and Guam began using a NASA-enhanced website that was developed to strengthen mosquito control efforts in California. The invasive mosquito surveillance system, called CalSurv (short for California Vectorborne Disease

Surveillance System), helps mosquito control agencies and public health officials monitor and respond to potential outbreaks of mosquito-borne diseases by mapping suitable habitats for the insects that can carry deadly viruses such as WNV, Dengue, and Zika. According to the Centers for Disease Control and Prevention (CDC), the number of cases of mosquito-borne disease in the United States is growing – the rate of these infections was 10 times higher in 2016 than in 2004. Expanding surveillance of mosquitoes in the United States is becoming more pressing. Previously, NASA HAQ worked with the state of California to enhance CalSurv with a variety of Earth observations, including output from the NASA Terrestrial Observation and Prediction System. These Earth observations are now incorporated into UtahSurv, JerseySurv, and other iterations of the project. These results were showcased in a NASA web feature in November 2019: <https://www.nasa.gov/feature/nasa-helps-fight-the-mosquito-bite-coast-to-coast>

- A team led by Rajesh Kumar (National Center for Atmospheric Research, NCAR) incorporated satellite measurements of aerosol optical depth (every three hours) into the National Oceanic and Atmospheric Administration (NOAA) National Air Quality Forecast Capability (NAQFC). Particulate matter (PM), comprised of solid and liquid particles suspended in the air, are air pollutants that can range in size and composition. Inhalation of particulate matter, including PM_{2.5} and PM₁₀, can affect respiratory and cardiovascular morbidity and mortality. Integrating NASA's Earth-observing satellite data in daily U.S. air quality forecasts for particulate matter could potentially produce more accurate forecasts. With an estimated 38% improvement in the accuracy of reported particulate pollutants in NAQFC tests, these changes may positively contribute to daily Air Quality Index forecasts created by the U.S. Environmental Protection Agency (EPA). These results were showcased in a NASA web feature in August 2019: <https://www.nasa.gov/feature/nasa-data-strengthens-us-air-quality-warnings>
- Air quality forecasting plays an important role in informing the general public and decision-makers about reducing exposure to air pollution. Air quality models simulating atmospheric constituents such as PM_{2.5} are often used to provide daily forecasts. In 2019, Jun Wang (University of Iowa) successfully incorporated Moderate Resolution Imaging Spectroradiometer (MODIS)-type Visible Infrared Imaging Radiometer Suite (VIIRS) aerosol products into the operational Remote Sensing Information Gateway (RSIG) at the U.S. EPA. Subsequently, the project transferred RSIG's PM_{2.5} estimates to the Environmental Public Health

Tracking Network (EPHTN) at the CDC for use by environmental health scientists and epidemiologists.

- Along coastal waters, red tides, which are toxic to human and marine health, can result from the accumulation of the dinoflagellate *Karenia brevis*. In 2019, a team led by Richard Stumpf (NOAA) strengthened and extended partnerships to monitor and forecast these blooms along the Florida Gulf Coast. Partners included the Florida Fish and Wildlife Conservation Commission, the Gulf of Mexico Coastal Ocean Observing System, Pinellas County Environmental Management, and the University of South Florida. In 2018, the team developed a [24-hour Experimental Red Tide Respiratory Forecast](https://coastalscience.noaa.gov/news/experimental-red-tide-forecast-expanded-to-include-sanibel-island/) (updated every three hours) along Florida's Gulf Coast, focusing on Pinellas County. Data from NASA's Terra and Aqua satellites and the European Space Agency's Copernicus Sentinel-3 satellite were used in conjunction with the HABscope smartphone app that enables video uploads by citizen scientists to map the extent of algal blooms. In 2019, the team expanded this forecasting tool to three Sanibel Island beaches. These results were showcased in a NOAA web feature in November 2019: <https://coastalscience.noaa.gov/news/experimental-red-tide-forecast-expanded-to-include-sanibel-island/>

IV. Health and Air Quality Applied Sciences Team

In 2019, the NASA Health and Air Quality Applied Sciences Team (HAQAST) (<http://haqast.org>), led by Tracey Holloway at the University of Wisconsin-Madison, continued its mission of linking NASA's satellites and data products to public stakeholders in the air quality and public health communities. The 13-member team was particularly excited to have been granted an extension of the original three-year mandate to an additional fourth year. HAQAST will now conclude in August 2020. This extension has allowed Tiger Teams to expand their work to maximize impact. Each Tiger Team is a short-term, high-impact collaborative effort between HAQAST members and public stakeholders to identify and solve an immediate problem using NASA data and products. Each Tiger Team draws on the expertise of multiple HAQAST Principal Investigators (PIs) to find the best, multifaceted solutions to pressing health and air quality issues.

The four current Tiger Teams, launched in the summer of 2018, were chosen from eight proposals that underwent a competitive review process by stakeholders from end-user organizations. All four Tiger Teams have met regularly with stakeholders and are in the

final stages of transferring their deliverables to their stakeholder partners. Current Tiger Teams include:

1. *Satellite-Evaluated and Satellite-Informed O₃ Distributions for Estimating U.S. Background O₃*, led by Jessica Neu (NASA Jet Propulsion Laboratory [JPL]).
 - The delivery of a variety of O₃ boundary conditions, in the most popular file formats identified by air-quality stakeholders, for use in modelling O₃ transport from other countries into the U.S.
2. *Supporting the Use of Satellite Data in Regional Haze Planning*, led by Arlene Fiore (Columbia University/Lamont Doherty Earth Observatory).
 - A series of technical guidance documents, aimed at regional air-quality managers, and intended to help them evaluate regional haze in their planning. These documents are archived at <https://airquality.gsfc.nasa.gov/hazevisibility-planning>.
3. *Using Satellite Remote Sensing to Derive Global Climate and Air Pollution Indicators*, led by Susan Anenberg (George Washington University).
 - A series of presentations, informational webinars, visualizations, data, and technical guidance documents, all concerning the derivation of global climate and air pollution indicators from satellite data. Many of these deliverables have “gone live” and are archived and publicly available here: <https://haqastindicators.org>.
4. *Air Quality and Health Burden of 2017 California Wildfires*, led by Susan O’Neill (U.S. Forest Service).
 - The completion of a fire emissions inventory, air quality modeling for smoke, a health impact analysis of California’s 2017 wildfire season, and a series of training videos, all aimed at fire managers in the U.S. Many of these final deliverables are at or near operational status, and are available here: <https://sites.google.com/firenet.gov/wfaqrp-airfire/projects/haqast/2017NorthernCAWildfiresTT?authuser=0>.

HAQAST communication outreach continues to focus on media outreach and public engagement, reach a wide audience through regular e-newsletters (sent to a mailing list of 744 subscribers) and Twitter (@NASA_HAQAST currently has more than 4,100 followers). HAQAST’s applied research has been profiled in *US News & World Report*;

Europapress (Spain); the award-winning documentary film, *Dust*; a number of NASA stories and web features; and has also appeared in many other popular media outlets.

Of special note, four Maryland high-school students designed an app called DustWatch that will allow faster access to dust storm information. "The project got started in middle school when we were watching a documentary about dust storms in class, and we really saw how devastating dust storms could be," said Bill Tong, a rising senior at Atholton High School in Clarksville, Maryland. Bill's father, Daniel Tong, supported his interest in the project. Daniel Tong is dust researcher at George Mason University who works with HAQAST. HAQAST researchers are partnering with dust forecasters at the National Weather Service to improve these critical forecasts for the U.S. Southwest and across the country. This inspirational story was the subject of a NASA web feature in August 2019: <https://www.nasa.gov/feature/goddard/2019/students-create-app-to-warn-of-dangerous-dust-storms>

The [HAQAST website](#) continues to be a "one-stop shop" for relevant NASA data and tools. The website logged 8,011 users in 2019, an increase of 24 percent over 2018. The most popular pages were the ones relating to HAQAST meetings, tiger teams, Principal Investigators' biographies, and NASA tools.

HAQAST has hosted meetings every six months from its inception in 2016 through summer 2019, with a focus on progress review and stakeholder engagement. HAQAST conferences have gained the reputation as friendly, intellectually fulfilling, and publicly useful venues for disseminating the latest and greatest applied air quality and environmental health research, as well as a valuable opportunities for researcher/public stakeholder networking.

The fifth HAQAST meeting—HAQAST5—was co-hosted by Arizona State University and the Maricopa County Air Quality Department from January 3 – 4 in Phoenix, Arizona, and HAQAST6 was hosted by NASA Jet Propulsion Laboratory (JPL) from July 10 – 12, in Pasadena, California. A wide range of stakeholders were in attendance across these meetings, including the Clean Air Institute, the National Weather Service, the City of Albuquerque's Environmental Health Department, the Louisiana Department of Health, the American Cancer Society, Maricopa County (Arizona) Air Quality Department, Western States Air Resources Council (WESTAR), Western Regional Air Partnership (WRAP), the National Institute of Health, the American Lung Association, United Nations Children's Fund (UNICEF), and the Government Accountability Office. All slides, presentations, pictures, and posters from both conferences can be found at the Past Meetings tab of the HAQAST website. .

In-person participation at the semi-annual HAQAST meetings has averaged ~120 attendees since HAQAST3. We continue to attract a strong online presence to our

streamed conference service (see Fig.1). A lower than usual in-person attendance at HAQAST5 in Arizona, and an associated jump in the unique remote views, may have been due to the impact of the 2019 government shutdown.

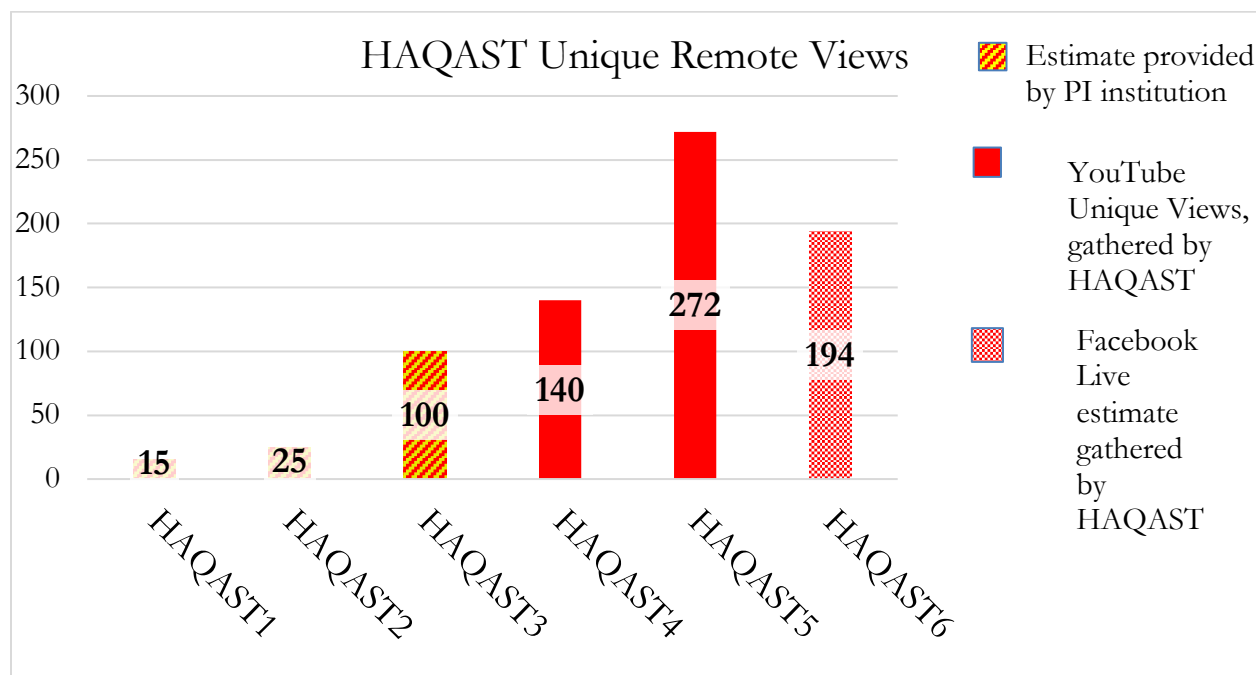


Fig. 1: Remote unique attendees.

HAQAST continues to adapt meeting formats based on stakeholder requests, with HAQAST6 featuring a half-day of hands-on, breakout sessions. These tutorials and workshops were well attended and received positive feedback indicating that HAQAST should continue offering such workshops in the future. HAQAST6 workshops included: (1) Satellite Data for Air Management: State, Local, and Tribal Air Quality Needs (led by Mary Uhl/WESTAR); (2) Visualizing Satellite Data: How to Use NASA’s Giovanni Data Visualizer (presented by Xiaomeng Jin/Lamont-Doherty); (3) Communicating Your Science for Maximum Impact (presented by Aries Keck/NASA); (4) How to Use NASA Data for Exceptional Event Analysis (presented by Michael Geigert/ Connecticut Department of Energy and Environmental Protection, Mike Newchurch/University of Alabama-Huntsville/NASA Airborne Science Program, Bryan Duncan/NASA Goddard Space Flight Center (GSFC), and Ali Omar/NASA Langley Research Center [LaRC]); (5) Satellites and Health Assessments: Best Practices and Future Opportunities (presented by Jason West/University of North Carolina, Chapel Hill and Abbey Nastan/NASA JPL); and (6) Looking Back to Move Ahead: A Roundtable Discussion on HAQAST and Ideas for the Future (led by Team Lead Tracey Holloway/University of Wisconsin-Madison).

Active publication of HAQAST members' applied research continued in 2019, with at least 60+ papers published (see Figure 2 for preliminary estimates).

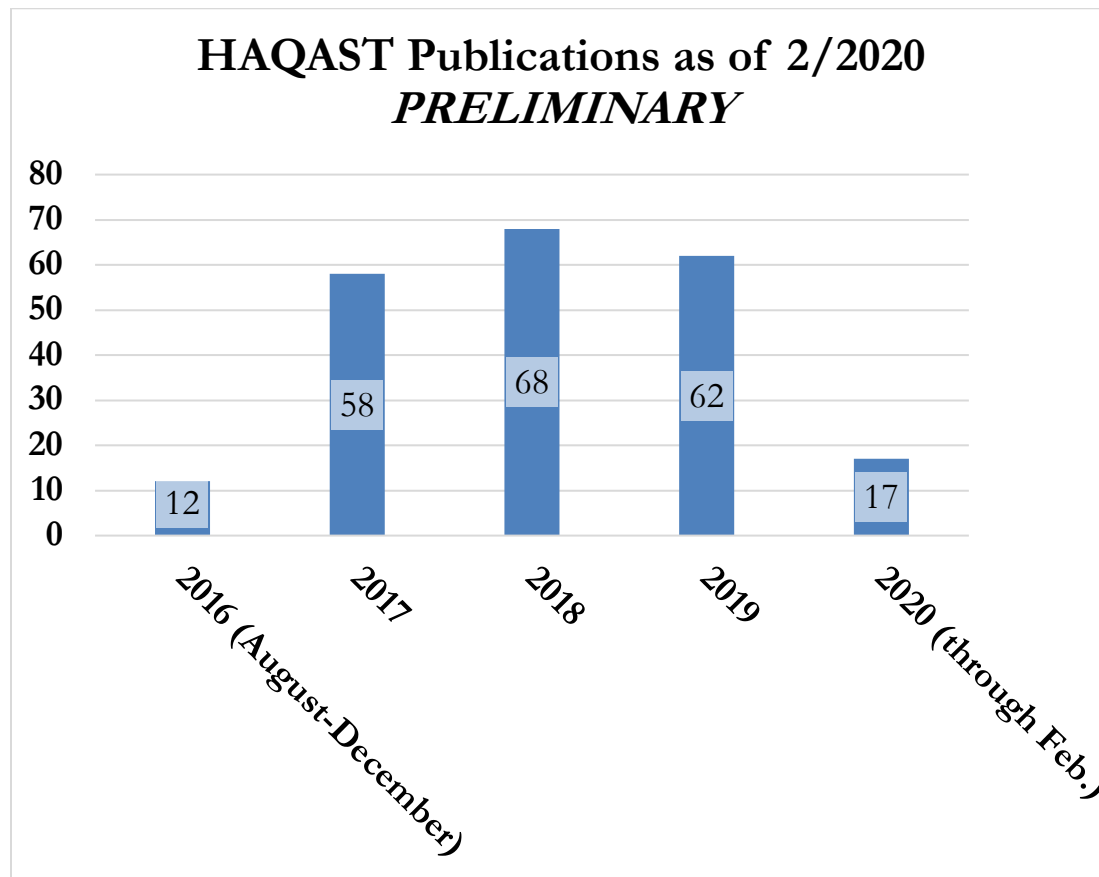


Figure 2: Total HAQAST publications (Preliminary, as of 2/2020).

V. Assessment

Overall, the HAQ Applications portfolio exceeded technical performance expectations in 2019 with several projects reaching top-tier Application Readiness Levels (ARLs) of 7 to 9.

The portfolio continued to carry a relatively high burden of uncosted funds in 2019. Associates worked diligently with Principal Investigators to uncover issues at their institutions. Many times such discrepancies appeared to result from “invoice lag” between NASA and the institutions, with costed funds not showing on NASA accounts until long after invoices had been submitted by grantees. However, significant progress

was made -- FY17 uncosted funds were down ~97 percent from December 2018 to December 2019; FY18 uncosted funds were down ~80 percent over the same period.

Overall, the HAQ Applications portfolio remained on schedule in 2019 and significant results were accomplished in all areas, with a bright outlook for 2020.

VI. Project Portfolio

At the end of 2019, the HAQ Applications portfolio included 18 active projects along with the activities of the 13-member HAQAST. The portfolio met or exceeded expectations on technical performance. By the end of the year, five projects had an ARL of 1-3; ten projects had ARLs of 4-6; and three projects had achieved an ARL of 7-9. One hundred percent of projects increased at least one ARL from November 2018 to November 2019, and 43 percent increased by two or more ARLs over the same period.

VII. Program Management

In September 2019, the NASA HAQ Applications Team, led by Sue Estes (University of Alabama-Huntsville), conducted the 11th annual HAQ Applications Program Review with approximately 35 attendees in Rapid City, South Dakota. Principal Investigators presented information about each project in the portfolio including milestones achieved over the past year, plans for the coming year, ARL estimates, budgets, and any risks/opportunities foreseen. The CDC provided the keynote partner address. Invited speakers presented information about NASA Communications, NASA Prizes and Challenges, HAQAST, and NASA Training and Capacity Building (including the Applied Remote Sensing Training program [ARSET], SERVIR, and DEVELOP). A special invited speaker—Stacie Hull, General Manager of The Mount Rushmore Inn—is a survivor of WNV. Her talk provided team members with an example of the human impact of this disease and how important NASA applied research is for the community.

John Haynes serves as Program Manager for HAQ Applications at NASA Headquarters. The HAQ Applications program added two new Associate Program Managers in 2019—Helena Chapman (NASA Headquarters/Booz Allen Hamilton) and Laura Judd (NASA LaRC, Science Systems and Applications Incorporated). Sue Estes (University of Alabama-Huntsville) continues to serve as Senior Associate Program Manager.

VIII. Community Leadership

The applications area presented and led sessions at meetings of the American Meteorological Society (AMS), the American Thoracic Society (ATS), the Air and Waste

Management Association (A&WMA), the American Public Health Association (APHA), and the American Geophysical Union (AGU). The AMS Annual Meeting, with theme *Understanding and Building Resilience to Extreme Events by Being Interdisciplinary, International, and Inclusive*, was held in January 2019 in Phoenix, Arizona. As part of the embedded 10th Conference on Environment and Health, NASA supported the session entitled, *NASA Earth Observation Systems and Applications for Health: Looking at Predicting Extreme Environmental Events and How it Affects Health*, with four scientific talks and more than 70 attendees. The HAQ program also supported the Multi-Angle Imager for Aerosols (MAIA) Applications Town Hall session. Additional scientific talks were presented at the NASA Hyperwall at the booth in the exhibit hall.

In March 2019, John Haynes was invited to serve on a keynote panel with colleagues from the National Institute of Environmental Health Sciences (NIEHS) and the National Oceanic and Atmospheric Administration (NOAA) at the opening session of the U.S. Department of State Bureau of Educational and Cultural Affairs' International Visitor Leadership Program on Global Health Security in Washington DC. Keynote presentations focused on Early Warnings for Health, and each panelist spoke about the role of their agencies and the importance of partnerships between agencies and sectors related to global health security.

For National Public Health Week in April 2019, the NASA HAQ Applications and Communications Teams shared five projects on the NASA Applied Sciences Program's Making Space for Earth [website](#) that promoted the use of Earth observations to encourage community engagement in environmental health issues. These projects included [Space Views Aid Florida 'Red Tide' Health Alerts](#) (Richard Stumpf, NOAA), [NASA Helps New Yorkers Cope with Summer Swelter](#) (Tabassum Insaf, New York State Department of Health), [Understanding Your UV Exposure Risk](#) (Centers for Disease Control and Prevention's Environmental Tracking Program), [Mosquito Meets MODIS: South Dakota Fights West Nile Virus](#) (Michael Wimberly, University of Oklahoma), and [NASA Satellites Help Scientists Determine the Global Burden of Asthma](#) (Susan Anenberg, George Washington University; Daven Henze, University of Colorado-Boulder). These public health stories emphasized the need for transdisciplinary collaborations that integrate innovative data and technology into public health applications, advancing our knowledge about the surrounding environment. These project highlights were also widely disseminated on social media, with the support of the APHA Veterinary Public Health Primary Interest Group, George Washington University, NASA HAQAST, the New York State Department of Health, the One Health Commission, and the One Health Initiative. Helena Chapman published this event summary in the [Spring 2019 issue](#) of the APHA Veterinary Public Health's *One Health Newsletter*.

In April 2019, Helena Chapman presented, *A Career in One Health with the Federal Government*, for the University of Florida's Masters of Public Health (MPH) Alumni Seminar Series, held in Gainesville, Florida. She described her professional training beyond her MPH graduation and shared pivotal reflections and collaborations along her career path.

The ATS International Conference was held in May 2019 in Dallas, Texas. NASA sponsored a session entitled, *NASA Remote Sensing Satellite Observations: Applications for Respiratory Health*, with four scientific talks and more than 75 people in attendance. As part of this conference, Helena Chapman also attended the *Teaching and Researching in Resource Constrained Settings: A Guide to Global Pulmonary Critical Care Medicine* workshop, which offered academic presentations and group dialogue on environmental health topics, including air pollution.

In May 2019, John Haynes and Helena Chapman were invited to present talks at the American Mosquito Control Association's (AMCA) 21st Annual Washington Conference 2019, held in Alexandria, Virginia. This event provided the first networking opportunity for the NASA HAQ Team and AMCA leadership. Presentation topics included *Earth Observations Applied to a Changing World: NASA Health and Air Quality Applications* and *Using Earth Observations to Strengthen One Health Networks in Vector Control*. With more than 100 AMCA members in attendance, the presentations were well received and facilitated an open dialogue with AMCA membership about the use of Earth observations for "One Health" applications, which link human, animal, and environmental health. The success of these presentations led to an invitation for NASA to present at the AMCA Annual Meeting in Portland, Oregon, in March 2020.

NASA HAQ Applications investigators and stakeholders presented at the ARSET Advanced Webinar, *High Resolution NO₂ Monitoring from Space with TROPOspheric Monitoring Instrument (TROPOMI)*, which was held from May 28 to June 3, 2019.

In June 2019, the NASA HAQ Applications Team attended the MAIA Science Team Meeting and Early Adopters Workshop, held in Pasadena, California. The MAIA Science Team Meeting offered expert talks on various topics related to MAIA instrument development and data products, including interagency and international partnerships, speciated particulate matter filter stations, science data systems and algorithms, data validation, and target area implementation details. The inaugural MAIA Early Adopters Workshop provided an overview of MAIA scientific goals and data products as well as an opportunity to expand end-user community networks for using MAIA observations.

John Haynes was invited to present at the National Drought & Public Health Summit, held in June 2019 in Atlanta, Georgia. This meeting facilitated dialogue among various stakeholders about drought preparedness and response measures to mitigate risk to

human health. John Haynes presented the topic, *Earth Observations Applied to a Changing World: NASA Health and Air Quality Applications*, focusing on environmental health risks related to extreme heat, drought, and wildfires.

The HAQ Applications program co-sponsored the 2019 A&WMA Annual Conference & Exhibition Meeting in June 2019 in Quebec City, Quebec, Canada. The A&WMA is the most comprehensive conference on environmental technology and regulation; therefore, the program has identified A&WMA as one of the boundary organizations that will provide a bridge between applications research and air quality practitioners. The NASA HAQ Team convened a session attended by approximately 65 participants, where five panelists discussed and presented NASA's satellite and sub-orbital measurements and models to address air quality and health applications. Helena Chapman also made a presentation titled, *Strengthening "One Health" Collaborations in Air Quality Management*, in the Health Effects & Exposure session. The NASA exhibit booth and Hyperwall display showcased Hyperwall talks that illustrated NASA satellite observations and modeling animations related to air quality topics.

For [National Mosquito Control Awareness Week 2019](#) in June 2019, the NASA HAQ Applications and Communications Teams promoted a web feature on NASA's Making Space for Earth blog. This web feature, [Fighting Mosquitoes from Space](#), was developed to support this campaign of the AMCA. HAQ Applications projects featured on this site include the investigation of potential transmission of Zika virus in California, mapping malaria hotspots in the Amazon, testing a surveillance and response system for vector-borne diseases in South America, and developing early warning systems for malaria in Myanmar and human WNV in South Dakota.

In July 2019, John Haynes presented at the NASA Weather and Air Quality Workshop held in College Park, Maryland. Operational representatives from U.S. agencies (NOAA, Naval Research Laboratory, Air Force Weather Agency, EPA) and international partners (JMA, ECMWF, United Kingdom Met Office, European Commission) were brought together to discuss the potential for Aerosols and Clouds, Convection and Precipitation (A-CCP) geophysical variables to be assimilated into their operational modeling frameworks. A-CCP is a designated observable named in the 2017 National Research Council (NRC) Decadal Survey, [Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space](#).

In August 2019, the NASA Earth Observatory's [Image of the Day](#) showcased the risk of sunburn across counties in the contiguous United States. The HAQ Applications program and the CDC partnered to create this first publicly available map of ultraviolet (UV) radiation. Available on the CDC's [National Environmental Public Health Tracking Network](#), this dataset (2005–2015) delivers information about health issues related to environmental factors.

In August 2019, the American Academy of Pediatrics, and the American Lung Association hosted a NASA HAQ Applications webinar in Washington, DC, in support of the [Year of Air Pollution and Health 2019](#). John Haynes presented, *Earth Observations Applied to a Changing World: NASA Health and Air Quality Applications*, describing a selection of environmental health projects related to air pollution, drought, extreme heat, and wildfires. A total of 20 in-person and 70 virtual participants attended the webinar, representing federal and state agencies (California, Minnesota, North Carolina, New Hampshire, South Carolina, Tennessee, Virginia, Washington), academic and health institutions, and air quality management agencies. This [webinar](#) was the first NASA collaboration with the American Lung Association, and the two organizations plan to continue these educational efforts on health and air quality topics.

In September 2019, NASA HAQ Applications and the CDC's National [Environmental Public Health Tracking Network](#) coordinated the 2019 Fall Recipient Workshop to recognize the achievements of 15 years of successful partnership between the two agencies. A total of 250 (200 in-person, 50 online) people attended this three-day workshop, held in Atlanta, Georgia. The first day of the workshop opened with a plenary session led by Erik Svendsen (CDC), Lawrence Friedl (NASA), John Haynes, and Yang Liu (Emory University), followed by presentations on NASA/CDC collaborations. Three plenary sessions—Air Quality, Extreme Heat and Pollen, and Harmful Algal Blooms and Vector-borne Diseases—incorporated insightful presentations by CDC staff, academic faculty, and local and state public health practitioners.

In October 2019, the HAQ Applications Team attended the Tropospheric Emissions: Monitoring of Pollution ([TEMPO](#)) [Health Applications Conference](#), *New Applications in the Use of Satellite Data Monitoring for Population Health*, in Huntsville, Alabama. A total of 84 people (45 in-person, 39 online) attended this meeting. The [agenda](#) highlighted presentations and posters divided into *Future Remote Sensing Data for HAQ Studies* and *End User Perspectives*, presented by faculty members, HAQAST researchers, and Deputy Program Applications Leads for MAIA (Abbey Nastan, Jet Propulsion Laboratory) and Tropospheric Emissions: Monitoring of Pollution (TEMPO) (Aaron Naeger, University of Alabama-Huntsville). Kelly Chance (TEMPO Principal Investigator, Harvard Smithsonian Astrophysical Observatory), Susan Alexander (University of Alabama, Huntsville), and Michael Newchurch (University of Alabama, Huntsville) introduced the event. This meeting followed two TEMPO Early Adopter meetings, held in July 2016 (Huntsville, Alabama) and April 2018 (Fort Collins, Colorado). Specific goals for this meeting included: 1) review the TEMPO mission and capabilities for HAQ end-users and stakeholders, 2) define needs of the health community for effective application of TEMPO data, and 3) discuss necessary next steps for ensuring these needs are met during the pre-launch phase.

At the American Public Health Association (APHA) Annual Meeting & Expo in November 2019 held in Philadelphia, Pennsylvania, the NASA HAQ Applications Team sponsored the session, *Using Earth Satellite observations to Understand, Detect, Prevent, Monitor, Predict and Respond to Environmentally-Sensitive Disease Outbreaks and Risks for the Future*, that included five scientific talks and was attended by an estimated 50 people. The NASA Hyperwall included three talks at the exhibit hall booth, and the Hyperwall won the blue ribbon as best conference exhibit for the third time.

For [One Health Day](#) in November 2019, the NASA HAQ Applications and Communications Teams shared three projects on the NASA Making Space for Earth [website](#) that promoted the use of Earth-observing satellite data to solve down-to-Earth issues that affect human and animal health. These project stories included [New Map Shows Risk of Sunburn Across the United States](#) (NASA/CDC National Environmental Public Health Tracking Network), [NASA Helps Fight the Mosquito Bite Coast-to-Coast](#) (Chris Barker, University of California, Davis), and [NASA Data Strengthens United States' Air Quality Warnings](#) (Rajesh Kumar, National Center for Atmospheric Research). This web feature has been promoted on the One Health Commission's [One Health Day global events webpage](#).

In November 2019, NASA HAQ Applications Team members were invited panelists at the Food and Drug Administration's (FDA) *FY2020 One Health Forum*. This first annual forum aimed to promote One Health collaborations in the FDA and coordination with other agencies that also conduct One Health activities. Representatives from the eight FDA centers and offices presented five-minute introductions to describe their objectives and activities. Then, the Stakeholder's Initiatives Panel – consisting of representatives from the U.S. Health and Human Services, U.S. Department of Agriculture, and NASA Applied Sciences Program (John Haynes, Helena Chapman) – highlighted objectives and activities that can foster collaborations with the FDA. John Haynes and Helena Chapman presented an overview of the NASA Applied Sciences Program and highlighted selected HAQ Applications projects that integrate the use of Earth observations for public health (One Health) applications. This One Health Forum was well received by over 50 attendees, who showcased their enthusiasm through active engagement with presenters.

In November 2019, John Haynes and Helena Chapman were invited lecturers to the *Graduate Seminar in Global Infectious Diseases* at Georgetown University in Washington DC. They provided an overview of the NASA Applied Sciences Program and described an array of HAQ Applications projects that use Earth observations for public health applications.

In November 2019, Helena Chapman participated as a virtual panelist for the *One Health Young Professional Panel Discussion*, moderated by Lt. Caitlin Cossaboom

(CDC Division of High-Consequence Pathogens and Pathology). Part of the One Health Intellectual Exchange 2019 effort, this One Health course is an academic collaboration between Duke University, University of North Carolina, and North Carolina State University.

In December 2019, Helena Chapman gave a keynote presentation, *One Health and Combating Infectious Diseases*, for the U.S. Department of State Bureau of Educational and Cultural Affairs' International Visitor Leadership Program on Combating Infectious Diseases. She stressed that innovative data and technology are essential to address emerging One Health threats, including air pollution and vector-borne disease transmission.

The American Geophysical Union (AGU) Fall Meeting 2019, was held in San Francisco, California, in December 2019. As part of the GeoHealth section, the NASA HAQ Applications Team coordinated an oral and poster session, *NASA Earth Observation Systems and Applications for Public Health, Air Quality, Environmental Management, and Public Outreach*. The session, which was attended by 120 individuals, featured eight scientific talks and 19 posters, including the HAQ poster, *Advancing Environmental Health Applications to Mitigate Emerging One Health Threats*. Laura Judd also presented the poster, *Using Airborne High-resolution NO₂ Columns to Evaluate the Copernicus Sentinel-5 Precursor (S5P) TROPOMI Tropospheric NO₂ Product during LISTOS*. At the NASA Earth Science Division's Hyperwall, Laura Judd presented a talk entitled, *Air Quality Research Campaigns Supporting the Preparation for Geostationary Observations*. Additionally, John Haynes and Tracey Holloway served as invited panelists on the GeoHealth Early Career Panel, *Navigating a Career in GeoHealth*. During this session, which was attended by 30 individuals, they shared their career trajectory and provided advice on interdisciplinary research and practice in Earth and health sciences.

The program continued its active participation in the U.S. Global Change Research Program (USGCRP) Climate Change and Human Health Working Group (CCHHG) in 2019.

IX. International Activities

The Group on Earth Observations (GEO) Health and Environment Community of Practice (CoP) is a global network of governments, organizations, and observers that seeks to use environmental observations to improve health decision-making at the international, regional, country, and district levels. The GEO Health and Environment CoP continued to expand its activities in 2019 under the chairmanship of HAQ

Applications Program Manager, John Haynes. The CoP hosted membership-wide telecons to discuss key topics at the nexus of Earth observations and health, ways to support the 2020-2022 GEO Work Programme, and development of a work plan to implement the 2020-2022 GEO Work Programme. The CoP also expanded its [website](#) to keep the community informed of activities, news, and opportunities.

In February 2019, the GEO Health CoP held a [quarterly telecon](#) to provide program/project updates and finalize the GEO Health CoP goals and work plan. This work plan supports GEO efforts and advances development of the [EO4HEALTH](#) community activity to an initiative. Kristin Wegner (University Corporation for Atmospheric Research/Global Learning and Observation to Benefit the Environment [GLOBE]) presented a brief description of the [GLOBE Zika Education and Prevention project](#) and the [GLOBE Mission Mosquito campaign](#) at this meeting. A total of 30 participants, representing different agencies in public and private sectors, participated on the telecon.

In April 2019, the U.S. GEO Workshop on the GEO Work Programme was held at NASA Headquarters, in Washington, DC. This meeting served as a platform to unite U.S. GEO members across sectors, provide updates on GEO Work Programme activities, and assess U.S. contributions to the GEO Work Programme for 2020-2022. As Co-Chair of the GEO EO4HEALTH activity, John Haynes presented an informative update about EO4HEALTH projects and accomplishments.

In May 2019, the NASA HAQ Applications Team participated in the GEO Symposium 2019, held at the World Meteorological Organization (WMO), in Geneva, Switzerland. This symposium highlighted the GEO Work Programme activities, initiatives, and flagships, and participants shared updates and plans to enhance the use of Earth observation data for sustainable development. More than 90 attendees participated in-person in this symposium. The [agenda](#) covered various topics, including *Earth Observations for Health and Urban Resilience*; *GEO Support to the Paris Agreement, Sendai Framework, and the 2030 Agenda for Sustainable Development*; *GEO Knowledge Hub*; *Cross-cutting Activities*; and *Regional GEOs*. In the *Earth Observations for Health and Urban Resilience* session, John Haynes presented an update on EO4HEALTH, which included plans for integration with AmeriGEO and promoting EO4HEALTH from a community activity to an initiative in the new GEO Work Programme. In the concurrent poster presentation session, John Haynes and Helena Chapman presented the GEO Health Community of Practice poster.

In August 2019, as part of the webinar series sponsored by the Central American Integration System (Sistema de la Integración Centroamericana, SICA), Helena Chapman (NASA Headquarters) presented the webinar session, *Using Earth Observation Data to Inform Health Decision-making*, about the EO4HEALTH activity

and wider GEO Health Community of Practice. This webinar described current objectives, funded projects, and collaborative activities within the seven GEO Health Community of Practice [work groups](#).

In August 2019, the NASA HAQ Applications Team participated at AmeriGEO Week 2019, held at the National Aerospace Research and Development Commission ([Comisión Nacional de Investigación y Desarrollo Aeroespacial, CONIDA](#)), the headquarters of the Peruvian Space Agency, in Lima, Peru. Attended by more than 90 participants, this event highlighted the GEO Work Programme activities and initiatives in the Americas Region, sharing updates and plans to enhance the use of Earth observation data for sustainable development. The [agenda](#) covered various topics, including *Strengthening Partnerships and Advancing Decision-making in the Americas* and six Work Sessions: *Advancing the Sustainable Development Goals Agenda*; *Agriculture Biodiversity and Ecology*; *Water*; *Foundational Tasks*; *Disasters*; and *New Opportunities and Collaborations*. The *New Opportunities and Collaborations* session offered an overview and three project updates of EO4HEALTH: *Introduction to EO4HEALTH*, *Environmental Determinants of Enteric Infectious Diseases*, *Geospatial Surveillance for Vector-borne Disease* and *Early Warning System for Malaria Risk in the Amazon*. In the concurrent poster presentation session, John Haynes and Helena Chapman presented the GEO Health Community of Practice poster. At the conclusion of this event, health was officially adopted as a crosscutting priority of AmeriGEO.

In November, the GEO Plenary 2019, held in Canberra, Australia, highlighted Earth observations in public health applications. First, the U.S. GEO delegation (Zdenka Willis, NASA) supported the coordination of two health stories for the U.S. GEO Exhibit: *Cholera and Harmful Algal Blooms across Florida's Gulf Coast*. Second, with the support and coordination of Merrie Beth Neely (NOAA), EO4HEALTH and the GEO Health CoP were highlighted in oral and poster presentations as part of the [Water for Life side event](#). Finally, EO4HEALTH was formally promoted to an initiative in the new GEO Work Programme.

In November 2019, the GEO Health CoP held a [quarterly telecon](#) to provide updates on past GEO meetings and upcoming Work Group activities. John Haynes shared the news that the EO4HEALTH Community Activity was formally named EO4HEALTH Initiative at the GEO Plenary 2019 in Canberra, Australia. Juli Trtanj (NOAA) and Helena Chapman provided a brief summary about next steps needed to accomplish the Work Group activities. Invited speakers included Gina Tsarouchi (HR Wallington) who described the [Dengue MOdel forecasting Satellite-based System \(D-MOSS\)](#) and Joy Shumake-Guillemot (WMO) who introduced the [Global Heat Health Information Network \(GHHIN\)](#). After consultation with the GEO Secretariat, D-MOSS was officially adopted as an EO4HEALTH project. A total of 25 participants, representing different agencies in public and private sectors, participated on the telecon.

In December 2019, the GEO Health CoP and AGU partnered to hold the [GEO Health CoP Meeting at AGU 2019](#) in San Francisco, California. Presenters included experts from the GEO Secretariat (Doug Cripe), AGU (Mark Shimamoto), NASA (John Haynes, Helena Chapman), NOAA (Juli Trtanj), National Institute of Environmental Health Sciences (John Balbus), and AquaWatch/Blue Planet (Merrie Beth Neely). GEO EO4HEALTH project updates were provided by Antarpreet Jutla (University of Florida), Ben Zaitchik (Johns Hopkins University), Gina Tsarouchi (HR Wallington), and John Malone (Louisiana State University). GEO Activity Updates were given by Mike Gill (GEO Biodiversity Observation Network), Daniel Juhn (GEO Earth Observations for Ecosystem Accounting), and Merrie Beth Neely (Blue Planet, Aqua Watch). With 41 attendees (31 in-person, 10 virtual), this meeting provided an opportunity for Earth and health scientists and practitioners to describe key international projects and updates, enhance professional networks, and discuss priority focus areas that advance GEO/AGU efforts.

The NASA Applied Sciences Program issued a solicitation to support the GEO Work Programme through Research Opportunities in Space and Earth Sciences (ROSES) 2016. This solicitation included a section targeting the EO4HEALTH Initiative. Awards from this solicitation were announced in October 2017 for a three-year period of performance. In 2019, the following were noted as key accomplishments of these projects:

- A project led by Dr. Antarpreet Jutla (University of Florida) integrated satellite data systems into the weekly time step for the epidemic and endemic models of cholera for Africa. Decision-making activities have been ongoing and timely, while collaborating with the United Kingdom Department for International Development (UK-DFID), UNICEF, and AfriGEO. For example, the team applied their innovative cholera risk model, which includes NASA Earth observations, to identify high-risk regions of cholera in Mozambique after Cyclone Idai struck the nation in March 2019. The successful results of this model adaptation to Mozambique suggest that the forecast model has the potential to fundamentally change how the local and international communities understand and mitigate the spread and risk of cholera.
- A project led by Dr. Tatiana Loboda (University of Maryland, College Park) has assembled a fully functioning prototype of the malaria forecasting system for a geographic subset of Myanmar, testing its performance for the 2017 calendar year. The team plans to meet with stakeholders to present the model and request their feedback, as well as additional data for validation and to improve the model's resolution and accuracy for

service-based components. The team is actively engaged in building capacity by developing workshops and training opportunities for in-country collaborators and end users. They have conducted a set of meetings with stakeholders and are incorporating their feedback into the modeling framework.

- A project led by Dr. Jack Malone (Louisiana State University) used bi-monthly Soil Moisture Active Passive (SMAP) L4 soil moisture data for 2017 to produce visceral leishmaniasis (VL) risk maps for Sao Paulo and Bahia states (Brazil) using Maxent software and then compared these results to Maxent risk maps based on WorldClim long term normal climate data (monthly temperature and precipitation). Similar patterns seen in results suggest that direct measurement of soil moisture by SMAP L4 may be used in lieu of environmental moisture values calculated from classical climate station data to evaluate VL risk in Brazil.
- A project led by Dr. Benjamin Zaitchik (Johns Hopkins University) on environmental determinants of gastrointestinal diseases connected rotavirus predictive models to objective regionalization and visualization systems, demonstrating a pilot of how all project components will integrate. The team resolved several technical and conceptual issues and continued to refine the integration work flow. They have completed the entire integration work flow for one gastrointestinal disease (rotavirus), and refined the models of two other gastrointestinal diseases. The team has recently shared results with end-user disease control partners and plans to operationalize the risk assessments for those diseases.

In November 2019, Laura Judd traveled to the European Space Agency/European Space Research Institute in Frascati, Italy, to participate in the Copernicus Sentinel-5 Precursor (S5P) Validation Team Workshop. Copernicus S5P was launched in October 2017 and hosts one instrument, TROPOMI, which monitors key tropospheric constituents related to air quality. This workshop gathered feedback about the quality and uncertainty characteristics of all publicly released TROPOMI products. The workshop also fed discussions about best data-use practices.

In December 2019, John Haynes was part of a panel session during the biennial International Center for Earth Simulation (ICES) meeting in Geneva, Switzerland. He presented an overview of NASA HAQ Applications. The theme of the panel was Healthy Planet, Healthy People. This event was attended by 40 people and facilitated an open discussion on Earth observations for diverse applications related to global ecosystems.

X. Looking Ahead

During 2020 and beyond, the HAQ Applications program will continue to expand and grow its relationship with current and future relevant NASA missions and designated observables, as well as field and Earth Venture (EV) campaigns. The program looks forward to the HAQAST 2020 Webinar Series in February and March 2020, as well as the final showcase of HAQAST results at NASA Headquarters in July 2020. The program also plans to release an open solicitation to re-compete HAQAST membership as part of ROSES 2020 in February 2020. Selections of the new HAQAST members are expected to be announced in October 2020.

In 2020, HAQ Applications program personnel plan to participate in relevant sessions of the AMS Annual Meeting, the AMCA Annual Meeting, the A&WMA Annual Meeting, the ATS Annual Meeting, the APHA Annual Meeting, and the AGU Fall Meeting.

The program will continue to engage schools of Public Health at various venues throughout the year to inform students and faculty of NASA Earth Science capabilities and discuss opportunities for future collaborations. In 2020, meetings are planned with Boston University, Oregon Health and Science University, Portland State University, and Drexel University.

The program will keep abreast of studies and opportunities related to Program of Record missions (e.g., Plankton, Aerosol, Clouds, ocean Ecosystem [PACE]) and Designated Observables outlined in the *Decadal Survey for Earth Science and Applications from Space*, of the National Academies of Sciences, Engineering and Medicine, released in January 2018. The Decadal Survey identified Aerosols (A) and Clouds, Convection and Precipitation (CCP) as high priority Designated Observables to be addressed, which are particularly relevant to this program. Additionally, the program is active in applications planning for the upcoming TEMPO Earth Venture mission, the MAIA Earth Venture mission, and the GeoCarb mission.

The program will continue to examine “grand challenges” to the community—particularly those outlined in the Decadal Survey—in collaboration with the NASA Earth Science Research and Analysis Program. For example, obtaining accurate ground-level aerosol and constituent measurements from remotely-sensed columnar values are a critical challenge. While progress has been made in this area, thanks to investments in algorithm development and targeted field campaigns, large discrepancies remain. Ozone is a key issue in this regard; measurements of aerosols over land areas with high albedo also have large errors. Even developed countries, such as the U.S., have relatively sparse ground-level aerosol networks and remotely-sensed observations provide critical data to fill coverage gaps. Developing countries have even fewer ground sensors, and sometimes none at all. Boundary layer processes are critical to air quality

forecasts, as this is where people live and breathe. Satellite observations for air quality will be increasingly vital in the coming years. The upcoming launch of TEMPO and its Korean (Geostationary Environment Monitoring Spectrometer [GEMS]) and European (Copernicus-Sentinel-4) constellation partners will allow unprecedented high temporal and spatial resolution measurements of tropospheric ozone, aerosols, and their precursors to create a revolutionary dataset that will address some of these challenges.

The HAQ Applications program has established strong relationships with federal, state, local, and international partners to identify unique applications of NASA satellite observations and realize their operational use. These applications provide critical components for integration with various forecasts, models, and decision support systems. This will continue to be the case with the launch of upcoming NASA satellite missions. NASA's participation in health and air quality applications research and the related transition to operations of results with EPA, NOAA, CDC, and others fills a significant niche in national capabilities and is a vital component of both current and future domestic and international programs and plans.

XI. Appendix

A. Abbreviations and Acronyms:

A&WMA: Air and Waste Management Association
A-CCP: Aerosols and Clouds, Convection and Precipitation
AGU: American Geophysical Union
AMCA: American Mosquito Control Association
AMS: American Meteorological Society
APHA: American Public Health Association
ARL: Application Readiness Level
ARSET: Applied Remote Sensing Training program
ATS: American Thoracic Society
CCHHG: Climate Change and Human Health Working Group
CCP: Clouds, Convection and Precipitation
CDC: Centers for Disease Control and Prevention
CONIDA: Comisión Nacional de Investigación y Desarrollo Aeroespacial
CoP: Community of Practice
D-MOSS: Dengue MOdel forecasting Satellite-based System
EPA: Environmental Protection Agency
EPHTN: Environmental Public Health Tracking Network
ESD: Earth Science Division
EV: Earth Venture
FDA: Food and Drug Administration

GEO: Group on Earth Observations
GHHIN: Global Heat Health Information Network
GLOBE: Global Learning and Observation to Benefit the Environment
GSFC: Goddard Space Flight Center
HAB: Harmful Algal Bloom
HAQ: Health and Air Quality
HAQAST: Health and Air Quality Applied Sciences Team
ICES: International Center for Earth Simulation
JPL: Jet Propulsion Laboratory
LaRC: Langley Research Center
MAIA: Multi-Angle Imager for Aerosols
MODIS: Moderate Resolution Imaging Spectroradiometer
MPH: Masters of Public Health
NAQFC: National Air Quality Forecast Capability
NASA: National Aeronautics and Space Administration
NCAR: National Center for Atmospheric Research
NIEHS: National Institute of Environmental Health Sciences
NLDAS: North American Land Data Assimilation System
NOAA: National Oceanic and Atmospheric Administration
NRC: National Research Council
PACE: Plankton, Aerosol, Clouds, ocean Ecosystem
PI: Principal Investigator
PM: Particulate Matter
PM_{2.5}: Fine Particulate Matter
ROSES: Research Opportunities in Space and Earth Sciences
RSIG: Remote Sensing Information Gateway
S5P: Copernicus Sentinel-5 Precursor
SBA: Societal Benefit Area
SDDOH: South Dakota Department of Health
SICA: Sistema de la Integración Centroamericana
SMAP: Soil Moisture Active Passive
TEMPO: Tropospheric Emissions: Monitoring of Pollution
TROPOMI: TROPOspheric Monitoring Instrument
UK-DFID: United Kingdom Department for International Development
UNICEF: United Nations Children's Fund
USGCRP: U.S. Global Change Research Program
UV: Ultraviolet
VIIRS: Visible Infrared Imaging Radiometer Suite
VL: visceral leishmaniasis
WESTAR: Western States Air Resources Council
WMO: World Meteorological Organization
WNV: West Nile Virus

WRAP: Western Regional Air Partnership

B. Contacts in the NASA Applied Sciences Program - HAQ Applications Area:

Program Manager:

John Haynes

jhaynes@nasa.gov

Senior Associate Program Manager:

Sue Estes

sue.m.estes@nasa.gov

Associate Program Managers:

Helena Chapman

helena.chapman@nasa.gov

Laura Judd

laura.m.judd@nasa.gov