REQUEST FOR APPLICATIONS (RFA) 25-1
ADVANCING SATELLITE-DERIVED AIR QUALITY DATA AND APPROACHES FOR USE IN HEALTH STUDIES

INTRODUCTION

As datasets of air quality derived from satellite remote sensing have become more widespread, their applications in health, including epidemiology and burden assessment, have grown. Additionally, new satellite instruments are being launched to monitor air quality at higher spatial and temporal resolution and for more pollutants than have been previously available. To address the new opportunities and potential pitfalls to avoid, the Health Effects Institute (HEI) held a public workshop on the current and future capabilities of satellite remote sensing for air quality and health applications. The workshop identified opportunities to improve satellite-derived air quality products and to characterize the inherent uncertainties. Satellite-derived air quality products often combine satellite data with other data sources to infer ground level air quality concentrations. Thus, uncertainties in these air quality products can reflect uncertainties in the satellite data themselves or in the models or data that are used to create the air quality concentration estimates. HEI now seeks to fund studies that will develop a resource for health research that links satellite-derived air quality products to quantified uncertainties for exposure, epidemiological, and health assessment applications. Proposed studies should develop new approaches, satellite-derived air quality datasets with quantified uncertainties, or tools to provide or improve the use of satellite-derived air quality data in health studies. To the extent possible, they should assess the uncertainties in the approaches, datasets, or tools; the determinants of these uncertainties; and the implications of these uncertainties for health research.

BACKGROUND AND RATIONALE

Applications of Satellite-Derived Air Quality Data in Health Studies

Satellite-based estimates of ground-level air pollution have emerged as an important source of information on human exposure to pollutants such as nitrogen dioxide (NO_2), ozone (O_3), and fine particulate matter ($PM_{2.5}$; particulate matter with an aerodynamic diameter of 2.5 µm or smaller). Health effects researchers are increasingly using satellite-derived estimates of these and other air pollutants in both epidemiological research and risk assessment (e.g., Boogaard et al. 2024; Health Effects Institute 2024). The main advantage of satellite-derived air quality data over ground monitoring data is their vast spatial coverage (Holloway et al. 2021), especially in parts of the world where air quality and air pollutant emissions data are not widely available (Fosu-Amankwah et al. 2021; Odo et al. 2022). Large-scale epidemiological studies are often made possible through exposure assessment using hybrid models based on publicly available datasets, including measurements of ground air pollution levels, satellite-derived air quality surfaces, and air quality models. Satellite-derived air quality estimates have also proven essential for comprehensive global, world region, national, and city-level analyses of pollutant concentrations and trends in air quality and the associated effects on mortality and other health outcomes (Anenberg et al. 2022; Dey et al. 2020; Health Effects Institute 2024; McDuffie et al. 2021; Singh et al. 2024). Satellite-derived air quality data have also been used to assess within-city disparities in exposures to NO_2 and O_3 (Dressel et al. 2022, 2024; Kerr et al. 2024).

Deriving air quality information from satellite data

Satellite retrievals

Satellite remote sensing instruments measure physical properties that can be used to infer air pollutant concentrations, rather than directly measuring air pollution concentrations (Duncan et al. 2014; Holloway et al. 2021; Ma et al. 2022). Generally, satellite remote sensing instruments passively detect outgoing radiation over a wide range of wavelengths. The intensity of the reflected or emitted radiation to space is influenced by properties of the ground surface and atmosphere (Falah et al. 2021). Through the application of multiple physics-based models (i.e., retrieval algorithms), users infer physical quantities (e.g., number density, partial pressure, and column amount) in a vertical column based on the spectral signature for each atmospheric constituent. Retrieval algorithms are able to quantify atmospheric components such as aerosol optical depth (AOD) and vertical column density of trace gases and particulate matter precursors, including NO_2, sulfur dioxide (SO_2), O_3, carbon monoxide (CO), ammonia (NH_3), methane (CH_4), and carbon dioxide (CO_2) (Levelt et al. 2006; Ma et al. 2022; Wolfe et al. 2024).

The spatial and temporal resolution of satellite observations and the length of the data record vary for different satellite instruments. Satellite instruments provide air quality data on spatial resolutions of 1 km to hundreds of km and temporal resolutions of several minutes to several days (Holloway et al. 2021; Kim et al. 2020). The spatial coverage and frequency of observations are determined largely by whether the instrument is mounted on a polar-orbiting or geostationary satellite. Polar-orbiting, or low Earth orbit, satellites have global coverage but take only one snapshot (sometimes fewer) per day (Holloway et al. 2021). Geostationary satellites have partial global coverage but take many snapshots (about 12) per day that can allow them to characterize diurnally varying sources. For example, the Ozone Monitoring Instrument (OMI) is mounted on a polor-orbitting satellite and has made observations globally at a nominal spatial resolution of 24×13 km^2 and frequency of once per day since October 2004. Tropospheric Emissions: Monitoring of Pollution (TEMPO) is mounted on a geostationary satellite and has made observations over North America at a nominal spatial resolution of 1 km^2 and hourly frequency since 2023.

The accuracy of the satellite observations also varies by pollutant, location, and conditions that vary over time. Satellite instruments have different sensitivities to specific wavelengths used for retrievals related to different pollutants (Kim et al. 2020; Zhang et al. 2024). Additionally, the optical signal can be affected by cloud cover, vertical profile and interfering species concentrations within the column, and surface reflectivity and other ground surface characteristics, including land use and development. Because most satellite-borne instruments rely on backscattered radiation, their observations are restricted to daytime hours, with some functionality at the day–night interface.

Converting satellite retrievals to air pollutant concentrations

Physical or statistical models are required to infer trace gas and aerosol surface concentrations from the direct measurements of physical properties of the vertical column (Holloway et al. 2021). For example, chemical transport models are often used to estimate the fraction of the pollutant that is at ground level for $PM_{2.5}$ and other pollutants where the vertical distribution of air pollutant concentrations is non-uniform (e.g., Di et al. 2017). Other parameters such as meteorology, major roads, and land use might be added as covariates to improve and stabilize performance (e.g., Larkin et al. 2023). Model structures include statistical models (multivariate regressions, mixed-effects models, generalized additive models, geographically weighted regression models, hybrid models, multi-state models, or spatiotemporal kriging) and machine learning models (random forest, gradient boosting, neural network, deep learning) (Cooper et al. 2020; Diao et al. 2019; Holloway et al. 2021; Kim et al. 2024; Lee et al. 2016; Sorek-Hamer et al. 2022; van Donkelaar et al. 2021; Zhu et al. 2022). Approaches to infer ground-level air pollutant concentrations from satellite retrievals often combine information from multiple sources, including remote sensing, model-based estimates, and ground-level measurements from high-quality monitors or low-cost sensors in both urban and rural environments. Remote sensing and in situ observations both can include ground-based measurements or measurements by instruments borne by aircraft or drones. At all stages of development of satellite-derived air quality estimates at ground level, the various sources of data contribute different strengths and limitations (Paciorek and Liu 2012; Sorek-Hamer et al. 2016). Data fusion methods can combine data from different satellites and other data sources in attempts to build on strengths and overcome the quality limitations of the different products.

Evaluation of air quality surfaces

Satellite-derived air quality surface products are often trained with ground measurements, and their performance is evaluated based on agreement with measurements made by ground level or above ground tropospheric instruments (including from Pandora and AERONET, airplanes, or ships), which have their own uncertainties and limitations (e.g., Kim et al. 2020; Lee et al. 2016). Uncertainties in the satellite-derived air quality surfaces derive from uncertainties in the satellite observation itself and uncertainties in the modeled relationships between air pollutant concentrations and the satellite retrievals and might change as retrieval algorithms and other models are improved (Cooper et al. 2020; Diao et al. 2019; Paciorek and Liu 2012). Identified sources of uncertainty include limited spatial density or duration of ground monitoring (Chen et al. 2018), missing values and associated biases when clouds are present (Gupta et al. 2020; Katoch et al. 2023; Sorek-Hamer et al. 2016), and methods to interpolate missing satellite retrievals (Chen et al. 2020). NO_2 and $PM_{2.5}$ can serve to illustrate the issues described because they are health relevant and estimates of their concentrations are provided by widely used satellite-derived air quality products. The largest sources of uncertainties in the satellite estimates of urban NO_x have been reported to be the tropospheric column measurements, wind speed and direction, and spatial definition of each city (Goldberg et al. 2021). At least for NO_2, satellite-derived air quality can under or overpredict surface concentrations, depending on the site (Cooper et al. 2020). An active area of $PM_{2.5}$ research is moving from chronic exposures (e.g., monthly or annual) to acute exposures (daily or subdaily) while accounting for the increased uncertainties as the temporal resolution increases (Sorek-Hamer et al. 2020).

OBJECTIVES OF RFA 25-1

The overarching goal of this RFA is to develop a resource for health research that links satellite-derived air quality products to quantified uncertainties and strengthens the understanding of the implications of such uncertainties for exposure, epidemiological, and health assessment research. HEI seeks to fund studies that can accomplish the following specific objectives:

1. Develop new approaches, satellite-derived air quality data products with quantified uncertainties, or tools to produce and share satellite-derived air quality data products and their associated uncertainties. A focus should be on reporting the air pollutant concentrations, their overall uncertainties, and the determinants of those uncertainties in forms that facilitate their use in future epidemiological analyses and other health studies.
2. Evaluate regional and local accuracy of the new approaches, satellite-derived air quality data products, or tools relative to observational datasets that are independent to the extent possible, with consideration that changes to improve estimates overall could either improve or degrade accuracy or bias for different locations, time scales, or pollutant concentrations.

BUDGET AND TIMELINE

HEI seeks to fund 2-3 studies of no more than $500,000 each, for a maximum program budget of $1,000,000. Study duration will be 1–2 years, including the time to write the final report.

CRITICAL STUDY DESIGN CONSIDERATIONS

Applicability to Research on Health Effects of Air Pollution

The RFA focuses on preparing outputs that can be widely used in epidemiological and health assessment studies. Proposals must discuss potential future applications of the study output in health studies and justify how the proposed outputs would substantially contribute to improvements in those applications beyond what already exists. The proposal should include details on how the spatial and temporal resolution of the proposed air pollutant concentration and uncertainty outputs relate to relevant temporal and spatial scales for potential health outcomes in the described applications. Additionally, the proposed file formats and geographic aggregation of outputs should be accessible to health researchers. This RFA does *not* include funding to conduct research on specific health outcomes or a follow-on health study because the focus is on improving data for use in many future applications.

Relevant Satellite Data Products

Responsive applications might propose to use data products from a geostationary or polar-orbiting platform, or to use data fusion methods that combine observations from multiple satellite-based instruments to try to overcome the limitations in the different types of data products. The satellite-derived air quality and associated uncertainty data products developed or used in the proposed work should have sufficient spatial resolution (either native or after processing) for use in high-resolution (e.g., 1-km) health study applications. Commonly used approaches (e.g., assessment of $PM_{2.5}$ using Moderate Resolution Imaging Spectroradiometer [MODIS] AOD) will not be responsive unless the proposed work also substantially addresses the variability and uncertainty in the data. At least one year of observations from the satellite-based instrument should be available before the start of the study.

Population of Interest

The study should focus on air quality in the United States and must clearly articulate the relevance and substantial added value of the research to the human health effects of air pollution in the United States. Studies that include evaluation of satellite-derived air quality estimates in rural areas and other places where ground-based air pollutant measurements are lacking are of particular interest. Proposals should include discussion of the extent to which the deliverables from the study would be useful for studies in the general population and to specific populations or communities that experience high exposures.

Pollutants

Proposed studies should consider exposures to multiple pollutants to the maximum extent possible. Proposals should discuss the relative levels of uncertainty in any pollutants included in the study and the extent of alignment of data for different pollutants in space and time. Pollutants of particular interest include NO_2, O_3, and PM (including both mass measurements and physical and chemical properties).

Approaches

Satellite retrievals to infer air pollutant concentrations should be an important component of the overall approach, and the approaches to data analysis and modeling should be designed to address the objectives of the RFA directly. Proposals may use satellite data and approaches that emphasize a long historical record or take advantage of the latest technologies; the approach should explain the strengths and limitations of the selected data for use in existing health cohorts with extensive existing records and for use in prospective health studies. Approaches should include uncertainty estimates in air pollutant concentrations and account for source emissions that vary in space and time, as applicable. The use of new statistical and computer modeling approaches (e.g., machine learning, artificial intelligence, and Bayesian nonparametric ensembles) is encouraged where relevant. Other approaches — including land use regression modeling, modeling of physiochemical processes such as vertical mixing, and integration with other datasets — are also welcomed. If comparable air quality data from earlier approaches and technologies or independent validation datasets are available, novel outputs from the proposed study should be compared to those earlier data to assess the value added.

Supporting data for evaluation and uncertainty quantification

This proposal is intended to leverage existing data and ongoing studies for evaluation and uncertainty quantification. Sources of data used for evaluation of the satellite-derived air quality products can include routine ground monitoring of air quality, intensive field studies, ground-based remote sensing (e.g., Differential Optical Absorption Spectroscopy [DOAS] or Pandora), low-cost sensor networks for high spatial resolution, and chemical transport modeling, among other possibilities. Proposals should assess the suitability of the proposed datasets for the intended uses and address the limitations in available ground-based or other monitoring data that can be used to evaluate satellite-derived air quality concentration estimates. Proposals should consider the availability of datasets of ground-based observations to validate gradients of satellite-derived air quality concentration estimates in rural versus urban locations and for sparsely monitored pollutants such as some $PM_{2.5}$ components. Proposals should also consider the ability to quantify uncertainties in temporal variability, especially the ability to quantify uncertainties at high pollutant concentrations that can occur during pollution episodes such as wildfire smoke events, when ground-based monitors might not provide accurate readings. If data needed for evaluation (e.g., ground measurements) are missing, the study should demonstrate knowledge gaps and provide clear directions on how the gaps can be closed with future measurement or modeling approaches.

Statistical Methods

Proposals should include appropriate statistical and analytical methods and sensitivity analyses. The proposal should discuss how the uncertainty analyses would provide information on the accuracy, precision, and bias of the estimated air pollutant concentrations. It should also articulate how the statistical outputs can be used directly in future epidemiological analyses or otherwise inform those analyses. For example, high R^2 in comparison with ground monitors is an important aspect of air quality surface evaluation but does not capture all the important information to understand fully the variability and uncertainty in the air quality estimates. There can be bias from missing data (e.g., because of cloud cover) or other factors. Additionally, there can be temporal variations such that R^2 is higher or lower at different times. Therefore, variability and uncertainty in the concentrations should be reported using statistics that account for bias and imprecision, not only R^2.

Data Access and Transparency

Applicants are encouraged to use only publicly available input datasets, code, and tools. If restricted resources are used, the proposal must include information on how other researchers can also access and evaluate the data. All resources developed under this RFA must be made publicly available and documented with sufficient explanation to be used in future epidemiological or health assessment research. Potential resources include data files (e.g., air pollution surfaces with uncertainties attached) or code packages. Investigators must also follow all other protocols in HEI's QA/QC Policy and Data Access Policy. See below for general information on the Data Access Policy.

Feasibility

The budget and timeline should closely align with the selected specific objectives and scope of work and should include preparation of the final report. Resources, including access to necessary data and computing resources, should be demonstrated as part of the application. The study should leverage existing observational datasets or concurrent studies to the extent possible; new data collection is allowed but not expected.

Complementary to Other Efforts

This RFA is intended to complement ongoing research to develop new satellite-derived air quality data products (e.g., NASA and NSF research programs) and to produce epidemiological associations of health outcomes with air pollution (e.g., NIH and EPA programs). Funded research will contribute to bridging the gap where there is little funding for issues at the intersection of satellite-derived air quality products and epidemiological studies that heavily rely on those data products. Study team members will be expected to leverage ongoing related work where possible and to collaborate with other ongoing research teams conducting related research – for example the NASA Health and Air Quality Applied Sciences Team (HAQAST) members working on studies related to satellite observation validation, air quality exposures, and epidemiology – as applicable.

RESEARCH TEAM

The research team must be multidisciplinary and hold the full range of expertise necessary to conduct the proposed research. Areas of expertise should bridge satellite data retrieval or processing algorithms, data products, exposure assessment, epidemiology, or other applicable fields. It is expected that collaboration of the satellite engineers, health researchers, and people familiar with the key issues related to air pollution sources in the study region will result in important insights. The Principal Investigator (PI) must demonstrate a record of producing high-quality and objective research in areas relevant to the proposed work and be affiliated with an established research organization. A laboratory QA manager must be named to meet criteria in HEI's QA/QC Policy.

The proposal must clearly identify each team member, their affiliation, and role in the research. The team should have access to study sites (as evidenced by letters of support in the proposal, if applicable) and have or obtain access to facilities, equipment, and instrumentation needed to support the proposed research. To the extent appropriate for the study locations, applicants should be attuned to and knowledgeable about the regions in which the studies will take place. If investigators plan to use data or materials (e.g., filter samples) from previous research, information on the type of data available (including the period, location, and frequency of observations) and quality assurance should be included. The application should include a letter from the owner of any data or materials to be used that states willingness to share the data with the applicant and with HEI, if requested.

MULTI-SECTORAL ENGAGEMENT

The proposal should be informed by engagement with experts who represent multiple sectors (e.g., academia, regulatory and public health agencies, industry, non-governmental organizations, and communities). The proposal should describe how specific individuals from multiple sectors will be consulted or included in the research to ensure that the final data product is useful and that the research outputs reflect real-world conditions.

POLICY ON DATA ACCESS

Providing other researchers with access to data is an important element in ensuring scientific credibility and is particularly valuable when studies are of regulatory interest. HEI has a long-standing policy to provide access to data for studies that it has funded in a manner that facilitates the review and validation of the work. The policy also protects the confidentiality of any subjects who may have participated in the study and respects the intellectual interests of the investigators who conducted the study. Please refer to the HEI Policy on the Provision of Access to Data Underlying HEI-Funded Studies.

Applicants will be expected to include a plan for data sharing and accessibility at the end of the study. Where data are provided by a third party, a process for other researchers to obtain and work with the data should be outlined.

APPLICATION PROCESS AND DEADLINES

The submission and review of applications for RFA 25-1 will entail a two-stage process.

- Applicants should submit a **Preliminary Application by May 27, 2025**. The HEI Research Committee will discuss the preliminary applications and invite a limited number of investigators to submit a full application. Responses will be provided in July 2025.
- Invited applicants should submit a **Full Application by September 24, 2025**. Full applications will be reviewed by external reviewers and an ad-hoc Special Review Panel before consideration by the Research Committee. Applicants will be notified about the funding decision in December 2025.

PRELIMINARY APPLICATION

Applicants should submit a Preliminary Application using the form provided on the HEI website. The preliminary application should include the following information: title, plain language project summary, scientific background and rationale, hypotheses and specific aims, study design and methods, statistical analyses, anticipated results, and a multi-sectoral engagement plan (where applicable). It should also briefly discuss the applicant's qualifications and include a biographical sketch for each co-investigator (maximum two pages per person). An estimated total budget and study duration should be provided. No detailed budget forms are needed at this stage.

The preliminary application should not exceed 5 pages excluding references, biosketches, and any supporting letters, as indicated in the application instructions and form. Please note that the required font size is 11 points with 1-inch margins.

Submission and Deadline

Preliminary applications should be submitted electronically in PDF format to funding@healtheffects.org no later than **May 27, 2025**. HEI will acknowledge receipt of the application. Questions regarding the RFA and how to apply should be directed to Dr. Allison Patton (apatton@healtheffects.org).

FULL APPLICATION

Invited full applications should provide in detail the study aims, design, rationale, methods, and statistical analyses. If data from other studies are going to be used, information on the type of data available (including the period, location, and frequency of when the measurements were taken) and quality assurance should be included. Investigators should also discuss whether they will need to obtain IRB approval. Where applicable, a letter from the investigator who owns the data should be submitted and state their willingness to share the data with the applicant and with HEI, if requested (see HEI Policy on the Provision of Access to Data Underlying HEI-Funded Studies). In addition, the full application should include a plan for data sharing and accessibility at the end of the study.

Application forms can be downloaded from https://www.healtheffects.org/research/funding. Investigators invited to submit a full application should use forms F-1 to F-12 and consult the application instructions. Please note that the required font size is 11 points with 1-inch margins.

Form F-12 is separated from the rest of the application upon receipt. The data are kept confidential and not considered for funding decisions. **The application forms should be converted to a PDF with appropriate bookmarks before submitting.**

Submission and Deadline

Invited Full Applications should be submitted to **funding@healtheffects.org** no later than **September 24, 2025**. The application should be in PDF format with a maximum file size of 20 MB. HEI will acknowledge receipt of the application.

Full applications without pre-submission of a preliminary application and invitation from the Research Committee will not be considered.

EVALUATION PROCESS FOR FULL APPLICATIONS

Full applications will be evaluated in a two-stage process: an external review followed by an internal review.

EXTERNAL REVIEW

Applications undergo a competitive evaluation of their scientific merit by an ad hoc panel of scientists selected for their expertise in relevant areas. Applications might also be sent to external scientists for additional evaluation, if necessary, in areas of expertise that are not covered by the Panel or where there are conflicts of interest. The panel will evaluate applications according to the following criteria:

- Relevance of the proposed research to HEI's goals
- Scientific merit of the proposed study design, approaches, methodology, analytic methods, and statistical procedures
- Personnel and facilities, including
    - Experience and competence of the PI, scientific staff, and collaborating investigators
    - Extent of collaboration among investigators in pertinent fields who will contribute to the conduct of the study
    - Adequacy of effort on the project by scientific and technical staff
    - Adequacy and validity of existing data and data to be collected
    - Adequacy of facilities
- Reasonableness of the proposed cost

INTERNAL REVIEW

The internal review is conducted by the HEI Research Committee and generally focuses on the applications ranked highly by the external review panel. The review is intended to ensure that the studies recommended for funding constitute a coherent program and address the objectives of the Institute. The Research Committee makes recommendations regarding funding of studies to the Institute's Board of Directors, which makes the final decision.

CONFLICTS OF INTEREST

HEI's procedures for conflicts of interest are similar to the guidelines set forth by NIH. Members of HEI's sponsor community are excluded from participating in RFA development, applying for support, application review, and funding decisions.

HEI invites external reviewers (or in the case of a major RFA, Review Panel members) who are unlikely to have a conflict of interest with the proposal(s) they are asked to review. A conflict occurs when the reviewer is named on the application in a major professional role; the reviewer (or close family member) would receive a direct financial benefit if the application is funded; the PI or others on the application with a major role are from the reviewer's institution or institutional component (e.g., department); during the past three years, the reviewer has been a collaborator or has had other professional relationships (e.g., served as a mentor) with any person on the application who has a major role; the application includes a letter of support or reference letter from the reviewer; or the reviewer is identified as having an advisory role for the project under review. In addition, HEI staff screen external reviewers for potential conflicts of interest with other applicants who have submitted a proposal under the same RFA. All Panel members complete a confidential conflict of interest form and are asked to recuse themselves if there is any actual or perceived conflict of interest.

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