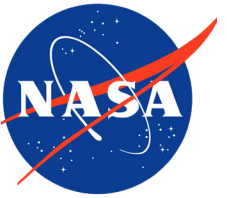


EARTH SCIENCE  
APPLIED SCIENCES



# ARSET 2021 ANNUAL REPORT



Since 2009, NASA's Applied Remote Sensing Training (ARSET) Program has been delivering critical knowledge and expertise to the global remote sensing community on how to leverage NASA's publicly available datasets. 2021 was no exception. The program delivered online training and materials on novel topics ranging from the use of LiDAR for deriving bathymetry to using Synthetic Aperture Radar (SAR) in conjunction with optical imagery to identify crops from space.

Each training was born out of a specific need expressed by the community, and each training reached hundreds or thousands of remote sensing students and professionals worldwide. In addition, we built and strengthened multiple partnerships and collaborations with academic institutions, international space agencies, and other programs within NASA to bring the maximum level of expertise to bear on these topics. The timely, relevant, and well-informed training opportunities that resulted from the hard work of our team as well as our generous collaborators and guest instructors resulted in the further growth of the program and advancement of the remote sensing community at large.

In order to assess our impact and help us better serve the community, we collect quantitative as well as qualitative evidence to gauge our impact. In this Annual Report you will find both. In this brief summary of our accomplishments, you will find our yearly successes outlined in statistics, charts, and maps, a detailed list of trainings from 2021 with links to materials, and anecdotal stories from individuals who have benefited. We hope you enjoy. To close out, we would like to express our heartfelt gratitude to our constituency, whether it be our collaborators, long-time participants in our program, or those just discovering the world of remote sensing for the first time. We hope you will continue to engage with us so we can provide the best possible remote sensing training to meet your needs.

Ad astra.  
The ARSET Team

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## 2021 STATISTICS

This year, ARSET has trained a total of **27,182** participants, bringing the total participants trained since 2009 to **86,472**.

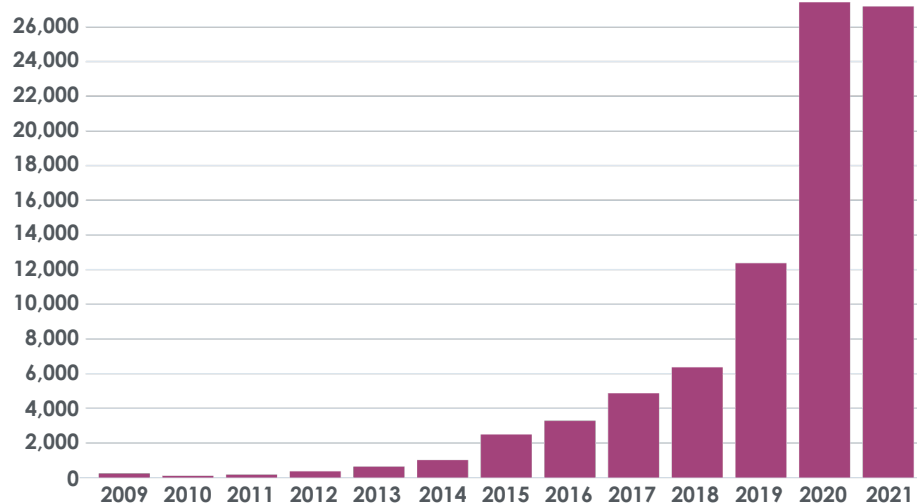
**Three-quarters** of respondents found the instructor lectures, training materials, and examples of remote sensing data use “extremely helpful” for improving their ability to access and use remote sensing data.

Across **all** ARSET trainings, **98%** of participants indicated that their knowledge improved, with **85%** of respondents noting that they improved their understanding and abilities in regard to key learning objectives for that training.

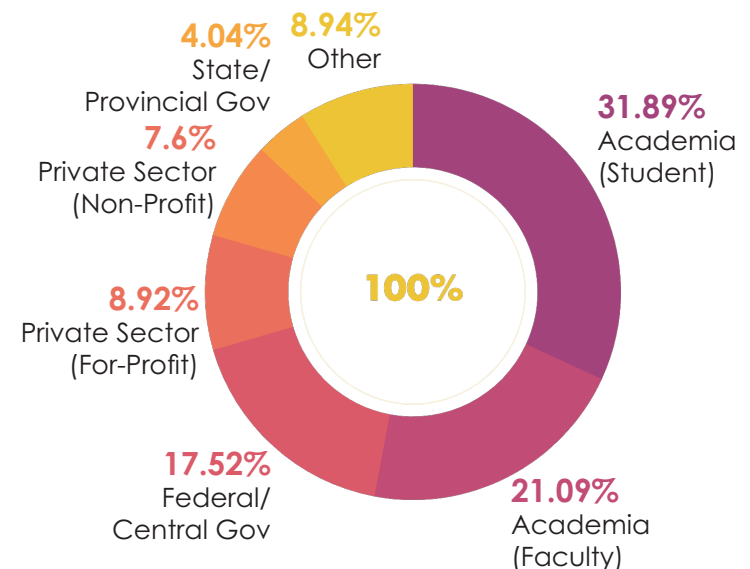
**More than a quarter** of respondents identified as one of their top three intentions their plans to share information learned in the ARSET training with colleagues.

**60%** of the total participants trained since 2009 came from the last two years (2020 and 2021).

### Participation by Year

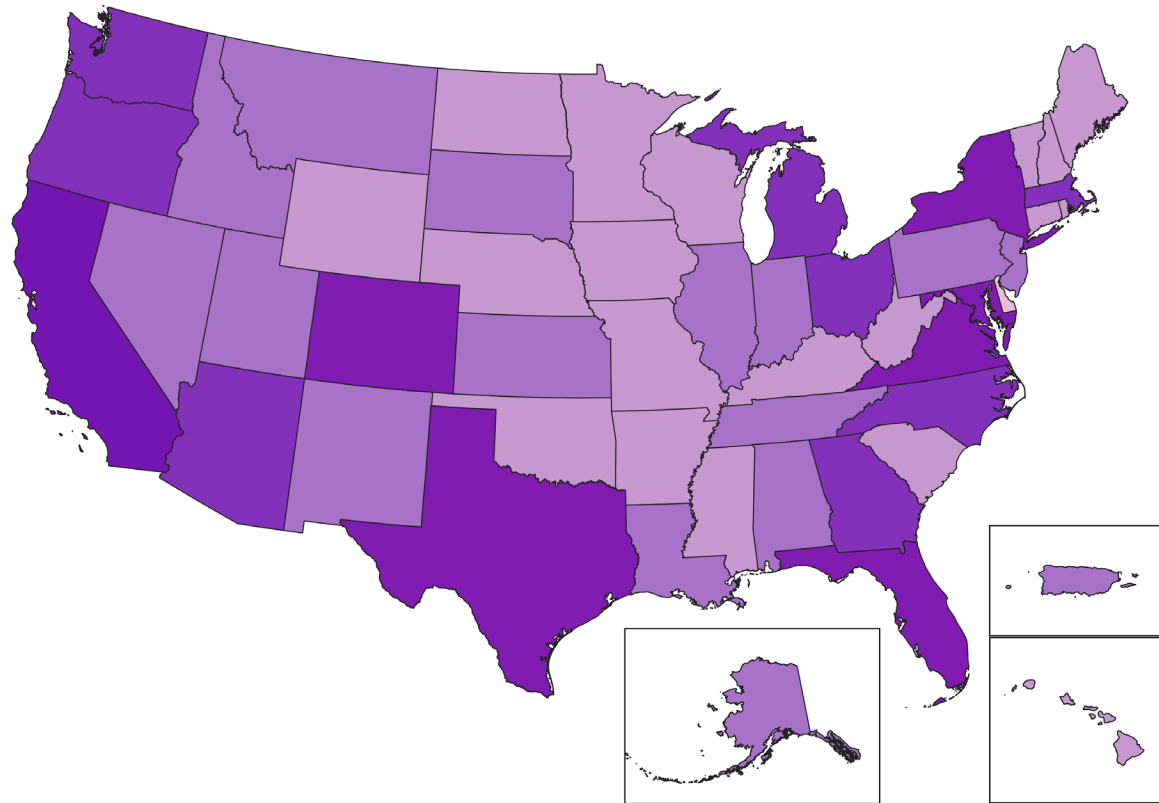


### 2021 Participation by Sector



# 2021 STATISTICS

Participants: **27,182** Organizations: **5,911** Countries: **166** US States: **50**



2021 Participation

Number of Participants

□ No Participation

□ 0 - 5

□ 6 - 25

□ 26 - 50

□ 51 - 100

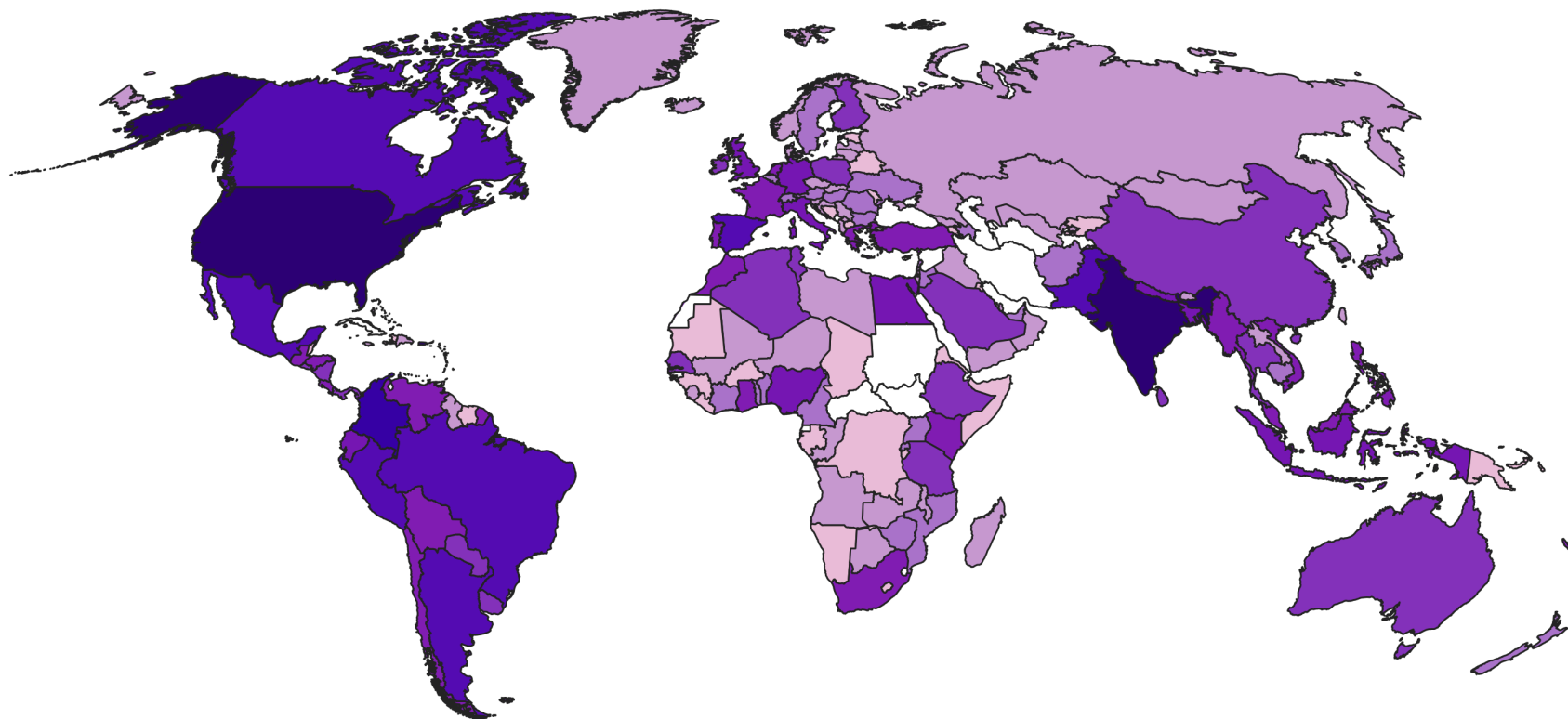
□ 101 - 250

□ 251 - 500

□ 501 - 1000

□ 1001 - 2000

□ 2000+





# 2021 PARTICIPANT HIGHLIGHTS

## Dr. Shankharoop Ghoshal

Geospatial Data Scientist  
Boomitra



“The ARSET training programmes have been very helpful to me in increasing my knowledge of the latest applications in the field of remote sensing of the environment. I have applied the knowledge gained from ARSET in investigating the disturbance dynamics of forests in the western Himalayas of India and studying mangrove vegetation dynamics in a region in Kerala, India. The ARSET programmes have also been very helpful to me in training graduate students in the field of applications of Remote Sensing and GIS in Environmental Sciences. I thank the ARSET team for these training sessions and I wish that they continually provide this wonderful service to humankind.”

## Lucy Luong

Architect and Remote Sensing Researcher



“ARSET has removed barriers and opened the door to the Remote Sensing (RS) field for a novice in the RS field like me. Various research and data collection methods, analysis tools, data sources, and their applications in air, water, and land sessions are introduced and carefully explained in webinars. Furthermore, the program teaches attendees how to analyze differences RS data. The NDVI webinar trained me not only NDVI but also the QGIS software and the steps to pre-processing, processing and post-processing Landsat images. For example, from NDVI webinars, I knew Raster calculator; Merge command locates in Raster Tab, under Miscellaneous; image classification can be found in processing toolbox and what to do with them. I applied learnt knowledge in calculating LST following NDVI threshold methods mainly following the papers of Sobrino et al, 2008; Sekertekin & Bonafoni 2019. The result of these practices was written in a paper “Surface urban heat island mapping: The case of Hanoi” and submitted for reviews to Frontiers of Architectural research journal. Thanks to ARSET, I can attain this result. This initial understanding made me feel more confident in learning and practising RS. I much appreciate the efforts of all ARSET teams in providing a useful scientific informative webinar for learners. This is the most wonderful online program that I have attended so far.”

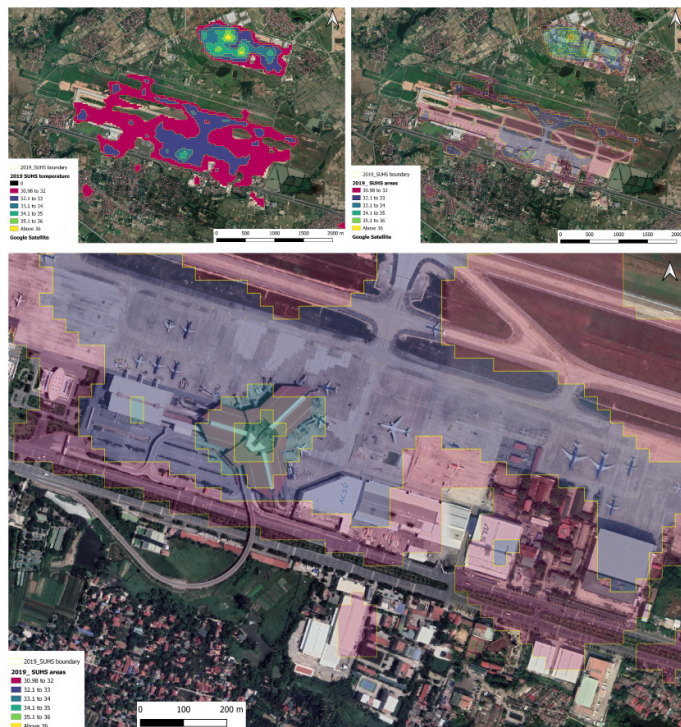


Figure 15: Locations of heat on Noi Bai Airport - urban heat analysis 2019

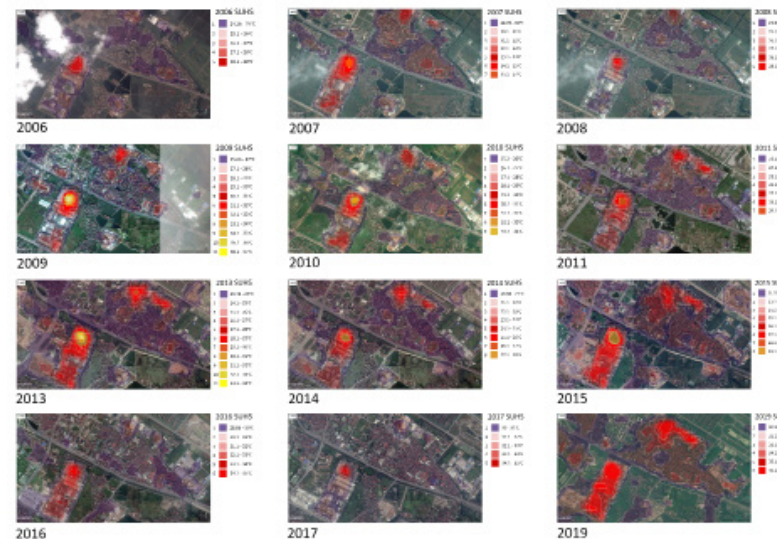


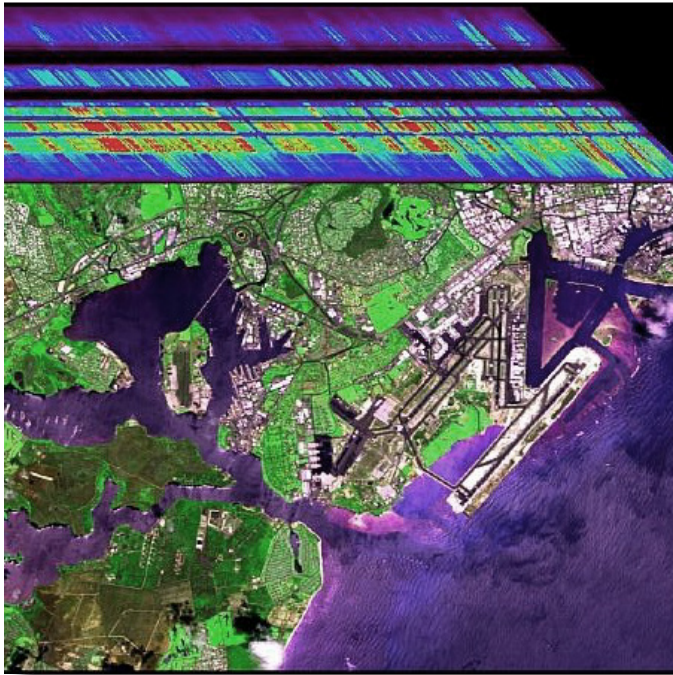
Figure 9: Surface urban heat hot spot - Sai Dong industrial zone





# 2021 TRAININGS

JAN 19 - FEB 2



## HYPERSPECTRAL DATA FOR LAND AND COASTAL SYSTEMS

INTRODUCTORY ONLINE ECO FORECASTING

Hyperspectral data collects detailed information using very small intervals of both visible and non-visible light wavelengths. Applications of hyperspectral data include plant species identification, assessment of phytoplankton functional types, mapping of wetlands and shallow benthic communities, and detection of harmful algal blooms (HABs). Hyperspectral data allows decision-makers to better understand critical components of ecosystem dynamics such as invasive species encroachment, forest decline and pest infestation, and ocean dynamics because of its ability to characterize chemical, physiological, and morphological traits.

**1,935**  
Participants

**950**  
Organizations

**109**  
Countries

**49**  
US States

## MAPPING AND MONITORING LAKES AND RESERVOIRS WITH SATELLITE OBSERVATIONS

INTRODUCTORY ONLINE WATER RESOURCES

A variety of factors can affect the water level and quality of lakes and reservoirs, including climate variability and change, land use, and other watershed activities influencing surface runoff and groundwater. Monitoring the water quantity and quality of lakes and reservoirs is crucial for their sustainable management. This three-part training focused on introducing remote sensing observations for monitoring the water level of lakes: a critical surface water component affecting the residential, economical, and recreational sectors in the area. Recent observations of lake bathymetry based on remote sensing observations were also presented.

**1,736**  
Participants

**800**  
Organizations

**114**  
Countries

**47**  
US States

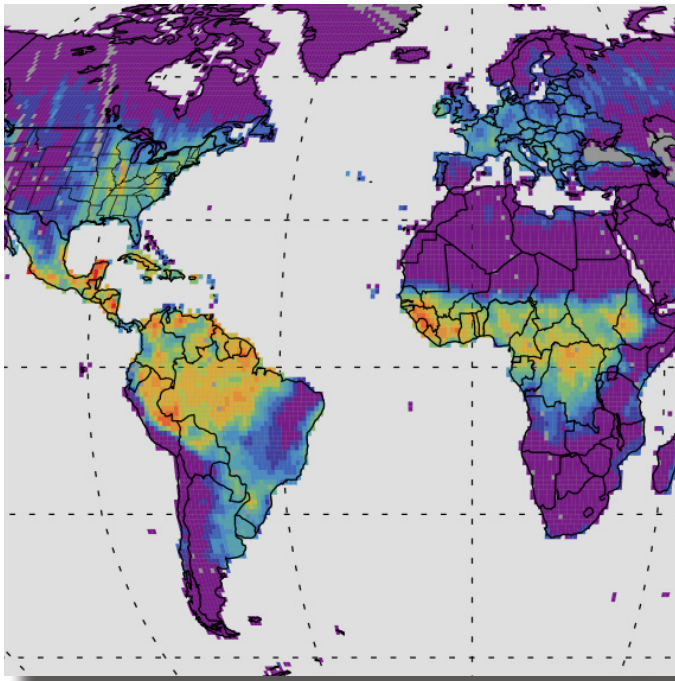


FEB 9 - FEB 23





MARCH 16 - MARCH 25



## USE OF SOLAR INDUCED FLUORESCENCE AND LIDAR TO ASSESS VEGETATION CHANGE AND VULNERABILITY

INTERMEDIATE ONLINE BILINGUAL (SP) **DISASTERS**

This introductory webinar series covered the fundamentals of Solar Induced Fluorescence (SIF) and LIDAR, their applications, and provided an overview of different satellite data sources that are openly available. In addition, it also included a step-by-step guide on how to access, open, and interpret SIF and LIDAR data. SIF is a relatively new emerging satellite product, which provides information on photosynthetic activity versus NDVI, which is a greenness index. It serves as a strong proxy to gross primary production (GPP), capturing dynamic responses of vegetation to stressors such as drought and temperature. LIDAR is a sensor system that illuminates a target and measures distance through the time taken for a pulse to reflect back to the sensor. LIDAR can be used to generate topography and vegetation height maps and retrieve digital elevation data necessary for flood modeling and vulnerability, along with risk analysis.

**1,632**  
Participants

**800**  
Organizations

**109**  
Countries

**42**  
US States

MARCH 30 - APRIL 6

## INTRODUCTION TO POPULATION GRIDS AND THEIR INTEGRATION WITH REMOTE SENSING DATA FOR SUSTAINABLE DEVELOPMENT AND DISASTER MANAGEMENT

INTRODUCTORY ONLINE **DISASTERS**

This two-part training, developed and presented by members of the POPGRID Data Collaborative, focused on the different global population grids and their application to a range of topics related to development planning and monitoring of the SDGs (e.g., environment, hazards, and access to resources). Attendees were exposed to the latest data and methods used to produce global grids, how the grids incorporate remote sensing inputs, and how population grids can be used in conjunction with other types of data.

**1,038**  
Participants

**500**  
Organizations

**111**  
Countries

**35**  
US States





## SATELLITE OBSERVATIONS AND TOOLS FOR FIRE RISK, DETECTION, AND ANALYSIS

INTERMEDIATE

ONLINE

BILINGUAL (SP)

MULTIPLE

Fires are a growing concern, especially in regions with longer fire seasons, expanded wildland/urban interfaces, and severe and frequent droughts. Whether naturally occurring or anthropogenic, fires produce a significant change in the structure and reflectance of vegetation and soil properties and atmospheric chemistry. Remote sensing can be used to monitor pre-, during-, and post-fire conditions, including weather and climate conditions, fuel characterization, fire risk, smoke detection, monitoring, and forecasting, fire behavior and the post-fire landscape. This 6-part training provided lectures and case studies focused on the use of Earth observations for operational fire monitoring: pre-, during-, and post-event.

**2,544**

Participants

**1,200**

Organizations

**110**

Countries

**47**

US States

### Satellite Observations and Tools for Fire Risk, Detection, and Analysis

was our first training that required the expertise of all our trainers from every application area (Disasters, Eco Forecasting, Health & Air Quality, & Water Resources). It was a massive undertaking and required all hands on deck to deliver. It was also the longest-running ARSET training, with a total of 6 sessions in English and another 6 in Spanish. As a result, this ended up being one of our most well-attended trainings ever, and those who participated were pleased with the experience.

*“It was an excellent experience, and as I already mentioned in a shared email, there is nothing left to do but thank the altruism they show with these trainings. The recent emergence of certain tools (such as Google Earth Engine), has meant a total paradigm shift, previously we had to use expensive software, with powerful machines, but all that was left behind, it is relatively simple to use and process excellent satellite images (for the scales of this type of analysis), spatial, temporal and spectral resolutions, which both NASA and ESA make freely available to us. In countries like Chile, this represents a radical change in the improvement of capacities to face these catastrophic events, so we are moving forward. Greetings and thank you very much for everything.”*  
- Faculty, Chile

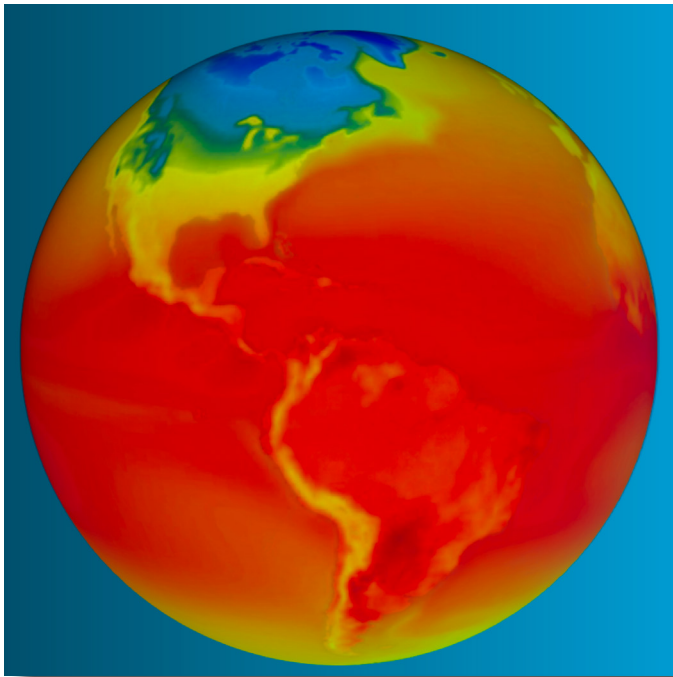
*“I considered that the course was very complete and exceeded my expectations. The organization in the three modules was key to understanding the availability of products and the different tools.”*  
- Faculty, Argentina

**TRAINING  
HIGHLIGHT**





JUNE 1 - JUNE 22



## NASA EARTH OBSERVATIONS FOR ENERGY MANAGEMENT

INTRODUCTORY ONLINE MULTIPLE

Energy impacts everything we do, from simplifying basic tasks like cooking and cleaning to providing development opportunities and fueling innovation. Energy management- its production, transmission, and distribution- is impacted by environmental and climate conditions, including weather patterns or extremes and climate change. This training offered an introduction to how NASA Earth Observations can contribute to a greater understanding of energy management applications. Attendees gained familiarity with a broad set of relevant NASA datasets, tools, platforms, and resources, as well as learn about case studies and real-world applications related to climate resilience, energy efficiency, and renewable energy.

**851**  
Participants

**400**  
Organizations

**96**  
Countries

**31**  
US States

JUNE 16 - JUNE 30

## USING GOOGLE EARTH ENGINE FOR LAND MONITORING APPLICATIONS

INTERMEDIATE ONLINE ECO FORECASTING

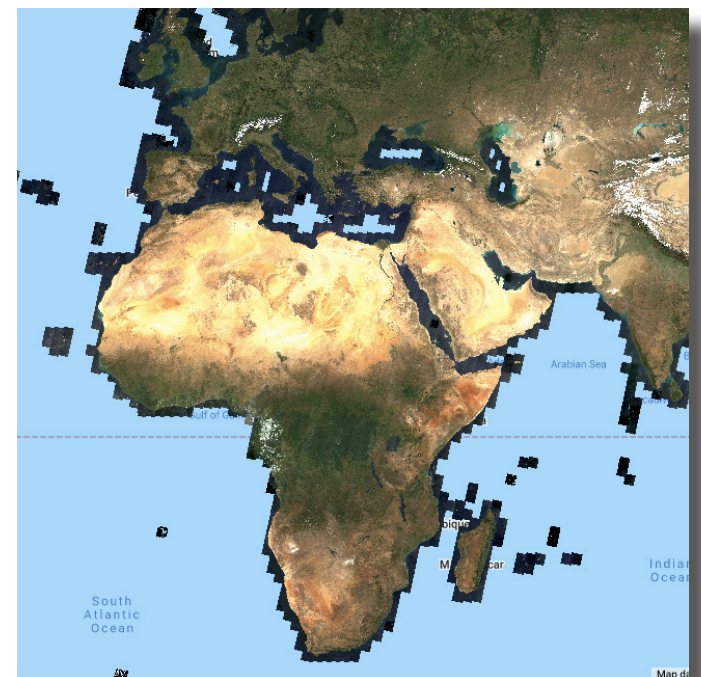
Google Earth Engine (GEE) for remote sensing applications is quickly becoming one of the most utilized tools in the scientific and decision-making community. GEE provides unparalleled access to large-scale data analysis through cloud computing technology. The online interface allows users to access and analyze stores of NASA Earth data without the need for any locally stored data or software. This training covered the GEE Code Editor and included hands-on exercises on change detection, time series analysis, land cover classification, and accuracy assessment of optical imagery. Attendees were provided scripts for conducting these analyses in GEE and instructed on how to execute these scripts to produce maps and visualizations.

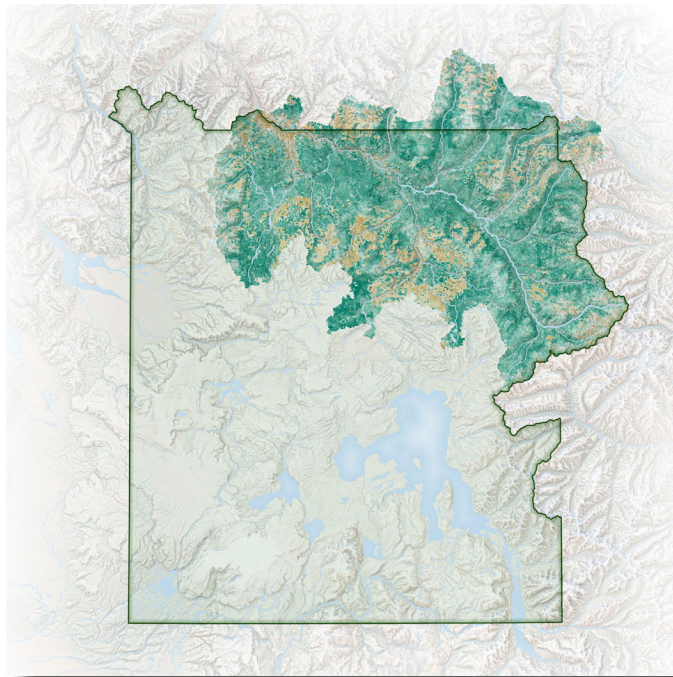
**2,745**  
Participants

**1,350**  
Organizations

**123**  
Countries

**50**  
US States





## SPECIES DISTRIBUTION MODELING WITH REMOTE SENSING

INTERMEDIATE ONLINE ECO FORECASTING

Species Distribution Models (SDMs) play a critical role in biodiversity, conservation, and understanding the potential impacts to ecosystems under changing climate conditions. SDMs contextualize future scenarios based on known or projected ecological parameters and are the cornerstone for adaptive planning around short- and long-term changes to landscapes. This training provided an overview of SDMs, showed how to use remote sensing data for landscape characterization, and highlighted multiple Applied Sciences projects that have developed tools for conducting SDM for a variety of ecosystems. This training also included a special session on the Wallace R-based platform for modeling of species niches and distributions.

**2,150**

Participants

**1,000**

Organizations

**116**

Countries

**47**

US States

## SATELLITE OBSERVATIONS FOR ANALYZING NATURAL HAZARDS ON SMALL ISLAND NATIONS

INTERMEDIATE ONLINE BILINGUAL (SP) DISASTERS

Small island nations are highly vulnerable to climate change and natural disasters; among them hurricanes, cyclones, and other violent storms. These disasters can lead to severe flooding, landslides, and loss of life and property. In addition, a rise in global mean sea level places island nations at a higher risk for permanent submersion of land, coastal erosion, coastal ecosystem loss or change, salinization, and impeded drainage. This three-part training series focused on small island nations while introducing the data, methods, and tools useful for monitoring natural hazards. Case studies were used to demonstrate methodologies applying satellite and model data and open access tools to analyze storm impacts, sea level rise, and landslides on small island nations.

**755**

Participants

**350**

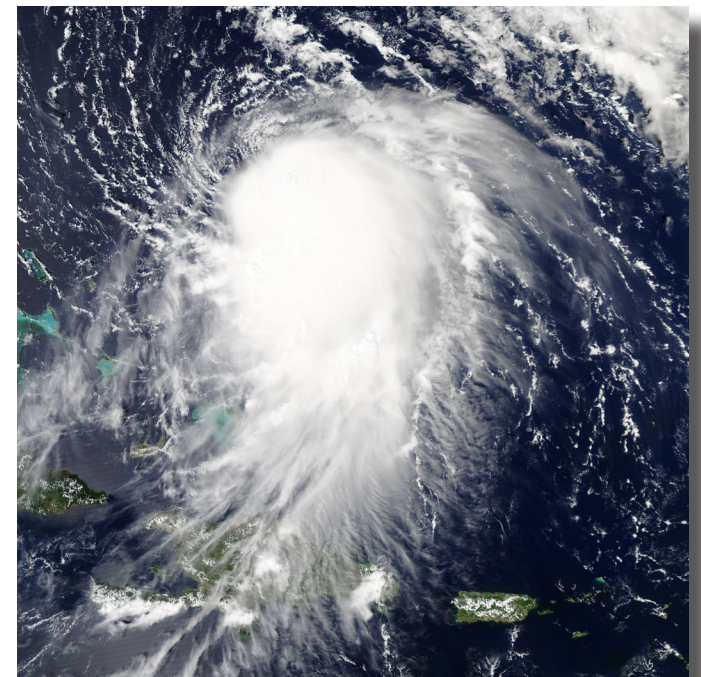
Organizations

**93**

Countries

**27**

US States



*“I have used historic NOAA hurricane track data with Esri ArcMap to examine past infrastructure and population hazards. This training session was very good. I appreciated the in-depth training on sea level rise and contributing factors.”*  
- Student, Canada







## MONITORING COASTAL AND ESTUARINE WATER QUALITY: TRANSITIONING FROM MODIS TO VIIRS

INTERMEDIATE ONLINE BILINGUAL (SP) WATER RESOURCES

Estuaries are water bodies where freshwater from rivers and streams meets with seawater. Coastal and estuarine waters are important to humans as they are highly productive habitats supporting a variety of fish and wildlife. These environments provide resources, economic benefits, and ecosystem services. This three-part training provided an overview of recent satellites and sensors used for extending the MODIS long-term water quality time series, specifically focusing on VIIRS image processing using the NASA Ocean Color software, SeaDAS. This training pointed out similarities and differences between MODIS and VIIRS and demonstrated water quality monitoring procedures using these sensors in selected coastal and estuarine regions.

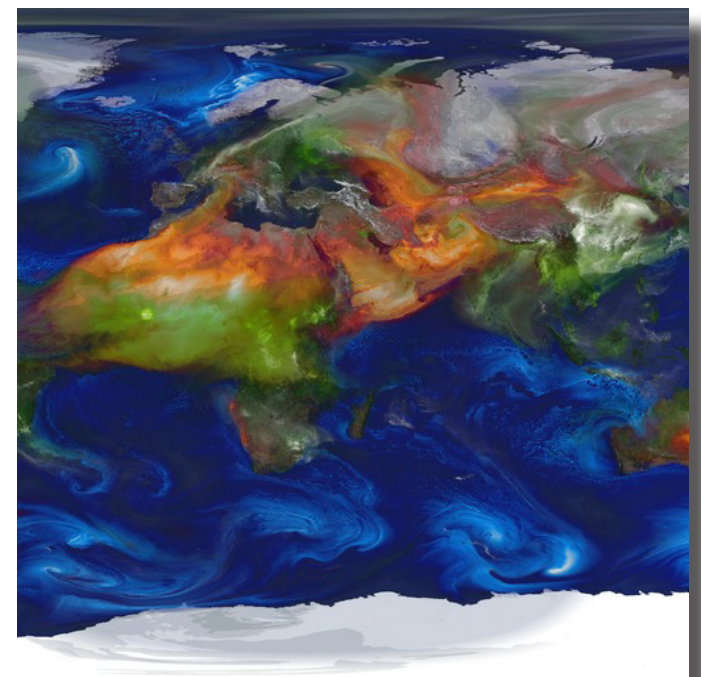
<b>802</b>	<b>400</b>	<b>93</b>	<b>24</b>
Participants	Organizations	Countries	US States

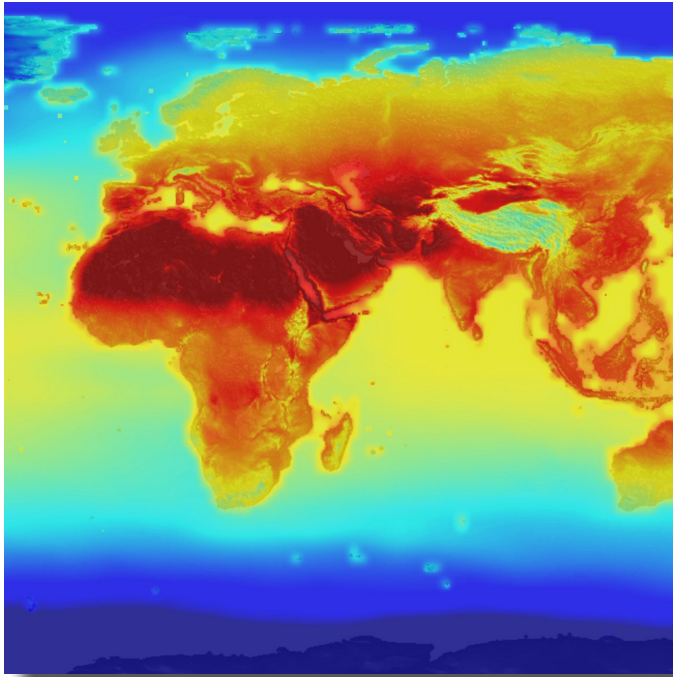
## INTRODUCTION AND ACCESS TO GLOBAL AIR QUALITY FORECASTING AND TOOLS

ADVANCED ONLINE HEALTH & AIR QUALITY

This first of its kind ARSET training focused on NASA and European Center for Medium-Range Weather Forecasts (ECMWF) global air quality (AQ) forecasting capabilities. Delivered in collaboration with the Copernicus Atmosphere Monitoring Service (CAMS), this training discussed the basics of AQ forecasting and taught users how to access and interpret global air quality forecasts. This training series also described currently available global air quality forecasts, their different frameworks, and how they use satellite and ground observations to improve and evaluate their forecasts. Participants learned how to access forecast information and images, and how to download output for their own visualization or analysis.

<b>696</b>	<b>300</b>	<b>86</b>	<b>29</b>
Participants	Organizations	Countries	US States





## INTRODUCTION TO NASA RESOURCES FOR CLIMATE CHANGE APPLICATIONS

INTRODUCTORY ONLINE CLIMATE

Scientists use observations from the ground, air, and space, along with theoretical models and scenarios of future emissions, to monitor and study past, present, and future climate change. Climate data records provide evidence of climate change key indicators. This climate information is the fundamental basis for mitigation, adaptation, and risk management planning in all parts of the world and across many elements of society and ecosystems. This training, co-produced by ARSET and the NASA Goddard Institute for Space Studies (GISS), provided an overview of NASA resources for monitoring climate change and its impacts, including terminology and the role of Earth observations in climate change assessment.

**1,402**

Participants

**700**

Organizations

**114**

Countries

**48**

US States

### Introduction to NASA Resources for Climate Change Applications

was ARSET's first ever climate-focused training. In 2021, ARSET introduced a dedicated Climate application area. Currently under development, in the future we will have climate-specific trainers dedicated to putting together content. This introductory training provides foundational knowledge and was designed to set the stage for our future climate trainings. We highly recommend anyone who is interested in using remote sensing for climate applications take this introductory training.

*“The most helpful I find is that all the materials related to the training are still available and downloadable from the NASA ARSET, this has been helped me much in gaining deep understanding about the topic I am interested in as I can study from the video and the materials.”*

*- Faculty, Indonesia*

*“In Mongolia, livelihood of rural people, particularly the herders’ much depends from drought, heavy snowfall, storms, pasture productivity, and wildfire. Distribution of knowledge of remote sensing in rural provinces will improve much their sustainable development policy, and monitoring and evaluation of its implementation.*

*I downloaded many ARSET training materials and translated into Mongolian, and introducing to my colleagues. Thank you very much for your excellent training.” - NGO Employee, Mongolia*

*“The presentations slides are impressively clear and to the point. I think this will be a great tool to convey climate science to the public and that this talk should be basic training for all federal employees in land management.”*

*- Federal Employee, USA*

**TRAINING  
HIGHLIGHT**







## AGRICULTURAL CROP CLASSIFICATION WITH SYNTHETIC APERTURE RADAR AND OPTICAL REMOTE SENSING

INTERMEDIATE ONLINE BILINGUAL (SP) MULTIPLE

This five-part training focused on the use of synthetic aperture radar (SAR) from Sentinel-1 and optical imagery from Sentinel-2 to map crop types and assess their biophysical characteristics. This training also included a SAR and optical refresher along with pre-processing and analysis of Sentinel-1 and Sentinel-2 data using the Sentinel Application Platform (SNAP) and Python code. The training also covered an operational roadmap for mapping crop type, including best practices for collecting field data to train and validate models for classifying crops on a national level. The final session of this series covered crop biophysical variable retrievals using optical data.

**1,735**  
Participants

**800**  
Organizations

**125**  
Countries

**43**  
US States

**Agricultural Crop Classification with Synthetic Aperture Radar and Optical Remote Sensing** was a unique training for us. Not only because of the novelty of the learning material, but also because of the amount of collaboration it took to put this five-part training together. We would like to thank the European Space Agency (ESA), Agriculture and Agri-Food Canada (AAFC), the Indian Space Research Organization (ISRO), and the CEOS Working Group on Capacity Building and Data Democracy (WGCapD) for making this happen.

*“This was another great webinar that went further deep into new interesting and impressive methodologies! This webinar was also great in explaining the basic science for the biophysical variable assessment! Thank you all in NASA ARSET and all the instructors and guest scientists! Please continue promoting and bringing everybody new tools and fresh scientific work in Remote Sensing.”*  
- Water Utility Employee, Greece



**Committee on  
Earth Observation  
Satellites**

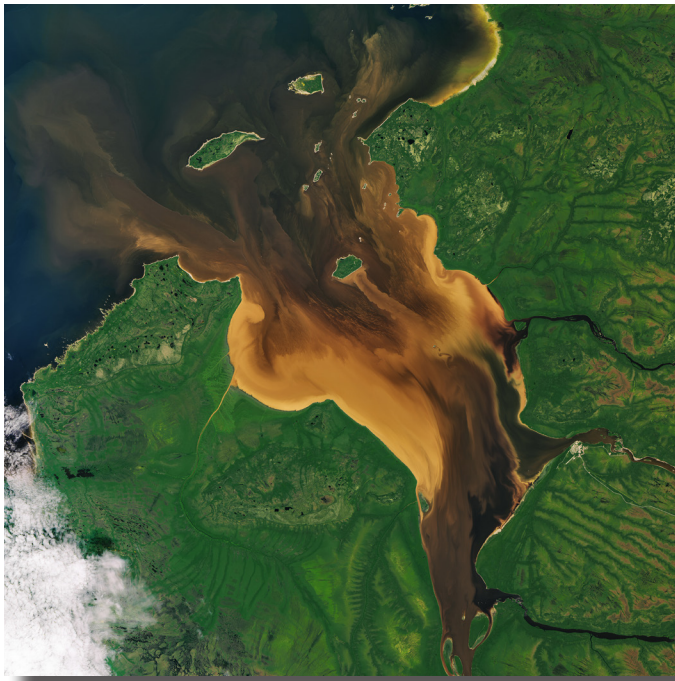


Agriculture and  
Agri-Food Canada

Agriculture et  
Agroalimentaire Canada

**UCLouvain**





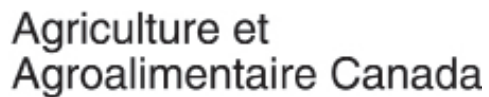
# MONITORING COASTAL AND ESTUARINE WATER QUALITY USING REMOTE SENSING AND IN SITU DATA

ADVANCED ONLINE WATER RESOURCES

This two-part, advanced webinar series was a follow-on to the training on coastal and estuarine water quality held in September 2021. It was a hands-on training with demos provided by instructors, followed by an hour of lab time for participants to use Level-1 MODIS and VIIRS data provided by the Ocean Biology DAAC (OB.DAAC) and SeaDAS and OCSSW software for deriving water quality parameters. These included chlorophyll-a concentration, sea surface temperature, and suspended particulate matter from optical satellite imagery and in situ measurements using the SeaWiFS SeaBASS and SeaDAS.

<b>619</b> Participants	<b>300</b> Organizations	<b>97</b> Countries	<b>26</b> US States
----------------------------	-----------------------------	------------------------	------------------------

## THANK YOU TO OUR COLLABORATORS



ICE, CLOUD, AND LAND ELEVATION SATELLITE-2





# PARTICIPANT FEEDBACK

*“I’d suggest to make an extra webinar after each regular one, and/or to make it a part of the same webinar. Talking about how to process the data, for example myself I’d prefer python, however others are using R, and some others Earth Engine. So I think to consider these three open source softwares as processing platforms for each webinar. In this case your followers from around the world will have the vast capability of selecting the best platform to meet their challenges.”*

*- Researcher, Finland*

*“One of the major challenges that face lakes and reservoirs is “Sedimentation”. It would be very useful to know are Remote Sensing can help in sedimentation monitoring in lakes and reservoirs.”*

*- Student, Algeria*

*“They could probably make a list of ARSET courses for the next 6 months. With that, you can know which courses to take and plan work activities so that they do not intersect with ARSET courses.”*

*- IGO, Ecuador*

*“I want to learn how to calculate land displacements before and after landslides and earthquakes using SAR data in the form of a hands-on exercise. It would be great if this exercise could start from the selecting and downloading a dataset, because one of the SAR characteristics is polarization. In urban areas, it is said that HH is preferred for land cover classification, but for earthquakes and landslides I am not sure. This skill would be helpful to me in utilizing remote sensing data to further understand disasters in urban areas.”*

*- Student, New Zealand*

*“Climate change mainstreams all territorial problems. It would be interesting to learn how to manipulate data to make climate models of the future. On the other hand, having specific training, such as climate change and floods, or climate change and mass movements, or climate change and food security, and being able to play with the available data to approximate those future realities.”*

*- Student, Colombia*

*“I genuinely found the training very useful as someone with almost no knowledge of/background in satellite tech and remote sensing. The information was valuable and easy to take in. The only thing that might have made it more engaging are more ‘activities’ interspersed through the lecture - polls, trivia questions, etc.”*

*- Student, USA*

*“The demonstrations with the GEE code editor are ordered in your training courses, but we would like to have the training materials as soon as possible, even weeks before the training to try to familiarize ourselves with the code as much as possible so that on the day of the training we can concentrate on the explanations of the instructor to understand more.”*

*- Student, Morocco*

*“I would suggest giving small homework exercises at the end of each session to consolidate the learning. Perhaps even a small code it yourself activity, even if it’s as simple as moving the locality and changing dates, etc.”*

*- Student, South Africa*



## THE ARSET TEAM

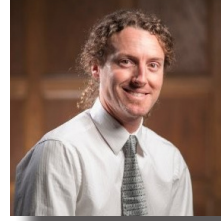
### DISASTERS & WATER RESOURCES



AMITA MEHTA, PhD



ERIKA PODEST, PhD



SEAN McCARTNEY

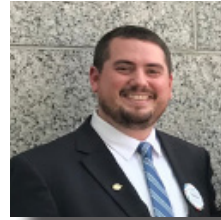
### ECO FORECASTING



AMBER McCULLUM,  
PhD



JUAN TORRES-  
PÉREZ, PhD



ZACH BENGTSSON

### HEALTH & AIR QUALITY



MELANIE FOLLETTE-  
COOK, PhD



PAWAN GUPTA, PhD



SARAH STRODE,  
PhD

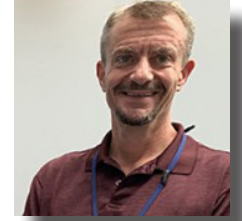
### LEADERSHIP



ANA PRADOS, PhD



MELANIE FOLLETTE-  
COOK, PhD

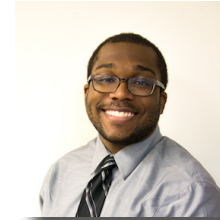


MICHAEL  
BOSILOVICH, PhD

### COORDINATION & COMMUNICATIONS



BROCK BLEVINS



SELWYN HUDSON-  
ODOI



SARAH CUTSHALL



DAVID BARBATO



ANNELISE  
CARLETON-HUG,  
PhD



JONATHAN O'BRIEN



MARINES MARTINS

*We would like to extend a very special thank you to Nancy Searby and all those at the NASA Applied Sciences Program who make this work possible.*







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