

# Capacity Building Program

2021 Annual Summary



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# INTRODUCTION & OVERVIEW



EARTH SCIENCE  
APPLIED SCIENCES

## Welcome

Thank you for taking the time to explore the work of NASA's Capacity Building Program through our 2021 Annual Report. The past two years have been anything but average, and our work reflects the adaptations required (and opportunities that have been facilitated) by ongoing public health realities due to the COVID-19 pandemic. Despite these challenges, our team has responded with increased dedication to continue to build awareness and use of Earth observations for societal benefit.

Our core elements have experienced growth and change in 2021. DEVELOP saw a 35% increase in projects over 2020, a 45% increase in the number of participants and Fellows, and new additions to its leadership team. Sixty percent of ARSET's total participation over its 12-year history came from the past two years (2020 and 2021). SERVIR launched a number of new tools and applications, including ClimateSERV 2.0, and announced numerous new partnerships and initiatives, including the Forest Data Partnership and contributions to the President's Emergency Plan for Adaptation and Resilience (PREPARE).

We also welcomed new elements to our portfolio in November 2021: Prizes & Challenges and Equity & Environmental Justice are new areas of focus under the umbrella of Capacity Building, and the Indigenous Peoples Initiative (formerly pilot) has expanded to a long-term effort. All of our teams will incorporate additional thematic focus on Climate and Wildfires moving forward in response to these new program areas in Applied Sciences.

Despite our continued remote work environment, our team participated in numerous virtual meetings, conferences, and workshops, standing out as a leader in many communities, including AmeriGEO Week, the Indigenous Mapping Workshop, and the 2<sup>nd</sup> National Imaging Summit, to name a few. NASA's 2021 Applied Sciences Week, organized by Capacity Building Program leads, convened work across Applied Sciences and beyond, and we were able to gather in-person again at the 2021 American Geophysical Union Fall Meeting in New Orleans, LA.

On behalf of the Capacity Building Program Team, I'd like to thank our many stakeholders, supporters, and the community that help us impact so many across the globe. We invite you to read on to learn about the highlights and challenges of 2021 and to look forward to 2022 with us.

**Nancy D. Searby, Ph.D.**

*Capacity Building Program Manager*

## Introduction

The Earth Science Division's (ESD) [Applied Sciences Program](#) (ASP) promotes efforts to discover and demonstrate innovative and practical applications of Earth observations. ASP activities collaborate with organizations across all sectors to apply scientific findings and satellite data in their decision-making activities. The Program has three primary lines of business: Applications, Capacity Building, and Mission Engagement. Program activities support our goals to deliver near-term uses of Earth observations, build capabilities to apply Earth science data, and liaison with the science teams for NASA satellite missions.

The Applied Sciences' [Capacity Building Program](#) (CBP) builds capacity around the globe to expand the Earth observations user base and increase awareness within non-traditional audiences of NASA Earth observations data and products. CBP engages across the ASP Application Areas' portfolios of Water Resources, Disasters, Ecological Forecasting, Health & Air Quality, and Agriculture, as well as other application areas including Energy, Urban Development, Transportation & Infrastructure, and most recently, Climate and Wildfires. CBP works through both program and element activities. Program activities include participating in domestic and international capacity building groups, such as the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS), as well as initiating the network of networks called the Earth Observation Training, Education, and Capacity Development Network (EOTEC DevNet). CBP includes four Center-based elements: the Applied Remote Sensing Training Program (ARSET), DEVELOP, SERVIR, and the Indigenous Peoples Initiative (IP). CBP also includes two elements managed at Headquarters: Equity and Environmental Justice (EEJ) and Prizes & Challenges (PC).

## Element Descriptions

[ARSET](#) provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools. Through online trainings designed for all skill levels, the program teaches basic to advanced remote sensing skills to a worldwide audience using freely available data and software.

[DEVELOP](#) addresses environmental and public policy issues through interdisciplinary feasibility projects that apply NASA Earth science information and resources to community concerns. These projects provide

experiential learning and workforce development opportunities for both participants and partner organizations to utilize geospatial data and resources and inform decision making processes.

[SERVIR](#) is a joint initiative of NASA, USAID, and leading geospatial organizations in Asia, Africa, and Latin America. SERVIR partners with countries and organizations in these regions to address critical challenges in climate change, food security, water and related disasters, land use, and air quality. Using satellite data and geospatial technology, SERVIR co-develops innovative solutions through a network of regional hubs to improve resilience and sustainable resource management at local, national, and regional scales.

The [Indigenous Peoples Initiative](#) (IP) engages with Indigenous communities to foster ethical and culturally relevant space for the use of Earth observations in monitoring, mapping, and managing natural and cultural resources. The pillars of this work include community engagement and the co-production of place-based remote sensing trainings specific to Indigenous lands and territories. The initiative aims to strengthen the relationships between NASA and Indigenous communities through meetings and knowledge sharing activities. Through dialogue and discussion focused on Indigenous needs and priorities, remote sensing trainings provide participants with the data and resources needed to address specific natural resource issues facing their lands. In November, IP has begun to focus on equity and environmental justice.

[Prizes and Challenges](#) crowdsources ideas, technologies, scientific advances, and other “solutions” from people around the world through incentivized competitions. By opening missions and questions, we multiply the number of people sharing interdisciplinary knowledge and collaborating to tackle challenges together – all increasing the likelihood of generating practical and effective solutions to our planet’s toughest problems. The element partners with other federal agencies, international space agencies, and private organizations to host competitions, sharing focused, defined problems, or “challenges”, and awarding cash prizes, recognition, and other incentives for winning solutions. Prizes and challenges allow us to reach people with diverse backgrounds, skillsets, and experiences, and bring out-of-discipline perspectives and tools to the table.

Work related to [Equity and Environmental Justice](#) (EEJ) reflects NASA’s long-term commitment to create an inclusive open science community by expanding awareness, accessibility, and use of Earth science data and integrating social science datasets to enable transdisciplinary science. In partnership with nongovernmental organizations (NGOs), private sector partners, local governments, and other federal agencies, the EEJ line of work began in earnest in mid-2021 with the opening of ROSES-21 A.49 “Earth Science Applications: Equity and Environmental Justice,” which is soliciting EEJ projects, including landscape analyses, feasibility studies, and data integration projects that will begin in mid-2022. The EEJ element will also work across ESD and the agency to connect other EEJ and climate justice (CJ) efforts.

## 2021 Overview

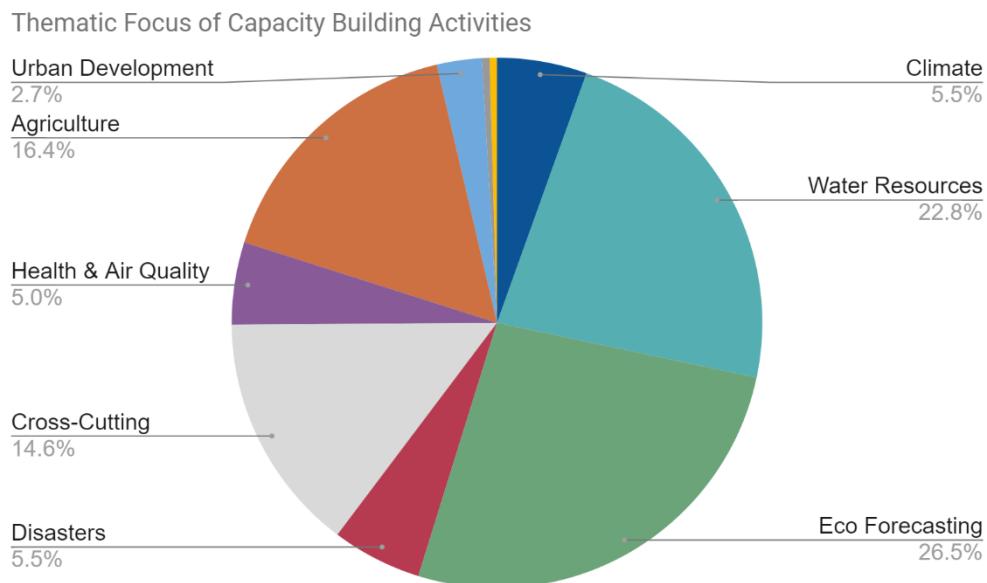
Throughout 2021, the Capacity Building Program continued to contribute to Applied Sciences’ goals with a broad reach across sectors, thematic areas, and geographies. In this section, you can explore the program’s general 2021 reach “by the numbers” and “by the map.” However, impact cannot always be measured in numbers and metrics; read our [Impact Stories](#) to learn more about the effect of our work on specific people and places.

### 2021 By the Numbers

The Capacity Building Program engages individuals and institutions through a variety of methods for building capacity to use Earth observations: trainings, feasibility studies, partnerships, competitions, and projects. In 2021, the program conducted **104** trainings, **58** feasibility studies, and **123** projects.

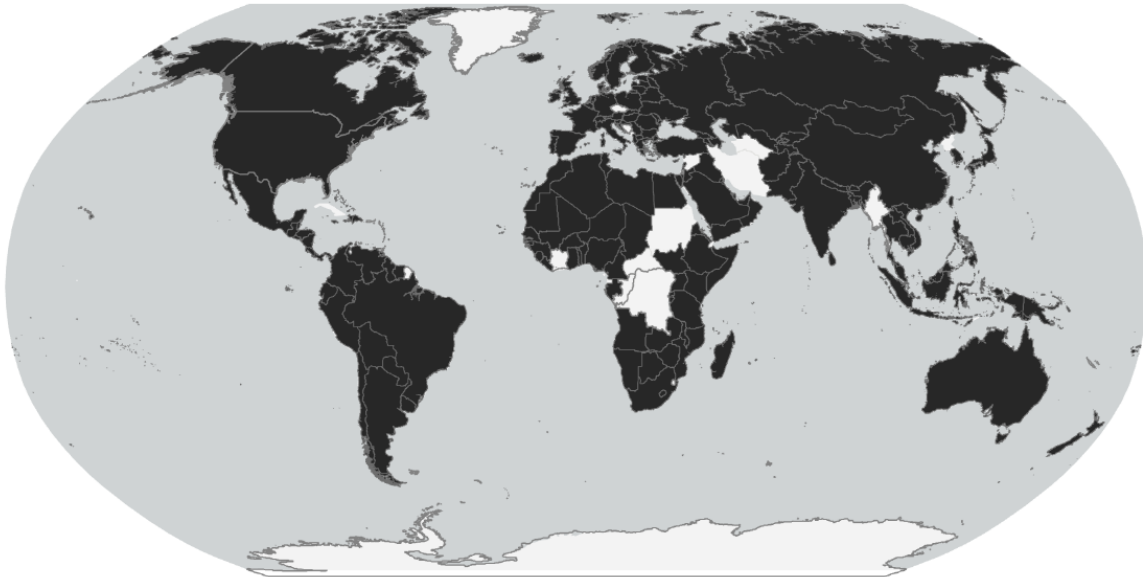


CBP activities addressed nine thematic topics in alignment with the Applied Sciences’ Application Areas: Agriculture, Disasters, Ecological Forecasting, Energy, Health & Air Quality, Transportation & Infrastructure, Urban Development, Water Resources, and Climate, as well as topics that cut across these application areas.

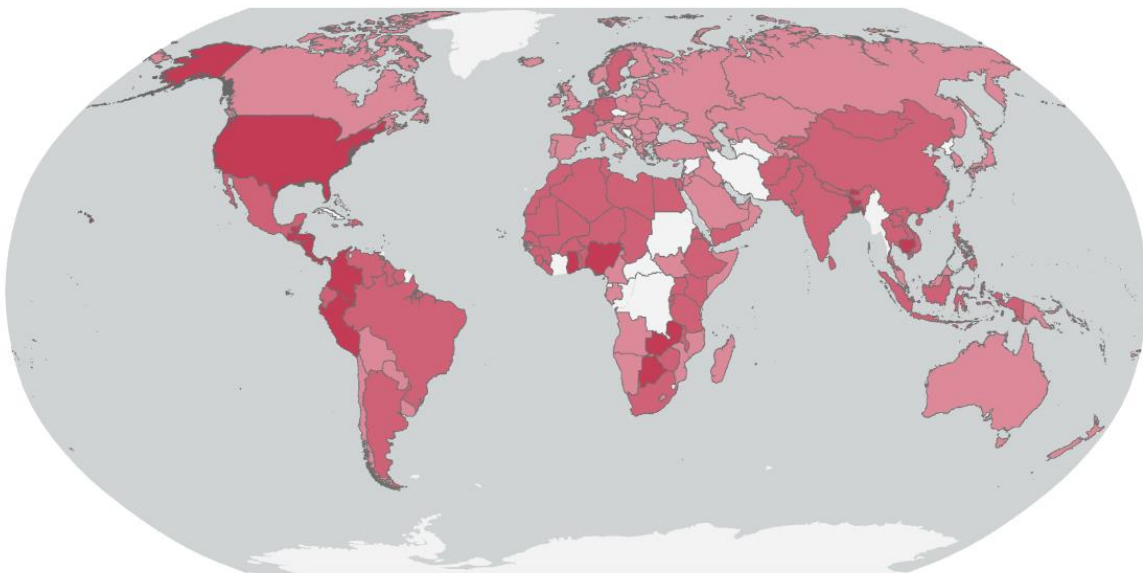


## 2021 By the Map

Since the start of the COVID-19 pandemic, there is a greater need for connection and access, and CBP has been able to expand the networks of individuals and institutions aware of, able to access, and able to apply Earth observations. In 2021, CBP activities reached **166** countries, noted in black on the map below. CBP activities also impacted all **50** states and **2** US territories.

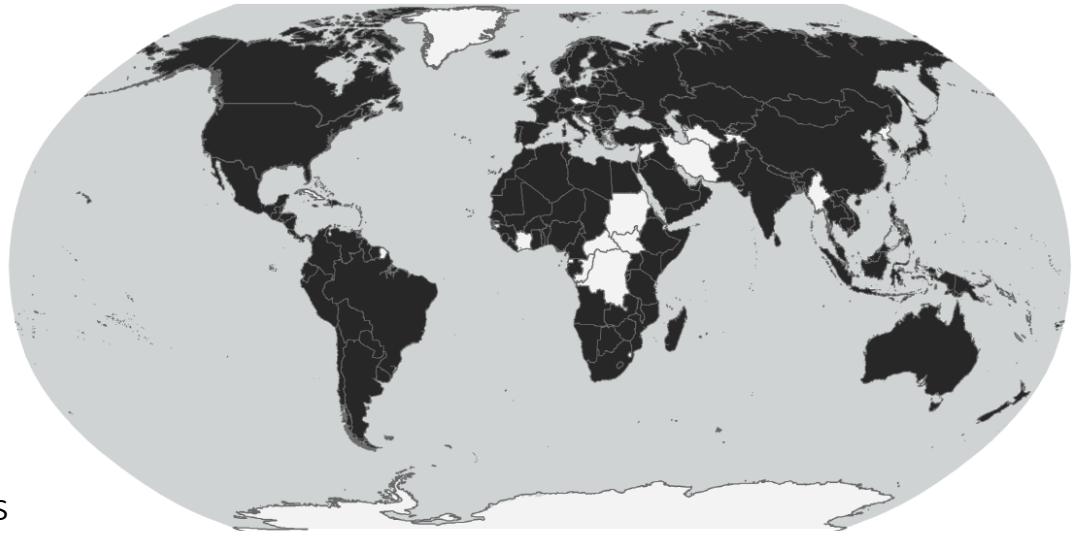


*CBP Global Reach in 2021*



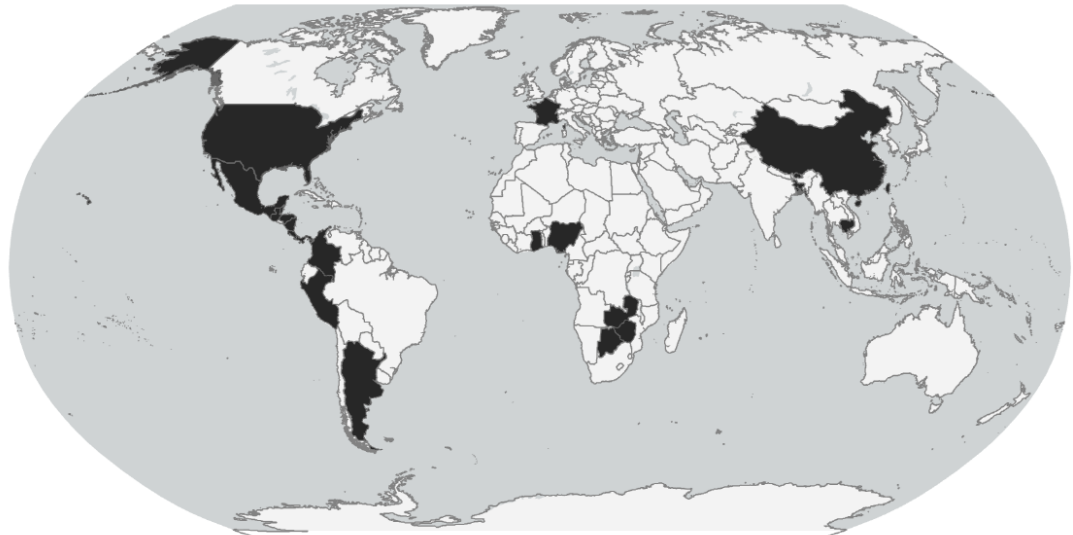
*Number of CBP elements reaching each country in 2021.  
Darker colors denote more elements working in or with a country.*





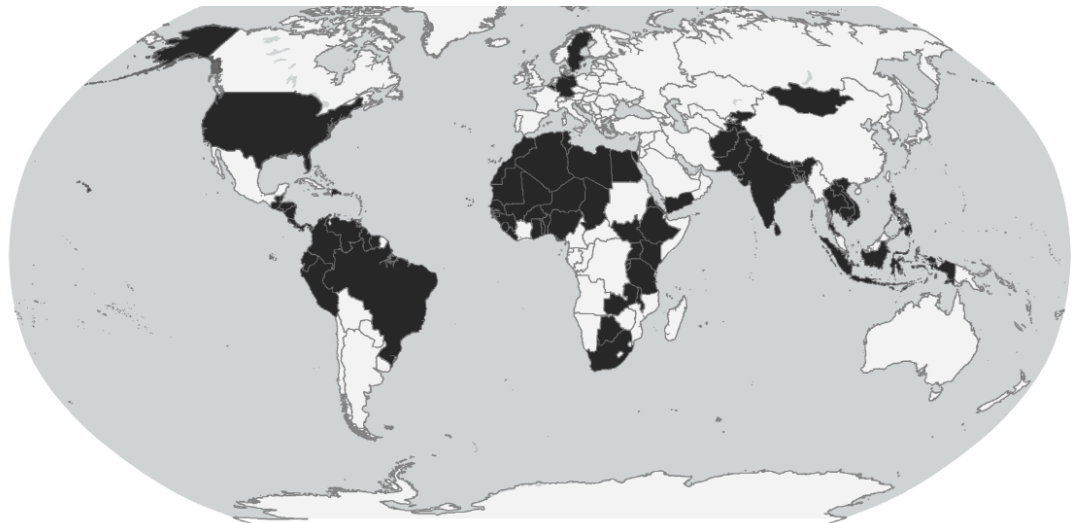
## ARSET

162 countries



## DEVELOP

21 countries



## SERVIR

72 countries



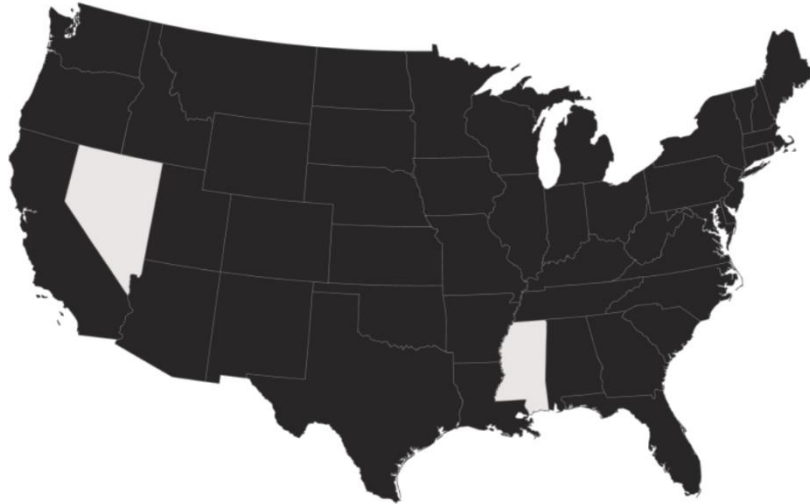
## ARSET

50 states



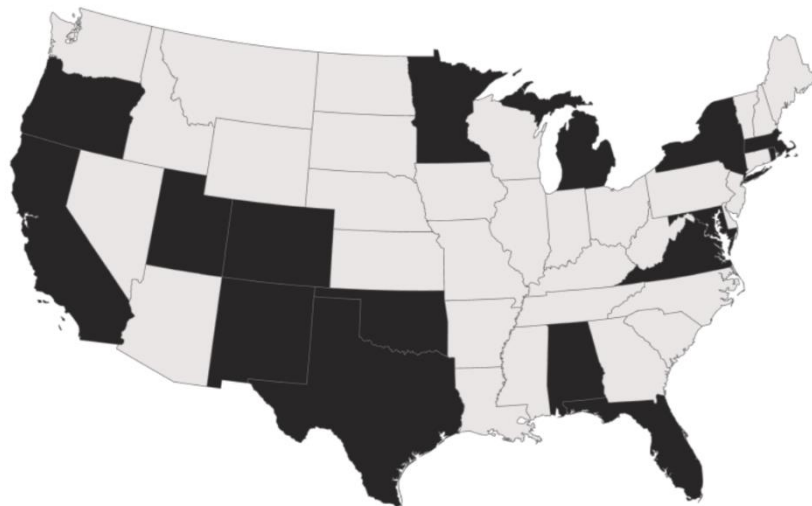
## DEVELOP

47 states



## SERVIR

17 states



# HIGHLIGHTS & MILESTONES



EARTH SCIENCE  
APPLIED SCIENCES

# ARSET

## *2021 Overview*

ARSET opened a new thematic area in 2021. The new Climate thematic area delivered our [first Climate training](#) to serve as a foundation for follow on trainings in that topic area. In addition to the opening of a new application area, ARSET trained on a number of novel topics including the use of hyperspectral data, using solar induced fluorescence (SIF) to monitor vegetation health, integrating population grids with remote sensing data, and using synthetic aperture radar (SAR) combined with optical data to map crop types, just to name a few. ARSET also conducted a six-session bilingual training focused on fire risk, detection, and analysis, which was the first training to cut across all ARSET themes and involve the entire team. Thanks to the help of collaborators, ARSET was able to reach 27,182 participants from 5,911 unique organizations. These participants came from all over the world, reaching 166 countries and all 50 states.

## *Highlight Story*

Lucy Luong is an architect that started with very little experience in remote sensing and Geographic Information Systems (GIS). Through a Google search, she came across ARSET's training materials online. Before long, Lucy was undertaking a research project where she used satellite imagery to calculate the surface urban heat island over the city of Hanoi, Vietnam. She is currently working on publishing a paper on her study in a remote sensing journal.



*Lucy Luong.*

*Image credit: Lucy Luong.*

“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. 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 practicing 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.” - Lucy Luong

# DEVELOP

## *2021 Overview*

In 2021, DEVELOP continued to work virtually, engaging 287 participants and Fellows (a 45% increase from 2020) and 164 partner organizations (a 75% increase over 2020) through 58 feasibility projects. The projects reached 44 U.S. states and 16 countries and spanned eight thematic areas. The program also increased its presence at a multitude of virtual conferences with a highlight being six co-presentations given by a DEVELOP Fellow and a partner representative at the 2<sup>nd</sup> Annual National Imaging Summit in September. DEVELOP was also able to send representatives to the American Geophysical Union’s Fall Meeting – the first travel in nearly two years. Responding to needs within the program, new Fellow positions were created to expand project coordination support and the National Program Office welcomed new members all to increase the program’s bandwidth to conduct more projects and engage with more people and organizations. DEVELOP also created a new science communication campaign called “DEVELOPping Connections” which included a series of blog posts on the program’s website that highlighted past project successes.

## *Highlight Story*

Food and nutritional security stands out as one of the most critical priorities society faces today. Maintaining crop genetic resources, or the genetic diversity of crop plants and their wild relatives, is vital to meeting global agriculture and food security needs. To safeguard crop diversity, the United States Department of Agriculture (USDA) Agricultural Research Service’s National Plant Germplasm System (NPGS) has a mission to acquire, conserve, and characterize crop germplasm.



*Texas wild rice growing in the San Marcos River in Texas.  
 Image credit: Ryan Hagerty, US Fish and Wildlife Service.*

Colin Khoury, a researcher at the NPGS describes his work as “trying to map and understand where diversity is and what to do about it. The big question is... how complete is our national collection in seed banks? ... That collection is primarily agricultural species, but it also includes wild plants. Are we doing a good job at adequately conserving genetic diversity?” He first teamed up with the NASA DEVELOP Colorado – Fort Collins location for a project during the spring 2018 term to study

northern wild rice (*Zizania palustris*) and Texas wild rice (*Zizania texana*). Northern wild rice is a wild grain native to North America, which is important for food security and cultural purposes in many Native American cultures of the Great Lakes region. Texas wild rice, endemic to the state of its namesake, is a Federally and State-listed endangered species.

The project aimed to use NASA Earth observations to detect the distributions of both species in order to effectively plan out targeted field collections and make strategic plans for habitat conservation. Khoury stated that DEVELOP gave the NPGS an opportunity to work with new methods since it typically works “with relatively orthodox and standard methodologies that don’t currently incorporate satellite [or] remotely sensed information. They instead use environmental predictors, [like] climatic information or soil information, [which] don’t tend to be high enough resolution for some of our conservation needs.”

The spring 2018 DEVELOP team used Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), Sentinel-1 C-band Synthetic Aperture Radar (C-SAR), and National Agricultural Imagery Program imagery in conjunction with the Variable Selection using Random Forest (VSURF) library in R Studio to find significant spectral signature values. They used these values as training data for their random forest model. Their geospatial methods were then used to estimate where diversity differs in the study area.

Given the success of this spring 2018 project, the NPGS partnered with NASA DEVELOP again in fall 2018 to study wild cranberries (*Vaccinium macrocarpon*) in Wisconsin. This project used modeling techniques in tandem with NASA Earth observations from Landsat 5 TM, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 OLI, Sentinel-2 Multispectral Imager (MSI), and the Shuttle Radar Topography Mission.



*Wild cranberries growing in their natural habitat.*

*Image credit: fotoblend on Pixabay.*

The second term DEVELOP team was able to map the distributions of wild cranberries in Google Earth Engine, provide the partners with a distribution map, and deliver a distribution modeling and mapping tutorial. The team studied wild cranberries since they are the progenitor of the domesticated crop species and may contain important traits for the improvement of the crop in the future. Ultimately, Khoury said the work done for this project was distributed “to two agricultural

research service labs that are interested, and then to the forest service land managers that actually manage land in the focal area... [the data were] to be distributed immediately.”

Khoury continued working with DEVELOP at its Colorado – Fort Collins location for the third time as a project partner for the Minnesota Agriculture & Food Security project in spring 2019. This time around, the DEVELOP team returned to the main question of the study: is it feasible for crop wild relatives to be detected from space? The project returned to northern wild rice, which grows in shallow lakes in the upper Midwest. As Khoury states, “The task this time was to engage intensively with conservation stakeholders, including not only [the] USDA, but also the Minnesota Department of Natural Resources and the University of Minnesota, to determine how well the open access NASA information and related geospatial tools and methodologies could be combined to accurately detect these useful wild plants.”

The third term utilized optical and radar sensors from both previous iterations of the project: Landsat 8 OLI, Sentinel-1 C-SAR, and Sentinel-2 MSI. By focusing on validation of the previous model and refining their modeling process, the study found great success. As Khoury stated, “employing a variety of validation tools, including field data collected by the first term, the team was able to detect wild rice with high accuracy.” The results were published in an open access journal, Remote Sensing, in a peer-reviewed article entitled “Improved Remote Sensing Methods to Detect Northern Wild Rice (*Zizania palustris* L.).”



*Map created by the Minnesota & Texas Agriculture & Food Security team depicting the presence or absence of wild rice.*

*Image credit: NASA DEVELOP*

The work done by NASA DEVELOP at the Colorado – Fort Collins location has provided the NPGS with methodologies for incorporating remotely sensed data to further assist their monitoring and field collection efforts. In addition, utilization of NASA Earth observations allows for a larger study area since analysis and assessments are overall no longer reliant on field data collection. Khoury says that the work done by DEVELOP will not only help the people that work at the NPGS, but the whole Department of Agriculture network. Khoury shared the results and end products with the US Forest Service, another organization under the USDA, with the aim of eventually increasing and securing plants’ genetic diversity on Forest Service lands.

# SERVIR

## *2021 Overview*

During 2021, SERVIR continued to provide science and geospatial technology support for decision making across the SERVIR network of five regional hub organizations, connecting hub stakeholders to Earth observation information, Earth science, and technology, and drawing on scientific expertise from NASA Centers, United States Government (USG)/USG-supported organizations, and academia in response to needs identified by users. SERVIR launched tools and applications addressing local needs, including SERVIR-Amazonia's Radar Mining Monitoring (RAMI) tool, which can be used to identify mining sites, differentiate between illegal, informal, and formal mining, and track mining-related deforestation in the Peruvian Amazon; and SERVIR-Hindu Kush Himalaya (HKH)'s Regional Land Cover Monitoring System (RLCMS), an operational system for annual land cover mapping and change analysis which allows regional stakeholders to visualize land cover across the region and identify biodiversity hotspots. Multiple SERVIR services now use ClimateSERV 2.0, which had a soft launch in conjunction with the 2021 United Nations Climate Change Conference (COP26). ClimateSERV is a web-accessible system that allows users to access, visualize, and analyze historical Earth observations to make improved decisions. Co-developed with SERVIR Applied Sciences Teams (ASTs), SERVIR Amazonia's Amazon Dashboard produced the 2021 Seasonal Fire Forecast for the Southern Amazon, with uptake by the Monitoring of the Andean Amazon Project, while the Mekong Landslide Hazard Assessment for Situational Awareness (LHASA-Mekong) allows the SERVIR Mekong hub to monitor and forecast landslide risk and support users like Thailand's Department of Mineral Resources. Constraints to travel and in-person meetings continued to present schedule challenges for training events and field validations in 2021, but the SERVIR network (including hubs, Applied Science Teams (ASTs), and Subject Matter Experts) were able to build capacity through virtual training events, webinars and hackathons.

## *Highlight Stories*

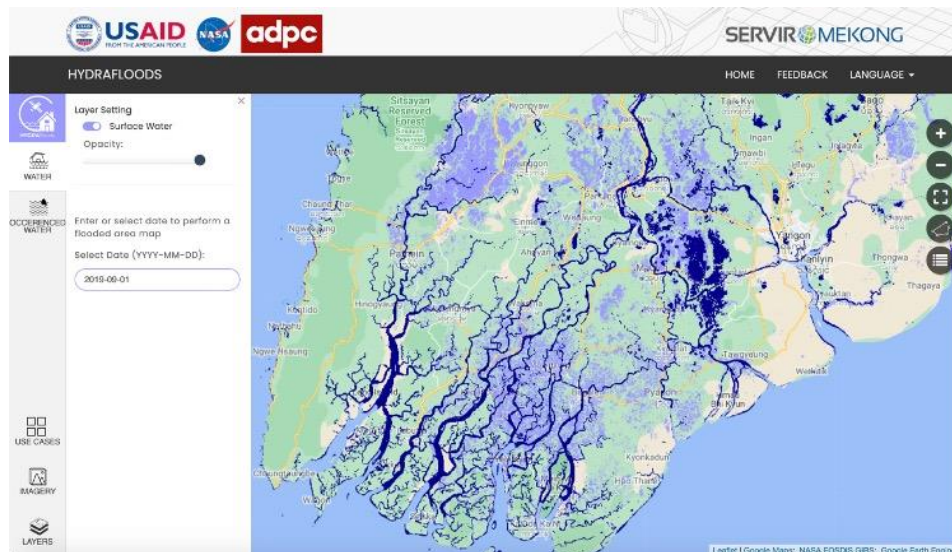
### **SERVIR-Mekong's HYDRAFloods tool**

HYDRAFloods, or the HYDrological Remote sensing Analysis for Floods tool, was co-developed by SERVIR-Mekong consortium members and the SERVIR Science Coordination Office (SCO) to provide near-real time updates on flood extent. By consolidating imagery from different Earth-observing satellites with different flyover intervals, the tool can provide updates more regularly than alternative methods.

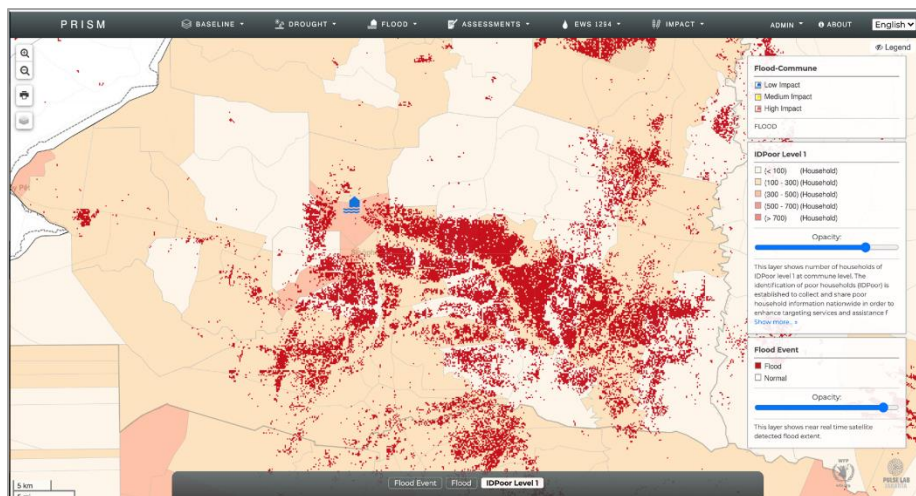
To help build community resilience for multiple hazards and increase food security, the World Food Programme (WFP) integrated SERVIR services and data into their interactive Platform for Real-time Impact and Situation Monitoring (PRISM)—which helps authorities allocate resources based on socioeconomic vulnerability data. [A](#)



[new version of PRISM was released](#), ingesting information for Cambodia from HYDRAFloods and SERVIR-Mekong’s Regional Drought and Crop Yield Information System (RDCYIS).



In 2021, results from a joint SERVIR – WFP evaluation indicate that during the October 2020 floods in Cambodia, flood extent maps from SERVIR’s HYDRAFloods tool contributed valuable information to PRISM. These maps were used in preparing the design and roll-out of the Humanitarian Response Forum’s \$2.2+ million dollar aid plan, providing aid to over 200,000 affected people. This aid included food, sanitation, medicine, and shelters, and complemented the efforts of the Cambodian Red Cross and local governments. The full evaluation, led by the SERVIR SCO and partners from SERVIR-Mekong and WFP, is planned for completion in mid-2022.



*Image credit: World Food Programme*

HYDRAFloods has also been incorporated into a new World Bank-funded webtool from Deltares. The service provides forecasts and ‘now-casts’ of flood impacts on transportation infrastructure. Combining HYDRAFloods and infrastructure

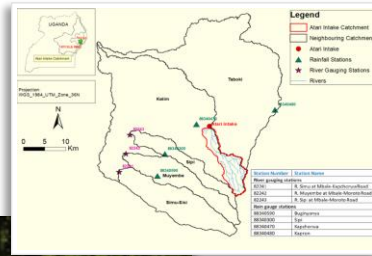
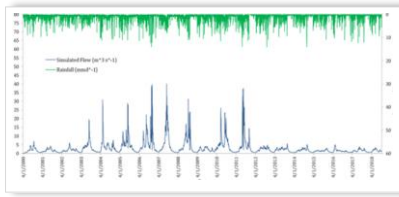
data, the Deltares tool can help map where roadblocks and congestion will occur, estimate the duration of those disruptions, and better inform emergency services to improve disaster-resilient infrastructure. In a case study

for Myanmar, Deltares demonstrated how HYDRAFloods' near real-time flood mapping makes it possible to evaluate how floods will disrupt transportation networks on-the-fly.

### **Uganda Use Case for the Ensemble Framework for Flash Flood Forecasting**

SERVIR Eastern & Southern Africa's Regional Stream Flow Monitoring and Forecasting Service provides real-time stream flow and flood forecasts for several watersheds in East Africa as well as bias-corrected satellite precipitation products that enable the timely prediction and monitoring of water resources and extreme hydrological events (flood and drought). The service builds the capacity of stakeholders to use the streamflow and hydrological modelling products to support water resources development and management in the region. As part of the service, the hub uses a SERVIR AST-led effort on [Ensemble Framework for Flash Flood Forecasting \(EF5\)](#). The AST project provided trainings for users in the region on effective use of the EF5 model and on the service at large; trainings are now being led by hub trainers.

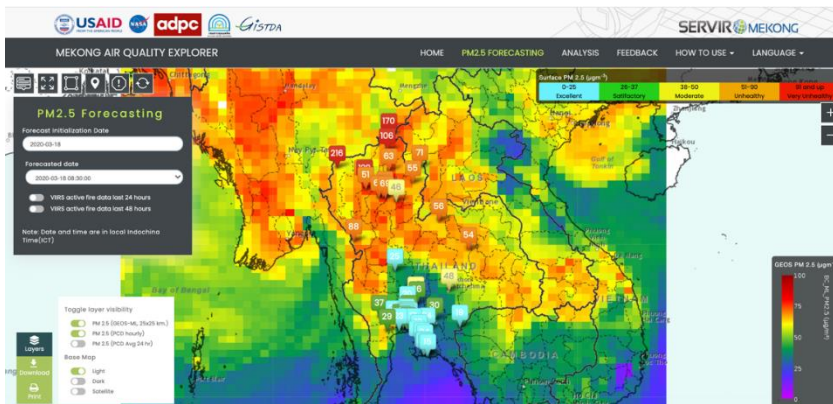
Serendipitously, participants from Uganda that attended these AST and hub trainings got an opportunity to use the model products. Uganda's Directorate of Water Resources Management (DWRM) needed to design a new water intake system for ungauged rivers across the country as part of Uganda's commitments to the United Nation's Sustainable Development Goal on safe drinking water. Their exposure and training of the EF5 model and the broader satellite-based streamflow forecasting service enabled them to use the model calibrations from a nearby gauged watershed and apply the calibration parameters to an ungauged basin in the country's fast-growing central Kyoga management zone. Reliable assessments of stream flow have historically been costly and difficult due to lack of *in situ* stream gauges, so the satellite-based service enables DWRM to assess a sustainable rate of water intake without risk to downstream ecosystems. The water intake plant is designed for one ungauged river and the construction is expected to begin in 2022. More importantly, DWRM plans to use this service to design sustainable water intake systems for other parts of the country in the future. [More info](#).



The photo at left shows the proposed inlet for the municipal water supply station. Modeled streamflow from SERVIR's satellite-based streamflow forecasting service (top left) shows the low-flows which provides the basis for the location and sizing of the water supply station in the context of existing watershed (top right).  
(Image credit: SERVIR Eastern & Southern Africa)

### SERVIR Mekong Air Quality Explorer

Agricultural burning and forest fires, including transboundary haze, contribute to high levels of pollution for much of Southeast Asia, and fine inhalable particles with diameters that are generally 2.5 micrometers and smaller (PM2.5) released from these fires have a huge impact on human health. In response to chronic seasonal air pollution in Thailand, SERVIR Mekong developed the Air Quality Explorer tool in partnership with the Thailand Pollution Control Department and the Geo-Informatics & Space Technology Development Agency (GISTDA), Thailand's space agency.



The Air Quality Explorer combines NASA



satellite data, ground-sensor data, and machine-learning techniques to enable large-scale monitoring and forecasting of air quality. This information helps authorities devise data-driven policies and strategies to tackle air pollution.

During 2021, a team led by Dr. Nion Sirimongkonlertkul of Thailand’s Rajamangala University of Technology worked with the provincial government in Chiang Rai Province in Northern Thailand to develop the Smoke Watch App using data from the Air Quality Explorer tool. Smoke Watch can locate forest fires in near real-time and can be used by officials to monitor and manage forest fires and push air quality warnings to nearby communities. By leveraging satellite data from SERVIR-Mekong’s Air Quality Explorer to detect wildfires as they happen, first responders and forest rangers can undertake targeted interventions to put out fires.

A two-part Training on Satellite Observations and Tools for Fire Detection was held for regional stakeholders August 26-27 and September 9-10, led by Dr. Pawan Gupta (MSFC/USRA) and facilitated by Mr. Aekkapol Aekakkararungroj (ADPC/SERVIR Mekong). The training provided details on the applications of NASA resources to decision-making activities related to fire detection, air quality monitoring, forecasting, and PM2.5 monitoring, and concluded with a demonstration of the Air Quality Explorer. The Air Quality Explorer and Smoke Watch were both featured in a NASA.gov video, which was shown at the virtual SERVIR Mekong Symposium, during the Air Quality and Health session on October 20. The Smoke Watch App was one of ten recipients of a [Thailand National Innovation Award](#) in the “Social and Environmental Protection” division.

# Indigenous Peoples Initiative

## 2021 Overview

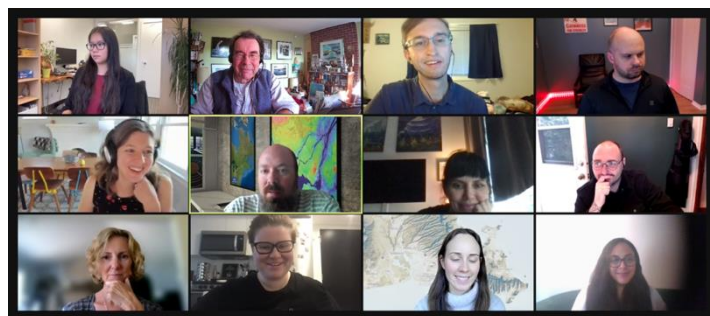
In 2021 the Indigenous Peoples Initiative focused on continued community engagement and place-based training activities while developing a long-term strategy. The strengths of this initiative were highlighted by the team’s partnerships with other space agencies and with Indigenous communities. Throughout 2021, the team coordinated meetings, panels, and presentations both internally and with their networks. For example, in July, IP organized and moderated a panel for the American Water Resources Association (AWRA) Virtual Summer Conference and presented for the Inter-Tribal Environmental Council Conference. The initiative also began conversations with other federal partners (e.g., NOAA, USGS, and EPA) around tribal engagement strategies, which will hopefully lead to long term sustained partnerships.

## Highlight Story

The Indigenous Mapping Workshop (IMW 2021), hosted by the Firelight Group, supports geospatial capacity building that generates facilities, programs, and resources to promote Indigenous Peoples’ ability to collect, analyze, and visualize community-based geospatial information. The IP team collaborated with the Canadian Space Agency (CSA), to create a series of 12 optical and radar remote sensing trainings in coordination with other contributors, like Google, Esri Canada, and Mapbox. The 45-minute-long remote sensing sessions were prepared by 8 subject experts and delivered to an online audience of predominantly Indigenous workshop participants. The total IMW attendance was over 500, with approximately 300 participants in attendance for the

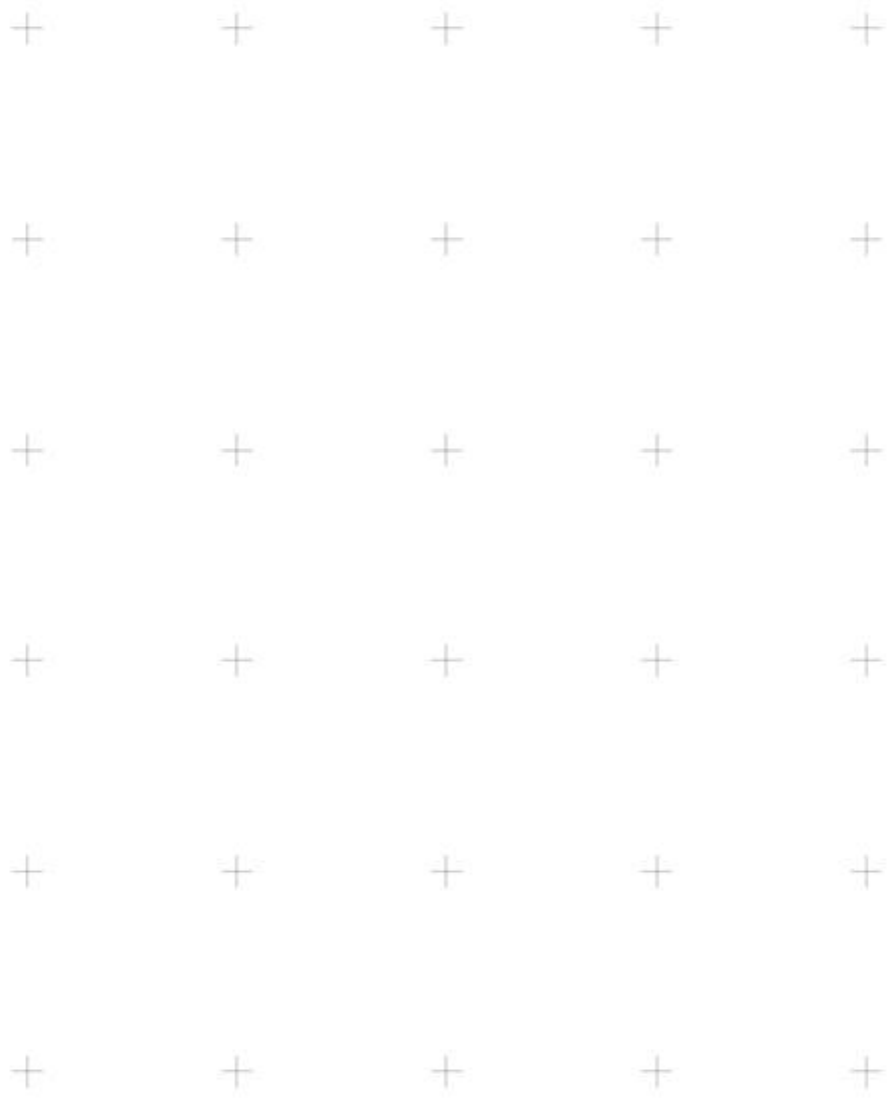


*Participant locations for the IMW 2021 online workshop. The Workshop reached participants in 35 countries.*



NASA/CSA/ESRI Canada session. This training series has initiated a continued partnership between CSA and NASA and plans for IMW 2022 are already underway.

*IMW 2021 programming committee during a meeting.*



# FOCAL POINTS



EARTH SCIENCE  
APPLIED SCIENCES

2021 presented a significant shift in the landscape of CBP's work due to new initiatives and priorities, an evolving global landscape, and an increased emphasis on cross-cutting issues, such as climate and equity. CBP's response to this changing environment reflects the flexibility and adaptability of our work and of our team. Read more about CBP's responses to different focal areas throughout 2021 below.

## Equity and Environmental Justice

The US EPA defines environmental justice (EJ) as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." The White House Environmental Justice Advisory Council further defines environmental justice *communities* as "geographic locations within the U.S. and its territories with significant representation of persons of color, low-income persons, indigenous persons or members of Tribal nations, where such individuals experience, or are at risk of experiencing, higher or more adverse human health or environmental outcomes." Climate justice (CJ), which is related to environmental justice, is an acknowledgement that climate change can result in poor and marginalized communities having a disproportionate exposure and vulnerability to environmental impacts, particularly in developing countries. Equity and Environmental Justice officially became an element of CBP's work in 2021, although the groundwork was laid in previous years.

Since 2018, a collaboration between NASA DEVELOP, Groundwork USA and its network of trusts, the AGU Thriving Earth Exchange, and local municipalities such as the cities of San Diego, CA; Austin, TX; Cambridge, MA; and Sacramento, CA has culminated in a series of 20 projects focused on assessing vulnerability to environmental threats such as extreme heat and flooding. These projects have explored the integration of satellite data and socioeconomic data to discern populations at risk of being negatively impacted. These projects align with initiatives like Groundwork USA's Climate Safe Neighborhoods that explore the relationship between historical race-based housing segregation and current and predicted impacts of climate change. At the end of 2021, the DEVELOP program established a Fellow position focused on EJ and management of the growing EJ project portfolio, engagement with EJ communities and partners, and identifying opportunities for new projects and partnerships.

Indigenous communities are inexorably linked to EJ as a result of numerous anthropogenic events of extreme natural resource extraction that have occurred within Indigenous homelands. EJ for Indigenous communities is a way to restore balance to the environment to create sustainable homelands. Increasing the capacity for tribal nations and communities to use EO for land monitoring puts additional information into the hands of the individual that can serve to support efforts around land sovereignty, protection, and restoration. A current team

member, and past HQ intern, Sativa Cruz focused her work in 2021 around identifying the EEJ landscape and what it could mean to NASA. Moving forward, the IP initiative will continue to expand EEJ efforts.

Although EEJ work is generally focused on the geographic extent of the US, CJ and EJ communities can be found worldwide. In 2021, ARSET had 25 participants from Tribal/Indigenous Organizations from around the globe including the Organization of the Siona Indigenous Nationality (Ecuador), Santa Rosa First Peoples Community (Trinidad and Tobago), Little Traverse Bay Bands of Odawa Indians (USA), and the Bawinu Foundation (Myanmar). Dr. David Salisbury at the University of Richmond, who is Co-Investigator on the SERVIR AST project ‘Quantifying the Effects of Forest Cover Changes on Provisioning and Regulating Ecosystem Services in the Southwestern Amazon’, visited the Saweto community in Peru from November 7-14, 2021, at the invitation of community leaders and members. One of the objectives of his visit was to raise community awareness of the threat and past impacts of road building and logging, through posters and maps created through the project. The *Threats, Protection and Development in the Amazon Borderlands Congress* was held the week after his visit, and in preparation, Dr. Salisbury worked with two members of the Saweto delegation on how best to present information from AST-produced posters and maps of Saweto during the Congress.

## Diversity, Equity, Inclusion, and Accessibility

At CBP, as at NASA, we believe that by fostering an atmosphere of inclusion and respect, we can continue to value and appreciate the strengths afforded by both the commonalities and differences between us. This in turn will drive innovation, creativity, and a culture of respect.

SERVIR works to make geospatial technologies and professions more gender responsive and inclusive by: 1) Supporting women leaders & gender champions in SERVIR, creating an equal opportunity work environment; 2) Empowering women and girls to explore STEM fields in countries and regions where we operate; 3) Integrating gender considerations in service planning through gender analyses and participatory review and 4) Using remote sensing and GIS to address issues disproportionately impacting groups characterized by gender, ethnicity, age, and/or social status.

In 2021, SERVIR continued efforts to provide thought leadership on including gender in the design of geospatial services. SERVIR SCO team members presented on SERVIR’s Gender and Social Inclusion Strategy and activities to MSFC’s Engineering Management Council and to the Office of Diversity and Equal Opportunity Leaders’ Meeting at NASA Headquarters, and supported Women’s Economic Empowerment (WEE) in coordination with Arizona State University, focused on early career women in hub regions. SERVIR HKH continued the highly successful series of “Empowering women in geospatial information technology” trainings, held for participants



across Afghanistan, Bangladesh, Bhutan, Nepal & Pakistan. Partnering with the International Union for Conservation of Nature's Advancing Gender in the Environment (AGENT), the SERVIR Service Planning Toolkit was updated with guidance on opportunities to make the service planning approach more gender inclusive and responsive, and AGENT engaged hubs in conducting gender analyses for hub services.

In 2021, DEVELOP sought to better understand the diversity of applicants, so the team used voluntarily-provided demographic data analysis to determine how the program transformed its geographic reach and racial diversity of participants pre-pandemic to present. In that time, DEVELOP has seen a broader distribution of applicants and increases in its Hispanic and Asian participants. Looking forward to 2022, the program will be exploring new targeted recruitment methods and building relationships with organizations and universities to reach diverse candidates and potential advisors.

The IP initiative aims to improve understanding and interactions with Earth through the valuation of shared Indigenous knowledge systems, by building capacity among Indigenous people to use NASA data, and by increasing Indigenous representation at NASA. At its core, this project aims to eliminate barriers and to increase the opportunities for Indigenous people to connect to and work within CBP. The IP Initiative seeks to value the "2-eyed seeing" perspective, as an Etuaptmuk (Mi'Kmaq) Indigenous colleague referred to as being the inclusion of Indigenous and western science knowledge systems equally. The IP team has actively engaged and advocated for an increase in Indigenous voices at NASA, and have included these themes in trainings, presentations, and at national and international forums.

## Transform to Open Science

Open-source science requires a culture shift to a more inclusive, transparent, and collaborative scientific process, which will increase the pace and quality of scientific progress. Open-source science has the potential to lower barriers to entry for historically excluded communities, help scientists understand how people utilize NASA data and code, and increase opportunities for collaboration while promoting scientific innovation, transparency, and reproducibility. CBP is committed to open-source science principles and initiatives.

In order to make ARSET training materials as accessible as possible to a global audience, ARSET relies strictly on open-source software for any processing or analysis. This ensures our participants can replicate the methodologies regardless of what software they have access to. Two of the most popular open-source softwares in recent ARSET trainings are Google Earth Engine (GEE) and QGIS. ARSET also offers synchronous and asynchronous training options for those who may have limited access to the internet.

SERVIR continues to develop methods and strengthen capacity for using open-source Earth observation data to address local challenges in climate change, food security, water and related disasters, land use, and air quality. During 2021, Subject Matter Experts provided workshops and training events on Machine Learning and Google Earth Engine -- used increasingly in SERVIR services because of flexibility and open-source access to algorithms and high-resolution imagery. With Planet Labs, Inc., SERVIR delivered training on use of high spatial & temporal resolution multispectral Planet imagery available through support from Norway's International Climate and Forest Initiative (NICFI) – focused on how that data can be integrated into services such as the gold mining monitoring services for SERVIR West Africa and for SERVIR Amazonia. SERVIR hosted a workshop on 'Making Open EO Open to Everyone' at the Free and Open Source Software for Geospatial (FOSS4G) Virtual Conference in October and presented on 'Geospatial Services for All: SERVIR's Inclusive Approach to Service Design'.

DEVELOP expanded its virtual offerings of Software Carpentry workshops and coding trainings for both those participating in DEVELOP and partnering organizations, training and strengthening coding skillsets in 391 people. The program increased its use of GitLab for enhanced management of code and shared use within the program and outlined a plan to increase the number of tutorials and how-to guides produced by project teams. DEVELOP also continued efforts to expand access to tools and results created by its feasibility projects through its publicly available GitHub portal of data processing tools and saw NASA's Software Release Authority approve release of 17 tools for public dissemination.

## Prizes & Challenges

The Applied Sciences Prizes and Challenges Program celebrates NASA's long history of open innovation by inviting the public to participate in incentivized competitions called prizes and challenges. We share focused, defined problems, or "challenges," formulated from the agency's ongoing scientific and technical explorations, and often in collaboration with other federal agencies, international space agencies, and private organizations. Teams and individuals who submit winning "solutions," including novel ideas, technologies, scientific advances, hardware and software products, and services, are awarded cash prizes and other incentives to recognize their contributions.

Prizes and challenges allow us to reach people around the world with diverse backgrounds, skillsets, and experiences, bring out-of-discipline perspectives and tools to address our planet's toughest problems, and catalyze new discoveries and technology development for tomorrow.

2021 was a busy year for the Prizes and Challenges Program, punctuated with exciting milestones, such as the tenth anniversary of the International Space Apps Challenge Hackathon. To mark this milestone, the program led

the development of a challenge addressing environmental injustices. This challenge spawned 111 projects from 187 teams around the world, including the final ‘Most Inspirational’ award winning project ‘[Bioshi](#),’ which addresses deforestation in the Amazon rainforest. Beyond the Space Apps Challenge Hackathon, the program continued the development of four prize competitions covering topics such as harmful algal blooms, air quality, and resiliency. The program supported three challenges from partner NASA programs addressing food security ([Deep Space Food Challenge](#)), remote sensing ([NASA Techrise Student Challenge](#)), and private sector engagement in NASA’s climate activities ([NASA iTech 2021 Cycle II Forum](#)).

In addition to managing programmatic activities, Program Manager Shobhana Gupta served on the USGEO Innovation Task Team to engage the Earth observations enterprise to advance research and development through activities with accelerators, incubators, and industry clusters, and to scope open-competitions for innovations in EO. Shobhana also started a part-time residency at the NASA Center of Excellence for Collaborative Innovation, part of the Space Technology Mission Directorate’s Prizes, Challenges and Crowdsourcing Program that is based at NASA Johnson Space Center. This engagement has allowed the program to streamline project development, competition vendor selection, and onboarding processes.

## Global Networks

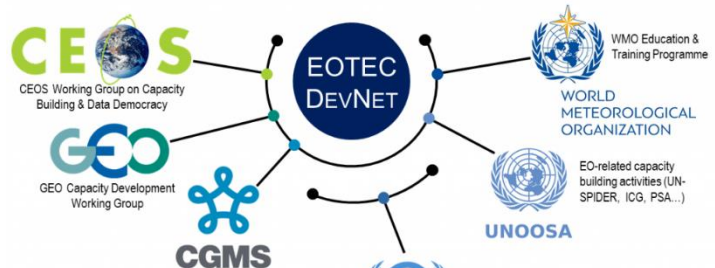
CBP continued to build and strengthen international partnerships through participation in multiple global networks and took a leading role in establishing new connections between these groups. As an active member of the [Group on Earth Observations](#) (GEO), CBP prepared contributions to [AmeriGEO Week](#) in August 2021. One AmeriGEO project funded through ROSES-16 A.50 completed capacity development activities with indigenous groups in Ecuador and Peru, and the remaining three projects were extended into 2022 to continue to strengthen agricultural monitoring, strengthen the pole-to-pole marine biodiversity observation network, and build capacity to apply synthetic aperture radar to disasters and other applications. Two GEO Human Planet Initiative (HPI) projects focused on assessment of human settlements and applications of VIIRS night light data concluded in 2021. The third HPI project was extended into 2022 to increase the use of human demographic data in sustainable development goals, including the Human Settlement Toolkit. As Co-Chair of the GEO [Capacity Development Working Group](#), the Program Manager participated in the development of the Climate/Disaster Risk Reduction/Capacity Development Working Group cross-GEO Work Programme survey and is supporting analysis of the results, expected in 2022.



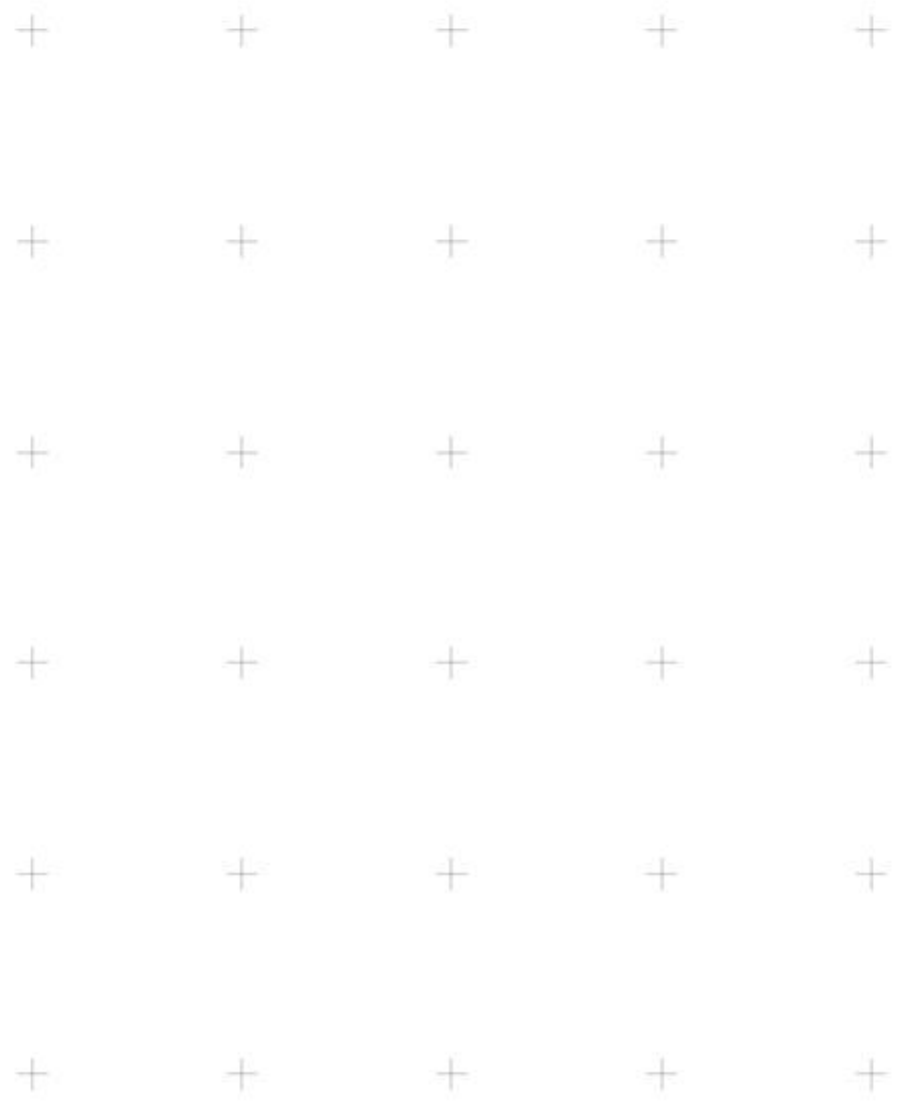
*Members of CEOS WGCapD in the October 2021 monthly meeting.*

CBP continued to engage with CEOS [Working Group on Capacity Building and Data Democracy](#) (WGCapD). NASA, represented by Nancy Searby, concluded its term as chair of the WG and passed the leadership on to the UN Office of Outer Space Affairs (UNOOSA) at the plenary in November 2021. In NASA’s final year of leadership, CBP organized the virtual tenth anniversary meeting of WGCapD in March 2021 and a work planning meeting in September. CBP continued to produce deliverables in cooperation with other CEOS members, including a CEOS Webinar Toolkit, encompassing guidance on best practices, templates, and workflows to design and conduct CEOS webinars; over nine hours of training material preceding the XIX International SELPER Symposium regarding SAR for vegetation and natural disasters; and a Jupyter Notebook Awareness Webinar, which trained 288 attendees across two sessions in the uses and value of Jupyter Notebooks for geospatial analysis and remote sensing.

While working across these global networks, leadership at CBP recognized the value in connecting the leaders of these networks around shared capacity development priorities related to sustainable development. This need for coordination and communication resulted in the creation of the [Earth Observation Training, Education, and Capacity Development Network](#) (EOTEC DevNet) which began pilot operations as a CEOS activity in 2021. This network of networks aims to bring the power of satellite-derived Earth information to more users around the globe by connecting global capacity development networks around shared resources and needs related to climate adaptation, mitigation, and disaster risk reduction. EOTEC DevNet completed the first phase of its pilot activities in November 2021 and received CEOS endorsement to continue phase 2 of the pilot through March 2023. CBP works closely with colleagues at the University of Jena on the secretariat for EOTEC DevNet, and meets regularly with leaders from GEO, CEOS, the World Meteorological Organization, UNOOSA, and the Coordination Group for Meteorological Satellites and with regional practitioners across the globe.



*Network of networks comprising EOTEC DevNet.*



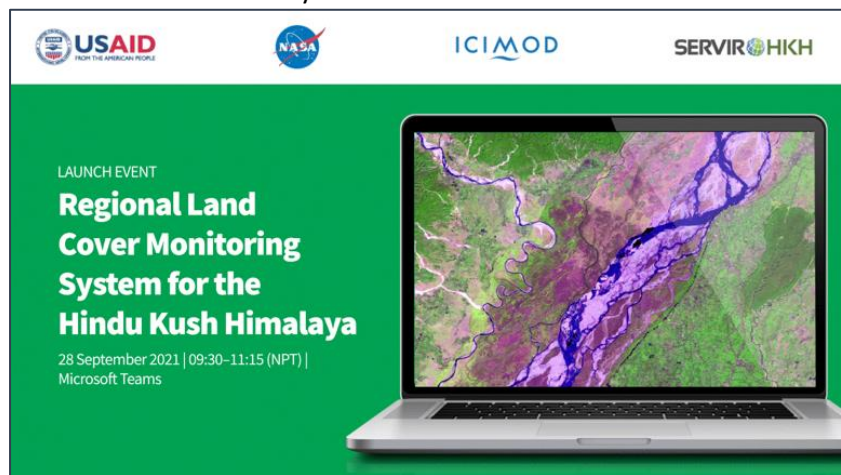
# IMPACT STORIES



The true impact of CBP’s work on the lives and livelihoods of people around the globe cannot always be captured with metrics but are sometimes best conveyed through stories and anecdotes about the specific benefit CBP activities provided. This selection of impact narratives aims to convey that impact.

### *SERVIR Launches Regional Land Cover Monitoring System*

Land cover across the Hindu Kush Himalaya region is changing at an accelerated rate due to rapid economic growth and population pressures. These changes impact long-term sustainability of ecosystems and services, including food, water, and energy. The SERVIR Hindu Kush Himalaya hub at the International Centre for Integrated Mountain Development, along with partners including Bangladesh’s Forest Department, Nepal’s Forest Research and Training Centre, the Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland, SilvaCarbon, and the United States Forest Services, collaborated with SERVIR- Mekong—the SERVIR hub that first developed



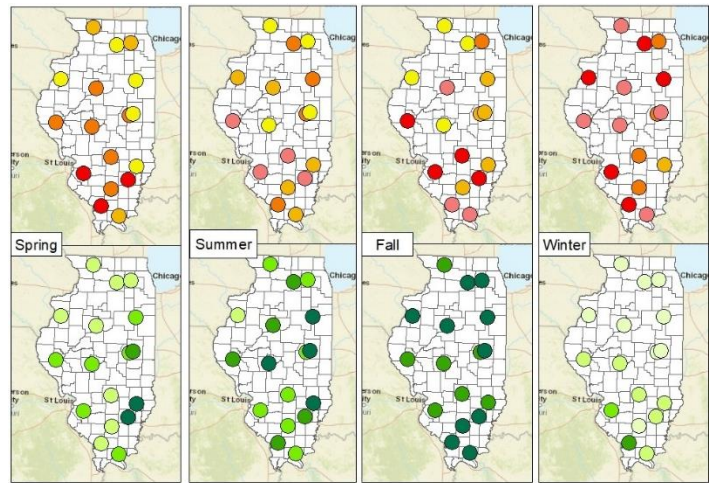
and launched the service—to replicate and re-scale it to better reflect the land use and land cover characteristics of Nepal, Bhutan, and Bangladesh. On September 28, SERVIR-Hindu Kush-Himalaya launched its own application of the Regional Land Cover Monitoring System (RLCMS). The event included service demos and the public release of almost twenty years of land cover data for the region. RLCMS allows partners to visualize land cover or biodiversity hotspots across the region, as well as measure trends in user-defined areas of interest.

#### *ARSET training survey response*

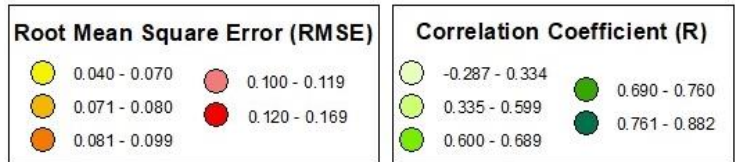
“In Mongolia, livelihood of rural people, particularly the herders’ much depends from drought, heavy snowfall, storms, pasture productivity, and wildfire. Distribution of knowledge of remote sensing in rural provinces will improve much their sustainable development policy, and monitoring and evaluation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

### Illinois Disasters

Soil moisture is a key indicator of drought and flood vulnerability, however in situ infrastructure is sparse and inadequate for large-scale drought monitoring. This project evaluated short-term and seasonal variability of in situ, satellite, and modeled soil moisture observations from SMAP and NASA SPoRT Land Information System. The team presented anomaly and percentile timeseries maps to the Illinois State Water Survey and USDA Midwest Climate Hub to provide a spatial overview of data bias and variability between datasets, informing partners of data product suitability for drought monitoring under various wet and dry conditions.



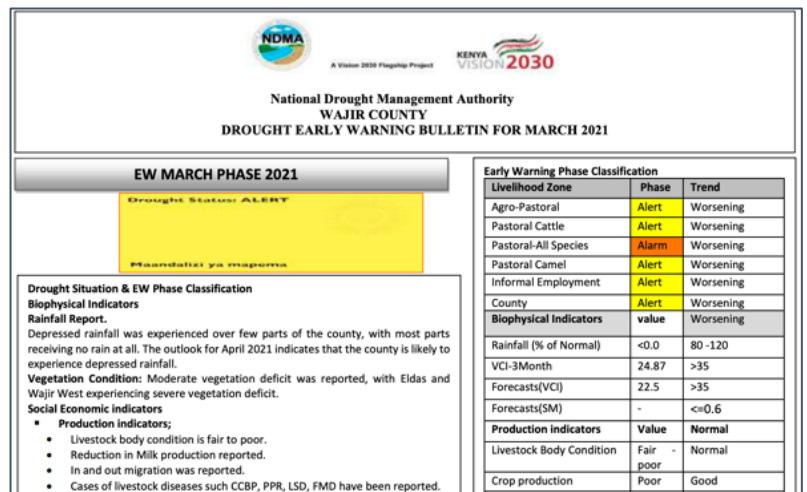
SMAP vs *In Situ* Soil Moisture (2015 – 2021)



"Soil moisture is a real challenge to measure and monitor at a state-level. The DEVELOP project helped us understand the differences between soil moisture information, which gives us a lot more confidence [in] drought monitoring." - **Trent Ford, Illinois State Climatologist**

### Vegetation data steer food aid in northeast Kenya

In collaboration with SERVIR Eastern & Southern Africa, Kenya's National Drought Mitigation Authority (NDMA) has integrated a MODIS/VIIRS-based Vegetation Condition Index (VCI) to improve their monthly Early Warning Bulletins, a critical resource for allocating food aid. NDMA is now generating actionable county-level reports on rangeland and crop conditions, an enhancement over their previous national-level analyses. In March of 2021, the county-level reports used VCI along with other data to point to areas of concern for Wajir County in northeastern Kenya. This contributed to a decision by the Kenyan government to distribute food aid to over 42,000 food-insecure households in Wajir County in northeast Kenya.



## Western Montana Ecological Forecasting

Monitoring for environmental contaminants is necessary for riverine ecosystems as exposure to these contaminants can have significant endocrine, neurological, and reproductive effects. They easily travel up the food chain and bioaccumulate in apex predators, including American mink and North American river otter, making them reliable indicator species of local environmental health. Partnering with Working Dogs for Conservation (WD4C), the DEVELOP team modeled habitat suitability in western Montana for the species from 2013 to 2020 and forecasted to 2040. Suitable habitat corresponded with herbaceous land cover, distance to river bodies, and deeper river locations.

"Our partnership with NASA DEVELOP is now poised to culminate in a number of deliverables, including mink habitat suitability maps, which will enable us to more efficiently identify viable focal species habitat and select sampling sites accordingly, to maximize the information that can be gathered relative to scat dog-handler team survey efforts."

- **Dr. Ngaio Richards, Forensics & Field Specialist, Working Dogs for Conservation**

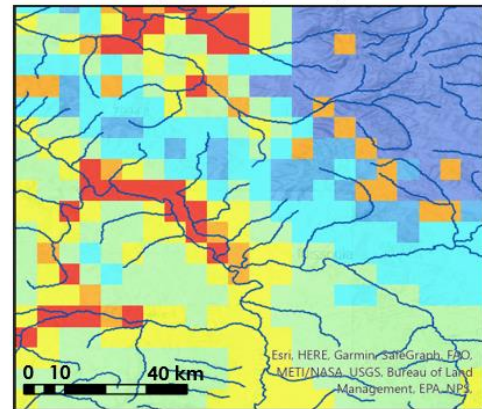
## Satellite Remote Sensing for Urban Heat

This training addresses the use of RS in determining where "hot spots" of land surface temperature are located in urban areas, why these areas are experiencing increased temperature, which populations are most vulnerable, and ways to mitigate the effects through adaptive land use planning.

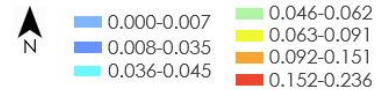
## ARSET training survey response

"Satellite remote sensing for urban heat island training with ARSET will improve my ability to use remote sensing data for monitoring urban heat islands. As a matter of fact **I am already working on an article on urban heat island using Google Earth Engine** based on the knowledge I received from this training. Thanks so much." – Student, Nigeria

Otter and Mink Habitat Suitability Map  
(2040 Projection)



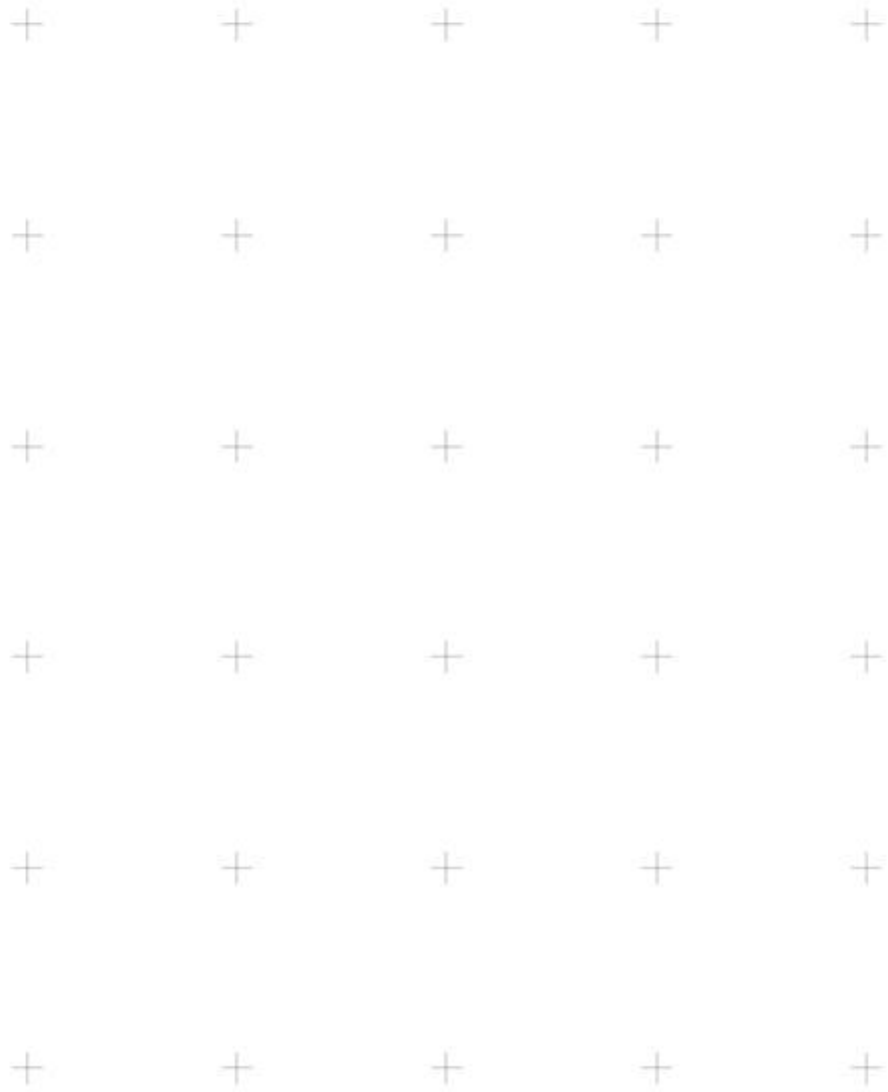
### Habitat Probability



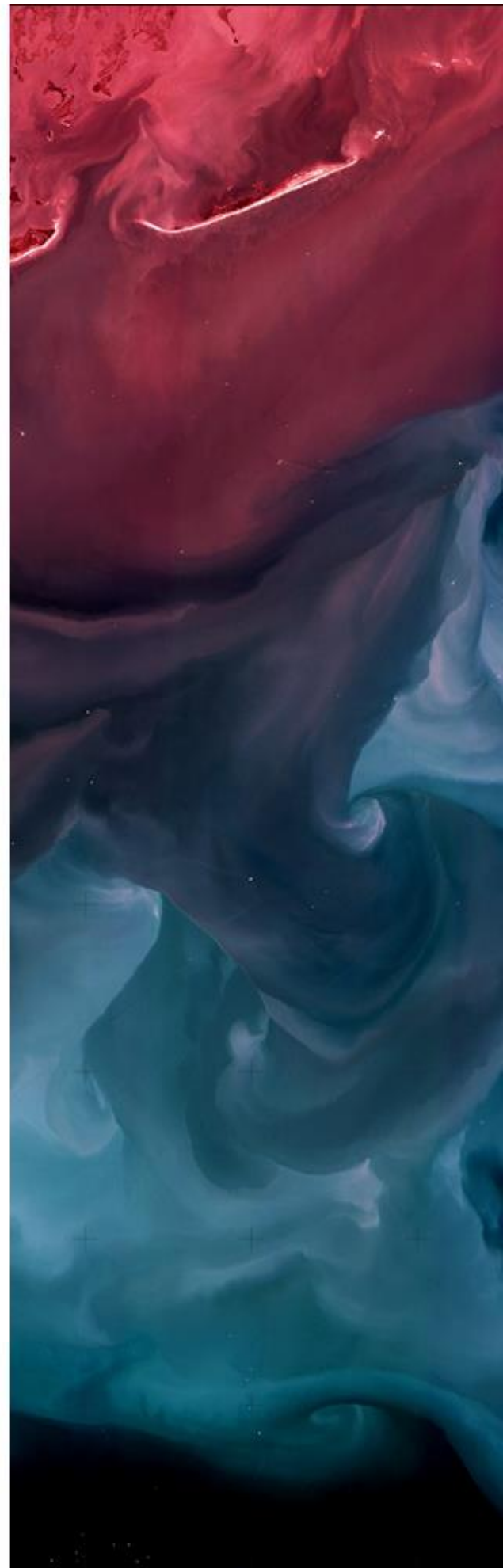
### Objectives

- **Derive** environmental predictor variables from Landsat 8 OLI, Terra MODIS, GPM, SRTM & SMAP for use in the Software for Assisted Habitat Modeling
- **Inform** sampling site selection for contaminant analysis conducted by WD4C





# LOOKING AHEAD



EARTH SCIENCE  
APPLIED SCIENCES

## Challenges

2021 was not without challenges, especially those incurred by the ongoing pandemic. At IP, one of the primary challenges was the inability to meet with partners in person for engagement activities and trainings due to COVID. A large part of IP's work centers around community connections and establishing trust, which is difficult to do virtually, especially in rural communities that may have limited bandwidth. IP has attempted to overcome these challenges by conducting virtual trainings with trusted partners who have community connections.

Similarly, SERVIR saw key activities impacted by international travel restrictions. This was especially seen in ongoing delays of some planned training and field work activities, which impacted some of the Year Two activities for the SERVIR AST projects, and impacted capacity building training events and service development at the hubs. At the same time, the network found ways to interface with the stakeholders and across hubs, leading or co-hosting virtual training events and webinars, and participating activities such as needs assessments through virtual means.

DEVELOP was also challenged by the uncertainty that accompanies return to onsite work. The virtual DEVELOP experience has many benefits, but also has limitations and challenges, such as limited team building, lack of building meaningful personal connections, minimal networking opportunities, diminished public speaking opportunities, risk of isolation, and increased complexities relating to pay rates and labor laws across many geographies. DEVELOP science advisors have risen to the challenge of virtual DEVELOP, but virtual projects are more time consuming and may require more support. Additionally, DEVELOP's programmatic organization around its office locations is challenged by a virtual program where 'place' is no longer the center of the participant experience and this also has repercussions for regional locations where many of the benefits of hosting a DEVELOP office have been eliminated in the virtual world.

ARSET adapted more smoothly to virtual work, but this does not mean the year was without challenges. The program experienced a change in website capability after migration to the new NASA Applied Science website.

CBP has been challenged to take on responsibility of the new Equity and Environmental Justice program, including rapidly developing a new solicitation and coordinating across ESD, with EPA, and with others actively working in this area without adequate staff. Plans to hire an EEJ Program Manager are underway to alleviate this challenge.

## Goals and Opportunities

Through the new climate thematic area and targeted outreach in 2022, ARSET hopes to establish new partnerships with NASA projects/programs and aims to build capacity in at least 2,000 new organizations. This will include targeted outreach to tribal organizations and minority-serving institutions. ARSET will also include innovative training types and storytelling, including case-study examples from underserved communities. ARSET plans to continue growing the international community of practice through the delivery of at least 50% of trainings in more than one language, and to offer translated slides for the remaining trainings.

In 2022, DEVELOP plans to test new project types, including listening and technical innovation projects, and plans to explore new recruiting opportunities focused on increasing diversity, equity, and inclusion. Throughout the year, DEVELOP will work to create a new strategic plan, increase its science communication activities with a partnership with the National Park Service's Communications team, and increase usability and reproducibility of project results and methods through an increased focus on tutorials and how-to guides.

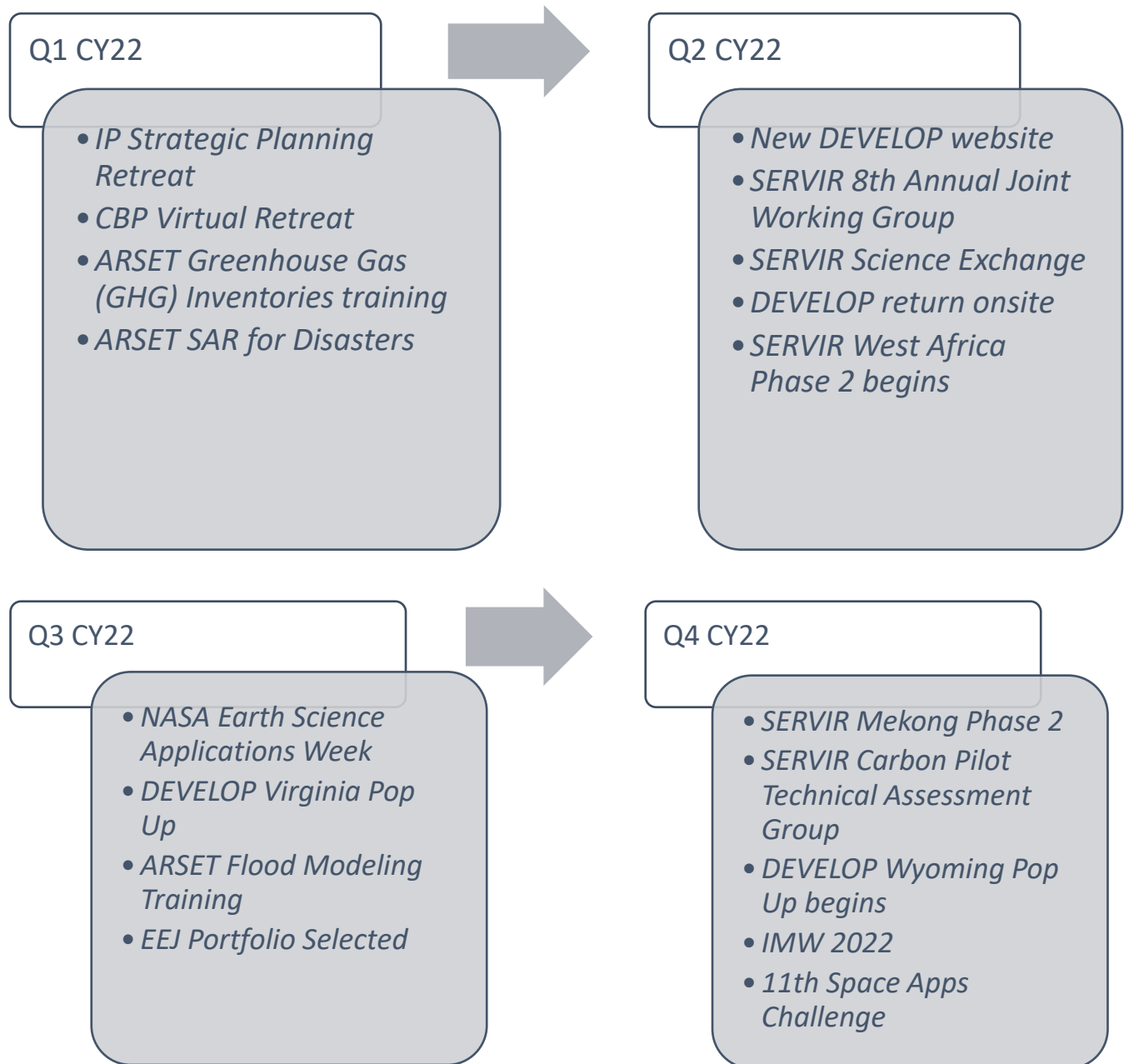
Throughout 2022, SERVIR will continue weaving the Strategic Plan into each of its services. The Science Coordination Office is dedicated to strengthening the sustainability and efficacy of SERVIR--promoting inclusivity through the Global Gender Strategy, accessibility through our sharing of open-source software, and scientific diplomacy through our commitment to Presidential initiatives like the Forest Data Partnership.

IP's major goal for 2022 is to create a 5-year plan, with a focus on four primary aspects through the lens of environmental justice: 1) continue successes with trainings, including a deep dive with a few projects and communities; 2) continue and expand our engagement with individuals and communities; 3) do more listening and information gathering with Indigenous communities on the value in the use of remote sensing for their needs, and 4) continue and increase connections inward with the NASA community.

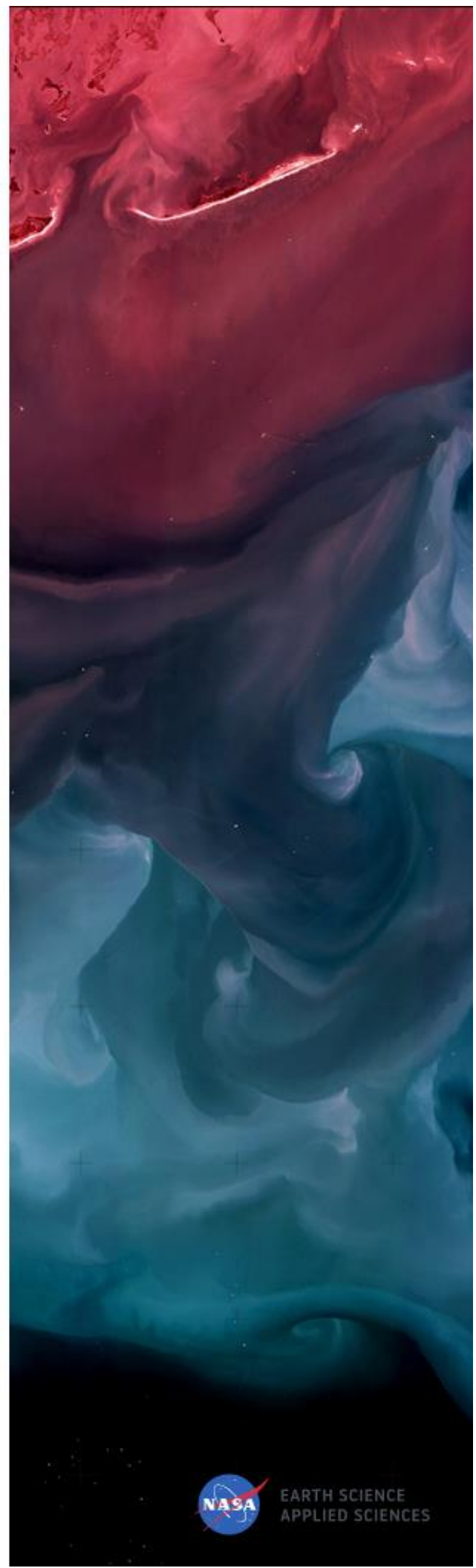
CBP is excited to include Prizes and Challenges and EEJ as part of our overall program. The team looks forward to a retreat to explore how we can synergize our work and collaborate more actively across the program.

## Launches

We hope to encourage CBP accomplishments and initiatives akin to how the agency approaches new satellite launches to reflect the relative significance and scale of these efforts within our program. Check out the chart below for some exciting CBP “launches” to look forward to in 2022!



# APPENDIX



EARTH SCIENCE  
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## Acronyms

ADPC: Asian Disaster Preparedness Center	MODIS: Moderate-resolution Imaging Spectroradiometer
ARSET: Applied Remote Sensing Training	MSI: Multispectral Imager
ASP: Applied Sciences Program	NASA: National Aeronautics and Space Administration
AST: Applied Sciences Team	NDMA: National Drought Mitigation Authority (Kenya)
AWRA: American Water Resources Association	NDVI: Normalized Difference Vegetation Index
CBP: Capacity Building Program	NGO: Non-Governmental Organization
CEOS: Committee on Earth Observation Satellites	NICFI: Norway's International Climate and Forest Initiative
CJ: Climate Justice	NOAA: National Oceanic and Atmospheric Administration
COP26: UN Climate Change Conference	NPGS: National Plant Germplasm System
CSA: Canadian Space Agency	OLI: Operational Land Imager
C-SAR: C-band Synthetic Aperture Radar	PC: Prizes and Challenges
DWRM: Directorate of Water Resources Management	PRISM: Platform for Real-time Impact and Situation Monitoring
EEJ: Equity and Environmental Justice	RAMI: Radar Mining Monitoring
EF5: Ensemble Framework for Flash Flood Forecasting	RDCYIS: Regional Drought and Crop Yield Information System
EJ: Environmental Justice	RLCMS: Regional Land Cover Monitoring System
EO: Earth Observations	SAR: Synthetic Aperture Radar
EPA: Environmental Protection Agency	SCO: Science Coordination Office
ESD: Earth Science Division	TM: Thematic Mapper
ETM: Enhanced Thematic Mapper	UNOOSA: United Nations Office of Outer Space Affairs
FOSS4G: Free and Open Source Software for Geospatial	USAID: United States Agency for International Development
GEE: Google Earth Engine	USDA: United States Department of Agriculture
GEO: Group on Earth Observations	VIC: Vegetation Condition Index
GIS: Geographic Information Systems	VSURF: Variable Selection using Random Forest
GISTDA: Geo-Informatics & Space Technology Development Agency	WGCAPD: Working Group on Capacity Building and Data Democracy
GLAD: Global Land Analysis and Discovery	WFP: World Food Programme
GRACE: Gravity Recovery and Climate Experiment	
HKH: Hindu Kush Himalaya	
HYDRAFloods: Hydrological Remote Sensing Analysis for Floods tool	
IMW: Indigenous Mapping Workshop	
IP: Indigenous Peoples Initiative	
LHASA: Landslide Hazard Assessment for Situational Awareness	

## Earth Observation Assets Employed by CBP

ALOS L-PALSAR	GRACE-FO	RadarSat-2
ALOS-2	Himawari-8	RapidEye
AMSR-2	IKONOS	Sentinel-1A
Aqua AMSR-E	IceSat-2	Sentinel-1B
Aqua MODIS	ISS ECOSTRESS	Sentinel-1 C-SAR
Suomi NPP ATMS	ISS GEDI	Sentinel-2 MSI
Aura OMI	ISS HICO	Sentinel-3 OLCI
AVHRR	Jason-2	Sentinel-3 SLSTR
CALIPSO CALIOP	Jason-3	Sentinel-5P TROPOMI
CloudSat	JPSS-1/NOAA 20	SMAP
Digital Globe	Landsat 4 TM	SMOS
ENVISAT	Landsat 5 TM	SRTM
EO-1 Hyperion	Landsat 7 ETM+	Suomi NPP VIIRS
ER-2 Jet AVIRIS	Landsat 8 OLI	SWOT
GCOM-C SGLI	Landsat 8 TIRS	TanDEM-X
GeoEye	Maxar High-Resolution	Terra ASTER
GEOS-5	Meteosat	Terra CERES
GOES	NISAR	Terra MISR
GPM DPR	OCO-2	Terra MODIS
GPM IMERG	PeruSat-1	TRMM TMI
GPM LIS	PlanetScope	Worldview
GPM TMPA	PROBA-V	Worldview-2
GRACE	RadarSat-1	

## Capacity Building Program Leadership

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**Background Image: Serene Expressions**

Sediment in the Gulf of Mexico off the  
Louisiana Coast.  
Date: March 13, 2016. Source: Landsat 8.

