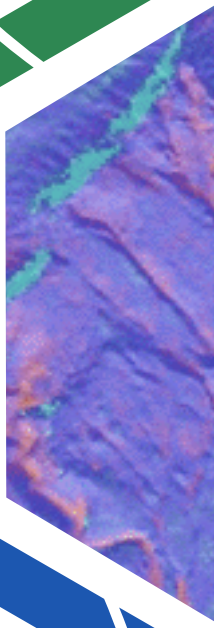
National Aeronautics and
Space Administration

NASA APPLIED SCIENCES' CAPACITY BUILDING PROGRAM'S

DEVELOP NATIONAL PROGRAM

2018 SUMMER PROJECT BOOKLET



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Letter from the
National Program Office

The DEVELOP National Program is proud to present our 2018 summer projects booklet. Our DEVELOP teams conduct applied Earth science feasibility projects to provide our partners and the general public a better understanding of NASA Earth observations.

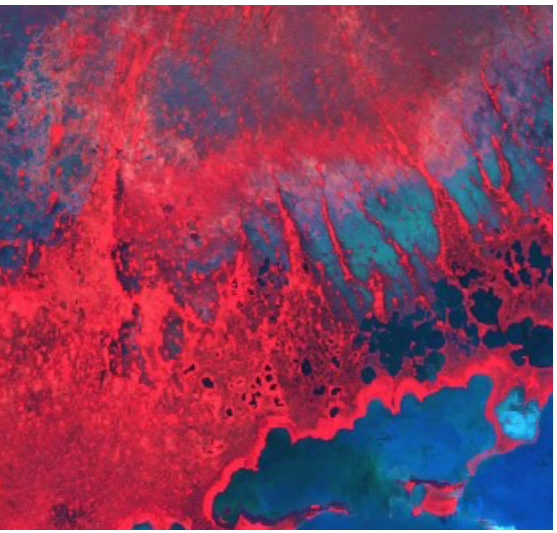
2018 is a milestone year for DEVELOP, marking the program's 20th anniversary. Since 1998, DEVELOP continues a tradition of producing relevant project results, engaging diverse partners, and delivering useful end products to our communities, fellow federal agencies, and NASA. Our outstanding participants, science advisors, mentors, and partners continue to work together to create innovative, high quality deliverables. The program has evolved from one team of three students at NASA Langley studying "Practical Applications of Remote Sensing," to building capacity in more than 4,600 participants conducting over 900 projects and engaging with hundreds of partners over the last 20 years. DEVELOP has worked with a wide array of great institutions, including the National Park Service, National Oceanographic and Atmospheric Administration, United States Geological Survey, Bureau of Land Management, Mobile County Health Department in Alabama, Wise County in Virginia, Maricopa County in Arizona, NASA, and many more.

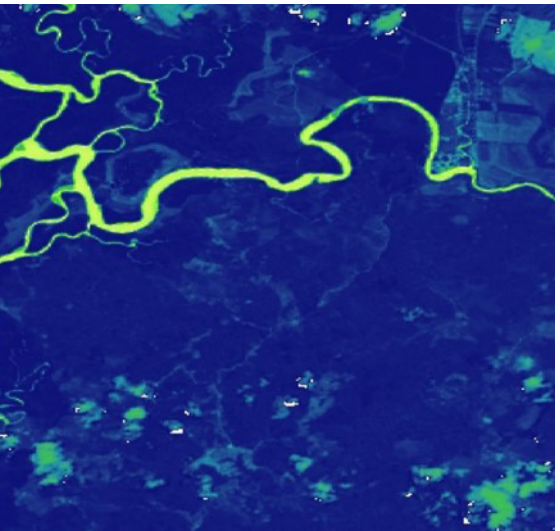
This past term, DEVELOP participants continued to demonstrate our broad national reach, from assessing wildfire risk in Alaska and quantifying sediment and marsh vulnerability in Massachusetts to analyzing site suitability for wind farms in New Mexico. Our efforts also spanned globally, including studying watershed health in Costa Rica, monitoring drought and precipitation patterns for coffee agriculture in Central America, and assessing water quality in Thailand. These are only a few examples of our global efforts, and we invite you to read about all 28 projects that were conducted this summer, by 100 DEVELOPers at 13 locations and working with 68 partners. We hope our projects provide you with an increased awareness of the many ways NASA science serves society.

We extend our sincere appreciation to our stakeholders for your support, which has directly contributed to our success. Your commitment and dedication to improve our planet is outstanding and made our success over the past 20 years possible.

Thank you for taking the time to learn more about DEVELOP.

With appreciation,
The DEVELOP National Program Office





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DEVELOP's **Vision:**

Shaping the future by integrating Earth observations into global decision making

About **DEVELOP**

DEVELOP addresses a wide array of environmental and public policy issues by partnering with a diverse group of end users to conduct interdisciplinary research projects that apply the lens of NASA Earth observations to community concerns around the globe.

DEVELOP is NASA's answer to society's need for rapid, reliable, and responsive application of the agency's Earth observations for data-driven decision making—from local to international, oceans to the atmosphere, and focused to expansive.

DEVELOP's dual-capacity building model cultivates skills and knowledge of NASA Earth observations in participants and partners alike. The program utilizes a rapid response and nimble program structure to expedite the project lifecycle through a short 10-week project timeline. This enables end users to experience timely benefits from sustainable tools and information specifically tailored to their decision-making needs.

About **Projects**

The foundation of DEVELOP is a portfolio of applied science projects focused on connecting NASA Earth science data to end users globally. Through 70-80 projects each year, DEVELOP engages with a broad array of current and potential users of NASA Earth observations—always striving for innovative, practical, and beneficial use.

As part of the Applied Sciences Program, DEVELOP works within the thematic application areas of Disasters, Health & Air Quality, Energy, Agriculture & Food Security, Ecological Forecasting, Urban Development, Water Resources, and Transportation & Infrastructure.

Each DEVELOP project is driven by a community concern that presents a decision-making need for one or more end user groups. DEVELOP partners with those end users to create tailored tools—based on NASA Earth observations—that can then be sustainably used to enhance the partner's decision making. In order to engage with as many end users as possible, DEVELOP conducts projects on a 10-week timeline, fostering rapid applied benefit.

About **Participants**

As a program with the goal of building broad capability to utilize NASA Earth observations for societal benefit, DEVELOP accepts participants with a variety of skills, backgrounds, and education levels.

Offering over 300 participant opportunities each year, the main requirements to be a DEVELOPer are a strong interest in Earth science and a passion for one's work to benefit society.

DEVELOPers fall into five categories: currently enrolled college students, recent graduates, early career professionals, transitioning career professionals, and active and recently transitioned U.S. military service members.

The program offers a unique opportunity for each individual to expand and enhance their personal and professional development in a challenging but rewarding environment.

About **Partners**

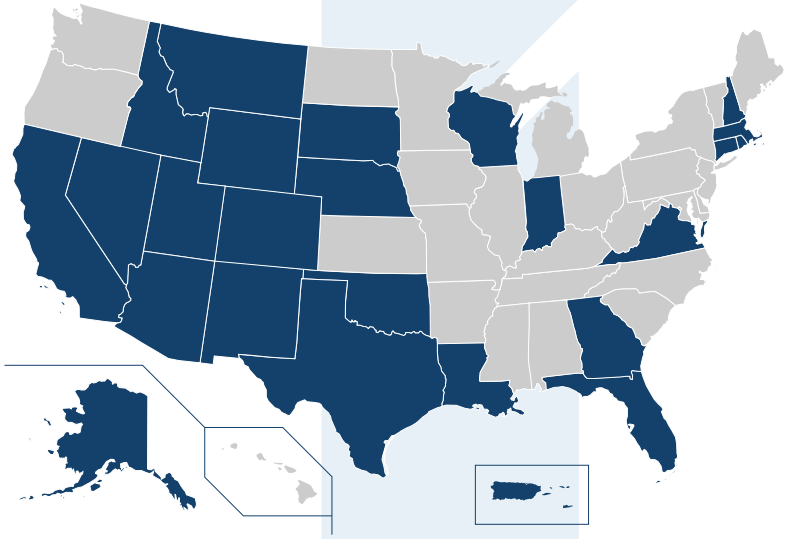
A wide variety of project partners are a vital ingredient in the DEVELOP model. Each year DEVELOP collaborates with over 100 organizations to generate and conduct projects that apply NASA Earth observations to decision-making processes around the globe.

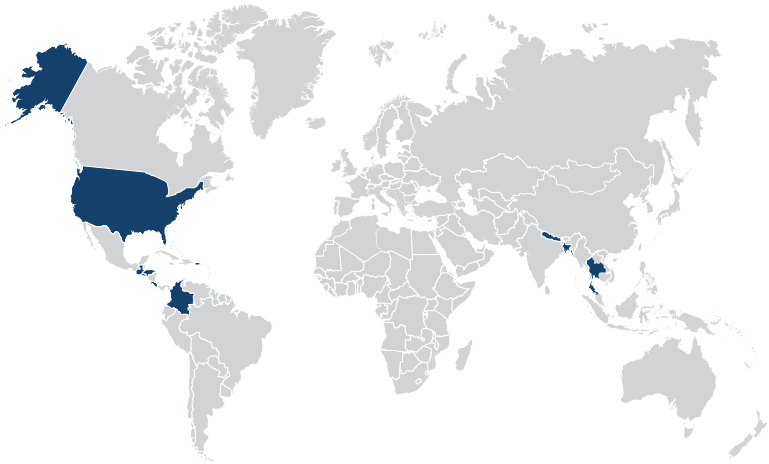
Partnerships often occur with local and state governments, regional consortiums, federal agencies, non-governmental and private organizations, academic institutions, and international governments and aid organizations.

By collaborating with DEVELOP, partners are introduced to NASA's Earth Science Division and its Earth observation resources. End users gain insight into satellite and airborne Earth observation capabilities and how they can augment and enhance their current decision-making practices. This provides potential cost and time savings, as well as the opportunity to engage with the future workforce, who will be well-versed in the use of NASA Earth observations.

2018 **Summer Term**

DEVELOP's 2018 summer term has been one of exciting collaborations with engaged partners in support of their decision-making needs. 100 DEVELOPers and 68 partners collaborated within the DEVELOP framework to conduct 28 rapid feasibility projects. These projects utilized NASA's Earth observations to monitor changes in the landscape that affect decision making and provide a synoptic view for understanding the Earth from the unique vantage point of space. Earth observations from 30 sensors, including data from 15 of NASA's spaceborne missions, were applied by the DEVELOP project teams to seven of the NASA Applied Sciences' National Application Areas: Agriculture & Food Security, Disasters, Energy, Ecological Forecasting, Health & Air Quality, Urban Development, and Water Resources.





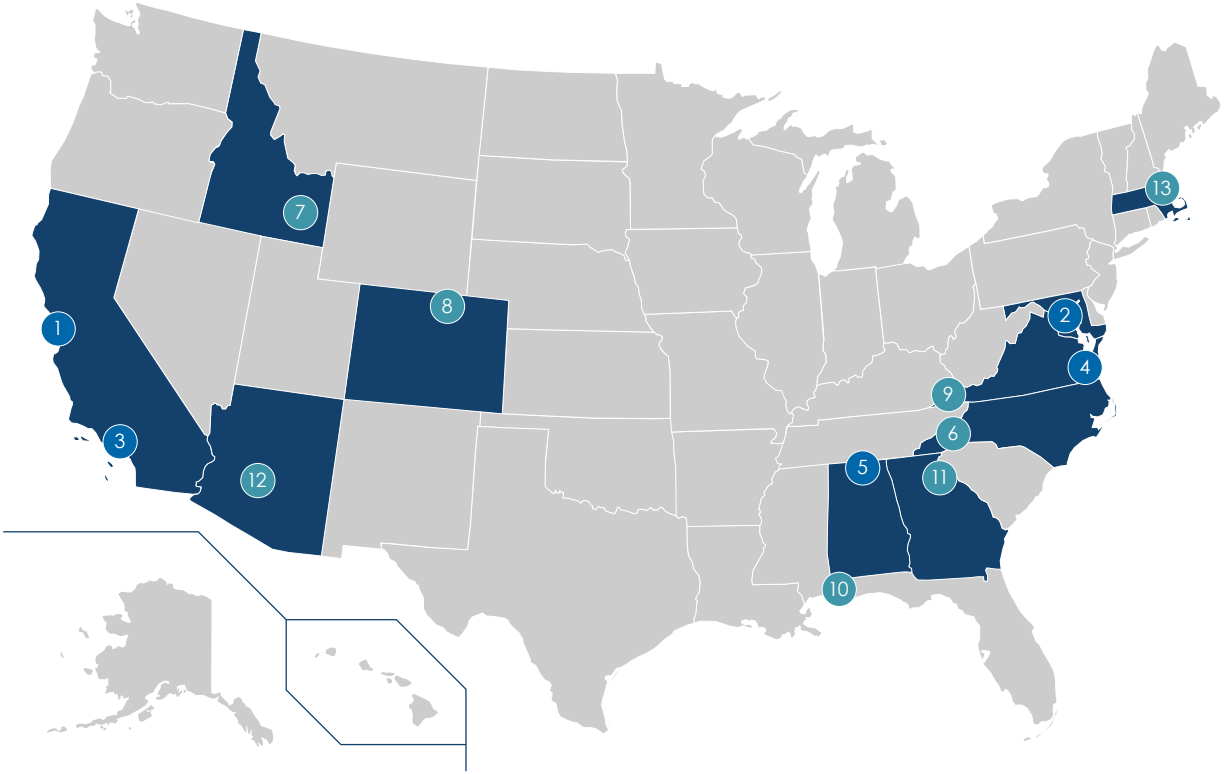
Partner organizations collaborating with DEVELOP represented a variety of sectors, including state, local and federal agencies, international governments, non-governmental organizations, academic institutions, and consortiums. This summer, DEVELOP collaborated with Groundwork USA, an environmentally-focused consortium between local communities, the U.S. Environmental Protection Agency, and the National Park Service on three projects focused on community concerns in urban areas. In addition, DEVELOP also supported the Group on Earth Observations' (GEO) AmeriGEOSS initiative by conducting five projects in the Americas addressing a variety of environmental topics including drought and agriculture, watershed health, and forest degradation.

NASA Center Locations

1. California – Ames
2. Maryland – Goddard
3. California – JPL
4. Virginia – Langley
5. Alabama – Marshall

Regional Locations

6. North Carolina – NCEI
7. Idaho – Pocatello
8. Colorado – Fort Collins
9. Virginia – Wise
10. Alabama – Mobile
11. Georgia – Athens
12. Arizona – Tempe
13. Massachusetts – Boston



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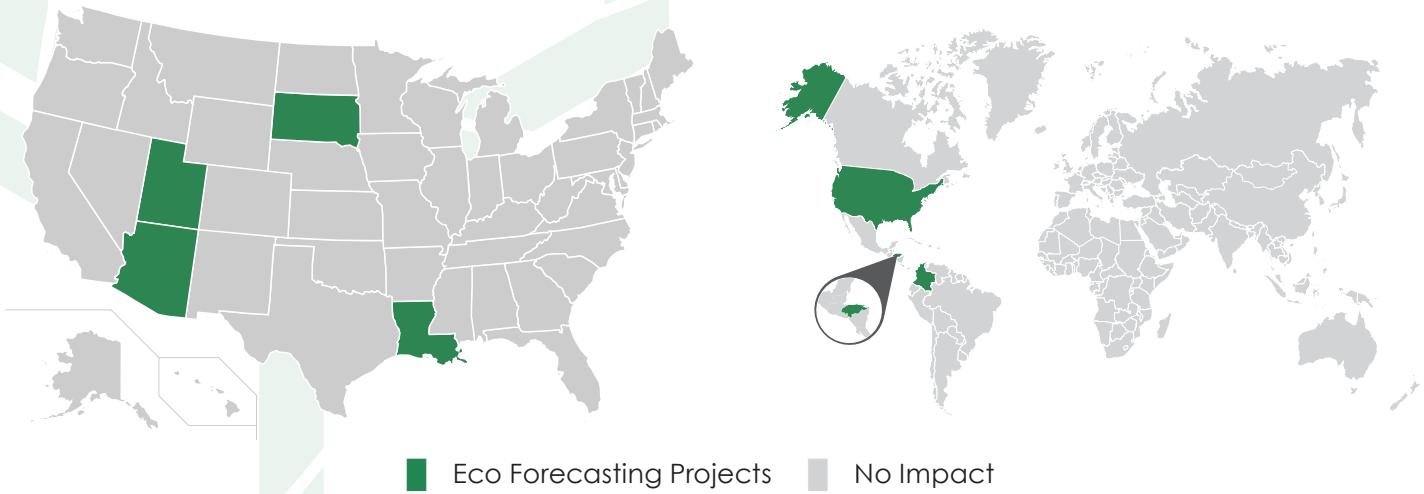
OVERVIEW

DEVELOP's Ecological Forecasting projects assist decision makers with access to science-based tools in order to understand and predict the impacts of environmental change on the ecosystems that support the existence of life on Earth. The projects apply NASA remote sensing and technologies to topics like conservation, habitat health and suitability, land use practices and planning, and invasive species. This summer, DEVELOP's Ecological Forecasting projects partnered with local and state governments, non-governmental organizations, federal agencies, and international organizations to provide reliable forecasts to improve natural ecosystem management.



PORTFOLIO

Glen Canyon Ecological Forecasting: Using NASA Earth Observations to Prioritize Locations for the Further Monitoring and Management of Cultural Resources in Glen Canyon National Recreation Area – *LaRC*

South Dakota Ecological Forecasting: Monitoring the Spread of Invasive Grasses and the Impacts on Grassland Management Practices in the Great Plains Using NASA Earth Observations and NOAA Climate Data Records – *NC*

Louisiana Ecological Forecasting: Monitoring and Predicting the Spread of the Roseau Cane Die-offs Connected to the Invasive Mealy Bug (*Nipponaclerda biwakoensis*) and Other Contributing Factors in the Mississippi River Delta Using NASA Earth Observations – *VA*

Honduras Ecological Forecasting: Utilizing NASA Earth Observations to Develop a Forest Change Detection Tool for Land Conservation in Honduras – *GA*

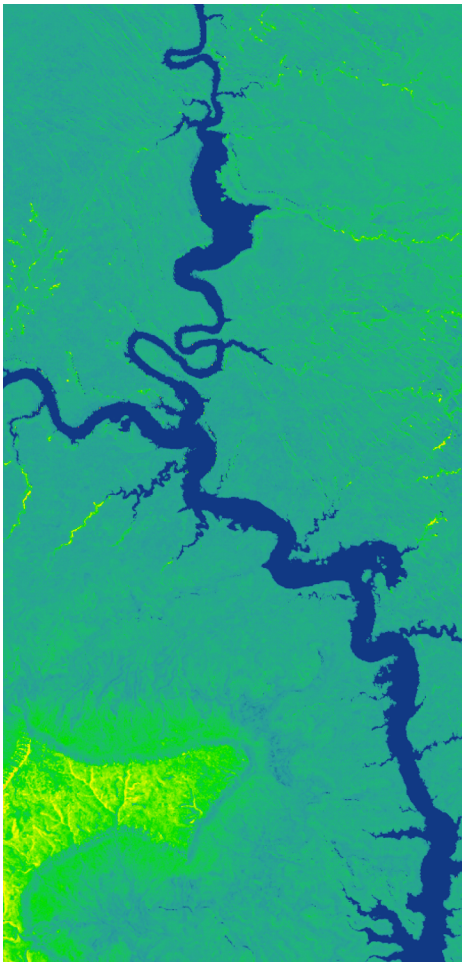
Colombia Ecological Forecasting: Validating the Effectiveness of the NASA Open Data Cube on Augmenting Deforestation Analysis in Colombia – *LaRC*

SENSORS

ALOS L-PALSAR
ALOS-2 L-PALSAR
AVHRR
Landsat 5 TM
Landsat 7 ETM+
Landsat 8 OLI
Sentinel-1 C-SAR
Sentinel-2 MSI

PARTNERS

Committee on Earth Observation Satellites
DOI, National Invasive Species Council Secretariat
Institute of Hydrology, Meteorology and Environmental Studies (Colombia)
Instituto de Conservación Forestal (Honduras)
National Park Service, Glen Canyon National Recreation Area
National Wildlife Federation
NOAA Regional Climate Services, Central Region
University of the Andes
USDA, Agricultural Research Service, High Plains Grasslands Research Station
Zamorano University



GLEN CANYON ECOLOGICAL FORECASTING

Using NASA Earth Observations to Prioritize Locations for the Further Monitoring and Management of Cultural Resources in Glen Canyon National Recreation Area

Virginia – Langley

TEAM: William Patrick Frier (Project Lead), Cecil Byles, Max Stewart
PARTNERS: National Park Service, Glen Canyon National Recreation Area
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI

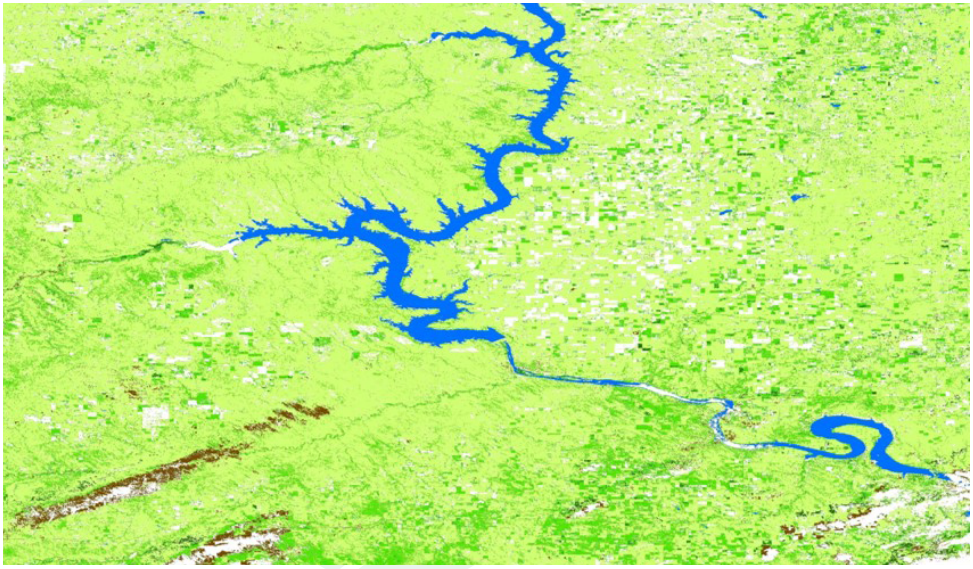
Glen Canyon National Recreation Area (NRA) contains a diverse suite of culturally and historically significant archaeological sites that are threatened by erosion and changing land cover dynamics. The National Park Service (NPS) is tasked with monitoring, studying, and preserving these archeological sites, many of which reside in extremely remote locations. At Glen Canyon NRA, perennial vegetation and cryptobiotic soil crusts help stabilize soils and mitigate erosion. The loss of such soil stabilizers is indicative of high erosion potential. This project calculated vegetation indices and generated a time series of vegetation and cryptobiotic soil crust maps across the entire extent of Glen Canyon NRA using Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), and Sentinel-2 Multispectral Instrument (MSI) data for the years 1995 to 2018. The project team then used multiple vegetation analyses from across the study period to provide an assessment of year-over-year loss and gain in stabilizing vegetation and cryptobiotic soil crusts. This approach allowed for a comprehensive assessment of vegetation and soil stabilization across a broad region that could not be assessed by traditional ground-based means. Finally, the team used these vegetation analyses as inputs into a predictive model and produced forecasted vegetation distribution maps through 2022. Land managers and archeologists at the NPS can use the results of this work to prioritize the monitoring and management of important archeological sites that could otherwise be lost to erosion.

SOUTH DAKOTA ECOLOGICAL FORECASTING

Monitoring the Spread of Invasive Grasses and the Impacts on Grassland Management Practices in the Great Plains Using NASA Earth Observations and NOAA Climate Data Records

North Carolina – NCEI

TEAM: Brooke Adams (Project Lead), Conor Mulderrig, Forest Kane Cook
PARTNERS: DOI, National Invasive Species Council Secretariat; NOAA Regional Climate Services, Central Region; USDA Agricultural Research Service, High Plains Grasslands Research Station
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 8 OLI, AVHRR



Invasive grass species, specifically B. tectorum (cheatgrass), B. japonicus (japanese brome), and Melilotus (sweet clover), have expanded out of the Great Basin and into the western Great Plains of the United States. Increased development and land use in western South Dakota have provided a gateway for these species to invade and dominate formerly native grasslands. This project evaluated the historic distribution of invasive species, by creating invasive species distribution maps on a county level for South Dakota from 1997-2018. Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) were used to classify regions of grassland and non-grassland in South Dakota. Invasive and native grasses were identified within the grassland regions using Earth Observations and phenological climate data records. Phenology variables from the NOAA Advanced Very High-Resolution Radiometer (AVHRR) climate data record included Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). Forwarn Phenology Parameter Products derived from MODIS also provided additional NDVI data. These phenology variables from AVHRR and Forwarn were studied to determine a method to distinguish between native and invasive grasses. The team validated the classification of native and invasive grasses using *in situ* data to cross reference and compare to the remote sensed data. This comparison also provided insight into the spatial and temporal completeness of the *in situ* data reporting in the area. Finally, the team used regression modeling to make future projections of land cover classification by county. The methods applied to our case study region of South Dakota will serve as a guide for historic and future invasive grass identification over the Great Plains region. The results will be used to inform local management practices and combat ecosystem threats, such as an increased risk of wildfire and an altered biomass of the region that impact cattle grazing patterns.

LOUISIANA ECOLOGICAL FORECASTING

Monitoring and Predicting the Spread of the Roseau Cane Die-offs Connected to the Invasive Mealy Bug *(Nipponaclerda biwakoensis)* and Other Contributing Factors in the Mississippi River Delta Using NASA Earth Observations

Virginia – Wise

TEAM: Jen Schellman (Project Lead), Michael Brooke, Beck Saults
PARTNER: National Wildlife Federation
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 8 OLI, Sentinel-2 MSI

The Roseau cane mealy bug (*Nipponaclerda biwakoensis*) is an invasive scale insect discovered in the United States during the 2016-2017 die-offs of Roseau cane (*Phragmites australis*) in the Mississippi River Delta, Plaquemines Parish, LA. Roseau cane stands stabilize sediment, protect against wave-action and storm surge, and provide critical habitat to wildlife. Roseau cane is the dominant vegetation type in the Mississippi River Delta and its loss will affect coastal marsh extent, shipping interests in the Mississippi River, and property owners along the lower Mississippi River Delta. The NASA DEVELOP Louisiana Ecological Forecasting team partnered with the National Wildlife Federation to use NASA Earth observations, including Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI), to monitor and assess the history of Roseau cane die-offs. These data, along with *in situ* observations and European Space Agency Sentinel-2 Multispectral Instrument (MSI) imagery, were input into the Software for Assisted Habitat Modeling (SAHM) to forecast and predict the vegetative health of the marsh to 2030. Normalized Difference Vegetation Index (NDVI) maps assessed yearly changes and overall trends throughout the study period to identify areas of the marsh most impacted by major disturbance events (e.g. hurricanes, storm surges, oil spills, etc.) elucidating critical areas of interest for mitigation and restoration planning. Modeling with SAHM indicated a continued threat to Roseau cane stands through 2030 as overall marsh health continues to decline and relative sea-level rise coupled with subsidence continues to raise water levels and increase saline conditions for marsh plants.

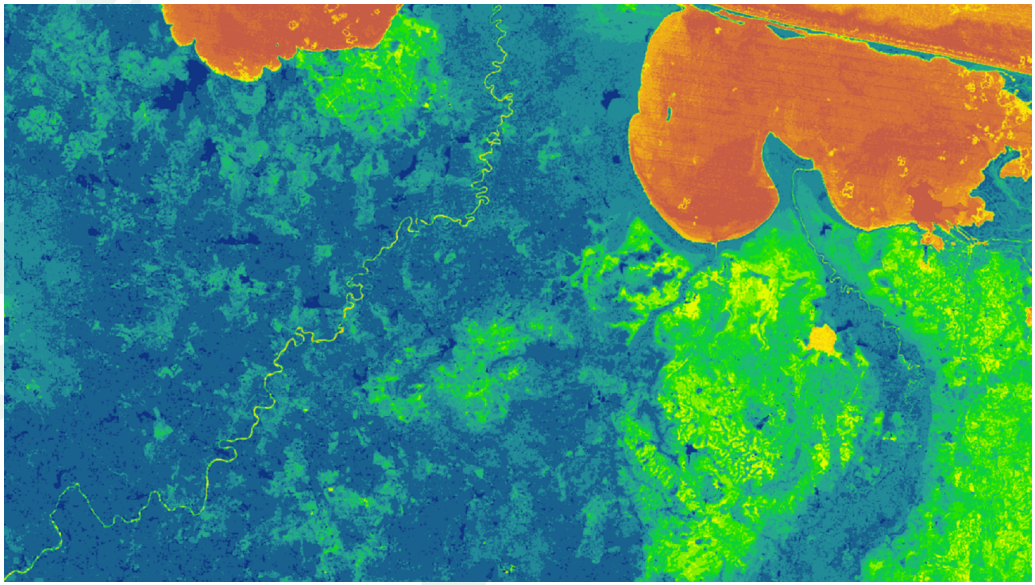
HONDURAS ECOLOGICAL FORECASTING

Utilizing NASA Earth Observations to Develop a Forest Change Detection Tool for Land Conservation in Honduras

Georgia – Athens

TEAM: Melanie Callihan (Project Lead), Emad Ahmed, Wei Xu, Austin Stone
PARTNERS: Instituto de Conservación Forestal (Honduras), Zamorano University
EARTH OBSERVATIONS: Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI

The Instituto de Conservación Forestal (ICF) in Honduras is in charge of managing and conserving millions of acres of public and privately-owned forest, including the pristine Río Plátano Biosphere Reserve. Although one of ICF's main goals is forest conservation, illegal deforestation in Río Plátano accounts for 11% of the total Honduran deforestation. These changes are devastating for the delicate ecosystem, endangered species, and to the indigenous population. The ICF currently has limited resources and staff to continuously monitor and assess forest change and local disturbances. NASA DEVELOP partnered with ICF to create a user-friendly Forest Change Detection Tool in Google Earth Engine API. The team analyzed various data sets, including Landsat 7 ETM+, Landsat 8 OLI, and Sentinel-2 MSI, and investigated methods to detect small to moderate forest disturbances. Additionally, the team used *in situ* data provided by ICF to cross-reference pre-existing forest changes. The Google Earth Engine API user interface displays changes in the Normalized Difference Vegetation Index (NDVI), Relative Greenness, and the Enhanced Vegetation Index (EVI) to detect the area with a high probability of deforestation. This tool will create a near cloud-free composite used to produce a map of deforestation across the area. The tool creates monthly results that can be used by ICF scientists to aid in conservation and mitigation efforts.

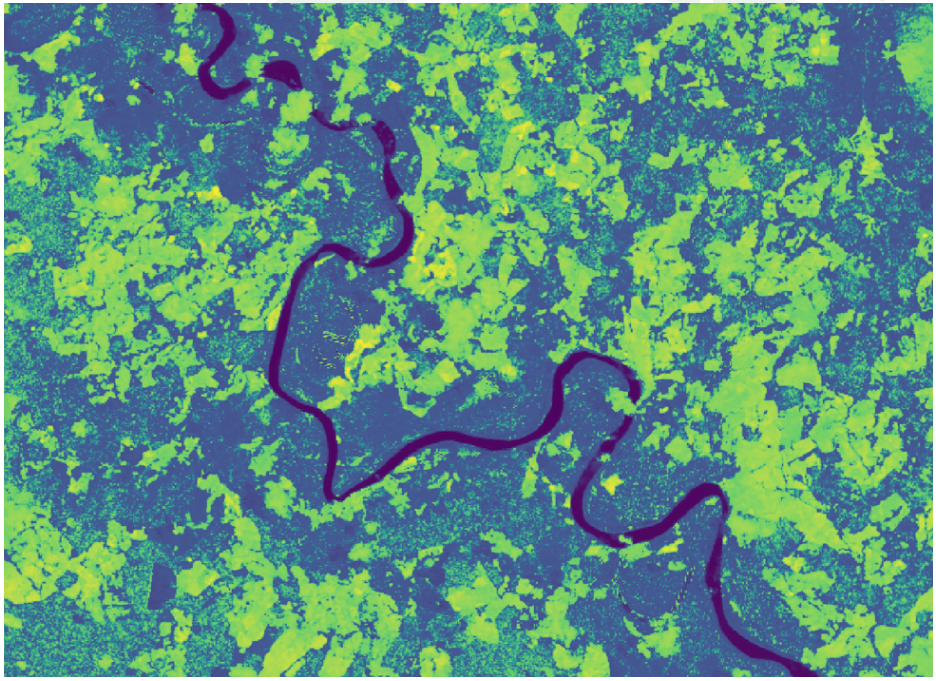


COLOMBIA ECOLOGICAL FORECASTING

Validating the Effectiveness of the NASA Open Data Cube on Augmenting Deforestation Analysis in Colombia

Virginia – Langley

TEAM: Ryan Theurer (Project Lead), William Crowley, Megan Link, Shaifali Prajapati, Thomas Richards
PARTNERS: Institute of Hydrology, Meteorology and Environmental Studies (Colombia); University of the Andes; Committee on Earth Observation Satellites
EARTH OBSERVATIONS: Landsat 7 ETM+, Landsat 8 OLI, Sentinel-1 C-SAR, ALOS L-PALSAR, ALOS-2 L-PALSAR



Colombia contains a variety of endemic species, making it one of the most biodiverse regions in the world. Due to a recent peace treaty between the Revolutionary Armed Forces of Colombia (FARC) and the Colombian government, Colombia's rainforest has become more vulnerable to illegal deforestation. This is especially true within the department of Caquetá, located in the southwestern portion of the country. With satellite data becoming more widely available, the Committee on Earth Observation Satellites (CEOS), working directly with the Colombian Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), has developed the Colombian Data Cube. Using compiled images from Landsat 7 Enhanced Thematic Mapper (ETM+), Landsat 8 Operational Land Imager (OLI), Advanced Land Observing Satellite (ALOS), and Sentinel-1 Synthetic Aperture Radar (SAR), the Colombian Data Cube allows for access to analysis ready satellite imagery without large downloads or processing requirements. The NASA DEVELOP team, working with the University of Andes and IDEAM, aimed to utilize the Colombia Data Cube by refining land change algorithms and vegetation indices to validate field data provided by IDEAM, as well as optimizing their respective interfaces. The results of this project will be useful to IDEAM's mission to help monitor deforestation hotspots and assist their government with developing strategies to combat deforestation. Additionally, the University of the Andes can use this project as an educational tool to teach students about the Colombian Data Cube and its many applications, including deforestation. This project will also be valuable as a case study for other countries looking to develop the Open Data Cube and apply important NASA data to local issues.

OVERVIEW

DEVELOP's Agriculture & Food Security projects promote innovative use of NASA satellite data, model products, and scientific findings to assist with agricultural monitoring and management. The projects focus on topics associated with the production and availability of food products around the globe. This summer, DEVELOP's Agriculture projects partnered with non-governmental organizations, federal agencies, regional consortiums, and academic institutions to support agricultural management, policy making, and global food security.

PORTFOLIO

New England Agriculture & Food Security: Incorporating NASA Earth Observations into an Assessment Tool to Identify Correlations between Factors Associated with Bee Health – *GSFC*

North Dakota & Georgia Agriculture & Food Security II: Using NASA Earth Observations and Synthetic Aperture Radar to Enhance Crop Classification Accuracy from Ground Surveys to Larger Scales in the Long Term Agroecosystem Research Network – *LaRC*

Central America Agriculture & Food Security: Utilizing NASA Earth Observations and NOAA Climate Data Records to Monitor Drought and Precipitation Patterns for Coffee Agriculture Management in Guatemala, Honduras, and El Salvador – *NC*

SENSORS

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GPM IMERG
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Landsat 8 OLI
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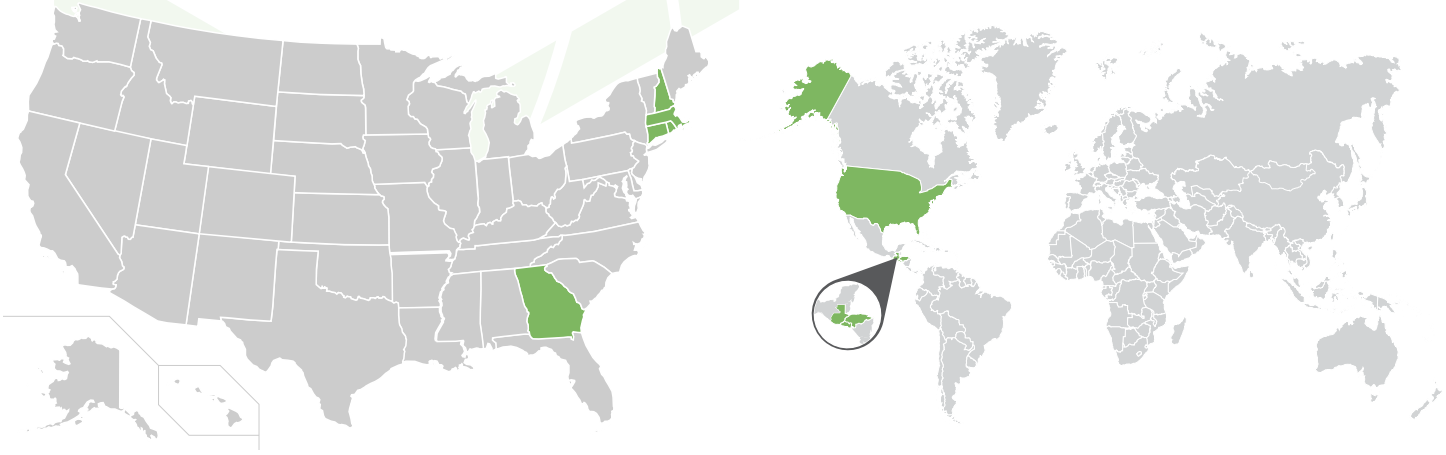
Sentinel-2 MSI
SMAP
SRTM
Terra MODIS



Agriculture & Food Security Projects No Impact

PARTNERS

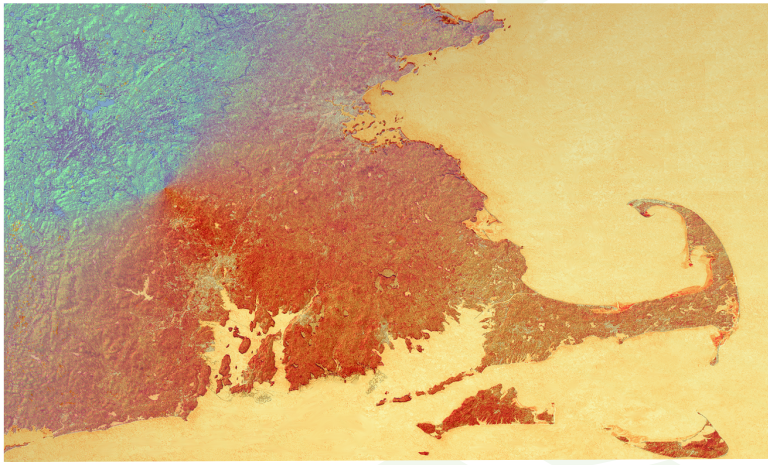
BeekeepingIO
Conservation International
International Center for Tropical Agriculture (CIAT)
The Bee Informed Partnership, Inc.
University of Maryland, vanEngelsdorp Honey Bee Research Lab
Urban Beekeeping Laboratory and Bee Sanctuary, Inc.
USAID, Feed the Future Alliance for Resilient Coffee
USDA, Agricultural Research Service, Northern Great Plains Research Laboratory
USDA, Agricultural Research Service, Southeast Watershed Research Laboratory
USDA, National Agricultural Statistics Service, Spatial Analysis Research Section

NEW ENGLAND AGRICULTURE & FOOD SECURITY

Incorporating NASA Earth Observations into an Assessment Tool to Identify Correlations between Factors Associated with Bee Health

Maryland – Goddard

TEAM: Jeremy Rapp (Project Lead), Victor Lenske, Eyob Solomon, Ryan Young
PARTNERS: Urban Beekeeping Laboratory and Bee Sanctuary, Inc.; The Bee Informed Partnership, Inc.; University of Maryland, vanEngelsdorp Honey Bee Research Lab; BeekeepingIO
EARTH OBSERVATIONS: Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI, SMAP, SRTM, GPM IMERG



Honey bees (*Apis mellifera*) are a vital component to global agriculture, however, over recent decades their populations have been declining. Honey bees provide pollination services to more than 90% of the leading 107 global crop types, and without them it is estimated that 5-8% of global production would be lost. Anthropogenic drivers such as land use change, habitat fragmentation, existence of vegetative land cover (native or agricultural), climate, and the use of fertilizers and pesticides, contribute to honey bee health complications and annual population losses. Also, the presence of invasive pests (Varroa mite [*Varroa destructor*], tracheal mites, and small hive beetles) and pathogens (e.g. *Nosema*) further compound these issues. Leveraging citizen science, NASA Earth observations, and nationally reported statistics, a comprehensive methodology was developed to illuminate environmental variables that are linked to honey bee prosperity in the New England region of the United States from 2015 to 2018. The team created a tool harnessing Google Earth Engine to incorporate *in situ* data collected from local hives and apiaries and biophysical variables, such as vegetation indices, and soil moisture collected from satellite data. The tool will aid in the development of historical trends in honey bee welfare and will provide insight for better understanding of bee habitat suitability conditions.

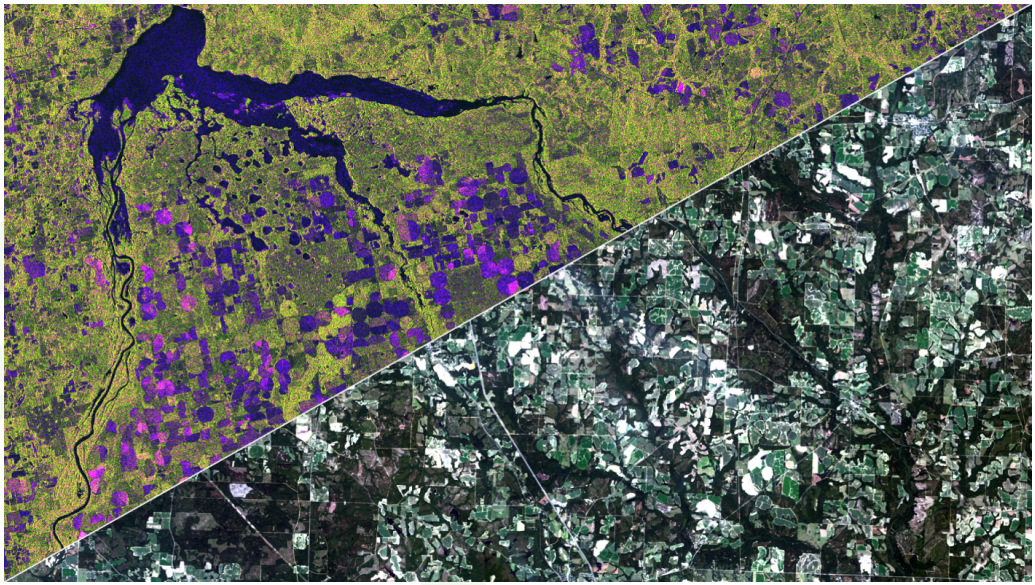
NORTH DAKOTA & GEORGIA AGRICULTURE & FOOD SECURITY II

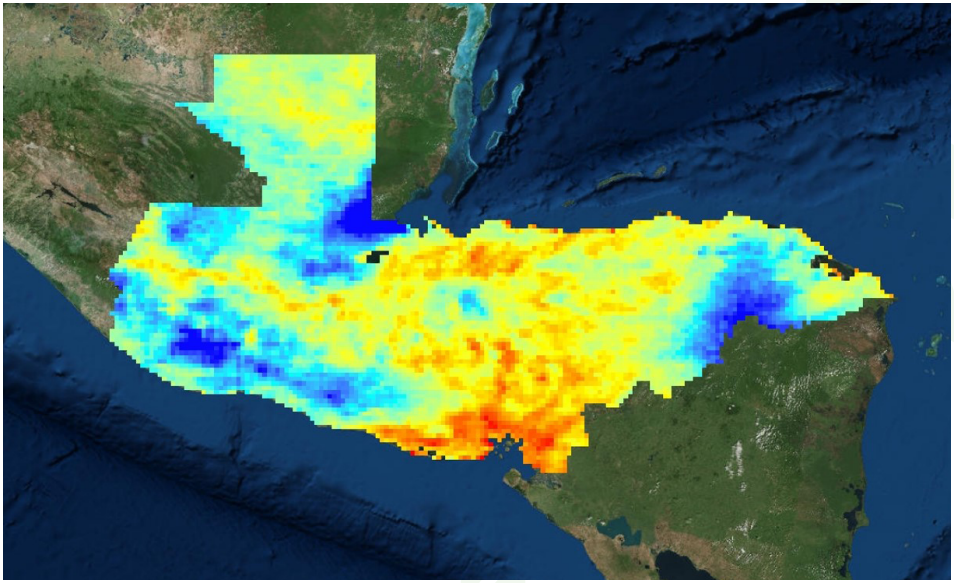
Using NASA Earth Observations and Synthetic Aperture Radar to Enhance Crop Classification Accuracy from Ground Surveys to Larger Scales in the Long Term Agroecosystem Research Network

Virginia – Langley

TEAM: Connor Holzmann (Project Lead), Jared Belvin, Hannah Mosiniak
PARTNERS: USDA, Agricultural Research Service, Southeast Watershed Research Laboratory; USDA, Agricultural Research Service, Northern Great Plains Research Laboratory; USDA, National Agricultural Statistics Service, Spatial Analysis Research Section
EARTH OBSERVATIONS: Landsat 7 ETM+, Landsat 8 OLI, Sentinel-1 C-SAR, Sentinel-2 MSI

Each year, the United States Department of Agriculture (USDA) releases a Cropland Data Layer (CDL) that serves as a nationwide classification system and statistical service for the United States agriculture industry. The CDL is compiled using Landsat 8 Optical Land Imager (OLI) and Sentinel-2 Multispectral Imager (MSI) data, among other sources. This optical satellite imagery is susceptible to temporal restrictions and inclement weather, which limits the number of scenes available each year and impedes analysis. As a combined effort between the USDA's Agricultural Research Service (ARS), National Agricultural Statistics Service (NASS), and NASA DEVELOP, this project explored the effectiveness of Synthetic Aperture Radar (SAR) to accurately classify crops. SAR has both day and night time capabilities as well as the ability to pierce cloud cover, which will increase data availability when compiling the CDL. For the 2016 and 2017 growing seasons, multispectral and SAR imagery were compared for test sites near Tifton, GA. A time series of SAR imagery was created to show that different crop types exhibit distinct backscatter signatures, allowing for more refined crop classification.





CENTRAL AMERICA AGRICULTURE & FOOD SECURITY

Utilizing NASA Earth Observations and NOAA Climate Data Records to Monitor Drought and Precipitation Patterns for Coffee Agriculture Management in Guatemala, Honduras, and El Salvador

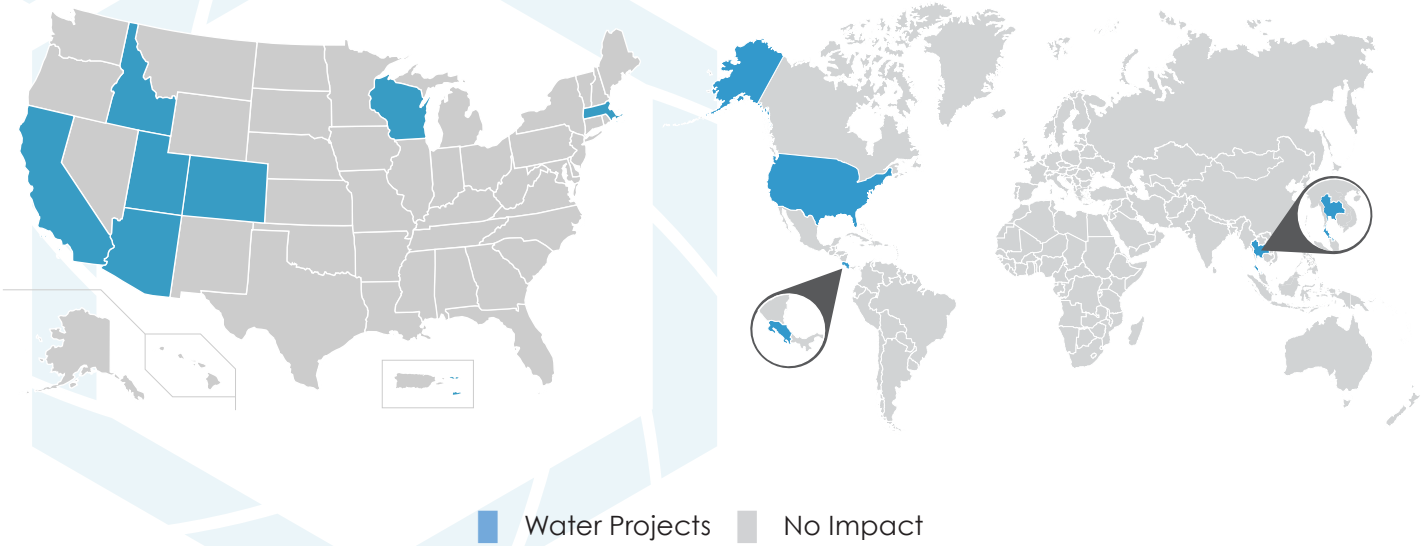
North Carolina – NCEI

TEAM: Alexa Kennedy (Project Lead), Danielle Curtis, Andrew Shannon, Meghan Russell
PARTNERS: USAID, Feed the Future Alliance for Resilient Coffee; International Center for Tropical Agriculture; Conservation International
EARTH OBSERVATIONS: Terra MODIS, AVHRR

In November of 2017, Guatemala, Honduras, and El Salvador produced over 12 million kg of coffee combined, accounting for half of Central America's total output. However, in the last 20 years Central America has experienced crop declines between 50% and 90%, due largely to drought and irregular rainfall. These irregularities in the weather patterns have increased coffee crop vulnerability to diseases, such as coffee rust, as well as significantly decreased the productivity and overall quality of coffee crops. In particular, the 2015-2016 El Niño spurred a drought lasting for two years, the most severe drought in Central America in recent history. This project partnered with the United States Agency for International Development (USAID) Feed the Future Alliance for Resilient Coffee, International Center for Tropical Agriculture, and Conservation International to produce detailed analyses of precipitation anomalies for next generation coffee farmers, co-ops, and regional planners. The team created an atlas of El Niño-Southern Oscillation (ENSO) phases using the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), and a time-series analysis of the frequency and intensity of historical drought periods using the Scaled Drought Condition Index (SDCI). Analyses will be used to assist partners in early warning detection by observing anticipated rainfall conditions aiding in determining adaptive management options.

OVERVIEW

DEVELOP's Water Resources projects address concerns and decision processes that are related to water availability, water forecasting, and water quality. The goal of the Water Resources theme is to apply NASA satellite data to improve the decision support tools of user groups that manage water resources. This summer, DEVELOP's Water Resources projects partnered with international organizations, local and federal agencies, and non-governmental organizations to improve water management around the globe.



SENSORS

Aqua MODIS
GPM DPR
GPM GMI
Landsat 5 TM
Landsat 7 ETM+
Landsat 8 OLI
PERSIANN-CDR
PlanetScope
Sentinel-2 MSI
SMAP
SMAP/Sentinel-1 C-SAR
SRTM
Terra ASTER
Terra MODIS
TRMM PR
TRMM TMPA

PARTNERS

Asian Disaster Preparedness Center
Asian Institute of Technology
Bangkok Metropolitan Administration
California Department of Fish and Wildlife
College of Charleston
Groundwork USA, Groundwork Milwaukee
Grunion Greeters Project
Idaho Department of Fish and Game, Southeast Regional Office
Idaho National Laboratory
Kent State University
Long Term Ecological Research Network, Plum Island Ecosystems LTER
NASA SERVIR Science Coordination Office
National Park Service, Capitol Reef National Park
National Park Service, Grand Canyon National Park
National Park Service, Inventory & Monitoring Division, Northern Colorado Plateau Network
National Park Service, Northern Colorado Plateau Network
National Park Service, Water Resources Division
Osa Conservation
Royal Thai Embassy, Office of Science & Technology
University of the Virgin Islands
Upper Colorado River Basin Endangered Fish Recovery Program
US Fish and Wildlife Service, Eastern Idaho Field Office
US Fish and Wildlife Service, Parker River National Wildlife Refuge
US Virgin Islands Department of Planning and Natural Resources, Coastal Zone Management
USDA, Agricultural Research Service, Northwest Watershed Research Center
USDA, Natural Resources Conservation Service, Pocatello Field Office
USGS, Fort Collins Science Center, Ecosystem Dynamics Branch
USGS, Woods Hole Coastal and Marine Science Center

PORTFOLIO

Grand Canyon Water Resources: Employing NASA Earth Observations to Model Availability of Ephemeral Water Sources and Vegetation Change in Support of a USGS Feasibility Assessment and Management Strategy of Bison – *CO*
Utah & Colorado Water Resources: Designing a Modeling User Interface Incorporating Landsat to Monitor Changes in Riparian Vegetation and Endangered Fish Habitat – *CO*
Idaho Water Resources: Estimating Soil Moisture in Semi-arid Sagebrush Steppe Utilizing NASA Earth Observations – *ID*
Lake Michigan Water Resources: Utilizing NASA Earth Observations and Community Science to Detect and Map the Displacement of *Cladophora* along the Milwaukee County Shoreline – *ARC*
Chao Phraya Water Resources: Assessing Water Quality in Thailand's Chao Phraya Watershed through Modeling Sediment Concentration and Urban Footprint – *MSFC*
Osa Peninsula Water Resources II: Utilizing NASA Earth Observations to Evaluate Effects of Land Use Change on Watershed Health and Carbon Sequestration in the Osa Peninsula, Costa Rica – *GA*
Plum Island Estuary Water Resources II: Employing Remote Sensing Techniques to Quantify Sediment Supply and Evaluate Marsh Vulnerability in the Plum Island Estuary – *MA*
Southern California Water Resources II: Predicting Grunion Migration Patterns and Spawning Areas in Response to Changes in California's Oceans – *JPL*
US Virgin Islands Water Resources: Analyzing Historical Hurricane Influences on Coastal Water Quality and their Impact to Marine Ecosystems – *ARC*
Fremont River Basin Water Resources II: Water Availability Assessment from Annual Snow Cover in the Fremont River Basin Based on NASA Earth Observations and *In Situ* Data – *VA*

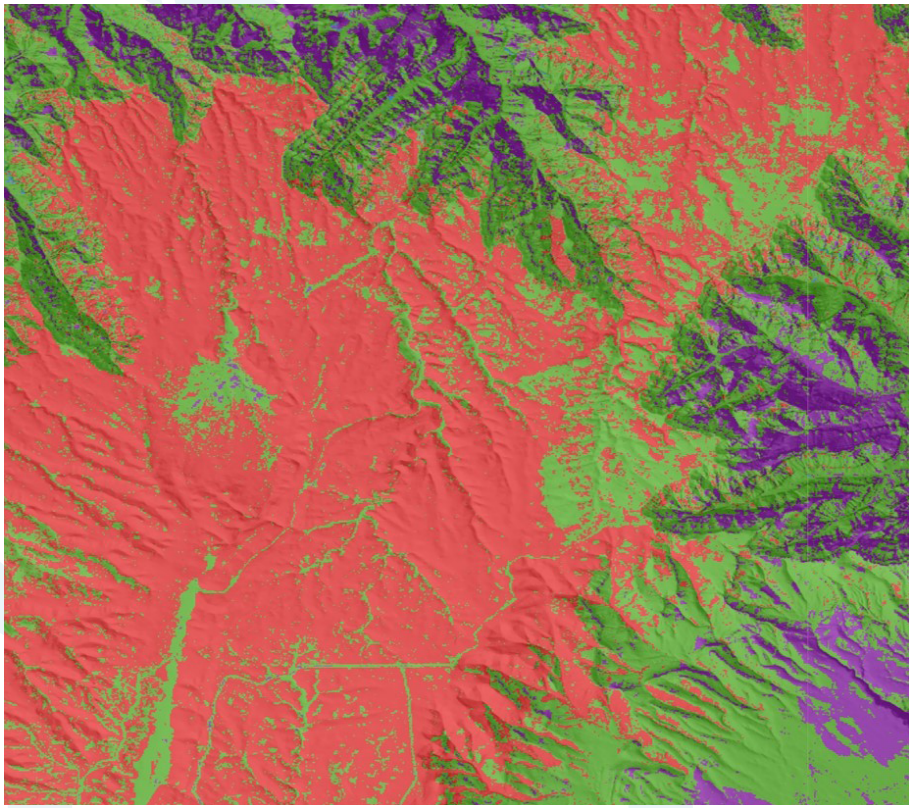
GRAND CANYON WATER RESOURCES

Employing NASA Earth Observations to Model Availability of Ephemeral Water Sources and Vegetation Change in Support of a USGS Feasibility Assessment and Management Strategy of Bison

Colorado – Fort Collins

TEAM: Jillian LaRoe (Project Lead), Timothy Mayer, Shaunie Rasmussen, Mikhail Schee, Griffin Shelor
PARTNERS: National Park Service, Grand Canyon National Park; USGS, Fort Collins Science Center Ecosystem Dynamics Branch
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI

The United States Geological Survey (USGS) and National Park Service (NPS) are concerned by the increasing Kaibab Plateau bison population on the North Rim of Grand Canyon National Park (GRCA). Currently, within the park's boundaries, the bison have no predators and hunting is prohibited, resulting in an increasing bison population. This growing population has led to significant impacts on resources such as vegetation, water resources, soils, and archaeological sites from extensive grazing, trampling, and wallowing behavior. Wallowing, or the act of bathing in dust or loose soil to deter insects, is one of the chief concerns of the NPS because continuous wallowing slows the recovery of vegetation in arid environments. The NPS is tasked with sustaining the health of the park for future generations, but there is limited information available to quantify the impacts of bison. This study utilized NASA Earth observation data from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), Landsat 8 Operational Land Imager (OLI), and the European Space Agency's Sentinel-2 MultiSpectral Instrument (MSI) to analyze the changes in vegetation and water resources before and after intensive bison activity. Shuttle Radar Topography Mission (SRTM) version 3 data were paired with additional spectral information to model impacted resources for comparison with potential bison distribution. Final maps of water availability, vegetation change, and potential bison movement corridors will be used by the USGS and NPS to inform herd population management efforts and site level restoration.

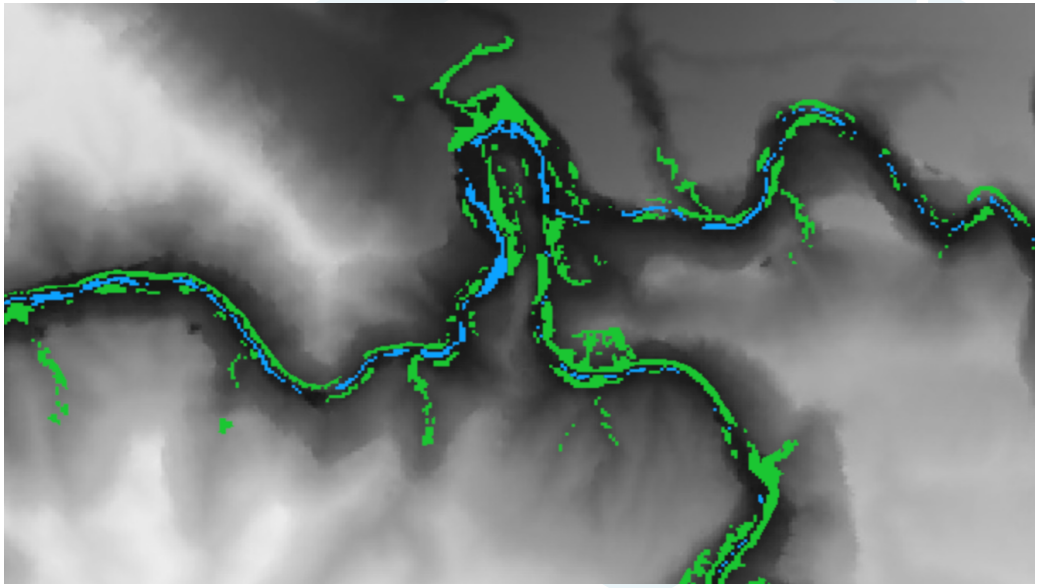


UTAH & COLORADO WATER RESOURCES

Designing a Modeling User Interface Incorporating Landsat to Monitor Changes in Riparian Vegetation and Endangered Fish Habitat

Colorado – Fort Collins

TEAM: Margaret Mulhern (Project Lead), Daniel Carver, Kristen Dennis, Nathaniel Penrod
PARTNERS: National Park Service, Water Resources Division; National Park Service, Inventory & Monitoring Division, Northern Colorado Plateau Network; Upper Colorado River Basin Endangered Fish Recovery Program
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI, SRTM



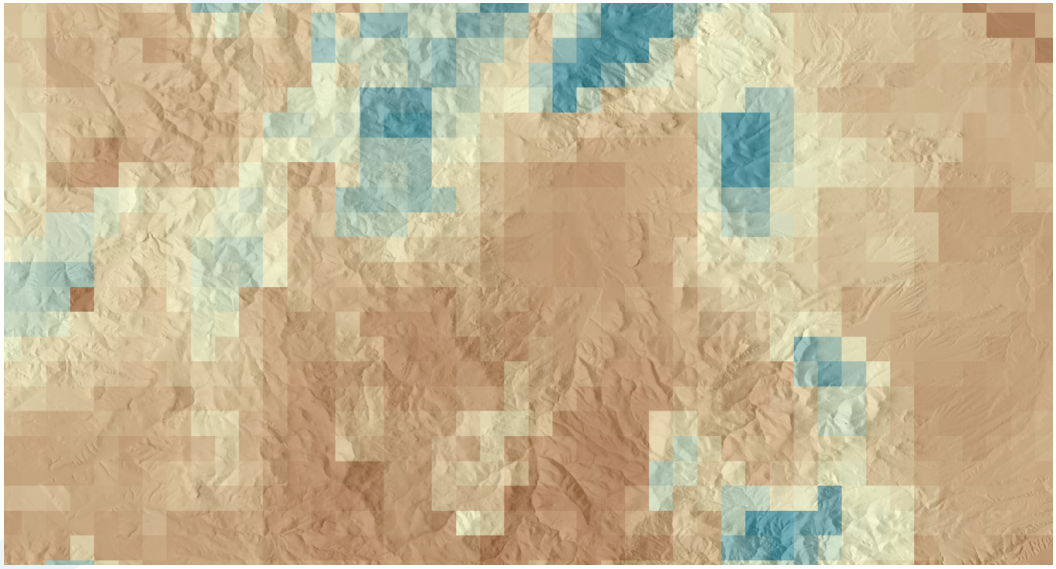
Since the completion of the Flaming Gorge Dam in 1964, artificial flow releases along the Green River have promoted channel narrowing and encouraged non-native vegetation encroachment into the active stream channel. These changes in the Green River's flow regime have reduced the backwater habitat of four native endangered fish species: the Colorado pikeminnow (*Ptychocheilus lucius*), Razorback Sucker (*Xyrauchen texanus*), Humpback Chub (*Gila cypha*), and Bonytail (*Gila elegans*). To promote population recovery, this project developed the River Morphology Evaluation Toolbox (RMET), a Google Earth Engine (GEE) tool, to more efficiently and cost-effectively monitor changes in vegetation and hydrology across large spatial and temporal scales. Using imagery collected from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Shuttle Radar Topography Mission (SRTM), and Sentinel-2 Multispectral Instrument (MSI) satellites, the team used the normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), modified normalized difference water index (MNDWI), and normalized difference water index (NDWI) to detect landcover changes. Trends in spectral index changes over user-selected focal years and the magnitudes of those changes were isolated and visualized through RMET. The project partners at the National Park Service and the Upper Colorado River Basin Endangered Fish Recovery Program will use RMET to identify potential sites where changes in riparian vegetation and the active stream channel may have reduced fish habitat to make more informed recommendations for flow releases from the Flaming Gorge Dam.

IDAHO WATER RESOURCES

Estimating Soil Moisture in Semi-arid Sagebrush Steppe Utilizing NASA Earth Observations

Idaho – Pocatello

TEAM: Ian Lauer (Project Lead), Dane Coats, Leah Kucera, Zach Sforzo, Madi Broddle
PARTNERS: US Fish and Wildlife Service, Eastern Idaho Field Office; Idaho Department of Fish and Game, Southeast Regional Office; USDA, Natural Resources Conservation Service, Pocatello Field Office; Idaho National Laboratory; USDA, Agricultural Research Service, Northwest Watershed Research Center
EARTH OBSERVATIONS: GPM GMI, SMAP, SMAP/Sentinel-1 C-SAR, Terra MODIS



Soil moisture is a critical component of ecosystem health, particularly in semi-arid landscapes where seasonal and infrequent precipitation is one of the primary controls on vegetative health. Current land management practices of soil moisture data collection rely on costly and time-consuming field sampling or on extensive modeling. The introduction of remotely sensed soil moisture measurements from NASA Earth observations (EO) will provide low-effort, high spatio-temporal coverage datasets for management agencies such as our primary partners at the US Fish and Wildlife Service (USFWS). Validating remotely-sensed data with field observations from Reynolds Critical Experimental Watershed (RCEW) in Idaho will increase the confidence in remotely sensed soil moisture data. This project evaluated methods for monitoring soil moisture in semi-arid ecosystems using data from NASA Soil Moisture Active Passive (SMAP) sharpened with European Space Agency (ESA) Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR) backscatter, Global Precipitation Measurement (GPM), Terra Moderate Resolution Imaging Spectroradiometer (MODIS) derived Normalized Difference Vegetation Index (NDVI), and modeled soil moisture from TopoFire for the period between December 2016 to July 2018. The Idaho NASA DEVELOP team created useful maps and established a workflow to allow land managers to easily access and visualize soil moisture in their area of interest. Linear regression analysis was used to quantify correlations between soil moisture, precipitation, and vegetation health. Preliminary correlations between SMAP and *in situ* soil moisture were positive at all sites, but results fell into three categories: 60% had a moderate correlation at good confidence, 25% had a high correlation at high confidence, and 15% had a low correlation at low confidence.

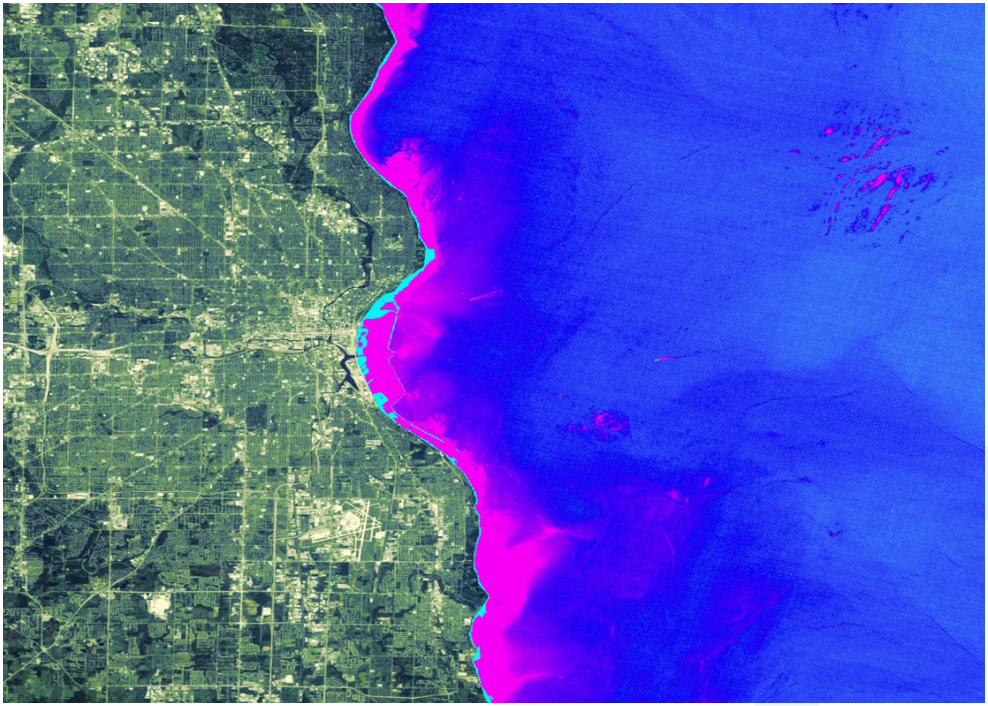
LAKE MICHIGAN WATER RESOURCES

Utilizing NASA Earth Observations and Community Science to Detect and Map the Displacement of *Cladophora* along the Milwaukee County Shoreline

California – Ames

TEAM: Jerrold Acdan (Project Lead), Steven Chao, Lawrence Fujiwara, Ella Golovey
PARTNERS: Groundwork USA, Groundwork Milwaukee
EARTH OBSERVATIONS: Aqua MODIS, Landsat 8 OLI

Although *Cladophora* is naturally occurring and nontoxic, the accumulation and decay of this green macroalgae creates salient socioeconomic issues for communities situated along the shoreline of Lake Michigan. When *Cladophora* washes ashore and decays, it creates unaesthetic and unpleasant smelling beaches, potentially endangering public health and threatening the local tourism economy. Furthermore, decaying *Cladophora* promotes the growth of toxic bacteria, which can impact organisms that come into contact with it. In collaboration with Groundwork Milwaukee, the 2018 NASA DEVELOP Lake Michigan Water Resources team created *Cladophora* Habitat Suitability and Washup Predictive Maps to identify areas where the algae grows and predict where it will most likely come ashore. These maps were created using Landsat 8 Operational Land Imager (OLI) and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) imagery of Lake Michigan near Milwaukee, WI, from June to September for the years 2016 and 2017. The results of this project will be validated during the fall 2018 DEVELOP term using *in situ* data of *Cladophora* sightings collected by Groundwork Milwaukee using an ArcGIS Collector App. To encourage community involvement, the team developed a project story map and provided Groundwork Milwaukee with content for their community science social media campaign that highlights the significance of this project while informing members of the general public about how they can contribute to cleanup efforts. These products will allow local organizations such as Groundwork Milwaukee to identify, monitor, and predict the movement of *Cladophora* and allocate cleanup resources more efficiently along the shores of Lake Michigan.

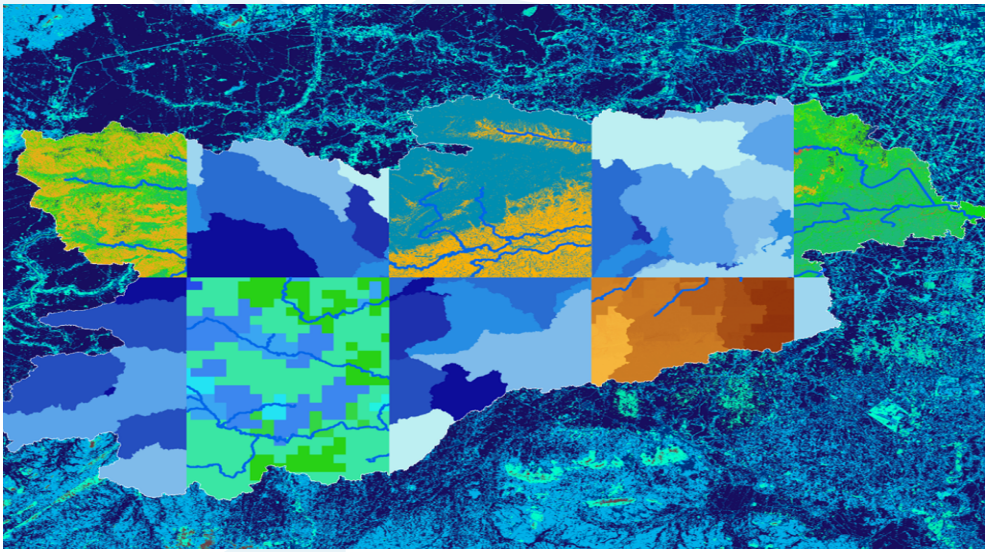


CHAO PHRAYA WATER RESOURCES

Assessing Water Quality in Thailand's Chao Phraya Watershed through Modeling Sediment Concentration and Urban Footprint

Alabama – Marshall

TEAM: Kathrene Garcia (Project Lead), Matthew Preisser, Claire Nauman
PARTNERS: Bangkok Metropolitan Administration; Asian Institute of Technology; Royal Thai Embassy, Office of Science & Technology; Asian Disaster Preparedness Center; NASA SERVIR Science Coordination Office
EARTH OBSERVATIONS: SRTM, TRMM TMPA



The Chao Phraya River and surrounding watershed has seen an extensive increase in urban development in the last century, while simultaneously experiencing significant degradation in water quality. Covering 30% of Thailand, the Chao Phraya watershed encompasses rural areas and major metropolitan centers, including Bangkok. The poorest water quality is found in the southernmost reaches of the river, which directly flows through the administrative capital. Due to rising concerns from the Bangkok Metropolitan Administration (BMA) and the Asian Institute of Technology (AIT), this study identifies locations to prioritize watershed remediation efforts. Using the Tropical Rainfall Measuring Mission (TRMM) Multi-Satellite Precipitation Analysis (TMPA) and Shuttle Radar Topography Mission (SRTM) datasets as inputs, this study applied the Soil and Water Assessment Tool (SWAT) to model the change in water quality over 5-year increments from 2003-2017. The change in water quality, defined as sediment concentration, was analyzed in comparison with the historical changes in the urban footprint. Additionally, a regression analysis was completed to determine the potential relationship between urbanization and sediment concentrations. The team found that the greatest increases in sediment contributions occurred in the upper and middle sub-basins of the watershed. No correlation was found between percent change in urbanization and percent change in sediment contribution from 2003-2017, suggesting that urban land cover change does not directly impact sediment loads. The results from this analysis will be used by project end users for future mitigation efforts and, more generally, to expand their use of GIS and NASA Earth observations.

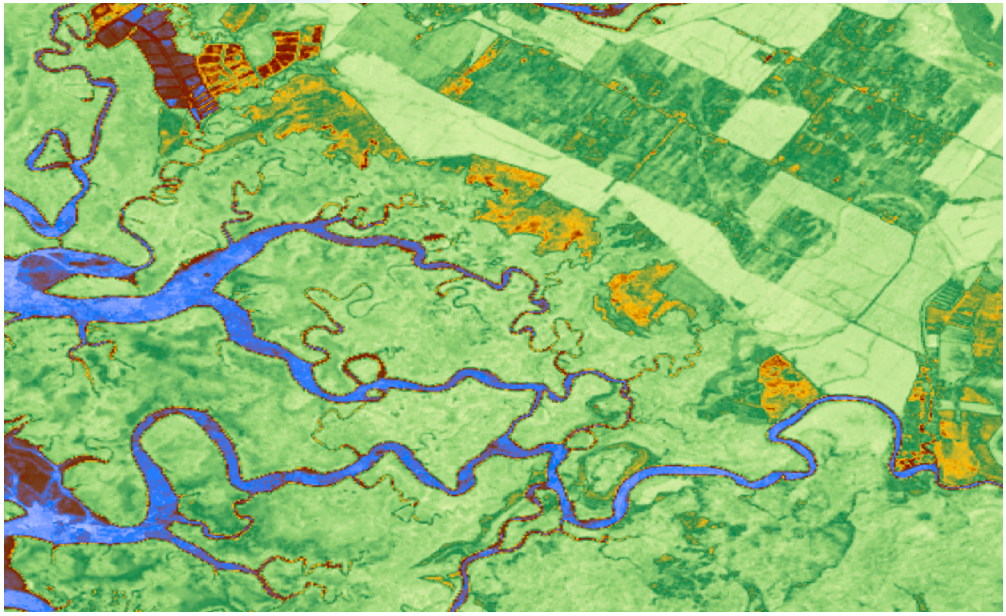
OSA PENINSULA WATER RESOURCES II

Utilizing NASA Earth Observations to Evaluate Effects of Land Use Change on Watershed Health and Carbon Sequestration in the Osa Peninsula, Costa Rica

Georgia – Athens

TEAM: Suravi Shrestha (Project Lead), Tanner Johnson, John Langstaff, Taufiq Rashid
PARTNER: Osa Conservation
EARTH OBSERVATIONS: GPM DPR, Landsat 5 TM, Landsat 8 OLI, PlanetScope, Terra ASTER, TRMM PR

The Osa Peninsula, located in the southern region of Costa Rica's Pacific Coast, is one of the most biologically-diverse places on Earth and a popular ecotourism destination. Previous work through NASA DEVELOP showed positive trends in land use since the implementation of the 1996 Forest Law legislation, which supported reforestation and riparian health. However, the area still faces watershed degradation and loss of biodiversity due to deforestation, pollution from agriculture, and human settlement. NASA DEVELOP partnered with Osa Conservation to analyze land cover change in the peninsula to better understand threats to river water quality and watershed health. This project used Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) to create land use maps, which were used to analyze change in riparian case study areas. Additionally, the team used a Soil Water Assessment Tool (SWAT) model to predict and visualize the effects of riparian restoration on river water quality. The model examines Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) elevation data, Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR) data, soil data, and land use data. *In situ* water quality data provided by the partners were used for model calibration and validation. The partners will use and distribute results of this project to the National System of Conservation Areas (SINAC), Ministry of Environment and Energy (MINAE), and local communities to inform land management decisions, policy enforcement, education and outreach initiatives, and watershed restoration and monitoring.



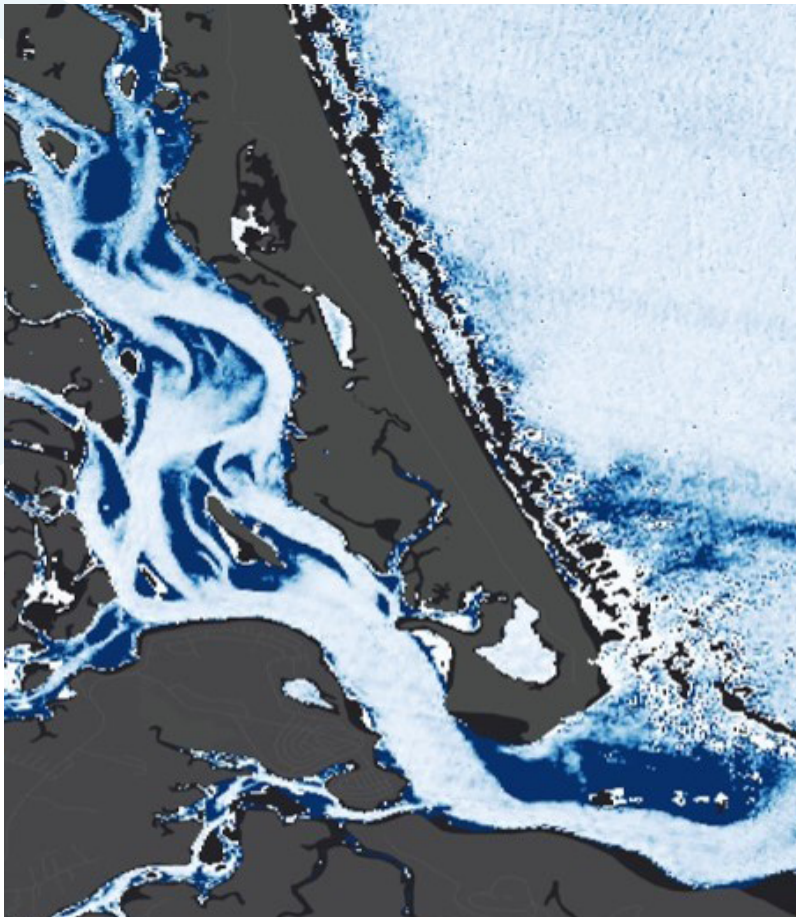
PLUM ISLAND ESTUARY WATER RESOURCES II

Employing Remote Sensing Techniques to Quantify Sediment Supply and Evaluate Marsh Vulnerability in the Plum Island Estuary

Massachusetts – Boston

TEAM: Henrik Westerkam (Project Lead), Ruizhe Guo, Sydney Neugebauer, Linnea Smith
PARTNERS: USGS, Woods Hole Coastal and Marine Science Center; US Fish and Wildlife Service, Parker River National Wildlife Refuge; Long Term Ecological Research Network, Plum Island Ecosystems LTER
EARTH OBSERVATIONS: Landsat 8 OLI, Sentinel-2 MSI

The Plum Island Estuary (PIE) in Massachusetts is New England's largest salt marsh. This dynamic ecosystem plays an important role in the surrounding communities by providing ecosystem services and acting as a center for education, research, and recreation. However, marshes around the world are threatened by sea level rise. As the equilibrium between sediment supply, erosion rates, and vegetation growth is unbalanced by rising waters, marshes are liable to recede, or even drown. Because sediment is so crucial, researchers use sediment budgets as a metric to assess the Plum Island Estuary's vulnerability to rising seas; however, established data collection methods are limited in scope. The project employed five years of imagery from Landsat 8 Operational Land Imager (OLI) and three years of imagery from Sentinel-2 Multispectral Instrument (MSI), in conjunction with *in situ* data, to generate and refine a local algorithm that derives suspended sediment concentration from remote sensing reflectance. This information was applied to a flux model to analyze transport patterns and possible sediment sources, particularly the Merrimack River. The use of remote sensing techniques will provide our partners at the US Geological Survey, US Fish and Wildlife Service, and Plum Island Ecosystems Long Term Ecological Research Network with higher spatial and temporal resolution data, which will allow for the development of more effective management practices.



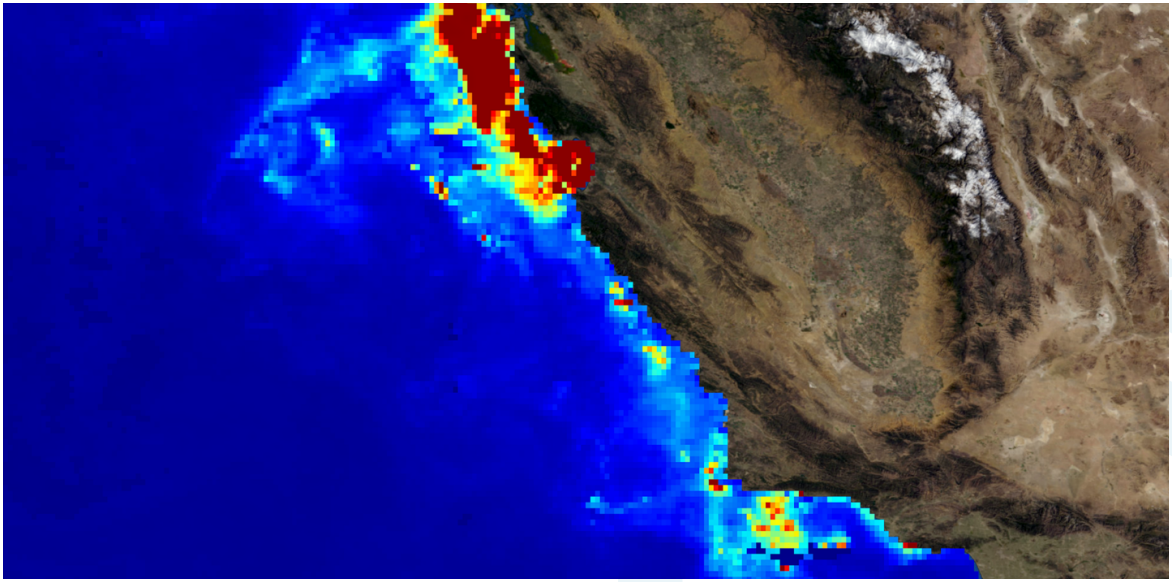
SOUTHERN CALIFORNIA WATER RESOURCES II

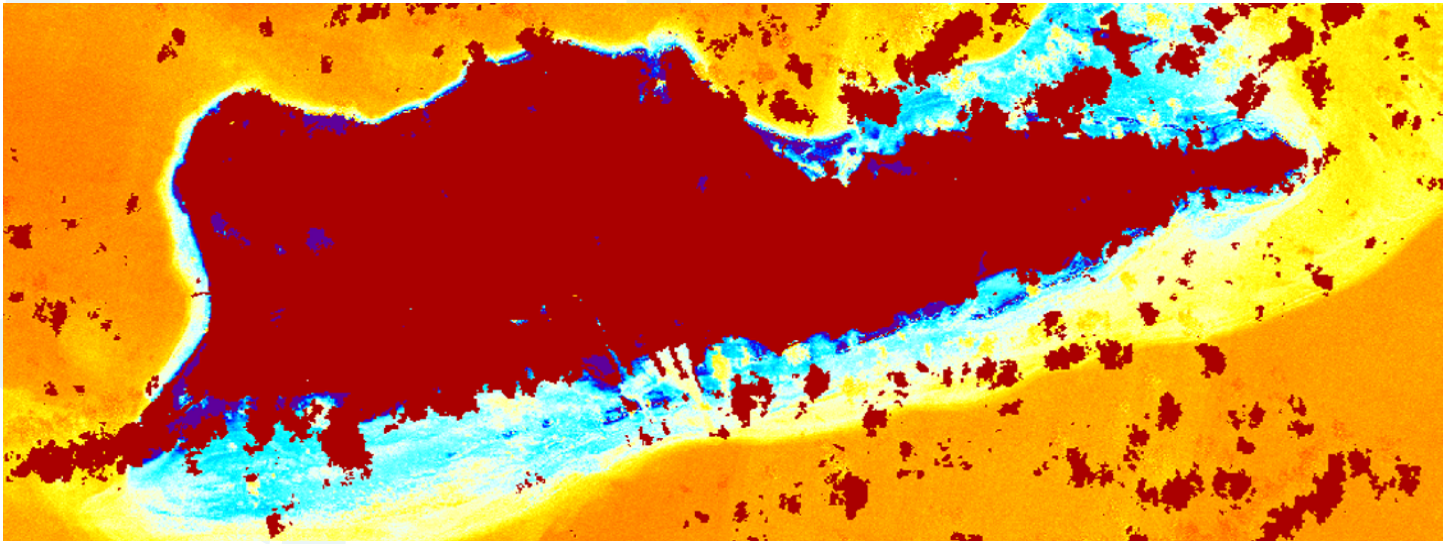
Predicting Grunion Migration Patterns and Spawning Areas in Response to Changes in California's Oceans

California – JPL

TEAM: Alexandra Jones (Project Lead), Harrison Knapp, Annemarie Peacock, Lael Wakamatsu
PARTNERS: Grunion Greeters Project, California Department of Fish and Wildlife
EARTH OBSERVATIONS: Aqua MODIS

The California grunion (*Leuresthes tenuis*) is a species of fish endemic to the California coastline that plays an important role in the marine food chain as a consumer of zooplankton and a food source for larger marine creatures. Grunion spawning events, commonly referred to as "grunion runs," occur when the tide is highest during nights surrounding a new or full moon, allowing the fish to "run" up the beach to deposit and fertilize their eggs before returning to sea. These runs happen most frequently during the summer months along beaches in Los Angeles, Orange, and San Diego counties. However, spawning events documented over the last three decades in the San Francisco Bay suggest a pattern of northern migration caused by changes in ocean conditions and increased human beach activity. In collaboration with the Grunion Greeters Project and the California Department of Fish and Wildlife, the team evaluated oceanic environmental and ecological factors that affect grunion spawning patterns. Earth observation data products, including NASA Multi-scale Ultra-high Resolution Sea Surface Temperature (MUR SST) and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) chlorophyll-a (chl-a), were used to create time series of the California coastline and nearby Pacific Ocean from 2003 to 2018. Upwelling, sea surface current, air temperature, and harmful algal bloom (HAB) data were also considered to derive correlations between the above parameters and grunion spawning events. Analyzing how a changing ocean affects the California grunion will allow for more accurate predictive modeling of spawning behavior and will provide the knowledge base needed to protect this unique species.





US VIRGIN ISLANDS WATER RESOURCES

Analyzing Historical Hurricane Influences on Coastal Water Quality and their Impact to Marine Ecosystems

California – Ames

TEAM: Megs Seeley (Project Lead), Fadwa Bouhedda, Brendan Lum, Tyler Anderson
PARTNERS: US Virgin Islands Department of Planning and National Resources, Coastal Zone Management; University of the Virgin Islands; College of Charleston; Kent State University
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 8 OLI, Sentinel-2 MSI

Several major and small-scale hurricanes have swept over the US Virgin Islands (USVI) dating back to 1989. Often originating near the Cabo Verde islands near western Africa, these major hurricanes travel westward towards the USVI, leaving destructive impacts upon landfall. Nearshore marine ecosystems in the USVI have adapted to hurricane forces, but as urban development alters native vegetation and hurricanes intensify with the changing climate, marine ecosystems may not always withhold resilience. Increased sediment and nutrient loads from runoff adversely impact coral reefs and other marine organisms. These marine resources are vital to the economy of the USVI, accounting for 80% of the gross domestic product and attracting millions of tourists annually. Marine resources such as coral reefs help protect residents from floods, storms and maintain high levels of marine biodiversity. The project partner, the USVI Department of Planning and Natural Resources - Coastal Zone Management currently uses *in situ* measurements and qualitative observations to monitor nearshore marine water quality. The analysis quantified water quality data post-hurricane season for Hurricane Hugo (1989), the 2017 hurricane season (Hurricanes Irma and Maria), and 2016 for baseline data using Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), and Sentinel-2 Multispectral Instrument (MSI) data. Using the select data, along with the 2017 NASA DEVELOP USVI Ecological Forecasting land use classifications (updated by Christopher McDonald), the team examined the complex interactions between hurricanes, land development, and water quality.

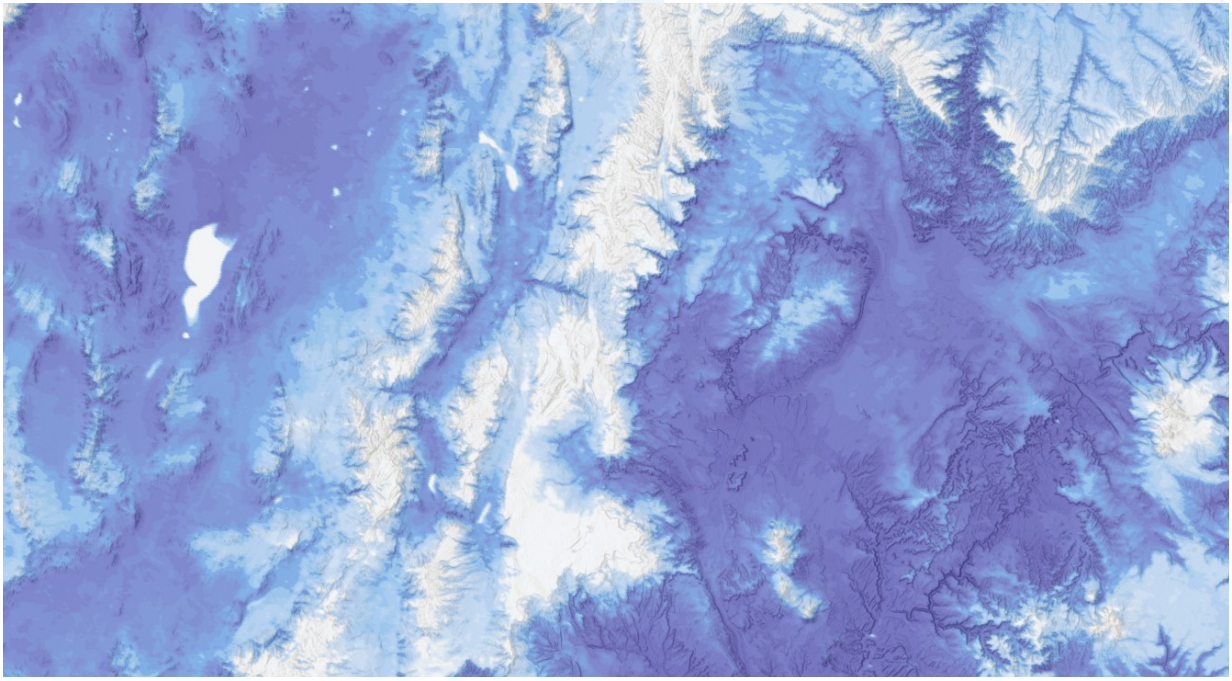
FREMONT RIVER BASIN WATER RESOURCES II

Water Availability Assessment from Annual Snow Cover in the Fremont River Basin Based on NASA Earth Observations and *In Situ* Data

Virginia – Wise

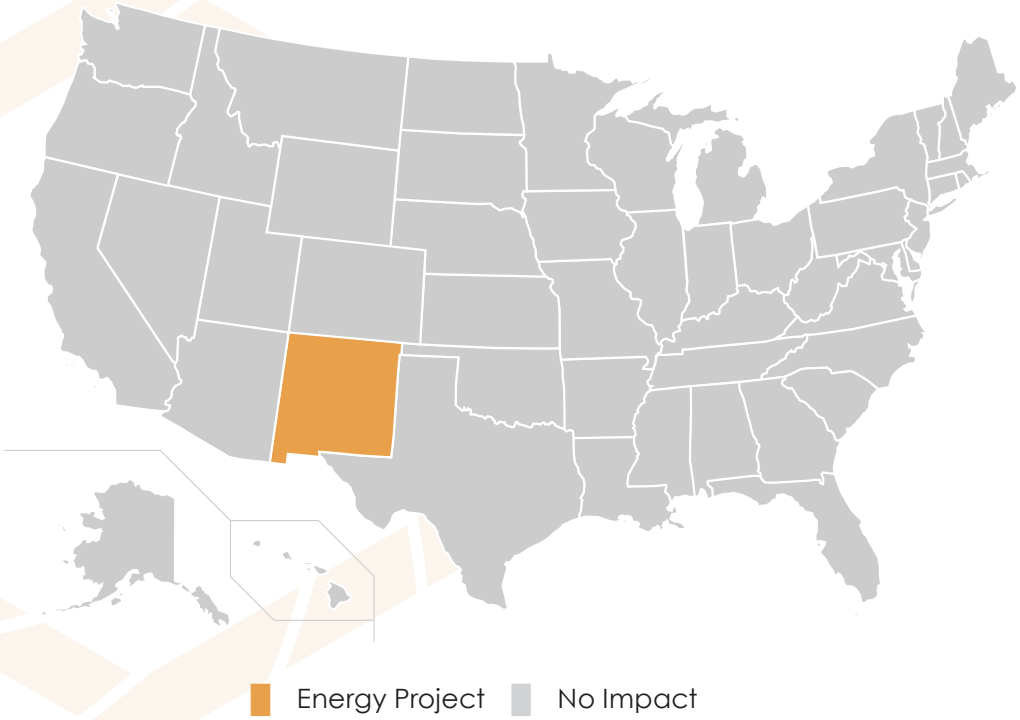
TEAM: Jessica Li (Project Lead), Zhuoyan He, Chenyu Shi
PARTNERS: National Park Service, Northern Colorado Plateau Network; National Park Service, Capitol Reef National Park
EARTH OBSERVATIONS: Terra MODIS, PERSIANN-CDR

As a largely snowmelt-fed watershed, Utah's Fremont River Basin provides year-round irrigation for approximately 16,000 acres of agricultural areas, including historic orchards and pastures maintained by Capitol Reef National Park (CARE). However, forecasts for seasonal water availability within the basin based on *in situ* snowpack data have been unreliable compared to water use allocations in the past. For this reason, a more robust method was required to provide accurate water availability assessments that help CARE plan future water allocations more effectively. Multiple NASA Earth observations and *in situ* data were employed to derive key trends and data insights for snowmelt and relevant climate variables across the watershed. Furthermore, a forecasting tool that predicts seasonal streamflow in the Fremont River Basin was created using machine learning models. The results of the snowmelt and climate analyses along with the forecasting tool will inform water resource management and enhance future irrigation allocation plans at CARE.



OVERVIEW

DEVELOP's Energy projects support activities with the management, monitoring, and forecasting of critical energy resources including coal, oil and gas, as well as renewable energy sources such as solar, wind, and hydropower. The projects apply NASA satellite data and derived products to effective siting of energy production. This summer, DEVELOP's Energy project partnered with state and federal agencies to improve energy management strategies.



SENSORS

SRTM
Suomi NPP VIIRS

PARTNERS

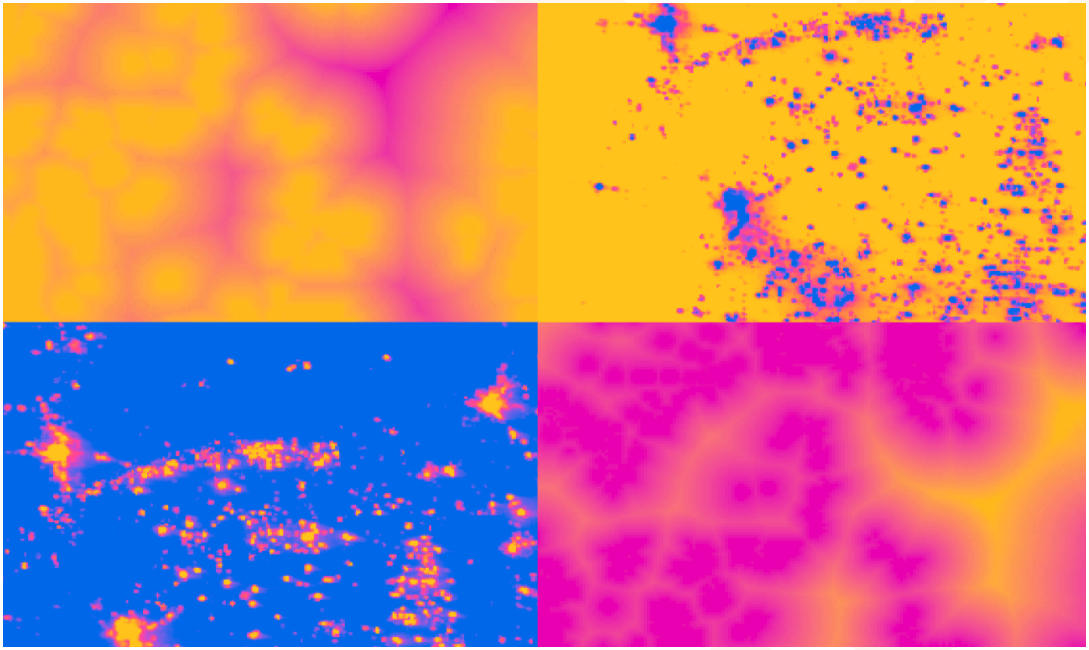
New Mexico Energy, Minerals & Natural Resources Department, Energy Conservation & Management Division
New Mexico Department of Game & Fish
US Department of Energy, National Renewable Energy Laboratory

NEW MEXICO ENERGY

Identifying Optimal Site Locations for Wind Energy Farms Considering Ecological and Social Impacts

Alabama – Marshall

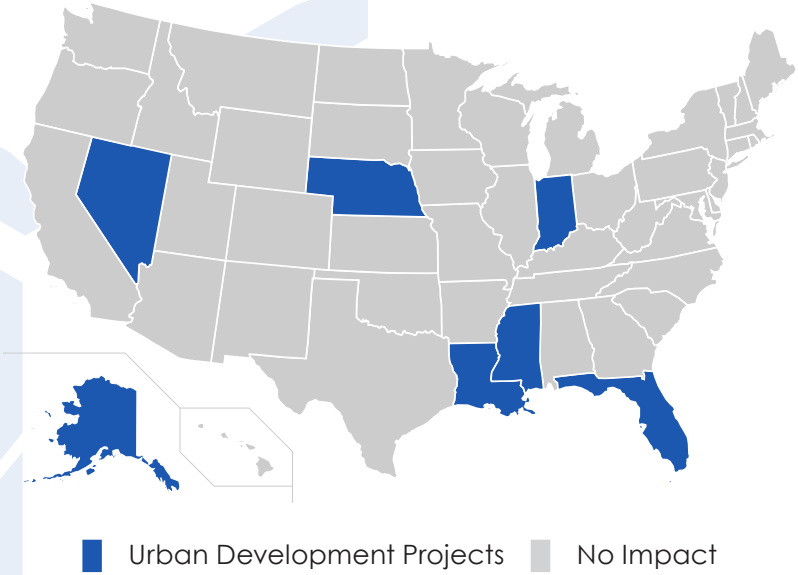
TEAM: Kara Cassano (Project Lead), Joy Marich, Franny Senkowsky
PARTNERS: New Mexico Energy, Minerals & Natural Resources Department, Energy Conservation & Management Division; New Mexico Department of Game and Fish; US Department of Energy, National Renewable Energy Laboratory
EARTH OBSERVATIONS: SRTM, Suomi NPP VIIRS



With the increasing cost and declining availability of fossil fuels, renewable energy, specifically wind power, has become one of the fastest growing sources of energy in New Mexico. To assist with the goals set by the state's Renewables Standard Portfolio established in 2004, the NASA DEVELOP team created three Optimal Wind Farm Suitability maps that consider social impact, ecological impact, and power production efficiency. Along with the National Renewable Energy Laboratory (NREL), project partners included the New Mexico Energy, Minerals & Natural Resources Department's Energy Conservation & Management Division (ECMD), and New Mexico Department of Game and Fish (NMDGF). The team utilized datasets from February 2013 – May 2018 including NASA Earth observations from the Shuttle Radar Topography Mission (SRTM) and Suomi National Polar-orbiting Partnership (NPP) to take into account vulnerable species, average wind patterns, and U.S. Air Force Base locations. These three maps were combined into a final suitability map for optimal wind farm placement. Fuzzy Logic modeling was implemented to identify areas of low social and ecological impact and of high wind power productivity. The Land-Use Conflict Identification Strategy (LUCIS) combined the Fuzzy Logic model outputs to predict regions that may be overall suitable for wind farms.

OVERVIEW

DEVELOP's Urban Development projects focus on the application of NASA Earth observations to enhance urban planning, monitoring of land change over time, assessment of urban footprints, and the development of sustainable and resilient urban environments. These projects support sustainability, resilience and safety of cities and human settlements through informed planning and management of climate and disaster risks. This summer, DEVELOP's Urban Development projects partnered with local and federal agencies and consortiums to address urban issues.



PARTNERS

Groundwork USA, Groundwork New Orleans
National Park Service, Natural Sounds and Night Skies Division, Night Skies Program
Stantec Consulting Service, Inc.
Washoe County Health District, Air Quality Management Division

SENSORS

Landsat 5 TM
Landsat 8 OLI/TIRS
Sentinel-1 C-SAR
Sentinel-2 MSI
Suomi NPP VIIRS
Terra ASTER
Terra MODIS

PORTFOLIO

New Orleans Urban Development: Utilizing Earth Observations to Assist Groundwork New Orleans in Reducing Flood Vulnerability in New Orleans, Louisiana, Metropolitan Area – *AL*
US Urban Development: Generating Hemispherical Visualizations of Artificial Sky Brightness Using Updated Sky Glow Estimation Tools on Suomi NPP-VIIRS Data – *LaRC*
Washoe County Urban Development: Utilizing NASA Earth Observations to Assess Urban Heat Island Reduction Strategies in Washoe County, Nevada – *AZ*

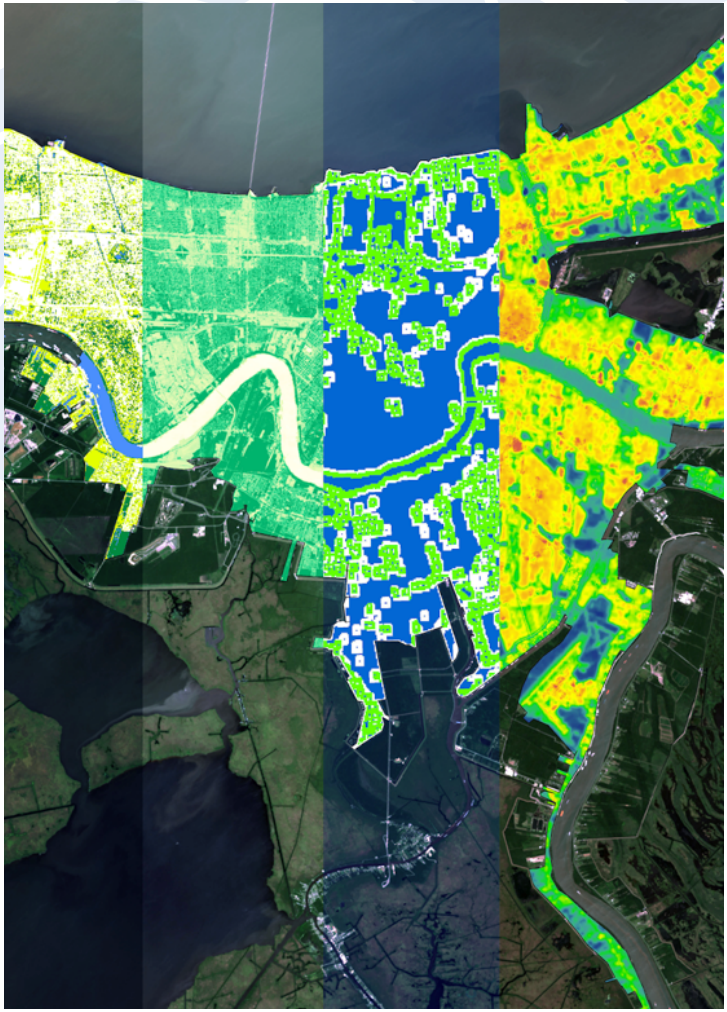
NEW ORLEANS URBAN DEVELOPMENT

Utilizing Earth Observations to Assist Groundwork New Orleans in Reducing Flood Vulnerability in New Orleans, Louisiana, Metropolitan Area

Alabama – Mobile

TEAM: Rupsa Bhowmick (Project Lead), Lulin Zheng, Madison Murphy, Chelsea Randall
PARTNERS: Groundwork USA, Groundwork New Orleans
EARTH OBSERVATIONS: Landsat 8 OLI/TIRS, Sentinel-1 C-SAR, Sentinel-2 MSI, Terra MODIS

Flooding in New Orleans, Louisiana has increased in intensity and frequency due to sea level rise and land subsidence. Considered one of the rainiest cities in the country, New Orleans often experiences localized street flooding, causing damages to homes and businesses. Groundwork New Orleans (GWNO) is dedicated to increasing urban resilience to flooding by implementing green infrastructure. However, the current practices for site selection and assessment implemented by GWNO are costly and time consuming. NASA and ESA Earth observation data were acquired and used to create end products that can supplement GWNO's current methods. The project utilized Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Sentinel-2 Multispectral Instrument (MSI), Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR), and Terra Moderate Resolution Imaging Spectroradiometer (MODIS) imagery from 2013 to 2018. Data were acquired for summer months with consideration to the Atlantic hurricane season to quantify the impact of GWNO's tree planting campaigns and provide additional data to supplement GWNO's current practices towards mitigating flood risk in the area. The team used remote sensing and geospatial analysis to map areas with high surface runoff and flood vulnerability. A land cover classification product and Normalized Difference Vegetation Index (NDVI) assessment were produced to monitor changes in urban tree canopy and impervious surface cover. The Normalized Difference Flood Index (NDFI) and Normalized Difference Flood Vegetation Index (NDFVI), along with land surface temperature data were computed to create a discrete-time series analysis of flood extent along with outlining shallow water in short vegetation and monitor the urban heat island effect in flood vulnerable communities. Project end products will provide GWNO with geospatial evidence of the effectiveness of their current tree-planting project for increasing the urban tree cover and improving community resilience to flooding over time.



US URBAN DEVELOPMENT

Generating Hemispherical Visualizations of Artificial Sky Brightness Using Updated Sky Glow Estimation Tools on Suomi NPP-VIIRS Data

Virginia – Langley

TEAM: Maximilian Ioffe (Project Lead), Julia Hink, Tyler Jameson, Charlie McClay
PARTNERS: National Park Service, Natural Sounds and Night Skies Division, Night Skies Program
EARTH OBSERVATIONS: Suomi NPP VIIRS

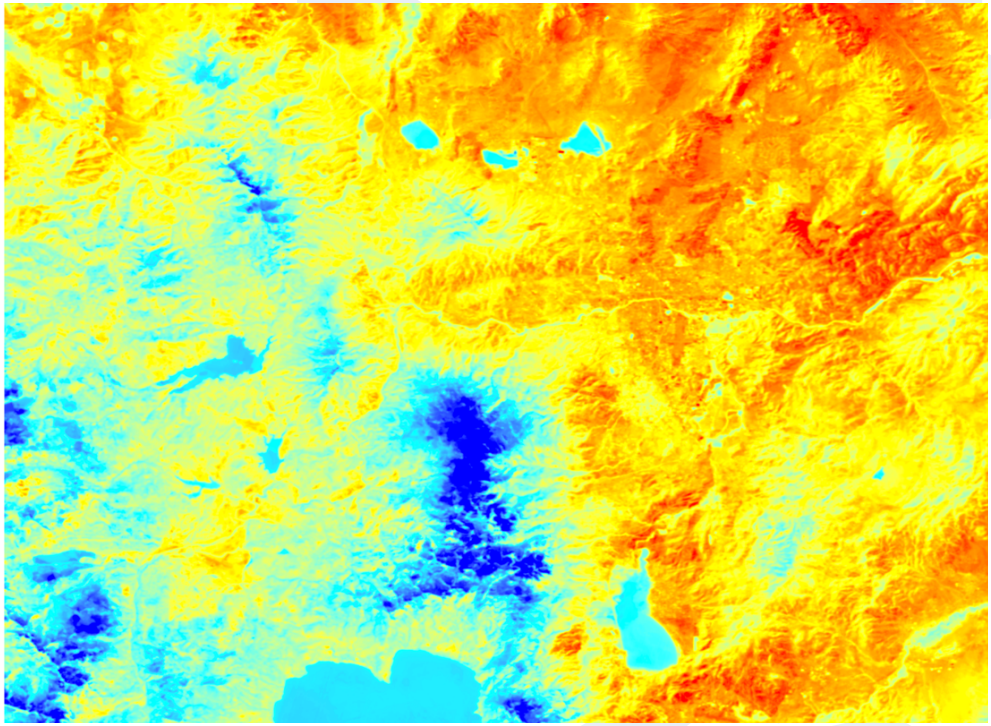
The expansion of the global population in conjunction with rapid industrialization has caused an increase in artificial light pollution, also known as artificial sky glow. Anthropogenic light pollution disturbs the world's ecosystems by interfering with the interconnected life of flora and fauna, degrading night sky quality for astronomical and aesthetic viewing, and disrupting human circadian rhythms and melatonin production, which can have lasting negative effects on health. The Skyglow Estimation Toolbox (SET) calculates artificial sky glow by applying a model of light propagation to visible light radiance imagery from the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). The previous iteration of SET was further expanded by adding a hemispherical visualization feature compiled from individual skyglow maps with different zenith/azimuth angle combinations at one location. The graphical user interface (GUI) of SET was also updated to include all functions of the command line interface, and the overall code repository now works with all versions of Python 2.7 and above. Written unit tests were installed to prevent future code breaks, and several issues were fixed such as logic errors, repository bloat, and lack of documentation. The revised SET was tested on four United States national parks to ensure functionality across different environments. The resulting hemispherical visualizations were provided to the National Park Service (NPS) to compare with *in situ* measurements. The team explored validation methods, which provided a basis for future action for measuring and managing light pollution around national park units.

WASHOE COUNTY URBAN DEVELOPMENT

Utilizing NASA Earth Observations to Assess Urban Heat Island Reduction Strategies in Washoe County, Nevada

Arizona – Tempe

TEAM: Julia Heslin (Project Lead), John Dialesandro, Mariah Heck, Chenxi Lin
PARTNERS: Washoe County Health District, Air Quality Management Division; Stantec Consulting Service, Inc.
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 8 OLI/TIRS, Terra ASTER



Extreme heat events (EHEs) are one of the leading causes of natural hazard-related deaths in the world. With rising global temperatures, these events will continue to increase in frequency, duration, and magnitude. The urban heat island (UHI) effect exacerbates the consequences of EHEs, discourages active transportation, necessitates greater energy expenditures for air conditioning, and elevates the risk of heat-related and respiratory illness in urban populations. The NASA DEVELOP Washoe County Urban Development Team utilized NASA Earth observations including Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), and Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) to identify the biophysical characteristics, such as impervious surfaces, vegetation, and tree canopy cover, that contribute to the UHI effect and which ones have the greatest influence on land surface temperature (LST). The team also created a heat vulnerability index (HVI) by combining socioeconomic and health data from the US Census and the Centers for Disease Control and Prevention (CDC), respectively. These processed datasets were integrated onto a web map platform for users to visualize areas of high heat and high vulnerability. Results showed that urbanized areas of the Truckee Meadows region were warmer on average than surrounding suburban areas. Areas that experienced highest temperatures occurred in the northeast portion of the Reno-Sparks districts. The confluence of these highly vulnerable areas and biophysical characteristics will assist the Washoe County Health District's Air Quality Management Division (AQMD) with decision-making related to UHI mitigation strategies in the Truckee Meadows region.

OVERVIEW

DEVELOP's Disasters projects utilize NASA's capabilities in spaceborne, airborne, and surface observations, as well as modeling and data analysis to improve natural disaster forecasting, mitigation, and response. The projects contribute to improved understanding of the natural processes that produce hazards, the vulnerability of local communities, and development of hazard mitigation technologies. This summer, DEVELOP's Disasters projects partnered with decision makers around the globe to provide disaster-related information where and when it is needed.

PORTFOLIO

Kenai Disasters: Evaluating Grassland Conversion and the Related Likelihood of Fire Disturbance to Enhance Fire Monitoring and Management in the Kenai Peninsula, Alaska – *GSFC*

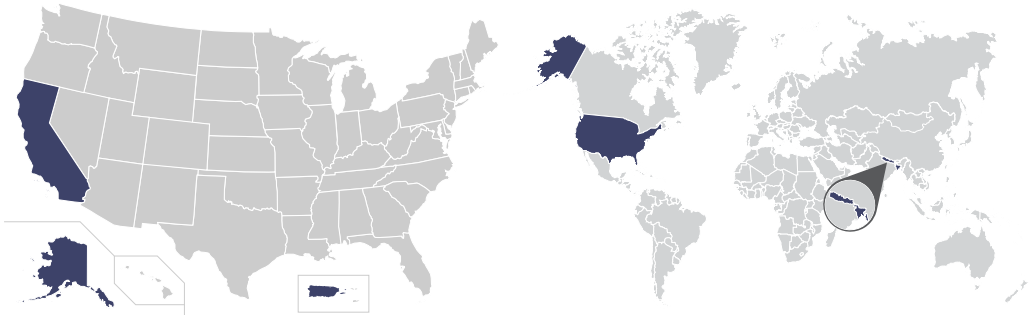
Southern California Coast Disasters: Improving Flood Extent Mapping Using the Coastal Storm Modeling System (CoSMoS) Tool with NASA Earth Observations and UAVSAR within Southern California – *JPL*

Puerto Rico Disasters: Assessing Changes in Cloud Dynamics in the Luquillo Tropical Montane Cloud Forest Using NASA Earth Observations and *In Situ* Measurements Following Defoliation from Hurricane Maria – *GA*

Hindu-Kush Himalayan Disasters: Integrating NASA Earth Observations to Monitor Thunderstorms and Assess Lightning Exposure and Risk in the Hindu-Kush Himalayan Region – *MSFC*

Disaster Projects

No Impact



PARTNERS

Bangladesh Meteorological Department
International Centre for Integrated Mountain Development
Ministry of Population and Environment, Department of Hydrology and Meteorology (Nepal)
NASA Global Hydrology Resource Center Distributed Active Archive Center
NASA SERVIR Science Coordination Office
US Fish and Wildlife Service, Kenai National Wildlife Refuge
USDA, US Forest Service, International Institute of Tropical Forestry
USGS National Research Program
USGS, Pacific Coastal and Marine Science Center

SENSORS

Aqua MODIS
CALIPSO CALIOP
GPM IMERG
ISS LIS
Landsat 4 TM
Landsat 5 TM
Landsat 7 ETM+
Landsat 8 OLI
NASA Gulfstream III UAVSAR
SRTM
Terra MODIS
TRMM LIS/PR/TMI

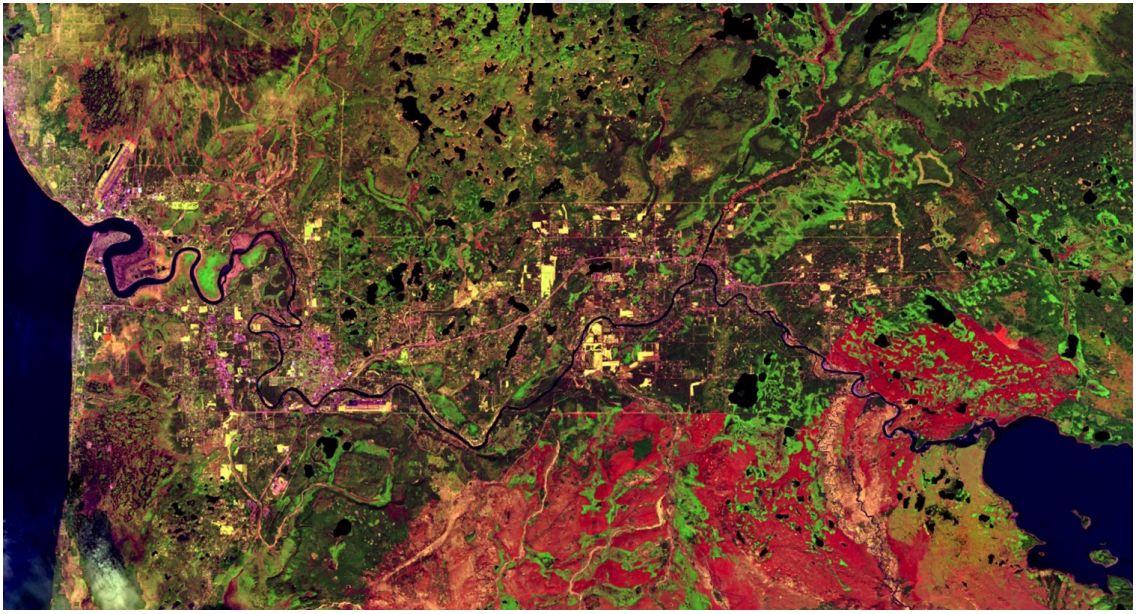
KENAI DISASTERS

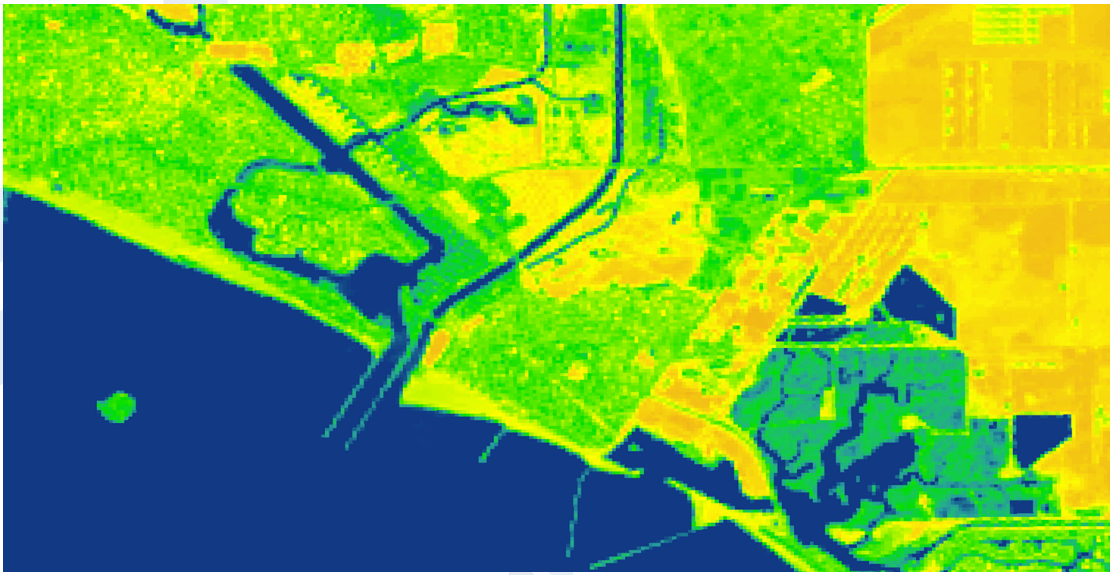
Evaluating Grassland Conversion and the Related Likelihood of Fire Disturbance to Enhance Fire Monitoring and Management in the Kenai Peninsula, Alaska

Maryland – Goddard

TEAM: Katherine Hess (Project Lead), Jeanette Cobian, Cheila Cullen, Victor Lenske, Jacob Ramthun
PARTNERS: US Fish and Wildlife Service, Kenai National Wildlife Refuge
EARTH OBSERVATIONS: Aqua MODIS, Landsat 4 TM, Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Terra MODIS

Spruce beetle-induced (*Dendroctonus rufipennis* (Kirby)) mortality on the Kenai Peninsula has heightened local wildfire risk as canopy loss facilitates the conversion from forest to fire-prone grassland. We collected images from NASA Earth observations to visualize land cover succession at roughly five-year intervals following a severe, mid-1990's beetle infestation to the present. Using ArcGIS Pro, we classified these data by vegetation cover type to quantify grassland encroachment patterns over time. We used the raster calculator in ArcGIS Pro to conduct a change detection analysis on the land cover classifications. The resulting change image will give the Kenai National Wildlife Refuge (KENWR) ecologists a better understanding of where forests have converted to grassland since the 1990s. These classifications provided a foundation for us to integrate digital elevation models (DEMs) and geospatial temperature and precipitation data into a model using R for assessing and mapping changes in wildfire risk. Spatial representations of this risk will contribute to a better understanding of ecological trajectories of beetle-affected landscapes, thereby informing management decisions at KENWR.





SOUTHERN CALIFORNIA COAST DISASTERS

Improving Flood Extent Mapping Using the Coastal Storm Modeling System (CoSMoS) Tool with NASA Earth Observations and UAVSAR within Southern California

California – JPL

TEAM: Brian Lee (Project Lead), Manda Au, Erika Higa, Neda Kasraee
PARTNER: USGS, Pacific Coastal and Marine Science Center
EARTH OBSERVATIONS: Landsat 8 OLI, NASA Gulfstream III UAVSAR

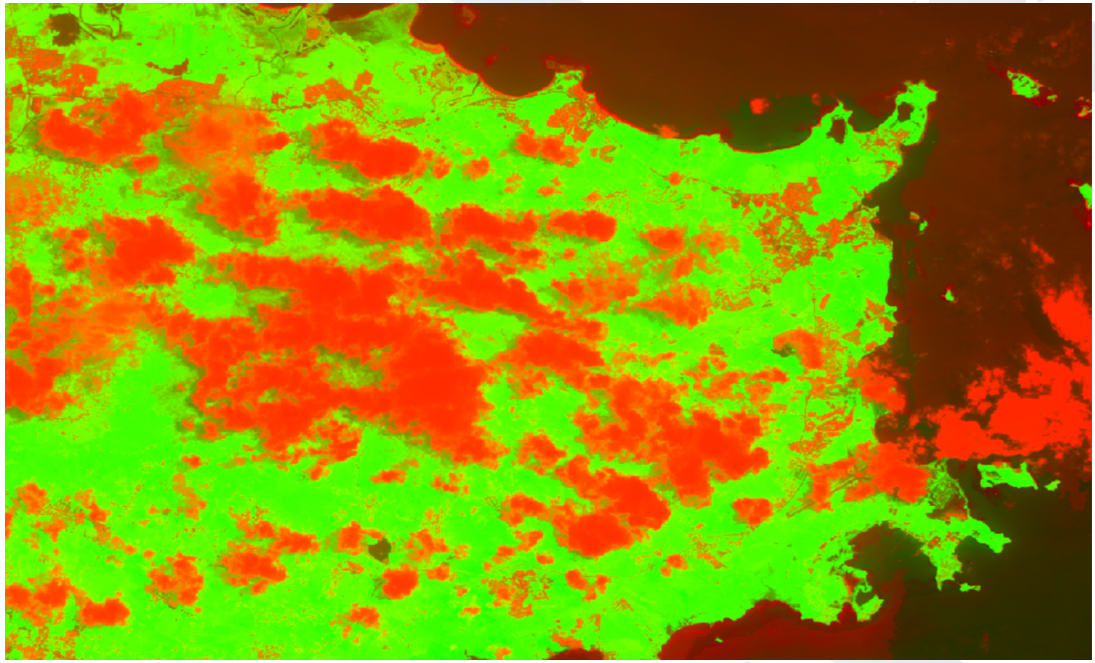
The Southern California coast, from Point Conception to the Tijuana River wetland, has become more sensitive to flooding as king tides have increased in magnitude. These king tides are thought to be intensifying due to numerous environmental factors such as storm surges, strong winds, and sea level rise as the result of a changing climate. Subsequently, king tides cause flooding along the southern coast, and it is predicted that the previously minor damages incurred from these tides will become more severe and hazardous to those who live on the coast. The US Geological Survey (USGS) Pacific Coastal and Marine Science Center has created their own flood prediction model, the Coastal Storm Modeling System (CoSMoS). The USGS currently uses their model to predict areas that may flood preceding a high tide and this project aimed to make the model more accurate by mapping landward extents. To do this, different remote sensing methods were used in conjunction with Earth observations such as NASA's Uninhabited Aerial Vehicle Synthetic Aperature Radar (UAVSAR) and Landsat 8 Operational Land Imager (OLI). The team acquired imagery reflecting baseline tide levels and king tide events. The imagery underwent a change detection algorithm which produced a shapefile that highlighted areas most affected by extreme high tide events. The USGS Pacific Coastal and Marine Science Center will use this shapefile to validate their storm flood models, including the CoSMoS.

PUERTO RICO DISASTERS

Assessing Changes in Cloud Dynamics in the Luquillo Tropical Montane Cloud Forest Using NASA Earth Observations and *In Situ* Measurements Following Defoliation from Hurricane Maria

Georgia – Athens

TEAM: Flavia Dias de Souza Moraes (Project Lead), Justin Bucher, Andrew Walz
PARTNERS: USDA, US Forest Service, International Institute of Tropical Forestry; USGS National Research Program
EARTH OBSERVATIONS: CALIPSO CALIOP, Landsat 8 OLI, Terra MODIS



The Luquillo Mountains in the El Yunque National Forest contain the most biologically diverse forest in the United States. It is a cloud forest rich in endemic species and its streams bring clean water to the people of Puerto Rico. This unique environment was exposed in the aftermath of Hurricane Maria, which devastated Puerto Rico during its landfall on September 20th, 2017. One of the numerous effects hurricane Maria had on the landscape was substantial defoliation of the forest within the Luquillo Mountains. Large scale defoliation events have been linked to changes in the physical environment as well as cloud formations potentially related to a decrease in evapotranspiration (ET) rates from vegetation. This project investigated how hurricane Maria impacted cloud dynamics in the Luquillo Mountains. It is known that relatively small changes in cloud base height (CBH) can have a drastic impact on the flora and fauna of the area that have evolved to live in near constant cloud immersion. The team utilized Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) data to determine CBH over the study area and calibrated it against the theoretical CBH from radiosonde data. The team also used Terra Moderate Resolution Imaging Spectroradiometer (MODIS) cloud mask data to analyze changes in cloud coverage pre- and post- Maria. This work provides the US Forest Service International Institute for Tropical Forestry (IITF) with an estimated change in CBH and cloud distribution before and after Maria that can be incorporated in IITF's management plans.

HINDU-KUSH HIMALAYAN DISASTERS

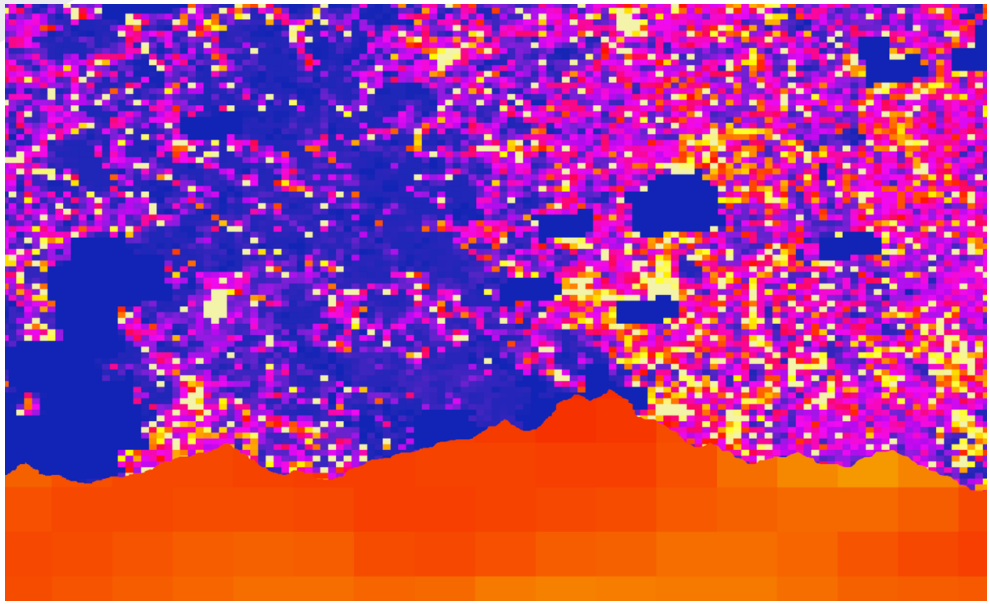
Integrating NASA Earth Observations to Monitor Thunderstorms and Assess Lightning Exposure and Risk in the Hindu-Kush Himalayan Region

Alabama – Marshall

TEAM: Christine Evans (Project Lead), Sisam Shrestha, Essence Raphael

PARTNERS: Bangladesh Meteorological Department; Ministry of Population and Environment, Department of Hydrology and Meteorology (Nepal); International Centre for Integrated Mountain Development (ICIMOD); NASA SERVIR Science Coordination Office; NASA Global Hydrology Resource Center Distributed Active Archive Center

EARTH OBSERVATIONS: ISS LIS, GPM IMERG, SRTM, TRMM LIS/PR/TMI



Intense thunderstorms throughout the Hindu-Kush Himalayan (HKH) region have resulted in an upsurge of lightning-related deaths due to an increase in population. Partnering with the NASA Global Hydrology Resource Center Distributed Active Archive Center, NASA SERVIR Science Coordination Office, Bangladesh Meteorological Department (BMD), Nepal Department of Hydrology and Meteorology (DHM), and the International Centre for Integrated Mountain Development, this study investigated the lightning risks in the HKH region and the correlation between precipitation and lightning. The team plotted lightning flash point data collected by the Lightning Imaging Sensor (LIS) aboard the Tropical Rainfall Measuring Mission (TRMM) and International Space Station (ISS) to determine the locations where the highest concentrations of lightning strikes occurred from January 2000 to December 2017. Additionally, the team used the TRMM Microwave Imager (TMI), TRMM Precipitation Radar (PR) and Global Precipitation Measurement (GPM) mission Integrated Multi-Satellite Retrievals (IMERG) data to determine areas with the highest precipitation totals over Bangladesh and Nepal. A Lightning Risk Map, created to highlight lightning-prone areas and regions with vulnerable populations, showed that populations in Bangladesh were comparatively more vulnerable to lightning than those in Nepal. A Precipitation and Lightning Correlation was determined, indicating if areas experiencing heavier precipitation corresponded with areas experiencing higher lightning totals. These end products will assist the BMD and the DHM to increase hazard awareness and issue earlier warning times to reduce lightning casualties.

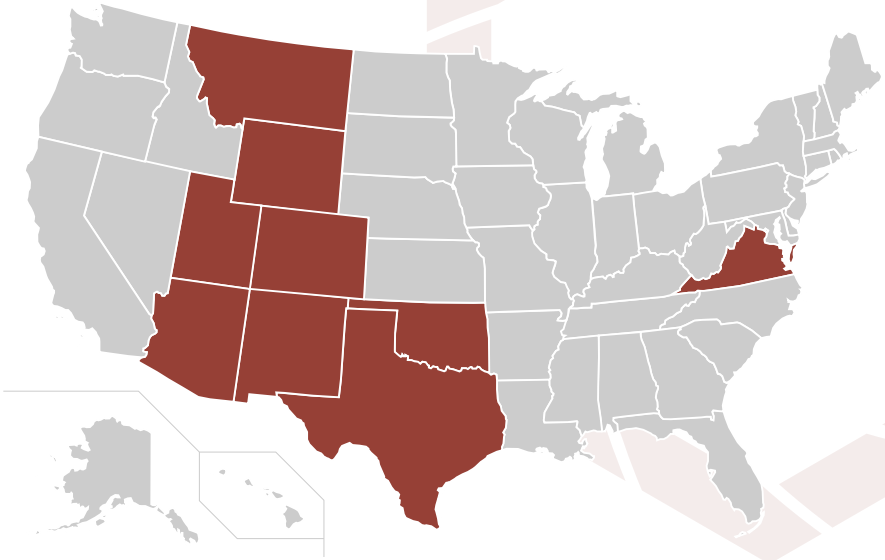
OVERVIEW

DEVELOP's Health & Air Quality projects utilize satellite and airborne Earth observations, model products, and scientific findings to support air quality and public health management, as well as policy makers. This summer, DEVELOP's Health & Air Quality projects partnered with local and federal organizations to better understand and improve air quality monitoring across the U.S.

PORTFOLIO

Richmond Health & Air Quality: Synthesizing Temperature, Reflectance, and Land Change to Provide Spatial and Temporal Temperature Analyses in Richmond, Virginia – *LaRC*

Intermountain West Health & Air Quality: Monitoring Regional Air Quality to Address Air Pollution in National Parks through the Application of NASA Earth Observations – *LaRC*



Health & Air Quality Projects No Impact

PARTNERS

Groundwork USA, Groundwork RVA
National Park Service, Air Resources Division
National Park Service, Intermountain Region
Science Museum of Virginia

SENSORS

Aura OMI
Landsat 5 TM
Landsat 8 OLI/TIRS
Terra ASTER

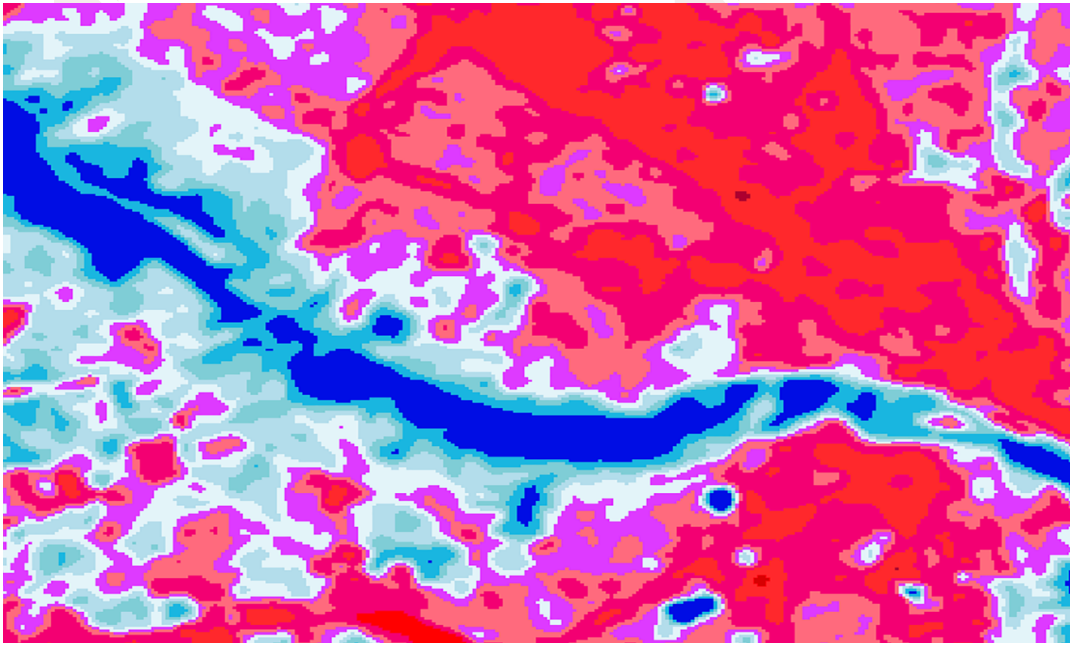
RICHMOND HEALTH & AIR QUALITY

Synthesizing Temperature, Reflectance, and Land Change to Provide Spatial and Temporal Temperature Analyses in Richmond, Virginia

Virginia – Langley

TEAM: Meg Fredericks (Project Lead), Simeon Brown, Patricia Abduragimova, Josh Turner
PARTNERS: Groundwork USA, Groundwork RVA; Science Museum of Virginia
EARTH OBSERVATIONS: Landsat 5 TM, Landsat 8 OLI/TIRS, Terra ASTER

Cities around the world are adopting adaptation and mitigation strategies for extreme heat events, which are projected to increase in upcoming years. As Richmond, Virginia continues to grow, its residents are more likely to experience more extreme temperatures resulting from the urban heat island effect. An increase in impervious surfaces such as asphalt and concrete, which retain more heat energy than the natural environment, drive this effect. Efforts to alleviate these problems include supporting interventions by local non-profits, including Groundwork RVA, and working with the Richmond City Planning Office to prioritize increased tree cover in the area. In this project, we used Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), and Terra Advanced Spaceborne Thermal Emission and Reflection (ASTER) data to analyze these patterns in land surface temperature. To inform these patterns, we also examined the significance of the city's infrastructure and land use choices. Land cover was assessed for selected years using data from the Virginia GIS Clearinghouse and the National Agriculture Imagery Program. Heat vulnerability indicators and land cover data were synthesized using US Census and health records and Centers for Disease Control (CDC) Social Vulnerability Indicators. These indicators depict the sensitivity of the population to extreme heat and identify where vulnerable populations reside. Along with identifying these areas of concern, our results indicated that the urban heat profile of Richmond has dramatically increased and expanded in the last twenty years. Groundwork RVA can use temperature assessment maps along with these heat vulnerability indicators to establish, carry out and prioritize green infrastructure projects in the city.

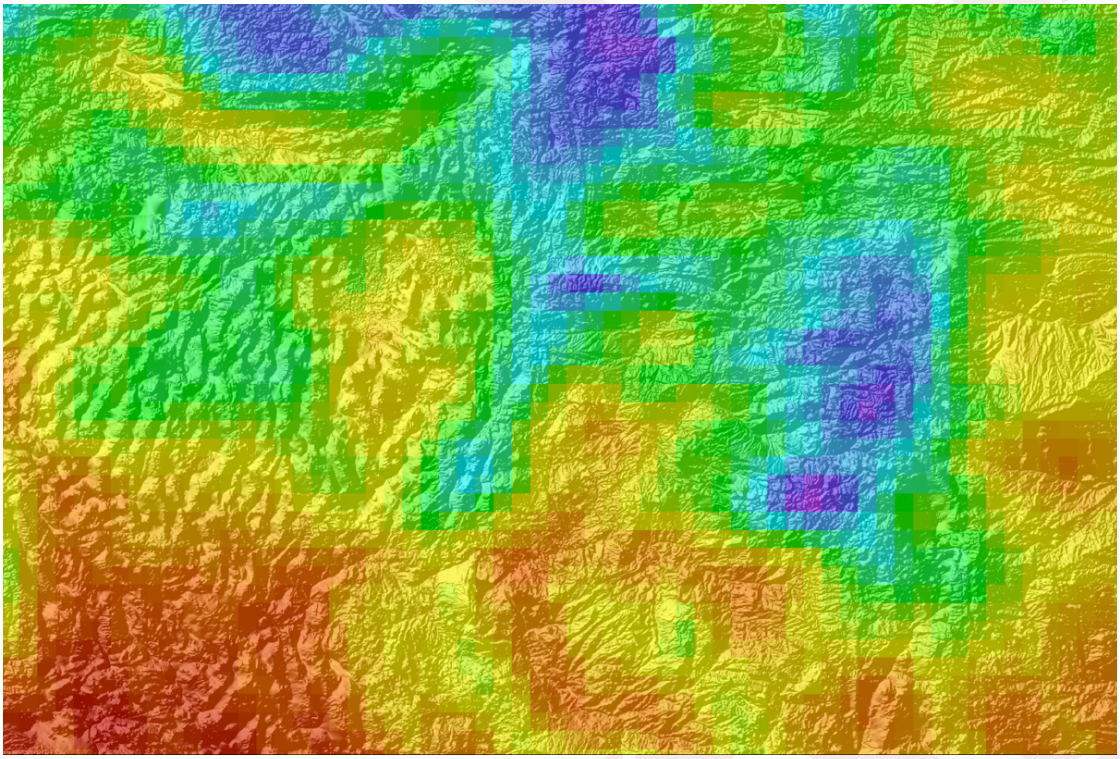


INTERMOUNTAIN WEST HEALTH & AIR QUALITY

Monitoring Regional Air Quality to Address Air Pollution in National Parks through the Application of NASA Earth Observations

Virginia – Langley

TEAM: Chet Warren (Project Lead), Jared Goldbach Ehmer, Zac Peloquin
PARTNERS: National Park Service, Intermountain Region; National Park Service, Air Resources Division
EARTH OBSERVATIONS: Aura OMI



Good air quality is critical for the Intermountain Region of the National Park Service (NPS) to uphold legal mandates, such as the Clean Air Act, to protect park visitor health, the ecological health of the park flora and fauna, and the preservation of the vistas of the parks for the present and future generations. Unfortunately, nitrogen dioxide (NO_2) harms air quality related values and the health of guests that visit the parks. This project utilized the Ozone Monitoring Instrument aboard Aura, a NASA Earth observation satellite, to create spatial and temporal trend maps as well as visual displays of NO_2 data from January 2005 to December 2017. By applying NASA Earth observations, the NPS can complement their ground-level data from monitoring programs. This uncovers trends of persistent concentrations of NO_2 in the Intermountain Region and its surrounding areas. With the help of NASA Earth observations, the NPS is able to determine source regions of NO_2, allowing them to develop mitigation strategies and create long term management action plans involving visibility, air quality, and the parks' natural resources.

DEVELOP **Participants**

SENIOR FELLOWS
Amanda Clayton
Georgina Crepps
Jordan Vaa

AL – MOBILE
Farnaz Bayat
Rupsa Bhowmick +
Madison Murphy
Danielle Quick *
Chelsea Randall
Lulin Zheng

AL – MSFC
Helen Baldwin
Mercedes Bartkovich *
Kara Cassano +
Christine Evans +
Kathrene Garcia +
Joy Marich
Clair Neuman
Matt Preisser
Essence Raphael
Franny Senkowsky
Sisam Shrestha

AZ – TEMPE
John Dialesandro
Liz Dyer
Mariah Heck
Julia Heslin +
Chenxi Lin
Lance Watkins

CA – AMES
Jerrold Acdan +
Tyler Anderson
Fadwa Bouhedda
Steven Chao
John Dilger *
Lawrence Fujiwara
Ella Golovey
Brendan Lum
Megs Seeley +
Jenna Williams

CA – JPL
Manda Au
Kate Cavanaugh
Erika Higa
Alexandra Jones +
Neda Kasraee
Harrison Knapp
Brian Lee +
Annemarie Peacock
Nick Rousseau *
Lael Wakamatsu

CO – FT. COLLINS
Daniel Carver *
Kristen Dennis
Jillian LaRoe +
Timothy Mayer
Margaret Mulhern +
Nathaniel Penrod
Shaunie Rasmussen
Mikhail Schee
Griffin Shelor

GA – ATHENS
Emad Ahmed
Justin Bucher
Melanie Callihan +
Tanner Johnson
John Langstaff
Flavia Moraes +
Taufiq Rashid
Caren Remillard
Suravi Shrestha *+
Austin Stone
Andrew Walz
Wei Xu

ID – POCATELLO
Madison Broddle
Dane Coats
Leah Kucera *
Ian Lauer +
Zach Sforzo

MD – GSFC
Cheila Avalon Cullen
Jeanette Cobian
Kate Hess +
Victor Lenske
Jacob Ramthun *
Jeremy Rapp +
Eyob Solomon
Ryan Young

MA – BOSTON
Zach Bengtsson
Ruizhe Guo
Sydney Neugebauer
Linnea Smith
Henrik Westerkam +

NC – NCEI
Brooke Adams +
Forest Kane Cook
Danielle Curtis
Alexa Kennedy +
Aaron Mackey
Conor Mulderrig
Meghan Russell
Andrew Shannon *

VA – LaRC
Patricia Abduragimova
Jared Belvin
Simeon Brown
Cecil Byles
William Crowley
Jared Goldbach Ehmer
Meg Fredericks +
William Patrick Frier +
Julia Hink
Connor Holzmann +
Maximilian Ioffe +
Tyler Jameson
Megan Link
Charlie McClay
Hannah Mosiniak
Carlos Murillo
Jonathan O'Brien
Zac Peloquin
Shaifali Prajapati
Thomas Richards
Max Stewart
Ryan Theurer +
Josh Turner
Chet Warren +

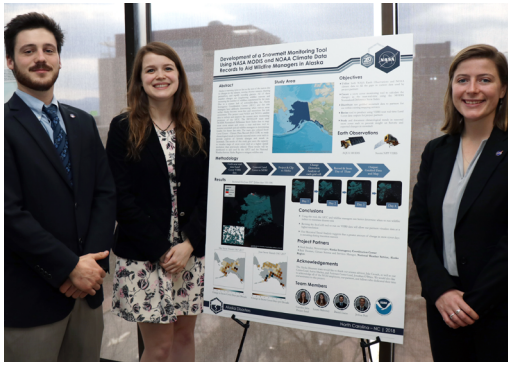
VA – WISE
Michael Brooke *
Brooke Colley
Zhuoyan He
Jessica Li +
Beck Saults
Jen Schellman +
Chenyu Shi

Fellow
Project Lead +
Center Lead
Assistant Center Lead *

DEVELOP is a dynamic program that offers multiple avenues for involvement to a wide variety of people.

If interested, we suggest reaching out to the program today!

Engage as a **DEVELOPer:**



DEVELOP runs three application periods per year—spring, summer and fall. Anyone 18 and over who is interested in pursuing experience in the Earth sciences and remote sensing, including currently enrolled college students, recent graduates, early career professionals, transitioning career professionals, and active & recently transitioned U.S. military service members, is eligible to apply. Participants from all education levels and backgrounds are welcome to apply. DEVELOP offers both paid and volunteer opportunities.

Applicants must have a minimum 3.0 GPA on a 4.0 scale at their current or last institution of higher learning, the ability to transport themselves to and from the DEVELOP location, and a strong desire to learn more about NASA Earth observations, GIS, and remote sensing.

U.S. CITIZENS – Eligible to apply to all DEVELOP locations in the United States.
FOREIGN NATIONALS – International applicants who are currently enrolled or recently graduated from a U.S. accredited university are eligible to apply to DEVELOP's regional locations, but not NASA or NOAA locations. Acceptance of foreign nationals is conditional upon proof of a valid visa, I-20 form, and an approved CPT/OPT that allows legal employment within the United States. Applicants who do not meet these requirements are not eligible to participate.

Engage as a **Project Partner:**

Any organization making decisions related to environmental concerns and interested in incorporating NASA Earth observations into their decision-making process is welcome to contact DEVELOP to discuss potential collaborations.

A project request form can be found on the DEVELOP website at **develop.larc.nasa.gov/projects.php.**
Please visit the website for more information on partnering with DEVELOP.

Engage as an **Advisor:**

A broad spectrum of advising supports DEVELOP projects, ranging from remote sensing experts to specialists in specific project topics. If you are interested in volunteering your time advising a DEVELOP project, please contact the DEVELOP National Program Office to discuss potential opportunities at **NASA-DL-DEVELOP@mail.nasa.gov.**

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DEVELOP.

DEVELOP
National Program

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