National Aeronautics and
Space Administration

NASA APPLIED SCIENCES' CAPACITY BUILDING PROGRAM'S

DEVELOP NATIONAL PROGRAM

2016 SUMMER PROJECT BOOKLET

www.nasa.gov

Letter from the
National Program Office

Thank you for taking the time to learn more about our 2016 summer projects. We are very proud of our DEVELOP team and hope you gain a better appreciation of our mission to apply science in service to society.

In 2016, DEVELOP reached new heights in terms of project strength, partner involvement, and participant contributions to our communities, fellow federal agencies, and NASA. DEVELOP's amazing innovation continued with expanded projects and new initiatives resulting in more scripting-based decision-support tools than ever before. As a team, we are honored to support one of the greatest institutions in America, the National Park Service (NPS), in celebrating their centennial by contributing research across the NPS system in the areas of water resource management, air quality planning, and invasive plant distribution, just to name a few. This past term, we continued to demonstrate our broad national reach, from monitoring mangrove extent in the Florida Everglades to assessing drought conditions in California and detecting changes in snowpack in the Northern Great Plains. Our efforts also spanned globally, from studying water management in Costa Rica to crop
productivity research in the Mekong Basin and assessing landslides in east Africa. These are but a few of our global efforts, and we invite you to read about the 30 projects that our 138 DEVELOPers conducted at 12 locations working with 72 partners in the summer of 2016. We think you will be impressed with the depth and breadth of our research efforts.

We are very grateful to our partners and end users, for without "customers", DEVELOP would not be where we are today. Our participants are the key to DEVELOP's success, as their commitment and dedication to improve our planet is unparalleled. We honor them. And to our sponsors at NASA and beyond, we know that without your support progress would not be possible.

In closing, we extend our thanks to you, the reader, who we hope will take an active interest in getting to know our participants and projects better.

With appreciation,
The DEVELOP National Program Office

Georgina S Crepps

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Karen Allilunk

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Lauren Clinton

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DEVELOP **Vision**

Shaping the future by integrating Earth observations into global decision making.

About **DEVELOP**

DEVELOP addresses a wide array of environmental & 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 90+ 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 Agriculture, Climate, Disasters, Ecological Forecasting, Energy, Health & Air Quality, Oceans, Water Resources, Weather, and Cross-Cutting.

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.

Discovery • Innovation • Passion • Collaboration

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 400 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 is a vital ingredient in the DEVELOP model. Each year DEVELOP collaborates with over 150 organizations to generate and conduct projects that apply NASA Earth observations to decision-making processes around the globe.

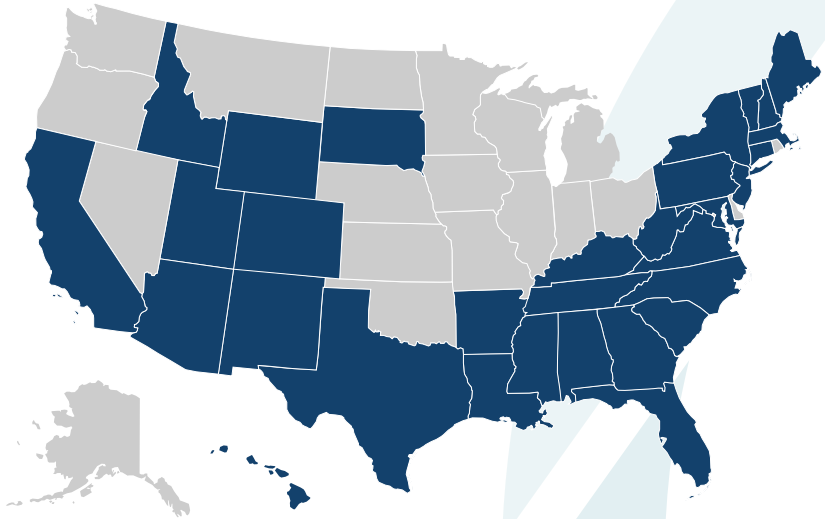
Partnerships often occur with local and state governments, regional consortiums, federal agencies, non-governmental and private organizations, academic institutions, and international governments and aid organizations.

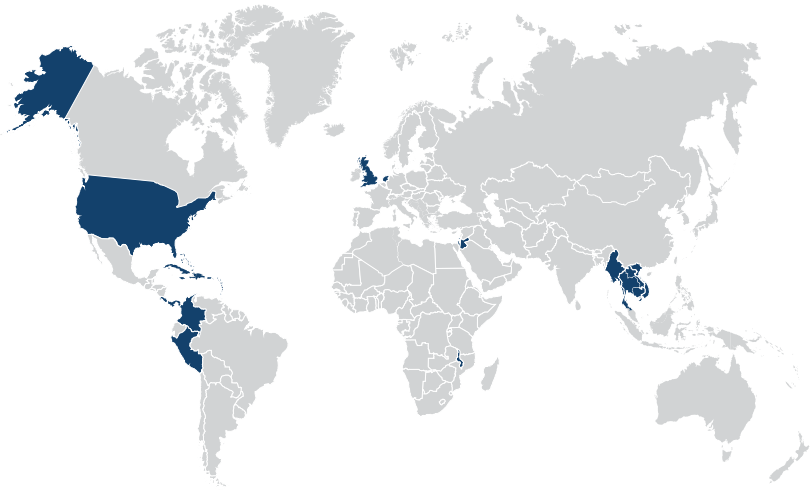
By collaborating with DEVELOP, partners are introduced to NASA's Earth Science Division and its Earth observation resources. End users gain insight into satellite and airborne Earth observation capabilities and how they can augment and enhance their current decision-making practices. This provides potential 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.

2016 **Summer Term**

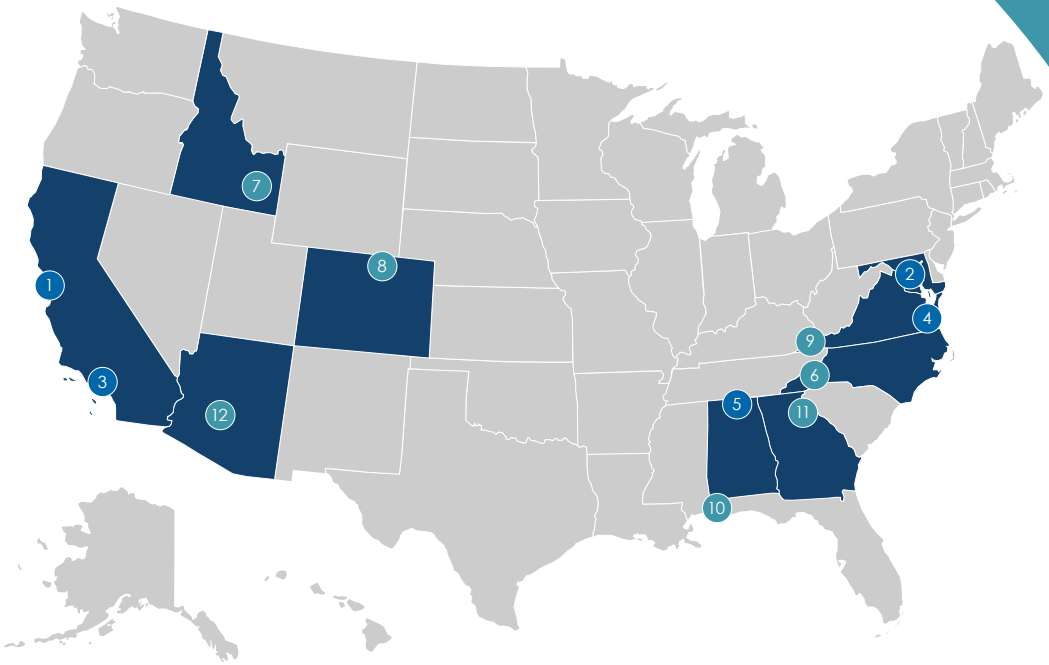
DEVELOP's 2016 summer term has been one of exciting collaborations with engaged partners in support of their decision-making needs. 138 DEVELOPers and 72 partners collaborated within the DEVELOP framework to conduct 30 rapid feasibility projects. These projects utilized NASA's Earth observations to monitor 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 34 sensors, including data from 16 of NASA's spaceborne missions, were applied by the DEVELOP project teams to seven of the NASA Applied Sciences' National Application Areas– Agriculture, Climate, Disasters, Ecological Forecasting, Health & Air Quality, Oceans, 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 regional organizations. In support of the National Park Service Centennial, DEVELOP conducted nine projects with national parks, monuments, and inventory and monitoring networks across the U.S. DEVELOP collaborated with the Embassy of Costa Rica on two projects this summer in partnership with environmental managers in Costa Rica with decision-support tools focused on water management.



NASA Center Locations

1. **NASA Ames Research Center** – *Moffett Field, CA*
2. **NASA Goddard Space Flight Center** – *Greenbelt, MD*
3. **NASA Jet Propulsion Laboratory** – *Pasadena, CA*
4. **NASA Langley Research Center** – *Hampton, VA**
5. **NASA Marshall Space Flight Center at NSSTC** – *Huntsville, AL*

*** The DEVELOP National Program Office is also located at Langley.**

Regional Locations

6. **NOAA National Centers for Environmental Information** – *Asheville, NC*
7. **BLM at Idaho State University GIS TReC** – *Pocatello, ID*
8. **USGS at Colorado State University** – *Fort Collins, CO*
9. **Wise County and City of Norton Clerk of Court's Office** – *Wise, VA*
10. **Mobile County Health Department** – *Mobile, AL*
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OVERVIEW

DEVELOP's Agriculture 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 state and federal agencies, regional consortiums, and international governments and academic institutions to support agricultural management, policy making, and global food security.

PORTFOLIO

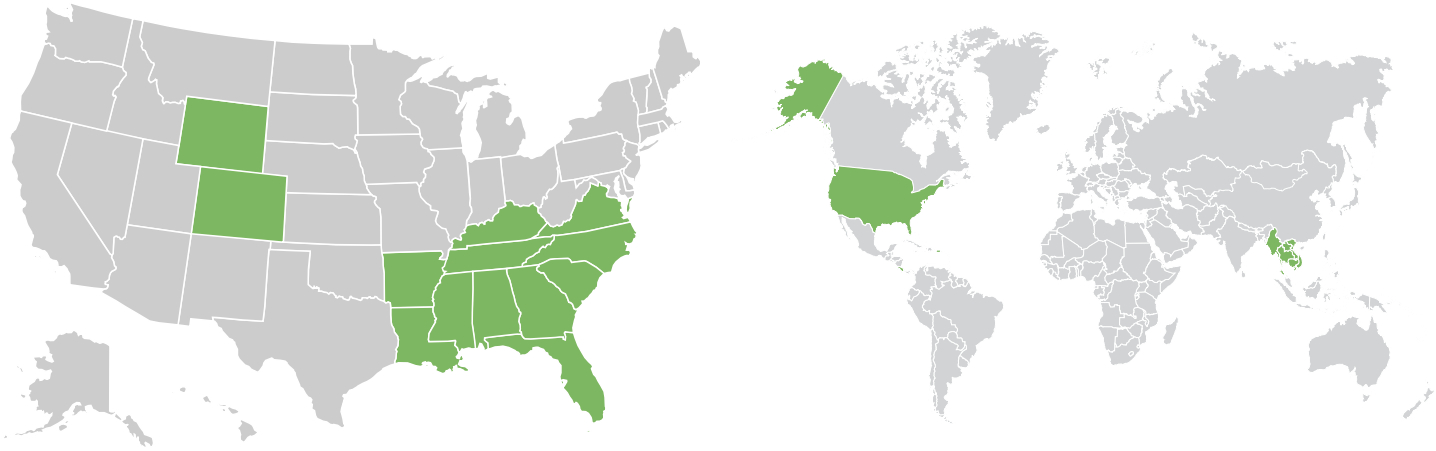
Rocky Mountain Agriculture: Utilizing NASA Earth Observations to Reconstruct and Identify Historical Forest Disturbances in the Southern Rocky Mountains for Enhanced Forest Management – *FC*

Puerto Rico Agriculture: Utilizing NASA Earth Observations to Map the Spread of the Red Palm Mite in Puerto Rico for Detection, Management, and Conservation – *GSFC*

Costa Rica Agriculture: Applying ECOSTRESS Diurnal Cycle Land Surface Temperature and Evapotranspiration to Agricultural Soil and Water Management – *JPL*

Mekong River Basin Agriculture: Utilizing NASA Earth Observations to Enhance Drought Management Decisions within the Mekong River Basin's Agricultural Fields – *MSFC*

Southeast United States Agriculture: Incorporating NASA Earth Observations into the USDA Southeast Regional Climate Hub Lately Identified Geospecific Heightened Threat System to Assist Farmers in Making Informed Decisions on Water and Crop Management – *WC*



Agriculture Projects No Impact

PARTNERS

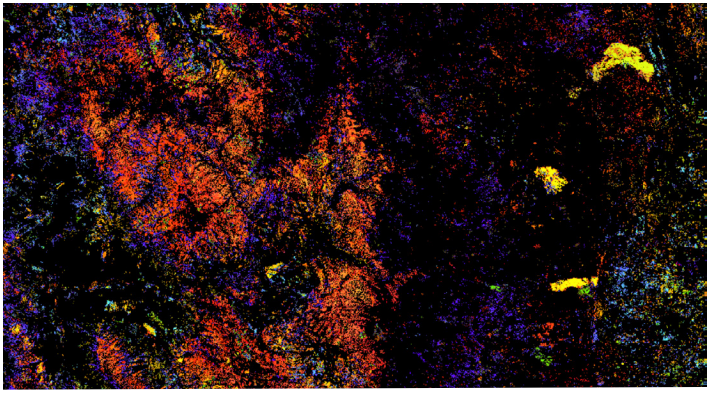
Asian Disaster Preparedness Center
Bioenergy Alliance Network of the Rockies, Feedstock Supply Team
Colorado Forest Restoration Institute
EARTH University
NASA SERVIR Coordination Office at MSFC
National Park Service, Rocky Mountain National Park
Royal Thai Embassy
SERVIR Mekong Hub
University of Puerto Rico
USDA, Southeast Regional Climate Hub
USDA, Agricultural Research Service

SENSORS

Aqua/Terra MODIS
EO-1 Hyperion
GPM GMI
IKONOS
Landsat 4/5 TM
Landsat 7 ETM+
Landsat 8 OLI
SMAP
SRTM
Suomi NPP VIIRS
Terra ASTER GED
TRMM PR

ROCKY MOUNTAIN AGRICULTURE

Utilizing NASA Earth Observations to Reconstruct and Identify Historic Forest Disturbances in the Southern Rocky Mountains for Enhanced Forest Management
USGS at Colorado State University



Team – Peder Engelstad (Project Lead), Christopher Beddow, Stephanie Krail, Amandeep Vashisht
Partner – National Park Service Rocky Mountain National Park; Colorado Forest Restoration Institute; Bioenergy Alliance Network of the Rockies, Feedstock Supply Team
Earth observations – Landsat 4/ 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM

In recent decades, the Rocky Mountains of northern Colorado and southern Wyoming have experienced extremely high levels of forest disturbance. Methodologies for mapping and labeling disturbance and classifying historical harvest events on the landscape level have not been readily available in the past. However, recent literature has paved the way for refined approaches, such as change detection software and predictive classification models. This project provided a more complete dataset for the National Park Service Rocky Mountain National Park, the Colorado Forest Restoration Institute , and the Bioenergy Alliance Network of the Rockies Feedstock Supply Team. Landsat 4 and 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper Plus, and Landsat 8 Operational Land Imager imagery were integrated into the LandTrendr algorithm to detect magnitude, duration, and extent of past forest disturbances. A suite of classification algorithms, including the Boosted Regression Trees and the Random Forests classification models, were used to conduct analyses at the landscape level across a temporal scale of over 30 years. A labeled forest disturbance history was provided to project partners, which filled gaps in their past records and led to enhanced decision making in the future.

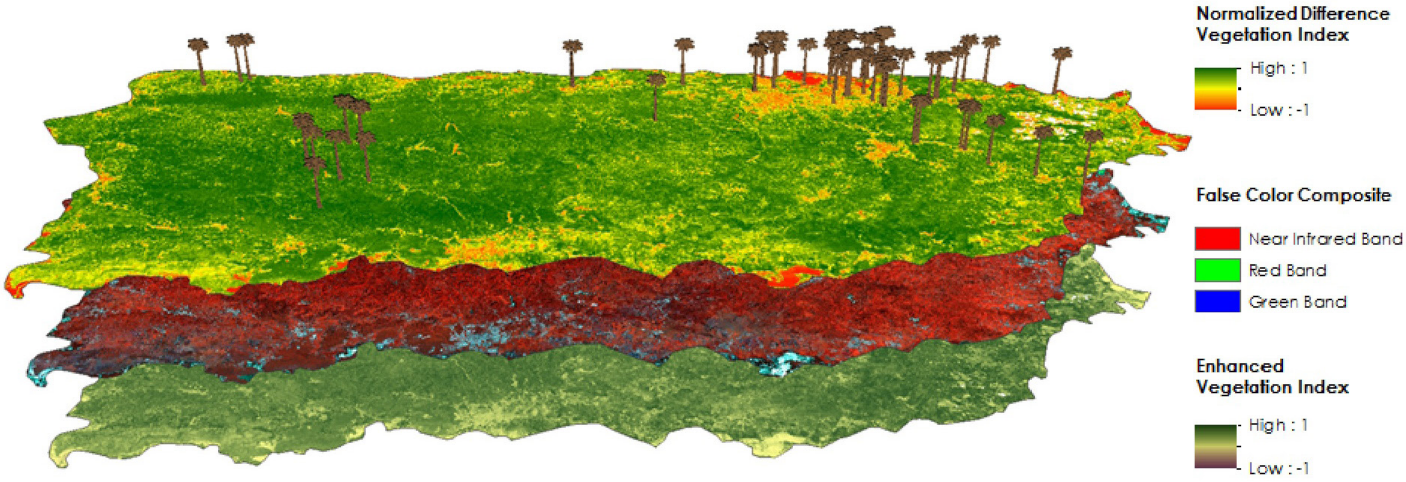
PUERTO RICO AGRICULTURE

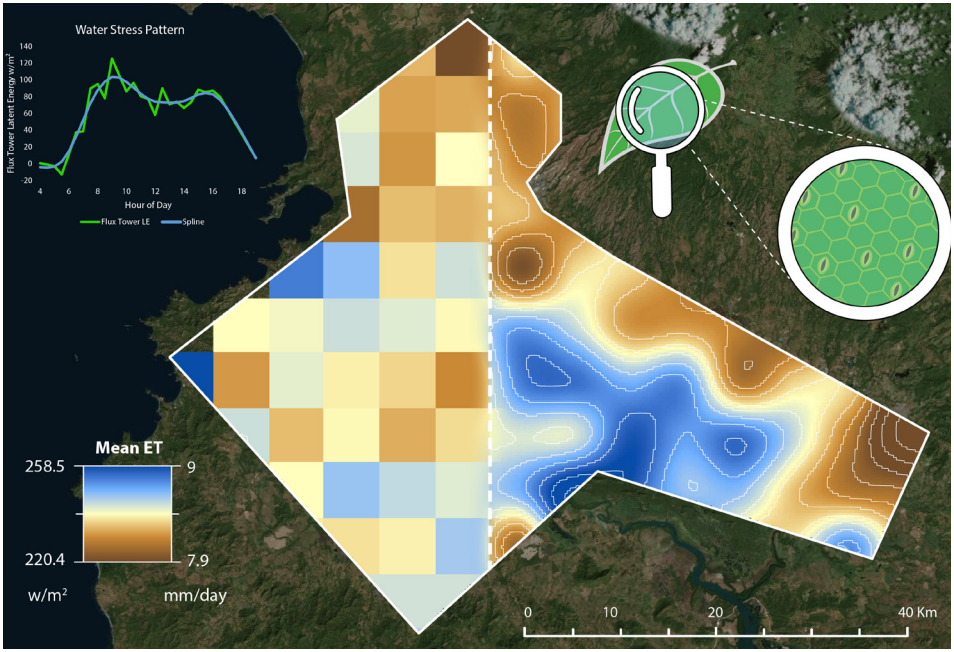
Utilizing NASA Earth Observations to Map the Spread of the Red Palm Mite in Puerto Rico for Detection, Management, and Conservation

NASA Goddard Space Flight Center

Team – Dr. Sara Lubkin (Project Lead), Julia Marrs, Sean McCartney, Alison Thieme
Partner – University of Puerto Rico; USDA, Agricultural Research Service
Earth observations – Landsat 7 ETM+, Landsat 8 OLI, EO-1 Hyperion, IKONOS

The rapid spread of the red palm mite, *Raoiella indica*, has devastated coconut palm, banana, and plantain crops throughout the Americas and the Caribbean since its introduction into the hemisphere in 2003. Red palm mites feed on the stomata of plant hosts' leaves using specialized mouthparts, resulting in accelerated water loss, decreased crop yield, and a characteristic pattern of leaf yellowing and senescence that can be remotely detected using multispectral imagery and calculated spectral vegetation indices from Landsat 7 Enhanced Thematic Mapper Plus, Landsat 8 Operational Land Imager, Earth Observing-1 Hyperion, IKONOS platforms, and aerial imagery. In conjunction with the United States Department of Agriculture Agricultural Research Service and the University of Puerto Rico, the distribution of red palm mite infestation in Puerto Rico was tracked from 2002 to 2016 and maps were produced showing the geographic spread of the red palm mite infestation during this time. The high adaptability of red palm mites to multiple plant hosts, adverse environmental conditions, diverse dispersal pathways, and the absence of known biotic countermeasures makes the mite an urgent environmental and economic threat throughout Southeast Asia, Oceania, and the Americas. Understanding past red palm mite invasions will help to prevent its spread into proximal agricultural areas and limit exposure and resulting crop destruction. The tracking methodology and tools established here can be applied to other geographical areas in an effort to mitigate current mite infestations and to monitor and prevent probable future invasions.





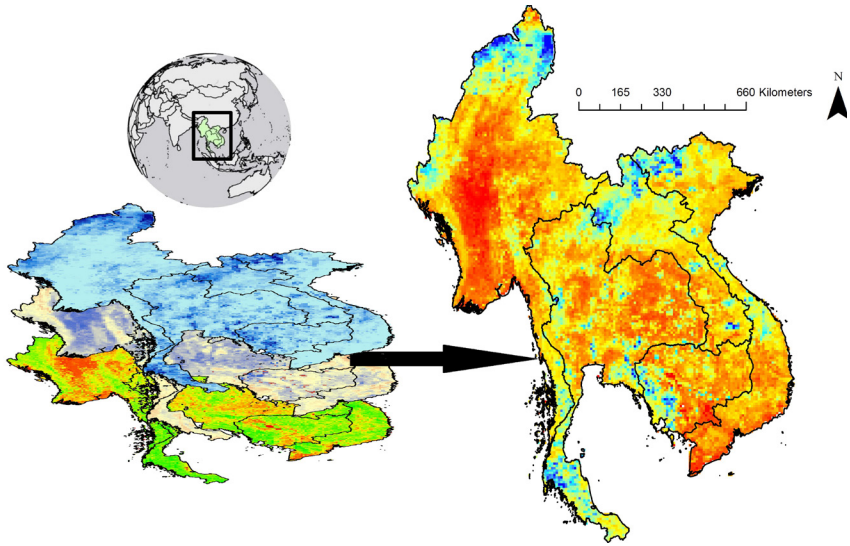
COSTA RICA AGRICULTURE

Applying ECOSTRESS Diurnal Cycle Land Surface Temperature and Evapotranspiration to Agricultural Soil and Water Management

NASA Jet Propulsion Laboratory

Team – Gregory Halverson (Project Lead), Mark Barker, Savannah Cooley, Steven Pestana
Partner – EARTH University
Earth observations – Terra MODIS, Suomi NPP VIIRS, Terra Aster GED

Increased demand for agricultural products and limited water supplies in Costa Rica have encouraged decision makers to seek improved water management practices to increase the efficiency, allocation, and impact of their resources. Remotely-sensed evapotranspiration data can provide officials with insights into variables like crop health and water loss, as well as provide direction as to when and how much water should be used. Currently, EARTH University's data are limited to *in situ* observations and will greatly benefit from expanded measurement collection over larger areas. In this project, remotely-sensed Moderate Resolution Imaging Spectroradiometer (MODIS) evapotranspiration data were modified for this purpose with increased spatial and temporal coverage through the resampling of ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) data. The MODIS Priestly-Taylor Jet Propulsion Laboratory 5 km evapotranspiration product was resampled to 70 m resolution to simulate the Level-3 ECOSTRESS product. This simulated, high-resolution data can demonstrate the use of future ECOSTRESS data in managing and implementing healthy and productive sustainable farms throughout the region of Guanacaste. This investigation of the diurnal cycle of land surface temperature, net radiation, and evapotranspiration will advance the model science of ECOSTRESS to be launched in 2018 on the International Space Station.



MEKONG RIVER BASIN AGRICULTURE

Utilizing NASA Earth Observations to Enhance Drought Management Decisions within the Mekong River Basin's Agricultural Fields

NASA Marshall Space Flight Center

Team – Daryl Ann Winstead (Project Lead), Waritchana Rakumthong, Pumichat Raksaphaeng, Allison Daniel
Partner – NASA SERVIR Coordination Office at MSFC; Royal Thai Embassy; Asian Disaster Preparedness Center; SERVIR Mekong Hub
Earth observations – GPM GMI, TRMM PR, Aqua/Terra MODIS

The Mekong River Basin region is one of the world's largest contributors in the global rice production market with rice paddies on over more than 10 million hectares of land. The production of these crops contributes significantly to the local economies and workforce within this region. The Mekong River Basin experiences seasonal flooding, as well as periods of drought, which affect the rice yield. The majority of the rice fields in the Mekong River Basin rely on rainwater for irrigation rather than using groundwater, which can be problematic during extended periods of drought. The NASA SERVIR Coordination Office located at the Marshall Space Flight Center has partnered with the Asian Disaster Preparedness Center through the SERVIR Mekong Hub in order to improve on climate resilience in the Mekong River Basin region. This project focused on applying the Scaled Drought Condition Index, an index used for agricultural drought, throughout Thailand, Myanmar, Laos, Vietnam, and Cambodia in the Mekong River Basin. This index was created by using precipitation data from Tropical Rainfall Measuring Mission and Global Precipitation Measurement, land surface temperature from the Moderate Resolution Imaging Spectroradiometer (MODIS), and Normalized Difference Vegetation Index data from MODIS. The SDCI was used in creating a time series and compiling a near real-time monitoring tool that aided in mitigation efforts against prolonged drought in the Mekong River Basin.

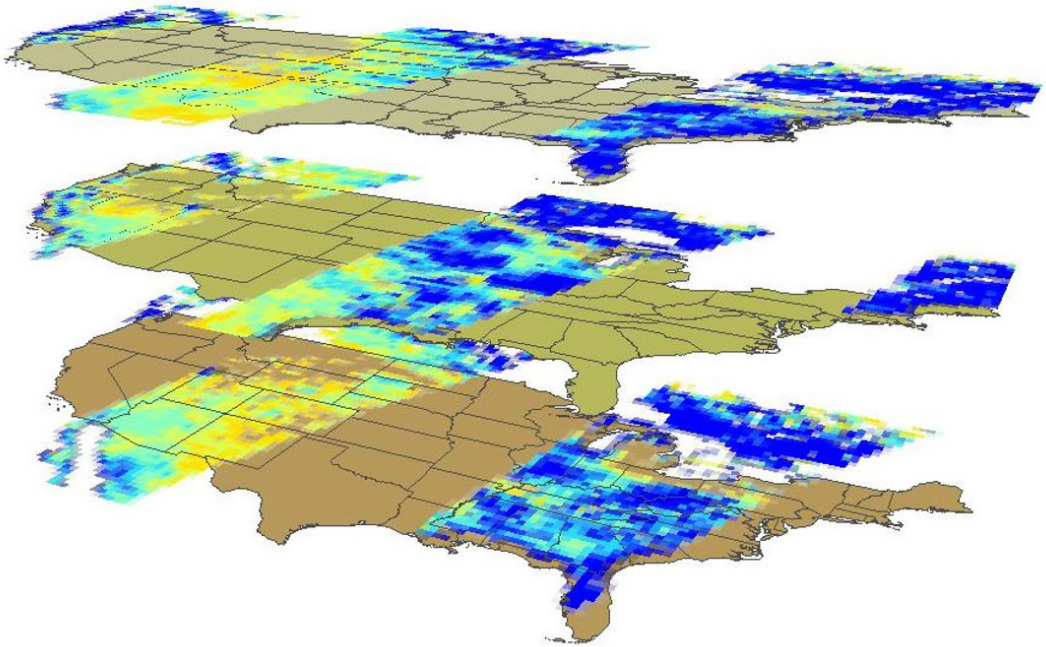
SOUTHEAST UNITED STATES AGRICULTURE

Incorporating NASA Earth Observations into the USDA Southeast Regional Climate Hub Lately Identified Geospecific Heightened Threat System (SERCH LIGHTS) to Assist Farmers in Making Informed Decisions on Water and Crop Management

Wise County and City of Norton Clerk of Court's Office

Team – Yaping Xu (Project Lead), Yousra Benchekroun, Kimberly Berry, Grant Bloomer
Partner – USDA Southeast Regional Climate Hub (SERCH)
Earth observations – SMAP

Regional climate variability in the southeastern United States is a concern for agricultural and forestry management. Droughts are an important consequence of this variability, affecting both the agricultural and forestry sectors' ability to manage their water resources. The United States Department of Agriculture Southeast Regional Climate Hub (SERCH) has thus developed a tool called Lately Identified Geospecific Heightened Threat System (LIGHTS) in order to provide information for its users that would increase water management efficiency. It identifies and alerts users to changes in drought, temperature, and precipitation patterns. However, LIGHTS lacks soil moisture information, which also affects drought patterns. This project aims to update the current drought monitoring system by incorporating Soil Moisture Active Passive (SMAP) level 3 data as a support layer, by retrieving Standardized Soil Moisture Index as a measure, and by using Python as the programming language. Ground truth soil moisture data from Soil Climate Analysis Network were collected for validation. As a result, this integration of SMAP data into SERCH LIGHTS will increase the end user's water management capabilities in response to drought conditions.



OVERVIEW

DEVELOP's Climate projects support activities associated with the implementation of climate standards, policies, and regulations for environmental, economic, and human welfare. The projects apply NASA satellite and airborne data, model products, and scientific findings to climate mitigation and adaptation decisions. This summer, DEVELOP had one Climate project in its portfolio that partnered with Perú to improve adaptation and mitigation decisions for traditional potato farming.

PERÚ CLIMATE III

Monitoring and Forecasting Shifting Climate and Land Change Impacts in Perú's Parque de la Papa for Enhanced Agricultural Management

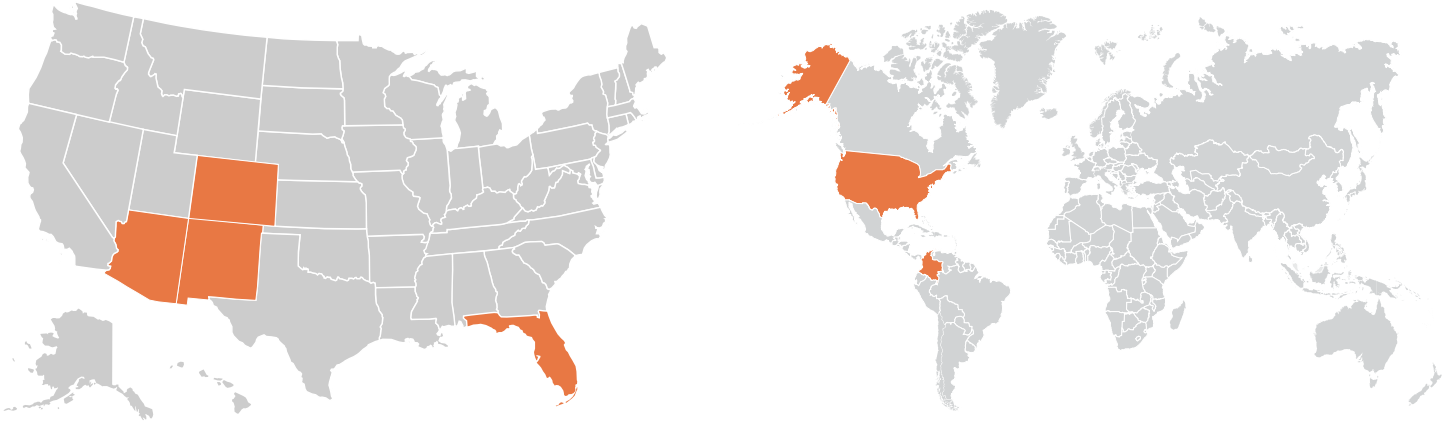
University of Georgia

Team – Caren Remillard (Project Lead), Shirin Esmaeili, Dorris Scott, Parul Singh
Partner – International Potato Center; Association Para la Naturaleza y el Desarrollo Sostenible
Earth observations – Landsat 8 OLI, Terra ASTER

Agricultural systems in tropical montane regions are particularly vulnerable in the face of global climate change. Anecdotal evidence from Parque de la Papa, located in the Peruvian Andes, indicates that farmers following traditional practices have moved potato crops to higher elevations seeking suitable growing conditions for the potato varieties they have cultivated for centuries. The primary threat to native potatoes is increased mortality rates stemming from pests and diseases. In particular, rising temperatures have led to increases in the population and habitat range of the Andean potato weevil (*Premnotrypes*). The project used a mixed model approach combining quantitative and qualitative information to create a suitability model identifying areas that are currently suitable for potato planting and cultivation. Another goal of this project was to create a risk assessment of areas that will become unsuitable for potato cultivation in the future. This model was based on Landsat-derived land cover and land use, soil, climate data, and local knowledge. It will be used to predict optimal areas for potato cultivation and will be given to the International Center for Potatoes for use in a management plan to inform the farming efforts of the indigenous communities within Parque de la Papa.

OVERVIEW

DEVELOP's Cross-Cutting projects explore applications of Earth observations across a variety of environmental themes that align with NASA's Applied Sciences' Application Areas, but extend beyond to incorporate additional societal concerns. These projects focus on innovative technologies and methods to apply NASA satellite and airborne data to create new decision-making tools and management applications. This summer, three projects focused on illustrating the ability of Earth observations to support the National Park Service's conservation efforts, the indicator monitoring of the United Nation's Sustainable Development Goals, and improving the interface for CALIPSO data users.



Cross-Cutting Projects No Impact

PORTFOLIO

CALIPSO Cross-Cutting: Enhancing the Usability of *Visualization of CALIPSO* Through a Test-Case-Driven Approach – *LaRC*
Chaco Canyon Cross-Cutting: Utilizing NASA Earth Observations to Identify Chacoan Community Signature Profiles throughout the Chaco Canyon to Assist Preservation and Protection Strategies – *MSFC*
SDGs Cross-Cutting: Integrating NASA Earth Observations into the Global Indicator Framework for Monitoring the United Nations' Sustainable Development Goals – *LaRC*

SENSORS

Aqua/ Terra MODIS
CALIPSO CALIOP
Landsat 5 TM
Landsat 8 OLI
SRTM
Terra ASTER GED
& TIR

PARTNERS

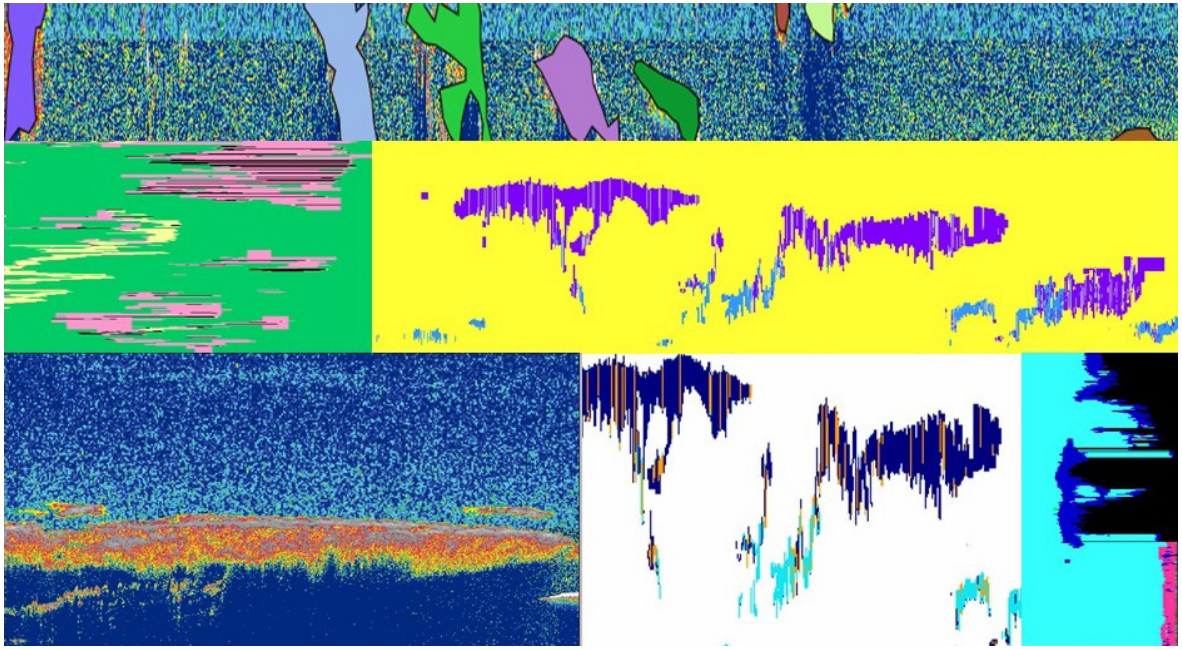
Binghamton University
NASA Applied Sciences Program
NASA CALIPSO Science Team
National Park Service, Intermountain Region Cultural Resources Department
Group on Earth Observations
University of Colorado Boulder
University of Nebraska-Lincoln

CALIPSO CROSS-CUTTING

Enhancing the Usability of *Visualization of CALIPSO* Through a Test-Case-Driven Approach
NASA Langley Research Center

Team – Dr. Kathleen Moore (Project Co-Lead), Ahmad Aburizaiza (Project Co-Lead), Andrea Martinez, Adama Ba, Joseph Driscoll
Partner – NASA CALIPSO Science Team
Earth observations – CALIPSO CALIOP

The relationship that exists between cloud nuclei and aerosols plays a vital role in Earth's climate system. For the purpose of detection, the Cloud-Aerosol Light Detection and Ranging and Infrared Pathfinder Satellite Observations (CALIPSO) satellite offers scientists the ability to better understand the relationship between clouds, aerosols, and climate by measuring the backscatter created by embedded atmospheric aerosols. The standard visualizer for CALIPSO satellite data is limited by the proprietary programming language in which it is written. Hence, development of a new, enhanced visualizer, *Visualization of CALIPSO* (VOCAL), has been in development by NASA DEVELOP teams since the spring of 2015. Written in Python, VOCAL displays CALIPSO curtain Hierarchical Data Format files for both backscattered and depolarized Level 1, Version 3 data. In addition, the user can draw polygons overlaying the displayed data, to mark potential regions-of-interest. Subsequently, these regions can be tagged with attributes and notes. VOCAL can export to a database or to JavaScript Object Notation files any shapes that the user may want to save. This term, the CALIPSO Cross-Cutting team added support for the newest CALIPSO data product (Version 4), alternative viewing options for the data in VOCAL, as well as a suite of use-cases for the software.



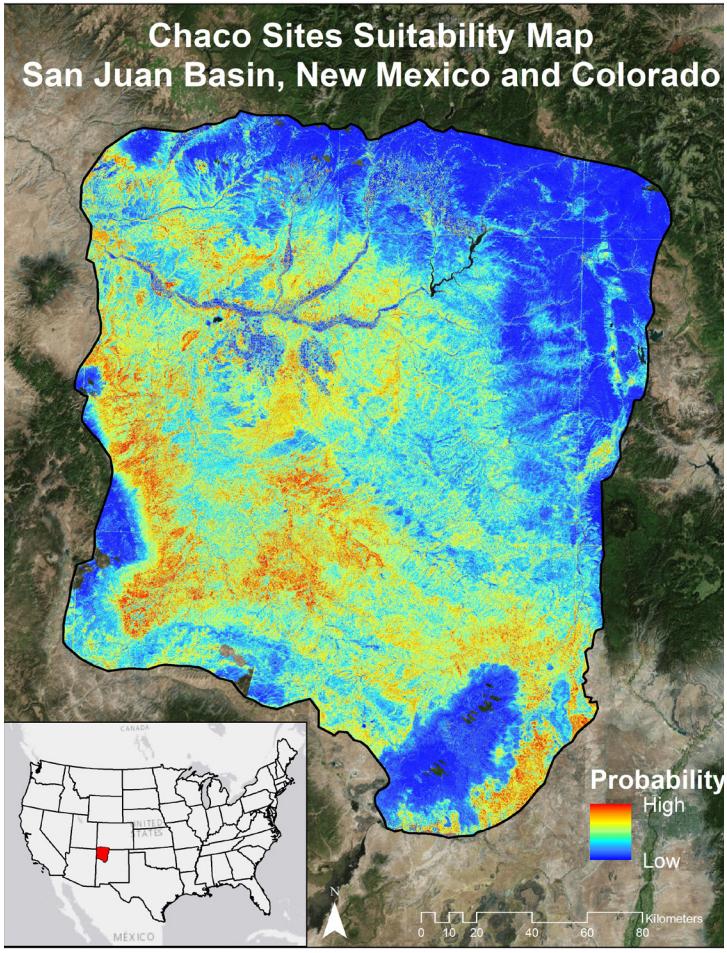
CHACO CANYON CROSS-CUTTING

Utilizing NASA Earth Observations to Identify Chacoan Community Signature Profiles throughout the Chaco Canyon to Assist Preservation and Protection Strategies

NASA Marshall Space Flight Center

Team – Kelsey Herndon (Project Lead), Dashiell Cruz, Sydney Neeley, Ryan Schick
Partner – National Park Service, Intermountain Region; Binghamton University; University of Nebraska-Lincoln; University of Colorado Boulder
Earth observations – Landsat 8 OLI, SRTM, Terra ASTER GED/TIR

The Chacoan people flourished in northwest New Mexico between 850 and 1150 AD. Today, remnants of their monumental architecture draw over 40,000 visitors a year to Chaco Canyon National Park to experience the natural grandeur of the area and to learn about Native American history throughout the San Juan Basin. However, many Chacoan roads and communities are located outside the boundaries of the National Park. These unprotected sites are threatened by encroaching infrastructure associated with resource extraction, such as drill pads with requisite access roads and pipelines. Currently, the National Park Service, Binghamton University, the University of Nebraska-Lincoln, and the University of Colorado Boulder rely on expensive and time-consuming ground surveys, imagery from Google Earth, and the Landsat collections to identify the extent of Chacoan roads and houses. This project utilized Landsat 8 Operational Land Imager surface reflectance, Shuttle Radar Topography Mission Version 2 digital elevation models, Terra Advanced Spaceborne Thermal Emission and Reflectance Radiometer emissivity data, Thermal Infrared Multispectral Scanner data, Hyperspectral Thermal Emission Spectrometer data, Sentinel-1A Synthetic Aperture Radar data, and Sentinel-2 MultiSpectral Instrument data to identify highly probable locations of unknown Chacoan sites, to determine sites at risk from infrastructure development and to identify the spectral signatures of these ancient communities. Documenting Chacoan community signature profiles and determining which areas are at risk of being affected by encroaching development will help the project partners to better understand the Chacoan landscape, as well as to better protect and preserve these ancient sites.



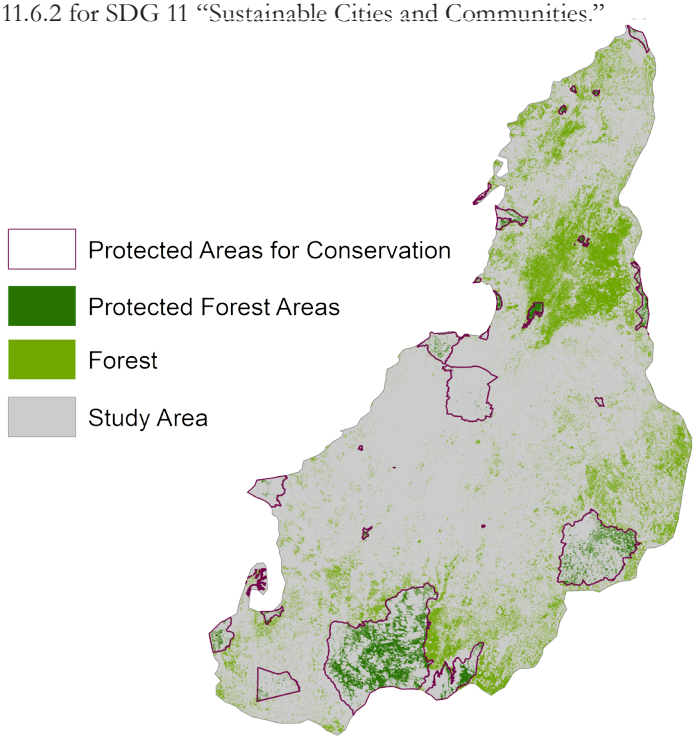
SDG CROSS-CUTTING

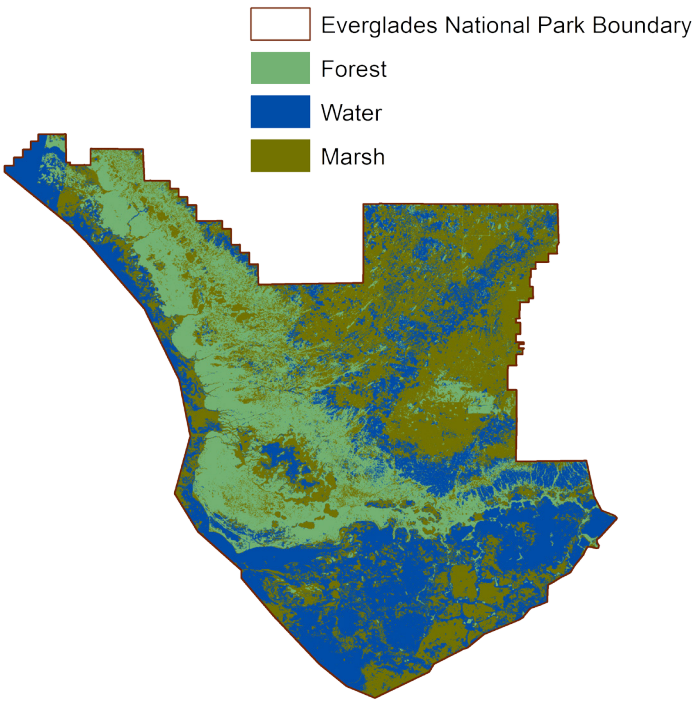
Integrating NASA Earth Observations into the Global Indicator Framework for Monitoring the United Nations' Sustainable Development Goals

NASA Langley Research Center

Team – Georgina Crepps (Project Lead), Emily Gotschalk, Lauren Childs-Gleason, Jamie Favors
Partner – NASA Applied Sciences Program; Group on Earth Observations
Earth observations – Landsat 5 TM, Landsat 8 OLI, Aqua/Terra MODIS

In September 2015, the United Nations adopted the 2030 Agenda for Sustainable Development. This plan outlines 17 Sustainable Development Goals (SDGs) which lay out the overarching objectives for all countries to meet by 2030. These goals address such global concerns as ending poverty and hunger, ensuring gender equality, access to clean water, and environmental sustainability. Each SDG consists of several targets to achieve, as well as a set of indicators that provide the framework by which to evaluate progress towards achieving those targets. Determining appropriate methodologies for the wide array of indicators created is a complex task, with diverse data sources providing various abilities and challenges. This project built upon the Group on Earth Observations and NASA Applied Sciences Program efforts to identify SDG indicators that could integrate Earth observations into the SDG's monitoring methodologies. DEVELOP projects that align with SDGs were identified and case studies created that provide examples of how EO can be integrated into SDG monitoring. This project identified potential methodologies for indicator 15.2.1 under SDG 15 "Life on Land", as well as 11.6.2 for SDG 11 "Sustainable Cities and Communities."





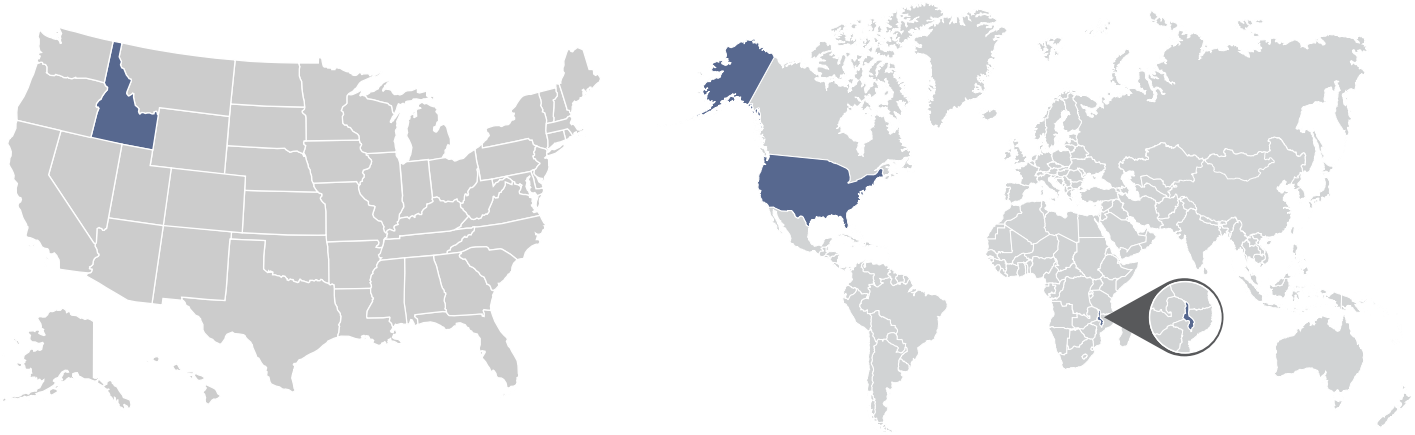
OVERVIEW

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

Eastern Idaho Disasters: Utilizing NASA Earth Observations to Identify Wildlife Habitat Areas Threatened by Heightened Wildfire Susceptibility for Improved Conservation and Management Practices – *ID*

East Africa Disasters II: Assessing Landslide Characteristics and Developing Susceptibility and Exposure Maps in Malawi – *MSFC*



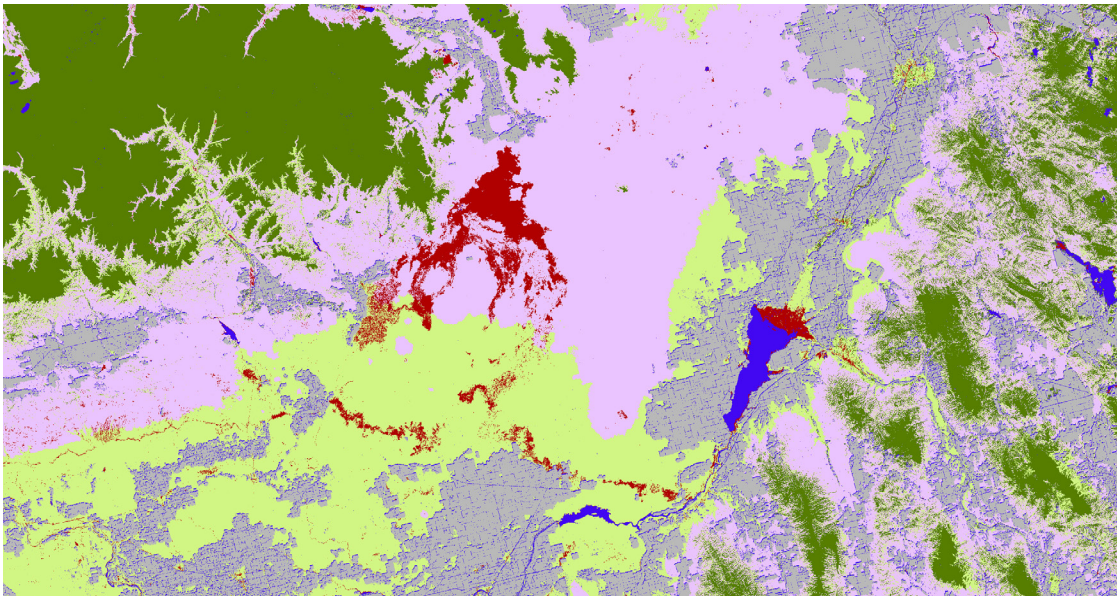
Disaster Projects No Impact

PARTNERS

Bureau of Land Management, Pocatello Field Office
Idaho Department of Fish and Game
NASA SERVIR Applied Sciences Team at NASA GSFC
NASA SERVIR Coordination Office at MSFC
National Park Service, Craters of the Moon National Monument and Preserve
Regional Centre for Mapping of Resources for Development
USDA Forest Service, Caribou-Targhee National Forest

SENSORS

GPM IMERG
Landsat 5 TM
Landsat 8 OLI
Sentinel-2A
SRTM
TRMM PR
WorldView



EASTERN IDAHO DISASTERS

Utilizing NASA Earth Observations to Identify Wildlife Habitat Areas Threatened by Heightened Wildfire Susceptibility for Improved Conservation and Management Practices

BLM at Idaho State University GIS TReC

Team – Courtney Ohr (Project Lead), Jenna Williams, Priscilla Addison
Partner – Bureau of Land Management, Pocatello Field Office; National Park Service, Craters of the Moon National Monument and Preserve; Idaho Department of Fish and Game; USDA Forest Service, Caribou-Targhee National Forest
Earth observations – SRTM, Sentinel-2A, Landsat 8 OLI

Wildfires can be disastrous for declining, threatened, or endangered wildlife species. Encroachment of non-native annual grasses, such as cheatgrass, or woody-vegetation, such as juniper, have increased fuel loads, intensified wildfire severity, and altered fire regimes throughout the Great Basin and Intermountain West. This project partnered with Craters of the Moon National Monument and Preserve and the Bureau of Land Management in Idaho to identify wildlife habitats with increased susceptibility to wildfires due to fuel loads. This project is unique in its inclusion of kipukas, islands of wildlife habitats found throughout lava formations. Wildlife habitats of the diminished Greater Sage-grouse (GRSG) (*Centrocercus uraphasignus*) and declining mule deer (*Odocoileus hemionus*) were included in the study. Two primary non-anthropogenic threats to GRSG sustainability are wildfires and invasive annual grasses dominating low- to mid-elevation sagebrush. This project leveraged Landsat 8 Operational Land Imagery data from June 2015, Sentinel-2 data from June 2016, fuel loads measured in tons per acre, and topographic variables to produce an at-risk habitat wildfire susceptibility model. Weightings from expert opinion and industry standards were applied to model variables to discern fire behavior and habitat vulnerability. Methods developed provided decision makers with new and effective ways to monitor remote areas and threatened habitats.

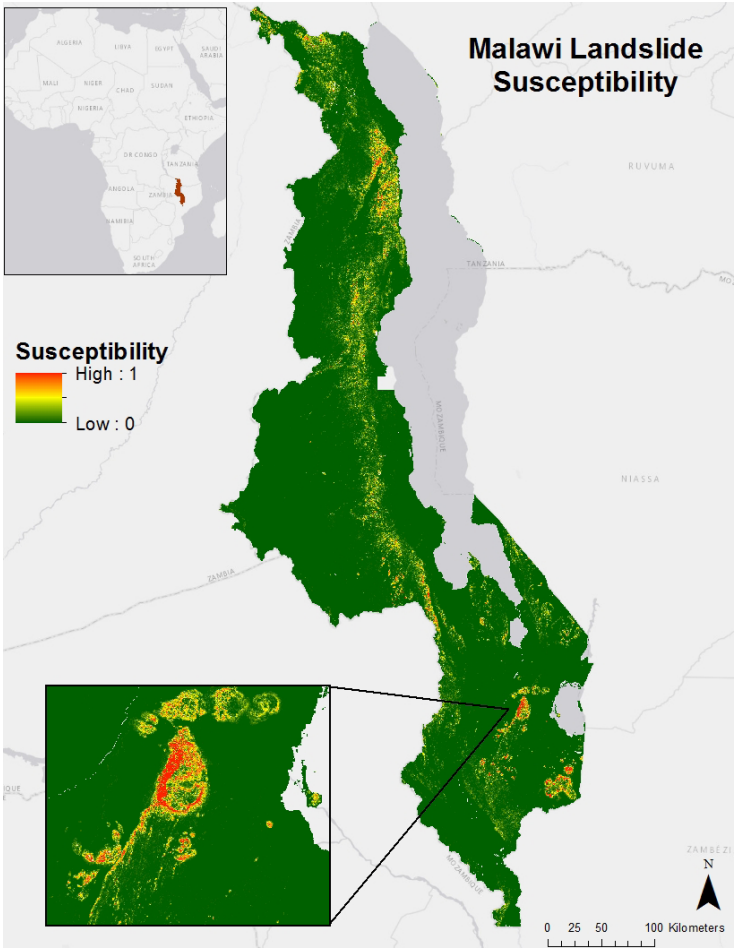
EAST AFRICA DISASTERS II

Assessing Landslide Characteristics and Developing Susceptibility and Exposure Maps in Malawi

NASA Marshall Space Flight Center

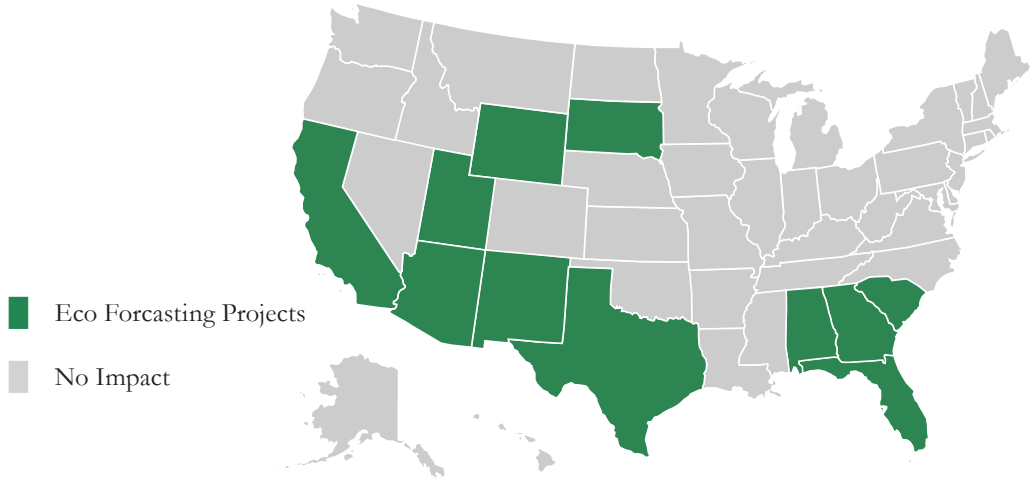
Team – Maggi Klug (Project Lead), Max Grossman, Jordan Cissell
Partner – Regional Centre for Mapping of Resources for Development; NASA SERVIR Coordination Office at MSFC; NASA SERVIR Applied Sciences Team at NASA GSFC
Earth observations – Landsat 5 TM, Landsat 8 OLI, GPM IMERG, TRMM PR, SRTM, WorldView

Malawi has become increasingly prone to landslides in the past few decades. This can be attributed to the terrain, types of soil and vegetation, increased human interference, and heavy flooding after long periods of drought. In addition to the floods and droughts, landslides cause extra stress on farmlands, thus exacerbating the current food security crisis in the country. It can be difficult to pinpoint just how many people are affected by landslides in Malawi because landslides often occur in rural areas or are grouped with other disasters, such as floods or earthquakes. This project created a Landslide Susceptibility Map to assess landslide-prone areas in Malawi using variables such as slope, distance to roads, soil type, land cover type, and precipitation. These variables were derived using imagery from Landsat 8 Operational Land Imager, Shuttle Radar Topography Mission Version 3, Global Precipitation Measurement (GPM), and Tropical Rainfall Measuring Mission (TRMM) satellites. This project created Landslide Exposure Maps to estimate how much of the local population lives in susceptible areas by intersecting population data with the Landslide Susceptibility Maps. Additionally, an assessment of GPM and TRMM precipitation measurements was generated to better understand the reliability of both measurements for landslide monitoring. Finally, this project updated NASA SERVIR's Global Landslide Catalog for Malawi by using WorldView data from Google Earth and Landsat 8 OLI. These end products were used by NASA SERVIR and the Regional Centre for Mapping of Resources for Development for aiding in disaster management throughout Malawi.



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

Elkhorn Slough Ecological Forecasting: Detecting Eutrophication Sources, Hotspots, and Nutrient Levels in a Central California Estuary to Support Watershed Management Decisions – *ARC*

Laramie Mountains Ecological Forecasting II: Modeling Aspen Distribution Utilizing NASA Earth Observations to Identify Critical Habitat for Mule Deer and Elk in the Laramie Range, Wyoming – *FC*

Northern Great Plains Ecological Forecasting: Utilizing NASA Earth Observations to Map Temporal and Spatial Patterns of Annual Bromes in the Northern Great Plains to Develop a Management Plan for Invasive Species Control – *GSFC*

Everglades Ecological Forecasting: Improving the Capacity of the Everglades National Park to Monitor Mangrove Extent using NASA Earth Observations – *LaRC*

Southwest U.S. Ecological Forecasting: Mapping Invasive Species to Efficiently Monitor Southwestern National Park Areas – *LaRC*

Southeast U.S. Ecological Forecasting III: Utilizing NASA Earth Observations and Proximal Remote Sensing for Mapping the Spatio-Temporal Distribution of *Hydrilla verticillata* – *UGA*

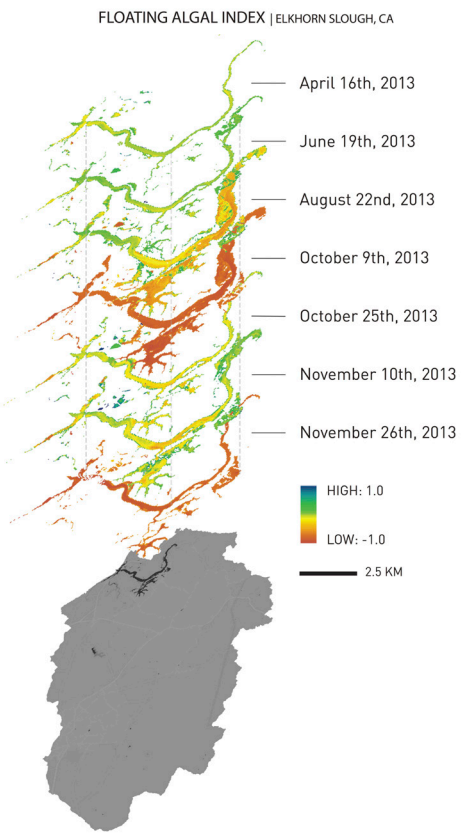
Mobile Bay Ecological Forecasting and Water Resources II: Monitoring Marsh Conditions in Coastal Alabama Using NASA Earth Observations to Support the Alabama Coastal Foundation's Restoration and Conservation Initiatives – *MCHD*

SENSORS

Aqua/Terra MODIS
Landsat 5 TM
Landsat 7 ETM+
Landsat 8 OLI/TIRS
Sentinal-1A C-SAR
Sentinel-2A MSI
SRTM

PARTNERS

Alabama Coastal Foundation
Colorado State University, National Resource Ecology Laboratory
Dauphin Island Sea Lab
Elkhorn Slough National Estuarine Research Reserve
Group on Earth Observations, Blue Planet Initiative
Henry County Water Authority, Cubihatchi Outdoor Education
Monterey Bay Aquarium Research Institute
National Park Service, Colorado Plateau Cooperative Ecosystem Studies Unit
National Park Service, Everglades National Park
National Park Service, Intermountain Region
National Park Service, Rocky Mountain National Park
National Park Service, Inventory & Monitoring Program, Northern Great Plains Network
National Park Service, Southwest Exotic Plant Management Team
Old Dominion University, Mitigation and Adaptation Research Institute
U.S. Army Corps of Engineers, J. Strom Thurmond Project
USDA Forest Service, Laramie Ranger District
USGS, Northern Prairie Wildlife Research Center
Wyoming Game and Fish Department



ELKHORN SLOUGH ECOLOGICAL FORECASTING

Detecting Eutrophication Sources, Hotspots, and Nutrient Levels in a Central California Estuary to Support Watershed Management Decisions

NASA Ames Research Center

Team – Irma Caraballo Álvarez, Abigail Childs, Kirsten Jurich, Martha Sayre
Partner – Elkhorn Slough National Estuarine Research Reserve; Monterey Bay Aquarium Research Institute
Earth observations – Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI

Elkhorn Slough in Monterey, California has experienced substantial nutrient loading and eutrophication over the past 21 years as a result of fertilizer-rich runoff from nearby agricultural fields. This study seeks to identify and track spatial patterns of eutrophication hotspots and the correlation to land use changes, possible nutrient sources, and general climatic trends using remotely-sensed and *in situ* data. Threats of rising sea level, subsiding marshes, and rising numbers of eutrophication hotspots demonstrate the necessity to analyze the effects of increasing nutrient loads, relative sea level changes, and sedimentation within Elkhorn Slough. The Soil & Water Assessment Tool model integrated specified inputs to assess nutrient and sediment loading and their sources. TerrSet's Land Change Modeler forecasted the future potential of land change transitions for various land cover classes around the slough as a result of nutrient loading, eutrophication, and increased sedimentation. TerrSet's Earth Trends Modeler provided a comprehensive analysis of image time series to rapidly assess long term eutrophication trends and detect spatial patterns of known hotspots. Results from this study will inform future coastal management structures and provide greater spatial and temporal insight into Elkhorn Slough eutrophication dynamics.

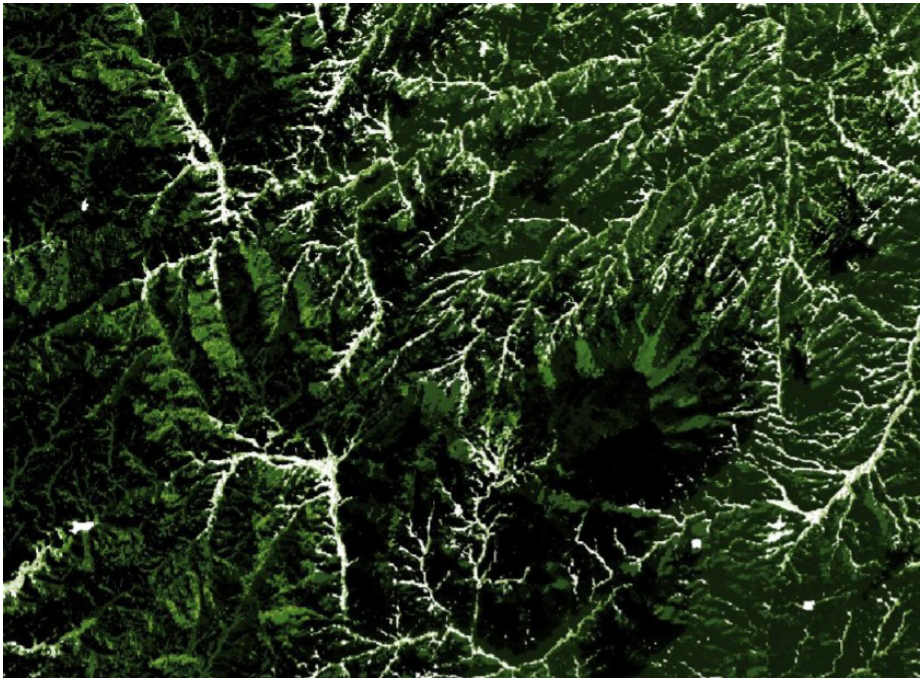
LARAMIE MOUNTAINS ECOLOGICAL FORECASTING II

Modeling Aspen Distribution Utilizing NASA Earth Observations to Identify Critical Habitat for Mule Deer and Elk in the Laramie Range, Wyoming

USGS at Colorado State University

Team – Sarah Carroll (Project Lead), Katie Butler, Aubrey Hilte, Megan Vahsen
Partner – Wyoming Game and Fish Department; USDA Forest Service, Laramie Ranger District; Colorado State University, National Resource Ecology Laboratory
Earth observations – Landsat 8 OLI, SRTM

In the Laramie Mountain Range in southeastern Wyoming, Quaking aspen (*Populus tremuloides*) stands support a diverse community of vertebrate species and are a source of high biomass productivity. Mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) are dependent on mature Aspen communities for forage and fawning habitat. Threats to Aspen habitat include climate change, over-browsing by wild and domestic ungulates, fire suppression, and large scale aspen die-off, known as Sudden Aspen Decline). Aspen cover data are limited and incomplete in the region making it difficult for wildlife managers to evaluate existing habitat. This project utilized Landsat 8 Operational Land Imager data from June of 2016, Shuttle Radar Topography Mission V2, and aspen survey data to develop a current aspen distribution model in the Laramie Range. The resulting map of aspen canopy cover probability was then compared with fire history data to investigate the relationship between fire and aspen regeneration. Additionally, topographic and climate data were utilized to model a bioclimatic niche for existing aspen and to predict future suitable aspen habitat across Wyoming. The Wyoming Game and Fish Department will utilize the datasets and map products to estimate the carrying capacity for mule deer and elk in the region, plan effective population management strategies, and support future aspen regeneration and management efforts.



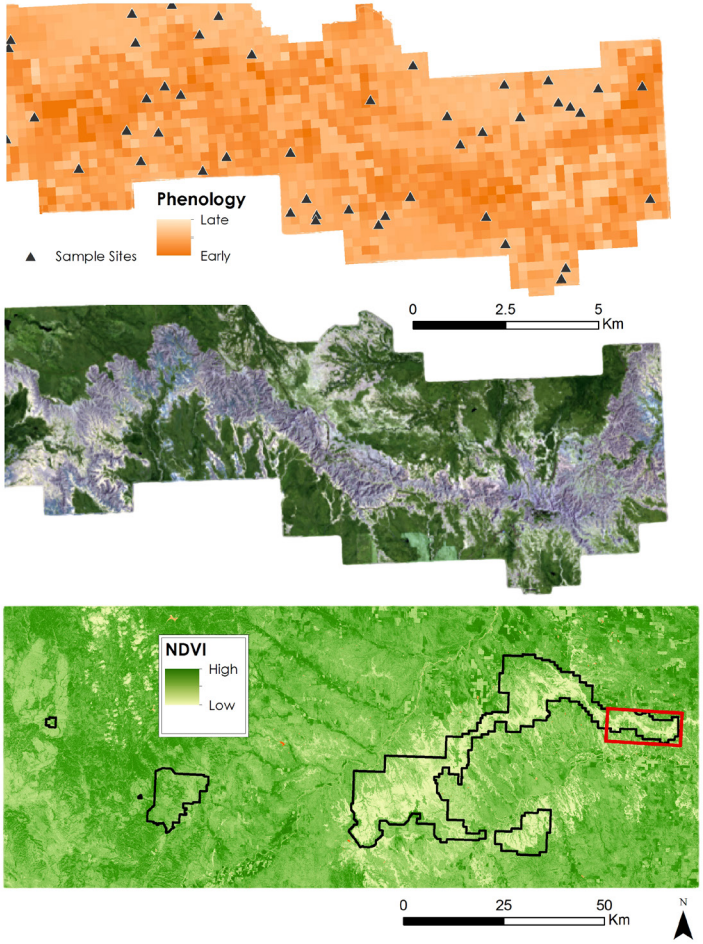
NORTHERN GREAT PLAINS ECOLOGICAL FORECASTING

Utilizing NASA Earth Observations to Map Temporal and Spatial Patterns of Annual Bromes in the Northern Great Plains to Develop a Management Plan for Invasive Species Control

NASA Goddard Space Flight Center

Team – Amanda Clayton (Project Lead), Jessica Fayne, Carl Green, Jared Tomlin
Partner – National Park Service, Inventory & Monitoring Program, Northern Great Plains Network; USGS, Northern Prairie Wildlife Research Center
Earth observations – Landsat 5 TM, Landsat 8 OLI, Sentinel-2 MSI, Terra/Aqua MODIS

Cheatgrass (*Bromus tectorum*) and Japanese brome (*Bromus japonicus*) are widespread invasive annual brome grasses that are distributed throughout the western United States. In the Northern Great Plains (NGP), the presence of these invasive brome species has led to a decrease in native plant diversity, reduced soil water content, and altered fire regimes—leading to more frequent fires of higher intensity. The National Park Service Northern Great Plains Network (NGPN) Inventory & Monitoring Program conducts vegetation monitoring throughout national park units to develop management practices for habitat restoration and invasive species control. Incorporating remotely-sensed NASA Earth observation data enables the NGPN to efficiently monitor the regional extent of brome abundance over time. The spatial and temporal resolution of Aqua/Terra Moderate Resolution Imaging Spectroradiometer, Landsat 8 Operational Land Imager, Landsat 5 Thematic Mapper), and Sentinel-2 Multispectral Instrument were leveraged to capture the vegetation phenology of these invasive brome species across the NGP. The satellite-derived Normalized Difference Vegetation Index (NDVI) was used to determine the distinct and early green up and senescence patterns of brome. Using unsupervised classification methods, the invasive bromes were identified from the surrounding native grassland species and associations were made between brome abundance and NDVI phenology metrics. Understanding the behavior of these invasive species through space and time will aid managers in developing a successful annual brome management strategy for NGP park units and identify areas for targeted management efforts.



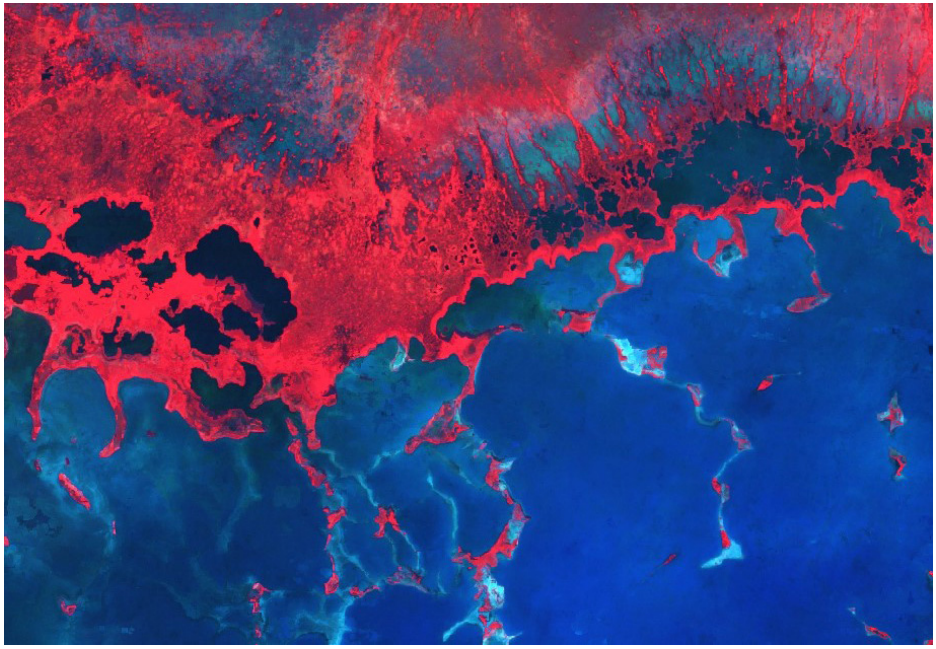
EVERGLADES ECOLOGICAL FORECASTING

Improving the Capacity of the Everglades National Park to Monitor Mangrove Extent Using NASA Earth Observations

NASA Langley Research Center

Team – Donnie Kirk (Project Lead), Caitlin Toner, Emily Gotschalk, Rachel Cabosky, Brad Gregory, Candace Kendall
Partner – National Park Service, Everglades National Park; Group on Earth Observations, Blue Planet Initiative; Old Dominion University, Mitigation and Adaptation Research Institute
Earth observations – Landsat 5 TM, Landsat 8 OLI, Terra MODIS

Mangroves act as a transition zone between fresh and salt water ecotones by filtering and monitoring salinity levels along the coast of the Florida Everglades. Mangroves offer specialized habitats and provide shoreline stabilization, critical to a region beset by tropical storms. These areas give way to marshlands that depend on the services mangroves provide, as they require larger quantities of freshwater. In an attempt to assist the health of the threatened mangrove species, efforts have been made within the park to rebalance the ecosystem. The National Park Service requires a way to track the distribution of marshes and mangroves. The Everglades Ecological Forecasting team utilized Google Earth Engine and satellite imagery from Landsat 5 and 8 with comparison to existing vegetation maps. The team was able to conduct the classification to display mangrove and marsh regions in 1995, 2005, and 2015. After considering several geospatial analysis platforms, Google Earth Engine was selected due to the accessibility of its open source platform. In order to make the process replicable for the Everglades National Park, a comprehensive methodology of classifying mangroves in Google Earth Engine was developed. The process was designed with the intent that the methodology be transferrable to personnel at Everglades National Park. The current extent map, in conjunction with TerrSet and transition maps, supported the creation of forecasted models.



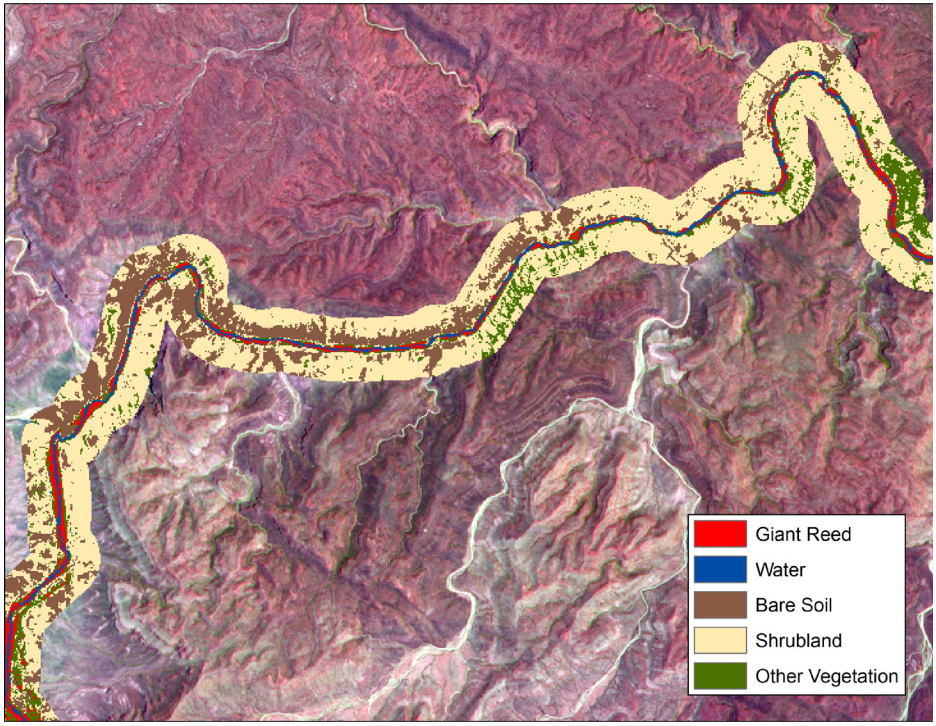
SOUTHWEST U.S. ECOLOGICAL FORECASTING

Mapping Invasive Species to Efficiently Monitor Southwestern National Park Areas

NASA Langley Research Center

Team – Ryan Avery (Project Lead), Katherine Landesman, Jordan Vaa, Timmera Whaley, Dakoyta Greenman
Partner – National Park Service, Southwest Exotic Plant Management Team; National Park Service, Colorado Plateau Cooperative Ecosystem Studies Unit
Earth observations – Terra MODIS, Landsat 8 OLI, Landsat 5 TM, Sentinel-2A, Landsat 7 ETM+

The southwestern United States spans six states, over 55 national parks, and a wide range of ecosystems, historical landmarks, and culturally significant landscapes. Of these parks, Bandelier National Monument (NM), Big Bend National Park (TX), Glen Canyon National Recreation Area (AZ, UT), and Valles Caldera National Preserve (NM) are threatened by three particularly problematic invasive plant species: cheatgrass (*Bromus tectorum*), ravenna grass (*Saccharum ravennae*), and giant reed (*Arundo donax*). Currently, park management uses field observations to monitor these species, which require a significant investment in time, effort, and money by the National Park Service (NPS). The NPS is interested in mapping and predicting the presence of invasive species by using NASA's Earth observations. To this end, the Southwest U.S. Ecological Forecasting team created classified species distribution maps using Moderate Resolution Imaging Spectroradiometer, Landsat 5 Thematic Mapper, and Landsat 8 Operational Land Imager data for the years 2000, 2008, and 2016. This project also used vegetation and topographic indices, as well as field data to predict invasive species presence using a Species Distribution Model for each national park area and generated likelihood maps of species presence and absence.



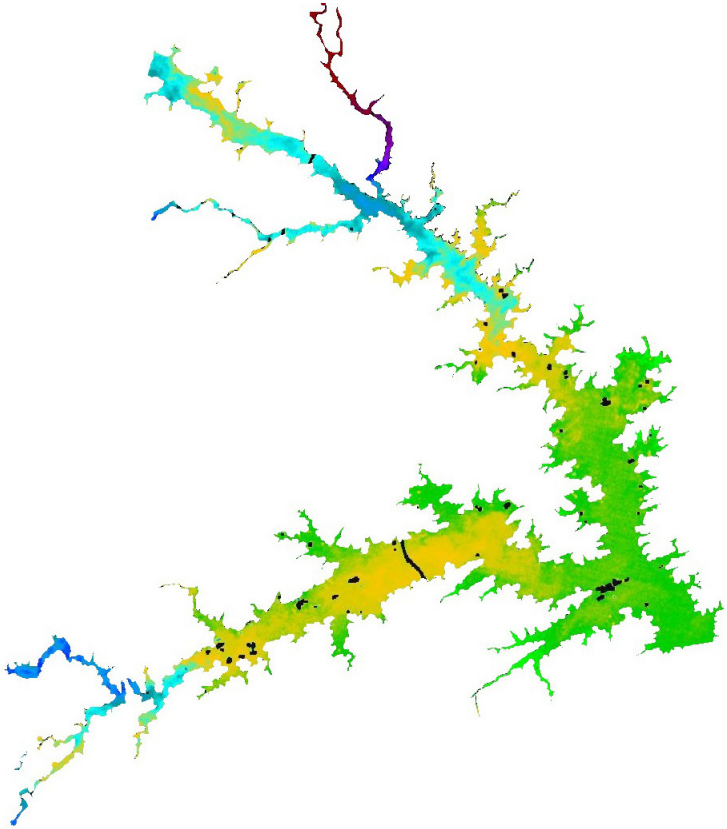
SOUTHEAST U.S. ECOLOGICAL FORECASTING III

Utilizing NASA Earth Observations and Proximal Remote Sensing for Mapping the Spatio-Temporal Distribution of Hydrilla verticillata

University of Georgia

Team – Shuvankar Ghosh (Project Co-Lead), Austin Haney (Project Co-Lead), Frank Braun, Zachary Conner, Christopher Cooper, Abhishek Kumar
Partner – U.S. Army Corps of Engineers, J. Strom Thurmond Project; Henry County Water Authority, Cubihatchi Outdoor Education
Earth observations – Landsat 8 OLI

Hydrilla verticillata is an invasive aquatic plant which has rapidly spread through many inland water-bodies across the Southeastern United States, mainly through inadvertent transfer. Once in a water body, this invasive species generally out-competes native aquatic plants and becomes established as the most dominant vegetative species. Consumption of water for drinking, power generation, and recreational use of lakes has been threatened by the spread of Hydrilla. In recent years it was discovered that Hydrilla serves as a host for an epiphytic, toxic cyanobacteria (*Aetokthonos hydrillicola*) in some water bodies. *Aetokthonos hydrillicola* is now known to be the causative agent of the neurodegenerative disease avian vacuolar myelinopathy, which affects waterfowl, raptors, and amphibians. Using Landsat 8 Operational Land Imager imagery, a rapid assessment tool was developed to accurately map the extent of Hydrilla on Lake Thurmond (GA/SC) and Long Branch reservoir in Henry County, Georgia. This tool will act as the foundation for later models intending to predict future locations in need of Hydrilla management.



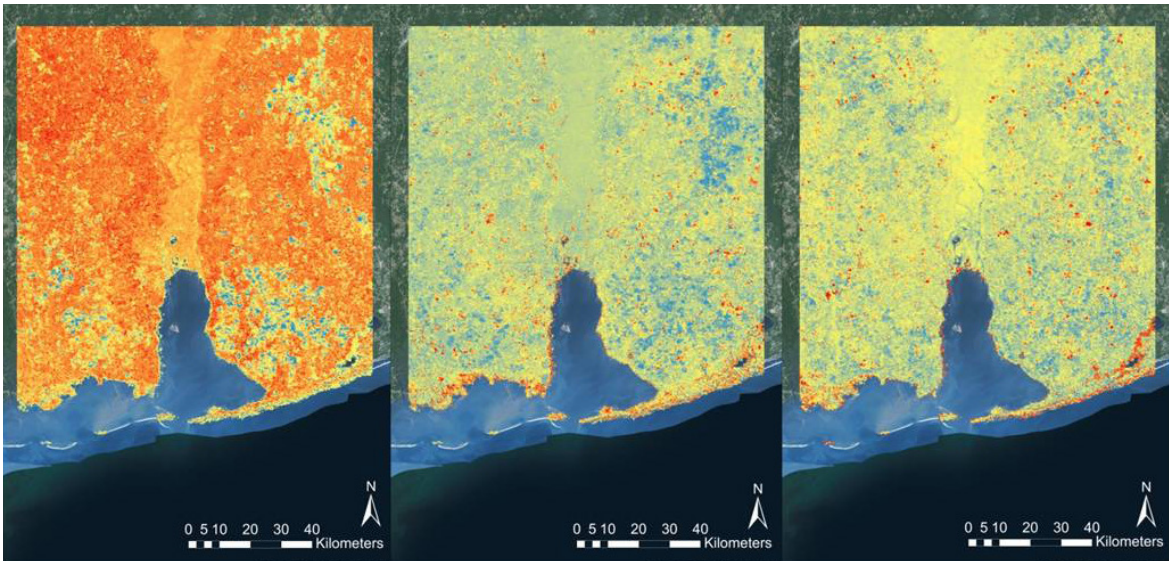
MOBILE BAY ECOLOGICAL FORECASTING AND WATER RESOURCES II

Monitoring Marsh Conditions in Coastal Alabama Using NASA Earth Observations to Support the Alabama Coastal Foundation's Restoration and Conservation Initiatives

Mobile County Health Department

Team – Darius Hixon (Project Lead), Austin Clark, Tyler Lynn, Manoela Rosa
Partner – Alabama Coastal Foundation (ACF); Dauphin Island Sea Lab
Earth observations – Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI & TIRS, Aqua/Terra MODIS

The marshlands fringing Mobile and Baldwin Counties collectively comprise one of the most dynamic ecosystems in the Northern Gulf of Mexico. Coastal Alabama wetlands are an important ecological region, providing a number of important ecosystem support services, such as breeding and nursing habitats, creating buffer zones for storm surge, and water filtration. However, many marsh areas have deteriorated both in health and extent due to a combination of anthropogenic and natural stressors, including nutrient pollution, turbidity, and urbanization. This study used NASA Earth observations to investigate the present and future health of wetlands in coastal Alabama. The datasets were derived from the United States Department of Agriculture Forest Service ForWarn Normalized Difference Vegetation Index (NDVI), which uses imagery captured by Moderate Resolution Imaging Spectroradiometer. Additionally, data from Landsat satellites 5, 7, and 8 were used to provide higher resolution imagery over larger temporal scales to aid in land use and land cover classifications. The NDVI was used in conjunction with data from the Coastal Change Analysis Program to classify marsh type, health, and extent over several decades. The data were then used for modeling of future marsh health using TerrSet Geospatial Monitoring and Modeling System Land Change Modeler software. Collectively, these analyses provided a holistic assessment of current and future marsh health for select watersheds over wide temporal and spatial scales. The Alabama Coastal Foundation can use these results to more efficiently direct restoration efforts to the most critically impaired watersheds.



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.

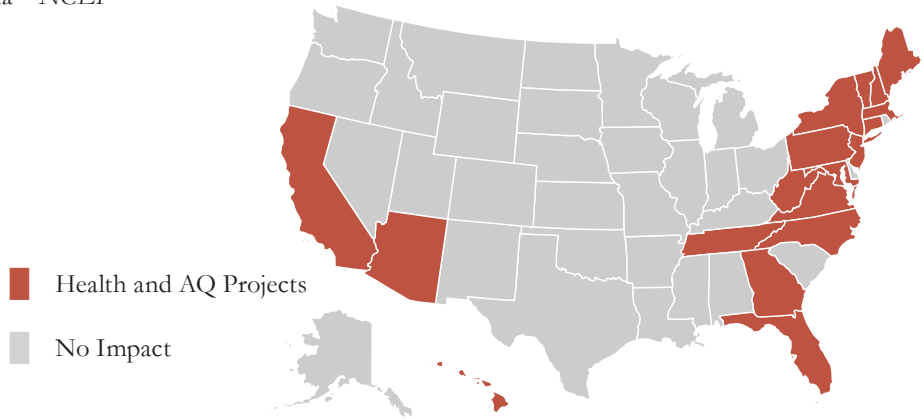
PORTFOLIO

San Francisco Bay Area Health & Air Quality: Using Satellite, Aircraft, and Ground-Based Observations to Monitor Methane and Improve a Greenhouse Gas Inventory Network for the San Francisco Bay Area – *ARC*

Maricopa County Health & Air Quality: Monitoring PM10 Concentrations for Enhanced Maricopa County Department of Public Health and Maricopa County Air Quality Department Decision Making and Epidemiology – *AZ*

Appalachian Trail Health & Air Quality: Monitoring Ozone in the Troposphere to Help Regulate Point Source Emissions and to Improve Ozone Advisory Messages by the National Park Service – *LaRC*

Coastal U.S. Health & Air Quality: Understanding the Temporal and Spatial Variation of Air Quality to Support the Use of Satellite Aerosol Data – *NCEI*



PARTNERS

Bay Area Air Quality Management District
Maricopa County Air Quality Department
Maricopa County Department of Public Health
NASA Alpha Jet Atmospheric eXperiment
National Park Service, Appalachian National Scenic Trail
National Park Service, Great Smoky Mountains National Park
National Park Service, Harpers Ferry National Historical Park
National Park Service, Inventory & Monitoring Program, Northeast Temperate Network
National Park Service, Natural Resource Stewardship and Science Directorate, Air Resources Division
National Park Service, Northeast Region
National Park Service, Shenandoah National Park
U.S. Centers for Disease Control
U.S. Environmental Protection Agency, AirNow Program

SENSORS

Aqua/Terra MODIS
Aura OMI/MLS
Landsat 5 TM
Landsat 7 ETM+
Landsat 8 OLI
NOAA-7
NOAA-15
NOAA-19
AVHRR
PlanetScope Constellation
RapidEye Constellation

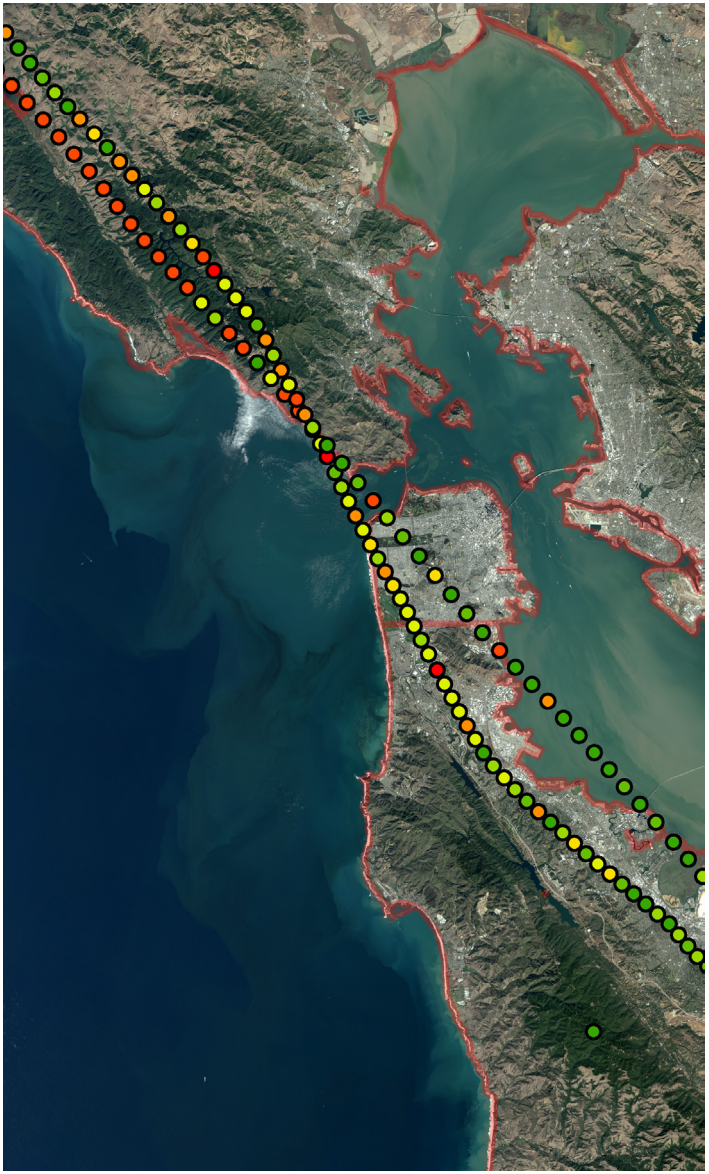
SAN FRANCISCO BAY AREA HEALTH & AIR QUALITY

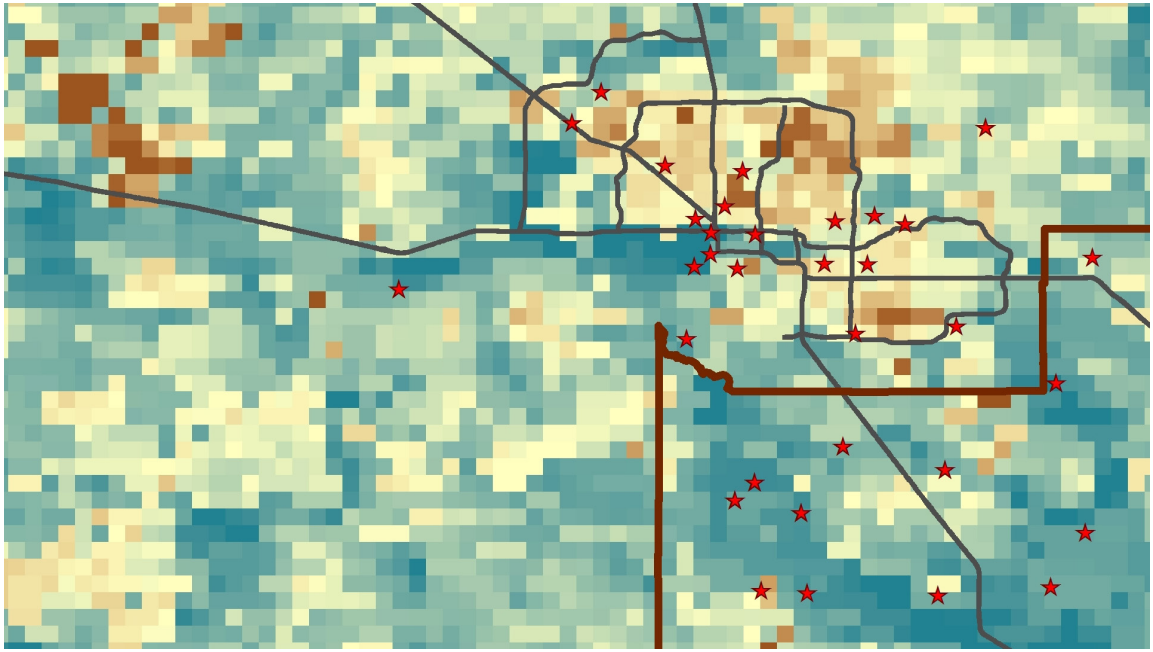
Using Aircraft In Situ Observations for Methane Monitoring and Hotspot Detection over the San Francisco Bay Area

NASA Ames Research Center

Team – Maya Midzik (Project Lead), Joseph Abbate, Garima Raheja
Partner – Bay Area Air Quality Management District; NASA Alpha Jet Atmospheric eXperiment
Earth observations – NASA Alpha Jet Atmospheric eXperiment

CH_4 is the second most important anthropogenic greenhouse gas in terms of radiative forcing, with methane emissions coming from a variety of human-induced sources in populated areas, such as livestock, landfill, and wastewater. The Bay Area Air Quality Management District (BAAQMD) uses traditional bottom-up methodologies to produce source-specific emissions estimates for their regional greenhouse gas inventory; however, recent literature demonstrates that bottom-up methodologies are underestimating CH_4 emissions by up to 50% in many regions of California, including the San Francisco Bay Area. This discrepancy is investigated in this project by comparing ground-based *in situ* greenhouse gas measurements with sub-Planetary Boundary Layer aircraft measurements from the NASA Alpha Jet Atmospheric eXperiment. Understanding the spatial and temporal variations in CH_4 can help identify hotspots and trace the sources of high-CH_4 plumes. Additionally, this project utilized land classification to identify the associated sources and search for other similar sources that are not included in the current BAAQMD emissions inventory. Integrating these findings into their traditional bottom-up methodologies has offered a more accurate approach to compiling this inventory. Furthermore, the identification of possible high-emission point sources may suggest areas of future *in situ* measurement for the agency's Mobile Greenhouse Gas Measurement Network, or remotely-sensed total column measurements by targeted greenhouse gas satellites, such as Greenhouse Gases Observing Satellite.





MARICOPA COUNTY HEALTH & AIR QUALITY

Monitoring PM10 Concentrations for Enhanced Maricopa County Department of Public Health and Maricopa County Air Quality Department Decision Making and Epidemiology

Maricopa County Department of Public Health and Arizona State University

Team – Jason Hodgson (Project Lead), Leslie Araujo, Tamara Dunbarr
Partner – Maricopa County Department of Public Health; Maricopa County Air Quality Department
Earth observations – Aqua/Terra MODIS, Landsat 5 TM

One of the most prevalent issues with air quality monitoring is the lack of distribution of sampling sites that gather data regarding particulate matter concentrations in the surrounding environment. By utilizing data from the Moderate Resolution Imaging Spectroradiometer on the Aqua and Terra satellites, the team constructed a mixed model to provide a significantly high correlation between aerosol optical depth and PM10 concentrations. Due to the mixed model's use of additional periodic variables – such as meteorological and environmental factors – the model can be used in conjunction with satellite data in the absence of ground-based monitors to present a better picture of the air quality in Maricopa County, Arizona. By employing such a model, both the Maricopa County Department of Public Health and the Maricopa County Air Quality Department can apply the model data to future epidemiological research, policy making, environmental justice analyses, and other important processes and decisions regarding air quality and public health improvements. The products of the Maricopa County Health & Air Quality project are ultimately intended to benefit the Maricopa County community by contributing to the area of public health and potentially even influencing future changes and the overall development of the county.

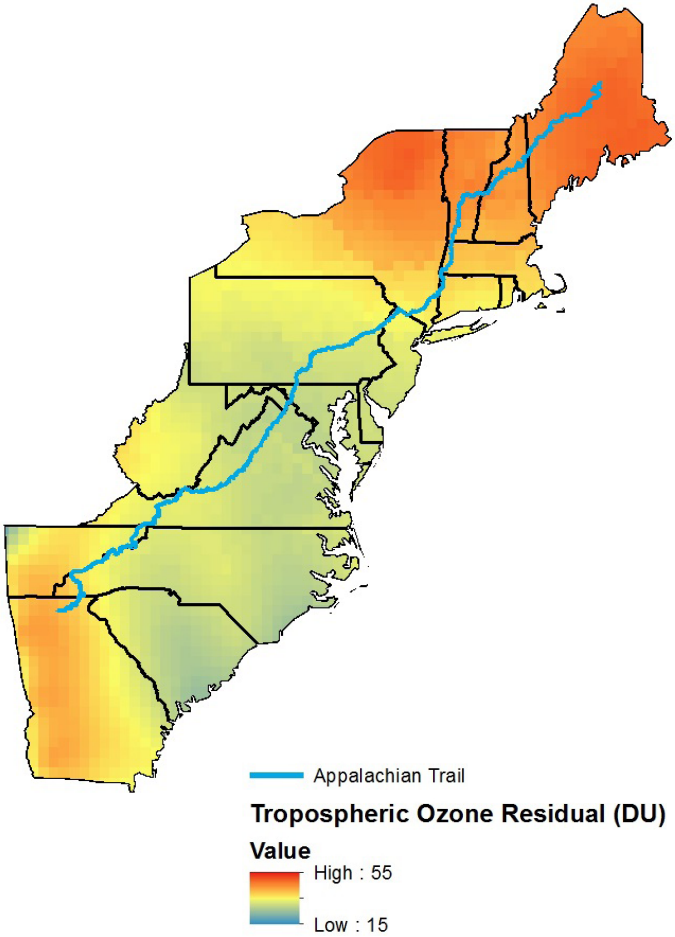
APPALACHIAN TRAIL HEALTH & AIR QUALITY

Monitoring Ozone in the Troposphere to Help Regulate Point Source Emissions and to Improve Ozone Advisory Messages by the National Park Service

NASA Langley Research Center

Team – Amy Wolfe (Project Lead), Amber Showers, Emily Beyer, Eric White, Tyler Rhodes
Partner – National Park Service, Shenandoah National Park; National Park Service, Harpers Ferry National Historical Park; National Park Service, Great Smoky Mountains National Park; National Park Service, Natural Resource Stewardship and Science Directorate, Air Resources Division; National Park Service, Northeast Region; National Park Service, Inventory & Monitoring Program, Northeast Temperate Network; National Park Service, Appalachian National Scenic Trail
Earth observations – Aura OMI/MLS

Ozone in the stratosphere serves as a boundary that absorbs harmful ultraviolet radiation from the sun. Ozone in the troposphere is hazardous to both human and plant health. Anthropogenic activities, such as fossil fuel combustion, are the main catalysts for high levels of tropospheric ozone, nitrogen oxides, and sulfur oxides. The warmer months, from May to September, typically display higher levels of tropospheric ozone located near urban areas with large populations. Tropospheric ozone forms from nitrogen oxides and volatile organic compounds (VOCs), reacts with sunlight, and fluctuates throughout the day displaying its peak concentration during mid-to-late afternoon. Lower concentrations occur during the early morning when the planetary boundary layer is lowest and ozone molecules have not formed from the nitrogen oxide and VOCs reacting. NASA Earth observations can be used to monitor these atmospheric constituents. This project used Aura's Ozone Monitoring Instrument (OMI) and Microwave Limb Sounder (MLS) to look at tropospheric ozone, nitrogen dioxide, and sulfur dioxide. The analysis and mapping of these atmospheric constituents provided data to compare to the National Park Service's ground-level air quality stations. This project determined whether OMI and MLS are effective sensors for observing air pollutants in the troposphere and create visual aids of correlations and general trends.



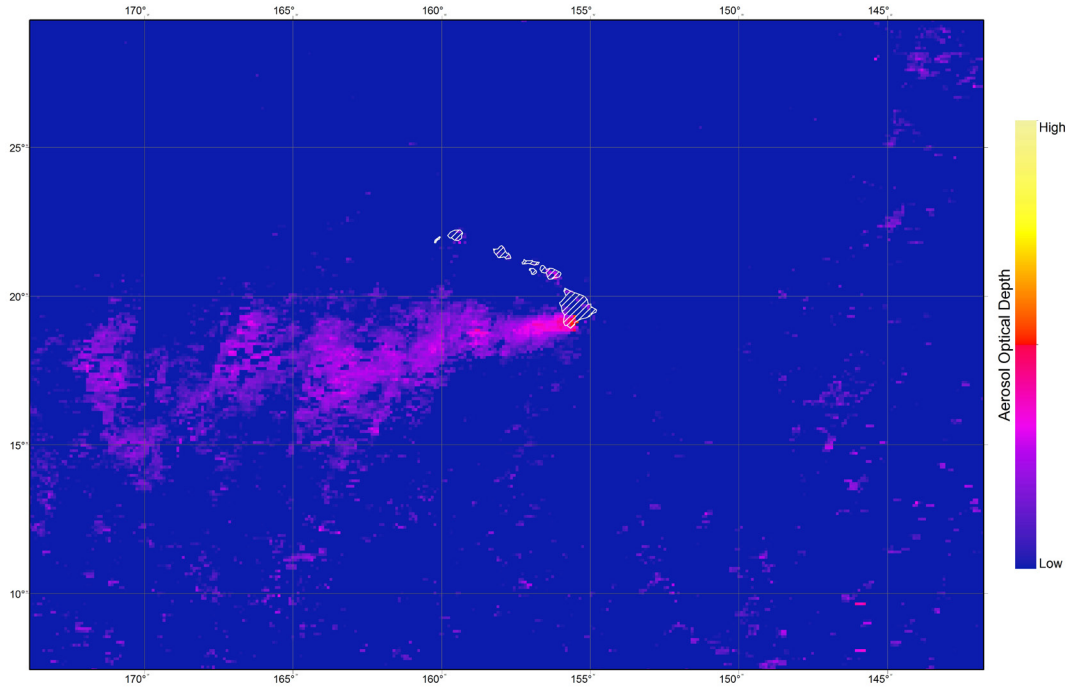
COASTAL U.S. HEALTH & AIR QUALITY

Understanding the Temporal and Spatial Variation of Air Quality to Support the Use of Satellite Aerosol Data

NOAA National Centers for Environmental Information

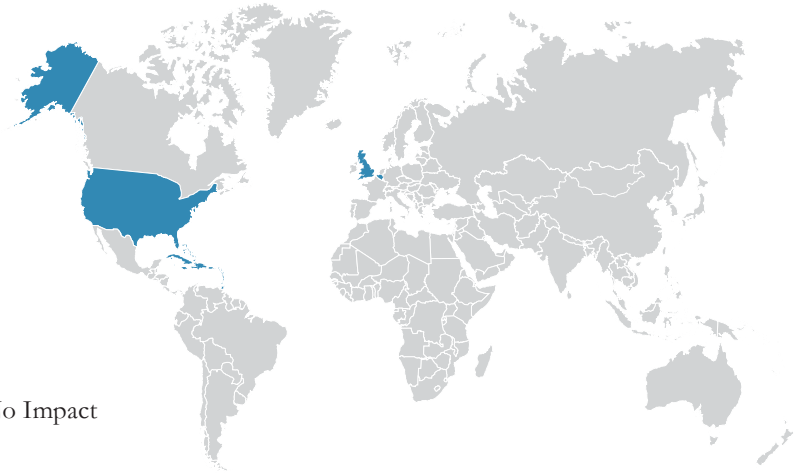
Team – Christie Stevens (Project Lead), Toni Strauch, Alec Courtright
Partner – U.S. Centers for Disease Control; U.S. Environmental Protection Agency, AirNow Program
Earth observations – NOAA-7. NOAA-15, NOAA-19, AVHRR, Aqua/Terra MODIS

Outdoor air pollution can have severe impacts on human health, endangering the lives of vulnerable children and adults. Particulate matter air pollution is particularly hazardous, contributing to an estimated 800,000 premature deaths every year, as recorded by the World Health Organization. Organizations such as the Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention (CDC) have an increasing need to provide accurate air quality assessments to properly mitigate adverse health effects. The EPA monitors air quality levels for the United States with AirNow, an online tool that uses *in situ* data to calculate an Air Quality Index for real-time updates and forecasts in air quality. This product allows for reliable air quality estimates, but is limited to the specific location of monitoring stations and to terrestrial regions within the contiguous United States. Though current projections estimate that approximately 48% of the U.S. population will live in coastal regions by the year 2020, there is no long-term record of air quality measurements for the coastal United States. This project will utilize NASA's Aerosol Optical Depth and the National Oceanic and Atmospheric Administration's Aerosol Optical Thickness datasets to create a long-term analysis of Hawaii and coastal Florida air quality from January 1981 to December 2015. This analysis will be used to identify anomalous months, seasons, and other periods as well as identify trends in aerosol concentrations and patterns. Satellite and ground station data verification will provide statistical and quantitative support for incorporating satellite data into both the EPA's and CDC's current air quality reporting efforts and further serve their needs by building the foundation for a comprehensive air quality tool.



OVERVIEW:

DEVELOP's Ocean projects utilize NASA Earth observations to understand changes in ocean health, salinity, and water quality. These projects help monitor current and future trends in our planet's interconnected oceans to assist decision makers in resource management. This summer, DEVELOP had one Oceans project in its portfolio that partnered with a variety of organizations in the Caribbean to improve monitoring capabilities of Sargassum in the region.

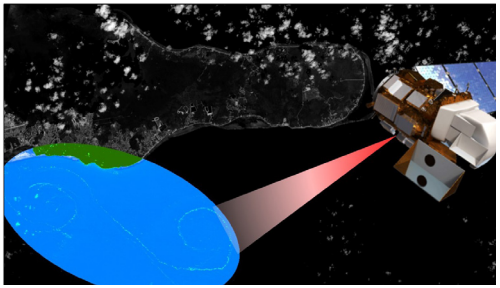


Oceans Projects No Impact

CARIBBEAN OCEANS II

Addressing Inundation Events: A Comparative Study of Remote Sensing Techniques Utilizing NASA Earth Observations to Identify Sargassum for Caribbean

NASA Ames Research Center

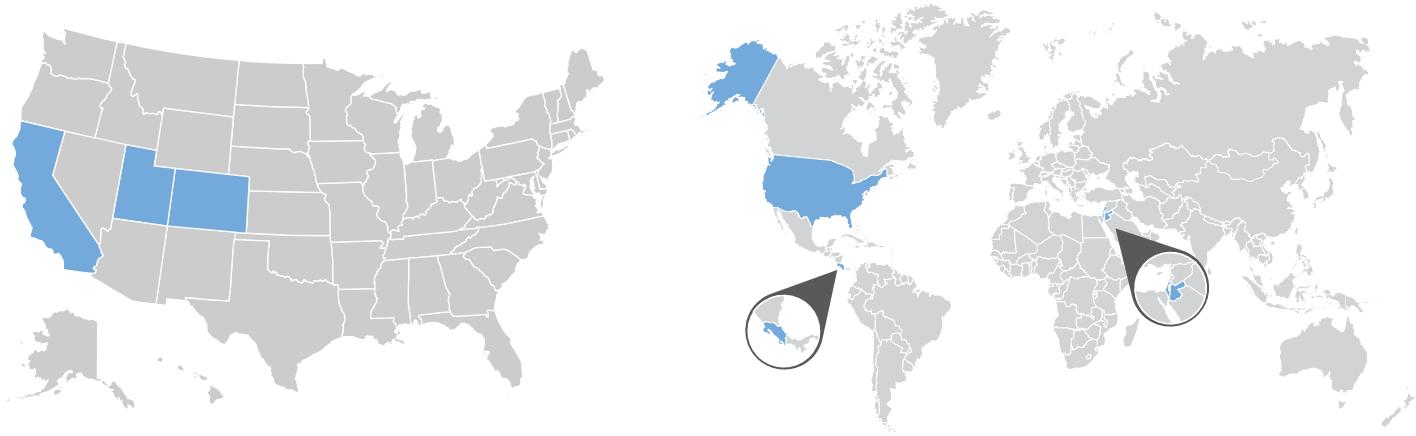


Team – Jordan Ped (Project Lead), Emma Accorsi, Maria Lopez-Peña
Partner – Consorcio de Instituciones de Investigación Marina del Golfo de México y del Caribe; Comisión Nacional para el Conocimiento y Uso de la Biodiversidad; University of Puerto Rico, Department of Marine Sciences; Regional Activity Center for Specially Protected Areas and Wildlife; Sea Education Association
Earth observations – Aqua MODIS, Landsat 8 OLI, SAC-D Aquarius, AVHRR

In 2015, Caribbean nations were overwhelmed by an unprecedented quantity of Sargassum that washed ashore. This issue prompted international discussion to better understand the origin, distribution, and movement of Sargassum, a free-floating brown seaweed with ecological, environmental, and economic importance. In the open ocean, Sargassum mats serve a vital ecological function. However, when large quantities appear onshore without warning, Sargassum threatens local tourist industries and near-shore ecosystems. As part of the international response, this project investigated the proliferation of this seaweed using NASA Earth observations for the detection of Sargassum across the region. This project compared Landsat 8 Operational Land Imager (OLI) imagery to Aqua Moderate Resolution Imaging Spectroradiometer imagery across a number of indices for the identification of Sargassum. The Floating Algal Index using Landsat 8 OLI imagery was utilized to effectively detect floating Sargassum mats and windrows. In response to limited ground truth data on Sargassum presence, the team assessed the accuracy of Instagram as a tool for use during Sargassum inundation events and found that Sargassum presence could be visually confirmed in 79% of Landsat scenes with corresponding Instagram hashtags. As part of the international effort to better understand the life cycle of Sargassum in the Caribbean, the results of this project will assist local economies and help promote sustainable management practices.

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.



Water Projects No Impact

PORTFOLIO

California Water Resources: Quantifying the Impact of the 2015-2016 El Niño Event on California's Historic Drought to Improve Water Resource Management – *JPL*

Middle East Water Resources: Utilizing NASA Earth Observations to Create a Precipitation Climatology of Jordan, Israel, and the West Bank to Identify Optimal Rainwater Harvesting Locations for Underserved Schools – *LaRC*

Western U.S. Water Resources: Assessing Landscape Vulnerability to Drought and Climate Change in National Parks in the Western United States – *LaRC*

Costa Rica Water Resources: Monitoring Drought and Water Balance in the Guanacaste Province to Enhance Decision Making and Response Planning in Costa Rica – *UGA*

Northern Great Plains Water Resources: Discovering Archeological Sites Utilizing NASA Earth Observations to Detect Changes in Snowpack Coverage in Intermountain National Parks – *WC*

Atlanta Water Resources II: Identifying Key Urban Areas to Reduce Stormwater Runoff and Maximize Conservation Efforts in Metropolitan Atlanta – *UGA*

Pacific Water Resources II: Enhancing Decision Making to Help Manage Freshwater Resources: Using NASA Earth Observations and NOAA CDRs to Provide Near Real-Time Precipitation Estimates for Forecasters in the U. S. Affiliated Pacific Islands – *NCEI*

PARTNERS

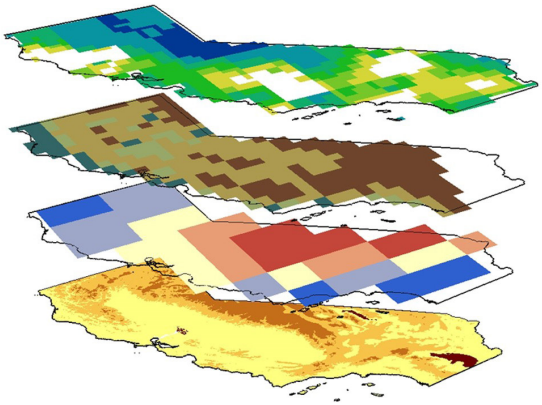
Costa Rica Ministry of Environment and Energy
Costa Rica's National Service of Underground Water, Irrigation, and Drainage
Earth Resources Technology
Embassy of Costa Rica to the United States
National Park Service, Intermountain Region
National Park Service, Rocky Mountain National Park
NOAA, National Weather Service, Los Angeles/Oxnard Weather Forecast Office
NOAA, Regional Climate Services
The Nature Conservancy
University of Costa Rica
USGS Southwest Biological Science Center
Water Resources Action Project, Inc.
National Park Service, Inventory & Monitoring Program, Northern Colorado Plateau and Greater Yellowstone Networks

SENSORS

Aqua/Terra MODIS
GPM DPR & GMI
GRACE
Landsat 5 TM
Landsat 8 OLI/TIRS
PERSIANN CDR
SMAP
SMOS MIRAS
SRTM
Terra ASTER
TRMM PR

CALIFORNIA WATER RESOURCES

Quantifying the Impact of the 2015-2016 El Niño Event on California's Historic Drought to Improve Water Resource Management
NASA Jet Propulsion Laboratory



Team – Justin Lawrence (Project Lead), Lauryn Gutowski, Nick Rousseau, Brittany Zajic
Partner – NOAA, National Weather Service, Los Angeles/Oxnard Weather Forecast Office
Earth observations – TRMM PR, GPM DPR, GRACE, SMAP

2015 marked the arrival of the strongest El Niño ever recorded, surpassing the 1997-1998 event that brought significant rainfall to the southwestern United States. As sea surface temperatures in the Central Pacific increased, it was forecasted that this event may have similar effects to, and alleviate, what the U.S. Drought Monitor classifies as "exceptional" drought across California. However, the effects from the drought, now in its fifth year, continue to strain both municipal and agricultural water supplies throughout the state. Our team utilized data from NASA's Gravity Recovery and Climate Experiment (GRACE), Global Precipitation Measurement, Tropical Rainfall Measuring Mission, and Soil Moisture Active Passive Earth observations, meteorological surface observations from the National Oceanic and Atmospheric Administration (NOAA), and historical reservoir levels from the California Department of Water Resources to gain a more complete understanding of water resources in California. Together with the team's partners at the NOAA/National Weather Service regional office in Oxnard, CA, the team's study employs NASA Earth observations to better quantify impacts of the 2015-16 El Niño event and determine how much drought recovery occurred throughout the state over the course of the wet season. Specifically, monthly GRACE measurements of terrestrial water storage allow for a better understanding of subsurface resources, a parameter often omitted from drought assessments. The team also analyzed monthly precipitation and temperature trends in relation to droughts and ENSO patterns with climatological history from NOAA dating back to 1985.

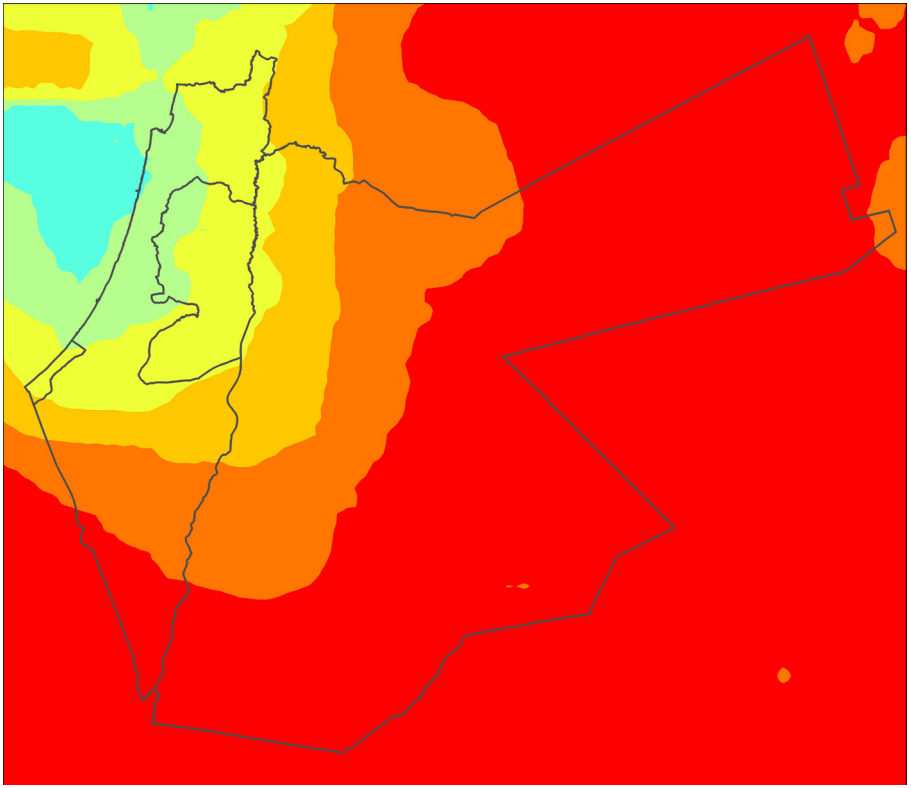
MIDDLE EAST WATER RESOURCES

Utilizing NASA Earth Observations to Create a Precipitation Climatology of Jordan, Israel, and the West Bank to Identify Optimal Rainwater Harvesting Locations for Underserved Schools

NASA Langley Research Center

Team – Hannah Rosenblum (Project Lead), Vishal Arya, Michael Sclater, Raghda El-Behaedi, Brad Schroeder, Labreshia Mims
Partner – Water Resources Action Project, Inc.
Earth observations – TRMM PR, GPM DPR, SRTM, GRACE, Terra MODIS

Water resources are declining in the Middle East as a result of the combination of diminished supply from overexploitation and drought, increased demand due to growing populations, and inadequate infrastructure. Water shortages have led to sanitation issues in schools and, in severe cases, even school closures. Rainwater harvesting is an eco-friendly, low-tech, and cost effective method of collecting and storing water for local use. The Water Resources Action Project, Inc. (WRAP) provides rain barrels and cisterns to underserved schools in the region to increase their water resources for sanitation purposes. This study used data from Tropical Rainfall Measurement Mission, Global Precipitation Measurement, and other NASA Earth observations to quantify and visualize precipitation to identify locations most suitable for rainwater harvesting. Results indicate that precipitation is greatest in the north nearest to the Mediterranean Sea, and along the Jordan Rift Valley. The team created an interactive climatology map which characterizes the precipitation regime of the region, as well as an interactive interface to help WRAP determine which schools would benefit most from their assistance. The interface will be shared with the schools to which WRAP provides rainwater harvesting systems as an educational tool. This is expected to improve the students' understanding of the region's precipitation and climate as well as Geographic Information Systems and other monitoring and analysis technologies.



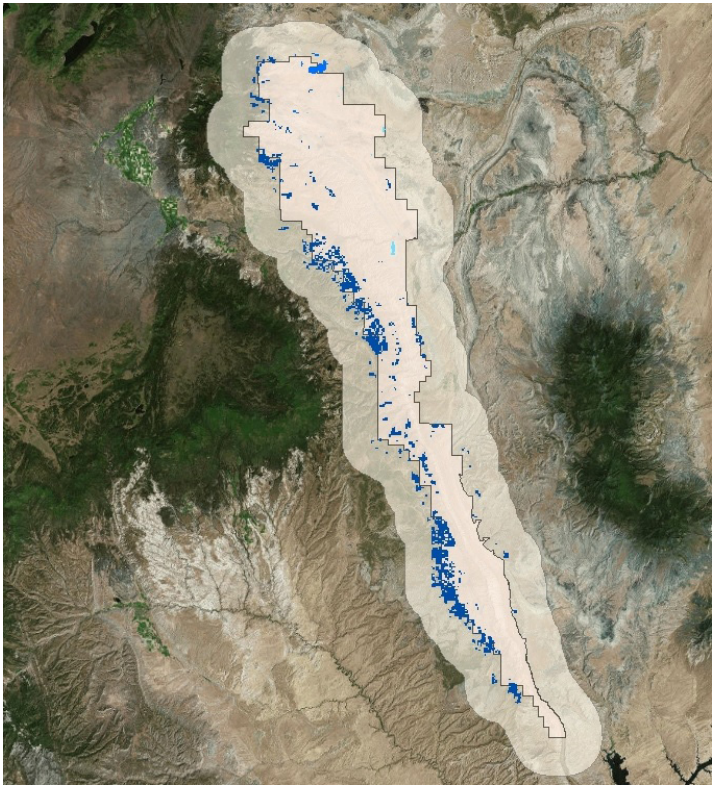
WESTERN U.S. WATER RESOURCES

Assessing Landscape Vulnerability to Drought and Climate Change in National Parks in the Western United States

NASA Langley Research Center

Team – Kelly Meehan (Project Lead), Molly Spater, Teresa Fenn, Thomas Smith, Kaylie Taliaferro, Grant Jaccoud
Partner – National Park Service, Inventory & Monitoring Program, Northern Colorado Plateau and Greater Yellowstone Networks; USGS Southwest Biological Science Center
Earth observations – Terra MODIS

The changing climate has been an issue of growing concern over recent decades. Drought frequency has increased and water availability has become limited, especially in the western United States. With semi-arid regions typically becoming warmer and dryer, knowledge on how to identify shifts in vegetation productivity, which are early warning signs of changes in ecosystem stability, are of great interest to National Park land managers. Guided by project partners from the National Park Service (NPS) and the United States Geological Survey (USGS), this project utilized a climate pivot point framework to assess the capacity of vegetation in Utah's Capitol Reef National Park to resist drought when water is scarce. Multiple climatic variables including precipitation, temperature, evapotranspiration, and water deficit were analyzed against the normalized difference vegetation index (NDVI) across a 15 year time span from 2000 to 2015. This project will benefit our partners by providing information about which vegetation types are the most vulnerable to climate change and drought. The framework of this analysis can be replicated for other national parks and can be used by land managers to make critical decisions.



Precipitation Pivot Points
Capitol Reef National Park, Utah

- 4 km buffer
- Park Boundary
- Grasslands: 216.48 Lag Time: 3
- Sagebrush: 202.58 Lag Time: 4
- Pinyon-Juniper: 230.68 Lag Time: 1

* Precipitation Millimeters
Lag Time: Months

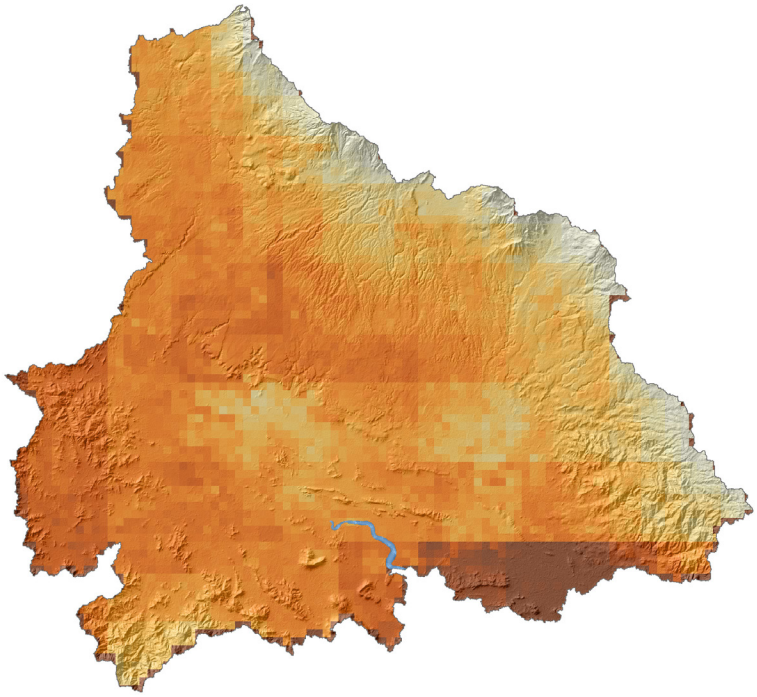
COSTA RICA WATER RESOURCES

Monitoring Drought and Water Balance in the Guanacaste Province to Enhance Decision Making and Response Planning in Costa Rica

University of Georgia

Team – Rachel Durham (Project Co-Lead), María José Rivera-Araya (Project Co-Lead), Diyang Cui, Madison Davis, Luis Quesada, Nelson Venegas
Partner – Costa Rica Ministry of Environment and Energy; Costa Rica's National Service of Underground Water, Irrigation, and Drainage); Embassy of Costa Rica to the United States; University of Costa Rica
Earth observations – TRMM PR, GPM DPR/GMI, Aqua/Terra MODIS, Landsat 8 TIRS, SRTM, SMOS MIRAS

The Arenal-Tempisque watershed in northwestern Costa Rica has experienced severe drought conditions during the last four years, complicating water management and agricultural production. Additional information for response planning and management is required to tackle the consequences of drought. In partnership with the Costa Rica Ministry of Environment and Energy (MINAE), Costa Rica National Service of Underground Water, Irrigation, and Drainage (SENARA), the University of Costa Rica and the Costa Rican Embassy in Washington, D.C., the DEVELOP team used data from various Earth observing satellites – Landsat 8, Aqua, Terra, Global Precipitation Measurement, Tropical Rainfall Measuring Mission, and Soil Moisture and Ocean Salinity – as well as *in situ* stations to analyze and monitor the current state of meteorological and agricultural drought across the Arenal-Tempisque watershed. The Standardized Precipitation Index was used in monitoring meteorological drought and the Scaled Drought Condition Index and Soil Moisture Index were used in monitoring agricultural drought. The team also created information for a water balance assessment using the Soil Water Assessment Tool model by combining NASA Earth observations, ancillary data sources, and *in situ* data. The model's results were calibrated and validated through the use of SWAT Calibration and Uncertainty Procedures. Upon receiving the hydrological data and tools, project partners at SENARA and MINAE will be able to replicate the project's methods to continuously update their understanding of watershed conditions. These results will allow project partners to make a more efficient water management plan, benefitting the local inhabitants and stakeholders.



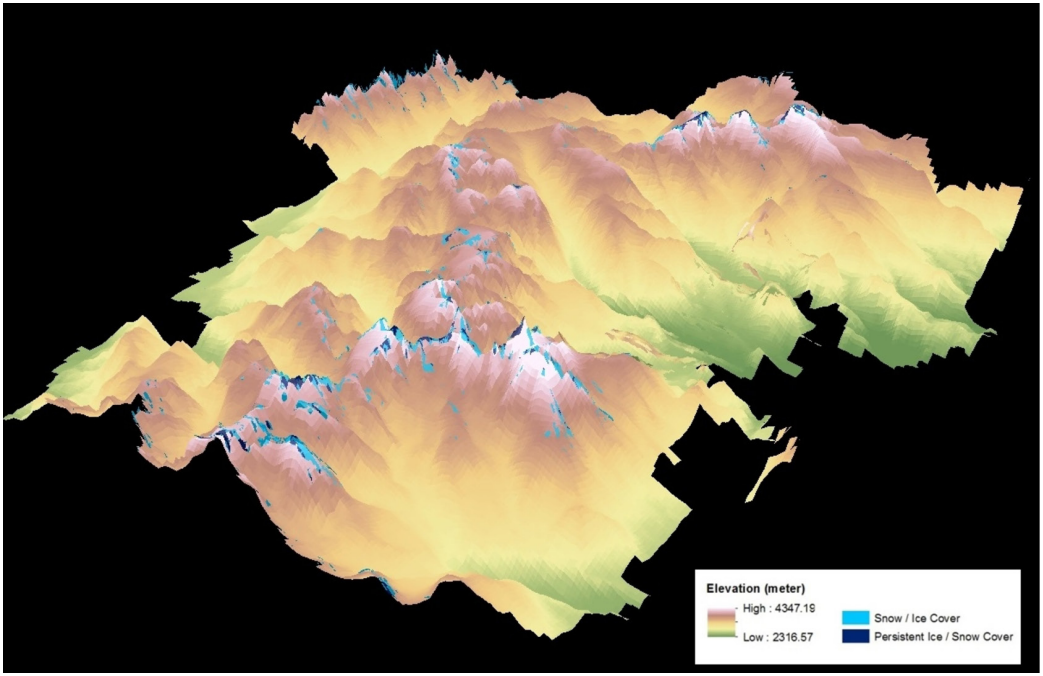
NORTHERN GREAT PLAINS WATER RESOURCES

Discovering Archaeological Sites Utilizing NASA Earth Observations to Detect Changes in Snowpack Coverage in Intermountain National Parks

Wise County and City of Norton Clerk of Court's Office

Team – Anne Gale (Project Lead), Michael Brooke, Xin Hong, Cody Vineyard
Partner – National Park Service, Intermountain Region; National Park Service, Rocky Mountain National Park
Earth observations – Landsat 5 TM, Landsat 8 OLI

National Parks in the Intermountain region of the northern United States Great Plains are experiencing snow and ice melt due to changes in climate. As the ice recedes, it has the potential to reveal previously undiscovered archaeological sites. Therefore, investigating the changes of Persistent Ice and Snow Cover (PISC) in this region is crucial to identifying archaeological sites. To address the changes of PISC, a two phase methodology was implemented: 1) map the PISC in the Rocky Mountain National Park, CO over the period from 1998 to 2014 using Landsat scenes; and 2) detect the changes of PISC over time. This research was a case study to document the retreat of PISC in the Intermountain National Parks, namely Rocky Mountain National Park, by applying NASA Earth observations. This research can also aid in testing hypotheses about the drivers of human behavioral variability and support the National Park Service in its mission to mitigate impacts of climate change to mountain cultural heritage resources.



ATLANTA WATER RESOURCES II

Identifying Key Urban Areas to Reduce Stormwater Runoff and Maximize Conservation Efforts in Metropolitan Atlanta

University of Georgia

Team – Christopher Cameron (Project Lead), Ike Astuti, Mark Beatty, Natalia Bhattacharjee, Manasi Parkhi, Alex Smith
Partner – The Nature Conservancy
Earth observations – Landsat 8 OLI/TIRS, Terra ASTER

Residents of metro Atlanta pay the highest rates in the nation for municipal water and sewer, in part due to massive recent investments in infrastructure to manage stormwater runoff. As development continues at a rapid pace in Atlanta and its suburbs, expanding areas of impervious surface will continue to exacerbate this problem. Forested land is known to slow runoff during storms, allowing water to infiltrate, and the soil to absorb particles and contaminants before entering the surface water. Enabling the protection of existing green infrastructure, or strategically planting more trees to intercept stormwater runoff, will help reduce sediment and nutrient-laden stormwater runoff in local watersheds in addition to limiting the needs of future city infrastructure. The DEVELOP team at the University of Georgia partnered with The Nature Conservancy to identify conservation targets in the Atlanta region to improve existing green infrastructure and locate additional areas suitable for expansion of reforestation efforts using data from Landsat 8 and Terra satellites. This was accomplished through a combined, watershed-scale assessment of metro Atlanta using the Land-Use Conflict Identification Strategy (LUCIS) and Soil and Water Assessment Tool (SWAT) models. The LUCIS model was employed in this project to identify areas of land use prioritization as it relates to existing and future conservation areas in Atlanta. The SWAT model produced an analysis of streamflow and runoff within the study area. Together, these model results provided project partners with an integrated understanding of water resource issues in metro Atlanta that emphasize land use scenarios.

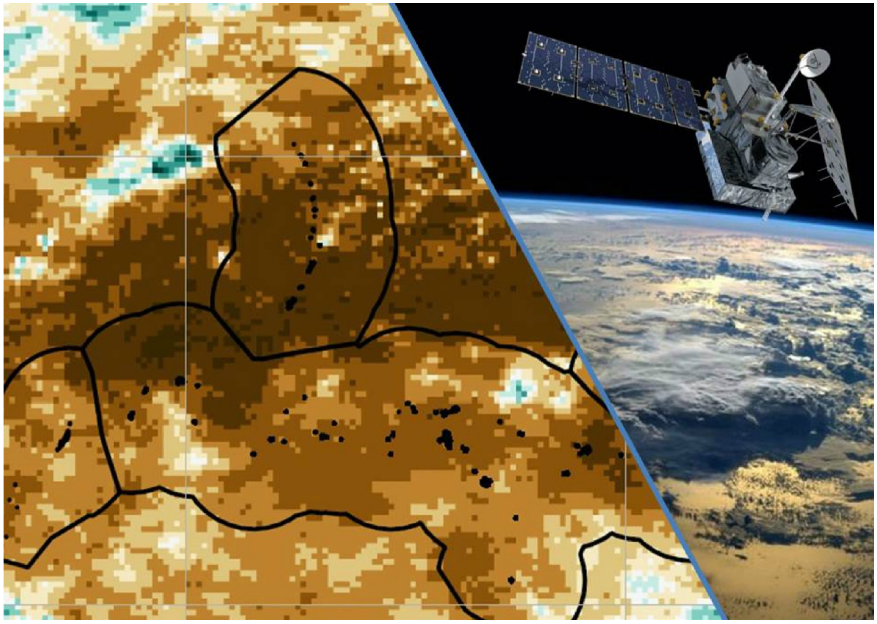
PACIFIC WATER RESOURCES II

Enhancing Decision Making to Help Manage Freshwater Resources: Using NASA Earth Observations and NOAA CDR's to Provide Near Real-Time Precipitation Estimates for Forecasters in the U. S. Affiliated Pacific Islands

NOAA National Centers for Environmental Information

Team – Nicholas Luchetti (Project Lead), Zachary Vozzelli, Kyle Jones
Partner – Earth Resources Technology; NOAA, Regional Climate Services
Earth observations – GPM DPR, TRMM PR, PERSIANN CDR

The United States Affiliated Pacific Islands (USAPI) are extremely vulnerable to the precipitation shifts associated with the El Niño Southern Oscillation (ENSO). For example, the 2015-2016 ENSO event caused crippling drought conditions for the USAPI that extended several seasons. In the past, scientists in the region utilized a spatially-limited, *in-situ*-based, ENSO climatology to inform their drought mitigation decisions. To fill this spatial gap, the Pacific Water Resources I team successfully delivered an updated, ENSO-based precipitation climatic reference atlas derived primarily using remotely-sensed data from National Oceanic and Atmospheric Administration's Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Climate Data Records (PERSIANN-CDR), which provides a 30-year record of daily precipitation at 0.25° spatial resolution. While the atlas has been heavily utilized by scientists in the region following the Pacific Water Resources I project, it is somewhat limited in that it does not provide near real-time precipitation estimates. The Pacific Water Resources II project filled this limitation through the utilization of near real-time precipitation data from NASA's Global Precipitation Measurement (GPM) satellite which provides 30-minute rainfall estimates at 0.1° spatial resolution. To fully understand whether satellite-derived rainfall estimates from GPM can be used operationally in a near-real-time anomaly product, an analysis comparing the satellite products (PERSIANN-CDR, GPM) to 27 Global Historical Climate Network Daily (GHCN-D) stations in the west Pacific was completed. Results of this validation study suggest that both the PERSIANN-CDR and GPM tend to underestimate the daily precipitation estimates when compared to the GHCN observations. That being said, while the raw station values do not necessarily line up exactly with those from satellite-derived rainfall estimates, the direction of the trends are the same. For example, when the station data suggests periods of dryness, satellite estimates also suggest the same, and vice-versa. Therefore, results herein confirm the usefulness of using GPM precipitation estimates to accurately capture the seasonal precipitation trends found across the USAPI. The end results from this project provided a suite of near real-time precipitation forecasting tools that can enhance short-term water resources management.



DEVELOP **Participants**

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Tiffani Miller

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

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

Get involved 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. Acceptances for foreign nationals are conditional upon proof of a valid visa, I-20 form, and an approved CPT/OPT that allow legal employment within the United States. Applicants who do not meet these requirements are not eligible to participate.

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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 on the Projects page at **http://develop.larc.nasa.gov/projects.php**. Please visit the website for more information on partnering with DEVELOP and contact information.

Get involved 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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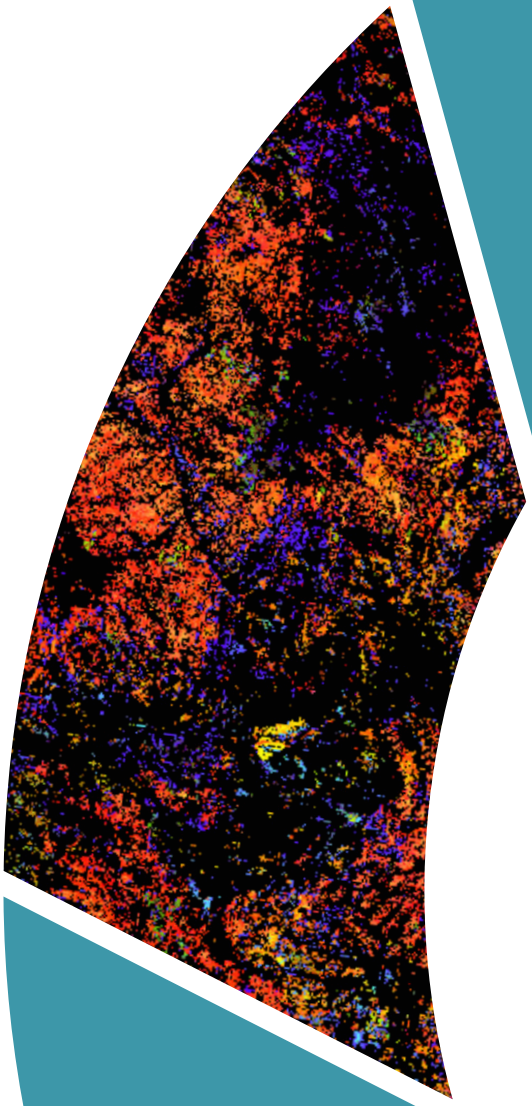

DEVELOP National Program

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