National Aeronautics and Space Administration

2014 WILDLAND FIRES

NASA Earth Science Applied Sciences Program

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Wildland Fires: 2014 Annual Summary

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I. Introduction

The ESD Applied Sciences Program promotes efforts to discover and demonstrate innovative and practical uses of Earth observations. The Program funds applied science research, capacity development activities, and applications projects to enable near-term uses of Earth observations, formulate new applications, integrate Earth observations and related products in practitioners' decision making, and transfer the applications. The projects are carried out in partnership with public and private sector organizations to achieve sustained use and sustained benefits from the Earth observations.

The Applied Sciences Program's applications themes are currently focused on four of the nine Societal Benefit Areas of the interagency U.S. Group on Earth Observations: Health (including Air Quality), Disasters, Ecological Forecasting, and Water Resources.[1] The Program includes climate-related influences and impacts within each of these themes.

Fires, especially wildland fires or wildfires, constitute a topic in Earth system science that touches on aspects of many applications areas. From 2002 to 2011, the Applied Sciences Program supported projects and activities related to wildfires in several applications areas. In 2011, the Program created an element focused specifically on wildfires, addressing issues from pre-fire through active-fire to post-fire. The Program issued a dedicated solicitation and selected 17 projects in 2012, continuing a subset of those in 2014.

II. Overview of 2014

The past year was a very productive one for the Wildland Fires program (aka, Wildfires program). The primary programmatic activities were the review of the 17 feasibility projects (Phase 1) along with the selection and funding of nine projects to continue into the in-depth, applications-development stage (Phase 2). By the end of the year, six projects had advanced one or more Application Readiness Level (ARL).

The year was also a very busy one. There were numerous events, conferences, and committees to which the Wildfires program management team and project teams contributed. As detailed in Sections VII and VIII below, NASA Wildfires representatives participated in 11 conferences and workshops, such as the Large Wildland Fires Conference, the International Union of Forest Research Organizations World Congress, the National Fire Science Exchange Meeting, and the Pecora 19/Sustaining Land Imaging conference. Wildfires associate Amber Soja represented NASA on a high-level, interagency Wildland Fire Science and Technology Task Force, and Wildfires associate Vince Ambrosia continued his co-chair role on the Tactical Fire Remote Sensing Advisory Committee, and as a NASA representative on the Interagency Arctic Research Policy Committee's Wildfire Implementation Team.

[1] The nine USGEO SBAs are Agriculture, Climate, Disasters, Ecological Forecasting, Energy, Health, Oceans, Water Resources, and Weather.

The NASA Earth Science Division launched the *GPM* and *OCO-2* satellites in 2014. The former will makes precipitation observations, and the latter will measure carbon dioxide levels globally. As products become available after calibration, validation, and product processing, the Wildfires program team will support efforts to examine potential uses and value for wildfires applications. The *SMAP* mission, which measures soil moisture, moved to a January 2015 launch date. *SMAP* data products are likely to be applicable and beneficial to the wildfire management community.

In 2014, the United States experienced a below average total number of fires and fire acreage consumption, in comparison with the 10-year average. There were a total of 63,345 fires, which was approximately 13 percent lower than the 10-year average.[2] The total area burned totaled 3.6 million acres, which was roughly 51 percent lower in acreage compared with the 10-year average. The Carlton Complex Fire in Washington state burned more than 256,000 acres and was the largest fire in the state to date.[3] The Buzzard Complex Fire in Oregon burned 395,747 acres, which was the largest recorded wildfire in the United States in 2014. Some of the other large, single wildfire events occurred in northern California, with the Happy Camp Complex Fire (135,000 acres) and the King Fire (97,000 acres). These two fires accounted for 50 percent of the northern California total acreage consumed by wildland fires in 2014. Three of the program's wildfires projects were directly involved with the 2014 fire-fighting and post-fire recovery efforts. In addition, the Autonomous Modular Sensor (AMS), which NASA transferred to United States Forest Service (USFS) in 2013, made its debut in USFS wildfires operations. The AMS supported two major wildfires and five prescribed fires in April and May, and it was the only national asset available for the Brown Fire in Arizona and the Signal Fire in New Mexico during spring wildfire events in the southwestern United States.

At the end of the year, the program management team was planning the first Wildfires program team meeting for mid-February 2015. The meeting will include end users, such as wildfire management personnel, task leaders, and incident commanders. The meeting will be co-hosted by the USFS Remote Sensing Applications Center (RSAC).

III. Major Accomplishments

One of the major accomplishments for 2014 was the review and selection of nine projects from the ROSES-2011 Wildland Fire solicitation (aka ROSES-2011 A.35) to continue into Phase 2 applications development; Sections IV and VI below describe this in more detail. The nine projects represent a cross-section of fire stages originally called out in the solicitation, including improving wildfire applications in pre-, active-, and post-fire environments. The projects also include geographic diversity from regional- to global-scales. Another accomplishment was the achievement of near parity in the Phase 2 resources from NASA and those resource contributions pledged by the projects' partners.

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[2] That total number represents only grass fires that are greater than 300 acres in size and timber fires that are greater than 100 acres in size; information as of Dec. 31, 2014 (final 2014 statistics available ~ March 2015).
[3] *http://www.iii.org/fact-statistic/wildfires*

Additional accomplishments included the productivity of the projects themselves. As reported below, the projects made substantial increases in their ARLs and were quite prolific with publications. As Section X.A shows, there were numerous publications in both peer-reviewed and popular literature; proceedings; conference presentations; press releases; and television coverage.

A few projects stand out for their progress in 2014 and their early capability adoption by partners and operational entities:

- A project, led by Wilfrid Schroeder of the University of Maryland, is developing VIIRS 375m I-Band data for operational fire monitoring systems in the United States. The data product reached beta-test use with the USFS Remote Sensing Applications Center. The data product is available at RSAC's daily Web services location as a product for evaluation by the fire management community.

- Project efforts led by Mary Ellen Miller, Michigan Tech Research Institute, showed operational utility at wildfire incident command centers at a few fires in California (French, Happy Camp, Silverado, and King fires). Miller's work, using online tools and data sets as well as modelling, supported Burned Area Emergency Response (BAER) in developing remediation strategies for those fires. The effects of proposed treatment areas were modeled (predicted reduction in erosion rate due to proposed mulching) in order to assist the BAER team in prioritizing the spatial application of mulching treatments. The team's work was integrated into the King Fire burn area assessment and the other fire area assessments in 2014.

- The Urban and Regional Information Systems Association (URISA) selected the RECOVER project, led by Keith Weber at Idaho State University, for its Exemplary Systems in Government award in 2014. The project entails development of spatial tools and cloud service processing to provide rapid post-fire assessments for BAER teams. The project team's modelling supported wildfire incidents in Idaho during the 2014 wildfire season, helping to reduce remediation time and costs.

IV. Program Assessment

Overall, the program management team was extremely pleased with the performance of the project portfolio and program element in 2014, though the team wished that it could have funded more projects to continue into Phase 2 for in-depth applications development.

One of the original goals of the Wildfires initiative was to broaden the application and applicability of Earth science data, models, and knowledge beyond the traditional area of active wildfire response. The set of Phase 1 feasibility projects included several studies focused on supporting pre-fire and post-fire management. The results demonstrated in the Phase 1 reports indicated such applicability as well as interest by managers and users from partnering organizations that address pre- and post-fire issues (e.g., fuels assessments and BAER teams).

As discussed in Section VI below, the review of the Phase 1 projects indicated a strong project portfolio with the vast majority of projects scoring good to excellent by the peer-review evaluation panel. The program management team used a novel review format, which allowed for the review panel to pose questions to the project teams and their partners as part of the review. This approach allowed for an improved understanding by the panelists of the projects' progress, goals, plans, and expected impacts to more effectively evaluate project advancement potential. This process also allowed the investigators to clarify project content that might not have been absorbed by the review panel through reading of a short report document. The management team was very pleased with the additional information and insights that the interaction permitted.

The management team recognized (and heard directly from some projects) that the two-stage nature of this solicitation might have created some stress and competition, or at least impeded some collaboration. At the same time, the results indicated strong performance and attention in Phase 1 to testing the feasibility of an application and working with the partners.

The two-stage approach appears to be achieving its intent of developing "buy-in" and commitment by the benefitting partner organizations. The true test will be the adoption and continuation of the applications into their operations. When the program issued the original solicitation, it stipulated a budget profile in which the partners provided increasing levels of resources in Phase 2. The program posited that this type of profile can ensure a shared commitment to help enable project success, transition, and adoption. Table 1 shows the funding levels by year in Phase 2; figures are total dollars across all Phase 2 projects. The partners' share are those funds pledged in the Phase 1 reports. As the table indicates, there is relative parity between the total NASA share and that of the partners. Also, the profile shows NASA funding declining with partner funding increasing over Phase 2.

Wildfires	*Phase 2 of Project*			
Project Funding: Phase 2 ($ in 000s)	2014	2015	2016	Total
NASA share	$2,505	$2,161	$1,611	$6,277
Partners share	$1,673	$1,946	$2,375	$5,994
Total	$4,178	$4,107	$3,986	$12,271

Table 1. Wildfires Phase 2 Funding

As mentioned, the program team was disappointed that it could not support more projects to continue into Phase 2. There were another half dozen or so projects that the program team would have liked to continue, especially because the projects had interested, committed, and engaged partners. The limitation was due to financial constraints.

There was some delay in getting funding to the Phase 2 projects. This delay was due to two factors. One was a delay in getting the panel review materials prepared for the ESD Steering Committee for their approval to proceed; a second was developing the financial paperwork on

the continuing grants. Once those issues were overcome, with project funding in place, the projects proceeded toward successful realization of their applications goals and adoption by partners.

The year proved to be a very active, productive one in terms of the Wildfires program's participation in domestic and international activities. The program participated in three interagency committees, five domestic conferences, four international conferences, two workshops, and one international work project. Beyond reflecting the commitment and capabilities in the wildfires community to connect research and management, these activities reflect growing interest in the use of Earth observations.

In 2014, the Wildfires program team observed that fire science and fire processes are increasingly recognized and appreciated beyond the fire management community. For example, there's a growing appreciation of fire as consequential feedback to climate and land cover change. Fire is recognized as a catalyst for change and as an integral feedback with the climate system, as well as one that controls the beginning and end of successional stages. Some of this has been known in smaller communities, although fire was not recognized as integral until relatively recently (e.g., investigation of Arctic haze during spring ARCTAS). The program team noted that increasingly fire scientists are requested by groups across disciplines and topics, such as the Arctic, climate, cloud, radiation, atmosphere, and even the Greenland Ice Sheet. This recognition bodes well for opportunities for fire science to inform policy and management decisions across fields as well as for the fields to identify rich research questions.

Within the program, the team noted an increase in requests for the associates and other NASA representatives at national and international events focused on planning. The program will need to assess this trend and its pace to determine what steps to take. For example, if the rate increases substantially, the program could consider an "ambassadors" effort to inform the event organizers about fire-related people with the particular skills and knowledge desired for the event.

In 2015, the program team will put special emphasis on the upcoming Earth Science Decadal Survey. Organized by the National Research Council, the Decadal Survey articulates the priorities of the Earth science community for the next 10-plus years. The Wildfires program recognizes a significant opportunity for the wildfires community to provide representatives and input to the Decadal Survey panels regarding key research and applications challenges that would advance Earth systems science and its use in fire management. The team also sees opportunities with the Applied Remote Sensing Training (ARSET) program within Applied Sciences to develop wildfire training modules. The modules will be initially offered to the wildfires community in spring 2015 and further expanded later in 2015 and beyond.

V. Project Portfolio

In 2014, the project portfolio for the Wildfires program element contained nine projects in the Phase 2 applications development stage. The projects' foci were evenly split between pre-fire,

active-fire, and post-fire applications activities. The organizations for the principal investigators of the nine projects include universities (three), federal government (five), and one nongovernmental organization. All the projects had partner organizations as co-investigators or collaborators.

Of the nine projects, three have a particular focus on fuels; four address aspects of fire detection, behavior, and forecasting; and two focus on post-fire remediation. A brief description of each project appears below, and Section X.B contains additional information on each project.

Regarding the Earth observations applied in the projects, most projects focused on use of MODIS, *S-NPP* VIIRS, and *Landsat* data and products (and combinations of them). Collectively, projects also used data products from other space-based sensors and satellites ASTER, AMSR-E, AVHRR, ESA ATSR, MOPITT, *CALIPSO*, DLR *FireBird*, OMI, *GLAS*, and *SMOS*; data from aerial imagery, airborne lidar scanning (ALS), AVIRIS, and UAVSAR; data from community databases, such as MTBS, DEMs and LANDFIRE; and many models and model outputs, such as GEOS.

Each project recorded its ARLs during the year. At the end of 2014, the portfolio had three projects in the ARL 1–3 range, six projects in the ARL 4–6 range, and none above ARL 6. The mean ARL was 4.3 and the mode was ARL 4. For the FY 2014 performance year (ending September 2014), six of the nine projects (67 percent) advanced one or more ARL, and five projects (58 percent) advanced two or more ARLs.

Wildfires Projects	
End of 2014	
ARL	*Projects*
ARL 9	0
ARL 8	0
ARL 7	0
ARL 6	2
ARL 5	2
ARL 4	2
ARL 3	3
ARL 2	0
ARL 1	0

The following are the nine Phase 2 projects; Section X.B contains a summary of each project.

TOPOFIRE: A System for Monitoring Insect and Climate-induced Impacts on Fire Danger in Complex Terrain; Principal Investigator: Zachary A. Holden, USFS
This project integrates NASA remote sensing and climate products into a decision support tool, TOPOFIRE, which delivers a suite of high spatial resolution real-time information sets essential to wildland fire management. The end users/partners include the modeling community employing the Wildland Fire Assessment System (WFAS) and the Wildland Fire Decision Support System (WFDSS).

Utilization of Multi-Sensor Active Fire Detections to Map Fires in the United States: The Future of Monitoring Trends in Burn Severity; Principal Investigator: Stephen Howard, U.S. Geological Survey (USGS)*:* This project applies fire detection data from MODIS, AVHRR, *GOES* (fire and smoke sensing), federal fire occurrence data, and NOAA Hazard Mapping System information to identify undocumented fires, improving the Monitoring Trends in Burn Severity (MTBS) mapping process, and developing user-friendly tools and

applications that can be installed locally to support local fire assessments. The end users/partners include the two major entities that provide the MTBS products for the fire community: USFS RSAC and USGS-EROS.

Linking Remote Sensing and Process-based Hydrological Models to Increase Understanding of Wildfire Effects on Watersheds and Improve Post-fire Remediation Efforts; Principal Investigator: Mary Ellen Miller, Michigan Tech Research Institute: This project creates an online spatial database to instantaneously provide end users with the basic tools and data needed to incorporate Earth observations (*Landsat 8*, ASTER, MODIS, VIIRS, process-based hydrological models, spatial dry ravel model) into process-based erosion models. Improving accessibility of both modeling capabilities and the required data sets will lead to better assessment tools and support post-fire remediation through erosion modeling. The project focused on supporting end users and partners from the BAER teams, land managers, and researchers.

Enhanced Wildland Fire Management Decision Support Using Lidar-infused LANDFIRE Data; Principal Investigator: Birgit Peterson, USGS: This project is developing a tool to incorporate lidar data (ALS and GLAS) and data from the LANDFIRE program. The Creating Hybrid Structure from LANDFIRE/lidar Combinations (CHISLIC) tool allows users to automatically generate a suite of improved vegetation structure and wildland fuel parameters from lidar data and infuse these into existing LANDFIRE data sets, ensuring the best data are available to support tactical and strategic wildland fire management decisions. End users include those who utilize both WFAS and WFDSS in their assessment tools.

Wildland Fire Behavior and Risk Forecasting; Principal Investigator: Sher Schranz, Colorado State University: This project applies data from MODIS and VIIRS to derive NDVI and NDWI maps, and government databases (LANDFIRE and fuel moisture from the network of Remote Automated Weather Stations) to test the probability of providing forecasting of wildland fire behavior and risk, integrated within NOAA fire weather forecasting systems. This effort supports decision making by providing integrated local numerical prediction of weather, fuel properties, fire risk, and fire behavior.

Development and Application of Spatially Refined Remote Sensing Active Fire Data Sets in Support of Fire Monitoring, Management and Planning; Principal Investigator: Wilfrid Schroeder, University of Maryland: This project builds on proven science algorithms (fire detection from MODIS) to apply new spatially refined satellite active-fire detection products from VIIRS and *Landsat 8* that yield significantly improved fire information. The project team uses these products to initialize and validate fire growth predictions in a coupled weather-fire model, an approach that can be applied to monitor and predict the growth of a fire or a group of simultaneous wildfires in a

management unit from first detection until containment. The partners include USFS, NWS, and WFDSS.

An Integrated Forest and Fire Monitoring and Forecasting System for Improved Forest Management in the Tropics; Principal Investigator: Karyn Tabor, Conservation International: This project is building a near-real-time alert system (Firecast) that incorporates active-fire identification from VIIRS and MODIS to improve decision making related to forest and fire management in "under-served" communities. The system addresses the challenges decision makers face in making timely decisions related to wildland fire management and prevention that have immediate conservation impacts. The partners include Servicio Nacional de Áreas Naturales Protegidas por el Estado in Peru, the Ministry of Environment and Forests in Madagascar, the Department of Conservation Areas Wildlife Reserves in Indonesia, and Flora and Fauna International based in the United Kingdom.

Improving National Shrub and Grass Fuel Maps Using Remotely Sensed Data and Biogeochemical Modeling to Support Fire Risk Assessments; Principal Investigator: James Vogelmann, USGS: This project is applying *Landsat* and MODIS data to improve shrub and grassland mapping for fire applications, develop temporally frequent data sets, and therefore determine if improvements in shrub and grassland data layers will alter and improve fire behavior model results. The end-user partners include the USFS, Bureau of Land Management (BLM), and Multi-Resolution Land Characteristics Consortium.

An Automated Burned Area Emergency Response Decision Support System for Post-fire Rehabilitation Management of Savanna Ecosystems in the Western United States; Principal Investigator: Keith T. Weber, Idaho State University: This project integrates the rapid resource allocation capabilities of cloud computing to automatically collect Earth observations data (*Landsat 8*, MODIS, AMSR-E, MERRA), derived decision products, and historic biophysical data for BAER teams. The result is a comprehensive RECOVER (Rehabilitation Capability Convergence for Ecosystem Recovery) data set in a GIS analysis environment that is customized for the target wildfire, thus reducing from days to minutes the time required to assemble and deliver crucial wildfire-related data. The partners include the BLM, Idaho Department of Lands, and BAER teams.

URISA selected the RECOVER project for its Exemplary Systems in Government award in 2014.

Due to results of the peer review assessment, programmatic priorities, or lack of funding, the Wildfires program was unable to continue the following projects into Phase 2:

Applications of Satellite Measurements to Improve Prescribed Fire Management; Principal Investigator: Yuhang Wang, Georgia Institute of Technology: This project employed MODIS and HMS observations and models to examine the feasibility of quantitative forecasting for air quality impacts of prescribed fires, which would provide prescribed fire management guidance to the Georgia Forestry Commission, Georgia Environmental Protection Division, and EPA. This system would improve the activities of near-real-time air quality forecasts and help protect human health by limiting prescribed burning when the weather is conducive to poor air quality. On request, the program provided a nominal level of funds for this project to close out its work and prepare a paper. The team's paper will focus on the viability of applying near-real-time satellite observations to improve the air quality impact assessment and management of prescribed burning in Georgia. The team plans to submit this paper to *Atmospheric Environment* in 2015.

Automated Fuels Treatment Effectiveness Evaluation Using Remote Sensing Information (AFTEERS); Principal Investigator: Stacy A. Drury, Sonoma Technology, Inc.: This project demonstrated that it is feasible to use Earth observations products such as MODIS and MTBS to evaluate the ability of fuels treatments to mitigate wildfire hazard. The project team created a set of methods that provide land manager partners (USFS, National Park Service, and Bureau of Indian Affairs) with easy-to-use, cost-effective data products that use satellite observations to evaluate fuels treatment options. On request, the program provided a nominal level of funds for this project to close out its work and prepare papers. The additional support allowed a transfer of the available modeling framework and environment to partners to continue the AFTEERS development outside of NASA Phase 2 support.

Classification of Whitebark Pine and Spruce-Fir Forests to Improve Wildland Fire Decision Support Tools in the USFS Northern Region; Principal Investigator: Linda Vance, University of Montana: This project investigated the feasibility of using Earth observations (*Landsat* and high resolution aerial imagery) to address accurate and precise mapping of whitebark pine and spruce-fir forests to enhance wildland fire modeling decision support tools in the USFS Northern region. The partnerships included USFS, USGS, and the Greater Yellowstone Coordinating Committee.

Enhancing Wildland Fire Decision Support and Warning Systems; Principal Investigator: Son Nghiem, Jet Propulsion Laboratory: This project used satellite data (*QuikSCAT*/*Oceansat-2*/AMSR-E) to derive soil moisture products. It showed the utility of the future *SMAP* higher-resolution soil moisture information capabilities for improving predictions of wildfire danger. Coupling the soil moisture data with high-resolution weather forecast and fire behavior models allowed the project team to test the feasibility of improving fire risk and danger assessments months prior to fire incidents in southern California. The partners included the National Fire Danger Rating System, WFDSS, National Weather Service (NWS), and other agencies.

Development of New Geospatial Tools for Wildland Fire Management and Risk Reduction; Principal Investigator: Siamak Khorram, University of California at Berkeley: This project explored the feasibility of using satellite and airborne remote sensing data to substantially improve the Emission Estimation System and the First Order Fire Effects Model, leading to better estimates of emissions from wildland fires. The overall goal was to enhance resource managers' decision making for fire and smoke management related to wildland fires, and to support improved public notification of air quality effects of those smoke and fire events.

Daily Forecasts of Wildland Fire Impacts on Air Quality in the Pacific Northwest: Enhancing the Air Indicator Report for Public Awareness and Community Tracking (AIRPACT) Decision Support System; Principal Investigator: Steve L. Edburg, Washington State University: This study examined the feasibility of coupling a dynamic fire-atmosphere model (WRF-SFire) with the project's air quality decision support system, AIRPACT, to improve the representation of fire dynamics and plume rise in air quality forecasts. The project used Earth observations from MOPITT, OMI, and other NASA sources. It engaged partners from NW-AIRQUEST consortium members, EPA Region 10, the Nez Perce Tribe, Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, Lane Regional Air Protection Agency, Washington Department of Ecology, and others.

Improving Agricultural and Wildland Fire Source Emission Products and Access to Information for Atmospheric Science and Smoke Modeling Applications; Principal Investigator: Nancy French, Michigan Tech Research Institute: This project focused on developing models to determine the feasibility of the Wildland Fire Emissions Information System as a tool for addressing the decision-making challenge of mapping wildland and agricultural fire emissions across regions. It engaged partners from the regional air quality community, such as the National Wildfire Coordinating Group–Smoke Committee, EPA/CMAQ, USFS RSAC, and the carbon modeling community (e.g., CASA-GFED, NASA-CMS, CarbonTracker).

Wildfire Risk and Treatment Effectiveness of Protecting Highly Valued Resources and Assets with Fuels Management; Principal Investigator: Mark Cochrane, South Dakota State University: The project integrated MODIS and *Landsat* data into wildfire simulation modeling, to demonstrate the feasibility of quantifying fuel treatment effectiveness in terms of HVRA (highly valued resource and asset) exposure, linking past treatments to incident decision making and suppression activities, and exploring treatment impacts on fire behavior under alternative fire weather conditions.

Rapid Response: King Fire

The King Fire started September 13, 2014, in an area north of Pollock Pines, California. Drought conditions and low humidity contributed to its rapid spread, particularly on September 17, when the fire made an approximately 50,000-acre run up the Rubicon River drainage. Overall, the fire burned more than 97,000 acres, destroying 12 single residences and 68 other minor structures.

Figure 1. King Fire from Aqua/MODIS

In 2014, the Wildfires program element allocated funds to sponsor a rapid response proposal to collect observations of the King Fire. The goal of the project is to provide assets and data for pre-burn forest condition class, fuel moisture, fire behavior, post-fire burned area and severity, post-fire forest structure, erosion, re-vegetation, and targeted mitigation for fire science and management.

The King Fire was the latest example of an emerging class of mega-fires changing the landscape of the western United States. Mega-fires may represent a tipping-point transition to a new fire regime, one that could reshape U.S. landscapes. Much of the King Fire burn area was (serendipitously) surveyed shortly before the fire and was comprehensively measured by the pre-HyspIRI airborne sensor campaign during its active burning phase. This rapid response project complements those observations with post-fire observations of forest structure change (lidar), topography, and burn severity (imaging spectroscopy) to obtain baseline science data for use in immediate post-fire mitigation activities with agency partners. This project provides data critical to understanding the behavior and post-fire ecological recovery for extreme mega-fires and informing post-fire and long-term management responses.

Specifically, the project will process all available pre-HyspIRI imaging spectroscopy data (VSWIR and thermal) to produce fire science and mitigation-relevant L3 and L4 data products. Then, the project will collect immediate post-fire lidar data to document forest structural change, and to support the BAER team. Also, in collaboration with other Wildfires projects, this project team will process and distribute science- and application-ready data, including inputs to the CAWFE model.

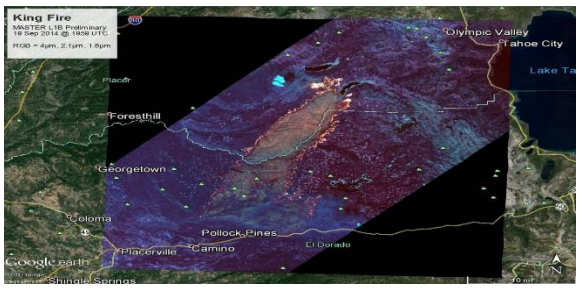

Figure 2. MASTER image of King Fire, 19 Sept 2014.

The airborne and field campaigns started in November 2014 and will continue into 2015, with additional airborne sensor assessments to look at burn area recovery following winter 2014-15. The USFS Region 5 is a full partner in the project, contributing 50 percent of the resources to the effort. Key team members include David Schimel (PI-JPL), Natasha Stavros (JPL), Carlos Ramirez (USFS), and Janice Coen (NCAR).

VI. Program Management

In 2014, Vince Ambrosia and Amber Soja continued to serve as associate program managers for the Wildfires program element. They each managed a portfolio of projects, tracking progress, financials, and applications performance. They enhanced routine Applied Sciences communications with the PIs, project teams, and their partner organizations. Among their activities, the associates discussed projects and program objectives with the project teams; evaluated project progress; assessed ARLs; described expectations for Phase 2 activities; and addressed PI questions and concerns.

Phase 1-2 Peer-Review Panel

In January, the Wildfires program conducted a peer review of the 17 Phase 1 feasibility study projects. This peer review provided community input on scientific, technical, and management aspects of the projects. The program management team used this information, along with programmatic strategy and direction, to select nine projects to continue into Phase 2 as in-depth applications development projects.

The panel reviewed the projects' written summary reports, which contained two distinct sections. Part One discussed the fire-related challenge and decision-making activity, application of Earth observations, the proposition tested in the study, starting and ending ARLs, results of the feasibility study, baseline performance, and partner involvement assessment. Part Two provided a preliminary plan for Phase 2 activities, including the approach to implement the application, potential benefit and measurable impact, partner organization involvement and commitment, preliminary transition approach, key milestones, and challenges.

The Wildfires program introduced a novel approach to this peer-review process. Each project team presented their project accomplishments and plans "virtually" during the first half of the peer-review panel's consideration of the project. Each team had approximately 10 minutes to discuss its project, and the panel then had about 10 minutes to query the project team about its project, the presentation, or items in the written report needing clarification. Following this interactive period, the project team disengaged from the teleconference, and the panel discussed and evaluated the project internally. Both the panelists and the project teams indicated that this approach was highly successful and welcome, as it allowed the project teams to clarify any items in the written report that were unclear or left unaddressed because of space limitations. The peer-review panelists also found it valuable by enabling direct questioning of the project teams on concepts in the report and proposed plan which needed further clarification.

Of the 17 projects reviewed, 15 scored a three or higher (on a five-point scale). The vast majority of the projects were rated "Very Good."

Following the peer review panel, the program management team selected nine projects to continue into Phase 2. The management team presented its recommendations to the NASA Earth Science Division's Executive Committee, which approved the recommended projects. The

management team then announced the awards and arranged the funding for the Phase 2 projects. To allow for smooth closeout, the management team offered nominal funding to those projects ending at the feasibility stage (i.e., not advancing to Phase 2) in order to complete their efforts and develop any closeout documentation. Two of the eight concluding projects accepted this offer (PIs S. Drury and Y. Wang).

Project Teleconference and 2015 Team Meeting
On December 8, 2014, the program management team held a teleconference with the PIs/project teams to highlight and identify objectives, goals, expectations, reporting metrics, etc., for the coming project year. The associates discussed the plans for the first Wildfires Project Team Meeting in mid-February 2015 in Salt Lake City. During the review, the project teams will have an opportunity to highlight their progress and their upcoming 2015 project plans, identify challenges or programmatic issues, receive instructions and updates on project metrics reporting, and other topics related to improving project performance and project maturation to partner application adoption. The meeting will devote time to visit wildfires-related facilities and offices in the Salt Lake City area, including the USFS Remote Sensing Application Center, USFS Geospatial Service and Technology Center, and the Great Basin Geographic Area Coordination Center. The meeting will include end users, such as task leaders and incident commanders, to build connections and ensure that the views of managers and practitioners are well represented.

Rapid Response: King Fire
As described in Section V above, the Wildfires program element reviewed and sponsored a proposal through the NASA Rapid Response and Novel Research in Earth Science solicitation (aka ROSES-2014 A.27). David Schimel, NASA-JPL, submitted the proposal to collect timely observations of the 2014 King Fire area in California. The goal of the project is to provide assets and data for pre-burn forest conditions, fuel moisture, fire behavior, burned area and severity, post-fire forest structure, erosion, re-vegetation, and targeted mitigation for the fire science and management communities. This one-year project is jointly supported by USFS and will extend into late 2015.

Autonomous Modular Sensor Instrument Transfer to USFS
In 2014, the NASA-developed Autonomous Modular Sensor (AMS), made its debut in USFS airborne wildfires operations. The USFS/National Interagency Fire Center (NIFC) – National Infrared Operations (NIROPS) installed the AMS on a USFS Cessna Citation jet and employed it to support two major wildfires and five prescribed fires in April and May: Brown Fire, Signal Fire, Elk Post Prescribed Fire, Pole Mill Prescribed Fire, Crooked Prescribed Fire, Pine Creek Prescribed Fire, and the Rough Creek Prescribed Fire.

Following a successful run supporting NASA Earth science research, technology demonstration, and applied research activities, NASA transferred the scanning spectrometer to USFS in 2012-2013 through a cooperative transfer agreement between NASA Ames Research Center and USFS Fire and Aviation Management. Of note, USFS invested more than $100,000 with NASA

(Ames Research Center) to support FY 2013–2015 training, sensor calibration, and software enhancements.

AMS made its USFS debut in April, 2014, when it was called up for active service (from its checkout, calibration, and system training flights) for operational use in support of the response to the Brown Fire in Arizona. The sensor produced data that confirmed a limitation of the fire spread, which allowed incident commanders to downgrade fire acreage and demobilize resources. This determination resulted in reductions in fire crews and costs to the agency.

In May, USFS again used AMS to support the response to the Signal Fire in New Mexico. It provided the first thermal infrared collections on the fire, as there was no previous intelligence on fire size, movement, or fire growth available from other resources. As such, the AMS collection allowed the initial attack incident command team to plan and focus resources for the next morning's deployment of fire crews.

In both these cases, the AMS was the only national asset ready and available for immediate response. It flew on a USFS Citation aircraft for these fires.

For the remainder of the 2014 fire season, USFS conducted further calibration activities and checks on additional USFS aircraft assets. USFS expressed interested in using the AMS to support surge capability during mid- to late-summer when USFS imaging assets are typically stretched thin. As the 2014 fire season was below average (see Section II), this surge capability was not required.

Communications

The Wildfire program management team worked with the project teams to develop two-page, glossy summary documents for each project for distribution at conferences, to partner agencies, and to program visitors. The project summary documents highlight the projects' objectives, major milestones, and implementations. The documents serve as a baseline description of the projects with graphics designed to capture the attention of the general public and to highlight the role of NASA Applied Science Program efforts to improve wildfire characterization with remote sensing assets, data, models, technology, and science. These project handouts were available at numerous conferences in 2014, such as those listed in Sections VII and VIII. Section X.B includes these project summary documents.

VII. Community Leadership

The Wildfires program element sponsored and supported numerous activities in 2014 as part of overall efforts to enhance the use of Earth observations and wildfire science in wildfire-related management decisions and actions. The following summarize participation in key interagency committees as well as conferences and symposia:

NASA/USFS Tactical Fire Remote Sensing Advisory Committee (TFRSAC)
Vince Ambrosia continued to serve as a co-chair of the NASA/USFS TFRSAC, which addresses efforts to share information on wildfire imaging capabilities, technologies, and projects that employ spaceborne, airborne, and *in situ* assets to improve wildfire characterization capabilities, including pre-fire assessment, active-fire observations, and post-fire recovery and rehabilitation. The community is composed of incident managers, situation unit leaders, wildfire scientists, geospatial specialists, company representatives, and sensor engineers. The TFRSAC community has become increasingly focused on the use of small UAS, given the interest in federal and state agencies to near-real-time wildfire information support on events to support the safety of line crew operations, provide tactical-level observations during night operations, and in post-fire hotspot detection.

The April 2014 TFRSAC meeting involved 30 participants in person and an additional 25 individuals via webcast. Participants represented federal and state agencies, universities, private companies, and international institutions. This meeting included briefings from several projects in the NASA Wildfires portfolio on their project strategies and partner organizations. The meeting included a live flight demonstration of a near-real-time, inexpensive aircraft sensor system and Web-map application that provides fire information to incident command on wildfire events, which can be transmitted to line crews, retardant drop aircraft, etc.

In October 2014, the Desert Research Institute in Reno, Nevada, hosted the Fall TRFRSAC meeting with 40 people in attendance and an additional 28 participants via WebEx. This meeting included a presentation of Wilfred Schroeder's project involving the integration of VIIRS I-Band data observation capabilities for improved spatial resolution of fire progression (aka, growth) through multiple-daily and multi-day observations. In addition, the California Department of Forestry and Fire Protection demonstrated that it is integrating orbital asset information more frequently into large-scale fire operations, as showcased by its use of VIIRS data on California fires in summer 2014.

Wildland Fire Science and Technology Task Force
Amber Soja continued to represent NASA on this interagency task force, which is drafting a document that identifies opportunities and mechanisms for increased coordination and cooperation to support the development, access to, and application of science and technology in wildland fire management, mitigation, response, and recovery. Composed of representatives from 26 federal wildland fire management and wildland fire science and technology organizations, this ad hoc task force served under the auspices of the National Science and Technology Council's Committee on Environment and the Natural Resources, and Sustainability Subcommittee on Disaster Reduction. Specifically, task force coordination and cooperation is intended to support the following three overarching national goals: restore and maintain landscapes that are resilient to fire-related disturbance; encourage fire-adapted communities; and promote safe, effective, and efficient risk-based wildfire response management decisions.

In April 2014, the task force held a kickoff meeting in Washington, D.C., to review the task force charter, scope and objectives, membership and agency roles, and the timeline to complete milestones and goals. There were 33 participants representing 20 federal organizations. Recognizing a changing climate and increased urban-wildland communities at risk, participants expressed excitement over the level of commitment across an important mix of federal wildland fire representatives to accomplish the objectives assigned to this task force.

In June 2014, the task force met in Washington, D.C., to analyze the current landscape of wildfire management and available pertinent science and technology; establish current agency baseline capacities; identify critical gaps and opportunities for long-term coordination; and to measure progress on meeting the previous Grand Challenges strategic actions. During the three-day meeting, there were talks from two dozen federal sub-groups (mainly from USFS); Amber Soja presented information on the NASA Wildfires program and a host of additional NASA fire projects that included examples from Land Cover Land Use Change, Terrestrial Ecology and the InterDisciplinary Science programs. She also submitted a 10-page report to the task force that described NASA's past, present, and projected future commitments and actions in support of fire science, technology, instruments, models, and funded projects.

In October 2014, the task force met to review, collate, and discuss input submitted by each agency. They discussed progress on strategic action of the Grand Challenges, agency roles and responsibilities, and current and future national-level challenges. Based on the information and discussions, the task force identified critical thematic and programmatic gaps and opportunities for long-term coordination of federal fire science.

In early 2015, the task force intends to summarize multi-agency wildland fire management priorities. The summary will likely describe current and future national challenges for decreasing the undesired effects and increasing the desired effects of wildland fire, and it will identify critical gaps and opportunities for long-term coordination and cooperation across organizations to define strategic objectives, maximize efficiencies, and promote effective collaboration.

Presidential Policy Directive/PPD-8: National Preparedness
Wildfires associate Amber Soja provided input to a Presidential Policy Directive/PPD-8 on wildland fire science and technology. The overall activity developed a catalog of existing Federal science and technology programs that support national preparedness activities to address wildland fire hazards. Focusing on wildland fire threats and hazards that can be measured and evaluated through NASA programs, her input included information on the NASA programs that develop applicable data, products and models.

IARPC Wildfire Implementation Team
The Interagency Arctic Research Policy Committee (IARPC) is charged with enhancing both the scientific monitoring of and research on local, regional, and global environmental issues in the Arctic. IARPC consists of 16 federal agencies and offices.

Vince Ambrosia represents NASA on the IARPC's Wildfire Implementation Team, or WIT. The WIT addresses the frequency, extent, and severity of wildfires in the arctic as a component of understanding high-latitude terrestrial ecosystem process, ecosystem services and climate feedbacks. Ambrosia was the lead author of a report, *Satellite and Airborne Fire Sensor Systems for Arctic Wildfire Observations,* which cataloged and highlighted the orbital and airborne sensor capabilities that are available for observations of wildfire events or for post-fire assessment in the arctic (and applicable throughout the globe).[4] In 2015, the authors expect to finalize the document, and the WIT plans to hold a webinar or workshop to highlight the various satellite and airborne sensing systems capabilities for observing fires in the arctic.

JFSP National Fire Science Exchange Meeting

The interagency Joint Fire Science Program (JPSP) hosted a National Fire Science Exchange Meeting in Tucson, Arizona. The event brought together the fifteen regional, US-based Knowledge Exchange Consortia groups to share their regional capabilities and inform the fire management practitioners of JFSP-supported fire science activities. Similar to the JFSP overall, the objectives of the regional consortia are to translate science to outputs, outcomes, and measureable societal impacts. Approximately 75 people participated in this May 2014 event, including Wildfires Associates Vince Ambrosia and Amber Soja.

Ambrosia and Soja informed the Consortia of the NASA Earth Science capabilities and efforts to support wildfire applications, and some Consortia members had not been previously aware of NASA's capabilities. Many consortia members expressed interest in gaining more information, maintaining contact and sharing NASA data and knowledge with their regional fire management and support communities (e.g., through the Consortia regional workshops. Soja and Ambrosia continued to engage with the Consortia after the meeting.

Large Wildland Fires Conference: Social, Political and Ecological Effects

This May 2014 conference (*http://largefireconference.org/*) attracted more than 600 participants from over 10 countries to share the latest research findings, management applications, and policy initiatives concerning the ecology and management of large wildland fires. The International Association of Wildland Fire (IAWF) and Association of Fire Ecology (AFE), among others, were key sponsors of the event in Missoula, Montana. Major themes included: Fuel Treatments, Large Fires, Global Changing Wildland Fire regimes, Fire Ecology, Fuels Management, Socio-Ecological Effects of Wildfires, Rim Fire, Smoke, Climate Change, Social Issues, Fire Severity, Fire Management Spatial Analysis, Fire History, Fire Suppression, Wildland Fuels, and Fire Behavior.

A topic raised throughout the meeting was the recognition that changing climate regimes are having a profound effect on fire sizes, intensity, and power. In addition, participants noted that fuel treatments effectiveness is a measurable variable that is not readily undertaken or known

[4] The document is currently publically available on the IARPC website (draft version at *http://www.iarpccollaborations.org/uploads/cms/documents/wildfire-sensor-systems_v5.pdf*). Co-authors were L. Giglio, W. Schroeder, I. Csiszar, and B. Quayle.

and can reduce the magnitude of future fire events in those treated regimes. NASA attendees noted that Earth observations data and information on Fuel Treatment Effects and Land Disturbance products could provide support to operational assessments of catastrophic wildfire risk. Both Associate program managers attended, and five of the wildfires project teams gave oral or poster presentations (Peterson, Holden, Schranz, Miller, and Drury).

Wildfire Futurecasting Summit
In February, Intel and the US Air Force Academy hosting a special event to examine future capabilities and technology that would enhance the wildfire knowledge of communities, governments, and incident responders. Using a "futurecasting" approach to figuratively put people in the year 2024, the attendees discussed different scenario perspectives of wildfire management (from perspective of firefighter, incident manager, politicians, citizens in fire-affected areas) and how those various community entities will have advanced technological capabilities at their disposal. In examining the years 2014-2024, they discussed barriers to implementation of technology, knowledge systems, communications barriers, geo-political barriers and budgetary barriers. Vince Ambrosia represented NASA.

Findings from the summit included the nature of the barriers appeared to be primarily budgetary and policy in nature rather than technological; near-real-time Earth observations data (and models) to support wildfire observation management strategies from the citizen through the incident teams and politicians should be readily available; Key area of growth is the ability to mine the vast resources of data and models to allow sufficient management strategies to occur to mitigate wildfire effects on populations, infrastructure and ecosystem natural processes disruptions.

Second Suomi NPP Applications Workshop
In November 2014, the Applied Sciences Program held the second *S-NPP* Applications workshop. Held in Huntsville, Alabama, the event provided the Earth science and applications communities with an update on *S-NPP* instrument performance, data characteristics, and data access from NASA and NOAA portals. Participants discussed current applications and new ideas, with particular focus on the areas of disaster, ecological forecasting, health and air quality, wildfires, and water resources. These sessions helped identify barriers to the integration of *S-NPP* observations into existing and future applications. Amber Soja presented for the Wildfires element, demonstrating applicable and successful uses of *S-NPP* data, with a particular focus on the VIIRS instrument.

Pecora 19/Sustaining Land Imaging Conference
The biannual Pecora conference focuses strongly on remote sensing applications, and this Pecora 19 conference was jointly held with the ISPRS symposium for Technical Commission I on Sensors and Platforms for Remote Sensing. These events occurred in Denver, Colorado, in November 2014. The joint event focused on how remotely-sensed data, acquired using the latest technology, sensors and platforms, help further our understanding of an ever-changing Earth and are used to improve the information delivered for managing our natural resources.

Symposium topics included: Detecting and Monitoring Changes in the Earth's Surface at Regional, Landscape and Sub-pixel Scales; Using Remotely Sensed Observations to Managing Natural Resources within Nations, Counties and Cities; Emergence of UAS and Other New Remote Sensing Technologies for Studying Terrestrial and Aquatic Ecosystems; and Data Mining and Computer-Assisted Image Analysis in the Era of Big Data.

Jim Vogelman, Wildfires PI, was a member of the Pecora 19 Steering Committee. The NASA Wildfires program organized two special sessions on its projects, and seven project teams participated in the event. The session included an additional discussion period with the audience regarding the upcoming Earth Science Decadal Survey. Vince Ambrosia organized the session, and Amber Soja chaired it.

American Geophysical Union (AGU) Fall Meeting
At the AGU event in December 2014, scores of sessions included wildfire-related topics, and several Wildfires project teams gave oral or poster presentations. On behalf of the Wildfires team, Vince Ambrosia presented "NASA and Wildfires: Science and Technology Supporting the Nation" on December 18, at the NASA hyperwall exhibit. The NASA booth included literature on the Wildfires program, especially Wildfires project summaries.

American Society of Photogrammetry and Remote Sensing (ASPRS) Special Symposium
ASPRS held a special-topic symposium on UAS in October 2014 in Reno, Nevada. This "UAS Mapping 2014" symposium and technical demonstration sought to advance knowledge and improve the understanding of UAS technologies and their safe and efficient introduction into the national airspace, government programs and business. Representatives of academia, UAS developers, survey and mapping companies, and government agencies shared information, showcased new technologies, and demonstrated UAS systems in flight. Vince Ambrosia gave an invited keynote address on the NASA/USFS UAS wildfire observations partnership, and NASA supported a booth that displayed UAS systems in applications development for wildfire testing and evaluation. At the meeting overall, land management agencies highlighted the needs and limitations for resource monitoring with small UAS, and the UAS community expressed their readiness to provide operational services to the marketplace and the agencies. Overall, the discussions informed the UAS community about key factors and agencies' needs to ensure the proper integration of UAS capacity into agency land management and monitoring operations.

VIII. International Activities
The Wildfires program element included more international activities in 2014 and increased its contributions to a wildfires task of the intergovernmental Group on Earth Observations (GEO). The following text summarizes participation in a key international committee, conferences, and the GEO task.

GOFC-GOLD Fire Implementation Team (FIT) Meeting
Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD), a panel of the Global Terrestrial Observing System (GTOS), improves the quality and availability of observations and

information projects of forests and land cover at regional and global scales for a wide variety of users. The GOFC-GOLD Fire Mapping and Monitoring Theme is aimed at refining and articulating the international observation requirements and making the best possible use of fire products from the existing and future satellite observing systems, for fire management, policy making, and global change research.

The Theme held a *Fire Mapping and Monitoring Implementation Team Meeting* in July 2014 to promote collaboration among the U.S. and international researchers focusing on satellite remote sensing of fires. The purpose was to review the current progress, recent developments and future prospects of satellite-based fire monitoring and science for forest/natural resource management and other applications. The Wildfires Associates, one of the project PIs, W. Schroeder, and several Wildfires team members were among the approximately 50 people participating in this meeting in College Park, Maryland.

The meeting included briefings on the development of operational fire products from the Suomi NPP mission and VIIRS Fire Detection Capabilities. For example, talks included: *I-Band for VIIRS Fire Retrieval* (Schroeder), *Development of VIIRS M-band Fire Detection* (L. Giglio and I. Csiszar), *Global Wildfire Information System* (San Miguel Ayanz), *ESA Sentinels* (Arino), *NOAA Hazard Mapping System* (Ruminski), and regional networks from Southern Africa, Latin America, Mexico, Southeast Asia, and the Balkans. Post-fire recovery operational developments were also a focus area for presentations and future developments. Ambrosia presented the Applied Sciences Program and its Wildfires element.

A key highlights of the meeting included the announcement of the operational production (beta version) of VIIRS data within the USFS Rapid Response System (RSS). The regional networks emphasized the standardization of fire burnt area products and validation with higher resolution, globally-available products (*Landsat*, Sentinel, etc.). Also, the Fire Implementation Team discussed working to enable improved TIR radiometric sensors and temperature saturation points for upcoming systems to enhance fire detection capabilities.

IUFRO World Congress: Sustaining Forests, Sustaining People

The International Union of Forest Research Organizations, IUFRO, held its 24th World Congress in October 2014, with the theme of *Sustaining Forests, Sustaining People: The Role of Research.* This event had the following themes: Forests for People, Forest Biodiversity and Ecosystem Services, Forests and Climate Change, Forest and Water Interactions, Forest Biomass and Bioenergy, Forests and Forest Products for a Greener Future, and Forest Health in a Changing World.

The Applied Sciences Program was a gold sponsor of this Congress, and the NASA exhibit featured NASA Earth Science activities in arenas related to the conference themes, especially wildfires, forest health, and carbon monitoring. Associates Ambrosia and Soja attended along with Cindy Schmidt and Andrew Nguyen from the Program's Capacity Building DEVELOP program. More than 3,900 people attended this World Congress in Salt Lake City.

This conference provided a key opportunity to reach people and organizations who were previously unaware of NASA's capacity with Earth observations, research, and applications to support science and management in forest, fire, carbon, fuels, and ecosystem functions and services.

VII International Conference on Forest Fire Research (ICFFR)
Over 280 people representing 23 countries attended this November 2014 conference, which focused on themes of Human and Institutional Factors of Wildfire, Forest Management and Fire Prevention, Fire at the Wildland Urban Interface, Forest Fire Risk Assessment and Climate Change, Fire Detection and Monitoring, Remote Sensing, Fire Management, Fire Suppression and New Technologies, Large Fires, Fire Safety, Economic Issues, Fire Ecology and Evaluation, and Management of Burned Areas.

This conference, which focuses on fire research, is held every four years in Portugal. The 2014 conference marked the first time ICFFR had a dedicated component on remote sensing of wildfires, including 12 papers in two sessions. Associate Program Manager Ambrosia represented NASA Earth Science, chairing a session on Remote Sensing of Fires and Fire Suppression and New Technologies. He also presented the Applied Science Program's Wildfire element and the advancing orbital and suborbital remote sensing information improvements to wildfire observations, modeling and management.

International Union for Conservation of Nature (IUCN) World Parks Congress
Held once a decade, this congress provides a global forum on parks and protected area management. NASA had a strong presence, including the hyperwall exhibit and numerous in-booth presentations. Held in Sydney, Australia, in 2014, the theme was *Parks, People, Planet – Inspiring Solutions*. In addition to Applied Sciences personnel, Karyn Tabor, a Wildfires PI from Conservation International, and her colleagues supported NASA's presence, providing substantial material for the hyperwall to showcase how NASA science and applications supports park management around the world.

Group on Earth Observations: Global Wildfire Information System
The Group on Earth Observations (GEO) is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO coordinates efforts to build a Global Earth Observation System of Systems (GEOSS). GEOSS incorporates national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, airborne, in situ, and space-based instruments. GEO and its GEOSS implementation focuses on Earth observations for nine areas of societal benefit: Agriculture, Biodiversity, Climate, Disasters, Ecosystems, Energy, Health, Water, and Weather.

In its 2013 work plan, GEO initiated a wildfires task component, Global Wildfire Information System, GWIS (aka, DI-01-C4 in the work plan). The objective of this task component is to

provide a platform for harmonized information and to enable the exchange and coordination of information among major national and regional fire information providers (e.g., existing systems in the United States, Canada, South Africa, Russia, Australia, and China). This GWIS platform aims to provide information to all aspects of fire management, from pre-fire danger forecast to active-fire monitoring and post-fire assessments, including burned area maps, land cover alteration, damage in protected areas, fire emissions, and potential soil erosion.

The task builds on existing fire communities, such as the GOFC Fire Implementation Team and its regional networks. Part of the task follows the scheme of the European Forest Fire Information System. The wildfire component is aimed at linking various national, global and regional systems to make complementary spatial Earth Observation data more readily available, through a harmonized global wildfire information system of systems. The task will build on the ongoing activities of the GOFC-GOLD Fire Implementation Team, the associated Regional Networks, complementing existing, related activities that are on-going around the world, with respect to wildfire information gathering.

In 2014, GEO accepted USGEO's nomination of Vince Ambrosia to serve as one of the Leads in this task component. He coordinated with the other Component Leads to understand plans and direction as well as to characterize more fully US interests and priority contributions.

Key GWIS component actions in 2014 focused on:

1. Establish a prototype spatially-explicit and web-accessible GWIS, providing harmonized fire information (e.g. fire danger, burnt areas, emissions, and fuels) and building on initial activities of the GOFC-GOLD Fire Implementation Team.
2. Undertake a review of wildfire information systems building on existing literature and reviews of operational systems for fire danger information.
3. Promote the networking of major national and regional fire information providers (where possible using the existing regional fire networks), including organizing workshops convening key national and regional providers.
4. Link with fire communities generating global scale fire-related data sets (e.g. burnt area assessment, emission estimates).

In addition to continuing work on these items, a key activity planned for 2015 is the further development of GWIS by integrating regional wildfire information sources.

IX. Looking Ahead

The Wildfires program management team will hold the first Wildfires team meeting in mid-February 2015. The meeting is planned for Salt Lake City to enable direct interaction by the project teams with wildfires-oriented organizations located there, such as the USFS Remote Sensing Applications Center and the National Interagency Fire Center's Great Basin Geographic Area Coordination Center (*http://gacc.nifc.gov/gbcc/*). The meeting will include end users, such as task leaders and incident commanders, to build connections and ensure the views of managers and practitioners are well represented. This meeting is intended to help the wildfires

community begin organizing its priorities and input for the upcoming Earth Science Decadal Survey.

In January 2015, NASA plans to launch the *Soil Moisture Active Passive* (*SMAP*) satellite. This satellite will measure soil moisture and freeze/thaw state. As products become available after calibration, validation, and product processing, the Wildfires program team will support efforts to examine these novel measurements and their potential uses and value for wildfires applications. The *SMAP* website is *http://smap.jpl.nasa.gov/*.

The 36th International Symposium on Remote Sensing of Environment (ISRSE) will occur in May 2015 in Berlin, Germany. NASA is a major sponsor of this event, and has helped organize sessions focused on forests, wildfires, and numerous other topics. A few of the NASA Wildfire projects will participate in a series of Special Sessions organized on Wildfire Remote Sensing Observations. The symposium website is *http://www.isrse36.org*.

In 2015, the King Fire Rapid Response project team will conduct an airborne campaign over the King Fire area and conduct further field data collection efforts. The team expects to begin providing level 3 data products to the Earth science and wildfires communities in early April 2015.

In April 2015, the Applied Science Program's ARSET training element will conduct a webinar series entitled "Introduction to Remote Sensing for Wildfire Applications." The webinars will take place one hour a week for five weeks. The series will provide an overview of remote sensing, details on how to access and visualize relevant NASA Earth science data, and how to use these data for wildfire applications. Additionally, the course will assist wildfire management professionals in decision making through the use of NASA data, relevant tools, and assessment methods. The ARSET website, including information about the program and its training opportunities, is *http://arset.gsfc.nasa.gov*.

In October 2015, ARSET will conduct a three-day wildfire remote sensing training class at Idaho State University. PI Keith Weber, ISU GIS director, is hosting the training.

The Wildfires program team expects to continue its discussions with USFS RSAC, JFSP, and NIFC GACCs (among other groups) concerning collaborations and communications on wildfire science and applications. The team expects the report from the interagency Wildland Fire Science and Technology Task Force, and it will continue efforts to support the GEO GWIS task component and other interagency and international committees and conferences. The team will also support efforts by the wildfire science and management communities to organize input for the upcoming Earth Science Decadal Survey.

X. Appendix

A. Publications, Related Items, and Media Coverage

This appendix highlights peer-reviewed publications, conference proceedings, presentations, and other items regarding the Applied Sciences Program Wildland Fire program element. Bolded text indicates authors and co-authors who are principal investigators, co-investigators, and programmatic management staff within the Applied Sciences Program - Wildfire program element. *Note: This appendix includes some publications from 2013 because the 2013 Wildfires Annual Summary did not include publications.*

Publications:

Agoston, R., **E. A. Hinkley**, and **V. G. Ambrosia**, (2014) An Approach for Measuring the Effectiveness of Fire Detection Systems in Different Dimensions. Bolyai Szemle, *National Civil Service Technical University Military Materials Journal*, Published by Heyesi Joseph, Exec. Director, DTP: Tordas & Co. Limited, Hungary, No. 3, Vol. 23, ISSN. 1416-1443, pp. 283-296, 2014.

Ambrosia, V. G. and T. Zajkowski, (2014) Selection of Appropriate Class UAS/Sensors to Support Fire Monitoring, Real-Life Experiences in the U.S. In Valavanis, K.P. and Vachtsevanos, G.J. (Eds.), *Handbook of Unmanned Aerial Vehicles*, Springer Netherlands, Dordrecht, DOI 10.1007/978-90-481-9707-1_73, Chapter 113, pp. 2723-2754, 2014.

Buckley, M., N. Beck, P. Bowden, **M. E. Miller**, B. Hill, C. Luce, **W.J. Elliot**, N. Enstice, K. Podolak, E. Winford, S. L. Smith, M. Bokach, M. Reichert, D. Edelson, and J. Gaither (2014) Mokelumne watershed avoided cost analysis: Why Sierra fuel treatments make economic sense. A report prepared for the Sierra Nevada Conservancy, the Nature Conservancy, and U.S. Department of Agriculture, Forest Service. Sierra Nevada Conservancy. Auburn, California. Online: *http://www.sierranevadaconservancy.ca.gov/mokelumne*.

Carroll, M. L., J. L. Schnase, K. T. Weber, M. E. Brown, R. L. Gill, G. W. Haskett, and T. A. Gardner (2013) A New Application to facilitate Post-Fire Recovery and Rehabilitation in Savanna Ecosystems. *IEEE EarthZine*. 22 June.

Coen, J., and Schroeder, W. (2013), User of spatially refined satellite remote sensing fire detection data to initialize and evaluate coupled weather-wildfire growth model simulations. *Geophysical Research Letters*, doi:10.1002/2013GL057868.

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Gallegos, A. J. (2014) Silverado Fire Debris Flow Hazard Assessment Report Burn Area Emergency Response (BAER) Assessments Cleveland National Forest Trabuco Ranger District, **M.E. Miller** highlighted *https://fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3822411.pdf*.

Hinkley, E.A., V.G. Ambrosia, S. Wegener (2014) "Unmanned Aircraft Systems in Environmental Monitoring Applications." In W. Messner (Ed.), *Autonomous Technologies: Applications that Matter*, SAE International, Warrendale, Pa., Chapter 8, pp, 138-156.

Holden, Z.A., A. Klene, G. Moisen and R. Keefe (2013) Design and evaluation of a low-cost solar radiation shield for monitoring surface air temperatures. *Agric. For. Meteor*.

Kochanski, A. K., Jenkins M. A., Yedinak K., **Mandel J.**, Beezley J. D., Lamb B., (2014) Toward an Integrated System for Fire Smoke and Air Quality Simulations, *physics.ao-ph*, arXiv:1405.4058v1, 16 May.

Luce C., V. Lopez and **Z. Holden** (in press) Modeling snowpack sensitivity and storage with spatial and temporal analog models. *Water Resources Research*.

Luce C., **J. Abatzoglou and Z. Holden** (2013) The missing mountain water: Slower westerlies decrease orographic enhancement in the Pacific Northwest U.S. *Science*.

Mandel J., Amram S., Beezley J. D., Kehman G., **Kochanski A. K.**, Dondratenko V. Y., Lynn B. H., Regev B., Vejmelka M., (2014) Recent Advances and Applications of WRF-SFIRE, *National Hazards Earth System Science*, 31 October.

Oliva, P. and **Schroeder, W**. (2015), Preliminary assessment of VIIRS 375 m active fire detection product for direct burned area mapping: Limitations and capabilities. *Remote Sensing of Environment, http://dx.doi.org/10.1016/j.rse.2015.01.010*.

Robichaud P., Elliot, B. and Miller, M. E. (in review) Predicting Post-fire Erosion with Online Tools. *International Journal of Wildland Fire*.

Schroeder, W., E. Ellicott, C. Ichoku, M. Dickinson, R. Ottmar, C. Clements, D. Hall, **V. Ambrosia**, R. Kremens, (2014) Integrated Active Fire Retrievals and Biomass Burning Emissions Using Complementary Near-Coincident Ground, Airborne and Spaceborne Sensor Data. *Remote Sensing of Environment*, (2014), Vol. 140, pp. 719–730.

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Steininger, M. K., **K. Tabor**, J. Small, C. Pinto, J. Soliz, E. Echeverria, (2013) A satellite model of forest flammability. *Environmental Management* 52(1):136-150.

Weber, K. T. (2014) Accelerating Wildfire Recovery. *ArcUser magazine*. pp. 20-22, *http://giscenter.isu.edu/research/Techpg/nasa_RECOVER/pdf/ArcUser_Spring2014.pdf.*

Conference Proceedings/Presentations:

Ambrosia, V. G. *NASA / USFS Collaboration: Advances in Wildfire Observations with UAS*. Applications of UAS to Land and Natural Resource Management Workshop, Argonne, IL, 16-17 July 2014.

Ambrosia, V. G., *NASA and Wildfires: Science and Technology Supporting the Nation*. Future of Wildfires Futurecasting Summit, U.S. Air Force Academy, CO. Springs, CO., 13-14 February 2014.

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11/9/2014: KNIN (FOX) - Boise, ID; FOX 9 News On Your Side News
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B. Project Descriptions

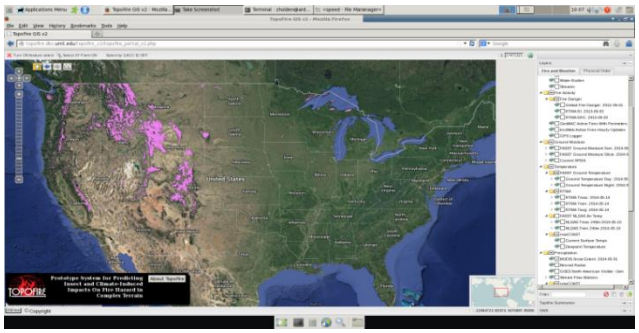
This appendix presents information on each of the nine Phase 2 projects in the Wildfires program portfolio. The appendix includes the project summary documents developed in 2014 on each project.

TOPOFIRE: A System for Monitoring Insect and Climate Induced Impacts on Fire Danger in Complex Terrain

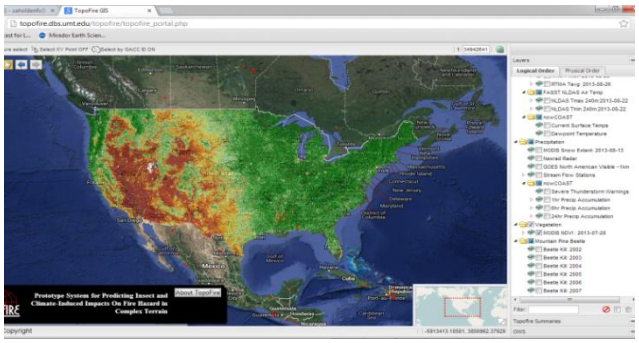
The fire environment is loosely defined by three factors: fuel, weather and topography. Both fuel and weather vary strongly both seasonally and spatially. Many weather factors such as temperature, humidity, wind, radiation, precipitation and snow cover influence ignition probability and regulate the behavior of that fire upon ignition. These conditions vary dramatically in complex terrain. However, operational fire management tools, such as the National Fire Danger Rating System (NFDRS) and the Wildland Fire Decision Support System (WFDSS) are applied at a single point, (usually the nearest remote automated weather station) and these conditions are assumed to be representative of the landscape-scale conditions where the decisions are being made. Operational fire danger and fire behavior assessment tools ignore fine-scale spatial variation in weather and this can have a pronounced effect on the decisions made using those tools.

To address the issues described above, we have developed an open source interactive web server called TOPOFIRE (topofire.dbs.umt.edu), designed as the next generation of the Wildland Fire Assessment System (WFAS). TOPOFIRE integrates very high resolution climate data, NASA imagery, and gridded FASST hydrologic model outputs with national decision support tools to provide spatial information critical to nearly every aspect of wildland fire management decision support. The primary goal of the system is to provide more finely resolved spatial information about fuel conditions in the wildland fire environment.

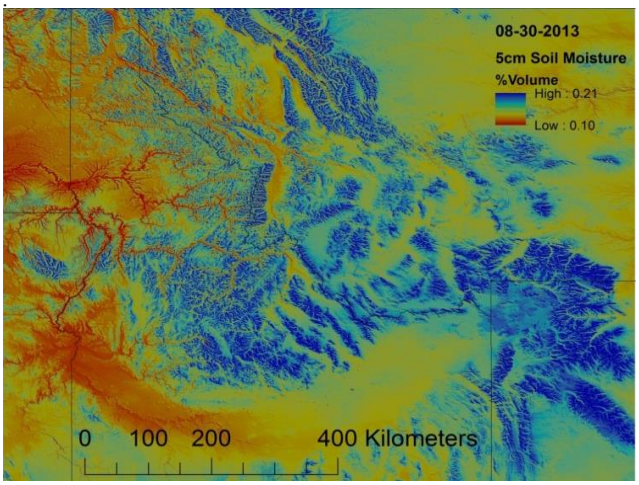
Data from thousands of low-cost temperature and humidity sensors distributed across the Pacific Northwest are used to downscale the National Land Data Assimilation System (NLDAS) dataset to 240 meter resolution. These terrain-corrected data, modeled wind and radiation data from WindNinja and MODIS snow extent data are used to drive the FASST hydrologic model. Daily duff and soil moisture maps are produced each day at 240 meter resolution. Fuel moisture and fire danger calculations are made using modeled near-surface air temperatures, to better account for the physical and topo-climatic influences on fire danger.



MODIS 8-day snow extent data are assimilated into TOPOFIRE and incorporated into fuel moisture and fire danger calculations.



MODIS 16-day day vegetation indices are used to calculate relative greenness, a key indicator of fire danger currently estimated using AVHRR in the Wildland Fire Assessment System.



FASST modeled duff moisture output from TOPOFIRE, August 30th 2013.

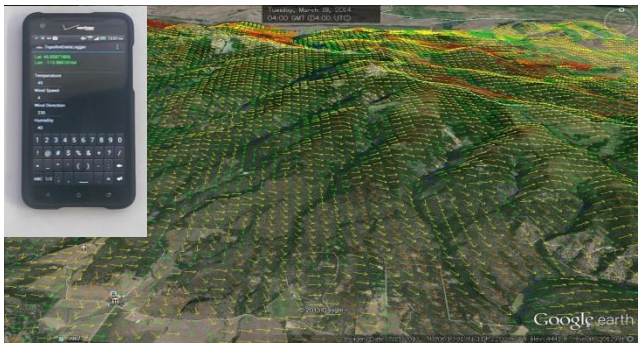
Discovering and Demonstrating Innovative and Practical Applications of Earth Observations

Mapping Mountain Pine Beetle Mortality with MODIS imagery

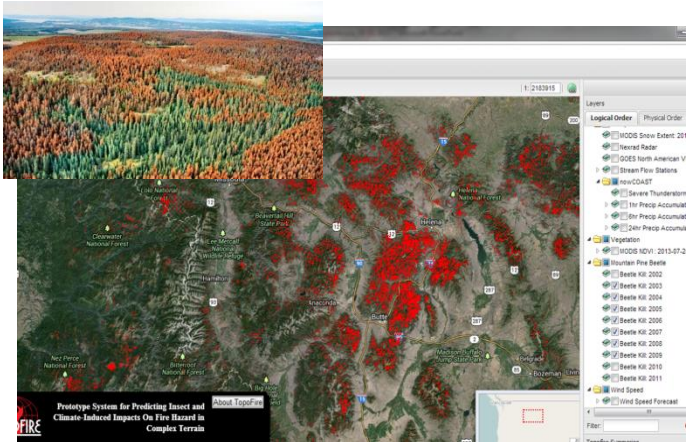
Recent Mountain Pine Beetle outbreaks are affecting the surface and canopy fuel distributions across millions of acres of Western US forests and these fuel changes can result in extreme fire behavior, particularly in the early "red" stages of attack. Fire managers currently rely on hand-drawn aerial survey maps for information on the location of beetle-killed areas. These maps generally represent last year's conditions, and surveys usually miss large areas each year.. Accurate, timely maps of historical and emerging insect-induced tree mortality are essential for safely and effectively managing wildland and prescribed fires. TOPOFIRE integrates aerial survey maps with MODIS VI time series to produce annual maps of MPB attack.

Crowd sourced Data collection and Distribution via Smartphone

Smartphones have evolved into powerful GPS and camera enabled personal computers. TOPOFIRE harnesses smartphone technology by assimilating weather observations and photos collected during fire incidents. Additionally, firefighters will be able to request Windninja wind speed simulation forecasts as well as maps of fire danger and potential fire behavior. Outputs from simulations run on TOPOFIRE will be delivered to user phones in near real time.



The TOPOFIRE smartphone application assimilates weather observations and photos from wildfire incidents, which can be used by fire managers and fire weather forecasters. Users can also request WindNinja simulation and fire danger forecasts via phone in real time.



The BFAST algorithm is applied each year to MODIS vegetation index data and then combined with historical aerial survey data to produce maps of recent MPB-induce tree mortality. These maps and data are available on TOPOFIRE and will be integrated into fire behavior simulations performed through WFDSS for improved characterization of potential for extreme fire behavior.

Impacts on Wildland Fire Decision Support

The TOPOFIRE modeling system will provide information for both strategic and tactical decisions on fire incidents. Data and models from TOPOFIRE will be integrated into both WFAS and WFDSS, the two primary national decision support systems in the US. will provide access to data and tools that are critical to nearly every aspect of wildland fire management. Firefighters will be able to interface with TOPOFIRE via smartphones, providing data to improve real-time models, and receiving corrected model outputs in real-time.

Strategic and tactical management impacts include:

- *Strategic resource placement prior to fire incidents*
- *predetermining fire management objectives*
- *Determine staffing requirements for initial attack of fire*
- *Improved modeling of wildfire spead and behavior that accounts for spatial variability in fuel conditions*
- *Rapid communication during fire incidents via smartphone applications*

Products and Tools developed through TOPOFIRE include:

- *Modified fire behavior models that assimilate user-defined gridded fuel moisture and weather grids*
- *Very high resolution gridded historical weather data*
- *Easy access to Historical NASA imagery*
- *Smartphone applications for Android and iOS*

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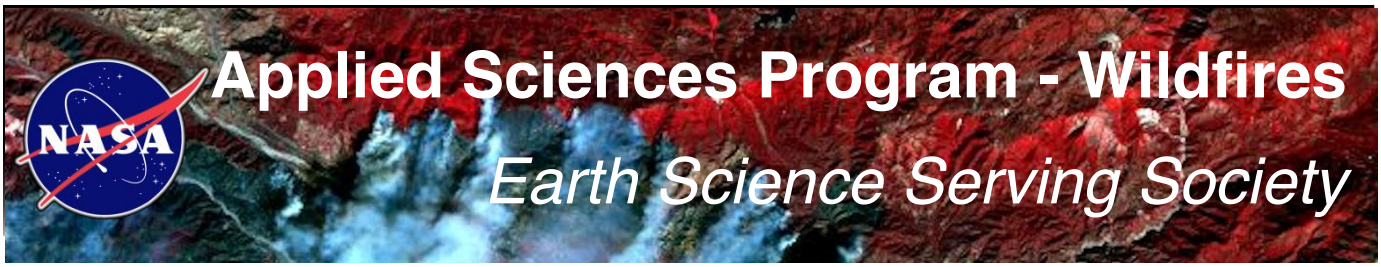
TOPOFIRE web link: topofire.dbs.umt.edu

Applied Sciences Program

http://www.nasa.gov/applied-sciences



Utilization of Multi-Sensor Active Fire Detections to Map Fires in the United States

Background

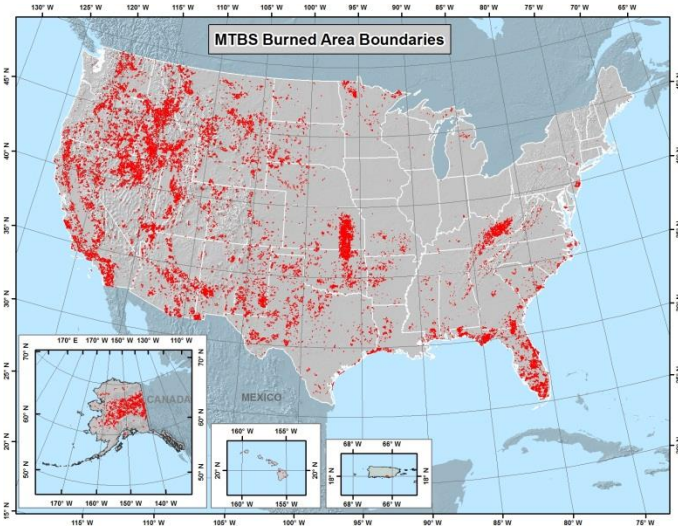
The Monitoring Trends in Burn Severity (MTBS) was established in 2006 by the Wildland Fire Leadership Council (WFLC) to address two policy mandates:

- The Government Accountability Office recommended the development of a comprehensive interagency methodology to consistently map and assess the effects of fire across the landscape and to improve land management practices in the context of fire disturbances, and
- The WFLC was tasked to monitor the effectiveness of the National Fire Plan and the Healthy Forests Recovery Act, and to provide a base of information to assess fire impacts and trends.

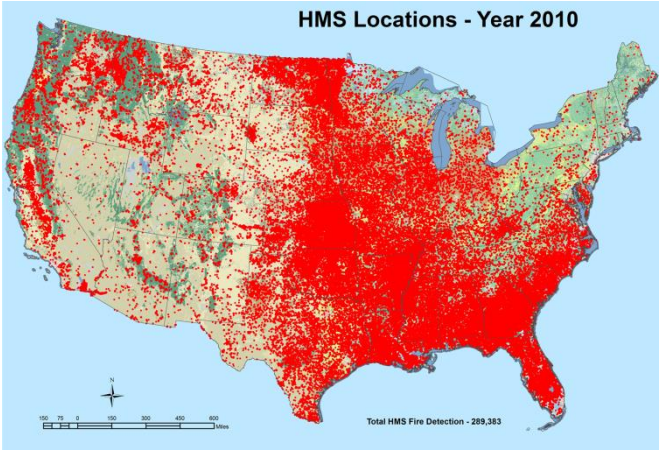
To meet these goals, it was necessary to develop a national baseline of consistent fire information from which to base management decisions at local, regional, and national scales. Subsequently, it was decided to utilize Landsat 30 meter imagery to map and assess all "large" fires (greater than 1,000 acres in the West and 500 acres in the East) across the nation. By 2014, MTBS partners, USGS Earth Resources Observation and Science (EROS) Center and the USFS Remote Sensing Applications Center, have mapped over 17,900 fires which are available via http://mtbs.gov.

Currently, MTBS relies upon state and federal fire occurrence data to guide Landsat scene selection and manual procedures to assess the fires. However, many fires on private lands are not be reported and escape evaluation. This problem is especially acute in the Southeast. Additionally, manual procedures limit the potential to increase the number of fires assessed.

Our project will utilize NOAA's Hazard Mapping System (HMS) active fire detections to augment Federal and state fire records. Also, rule based models have been developed to automatically identify fire-burned areas on Landsat imagery. These sources of fire occurrence will be combined to automate the selection of Landsat scenes to be used to assess each fire. Additional automated image processing techniques will be implemented to increase the efficiency of fire assessments and product generation, and all developed processing tools will be implemented in open source software and distributed freely to regional and local land management agencies.



MTBS fire occurrence database 1984 – 2012. Over 17,900 fires greater than 1000 acres in the West, greater the 500 acres in the East. Source: http://mtbs.gov



HMS Active Fire Detections of MODIS, AVHRR and GOES satellites from 2010; over 289,000 detections. Source:http://satepsanone.nesdis.noaa.gov/FIRE/fire.html

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Study Area

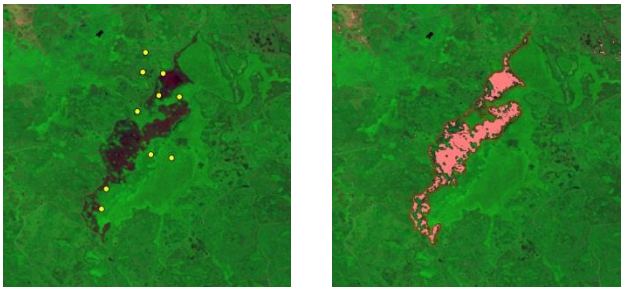
Our key partnership in Phase 1 has been three national forests in Florida: the Apalachicola, Osceola, and Ocala. These forests are covered by three Landsat Path/Rows in the Southern Coastal Plain, a region with a long history of prescribed burning for clearing undergrowth, reducing hardwood encroachment into pinelands, and promoting various wildlife species. The abundance of undocumented prescribed fire in this region compelled this study. We obtained the historical fire records for the forests and used them to help confirm the utility of our process.

Inputs

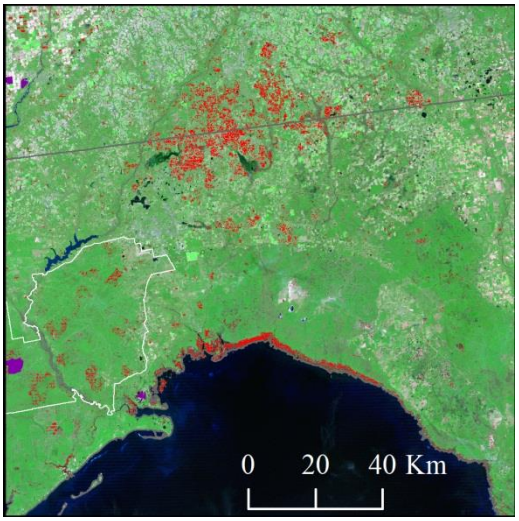
The Hazard Mapping System (HMS) utilizes satellite-based fire detections that are collected daily by GOES, AVHRR, and MODIS sensors. The detections are logged as often as every 15 minutes and allow for a more timely and spatially complete record of fire occurrence than is available from federal and state fire records. Rule based models were developed to search for fire signatures in historical Landsat scenes and create a preliminary fire burned area polygon.

Results

Approximately 1,800 Landsat scenes (1984 – 2012) and 88,000 HMS points (2003 – 2012) were assessed. We identified approximately 300,000 burned area polygons. The average size of these fires was 257 acres, and almost 18,000 fire polygons exceeded the MTBS 500-acre minimum threshold. By comparison, MTBS mapped 1,400 fires greater than 500 acres covering the 1984 -2011 time period. This suggests there are many unreported fires above the MTBS size thresholds. Additionally, it is clear this approach identifies many smaller fires; however, we have not yet determined the minimum fire size threshold that can be reliably delineated and mapped.



The Mother's Day fire in central Florida started on May 9, 2010. HMS points (yellow points) collected on May 10-12 overlay a June 14 acquisition. A rule-based burned/not burned model identifies burned area (pink) and is used to delineate an initial perimeter.



Landsat scene from 2004 showing the Apalachicola National Forest (white) and fires mapped by the MTBS project in purple. Fires found using rule-based models are shown in red . This suggests the extent of undocumented fires in the panhandle region of Florida. Note: the red along the coast is the result of commission errors.

Phase 2

The rule-based burned area polygon delineation process will be improved to reduce errors of commission and customized for various regions and land cover types. The several stand –alone procedures developed in Phase 1 will be integrated into a process requiring less analyst intervention. Near real-time processing of HMS data and Landsat acquisitions will be tested and implemented to speed the availability of initial fire assessments. We plan to estimate the magnitude of historical undocumented fires across the United States.

We will create and freely distribute a package of open source processing tools for fire managers who wish to assess the smaller fires that MTBS does not have the resources to evaluate.

Point of Contact:
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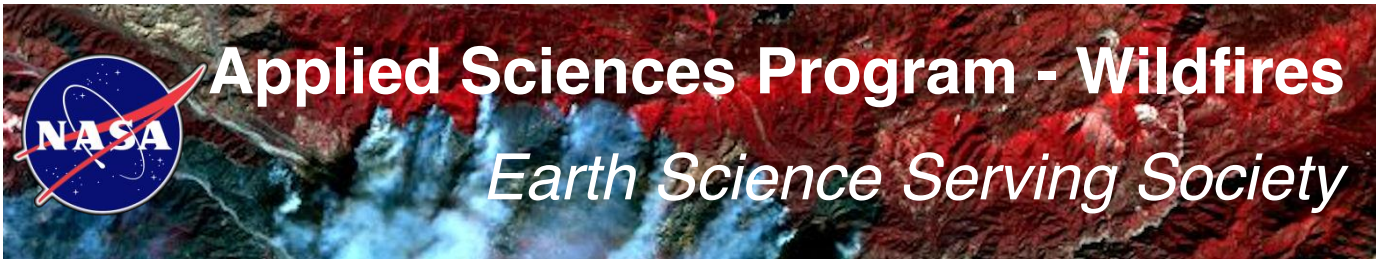
http://mtbs.gov

Applied Sciences Program

http://www.nasa.gov/applied-sciences

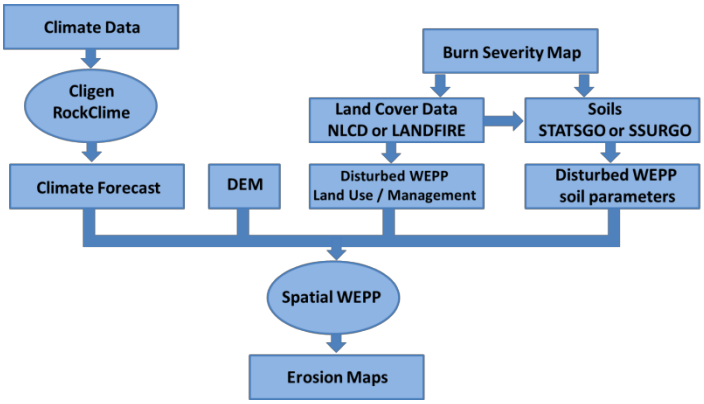


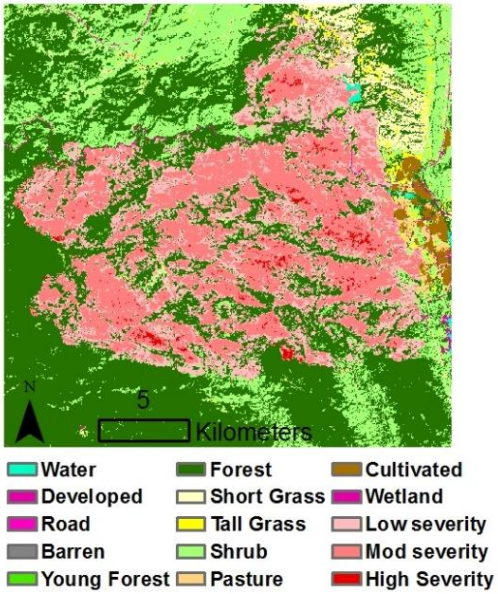
NASA BAER Project: Improving Post-Fire Remediation Through Hydrological Modeling

A joint partnership between Michigan Tech Research Institute, NASA and the Forest Service has lead to the creation of an online spatial database for the state of Colorado to support post-fire remediation through hydrological modeling. Our database rapidly creates spatial model inputs derived from Earth Observations of burn severity so that the modeling work can be carried out quickly and the results used to improve decision-making activities related to post-fire risk assessment and rehabilitation. The new website and prepared datasets deliver spatial model inputs in mere seconds; previously, assembling and formatting this type of data would have taken multiple days.

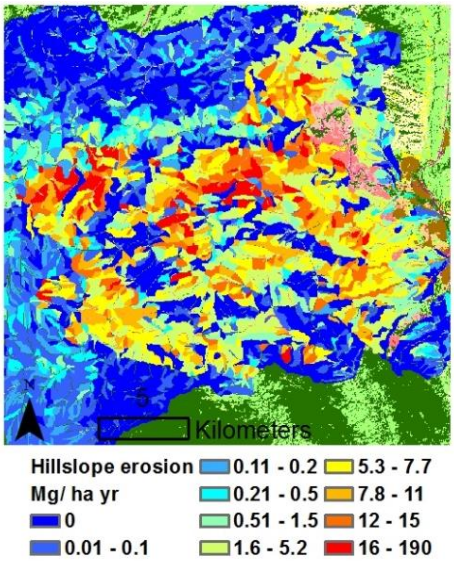
Post-fire flooding and erosion can pose a serious threat to life, property and municipal water supplies. To respond to this threat, interdisciplinary Burned Area Emergency Response (BAER) teams are formed to assess potential erosion and flood risk from burned areas. BAER teams must quickly determine if expensive remediation treatments are needed and prioritize their spatial application. One of the primary sources of information for making these decisions is a burn severity map that reflects fire induced changes in vegetative cover and soil properties. Slope, soils, land cover and climate are also important parameters in assessing risk. Process-based hydrological models, such as the Water Erosion Prediction Project (WEPP) are needed to estimate the effects of these parameters.

Modeling Database: http://geodjango.mtri.org/geowepp/





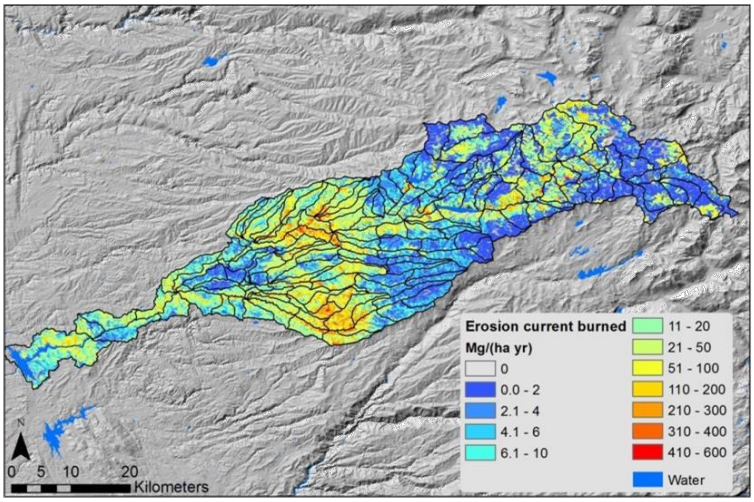
A land cover map created by the project's online datebase. A NASA Landsat derived burn severity map of the High Park Fire, Fort Collins, CO that burned in 2012 was uploaded into the database where it was rapidly combined with a LANDFIRE land cover map and soils data in order to create spatial model inputs.



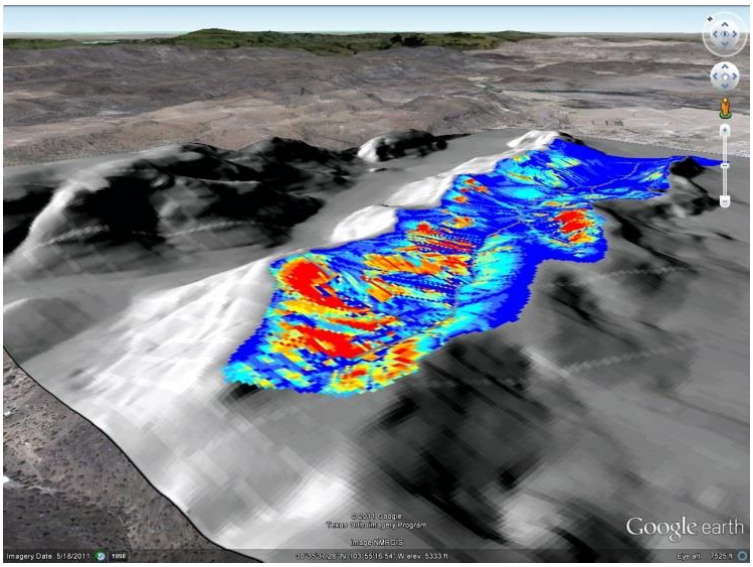
Hillslope erosion predictions created using spatial inputs derived from combining burn severity maps with land cover and soils data. The database also provides a co-registered DEM and all the necessary WEPP ancillary files needed for modeling.

Discovering and Demonstrating Innovative and Practical Applications of Earth Observations

Process-based hydrological models, such as WEPP are currently under-utilized because the time and skills required to prepare spatial input data is prohibitive, particularly post-fire. Our database will enable more BAER Teams to use process-based models as it eliminates time consuming data preparation. Open source software available within our online database modifies land cover and soil layers with burn severity maps and then delivers the data preformatted for use in spatial WEPP models. Work is underway to expand the database to cover the Western US and we are seeking other post-fire erosion models to support; we currently have plans to create datasets for a post-fire debris flow model. Our overall vision is that advanced GIS surface erosion and mass failure prediction tools capable of utilizing Earth Observation data will easily be applied to post-fire analysis using readily available spatial information from a single online site.



Predicted first-year post-fire hillslope erosion for the Upper Mokelumne Basin using fire behavior modeling to predict burn severity and spatial WEPP tools to predict post-fire erosion.



Erosion predictions for the Rock House Fire converted to KML; Fire Date: April 9, 2011; Location: Fort Davis, TX Size: 314,444 acres; Hospital Canyon: 536 acres; BAER Team: U.S. National Park Service.

The datasets and tools developed under this project have additional utility for planning fuels treatments. Land management agencies in California asked us to model the effects of fuel reduction treatments on post-fire erosion in the Mokelumne Basin. To assist these land managers we used our datasets and tools in conjunction with fire behavior modeling to predict erosion from hillslopes in the Mokelumne Basin under four distinct conditions. 1) Current vegetation conditions in the absence of fire; 2) after a fire assuming current fuel conditions; 3) after proposed fuel treatments; 4) and finally, after a fire following the application of the fuel treatments. Modeling results are being used in two ways: the first is to prioritize treatments based on post-fire erosion; the second application is to synthesize modeling results from the four runs to quantify the benefits and compare them to the cost of treatments.

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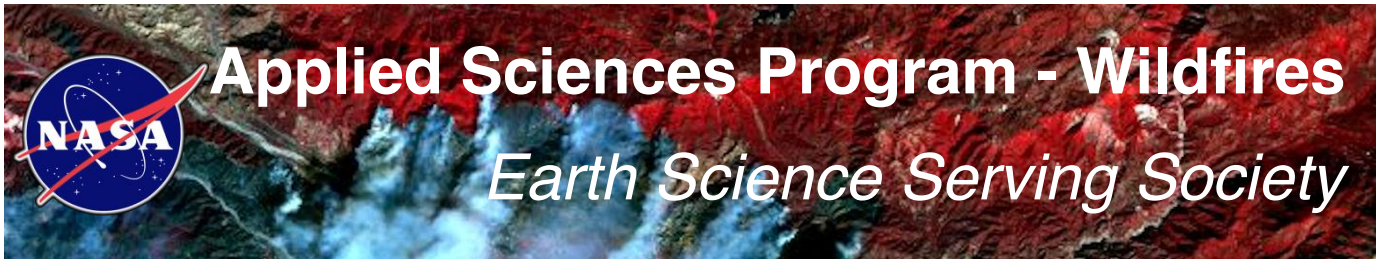
For more information on the NASA Applied Sciences Program, visit: http://appliedsciences.nasa.gov.



Enhanced Wildland Fire Management Decision Support Using Lidar-Infused LANDFIRE Data

The United States has experienced increases in severe wildfire behavior, property losses, and costs. Concurrently, recognition of the role of fire in restoring and maintaining resilient ecosystems has increased. These factors intertwine to create difficult decision-making for land managers and society at large, in which some fires are extinguished while others are allowed to burn. As society begins to learn how to live with fire, land managers are attempting to develop consistent strategies and tactics to safely and efficiently manage fire for benefit while protecting people and communities from harm. New decision support tools are continuously being developed to support this endeavor.

The Wildland Fire Decision Support System (WFDSS) is the de-facto decision support tool for federal fire managers. WFDSS integrates fire behavior prediction models and economic tools to assess wildfire-threatened values, such as houses or infrastructure. The resulting risk and vulnerability assessments provide a consistent and quantitative framework for decision-makers.

Vegetation structure and fuels products from the Landscape Fire and Resource Management Planning Tools Program (LANDFIRE) provide data that inform decision support tools such as WFDSS. LANDFIRE provides nationally continuous data using consistent methodologies which are used to support national and regional strategic planning. However, these data are often inadequate for developing local strategies and tactics, placing considerable demand on local units to develop local data. In particular, information related to the 3D arrangement of material within vegetation canopies is not well represented in the LANDFIRE maps. This is, in part, driven by LANDFIRE's reliance on Landsat imagery as the sole remote sensing data input for mapping; such imagery does not directly capture the vertical distribution of canopy elements.

Detailed vegetation structure information derived from lidar, as compared to Landsat imagery (Figure 1), can be integrated with the LANDFIRE product suite to generate locally enhanced vegetation structure and fuels maps. Among remote sensing data, lidar is uniquely suited for estimating canopy structure and fuels characteristics. However, lidar-derived fuel data are still relatively scarce, which can be attributed in part to two underlying issues. First, the LANDFIRE program has become the default source of large scale fire behavior modeling

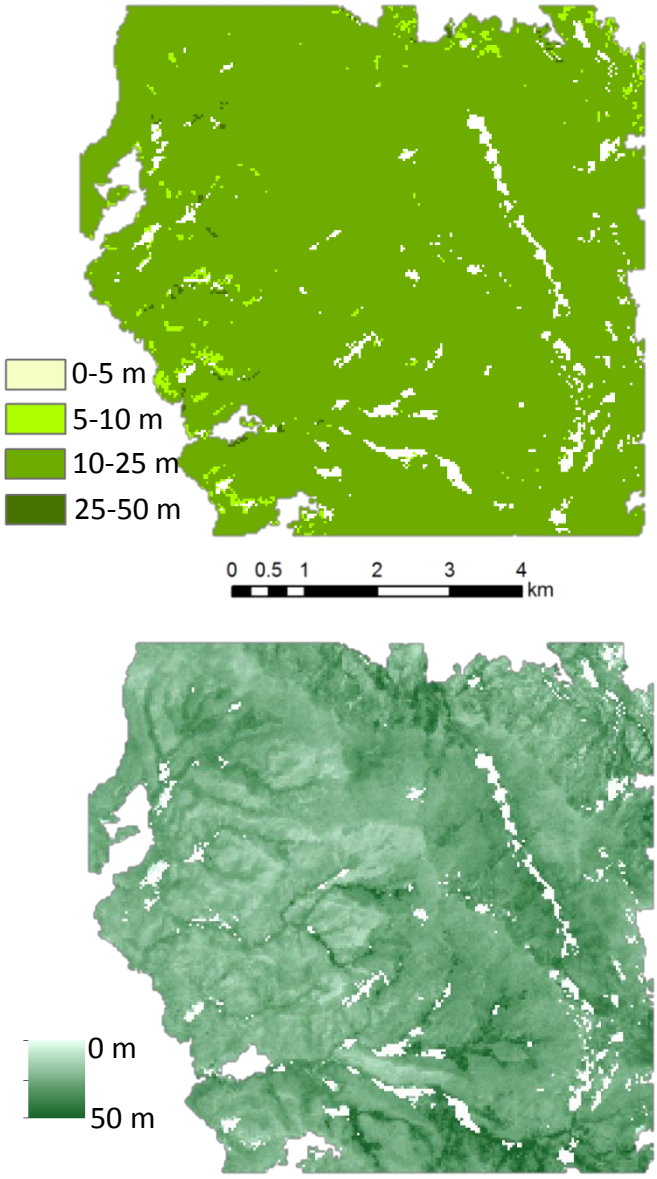


***Figure 1**. Canopy height products from Landsat-based LANDFIRE (top) and lidar-derived CHISLIC. Because of the source of the input data for the LANDFIRE canopy height product the legend needs to be binned. The CHISLIC canopy height product, mapping a continuous variable, better represents the heterogeneity of canopy height across this landscape in Grand County, CO.*

inputs because it provides consistent, nationwide data regarding the distribution of vegetation structure and canopy fuel across the landscape. However, LANDFIRE does not currently incorporate lidar data into the vegetation and fuel mapping process because they are not consistently available nationwide. Second, while lidar data are available for many land management units across the United States, these data are underutilized for fire behavior applications. This is partly due to a lack of local personnel trained to process and analyze lidar data. This project is addressing both of these issues by developing the Creating Hybrid Structure from LANDFIRE/lidar Combinations (CHISLIC) tool.

Many wildland fire analysts and managers, who regularly use LANDFIRE data and who would benefit most from lidar data use, fail to do so because of a lack of familiarity with these data and the tools available to process them. CHISLIC has been created to enable the easy integration of lidar data into LANDFIRE canopy height, canopy cover, and canopy base height products. This accomplishment significantly advances the likelihood of available lidar data being applied in fire behavior analyses and related research and management concerns. The potential impact of integrating lidar-derived structure with LANDFIRE products can be seen in Figure 2.

Continued development of CHISLIC will foster the integration of lidar data with LANDFIRE, thereby leading to the generation of products derived from the best data available. Furthermore, no lidar data are currently used operationally to support wildland fire management decisions. CHISLIC is the first tool of its kind that is specifically designed to leverage airborne and spaceborne lidar data to improve the canopy fuel maps that are critical to support wildland fire management decisions. Future plans for CHISLIC include the development of additional functionalities to broaden CHISLIC's utility and improvements to make CHISLIC more robust. CHISLIC will also be ported to a web server-based platform to make it more accessible to a larger group of users. Continued support will also allow the establishment of a permanent operational base for CHISLIC at WFDSS that will foster development and support into the future.

The USGS and the USFS are working together to further develop the utility of CHISLIC and to transition it to an operational application hosted at WFDSS. Over the next three years CHISLIC will become a go-to tool for those in the fire community to use and integrate lidar into LANDFIRE data.

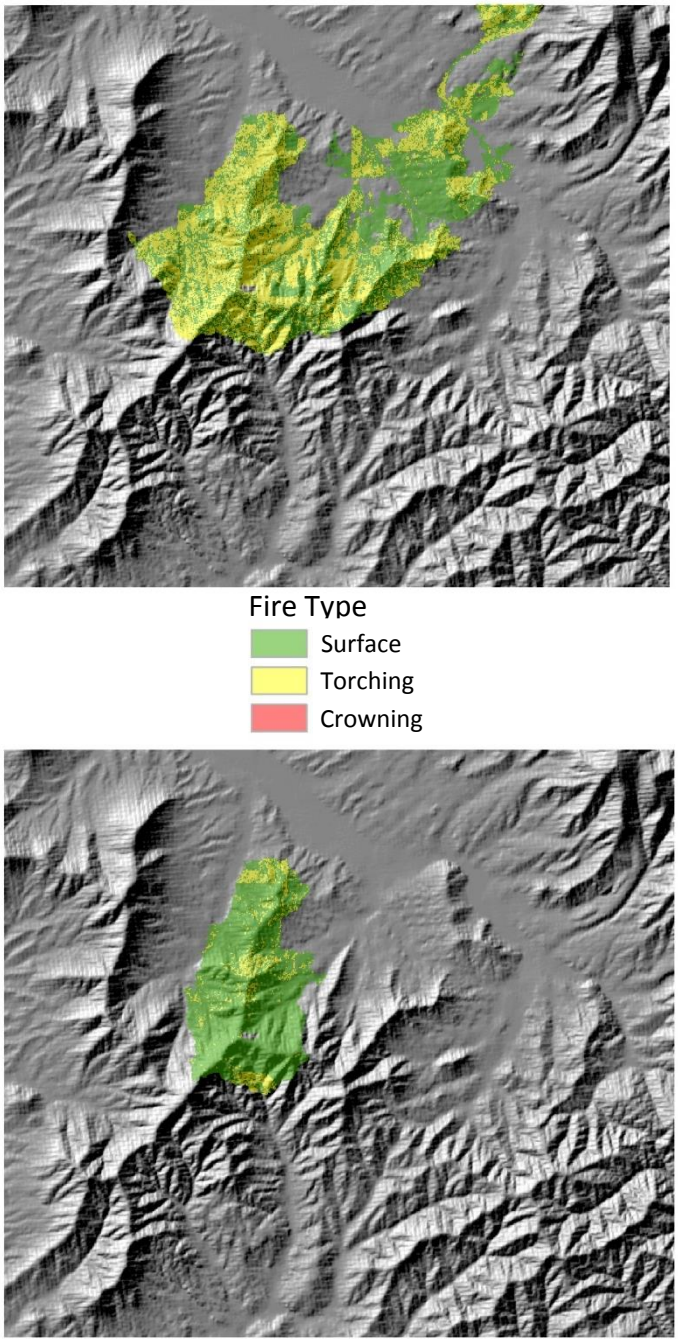


Figure 2. Example of impacts in using LANDFIRE (top) products vs. CHISLIC (bottom) products on modeled fire type using data from an area near Coeur d'Alene, ID.

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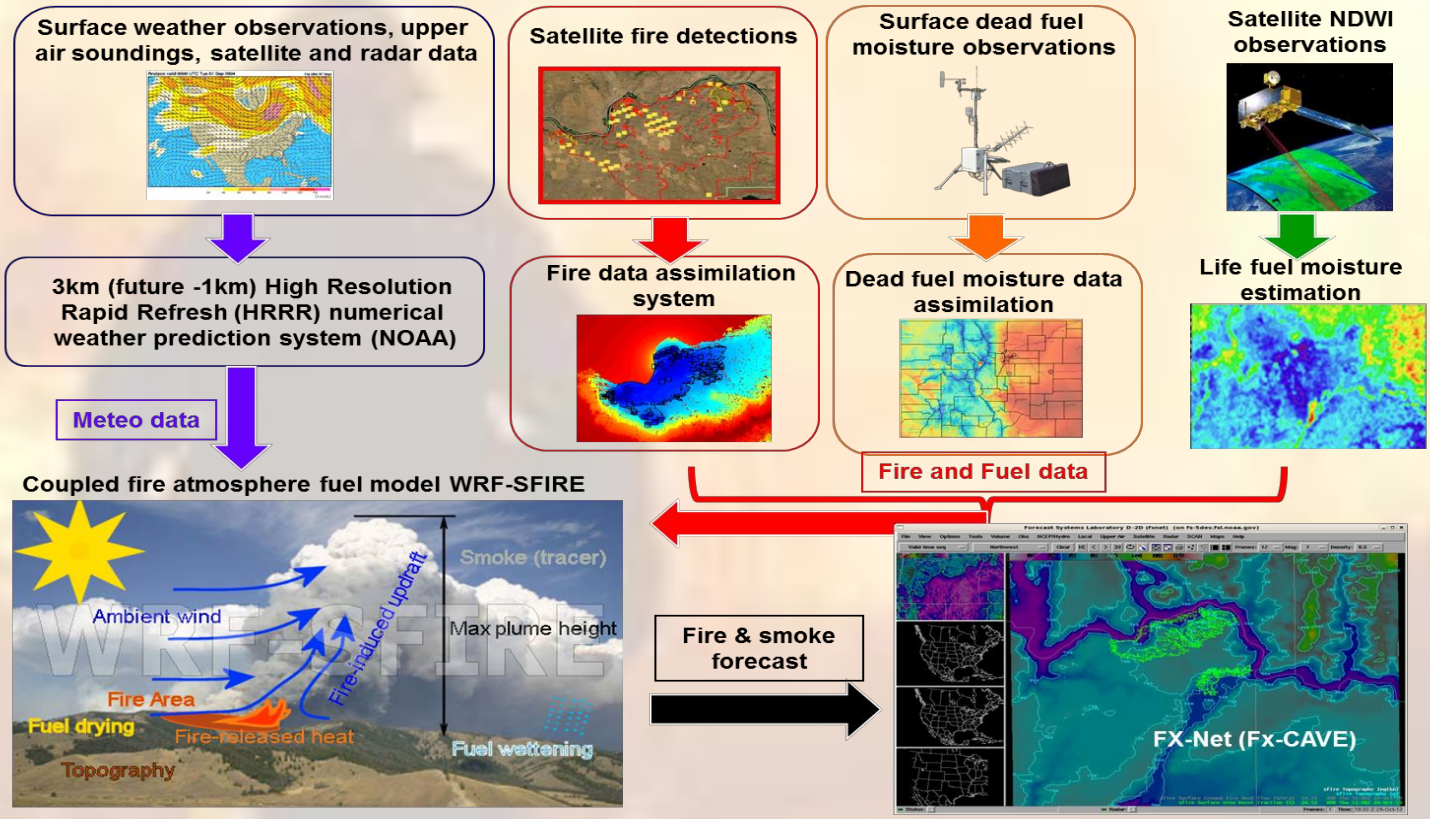
Applied Sciences Program – Wildfires

Earth Science Serving Society

WRF-SFIRE: Wildland Fire Behavior and Risk Forecasting; Coupling Weather and Fire Behavior Models

Coupled Model: To manage and suppress wildland fires effectively, safely and economically, fire managers need timely, accurate and detailed fire weather and fire behavior information. The variability of the atmosphere is the highest impact factor in the prediction of extreme fire behavior. Current fire behavior and weather prediction models do not account for the interaction of the fire with the full 3-D atmosphere. This understanding is fundamental to the accuracy of both fire weather and fire behavior forecasting.

The SFIRE model is an advanced version of WRF-Fire, which is a part of WRF. Operationally running WRF at high resolution in regions of interest will produce fire spread forecasts as well as microscale weather forecasts that take into account the substantial impact large fires can have on the weather. SFIRE is coupled with the Weather Research Forecasting model (WRF), and driven by fire detection and surface data from NASA and NOAA satellites.



Coupled SFIRE Model and FX-Net Systems

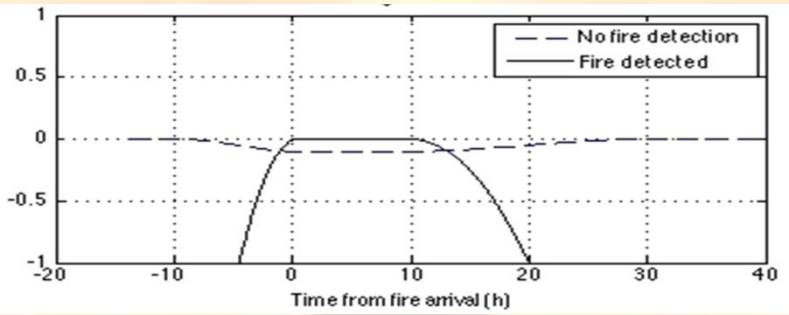
Forecasting System: FX-Net, operated by NOAA, is used operationally by the USFS, NIFC Predictive Services forecasters in all of the Geographical Area Coordination Centers. FX-Net is an integrated system for atmospheric data and fire spread output analysis and visualization. The core of FX-Net is a Java application that ingests data from the operational NWS NOAAPort data stream as well as data from other sources, such as fire weather models from USFS FCAMMS.

This project will provide an advanced tool for fire spread forecasting and improved fire weather prediction in the hands of fire support personnel, integrated into an environment, with which they are already familiar and use routinely.

Discovering and Demonstrating Innovative and Practical Applications of Earth Observations

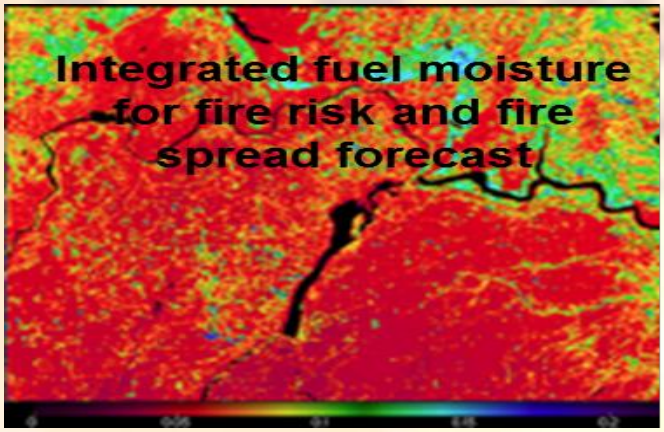
Assimilation of MODIS and VIIRS Active Fires Detection:

- Maximize the sum of log likihoods of the sensed pixel values for all pixels except those under the cloud mask, over smooth changes in fire arrival time.
- Go back in time, spin up the atmosphere for a consistent coupled state.



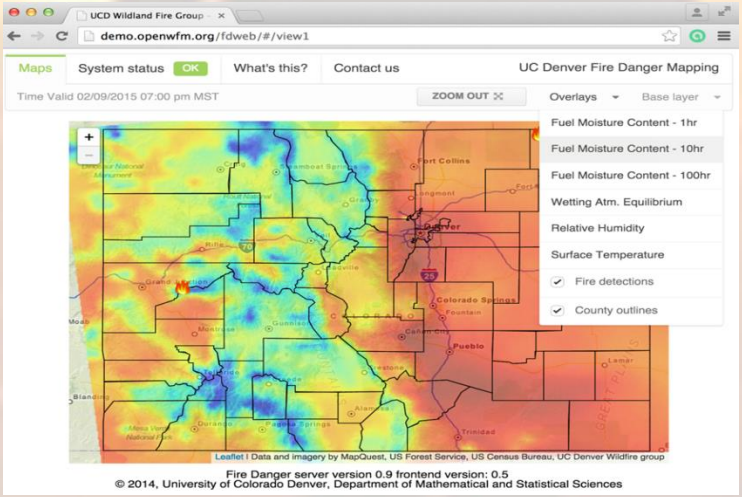
Fuel Moisture Assimilation for Fire Spread:

- Assimilate 1h, 10h and 100h fuel moisture
- Assimilate NDWI-derived live fuel moisture



Remote Execution Through Web Portal - to allow field forecasters the ability to remotely execute SFIRE system:

- Web server is in the cloud
- Supercomputer cluster back-end and mass storage at CU
- Parallel submission of multiple fire forecast incidents
- Aggregating and mapping satellite fire detections from AVHRR, VIIRS and MODIS



Field Delivery:

- FX-Net (AWIPS I)
- Transitioning to FXCAVE (AWIPS II)
- All SFIRE satellite, fuels and model output data delivered to field systems

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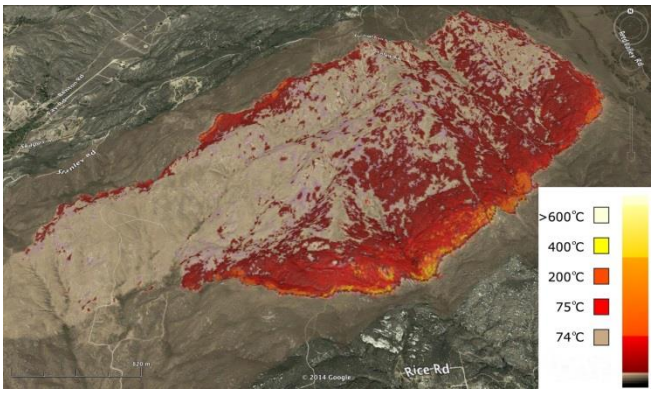
Applied Sciences Program - Wildfires

Earth Science Serving Society

Development and Application of Spatially Refined Remote Sensing Active Fire Data Sets in Support of Fire Monitoring, Management and Planning

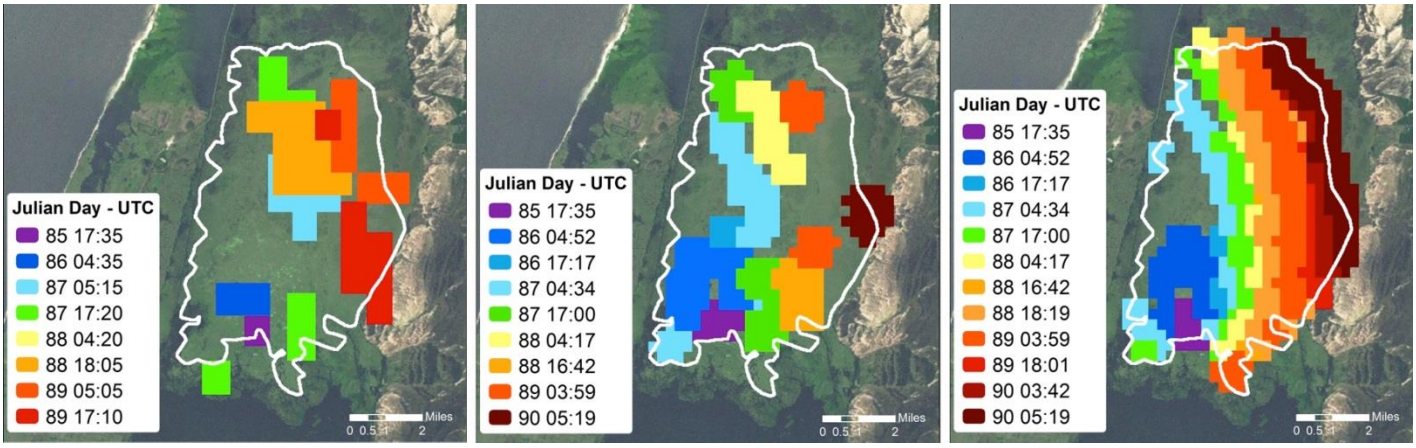
In the U.S., wildfires burn an average of 2.6 million hectares of land each year. Large catastrophic wildfires have become commonplace, especially in association with extended drought and extreme weather. The demand for timely, consistent and quality fire information is high and peaks each summer when interagency fire operations and resource requests are maximized in response to multiple large wildfires.

Wildfire response at all government levels requires current and predictive fire information for tactical firefighting, evacuation, and strategic planning to avert or mitigate impacts. In this context, remote sensing active fire datasets, fire modeling tools, and associated geospatial products are essential to Forest Service and interagency fire operations. They provide critical support to fire managers and help inform the public in areas threatened by wildfires. Recent advances in satellite-based fire detection and mapping, airborne fire mapping and measurement, and coupled weather-wildland fire modeling present a new opportunity to routinely map fire extent and progression, examine active fire areas in greater detail, and predict fire growth, intensification, and extreme behaviors of wildfires lasting several days.



USFS Pacific Southwest Research Station FireMapper mapping of the Buck wildfire on 14 August 2012.

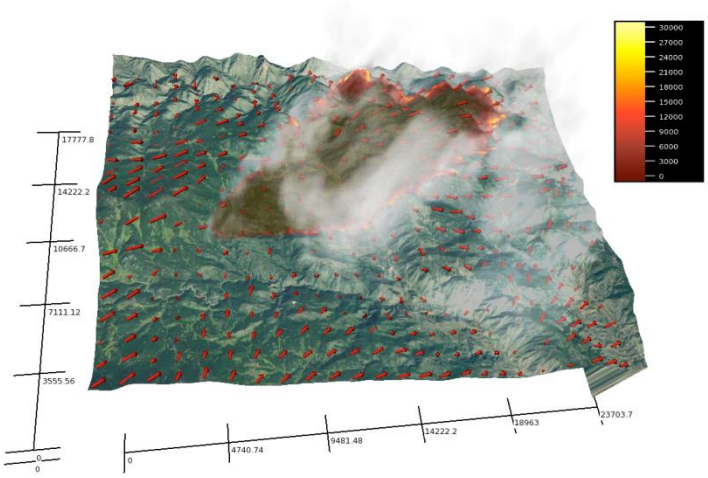
The Visible Infrared Imaging Radiometer Suite (VIIRS) was launched aboard the NASA/NOAA Suomi-NPP satellite in October 2011. A suite of environmental monitoring parameters are generated using VIIRS data acquired over the entire globe every 12h or less at spatial resolutions of 375 m and 750 m. Compared to coarser resolution products, the new VIIRS 375 m active fire detection product enables early detection of small fires and improved mapping of large wildfires. These data are being used to complement other spatially refined airborne (e.g., NIROPS, FireMapper) and spaceborne (e.g., Landsat-8 and upcoming Sentinel-2) fire data sets of more limited geographic and/or temporal coverage.



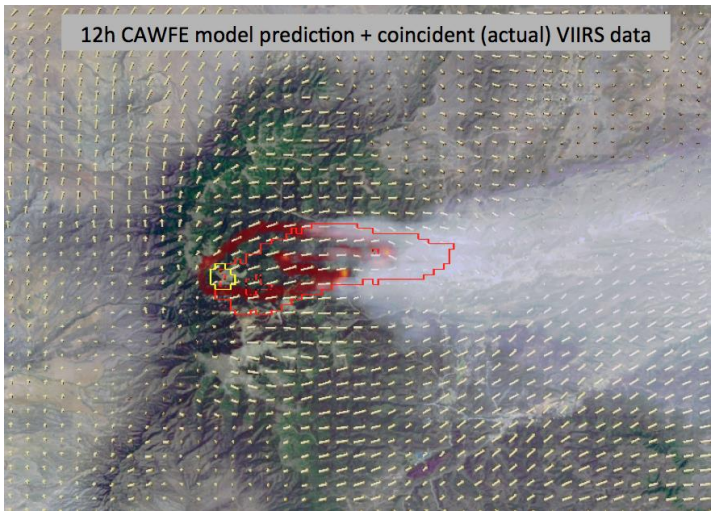
Aqua/MODIS 1 km (left) and near-coincident Suomi-NPP/VIIRS 750 m (center) and 375 m (right) mapping of wildfire progression at the Taim Ecological Reserve/Brazil during 26-31 March 2013 (Julian days 85-90). Colored polygons describe the active fire pixel footprints of MODIS and VIIRS. The white polygon outlines the fire-affected area mapped using Landsat-7 image acquired on March 31st.

Discovering and Demonstrating Innovative and Practical Applications of Earth Observations

NCAR's Coupled Atmosphere-Wildland Fire Environment (CAWFE) model and the Weather Research and Forecasting (WRF) model with WRF-Fire each couple a numerical weather prediction model with wildland fire behavior algorithms to simulate fire behavior. These not only predict a fire's shape and extent, but extreme behaviors such as fire whirls, blow-ups, flank runs, and pyrocumulus, all resulting from a fire's interaction with its environment, i.e. how the fire 'creates its own weather'. The coupled models have been evaluated on numerous cases capturing overall unfolding of events, locations where fires intensified and accelerated, splitting of the head, and flank runs. CAWFE has been successfully initialized and validated using the new VIIRS 375 m fire data, enabling accurate simulation of complex fire behavior during long-lasting wildfires. Compared to traditional models, this approach can now be applied to monitor and predict the growth of a fire or a group of simultaneous wildfires in a management unit from first detection until containment – a previously unattainable goal due to accumulation of model error.



CAWFE simulation of the 2012 High Park wildfire. The rate of heat release ($W.m^{-2}$) is shown, according to the color bar. Intensely burning regions are yellow and orange. The misty field shows the smoke concentration, which is thicker and darker where concentrations are higher. Vectors show the modeled wind field near the surface, with longer arrows indicating faster winds.



CAWFE simulation of the 2012 Little Bear Fire. The yellow shape is the VIIRS fire perimeter used for initialization. The red shape is the VIIRS fire perimeter at the time of the simulation 12 h later.

Combined application of these refined fire remote sensing and modeling technologies improves and extends current fire mapping, monitoring, and prediction tools. In particular: (i) new VIIRS and Landsat-class fire products can routinely monitor the extent of larger fires, (ii) CAWFE uses these data, providing a detailed understanding and prediction of how fires evolve, and (iii) FireMapper data enable detailed mapping of fire behavior and surface temperatures associated with fire intensity on selected fires, while validating both satellite fire maps and CAWFE. Decision support applications include managing wildland fires, estimating emissions of carbon, trace gases, and particulates, and anticipating air quality, watershed, and land surface impacts.

This project is funded by NASA Applied Sciences Program - Wildfires, with contribution from partner agencies including the USDA Forest Service, NOAA/NESDIS, National Weather Service, and German Aerospace Center.

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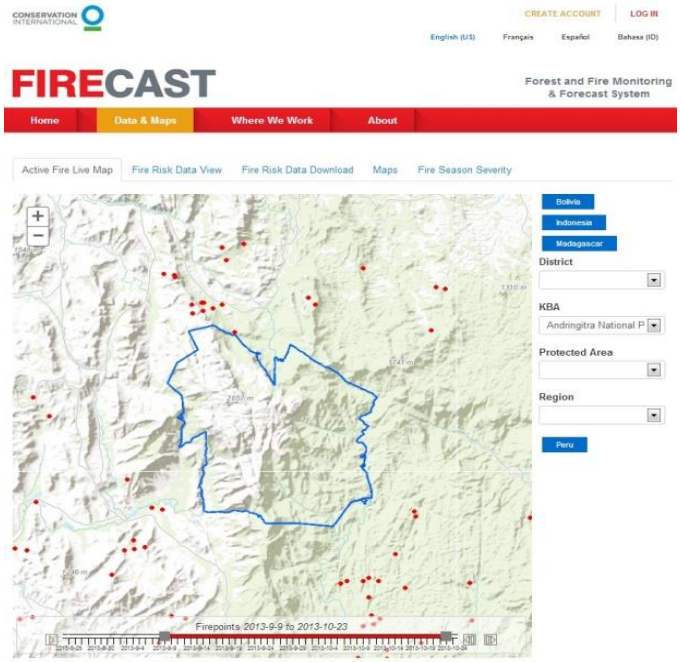
Firecast: A Near-Real-Time Monitoring System Improving Forest Management in the Tropics

The loss of the world's natural habitat through timber extraction, wildland fires, and agricultural expansion is causing wide-ranging environmental and economic impacts.

Projected increases in frequency and intensity of drought conditions will increase the incidence of wildland fires. Drought and fire cause economic strain, displacement, and food insecurity while also impacting biodiversity and the provision of ecosystem services such as water availability, water quality, and pollination. In addition, fire disasters cause health problems from poor air quality and spread of disease.

Firecast is a tool designed to help prevent the destructive effects of fires on natural habitats and human well-being. Firecast uses emerging technologies and cutting-edge research to empower local stakeholders with timely monitoring and forecasting information. The system delivers short-term, fire-risk forecasting and near-real-time (NRT) detection of fires, droughts, and deforestation to subscribers through email alerts, maps, and reports.

Conservation International works directly with in-country partners and decision-makers to understand the challenges users face managing fire risk and fire incidence. The system currently operates in Bolivia, Peru, Madagascar, and Indonesia.



CI's automated forest monitoring system detects "deforestation in-action," disseminating daily email alerts of fire activity observed by NASA satellites. Users can tailor their alert subscriptions to specific areas of interest, language of choice, and download monthly reports and maps documenting historic forest fire activity.

Firecast delivers daily forest flammability alerts that are used by partner, Fundación Amigos de la Naturaleza (FAN), *in Bolivia to warn farming communities of dangerous fire conditions.*

Discovering and Demonstrating Innovative and Practical Applications of Earth Observations

Fire Risk Forecasting

The forest flammability model uses satellite-based estimates of weather conditions derived from the MODerate Resolution Imaging Spectroradiometer (MODIS) and Tropical Rainfall Measuring Mission (TRMM) to generate a daily risk indicator for forested areas in the Amazon region.

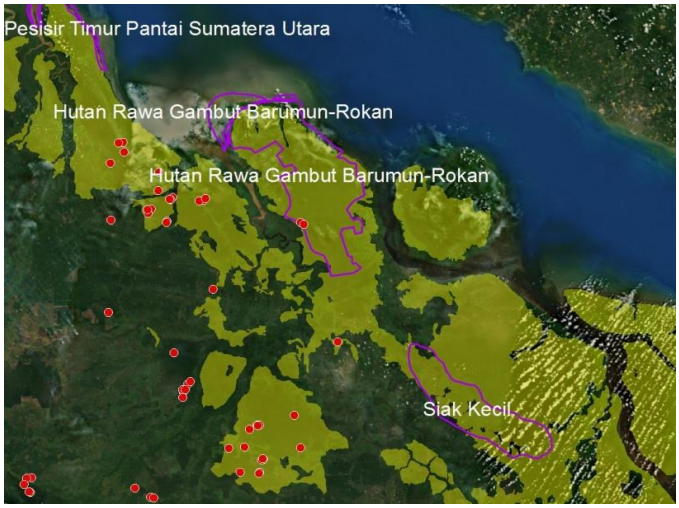
Fire Season Severity Forecasting

These forecasts monitor Sea Surface Temperatures (SSTs) in the North Atlantic and Pacific and forecast the expected intensity of fire activity several months before the fire season. Knowing potential fire season severity in advance is extremely useful for fire management and prevention, protected area management, and sustainable land use planning.

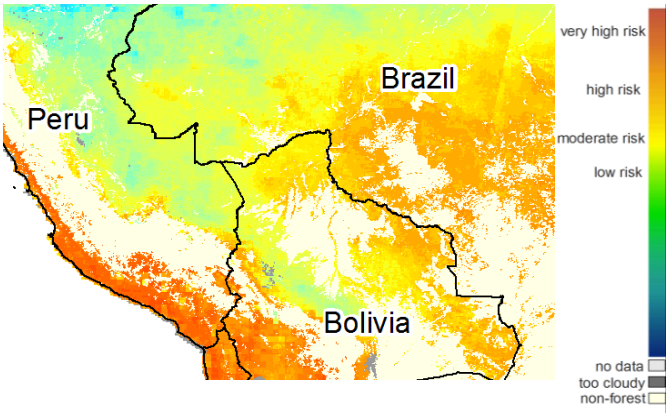
Fire season severity for the 2013 dry season for Santa Cruz, Bolivia. The model forecasted considerably higher fire activity compared to the 2011 and 2012 dry seasons.

Active Fire Alerts

Firecasts delivers daily MODIS active fire alerts to subscribers who use the data for active fire control, policing of illegal forest activities, fining landowners, land use planning, Reduced Emissions from Deforestation and forest Degradation (REDD+) monitoring, and community outreach and education.



Fires in Indonesia August 6, 2013 (shown in red). Firecast allows users to select highly customized criteria for alerts that include Key Biodiversity Areas (outlined in purple) and peat lands (in yellow-green).



Daily risk of forest flammability for the Amazon region. Elevated risk of fire due to drought conditions (shown in orange and red in this map).

Phase II Activities

Upcoming additions to Firecast's suite of NRT products include: VIIRS active fire alerts, QUICC 5km and 250m disturbance alerts, MODIS-derived burned area product, and Landsat-derived deforestation. Firecast will expand geographically to include Colombia and the forest flammability model will be enhanced and improved in partnership with FAN. Outreach and engagement will continue with current and potential new users through training, workshops, communications, and publications.

Anticipated Impacts

Firecast is a critical tool for improved fire and forest management and avoided emissions. Through phase II system enhancements and in-country engagement, Firecast can be used to:

- effectively monitor and protect millions of hectares of high-biodiversity habitat
- prevent fire spread from prescribed burning in farming communities in Santa Cruz, Bolivia
- prevent of more than 100 million tons of CO_2 emissions through conservation and sustainable management of tropical forest and peat landscapes in Indonesia
- build capacity on Monitoring, Reporting and Verification in Peru and Colombia
- help to create markets for sustainably-sourced products and supply chain efforts globally.

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CONSERVATION INTERNATIONAL

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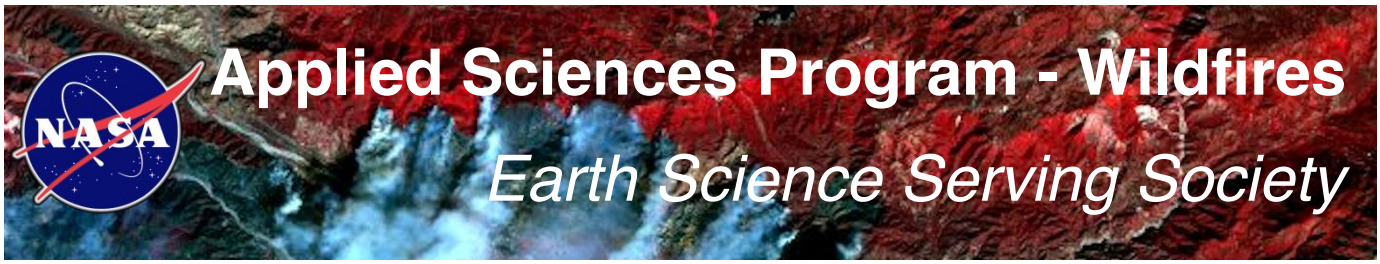
Applied Sciences Program
http://www.nasa.gov/applied-sciences



Improving Shrub and Grass Fuel Maps Using Remotely Sensed Data to Support Fire Risk Assessments

Shrub and grassland ecosystems in the western United States are especially prone to fire events, yet available data for assessing fire risk in these areas are inadequate. The reasons for the difficulties in being able to effectively characterize shrub and grasslands for fire applications are varied and many, but part of the problem revolves around the high degree of intra- and inter-annual variability in fuel characteristics in these areas, necessitating higher level understanding of the dynamics of these systems. It is clear that we need to develop better understanding of the conditions that lead to wildland fire in shrub and grasslands. This information is of special importance to projects such as LANDFIRE, which has the goal of providing fire managers with nationally consistent and detailed spatial information about vegetation and fuel structure.

Through the support of the NASA Applied Sciences Program, we embarked on an assessment to derive better fuel characterizations in western US shrub and grassland ecosystems. Our primary objectives of the first phase of the project included the following: 1) Improve upon shrub and grassland mapping for fire applications; 2) Develop intra-seasonal (e.g. monthly) fuel data sets in shrub and grassland areas using a combination of Landsat and MODIS data; and 3) Determine if improvements in shrub and grassland data layers will alter and improve fire behavior model results.

While our long term goals are to expand our assessments to include all of the western United States, we are currently focused on an area in the Owyhee Basin of Idaho, Nevada and Oregon, and an eastern adjacent region, where access to additional field information collected by the US Bureau of Land Management was available. This area is the site of many large and frequent shrub and grassland fires. The shrubland areas are dominated by sagebrush (*Artemisia* spp), and the grassland areas have a substantial amount of cheatgrass (*Bromus tectorum*) associated with them (Figure 1).

Many fires occurred within the study area (Figure 2) from 1984 to present, and most but not all were in the shrub and grassland areas. We consider years 1985, 1996, 2005, 2006, 2007 and 2010 to be "high fire years", when at least 1,500 km^2 burned within the study area.

Figure 1. Western US shrub systems. Left: Sagebrush ecosystem representing typical natural historic conditions. Right: Recently burned shrub system in the background with invasive grass cover in the foreground.

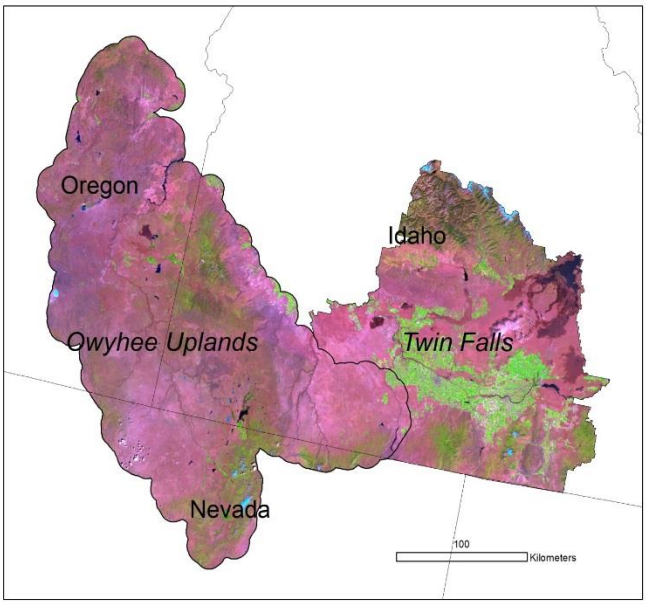


Figure 2. Landsat mosaic of Owyhee Upland and Twin Falls study area. Pink depicts areas dominated by shrub and grass vegetation. An agricultural zone is depicted by bright green near Twin Falls. A lava flow can be seen in upper right part of the mosaic.

Discovering and Demonstrating Innovative and Practical Applications of Earth Observations

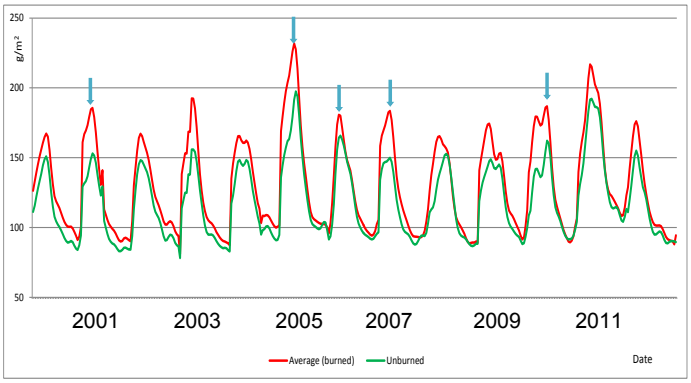


Figure 3. Seasonal live biomass profile for shrublands in the study region. Red indicates live biomass for sagebrush sites that have burned at least once between 1984 and 2010 according to the Monitoring Trends in Burn Severity (MTBS) project. Green indicates sites that did not burn during the time period. Blue arrows indicate high fire years.

MODIS Analyses

As depicted in Figure 3, the shrub and grassland areas of the region are characterized by high levels of biomass variability detectable through time series data analyses from the MODIS sensor. Those areas that have burned recently tend to have higher levels of biomass than those that have not. Understanding these patterns helps the fire management community to recognize which areas have high likelihood of burning in the future, thus enabling them to anticipate and plan accordingly.

Improving Grass and Shrub Fuel Maps To Support Fire Risk Assessments

Fire Behavior Fuel Models

Custom fire behavior fuel models for grasslands and shrubland were created to evaluate the impacts of surface fuel changes on fire behaviors. For comparison with the existing static fuels data, we also included the low-load, dry climate grass (GR2) and moderate load, dry climate grass-shrub (GS2) fire behavior fuel models from LANDFIRE. Then, we calculated 2 indices commonly used for fire management decisions: the Energy Release Component (ERC) and Flame Length (FL). Fire behavior indices and simulated burned area showed differences with fuel load estimates in different years. For instance, ERC and FL were predicted to be greater in years with high fuel loads (2005 and 2007) than years with low fuel loads (2008) in both grass and shrub vegetation types (see Table 1).

A Few Next Steps

Given the results from our first set of investigations, we are now initiating the second phase of the study. This will include: (1) expansion of our work to other western US shrub and grassland areas, (2) expanding our collaboration with external partners, including the Multi-Resolution Land Characteristics (MRLC) consortium and the Bureau of Land Management (BLM), and (3) transitioning the process into operations through interactions with LANDFIRE.

		Fuel load (ton ha^{-1})				
Fuel type	Fuel Load	Live herbaceous	Live woody	1-hour dead	ERC[1] (KJ m^{-2})	FL[2] (m)
Grass	High (2005)	3.27	0	3.92	10424.74	3.41
Grass	Moderate (2007)	2.6	0	4.5	10208.98	3.38
Grass	Low (2008)	2.08	0	0.45	3043.39	1.95
Grass	Default (GR2)	2.24	0	0.22	2952.54	1.92
Shrub	High (2005)	1.75	9.95	3.12	20043.21	3.23
Shrub	Moderate (2007)	1.3	9.64	3.52	19543.55	3.23
Shrub	Low (2008)	1.14	1.52	0.36	3770.17	1.58
Shrub	Default (GS2)	1.34	2.24	1.12	6347.96	2.16

Table 1. Fuel load values and simulated fire behavior indices for different fuel load scenarios. ERC is Energy Release Component, and FL is Flame Length. Default refers to fuel conditions as represented by LANDFIRE data set. Characterizing the intra- and inter-annual shrub and grass fuel loads is important for predicting ERC and FL, both of which are important to the fire management community.

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Applied Sciences Program

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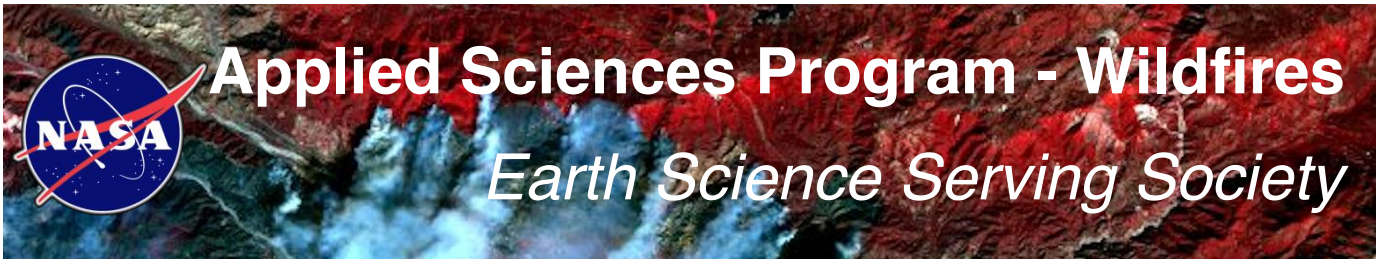


NASA RECOVER Supports Wildfire Rehabilitation

Five minutes. That's how long it takes to produce a custom web map that gives the Bureau of Land Management (BLM) and other agency wildfire managers the information needed to fight an active wildfire and plan post-fire recovery.

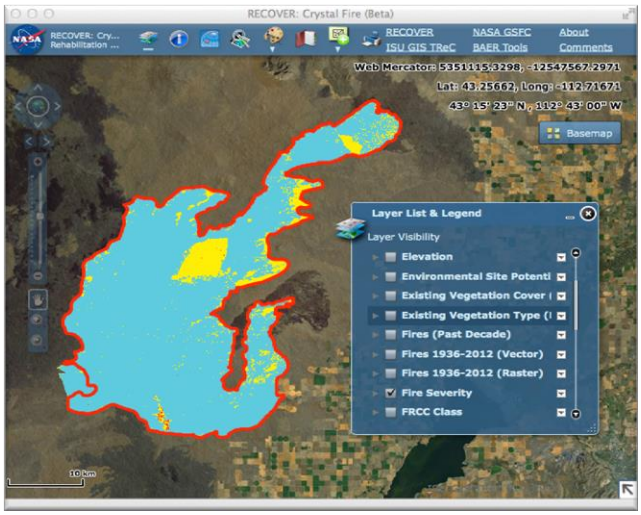
In the past, the information collected on everything from burn severity and fire intensity, to slope, vegetation, and soil type would have taken as long as a week to collect and distribute. Now the distribution of that same information – to firefighters in the field using mobile devices or analysts in offices using desktop computers – takes just minutes using the NASA Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER) system.

RECOVER was developed for the state of Idaho by NASA's Applied Sciences Program, NASA Goddard Space Flight Center, and the Idaho State University GIS Training and Research Center. Over the next three years this innovative program and wildfire tool will be expanded to cover the Western United States.

RECOVER uses NASA satellite observational data and Geographic Information System (GIS) technologies to allow managers quick access to pertinent information. Wildfire managers and firefighters now also have the ability to update GIS maps almost instantaneously using their mobile devices. ISU and NASA worked in partnership with the BLM and Idaho Department of Lands on the pilot project and will have many new partners as the program expands.

The new program was tested in 2013 on several Idaho wildfires, including the Pony and Elk Creek Complex in south-central Idaho and the Mabey Fire near Bancroft.

"The RECOVER project is an important contributuion by the NASA Applied Sciences Program to the nation's wildfire management efforts," said John Schnase, senior computer scientist at the NASA Goddard Space Flight Center. "We're using a variety of advanced cloud computing, web services, and data grid technologies to dramatically improve the decision-making activities associated with fighting wildfires. We're also setting the stage to use climate model outputs and new types of observational data that will be produced by upcoming NASA missions."



RECOVER Web Map GIS Client

An Idaho wildfire (photo courtesy Idaho State Journal)

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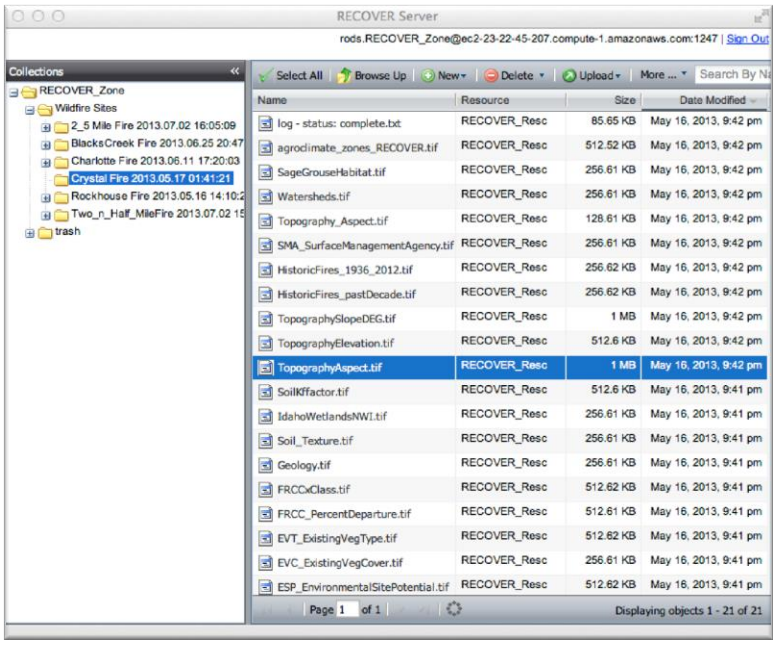
Charlotte Fire outside Pocatello, Idaho (photo courtesy Idaho State Journal)



RECOVER Cloud-Based Server

NASA RECOVER Supports Wildfire Rehabilitation

RECOVER uses state-of-the-art cloud-based data management technologies developed by NASA Goddard Space Flight Center to improve performance, reduce cost and provide site-specific flexibility for each fire. This technology is also being used in the NASA Center for Climate Simulation (NCCS), which sets the stage for using climate data products in future versions of RECOVER.

Those accomplishments are gaining notice: BLM wildfire managers on the state, regional and national level have already contacted the ISU GIS Center expressing their excitement about the application.

"What we all are realizing as we develop RECOVER is that it has many uses beyond helping to fight wildfires," said Keith Weber, Director of the ISU GIS Training and Research Center. "The system could be used to help with the response and recovery in any natural disaster, from landslides and earthquakes, to hurricanes and floods. RECOVER could become the framework to support management decision-making in these events and provide short- and long-term monitoring."

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For more information on the RECOVER project, visit http://giscenter.isu.edu/research/Techpg/nasa_RECOVER/index.htm or http://www.earthzine.org/2013/06/22/a-new-application-to-facilitate-post-fire-recovery-and-rehabilitation-in-savanna-ecosystems/.

To view a demonstration of the RECOVER system, visit http://www.youtube.com/watch?v=LQKi3Ac7yNU (RECOVER Server) and http://www.youtube.com/watch?v=SGhPpiSYpVE (RECOVER Client).

Applied Sciences Program

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C. Abbreviations

AFTEERS: Automated Fuels Treatment Effectiveness Evaluation Using Remote Sensing
AIRPACT: Air Indicator Report for Public Awareness and Community Tracking
ALS: Airborne Lidar Scanner
AMS: Autonomous Modular Sensor
AMSR-E: Advanced Microwave Scanning Radiometer-EOS
ARC: Ames Research Center
ARCTAS: Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARL: Application Readiness Level
ARSET: Applied Remote Sensing Training
ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATSR: Along Track Scanning Radiometer
AVHRR: Advanced Very High Resolution Radiometer
AVIRIS: Airborne Visible/Infrared Imaging Spectrometer
BAER: Burned Area Emergency Response
BESR: Board on Earth Sciences and Resources
BLM: Bureau of Land Management
CAWFE: Coupled Atmosphere-Wildland Fire Environment
CAL FIRE: California Department of Forestry and Fire Protection
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CATS: Cloud-Aerosol Transport System
CHISLIC: Creating Hybrid Structure from LANDFIRE/lidar Combinations
CMAQ: Community Multi-scale Air Quality
CY: calendar year
DEM: Digital Elevation Model or 3-D representation of a terrain's surface
DLR: German Aerospace Center
DoD: Department of Defense
DOI: Department of the Interior
EES: Emission Estimation System
EPA: U.S. Environmental Protection Agency
ESA: European Space Agency
ESD: Earth Science Division
FAO: Food and Agriculture Organization of the United Nations
FARSITE: Fire Area Simulator
FASST: Fast All-season Soil Strength
FOFEM: First Order Fire Effects Model
FY: fiscal year
GEO: Group on Earth Observations
GEOSS: Global Earth Observation System of Systems
GFED: Global Fire Emissions Database
GIS: geographic information system
GLAS: Geoscience Laser Altimeter System
GOES: Geostationary Operational Environmental Satellite
GOFC-GOLD: Global Observation of Forest and Land Cover Dynamics

GTOS: Global Terrestrial Observing System
GWIS: Global Wildfire Information System
HMS: Hazard Mapping System
HVRA: highly valued resource and asset
HyspIRI: Hyperspectral Infrared Imager
IAWF: International Association of Wildland Fire
IFTDSS: Interagency Fuels Treatment Decision Support System
ISPRS: International Society for Photogrammetry and Remote Sensing
JFSP: Joint Fire Science Program
JPL: Jet Propulsion Laboratory
JRC: Joint Research Center
LANDFIRE: Landscape Fire and Resource Management Planning Tools
LaRC: Langley Research Center
MERRA: Modern Era Retrospective-Analysis for Research and Applications
MODIS: Moderate Resolution Imaging Spectroradiometer
MOPITT: Measurement of Pollution in the Troposphere
MTBS: Monitoring Trends in Burn Severity
NASA: National Aeronautics and Space Administration
NASA-CMS: NASA Carbon Monitoring System
NDVI: Normalized Difference Vegetation Index
NDWI: Normalized Difference Water Index
NFDRS: National Fire Danger Rating System
NIFC: National Interagency Fire Center
NIROPS: National InfraRed OPerations Group
NOAA: National Oceanic and Atmospheric Administration
NPS: National Park Service
NW-AIRQUEST: Northwest International Air Quality, Environmental Science & Technology
NWS: National Weather Service
OCO-2: Orbiting Carbon Observatory-2
OLIA: Office of Legislative and Intergovernmental Affairs
OMI: Ozone Monitoring Instrument
PI: principal investigator
PPD: Presidential Policy Directive
RAMS: Regional Atmospheric Modeling System
RapidScat: Rapid Scatterometer
RECOVER: Rehabilitation Capability Convergence for Ecosystem Recovery
ROSES: Research Opportunities in Space and Earth Sciences
RSAC: Remote Sensing Applications Center
S-NPP: Suomi National Polar-orbiting Partnership
SBIR: Small Business Innovation Research
SMAP: Soil Moisture Active Passive
SMOS: Soil Moisture Ocean Salinity
TFRSAC: Tactical Fire Remote Sensing Advisory Committee

TRMM: Tropical Rainfall Measuring Mission
UAS: unmanned aircraft system
UAVSAR: Uninhabited Aerial Vehicle Synthetic Aperture Radar
USFS: United States Forest Service
USGS: United States Geological Survey
VIIRS: Visible Infrared Imaging Radiometer Suite
VIRS: Visible and Infrared Scanner
WAI: Wide Area Imager
WFAS: Wildland Fire Assessment System
WFDSS: Wildland Fire Decision Support System
WFEIS: Wildland Fire Emissions Information System
WRAP: Wildfire Research and Applications Partnership
WRF: Weather Research and Forecasting
WRF-SFire: WRF-Spread Fire