National Aeronautics
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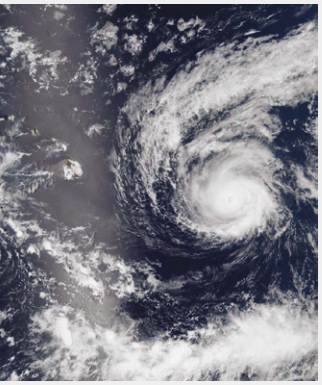

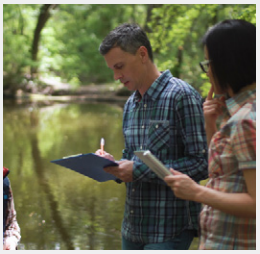

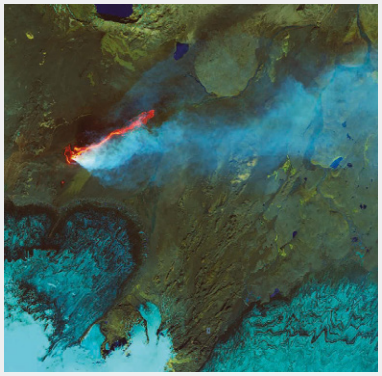

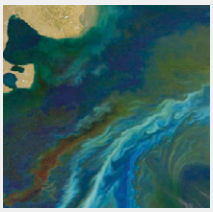

2018
Annual Summary

NASA Earth Science
Applied Sciences Program

Wildland Fire

Wildland Fire: 2018 Annual Summary

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I. Introduction

The NASA Earth Science Division's (ESD) Applied Sciences Program promotes efforts to discover and demonstrate innovative, practical, and beneficial uses of Earth-observing environmental satellite data, models, and scientific knowledge. All Program activities support goals to deliver near-term applications of Earth observations, build capabilities to apply Earth-science data, and contribute to satellite mission planning. The Program conducts projects in partnership with private and public-sector organizations to inform their decisions and actions, transitioning successful, mature applications to sustain the benefits of Earth science to society.

The Applied Sciences Program's applications themes are currently focused on four of the eight societal benefit areas of the international Group on Earth Observations (GEO): Health (including Air Quality), Disasters, Ecological Forecasting, and Water Resources.[11] In addition, there is a Wildland Fires theme and an initiative on Food Security. The Program includes the impacts from a changing climate within each of these topics.

Fire, especially wildland fire (aka, wildfires), constitutes a crosscutting issue in Earth system science and touches on aspects of many applications areas. From 2002 to 2011, the Applied Sciences Program supported numerous projects and activities related to wildland fire in several applications areas. In 2011, the Program created an element focused specifically on wildland fire, addressing issues from pre-fire through active-fire to post-fire stages. The Wildland Fires program issued a dedicated solicitation in 2011 and selected 17 feasibility studies (Phase I). In 2014, the program selected nine of these studies to continue as full-scale applications projects (Phase II). Most of those nine projects completed their efforts in FY18, or will be completing soon (early FY219), with NCE allowed for those finishing and/or transitioning capabilities to partner entities.

II. Overview of 2018

This year was the final project closeout year for the majority of the nine NASA ROSES-2011, A.35 Wildland Fire-supported projects. It was also the final year of the Wildland Fire program; in 2019, the program and theme will be subsumed within two applications programs, Disasters and Ecological Forecasting.

The nine Wildland Fire projects were finalizing their efforts and transitioning their models, data, and processes to their partners or reaching high Applications Readiness Levels (ARLs). Some of the projects and their partners were the subject of press releases and videos and received media attention for their achievements and support to wildfire events throughout the U.S. and internationally. Wildland fire project-related workshops,

[1] The eight GEO SBAs are: Disaster Resilience; Food Security and Sustainable Agriculture; Biodiversity and Ecosystem Sustainability; Energy and Mineral Resources Management; Public Health Surveillance; Infrastructure and Transportation Management; Urban Development; and, Water Resources Management.

webinar series, and training were extremely successful, drawing on expertise from across the program portfolio and the NASA ARSET program. These materials can be accessed at the NASA Applied Sciences Wildland Fire website (https://appliedsciences.nasa.gov/programs/wildfires-program) in the "Videos", "Program Library", and "Program News" sections.

Four of the Wildland Fires program project teams were also awarded additional one-year funds to develop a socioeconomic (SE) analysis of the use of EO data in support of wildland fire management. These four projects were finalizing their SE findings reports at the end of FY18, and providing to NASA management by the end of the first quarter of FY19. The Wildfire SE projects highlight the socioeconomic successes and barriers of adaptation of EO data into routine wildfire management practices. The analysis focuses on surveys, interviews and rigorous economic analysis of benefits in time/cost savings of EO data being used for reducing risk or impacts on the communities affected by fire.

In addition to all of the project-focused activities, there were numerous events, conferences, and committees in which the Wildland Fire program management team and project team members contributed. In the third week of May, the program held its fourth and final Wildland Fire team meeting. That meeting took a different form-factor than the previous three meetings, and was organized as special paper sessions, workshops, and "lightning talks" at the International Association of Wildland Fire (IAWF)/Association of Fire Ecology (AFE) "*Fire Continuum Conference*" in Missoula, Mont. This allowed the program investigators and partners to engage a greater audience in showcasing their developments over the past few years. The conference special paper session, workshop, and lightning talks helped further interactions across projects and inform partners of the applications and their progress. The attendees explored key issues and challenges faced by wildland fire management practitioners and scientists identifying research and applications advances that would improve the understanding and management of wildland fires.

Throughout the year, the Wildland Fires program management team and project teams actively participated in other symposia, conferences, and workshops. Examples of major events included the Second Annual National Cohesive Wildland Fire Management Strategy Workshop (Reno, Nev.), the aforementioned Fire Continuum Conference (Missoula, Mont.), the Colorado Wildland Fire Conference (Crested Butte, Colo.), the 2018 ForestSAT meeting and the affiliated Global Observation of Forest & Land Cover Dynamics Fire Implementation Team Meeting (College Park, Md.), and the Fall American Geophysical Union (AGU) Meeting in Washington D.C. Smaller local/regional meetings were also supported by the wildfire project teams, where they highlighted and trained wildfire community members in the use of EO data and modeling for improving their fire management capabilities.

The U.S. endured a long and destructive fire season in 2018. The numbers of fires nationwide in 2018 were below the 10-year running averages (55,911 fires vs. 10-year running average of 61,655 fires, but the acreage consumed were above the 10-year running averages (~8,600,000 acres consumed vs. 10-year running average of 6,114,857 acres). Nationwide, the number of fires recorded during the year has been declining, indicating a trend towards lower fire counts—but with greater acreage consumption by wildfires! Of the 10 fire regions in the U.S., the summaries of the five areas with the greatest acreage consumed by fire are: Great Basin (2,091,135 acres), Northern California (1,498,764 acres), Southern U.S. area (1,375,808 acres), Northwest (1,333,639 acres), and Rocky Mountain area (748,597 acres). Alaska, usually cursed with large burned-area acreage year-to-year, had a relatively "mild" fire season with 367 fires, consuming 410,683 acres.

There were numerous large or significant fires, some which set records for loss of life, burned area extent, property lost (homes and businesses) and fire suppression costs (values of loss). According to Verisk's 2017 Wildfire Risk Analysis, 4.5 million U.S. homes were identified at high or extreme risk of wildfire, with more than 2 million in California alone.[2]

California, again suffered through some of the largest and most destructive fires in its history (and in the nation), with a few late summer/fall significant events; the Mendocino Complex Fire (late July) in Northern California grew to be the largest fire in state history with 459,123 acres burned.

- The Carr Fire, at the same time in Northern California was the sixth most destructive fire in the state's history (seven fatalities, 1,604 structures destroyed, 229,651 acres burned). Destruction from those two fires damaged or destroyed more than 8,800 homes/329 businesses, and other types of property.
- In early November, the Camp Fire broke out in Butte County, Northern California, and became the deadliest and most destructive fire on record (~88 fatalities, ~153,000 acres burned, and 18,800 structures destroyed), primarily burning through the city of Paradise, and surrounding enclaves and communities.
- Further south two other major fires, the Hill and Woolsey Fires, also caused considerable damage. Both fires started on November 8. The Woolsey Fire burned ~97,000 acres and destroyed ~1,600 structures and killed three people. The Hill Fire burned about 4,500 acres and destroyed four structures. Although insured losses from the Camp and Woolsey Fires have not been released, they are likely to be the costliest wildfires on record.

[2] https://www.iii.org/fact-statistic/facts-statistics-wildfires

These 2018 California fires surpassed the 2017 Northern California Wine Country Fires in destructive force. The 2017 Northern California Wine Country Fires (primarily the Tubbs Fire), which at the time (October 2017) was the most destructive fire in California history (over 8ooo building destroyed) and the costliest disaster in California history (over $1.2 Billion spent) was surpassed in damage and lives lost by the Camp Fire 13 months later in 2018! This extends a pattern of larger, more intense and destructive events occurring almost annually in the fire-prone Western U.S.

Outside of the U.S., major, unique, or significant fires were observed in 2018 in British Columbia, Canada (3,208,550 acres consumed; largest annual total burn area in British Columbia history), topping the previous burned area record set in 2017), the United Kingdom, Sweden, Portugal, and Greece. The 2018 European fires were suspected to have been the result of a significant mid-summer heat wave.

In 2018, some of the wildfire project teams again assisted and supported in fire suppression and post-fire recovery activities on the fires mentioned above. For example, the RECOVER project team (led by PI Keith Weber, Idaho State University) supported the Southern California wildfire management teams and post-fire recovery teams, particularly on the Carr Fire, Mendocino Complex, Camp Fire, and Woolsey Fire.

The NASA Rapid Response Erosion Database (RRED) project team (led by PI Mary Ellen Miller (MTRI)) provided new dry ravel products on the Thomas and Emerald Fires. Operational partners in the Forest Service are interested in predicting dry ravel (erosion due to gravity), as once vegetation is removed, ravel fills dry channel beds and is available for transport during rain events. NASA RRED was also used on the Valley, Emerald, and High Park fires to study the effectiveness of post-fire remediation treatments and to support research on improving predicative models. Their combined efforts provided short-turn-around data on the active fire mapping, burn severity mapping, and potential soil erosion/landslide potential in sensitive watersheds of those fires. Both teams' investigators supported other fires throughout the United States, and other investigators supported fire management activities with EO data and access, and provided expert knowledge on a number of additional events.

In March 2018, the four Wildland Fire project teams that received Applied Sciences Program supplemental funds to develop a SE assessment of their applications efforts, briefed management on their mid-project efforts. They are currently preparing their final project phases and development of their SE assessment reports to be submitted by the end of 2018. Those SE efforts are highlighted in this Annual Summary in Section 5 (Project Portfolio, *Socioeconomic Impact Assessments).*

In 2018, the NASA Wildland Fire program continued support to the Group on Earth Observations (GEO) Global Wildfire Information System (GWIS) initiative. Associate PM Vince Ambrosia represents NASA on the GWIS element. GWIS is developing a global database and web map service to provide EO-acquired active fire, burned area, and

other fire-related information. In July 2018, a NASA ARSET webinar on the GWIS WMS was held, and in early October the GOFC-GOLD Wildfire Implementation Team, organized a workshop on GWIS, in conjunction with the ForestSAT Conference at College Park, Md. The three NASA GEO-GWIS funded projects continue to add or enhance new capabilities to the GWIS, and they all participated in the workshop at the University of Maryland in early October 2018.

With the recent launches of GOES-16 (GOES East) and GOES-17 (GOES West) geostationary weather satellites, and their recent calibrations and product assessments in 2018, the fire community is excited about the potential to increase the spatial and temporal capabilities they afford for near-real-time hot spot detection.[3] The two satellites have increased spatial (0.5 to 2km) and temporal resolution (5-minute refresh), and will undoubtedly improve the early detection and observation of wildfires in the U.S. The two systems will provide complete U.S. lower-48 coverage of wildfire events at those improved temporal and spatial scales.

III. Major Accomplishments

The Wildland Fires program's nine projects completed their final year of effort in 2018 or extended their efforts for short periods into 2019 through an NCE of their project. They made substantial increases in their ARL levels (see sections below), reaching their original goal metrics or providing insights into their project advances and adaptation potential with their partner entities. The project teams were prolific with publications and presentations (see Appendix), and they received coverage of their results in news media clips, videos, and press releases. In 2018, there were a number of webinars, workshops and outreach meetings that the investigator teams engaged in to provide training on the modeling, analysis and utility of their projects and services.

The nine projects deserve recognition for their progress in 2018—the advancements represent emergency support to wildland fire management; maturation of a new EO wildland fire observation capability; a new "catalog request system" for automated access to pre- and post-fire EO data for a specified fire region; simplifying access and modeling with lidar data to improve vegetation structure information for fire modeling efforts; and development and hosting of workshops with national and international agencies to enable increased use of EO data in wildland fire management scenarios. The following subsections detail those accomplishments:

- In 2018, Keith Weber's team increased the data layers in RECOVER to support 26 distinct data layers and features to expand capabilities for modeling for fire management teams, including adding an "Ecological Resilience and Resistance" layer. RECOVER completed a new partnership arrangement with the USGS Landslide Hazards Program to allow for improved ingestion of post-fire debris

[3] https://www.nesdis.noaa.gov/goes-r-series-satellites.html

flow map layers into RECOVER, and partnership arrangement developments with the Bureau of Land Management (BLM) and USFS to fund RECOVER services for the coming year or more. In 2018, RECOVER was employed on 40+ fires, bringing the three-year total to more than 80 fires across eleven western states. He also provided RECOVER support to Southern California wildfire management teams, and numerous wildfire support teams in Idaho. These proved valuable to the post-fire assessment teams, particularly those working on debris flow issues.

- Mary Ellen Miller's model results were used by the BAER team to support post-fire debris flow assessment following a number of fires in 2018. In 2018, Miller started development of a new Forest Service interface that allows users to forecast burn severity using historical data and machine learning.[4] This method, although not perfect, is an improvement over older methods the fire community had been using. Resulting maps will be used for fuel's planning from a watershed perspective along with RRED. RRED and the new burn severity prediction tool will be used by the Forest Service and the EPA for a large-scale fuels project covering major watersheds in the Western US. The RRED system is currently being transferred to Washington State University where they would maintain and manage the running of the modeling efforts for the USFS partner access. This will bring the Miller project efforts to ARL 9.

- Both Keith Weber (RECOVER) and Mary Ellen Miller (NASA BAER project) supported the Incident teams and BAER teams on wildfire events in California, including the Northern California Mendocino Complex (RECOVER use), the Carr Fire (working with NPS on RECOVER products), and the Woolsey Fire (So. Calif.; employing RECOVER). For the Woolsey Fire support, RECOVER effort produced a fire-affected vegetation layer. Their support helped to effect post-fire rehabilitation strategies on the fire, particularly during mop-up operations and in post-fire precipitation events, which caused severe mud slides in regions burned by the fire, affecting infrastructure and homes in their path.

- In 2018, Wilfrid Schroeder (project PI) accepted a position at NOAA and transitioned the PI management of his project in his final year to Louis Giglio (University of Maryland). Janice Coen (modeling lead on Wilfrid Schroeder's team) identified new uses for her model to locate rapid growth in complex terrain to support pre-fire mitigation strategies. She implemented new approaches make use of NASA lidar-derived fuels and the Coupled Atmosphere Wildland Fire Environment model (CAWFE) to provide better information on fuel type and structure to simulate real and potential complex fire events in our national forests. The USDA Forest Service is using this approach to test the impact of its planned fuel mitigation strategies on wildfires within its Tahoe National Forest and evaluate the most effective strategy for shaping fire

[4] https://apps.mtri.org/burnsev/get

behavior in an effort to avoid the next big conflagration. Schroeder/Giglio ported the Sentinel-2/MSI fire algorithm to RSAC in anticipation of the 2018 fire season in the U.S., and provided continued support to ensure proper usage/dissemination of the new VIIRS data. The Schroeder and Giglio team have also been developing a Landsat 8 active fire-mapping product to augment the USFS Active Fire Mapping Program and web services.

- Joshua Picotte and his team completed the development of an open-source-software tool (QGIS Fire Mapping Tool) that will enable the mapping of all fires nation-wide, regardless of their size, in the USGS and USFS Monitoring Trends in Burn Severity (MTBS) program. This tool identifies fire occurrences using satellite-based active-fire detections and delineates the spatial extent of burn scars in Landsat data. Ultimately, MTBS mapping and assessment is improved by accounting for fires that would not otherwise be documented and by automating perimeter generation. This tool provides local fire managers and research scientist a "public" tool to map and assess fires that MTBS may not evaluate. With this tool, the MTBS could potentially map twice the fire acreage, if all fires were mapped regardless of size and on non-federal lands. Picotte then led a NASA ARSET-organized webinar on the use of the QGIS Fire Mapping Tool with fire management participants from throughout the country participating. The Picotte team NASA grant period ended in late 2017, but the team continued work on transitioning the capabilities to operations with in-house support, and reached their goal ARL level in 2018, with operationalization of their QGIS tool.

- Karyn Tabor and the FIRECAST team expanded FIRECAST in 2018 and into 2019 to expand the FIRECAST system to Ecuador to build an early fire warning system, and to provide capacity-building workshops and trainings in FIRECAST use. This work will be aligned with the NASA Capacity Building initiative of AmeriGEOSS. They achieved their ARL goal of 9, by operationalizing the FIRECAST system in numerous countries and regions. FIRECAST now has more than 1000 subscribers and operates in six countries (Peru, Columbia, Bolivia, Suriname, Madagascar, and Indonesia).

- In 2018, Sher Schranz and team collaborated with their transition partner (USFS Rocky Mountain Research Center) and with Colorado State University's Cooperative Institute for Research in the Atmosphere (CIRA) to utilize CSU computing systems, atmospheric scientists, and technology specialists and engage the WRF-SFIRE team to install and evaluate the coupled fire-atmosphere forecasting system for use by Predictive Services Forecasters, and utilize it to provide data for regression models predicting large-fire ignition probabilities for Predictive Services Areas (PSA). The team has developed a prototype of a fire forecasting system that integrates a high-resolution coupled numerical fire-weather prediction with fuel moisture and smoke forecast. They have also built and deployed a near real-time fuel moisture data assimilation system, providing

near real-time dead fuel moisture data, developed a prototype of the VIIRS/MODIS fire data assimilation system, and deployed web portals for simulation initialization (backend) and result presentation (frontend).

- In 2017, the Jim Vogelmann project team completed their effort and demonstrated that: (1) Intra- and inter-annual spectral variability in shrublands/grassland ecosystems is high; (2) Spectral variability is highly correlated with climate variables, especially precipitation; (3) Fire activity is more likely in areas where the spring normalized difference vegetation index (NDVI) values are high and late summer NDVI values are low; and (4) Programs such as STARFM and their derivatives can be effectively used to combine the temporally rich attributes of MODIS data (which has relatively low spatial resolution for LANDFIRE applications) with spatially detailed Landsat data (which has relatively low temporal resolution for intra-annual fire applications). During the project they matured the STARFM modeling efforts to operational use in LANDFIRE, by developing a "user manual" and improved algorithms. Although their grant work is completed, the project team is continuing with enhancing the capabilities of STARFM and verifying accuracies with field biomass measurements, to allow further acceptance of the methodology by the community. The Vogelmann team is also assisting the LANDFIRE team with further refinements of the algorithm development and integration into expanded use.

- Zack Holden and team also completed their grant period in 2017, but continued in 2018 to further enhance the TOPOFIRE project, developing and refining historical and near real time gridded weather, drought, fuel moisture and wildfire danger grids for wildfire danger assessment from the inclusion of various EO layers. In 2018 (and into 2019) the team is/will continue working on several steps to fully complete their project. In 2018, fire danger grids were translated into percentiles, the primary metric used by fire managers for assessing fire danger. Forecast grids are currently generated for a four-day period. Seven-day forecasts are essential for planning, and work continues on extending the National Weather Service precipitation probabilities into quantitative precipitation forecasts. Finally, they will add insect mortality maps being produced by the Forest Health Technology Enterprise Team to their TOPOFIRE services.

- In 2018, Birgit Peterson and team has added new functionality to the Creating Hybrid Structure from LANDFIRE/Lidar Combinations (CHISLIC tool), focusing on including the derivation of Canopy Bulk Density (CBD) and surface fuels. Furthermore, on the web-interface the extrapolation of metrics from areas where airborne lidar has been collected to surrounding areas has matured. This process utilizes Landsat mosaics and is key for addressing spatial data gaps in a meaningful way. As lidar data collections becomes more prevalent in the National Forests, and lidar from orbital assets supplements those airborne

collections, the CHISLIC tool will become more prevalent in its use as a simple, effective tool for incorporating new volumetric information into forest fire hazard mapping scenarios.

- Four of the Wildland Fire program Phase II projects (Miller, Holden, Weber, and Schranz) were selected in 2017 for supplemental support to develop a socioeconomic impact study of their respective project advancements. The projects were required to collaborate with a social- or economic scientist to evaluate the potential benefits their projects make to the wildfire management communities. The one-year project assessments ran concurrent to their Phase II, final year efforts. The four socioeconomic projects, finishing in late 2018 and early 2019, have all identified improved social and economic benefit of employing EO data into fire management processes. This element is further highlighted in Section V.

IV. Program Assessment

Overall, the Wildland Fire management team considers the performance of the projects in the portfolio to be exceptional. The program's advancements were significant and noteworthy. The investigator teams routinely tracked and monitored their project progression through the ARLs; this capability enhanced the awareness of the stage of project development and allowed a self-assessment of the track that the PIs were on towards operational integration by their partners.

Through the press coverage, videos, policy impacts, and awards, it was rewarding to see the project teams, partners, and wildfires community recognized for their innovations and achievements. The management team was also pleased by the commitments and contributions of the partner entities as well as efforts to leverage new resources to support adaptation of the QGIS Fire Mapping Tool in the USGS/USFS MTBS program (J. Picotte, PI) and the Water Erosion Prediction Project (WEPP) model (Miller, PI) in the BAER teams toolbox.

2018 proved to be a very active and productive one in terms of the Wildland Fire program's participation in domestic and international activities. Associate PM Amber Soja was elected in 2018 to serve as a Board Member of the International Association of Wildland Fire (IAWF), where she will help direct policy for the organization and develop symposia and conference/training/workshops in support of the mission of the organization. Amber Soja is also serving on the NASA/NOAA Interagency Mission Planning Committee for FIREX-AQ, to support airborne and satellite missions over fires in 2019 and beyond.

Amber Soja served on the IAWF Conference Committee for the 2018 AFE/IAWF Fire Continuum Conference: Preparing for the Future of Wildland Fire (May 2018), where

she led the effort to acquire significant exhibit hall space for the NASA Applied Sciences Program at the conference and supported the booth during the conference, providing materials to the attendees, and explaining the role of NASA ASP in Earth Science issues. Additionally, she supported the NASA Wildland Fire Applications Toolbox Workshop, and presented two papers at the conference.

Associate PM Vince Ambrosia served on a number of Scientific or Technical Planning Committees for International Conferences including the 6th Conference on Remote Sensing and Geoinformation on Environment (Cyprus). He served as a Guest Editor & Section Chair of "*New Platforms and Sensors"*, in the 2nd International Electronic Conference on Remote Sensing (March 22-April 5, 2018). He also served as a Guest Editor of the Remote Sensing Journal Special Issue: *New Trends in Forest Fire Research Incorporating Big Data and Climate Change Modeling in 2018*. He also continued his roles and participation in various fire committees in the U.S. and internationally, including GEO-GWIS, GOFC-GOLD, and the Thermal Working Group.
He continued to serve a reviewer for journals with fire science/applications submissions, including Remote Sensing, Remote Sensing of Environment, PE&RS, Fire Ecology, IEEE TGARSS and others. He also served as a reviewer for NASA Small Business Innovative Research (SBIR) and USDA-Forest Service SBIR programs that involve fire-sensing technologies.

On the program's financial front, the program management team tracked spending/costing by the funded PI and partner institutions in 2018, to ensure funds were fully costed in this final program year. There were still some uncosted project funds that institutions had not "spent" or costed at the end of 2018, but most projects are in good financial shape, and a few project efforts have been extended into 2019 on NCE, and will be costing their funds in 2019. The program management team will work closely with the nine PIs, and their institutions to ensure that their costing is appropriately completed by 2018 or early 2019.

In 2018, the Wildland Fire program solicited augmentation proposals from the nine project teams, focused on Socioeconomic Benefits of EO data. Four proposals were submitted and funded. The four projects supplemental efforts ran concurrently with their final project year (2018), and more information on the SE project activities is found in Section V.

In 2018, final year of the projects, we focused attention on the transition to—and adoption by—the partner organizations of the applications or information products developed by the PI teams. We were extremely pleased with the projects that demonstrated successful operations of their models or capabilities and have actively participated in "live" demonstrations and support of wildland fire management on various fire incidents. Even for those projects that did not reach their "goal" ARL, the management team was impressed with the PI team diligence in highlighting the various barriers to ful

l implementation. In many cases, it becomes more important to know where barriers exist and how to overcome them in future project endeavors, than it is to complete a project with no setbacks and introspective analysis.

During the various transition stages of our projects in 2018, we noted an issue with some of our project's adoption of their application by the partners. Despite strong intentions and commitments by the partner organizations at the transition from Phase I to Phase II, there has been an indication on the loss or re-prioritization of funding by the partner agencies/organization, which affects their adoption efforts. For instance, the U.S. Forest Service has indicated that the increased costs for active fire suppression has impacted their commitments to, and investments in, research, research communication, and pre-fire management. These issues are difficult to overcome (but easy to predict), as priorities change for organizations or employees are lost or transferred to other efforts. This can be recognized as a persistent issue in transitioning new technologies/ knowledge and adoption of those same, from partner agencies.

As the projects submit their final reports/analyses, we will also focus greater attention on lessons learned from the project teams and partners. The lessons will likely cover a range of topics, such as barriers to implementation, data products and format incompatibilities, organizational relationships, engagement efforts, methods to achieve applications, training needs and approaches, and unforeseen risks—such as changes in priorities for partner organizations, among others.

V. Project Portfolio

In 2018, the portfolio contained nine projects, and the projects' foci were evenly split between pre-fire, active-fire, and post-fire applications activities. Three of the projects' institutional leads were from universities, five were from the federal government, and one from a non-governmental organization. All the projects had partner organizations as co-investigators and collaborators, which included federal and state agencies, interagency work groups, and international collaborations.

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 is below; more information is in the Wildland Fire section of the Applied Sciences Program website.

The majority of projects focused on the 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 including GOES, 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 numerous models and model outputs.[5]

Project Summaries

The following section describes the nine active Wildland Fire projects. Further information on these projects can be accessed at the NASA Applied Sciences Wildland Fire program web page.

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 user/partners includes 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: Josh Picotte and Stephen Howard (retired), 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, for identifying 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 public and two major entities that provide the MTBS products for the fire community: USFS Geospatial Technology Applications Center (GTAC, formerly Remote Sensing Applications Center (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 have lead to better assessment tools and post-fire remediation support through erosion modeling. The project focused on supporting end users and partners from the Burned Area Emergency Response (BAER) teams, land managers, and researchers.

[5] See Abbreviations and Acronyms in Appendix B.

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. The partner/end-user community involves those that utilize both the Wildland Fire Assessment System (WFAS) and the Wildland Fire Decision Support System (WFDSS) in their assessment tools for wildfire management and reporting.

Wildland Fire Behavior and Risk Forecasting; Principal Investigator: Sher Schranz, Colorado State University: This project applies data from MODIS and VIIRS to derive Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) maps, and government databases (LANDFIRE and fuel moisture from the network of Remote Automated Weather Stations (RAWS)) to test the probability of providing forecasting of wildland fire behavior and risk, integrated within the 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 the VIIRS and Landsat 8 sensors that yield significantly improved active 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 involved include USFS, NWS, and WFDSS.

An Integrated Forest and Fire Monitoring & Forecasting System for Improved Forest Management in the Tropics; Principal Investigator: Karyn Tabor, Conservation International: This project is enhancing 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 and better addresses the challenges decision makers face in making timely decisions related to wildland fire management and prevention that have immediate conservation impacts. Specific improvements to FIRECAST are the inclusion of fire-risk warnings, seasonal severity forecasting, an interactive website, as well as email alerts and mobile systems that are explicitly

designed based on management request. The partners in this effort have traditionally included 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. Due to interest expressed by the government of Suriname, FIRECAST was expanded to that country in September 2017.

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 included the USFS, 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 EO data (Landsat 8, MODIS, AMSR-E (historical, non-operational since October 2011), and Modern Era Retrospective Analysis for Research and Applications (MERRA)), derived decision products, and historic biophysical data for BAER teams to have a comprehensive RECOVER (Rehabilitation Capability Convergence for Ecosystem Recovery) data set in a GIS analysis environment. The data set is customized for the targeted wildfire, thus reducing the time required to assemble and deliver crucial wildland fire-related data from days to a matter of minutes. The partners include the BLM, Idaho Department of Lands, and BAER teams.

Project Application Readiness Level (ARL) Metrics

At the conclusion of the nine Wildland Fire program projects in 2017/2018, the portfolio had three projects at ARL 9, two projects at ARL 8, one project at ARL 7, and three projects at ARL 6. The mean ARL was 7.67 (compared to 6.8 in 2017) and the mode was ARL 9 compared to an ARL mode of 7 in 2017). Overall, all projects advanced one or more ARL levels in 2018, and they contributed to the Applied Sciences Program meeting its annual performance goal for 2018. Further, of the nine projects, four met their original ARL goal, two came within one level of their ARL goal, and the remainder finished within two levels of their ARL goal. Those that did not achieve their ARL goals were nonetheless successful in carrying their capabilities to high readiness metric levels, and their original ARL goals will probably be met in 2019, as partner entities more fully adopt the capabilities developed into a more operational context. Not all of the projects

had an end-ARL goal of 9, and therefore the final, lower ARL metrics achieved by those projects, can still be seen as a successful attainment of their objectives and an indication of realistic project management through the years of the effort. The NASA Wildland Fire management team is extremely pleased with the project advances achieved by all nine projects, and their diligence in monitoring their ARL levels as a tracking mechanism for project progression.

Wildfire Projects	
End of 2018	
ARL	**Projects**
ARL 9	3
ARL 8	2
ARL 7	2
ARL 6	2
ARL 5	0
ARL 4	0
ARL 3	0
ARL 2	0
ARL 1	0

Socioeconomic Impact Assessments

The Wildland Fires program selected four projects for a quantitative analysis and valuation (in social and economic terms) of the benefits from the project and the use of Earth observations applications. We provided supplemental funding to these four projects, and the analyses ran concurrently with the final year of the project. The following list identifies the four SE projects, and preliminary results of their economic analysis.

- *SE Impact Study: Evaluating the Socioeconomic Impacts of Rapid Assembly and Deployment of Geospatial Data in Wildfire Emergency Response Planning (PI: Weber)*
    - **Preliminary findings**: The use of the RECOVER services and EO data was shown to save >800 hours of staff time; ~16-hours per fire, and validated or altered decisions on fire management by over $1.2M. This analysis was derived from interviews with fire management staff that employed RECOVER on fires in 2017-2018.

- *SE Impact Study: Using Earth Observations to Assess the Socioeconomic Impact of Human Decision Making During the Suppression of a Wildland Fire (PI: Schranz)*
    - **Preliminary Findings***:* Simulation results of hind-casting EO data and WRF-SFIRE into fire management decisions on the 2011 Los Conches Fire (Santa Fe, N.M.), and integrating interviews with the fire management personnel on the hind-casted data, conclude that simulation results, if in place at the time of the fire, would have altered the fire operations, and would have saved ~$600K in property and timber and even more over a longer-term forecasting period.

- *SE Impact Study: Quantifying Potential Economic Benefits of Incorporating Gridded Fuel Moisture and Weather Data into Wildland Fire Decision Support in the Northern Rocky Mountains (PI: Holden)*
    - **Preliminary Findings***:* Quantifying the potential economic benefits of including TOPOFIRE gridded data into the Aerial Firefighting Use and Effectiveness (AFUE) models can result in significant savings (millions of dollars) per year by helping to quickly determine areas where TOPOFIRE indicates either effectiveness of a potential drop area or areas where drops will be ineffective.

- *SE Impact Study: Socioeconomic Impact Analysis of the Rapid Response Erosion Database (RRED) (PI: Miller)*
    - **Preliminary Findings***:* Using two case study fires (Canyon Creek and King Fire), fire management records from those events, and questionnaires to RRED users, the SE impact analysis showed erosion predictions for the King Fire helped justify and target $1M in mulching operations on the post-fire burned areas, while the Sacramento Municipal Utility District provided a portion of the funds to protect a hydroelectric and water supply reservoir downstream of the fire. Database users and usage were tracked for two years in order to estimate the time savings provided by RRED. By automating the creation of model inputs between 60-80 hours of an analyst's time is saved. Average salaries of hydrologists from the Forest Service, BLM, and EPA as well as much lower student stipends were used to calculate savings to be ~$695K over two years. This indicates a significant economic benefit delivered from the inclusion of EO data in modeling efforts, supporting fire planning, and post-fire remediation.

The four SE projects each identified "challenges"/"hindrances" to the adaptation of EO information in support of wildfire management. The most common challenges encountered by the four projects included:

- Lack of understanding and trust of the data/information;
- Data/information is difficult to interpret;

- Reluctance to fully adopt GIS or decision support tools;
- Not always able to quantify impacts (difficult in measuring monetary savings from the improvements provided by EO data).

The four Socioeconomic Impact analysis projects will be finalizing and reporting their results at the end of 2018/1st Q of 2019.

NASA Rapid Response and Novel Research in Earth Science (RRNES) Solicitation Project

In early 2018, NASA selected a proposal (funded jointly by Disasters and Ecological Forecasting programs) submitted to the ROSES-17, A.19 Rapid Response and Novel Research in Earth Science (RRNRES) solicitation, entitled "*Post-Fire Assessment, Mapping and Monitoring in Sonoma County in Response to the Pocket, Tubbs, and Nuns Fires*". The project, led by K. Gaffney of the Sonoma County Agricultural Preservation and Open Space District, is a one-year effort focusing on analysis of EO data for assessment of burn variables in the region of the Northern California Wine Country Fires. The objective of the efforts are to update existing Sonoma County vegetation data sets using EO data following the October 2017 wildfires, discover and quantify relationships between fire burn severity and fire recovery against landscape characteristics, and evaluate the value of the NASA-funded Sonoma vegetation map data in fire response, recovery and resilience planning. The project is collecting, analyzing, highlighting, sharing, and training the use of EO data to other county management entities to expand the use and knowledge of EO information and availability for the local community.[6] In 2018, the team has developed burn intensity (burned completeness) for the Sonoma County area, and integrated that with previously collected (2013) lidar data to assess the contribution of ladder fuel height to the variously burned polygons. Activities in the 4th Quarter of 2018, focused on evaluating the value of the NASA Sonoma Vegetation Map data in fire response, recovery and resilience planning, by querying the various county management personnel through a survey questionnaire. In 2019, the team will develop a "Story Map" of the fires to inform the greater community and private citizens about the fires and effects on the ecosystem and vegetation dynamics. The "Story Map" will focus on the fire effects on the natural landscape of Sonoma County, informs on the extreme weather conditions and the progression of the fire storm, discusses how the fire events fit into the historical context of vegetation and fuels management in the county, and will conclude with a section about "living with fire", and how to better manage lands for fire. The project efforts will be completed in spring 2019 and the results/reports will be available through the NASA Applied Sciences website next year and also available at the Sonoma County Agriculture and Open Space District website.

[6] https://www.sonomaopenspace.org/news-and-features/2018/05/ag-open-space-awarded-90000-grant-from-nasa/

VI. Program Management

In 2018, Vince Ambrosia and Amber Soja continued to support NASA Earth Science as Associate Program Managers for the Wildland Fire program element. They each managed a portfolio of projects, tracking progress, budgets, spending plans, and applications performance. They also further enhanced routine 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, and addressed PI questions and concerns. They also represented NASA and the Wildland Fire program by serving on various national and international committees, and at various conferences, symposia, workshops and exhibitions, all while communicating the program capabilities and accomplishments.

2018 Team Meeting

The NASA Wildland Fire program held its 2018 annual project team meeting in a little different format than in previous years. Since 2018 was the final year of the Wildland Fire program for many of the PI teams (some had completed efforts in 2017), the management team planned that project reporting could be done as a "final" presentation in a Special Session organized at the Fire Continuum Conference in May at the University of Montana; Missoula, Mont. This concept allowed a number of "captured audience members" (those attending the Conference), to hear about the applications developments of the PI teams and partners. We also had additional presentations in the session on Socioeconomic Impacts of Wildfire EO projects, and partner presentations on adoptability of those efforts matured by the project teams. We also designed a series of "lightning talks" at the NASA Exhibit in the Exhibit Hall, where various program investigators could brief an audience on their applications for five-to-seven minutes, during session breaks (coffee and afternoon snack breaks). In addition, we organized a pre-conference workshop, focusing on training and hands-on activities for attendees engaging with the nine project PIs and their team members. We had ~18 attendees at the half-day workshop. Throughout the week of the conference, the PI team had an opportunity to interact with those attendees interested in their developments. The NASA exhibit area, proved to be a successful venue to gather people interested in our wildfire applications developments and to learn about NASA Applied Sciences and other program areas through streaming videos we had on a large screen monitor, and from all the available materials we had on various projects at NASA. Those information data sets included two-page glossy handouts of each project, as well as other briefing materials provided by NASA-ESD. The meetings, special sessions, workshop, lightning talks, and NASA exhibit area were a successful finale to our annual review meetings series; and provided the PI teams with a stress-free environment to share their many years of diligent work on their projects, while engaging new potential partners who might not have otherwise seen their efforts on display had they not attended the Fire Continuum Conference.

Communications

In 2018, the Applied Sciences Program website was continually updated with new materials and content from wildland fire-related meetings, conferences and symposia.[7] We continued to produce video blogs to convey information about the program to the wildland fires community, NASA news releases, other articles in the press, and NASA web features related to Wildland Fire projects.

In 2018, the NASA program management team continued to highlight the Wildland Fire program and projects through presentations and briefings to the community. We updated and distributed the two-page glossy project highlights at numerous conferences and events (see sections VII and VIII). The Wildland Fires program was a contributing sponsor at the AFE/IAWF Fire Continuum Conference, continuing a tradition of support where NASA plays a major role in the topical areas of the symposia. The program also continues to support the TFRSAC meetings, hosting the meeting documents and presentation materials at the NASA ASP-Wildland Fire website for easy access by the community. The Wildland Fire program management team also supported NASA exhibit booth space at a few conferences, including the Fire Continuum Conference, the 6th International Conference on Remote Sensing and Geoinformation of the Environment, and the AGU Fall Meeting. The Fire Continuum Conference exhibit space for NASA was by far the most expansive presence for the Wildland Fire program. Besides having various NASA programmatic handouts, and glossy materials about the wildfire projects, the exhibit space was furnished with a large monitor for streaming videos of various projects, briefings from the management team, and video clips from news services and other materials to highlight project activities. The management team also organized a series of "lightning talks" at the exhibit by various management personnel, the PI teams, and partner entities; these occurred during the daily session break periods when conference attendees relaxed in the exhibit hall area.

As part of the communications efforts of the program, the project summaries (one-page glossy notes), press releases, video blogs, reports, outreach, and programmatic materials are all made available via the Wildland Fire page on the Applied Sciences Program website.

VII. Community Leadership

The Wildland Fire program sponsored and supported numerous community activities in 2018 as part of overall efforts to enhance the use of Earth observations and wildland fire science in fire-related management decisions and actions. The following items summarize leadership of, and participation in, key interagency committees as well as conferences and symposia.

[7] http://appliedsciences.nasa.gov/programs/wildfires-program

International Association of Wildland Fire (IAWF)

In 2018, Amber Soja was elected to serve as a Board Member of the International Association of Wildland Fire (IAWF), where she will help direct policy for the organization and develop symposia and conference/training/workshops in support of the mission of the organization.

AFE/IAWF Fire Continuum Conference Participation

In May 2018, NASA was a major sponsor and contributor to the AFE/IAWF Fire Continuum Conference, held at the University of Montana, Missoula, Mont. NASA's Wildland Fire management team participation included organizing a "hands-on" workshop on the NASA Wildland Fire program projects and how to access, and employ the information, models, and data that resulted from the efforts by the PIs. All nine project PIs were involved in the workshop. NASA also attended to a large exhibit display at the conference where the team provided handouts, other documents, and reports that highlighted both the Wildland Fire program, and NASA Applied Sciences. A series of "lightning talks" about "NASA and fire science and applications" were presented on a large monitor screen in the exhibit space. Lawrence Friedl opened the lightning talk session with a welcoming address and a briefing on NASA Applied Sciences Program; this was the first time the "lightning yalk" format occurred at the AFE/IAWF Conference series. A Special Session "*NASA Applied Science Efforts: Collaborations in Earth Observation Data, Information, Models and Tools Supporting Wildland Fire Management*" was organized by NASA with the Wildland Fire PI teams presenting their project status and findings.

NASA/USFS Tactical Fire Remote Sensing Advisory Committee (TFRSAC)

Associate PM Vince Ambrosia continued to serve as a co-chair of the NASA/USFS TFRSAC. The TFRSAC addresses efforts to share information on wildland fire imaging capabilities, technologies and projects that employ space-borne, airborne, and in situ assets to improve wildland fire characterization capabilities; including pre-fire assessment, active-fire observations, and post-fire recovery and rehabilitation. The community is composed of various federal and international fire management organizations (CAL FIRE, USFS, BLM, DOI, Canada Forestry Service, etc.). Individuals represent Incident Management Team members, wildland fire scientists, geospatial specialists, private industry representatives, U.S. Intelligence community personnel, and University partners. The TFRSAC provides an applications forum for wildland fire management practitioners to engage with the technology/scientific communities to assess and enable new/evolving technologies and capabilities in Earth observations of wildland fire.

The TFRSAC held its spring 2018 meeting at NASA Ames Research Center on 9-10 May, with 38 attendees and ~35 virtual attendees. The Fall TRFRSAC meeting was held at the National Interagency Fire Center (NIFC) in Boise, Idaho, on October 24, 2018, with 40 attendees and 24 virtual attendees. All TFRSAC meeting presentation materials are

available through the NASA Applied Science Wildfire Program website by linking to the meeting agendas in the "Library" section or the "Past Events" section.

NASA/NOAA FIREX-AQ

The NASA-led *FIREChem* airborne campaign[8] and the NOAA-led *Fire Influence on Regional and Global Environments Experiment* (FIREX) [9] campaign announced a joint campaign, the "*Fire Influence on Regional and Global Environments and Air Quality (FIREX-AQ)* campaign*,* which will occur in 2019. The combined campaigns will leverage interagency efforts to understand the atmospheric impacts of biomass burning on the atmosphere and air quality.

Associate PM Amber Soja continued to serve on the interagency planning committee for FIREX-AQ, and is a PI on one of the FIREX-AQ projects. Both Soja and Ambrosia have made themselves available as necessary to support the successful implementation of the campaign, although Soja will play a larger role in the airborne missions through its campaign duration.

American Geophysical Union Fall Meeting

The AGU Fall Meeting in December 2018, in Washington D.C., included sessions with wildland fire-related topics. Such as the Special Paper & Poster session (*NH23E: Wildfires: Triggers, Predictability, and Impact Assessment*), co-convened and chaired by Amber Soja. Amber also presented a NASA Hyperwall talk in the Exhibit Hall entitled: "*Dynamic Global Fire Connections"*. The NASA booth included literature on the Wildland Fire program, especially the one-page project summaries, as part of the materials available to the delegates.

Remote Sensing Journal Special Issue

In 2018, Assoc. PM, Vince Ambrosia served as a guest editor of the online journal *Remote Sensing* Special Issue entitled, "New Trends in Forest Fire Research Incorporating Big Data and Climate Change Modeling".

VIII. International Activities

The Wildland Fire program participated and contributed to a number of internationally focused activities in 2018, and increased its activities in a wildland fire task of the intergovernmental Group on Earth Observations (GEO). The following summarize participation in key international committees, conferences, workshops, and the GEO task.

Earth Observing Summit 2017: Wildfire Remote Sensing Workshop Report

[8] https://espo.nasa.gov/firechem/
[9] https://www.esrl.noaa.gov/csd/projects/firex/

In 2018, the findings of the Wildfire Remote Sensing Workshop held in 2017 were published. The Natural Resources Canada—Canadian Forest Service organized the workshop, held in conjunction with the 38th Canadian Symposium on Remote Sensing (CSRS) in Montreal, Canada (June 2017).[10] Associate PM Vince Ambrosia served on a discussion panel (Air, Ground and Space) at the workshop and highlighted the NASA Wildland Fire program. The workshop report highlights the status and areas of international collaborative research and applications in Earth observations of wildland fire.[11]

6th International Conference on Remote Sensing and Geoinformation of Environment

The Sixth International Conference on Remote Sensing and Geoinformation of Environment meeting was held March 26-29, 2018 in Paphos, Cyprus.[12] Associate PM Ambrosia served on the conference International Technical Planning Committee, presented a Keynote Address entitled: "*NASA'S Global Perspective: Observations, Programs, and Future Missions*", and chaired a session titled "Land Cover and Urban Areas" and also two "Forests" sessions.

Group on Earth Observations - Global Wildfire Information System

The Group on Earth Observations (GEO) Work Programme included a task entitled the *Global Wildfire Information System (GWIS),* and GEO included GWIS in the 2017-2019 Work Programme. [13] The GWIS initiative provides a platform for harmonized information and enables the coordination of information among major national and regional fire information providers. GWIS relies on collaborative sharing of international EO data systems, as well as national and regional information sources (fire records, etc.). It provides a web-based, gap-filler system for countries and regions that do not maintain a comprehensive wildfire database. For countries and regions where wildland fire information systems exist, GWIS provides a complementary and independent source of harmonized information adding to national and regional information sources. There are four main GWIS elements: Harmonized Fire Information Data Sets; International Networking; Workshop Training; and Cross-Platform Info Sharing at Common Scales.[14] The GWIS seeks to link various national, global and regional systems to make complementary Earth observations data more readily available on wildland fires.

The Applied Sciences Program included GWIS in the ROSES-16 A.50 solicitation, and in early 2018 a selection of three PI-led GWIS development projects was made. The three projects and their Principal Investigators are:

[10] https://crss-sct.ca/earth-observation-eo-summit-2017/
[11] https://crss-sct.ca/wp-content/uploads/2018/04/EO-Summit-2017-Wildfire-Remote-Sensing-Workshop-Report-2018-04-11.pdf
[12] http://www.cyprusremotesensing.com/rscy2018/
[13] https://www.earthobservations.org/activity.php?id=126
[14] http://gwis.jrc.ec.europa/eu/

- *"Using the NASA Polar Orbiting Fire Product Record to Enhance and Expand the Global Wildfire Information System (GWIS)",* (PI: L. Boschetti, University of Idaho);
- *"Enhancement to the Global Wildfire Fire Information System: Fire Danger Rating and Applications in Indonesia", (PI: Robert Field, Columbia University);*
- *"Development of a Harmonized Multi-Sensor Global Active Fire Data Set*", (PIs: Louis Giglio (University of Maryland)/Wilfrid Schroeder (NOAA)).

The GEO GWIS program management efforts are within the NASA ASP – Disasters program area (PM: David Green), and Associate PM Vince Ambrosia supports the three project's oversight and metrics compliance. Ambrosia will also continue in his role as the NASA U.S. Lead on the GEO Work Programme 2017-2019, GEO-GWIS element.

In 2018, three GEO-GWIS workshops/webinars involving the three PI teams were organized:

- July 19, 2018: NASA ARSET webinar: Introduction to the GEO-GWIS system;[15]
- July 16-20, 2018: Indonesian Fire Danger Rating System: Training Program and Technical Enhancements (Jakarta, Indonesia, led by R. Field (Columbia University));[16]
- October 1-2, 2018: 3rd GWIS and GOFC-GOLD Fire IT meeting (University of Maryland).[17]

The GEO-GWIS projects are tracking to their metrics and goal ARLs and providing quarterly reports on their project activities to the Disaster program management team. They have all been working closely with the GEO-GWIS program management team at the Joint Research Centre (JRC), in Ispra, Italy, where the GEO-GWIS Web Map Services (WMS) data are served and maintained. The three projects are scheduled to complete their efforts in 2021.

IX. Looking Ahead

Wildland Fire Program Projects

In 2019, a few of the nine Wildland Fire projects have NCEs that continue into 2019. Those efforts will then provide their final reports to the program management team and contracting officials. The four Socioeconomic Impact Assessment projects will also be

[15] https://arset.gsfc.nasa.gov/land/webinars/adv-wildfire-2018

[16] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwi_j5W-2qDfAhUIcq0KHW25BJoQFjAAegQICRAB&url=https%3A%2F%2Fwww.bmkg.go.id%2Fberita%2F%3Fp%3Dworkshop-on-the-indonesian-fire-danger-rating-system-training-program-and-technical-enhancements%26lang%3DID&usg=AOvVaw2SQRW_owmKugJLp-64mZRW

[17] http://gofc-fire.umd.edu/meeting/static/GOFC_Fire_IT_2018/index.php

finalizing and submitting their reports by early 2019, and these materials will be shared at the website.

Sonoma County Fires RRNES Project

The Sonoma County Agriculture and Open Space District project (Post-Fire Assessment, Mapping and Monitoring in Sonoma County in Response to the Pocket, Tubbs, and Nuns Fire), co-funded by NASA Disaster and Ecological Forecasting programs, will host a quarterly review of project accomplishments in January 2019, and the project will be completed in spring 2019. The results/reports will be available through the NASA Applied Sciences website and the Sonoma County Ag and Open Space District website next year.

GEO GWIS

The GEO GWIS activities will continue with NASA involvement in the GEO Work Programme 2017-2019. The major focus will be on building capacity in under-served regions for utilizing and feeding information into GWIS, and training uses of the system through regionally oriented workshops and webinars in 2019. The program will support the management of the three GWIS-related projects that were selected from the ROSES-16 A.50 solicitation.

Partnership Efforts

The Wildland Fire program team expects to continue its discussions with USFS GTAC, JFSP, NIFC, and others concerning collaborations and communications on wildland fire science and applications. Program Manager Lawrence Friedl will continue to serve as a Co-Lead of a GEO task on the Sustainable Development Goals, and he will look for opportunities for the program to contribute to the use of Earth observations on wildland fire-related goals. Associate PM Soja is supporting the NASA FIRE-AQ Campaign from 2018 forward, and she was elected in 2018 to serve as a Board Member of the International Association of Wildland Fire (IAWF). Associate PM Ambrosia will continue activities with GEO-GWIS, TFRSAC, the Disasters program, and advising and supporting wildfire EO capabilities with the community.

NASA Disaster Program Support

In 2018, the Applied Sciences Disasters program[18] subsumed the Wildland Fire program. In 2018, the Disasters program offered a solicitation (ROSES 2018 A.37 Disasters) with a component that included wildland fire applications. Proposals were reviewed in late 2018, and the resultant successful proposal submissions will be announced in December 2018/early 2019.

In 2019, if any wildfire-related proposals are submitted in response to the Rapid Response and Novel Research in Earth Science solicitation (RRNRES), they will be reviewed and managed by the NASA Earth Science Research and Analysis or Applied

[18] https://appliedsciences.nasa.gov/programs/disasters-program

Sciences Program management team members, where the proposals are most closely affiliated.

x. Final Comments

As we close out and transition the Wildland Fire program to the Disasters program (and other Applied Science Program areas, where appropriate), the management team would like to sincerely thank all the project team members who contributed to the growth and expansion of the wildfire community's use of Erath observations in their daily management practices. Each of the projects that were incubated over the past four-to-five years increased the knowledge and use of EO data; and by doing so, they have contributed a valuable service to the public by assisting in improving fire prediction capabilities, active fire management, and recovery and rehabilitation efforts on affected ecosystems and urban communities. The fire management community is in a more informed position than they were just five years ago, thanks to all the teams efforts and diligence in maturing EO data, models, and information systems, into useable/applicable solutions.

Look for future information on the wildfire element at our NASA Applied Sciences Program website, and as content in annual summaries provided by the other Applied Sciences program areas—specifically the Disasters and Ecological Forecasting programs.

XII. Appendix

A. Publications

This appendix highlights 2018 peer-reviewed publications, white papers, reports, conference proceedings, presentations, abstracts, workshops, blogs and press releases related to the Applied Sciences Program's Wildland Fires program. Bolded text indicates authors and co-authors that are Principal Investigators, Co-Investigators, and programmatic management staff with the Wildland Fire program element.

Clements, C., **A. Kochanski**, D. Seto, B. Davis, C. Camacho, W. Heilman, S. Krueger, B. Butler, J. Restaino, R. Ottmar, R. Vihnanek, J. Flynn, J.-B. Filippi, T. Barboni, **J. Mandel**, **M. A. Jenkins**, J. O'Brien, and B. Hornsby. (2018). The FireFlux II Experiment (FF2): A model-guided field experiment to understand fire-atmosphere interactions and fire spread. *International Journal of Wildland Fire*, (in revision).

Coen, J. L. (2018), Some Requirements for Simulating Wildland Fire Behavior Using Insight From Coupled Weather-Wildland Fire Models. *Fire, 1*(1); https://doi.org/10.3390/fire1010006, 9 February 2018.

Coen, J. L., E. N. Stavros, and J. A. Fites-Kaufman (2017), Deconstructing the King Megafire. *Ecological Applications*, 2018 Sept.; 28(6): 1565-1580, doi: 10.1002/eap. 1752, Epub June 29 2018.

Cooper, L.A., A. Ballantyne, **Z.A. Holden** and E.L. Landguth (2017). Disturbance Impacts on Land surface Temperature and Gross Primary Productivity in the Western United States. *Journal of Geophysical Research Biogeosciences*, doi: 10.1002/2016JG003622.

Elliot, W., Cao, L., Long, J.W., Dobre, M., Lew, R., **Miller, M.E**. (2018) Estimates of Surface and Mass Erosion Following the 2016 Emerald Wildfire. *Final Report to the Lake Tahoe West Shore Restoration Project*. October 2018. 27p.

Farguell Caus A., J. Haley, **A. K. Kochanski**, A. Cortes Fite, and **J. Mandel**. Assimilation of fire perimeters and satellite detections by minimization of the residual in a fire spread model. *Lecture Notes in Computer Science*, 10861:711–723, 2018. Proceedings ICCS 2018, Part II.

Haley, J., A. Farguell Caus, **A. K. Kochanski, S. Schranz,** and **J. Mandel**, Data Likelihood of Active Fires Satellite Detection and Applications to Ignition Estimation and Data Assimilation, *Advances in Forest Fire Research 2018*, D. X. Viegas (Ed.), University of Coimbra Press, (to appear).

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B. Abbreviations and Acronyms

AFE: Association of Fire Ecology
ALS: Airborne Lidar Scanner
AMSR-E: Advanced Microwave Scanning Radiometer-EOS
ARC: Ames Research Center
ARL: Application Readiness Level
ARSET: Applied Remote Sensing Training
ASP: Applied Sciences Program
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
BLM: Bureau of Land Management
CAL FIRE: California Department of Forestry and Fire Protection
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CHISLIC: Creating Hybrid Structure from LANDFIRE/Lidar Combinations
DEM: Digital Elevation Model or 3-D representation of a terrain's surface
DLR: German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)
DOI: Department of the Interior
EES: Emission Estimation System
EO: Earth Observing
EPA: United States Environmental Protection Agency
ESA: European Space Agency
ESD: Earth Science Division
FIREX-AQ: Fire Influence on Regional to Global Environments and Air Quality
FY: fiscal year
GEO: Group on Earth Observations
GEOSS: Global Earth Observation System of Systems
GIS: geographic information system
GLAS: Geoscience Laser Altimeter System
GOES: Geostationary Operational Environmental Satellite
GOFC-GOLD: Global Observation of Forest and Land Cover Dynamics
GTAC: Geospatial Technology Center
GWIS: Global Wildfire Information System
IAWF: International Association of Wildland Fire
JFSP: Joint Fire Science Program
JRC: Joint Research Center
LANDFIRE: Landscape Fire and Resource Management Planning Tools
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

NCE: No Cost Extension
NDVI: Normalized Difference Vegetation Index
NDWI: Normalized Difference Water Index
NIFC: National Interagency Fire Center
NOAA: National Oceanic and Atmospheric Administration
NPS: National Park Service
NWS: National Weather Service
OMI: Ozone Monitoring Instrument
PI: Principal Investigator
PM: Program Manager
RECOVER: Rehabilitation Capability Convergence for Ecosystem Recovery
RRED: Rapid Response Erosion Database
RRNRES: Rapid Response and Novel Research in Earth Science
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
SE: Socioeconomic
SMOS: Soil Moisture Ocean Salinity
TFRSAC: Tactical Fire Remote Sensing Advisory Committee
UAVSAR: Uninhabited Aerial Vehicle Synthetic Aperture Radar
USDA: United States Department of Agriculture
USFS: United States Forest Service
USGS: United States Geological Survey
VIIRS: Visible Infrared Imaging Radiometer Suite
WFAS: Wildland Fire Assessment System
WFDSS: Wildland Fire Decision Support System
WRF: Weather Research and Forecasting
WRF-SFire: WRF-Spread Fire