Summary of the USFS–NASA Joint Applications Workshop on Satellite Data for Natural Resource Management

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Introduction

A joint U.S. Forest Service (USFS)–NASA Applications Workshop took place April 29–May 2, 2019. The USFS hosted the meeting at its Geospatial Technology and Applications Center (GTAC) in Salt Lake City, UT. This unique collaborative venture bought together representatives from USFS, multiple NASA missions and projects, several NASA data centers, and other relevant entities (detailed later). The workshop provided an opportunity to increase awareness of the application of Earth observation (EO) data in support of land and natural resource management goals.

The three-day workshop served as a forum to share and demonstrate the capabilities of NASA's data products, as well as to foster connections and strengthen partnerships between the USFS, NASA, and other partners. In support of these goals, the meeting objectives were to:

- provide an overview of NASA's missions and projects, data, and tools supporting natural resource management;
- share and prioritize USFS operational needs with NASA;
- identify opportunities for collaboration; and
- expand USFS awareness of NASA's EO data sources and tools and explore ways to advance information delivery.

To address these objectives, the meeting agenda included a mix of informative sessions punctuated by breakout sessions, hands-on data tutorials, and a poster session. The summary that follows begins with a few words on the motivation for the workshop followed by a summary of the content. The full agenda and presentations can be found at the workshop website, *https://www.regonline.com/builder/site/default.aspx?EventID=2536184*.

Motivation for the Workshop

The USFS is facing natural resource management challenges exacerbated by climate change. From 1995 to 2015, the portion of the USFS annual budget devoted to fire preparedness and suppression programs increased from 16% to over 50%.[1] The average area burned by wildfires each year in the U.S. has nearly doubled since the 1990s, driven largely by declines in summer precipitation in western states. As more and more of the agency's resources are spent each year to provide the firefighters, aircraft, and other assets necessary to protect lives, property, and natural resources from catastrophic wildfires, fewer and fewer funds and resources are available to support other agency work. In addition to wildfire impacts, hundreds of millions of trees have died in the twenty-first century in the U.S. from unprecedented droughts and insect outbreaks. Recently, U.S. Department of Agriculture (USDA) designated rangelands in 25 counties in New Mexico and Arizona as primary natural disaster areas from persistent drought.

With fewer "boots on the ground," the use of remote sensing is an increasingly appealing option for gathering the key information needed to inform land-management decisions. Remote sensing and geographic information system (GIS) technologies can provide USFS natural resource managers a more cost-effective approach to monitoring natural resources on national forest lands, helping to inform key sustainable management decisions, and delivering benefits to the public.

Workshop Structure

NASA and USFS worked together to plan the workshop, with logistical support provided by NASA's Soil Moisture Active Passive (SMAP) mission and, in part, by the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) mission, with in-kind support from USFS. **Chalita Forgotson** [Science Systems and Applications Inc. (SSAI)/NASA's Goddard Space Flight Center (GSFC)—*SMAP Research Scientist* and *Applications Lead*] and **Erik Johnson** [USFS—*Program Analyst, Office of Sustainability and Climate*] co-led workshop planning and organization efforts with support from a planning committee composed of participants from USFS, NASA's GSFC, NASA/Jet Propulsion Laboratory (JPL), National Snow and Ice Data Center (NSIDC), Oak Ridge National Laboratory (ORNL),

[1] To learn more, visit *https://www.fs.fed.us/sites/default/files/2015-Fire-Budget-Report.pdf*.

Alaska Satellite Facility (ASF), U.S. Geological Survey (USGS), and Boise State University.

Four of NASA's Earth Science satellite missions were represented at the workshop: SMAP; the joint NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar [NISAR]; ICESat-2; and the Global Ecosystem Dynamics Investigation (GEDI). NASA's Carbon Monitoring System (CMS) was also represented.

The workshop focused on four key research areas that are relevant for USFS management needs which can feasibly be addressed with a suite of EO data products and tools. The areas were:

- **Soil moisture and hydrology**. Topics included soil moisture dynamics, soil productivity and erosion, inventory and condition of wetlands, riparian areas, and groundwater-dependent ecosystems, aquatic habitat suitability, and land cover and hydrological change and vulnerability.
- **Vegetation condition**. Functional areas covered included vegetation structure and function, silviculture, rangeland management, fire and fuels, wildlife habitat, forest health, and carbon monitoring.
- **Emissions and flux**. Foci in this area included fluxes and emissions of aerosols and greenhouse gases (GHGs), and carbon flux.
- **Detecting, assessing, and monitoring ecosystem vulnerabilities**. These topics arise due to changing environmental conditions, such as climate change and other abiotic stressors.

An additional category of data and tools (called *knowledge synthesis*) focused on developing integrated decision-support tools e.g., to address the need to prioritize restoration projects with positive carbon benefits), supported data formats, cloud computing (e.g., big data handling), integration (mission, tools), and technology transfer to operational organizations (e.g., USFS—for this workshop, USGS, or the National Oceanic and Atmospheric Administration (NOAA).

Overview of USFS Management Goals and Information Needs

Everett Hinkley [USFS—*National Remote Sensing Program Manager*] welcomed attendees and provided a brief overview of the workshop, emphasizing that the goals were to identify gaps between existing NASA capabilities and USFS data and information needs and ways to close those gaps.

Cynthia West [USFS—*Director of Office of Sustainability and Climate*] emphasized the impacts of climate change on water supply and forest health, resulting in new management challenges arising from prolonged droughts and more expansive wildfires. She highlighted that forest managers need to be able to: detect change in forest cover, to guide policies and practices; detect changes in forest soil moisture, to guide restoration decisions; develop an early warning system for drought stress, to prioritize treatments; detect changes in snowpack, to guide annual water management and adaptation practices; monitor streamflow, to guide water management; and measure changes in range productivity, to guide herd and range allotment. At the end of her presentation, West illustrated the gap between research and operational applications at the USFS—see **Figure 1.** The graphic demonstrates a potential path for NASA and USFS to work together in bringing more of NASA's research-level capabilities to operation at the USFS, with USFS Research and Development playing an important *technology translator* role, as referenced throughout the workshop.

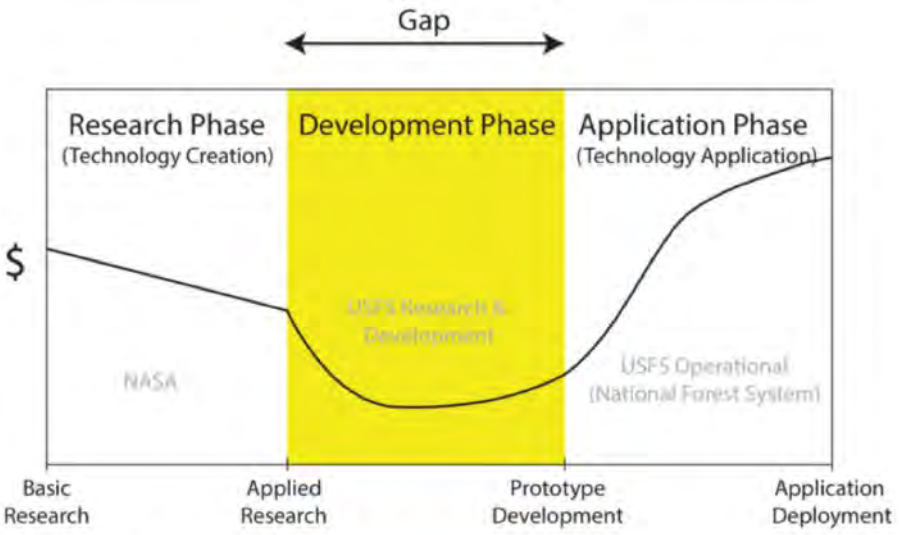

Figure 1. This figure illustrates the timeline of technology transfer, from research to operations, and the funding typically available during each stage. Funding opportunities are more widely available during the Research Phase, but decline during the Development Phase, then tend to rise again during the Application Phase. Many technologies, however, stall in this "gap" and fail to reach the Application Phase. Hence, this area of the timeline is sometimes referred to as "the Valley of Death"—e.g., *https://www.nap.edu/read/10658/chapter/4.* **Image credit:** Cynthia West

Following West's presentation, USFS managers and researchers outlined agency land management goals and information needs; current applications of EO data; and technical and systemic challenges affecting broader adoption of operational EO data applications related to a variety of topics. The presentations topics are summarized in **Table 1,** below.

The information presented made it clear that monitoring activities and management decisions take place across a range of spatial scales, from the project (single-hectare scale) and watershed level to the regional and national level. While USFS has historically relied heavily on *in situ* measurements to inform decision making, EO data are increasingly capable of providing information at spatial and temporal scales that would otherwise be too costly or difficult to collect. However, there are challenges around integrating EO data into existing decision-support systems, including spatial and temporal resolutions; data latency,[2] including the need to balance the time it takes to adopt EO data with mission lifetimes; users' awareness and understanding of EO data; and users' technical capabilities to process EO data.

Reports on NASA Missions, Projects, and Applications

Dara Entekhabi [Massachusetts Institute of Technology (MIT)—*SMAP Science Team Leader*] introduced SMAP as a mission designed to increase our understanding of the processes that link the terrestrial water, energy, and carbon cycles. The primary data products of the SMAP mission are maps of surface- and root-zone soil moisture, while soil freeze/thaw state, carbon net ecosystem exchange, calibrated brightness temperature, and vegetation optical depth products are also generated. Entekhabi identified several current and future application areas where SMAP can support USFS management needs, including forest and rangeland monitoring, hazards assessments, forest fuel load, dryness and ignition hazard, tree mortality, and carbon stocks. He also demonstrated applications of SMAP soil moisture for drought monitoring and early warning. In addition, **Andreas Colliander** [NASA/Jet Propulsion Laboratory (JPL)—*SMAP Project Team Member*] presented information on SMAP soil moisture across different vegetation types and discussed an upcoming SMAP field campaign focused on trees and forested areas. **Matt Reeves** [USFS] presented material on how SMAP soil moisture could be used to support a rangeland monitoring system.

Amy Neuenschwander [University of Texas at Austin—*ICESat-2 Land and Vegetation Data Product Lead*] provided an overview of the ICESat-2 mission and data products relevant to land managers, and reviewed the Along-track Land/Vegetation Data Product (ATL08). In addition to its focus on the poles, ICESat-2 will also collect range measurements of terrain, vegetation, and water, globally. These include estimates of vegetation height—differentiated between flooded and nonflooded vegetation (e.g., mangroves)—ocean surface height, inland water height, and nearshore bathymetry. She explained that this information has a range of potential land management applications, including biomass mapping, habitat and biodiversity monitoring, fuel load estimating, and snowpack monitoring, among others. **Birgit Peterson** [USGS] demonstrated the use of ICESat-2 data for operational wildland fuels assessment and mapping, while **Randolph Wynne** [Virginia Tech] described the application of satellite imagery and lidar data to monitoring and assessment of forest growth, removals (e.g., clearcut logging), and management intensity (e.g., thinning for fire prevention).

Ralph Dubayah [University of Maryland, College Park (UMD)—*GEDI Principal Investigator*] described GEDI as a science investigation mission that seeks to quantify forest biomass, disturbance and recovery, carbon sequestration potential, and vertical forest structure and its relationship to biodiversity. Dubayah and **John Armston** [UMD] explained how GEDI could provide valuable data for a variety of USFS applications, including county-scale biomass estimates from Forest

[2] Latency is defined as the approximate time it takes from data acquisition by a satellite until those data reach an end-user in a usable format.

Table 1. List of presenters from USFS and topics covered.

Presenter [*Title*]*	Topic
Raha Hakimdavar [*Hydrologist*]	Soil Moisture and Hydrology
Michele Slaton [*Ecologist*]	Vegetation Structure and Function
Grant Domke [*Research Forester*]	Emissions and Flux
Danny Lee [*Director of Eastern Forest Environmental Threat Center*]	Information Needs for Early Warning Systems
Kevin Megown [*Resource, Mapping, Inventory, and Monitoring Program Lead*]	Resource Mapping Inventory and Monitoring

*All presenters were from USFS.

meeting summaries

Inventory and Analysis (FIA)[3] for both calibration and validation, initialization data for prognostic ecosystem and carbon flux models, conservation and biodiversity studies, and parameterization of fire models. Even though GEDI's relatively short nominal mission length of two years may limit operational applications of its data, USFS attendees were encouraged to be creative in developing applications that demonstrate the usefulness of GEDI data to provide support for follow-on mission proposals. First delivery of GEDI data to NASA Distributed Active Archive Center (DAACs) is scheduled to occur in fall 2019.

Sassan Saatchi [JPL] and **Natasha Stavros** [JPL—*NISAR Deputy Program Applications (DPA) Co-Lead*] demonstrated how NISAR could help the USFS detect changes in biomass, disturbance, and inundation. Saatchi emphasized that NISAR will provide the first dedicated global observations to be used for monitoring changes of forest carbon stocks; forest cover from disturbance (e.g., fire, hurricane, insects, and droughts); recovery after disturbance or timber logging; and forest health and productivity, by providing habitat structure, changes of canopy water content, monitoring soil moisture changes, and drought stress.

George Hurtt [University of Maryland (UMD)—*CMS Science Team Leader*] provided an overview of NASA's Carbon Monitoring System (CMS). **Edil Sepulveda Carlo** [SSAI/GSFC—*CMS Deputy Program Applications Lead*] described CMS data products and applications. Both presentations highlighted examples of CMS data products related to carbon stocks, emissions, and flux that could be useful for USFS. **Andrew Lister** [USFS Northern Research Station] and **Hans-Erik Andersen** [USFS Pacific Northwest Research Station—*CMS Co-Investigator*] described how the USFS FIA units employ high-resolution aerial imagery for field campaign preplanning—thereby saving time and money—as well as intersurvey, image-based change estimation. As an example, he showed high-resolution aerial imagery from the National Agricultural Imagery Program.[4]

Breakout Sessions Focus on Data Gaps, Technology Challenges, and Opportunities

The workshop featured three breakout sessions on soil moisture and hydrology, emissions and flux, and vegetation structure and function. During each of these breakouts, participants discussed key opportunities and challenges around NASA technology utilization by land management agencies. Based on the soil moisture and hydrology panel discussion, the sparse forest soil moisture network limits the ability of USFS managers to monitor and detect changes to guide management decisions. Meanwhile, the vegetation structure and function panel discussion highlighted information needs on post-disturbance recovery, species specific density and canopy cover, and understory and shrub characterization and phenology. The emissions and flux panel discussion emphasized that despite the number of carbon monitoring maps available worldwide, not all maps are compatible with a country's institutional needs and readiness. All three panels agreed that there are gaps in science and applications of satellite data products, along with challenges in translation of agency language and needs, preventing managers from holistically using satellite data in their decision-support systems.

Based on these sessions, key opportunity areas for USFS and NASA collaboration may include developing a strategic framework for collaboration and coordination; supporting working groups and engaging in NASA mission Early-Adopter programs; developing needs requirements and study feasibility; and collaborating to integrate tools and data.

Tools and Hands-On Data Tutorials

The workshop also included presentations and hands-on data tutorials aimed at increasing awareness of existing USFS relevant tools and build capacities to integrate NASA data products to support natural resource management needs. The sessions showcased tools[5] to visualize, access, and download NASA data, including presentations from the USFS and several of NASAs Distributed Active Archive Centers.[6] Presenters included **Sean Healey** [USFS—*CMS Principal Investigator* and *GEDI Science Definition Team Member*], **Jeremy Kirkendall** [NASA HQ—*Senior GIS Administrator in Applied Science Program*], **Paul Moth** [National Snow and Ice Data Center (NSIDC)], **Yaxing Wei** [ORNL], **Amy FitzGerrell** [NSIDC], and **Heidi Kristenson** [Alaska Satellite Facility (ASF)].

In addition, the workshop facilitated two scenario-based, hands-on data tutorials. **Paul Moth**, **Yaxing Wei**, **Heidi Kristenson**, and **Marc Shapiro** [all from Creare, LLC] conducted a tutorial on soil moisture

[3] The USFS Forest Inventory and Analysis program is a continuous forest census that provides the information needed to assess America's forests through annual surveys. Learn more at *https://www.fia.fs.fed.us/library/fact-sheets/index.php*.

[4] The National Agriculture Imagery Program (NAIP) acquires aerial imagery during the agricultural growing seasons in the continental U.S. A primary goal of the NAIP program is to make digital orthorectified photography available to governmental agencies and the public within a year of acquisition. Learn more at *https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/index.*

[5] The tools demonstrated are described in the workshop agenda referenced earlier.

[6] To learn more about NASA's DAACs and related data distribution topics, see "Earth Science Data Operations: Acquiring, Distributing, and Delivering NASA Data for the Benefit of Society" in the March–April 2017 issue of *The Earth Observer* [**Volume 29**, **Issue 2**, pp. 4-18—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/March%20April%202017%20color%20508.pdf#page=4*]. **Note**: A Table listing the DAACs is found on pp. 8-9 of this article.

trends called "What is the trend in soil moisture and how does this compare to regional trends?" **Birgit Peterson** [USGS], **Jim Ellenwood** [USFS], and **Nolan Cate** [USFS] led a tutorial on vegetation structure assessments, called "How to leverage sampling observations for regional vegetation structure assessments (approaches and limitations)."

The vegetation structure assessments tutorial allowed participants to learn how to access and analyze an ICESat-2 vegetation data granule, which had been released exclusively for the workshop. It also highlighted prelaunch research findings from **Lana Narine** [Texas A&M University] and from two ICESat-2 Early Adopters,[7] **Nancy Glenn** [Boise State University] and **Randolph Wynne** [Virginia Polytechnic Institute and State University]. In addition, **Birgit Peterson** and **Sabrina Delgado Arias** [GSFC/SSAI—*ICESat-2 Program Applications Coordinator*] provided an overview of NASA's Early Adopter Program.

Conclusion and Follow-On Activities

The workshop was the first collaborative effort to bring together multiple representatives from NASA missions and projects, NASA DAACs, USFS, and other relevant entities. This user-driven workshop promoted and strengthened partnerships across agencies to increase use of EO data in support of land and natural resource management goals.

The workshop concluded with a plenary session to share and discuss initial findings from the workshop, prioritize identified gaps and plans to close the gaps, and solidify and plan for follow-on activities—including coauthoring the workshop proceedings. Further, USFS and NASA are working on ways to foster continued engagement, more efficiently share data, and identify further commonalities. This also includes developing formal agreements for future collaboration.

Attendees deemed the workshop successful and voiced their commitment to maintaining the momentum built during the meeting. Post-workshop meetings of the workshop planning committee are ongoing and aimed at continuing the collaboration and coordination of follow-on activities to enhance the use of NASA data products to support sustainable natural resource management.

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[7] ICESat-2 Early Adopters are groups and individuals who have a direct or clearly defined need for ICESat-2 data, who have an existing application, who have an interest in utilizing a proposed ICESat-2 product, and who are capable of applying their own resources (funding, personnel, facilities, etc.) to demonstrate the utility of ICESat-2 data for their particular system or model. To learn more, see "Early Adopters Prepare the Way to Use ICESat-2 Data" in the July–August 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 4**, pp. 31-35—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/July%20August%202015_col_508.pdf#page=31*].