Improving NASA's Earth Observation Systems and Data Programs Through the Engagement of Mission Early Adopters

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Abstract This chapter provides an overview of the NASA Early Adopter Program from the perspective of three new and planned satellite earth observing missions—SMAP, ICESat-2 and SWOT. The level of activity and engagement of the mission's applications is directly related to the maturity of the mission products and algorithms. Early Adopters were introduced to NASA through the SMAP Mission Applications Program in 2010 and it quickly became adopted by other missions (ICESat-2 2013 and SWOT in 2014). Early Adopters work with the mission scientists to test the thematic uses and applications of mission products, while providing feedback on the accomplishments and challenges of the data.

1 Overview

This chapter will give an overview of the NASA Early Adopter Program from the perspective of three missions, SMAP, ICESat-2, and SWOT. The development of a NASA Applications Program is broken up into stages that complement the development of science product development. The level of activity and engagement of the mission's applications is directly related to the maturity of the mission products and algorithms. Early Adopters were introduced to NASA through the SMAP Mission Applications Program in 2010 and it quickly became adopted by other missions (ICESat-2 2013 and SWOT in 2014). Early Adopters work with the mission scientists to test the thematic uses and applications of mission products, while providing feedback on the accomplishments and challenges of the data. Early Adopters are a subset of the mission's community of users that volunteer their efforts and resources to use prelaunch mission data in their organization. The Early

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adopter feedback, experience, and recommendations are incorporated into the mission development through strategic communication activities and outreach that help the mission scientist gain an outside perspective of how the science can be used by society. In return, the early adopters are provided guidance and mentorship from the science team in the development of their research and they are given the opportunity to present their results to NASA before any mission data become publically available, accelerating the early adopters research results, and applications after launch. NASA embraced the effort of including Early Adopters into the mission life cycle as a new standard for future missions during the SMAP mission life cycle. Understanding *how* NASA data are used in different types of applications will continue to inform future science for NASA. Incorporating user feedback during mission development and fostering Early Adopters in the development stages of the mission life cycle is also a way of accelerating product knowledge and relevance after launch. The Early adopter program is part of NASA's new approach for making science an integral part of society. Through the Early Adopters, missions incorporate feedback and leverage relationship in an effort to make science applications more impactful and relevant to the everyday users. Application Programs and Early Adopters are redefining how NASA develops science and shares knowledge with the public. The new decadal survey missions now require Early Adopters to be a part of the project architecture from conception through the end of the mission's life cycle, making sure science is not only unique and informative but useful and impactful.

2 Introduction

Satellite data provide continuous information for most Earth systems. These data are valuable for developing scientific products that explain the how earth's systems are integrated. These data can be integrated into models and decision support systems that enhance our knowledge and enable improved natural resource management, disaster prevention and response, and other benefits to society. However, the value is best understood through thematic presentations and explicit communications describing how the data impacts our everyday lives. Providing science data in a user-friendly fashion (format, language, scale, etc.) to decision-makers is a priority for NASA, particularly for the issues that surround climate and climate change. Although satellite data and products prove to be useful, it is still necessary to describe the utility of those product and link them to societal relevant topics so the science resonates with the everyday user and benefactor of the information. Asking, 'how can we identify the policies and decisions that benefit from integrating satellite data products?' is how NASA is addressing applications for future missions. One of NASA's Applied Sciences Program (ASP) strategic goals for science applications is to "ensure that NASA's flight missions plan for and support applications goals in conjunction with their science goals, starting with project planning and extending through the project life cycle" (NASA 2009). An action item related to this goal is to "evaluate the potential for current and planned NASA missions to meet societal needs through applied sciences participation in mission science teams."

United States launched its first Earth satellite on January 31, 1958, when *Explorer 1* documented the existence of radiation zones encircling the Earth. With over 20 satellites orbiting in operations today, NASA remains a leading force in scientific research. The objectives of the existing missions are strategic, identified in decadal surveys from the National Academy of Sciences, and created to meet national or agency objectives. Others are competed missions selected in response to open solicitations. All missions are challenging endeavors that seek to understand science at different capacities and applications.

These missions take years to evolve and they progress in phases (Pre Phase A through Phase F). Each phase of a mission has specific science objectives and goals it must reach before "graduating" to the next phase. Phases Pre-Phase A through D are the "pre-launch" stages of a mission where the algorithms for the science are in development and the calibration and validation of field data against those algorithms are in full effect. As the mission progresses from Phase A to Phase D, a science definition (SDT) team is selected to design the science products for the mission. During this process is when the applications of the science products are defined. Pre-launch can take anywhere from 5 to 8 years to complete before reaching launch (Phase E). Phase E is the "operational" stage of the mission life cycle, beginning at launch, Phase E lasts until the satellite is decommissioned. Phase E is where the satellite observations are developed into actual science products promised by the mission. Leading up to Phase E, the SDT also is recompleted as a new science team (ST), no longer in development of algorithms. The focus of the science team is now to calibrate and validate the actual satellite observations with the algorithms developed in the prelaunch phases of the mission's life cycle. Phase E is also the phase were the public has access to the data and can start using the mission products in their research. Because NASA is a research organization, the operational stages of a mission are designed to last 3–5 years. Some mission lasts much longer than the 3–5 year life expectancy (like MODIS) and continue to operate until it is no longer operational. However, the intent is to have 3–5 years collected and then handed off to an operational user (NOAA, USGA, DoD, etc.) for its continued use. Phase E, traditionally, is when society learns most about the applications of the science products. However, learning about applications after the design and development mission have all been made, makes it an expensive challenge for implementing feedback or making improvements to the science products. Early Adopters were introduced to NASA by the Soil Moisture Active Passive (SMAP) mission in an effort to implement feedback into the design of mission product development. The introduction of Early Adopters to NASA will forever change the way science is developed.

In 2007, the National Research Council (NRC) released the first Decadal Survey for Earth Science (National Research Council 2007). The Decadal Survey outlined research initiatives of national importance for the next decade and identified the development of applications of satellite data as a priority for all future missions.

The Applied Sciences Division responded to the NRC guidance by 'identifying applications leads for all Tier 1 Decadal Survey missions and making applications an integral part of all decadal survey missions'. The intent of this response is for those leading application for missions to engage with the project scientists during the prelaunch development process and to facilitate interaction with the relevant communities of users to ensure that mission data products will achieve maximum value. Because satellite missions can take a decade or more to develop, engaging with potential data users during the early stages of mission development is the best way to ensure that new observations meet the most urgent demands of users and have the broadest impact. Through early engagement in the prelaunch development stage of a project, each individual mission's applications program generates feedback loops that feed into the development of products making more relevant and user-friendly data products at launch. This feedback helps connects end users with science data product developers and distributors (such as the Distributed Active Archive Centers (DAACs)), increasing the visibility of the products and enabling the maximum benefit to society from satellite missions.

The 2007 Decadal Survey served as the catalyst for the development of a formalized Applications Program for NASA missions (National Research Council 2007). The NASA Applied Science Program redefined the way it conducts applications through the NRC guidance and is quickly providing examples of socioeconomic benefits of satellite data through project-specific Early Adopter Programs. The Early Adopter program is a component within each NASA Mission's Applications Program (Moran et al. 2015).

3 The Early Adopter Program

Early Adopters are an inclusive community of users, representing science, commercial, private, academic, and federal organizations that are willing to work alongside mission scientists and provide feedback to the mission scientists related to how the science product(s) are used in their field of expertise. The goal of the Early Adopter Program is to facilitate feedback on mission products prelaunch, and to accelerate the use of these products *post-launch*, by providing specific guidance and early mission data access to Early Adopters who commit to engage in applied research. The Early Adopter program is a non-funded activity that leverages existing resources, relationships, and opportunities. The program provides a framework for building a broad and well-defined user community during the prelaunch phases of the mission to maximize the use of data products after launch and to provide early insight into the range of potential uses of the mission data (Moran et al. 2014).

NASA's SMAP Mission was the first to implement an Early Adopter Program into the mission development structure during prelaunch stage of the mission and continued working with Early Adopters through operations. The overarching objective of the program was to broaden and strengthen the knowledge of the community to the science of SMAP, improve the knowledge of the applications for the science team and demonstrate the value of the data uses in ways that facilitate the science to help society. The Early Adopter program will identify communities of users for the Earth Observation (EO) missions at NASA that will communicate lessons learned for how the mission data are used in areas of society that have an impact on health, natural resources, and the economy. Early Adopters promote applications research to provide a fundamental understanding of how the mission data products can be scaled and integrated into an organization's policy, business or management activities to improve decision-making efforts (Escobar and Arias 2015). Through their use of the Early Adopter program, NASA Earth Observer (EO) missions described in this chapter create the necessary feedback loops between the mission and user communities for an understanding of the utility of mission data products within different decision-making contexts. As a result of SMAP's success with Early Adopters, the program was highlighted as a best practice in the 2012 National Academies Midterm Assessment report (http://www.nap.edu/catalog/13405/earth-science-and-applications-from-space-a-midterm-assessment-of).

All Early Adopters are unique because the conduct applied research at a variety of spatial and temporal scales, aimed towards answering targeted questions that clearly link how science is helping our everyday lives. The benefit of participating in an Early Adopter program is not only the access to early mission data but also the relationships that develop within science team and other Early Adopters (Fig. 1). Mission scientists benefit greatly from Early Adopter feedback, gaining perspective on the utility and challenges of the mission data, while they are still in development. Using feedback early in mission development allows for corrections and adjustments to data products can be made without an increased cost to the mission. These adjustments address things like latency, format and resolution, optimizing cost, and improving the mission understanding of uses of products after launch.

Feedback provides opportunity for improvements to data products not only through mission product design but also data delivery. One example of this improvement comes from the 2012 community assessment of the SMAP community (Brown and Escobar 2014). Here the goal of the assessment was to solicit data requirements, accuracy needs and current understanding of the SMAP mission by the user community. The SMAP user community was asked to describe accuracy needs for spatial, temporal, and latency characteristics of their data use and applications. The results of the assessment identified gaps in the fields of scientific research, operations, and those involved in public policy and decision-making. The results showed 80 % of the reviewers were involved in carrying out soil moisture related research, and 60 % of those reviewers stated that they were not involved policy or decision-making applications (Brown and Escobar 2014). By making the Google Earth file format, (KMZ), a standard format for SMAP data product, the mission enabled policy and decision-making communities who use satellite data, to use a more familiar format for applying SMAP to their efforts. Feedback such as this continues to bring value to NASA and the applications of mission data.

Participants in the Early Adopter program not only gain exclusive access to early mission data but they get increased engagement with the mission science team. The

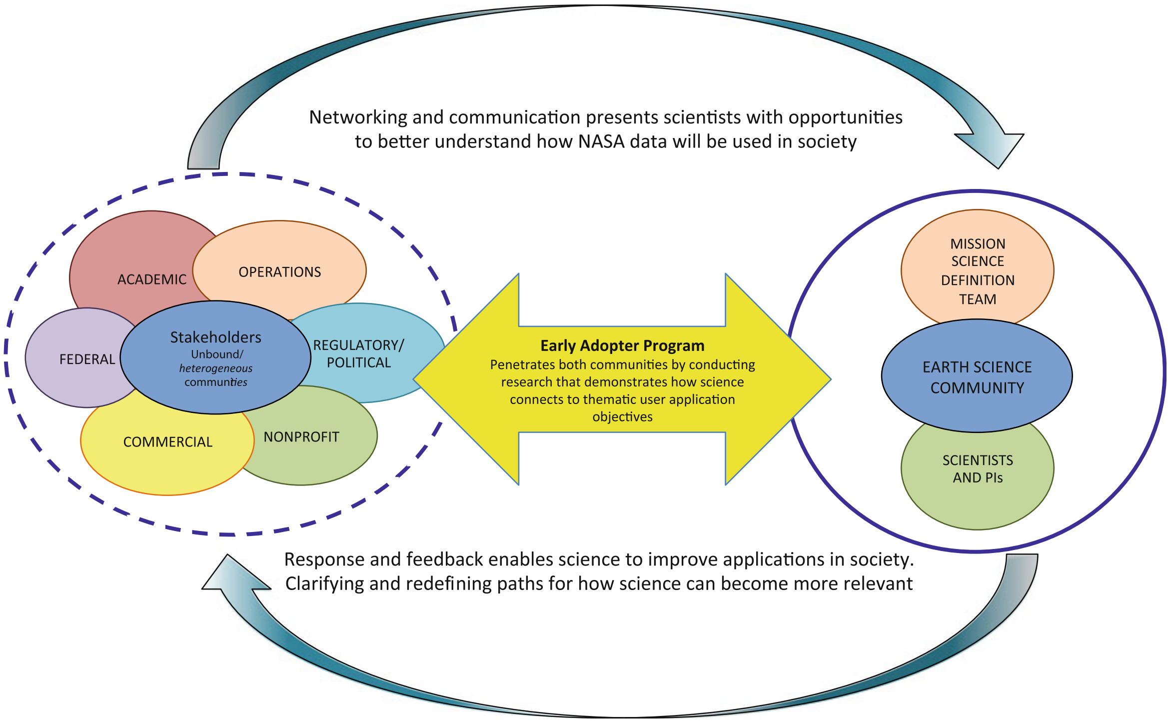


Fig. 1 Early Adopter Program Schematic. Early Adopters penetrate stakeholder groups and the Earth Science community through research that demonstrates how science connects to thematic user application objectives

early mission data provides an advanced into what the mission will produce after launch. This gives the Early Adopter time to prepare and develop methods for ingesting the data; cutting back on time and resources needed had waited to adopt the data after launch. Early Adopters benefit from early mission science and technology to improve their operating or decision-making systems. Both the mission scientists and the Early Adopters gain the unique opportunity to develop relationships that help identify the impact of science and implement lessons learned that reveal products that inform societally relevant applications.

How an Early Adopter Program is implemented and how it evolves is unique to each mission and the science objectives of that mission. NASA's SMAP Mission, the Ice Cloud and Elevation Satellite (ICESat-2) Mission and Surface Water and Ocean Topography (SWOT) Mission have each designed their Early Adopter Program in accordance with the mission science objectives and a targeted user community. Throughout the life of the program, the applications of the mission science and the targeted community expand to include new applications and users organically. The SMAP, ICESAt-2, and SWOT projects are currently at different stages in the project life cycle, therefore each project has different activities they are conducting with their Early Adopter community. All three missions use their Early Adopter program as bridges between the mission science and the end users providing thematically specific sample of how the mission science will benefit from their research objective, which is directly linked to a policy or decision process that is relevant to the user community. The objectives of this chapter are to provide you an understanding of NASA's Early Adopter Program, demonstrate how the program works for three different NASA missions, and give examples of the type of research Early Adopters are conducting for missions at different phases of the mission life cycle.

4 Examples of Mission Early Adopters and Case Studies

The Early Adopter programs described below are a learning experience that provide direction for how mission planning is conducted at NASA and setting some context for the next NRC decadal survey in 2017.

5 NASA's SMAP Mission

One of the first missions recommended by the NRC decadal survey was the SMAP mission (Fig. 2), launched on January 31 2015. The SMAP mission is designed to provide global soil moisture and freeze–thaw measurements from space for applications in fields of weather, climate, drought, flood, agricultural production, human health, and national security. The SMAP mission provides high quality; daily, global soil moisture data, which have both high science and applications value. SMAP measurements are used to enhance the understanding of processes that link

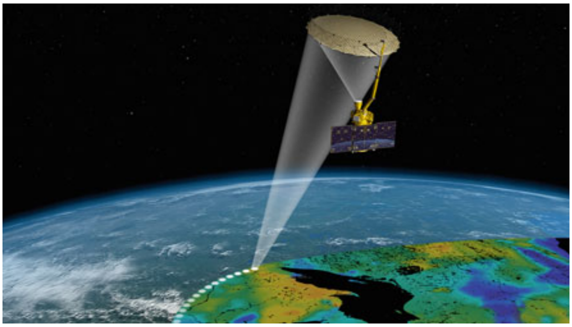


Fig. 2 SMAP Satellite Image Credit: NASA JPL

the water, energy, and carbon cycles, and to extend the capabilities of weather and climate prediction models (Brown et al. 2012). The satellite orbit provides an 8-day revisit with optimum coverage of global land area at 3-day average intervals.

The range of applications in weather, flooding, drought, agriculture, health, and national security for SMAP are defined partly by the spatial resolution and latency of the SMAP products, ranging from approximately 1–3 km for the synthetic aperture radar (SAR) data to the 39 km × 47 km radiometer data, nominally referred to as 40-km resolution (Moran et al. 2015). The high resolution of the radar is critical for accurate determination of freeze–thaw state, and the low-resolution radiometer measurements are key to deriving the soil moisture product. The radar and radiometer measurements are combined to generate a mid-resolution product that optimizes the resolution and accuracy attributes of the radar and radiometer. Sadly, after 10 weeks of postlaunch measurements the SMAP radar stopped transmitting on July 7 2015. In response, the SMAP Early Adopters conducted investigations of products other than soil moisture and freeze/thaw to increase the science and applications value of SMAP radiometer data stream. The Early Adopters are conducting short-term studies with the 10-week SMAP radar/radiometer product stream to report on the value of the unique SMAP radar/radiometer data for applications.

Some Early Adopters and the SMAP community are assisting to develop and test SMAP science recovery of higher resolution soil moisture and FT. The SMAP Applications Team is engaging with Early Adopters to provide feedback to the mission. This unexpected, yet important, effort will provide lessons learned to NASA Headquarters.

In 2009, SMAP Project funded the first formal Applications Program that engaged with data users (science and commercial) early enough in the mission design to have impact on the developed mission products. The SMAP Early Adopter Program was initiated in 2010 to support prelaunch applied research, which provided fundamental knowledge of how SMAP data products could be scaled and integrated into users' policy, business, and management activities to improve decision-making efforts. Since its inception, the SMAP Early Adopter Program has been recognized by NASA Headquarters as the most valuable component of the SMAP Applications Program. SMAP Early adopters are formally defined as those users who have a direct or clearly defined need for SMAP-like data and who are planning to apply their own resources to demonstrate the utility of SMAP data for their particular system or model.

The goal of the SMAP Early Adopter is to provide quantitative metrics designed to benefit the users, as well as the SMAP Project. With a total of 55 Early Adopters (Fig. 3 and Appendix 1), SMAP Early Adopters conduct research in unprecedented prelaunch preparation for SMAP applications, provided critical feedback to the mission to improve product specifications, are helping improve the distribution of products for postlaunch applications, and provide perspective to the impact SMAP data products have on societal areas of interest. After launch in early 2015, Early Adopters continued to work on their research effort with the use of real observations, each one achieving unique milestone as they progressed. Because Early Adopter feedback was so important to the mission, Phase E case studies were proposed as part of the post-launch applications efforts. Case studies are example projects that demonstrate scientific and societal impact through the efforts of the research. For SMAP Phase E case studies, select Early Adopters demonstrate how SMAP science data are (1) ingested and (2) used technically by their organization, (3) while providing feedback about any challenges, changes, or improvements to their system processes. The Phase E case studies for SMAP show the data life cycle and scientific knowledge gain from the products. Through case studies, SMAP learns about how the use of the data affects the research hypothesis of the Early Adopters but also understand if the science has the potential to impact an application or a decision. The SMAP mission plans to qualify the results for six individual case studies and publish their results after 2018. In this next section, the most recent SMAP Early Adopter case study preliminary results are presented.

Fig. 3 The logos of 55 SMAP Early Adopters

6 SMAP Early Adopter Examples

SMAP Early Adopters are a diverse and international group of scientist, engineers, manages, and entrepreneurs representing applications in a broad range of areas (Fig. 4). The examples of SMAP Early Adopters that follow provide an overview of the program and the areas of SMAP applications. The examples below as a sample of the contributions that continue to be made to the project and demonstrate the value of early mission engagement and stakeholder relationships. The project is enormously grateful for the effort of our Early Adopter community. More results, updates on Early Adopters, and biographies can be found on the SMAP Mission Applications website at http://smap.jpl.nasa.gov/science/applications/.

6.1 *Weather and Climate Forecasting*

Soil moisture information is important for temperature and precipitation forecasting. Initialization of numerical weather prediction and seasonal climate models with accurate soil moisture information enhances their prediction skills and extends their skillful lead times. Improved seasonal climate predictions benefit climate-sensitive socioeconomic activities, including water management, agriculture, fire, flood, and drought hazards monitoring. SMAP data products are used to constrain land surface models. NOAA researchers Kyle McDonald, Michael Ek, Marouane Temimi, Xiwu Zhan, and Weizhong Zhen are working together on the development of proxies for

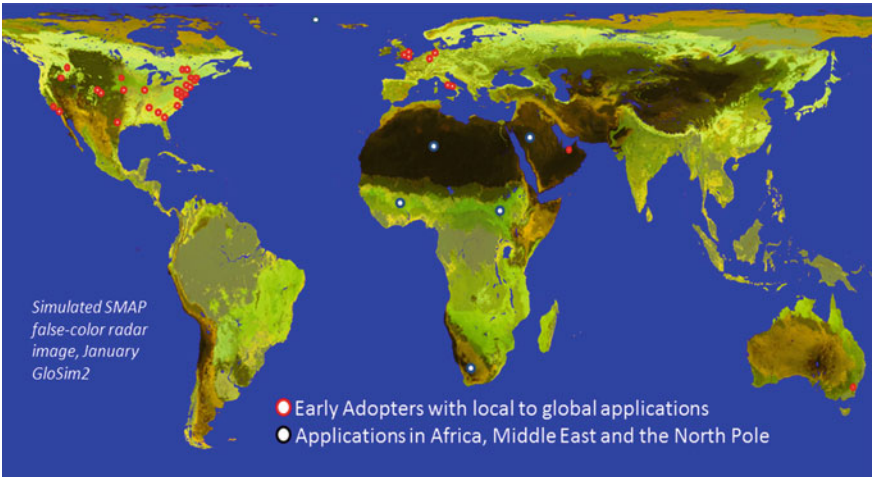


Fig. 4 A simulated image of SMAP radar data scaled backscatter triplets in the order VV, HH, and HV to a 24-bit color map and overlain with the locations of 37 of 55 early adopters conducting applied research over local-to-global domains, and specific applications in Africa, the Middle East, and the North Pole (Moran et al. 2015)

Product	Description	Gridding (Resolution)	Latency**	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	Instrument Data
L1A_Radar	Radar Data in Time-Order	-	12 hrs	
L1B_TB	Radiometer T_B in Time-Order	(36×47 km)	12 hrs	
L1B_S0_LoRes	Low-Resolution Radar σ_o in Time-Order	(5×30 km)	12 hrs	
L1C_S0_HiRes	High-Resolution Radar σ_o in Half-Orbits	1 km (1–3 km)#	12 hrs	
L1C_TB	Radiometer T_B in Half-Orbits	36 km	12 hrs	
L2_SM_A	Soil Moisture (Radar)	3 km	24 hrs	Science Data (Half-Orbit)
L2_SM_P*	Soil Moisture (Radiometer)	36 km	24 hrs	
L2_SM_AP*	Soil Moisture (Radar + Radiometer)	9 km	24 hrs	
L3_FT_A*	Freeze/Thaw State (Radar)	3 km	50 hrs	Science Data (Daily Composite)
L3_SM_A	Soil Moisture (Radar)	3 km	50 hrs	
L3_SM_P*	Soil Moisture (Radiometer)	36 km	50 hrs	
L3_SM_AP*	Soil Moisture (Radar + Radiometer)	9 km	50 hrs	
L4_SM	Soil Moisture (Surface and Root Zone)	9 km	7 days	Science Value-Added
L4_C	Carbon Net Ecosystem Exchange (NEE)	9 km	14 days	

Fig. 5 SMAP data product table

SMAP freeze/thaw data product. They plan to use SMAP data to assess the improvement in the performance of the NCEP Noah land surface model and assess the assimilation of SMAP freeze/thaw product on the performance NCEP weather forecast models. NOAA Soil Moisture Product System (SMOPS) will ingest available satellite soil moisture observations to NOAA's National Weather Prediction and other operations and research. Preliminary test shows that SMOPS could retrieve soil moisture products from L1B TB (Fig. 5) data with shorter latency, ultimately helping improve operational weather predictions.

SMAP has a total of seven Early Adopters focused on weather and climate forecasting. Table 1 lists SMAP Early Adopters who address weather related applications.

6.2 Droughts and Wildfires

Soil moisture strongly affects plant growth and hence agricultural productivity, especially during conditions of water shortage and drought. Soil moisture information can be used to predict wildfires, determine prescribed burning conditions, and estimate smoldering combustion potential of organic soils. For wildfires, SMAP soil moisture products provide more useful and accurate data on toxic air-quality events and smoke whiteouts (thus increasing transportation safety) and can inform prescribed fire activities (increasing efficiency). Early Adopters focused on drought will use data assimilation to assimilate SMAP data into land surface models. These models can be run at any scale, and the SMAP retrievals act as a constraint on the model, so while the loss of the radar does mean that there is a reduced quality of information, it is not a fundamental limitation.

Table 1 Weather and climate forecasting early adopters

Weather and climate forecasting	
Researcher	Organization
* Stephane Bélair	Meteorological Research Division, Environment Canada (EC)
* Lars Isaksen and Patricia de Rosnay	European Centre for Medium-Range Weather Forecasts (ECMWF)
* Xiwu Zhan, Michael Ek, John Simko and Weizhong Zheng	NOAA National Centers for Environmental Prediction (NCEP), NOAA National Environmental Satellite Data and Information Service (NOAA-NESDIS)
* Michael Ek, Marouane Temimi, Xiwu Zhan and Weizhong Zheng	NOAA National Centers for Environmental Prediction (NCEP), NOAA National Environmental Satellite Data and Information Service (NOAA-NESDIS), City College of New York (CUNY)
* John Galantowicz	Atmospheric and Environmental Research, Inc. (AER)
◊ Jonathan Case, Clay Blankenship and Bradley Zavodsky	NASA Short-term Prediction Research and Transition (SPoRT) Center
◊ Steven Quiring	Texas A&M University

* Early Adopters selected in 2011–2012. ◊ Early Adopters selected from 2013 forward

Famine Early Warning Systems Network (FEWS NET), was created in 1985 by the US Agency for International Development (USAID) after devastating famines in East and West Africa, FEWS NET is a leading provider of early warning and analysis on acute food insecurity and provides objective, evidence-based analysis to help government decision-makers and relief agencies plan for and respond to humanitarian crises in Central Asia and North Africa. Analysts and specialists in 22 field offices work with US government science agencies, national government ministries, international agencies, and NGOs to produce forward-looking reports on more than 36 of the world's most food-insecure countries.

The network of researchers and analysts provide monthly reports and maps detailing current and projected food insecurity, timely alerts on emerging or likely crises and specialized reports on weather and climate, markets and trade, agricultural production, livelihoods, nutrition, and food assistance.

Improved seasonal soil moisture forecasts using SMAP data will benefit famine early warning systems particularly in sub-Saharan Africa and South Asia, where hunger remains a major human health factor and the population harvests its food from rain-fed agriculture in highly monsoonal (seasonal) conditions. Improving the ability to forecast agricultural drought has the potential to improve forecasts of food-related economic stresses in local areas within this region, and this will improve both medium-term and long-term decision-making among several agencies about where, when and how to distribute food aid. In order for SMAP soil moisture data to be informative to the FEWS-NET analysis, the data need to show clear value of SMAP data for estimating agricultural drought, and relevance to forecasting local

Table 2 Drought and wildfires early adopters

Droughts and wildfires	
Researcher	Organization
* Jim Reardon and Gary Curcio	US Forest Service (USFS)
* Chris Funk, Amy McNally and James Verdin	USGS & UC Santa Barbara
◊ Brian Wardlow and Mark Svoboda	Center for Advanced Land Management Technologies (CALMIT), National Drought Mitigation Center (NDMC)
◊ Uma Shankar	The University of North Carolina at Chapel Hill—Institute for the Environment
◊ Javier Fochesatto	University of Alaska
◊ Amir AghaKouchak	University of California, Irvine
◊ Renato D'Auria	ALTEC S.p.A
◊ Rong Fu	University of Texas; SMAP contact: Randy Koster

* Early Adopters selected in 2011–2012. ◊ Early Adopters selected from 2013 forward

food availability and economic stress. Primarily, this is expected to happen by demonstrating that SMAP can facilitate improvements to monthly rainfall estimates used by FEWS-Net analysts. The primary challenge is if the value of SMAP-derived drought analysis products is not clearly demonstrated in case studies, the analysts will not incorporate this information into their routine efforts. So far, this SMAP Early Adopter project has demonstrated that SMAP generally quantitatively and qualitatively agrees with precipitation-forced model simulations of soil moisture drought. This shows that SMAP can be *expected* to do no harm. The "no-harm" analysis must be expanded to cover some very clear and specific significant past events, rather than just statistics calculated over the entire historical record. For more information about FEWS NET, please visit www.fews.net.

Table 2 lists Early Adopters who are working with SMAP data products to address applications focused on drought and wildfires.

6.3 *Flood and Landslide*

Floods affect more people globally than any other type of natural hazard, causing some of the largest economic, social, and humanitarian losses (Zurich Reinsurance 2015). Soil moisture is a key variable in water-related natural hazards including floods and landslides. High-resolution observations of soil moisture and landscape freeze/thaw status will lead to improved flood forecasts, especially for intermediate to large watersheds where most flood damage occurs. The use of SMAP data will help improve the communication and response of government agencies and emergency managers to a full range of emergencies and disasters. SMAP Early

Adopter, Dr. Luca Brocca from the Research Institute for Geo-Hydrological Protection in Italy is working with SMAP data to address flood prediction estimates to better inform the Umbria Region Civil Protection Centre and the National Department of Civil Protection. There are hosts of ways in which research can enhance flood resilience. Understanding potential flood threats to help aid in planning resources for preparedness and flood response is one way Dr. Brocca is focused on improving. Dr. Brocca's SMAP EA project aims is to understanding the capability of using SMAP soil moisture for operational hydrological applications throughout Europe. Specifically, his Early Adopter project uses soil moisture data for (1) assimilation into continuous rainfall runoff modeling to demonstrate the impact on runoff prediction with emphasis on extremes, and (2) to address the estimation of rainfall from soil moisture data. The work on data assimilation will be implemented by the Umbria Region Civil Protection Centre for improving the early warning system for flood and landslide forecasting in Umbria, Italy (Fig. 6). The use of soil moisture data to correct and/or replace precipitation estimates are applied to the entire Italian territory for the hydrometeorological and hydraulic risk assessment at the Italian Department of Civil Protection. Combining this applications research with the operational user's guide to improve communications of the flood risk to come will help people make better choice and take mitigating actions.

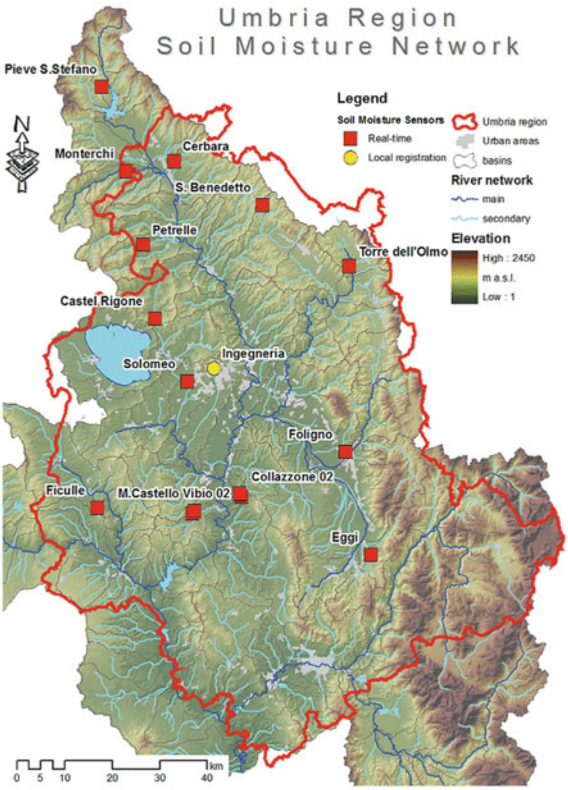
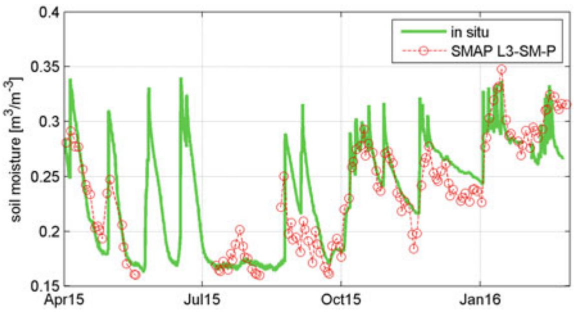


Fig. 6 Umbria Region Soil Moisture Network

Fig. 7 Soil Moisture correlation between SMAP and in situ data from Umbria Region Soil Moisture Network



As an Early Adopter, during the prelaunch stages of SMAP, Dr. Brocca worked with the mission to apply simulated data as a "fit" for his early model runs and prepare for using real SMAP observations. Using proxy data (European soil moisture data sets SMOS, (Soil Moisture Ocean Salinity) Mission), and prelaunch preparations with SMAP, Dr. Brocca was able to quickly demonstrate how the ground observations in the Umbria Region Soil Moisture Network correlated very well with the SMAP soil moisture passive data through the real-time monitoring network operating (Fig. 7). Through Dr. Brocca's work, the Umbria Region Civil Protection Centre will have a 6–8 month lead time for implementing the most up to date satellite data to inform flood planning enabling better preparedness and community planning for early warning systems that save lives and get people to safety faster. The SMAP project intends to assess how this Early Adopter research will potentially impact the decisions made by flood management and emergency response personnel at the Italian Department of Civil Protection and provides that feedback to NASA.

Table 3 lists all SMAP Early Adopters working with SMAP data products to address flood and landslide applications.

Table 3 Flood and landslides

Floods and landslides	
Researcher	Organization
* Fiona Shaw	Willis, Global Analytics
* Kashif Rashid and Emily Niebuhr	UN World Food Programme
◊ Konstantine Georgakakos	Hydrologic Research Center
◊ Luca Brocca	Research Institute for Geo-Hydrological Protection, Italian Dept. of Civil Protection
◊ Jennifer Jacobs	University of New Hampshire
◊ Huan Wu, Xiwu Zhan, and Robert F. Adler	University of Maryland, NASA Jet Propulsion Laboratory (JPL), and NOAA/NESDIS/STAR
◊ G. Robert Brakenridge	Dartmouth Flood Observatory, University of Colorado

* Early Adopters selected in 2011–2012. ◊ Early Adopters selected from 2013 forward

6.4 Agriculture Productivity

According to UN projections, the world's population could reach 9.15 billion by 2050, creating a 60 % increase in demand for food. Research on global agricultural productivity focuses on quantifying comparable productivity growth measures for countries and regions worldwide. SMAP data will provide information on water availability and environmental stress for estimating plant productivity and potential yield. The availability of direct observations of soil moisture status and the timing and extent of potential frost damage from SMAP will enable significant improvements in operational crop productivity and water stress information systems by providing realistic soil moisture and freeze/thaw observations as inputs for agricultural prediction models. Improved models will provide crucial information for decision-makers managing water and other resources, especially in data-sparse regions. Another Early Adopter for the SMAP mission is the USDA National Agricultural Statistics Service (NASS). The USDA publishes weekly national and state-level reports of crop progress, crop conditions, and soil moisture during the growing season (Bolten et al. 2009). These reports require accurate, spatially and spectrally detailed, timely satellite data and products of soil moisture, inundation, drought, etc., for monitoring and assessment of agriculture. The USDA's National Agricultural Statistics Service conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. SMAP Early Adopters Zhengwei Yang and Rick Mueller efforts focus are to study the feasibility of using SMAP mission results to support US national crop condition monitoring and other NASS operational data needs, such as crop yield modeling needs, to improve NASS cropland soil moisture monitoring results in consistency, reliability, objectivity, and efficiency, and to reduce survey burden and cost.

Production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use, and changes in the demographics of US producers. NASS currently relies heavily on 4,000 "enumerators" around the country to produce its assessments of crop conditions and soil moisture. SMAP data is a gold mine of objective, reliable and accurate moisture data for the agency. It promises to sharpen NASS's reporting and possibly replace part of that enumerator network, which would be a huge cost savings to the agency, according to Rick Mueller, head of spatial analysis research at NASS. NASS is also preparing to use SMAP data to improve its state-by-state assessments of soil moisture released in USDA's weekly crop progress reports.

Below in Table 4 are the Early Adopters working with SMAP data products to address agricultural productivity.

Table 4 Agricultural productivity

Agricultural productivity	
Researcher	Organization
* Catherine Champagne	Agriculture and Agri-Food Canada (AAFC)
* Zhengwei Yang and Rick Mueller	USDA National Agricultural Statistical Service (NASS)
* Amor Ines and Stephen Zebiak	International Research Institute for Climate and Society (IRI) Columbia University
* Jingfeng Wang, Rafael Bras, Aris Georgakakos and Husayn El Sharif	Georgia Institute of Technology (GT)
* Curt Reynolds	USDA Foreign Agricultural Service (FAS)
◇ Alejandro Flores	Boise State University
◇ Barbara S. Minsker	University of Illinois and sponsored by John Deere Inc.
◇ Lynn J. Torak	U.S. Geological Survey, Georgia Water Science Center
◇ Kamal Labbassi	Faculty of Sciences, MARSE, El Jadida, Morocco
◇ Shibendu Ray	Mahalanobis National Crop Forecast Centre, New Delhi, India
◇ Niladri Gupta	Tocklai Tea Research Institute

* Early Adopters selected in 2011–2012. ◇ Early Adopters selected from 2013 forward

6.5 Human Health

Soil moisture has a direct effect on dust generation and air quality in desert and arid environments. Improved seasonal soil moisture forecasts using SMAP data help inform early warning systems for famine in agriculture/food production, it will benefit environmental risk models and early warning systems related to the potential expansion of many disease vectors that are constrained by the timing and duration of seasonal frozen temperatures. Indirect benefits are realized, as SMAP data will enable better weather forecasts that lead to improved predictions of heat stress and virus spreading rates. SMAP Early Adopter, Dr. Hosni Ghedira, Dr. Imen Gherboudj, and Dr. Naseema from the Masdar Institute in the United Arab Emirates are working on health applications using SMAP data. The team is quantifying the effects of soil moisture on the total dust emission over the Middle East and North Africa (MENA) region (as illustrated in Fig. 8) using a parameterization scheme that requires satellite/reanalysis data, such as soil moisture, wind speed, soil texture, grain size distribution, soil erodibility, aeolian surface roughness, and vegetation cover, all either measured or estimated. This Early Adopter research is expected to improve the accuracy of estimating dust emissions. To date, Dr. Ghedira and his

Fig. 8 Dust storm in Abu Dhabi. *Source* http://forum.skyscraperpage.com

team have run an analysis of their research comparing maps from the European Space Agency's Soil Moisture and Ocean Salinity (SMOS) mission and the Advanced Microwave Scanning Radiometer—Earth Observing System (AMSR-E). The simulated dust flux shows better correlation with the SMOS soil moisture estimates than the AMSR-E soil moisture estimates, especially in the seasonal scale. Results demonstrated that when the soil moisture increases by 10 %, the dust fluxes decrease by 20–45 % over the Arabian Peninsula desert and less by 20 % over North Africa deserts. Information about increases or decreases dust fluxes can later be shared with public health organizations as an early warning of potential dust storms that could impact respiratory conditions. This Early Adopter research continues to be modified as new information from SMAP becomes available.

Table 5 shows all SMAP Early Adopters focused on health applications.

Table 5 Human health early adopters

Human health	
Researcher	Organization
* Hosni Ghedira	Masdar Institute, UAE
* Kyle McDonald and Don Pierson	City College of New York (CUNY) and CREST Institute, New York City Dept. of Environmental Protection
◇ James Kitson, Andrew Walker and Cameron Hamilton	Yorkshire Water, UK
◇ Luigi Renzullo	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
◇ David DuBois	New Mexico State University

* Early Adopters selected in 2011–2012. ◇ Early Adopters selected from 2013 forward

6.6 National Security

National security includes mobility of soldiers and equipment through data scarce remote regions around the world. Information on surface soil moisture and freeze/thaw is critical to evaluating ground mobility of military vehicles through these areas. The integration of soil moisture has been determined to be the single most critical parameter in state-of-the-ground mobility models Soil moisture and freeze/thaw data are key to a broad array of military and civil works capabilities including road and bridge building, dam and levee assessment/construction, mining, forestry, and tactical decision aid design and development. The application of SMAP data to unmanned vehicle applications is essential to effective autonomous cross-country route selection as well as route recommendations to the users of these vehicles.

SMAP Early Adopter, Mr. Derek Ward, Lockheed Martin, is working in collaboration with all U.S. Department of Defense (DoD) Early Adopters to develop comprehensive feedback for worldwide route invariant mobility predictions for friendly, neutral, and threat vehicles across the globe. The objective is to use SMAP data paired with high-resolution soil type data to provide enhanced manned/ unmanned ground vehicle mobility mapping. The group examined the use of SMAP data for assessing the movement of a variety of manned and unmanned vehicles operating in a cross-country mode in the Pacific Rim. Preliminary result from this DoD effort demonstrated success in using SMAP radar data (when available) over the mapped terrain; areas that previously looked dark (saturated and un-maneuverable in terms of vehicle weight, tire pressure and soils strength) appeared bright and "useable" and able to sustain the weight, tire pressure of specified vehicles without risk of getting stuck (Fig. 9). This detailed information was only made possible through the use of the observed soil moisture content measured by the SMAP radar paired with existing high resolution-soil maps. Since the loss of the SMAP radar, the passive product from SMAP (radiometer) is used to derive a radar analog by pairing the lower resolution radiometer soil moisture measurements with existing 1 km resolution soil type maps. Knowing the underlying soil type/saturation behaviors, elevation data, reported local weather, as well as the measured radiometer soil saturation value allows an inference to be made of the current soil type saturation state at the native resolution of the soil map (1 km). This methodology scales easily to instrument resolution, and so enables a complete exploration of the instrument resolution space, while providing breakpoints and desired specifications for future passive or active instruments. Direct comparison of the radar data to the radiometer/soil type high resolution-inference, is also possible. Vehicle specific mobility maps generated for this effort helped assess the value and potential impact of this instrument, but more importantly provided NASA with a more detailed understanding of how such soil saturation data is used operationally—defining a path for DoD, NATO, ESA, and NASA to collaborate in the future with regards to instrument specification, design, and most importantly joint funding on dual use missions. Table 6 lists the Early Adopters working in the area of National Security.

Fig. 9 Canadian Leopard Tank in Afghanistan, stuck in transit. Courtesy of Derek ward

Table 6 National security early adopters

National security	
Researcher	Organization
* John Eylander and Susan Frankenstein	U.S. Army Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL)
* Gary McWilliams, George Mason, Li, Andrew Jones and Maria Stevens	Army Research Laboratory (ARL); U.S. Army Engineer Research and Development Center (ERDC) Geotechnical and Structures Laboratory (GSL); Naval Research Laboratory (NRL); and Colorado State University (CSU)
◊ Kyle McDonald	City College of New York (CUNY)
◊ Georg Heygster	Institute of Environmental Physics, University of Bremen, Germany
◊ Lars Kaleschke	Institute of Oceanography, University of Hamburg
◊ Jerry Wegiel	Headquarters Air Force Weather Agency
◊ Matthew Arkett	Canadian Ice Service
◊ Derek Ward	Lockheed Martin Missiles and Fire Control
◊ David Keith	U.S. National Ice Center, Naval Research Laboratory
◊ Christopher Jackson and Frank Monaldo	NOAA NESDIS Center for Satellite Applications and Research (STAR)

* Early Adopters selected in 2011–2012. ◊ Early Adopters selected from 2013 forward

In addition to the application topics presented above, SMAP has Early Adopters in areas of decision services such as technology-communication, software, and policy. These commercial applications will help improve technology used for communicating information with regards to farming, drought, emergency response to weather, and carbon emissions. Table 7 lists SMAP Early Adopters in other general application for communicating and expanding.

Table 7 General application early adopters

General	
Researcher	Organization
◊ Srini Sundaram	Agrisolum Limited, UK
* Rafael Ameller	StormCenter Communications, Inc.
◊ Joey Griebel	Exelis Visual Information Solutions
◊ Kimberly Peng	Africa Soil Information Service (AfSIS) and Center for International Earth Science Network (CIESIN)
◊ Tyler Erickson and Rebecca Moore	Google Earth Engine, Google, Inc
◊ Jeff Morisette	USGS and DOI North Central Climate Science Center, the National Drought Mitigation Center
◊ Benjamin White	Integra, LLC

* Early Adopters selected in 2011–2012. ◊ Early Adopters selected from 2013 forward

The unexpected loss of the SMAP Radar has increased the importance of feedback from Early Adopters. An additional effort was recently added to the SMAP Mission Phase E Applications Plan that include using the existing 10 weeks of Radar data SMAP collected. Because of the ongoing relationships with Early Adopters, the mission has been able to communicate this need to the Early Adopter community openly in an effort to collect examples of the value of SMAP radar data to inform the next Earth Science Decadal Survey.

The SMAP Applications Program expects to see improvements across many applications but especially those focused on weather forecasting, drought and flood prediction, and agriculture productivity. Early Adopters have pushed the envelope of science applications and provided a unique and valuable perspective to the uses of SMAP products that would not have been available to the mission scientists if not for the Early Adopter engagement. The SMAP program anticipates that the Early Adopters will make discoveries that the SMAP science team did not expect, that there will be new science questions that develop from Early Adopter efforts, and that there will be unique and innovative ways people use SMAP data because of the feedback from and lessons learned by the Early Adopters.

More details on SMAP Applications, the SMAP Early Adopters and the Case Study progress can be found be going to the SMAP Applications website: http://smap.jpl.nasa.gov/science/applications/.

7 The Ice Cloud and Elevation Satellite (ICESat-2) Mission

The ICESat-2 mission (Fig. 10) is the second decadal survey mission to implement a formal Early Adopter program. The ICESat-2 Applications program follows the SMAP model and works in conjunction with the ICESat-2 Project Science Office to

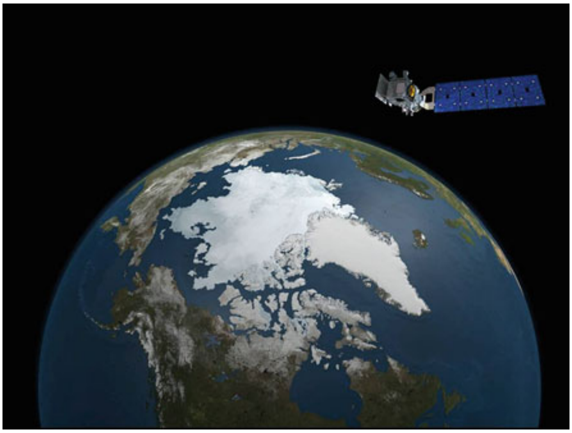


Fig. 10 ICESat-2 Satellite Image Credit: Orbital; Earth image illustrating AMSR-E sea ice; *Image Credit* NASA Scientific Visualization Studio

provide a framework for building a broad and well-defined user community during the prelaunch phases of the mission with the goal to maximize the use of the data products after launch in 2017. The application program seeks to identify applications related to the mission science objectives driving the instrument design—studies of ice sheets, sea ice, and vegetation—and those related to areas of interest to the mission for which its developing data products, but for which it does not have mandated science requirements: atmosphere, inland water, and ocean.

The ICESat-2 Applications Team seeks to *achieve the greatest possible utility of NASA's Investment in Earth Science and observations by enabling its application to practical societal needs*. The program is structured to address three overarching goals: (1) enhance applications research, (2) increase collaboration, and (3) accelerate applications. The main objective for enhancing applications research is to show the expected and actual value that the satellite data has for different end users.

In the prelaunch period of the mission, the applications program is identifying and collaborating with a variety of organizations and individuals in order to understand and clarify their specific requirements and needs for ICESat-2-like data. The following are some of the questions that the program seeks to elucidate through engagement with different stakeholders:

- **WHY?** What key decisions need to be addressed?
- **WHAT?** What are current data sources and existing data requirements?
- **WHEN?** What are latency needs?
- **HOW?** How do we translate science to end use and decision support? What methods are needed?

In 2013, the ICESat-2 mission accepted its first Early Adopter and continues to attract individuals and groups from all over the world who volunteer to test the utility of ICESat-2 for a specific decision process or operation. One year prior to its expected launch date of October 2017, the Early Adopter program now hosts 16 early adopters who are providing insight into a range of potential uses for the mission, as described below.

7.1 ICESat-2 Applications

ICESat-2 Early Adopters have identified various applications their research can potentially inform with the use of the new satellite observations. The next section describes the Early Adopter research that supports the primary objectives of the mission or those related to sea ice, ice sheets, and vegetation.

7.1.1 Sea Ice

ICESat-2 has a science objective to estimate sea ice thickness to examine ice/ocean/atmosphere exchanges of energy, mass, and moisture. It will produce monthly maps of sea ice above-water height, or freeboard, for the Arctic and Southern Oceans. Four Early Adopters (Table 8) are exploring the use of ICESat-2 for prediction of the changing ice environment. The following snapshots of their work where developed from their Early Adopter proposals.

Investigators from the U.S. Naval Research Laboratory have proposed to use ICESat-2 within the Navy's Arctic Cap NOWCAST Forecast System to improve ice edge forecasts in the northern hemisphere. Successful implementation is expected will translate to improved quality of the U.S. Navy, NOAA, and National Guard's National Ice Center's ice analysis and tactical sea ice forecasts which are of essence for navigation and arctic shipping (Fig. 11), as well as contribute to increasing the public's understanding of recent changing conditions in the Arctic (Posey et al. 2013).

Andrew Roberts and the researchers at the Naval Postgraduate School, University of Colorado at Boulder, and Los Alamos National Laboratory are working together to develop an ICESat-2 emulator that can be used in earth system models to sample simulated sea ice freeboard (sea ice above-water height) and snow cover. The emulator is expected to allow an apple-to-apple comparison of sea ice state statistics (e.g., ice concentration, ice thickness, and snow cover) with the upcoming ICESat-2 observations that would not be possible with the current sampling regime used within the models. Successful implementation of the

Table 8 Sea ice application early adopters

Prediction of changing ice environment—sea ice	
Early adopter PI(s)	Organization
* Pamela G. Posey	Naval Research Laboratory at John C. Stennis Space Center
◊ Andrew Roberts, Alexandra Jahn, Adrian Turner	Naval Postgraduate School, University of Colorado at Boulder & Los Alamos National Laboratory
◊ Andy Mahoney	Geophysical Institute, University of Alaska Fairbanks
◊ Stephen Howell	Environment Canada, Climate Research Division

* Early Adopters selected in 2013. ◊ Early Adopters selected from 2014 forward

Fig. 11 U.S. Coast Guard navigating through Sea Ice in the Arctic

ICESat-2 emulator is expected to improve the U.S. Department of Defense (DoD) (an ICESat-2 Early Adopter end user) capability and capacity to operate in the Arctic in changing climate and geostrategic situations (Roberts et al. 2014).

Lack of a reliable means for mapping landfast ice in an automated fashion from remote sensing data is one of the motivations for the Early Adopter research being conducted at the Geophysical Institute at the University of Alaska Fairbanks. Operational sea ice analysts, such as those from the NOAA National Weather Service Ice Desk, rely on their skilled interpretation to delineate landfast ice in operational ice charts. This work is considered laborious and subject to a level of objectivity that makes it challenging to analyze trends and interpret events. Use of ICESat-2 data to automate the process of deriving landfast ice extent may improve scheduling coastal deliveries and the identification of potential places of refuge for vessels needing safe anchorage in protected bays, among other applications (Mahoney 2014).

Environment Canada is exploring the use of ICESat-2 ice thickness estimates for use in a variety of research activities including seasonal and decadal model validation and optimization, ice operations, and understanding sea ice variability and change. The accuracy of sea ice thickness data is considered crucial for mid-range forecasts and correctly simulating short-term events such as ice internal pressure buildups, which are also considered very important for navigation purposes. Environment Canada will collaborate with the Canadian Ice Service to provide operationally up to date and accurate sea ice information to mariners (Howell et al. 2014).

7.1.2 Ice Sheets

ICESat-2 has two science objectives for ice sheets:

1. Quantify polar ice-sheet contributions to current and recent sea level change and the linkages to climate conditions; and

2. Quantify regional signatures of ice-sheet changes to assess mechanisms driving those changes and improve predictive ice sheet models.

Proposed Early Adopter research (Table 9) using ICESat-2 ice surface elevation products include work by the Florida Atlantic University (FAU) and the State University of New York (SUNY) at Buffalo. The following snapshots of their work were developed from their Early Adopter proposals. Figure 12 shows a typical polar ice sheet.

Early Adopter research proposed by researchers at FAU involves using the new ICESat-2 elevation information to compute a more precise past/current ice volume discharge for automatically generating an improved Dynamic DEM (DDEM). The DDEM is expected will allow for improved monitoring of sudden increases in sea level for coastal communities (Nagarajan et al. 2013).

Improved volcanic deformation monitoring and eruption forecasting are two motivations for the current Early Adopter research being conducted at the SUNY at Buffalo. ICESat-2 observations may allow for the generation of high spatial and temporal resolution Digital Elevation Models (DEMs) needed as model inputs for the prediction of evolving pyroclastic density currents. These hot avalanches of volcanic rock and gas pose a hazard during ongoing eruptive crises when topographic changes make in-filled valleys less able to contain them. Another focus of this research involves determining surface change histories related to subglacial

Table 9 Land ice application early adopters

Hazard monitoring and forecasting—land ice	
Early adopter PI(s)	Organization
* Greg Babonis	State University of New York at Buffalo
* Sudhagar Nagarajan	Florida Atlantic University

* Early Adopters selected in 2013. ◊ Early Adopters selected from 2014 forward

Fig. 12 Polar ice sheet. *Image Credit:* Christy Hansen, NASA, 2012

volcanic events in areas such as Antarctica, Iceland, and in southern Andean ice fields (Babonis et al. 2013). Table 9 lists Hazard Monitoring and Forecasting for Land Ice Early Adopters.

7.1.3 Vegetation

ICESat-2 has an objective to measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change. The mission will develop high-precision (centimeter-level) elevation measurements over land with a track density of 2 km along the equator after 2 years through off-nadir pointing.

7.1.4 ICESat-2 Data for SemiArid Vegetation Mapping

Researchers at Boise Center Aerospace Laboratory are exploring the use of ICESat-2, both independently and leveraging synergistic remote sensing data, for quantifying the composition and structural variability of short-statured semiarid vegetation like that in Fig. 13. Having estimates of semiarid ecosystem vegetation biomass is expected to allow for quantification of carbon and fuel loads, and to monitor change in regions such as the Great Basin in the western US This is of interest to various end users including the U.S. Forest Service, USDA Agricultural Research Service, and U.S. Geological Survey for long-term land management and understanding ecosystem vulnerability (Glenn et al. 2013).

Estimating above-ground biomass, tracking forest growth over time, as well as monitoring forest-related harvesting and land use are the primary motivations behind the Early Adopter research being conducted at Virginia Polytechnic Institute and State University (Virginia Tech). The Early Adopter group at Virginia Tech is developing algorithms and software to identify ground, top-of-canopy, and canopy height using simulated ICESat-2 data in preparation for the postlaunch observations. Successful processing of ICESat-2 will translate into improved accuracy of

Fig. 13 *Image Credit:* U.S. Fish and Wildlife Service, 2013

canopy height estimates for both of the government and private industry end users identified for this research: the USDA Forest Service and the American Forest Management (Wynne et al. 2013).

Early Adopter research being conducted at the Hunter College of the City University of New York proposes using ICESat-2 data within an existing web service architecture that already fuses GLAS data with Landsat-scale datasets on demand. ICESat-2 is expected to provide additional vegetation structure information at high spatial resolution that may improve the accuracies of the current vegetation products generated by a web service, including vegetation heights and maps of vertical foliage profiles (Ni-Meister 2014).

Of expressed interest to the USDA Forest Service Pacific Northwest Station Forest Inventory is the Early Adopter research proposed by the Geophysical Institute at the University of Alaska Fairbanks, which consists of analyzing the ICESat-2 prelaunch data to differentiate high latitude vegetation architecture type, landscape gradients and stands, and improve classification in two scenarios: Arctic Tundra and Boreal Forest. Successful post-launch processing of ICESat-2 data will benefit the continuous monitoring of vast regions of responsibility by the USDA Forest Service (Fochesatto and Huettmann 2015). Table 10 lists these Early Adopters, and Table 11 lists those for Inland Water and Atmosphere applications.

The table in Appendix 2 shows the work proposed by all of the ICESat-2 Early adopters. It provides an initial look at how the ICESat-2 observations can be integrated into applications of benefit to society. An ongoing goal of the Applications program is to discover new applications for the mission and identify gaps in the communities engaged. The following table shows the Early Adopters that have proposed research supporting applications relating to inland water and atmosphere.

The full ICESat-2 Applications plan and strategy can be found on the ICESat-2 applications website at http://icesat.gsfc.nasa.gov/icesat2/apps-ov.php.

Table 10 Vegetation application early adopters

Monitoring and planning for land management—vegetation	
Early adopter PI(s)	Organization
* Nancy F. Glenn	Boise Center Aerospace Laboratory, Boise State University
* Lynn Abbott & Randy Wynne	Virginia Polytechnic Institute and State University
* Wenge Ni-Meister	Hunter College of The City University of New York
◊ G. Javier Fochesatto, Falk Huettmann	University of Alaska Fairbanks

* Early Adopters selected in 2013. ◊ Early Adopters selected from 2014 forward

Table 11 Inland water and atmosphere application early adopters

Hazard monitoring and forecasting—inland water and atmosphere	
Early adopter PI(s)	Organization
* Lucia Mona	Institute of Methodologies for Environmental Analysis of the National Research Council of Italy
◇ Birgit Peterson	U.S. Geological Survey
◇ Charon Birkett	Earth System Science Interdisciplinary Center, University of Maryland
◇ Guy J-P. Schumann	Joint Institute for Regional Earth System Science and Engineering, University of California
◇ Kuo-Hsin Tseng	Center for Space and Remote Sensing Research, National Central University, Taiwan
◇ Rodrigo C.D. Paiva	Hydraulic Research Institute at Federal University of Rio Grande do Sul, Brazil

* Early Adopters selected in 2013. ◇ Early Adopters selected from 2014 forward

8 The Surface Water and Ocean Topography (SWOT) Mission

NASA and the French space agency, CNES, with contributions from the Canadian Space Agency (CSA) and United Kingdom Space Agency (UKSA) are developing new wide swath altimetry technology that will measure the height of surface water (i.e., lakes, rivers, wetlands) and the global ocean with unprecedented spatial coverage, temporal sampling, and spatial resolution compared to existing technologies. The data and information products from the Surface Water and Ocean Topography (SWOT) mission (Fig. 14), along with the airborne concept-validation project, AirSWOT, will benefit society in two critical areas; freshwater on land, and the oceans' role in climate change. It will provide important observations of the amount and variability of water stored in global lakes, reservoirs, wetlands, and river channels and will support derived estimates of river discharge. SWOT will also provide critical information necessary for water management, particularly in international hydrological basins, and will be useful for monitoring the hydrologic cycle, flooding, and characterizing human impacts on a changing environment. The SWOT mission is in development and preparing for launch in 2020.

The applied science community is a key element in the success of the SWOT mission in demonstrating the high value of the science and information products for addressing societal issues and needs. The SWOT applications framework includes a network of scientists, applications specialists, academics, and SWOT Project members to promote applications research and engage a broad community of potential SWOT data users. A defined plan and a guide describing the SWOT Early Adopters program includes providing proxies for SWOT data, including sophisticated ocean and hydrology simulators, AirSWOT data sets, and other satellite datasets as cornerstones for the program (Srinivasan et al. 2015).

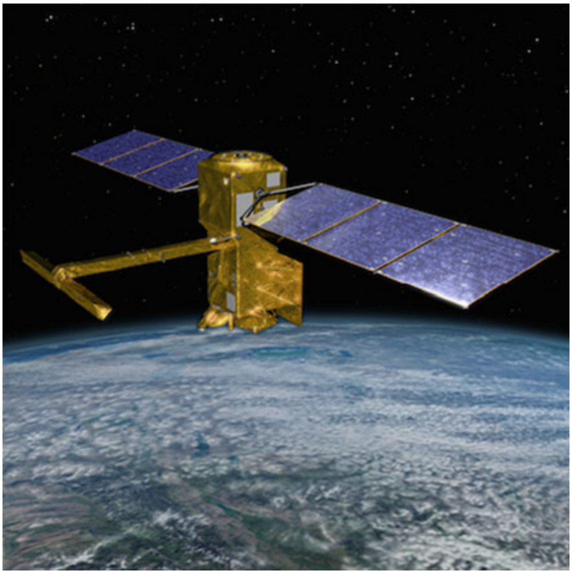


Fig. 14 Artist rendition of the SWOT spacecraft Credit: NASA/JPL

The anticipated science and engineering advances that SWOT will provide may be transformed into valuable services to decision-makers, operational users, and governing organizations focused on addressing global disaster risk reduction initiatives and potential science-based mitigation activities for water resources challenges of the future. A broad range of applications can inform inland and coastal managers and marine operators of terrestrial and oceanic phenomena relevant to their operations.

SWOT will extend existing space-based altimetry, a mature remote sensing technique with over 23 years of continuous ocean observations from the Jason-series of satellites and other international platforms. The suite of operating altimetry satellites provide highly accurate satellite-to-surface measurements, allowing for global and long-term monitoring of ocean circulation up to mesoscale (200 km and larger) processes. Many applications in scientific and operational areas can be realized. With continued altimetry observations, it has been possible to observe phenomena occurring over long time periods; the rise in global mean sea level and climatic events such as El Niño, La Niña, and the Pacific Decadal Oscillation. Moreover, as data are made available within a few hours, the measurements can be used in ocean, meteorological, and climate forecast models.

The next section describes potential SWOT Early Adopters and the best-suited EA application topics for SWOT data products.

9 SWOT Early Adopters and Potential Applications

Satellite altimetry revolutionized the study of the global oceans over two decades. Altimetry measurements have also been applied to the study of river and lake water levels but are limited by the coarse resolution of the data. Key hydrological questions on the storage of water on land and its discharge remain unanswered (Fu et al. 2009). The repeated high-resolution elevation measurements projected for SWOT would directly support science findings and operational uses by hydrologists and oceanographers who are focused on applications in the areas of ocean circulation, coastal management, and water management (Fu et al. 2009). Aside from science investigators, applications users would include representatives from the U.S. National Oceanographic and Atmospheric Administration (NOAA), the Navy, the U.S. Geological Survey (USGS), and international weather/climate organizations.

Similar to SMAP and ICESat-2, the primary goals of the SWOT applications program is to (1) promote the use of SWOT data products for the benefit of society and (2) to educate the community of potential SWOT end users and decision-makers so that they understand the mission capabilities for their specific application. In order to achieve these objectives, NASA's ASP, the mission international partners, and the SWOT applications team will facilitate the development of accessible data and information products that may be used by end users, known as the community of practice. From this community of users, SWOT Early Adopters are identified. The SWOT Early Adopter Program is modeled after the successful NASA SMAP program and aims to provide similar feedback mechanisms between the mission scientists and the community. Once the mission is launched in 2020, the SWOT Early Adopters will contribute to the mission successes by demonstrating the benefits of SWOT data to society (Srinivasan et al. 2012, 2014).

The SWOT science focus has traditionally divided the mission science objectives into the categories of hydrology and oceanography. The following are the primary areas of application for the SWOT mission:

- Hydrology: developing world water problems, food security (flooding and drought)
- Oceanography: coastal applications (circulation, impacts), marine operations support/open ocean issues
- Climate: regional capabilities, coastal and agricultural impacts

In addition to science focus areas, the operational applications and societal benefits for the SWOT mission may include;

- Water management: reservoirs, floods, ecology,
- International rivers: flood and drought management,
- Insurance: hydrodynamics and flood risks,
- Transportation: shipping, barges,
- Agriculture: water management to support irrigation,
- Energy: water availability in new regions,

- Spills and pollution: mapping of potential spill,
- Ocean and coastal circulation models,
- Climate studies: ocean circulation, heat content, regional sea level studies.

By the time of the SWOT launch in 2020, the applications team will have engaged a core group of potential users capable of incorporating the measurements and information products from SWOT in their operations. Methods for engagement and communication will be modeled after the predecessors, and then modified to fit the specific needs of SWOT. Below are three potential activities that may be common to SWOT application communities. Grouping these users into the activity areas identified can facilitate collaboration and the development of tools and models to better utilize potential SWOT data products (Srinivasan et al. 2013).

Forecasting applications may use improved models developed from potential SWOT data to support forecasts of a quantity or system status, for example, reservoir storage next month or an ocean state in two weeks. These forecasts could then be used in decision-making contexts. Important considerations for this perspective include; data latency, observations, and uncertainties used by other models.

- A potential Early Adopter for this application will be the U.S. National Weather Service (NWS) regional flood forecasting center. SWOT measurements will be used to update their system-wide storage and flow databases and to aid in operations. Other applications may include large-scale river basin monitoring to facilitate sharing of water resources across international borders, and more accurate weather and climate forecasting. Existing altimeter data can be assimilated into flood models for SWOT, and synergistic use of other satellite missions (Landsat, SMAP, SMOS, Sentinel satellites, other altimetry missions, etc.) can provide additional value for water stage and flood extent (event-based) information.

Planning/Engineering applications would utilize the entire time series of SWOT observations. Over the mission life, what range of quantities or system states (e.g., minimum, maximum, and mean of given parameters) may be measured by SWOT. At a minimum, future systems should be designed to accommodate the observations. Can a model be developed or calibrated to reproduce the SWOT observations? If so, can it be used to simulate other potential scenarios or conditions? Other important considerations for this perspective include; time series data, boundary conditions for other models, and new data for many locations around the globe.

- Applied uses in this activity area include improved flood modeling, potentially providing regional and local planners, insurance organizations, and infrastructure managers to mitigate hazards to life and property. FM Global and other insurance companies develop models to predict floods (e.g., 100-year floods) and will be among the first SWOT Early Adopters.

Management applications are similar to forecasting in data latency but less focused on modeling of future conditions and more on the current status of systems that will influence decision trees. Important considerations for this perspective include data latency and observations that may be difficult to obtain from existing data.

- Applied uses in this area may include managing freshwater for urban, industrial, and agricultural consumption, reducing environmental risk, or contributing to public policy decision-making processes. SWOT will provide water supply services and distribution companies and organizations requiring information about major reservoirs, rivers, and catchment areas, enabling better planning for future stocks. Water resources managers require constant updating of available storage, particularly when multiple reservoirs are involved. SWOT will be able to facilitate the system integration of storage changes in these circumstances. Through existing relationships with the Water Management Bureaus in California, and other western U.S. states, SWOT will seek partnership from water managers to guide an early adopter effort.

The SWOT mission concept and data will provide completely new measurement, data management, and observational paradigms for the earth systems it will measure. In addition to the mission and applications objectives noted above, the SWOT data will be useful for a variety of other scientific and operational applications as the mission science and data systems mature. Although it is impossible to foresee all the applications that could be made of the SWOT data, a number of applications are natural candidates for consideration

1. SWOT data can be complementary to the operational oceanographic altimeters to improve the understanding of global and regional sea level change.
2. SWOT data can potentially be used for mapping the thickness of floating sea ice by measuring sea ice freeboard to support marine operations and shipping.
3. SWOT can collect data over the tidally affected portions of rivers, and estuaries and wetlands, to help better understand the dynamics of freshwater/marine interaction dynamics.
4. SWOT data can be used to improve Earth's mean land/ice topography, its changes and potential land-cover classifications.
5. SWOT could provide valuable information for modeling water circulation in large lakes such as the Caspian Sea, African lakes, Lake Baikal and Lake Titicaca, and the Great Lakes of North America.

These applications will bring synergistic value to the mission's science (Rodriguez 2015). A SWOT survey to determine user needs (https://www.surveymonkey.com/r/SWOTusersurvey2015) has been designed to identify ways in which the proposed SWOT data and information products may be useful to operational, private, institutional, and other individuals and organizations. The survey helps identify the capabilities and areas of interest of potential SWOT data users and guides the Early Adopter interests for the mission. The application process is described in the 'SWOT Early Adopters Guide' is accessible from swot.jpl.nasa.gov/applications. Applications will be accepted beginning in 2016.

10 Conclusion and Way Forward with Prospects of the Early Adopter Program

The NASA Early Adopter program was started so the mission could learn more about their product applications. What evolved was a mechanism that provides feedback and guidance to the utility and value of satellite data for all of NASA. NASA data have the potential to improve models, forecasts, and operational activities, and with the understanding and advocacy of Early Adopters, the science can reach this potential faster and will less cost to the taxpayer. Applied research activities and the efforts from Early Adopters support NASA science designed to inform policy, climate, education, business, and decision-making activities that impact society. The Early Adopters provide a quantifiable impact to the uses of satellite data.

SMAP will complete its mission operations for Phase E in 2018 and provide a quantitative assessment of SMAP product value for weather, agriculture, flooding, drought, health, and national security. Additionally, the feedback from Early Adopters regarding the loss of the SMAP Radar will help inform the new decadal survey and provide quantitative examples of the long-standing need for new radar mission.

ICESat-2 continues to implement its Early Adopter Program and will soon transition into operations with approximately 20 early adopters working to inform a variety of applications. Quantitative research is lined up for operational sea ice forecasting for Arctic shipping, coastal deliveries, water resources management, monitoring of high water levels, weather hazards, sea level rise monitoring, fire fuel mapping, monitoring ecosystem, and biodiversity change over large regions (Arctic Tundra, Boreal forest), and national defense environmental forecasting.

SWOT's Early Adopter program begins in 2016. The Early Adopter targeted by SWOT will champion the first set of science application questions and begin exploring how SWOT data fit into the mission science objectives. Feedback from the Early Adopters will provide detailed accomplishments and challenges to the use of the products so the science team can help improve upon the development.

The Early Adopter program has spread across NASA missions and the 2017 Decadal Survey includes a strong focus on applications. Formal and appropriately scaled EA programs will ultimately extend to future NASA EO programs impacting capacity building programs like DEVELOP, SERVIR as well as smaller satellite missions like the Earth Venture Initiatives (EVIs). EVIs, unlike decadal survey missions (SMAP, ICESAT-2, and SWOT) operate under a shorter timeline for planning the mission and launching into operation. EVI missions have two-year process effort. EVIs like CYGNSS and ECOSTRESS are actively pursuing Early Adopter programs that selects two to three specific case studies scaled to leverage the science objectives of the mission and demonstrate the impact of the science through a specific partner in a particular are of applications. Early Adopter programs across all NASA will be modified to meet needs such as this and allow opportunity for user feedback for all NASA time lines. As NASA's culture shifts to integrate more applications into their mission life cycle, EVIs will also have the benefit of integrating with stakeholders during the mission development.

Crosscutting themes between water, energy, food, and health requires there to be scientific and end user guidance. Integrating feedback on the utility of data products produces more streamlined and user-friendly products for science and stakeholders. The Early Adopter approach provides NASA insight on how science addresses the specific needs of an ever changing society. Development of strategic partnerships with industry or private sector entities should benefit both scientific and research objectives, as well as societal needs. Building upon the cooperative partnering described in the few examples here, we are in a position to leverage the combined observational power of current and future Earth observing platforms and expand the societal applications of these assets. Already funded by the tax-paying public, the innovations of new missions and maturing data and modeling systems can support a robust business model between scientific research communities and stakeholders that can support sustainable partnerships for moving into the next decade of sustained and experimental observations.

The Early Adopter Program demonstrates that there is a deep-rooted drive among several communities to ensure that science touches lives. Early Adopters present science from a perspective we can all identify with and see the impacts of soil moisture, ice, and other data and information products in a context that makes it personal. Making science applications personal helps demonstrate that satellite data provide value to society (better health, efficiency, and cost savings). The clear value of the Early Adopter program is further demonstrated by the decision to implement similar activities across other NASA missions (future missions as well as those currently in operation).

Appendix 1

See Table 12.

Table 12 SMAP early adopter table

SMAP Early Adopters†, SMAP project contacts, and applied research topics. Many Early Adopters cross multiple applications.	
Early Adopter PI and institution SMAP Contact	**Applied Research Topic**
Weather and Climate Forecasting	
* **Stephane Bélair**, Meteorological Research Division, Environment Canada (EC); SMAP Contact: **Stephane Bélair**	Assimilation and impact evaluation of observations from the SMAP mission in Environment Canada's Environmental Prediction Systems
* **Lars Isaksen and Patricia de Rosnay**, European Centre for Medium-Range Weather Forecasts (ECMWF); SMAP Contact: **Eni Njoku**	Monitoring SMAP soil moisture and brightness temperature at ECMWF
* **Xiwu Zhan, Michael Ek, John Simko and Weizhong Zheng**, NOAA National Centers for Environmental Prediction (NCEP), NOAA National Environmental Satellite Data and Information Service (NOAA-NESDIS); SMAP Contact: **Randy Koster**	Transition of NASA SMAP research products to NOAA operational numerical weather and seasonal climate predictions and research hydrological forecasts
* **Michael Ek, Marouane Temimi, Xiwu Zhan and Weizhong Zheng**, NOAA National Centers for Environmental Prediction (NCEP), NOAA National Environmental Satellite Data and Information Service (NOAA-NESDIS), City College of New York (CUNY); SMAP Contact: **Chris Derksen**	Integration of SMAP freeze/thaw product line into the NOAA NCEP weather forecast models
* **John Galantowicz**, Atmospheric and Environmental Research, Inc. (AER); SMAP Contact: **John Kimball**	Use of SMAP-derived inundation and soil moisture estimates in the quantification of biogenic greenhouse gas emissions
◊ **Jonathan Case, Clay Blankenship and Bradley Zavodsky**, NASA Short-term Prediction Research and Transition (SPoRT) Center; SMAP Contact: **Dara Entekhabi**	Data assimilation of SMAP observations, and impact on weather forecasts in a coupled simulation environment
◊ **Steven Quiring**, *Texas A&M University*; SMAP Contact: **Dara Entekhabi**	Hurricane power outage prediction
Droughts and Wildfires	
* **Jim Reardon and Gary Curcio**, US Forest Service (USFS); SMAP Contact: **Dara Entekhabi**	The use of SMAP soil moisture data to assess the wildfire potential of organic soils on the North Carolina Coastal Plain
* **Chris Funk, Amy McNally and James Verdin**, USGS & UC Santa Barbara; SMAP Contact: **Susan Moran**	Incorporating soil moisture retrievals into the FEWS Land Data Assimilation System (FLDAS)
◊ **Brian Wardlow and Mark Svoboda**, Center for Advanced Land Management Technologies (CALMIT), National Drought Mitigation Center (NDMC); SMAP Contact: **Narendra Das**	Evaluation of SMAP soil moisture products for operational drought monitoring: potential impact on the U.S. Drought Monitor (USDM)
◊ **Uma Shankar,** The University of North Carolina at Chapel Hill – Institute for the Environment**;** SMAP Contact: **Narendra Das**	Enhancement of a bottom-up fire emissions inventory using Earth observations to improve air quality, land management, and public health decision support
◊ **Javier Fochesatto,** University of Alaska**;** SMAP Contact: **John Kimball**	Soil moisture in Alaskan ecosystem soils
◊ **Amir AghaKouchak,** University of California, Irvine**;** SMAP Contact: **Dara Entekhabi**	Integrating SMAP into the Global Integrated Drought Monitoring and Prediction System: Toward near real-time agricultural drought monitoring
◊ **Renato D'Auria,** ALTEC S.p.A**;** SMAP Contact: **Randy Koster**	Satellite soil moisture accuracy evaluation for hydrological operative forecasting (SMAHF)
◊ **Rong Fu**, University of Texas; **SMAP contact: Randy Koster**	Using SMAP data to improve drought early warning over Texas and the U.S. Great Plains
Floods and Landslides	
* **Fiona Shaw**, Willis, Global Analytics; SMAP Contact: **Robert Gurney**	A risk identification and analysis system for insurance; eQUIP suite of custom catastrophe models, risk rating tools and risk indices for insurance and reinsurance purposes
***Kashif Rashid and Emily Niebuhr**, UN World Food Programme; SMAP Contact: **Eni Njoku**	Application of a SMAP-based index for flood forecasting in data-poor regions
◊ **Konstantine Georgakakos,** Hydrologic Research Center; SMAP Contact: **Narendra Das**	Development of a strategy for the evaluation of the utility of SMAP products for the Global Flash Flood Guidance Program of the Hydrologic Research Center
◊ **Luca Brocca,** Research Institute for Geo-Hydrological Protection, Italian Dept. of Civil Protection; SMAP contact: **Dara Entekhabi**	Use of SMAP soil moisture products for operational flood forecasting: data assimilation and rainfall correction
◊ **Jennifer Jacobs,** University of New Hampshire; SMAP contact: **Narendra Das**	Satellite enhanced snowmelt flood predictions in the Red River of the North Basin

(continued)

Table 12 (continued)

◊ **Huan Wu, Xiwu Zhan, and Robert F. Adler,** University of Maryland, NASA Jet Propulsion Laboratory (JPL), and NOAA/NESDIS/STAR; SMAP contact: **Seungbum Kim**	Improving the Global Flood Monitoring System (GFMS) with GPM precipitation, SMAP soil moisture and surface water mask information
◊ **G. Robert Brakenridge**, Dartmouth Flood Observatory, University of Colorado; **SMAP contact: Seungbum Kim**	Use of SMAP data for early detection of inland flooding
Agricultural Productivity	
* **Catherine Champagne**, Agriculture and Agri-Food Canada (AAFC); SMAP Contact: **Stephane Bélair**	Soil moisture monitoring in Canada
* **Zhengwei Yang and Rick Mueller**, USDA National Agricultural Statistical Service (NASS); SMAP Contact: **Wade Crow**	US National cropland soil moisture monitoring using SMAP
* **Amor Ines and Stephen Zebiak**, International Research Institute for Climate and Society (IRI) Columbia University; SMAP Contact: **Narendra Das**	SMAP for crop forecasting and food security early warning applications
* **Jingfeng Wang, Rafael Bras, Aris Georgakakos and Husayn El Sharif,** Georgia Institute of Technology (GT); SMAP Contact: **Dara Entekhabi**	Application of SMAP observations in modeling energy/water/carbon cycles and its impact on weather and climatic predictions
* **Curt Reynolds**, USDA Foreign Agricultural Service (FAS); SMAP Contact: **Wade Crow**	Enhancing USDA's global crop production monitoring system using SMAP soil moisture products
◊ **Alejandro Flores,** Boise State University; SMAP Contact: **Dara Entekhabi**	Data fusion and assimilation to improve applications of predictive ecohydrologic models in managed rangeland and forest ecosystems
◊ **Barbara S. Minsker**, University of Illinois and sponsored by John Deere Inc.; SMAP Contact: **Wade Crow**	Comprehensive, large-scale agriculture and hydrologic data synthesis
◊ **Lynn J. Torak**, U.S. Geological Survey, Georgia Water Science Center; SMAP contact: **Dara Entekhabi and Vanessa Escobar**	Downscaling SMAP soil-moisture data to improve crop production and efficient use of energy and water resources and to assess water availability in the Apalachicola-Chattahoochee-Flint River basin
◊ **Kamal Labbassi**, Faculty of Sciences, MARSE, El Jadida, Morocco; SMAP contact: **Susan Moran**	Hydrologic models and remote sensing data to assess indicators for irrigation performance monitoring in Morocco
◊ **Shibendu Ray**, Mahalanobis National Crop Forecast Centre, New Delhi, India; SMAP contact: **Narendra Das**	Evaluation of SMAP soil moisture products for drought assessment under National Agricultural Drought Assessment and Monitoring System (NADAMS) of India
◊ **Niladri Gupta,** Tocklai Tea Research Institute; SMAP contact: **Susan Moran**	Crop management advisory service using SMAP in tea growing regions of northeast India
Human Health	
* **Hosni Ghedira**, Masdar Institute, UAE; SMAP Contact**: Dara Entekhabi**	Estimating and mapping the extent of Saharan dust emissions using SMAP-derived soil moisture data.
* **Kyle McDonald and Don Pierson**, City College of New York (CUNY) and CREST Institute, New York City Dept. of Environmental Protection; SMAP Contact: **Erika Podest**	Application of SMAP freeze/thaw and soil moisture products for supporting management of New York City's potable water supply
◊ **James Kitson, Andrew Walker and Cameron Hamilton,** Yorkshire Water, UK; SMAP Contact: **Robert Gurney**	Using SMAP L-2 soil moisture data for added value to the understanding of land management practices and its impact on water quality
◊ **Luigi Renzullo**, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia; SMAP Contact: **Jeff Walker**	Preparing the Australian Water Resources Assessment (AWRA) system for the assimilation of SMAP data
◊ **David DuBois**, New Mexico State University; **SMAP Contact: Dara Entekhabi**	Tracking and assessment of dust storm events in Southwestern US
National Security	
* **John Eylander and Susan Frankenstein**, U.S. Army Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL); SMAP Contact: **Steven Chan**	U. S. Army ERDC SMAP adoption for USACE civil and military tactical support
* **Gary McWilliams, George Mason, Li Li, Andrew Jones and Maria Stevens,** Army Research Laboratory (ARL); U.S. Army Engineer Research and Development Center (ERDC) Geotechnical and Structures Laboratory (GSL); Naval Research Laboratory (NRL); and Colorado State University (CSU); SMAP Contact: **Steven Chan**	Exploitation of SMAP data for Army and Marine Corps mobility assessment
◊ **Kyle McDonald**, City College of New York (CUNY); SMAP Contact: **Simon Yueh**	Integration of SMAP datasets with the NRL environmental model for operational characterization of cryosphere processes across the north polar land-ocean domain

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Table 12 (continued)

◊ Georg Heygster, Institute of Environmental Physics, University of Bremen, Germany; SMAP Contact: Simon Yueh	SMAP-Ice: Use of SMAP observations for sea ice remote sensing
◊ Lars Kaleschke, Institute of Oceanography, University of Hamburg; SMAP Contact: Simon Yueh	SMOS to SMAP migration for cryosphere and climate application
◊ Jerry Wegiel, Headquarters Air Force Weather Agency; SMAP contact: Peggy O'Neill	Optimization of NASA's Land Information System (LIS) at HQ Air Force Weather Agency (AFWA)
◊ Matthew Arkett, Canadian Ice Service; SMAP contact: Simon Yueh	Pre-launch evaluation of SMAP L-band SAR data for operational sea ice monitoring
◊ Derek Ward, Lockheed Martin Missiles and Fire Control; SMAP contact: Steven Chan	Manned and unmanned vehicle ground mobility predictions and route selection
◊ David Keith, U.S. National Ice Center, Naval Research Laboratory; SMAP contact: Simon Yueh	NIC cryospheric investigations in support of NASA ROSES arctic sea ice applications of geodetic imaging
◊ Christopher Jackson and Frank Monaldo, NOAA NESDIS Center for Satellite Applications and Research (STAR); SMAP Contact: Simon Yueh	Ocean surface wind and sea ice measurements derived from SMAP SAR data
General	
◊ Srini Sundaram, Agrisolum Limited, UK; SMAP Contact: Robert Gurney	Application of SMAP data products in Agrisolum - A bigdata social agritech platform
* Rafael Ameller, StormCenter Communications, Inc.; SMAP Contact: Randy Koster	SMAP for enhanced decision making
◊ Joey Griebel, Exelis Visual Information Solutions; SMAP Contact: Barry Weiss	Utilization of SMAP Products in ENVI, IDL and SARscape - Products L1 to L4
◊ Kimberly Peng, Africa Soil Information Service (AfSIS) and Center for International Earth Science Network (CIESIN); SMAP contact: Eric Wood	Input generator for digital soil mapping
◊ Tyler Erickson and Rebecca Moore, Google Earth Engine, Google, Inc.; SMAP contact: Narendra Das and Amanda Leon	Making SMAP data products available in the Google Earth Engine Analysis Platform
◊ Jeff Morisette, USGS and DOI North Central Climate Science Center, the National Drought Mitigation Center; SMAP Contact: John Kimball	Evaluation of SMAP data for incorporation into the USGS's Software for Assisted Habitat Modeling
◊ Benjamin White, Integra, LLC; SMAP Contact: John Kimball	Application of SMAP L4_C and related products to REDD+ monitoring reporting and validation (MRV)

NOTES:
† *Early Adopters* are defined as those groups and individuals who have a direct or clearly defined need for SMAP-like soil moisture or freeze/thaw data, and who are planning to apply their own resources (funding, personnel, facilities, etc) to demonstrate the utility of SMAP data for their particular system or model. The goal is to accelerate the use of SMAP products after launch by engaging in applied research that would enable integration of SMAP data in applications. This research would promote understanding of how SMAP data products can be scaled and integrated into policy, business and management activities to improve decision- making efforts.
* *Early Adopters selected in 2011-2012* agreed to engage in pre-launch research that will enable integration of SMAP data after launch in their application, complete the project with quantitative metrics prior to launch, and take a lead role in SMAP applications research, meetings, workshops, and related activities.
◊ *Early Adopters selected from 2013 forward* agreed to engage in pre-launch research that will enable integration of SMAP data after launch in their application, and to provide feedback to the SMAP project upon request concerning their experience in using the data.

Appendix 2

See Table 13.

Table 13 ICESat-2 early adopter table

Early adopter	Science theme	Regions	Early adopter title	End user(s)	Applications
Pamela G. Posey, Naval Research Laboratory SDT/Project Office Partner: Sinead L. Farrell	Sea Ice	Full Arctic Region	Use of ICESat-2 data as a Validation Source for the U.S. Navy's Ice Forecasting Models	U.S. Navy, POC: Bruce McKenzie, Naval Oceanographic Office U.S. National/Naval Ice Center, POC: LTJG David Keith	Navigation; Arctic shipping
Nancy Glenn, Boise Center Aerospace Laboratory (BCAL) SDT/Project Office Partner: Amy Neuenschwander	Vegetation	Semiarid regions; western U.S.	Improved Terrestrial Carbon Estimates with Semiarid Ecosystem Structure	USDA (US Forest Service and Agricultural Research Service, POC Dr. Stuart Hardegree) DOI (BLM, POC: Anne Halford; including the Great Basin Landscape Conservation Cooperative (LCC), and USGS, POC: Dr. Matt Germino) DoD (Charles BaunIdaho Army National Guard) Regional partners (Great Basin Research and Management Partnership and Joint Fire Sciences Program)	Long-term land management. Use estimates of aboveground biomass to quantify carbon, fuel loads, and monitor change in semiarid regions

(continued)

Table 13 (continued)

Early adopter	Science theme	Regions	Early adopter title	End user(s)	Applications
Lucia Mona, National Research Council of Italy—Institute of Methodologies for Environmental Analysis (CNR-IMAA) SDT/Project Office Partner: Steve Palm	Atmospheric Sciences	Polar Region	APRIL—Aerosol optical Properties in polar Regions with ICESat-2 Lidar	NASA, policy makers at local (Polar regions) and global (climate change) scale Examples: Aerocom, WMO	Climate; Air quality (effects on health and environment); Volcanic Hazards
Greg Babonis, SUNY at Buffalo SDT/Project Office Partner: Alex Gardner	Ice Sheets; Solid Earth	Subglacial volcanic events in areas such as Antarctica, Iceland, and in southern Andean ice fields	Applications of ICESat-2 in Volcanic and Geohazards-related research	Volcano Observatories, Vhub user group, UB GMFC (Geophysical Mass Flow Group)	Volcanic hazard mitigation, monitoring, and forecasting.
Lynn Abbott, Virginia Polytechnic Institute and State University SDT/Project Office Partner: Sorin Popescu	Vegetation	Not specified (global)	Detection of ground and top of canopy using simulated ICESat-2 lidar data	American Forest Management, POC: John Welker; USDA Forest Service, POC: John Coulston	Monitor forest-related harvesting and land use

(continued)

Table 13 (continued)

Early adopter	Science theme	Regions	Early adopter title	End user(s)	Applications
Sudhagar Nagarajan, Florida Atlantic University SDT/Project Office Partner: Bea Csatho	Ice Sheets	Not specified (global)	Incorporation of simulated ICESat-2 (MABEL) data to increase the time series and accuracy of Greenland/Antarctica Ice Sheet DDEM (Dynamic DEM)	Center for Environmental Studies, POC: Dr. Leonard Berry (works with local, national, and international government organizations on sea level rise)	Sea level rise monitoring/forecasting
Andy Mahoney, Geophysical Institute, University of Alaska Fairbanks SDT/Project Office Partner: Sinead L. Farrell, Ron Kwok	Sea Ice	Alaska's Northern Coastline; Arctic Coastal System	Repeat altimetry of coastal sea ice to map landfast sea ice extent for research and operational sea ice analysts	NOAA National Weather Service Ice Desk, POC(s): James Nelson, Meteorologist in Charge, (james.a.nelson@noaa.gov) Rebecca Heim, Ice Forecaster, (Rebecca.Heim@noaa.gov)	Operational ice charts/navigation; coastal deliveries; monitoring habitat of marine wildlife; offshore oil and gas industry roads; travel/transportation;
Charon Birkett, ESSIC, University of Maryland SDT/Project Office Partner: Mike Jasinski	Hydrology	Global (requirement: observations of lakes/reservoirs at least down to 10km2 target sizes)	The Application of Altimetry Data for the Operational Water Level Monitoring of Lakes and Reservoirs	USDA/FAS (POC: Dr. Curt Reynolds, Office of Global Analysis)	Hydrological drought; agricultural drought; monitoring of high water (flood) levels; monitoring of crop condition and production

(continued)

Table 13 (continued)

Early adopter	Science theme	Regions	Early adopter title	End user(s)	Applications
Guy Schumann, Joint Institute for Regional Earth System Science & Engineering, University of California, Los Angeles (UCLA) SDT/Project Office Partner: Mike Jasinski	Hydrology	California Bay Delta; Niger Inland Delta	Assessing the value of the ATL13 inland water level product for the Global Flood Partnership	Global Flood Partnership (GFP) (POCs: Dr. Florian Pappenberger; Global Flood Service and Toolbox Pillar; Dr. Guy Schumann, member of the Global Flood Partnership)	Prediction and managing of flood disaster impacts and global flood risk
Kuo-Hsin Tseng, SUNY at Buffalo SDT/Project Office Partner: Mike Jasinski	Hydrology	Ganges-Brahmaputra-Meghna (GBM) river basin covering India, Nepal, China, Bhutan, and Bangladesh	Using ICESat-2 Ground and Water Level Elevation Data towards Establishing a Seasonal and Flash Flood Early Warning System in the lower Ganges-Brahmaputra-Meghna River Basin	Institute of Water Modelling (POC: Zahirul Haque Khan), Bangladesh Water Development Board (POC: Engr. Zahirul Islam), Bangladesh Inland Water Transport Authority (POC: Md. Mahbub Alam)	Water resource management; observation of freshwater storage change
Andrew Roberts, Naval Postgraduate School Alexandra Jahn, University of Colorado at Boulder	Sea Ice	Central Arctic analysis domain	An ICESat-2 emulator for the Los Alamos sea ice model (CICE) to evaluate DOE, NCAR and DOD sea ice predictions for the Arctic	U.S. Department of Energy (POC: Elizabeth Hunke); National Center for Atmospheric Research (POC: Marika Holland, Jennifer Kay)	Sea ice forecasting; national defense environmental forecasting; coordinated disaster response: oil spill mitigation, field

(continued)

Table 13 (continued)

Early adopter	Science theme	Regions	Early adopter title	End user(s)	Applications
Adrian Turner, Los Alamos National Laboratory SDT/Project Office Partner: Ron Kwok				U.S. Department of Defense (POC: Wieslaw Maslowski, Ruth Preller) University of Colorado Boulder (POC: John Cassano)	campaigns; improved climate projections at all latitudes
Stephen Howell, Environment Canada SDT/Project Office Partner: Ron Kwok	Sea Ice	Canadian Arctic	Use of ICESat-2 Data for Environment Canada observational applications and prediction systems	Climate Research Division (POC: Howell) Canadian Meteorological Centre (POC: Belair) Canadian Ice Service (POC: Arkett) Canadian Centre for Climate Modelling and Analysis (POC: Derksen)	Climate data records; operational sea ice forecasting for Arctic shipping; sea ice info for mariners; weather hazards; prevention/mitigation of atmospheric catastrophes
Wenge Ni-Meister, Hunter College, The City University of New York, SDT/Project Office Partner: Sorin Popescu	Vegetation	Global	Mapping Vegetation with On-Demand Fusion of Remote Sensing Data for Potential Use of U.S. Forest Service Inventories and Fire Fuel Estimates	U.S. Forest Service	Forest inventories and fire fuel mapping

(continued)

Table 13 (continued)

Early adopter	Science theme	Regions	Early adopter title	End user(s)	Applications
Birgit Peterson, USGS Earth Resources Observation and Science Center SDT/Project Office Partner: Amy Neuenschwander	Vegetation	United States	Evaluation of ICESat-2 ATLAS data for wildland fuels assessments	U.S. Forest Service's Wildland Fire Assessment System (POC W. Matt Jolly, mjolly@fs.fed.us, Project Manager)	Wildfire decisions; fire behavior modeling variables
G. Javier Fochesatto, Geophysical Institute University of Alaska Fairbanks Falk Huettmann, Institute of Arctic Biology, University of Alaska Fairbanks SDT/Project Office Partner: Lori Magruder	Vegetation	Arctic Tundra and Boreal Forest; Interior Alaska	Using ICESat-2 prelaunch data in high latitude terrestrial ecosystems to allow for continuous monitoring of boreal forests and Arctic tundra	USDA Forest Service PNW Research Station (POC: Dr. Hans-Erik Andersen)	Land Management and monitoring over large regions (Arctic Tundra, Boreal Forest)

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