ICESat-2: Mission Overview

Why Study Ice?

Understanding the causes and magnitudes of changes in the cryosphere remains a priority for Earth science research. NASA's Ice, Cloud, and land Elevation Satellite (ICESat) mission, which operated from 2003 to 2009, pioneered the use of laser altimeters in space to study the elevation of the Earth's surface and its changes.

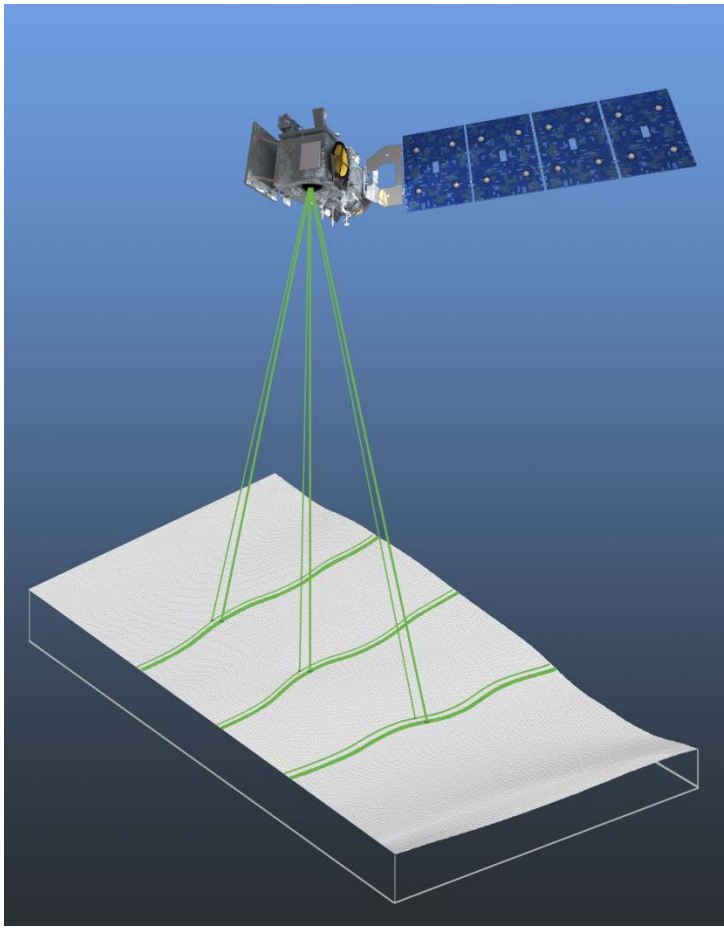
Why we need ICESat-2

As a result of ICESat's success, the National Research Council's (NRC) 2007 Earth Science Decadal Survey recommended a follow-on mission to continue the ICESat observations. In response, NASA tasked its Goddard Space Flight Center (GSFC) with developing and deploying the ICESat-2 mission - now scheduled for launch in 2017. The primary goals of the ICESat-2 mission are consistent with the NRC's directives: *to deploy a spaceborne sensor to collect altimetry data of the Earth's surface optimized to measure ice sheet elevation change and sea ice thickness, while also generating an estimate of global vegetation biomass.*

ICESat-2, slated for launch in 2017, will continue the important observations of ice-sheet elevation change, sea-ice freeboard, and vegetation canopy height begun by ICESat in 2003. Together, these datasets will allow for continent-wide estimates in the change in volume of the Greenland and Antarctic ice sheets over a 15-year period, and long-term trend analysis of sea-ice thickness.

ICESat-2: Instrument

The sole instrument on ICESat-2 will be the Advanced Topographic Laser Altimeter System (ATLAS). The ATLAS laser will emit visible, green laser pulses at a wavelength of 532 nm.
The laser is developed and built by Fibertek Inc. As ICESat-2 orbits, ATLAS will:
Split the laser into 6 beams, arranged in 3 pairs, with 3.3 km between pairs
Fire at a rate of 10 kHz - 10,000 times per second.



Instrument Design

In contrast to the original ICESat design, ICESat-2 will use a micro-pulse, multi-beam approach. This provides dense cross-track sampling to help scientists determine a surface's slope with each pass of the satellite.
The sensor will have a high pulse-repetition rate of 10 kHz (exact number still TBD). This allows the satellite to take measurements every 70 cm along the track.
These instrument features will improve the elevation estimates in sloped areas, as well as rough land surfaces such as crevasses. The ICESat-2 instrument will also improve the ability to estimate the height difference between the polar oceans and sea ice.

http://icesat.gsfc.nasa.gov/icesat2/instrument.php

ICESat-2: Status Updates

February 18, 2014:

ICESat-2 passed its Mission Critical Design Review! Now, on to building and testing software and hardware for flight.

January 17, 2014:

ICESat-2 passed its Instrument Critical Design Review! We are now moving full-speed ahead to Mission CDR and instrument I&T start.

September 6, 2013:

On Sept. 5, 2013, ICESat-2 passed its Ground Systems Critical Design Review, or CDR. An independent review board met Sept. 3-5 at Goddard Space Flight Center in Greenbelt, Md., to examine details of the entire design of the mission's ground system, including the Mission Operations Center, the Instrument Support Facility, and the Science Investigator-led Processing System.

February 28, 2013:

NASA's Launch Services Program has selected United Launch Alliance's Delta II launch vehicle to launch the ICESat-2 mission. **http://www.onlineamd.com/aerospace-NASA-ULA-ICESat-022813.aspx**

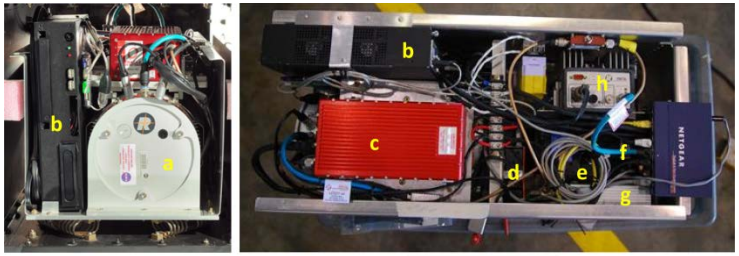
http://icesat.gsfc.nasa.gov/icesat2/status.php

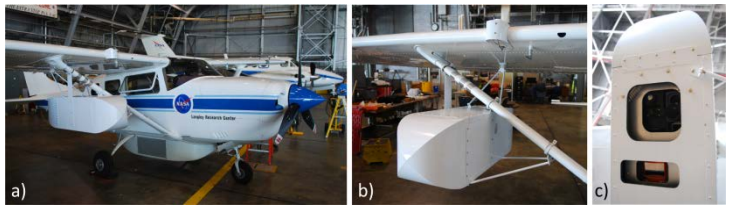
Veg Science from ICESat 2

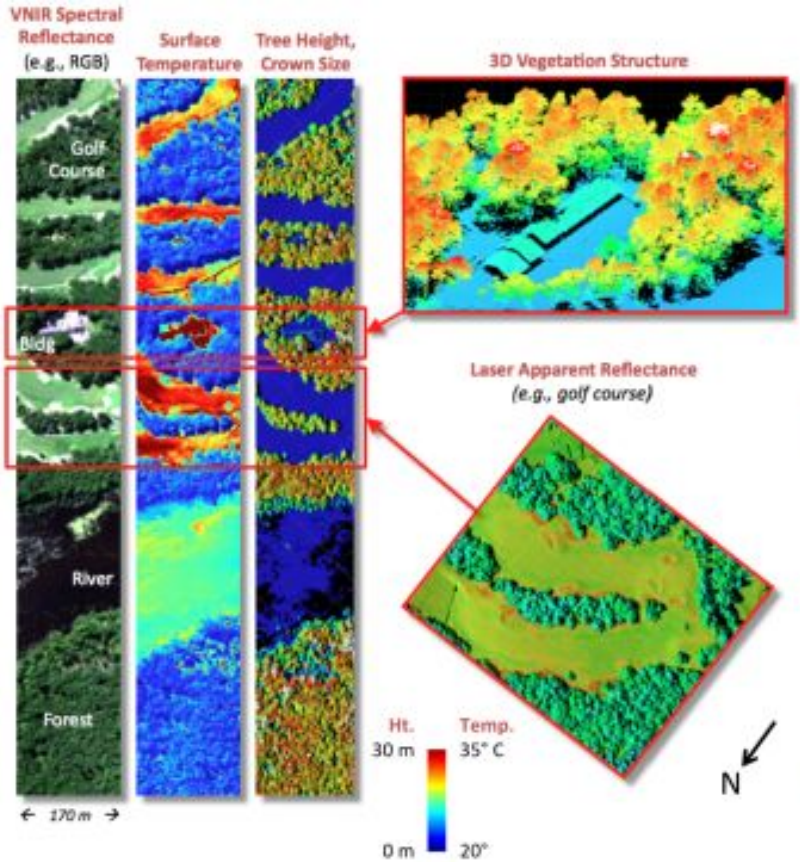
New on the I2 front? Not much. We just had a second "bake-off" where we compared veg ground and crown finding algorithms from Univ Texas, Texas A&M, and U Colorado/Boulder. Similar results among the 3 algorithms considered. About a 1.5m RMSE identifying GLiHT ground and 5.2m RMSE identifying GLiHT top-of-canopy. The study areas were GLiHT and MABEL lines flown in the SE US - predominantly pine forests. These numbers (1.5, 5.2m) should improve as we tweak algorithms, but that's where we stand now. The critical question here is, can we use I2 for canopy structural measurement (height, canopy density) and carbon/biomass assessment? I think answer to this is yes in the SE US; the ground/crown (g/c) finding algorithms are pulling out canopy structure and we'll be able to use it to estimate biomass, but I suspect it's predictive capability will be about on par with GLAS in forests like you see out your window at Goddard. What we don't know yet are two things cuz we currently don't have MATLAS data (i.e., airborne MABEL data massaged to look like ICESat-2 ATLAS photon-counting data) in dense tropical forests nor in really sparse boreal forests. My concern is that I2 will not be able to consistently penetrate tropical canopies to measure ground (>96% canopy closure) and it may not be able to see/measure very sparse, relatively short, small-canopy-diameter conifers in the boreal taiga and tundra zones (ground will be no problem there). We may be able to address that 2nd concern within the year: MABEL overflew 2 of our longer Alaska GLiHT lines a few weeks ago; these lines transect some very sparsely vegetated areas. We'll use these coincident flights and take a look at I2 capabilities in the boreal. Currently there are no plans for a tropical deployment, so that question may remain unanswered. Short rule-of-thumb answer from me: From what I see in sim results, I2 will do approximately what GLAS can do in terms of canopy structure retrievals and as regards biomass/carbon retrievals. But if all goes according to plan, I2 will acquire a hell of a lot more data spatially. Where GLAS sent down 1 beam for 30-40 days at a time twice a year (approx), I2 will be sending down 3 useful veg beams 24/7/365 for 3-5 years. In terms of spatial coverage, it's going to blow the doors off of GLAS. And remember, as with any profiler (or scanner, for that matter), we don't need to see the ground all the time; in the tropics, we can play a connect-the-dots game and infer a ground surface between good ground locations. And I2 will give us a lot more looks at holes in the canopy. It's still not a veg lidar, but it will be a far site better than GLAS - personal opinion. And if all goes well, I2 (fall 2017 launch currently, 3-5 yr mission) will be up and flying with GEDI (2019 - 2020, nominally a 2 year mission, I think, though probably more if lasers last and they keep funding the ISS past 2020). Enjoy your symposium. Everything that I wrote you above is (1) my opinion and (2) can be freely shared with anyone who's interested. Ross

G-LiHT http://gliht.gsfc.nasa.gov/

Cook, B. D., L. W. Corp, R. F. Nelson, E. M. Middleton, D. C. Morton, J. T. McCorkel, J. G. Masek, K. J. Ranson, V. Ly, and P. M. Montesano. 2013. NASA Goddard's Lidar, Hyperspectral and Thermal (G-LiHT) airborne imager. Remote Sensing 5:4045-4066, doi:10.3390/rs5084045.







MEASUREMENT CHARACTERISTICS*

Scanning lidar	
Swath width/FOV	387 m (60°)
Footprint diameter	10 cm (0.3 mrad)
Range precision	5 cm (2 σ)
Sampling density at surface	6 pulses m^{-2}
Max. returns per pulse	8
Irradiance spectrometer	
Swath width/FOV	hemispheric (180°)
Spectral range	350 to 1,100 nm
Sample/Band width	1.5 and 1.5 nm
Acquisition rate	1 Hz
Imaging spectrometer	
Swath width/FOV	310 m (50°)
Cross track pixels	1,004
Spectral range	420 to 950 nm
Sample/Band width	1.5 and 5.0 nm
Acquisition rate	50 Hz
Thermal camera	
Swath width/FOV	173 m (30°)
Imaging array size	384 × 288
Spectral range	8 to 14 µm
Sensitivity (NETD)	>50 mK at 30°C
Acquisition rate	25 Hz
Spatial resolution of data products	1 m

** Flying at 335 m AGL and 110 kt.*

Co-flights with HyPlant (PI, Uwe Rasher) in Duke Forest and Parker Tract, NC (September 2013)

Emerald Ash Borer and NASA/USDA forest health study, upstate NY (June 2014)

Tanana Valley, AK (July 2014)

Glouster Point, VA (July 2011; Mar 2012; May 2012)

Parker Track (loblolly pine plantation and Ameriflux site), near Plymouth, NC (July 2011)

NCSU Agricultural Research Plots, NC (July 2011)

Smithsonian Environmental Research Center (SERC), near Edgewater, MD (Oct 2011; Mar 2012; June 2012)

State Forests (pre- and post-harvest), Eastern Shore, MD (Oct 2011; May-June 2012)

Stereo IKONOS is a viable tool for measuring forest canopy height

Christopher Neigh, Jeffrey Masek & Bruce Cook, Code 618, NASA GSFC

Forest carbon is a critical and poorly understood component of the carbon cycle, and is related to forest height. Accuracy of results achieved are comparable to best available height measurements of forest canopies from space.

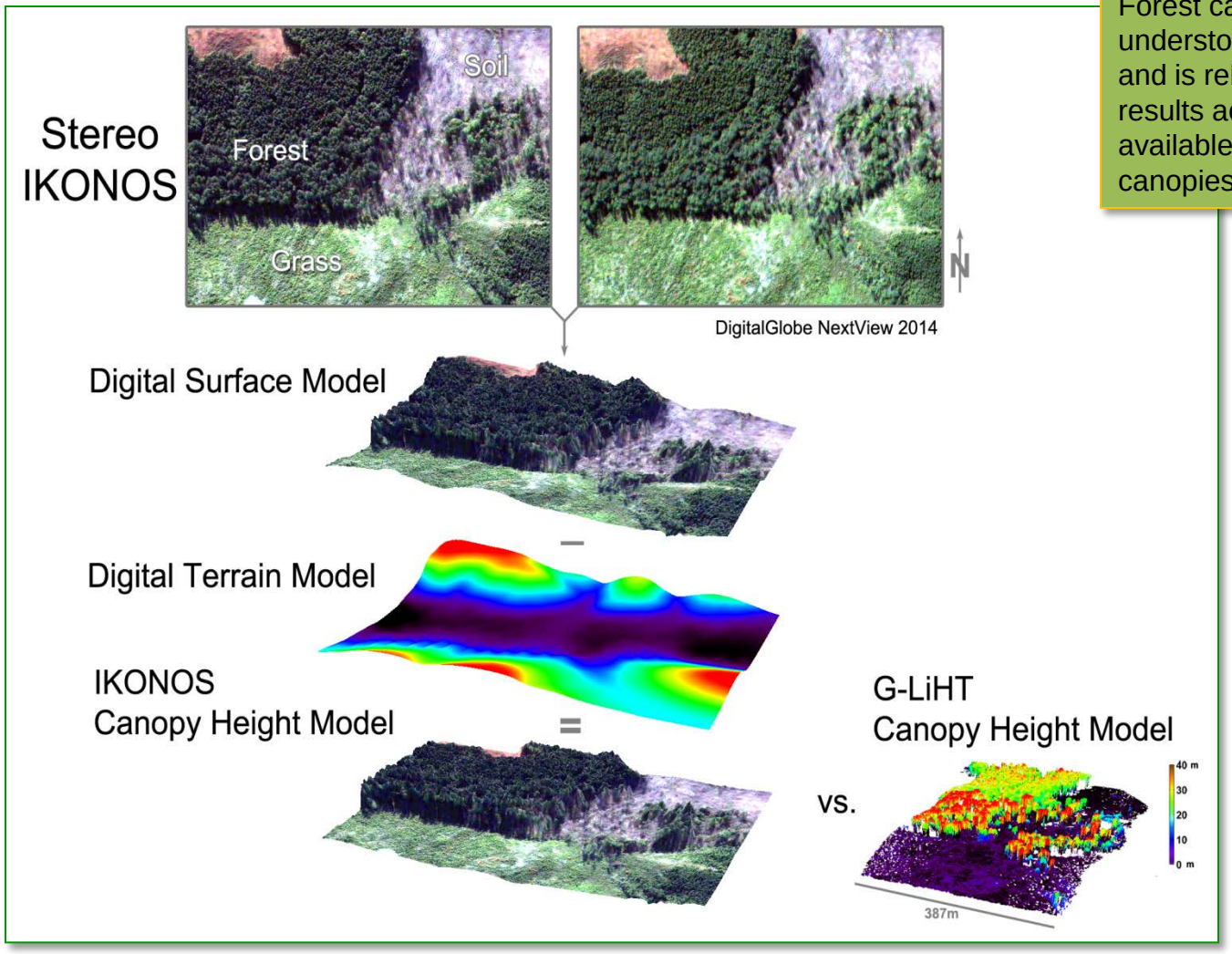


Figure 1. Methods for generating canopy height models from stereo IKONOS imagery. We compared canopy height models between IKONOS and LiDAR from G-LiHT which served as truth to evaluate the accuracy of high-resolution imagery for mapping forest canopy height.

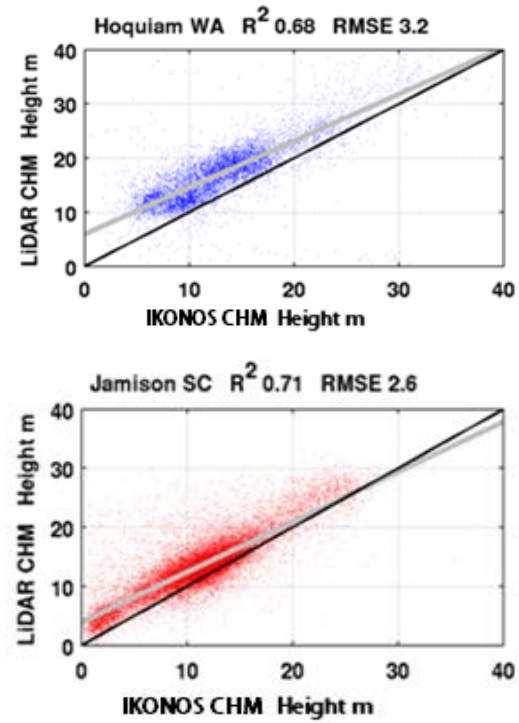


Figure 2. Results of comparison between G-LiHT canopy height models (CHMs) and IKONOS CHMs in two regions of the US.

Soil Moisture Active Passive

SMAP is one of four first-tier missions recommended by the NRC's Decadal Survey 2007. SMAP data have both high science value and high applications value. The accuracy, resolution, and global coverage of SMAP soil moisture and freeze/thaw measurements are invaluable across many science and applications disciplines including hydrology, climate, carbon cycle, and the meteorological, environmental and ecology applications communities.

https://smap.jpl.nasa.gov/

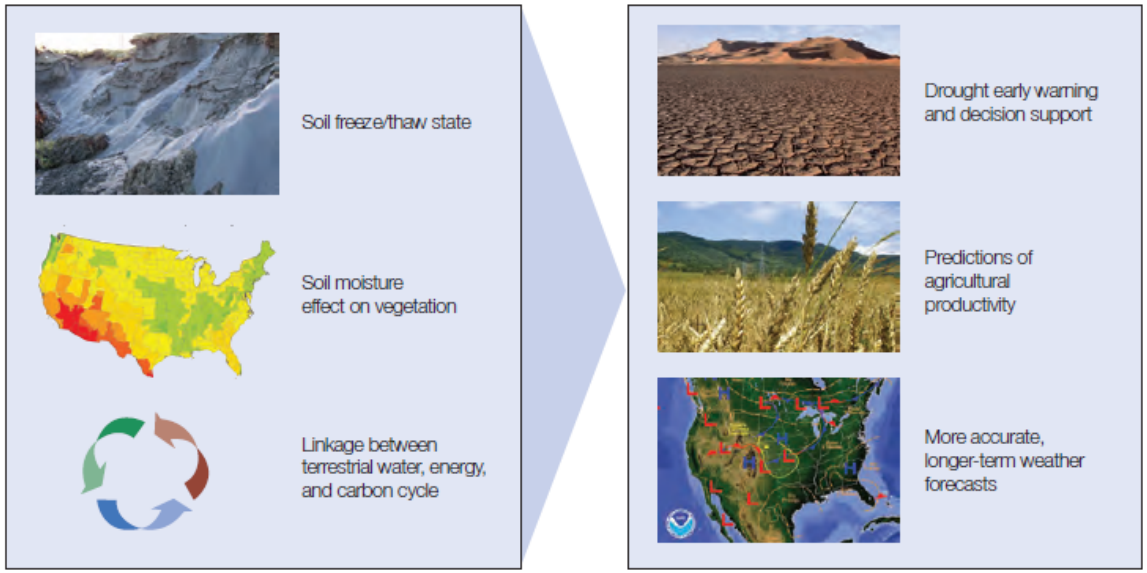
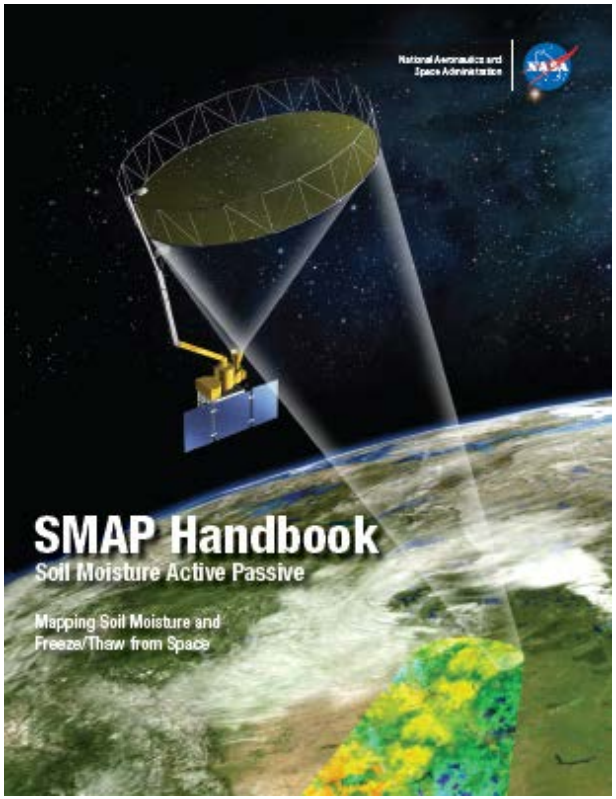
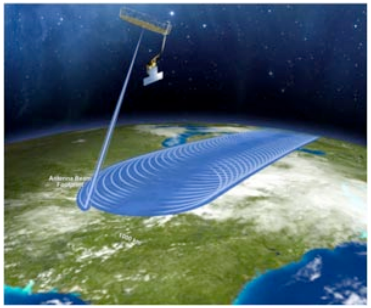


Figure 1. Some of the applications associated with SMAP data products highlighted in the Decadal Survey report.



https://smap.jpl.nasa.gov/files/smap2/SMAP_Handbook_FINAL_1_JULY_2014_Web.pdf

Instrument Overview



Radar
Frequency: 1.26 GHz
Polarizations: VV, HH, HV (not fully polarimetric)
Relative accuracy (3 km grid): 1 dB (HH and VV), 1.5 dB (HV)
Data acquisition:
- High-resolution (SAR) data acquired over land
- Low-resolution data acquired globally

Radiometer
Frequency: 1.41 GHz
Polarizations: H, V, 3rd & 4th Stokes
Relative accuracy (30 km grid): 1.3 K
Data collection:
- High-rate (sub-band) data acquired over land
- Low-rate data acquired globally

Antenna
Conically-scanning deployable mesh reflector shared by radar and radiometer
Diameter: 6 meters
Rotation rate: 14.6 RPM
Beam efficiency: ~90%
Spatial Resolution:
- Radiometer (IFOV): 39 km x 47 km
- SAR: 1-3 km (over outer 70% of swath)

Swath width: 1000 km

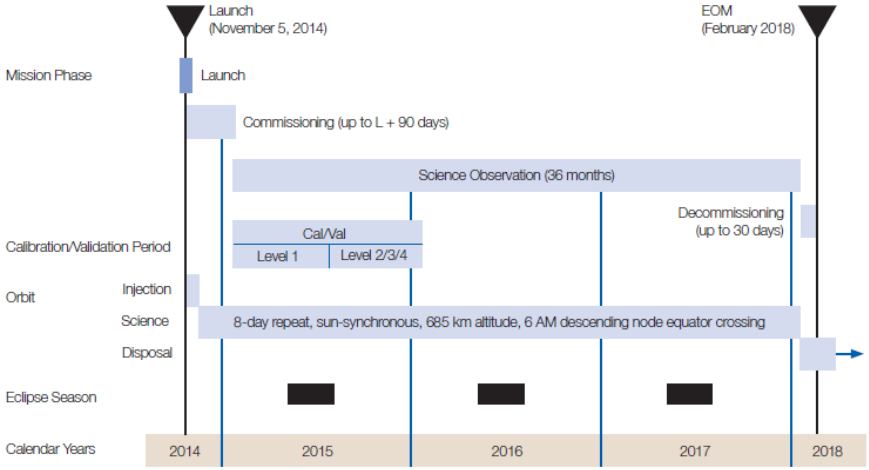


Figure 4. SMAP mission timeline.

Antenna System

Radar Data

The radar high-resolution measurement samples are created within the radar real-aperture footprint by synthetic aperture processing in range and azimuth. The synthesized single-look samples have variable spatial resolution in the azimuth direction. The single-look samples are averaged (multi-looked) onto 1-km grid pixels to form the L1C_S0_HiRes data product. The spatial resolution of the data in this product is better than 3 km over the outer 70% of the 1000-km swath.

(See Radar resolution and gridding.)

The L1C_S0_HiRes HH and VV data have uncertainty from all sources (excluding rain) of 1.0 dB or less (1-sigma) defined at 3 km spatial resolution and for surfaces of radar cross-section greater than -25 dB. The HV data have uncertainty from all sources (excluding rain) of 1.5 dB or less (1-sigma) defined at 3 km spatial resolution and for surfaces of HV radar cross-section greater than -30 dB.

Radiometer Data

The radiometer instantaneous field of view (IFOV) or 3-dB footprint is 39 km x 47 km. The radiometer L1B_TB data product includes compensation for effects of antenna sidelobes (outside the main beam), cross-polarization, Faraday rotation, atmospheric effects (excluding rain), and solar, galactic and cosmic radiation.

The L1B_TB have mean uncertainty from all sources (excluding rain) of 1.3 K or less (1-sigma) in the H and V channels, defined on the basis of binning the fore- and aft-look samples onto hypothetical swath-oriented 30 km x 30 km grid cells (a different grid is used for the actual L1C_TB data product).

Project Status

NASA initiated SMAP project formulation in 2008. The project went through design studies and formulation in its initial years, and successfully completed its Critical Design Review in July 2012. During May 2013 the project was approved to proceed into System Integration and Test (Phase D). The SMAP launch is currently scheduled for November 5, 2014. The SMAP mission is being developed by NASA's Jet Propulsion Laboratory, which is building the spacecraft, the instrument (except for the radiometer), and the science processing system. NASA Goddard Space Flight Center is providing the L-band radiometer and Level 4 science processing. The Canadian Space Agency (CSA) is also a mission partner to provide critical support to science and calibration/validation (pre- and post-launch). SMAP will be launched from Vandenberg Air Force Base in California on a Delta II launch vehicle, and will be placed into a polar sun-synchronous 6 AM/6 PM orbit with a 685 km altitude. The L-band SAR and radiometer share a 6-m mesh deployable offset-fed reflector antenna that rotates at 13 to 14.6 rpm to provide high spatial resolution with a 1000 km measurement swath that enables global coverage every 2–3 days (Figure 2). Major challenges that have been and are being addressed by SMAP include: (1) mitigation of L-band radio frequency interference to both radiometer and SAR measurements from terrestrial and other spaceborne sources; (2) use of a mesh reflector antenna for L-band radiometry measurements; (3) dynamics and control of a relatively large spinning payload by a comparatively small spacecraft bus; (4) cost-effective adaptation of an existing avionics architecture to accommodate the unique demands of a high-data-volume SAR; and (5) accommodating a relatively late in the design lifecycle selection of launch services and vehicle.

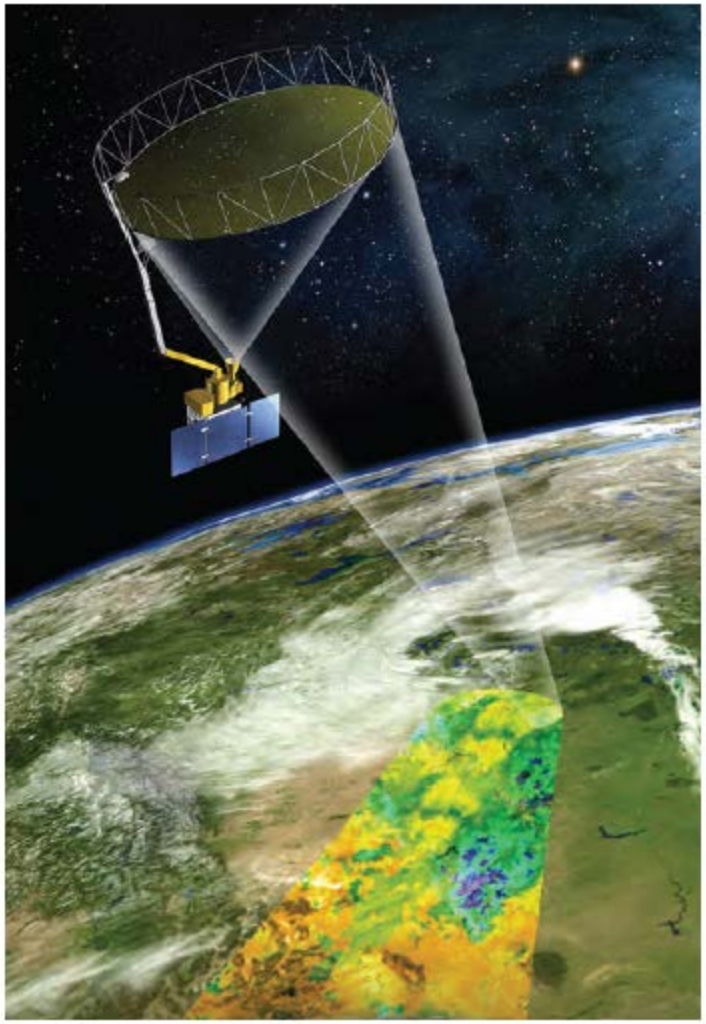


Figure 2. The SMAP observatory is a dedicated spacecraft with a rotating 6-m lightweight deployable mesh reflector. The radar and radiometer share a common antenna feed.

References

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