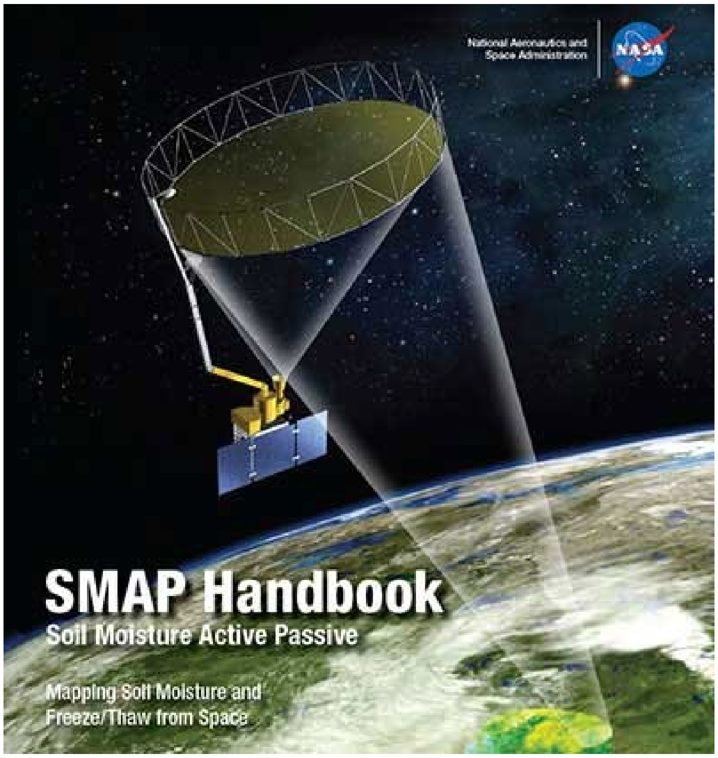
Soil Moisture Active Passive (SMAP) Mission

SMAP Handbook

"A rare characteristic of the SMAP Project is its emphasis on serving both basic Earth System science as well as applications in operational and practice-oriented communities."



Download Handbook

Contents of Full Handbook

SMAP Handbook Excerpts on ASF's Roles

The Alaska Satellite Facility (ASF) is one of four ground stations that support the SMAP mission and one of two NASA DAACs that distribute SMAP data. The SMAP baseline science data products will be generated within the project's Science Data System and made available publicly through the two NASA-designated Earth-science data centers. The ASF Synthetic Aperture Radar (SAR) Distributed Active Archive Center (DAAC) will provide Level 1 radar products, and the National Snow and Ice Data Center (NSIDC) DAAC will provide all other products. The excerpts below from the SMAP Handbook focus on ASF's roles. Read more about ASF

Ground Data System (GDS)

The primary path for commanding the SMAP observatory and returning science and engineering data is through three northern-hemisphere tracking stations and one southern-hemisphere station in Antarctica. Data return at the northern-hemisphere stations is via 11.3-m antennas located at Wallops, Virginia (WGS), Fairbanks, Alaska (ASF), and Svalbard Island, Norway (SGS). Data return at the southern-hemisphere station is via the 10-m antenna at McMurdo Station, Antarctica (MGS). The table below gives characteristics of the four stations and average contact statistics from the science orbit. Because SMAP is in a near-polar orbit, the higher latitude stations have more frequent contact opportunities.

Ground Station	Antenna	Latitude	Average # of Contacts per day*	Average Coverage Minutes/day*
Svalbard (SGS) Norway	11.3 m	78.2ºN	10.3	88.3
Fairbanks (ASF) Alaska	**11.3 m**	**64.9ºN**	**6.8**	**53.7**
Wallops (WGS) Virginia	11.3 m	37.9ºN	3.3	25.8
McMurdo (MGS) Antarctica	10.0 m	77.8ºS	10.4	90.7

ASF DAAC Support of NASA Missions

The ASF DAAC provides support for NASA and NASA-partner missions assigned to it by the Earth Science Data and Information System (ESDIS) Project. The ASF DAAC has extensive experience managing diverse airborne and spaceborne mission data, working with various file formats, and assisting user communities to further the use of SAR data.

These efforts are facilitated, in part, by ASF Scientists and Data Managers, who interact with mission teams, provide subject matter expertise, inform data and metadata formats, evaluate data structure and quality, and address data support needs. A key project component at ASF is the core product team, which provides integration of new datasets into the ASF data system and ensures efficient coordination and support of each mission. The team members have mission-specific expertise and consist of the following personnel:

- The Project Manager is the team leader who oversees mission activities at ASF and coordinates with external groups.
- The Product Owner is a primary product stakeholder and oversees ingest, archive, documentation, and distribution of data products as well as managing interactions with mission and ASF scientists and other stakeholders.
- The User Services Representative (uso@asf.alaska.edu) supports data users with products and software tools and communicates user feedback or suggestions for improvement to the Project Manager and Product Owner.
- Software Engineers design, develop, and maintain software for the acquisition, processing, archiving, and distribution of satellite and aerial remote sensing data.
- Software Quality Assurance Technicians provide software and web-based-application testing prior to delivery to the production data system to ensure integrity, quality, and overall proper functionality through testing methods to uncover program defects, which in turn are reported to software engineers.
- The Technical Science Writer composes and edits a variety of ASF materials, from newsletter articles to technical documentation.

The core product team's responsibilities for data management include:

- Ingesting, cataloging, archiving, and distributing data
- Providing guidance on file formats and integration of new file formats into the ASF data system
- Describing data products and producing user manuals and guide documents
- Creating metadata and exporting it to CMR and GCMD (Global Change Master Directory)
- Ensuring accurate metrics are reported to EMS (ESDIS Metrics System)
- Designing, developing, and deploying specialized data portals that allow online access to data products and information
- Creating software tools for data interpretation and analysis
- Assisting users with the selection and usage of data

ASF also supports NASA and partner missions through the operation of a ground station with two 11-m antennas, providing complete services, including data downlinking, commanding, and range/Doppler tracking. ASF is part of the NASA Near Earth Network (NEN) supporting a variety of low-Earth-orbit spacecraft.

ASF DAAC Data Systems

The ASF DAAC operates a custom data system designed, implemented, and supported by DAAC personnel. During its evolution, the ASF data system has moved from using primarily custom software on capital equipment to commodity hardware and commercial off-the-shelf (COTS) software and hardware solutions. This has greatly lowered development and maintenance costs for the data system, while simultaneously providing a higher level of performance. The ASF DAAC data system provides the following capabilities:

Data Ingest

- Automated data ingest occurs from the ASF ground station as well as external data providers in a variety of media and formats.
- Ingested data are pre-processed when necessary, providing browse or derivative products.

Data Archive

- The central ASF data system archive is provided by a Data Direct Networks gridscaler storage system.
- This system provides direct access to over 1 PB of processed data as well as the capability for automated backups to an offsite location.
- Raw data are held in a robotic silo for access by the processing system. ASF maintains a backup in an external location in case of silo failure.

Data Distribution

- ASF provides direct http access to DAAC data products and utilizes NASA's User Registration System (URS) for user authentication.
- NASA data are provided to public users with no restrictions. Partner data are provided to NASA-approved users through URS for authentication and ASF's internal database for access control.
- The data system provides web-based access to the archive through Vertex. Vertex supports the data pool with direct download of processed data.
- Through custom portals and applications, the DAAC provides additional services such as mosaic subsetting, mosaicking, and time-series analysis.

Data Support

- ASF DAAC exports relevant metadata to NASA's ECHO system.
- ASF DAAC exports ingest, archive, and download metrics to NASA's EMS system.
- ASF DAAC assists users with data discovery and usage, maintains product documentation and use guides, and supports feedback between the ASF user community and the core product teams.

SMAP at ASF DAAC

ASF provides a variety of services, software tools, and user support to address the needs of the SMAP user community. The ASF core project team will leverage on-going collaborations with the SMAP Project to identify and prioritize SMAP user community needs, which in turn will inform development and implementation of data support and value-adding services for the mission. The SMAP website at

ASF will serve as an interactive data portal, providing users with relevant documentation, custom tools and services, and ancillary data and resources.

Post-Launch SMAP Data

ASF will ingest, distribute, archive, and support postlaunch Level 1 radar products for the SMAP mission. ASF will receive the Level 1 radar products from the SMAP Science Data System at the Jet Propulsion Laboratory (JPL) in Pasadena, California.

Non-SMAP Data of Interest to SMAP

ASF will cross-link from the SMAP website to data collections that complement SMAP data and are of interest to the user community. Some of these collections are distributed by ASF, including the following:

- Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) data products
- Jet Propulsion Laboratory Uninhabited Aerial Vehicle SAR (UAVSAR) data products
- Making Earth System Data Records for Use in Research Environments Inundated Wetlands (MEaSUREs) data products
- Advanced Land Observing Satellite-Phased Array L-band SAR (ALOS PALSAR)
- Japanese Earth Resources Satellite-1 (JERS-1) image data and mosaics

Acronyms

Acronym	Definition
ASF	Alaska Satellite Facility
ATBDs	Algorithm Theoretical Basis Documents
Cal/Val	Calibration and Validation
DAAC	Distributed Active Archive Center
HDF5	Hierarchical Data Format
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
NSIDC	National Snow and Ice Data Center
ROP	Routine Observations Phase
SMAP	Soil Moisture Active Passive
SAR	Synthetic Aperture Radar

Acronym	Definition
SDS	Science Data System
SOP	Science Operations Phase
UTC	Coordinated Universal Time

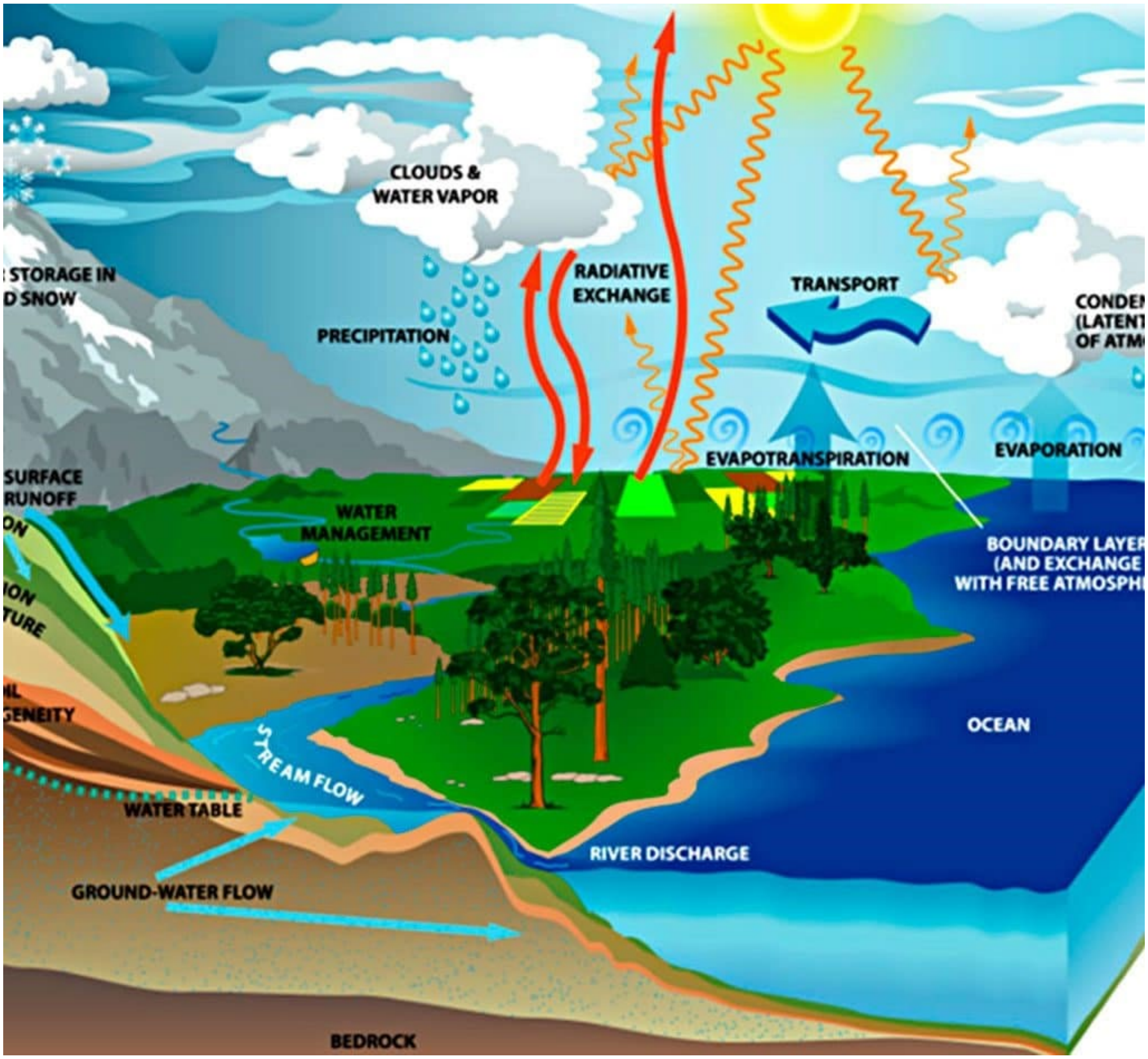
SMAP – Science Overview, Requirements, and Measurements

SMAP's spaceborne Earth-observation mission will enable global mapping of soil-moisture and freeze-thaw state with unprecedented accuracy, resolution, and coverage. SMAP science objectives are to acquire space-based, hydrosphere-state measurements over a three-year period to:

- Understand processes that link the terrestrial water, energy, and carbon cycles
- Estimate global water and energy fluxes at the land surface
- Quantify net carbon flux in boreal landscapes
- Enhance weather-forecast and climate-forecast skills
- Develop improved flood-prediction and drought-monitoring capabilities

Water and Energy Cycles, Weather, and Climate

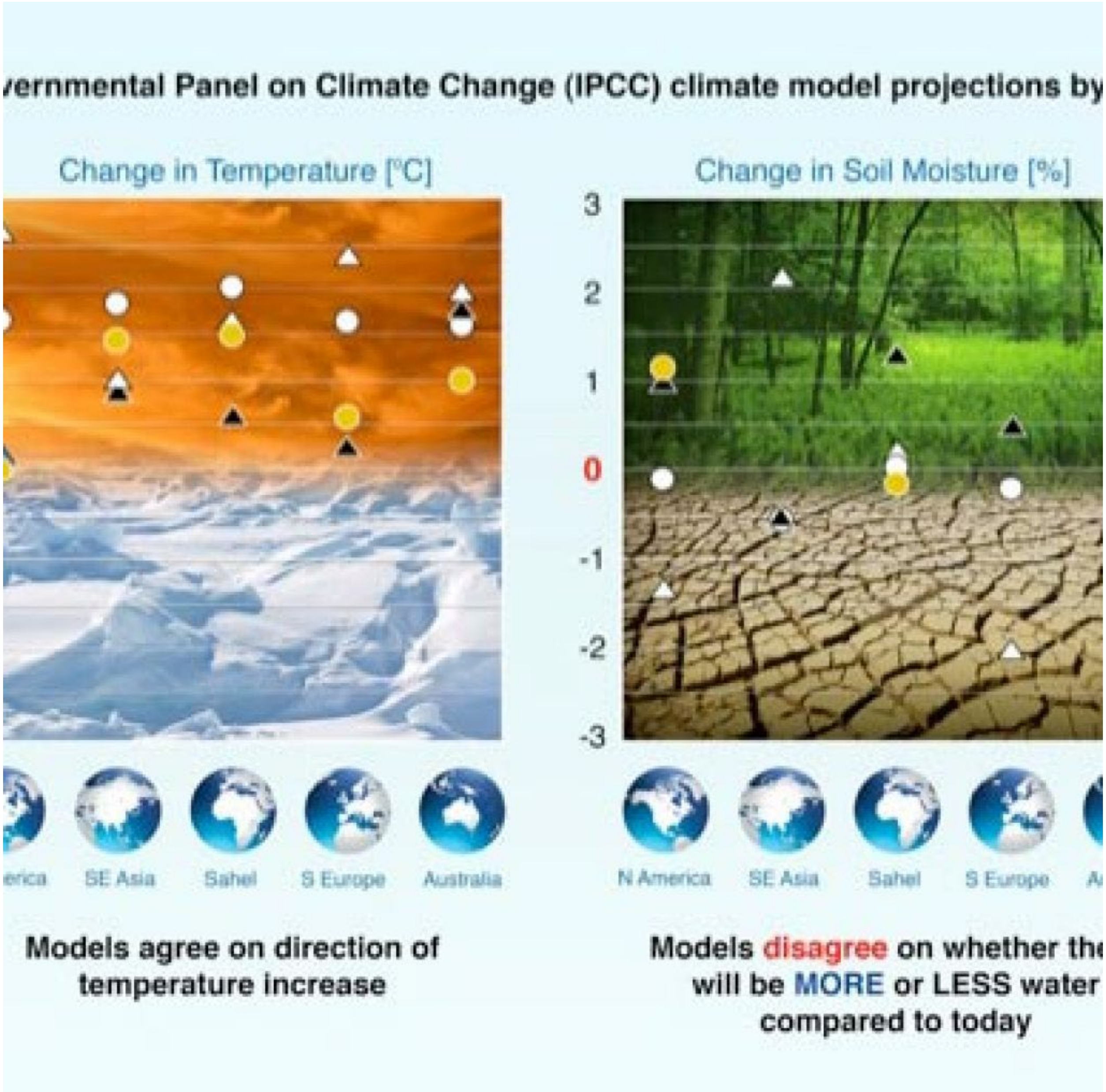
Recent model simulations of the effects of greenhouse gases on climate show that current models agree quite well in predicting temperature change but disagree significantly in predicting surface-moisture change and water-resource availability. Accurate soil-moisture information, such as data from SMAP, will improve the performance and enhance the predictive ability of numerical weather-prediction models and seasonal climate models. Soil moisture is a key control on evaporation and transpiration at the land-atmosphere boundary. Because vaporizing water requires large amounts of energy, soil-moisture control also has a significant impact on the surface energy flux. Soil-moisture variations affect the evolution of weather and climate, particularly over continental regions.



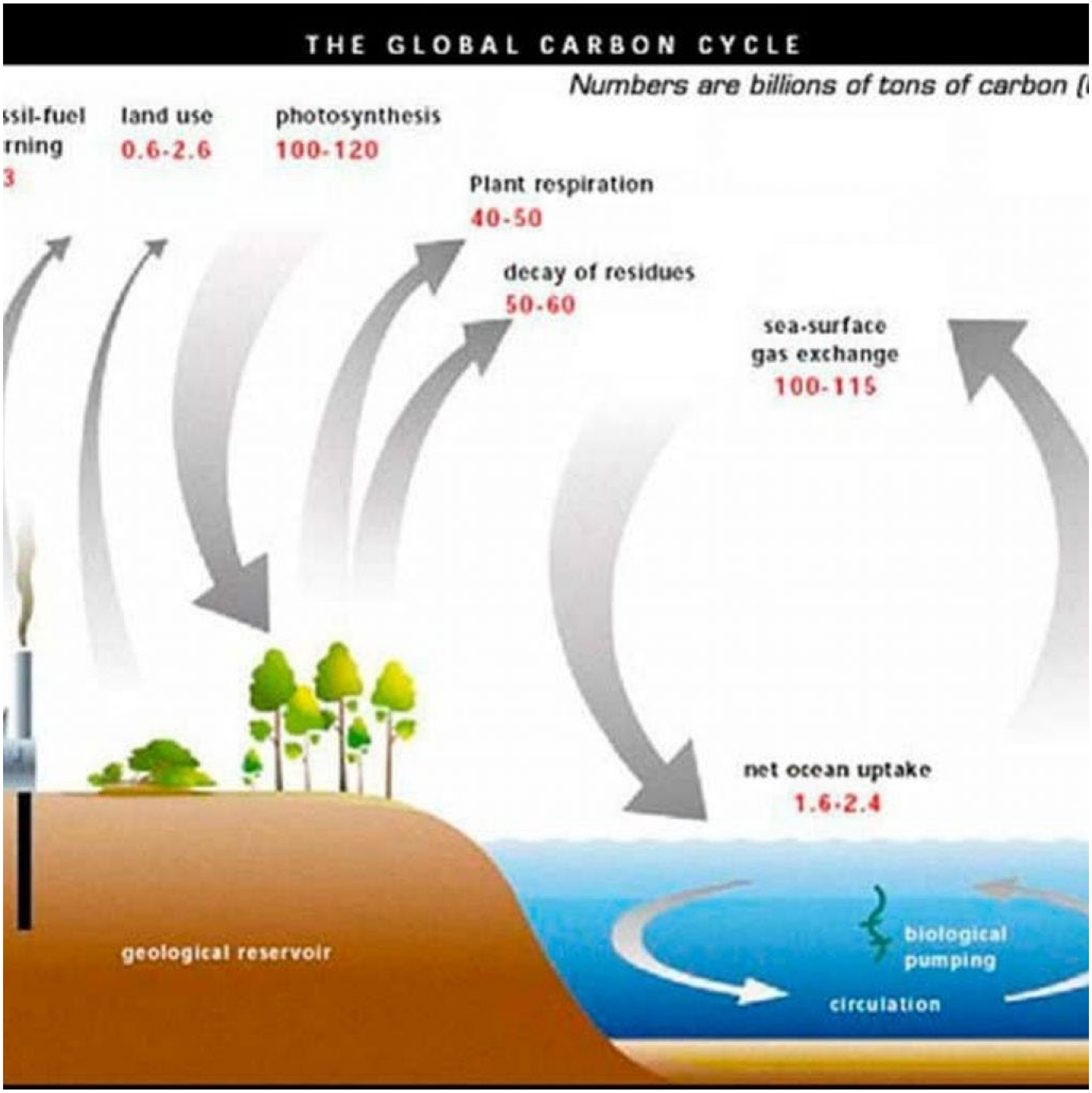
Earth's water cycle involves the transfer and storage of water in the atmosphere, on the planet's surface, underground, and by life in its many forms.

Carbon Cycle and Ecosystems

Soil moisture and its freeze-thaw state are also key determinants of the global carbon cycle. Carbon uptake and release in boreal landscapes is one of the major sources of uncertainty in assessing the carbon budget of the Earth system (the so-called missing carbon sink). The SMAP mission will quantify the nature, extent, timing, and duration of landscape seasonal freeze-thaw state transitions that are key to the estimation of terrestrial carbon sources and sinks. SMAP freeze-thaw state measurements will also contribute to understanding how ecosystems respond to and affect global environmental change, improving regional mapping and prediction of boreal-Arctic ecosystem processes.



Water availability is changing as a result of global climate change. SMAP data will help researchers understand how these changes affect water supply and food production.
Credit: NASA JPL



The global carbon cycle is the complex interaction of different carbon-based gases taking place among Earth's atmosphere, land, and oceans.

SMAP Goals

The SMAP Project is designed to collect measurements of surface soil moisture and freeze-thaw state, together termed the hydrosphere state. Soil moisture is defined in terms of volume of water per unit volume of soil. Freeze-thaw state is defined as the phase of the water contained within the landscape including soil and vegetation. To meet the goals of science and applications users, SMAP must:

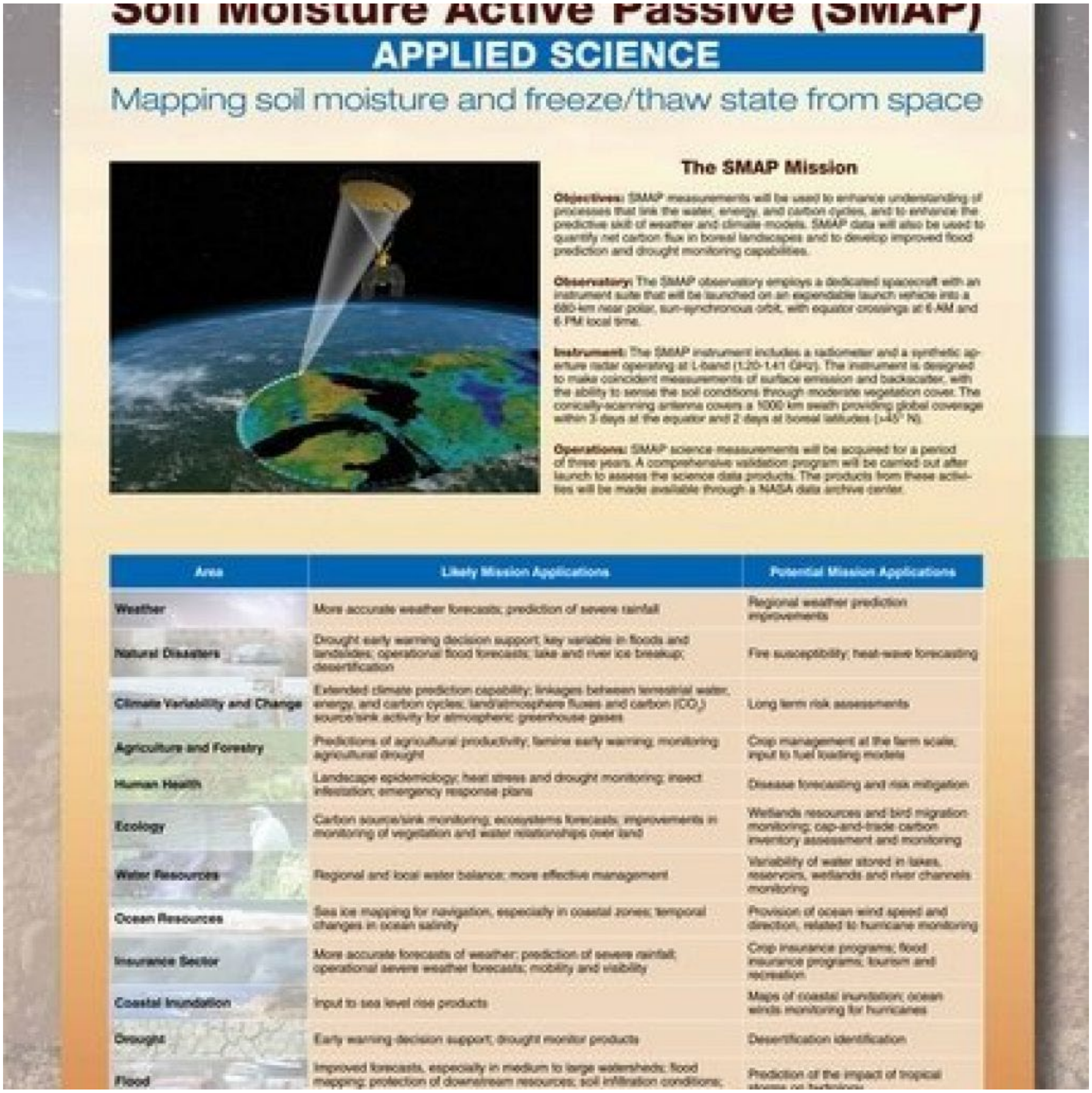
- Resolve hydrometeorological water and energy flux processes and extend weather and flood forecast skill, spatial resolution of 10 km and temporal resolution of 3 days are required.
- Resolve hydroclimatological water and energy flux processes and extend climate and drought forecast capability, spatial resolution of 40 km and temporal resolution of 3 days are required.
- Quantify net carbon flux in boreal landscapes, spatial resolution of 3 km and temporal resolution of 2 days are required. In addition, the SMAP mission will validate a space-based measurement approach that could be used for future systematic hydrosphere state monitoring missions.

SMAP News

NASA Soil Moisture Radar Ends Operations; Mission Science Continues
NASA Focused on Sentinel as Replacement for SMAP Radar

Baseline Science Requirements

- Estimates of soil moisture in the top 5 cm of soil with an error of no greater than 0.04 cm3/cm3 (one sigma) at 10-km spatial resolution and 3-day average intervals over the global land area, excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and vegetation with water content greater than 5 kg/m2 (averaged over the spatial resolution scale).
- Estimates of surface binary freeze-thaw state in the region north of 45N latitude, which includes the boreal forest zone, with a classification accuracy of 80% at 3-km spatial resolution and 2-day average intervals.
- Space-based measurements of soil moisture and freeze-thaw state for at least 3 years to allow seasonal and interannual variations of soil moisture and freeze-thaw to be resolved.
- The SMAP project shall conduct a calibration and validation program to verify data delivered meets the above requirements.



SMAP applied science poster. Credit: NASA/JPL.

Measurements

Approach

The SMAP mission will validate a space-based measurement approach that could be used for future systematic hydrosphere-state monitoring missions.

- To resolve hydrometeorological water and energy flux processes and extend weather- and flood-forecast skill, spatial resolution of 10 km, and temporal resolution of 3 days are required.

- To resolve hydroclimatological water and energy flux processes and extend climate- and drought-forecast capability, spatial resolution of 40 km and temporal resolution of 3 days are required.

- To quantify net carbon flux in boreal landscapes, spatial resolution of 3 km and temporal resolution of 2 days are required.

Accuracy

The science goal is to combine the attributes of the radar observations (high spatial resolution but lower soil-moisture accuracy) and radiometer observations (higher soil-moisture accuracy but coarse spatial resolution).

Joint processing of the radar and radiometer data will retrieve soil moisture at a spatial resolution of 10 km, and freeze-thaw state at a spatial resolution of 3 km.

The provision of constant incidence angle across the 1,000-km swath simplifies the data processing and enables accurate repeat-pass estimation of soil moisture and freeze-thaw.

Orbit Characteristics

The SMAP orbit is a 685-km altitude, near-polar, sun-synchronous, 6 a.m. / 6 p.m., eight-day, exact-repeat, frozen orbit.

- Near-polar orbit provides global land coverage up to high latitudes including all freeze-thaw regions of interest.

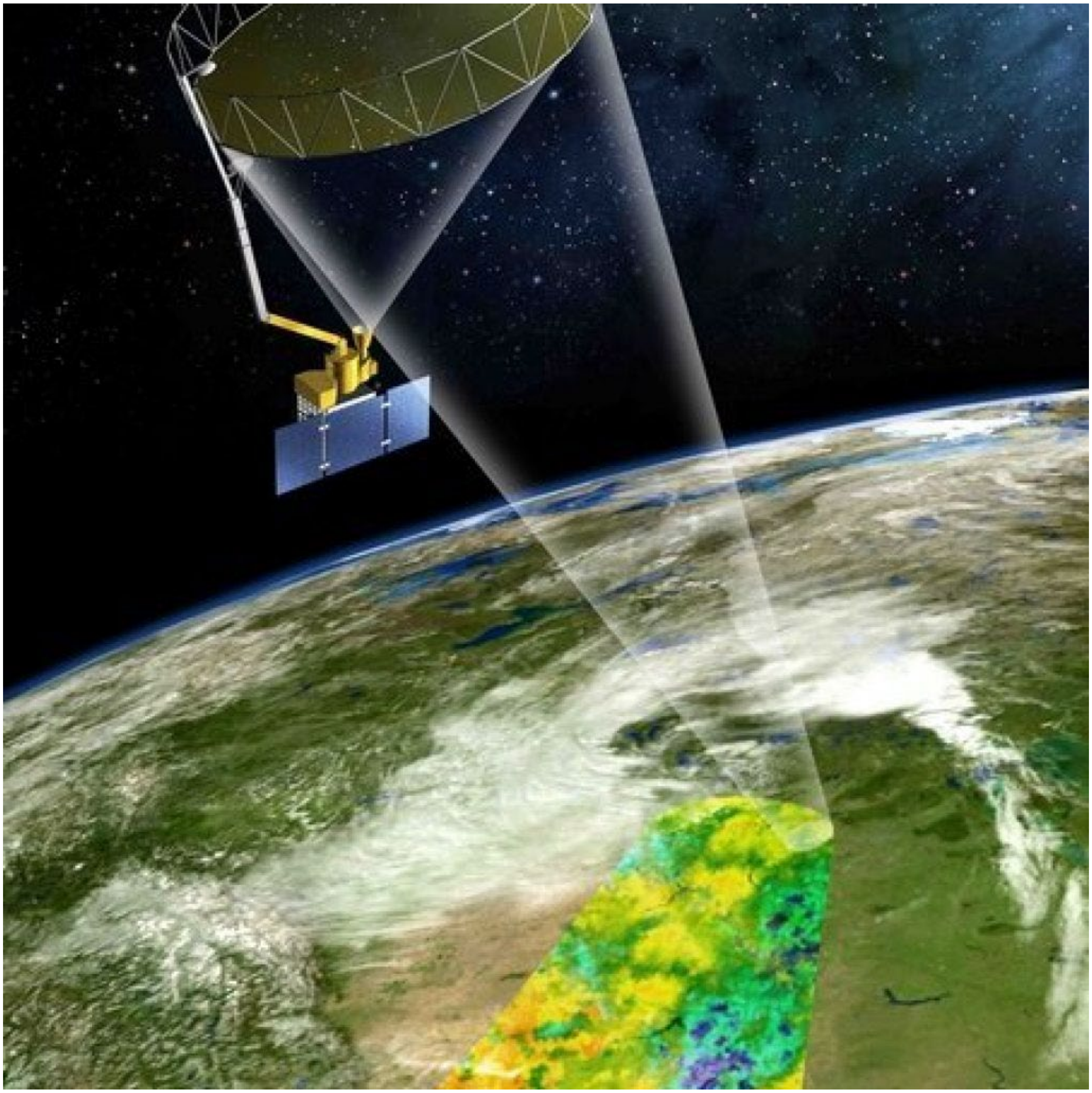
- Sun-synchrony provides observations of the surface close to the same local solar time each orbit throughout the mission, enhancing change-detection algorithms and scientific accuracy.

- Consistent 6 a.m. observation time is optimal because it minimizes the effect of Faraday rotation and impact on S/C design.

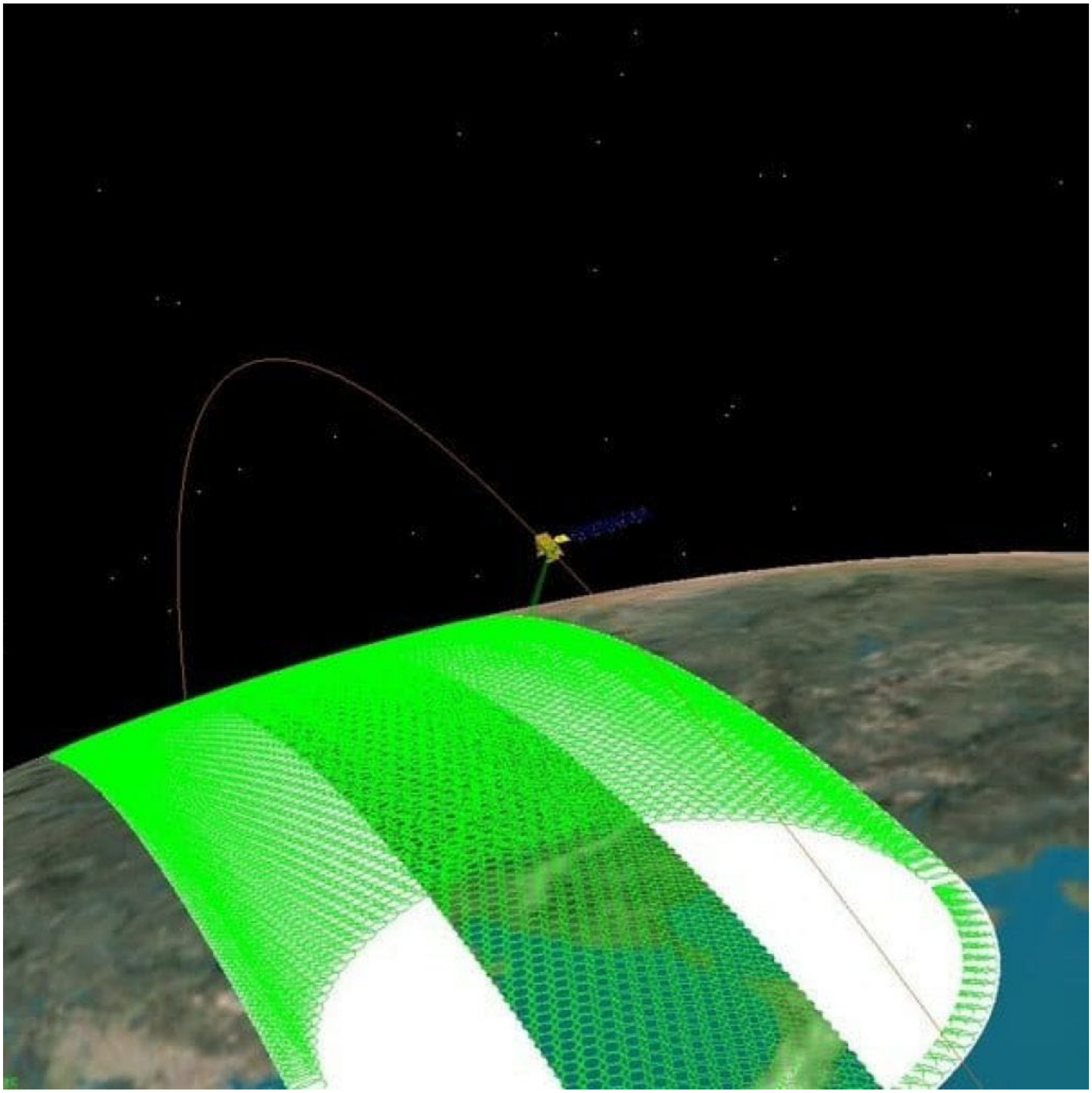
- Frozen orbit provides minimal altitude variation during an orbit, benefitting radar design and accuracy.

- 685-km altitude is an exact 8-day repeat orbit, advantageous for radar change-detection algorithms.

- Orbit provides optimum coverage of global land area at 3-day average intervals, and coverage of land region above 45N at 2-day average intervals.



SMAP spacecraft and its swath path. Credit: NASA/JPL.



SMAP antenna's scanning pattern. Credit: NASA/JPL.

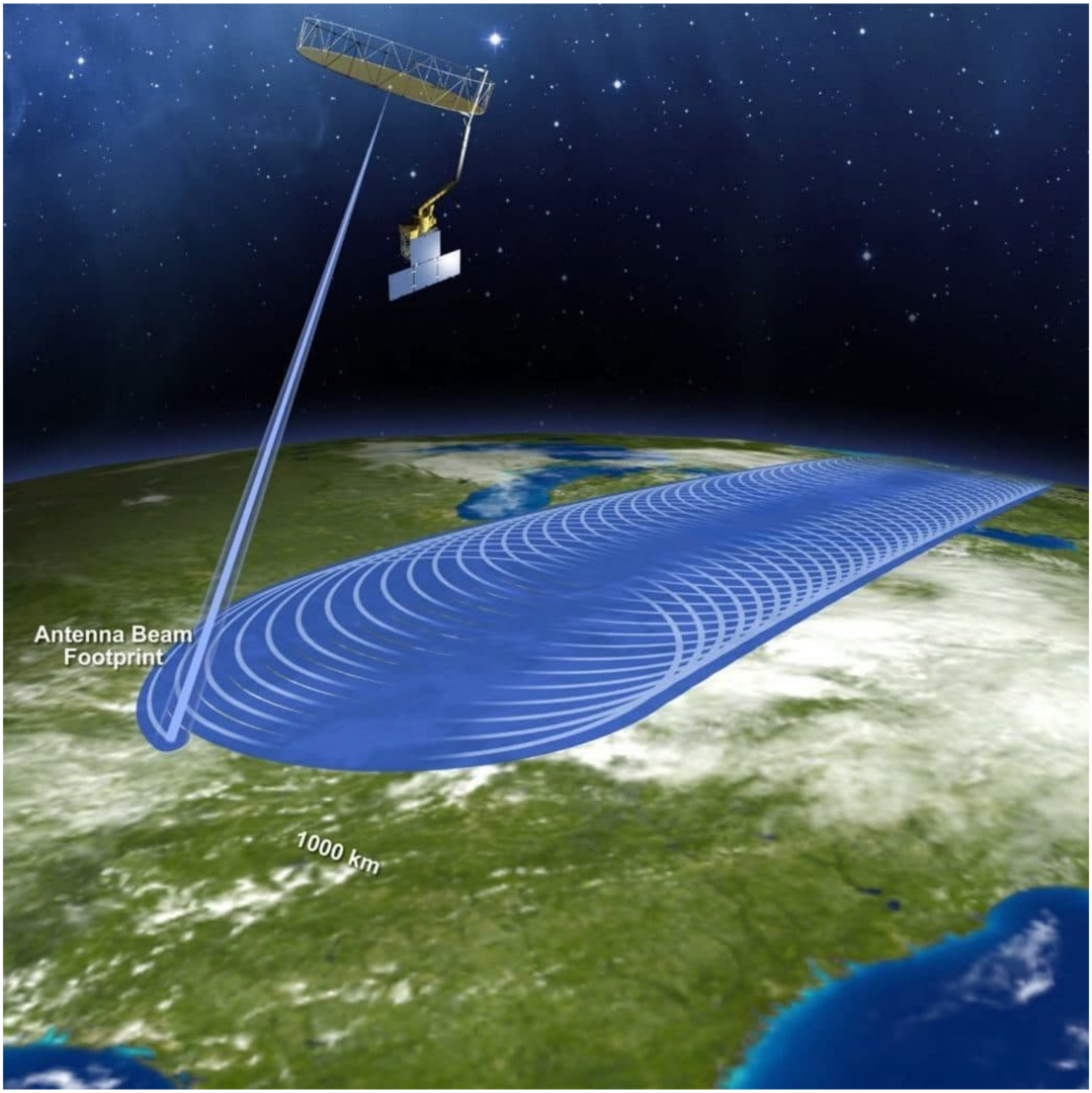
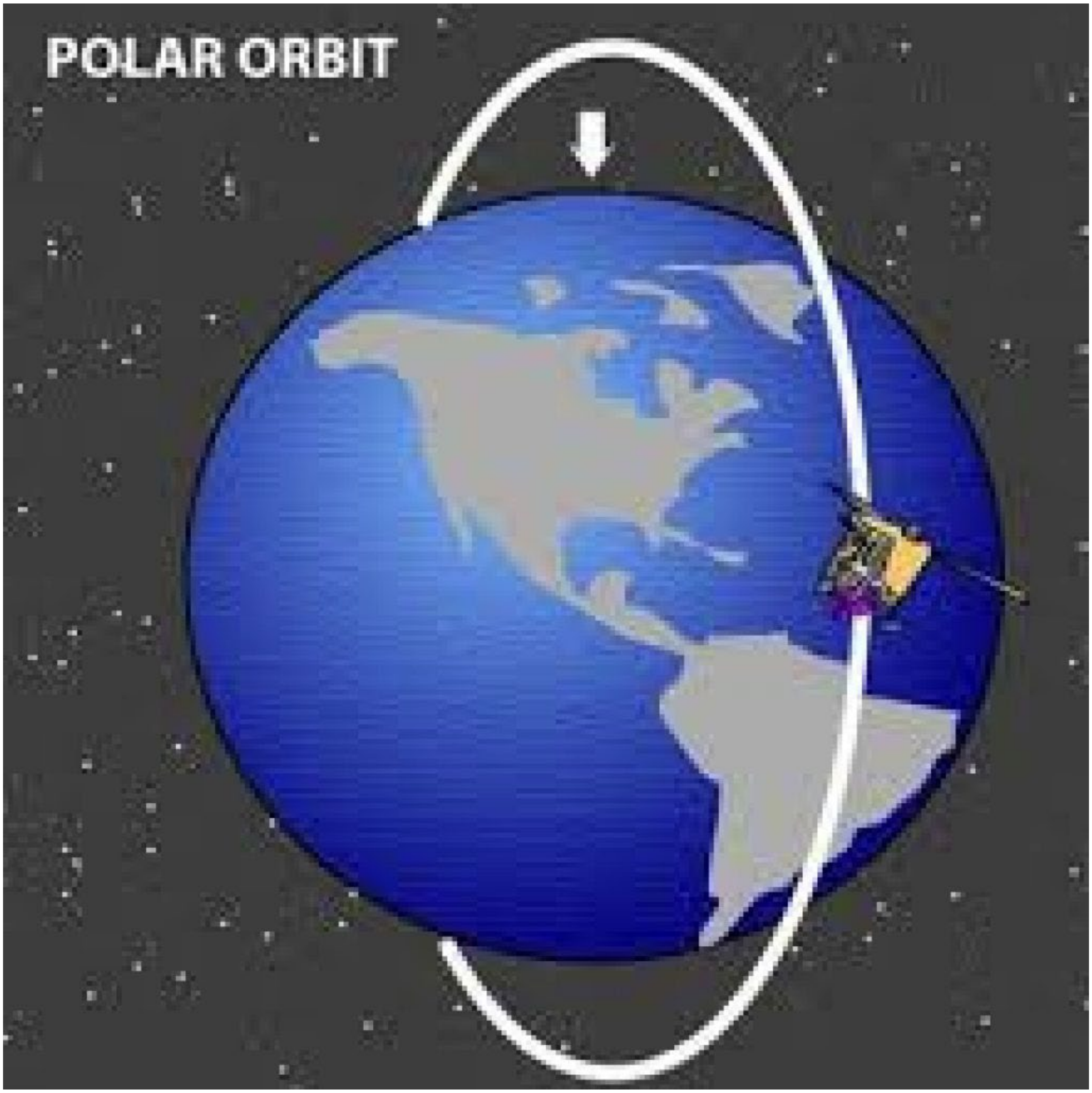


Image credit: NASA/JPL.



SMAP travels in a 98-degree
polar orbit.

Data Acquisition

Low-rate radiometer data and low-resolution radar data will be acquired continuously over fore and aft portions of the scan (full 360 degrees), as well as ascending and descending portions of the orbit.

High-resolution radar data will be acquired to include at a minimum:

- 360 degrees of the antenna scan (fore and aft looks) for the morning (6 a.m. equator crossing) half-orbit over the global land region (excluding the Antarctic)

- 180 degrees of the antenna scan (fore look) for the evening (6 p.m. equator crossing) half-orbit over the boreal land region (north of 45 degrees N latitude)
- 180 degrees of the antenna scan (fore look) for the morning half-orbit over the coastal ocean region (within 1,000 km of continental boundaries)
- The Science Operations Phase (SOP) begins after completion of the 90-day post-launch, in-orbit commissioning and lasts for three years. The first part of the SOP is the Calibration and Validation (Cal/Val) phase, which lasts for 12 months. Following the Cal/Val phase is the Routine Observations Phase (ROP), which lasts for 24 months.

SMAP – Instrument

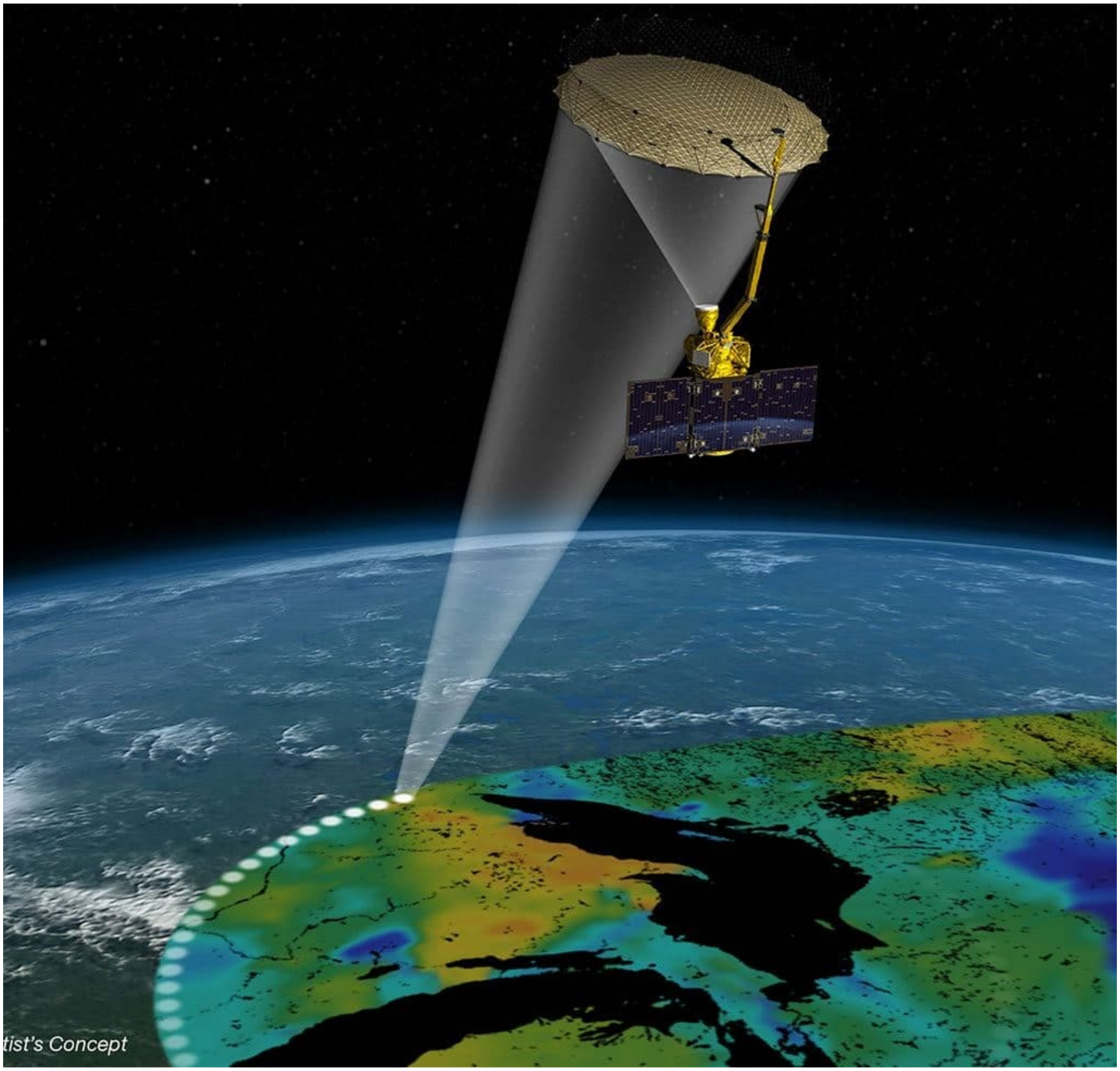
Soil Moisture Passive Active (SMAP) is a remote-sensing observatory with two instruments — a synthetic aperture radar (SAR) and a radiometer — that map soil moisture and determine the freeze or thaw state of the area being mapped. Both instruments help map soil-moisture content, and unique properties of SAR enable the freeze-thaw mapping. Externally, the instruments share a common, 20-foot mesh antenna and a feed assembly. Inside the spacecraft, their electronics differ. When combined, the SMAP radar and radiometer deliver high-accuracy, high-resolution global maps of the Earth's soil moisture and freeze-thaw state.

The radar **actively** sends pulses of radio waves down to a spot on Earth and measures the echo that returns microseconds later. The strength and "shape" of the echoes can be interpreted to indicate the moisture level of the soil, even through moderate levels of vegetation. The radiometer **passively** detects radio waves emitted by the ground from the same small area. The strength of the emission indicates temperatures.

News: NASA Soil Moisture Radar Ends Operations; Mission Science Continues

News: NASA Focused on Sentinel as Replacement for SMAP Radar

Instrument Events Timetable LINK



Artist's concept of SMAP observatory and its antenna-beam footprint. Credit: NASA.

Specifications

Spacecraft

Dimensions, bus only: 1.5 x .9 x .9 m

Weight: 944 kg

Power: 1,450 watts

Altitude: 685 km

Orbit path: Near-polar, sun-synchronous, equator crossings 6 a.m. and 6 pm. local time

Orbital inclination: 98.1 degrees

Radar: L-band

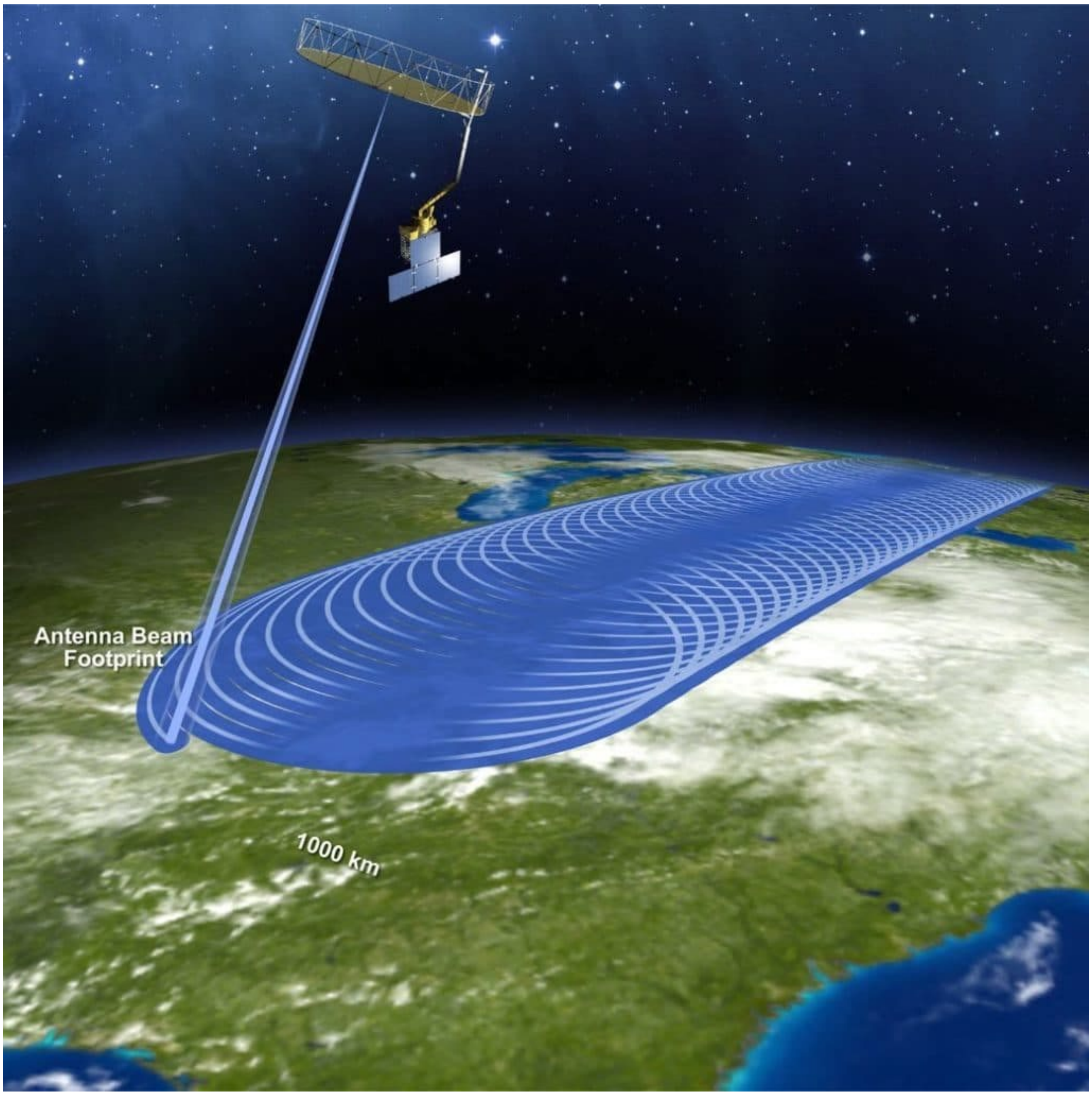
Frequency: 1.2 to 1.3 GHz

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



SMAP's antenna-beam footprint measures 1,000 km. Image credit: NASA/JPL.

Radiometer: L-band

Frequency: 1.41 GHz
Polarizations: H, V, 3rd and 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 m
Rotation rate: 14.6 RPM
Beam efficiency: ~90%
Beam surface incidence angle: 40°
Spatial Resolution:

- SAR: 1-3 km (over outer 70% of swath; ‘high-resolution’ radar)
- Radiometer (IFOV): 39 km x 47 km
- Real-aperture radar footprint resolution: 29 km x 35 km (‘low-resolution’ radar)

Swath width: 1,000 km

Radar Resolution and Gridding

The SMAP radar employs unfocused synthetic aperture radar (SAR) processing. The range and azimuth resolutions are determined by the unique antenna scan geometry.

The SAR single-look samples (time-ordered) are averaged (multi-looked) onto a swath-oriented 1-km grid to form the L1C_S0_HiRes product. The grid posting of the L1C_S0_HiRes product is fixed at 1 km, but the spatial resolution, number of looks, and signal-to-noise ratio (SNR) vary across the swath.

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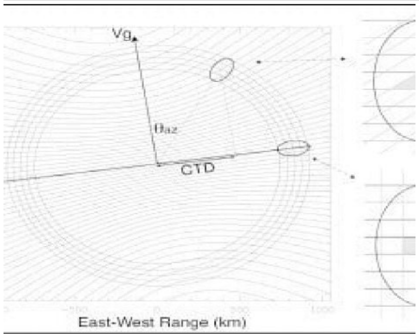
<td>
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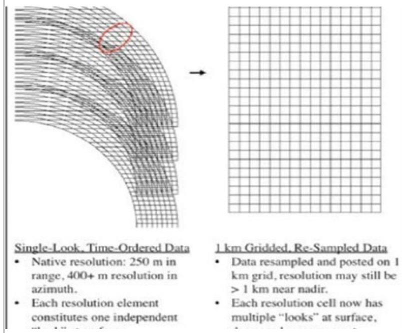
<td>
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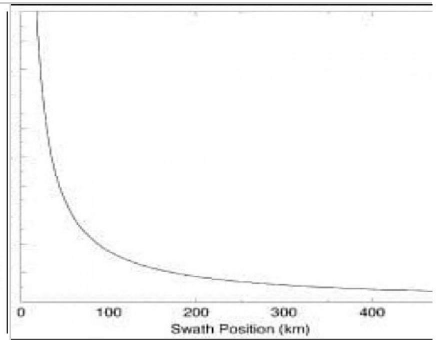
<td>
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<td>This panel illustrates the radar-measurement geometry showing the range and Doppler contours. The real aperture radar footprint ellipse is shown at two representative azimuth-scan angles. The radar 1-MHz bandwidth yields a ground-range resolution of ~250 m. The doppler diversity is maximum at a scan angle perpendicular to the satellite velocity (swath edge), leading to an azimuth single-look resolution of ~450 m. The single-look resolution degrades as the scan angles approach the satellite velocity vector. Image Credit: NASA/JPL.</td>
<td>This schematic, which is not drawn to scale, illustrates how the single-look data samples from successive fore-look scans are oriented and overlap relative to the 1-km gred. Image Credit: NASA/JPL.</td>
<td>This panel illustrates the variation as a function of swath position (distance from center track). Image Credit: NASA/JPL.</td>
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Frequency and Polarizations

The L-band frequency enables observations of soil moisture through moderate vegetation cover, independent of cloud cover and night or day. Multiple polarizations enable accurate soil moisture estimates to be made with corrections for vegetation, surface roughness, Faraday rotation, and other perturbing factors.

The SMAP instrument incorporates an L-band radar (VV, HH, and HV polarizations) and an L-band radiometer (V, H, and 3rd and 4th Stokes parameter polarizations).

Spatial Resolution

To obtain high spatial resolution, the radar employs range and Doppler discrimination.

To mitigate radio-frequency interference (RFI) from ground transmitters, the radiometer employs a digital backend and sub-banding approach. The radiometer 'high-rate' mode acquires sub-band data; the radiometer 'low-rate' mode acquires data averaged over the full band only.

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 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).

SMAP Documents, Tools, Acronyms

Documents

Name	Description
ATBD Documents	Algorithm theoretical basis documents are listed with the products available for download.
Product Specification Documents	Product specification documents are listed with the products available for download.
ASF SMAP User Guide	For Level 1 products, a streamlined guide to accessing data, using SMAP products, understanding acronyms and abbreviations, and more.
Radar Backscatter Calibration, L1B_S0_LoRes and L1C_S0_HiRes Beta Level Data Products	Provides analysis and assessment of calibration quality of SMAP radar normalized backscatter cross-section for the L1B_S0_LoRes and L1C_S0_HiRes beta level data products. Dated 8/5/2015.
SMAP Handbook	Written in 2013 as a compendium of information on the project near its time of launch. Contains essential information on programmatic, technological, and scientific aspects of the mission.
Ancillary Data Reports (table includes links to cited data)	Application-related descriptions of datasets used with science-algorithm software in generating SMAP science-data products, as well as links to EASE grid information relevant to SMAP products. Also included are links to the ancillary data cited in the reports.
Publications	Lists publications on remote sensing of soil moisture since 2001. Please submit additional publications to uso@asf.alaska.edu, with "SMAP Publications" on the subject line.
Worldview quick-look tool	This tool from NASA's EOSDIS provides the capability to interactively browse global, full-resolution satellite imagery and then download the underlying data. Most of the 100+ available products are updated within three hours of observation.
HDF Group	The HDF Group offers a list of software using HDF5.
ASF list of potentially useful software tools.	

Tools

Name	Description
ASF Software Tools	ASF offers several tools that can be used on many datasets.
SMAP Analysis Client	Interactive application developed by the Jet Propulsion Lab (JPL) / NASA for Soil Moisture Active Passive (SMAP) data. Users may want to start with the calendar icon on the far right of the page.
GDAL	The Geospatial Data Abstraction Library helps explore the general contents of SMAP Hierarchical Data Format (HDF) 5 data. The gdalinfo tool summarizes the data structure in the file. The gdal_translate tool can extract the SAR data out of the structure and store it into a more versatile GeoTIFF.
ArcGIS (commercial GIS system)	Recognizes the HDF5 structure and is able to extract the SAR data on the fly. Does not calculate standard statistics for this data layer and is slow in rendering the data this way. Can be significantly improved by converting the HDF5 data layer HH into a GeoTIFF file using the gdal_translate tool.
HDFView	Provided by the HDF group; looks at data in two ways. For quantitative analysis, the selected data layer must be opened as spreadsheet. For a visual analysis, HDFView provides the image view. The program has no options for stretching data in a statistical fashion. However, the user can manually change the brightness and contrast.
Panoply	Developed by NASA's Goddard Institute for Space Studies, primarily used for global datasets of lower resolution.
Interactive Data Language	The Interactive Data Language (IDL) provides a more programmatic means to visualize the SMAP HDF5 data. The IDL H5 browser has very limited functionality in terms of changing visual value ranges and stretching the imagery for visualization purposes, but it does provide users the ability to view the HDF5 products.
Worldview quick-look tool	This tool from NASA's EOSDIS provides the capability to interactively browse global, full-resolution satellite imagery and then download the underlying data. Most of the 100+ available products are updated within three hours of observation.
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ROP	Routine Observations Phase
SMAP	Soil Moisture Active Passive
SAR	Synthetic Aperture Radar
SDS	Science Data System
SOP	Science Operations Phase
UTC	Coordinated Universal Time

SMAP – Publications and Credits

Publications

Please submit additional relevant publications to uso@asf.alaska.edu, with "SMAP Publications" on the subject line.

Publication Year	Document title and download link (if available)
2014	Assessment of Soil Moisture Data Requirements by the Potential SMAP Data User Community: Review of SMAP Mission User Community – M.E. Brown, V.M. Escobar; Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, Vol. 7 No. 1, Jan. 2014, p.277-283, doi: 10.1109/JSTARS.2013.2261473.
2014	Automated L-Band Radar System for Sensing Soil Moisture at High Temporal Resolution– K. Nagarajan, Pang-Wei Liu, R. DeRoo, J. Judge, R. Akbar, P. Rush, S. Feagle,

Publication Year	Document title and download link (if available)
	D. Preston, R. Terwilleger; Geoscience and Remote Sensing Letters, IEEE, Vol. 11 No. 2, 2014, p. 504-508, doi: 10.1109/LGRS.2013.2270453
2014	The Soil Moisture Active Passive Experiments (SMAPEx): Toward Soil Moisture Retrieval From the SMAP Mission – R. Panciera, J.P. Walker, T.J. Jackson, D.A. Gray, M.A. Tanase, Dongryeol Ryu, A. Monerris, H. Yardley, C. Rudiger, Xiaoling Wu, Ying Gao, J.M. Hacker; Geoscience and Remote Sensing, IEEE Transactions on, Vol. 52 No. 1, Part 2, 2014, p. 490-507, doi: 10.1109/TGRS.2013.2241774
2014	Tests of the SMAP Combined Radar and Radiometer Algorithm Using Airborne Field Campaign Observations and Simulated Data – N.N. Das, D. Entekhabi, E.G. Njoku, J.J.C. Shi, J.T. Johnson, A. Colliander; Geoscience and Remote Sensing, IEEE Transactions on, Vol. 52 No.4, 2014, p. 2018-2028, doi: 10.1109/TGRS.2013.2257606
2013	A downscaling algorithm for combining radar and radiometer observations for SMAP soil moisture retrieval – Peng Guo, Jiancheng Shi, Tianjie Zhao; Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 731 – 734, doi: 10.1109/IGARSS.2013.6721261
2013	L-band active / passive time series measurements over a growing season using the ComRAD ground-based SMAP simulator – P. O'Neill, M. Kurum, A. Joseph, J. Fuchs, P. Young, M. Cosh, R. Lang; Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 37-40, doi: 10.1109/IGARSS.2013.6721086
2013	NASA's Soil Moisture Active Passive (SMAP) observatory – K. Kellogg, K., et al.; Aerospace Conference, 2013 IEEE, p. 1-20, doi: 10.1109/AERO.2013.6496938
2013	Performance characterization of the SMAP RFI mitigation algorithm using direct-sampled SMAPVEX 2012 data – S. Misra, J. Johnson, M. Aksoy, D. Bradley, Hsin Li, J. Mederios, J. Piepmeier, I. O'Dwyer; Radio Science Meeting (USNC-URSI NRSM), 2013 US National Committee of URSI National, p. 1, doi: 10.1109/USNC-URSI NRSM.2013.6524988
2013	A radar-radiometer surface soil moisture retrieval algorithm for SMAP, – R. Akbar, M. Moghaddam; Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 1095-1098, doi: 10.1109/IGARSS.2013.6721355
2013	A robust algorithm for soil moisture retrieval from the soil Moisture Active Passive mission radar observations – P.S. Narvekar, D. Entekhabi, Seungbum Kim, E. Njoku;

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	Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 45-48, doi: 10.1109/IGARSS.2013.6721088
2013	SMAP RFI mitigation algorithm performance characterization using airborne high-rate direct-sampled SMAPVEX 2012 data – S. Misra, et al.; Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 41 – 44, doi: 10.1109/IGARSS.2013.6721087
2013	The Soil Moisture Active Passive (SMAP) radar: Measurements at high latitudes and of surface freeze/thaw state – M. Spencer, S. Dunbar, C. Chen; Radar Conference (RADAR), 2013 IEEE, p. 1-5, doi: 10.1109/RADAR.2013.6586087
2013	State of the Art in Large-Scale Soil Moisture Monitoring – Tyson E. Ochsner, Michael H. Coshb, Richard H. Cuencac, Wouter A. Dorigod, Clara S. Drapere, Yutaka Hagimotof, Yann H. Kerrg, Eni G. Njokuh, Eric E. Smalli and Marek Zredaj; Soil Science Society of America Journal, Vol. 77 No. 6, p. 1888-1919; doi:10.2136/sssaj2013.03.0093.
2013	Towards a high-density soil moisture network for the validation of SMAP in Petzenkirchen, Austria – M. Vreugdenhil, et al.; Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 1865 – 1868, doi: 10.1109/IGARSS.2013.6723166
2013	US national cropland soil moisture monitoring using SMAP – Zhengwei Yang, R. Mueller, W. Crow; Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, p. 3746 – 3749, doi: 10.1109/IGARSS.2013.6723645
2012	*Advances in Earth observation for water cycle science (editorial) – D. Fernandez-Prieto et al., Copernicus Publications on behalf of the European Geosciences Union, Hydrol. Earth Syst. Sci., 16, p. 543–549, 2012, doi:10.5194/hess-16-543-2012*
2012	Active and passive airborne microwave remote sensing for soil moisture retrieval in the Rur catchment, Germany – C. Montzka, et al., Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International, p. 6956 – 6959, doi: 10.1109/IGARSS.2012.6352562
2012	An airborne simulation of the SMAP data stream – J.P. Walker et al.; Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International, p. 5-7 doi: 10.1109/IGARSS.2012.6351537
2012	Application of QuikSCAT Backscatter to SMAP Validation Planning: Freeze/Thaw State Over ALECTRA Sites in Alaska From 2000 to 2007 – A. Colliander, K. McDonald, R.

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	Zimmermann, R. Schroeder, J.S. Kimball, E.G. Njoku; Geoscience and Remote Sensing, IEEE Transactions on, Vol. 50 No. 2, 2012, p. 461 – 468 , doi: 10.1109/TGRS.2011.2174368
2012	Assessment of the impacts of radio frequency interference on SMAP radar and radiometer measurements – C.W. Chen, J.R. Piepmeier, J.T. Johnson, H. Ghaemi, H.; Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International, p. 1-4, doi: 10.1109/IGARSS.2012.6351538
2012	Comparison of Backscattering Models at L-Band for Growing Corn – A. Monsivais-Huertero, J. Judge, Geoscience and Remote Sensing Letters, IEEE, Vol. 8 No. 1, p. 24-28, doi: 10.1109/LGRS.2010.2050459
2012	Design and performance of Astromesh reflector onboard Soil Moisture Active Passive spacecraft – M. Mobrem, et al.; Aerospace Conference, 2012 IEEE, p. 1-10, doi: 10.1109/AERO.2012.6187094
2012	Development of SMAP (soil moisture active and passive) Freeze/Thaw algorithms adapted for the Canadian Tundra – P. Kalantari, M. Bernier, K.C. McDonald, J. Poulin; Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International, p. 5218 – 5221, doi: 10.1109/IGARSS.2012.6352433
2012	A dual-polarized, dual-frequency, corrugated feed horn for SMAP – P. Focardi, P.R. Brown, Antennas and Propagation Society International Symposium (APSURSI), 2012 IEEE, p. 1-2, doi: 10.1109/APS.2012.6349003
2012	End-to-end data flow on the Soil Moisture Active Passive (SMAP) mission – E. Deems, C. Swan, B. Weiss; Aerospace Conference, 2012 IEEE, p. 1-16, doi: 10.1109/AERO.2012.6187175
2012	An integrated active-passive soil moisture retrieval algorithm for SMAP for bare surfaces – R. Akbar, M. Moghaddam; Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International, p. 16 – 19, doi: 10.1109/IGARSS.2012.6350891
2012	Integration of Daily Inundation Extent Estimates into an Ecosystem-Atmosphere Gas Exchange Model – J. Galantowicz, A. Samanta, H. Tian, American Geophysical Union, Fall Meeting 2012, abstract #B41C-0303
2011	A 6-m mesh reflector antenna for SMAP: Modeling the RF performance of a challenging Earth-orbiting instrument – P. Focardi, P. Brown, Y. Rahmat-Samii; Antennas and

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	Propagation (APSURSI), 2011 IEEE International Symposium on, p. 2987- 2990, doi: 10.1109/APS.2011.5997157
2011	AIAA ICES 2011 – Preliminary Evaluation of Passive Thermal Control for the Soil Moisture Active Passive (SMAP) Radiometer – A.J. Mastropietro, Eug Kwack, Rebecca Mikhaylov, Michael Spencer, Pamela Hoffman, Douglas Dawson (JPL); Jeff Piepmeier, Derek Hudson, James Medeiros (GSFC). Download File
2011	An Algorithm for Merging SMAP Radiometer and Radar Data for High-Resolution Soil-Moisture Retrieval – Narendra N. Das, Dara Entekhabi, Eni G. Njoku, IEEE Transactions on Geoscience and Remote Sensing, Vol. 49, No. 5, May 2011.
2011	Dense Temporal Series of C- and L-band SAR Data for Soil Moisture Retrieval Over Agricultural Crops – Anna Balenzano, Francesco Mattia, Senior Member, IEEE, Giuseppe Satalino, and Malcolm W. J. Davidson, IEEE Transactions on Geoscience and Remote Sensing, Vol. 4, No. 2, June 2011.
2011	Effect of Soil Moisture on polarimetric-interferometric repeat pass observations by UAVSAR during 2010 Canadian Soil Moisture campaign – Scott Hensley, Thierry Michel, Jakob Van Zyl, Ron Muellerschoen, Bruce Chapman, Shadi Oveisgharan, Ziad S. Haddad,Tom Jackson, Iliana Mladenova, SMAP Cal/Val Workshop, May 3-5, 2011.
2011	IGARSS 2011 – Utilization of Ancillary Data Sets for SMAP Algorithm Development and Product Generation; Peggy E. O'Neill, Erika Podest, and Eni G. Njoku.
2011	Improving hydrologic predictions of a catchment model via assimilation of surface soil moisture – Chen, F., W.T. Crow, P.J. Starks, and D.N. Moriasi, Advances in Water Resources, 34, 526–536, 2011. Download File
2010	A quasi-global evaluation system for satellite-based surface soil moisture retrievals – Crow, W.T., D.G. Miralles and M.H. Cosh, IEEE Transactions on Geoscience and Remote Sensing, 48(6), 2516-2527. Download File
2010	A technique for estimating spatial sampling errors in coarse-scale soil moisture estimates derived from point-scale observations – Miralles, D.G., W.T. Crow and M.H. Cosh, Journal of Hydrometeorology, 11(6), 1404-1410,10.1175/2010JHM1285.1, 2010. Download File
2010	AGU 2010 – The Contribution of Soil Moisture Information to Forecast Skill: Two Studies; Randal Koster, Sarith Mahanama, and Ben Livneh.

Publication Year	Document title and download link (if available)
2010	AMS 2010 – NASA's Soil Moisture Active Passive (SMAP) Mission Applications in the Atmospheric and Hydrologic Sciences; Dara Entekhabi, Eni Njoku, Peggy O'Neill, R. Koster.
2010	An algorithm for merging SMAP radiometer and radar data for high resolution soil moisture retrieval – Das, N., Entekhabi, D., Njoku, E., IEEE-Transactions on Geoscience and Remote Sensing, In press.
2010	An improved approach for estimating observation and model error parameters for soil moisture data assimilation – Crow, W.T. and M.J. van den Berg, Water Resources Research, 46, W12519, 10.1029/2010WR009402, 2010. Download File
2010	Assimilation of SMAP measurements for soil moisture-based military trafficability assessment at tactical scales – Flores, L., D. Entekhabi, and R. L. Bras, IEEE Journal of Selected Topics in Earth Observations and Remote Sensing, 2009-00030.
2010	Backscattering coefficients, coherent reflectivities, and emissivities of randomly rough soil surfaces at L-band for SMAP applications based on numerical solutions of Maxwell equations in three-dimensional simulations – Huang, Shaowu, Tsang, Leung, Njoku, Eni and Chan, Kuan Shan, IEEE Transactions of Geoscience and Remote Sensing, Vol. 48, No. 6, June 2010, 2557-2568. Download File
2010	Evaluating the utility of remotely-sensed soil moisture retrievals for operational agricultural drought monitoring – Bolten, J.D., W.T. Crow, T.J. Jackson, X. Zhan and C.A. Reynolds. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 3, 57-66. Download File
2010	IGARSS 2010 – Forward Simulation of Passive Microwave Observation for the Soil Moisture Active Passive (SMAP) Mission; Steven Chan, Eni Njoku, and Scott Dunbar.
2010	IGARSS 2010 – Fostering Applications opportunities for the NASA Soil Moisture Active Passive (SMAP) Mission; M. Susan Moran, Peggy E. O'Neill, Dara Entekhabi, Eni Njoku and Kent Kellogg.
2010	IGARSS 2010 – QuikSCAT Backscatter Sensitivity to Landscape Freeze/Thaw State over ALECTRA Sites in Alaska from 2000 to 2007: Application to SMAP Validation Planning; A. Colliander, K. McDonald, R. Zimmermann, T. Linke, R. Schroeder, J. Kimball.
2010	IGARSS 2010 – The NASA Soil Moisture Active Passive (SMAP) Mission: Overview; O'Neil, Entekhabi, Njoku and Kellogg.

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2010	The impact of radar incidence angle on soil moisture retrieval skill – Crow, W.T., W. Wagner and V. Naeimi, IEEE Geoscience and Remote Sensing Letters, 7(3), 501-505, 10.1109/LGRS.2010.2040134, July 2010. Download File
2010	MicroRad 2010 – Utilization of Airborne and In Situ Data Obtained in SGP99, SMEX02, CLASIC and SMAPVEX08 Field Campaigns for SMAP Soil Moisture Algorithm Development and Validation; Colliander, A., S. Chan, S. Yueh, M. Cosh, R. Bindlish, T. Jackson, E. Njoku.
2010	PIEEE 2010 – The Soil Moisture Active and Passive (SMAP) Mission, Entekhabi, D., E. Njoku, P. O'Neill, K. Kellogg, W. Crow, W. Edelstein, J. Entin, S. Goodman, T. Jackson, J. Johnson, J. Kimball, J. Piepmeier, R. Koster, K. McDonald, M. Moghaddam, S. Moran, R. Reichle, J. C. Shi, M. Spencer, S. Thurman, L. Tsang, J. Van Zyl, Proceedings of the IEEE, 98(5).

Passive active L- and S-band (PALS) microwave sensor for ocean salinity and soil moisture measurements – Wilson, WJ; Yueh, SH; Dinardo, SJ; et al., IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 39 (5): 1039-1048 MAY 2001.

Credits

SMAP Team

Soil Moisture Active Passive (SMAP) is a directed mission within the NASA Earth Systematic Mission Program. The SMAP project is managed by the Jet Propulsion Laboratory (JPL) with participation by the Goddard Space Flight Center (GSFC).

JPL is responsible for project management, system engineering, instrument management, the radar instrument, mission operations and the ground data system, science-data processing, and delivery of science-data products to a designated archive for public distribution.

GSFC is responsible for the radiometer instrument, science-data processing, and delivery of science-data products to a designated archive for public distribution.

ASF and the National Snow and Ice Data Center (NSIDC) are responsible for distributing data to the public.

Key Program/Project Personnel

C. Bonniksen (NASA/Hq), Program Executive, NASA HQ
J. Entin (NASA/Hq), Program Scientist, NASA HQ
K. Kellogg (JPL), Project Manager, JPL

S. Yueh (JPL), Project Scientist, JPL
P. ONeill (GSFC), Deputy Project Scientist, GSFC

Science Team

The SMAP Science Team (ST) was selected competitively by NASA in 2013 through a ROSES proposal solicitation. ST members are responsible for advising the project on science requirements, science-product definition, science algorithms, calibration/validation planning and implementation, and for publishing science results and supporting education and public outreach for the project. The ST replaces the earlier Science Definition Team (SDT), whose tenure ended in 2013. The ST tenure extends through the end of the SMAP mission.

Science Team Leader

D. Entekhabi, Massachusetts Institute of Technology

U.S. ST Members:

W. Crow, U.S. Department of Agriculture
T. Jackson, U.S. Department of Agriculture
J. Johnson, Ohio State University
J. Kimball, University of Montana
R. Koster, NASA Goddard Space Flight Center
D. Le Vine, NASA Goddard Space Flight Center
S. Misra, Jet Propulsion Laboratory
M. Moghaddam, University of Southern California
S. Moran, U.S. Department of Agriculture
R. Reichle, NASA Goddard Space Flight Center
K. Sarabandi, University of Michigan
L. Tsang, University of Washington
J. van Zyl, Jet Propulsion Laboratory
E. Wood, Princeton University

International ST Members:

S. Belair, Environment Canada, Canada
R. Gurney, University of Reading, UK
Y. Kerr, CESBIO, France
N. Pierdicca, University of Rome, Italy
J. Walker, Monash University, Clayton, Australia

Applications Coordinator:

M. Brown, NASA Goddard Space Flight Center

Site Content

Adapted from JPL SMAP website.