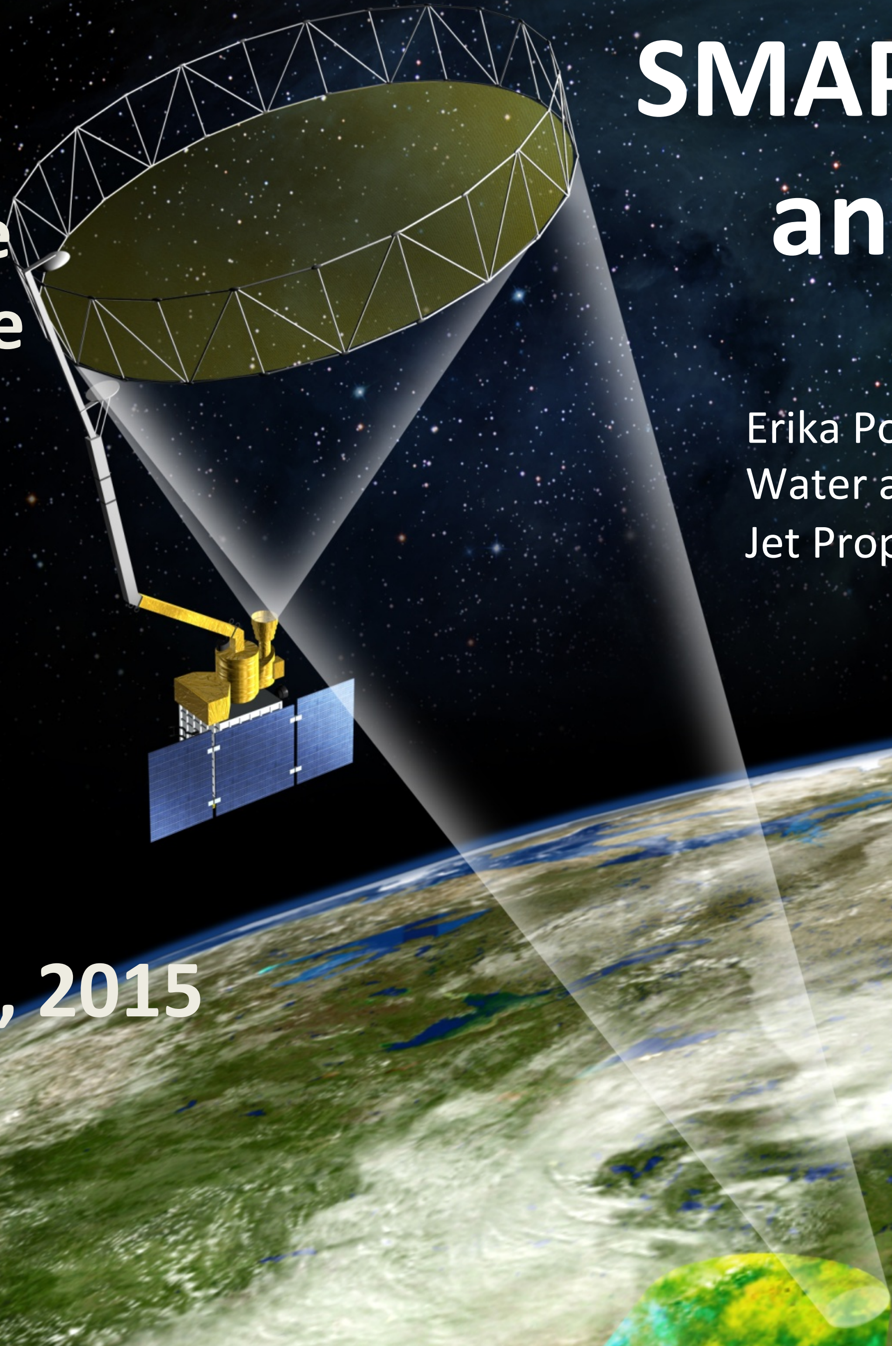
SMAP Overview and Status

Soil Moisture Active Passive Mission

SMAP



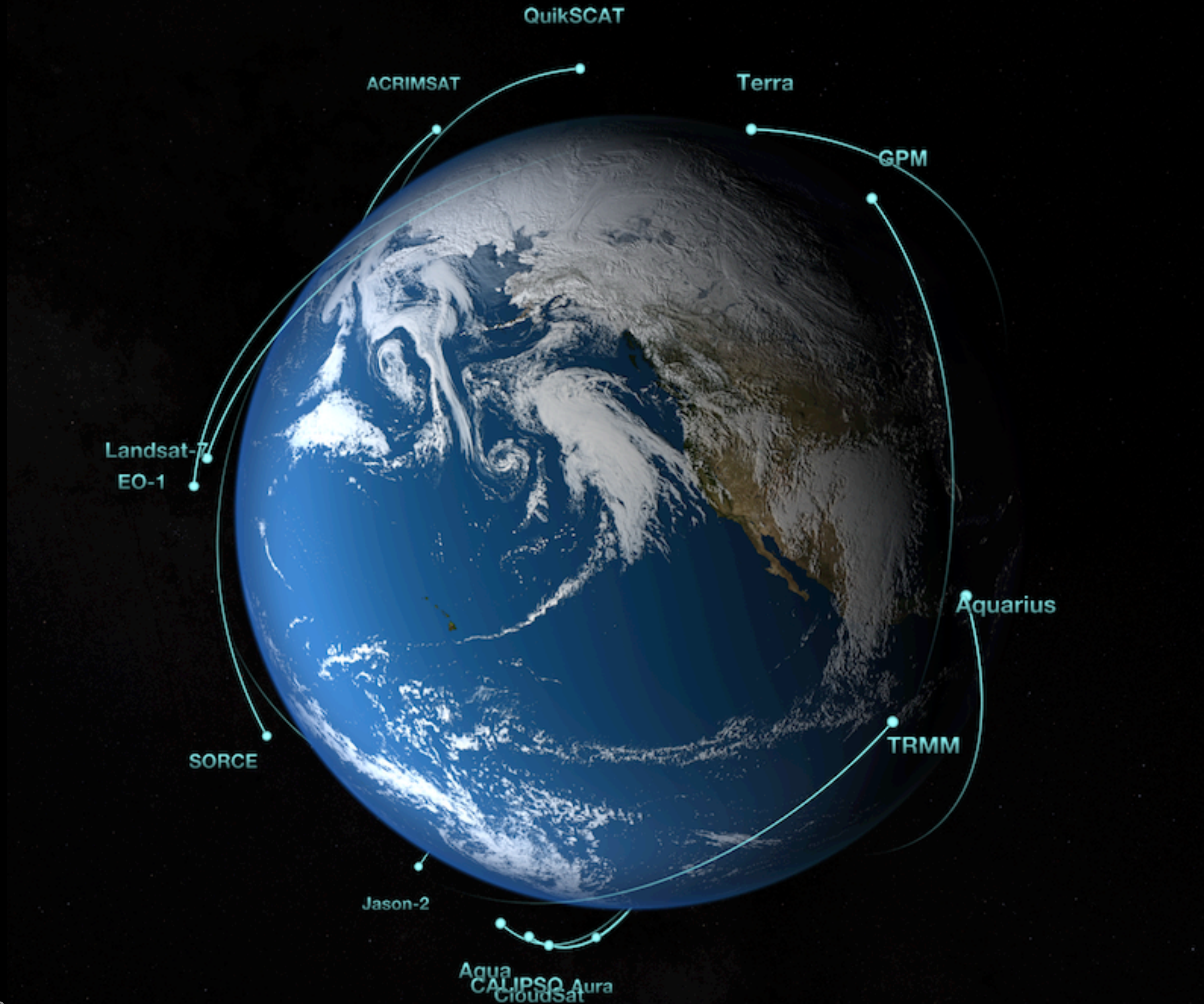
Erika Podest
Water and Carbon Cycles Group
Jet Propulsion Laboratory - NASA

May 27, 2015

Outline

1. *Background and Mission Objectives*
2. *Instruments (radar and radiometer)*
3. *Data Products*
4. *Calibration/Validation*
5. *Applications*

NASA Earth Observing Satellite Fleet



SMAP-3

Courtesy of the Goddard Visualization Lab

SMAP Primary Objectives

SMAP's objective is to provide high-resolution and frequent-revisit global maps of soil moisture and landscape freeze/thaw state.

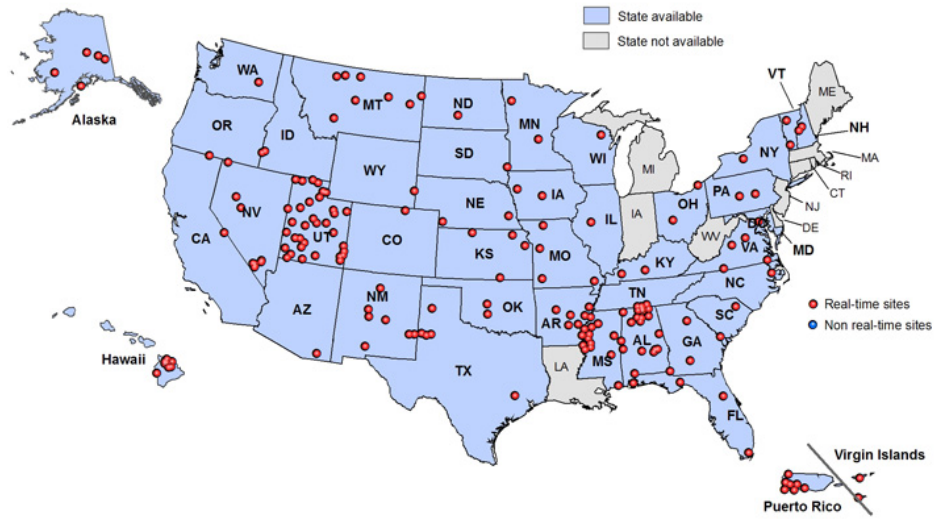
Limitations in measuring global soil moisture:

-current ground measurements of soil moisture are sparse and have limited coverage

-existing space-borne sensors have relatively low sensitivity and resolution

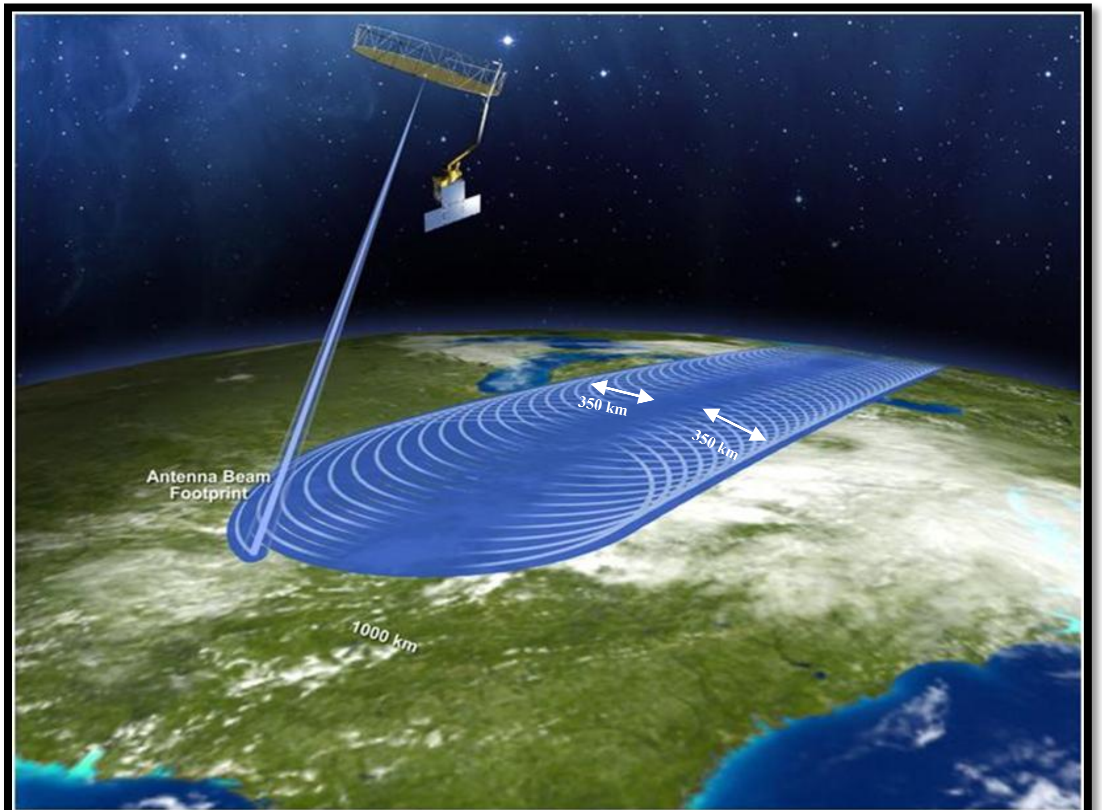
Science and applications addressed by SMAP:

- 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, flood and drought prediction
- Other applications such as agricultural productivity and human health



SMAP Instrument Overview

SMAP objective is to provide high-resolution and frequent-revisit global mappings of soil moisture and landscape freeze/thaw state



Launched: Jan. 31 2015 from Vandenberg Air Force Base in California onboard a Delta II.

- ***Radar*** - High spatial resolution (1-3 km) but more sensitive to surface roughness and vegetation
- ***Radiometer*** - High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)
- **Combined Radar-Radiometer** product provides optimal blend of resolution and accuracy to meet science requirements

SMAP Instrument Configuration

Radar
Frequency: 1.26 GHz
Polarizations: VV, HH, HV
Resolution: 3 km
Relative Accuracy: 1.0 dB (HH and VV), 1.5 dB (HV)

Radiometer
Frequency: 1.41 GHz
Polarizations: H, V, 3^{rd} & 4^{th} Stokes
Resolution: 40 km
Relative Accuracy: 1.3 K

Shared Antenna
6-m diameter deployable mesh antenna
Conical scan at 14.6 rpm
Constant incidence angle: 40 degrees
1000 km-wide swath
Swath and orbit enable 2-3 day global revisit

Orbit
Sun-synchronous, 6 am/pm orbit, **685 km** altitude

Mission Operations
3-year baseline mission

- Uniqueness: Continuous observations every 2-3 days

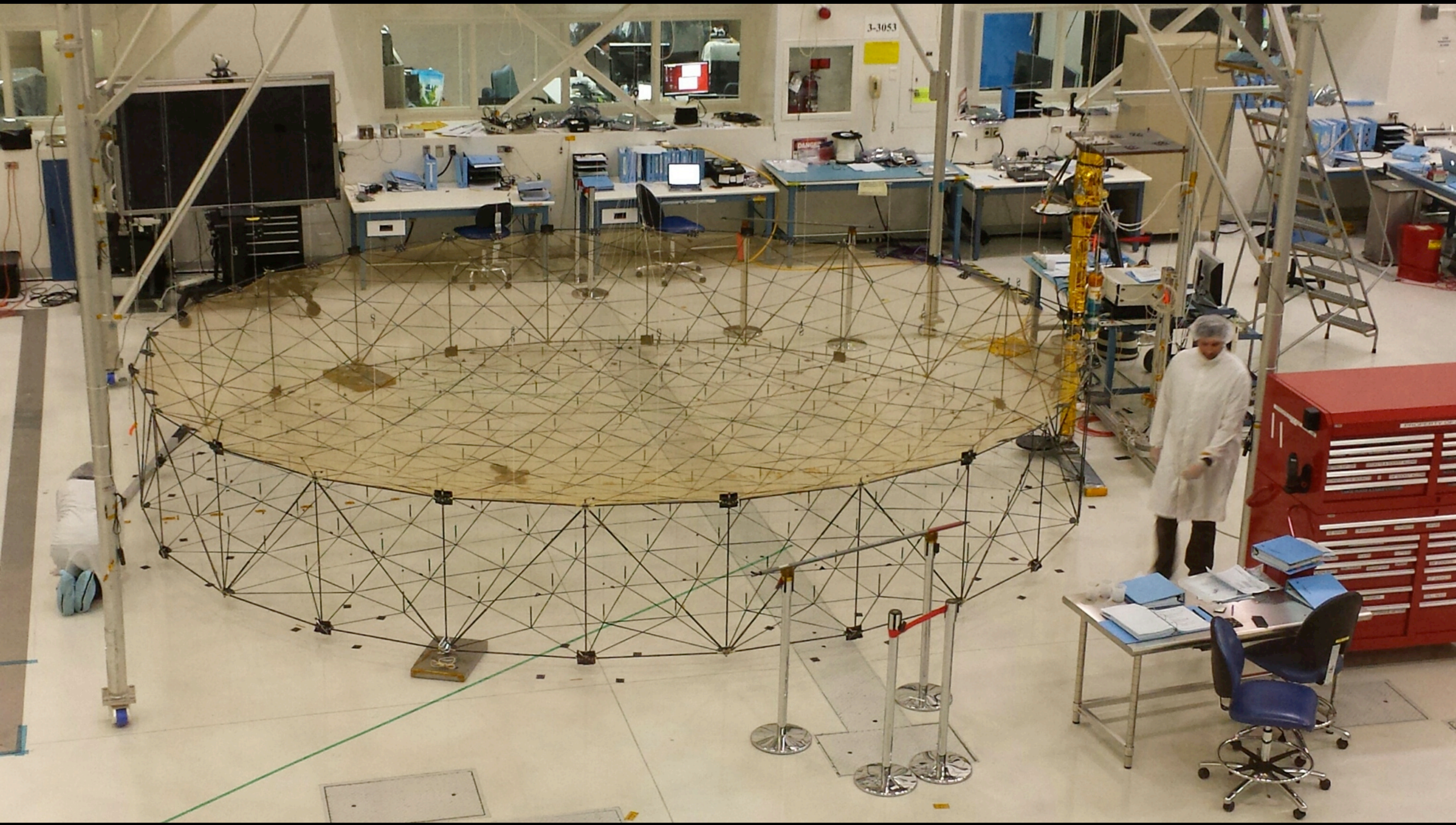
SMAP Level 1 Science Requirements

Requirement	Soil Moisture	Freeze/ Thaw
Resolution	**9 and 36 km**	3 km
Refresh Rate	3 days	2 days[1]
Accuracy	**0.04** [cm^3/cm^3] [2]	80% [3]
Duration	36 months	

[1] North of 45°N Latitude
[2] % volumetric water content, 1-sigma
[3] % classification accuracy (binary: Freeze or Thaw)

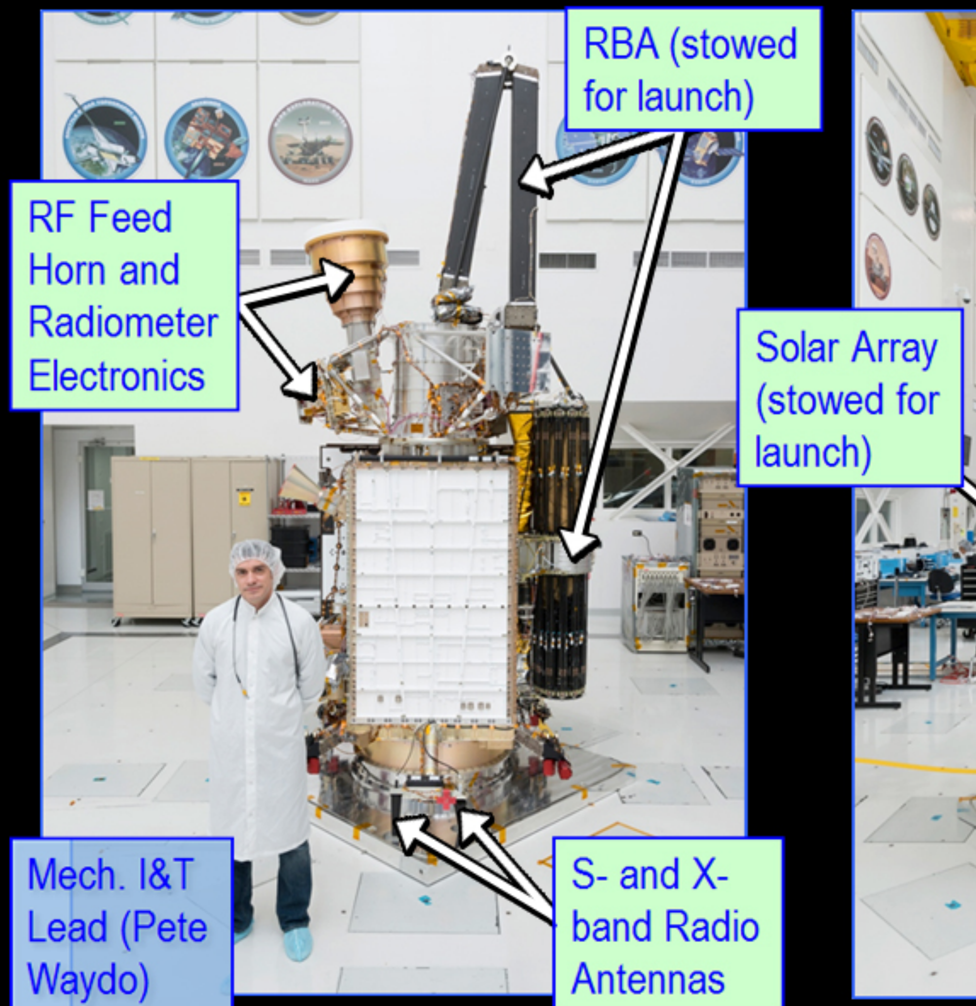
Product Short Name	Description	Data Resolution
L3_FT_HiRes	Daily Global Composite Freeze/Thaw State	1-3 km
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	36 km
L3_SM_AP	**Daily Global Composite Active-Passive Soil Moisture**	**9 km**
L4_SM	Surface & Root Zone Soil Moisture	9 km
L4_C	Carbon Net Ecosystem Exchange	3 km

SMAP Antenna



SMAP Spacecraft and Launch Configuration

SMAP Spacecraft in Its Launch

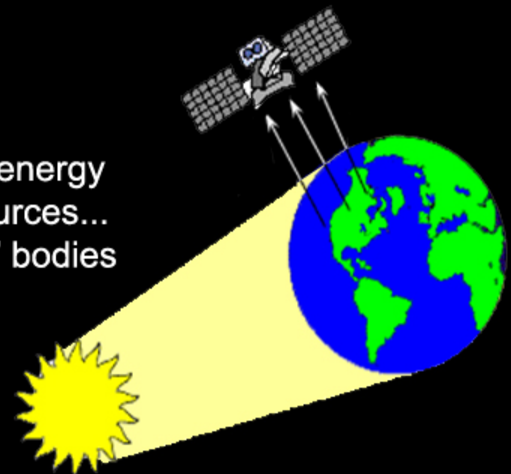


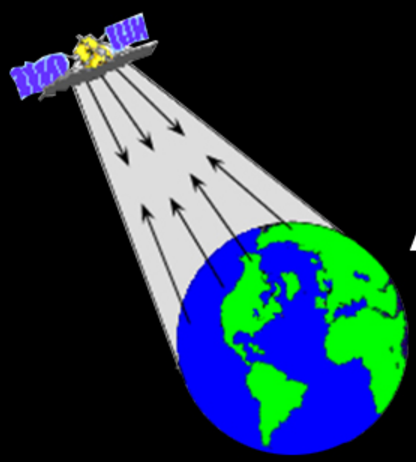
Passive and Active Sensing

SMAP uses both "Passive" and "Active"
Remote Sensing to measure Soil Moisture

Passive Sensors:

The source of radiant energy
arises from natural sources...
Sun, Earth, other "hot" bodies

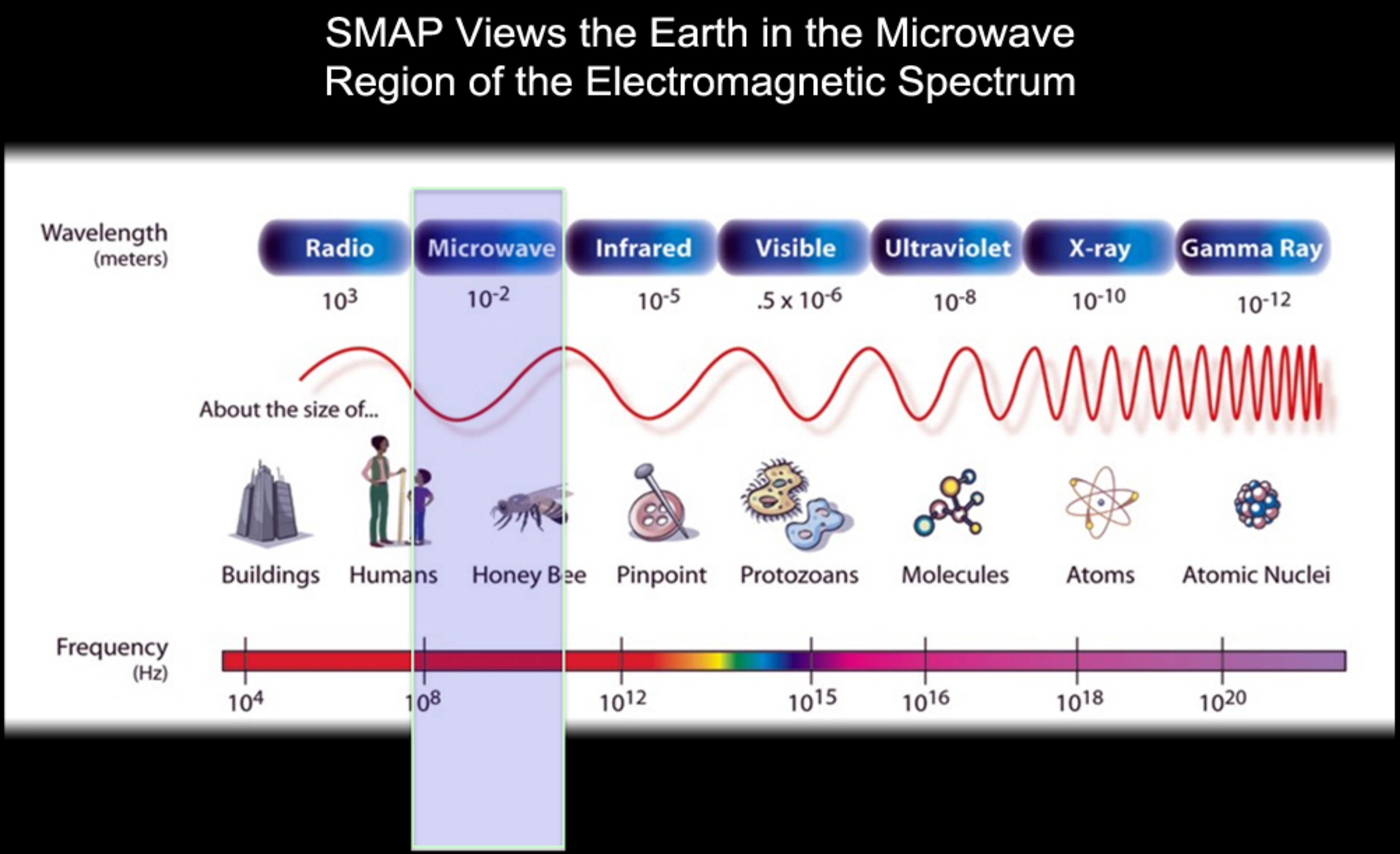




Active Sensors:

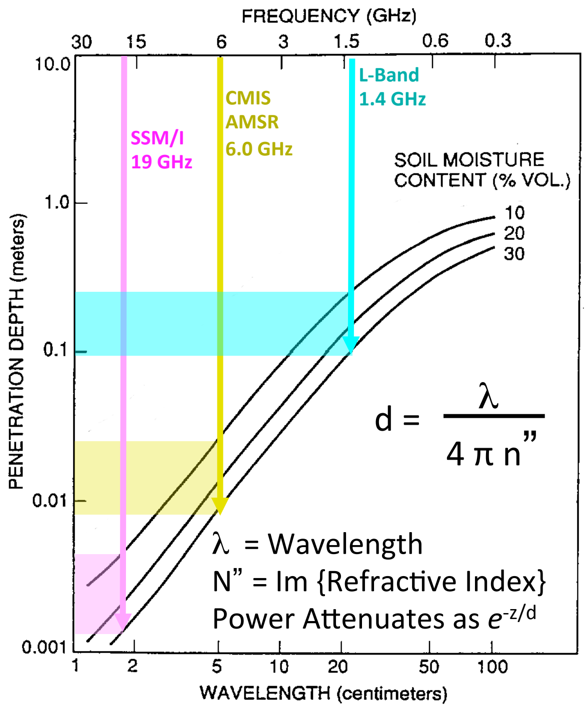
Provide their own artificial radiant energy
source for illumination... **RADAR, Synthetic Aperture Radar (SAR), LIDAR**

Microwave Sensing

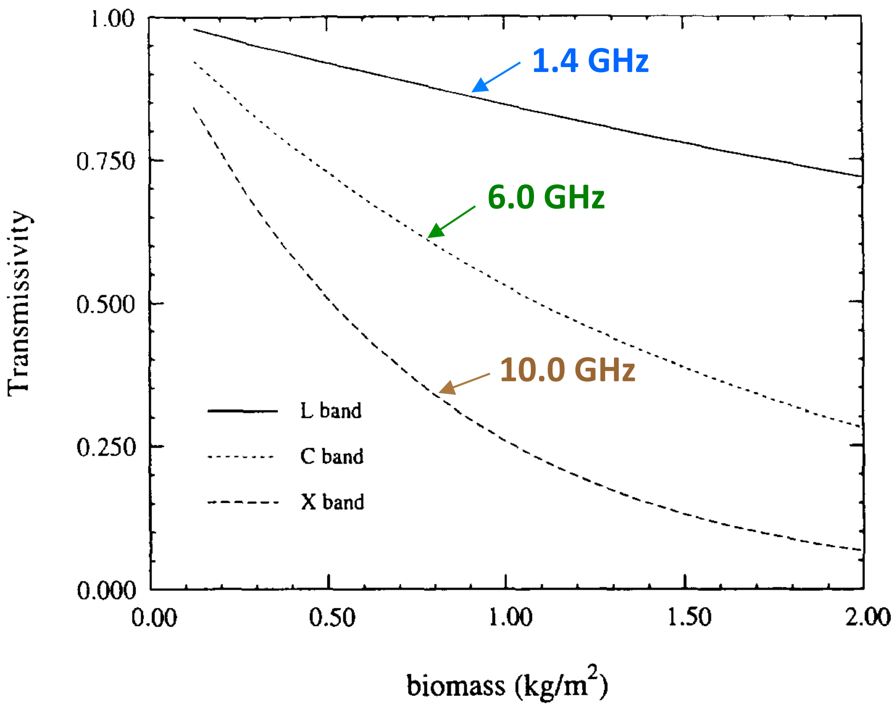


- With Visible and Infrared sensors the soil is masked by clouds and vegetation. Optical sensors operate by measuring scattered sunlight and are “daytime only”.
- Microwaves can penetrate through clouds and vegetation, operate day and night, and are highly sensitive to the water in the soil due to the change in the soil microwave dielectric properties.

Advantages of Sensing at L-Band



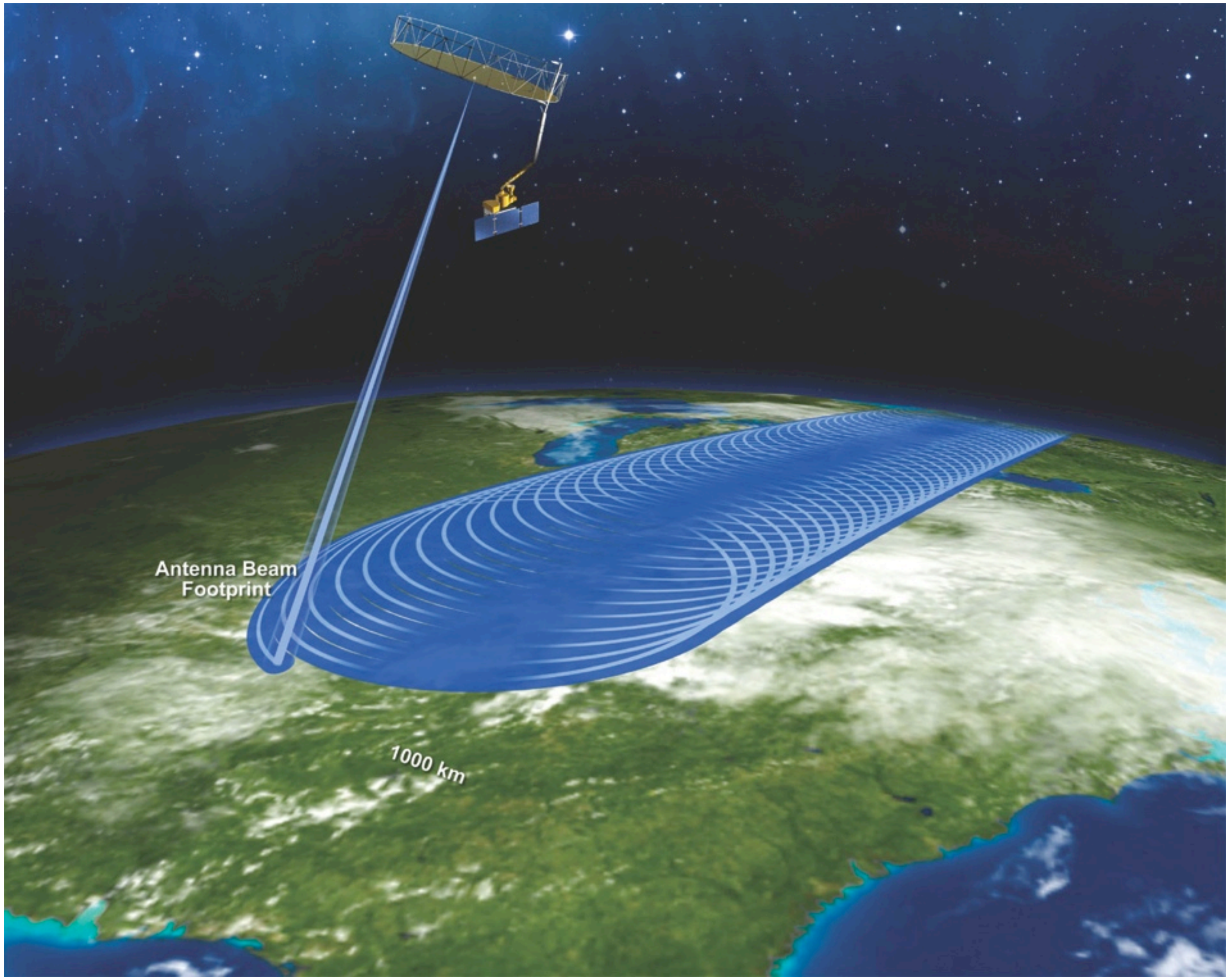
Effective sensing depth decreases with increasing measurement frequency



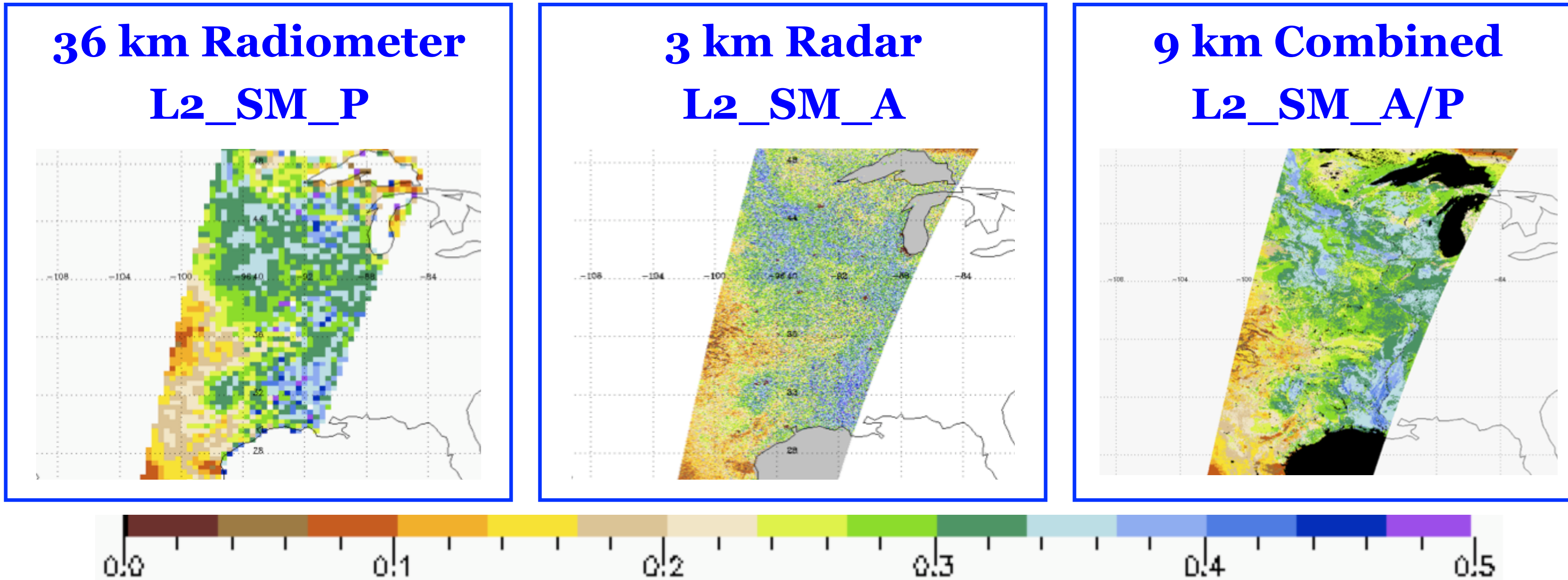
Vegetation attenuation increases with increasing measurement frequency

L-band provides significant improvements in soil moisture sensing capability over previous missions (e.g. AMSR-E at C-band)

SMAP Antenna Helical Scan Pattern



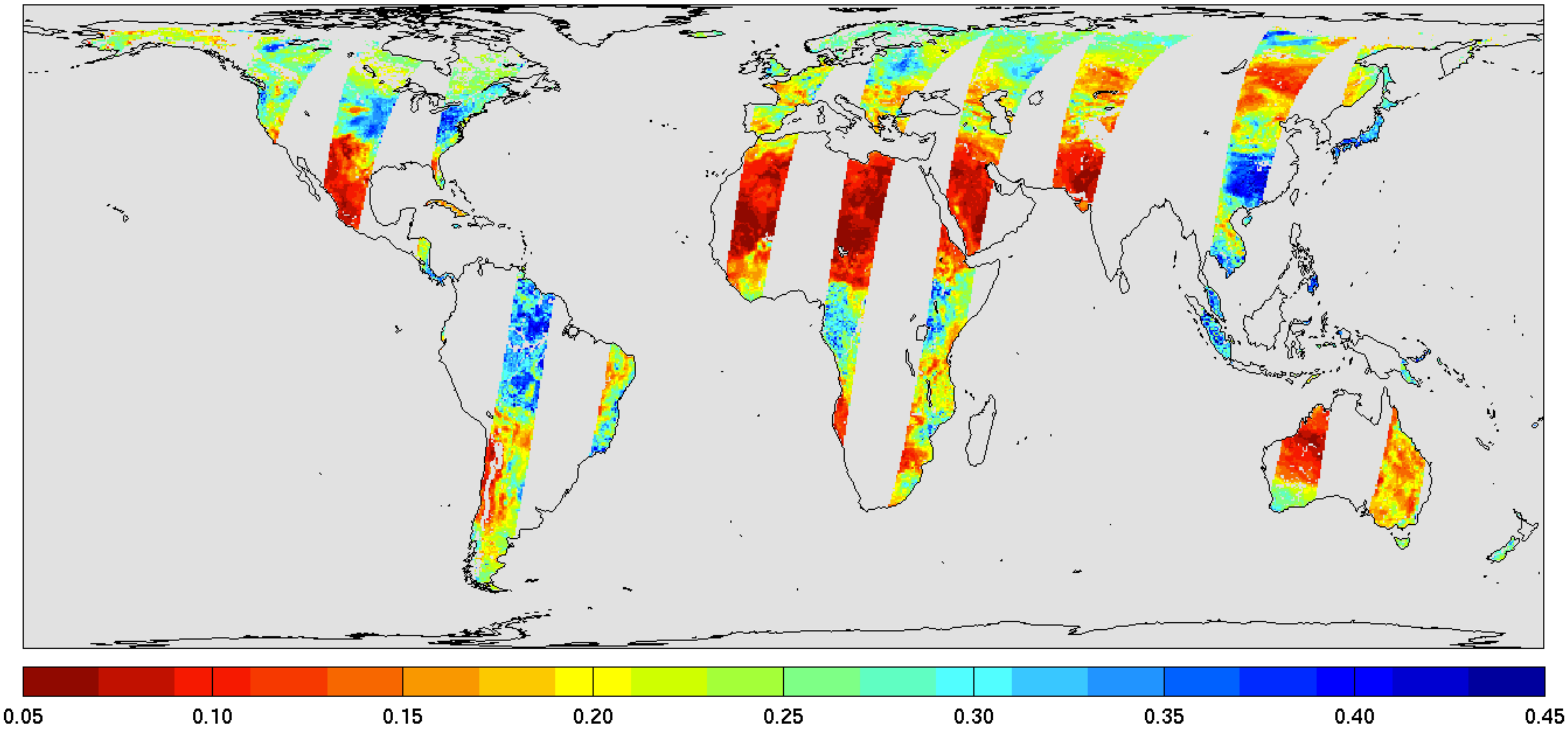
Simulated Level 2 Soil Moisture Products



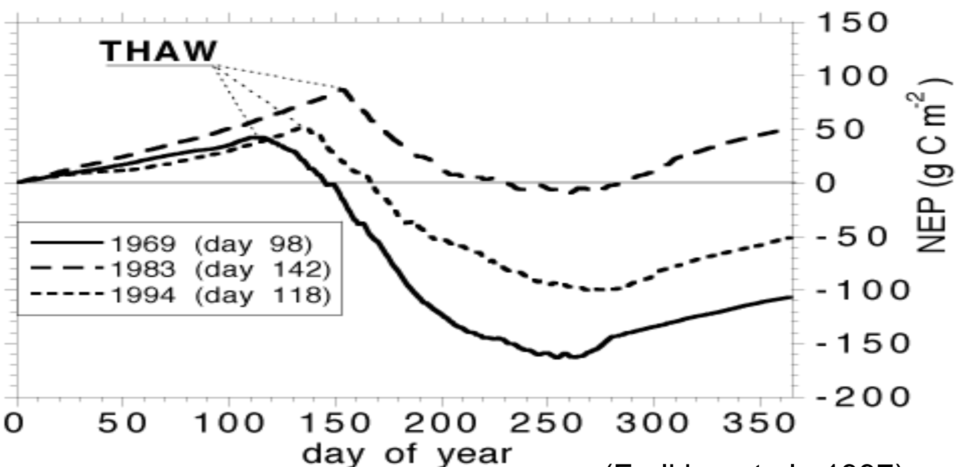
SMAP has three level 2 (L2) soil moisture products:

- They have been tested through end-to-end simulations: Geophysical data → orbit → observations → errors → inversion.
- Used baseline algorithms – other algorithms are being tested also as options.
- Software is implemented on the SMAP Science Data System (SDS).

Daily Global Soil Moisture Map (Level 3)



SMAP and Carbon

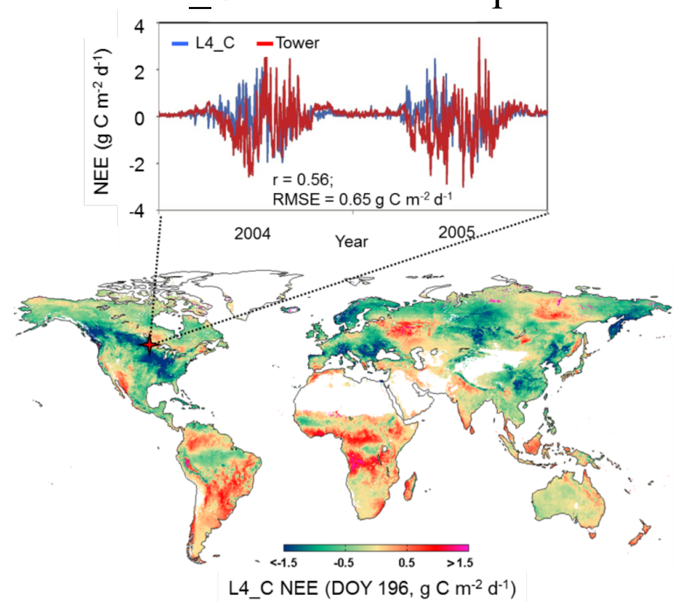


(Frolking et al., 1997)

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.

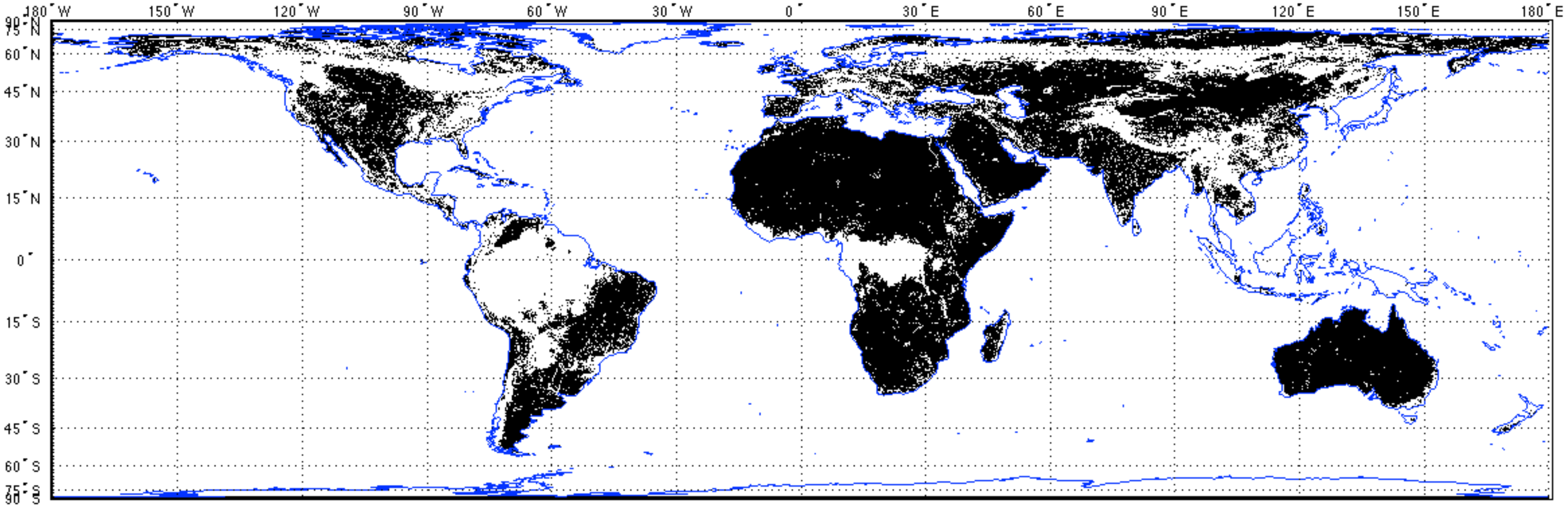
NEE quantifies the magnitude and direction of land-atmosphere net CO2 exchange and is a fundamental measure of the balance between carbon uptake by vegetation net primary production (NPP) and carbon loss through soil heterotrophic respiration (Rh).

L4_C Product Example



SMAP L1 Mask at 9 km

Regions Where SMAP Soil Moisture Retrievals Are Expected to Meet L1 Requirements

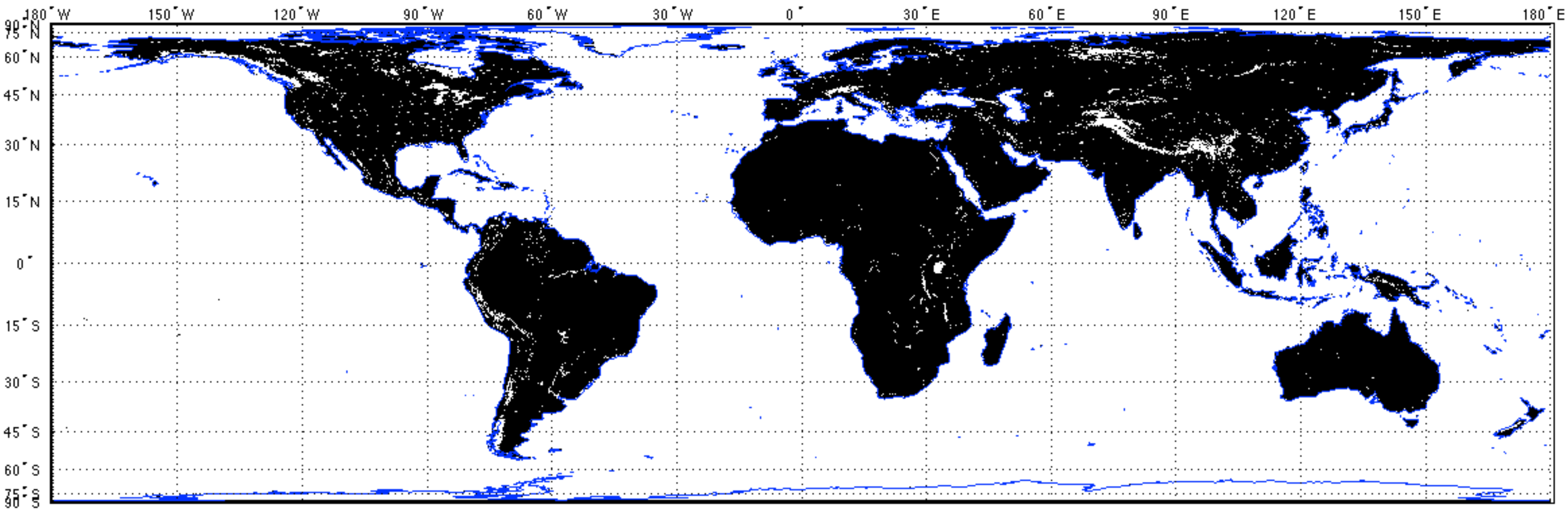


Retrievable Mask (Black Colored Pixels) Prepared With Following Specifications:

a) VWC ≤ 5 kg/m^2
b) Urban Fraction ≤ 0.25
c) Water Fraction ≤ 0.1
d) DEM Slope Standard Deviation ≤ 3 deg

SMAP Retrievable Mask at 9 km

Regions Where SMAP Soil Moisture Algorithms Will be Executed



Retrievable Mask (Black Colored Pixels) Prepared with Following Specifications:

a) Urban Fraction < 1

b) Water Fraction < 0.5

c) DEM Slope Standard Deviation < 5 deg

SMAP Data Products

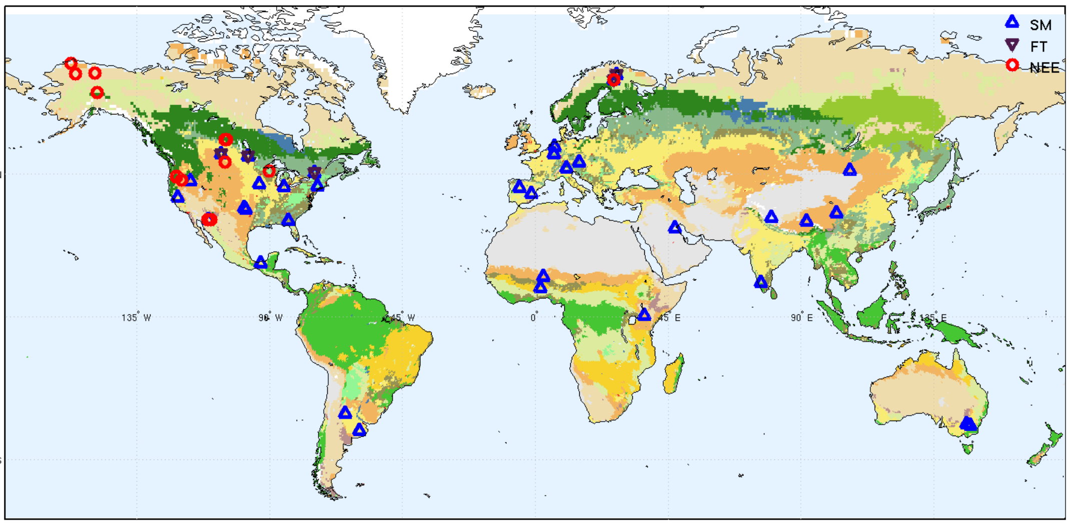
Product	Description	Gridding (Resolution)	Latency**	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	Instrument Data
L1A_Radar	Radar Data in Time-Order	-	12 hrs	
L1B_TB	Radiometer T_B in Time-Order	(36x47 km)	12 hrs	
L1B_S0_LoRes	Low Resolution Radar σ_o in Time-Order	(5x30 km)	12 hrs	
L1C_S0_HiRes	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	

Cal/Val Methodologies

Methodology	Role	Analysis tools and readiness
Core Validation Sites	Accurate estimates of products at matching scales for a set of conditions with spatially distributed in situ sensors	✓ Data transfer from Cal/Val Partners set up and/or automated ✓ Scaling methods defined ✓ Offset grid processing
Sparse Networks	One point in the grid cell for a wide range of conditions	✓ Triple collocation method tool completed ✓ Data transfer from Cal/Val Partners automated
Satellite Products	Estimates over a very wide range of conditions at matching scales	✓ Cross comparison tools developed for SMOS, GCOM-W and Aquarius ✓ Task Group formed
Model Products	Estimates over a very wide range of conditions at matching scales	✓ Developed high-res 3 and 9 km model products ✓ Statistical comparison methods developed
Field Campaigns	Detailed assessment of the scaling issues for a set of high priority conditions	✓ SMAPVEx15 and 16 campaigns defined ✓ Australia campaign planned in 2015

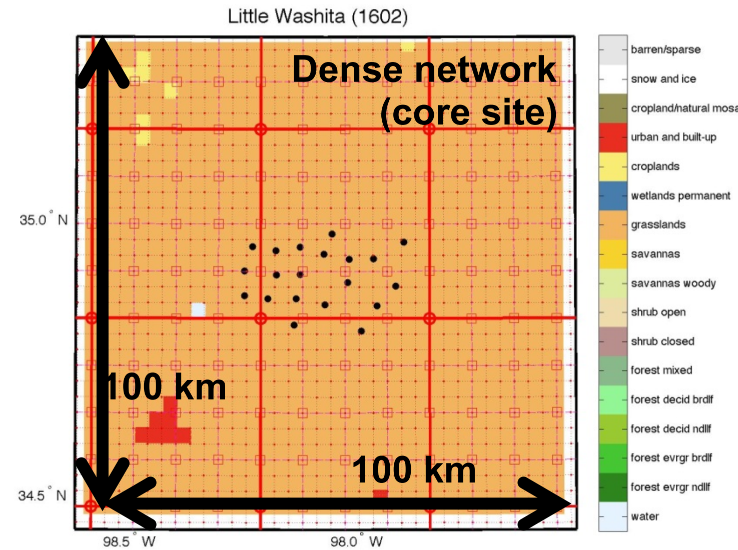
SMAP Soil Moisture Cal/Val Approach

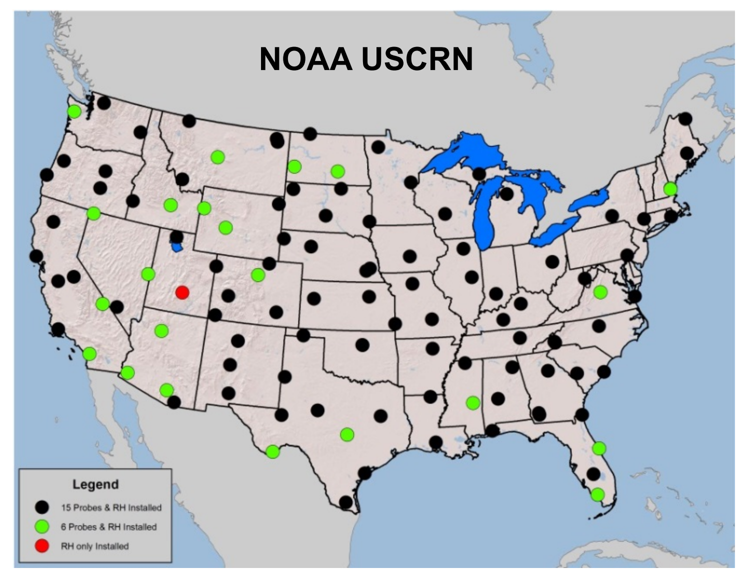
- Primary calibration and validation approach is utilization of dense in situ soil moisture measurements (multiple soil moisture measurement within the 3-km to 36-km SMAP footprint).



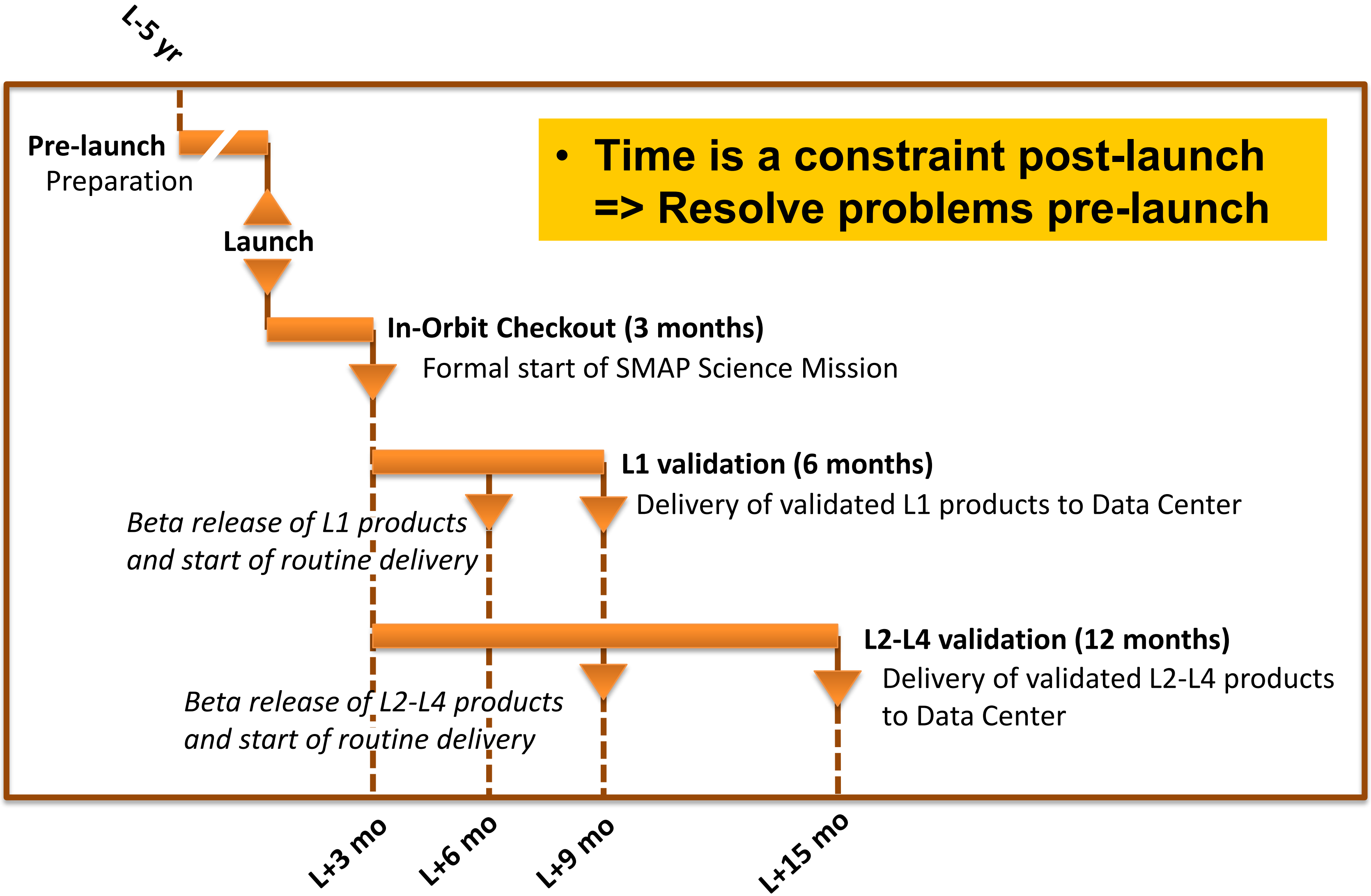
Global distribution of core validation sites

- Supplemental approach will utilize large-scale sparse networks (one measurement within footprint), and global remote sensing and model-based soil moisture data products





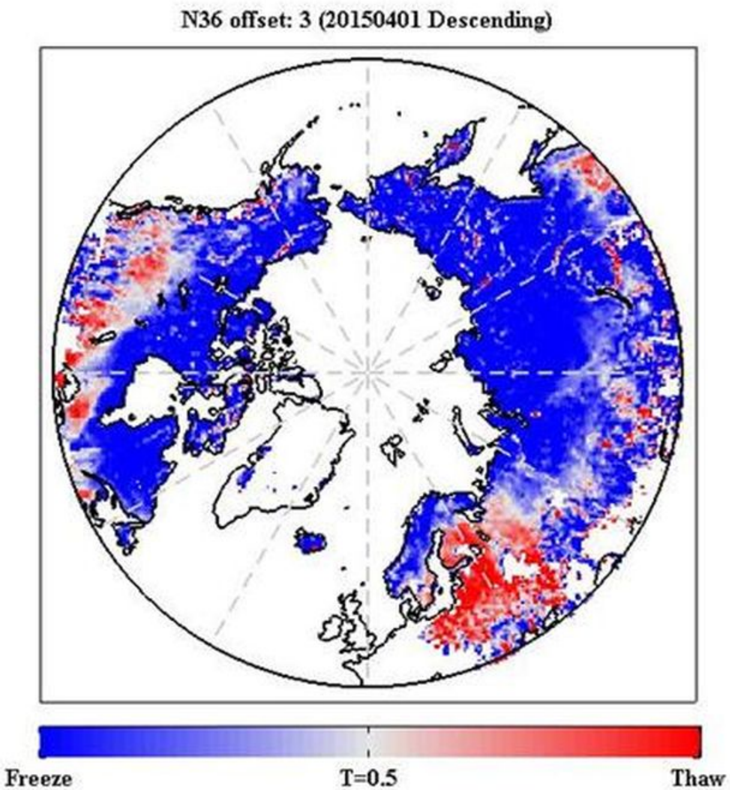
SMAP Cal/Val Timeline



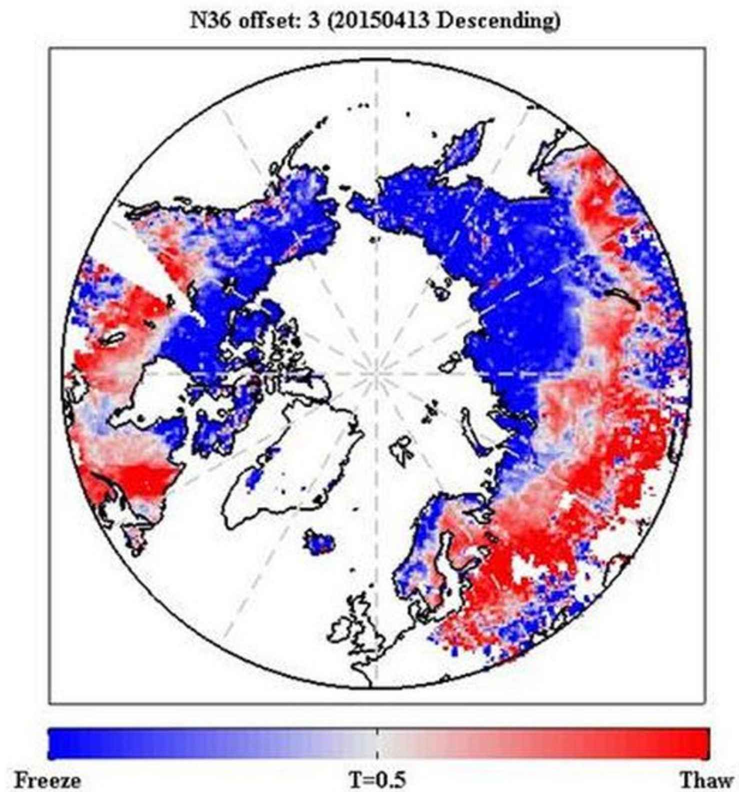
- **Time is a constraint post-launch => Resolve problems pre-launch**

SMAP Freeze/Thaw Map – 3 km

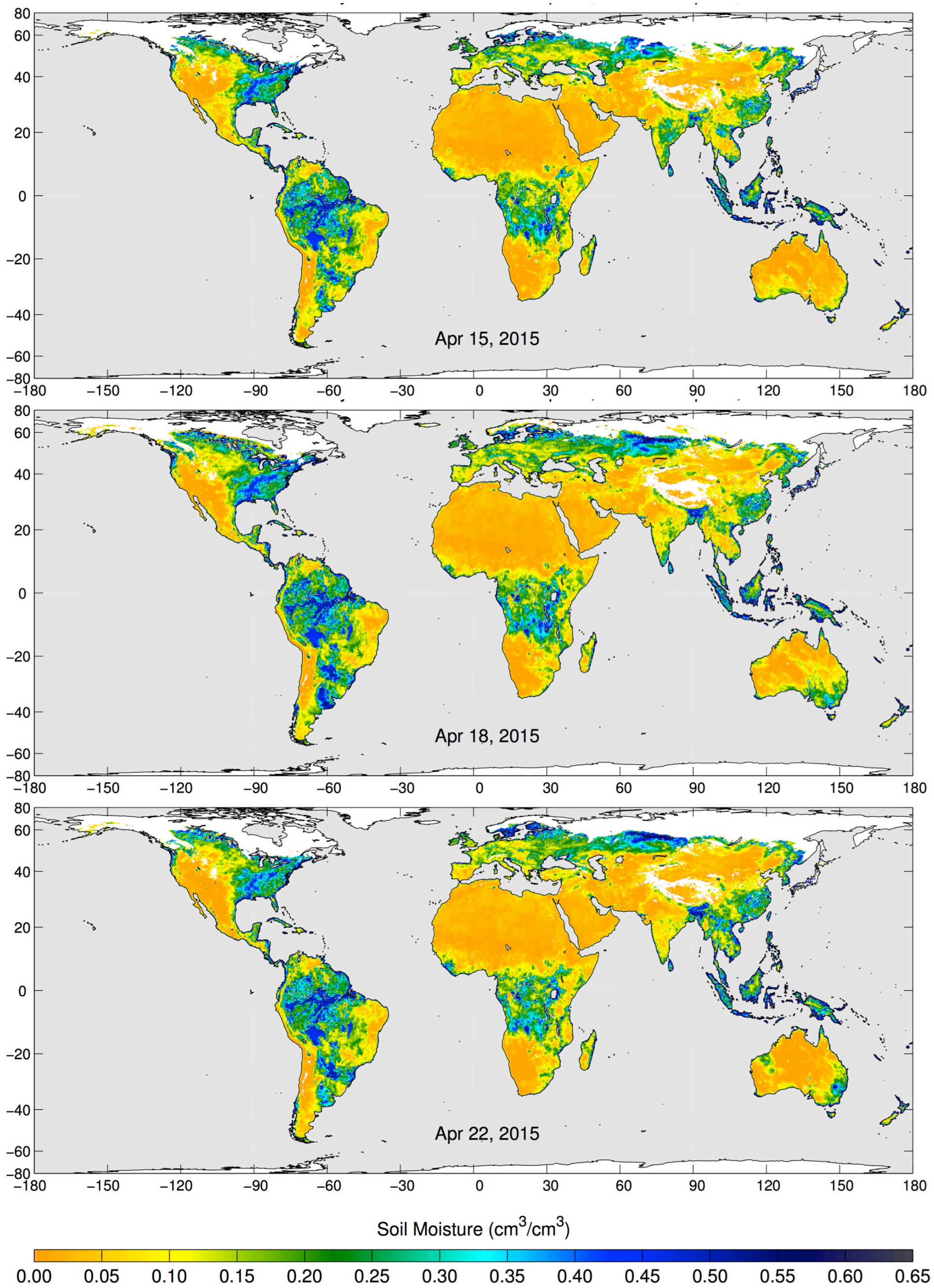
April 1, 2015



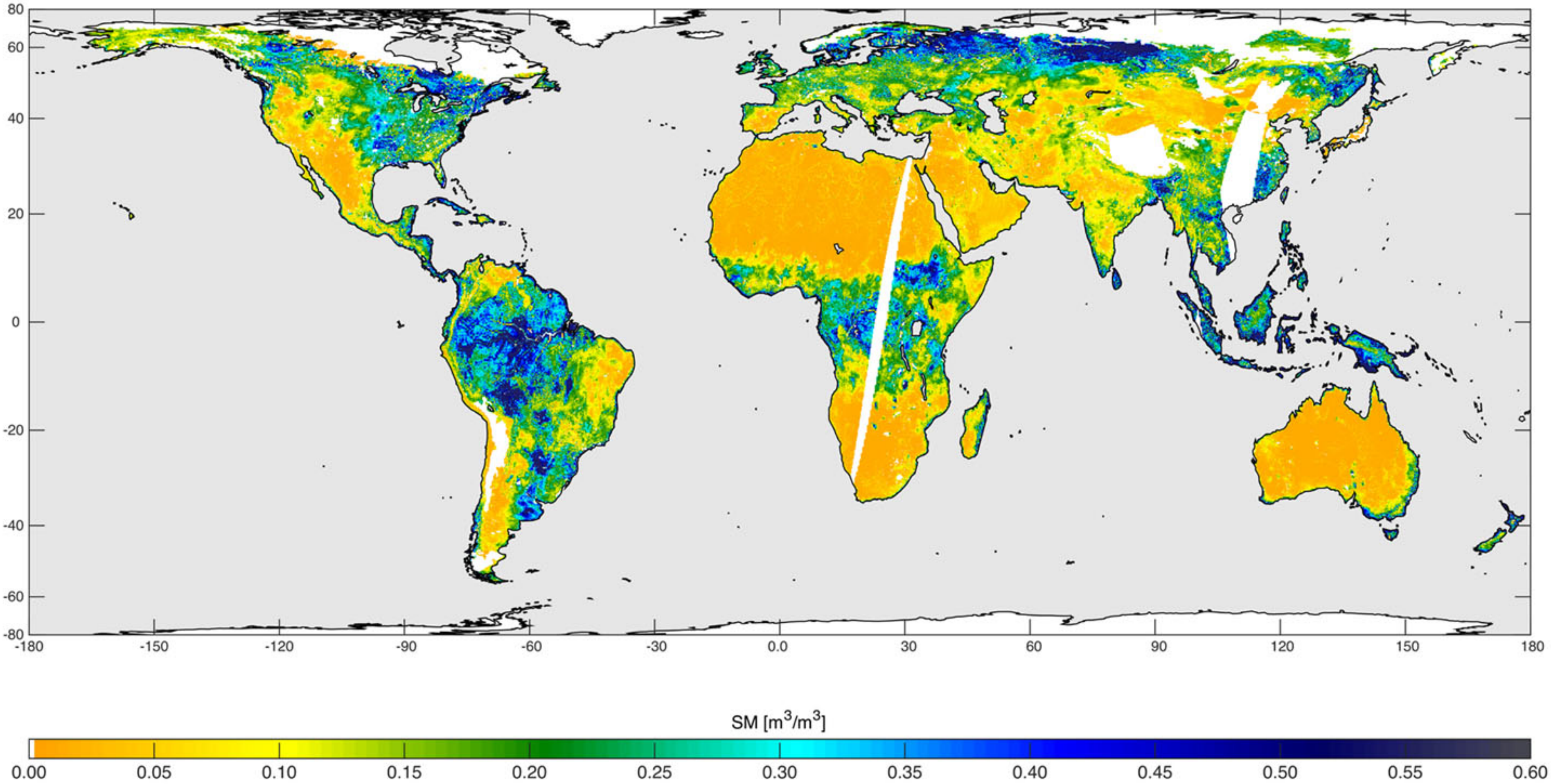
April 13, 2015



SMAP Global Soil Moisture Map – 36 km



SMAP Global Soil Moisture Map – 9 km



Images acquired between May 4 - 11

Availability of Validated Data Products

- The initial product delivery to the public will be three months after instrument commissioning, six months after launch. **These will be beta version products**.
  - Initial **validated** Level 1 products appear six months after instrument commissioning, or about nine months after launch.
  - Initial **validated** Level 2, Level 3 and Level 4 products appear twelve months after instrument commissioning, or about fifteen months after launch.

SMAP Data Access

SMAP data products will be **freely** available through the National Snow and Ice Data Center (NSIDC) and Alaska Satellite Facility (ASF)

- http://nsidc.org/data/smap (for all SMAP L2, L3, and L4 products and L1A, L1B, and L1C radiometer data)

- https://www.asf.alaska.edu/smap/data-imagery/ (for all SMAP L1 radar data- L1A_Radar, L1B_SO_LoRes, and L1C_S0_HiRes)

Applications of Soil Moisture

Better/enhanced weather & climate Forecasting

More accurate agriculture productivity

Drought early warning

Extent of flooding

Human health and Vector borne disease

Value of Soil Moisture Data to Weather & Climate

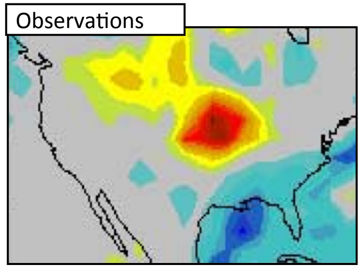
New space-based soil moisture observations and data assimilation modeling can improve forecasts of local storms and seasonal climate anomalies

Seasonal Climate Predictability

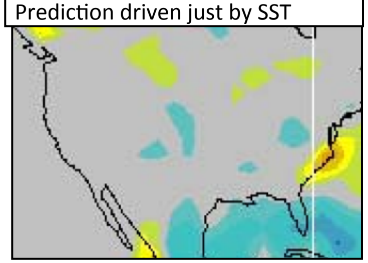
*Predictability of **seasonal climate** is dependent on boundary conditions such as sea surface temperature (SST) and soil moisture – **soil moisture** is particularly important over continental interiors.*

Difference in Summer Rainfall: 1993 (flood) minus 1988 (drought) years

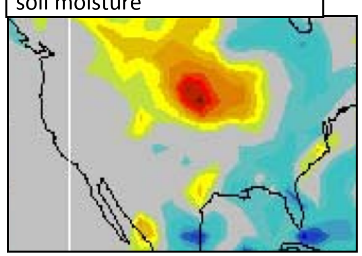
Observations



Prediction driven just by SST

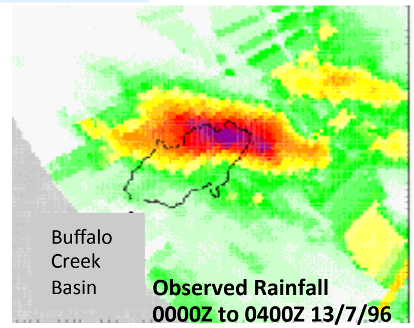


Prediction driven by SST and soil moisture

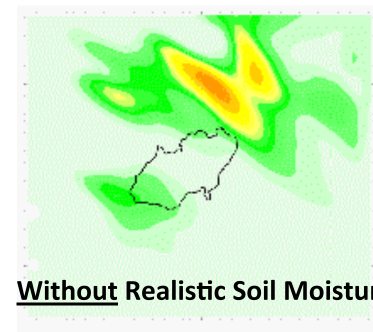


(Schubert et al., 2002)

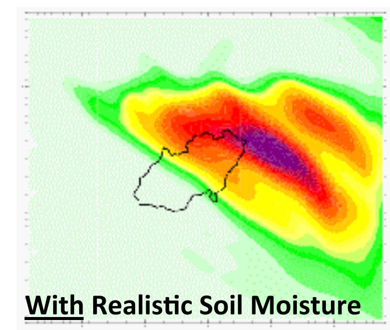
NWP Rainfall Prediction



(Chen et al., 2001)



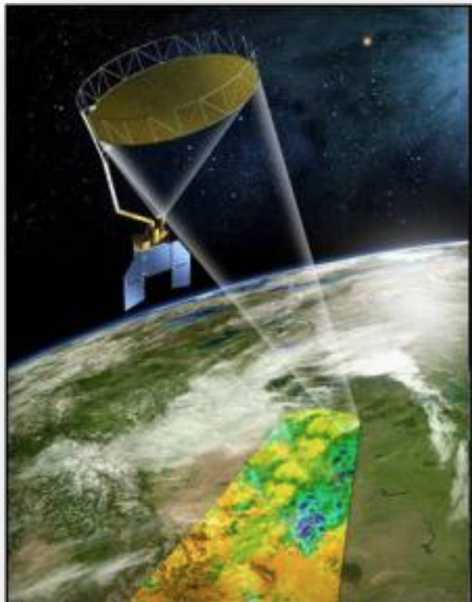
24-Hours Ahead High-Resolution Atmospheric Model Forecasts



In weather forecasting, SMAP surface soil moisture, with x10 higher resolution than existing model estimates, will result in enhanced predictions.

A Flood Example

Application of a SMAP-Based Index for Flood Forecasting in Data-Poor Regions

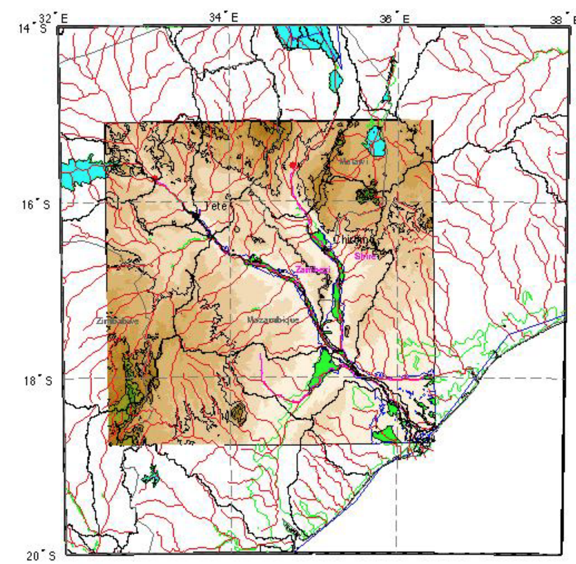


Current Capability: The UN-WFP uses satellite derived flood maps to locate floods and map delivery routes to affected areas.

Enhanced Capability: Use SMAP to expand their current flood database with look-up information that produces flood indices for a given rainfall forecast (ECMWF) and soil moisture condition (SMAP).

Study Area: Zambezi basin and its delta in Mozambique.

Algorithm Structure: VIC output on flow is input into a hydrodynamic model (LISFlOOD-FP), which is complemented with a sub-grid channel formulation to generate flood inundation variables (inundated area, floodplain water volume) for the lower Zambezi basin. ECMWF archived forecast rainfall data is used to compute flows for daily inundation patterns over 10 years.



Courtesy of Guy Schumann- UCLA

SMAP Applications Early Adopters

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: **Molly Brown**	Data assimilation of SMAP observations, and impact on weather forecasts in a coupled simulation environment
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: **Molly Brown**	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
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

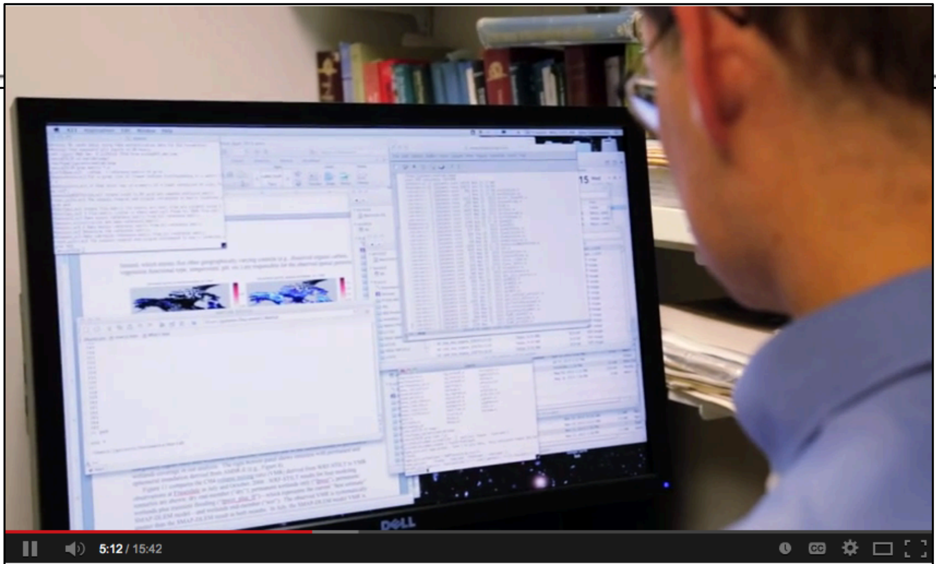
Early Adopter Video

SMAP Early Adopters video

This diverse group represents a cross-section of end-users of SMAP data who collaborate to ensure integration of SMAP data into operations that affect our day-to-day lives. Examples include the U.S. Forest Service, the UN World Food Programme, and the U.S. Department of Agriculture.

VTT files: English (VTT, 18 KB) | Italian (VTT, 18 KB) | Spanish (VTT, 19 KB)

Early Adopters



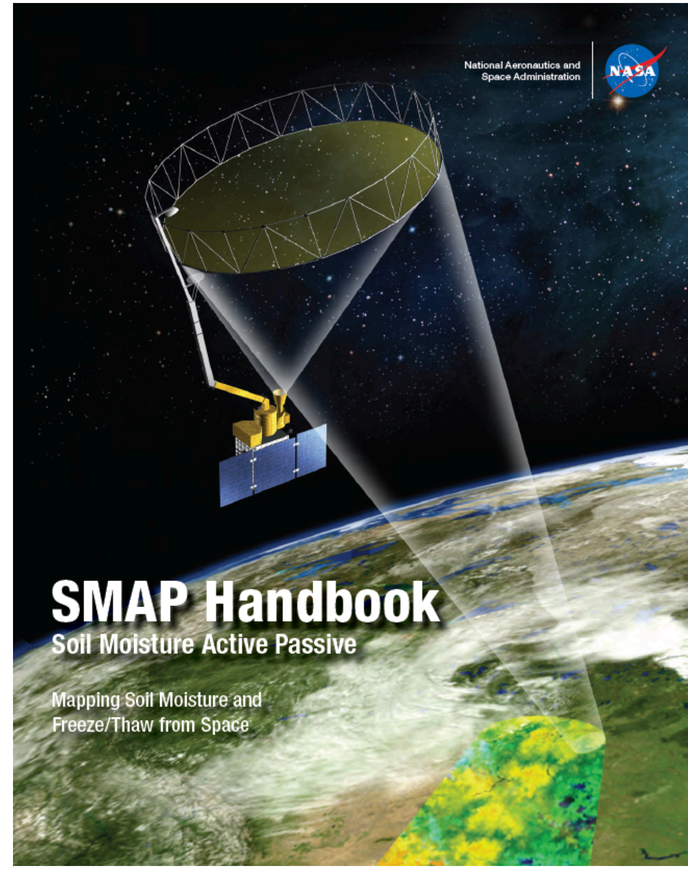
SMAP Early Adopters

http://smap.jpl.nasa.gov/applications/

The SMAP Handbook

Chapters

1. Introduction and Background
2. Mission Overview
3. Instrument Design and Data Products
4. Soil Moisture Data Products
5. The Value-Added Data L4_SM Product
6. Carbon Cycle Data Products
7. Calibration and Validation Plan
8. Applications and Applied Science
9. SMAP Project Bibliography



(192 Pages)

http://smap.jpl.nasa.gov/Imperative/

http://smap.jpl.nasa.gov

NASA / The Visible Earth / The COMET Program