SMAP Mission Science and Applications Overview

Societal Benefit through Mission Applications

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NRDC Conference, Valladolid, Spain

June 21-24, 2016

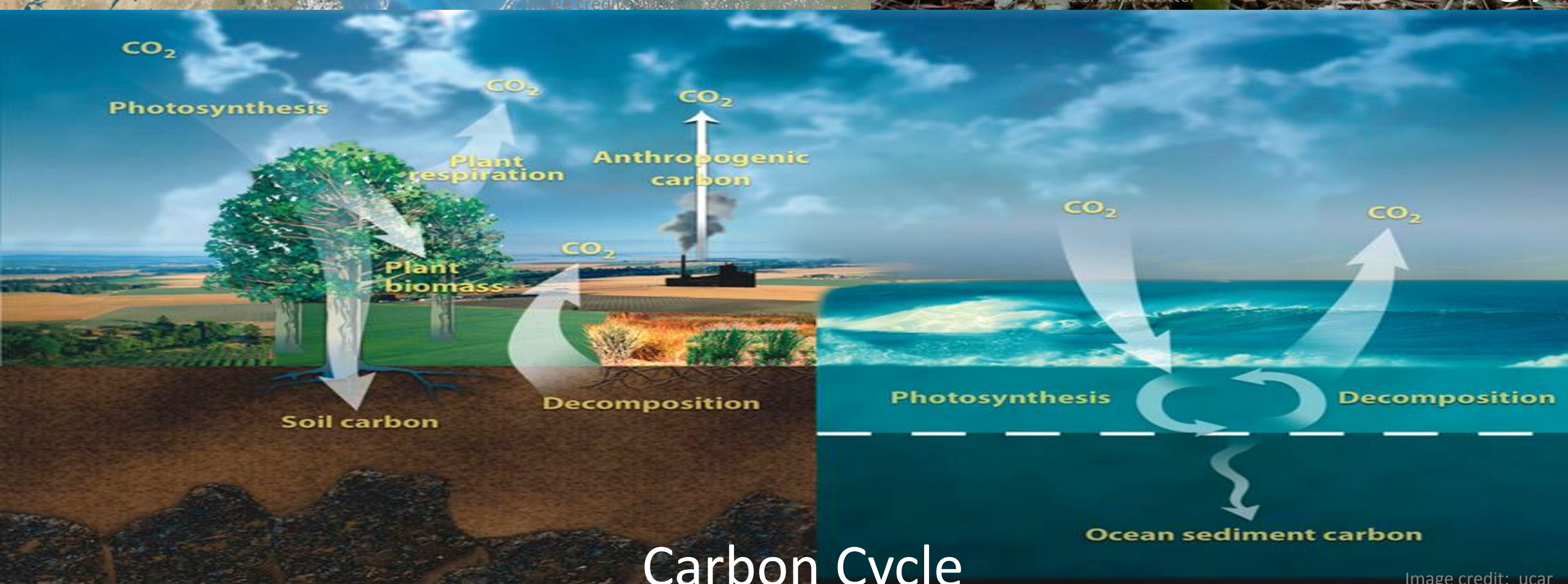
Outline

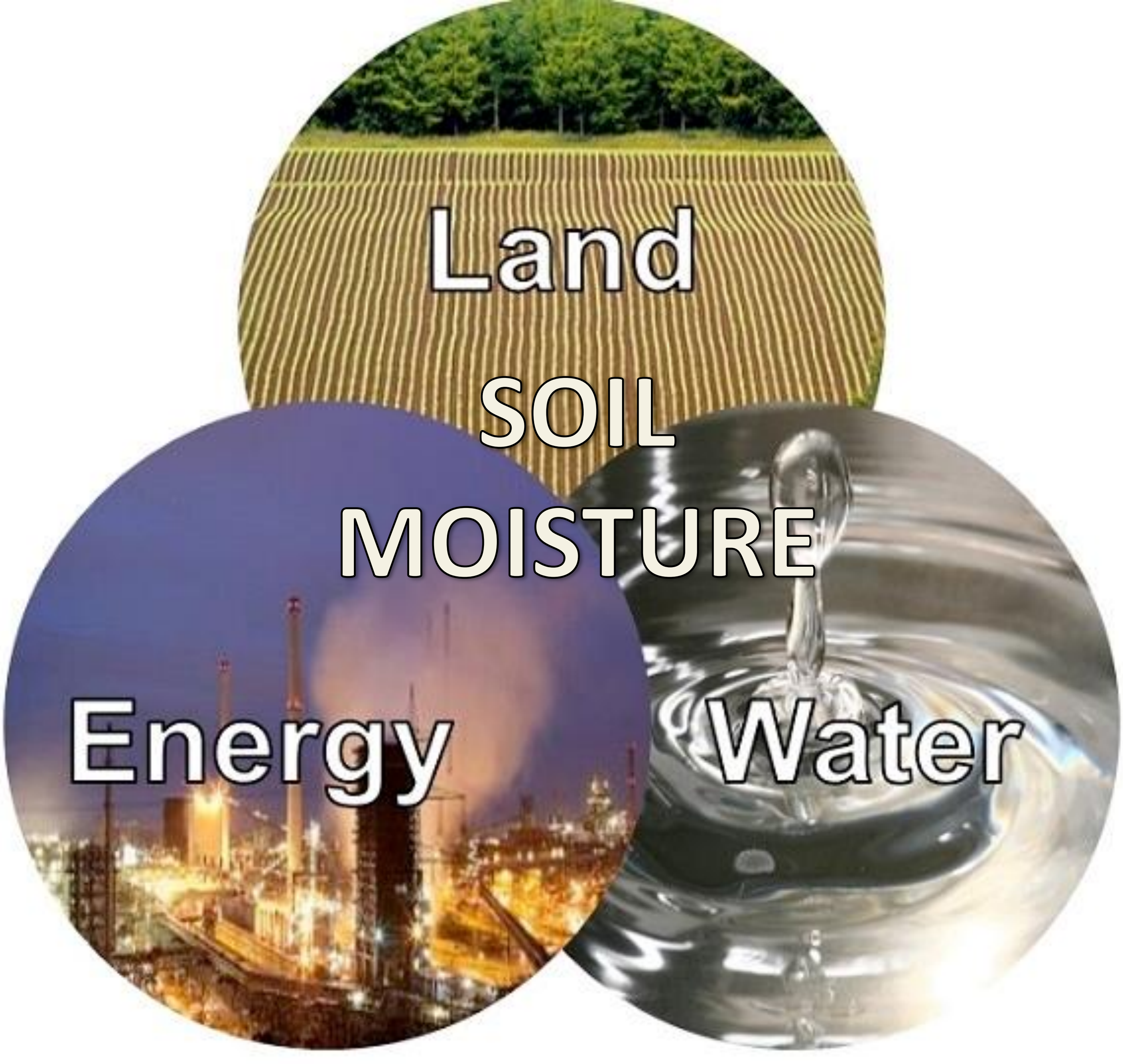
- SMAP Mission Objective and Overview
- SMAP Mission Status Post Radar
- SMAP Mission Products and Enhanced Products
- SMAP Mission Applications
- Early Adopter Program
- Tutorials, Data Centers and Future Opportunities

SMAP Mission Objective and Overview


Land Water


Energy
Image credit: twitter

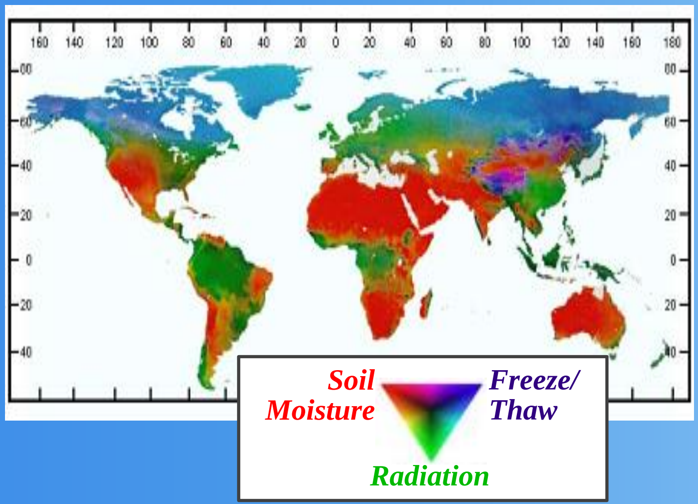

CO_2
Photosynthesis
CO_2
Plant respiration
CO_2
Anthropogenic carbon
CO_2
Plant biomass
Soil carbon
Decomposition
CO_2
CO_2
Photosynthesis
Decomposition
Ocean sediment carbon
Carbon Cycle
Image credit: ucar


Land
SOIL
MOISTURE
Energy
Water

SMAP Science and Application Returns

Science Returns

Soil Moisture *Links* the Global Land Water, Energy, and Carbon Cycles



1. Estimating global surface water and energy fluxes
2. Quantifying net carbon flux in boreal landscapes
3. Reduce uncertainty of climate model projections

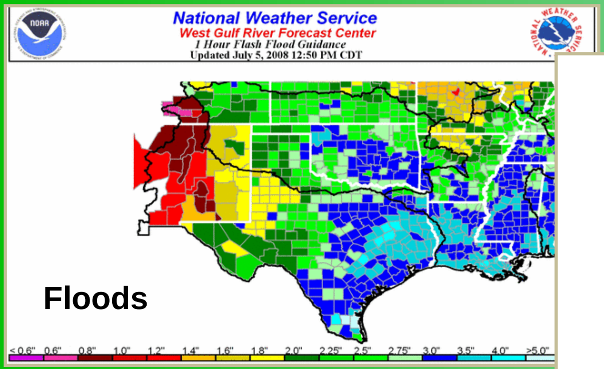
Approach

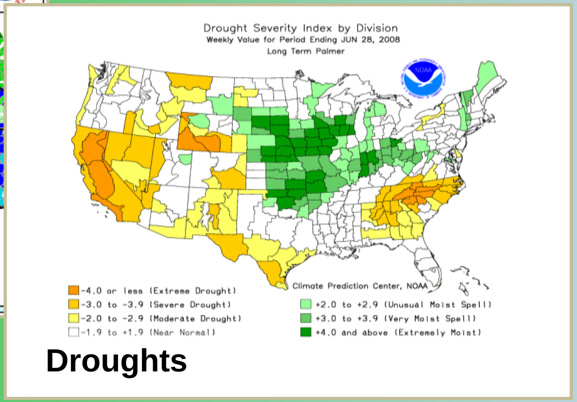
L-band (~21 cm; All-Weather; Canopy Penetration; Sensing Depth)

6m conically scanning (14 rpm) antenna for 1000 km swath

Global coverage every 2-3 days

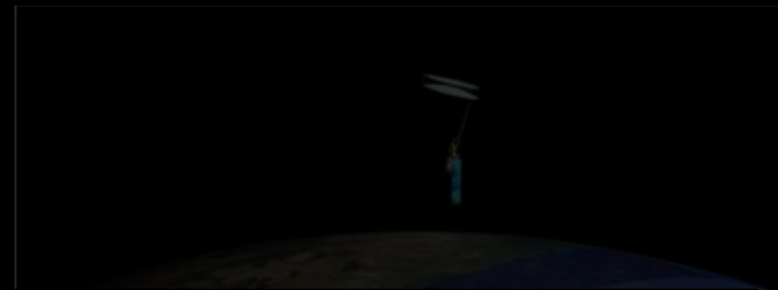
Applications Returns





4. Enhancing weather forecasts
5. Improving flood prediction and drought monitoring

SMAP Measurement Approach



Instruments:

Only July 7 the SMAP radar stopped transmitting due to a power supply problem.

The radar subsystem is no longer operable.
The radiometer continues to produce science data.

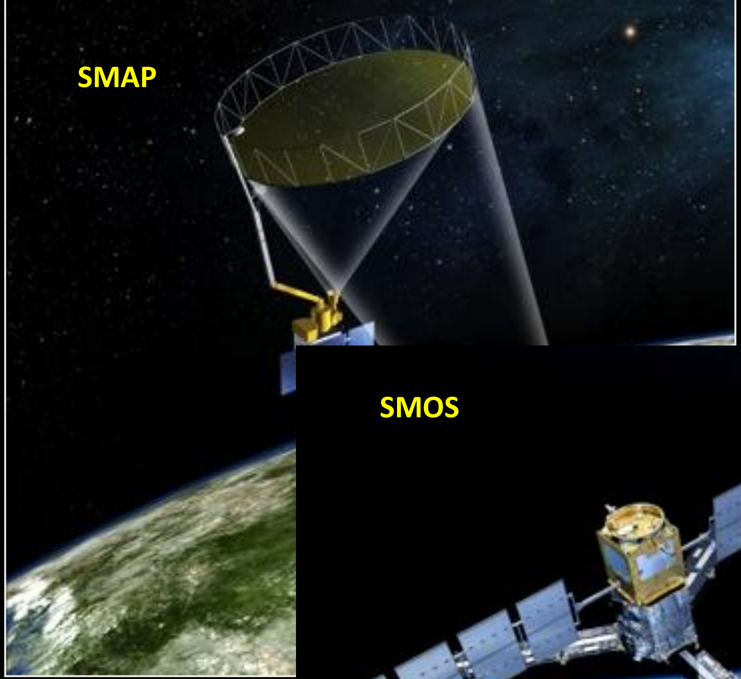
- **Radiometer: L-band (1.4 GHz)**
  - Moderate resolution, high accuracy soil moisture
  - 40 km resolution (3dB) resolution
- **Shared Antenna**
  - 6-m diameter deployable mesh antenna
  - Conical scan at 13-14 rpm
  - Constant incidence angle: 40 degrees
    - 1000 km-wide swath

- 6 am local time descending
- 6 pm local time ascending
- 685 km altitude
- Global coverage once every three days

- **Mission Operations:**
  - 3-year baseline mission (enough fuel for 5 year)

SMAP Lessons Learned

- Improved RFI challenges learned from SMOS (Soil Moisture Ocean Salinity Satellite from ESA)
- High Resolution and High accuracy products because of the combined radar radiometer
- Using L-band
  - Improvement from C-Band instruments (SMMR)
  - Deeper soil penetration (from 1cm to 5 cm)
  - Better sensing over vegetated areas



- Fixed incident angle (40 degrees) for improved sensing over vegetation.
- Conical scan, Contiguous 1000 km swath 2-3 days revisit
- Working with SMOS mission for continuity of soil moisture applications

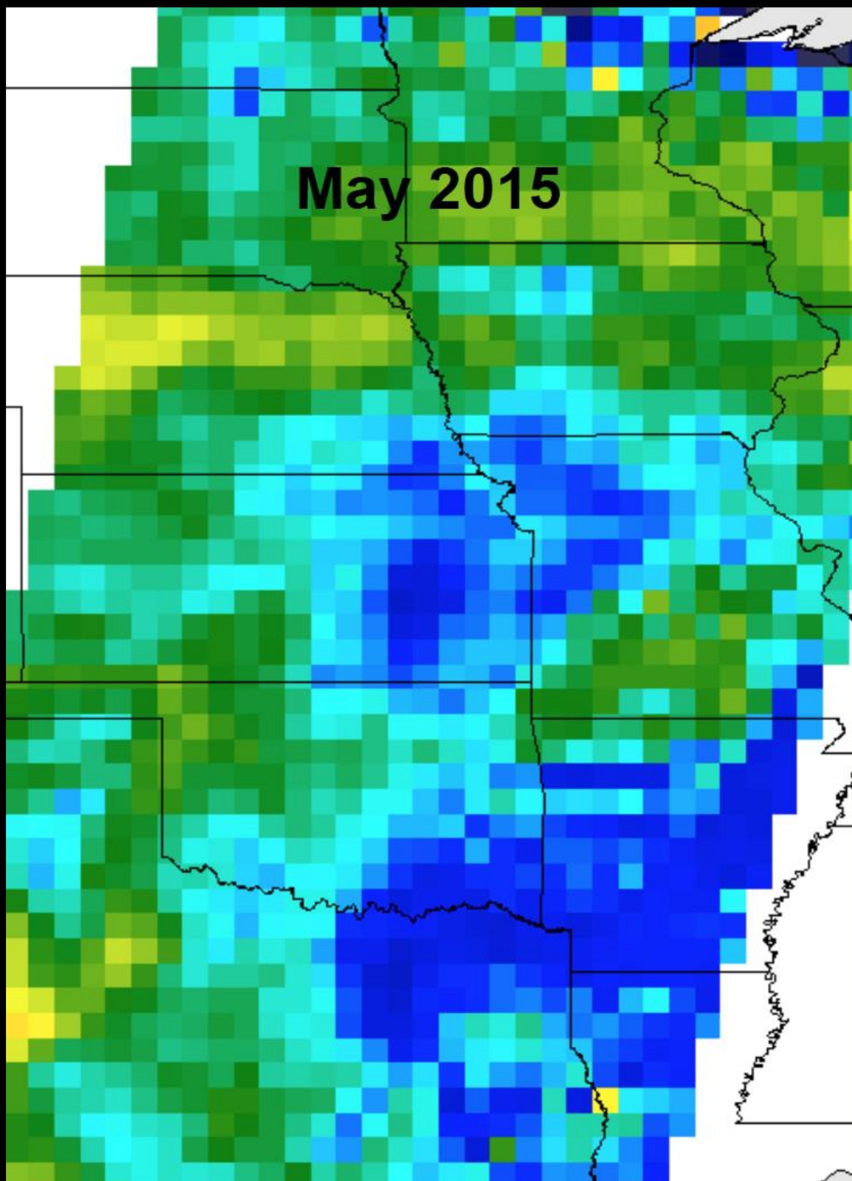
Mission Status Overview Post Radar

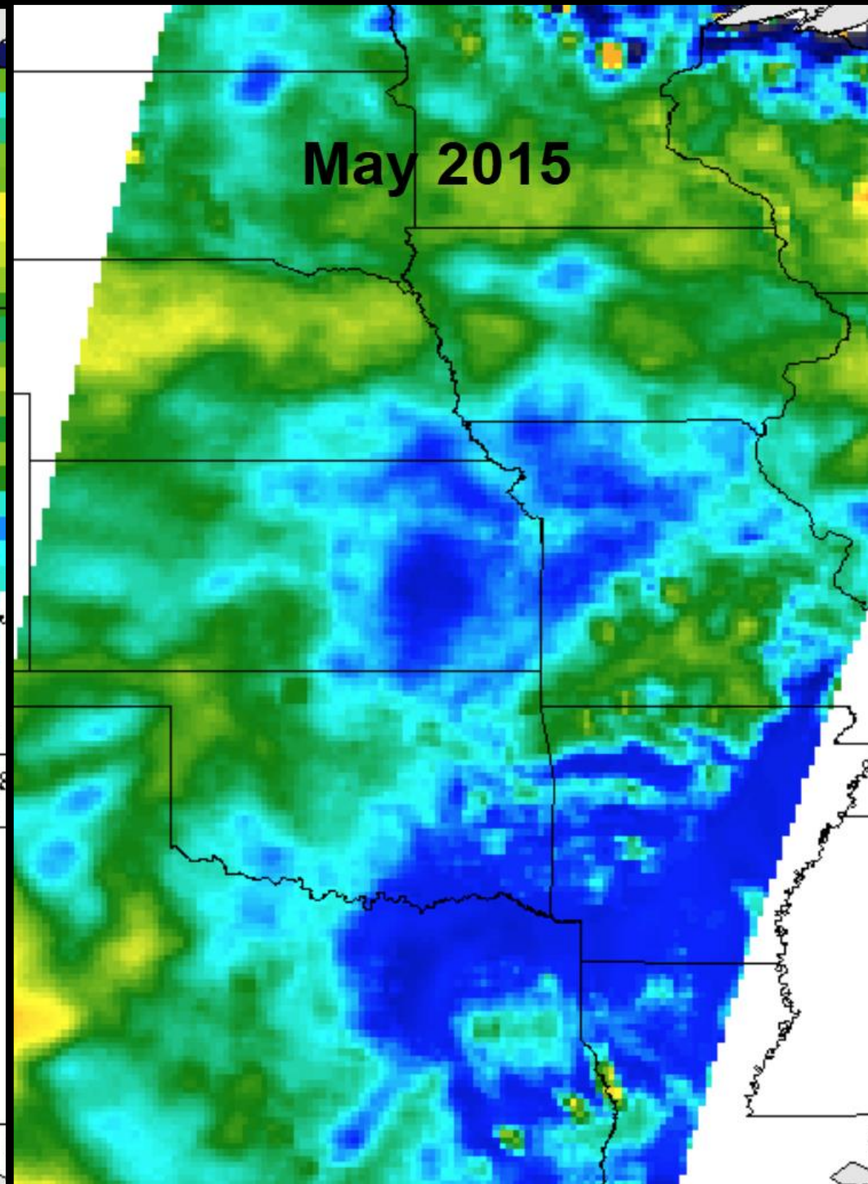
- SMAP launched on Jan 31st, 2015
- Science data acquisition started in April, 2015
- SMAP Radiometer and Radar worked in tandem with great success
- SMAP Radar malfunctioned on July 7th, 2015 and currently inoperable
- SMAP Beta-Product released to public on October 31st, 2015
- SMAP science data acquisition operation finished one year in April 2016
- SMAP Validated Products released on April 30th, 2016
- SMAP data is now freely available to public through the NASA DAAC at NSIDC

SMAP Mission Products

Product	Description	Gridding (Resolution)	Latency**	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	Instrument Data
[redacted]				
L1B_TB	Radiometer T_B in Time-Order	(36x47 km)	12 hrs	
[redacted]				
L1C_TB	Radiometer T_B in Half-Orbits	36 km	12 hrs	
[redacted]				
L2_SM_P	Soil Moisture (Radiometer)	36 km	24 hrs	Science Data (Half-Orbit)
[redacted]				
L3_SM_P	Soil Moisture (Radiometer)	36 km	50 hrs	Science Data (Daily Composite)
[redacted]				
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	

SMAP Enhanced Products

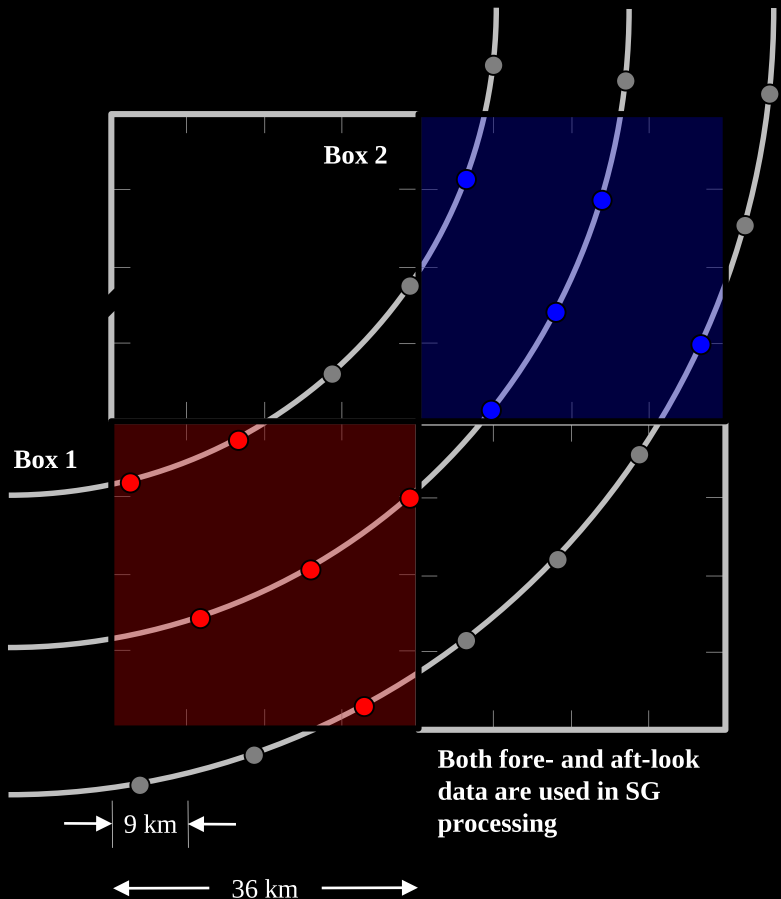




1. SMAP Enhanced Processing For Radiometer

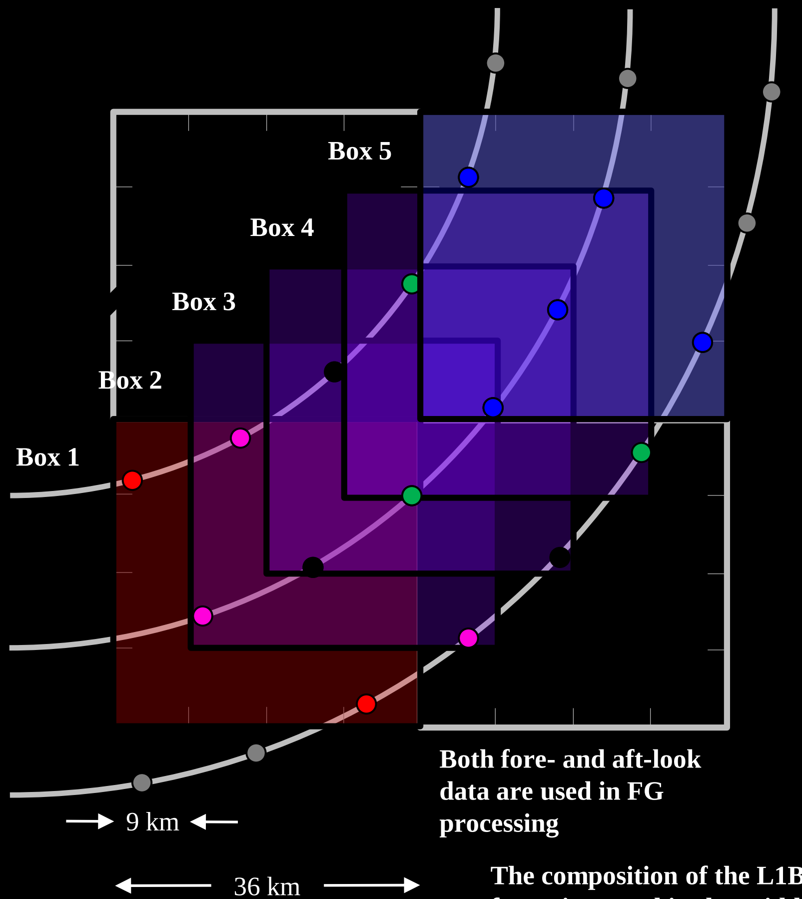
Existing
Standard Grid (SG) Processing

On SG, radiometer data transition is not fully captured from one box to another offset by 36 km



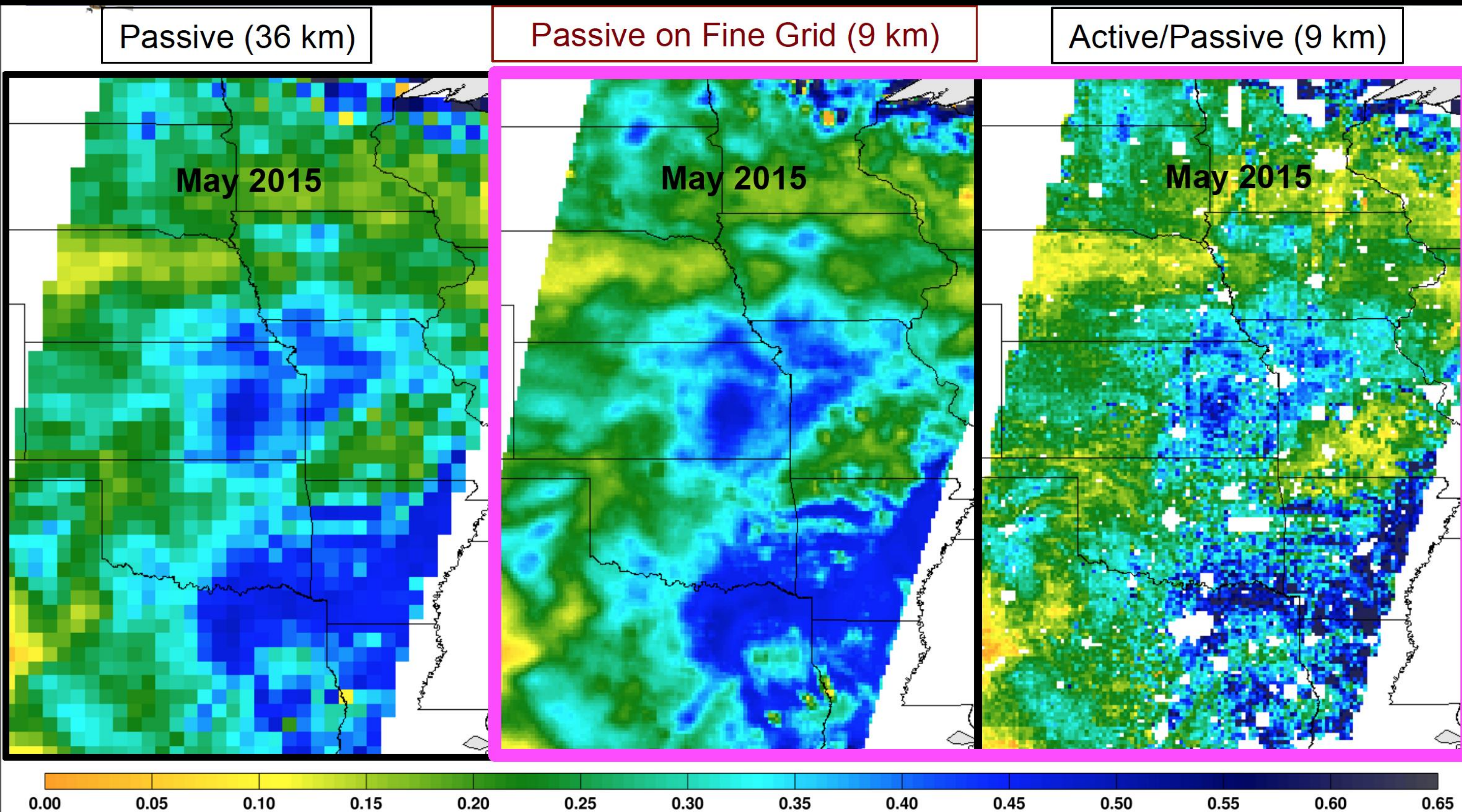
Proposed
Enhanced Processing

On enhanced, radiometer data transition is **more fully captured** from one box to another offset by 9 km



The composition of the L1B footprints used in the gridding process changes for each FG box

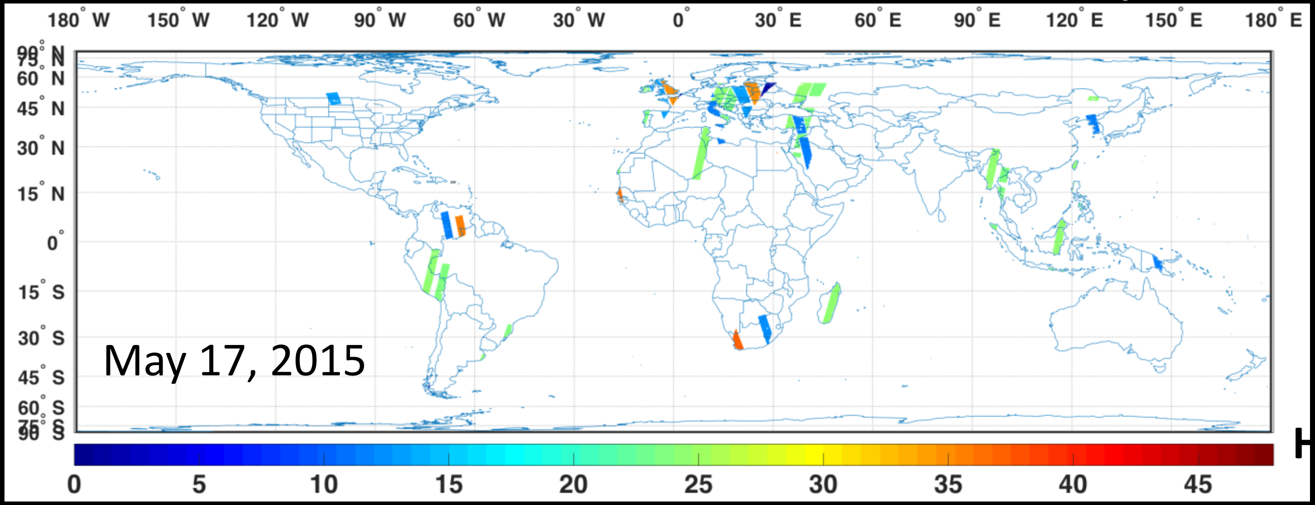
1. SMAP Enhanced Processing For Radiometer



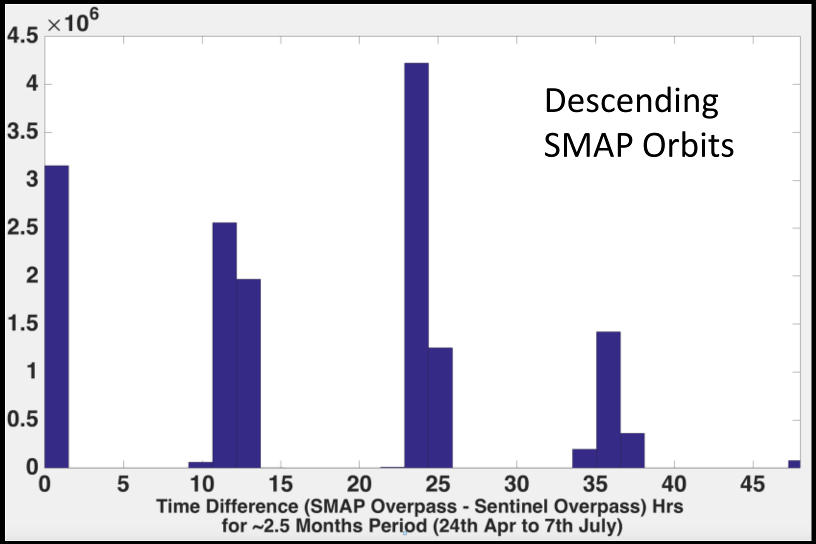
Passive retrieval on FG (middle) reveals spatial features not apparent in the current standard product (left); these features are nonetheless consistent with what the A/P product (right) demonstrated prior to radar failure

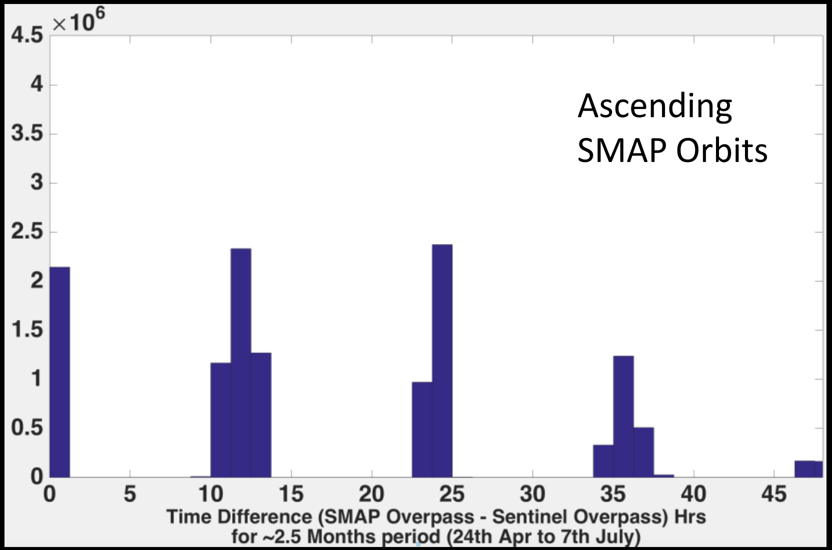
2. SMAP-Sentinel Active-Passive Product

SMAP and Sentinel Global Overlap



With the current orbits characteristics of SMAP and Sentinel the average time difference is ~18 hours that includes the Sentinel Asc. and Des. Overpasses for any given SMAP swath.





2. SMAP-Sentinel Active-Passive Product

Why Sentinel for AP Algorithm

Sensor Name	RADARSAT-2	Sentinel-1A	RISAT-1
Agency	Canadian Space Program (CSP)	European Space Agency (ESA)	Indian Space Research Organization (ISRO)
Instrument	C-band SAR (5.4 GHz)	C-band SAR (5.4 GHz)	C-band SAR (5.35 GHz)
Incidence Angle	Side-looking, 15-45° off-nadir	Side-looking, 15-45° off-nadir	36.85 deg.
Polarization	HH, HV, VV and VH	(VV and VH) or (HH and HV)	HH an HV
Sensor Height at Equator	798 km	693 km	542 km
Orbit	Sun Synchronous (dusk/dawn)	Sun Synchronous (dusk/dawn)	Sun Synchronous (dusk/dawn)
Revisit time (Orbit Repeat cycle)	24 days	12days	25 days
Resolution	100 m	5 m X 20 m	~25 meters
Swath Width	500 km (ScanSAR mode)	250 km (IWS mode)	115 km (MRS)
Mean local time	6:00 AM Descending	6:00 AM Descending	6:00 AM
Launch	Dec 14th, 2007	April 3rd, 2014	April 26th, 2012
Planned Lifetime	7 years minimum	7 years	5 years

2. SMAP-Sentinel Active-Passive Product

Why Sentinel for AP Algorithm

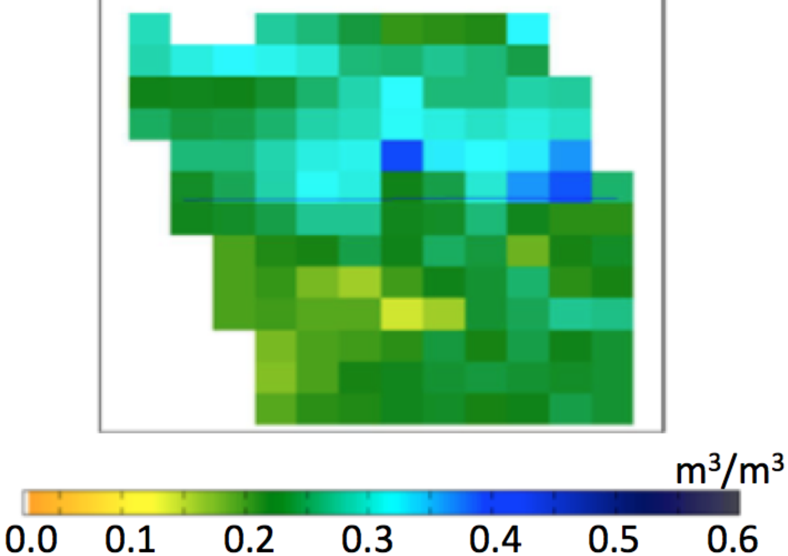
Sensor Name	RADARSAT-2	Sentinel-1A	RISAT-1
Current Data Access	Cost $$$	**Free**	Cost $$$
Future addition to mission	No	Yes-Launched April 2016	No

Recommendation is to use Sentinel data because:

- *it is free*
- *has better revisit interval*
- *has the required co-pol and x-pol measurements.*
- *With Sentinel-1B, the revisit interval will improve and have global coverage every 6 days.*

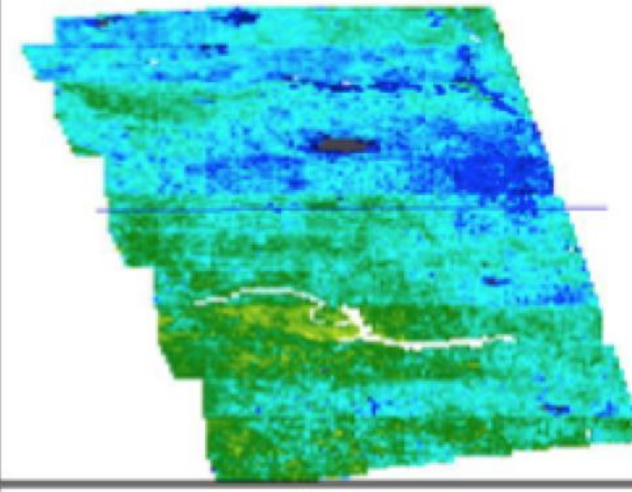
SMAP-only Passive Product

Retrieved Soil Moisture 36 km



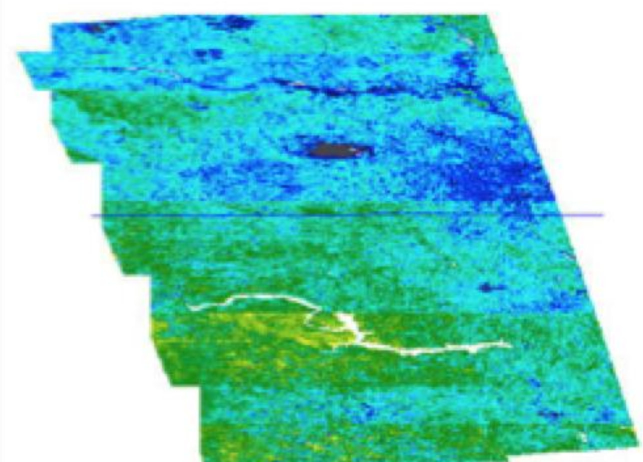
SMAP-Sentinel Active-Passive Product

Retrieved Soil Moisture 3 km



SMAP-Sentinel Active-Passive Product

Retrieved Soil Moisture 1 km



Soil Moisture at Different Resolutions
Retrieved for May 17th, 2015
Over Manitoba region Canada

Enhanced Product Suite

Product	Source	Description	Posted resolution
L2_SM_P AM/PM L3_SM_P AM/PM	L1C_TB	Standard L2_SM_P with passive FT flagging, AM & PM data, with ascending/descending L3_SM_P	36 km
L3_FT_P	L1C_TB	Passive FT retrieved on N. Polar grid from standard L1C_TB	36 km
L1B_TB_E	L1B_TB	Brightness temperatures on along/cross-track swath grid; Ta interpolated with Backus-Gilbert	3 km
L1C_TB_E	L1B_TB->FG L1B_TB_E->BG	Tb on EASE grid using Backus-Gilbert (BG) interpolated Tb and fine-grid (FG) processing algorithm	9 km
L2_SM_P_E	L1C_TB_E	Retrieved SM on 9 km EASE grid	9 km
L3_SM_P_E	L2_SM_P_E	Daily retrieved SM on global EASE grid	9 km
L3_FT_P_E	L1C_TB_E	Daily boreal passive FT from L1C_TB_E	9 km
L3_S0_S1	Sentinel 1	Preprocessed daily sigma0 from Sentinel 1A/1B	1 km
L3_SM_SP	L3_SM_P L3_S0_S1	SMAP/Sentinel active-passive retrieved SM	3 km/9 km

Enhanced Product Summary

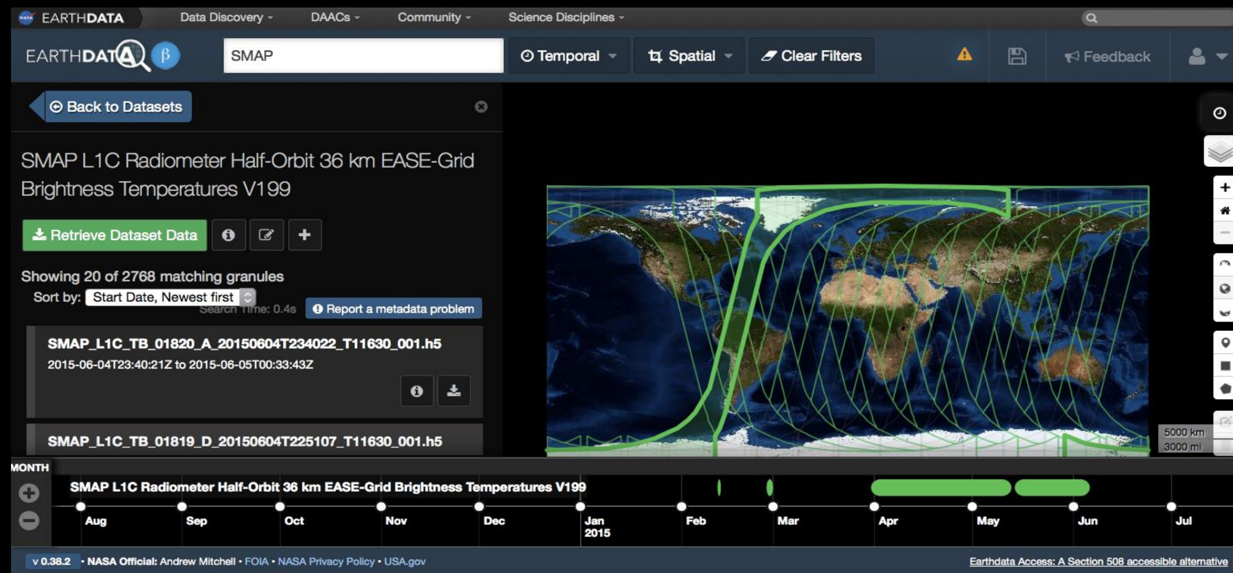
- The SMAP Validated-Products are already released and meet the mission requirements.
- The SMAP mission finished one year in April’16
- SMAP-Enhanced Products are being tested and look promising. SMAP-Enhanced products will be released by March’17.

Where to get the data?

Accessing SMAP Data

NSIDC.org/data/smap

ASF.alaska.edu/smap/



Direct Data Access

HTTPS
- Requires login with a NASA Earthdata username
- https://n5eil01u.ecs.nsidc.org/SMAP/

OPeNDAP
- Provides subsetting and reformatting
- Access to data files using Matlab and ArcGIS
- http://n5eil01u.ecs.nsidc.org/opendap/SMAP/

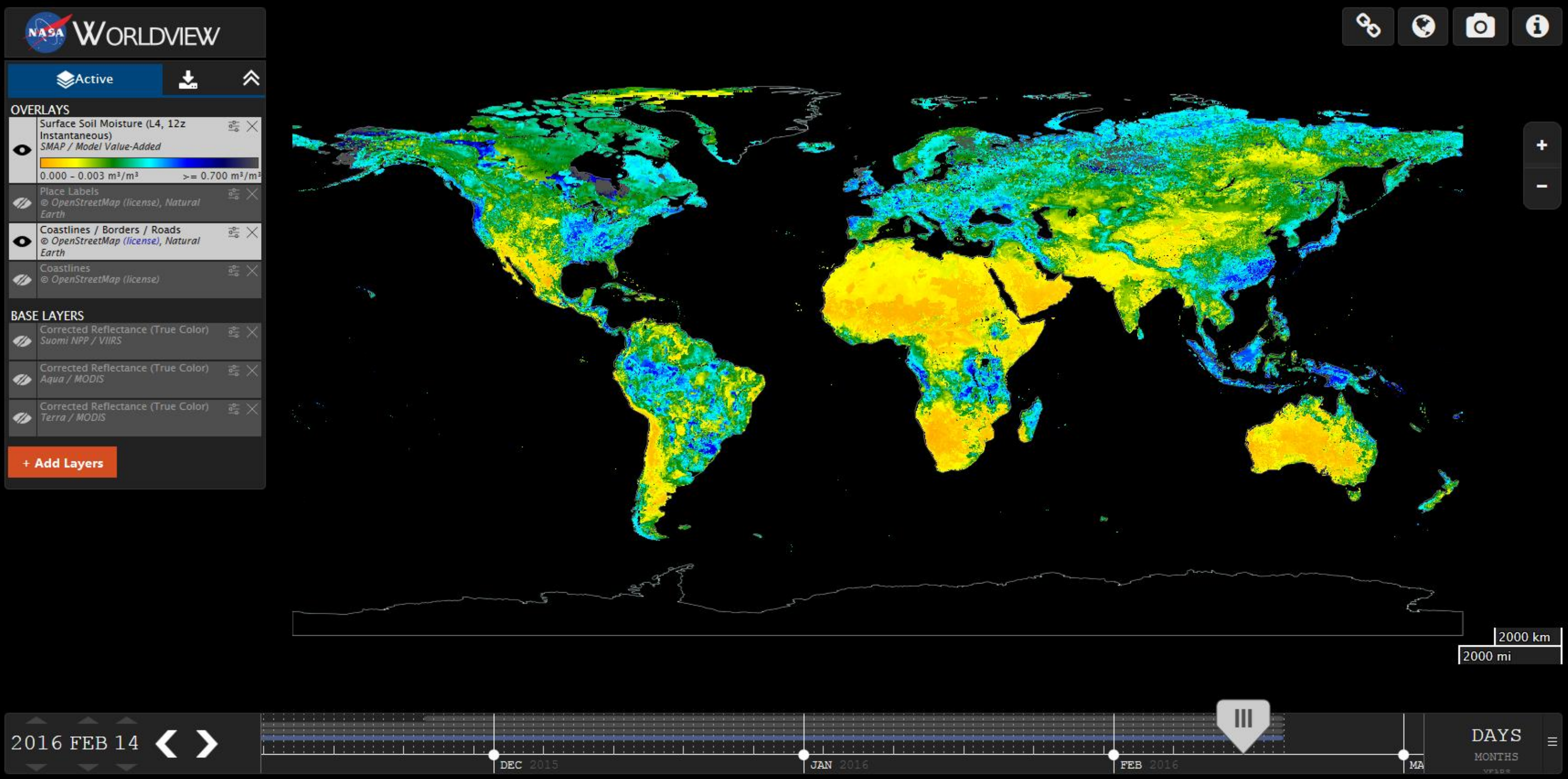
FTP
- Likely retired in late 2016
- ftp://n5eil01u.ecs.nsidc.org/SAN/SMAP/

Search & Order

SMAP data distributed by ASF and NSIDC DAACs, as well as all NASA Earth Science data, can be discovered and downloaded in the NASA Reverb and Earthdata Search clients.

http://reverb.echo.nasa.gov
https://search.earthdata.nasa.gov

Visualizing SMAP Data



The NASA Worldview client provides interactive browse and download of full-resolution NASA imagery as well as access to the source data.

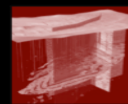
SMAP parameters and quality flags are available as imagery layers in Worldview.

http://earthdata.nasa.gov/labs/worldview

SMAP Data Services

On-Demand Data Services

- Available for Level 1C radiometer, Level 2, 3 and 4 products
- Access through Reverb and Earthdata Search



Subset

- Parameter
- Spatial area

Reformat

- KML
- GeoTIFF
- ASCII
- NetCDF
- HDF-EOS

Reproject

- Geographic
- Lambert
- Polar Stereo
- State Plane
- Transverse Mercator
- UTM

Tools

- Links to HDFView, EASE-Grid tools, and Panoply
- Sample Matlab, Python, IDL, and NCL code from the HDF Group.

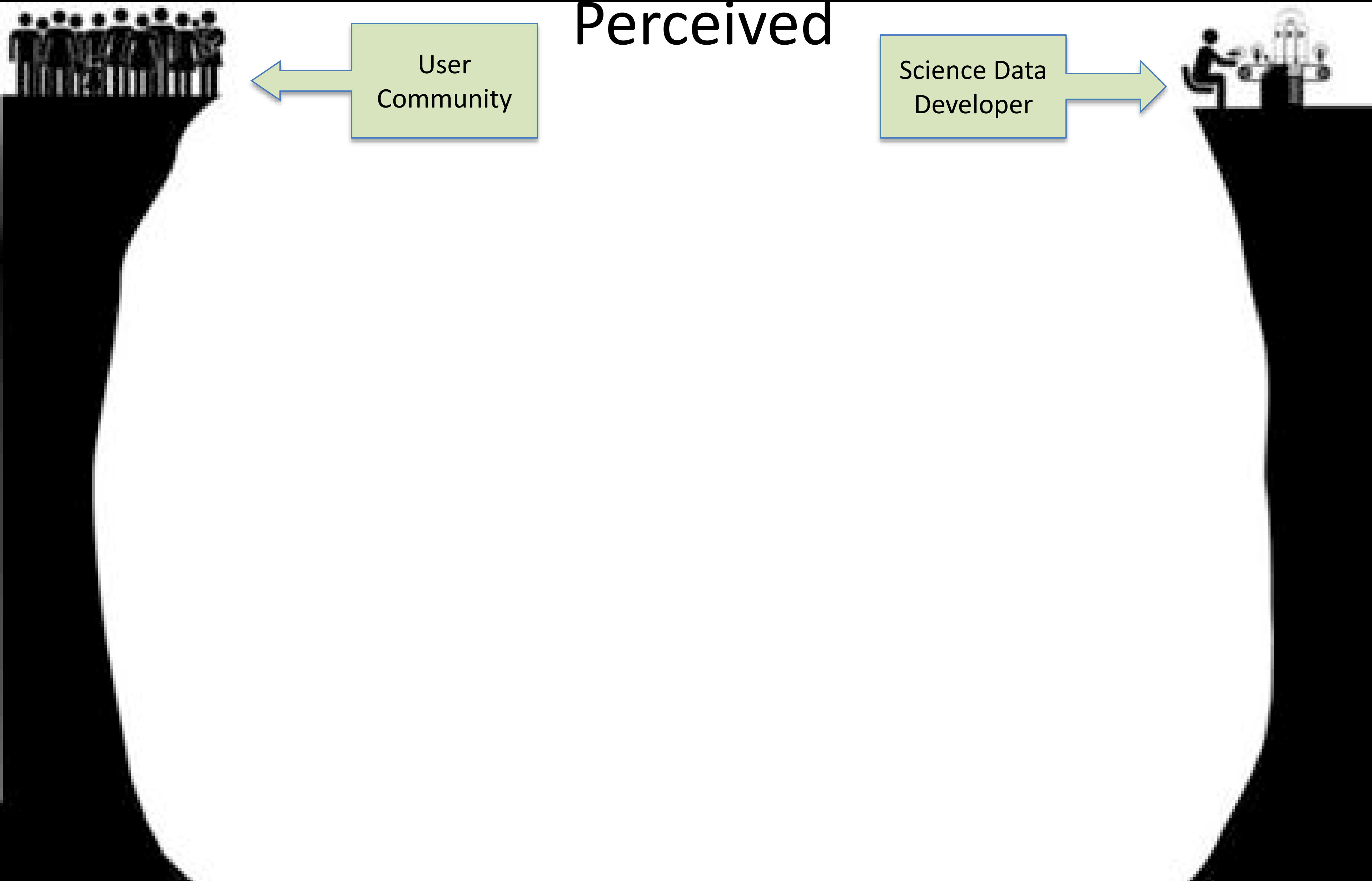
User Support

- FAQs & How Tos
- Personalized support for data users with SMAP data and tools.
  - **https://nsidc.org/data/smap**
  - Email: **nsidc@nsidc.org**

Applications

I do not think it means what you think it means.

How Science Data Development is Perceived



SMAP Applications

US National Research Council Report: “Earth Science and Applications from Space: National Imperatives for the next Decade and Beyond”

SMAP is one of four missions recommended by the NRC “Decadal Survey” for launch in the 2010–2013 time frame

Tier 1: 2010–2013 Launch
Soil Moisture Active Passive (SMAP)
ICESAT II
DESDynI
CLARREO
Tier 2: 2013–2016 Launch
SWOT
HYSPIRI
ASCENDS
GEO-CAFE
ACE
Tier 3: 2016–2020 Launch
LIST
PATH
GRACE-II
SCLP
GACM
3D-WINDS

SMAP Mission Applications

The SMAP mission is in the first tier recommended by the 2007 National Research Council (NRC) Earth Science Decadal Survey

Incorporating applications into mission plans is not optional, but rather

1) Mandated from Congress with the NASA authorization act,
2) Recommended as a requirement from the National Research Council.
3) Critical component of the SMAP Applied Sciences activities AND
4) Quickly become a measure for mission's success

What is an Application?

Applications are defined as innovative uses of mission data products in decision-making activities for societal benefit.

Applications research will provide fundamental knowledge of how mission data products can be scaled and integrated into users' policy, business and management activities to improve decision-making efforts.

User Community includes
- individuals or groups
- public or private sectors
- national or international organizations
- local to global scales of decision making

Application Strategies and Events

- Workshops and meetings
- Translate science for targeted applications
- Networking and identifying synergistic opportunities before and after launch.
- Thematic Focus sessions are hosted by our end users at their facility to highlight their uses and needs.
- Conduct data tutorials to educate on mission applications and have hands on opportunities to work with the data.
- The Early Adopter Program

Common theme: Building Relationships, leverage capabilities and address challenges as early as possible.

Pre Launch Goal: To engage SMAP end users

SMAP Applications Started back in 2009

Peggy O'Neill, Vanessa Escobar, **NASA GSFC**

Simon Yueh, Seungbum Kim, Erika Podest, Narendra Das, Steven Chan, Eni Njoku, **NASA JPL**

Amanda Leon, **NASA NSIDC DAAC**

Susan Moran, Wade Crow and Tom Jackson, **USDA**

So how was it done?

1st SMAP Applications Workshop

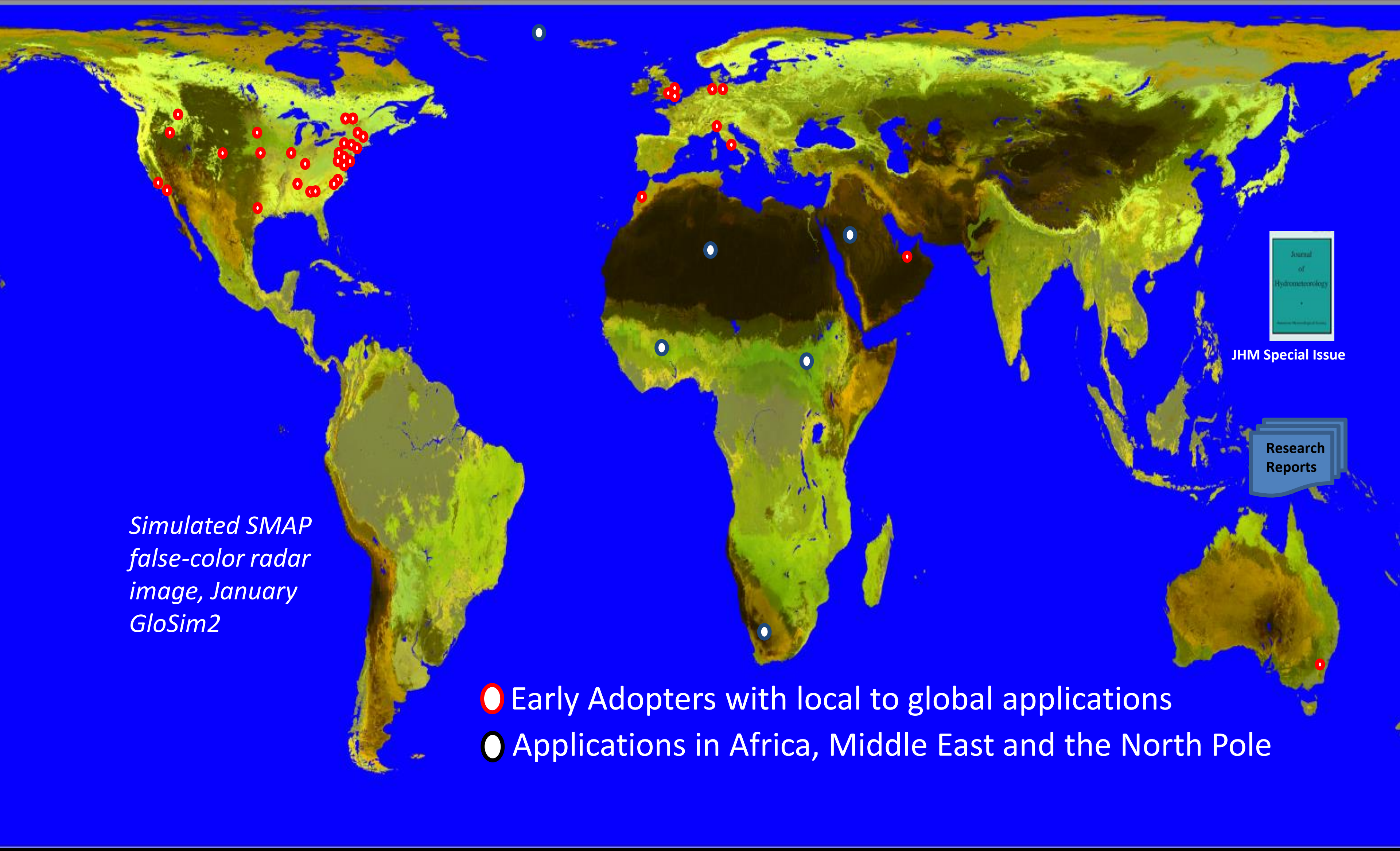
NOAA
Silver Spring, MD
9-10 Sept. 2009

118 attendees from dozens of organizations

Result: The 1st SMAP Applications Plan

Early Adopters

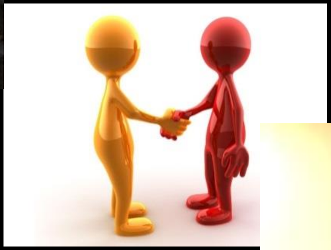
- The Early Adopters are a subset of the mission user community.
- The EA Program is a volunteered effort that links the EA to the SMAP ST to trade ideas, guidance and feedback in an effort to understand the applications of SMAP data


Simulated SMAP false-color radar image, January GloSim2
JHM Special Issue
Research Reports
Early Adopters with local to global applications
Applications in Africa, Middle East and the North Pole

SMAP Early Adopters are Spanning Agriculture, Weather, Emergency Response, Human Health, and Military Readiness

SMAP Early Adopter Program

- Short-term Prediction Research and Transition (SPoRT)
- Early Adopters working to assimilate SMAP observations into real-time, high-resolution land surface model output to support National Weather Service users
- Bradley Zavodsky (NASA/MSFC), Jonathan Case (ENSCO, Inc.), Dr. Clay Blankenship (USRA)



- NASA National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC)

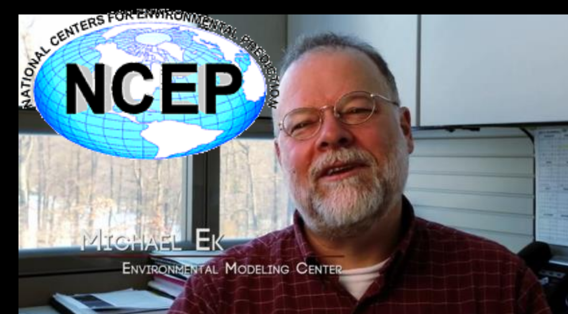
- Siri Jodha Khalsa, Amanda Leon, Karla LeFevre, Shannon Leslie, and Mike Laxer,

Who are the Early Adopters?

US Army: "When you are talking about soil moisture, you are talking about mobility or you are talking about water security."

National Drought Mitigation Center: "As we get these data at a higher resolution, covering the entire country, we are going to do our jobs better."

NASS: "Potentially, this could be a really big cost saving measure for our organization."



NOAA: "There is a number of conditions of the surface that we need to know. And soil moisture is probably one of the most important."

video at smap.jpl.nasa.gov, publications at journals.ametsoc.org/page/smap

Who are the Early Adopters?

Columbia University: “[SMAP] will protect not only the lives, but the livelihoods, of rural populations that are vulnerable to the impacts of drought and floods.”

aer
Atmospheric and Environmental Research

AER: “SMAP is going to have a capability to resolve more details in flood events at a more timely manner. This is important for disaster management…”

CUNY: “We are looking at the quality and amount of water that is available to the City of New York.”

video at smap.jpl.nasa.gov , publications at journals.ametsoc.org/page/smap

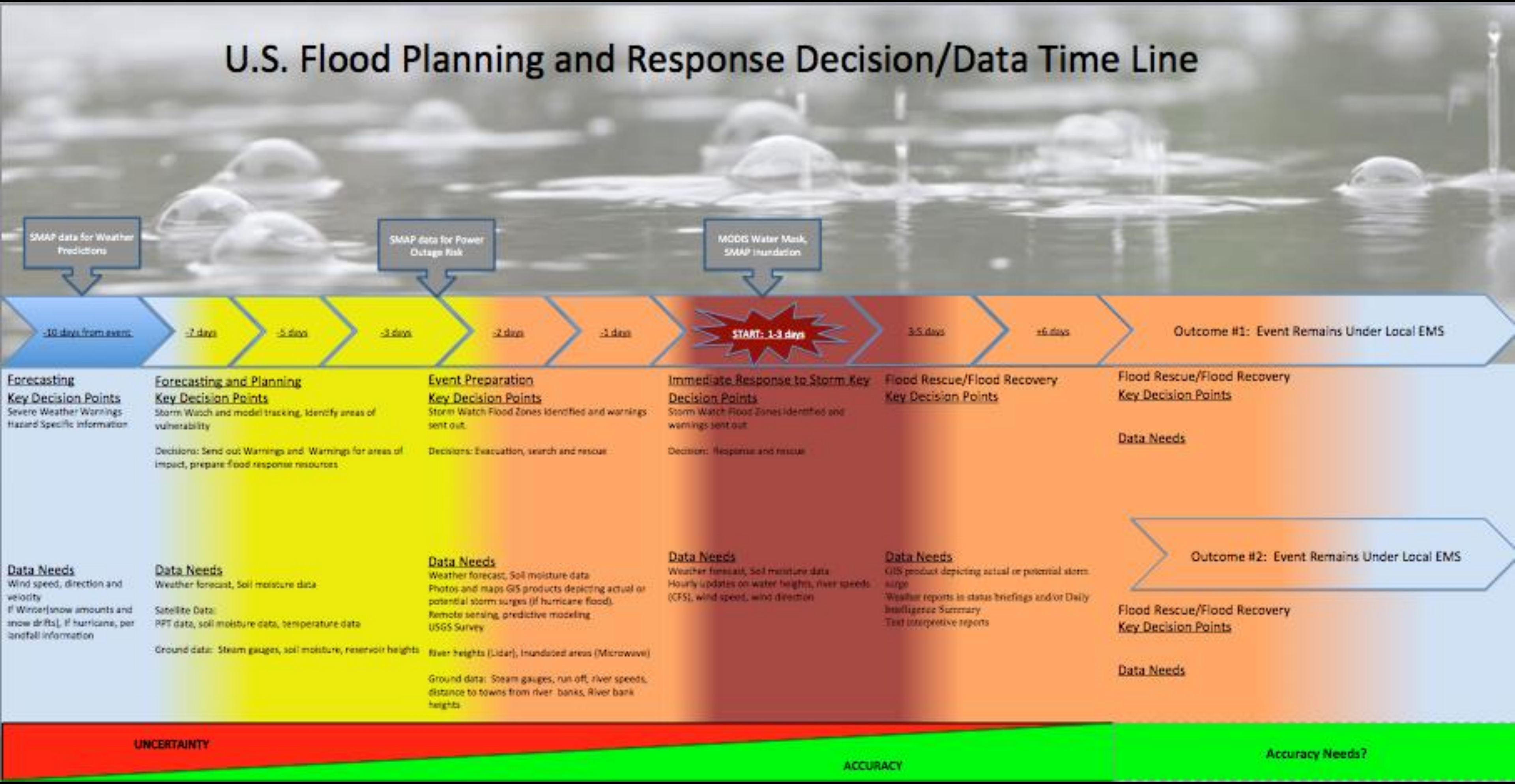
Early Adopters Post Launch

SMAP Mission Applications Themes	
Weather and Forecasting (5 EAs)	Agricultural Productivity (11 EAs)
Droughts (10 EAs)	Human Health (5 EAs)
Floods (8 EAs)	National Security/Mobility (4 EAs)
Carbon (1 EA)	
SMAP Mission Applications Themes-Expanded by EAs	
National Security-Sea Ice (5 EAs)	Decision Support/Communication Tools (6 EAs)

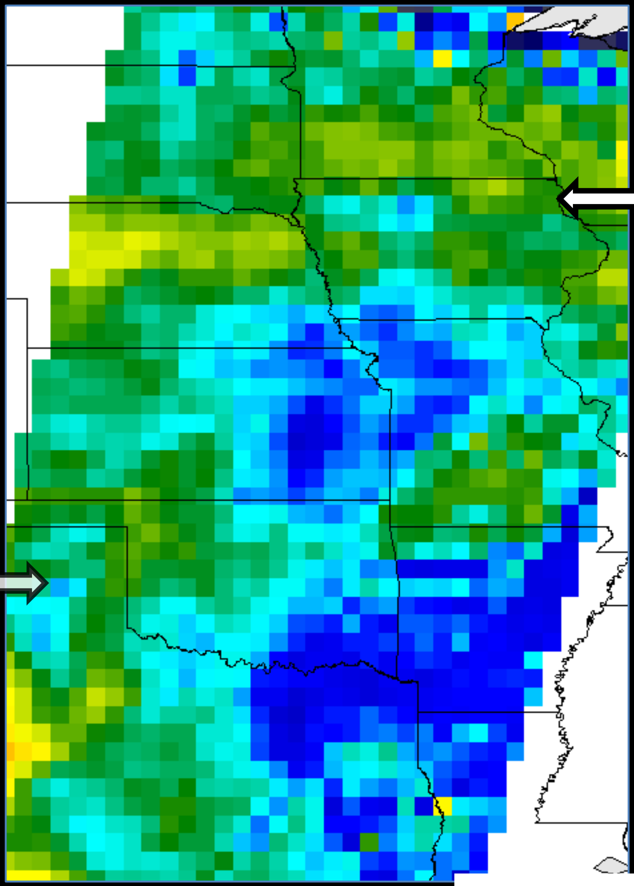
- Total of **55 Early Adopters** for SMAP Mission
- Research and collaboration between the SMAP ST and each EA organization will continue with each EA to provide clear metrics and an analysis of the value of soil moisture or freeze/thaw data in their application.
  - EA case study per EA category
- Early Adopters given the opportunity to apply for access to pre-beta-release products for their research through a formal request to the SMAP Applications Team

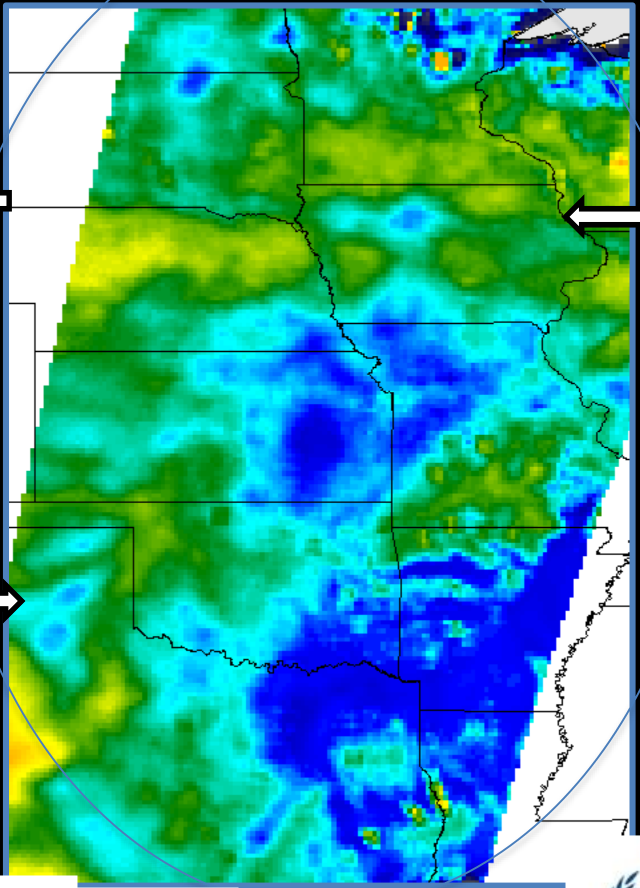
Early Adopter Feedback

- Improved Data Services for DAACs
- Tutorials and SMAP hands on learning
- Improved formats and context for broadening user community
- Inform and guide future mission on Applications Program
- Inform new decadal survey missions (EA Program already moving forward at NASA)
- Joint mission products and opportunities
- Commercial users for SMAP data
- Lessons Learned Document for NASA HQ
- Data Impact for societal applications-a need for **Case Studies**

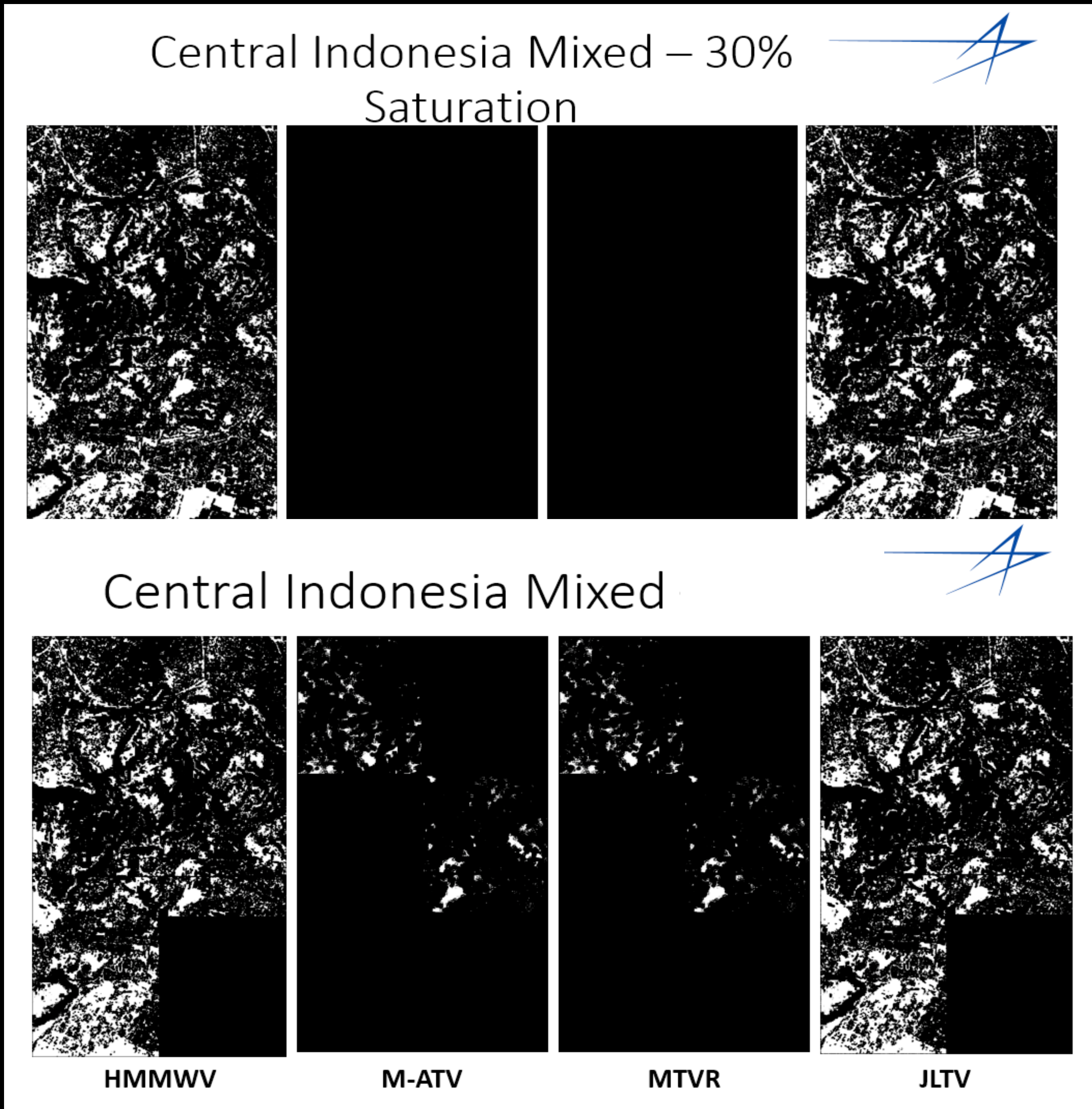

U.S. Flood Planning and Response Decision/Data Time Line
SMAP data for Weather Predictions
SMAP data for Power Outage Risk
MODIS Water Mask, SMAP Inundation
-10 days from event
-7 days
-5 days
-3 days
-2 days
-1 days
START: 1-3 days
3-5 days
+6 days
Outcome #1: Event Remains Under Local EMS
Forecasting
Key Decision Points
Severe Weather Warnings
Hazard Specific information
Forecasting and Planning
Key Decision Points
Storm Watch and model tracking, Identify areas of vulnerability
Decisions: Send out Warnings and Warnings for areas of impact, prepare flood response resources
Event Preparation
Key Decision Points
Storm Watch Flood Zones Identified and warnings sent out.
Decisions: Evacuation, search and rescue
Immediate Response to Storm Key Decision Points
Storm Watch Flood Zones identified and warnings sent out
Decision: Response and rescue
Flood Rescue/Flood Recovery
Key Decision Points
Flood Rescue/Flood Recovery
Key Decision Points
Data Needs
Data Needs
Wind speed, direction and velocity
If Winter(snow amounts and snow drifts), If hurricane, per landfall information
Data Needs
Weather forecast, Soil moisture data
Satellite Data:
PPT data, soil moisture data, temperature data
Ground data: Steam gauges, soil moisture, reservoir heights
Data Needs
Weather forecast, Soil moisture data
Photos and maps GIS products depicting actual or potential storm surges (if hurricane flood).
Remote sensing, predictive modeling
USGS Survey
River heights (Lidar), Inundated areas (Microwave)
Ground data: Steam gauges, run off, river speeds, distance to towns from river banks, River bank heights
Data Needs
Weather forecast, Soil moisture data
Hourly updates on water heights, river speeds (CFS), wind speed, wind direction
Data Needs
GIS product depicting actual or potential storm surge
Weather reports in status briefings and/or Daily Intelligence Summary
Text interpretive reports
Outcome #2: Event Remains Under Local EMS
Flood Rescue/Flood Recovery
Key Decision Points
Data Needs
UNCERTAINTY
ACCURACY
Accuracy Needs?

Improve how we communicate to practitioners





SMAP Radar Military Vehicle Mobility Capabilities-Derek Ward, Lockheed Martin



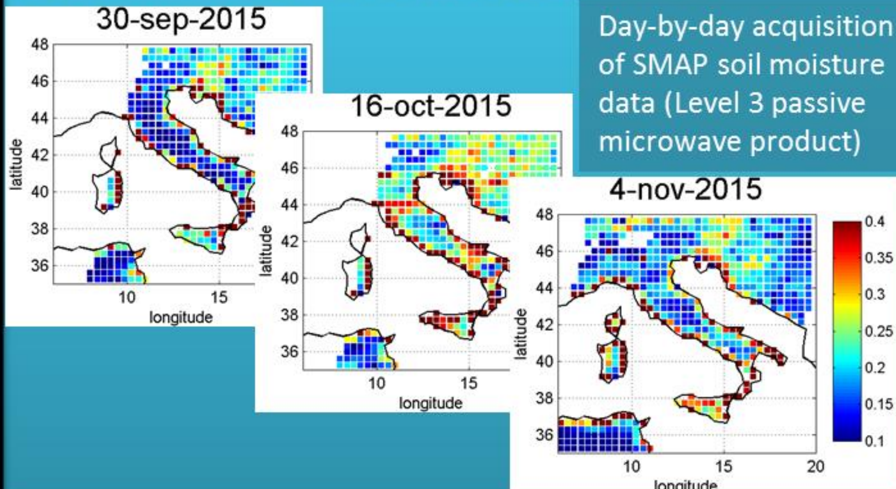
Top image-No SMAP data used. Bottom image-With SMAP Radar.

White denotes areas identified as "GO" mobility so with SMAP we are better able to predict mobility of vehicles.

In marginal cross country conditions…as we have multiple measurements in an area rather than one uniform estimate

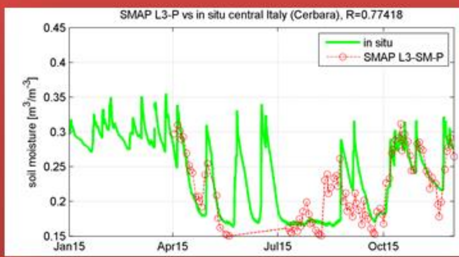
SMAP Radiometer for Flood Mitigation in Central Italy- Luca Brocca, Research Institute for Geo-Hydrological Protection

1 REAL-TIME ACQUISITION OF SMAP SOIL MOISTURE DATA OVER ITALY

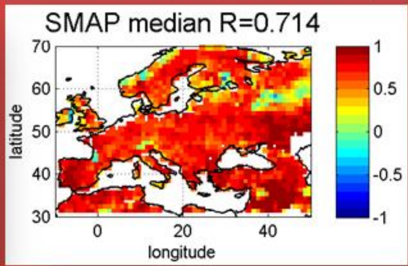


Day-by-day acquisition of SMAP soil moisture data (Level 3 passive microwave product)

2 REAL-TIME ASSESSMENT THROUGH IN SITU OBSERVATIONS



Correlation map between SMAP-derived and observed precip (Jul-Dec 2015)

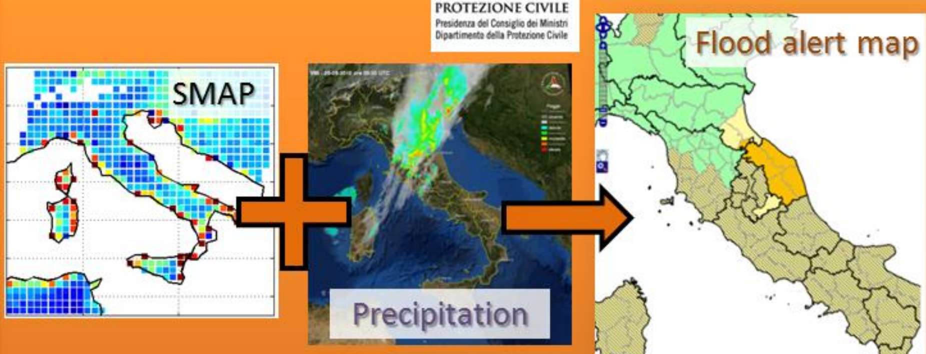


Validation with ground-based soil moisture observations (point scale)
Brocca et al. (2011)

Indirect validation with ground-based precipitation observations (large scale)
Brocca et al. (2014)

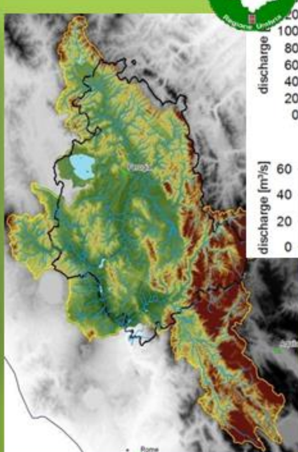
3 NATIONAL SCALE FLOOD WARNING SYSTEM

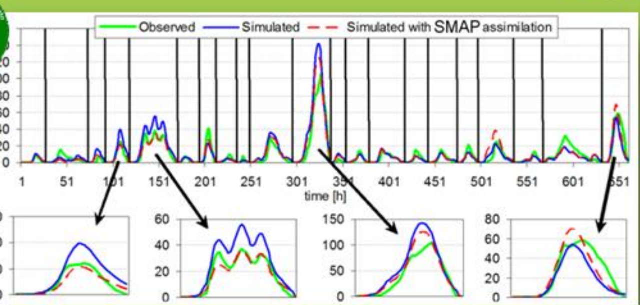
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile



Integration of SMAP soil moisture and ground-based precipitation observations for flood (and landslide) alert issuing at national scale.

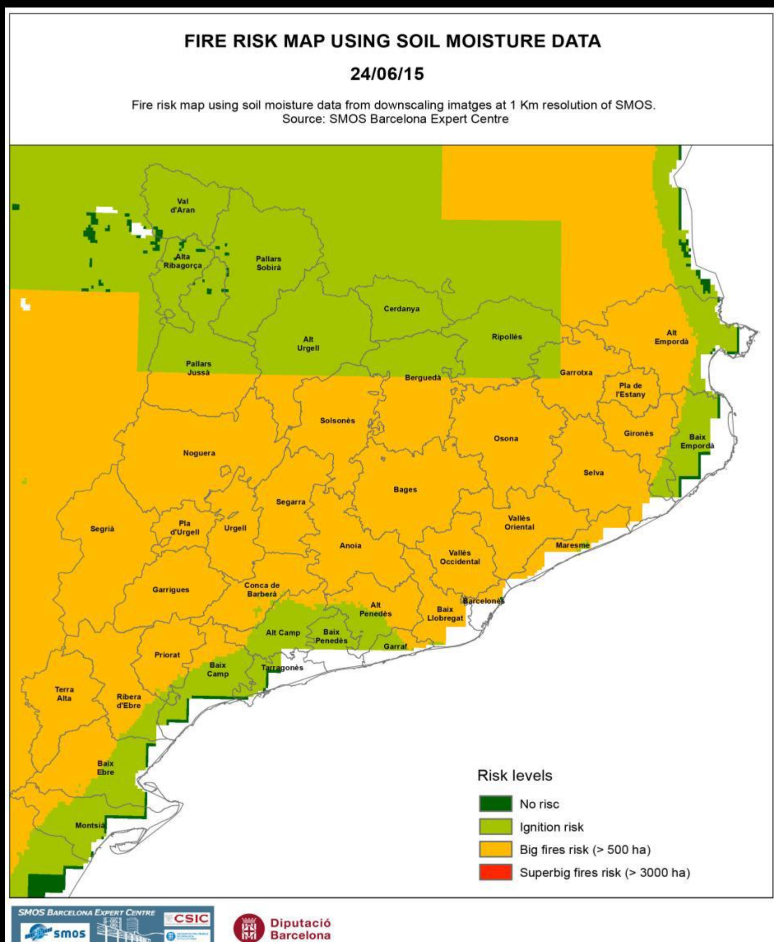
4 CENTRAL ITALY FLOOD FORECASTING SYSTEM

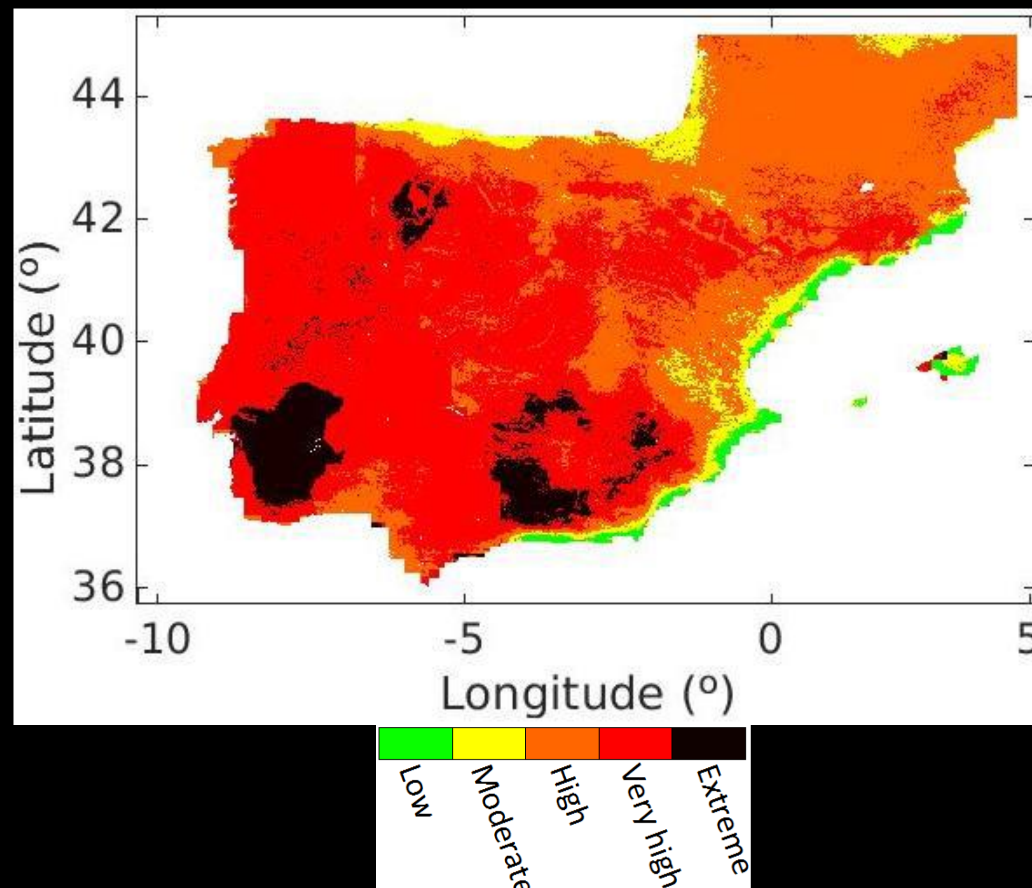




Real-time assimilation of SMAP data into the flood forecasting system operating in central Italy. Quantitative assessment of SMAP impact on flood hazard mitigation.
Brocca et al. (2012)

Improving Forest Fire Risk Maps, Maria Piles- Barcelona Expert Center, ICM/CSIC, UPC





Applications Bridge Science & Societal Application through EAs

What’s Happening Now?
Case Studies

- Case Study: an “example project” that can demonstrate both science and societal impact.

- We ask: *How are SMAP science products used in decision support systems and how does the new data stream affect the system performance?*

- For the SMAP Phase E case studies, select Early Adopters (EAs) will 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.

Case Study Approach

1. Follow data from the DAAC through the users/institution download/ingestion/analysis/results and decision making
   – Results: data life cycle and scientific knowledge gain

2. Understand the impact of the Data
   – How does the use of SMAP affect the research hypothesis/model performance metrics?
   – Qualify the value of the SMAP data ingestion by each user institutions metrics.

Case Study Approach

3. Understand the broader impact of the data
   - How has (will) the use of SMAP impacted the applications/decision framework or the operation?
   - Qualification of the potential/actual impact of the SMAP data on the EAs "societal application"

1 case study per category of SMAP Mission Applications by 2018.

- (Weather, drought, flood, agriculture, health and national security)

Currently working on understanding the societal impacts of EAs involved in weather, agriculture, flood and drought.

Case Studies will provide…

- an understanding of how the “end user” identified in the Early Adopter research, will apply the data to a societally relevant process (inform policy, support operational needs in society (sea ice navigation, fire danger alerts, drought warnings, etc.), or link to a suite of other products that support decisions, etc).

- qualitative assessment of the societal relevance of that science data on a decision process or policy.

- insight on how different types of institutions/projects prepare for and ingest SMAP data

Are there opportunities for collaboration with other attendees and workshop leads? (regional applications, data sharing, etc.)

YES!!

- EA relationships and engagement

- Future Tutorials and Joint Workshops
  - AUSTIN, AFRICA, SOUTH AMERICA
  - Next year in Italy on Flooding and Carbon

- New applications, feedback and lessons learned with SMAP

- **Become an “Application User”**
  - Any group or individual who downloads SMAP products from the DAAC for their applications, including policy, business and management activities, to improve decision-making efforts;

  - (AU) would pursue use of SMAP data in their applications in a manner paralleling the Early Adopters

  - Join the SMAP Community to participate in discussions of mission data products related to application needs and provide feedback on data uses.

Thank you for your attention!

Questions?

You can also email me: vanessa.escobar@nasa.gov

Discussion

- What kinds of applications are you interested in seeing developed?
- What types of data/algorithms are needed for your potential and/or existing application and information needs?
- Provide information on the actual or potential use of the presented algorithms/product/application in the context of your organization's needs.
- Are there particular challenges/shortcomings/unmet needs? Where can things be made better?
- Are there opportunities for collaboration with other attendees and workshop leads? (regional applications, data sharing, etc.)
- Discuss scenarios with the broader group to identify innovative ideas, potential improvements, etc.