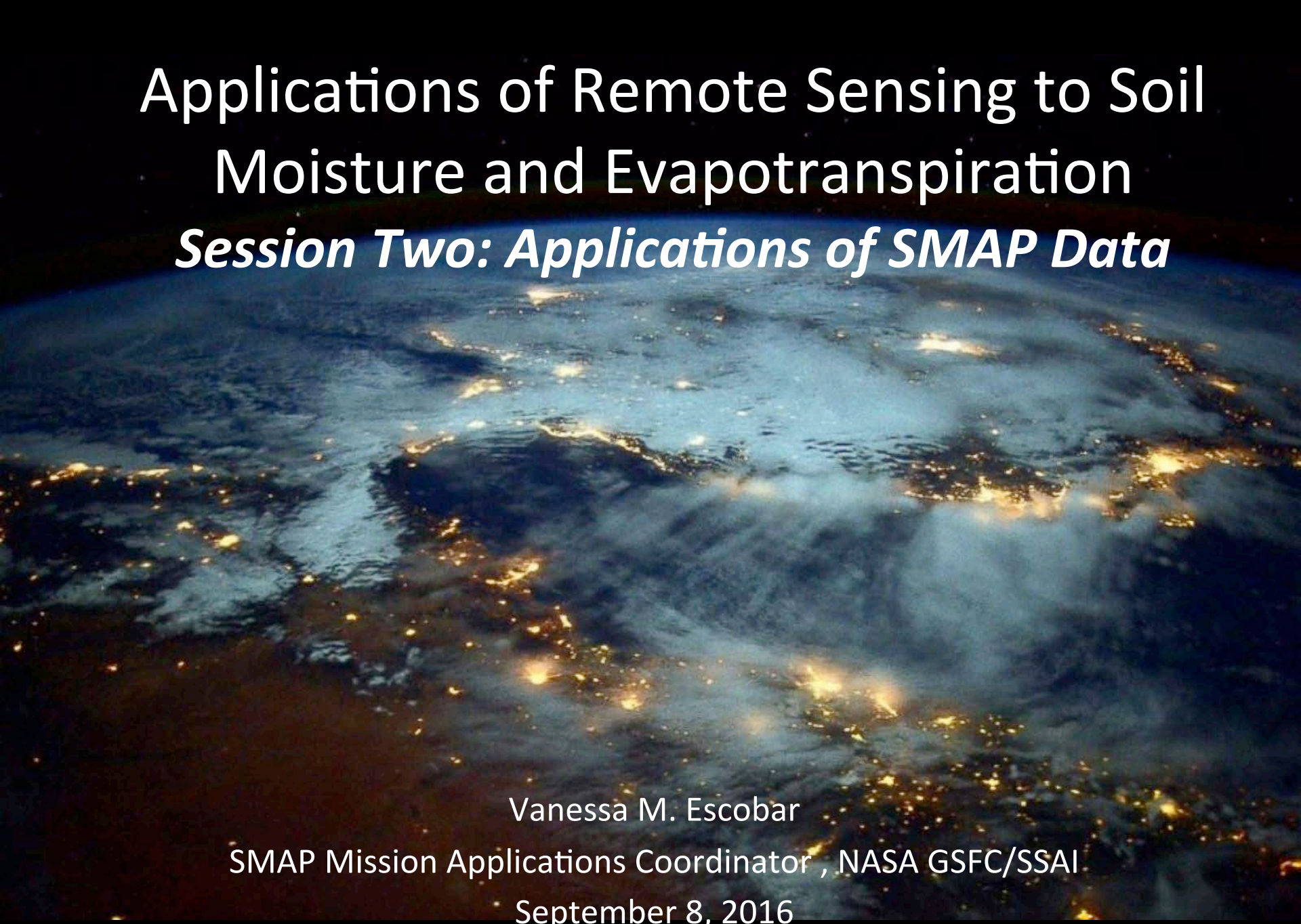
Applications of Remote Sensing to Soil Moisture and Evapotranspiration

Session Two: Applications of SMAP Data



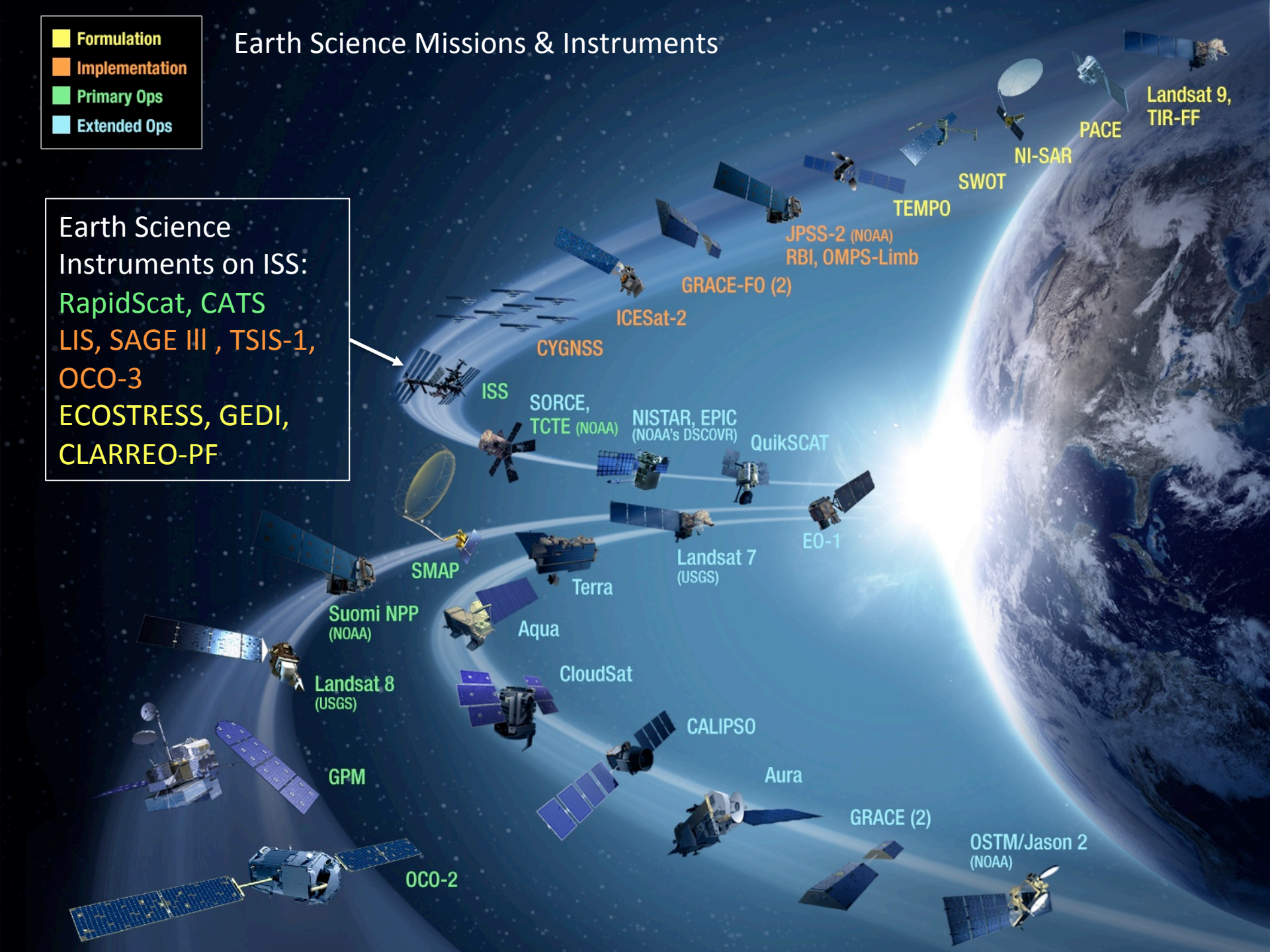
Vanessa M. Escobar

SMAP Mission Applications Coordinator , NASA GSFC/SSAI

September 8, 2016

Outline

- NASA Applied Science Overview
- SMAP Mission Overview
- SMAP Mission Applications
- Early Adopter Program
- Samples of SMAP Data Applications
- Questions and Discussion Opportunity


Formulation
Implementation
Primary Ops
Extended Ops
Earth Science Missions & Instruments
Earth Science Instruments on ISS:
RapidScat, CATS
LIS, SAGE III , TSIS-1,
OCO-3
ECOSTRESS, GEDI,
CLARREO-PF
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2

Why measure soil moisture?

- It is the major limiting factor on agricultural productivity in large parts of the world.
- Soil moisture has an impact on evaporation, and the partition of heat between sensible and latent heat, and impacts weather prediction.
- Dynamic global vegetation models, which feed the CO_2 budget, depend on soil moisture in the root zone.

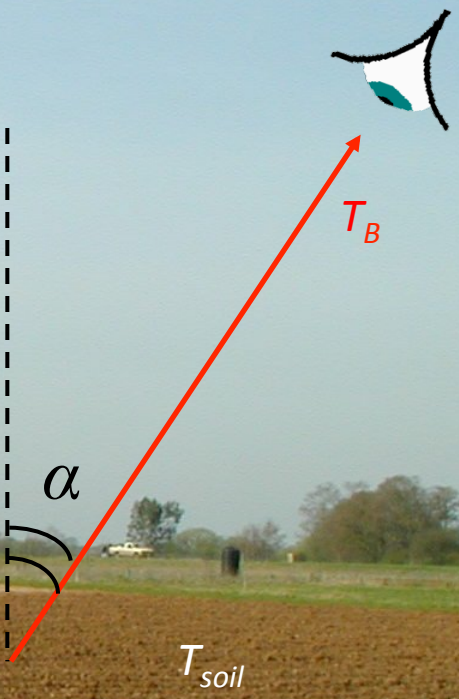

WET SOIL, LESS REFLECTIVE
DRY SOIL, MORE REFLECTIVE

$$T_B = \varepsilon_{soil} \cdot T_{soil}$$

Microwave brightness temperature

The emissivity of the soil ε_{soil} depends on…

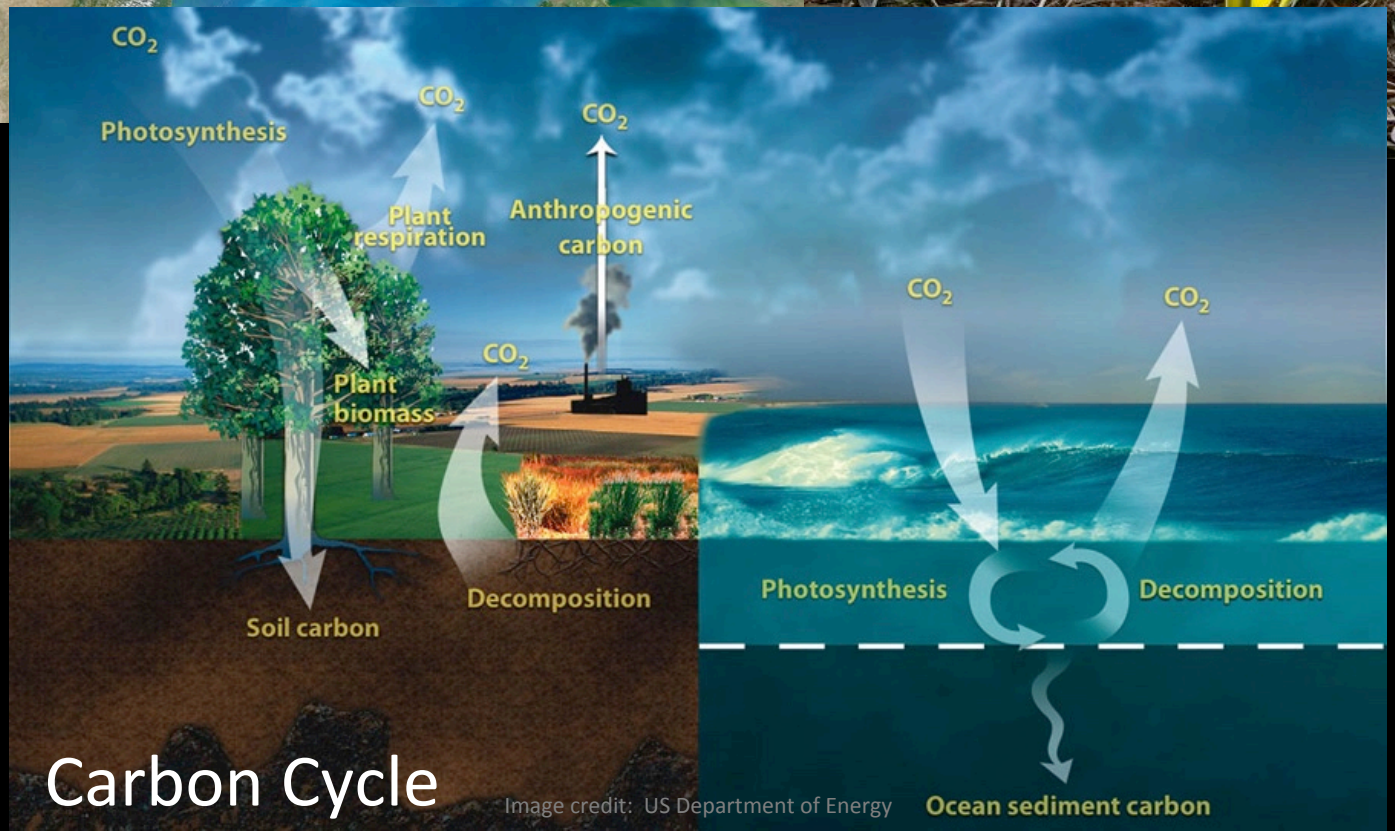
1. The look angle α
2. The polarisation of the radiation
3. The soil's dielectric constant, which depends on the soil moisture and texture



So, if we know the soil dielectric constant, we can use a standard relationship to calculate the soil moisture…

Land Water

Energy



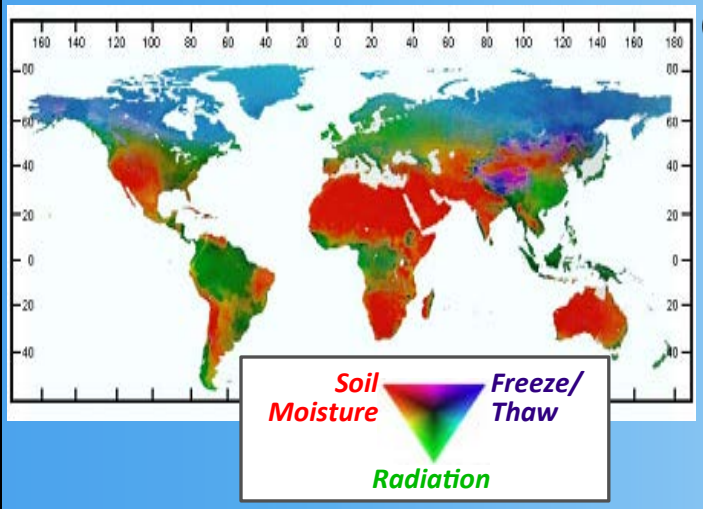
Carbon Cycle

Image credit: US Department of Energy

SMAP Science and Application Returns

Science Returns

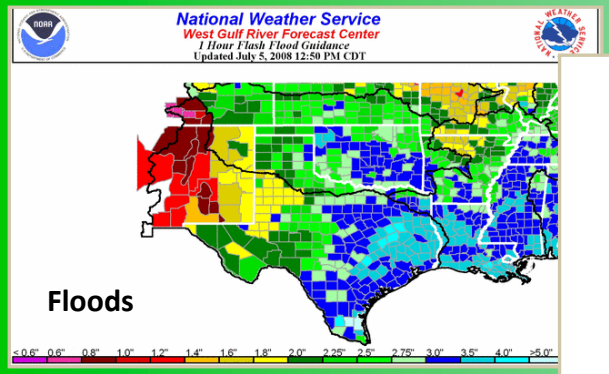
Soil Moisture *Links* the Global Land Water, Energy, Carbon Cycles

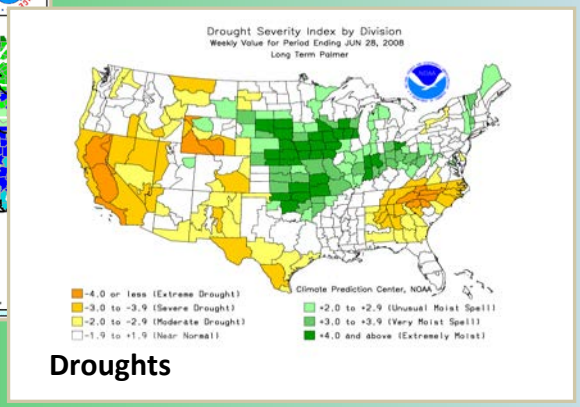


1. Estimating global surface water and energy fluxes
2. Quantifying net carbon flux in boreal landscapes
3. Reduce uncertainty of climate model projections

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

Applications Returns





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

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

Global coverage every 2-3 days

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.

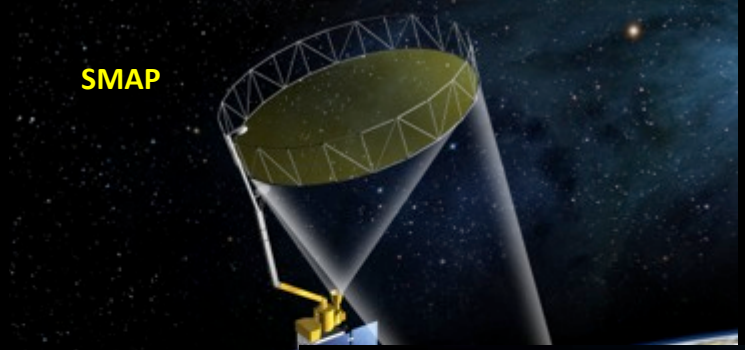
- Real-aperture mode: 30 x 6 km resolution
- **Radiometer: L-band (1.4 GHz)**
  - Moderate resolution, high accuracy soil moisture
  - 40 km resolution (3dB) resolution
- **Shared Antenna**
  - 6-m diameter deployable mesh antenna
  - Conical scan at 13-14 rpm
  - Constant incidence angle: 40 degrees
    - 1000 km-wide swath

- Sun-synchronous orbit
- 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

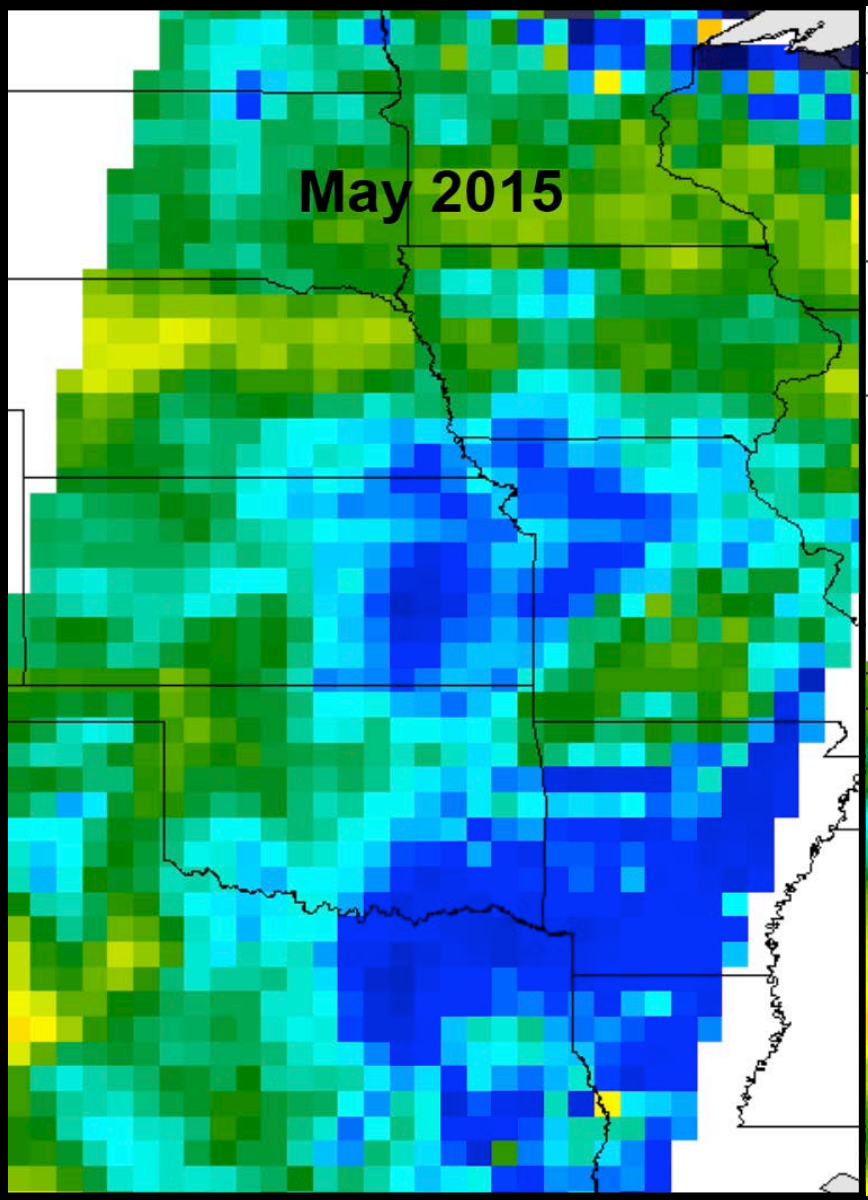
Mission Status Overview Post Radar

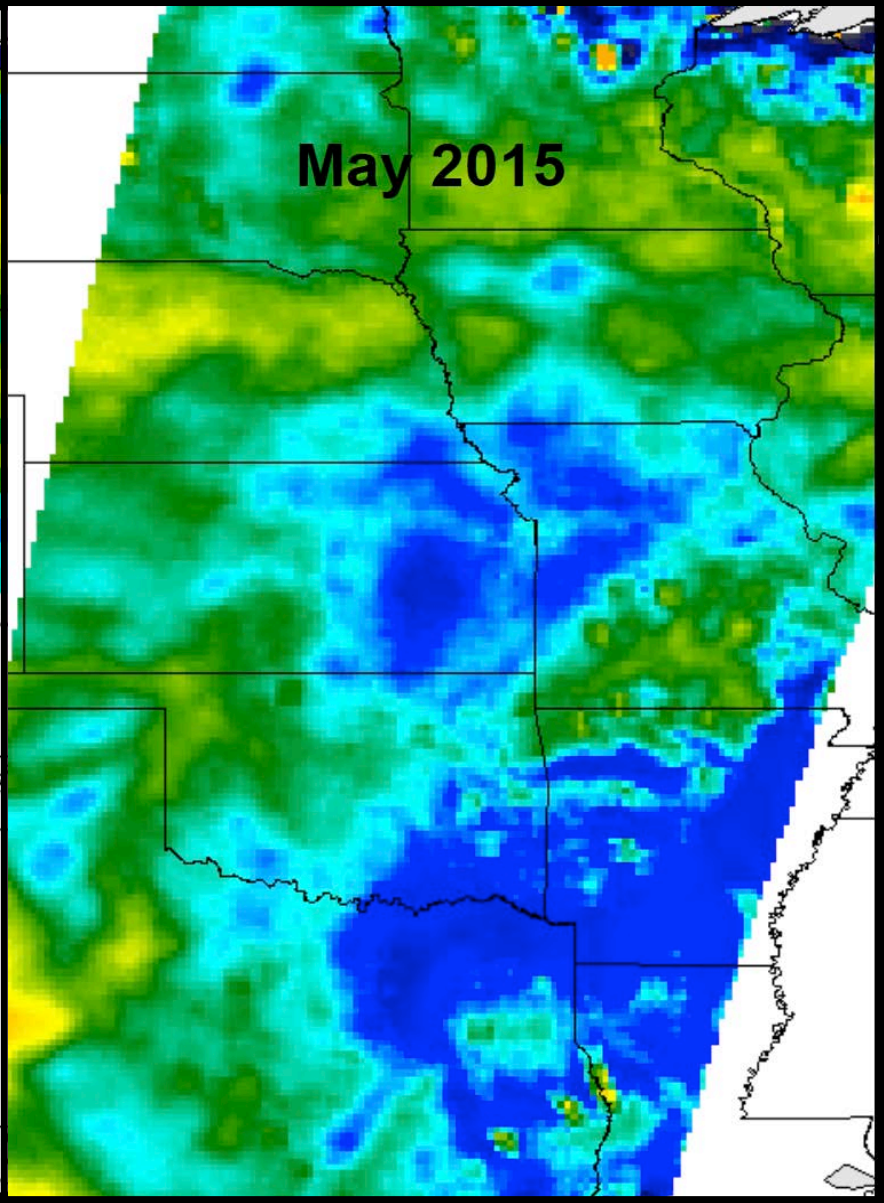
- SMAP launched on Jan 31, 2015
- Science data acquisition started in April 2015
- SMAP Radiometer and Radar worked in tandem with great success
- SMAP Radar malfunctioned on July 7, 2015, and is currently inoperable
- SMAP Beta-Product released to public on October 31, 2015
- SMAP science data acquisition operation finished one year in April 2016
- SMAP Validated Products released on April 30, 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
L1B_TB	Radiometer T_B in Time-Order	(36x47 km)	12 hrs	
L1C_TB	Radiometer T_B in Half-Orbits	36 km	12 hrs	
L2_SM_P	Soil Moisture (Radiometer)	36 km	24 hrs	Science Data (Half-Orbit)
L3_SM_P	Soil Moisture (Radiometer)	36 km	50 hrs	Science Data (Daily Composite)
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





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

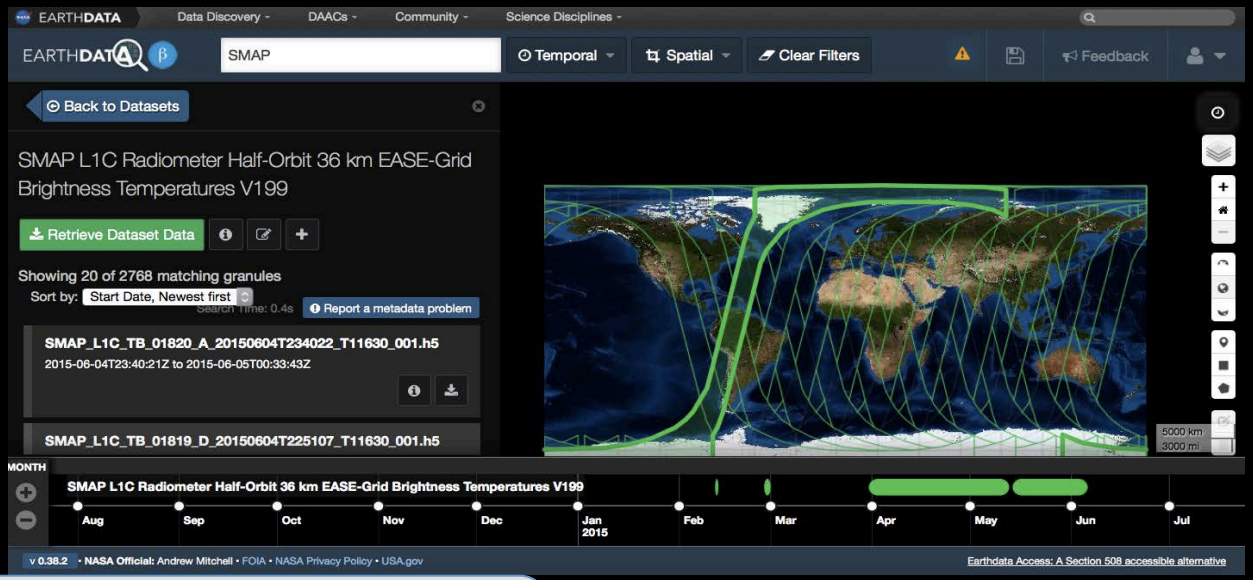
- The SMAP Validated-Products are already released and meet the mission requirements.
- The SMAP mission finished one year in April 16
- SMAP-Enhanced Products are being tested and look promising. Will be released by December 2016.

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

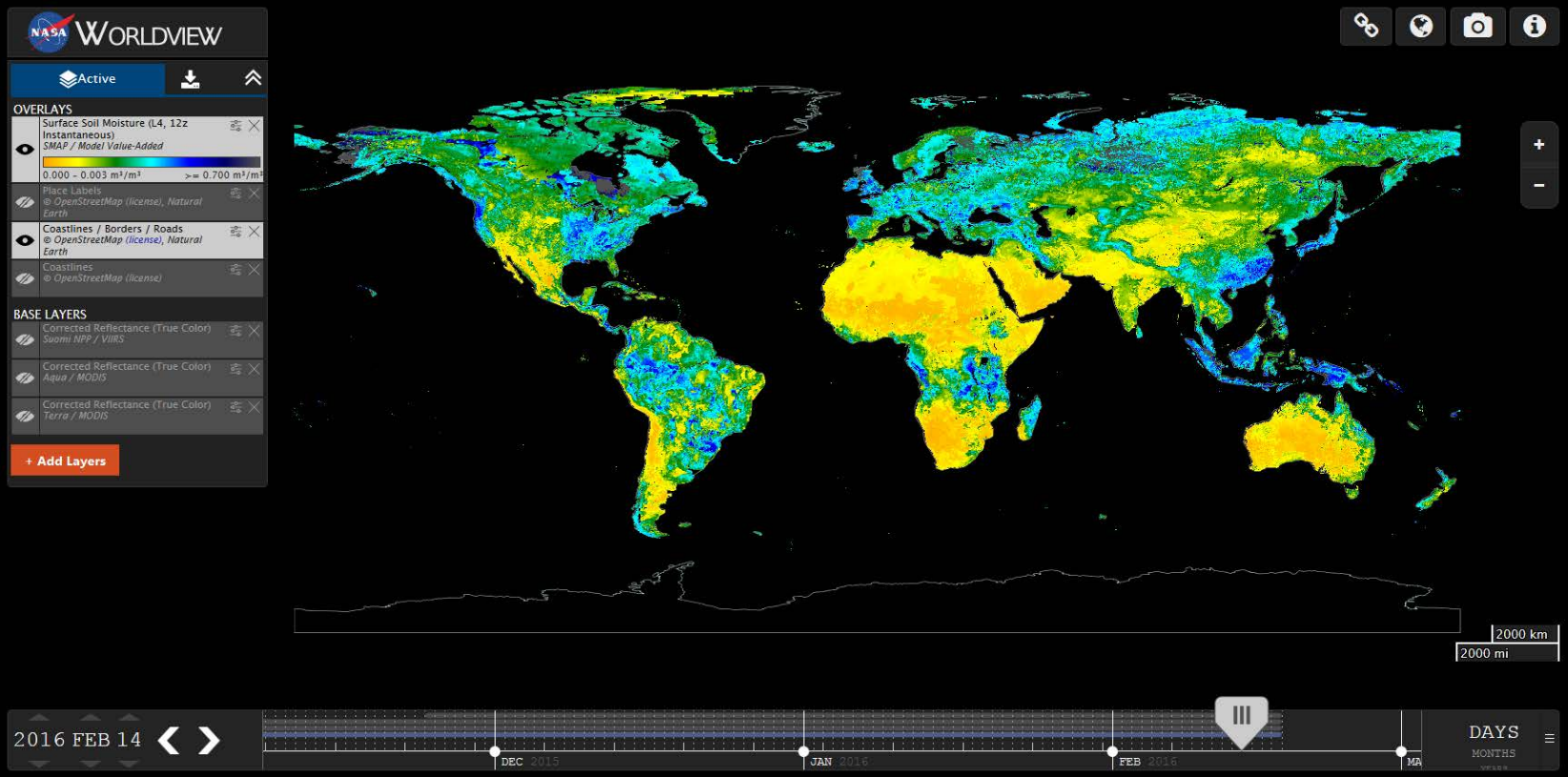
- Likely retired in late 2016
- ftp://n5eil01u.ecs.nsidc.org/SAN/SMAP/

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

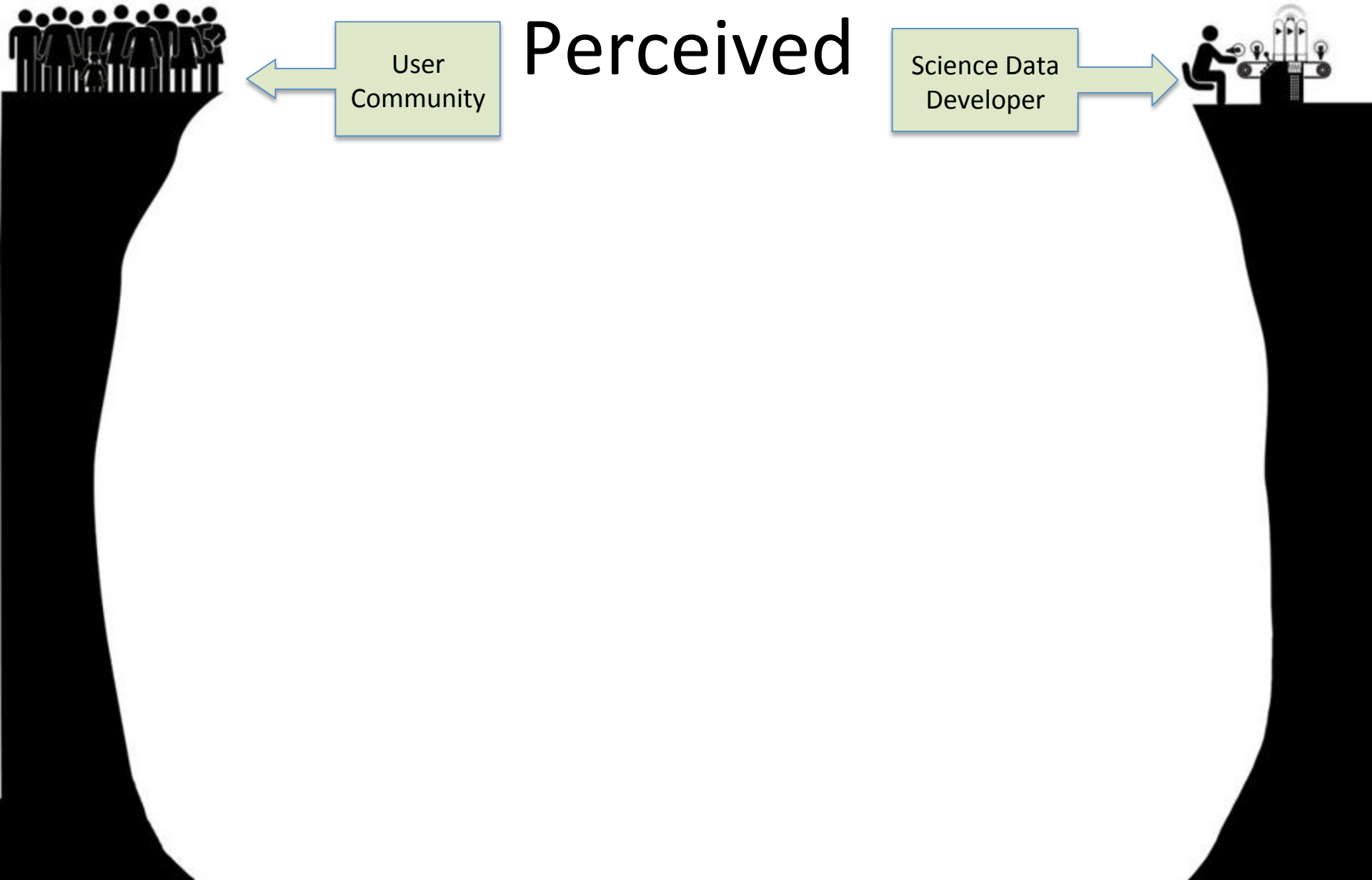
- FAQs & How To's
- Personalized support for data users with SMAP data and tools.
  - **https://nsidc.org/data/smap**
  - Email: **nsidc@nsidc.org**

That’s all the background we need for now….

APPLICATIONS

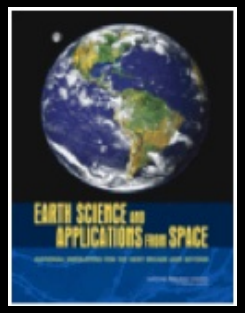
I do not think it means what you think it means.

How Science Data Development is Perceived



"I warned you that it wasn't user friendly!"

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

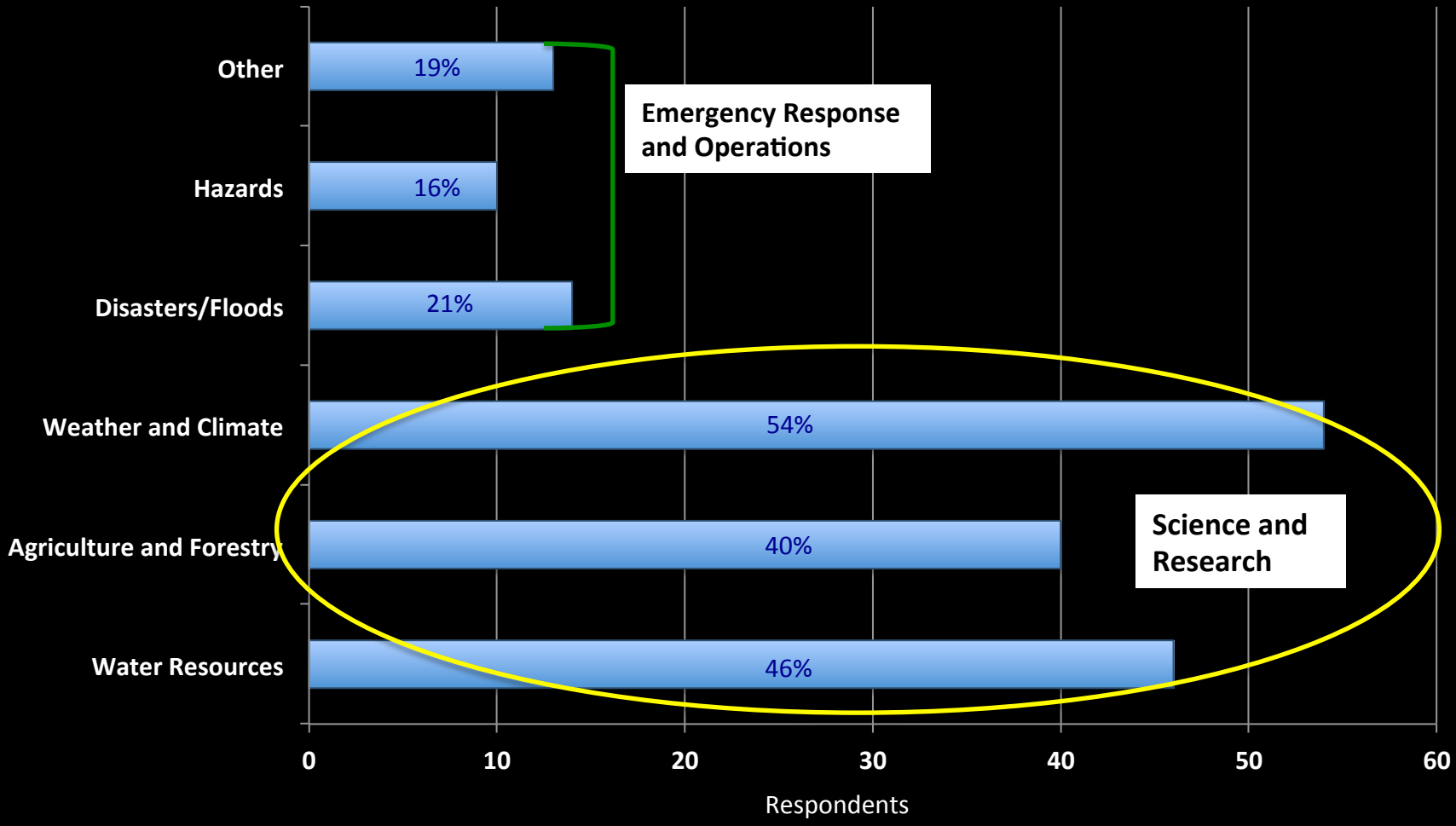
Assessing the SMAP community-SMAP Survey conducted in 2012

Results revealed that the SMAP user community had:

- Gap between research and policy applications
- High perceived value of soil moisture
- Uncertainty as to how ground observations will scale to remotely sensed data
- Where to access SMAP-like data

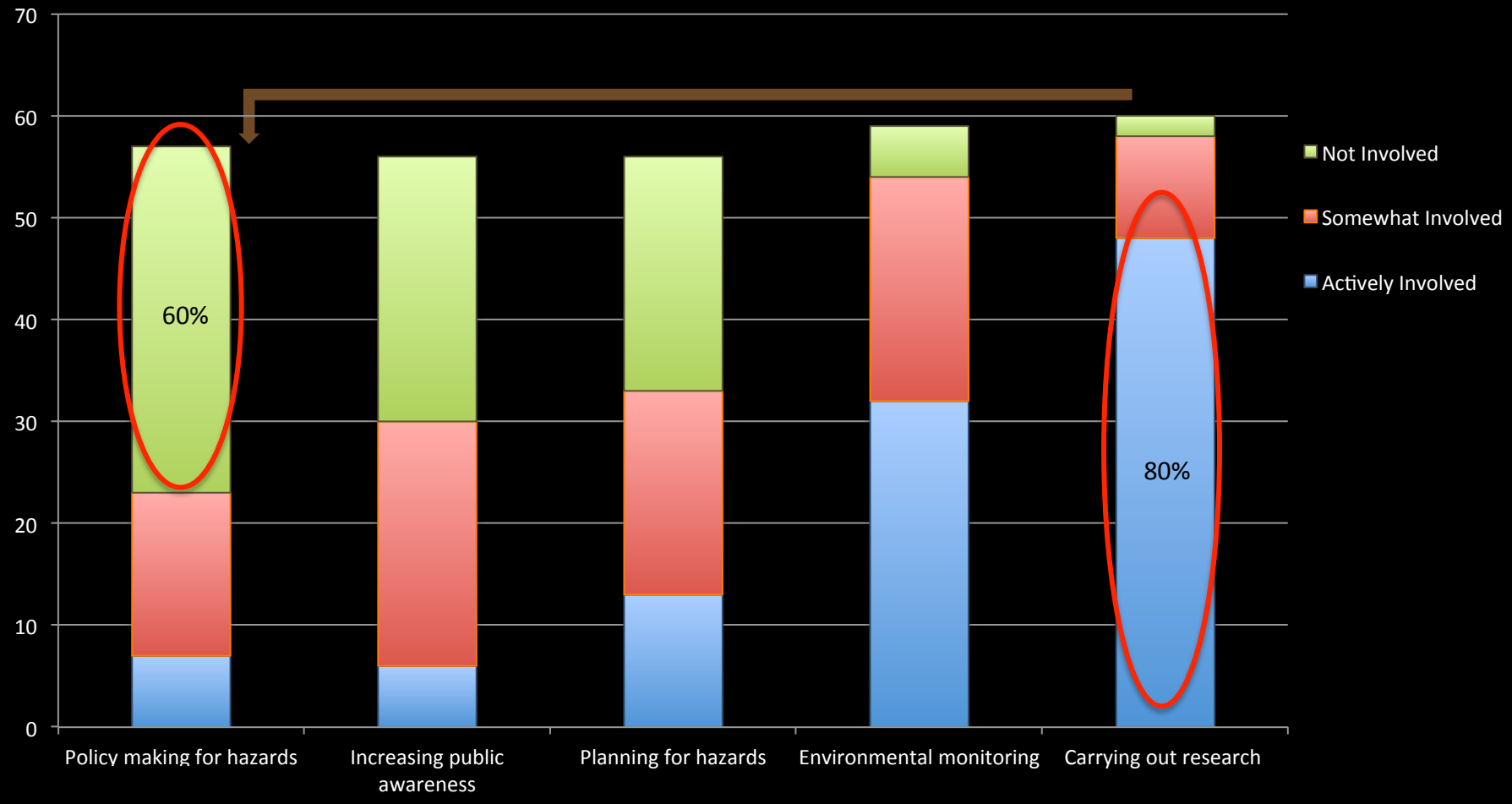
Applications will focus on bridging gaps

- Results show most users associated with SMAP are research/science users.
- Operational users were under-represented. *Our goal is to address this gap*



Move science into action

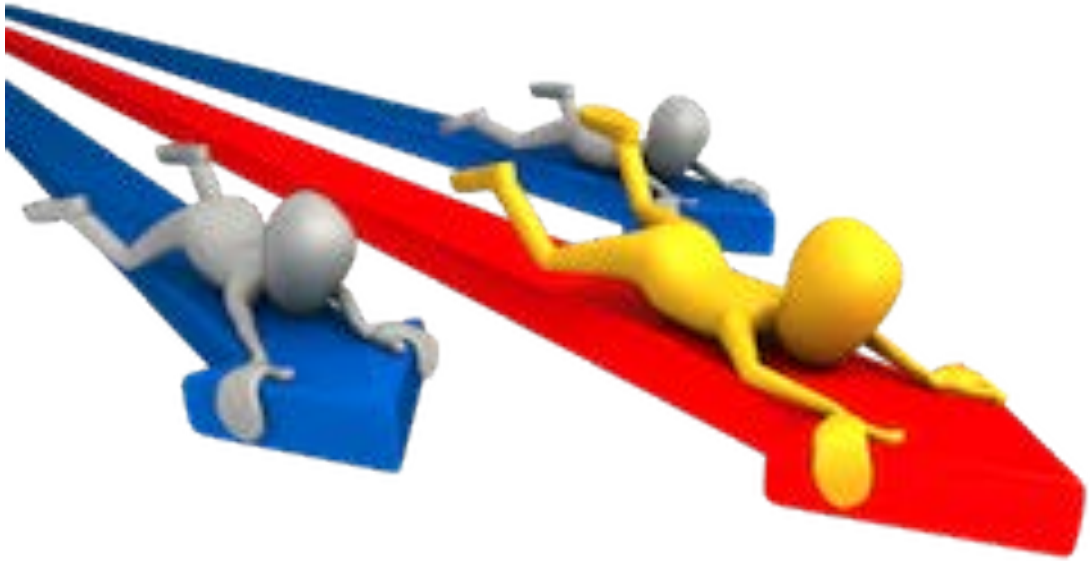
- A clear need to facilitate the movement of research into policy.

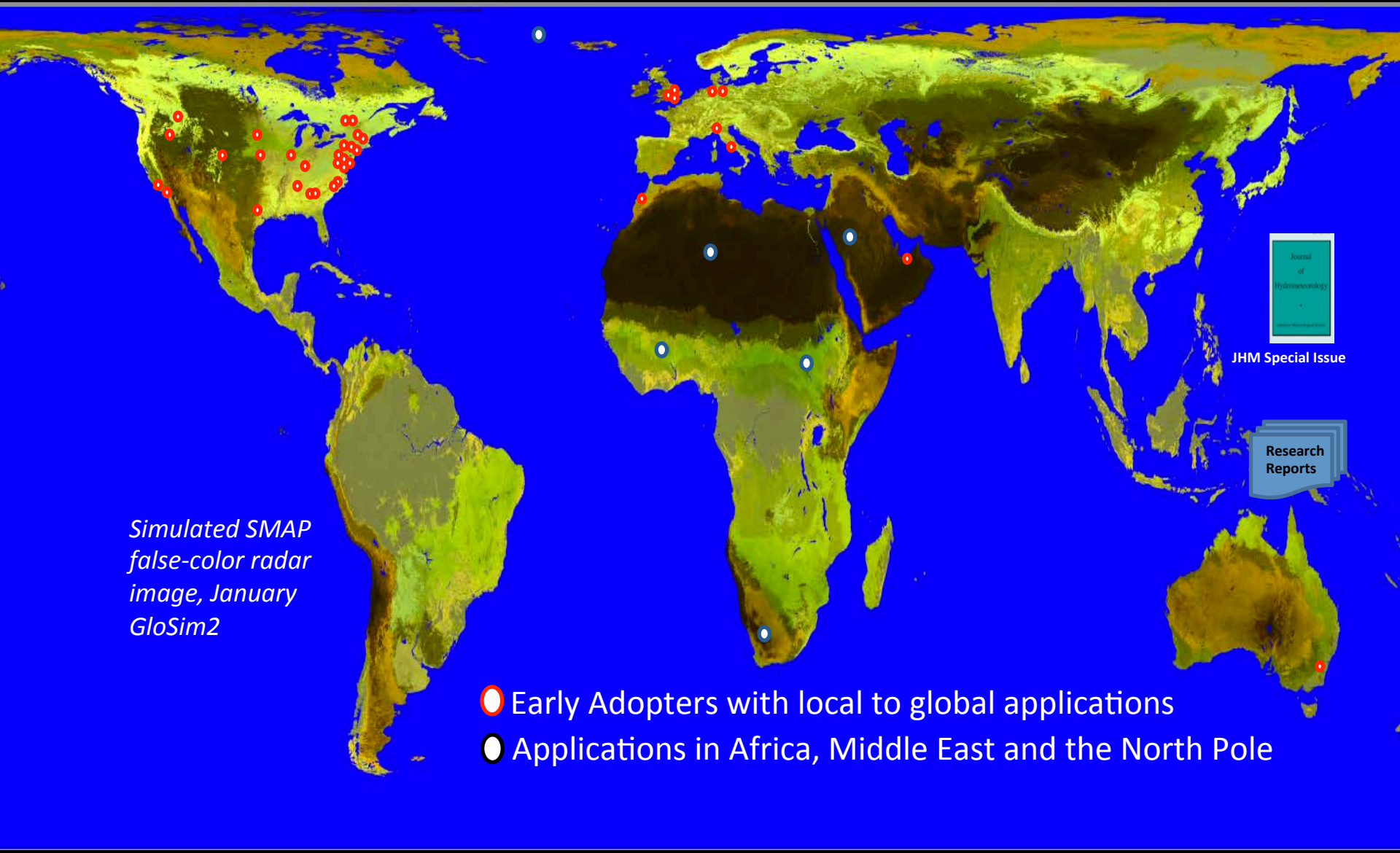


Early Adopters

- 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




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


UAF
UNIVERSITY OF ALASKA FAIRBANKS
EXELIS
Visual Information Solutions
CUNY The City University of New York
AIR FORCE WEATHER AGENCY
NASS
NCEP
USGS
BOISE STATE UNIVERSITY
NCFC
flire
SPORT
COLUMBIA UNIVERSITY
Dartmouth Flood Observatory
AGRISOLUM LIMITED
CONNECTING FARMERS
NORTH CENTRAL CLIMATE SCIENCE CENTER
UNIVERSITY CONSORTIUM
NATIONAL WEATHER SERVICE
irpi
Agriculture and Agri-Food Canada
PROTEZIONE CIVILE
Willis
YorkshireWater
WFP
World Food Programme
CSIRO
SMAP Early Adopters are Spanning Agriculture, Weather, Emergency Response, Human Health, and Military Readiness
ECMWF
aer
Atmospheric and Environmental Research
Universität Bremen
NYC Environmental Protection
Google
TOCKLAI
StormCenter COMMUNICATIONS, INC.
NM STATE
National Drought Mitigation Center
IRI
uae
Environment Canada
USDA
FOREST SERVICE
HRC
LOCKHEED MARTIN
ALTEC
Integra
UNC INSTITUTE FOR THE ENVIRONMENT
NESDIS
National Environmental Satellite, Data and Information Service
CRREL
Georgia Tech
JOHN DEERE
UNIVERSITY OF MARYLAND

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)

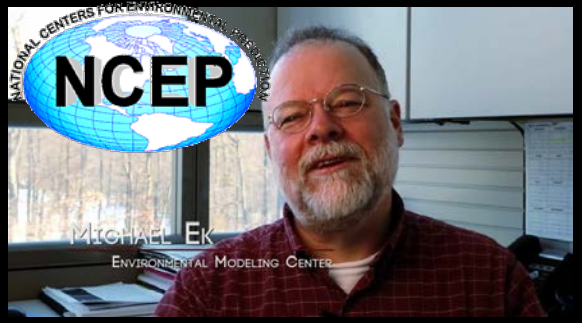
- NASA National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC)
- Siri Jodha Khalsa, Amanda Leon, Karla LeFevre, Shannon Leslie, and Mike Laxer,

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: "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 (9 EAs)	Human Health (5 EAs)
Floods (7 EAs)	National Security/Mobility (3 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 **52 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

SMAP Application Samples

Flooding

Global application of soil moisture for flooding

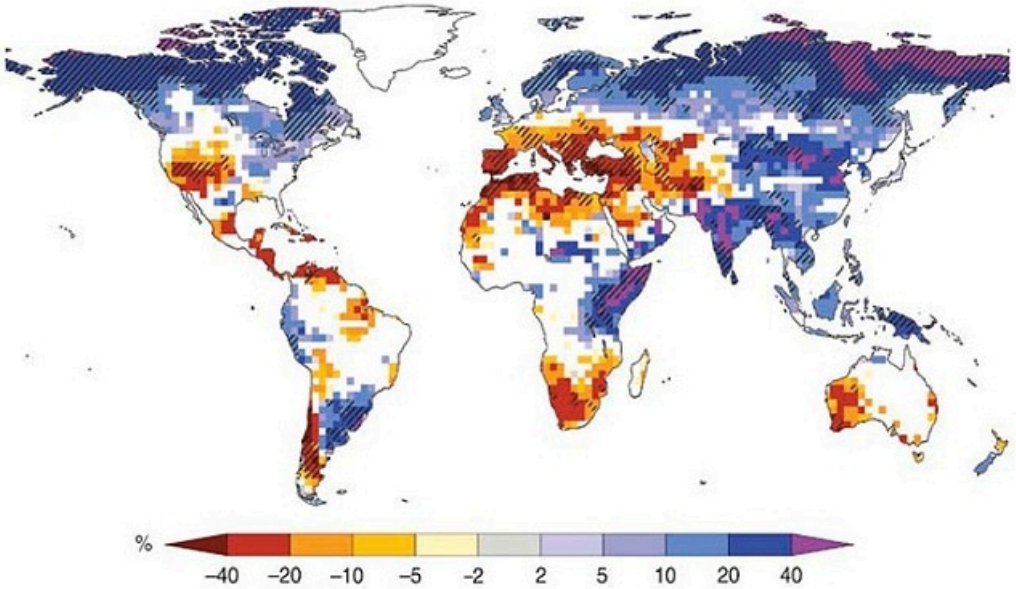
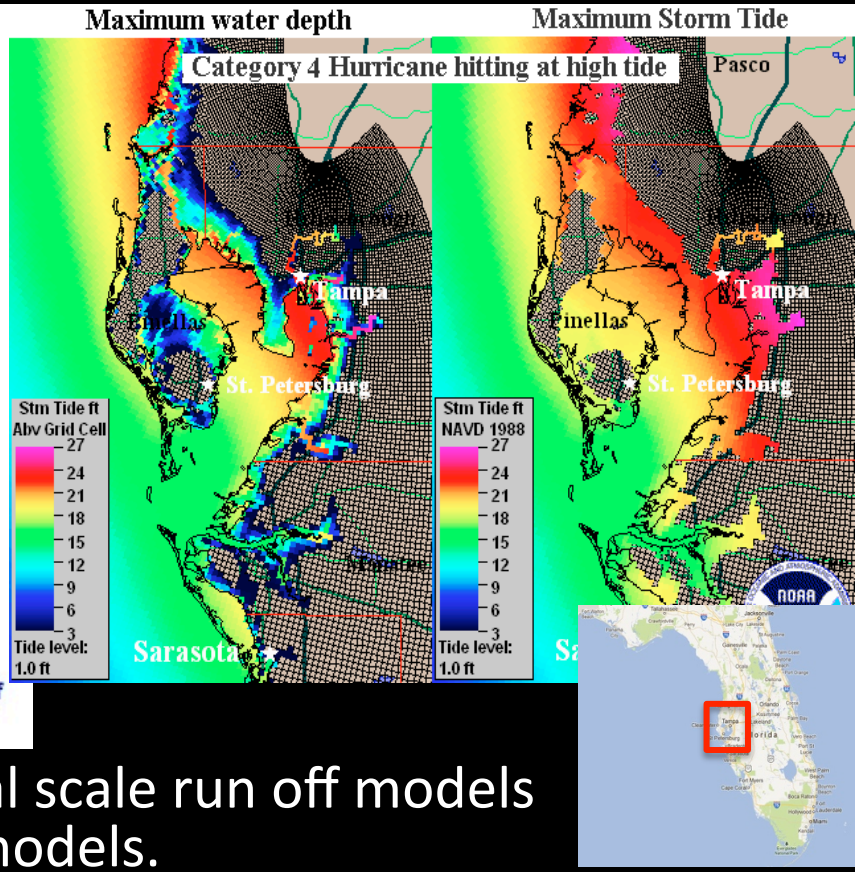
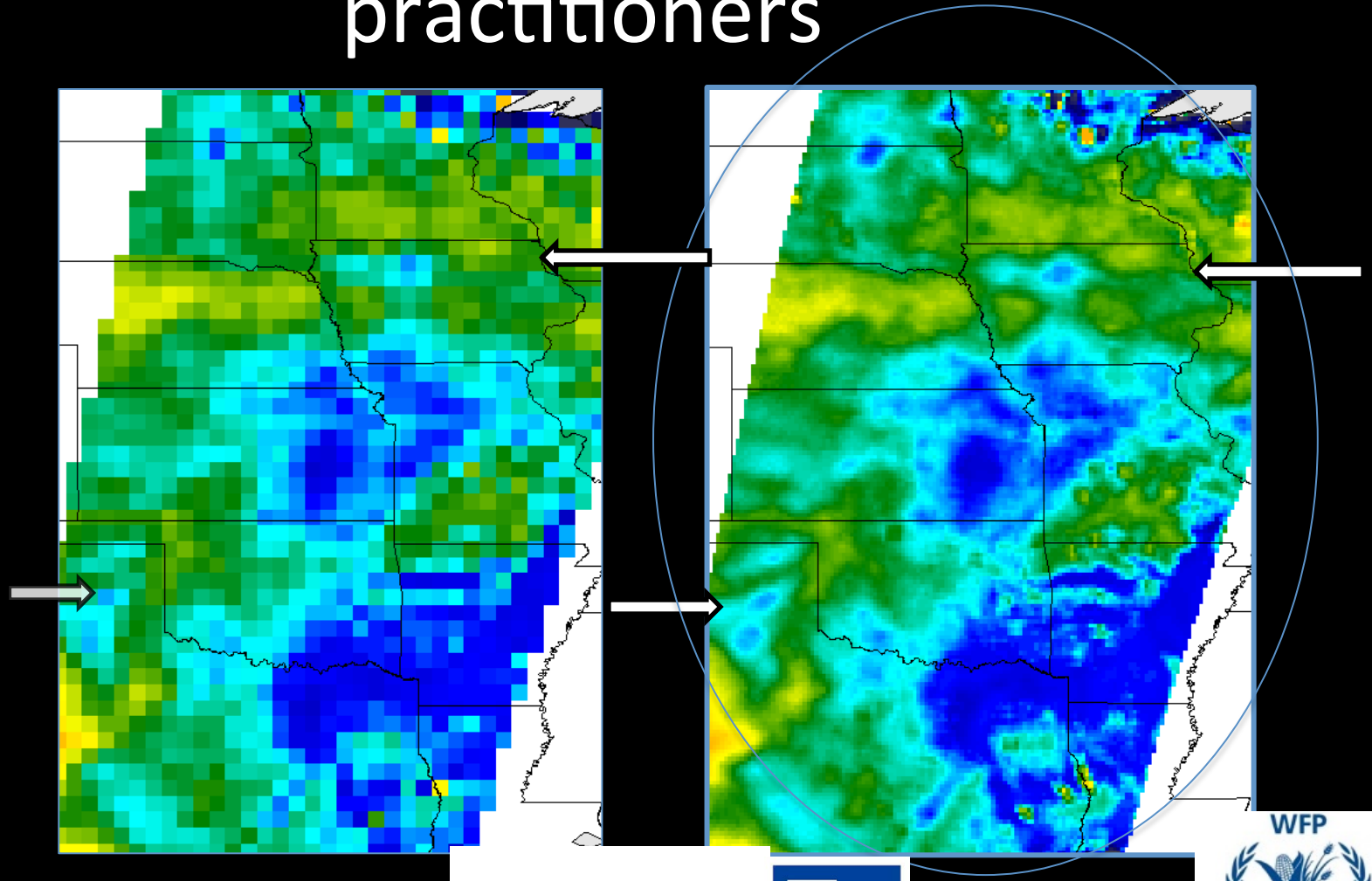


Figure 10.18 Runoff model projections of large-scale relative changes in annual runoff for the period 2090-2099 relative to 1980-1999. Courtesy IPCC



- Evaluate global scale run off models with climate models.
- Evaluate scenarios at the global scale using soil moisture data.
- Evaluate the scale of data needed for decision making.

Improve how we communicate to practitioners



StormCenter COMMUNICATIONS, INC.

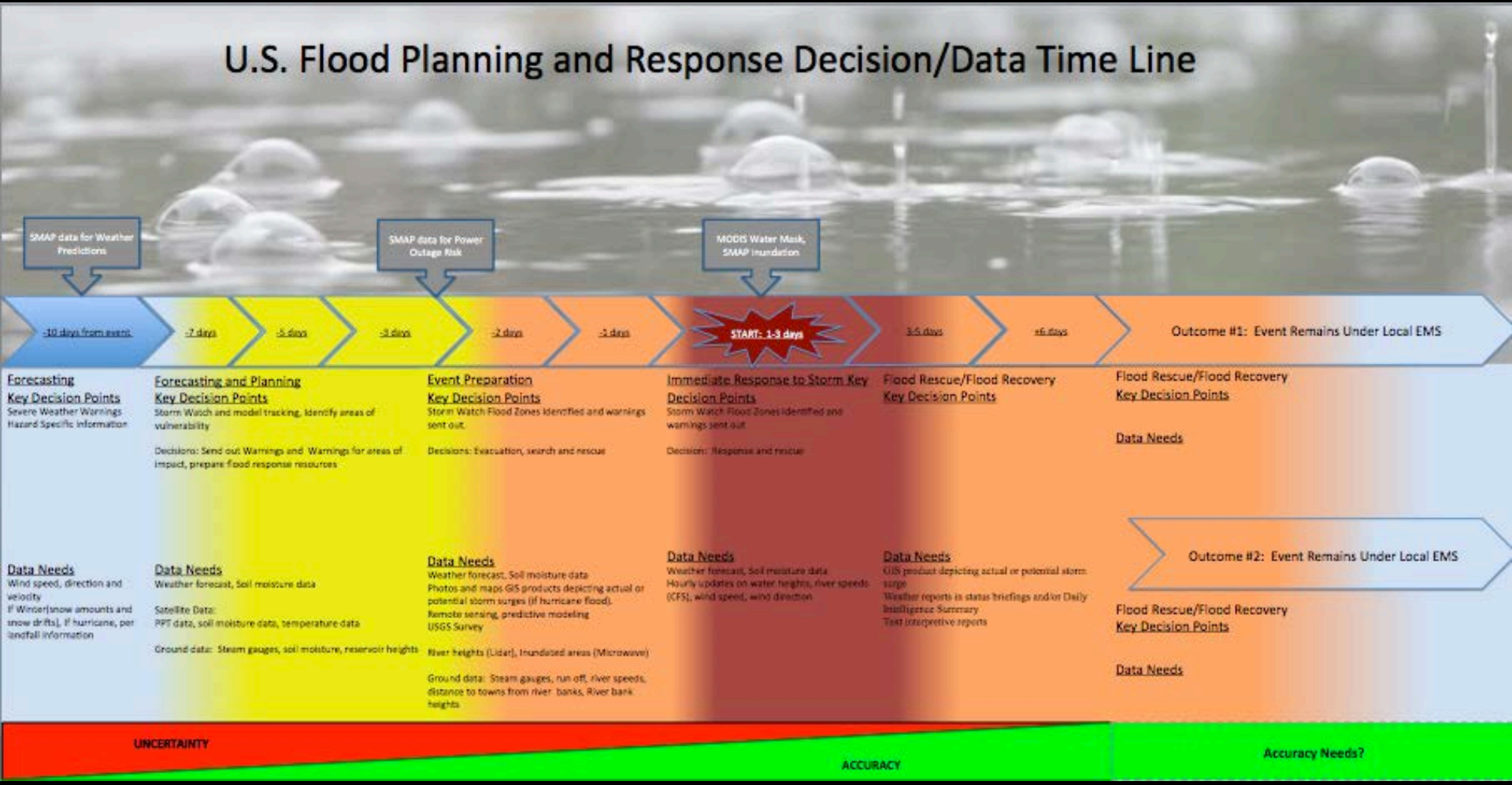
Google

NH

Willis

WFP World Food Programme

U.S. Flood Planning and Response Decision/Data Time Line



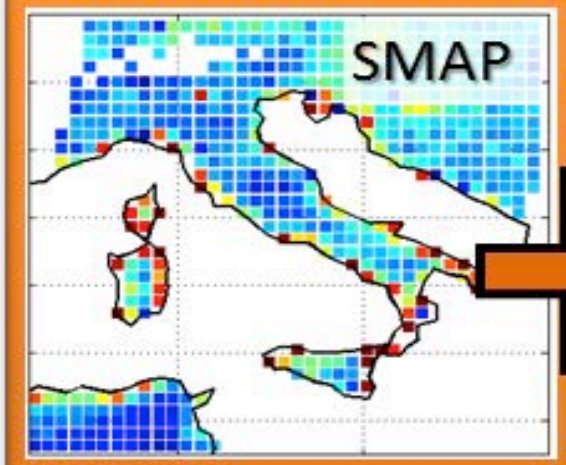
Flood Mitigation in Central Italy

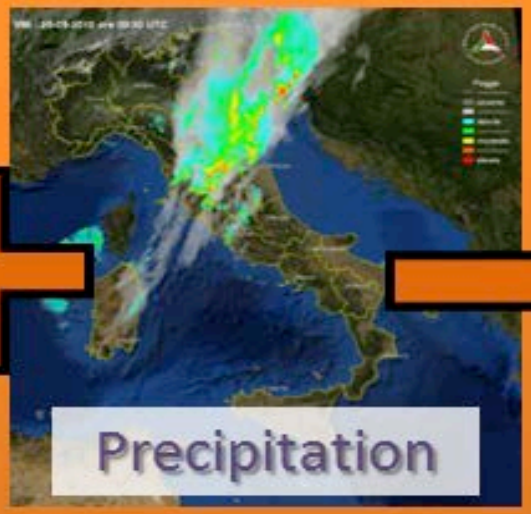
Research Institute for Geo-Hydrological Protection, *Luca Brocca*

NATIONAL SCALE FLOOD WARNING SYSTEM

3

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile



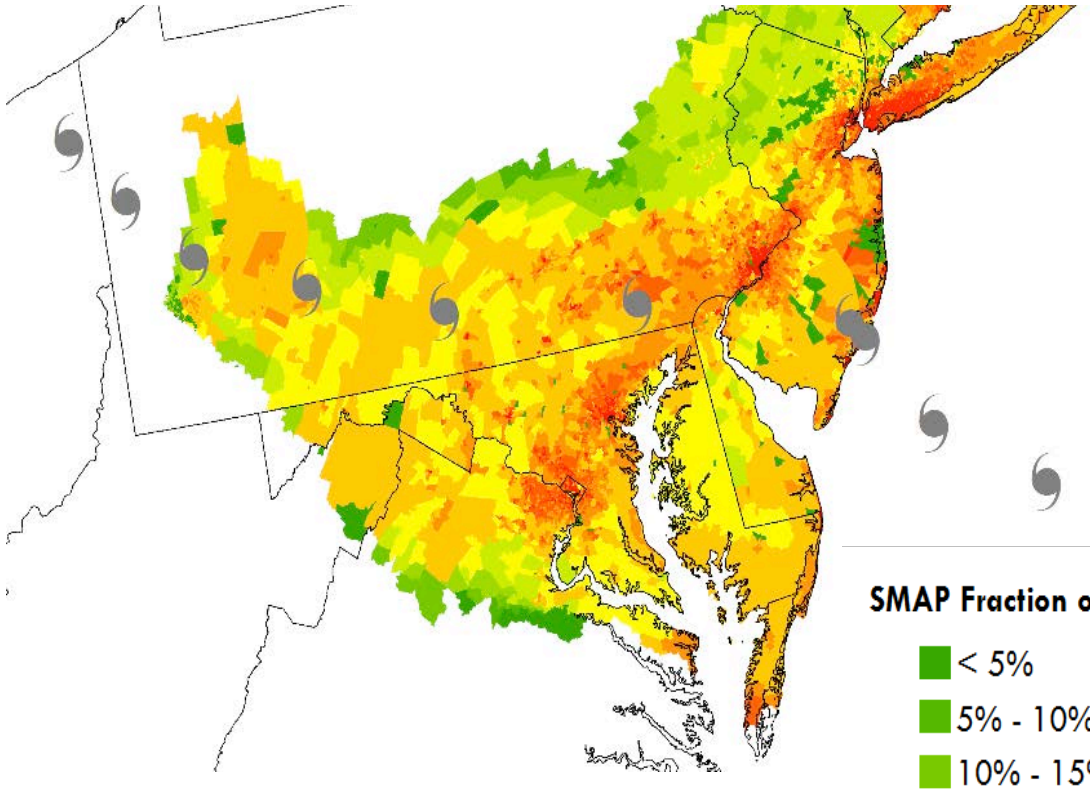


Integration of SMAP soil moisture and ground-based precipitation observations for flood (and landslide) alert issuing at national scale.

Hurricane Power Outage Prediction

Texas A&M University, *Brent McRobert, Steven Quiring*

Prediction of Power Outages for Sandy Wind Field
With modeled soil moisture: 15,989,091 people affected
With SMAP soil moisture: 16,327,051 people affected



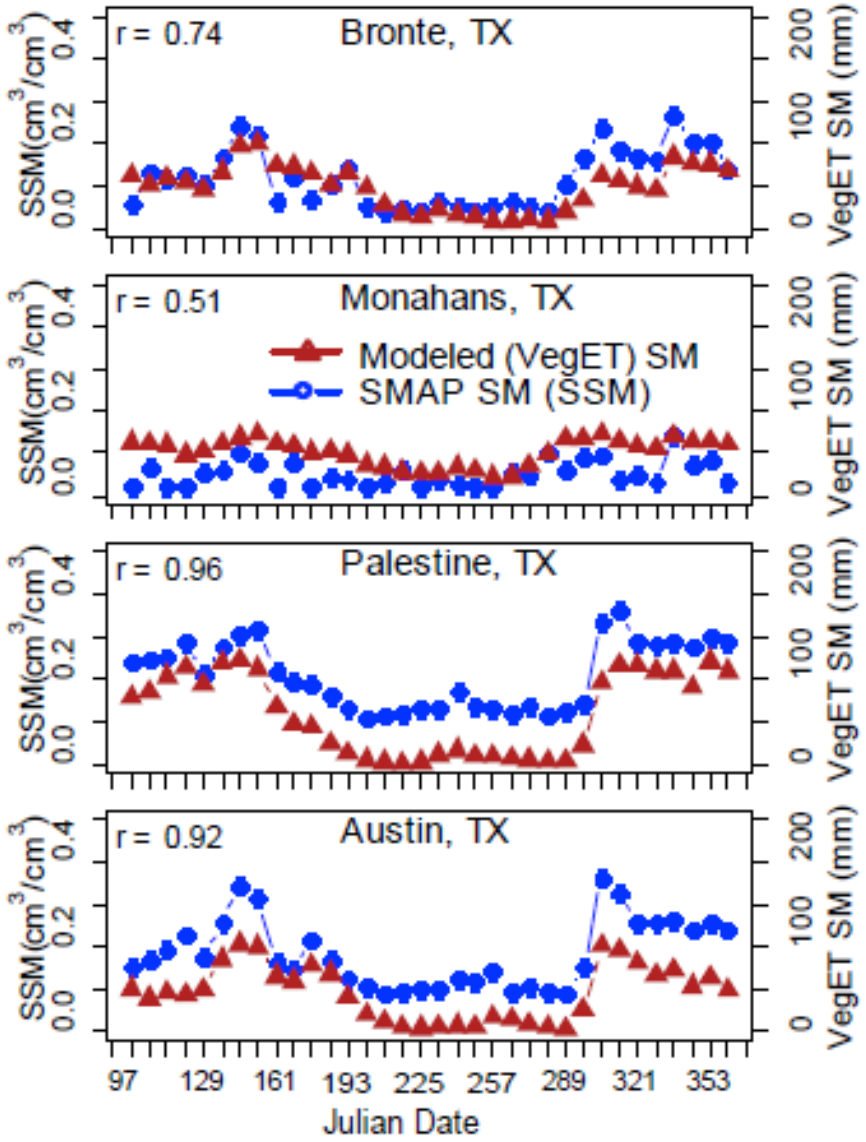
Outage predictions are sensitive to soil moisture.

Using SMAP data has a significant impact on predictions of people affected by outages.

Drought

Drought Monitoring

U.S. Geological Survey, *Manohar Velpuri, Jeff Morisette*



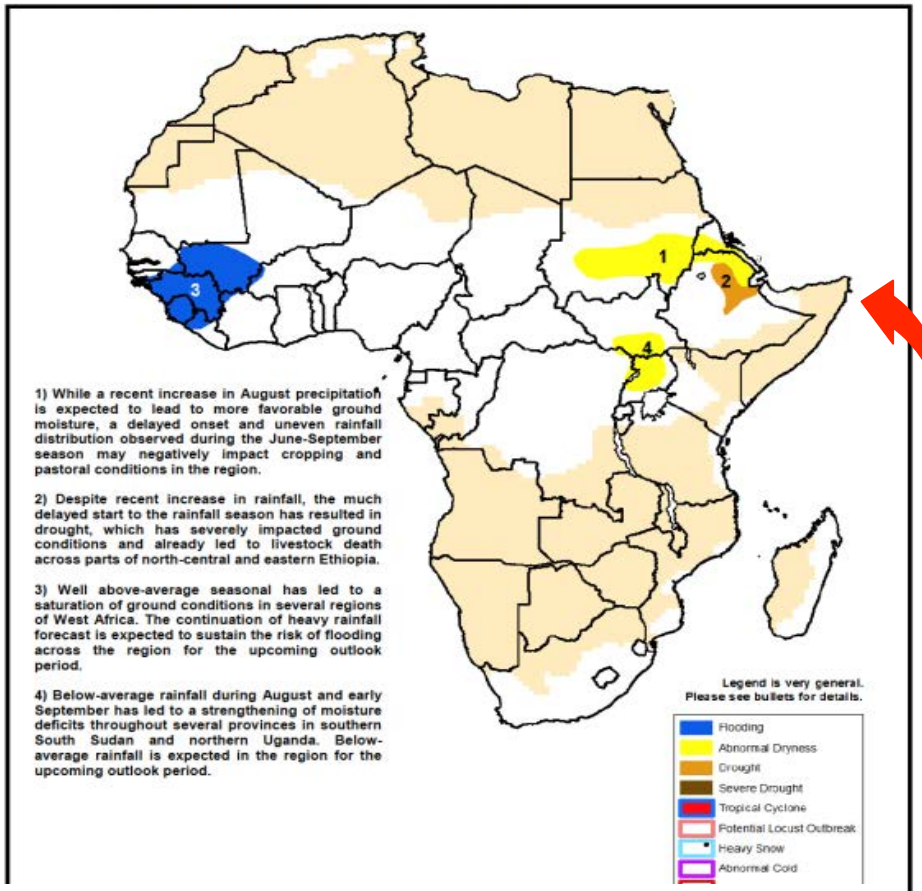
USGS conducts drought monitoring in areas dominated by grasslands and shrublands.

SMAP showed a reliable and expected response of capturing seasonal soil moisture dynamics in relation to precipitation, land surface temperature, and evapotranspiration.

Famine Early Warning System (FEWS) in Africa

USGS & UC Santa Barbara, *Chris Funk, Amy McNally and James Verdin*

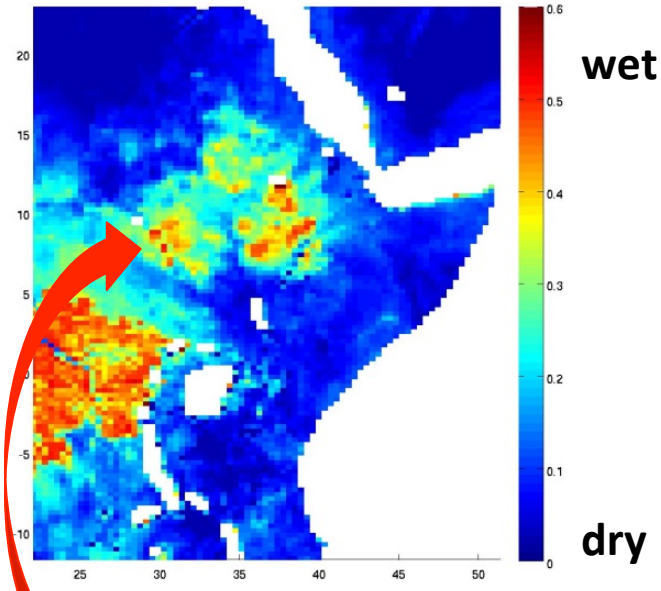
Climate Prediction Center's Africa Hazards Outlook
Sept. 24-30 2015



FEWS reports drought in Ethiopia but higher than average September rain.

SMAP images will be introduced to FEWS analysts for better famine prediction

Sept. flooding in East Africa is captured by SMAP L-3 regional images (Sept 10-18).



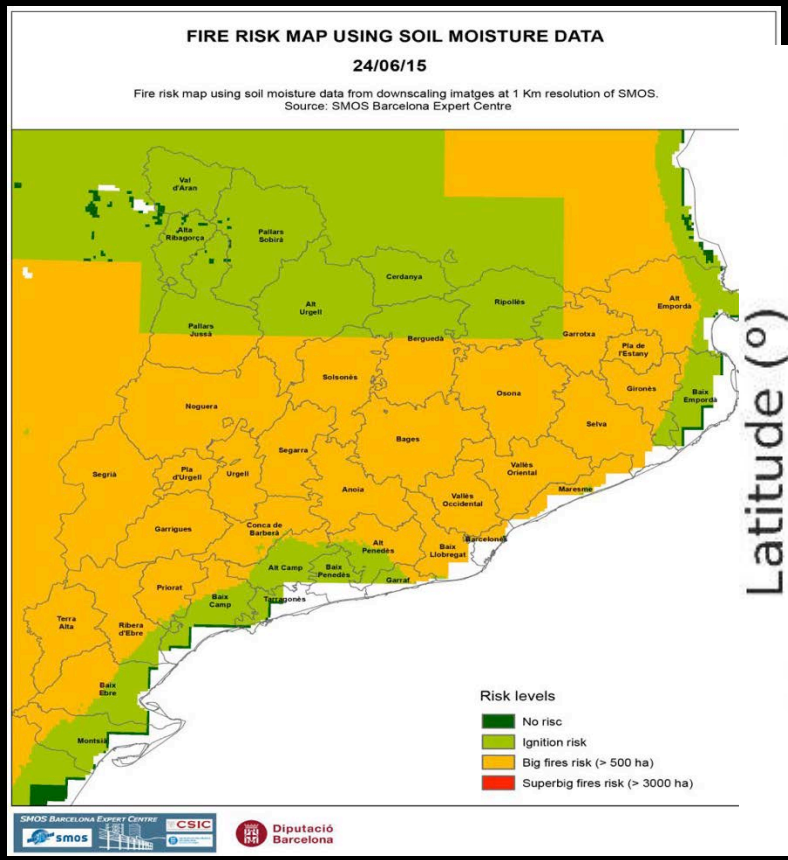
SMAP sees moderately-to-very wet soil.

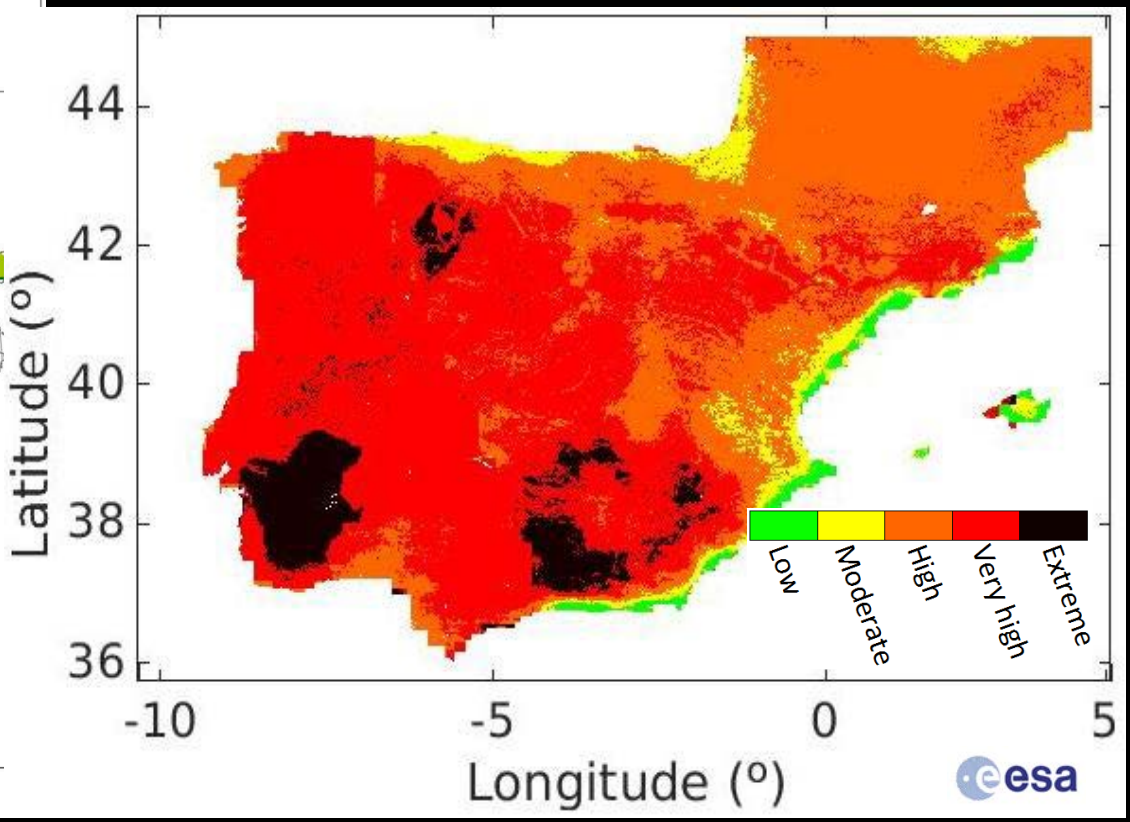
Improving Forest Fire Risk Maps

Barcelona Expert Center, ICM/CSIC, UPC, *Maria Piles*

The Barcelona Expert Center provides free access to fire risk maps.

Map showing 5 fire risk categories based on modeling and SMAP soil moisture product.



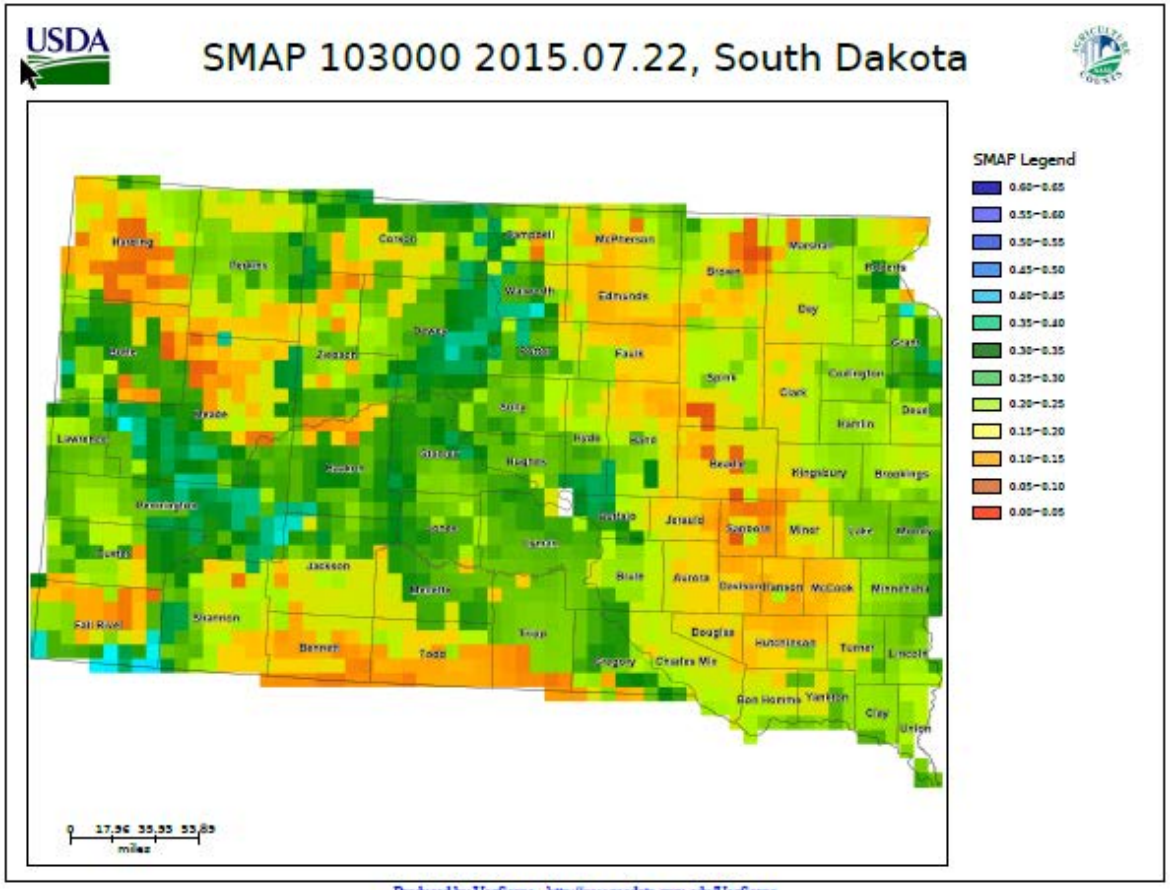


Decision Support Tools

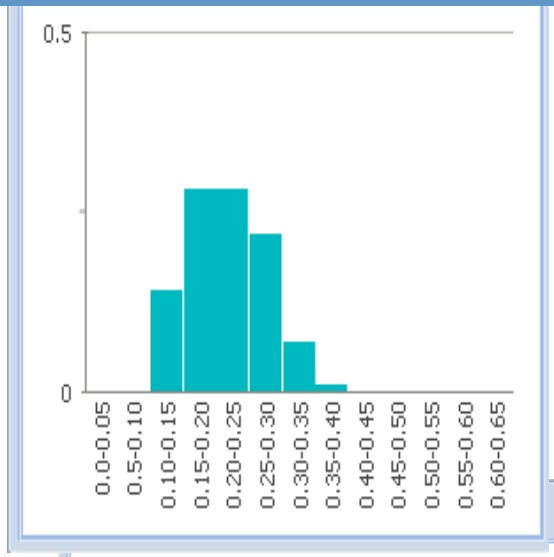
USDA Crop Condition Report

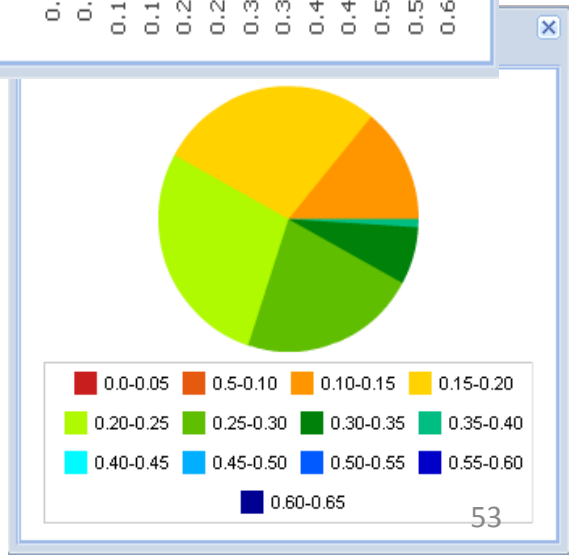
USDA National Agricultural Statistics Service, *Zhengwei Yang, Rick Mueller*

USDA NASS VegScape visualization, analytics and dissemination tool



Soil Moisture Statistics for South Dakota 2015.07.22

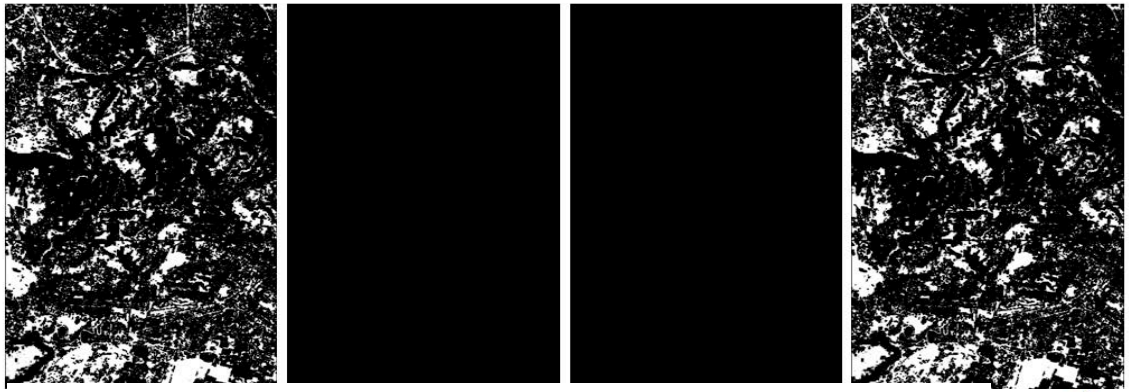




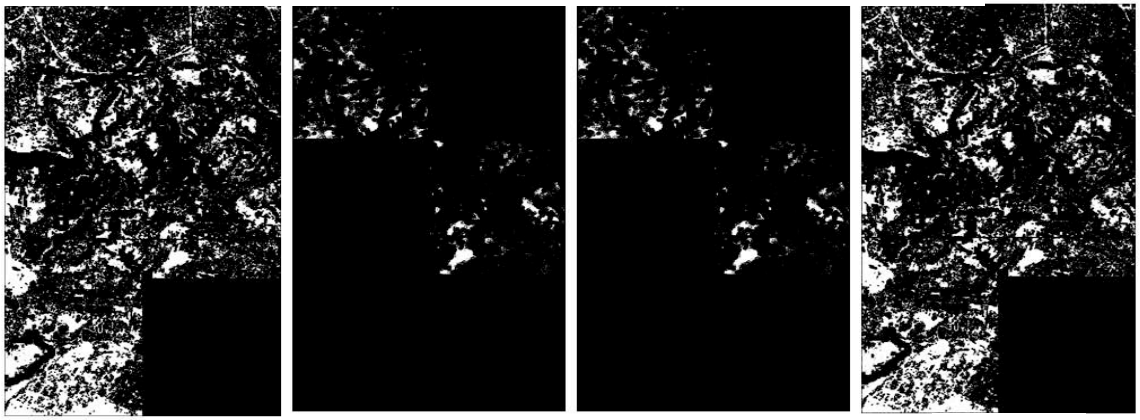
Military Vehicle Mobility

Lockheed Martin, *Derek Ward*

Mobility Map without using SMAP data,
Assuming soil 30% saturation



Mobility Map using SMAP data,
With a continuum of soil moisture information



HumVee | **ATV** | **Transport Truck** | **Light Truck**

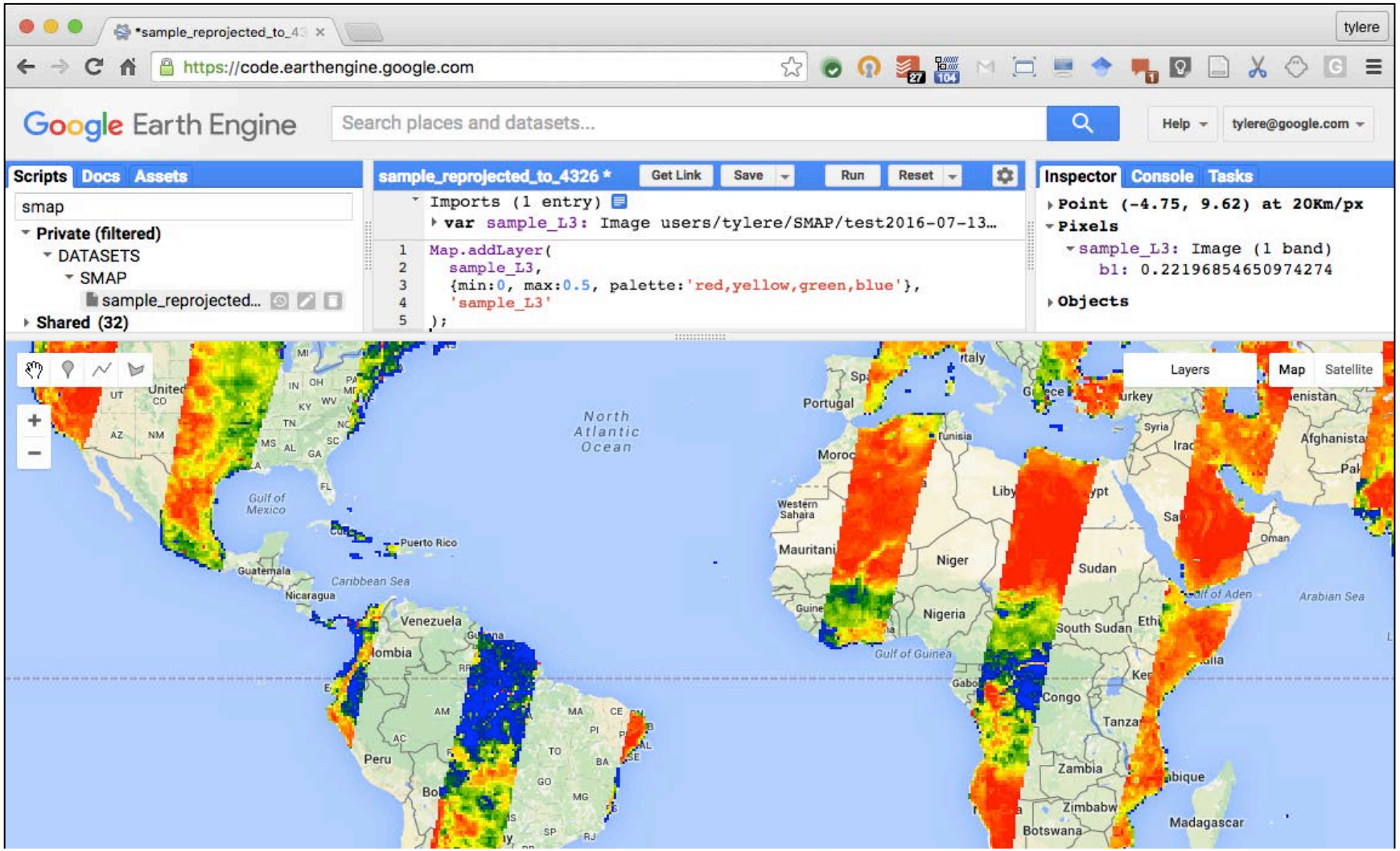
White denotes areas identified as GO mobility for 4 vehicle types.

With SMAP, we are better able to predict mobility of vehicles in Central Indonesia.

NATO Reference Mobility Model is the basis for the calculations.

Google Earth Engine Analysis Platform

Google Technology Company, *Tyler Erickson, Rebecca Moore*



Screenshot of a SMAP L3 Soil Moisture data product within the Earth Engine platform

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?*

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*.

Early Adopter Feedback

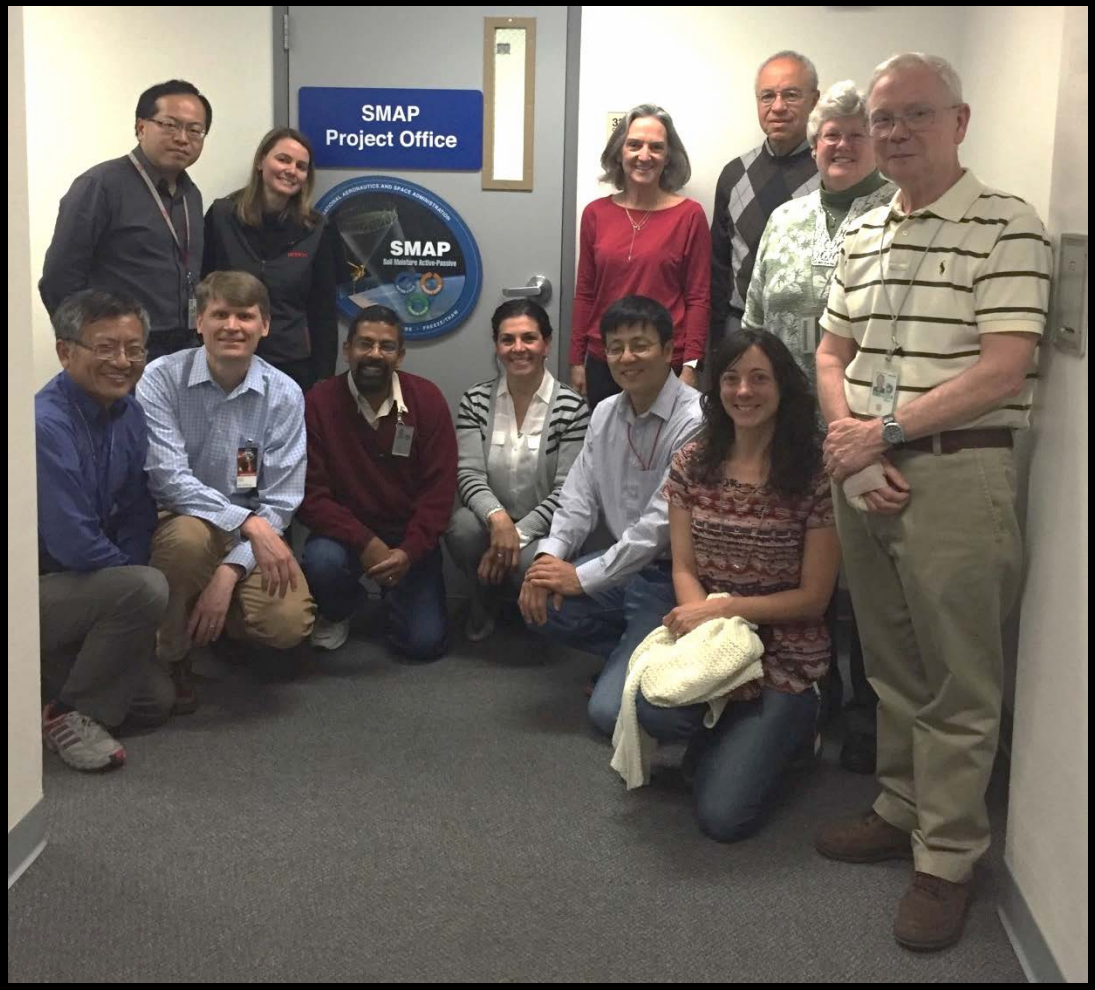
- Improved Data Services for DAACs
- Tutorials and SMAP hands-on learning
- Improved formats and context for broadening user community
- Inform and guide future mission on Applications Program
- Inform new decadal survey missions (EA Program already moving forward at NASA)
- Joint mission products and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

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.

Team Effort 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**

Thank you for your attention!

Questions?

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