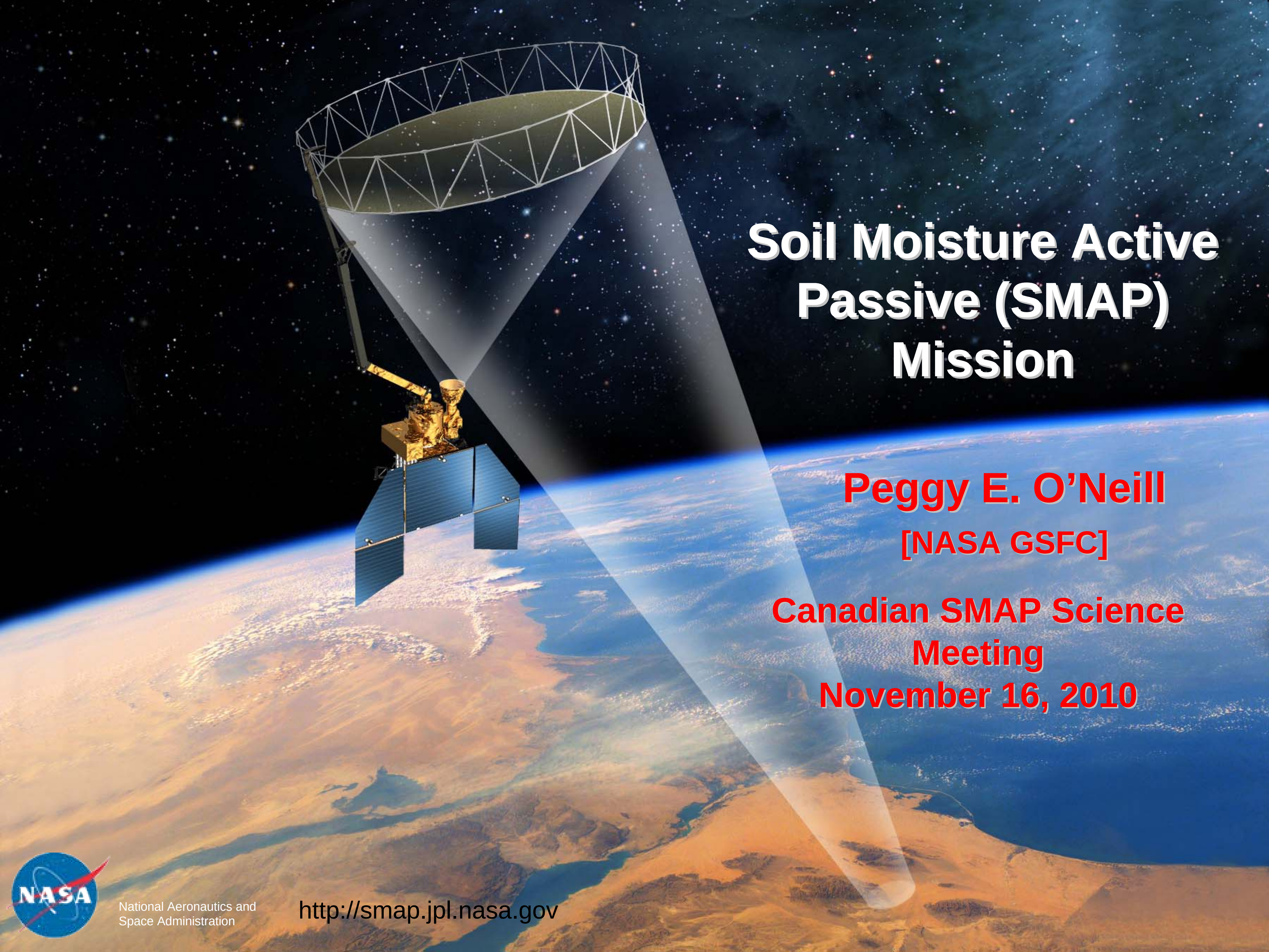


Soil Moisture Active Passive (SMAP) Mission

Peggy E. O'Neill

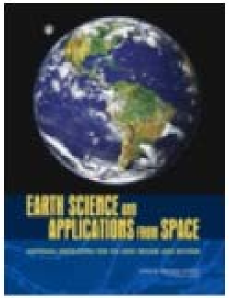
[NASA GSFC]

Canadian SMAP Science Meeting
November 16, 2010

National Aeronautics and
Space Administration

Mission Context

SMAP is one of four Tier-1 missions recommended by the U.S. NRC Earth Science Decadal Survey



"Earth Science and Applications from Space: National Imperatives for the next Decade and Beyond"

(National Research Council, 2007)
http://www.nap.edu

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

- **SMAP was initiated by NASA as a new start mission in February 2008**
- **SMAP leverages work done under Hydros (including Canadian contributions) & Aquarius**
- **SMAP now in Phase B – PDR scheduled for Mar 2011**
- **The target launch date for SMAP is November 2014**

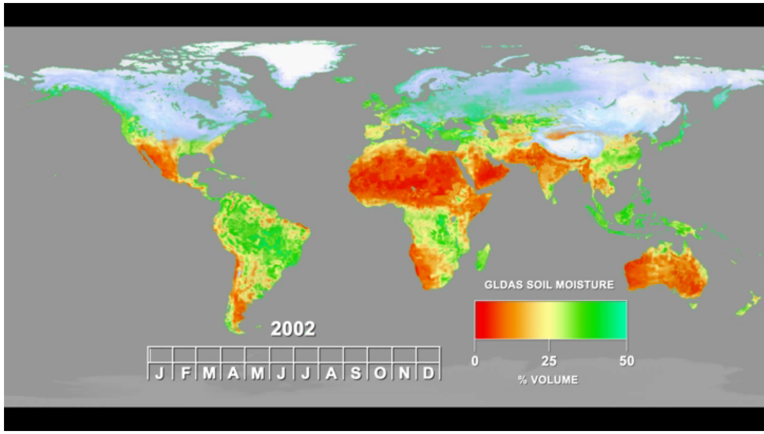
Science Objectives

National Aeronautics and Space Administration

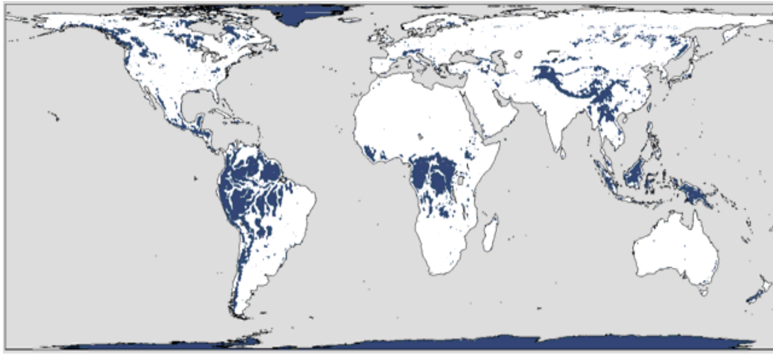
SMAP will provide high-resolution, frequent-revisit global mapping of soil moisture and freeze/thaw state to enable science and applications users to:

- **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 and climate forecast skill**
- **Develop improved flood prediction and drought monitoring capability**

Model simulation of SMAP L4 Soil Moisture Product



Regions where soil moisture retrieval is limited (dense vegetation, topography, snow/ice)



SMAP data will also be used in applications of societal benefit that range from agriculture to human health.

National Aeronautics and Space Administration

SMAP Level 1 Science Requirements

	Science Discipline Measurement Need			Level 1 Science Measurement Requirements			
				Baseline Mission		Threshold Mission	
	Hydro-Meteorology	Hydro-Climatology	Carbon Cycle	Soil Moisture	Freeze/Thaw[2]	Soil Moisture	Freeze/Thaw[2]
Resolution	4–15 km	50–100 km	1–10 km	10 km	3 km	10 km	10 km
Refresh Rate	2–3 days	3–4 days	2–3 days	3 days	2 days	3 days	3 days
Accuracy[(1)]	.04–.06 cm^3/cm^3	.04–.06 cm^3/cm^3	80–70%	.04 cm^3/cm^3	80%	.06 cm^3/cm^3	70%

Mission Duration Requirement:
3 Years Baseline; 18 Months Threshold

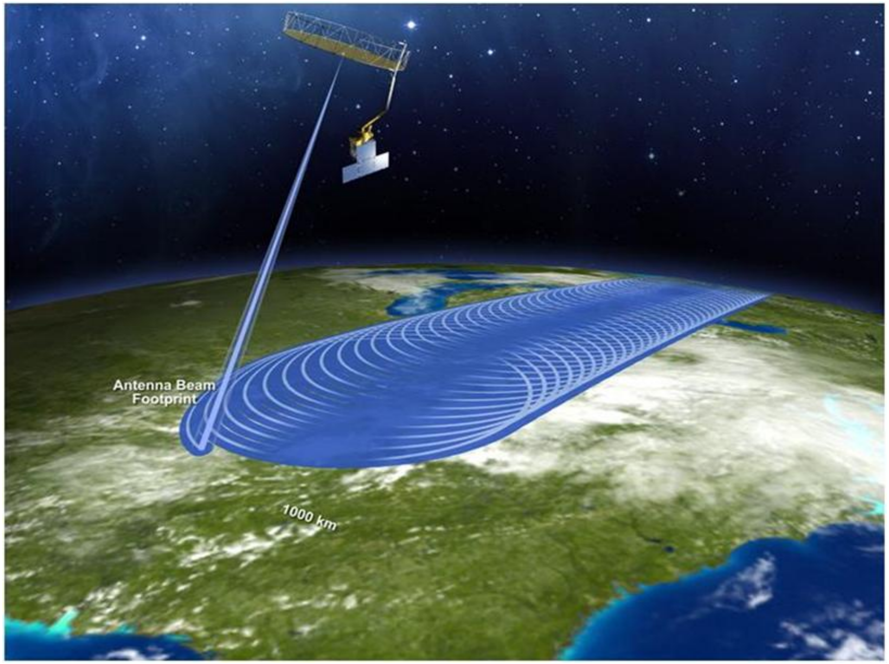
(1) volumetric soil moisture content (1-sigma) ; % classification accuracy (binary Freeze/Thaw)
(2) North of 45° N latitude

Derived from models and decision-support tools used in areas of application identified by decadal survey for SMAP

DS Objective	Application/Discipline	Science Requirement
Weather Forecast	Initialization of Numerical Weather Prediction (NWP)	Hydrometeorology
Climate Prediction	Boundary and Initial Conditions for Climate Models	Hydroclimatology
	Testing Land Surface Models in General Circulation Models	
Drought and Agriculture Monitoring	Seasonal Precipitation Prediction	Hydroclimatology
	Regional Drought Monitoring	
	Crop Outlook	
Flood Forecast	River Forecast Model Initialization	Hydrometeorology
	Flash Flood Guidance (FFG)	
	NWP Initialization for Precipitation Forecast	
Human Health	Seasonal Heat Stress Outlook	Hydroclimatology
	Near-Term Air Temperature and Heat Stress Forecast	Hydrometeorology
	Disease Vector Seasonal Outlook	Hydroclimatology
	Disease Vector Near-Term Forecast (NWP)	Hydrometeorology
Boreal Carbon	Freeze/Thaw Date	Freeze/Thaw State

Measurement Approach

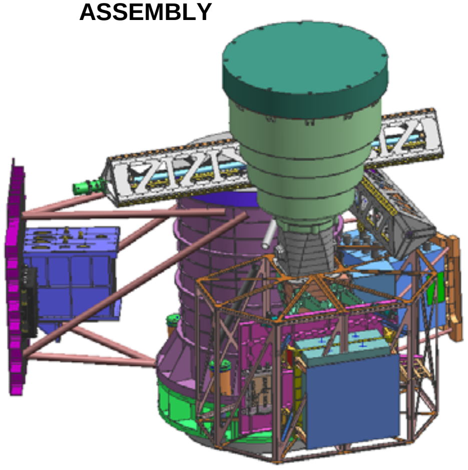
- **Instruments:**
  - **Radiometer: L-band (1.4 GHz)**
    - V, H, 3rd & 4th Stokes parameters
    - 40 km resolution
    - Moderate resolution soil moisture (high accuracy)
  - **Radar: L-band (1.26 GHz)**
    - VV, HH, HV polarizations
    - 3 km resolution (SAR mode); 30 x 5 km resolution (real-aperture mode)
    - High resolution soil moisture (moderate accuracy) and Freeze/Thaw state detection
  - **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



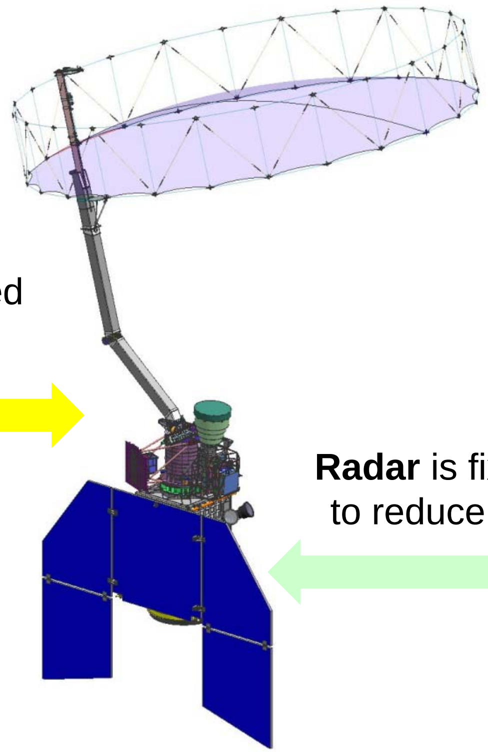
- **Orbit:**
  -- Sun-synchronous, 6 am/pm, 680 km altitude
  -- 8-day exact repeat
- **Mission Operations:**
  -- 3-year baseline mission
  -- Launch in November 2014

Instrument Overview

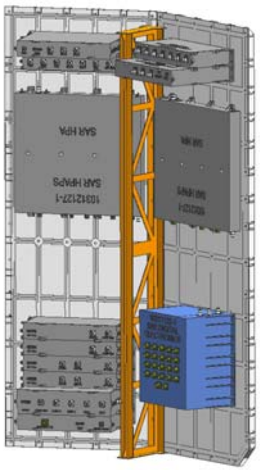
SPUN INSTRUMENT ASSEMBLY



Radiometer is spun-side mounted to reduce losses



Radar is fixed-mounted to reduce spun inertia



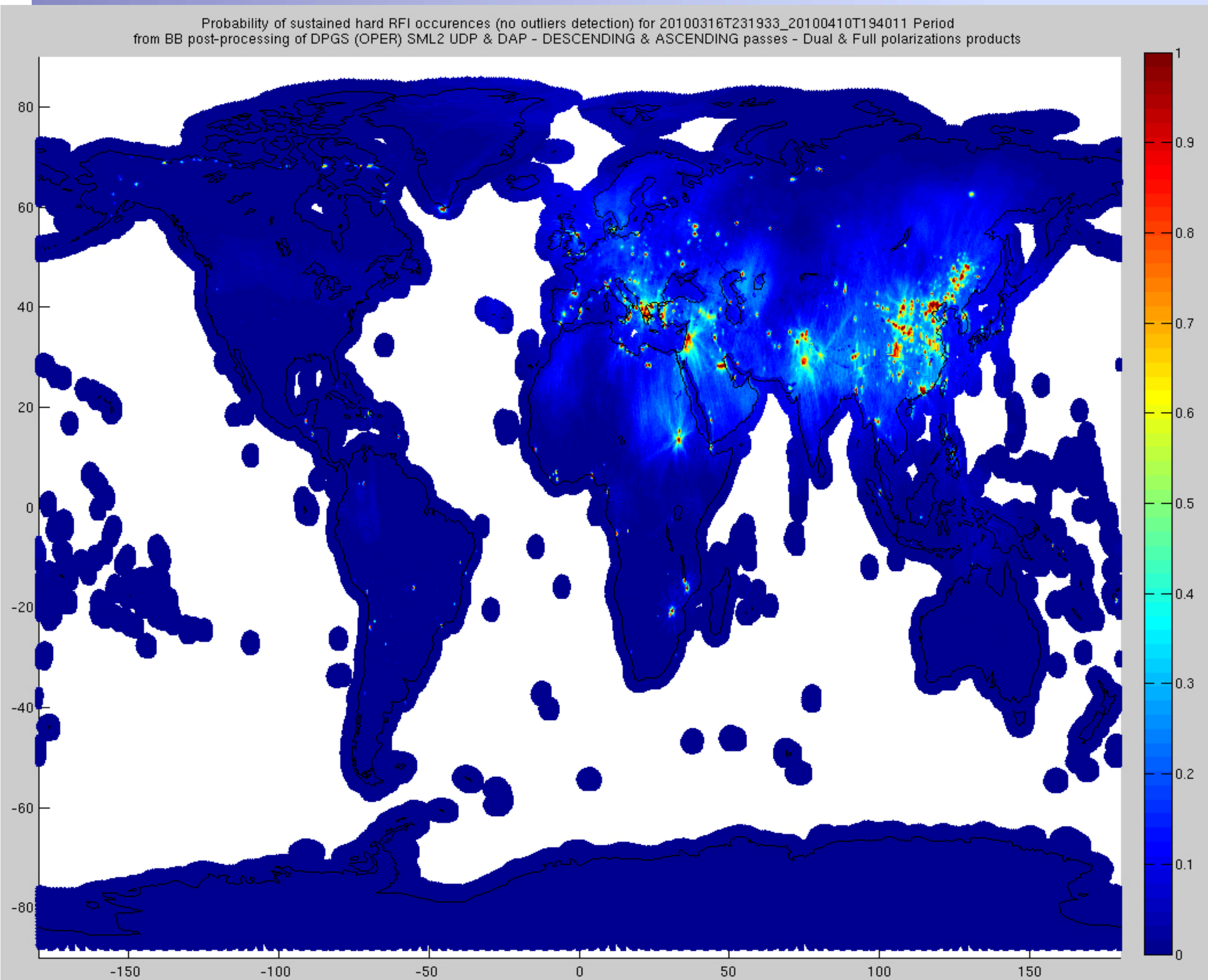
- **Radiometer**
  - Provided by GSFC
  - Leverages off Aquarius radiometer design
  - Includes RFI mitigation (spectral filtering)

- **Common 6 m spinning reflector**
  - Enables global coverage in 2-3 days
  - Spin Assembly (provided by Boeing) and Reflector Boom Assembly (provided by NGST-Astro) have extensive heritage

- **Radar**
  - Provided by JPL
  - Leverages off past JPL L-band science radar designs
  - RFI mitigation through tunable frequencies & ground processing

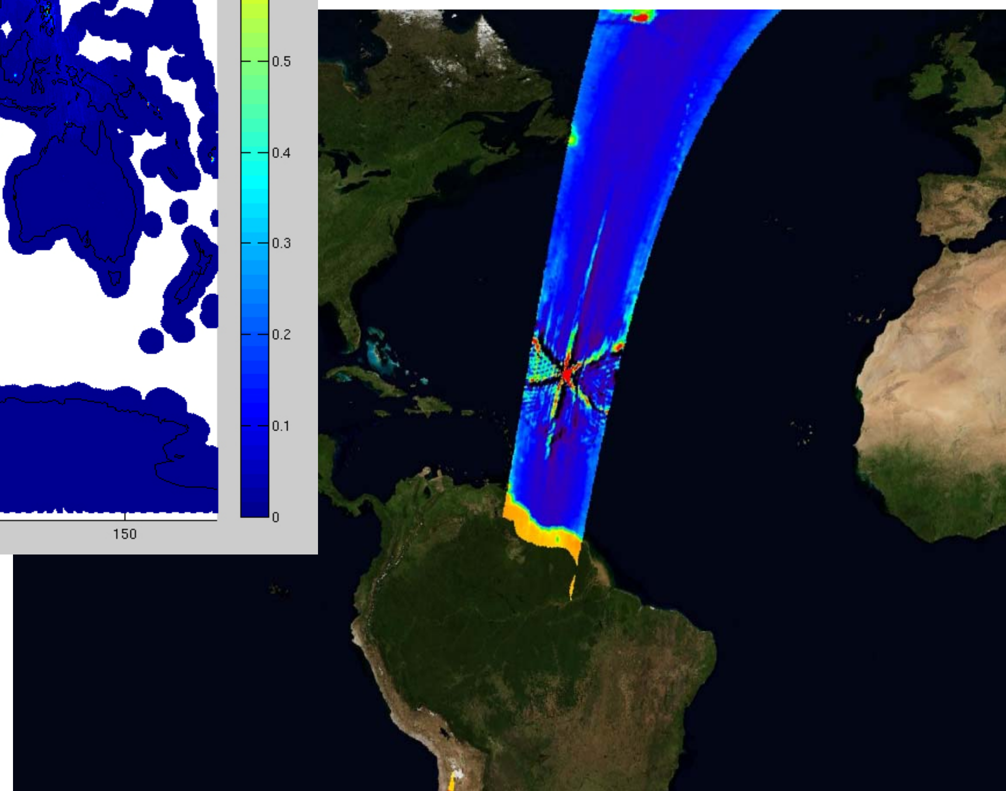
Anthropogenic Radio-Frequency Interference (RFI)

National Aeronautics and Space Administration



RFI is evident and wide-spread

(Data from SMOS)



SMAP is taking aggressive measures to detect and mitigate RFI in its instrument and data processing designs.

National Aeronautics and
Space Administration

Science Team Organization

Science Definition Team Leader
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Project Scientist
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J. Walker (Australia)

Working Groups:
1. RFI
2. Algorithms
3. Cal/Val
4. Applications

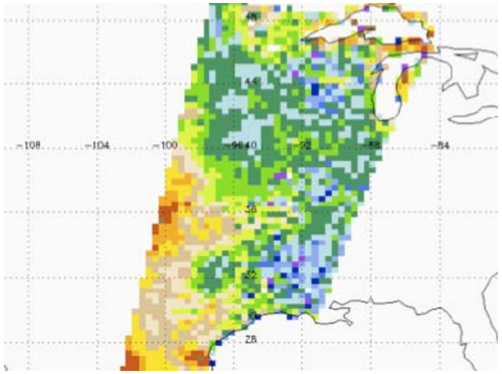
SMAP Data Products

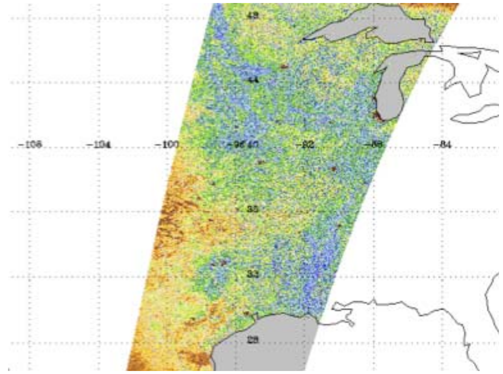
Product	Short Description	Resolution/ Grid	Latency	
L1A_S0	Radar raw data in time order	–	12 hours	Instrument Data
L1A_TB	Radiometer raw data in time order	–	12 hours	
L1B_S0_LoRes	Low resolution radar σ_o in time order	5x30 km	12 hours	
L1B_TB	Radiometer T_B in time order	36x47 km	12 hours	
L1C_S0_HiRes	High resolution radar σ_o	1-3 km	12 hours	
L1C_TB	Radiometer T_B	36 km	12 hours	
L2_SM_A	Soil moisture (radar)** [research product]	3 km	24 hours	Science Data (Half-Orbit)
L2_SM_P	Soil moisture (radiometer)	36 km	24 hours	
L2_SM_A/P	Soil moisture (radar/radiometer)	9 km	24 hours	
L3_SM_A	Soil moisture (radar)	3 km	24 hours	Science Data (Daily Composite)
L3_F/T_A	Freeze/thaw state (radar)	3 km	50 hours	
L3_SM_P	Soil moisture (radiometer)	36 km	50 hours	
L3_SM_A/P	Soil moisture (radar/radiometer)	9 km	50 hours	
L4_SM	Soil moisture (surface & root zone)	9 km	7 days	Science Value-Added
L4_C	Carbon net ecosystem exchange (NEE)	9 km	14 days	

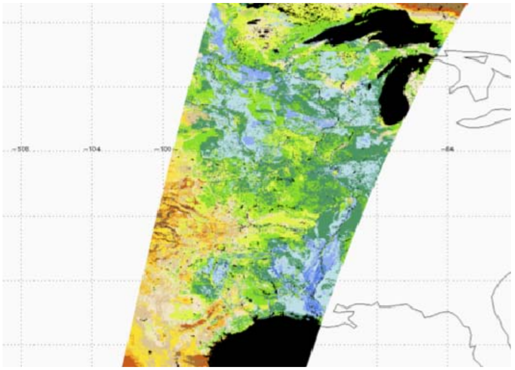
SMAP Algorithm Testbed

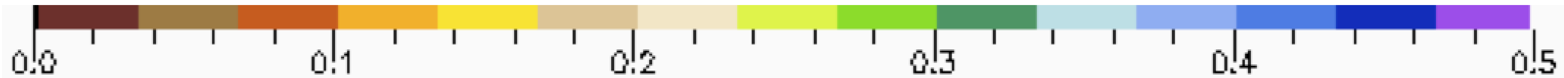
National Aeronautics and Space Administration

36 km Radiometer	3 km Radar	9 km Combined
L2_SM_P	L2_SM_A	L2_SM_A/P









SMAP Algorithm Testbed used for:

1. Testing baseline and optional algorithms and codes
2. Understanding error propagation in the retrieval models
3. Ingesting SMOS data as simulated SMAP data
4. Prototype SMAP Science Data Systems (SDS)
5. Support applications demonstration (future)

National Aeronautics and Space Administration

Potential Applications Identified at the SMAP Applications Workshop, Sept 2009

SMAP OBJECTIVES	POTENTIAL SMAP APPLICATIONS							
	Weather	Natural Disasters	Climate Variability & Change	Agriculture & Forestry	Human Health	Ecology	Water Resources	Ocean Resources
Soil moisture and freeze-thaw information for water, energy, and carbon cycle processes	More accurate weather forecasts; prediction of severe rainfall; operational severe weather forecasts; mobility and visibility	Drought early warning decision support; key variable in floods and landslides; operational flood forecast; lake and river ice breakup; desertification	Extend climate prediction capability; Linkages between terrestrial water, energy, and carbon cycles; land / atmos. fluxes	Predictions of agricultural productivity; famine early warning; Monitoring agricultural drought	Landscape epidemiology; heat stress and drought monitoring; insect infestation; emergency response plans	Carbon source/sink monitoring; Ecosystems forecasts; monitoring vegetation and water relationships over land	Global water balance; estimates of streamflow & river discharge; more effective management	Sea-ice mapping for navigation, especially in coastal zones; temporal changes in ocean salinity
		Fire susceptibility; global flood mapping; heat-wave forecasting		Crop management at the farm scale; Input to fuel loading models		Monitoring wetlands resources and bird migration	Monitoring variability of water stored in lakes, reservoirs, wetlands and river channels	Ocean wind speed and direction, related to hurricane monitoring

= likely mission application

= potential mission application

Mission Status

- **Schedule**

  -- next big milestone is project Preliminary Design Review in March 2011

  -- KDP-C at NASA HQ in June 2011 moves us into Phase C/D to build flight hardware

- **Possible Descopes**

  -- radar changes for FAA compliance (frequency hopping, H & V sequential transmit) may slightly increase radar SNR with minimal impact on science

  -- project is looking at cost of L4 products in budget exercise

  - might ask NASA HQ to fund L4 production outside the project

- **Launch Services**

  -- shared launch with DoD still a possibility on a Minotaur IV

Next Steps for Collaboration

Environment Canada Environnement Canada

Canada

Canadian Plan for SMAP

SMAP Canadian Workshop, Montreal Biosphere, October 2009

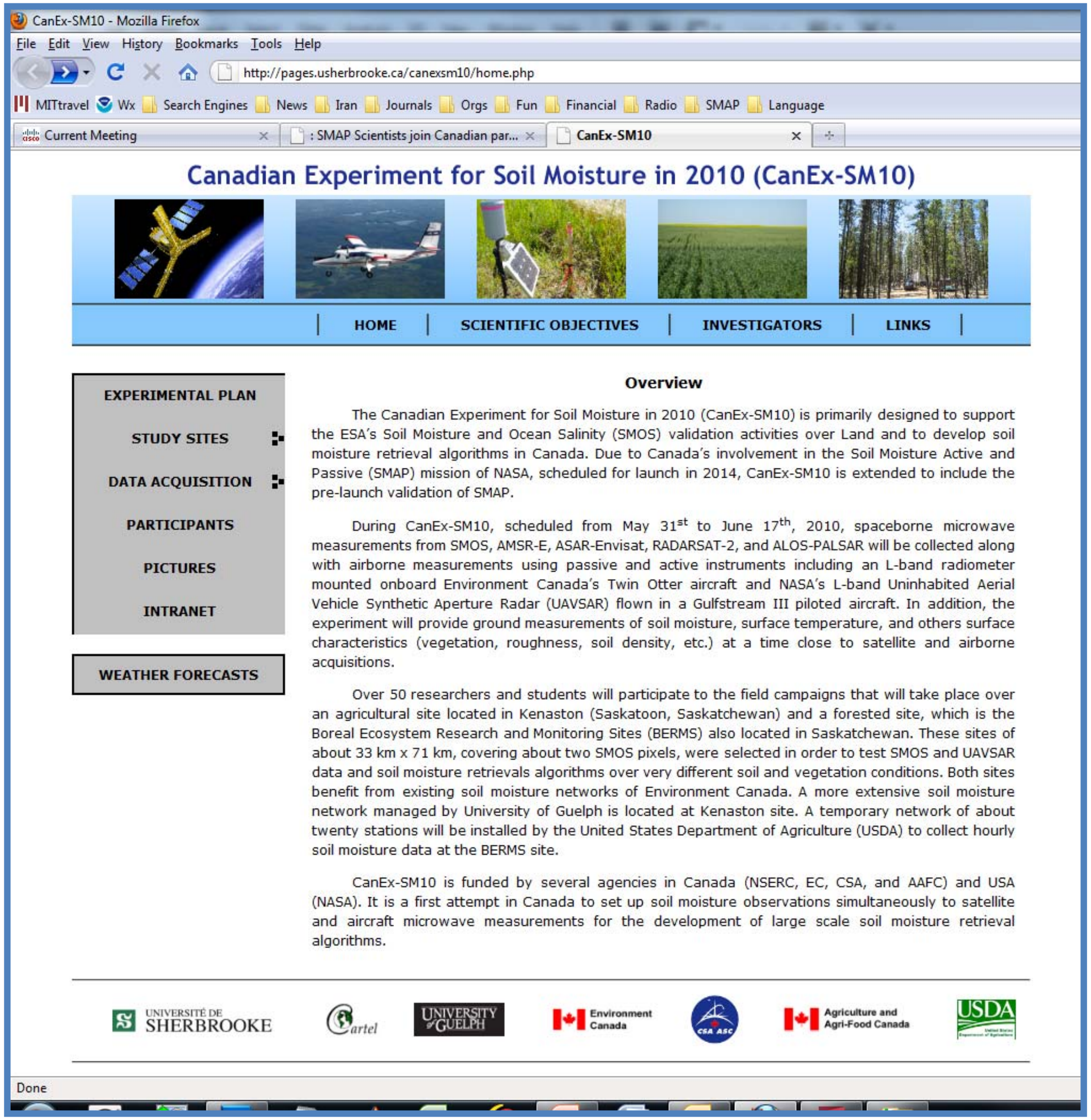
Stephane Belair

Science and Technology Branch,

Environment Canada

National Aeronautics and Space Administration

CanEx-SM10


CanEx-SM10 - Mozilla Firefox

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http://pages.usherbrooke.ca/canexsm10/home.php

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Current Meeting | : SMAP Scientists join Canadian par... | CanEx-SM10

Canadian Experiment for Soil Moisture in 2010 (CanEx-SM10)

HOME | SCIENTIFIC OBJECTIVES | INVESTIGATORS | LINKS

EXPERIMENTAL PLAN

STUDY SITES

DATA ACQUISITION

PARTICIPANTS

PICTURES

INTRANET

WEATHER FORECASTS

Overview

The Canadian Experiment for Soil Moisture in 2010 (CanEx-SM10) is primarily designed to support the ESA's Soil Moisture and Ocean Salinity (SMOS) validation activities over Land and to develop soil moisture retrieval algorithms in Canada. Due to Canada's involvement in the Soil Moisture Active and Passive (SMAP) mission of NASA, scheduled for launch in 2014, CanEx-SM10 is extended to include the pre-launch validation of SMAP.

During CanEx-SM10, scheduled from May 31st to June 17th, 2010, spaceborne microwave measurements from SMOS, AMSR-E, ASAR-Envisat, RADARSAT-2, and ALOS-PALSAR will be collected along with airborne measurements using passive and active instruments including an L-band radiometer mounted onboard Environment Canada's Twin Otter aircraft and NASA's L-band Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) flown in a Gulfstream III piloted aircraft. In addition, the experiment will provide ground measurements of soil moisture, surface temperature, and others surface characteristics (vegetation, roughness, soil density, etc.) at a time close to satellite and airborne acquisitions.

Over 50 researchers and students will participate to the field campaigns that will take place over an agricultural site located in Kenaston (Saskatoon, Saskatchewan) and a forested site, which is the Boreal Ecosystem Research and Monitoring Sites (BERMS) also located in Saskatchewan. These sites of about 33 km x 71 km, covering about two SMOS pixels, were selected in order to test SMOS and UAVSAR data and soil moisture retrievals algorithms over very different soil and vegetation conditions. Both sites benefit from existing soil moisture networks of Environment Canada. A more extensive soil moisture network managed by University of Guelph is located at Kenaston site. A temporary network of about twenty stations will be installed by the United States Department of Agriculture (USDA) to collect hourly soil moisture data at the BERMS site.

CanEx-SM10 is funded by several agencies in Canada (NSERC, EC, CSA, and AAFC) and USA (NASA). It is a first attempt in Canada to set up soil moisture observations simultaneously to satellite and aircraft microwave measurements for the development of large scale soil moisture retrieval algorithms.

UNIVERSITÉ DE SHERBROOKE | Cartel | UNIVERSITY of GUELPH | Environment Canada | CSA ASC | Agriculture and Agri-Food Canada | USDA

Done

Collaborative Airborne Experiment For Testing and Evaluation of Active and Passive Soil Moisture Data Products

Next Steps

- **Develop Collaborations on Science, Applications, Algorithms, and Cal/Val**
- **Promote Bilateral Programmatics and Agency Agreements**
- **Areas of Collaboration:**

1. Cal/Val

- **Airborne instruments co-flights**
- **Ground networks and sampling protocols – SMAP Request for Information for Core Validation Sites**
- **Understanding the scaling of in situ network measurements to pixel area**
- **Freeze/thaw cal/val and science**
- **Level 4 Root-Zone Soil Moisture (RZSM) and Net Ecosystem Exchange (NEE)**

2. Algorithms

- **Active/Passive**
- **Freeze/Thaw**
- **Integrated RZSM and NEE**

3. Applications

- **NWP and Seasonal Climate**
- **Sea-Ice Monitoring**
- **Agricultural Productivity**

Summary

- **SMAP provides high-resolution and frequent-revisit global mapping of soil moisture and freeze/thaw state that has:**
  - **Science value for Water, Carbon and Energy Cycles**
  - **Applications in Operational Weather Forecasting, Flood & Drought Monitoring, Agriculture, & other areas benefit society**
  - **Addresses priority questions on Climate and Climate Change**
  - **Leverages Hydros, Aquarius, and SMOS risk reduction, expertise, and lessons learned**
- **Project is getting ready for PDR and moving into Phase C/D**
- **Will leverage SMOS data and experience**
- **Project has and will continue to reach out to the broad science and applications communities**

  -- SMAP working groups and workshops

  -- Applications Plan and workshops

  -- EPO activities

BACKUP

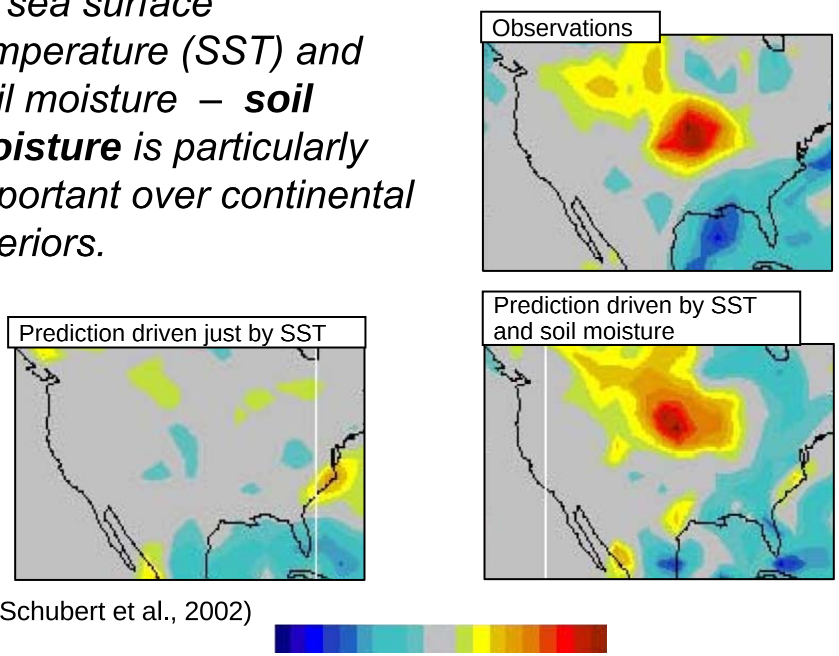
Value of Soil Moisture Data to Weather & Climate

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

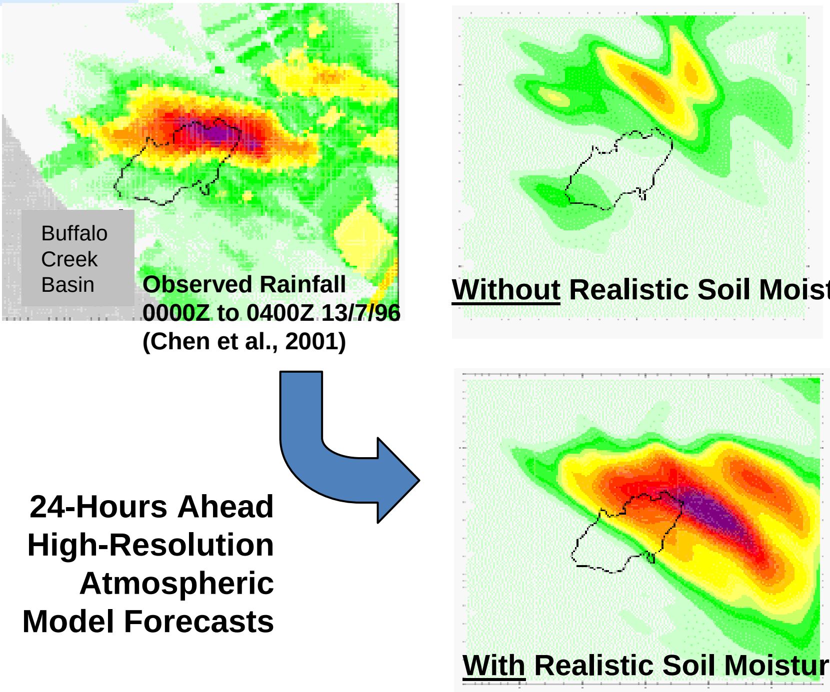
Seasonal Climate Predictability

*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

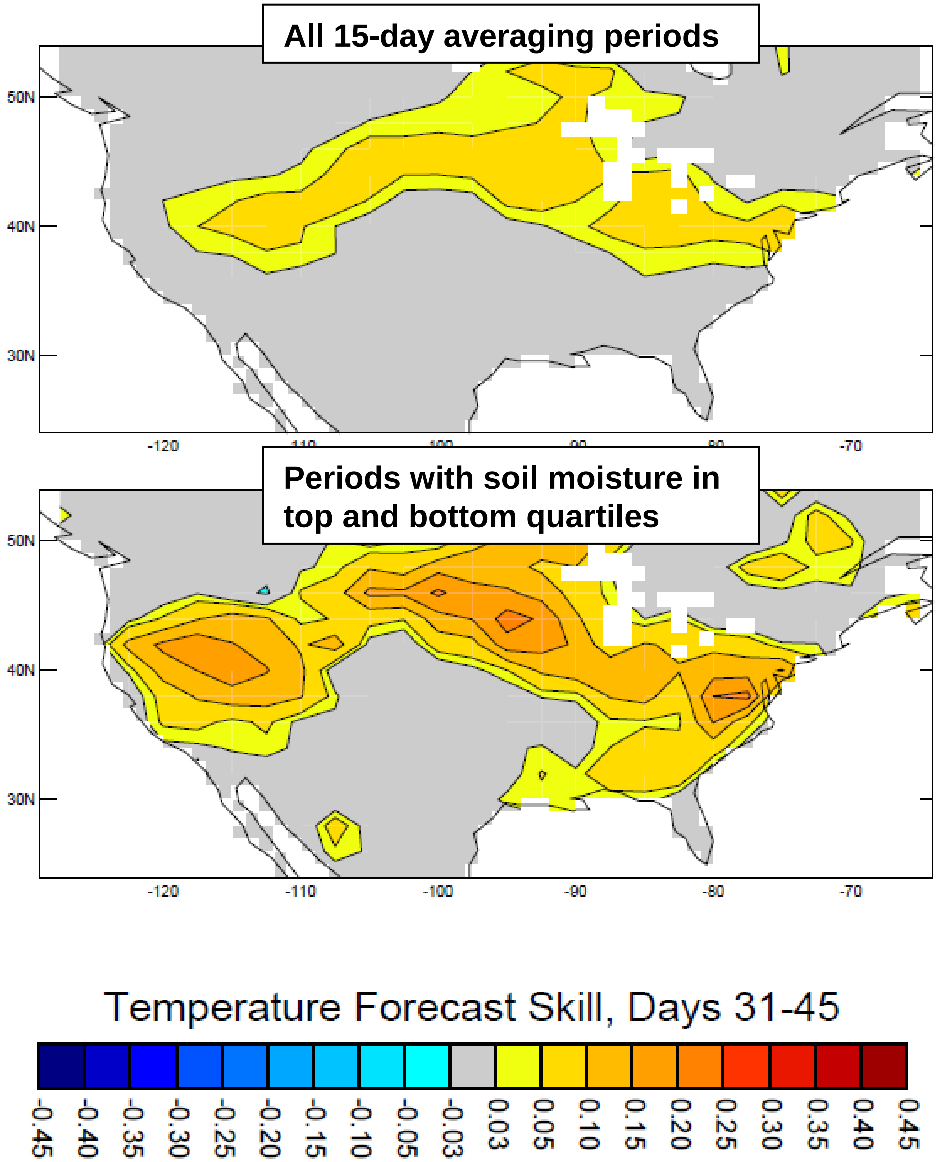


NWP Rainfall Prediction



High resolution soil moisture data will improve numerical weather prediction (NWP) over continents by accurately initializing land surface states

Seasonal Climate Prediction



Multi-model consensus view of land contribution to air temperature forecasts.

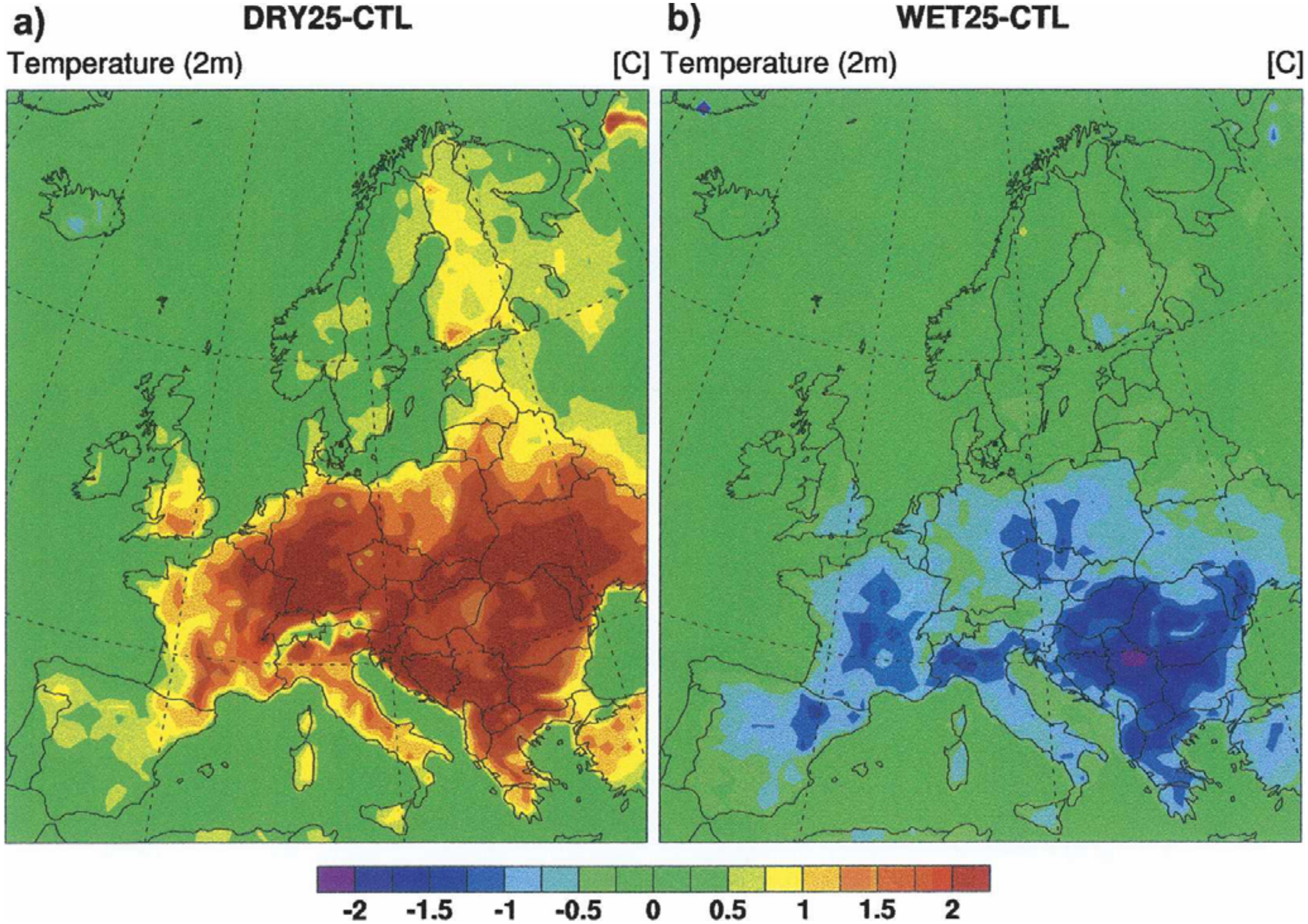
JJA Skill contribution at the 30-day lead (days 31-45).

From: Final Report of GLACE-2: Quantifying the Effects of Land Moisture Initialization on Precipitation Forecasts (PI: Randal Koster, 2010)

Human Health Application

National Aeronautics and Space Administration

European heatwave cause
35,000 deaths,
New Scientist, Oct. 2003.



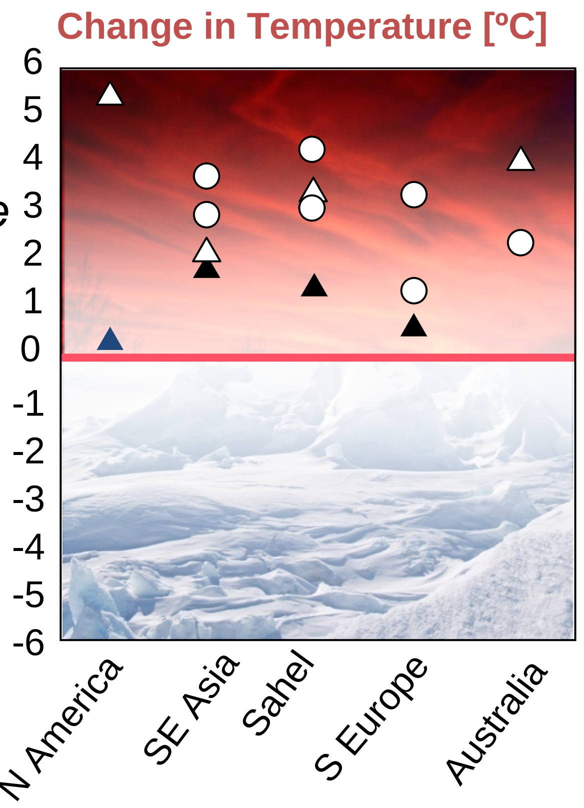
<u>Seasonal Climate Prediction</u>:
50 km Resolution
Initialize rootzone moisture

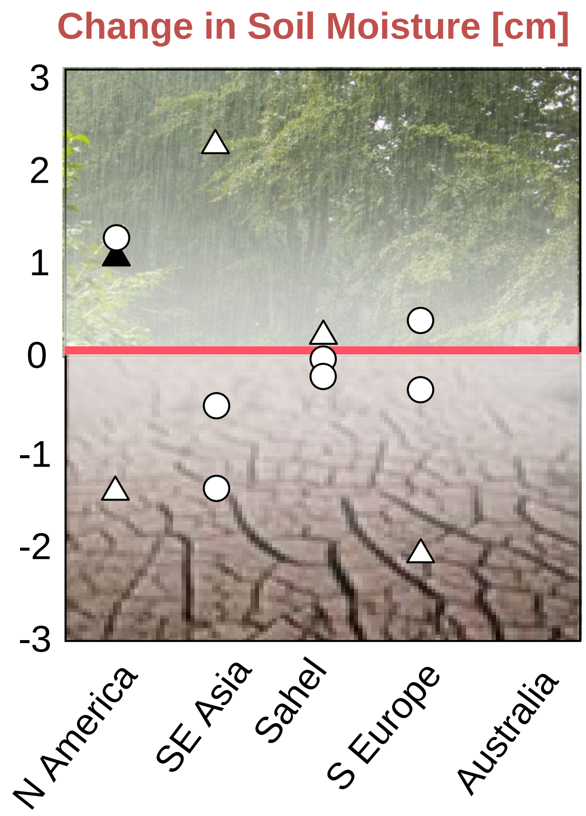
Fischer et al. (2007), *J. of Climate*, 20.

Climate Change and Water Cycle

Intergovernmental Panel on Climate Change (IPCC) AR4 climate model projections by region:

Models *agree* on basic temperature response



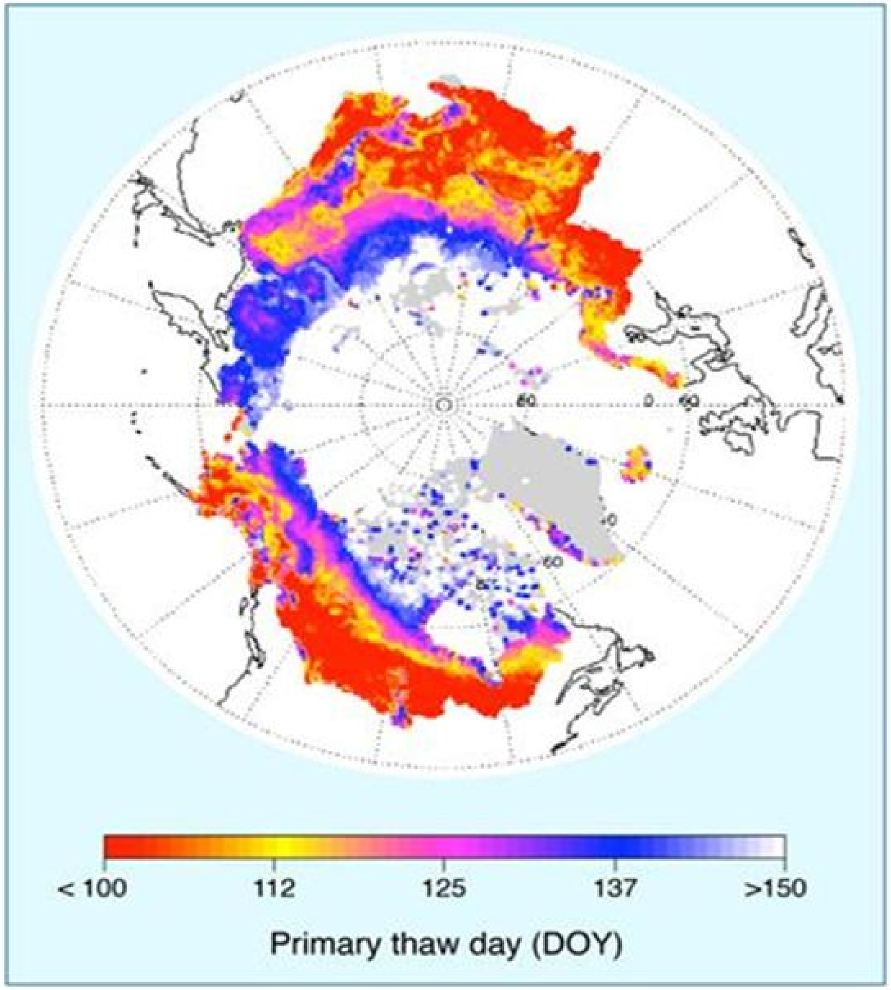


Models *disagree* on the *sign* of moisture change

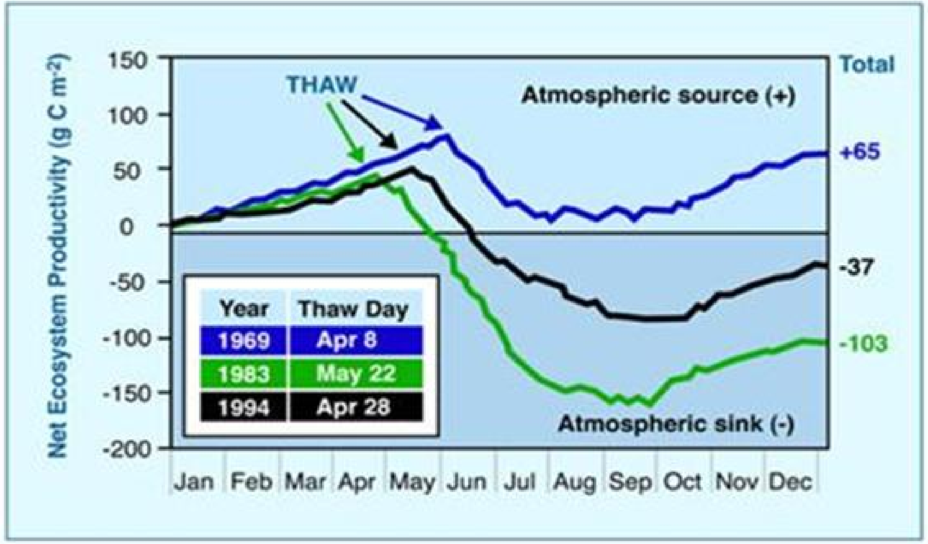
Li et al., (2007), *J. of Geophys. Res.*, 112.

Quantify Net Carbon Flux in Boreal Landscapes

Mean growing season onset for 1988 – 2002 derived from coarse resolution SSM/I data

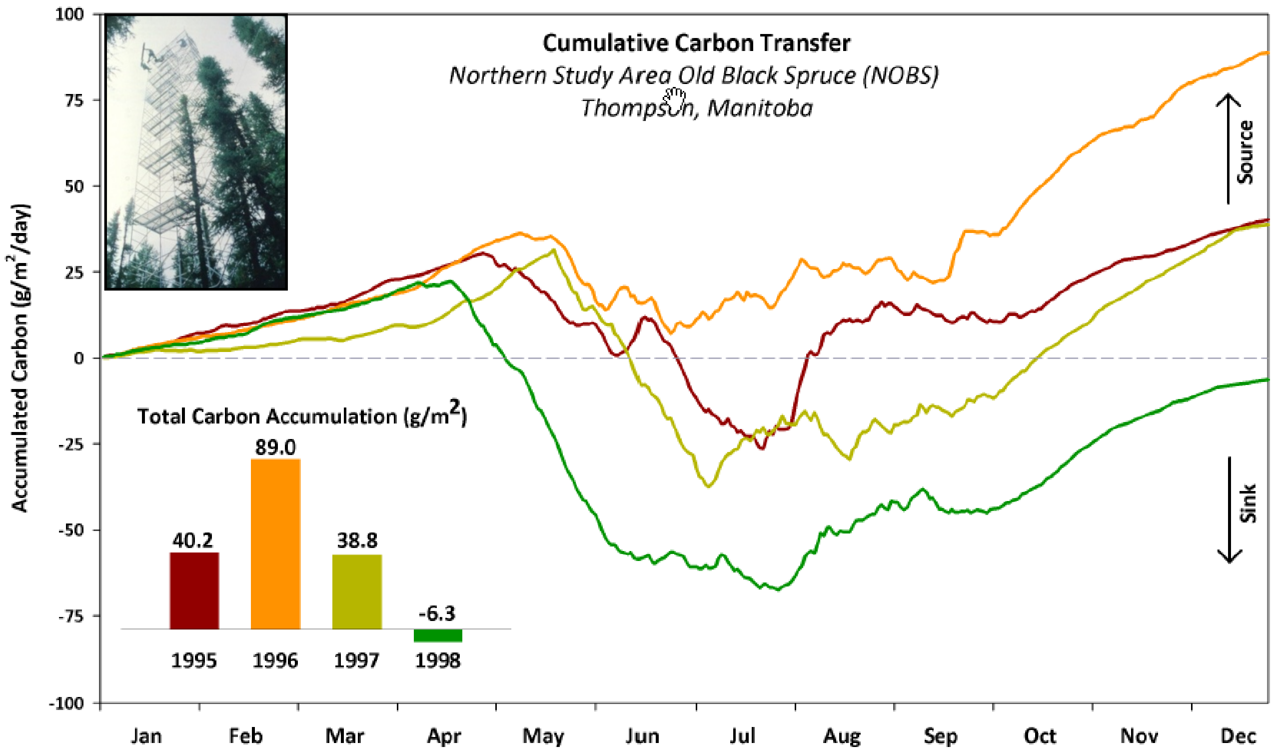


SMAP provides important information on the land surface processes that control land-atmosphere carbon source/sink dynamics. It will provide more than 8-fold increase in spatial resolution over existing spaceborne sensors.



McDonald et al. (2004): Variability in springtime thaw in the terrestrial high latitudes: Monitoring a major control on the biospheric assimilation of atmospheric CO2 with spaceborne microwave remote sensing. Earth Interactions 8(20), 1-23.

Carbon Budget in Boreal Landscapes



Normal to late thaw (May): Carbon Source [1995, 1996, 1997]

Early thaw (April 22): Carbon Sink [1998]

5/7 5/27 5/26 4/22 Spring thaw dates

A given location can be a net source or net sink of carbon, depending on freeze/thaw date. SMAP freeze/thaw measurements can help reduce errors in the closing of the carbon budget.

Goulden et al., 1998: Sensitivity of Boreal Forest Carbon Balance to Soil Thaw, *Science*, 279.

Herring, D. and R. Kannenberg: The mystery of the missing carbon, *NASA Earth Observatory*.

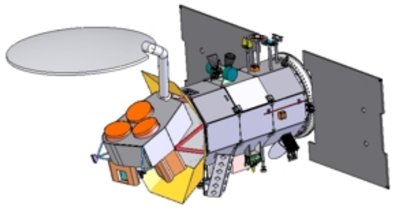
National Aeronautics and Space Administration

Synergistic Data and Experience from SMOS and Aquarius

- **SMAP complements SMOS and Aquarius:**
  - **Extends global L-band radiometry beyond these missions (yields long-duration land hydroclimate soil moisture datasets)**
  - **Significantly increases the spatial resolution of soil moisture data**
  - **Adds characterization of freeze thaw state for carbon cycle science**
  - **Adds substantial instrument and processing mitigations to reduce science degradation and loss from terrestrial RFI**
- **SMAP benefits from strong mutual science team members' engagements in missions**
  - **SMOS & Aquarius data are important for SMAP's algorithm development**
  - **SMAP will collaborate in and extend SMOS & Aquarius Cal-Val campaigns**
  - **SMOS and Aquarius will provide valuable data on the global terrestrial RFI environment which is useful to SMAP**

SMOS (ESA)
2009 Launch

Aquarius
2011 LRD

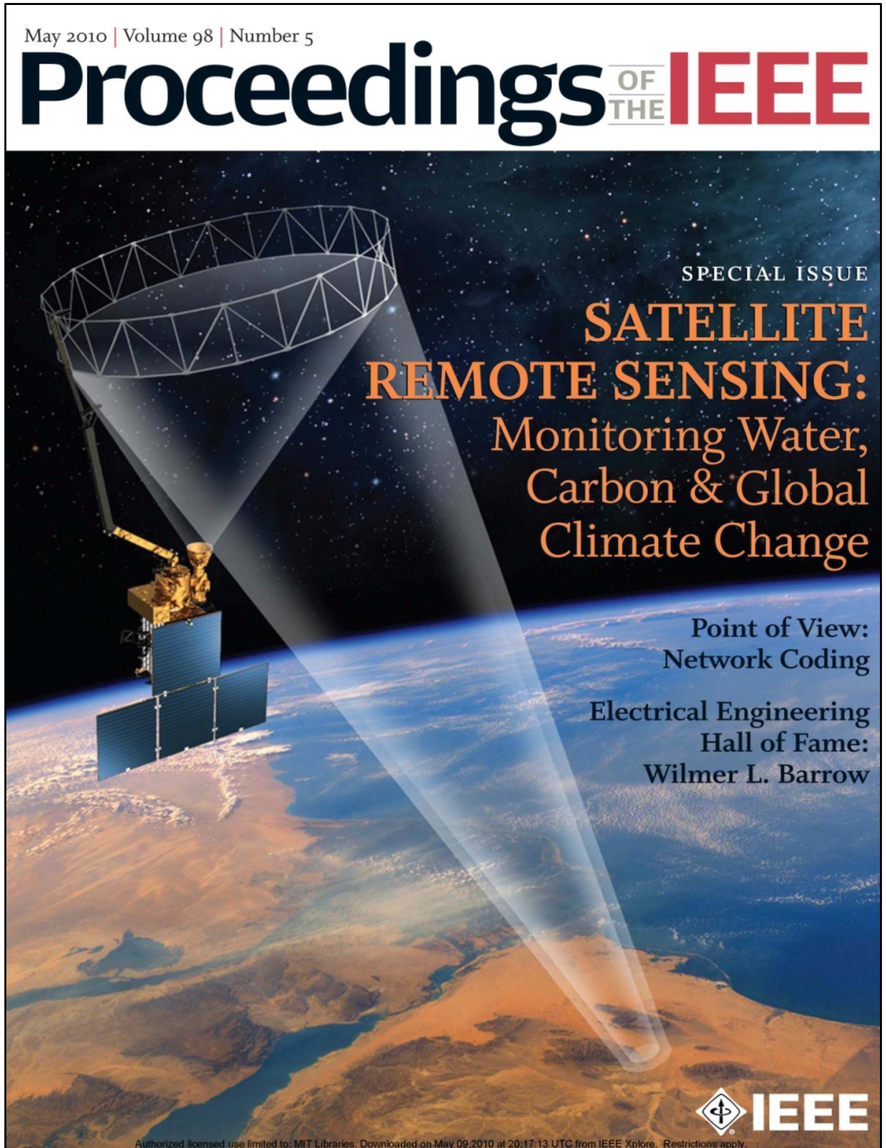


SMAP
2014 LRD

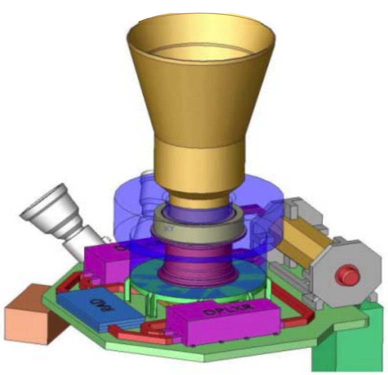
Mission	LRD	Measurement	Instrument Complement	Resolution/Revisit
SMOS	Nov '09	Soil Moisture Ocean Salinity	L-band Radiometer	50 km / 3 days
Aquarius	Apr '11	Ocean Salinity Soil Moisture (experimental)	L-band Radiometer, Scatterometer	100 km / 7 days
SMAP	Nov'14 *	Soil Moisture Freeze/Thaw State	L-band Radiometer, SAR (unfocused)	10 km / 2-3 days

National Aeronautics and
Space Administration

SMAP Mission Concept



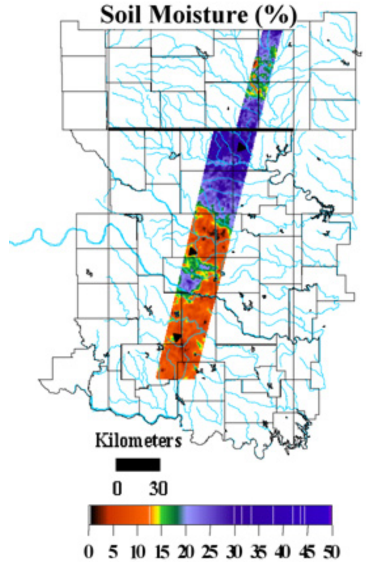
- L-band unfocused SAR and radiometer system, offset-fed 6 m light-weight deployable mesh reflector. Shared feed for
  - 1.26 GHz dual-pol <u>Radar</u> at 1-3 km (30% nadir gap)
  - 1.4 GHz polarimetric <u>Radiometer</u> at 40 km
- Conical scan, fixed incidence angle across swath
- Contiguous 1000 km swath with 2-3 days revisit
- Sun-synchronous 6am/6pm orbit (680 km)
- Launch November 2014
- Mission duration 3 years

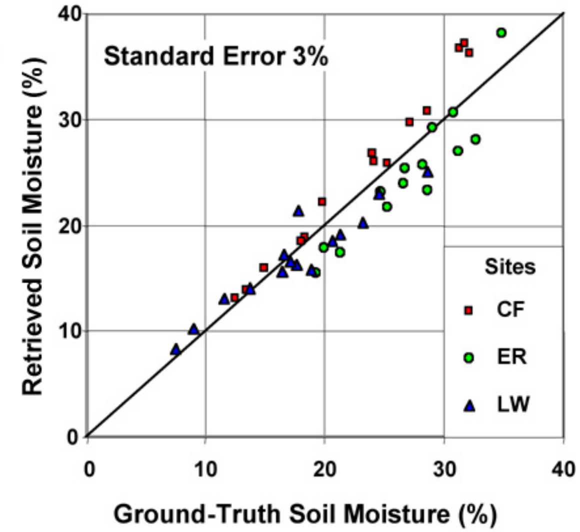


L-band Active/Passive Assessment

National Aeronautics and Space Administration

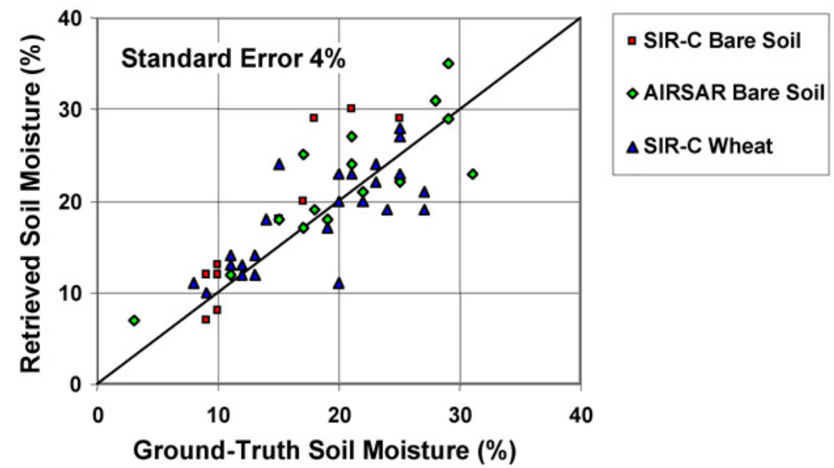
- Soil moisture retrieval algorithms are derived from a long heritage of microwave modeling and field experiments
  -- MacHydro'90, Monsoon'91, Washita92, Washita94, SGP97, SGP99, SMEX02, SMEX03, SMEX04, SMEX05, CLASIC, SMAPVEX08, CanEx10





- **Radiometer** - High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)

- **Radar** - High spatial resolution (1-3 km) but more sensitive to surface roughness and vegetation



- **Combined Radar-Radiometer** product provides optimal blend of resolution and accuracy to meet science objectives

Interested in joining the SMAP Working Group?

- Sign up at *http://smap.jpl.nasa.gov/science/wgroups*

1. Algorithms Working Group (AWG)
2. Calibration & Validation Working Group (CVWG)
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4. Applications Working Group (AppWG)