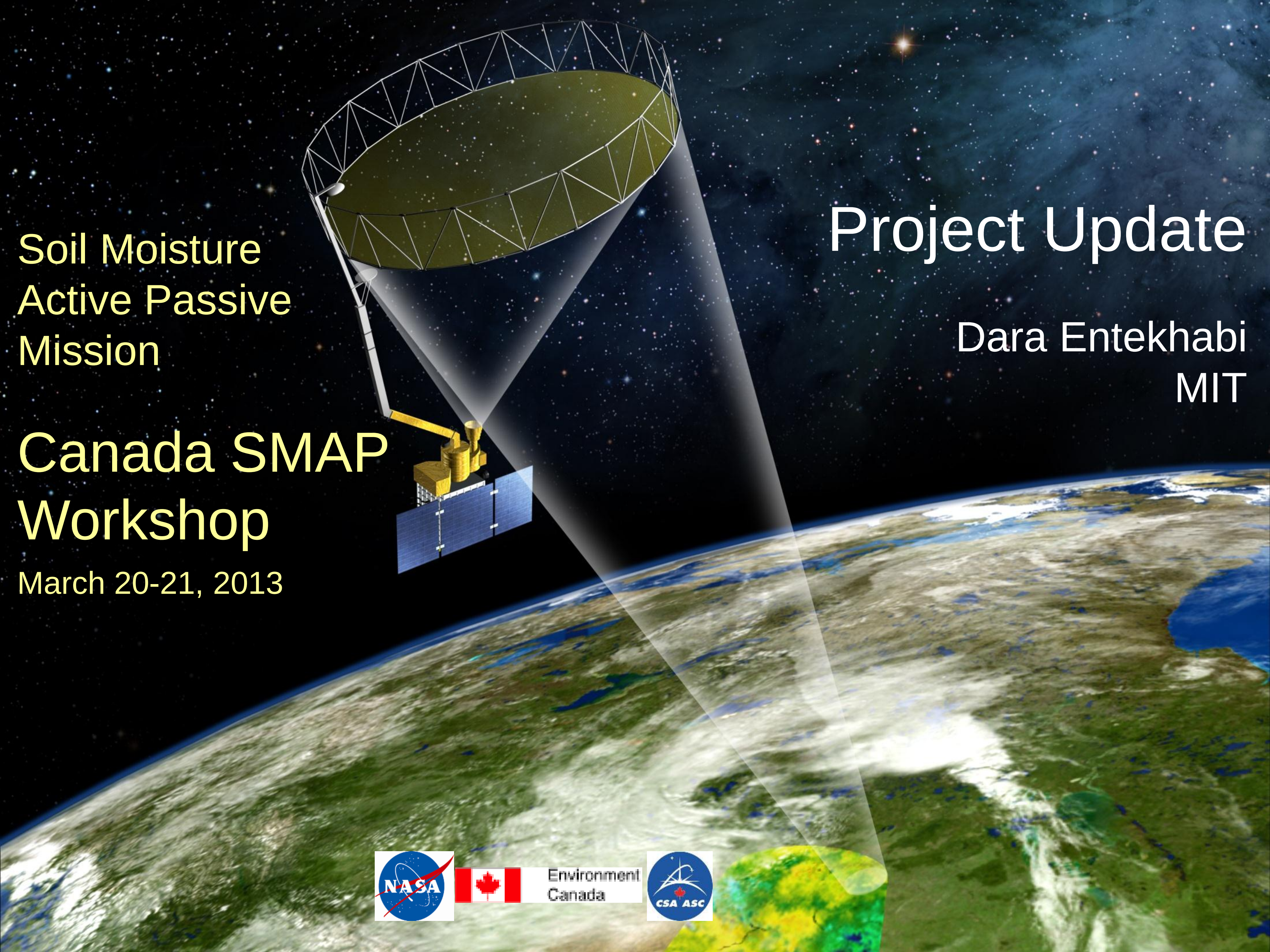


Soil Moisture
Active Passive
Mission

Canada SMAP Workshop

March 20-21, 2013

Project Update

Dara Entekhabi
MIT

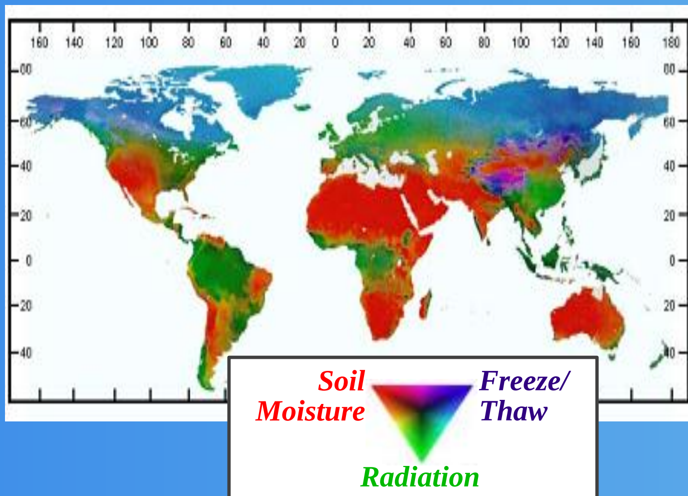
NASA Environment Canada CSA ASC

The Sequester

SMAP Science and Application Returns

Science Returns

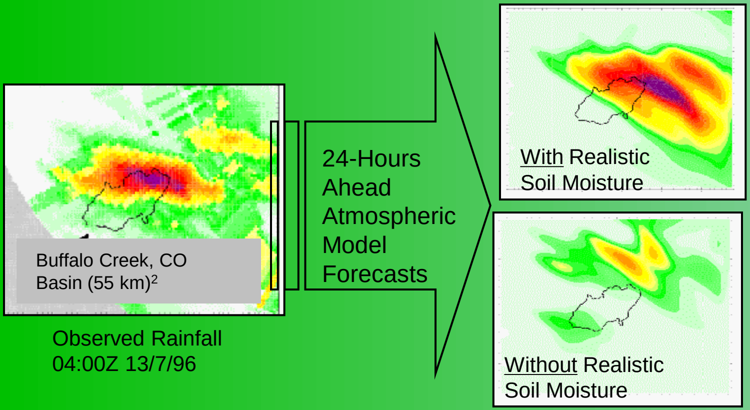
Soil Moisture ***Links*** the Global Land Water, Energy, and Carbon Cycles



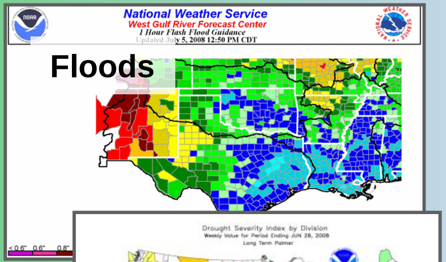
- **Estimating global surface water and energy fluxes**
- **Quantifying net carbon flux in boreal landscapes**
- **Improving climate models**

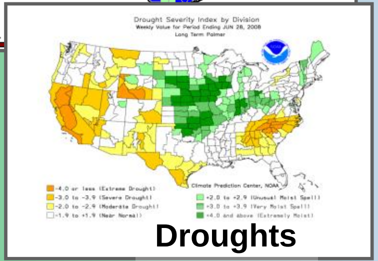
L-band radiometer and non-imaging synthetic aperture radar

Applications Returns



(Chen et al., *J. Atm. Sci.*, 2001)





- **Enhancing weather forecasts**
- **Improving flood prediction and drought monitoring**

Surface soil moisture 0.04 [cm^3 cm^{-3}] accuracy

3 km freeze/thaw 80% classification accuracy

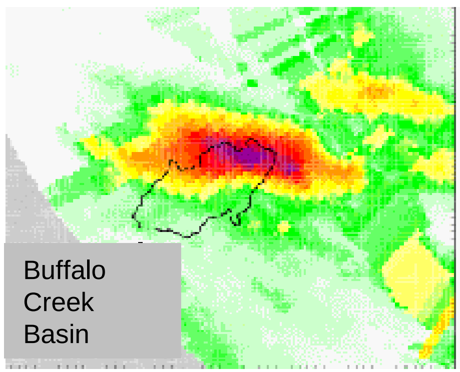
6m conically scanning (14 rpm) antenna for 1000 km swath

Global coverage every 2-3 days

Prediction of Extreme Rainfall

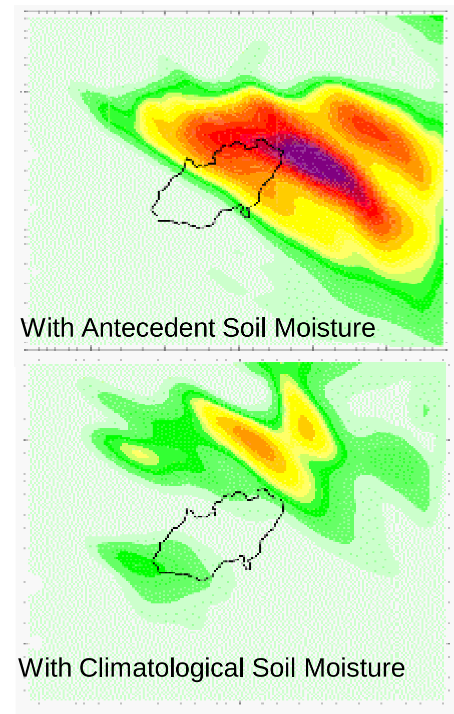
Flash flood event near Fort Collins
July 13, 1996

Chen et al. (2001), *JAS*, 58, 3204-3223.

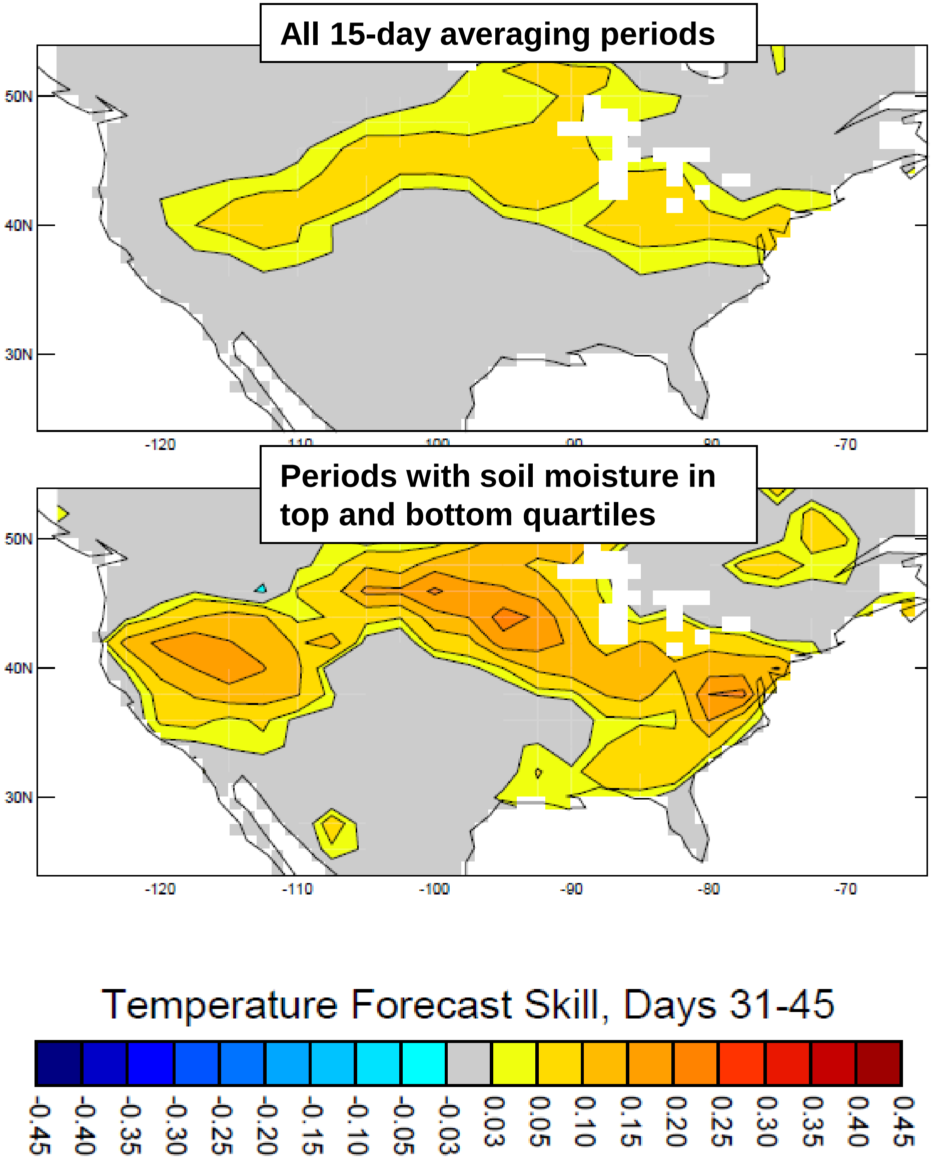


NEXRAD Observed Rainfall
0000Z to 0400Z 13/7/96

24-Hours ahead atmospheric model forecasts



Seasonal Climate Prediction



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

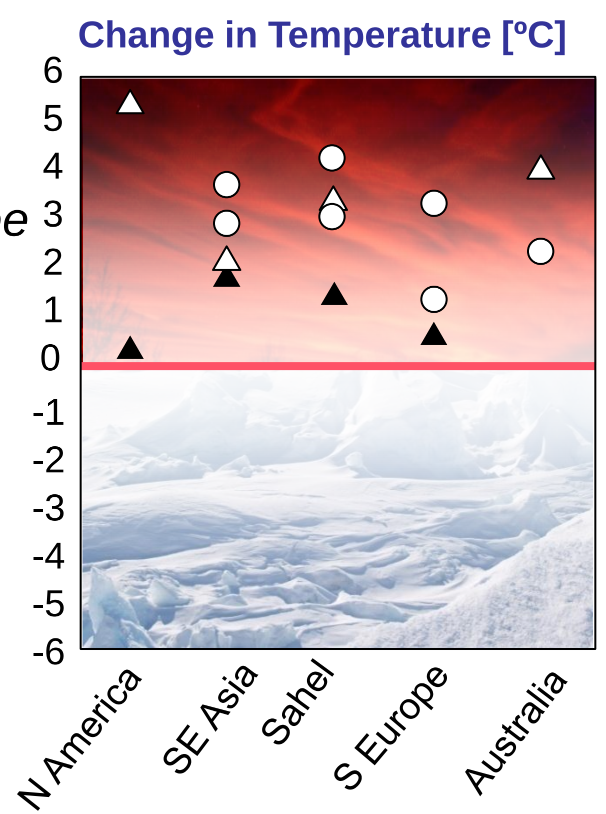
JJA Skill contribution at the 30-day lead (days 31-45).

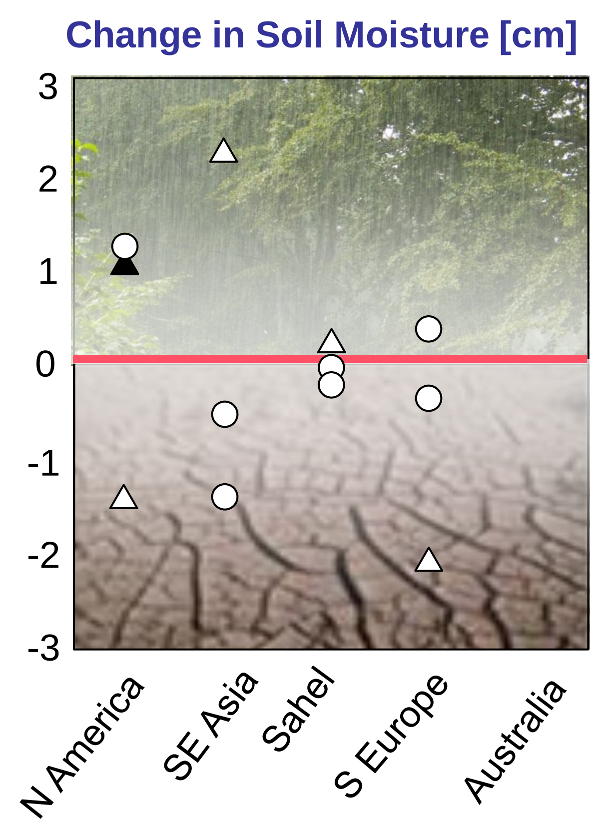
From: Final Report of GLACE-2: Quantifying the Effects of Land Moisture Initialization on Precipitation Forecasts (PI: Randal Koster, 2010)

Climate Change and Water Cycle

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

Models *agree* on basic temperature response

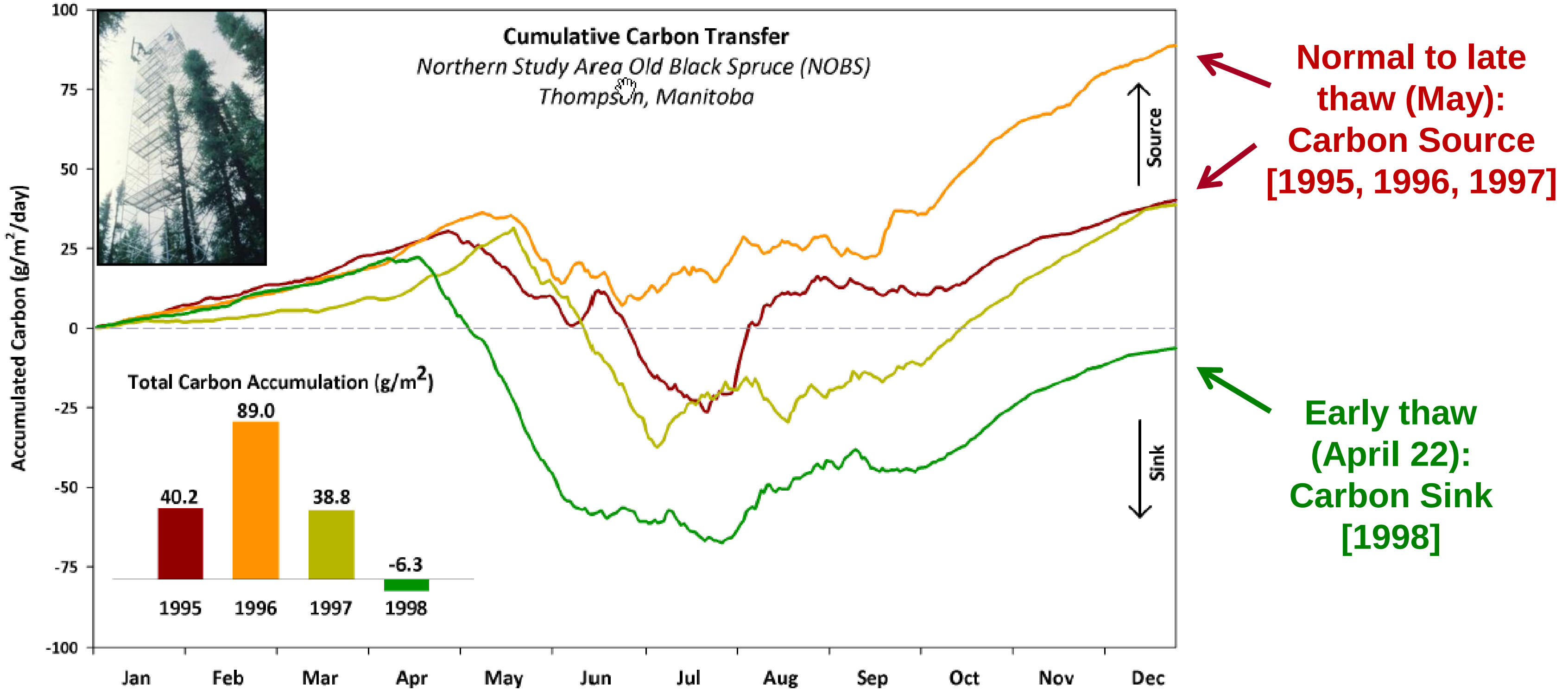




Models ***disagree*** on the ***sign*** of moisture change

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

Carbon Budget in Boreal Landscapes



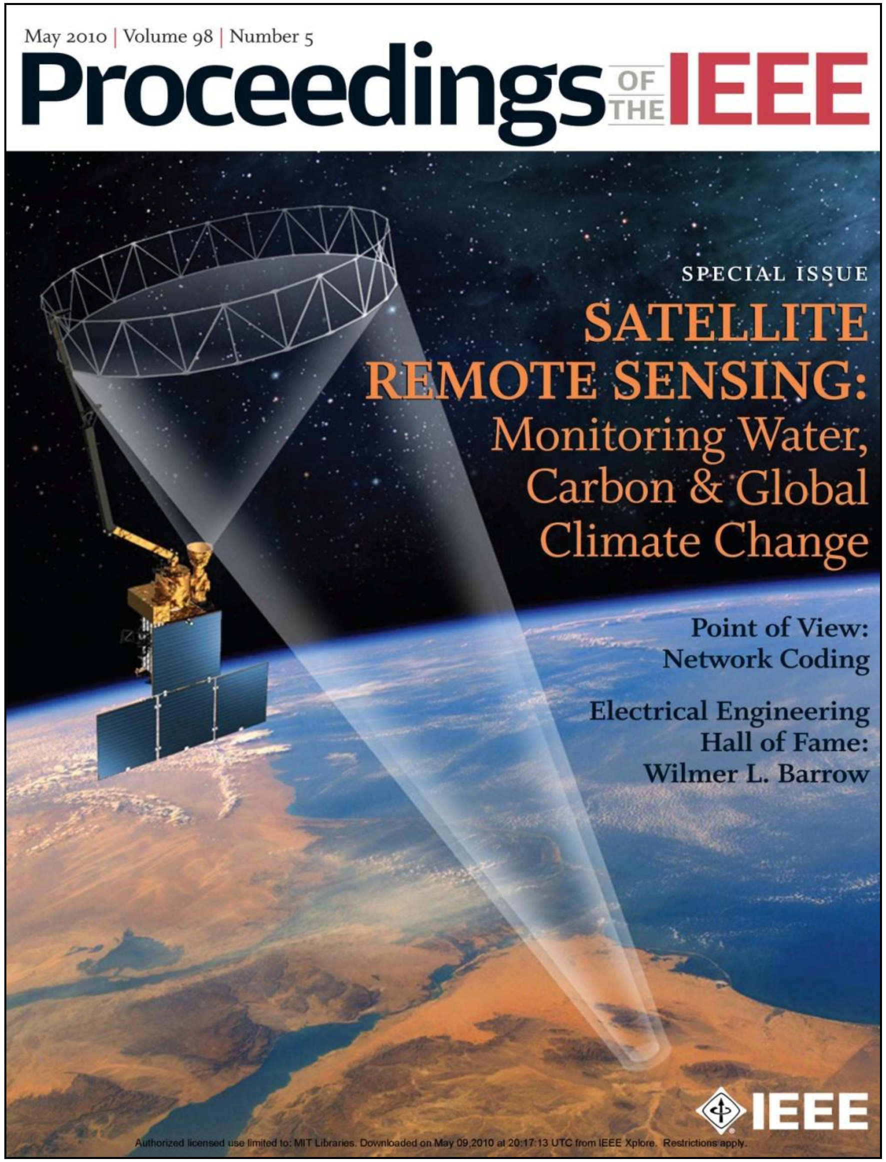
5/7 5/27 5/26 4/22 Spring thaw dates

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.

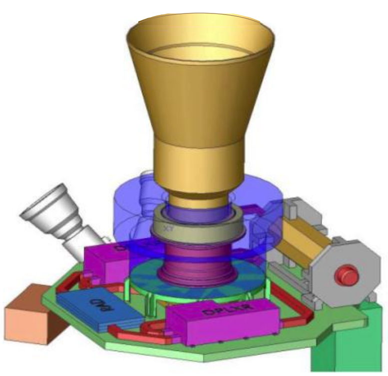
Goulden et al., 1998: Sensitivity of Boreal Forest Carbon Balance to Soil Thaw, *Science*, 279.

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

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 October 31, 2014

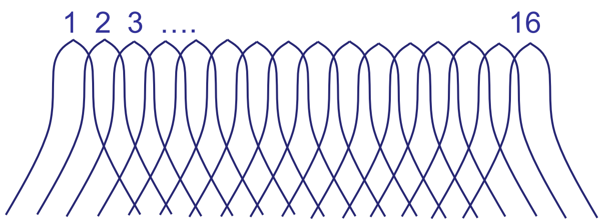


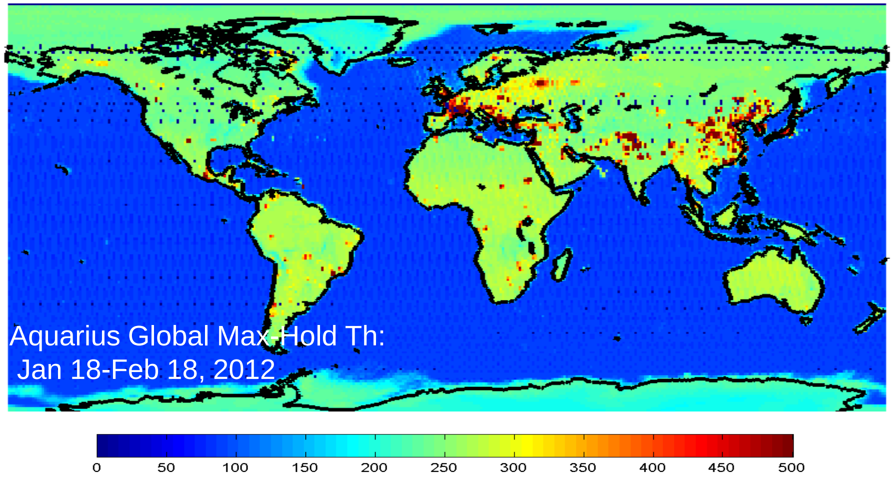
SMAP's RFI Detection-Mitigation

Aggressive approach to Radio-Frequency Interference (RFI) detection and mitigation

SMAP radiometer's Multi-layer defense:

1. Time-domain kurtosis
2. Acquire 3rd and 4th Stokes parameters
3. Spectral and temporal resolution (16x10 Spectograph)

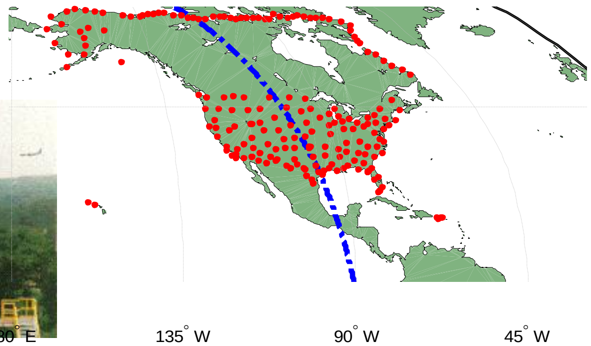




SMAP radar RFI:

- Land emitters
- Radio navigation signals (GPS, GLONASS, COMPASS, GALILEO)

Approach with tunable radar instrument



L-band Active/Passive Approach

- 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, <u>CanEx10</u>, <u>SMAPVEX12</u>

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

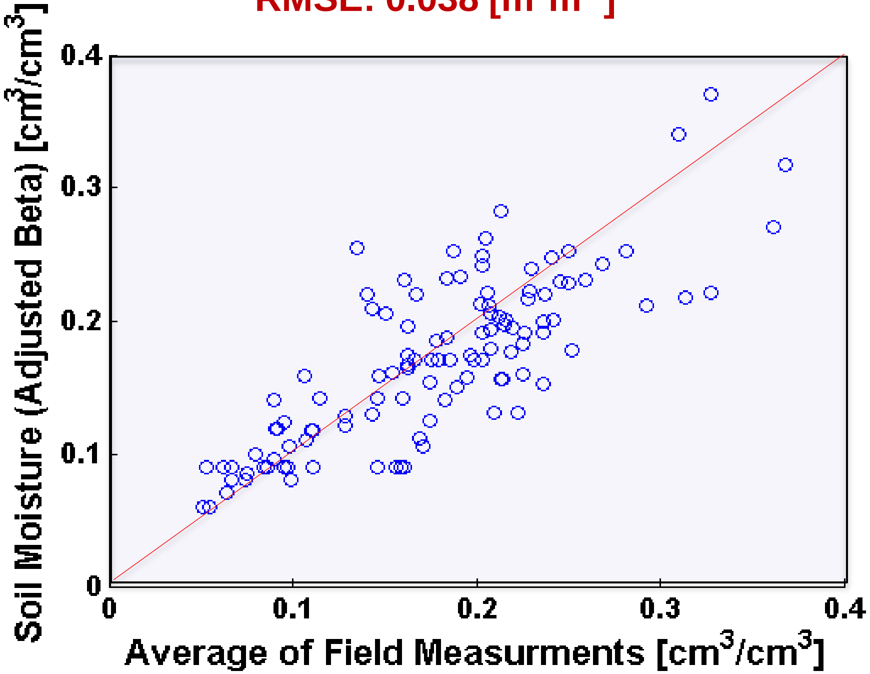
- **Radar** - High spatial resolution (1-3 km) but more sensitive to surface roughness and vegetation

  - **Combined Radar-Radiometer** product provides intermediate 9km resolution with 0.04 [cm^3 cm^{-3}] 1-σ accuracy to meet science objectives

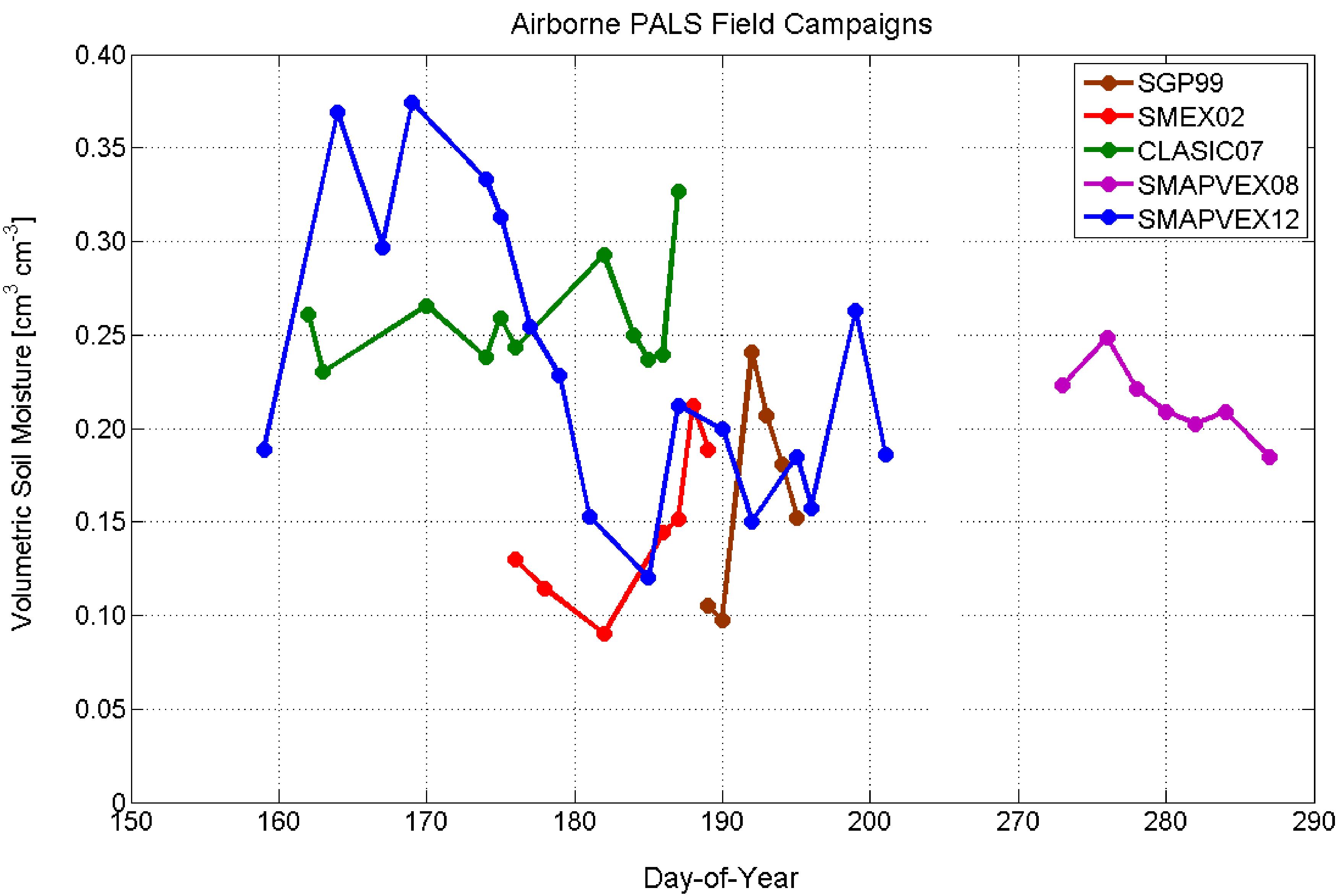
SMEX02 Study Region With PALS Airborne and *in situ* Ground-Truth

SMAP Baseline Active-Passive Algorithm

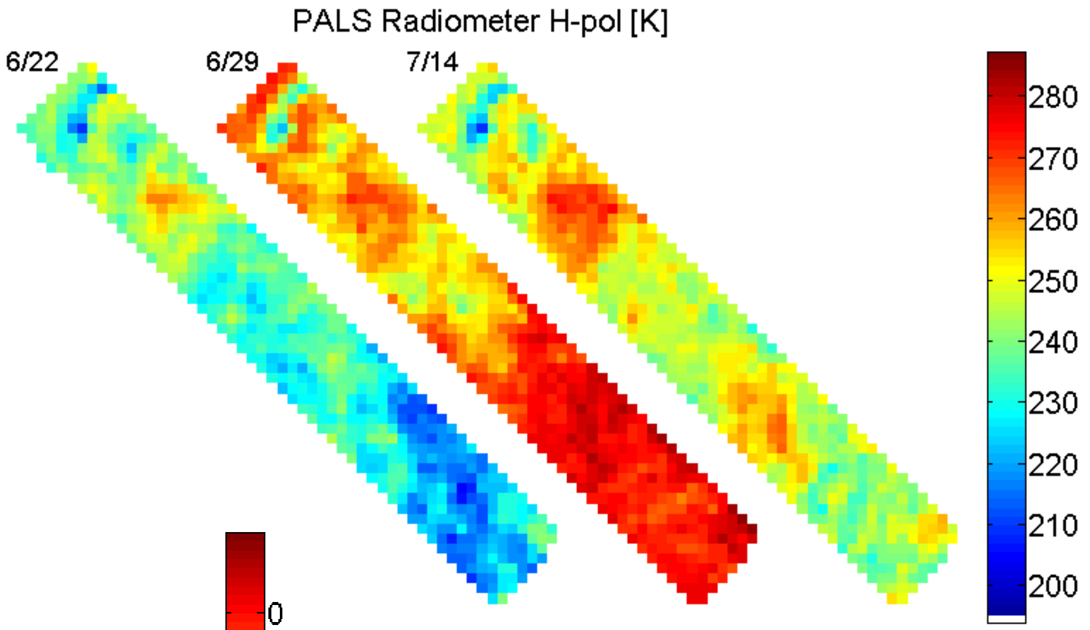
RMSE: 0.038 [m^3m^{-3}]

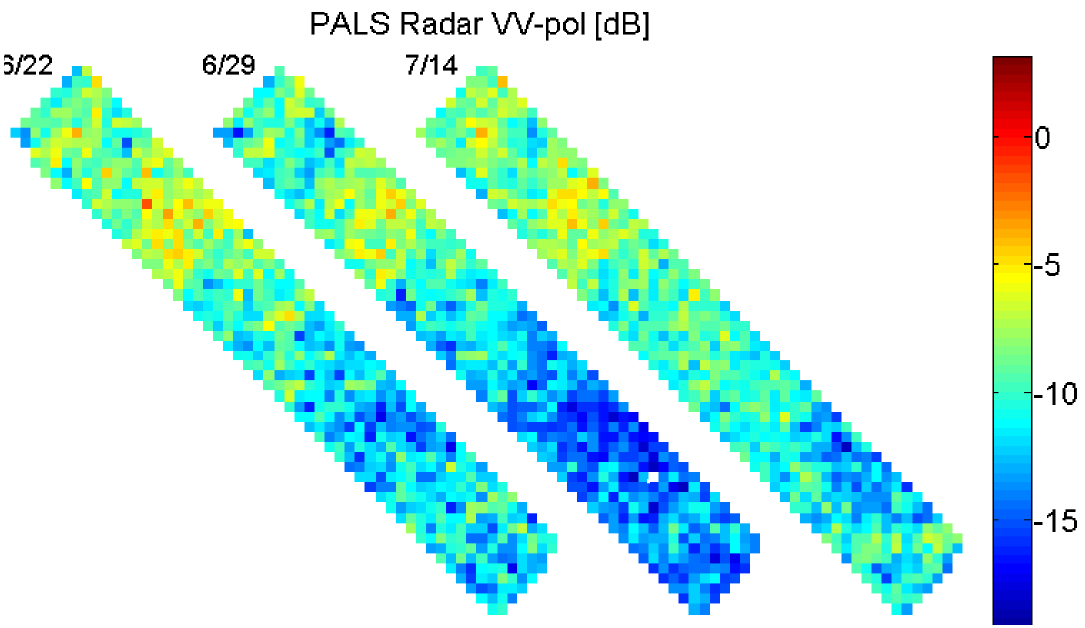


PALS Land Field Campaigns

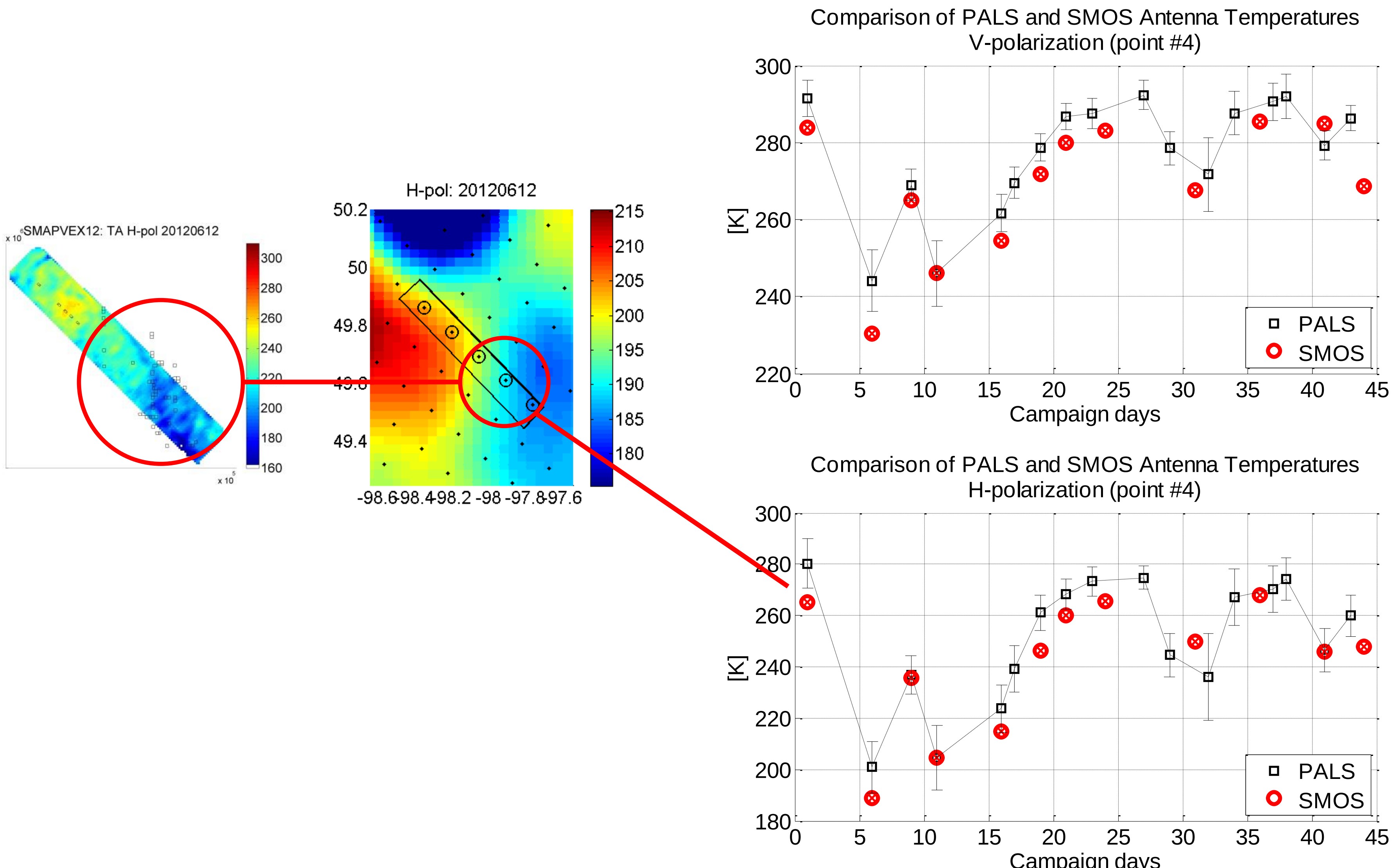


SMAPVEX12: PALS Radar and Radiometer





PALS Radiometer Comparison to SMOS



Source: A. Colliander

SMAP Science 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	

Science Organization

Science Definition Team Leader
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Project Scientist
E. Njoku (JPL)

Deputy Project Scientist
P. O'Neill (GSFC)

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S. Paloscia (Italy)
J. Walker (Australia)

Working Groups:

1. RFI
2. Algorithms
3. Cal/Val
4. Applications

Major Highlights

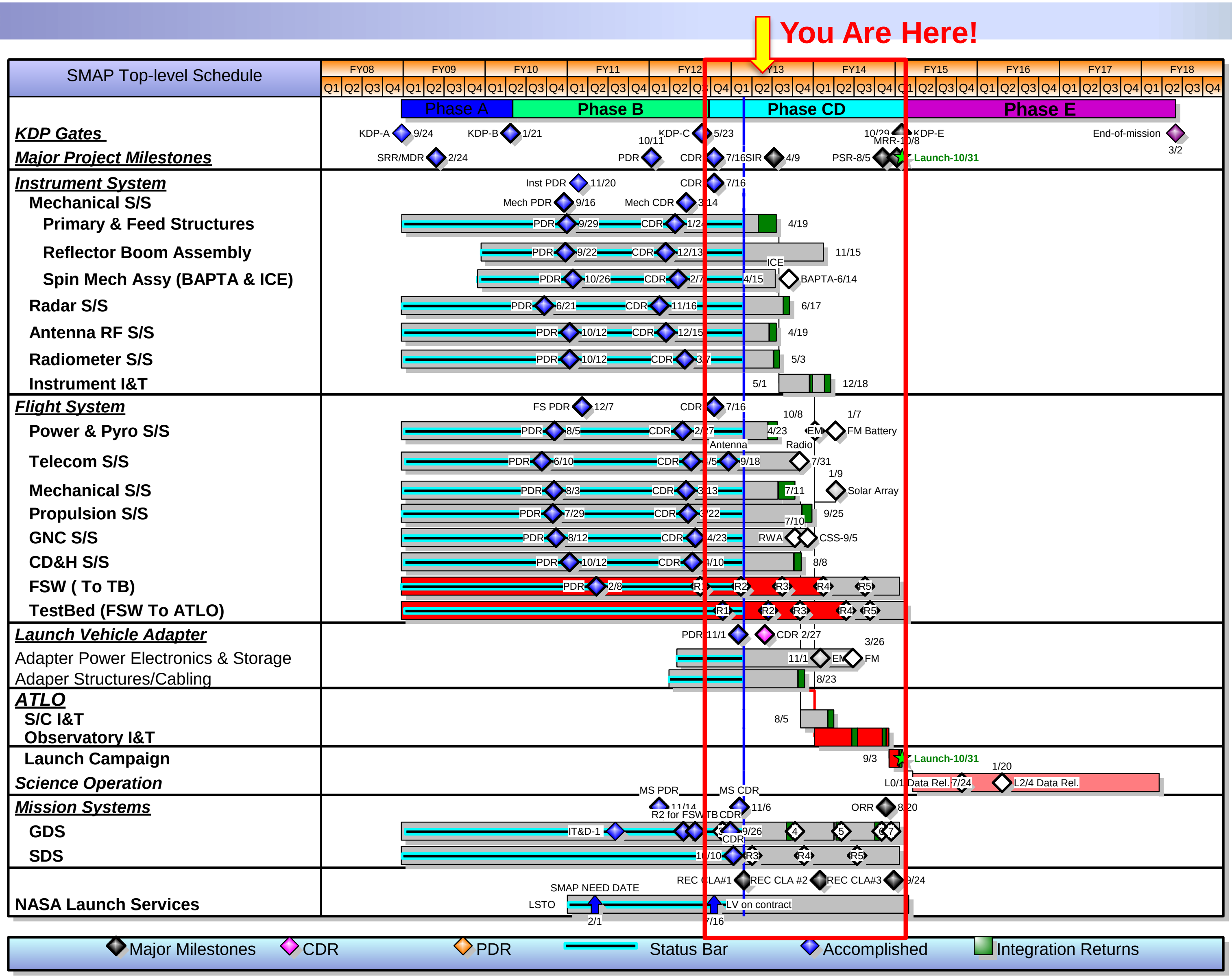
- SMAP is Now Eight Months into Phase C Since Successful CDR in July 2012
  - Algorithm Theoretical Basis Documents Have Matured and Released
  - Project's Major Prelaunch Field Campaign (SMAPVEX12) Successfully Completed
  - Excellent Progress In Launch Service Integration Following Delta II Selection

- Since CDR Instrument, Antenna and Spacecraft Subsystems Manufactured

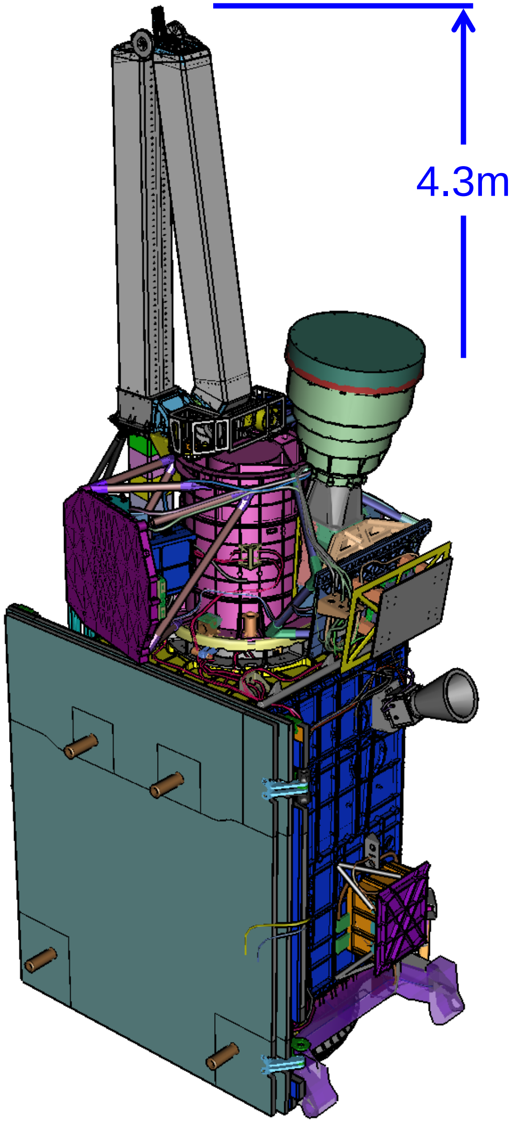
- System Integration and Test Phase has Matured for the Systems Integration Review (SIR): April 8-10, 2013

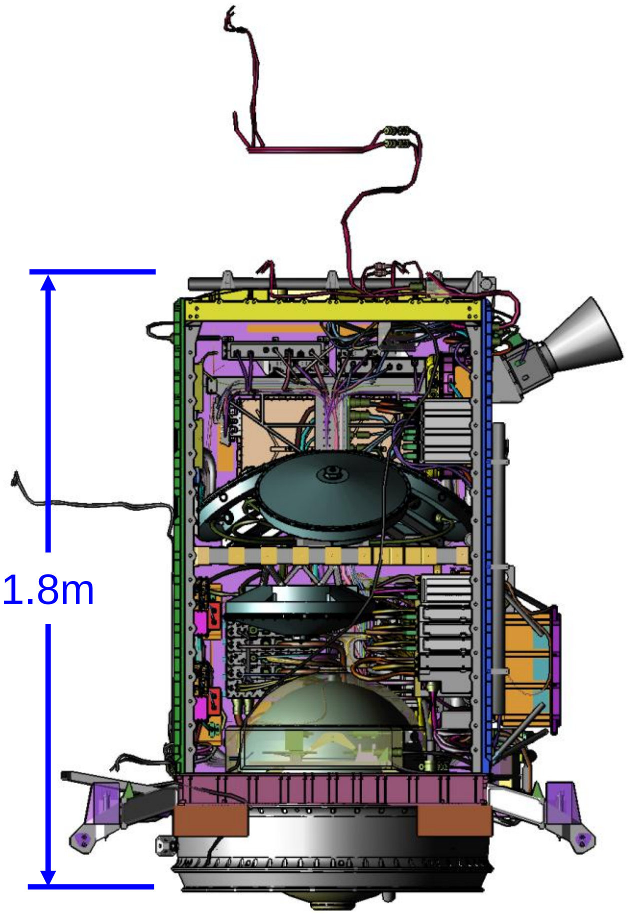
SMAP will be ready for launch on a Delta II rocket on October 31, 2014

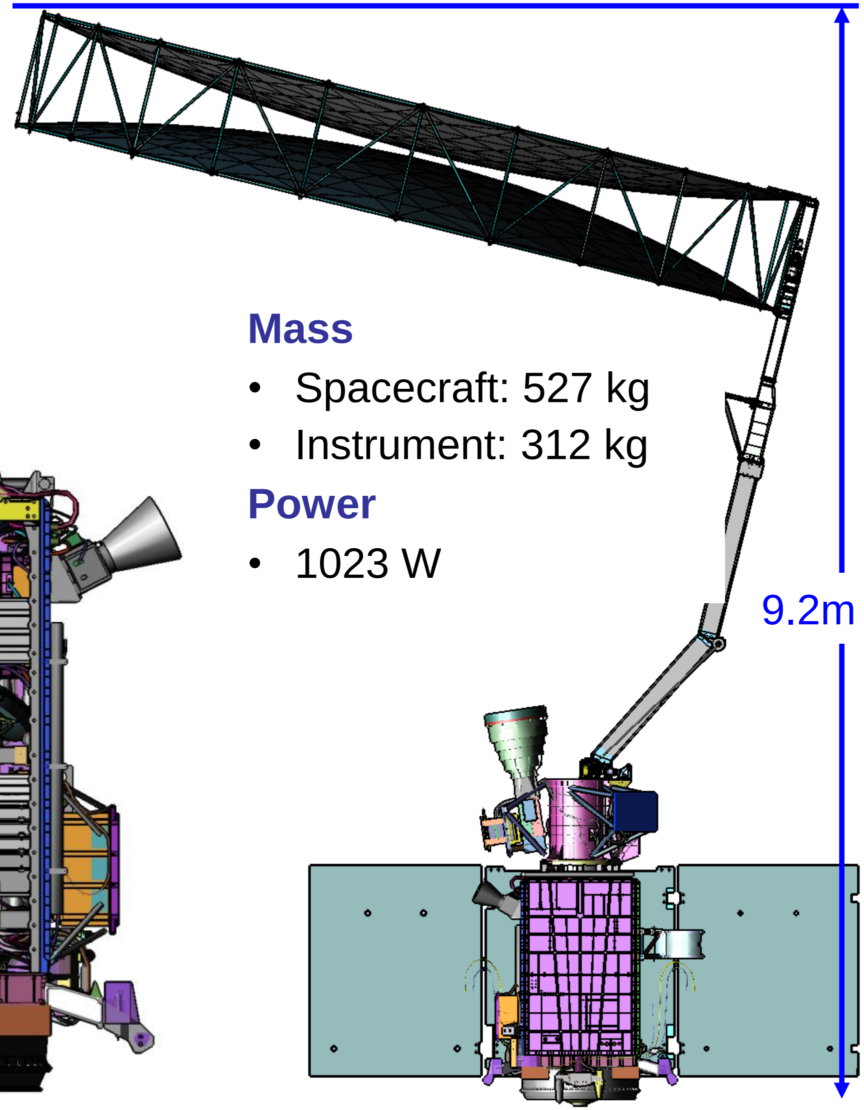
Schedule – Well Past Half Way Point



Observatory Configuration





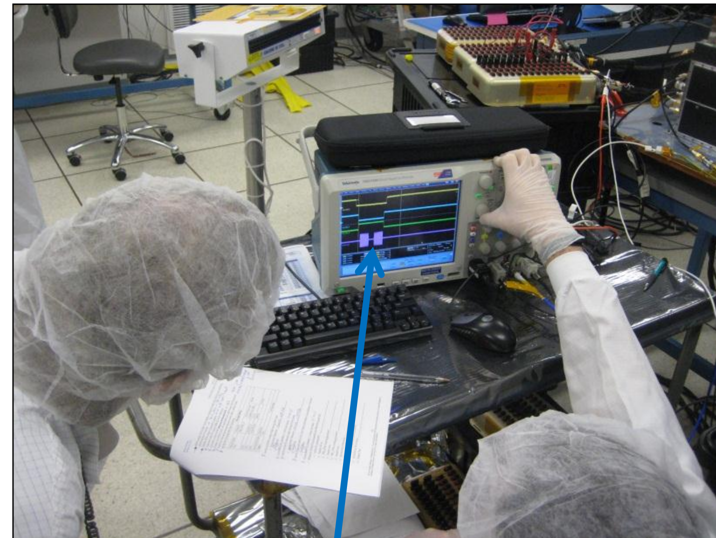


Mass
- Spacecraft: 527 kg
- Instrument: 312 kg

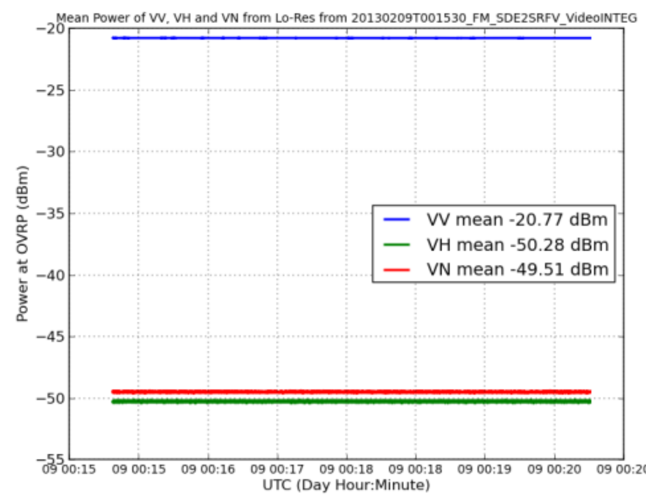
Power
- 1023 W

Radar Integration

Safe-to-mate measurements.



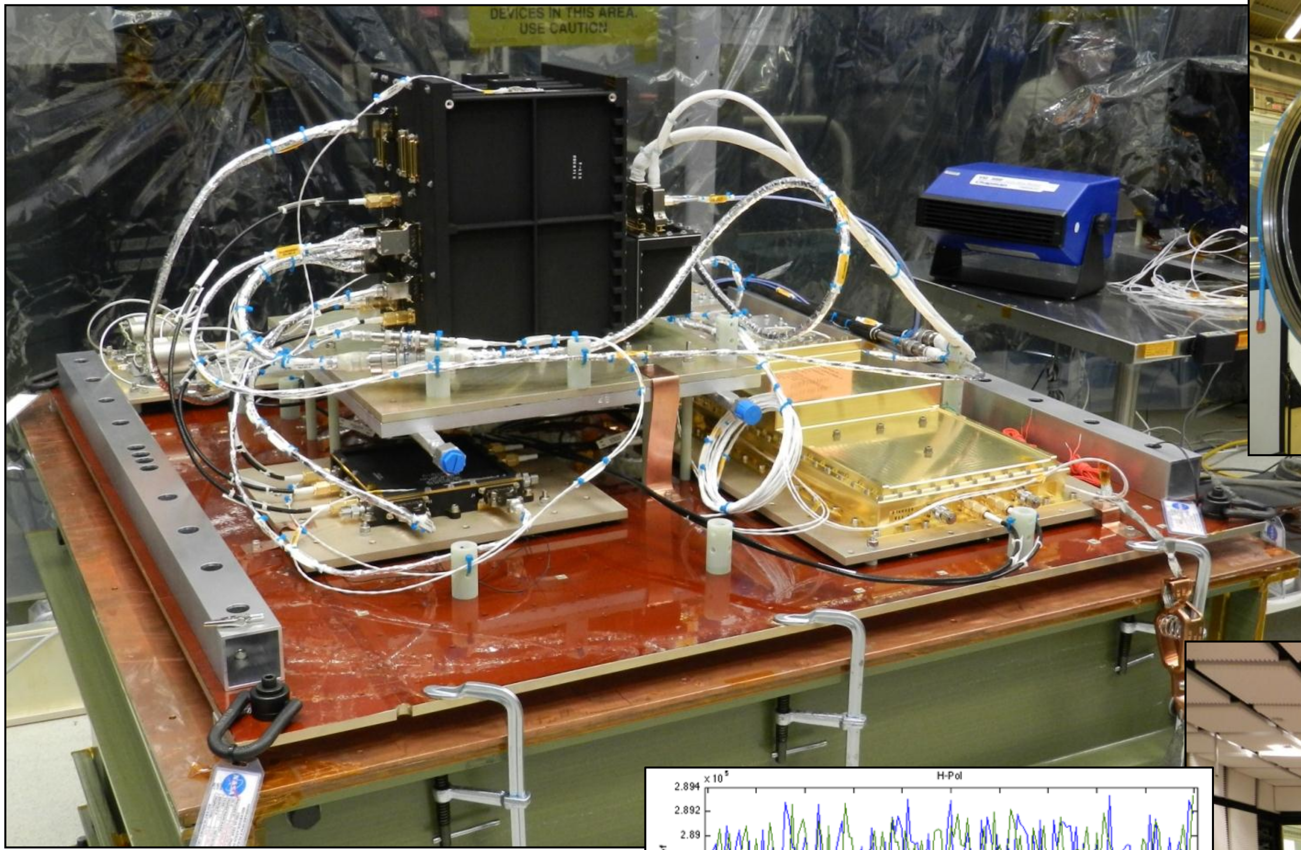
Transmit chirps!



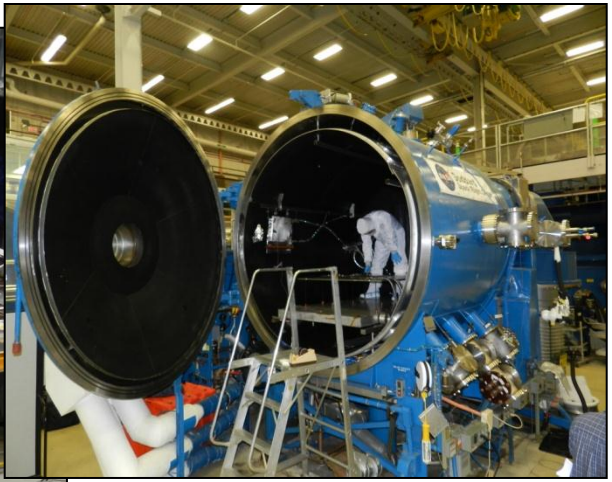
First-looks at high-rate science output data

Radar has been put together and is acting like a radar

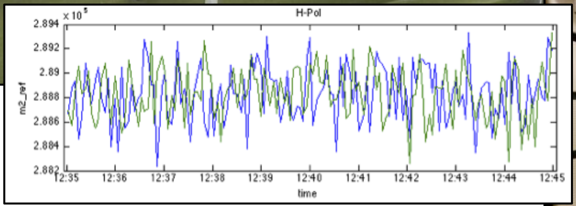
Radiometer Integration



Radiometer electronics integrated on test fixture



TVAC facility



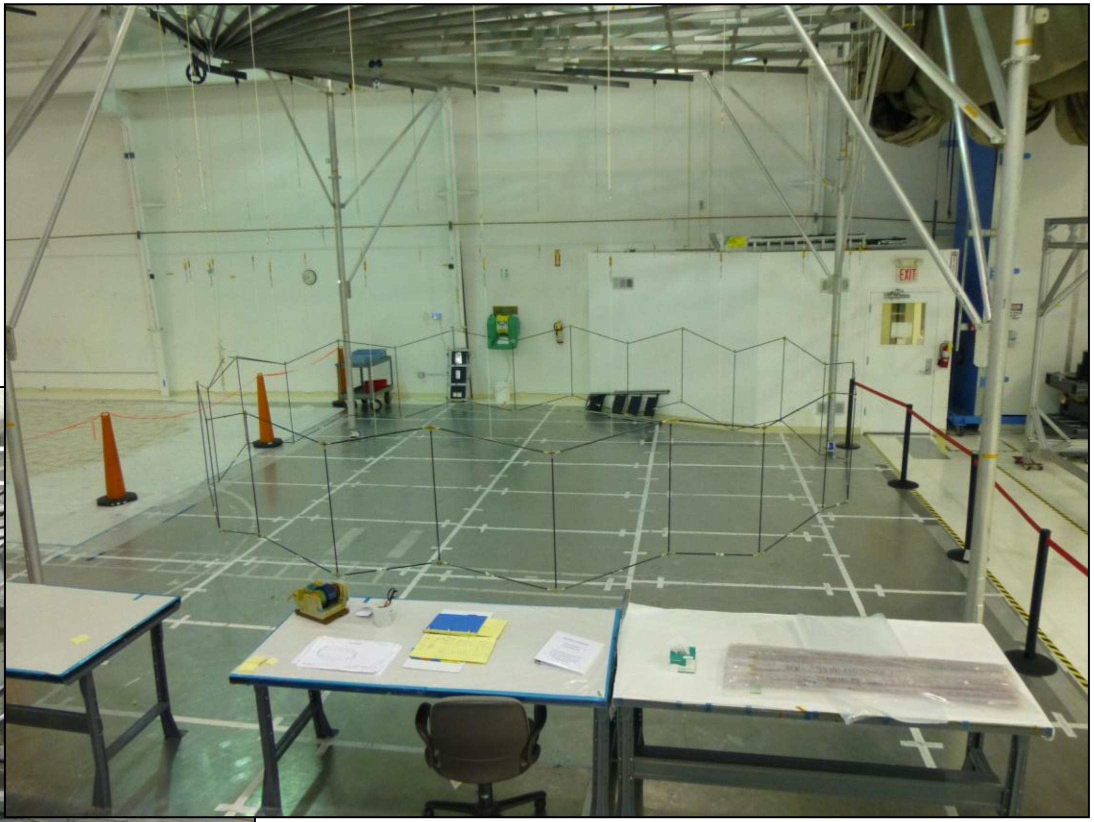
Reference load counts

EMI/EMC facility

Radiometer is integrated and undergoing environmental test

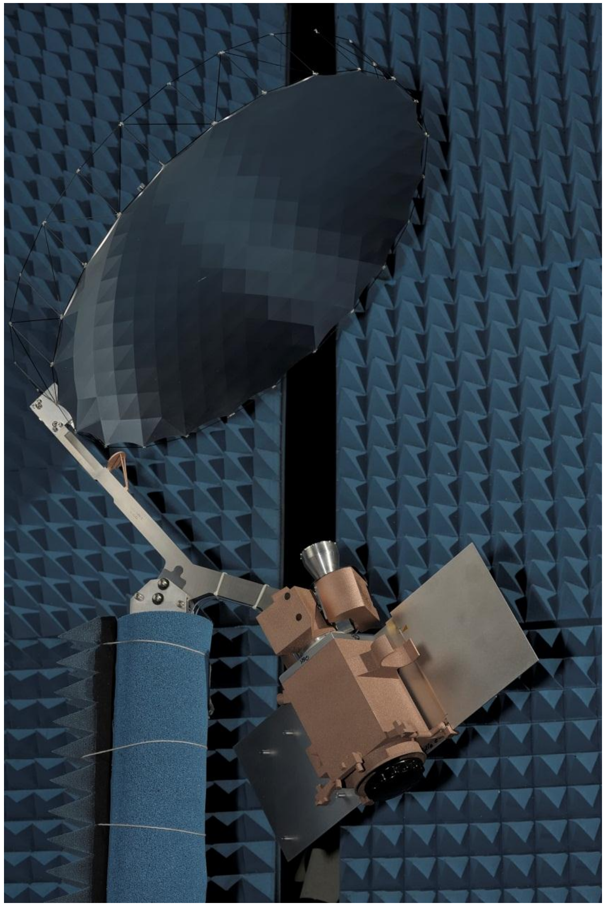
Reflector Status

Flight Rear Net Assembly

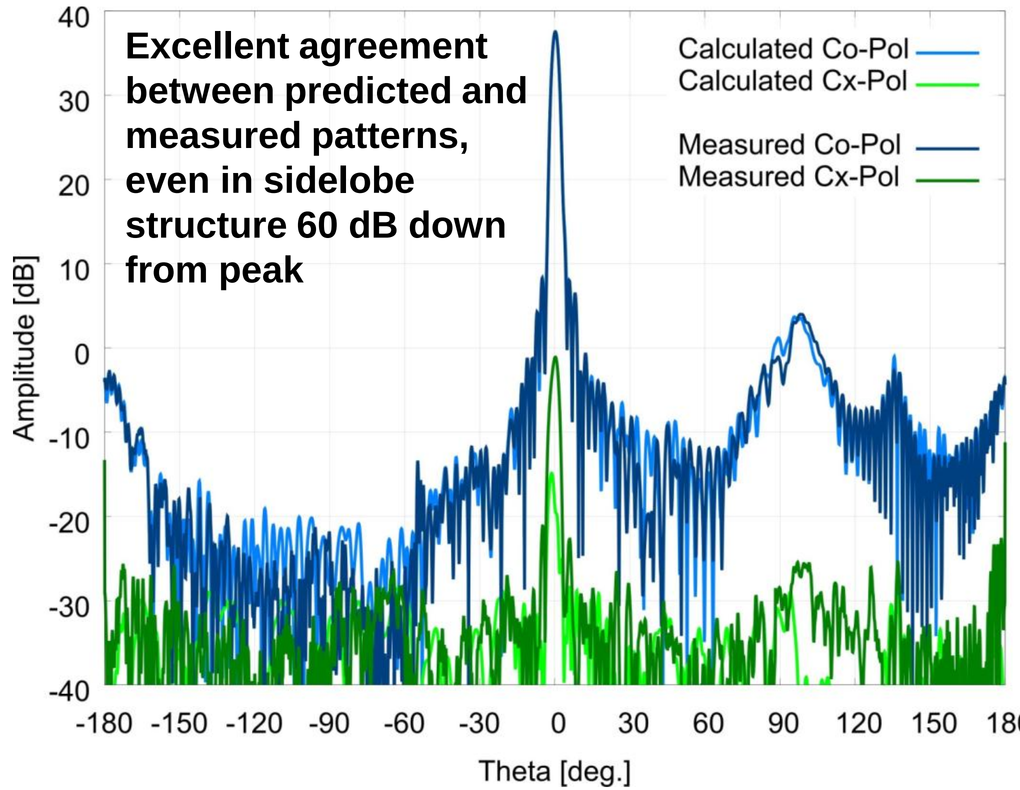


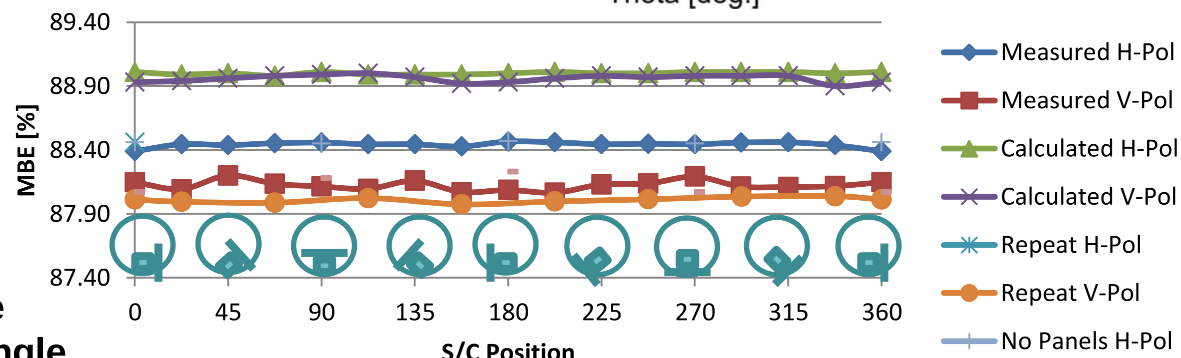
Flight Truss Assembly

Antenna Scale Model Results



~1/10 scale model
on near-field range





Results show that patterns are relatively insensitive to spin angle

Spacecraft in Loads Testing

Radar Co-Pol Error Budget (Feb 2013)

(Co-Pol calculated for lowest s0_HH or s0_VV of -25 dB)

L2-SR-46: s0 accuracy of 1 dB 1-sigma

- Total Kpc Allocation: 0.8 dB
- L3-Instr-59 Kpr (Calibration Stability) Allocation: 0.35
- L3-Instr-477: RFI Allocation: 0.4 dB
- Post-Launch Long-Term Calibration Allocation: 0.2 dB

		CDR	Feb 2013
Error Term	**Allocation**	**CBE**	**CBE**
Kpc	**0.8 dB**	0.67 dB	0.64 dB
Kpr	**0.35 dB**	0.35 dB	0.35 dB
RFI	**0.4 dB**	0.2 dB	0.2 dB
Post Launch Cal	**0.2 dB**	0.2 dB	0.2 dB
RSS Total		0.81 dB	0.78 dB
Requirement	**1.0 dB**	**1.0 dB**	**1.0 dB**
“Linear” Margin		0.19 dB	0.22 dB
“RSS” Margin		0.59 dB	0.63 dB

Radar Cross-Pol Error Budget (Feb 2013)

(X-pol calculated for lowest s0_HV or s0_VH of -30 dB)

L2-SR-376: s0 accuracy of 1.5 dB 1-sigma

- Total Kpc Allocation: 1.0 dB
- L3-Instr-59 Kpr (Calibration Stability) Allocation: 0.7
- L3-Instr-477: RFI Allocation: 0.8 dB
- Post-Launch Long-Term Calibration Allocation: 0.2 dB

		CDR	Feb 2013
Error Term	**Allocation**	**CBE**	**CBE**
Kpc	**1.0 dB**	0.88 dB	0.8 dB
Kpr	**0.7 dB**	0.7 dB	0.7 dB
RFI	**0.8 dB**	0.24 dB	0.24 dB
Post Launch Cal	**0.2 dB**	0.2 dB	0.2 dB
RSS Total		1.17 dB	1.11 dB
Requirement	**1.5 dB**	**1.5 dB**	**1.5 dB**
“Linear” Margin		0.33 dB	0.4 dB
“RSS” Margin		0.93 dB	1.01 dB

Radiometer Error Budget (Feb 2013)

L2-SR-45 : The L1B_TB brightness temperatures shall have mean uncertainty from all sources (excluding rain) of 1.3 K or less (1-sigma) in the H and V channels, computed by binning fore- and aft-look samples into 30 km x 30 km grid cells.

L3-Instr-TBD
Atmospheric Correction : 0.1 K

L3-Instr-232
Antenna Pattern Correction (Instr Contrib) : 0.6 K

L3-Instr-169
NEΔT 0.65 K

L3-Instr-599
Long Term Drift 0.4 K

L3-Instr-507
RFI 0.3 K

L3-Instr-685
Antenna Temperature Calibration 0.5 K

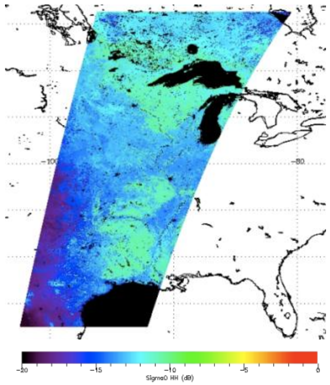
L3-MS-840->L4-SDS-535
Antenna Pattern Correction (SDS Contrib) : 0.5 K

Error Term	CDR Allocation	Feb 2013 Allocation	CDR CBE	Feb 2013 CBE
Antenna Pattern Correction (Instr Contrib)	**0.60 K**	**0.60 K**	0.40 K	0.62 K
Antenna Pattern Correction (SDS Contrib)	**-**	**0.5 K**	-	0.33 K
NEΔT	**0.65 K**	**0.65 K**	0.54 K	0.45 K
Antenna Temperature Calibration	**0.50 K**	**0.50 K**	0.44K	0.45 K
RFI	**0.30 K**	**0.30 K**	0.19 K	0.18 K
Long Term Drift	**0.40 K**	**0.40 K**	0.20 K	0.20 K
Atmospheric Correction	**0.10 K**	**0.10 K**	0.04 K	0.04 K
RSS Total			0.85 K	0.98 K
Requirement	**1.3 K**	**1.3 K**	**1.3 K**	**1.3 K**
"Linear" Margin			0.44 K	0.32 K
"RSS" Margin			0.92 K	0.85 K

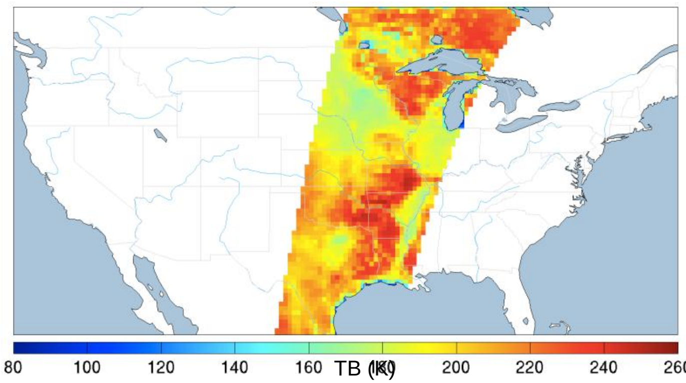
Pre-Launch: SMAP Algorithm Testbed

Simulated Products Generated with Algorithms

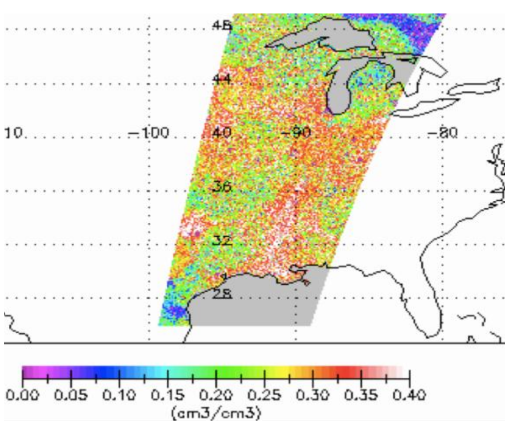
L1C_S0_Hi-Res Radar
Backscatter Product (1-3 km)



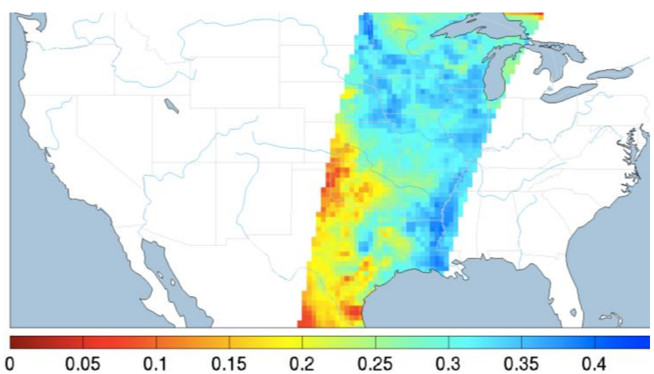
L1C_TB Radiometer
Brightness Temperature Product (36km)



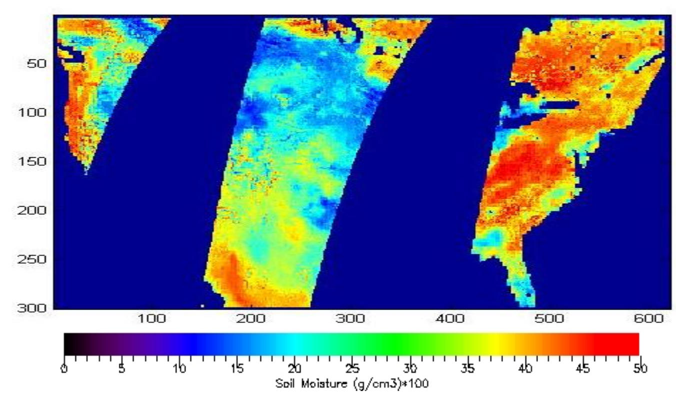
L3_SM_A Radar
Soil Moisture Product (3 km)



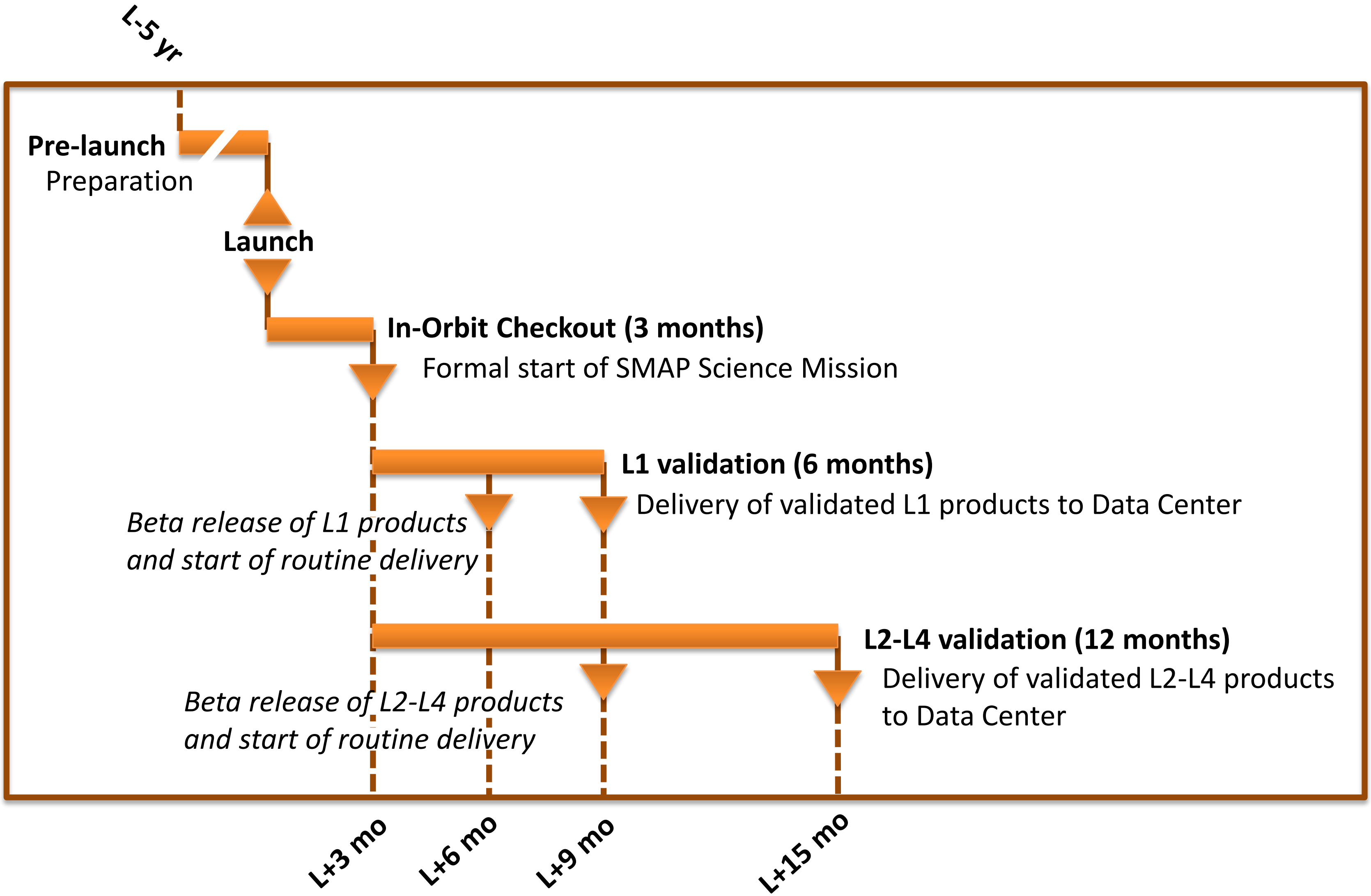
L2_SM_P Radiometer
Soil Moisture Product (36 km)



L2_SM_AP Combined
Soil Moisture Product (9 km)



Post-Launch: Science Data Delivery Timeline



Pre-Launch: SMAP Cal/Val Rehearsal Phases

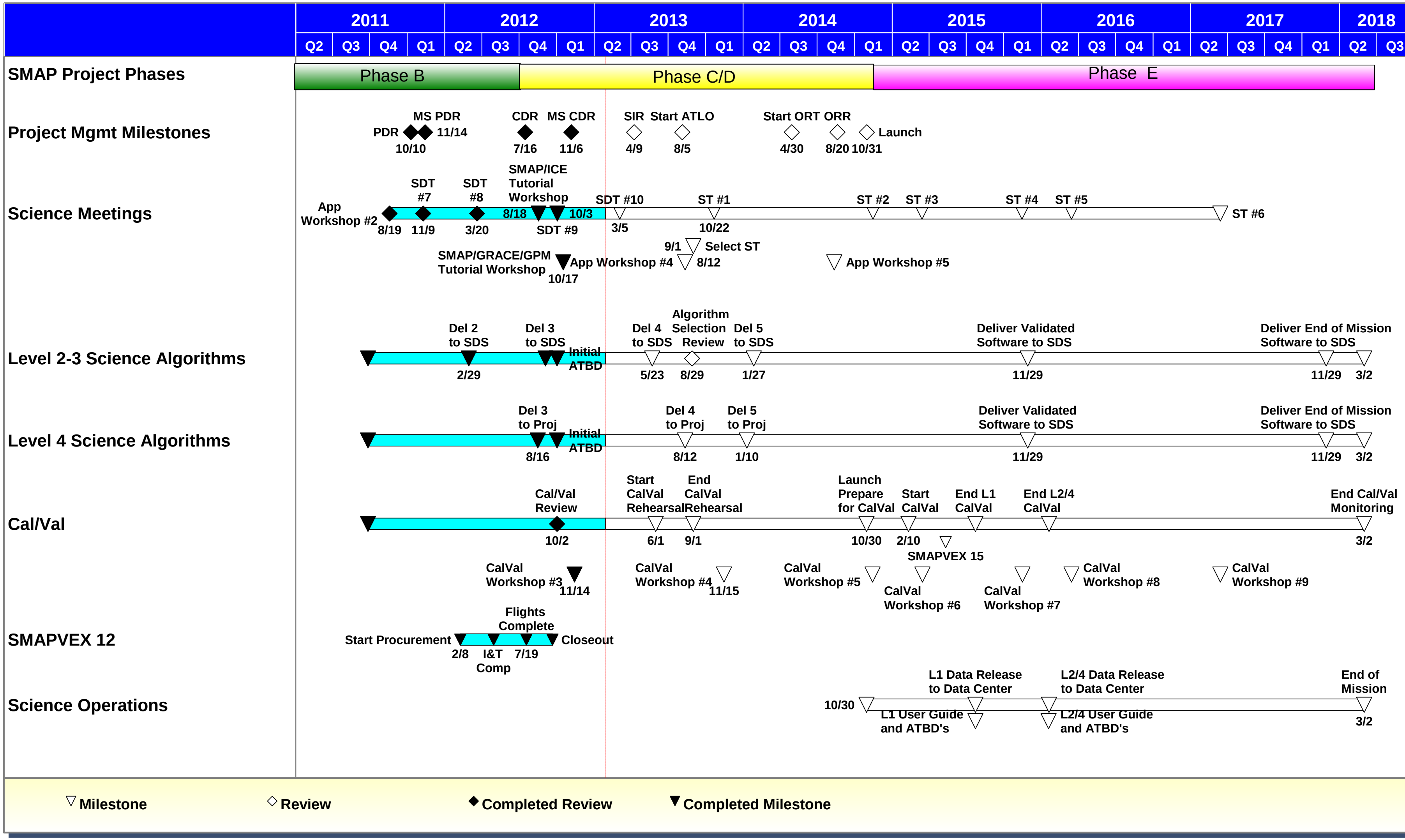
- Phase 1 (Summer 2013)
  - Emphasizes development of validation methods
    - Test cal/val methods that the team plans to use during mission cal/val
    - Confirm external validation resources
  - Researchers run code in research mode

- Phase 2 (Summer 2014)
  - Emphasizes effective use of tools in an operational setting
    - Ensure that the tools function in the operational environment
    - Ensure that tools operate on selected input appropriately
    - Ensure that tools generate anticipated output
  - Team members run code on SDS

Science Top Level Schedule

SMAP Science Top Level Schedule

Rev. 9/30/2012



Key Science Activities

Science Team Meetings

- SDT meeting #10, March 5-7, 2013
- ST (Science Team) meeting #1 November 19-21, 2013

Algorithms & Data Products

- Software Interface Specifications; Close Interactions Between ADT and SDS
- Data Product Specifications; Flags and Definitions
- Science Software Delivery 4: May 23, 2013
- Independent Panel Algorithm Review (Baseline Selection): September 10-12, 2013
- Science Software Delivery 5: L2/3 Jan 27, 2013
- Browse Products: Test Products; Discussions with DAACs

Key Science Activities

Cal/Val

- Rehearsal 1: June-September 2013
  - Includes L1 through L4
  - Identify Cal/Val requirements and develop Cal/Val tools
  - Initial test of core site/sparse network data collection, QC, and match-up analysis
- Rehearsal 2: May-July 2014
  - Expanded rehearsal based on lessons learned and updated tools
  - Tests in SDS operational environment
- Cal/Val Workshops:
  - #4 November 5-7, 2013, Oxnard, CA (review rehearsal 1; plan rehearsal 2)
  - #5 August 2014 (review rehearsal 2)

Applications

- Workshop: AMS, Feb 2014 (Focus on NWP and SMOS-SMAP Continuity)
- SMAP Applications Workshop: Spring 2014 (L-6 mths)
  - Focus on progress of Early Adopters

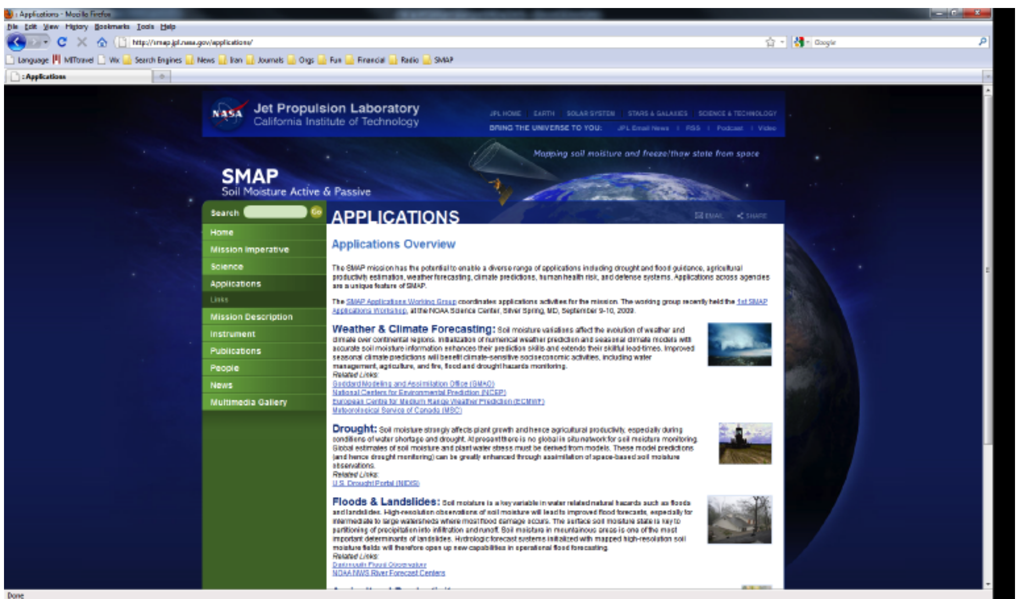
Documentation

- ATBD status
  - Initial Release (v.1); All Posted on SMAP Web Site
  - Final Pre-Launch Version (v.2): September 2014
- Ancillary Data Reports
  - Nine (of Twelve Total) Posted on SMAP Web Site; Remainder Imminent
- Data Product Specifications
  - Preliminary Versions Completed; Final Version: Oct. 2013
- Science Cal/Val Plans
  - Science Data Cal/Val Plan Initial Version July 2012
  - Project L1 Cal/Val Plan Draft
  - Project L2-L4 Cal/Val Plan Draft
- SMAP Handbook
- SMAP Tutorial

SMAP Community Working Groups

Join at http://smap.jpl.nasa.gov/science/wgroups

1. Algorithms Working Group (AWG)
2. Calibration & Validation Working Group (CVWG)
3. Radio-Frequency Interference Working Group (RFIWG)
4. Applications Working Group (AppWG)



Conclusions

- Project Healthy and On Track
- Canada Science and Project Partnership Now 10+ Years
- The Major Pre-Flight Field Campaign (SMAPVEX12) Successful With Canada SMAP Science Team Partnership
- From Here Onwards:
  - Canada Core Cal/Val Sites
  - Collaboration on Level 4 Data Assimilation Algorithms and Implementation
  - Applications Participation
  - Project Algorithms, Cal/Val Approach and Science

HYDROS

MIT JPL

HYDROS Science Team Meeting: April 19, 2004 Miami Beach, FL