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Soil Moisture Active and Passive (SMAP) Mission

Eni Njoku[1]
Dara Entekhabi[2]
Peggy O'Neill[3]

[1]Jet Propulsion Laboratory, Pasadena, CA
[2]Massachusetts Institute of Technology, Cambridge, MA
[3]NASA Goddard Space Flight Center, Greenbelt, MD

AMSR-E Science Team Meeting
Telluride, CO
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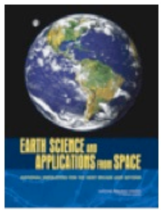
Program Context



"Earth Science and Applications from Space: National Imperatives for the next Decade and Beyond " (National Research Council, 2007)
http://www.nap.edu

SMAP is one of four missions recommended by the NRC Earth Science Decadal Survey for launch in the 2010-2013 time frame

- On Feb 2, 2008, NASA announced that SMAP will:
  - Begin Phase A in FY08
  - Launch in CY2012
- SMAP builds on Hydros heritage
- SMAP mission is led by JPL with GSFC participation and potential DoD and international partnerships

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

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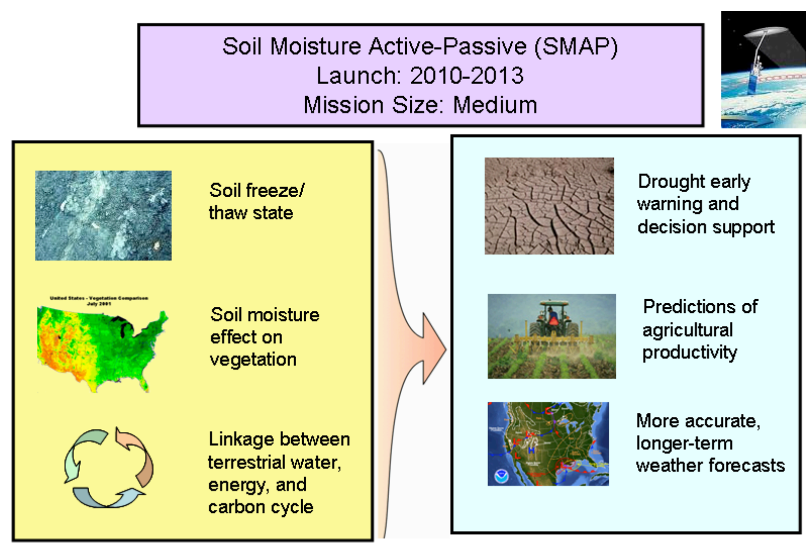
Decadal Survey Cited Applications

Decadal Survey Panels	Cited SMAP Applications
Water Resources and Hydrological Cycle	1. Floods and Drought Forecasts 2. Available Water Resources Assessment 3. Link Terrestrial Water, Energy and Carbon Cycles
Climate / Weather	1. Longer-Term and More Reliable Atmospheric Forecasts
Human Health and Security	1. Heat Stress and Drought 2. Vector-Borne and Water-Borne Infectious Disease
Land-Use, Ecosystems, and Biodiversity	1. Ecosystem Response (Variability and Change) 2. Agricultural and Ecosystem Productivity 3. Wild-Fires 4. Mineral Dust Production

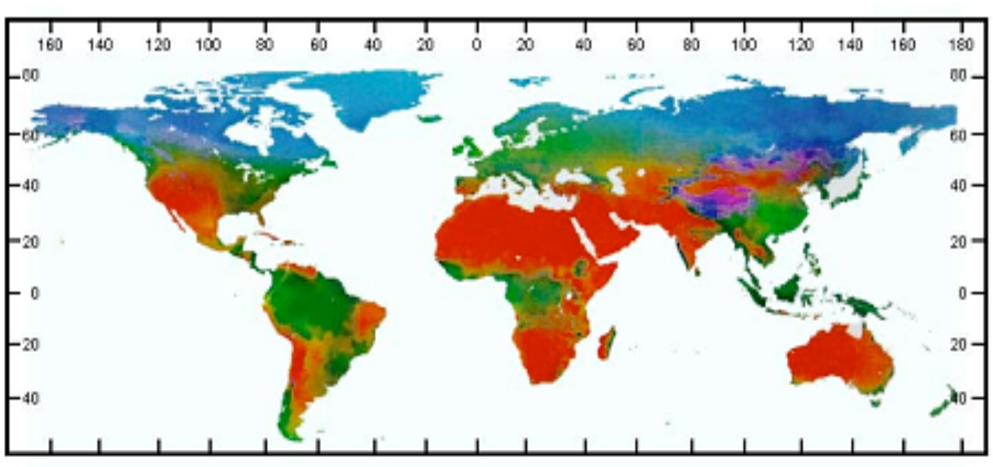
The SMAP applications cited by the Earth Science Decadal Survey can be accomplished with the currently baselined (Hydros heritage) flight instrument performance

– July, 2007 NASA Workshop



Mission Objectives

- Global mapping of Soil Moisture and Freeze/Thaw state to:
  - Understand processes that link the terrestrial water, energy & 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



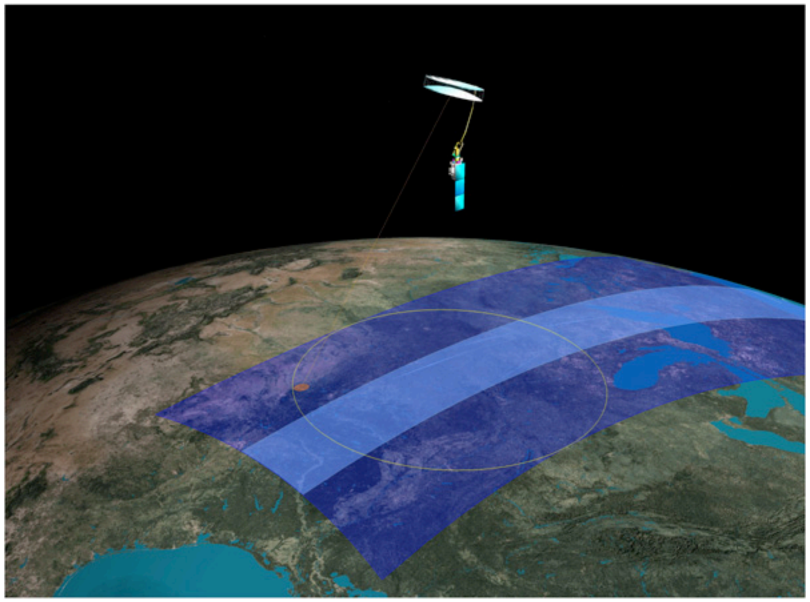
Primary Controls on Land Evaporation and Biosphere Primary Productivity

SMAP Enables DOD Applications

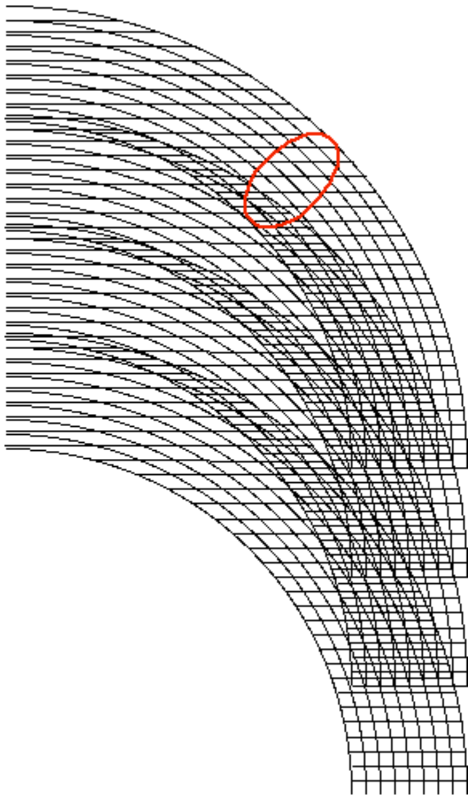
- SMAP provides a global, frequent revisit, all-weather mapping capability that supports DOD tri-service operations and decision-making needs
- Provides high-resolution microwave sensor data and soil moisture and freeze/thaw products
  - **Air Force:** To initialize weather prediction models for low-level fog, visibility, and severe weather forecasting
  - **Army:** As input to terrain trafficability assessments for battlespace force enhancement
  - **Navy** For all-weather high-resolution mapping of marine and littoral ice cover and ice characteristics

SMAP Mission Concept

- **Science Measurements**
  - *Soil moisture and freeze/thaw state*
- **Instruments:**
  - ***Radar, L-band (1.26 GHz)***
    - *Polarization: HH, VV, HV*
    - *SAR mode: 1-3 km resolution (degrades over center 30% of swath)*
    - *Real-aperture mode: 30 x 6 km resolution*
  - ***Radiometer, L-band (1.4 GHz)***
    - *Polarization: V, H, U*
    - *40 km resolution*
  - ***Antenna (shared by radar & radiometer)***
    - *6-m diameter deployable mesh antenna*
    - *Conical scan at 14.6 rpm*
    - *Incidence angle: 40 degrees*
    - *Contiguous footprints across 1000 km swath*
    - *Swath and orbit enable 2-3 day revisit*
- **Orbit:**
  - *Sun-synchronous, 6 am/pm orbit*
  - *670 km altitude*
- **Mission operations duration: 3 years**

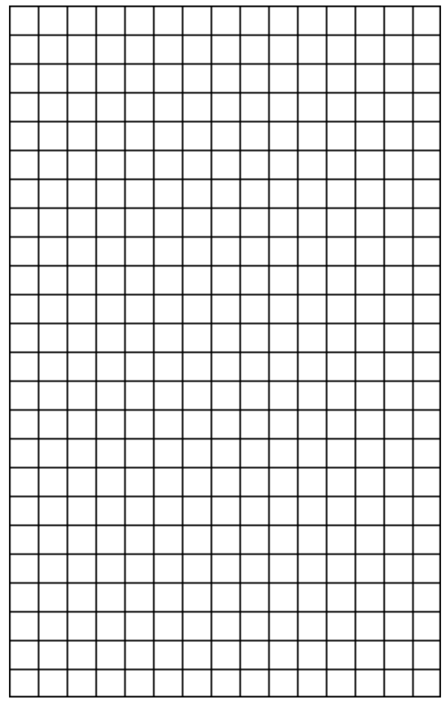


Radar Resolution and Precision



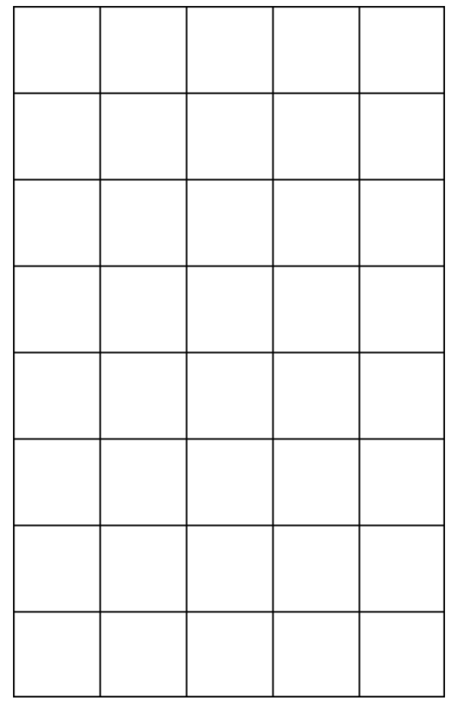
Single-Look, Time-Ordered Data

- Native resolution: 250 m in range, 365 - 1500 - 25000 m resolution in azimuth.
- Each resolution element constitutes one independent "look" at surface.



1 km Gridded, Re-Sampled Data

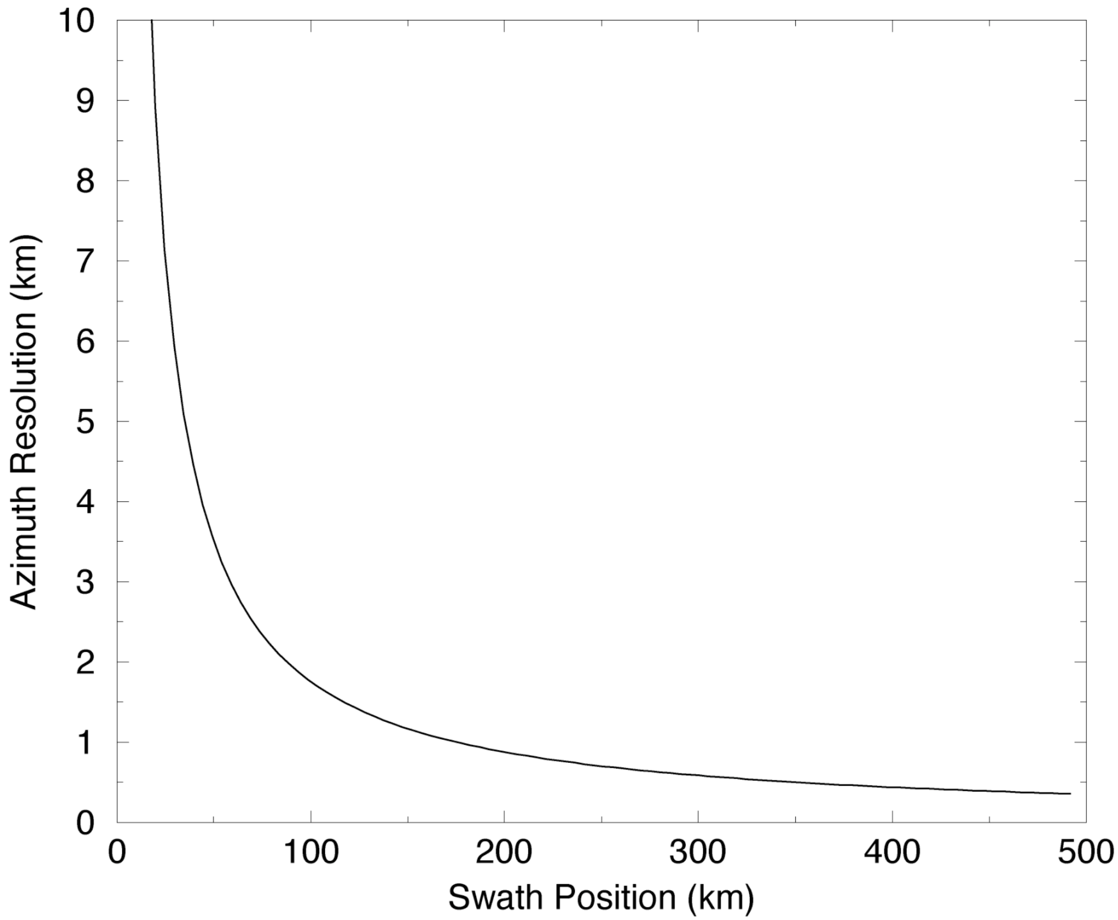
- Data resampled and posted on 1 km grid, resolution may still be > 1 km near nadir.
- Each resolution cell now has multiple "looks" at surface, decreased measurement variance.



3 km (or whatever) Average Data

- 1 km posted product can be averaged up to 3 km, 10 km, etc.
- Improved number of looks (and hence precision) at expense of spatial resolution.

Azimuth Resolution vs. Swath Position



- Elevation (along ground range) resolution approximately 235 m.

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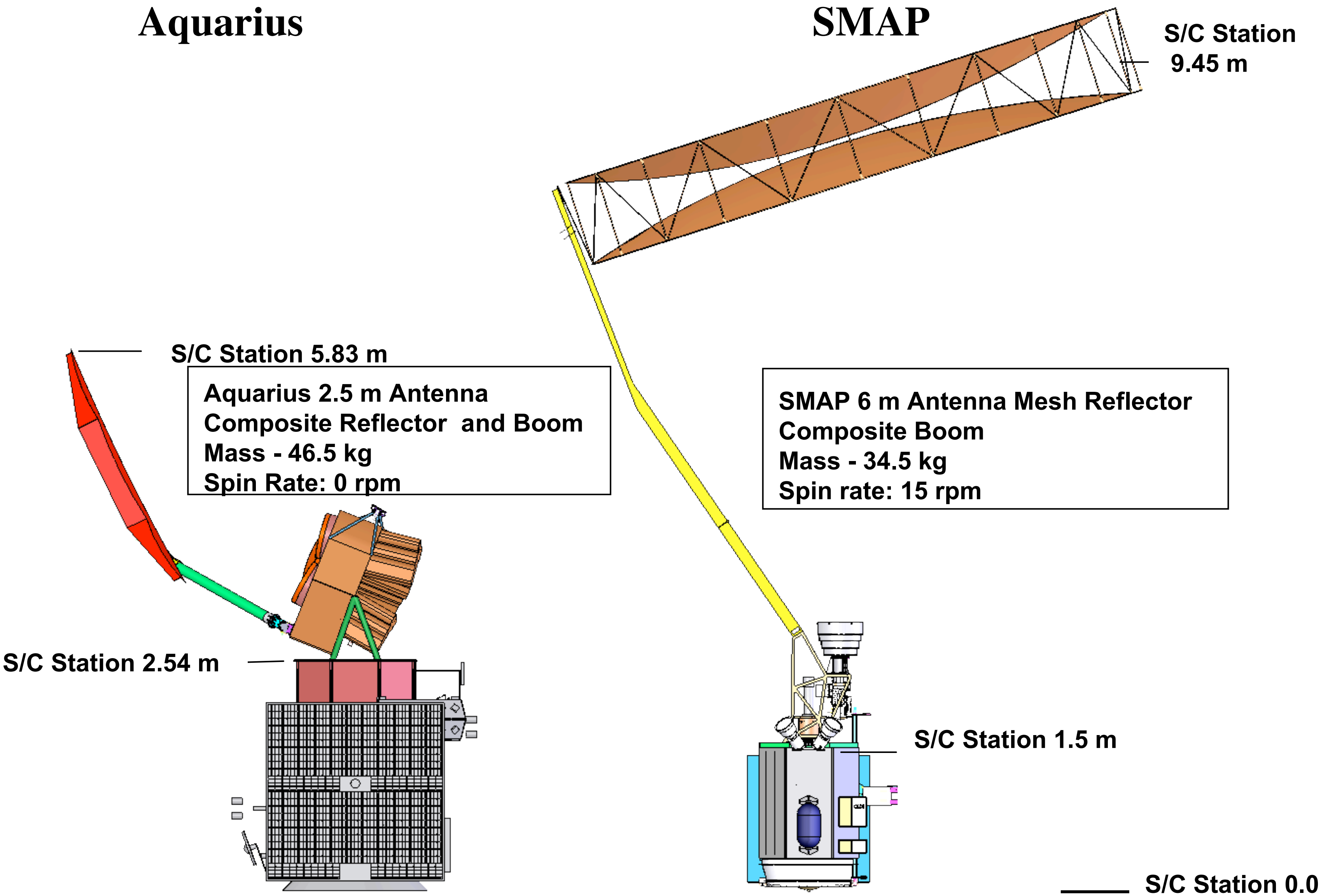
SMAP vs. Aquarius Scale Comparison



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SMAP Data Products

- SMAP Level 1-4 science data products are the same as those baselined for the Hydros mission

Data Product	Description
L1B_S0_LoRes	Low Resolution Radar σ^o in Time Order
L1C_S0_HiRes	High Resolution Radar σ^o on Earth Grid
L1B_TB	Radiometer T_B in Time Order
L1C_TB	Radiometer T_B on Earth Grid
L2/3_F/T_HiRes	Freeze/Thaw State on Earth Grid
L2/3_SM_HiRes	Radar Soil Moisture on Earth Grid
L2/3_SM_40km	Radiometer Soil Moisture on Earth Grid
L2/3_SM_A/P	Radar/Radiometer Soil Moisture on Earth Grid
L4_F/T	Freeze/Thaw Model Assimilation on Earth Grid
L4_4DDA	Soil Moisture Model Assimilation on Earth Grid

Draft Level 1 Science Requirements

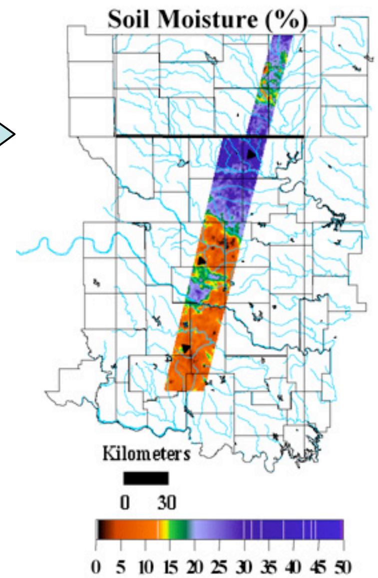
	Baseline Mission	Minimum Mission
Soil Moisture Measurement*	Provide estimates of soil moisture in the top 5 cm of soil with an accuracy of 4% volumetric at 10 km resolution and 3-day average intervals	Provide estimates of soil moisture in the top 5 cm of soil with an accuracy of 6% volumetric at 10 km resolution and 3-day average intervals
Freeze/Thaw Measurement	Provide binary estimates of surface transitions in region north of 45°N with a classification accuracy of 80% at 3 km resolution and 2-day average intervals	Provide binary estimates of surface transitions in region north of 45°N with a classification accuracy of 70% at 10 km resolution and 3-day average intervals
Mission Duration	At least 3 years	At least 2 years

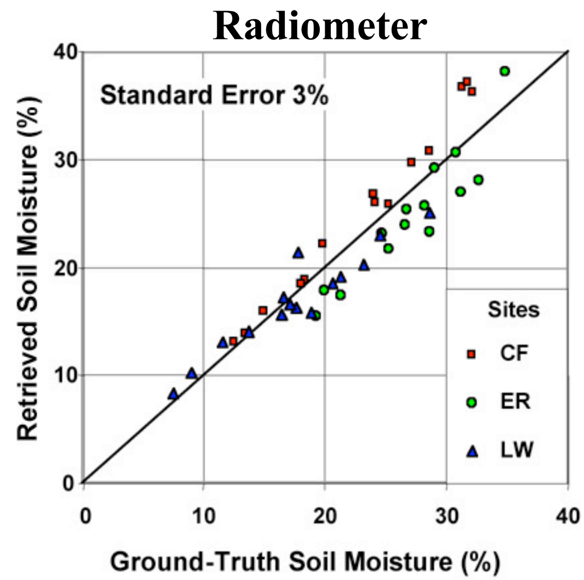
* Excludes forests (regions with vegetation water content greater than ~5 kg/m^2)

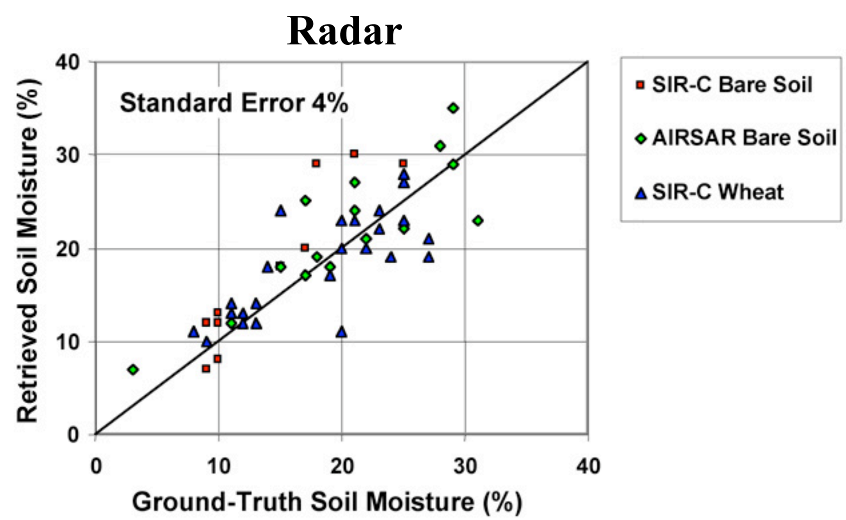
- Descoping from 3 years to 1 year removes the capability to calibrate and analyze interannual changes – additional science descope impacts are addressed in the STT report section
- The instrument descopes that could lead to the minimum mission include:
  - Reduction of radiometer channels from three (H, V, U) to one (H)
  - Reduction of radar channels from three (VV, HH, HV) to one (VV)
  - Loss of radar synthetic aperture capability (reduction to backup resolution enhancement approach)
  - Reduction of algorithm options to one (time series/relative change)

Retrieval Algorithms

- Retrieval algorithms are derived from heritage of multi-investigator microwave modeling and field experiment data
  - MacHydro’90, Monsoon’91, Washita‘92, FIFE, HAPEX, SGP’97,‘99, SMEX’02-‘05
- ***Radiometer*** - More accurate (less influenced by roughness and vegetation) but coarser resolution (40 km)
- ***Radar*** - High spatial resolution (1-3 km) but more sensitive to surface roughness and vegetation
- ***Combined radar/radiometer*** - algorithm generates optimal blend of resolution and accuracy
- Algorithm approach was demonstrated in Hydros simulation study; radiometer OSSE published (Crow et al., TGARS, 2005); and will be extended in SMAP Algorithm Testbed







SMEX'02 PALS Relative Change Images

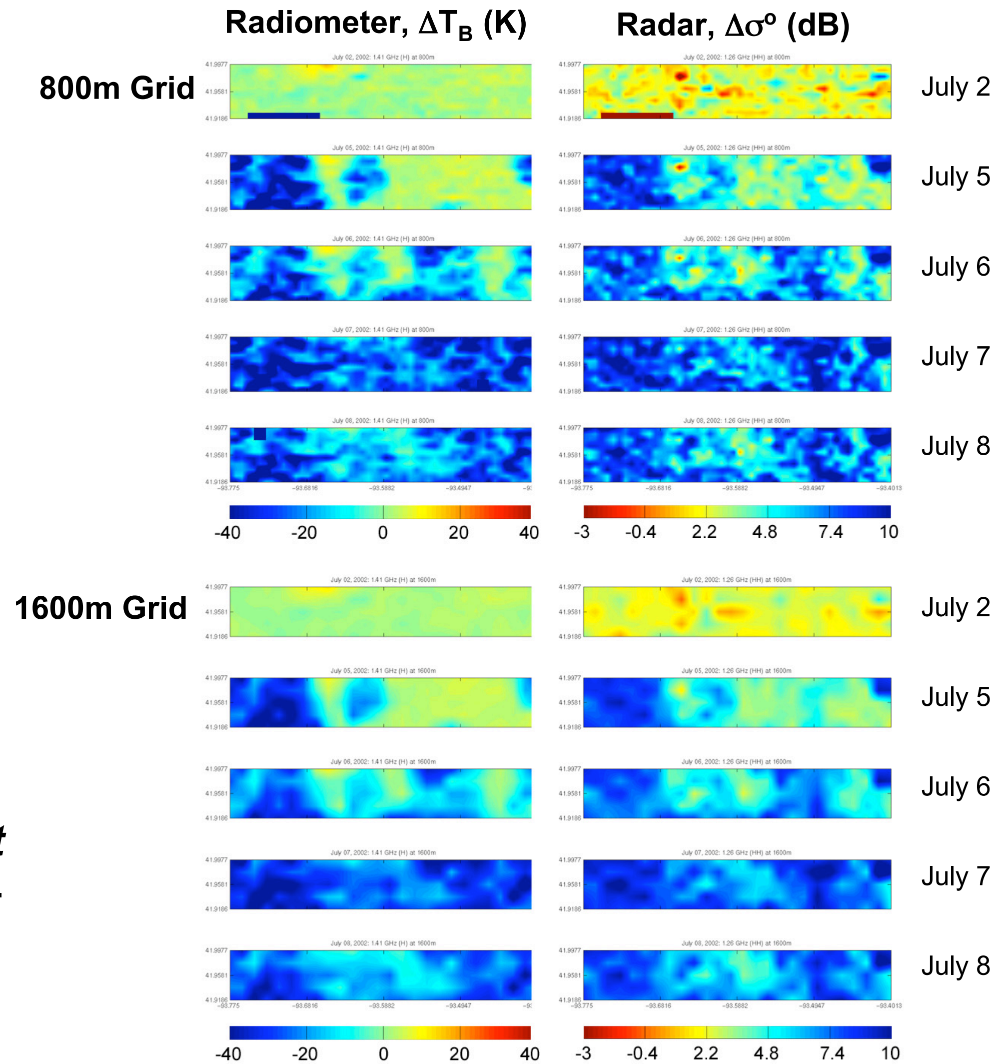
Differences from June 25 (dry conditions)

- Difference images show changes in sensor responses (ΔT_B and $\Delta\sigma^o$) due primarily to changes in moisture, but with some effects of vegetation growth

- Spatial patterns and temporal changes are consistent between the radar and radiometer

- Artificially degrading spatial resolution by a factor of two by linear averaging of ΔT_B (K) and $\Delta\sigma^o$ (dB) to 1600 m grid does not change the patterns of variability

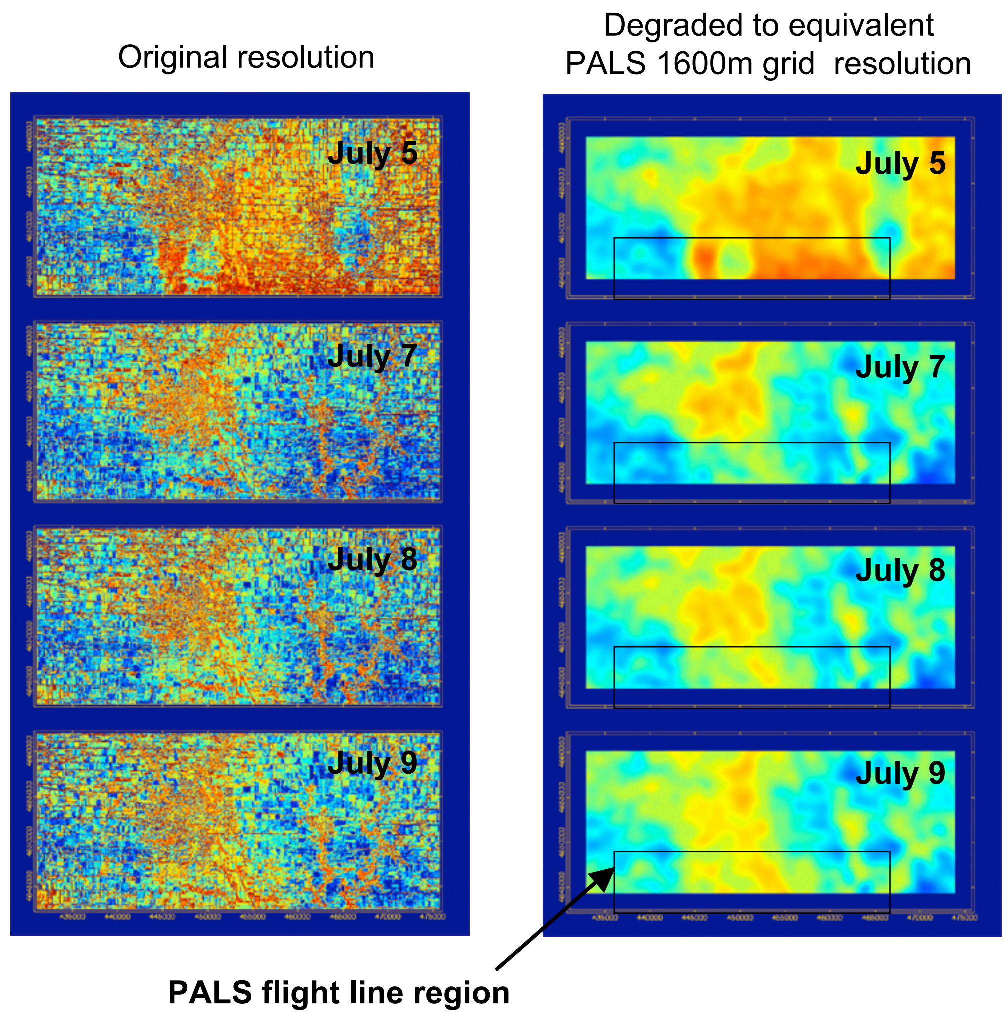
⇒ ***Effects of vegetation on radar and radiometer signatures are different, but temporal change patterns are similar – dominated by soil moisture***



SMEX'02 AIRSAR Relative Change Images

Differences from July 1 (dry conditions)

- The AIRSAR difference images ($\Delta\sigma^o$) show a response to soil moisture change that is similar to the PALS radar response
  - (Color scales are not matched between these images and the PALS images shown on the earlier chart)
- Degrading the AIRSAR image resolution to the PALS image resolution maintains the spatial patterns of moisture change, irrespective of underlying landcover heterogeneity



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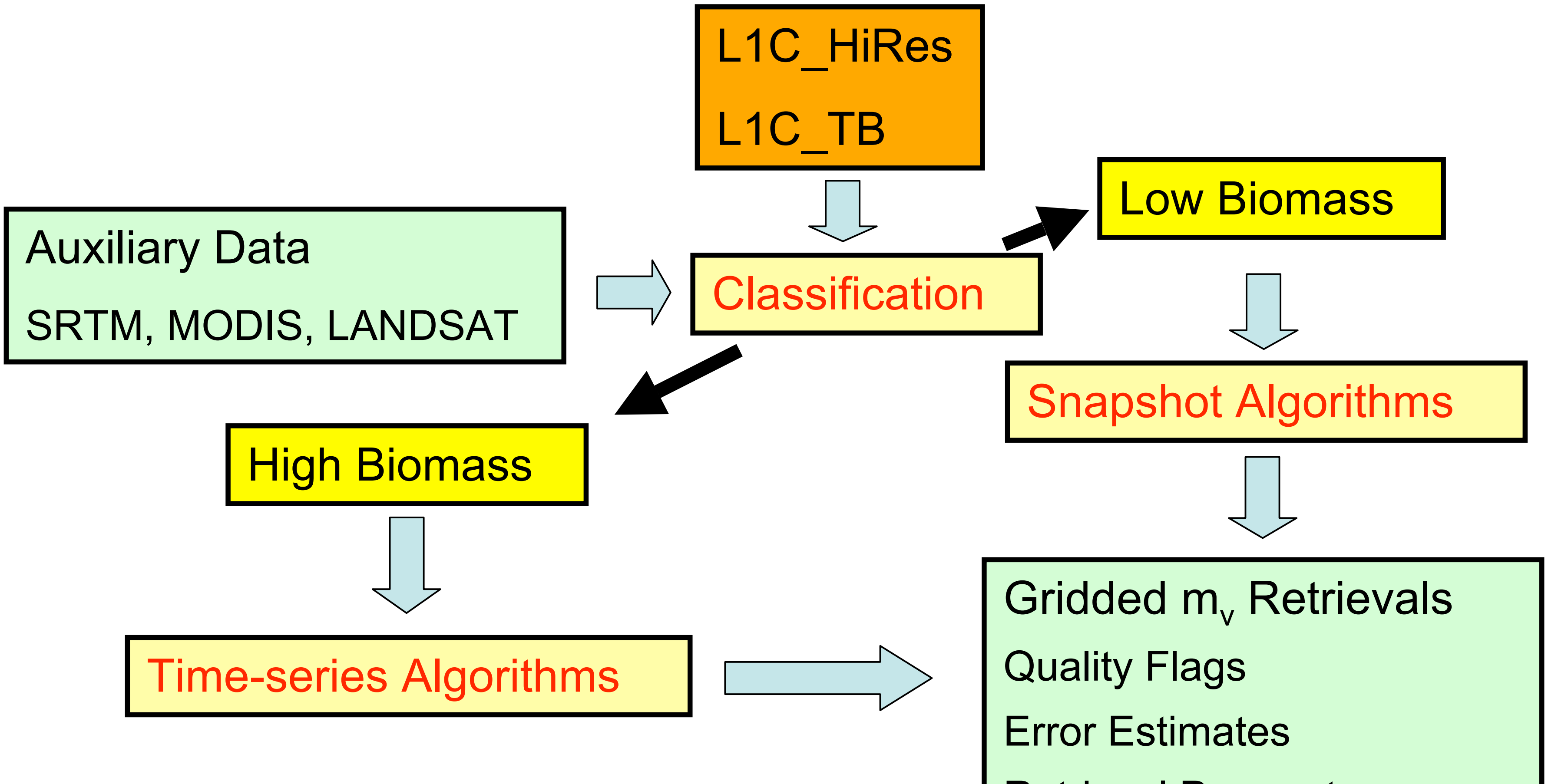
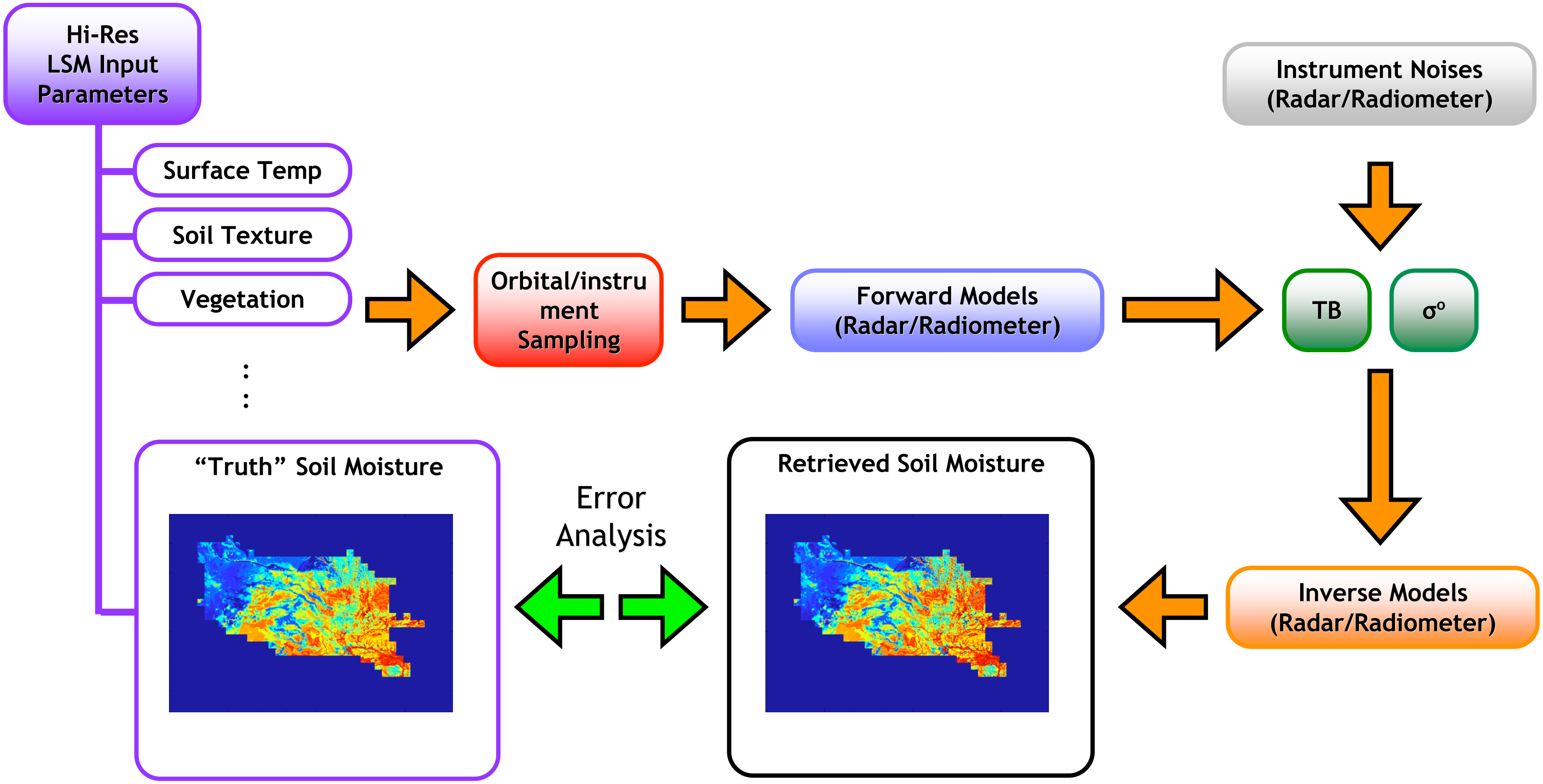
Hi-Res Processing Flow Chart

(UCSB Radar Workshop, 2005)



Benchmark is to improve upon the Hi-Res soil moisture estimated by assigning Lo-Res soil moisture to Hi-Res pixels

SMAP Algorithm Development Testbed



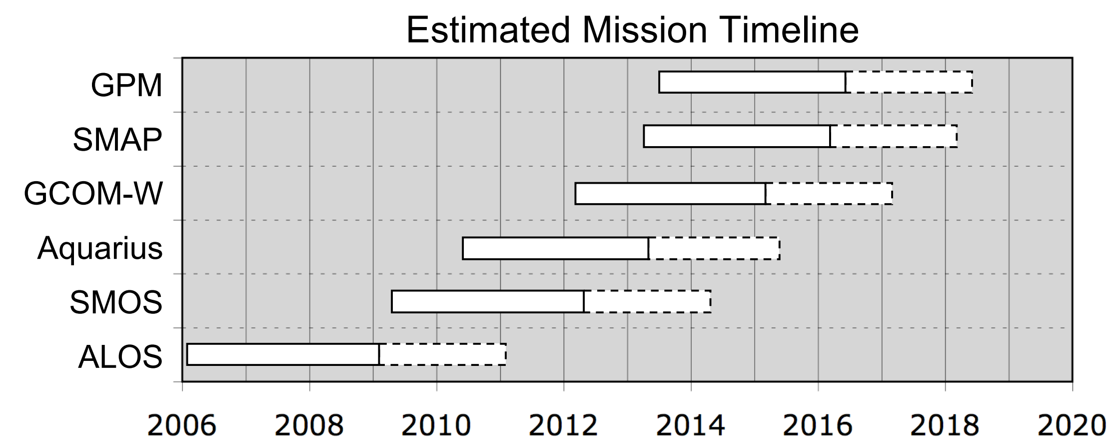
Science Organization and Roles

- Science Team Leader (D. Entekhabi, MIT), Project Scientist (E. Njoku, JPL), Deputy Project Scientist (P. O'Neill, GSFC) approved by NASA/Hq
- Science Transition Team (STT) in place through Sept 2008 (Hydros heritage)
- ROSES mechanism for selection of science teams beyond STT
  - Science Definition Team (SDT) will be in place until launch minus 1 year
    - Proposals due July 29, 2008; Selections in September 2008
    - Provides science guidance, requirements, trade studies and plans (algorithm development, cal/val, applications, data utilization)
  - Science Team (ST) will be in place from launch minus 1 year through end of mission
    - Provides cal/val and science analysis, data utilization and applications
- Level 1-4 algorithm software development and integration done through project at JPL and GSFC

Phase A Science Activities

- Work in progress:
  - Update draft documents: Level-1 Requirements, Algorithm Testbed, Cal/Val Plan and Validation Metrics, Applications Development Plan
  - Refine baseline and minimum mission science justification
  - Refine measurement error budgets and algorithm trades
  - Meetings: April 10, 2008 at JPL; July 6, 2008 in Boston, MA; October 2008, Oxnard, CA
- Conduct SMAPEX08 experiment in August to October 2008 to assess RFI suppression techniques and acquire data for active/passive algorithm studies (azimuthal and spatial scaling effects, forested areas)
- Deliverables:
  - Draft Level-2 Science Requirements Document by August 2008
  - Draft Algorithm Theoretical Basis Documents (ATBDs) and Science Validation Plan by SRR/MDR (December 2008)

Synergy with Other Missions



- SMAP provides continuity for L-band measurements of ALOS, SMOS, and Aquarius, and synergy with GPM and GCOM-W
- SMAP 1-3 km, 2-3 day, global L-band multi-polarization data provide potential for expanded microwave applications – similar to MODIS value for optical-IR
- SMAP soil moisture and co-orbiting GPM precipitation data will enable improved surface flux estimates and flood forecasts
- SMAP also benefits GPM by providing surface emissivity information for improved precipitation retrievals

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Summary

- The SMAP instrument/mission concept has evolved as a consequence of the requirements for soil moisture and freeze/thaw measurements of desired accuracy, spatial resolution, temporal revisit, and length of record, in addressing water, energy, and carbon cycle science and applications

- Remaining issues:
  - How can we best incorporate the evolving state of the art of microwave modeling and retrieval algorithms for utilizing the mission/instrument concept that has evolved for SMAP?
  - What activities need to be started now and implemented according to the mission schedule to have robust retrieval algorithms and data utilization applications developed for SMAP by launch?

- These issues are part of the subject of the Microwave Land Hydrology Workshop to be held in Oxnard, CA, Oct 20-22, 2008 (http://microwave-workshop.jpl.nasa.gov)