

# The Soil Moisture Active and Passive Mission (SMAP)

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***Canadian SMAP Applications and Cal/Val Workshop***
*Montreal, Canada, October 6-7, 2009*

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# SMAP Mission Context


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

SMAP is one of four Tier-1 missions recommended by the NRC Earth Science Decadal Survey for launch in the 2010–2013 time frame

- SMAP is one of two new start missions initiated by NASA in FY08
- Target launch date for SMAP is in 2014-2015 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 |

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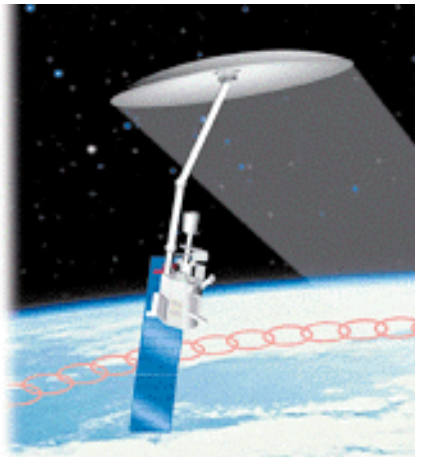
# Mission History

## SMAP leverages off previous Earth Science projects

- Aquarius project is currently in Phase C (2010 Launch)
  - Sea Surface Salinity Mission
  - Similar partnering arrangement (JPL lead with GSFC supporting)
  - L-Band Radar/Radiometer instrument
- Hydros project (discontinued in 2005 due to funding availability)
  - Soil Moisture Mission (with Canadian involvement)
  - Identical instrument approach: L-Band Radar/Radiometer with 6-meter spinning antenna
  - Professor Dara Entekhabi (MIT) was Principal Investigator (SMAP SDT Lead)
  - Conducted early Phase A risk reduction activities: soil moisture retrieval capabilities studies; antenna stability/performance studies
  - NASA investments in Hydros are directly applicable to SMAP

Aquarius



Hydros

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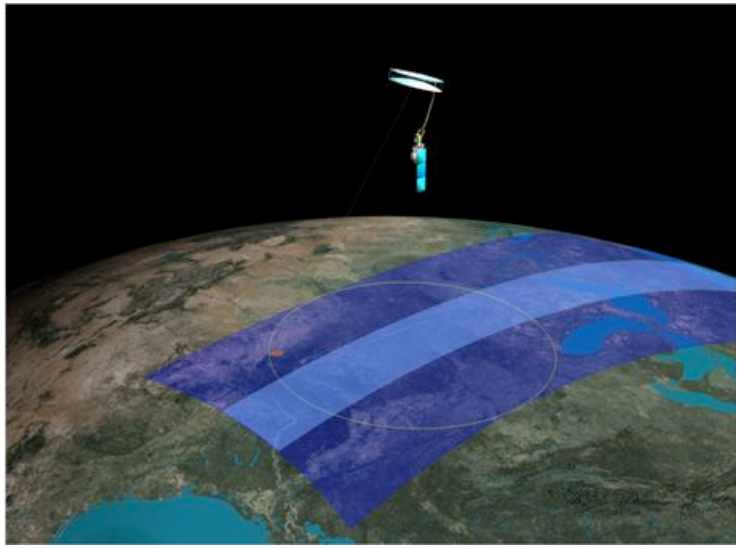
# SMAP Measurement Approach

- Instruments:
  - Radar: L-band (1.26 GHz)
    - High resolution, moderate accuracy soil moisture
    - Freeze/thaw state detection
    - SAR mode: 3 km resolution
    - Real-aperture mode: 30 x 6 km resolution
  - Radiometer: L-band (1.4 GHz)
    - Moderate resolution, high accuracy soil moisture
    - 40 km resolution
  - 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 revisit



- Orbit:
  - Sun-synchronous, 6 am/pm orbit
  - 680 km altitude
- Mission Operations:
  - 3-year baseline mission

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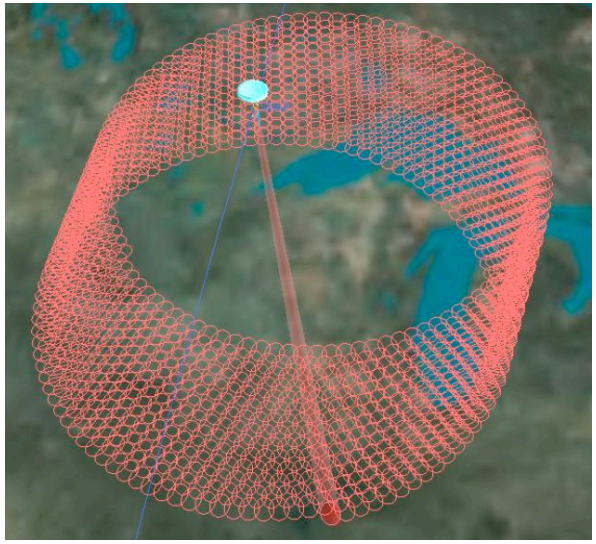
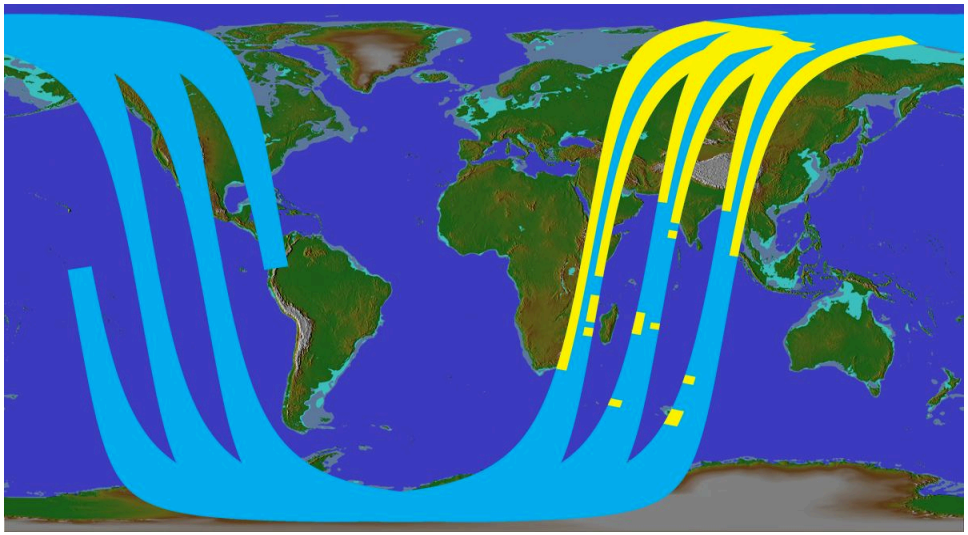
# SMAP Data Acquisition

- Radiometer data collected continuously:
  - Entire orbit.
  - All 360 degrees of antenna scan (both forward and aft).
  - Capability for periodic “cold sky” looks.
- High-resolution SAR data:
  - Collected only on forward arc of scan
  - Collected only on decending (AM) portion of orbit
  - Collected only over land (using built-in land mask file).
- Radar low-resolution, real aperture data
  - Collected continuously like radiometer data; entire orbit, 360 deg





**3 Sample SMAP Orbits**

Radiometer and Low-Res Radar

High-Res Radar

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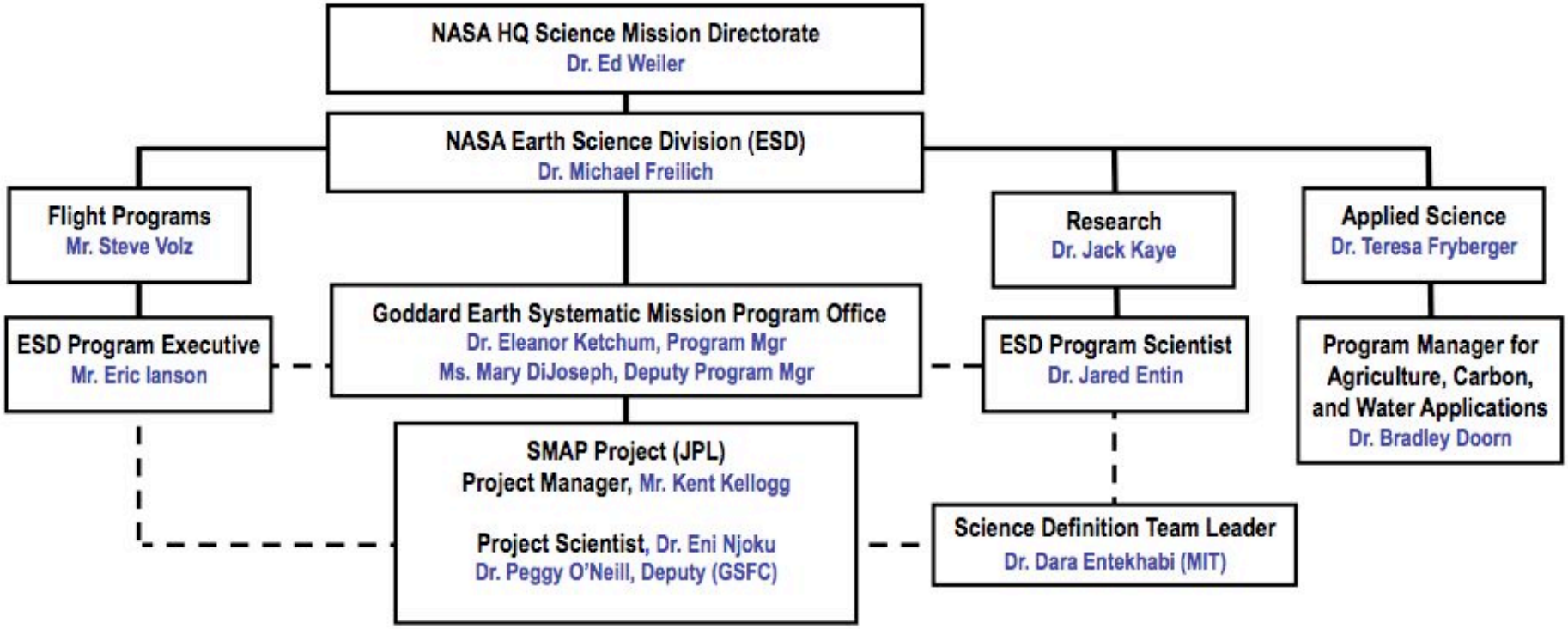
# SMAP Project Programmatic Reporting



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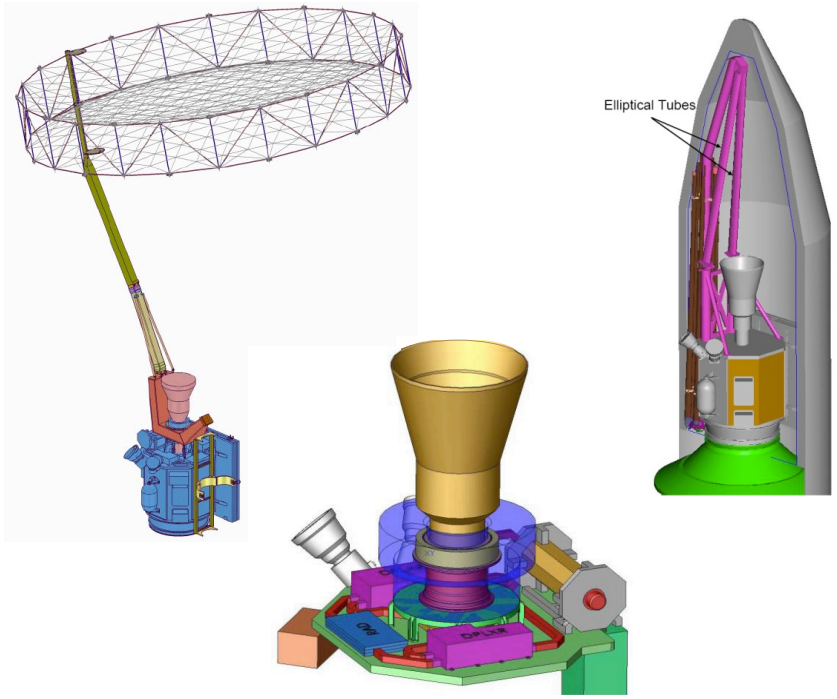
# Mission Implementation Overview

- Mission partners: JPL and GSFC
  - JPL provides overall mission management, Project Manager, Project Scientist, radar, and radar L1 algorithms
  - GSFC provides Deputy Project Scientist, radiometer, and radiometer L1 algorithms
- Science Team selected competitively by NASA
- Instrument lead: JPL
  - JPL provides Radar
  - GSFC provides Radiometer
  - Shared antenna, spin assembly procured from industry by JPL
- L3 and L4 Science data processing shared between JPL and GSFC




- Mission operations uses JPL's Earth Science Mission Operations infrastructure
  - Communications: NASA GN & SN

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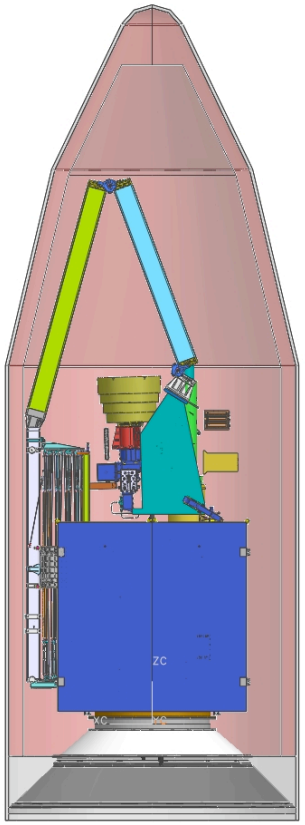
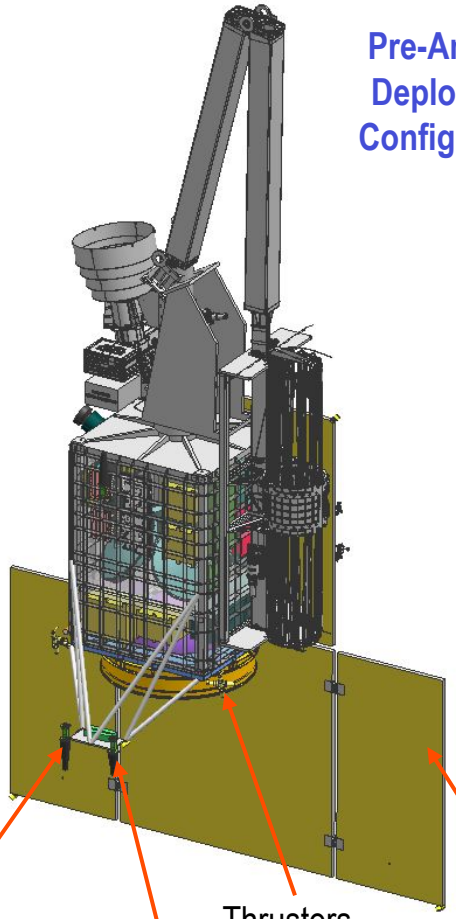
# Flight System Overview



Launch Configuration

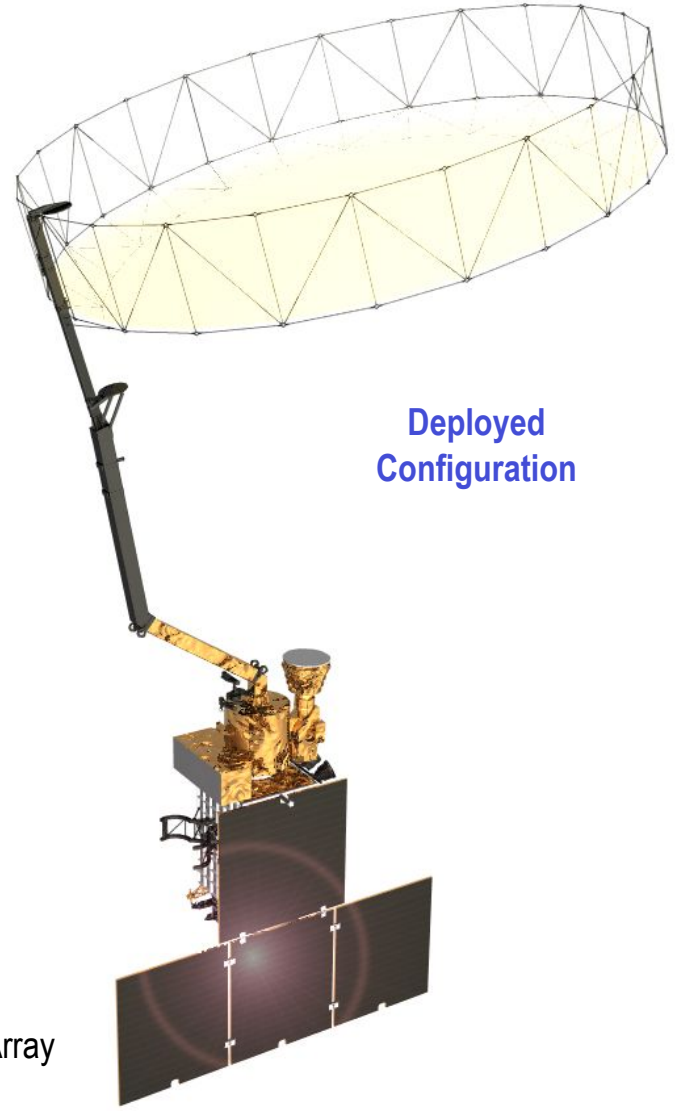


Pre-Antenna Deployment Configuration

S and X-band LGA

Thrusters clusters

4 panels,
6.5 $m^2$ Solar Array



Deployed Configuration

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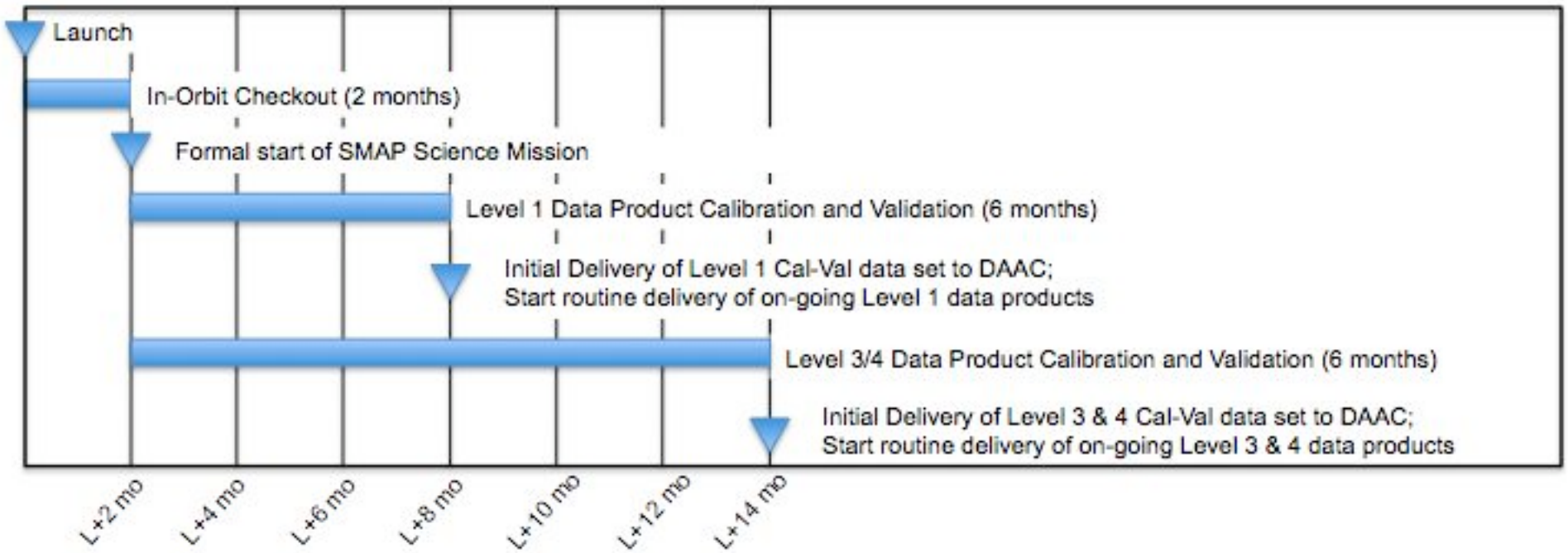
# Data Availability After Launch

- After In-Orbit Checkout (IOC) period, data product Cal/Val will be completed
  - 6 months for Level 1 products
  - 12 months for Levels 3 and 4
- During the data cal/val phase, data product distribution will be limited to SDT and Cal/Val team
- After each product's Cal/Val period, data will be publically available through a NASA-designated archive (DAAC)



# Project Support to Users of SMAP Data

- The SMAP Project strongly encourages the use of its data products by all scientific and operational and applications communities.
  - NASA, the SMAP Project and the SDT are taking steps to insure data product utility to the broadest science and applications communities

- Applications development and application-specific data flow provisions (such as near real time data delivery) that require deviation from capability required to meet science mission requirements cannot be implemented under direct (NASA) Project funds

- In the event such capability is required by users, the Project *can* explore working on a cost reimbursable basis to accommodate the additional capability or functionality *(caveat: that such capability does not interfere with or compromise meeting science mission requirements)*

# Project Status

- Project is continuing in formulation (Phase A)
  - Successfully completed first major gate review last February (System Requirements Review/Mission Definition Review/Preliminary Non-Advocate Review)
  - NASA & Project working to resolve funding profile, overall cost & launch date
  - Project expects to formally transition into Preliminary Design Phase (Phase B) at the start of the calendar year
- Contracts for Instrument Spin Mechanism Assembly and Reflector-Boom Assembly have been placed
- Proceeding with development of key instrument elements (radiometer, radar transmitter)
- Conducted field campaign last fall to provide data to assess RFI environment and to enable testing of algorithms
- Algorithm testbed has been established

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# Science Activities

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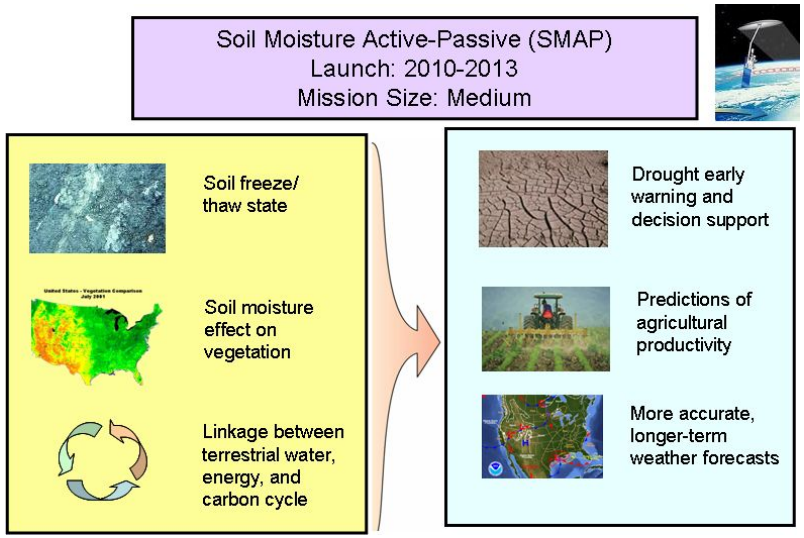
# SMAP Level 1 Science Requirements Derivation




- SMAP is unique because its measurements are relevant to a wide range of Earth sciences and their applications
- Disciplinary Decadal Survey panels cited SMAP applications

| Decadal Survey Panels # | Cited SMAP Applications |
|---|---|
| 1. Water Resources and Hydrological Cycle | 1. Floods and Drought Forecasts<br>2. Available Water Resources Assessment<br>3. Link Terrestrial Water, Energy and Carbon Cycles |
| 2. Climate / 3. Weather | 1. Longer-Term and More Reliable Atmospheric Forecasts |
| 4. Human Health and Security | 1. Heat Stress and Drought<br>2. Vector-Borne and Water-Borne Infectious Disease |
| 5. Land-Use, Ecosystems, and Biodiversity | 1. Ecosystem Response (Variability and Change)<br>2. Agricultural and Ecosystem Productivity<br>3. Wild-Fires<br>4. Mineral Dust Production |

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# SMAP Level 1 Science Requirements

| DS Objective | Application | Science Requirement |
|---|---|---|
| Weather Forecast | Initialization of Numerical Weather Prediction (NWP) | Hydrometeorology |
| Climate Prediction | Boundary and Initial Conditions for Seasonal Climate Prediction 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 |

| Requirement | Hydro-Meteorology | Hydro-Climatology | Carbon Cycle | Baseline Mission | | Minimum Mission | |
|---|---|---|---|---|---|---|---|
| | | | | Soil Moisture | Freeze/Thaw | Soil Moisture | Freeze/ Thaw |
| 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(1) | 3 days | 2 days(1) | 3 days | 3 days(1) |
| Accuracy | 4–6% ** | 4–6%** | 80–70%* | 4%** | 80%* | 6%** | 70%* |

(*) % classification accuracy (binary Freeze/Thaw)
(**) % volumetric water content, 1-sigma

(1)North of 45N latitude

**Mission Duration Requirement:**
**3 Years Baseline; 18 Months Minimum**

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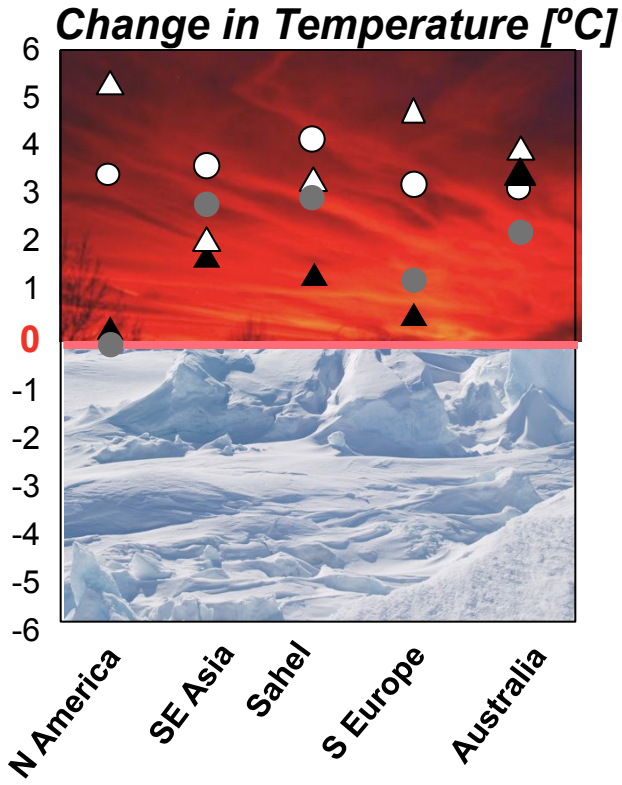
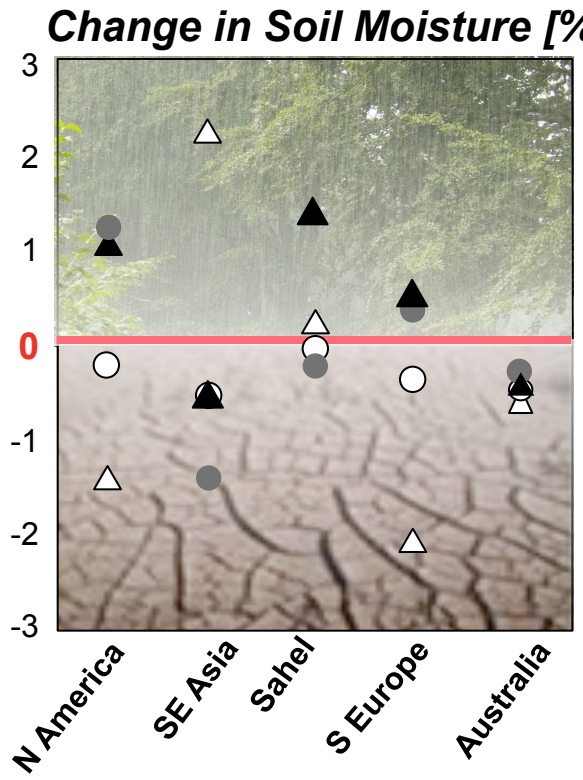
# SMAP Data Enable Reliable Estimates of Changes in Future Water Availability

**Change in water availability is a critical practical impact of global warming on society. How will global change affect water supply and food production?**

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

**Models agree on direction of temperature increase**




**Models *disagree* on whether there will be MORE or LESS surface water available compared to today**

Li et al., (2007): Evaluation of IPCC AR4 soil moisture simulations for the second half of the twentieth century, *Journal of Geophysical Research*, 112.

- **Without SMAP data we cannot tell which hydrology models are accurate.**
- **With SMAP data we would be able to make more reliable determination of future changes in available water.**

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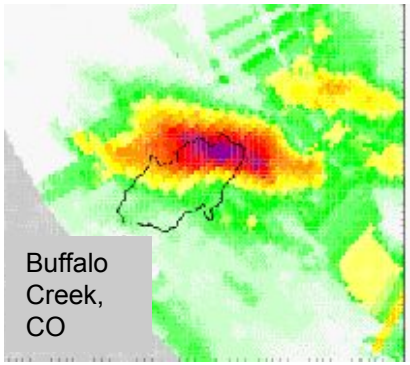
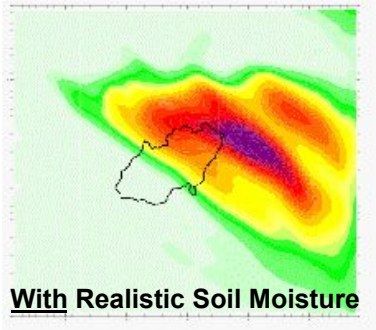
# Improved Weather & Climate Predictions

SMAP data will improve numerical weather prediction (NWP) over continents by more accurately initializing land surface states

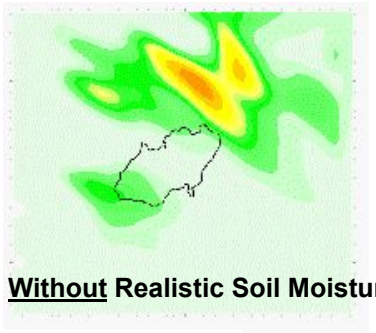



**Observed Rainfall**
0000Z to 0400Z 13/7/96

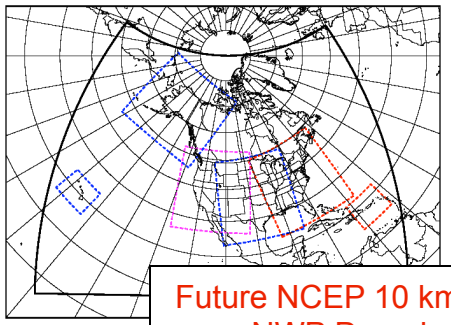
24-Hours Ahead Atmospheric Model Forecasts



**With Realistic Soil Moisture**



**Without Realistic Soil Moisture**



Future NCEP 10 km NWP Domains

SMAP will provide 10 km soil moisture data product to help meet operational user needs

Major operational weather centers linked to SMAP:

- **NOAA Weather** (NCEP)
- **Environment Canada**
- ECMWF
- **Air Force Weather**
- **NOAA Climate**

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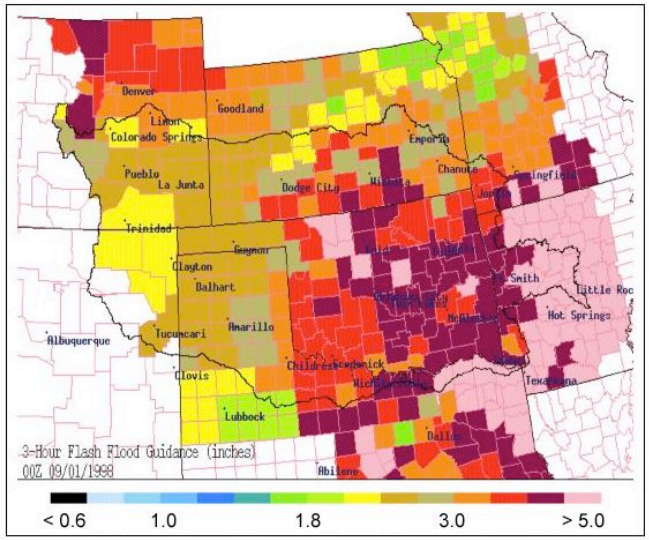
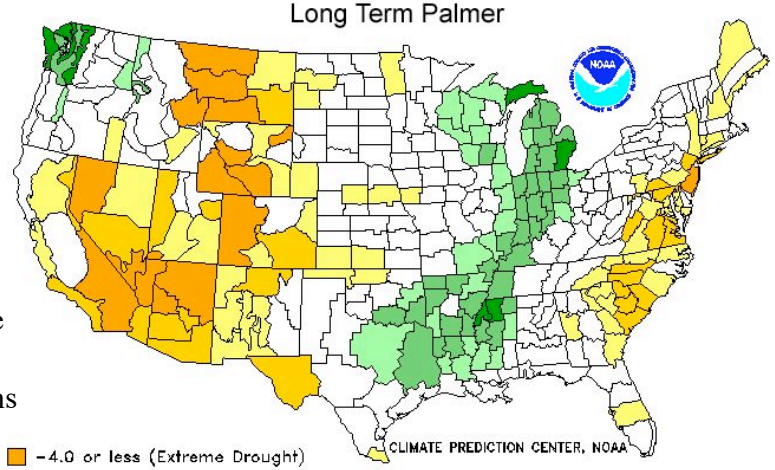
# Extreme Events (Floods and Droughts)

NWS Operational 3-Hour Flash Flood Guidance (Inches)
00Z 09/01/98




Drought Severity Index by Division
Weekly Value for Period Ending 13 APR 2002
Long Term Palmer




Close Ties:
Soil Moisture
Users and
Collaborations

*Model-based estimates of soil moisture deficit produced by NOAA for operational flash-flood guidance and drought monitoring will be augmented by SMAP observations of soil moisture*

NCEP NSIPP NASA ECMWF NOAA CPC

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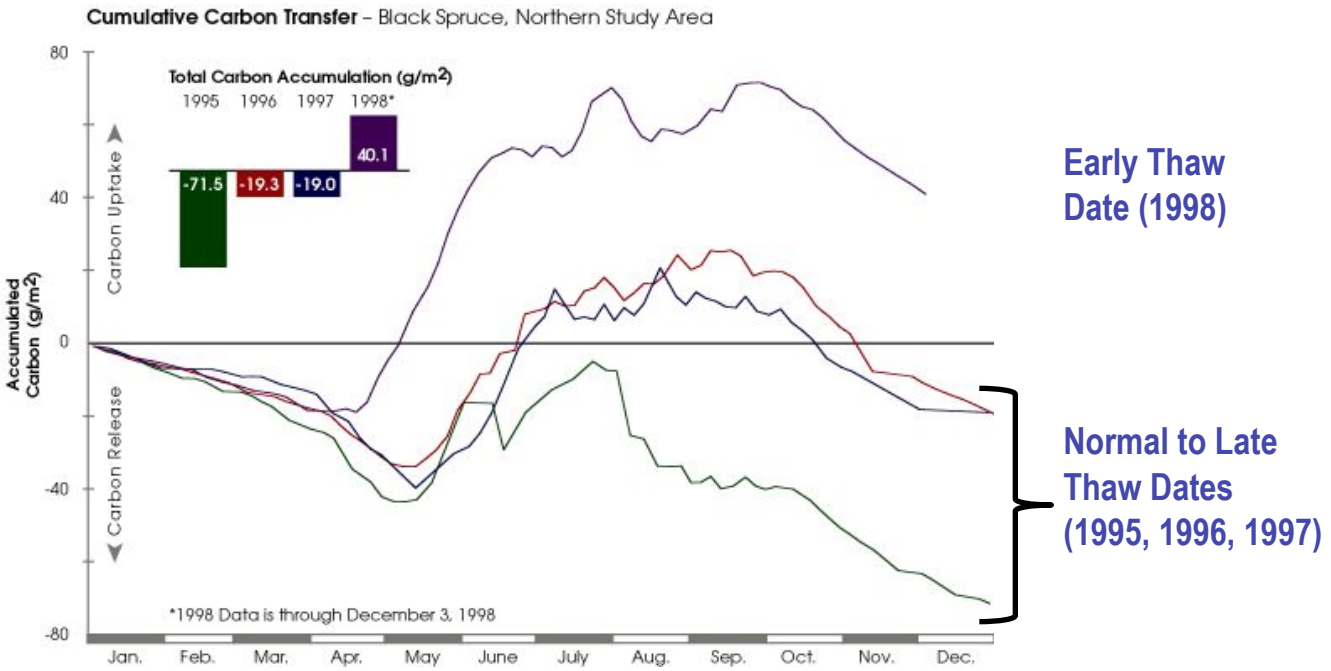
# Carbon Dioxide Exchange




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*.

The 'missing carbon': Depending on freeze/thaw date, same location can be a net source or net sink of carbon.

SMAP freeze/thaw measurements will help reduce errors in the closing of carbon budget.

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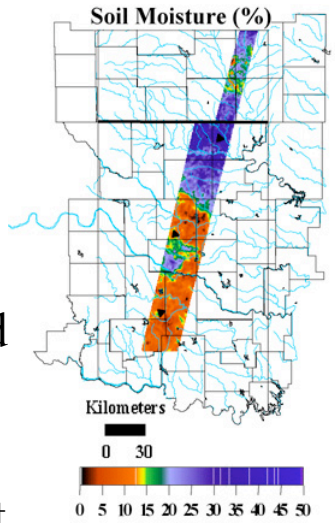
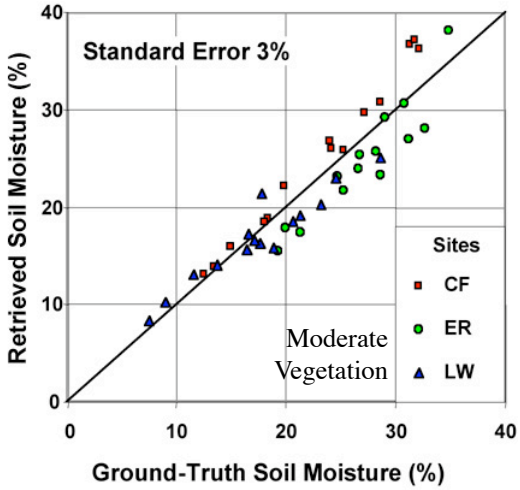
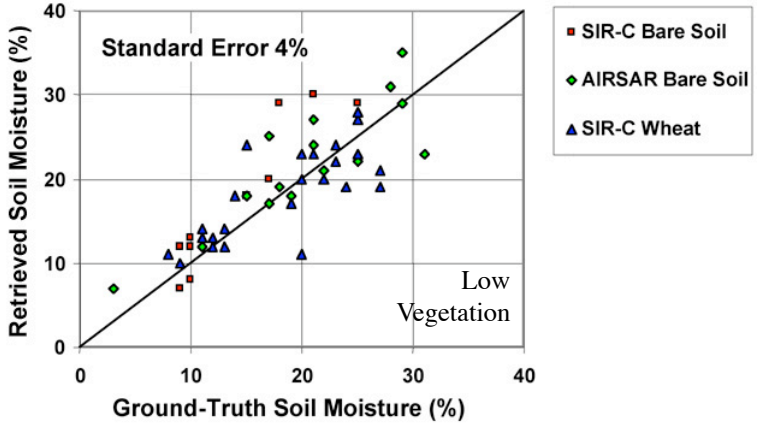
# L-band Active/Passive Approach

- Soil moisture retrieval algorithms are derived from a heritage of L-band microwave modeling and field experiments
  - MacHydro'90, Monsoon'91, Washita'92, FIFE, HAPEX, SGP'97,'99, SMEX'02–'05
- **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
- Algorithm approach demonstrated in Hydros risk-reduction & SMAP Phase A; development extended in testbed simulations and field campaigns (SMAPVEX'08, '11)



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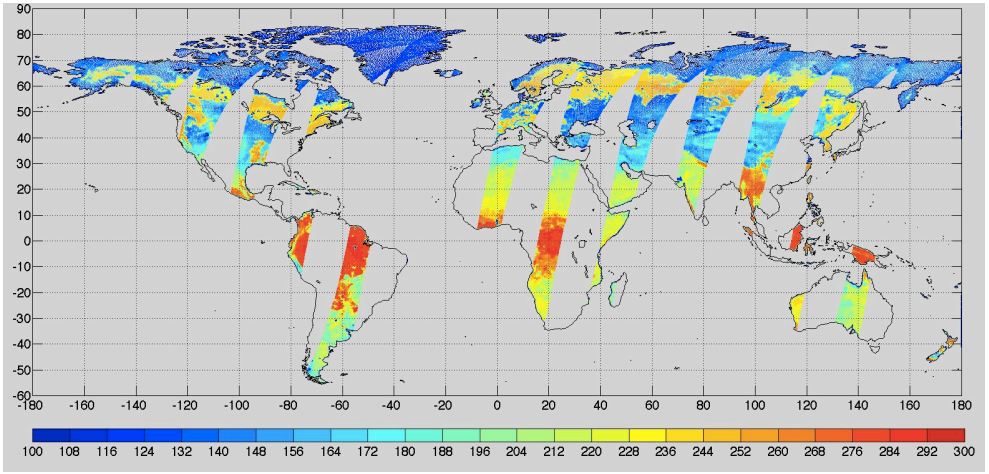
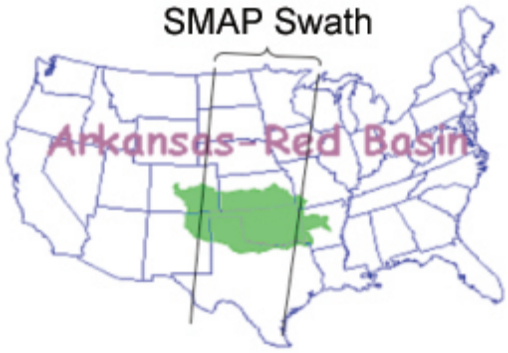
# Science Algorithm & Data Product Development

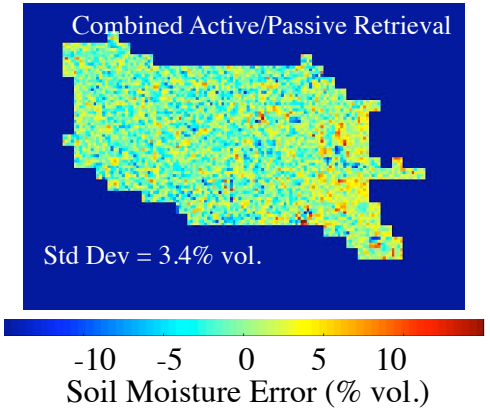
- Algorithm simulations are conducted regionally and globally to investigate effects of sensor noise, vegetation, and landscape heterogeneity on retrieval error

- Algorithms are also tested using field campaign data from airborne (PALS) and truck-based systems (COMRAD)

**Simulated SMAP 1.4 GHz H-pol, desc. pass, one-day coverage**
(3-dB FOV sampled at 5 km)



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# SMAP Baseline Science Data Products

| Data Product | Description | Spatial Resolution | Latency* |
|---|---|---|---|
| L1B_S0_LoRes | Low Resolution Radar $\sigma^o$ in Time Order | 30 km | 12 hours |
| L1C_S0_HiRes | High Resolution Rada $\sigma^o$ on Earth Grid | 1–3 km | 12 hours |
| L1B_TB | Radiometer $T_B$ in Time Order | 40 km | 12 hours |
| L1C_TB | Radiometer Brightness $T_B$ on Earth Grid | 40 km | 12 hours |
| L3_F/T_HiRes | Freeze/Thaw State on Earth Grid | 3 km | 24 hours |
| L3_SM_HiRes | Radar Soil Moisture (internal product) | 3 km | ------- |
| L3_SM_40km | Radiometer Soil Moisture on Earth Grid | 40 km | 24 hours |
| L3_SM_A/P | Radar/Radiometer Soil Moisture on Earth Grid | 10 km | 24 hours |
| L4_C | Carbon Net Ecosystem Exchange on Earth Grid | 10 km | 14 days |
| L4_SM | Surface & Root Zone Soil Moisture on Earth Grid | 10 km | 7 days |

*** The SMAP Project will make a best effort to reduce the data latencies beyond those shown in this table.**

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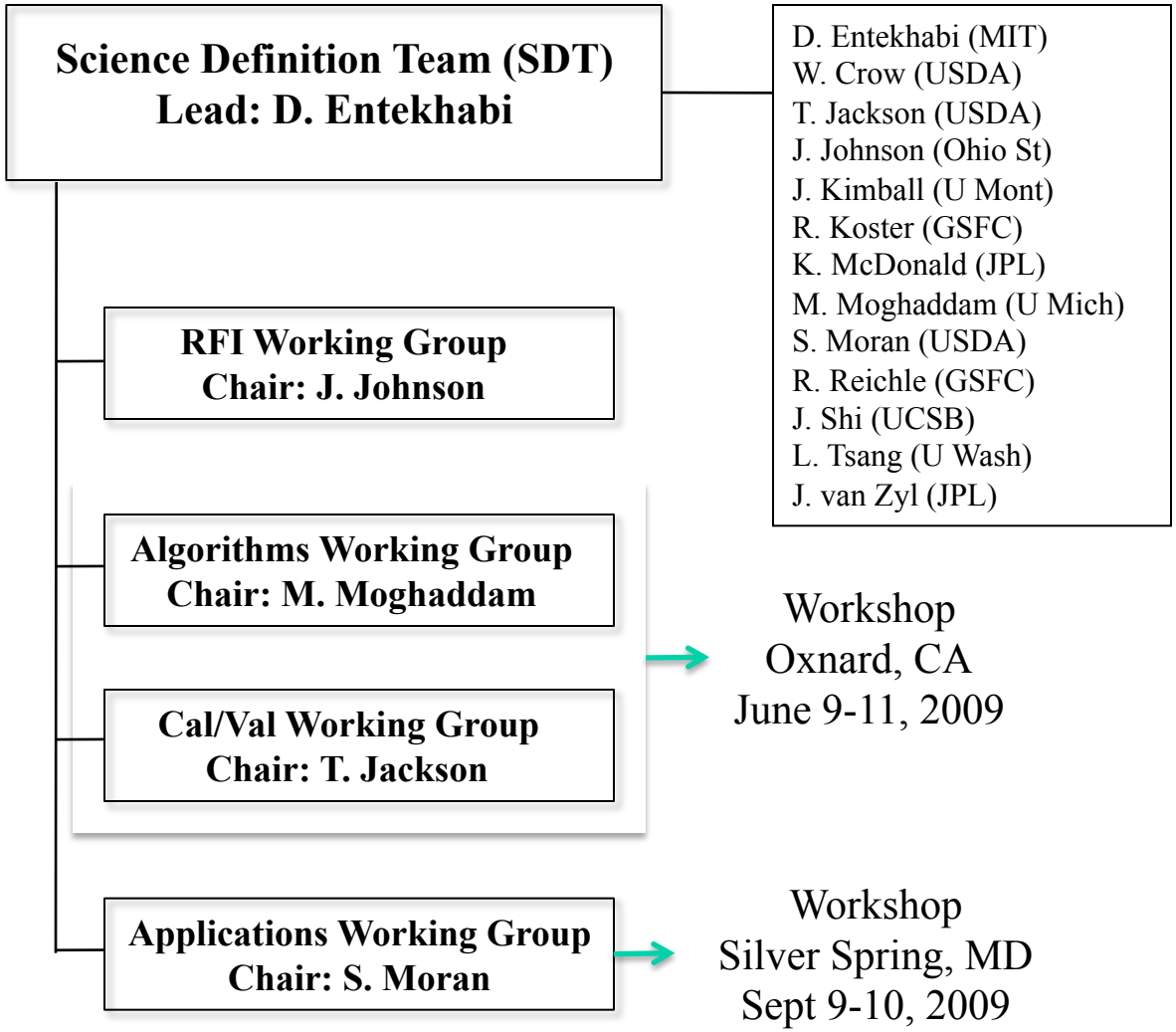
# SMAP SDT Working Groups

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

- Working Groups established to enable broad community participation in the SMAP mission
- Provide forums for interaction on issues related to SMAP science and applications
- Communicate via email and at meetings, conference sessions, workshops, and other venues



# Summary

- Two community workshops were held in 2009:
  - Algorithms & Cal/Val Workshop: June 9-11, 2009, Oxnard, CA
  - Applications Workshop: September 9-10, 2009, Silver Spring, MD

- SMAP Applications Plan is being prepared (draft: November, 2009)
- SMAP Cal/Val Plan is available (draft)
  - Draft Plan will be updated to incorporate inputs from:
    - Canadian SMAP Workshop
    - Ongoing SMAP Cal/Val Working Group activities (In Situ Testbed, Core Sites)
    - Other international programs and missions (SMOS, Aquarius)