Soil Moisture Focus Group

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Outline (Part 1)

- GCOS requirements for soil moisture
- Global soil moisture products
- CEOS LPV validation stage of product (your view)
- Summary/list of product accuracy as published in literature and corresponding references
- Main problems of referenced work and future validation
- Status of promised GCOS action item contributions (if any)

GCOS Requirements for Soil Moisture

- Product T.11 Global near-surface soil moisture maps (up to 5 cm soil depth)
- GCOS target requirements for the Soil Moisture ECV (Volumetric Soil Moisture)
  - Accuracy 0.04 m3/m3
  - Horizontal resolution 50 km
  - Temporal resolution Daily
  - Stability 0.01 m3/m3 per year
- Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)" December 2011 GCOS – 154

GCOS Requirements for Soil Moisture

- Main climate application
  - Soil moisture has an important influence on land-atmosphere feedbacks at climate time scales, in particular, because it has a major effect on the partitioning of incoming radiation into latent and sensible heat and on the allocation of precipitation into runoff, subsurface flow and infiltration. Changes in soil moisture have a serious impact on agricultural productivity, forestry, and ecosystem health. Monitoring soil moisture is critical for managing these resources.
- Contributing Network(s) **
  - International Soil Moisture Network (ISMN) (http://ismn.geo.tuwien.ac.at/)
- Contributing Network(s) Status **
  - The ISMN has been identified as the Global Terrestrial Network for Soil Moisture (GTN-SM). Currently funded by ESA. Long-term funding needs to be secured.
- Contributing Satellite Data
  - Active and passive microwave missions (e.g. ASCAT, AMSR-2, SMOS, etc.)
- Contributing Satellite Data Status
  - ASCAT fully operational with continuity on Post-EPS guaranteed. Also for multi-frequency microwave radiometers like AMSR-2 the long-term availability seems to be secured. Continuity of research missions (SMOS, SMAP) TBD.
- Current capability
  - In situ soil moisture data are provided by individual networks and for users with global interests by the International Soil Moisture Network (ISMN). Several satellite soil moisture data services are now operational (ASCAT, SMOS, AMSR-2, ..). ASCAT soil moisture data are available in near-real-time (NRT) suited for NWP applications. Recently, the ESA CCI soil moisture project has released the first long-term soil moisture data record obtained by merging active and passive microwave data.

Requirements for Soil Moisture at Surface

Requirements defined for *Soil moisture at surface* (8)

This tables shows all related requirements. For more operations/filtering, please consult the full list of Requirements

Note: In reading the values, goal is marked blue, breakthrough green and threshold orange

Id	Variable	Layer	App Area	Uncertainty	Stability / decade	Hor Res	Ver Res	Obs Cyc	Timeliness	Coverage	Conf Level	Val Date	Source
222	Soil moisture at surface	Land surface	GEWEX	0.01 m^3/m^3 0.02 m^3/m^3 0.05 m^3/m^3		15 km 50 km 250 km		24 h 3 d 10 d	10 d 15 d 30 d	Global land	tentative	1998-10-29	WCRP
301	Soil moisture at surface	Land surface	Global NWP	0.02 m^3/m^3 0.04 m^3/m^3 0.08 m^3/m^3		5 km 15 km 100 km		3 h 24 h 5 d	3 h 24 h 5 d	Global land	reasonable	2013-01-22	Erik Andersson
377	Soil moisture at surface	Land surface	High Res NWP	0.02 m^3/m^3 0.04 m^3/m^3 0.08 m^3/m^3		1 km 5 km 40 km		60 min 3 h 6 h	30 min 60 min 6 h	Global land	reasonable	2011-07-29	JF Mahfouf
407	Soil moisture at surface	Land surface	Hydrology	0.01 m^3/m^3 0.017 m^3/m^3 0.05 m^3/m^3		0.01 km 0.3 km 250 km		24 h 34 h 3 d	24 h 5 d 144 d	Global land	reasonable	2003-10-20	ET ODRRGOS
447	Soil moisture at surface	Land surface	Nowcasting / VSRF	0.01 m^3/m^3 0.02 m^3/m^3 0.05 m^3/m^3		5 km 10 km 50 km		60 min 6 h 24 h	60 min 6 h 24 h	Global land	reasonable	2013-04-03	P. Ambrosetti
49	Soil moisture at surface	Land surface	Agricultural Meteorology	0.01 m^3/m^3 0.017 m^3/m^3 0.05 m^3/m^3		0.1 km 0.215 km 1 km		24 h 46 h 7 d	24 h 41 h 5 d	Global land	reasonable	2003-10-20	ET ODRRGOS
574	Soil moisture at surface	Land surface	SIA	0.01 m^3/m^3 0.02 m^3/m^3 0.05 m^3/m^3		50 km 100 km 500 km		24 h 2 d 7 d	24 h 2 d 7 d	Global land	reasonable	2009-01-19	Laura Ferranti
678	Soil moisture at surface	Land surface	Climate-TOPC	0.005 m^3/m^3 0.007 m^3/m^3 0.01 m^3/m^3		50 km 60 km 100 km		7 d 11 d 30 d	360 d 1 y 2 y	Global land	speculative	2007-07-19	TOPC

Satellite Surface Soil Moisture Requirements (Global Numerical Weather Prediction)

Requirement	Threshold	GCOS Target	Goal	Breakthrough
Horizontal Resolution	100 km	50 km	15 km	5 km
Vertical Resolution	10 cm	5 cm	5 cm	Profile distribution
Observing Cycle	5 days	24 hours	24 hours	3 hours
Delay	5 days	24 hours	24 hours	3 hours
Accuracy (RMSE)	0.08 m3/m3	0.04 m3/m3	0.04 m3/m3	0.02 m3/m3

- This table is based on the info presented in previous slides but is the opinion of the presenter.

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Global Satellite-based Soil Moisture Products

Product Name	Source	Period of Record	Spatial Resolution (km)	Validation Stage	
ERS SCAT	ERS SCAT	1992-2010	25/50	3	Active Microwave
ASCAT	ASCAT	2006-	25/50	3	Active Microwave
NASA Standard	AMSR-E	2002-2011	40	3	Passive Microwave
LPRM	AMSR-E	2002-2011	40	3	Passive Microwave
JAXA	AMSR-E	2002-2011	40	3	Passive Microwave
JAXA GCOM-W	AMSR2	2012-	40	1	Passive Microwave
SMOS	SMOS	2009-	40	3	Passive Microwave
Aquarius	Aquarius	2011-	100	2	Passive Microwave
CCI	AMSR-E, ASCAT, etc.	1978-	0.25°	2	Active/Passive Microwave

Global Satellite-based Soil Moisture Products

Product Name	Source	Sensor Characteristics	Data Access Point
ERS SCAT	ERS SCAT		
ASCAT	ASCAT		
NASA Standard	AMSR-E		
LPRM	AMSR-E		
JAXA	AMSR-E		
JAXA GCOM-W	AMSR2		
SMOS	SMOS		
Aquarius	Aquarius		
CCI	AMSR-E, ASCAT, etc.		

Global Satellite-based Soil Moisture Products

- Mission/Product continuity
- Exploiting historic data sets
- JAXA involvement should be promoted

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Soil Moisture Validation/Accuracy

Data source						Soil moisture product		
Instru- ment	**Platform**	**Type**	**Band**	**Coverage**	**Availability**	**Spatial resolu- tion (km)**	**Temporal resolution (days)**	**Accuracy**
AMSR-E	EOS/Aqua	radiometer (passive)	C / X / Ku / Ka	global	2002–2011	~10–57	1–3	~0.050–0.148 m3/m3 (Champagne et al. 2010, de Jeu et al. 2008, Draper et al. 2007, Gruhier et al. 2008, Wagner et al. 2007a, Wagner et al. 2007b)
WindSat	Coriolis	radiometer (passive)	X / K / Ka	global	2003–now	~10–53	1–2	4% (Li et al. 2010a)
TMI	TRMM	radiometer (passive)	X / Ka	±38° lati- tude	1998–now	~32–50	1–3	2.5% (Bindlish et al., 2003)
SSM/I	DMSP F08 – F15	radiometer (passive)	Ku / Ka	global	1987–now	~15–70	1–3	~5.49% (Wen et al. 2005)
SMMR	Nimbus-7	radiometer (passive)	C / X / Ka	global	1978–1987	~27–150	1–6	N/A
ASCAT-A	Metop-A	scatterome- ter (active)	C	global	2006–now	~25–37	1–2	~0.035–0.060 m3/m3 (Albergel et al.,2009, Brocca et al. 2010)
ERS Scat- terometer	ERS-1, ERS-2	scatterome- ter (active)	C	global	1991–2011	~25–45	2–7	~0.022–0.084 m3/m3 (Drusch et al. 2004, Pellarin et al. 2006, Scipal 2002, Wag- ner et al. 2007a, Wagner et al. 1999, Wagner et al. 2007b)

From: Annex L to EOEP-STRI-EOPG-SW-11-0001: Soil Moisture ECV (Soil_Moisture_cci) ESA, Dec. 2011 Statement of Work

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Some of the Current Major Drivers for Soil Moisture Validation

- ESA CCI
  - Focuses on existing products
- NASA SMAP
  - Focus on incorporating best practices into mission validation

ESA Essential Climate Variables Climate Change Initiative-Soil Moisture

- Part of the ESA Programme on Global Monitoring of Essential Climate Variables (ECV), better known as the Climate Change Initiative (CCI), initiated in 2010 for a period of 6 years.
  - The CCI Programme wants to contribute to the data bases collecting ECVs required by GCOS (Global Climate Observing System) and other international parties.
  - R. Hollmann, et al. "The ESA Climate Change Initiative: Satellite Data Records for Essential Climate Variables"; Bulletin of the American Meteorological Society, 94 (2013), 10; 1541 - 1552.
- Overall objective of the project is to produce the most complete and most consistent global soil moisture data record based on active and passive microwave sensors.
- Plan
  - 2012: Engagement of the climate modelling community, definition of product specifications and algorithms selection
  - 2013: System prototyping and ECV production
  - 2014: Final production and user assessment
- Activities
  - Round Robin Exercise
  - Satellite Soil Moisture Validation & Application Workshop(s)

Round Robin for Soil Moisture Algorithm Comparison and Product Validation

- Objectives
  - Inform and engage the international scientific community in the CCI activities.
  - Identifying the most appropriate algorithms for soil moisture retrieval.
- Intercomparison exercises can be seen as a sign of maturity of the product.
- The Round Robin exercise allows comparing different algorithms and provides insight into their capacity to meet the targeted criteria defined in the Product Specification Document.
- Two separate exercises will be carried out.
  - Scatterometer measurements
  - Passive algorithms

Satellite Soil Moisture Validation & Application Workshop July 1-3, 2013 Frascati, Italy: Overview

- Objective: Discuss and reconcile recent methodological advances in the validation and application of global satellite soil moisture data.
  - Focus on soil moisture products derived from current and future active and passive microwave sensors operating in the low frequency range from 1 to 10 GHz.
- Goal: Collect material for a white paper on "Best practice guidelines for the validation of satellite soil moisture data using in situ data hosted by the International Soil Moisture Network (ISMN)"
  - Contribution to GEWEX, CEOS, TOPC, and WMO.
- Themes
  - Satellite soil moisture products - Status and algorithmic improvements
  - In-situ soil moisture networks and campaigns
  - Calibration and validation - Towards best practice guidelines
  - Methodological advances in data assimilation
  - Hydro-meteorological applications
  - Climate change science studies
  - Emerging soil moisture applications

Satellite Soil Moisture Validation & Application Workshop July 1-3, 2013 Frascati, Italy: Summary Comments

Generation of ECV data records – ESA's CCI and beyond

- Follow and apply the standards agreed by the "climate" community.
- Longest possible homogenous record needed.
- Provide the two different data sets - active and passive – separately complementing the merged product.
- It would be useful to have complementary high quality data sets covering shorter periods, e.g. passive microwave TMI, AMSR, AMSR-2, SMOS.
- CCI products shall include best possible error characterizations.
- The SM ECV should be "model-free", i.e. output from numerical land surface models shall not be used.
- There is the need for consistent auxiliary data sets not only within an ECV but also across different ECVs. In practice, this is difficult to achieve but at least be aware of the issue.
- No root zone product from surface soil moisture needed.
- It would be good to have additional initiatives complementing the CCI.
- TB records shall be kept for re-processing

Satellite Soil Moisture Validation & Application Workshop July 1-3, 2013 Frascati, Italy: Summary Comments

Recommendations for the In Situ Validation Networks

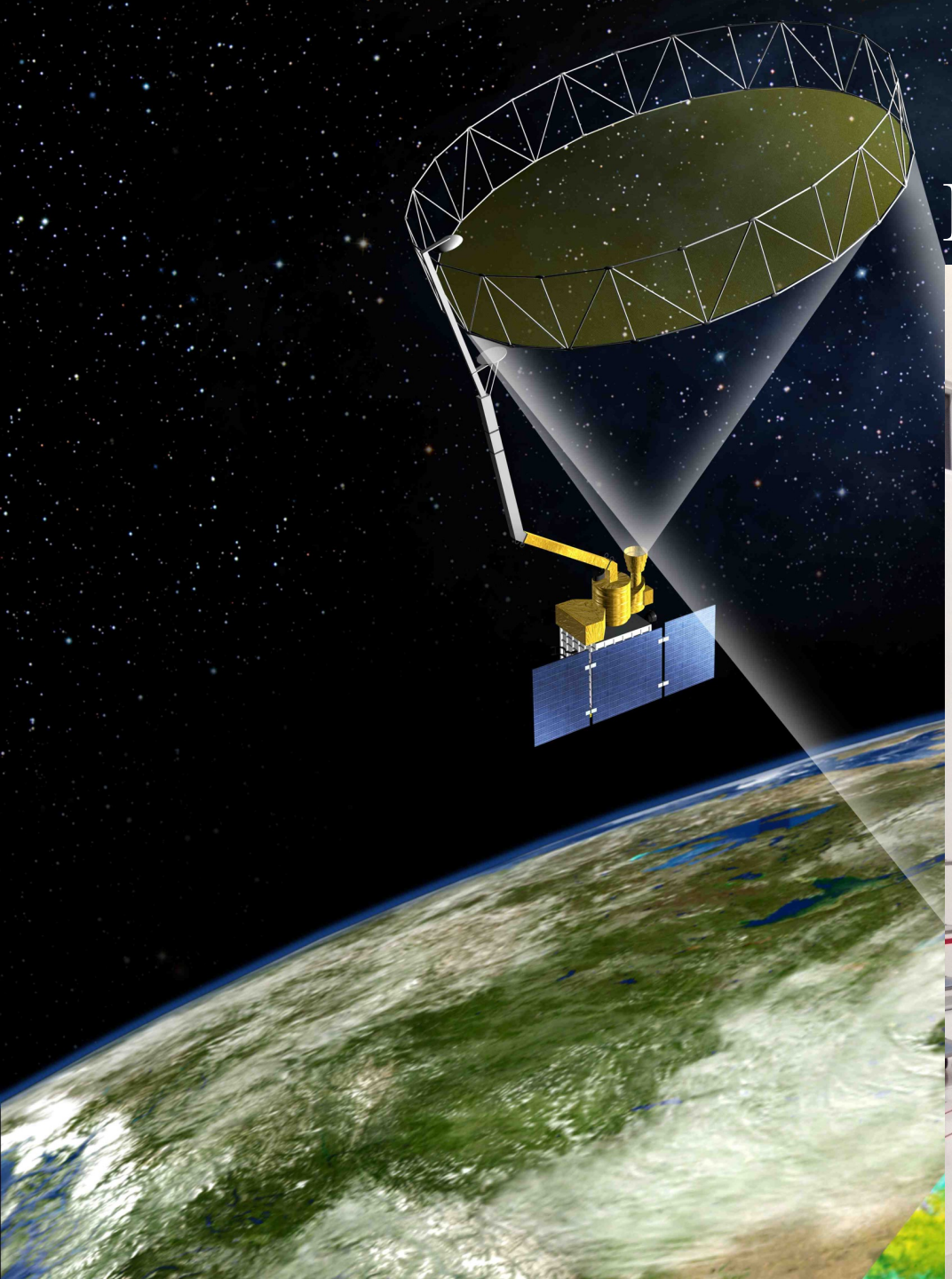
- More dense networks that provide spatial information for high resolution footprints (SMAP, Sentinel-1, etc.) are needed; need for good definitions for set up of stations.
- A Best Practice Guidance for the implementation of new in situ networks would be highly desirable
- Need for information on spatial heterogeneity/spatial representativeness for each in situ station as point information is insufficient
- Need to get backing/involvement of WMO etc. even if this requires significant and unacknowledged effort
- Recommendations specific for the ISMN
  - The ISMN has many users and should be continued
  - Potential funding beyond SMOS: National, EUMETSAT, Copernicus?
  - A centralistic approach is preferred in order to guarantee the quality and consistency of the data base
  - Nonetheless, some community-based approaches should be considered, e.g. more automatic interfaces to the data providers or voluntary quality control
  - Improve data latency and keep on holding up free data access principle (no commercial use)

Satellite Soil Moisture Validation & Application Workshop July 1-3, 2013 Frascati, Italy: Summary Comments

Recommendations for Best Practices for Validation

- Validation with in situ data is only one aspect of the overall validation; need instructions for maintenance, data processing etc. (consensus)
- Require to identify a preferred set of metrics (but as a function of methodology); only politicians need one number
- SMAP (and SMOS) work on the basis of approved validation plans; no need for updates
  - Area-representative 5 cm in situ measurements is the reference
  - RMSE is the main metric
  - Can be calculated over validation core sites (stored locally)
- For ASCAT/H-SAF the main metric is R; discussion on alternative error metrics is encouraged
  - ASCAT Validation Tool: http://rs.geo.tuwien.ac.at/validation_tool/ascat.html
    - Scope of this tool are not yet clear but the group welcomes it for enhancing the transparency of the validation process
    - Open Source Validation Code Library (Python, well documented in the code itself) is expected to be of value for the community
- No recommendations for the proposed “Best Practice” paper

SMAP Status
Launch Nov. 5, 2014



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	

* Over outer 70% of swath.

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

SMAP Cal/Val Program

- Available on the SMAP website
  - http://smap.jpl.nasa.gov/
- Every effort was made to incorporate best practices and a wide range of methodologies
  - Incorporates CEOS and WGCV LPV guidance (i.e. Validation Stages)
  - Input from team and Cal/Val Working Group
  - Series of open workshops
  - Reviews

Level 1 Science Requirements

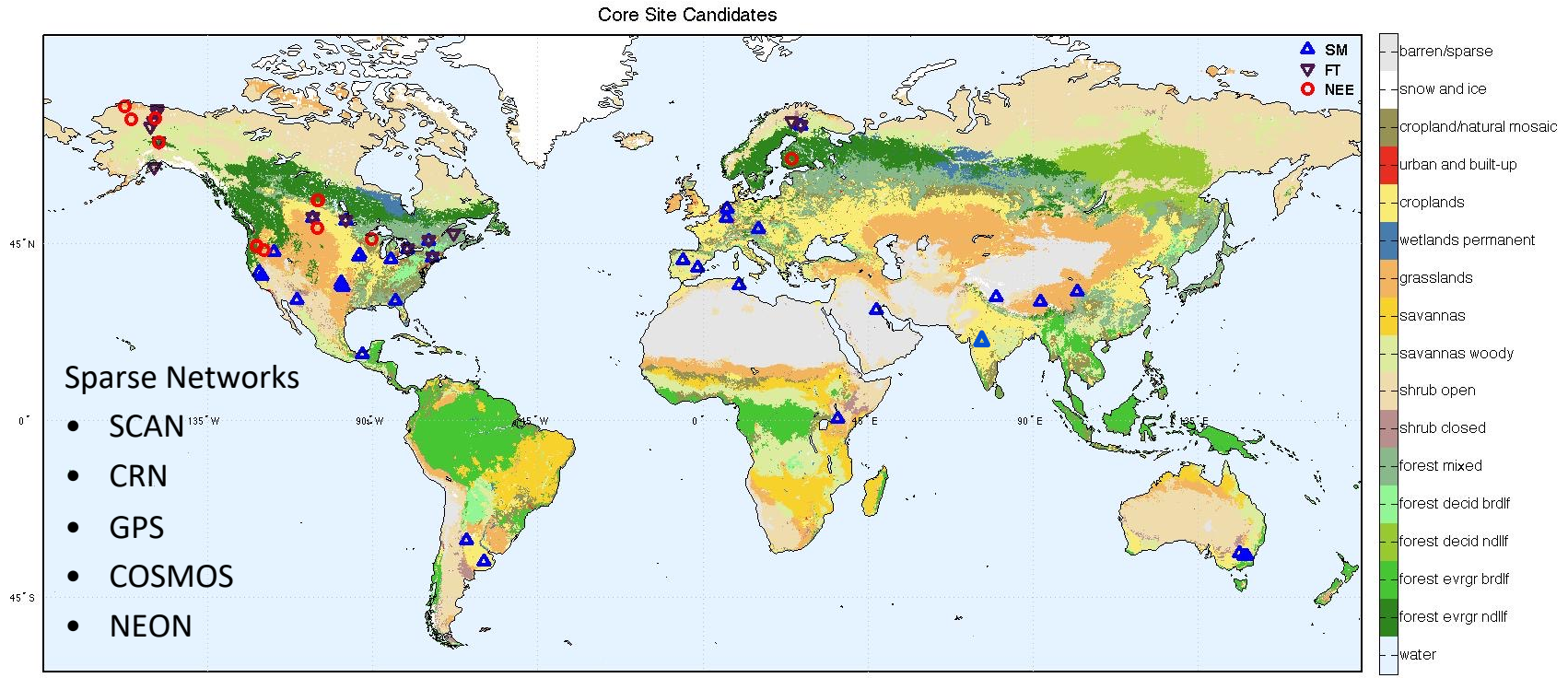
- The NSF Decadal Survey identified numerous potential applications for SM/FT observations.
- These were grouped into three categories with a spatial resolution, refresh rate, and accuracy.

Requirement	Hydro-Meteorology	Hydro-Climatology	Carbon Cycle	Baseline Mission		Threshold 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[a]	3 days	2 days	3 days	3 days
Accuracy	0.04-0.06 [c]	0.04-0.06 [c]	80–70% [b]	0.04 [c]	80%[b]	0.06 [c]	70%[b]
Mission Duration				36 months		18 months	

[a] North of 45N latitude, [b] Percent classification accuracy (binary freeze/thaw), [c] Volumetric water content, 1-σ in [cm^3/cm^3] units

- These are the L1 priority products and requirements. The define what the proposed mission must accomplish..
- The SMAP Project proposed the active-passive approach for meeting these requirements.

SMAP Core Validation Site Candidates



The current set of Partners covers a wide range of vegetation and climate conditions. There is still an opportunity for adding additional sites but these need to be fairly mature in order to be ready to go at launch.

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  - [IP-10 Action T13] Develop a record of validated globally-gridded near-surface soil moisture from satellites; (CCI)
  - [IP-10 Action T14] Develop Global Terrestrial Network for Soil Moisture (GTN-SM). (ISMN)