Soil Moisture Focus Group

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Outline (Part 2)

- Validation methods used for each product
  - Five methodologies (SMAP Examples)
- Most important (in situ) reference data set(s)
  - International Soil Moisture Network
  - USDA ARS Watersheds
  - JAXA Sites
- Dealing with
  - Spatial scale (in situ data representativeness at pixel scale, different spatial product resolutions, etc.),
  - Global representation of sites
  - Instrumentation and installations of in situ sites
  - Metrics used

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

SMAP L2-L4 Soil Moisture Product Validation Methodologies

Methodology	Role	Constraints	Resolution
Core Validation Sites	Accurate estimates of products at matching scales for a limited set of conditions	• In situ sensor calibration • Limited number of sites	• In Situ Testbed • Cal/Val Partners
Sparse Networks	One point in the grid cell for a wide range of conditions	• In situ sensor calibration • Up-scaling • Limited number of sites	• In Situ Testbed • Scaling methods • Cal/Val Partners
Satellite Products	Estimates over a very wide range of conditions at matching scales	• Validation • Comparability • Continuity	• Validation studies • Distribution matching
Model Products	Estimates over a very wide range of conditions at matching scales	• Validation • Comparability	• Validation studies • Distribution matching
Field Campaigns	Detailed estimates for a very limited set of conditions	• Resources • Schedule conflicts	• Airborne simulator • Partnerships

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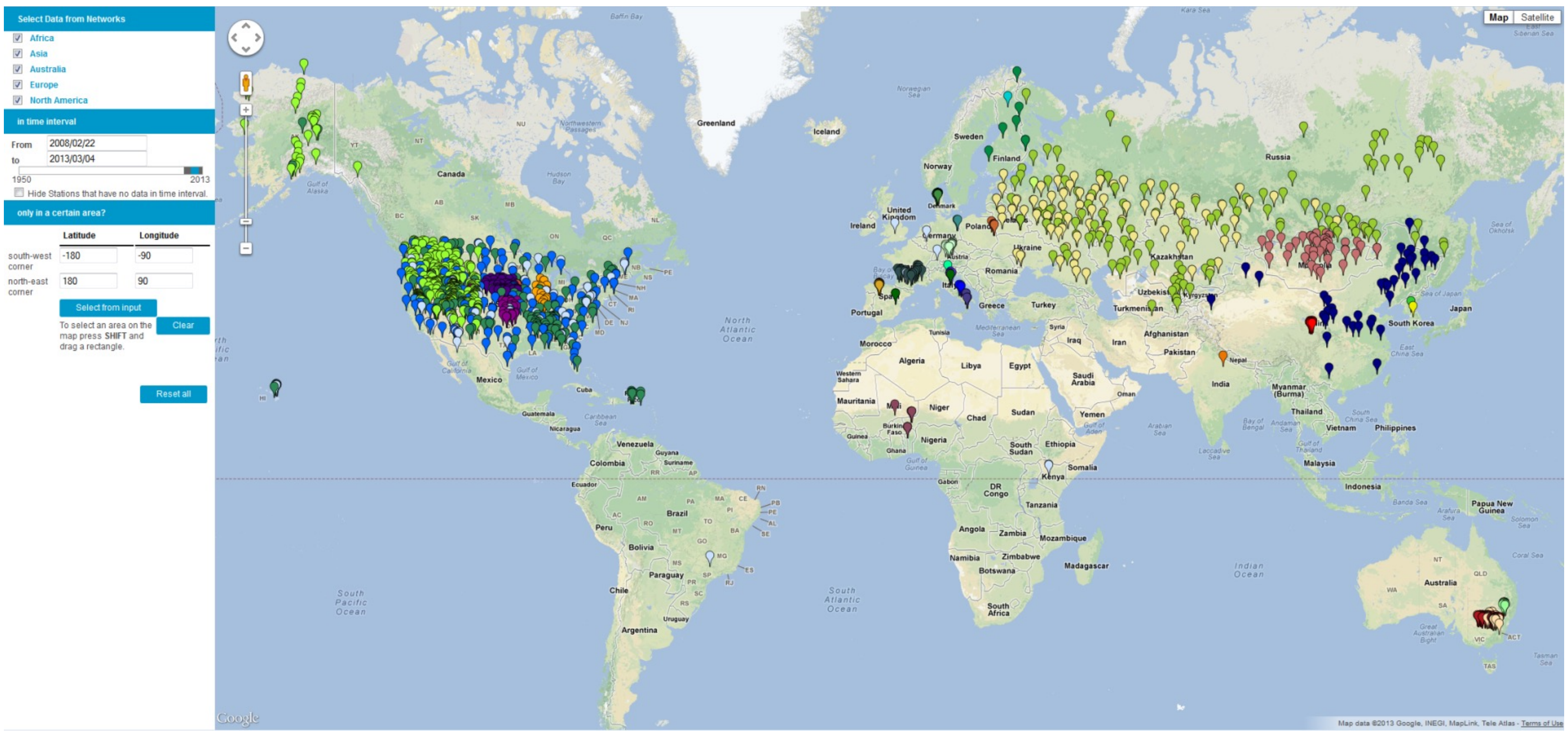
International Soil Moisture Network (ISMN)

- http://ismn.geo.tuwien.ac.at/

37 networks
~1500 stations
Period 1952 - now

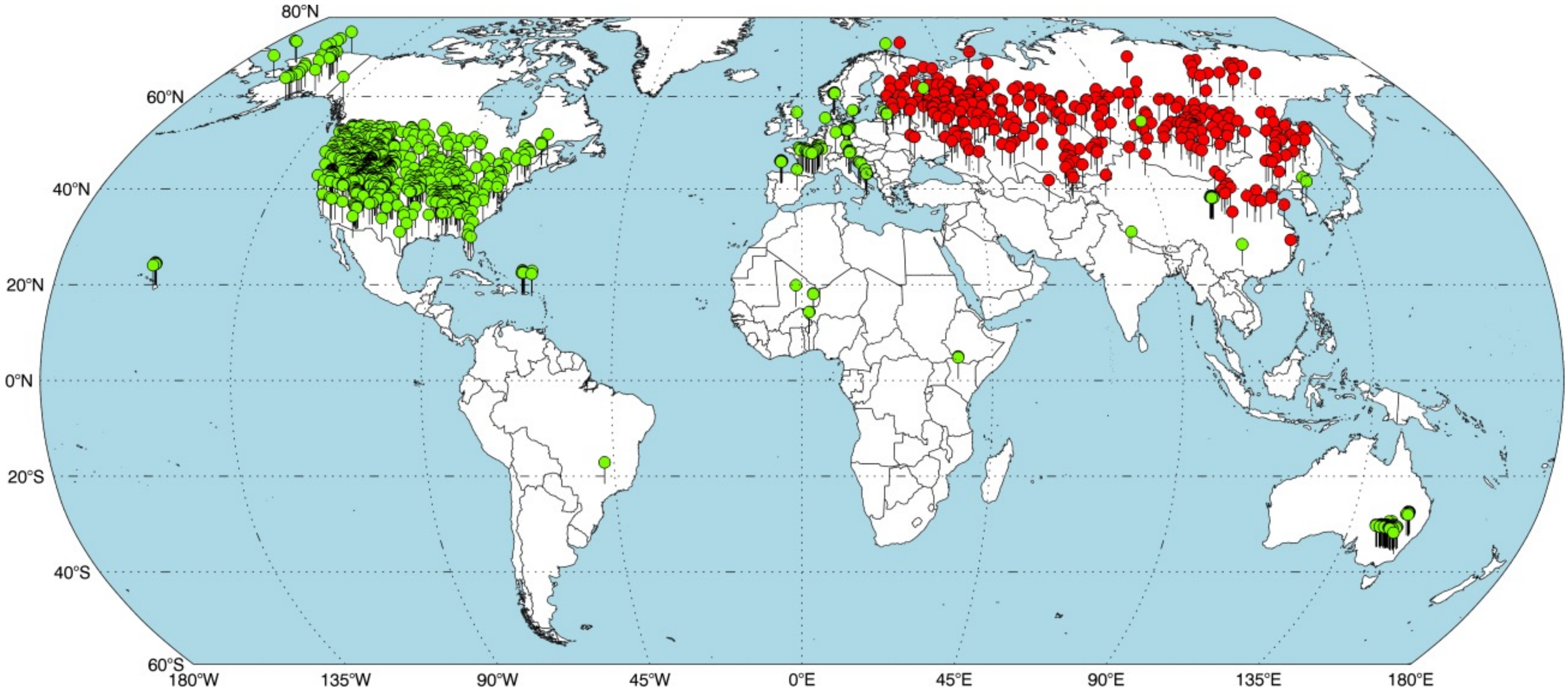


ISMN Recent Progress

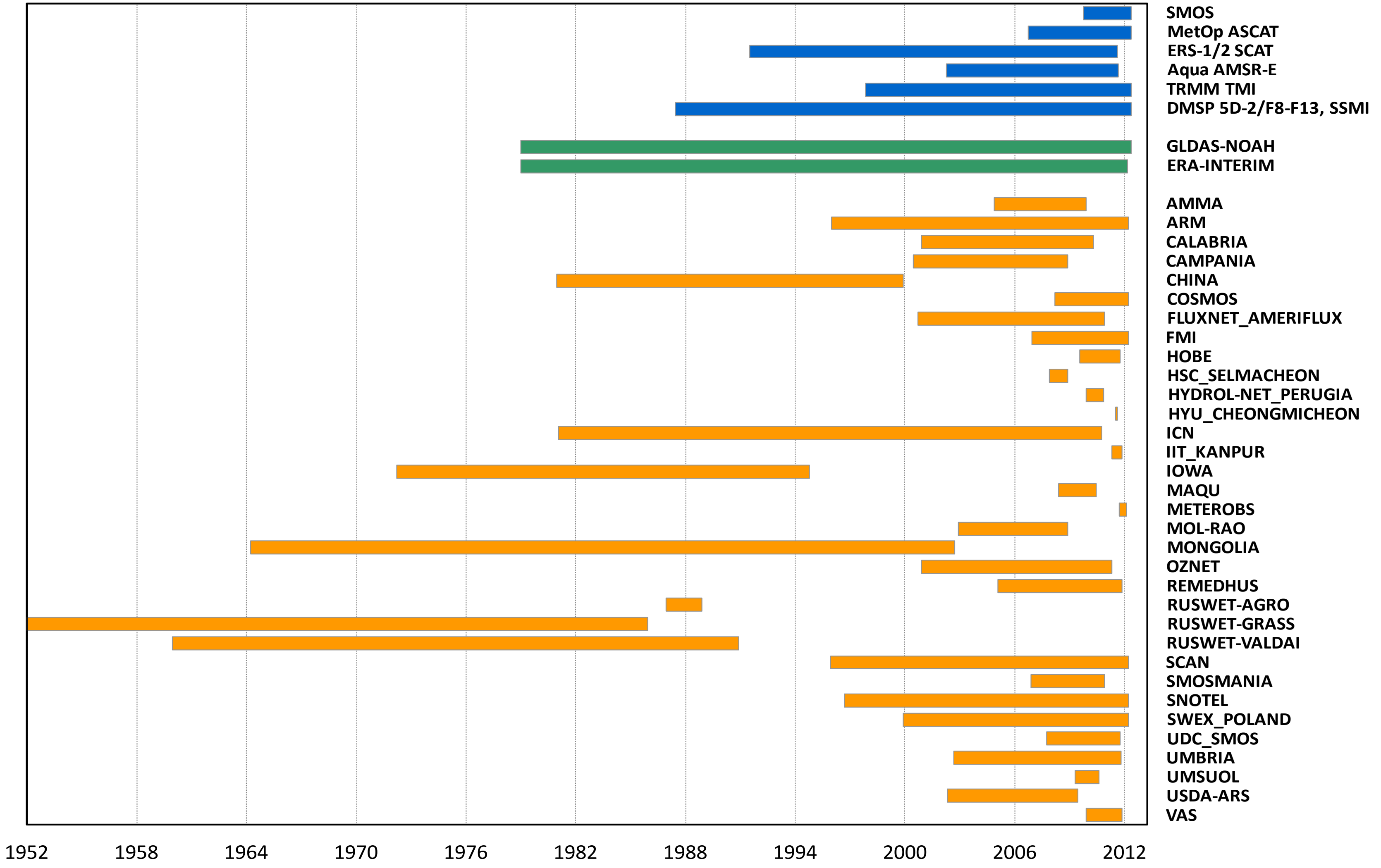
- Increase in number of networks/stations
- Most datasets updated automatically in NRT
- New quality control procedures and spatial representativeness measures developed

ISMN Spatiotemporal Availability

- Red = inactive Green = active

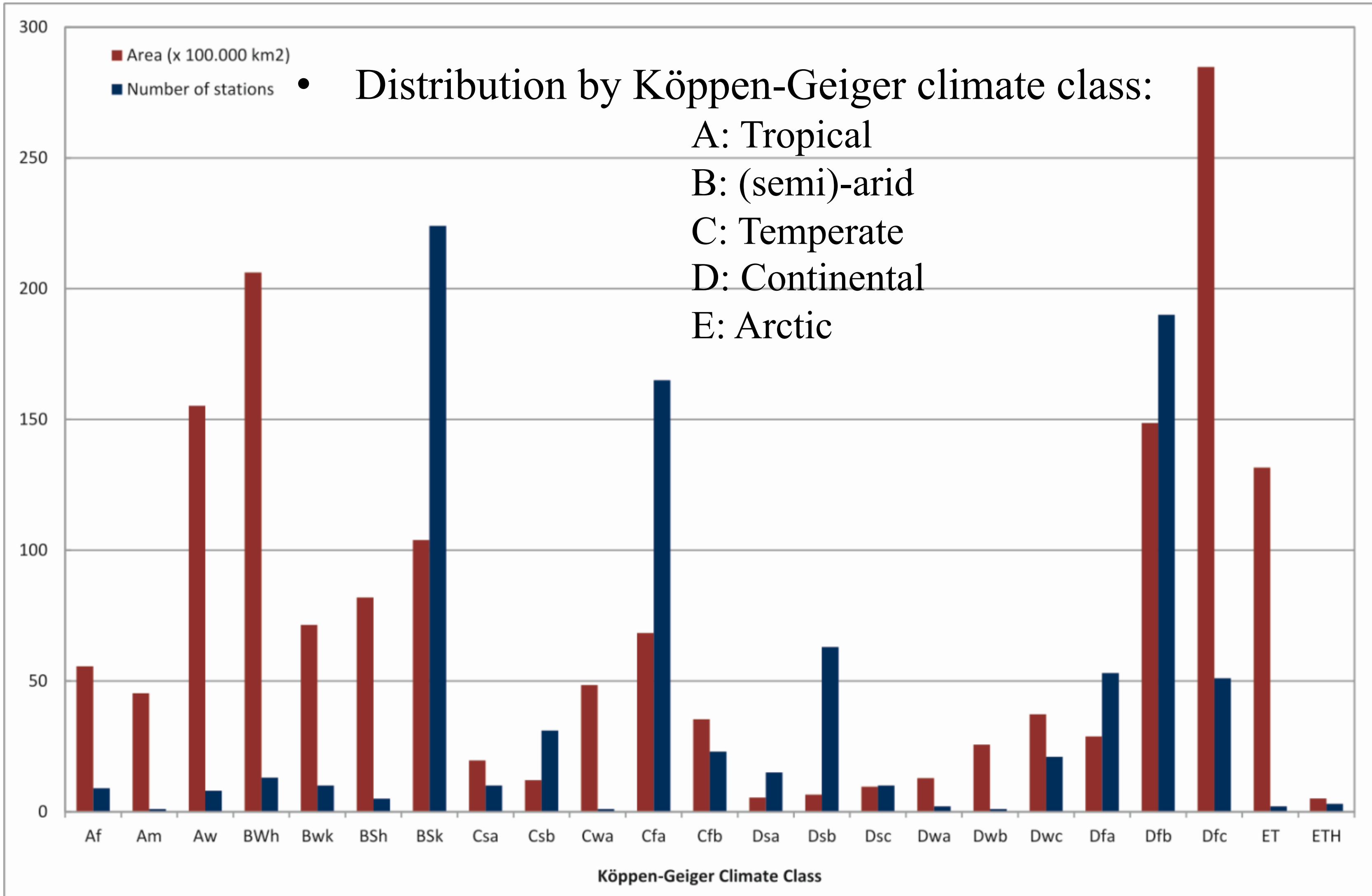


ISMN Periods of Record



ISMN Representativeness

- Distribution by Köppen-Geiger climate class:
  - A: Tropical
  - B: (semi)-arid
  - C: Temperate
  - D: Continental
  - E: Arctic



ISMN Quality Assessment

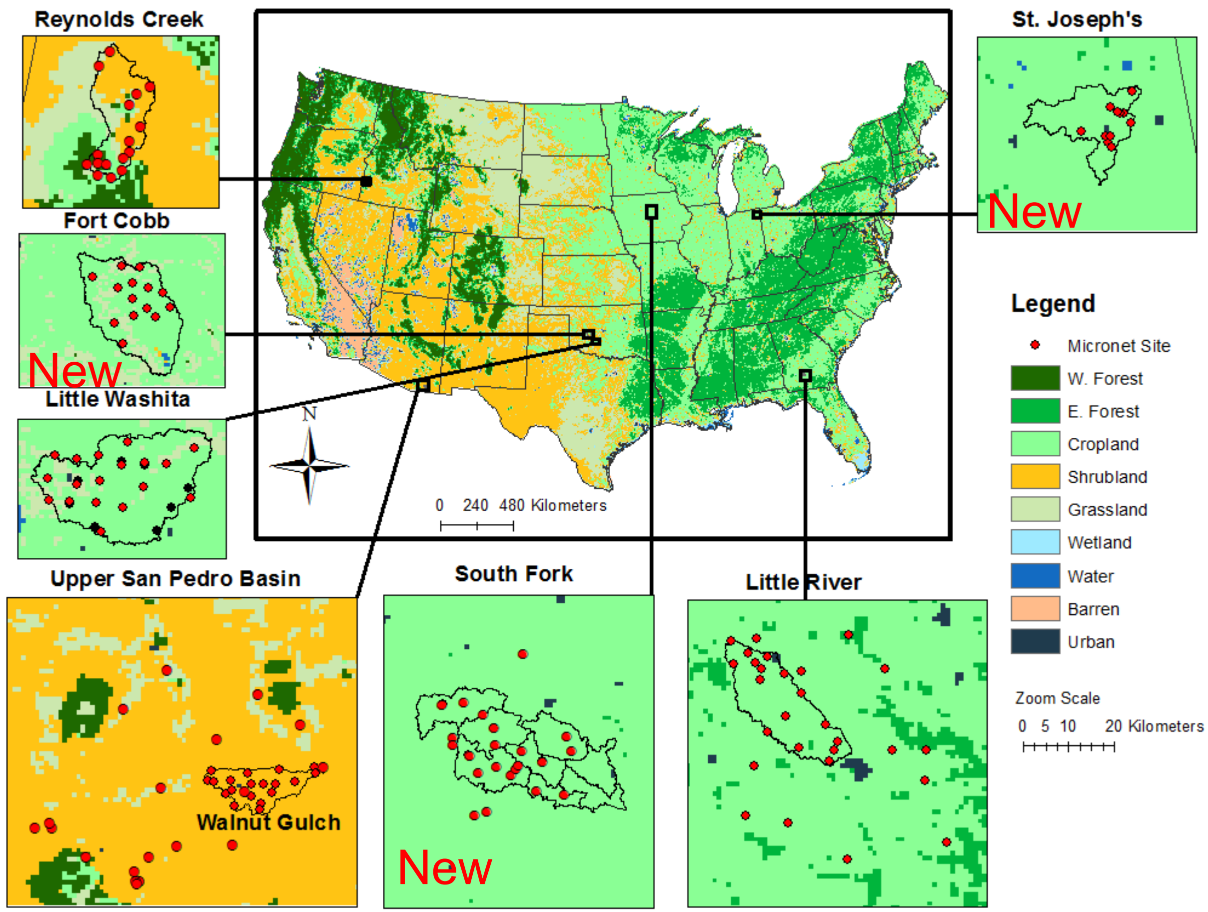
- Spectrum-based quality control
- Physical plausibility checks
- Spatial representativeness (random) error at network level based on triple collocation

ISMN References

- Dorigo, W., Van Oevelen, P., Wagner, W., Drusch, M., Mecklenburg, S., Robock, A., Jackson, T. (2011), "A new international network for in situ soil moisture data", Eos 92 (17), pp. 141-142.
- Dorigo, W.A., Wagner, W., Hohensinn, R., Hahn, S., Paulik, C., Xaver, A., Gruber, A., Drusch, M., Mecklenburg, S., van Oevelen, P., Robock, A., and Jackson, T., Jackson, T. (2011), "The International Soil Moisture Network: A data hosting facility for global in situ soil moisture measurements", Hydrology and Earth System Sciences 15 (5), pp. 1675-1698.
- Dorigo, W.A., Xaver, A. Vreugdenhil, M. Gruber, A., Hegyiová, A. Sanchis-Dufau, A.D., Zamojski, D. , Cordes, C., Wagner, W., and Drusch, M. (2013). Global Automated Quality Control of In situ Soil Moisture data from the International Soil Moisture Network. Vadose Zone Journal, vol. 12, doi:10.2136/vzj2012.0097
- Gruber, A., Dorigo, W.A., Zwieback, S., Xaver, A. Wagner, W. (2013). Characterizing coarse-scale representativeness of in-situ soil moisture measurements from the International Soil Moisture Network. Vadose Zone Journal, vol. 12, doi:10.2136/vzj2012.0170

USDA ARS Watershed Validation Sites

- Continuing record for the *four* USDA ARS sites distributed across the U.S. in different climate regions providing surface soil moisture. (2002-present)
- Focused on a large N and radiometer product scales.
- New sites available that are undergoing quality control (Fort Cobb, OK and St. Joseph, IN, and South Fork, IA).



USDA ARS Watershed References

- Jackson, T. J., Cosh, M. H., Bindlish, R., Starks, P. J., Bosch, D. D., Seyfried, M. S., Goodrich, D. C., and Moran, M. S. Validation of Advanced Microwave Scanning Radiometer soil moisture products. IEEE Transactions on Geoscience and Remote Sensing, 48: 4256-4272. 2010.
- Jackson, T. J., Bindlish, R., Cosh, M. H., Zhao, T., Starks, P. J., Bosch, D. D., Moran, M. S., Seyfried, M. S., Kerr, Y., Leroux, D. SMOS validation of soil moisture and ocean salinity (SMOS) soil moisture over watershed networks in the U.S. IEEE Transactions on Geoscience and Remote Sensing, 50: 1530-1543, 2012.

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Challenges in Soil Moisture Validation

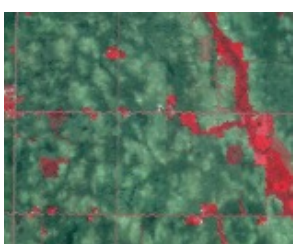
- Multiple scale variability of soil moisture
- Sensor footprint size (up to 40 km)
- Increasing the number and quality of in situ sites
- Different ground-based sensors and standards
- Different satellite sensors

Soil Moisture Variability

- Soil moisture exhibits multiple scale sources of variability.
- Extensive domains (large footprints) involve more sources.
- Most networks are sparse relative to the scales of variability.

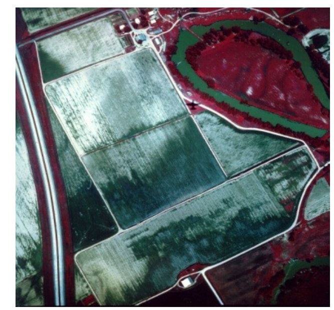
Tillage

Profile

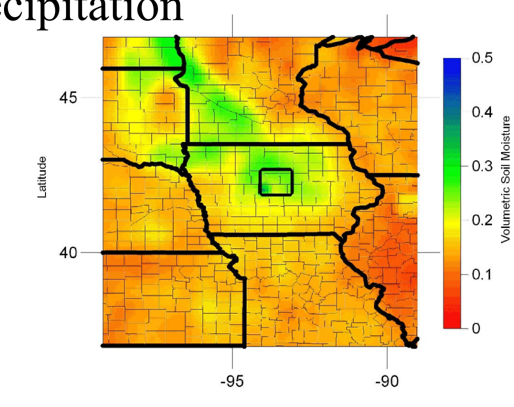


Soil Type

Within Field



Precipitation



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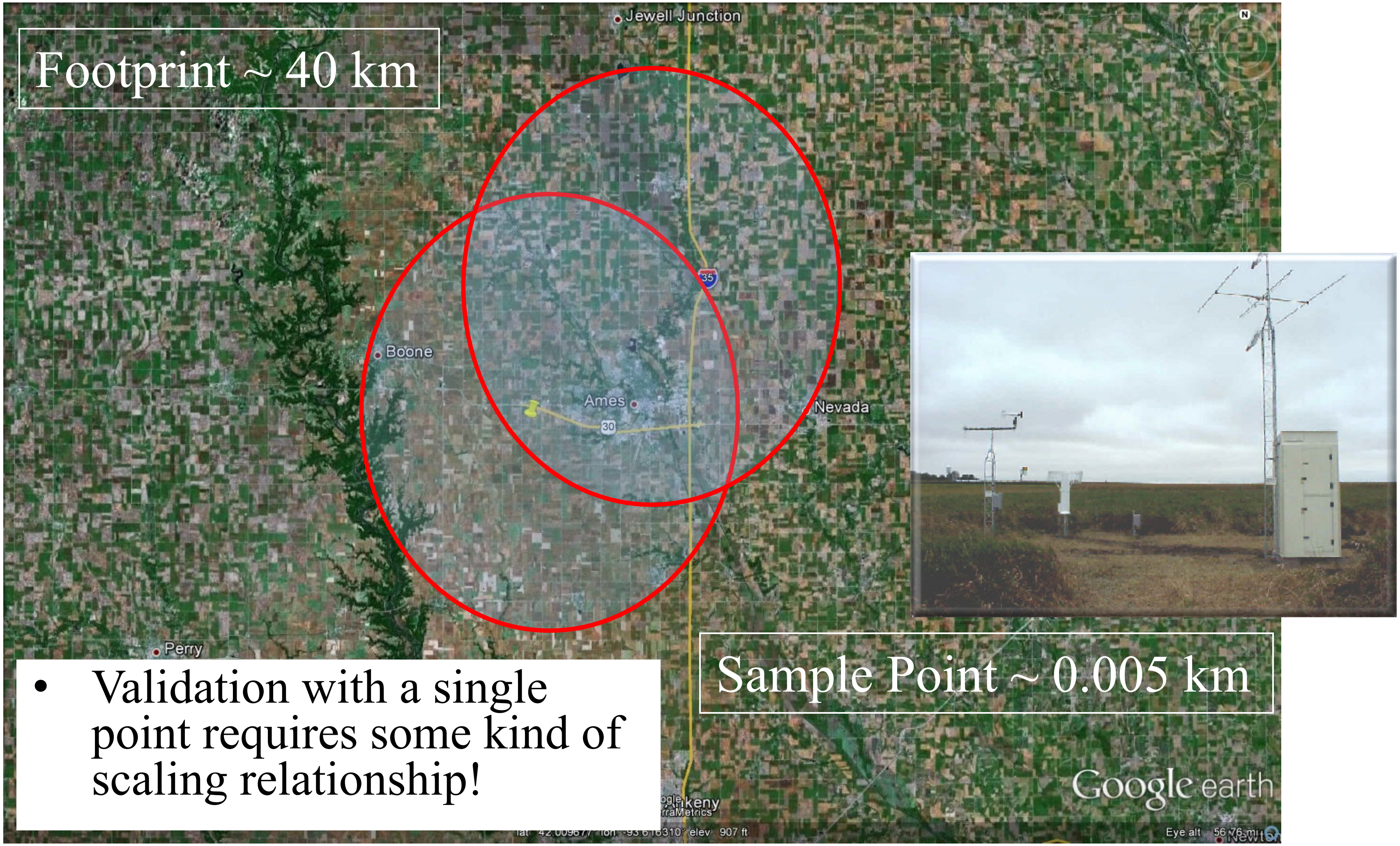
Sensor Footprint Size

- This is an inherent problem of passive methods and real aperture antennas.



- Validation with a single point requires some kind of scaling relationship!

SMAP Up-scaling Initiative

- *Issues:* There are many sparse network resources available. How can we reliably relate these to satellite products? How effective are existing up-scaling techniques?
- *Objectives:* Establish protocols and standards for establishing point to footprint scaling functions.
- *Approach:* White paper.
  - "Upscaling sparse ground-based soil moisture observations for the validation of coarse-resolution satellite soil moisture products", W. Crow, A. Berg, M. Cosh, A. Loew, B. Mohanty, R. Panciera, P. de Rosnay, D. Ryu, and J. Walker, *Reviews of Geophysics*, 50, RG2002, doi:10.1029/2011RG000372, 2012.

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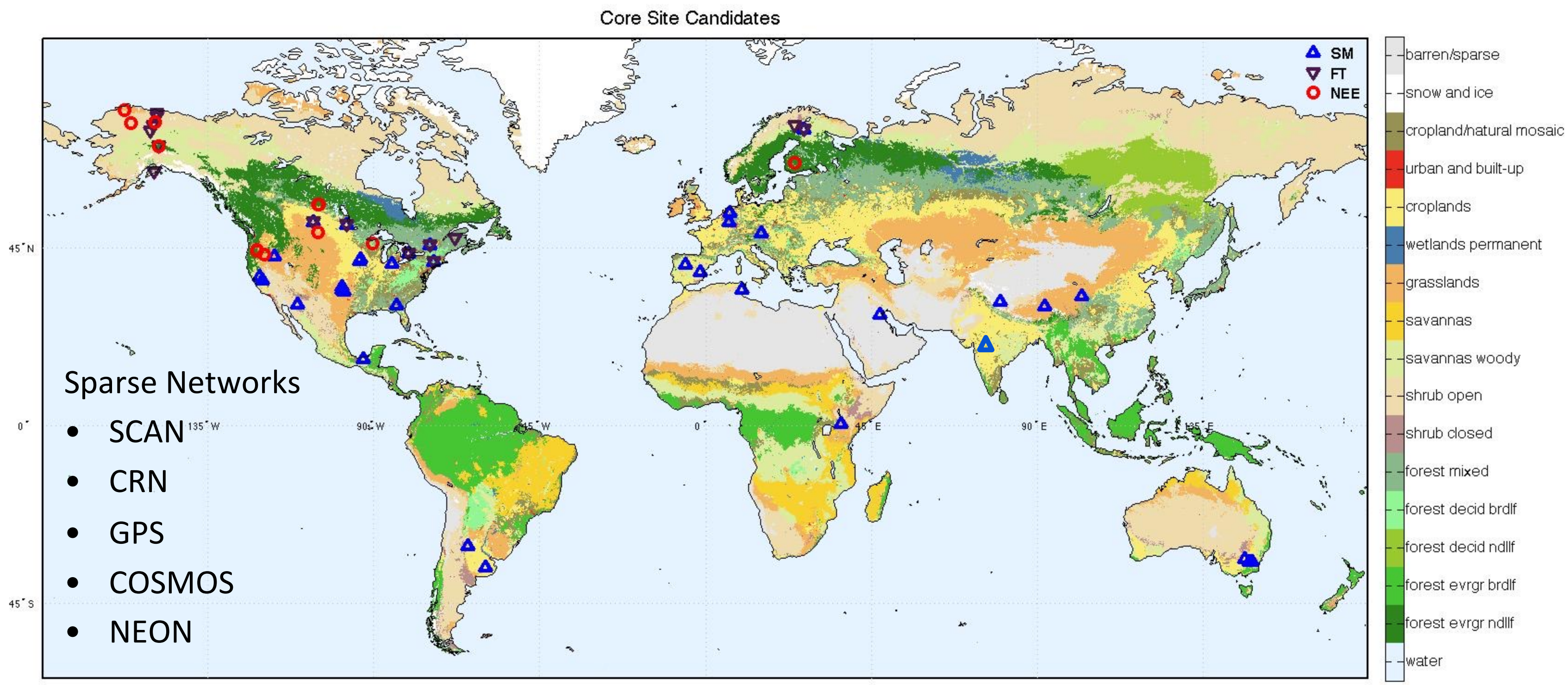
SMAP Cal/Val Partners Program

- In situ observations are essential to SMAP Cal/Val
- There were only a few high quality resources available
- Increasing the number was constrained by
  - The time and effort required to establish a site
  - No $ to support these
- Action: Cal/Val Partners Program
  - No cost collaboration
  - Minimum standards
  - In situ data in exchange for early access to SMAP products

SMAP Cal/Val Partners Program: Sites

- **Core Validation Sites**: In situ observing sites that provide well-characterized estimates of a L2-L4 product at a matching spatial scale, a direct benchmark reference for the products. Additional minimum criteria are:
  - Provides calibration of the in situ sensors
  - Up-scaling strategy provided by Partner
  - Provides data in a timely manner
  - Long term commitment by the sponsor/host
- **Supplemental Validation Sites**: In situ observing sites that provide estimates of a L2-L4 product but do not meet all of the minimum criteria for a Core Validation Site. (i.e. sparse networks)
  - Supplemental resource in assessing whether mission requirements have been met but can play an important role in Stage 2 Validation.
  - The baseline approach to using sparse networks is the triple-collocation technique. Efforts to improve this approach are desirable.

SMAP Cal/Val Partners Program: Core Validation Site Candidates



- The current set of Partners covers a wide range of vegetation and climate conditions.
- Ongoing qc evaluations and validation rehearsals are ongoing to down select.

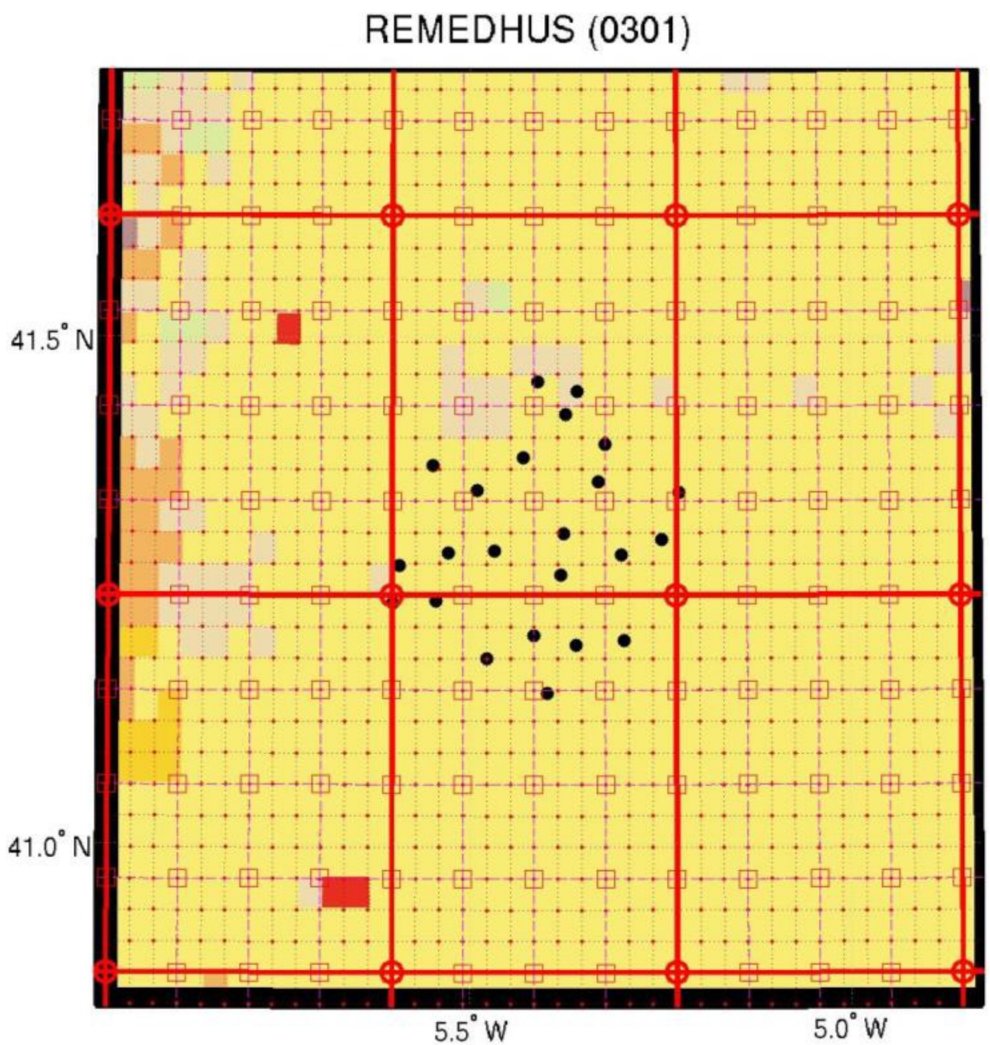
SMAP Science Products: 3 Spatial Resolutions

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.

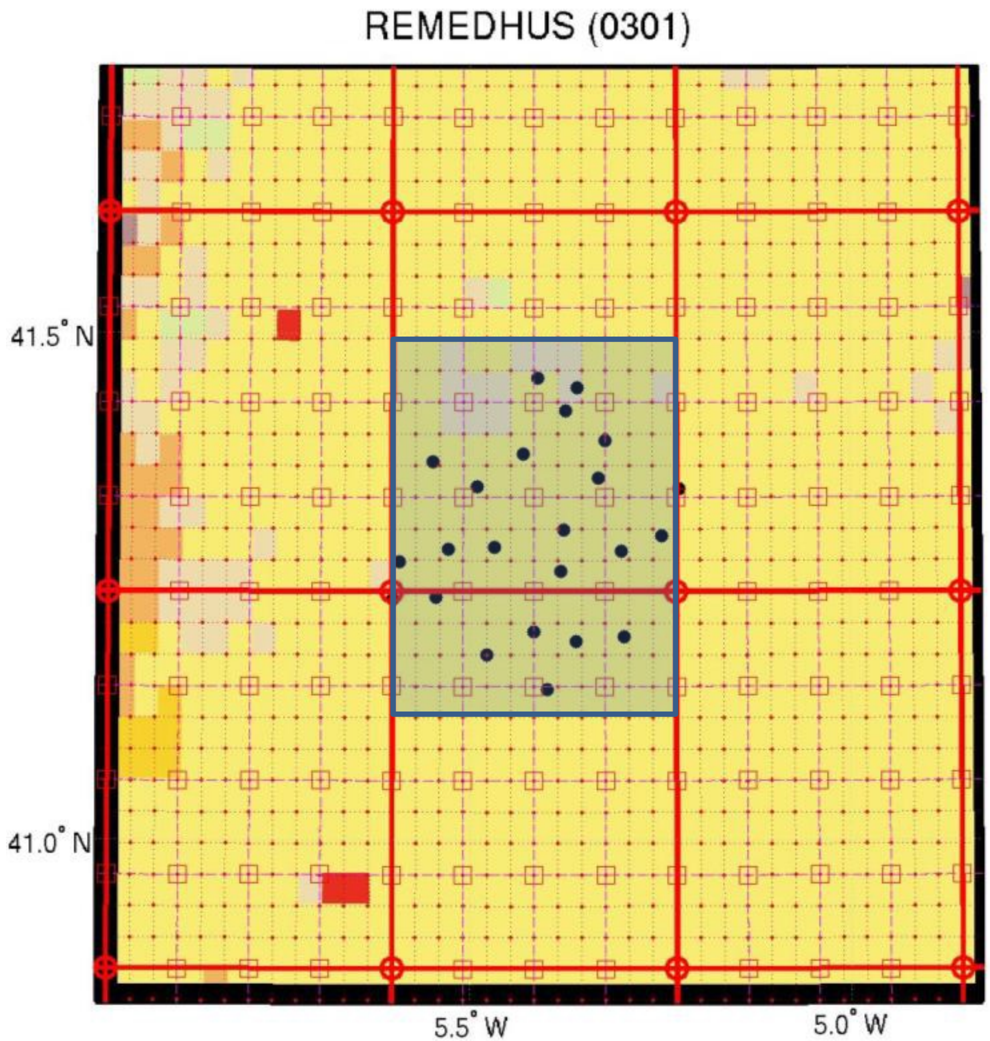
** The SMAP project will make a best effort to reduce the data latencies beyond those shown in this table.

Core Validation Sites and Scaling (1/3)



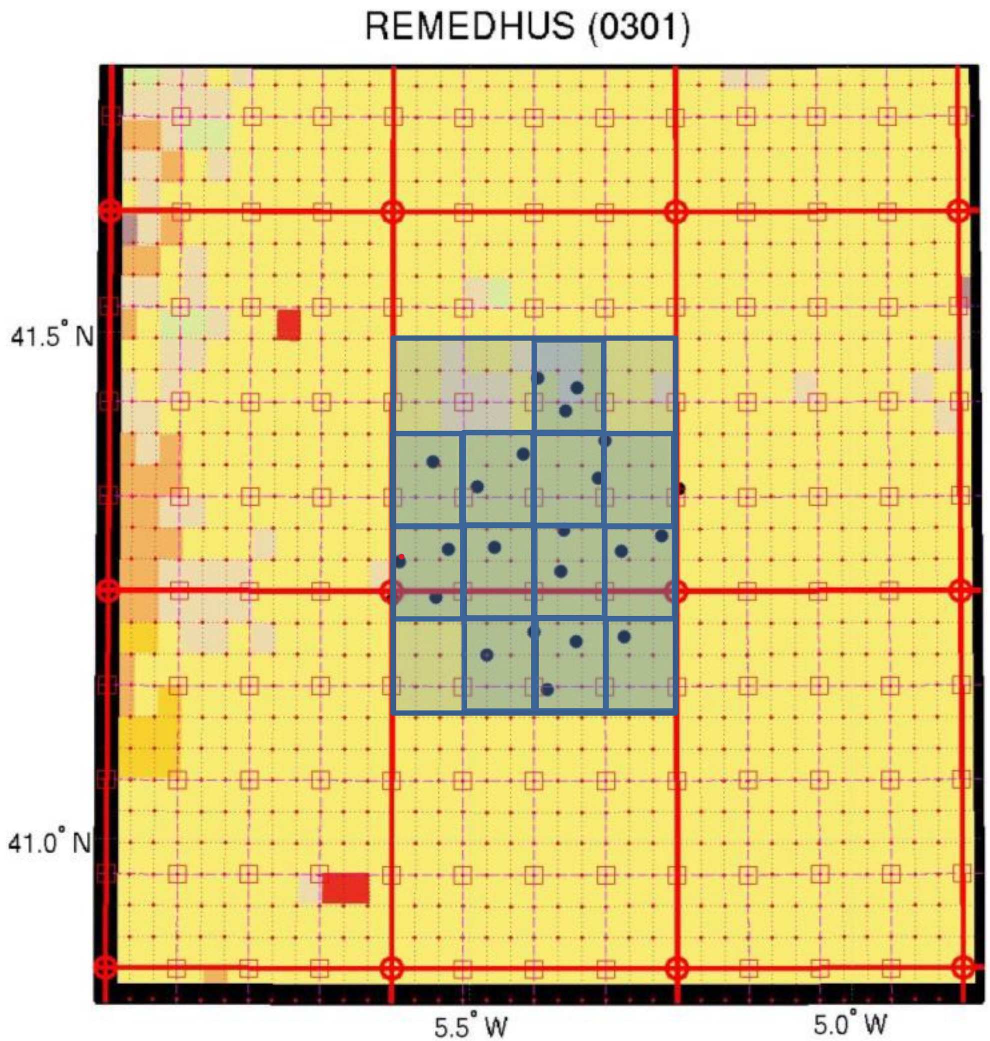
- We have a good set of sites to support the validation of the 36 km product (in part due to prior missions with 25-50 km resolutions) using standard statistical methods (N large).
- This is the actual SMAP grid for the 3, 9, and 36 km products over a site in Spain.
- In most cases, the distribution of the points at a site does not match the grid products to make N as large as possible.

Core Validation Sites and Scaling (2/3)



- Rather than have poorly distributed and small (N) data sets, we decided to shift the grid … just for validation.
- In most cases, the average of these points will provide a statistically significant estimate of the surface soil moisture.
- Not all sites will look this good!

Core Validation Sites and Scaling (3/3)



- New challenge: higher resolution products.
- There are fewer sites with enough points to support a standard statistical analyses.
- Some options
  - Ignore: 1 or 2 points in a grid cell is just fine!
  - More effort into up-scaling methodologies.

- Our confidence in using any specific site for assessments will depend on the quality of the calibration, representation, and up-scaling.

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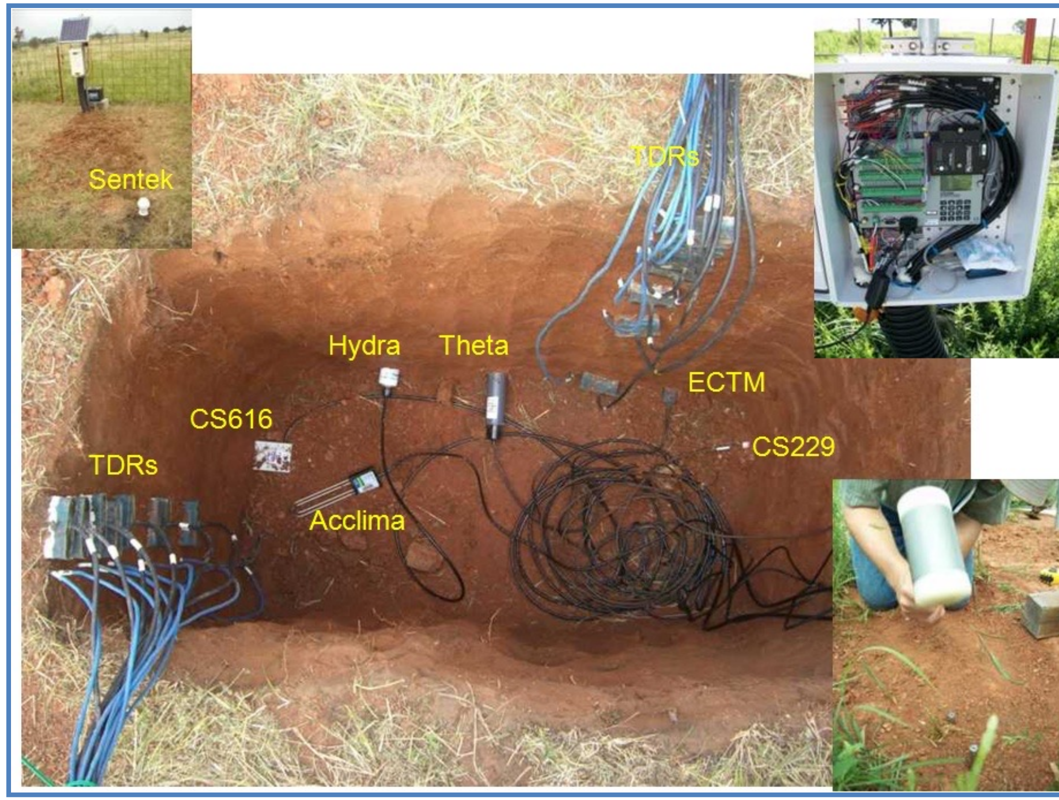
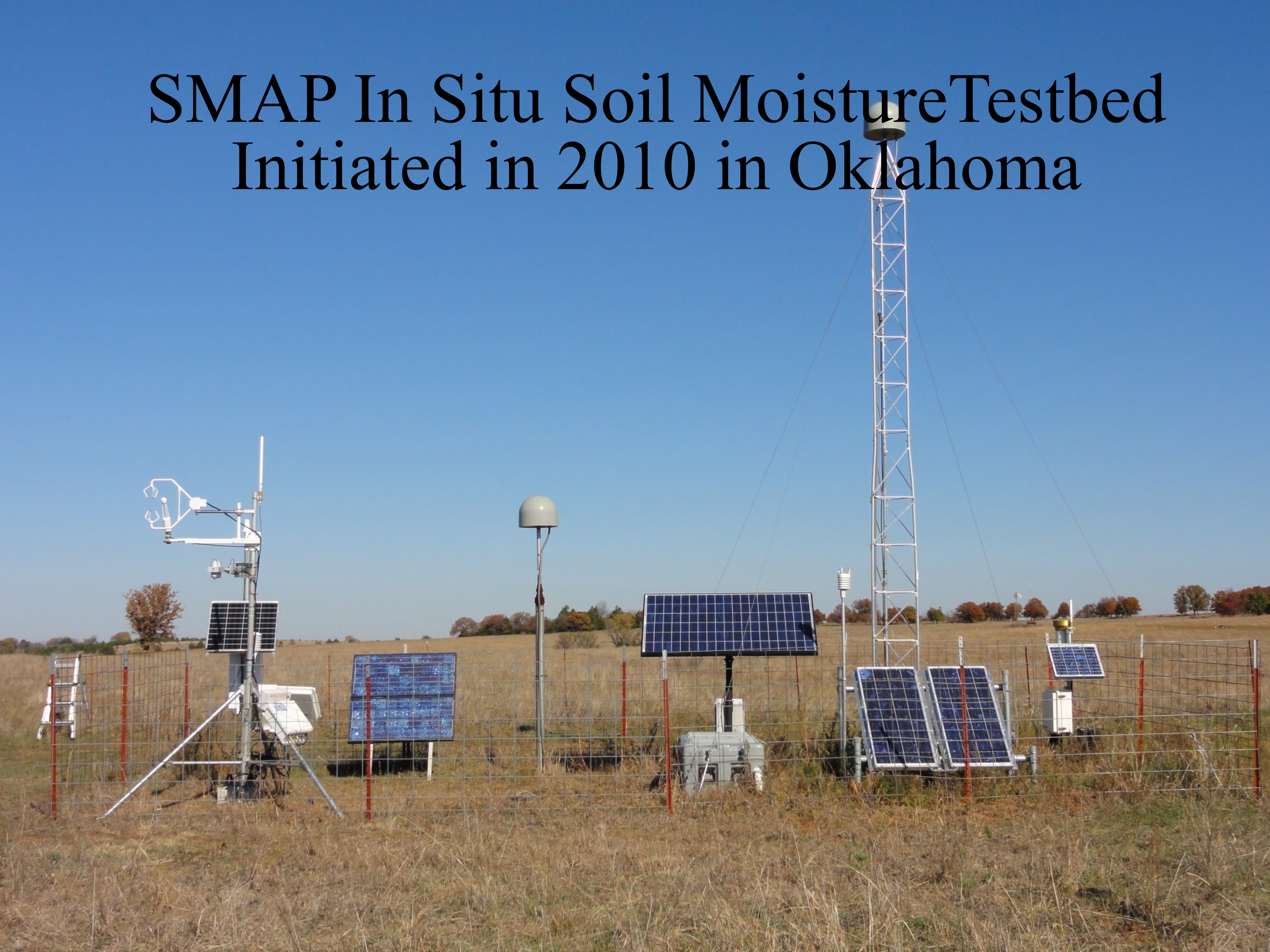
Different Ground-based Sensors and Standards

- Sensors/Networks have different measurement units, depths, contributing area/volume, calibration, and latency.
- In order to conduct an efficient validation program we need observations that are calibrated and referenced to the same standard.



SMAP In Situ Soil MoistureTestbed Initiated in 2010 in Oklahoma



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Satellites Providing a Soil Moisture Product

METOP/ASCAT
2006

SMOS
2009

Aquarius
2011

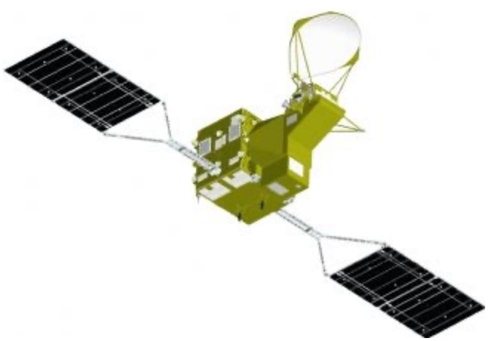
As a result of instrument designs these can have:

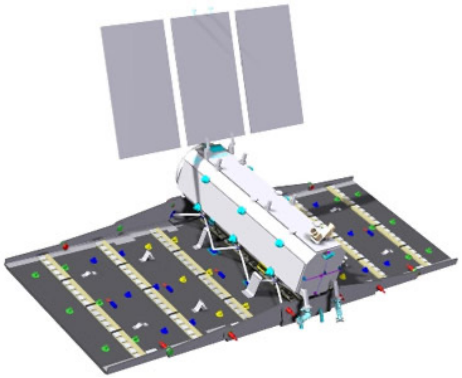
- Contributing areas
- Contributing depths
- Measurement units
- Program support for validation

GCOM-W
2012

SMAP
2014

SAOCOM
2014





Soil Moisture Validation Metrics

- Typical Metrics
  - RMSE, Bias, R, ubRMSE, ...
- Best Practice
  - Report them all.
  - Projects have performance targets that must be addressed.
- References
  - Entekhabi, D., R. Reichle, R. Koster and W. Crow, 2010. Performance metrics for soil moisture retrievals and application requirements, Journal of Hydrometeorology, 11(3), 832-840.
  - Albergel, C., L. Brocca, W. Wagner, P. de Rosnay, and J. Calvet, 2013. Selection of Performance Metrics for Global Soil Moisture Products: The Case of ASCAT Soil Moisture, pp. 431-447. in Remote Sensing of Energy Fluxes and Soil Moisture Content, Editor G. P. Petropoulos, CRC Press.

SMAP Level 1 Science Requirements

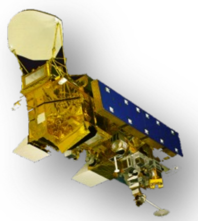
- The NSF Decadal Survey identified numerous potential applications for SM/FT observations.
- These were grouped into three categories with a spatial resolution, refresh rate, and accuracy.

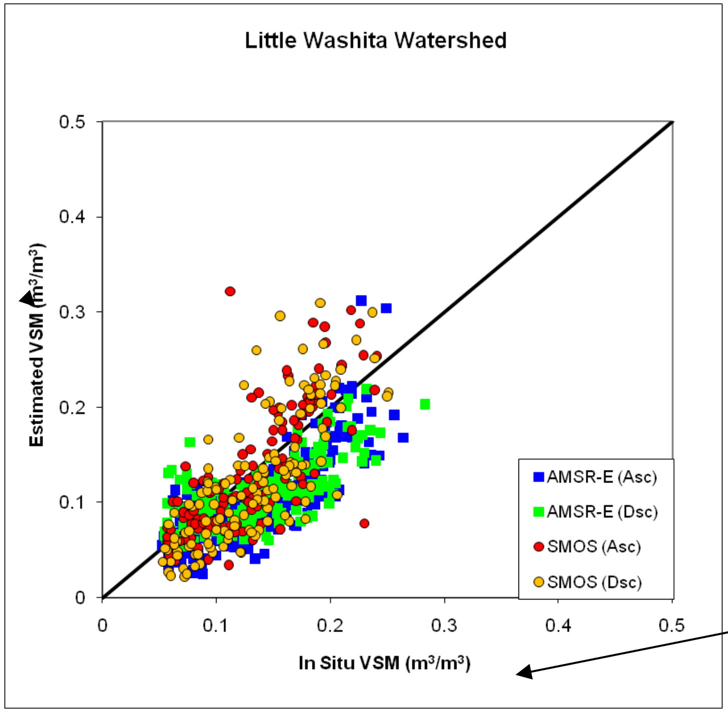
Requirement	Hydro-Meteorology	Hydro-Climatology	Carbon Cycle	Baseline Mission		Threshold Mission	
				Soil Moisture	Freeze/ Thaw	Soil Moisture	Freeze/ Thaw
Resolution	4–15 km	50–100 km	1–10 km	10 km	3 km	10 km	10 km
Refresh Rate	2–3 days	3–4 days	2–3 days[a]	3 days	2 days	3 days	3 days
Accuracy	0.04-0.06 [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	

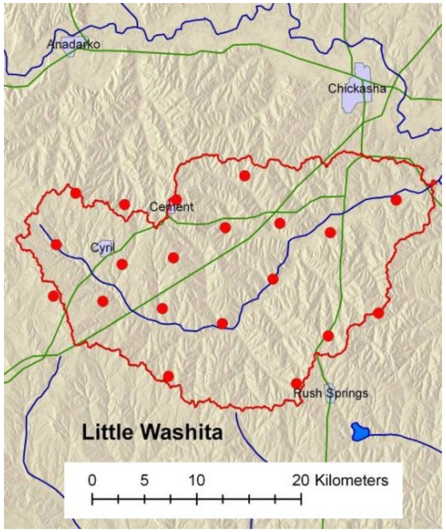
[a] North of 45N latitude, [b] Percent classification accuracy (binary freeze/thaw), [c] Volumetric water content, 1-σ in [cm^3/cm^3] units

- These are the L1 priority products and requirements. The define what the proposed mission must accomplish.
- *Cal/Val must provide information to assess mission performance.*

Core Validation Site Example
(Little Washita, SMOS, and AMSR-E)







Product	SMOS Asc. 0600 AMSR-E Dsc 0130				SMOS Dsc. 1800 AMSR-E Asc. 1330			
	RMSE	Bias	R	N	RMSE	Bias	R	N
SMOS	0.042	0.002	0.773	130	0.044	-0.008	0.775	134
AMSR-E	0.046	-0.029	0.709	214	0.048	-0.035	0.790	244