Aquarius/SAC-D Soil Moisture Product using V3.0 Observations

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Overview

- Soil moisture algorithm
- Soil moisture product
- Validation
- Linkage between Soil Moisture and SSS

Aquarius Soil Moisture Algorithm

- The baseline soil moisture algorithm uses the radiative transfer equation (τ−ω model). Same as the baseline SMAP L2 Soil Moisture algorithm, referred to as the Single Channel Algorithm (SCA).
  - τ-ω model

$$TB = T_{soil}(1 - R_{surf})\exp^{-\tau \sec\theta} + T_{veg}(1-\omega)(1-\exp^{-\tau\sec\theta})(1 + R_{surf}\exp^{-\tau\sec\theta})$$

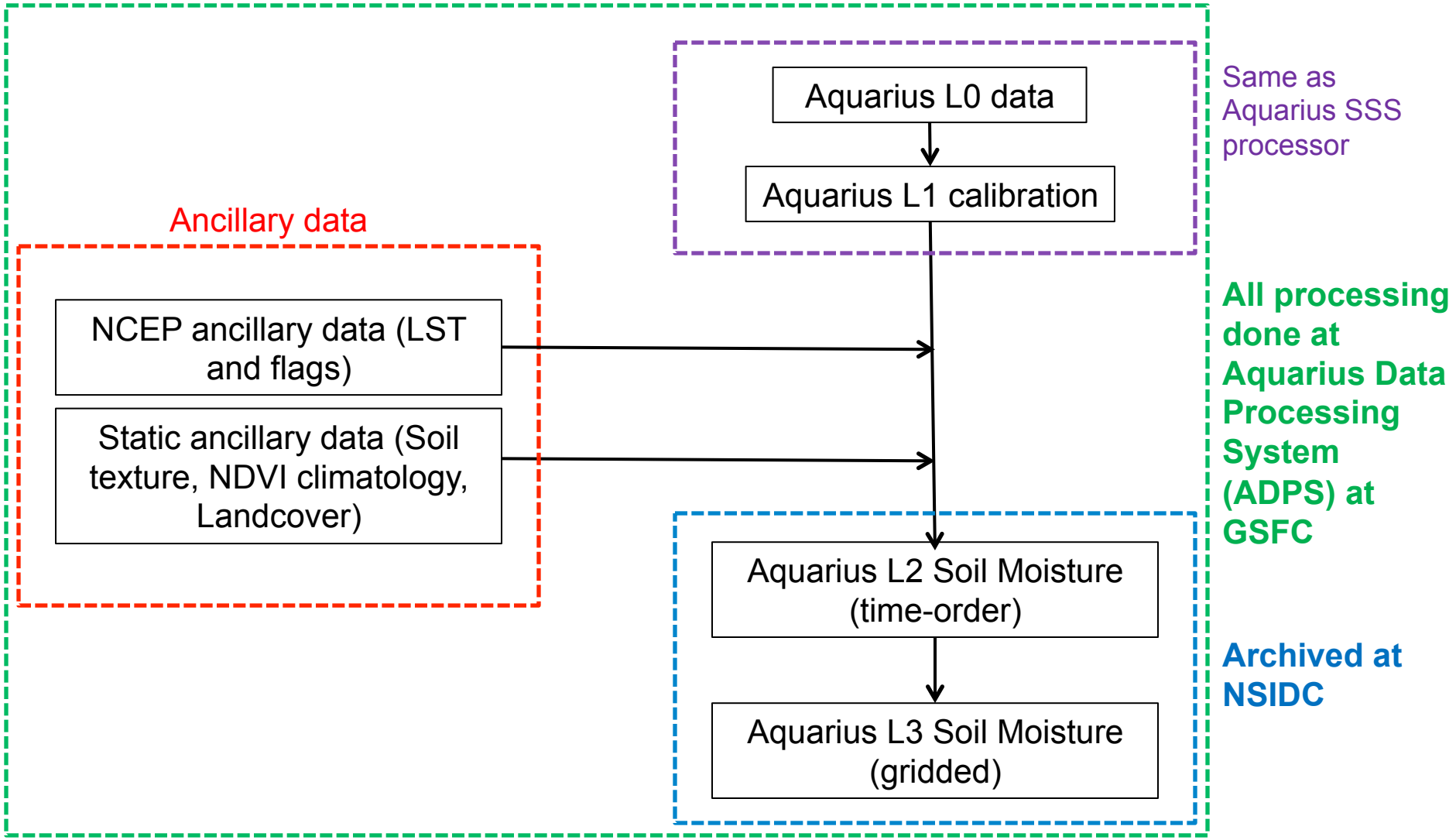
  - Fresnel equation (Horizontal Polarization)

$$R_{Soil}(\theta) = \left| \frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right|^2$$

Aquarius Ancillary datasets

- Surface temperature – NCEP (SMAP-GMAO)
- Precipitation flag – NCEP (SMAP-GMAO)
- Snow flag – NCEP (SMAP-GMAO)
- MODIS NDVI climatology (consistent with SMAP)
- MODIS IGBP landcover (consistent with SMAP)
- Soil texture – Harmonized soil texture dataset (consistent with SMAP)
- Plan to modify ancillary datasets and parameters consistent with SMAP

Aquarius SM Product Operational Flow Chart

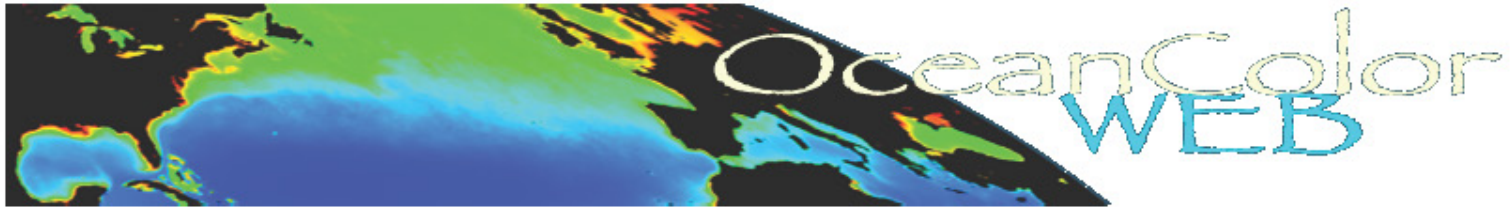


List of Aquarius SM Product Variables

Parameter	Name	Notes	Source
Mv	Aquarius estimated Volumetric Soil Moisture (m3/m3)		
sm_flag	Bit flag for soil moisture retrievals	Composite flag in bit format (next slide)	Next Slide
lat	Latitude	Beam Location	Aquarius L2 data
lon	Longitude	Beam Location	Aquarius L2 data
phi	Azimuth angle	Used to determine orbit direction	Aquarius L2 data
tbh	Aquarius h-pol radiometer observation (K)	Version 3.0 TB data	Aquarius L2 data
tbv	Aquarius v-pol radiometer observation (K)	Version 3.0 TB data	Aquarius L2 data
ke	NCEP skin surface temperature (K)	Ancillary data	NCEP
te	NCEP 0-10 cm surface temperature (K)	Ancillary data	NCEP
Att_ang	Spacecraft roll, pitch, yaw	Anomaly spacecraft position used for flagging	Aquarius L2 data
secGPS	GPS seconds	Time	Aquarius L2 data
Vsm	NCEP soil moisture (m3/m3)	Ancillary data for user analysis	NCEP
Lfr	Land Fraction	Used for Flagging (fractional coverage based on antenna pattern)	Available in Aquarius L2 data
Ifr	Snow/ice Fraction	Used for Flagging (fractional coverage based on antenna pattern)	NCEP
Swe	Snow water equivalent	Used for Flagging	NCEP
sigmahh	Scatterometer HH	Version 3.0	Aquarius L2 data
sigmahv	Scatterometer HV	Version 3.0	Aquarius L2 data
sigmavh	Scatterometer VH	Version 3.0	Aquarius L2 data
Sigmavv	Scatterometer VV	Version 3.0	Aquarius L2 data

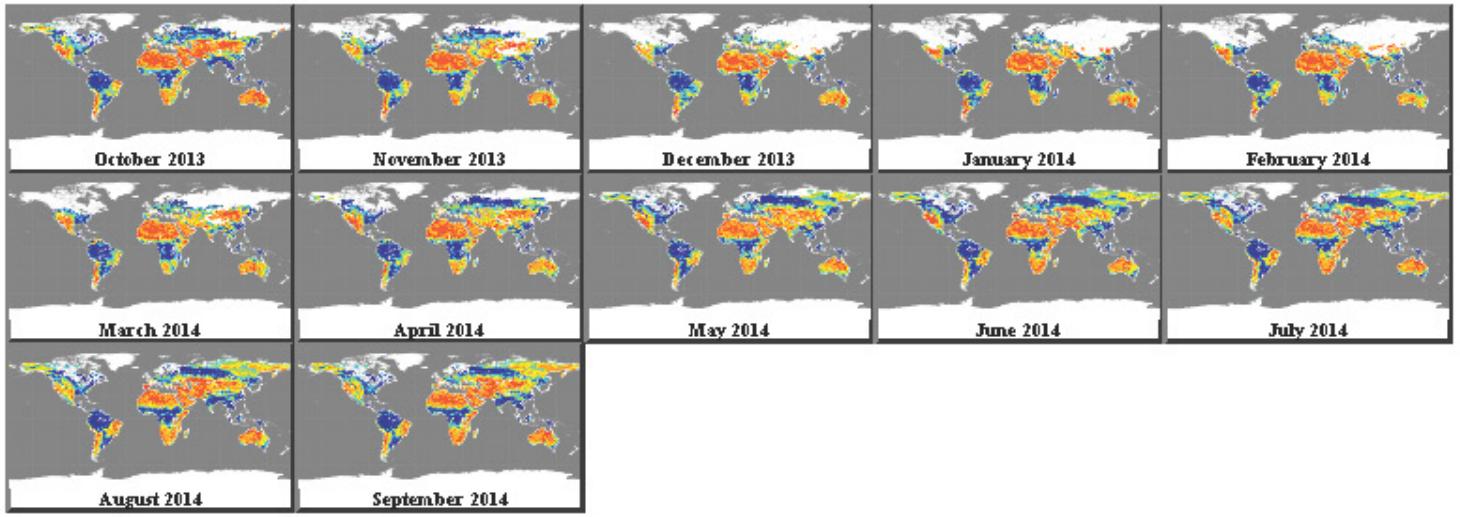
List of Aquarius SM Product Flags

Aquarius Soil Moisture Flags			
Bit Position	**Name**	**Value**	**Basis**
0	No SM Retrieval	Mv	Any bit flag value (except 9), No SCA retrieval
1	Brightness Temp	TB	Invalid latitude or longitude, TB(h/v)<0K, TB(h/v)>320K
2	Orbit Maneuvers	ORBIT	ACS mode =5, Roll>1, Pitch>1, Yaw>5
3	RFI	RFI	TB(h/v)<0K, TB(h/v)>320K, TB(h)>TB(v)
4	Surface Temp	TSURF	TB(h)>Tsurf, NCEP (te/ke)<0, NCEP (te/ke)> 330K, Missing data
5	Frozen Ground	FROZ	NCEP ke<273.15K, NCEP te<273.15
6	Snow	SNOW	SWE>10.0 kg/m2
7	Ice	ICE	NCEP Ice fraction > 0.1
8	NDVI	NDVI	MODIS NDVI climatology flag
9	Dense Vegetation	VEG	VWC> 5.0 kg/m2
10	Urban	URBAN	MODIS urban fraction (most likely class)
11	Soil	SOIL	Invalid soils data (0<sand/clay/porosity<100)
12	Water	WATER	Land Fraction <0.99, IGBP water class



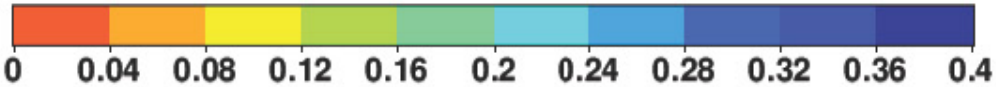
Standard ▼ | Aquarius Volumetric Soil Moisture V3.0 ▼

Monthly ▼ | 1 deg ▼ | 12 thumbnails



Aug11 Sep11 Oct11 Nov11 Dec11 Jan12 Feb12 Mar12 Apr12 May12 Jun12 Jul12 Aug12 Sep12 Oct12 Nov12 Dec12 Jan13 Feb13 Mar13 Apr13 May13 Jun13 Jul13
Aug13 Sep13 Oct13 Nov13 Dec13 Jan14 Feb14 Mar14 Apr14 May14 Jun14 Jul14 Aug14 Sep14

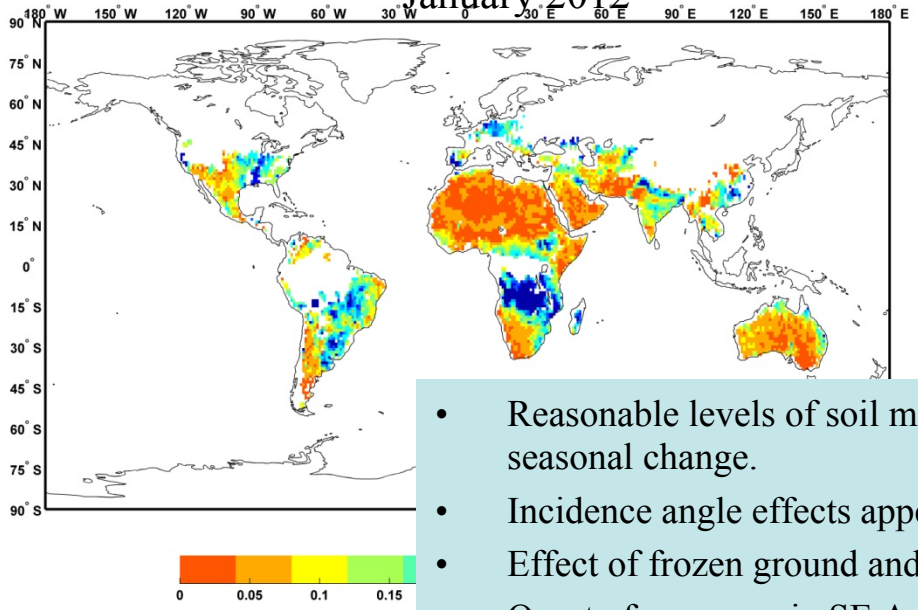
Soil Moisture (volumetric fraction)



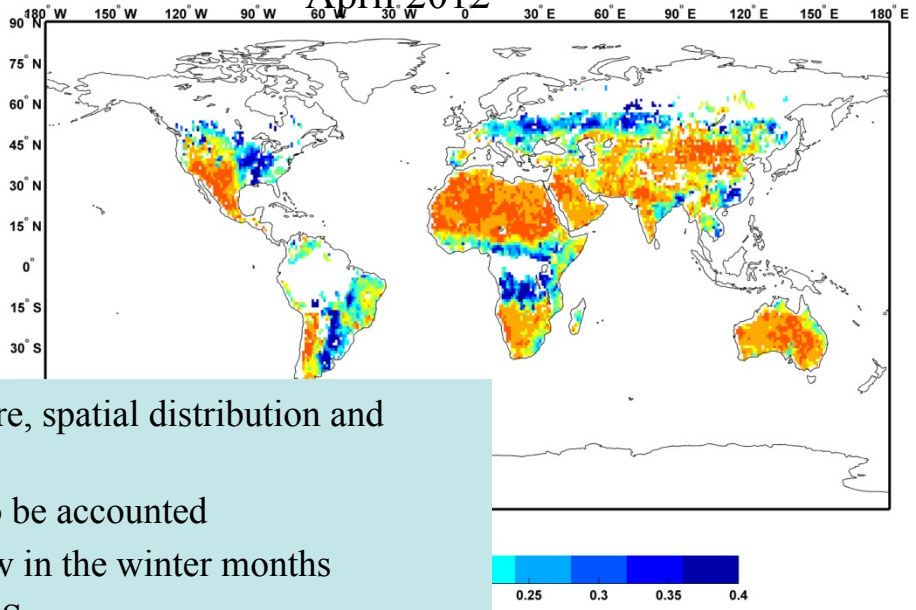
gene carl feldman (gene.c.feldman.gov) (301) 286-9428

Monthly Aquarius Soil Moisture

January 2012

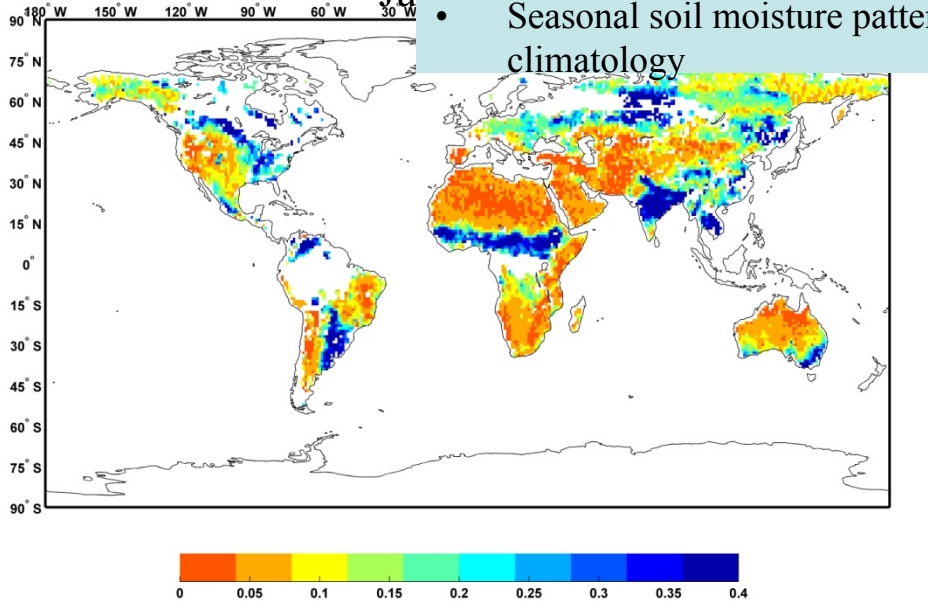


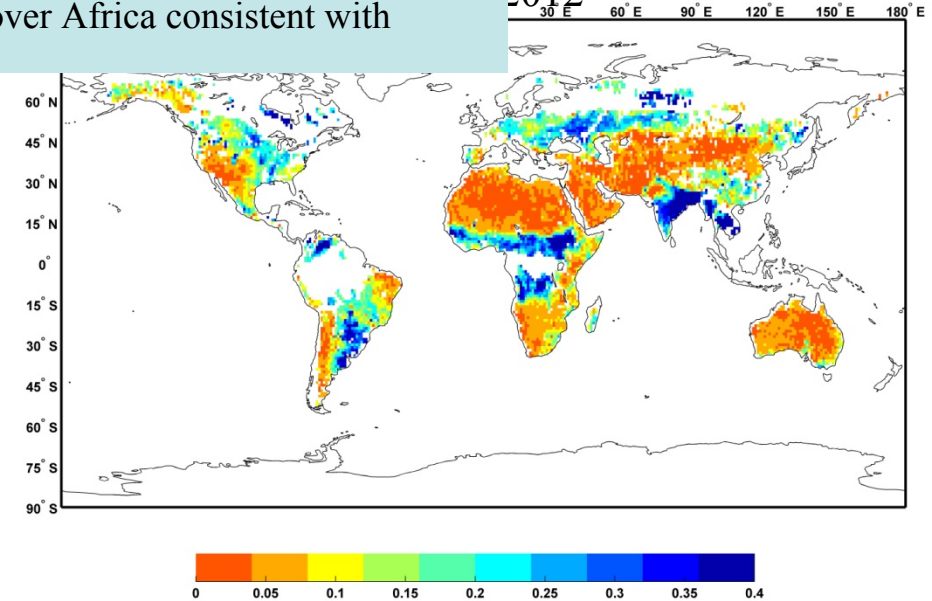
April 2012



- Reasonable levels of soil moisture, spatial distribution and seasonal change.
- Incidence angle effects appear to be accounted
- Effect of frozen ground and snow in the winter months
- Onset of monsoon in SE Asia in Summer
- Seasonal soil moisture pattern over Africa consistent with climatology

Ju 2012



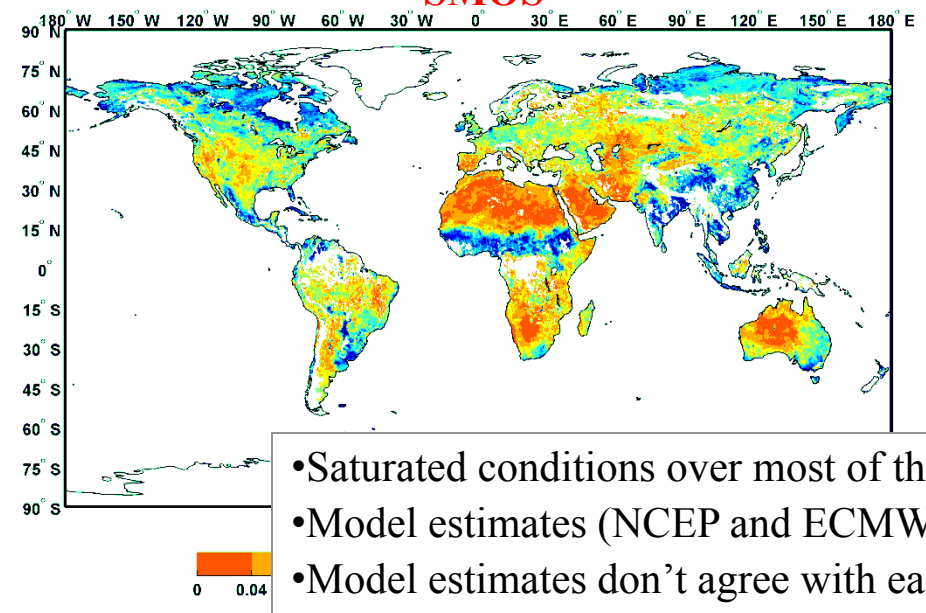


Aquarius SM Validation Results

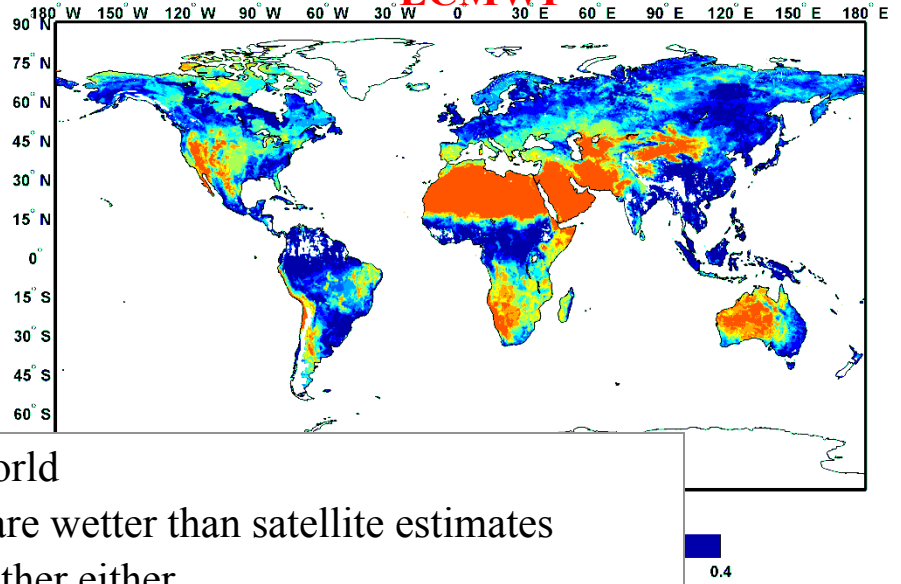
- Global SM inter-comparison
- USDA ARS Watershed sites
- Period of record – (Sept 2011-Sept 2014)
- Coverage issues
  - Aquarius footprint ~100 km
  - Aquarius has a repeat cycle of 7 days
  - Only one beam passes over a watershed area
  - Only Asc/Dsc overpass is available for a particular watershed

SM Products

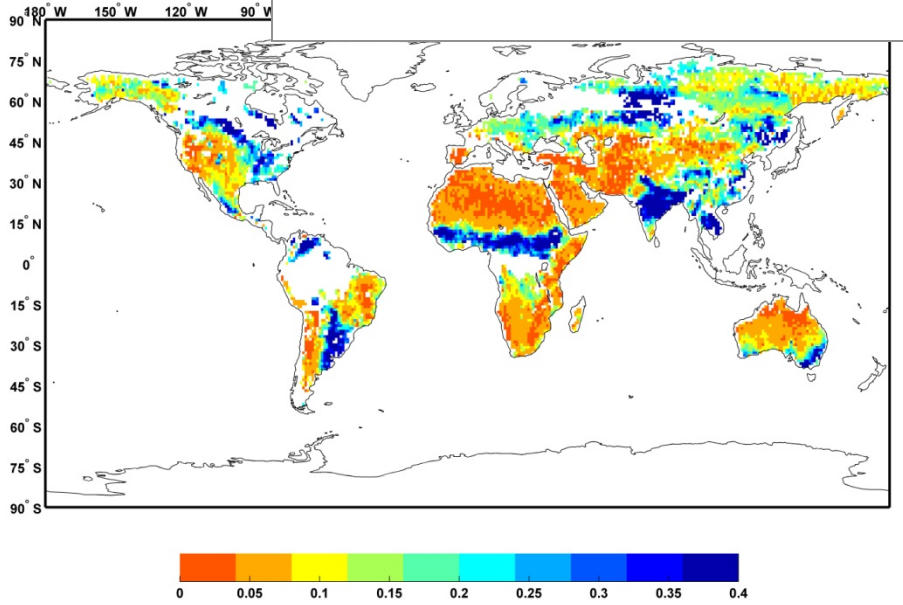
SMOS

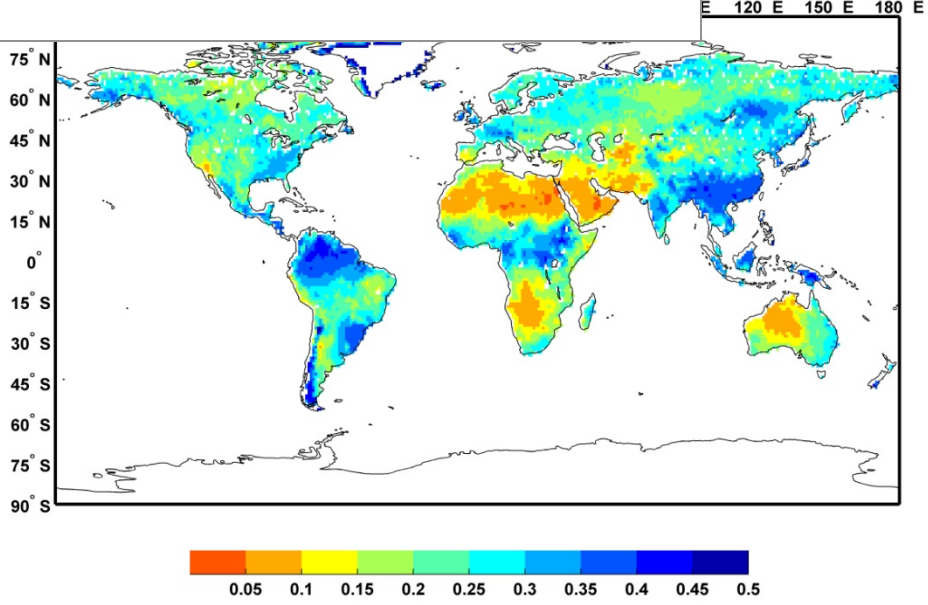


ECMWF



- Saturated conditions over most of the world
- Model estimates (NCEP and ECMWF) are wetter than satellite estimates
- Model estimates don't agree with each other either
- Soil moisture from the models cannot be used for cal/val (unlike SSS)

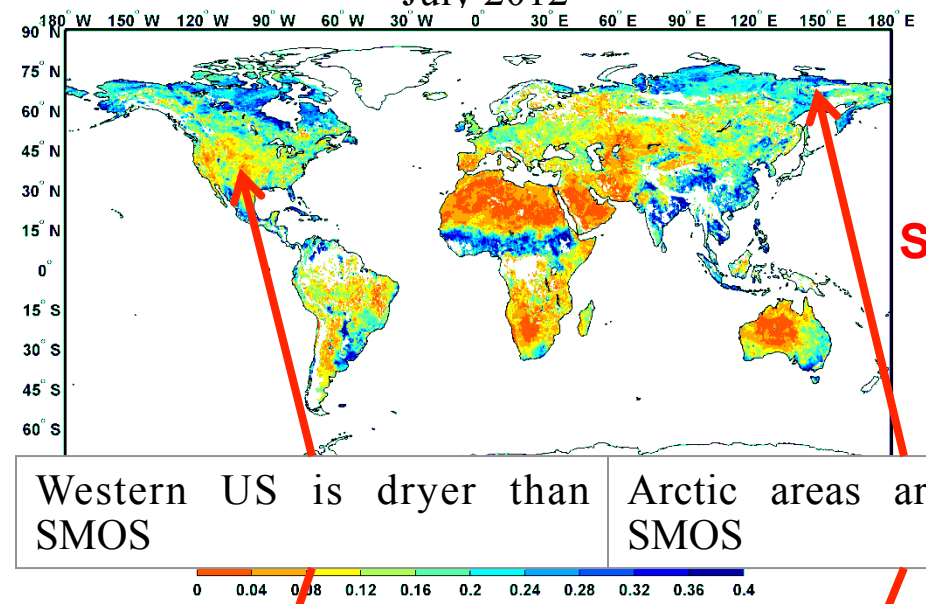




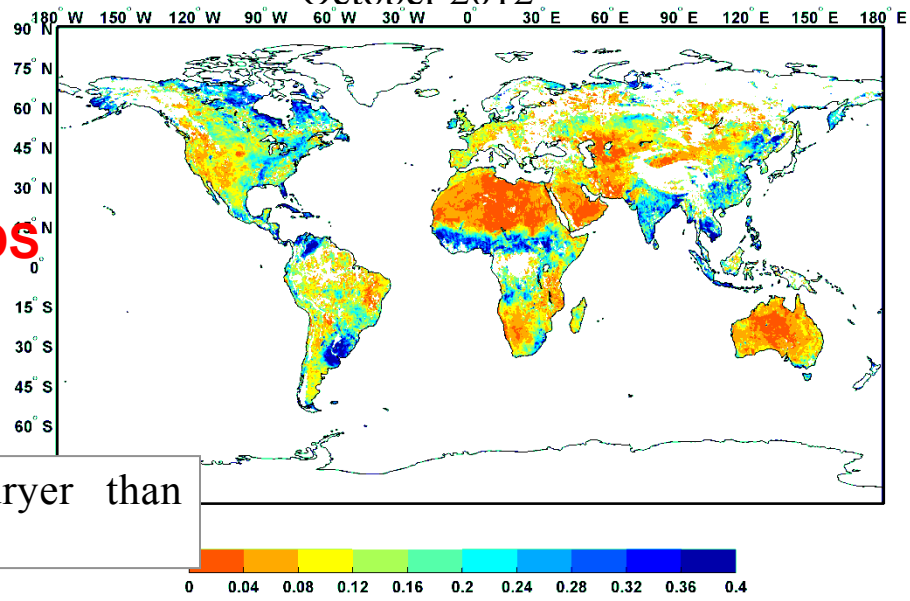
SMOS, Aquarius SM Products

July 2012

October 2012



SMOS

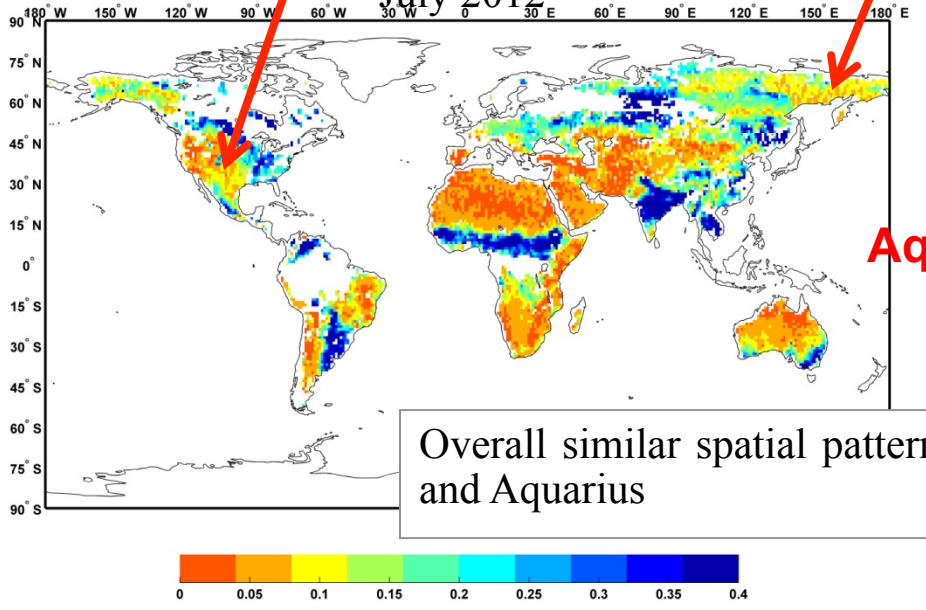


Western US is dryer than SMOS

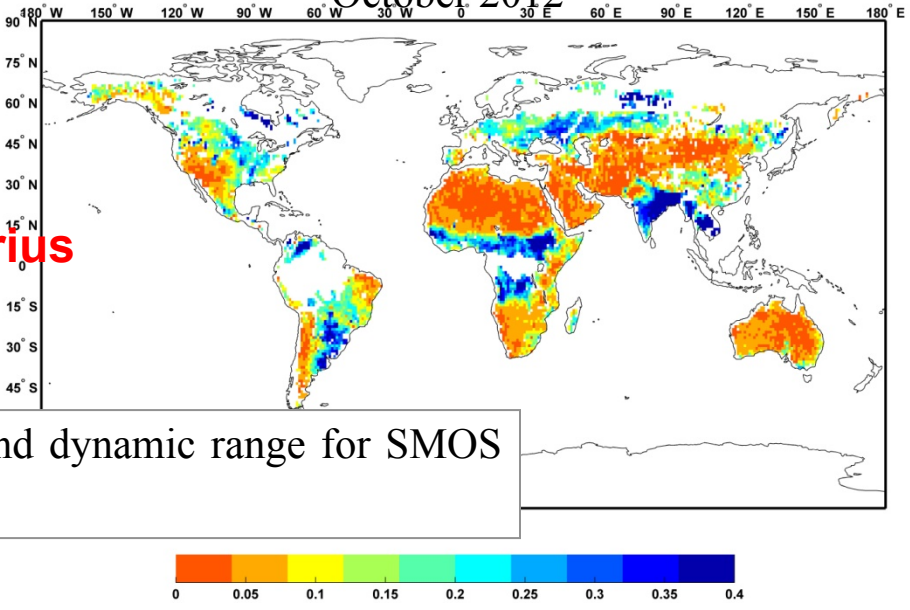
Arctic areas are dryer than SMOS

July 2012

October 2012

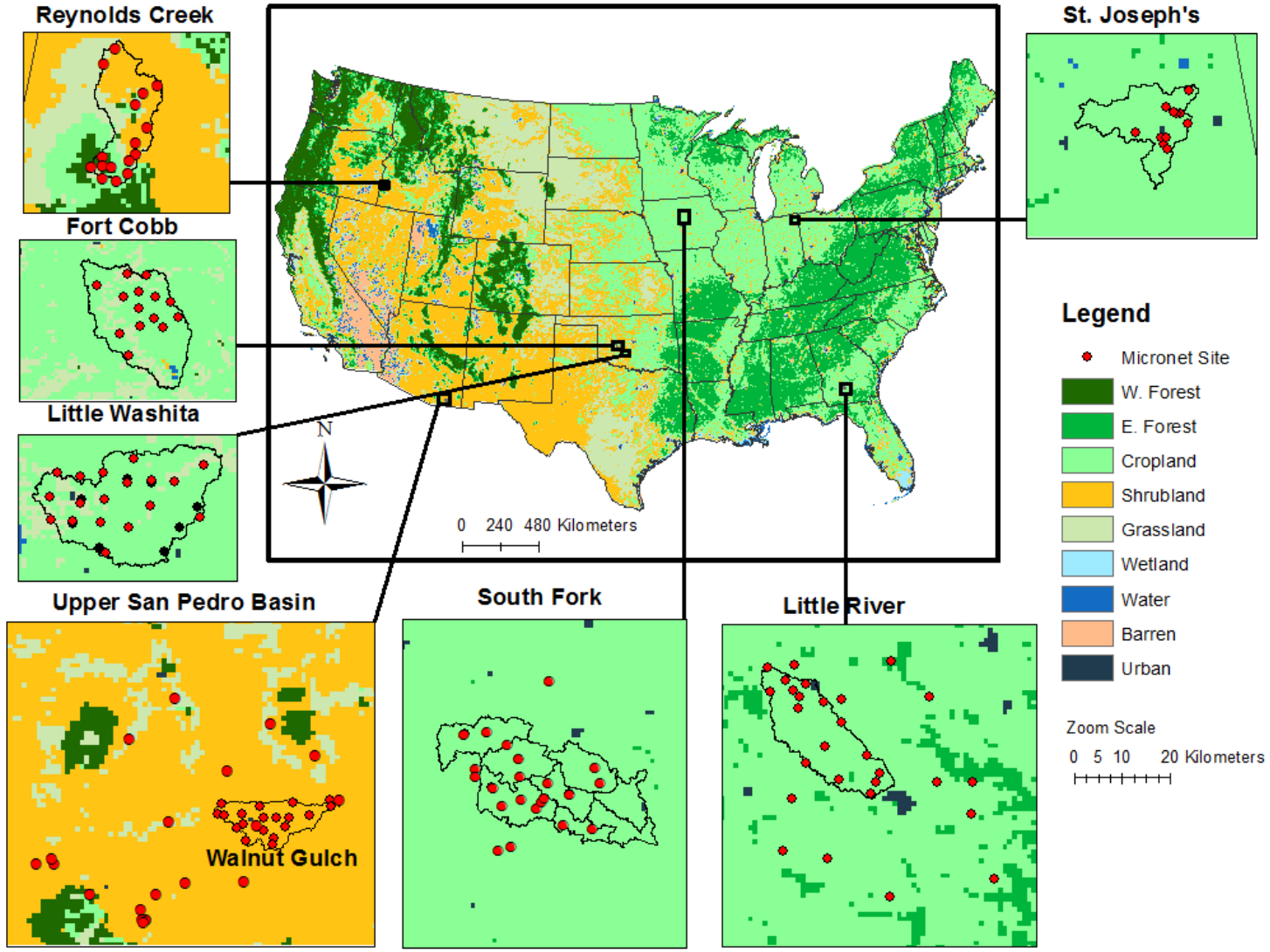


Aquarius



Overall similar spatial patterns and dynamic range for SMOS and Aquarius

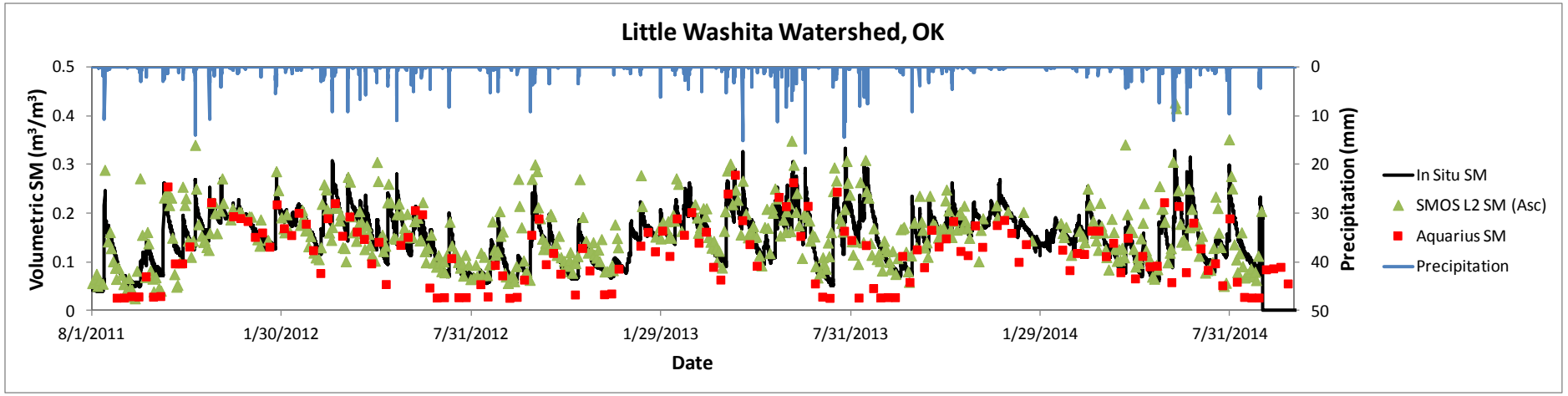
USDA-Agricultural Research Service Watershed Networks



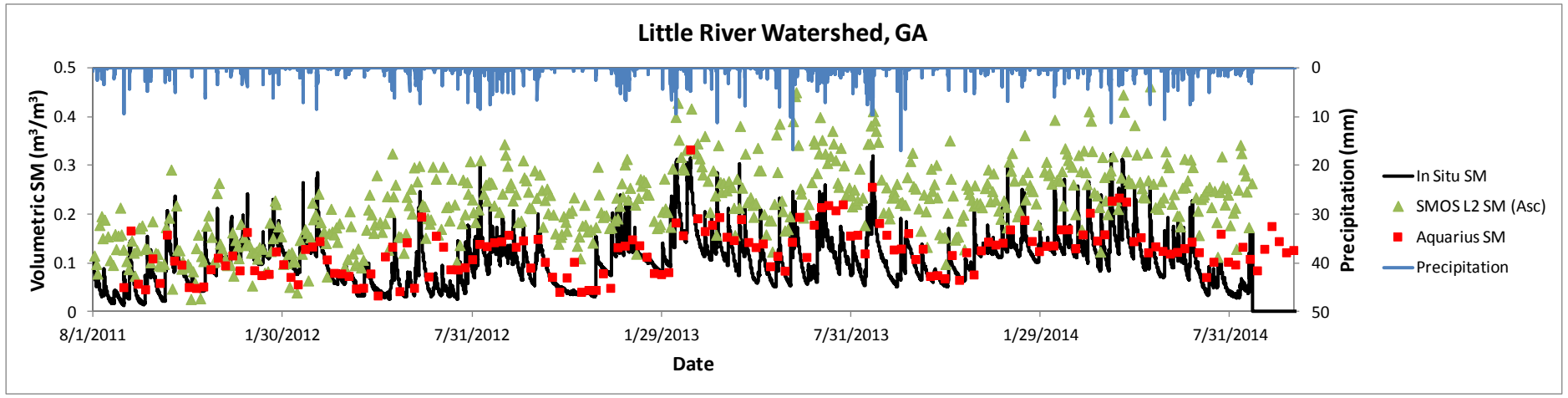
USDA-Agricultural Research Service Watershed Networks

Watershed	Size km^2	# of Sites	Climate	Annual Precip in mm	Landscape	Topography
Little Washita, OK	610	20	Sub humid	750	Range/wheat	Rolling
Walnut Gulch, AZ	148/2700	19/54	Semiarid	320	Range	Rolling
Little River, GA	334	33	Humid	1200	Row crop/forest	Flat
Fort Cobb, OK	813	15	Sub-humid	816	Row Crop/Range	Rolling
South Fork, IA	1800	15	Humid	835	Row Crop	Flat
St. Joseph's, IN	300	15	Humid	1010	Row Crop	Flat
Reynolds Creek, ID	238	19	Semiarid	500	Rangeland	Mountainous

Aquarius SM Validation Results

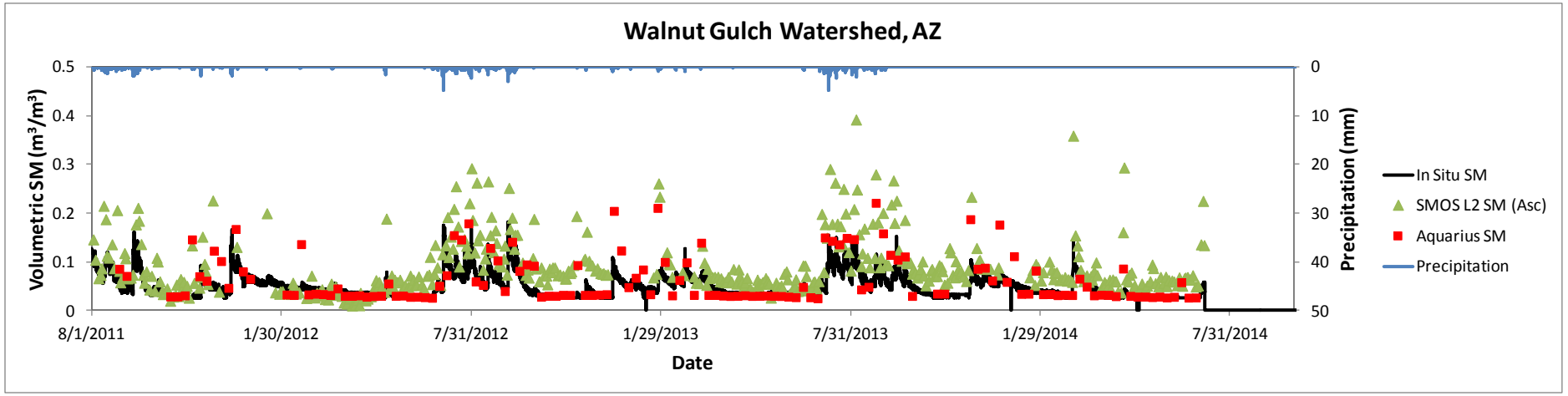


- Consistent range of soil moisture estimates
- Temporal pattern consistent with in situ observations of precipitation and soil moisture

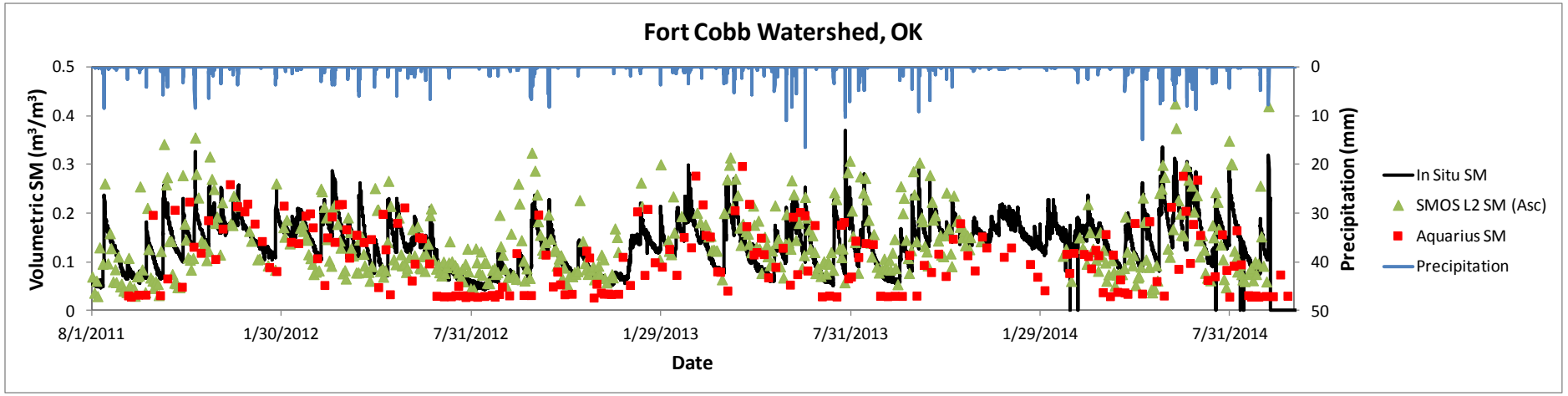


- Consistent range of soil moisture estimates
- SMOS retrievals have a positive bias

Aquarius SM Validation Results



- Semiarid watershed with convective precipitation in July-August
- Consistent range of soil moisture estimates



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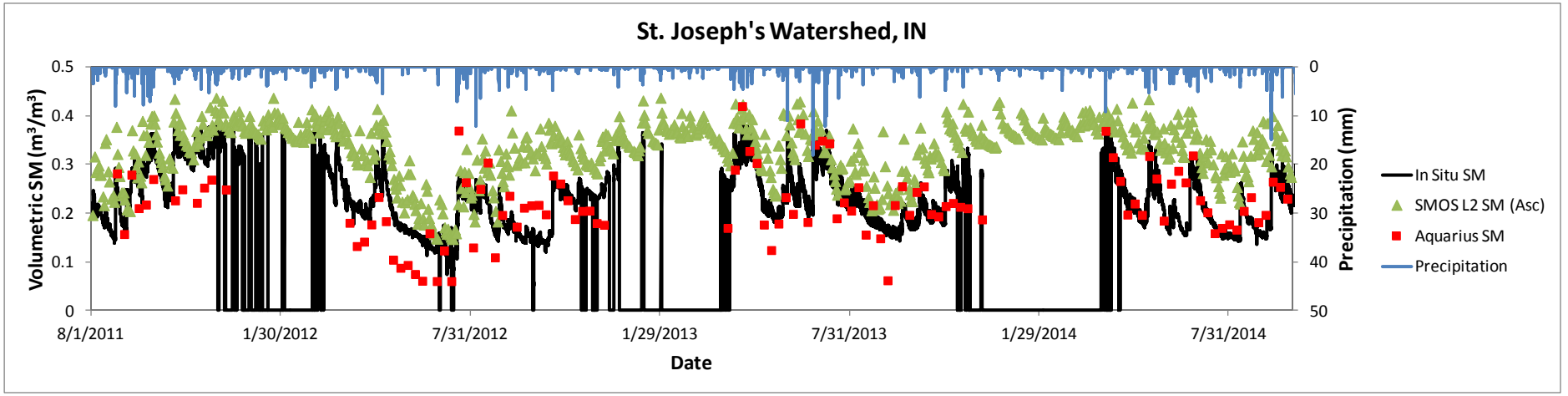
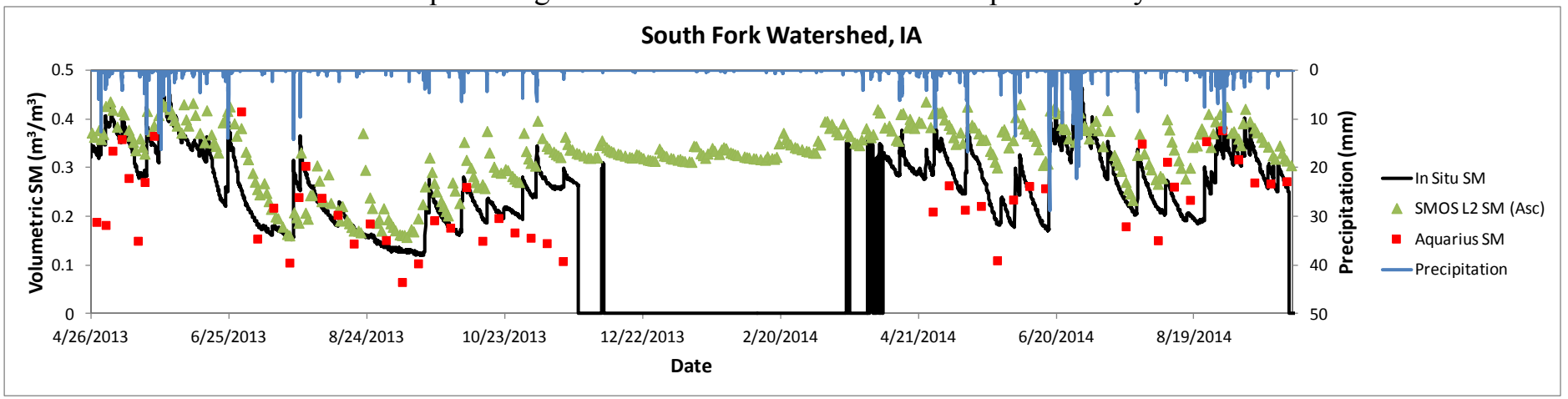
Aquarius SM Validation Results



- Humid agricultural domain with high amount of vegetation during summer
- "SMAP Candidate watershed" – in situ sensors located in a smaller domain; scaling to a larger domain?
- Overall both SMOS and Aquarius agree with in situ observations and capture the drydowns



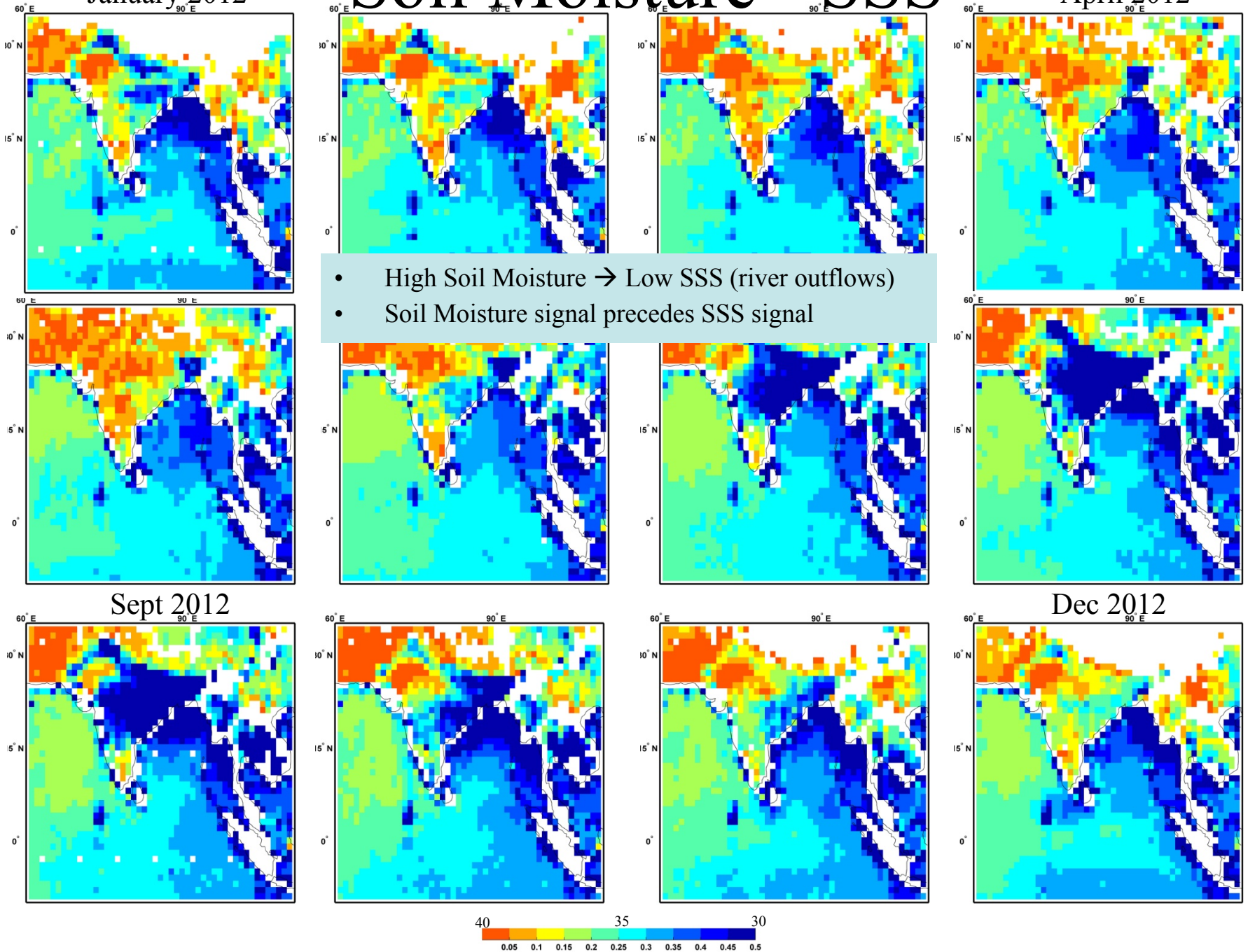
- Humid agricultural domain with high amount of vegetation during summer
- In situ network installed in 2013. Working on developing the scaling function for the domain.
- SMOS captures the drydown

Aquarius SM Validation Results

Watershed	Aquarius				
	RMSE	uRMSE	Bias	R	N
Little Washita, OK (Dsc)	0.043	0.031	-0.030	0.877	129
Little River, GA (Asc)	0.037	0.032	0.017	0.804	145
Walnut Gulch, AZ (Dsc)	0.044	0.038	0.021	0.695	123
Overall	**0.041**	**0.034**	**-0.013**	**0.838**	**397**
RMSE (Root mean square error), uRMSE (unbiased RMSE) and Bias are in m^3/m^3. R=Linear correlation coefficient, N=Number of samples					

- Size of the Aquarius footprint and fixed beam makes it challenging to validate the results
- Aquarius soil moisture compares well with in situ observations
- RMSE ~ 0.041 m^3/m^3, Bias ~ 0.013 m^3/m^3
- Small scale precipitation events in WG during July-Aug result in greater errors

Soil Moisture - SSS



- High Soil Moisture → Low SSS (river outflows)
- Soil Moisture signal precedes SSS signal

Summary

- Soil moisture algorithm tested and implemented at Aquarius Data Processing System and the data is available from NSIDC http://nsidc.org/data/aquarius/
- Our approach to soil moisture retrieval uses the SCA (SMAP baseline) with NCEP LST
  - Results are consistent with expected spatial patterns, SMOS, and observed soil moisture.
  - Validation results are encouraging.
- Aquarius Soil Moisture Product provides a synergy with SMAP and adds value to the mission
- We will continue to modify the Soil moisture algorithm to maintain consistency with the SMAP mission
- Plan to extend the validation activities to other domains (Australia, Europe, Asia, South America, Canada)
- Inter-comparison of Aquarius soil moisture with other satellite products (SMAP, SMOS, GCOM-W)

Aquarius Soil Moisture 9/2011-9/2013