National Aeronautics and Space Administration

New Directions for SMAP

Combining SMAP and Sentinel Data for High-Resolution Soil Moisture Product

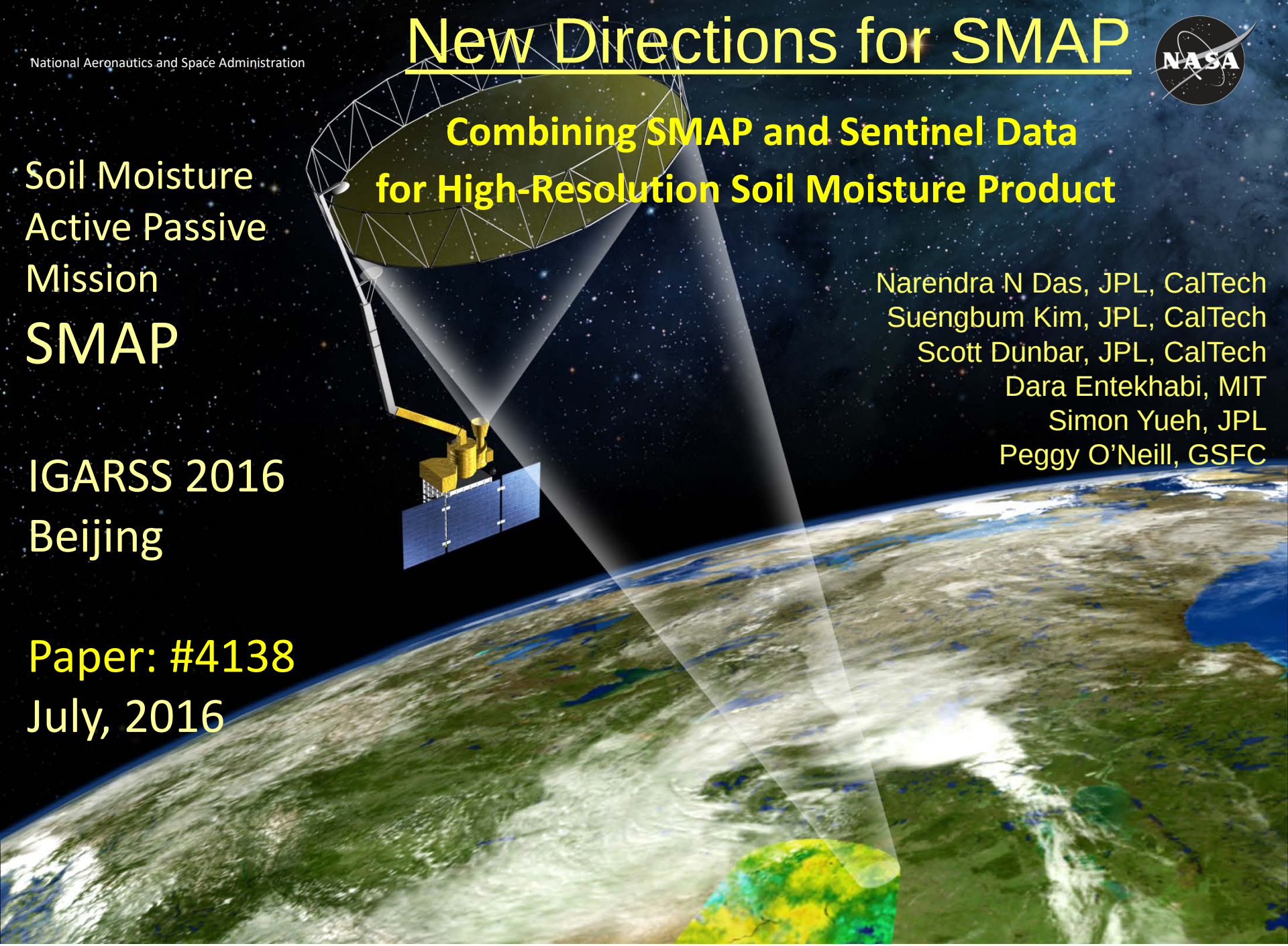
Narendra N Das, JPL, CalTech
Suengbum Kim, JPL, CalTech
Scott Dunbar, JPL, CalTech
Dara Entekhabi, MIT
Simon Yueh, JPL
Peggy O'Neill, GSFC

Soil Moisture Active Passive Mission

SMAP

IGARSS 2016
Beijing

Paper: #4138
July, 2016



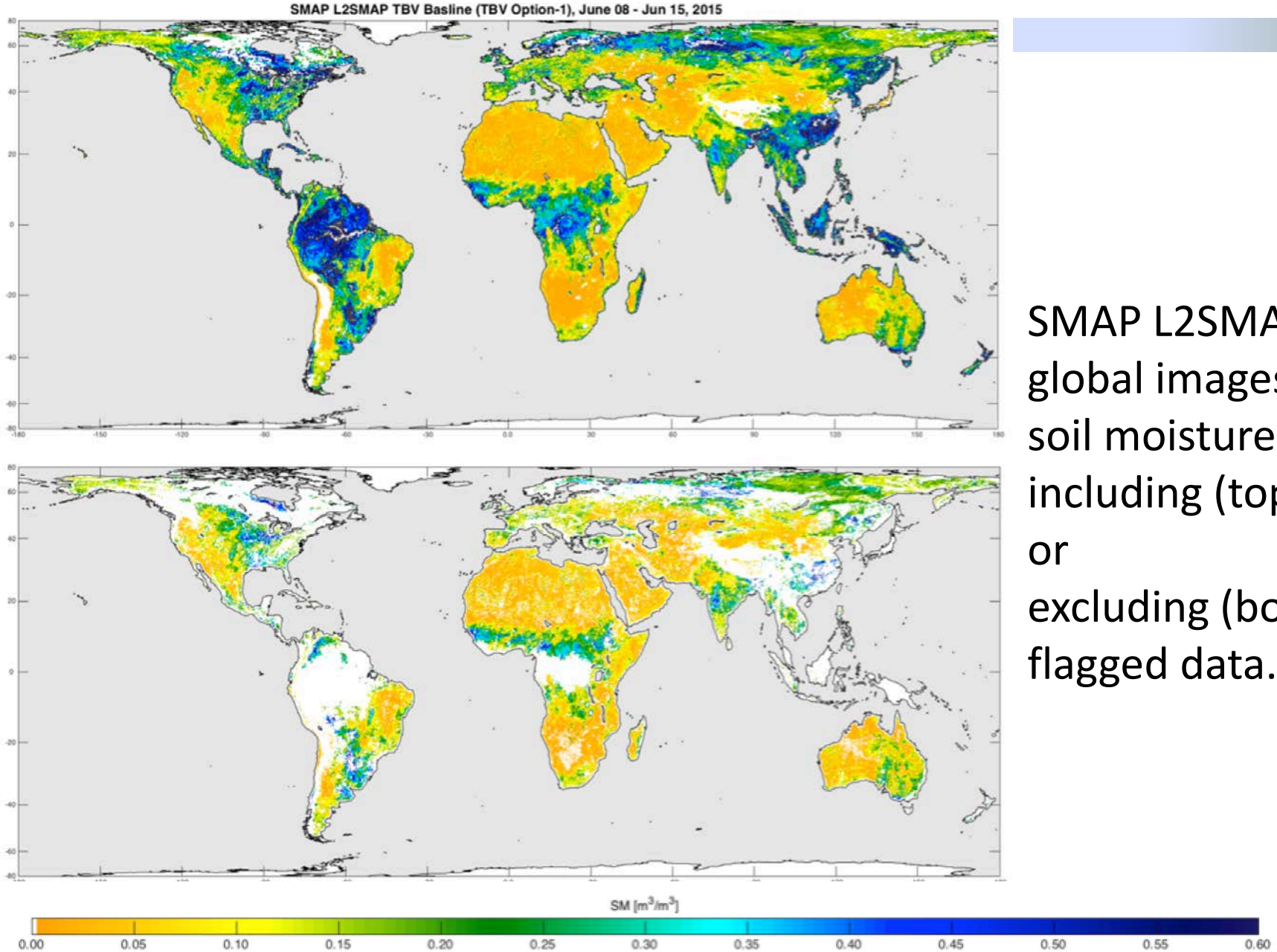
Outline

1. Status of SMAP Mission
1. SMAP L2SMAP Product
1. SMAP Post-Radar Period
1. SMAP-Sentinel Active-Passive Product for Fine Resolution Soil Moisture
1. Conclusion

Status of SMAP Mission

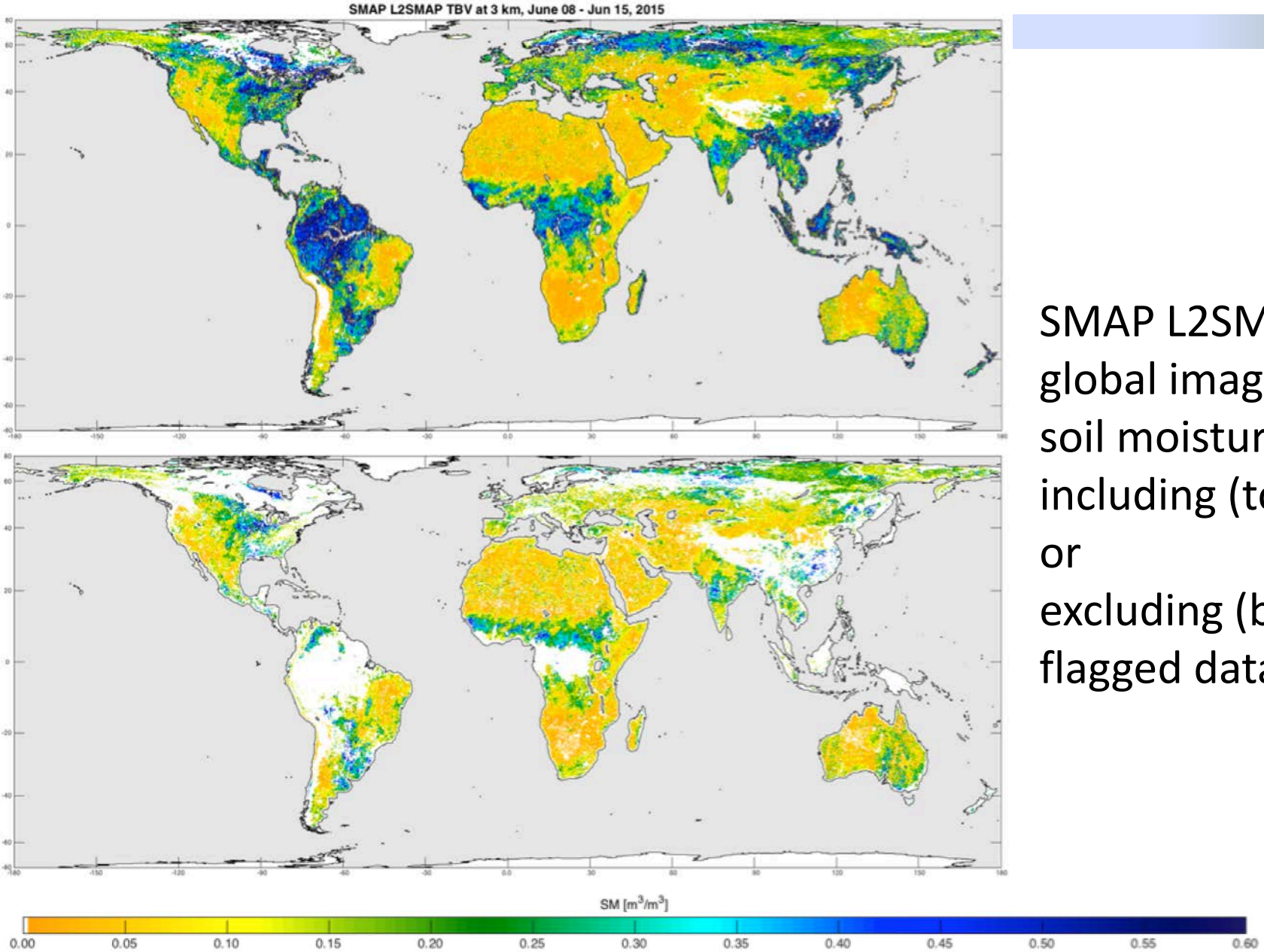
- SMAP launched on Jan 31st, 2015
- Science data acquisition started in April, 2015
- SMAP Radiometer and Radar worked in tandem with great success
- SMAP Radar malfunctioned on July 7th, 2015
- SMAP Radar is currently inoperable
- SMAP released Beta-Product to public on October 31st, 2015
- SMAP science data acquisition operation finished one year in April 2016
- SMAP released Validated-Product on April 30th, 2016
- SMAP data is now freely available to public through the NASA DAAC at NSIDC

SMAP L2SMAP Product at 9 km



SMAP L2SMAP global images of soil moisture including (top) or excluding (bottom) flagged data.

SMAP L2SMAP Product at 3 km



SMAP L2SMAP global images of soil moisture including (top) or excluding (bottom) flagged data.

National Aeronautics and
Space Administration

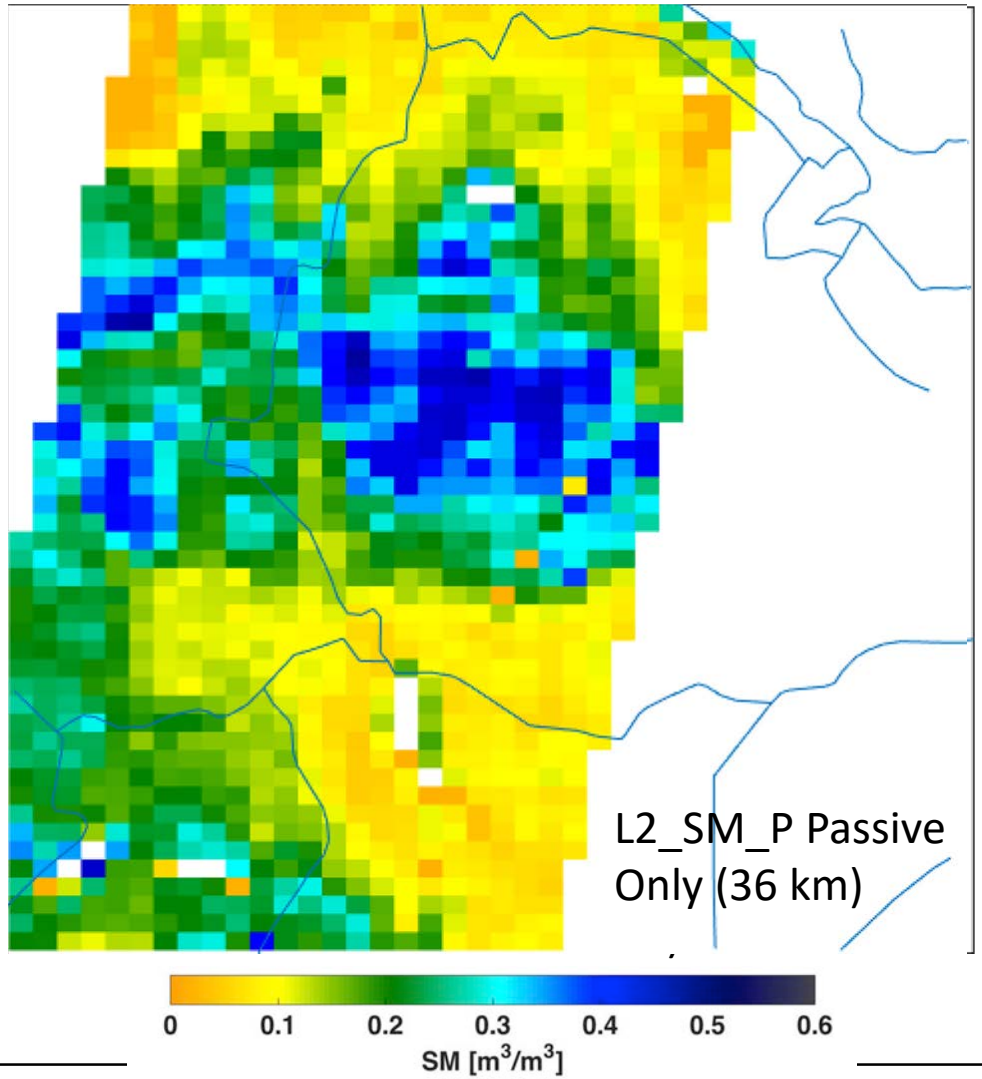
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

SMAP L2SMAP Product Validation

Detail Captured by SMAP Active-Passive Approach, July 1st, 2015

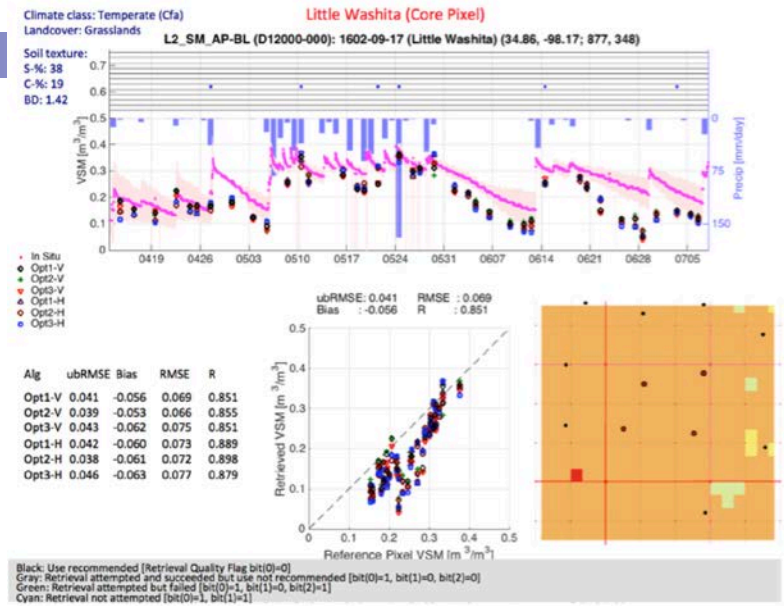
Comparison of SMAP Active-Passive Soil Moisture (3 km and 9 km) with the Passive-Only (36 km) soil moisture

Finer Details of Soil Moisture Captured in Increasing Spatial Resolution

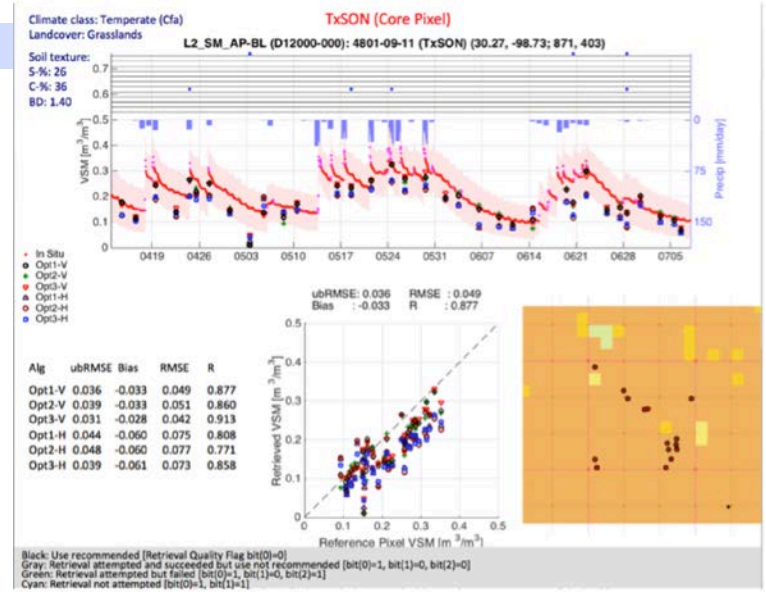


Example over Ethiopia, East Africa

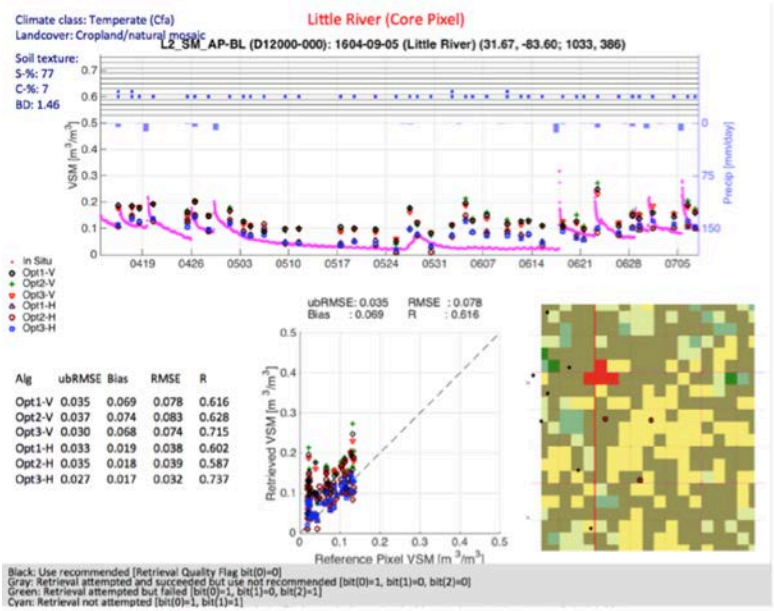
SMAP L2SMAP Product Validation



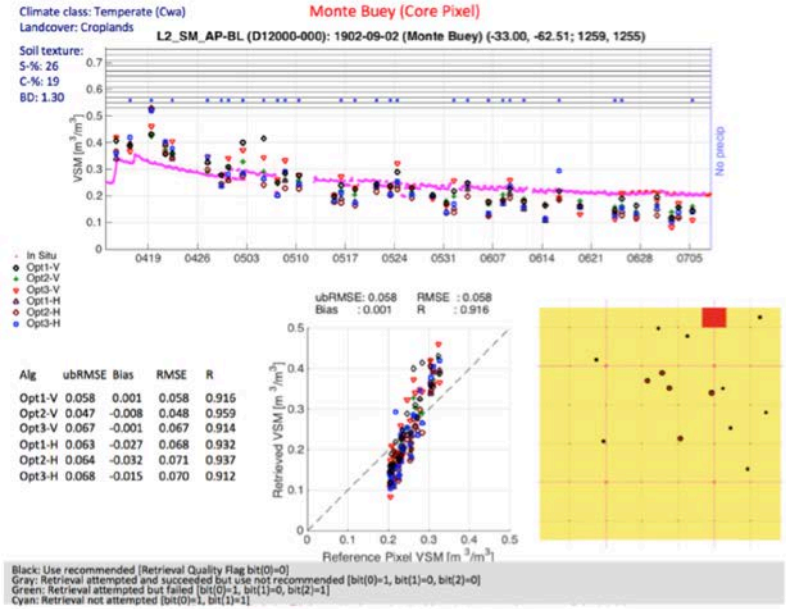
L2SMAP Assessment Tool Report for Little Washita, Oklahoma, USA.



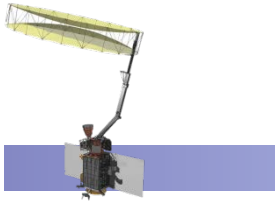
L2SMAP Assessment Tool Report for TxSON, Texas, USA.



L2SMAP Assessment Tool Report for Little River, Georgia, USA.



L2SMAP Assessment Tool Report for Monte Buey, Argentina.



SMAP L2SMAP Product Validation

SMAP L2SMAP Beta Release CVS Assessment for Disaggregated TBVs at 9 km

	ubRMSE (m^3/m^3)			Bias (m^3/m^3)			RMSE (m^3/m^3)			R		
Site name	**Opt-1**	**Opt-2**	**Opt-3**	**Opt-1**	**Opt-2**	**Opt-3**	**Opt-1**	**Opt-2**	**Opt-3**	**Opt-1**	**Opt-2**	**Opt-3**
Walnut Gulch	0.030	0.039	0.027	-0.015	-0.007	0.012	0.034	0.035	0.029	0.894	0.870	0.907
TxSON	0.036	0.039	0.030	-0.033	-0.033	-0.028	0.05	0.055	0.043	0.870	0.860	0.910
Tonzi Ranch	0.026	0.031	0.025	-0.067	-0.036	-0.072	0.072	0.048	0.077	0.814	0.670	0.814
Little Washita	0.041	0.039	0.043	-0.056	-0.053	-0.062	0.069	0.066	0.075	0.851	0.855	0.851
Little River	0.028	0.032	0.031	0.050	0.060	0.065	0.067	0.075	0.073	0.752	0.675	0.735
Kenaston	0.055	0.062	0.053	-0.026	-0.033	-0.021	0.061	0.070	0.057	0.651	0.591	0.512
Monte Buey	0.058	0.047	0.067	-0.001	-0.008	-0.001	0.058	0.048	0.067	0.915	0.959	0.914
Valencia	0.034	0.034	0.034	-0.037	-0.025	-0.046	0.050	0.042	0.057	0.537	0.500	0.510
Yanco	0.069	0.072	0.064	0.040	0.060	0.044	0.089	0.102	0.089	0.825	0.830	0.850
SMAP Average	**0.0418**	**0.043**	**0.041**	**-0.016**	**-0.008**	**-0.015**	**0.061**	**0.060**	**0.063**	**0.789**	**0.757**	**0.778**
Averages are based on the values reported for each CVS												

ubRMSE:
0.0418 m^3/m^3

SMAP L2SMAP Beta Release CVS Assessment for Disaggregated TBV and TBH at 3km

	ubRMSE (m^3/m^3)		Bias (m^3/m^3)		RMSE (m^3/m^3)		R	
Sites	TBV	TBH	TBV	TBH	TBV	TBH	TBV	TBH
Walnut Gulch	0.029	0.044	-0.010	-0.023	0.037	0.058	0.324	0.10
TxSON	0.034	0.044	-0.063	-0.013	0.070	0.046	0.921	0.828
Tonzi Ranch	0.034	0.049	-0.050	-0.059	0.061	0.076	0.773	0.640
St Josephs	0.109	0.098	0.053	0.018	0.122	0.100	0.508	0.334
Little River	0.043	0.044	-0.014	0.027	0.046	0.051	0.673	0.658
Kenaston	0.057	0.076	-0.064	-0.032	0.086	0.082	0.281	0.421
Monte Buey	0.065	0.100	-0.053	-0.031	0.084	0.105	0.817	0.693
Valencia	0.042	0.047	-0.064	-0.029	0.077	0.056	0.267	0.446
Yanco	0.071	0.074	0.005	0.027	0.071	0.079	0.728	0.682
SMAP Average	**0.054**	**0.064**	**-0.029**	**-0.013**	**0.072**	**0.073**	**0.59**	**0.54**
L2SMAP 9km	**0.042**	**0.044**	**-0.016**	**-0.036**	**0.061**	**0.069**	**0.79**	**0.72**

SMAP Post-Radar Period

- Lead to many research to recover the lost capabilities of the SMAP mission due to the radar failure.
- Two Approaches are followed:
  - -- Enhancing the SMAP radiometer resolution
  - -- Fine Grid processing of SMAP L2SMP data
  - -- Ingesting SAR data from different satellite for high resolution soil moisture

SMAP-Sentinel Active-Passive Product

Why Sentinel for AP Algorithm

Sensor Name	RADARSAT-2	Sentinel-1A	RISAT-1
Agency	Canadian Space Program (CSP)	European Space Agency (ESA)	Indian Space Research Organization (ISRO)
Instrument	C-band SAR (5.4 GHz)	C-band SAR (5.4 GHz)	C-band SAR (5.35 GHz)
Incidence Angle	Side-looking, 15-45° off-nadir	Side-looking, 15-45° off-nadir	36.85 deg.
Polarization	HH, HV, VV and VH	(VV and VH) or (HH and HV)	HH an HV
Sensor Height at Equator	798 km	693 km	542 km
Orbit	Sun Synchronous (dusk/dawn)	Sun Synchronous (dusk/dawn)	Sun Synchronous (dusk/dawn)
Revisit time (Orbit Repeat cycle)	24 days	12days	25 days
Resolution	100 m	5 m X 20 m	~25 meters
Swath Width	500 km (ScanSAR mode)	250 km (IWS mode)	115 km (MRS)
Mean local time	6:00 AM Descending	6:00 AM Descending	6:00 AM
Launch	Dec 14th, 2007	April 3rd, 2014	April 26th, 2012
Planned Lifetime	7 years minimum	7 years	5 years

SMAP-Sentinel Active-Passive Product

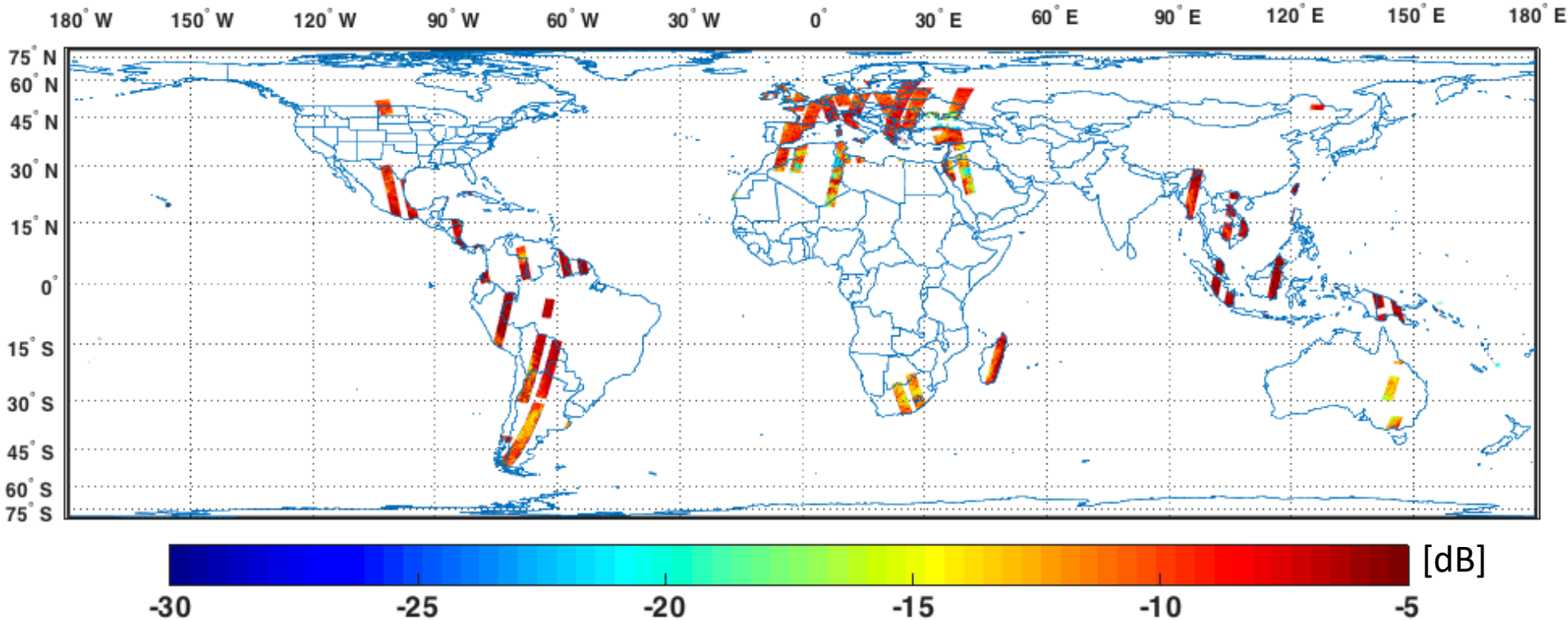
Why Sentinel for AP Algorithm cont'd

Sensor Name	RADARSAT-2	Sentinel-1A	RISAT-1
Current Data Access	Cost $$$	**Free**	Cost $$$
Future addition to mission	No	Yes, (Sentinel-1B to be launched in 2016)	No

Recommendation: Is to use Sentinel data because it is free, has better revisit interval, and has the required co-pol and x-pol measurements. With Sentinel-1B, the revisit interval will improve further.

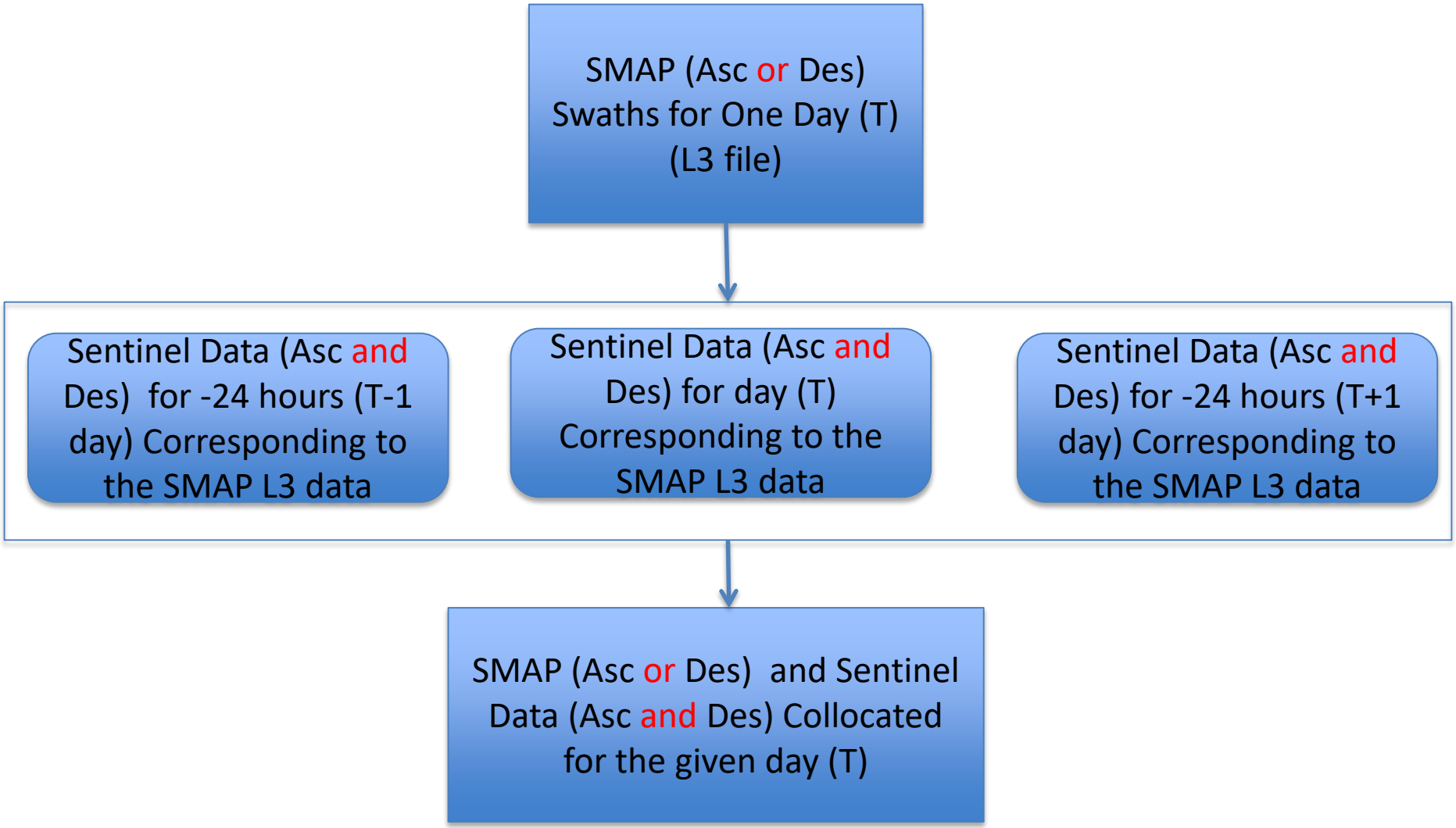
Sentinel Data Global Overview

May 15th to 17th, 2015. Coverage shown based on Sentinel IWS SDV data



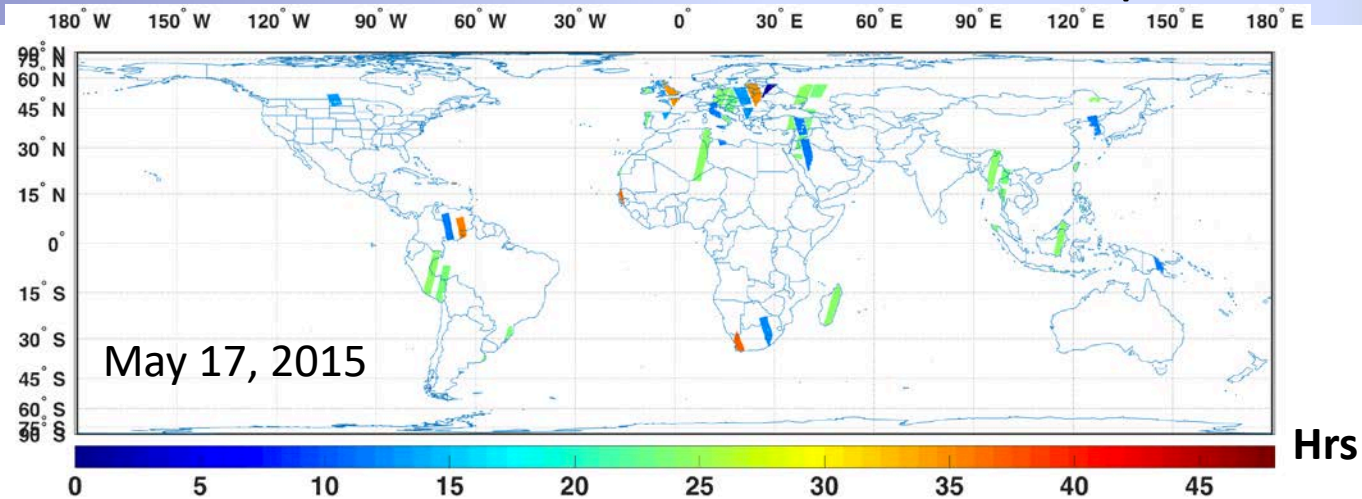
Currently, the total spatial coverage of Sentinel in IWS mode with co-pol and x-pol measurements are sparse. We also plan to use the IWS only co-pol measurements to increase the spatial coverage for any given day.

SMAP and Sentinel Global Overlap

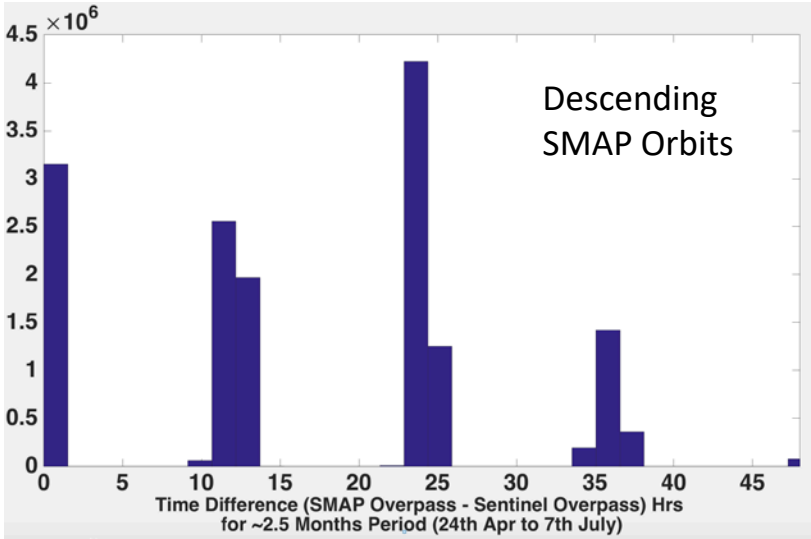


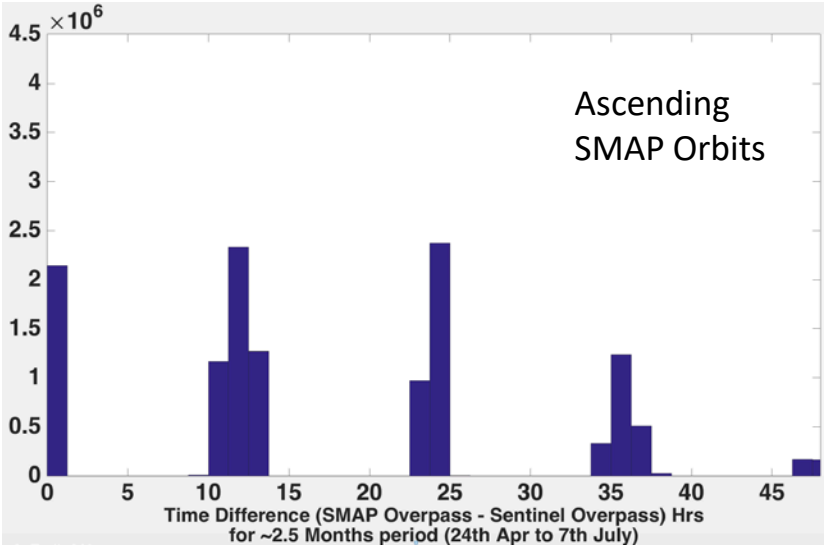
SMAP-Sentinel Active-Passive Product

SMAP and Sentinel Global Overlap



With the current orbits characteristics of SMAP and Sentinel the average time difference is ~18 hours that includes the Sentinel Asc. and Des. Overpasses for any given SMAP swath.





Active Passive Algorithm using Multi-Sensor (SMAP Radiometer and Sentinel Radar) data

$$T_{B_p}(M) = T_{B_p}(C) + \beta(C) \cdot \{ [\sigma_{pp}(M) - \sigma_{pp}(C)] - \Gamma(C) \cdot [\sigma_{pq}(M) - \sigma_{pq}(C)] \}$$

Forward model used for Beta estimation

$$\beta^{p-pp} = -\frac{f_F \cdot e^p_{VegB}}{f_B \cdot e^p_{VegL} + f_F \cdot e^p_{VegL}}$$

where

$f_F = e^{-4\cos^2\theta\, ks^2}$ is the Fresnel roughness loss

$f_B = 4\cos^2\theta\, ks^2\, kl^2$ is the Bragg roughness loss

$e^p_{Veg} = e^{-\frac{\pi\, d\, vol \left(\frac{2}{3}\mu\, \varepsilon_L + 4(1-\mu)\varepsilon_{St}\right)}{\lambda \cos\theta}}$ is the vegetation loss

where d is the canopy height, vol is the normalized canopy volume, and μ is the leaves-to-stalks dominance ratio.

ε_L and ε_{St} are the leaves and stalks dielectric constants (with polarization).

Parameters
Incidence angle (θ)
Wave length (λ)
Vertical roughness (ks)
Horizontal roughness (kl)
Vegetation height (d)
Vegetation volume fraction (vol)
Dielectric constant of leaves (ε_L', ε_L'')
Dielectric constant of stalks (ε_{St}', ε_{St}'')

VWC scales *d* and *vol*

β has angular dependence

Jagdhuber et al. (2015) show that

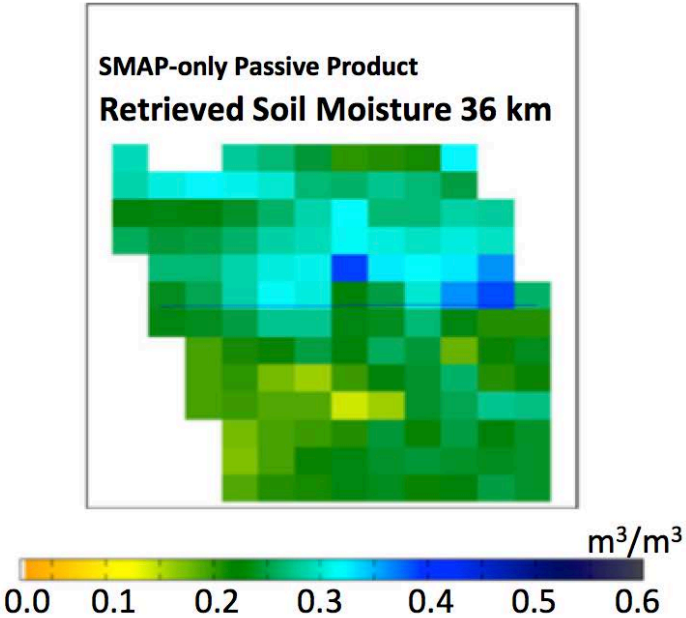
"…the β–parameter is physically related to the ratio of surface roughness and vegetation losses in the observed emission and backscatter."

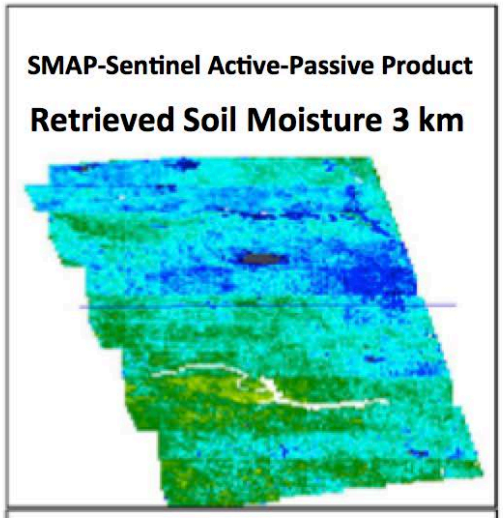
Jagdhuber, T., D. Entekhabi, I. Hajnsek, A. Konings, K. McColl, S. H. Alemohammad, N. Das and C. Montzka, 2015: Physically-based modeling of the SMAP active-passive soil moisture algorithm, in review, *Remote Sensing of the Environment*, 21 pages.

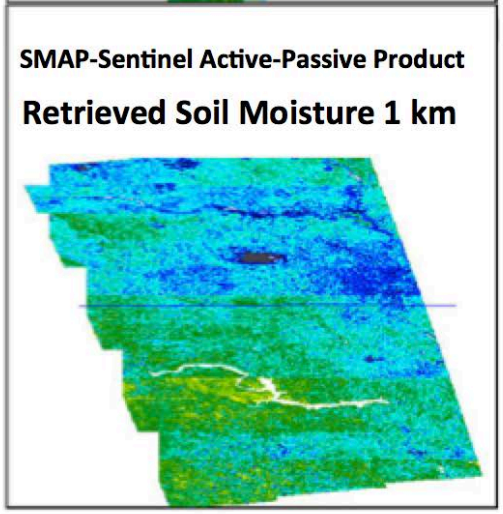
SMAP-Sentinel Active-Passive Product

SMAP Active-Passive Algorithm

$$T_{B_p}(M) = T_{B_p}(C) + \beta(C) \cdot \{ [\sigma_{pp}(M) - \sigma_{pp}(C)] - \Gamma(C) \cdot [\sigma_{pq}(M) - \sigma_{pq}(C)] \}$$





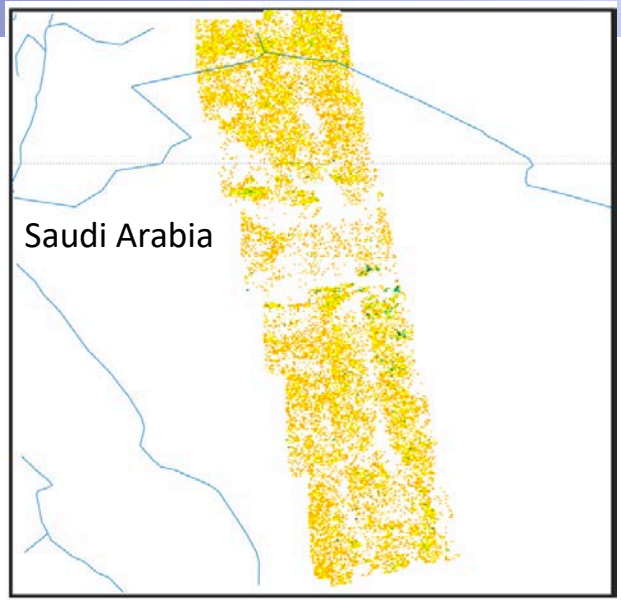


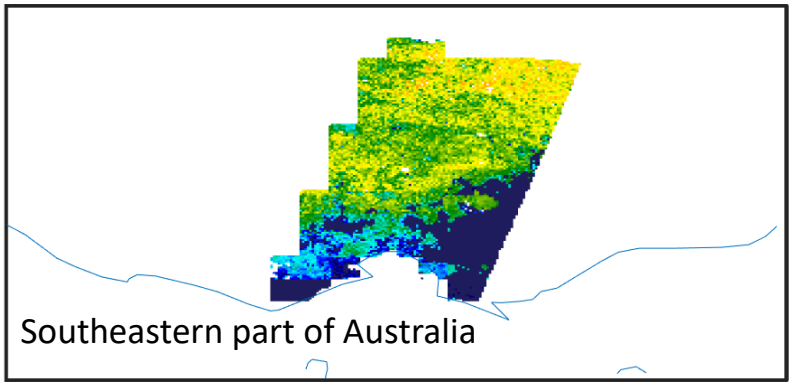
Soil Moisture at Different Resolutions Retrieved for May 17th, 2015 Over Manitoba region Canada

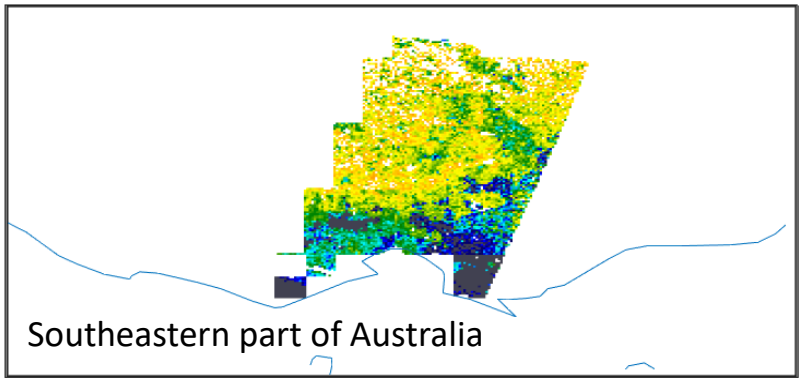
SMAP-Sentinel Active-Passive Product

SMAP_Sentinel-based 3 km

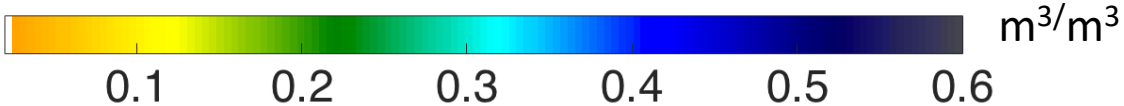
SMAP-based 3 km







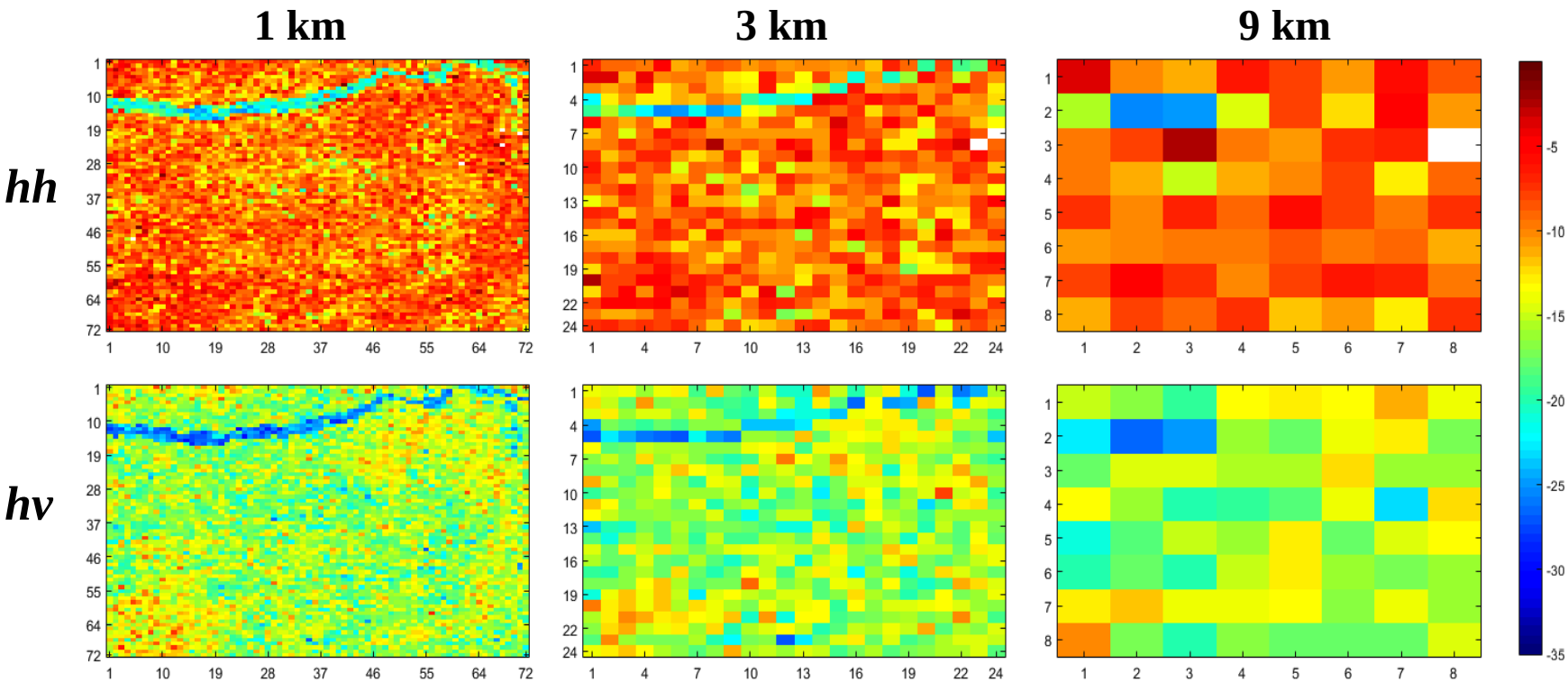
Retrieved Soil Moisture



m^3/m^3

Test of Active-Passive Approach Using SMAP and RISAT data

Backscattering Coefficient σ^0 (June 29, 2015)



Estimated parameters in 36 km EASE grid across study area

RISAT Incidence angle (deg)	
44.696	47.095
44.322	46.747

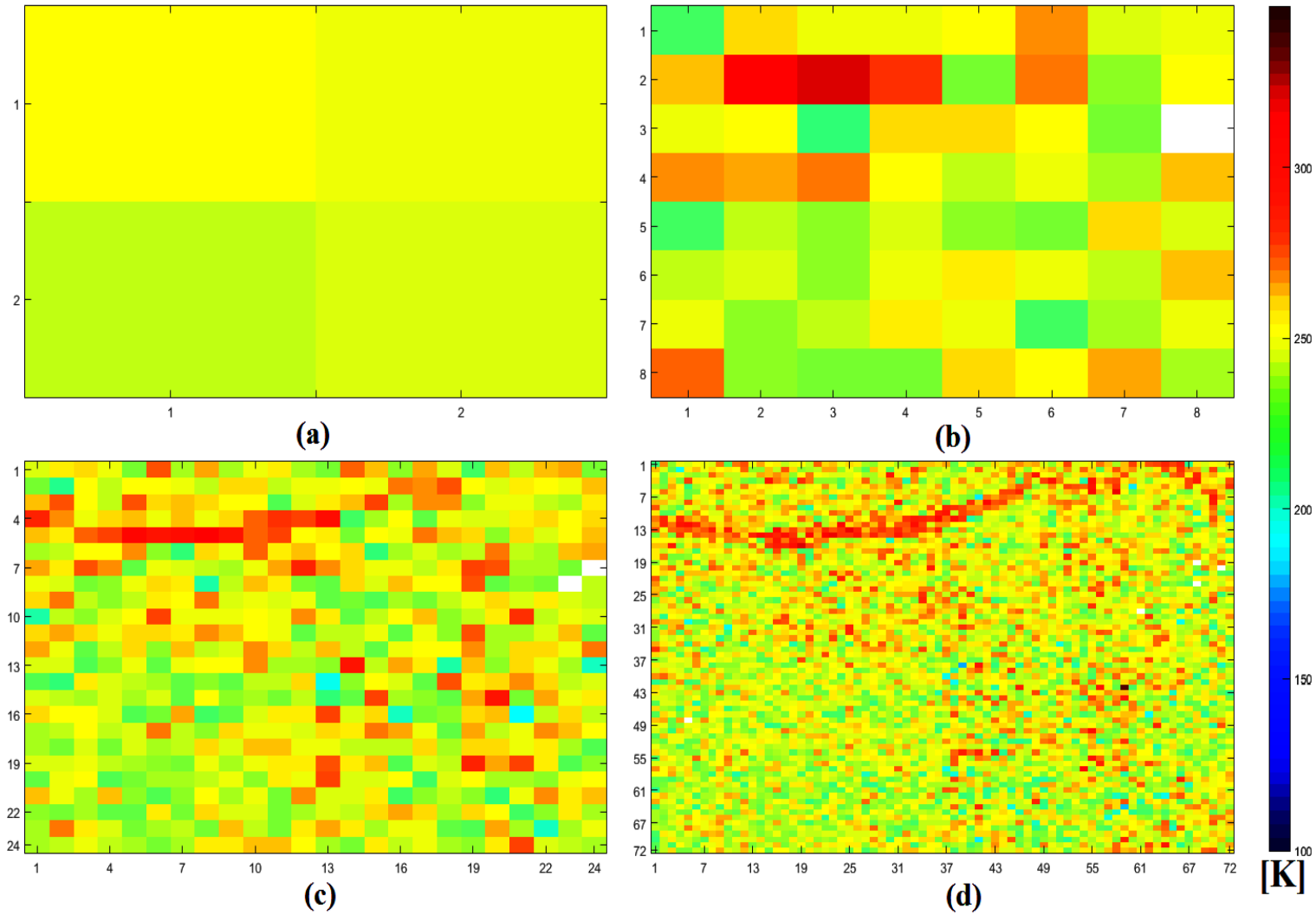
Vegetation water content (kg/m^2)	
2.062	2.372
2.801	1.582

Sensitivity parameter β_h	
-7.605	-6.989
-5.311	-10.595

Sensitivity parameter Γ	
0.862	0.766
0.451	0.492

Test of Active-Passive Approach Using SMAP and RISAT data

Disaggregated Brightness Temperature (June 29)



Brightness Temperature Map

(a) 36 km resolution (b) 09 km resolution (c) 3 km resolution (d) 1 km resolution

Conclusion

- The SMAP Validated-Products are already released and the products met the mission requirements
- The SMAP mission finished one year in April’16
- SMAP-Sentinel Enhanced Product is being tested and the looks promising. As per proposed schedule, the SMAP-Sentinel Enhanced product will be released by April’17.