Evaluation of passive microwave brightness temperatures simulations across multiple microwave frequencies and polarization over the test site of Kuwait Desert

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Outlines

- Objectives
- SM variations
- Intensive Field campaigns
- Simulation of Tb's for Bare Soil Model (SMAP/SMOS/AMSR2/SSM/I)
- Input / Output Parameters for TB Simulation
- Observed and Simulated Brightness Temperature
- Conclusions

Objectives

- Kuwait represents a **Unique site in Arabian Peninsula** with Unique Desert features (**Bare soil** and **low topography**).

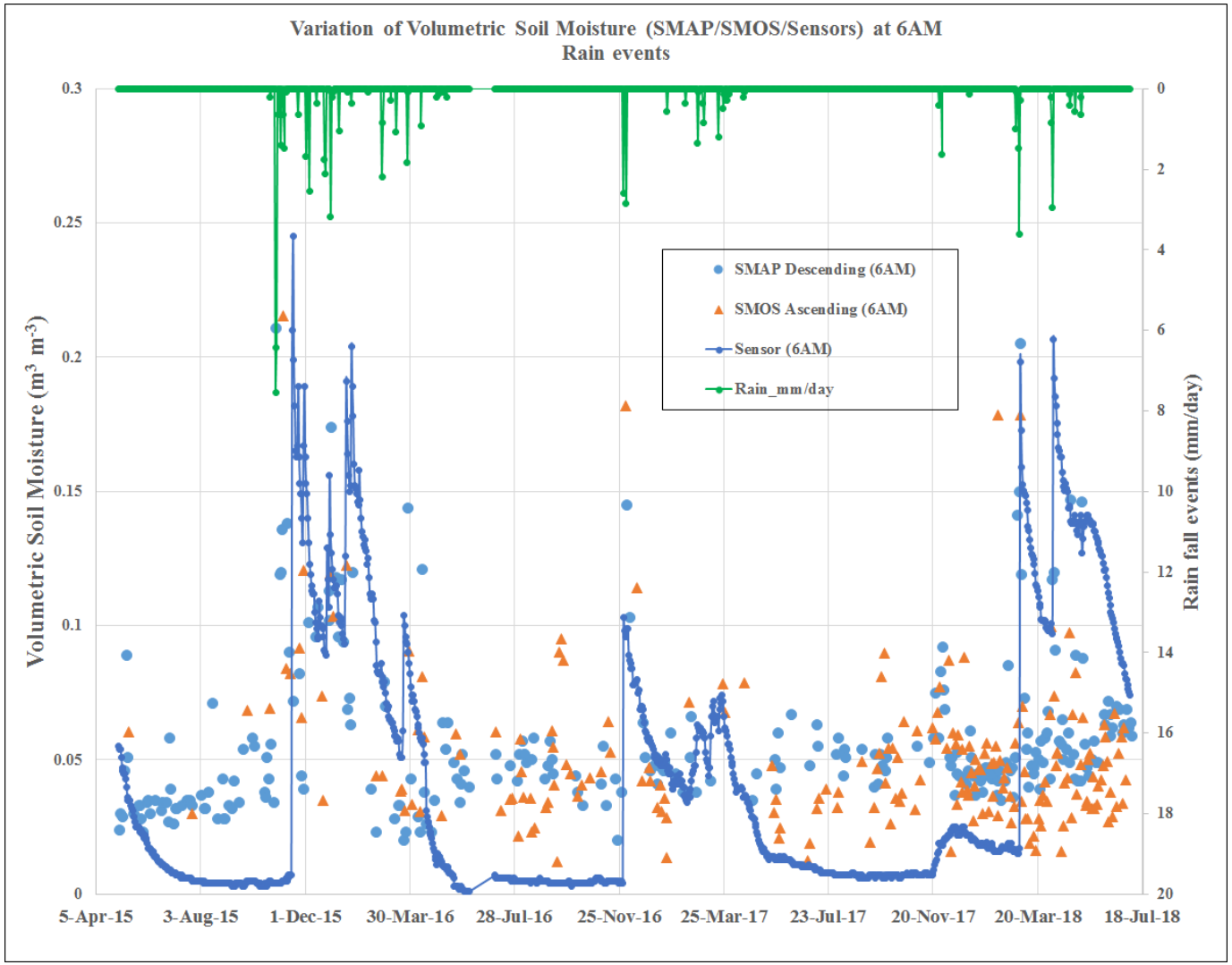
- This offer a unique opportunity to study the relationship between microwave frequency, SM, and roughness.

- Designed extensive field campaign to assess the performance of radiative transfer model in such **Desert Conditions** at different freq. and (H&V) polarization

- Simulation of different satellites TB's (from1.4 GHz to 19 GHz) then were compared with observed TB,s from (SMAP, AMSR2, SMOS, SSMI)

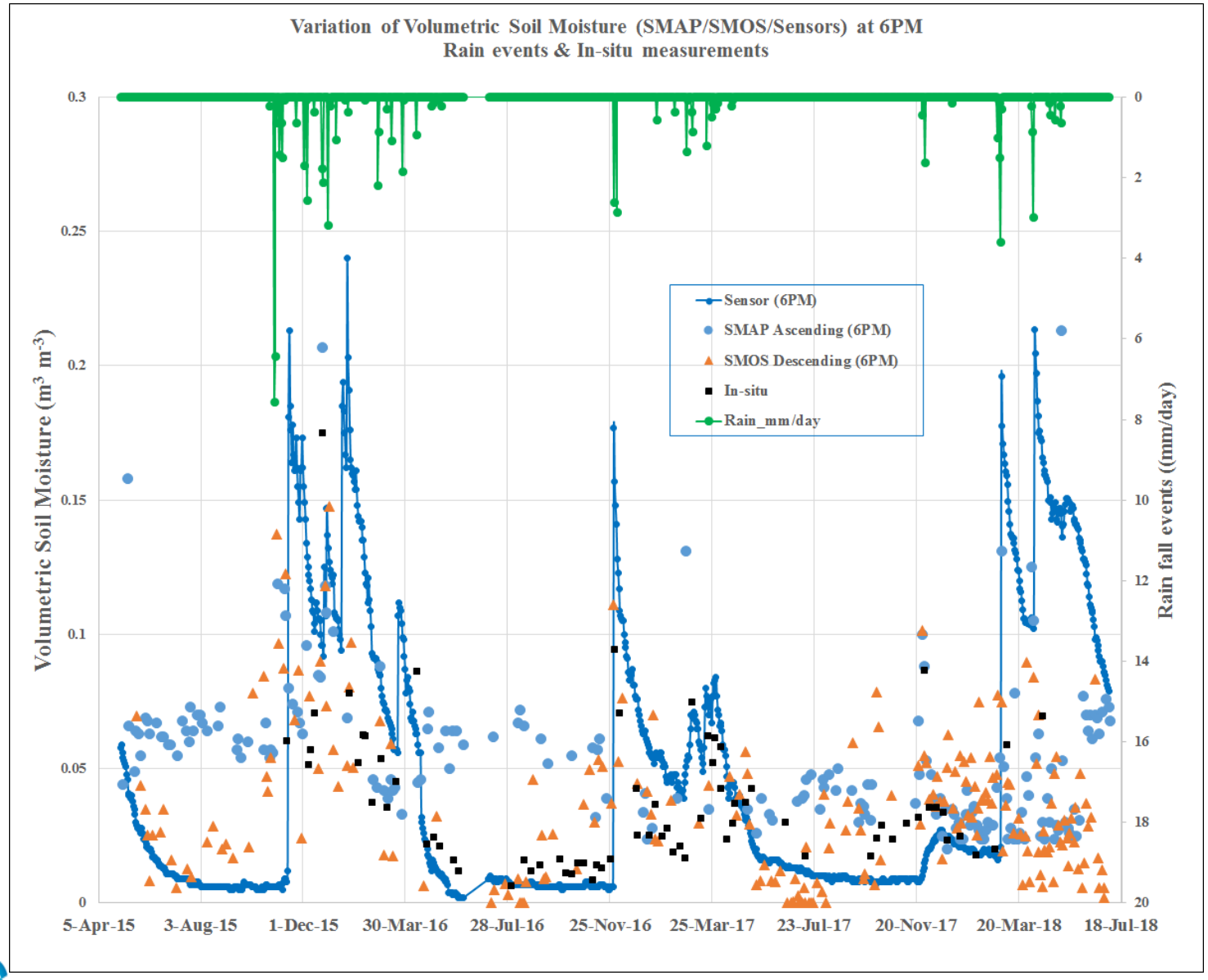
Soil Moisture Variations (6AM)

SMAP L3 radiometric global daily 36 km
SMOS L2

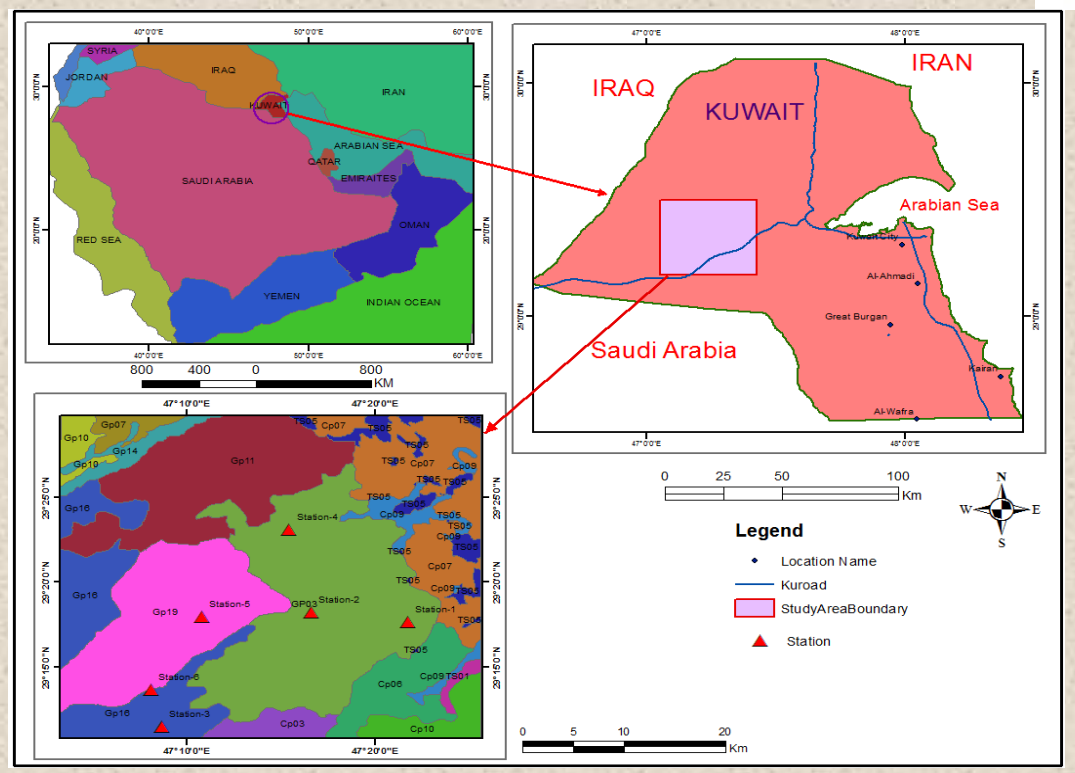


Soil Moisture Variations (6PM)

SMAP L3 radiometric global daily 36 km
SMOS L2

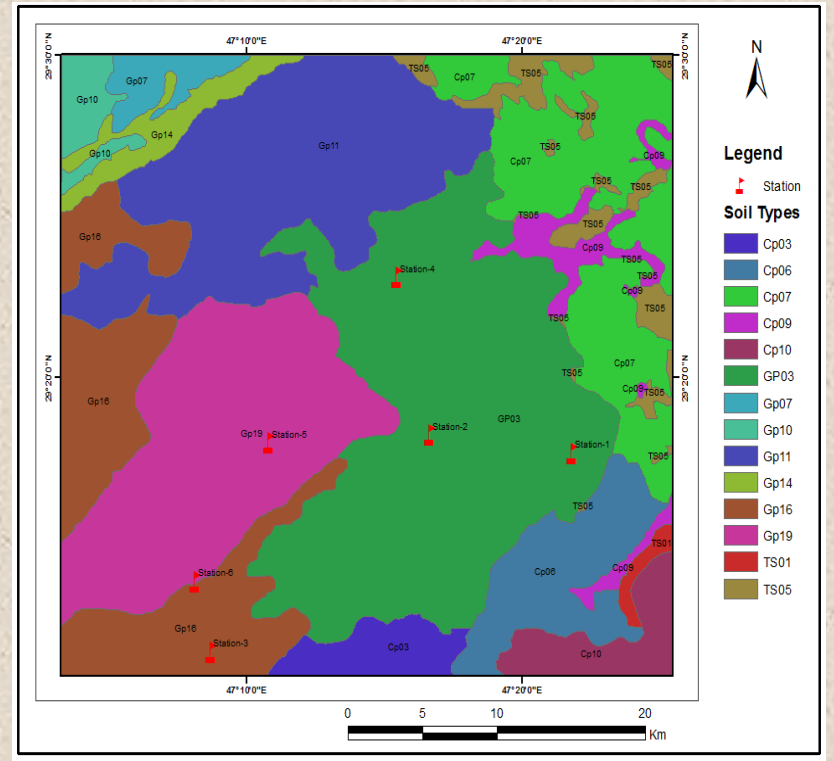


NASA SMAP Kuwait test site



- annual rain fall is 116 mm (28-260 mm)
- Evaporation rate (4.6 mm/day in January to 22.9 mm/day in June

NASA SMAP Kuwait test site

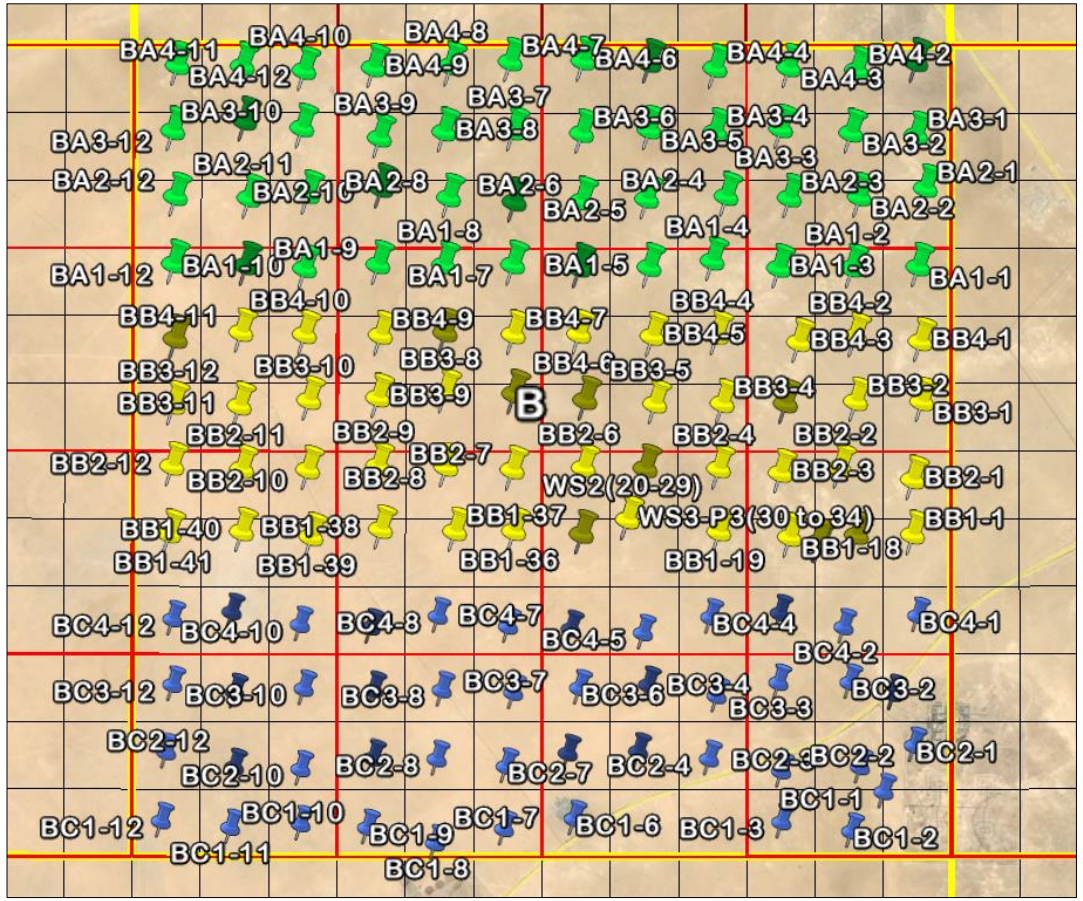


The test site of 36 km by 36 km with 14 soil types showing 6 in-situ stations

Legend	Soil Type	Area (Sq.Km)
Cp03	Calcic Petrocalcids - Petrocalcic Petrogypsids complex, nearly level	29.5
Cp06	Calcic Petrocalcids - Typic Petrogypsids complex, nearly level	68.05
Cp07	Calcic Petrocalcids - Typic Torripsamments complex, plain, nearly level	146.62
Cp09	Typic Petrocalcids - shallow, gently sloping	29.33
Cp10	Typic Petrocalcids - Calcic Petrocalcids complex, nearly level	35.15
Gp03	Petrocalcic Petrogypsids - shallow, nearly level	331.93
Gp07	Petrocalcic Petrogypsids - Calcic Petrocalcids complex, nearly level	18.4
Gp10	Petrocalcic Petrogypsids - Typic Petrogypsids - Typic Torripsamments complex, nearly level	19.1
Gp11	Petrocalcic Petrogypsids - Typic Torripsamments complex, nearly level	204.86
Gp14	Typic Petrogypsids - strongly sloping	26.38
Gp16	Typic Petrogypsids - Calcic Petrogypsids complex, nearly level	149.76
Gp19	Typic Petrogypsids - Typic Haplocalcids complex, nearly level	193.92
Ts01	Typic Torripsamments - smooth surface, gently sloping	6.12
Ts05	Typic Torripsamments - Calcic Petrocalcids complex, moderately steep	36.83

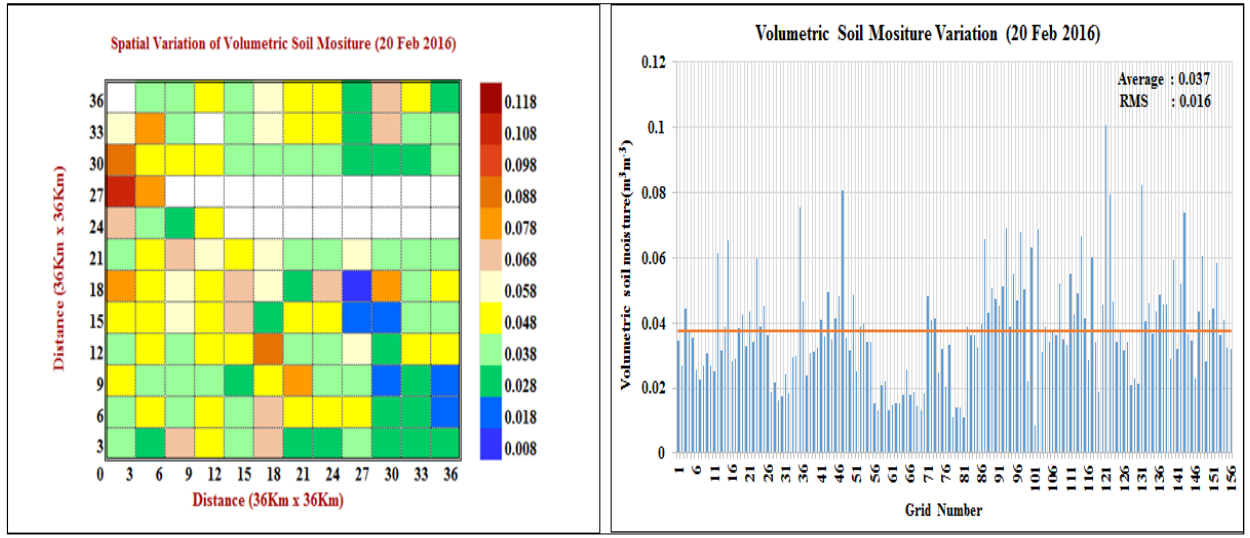
Intensive Field campaigns

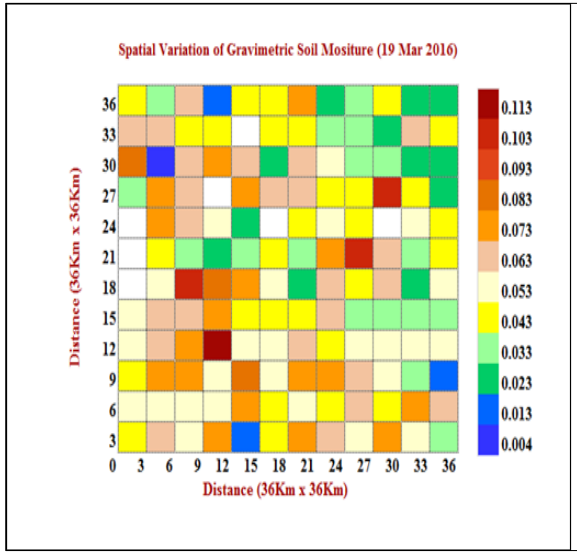
- 20th Feb 2016 and 19th Mar 2016 (7:30 AM to 6 PM approximately)
- 3 teams, covered the 36 km by 36 km SMAP pixel foe each day / sampled in every 3km (SM, soil texture, bulk density, roughness
- 20th Feb 2016, 156 samples covering 10 soil types, 19th Mar 2016, 166 samples covering 13 soil types.
- LST from different sources

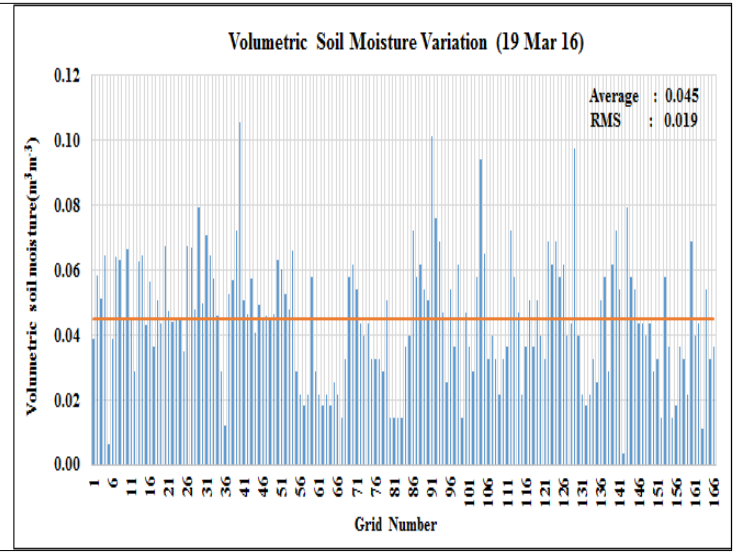


3km Thermo-gravimetric sample points

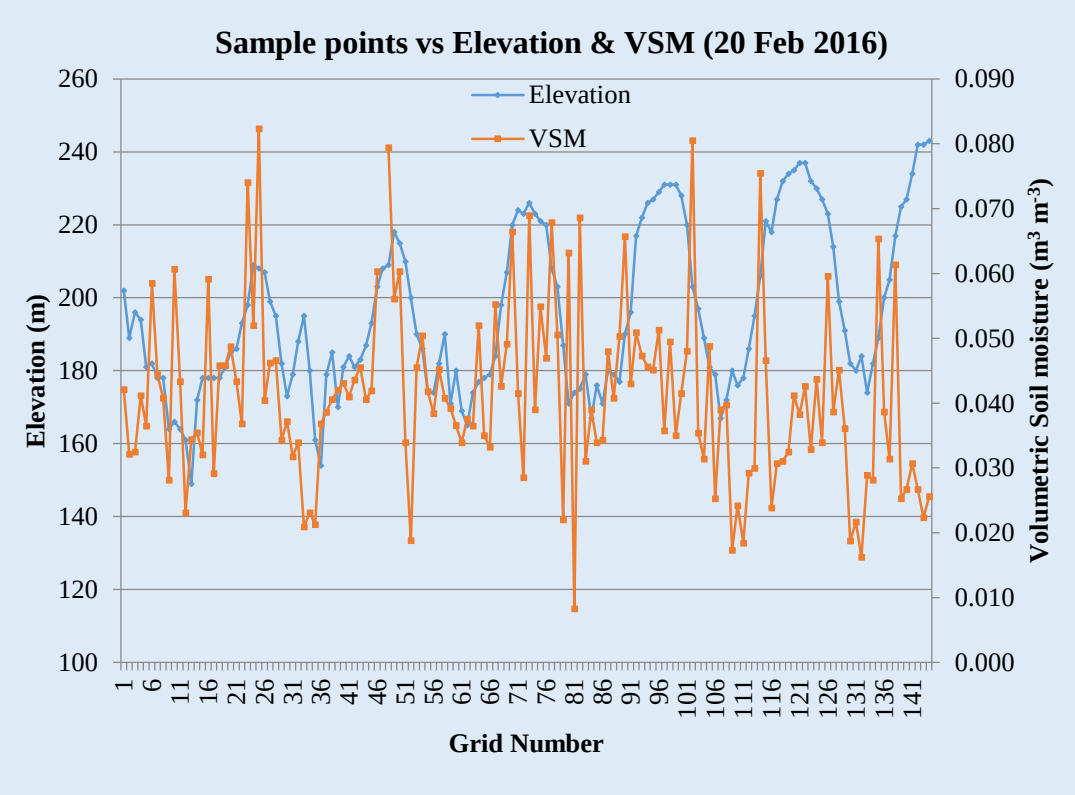
Spatial Variation of Soil Moisture

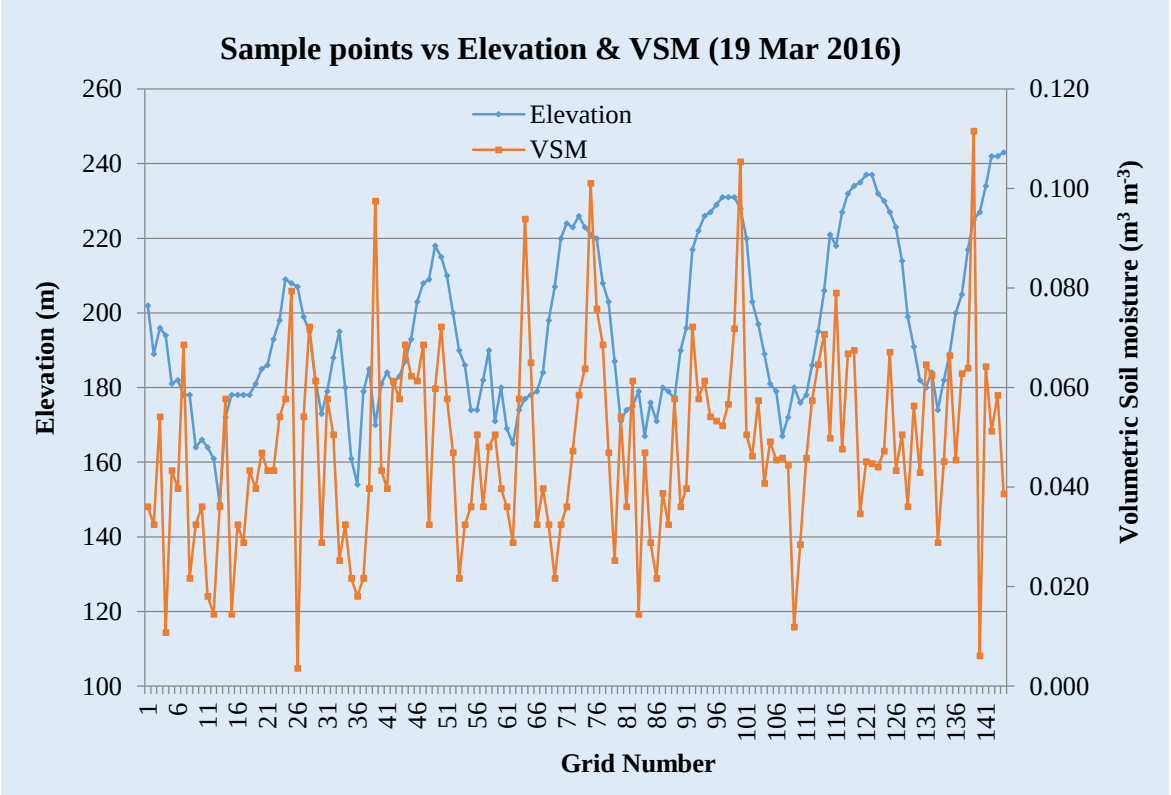






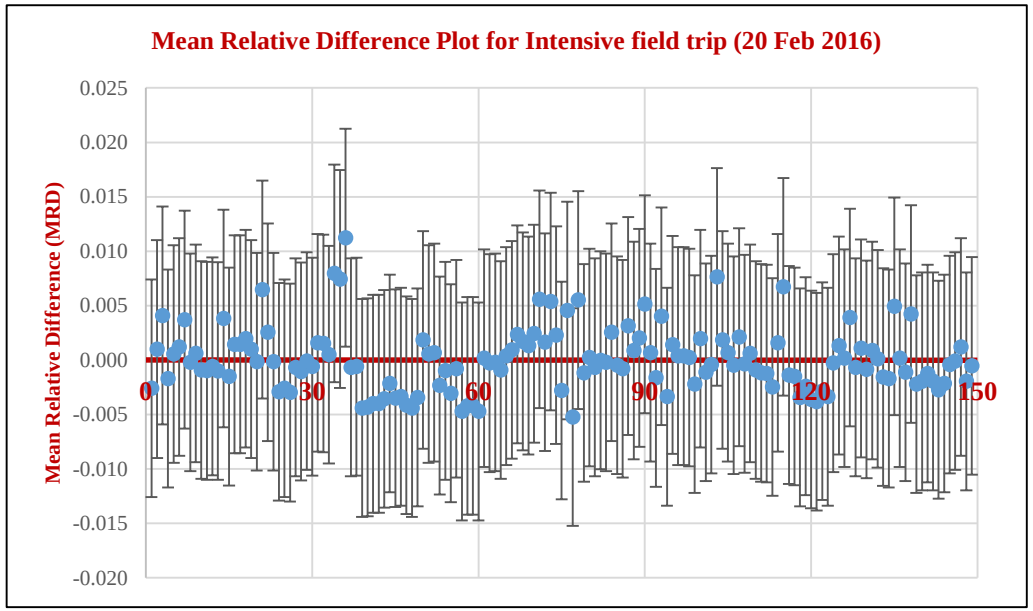
Variation of Soil Moisture with Elevation

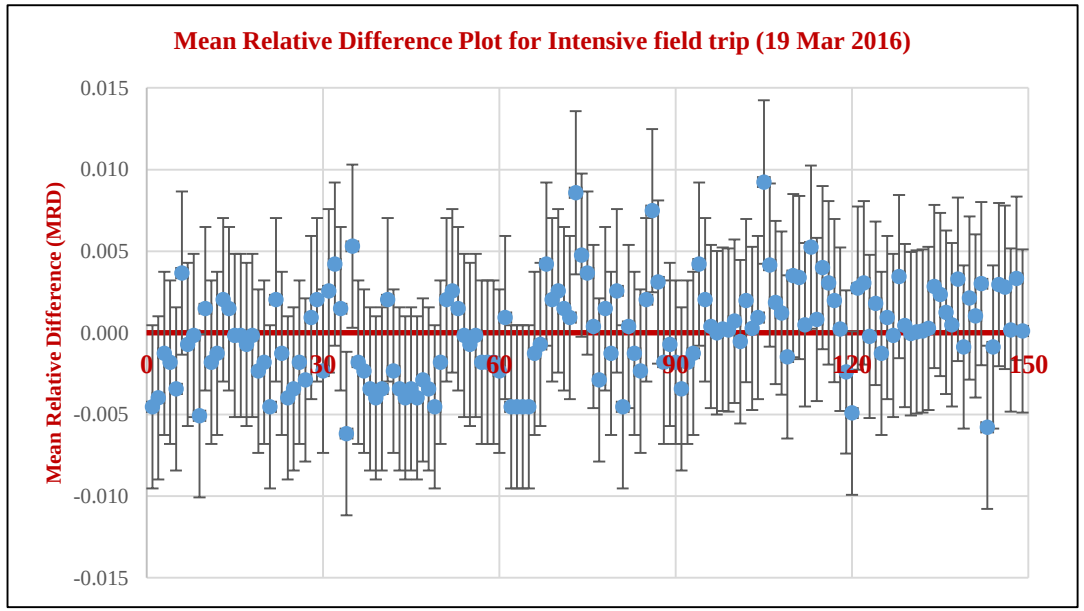




- study area gently sloping from North-East to South-East (from 140 m to 220 m)

Temporal & Spatial Stability of Soil Moisture





MRD value of ±0.005 for both intensive field campaigns, covering the day time from 7 am till 6 pm. This indicates the spatial and temporal stability for the change of soil moisture from early morning until evening

Simulation of Tb's for Bare Soil Model

Satellite Incidence Angle

Satellite 's Operating Microwave frequency

Smooth surface reflectivity (Fresnel Equation)

Dielectric Constant of Soil Solid Mixture (Soil, Water, Air)

[Dobson Model]

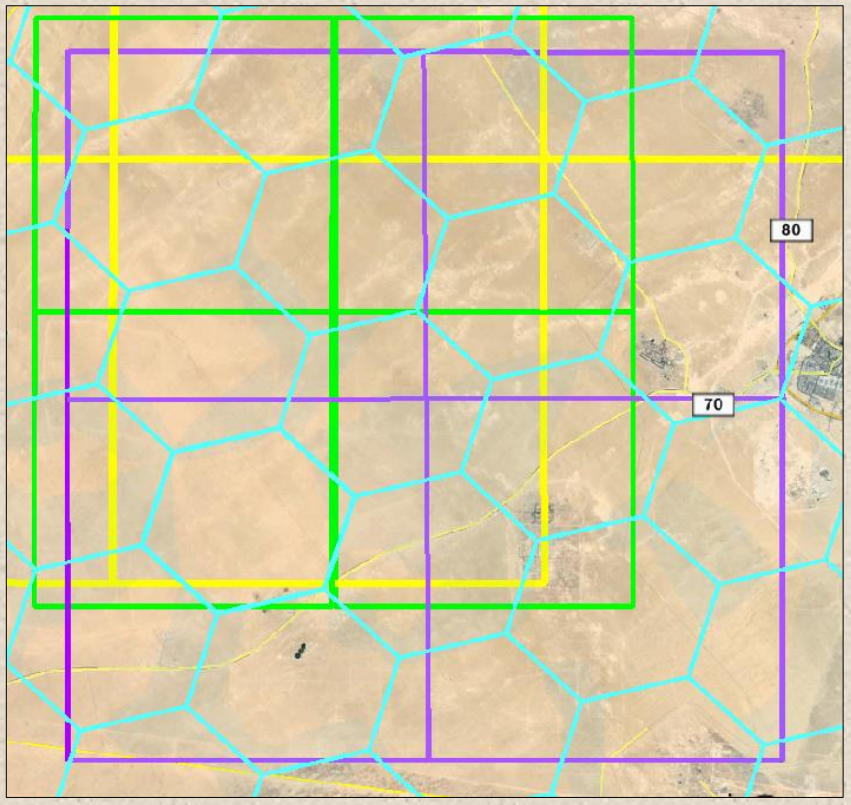
Bulk density, Sand/Clay fraction, Specific density, Volumetric Soil Moisture , Soil Temperature

Rough surface emissivity (Chaudhary et.al 1979)

Soil Roughness

Brightness Temperature

Satellite Grids over Kuwait test site



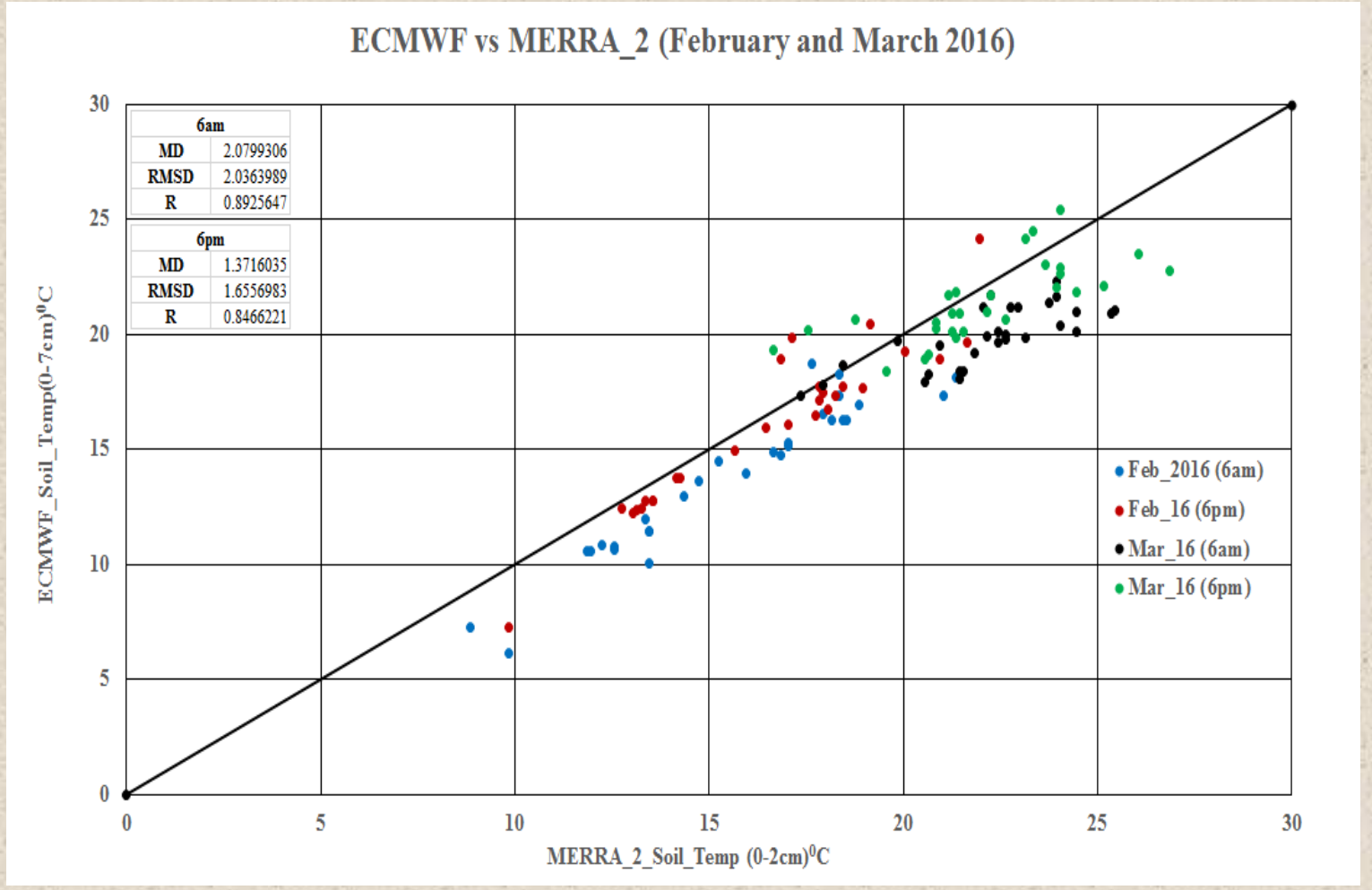
Legend	
Satellite	Pass time
SMAP	6pm&6am
SMOS	6AM
AMSR2	1:30PM
SSM/I	6:30PM

Satellite	Frequency (GHz)	Incidence Angle (degree)	*Gridding (km)	Over Pass time	Land Surface Temperature (LST)
SMAP	1.41	40	36 x 36	Ascending/ 6pm Descending/ 6 am	ECMWF/ERA-Interim/Land at 6pm MSG at 6am
SMOS	1.4	42.5	15 x15	Descending/ 6pm	ECMWF/ERA-Interim/Land at 6pm
AMSR2	6.9, 7.3, 10.7, 18.7	55	25 x25	Ascending/ 1:30pm	MODIS(Aqua) at 1:30pm
SSM/I	19	53.1	25 x25	Ascending/ 6:30pm	ECMWF/ERA-Interim/Land at 6pm

Brightness temperature is simulated using the thermo-gravimetric volumetric soil moisture data taken during the Intensive field campaigns over the test site and a comparison study is carried out between the observed brightness temperature from different satellites like SMAP, SMOS, AMSR-2 and SSM/I with the simulated brightness temperature.

Comparison between ECMWF & MERRA_2

- The results shows a cold bias of 1.6 to 2 degree.
- This result agrees with Trigo and Viterbo, 2003, and Trigo et al., 2015 for 6am and 6pm.



Input /Output Parameters for TB Simulation

20 FEB 2016

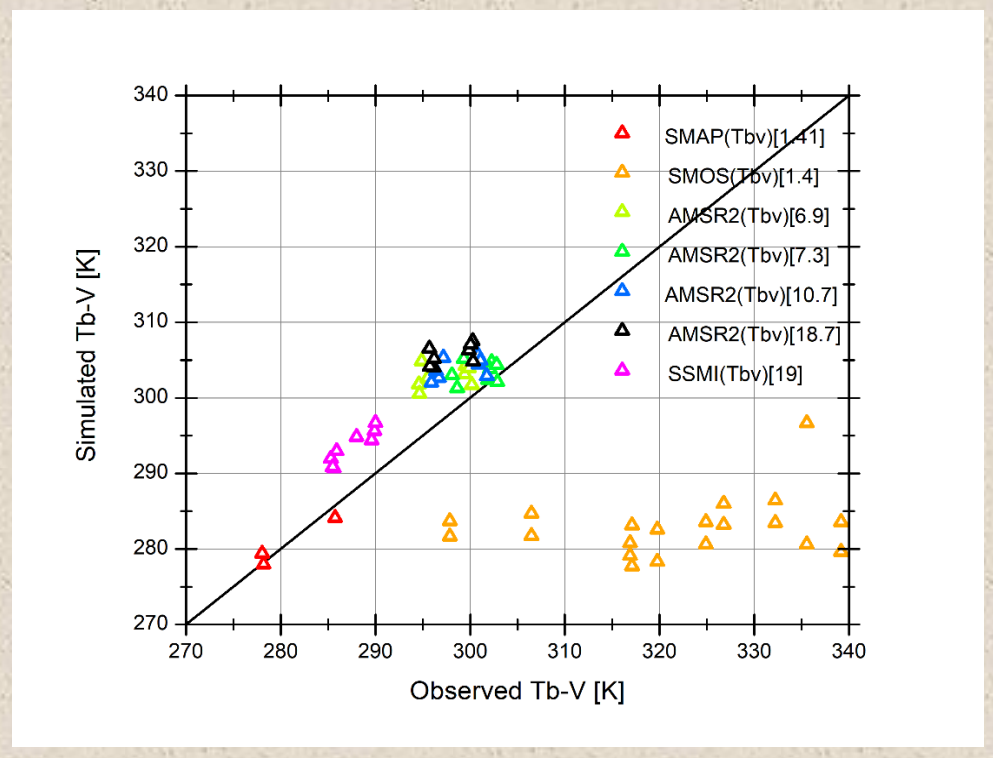
Satellite	Over Pass time	Frequency (GHz)	Incidence Angle°	Bulk Density (g cm^{-3})	Sand Fraction	Clay Fraction	LST(°C)	LST (Source/ Time)	VSM (m^3 m^{-3})	Roughness Height (cm)	Observed Tbv (°K)	Sim Tbv (°K)	Observed Tbh (°K)	Sim Tbh (°K)
SMAP (20 Feb 16 6AM)	6AM (Descending)	1.41	40°	1.75	0.87	0.03	20.68	MSG/ 6AM	0.040	0.750	278.19	277.95	249.20	254.68
SMOS (19 Feb 16 6PM)	6PM (Descending)	1.4	42.5°	1.63	0.85	0.05	22.16	ECMWF/ ERA/ 6PM	0.041	0.800	297.85	281.67	269.86	256.54
				1.73	0.85	0.05	21.09		0.044	0.800	316.88	279.11	276.53	253.09
				1.72	0.78	0.06	22.17		0.050	0.800	319.75	278.34	279.54	251.28
				1.72	0.94	0.03	22.04		0.053	0.829	317.10	277.74	279.32	250.99
				1.65	0.81	0.03	21.85		0.028	0.750	306.47	284.70	271.99	261.24
				1.82	0.87	0.03	20.98		0.038	0.800	324.89	280.65	277.44	255.61
				1.94	0.87	0.04	21.06		0.039	0.800	339.18	279.62	281.17	253.84
				1.86	0.84	0.06	22.55		0.034	0.829	332.22	283.46	271.13	259.64
				1.92	0.94	0.03	22.80		0.029	0.700	326.78	283.22	272.28	256.97
				1.83	0.89	0.04	21.69		0.041	0.829	335.55	280.63	271.29	255.57
AMSR2 (20 Feb 16 1:30PM)	1:30PM (Ascending)	6.9	55°	1.68	0.94	0.03	35.50	MODIS /1:30PM	0.036	0.550	294.59	301.80	245.08	245.18
				1.72	0.82	0.02	37.06		0.051	0.731	294.65	300.59	248.75	248.33
				1.65	0.81	0.03	37.16		0.030	0.500	294.89	304.88	247.24	248.41
				1.54	0.78	0.06	36.28		0.041	0.650	295.50	302.63	250.84	250.35
		7.3		1.68	0.94	0.03	35.50		0.036	0.638	301.88	302.43	250.28	250.67
				1.72	0.82	0.02	37.06		0.051	0.800	298.63	301.31	252.11	252.61
				1.65	0.81	0.03	37.16		0.030	0.500	299.34	305.18	251.49	251.56
				1.54	0.78	0.06	36.28		0.041	0.700	298.08	303.02	254.09	253.39
		10.7		1.68	0.94	0.03	35.50		0.036	0.587	296.69	302.64	248.75	249.17
				1.72	0.82	0.02	37.06		0.051	0.800	295.91	302.07	253.78	254.15
				1.65	0.81	0.03	37.16		0.030	0.500	297.18	305.32	249.96	249.90
				1.54	0.78	0.06	36.28		0.041	0.700	296.41	303.58	254.25	254.90
		18.7		1.68	0.94	0.03	35.50		0.036	0.600	296.17	304.06	254.35	254.17
				1.72	0.82	0.02	37.06		0.051	0.829	295.76	304.16	262.65	259.99
				1.65	0.81	0.03	37.16		0.030	0.500	295.70	306.55	256.69	256.52
				1.54	0.78	0.06	36.28		0.041	0.750	296.19	305.20	261.15	261.61
SSMI (18 Feb 16 6:30PM)	6:30PM (Ascending)	19	53.1°	1.66	0.85	0.05	22.34	ECMWF/ ERA/ 6PM	0.050	0.829	285.60	290.72	260.70	254.18
				1.59	0.87	0.04	22.75		0.042	0.800	285.30	292.00	260.60	256.49
				1.65	0.81	0.03	22.37		0.026	0.750	285.90	292.98	260.10	259.74
				1.74	0.94	0.03	21.85		0.037	0.700	285.50	290.86	260.70	252.07

Input /Output Parameters for TB Simulation

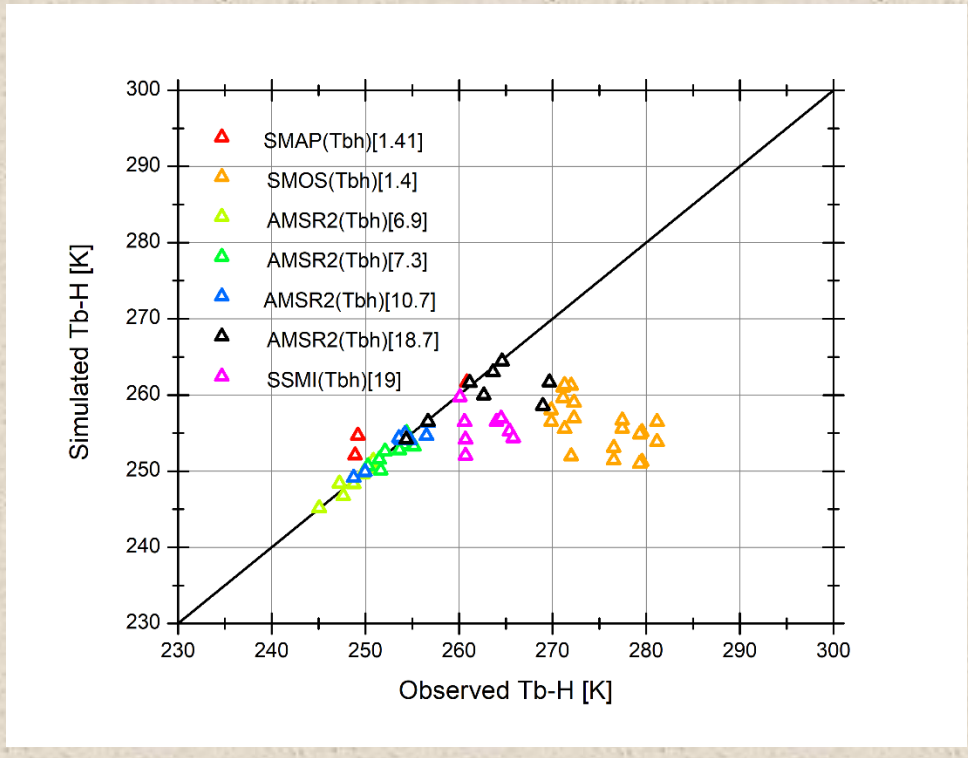
19 MAR 2016

Satellite	Over Pass time	Frequency (GHz)	Incidence Angle °	Bulk Density (g cm^{-3})	Sand Fraction	Clay Fraction	LST (°C)	LST (Source/Time)	VSM (m^3 m^{-3})	Roughness Height (cm)	Observed Tbv (^{0}K)	Sim Tbv (^{0}K)	Observed Tbh (^{0}K)	Sim Tbh (^{0}K)
SMAP (18 Mar 16, 6AM)	6AM (Descending)	1.41	40°	1.78	0.87	0.03	26.27	MSG/ 6AM	0.045	0.650	278.03	279.42	248.90	252.12
SMAP (18 Mar 16 6PM)	6PM (Ascending)	1.41	40°	1.78	0.87	0.03	27.42	ECMWF/ ERA/ 6PM	0.045	0.850	285.74	284.13	260.84	261.70
SMOS (19 Mar 16, 6AM)	6AM (Ascending)	1.4	42.5°	1.78	0.85	0.05	26.14	ECMWF/ ERA/ 6AM	0.047	0.850	297.85	283.71	269.86	258.03
				2.00	0.85	0.05	28.00		0.057	0.800	316.88	280.81	276.53	251.46
				1.78	0.78	0.06	27.59		0.054	0.829	319.75	282.60	279.54	255.16
				1.87	0.94	0.03	26.89		0.044	0.750	317.10	283.15	279.32	254.84
				1.89	0.81	0.03	28.41		0.051	0.750	306.47	281.75	271.99	252.00
				1.94	0.87	0.03	27.95		0.051	0.850	324.89	283.59	277.44	256.67
				2.03	0.87	0.04	26.67		0.042	0.800	339.18	283.57	281.17	256.47
				2.01	0.84	0.06	27.59		0.037	0.829	332.22	286.46	271.13	261.00
				1.87	0.94	0.03	27.56		0.037	0.750	326.78	286.02	272.28	259.01
				1.86	0.89	0.04	27.18		0.029	0.800	335.55	296.70	271.29	261.34
AMSR2 (19 Mar 16 1:30PM)	1:30PM (Ascending)	6.9	55°	2.00	0.94	0.03	39.76	MODIS /1:30PM	0.038	0.600	299.52	304.28	247.64	246.78
				1.87	0.82	0.02	39.3		0.047	0.731	299.44	303.11	250.41	250.81
				1.83	0.81	0.03	38.86		0.041	0.650	299.87	303.96	249.71	249.60
				1.99	0.78	0.06	39.12		0.053	0.800	300.19	301.74	250.86	251.39
		7.3		2.00	0.94	0.03	39.76		0.038	0.650	302.27	304.75	251.65	250.13
				1.87	0.82	0.02	39.3		0.047	0.800	302.08	303.80	254.38	255.05
				1.83	0.81	0.03	38.86		0.041	0.700	302.79	304.41	253.65	252.78
				1.99	0.78	0.06	39.12		0.053	0.829	302.88	302.12	255.19	253.26
		10.7		2.00	0.94	0.03	39.76		0.038	0.700	300.83	305.65	253.60	254.37
				1.87	0.82	0.02	39.3		0.047	0.800	300.89	304.44	256.69	256.37
				1.83	0.81	0.03	38.86		0.041	0.700	301.09	304.96	254.77	254.09
				1.99	0.78	0.06	39.12		0.053	0.829	301.77	302.87	256.53	254.63
		18.7		2.00	0.94	0.03	39.76		0.038	0.800	300.27	307.54	263.63	263.03
				1.87	0.82	0.02	39.3		0.047	0.829	299.87	306.29	269.65	261.69
				1.83	0.81	0.03	38.86		0.041	0.829	300.05	307.07	264.60	264.43
				1.99	0.78	0.06	39.12		0.053	0.829	300.31	304.84	268.97	258.60
SSMI (19 Mar 16 6:30PM)	6:30PM (Ascending)	19	53.1°	1.90	0.85	0.05	27.39	ECMWF/ ERA/ 6PM	0.049	0.829	289.60	294.43	265.40	255.24
				1.83	0.87	0.04	26.79		0.042	0.800	288.00	294.84	264.00	256.53
				1.83	0.81	0.03	28.31		0.044	0.750	289.90	295.63	265.80	254.38
				1.97	0.94	0.03	27.85		0.028	0.700	290.00	296.70	264.50	256.90

Observed & Simulated Brightness Temperature



Vertical Polarization



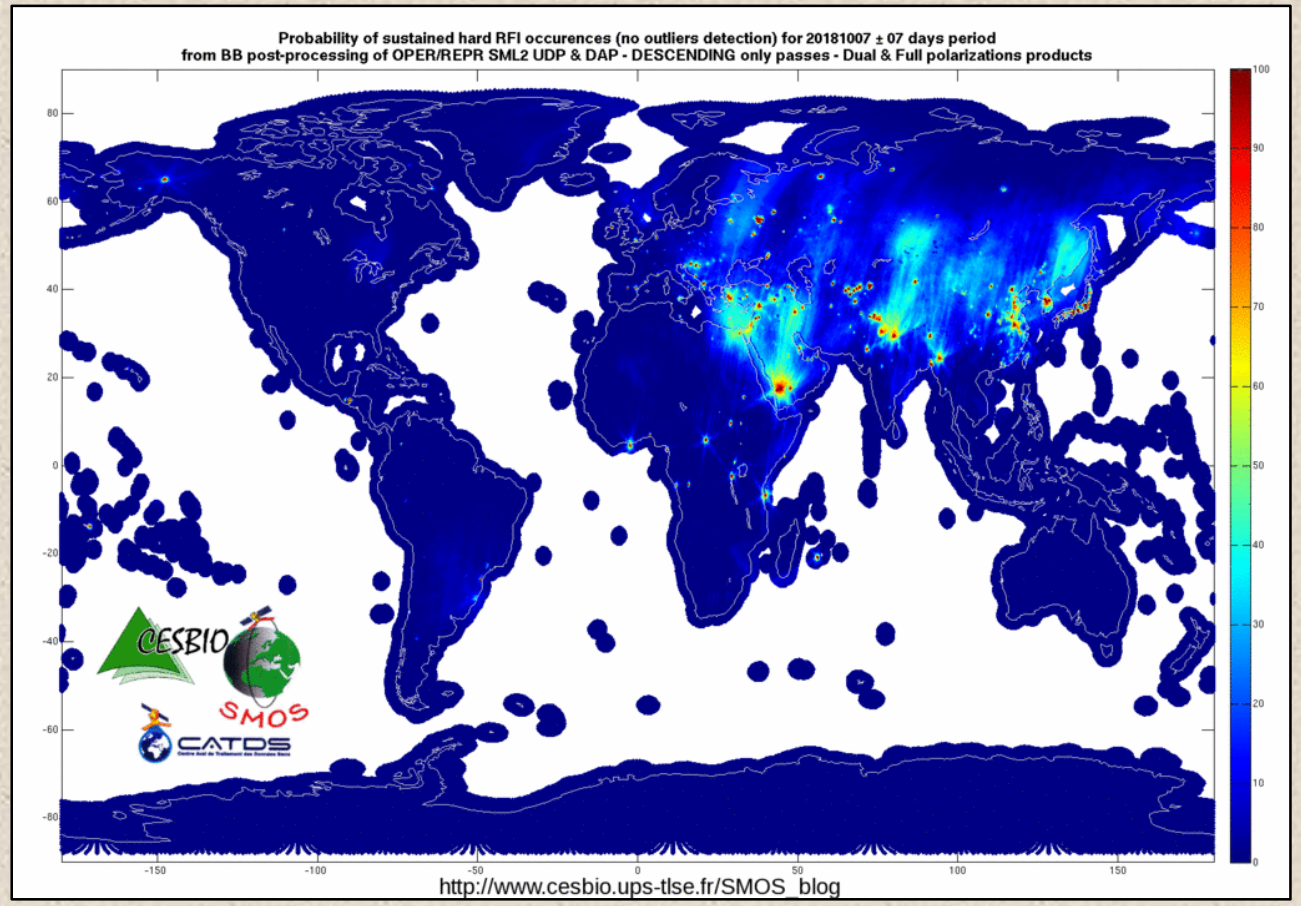
Horizontal Polarization

SMAP L1C
SMOS L3TB
AMSR2 L3TB
SSM/I L3

RFI Probability / SMOS blog

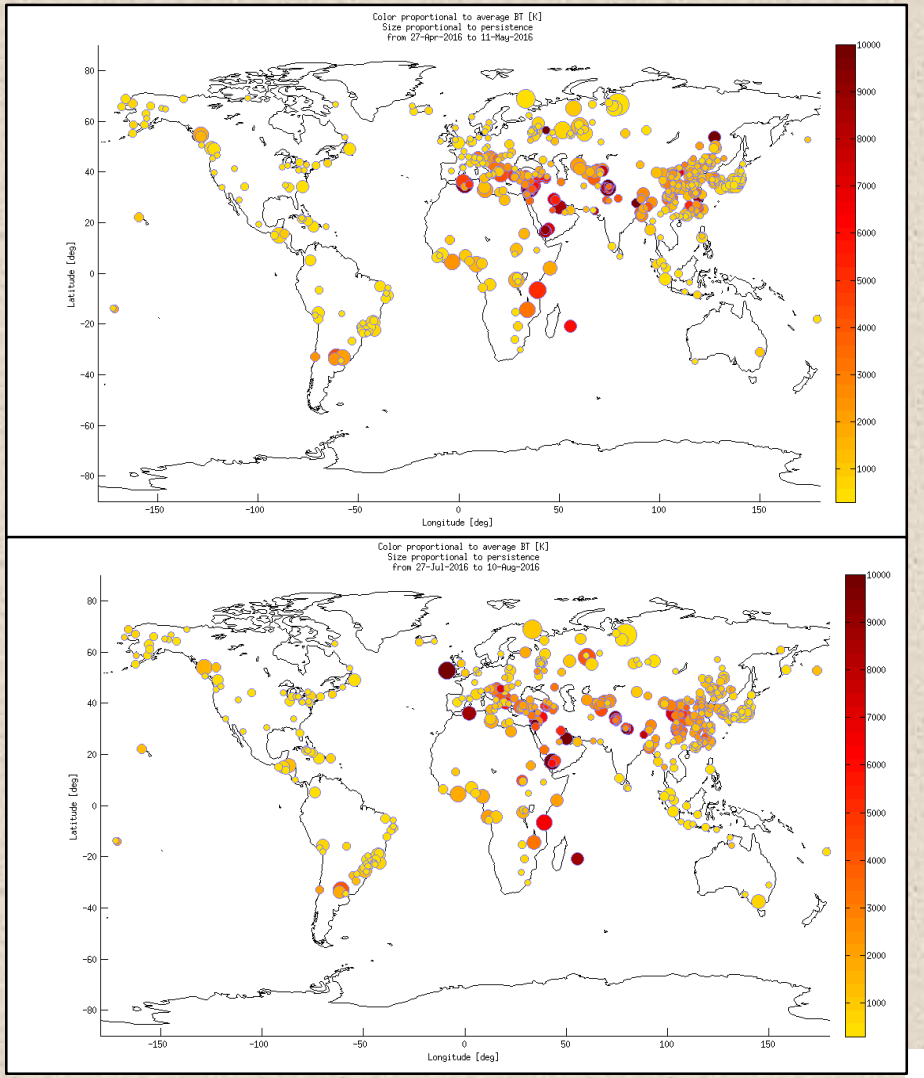
Radio-Frequency Interference (RFI) in SMOS context are artificial emissions made within the 1400-1427 MHz band

RFI presence
blue very low probability
red very high probability



RFI Characterization / SMOS blog

- The color of each RFI is proportional to its averaged BT.
- As RFI BTs are the sum of the natural thermal noise and the artificial emission, BT lower than 300K are not represented.
- The maximum of the color bar is fixed at 10000K in all images for consistency, but in many cases stronger RFI are present.
- The size of each point is proportional to RFI persistence in SMOS data, i.e. the number of times the RFI was detected.



Conclusions

- The simulation of the brightness temperatures from the forward radiative transfer model of brightness temperature are mostly impacted by soil moisture after accounting for surface roughness and soil temperature contributions.

- The SMAP 1.4 GHz brightness temperatures agree with simulated brightness temperatures from the forward model for both vertical and horizontal polarizations. The SMAP radiometer has RFI detection and mitigation capabilities and therefore it is less affected.

- The lower frequency microwaves show greater dynamic range and match with simulated brightness temperatures with in situ field measurements as input.

Conclusions

- NASA SMAP Kuwait test site / only Test Site in Arabian Peninsula /Unique Desert features and Electromagnetic Noise

- The SMOS 1.4 GHz measurements are apparently affected by RFI and have considerably higher brightness temperatures.

- At mid-range microwave AMSR2 frequencies, the vertical channel measurements are uncorrelated with the forward model simulations with in situ inputs but the horizontal polarization satellite measurements are well correlated.

- At the highest AMSR2 and SSMI frequencies (18.7 and 19 GHz respectively), even for bare soils, the satellite measurements at both polarizations cannot track changes in surface soil moisture due to both model sensitivity and atmospheric effect.

Acknowledgement

The authors are thankful to Kuwait Foundation for the Advancement of Sciences (KFAS) for sponsoring this Project no. P21544SP01. Also grateful to Kuwait University (KU) for their continuous support.