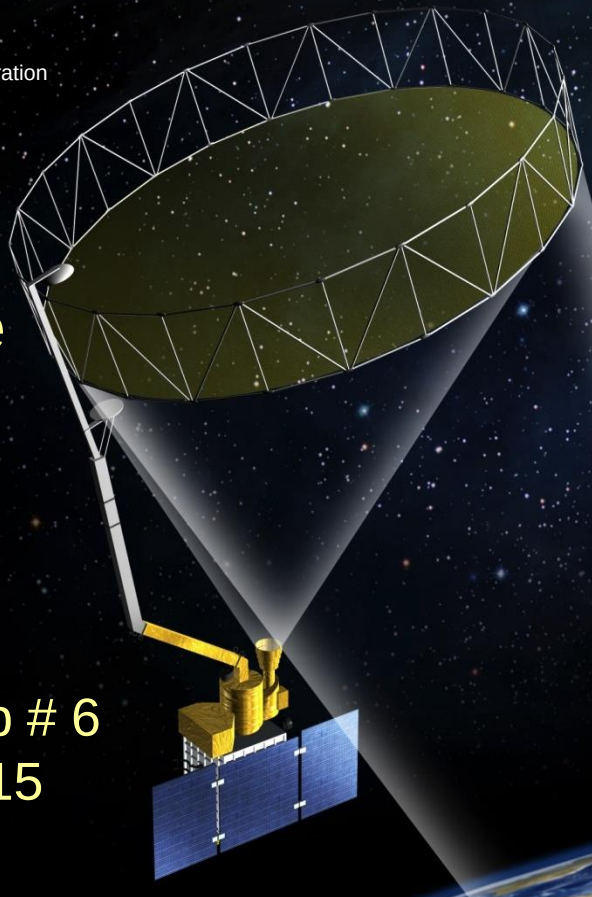
National Aeronautics and Space Administration



Soil Moisture Active Passive Mission

SMAP

Satellite-Based Products in SMAP L2-L4 Cal/Val

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Jet Propulsion Laboratory, California Institute of Technology

Cal/Val Workshop # 6
September 3, 2015

Background

Satellite Product intercomparison is one of five methodologies for SMAP L2-L4 Cal/Val

Methodology	Role
Core Validation Sites	Accurate estimates of products at matching scales for a set of conditions with spatially distributed in situ sensors
Sparse Networks	One point in the grid cell for a wide range of conditions
Satellite Products	Estimates over a very wide range of conditions at matching scales
Model Products	Estimates over a very wide range of conditions at matching scales
Field Campaigns	Detailed assessment of the scaling issues for a set of high priority conditions

Objectives

- Intercompare SMAP and other key satellite soil moisture products
  - Understand spatial and temporal patterns of SMAP soil moisture products relative to other key satellite products
  - Displays and statistics for satellite product intercomparisons with in situ data over SMAP core and candidate validation sites*
  - Not intended to encompass all known satellite products
- Include multiple products
  - Evaluation of satellite retrievals with SMAP L2/L3 products including L2/L3 SMAP baseline and optional product intra-comparison
  - Inclusion of in situ data is necessary to anchor the satellite product evaluations but is not the same as the DAART/ST validation and calibration task for L2/L3 soil moisture
- Desired outcome
  - Insights and statistics to support SMAP soil moisture product validation
  - Support for recommendations on SMAP algorithm refinement/upgrades

*) Metrics between Core Validation Sites and other satellite data products are not to be published without expressed consent by the respective Cal/Val Partner

Criteria

- Criteria for intercomparison products:
  - Must overlap in space and time with SMAP
  - Should be publicly available through a data center portal
  - Should have good documentation with metadata and ATBD (or equivalent)
  - Exclude model value-added products such as those produced by data assimilation and by ancillary data-driven disaggregation
  - Exclude FT and other retrieval by-products

Satellite Soil Moisture Data Characteristics

	Data avail.	Freq.	Spatial Res./ Grid (km)	Temporal Revisit	Orbit	Notes
SMAP	2015-present	L-band	P[1] (36) EASEv2 AP[1] (9) EASE v2 A[1] (3) EASE v2	~3 days	Sun-synch (6am *desc* / 6pm asc)	As discussed with Chan, Das and Kim
SMOS	2009-present	L-band	P L3 (25) on EASEv1/v2	~3 days	Sun-synch (6am *asc* / 6pm desc)	As recommended by Cabot/Kerr
Aquarius	2011-6/8/2015	L-band	P L2 v4 (76x94, 84x120, 96x156)	~ 7 days	Sun-synch (6pm asc / 6am *desc*)	As recommended by Bindlish
MetOP-B ASCAT	2014-present	C-band	A L2 (12.5)	~ 3 days	Sun synch (9:30pm asc / 9:30am *desc*)	Soil moisture index converted to volumetric soil moisture via porosity, flagging as recommended by Hahn/Wagner
GCOM-W/AMSR2	2012-present	C-, X-band	P L3 (0.25 deg)	~2 days	(1:30 pm asc / 1:30 am *desc*)	JAXA algorithm

[1] Baseline and options

All products are re-gridded to EASEv2 36-km

SMAP L2 SM P options inter-comparison

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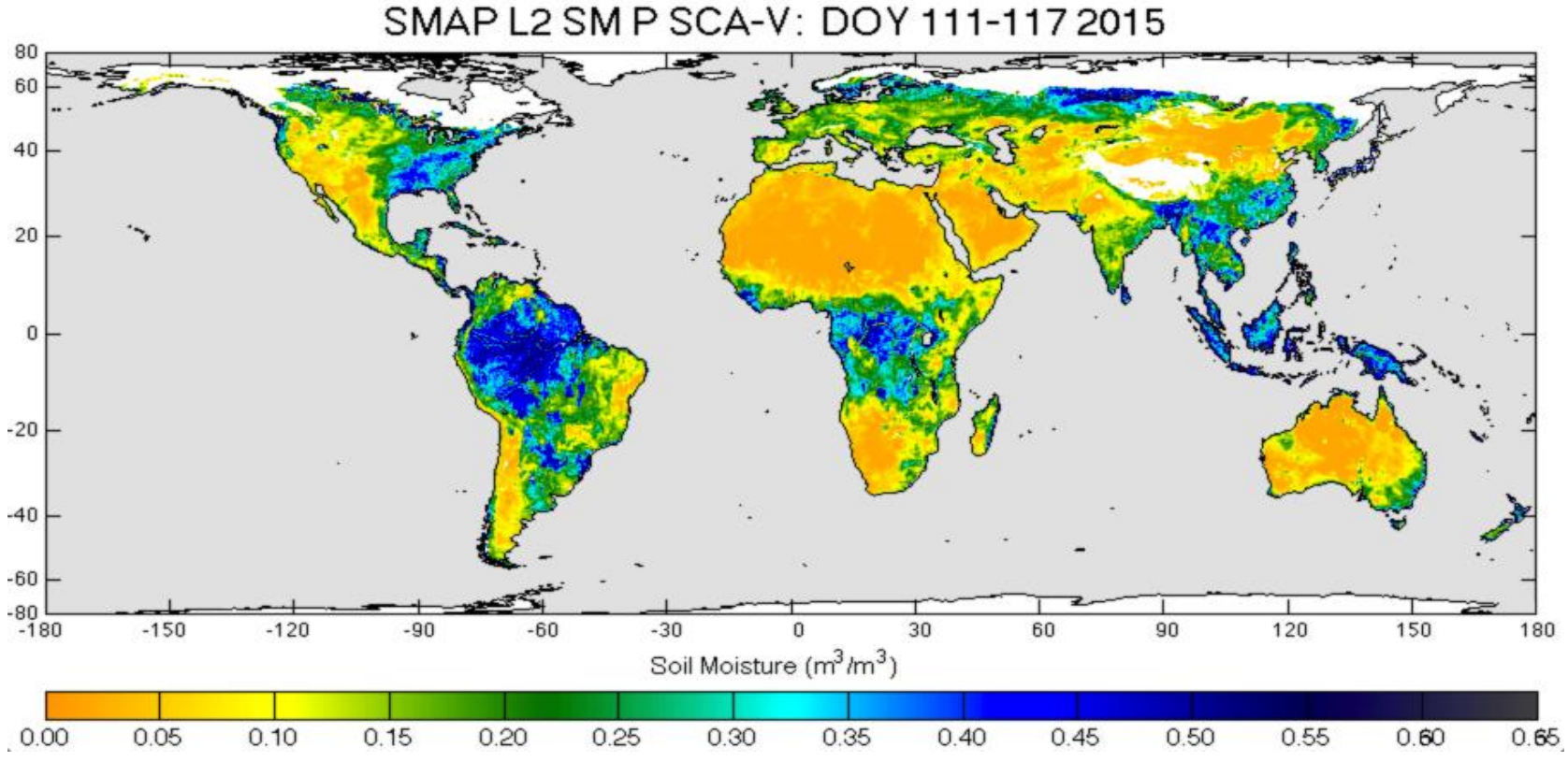
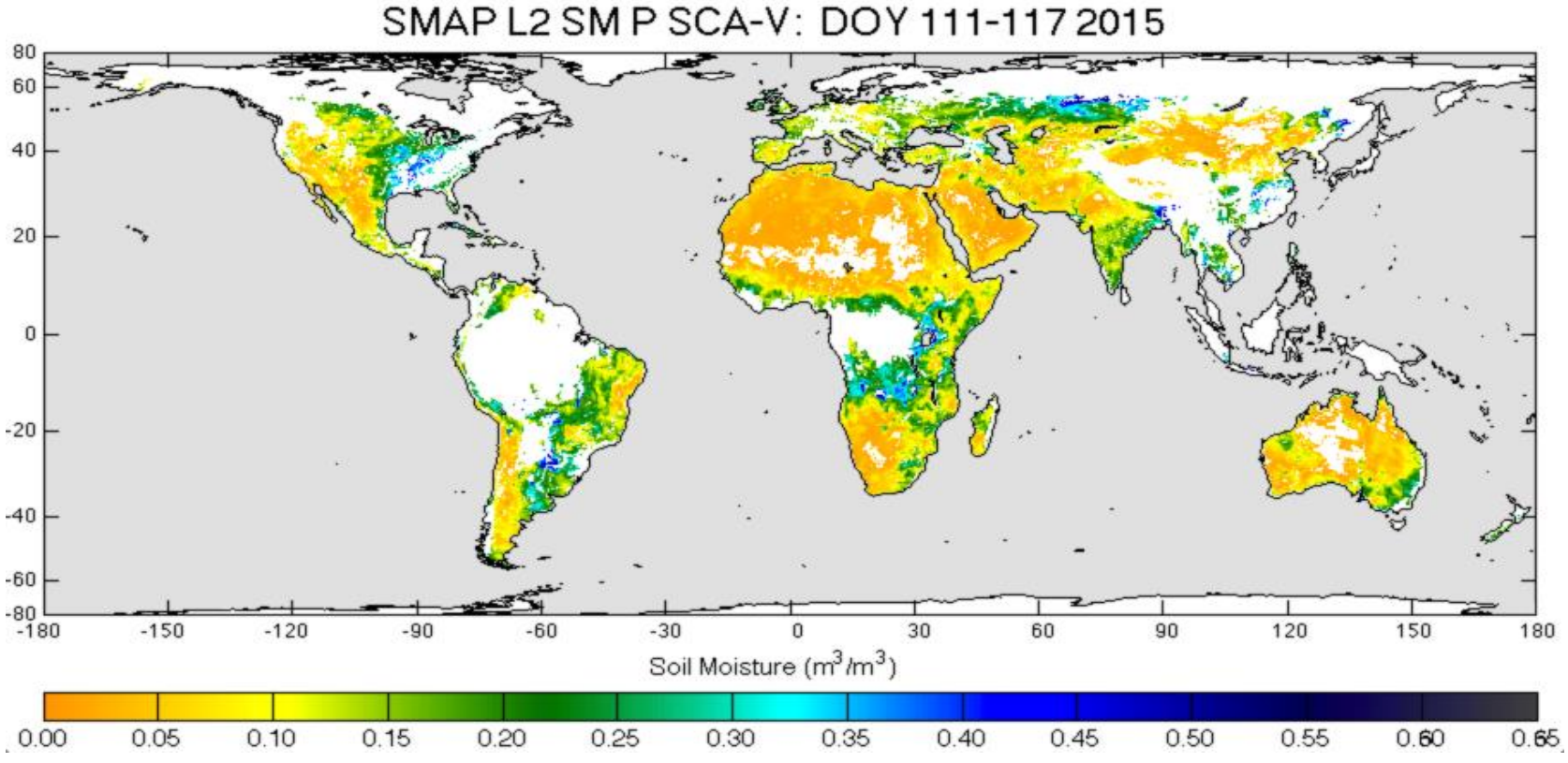
Raw available data set
DOY 111 – 117: April 21 – 27, 2015



SMAP L2 SM P CRID: 11880

SMAP L2 SM P options inter-comparison

Flagged data set used for comparison



Flagged soil moisture product: based on delivered 'recommended for retrieval' flag

- Pixels with high vegetation water content (VWC) are excluded as reliability of soil moisture algorithms is known to decrease with VWC > 5 kg/m^2

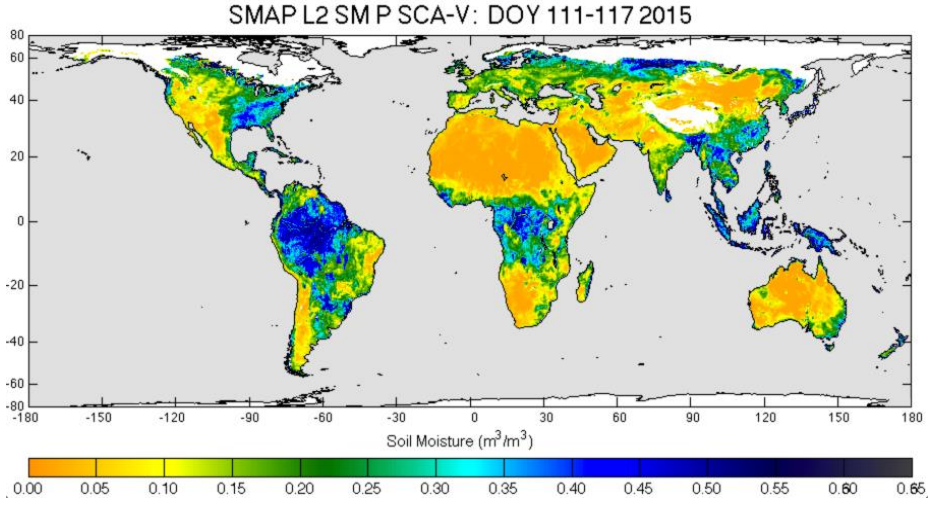
SMAP L2 SM P CRID: 11880

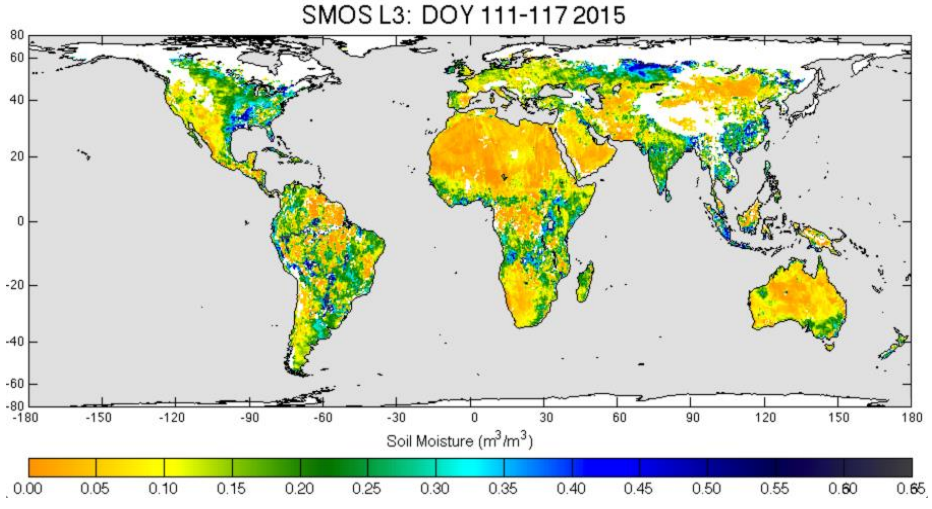
Global L2 SM P satellite inter-comparison

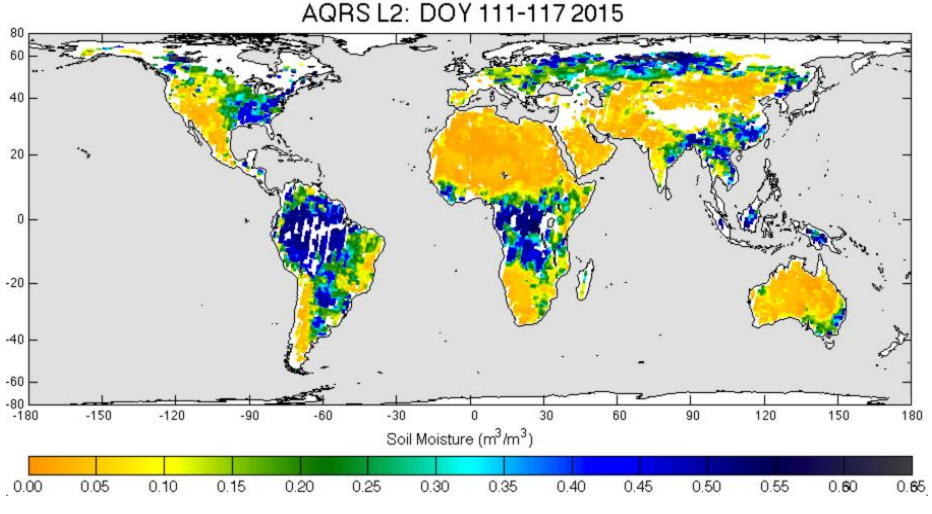
Jet Propulsion Laboratory
California Institute of Technology

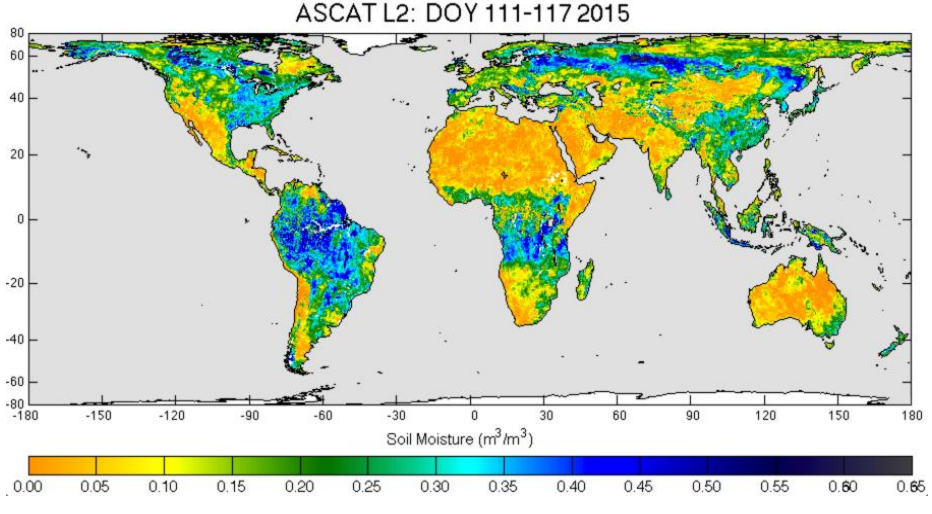
Raw available data set
DOY 111 – 117: April 21 – 27, 2015
➔ Aquarius v4 data not available for May, using v3

SMAP/SMOS: SMOS shows pixels with very dry soil moisture over forested areas (improved in v300 available from 5/1, earlier dates are currently being re-processed by SMOS)









SMAP/Aquarius: Aquarius flags out more pixels in the Middle-East, Aquarius shows wetter soil moisture over denser vegetation (fast transition)

SMAP/ASCAT: ASCAT shows more medium-range soil moisture (slow transition)

Global L2 SM P satellite inter-comparison

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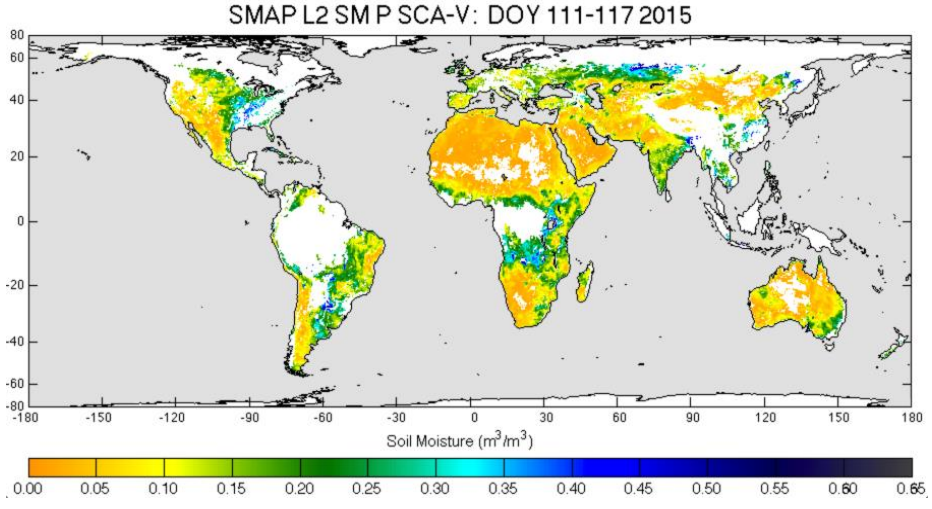
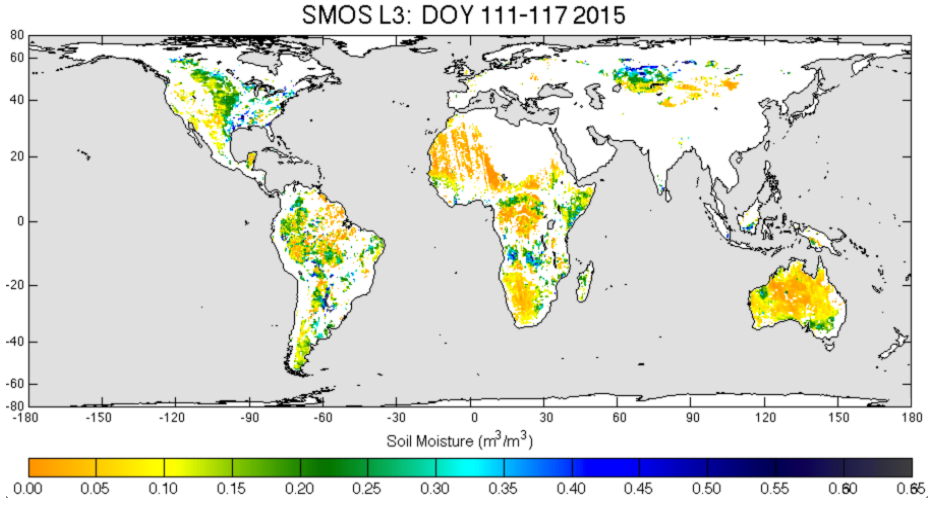
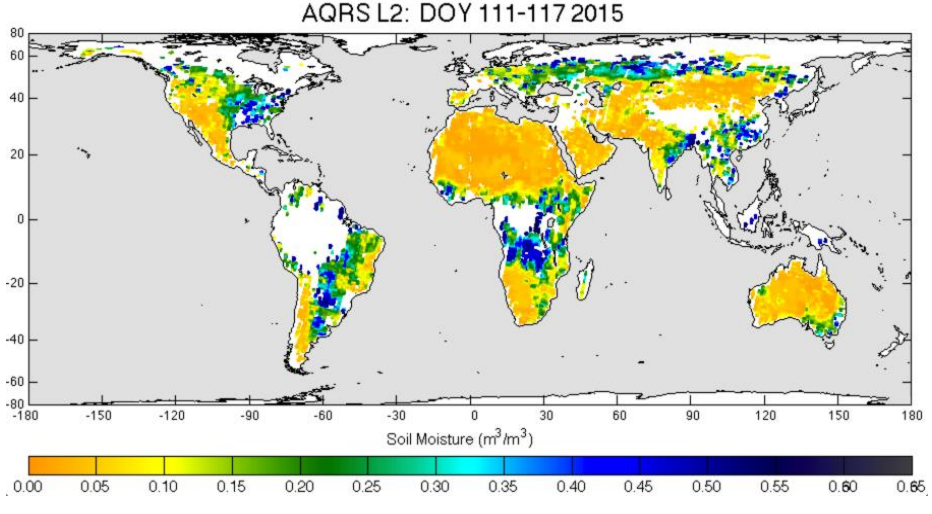
Flagged data set used for comparison

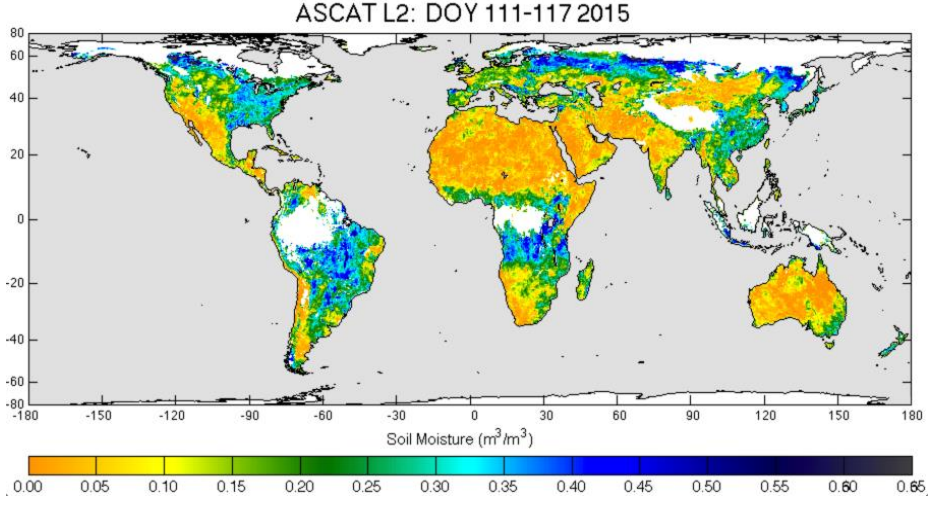
SMAP: 'recommended for retrieval' flag

SMOS: aggressive flagging for nominal conditions and RFI < 0.1 probability, RFI flagging eliminates all retrievals in Asia
➔ SMOS flagging appears to be too strict and will be revisited in coordination with SMOS team









Aquarius: Flagging for VWC < 5 kg/m^2, only pixels with land fraction > 90%, and no RFI flag raised

ASCAT: Flagging for snow, frozen ground, wetland, topography and soil moisture error probability < 50%

Global L2 SM P satellite inter-comparison

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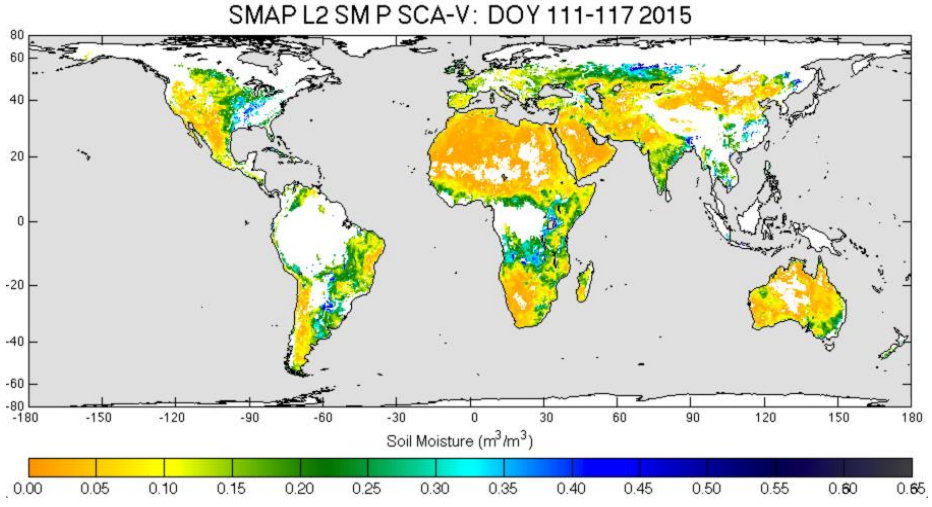
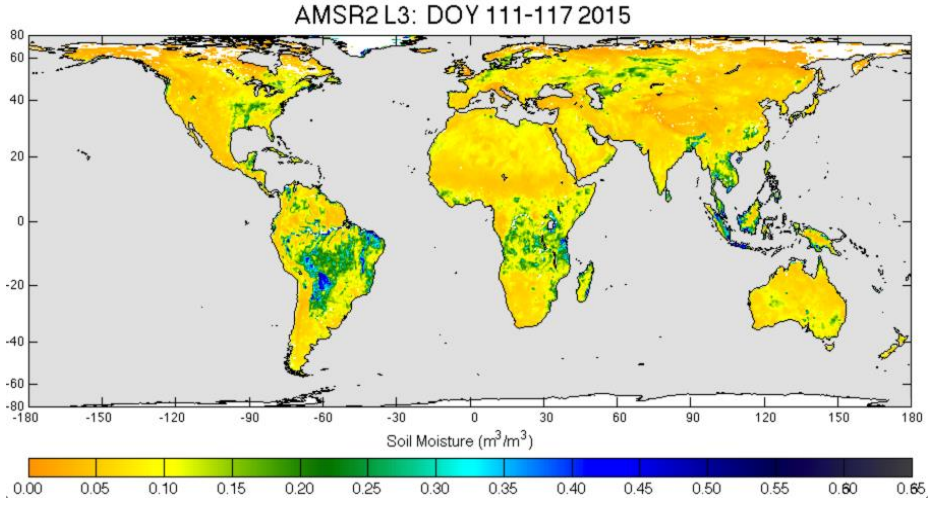
Flagged data set used for comparison

SMAP/AMSR2: global pattern looks different, general dry trend
AMSR2: no flags delivered with the soil moisture product





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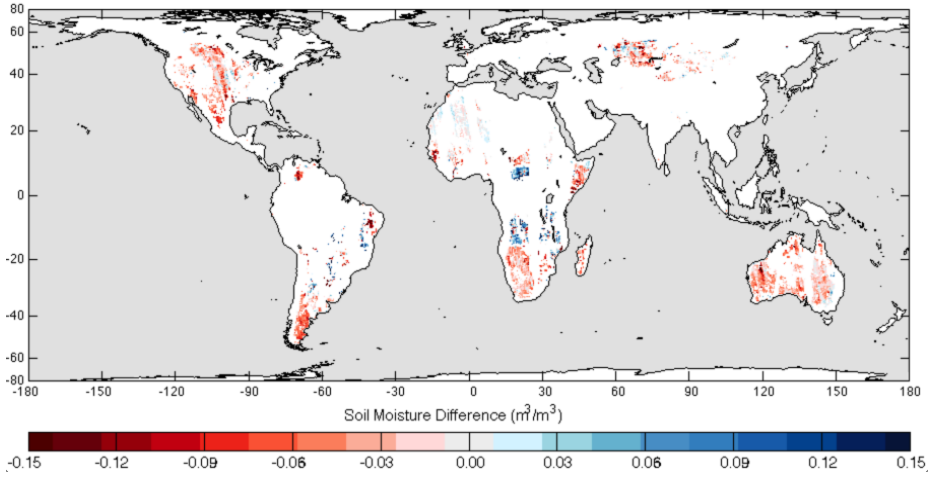
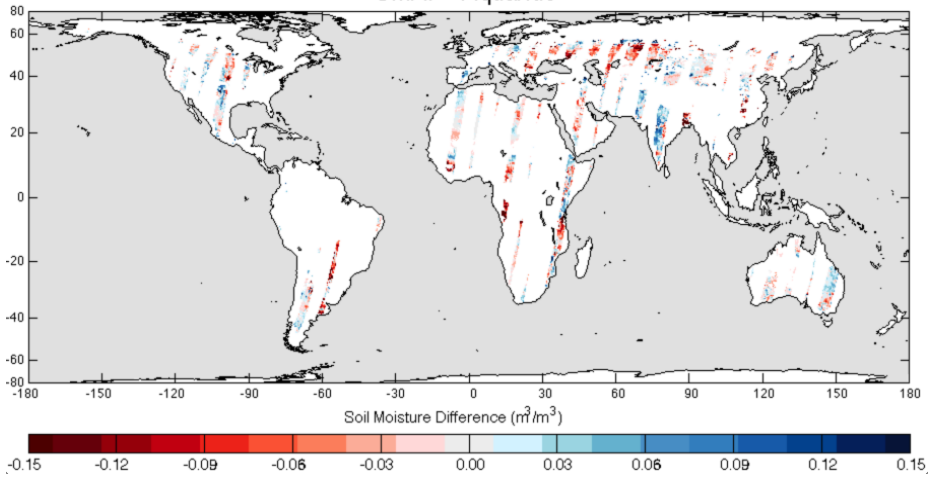
For statistical analysis, pairwise comparison over a longer time scale is necessary
➔ These figures show the daily differences over a single week

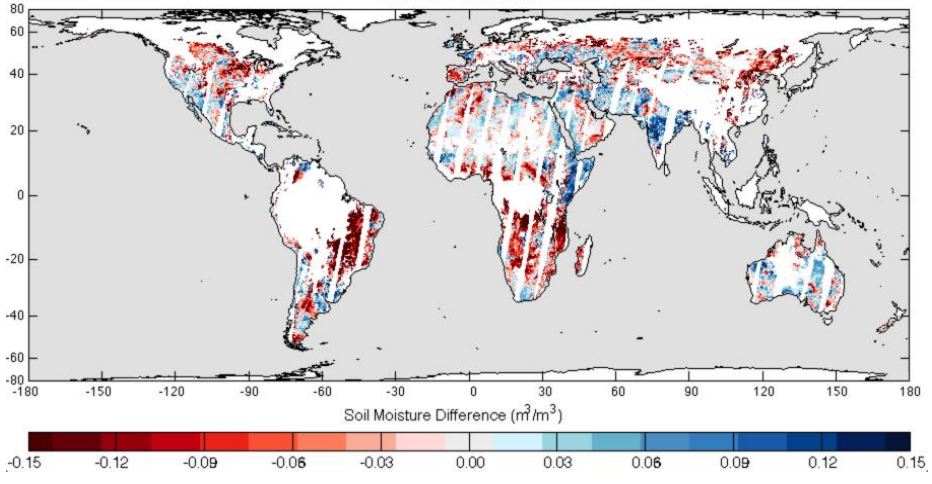
SMAP - SMOS



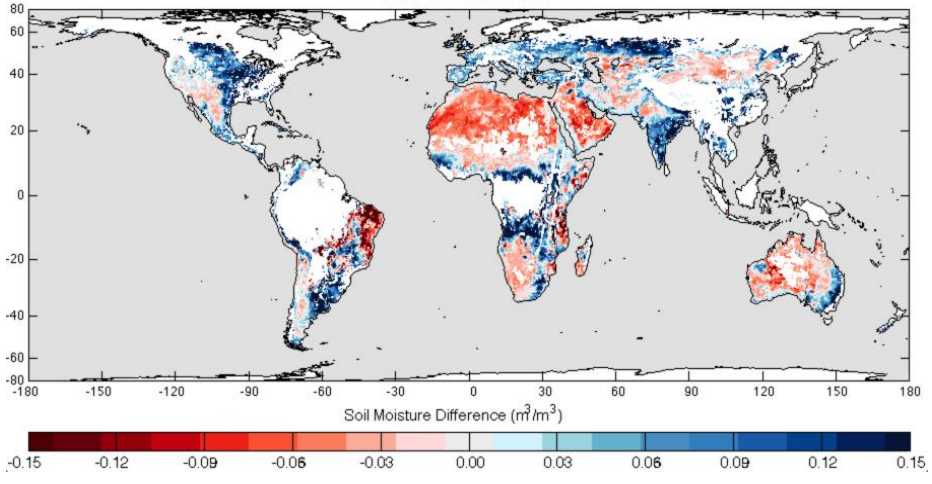
SMAP - Aquarius



SMAP - ASCAT



SMAP - AMSR2



Blue: SMAP wetter **Red**: SMAP drier

SMAP L2 SM P CRID: 11880

Global L2 SM P satellite inter-comparison

SMAP L2 SM P CRID: 11880

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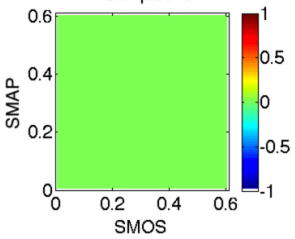
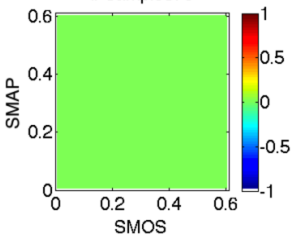
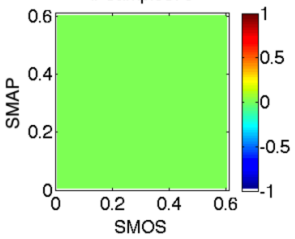
SMAP & SMOS for IGBP = 1
(Evergreen Needleleaf Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



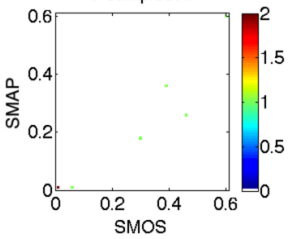
SMAP & SMOS for IGBP = 2
(Evergreen Broadleaf Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



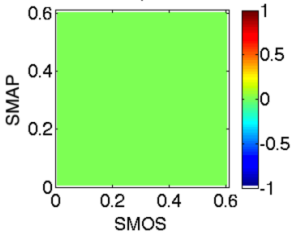
SMAP & SMOS for IGBP = 3
(Deciduous Needleleaf Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



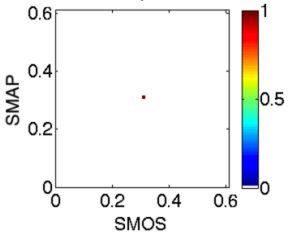
SMAP & SMOS for IGBP = 4
(Deciduous Broadleaf Forest)
ubRMSE = 0.0762, Bias = 0.013232
RMSE = 0.07734, R = 0.95115
# samples: 7



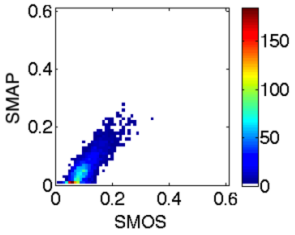
SMAP & SMOS for IGBP = 5
(Mixed Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



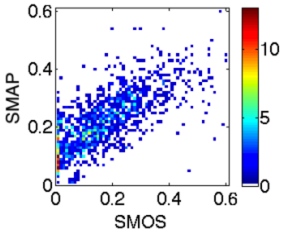
SMAP & SMOS for IGBP = 6
(Closed Shrublands)
ubRMSE = 0, Bias = -0.079051
RMSE = 0.079051, R = NaN
# samples: 1



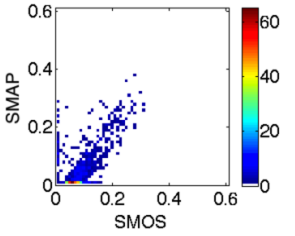
SMAP & SMOS for IGBP = 7
(Open Shrublands)
ubRMSE = 0.031653, Bias = -0.037577
RMSE = 0.049132, R = 0.83746
# samples: 4891



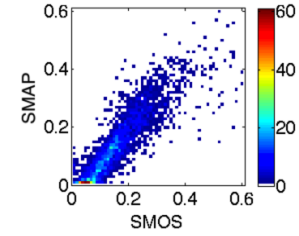
SMAP & SMOS for IGBP = 8
(Woody Savannas)
ubRMSE = 0.094134, Bias = 0.044219
RMSE = 0.104, R = 0.71486
# samples: 1280



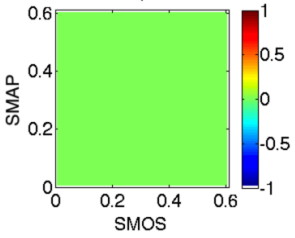
SMAP & SMOS for IGBP = 9
(Savannas)
ubRMSE = 0.066713, Bias = -0.03188
RMSE = 0.073939, R = 0.64205
# samples: 1387



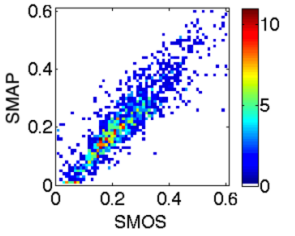
SMAP & SMOS for IGBP = 10
(Grasslands)
ubRMSE = 0.049093, Bias = -0.027464
RMSE = 0.056253, R = 0.87415
# samples: 3214



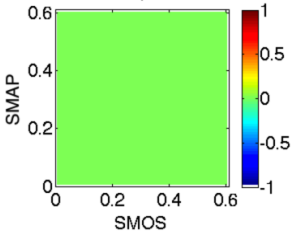
SMAP & SMOS for IGBP = 11
(Permanent Wetlands)
ubRMSE = 0.12497, Bias = -0.34448
RMSE = 0.36644, R = -0.45348
# samples: 9



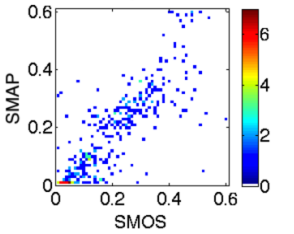
SMAP & SMOS for IGBP = 12
(Croplands)
ubRMSE = 0.05366, Bias = -0.028688
RMSE = 0.060847, R = 0.89025
# samples: 1430



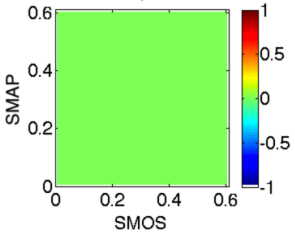
SMAP & SMOS for IGBP = 13
(Urban and Built-Up)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



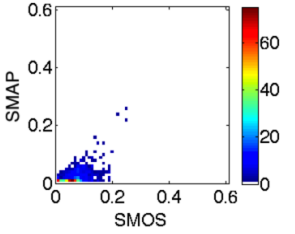
SMAP & SMOS for IGBP = 14
(Cropland/Nat. Veg. Mosaic)
ubRMSE = 0.078445, Bias = -0.02885
RMSE = 0.083581, R = 0.82412
# samples: 330



SMAP & SMOS for IGBP = 15
(Permanent Snow and Ice)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



SMAP & SMOS for IGBP = 16
(Barren or Sparsely Vegetated)
ubRMSE = 0.023273, Bias = -0.0051883
RMSE = 0.023844, R = 0.75004
# samples: 1164



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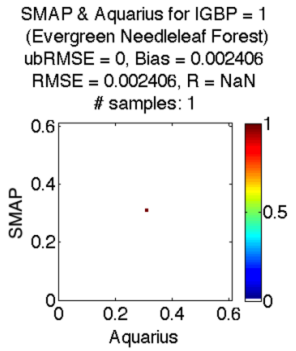
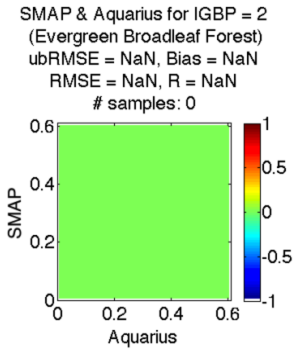
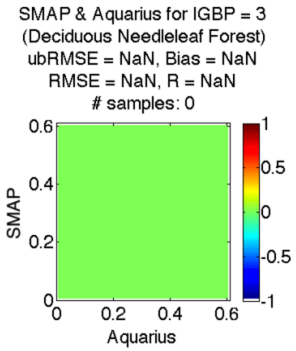
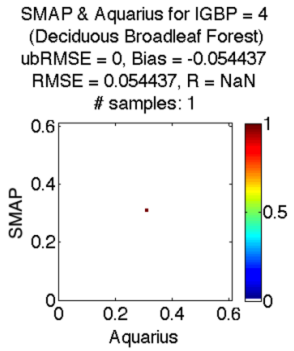
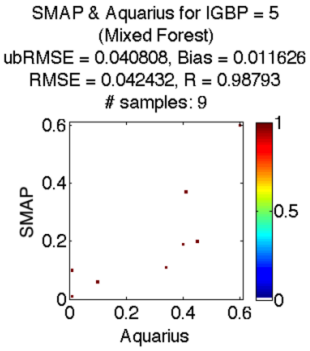
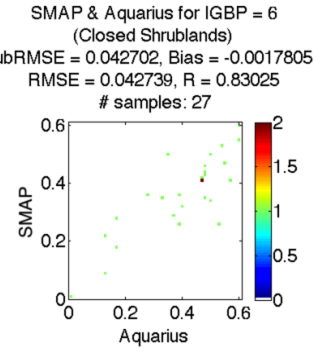


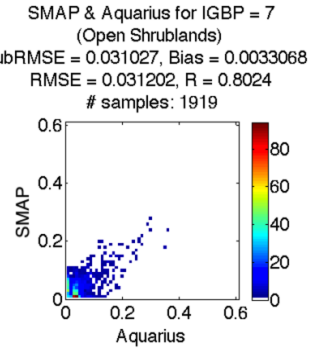


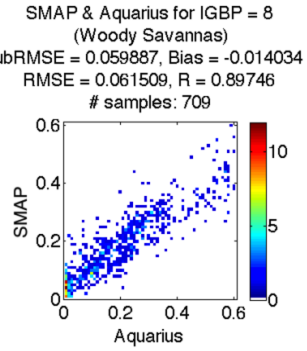


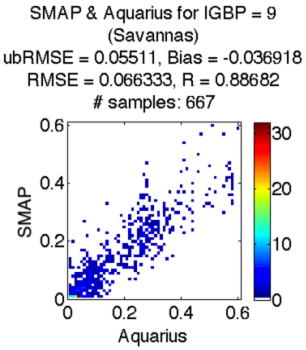


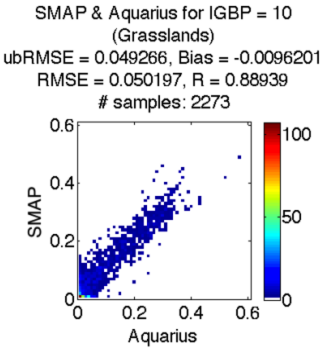


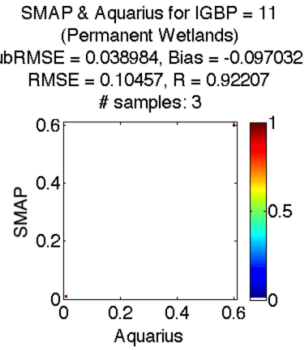


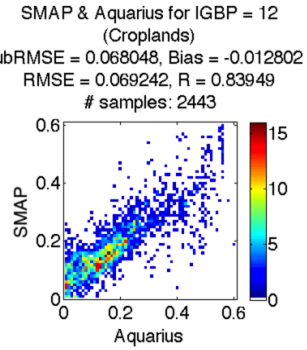


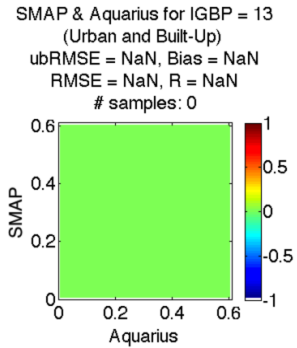


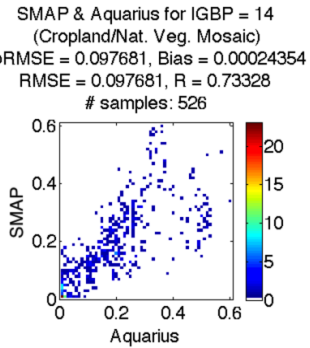


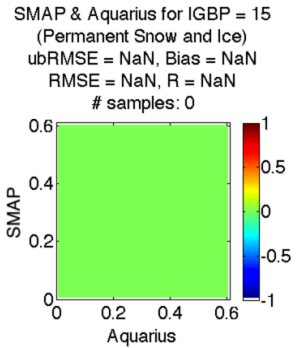


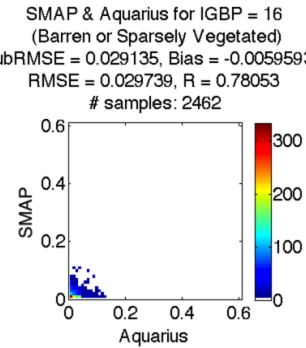










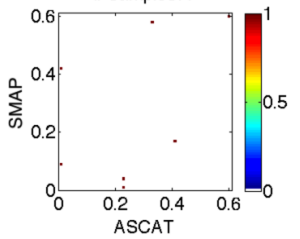


Global L2 SM P satellite inter-comparison

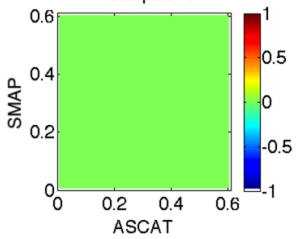
SMAP L2 SM P CRID: 11880

Jet Propulsion Laboratory
California Institute of Technology

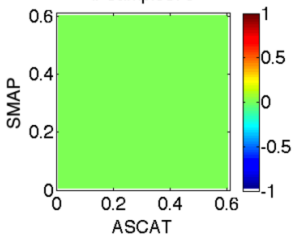
SMAP & ASCAT for IGBP = 1
(Evergreen Needleleaf Forest)
ubRMSE = 0.040453, Bias = 0.013755
RMSE = 0.042727, R = 0.43948
# samples: 7



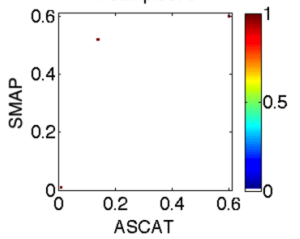
SMAP & ASCAT for IGBP = 2
(Evergreen Broadleaf Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



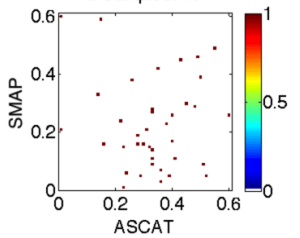
SMAP & ASCAT for IGBP = 3
(Deciduous Needleleaf Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



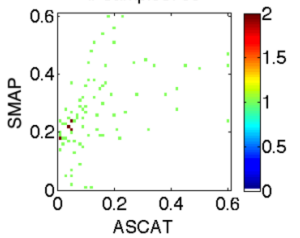
SMAP & ASCAT for IGBP = 4
(Deciduous Broadleaf Forest)
ubRMSE = 0.1189, Bias = -0.07718
RMSE = 0.14175, R = 0.7686
# samples: 3



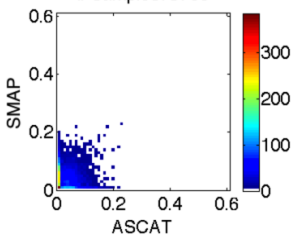
SMAP & ASCAT for IGBP = 5
(Mixed Forest)
ubRMSE = 0.096853, Bias = -0.12513
RMSE = 0.15823, R = 0.68817
# samples: 40



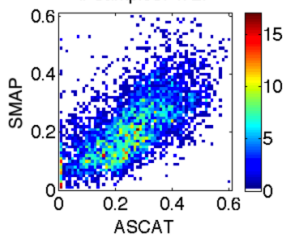
SMAP & ASCAT for IGBP = 6
(Closed Shrublands)
ubRMSE = 0.087791, Bias = 0.070576
RMSE = 0.11264, R = 0.47465
# samples: 85



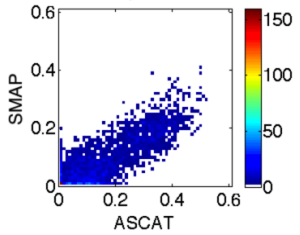
SMAP & ASCAT for IGBP = 7
(Open Shrublands)
ubRMSE = 0.068187, Bias = 0.0083605
RMSE = 0.068698, R = 0.47525
# samples: 9755



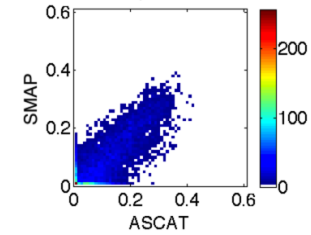
SMAP & ASCAT for IGBP = 8
(Woody Savannas)
ubRMSE = 0.091215, Bias = -0.03515
RMSE = 0.097753, R = 0.6445
# samples: 4727



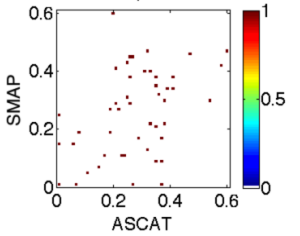
SMAP & ASCAT for IGBP = 9
(Savannas)
ubRMSE = 0.086812, Bias = -0.067125
RMSE = 0.10974, R = 0.72908
# samples: 6298



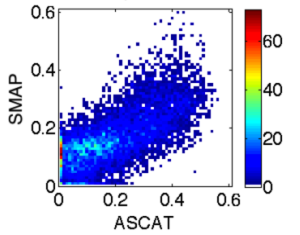
SMAP & ASCAT for IGBP = 10
(Grasslands)
ubRMSE = 0.079299, Bias = -0.028758
RMSE = 0.084352, R = 0.69613
# samples: 12657



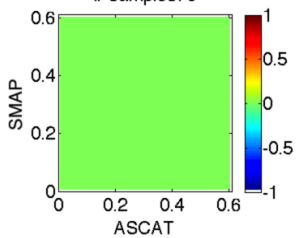
SMAP & ASCAT for IGBP = 11
(Permanent Wetlands)
ubRMSE = 0.15355, Bias = 0.064152
RMSE = 0.16641, R = 0.46317
# samples: 51



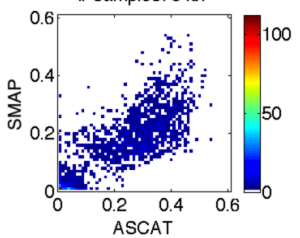
SMAP & ASCAT for IGBP = 12
(Croplands)
ubRMSE = 0.09769, Bias = -0.016395
RMSE = 0.099057, R = 0.65526
# samples: 11711



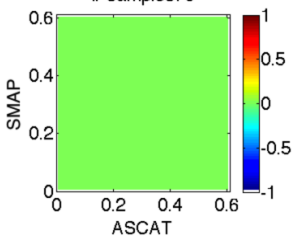
SMAP & ASCAT for IGBP = 13
(Urban and Built-Up)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



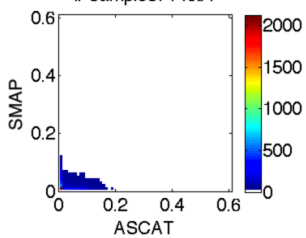
SMAP & ASCAT for IGBP = 14
(Cropland/Nat. Veg. Mosaic)
ubRMSE = 0.10808, Bias = -0.043275
RMSE = 0.11642, R = 0.68332
# samples: 3467



SMAP & ASCAT for IGBP = 15
(Permanent Snow and Ice)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



SMAP & ASCAT for IGBP = 16
(Barren or Sparsely Vegetated)
ubRMSE = 0.053896, Bias = 0.0041757
RMSE = 0.054057, R = 0.26101
# samples: 14091

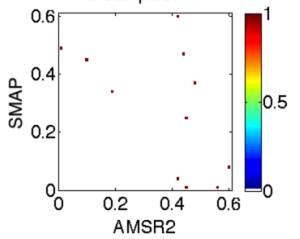


Global L2 SM P satellite inter-comparison

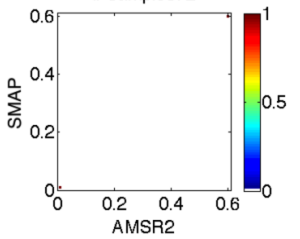
SMAP L2 SM P CRID: 11880

Jet Propulsion Laboratory
California Institute of Technology

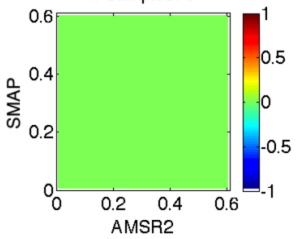
SMAP & AMSR2 for IGBP = 1
(Evergreen Needleleaf Forest)
ubRMSE = 0.032509, Bias = 0.058307
RMSE = 0.066757, R = -0.55347
# samples: 11



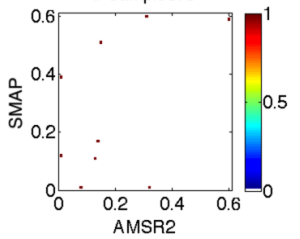
SMAP & AMSR2 for IGBP = 2
(Evergreen Broadleaf Forest)
ubRMSE = 0.0095858, Bias = 0.062716
RMSE = 0.063444, R = 1
# samples: 2



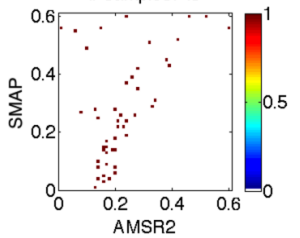
SMAP & AMSR2 for IGBP = 3
(Deciduous Needleleaf Forest)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



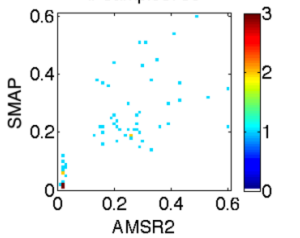
SMAP & AMSR2 for IGBP = 4
(Deciduous Broadleaf Forest)
ubRMSE = 0.12794, Bias = 0.054772
RMSE = 0.13917, R = 0.48416
# samples: 9



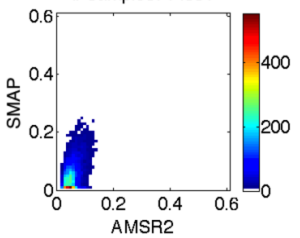
SMAP & AMSR2 for IGBP = 5
(Mixed Forest)
ubRMSE = 0.089021, Bias = 0.10604
RMSE = 0.13846, R = 0.86526
# samples: 49



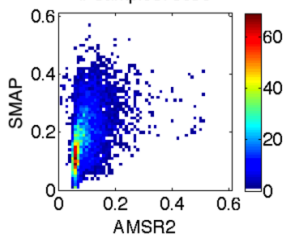
SMAP & AMSR2 for IGBP = 6
(Closed Shrublands)
ubRMSE = 0.053871, Bias = 0.048442
RMSE = 0.072448, R = 0.69948
# samples: 63



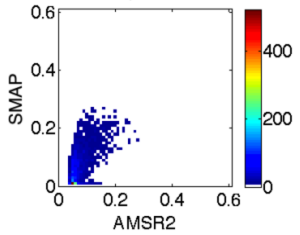
SMAP & AMSR2 for IGBP = 7
(Open Shrublands)
ubRMSE = 0.040959, Bias = -0.004033
RMSE = 0.041157, R = 0.56285
# samples: 14661



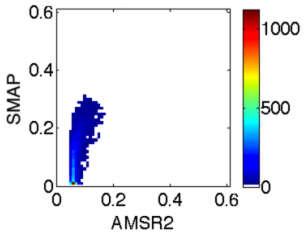
SMAP & AMSR2 for IGBP = 8
(Woody Savannas)
ubRMSE = 0.094451, Bias = 0.082635
RMSE = 0.1255, R = 0.37102
# samples: 6895



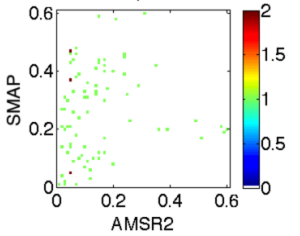
SMAP & AMSR2 for IGBP = 9
(Savannas)
ubRMSE = 0.092667, Bias = -0.012942
RMSE = 0.093566, R = 0.47247
# samples: 9692



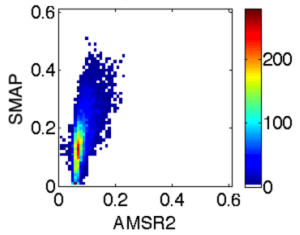
SMAP & AMSR2 for IGBP = 10
(Grasslands)
ubRMSE = 0.068211, Bias = 0.050013
RMSE = 0.084582, R = 0.61125
# samples: 19457



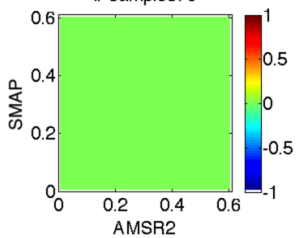
SMAP & AMSR2 for IGBP = 11
(Permanent Wetlands)
ubRMSE = 0.14993, Bias = 0.15268
RMSE = 0.21399, R = 0.09959
# samples: 82



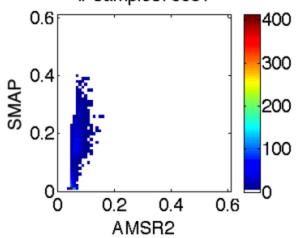
SMAP & AMSR2 for IGBP = 12
(Croplands)
ubRMSE = 0.076671, Bias = 0.09102
RMSE = 0.11901, R = 0.57356
# samples: 17601



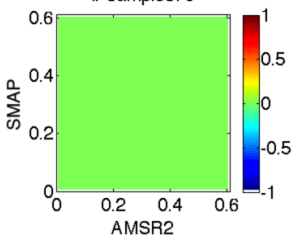
SMAP & AMSR2 for IGBP = 13
(Urban and Built-Up)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



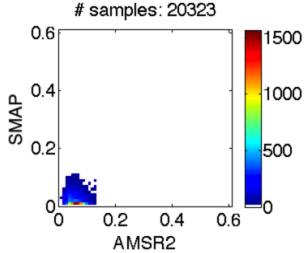
SMAP & AMSR2 for IGBP = 14
(Cropland/Nat. Veg. Mosaic)
ubRMSE = 0.11329, Bias = 0.10481
RMSE = 0.15434, R = 0.37587
# samples: 5581



SMAP & AMSR2 for IGBP = 15
(Permanent Snow and Ice)
ubRMSE = NaN, Bias = NaN
RMSE = NaN, R = NaN
# samples: 0



SMAP & AMSR2 for IGBP = 16
(Barren or Sparsely Vegetated)
ubRMSE = 0.035737, Bias = -0.033535
RMSE = 0.049008, R = 0.42626
# samples: 20323



Conclusions and Next Steps

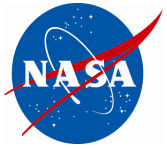
➔ **SMAP/SMOS statistics have been generated for 4/11/2015 – 7/14/2015 as part of the L2SMP Assessment Report (Tom Jackson will present)**

L2 SM P and other satellite products

- **SMAP** and **SMOS** show similar results for most short vegetation types, and there are significant differences in the retrievals over forests
- **SMAP** and **Aquarius** will be useful for further L-band comparisons once our data bases ingest Aquarius version 4
- **SMAP** and **ASCAT** show similar global pattern, but ASCAT shows a slower transition to wet soil moisture over denser vegetation
- **SMAP** and **AMSR2** show different global spatial patterns, with AMSR2 exhibiting a dry bias

Next steps:

- Re-calculate statistics of SMAP/SMOS with SMOS v300 and updated SMOS flagging
- Calculate statistics of SMAP/Aquarius once version 4 is ingested
- Calculate statistics of SMAP/SMOS over different seasons

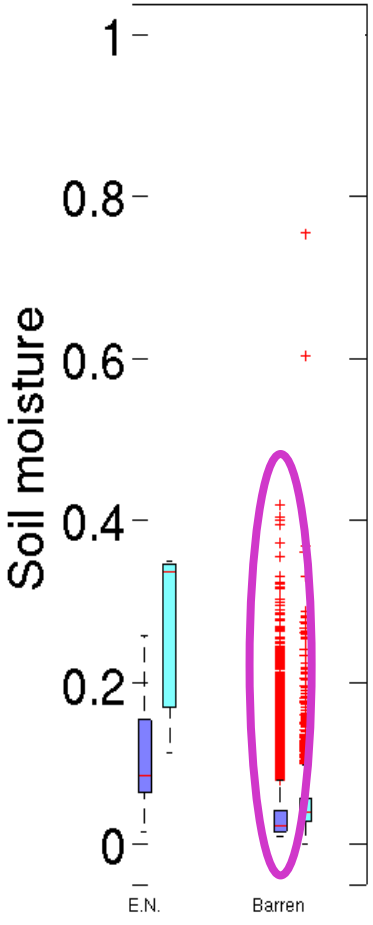


Backup

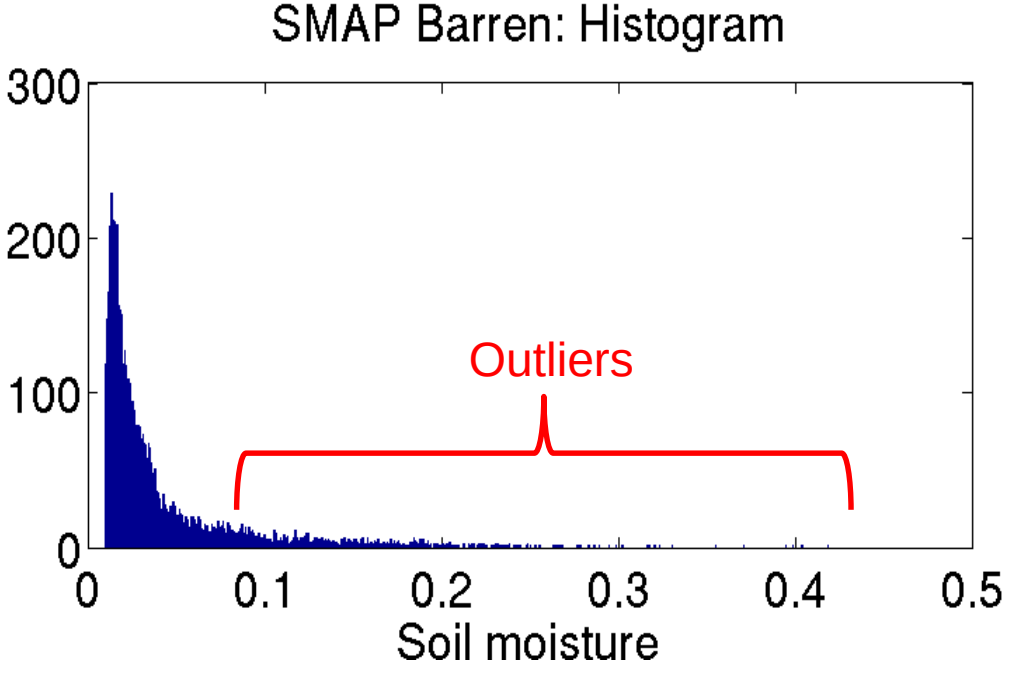
IGBP Land Cover Legend

Value	Description	Short-Name
1	Evergreen Needleleaf Forest	ENF
2	Evergreen Broadleaf Forest	EBF
3	Deciduous Needleleaf Forest	DNF
4	Deciduous Broadleaf Forest	DBF
5	Mixed Forest	MiF
6	Closed Shrublands	ClS
7	Open Shrublands	OpS
8	Woody Savannas	WSv
9	Savannas	Sav
10	Grasslands	Grss
11	Permanent Wetlands	PWe.
12	Croplands	Crp
13	Urban and Built-Up	U&B
14	Cropland/Natural Vegetation Mosaic	C/N
15	Permanent Snow and Ice	S&I
16	Barren or Sparsely Vegetated	Brn

Boxplots and the outliers



25th percentile (q1):	0.0159
75th percentile (q2):	0.0412
w	1.5
q2 + w*(q2-q1)	0.0793
q1 - w*(q2-q1)	-0.0222
Mean:	0.0383



Re-gridding to 36-km EASEv2

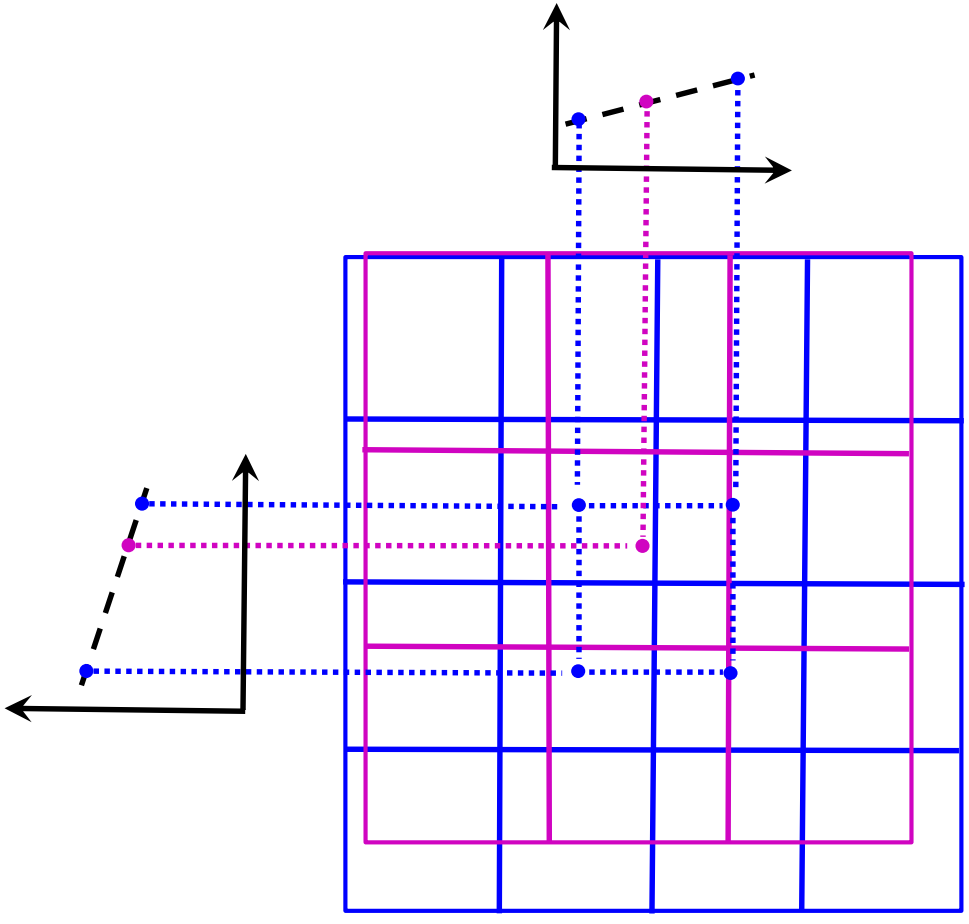
- **SMOS**
  - Data: P L3 on 25-km EASEv1/v2, L-band, using only ASC (6am)
  - Re-gridding method: Bilinear interpolation (Matlab: interp2 with ‘linear’ method), alternative: IDW
  - Flagging: Raw and flagged soil moisture product

- **Aquarius**
  - Data: P L2 v3 time-ordered, 3 beams (76x94 km, 84x120 km, 96x156 km), L-band, using only DESC (6am)
  - Re-gridding method: IDW (utilizing foot-print information from L2 TB files)
  - Flagging: Raw and flagged soil moisture product

- **ASCAT**
  - Data: P L2 time-ordered on 12.5 km grid, C-band, using only DESC (9:30am), using porosity to calculate volumetric soil moisture
  - Re-gridding method: IDW
  - Flagging: Raw and flagged soil moisture product

- **AMSR2**
  - Data: P L3 with 0.25 degree posting, C-/X-band, using only DESC (1:30am)
  - Re-gridding method: Bilinear interpolation (Matlab: interp2 with ‘linear’ method), alternative: IDW
  - Flagging: Raw and flagged soil moisture product

Bilinear interpolation

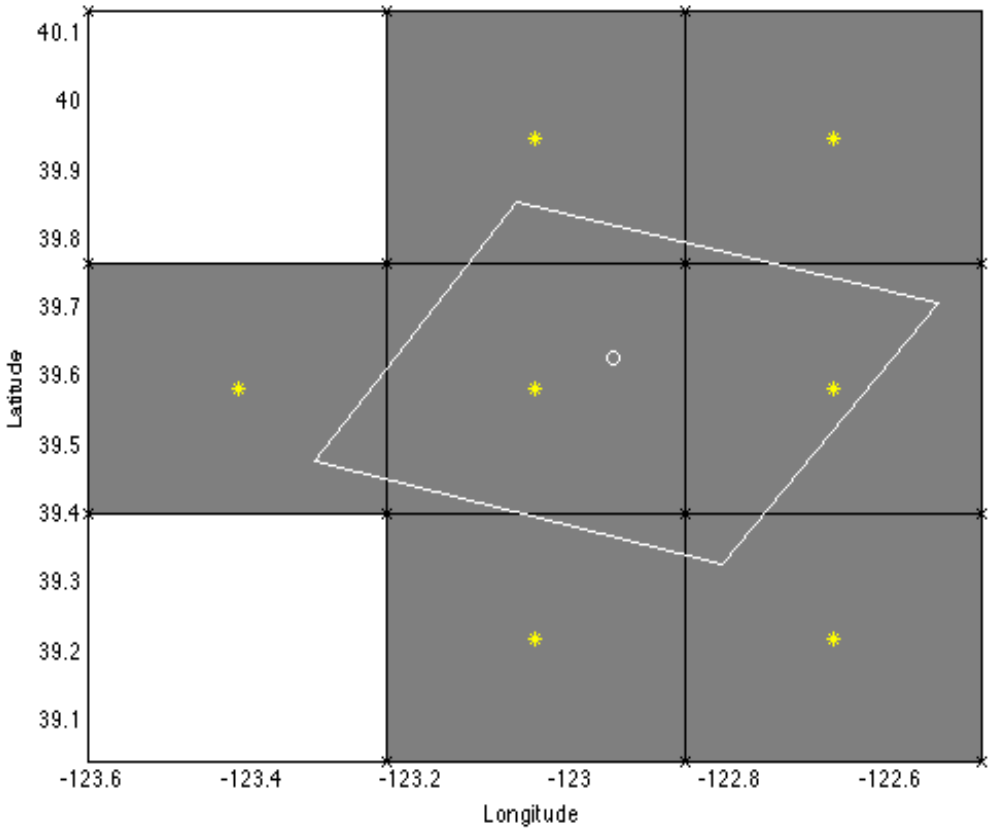


SMAP
SMOS/AMSR2

Matlab: interp2 with ‘linear’

Coordinated with Francois Cabot
(analyzed different interpolation methods)

Inverse Distance Weighting (IDW)



The white polygon is drawn based on the Aquarius 3 dB footprint corners (supplied by L2 TB files). The white circle is the Aquarius beam center. The yellow asterisks are the centers of the EASE2 grid. The grey grid cells contain overlapping area with the Aquarius footprint.

Aquarius/ASCAT

$$X_{IDW} = \frac{\sum_{i=1}^{n} X_i / (d_i)^p}{\sum_{i=1}^{n} (1/d_i)^p}$$

The swath data in each beam is separately converted to the 36-km EASE grid by averaging the data using the inverse distance weight (IDW) for each day, according to the above Equation. d_i is the distance between the EASEv2 grid center and the Aquarius footprint center. X_i is the swath data (soil moisture) and p = 2.

<u>Considerations for Aquarius:</u>

- Percentage land fraction > 90%
- Spacecraft attitude control system (ACS) mode == 5 (science)
- No RFI contamination: neither moderate contamination [7 <= samples < 15] nor severe contamination [samples < 7]

Coordinated with Xiaolan Xu
(same method when using Aquarius data for Freeze/Thaw analysis)

Re-gridded products: baseline and optional

- **SMOS** (based on discussion with Francois Cabot)
  - **Baseline**: raw soil moisture, time
  - **Optional**: flagged soil moisture, time

    Flagging mask (conservative flagging: if 1 out of 4 is “1”, new pixel is “1”):

    (S_Tree_1 == 12 & Science_Flags (Bit 1) == 0 & Event_Flags == 0 & Rfi_Prob < 0.1) |
    (S_Tree_1 == 11 & Science_Flags (Bit 3-10, 12-20) == 0) & Event_Flags == 0 & Rfi_Prob < 0.1)

    - S_Tree_1 == 11: Forest cover
    - S_Tree_1 == 12: Soil cover (means VWC < 4 kg/m2)
    - Science_Flags:
      - Bit 1: Non-nominal - Bit 1 is 1 if flags in Bits 3-10 and 12-20 are raised
      - Bit 3: Barren – radiometric fraction of barren surface above 5%
      - Bit 4: Strong Topography – radiometric fraction of strong topography surface type above 5%
      - Bit 5: Moderate Topography - radiometric fraction of moderate topography surface type above 10%
      - Bit 6: Open Water – radiometric fraction of open water surface type above 5%
      - Bit 7: Mixed Snow – radiometric fraction of mixed snow surface type above 5%
      - Bit 8: Wet Snow - radiometric fraction of wet snow surface type above 5%
      - Bit 9: Dry Snow - radiometric fraction of dry snow surface type above 5%
      - Bit 10: Forest - radiometric fraction forest surface type above 10%
      - Bit 12: Frost - radiometric fraction of frost surface type above 5%
      - Bit 13: Ice - radiometric fraction of ice surface type above 5%
      - Bit 14: Wetlands - radiometric fraction of wetlands surface type above 5%
      - Bit 15: Flood Probability – sum of ECMWF value for Large_Scale_Precip and Convec_Precip above 20 mm/h
      - Bit 16: Urban Low - radiometric fraction of urban surface type above 10%
      - Bit 17: Urban High - radiometric fraction of urban surface type above 30%
      - Bit 18: Sand – mean sand fraction is above 95%
      - Bit 19: Sea Ice – radiometric fraction of sea ice surface type (from ECMWF) is above 20%
      - Bit 20: Coast – Wetlands fraction in at least one cell is above 0 and the land cover class reports an intertidal area
    - Event_Flags == 0: No events detected
    - Rfi_Prob < 0.1: RFI probability (total number of RFI detected on a large period divided by the total number of TB measurements acquired during the same period) is below 10 percent

Re-gridded products: baseline and optional

- **Aquarius** (based on discussion with Rajat Bindlish, Xiaolan Xu)
  - **Baseline**: raw soil moisture, time
  - **Optional**: flagged soil moisture, time
    - Flagging from soil moisture product: consider only pixels with VWC < 5 kg/m^2 (radiometer_flags Bit 9)
    - Flagging from radiometer product: consider only pixels with land fraction > 90%, ACS mode == 5 and no RFI flag raised

- **ASCAT** (based on discussion with Sebastian Hahn and Wolfgang Wagner)
  - **Baseline**: raw soil moisture index (converted to volumetric soil moisture via porosity), time
    - Porosity: L4_SM (land module constants granule) porosity at 9 km, averaged to 36 km
    - Volumetric soil moisture: soil moisture index * porosity at 36 km
  - **Optional**: flagged soil moisture, time

    Flagging mask:

    (Snow probability < 50% & Frozen ground probability < 50% & Wetland probability < 50% & Topography probability < 50% & Soil moisture error < 50%)
    - Soil moisture error: Error propagation is applied to the TU Wien model leading to an estimate of uncertainty for soil moisture. Error is assumed to be normally distributed.

- **AMSR2**
  - **Baseline**: raw soil moisture, time
  - **Optional**: no flagged soil moisture

Status on 8/28/2015

- **SMOS**
  - Data: Available up to 8/17/2015 (regularly pushed), release of SMOS L3 v300(v620) began on 5/5/2015 (data from 5/1/2015 onwards is v300; previous data will be re-processed; in the mean time, time series analysis will contain data from two different versions)
  - Re-gridding: Bilinear interpolation (IDW is implemented as well)

- **Aquarius (EOM 6/8/2015)**
  - Data: Available up to 4/30/2015 (pushed in monthly chunks), version 4 soon available
  - Re-gridding: IDS (utilizing foot-print information from L2 TB files)

- **ASCAT**
  - Data: Available up to 8/16/2015 (regularly pushed), updated version starting 7/20
  - Re-gridding: IDW

- **AMSR2**
  - Data: Available up to 8/17/2015 (regularly pushed)
  - Re-gridding: Bilinear interpolation (IDW is implemented as well)

Nominal
To be observed
Action taken

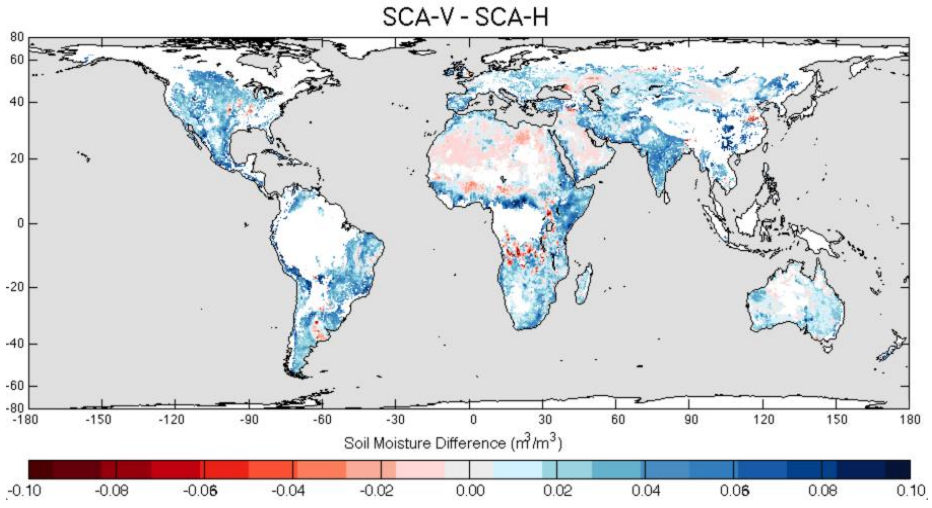
Outline

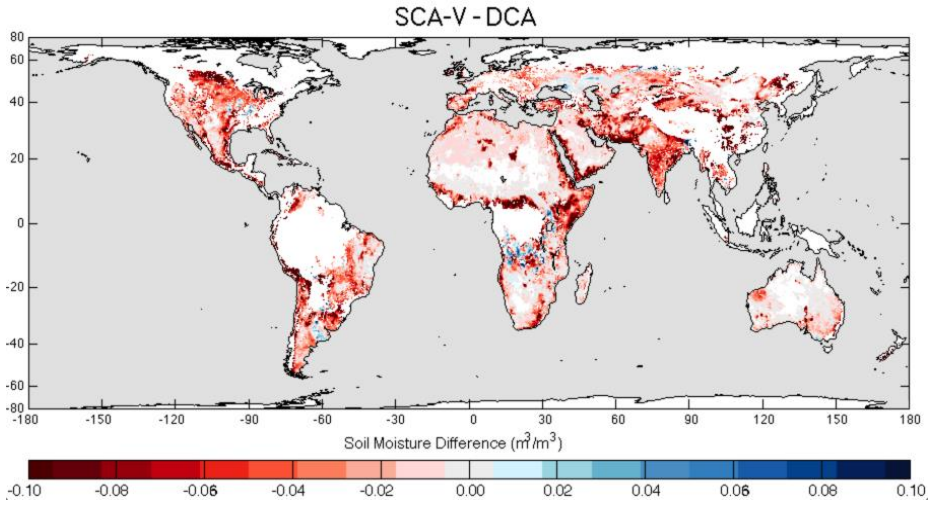
- SMAP L2 SM P BL + options intercomparison over a week (from 4/21 – 4/27)
- L2 SM P and satellite product intercomparison over a week (from 4/21 – 4/27)
- Statistics to support SMAP soil moisture product validation: L2 SM P and SMOS from 4/11 – 7/14

SMAP L2 SM P BL + options intercomparison

SMAP L2 SM P options inter-comparison

Jet Propulsion Laboratory
California Institute of Technology





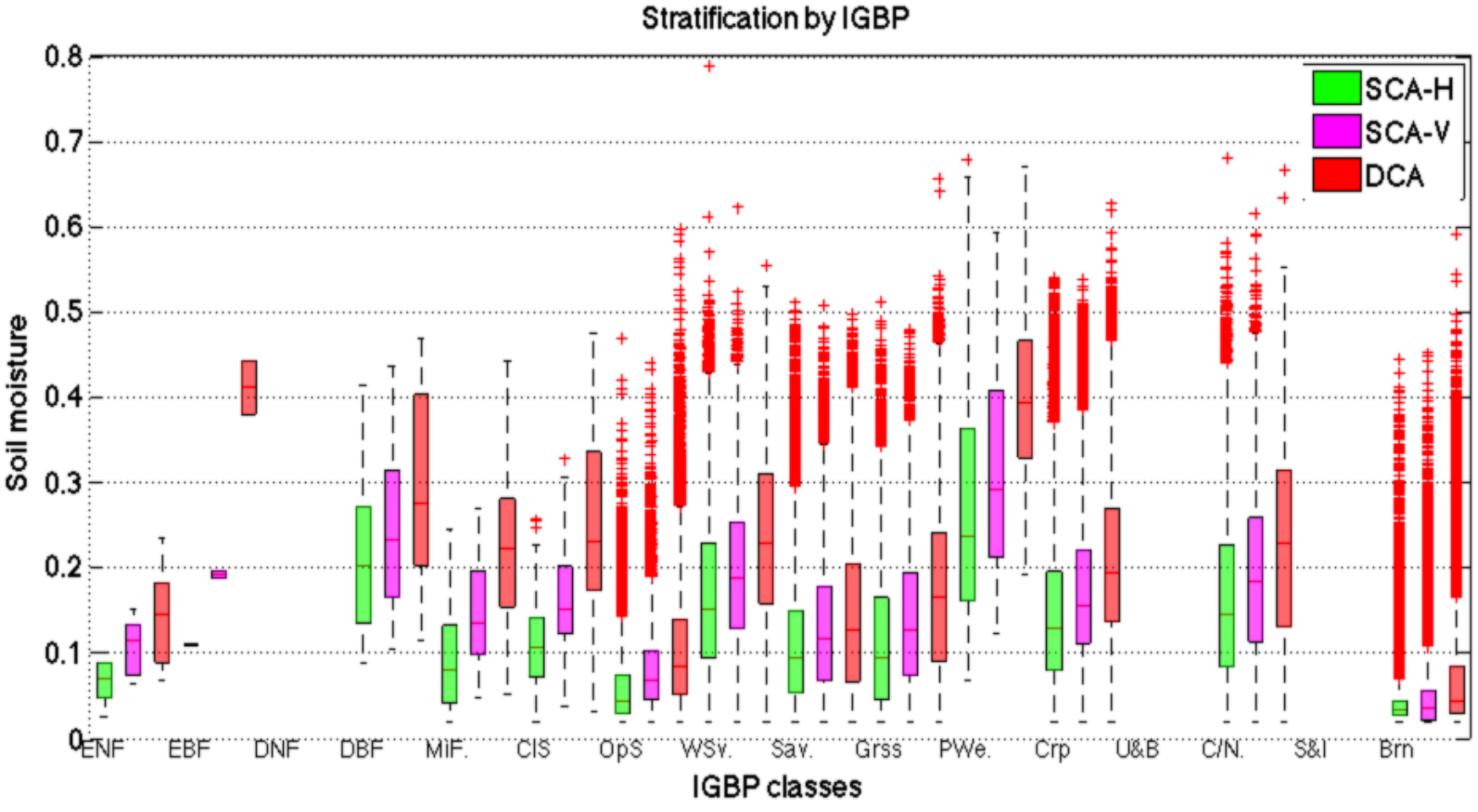
- SCA-V is the base line algorithm
- SCA-H is overall drier than SCA-V, while DCA is overall wetter than SCA-V
- Overall global patterns are similar

SMAP L2 SM P options inter-comparison

Jet Propulsion Laboratory
California Institute of Technology

Boxplot:

Central mark:	median
Edges of box:	25th and 75th percentile
Whiskers:	extend to most extreme data points
Red crosses:	outliers

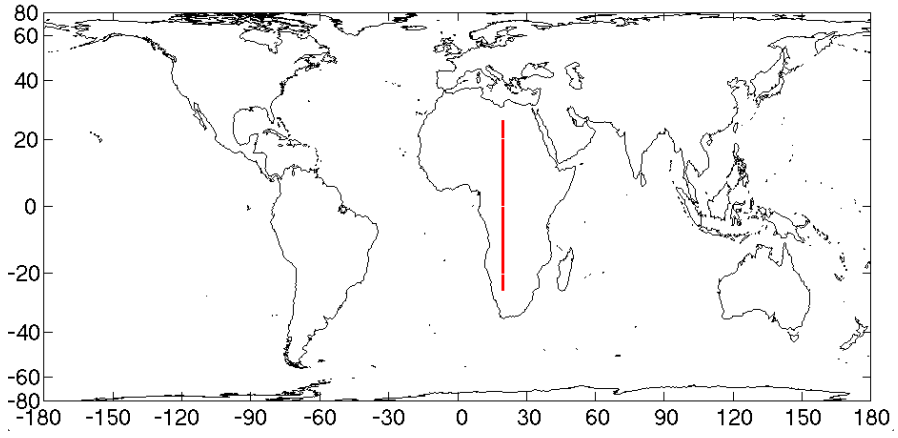


- SCA-V is the base line algorithm
- SCA-H is overall drier than SCA-V, while DCA is overall wetter than SCA-V

Showing only points existing in all data sets

SMAP L2 SM P options inter-comparison

Jet Propulsion Laboratory
California Institute of Technology

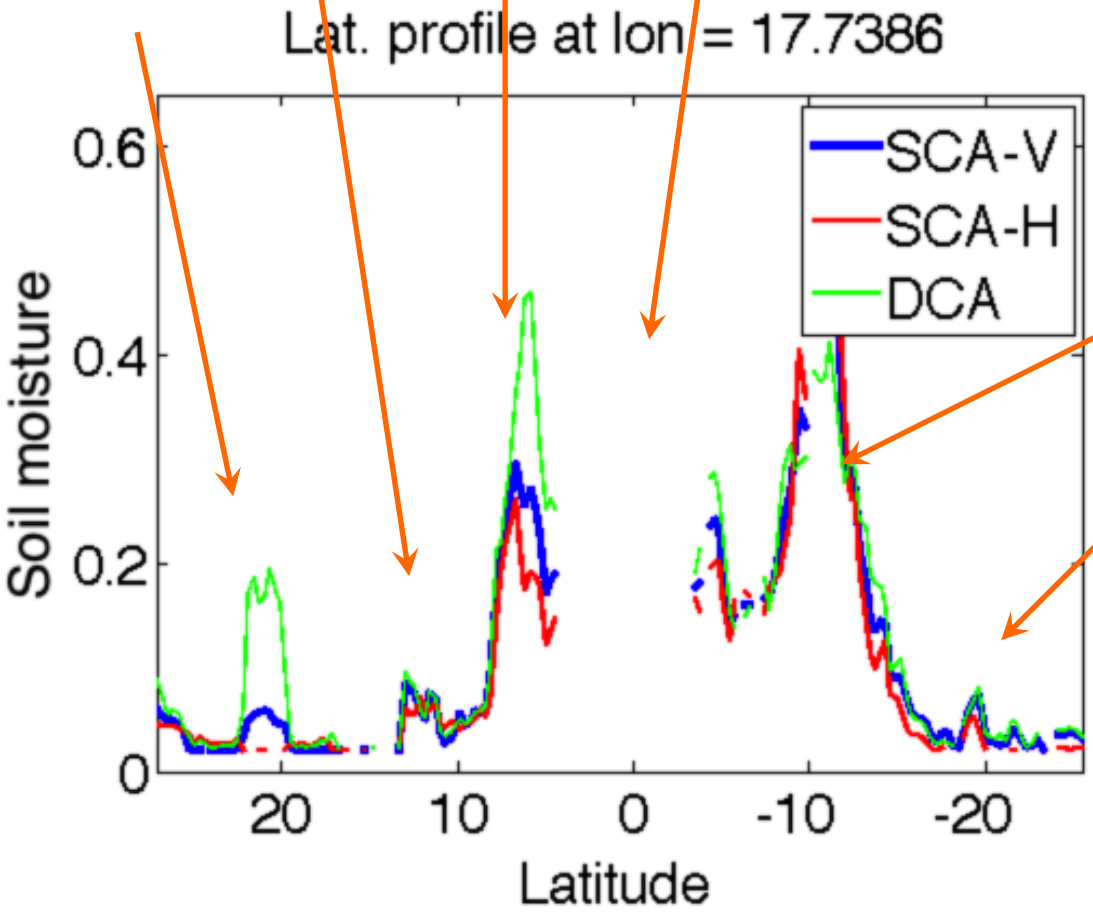


Sudanian Savanna
(tropical savanna)

Sahel
(semi-arid)

Congolian
rainforest

Sahara
(desert)



Zambezi &
Okavango
(inland deltas)

Namibian
desert

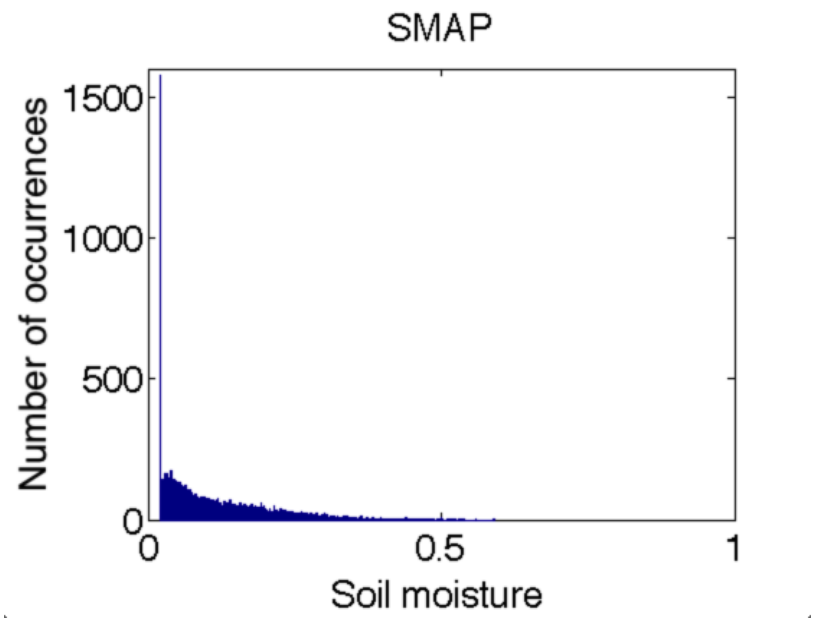
General trend of increasing differences with denser vegetation

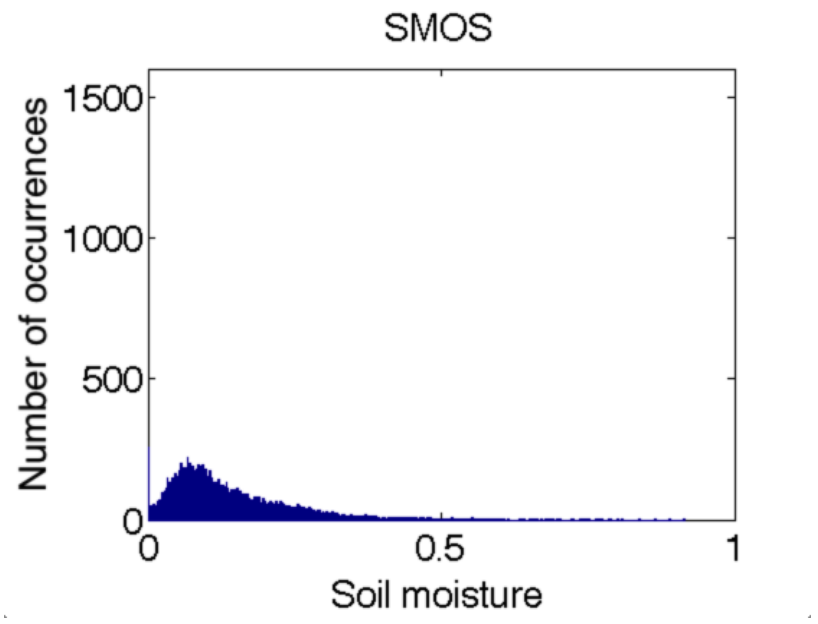
- Exception: Sahara

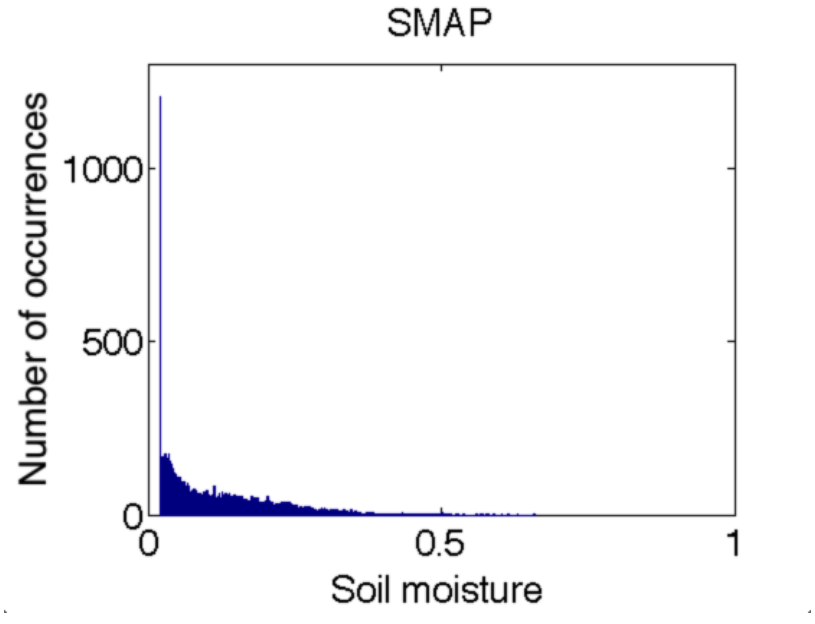
SMAP L2 SM P CRID: 11880

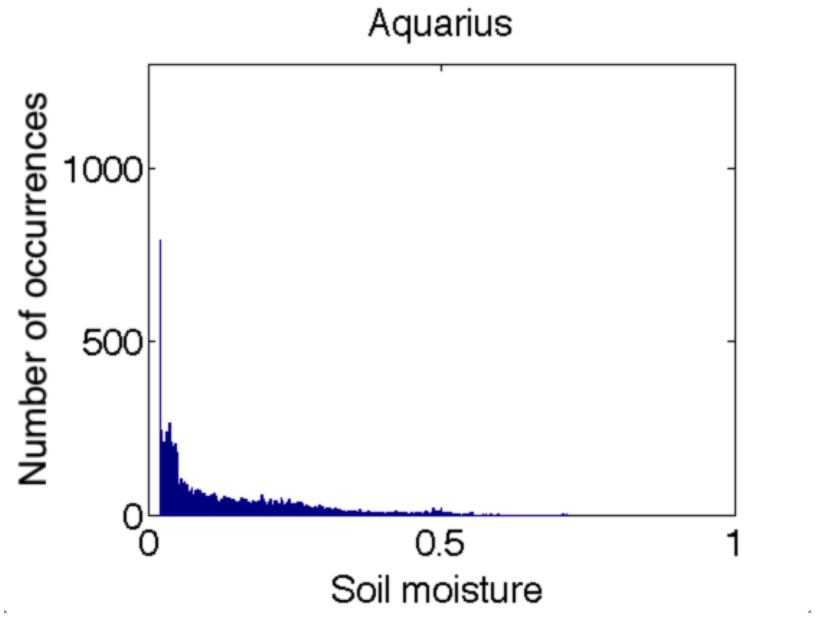
Global L2 SM P satellite inter-comparison

Jet Propulsion Laboratory
California Institute of Technology







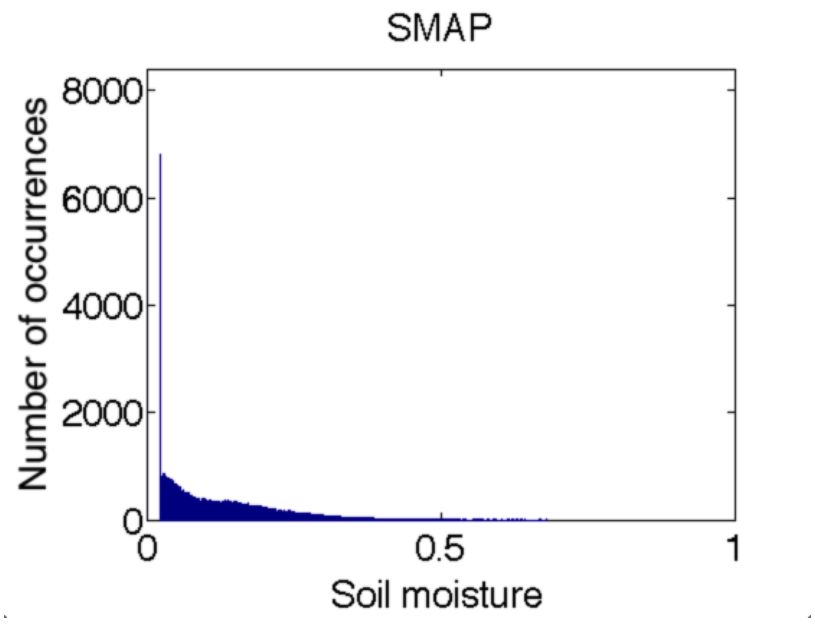


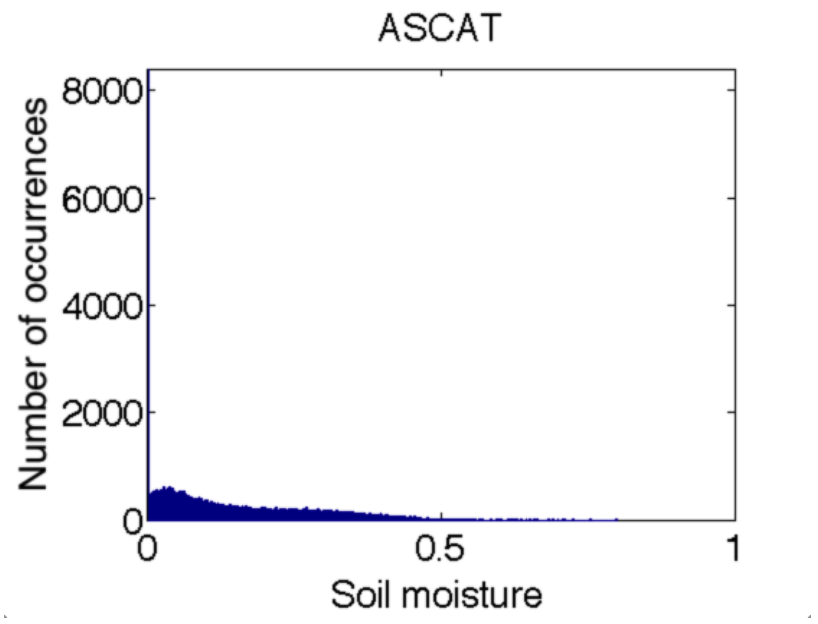
Showing only points existing in all data sets

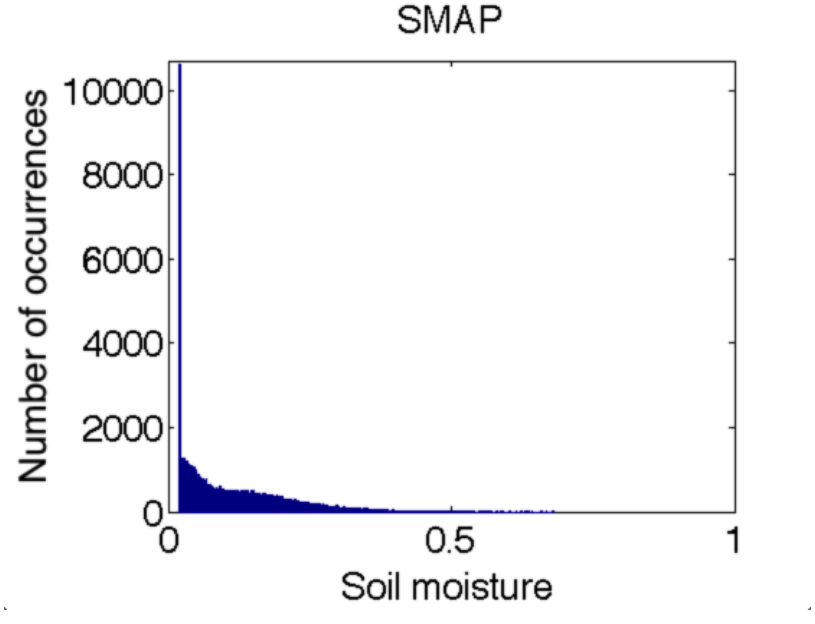
SMAP L2 SM P CRID: 11880

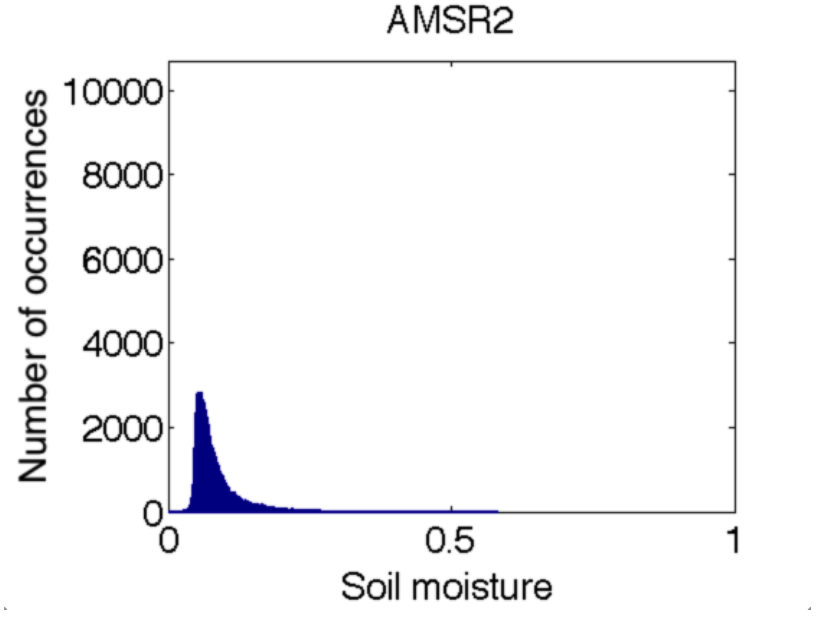
Global L2 SM P satellite inter-comparison

Jet Propulsion Laboratory
California Institute of Technology









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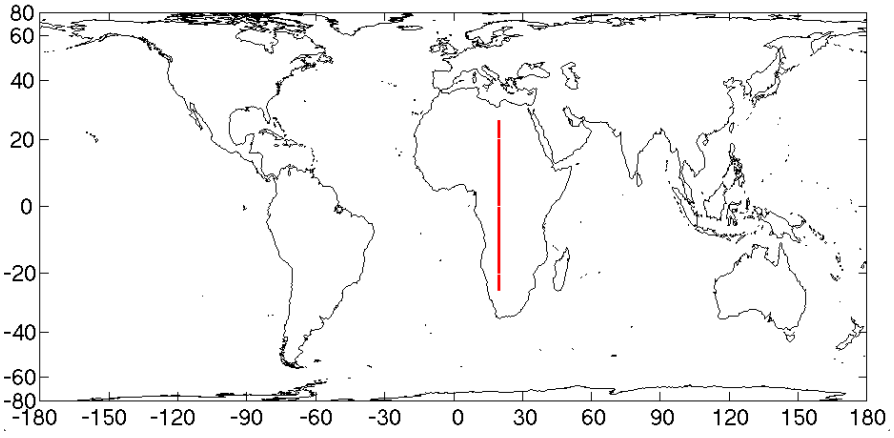
SMAP L2 SM P CRID: 11880

Global L2 SM P satellite inter-comparison

Jet Propulsion Laboratory
California Institute of Technology



Sudanian Savanna
(tropical savanna)

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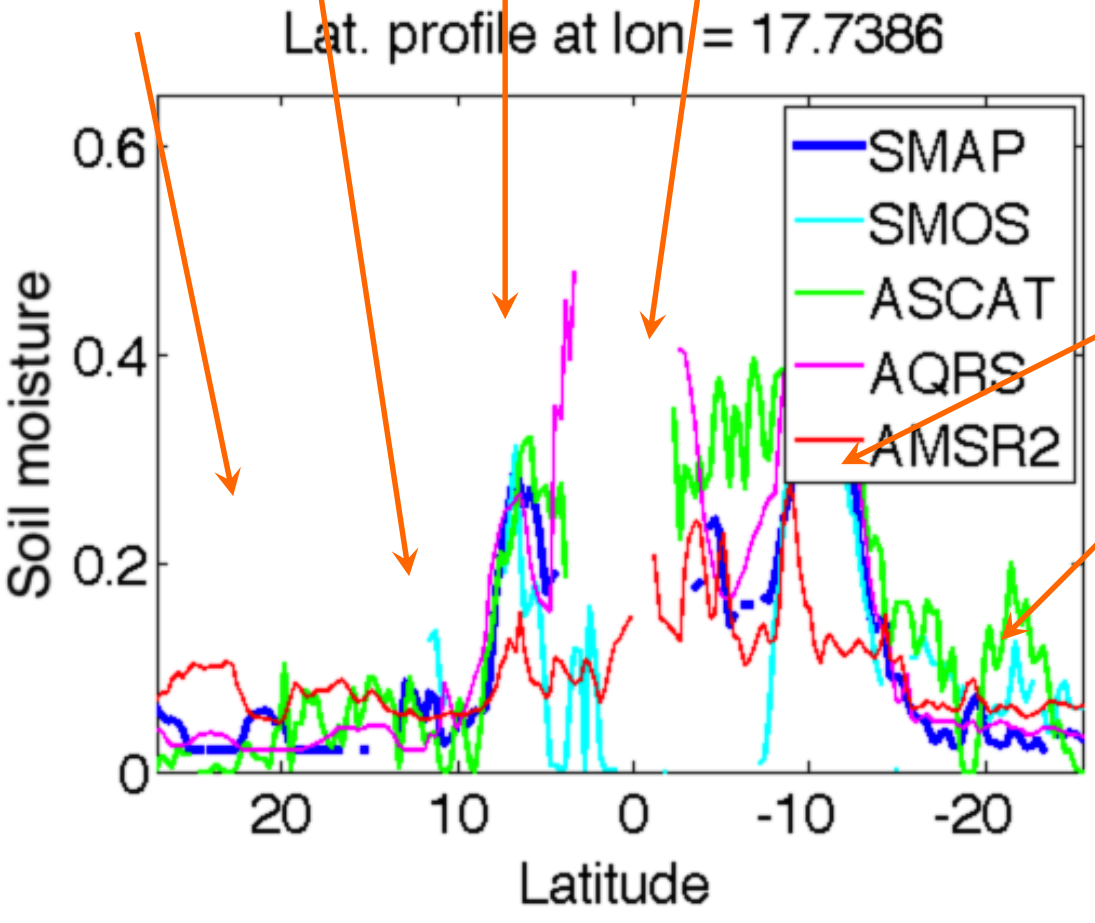


Zambezi &
Okavango
(inland deltas)

Namibian
desert

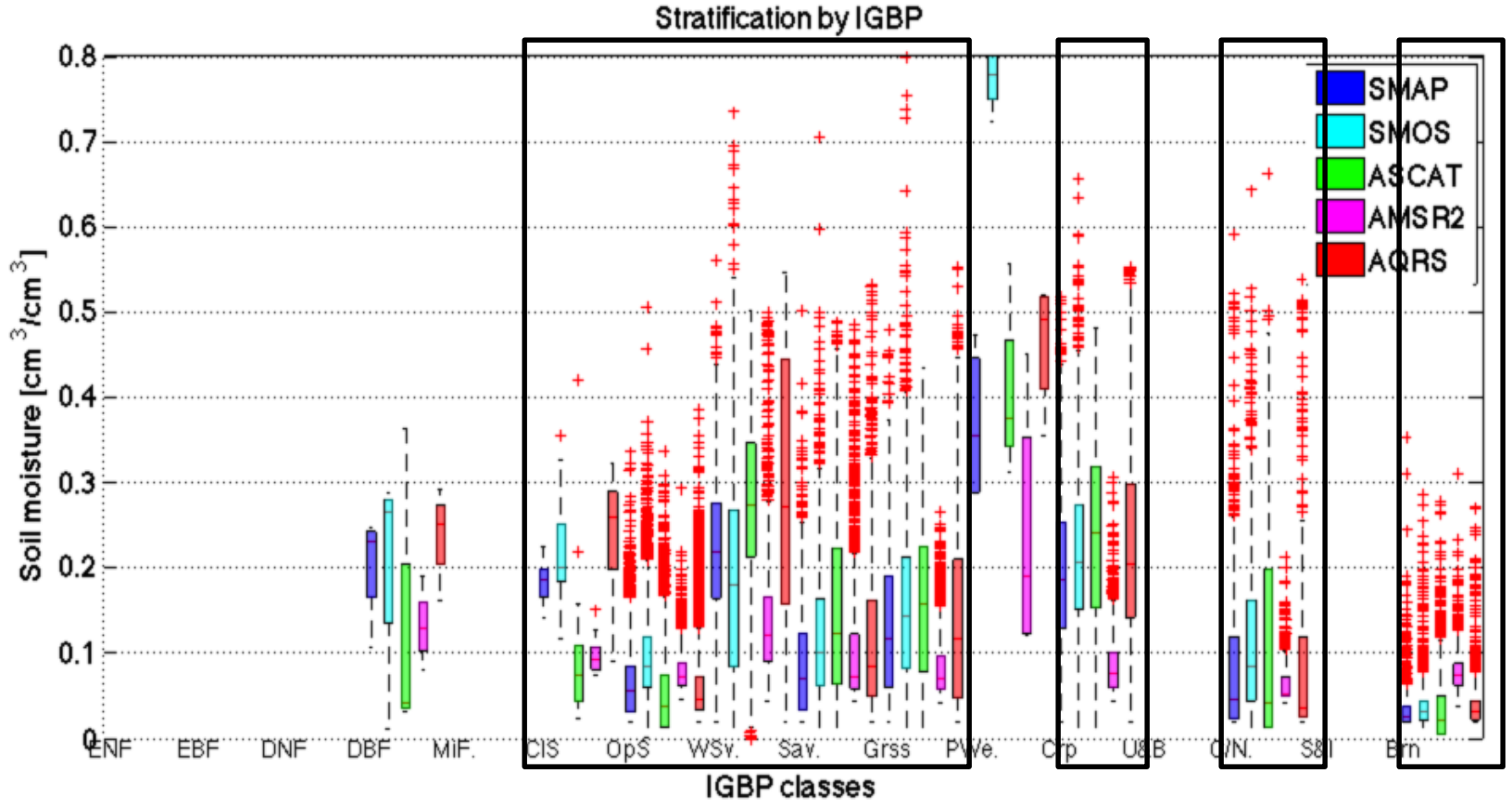
- SMAP/SMOS agree when disregarding very dry pixels over forests
- SMAP/ASCAT show similar trends
- SMAP/AMSR2 largely disagree

SMAP L2 SM P CRID: 11880

Global L2 SM P satellite inter-comparison

Jet Propulsion Laboratory
California Institute of Technology

Boxplot:
- Central mark: median
- Edges of box: 25th and 75th percentile
- Whiskers: extend to most extreme data points
- Red crosses: outliers



- SMAP/SMOS compare well (both L-band)
- SMAP and ASCAT (C-band)/AMSR2 (C-/X-band) show larger differences in denser vegetation

Showing only points existing in all data sets

SMAP L2 SM P CRID: 11880

L2 SM P and satellite product intercomparison

Statistics to support SMAP soil moisture product validation: L2 SM P and SMOS

Comparison of SMAP/SMOS for April 11 – July 14, 2015 (both products flagged)

	ubRMSE (m^3/m^3)			Bias (m^3/m^3)			RMSE (m^3/m^3)			R			N		
IGBP Class	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA
Evergreen needleleaf forest															
Evergreen broadleaf forest															
Deciduous needleleaf forest	0.083	0.080	0.089	-0.046	0.005	0.094	0.094	0.080	0.129	0.410	0.464	0.407	108	108	108
Deciduous broadleaf forest	0.080	0.078	0.075	-0.035	-0.003	0.033	0.087	0.078	0.082	0.822	0.832	0.807	45	45	45
Mixed forest															
Closed shrublands	0.083	0.076	0.075	-0.098	-0.057	-0.020	0.128	0.095	0.078	0.567	0.674	0.609	91	87	83
Open shrublands	0.067	0.053	0.060	-0.080	-0.048	0.003	0.105	0.071	0.060	0.619	0.804	0.825	54639	50626	51186
Woody savannas	0.101	0.095	0.106	-0.022	0.015	0.068	0.104	0.096	0.126	0.663	0.726	0.663	18258	18207	17832
Savannas	0.073	0.071	0.078	-0.038	-0.026	-0.019	0.082	0.076	0.081	0.742	0.757	0.724	12795	12247	11020
Grasslands	0.057	0.049	0.052	-0.037	-0.020	0.001	0.068	0.053	0.052	0.824	0.871	0.855	34451	32870	31776
Permanent wetlands	0.140	0.140	0.176	-0.028	-0.208	0.078	0.316	0.251	0.193	0.603	0.629	0.134	818	819	792
Croplands	0.073	0.056	0.056	-0.020	-0.010	0.005	0.075	0.057	0.056	0.748	0.841	0.841	16964	16437	16815
Urban and built-up															
Crop/Natural vegetation mosaic	0.091	0.081	0.083	-0.024	-0.021	-0.015	0.094	0.084	0.084	0.730	0.785	0.779	4801	4921	4528
Snow and ice															
Barren/Sparse	0.028	0.026	0.030	0.011	0.010	0.022	0.030	0.028	0.038	0.718	0.764	0.751	16046	16623	15840
AVERAGE	**0.078**	**0.066**	**0.071**	**-0.044**	**-0.023**	**0.011**	**0.089**	**0.070**	**0.071**	**0.700**	**0.797**	**0.795**			
AVERAGE is based on all sets of observations, not the average of the land covers.															

- This table should not be interpreted as one algorithm or product being right and another wrong
- SCA-V shows best performance of the three algorithms ➔ agrees with CVS and sparse networks
- Bias values indicate SMAP predicts lower soil moisture values than SMOS for SCA algorithms over most categories
- Permanent wetland shows large RMSE and ubRMSE (to be investigated; in the future SMAP will no longer retrieve soil moisture in this class)

Comparison of SMAP/SMOS for April 11 – July 14, 2015 (both products un-flagged)

	ubRMSE (m^3/m^3)			Bias (m^3/m^3)			RMSE (m^3/m^3)			R			N		
IGBP Class	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA	SCA-H	SCA-V	DCA
Evergreen needleleaf forest	0.094	0.088	0.099	0.082	0.111	0.157	0.124	0.142	0.186	0.537	0.576	0.490	13986	14046	13713
Evergreen broadleaf forest	0.135	0.136	0.148	0.087	0.149	0.158	0.160	0.202	0.217	0.355	0.329	0.254	35341	35652	24107
Deciduous needleleaf forest	0.063	0.063	0.085	-0.002	0.055	0.160	0.063	0.084	0.181	0.507	0.526	0.331	4206	4206	4154
Deciduous broadleaf forest	0.115	0.116	0.134	0.039	0.041	0.042	0.122	0.123	0.140	0.622	0.645	0.563	5888	6077	5979
Mixed forest	0.113	0.106	0.118	0.076	0.111	0.167	0.136	0.154	0.205	0.539	0.594	0.476	29055	29318	28121

- This table should not be interpreted as one algorithm or product being right and another wrong
- Large bias between SMAP and SMOS, with SMAP predicting wetter conditions than SMOS
  - ➔ can be in part explained by very dry pixels in forested areas for currently used SMOS version (4/11-5/1)