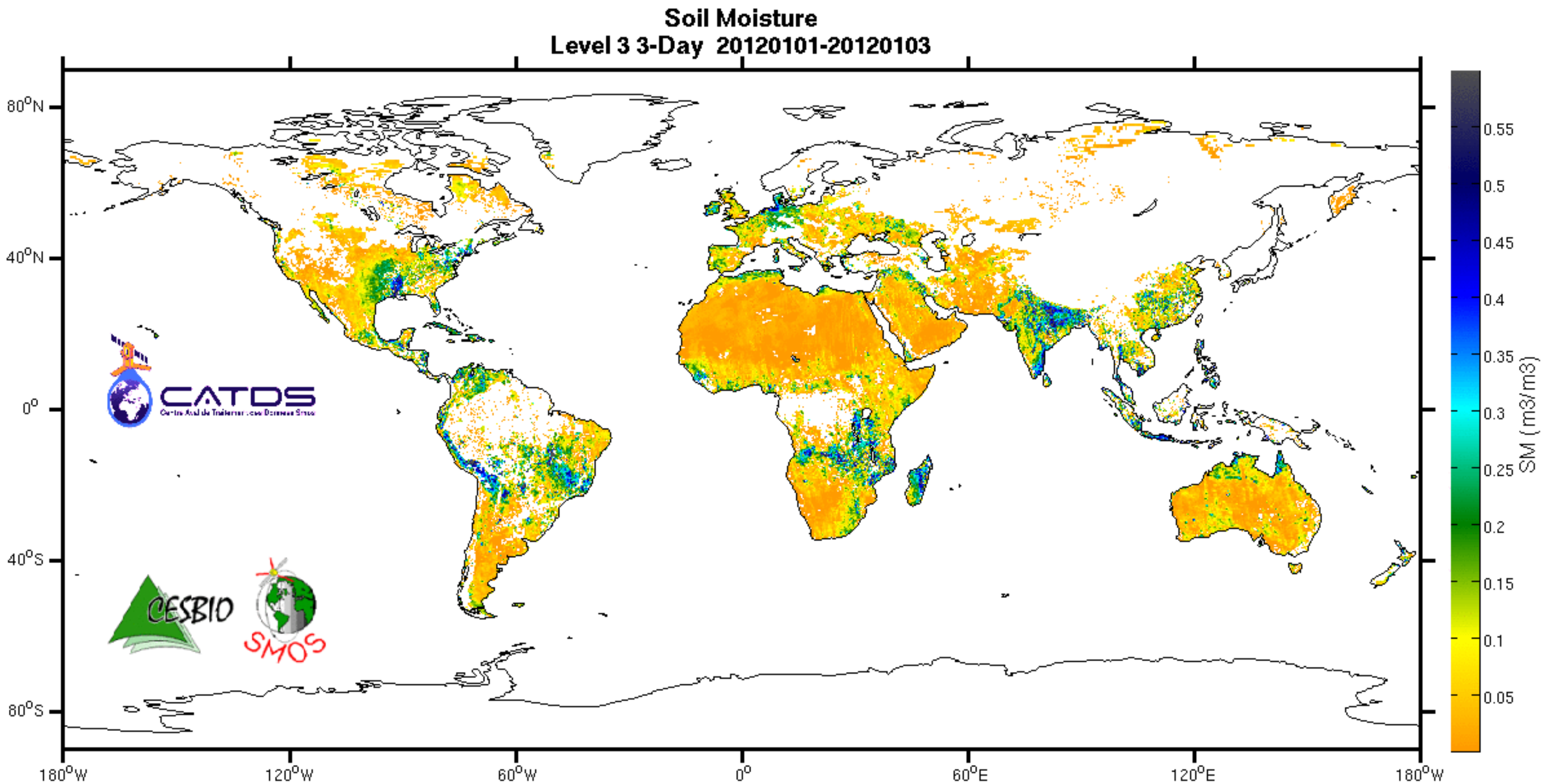
SMOS Land products developments and applications

Yann Kerr (CESBIO) and the ESL's
Steven Delwart, Matthias Drush and susanne Mecklenburg


Soil Moisture
Level 3 3-Day 20120101-20120103
80°N
40°N
0°
40°S
80°S
180°W
120°W
60°W
0°
60°E
120°E
180°W
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
SM (m3/m3)
CATDS

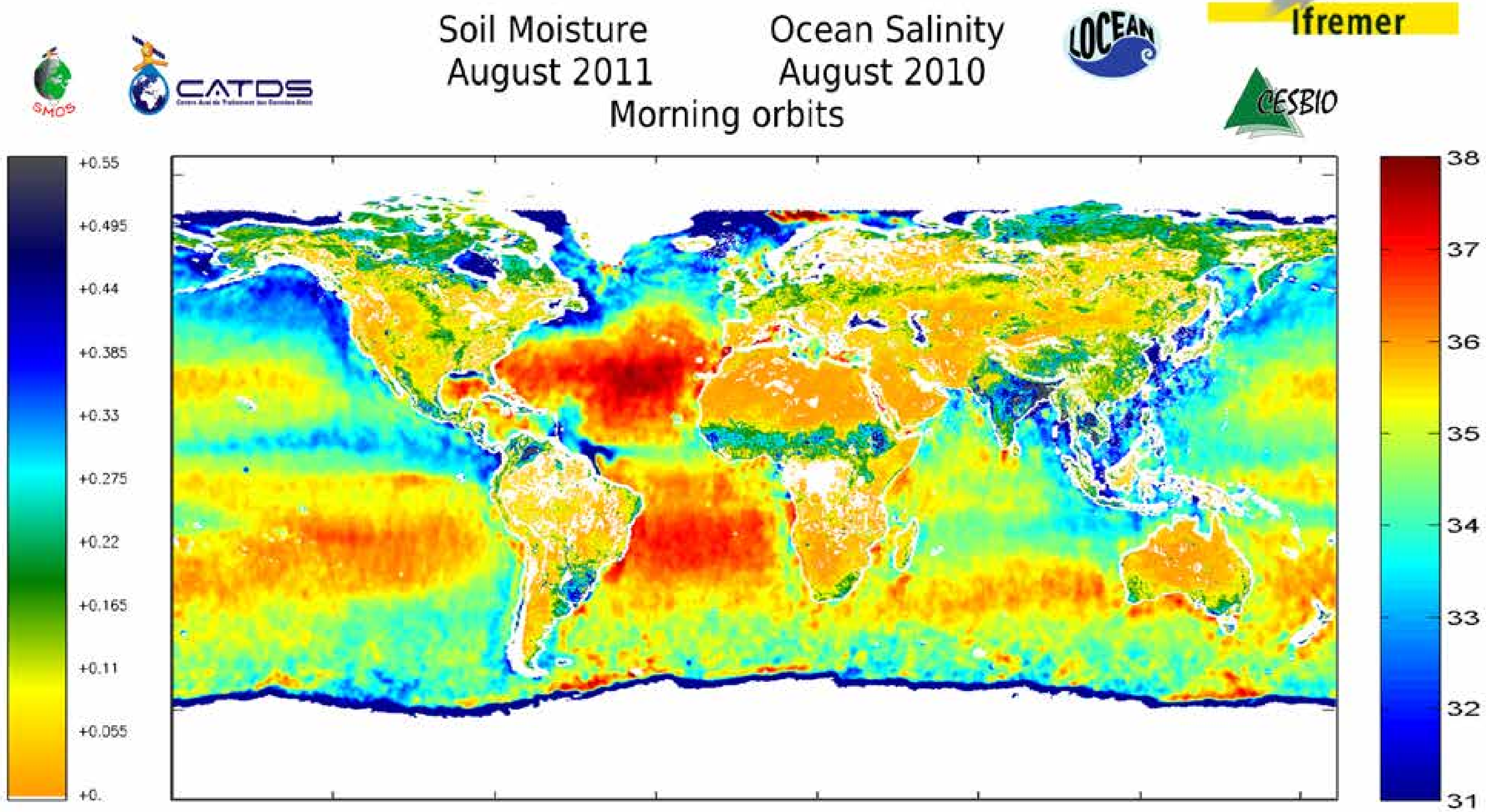
Layout

- SMOS status
- Some results
- Conclusion and way forward

SMOS
Principle and key points

- 2D L band Interferometric fully polarimetric radiometer
- Complete coverage of the globe in less than 3 days at both 6 am and 6 pm and multiangular acquisitions
- 43 km average (real) resolution
- Estimates of
  - Soil moisture, Vegetation opacity
  - Sea surface salinity
  - Wind speed (Hurricane)
  - Thin sea ice
  - drought, RZM
  - ....
- Launched november 2 2009

SMOS
Principle and key points



A few facts

- SMOS has now cumulated more than 4 years in operation (Jan 2010 to now)
- SMOS Extension for two years granted
- Operational Near real time Tb data disseminated
- Operational SM to be implemented at ECMWF
- Operational users of the data (latest is USDA)
- Pre operational products under test

- New products
  - Release of V620 this fall (ESA L1-L2) or now (CATDS L3)
    - Improved L1
    - Improved L2 / L3
  - Level 4
    - Drought index
    - Root zone soil moisture
    - Precip, floods etc…
- SMAP to be launched this November

Reprocessing

SMOS actually planning 2nd full mission reprocessing on v620. L1 available next fall, L2 next winter.

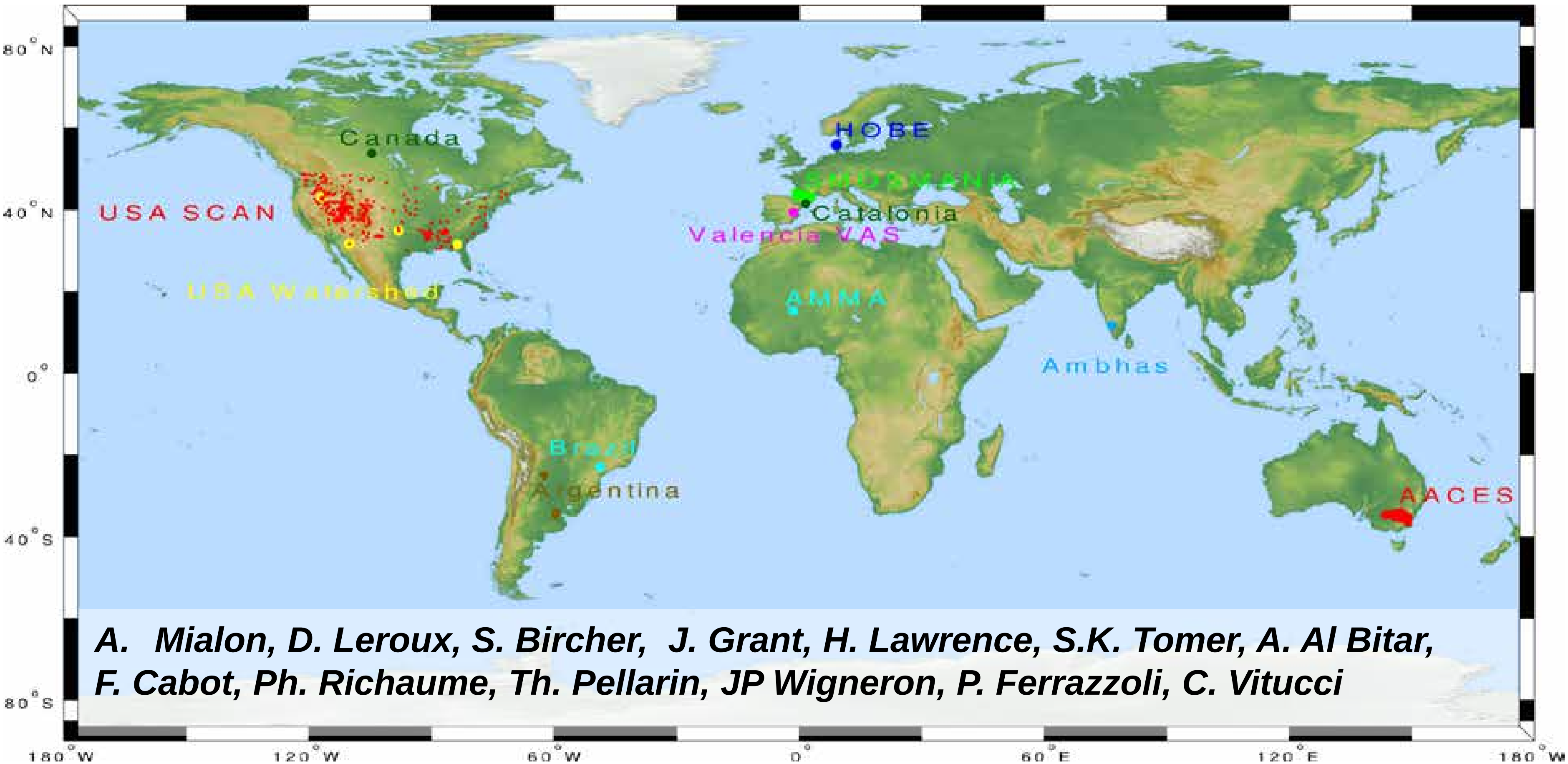
Based on preliminary results bias at Dome C down to below 1K

Aquarius soon distributing v3.0.

Cabot F.

	SMOS		Aquarius		Bias Aquarius-SMOS		Inter Version bias	
	V504	V611beta	V2.0	V2.7.1	V2.0/V504	V2.7.1/V611	SMOS (v611-v504)	Aquarius (v271-v2)
H	202,16	205,40	207,87	206,16	5,71	0,76	3,24	-1,71
V	189,40	192,78	195,62	193,07	6,22	0,29	3,38	-2,55
H	208,70	210,57	212,43	210,65	3,73	0,08	1,87	-1,78
V	186,99	188,86	192,15	189,38	5,16	0,52	1,87	-2,77
H	211,22	213,88	215,63	213,68	4,41	-0,20	2,66	-1,95
V	182,04	184,91	187,47	185,14	5,43	0,23	2,87	-2,33

Cal val : Many in situ datasets



A. Mialon, D. Leroux, S. Bircher, J. Grant, H. Lawrence, S.K. Tomer, A. Al Bitar, F. Cabot, Ph. Richaume, Th. Pellarin, JP Wigneron, P. Ferrazzoli, C. Vitucci

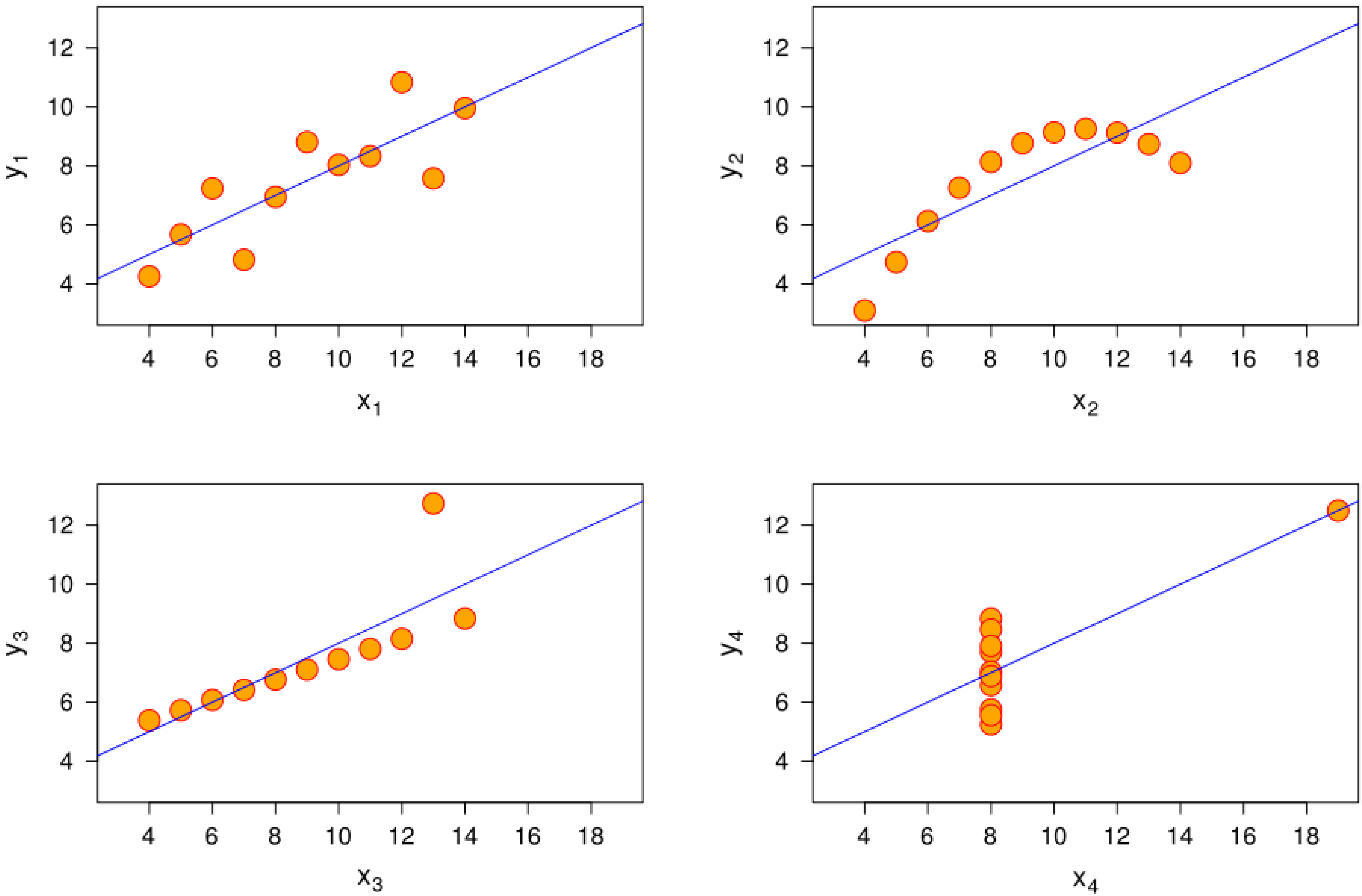
Collaborations : T. Jackson, R. Bindlish, E. Lopez, M. Sekhar, J. Walker, C. Rudiguer, E. Wood

Cal Val Metrics?

- Correlation coefficient or RMSE?
- Temporal or spatial?
- A couple of provocative examples

Satistics – the solution?

- Temporal evolution or statistics
  - 11 measurements … which is the best (Ascombe quartet)


12
10
8
6
4
y1
4 6 8 10 12 14 16 18
x1
12
10
8
6
4
y2
4 6 8 10 12 14 16 18
x2
12
10
8
6
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y3
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x3
12
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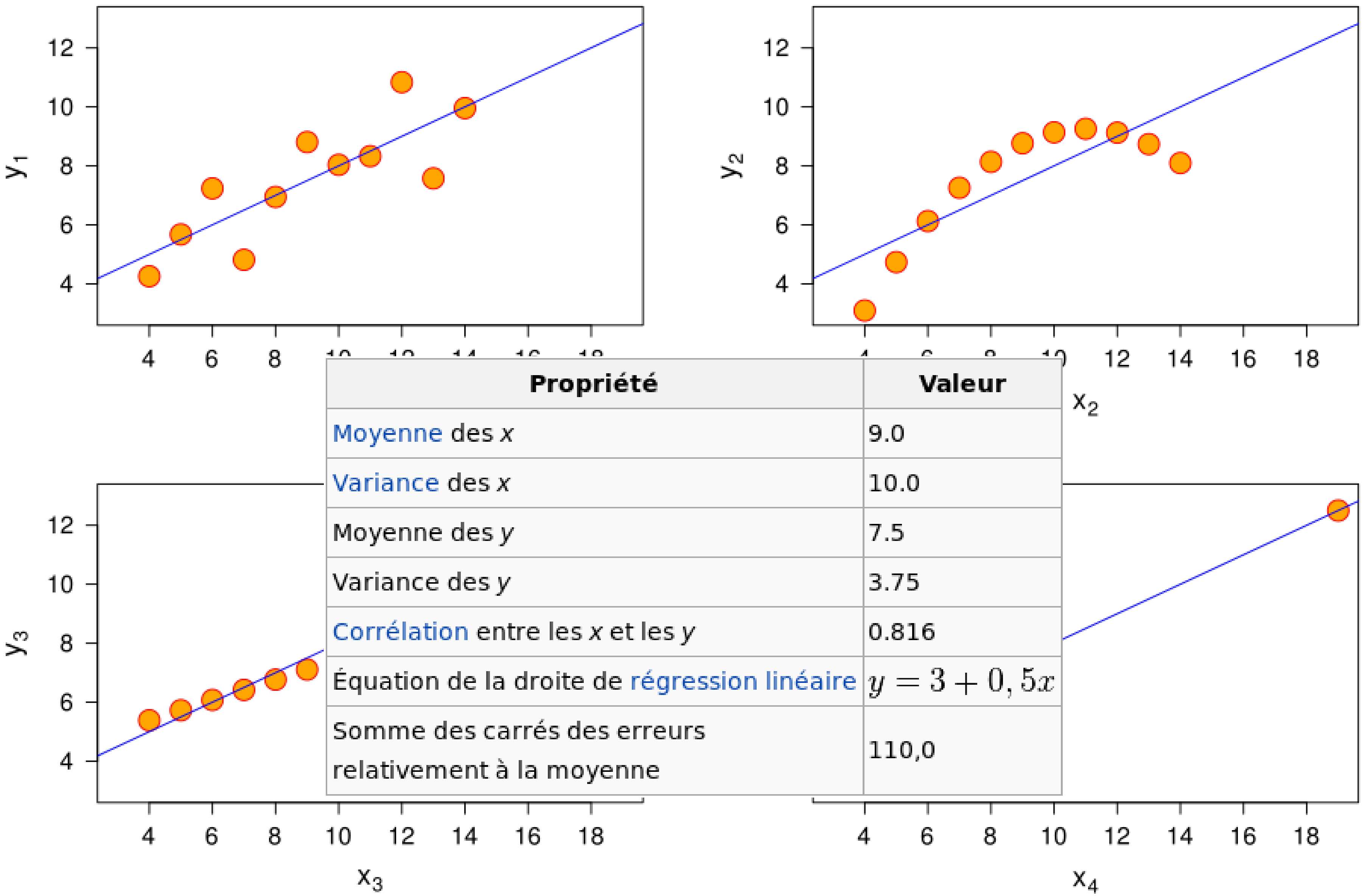
6
4
y4
4 6 8 10 12 14 16 18
x4



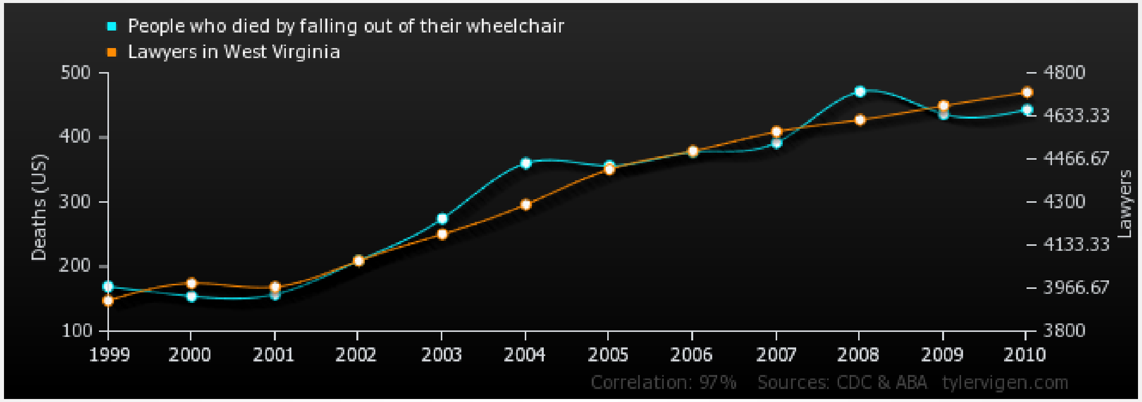
Propriété	Valeur
Moyenne des *x*	9.0
Variance des *x*	10.0
Moyenne des *y*	7.5
Variance des *y*	3.75
Corrélation entre les *x* et les *y*	0.816
Équation de la droite de régression linéaire	$y = 3 + 0,5x$
Somme des carrés des erreurs relativement à la moyenne	110,0

http://www.tylervigen.com

People who died by falling out of their wheelchair

correlates with

Lawyers in West Virginia



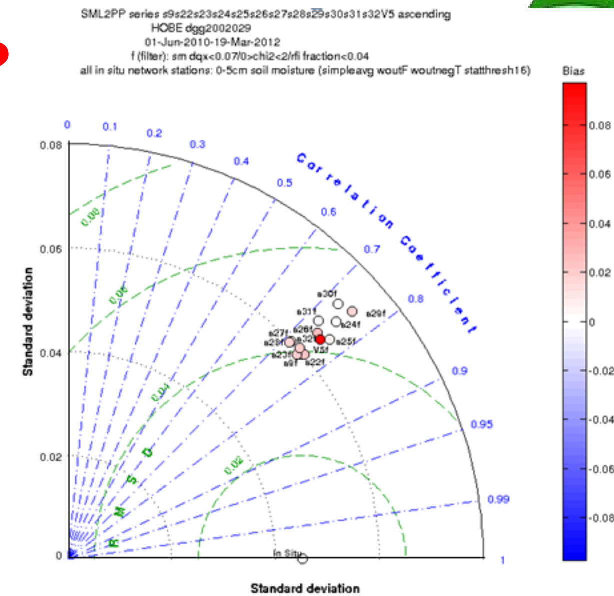
Upload this image to imgur

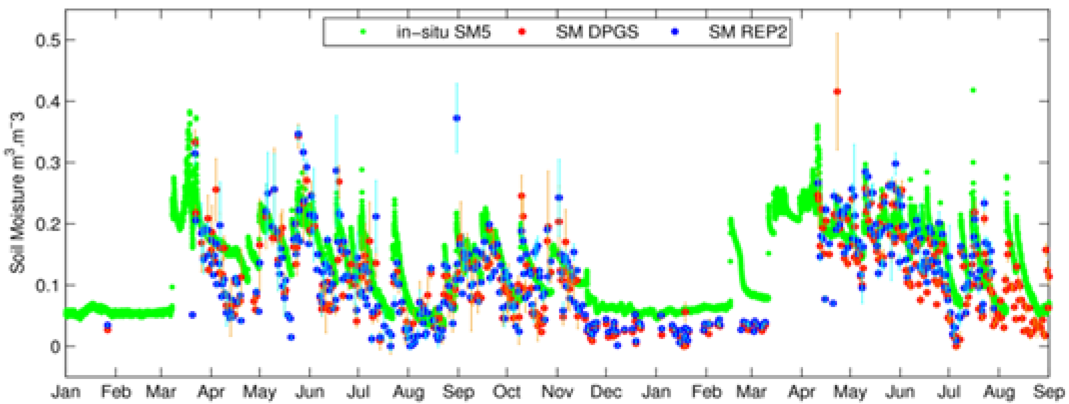
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
People who died by falling out of their wheelchair *Deaths (US) (CDC)*	169	154	157	209	274	360	356	377	392	471	436	443
Lawyers in West Virginia *Lawyers (ABA)*	3,918	3,985	3,971	4,072	4,175	4,290	4,426	4,497	4,572	4,618	4,672	4,725

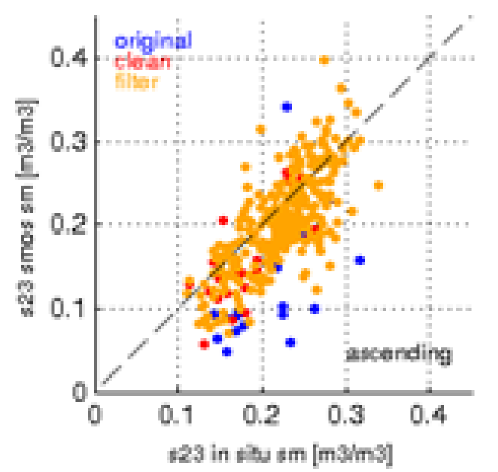
Correlation: 0.972699

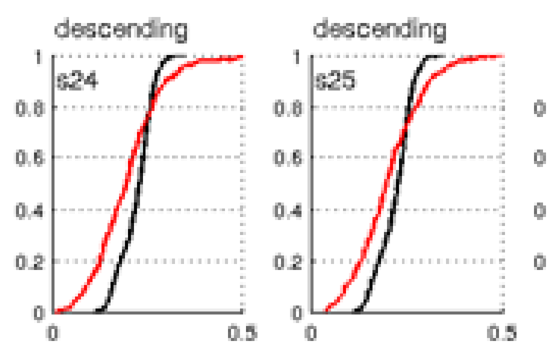
What do we need?

- Some common sense first
- Some reliable and characterised in situ data
- A panoply of tools
- Some mastering of statistics
- And …. a close look

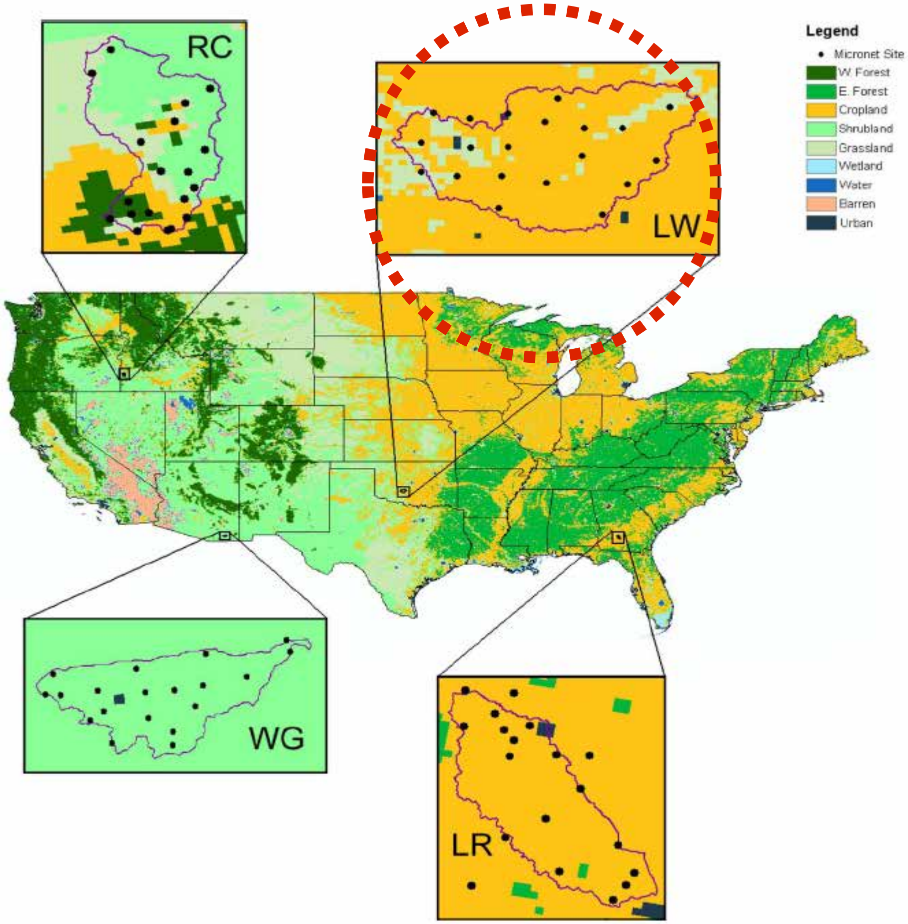






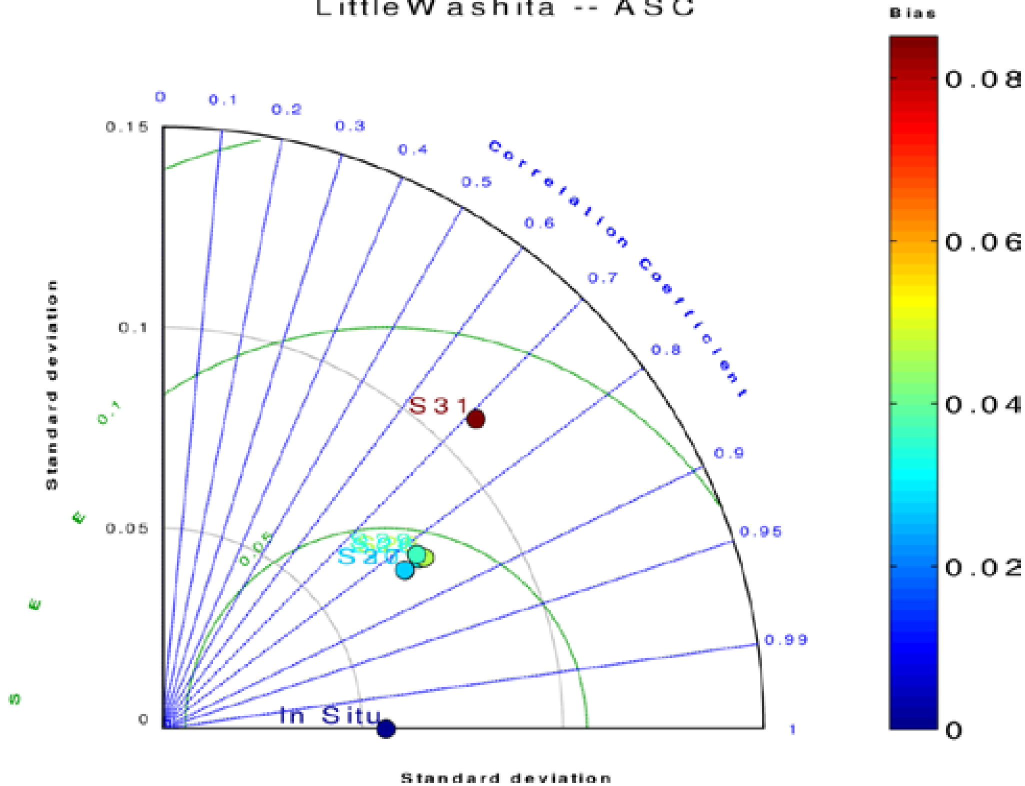


Little Washita

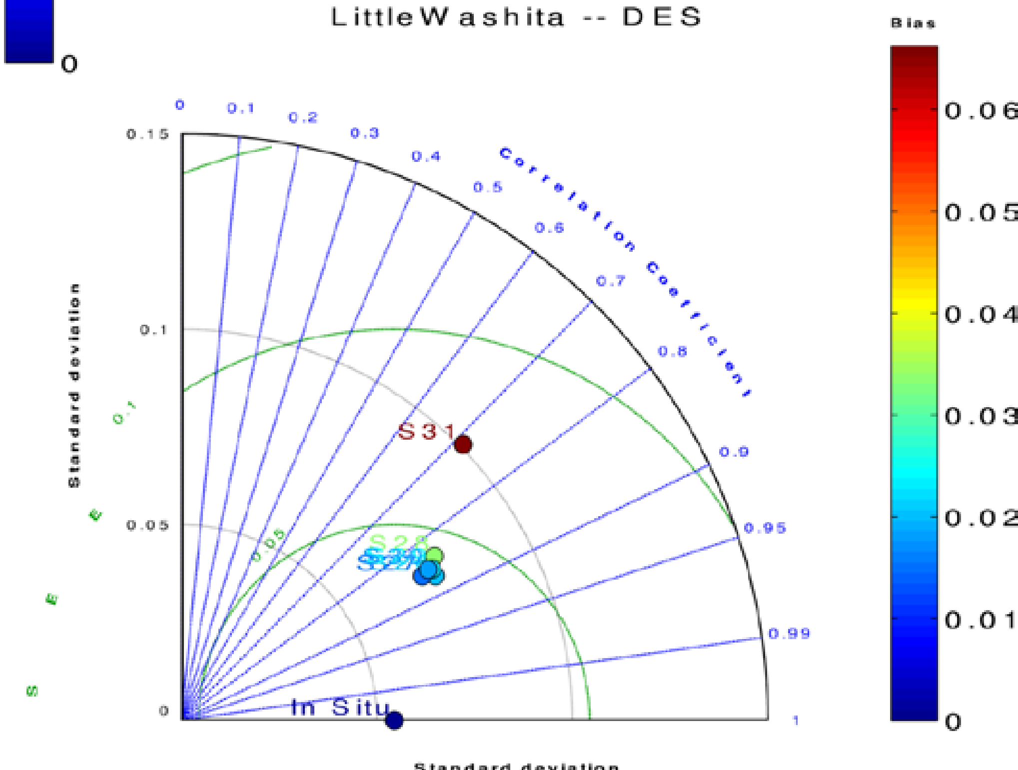


Climate : sub humid
Topography : rolling
Land use : range, wheat

Jackson et al., Validation of AMSR soil moisture products, IEEE Transactions on Geoscience and Remote Sensing, vol. 48, 2010.

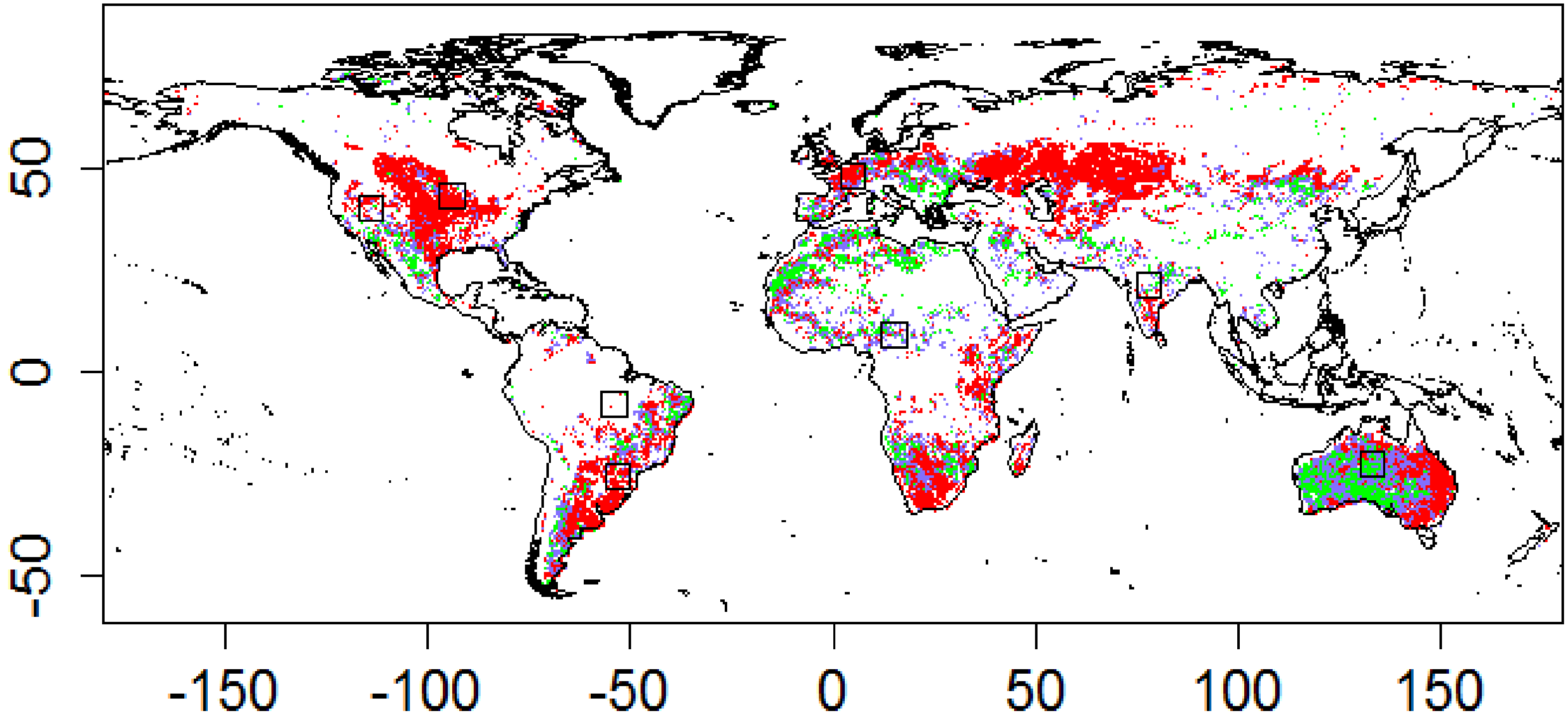


Little Washita



Blind test V620
Leroux Bindlish

Global Comparison between SMOS-L3 and AMSR surface soil moisture with SSM calculated by SM-DAS-2 .



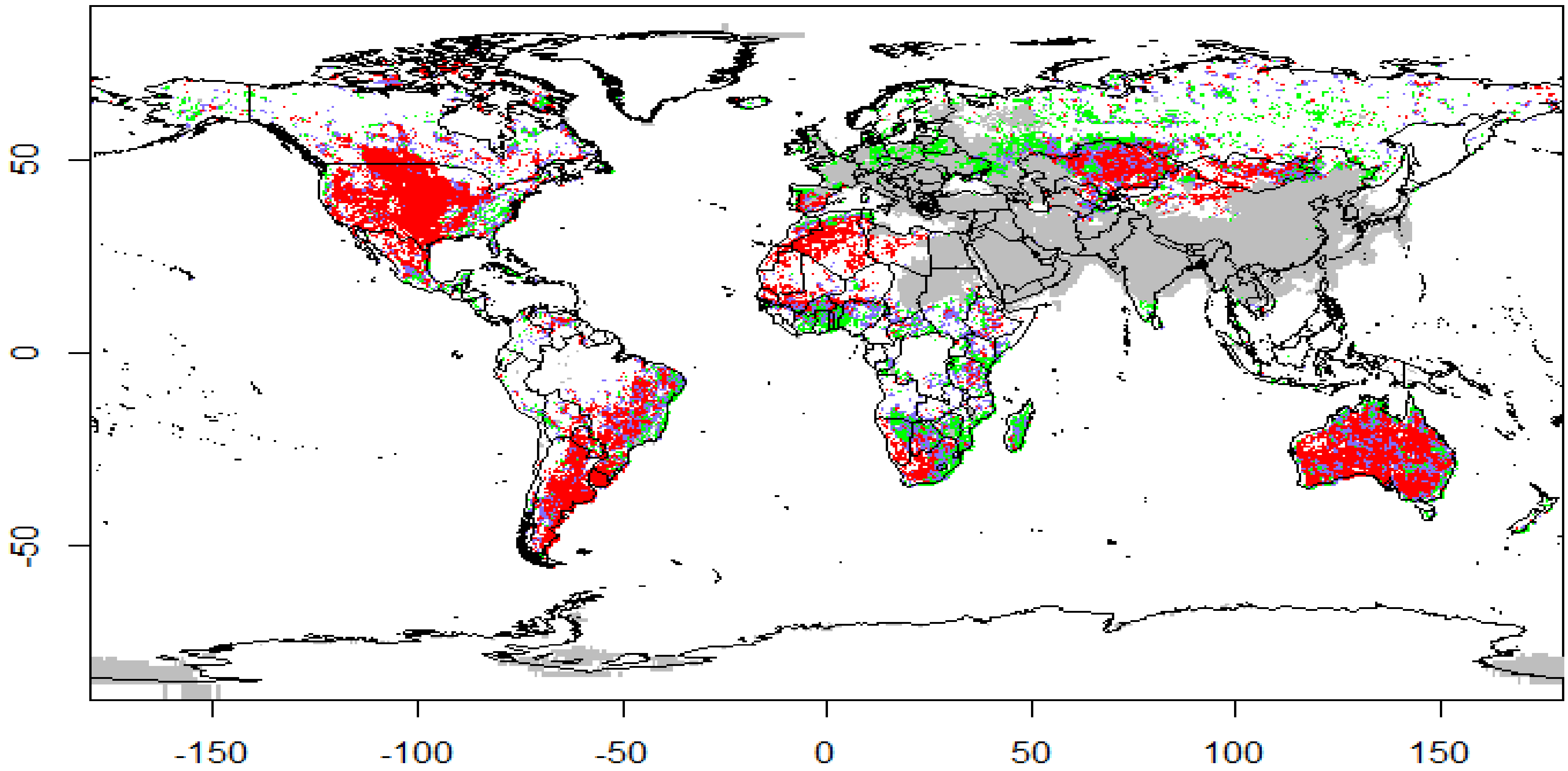
SMOS

correlates better to SM-DAS-2

AMSR

R coeff.
SM Anomalies (34 day window)

Correlation of SMOSL3 and ASCAT SM vs MERRA/land SM product (P value < 0.05) 2010–2012 period (Anomalies)

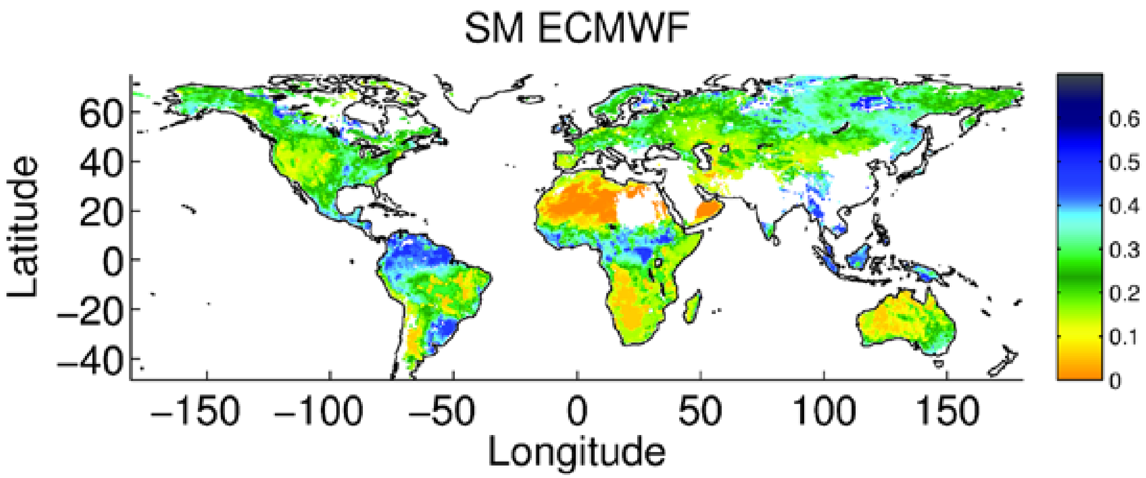


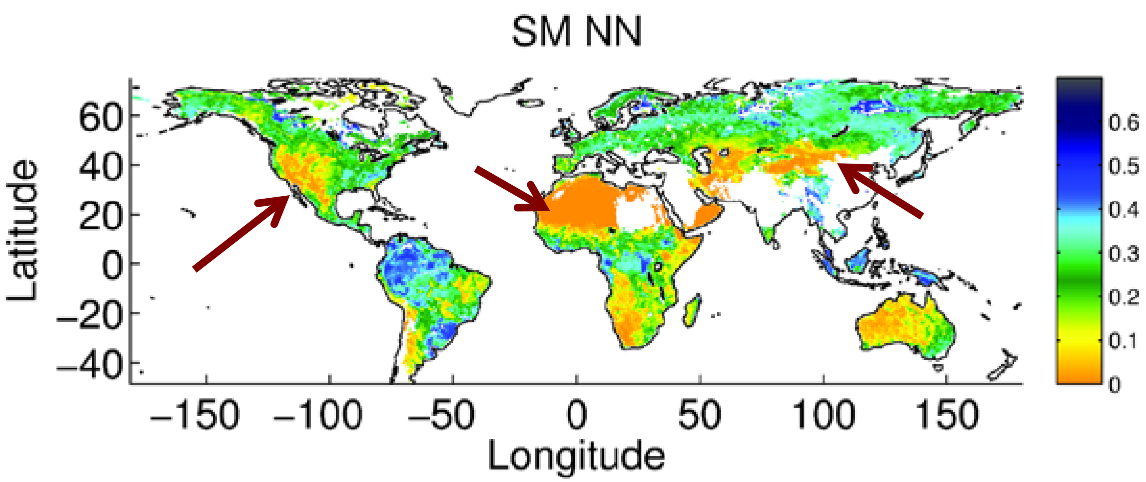
ASCAT: Global R=0.22
SMOS: Global R=0.29

A. Alyaari

NN retrievals

Juillet 2010



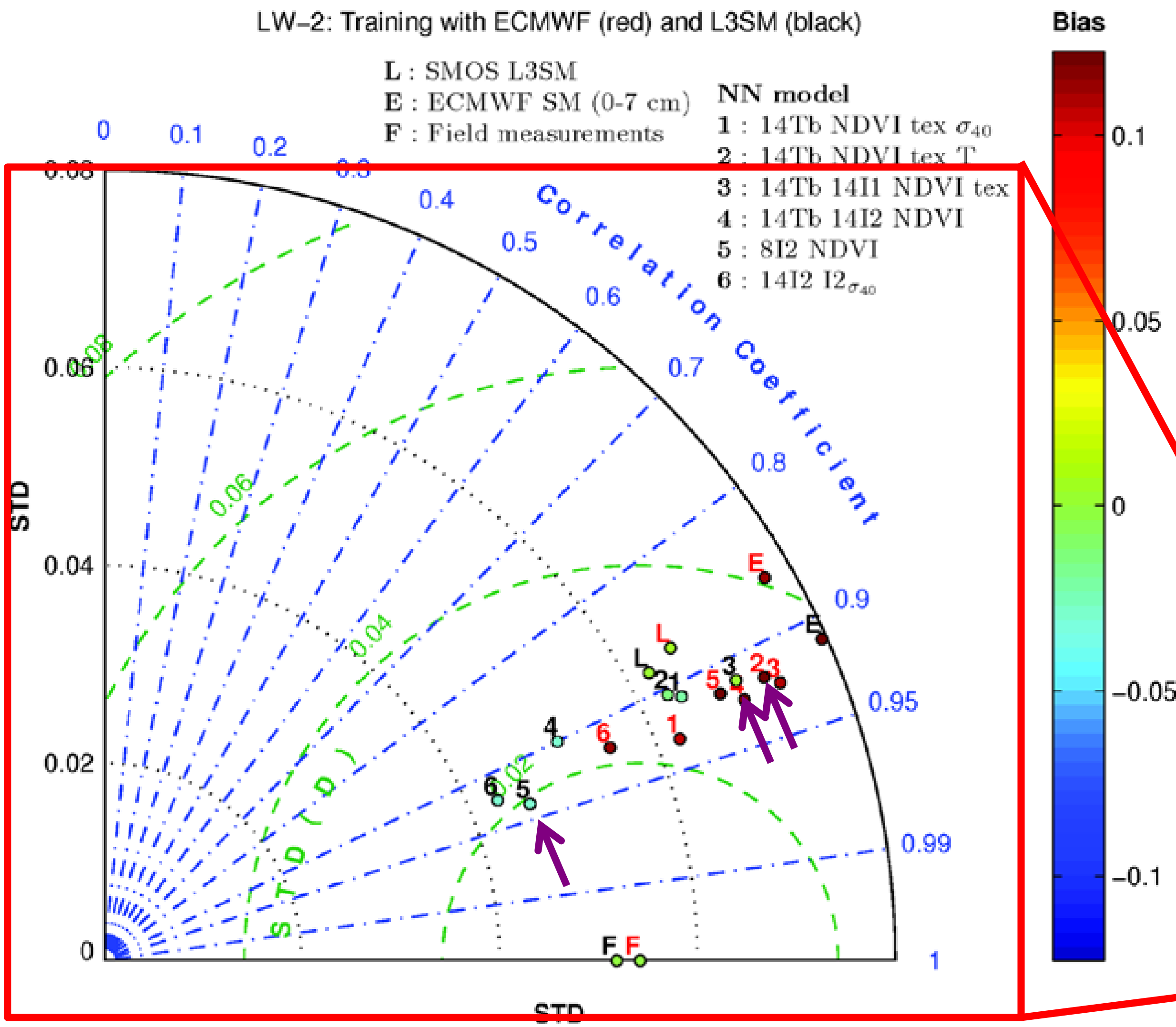


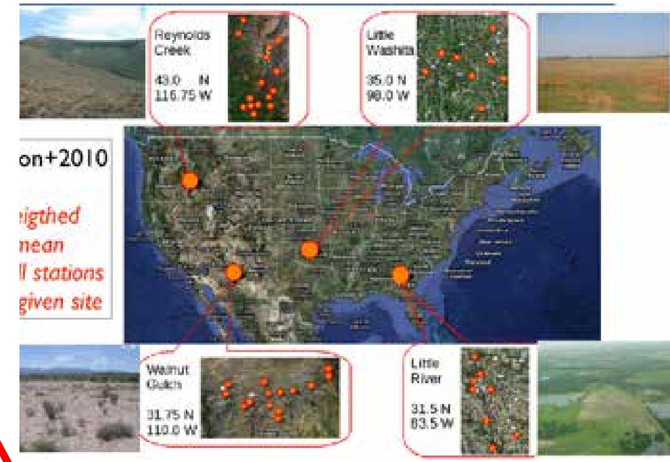
- Somewhat drier than ECMWF

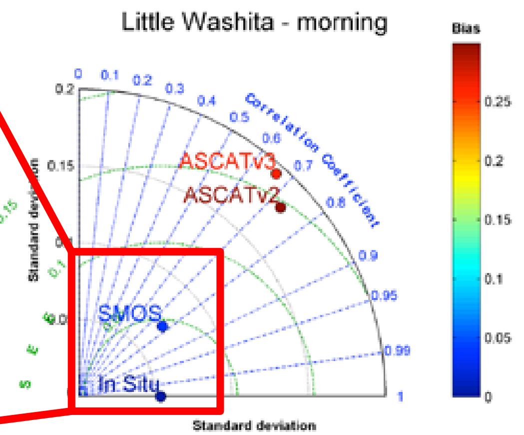
Evidence of possitive bias of ECMWF
- Muñoz-Sabater et al. (in prep)
- Albergel et al. 2012

N Rodriguez

Little Washita







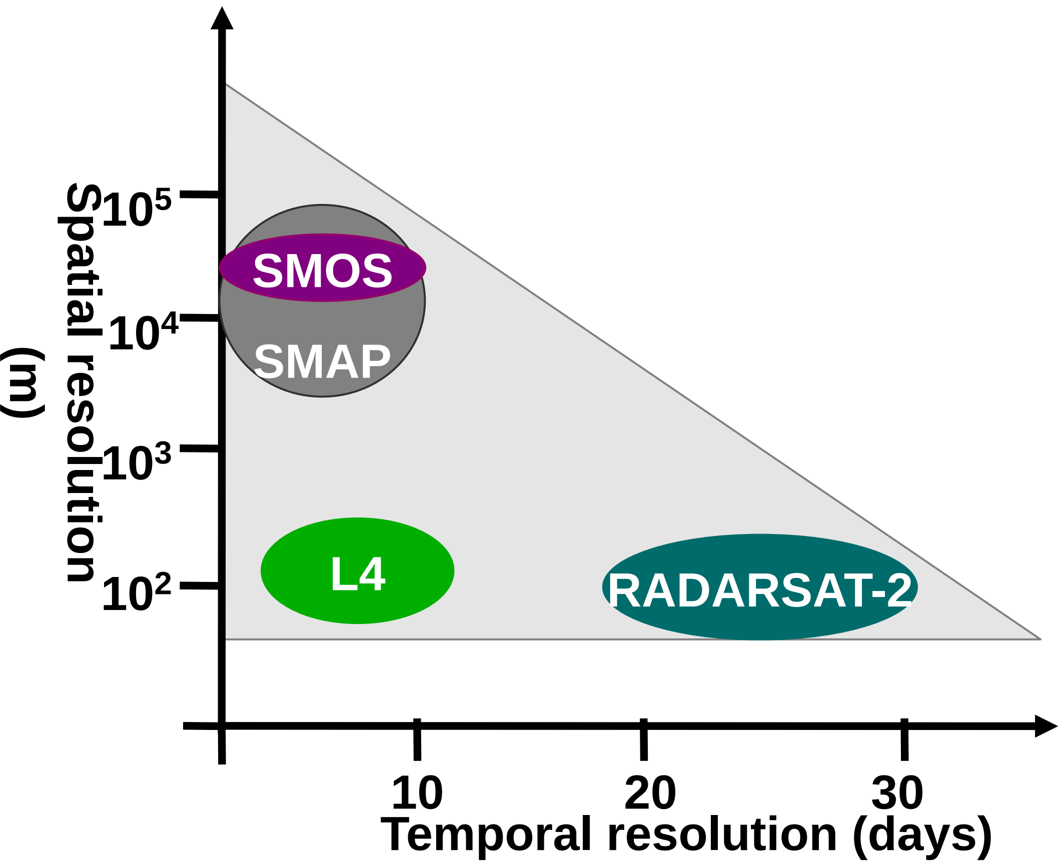
N Rodriguez

Different disaggregation schemes

- SMAP
  - à N Das et al approach
  - yesterday's presentation by Dara
  - Yesterday's presentation by Jeff
- Using Thermal and Infra red
  - Yesterday's presentation by Maria-Jo
- With sparse active microwaves
  - Radar every so often
  - Sat Kumar et al approach

Active Passive disaggregation (S Tomer)

- **L4: Combined high resolution active and passive Microwave soil moisture product**



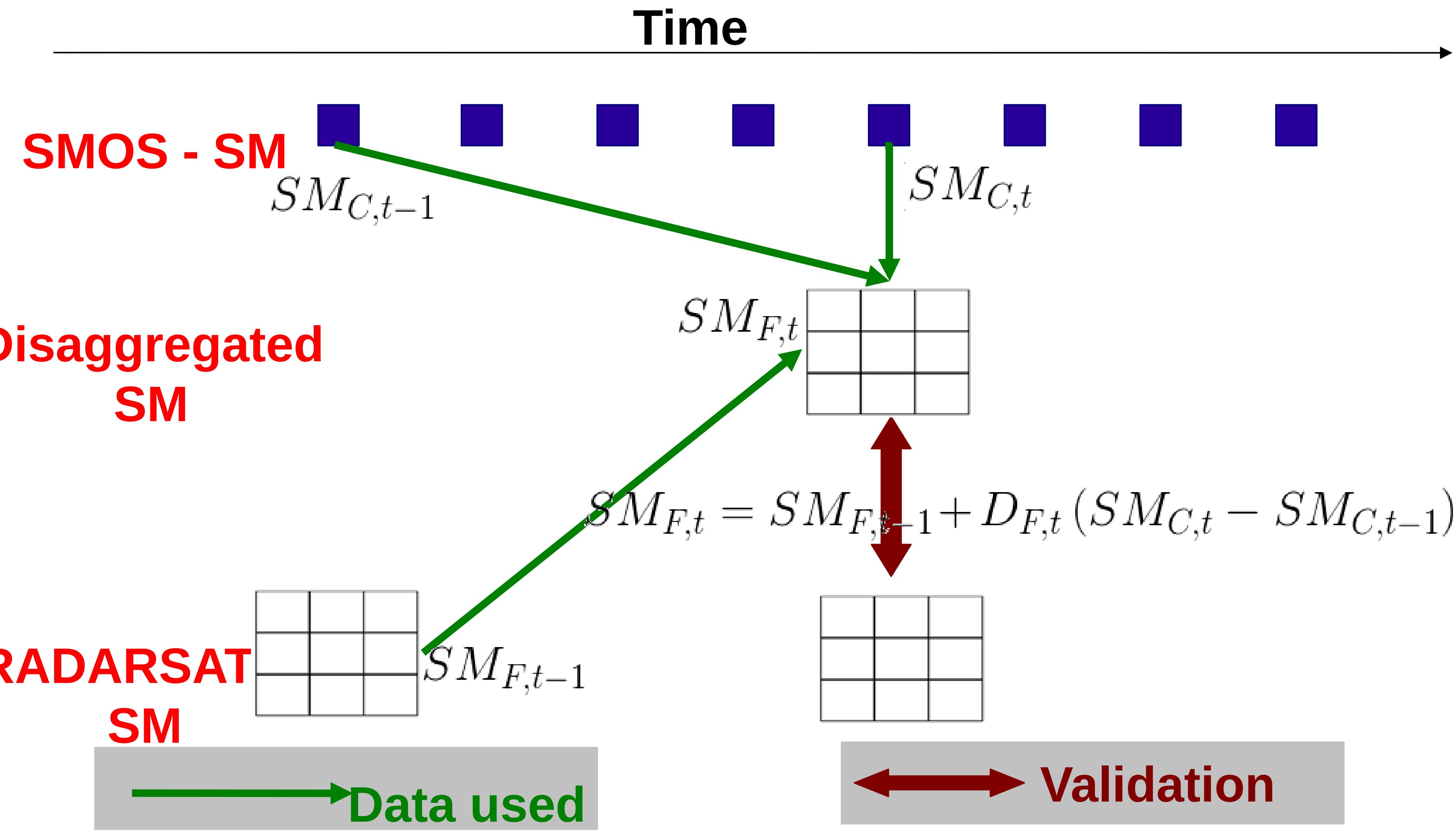
Passive (SMOS)

Spatial res. --> ~25 km
Temporal res. --> ~3 days

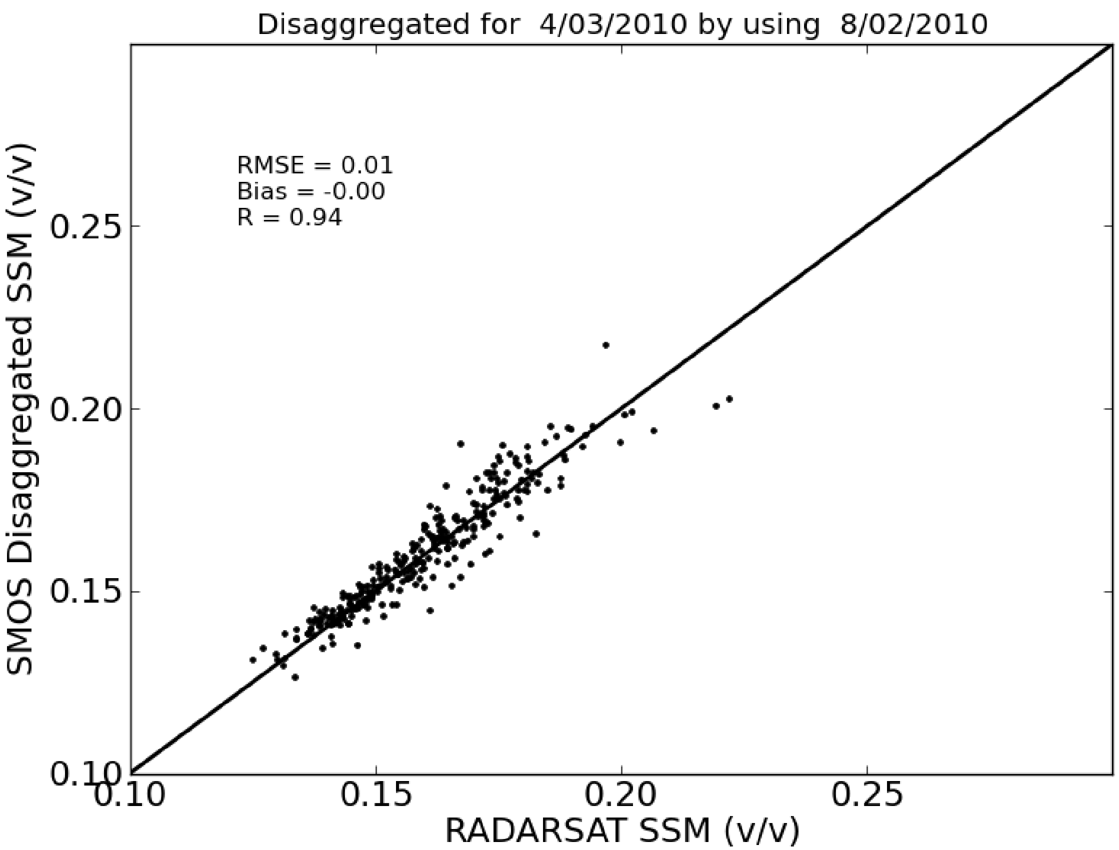
Active (RADARSAT-2)

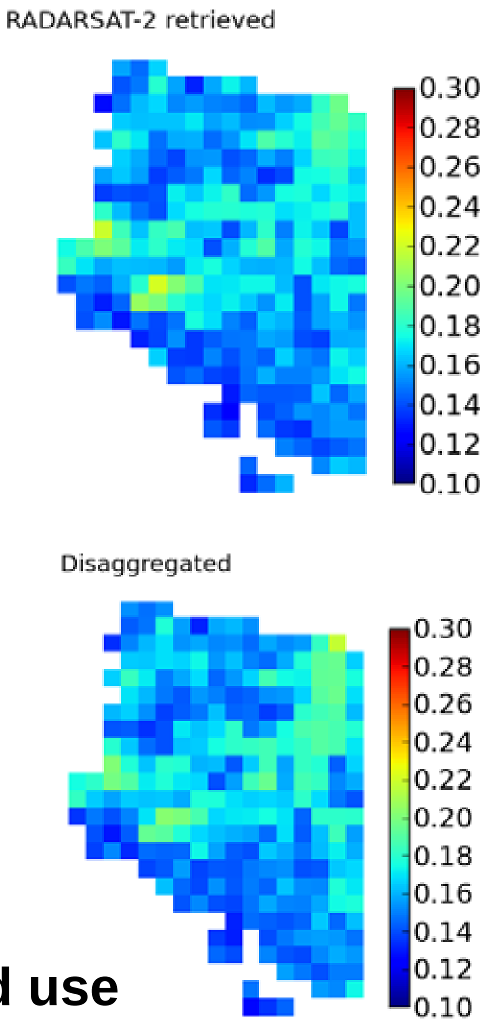
Spatial res. --> ~100m
Temporal res. --> ~24 days

Spatio-temporal disaggregation



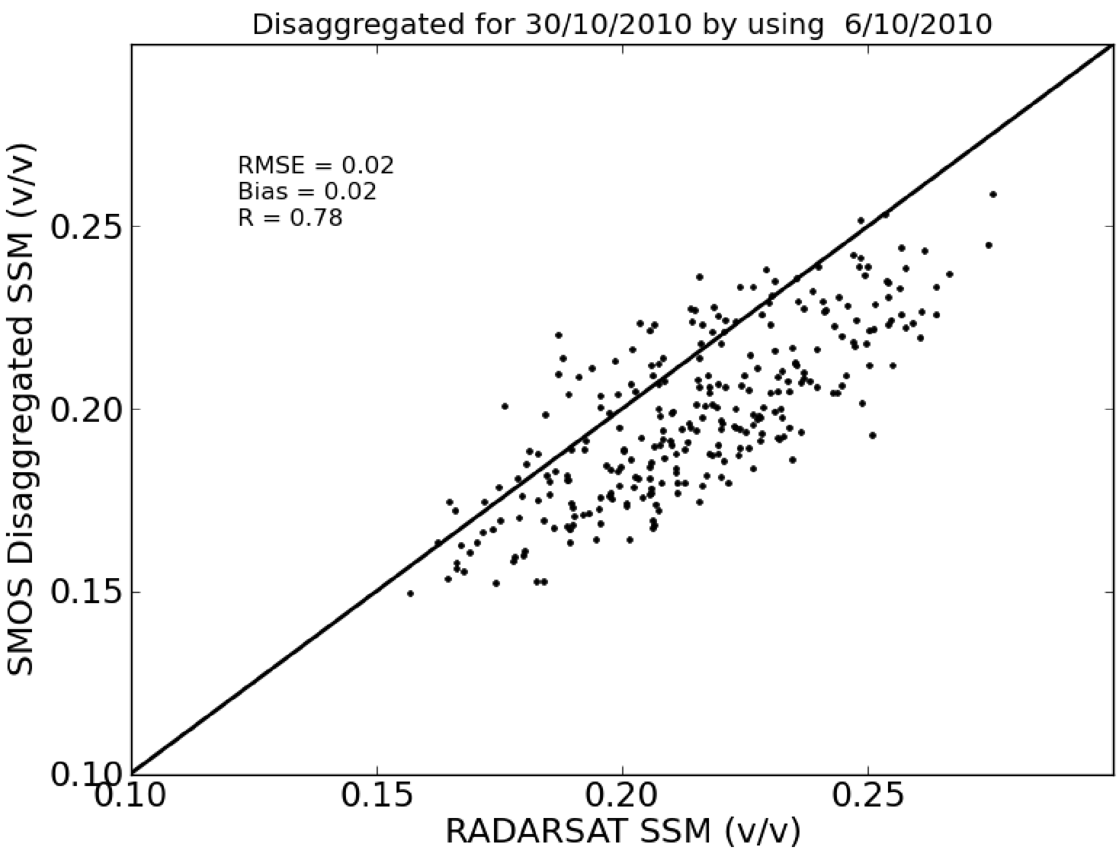
Validation of downscaled SMOS soil moisture with respect to RADARSAT-2 soil moisture

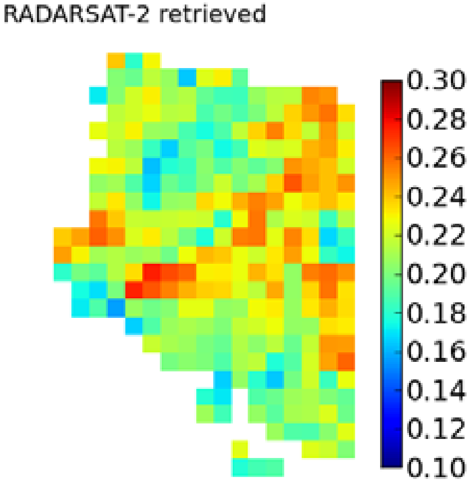


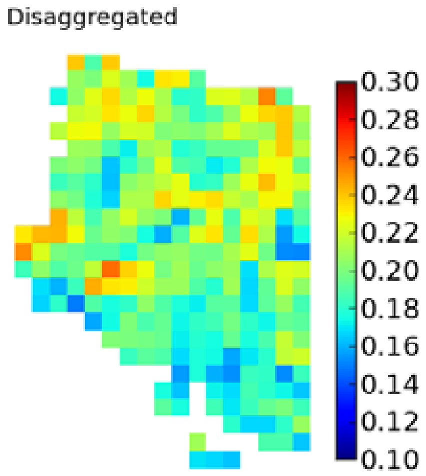


Ø**Disaggregation is not performed for the forest land use**

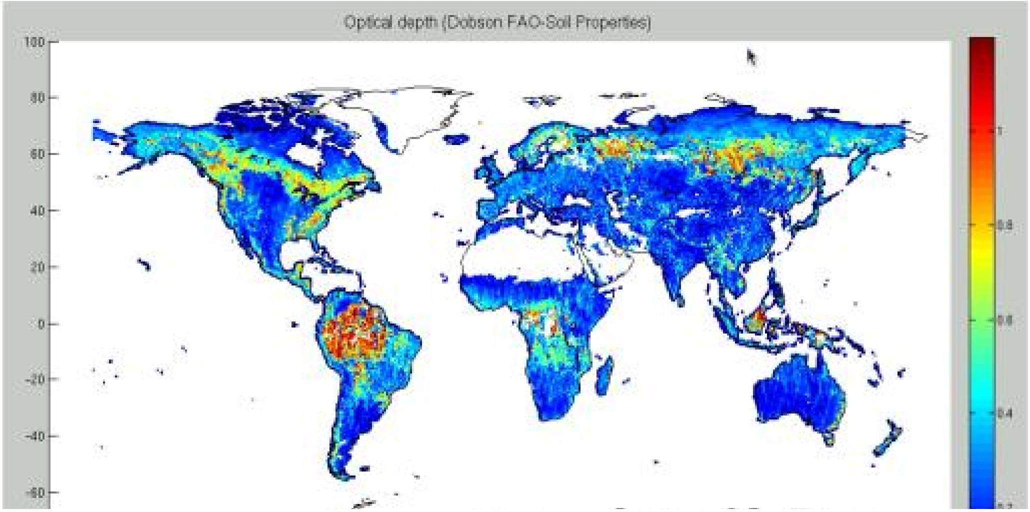
Validation of downscaled SMOS soil moisture with respect to RADARSAT-2 soil moisture

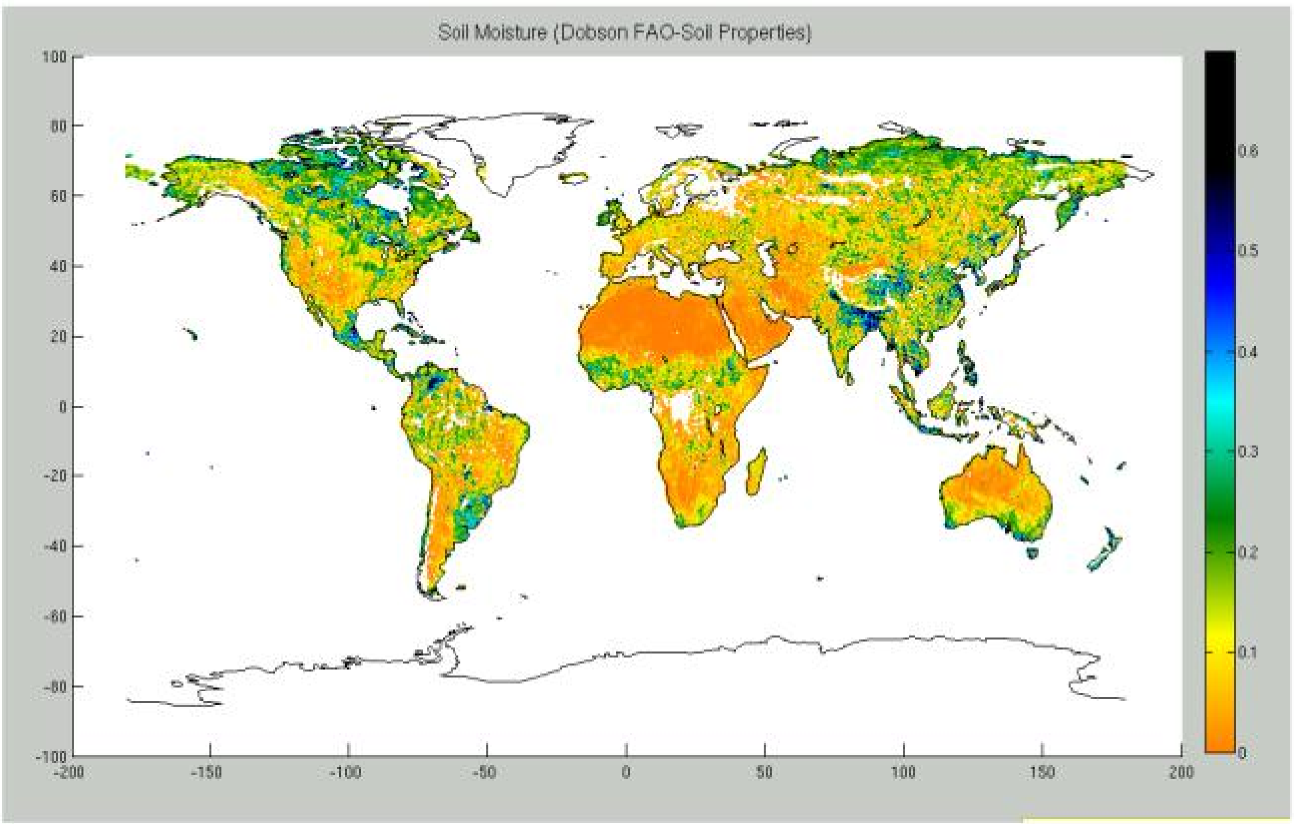


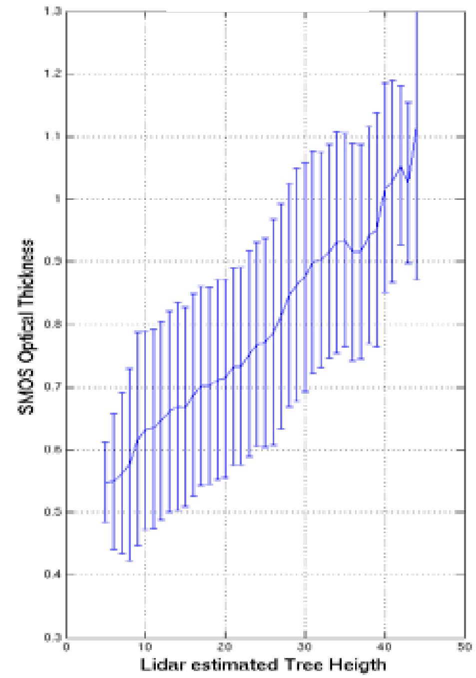




Global Map of retrieved optical thickness







For reference:
Forest height estimated by GLAS-ICESat Lidar (Simard et al., 2011)

Ferrazzoli

Rahmoune

And Global map of Soil moisture

SMOS+Hydro Project

Sat Kumar Tomer, Ahmad Al Bitar, Olivier Merlin, Yann Kerr
Centre d'Etudes Spatiales de la Biosphere, 31401 Toulouse, France

Hans Lievens, Niko Verhoest
Laboratory of Hydrology and Water Management, Ghent University, 9000 Ghent, Belgium

Valentijn Pauwels, Jeffrey Walker, Gift Dumedah
Department of Civil Engineering, Monash University, 3800 Victoria, Australia

Eric Wood, Ming Pan, Alok Sahoo
Land Surface Hydrology Group, Princeton University, 08544 Princeton, USA

Gabrielle De Lannoy, Rolf Reichle
Global Modeling & Assimilation Office, NASA Goddard Space Flight Center, 20770 Greenbelt, USA

Matthias Drusch
European Space Agency, 2200 AG Noordwijk, The Netherlands

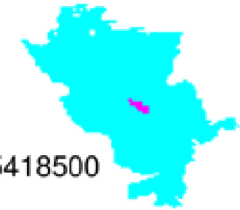
Objectives

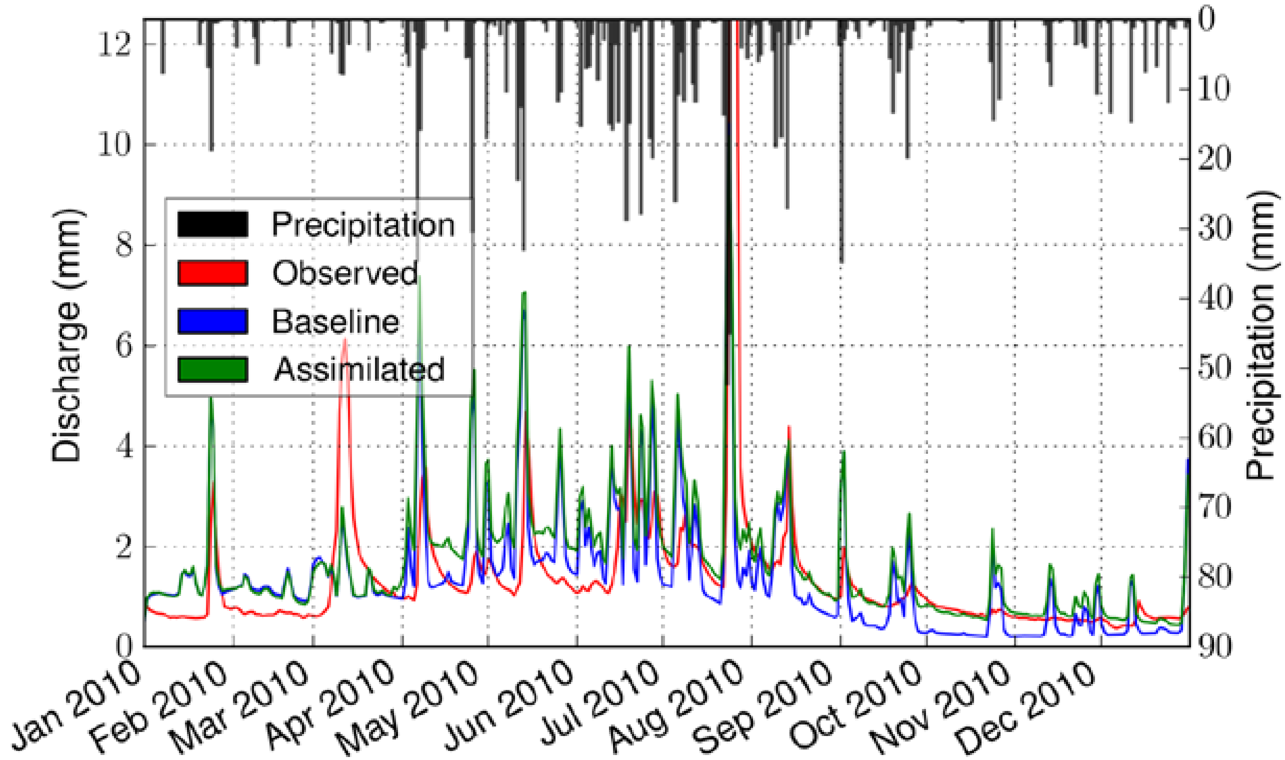
- Assimilation of SMOS data into VIC model to improve the flood prediction
  - Soil moisture
    - Coarse scale
    - Fine scale
  - Temperature brightness
- Streamflow routing
- Test the model setup at two different basins UMB (humid) and MDB (arid)

Assimilation results

	Baseline	Assimilation
KGE	0.41	0.49
Ratio of std	1.45	1.37
Bias	-0.17	0.20
Correlation	0.66	0.73

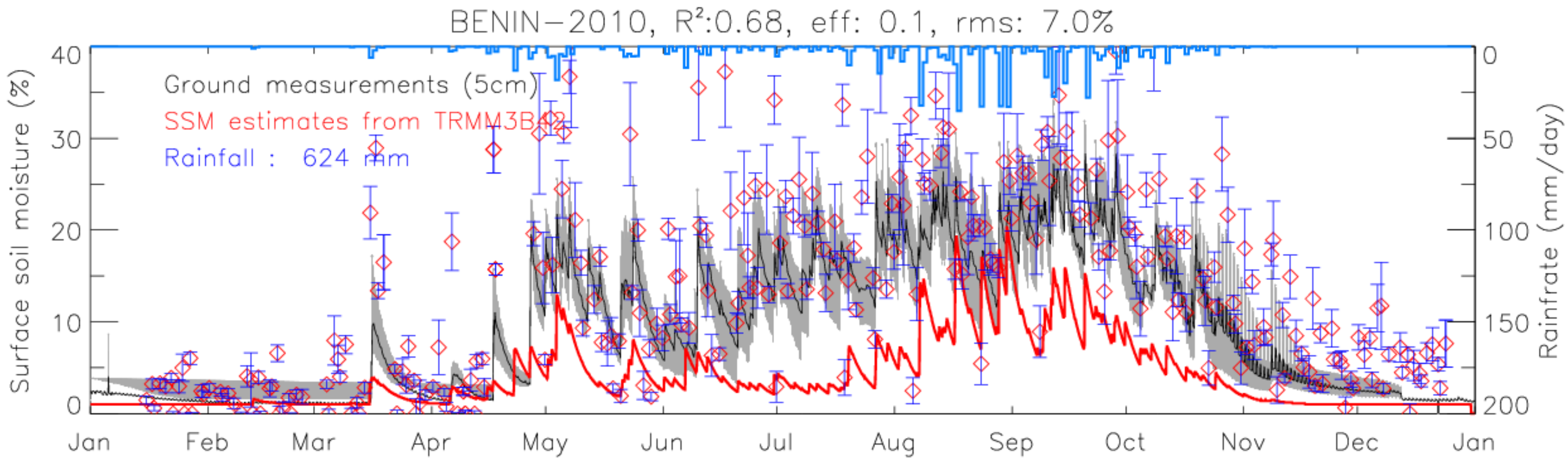
Gauge Site No. = 5418500

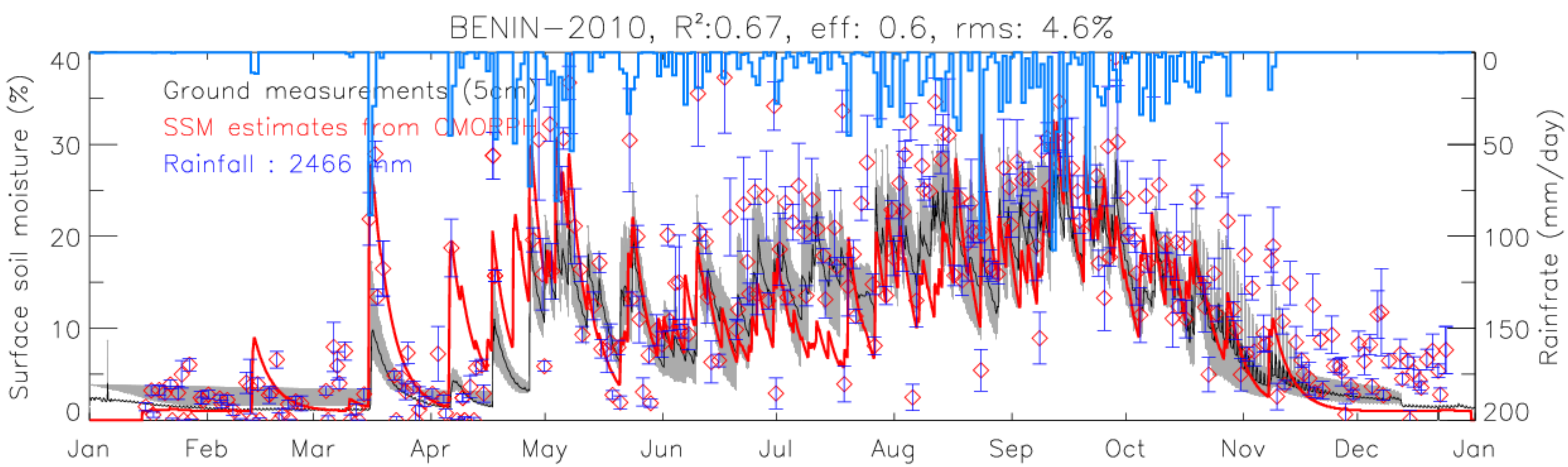




- **Soil moisture assimilation is enhancing the streamflow except the peak flow**

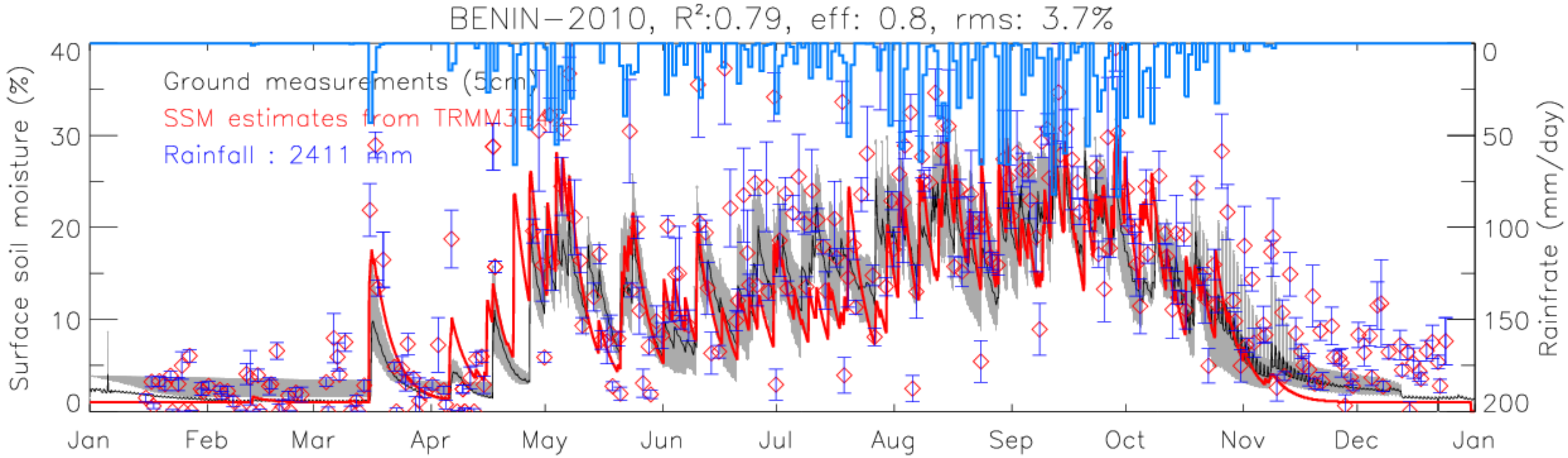
Estimated SSM without SMOS assimilation (Benin site)
Using TRMM-3B42 (top) and CMORPH rainfall products (bottom)

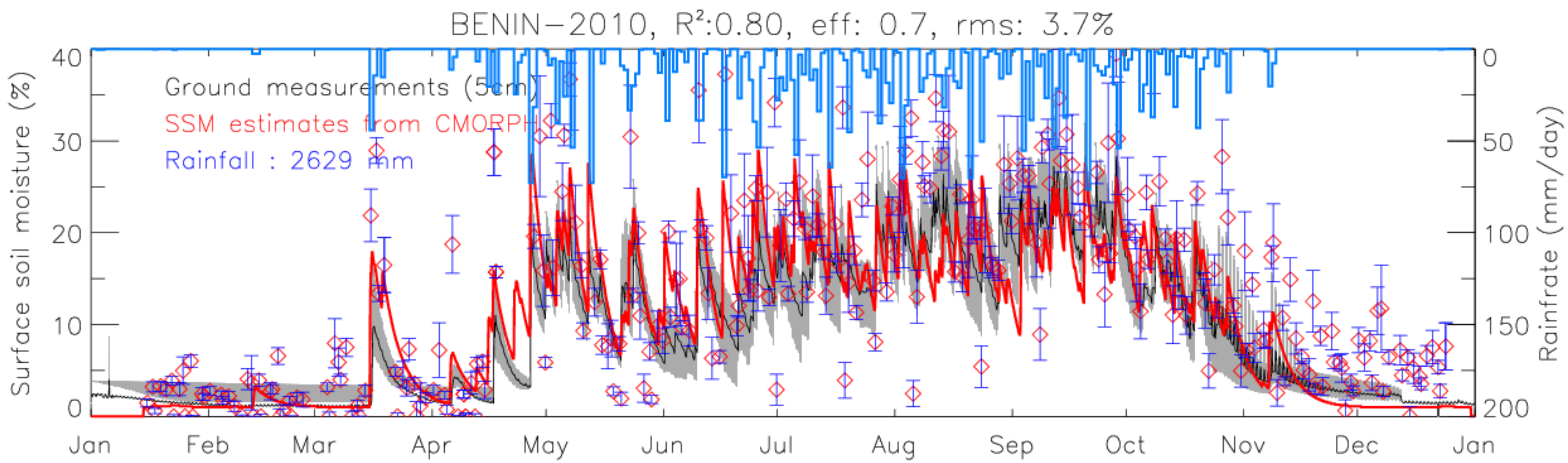




T. Pellarin

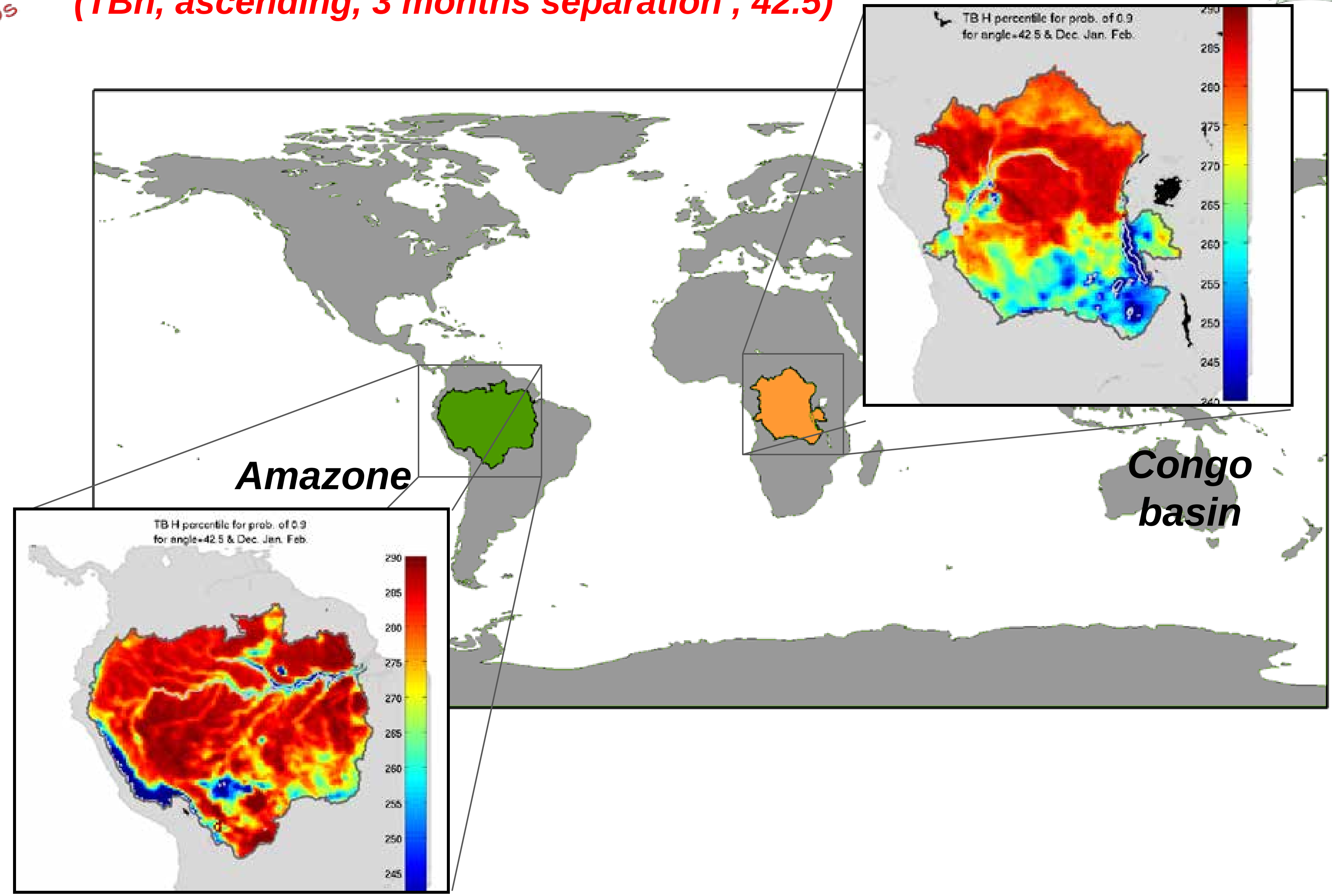
Estimated SSM with SMOS assimilation (Benin site)
Using TRMM-3B42 (top) and CMORPH rainfall products (bottom)





T. Pellarin

Seasonal dynamics of brightness temperatures
(TBh, ascending, 3 months separation , 42.5)



AL Bitar A., CESBIO

Root zone soil moisture

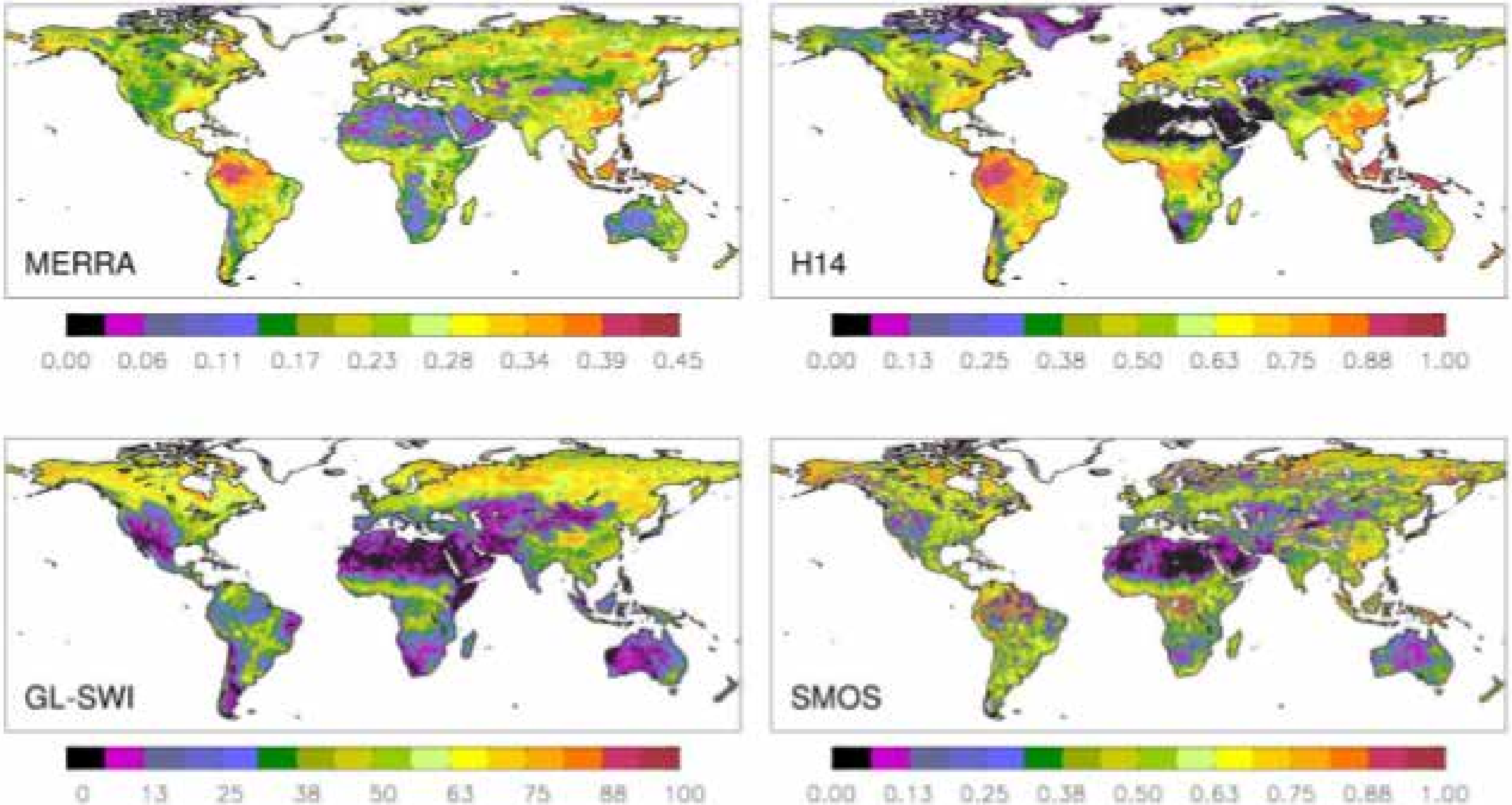
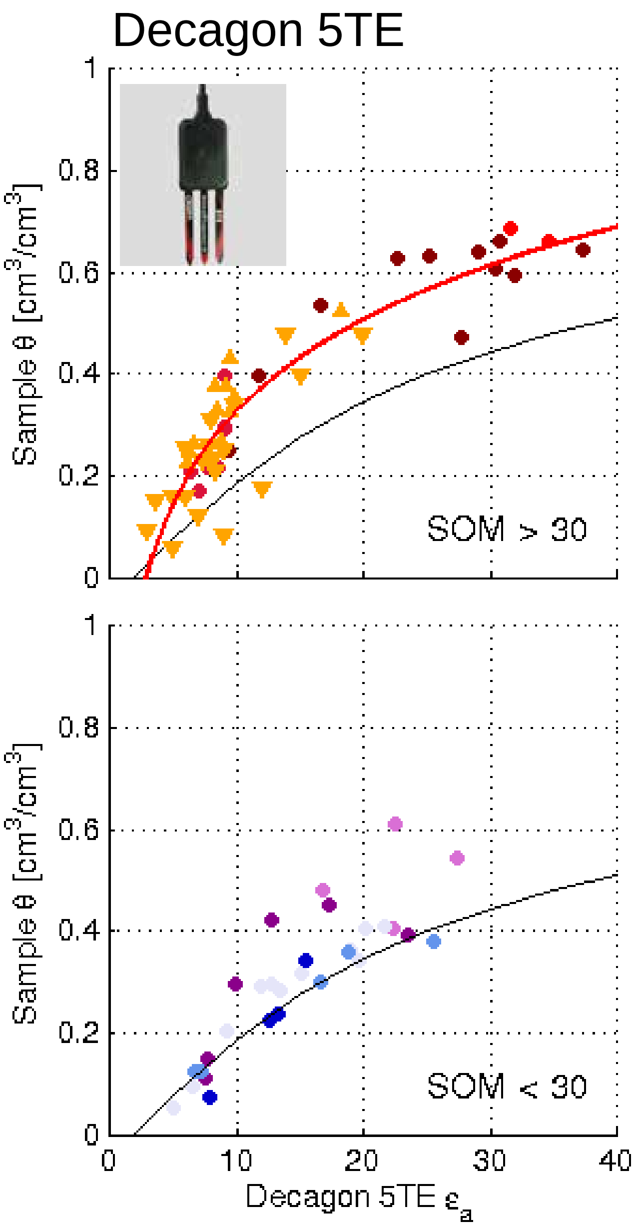


Figure 1: Annual mean root-zone soil moisture maps for MERRA, H14, GL-SWI and SMOS.

Pellarin et al

Bircher et al

Soil moisture sensor calibration



Organic (SOM >30%)

- ▲ HOBE Forest 1 Lab
- ▼ HOBE Forest 1 Field
- ● HOBE Heath
- ● FMI Forest
- ● HOBE Forest 2

Increasing SOM

— Default mineral

— Fit organic

Mineral (SOM <30%)

- ● FMI Forest
- ● HOBE Heath
- ● HOBE Forest
- ● FMI Heath 1
- ● FMI Heath 2

Increasing SOM

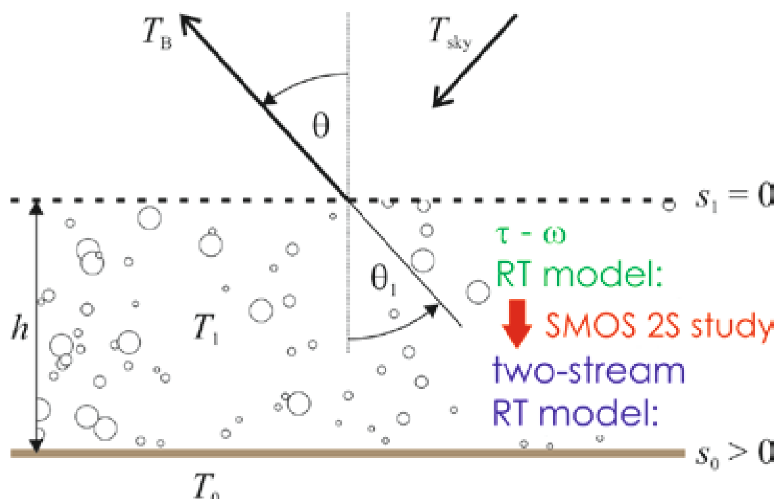
à Calibration curves fitted through organic data, to be used for re-calibration of in situ soil moisture of automatic network stations

à Mineral calibration curve as f(SOM) possible if further data acquired...

SMOS 2STREAMAP STUDY (SMOS 2S)

GAMMA REMOTE SENSING

Worbstr. 225, CH-3073 Gümligen, Switzerland
http://www.gamma-rs.ch/



SMOS 2S Project Overview

Major Project Goals:

- **Exploring the potential of replacing the *t* - *w* (TO) RT model used in the SMOS L2 SM processor with the Two-Stream (2S) Radiative Transfer (RT) model.**
- **SMOS 2S study shall allow taking the decision on a possible implementation of the proposed retrieval update in the operational SMOS SM retrieval.**

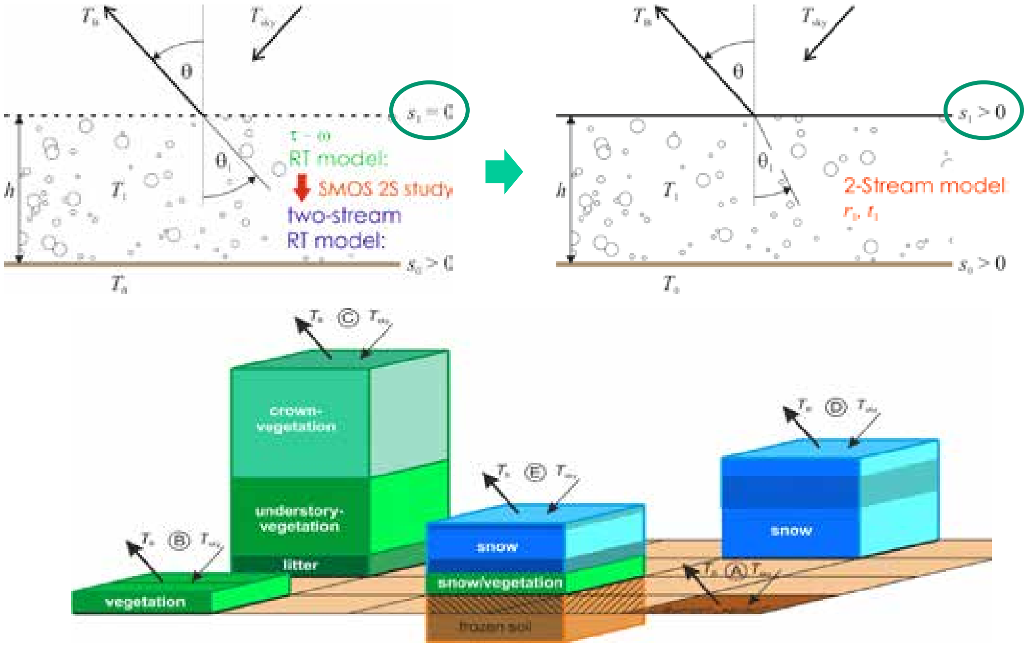
Pros of 2S RT over TO RT model:

1) **2S RT considers multiple reflections (higher order solution of RT equations).**

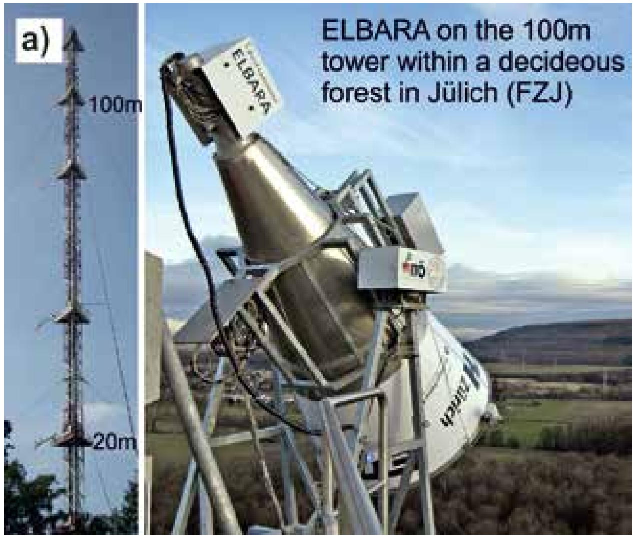
2) **"soft-layer" (s_1=0, q=q_1) assumption can be given up. "hard-layer" (s_1>0, q>q_1) necessary for e.g. soil beneath snow / litter.**

3) **2S RT allows to represent multiple layered systems.**

4) **All this is relevant to advance full exploitation of SMOS TB (novel data products).**

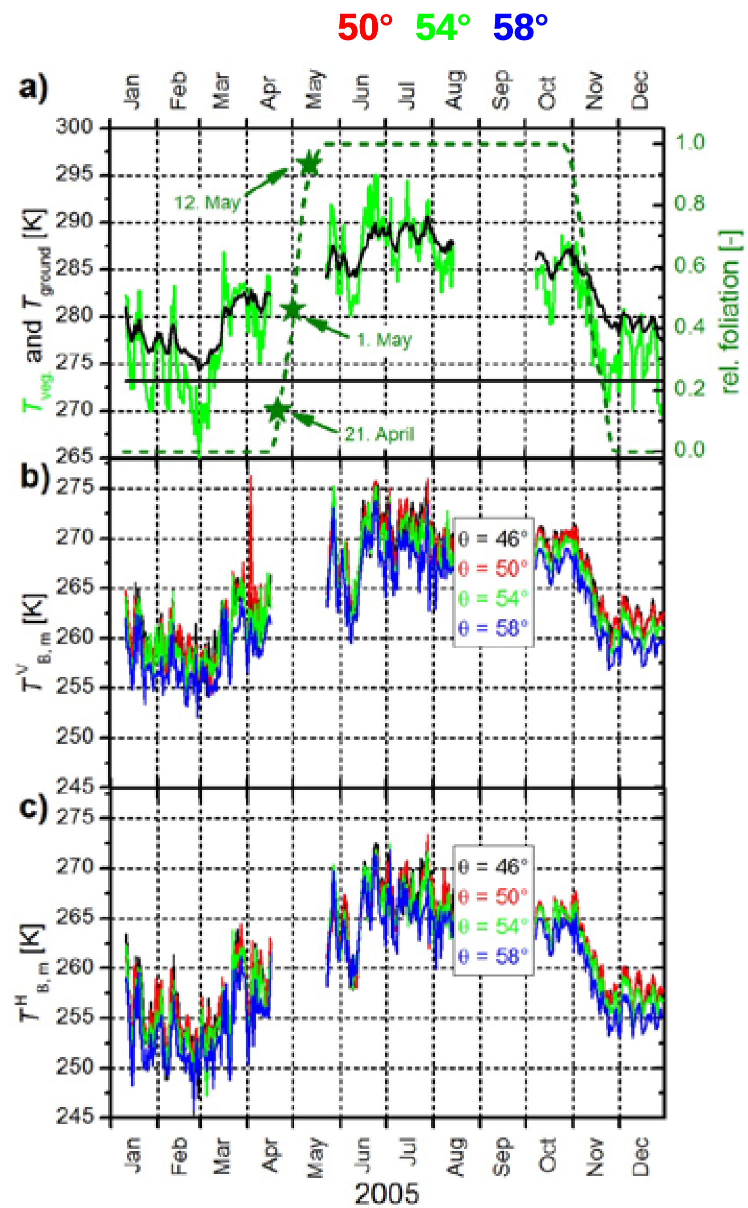


5) Comparative 3-P Retrieval Based on FOSMEX $T_B^p(q)$



3-P retrievals:

forest development 2005



Comparative 3-P Retrieval Based on FOSMEX $T_B{}^p(q)$

- **Footprints observed are:**
  between 2000 m² and 6000 m² for the q_k = 46°, 50°, 54°, 58° considered.
- **Deciduous forest comprising oak, birch, and beech:**
  tree age: 40 - 80 years
  average crown height 24 m.
  column density (dry) » 15 kg m^{-2}.
  max. fresh leave density » 1.14 kg m^{-2}
- **Configurations applied to the original retrieval and the updated retrieval scheme**

retrieved parameters P_i:				constant parameters P^{const}:	
P_i	P_i^{guess}	P_i^S	$P^{constrain}$	P^{const}	value
wc	0.2	0.2	0.0 £ wc £ 1.0	$tt_H = r_{ttHV}$	1.0
t^*	0.8	0.5	0.0 £ t^* £ 2.5	Dw^*	0.0
w^*	0.2	0.2	0.0 £ w^* £ 1.0	$T_{veg.}$ & T_{ground}	data shown
				$X_A = X_B$	0.3
				$clay$	0.160
				Q_H	0.0
				$N_{RV} = N_{RH}$	0.0
				H_R	1.2

$$CF = \frac{\underset{p=\mathrm{H,V};\,q_k}{\text{å}} \left(T^p_{\mathrm{B},k,\mathrm{m}} - T^p_{\mathrm{B},k,\mathrm{s}}\right)^2}{\left(T^S_{\mathrm{B}}\right)^2} + \underset{\#\mathrm{para.}\,i}{\text{å}} \frac{\underset{p=\mathrm{H,V};\,q_k}{\text{å}} \left(P_i^{\mathrm{guess}} - P_i\right)^2}{\left(P_i^S\right)^2}$$

measured

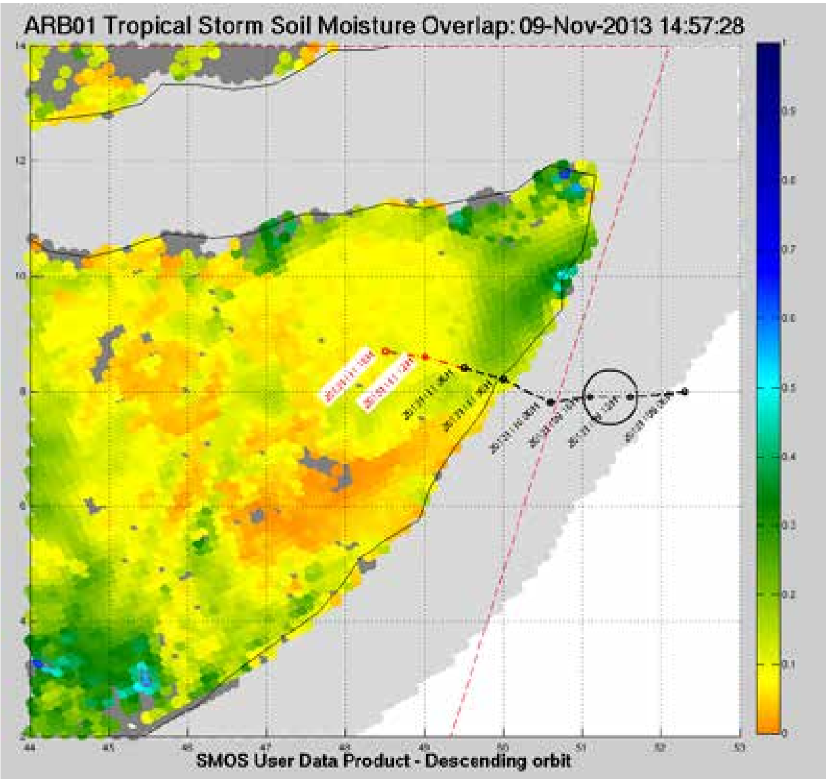
simulated

Summary

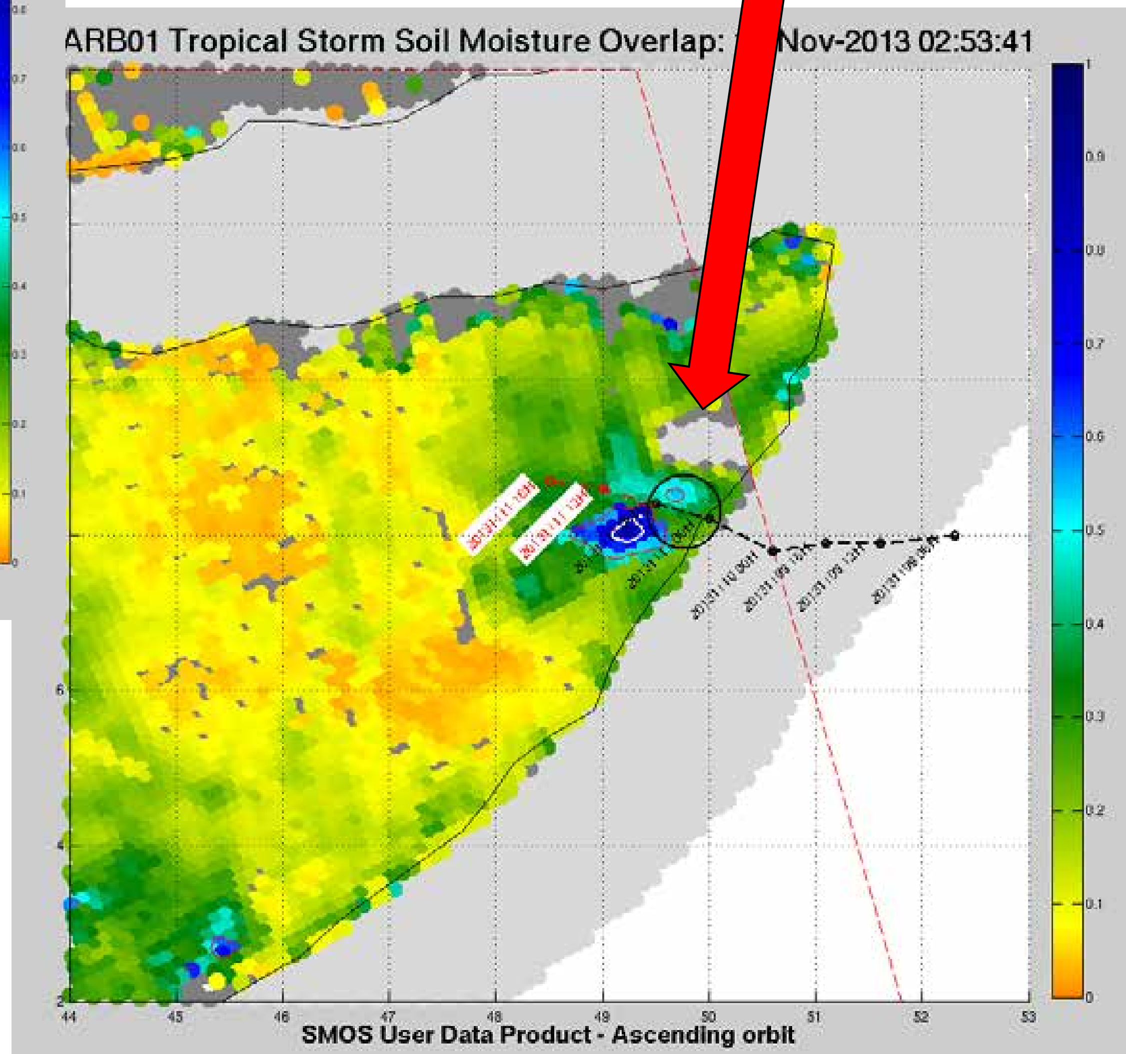
- After several years in orbit **SMOS, is behaving very well**
- SMOS as still **room for improvements** and is **evolving very positively**
  - Significant improvement in calibration and retrieval algorithms
  - Significant reprocessing efforts soon underway
  - Intercomparisons à Not a beauty contest but a base to learn and understand more
- **First applications are very interesting**
  - Many of them
  - Identification of research areas
- **Getting ready to bridging with SMAP** and establish long term data sets
- Synergistic approaches studies (AMSR, ASCAT, GCOM-W, Aquarius…)
- Next Step is the elaboration of an **Essential Climate Variable** by bridging several datasets

Example of Tropical storm Nov 2013

visit http://www.cesbio.ups-tlse.fr/SMOS_blog/



Rains > 20 mm/h for ECMWF



Thank you for your patience
Any questions?