The 2015 Workshop at MOISST:
The Dawn of the Soil Moisture Information Age?

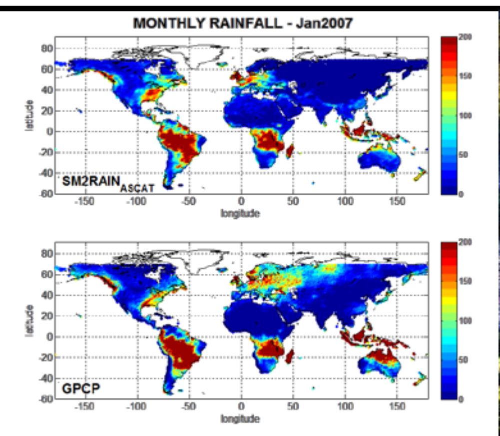
Stillwater
2nd June 2015

NEW INFORMATION CONTENT FROM SOIL MOISTURE DATA: RAINFALL ESTIMATION AND FLOOD MODELLING

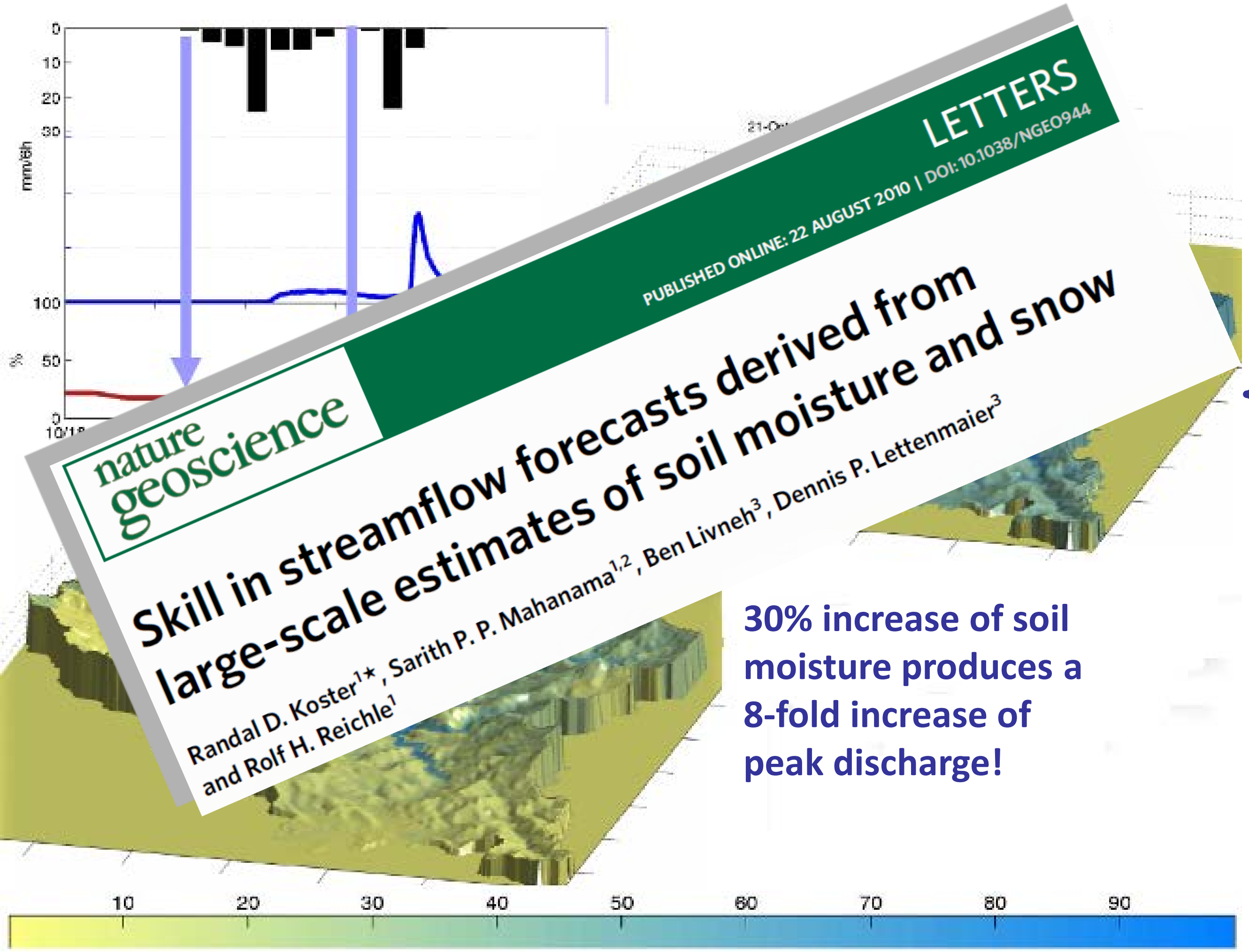
Luca Brocca, Christian Massari, Luca Ciabatta, Tommaso Moramarco

Research Institute for Geo-Hydrological Protection (IRPI-CNR), Perugia, Italy

…and many others: W. Wagner, W. Dorigo, S. Hahn, S. Hasenauer, C. Albergel, P. De Rosnay, S. Puca, S. Gabellani, R. Parinussa, R. De Jeu, P. Matgen, D. Penna, J. Martinez-Fernandez, V. Levizzani, …



INTRODUCTION



30% increase of soil moisture produces a 8-fold increase of peak discharge!

Runoff generation
Brocca et al. (2010, HESS+WRR, 2012 TGRS, …)

Drought monitoring
Rahmani et al. (2015, JAG, in press)

Erosion modelling
Todisco et al. (2015, HESSD)

Landslide prediction
Brocca et al. (2012, RS)

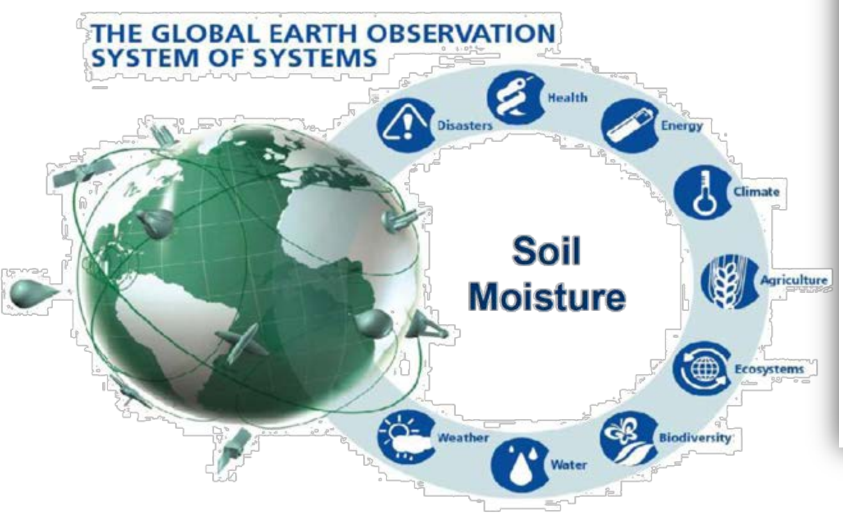
Numerical Weather Prediction
Capecchi & Brocca (2014, METZET)

Plant production
Bolten et al. (2010, JSTARS)

Water quality modelling
Han et al. (2012, HYP)

INTRODUCTION

Soil moisture is needed by all GEO Social Benefit Areas and was ranked the <u>second</u> top priority parameter (behind precipitation) in a year 2010 GEO report on "Critical Earth Observation Priorities".



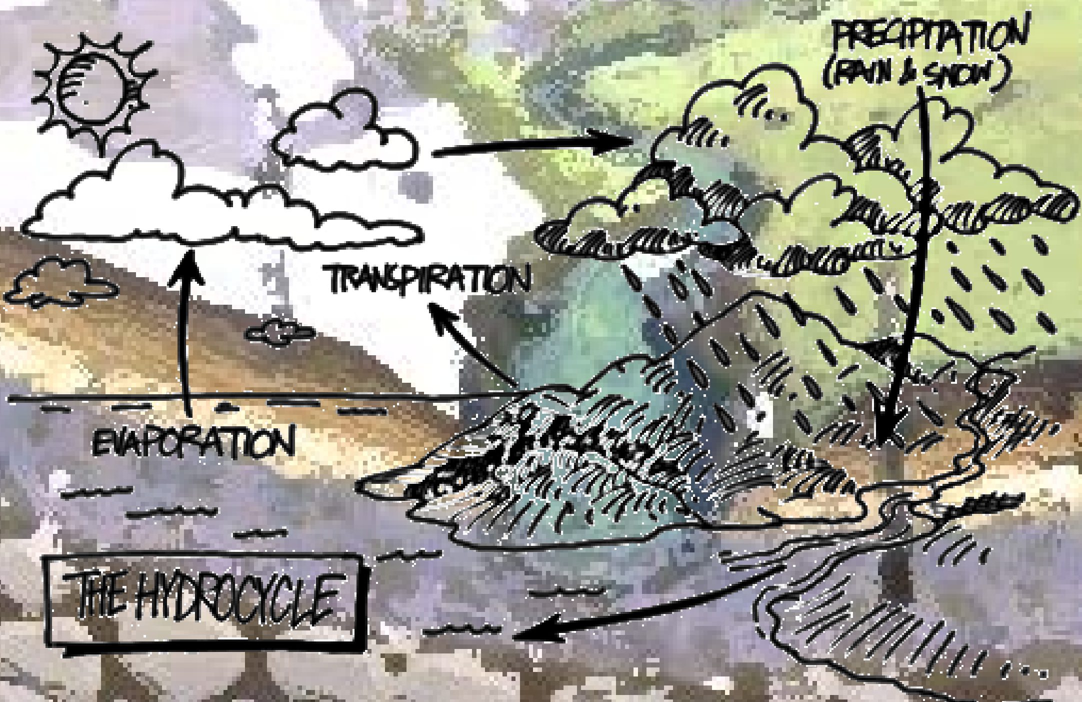
25 Highest-Ranked Earth Observations and Associated SBAs

Earth Observation Parameter	GEO Societal Benefits Areas*							
	Agriculture	Climate	Disasters	Ecosystems	Energy	Health	Water	Weather
Precipitation								
Soil Moisture								
Surface Air Temperature								
Surface Wind Speed								
Land Cover								
Surface Humidity								
Vegetation Cover								
Surface Wind Direction								
Normalized Difference Vegetation Index								
Sea Surface Temperature								

http://sbageotask.larc.nasa.gov/US-09-01a_SummaryBrochure.pdf

RAINFALL ESTIMATION FROM SOIL MOISTURE OBSERVATIONS:

SM2RAIN



What is SM2RAIN?

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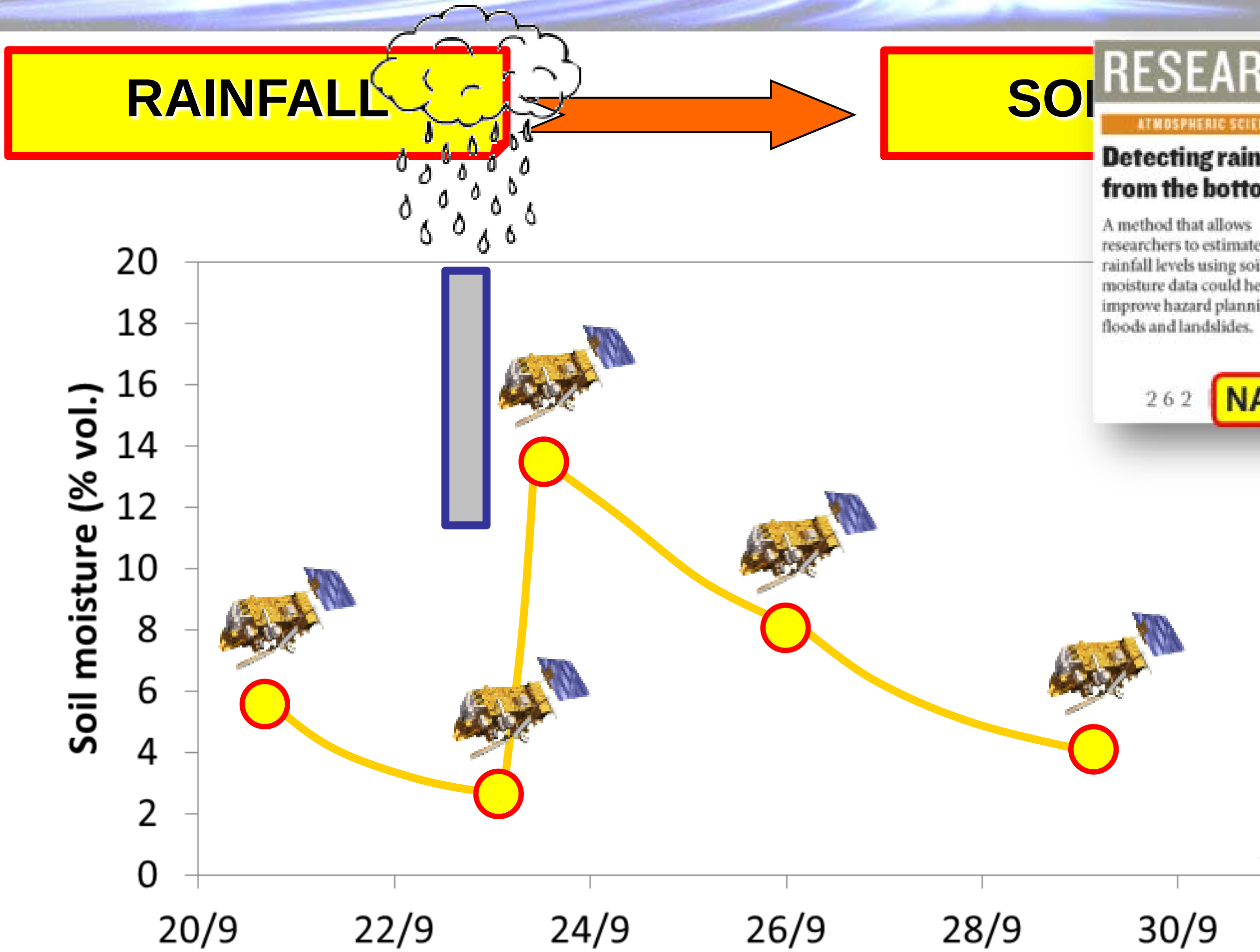
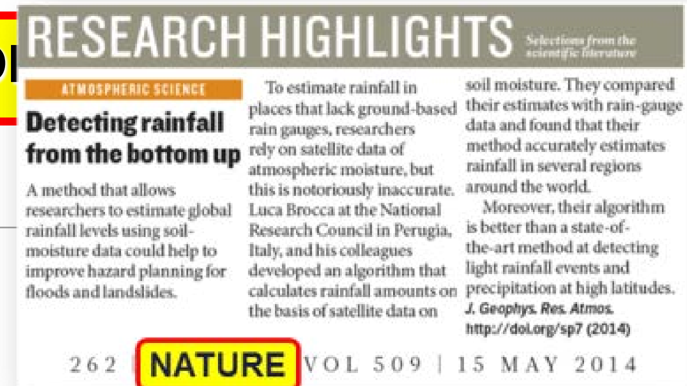




RESEARCH HIGHLIGHTS Selections from the scientific literature

ATMOSPHERIC SCIENCE

Detecting rainfall from the bottom up

A method that allows researchers to estimate global rainfall levels using soil-moisture data could help to improve hazard planning for floods and landslides.

To estimate rainfall in places that lack ground-based rain gauges, researchers rely on satellite data of atmospheric moisture, but this is notoriously inaccurate. Luca Brocca at the National Research Council in Perugia, Italy, and his colleagues developed an algorithm that calculates rainfall amounts on the basis of satellite data on soil moisture. They compared their estimates with rain-gauge data and found that their method accurately estimates rainfall in several regions around the world.

Moreover, their algorithm is better than a state-of-the-art method at detecting light rainfall events and precipitation at high latitudes.

J. Geophys. Res. Atmos. http://doi.org/sp7 (2014)

262 | NATURE | VOL 509 | 15 MAY 2014

The soil moisture variations are strongly related to the amount of rainfall falling into the soil. Therefore, we can use soil moisture observations for estimating rainfall by considering the "soil as a natural raingauge".

SM2RAIN

SM2RAIN algorithm

relative saturation

precipitation

surface runoff

drainage

$$Z\, ds(t)/dt = p(t) - r(t) - e(t) - g(t)$$

soil water capacity

= soil depth X porosity

evapotranspiration

Soil water balance equation

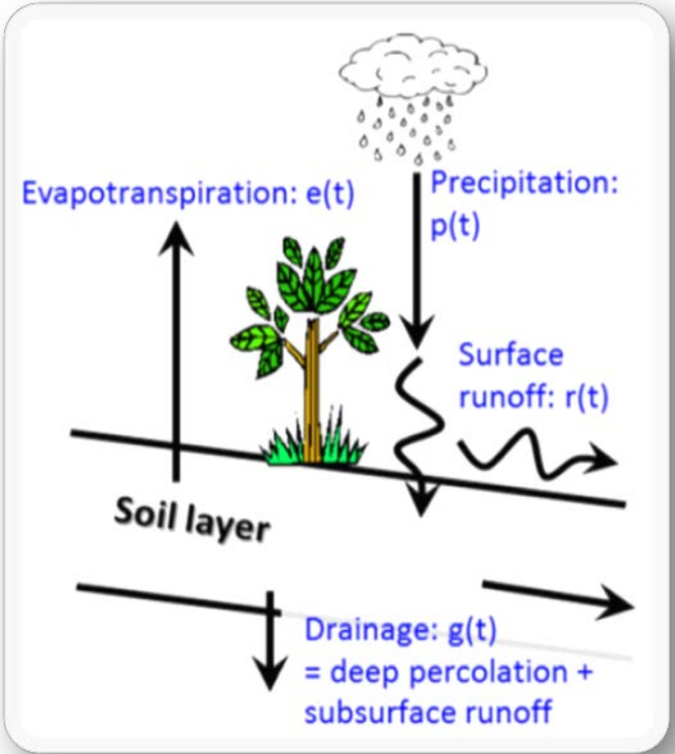
Inverting for *p(t)*:

$$p(t) = Z\, ds(t)/dt + r(t) + e(t) + g(t)$$

Assuming: $g(t) = a\, s(t)^b$ + $e(t)=0$ + $r(t)=0$

during rainfall

$$p(t) \cong Z\, ds(t)/dt + a\, s(t)^b$$



SM2RAIN: in situ observations

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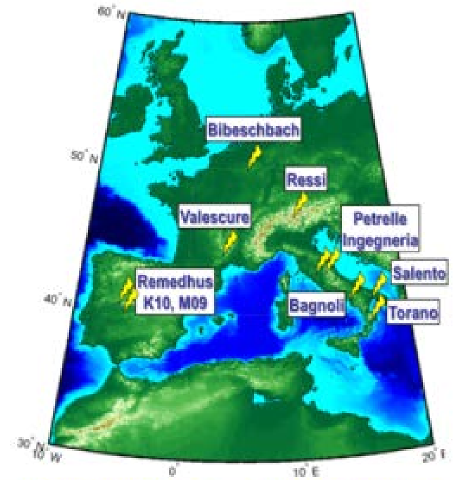
Hydrol. Hydromech., 63, 2015, X, XXX–XXX
DOI: 10.1515/johh-2015-0016

Rainfall estimation from in situ soil moisture observations at several sites in Europe: an evaluation of the SM2RAIN algorithm

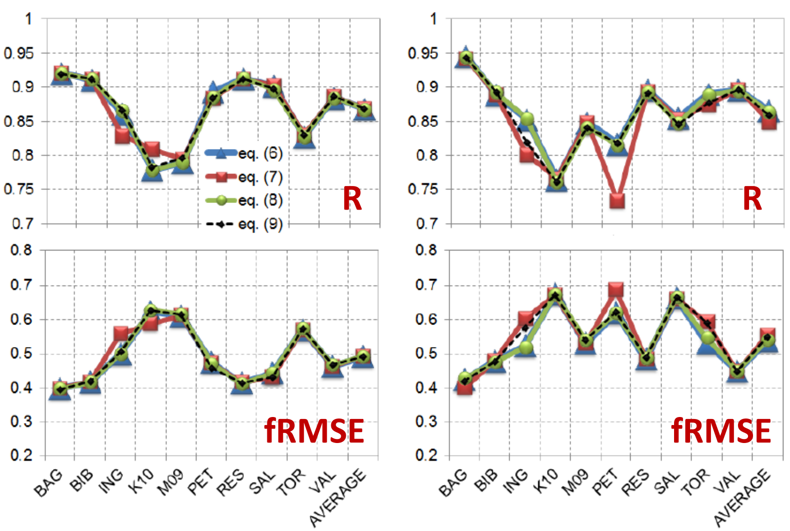
Luca Brocca[1*], Christian Massari[1], Luca Ciabatta[1], Tommaso Moramarco[1], Daniele Penna[2], Giulia Zuecco[3], Luisa Pianezzola[3], Marco Borga[3], Patrick Matgen[4], José Martínez-Fernández[5]



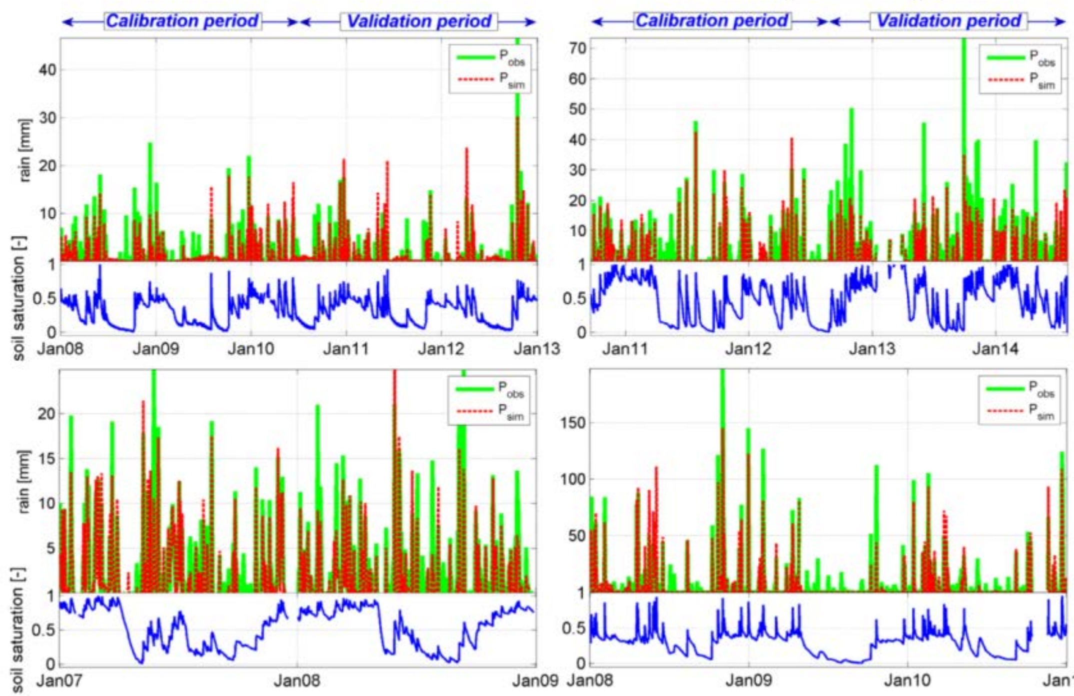
0.75<R<0.95

calibration

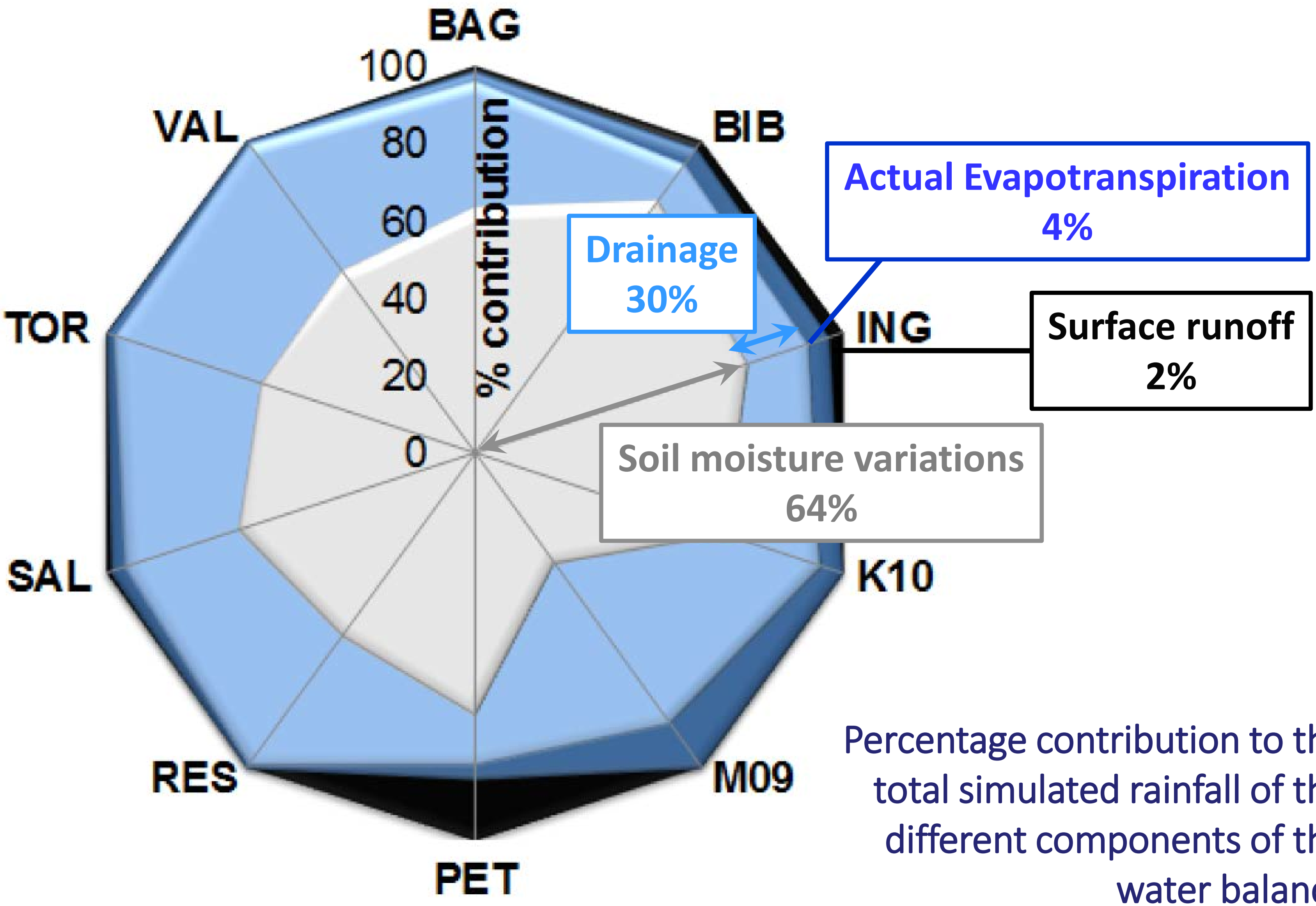
validation



In situ soil moisture observations

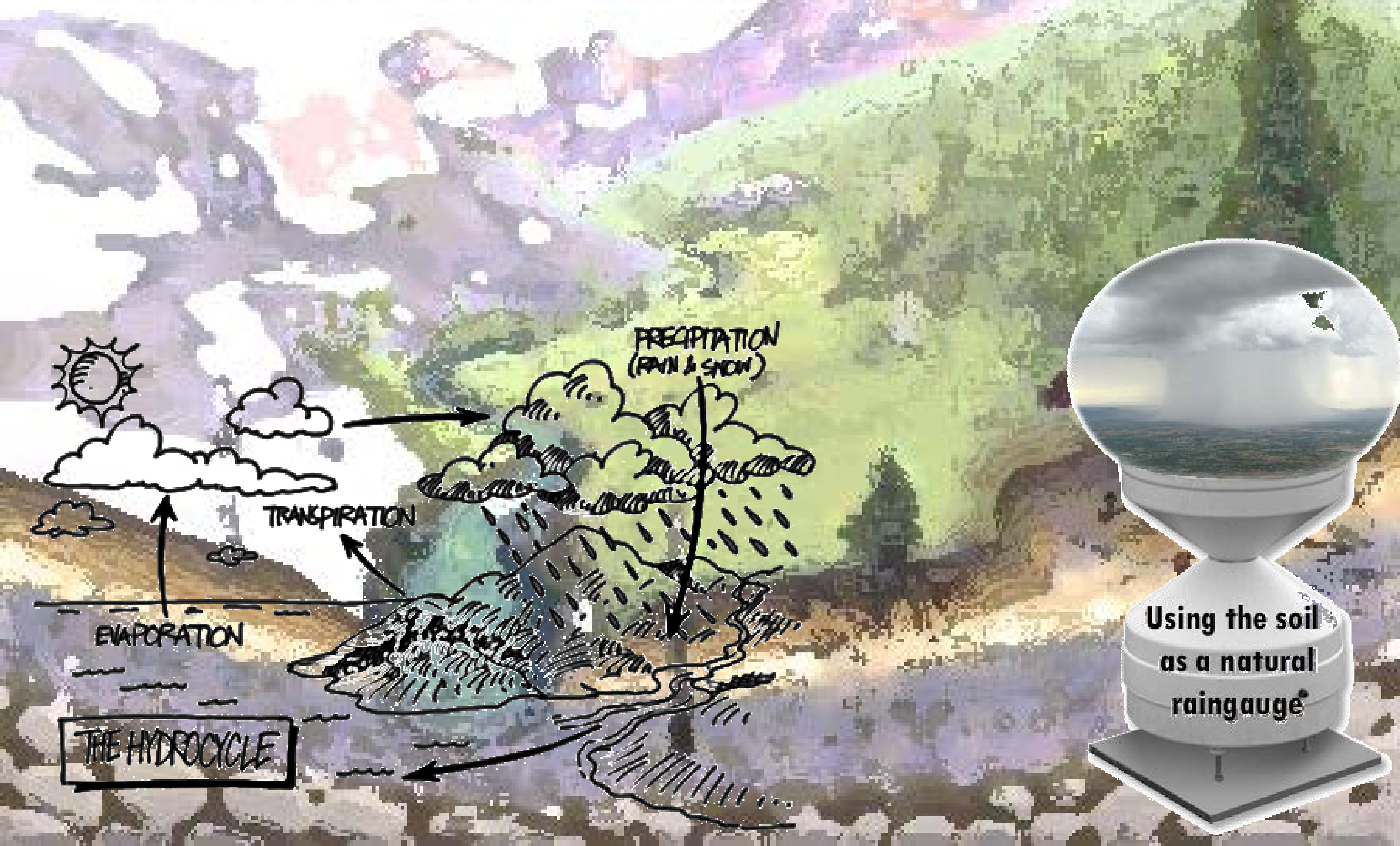


SM2RAIN: in situ observations

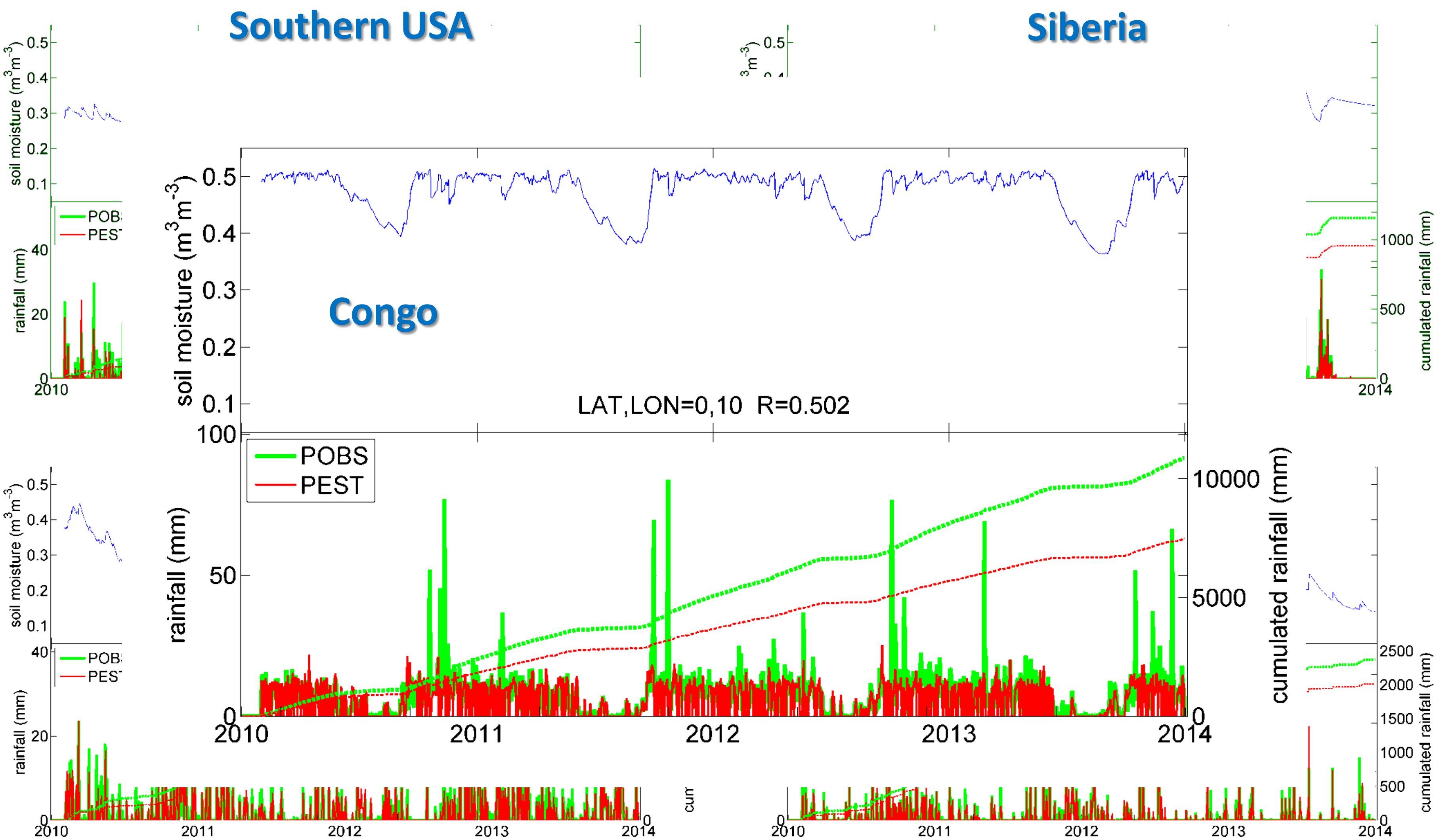


Percentage contribution to the total simulated rainfall of the different components of the water balance

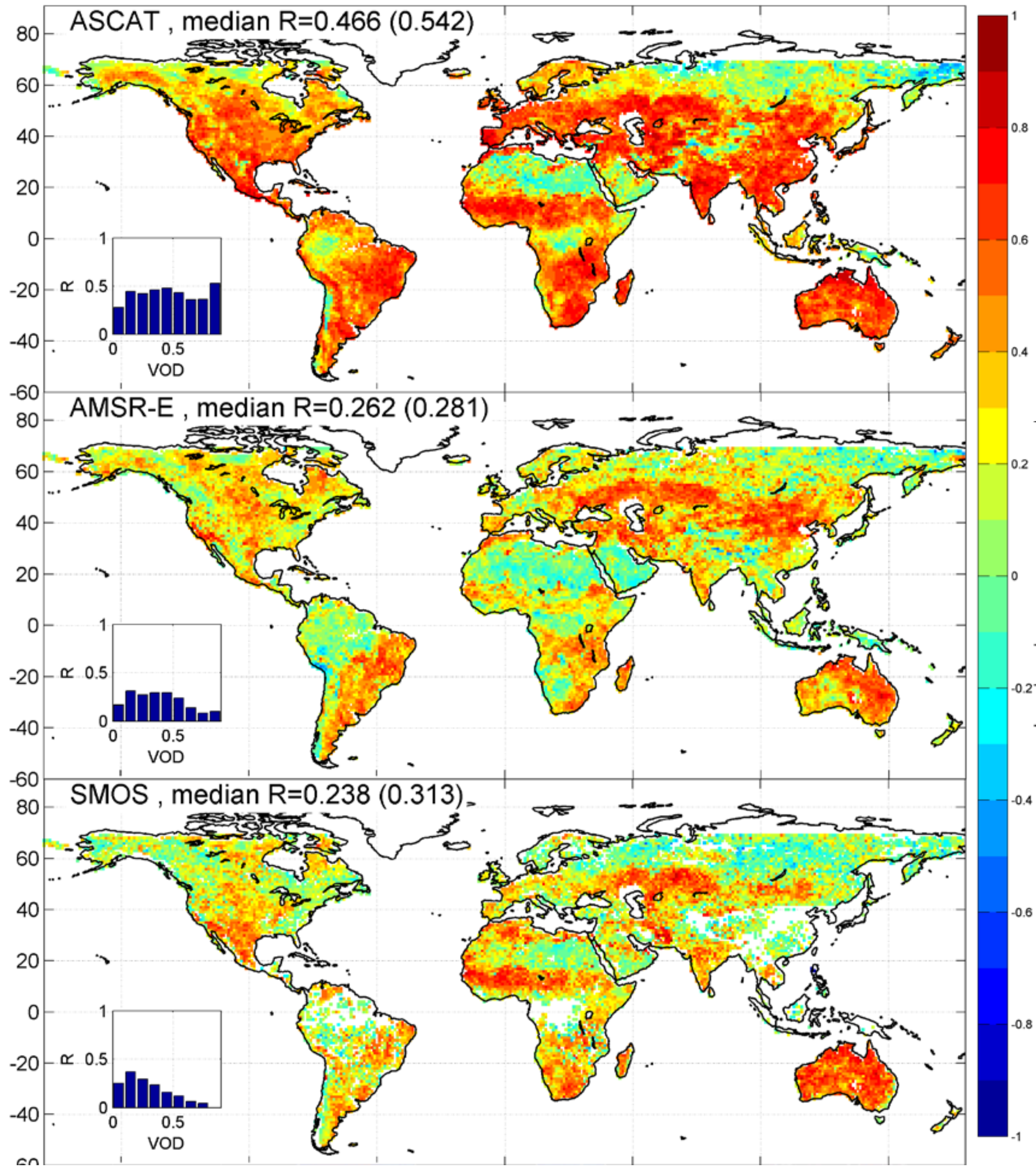
GLOBAL SCALE APPLICATIONS WITH SATELLITE SOIL MOISTURE PRODUCTS



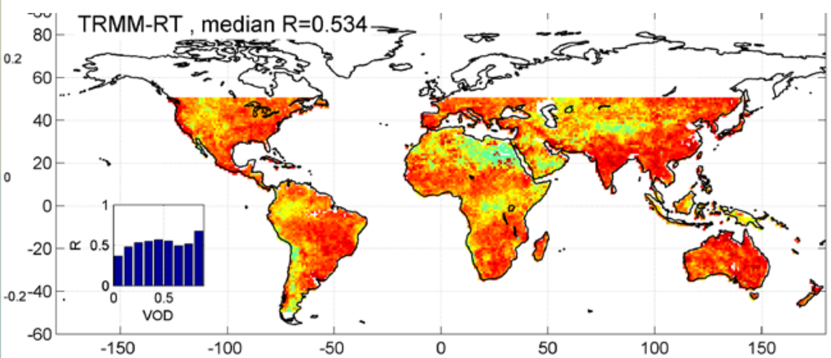
CRASH TEST: timeseries

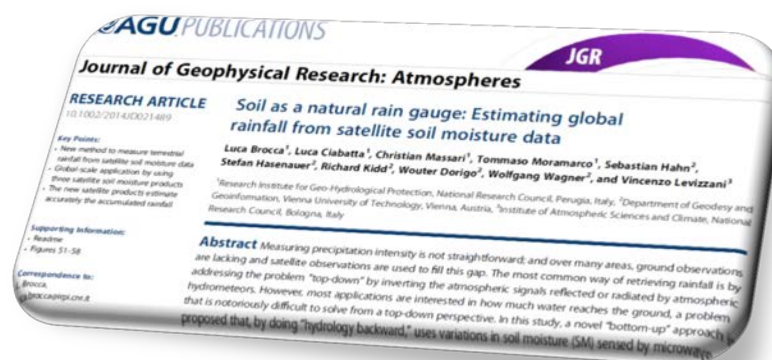


Global scale: real satellite observations



Correlation map between 5-day rainfall from GPCC and the rainfall product obtained from the application of SM2RAIN algorithm to ASCAT, AMSR-E and SMOS data plus TMPA 3B42RT (*VALIDATION period 2010-2011*)




AGU PUBLICATIONS

Journal of Geophysical Research: Atmospheres

JGR

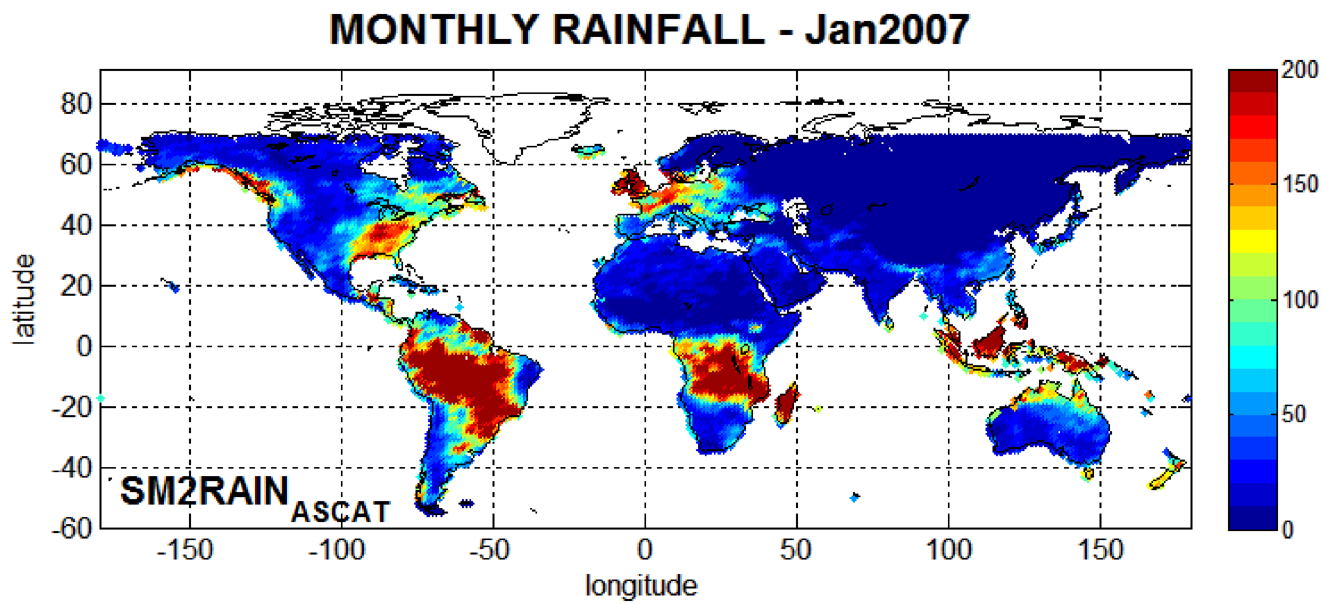
RESEARCH ARTICLE

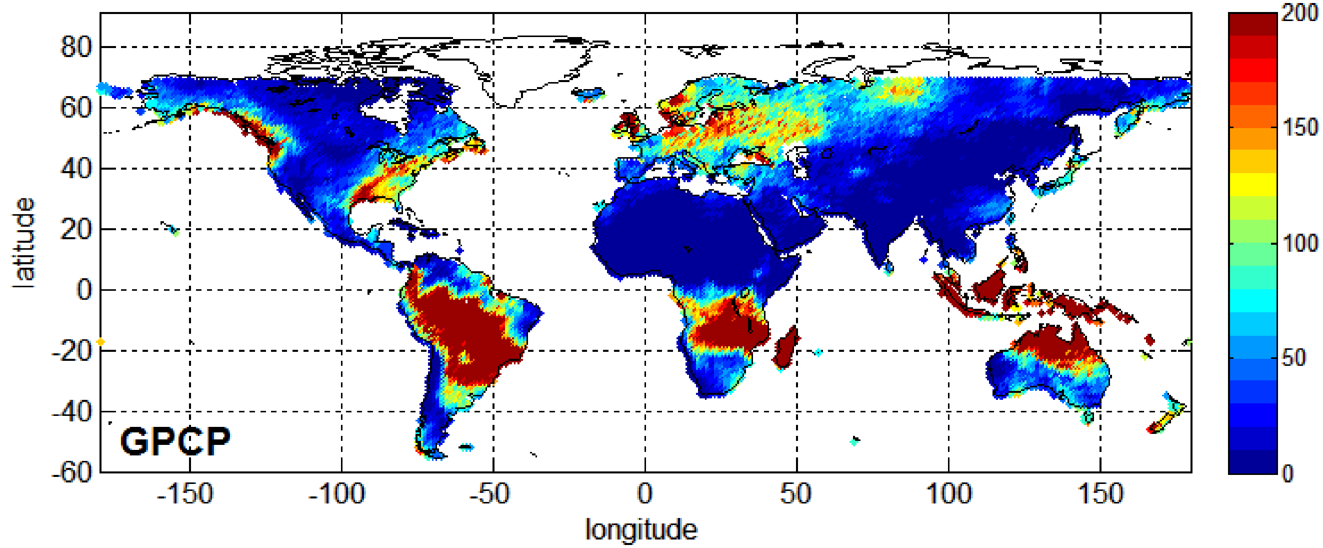
Soil as a natural rain gauge: Estimating global rainfall from satellite soil moisture data

Luca Brocca, Luca Ciabatta, Christian Massari, Tommaso Moramarco, Sebastian Hahn, Stefan Hasenauer, Richard Kidd, Wouter Dorigo, Wolfgang Wagner, and Vincenzo Levizzani

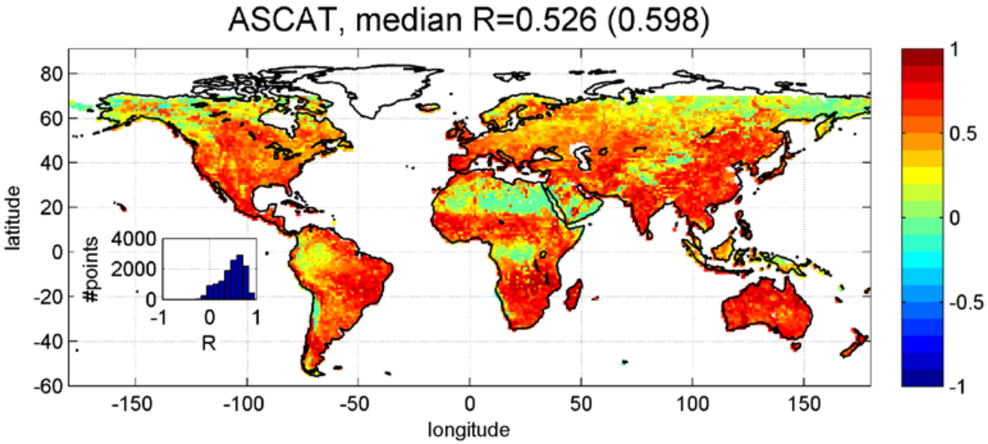
Abstract Measuring precipitation intensity is not straightforward; and over many areas, ground observations are lacking and satellite observations are used to fill this gap. The most common way of retrieving rainfall is by addressing the problem "top-down" by inverting the atmospheric signals reflected or radiated by atmospheric hydrometeors. However, most applications are interested in how much water reaches the ground, a problem that is notoriously difficult to solve from a top-down perspective. In this study, a novel "bottom-up" approach proposed that, by doing "hydrology backward," uses variations in soil moisture (SM) sensed by microwave

Global monthly rainfall from ASCAT

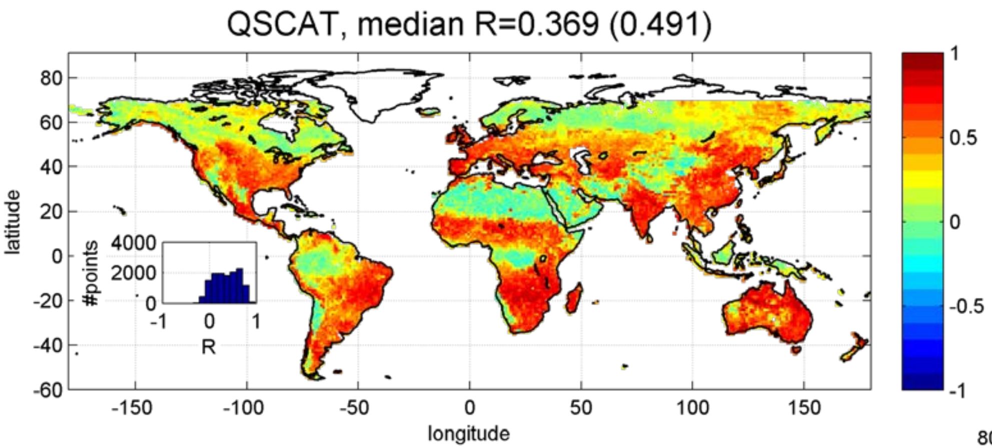




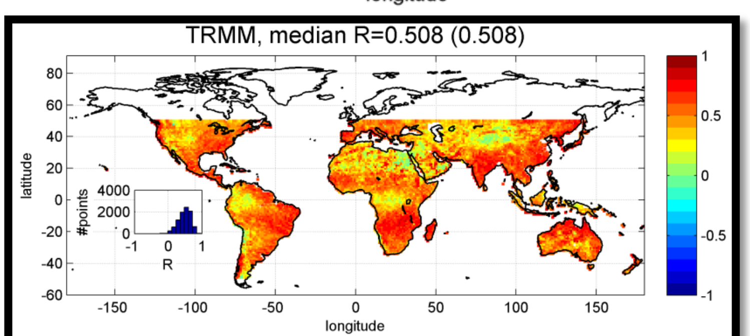
Application to QUIKSCAT, AMSR2



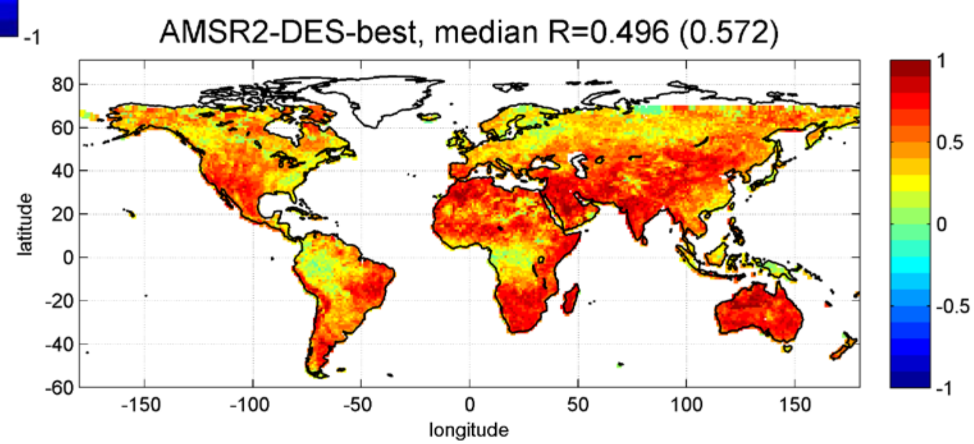
- ✓ 2007-2009
- ✓ Improved algorithm
- ✓ Distributed calibration
- ✓ Application of filtering techniques (e.g. wavelet)



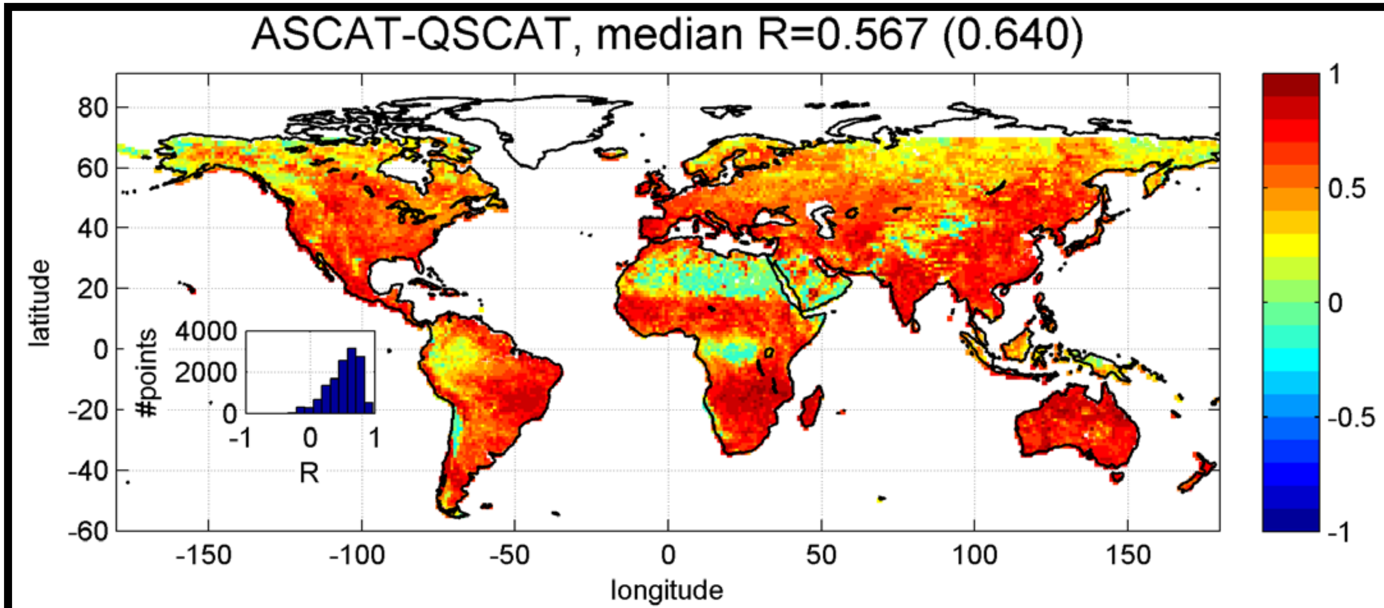
Application to QUIKSCAT (Ku-band scatterometer), 2007-2009

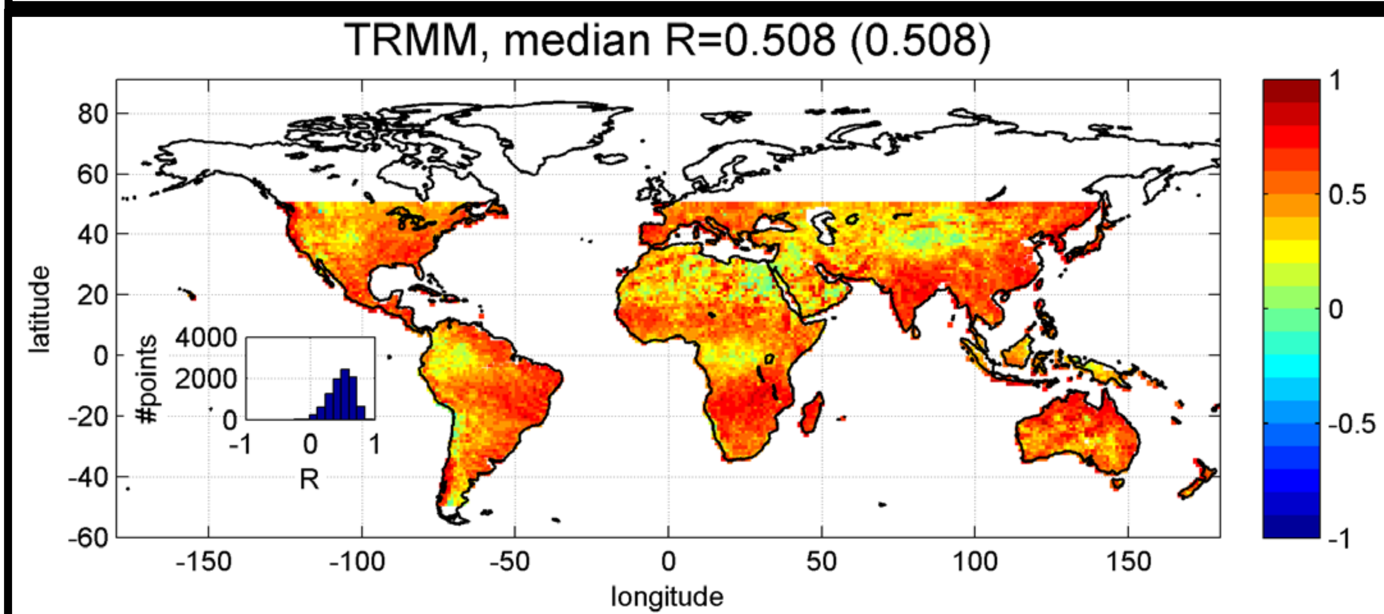


Application to AMSR2 (C+X-band radiometer) 2012-2014



ASCAT+QUIKSCAT vs TMPA-RT



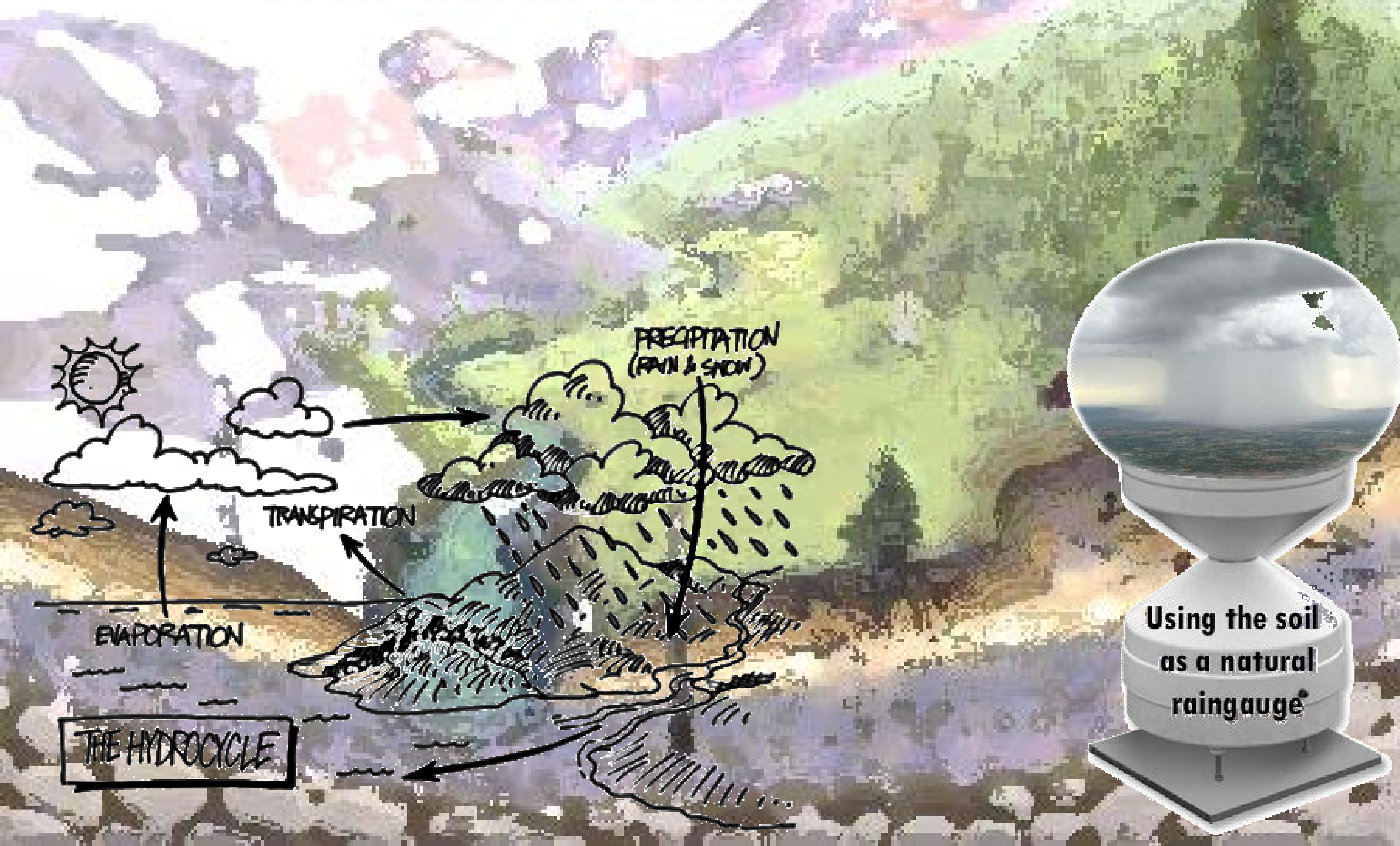


- ✓ 2007-2009
- ✓ ERA-Interim as benchmark
- ✓ 5-day cumulated

The correlation is 25% higher than TMPA real time rainfall product

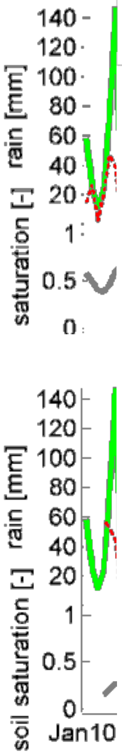
0.508 → 0 .640

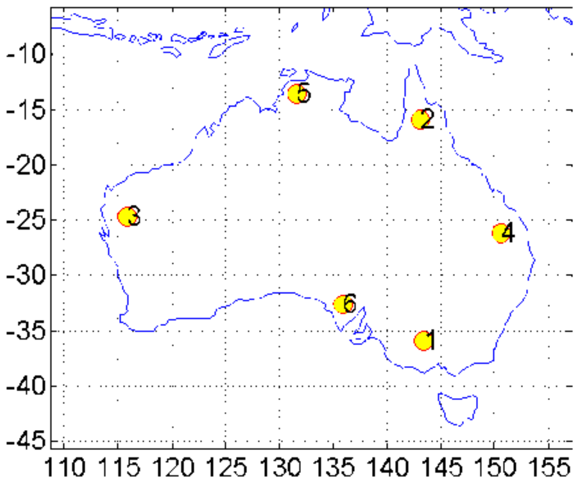
MERGING MULTIPLE SATELLITE SOIL MOISTURE PRODUCTS

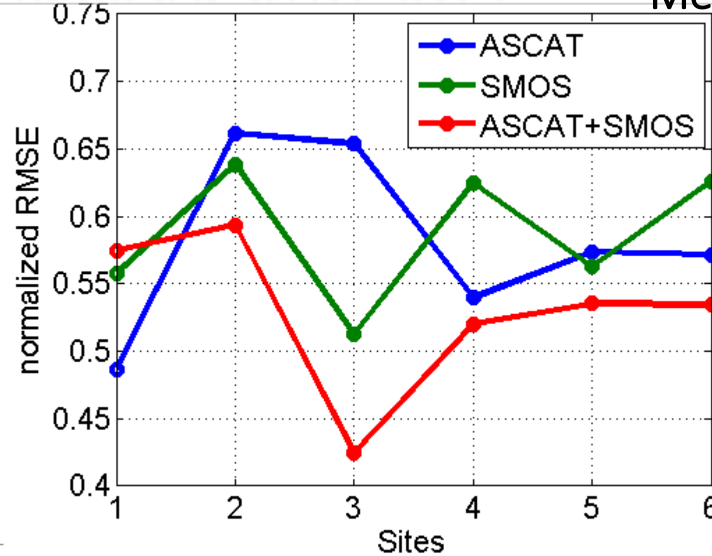


SMOS + ASCAT

EXTENDED PERIOD: 2010-2012







Mean values
0.58
0.59
0.53

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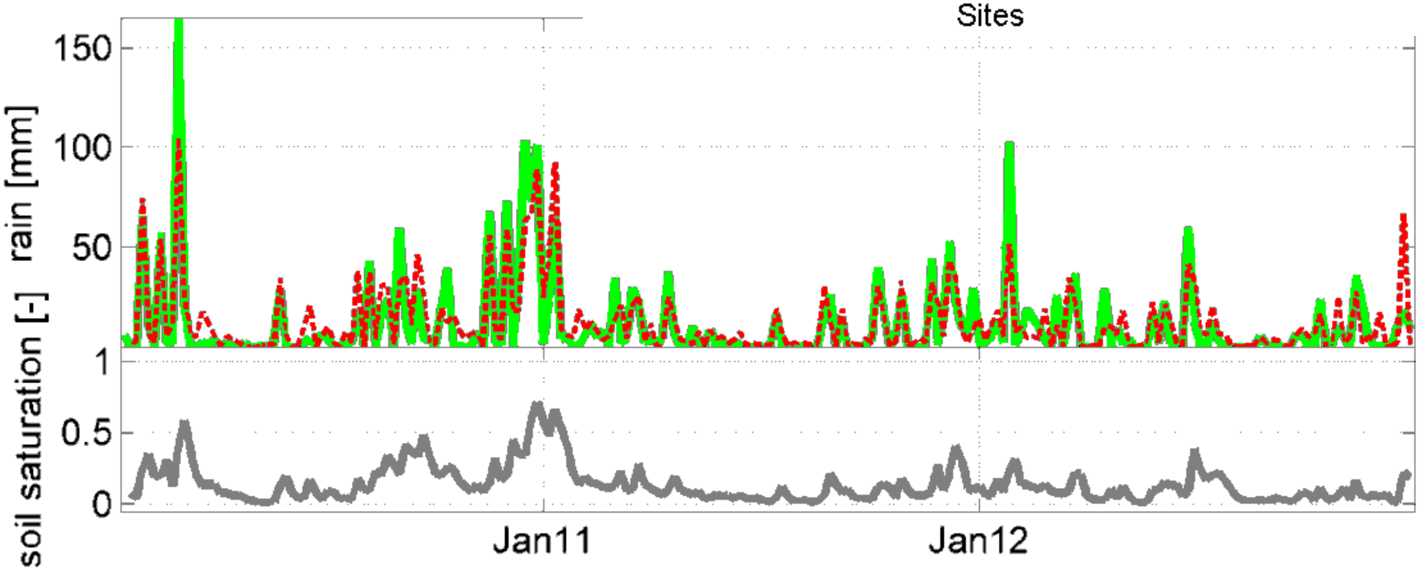
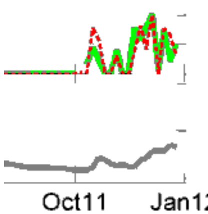


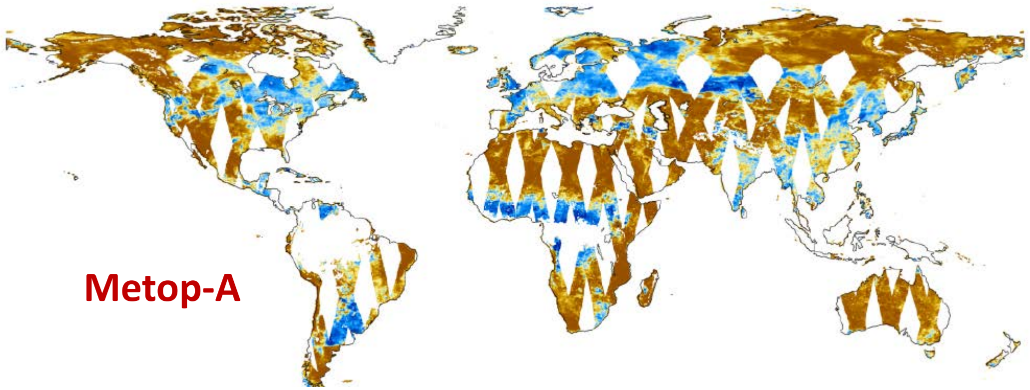
: 22.826 mm

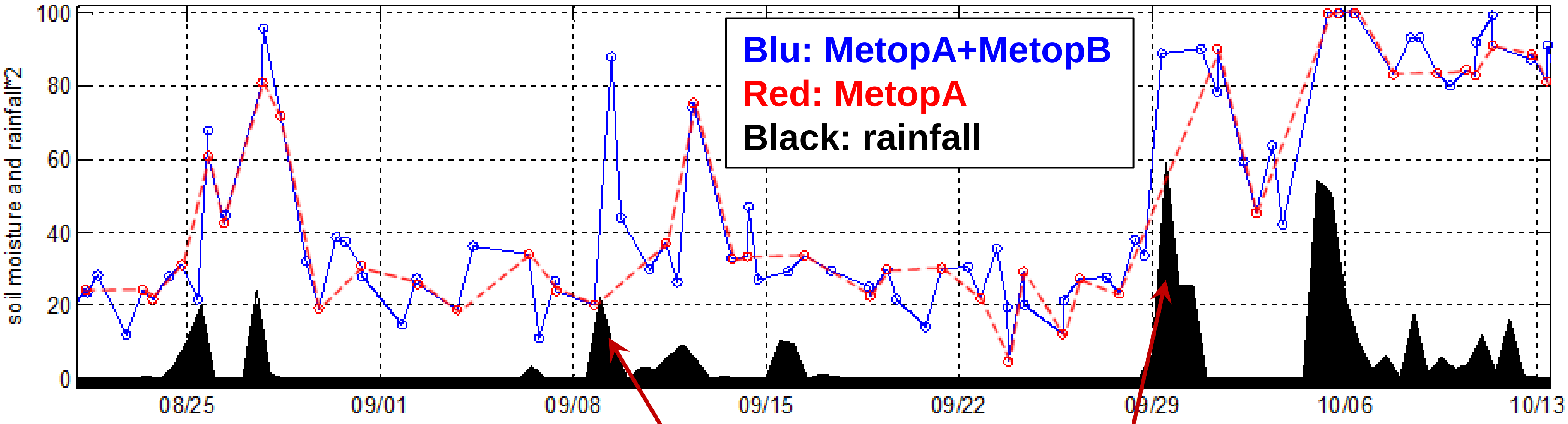
ASCAT+
SMOS



RMS

Merging Metop-A and B





Rainfall events detected only by considering both sensors Metop A and B

Merging Metop-A and B

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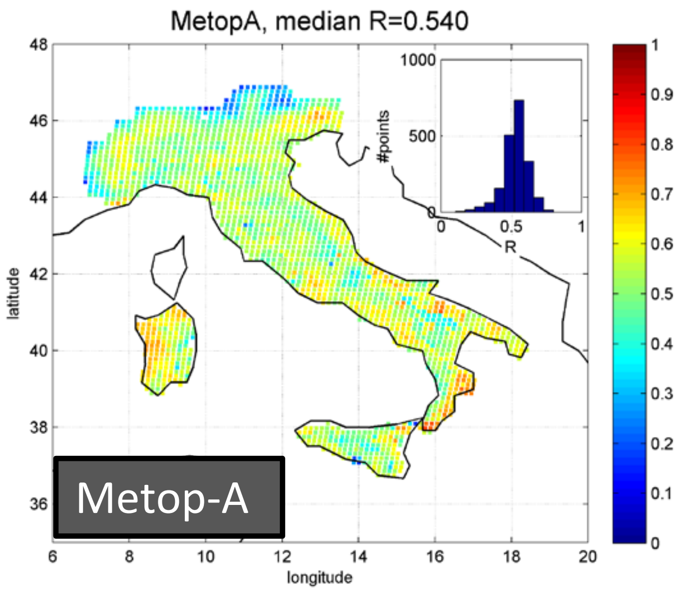
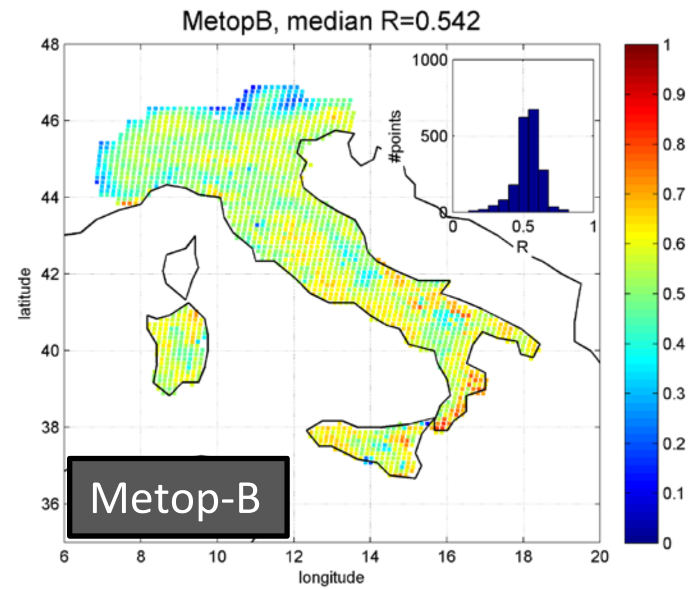


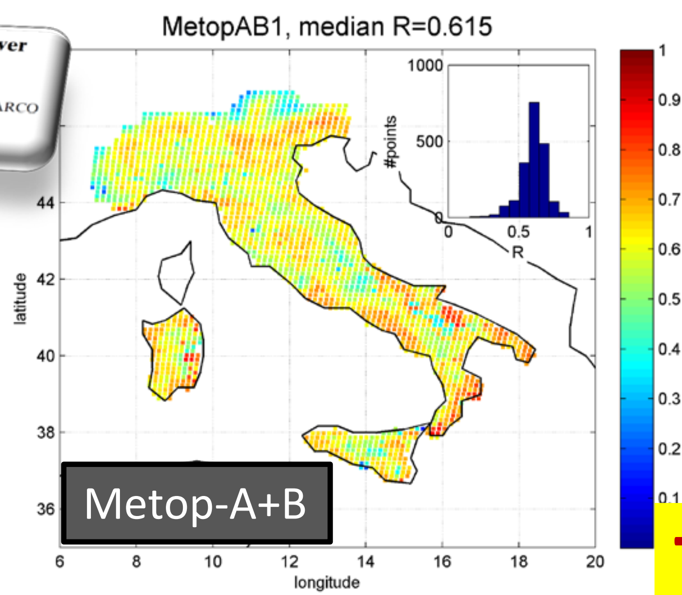


Integration of Satellite Soil Moisture and Rainfall Observations over the Italian Territory

LUCA CIABATTA, LUCA BROCCA, CHRISTIAN MASSARI, AND TOMMASO MORAMARCO

Research Institute for Geo-Hydrological Protection, National Research Council, Perugia, Italy

Ciabatta et al. (2015) – JHM
2010-2013
Median R= 0.44
T=0 (no SWI application)



Metop A+B improves by 14% wrt single sensors

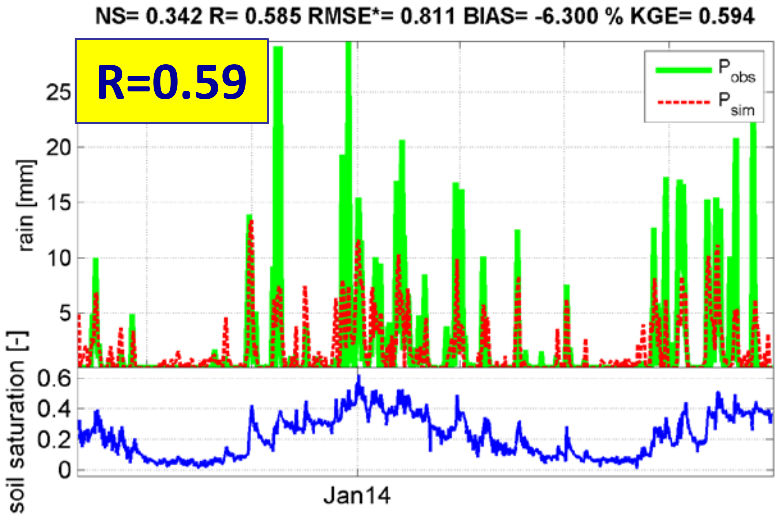
Metop A+B improves by 37% wrt Ciabatta et al. JHM (calibration period)

Data Period:
2-may-2013 → 31-dec-2014

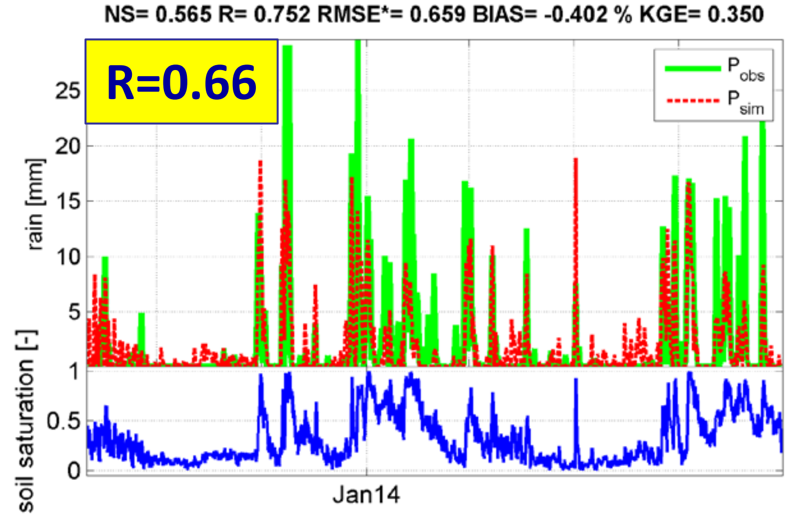
Time step: 1-day

Merging ASCAT and AMSR2

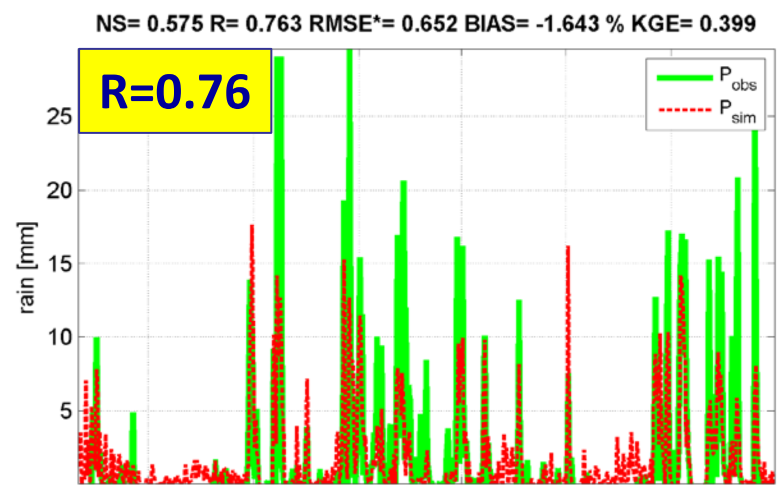
AMSR2



ASCAT



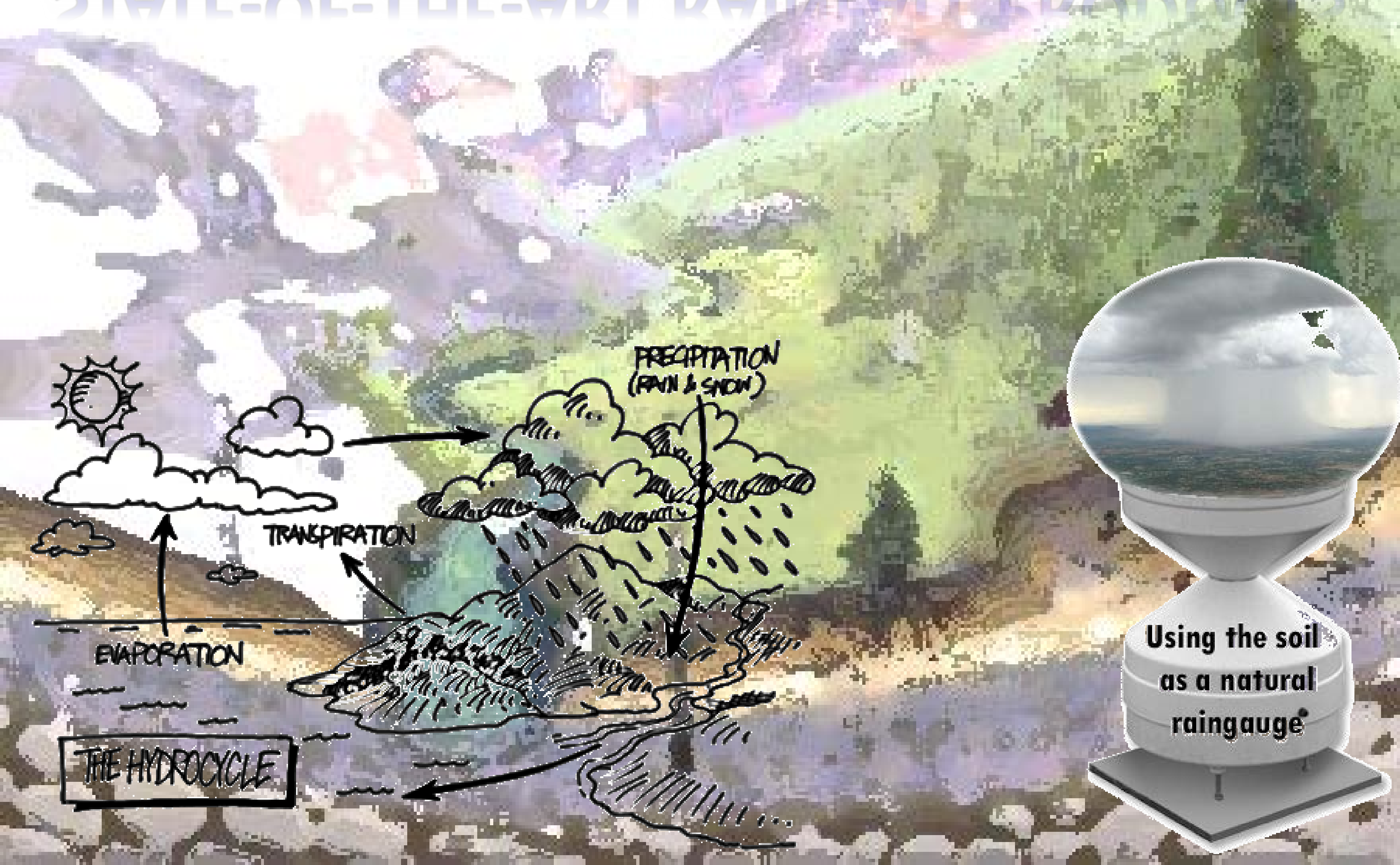
AMSR2+ASCAT



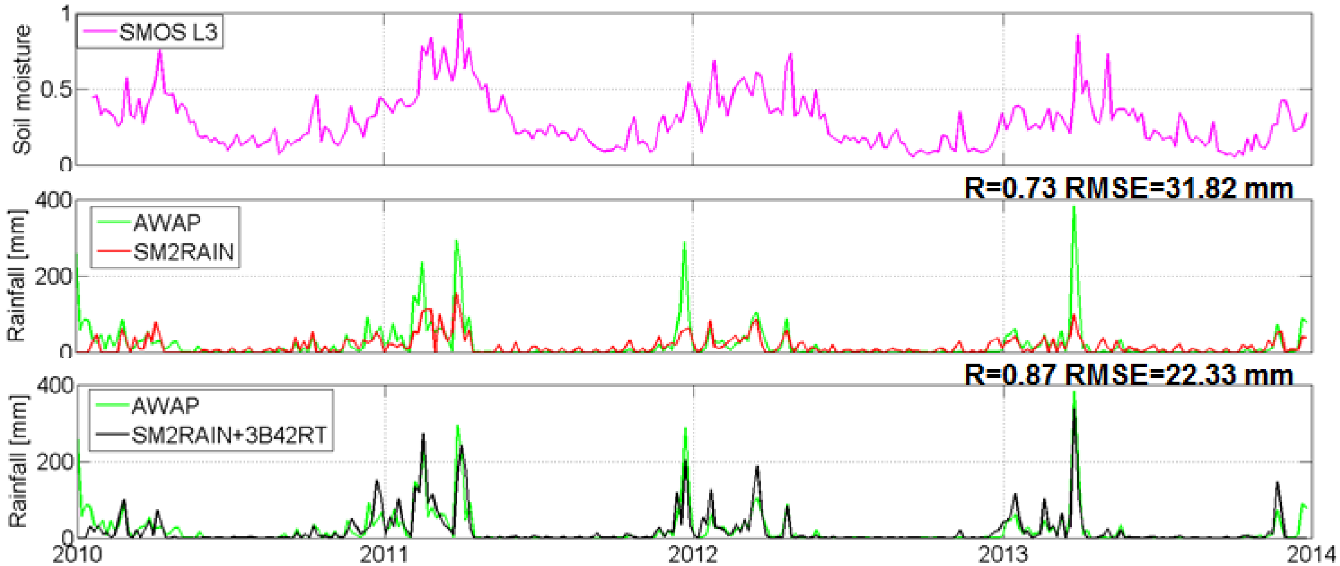
Lon,Lat: -5,40
Period: may 2013-dec 2014
ASCAT: Metop A+B
AMSR2: Asc+Desc, X-band
Benchmark: ERA-Interim

Time step: 1-day

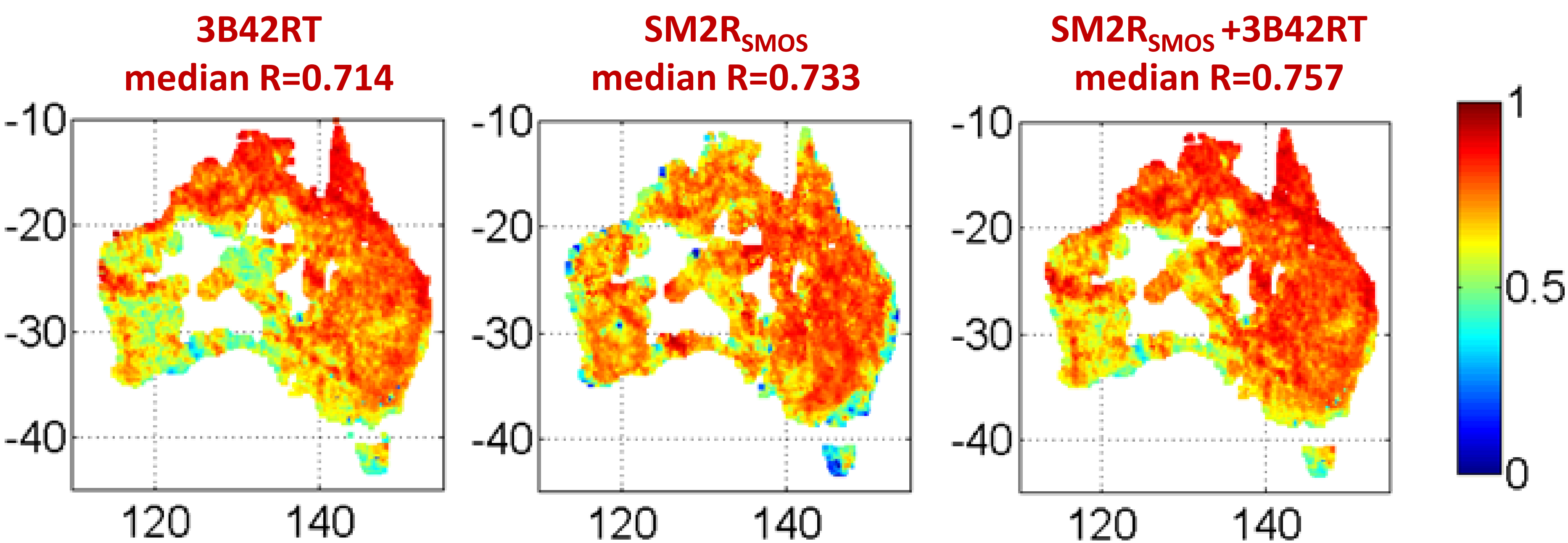
INTEGRATION OF SM2RAIN WITH STATE-OF-THE-ART RAINFALL PRODUCTS



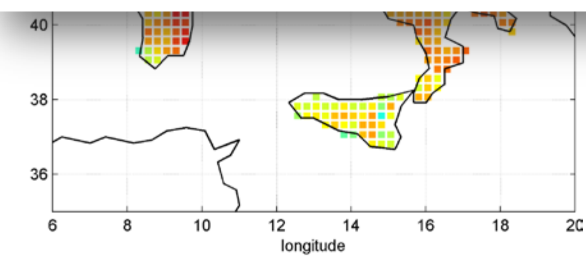
SMOS+TMPA in Australia

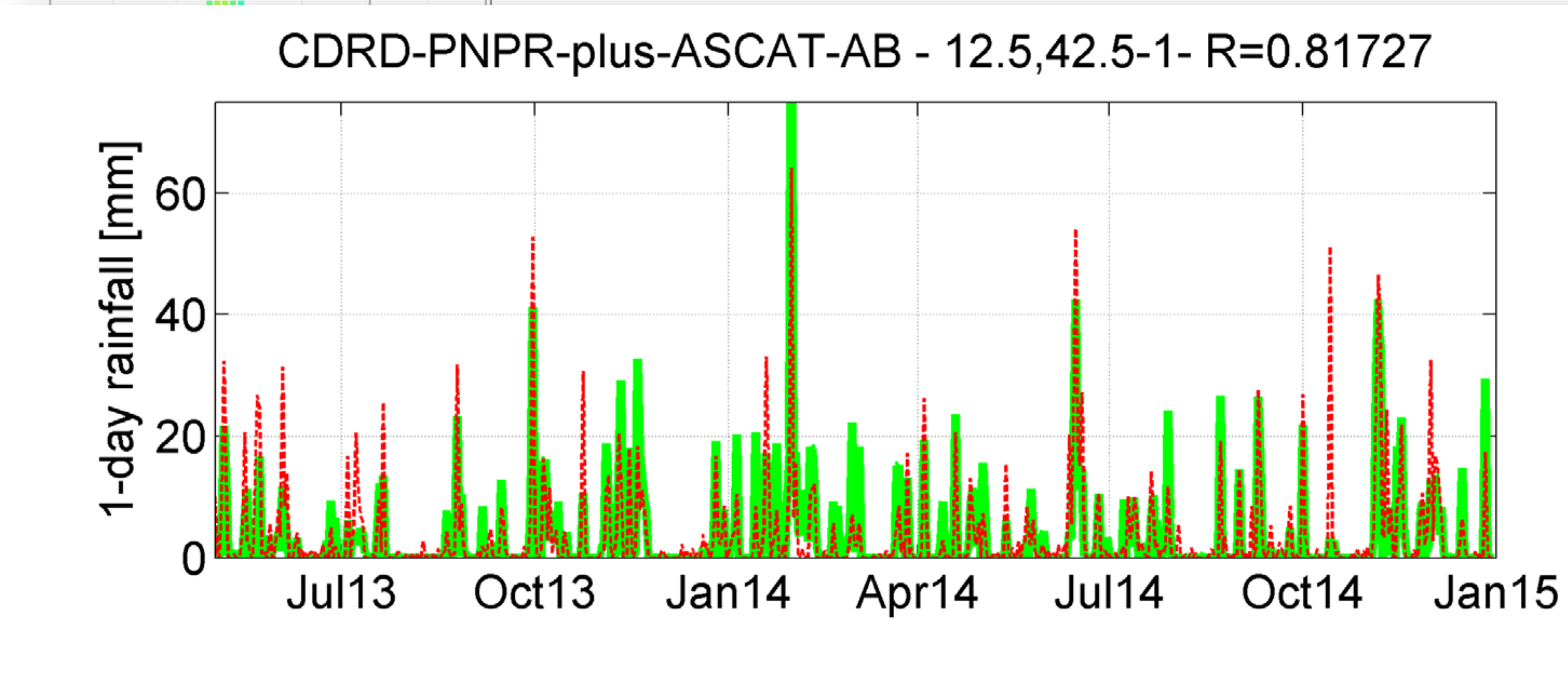


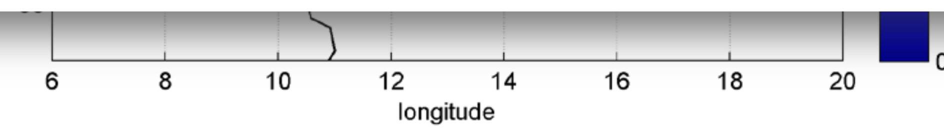
- Period 2010-2013
- AWAP rainfall as benchmark
- Calibration with 3B42
- 5-day cumulated



ASCAT+H-SAF in Italy

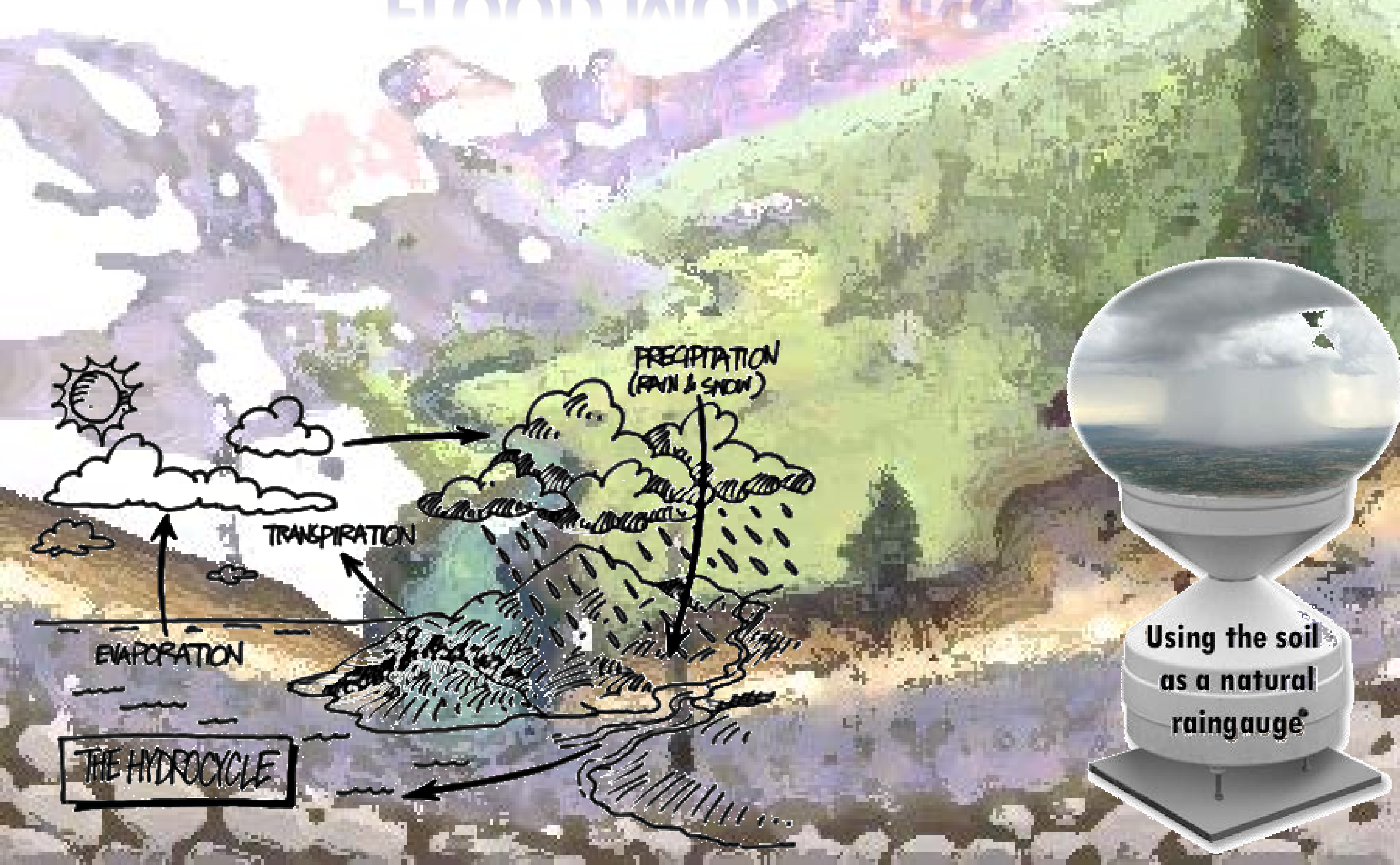




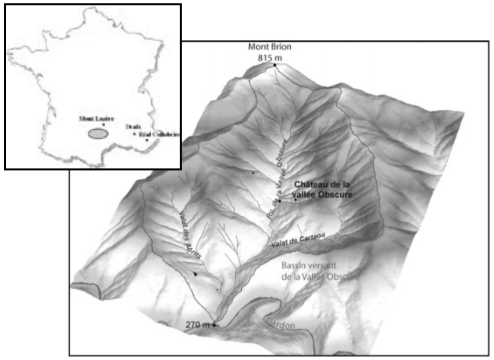


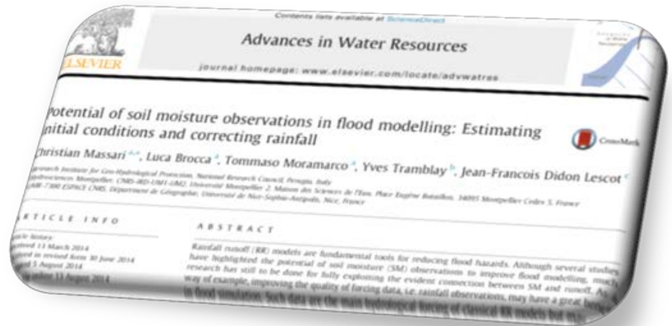
Time step: 1-day

SM2RAIN FOR IMPROVING FLOOD MODELLING



VALESCURE CATCHMENT (France)



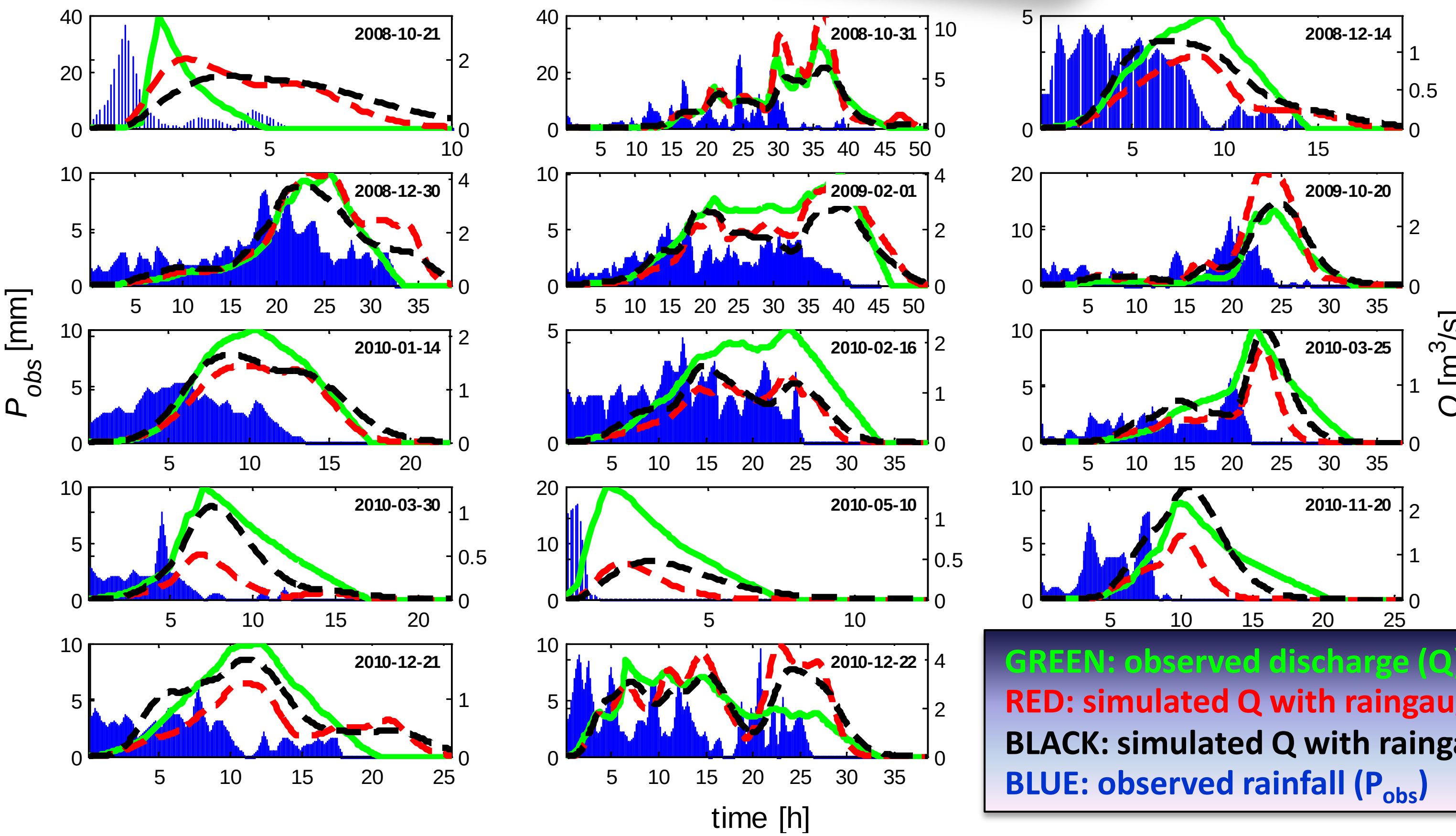

Advances in Water Resources

Potential of soil moisture observations in flood modelling: Estimating initial conditions and correcting rainfall

Christian Massari, Luca Brocca, Tommaso Moramarco, Yves Tramblay, Jean-Francois Didon Lescot

IN SITU OBSERVATIONS

We obtained an increase in performance from NS=0.49 to NS=0.83 when SM2RAIN-derived rainfall is used for correcting rainfall observations during the flood event

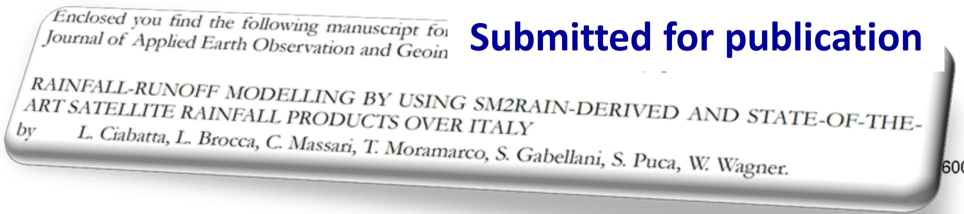


GREEN: observed discharge (Q)
RED: simulated Q with raingauge data only
BLACK: simulated Q with raingauge+SM2RAIN data
BLUE: observed rainfall (P_{obs})

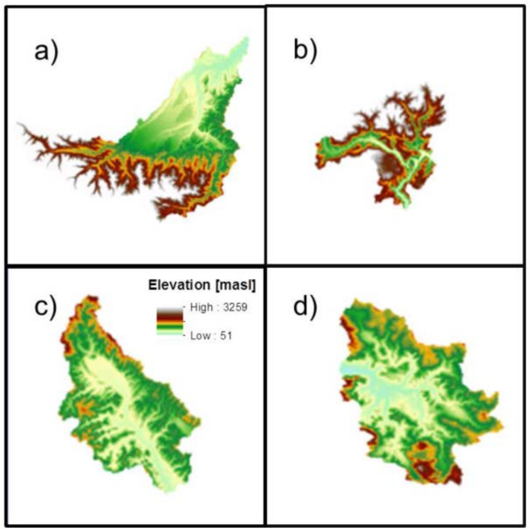
ITALY: 4 catchments

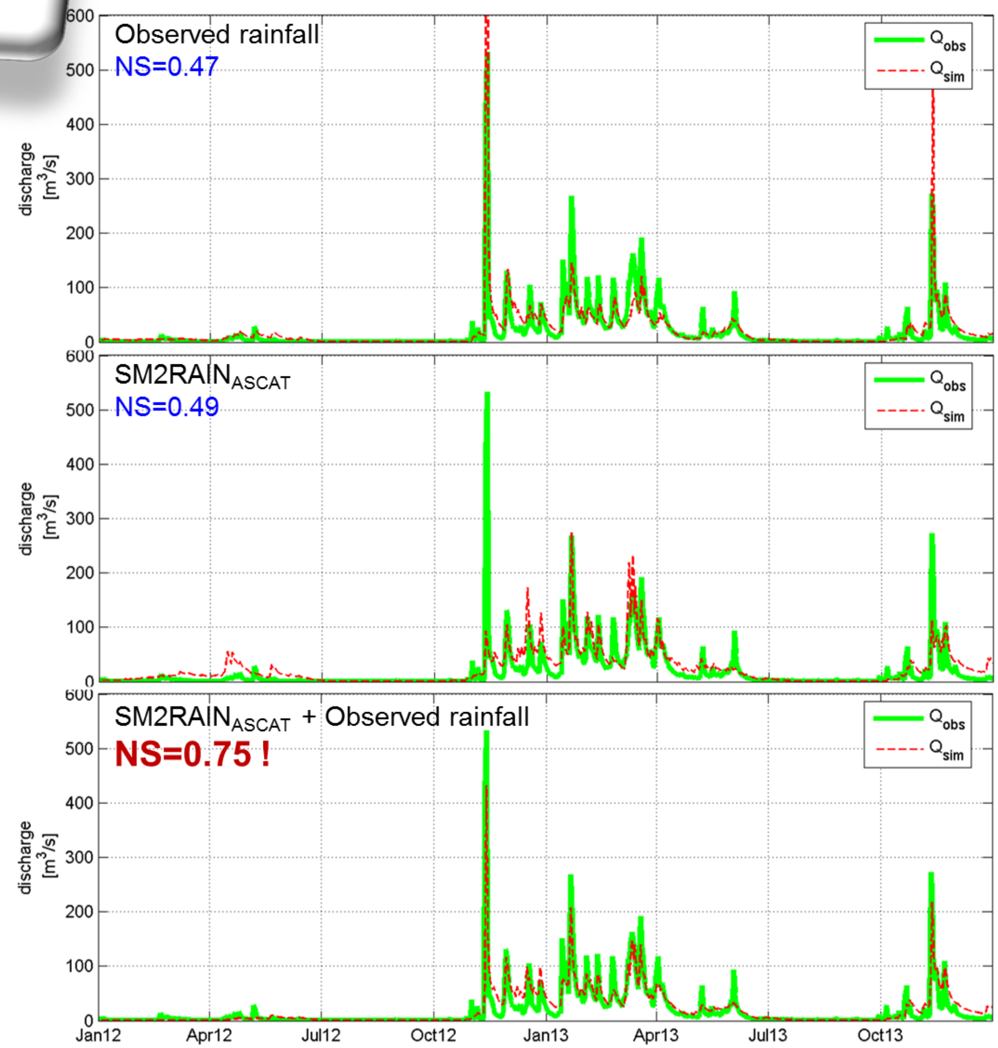
SATELLITE OBSERVATIONS

Submitted for publication


Enclosed you find the following manuscript for
Journal of Applied Earth Observation and Geoin

RAINFALL-RUNOFF MODELLING BY USING SM2RAIN-DERIVED AND STATE-OF-THE-ART SATELLITE RAINFALL PRODUCTS OVER ITALY
by L. Ciabatta, L. Brocca, C. Massari, T. Moramarco, S. Gabellani, S. Puca, W. Wagner.





Runoff simulation by using as input

1. Observed rainfall
2. SM2RAINASCAT
3. SM2RAINASCAT + Observed Rainfall

CONCLUSIONS

- Compelling evidence that it is possible to estimate rainfall from satellite soil moisture data
- The soil moisture derived products are found to estimate accurately the accumulated rainfall addressing the difficulties of estimating light rainfall from state-of-the-art products
- Merging multiple satellite soil moisture products allows to obtain good performance also at daily time scale
- The integration of the SM-derived products with state-of-the-art products provides a significant improvement, very useful for hydrological applications

FOR FURTHER INFORMATION
URL: http://hydrology.irpi.cnr.it/people/l.brocca
URL IRPI: http://hydrology.irpi.cnr.it

This presentation is available for download at:
http://hydrology.irpi.cnr.it/repository/public/presentations/2015/moisst-2015-l.-brocca