A study towards the Integration of SMOS Soil Moisture in a Consistent Climate Record

Richard de Jeu[1], Jean Pierre Wigneron[2], Yann Kerr[3],
Matthias Drusch[4], Robin van der Schalie[1], Amen Al Yaari[2],
and Nemesio Rodriguez[3]

1 VU University Amsterdam, 2, INRA, 3 CESBIO, 4 ESA

vrije Universiteit amsterdam

Outline

- **Introduction / Rationale**
- **Methods**
- **First Results**
- **Conclusions**
- **Future**

Within the ESA CCI program (phase 1) a 35+ year soil moisture record has been developed

**Record is based on passive and active microwave satellite data sets (see pres. Dorigo et al. (Thu))**

SMOS is not yet part of this record !

In ESA CCI Phase II, SMOS should become part of this record

vrije Universiteit amsterdam

SMOS can give an important contribution to the CCI
SMOS can be complementary towards the other sensors

Corr. between AMSR/SMOS and Soil moisture from ECMWF

Al Yaari et al., RSE, 2014   4
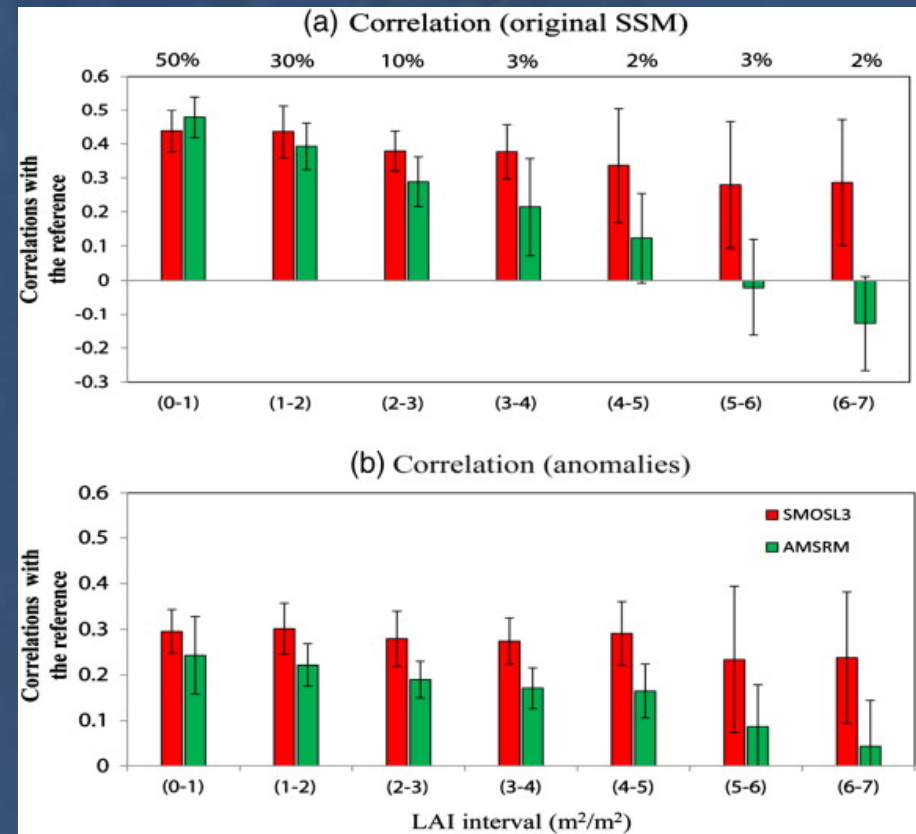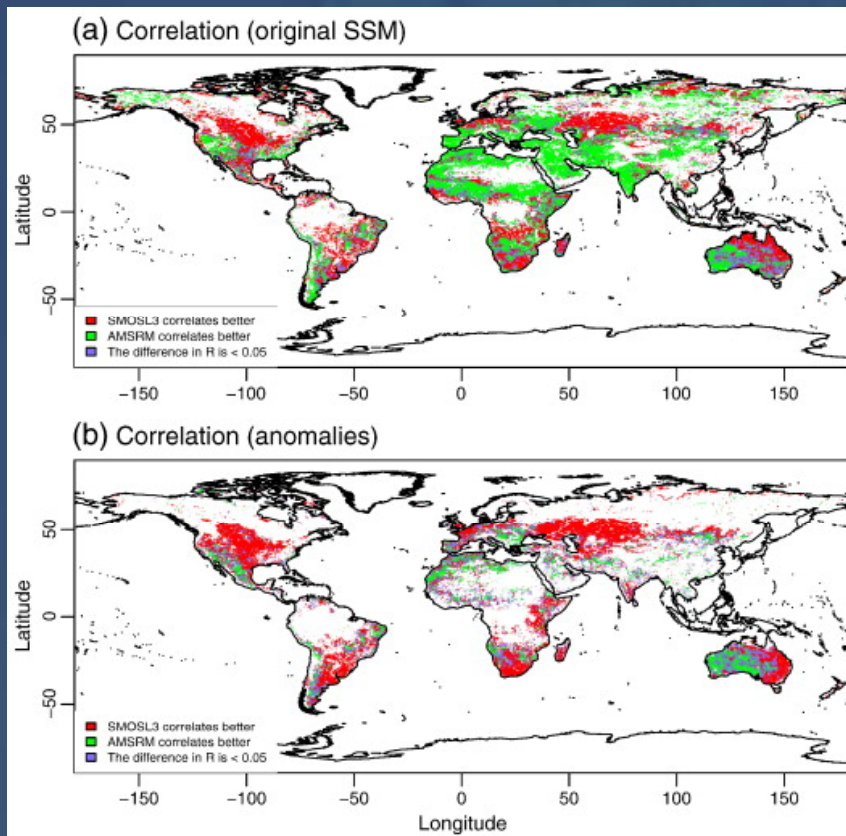
Microwave Soil Moisture Data Fusion

ESA EXPRO+ project (1 year project)

Joint project: VUA, INRA, CESBIO

<u>Objective:</u> provide guidelines for the further development of an ECV soil moisture product

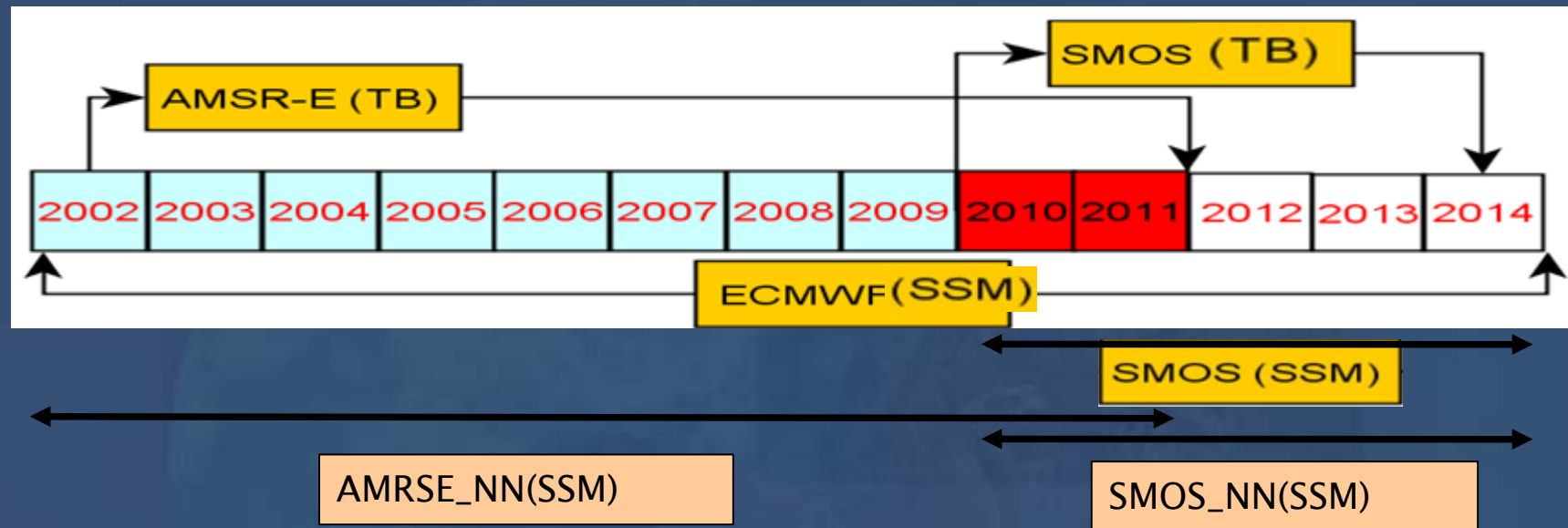vrije Universiteit amsterdam

Study plan:

Design and implementation of 3 different data fusion approaches for passive microwave observations using SMOS L3 (2010-2013) and AMSR-E L2 (2003-2011) over a 10 year period.

Evaluate the performance of the 3 approaches with predefined statistical metrics.

Methods

vrije Universiteit amsterdam
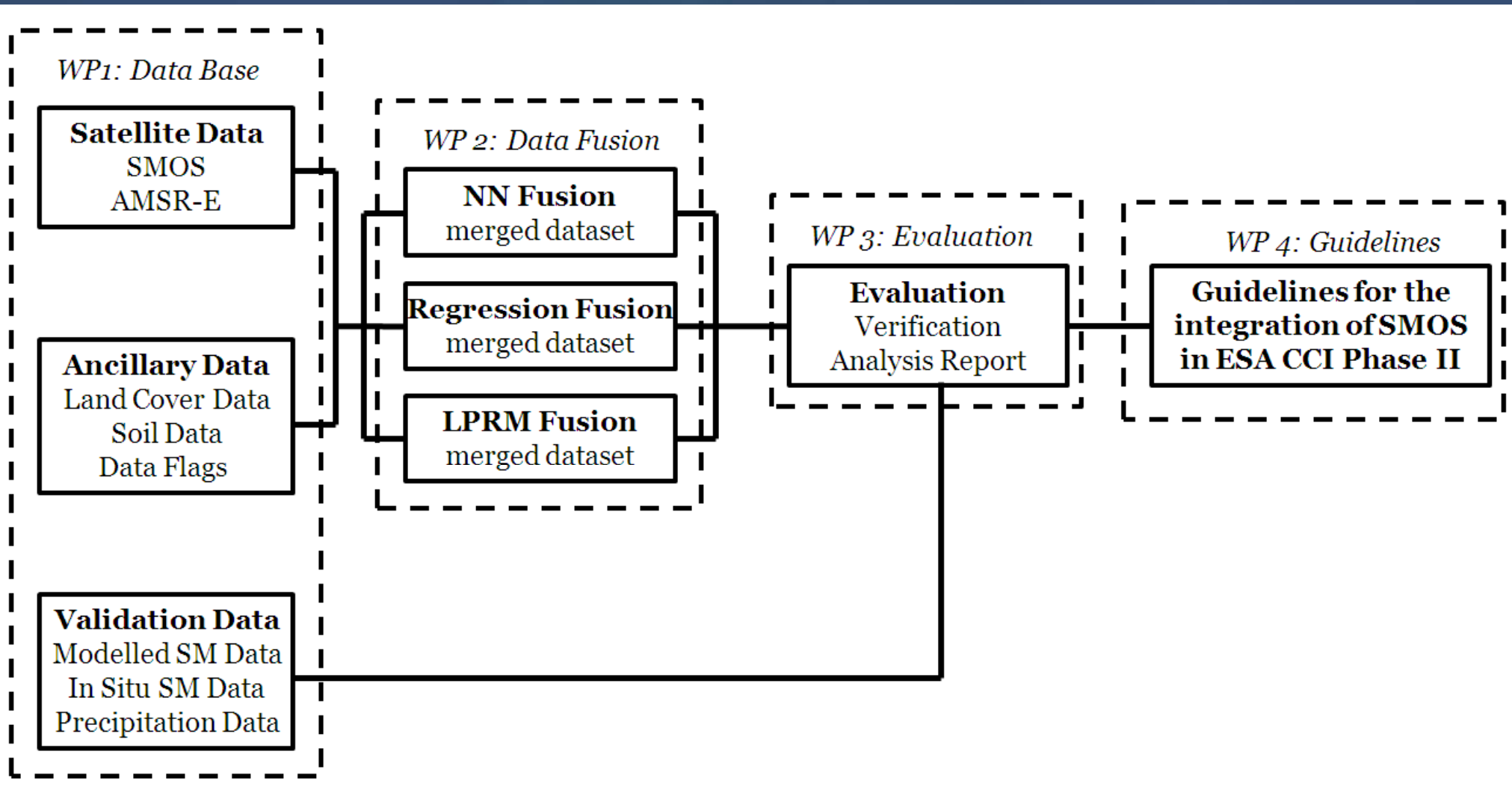
Methods: 1) NN Fusion (CESBIO)

- Train SMOS_NN in 2013 using SMOS TBs as input and either ECMWF SSM or SMOS L3 SSM as reference

- Apply SMOS_NN to SMOS TBs in 2010-2011 → output SMOS_NN(SSM)

- Use this SMOS_NN(SSM) to train AMSRE_NN with AMSR-E TBs as input in 2010-2011

- Apply AMSRE_NN to AMSR-E TBs in the period 2003-2009 → output AMRSE_NN(SSM)
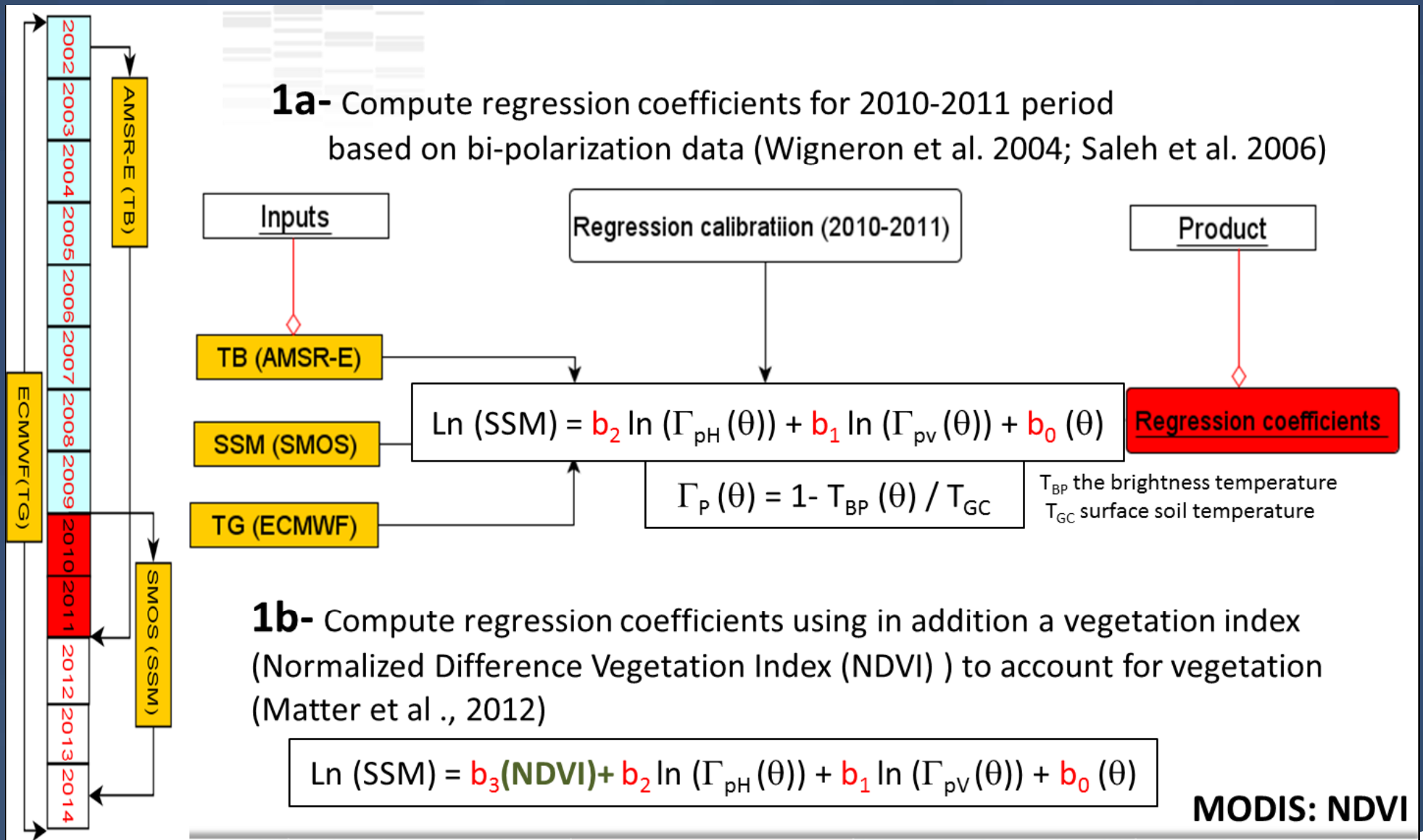
Methods: 1) NN Fusion (CESBIO)
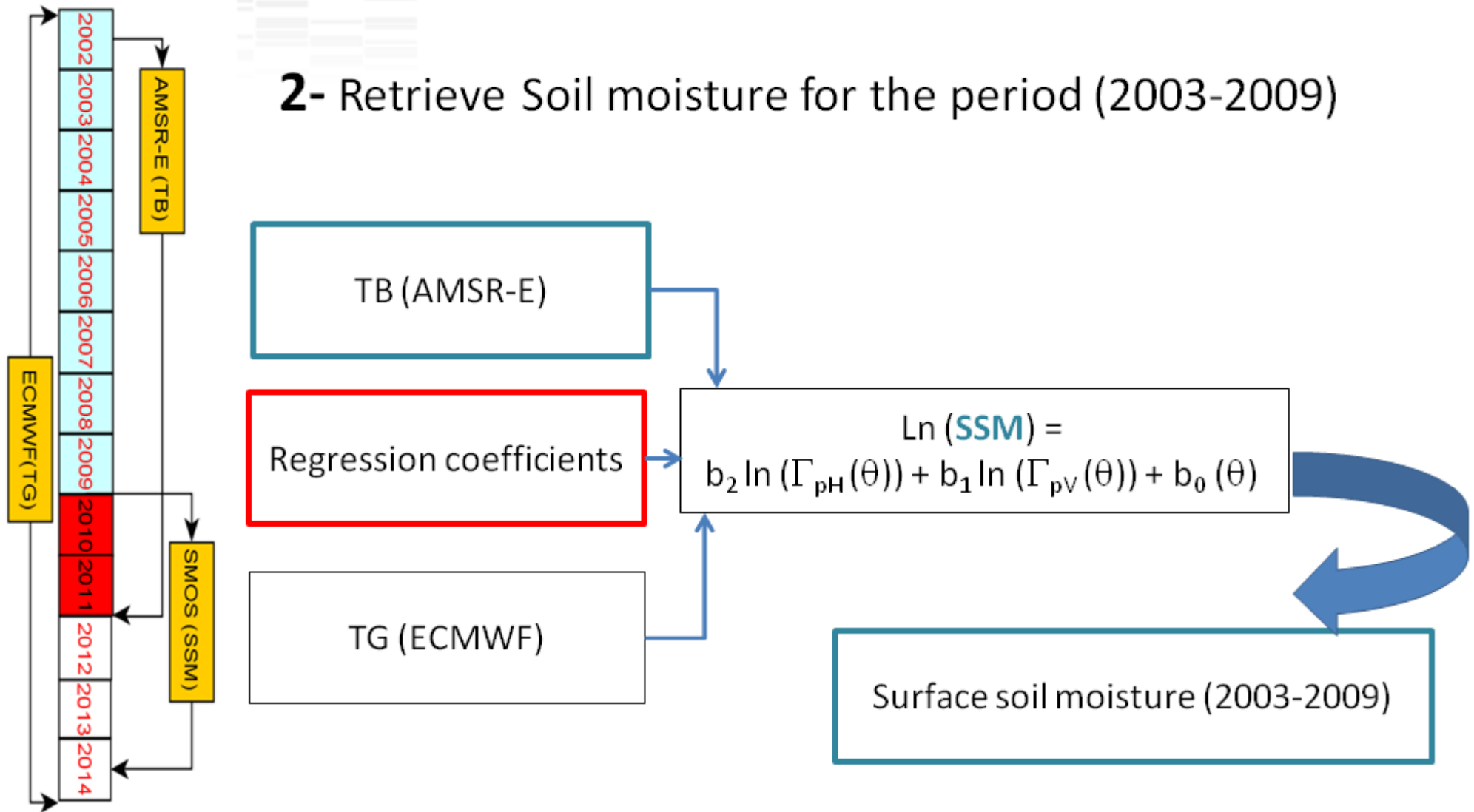

Alternatively:

9
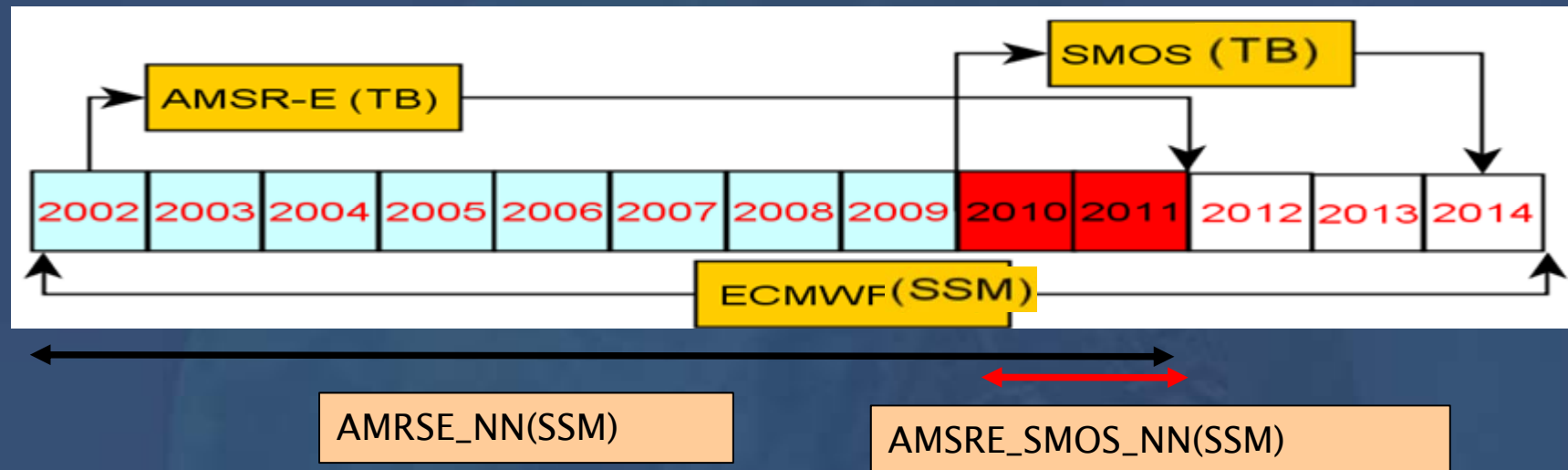
- Explore AMSR-E and SMOS synergy in 2010-2011 to train AMSRE_SMOS_NN with respect to ECMWF(SSM) to generate AMSRE_SMOS_NN(SSM)

- Use AMSRE_SMOS_NN(SSM) as SSM reference to train AMSRE_NN in 2010-2011

- Use AMSRE_NN in the 2002-2009 period to compute AMSRE(SSM)

# Methods: 2) Regression Fusion (INRA)

1a- Compute regression coefficients for 2010-2011 period based on bi-polarization data (Wigneron et al. 2004; Saleh et al. 2006)

Inputs

Regression calibratiion (2010-2011)

Product

TB (AMSR-E)

SSM (SMOS)

TG (ECMWF)

$$Ln\ (SSM) = b_2\ ln\ (\Gamma_{pH}\ (\theta)) + b_1\ ln\ (\Gamma_{pv}\ (\theta)) + b_0\ (\theta)$$

Regression coefficients

$$\Gamma_P\ (\theta) = 1 - T_{BP}\ (\theta)\ /\ T_{GC}$$

T_{BP} the brightness temperature
T_{GC} surface soil temperature

1b- Compute regression coefficients using in addition a vegetation index (Normalized Difference Vegetation Index (NDVI)) to account for vegetation (Matter et al ., 2012)

$$Ln\ (SSM) = b_3(NDVI) + b_2\ ln\ (\Gamma_{pH}\ (\theta)) + b_1\ ln\ (\Gamma_{pV}\ (\theta)) + b_0\ (\theta)$$

MODIS: NDVI

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

AMSR-E (TB)

ECMWF(TG)

SMOS (SSM)

vrije Universiteit amsterdam

Methods: 2) Regression Fusion (INRA)

2- Retrieve Soil moisture for the period (2003-2009)

TB (AMSR-E)

Regression coefficients

TG (ECMWF)

$$Ln\,(\mathbf{SSM}) = b_2\,\ln\,(\Gamma_{pH}(\theta)) + b_1\,\ln\,(\Gamma_{pV}(\theta)) + b_0\,(\theta)$$

Surface soil moisture (2003-2009)

vrije Universiteit   amsterdam

Methods: 3) LPRM Fusion (VUA)

- Apply the Land Parameter retrieval Model (LPRM)* on SMOS L3 and AMSR-L2 data
- Use the derived internal dielectric constants of SMOS and AMSR to merge the two datasets
- Try to avoid the use of ancillary data (e.g. land cover maps, LAI, soil maps)
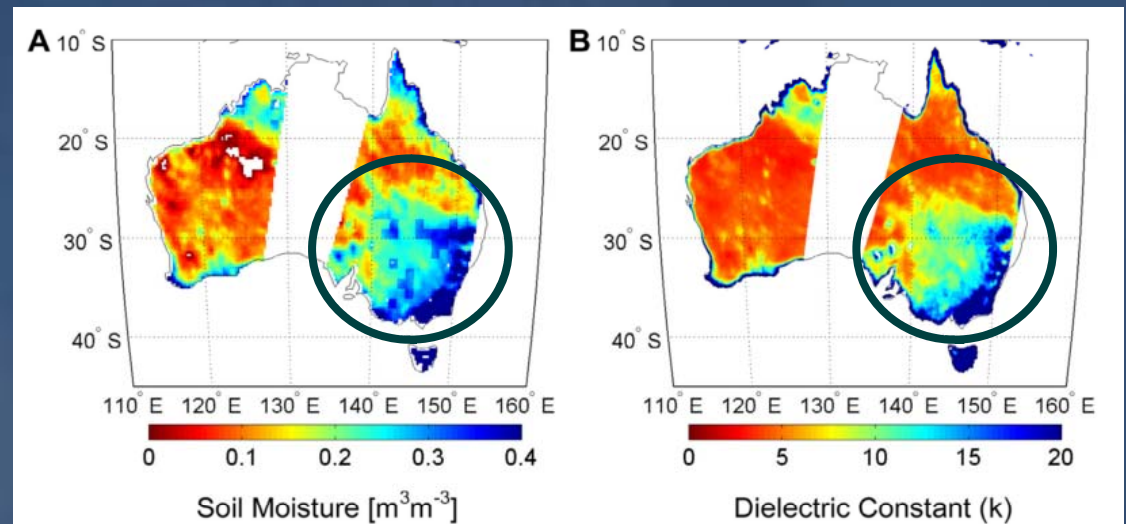
De Jeu et al., JoH, 2014

*LPRM is the baseline algorithm in CCI phase I

vrije Universiteit amsterdam

Methods: 3) LPRM Fusion (VUA)

Why dielectric constant:
- No ancillary data needed
- Large part is linear related with soil moisture
- Holds soil property info
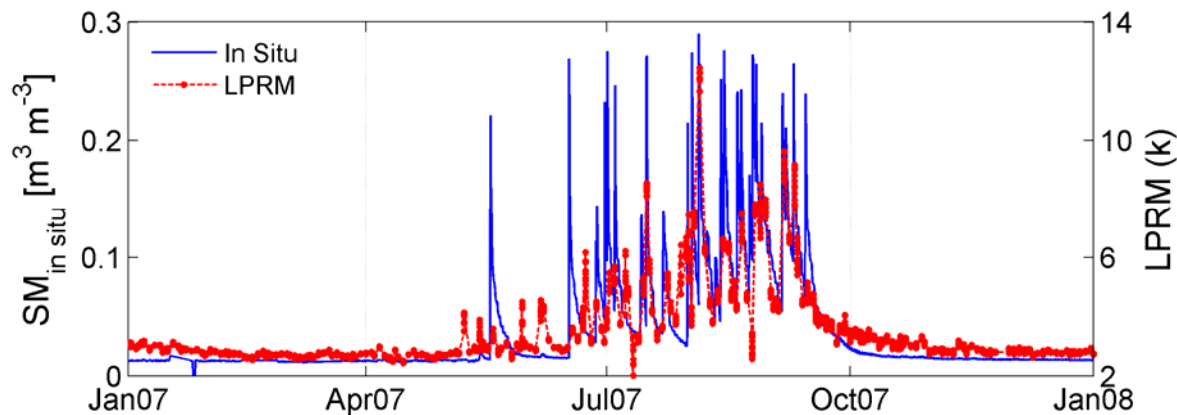
De Jeu et al., JoH, 2014
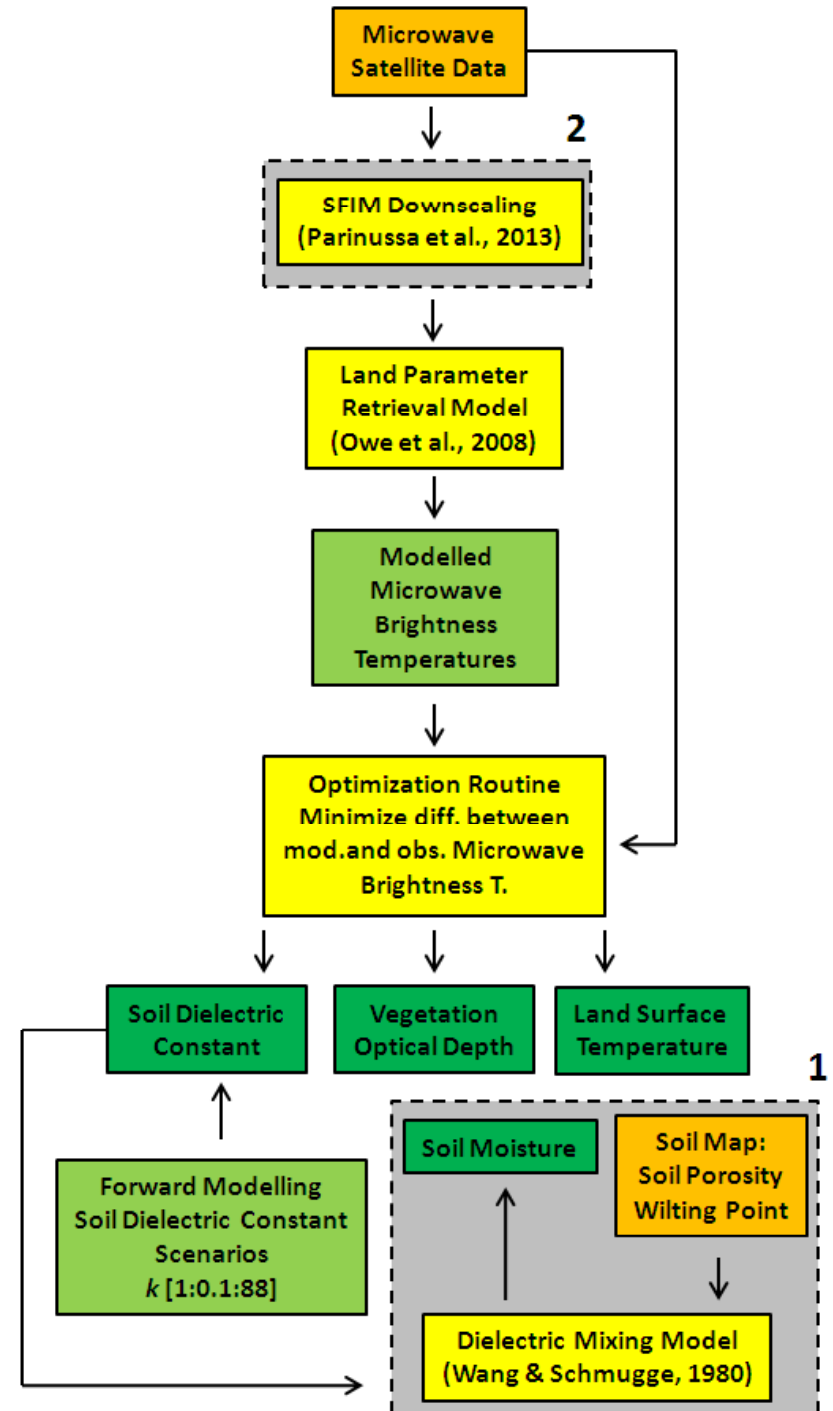
- Validation with In Situ data (standard metrics > Yann's Talk)
- Two global Evaluations
  - R-value Method (Parinussa et al., HESS, 2011)
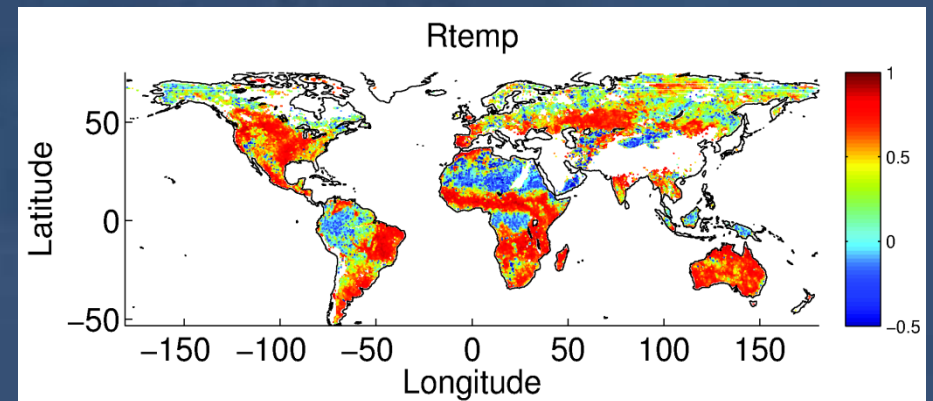 - Tripple Collocation Method (Dorigo et al., HESS, 2010)

Rvalue method for AMSR-E nighttime observations

R_{value}

- ASCAT
- AMSR
- Both

vrije Universiteit amsterdam
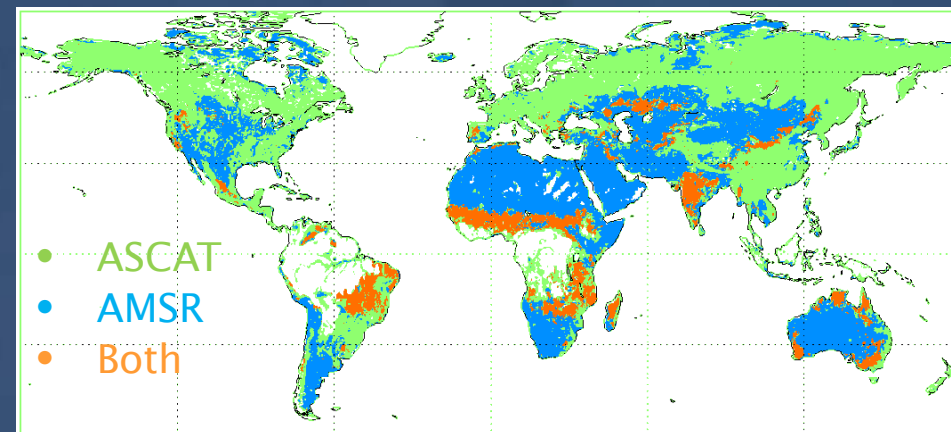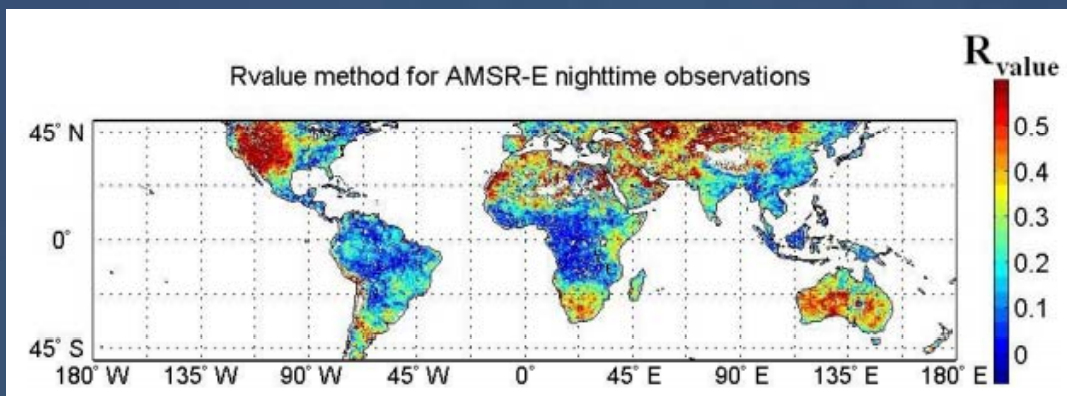
First Results (Method 1)

- SMOS_NN has been computed and trained with ECMWF SSM and SMOS L3 SSM
- The NN captures the temporal and spatial variability of SSM
- Validation against USDA SCAN sites gives the best statistics in comparison with ECMWF and SMOS L3 SSM → This product will be used as reference to train AMSRE_NN

Monthly mean of *daily* estimates for July 2010
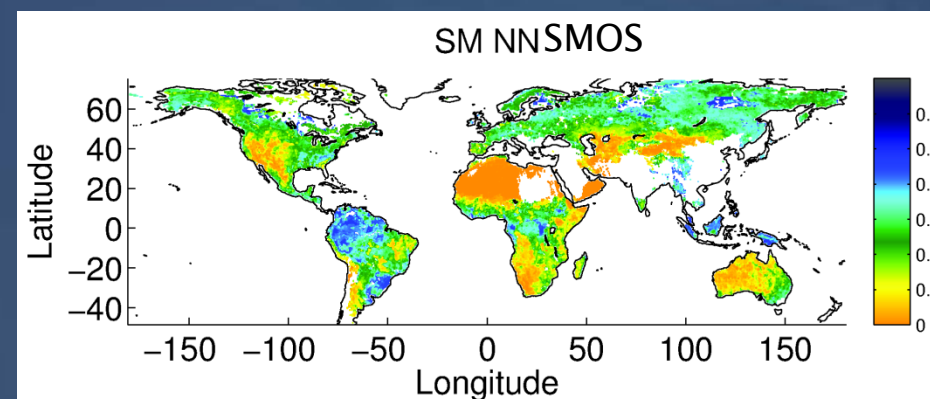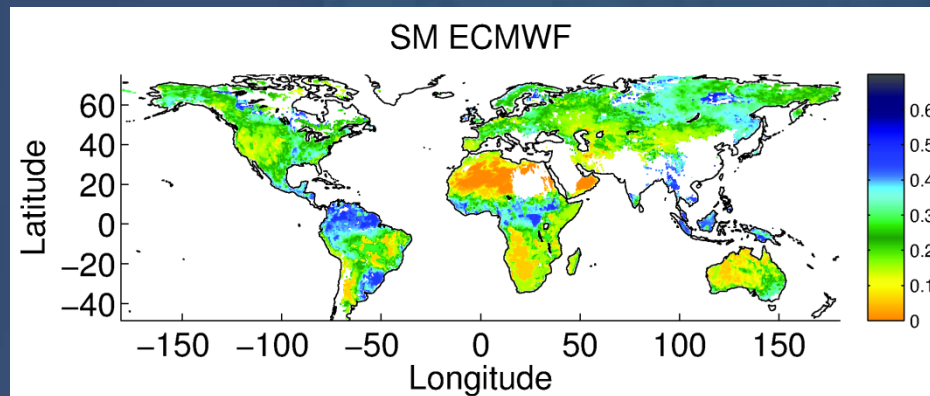
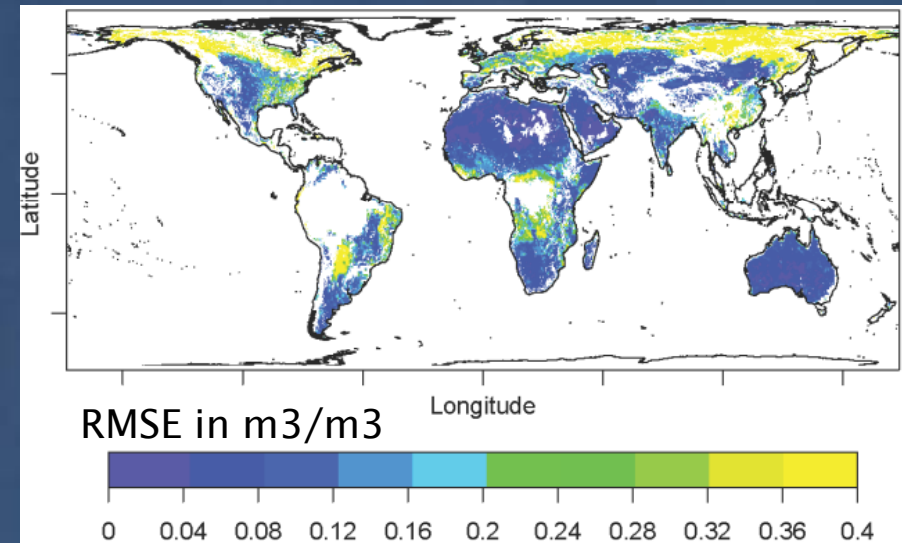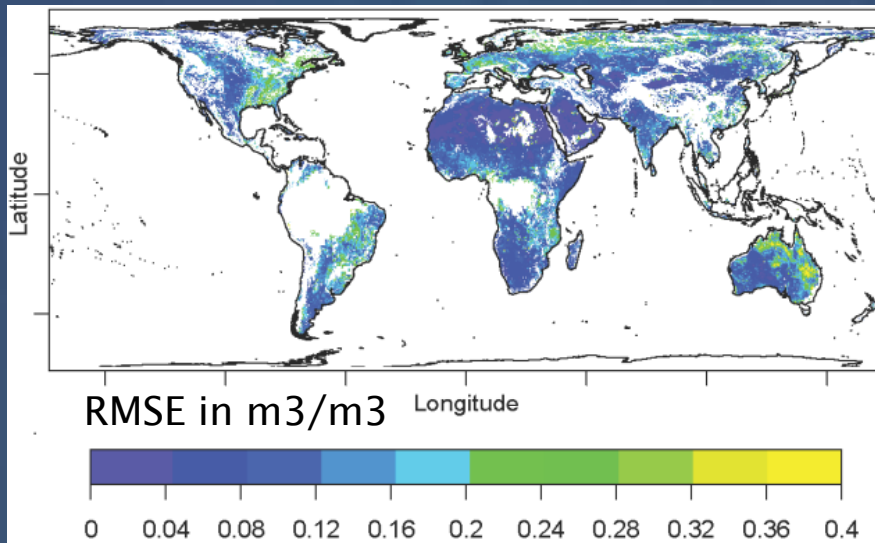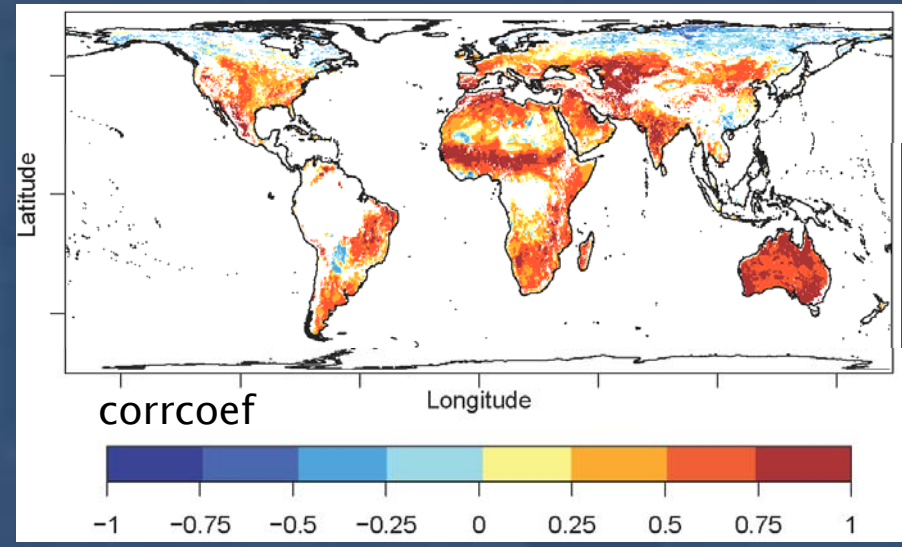Maps of temporal correlation and local time series variance

Rodriguez-Fernandez et al. IGARSS_2014
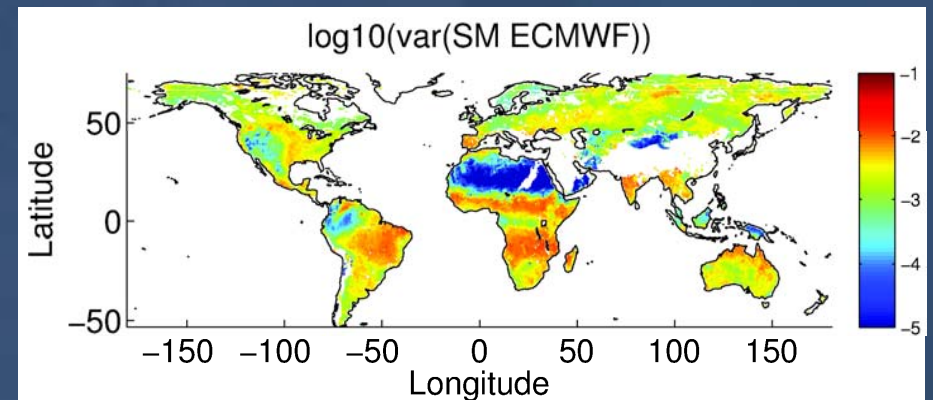
First Results (Method 2)

AMSR_REG /MERRA-Land

corrcoef

AMSR_LPRM/ MERRA-Land
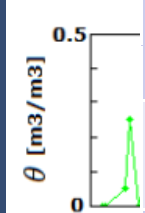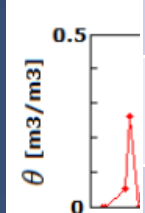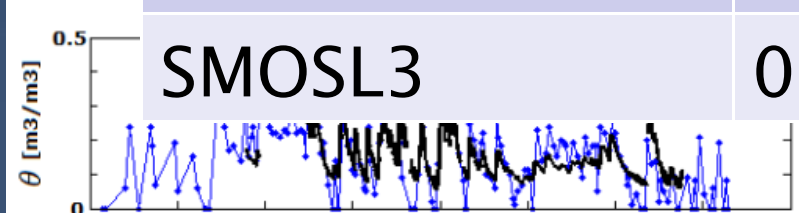

corrcoef

RMSE in m3/m3

RMSE in m3/m3

vrije Universiteit amsterdam
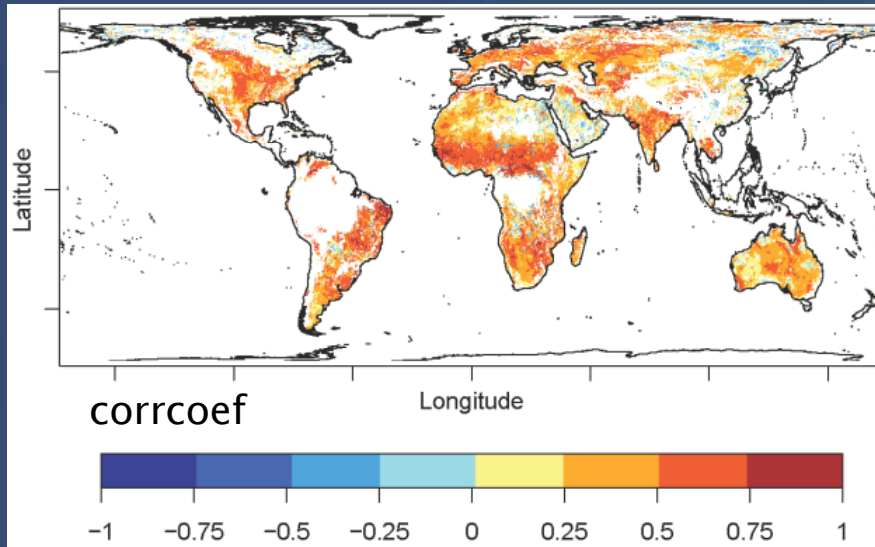
First Results (Method 3)

LPRM applied to SMOS over in situ sites of the Murrumbidgee catchment
Period: 2010-2011
Stations: 49 grouped in 17 cells (Su et al., 2013)
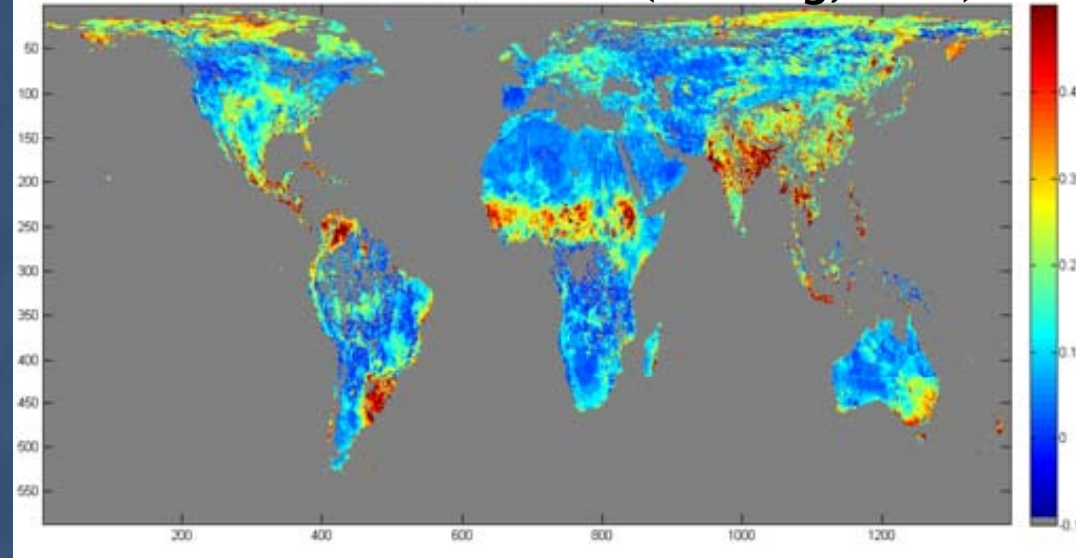
Product	R	RMSE	bias	N
45d LPRM	0.69	0.11	-0.01	1331
SMOSL3	0.75	0.09	0	1331
52.5d LPRM	0.70	0.09	-0.02	1423
SMOSL3	0.71	0.09	-0.01	1423
60 d LPRM	0.73	0.10	-0.01	1338
SMOSL3	0.76	0.09	-0.01	1338

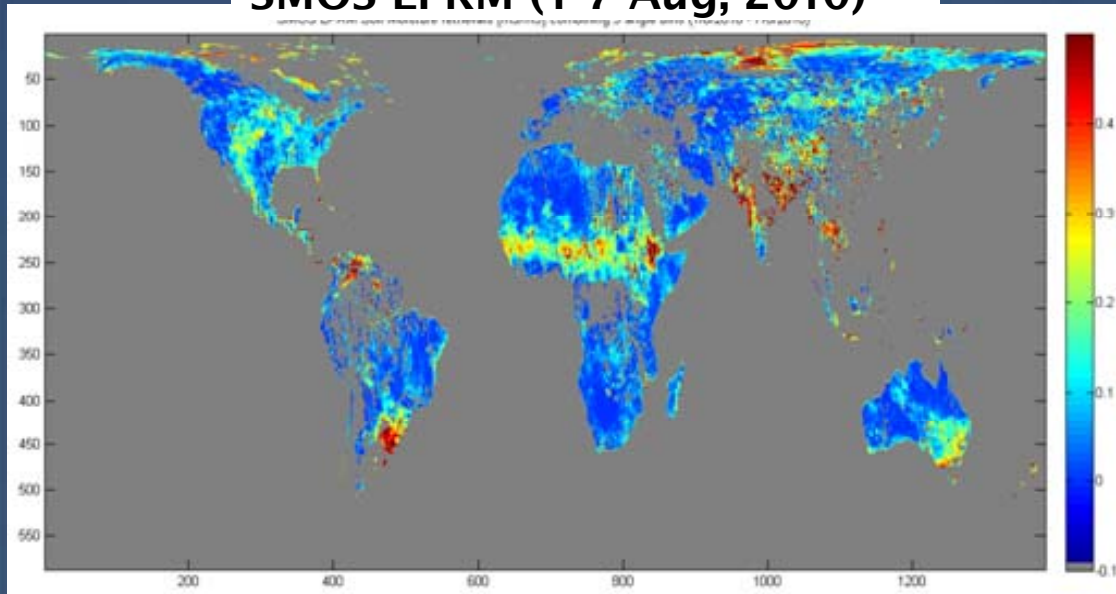Van der Schalie et al., RSE in review

First Results (method 3)

Spatial correspondence
SMOS L3 and SMOS_LPRM

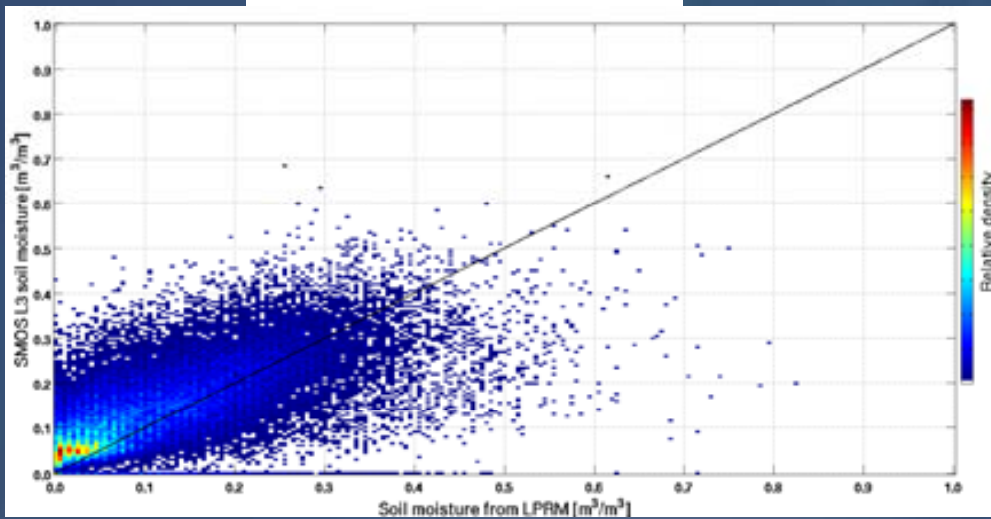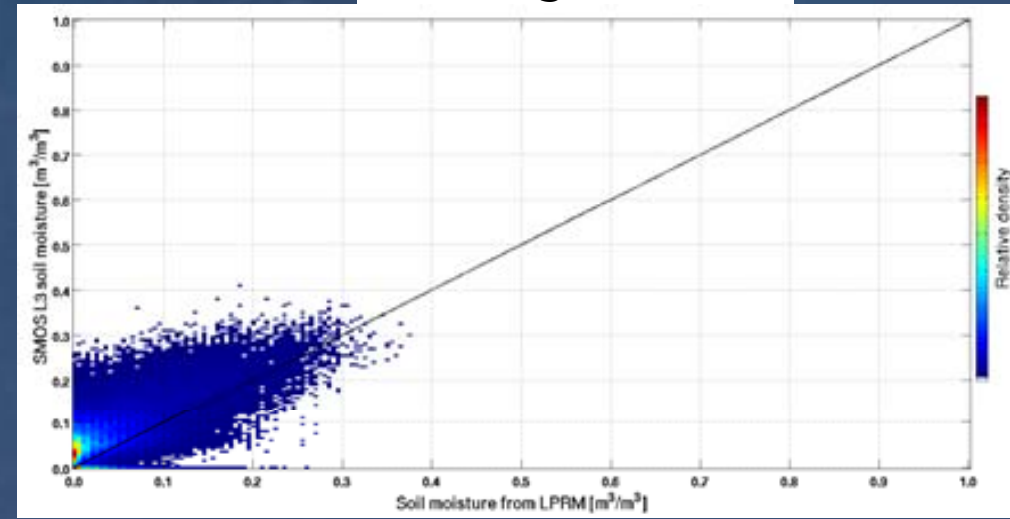SMOS L3 Soil Moisture (1-7 Aug, 2010)

SMOS LPRM (1-7 Aug, 2010)

First Results (method 3)

Spatial correspondence SMOS L3 and SMOS_LPRM
Scatter density plots (Y axis SMOSL3, X axis SMOS LPRM)
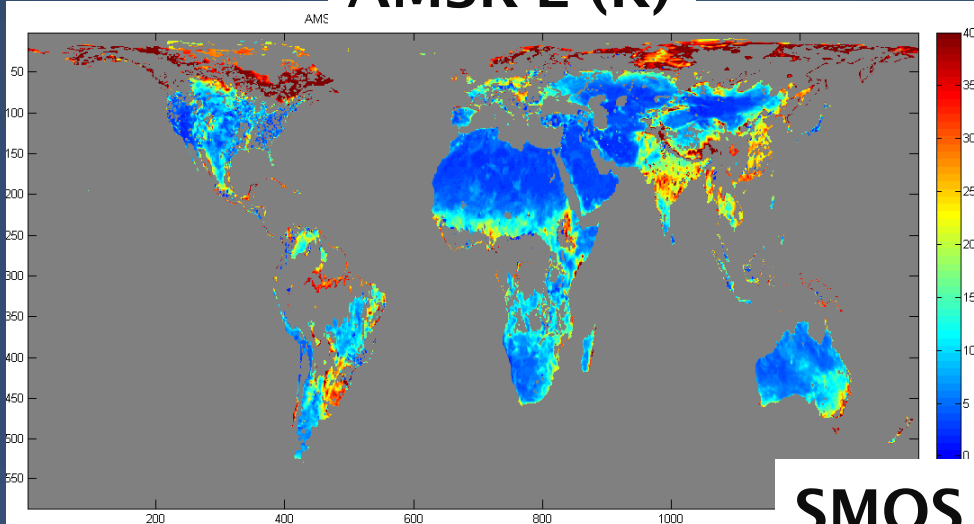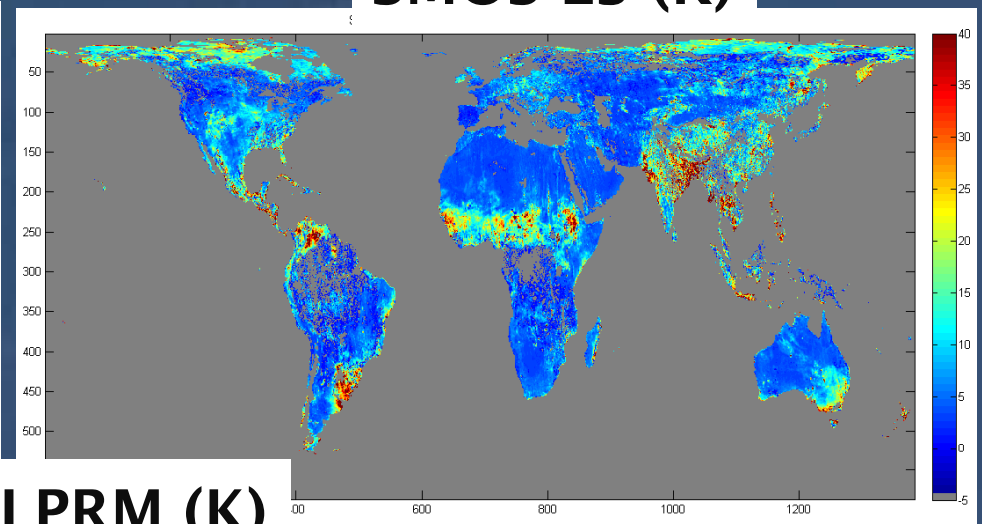
(3-9 Jan, 2010)

(1-7 Aug, 2010)

First Results (method 3)

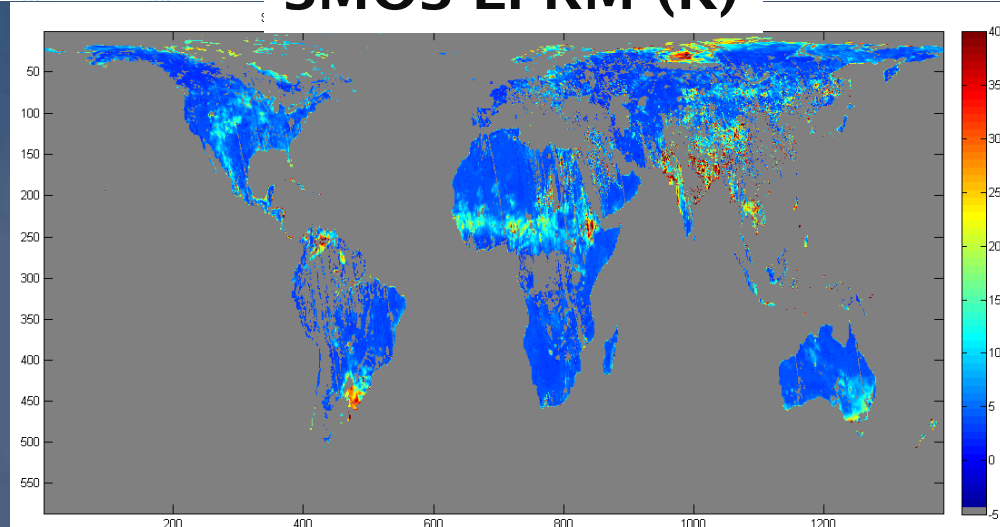## Dielectric constant (K) MOS L3 and SMOS_LPRM, AMSR-E,1-7 Aug2010

AMSR-E (K)

SMOS L3 (K)

SMOS LPRM (K)

vrije Universiteit amsterdam

Data Fusion project for SMOS integration in the CCI just started

3 Fusion methods will be tested

First results show the potential of all three different methods

vrije Universiteit   amsterdam

Next steps

- **Further development Fusion approaches**
- **Delivery of 10 year (2003-2013) merged datasets**
- **Evaluation datasets**
- **Guidelines CCI**