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Remote sensing of soil moisture

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FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

Acknowledgements

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- ESA-MOST Dragon II Advanced Training Course in Land Remote Sensing, lectures by T. Le Toan, Z. Su
- Presentation at the Kick-off of WACMOS project by W. Wagner, R. de Jeu
- Z. Su, R. Van der Velde, C. Prigent, 2006, Remote Sensing of Soil Moisture – A review, ESA summer school on environmental modelling and data assimilation
- ESA summer school on environmental modelling and data assimilation, lectures by Z. Su
- With contributions from J. Wen (CAREER/CAS), Y. Ma (ITP/CAS), R. van der Velde, L. Dente, Z. Vekerdy, L. Wang, Y. Zeng, S. Lv, P. Ferrazzoli (UR)

OBJECTIVES

- Basics in remote sensing of soil moisture
- Some examples of soil moisture products
- How good are these data?
- Current researches

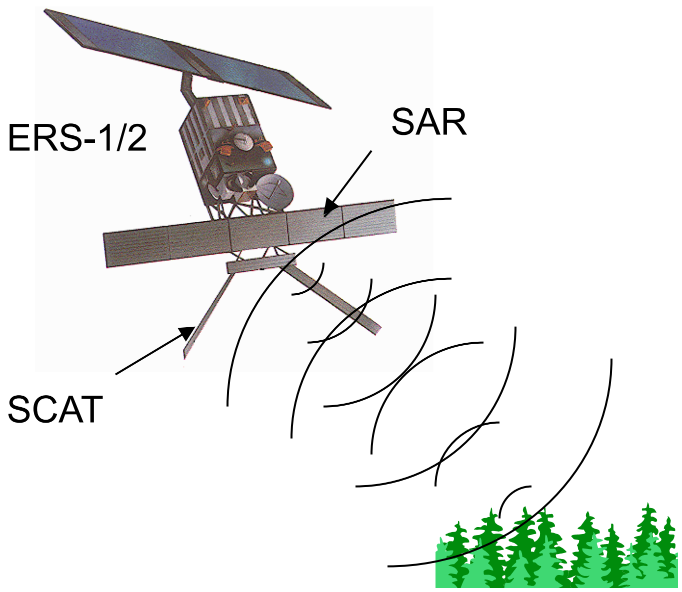
BASICS IN REMOTE SENSING OF SOIL MOISTURE

What is microwave ? How does it work?
What is the physical process involved?

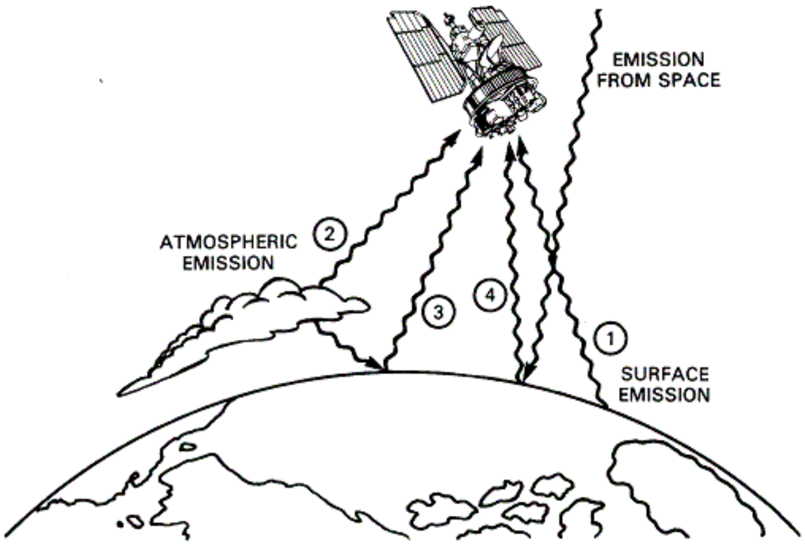
Measurement Principles

- Radars measure the energy scattered back from the surface
- Radiometers measure the self-emission of the Earth's surface
- Passive and active methods are interrelated through Kirchhoff's law:
  Emissivity = 1 – Reflectivity

Active Sensors

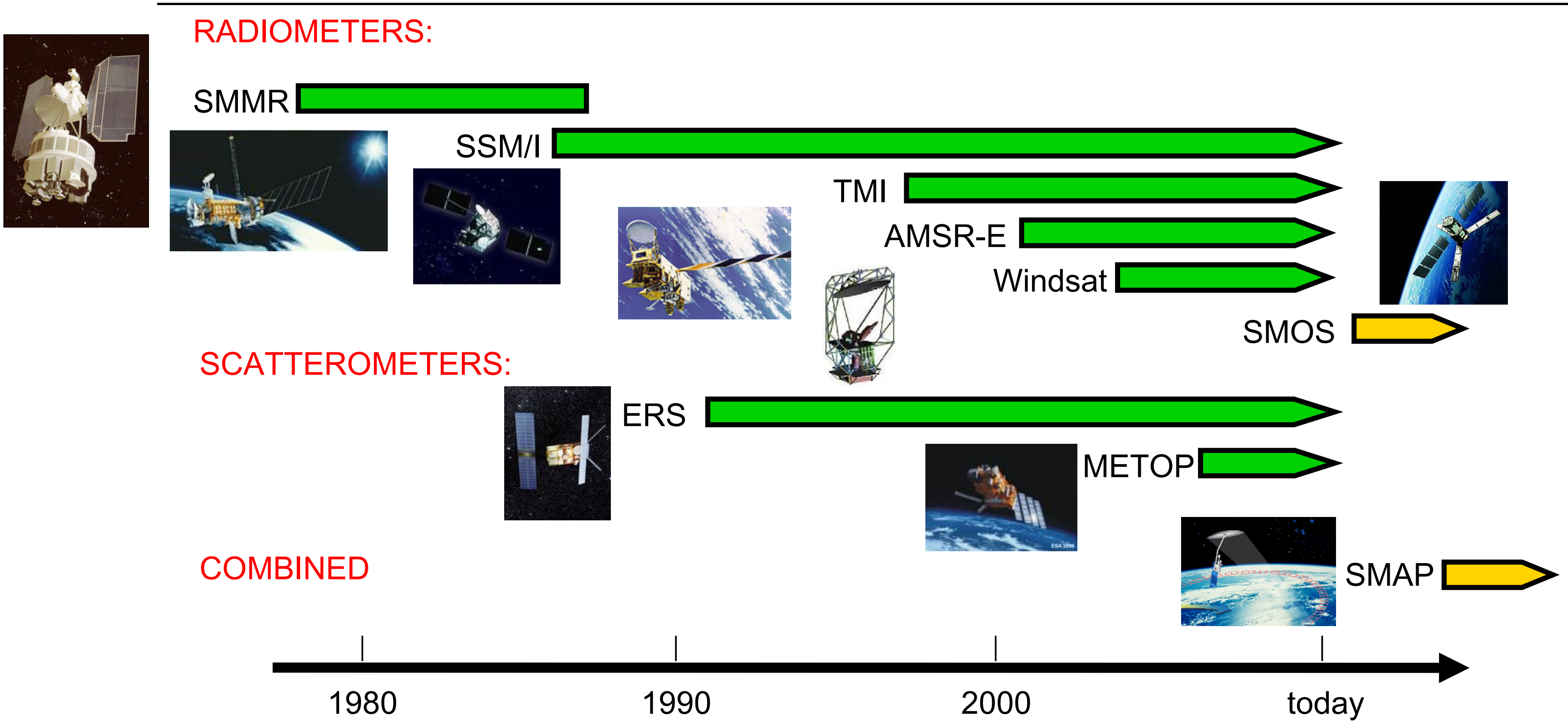


Passive Sensor



(Source: W. Wagner, R. de Jeu)

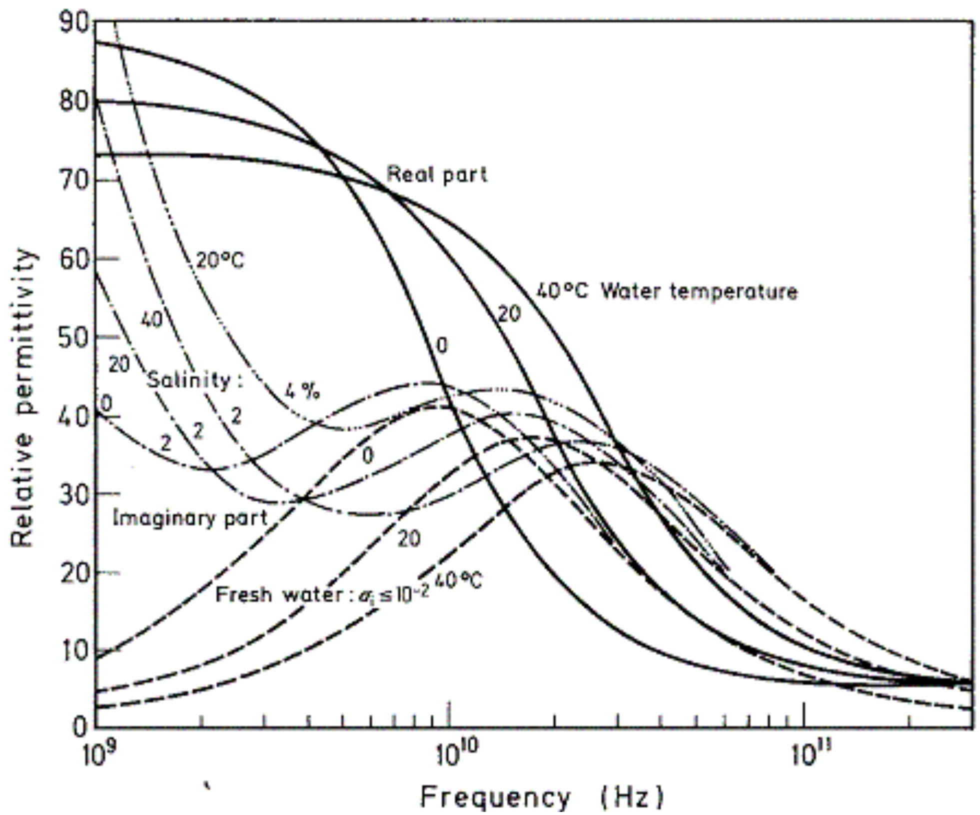
Microwave Sensors

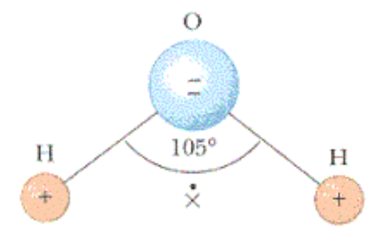


(Source: W. Wagner, R. de Jeu)

Dielectric properties of materials

- No-polar materials are chracterized by constant value of dieletric constant ϵ_r,
- For polar materials, dieletric constant ϵ_r can be expressed by the Debye equation



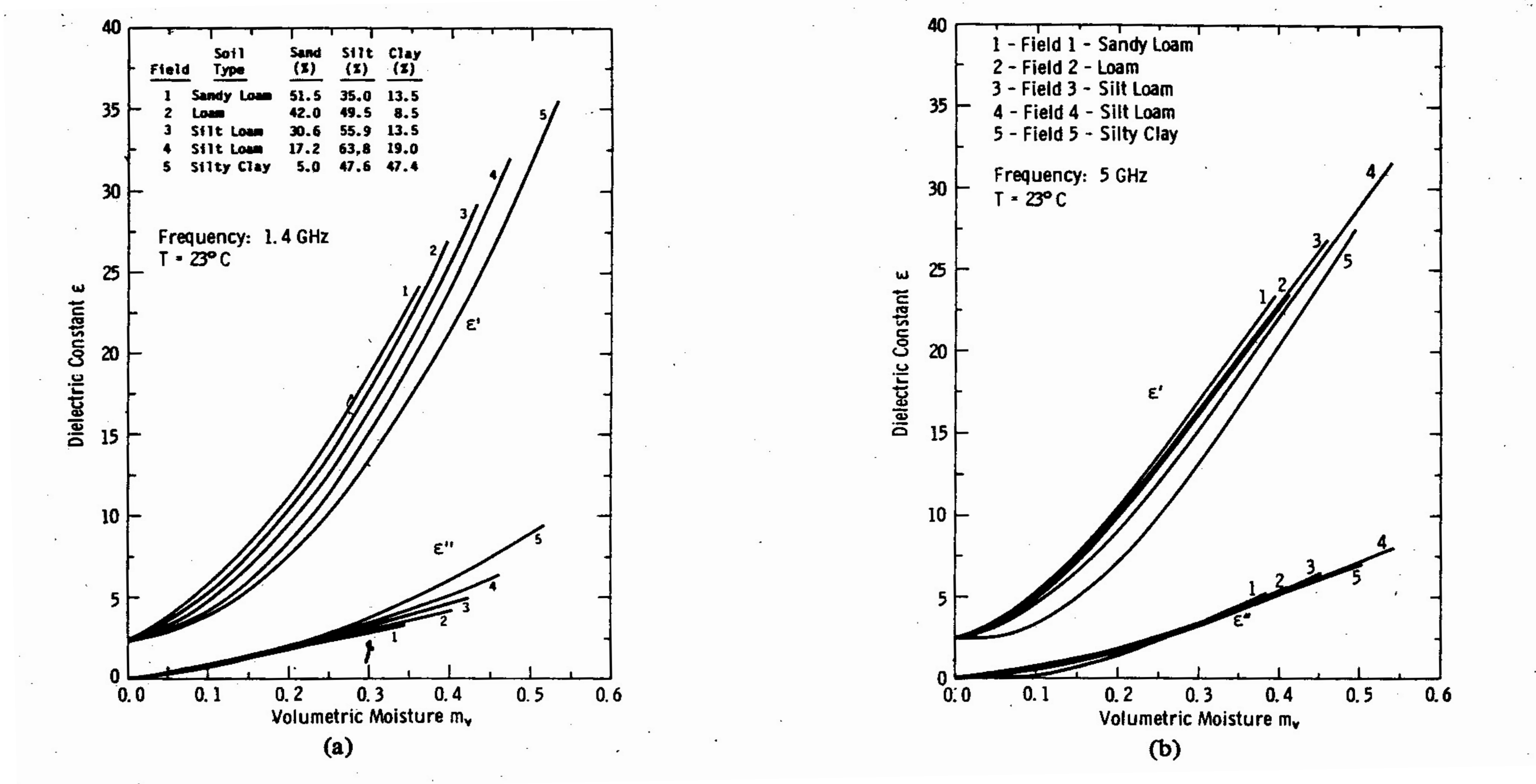


The dipole moment of water molecules causes “orientational polarization”, i.e. a high dielectric constant

Relative permittivity of pure water and sea water at 0, 20, 40 ^{0}C.

Dielectric constant and soil moisture

- On the basis of an estimate of the mixture dielectric constant derived from the Fresnel equations and soil texture information, volumetric soil moisture can be estimated (*Hallikainen et al. 1985).*



The radar cross-section

The radar cross-section (RCS) is defined as

$$\sigma_{pq} = 4\pi \left| S_{pq} \right|^2 = 4\pi R^2 \frac{P_s}{P_i} \qquad \left[\mathrm{m}^2\right]$$

R is the radar-target distance
P_i is the incident power,
P_s is the power scattered by the target.

(Source: T. Le Toan)

The backscattering coefficient

For **distributed targets** each resolution cell contains many scatterers and the phase varies rapidly with position.

The **differential backscattering coefficient**, σ^o, is

$$\sigma^o = \frac{4\pi R^2}{\Delta A} \frac{P_s}{P_i} \quad [m^2/m^2]$$

where ΔA is the area of the illuminated surface over which the phase can be considered constant.

(Source: T. Le Toan)

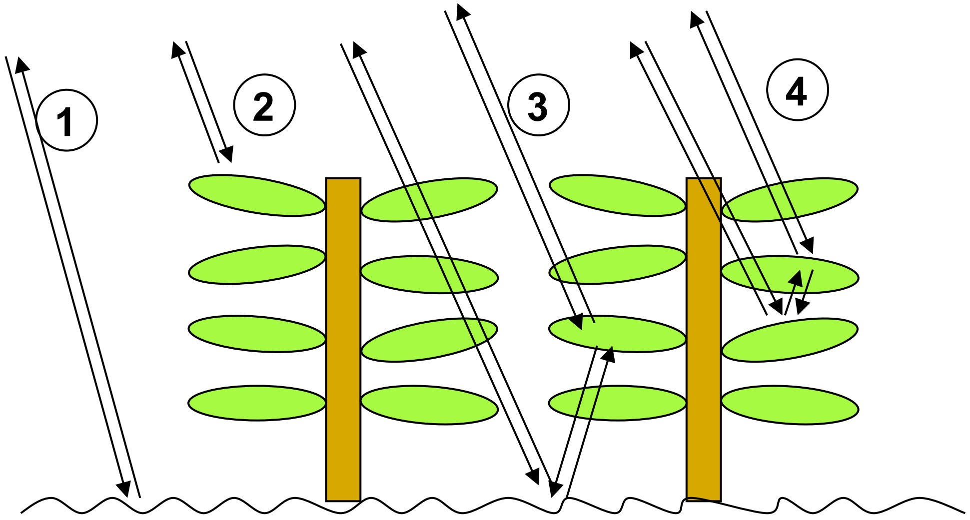
Dielectric properties of materials

- **Decibel (dB)** is defined as 10 times of the logarithm to the base 10 of an energy ratio, (dB) = 10 log

$$x\left(dB\right)=10\log_{10}X,\quad X=\frac{P_s}{P_i}\quad\left(-\right)$$

Microwave scattering approaches

- Microwave scattering terms that are typically represented in physical scattering methods



$$\sigma^o = \sigma^o_{sur} + \sigma^o_{veg} + \sigma^o_{sur-veg} + \sigma^o_{veg-veg}$$

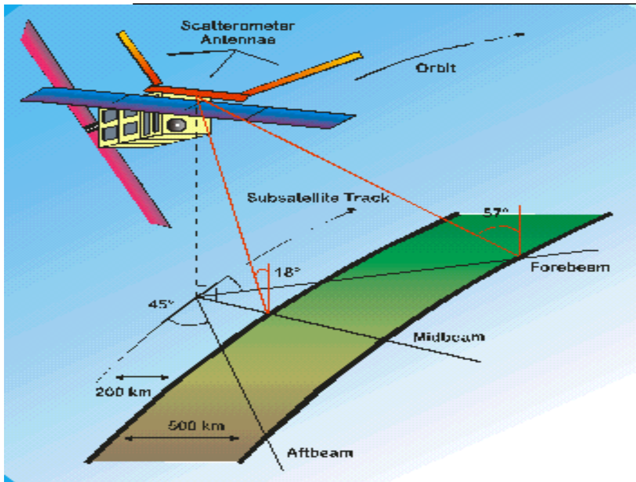
Physical processes in retrieval of soil moisture

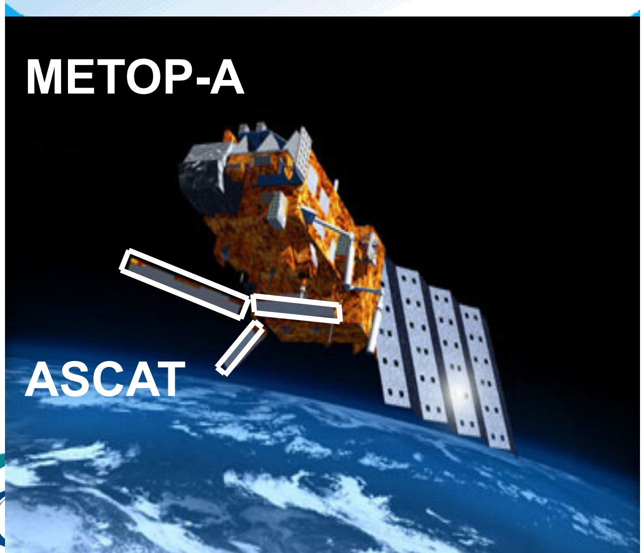
- The basic reason microwave remote sensing is capable of providing soil moisture information is that there is a large difference between the **dielectric constants of water (~80) and the soil particles (~4).**
- The Fresnel reflection equations (Ulaby *et al.*, 1986) predict the surface reflectivity (R_0^p) as a function of dielectric constant (ε_r) and the viewing angle (θ), (polarization p=horizontal-H or vertical-V).

$$R_0^H = \left| \frac{\cos\theta - \left(\varepsilon_r - \sin^2\theta\right)^{\frac{1}{2}}}{\cos\theta + \left(\varepsilon_r - \sin^2\theta\right)^{\frac{1}{2}}} \right|^2 \qquad R_0^V = \left| \frac{\varepsilon_r\cos\theta - \left(\varepsilon_r - \sin^2\theta\right)^{\frac{1}{2}}}{\varepsilon_r\cos\theta + \left(\varepsilon_r - \sin^2\theta\right)^{\frac{1}{2}}} \right|^2$$

- From the reflectivity, the dielectric constant of the soil can be estimated. The dielectric constant of soil is a composite of the values of its components: air, soil particles, and water (bound and free water).

Microwave remote sensing of soil moisture





- Retrieval with Radiative Transfer Equation (Wen and Su, 2003a, Phy. Che. Earth)
- Retrieval with change detection method (Wen and Su, 2003b, Geophys. Res. Letter)

Retrieval with Radiative Transfer Equation

For the three antennae forward (45°), sideways (90°), and afterward (45°), (Wen & Su, 2003)

$$\sigma^0(\theta) = [1 - F_c(1 - T^2(\theta))]\sigma^0_{soil} + F_c(\sigma^0_{\text{int}} + \sigma^0_{veg})$$

$$\sigma^0_{soil}(\theta) = \frac{|\Gamma(0)|^2 \exp\left(-\frac{\tan^2\theta}{2s^2}\right)}{2s^2\cos^4\theta}$$

$$\sigma^0_{veg}(\theta) = \frac{\kappa_s \cos\theta}{2\kappa_e}[1 - \exp(-2\kappa_e \sec\theta)] = \frac{1}{2}\omega_v \cos\theta[1 - T^2(\theta)]$$

Where:

$\sigma^0(\theta)$ is observed backscattering coefficient,

θ is incidence angle,

F_c is vegetation fractional coverage,

$T^2(\theta)$ is canopy transmittance in two ways of incoming and outgoing path,

σ^0_{soil} is contribution of soil, σ^0_{veg} is vegetation volumetric contribution,

σ^0_{int} is the contribution from land surface-vegetation interaction.

$s = \sqrt{2}\sigma / l$ is the root mean square (RMS) slope of surface height,

σ is standard deviation of the surface height,

l is horizontal distance between two different points on the surface using a Gaussian correlation function,

$\Gamma(0)$ is soil Fresnel reflectivity at normal incidence of a half-space.

κ_s and κ_e are scattering and extinction coefficient of vegetation discrete elements.

ω_v is the single scattering albedo of the vegetation scatters.

from above eqs, we solve for F_c, $\Gamma(0)$, s or T (with some additional input for vegetation)

Retrieval with Radiative Transfer Equation

Radar backscatter of tree antennae (three azimuth angles)

↓

Vegetation transmissivity, Reflectivity at nadir, Roughness slope ← Vegetation fractional coverage

↓

Dielectric constant (dielectric mixing model) ← Soil texture (percentage of sand and clay)

↓

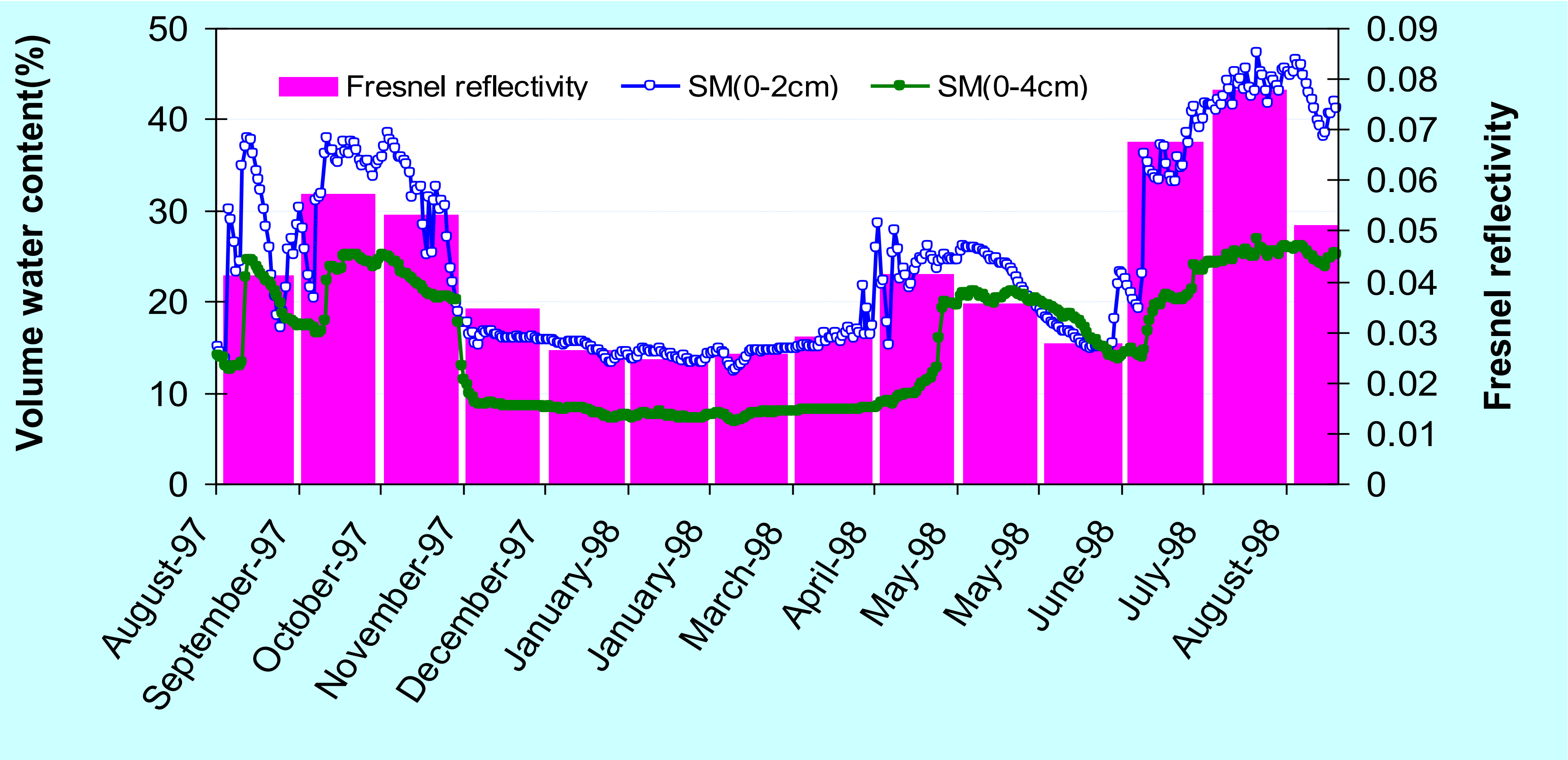
Soil moisture

Given Γ(0), we solve for the dielectric constant, ϵ_r (real part, $\epsilon = \epsilon_r - j\epsilon_i$)

$$\Gamma(0) = \left| \frac{1 - \sqrt{\varepsilon_r}}{1 + \sqrt{\varepsilon_r}} \right|^2$$

From ϵ_r, we solve for soil moisture Mv, using the dielectric mixing model of Dobson (1986), Peplinkski (1998).

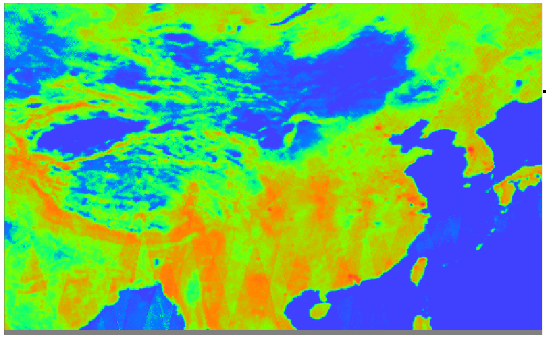
Estimated Fresnel reflectivity and ground measured volume soil water content



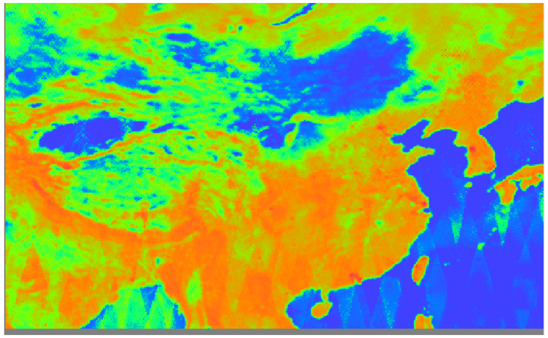
Some results with ASCAT data

(CEOP-AEGIS WP4)

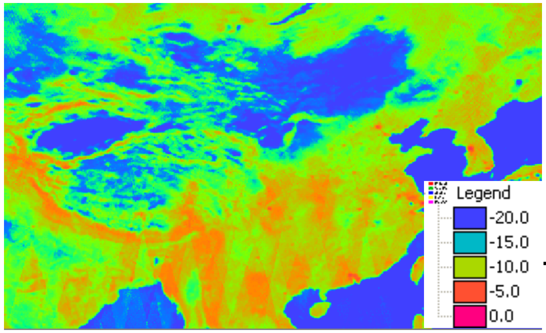
sigma zero triplet for values (dB)



sigma zero triplet mid values (dB)



sigma zero triplet after values (dB)



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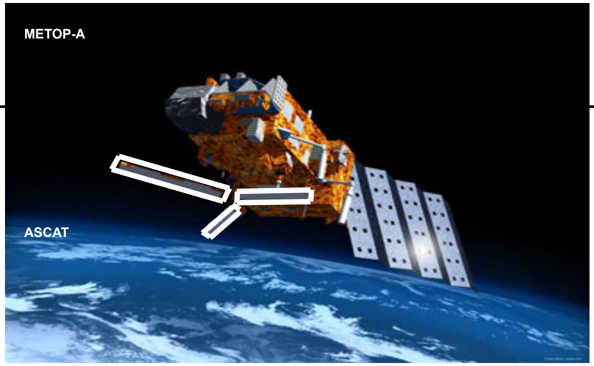
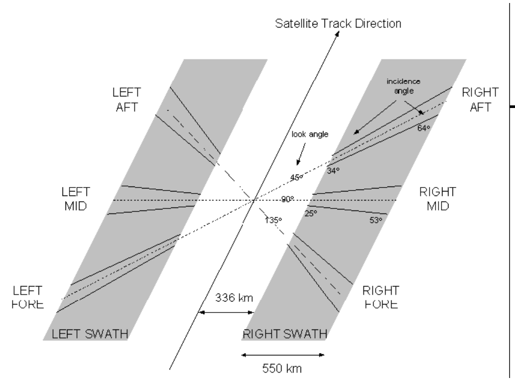
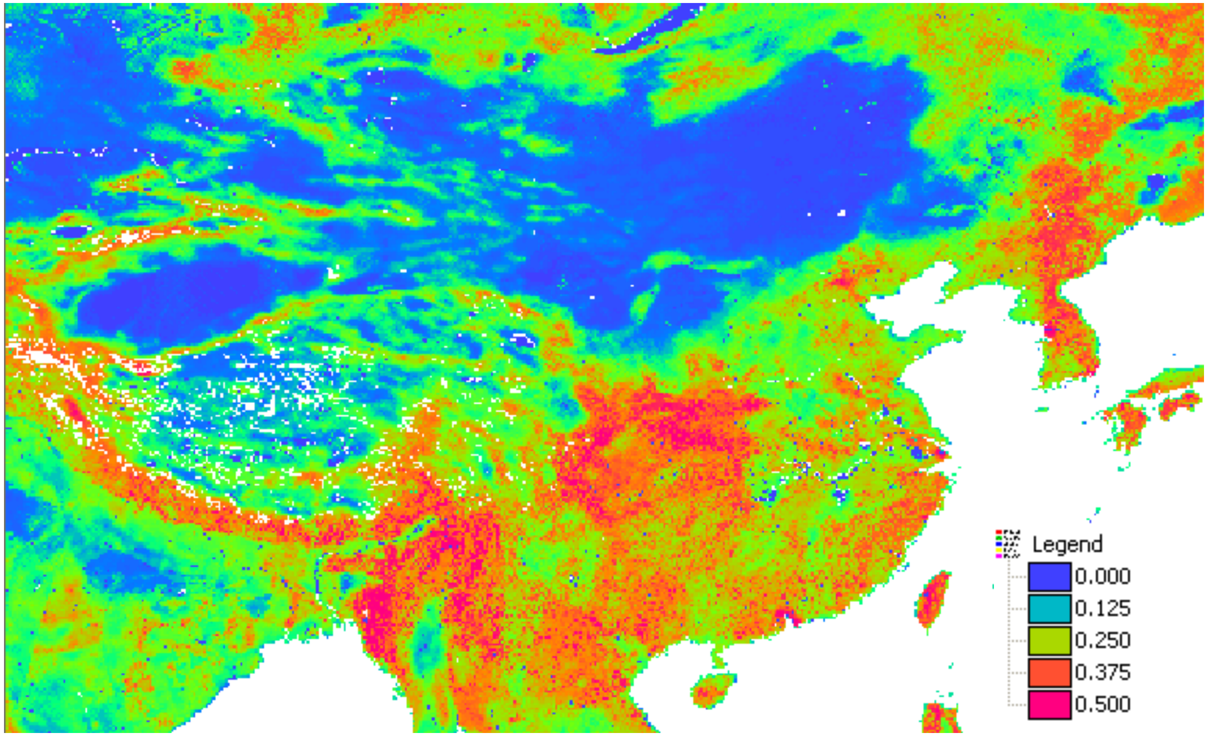




Soil moisture (m3/m3)



Microwave radiometer methods

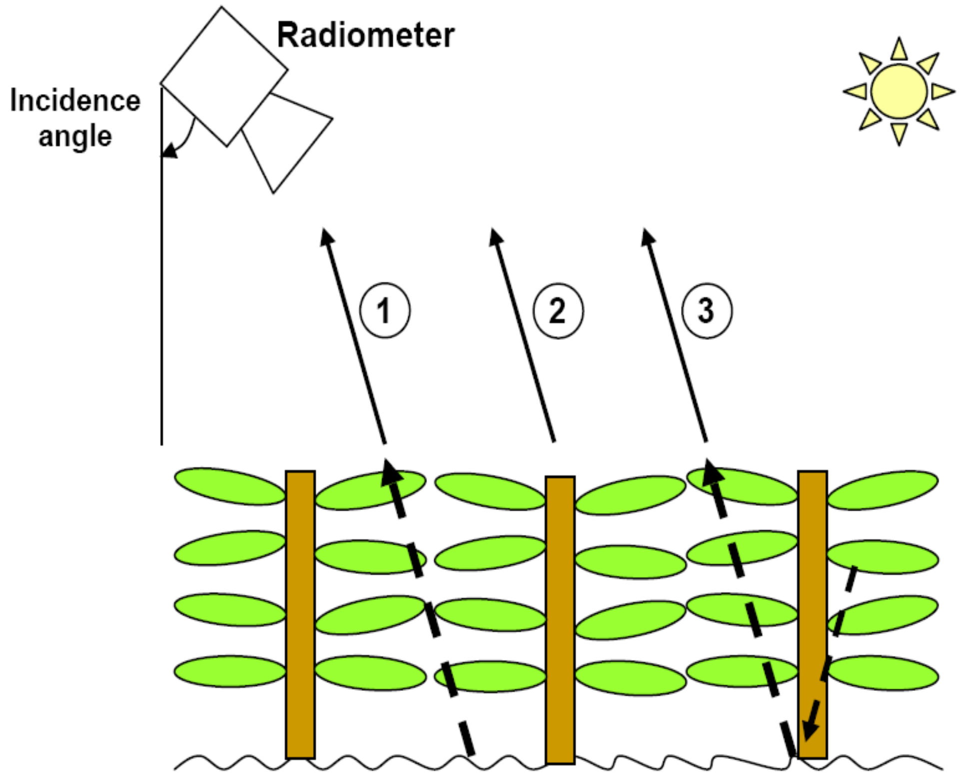


Figure 1. schematic representation of the different microwave emission terms over a vegetated surface.

$$T_B = (e_s \Gamma) T_s + (1-\omega)(1-\Gamma) T_c + (1-e_s)(1-\omega)(1-\Gamma) T_c$$

Passive microwave soil moisture retrieval algorithms

Overview algorithms	Input variables	Methods
Temperature correction: $e_l = \frac{T_B}{T}$	**Temperature of the emitting layer**	• Model inversion (Wen et al. 2003, and Bindlish et al. 2003) • 37 GHz microwave observations (Owe et al. 2001) • Other data sources, i.e. in-situ measurement, meteorological
Vegetation correction: $e_{surf} = 1 + [e_l - 1]\mathrm{e}^{\left(-2\tau/\cos\theta\right)}$	**Optical depth, single scattering albedo**	• 10.65 GHz MDPI (Wen et al. 2003) • 6.6 GHz MDPI and model simulations (Owe et al. 2001) • $\tau = bW$ where *W* represents the vegetation water content and NDVI is used as a surrogate variable
Surface roughness: $e_{smooth} = 1 - \left[1 - e_{surf}\right]\mathrm{e}^{\left(-h\cos^2\theta\right)}$	**Surface roughness**	• Derived from the ERS-Windscatterometer (Wen et al., 2003) • *h* is assumed to 0.1 (Jackson 1993 and Bindlish et al. 2003)
Dielectric constant (ε_r)	**Soil texture information**	Soil texture information can be obtained from national and international soil survey agencies

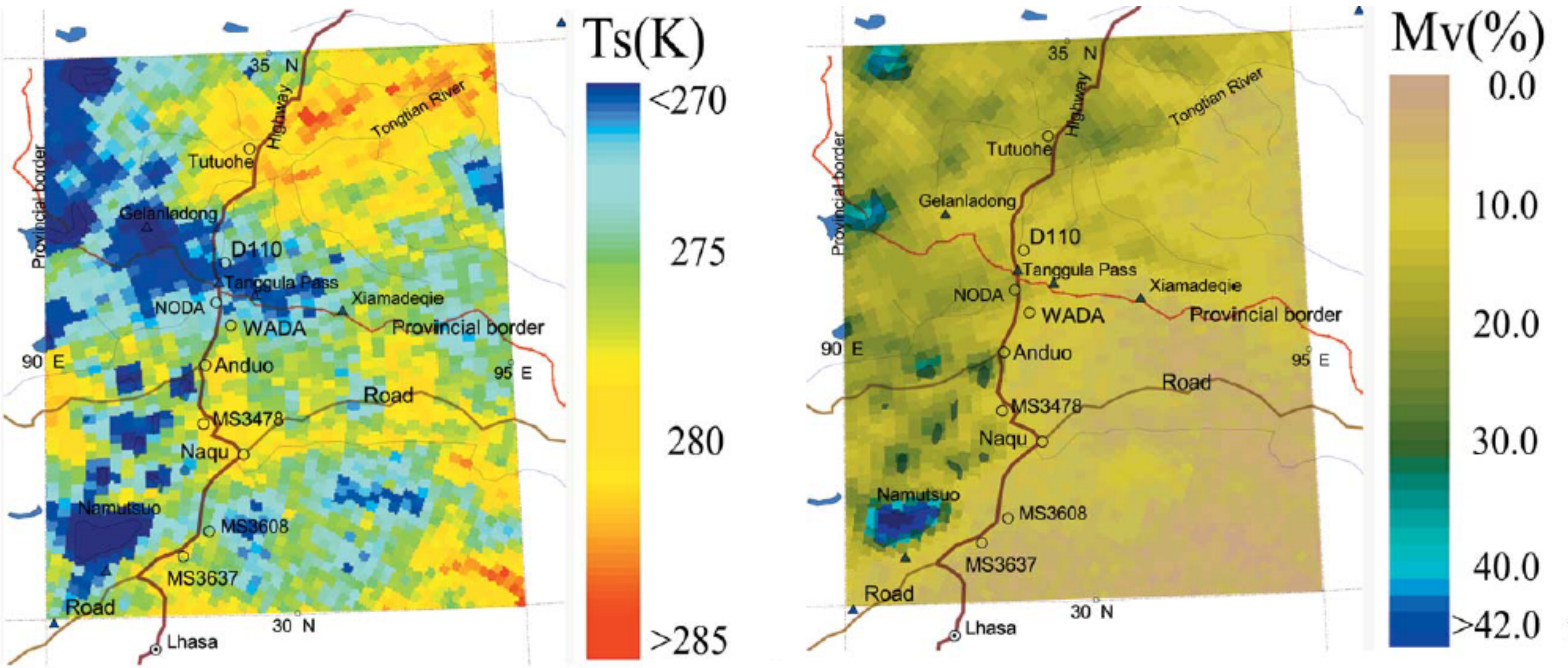
Ernesto

SOME EXAMPLES OF SOIL MOISTURE PRODUCTS

- Satellite retrievals
- Model outputs
- Reanalysis datasets

Retrieved land surface temperature and soil moisture from TRMM/TMI data compared to GAME/Tibet in-situ data

(Wen, Su, Ma, 2003, JGR)



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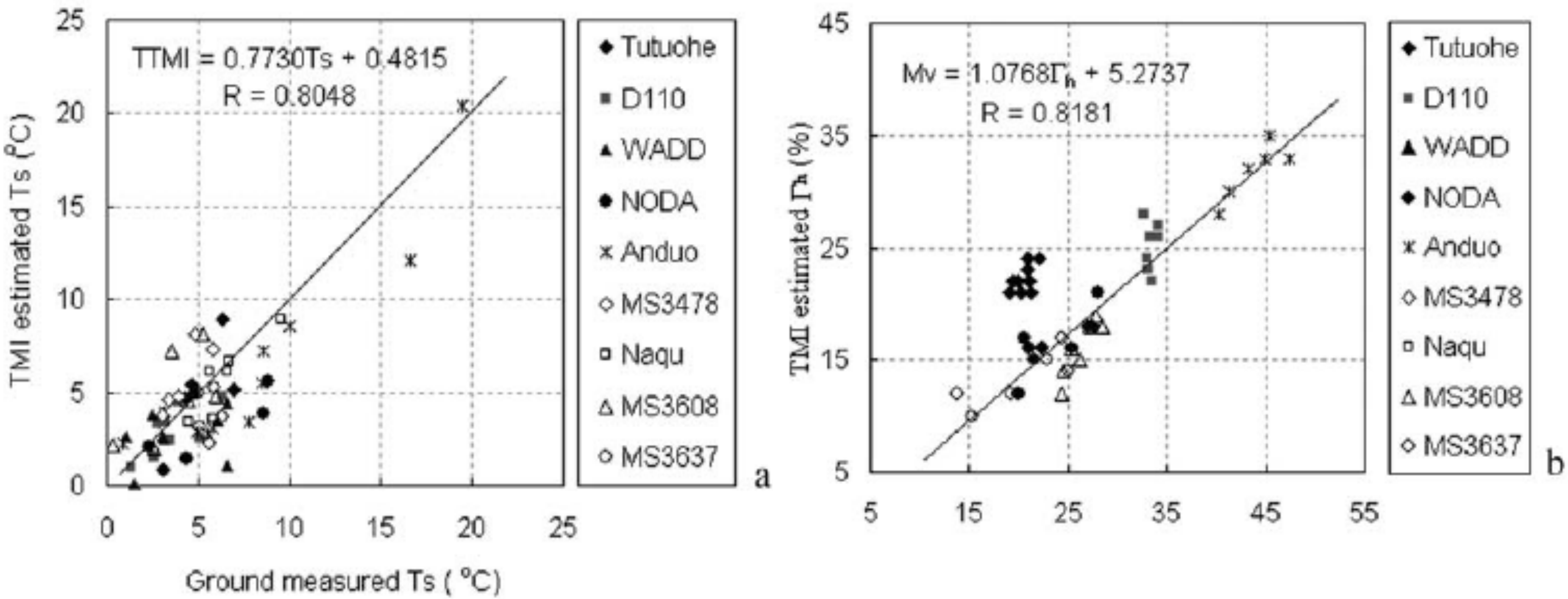
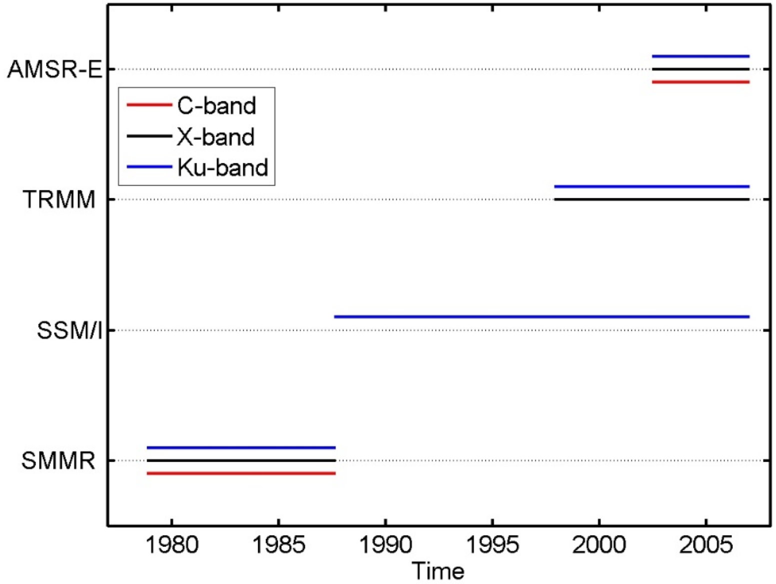


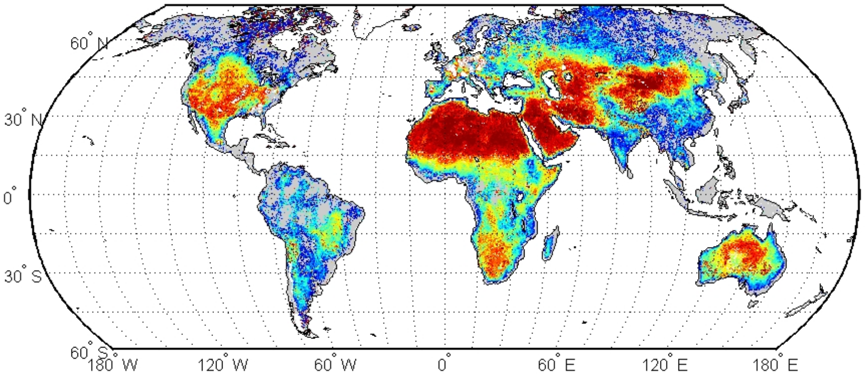
VUA Dataset

- A 30 year soil moisture dataset is derived using the Land Parameter Retrieval Model (LPRM)
  - Describes surface soil moisture (~ 1-2 cm)
    - ~ daily coverage
    - ~ 0.25 degree resolution
  - Sensors
    - SMMR
    - SSM/I
    - TMI
    - AMSR-E

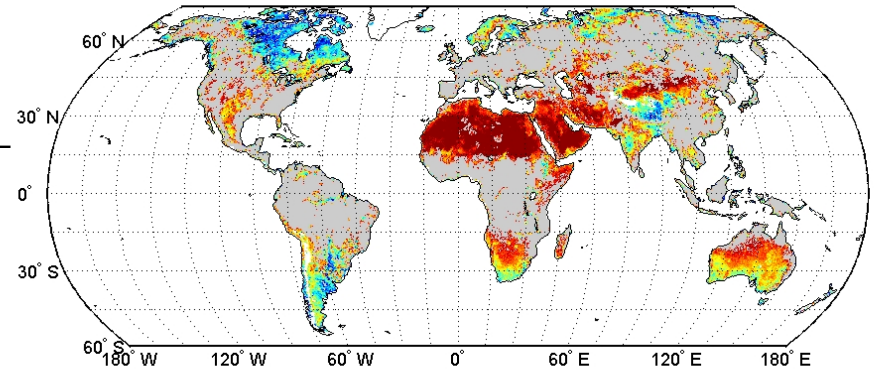


(Source: R. de Jeu)

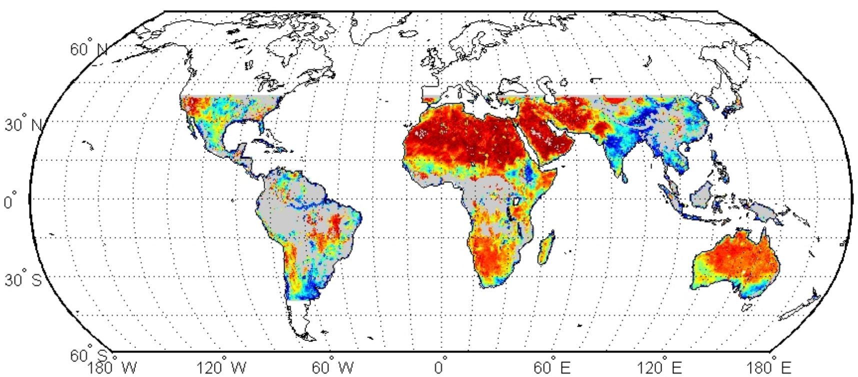
SMMR, July 1980 (C-band)
(1978-1987)



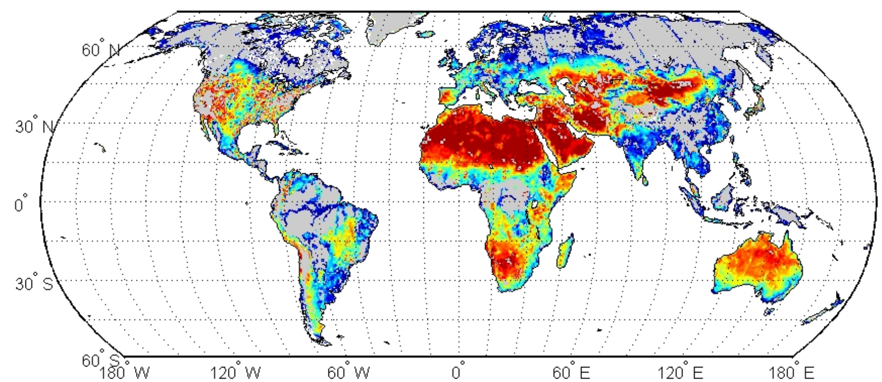
SSM/I, July 2004 (Ku-band)
(1987-Now)



TRMM, July 2004 (X-band)
(1997-Now)



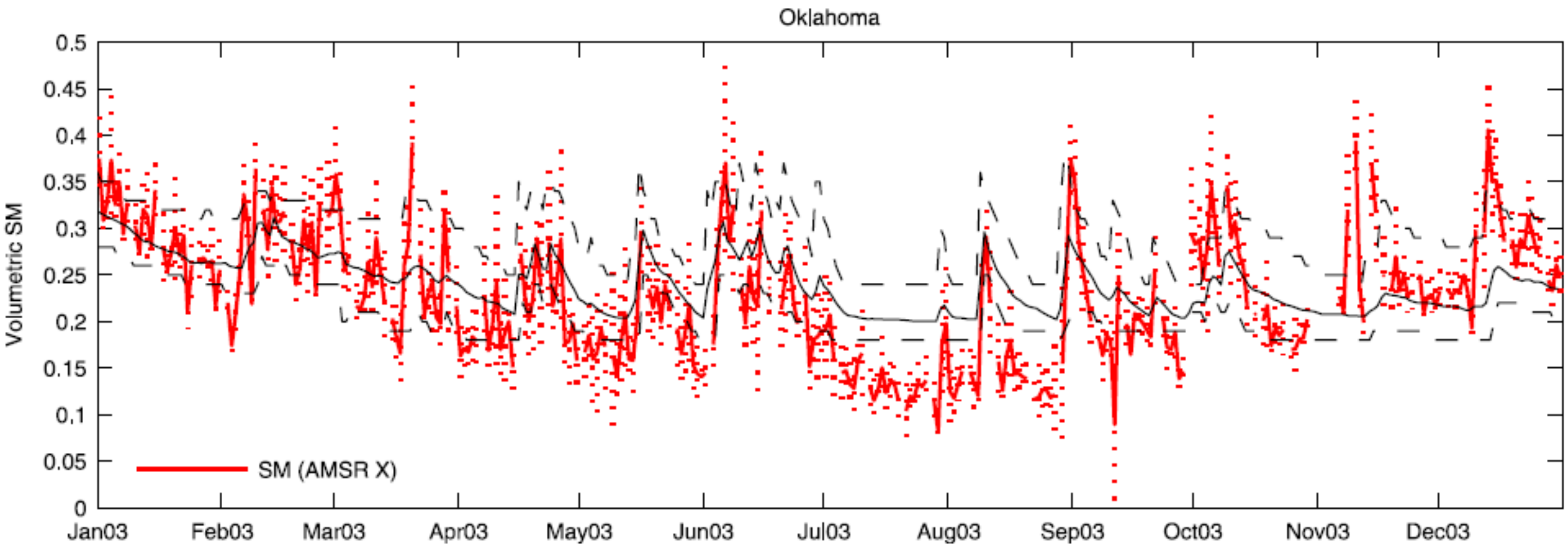
AMSR-E, July 2004 (C-band)
(2002-Now)



SM in m^3m^{-3}

(Source: R. de Jeu)

Comparision with In-situ measurements

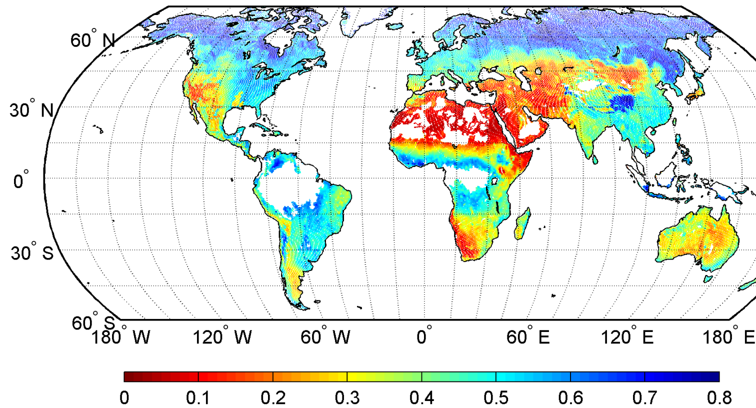


Soil Moisture Dynamics in Oklahoma, USA (from Owe et al, JGR, 2008)

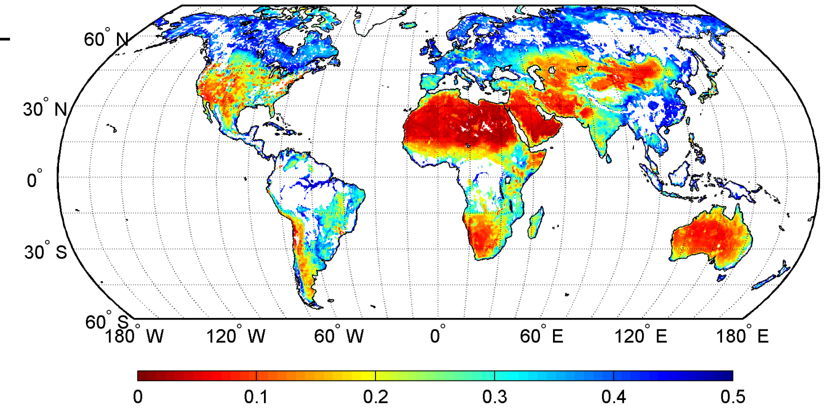
(Source: R. de Jeu)

Comparison SCAT and AMSR-E Soil Moisture

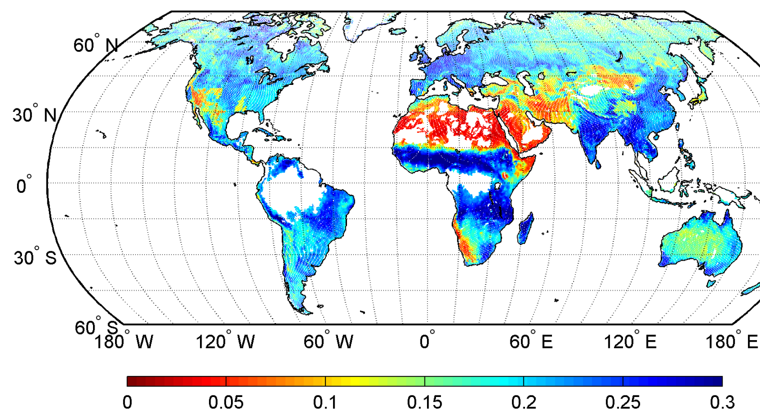
Mean SCAT



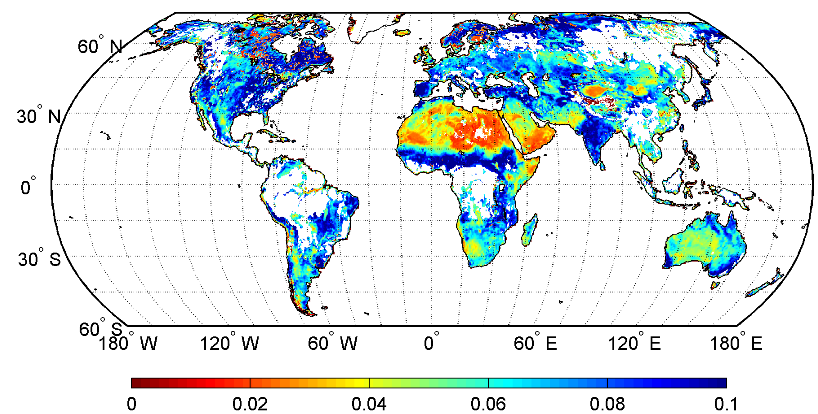
Mean AMSR-E



SCAT Seasonal Dynamics



AMSR-E Seasonal Dynamics



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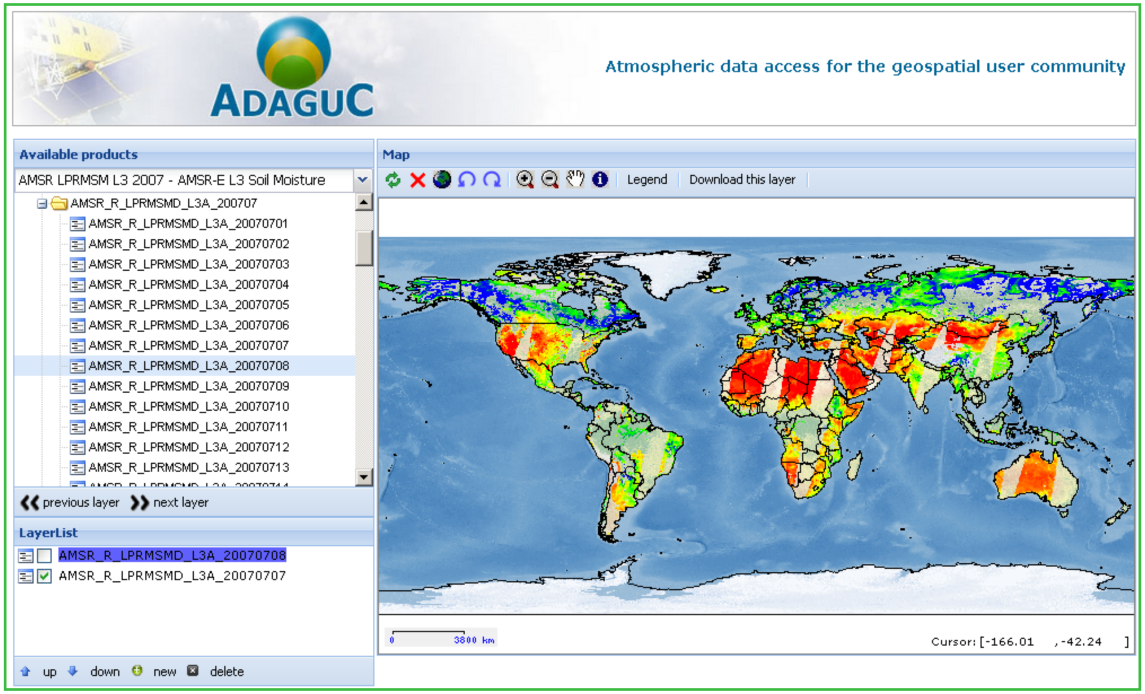
(Source: W. Wagner, R. de Jeu)

Data access

- Make use of the existing web portal (geoservices.falw.vu.nl)
- Data visualization
  - Data selection
  - Time
  - Region
  - Type
- Data download
  - HDF 5
  - NetCDF (3,4)
  - AAIGrid
  - GeoTIFF
- Plans for the Future
  - Near Realtime Data Access
  - Data Analysis



(Source: W. Wagner, R. de Jeu)

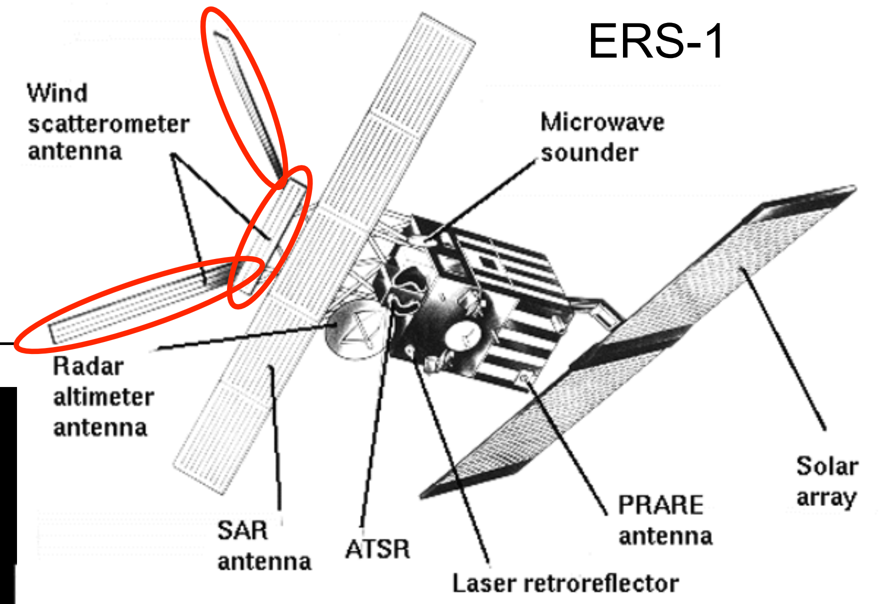
METOP Includes Advanced SCATterometer (ASCAT)

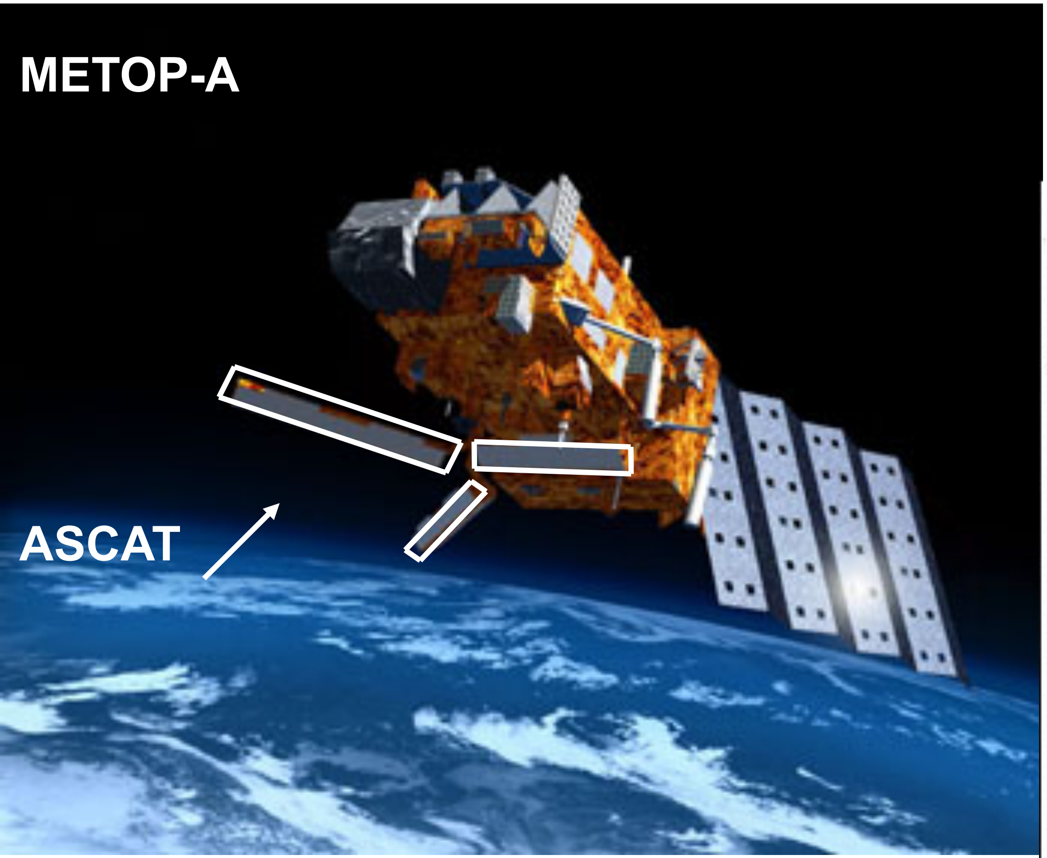
http://www.esa.int/esaLP/ESA266094UC_LPmetop_0.html

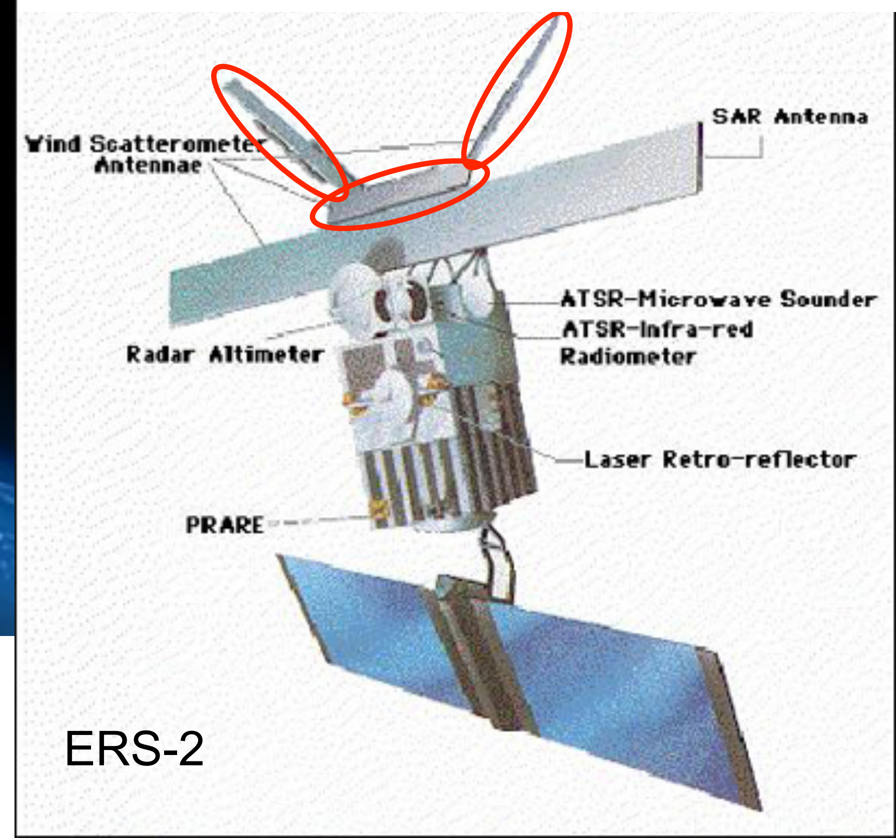
- METOP is a polar orbiting satellite
- Suit of 13 Instruments for measuring ocean, land and atmospheric variables
- ASCAT and GOME-2 are continuity instruments from ERS series
- Launched 19 October 2006
- Operated by EUMETSAT (not ESA) as a weather and climate satellite
- EUMETSAT is first polar orbiting satellite and 2nd largest after Envisat

METOP – Polar Orbit

Takes ~100 minutes to orbit the earth, 70 orbits for global coverage, complete coverage every 5 days


ERS-1
Wind scatterometer antenna
Microwave sounder
Radar altimeter antenna
SAR antenna
ATSR
Laser retroreflector
PRARE antenna
Solar array

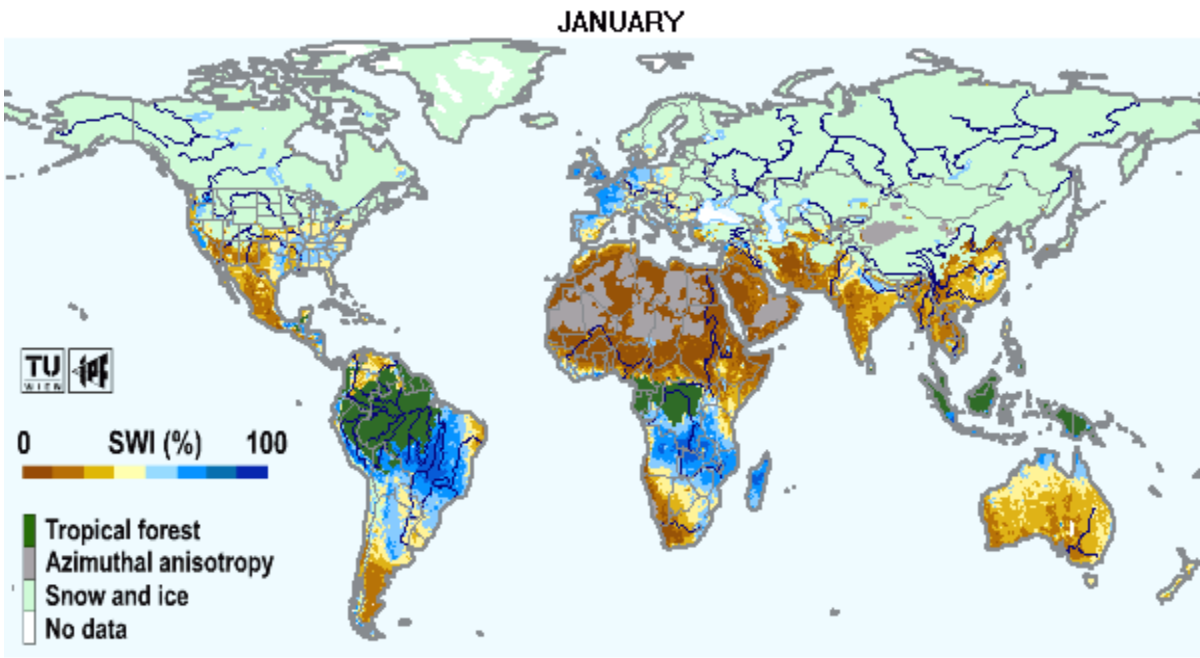

METOP-A
ASCAT


Wind Scatterometer Antennae
SAR Antenna
ATSR-Microwave Sounder
ATSR-Infra-red Radiometer
Radar Altimeter
Laser Retro-reflector
PRARE
ERS-2

A(SCAT): Towards global measurements of wind speed and direction over the oceans

- The Advanced Scatterometer, or ASCAT for short, is used to determine information about the wind for use primarily in weather forecasting and climate research
  - 1st scatterometer launched on ERS-1 1991
  - 2nd scatteometer launched on ERS-2 1995
- Advanced scatterometer launched on METOP-A in 2007
  - Spatial resolution 50 km (experimental ~25km)

- ASCAT will also find applications in a number of other areas such as:
  - The monitoring of land- and Sea-ice
  - Snow cover
  - **Global and regional soil moisture**



Monthly soil moisture mean 1992 - 2000

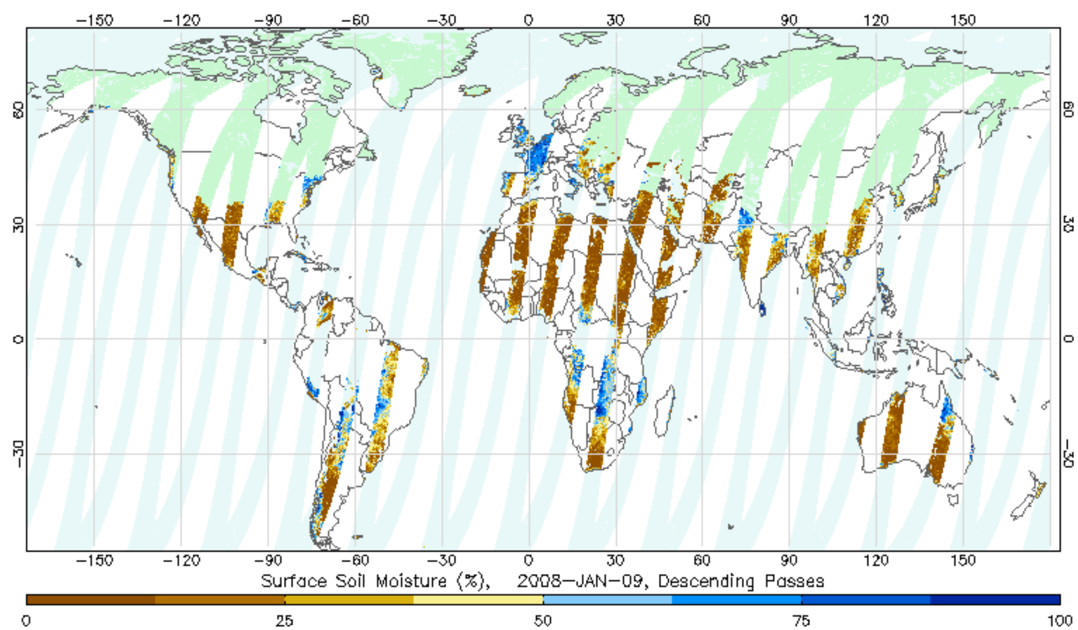
Processing Step	Mathematical Formulation
Step 1 *Estimated Standard Deviation of σ^0*	$ESD(\sigma^0) = \frac{SD(\sigma^0_{fore} - \sigma^0_{aft})}{\sqrt{2}}$
Step 2 *Incidence Angle Dependency*	$\sigma'(40,t) = C' + D' \cdot \Psi'(t)$ $\sigma''(40,t) = C'' + D'' \cdot \Psi''(t)$
Step 3 *Normalisation*	$\sigma^0(40,t) = \frac{1}{3}\sum_{i=1}^{3} \sigma^0_i(\theta,t) - \sigma'(40,t)(\theta - 40) - \frac{1}{2}\sigma''(40,t)(\theta - 40)^2$
Step 4 *Estimated Standard Deviation of $\sigma^0(40)$*	$ESD(\sigma^0(40)) = \sqrt{100 \cdot ESD(\sigma')^2 - \frac{5}{3} ESD(\sigma^0)^2}$
Step 5 *Dry and Wet backscatter references and normalisation of vegetation effects*	$\sigma^0_{DRY}(40,t) = C^0_{DRY} - D'\Psi'(t)(\theta_{DRY} - 40) - \frac{1}{2} D''\Psi''(t)(\theta_{DRY} - 40)^2$ $\sigma^0_{WET}(40,t) = C^0_{WET} - D'\Psi'(t)(\theta_{WET} - 40) - \frac{1}{2} D''\Psi''(t)(\theta_{WET} - 40)^2$
Step 6 *Wet backscatter reference correction*	$C^0_{WET} = C^0_{DRY} + (19 + 30 \cdot C')$ $C^0_{WET} = C^0_{DRY} + (17 + 30 \cdot C')$
Step 7 *Surface soil moisture*	$m_s(t) = \frac{\sigma^0(40,t) - \sigma^0_{dry}(40,t)}{\sigma^0_{wet}(40) - \sigma^0_{dry}(40,t)}$
Step 8 *Estimated standard deviation of surface soil moisture*	$ESD(m_s) = \frac{ESD(\sigma^0_{40})}{\sigma^0_{wet}(40,t) - \sigma^0_{dry}(40,t)}$

ASCAT SM Processing Stages

The processor has been developed by the Institute of Photogrammetry and Remote Sensing of the Vienna University of Technology http://www.ipf.tuwien.ac.at/radar/index.php?go=a2_data

ASCAT Products Levels 1 to 2

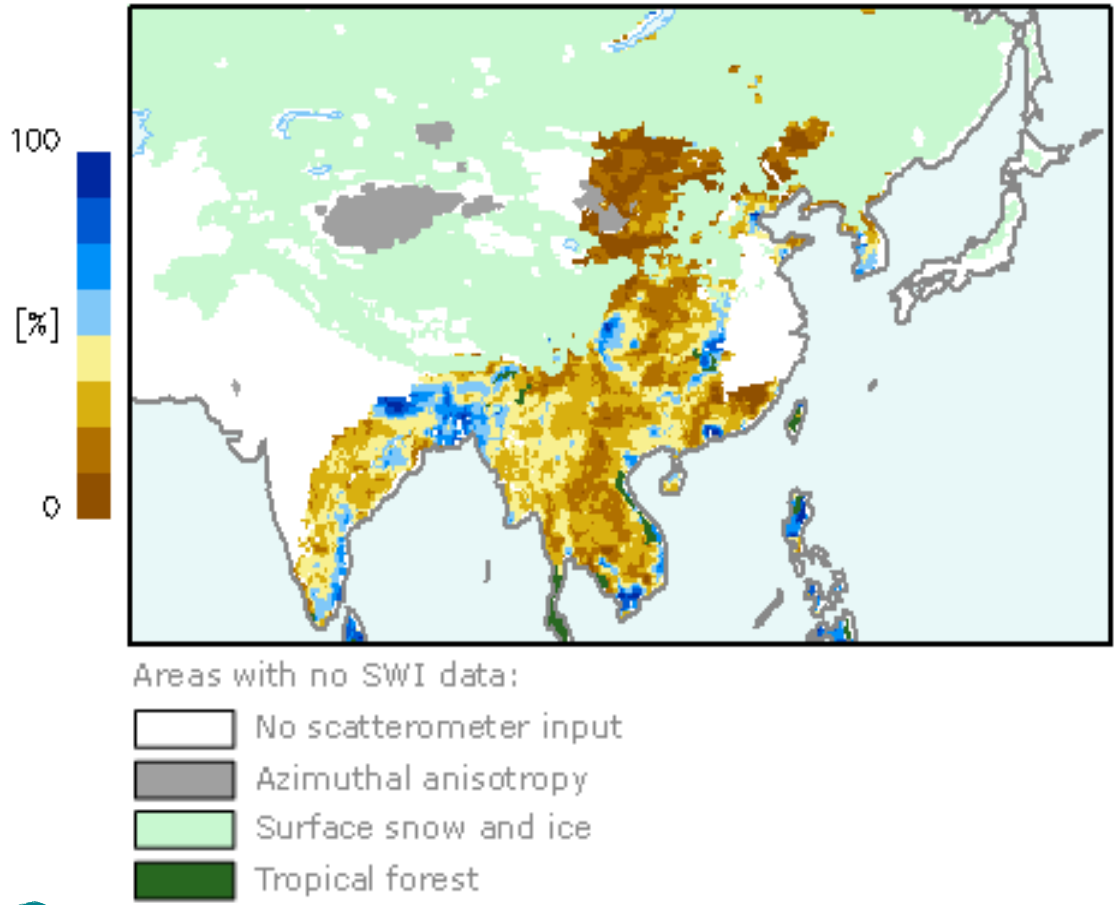
- ASCAT Level 0 (instrument packets)
- ASCAT Level 1b (normalised radar backscatter)
- ASCAT Level 2 wind (near surface ocean winds)
- ASCAT Level 2 soil moisture (surface soil moisture index)
  - ASCAT Level 2 soil moisture products is produced and distributed by EUMETSAT following the method developed and prototyped by the Technical University of Wien: http://www.ipf.tuwien.ac.at/radar/index.php?go=a2_data



ASCAT Level 2
Daily coverage

ASCAT Level 3 Products – Regional Monthly SWI

SE Asia region example for January 2008



Soil Water Index (SWI), i.e. a measure of the profile soil moisture content obtained by filtering the surface soil moisture time series with an exponential function. Data is made available on a monthly and regional basis for following regions:

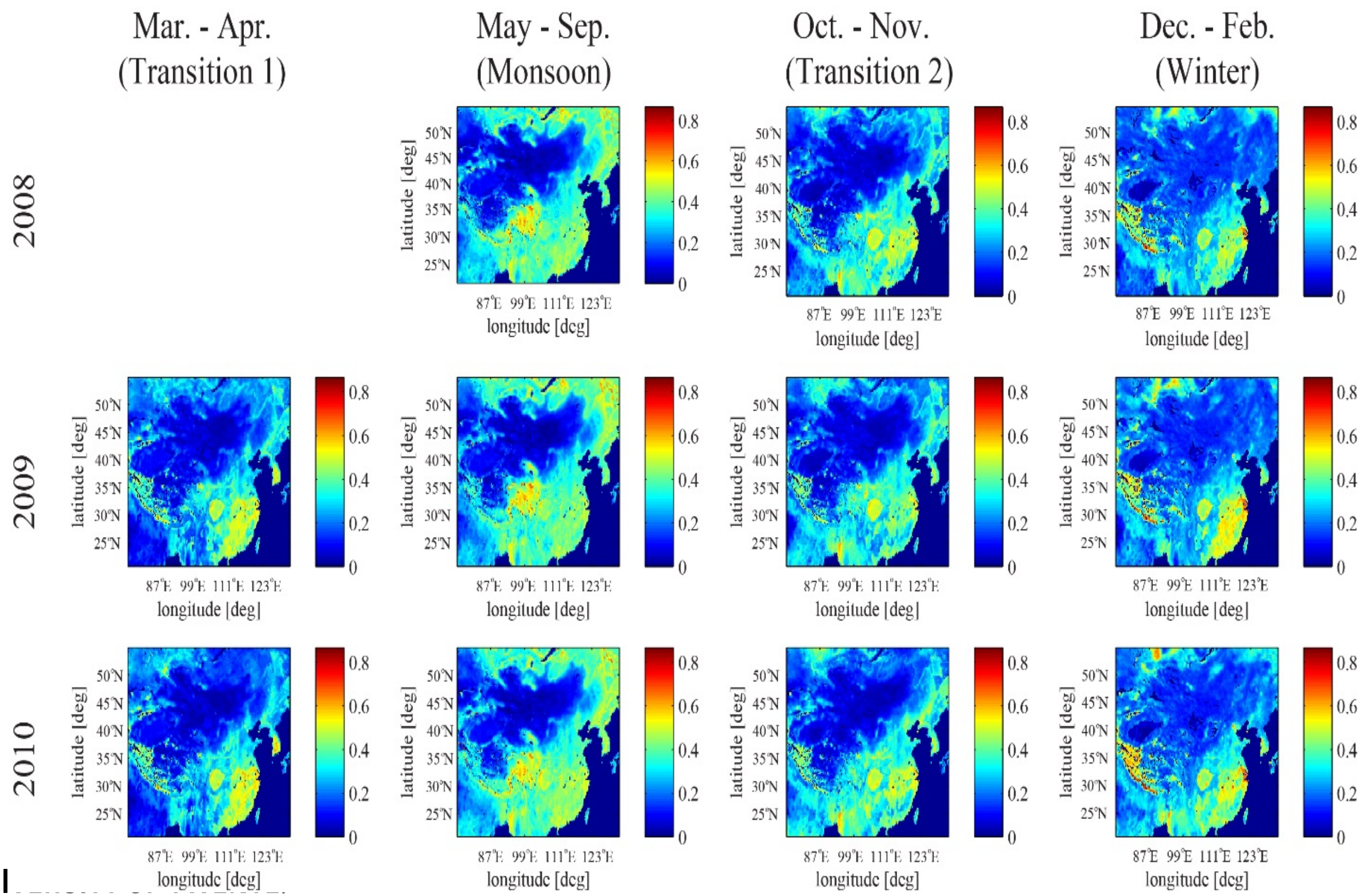
- Europe
- SE Asia
- North America
- South America
- Australasia

http://www.ipf.tuwien.ac.at/radar/index.php?go=a3_data

NEW: A Combined Soil Moisture Product over China Using Different Sensors (AMSR-E & ASCAT)

(Y. Zeng, L. Dente, L. Wang, J, Wen, Z. Su)

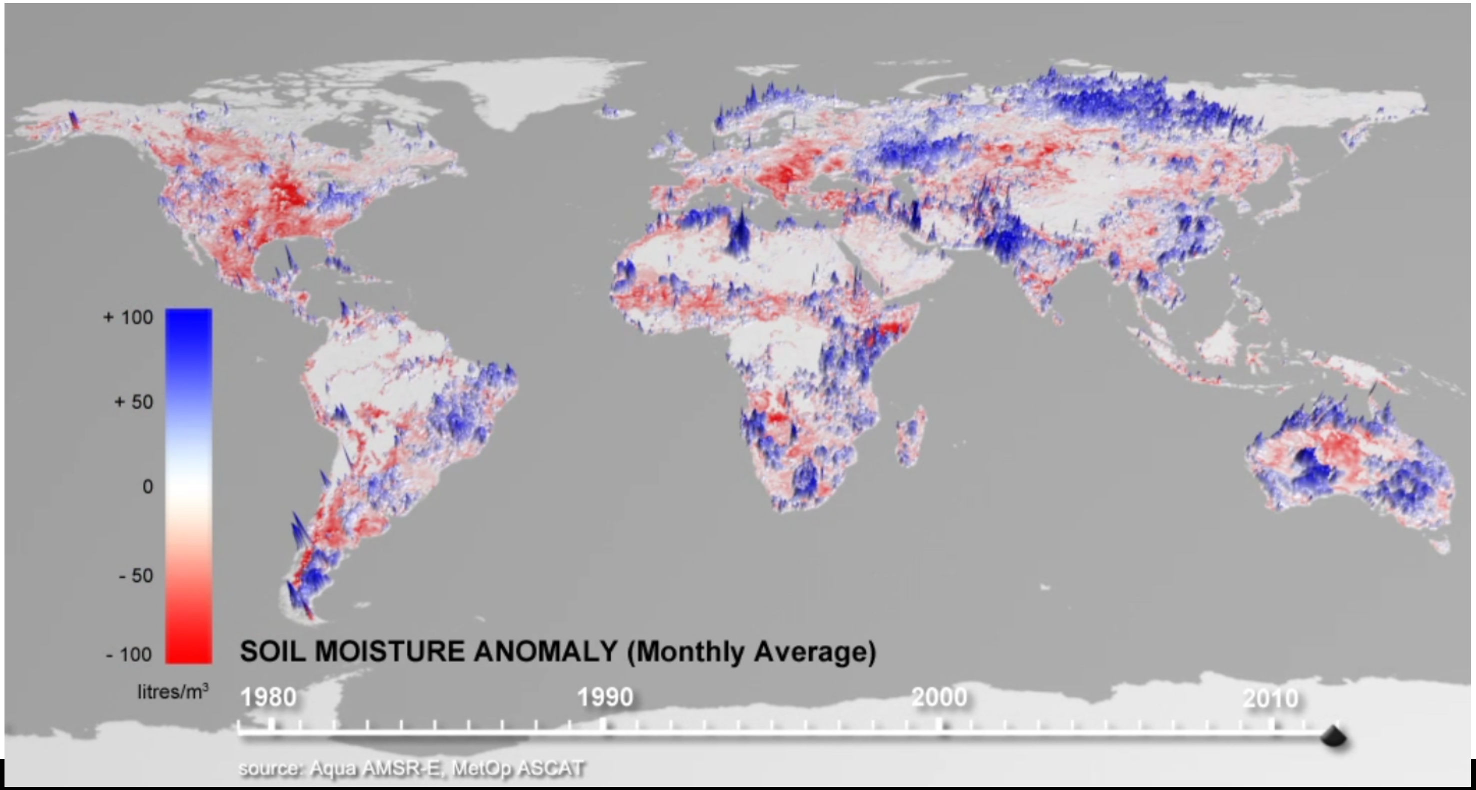
A simple Bayesian based method is used (bias correction, & variational method)



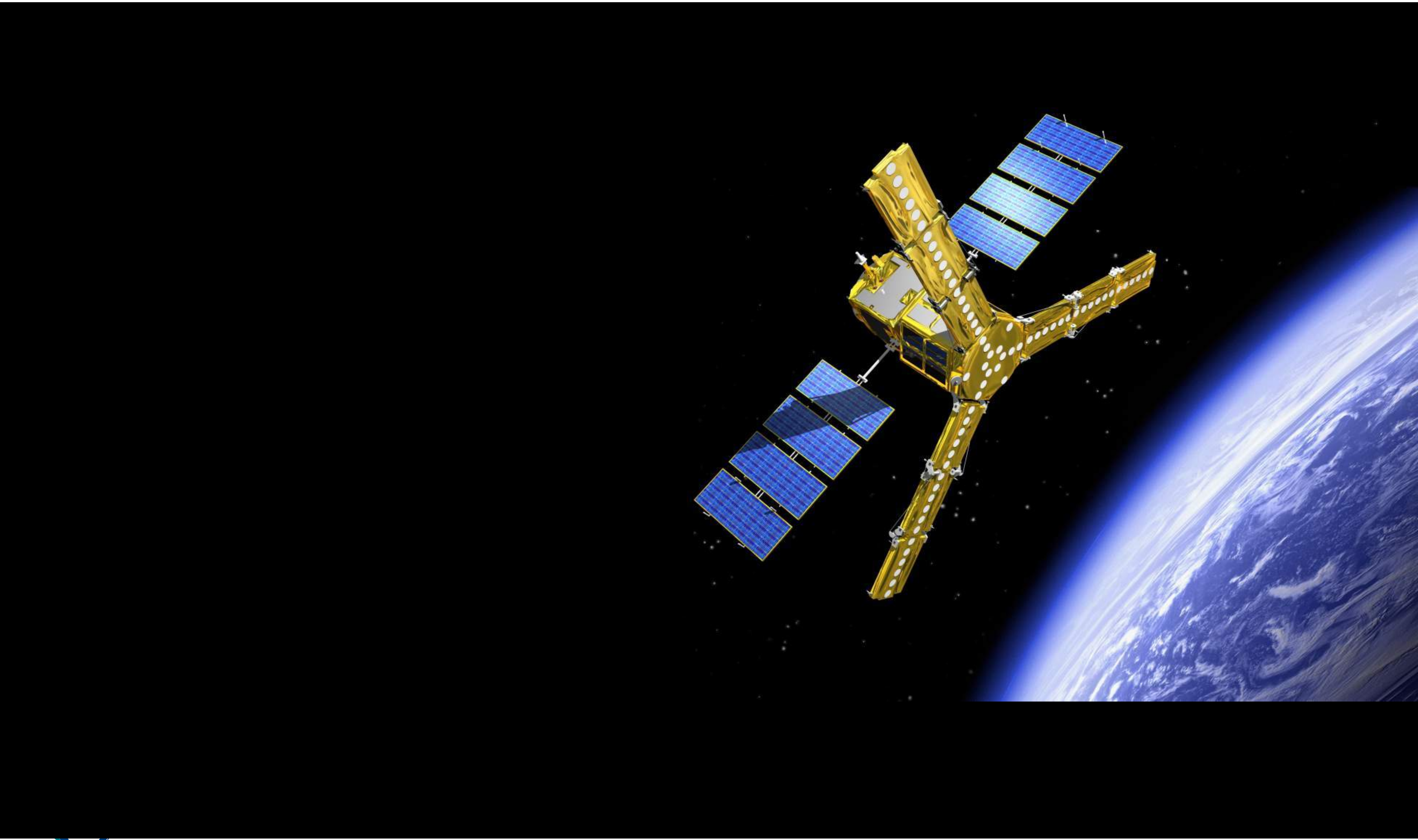
The WACMOS global soil moisture product

http://www.esa-soilmoisture-cci.org/node/127

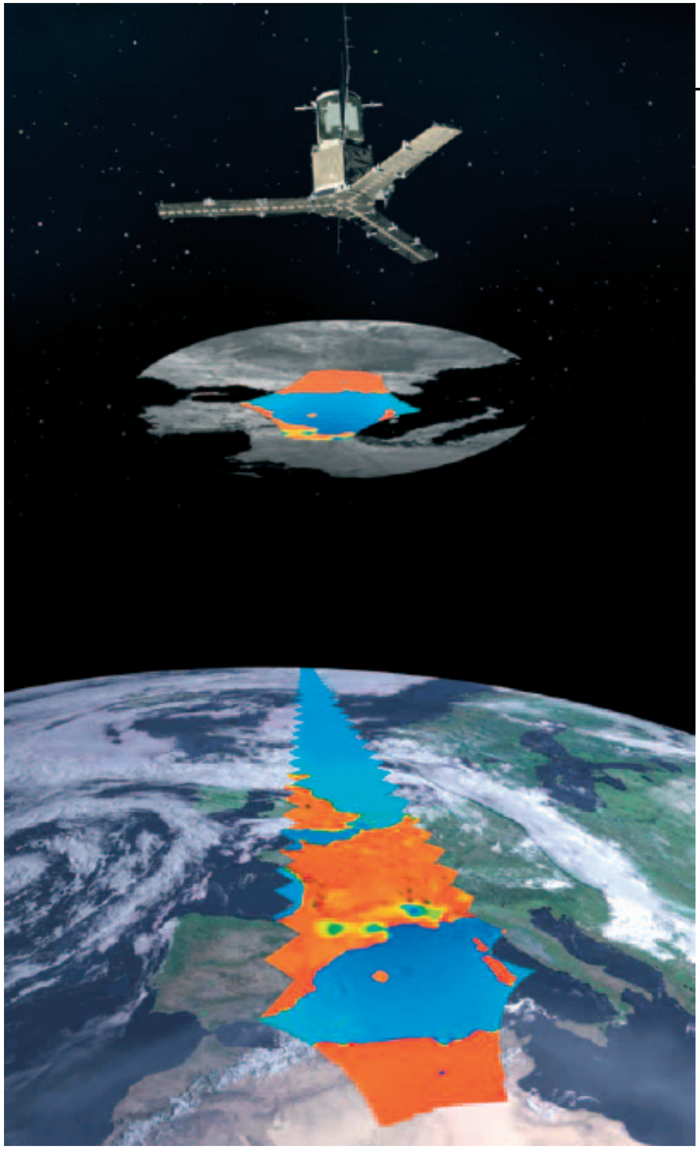
Global monthly averages of soil moisture in the early 1980s in litres per m3, followed by changes in global soil moisture to present. Major anomalies are highlighted, such as the 1992 flooding in Afghanistan, the 2005 drought in the central US, Russia's heatwave in 2010 and Australia's floods in Queensland in January 2011.



SMOS (Soil Moisture and Ocean Salinity) - a joint ESA / CNES / CDTI Earth Observation program

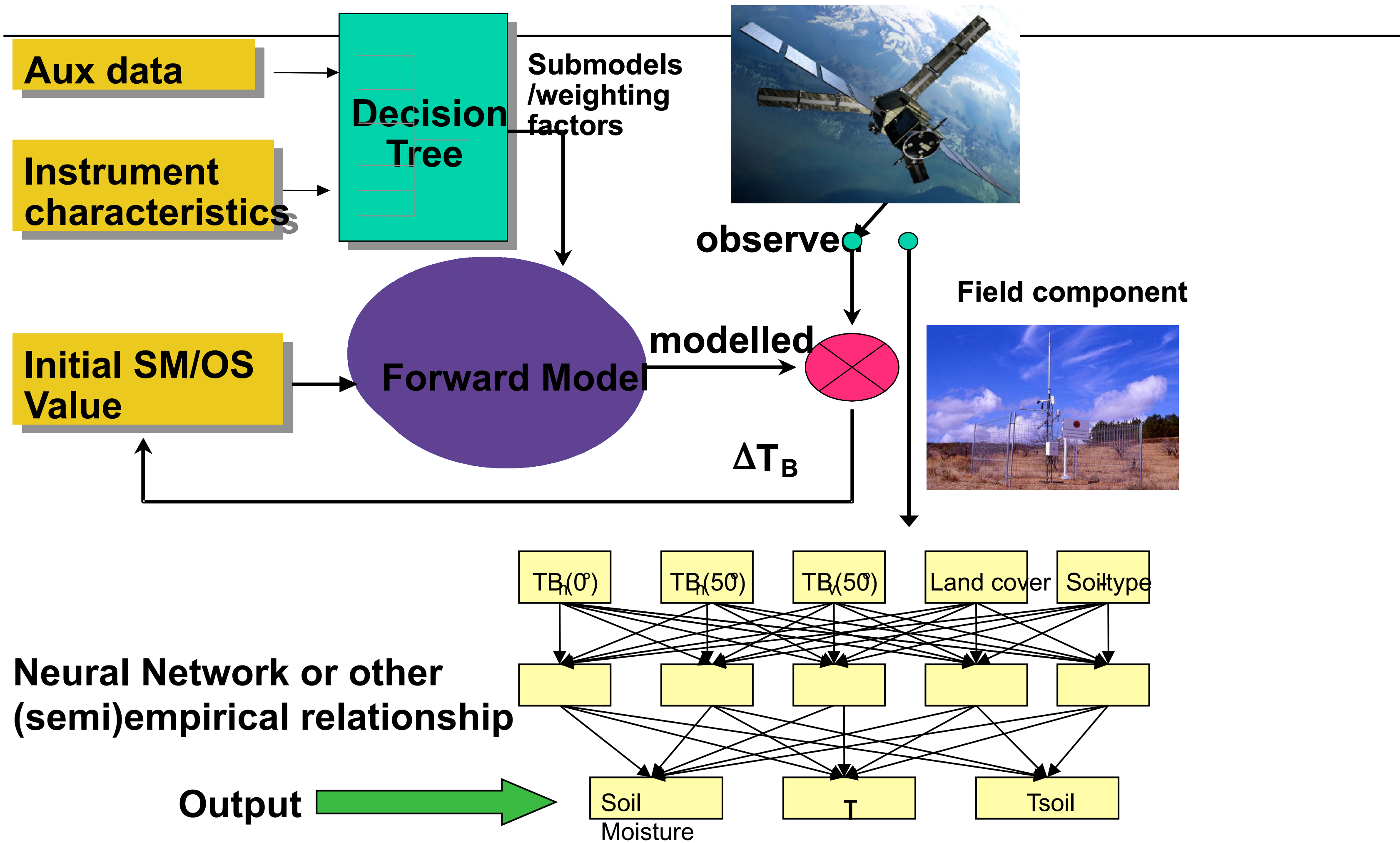


SMOS – MIRAS Hexagonal Foot Print



- Altitude of 763 km, antenna view area of almost 3000 km in diameter.
- Due to the interferometry principle and the Y-shaped antenna, the field of view is limited to a hexagon-like shape about 1000 km.
- Global coverage every 3 days
- Launch 2009

Retrievals - Forward Modeling by Iterative Minimisation



SMOS Data Access

- **How to access SMOS data**: https://earth.esa.int/web/guest/-/how-to-obtain-data-7329
- **SMOS Level 3 and Level 4 Data Products**: http://www.catds.fr/

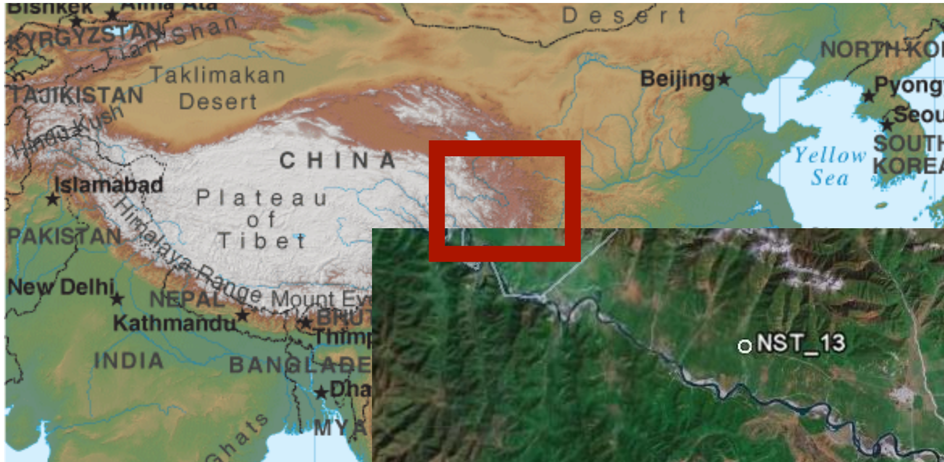
Ernesto

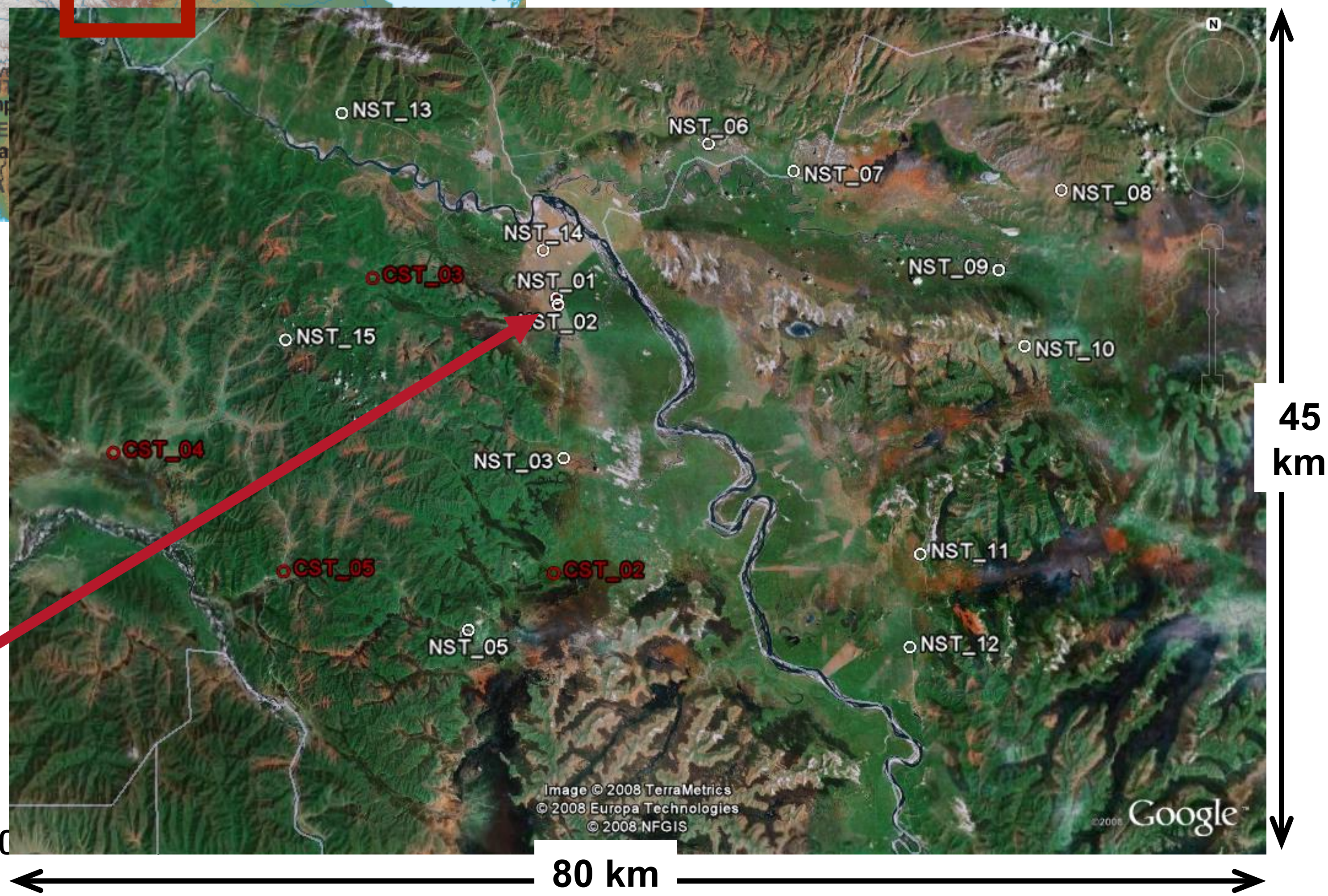
HOW GOOD ARE THESE DATA?

ITC GEO Soil Moisture Soil Temperature Networks

Maqu soil moisture network

20 soil moisture and soil temperature stations





Maqu: station description

- 2/3 soil moisture & temperature probes
- 5, 10 & 20 cm deep (few profiles deep 80 cm)
- 1 datalogger
- data collected every 15 min
- memory capacity of 1 year
- completely buried
- site revisit to download data:
  - beginning and end of monsoon season in Maqu

ITC GEO Soil Moisture Soil Temperature Networks

	Twente	Naqu	Maqu	Ngari
Nr. Domains	1	1	1	2
Nr. stations	22	7	20	20

	Twente	Naqu	Maqu	Ngari
Data Download	Per 3 Mons. (1 site automatic)	Per Year	Per 3/6 Mons (summer)	Per Year
Calibration	Gravimetric	Gravimetric	Gravimetric	Gravimetric

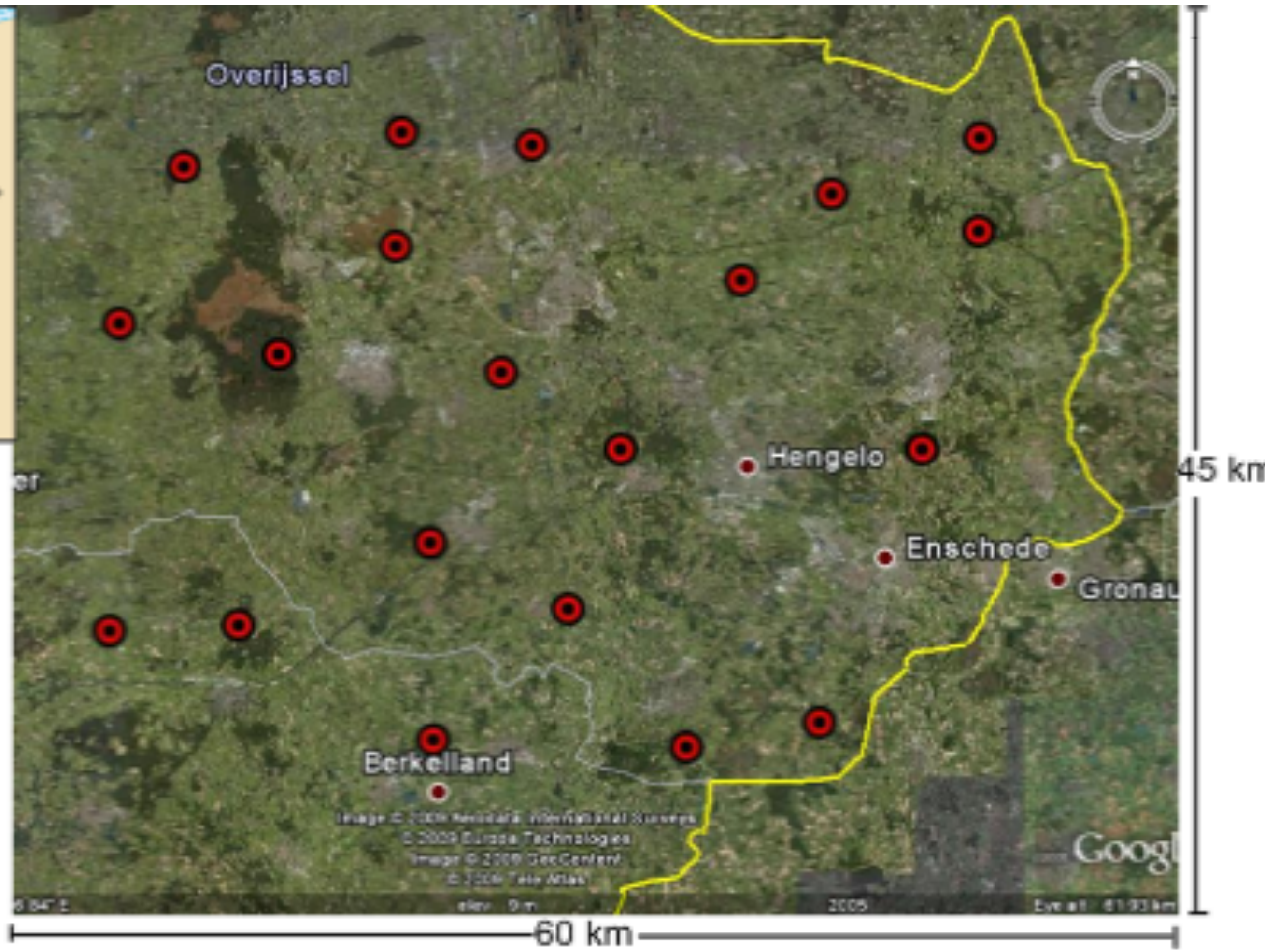
Measurement Type	Method	Depths
Soil Moisture Soil Temperature	ECH_2O (Capacitance probe) Type: EC-10 & EC-TM	Naqu Station -2.5, -7.5, -15, -30 , -60cm Maqu & Twente Station -5, -10, -20, -40, -80cm Ngari Station -5, -10, -20, -40, -60, -80cm
Micrometeorological	AWS, PBL Tower	1.5, 2, 5, 6.5, 10, 14.0 m

Twente SMST Network – technical details

20 sites

(52°05'–52°27'N, 6°05'–7°00'E).

EC-TM ECH2O probes (Decagon Devices, Inc., USA)

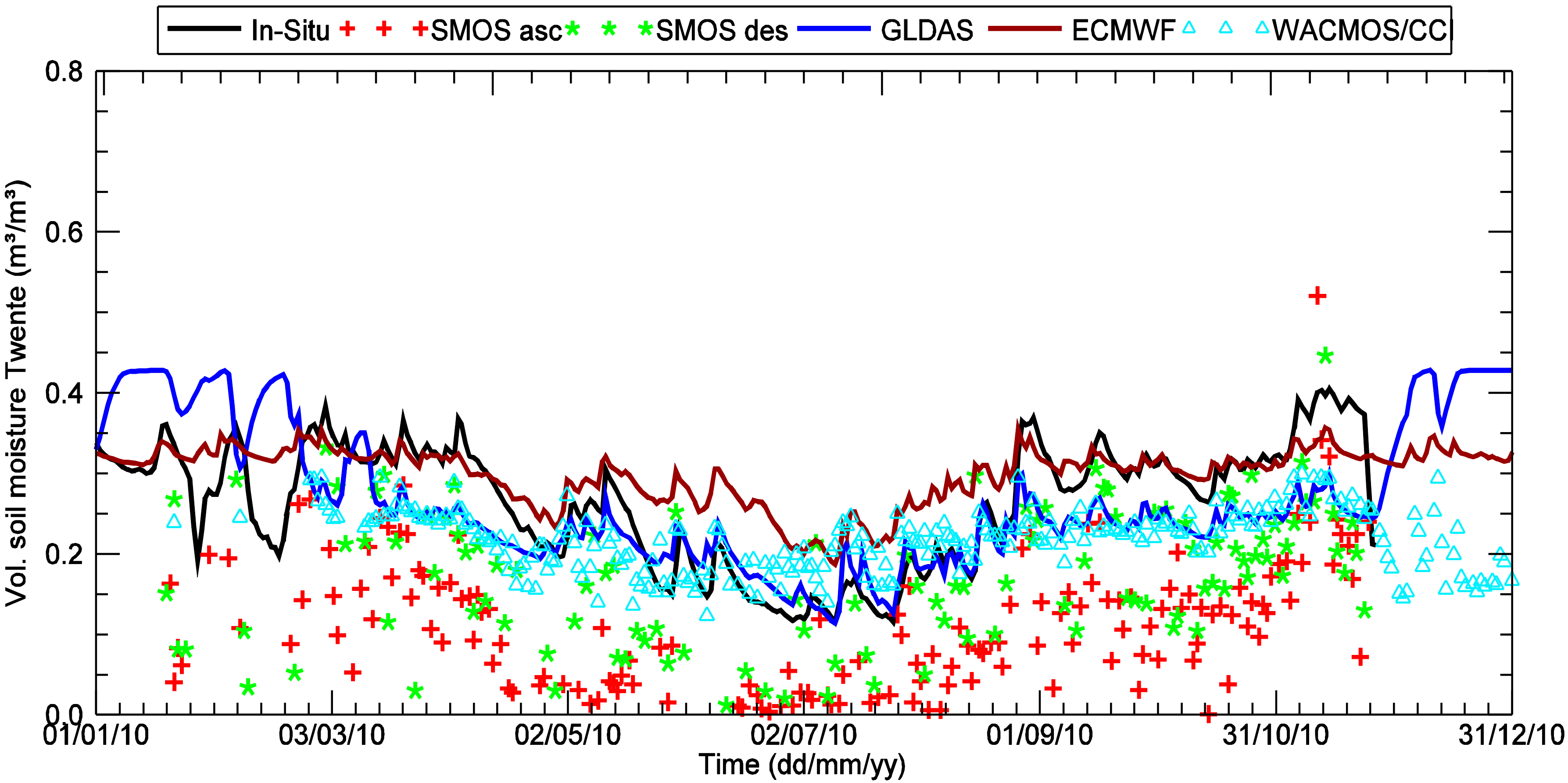


UNIVERSITY OF TWENTE.

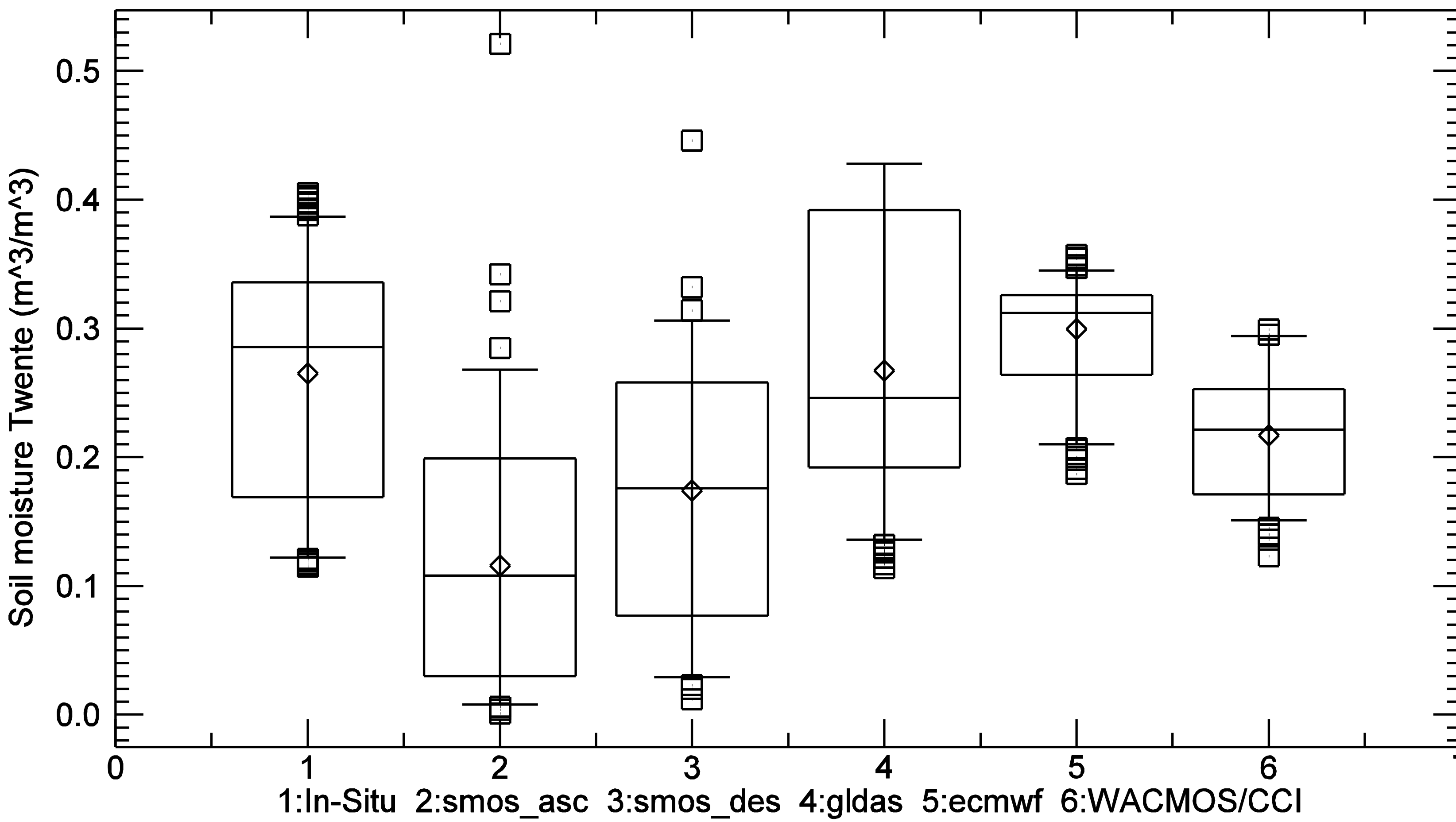
Twente SMST Network – technical details

UNIVERSITY OF TWENTE.

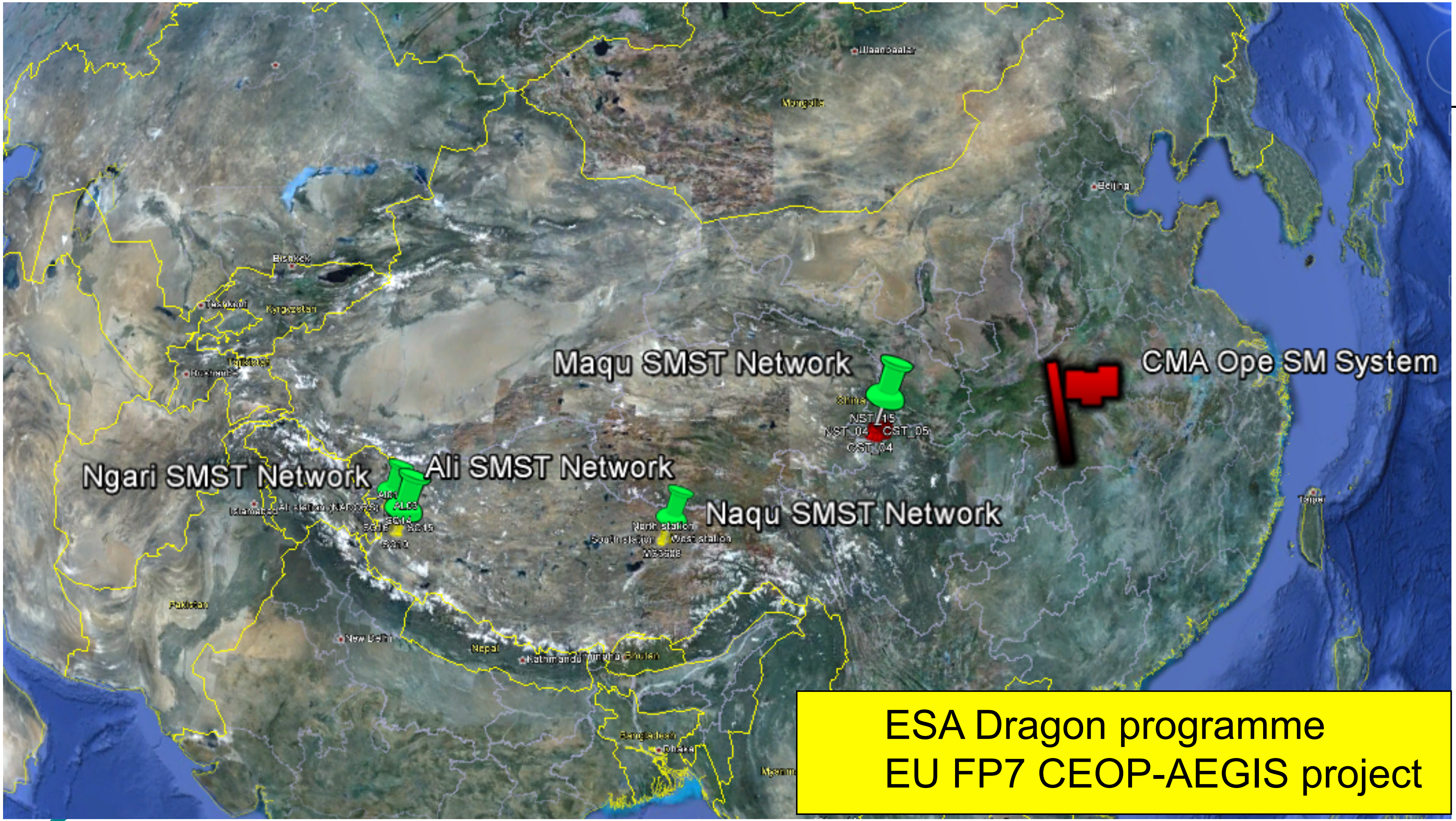
Twente SMST Network – validation results



Twente SMST Network – validation results



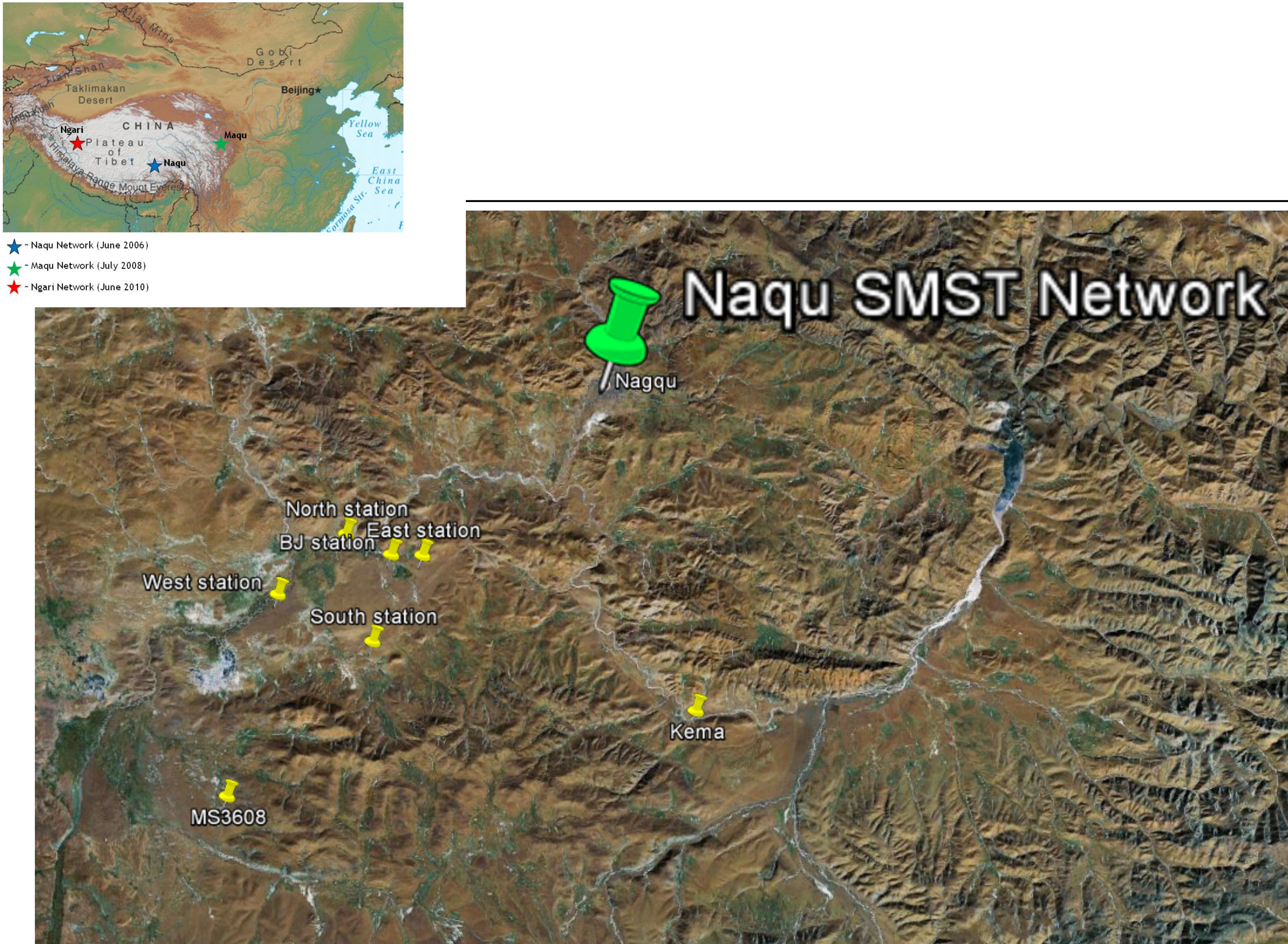
Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs)



UNIVERSITY OF TWENTE.

Su, Z., et al. 2011, Hydrol. Earth Syst. Sci., 15, 2303–2316, www.hydrol-earth-syst-sci.net/15/2303/2011/

Tibetan Plateau soil moisture and soil temperature Observatory (Tibet-Obs)



ITC Earth Observation Research and Education Sites

The Role of the Tibetan Plateau in Global Climate

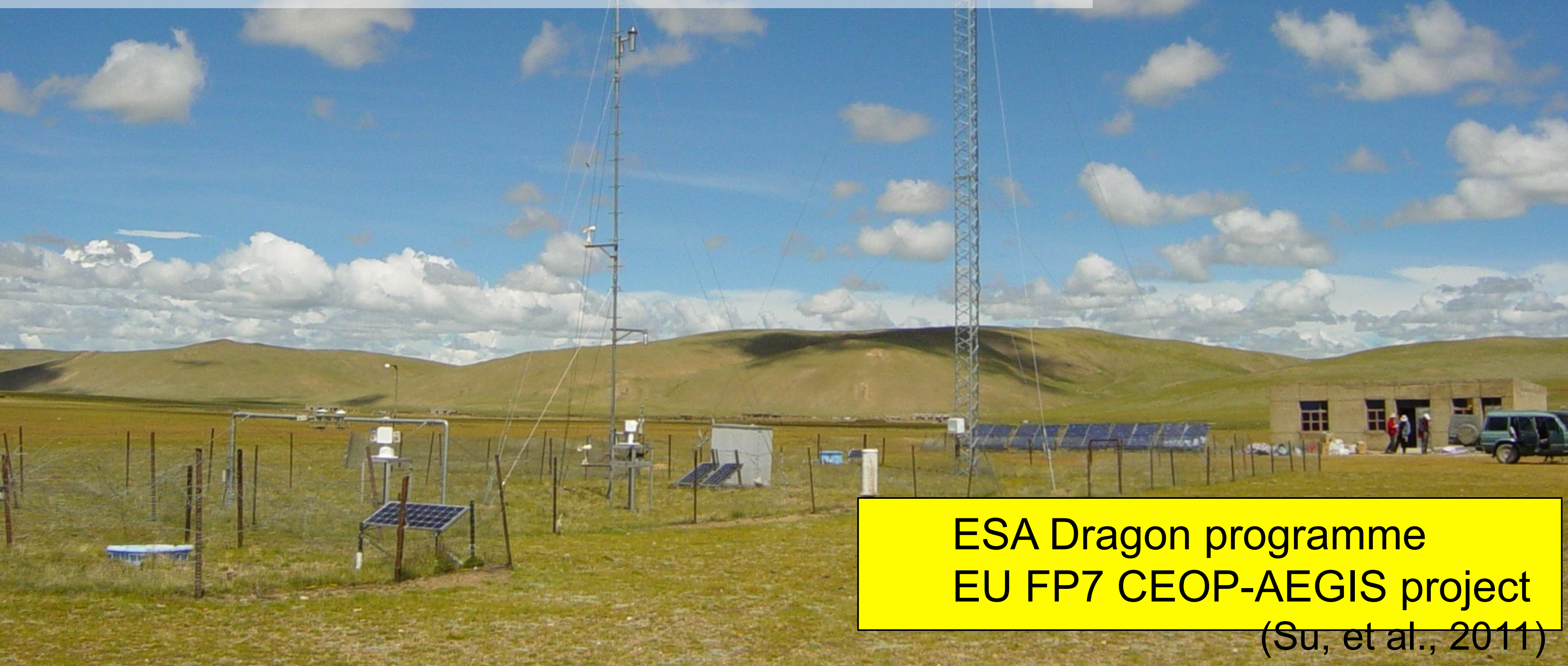
(Collaboration with Chinese Academy of Sciences)

GEWEX Asian Monsoon Experiment (GAME) on the Tibet Plateau (GAME/Tibet,1996-2000)

CEOP (Coordinated Enhanced Observing Period) Asia-Australia Monsoon Project on the Tibetan Plateau (CAMP/Tibet, 2001-2005)

Tibetan Observation and Research Platform (TORP, 2005 -2010)

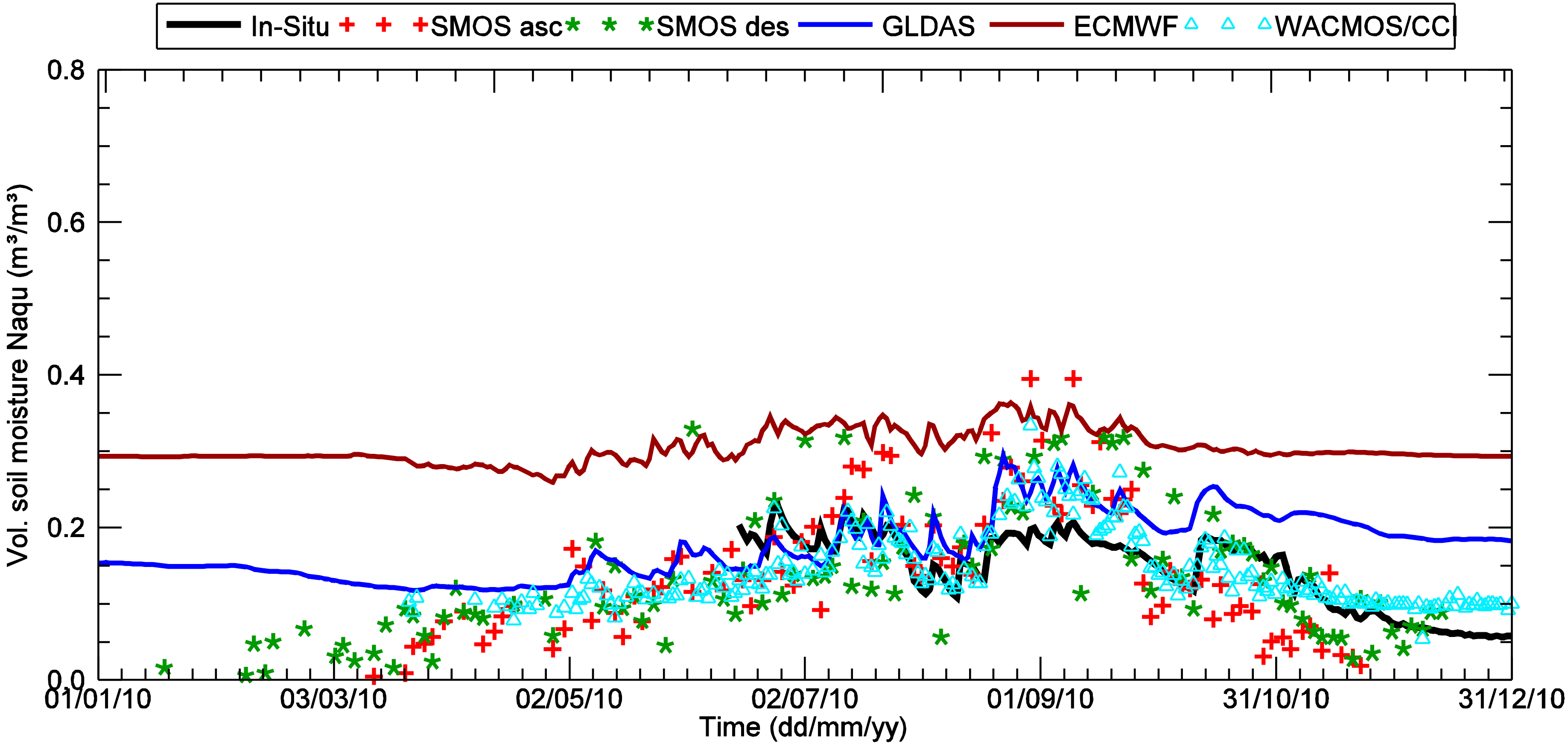
Third Pole Environment (2009 -2019)
Coordinators: Y.Ma & T.Yao (ITP/CAS)



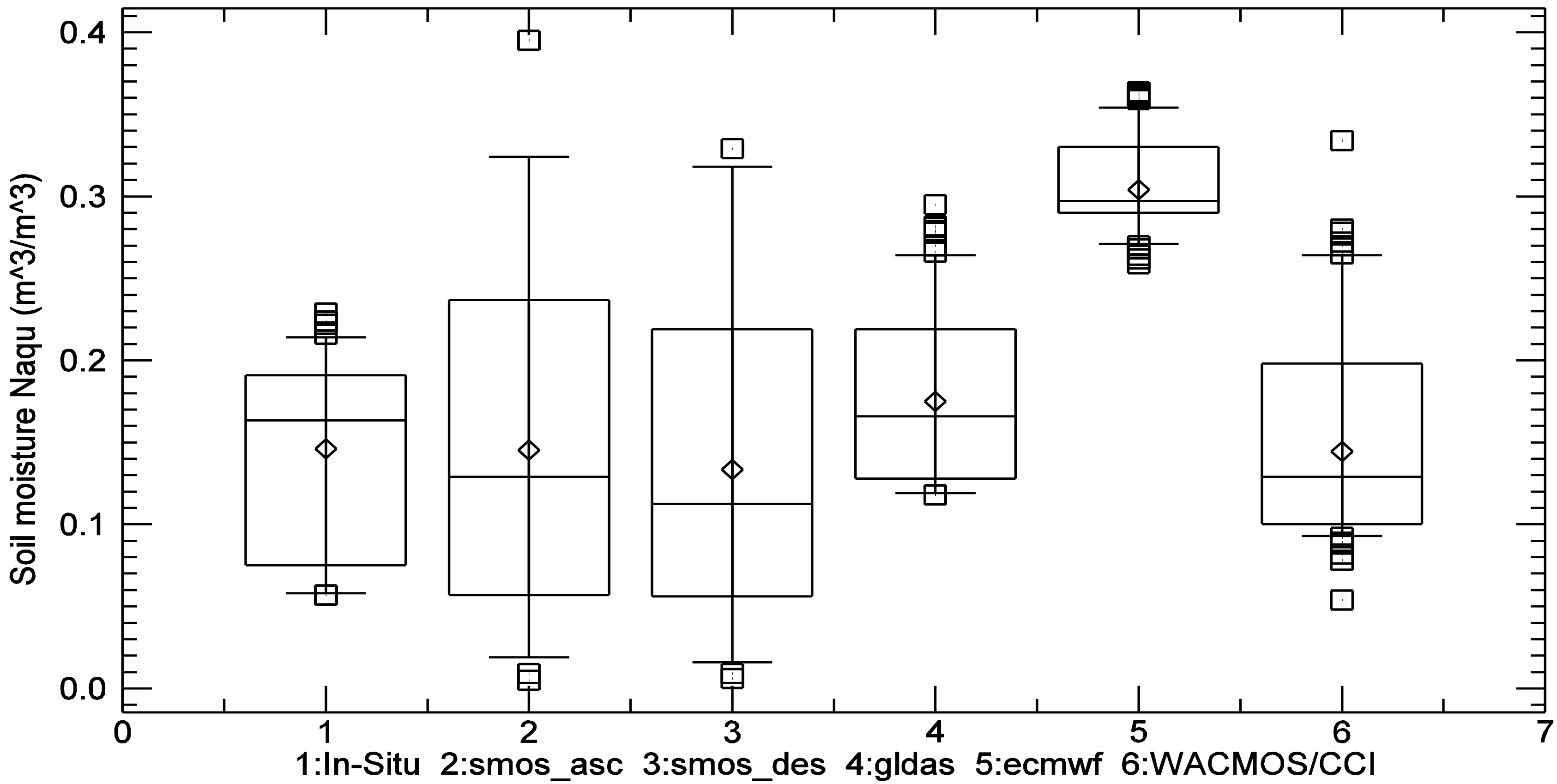
ESA Dragon programme
EU FP7 CEOP-AEGIS project

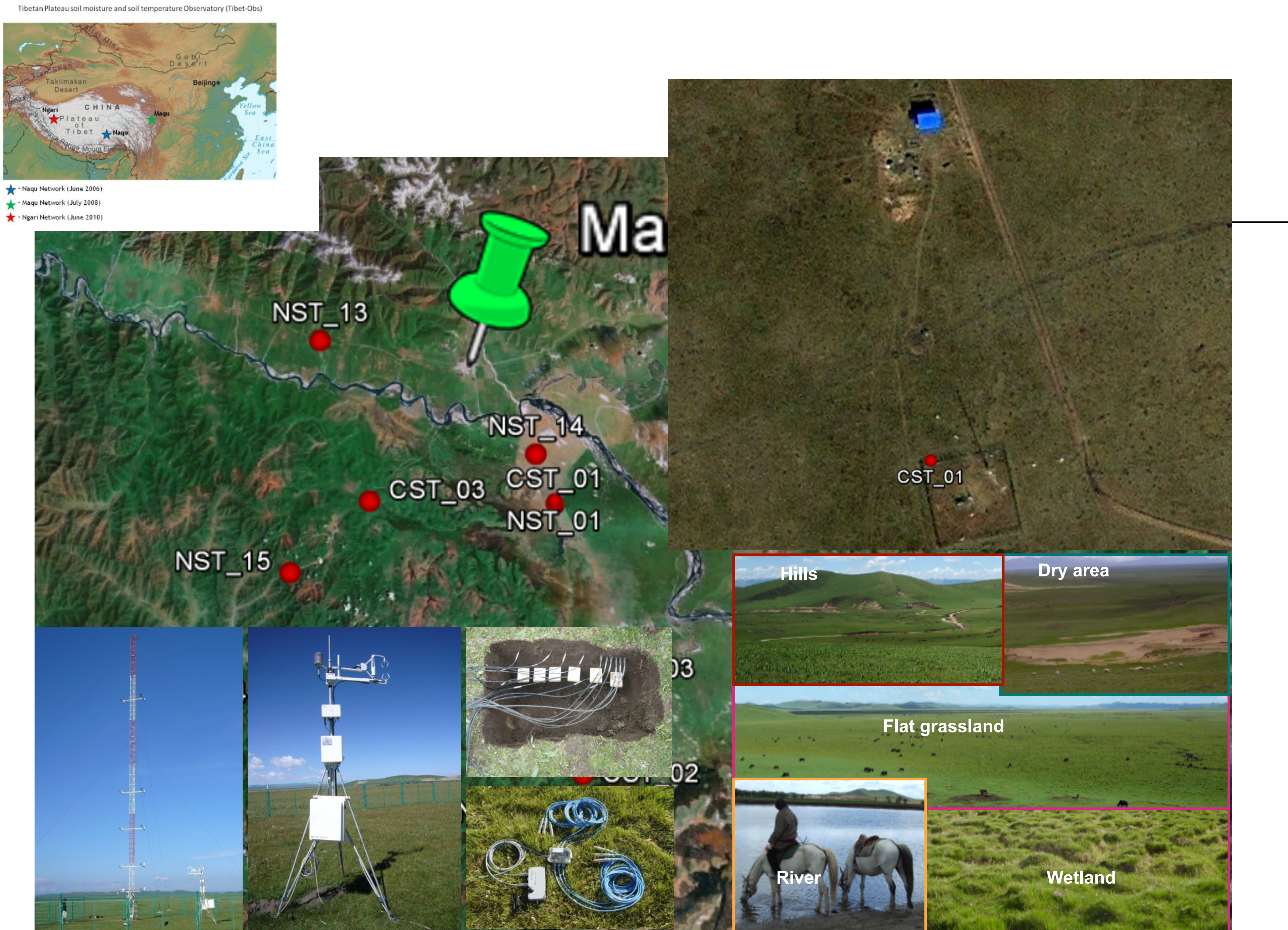
(Su, et al., 2011)

Naqu SMST Network – validation results

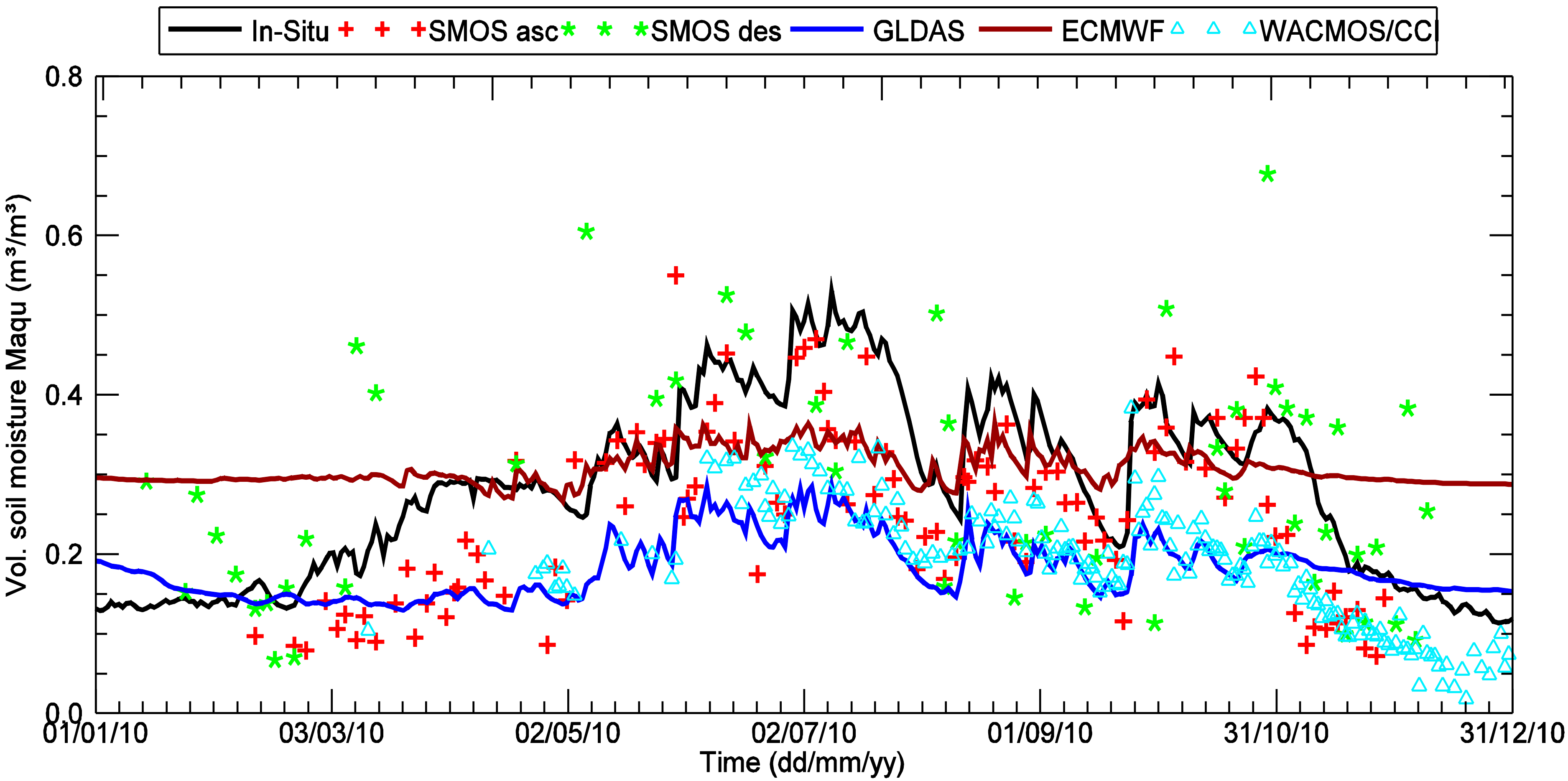


Naqu SMST Network – validation results

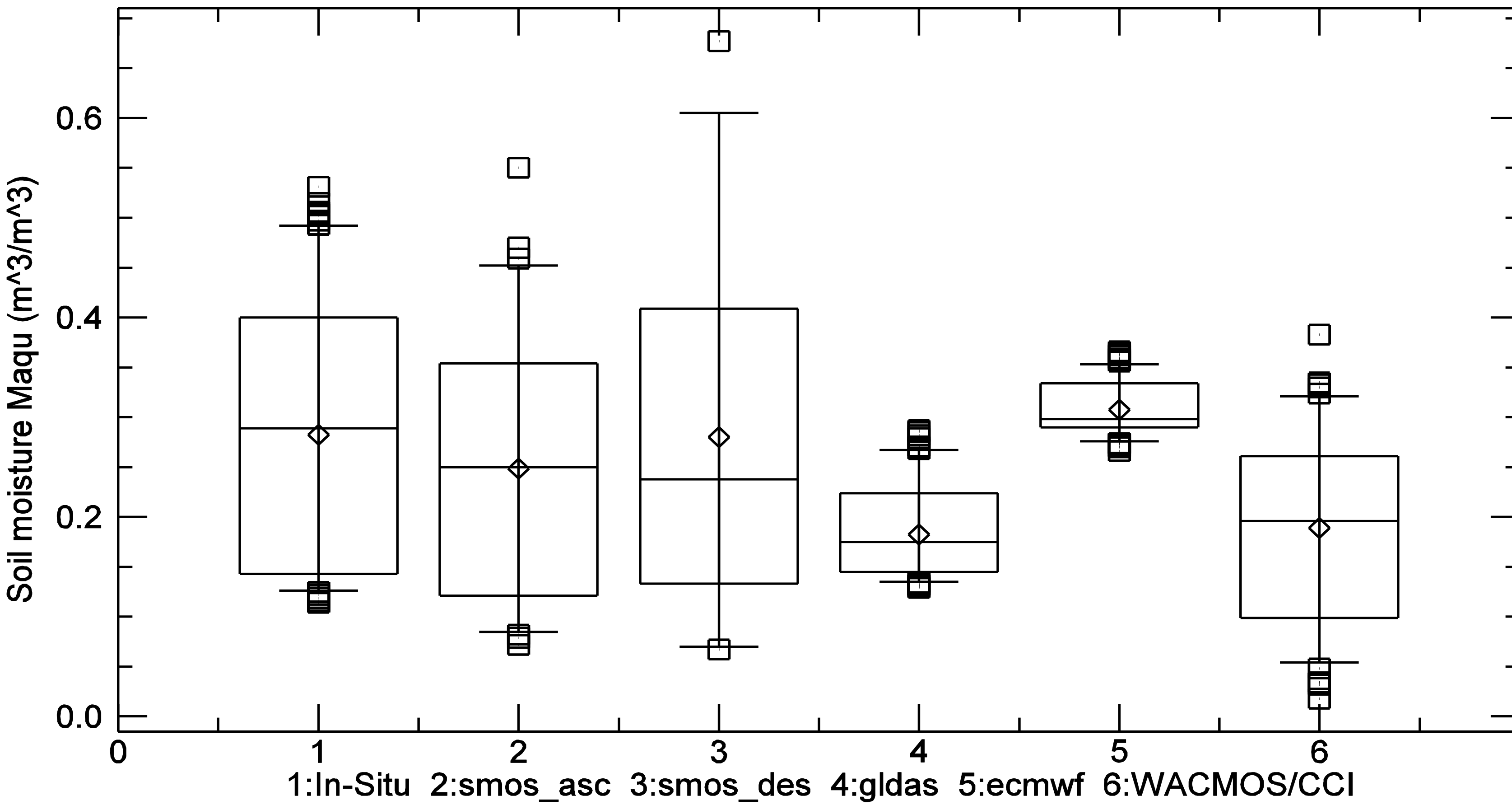



Tibetan Plateau soil moisture and soil temperature Observatory (Tibet-Obs)
Gobi Desert
Beijing
Taklimakan Desert
CHINA
Ngari
Maqu
Naqu
Plateau of Tibet
Yellow Sea
East China Sea
- Naqu Network (June 2006)
- Maqu Network (July 2008)
- Ngari Network (June 2010)
NST_13
NST_14
CST_03
CST_01
NST_01
NST_15
CST_01
Hills
Dry area
Flat grassland
River
Wetland

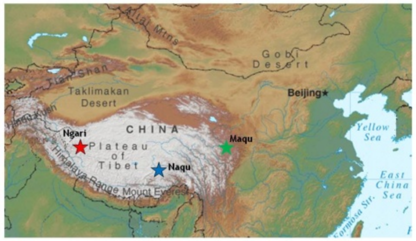
Maqu SMST Network – validation results



Maqu SMST Network – validation results

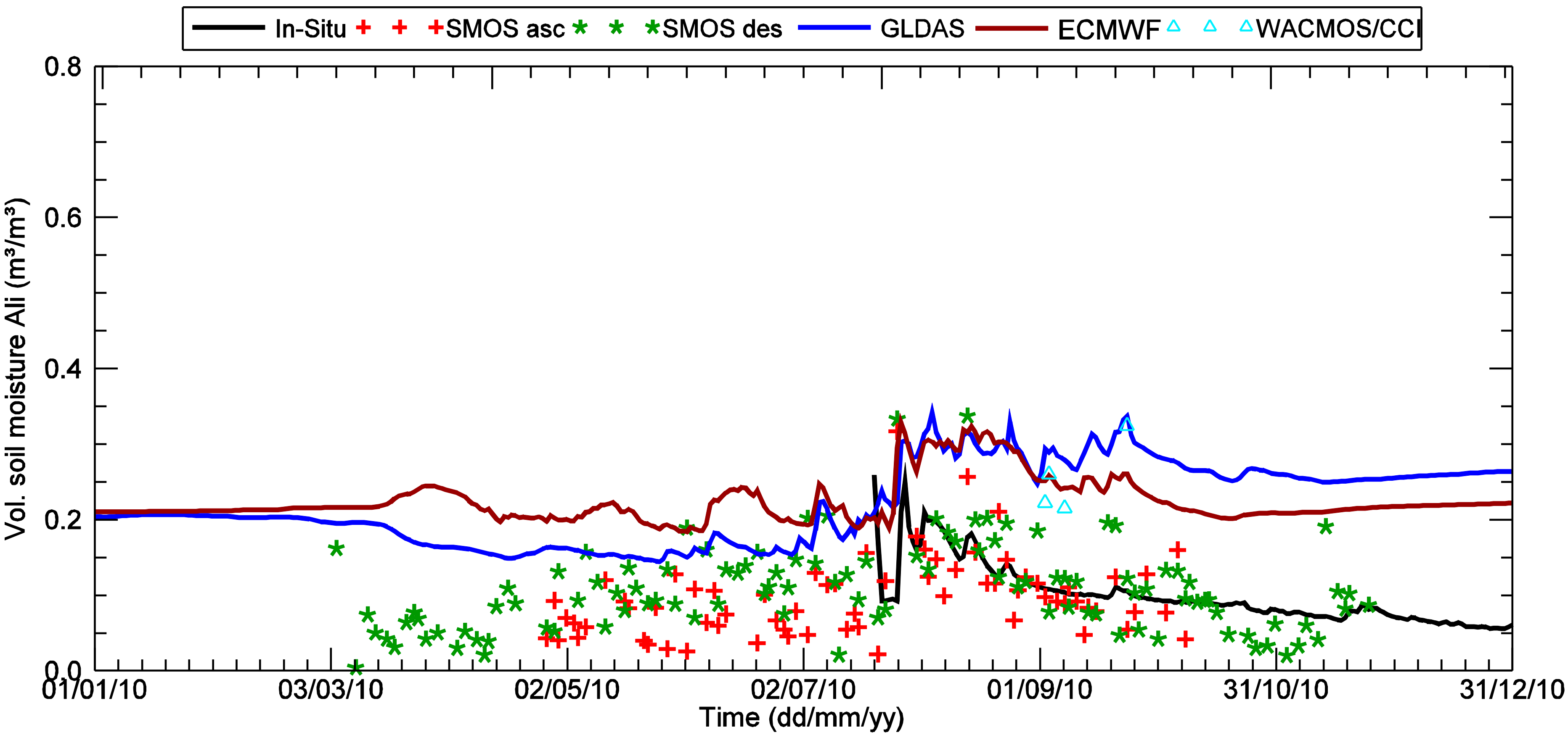


Tibetan Plateau soil moisture and soil temperature Observatory (Tibet-Obs)

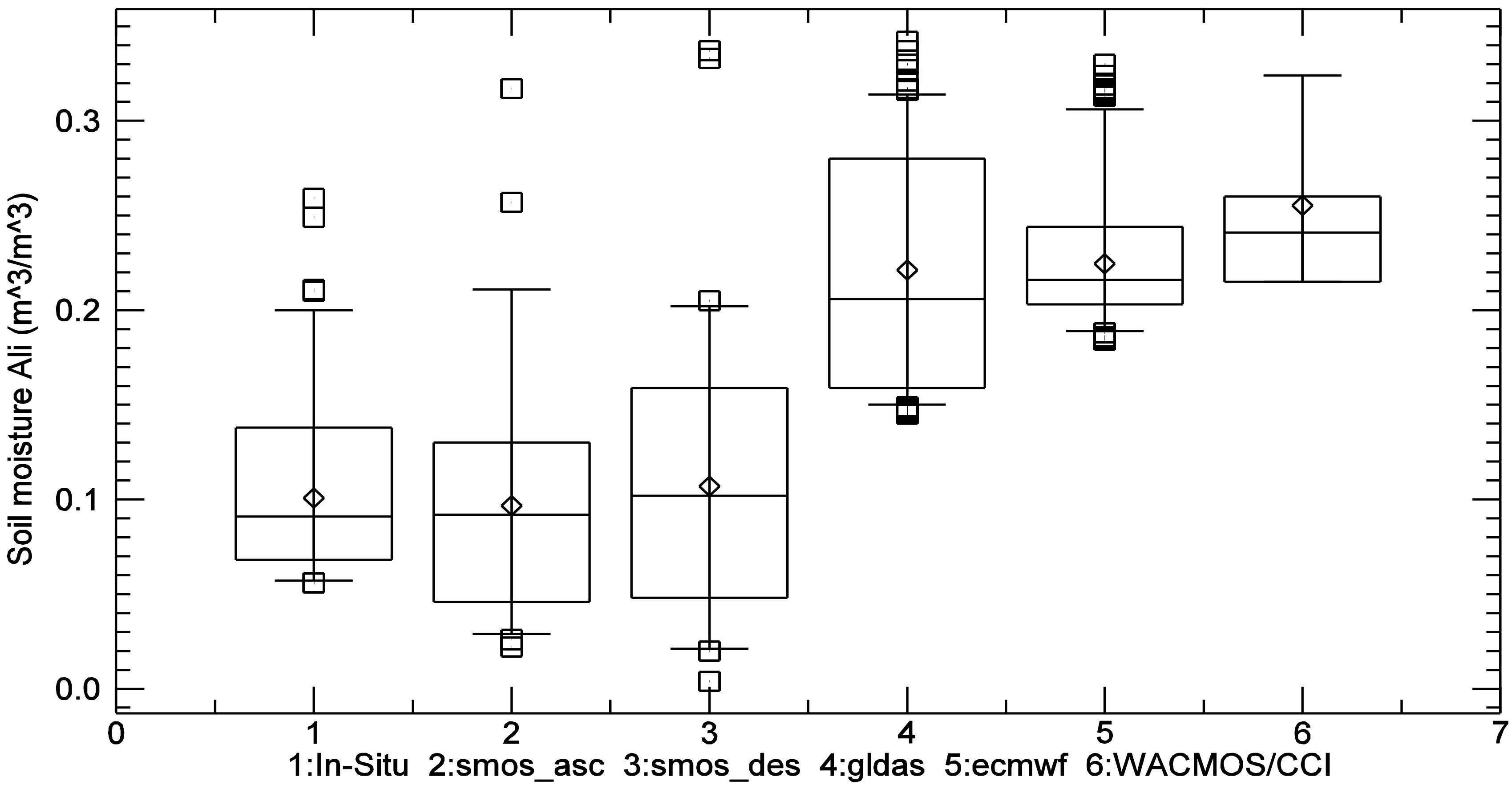


- Naqu Network (June 2006)
- Maqu Network (July 2008)
- Ngari Network (June 2010)

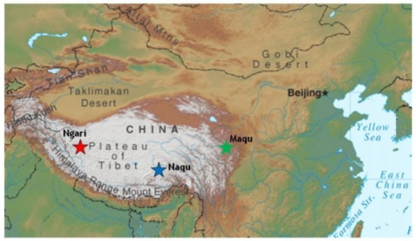
Ali SMST Network – validation results



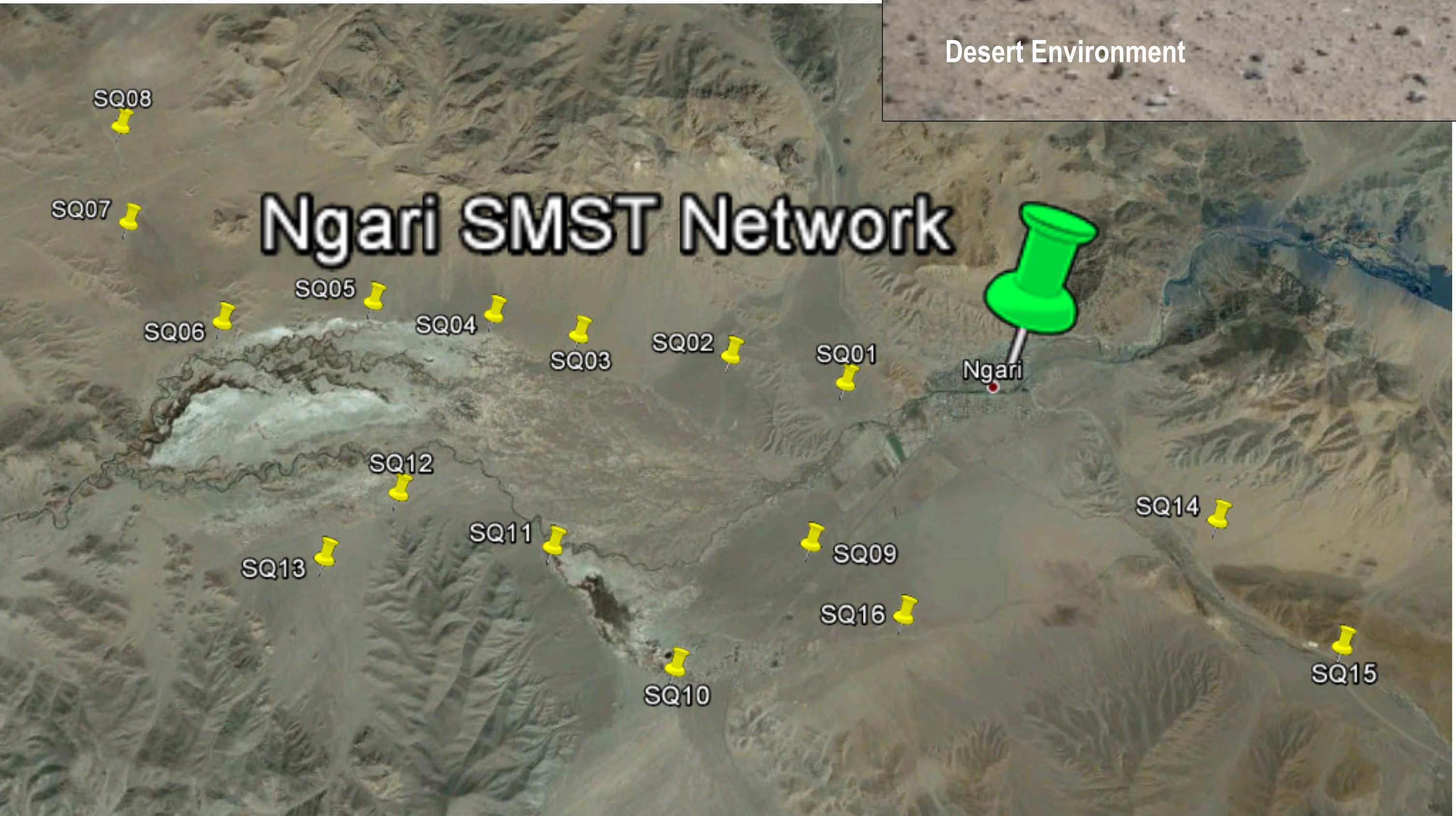
Ali SMST Network – validation results



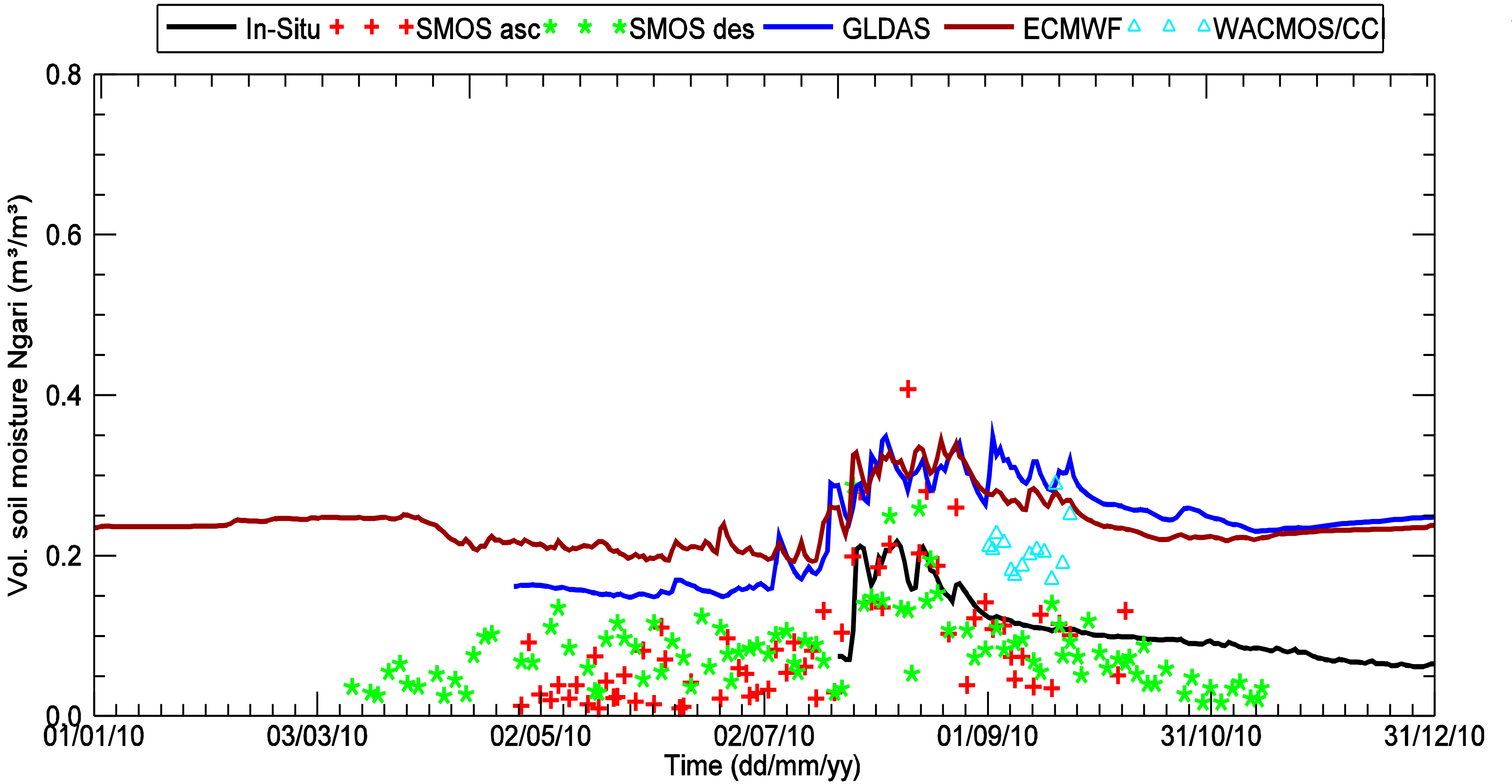
Tibetan Plateau soil moisture and soil temperature Observatory (Tibet-Obs)



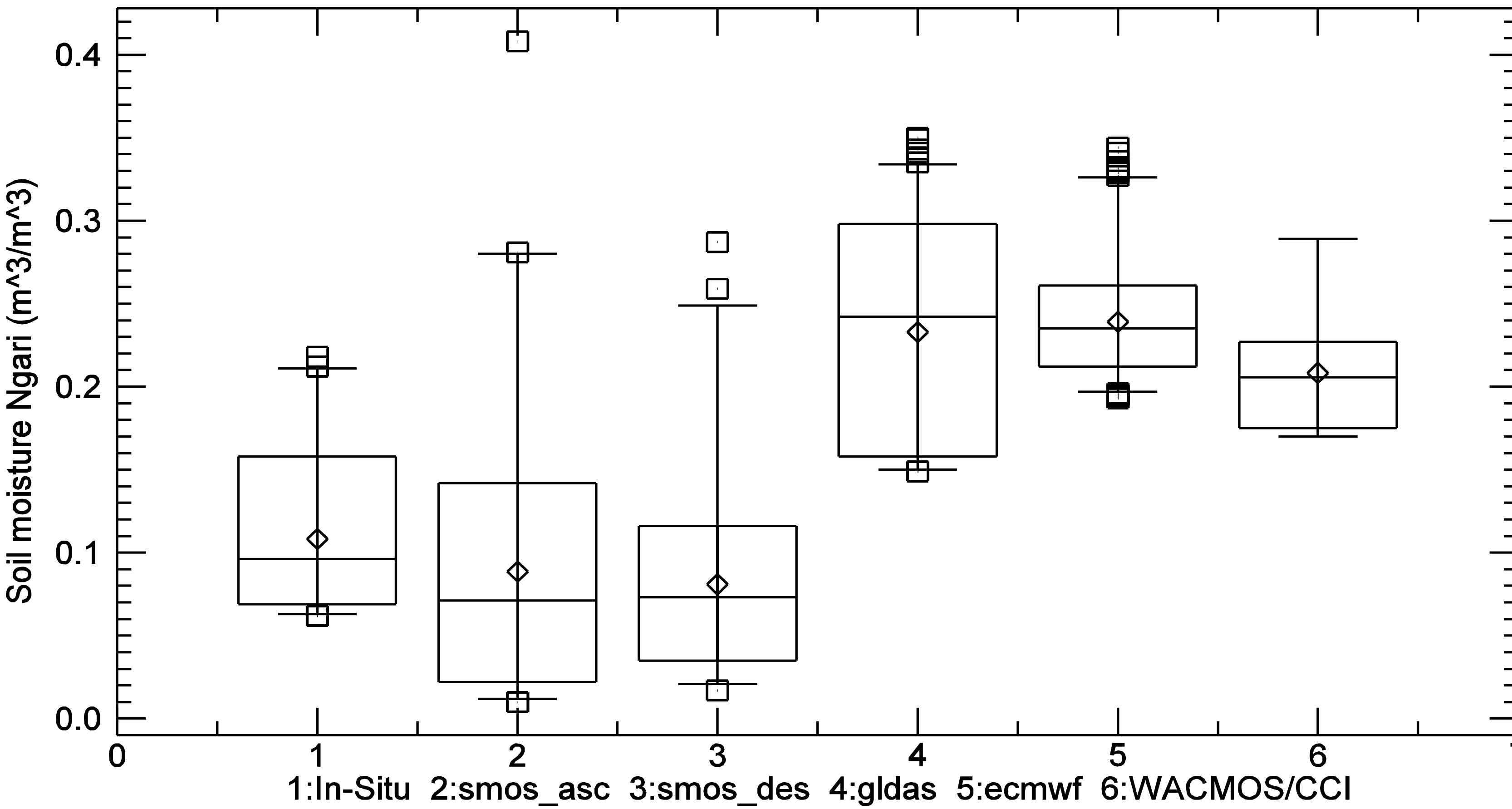
- Naqu Network (June 2006)
- Maqu Network (July 2008)
- Ngari Network (June 2010)



Ngari SMST Network – validation results

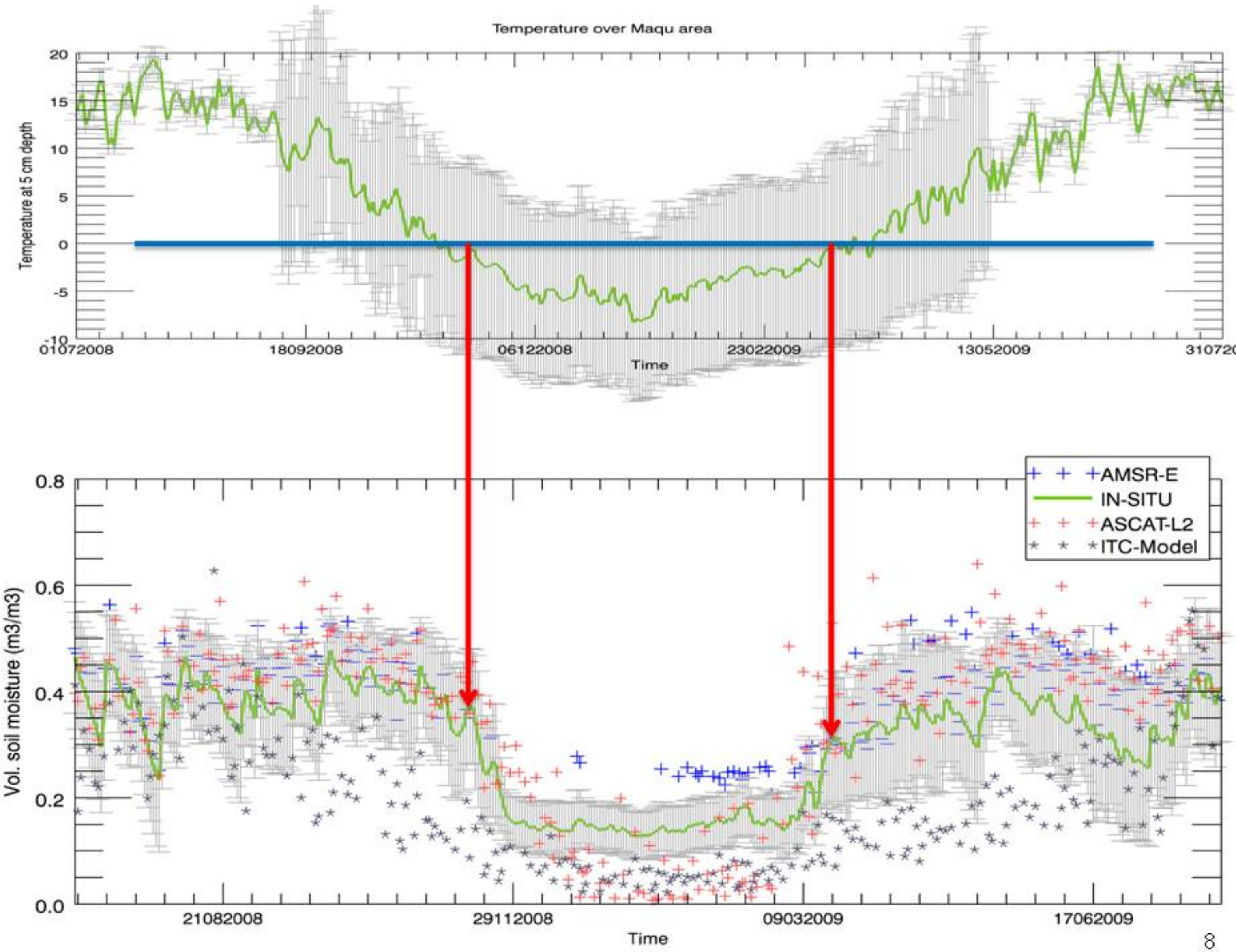


Ngari SMST Network – validation results

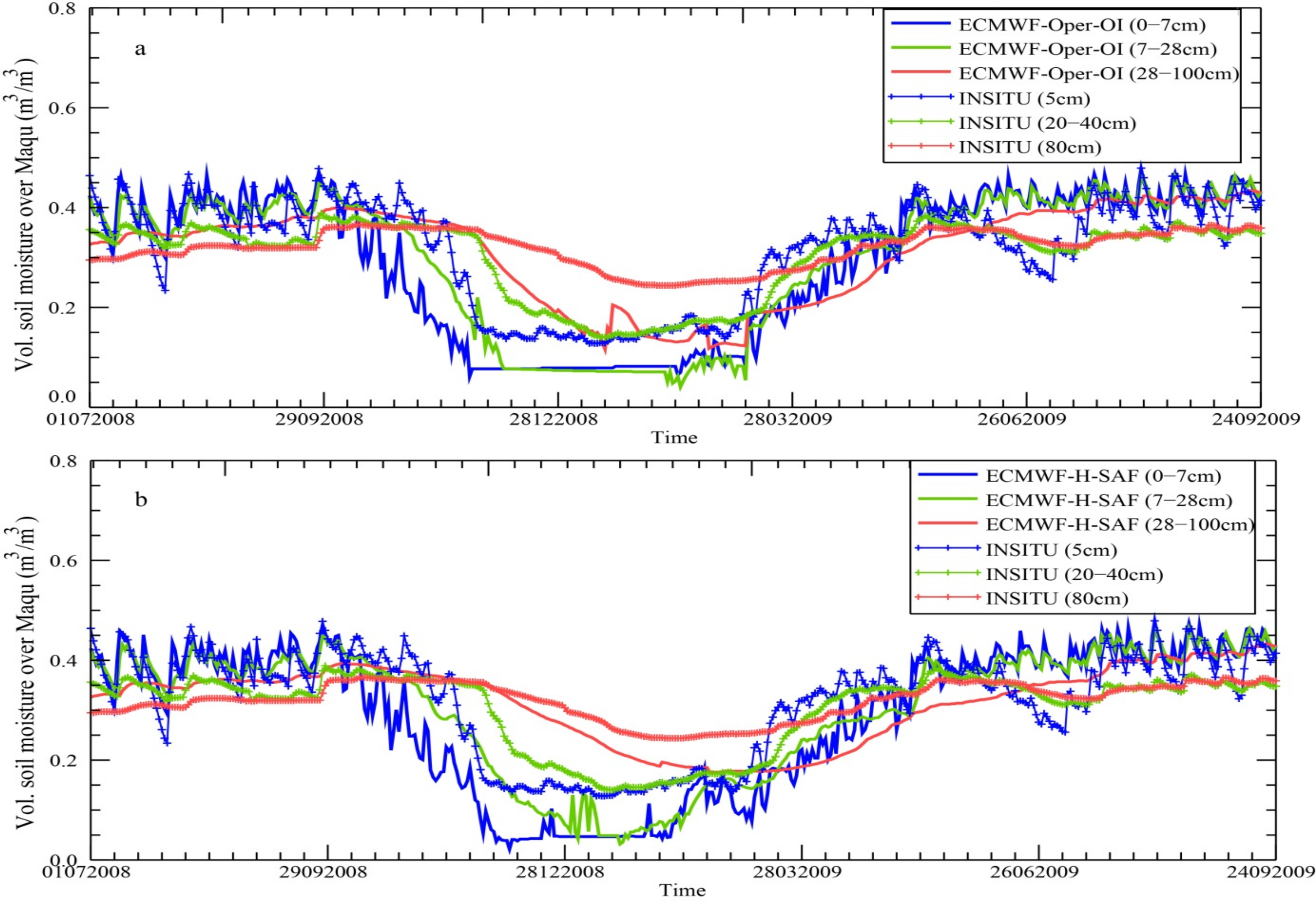


Some current research examples

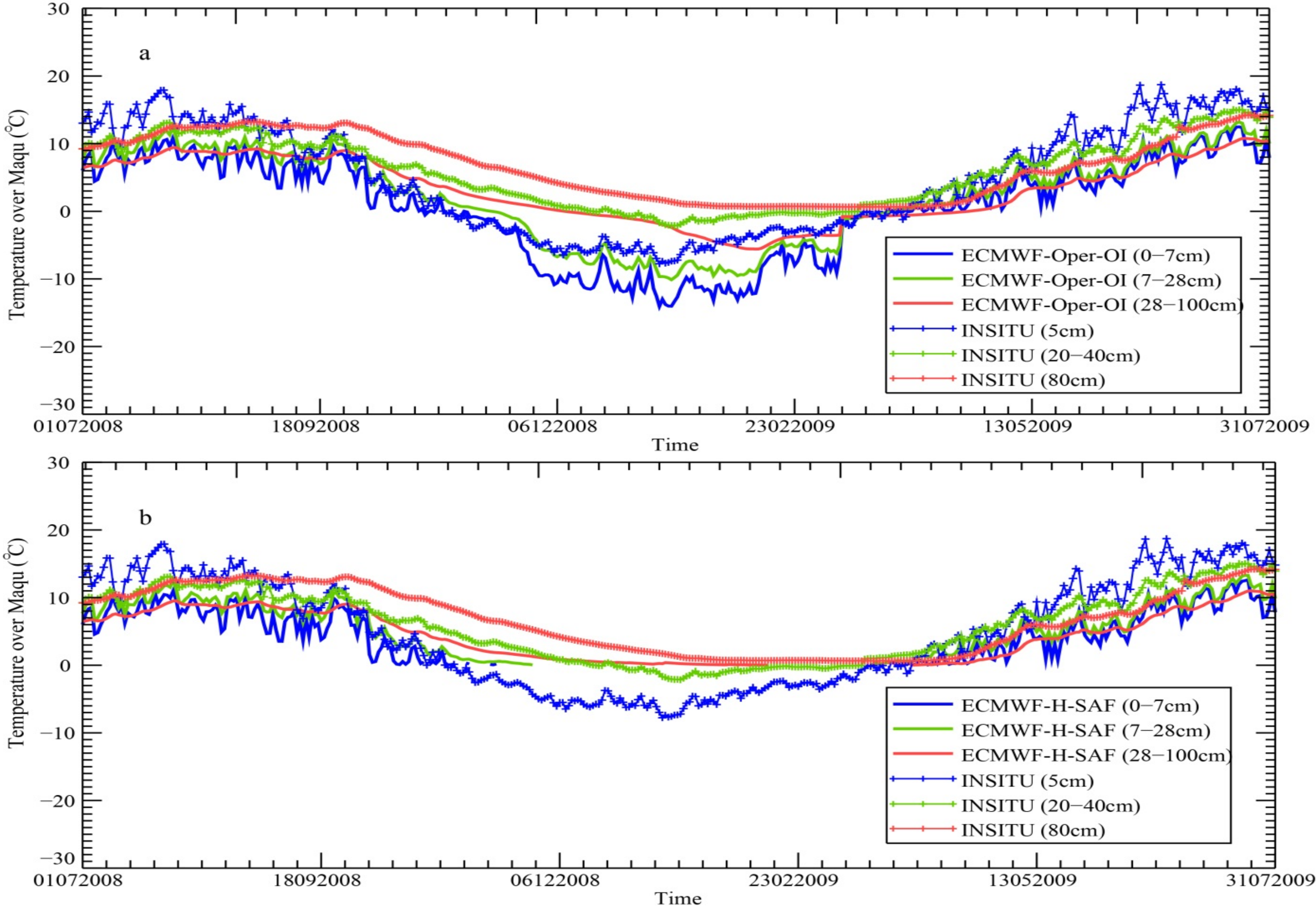
Quantification of uncertainties in global products (Su, et al., 2011)



How good is soil moisture analysis/assimilation? (Su & de Rosnay, et al. 2013)



How good is soil temperature simulation/analysis? (Su & de Rosnay, et al. 2013)



An Improved Two-layer Algorithm for Estimating Effective Soil Temperature using L-band Radiometry (Lv et al., 2014, RSE)

$$T_B = \varepsilon T_{eff}$$

$$T_{eff} = \int_0^\infty T(x)\alpha(x)\exp\left[-\int_0^x a(x')dx'\right]dx$$ (Ulaby et al. 1978; 1979)

$$\alpha(x) = \frac{4\pi}{\lambda}\varepsilon''(x) \Big/ 2\left[\varepsilon'(x)\right]^{\frac{1}{2}}$$ (Wilheit 1978)

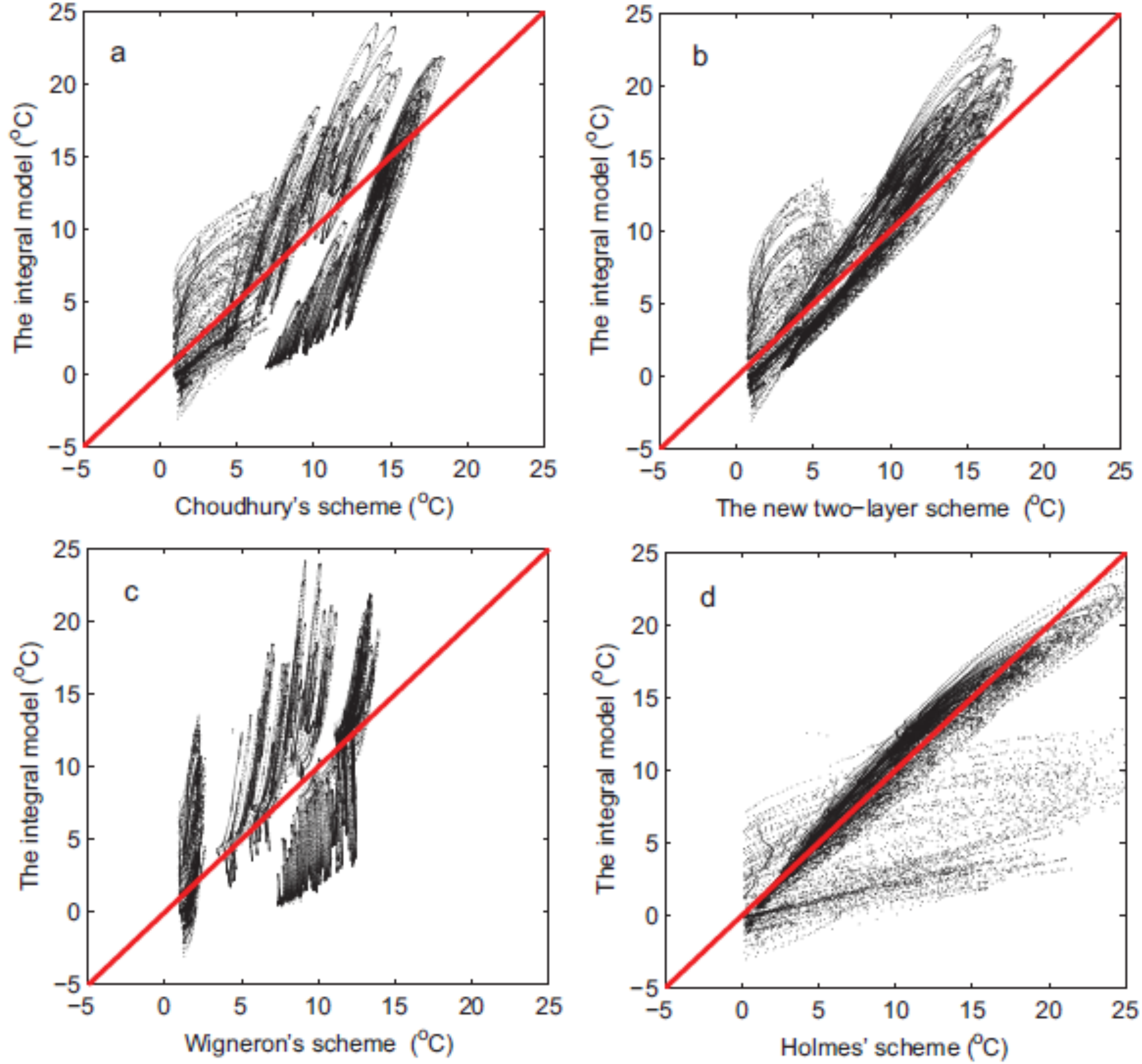
A two-layer system:

$$T_{eff} = T_0\left(1 - e^{-B_0}\right) + T_\infty e^{-B_0}$$

$$B_0 = \alpha_1 x_1$$

$$B_0 = \Delta x \cdot \frac{4\pi}{\lambda} \cdot \frac{\varepsilon''}{2\sqrt{\varepsilon'}}$$

$$\begin{aligned} C &= 1 - e^{-B_0} \\ &= 1 - \exp(-\Delta x \alpha_1) \\ &= 1 - \exp\left(-\Delta x \cdot \frac{4\pi}{\lambda} \cdot \frac{\varepsilon''}{2\sqrt{\varepsilon'}}\right) \end{aligned}$$


a
b
c
d
The integral model (°C)
Choudhury's scheme (°C)
The new two−layer scheme (°C)
Wigneron's scheme (°C)
Holmes' scheme (°C)

Tor Vergata Model – Simultaneous Modeling Of Active And Passive Microwave Signatures

- To use a single discrete scattering model to simulate both emission and backscattering, with a unique set of input parameters
- To combine the use of active and passive microwave satellite signatures to constrain the model
- To improve the modelling and understanding of microwave emissivity and backscattering coefficient over grassland with litter
- To contribute to an optimal use of SMAP-like data
- To improve the soil moisture retrieval

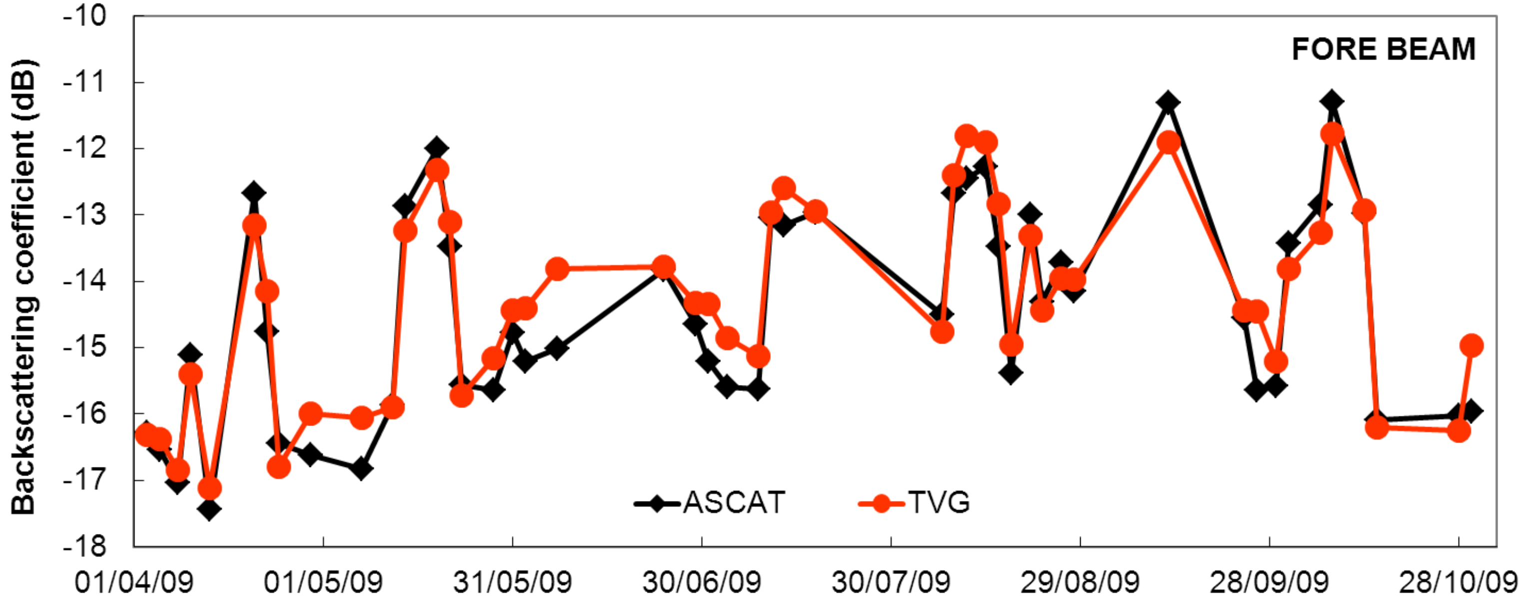
L. Dente, P. Ferrazzoli, Z. Su, R. van de Velde, L. Guerriero, 2014, Combined use of active and passive microwave satellite data to constrain a discrete scattering model, RSE.

PRELIMINARY ANALYSIS:
Model sensitivity to unavailable variables

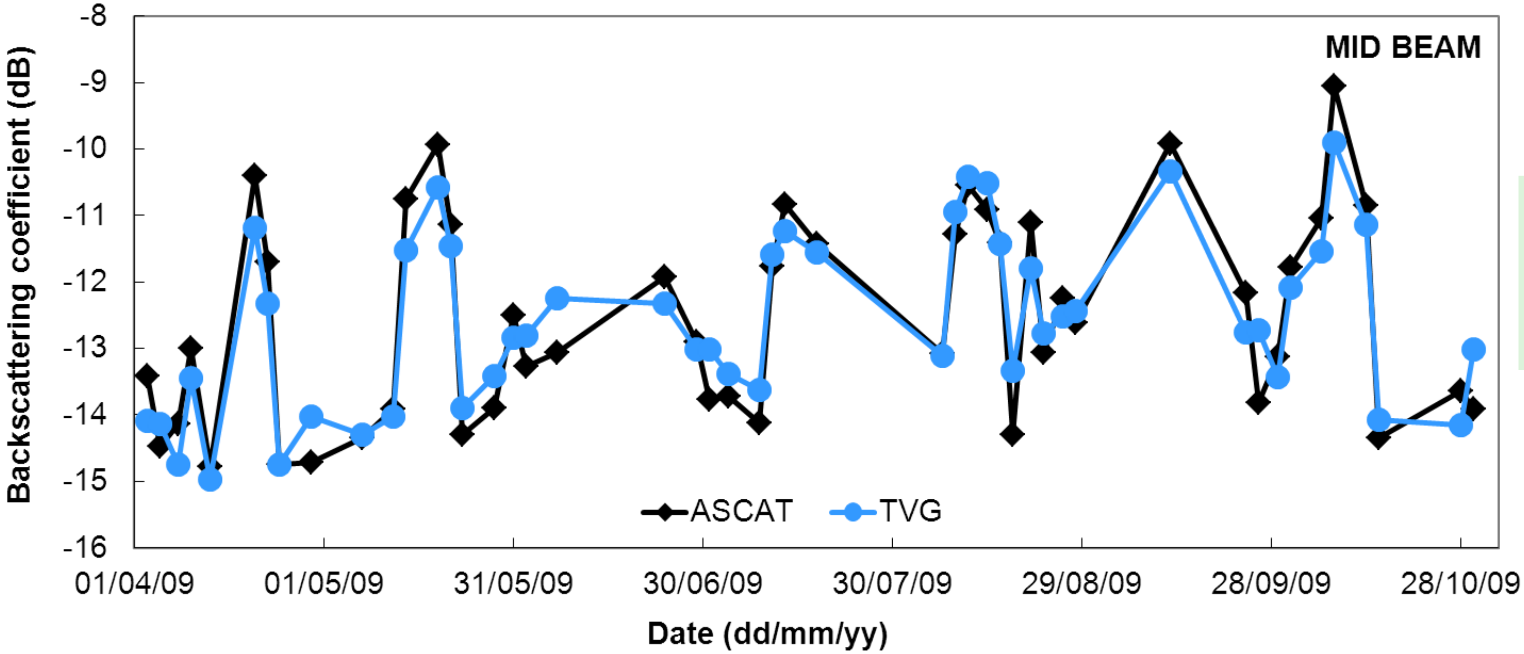
RESULTS:
Soil moisture and LAI (i.e. the measured variables) are the most important model inputs to simulate the temporal variability of emission and backscattering.
The unavailability of several model inputs can be managed by a proper parameter tuning.

height standard deviation	Calibrated
correlation length	Calibrated
autocorrelation function	Exponential
▪ Litter moisture content	Related to soil moisture, calibrated
▪ Litter biomass	Calibrated
▪ Leaf Area Index	MODIS/Terra+Aqua LAI 8-day
▪ Leaves: disc radius	Calibrated
▪ Leaves: disc thickness	0.02 cm
▪ Leaves: disc angular distribution	Random
▪ Plant moisture content	Calibrated

RESULTS: MODEL CALIBRATION (2009) – ACTIVE CASE

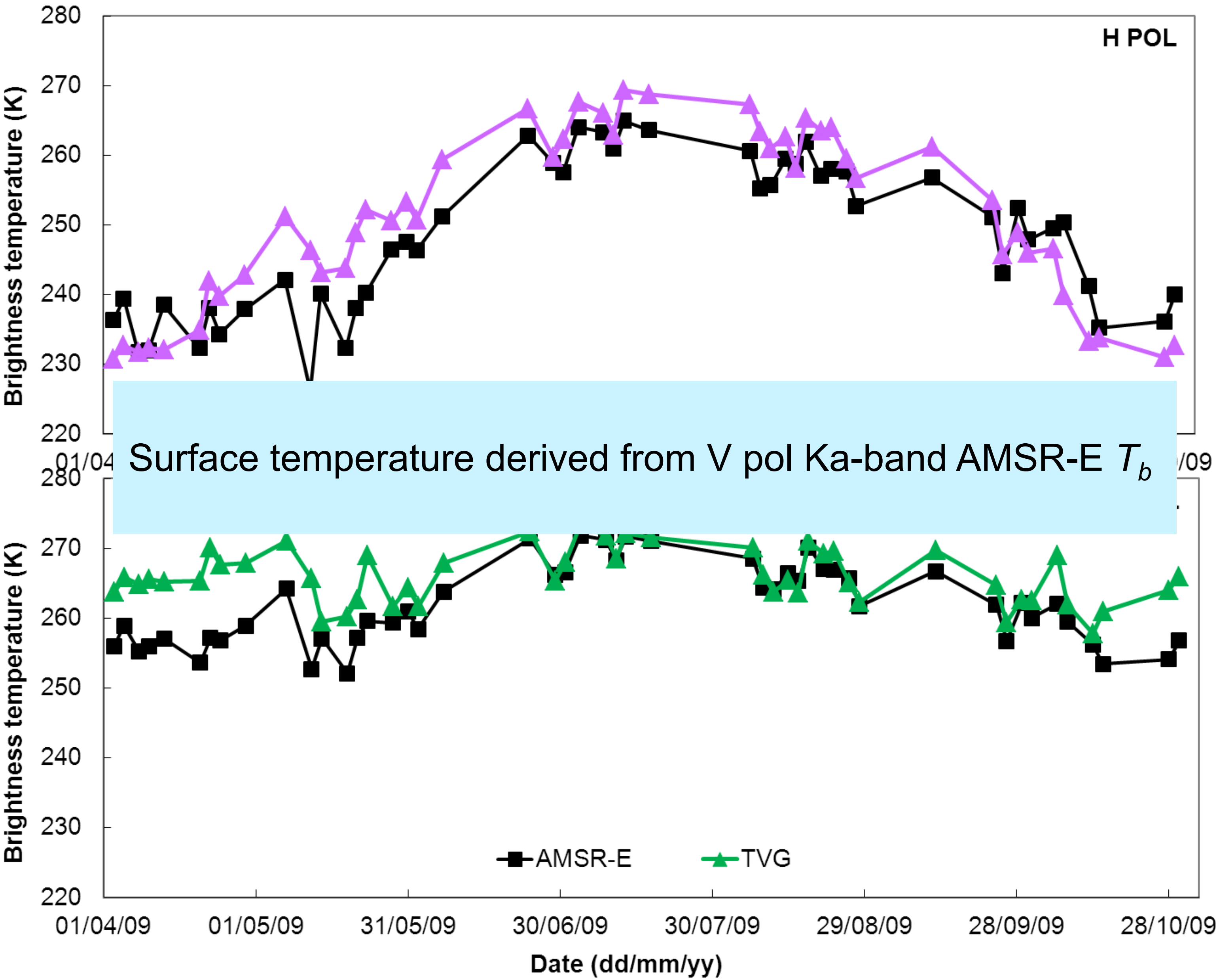


$R^2 = 0.9$
rmse = 0.5 dB
bias = 0.2 dB



$R^2 = 0.9$
rmse = 0.5 dB
bias = -0.04 dB

RESULTS: MODEL CALIBRATION (2009) – PASSIVE CASE (1)



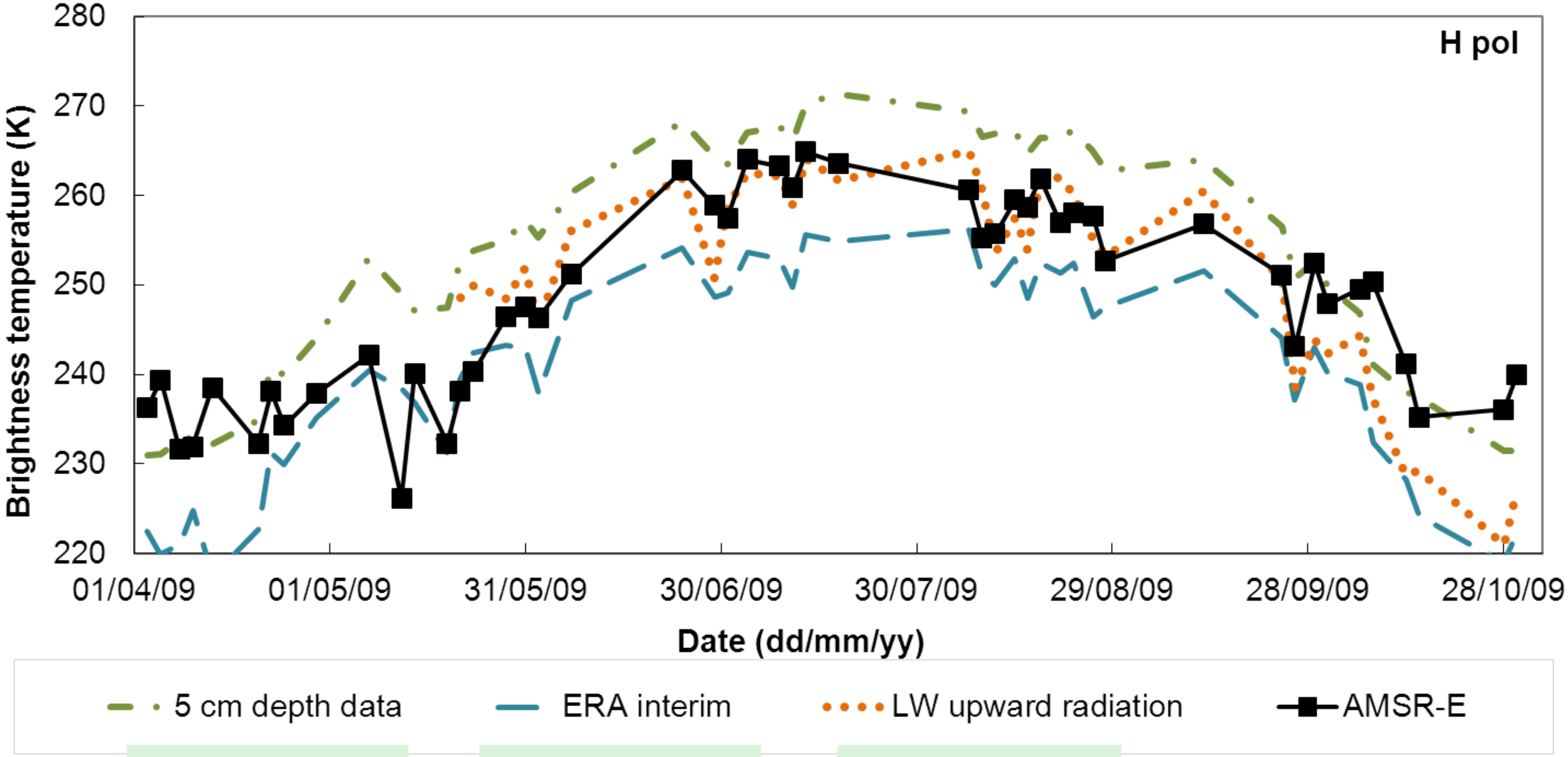
Surface temperature derived from V pol Ka-band AMSR-E T_b

R^2 = 0.8
rmse = 6.3 K
bias = 2.7 K

R^2 = 0.5
rmse = 5.9 K
bias = 4.3 K

RESULTS: MODEL CALIBRATION (2009) – PASSIVE CASE (2)

… when a different surface temperature is used.

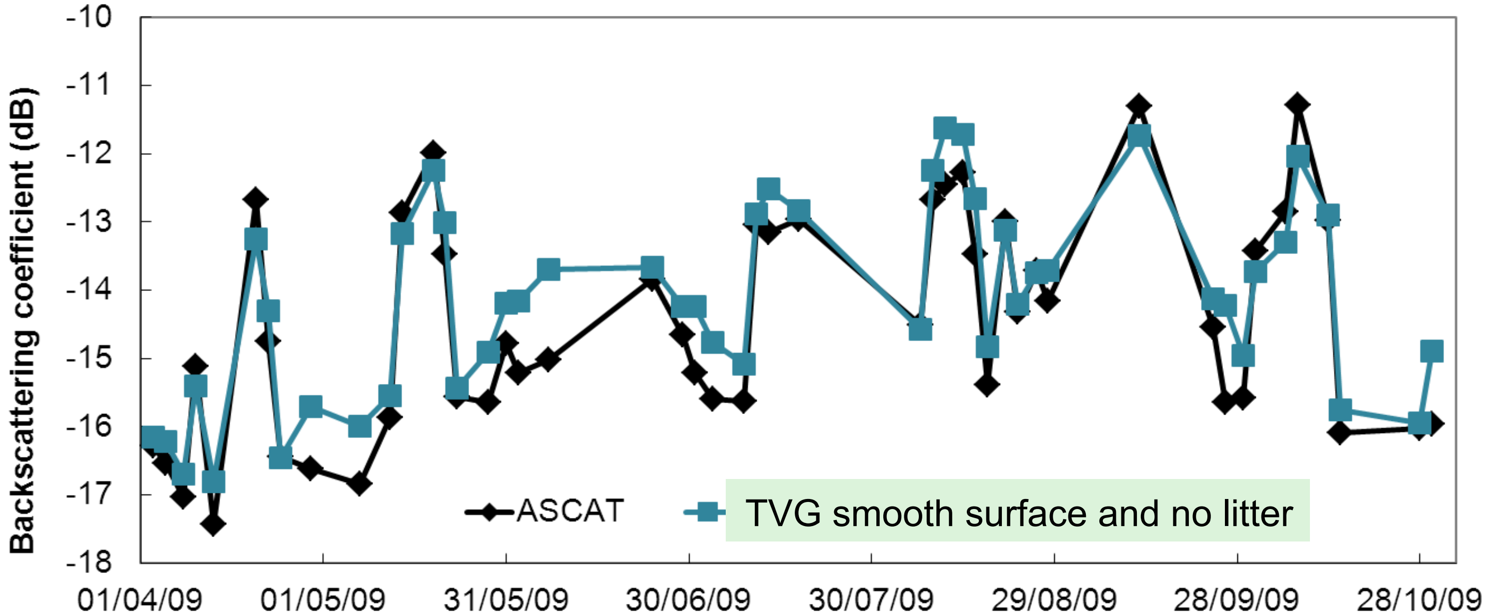


R^2 = 0.8
rmse = 8.2 K
bias = 5.1 K

R^2 = 0.8
rmse = 9.7 K
bias = -7.8 K

R^2 = 0.7
rmse = 6.2 K
bias = -1.7 K

IF ONLY THE ACTIVE MICROWAVE DATA WERE USED …

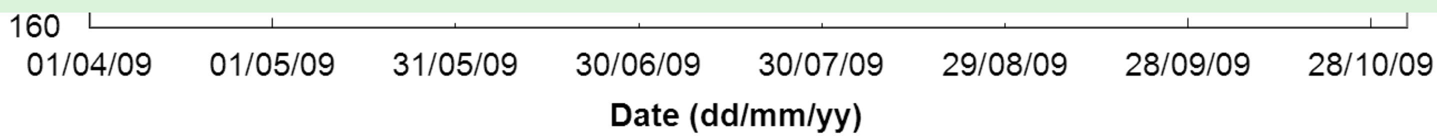


… a good match with ASCAT observations was possible with unrealistic assumptions:

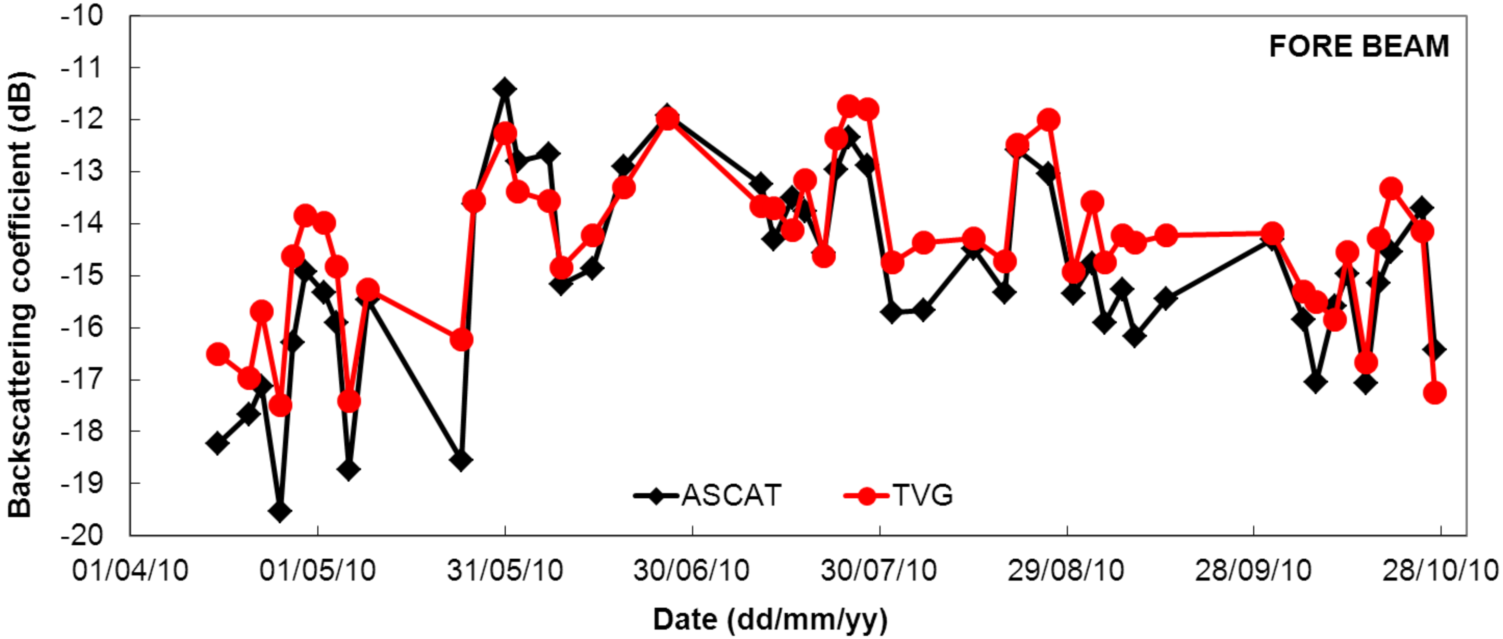
-absence of litter

-smooth surface

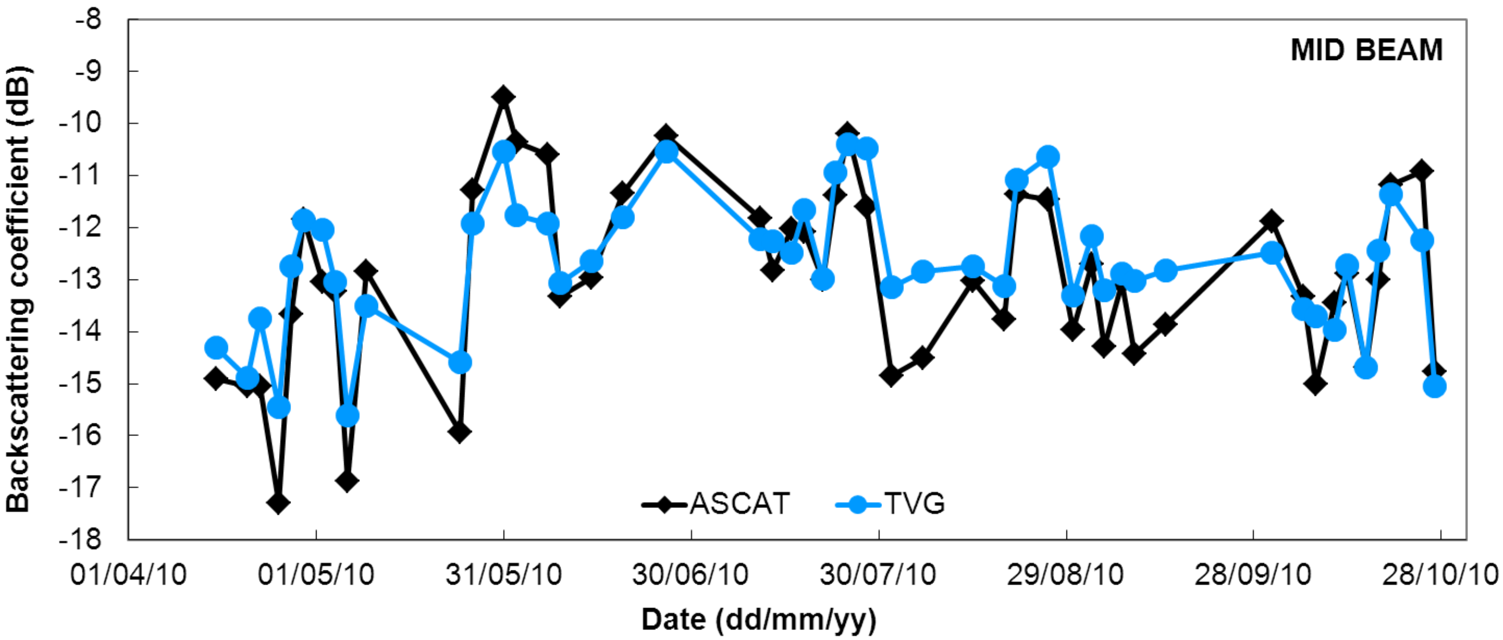
However, the same assumptions led to a large underestimation of T_b!



RESULTS: MODEL VALIDATION (2010) – ACTIVE CASE

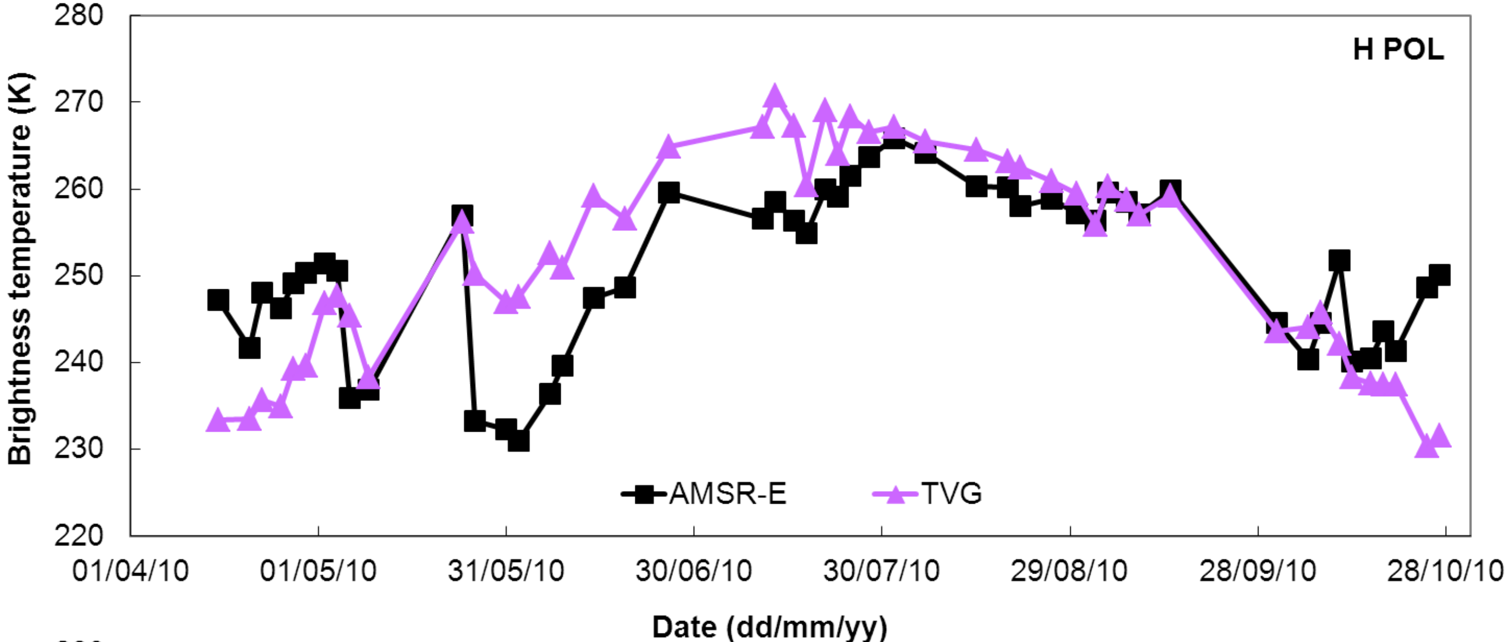


R^2 = 0.8
rmse = 1 dB
bias = 0.6 dB

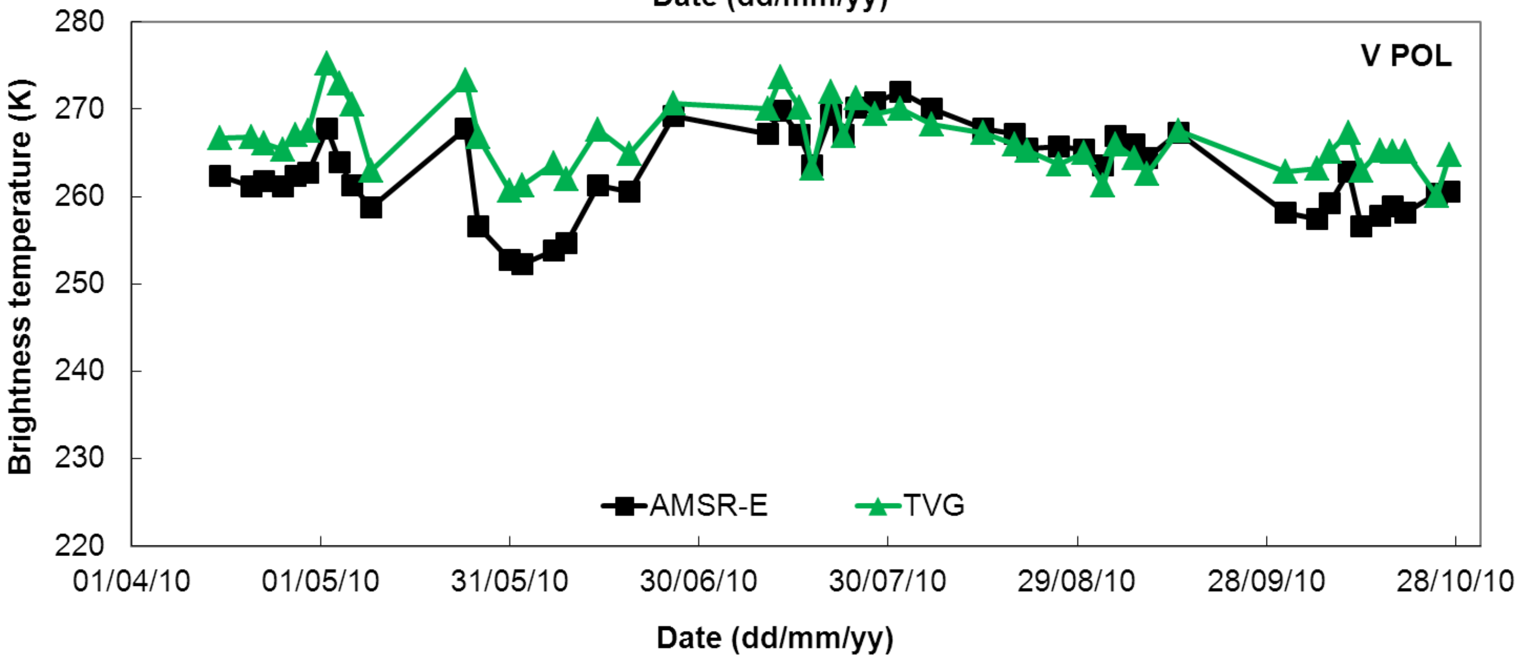


R^2 = 0.8
rmse = 0.8 dB
bias = 0.3 dB

RESULTS: MODEL VALIDATION (2010) – PASSIVE CASE



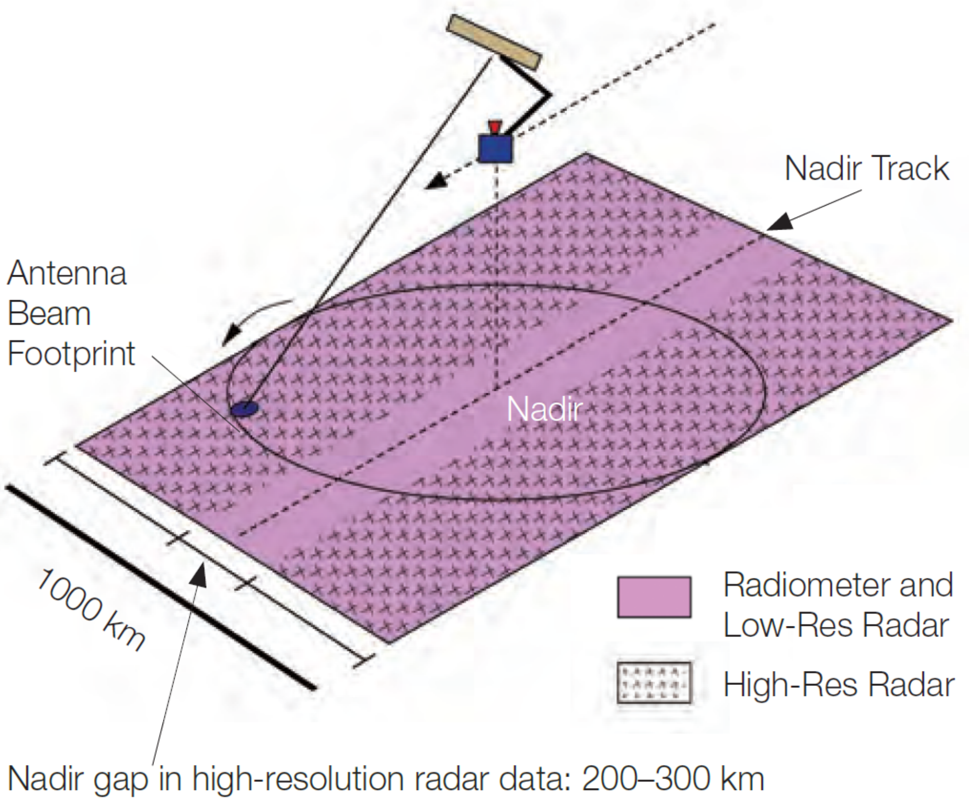
R^2 = 0.5
rmse = 8.7 K
bias = 1.3 K

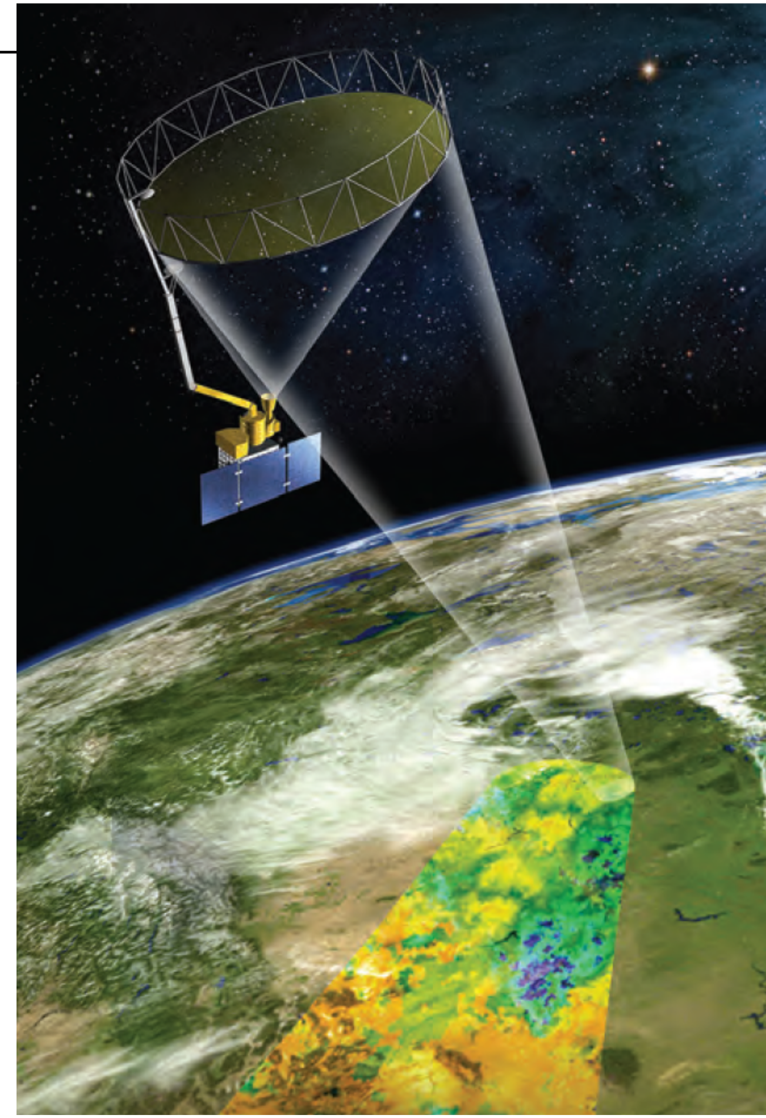


R^2 = 0.5
rmse = 5.0 K
bias = 3.4 K

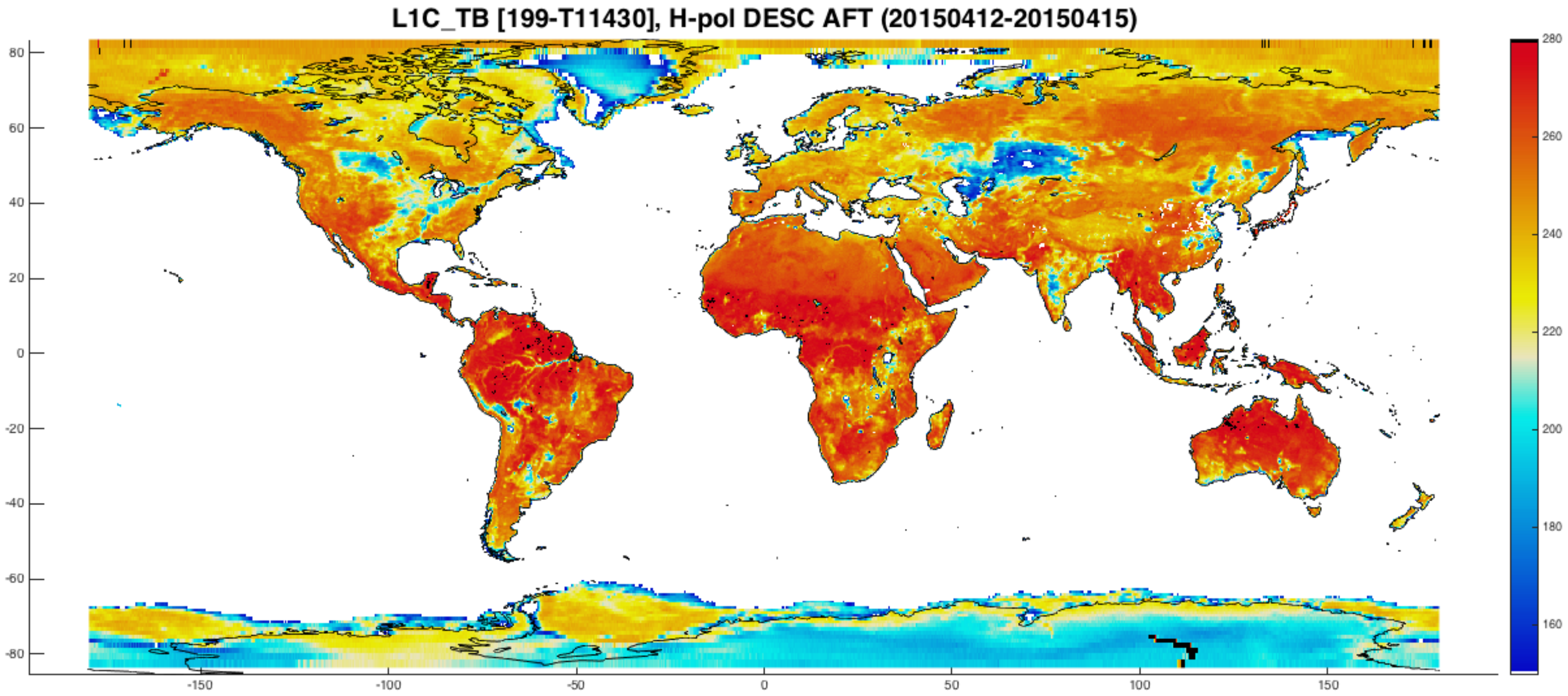
NASA SMAP – SOIL MOISTURE ACTIVE PASSIVE

LAUNCHED JAN 31 2015



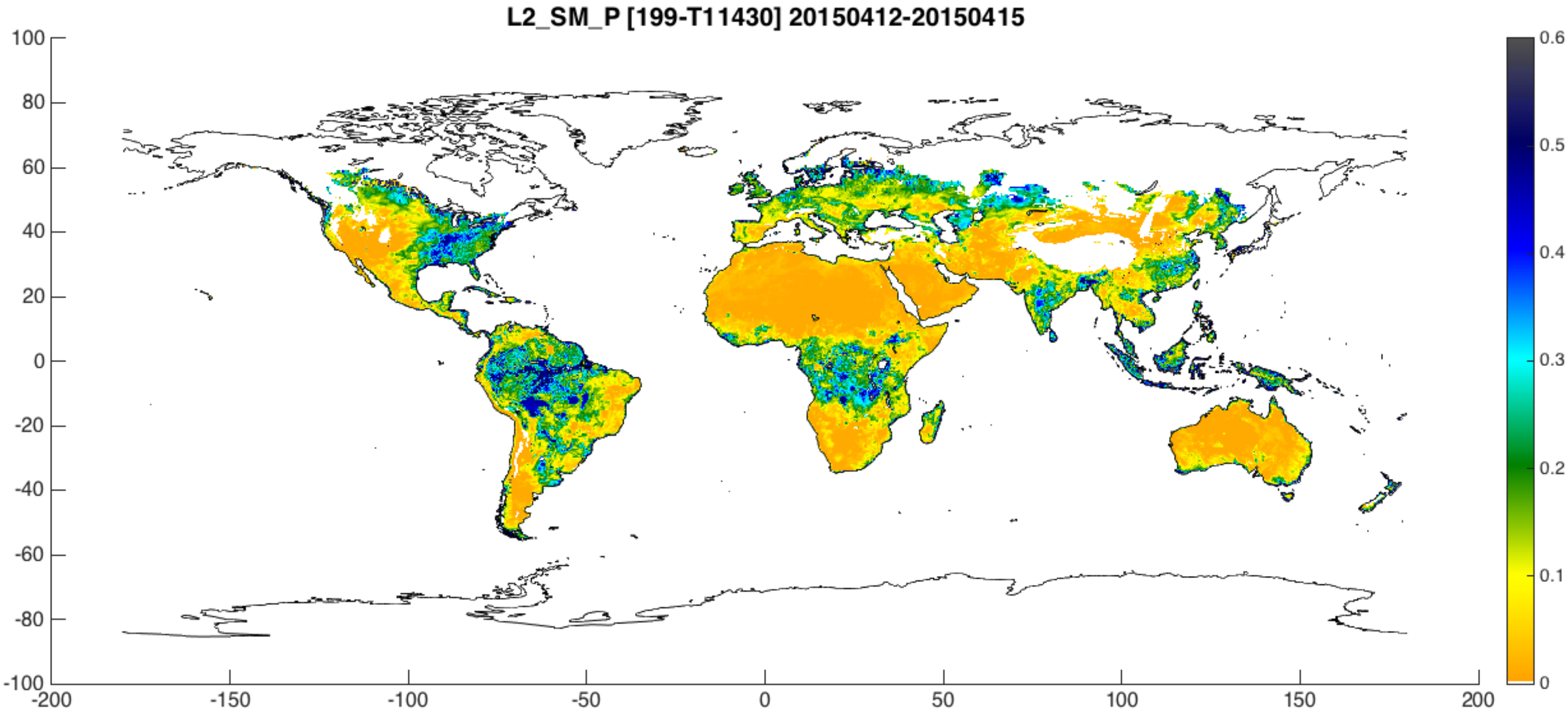


ACTUAL SMAP DATA: RADIOMETER



- Not fully calibrated at this time

ACTUAL SMAP DATA: L2_SM_P



- Baseline algorithm and only with minor parameterization updates

Referances/Further Readings

Su, Z., A. Yacob, Y. He, H. Boogaard, J. Wen, B. Gao, G. Roerink, and K. van Diepen, 2003, Assessing Relative soil moisture with remote sensing data: theory and experimental validation, Physics and Chemistry of the Earth, 28(1-3), 89-101.

Wen. J., Z. Su, 2003, Estimation of soil moisture from ESA Wind-scatterometer data, Physics and Chemistry of the Earth, 28(1-3), 53-61.

Wen, J., Z. Su, 2004, An analytical algorithm for the determination of vegetation Leaf Area Index from TRMM/ TMI data, International Journal of Remote Sensing, 25(6), 1223−1234.

Wen, J., Z. Su, 2003, A Method for Estimating Relative Soil Moisture with ESA Wind Scatterometer Data, Geophysical Research Letters, 30 (7), 1397, doi:10.1029/ 2002GL016557.

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van der Velde, R., Z. Su, 2009, Dynamics in land surface conditions on the Tibetan Plateau observed by ASAR, Hydrological sciences journal (in press).

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