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→ 4th ADVANCED TRAINING COURSE IN LAND REMOTE SENSING

Soil moisture & Water Resource Applications

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What is the difference?

What is Drought ?

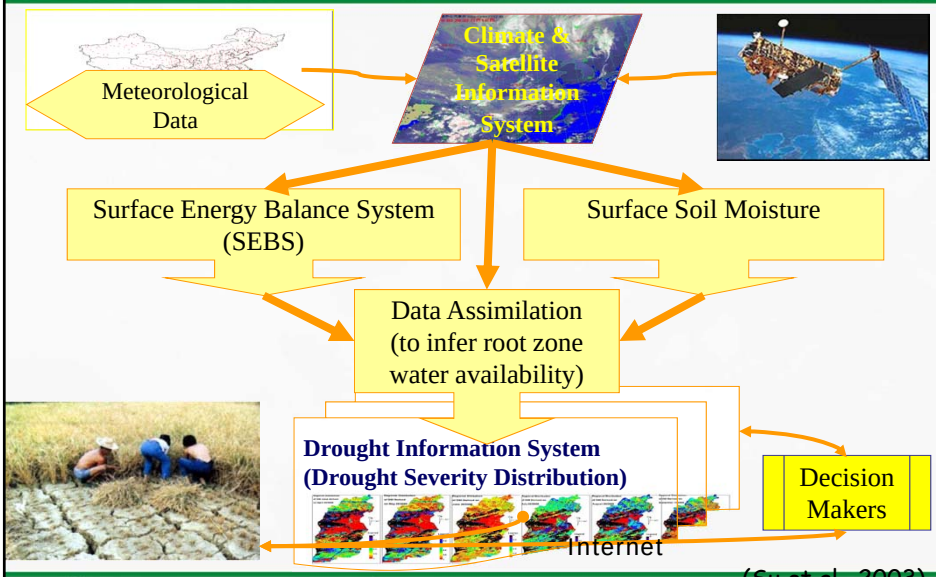
Approaches for Drought Monitoring and Prediction

- Approach 1: Surface Energy Balance
  - To derive relative evaporation & relative soil moisture in the root zone from land surface energy balance
  - To define a quantitative drought severity index (DSI) for large scale drought monitoring
- Approach 2: Soil Moisture Retrieval
  - To determine surface soil moisture
  - To assimilate surface SM into a hydrological model to derive root zone soil moisture

To validate the methodologies on the basis of large scale field experiments

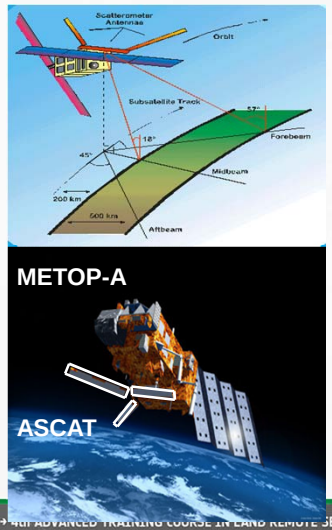
(Su et al., 2003)

Drought Monitoring & Prediction



(Su et al., 2003)

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°), we have

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

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

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

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.

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.

$s = \sqrt{2}\sigma / l$ 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.

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 fractional coverage

Vegetation transmissivity, Reflectivity at nadir, Roughness slope

Soil texture (percentage of sand and clay)

Dielectric constant (dielectric mixing model)

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).

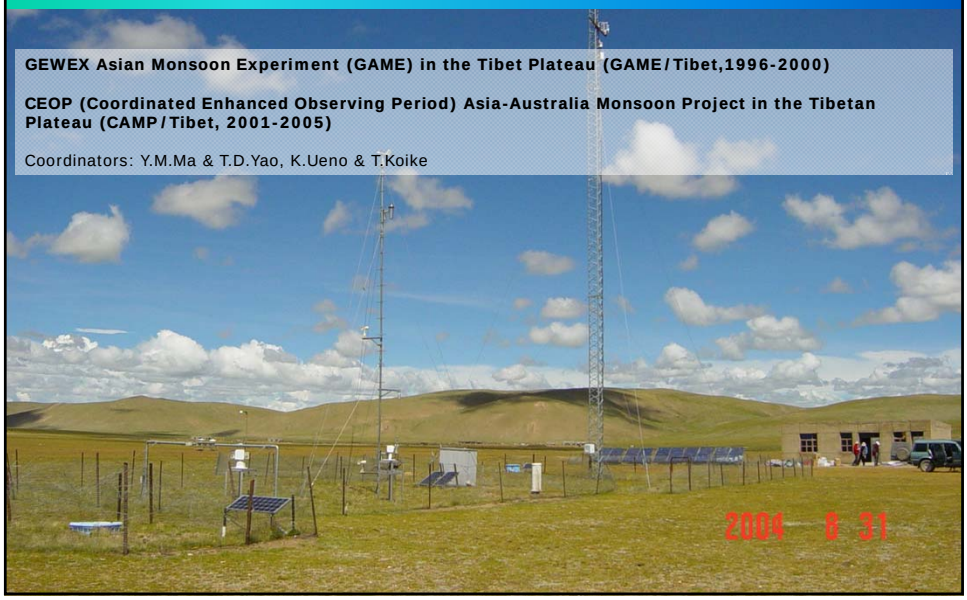
Tibetan Soil Moisture Experiments at location of CAMP/Tibet sites

(in collaboration with Y. Ma, J. Wen, K. Yang, Z. Hu, CAS)

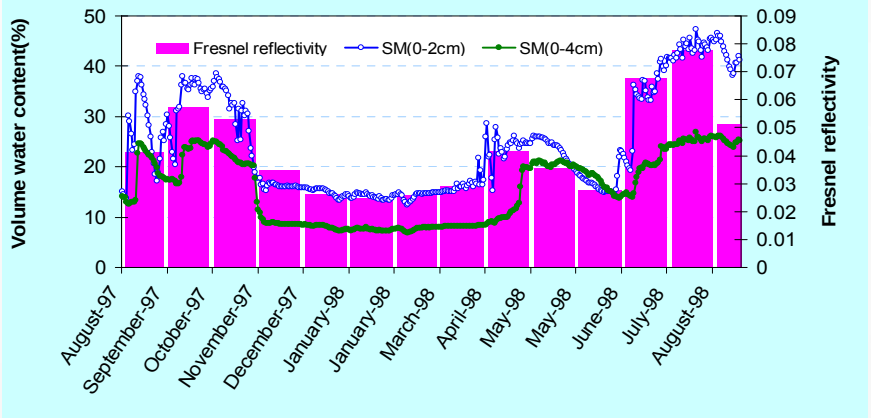
GEWEX Asian Monsoon Experiment (GAME) in the Tibet Plateau (GAME/Tibet,1996-2000)

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

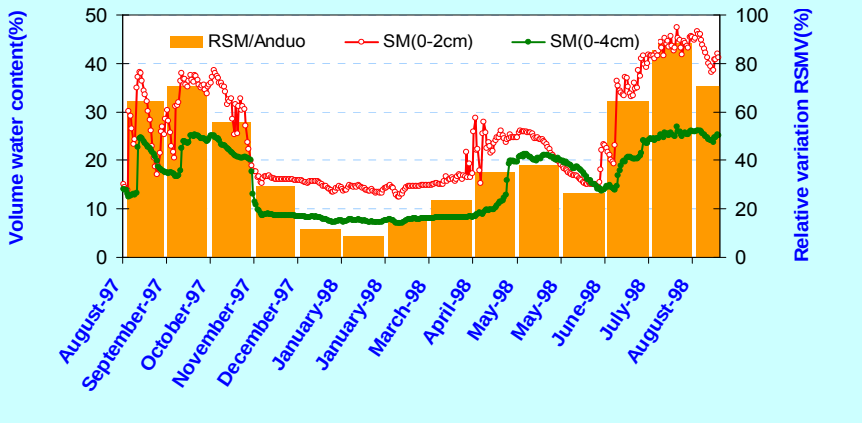
Coordinators: Y.M.Ma & T.D.Yao, K.Ueno & T.Koike



Estimated Fresnel reflectivity and ground measured volume soil water content



Retrieval with change detection method
(Wen and Su, 2003b, Geophys. Res. Letter)



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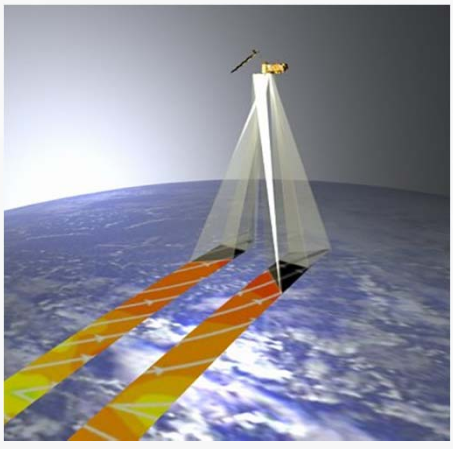
ASCAT Scanning Principle

- 5.255 GHz C-band radar scatterometer with three dual-swath (2 x 500 km width, offset 384 km left/right of ground track) antennas (fore/mid/aft)
- Radar backscatter at three azimuth angles to provide surface wind vectors of 4-24 m/s with accuracy ± 2 m/s & ± 20°
- Spatial resolution 50 km (25 km experimental)
- 0.57 dB radiometric accuracy
- Incidence angle range 25-65°



ASCAT's two 500km swaths, global coverage every 5 days, data acquired irrespective of daylight and cloud conditions

Global soil moisture maps (pixel size:15' by 15')

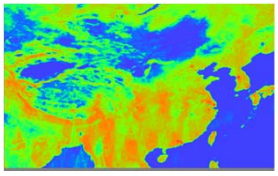
Retrieved using ASCAT data (the smoothed 12.5 km spatial resolution) temporal coverage from 1-7 July 2007.

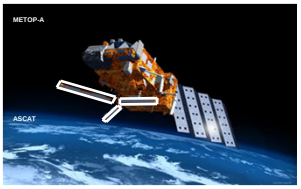
Input data:

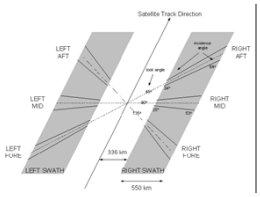
- ASCAT sigma triplet values (fore, mid, aft).
- Percentage of sand and clay maps obtained from ecoclimap website: http://www.cnrm.meteo.fr/gmme/PROJETS/ECOCLIMAP/page_ecoclimap.htm reterived derived from FAO (1988) soil texture database
- Land cover map also obtained from ecoclimap project
- Vegetation cover converted from LAI data using : Fc = 1-exp^(-0.5*LAI), where LAI is MODIS leaf area index 8-day global 1km product, temporal coverage 01-08 July 2007, obtained from: https://wist.echo.nasa.gov/~wist/api/imswelcome/

Some results with ASCAT data
(CEOP-AEGIS WP4)

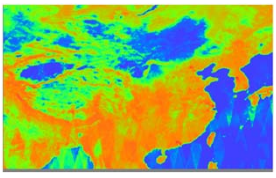
sigma zero triplet for values (dB)



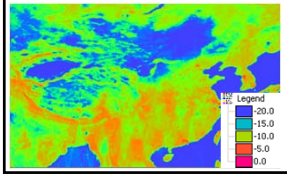




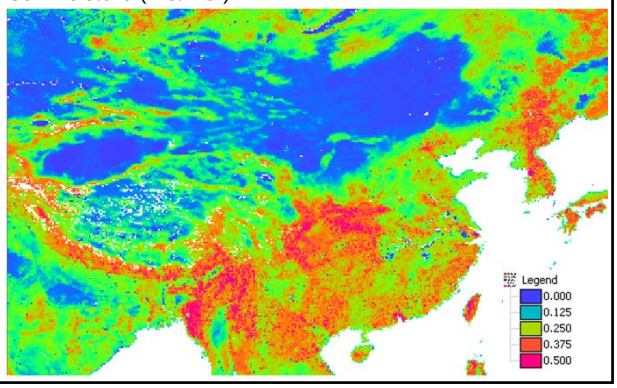
sigma zero triplet mid values (dB)



sigma zero triplet after values (dB)



Soil moisture (m3/m3)



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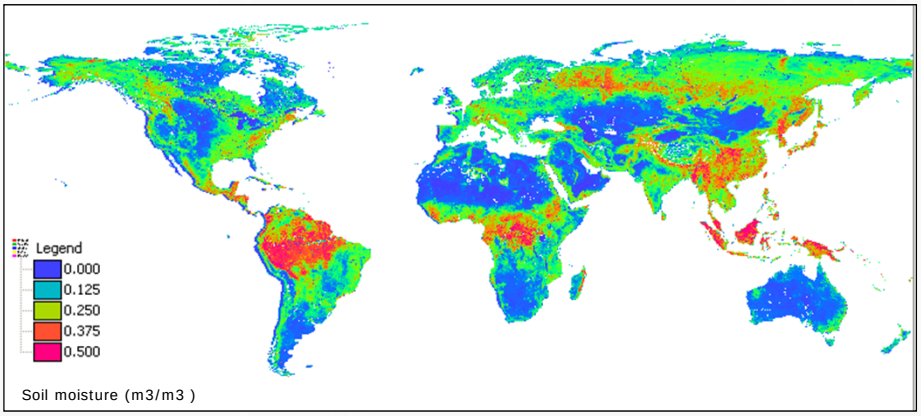
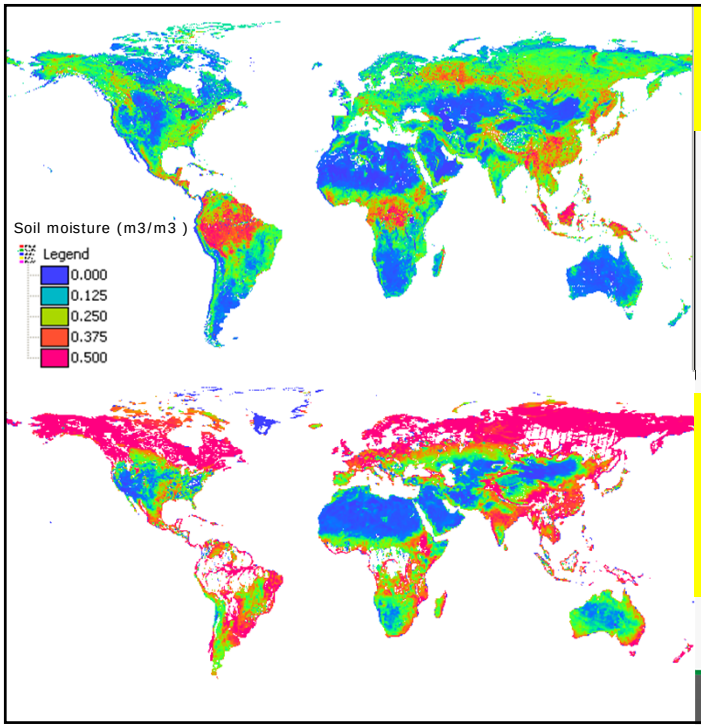
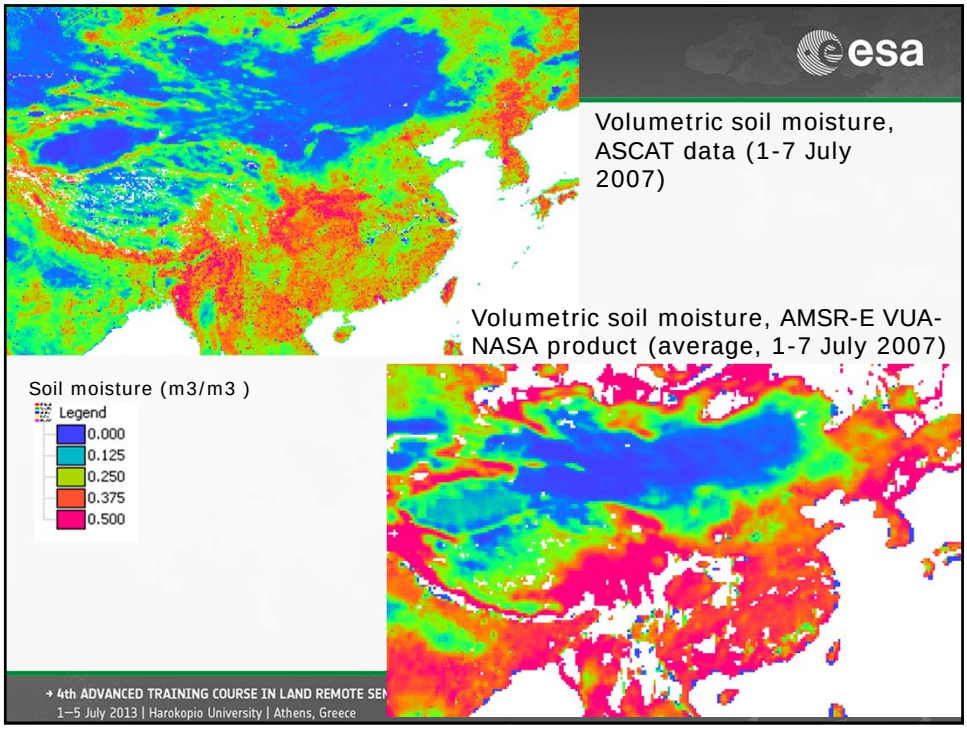
Volumetric soil moisture, ASCAT data, 1-7 July 2007





Volumetric soil moisture, ASCAT data, 1-7 July 2007

Volumetric soil moisture, AMSR-E VUA-NASA product, average 1-7 July 2007 (Pixel size 0.25°, White pixels = flag values = sea, ice, forest)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Volumetric soil moisture, ASCAT data (1-7 July 2007)
Volumetric soil moisture, AMSR-E VUA-NASA product (average, 1-7 July 2007)
Soil moisture (m3/m3)
Legend
0.000
0.125
0.250
0.375
0.500
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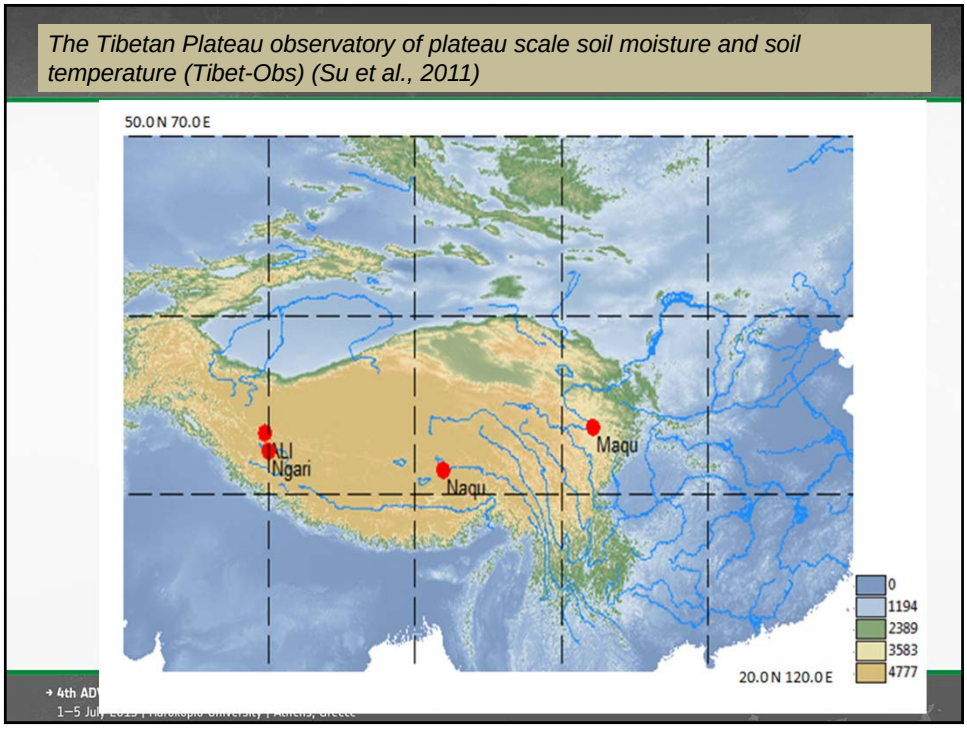
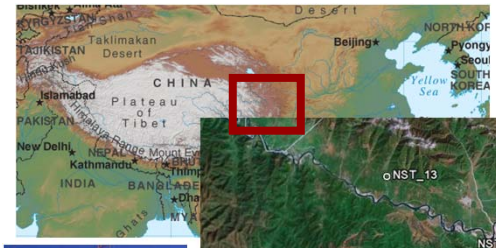
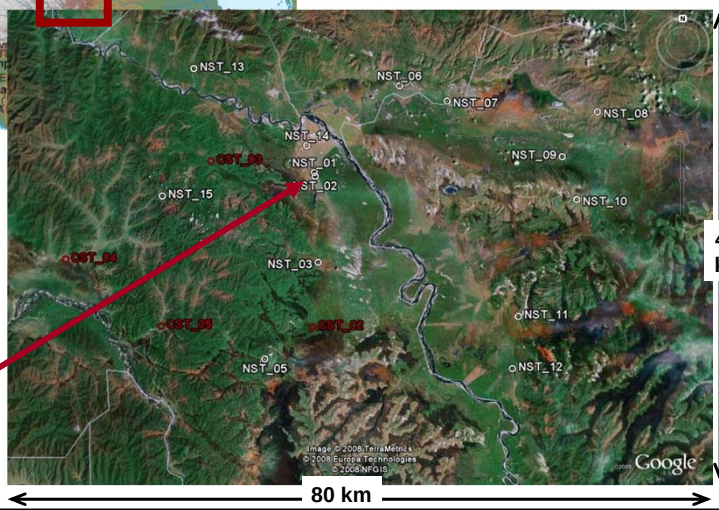

The Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs) (Su et al., 2011)
50.0 N 70.0 E
Ali
Ngari
Naqu
Maqu
20.0 N 120.0 E
0
1194
2389
3583
4777

Maqu soil moisture network



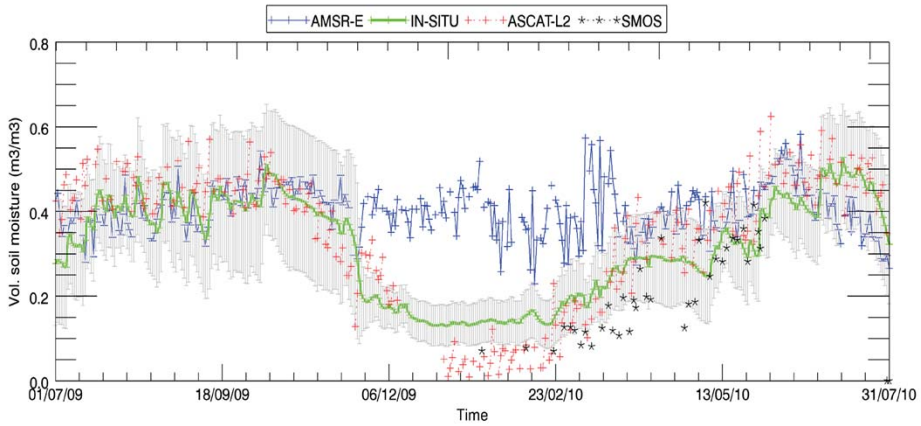
20 soil moisture and soil temperature stations



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

The Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs) – validation and calibration of global soil moisture data products (Su et al., 2011)



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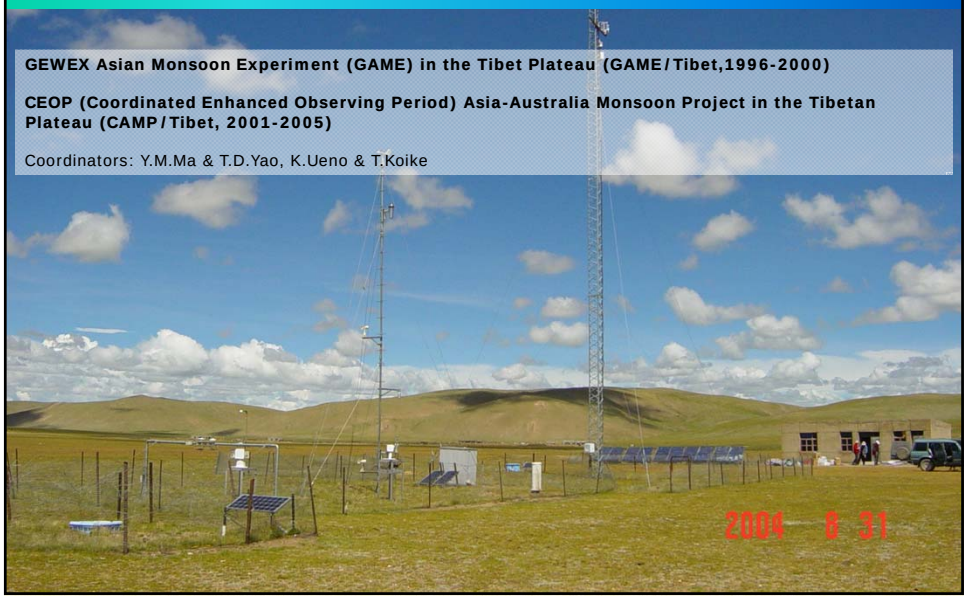

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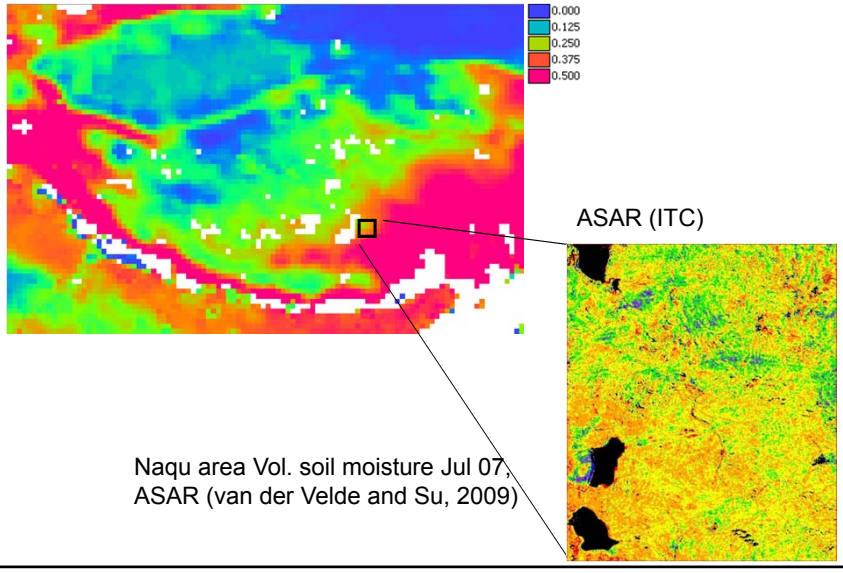
Tibetan Plateau Average vol. soil moisture 1-7 July 2007 AMSR-E VUA-NASA

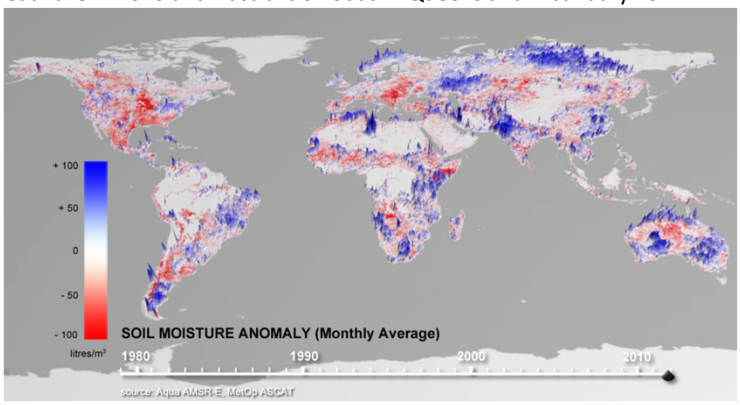


Naqu area Vol. soil moisture Jul 07, ASAR (van der Velde and Su, 2009)

The WACMOS global soil moisture product

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

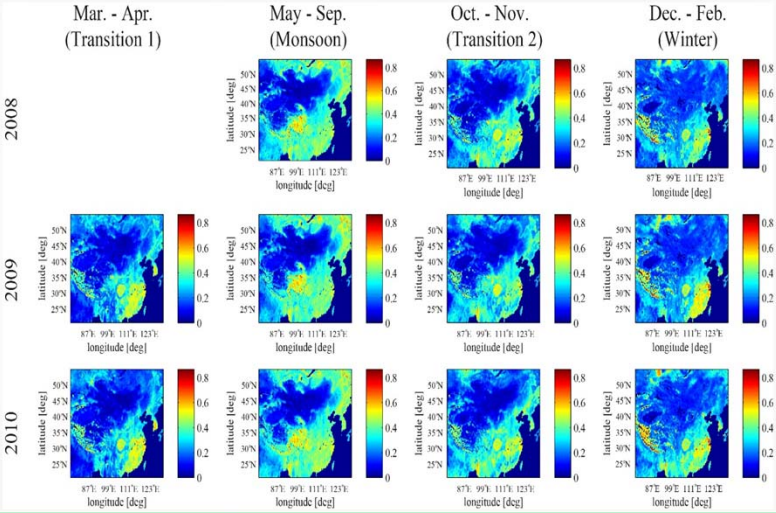
Global monthly averages of soil moisture in the early 1980s in litres per m3, followed by changes in global soil moisture to present. Major anomalies are highlighted, such as the 1992 flooding in Afghanistan, the 2005 drought in the central US, Russia's heatwave in 2010 and Australia's floods in Queensland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



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

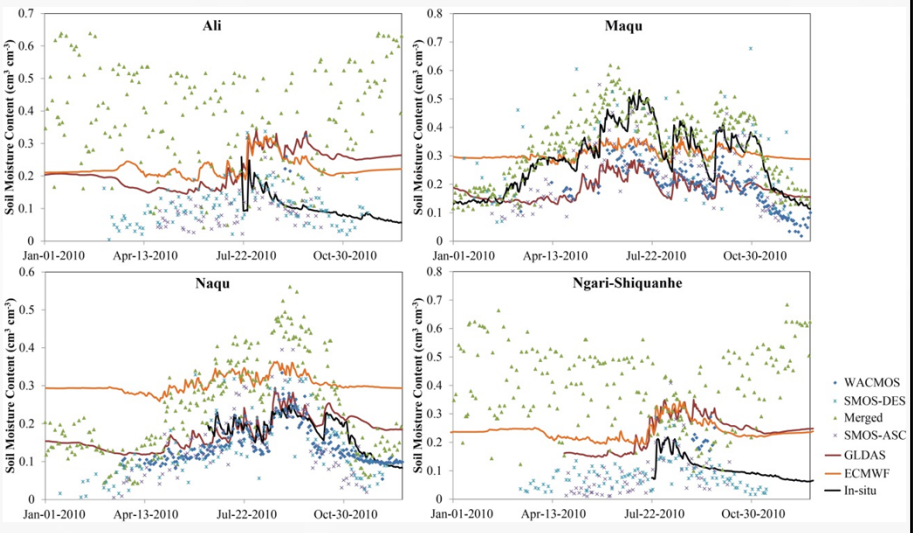
(Y. Zeng, L. Dente, L. Wang, J, Wen, Z. Su)

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



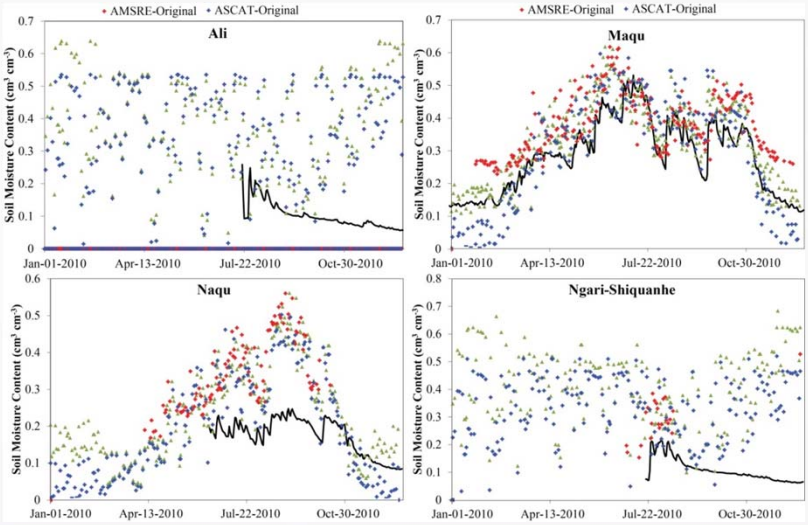
How good are the different products?

Comparison of different soil moisture products with the in-situ observation



Where is the problem?

Comparison among different original satellite soil moisture products with the in-situ observation



Conclusions & outlook

1. Many soil moistures products are now available.
2. It is recommended to validate the accuracy of these products, with in-situ data, before routine applications.
3. In-situ observations remain crucial, especially in places where little observational evidence exists.
4. Accurate retrieval of soil moisture remains a challenge.

Practical – soil moisture retrievals

Objectives

1. To retrieve soil moisture using the ITC retrieval model (an example of using METOP ASCAT L1B data).
2. To get familiar with soil moisture product retrieved from AMSR-E data.
3. To get familiar with EUMETSAT soil moisture product retrieved from ASCAT L2 data.
4. To get familiar with the SMOS soil moisture product.
5. To compare the soil moisture products.

Materials (Prepared by Lichun Wang, ITC)

- Exercise :Practical on analysis of soil moisture products

Software

- ILWIS & BEAM

Referances/Further Readings

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•*Dente, L., Vekerdy, Z., Wen, J., Su, Z., 2012, Maqu network for validation of satellite-derived soil moisture products, International journal of applied earth observation and geoinformation : JAG, 17, 55-65.*

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