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Land-Atmosphere Interactions on the Tibetan Plateau

– In-situ observation, remote sensing and modeling

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with contributions from
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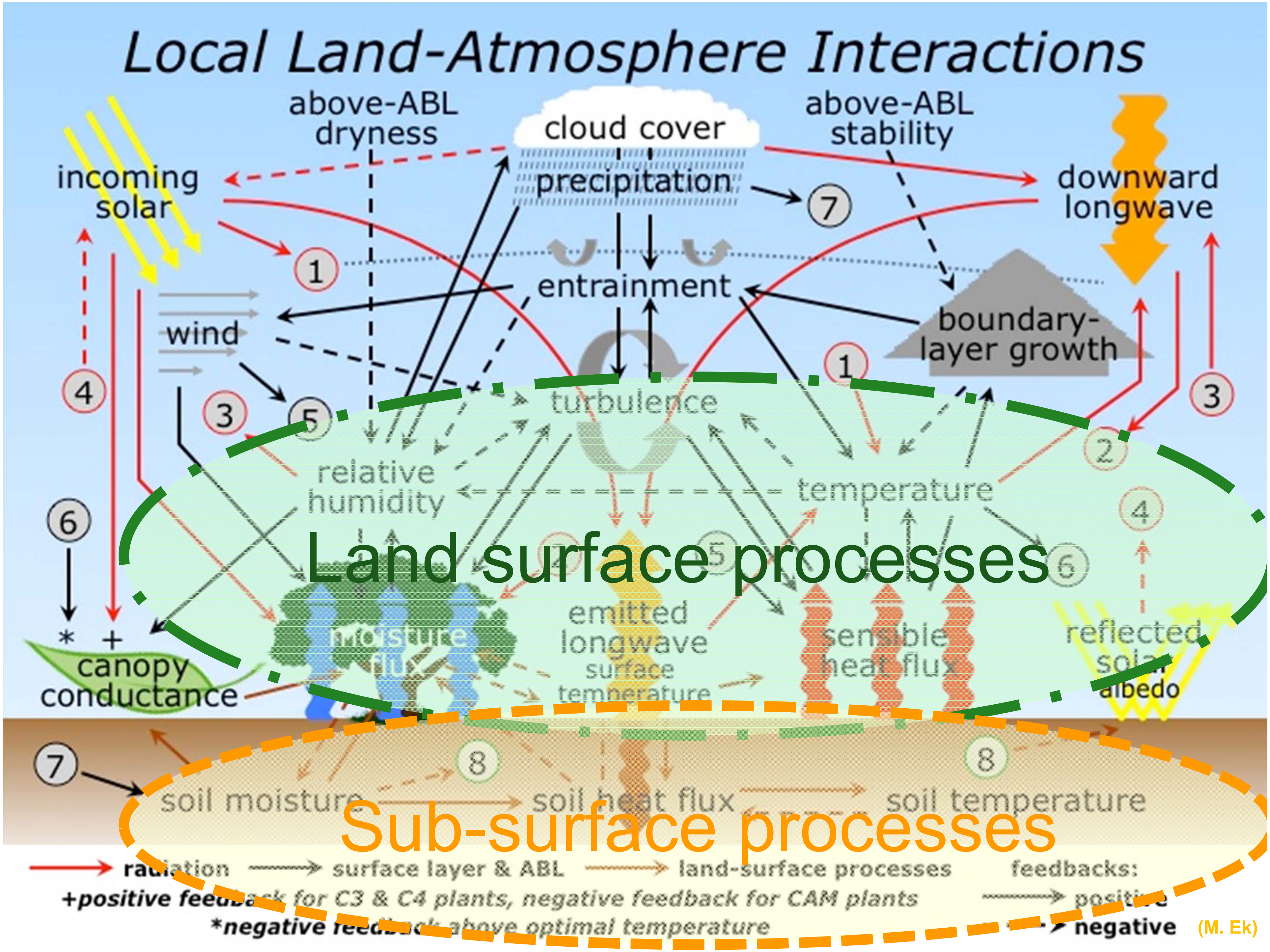
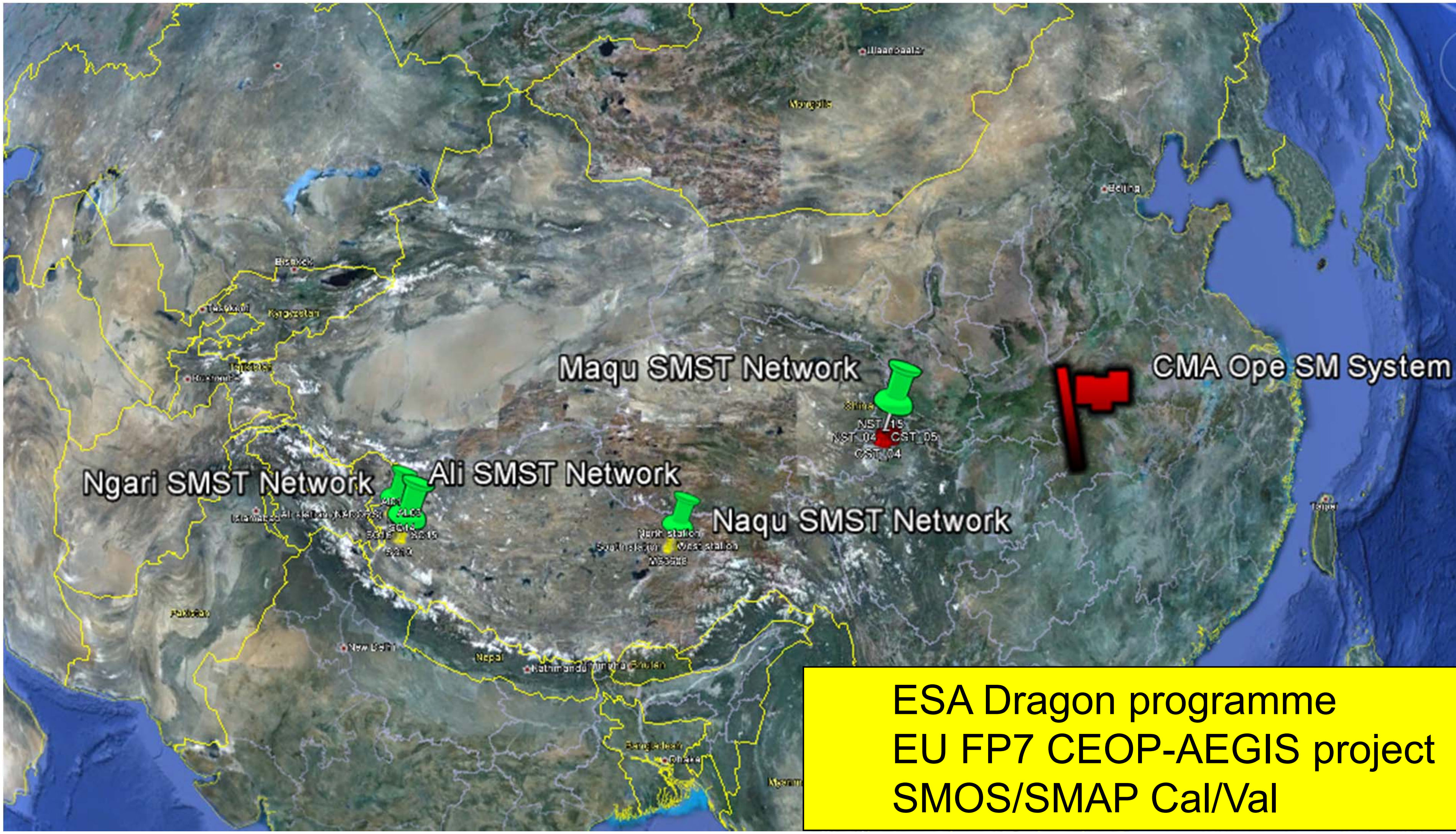
P. Ferrazzoli (UR), M. Schwank (ETH), Y. Kerr (CESBIO)

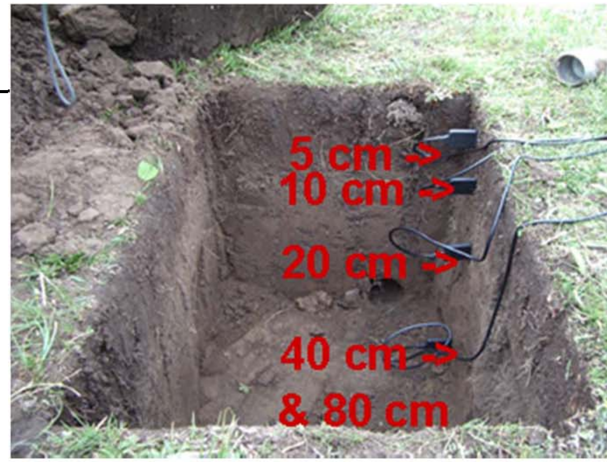

Local Land-Atmosphere Interactions
above-ABL dryness
cloud cover
above-ABL stability
incoming solar
precipitation
downward longwave
entrainment
wind
boundary-layer growth
turbulence
relative humidity
temperature
Land surface processes
emitted longwave
moisture flux
sensible heat flux
reflected solar
albedo
surface temperature
canopy conductance
soil moisture
soil heat flux
soil temperature
Sub-surface processes
radiation
surface layer & ABL
land-surface processes
feedbacks:
+positive feedback for C3 & C4 plants, negative feedback for CAM plants
positive
*negative feedback above optimal temperature
negative
(M. Ek)

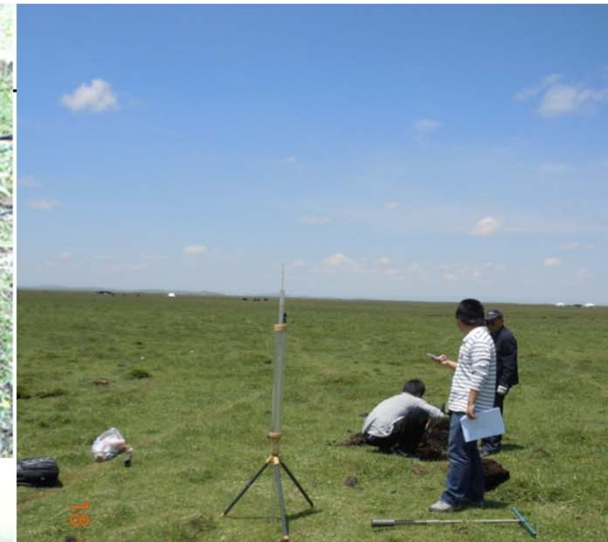
1. Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs)



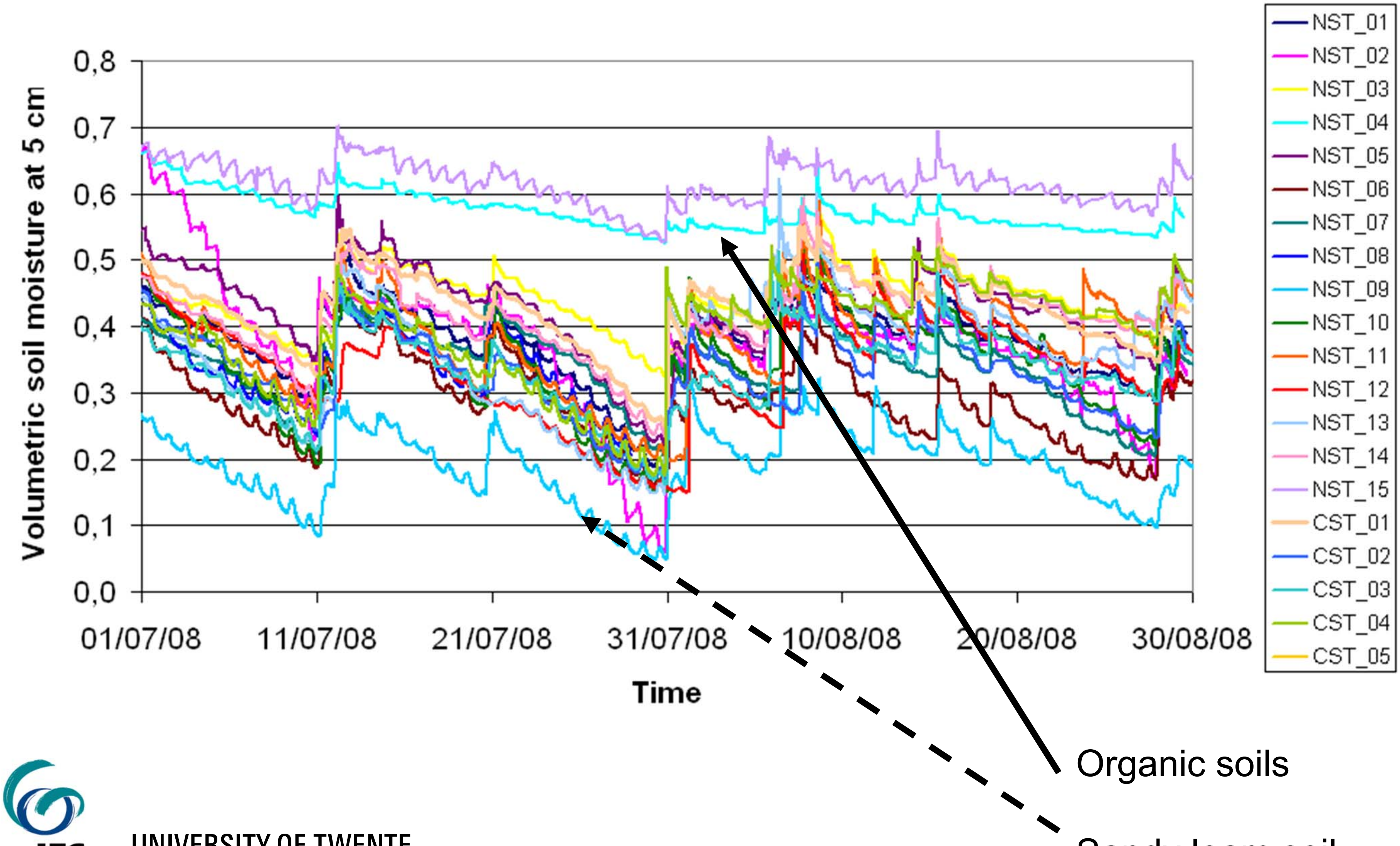
(Su et al. 2011, HESS)

Maqu Station: Field Site and Experiment





Maqu: Soil moisture at 5 cm depth



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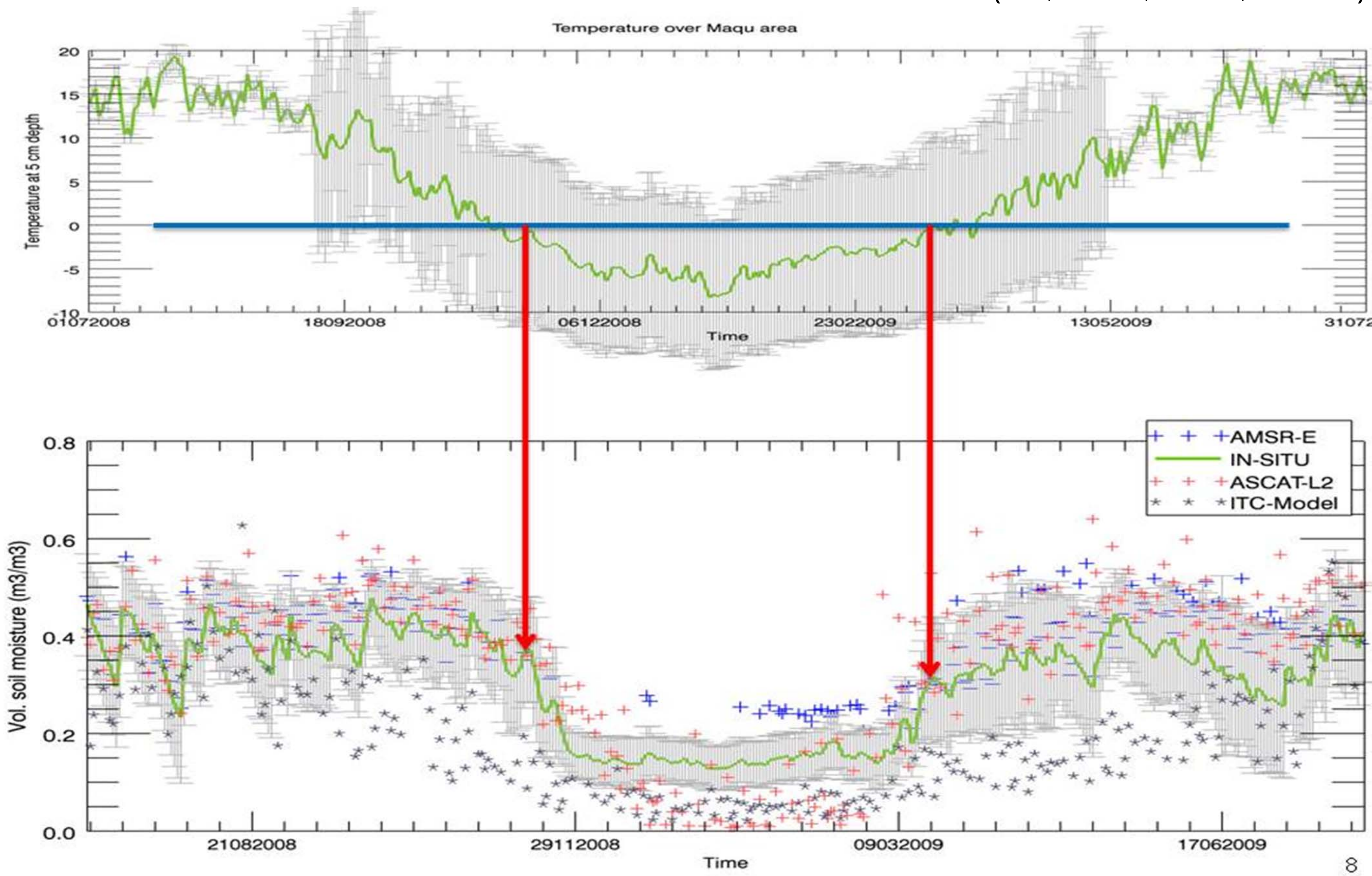
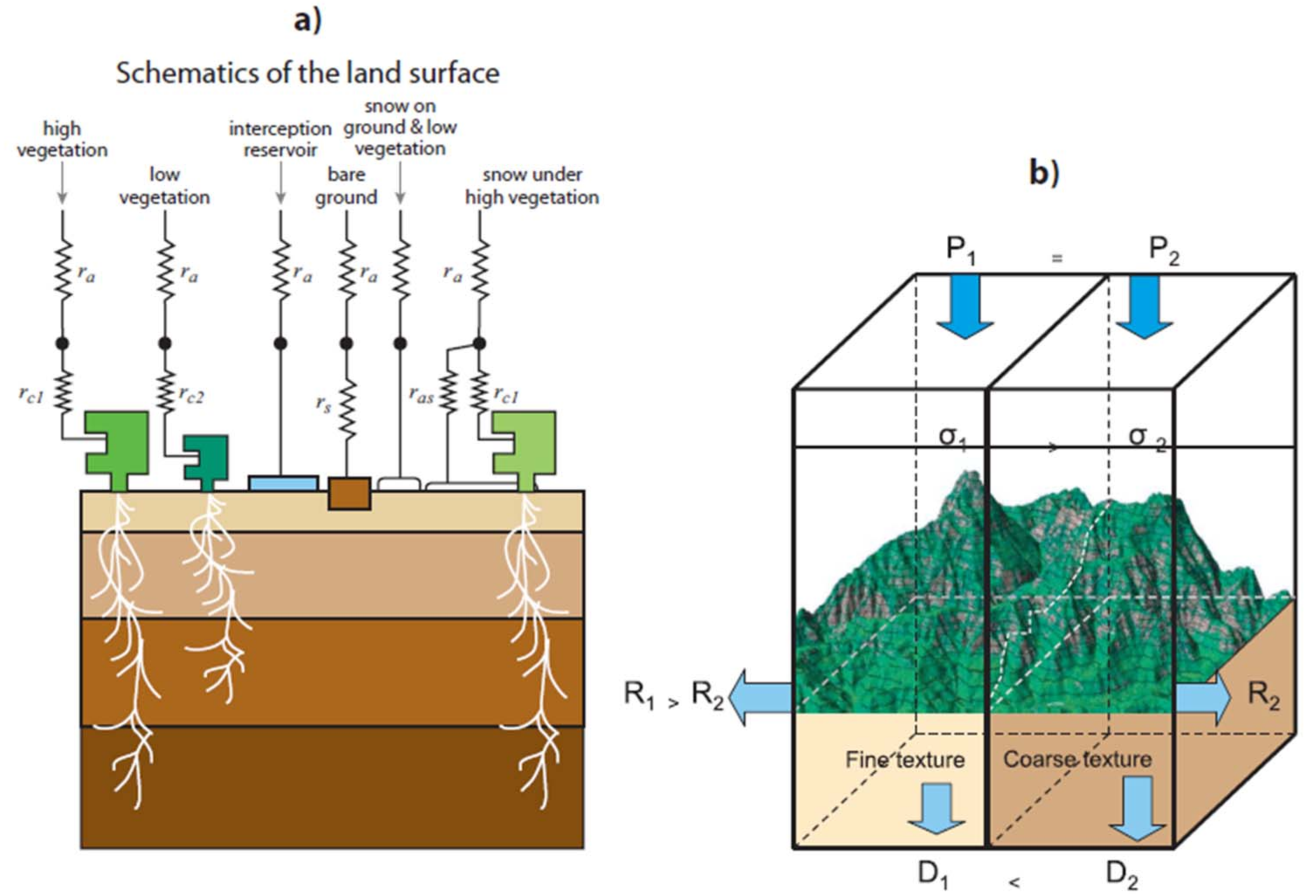
Quantification of uncertainties in global products

(Su, et al., 2011, HESS)



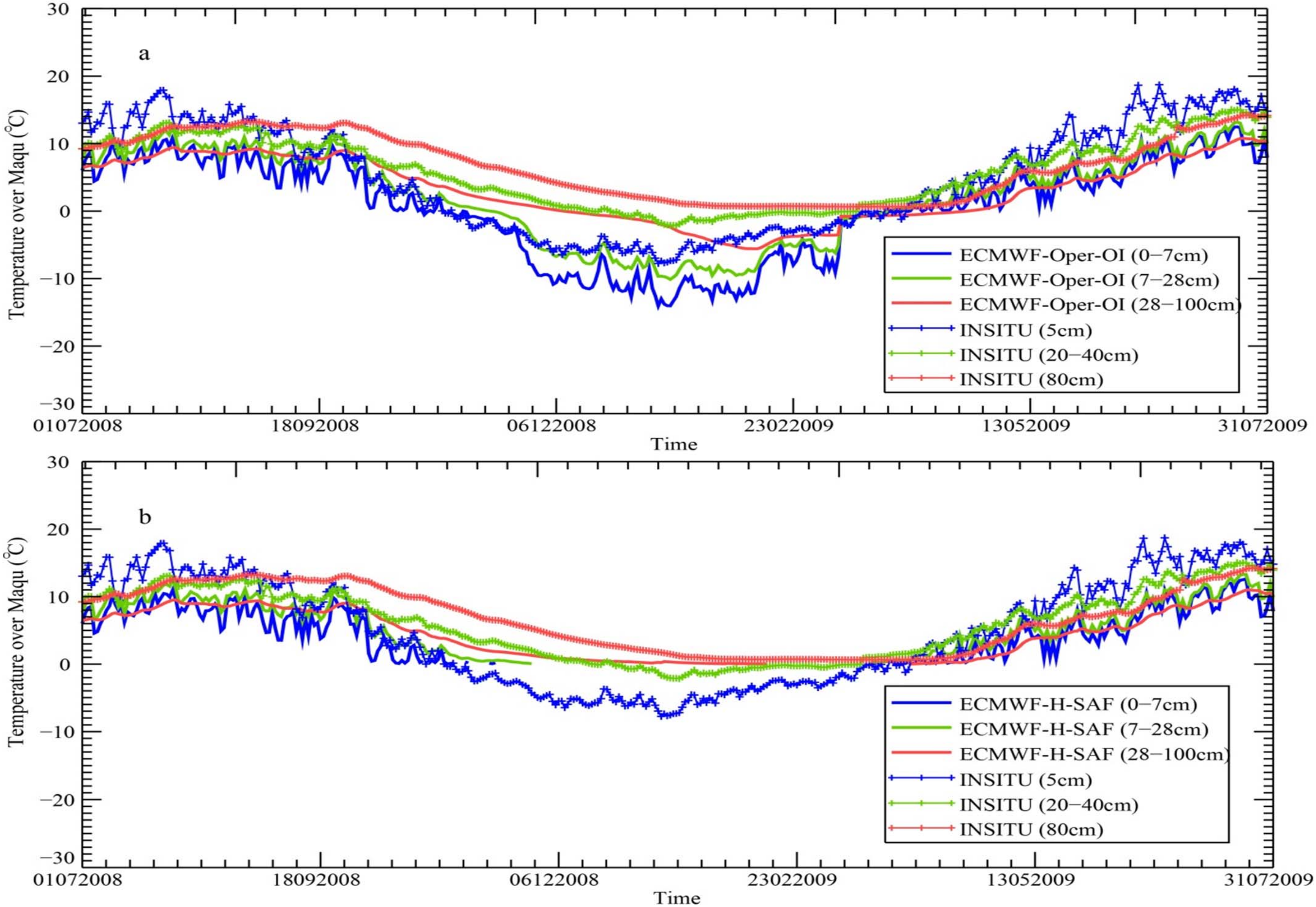
The Tiled ECMWF Scheme for Surface Exchanges over Land (TESSEL) & the HTESSEL (Hydrology TESSEL)



(a) TESSEL land-surface scheme, (b) spatial structure in HTESSEL
(for a given precipitation P1 = P2 the scheme distributes the water as surface runoff and drainage with functional dependencies on orography and soil texture respectively) (Balsamo et al., 2006)

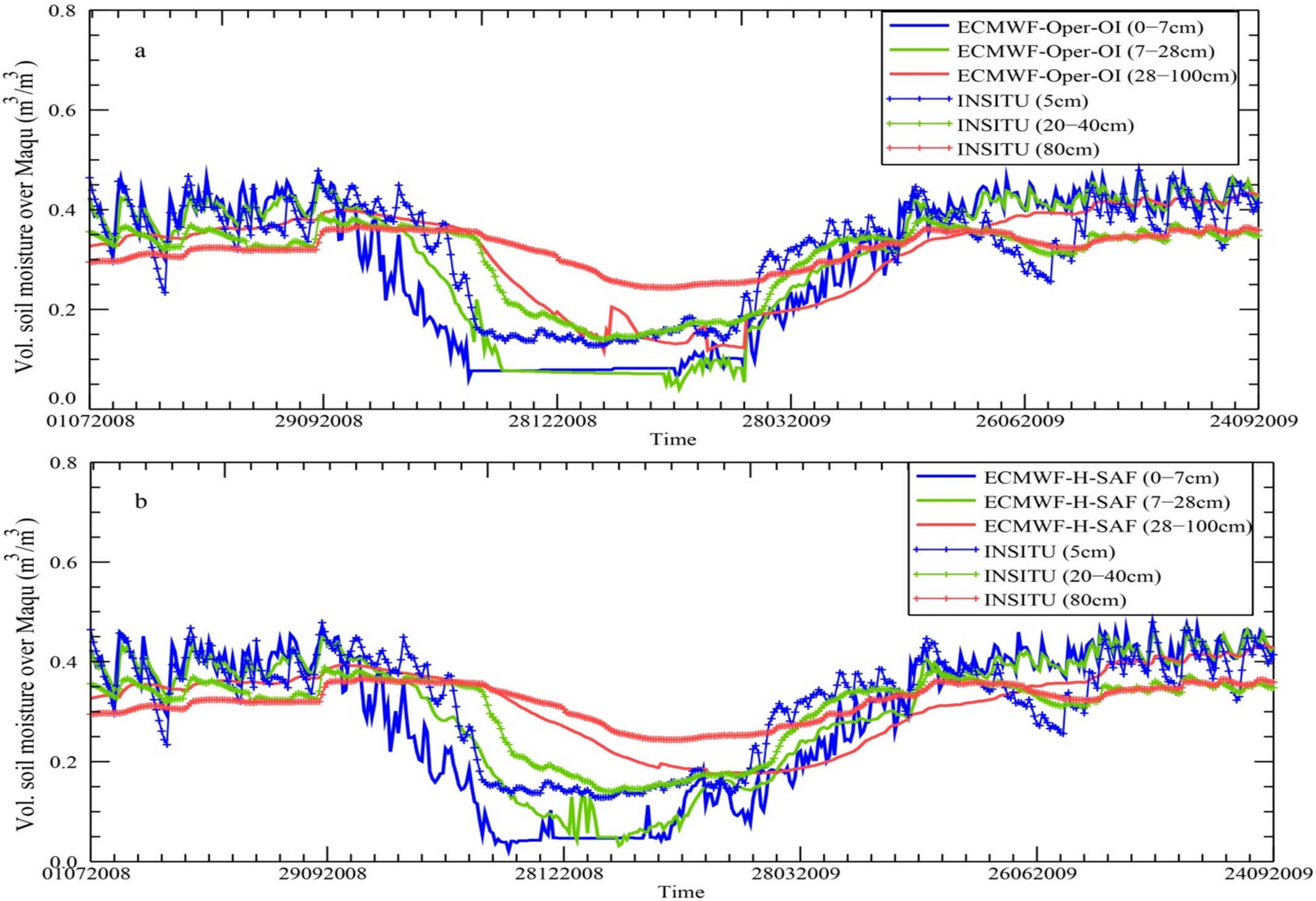
How good is soil temperature simulation / analysis?

(Su & de Rosnay, et al. 2013, JGR)

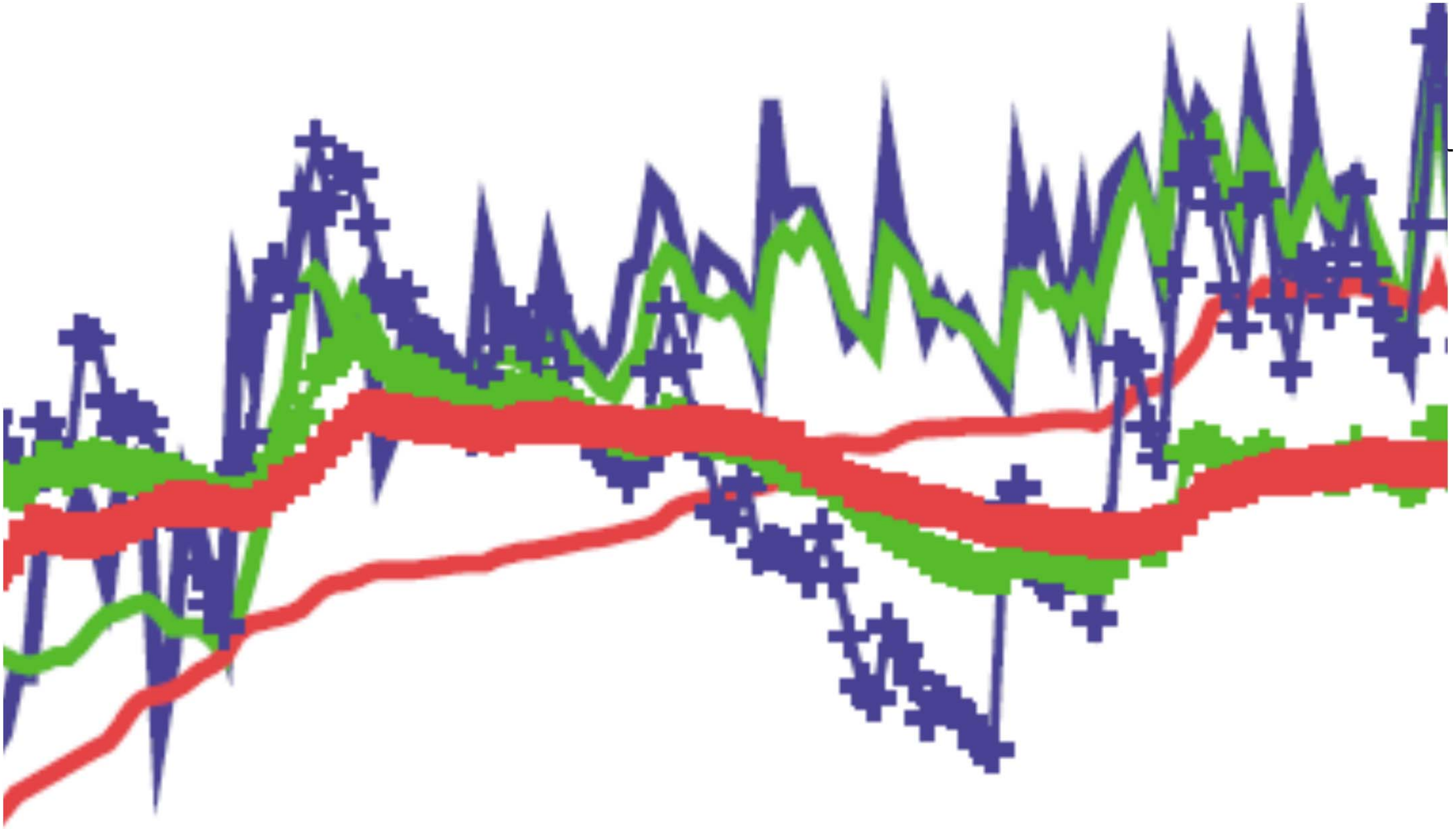


How good is soil moisture analysis/assimilation?

(Su & de Rosnay, et al. 2013, JGR)



How good is soil moisture assimilation?



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(Su & de Rosnay, et al. 2013, JGR)

Noah LSM

N: National Centers for Environmental Prediction (NCEP)
O: Oregon State University (Dept of Atmospheric Sciences)
A: Air Force (both AFWA and AFRL - formerly AFGL, PL)
H: Hydrologic Research Lab - NWS (now Office of Hydrologic Dev -- OHD)

Noah LSM provides a complete description of the physical processes with a limited number of parameters.

- Soil water flow;
- Soil heat flow;
- Heat exchange with the atmosphere;

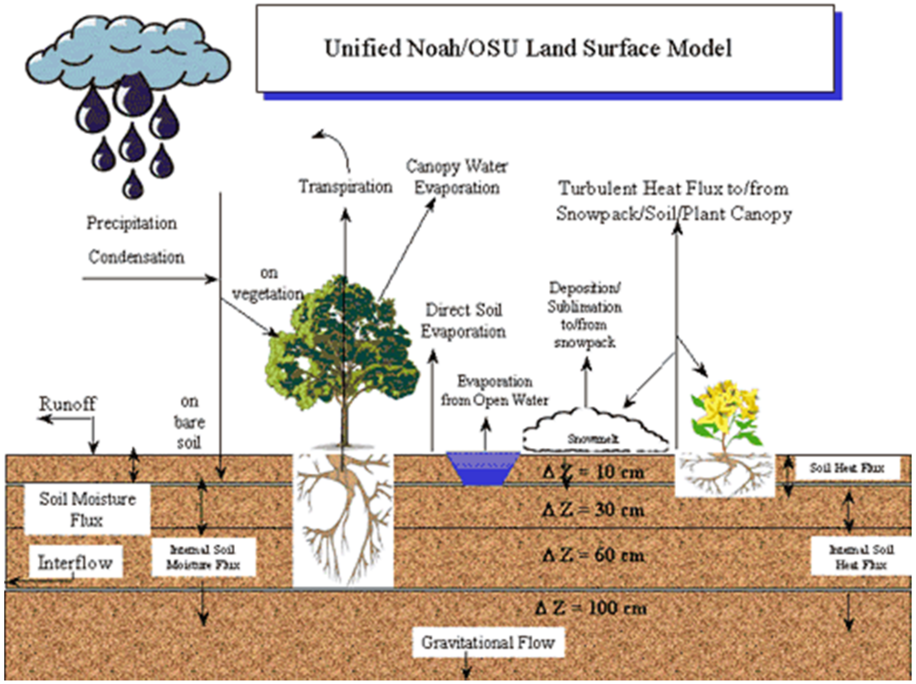
(Zheng et al., 2014, 2015a,b, JHM; Zheng et al. 2016, 2017, JGR)

- Snow pack;

(Malik et al., 2012, JHM; 2013, JGR; 2011, RSE)

- Frozen soil;

(NWO SMAP freeze/thaw, Zheng et al., 2017 TGRS)



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Augmentations to the Noah Model Physics for Application to the Yellow River Source Area. Part II: Turbulent Heat Fluxes and Soil Heat Transport

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YINGYING CHEN

Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China

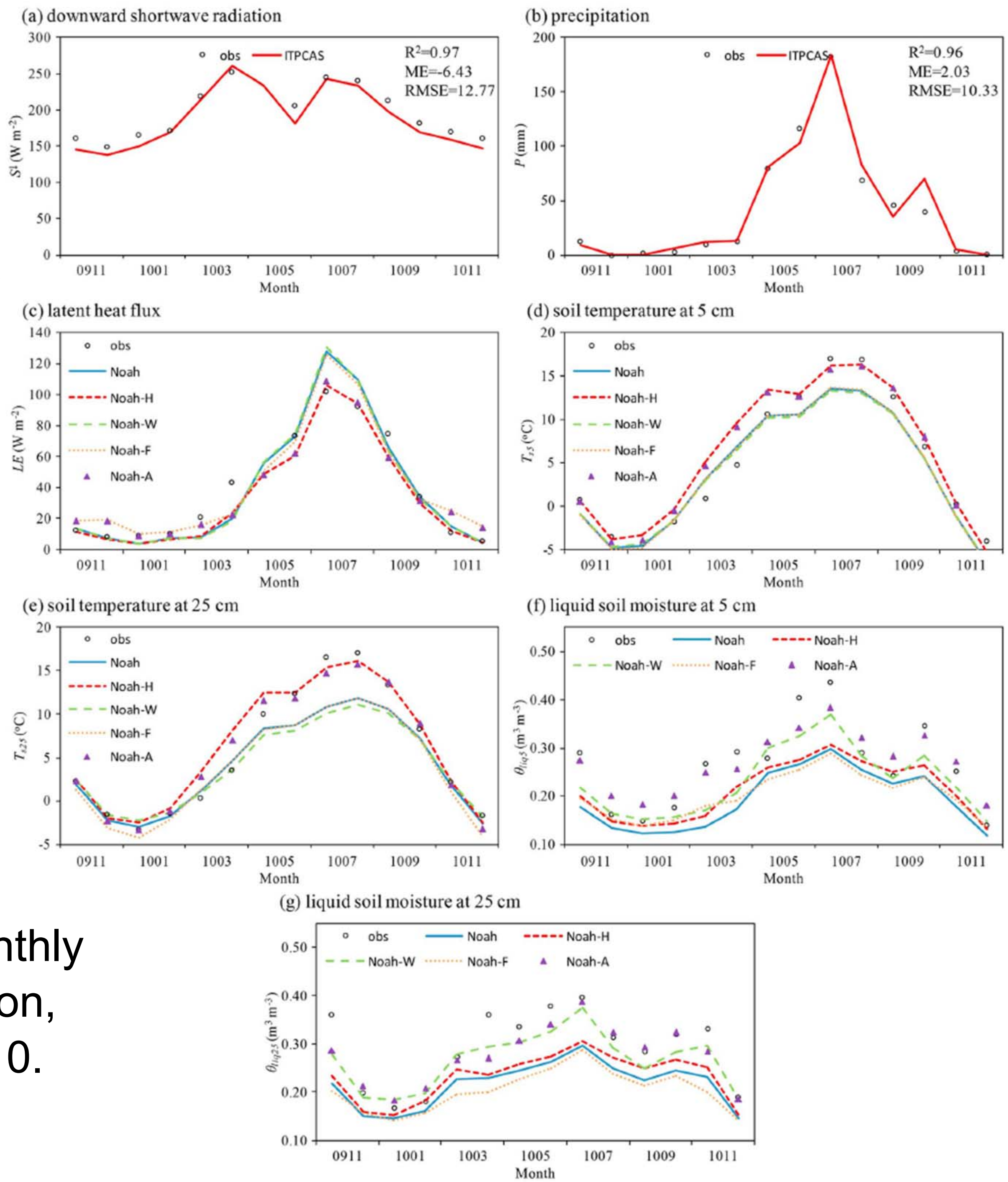
Zheng et al., 2014, JHM, 2015a,b, JHM

(https://www.itc.nl/resumes/zheng)

Fluxes & states

Augmentations:

- **Noah-H**: turbulent & soil heat transport
- **Noah-W**: soil water flow
- **Noah-F**: frozen ground processes
- **Noah-A**: all augmentations



Comparisons of monthly average, Maqu station, Nov. 2009–Dec. 2010.

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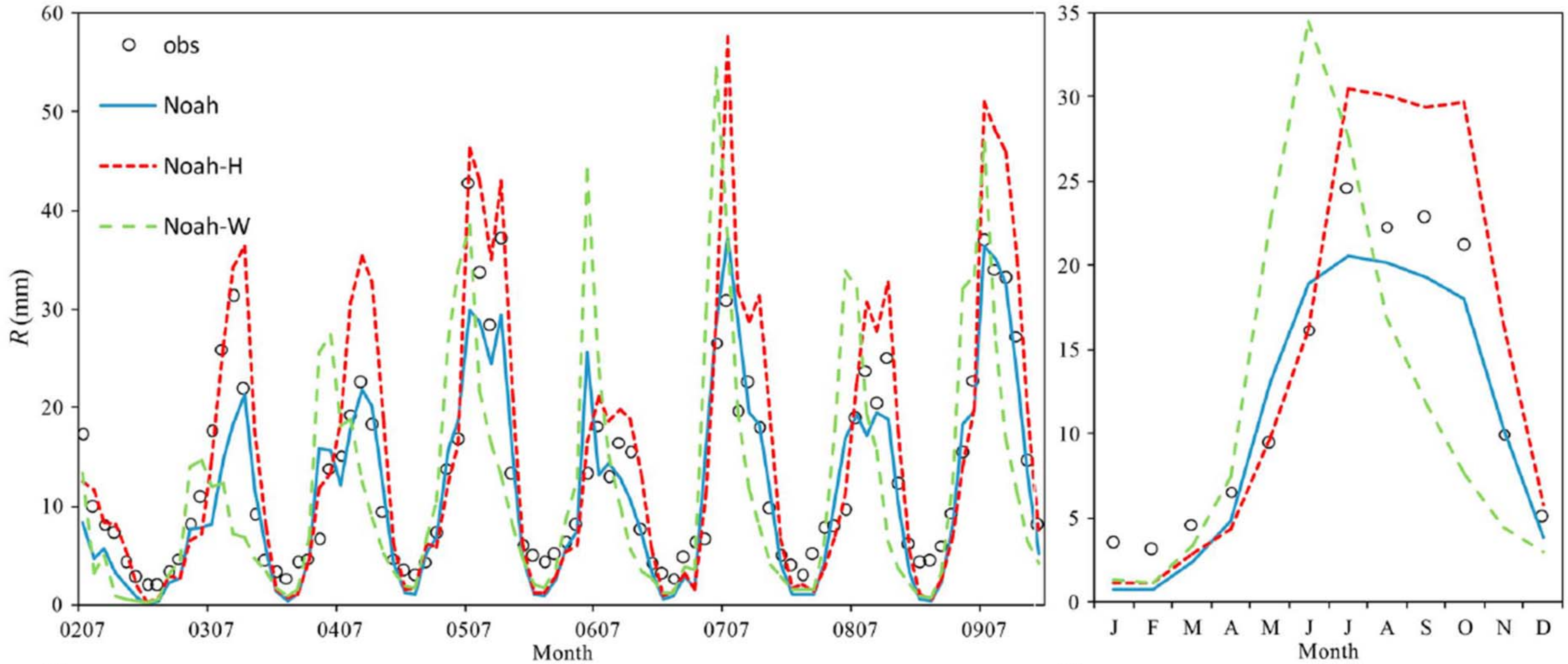
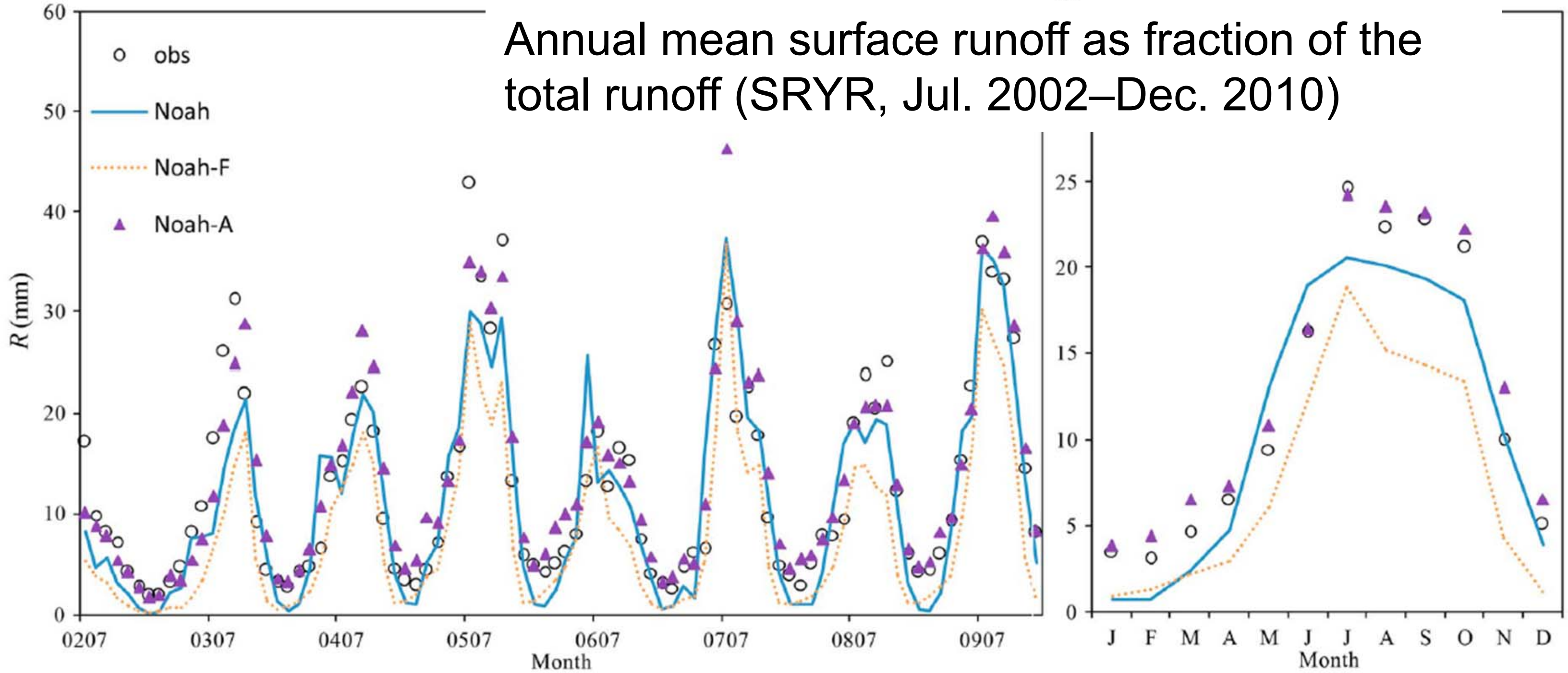
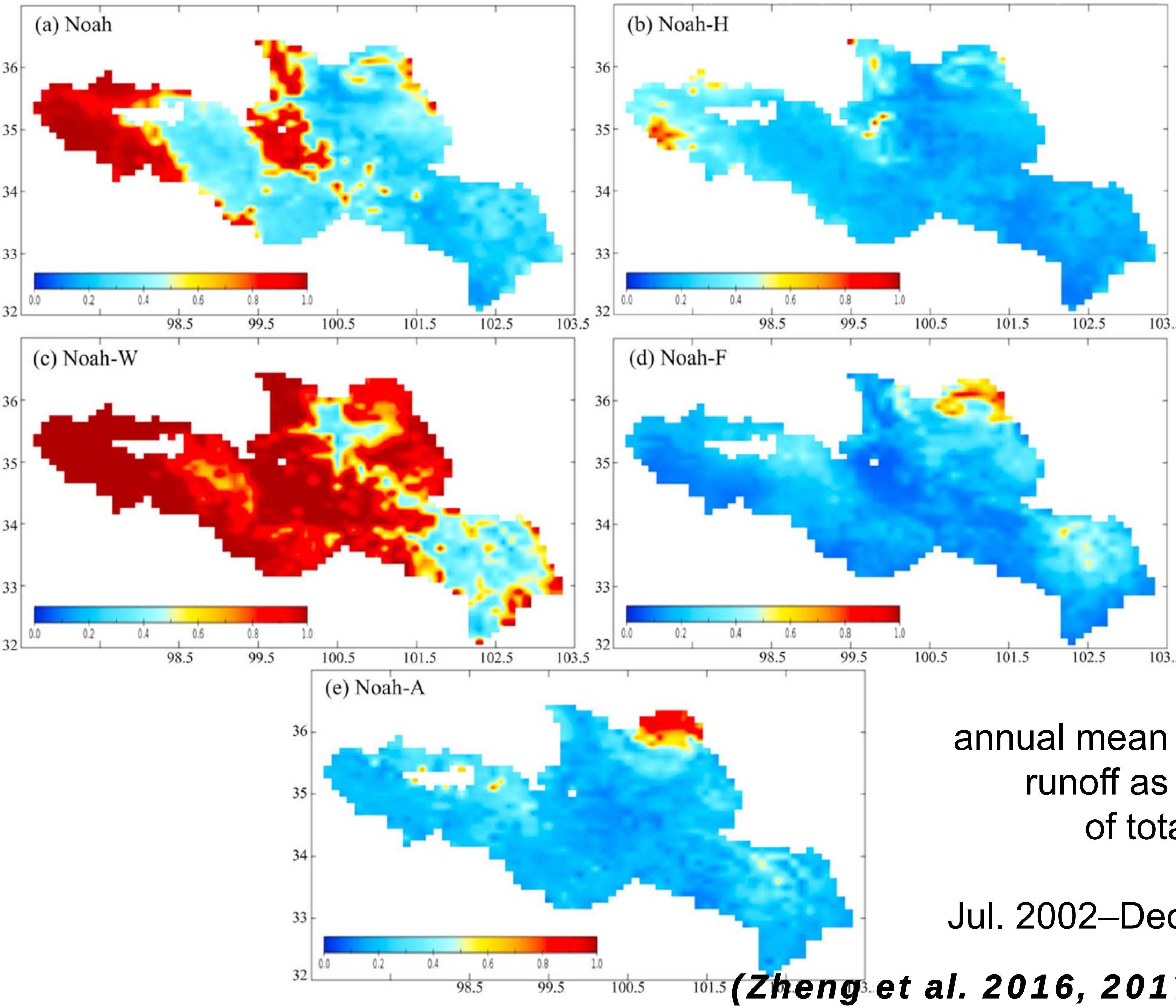


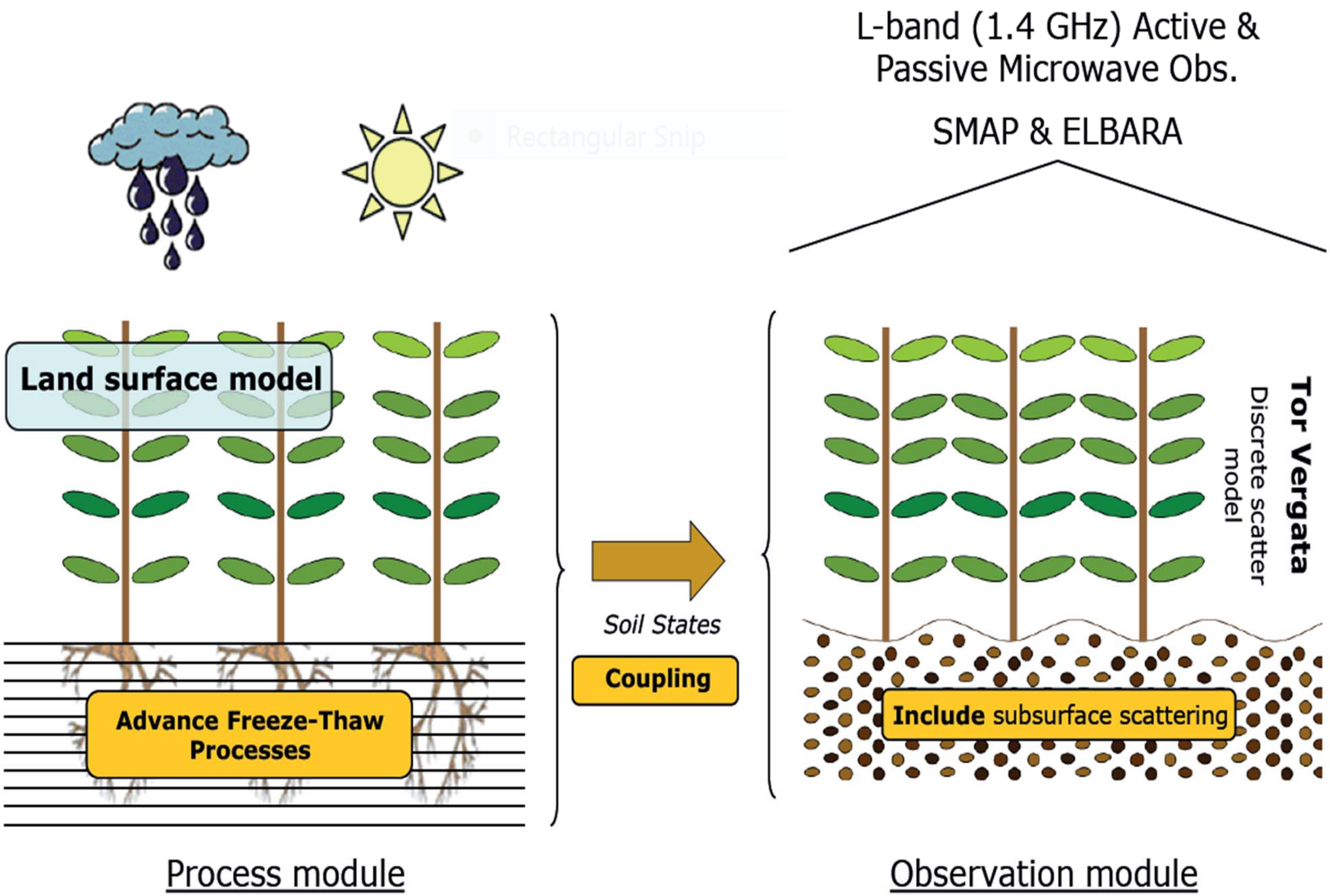
Annual mean surface runoff as fraction of the total runoff (SRYR, Jul. 2002–Dec. 2010)



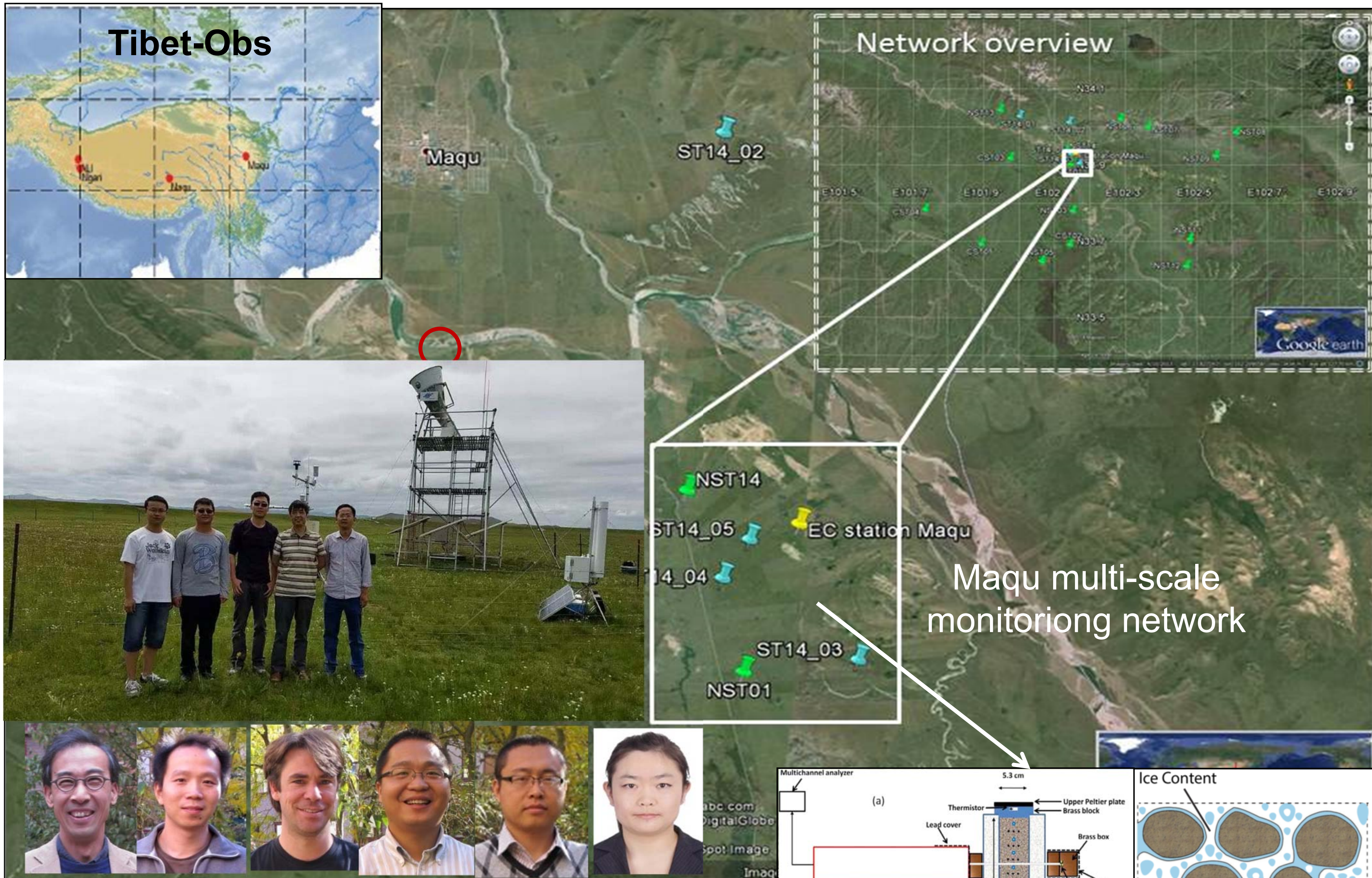


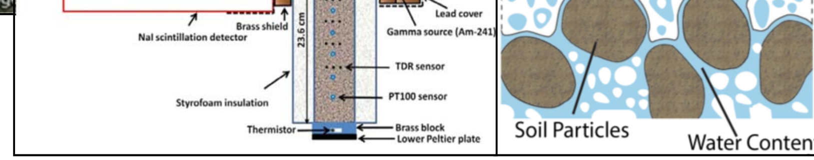
annual mean surface
runoff as fraction
of total runoff
(SRYR,
Jul. 2002–Dec. 2010)

(Zheng et al. 2016, 2017, JGR)



5. Coherent process modeling and radiative transfer modelling





Tibet-Obs (Su et al. 2011) is selected as one of the SMAP core international Cal/Val sites

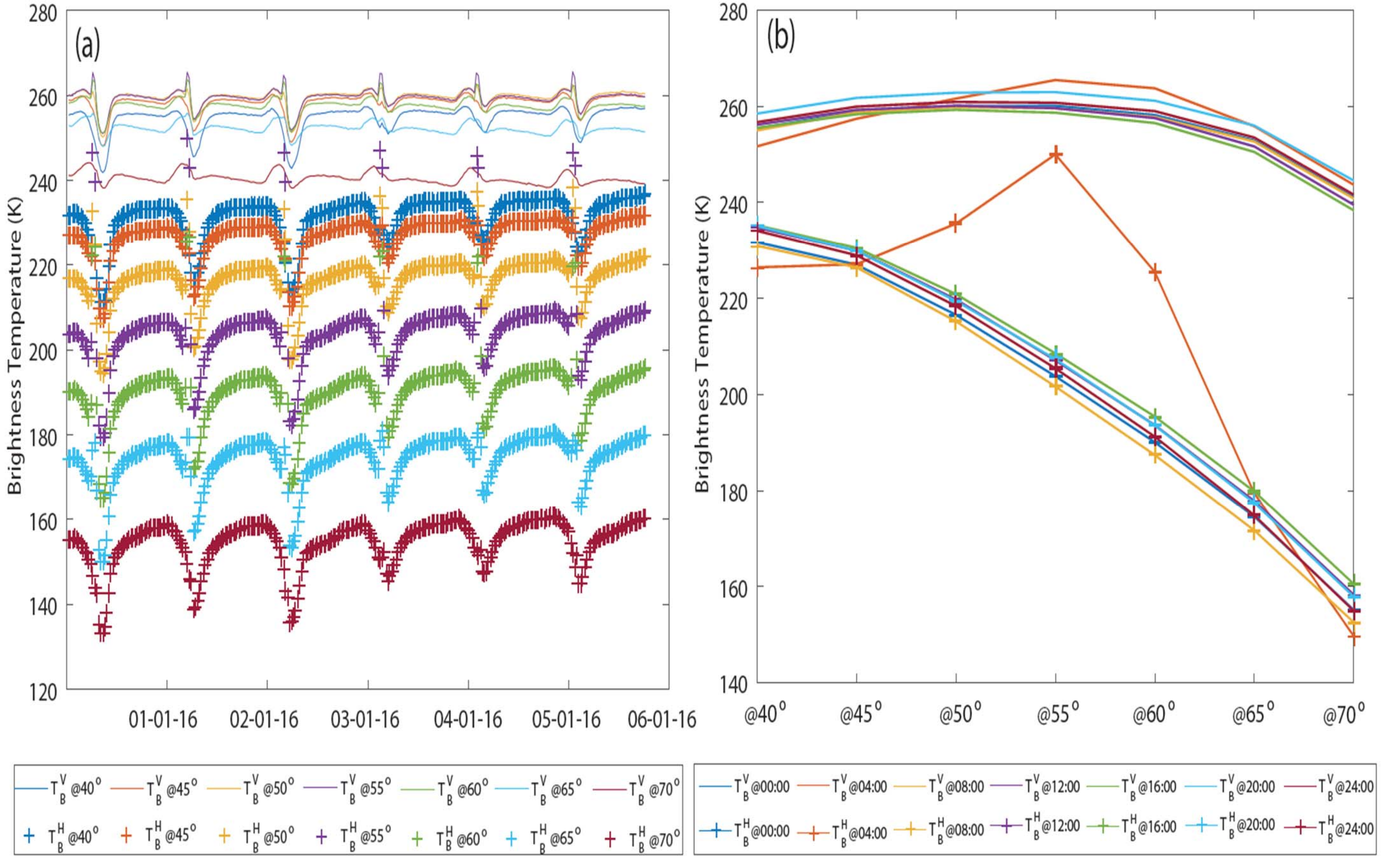
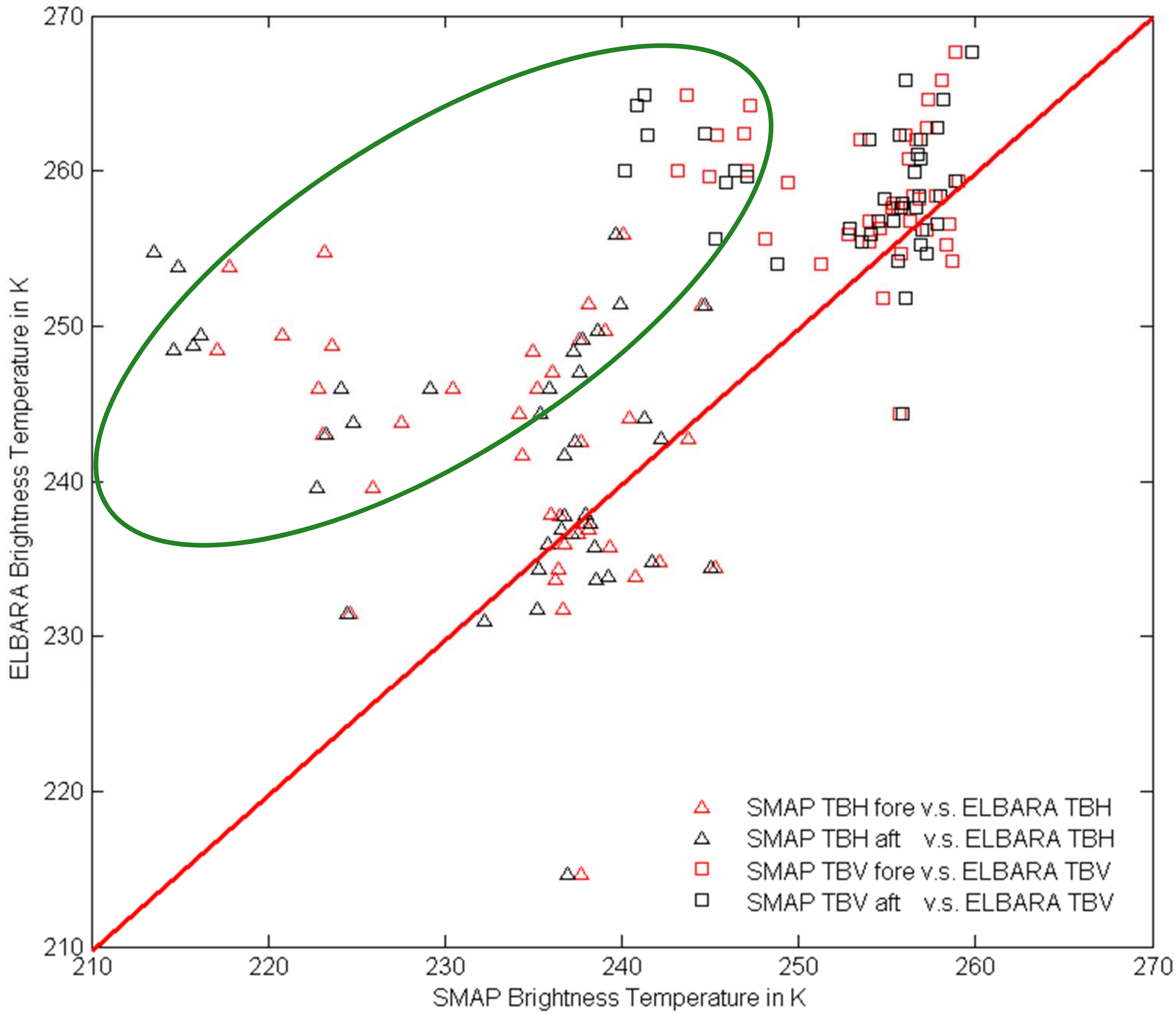


Figure 4 (a) time series of brightness temperature at both H and V polarization between 01-01-16 and 06-01-16; (b) the angular behavior of brightness temperature at both H and V polarization on 01-01-16 with 4-hour intervals (ELBARA III observations).

COMPARISON BETWEEN SMAP & ELBARA

SMAP TB L1C PRODUCT (HTTPS://WORLDVIEW.EARTHDATA.NASA.GOV/)



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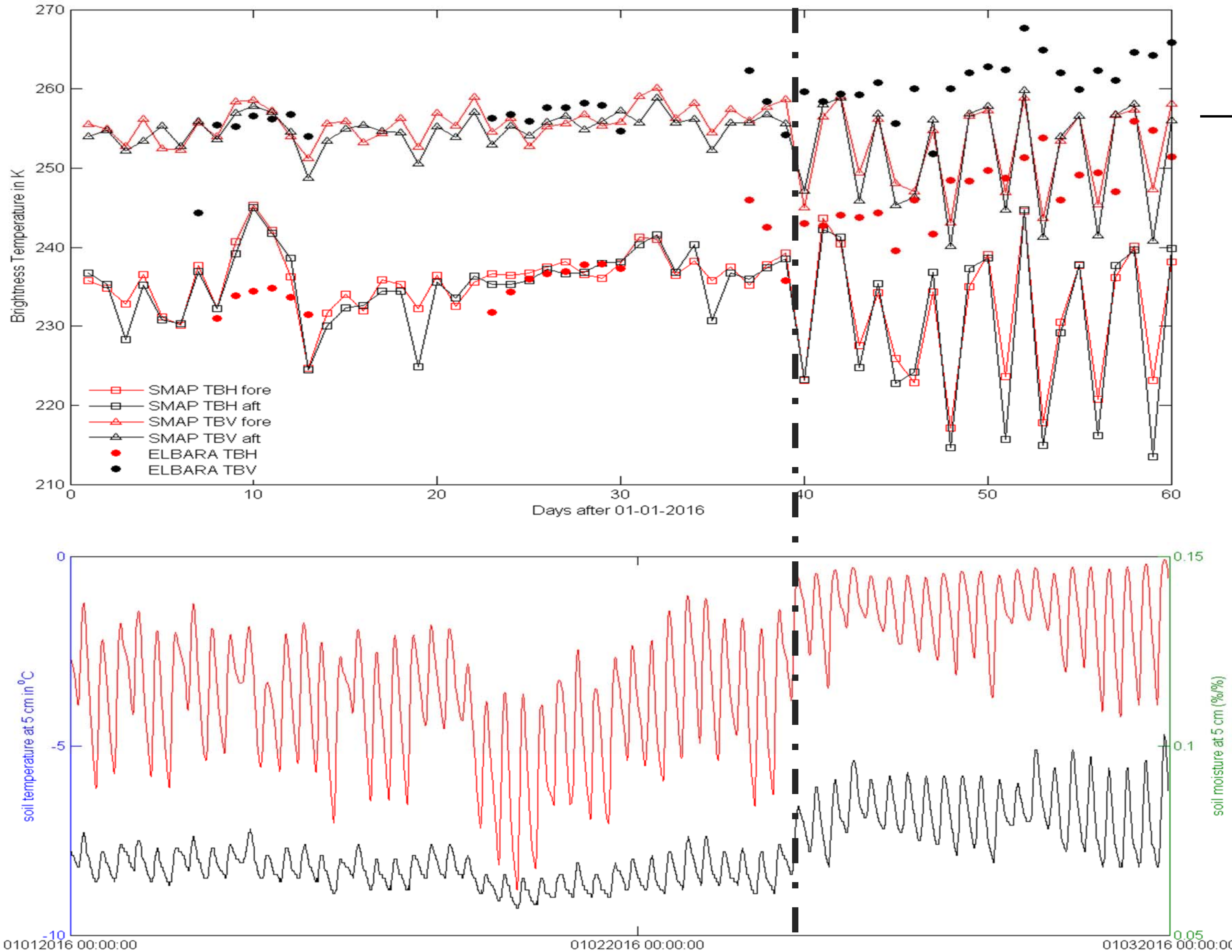
WHY DOES SMAP UNDERESTIMATE ELBARA TB?



DOY 1:
01-01-2016

DOY 40: 10-02-2016

DOY 60: 29-02-2016

6. A new 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)

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

A two-layer system:

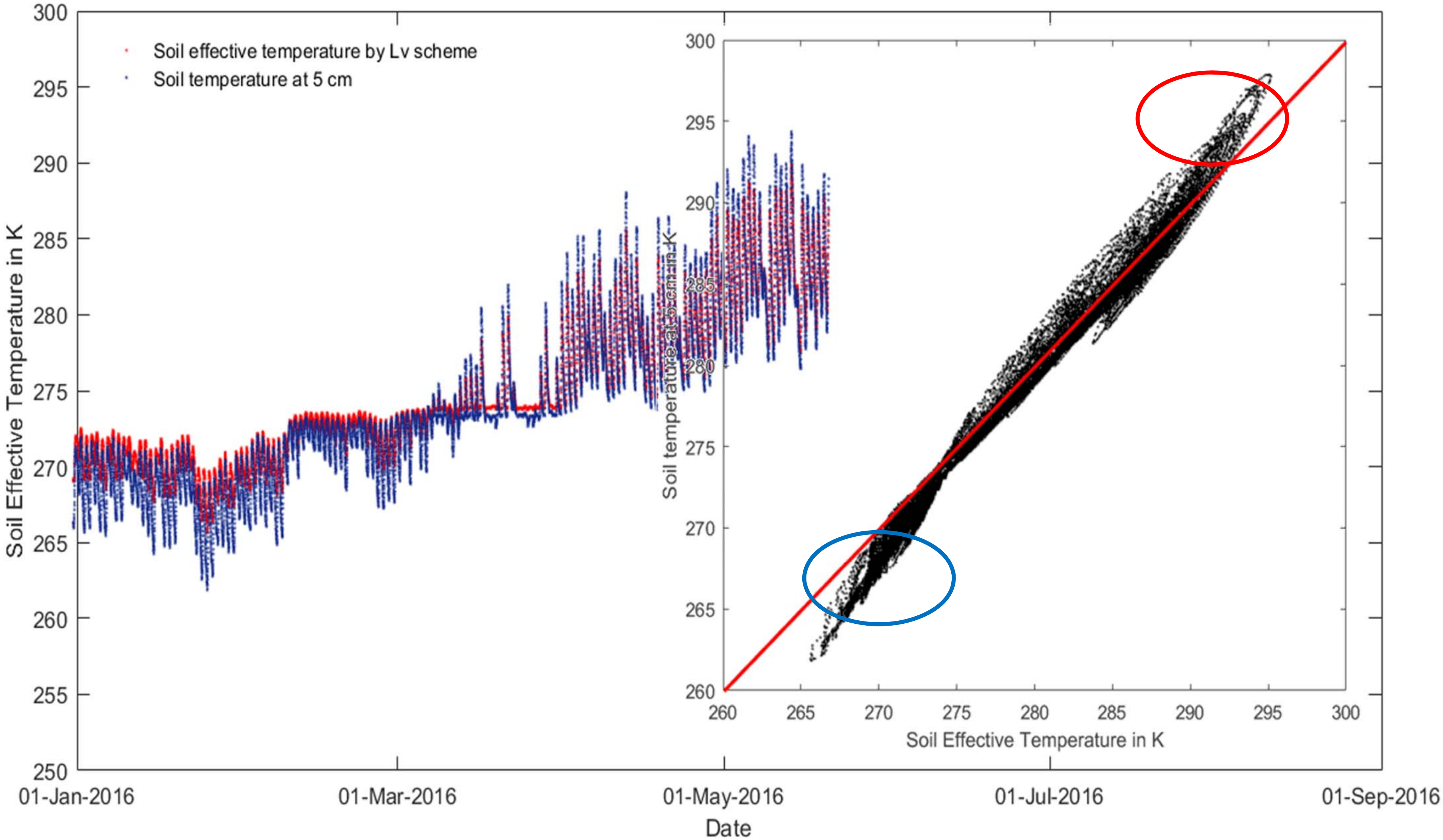
$$T_{eff} = T_0\left(1 - e^{-B_0}\right) + T_{\infty}e^{-B_0}$$

$$B_0 = \alpha_1 x_1$$

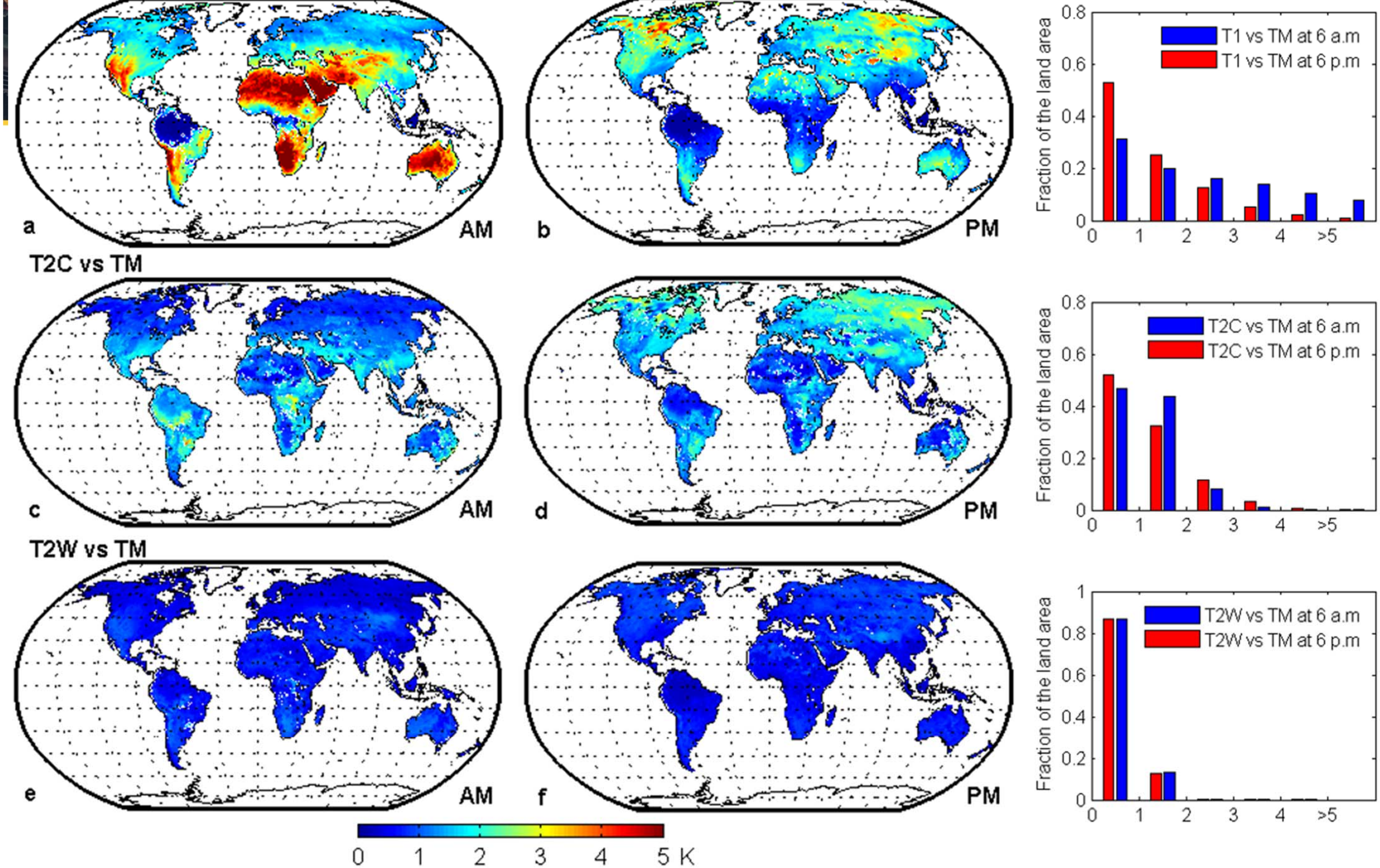
$$B_0 = \Delta x \cdot \frac{4\pi}{\lambda} \cdot \frac{\varepsilon''}{2\sqrt{\varepsilon'}}$$

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

Teff time series (Lv scheme) and soil temperature at 5cm over Maqu center site (NST-01) (Jan 1 - May 20, 2016 (Lv et al., 2015, RS)



(Lv et al. 2016, RSE)

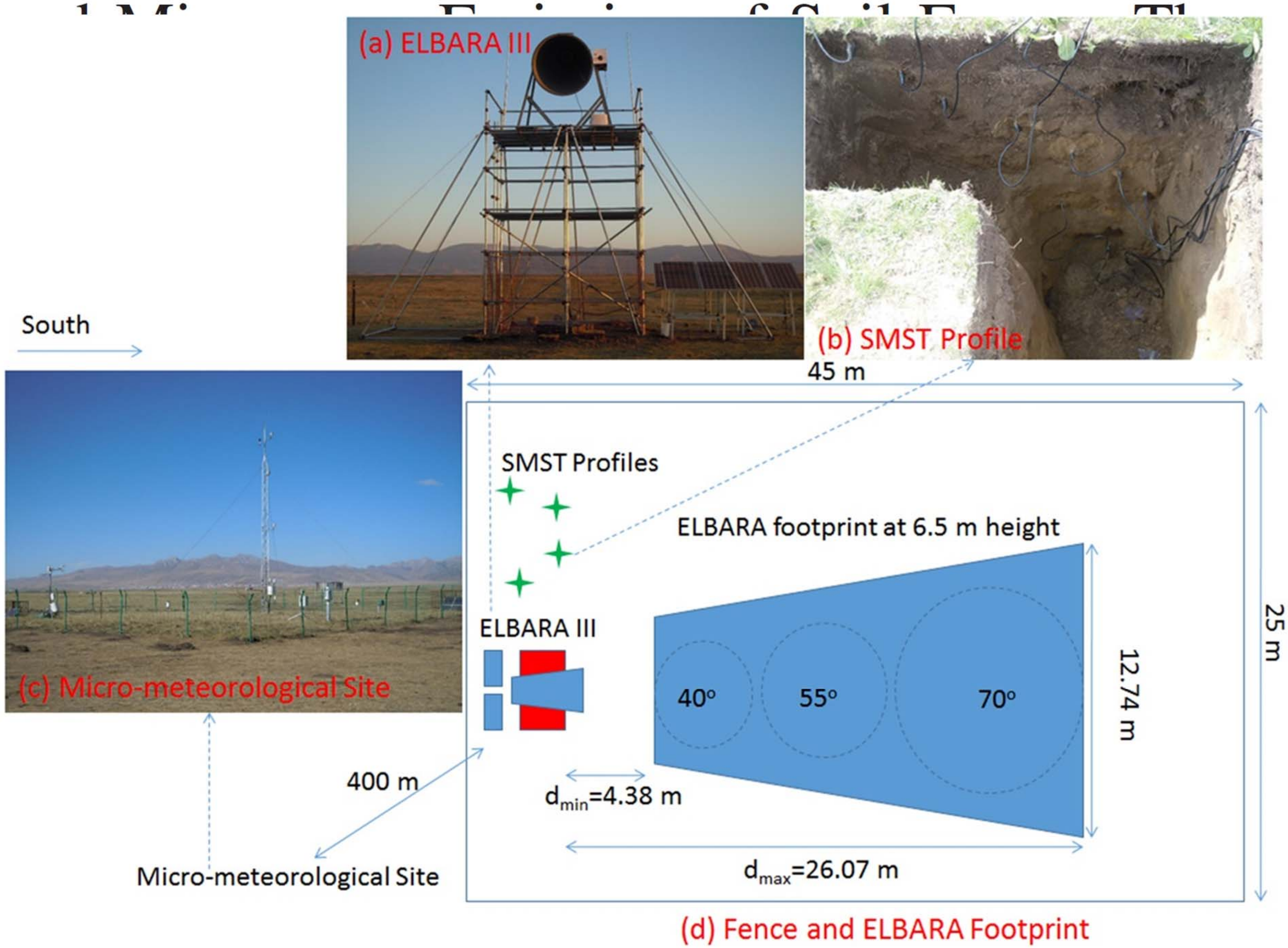


Global RMSD (in K) (SMAP beta scheme (T1) vs Lv's scheme (TM) (a and b), SMAP current scheme (T2C) vs TM (c and d), SMOS scheme (T2W) vs TM (e and f).

(MERRA-land in 2013 soil temperature and soil moisture profile)

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

L-B



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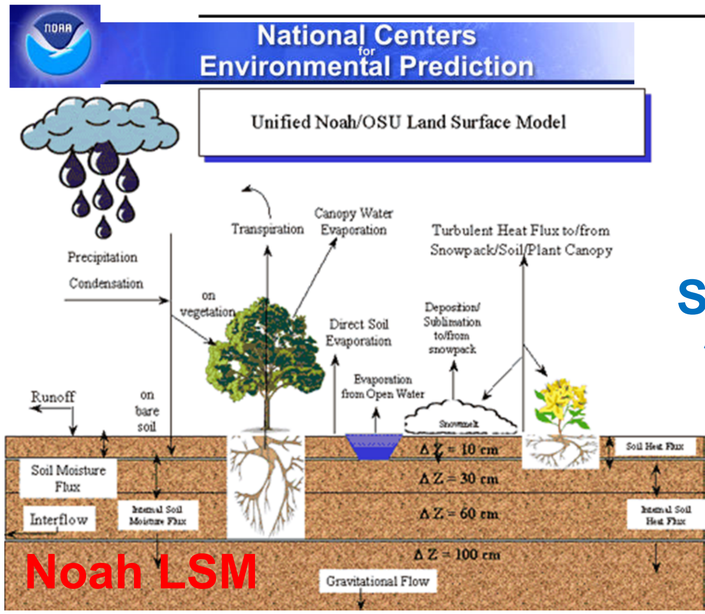
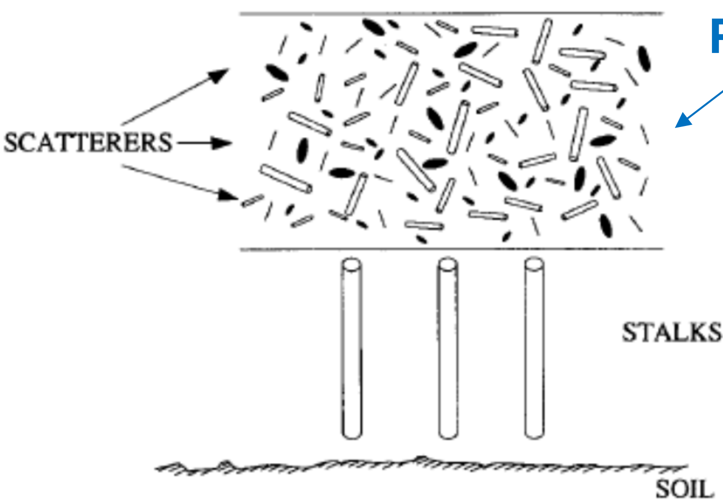
Noah-Tor Vergata OSSE (Observation Opearator)





Tor Vergata RT

Surface SMST

SMST Profiles

Permittivity

Emissivity

Four Phase Dielectric Mixing Model

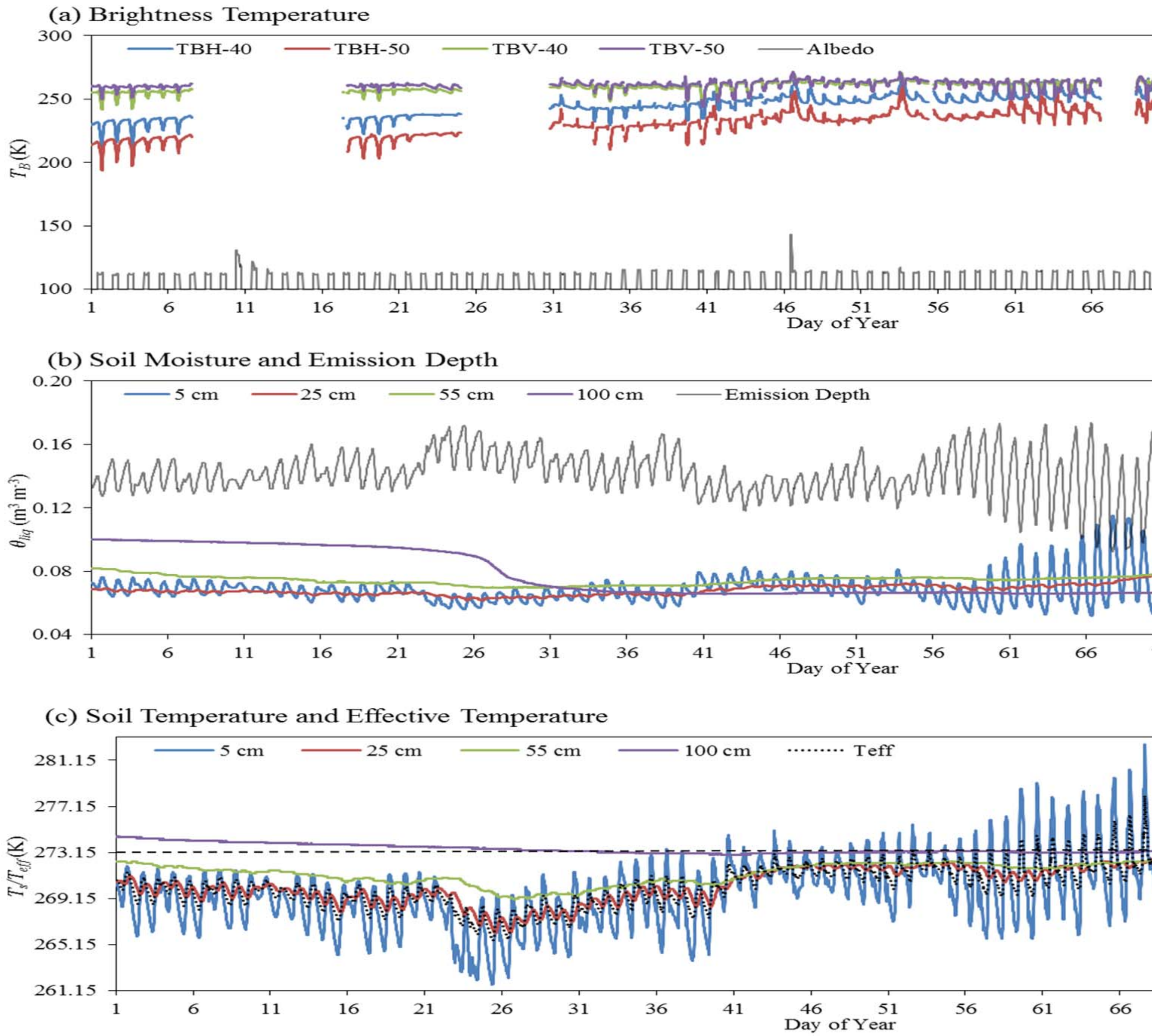
$$\varepsilon^{\eta} = (\theta_s - \theta)\varepsilon_{air}^{\eta} + \theta_{liq}\varepsilon_w^{\eta} + (\theta - \theta_{liq})\varepsilon_{ice}^{\eta} + (1 - \theta_s)\varepsilon_{matrix}^{\eta}$$

Effective Temperature

$$T_{eff} = \int_0^{\infty} T_s(z)\alpha(z)\exp\left[-\int_0^{z}\alpha(z')dz'\right]dz$$

Brightness Temperature

Long Term Analysis



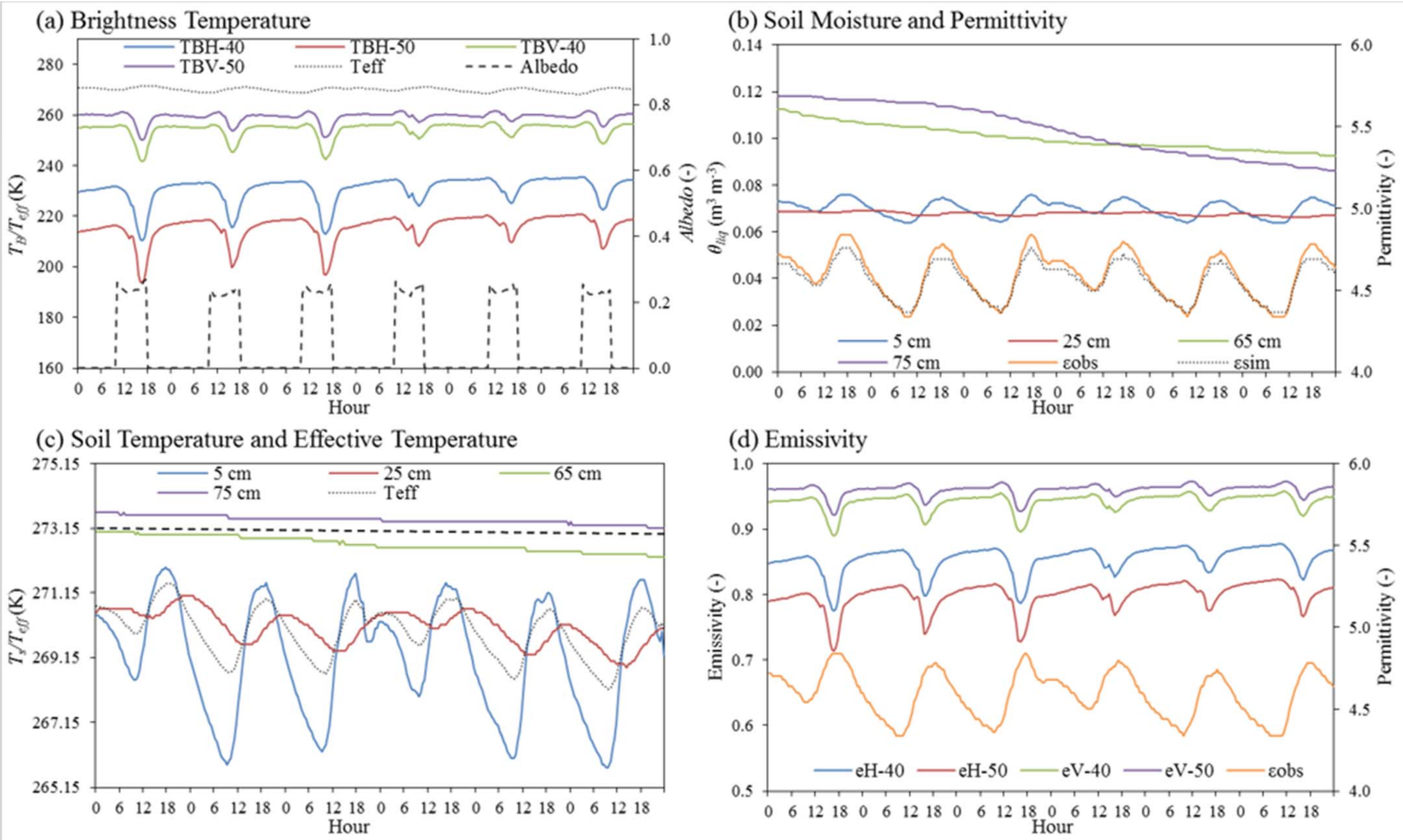
Period: Jan 1- April 5

a) Distinct periods of freezing and thawing are detected from the long-term measurements;

b) Emission depth ranges between 10 and 30 cm with the shallowest one located above 10 cm when the soil is thawed;

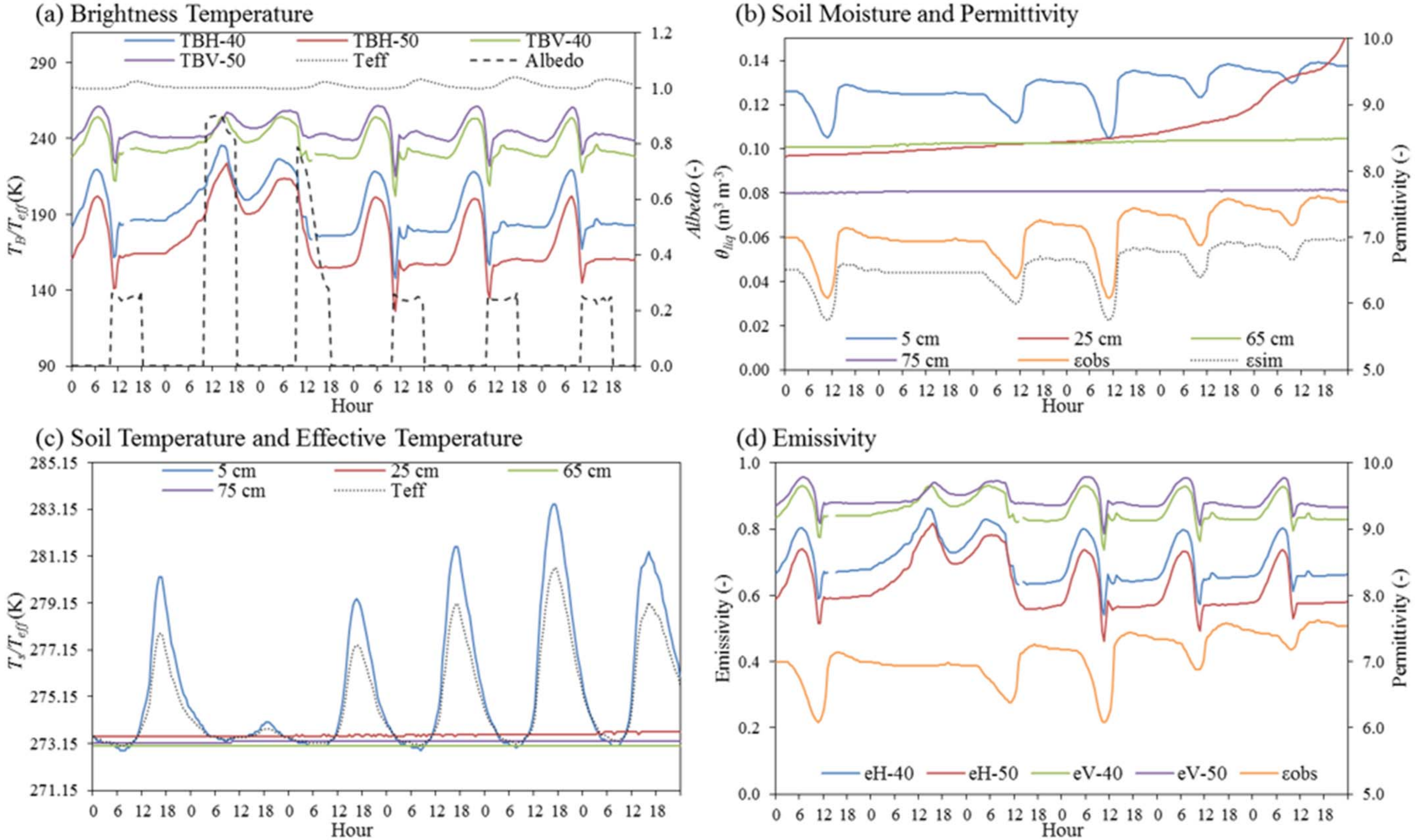
c) T_{eff} is comparable with the temperature at 25 cm depth when the soil liquid water is frozen, while it is closer to the one at 5 cm when the soil ice is thawing.

Diurnal Variations



Frozen Period, DOY 1 - 6

Diurnal Variations



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Thawing Period, DOY 88-93

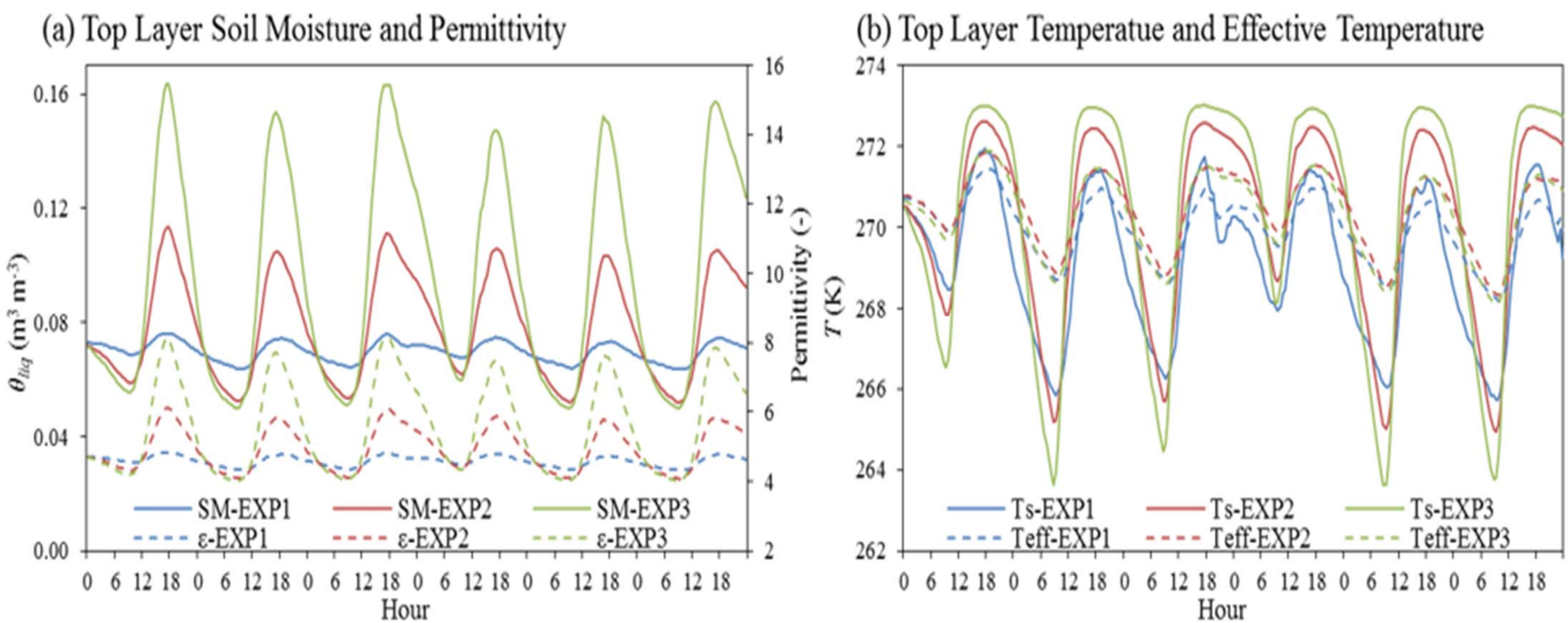
Noah-Tor Vergata Simulations

Frozen Period: DOY 1-6

EXP1: SMST in situ measurements at 5 cm

EXP2: SMST Noah 4-layer (0.1, 0.4, 1.0, 2.0) midpoint of top layer at 5 cm

EXP3: SMST Noah 5-layer (0.05, 0.1, 0.4, 1.0, 2.0) midpoint of top layer at 2.5 cm



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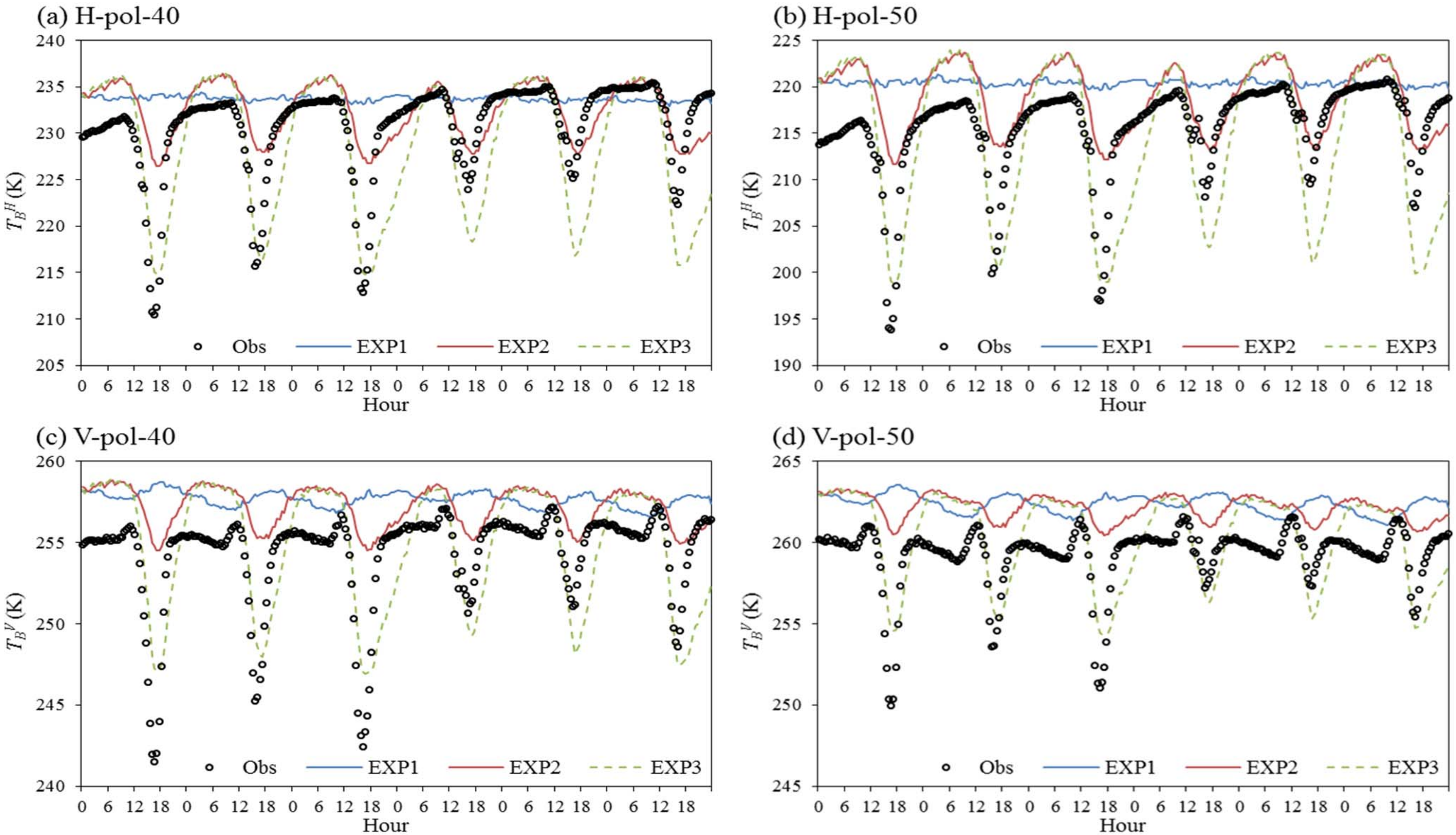
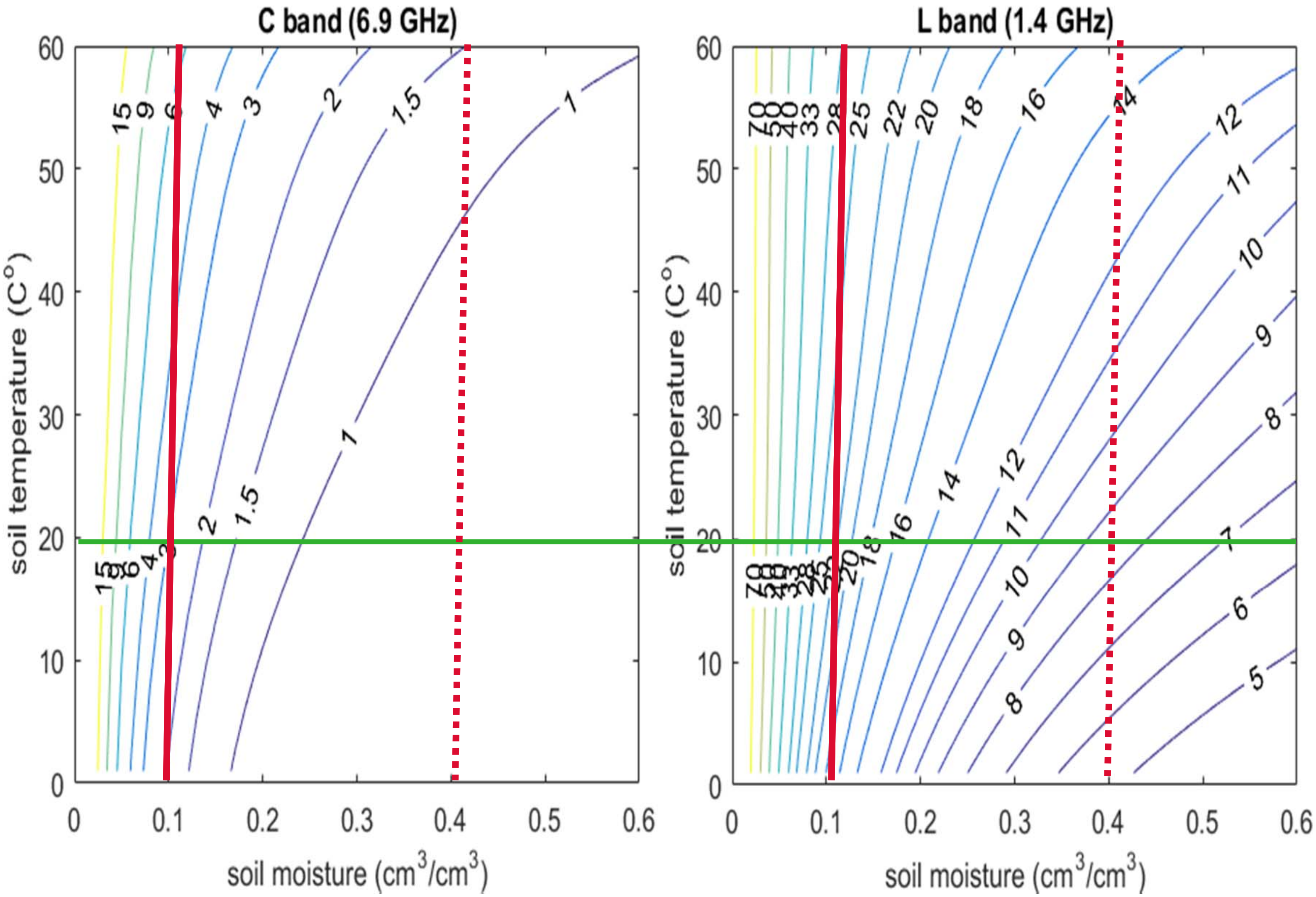
Noah-Tor Vergata Simulations



TB signature of diurnal soil freeze/thaw cycle is more sensitive to the liquid water content of soil surface layer than in situ measurements at 5 cm depth

The critical role of emission / penetration depth



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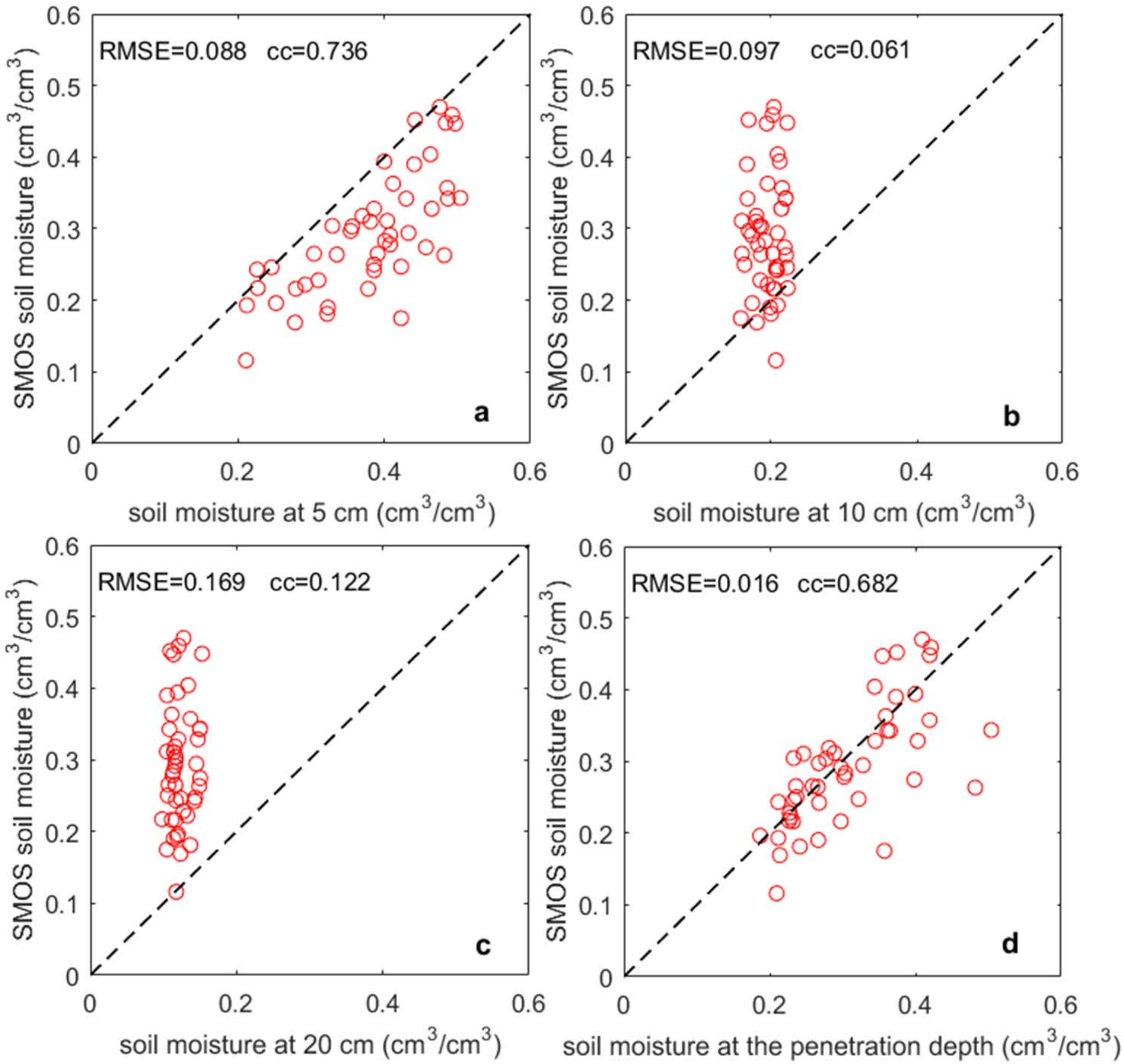
(Lv et al., 2017, RSE, in prep)

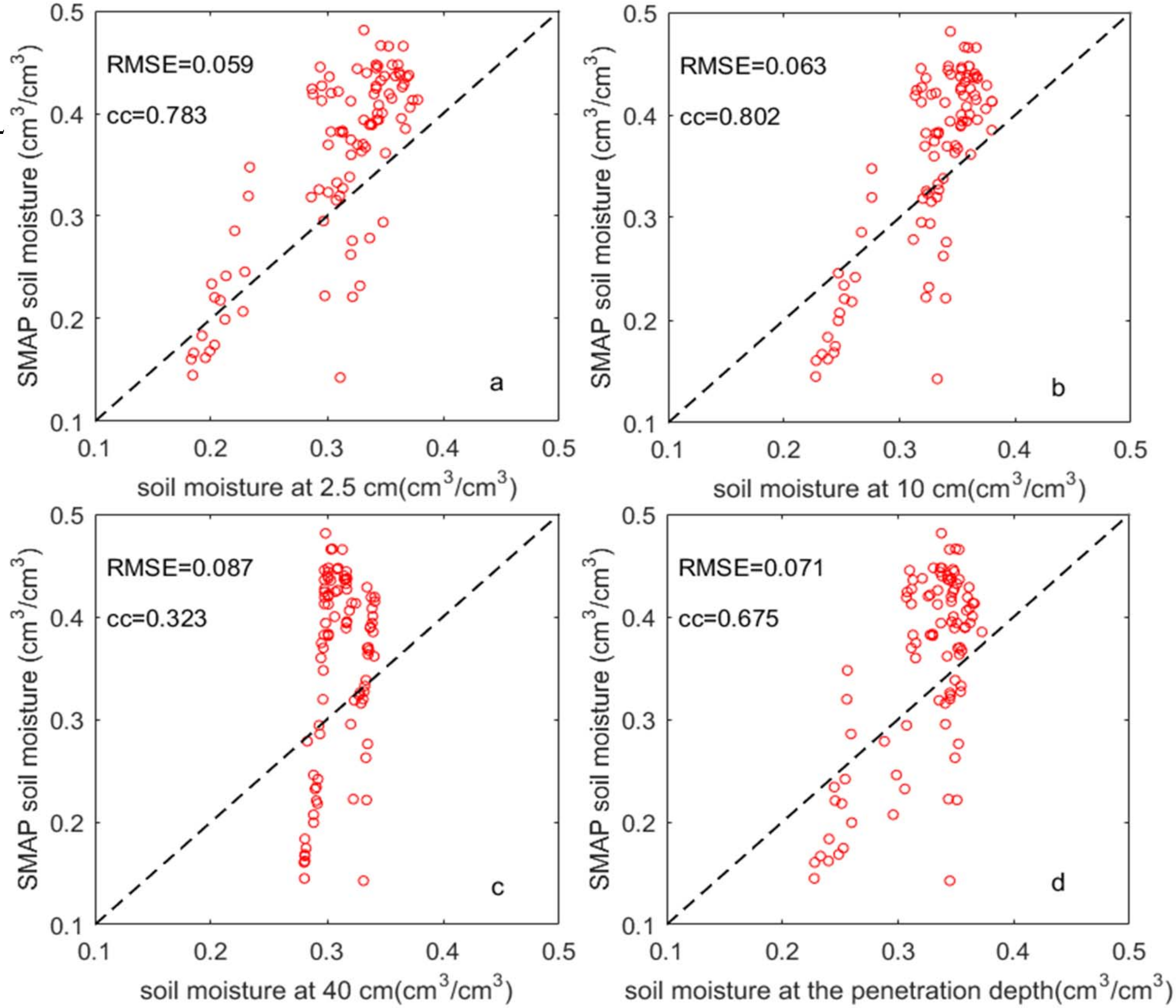
What signal is in SMOS?



June 12-28, 2010,
SM_{PD} Noah-A model interpolation of in-situ obs

(Lv et al., 2017, RSE, in prep)

What signal is in SMAP?



Aug. 6 - Nov. 27, 2016

SM_{PD} simple interpolation of in-situ obs

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(Lv et al., 2017, RSE, in prep)

CONCLUSIONS

- LSM Physics, Parameterization and Parameters are all important to fidelity in simulating Land-atmosphere interactions.
- Process understanding remains critical despite abundance of models and satellite data.
- Combined LSM-RT OSSE is needed to correctly explain and assimilate satellite signals.
- Satellite products would be more useful for DA if the emission/penetration depth is also provided.