ESA-MOST Dragon Cooperation

中国科技部-欧洲空间局“龙计划”合作

2017 DRAGON 4 SYMPOSIUM

2017年“龙计划”四期学术研讨会

(Dragon 4 id. 32070)

Monitoring Water and Energy Cycles at climate scale in the Third Pole Environment (CLIMATE-TPE)

European Lead PI	Chinese Lead PI
Prof. Z. Bob SU University of Twente, ITC z.su@utwente.nl (*coord. with Chinese LI, coord. European Partners, dev/val algorithms, coord. satellite data requests for all test sites and coord. field experiments, publ. & promotions of joint PhD students*)	**Prof. Yaoming MA** Institute of Tibetan Plateau Research ymma@itpcas.ac.cn (*coord. with European LI, coord. Chinese partners, dev/val algorithms (fluxes), coord. field experiments at the Tibetan sites*)

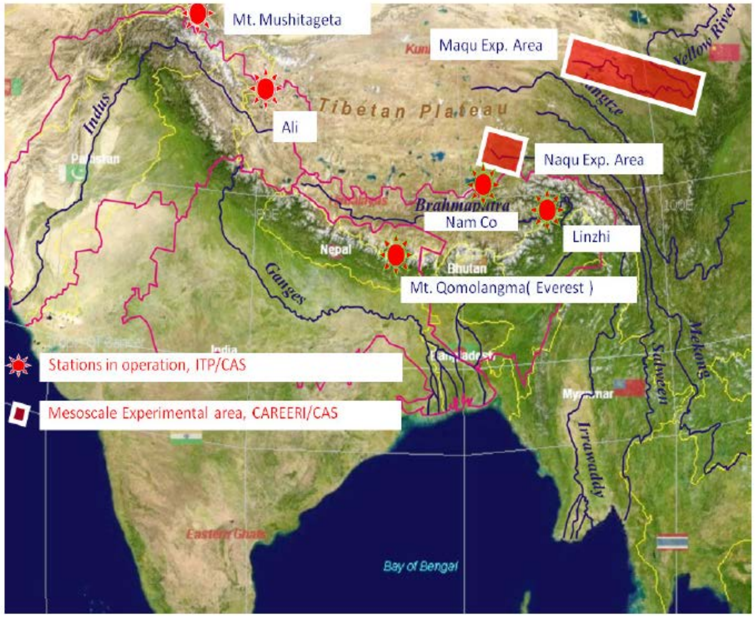
Project partners and roles

European PIs:	Chinese PIs:
Prof. Maria Jose Polo University of Córdoba, Spain, mjpolo@uco.es (*dev/val algorithms (water and energy fluxes), ass. scale effects associated to data sources, distributed modelling*)	**Prof. Jun Wen**, Chengdu University of Information Sciences, jwen@lzb.ac.cn (*soil moisture and land surface water process in SRYR, dev. retr. algorithms (MW) and coord. field exp.*)
Prof. Jose Sobrino, Universitat de Valencia, sobrino@uv.es (*dev/val TIR algorithms, joint analysis of reanalysis and satellite time series data*)	**Dr. Yanbo He**, National Meteorological Center, yanbohe@cma.gov.cn (*software dev/val satellite products, appl. algorithms, data proc., coord. data requests for routine meteor. data*)
Prof. Alexander Loew University of Munich (LMU) alexander.loew@lmu.de (*dev/val high resolution land surface products using HOLAPS/SEBS*)	**Prof. Xiaohua Dong**, China Three Gorges University, Yichang, China, xhdong@ctgu.edu.cn (*dev. RS appl. ecohydrological modelling and hydrological forecasting*)

Contribution and training of Young Scientists

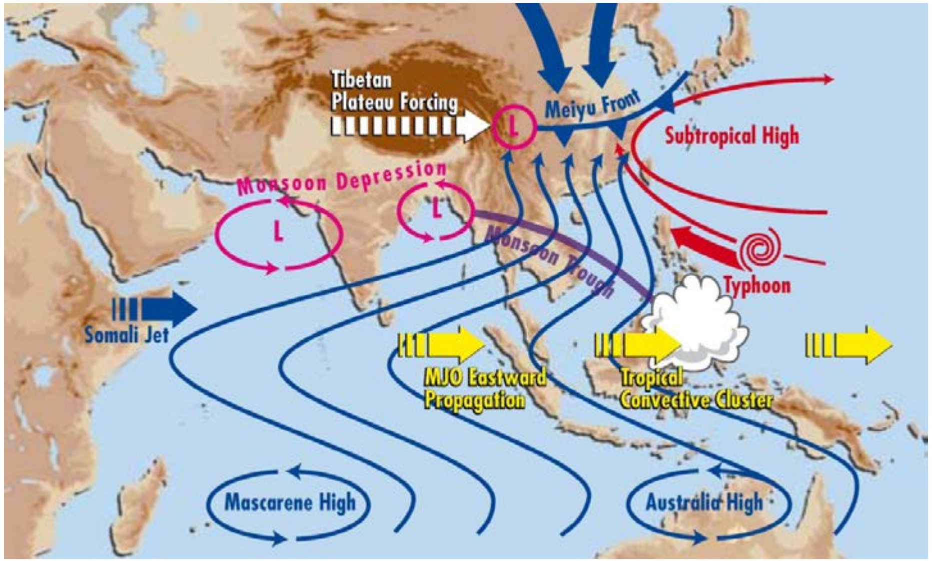
1. **Dr. Rogier van der Velde**, University of Twente, email: r.vandervelde@utwente.nl
2. **Dr. Yijian Zeng**, University of Twente, email: y.zeng@utwente.nl
3. **Dr. Xin Wang**, North-west Institute of Eco-Environmental Research, Chinese Academy of Sciences
4. **Dr. Xuelong Chen** (postdoc, UT) (land-atmosphere interactions, boundary layer processes)
5. **Dr. Donghai Zheng** (postdoc, UT) (water cycle in the upper Yellow River basin, hydrological modelling)
6. **Shaoning Lv** (PhD student, UT-CAREERI) (Microwave emission)
7. **Qiang Wang** (PhD student, UT) Soil moisture monitoring using Aquarius data
8. **Binbin Wang** (PhD student, UT-ITP) Energy balance of high plateau lakes
9. **Junping Du** (PhD student, UT-ITP) Urban hydroclimate observations10
10. **Xu Yuan** (PhD student, UT) Sea surface salinity in Indian Ocean and South Asian monsoon
11. **Hong Zhao** (PhD student, UT) Retrieval of soil thermal and hydraulic parameters from satellite observations
12. **Dongyu Jia** (PhD student, NIEER) land-atmosphere interaction study in cold region
13. **Dr. Cunbo Han** (postdoc, ITP) (land surface processes modelling)
14. **Lian Liu** (PhD student, ITP) Thermal and hydraulic parameters from satellite observations on the glaciers
15. **Dr. Cristina Aguilar,** University of Cordoba, e-mail: caguilar@uco.es
16. **Dr. Rafael Pimentel** (postdoc, UC) Data fusion and assimilation for snow and hydrological modelling
17. **Gabriel Delgado Leal** (PhD student, UC) Water and energy fluxes regime in snow mountain regions
18. **Marta Sáenz de Rodrigáñez** (PhD student, UC) Time series of snow and hydrological variables
19. **Dr. Jian Peng** (postdoc, LMU) Thermal and microwave remote sensing of surface energy and water fluxes
20. **Dr. Christiaan van der Tol**, University of Twente, Remote sensing of fluorescence
21. **Jan Hofste** (PhD student, UT), Remote sensing of land surface by scatterometry and spectroscopy

The Third Pole Environment



- *Vital source of water for 1.5 billion people across 10 countries in SE Asia*
- *Significant role in global atmospheric circulation*
- *highly sensitive to climate change*

- *Intensive exchanges of water and energy between the Asian monsoon, the plateau land surface (lakes, glaciers, snow and permafrost) and the plateau atmosphere at various temporal and spatial scales, but lack a fundamental understanding of the details of the coupling esp. at the climate scale.*



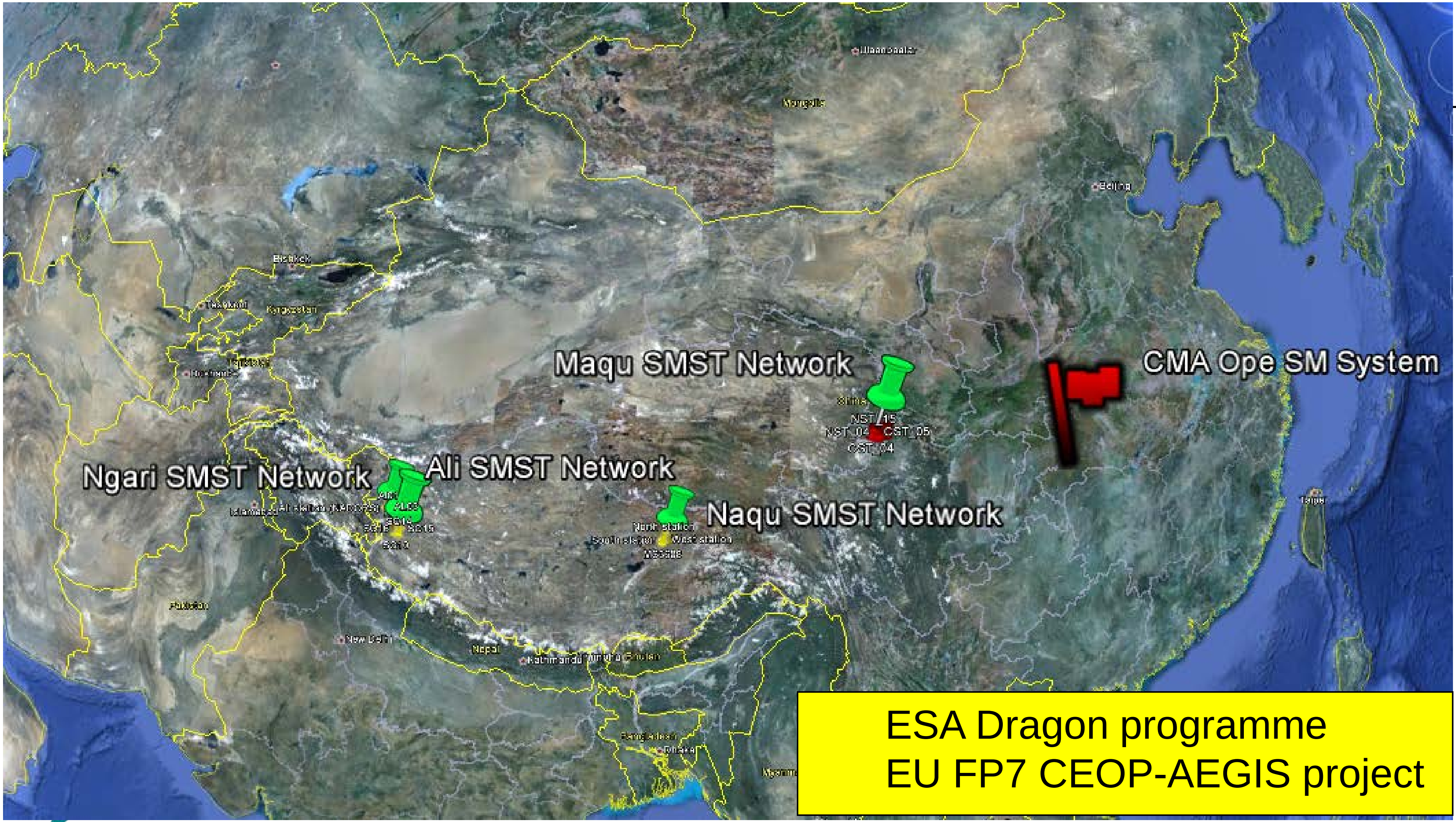
CLIMATE-TPE **aims**

- improve the understanding of the interactions between the Asian monsoon, the plateau surface (incl. its permafrost and lakes) and the Tibetan plateau atmosphere in terms of water and energy budgets
- assess and understand the causes of changes in cryosphere and hydrosphere in relation to changes of plateau atmosphere in the Asian monsoon system
- predict the possible changes in water resources in the Third Pole Environment

CLIMATE-TPE METHOD:

- use earth observation, in-situ measurements and modelling to advance process understanding relevant to monsoon scale predictions,
- improve and develop coupled regional scale hydroclimatic models to explain different physical links and scenarios that cannot be observed directly.

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



(Su, Z., et al. 2011, HESS)

WORK PACKAGES

WP1: Observation and modelling of microwave scattering and emission under complex terrains incl. permafrost and freeze and thawing

WP2: Advancement of physical understanding and quantification of changes of water and energy budgets in TPE

WP3: Advancement of quantifying changes in surface characteristics and monsoon interactions

WP1: Observation and modelling of microwave scattering and emission under complex terrains incl. permafrost and freeze and thawing (this talk)

1) conduct ELBARA measurements for two years, for advancing understanding of the mass and energy exchanges involved in the freeze/thaw process.

2) The collected ELBARA observations will be analysed with the recently developed effective temperature model by Lv et al. (2014) to better understand the microwave emission signals, incl. validation of SMOS/SMAP *T*b.

3) develop an approach to merge existing satellite data of different frequencies (e.g. for low resolution data SCAT/ASCAT, SSM/I, AMSRE-E/2, SMOS, and high resolution data ASAR/S-1) (Dente et al. 2014; Lv et al. 2014), so that a consistent soil moisture data product can be generated by using the same consistent framework, contributing to the ESA Climate Change Initiative.

WP2: Advancement of physical understanding and quantification of changes of water and energy budgets in TPE

Focus: integrate current understandings in the mechanism of changes in water and energy budget in TPE using satellite data products and numerical modelling.

1) - Observation and analysis of water and energy balance of the Namco Lake catchment area using the concept of water and energy balance closure.
- construct the water cycle budgets of the lake catchment together with the lake observation, satellite observations and modelling. (**Poster Binbin Wang**)

2) Recent advances in understanding land-atmosphere interactions with the Noah model at local scale (Zheng et al., 2014, 2015a,b) will be upscaled to plateau scale to generate consistent data sets for water and energy cycles in TPE. (**this talk**)

3) Development of high resolution land surface energy and water fluxes from satellite data using Sentinel data - the combined HOLAPS/SEBS models will be used at high spatial resolution. (**Poster Junping Du**)

4) Joint diagnoses of the products from 2-3) will be conducted to improve model physics, parameterisation and parameters for climate analysis.

WP3: Advancement of quantifying changes in surface characteristics and monsoon interactions

Water and energy budgets in TPE will subject to systematic analysis to ensure their consistence in terms of climate data records (albedo, veg coverage, soil thermal and hydraulic properties, LST, soil moisture, and lake levels and veg changes etc.).

1) Analysis of existing CDR/ECV data with the validation framework proposed in the EU CORE-CLIMAX project by Zeng et al. (2015)

2) Generating new and consistent land surface variables for the TPE, including in particular LST, soil moisture, soil thermal and hydraulic properties (**Poster Yawei Wang**)

3) Integration of these new consistent dataset into research of WP2

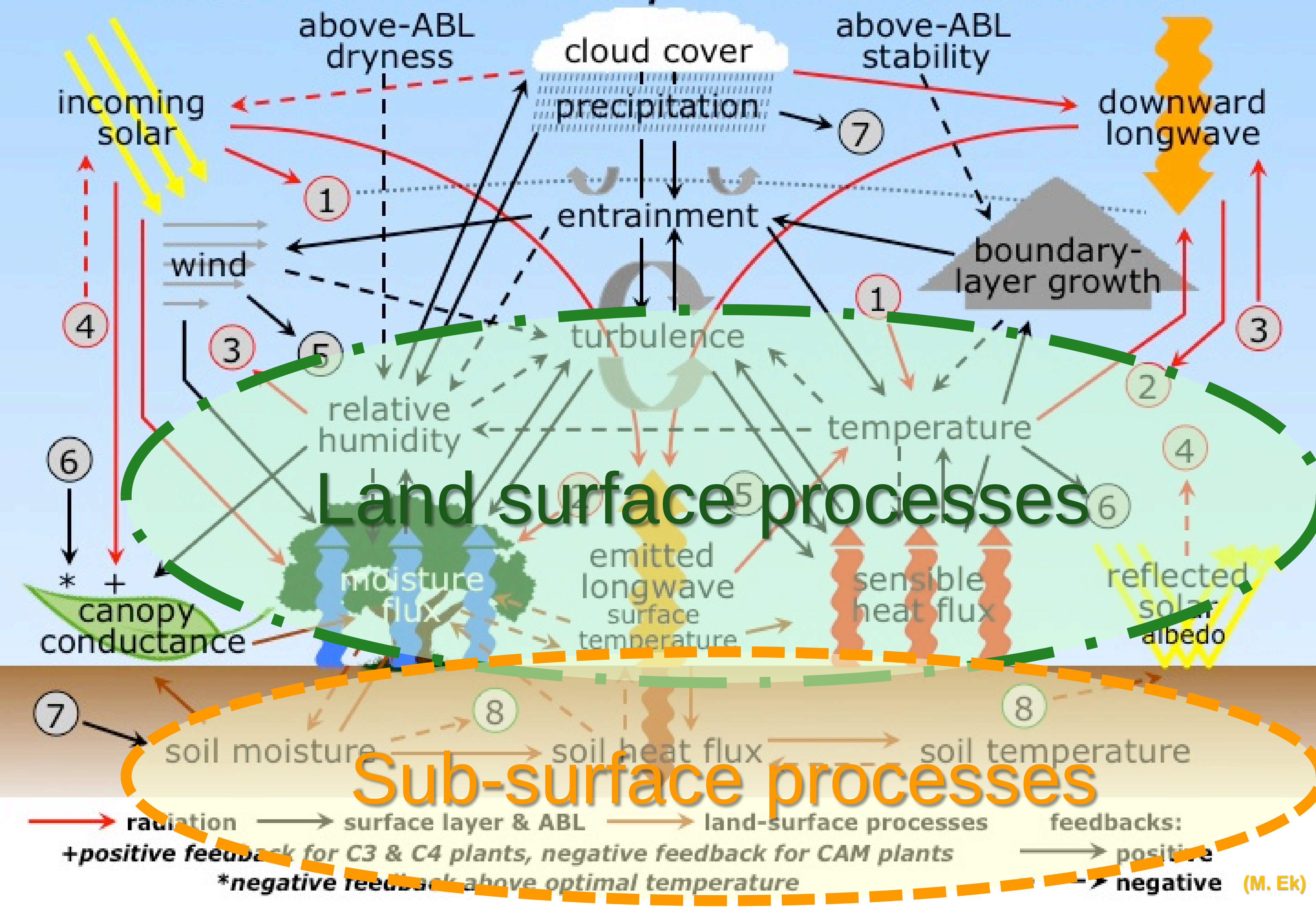
4) Assimilation of microwave observation from SMOS and SMAP into the WRF modelling system using the concept of observing depth of microwave sensing by Lv et al. (2014). a) assimilation with optimal interpolation with weights (with coupled emissivity- effective temperature); b) assimilation with retrieval of observing depth under special cases (for instance, homogeneous soil temperature).

5) Analysis of monsoon dynamics in relation to changes of plateau surface characteristics by using the WRF modelling system.

DELIVERABLES:

- scientific outputs in terms of peer reviewed journal publications,
- PhD theses,
- data sets in terms of novel data records of essential climate variables for quantification of water and energy cycle dynamics in the Third Pole Environment.

Local Land-Atmosphere Interactions



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;

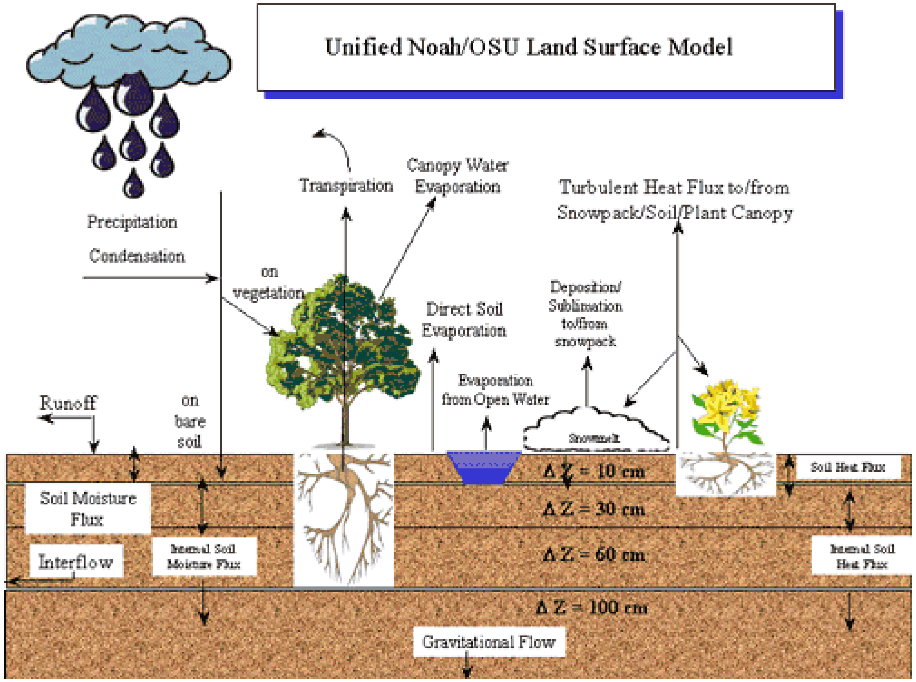
(Zheng et al., 2014, 2015a,b, JHM; Zheng et al. 2016, 2017, JGR)

- Snow pack.

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

- Frozen soil;

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



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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ROGIER VAN DER VELDE AND ZHONGBO SU

Faculty of Geo-Information Science and Earth Observation, University of Twente, Enschede, Netherlands

XIN WANG AND JUN WEN

Key Laboratory of Land Surface Process and Climate Change in Cold and Arid Regions, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

MARTIJN J. BOOIJ AND ARJEN Y. HOEKSTRA

Faculty of Engineering Technology, University of Twente, Enschede, Netherlands

YINGYING CHEN

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

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

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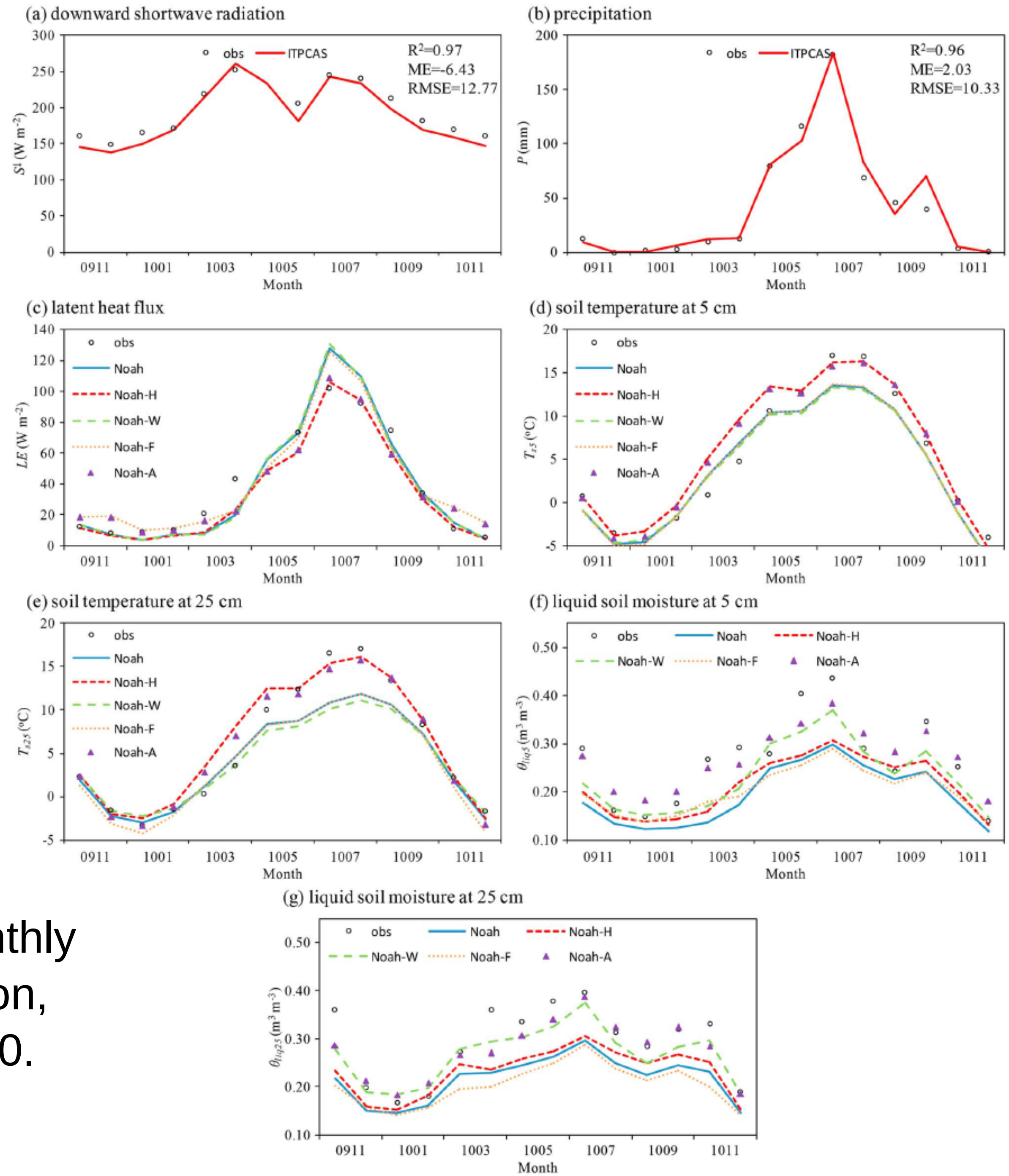
(https://www.itc.nl/resumes/zheng)

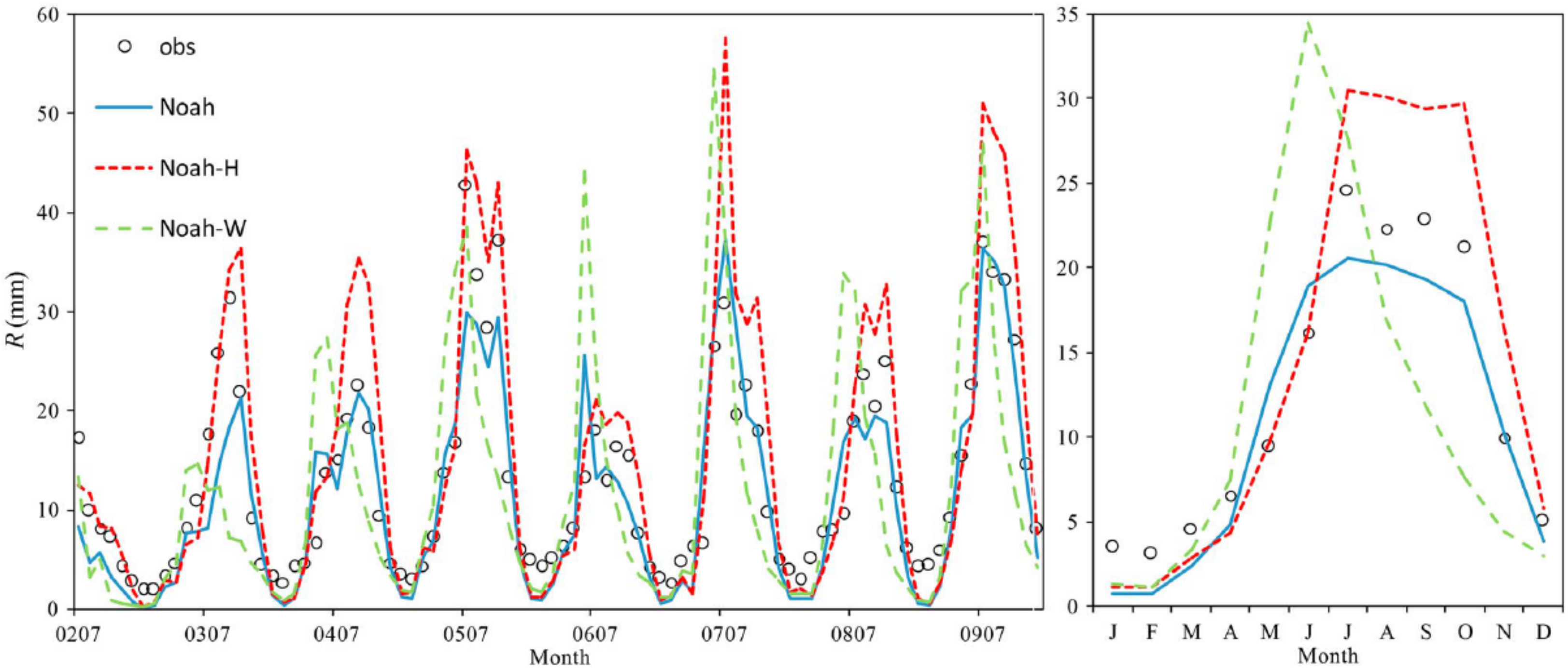
Fluxes and states

Augmentations:

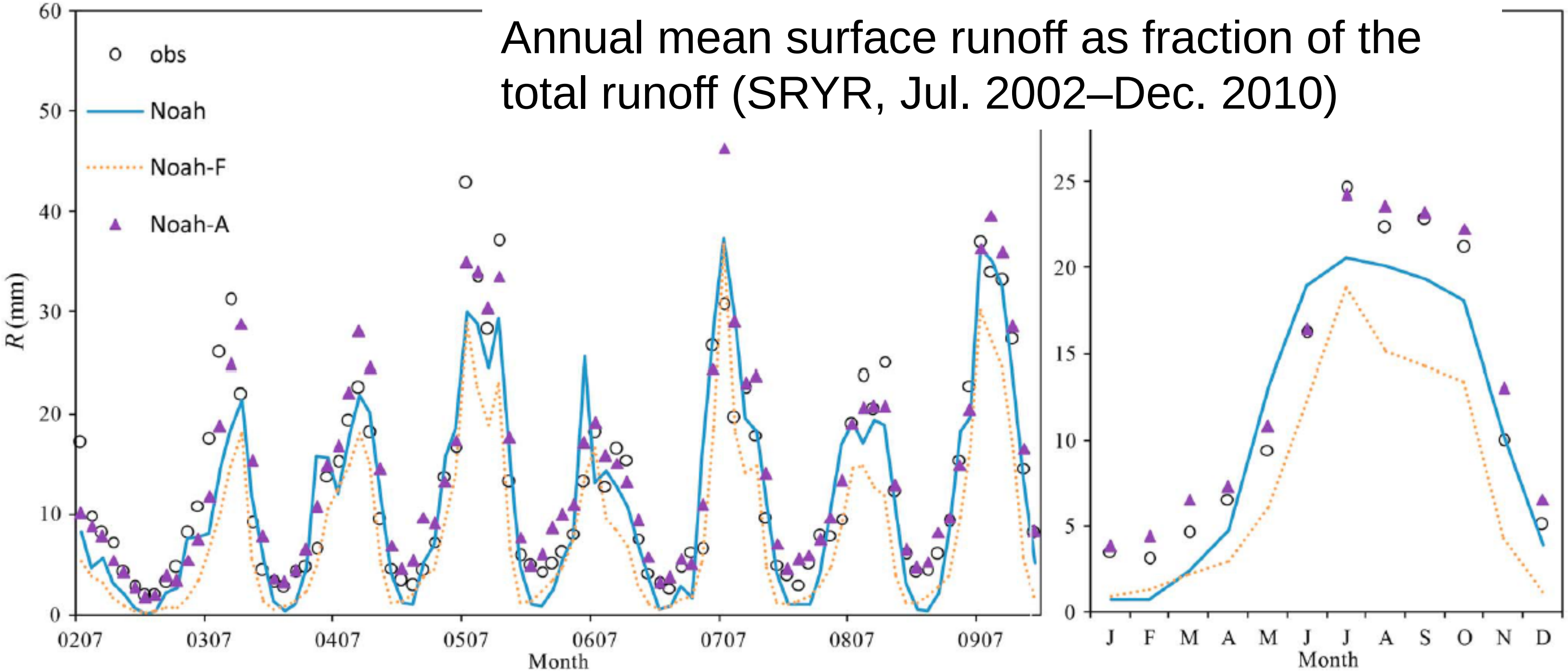
- **Noah-H**: turbulent & soil heat transport
- **Noah-W**: soil water flow
- **Noah-F**: frozen ground processes
- **Noah-A**: all augmentations

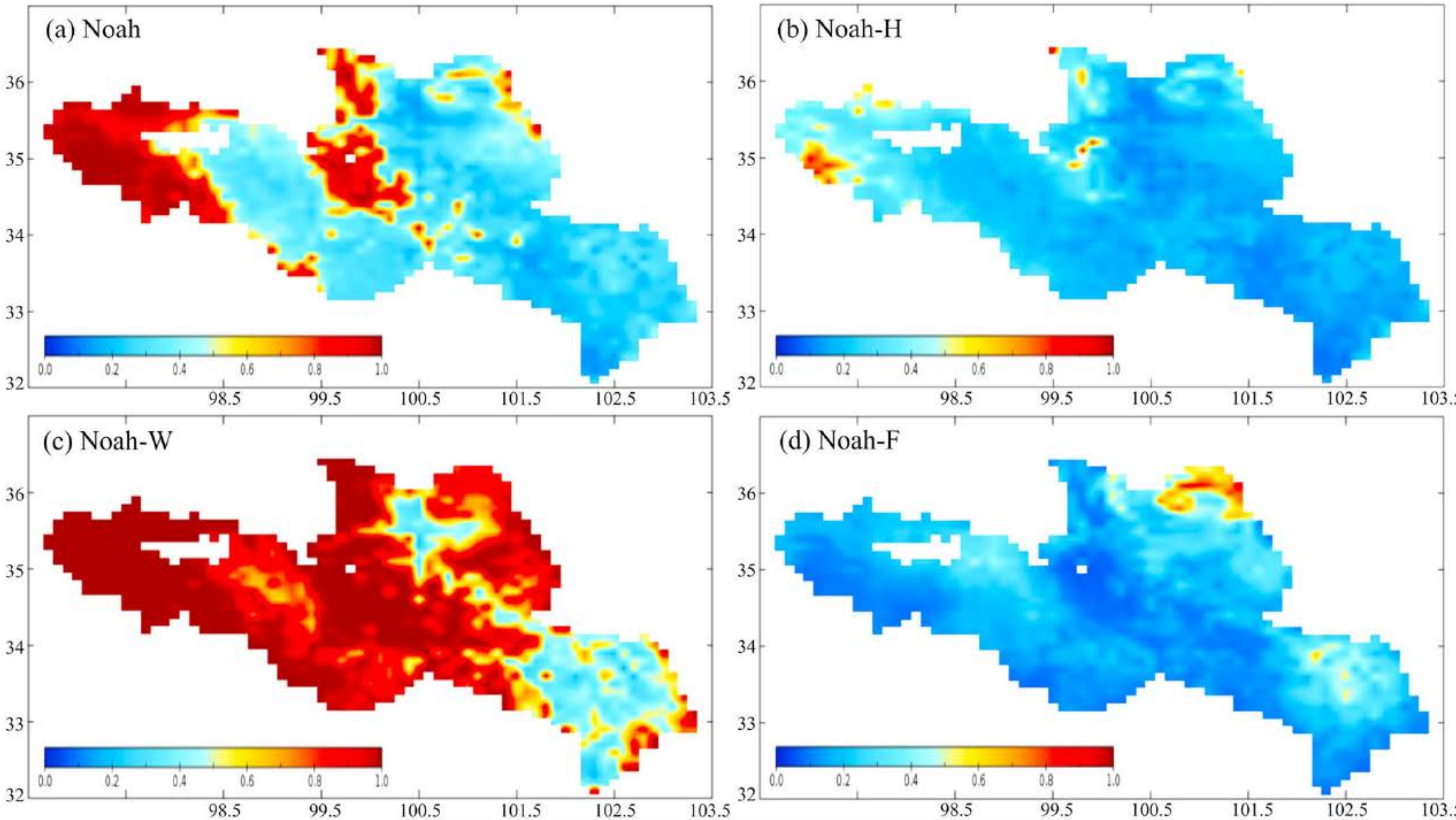


Comparisons of monthly average, Maqu station, Nov. 2009–Dec. 2010.



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





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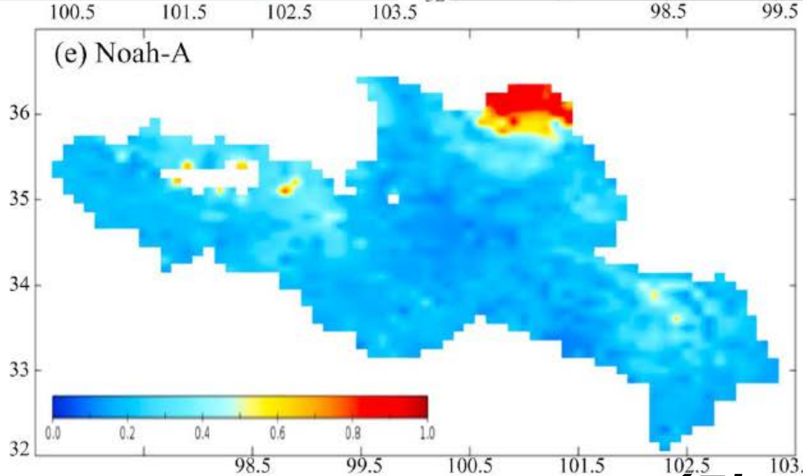


annual mean surface runoff as fraction of total runoff (SRYR, Jul. 2002–Dec. 2010)

ind

(Zheng et al. 2016, 2017, JGR)

schemes perform much better than

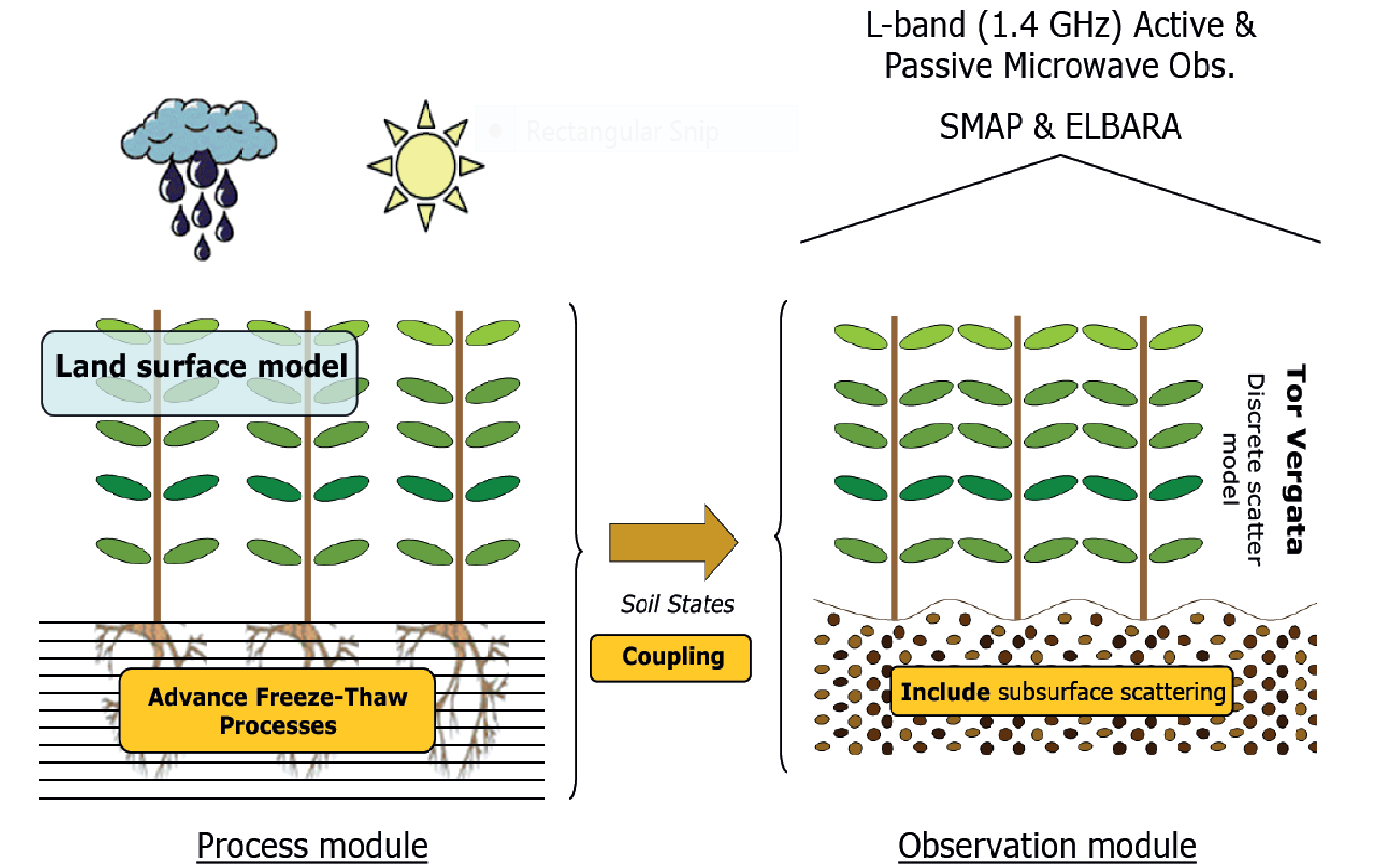
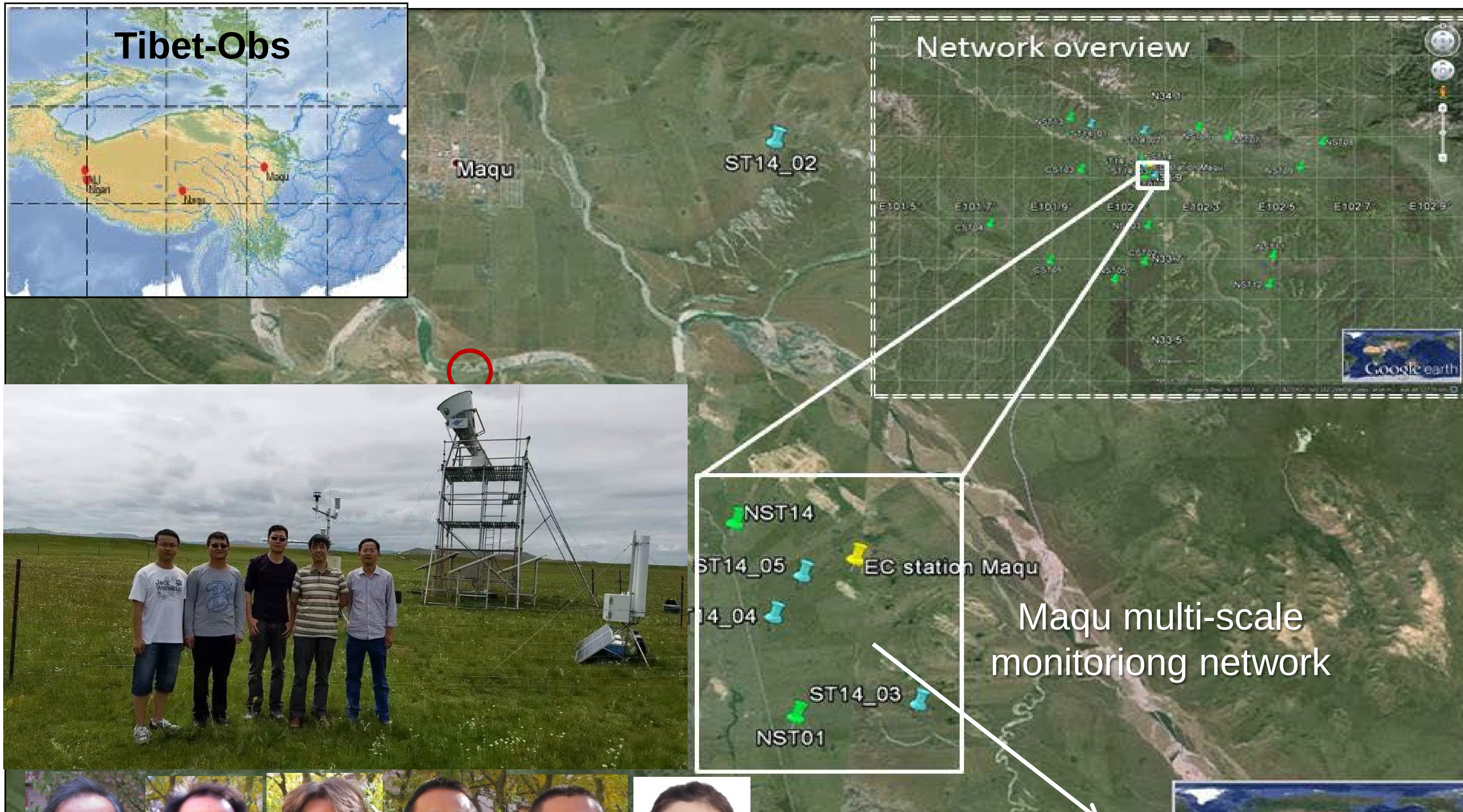
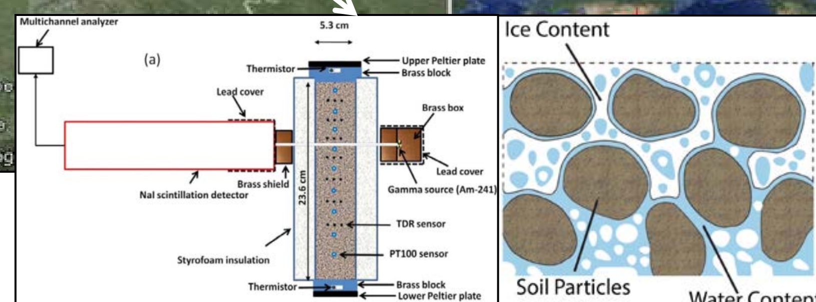


Figure 2 Coherent process modeling and radiative transfer modelling





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

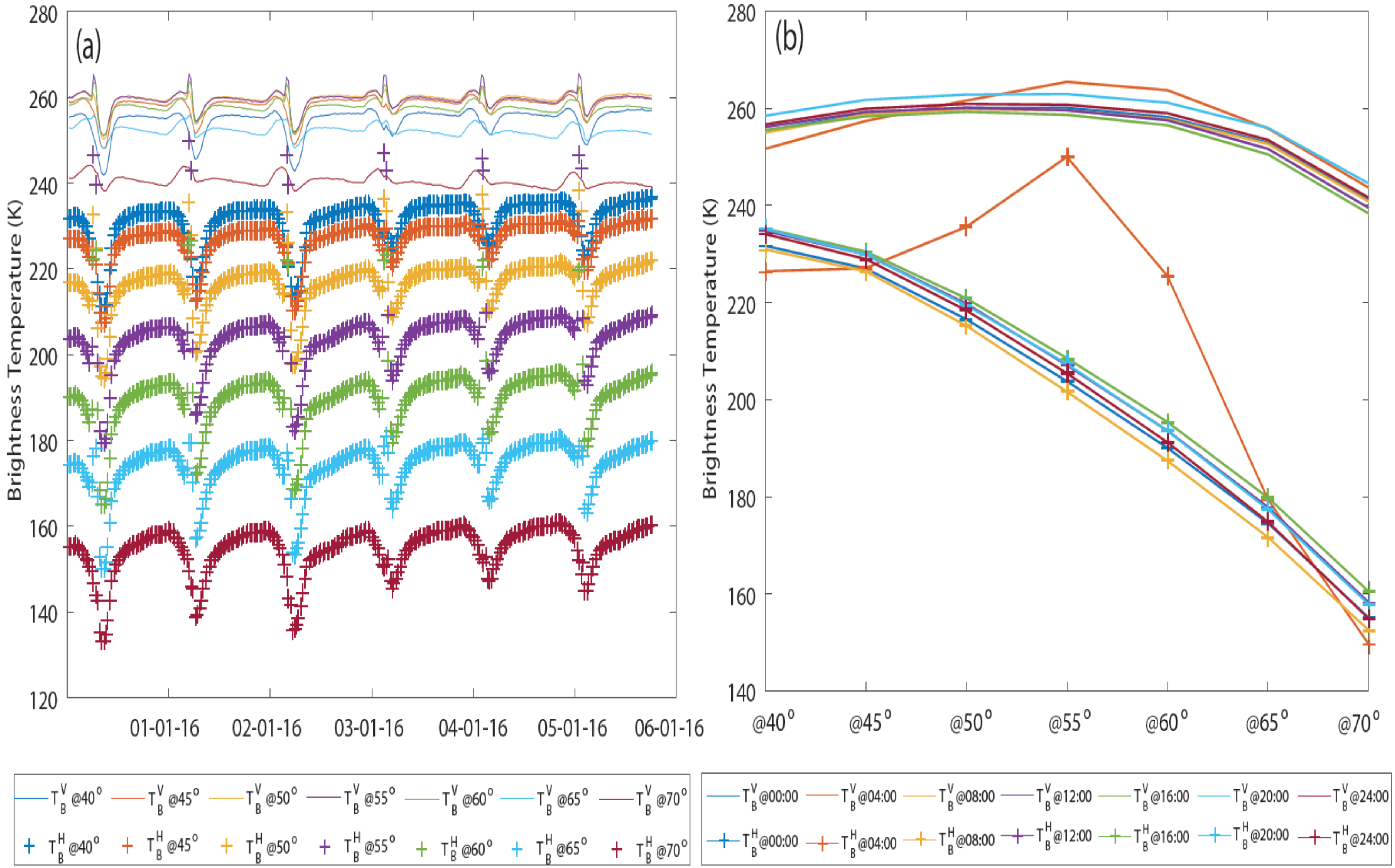
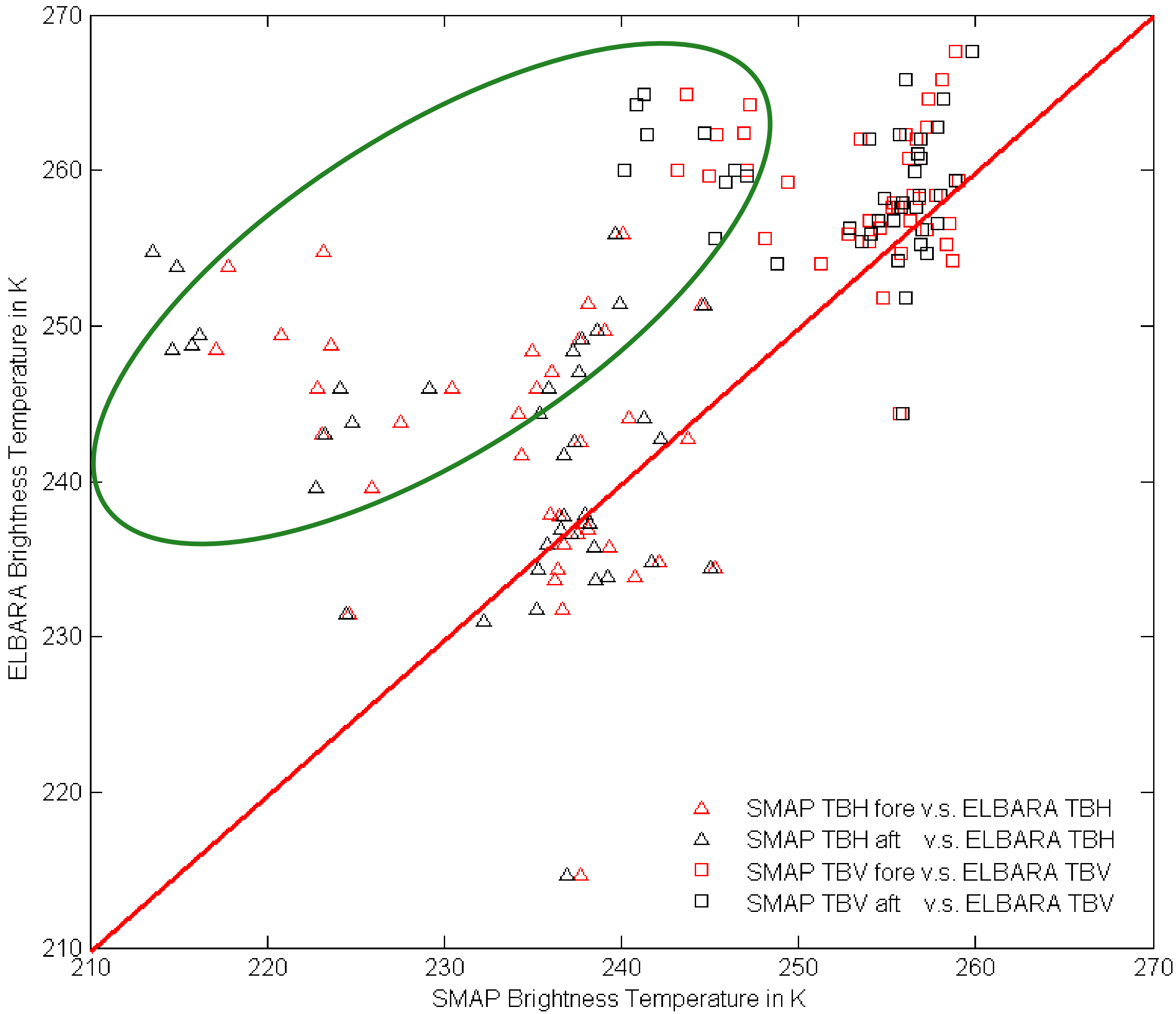


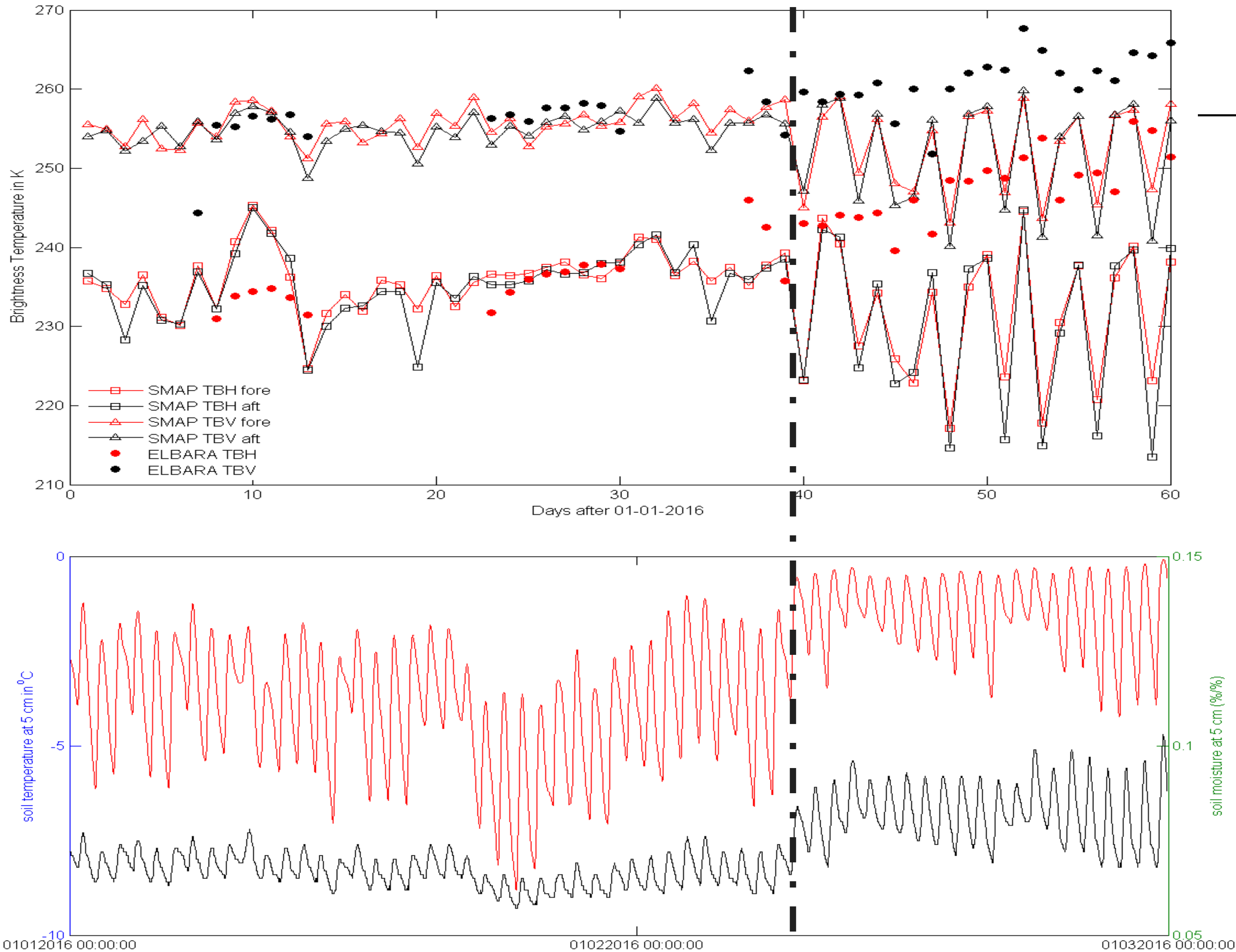
Figure 4 (a) time series of brightness temperature at both H and V polarization between 01-01-16 and 06-01-16; (b) the angular behavior of brightness temperature at both H and V polarization on 01-01-16 with 4-hour intervals (ELBARA III observations).

COMPARISON BETWEEN SMAP & ELBARA

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



WHY DOES SMAP UNDERESTIMATE ELBARA TB?



DOY 1:
01-01-2016

DOY 40:
10-02-2016

DOY 60:
29-02-2016

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)

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

A two-layer system:

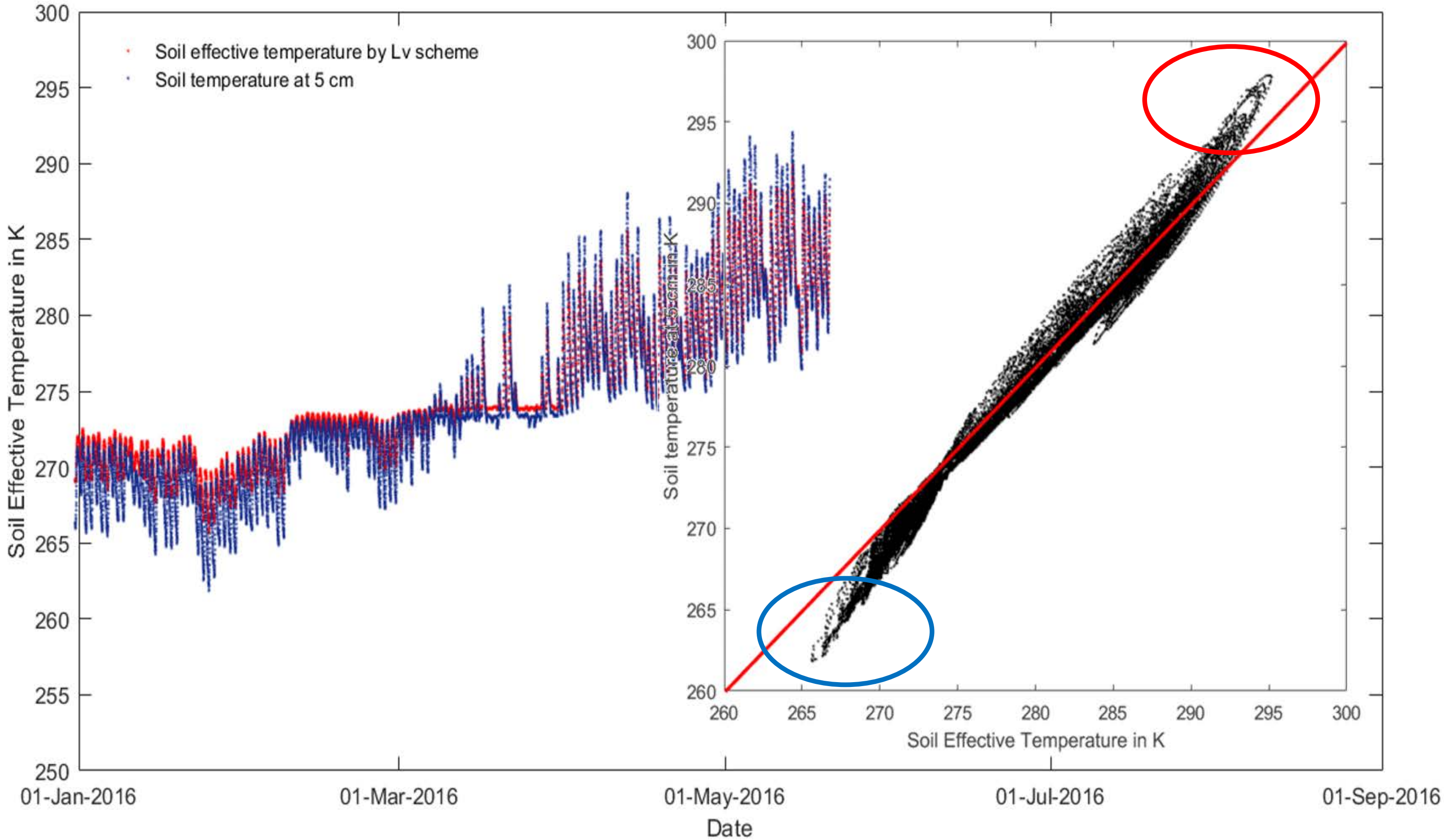
$$T_{eff} = T_0\left(1 - e^{-B_0}\right) + T_\infty e^{-B_0}$$

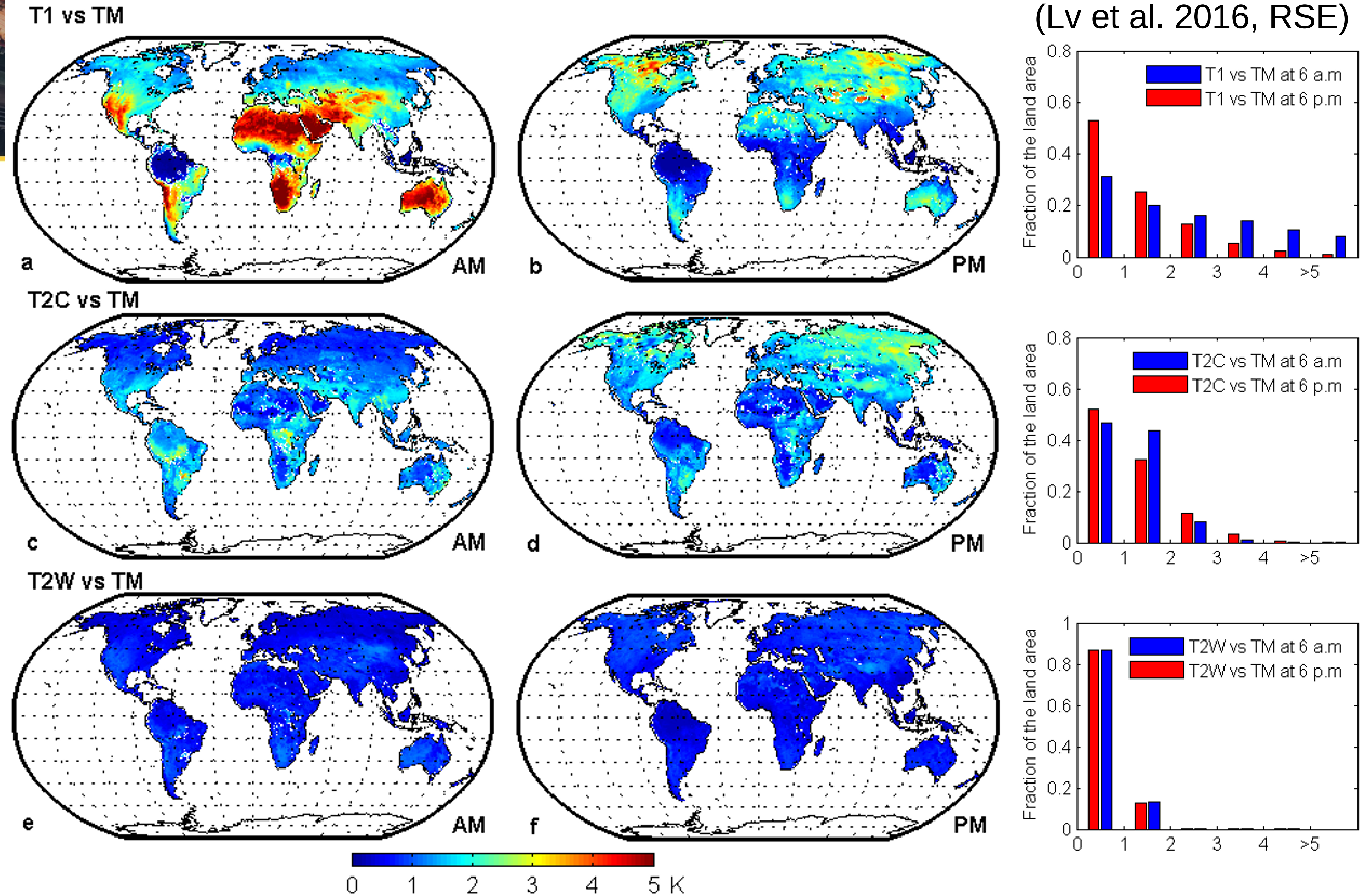
$$B_0 = \alpha_1 x_1$$

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

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

Teff time series (Lv scheme) and soil temperature at 5cm over Maqu center site (NST-01) from Jan 1 to may 20, 2016



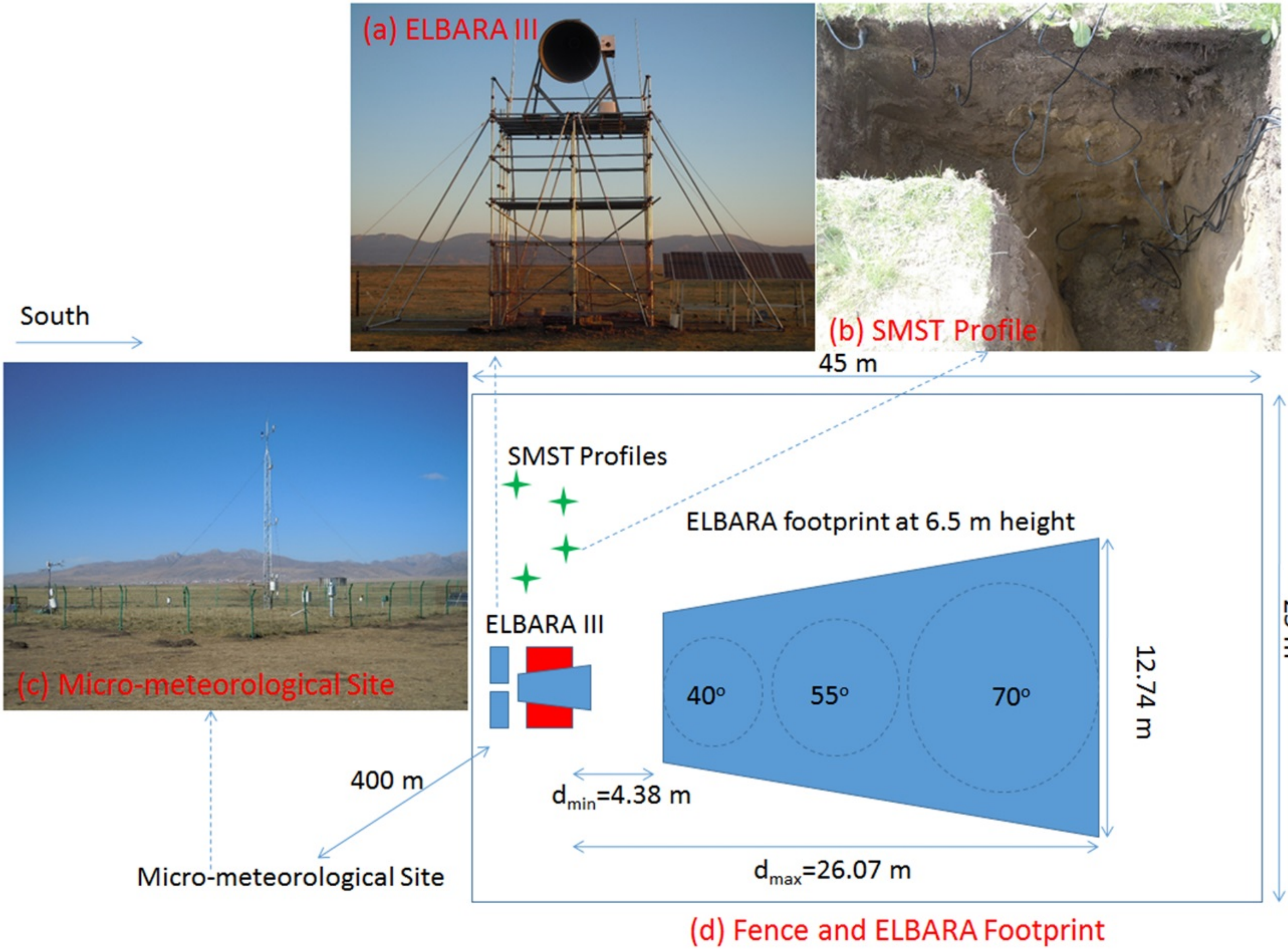


Global RMSD (in K) (SMAP beta scheme (T1) vs Lv's scheme (TM) (a and b), SMAP current scheme (T2C) vs TM (c and d), SMOS scheme (T2W) vs TM (e and f).

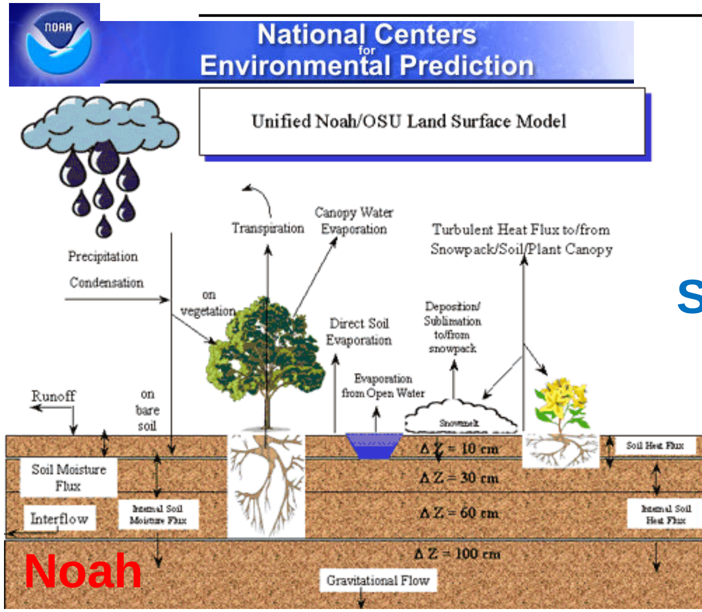
(MERRA-land in 2013 soil temperature and soil moisture profile)

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



Noah-Tor Vergata Model



Surface SMST

Four Phase Dielectric Mixing Model

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

SMST Profiles

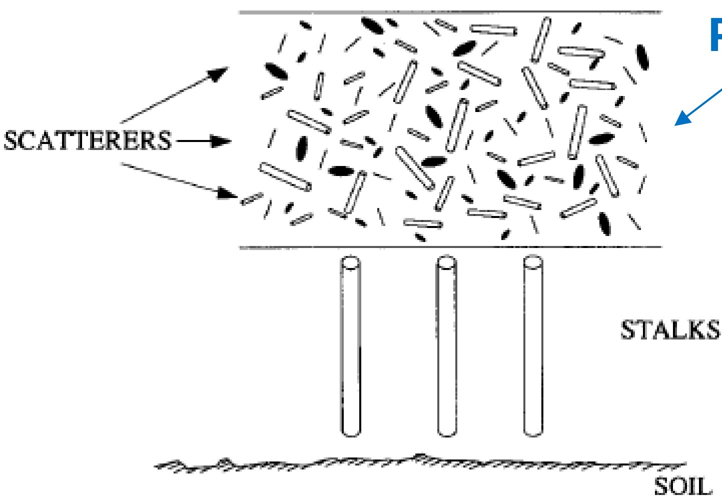
Effective Temperature

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

Permittivity

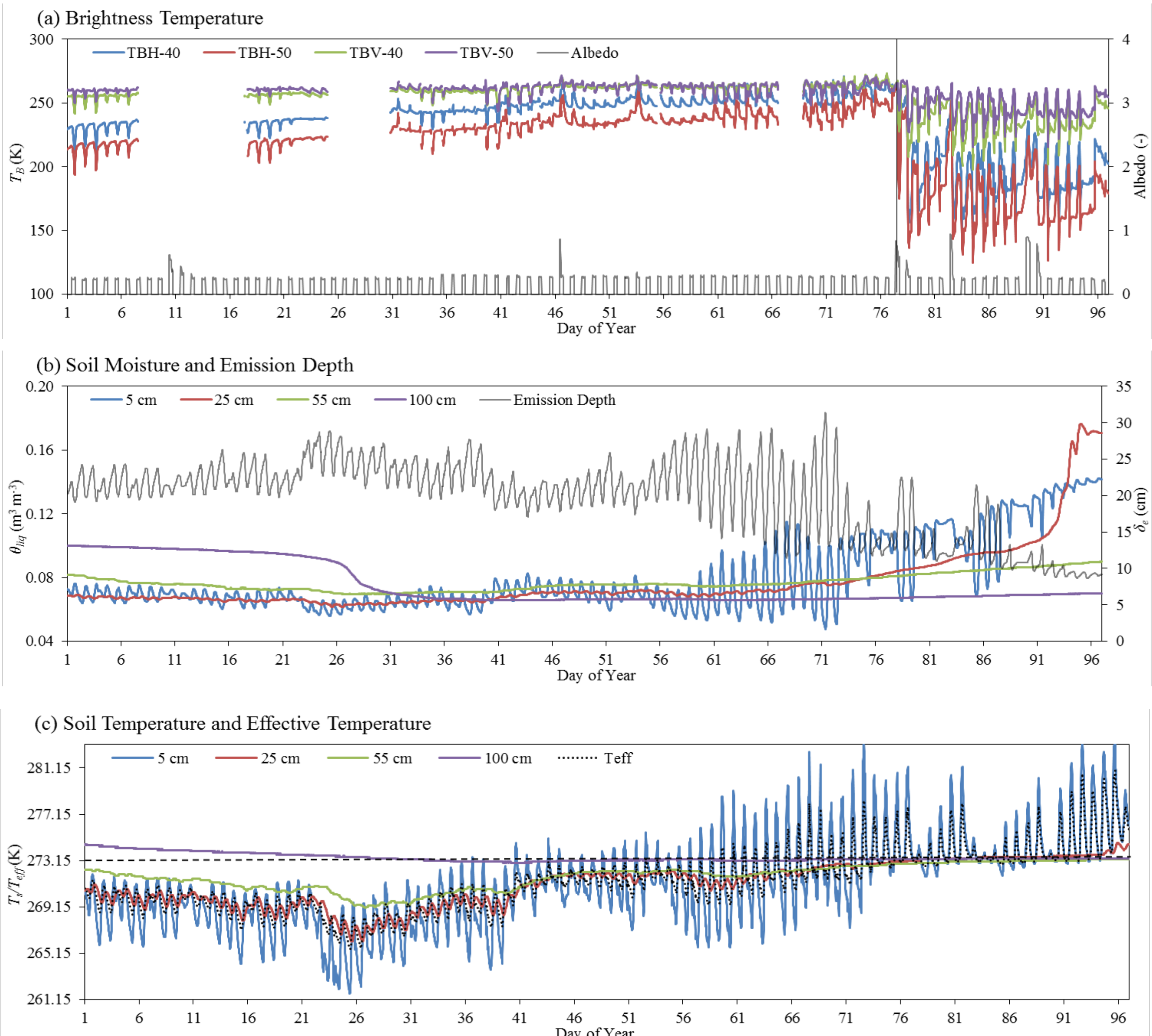
Emissivity

Brightness Temperature



Tor Vergata RT

Long Term Analysis



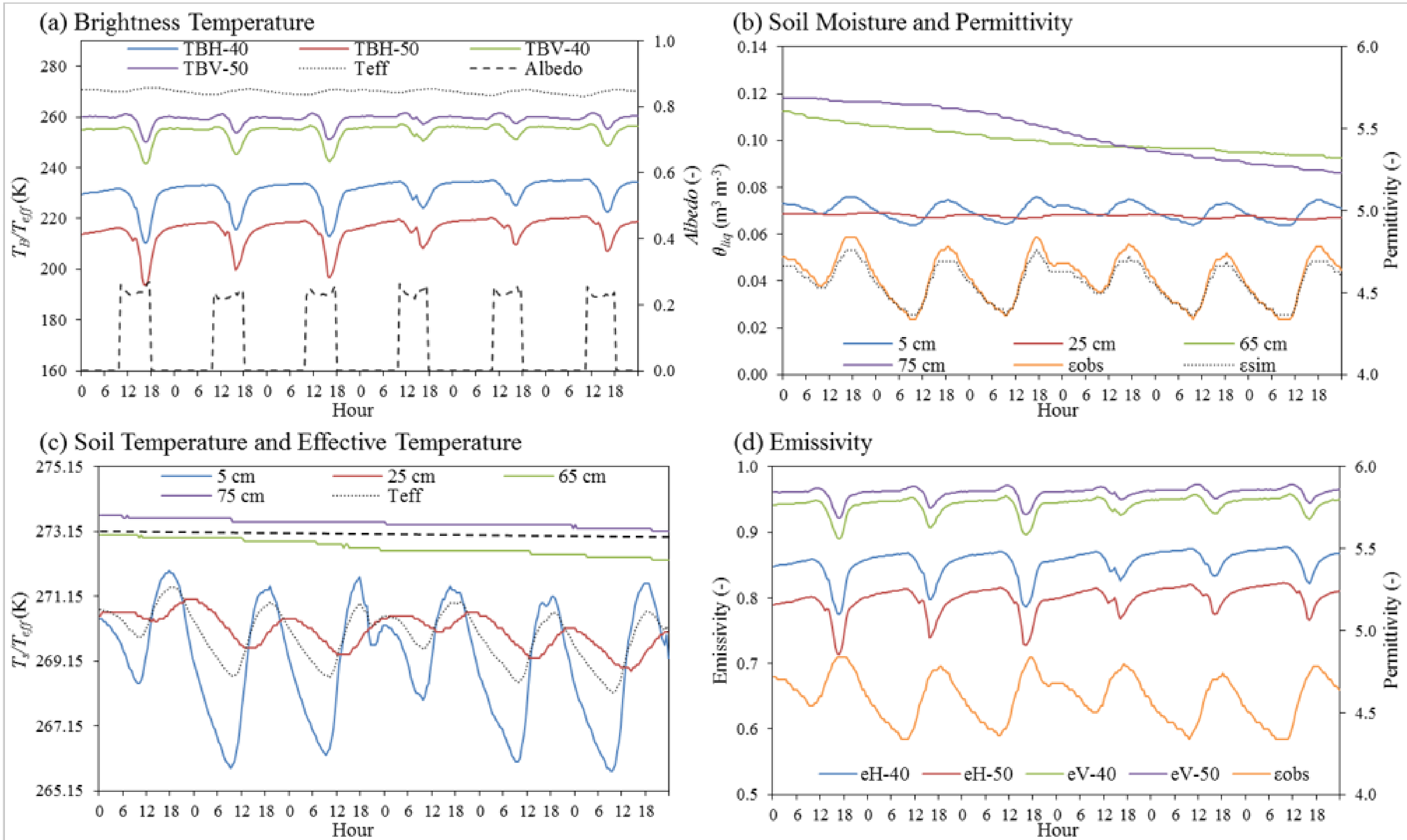
Period: Jan 1- April 5

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;

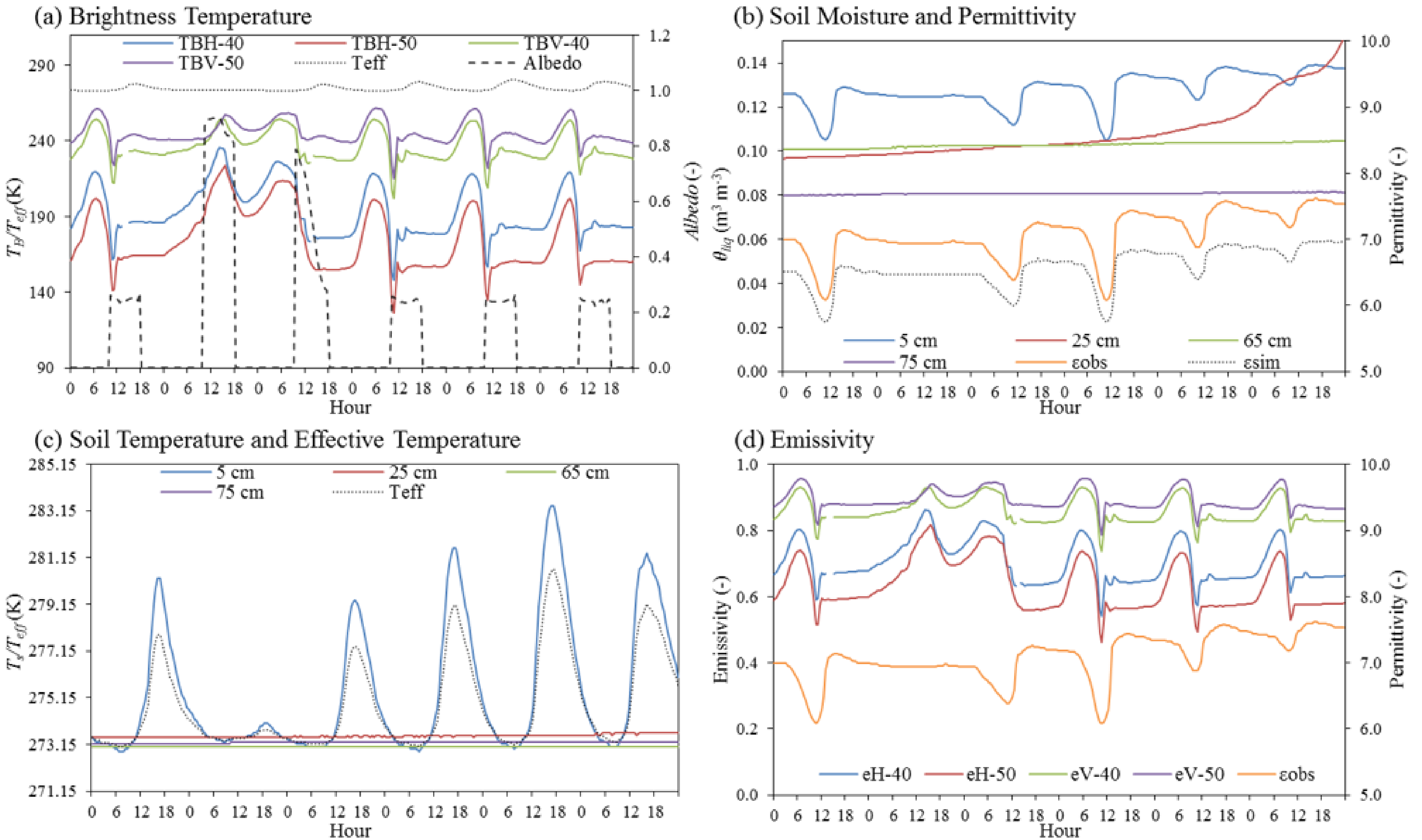
c) T_{eff} is comparable with the temperature at 25 cm depth when the soil liquid water is frozen, while it is closer to the one at 5 cm when the soil ice is thawing.

Diurnal Variations



Freezing Period, DOY 1 - 6

Diurnal Variations



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Thawing Period, DOY 88-93

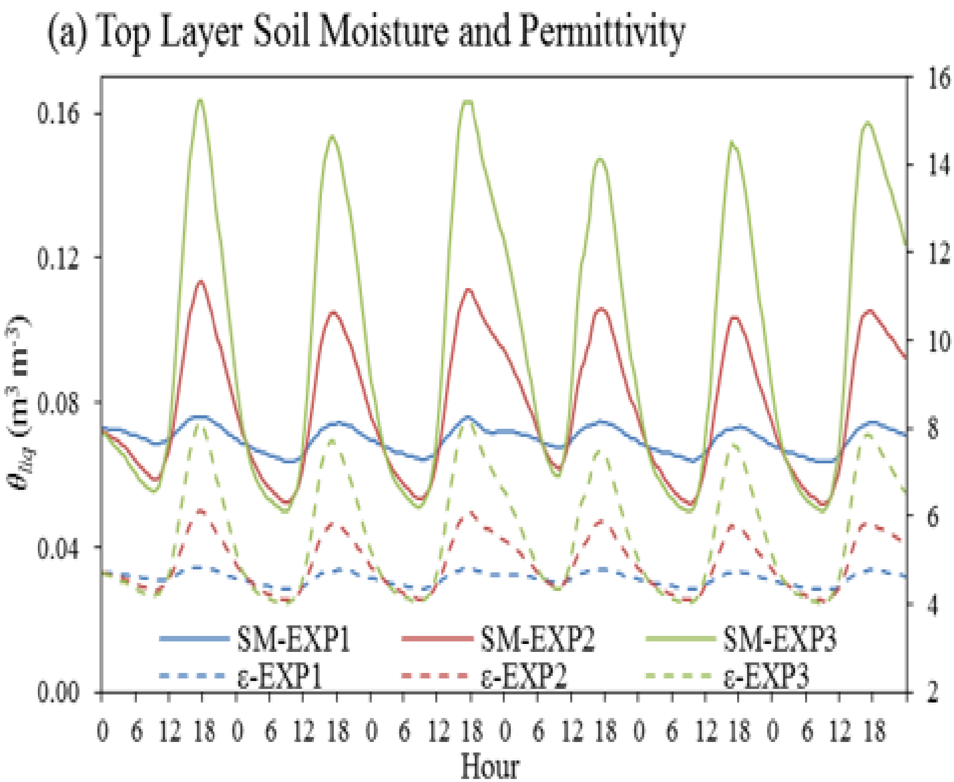
Noah-Tor Vergata Simulations

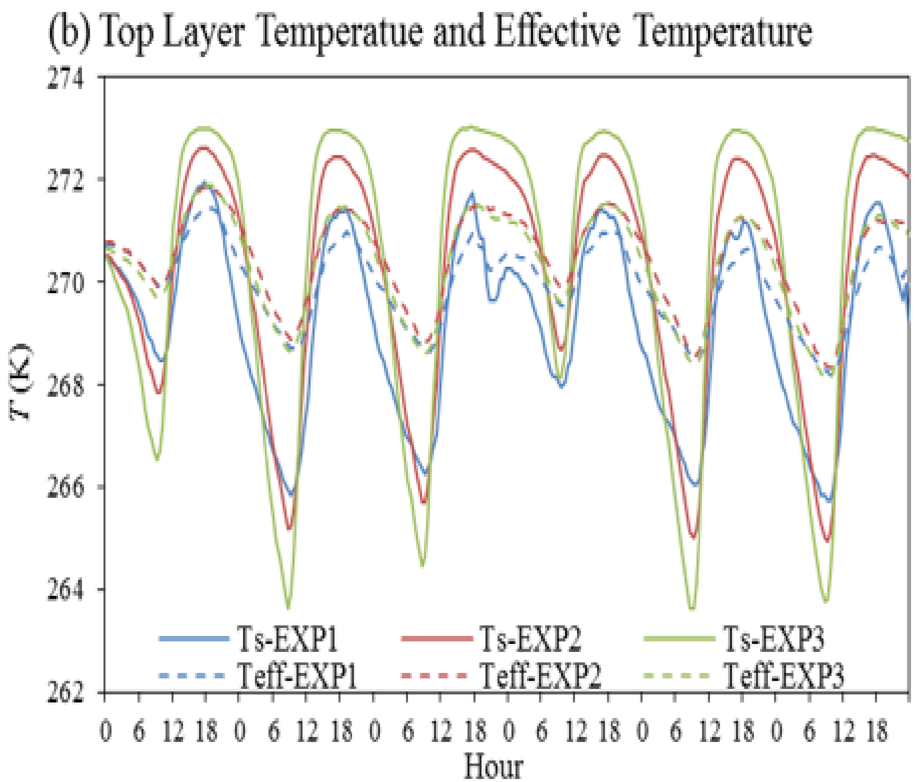
Freezing Period: DOY 1-6

EXP1: SMST from in situ measurements at 5 cm

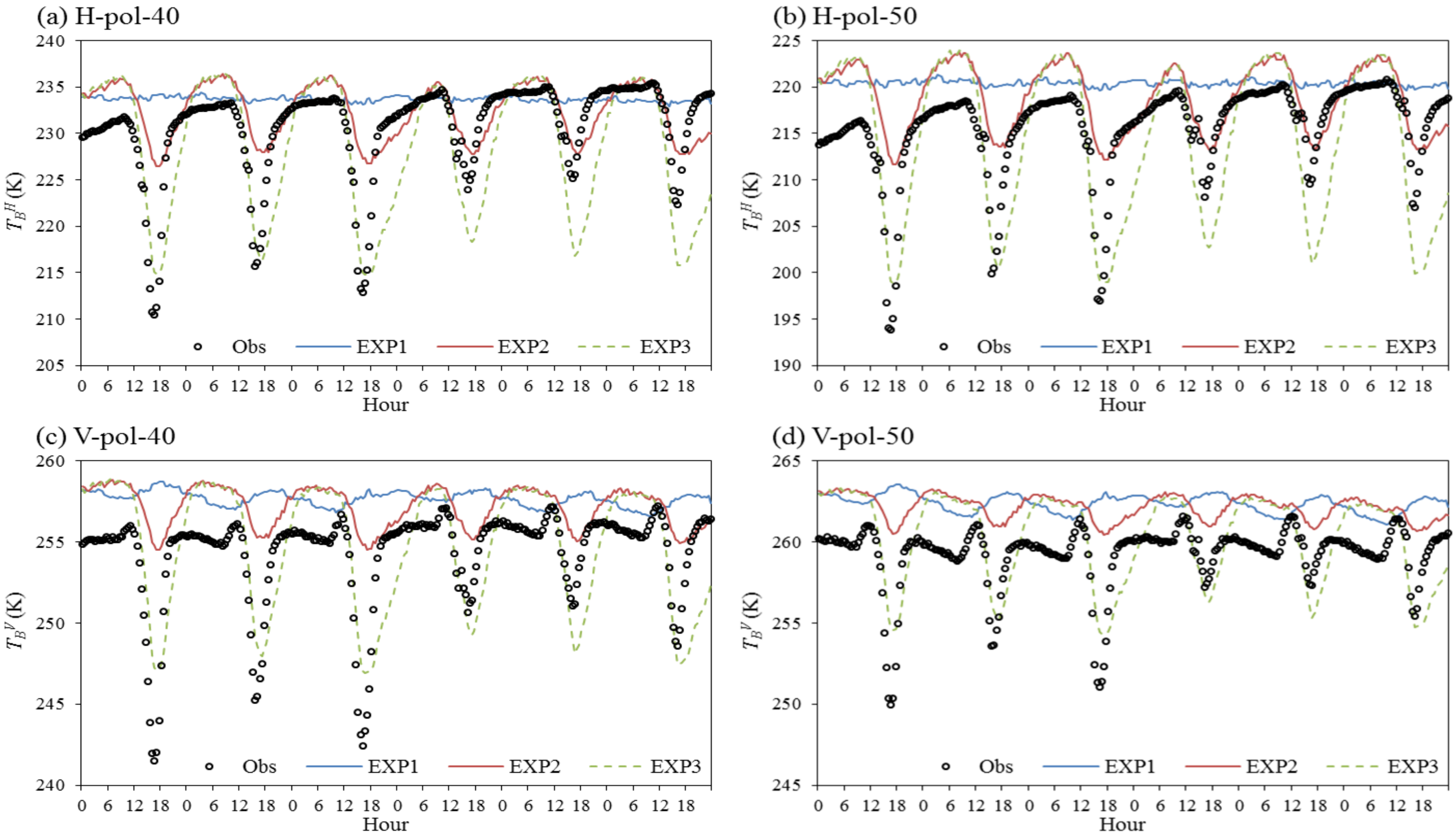
EXP2: SMST from Noah 4-layer (0.1, 0.4, 1.0, 2.0) Simulation with midpoint of top layer at 5 cm

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

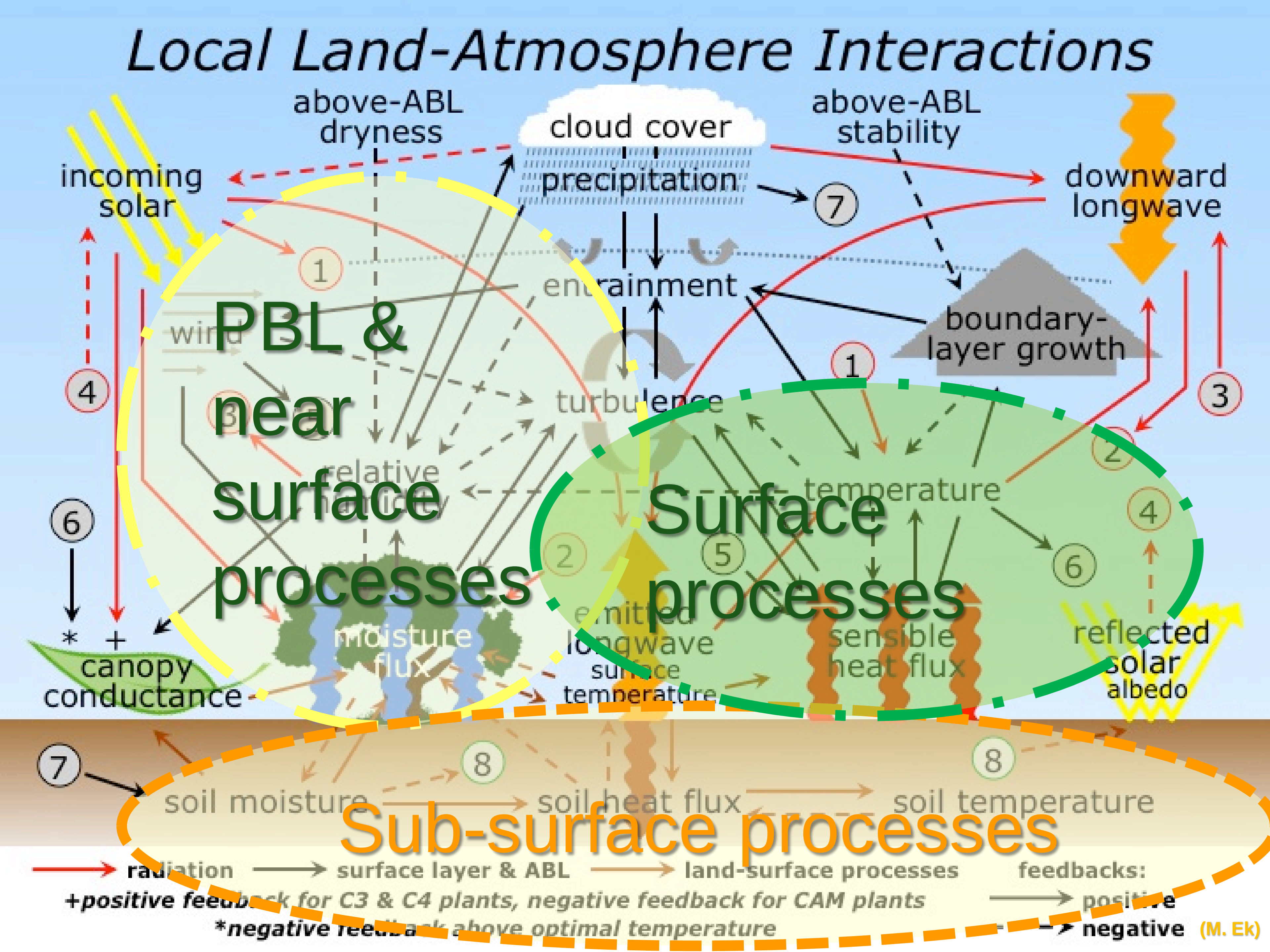




Noah-Tor Vergata Simulations



TB signatures 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



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

OTHER TALKS

- Maria Jose Polo: Snow observation using terrestrial cameras
- Jian Peng: Land surface energy and water fluxes by HOLAPS