(Dragon 4 id. 32070)

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

ESA–MOST Dragon Cooperation

2019 DRAGON 4 SYMPOSIUM

24–28 June 2019 | Ljubljana, Slovenia

中国科技部-欧洲空间局“龙计划”合作

2019 年“龙计划”四期学术研讨会

2019 年6月 24–28 日 斯洛文尼亚 卢布尔雅那

(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

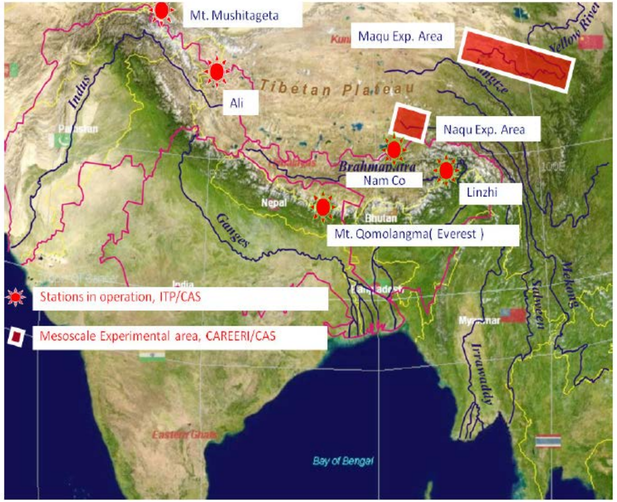
European PIs:	Chinese PIs:
Prof. Maria Jose Polo University of Córdoba, Spain, mjpolo@uco.es *(dev/val algorithms (water and energy fluxes), ass. scale effects associated to data sources, distributed modelling)*	**Prof. Jun Wen**, Chengdu University of Information Sciences, jwen@lzb.ac.cn *(soil moisture 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)*
Dr. Jian Peng niversity of Munich (LMU) jian.peng@ouce.ox.ac.uk *(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)*

ITC

Contribution and training of Young Scientists

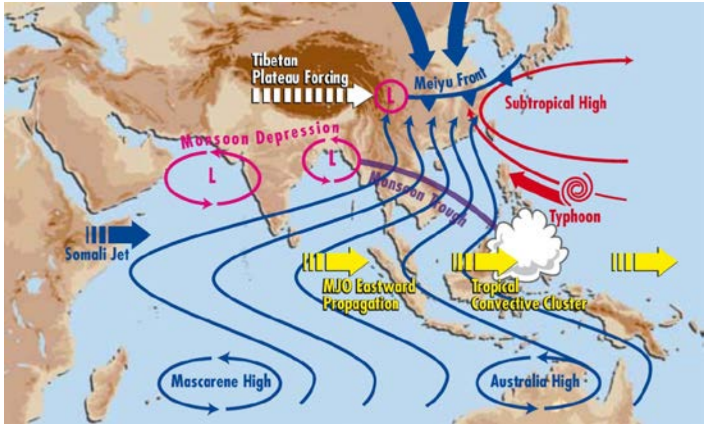
1. **Dr. Rogier van der Velde**, University of Twente, email: r.vandervelde@utwente.nl, remote sensing of soil moisture
2. **Dr. Yijian Zeng**, University of Twente, email: y.zeng@utwente.nl, data assimilation
3. **Dr. Xin Wang**, Northwest Institute of Eco-Environment and Resources, CAS, Lanzhou, xinwang@lzb.ac.cn, remote sensing of soil moisture
4. **Dr. Xuelong Chen** (ITP) land-atmosphere interactions, boundary layer processes
5. **Dr. Donghai Zheng** (ITP) water cycle in the upper Yellow River basin, hydrological modelling
6. **Dr. Shaoning Lv** (Graduate April 2019, UT-NIEER) Microwave emission and soil moisture, SMOS/SMAP signals
7. **Dr. Qiang Wang** (Graduate November 2018, UT) Soil moisture monitoring using Aquarius data
8. **Dr. Binbin Wang** (Graduate April 2019, UT-ITP) Energy balance of high plateau lakes
9. **Dongyu Jia** (PhD student, NIEER) land-atmosphere interaction study in cold region
10. **Prof. Weiqiang Ma**, Institute of Tibetan Plateau, CAS, email: wqma@itpcas.ac.cn, remote sensing and atmospheric modelling of land-atmosphere processes
11. **Prof. Lei Zhong**, University of Science and Technology of China, zhonglei@ustc.edu.cn, remote sensing and atmospheric modelling of land-atmosphere processes
12. **Lian Liu** (PhD student, ITP) Retrieval of thermal and hydraulic parameters from satellite observations on the glaciers
13. **Dr. Cristina Aguilar**, University of Cordoba, e-mail: caguilar@uco.es, ecohydrological modelling
14. **Dr. Rafael Pimentel** (postdoc, UC) remotely sensed data fusion and assimilation for snow and hydrological modelling
15. **Gabriel Delgado Leal** (PhD student, UC) Water and energy fluxes regime in snow mountain regions
16. **Marta Sáenz de Rodrigáñez** (PhD student, UC) Remote sensing data fusion to generate long and high resolution time series of snow and hydrological variables
17. **Jan Hofste** (PhD student, UT), University of Twente, email: j.g.hofste@utwente.nl, remote sensing of land surface by scatterometry and spectroscopy
18. **Hong Zhao** (PhD student, UT) Retrieval of soil thermal and hydraulic parameters from satellite observations
19. **Lianyu Yu** (PhD student, UT), Investigating Freeze/thaw Process of Permafrost over Tibetan Plateau under Climate Change
20. **Junping Du** (PhD student, UT-ITP), Observation and modeling of Urban heat and water fluxes in Lhasa
21. **Pei Zhang** (PhD student, UT), Modeling surface water and heat budgets using WRF-Hydro system on the Tibetan plateau
22. **Mengna Li** (PhD student, UT-CAU), Retrieving Aquifer Parameters from Satellite Measurements and In-situ Measurements
23. **Samuel Mwangi** (MSc student, UT), Assimilation of CRP Measurements for the Detection of Freezing-Thawing Process using the STEMMUS Model at Maqu Site, Tibetan Plateau

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.

WORK PACKAGES

WP1: Observation and modelling of microwave scattering and emission under complex terrains incl. permafrost and freeze and thawing
(Poster and talk: Jan Hofste; poster: Shaoning Lv; this talk)

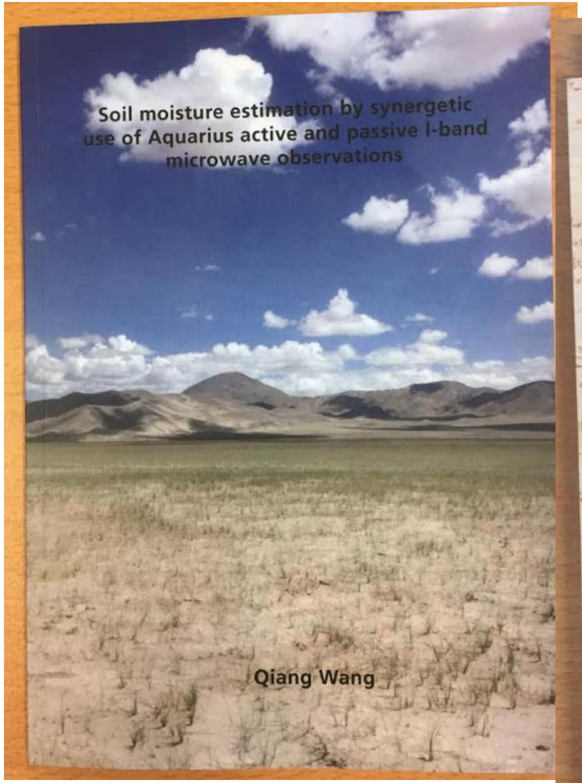
WP2: Advancement of physical understanding and quantification of changes of water and energy budgets in TPE
(Talk: Lei Zhong; Yiwei, Wang, Jian Peng)

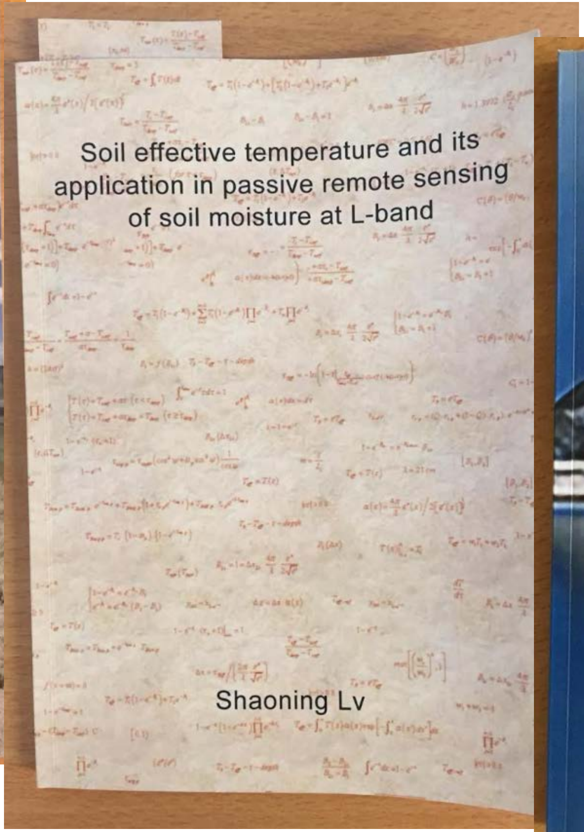
WP3: Advancement of quantifying changes in surface characteristics and monsoon interactions
(Talk: Lei Zhong;)

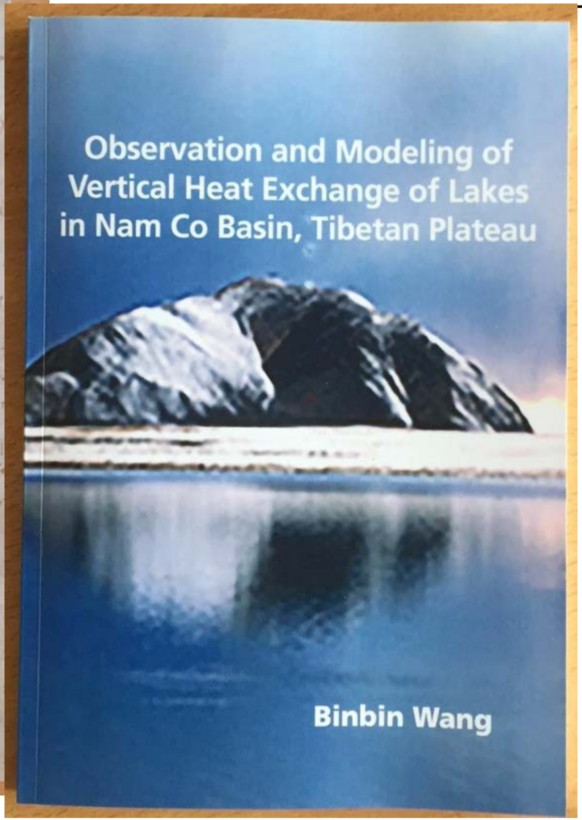
DELIVERABLES:

- scientific outputs in terms of peer reviewed journal publications (20 ISI papers),
- PhD theses (3),
- novel data sets of essential climate variables for quantification of water and energy cycle dynamics in the Third Pole Environment (STH parameters; radiometry; scatterometry; geophysics).

DELIVERABLES:







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Observation and modelling of radiative and heat-water transfer processes on the Tibetan Plateau

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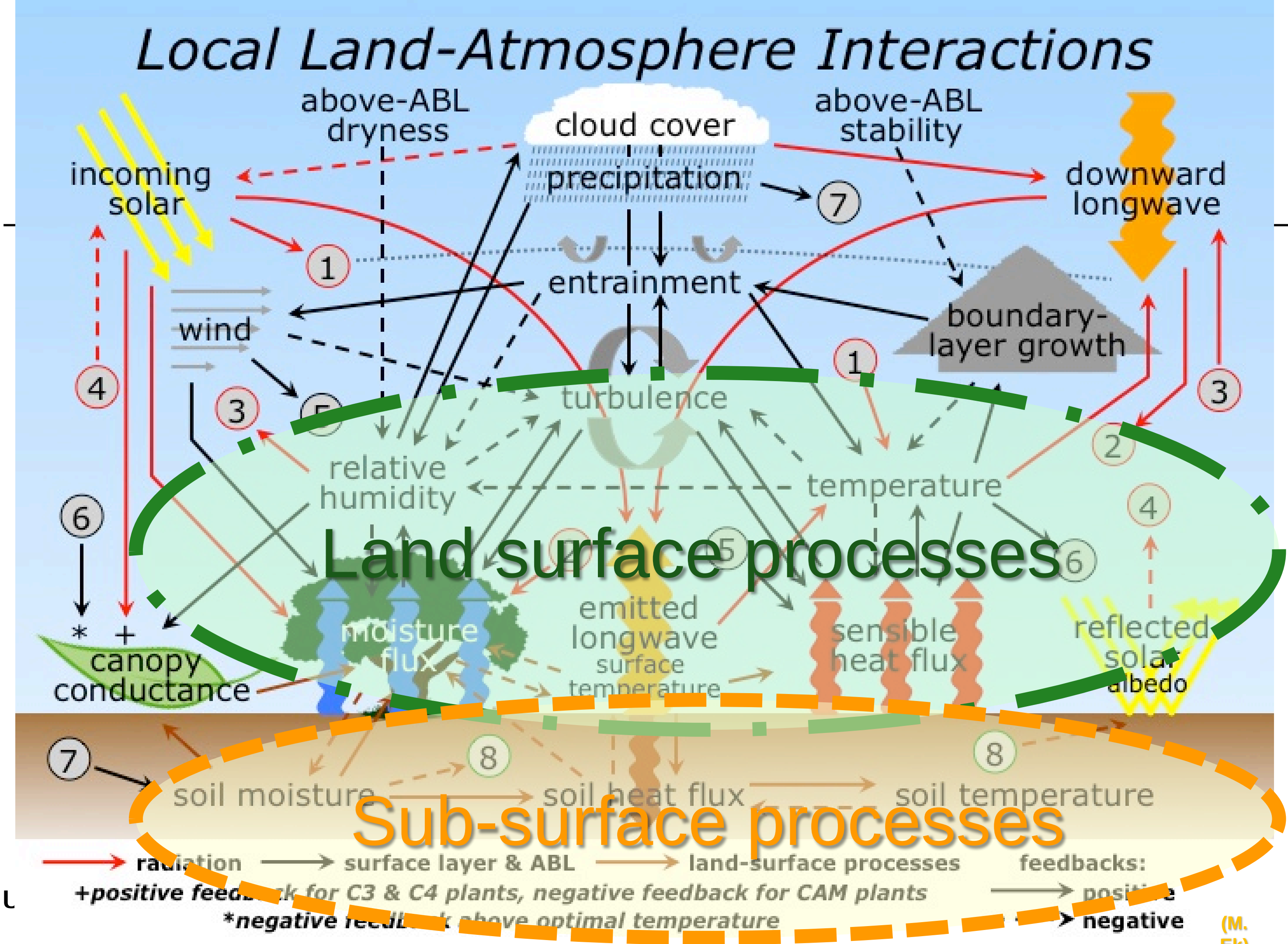
www.itc.nl/wrs

with contributions from
R. van der Velde, Y. Zeng, D. Zheng, X. Chen
S. Lv, Q. Wang, L. Yu, H. Zhao
J. Wen, X. Wang (NIEER/CAS), Y. Ma (ITP/CAS)

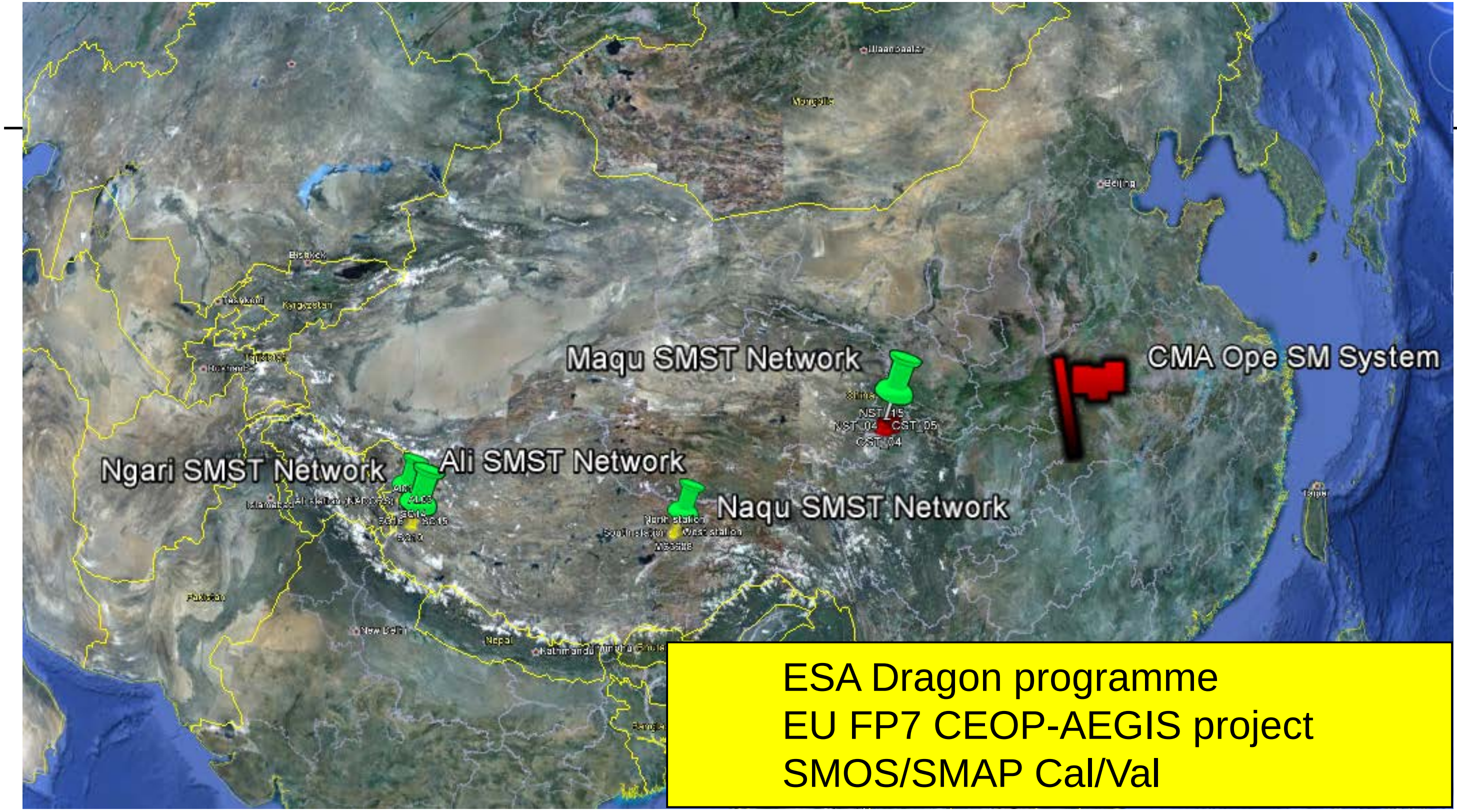
in collaboration with
P. de Rosnay, G. Balsamo (ECMWF), M. Ek (NCAR),
P. Ferrazzoli (UR), M. Schwank (ETH), Y. Kerr (CESBIO), A. Cilliander (JPL)

ITC


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
surface temperature
moisture flux
sensible heat flux
reflected solar
albedo
canopy conductance
soil moisture
soil heat flux
soil temperature
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)

ITC GEO Soil Moisture Soil Temperature Networks

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

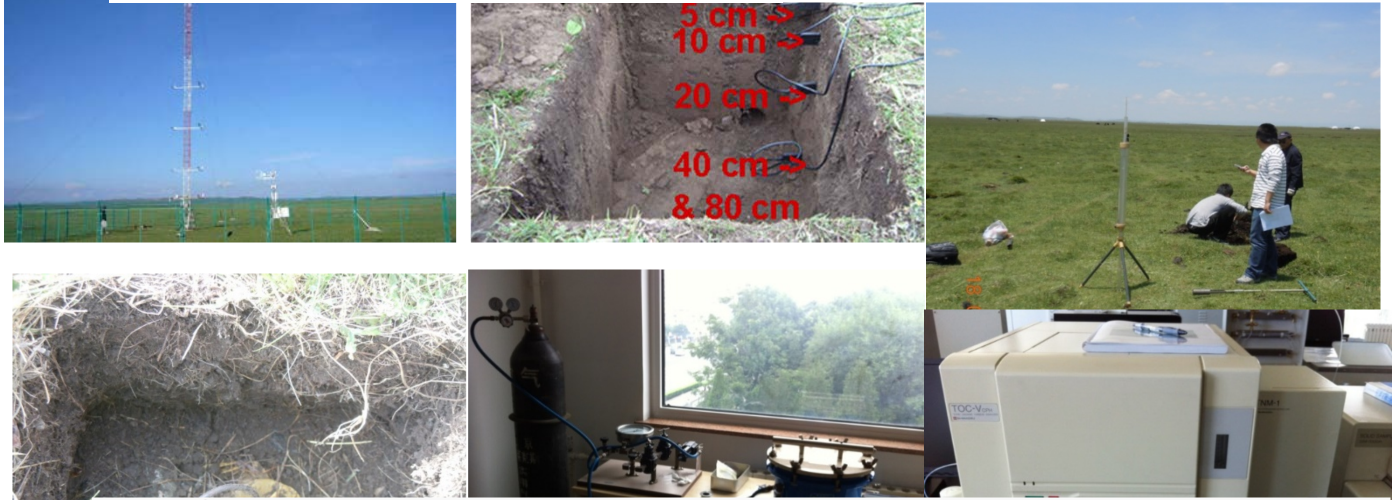


ESA Dragon programme
EU FP7 CEOP-AEGIS project
SMOS/SMAP Cal/Val

http://en.tpedatabase.cn/ *(Su et al. 2011, HESS)*

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

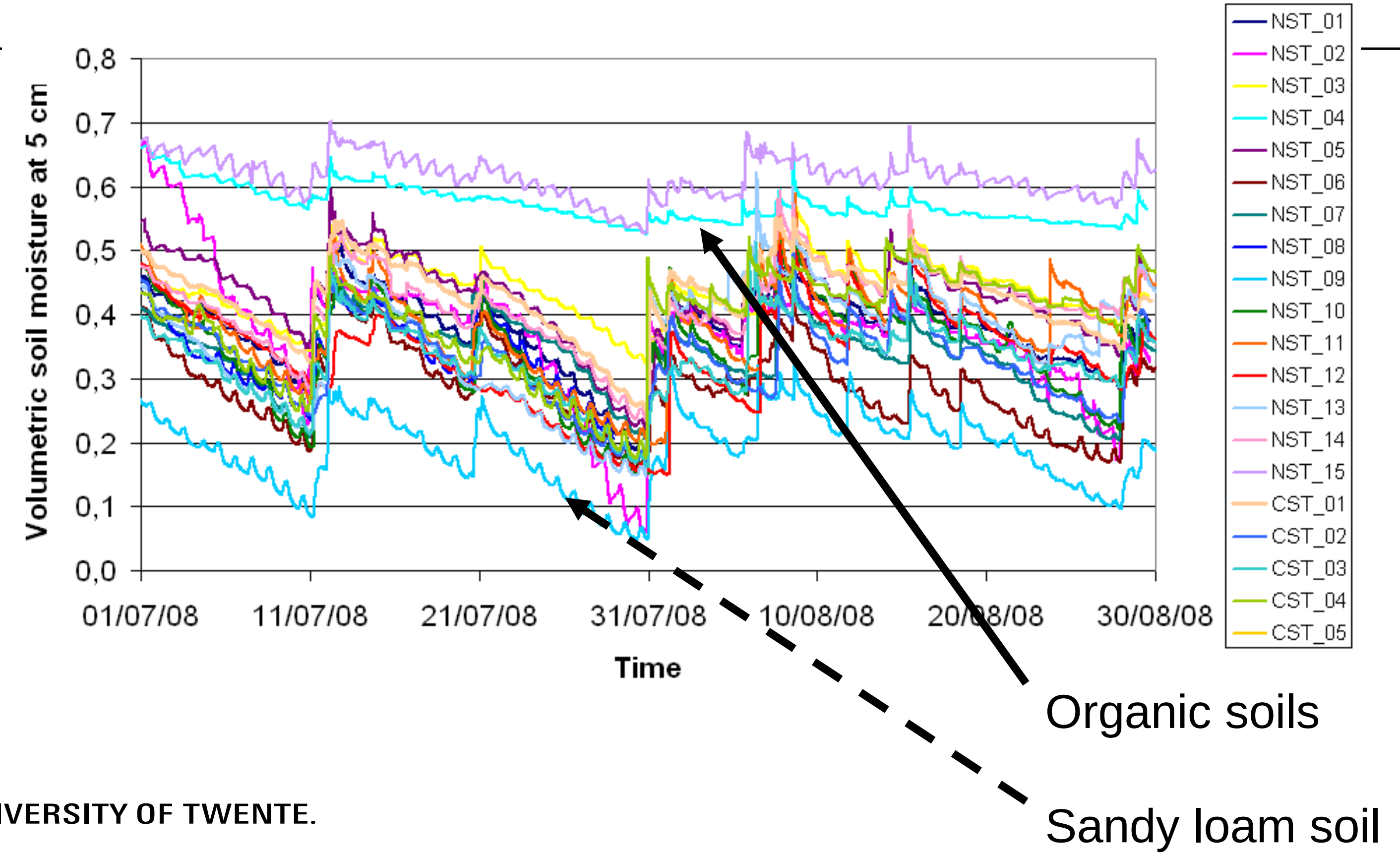
http://en.tpedatabase.cn/ *(Su et al. 2011, HESS)*



Dataset | Soil Hydraulic and Thermal Properties for Land Surface Modelling over the Tibetan Plateau

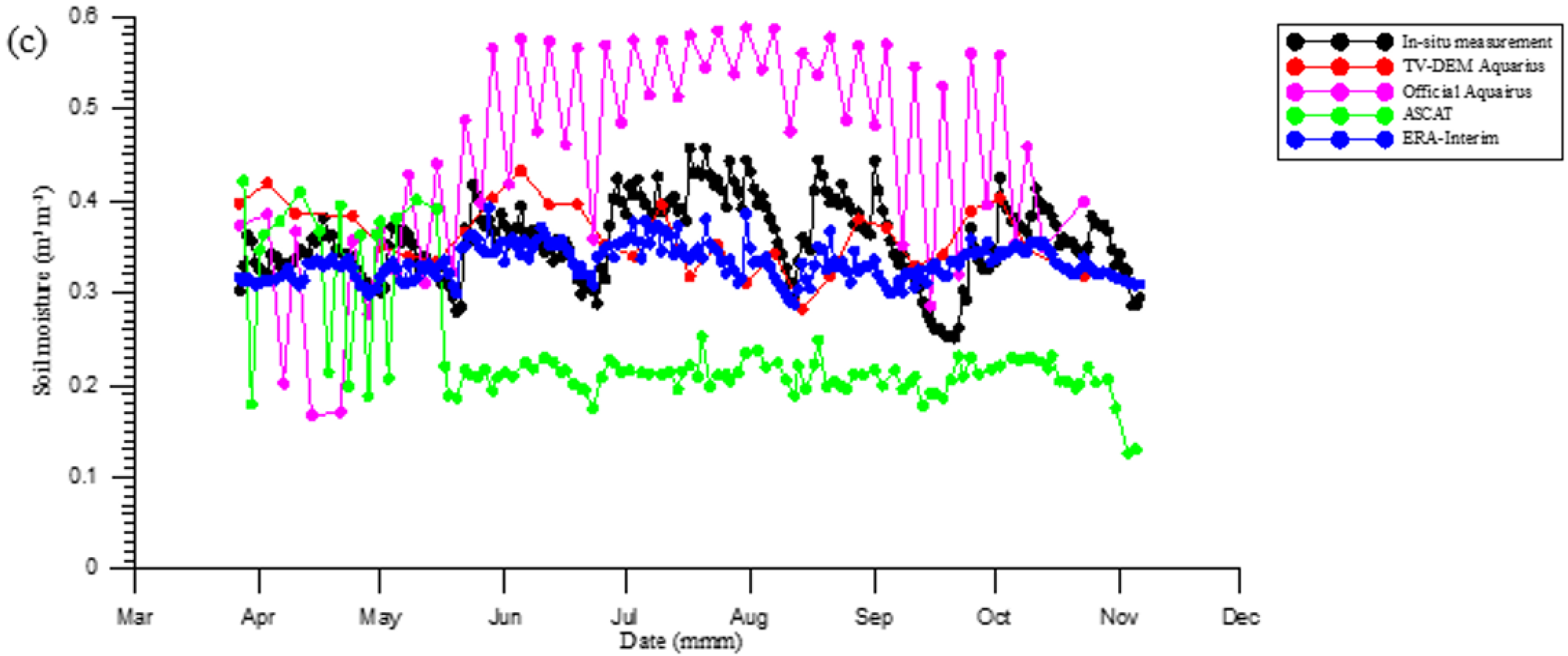
https://data.4tu.nl/ *(Zhao et al. 2018, ESSD)*

Maqu: Soil moisture at 5 cm depth



How good are some soil moisture products?

Ngari (a), Naqu (b) and Maqu (c) for year 2012



(Wang et al., 2019, JAG)

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An Algorithm for Estimating Effective Soil Temperature in L-band Radiometry

(Lv et al. 2014, RSE; 2016, RSE; 2018, RS)

$$T_B = \varepsilon T_{eff}$$ *[ε: Veg, roughness, SM profile; T_{eff} : T&SM profile]*

$$T_{eff} = \int_0^\infty T(x)\alpha(x)\exp\left[-\int_0^x a(x')dx'\right]dx$$ (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: $$T_{eff} = T_0\left(1 - e^{-B_0}\right) + T_\infty e^{-B_0}$$

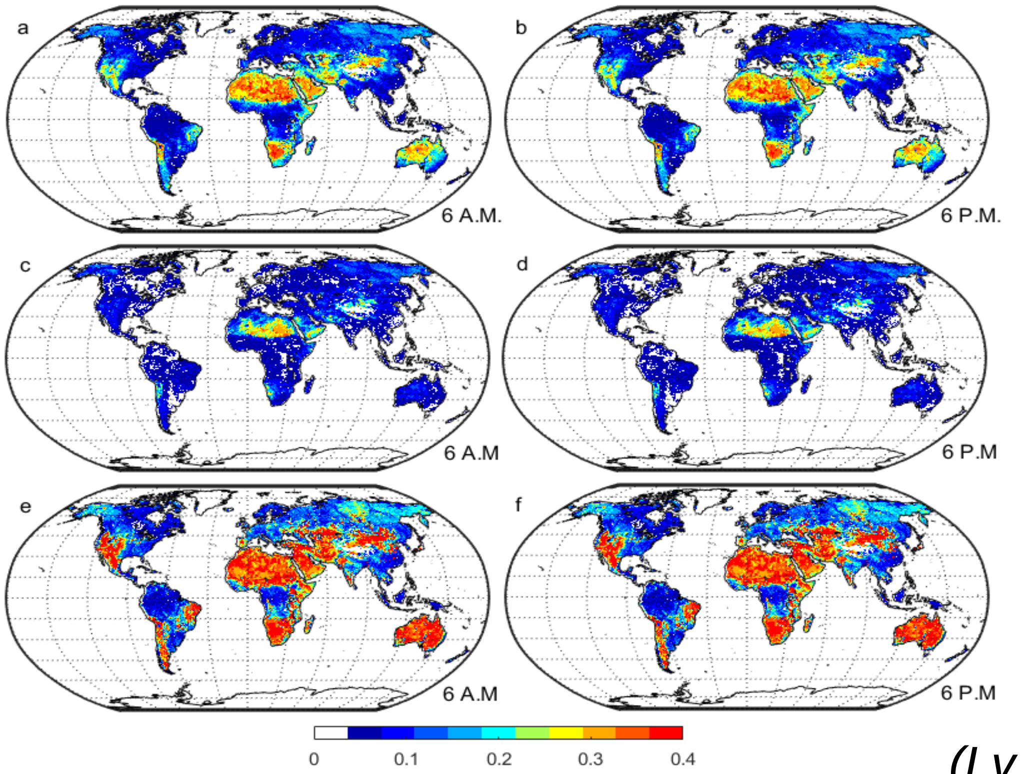
$$B_0 = \alpha_1 x_1$$

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

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

Global soil temperature sensing depth

a, b) mean; c, d) minimum; e, f) maximum at 6 am / pm local time, resp.



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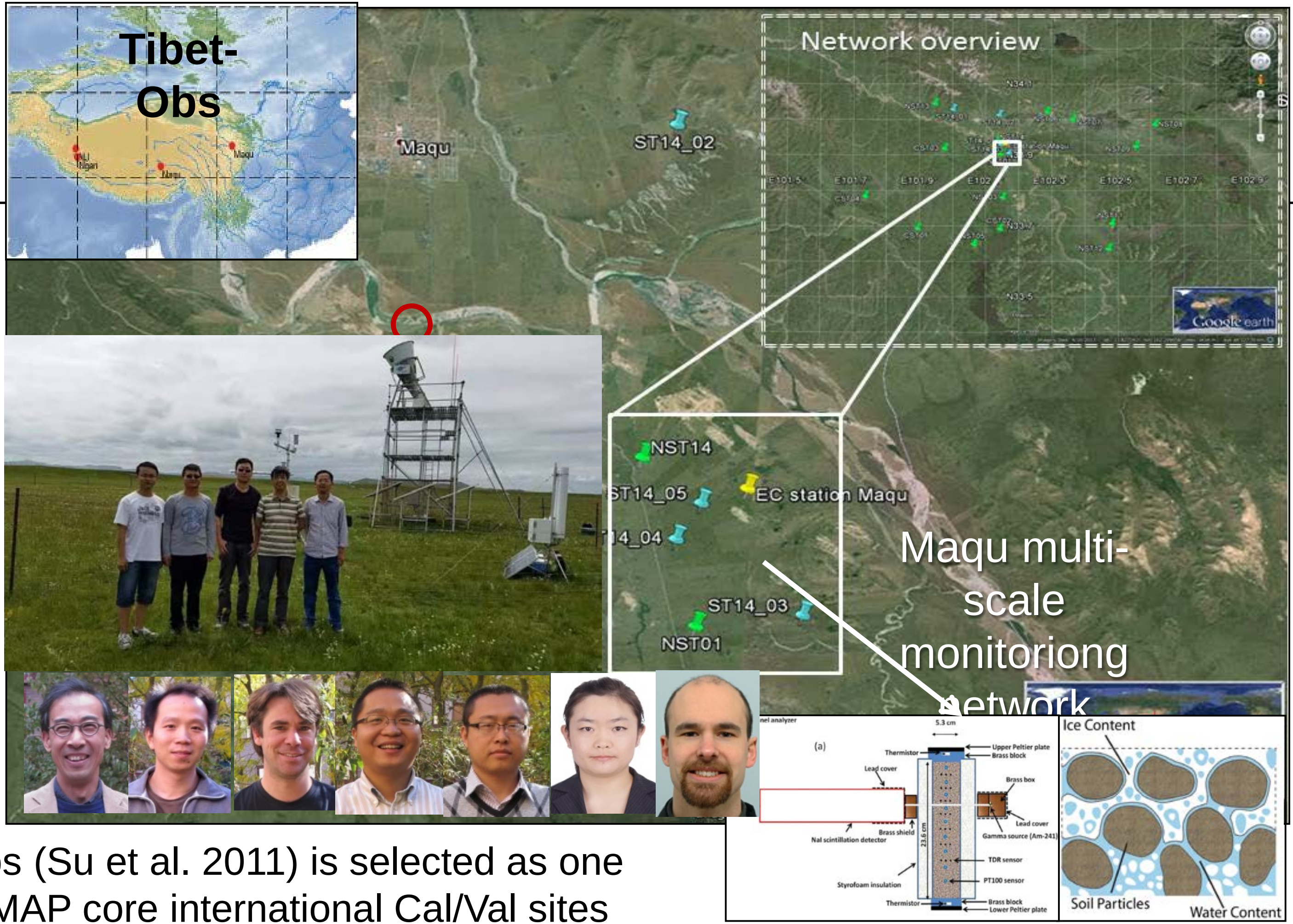
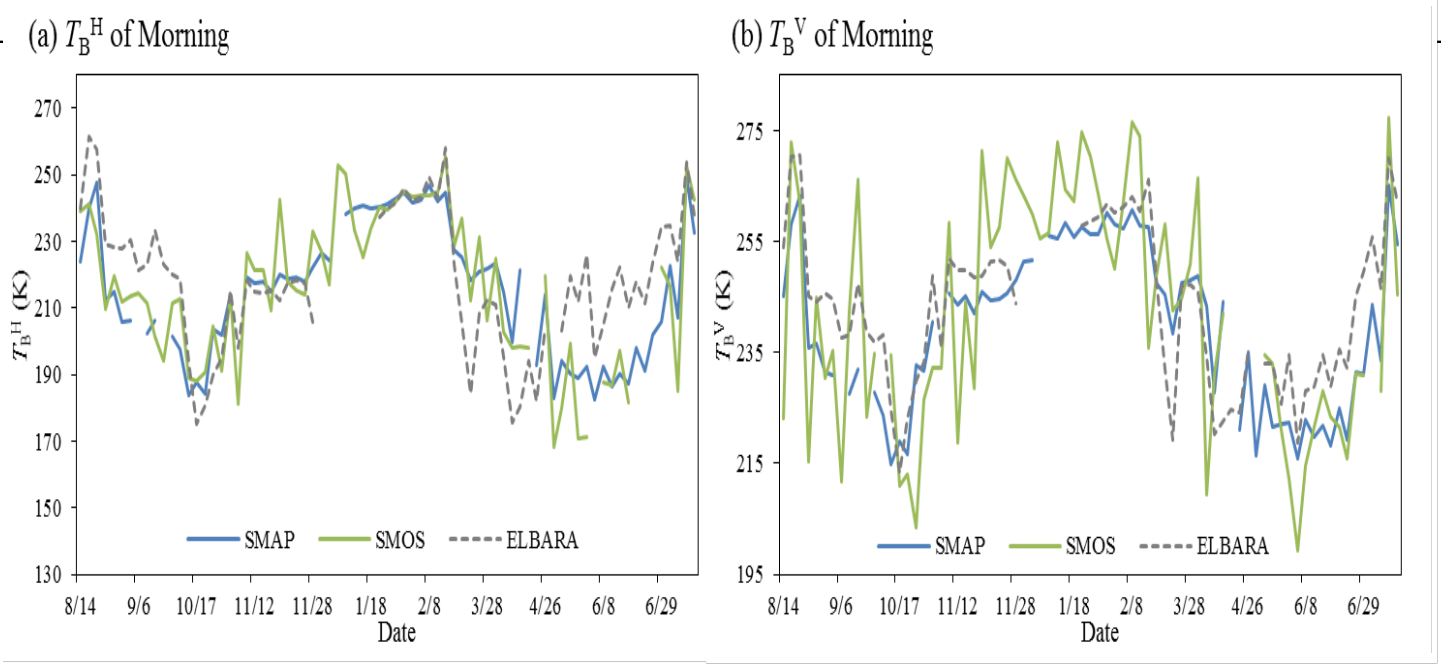
(Lv et al. 2018, RS)



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

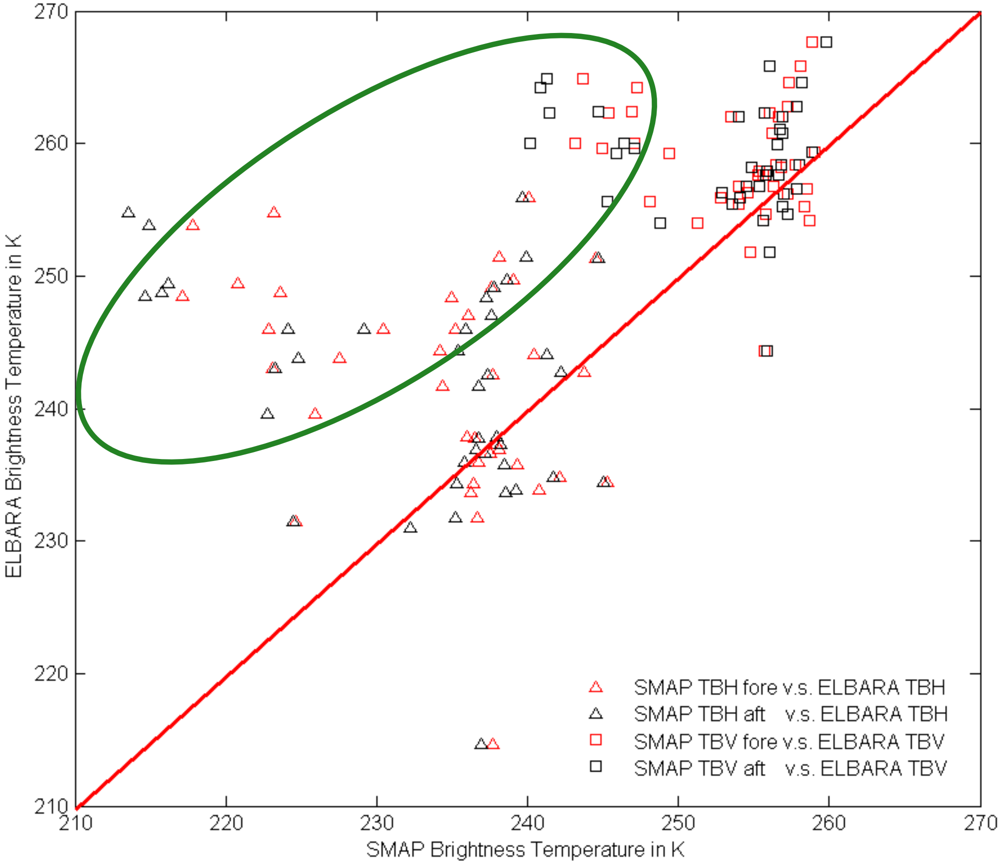
HOW GOOD IS THE SATELLITE SIGNAL? (TB)



Comparisons of SMAP, SMOS and ELBARA-III measured T_B^H and T_B^V during morning overpasses - Aug. 2016 and July 2017.

COMPARISON BETWEEN SMAP & ELBARA

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



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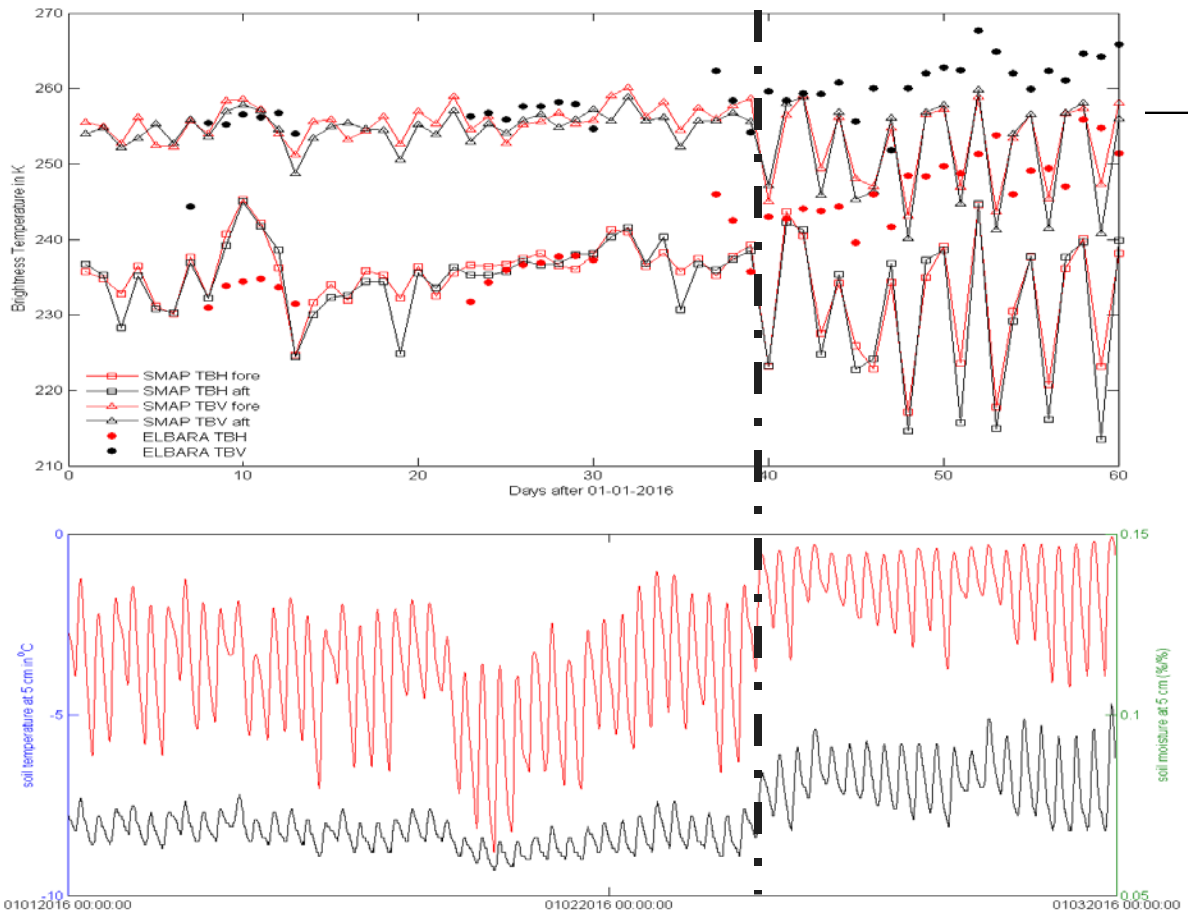
Why does SMAP underestimate ELBARA Tb?

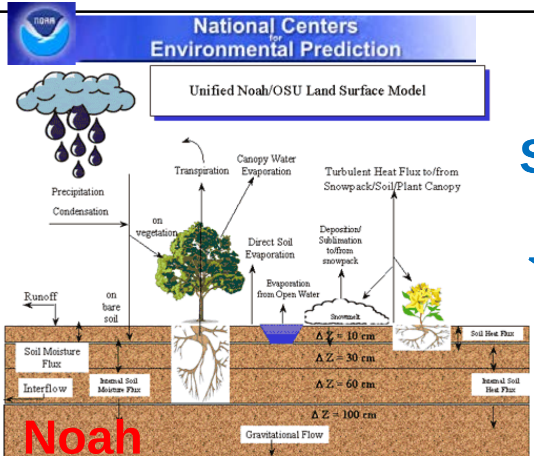


DOY 1:
01-01-2016

DOY 40:
10-02-2016

DOY 60:
29-02-2016

Noah-Tor Vergata Model



Noah

Surface SMST

SMST Profiles

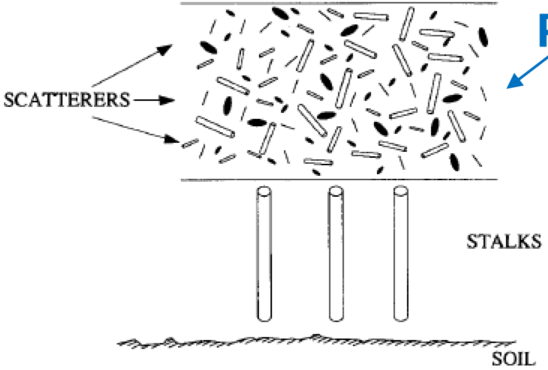
Permittivity

4-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

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



Emissivity

Brightness Temperature

U

Tor Vergata RT

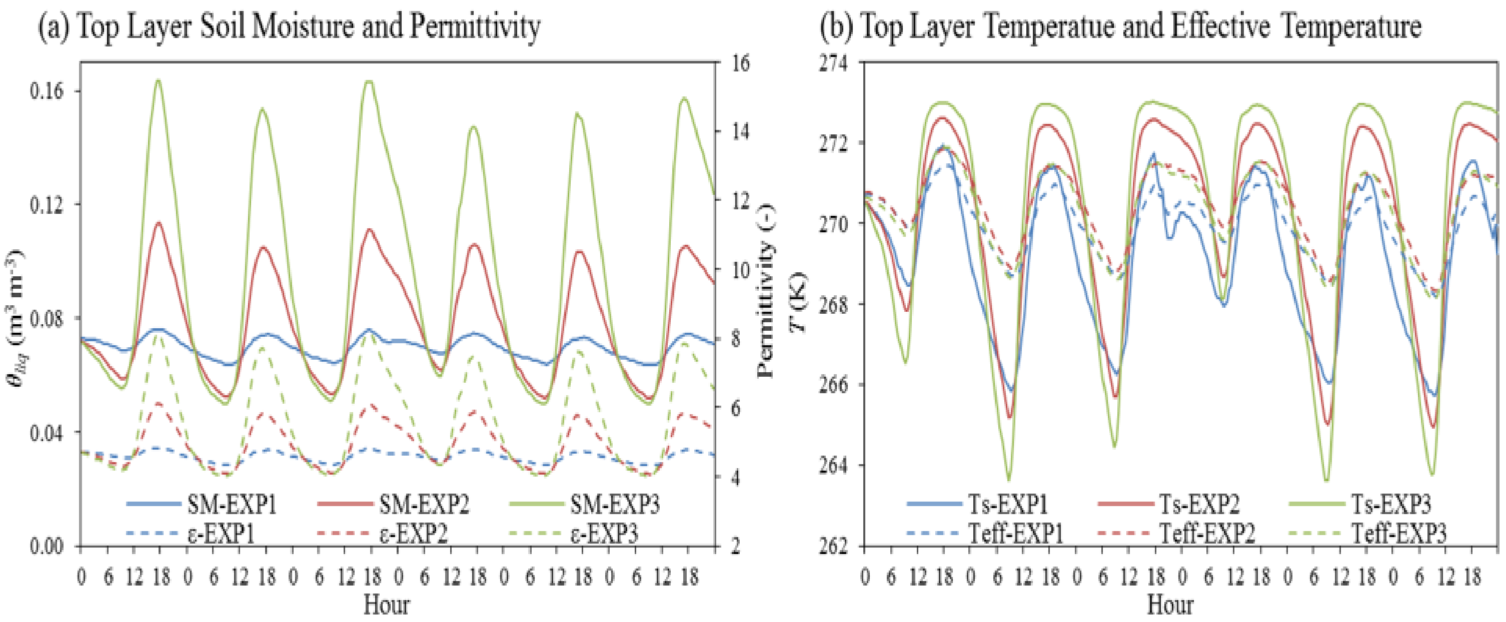
Noah-Tor Vergata Simulations

Freezing Period: DOY 1-6

EXP1: SMST from in situ measurements at 5 cm

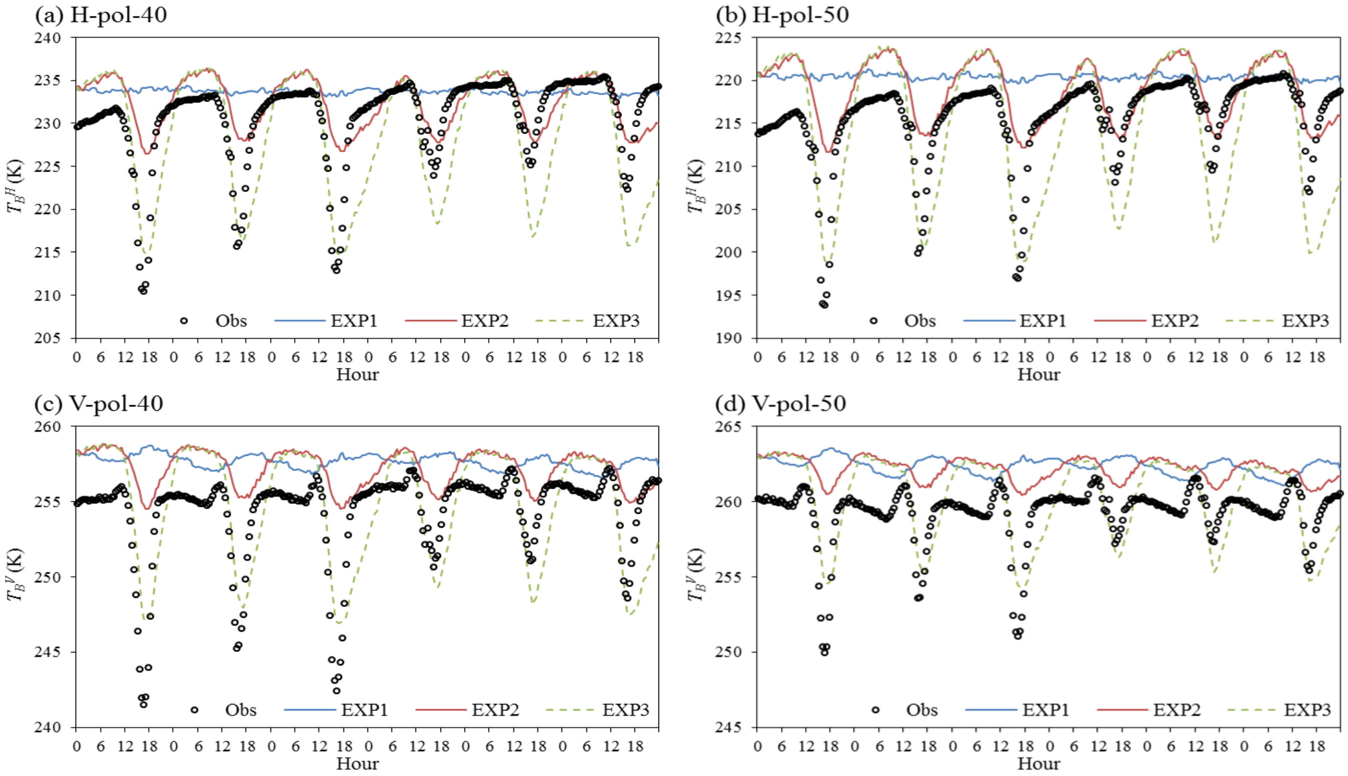
EXP2: SMST from Noah 4-layer (0.1, 0.4, 1.0, 2.0), Sim with midpoint of top 5 cm layer

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



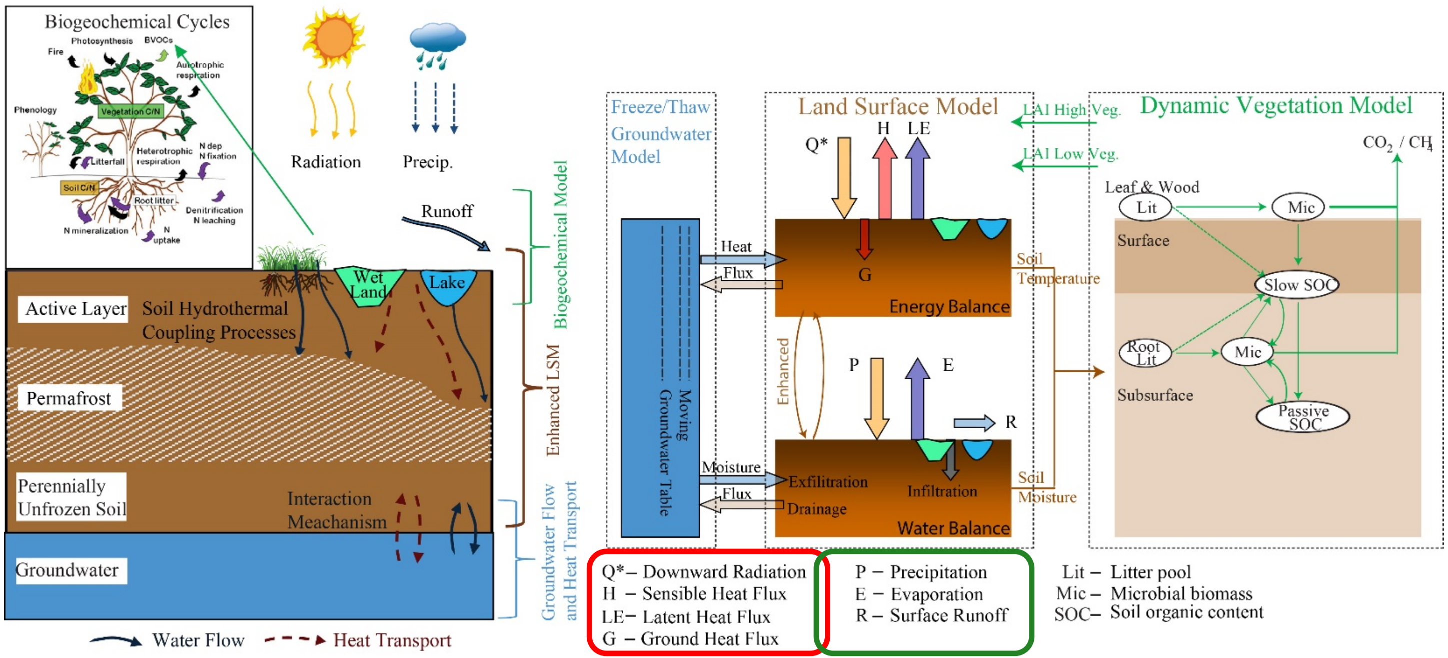
Noah-Tor Vergata Simulations

(Zheng et al., 2017 TGRS)



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

STEMMUS - Simultaneous Transfer of Energy, Momentum and Mass In Unsaturated Soil



a) Physical processes

b) Coupling processes

http://blogs.itc.nl/stemmus/

STEMMUS-FT (Freezing/Thawing) model

Soil Water Phase Change

Soil Water Transport

$$\frac{\partial}{\partial t}(\rho_L\theta_L+\rho_V\theta_V+\rho_i\theta_i)=$$

$$\rho_L\frac{\partial}{\partial z}[K(\frac{\partial h}{\partial z}+1)+D_{TD}\frac{\partial T}{\partial z}+\frac{K}{\gamma_w}\frac{\partial P_g}{\partial z}]+\frac{\partial}{\partial z}[D_{vh}\frac{\partial h}{\partial z}+D_{vT}\frac{\partial T}{\partial z}+D_{va}\frac{\partial P_g}{\partial z}]-S$$

Soil Heat Transport

$$\frac{\partial}{\partial t}[(\rho_s\theta_sC_s+\rho_L\theta_LC_L+\rho_V\theta_VC_V)(T-T_r)+\rho_V\theta_VL_0-\rho_i\theta_iL_f]-\rho_LW\frac{\partial\theta_L}{\partial t}$$

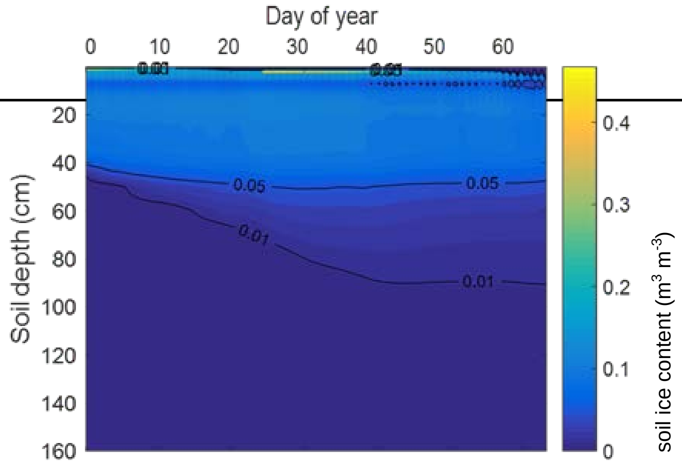
$$=\frac{\partial}{\partial z}(\lambda_{eff}\frac{\partial T}{\partial z})-\frac{\partial q_L}{\partial z}C_L(T-T_r)-\frac{\partial q_V}{\partial z}[L_0+C_V(T-T_r)]-C_LS(T-T_r)$$

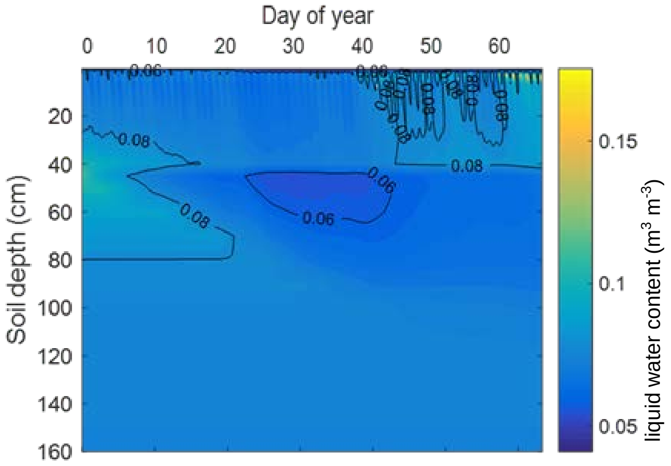
Soil Dry air Transport

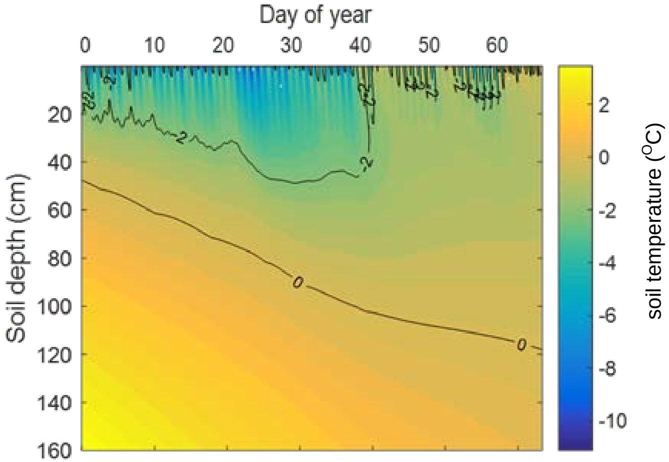
$$\frac{\partial}{\partial t}[\varepsilon\rho_{da}(S_a+H_cS_L)]=\frac{\partial}{\partial t}[D_e\frac{\partial\rho_{da}}{\partial z}+\rho_{da}\frac{S_aK_g}{\mu_a}\frac{\partial P_g}{\partial z}-H_c\rho_{da}\frac{q_L}{\rho_L}+(\theta_aD_{Vg})\frac{\partial\rho_{da}}{\partial z}]$$

(Zeng et al., 2011 JGR,
Zeng et al., 2011 WRR,
Yu et al., 2016, HESS, 2018, JGR)

STEMMUS-FT
Profile of ice, liquid water and temperature

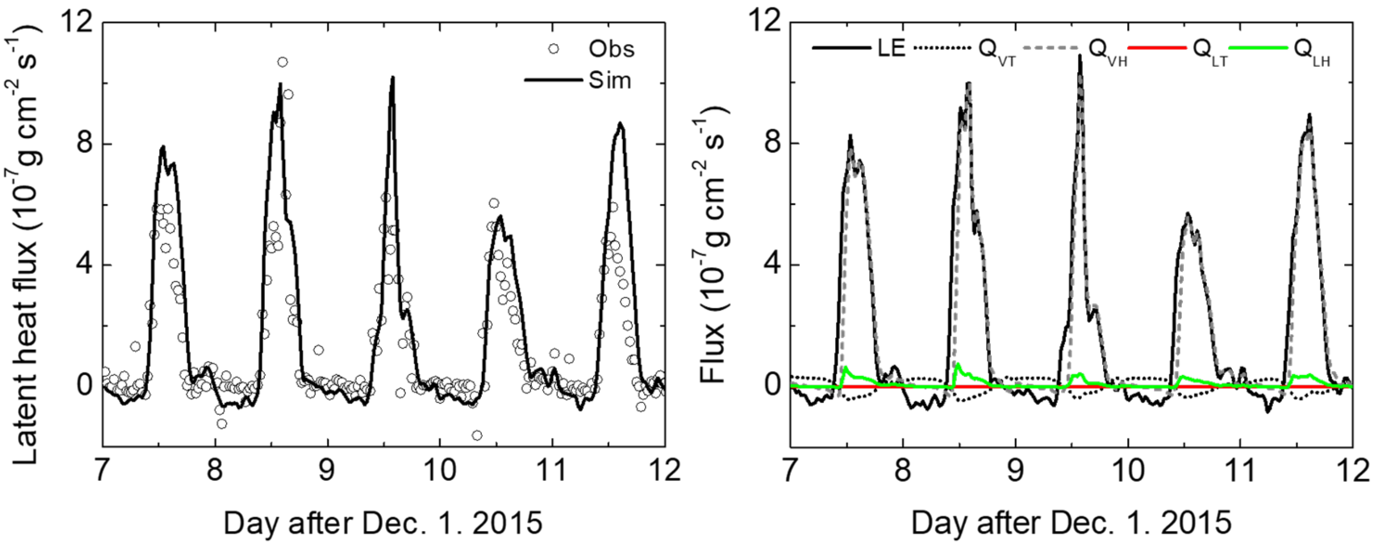






- Freezing front increase along with the zero isotherm
- Soil liquid water content behave nonlinearly

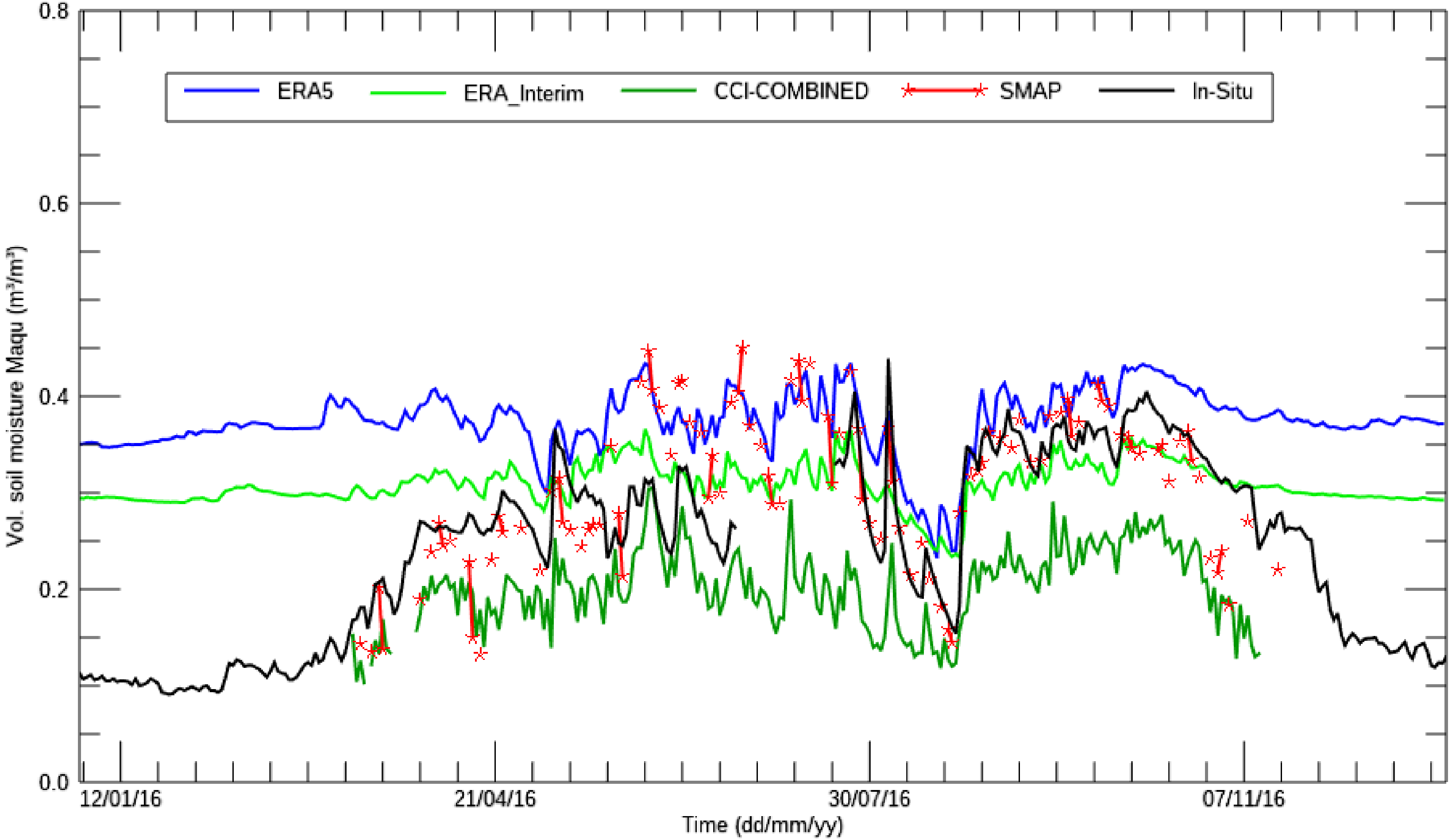
STEMMUS-FT results
Surface fluxes



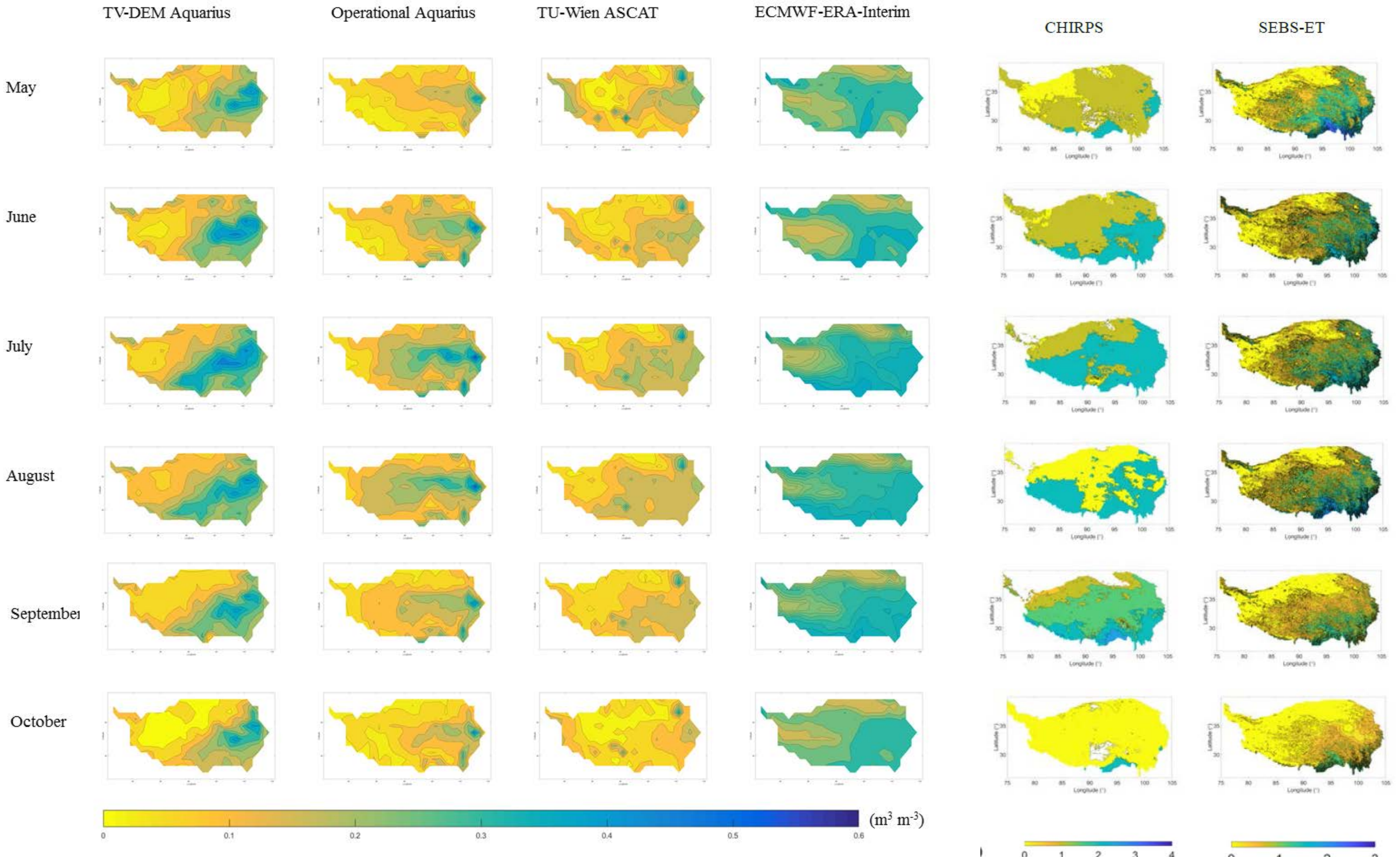
(a)Latent heat flux

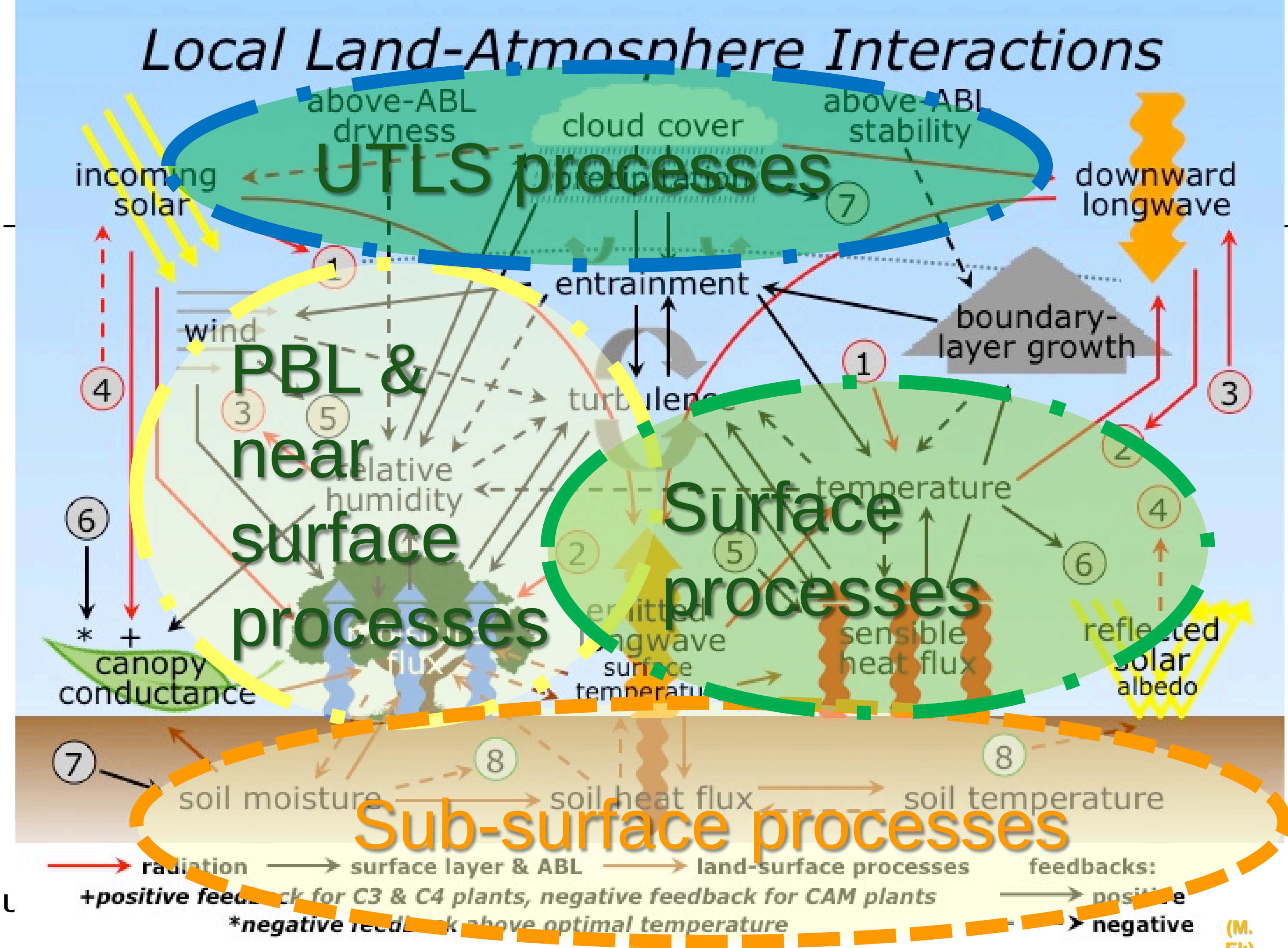
(b)Surface (0.1cm) thermal/isothermal liquid and vapor flux

(Yu et al., 2018, JGR)



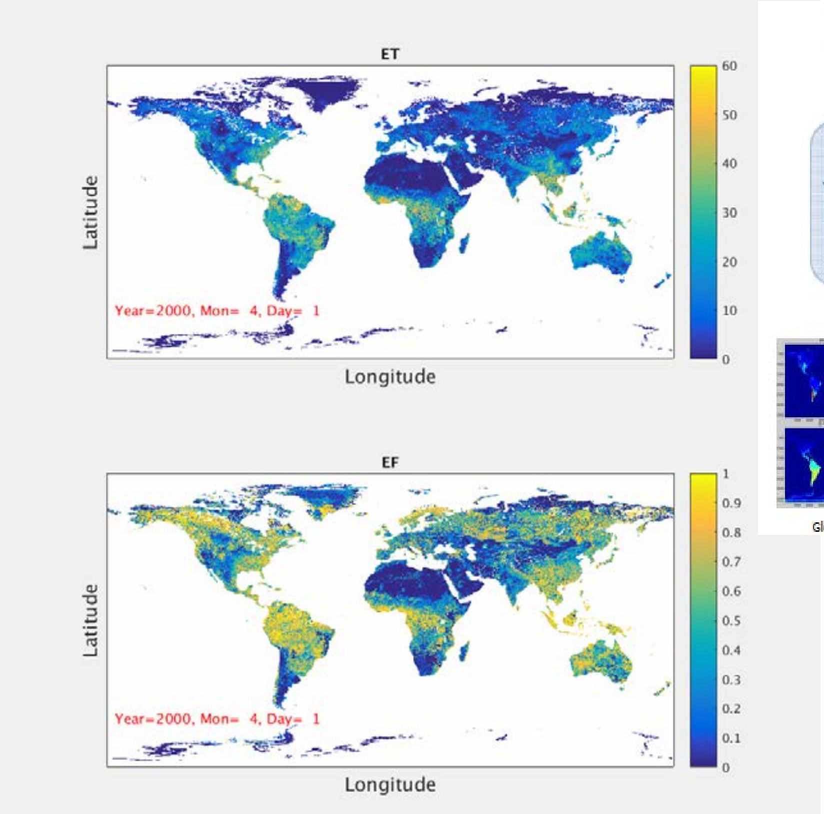
ERA5
ERA_Interim
CCI-COMBINED
SMAP
In-Situ
0.8
0.6
0.4
0.2
0.0
Vol. soil moisture Maqu (m³/m³)
12/01/16
21/04/16
30/07/16
07/11/16
Time (dd/mm/yy)

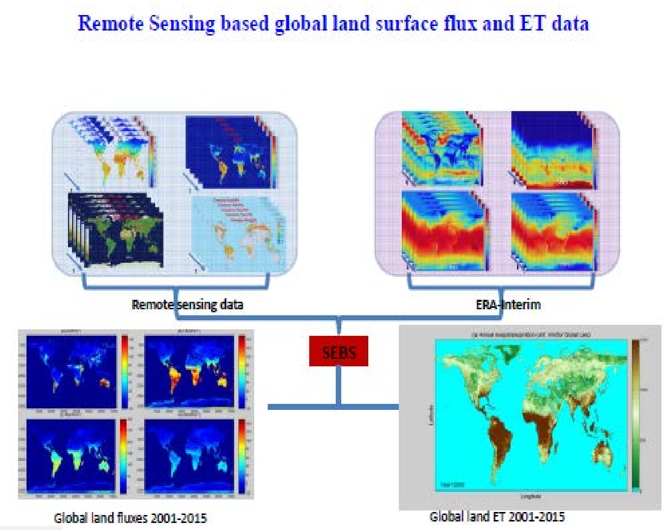

TV-DEM Aquarius
Operational Aquarius
TU-Wien ASCAT
ECMWF-ERA-Interim
CHIRPS
SEBS-ET
May
June
July
August
September
October
0
0.1
0.2
0.3
0.4
0.5
0.6
(m³ m⁻³)
0
1
2
3
4


Local Land-Atmosphere Interactions
above-ABL dryness
cloud cover
above-ABL stability
UTLS processes
incoming solar
downward longwave
entrainment
boundary-layer growth
wind
PBL & near surface processes
relative humidity
turbulence
temperature
Surface processes
emitted longwave
surface temperature
sensible heat flux
reflected solar
albedo
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
*negative feedback above optimal temperature
positive
negative

High Resolution Hydrologic and Ecosystem Fluxes

2000 – Near Present at 5km x 5km Daily Evaporation and Heat Fluxes





(Su, 2002, HESS; Chen et al., 2013, JAMC; Chen et al., 2014, ACP)

http://en.tpedatabase.cn/

CONCLUSIONS

- Process understanding based on measurements and modeling is of primary importance in land-atmosphere interactions:
  - Cal/Val needed to assure the stability and truthiness of observations and retrievals
  - Spatial scaling remains a challenge – what is the scale of interest?
  - Modeling and DA remains indispensable in understanding and efficient use of observations and retrievals
  - ESM needs to consider the land-atmosphere interactions in a dynamic manner instead of currently focus in parameterization