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

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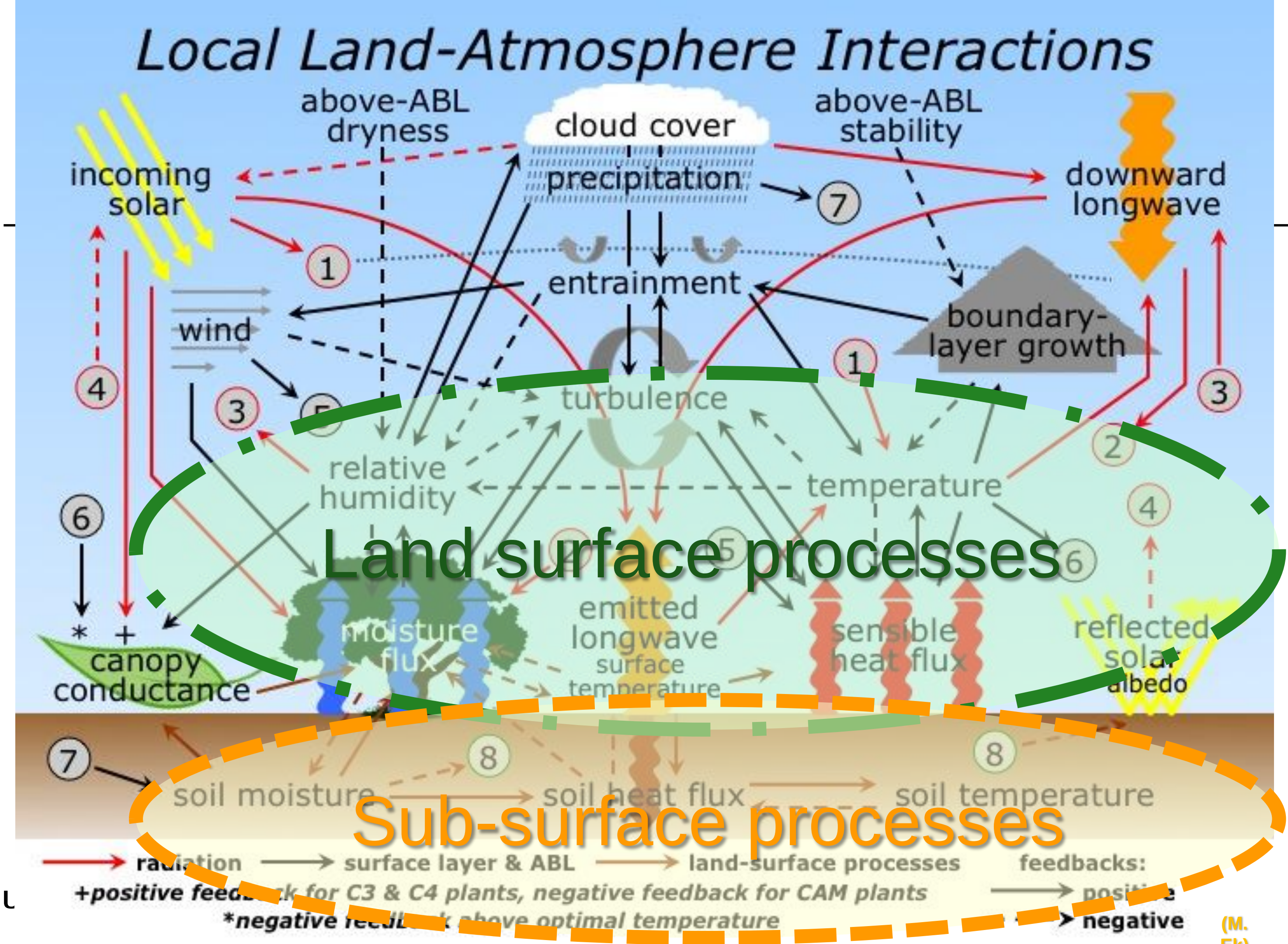
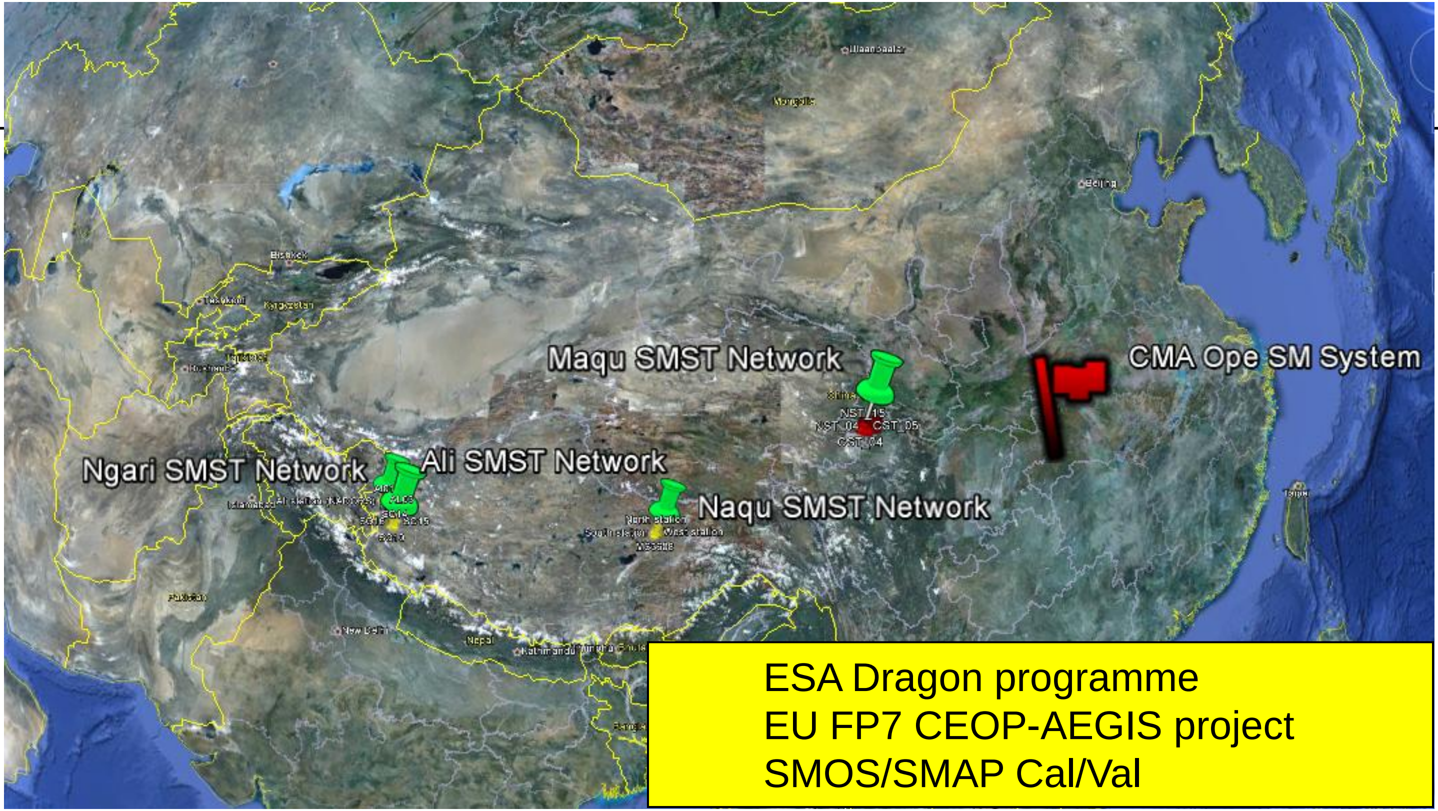

Local Land-Atmosphere Interactions
above-ABL dryness
cloud cover
above-ABL stability
incoming solar
precipitation
downward longwave
entrainment
wind
boundary-layer growth
turbulence
relative humidity
temperature
canopy conductance
moisture flux
emitted longwave
surface temperature
sensible heat flux
reflected solar
albedo
soil moisture
soil heat flux
soil temperature
Land 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)

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)

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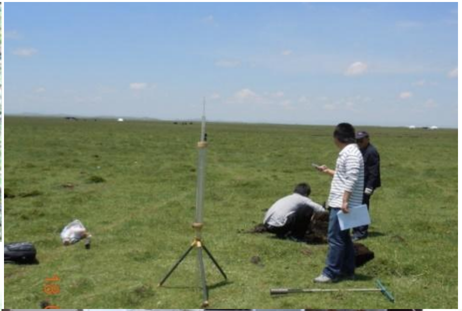
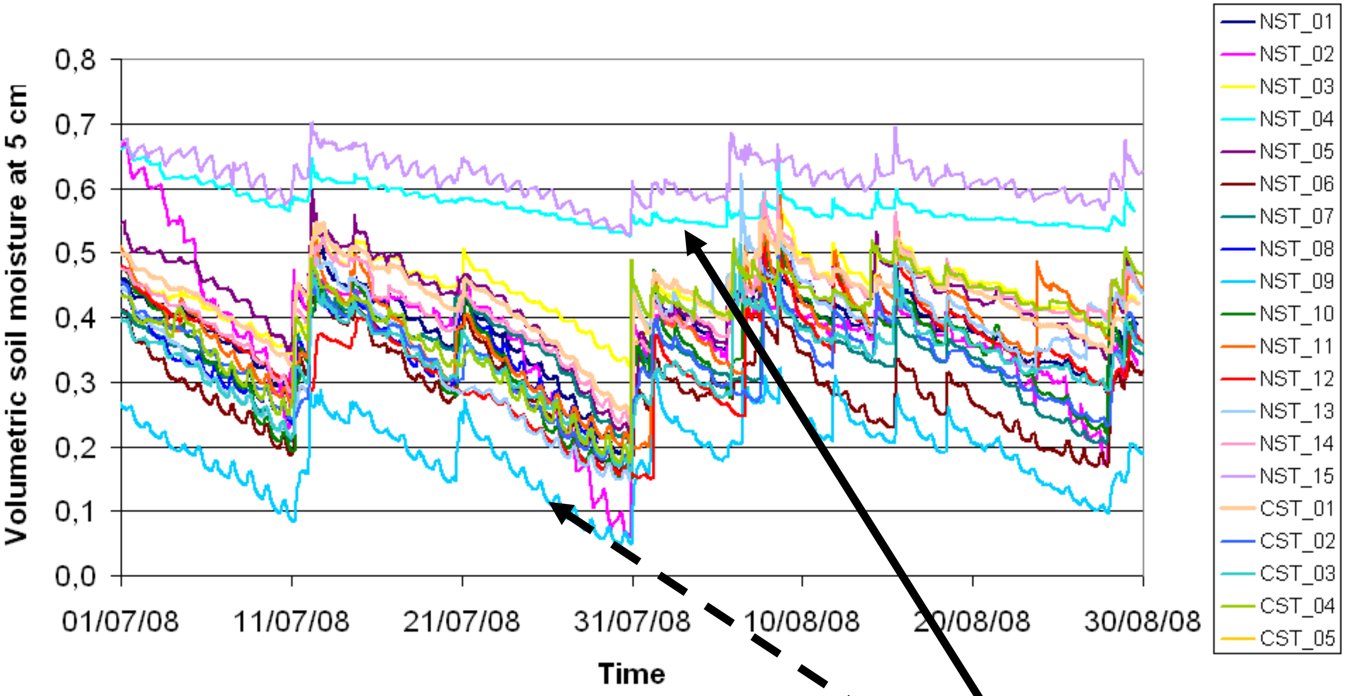


Dataset Soil Hydraulic and Thermal Properties for Land Surface Modelling over the Tibetan Plateau

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

Maqu: Soil moisture at 5 cm depth

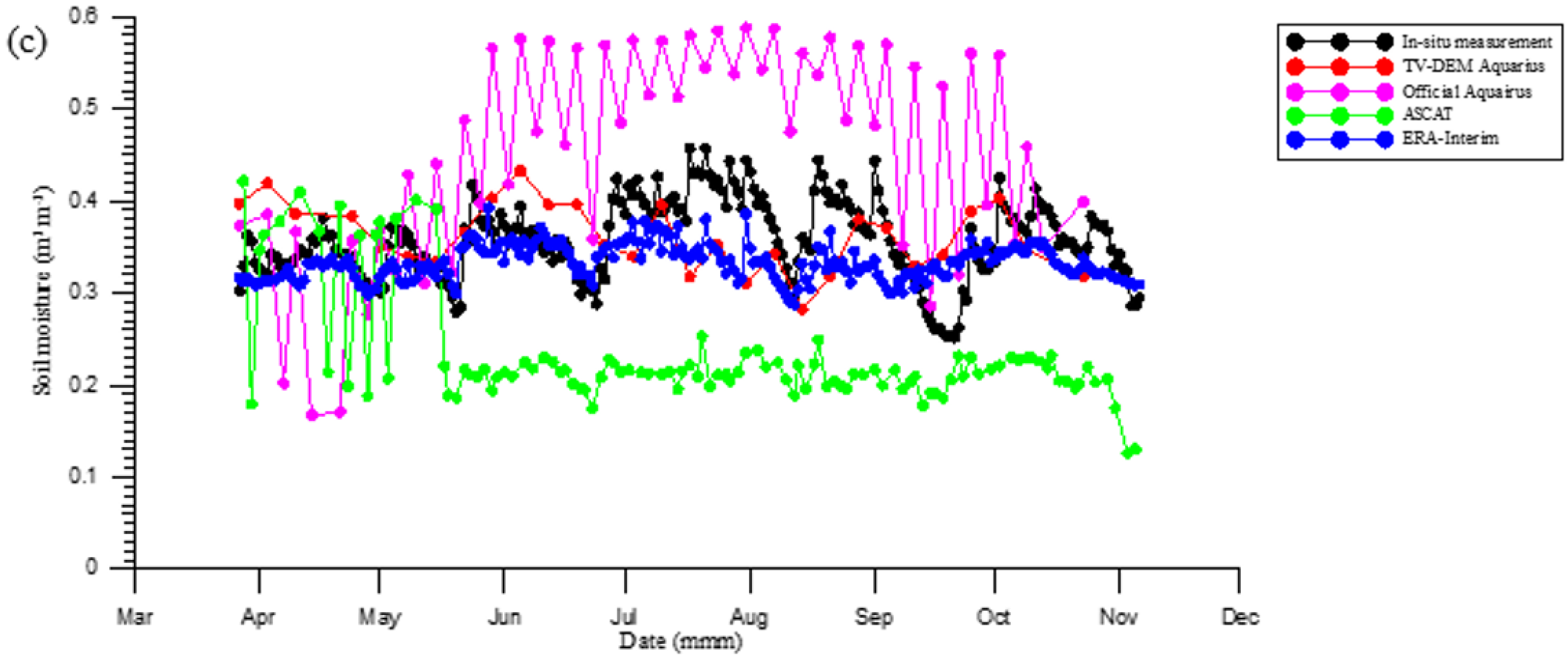


Organic soils

Sandy loam soil

How good are some soil moisture products?

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



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(Wang et al., 2018, PRS)

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

$$B_0 = \alpha_1 x_1$$

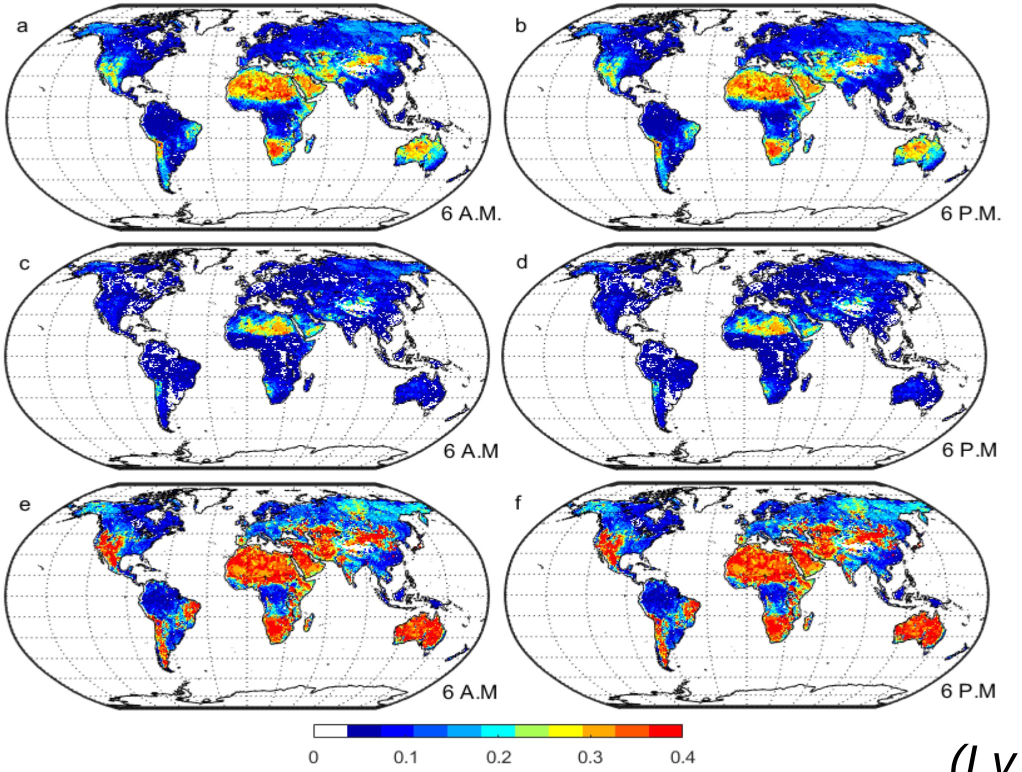
$$B_0 = \Delta x \cdot \frac{4\pi}{\lambda} \cdot \frac{\varepsilon''}{2\sqrt{\varepsilon'}}$$

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

ITC

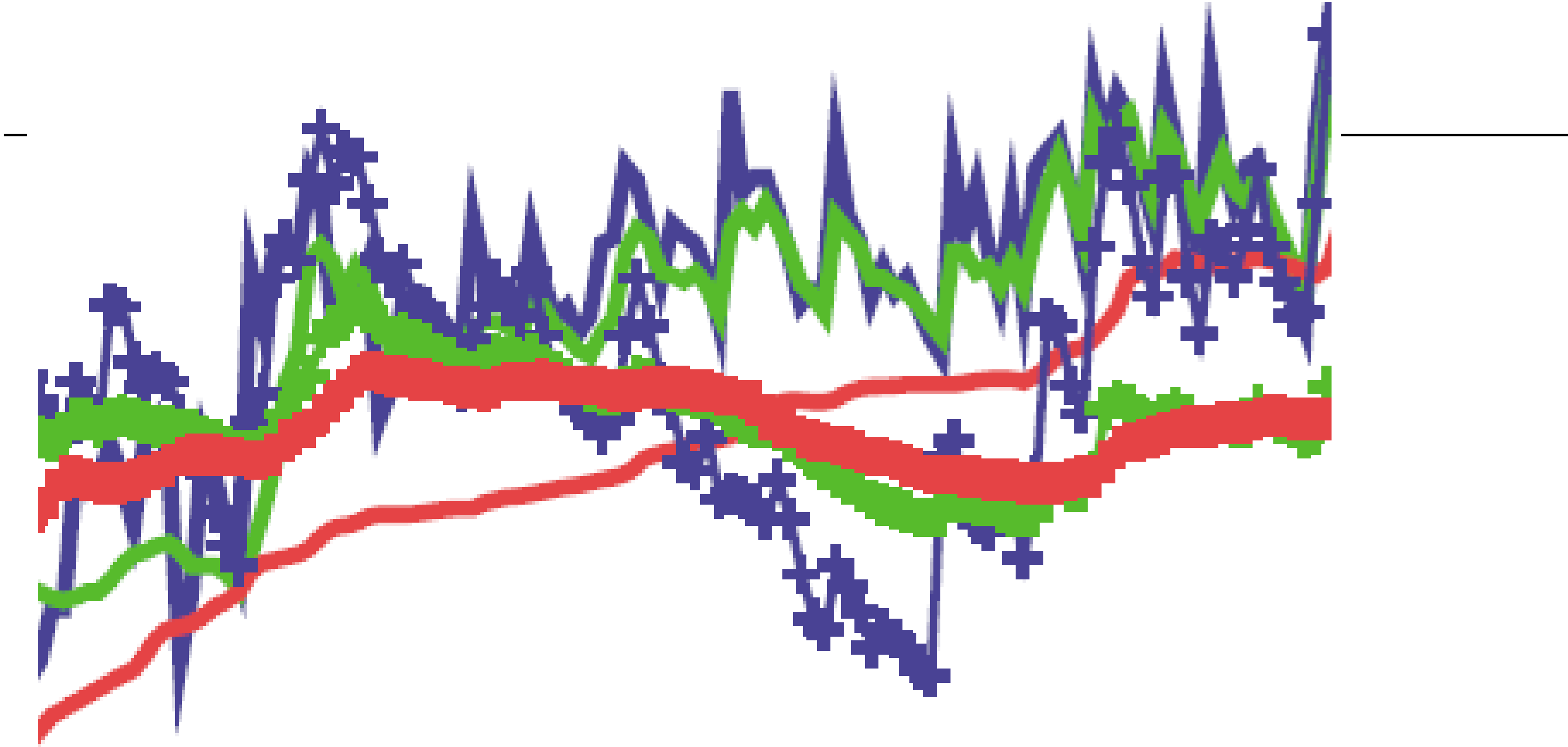
Global soil temperature sensing depth

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



(Lv et al. 2018, RS)

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;

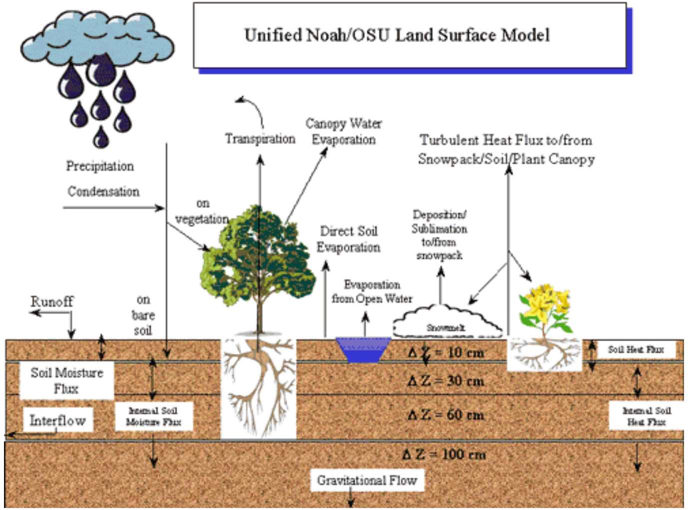
(Zheng et al., 2014, 2015a,b, JHM; Zheng et al. 2016, 2017, JGR)

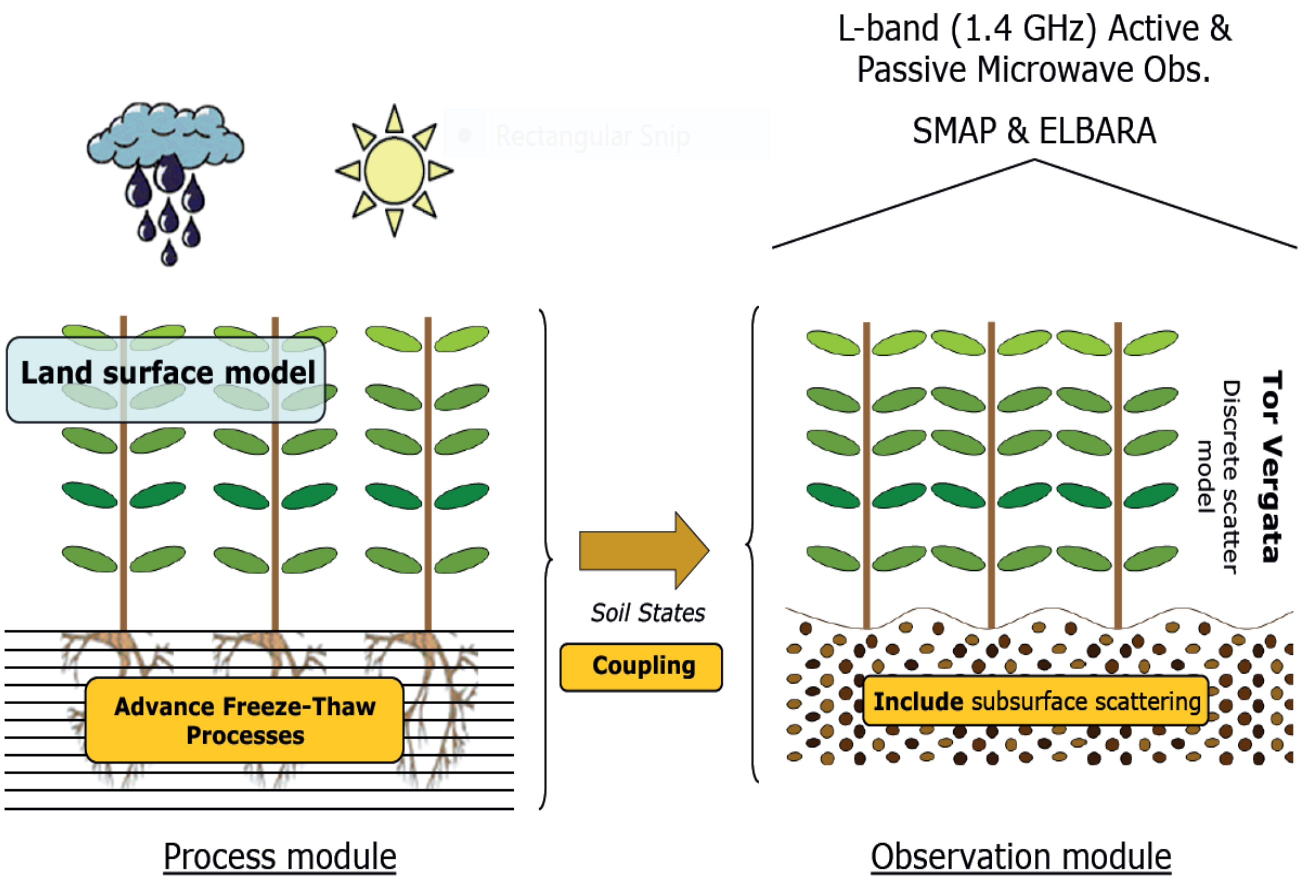
- Snow pack.

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

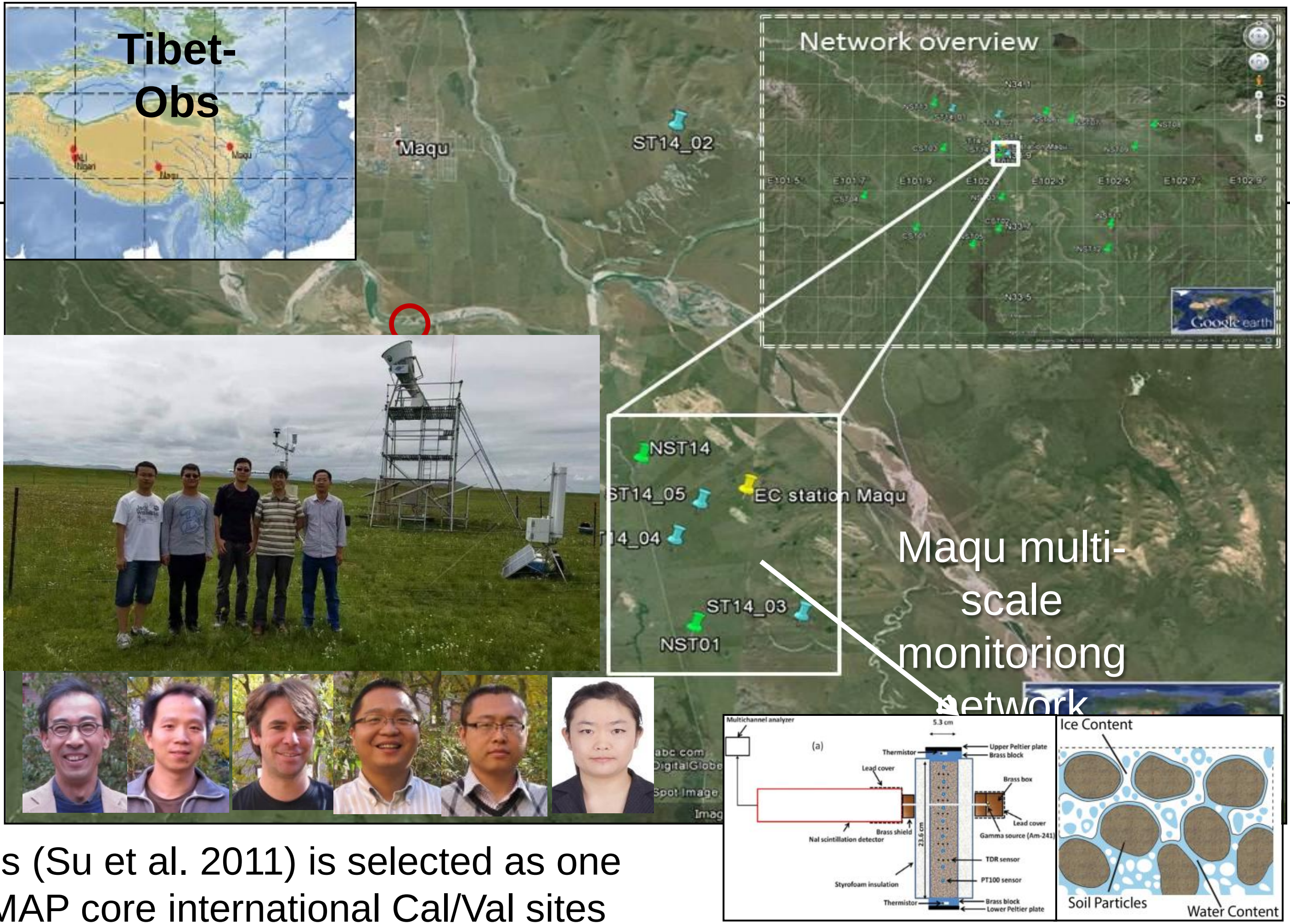
- Frozen soil;

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



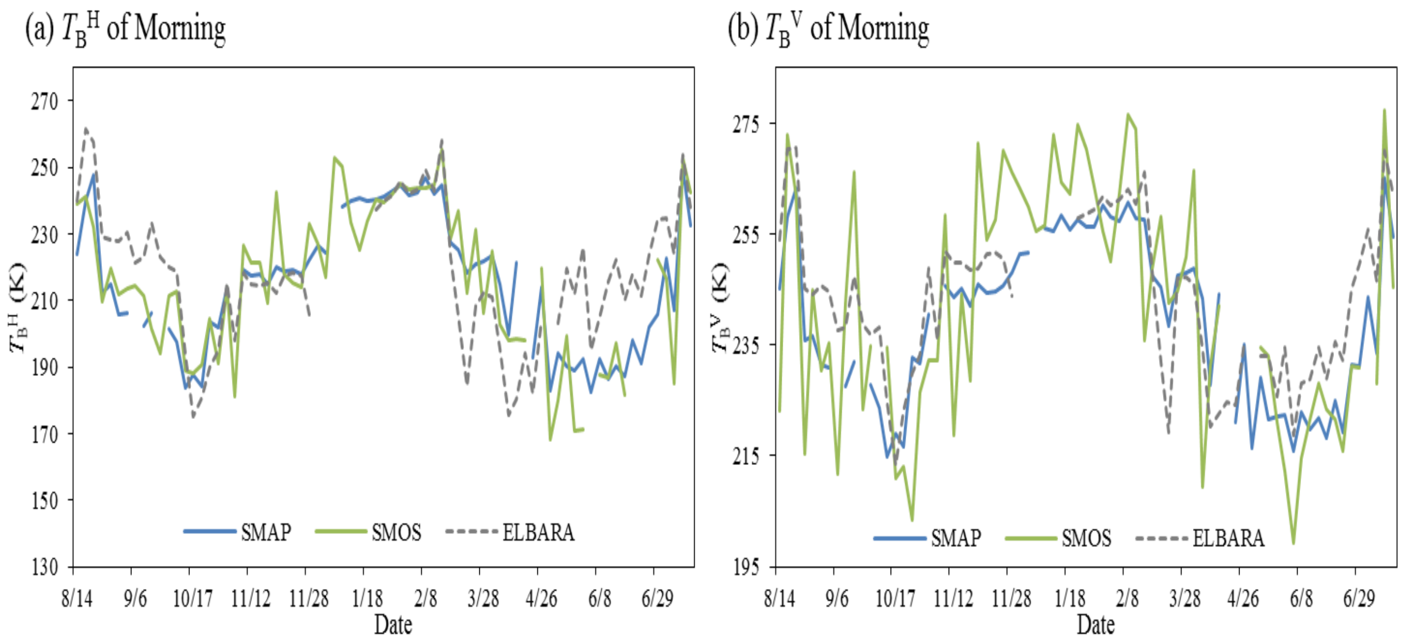


5. Coherent process modeling and radiative transfer modelling



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

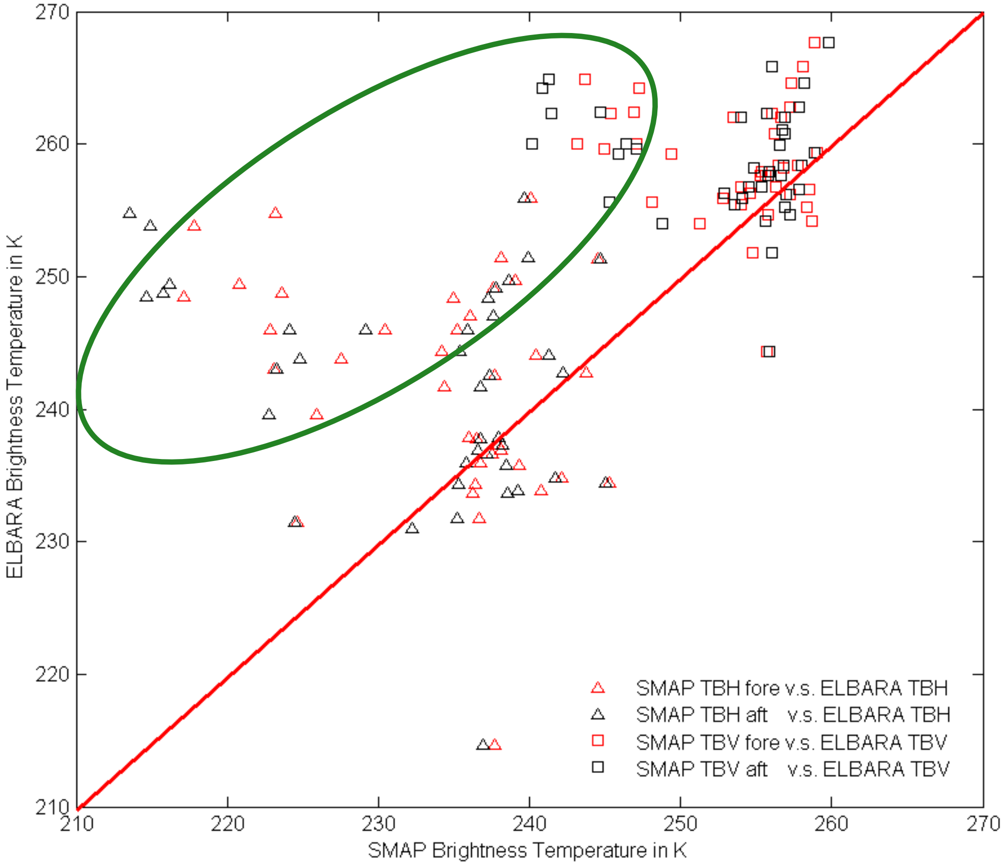
HOW GOOD IS THE SATELLITE SIGNAL? (TB)



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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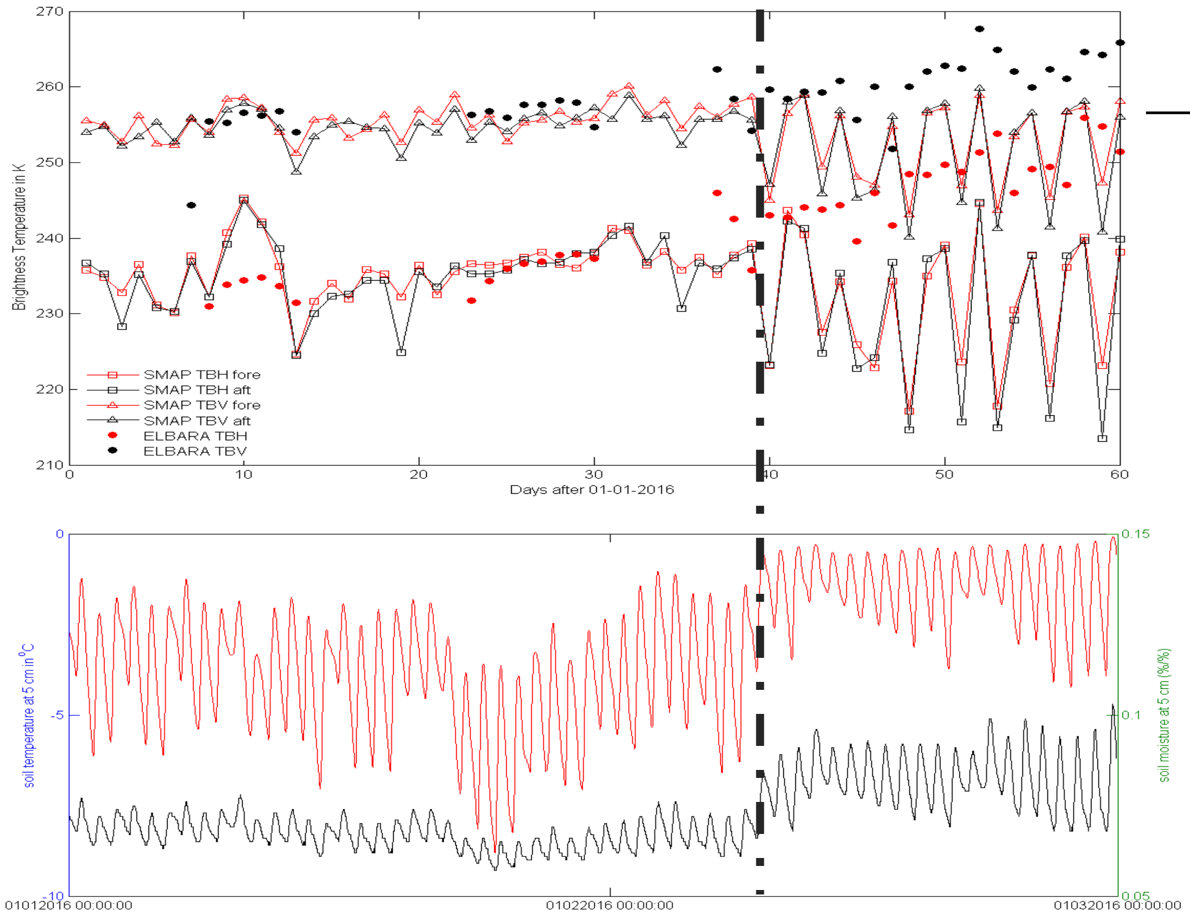
Why does SMAP underestimate ELBARA Tb?

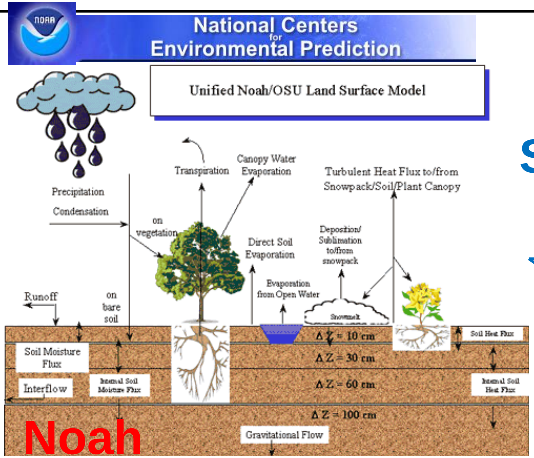


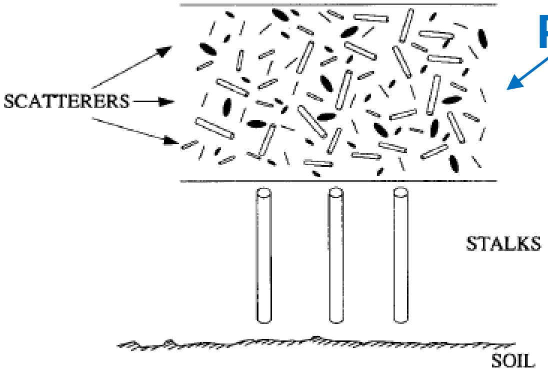
DOY 1:
01-01-2016

DOY 40:
10-02-2016

DOY 60:
29-02-2016

Noah-Tor Vergata Model





Surface SMST

4-Phase Dielectric Mixing Model

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

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

U

Tor Vergata RT

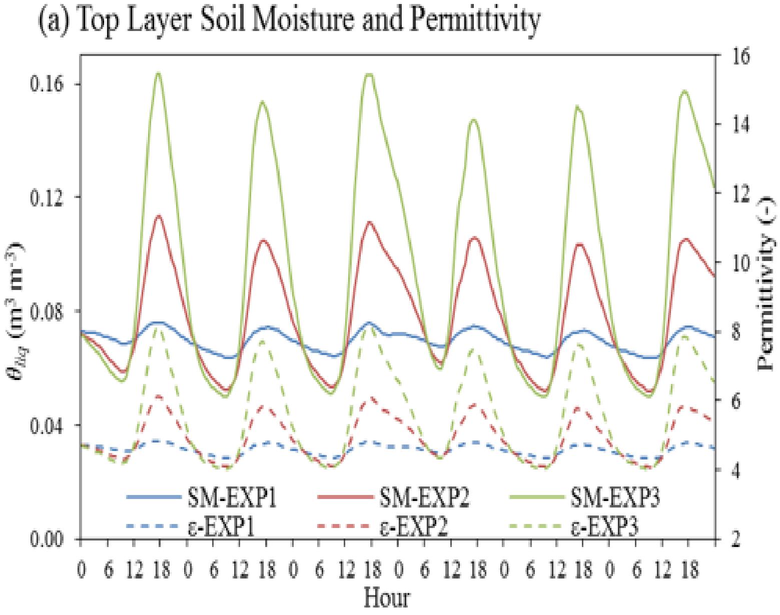
Noah-Tor Vergata Simulations

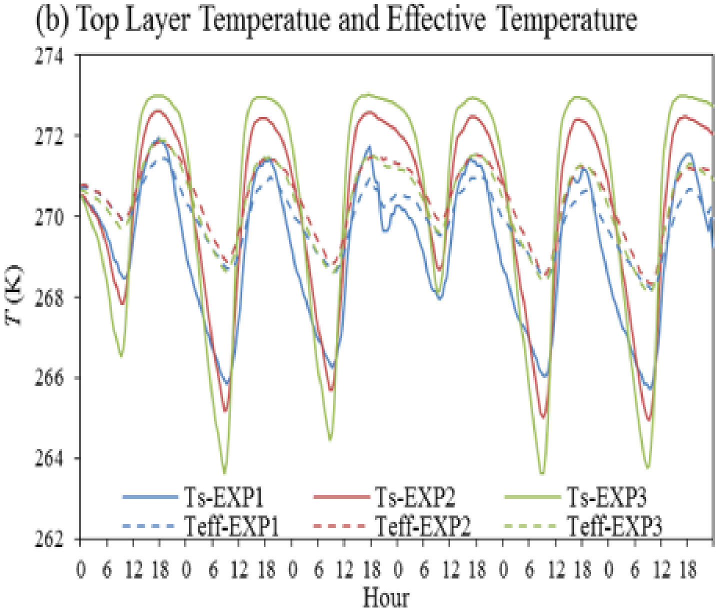
Freezing Period: DOY 1-6

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

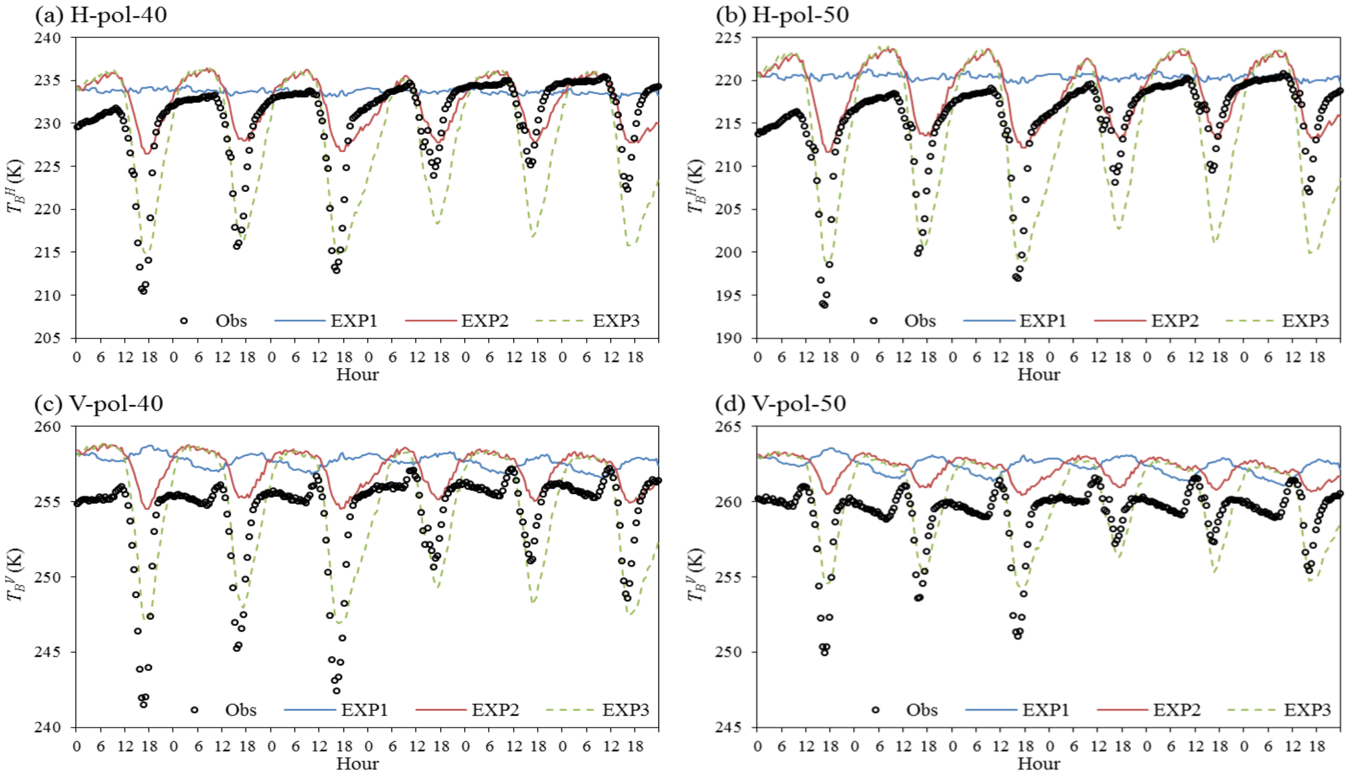
EXP3: SMST from Noah 5-layer (0.05, 0.1, 0.4, 1.0, 2.0), Sim with midpoint of top 2.5 cm layer





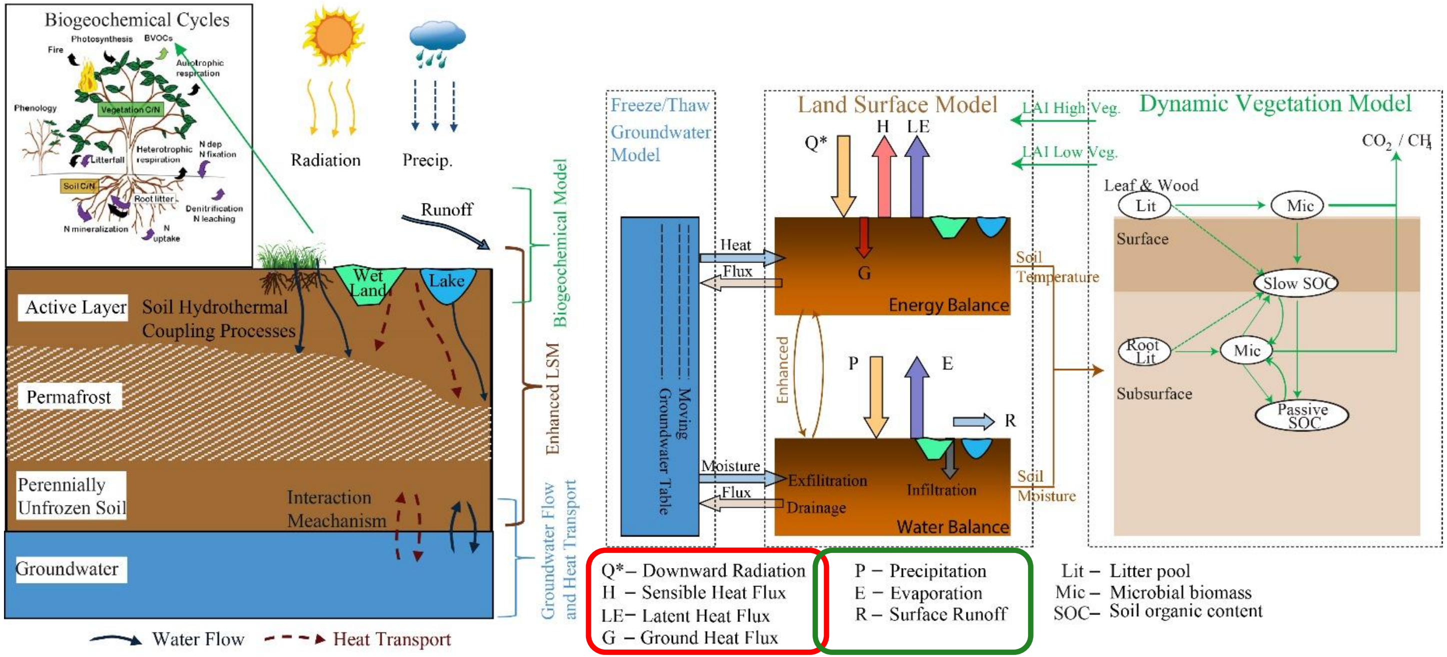
Noah-Tor Vergata Simulations

(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

$$\frac{\partial}{\partial t}[(\rho_s\theta_s C_s + \rho_L\theta_L C_L + \rho_V\theta_V C_V)(T - T_r) + \rho_V\theta_V L_0 - \rho_i\theta_i L_f] - \rho_L W\frac{\partial \theta_L}{\partial t}$$

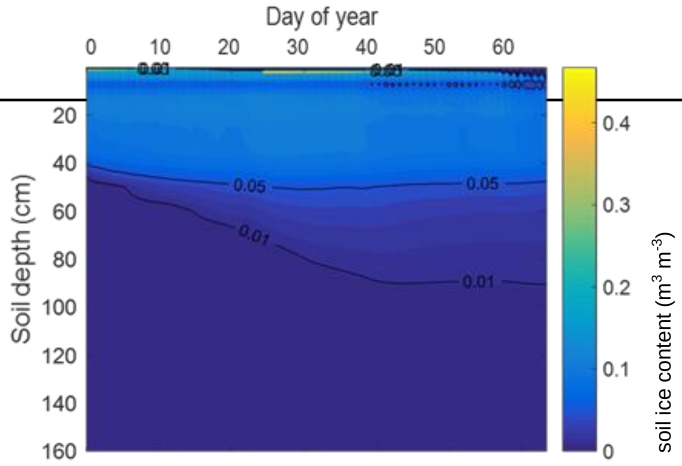
$$= \frac{\partial}{\partial z}(\lambda_{eff}\frac{\partial T}{\partial z}) - \frac{\partial q_L}{\partial z}C_L(T - T_r) - \frac{\partial q_V}{\partial z}[L_0 + C_V(T - T_r)] - C_L S(T - T_r)$$

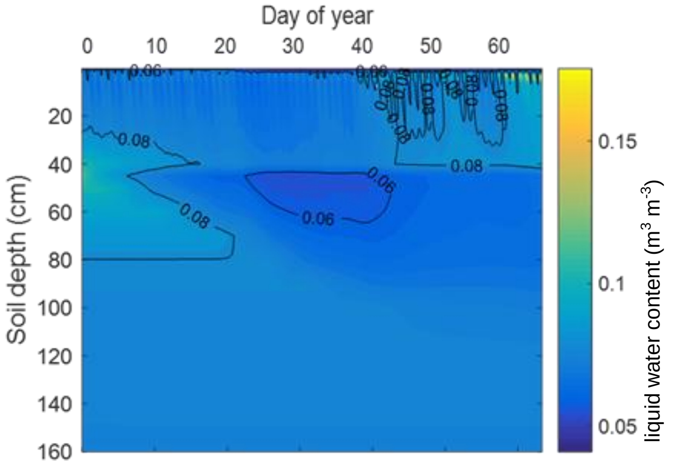
Soil Dry air Transport

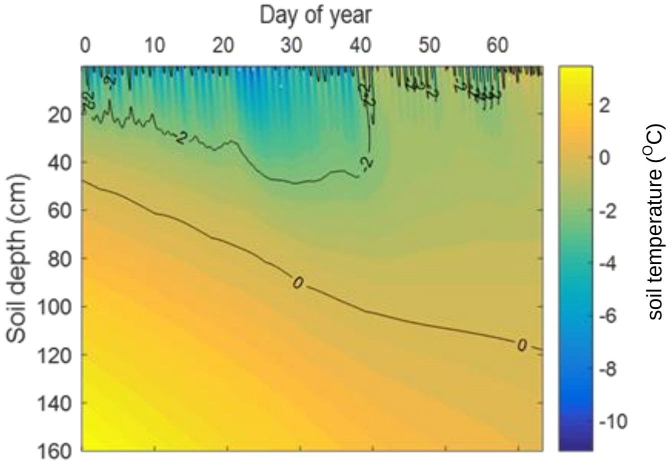
$$\frac{\partial}{\partial t}[\varepsilon\rho_{da}(S_a + H_c S_L)] = \frac{\partial}{\partial t}[D_e\frac{\partial \rho_{da}}{\partial z} + \rho_{da}\frac{S_a K_g}{\mu_a}\frac{\partial P_g}{\partial z} - H_c\rho_{da}\frac{q_L}{\rho_L} + (\theta_a D_{Vg})\frac{\partial \rho_{da}}{\partial z}]$$

(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

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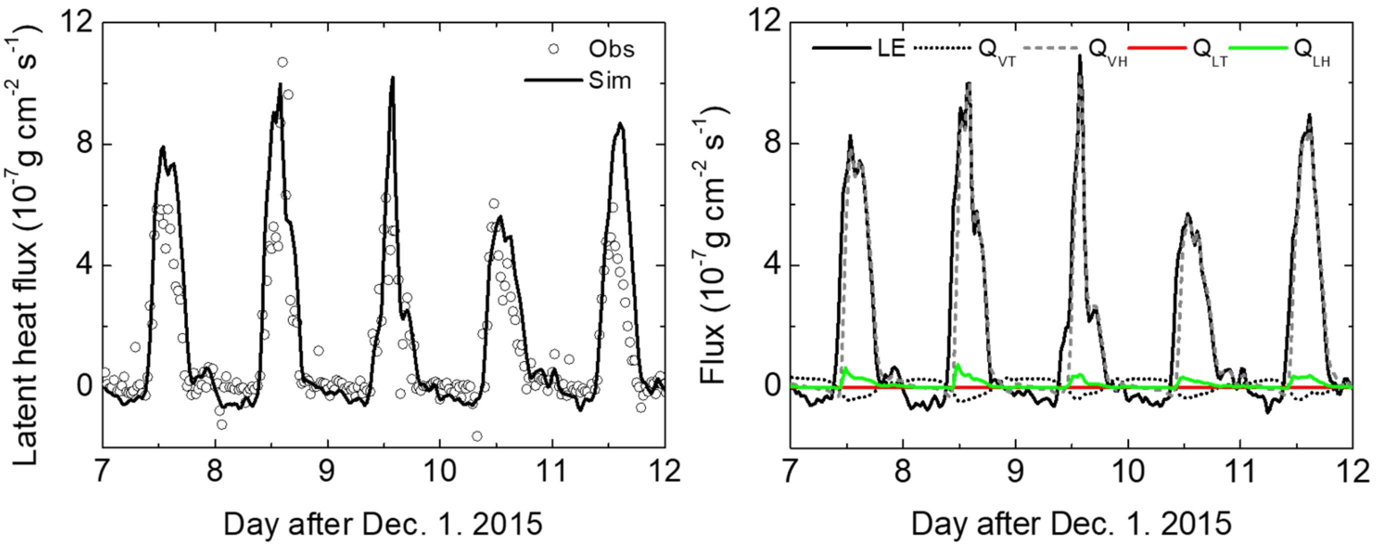
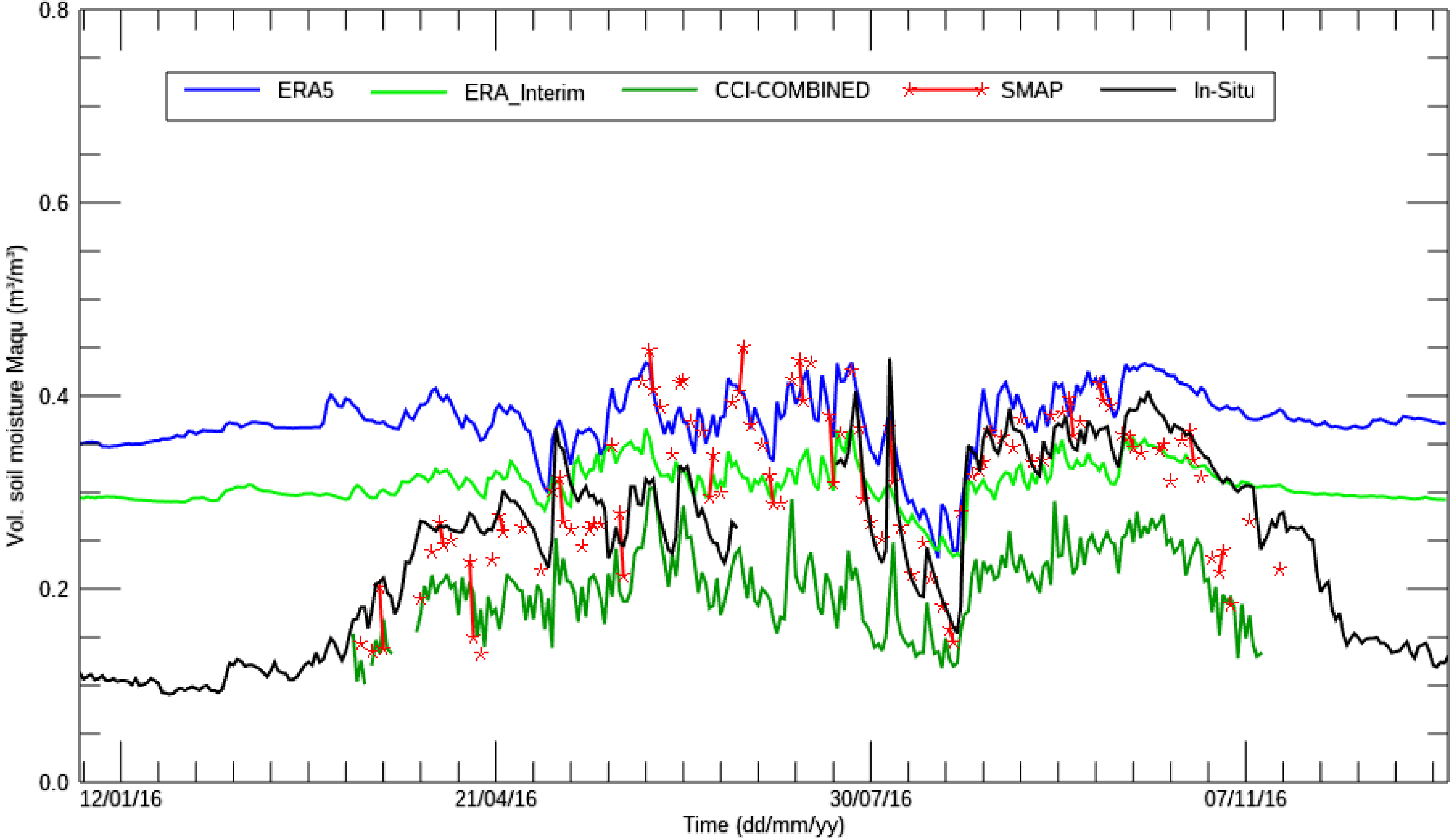
STEMMUS-FT results
Surface fluxes



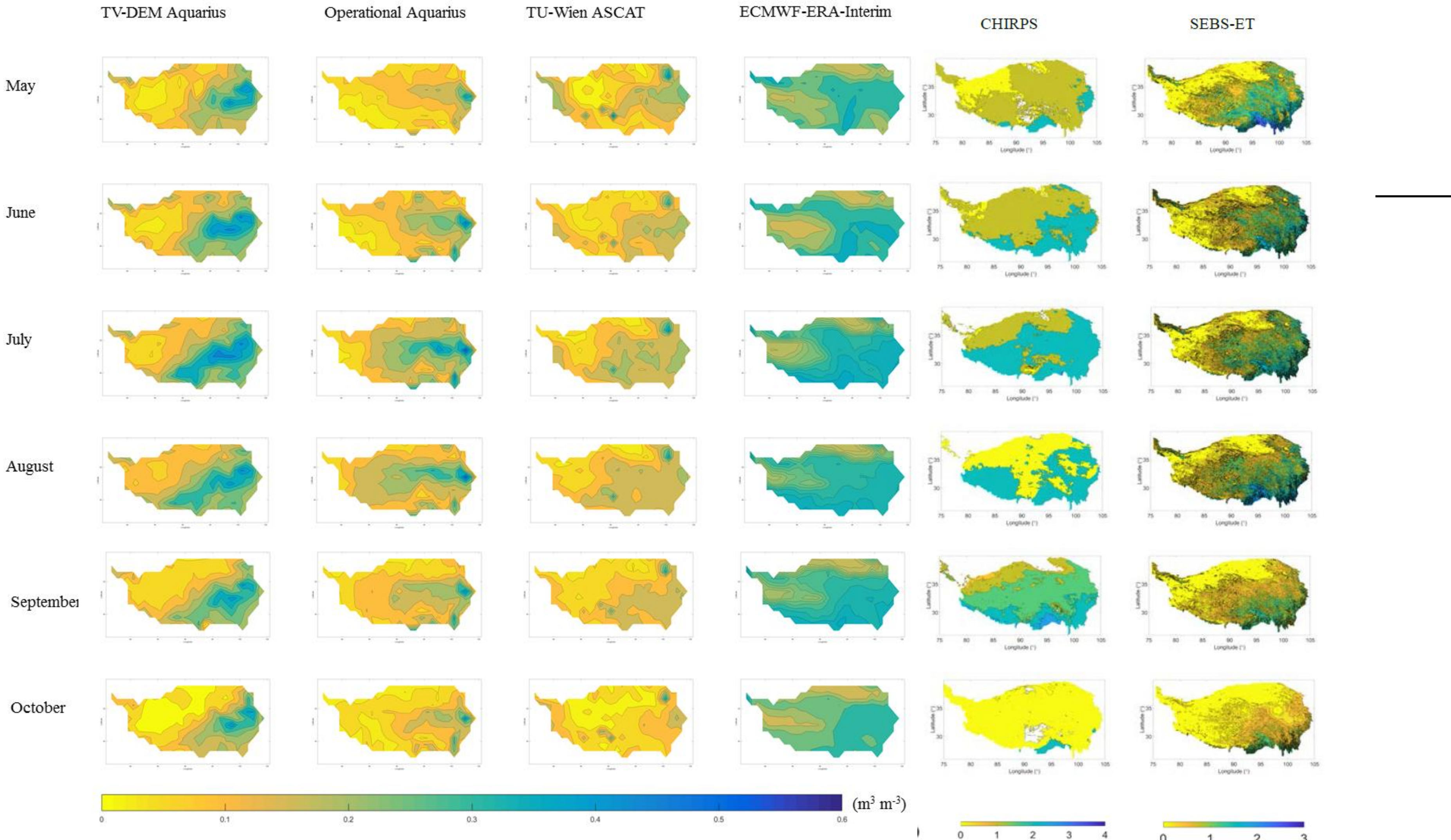
(a)Latent heat flux

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

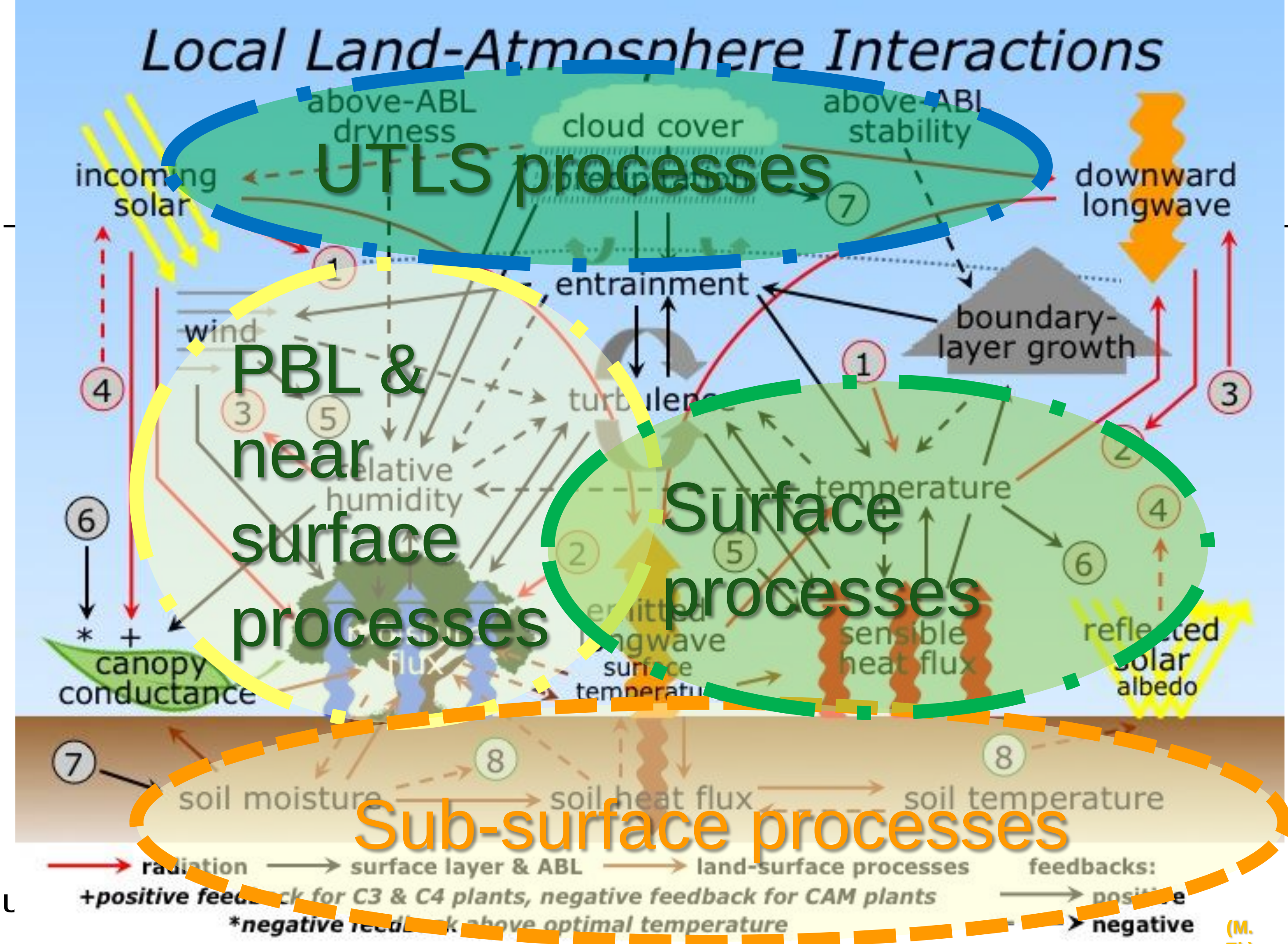
(Yu et al., 2018, JGR)



ERA5
ERA_Interim
CCI-COMBINED
SMAP
In-Situ
Vol. soil moisture Maqu (m³/m³)
0.8
0.6
0.4
0.2
0.0
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
0 1 2 3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PBL & near surface processes
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feedbacks:
positive
negative
+positive feedback for C3 & C4 plants, negative feedback for CAM plants
*negative feedback above optimal temperature

(M. Ek)

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