UNIVERSITY OF TWENTE.

Advances and Challenges in Land-atmosphere Interactions in TPE

– in-situ observation, remote sensing and modeling

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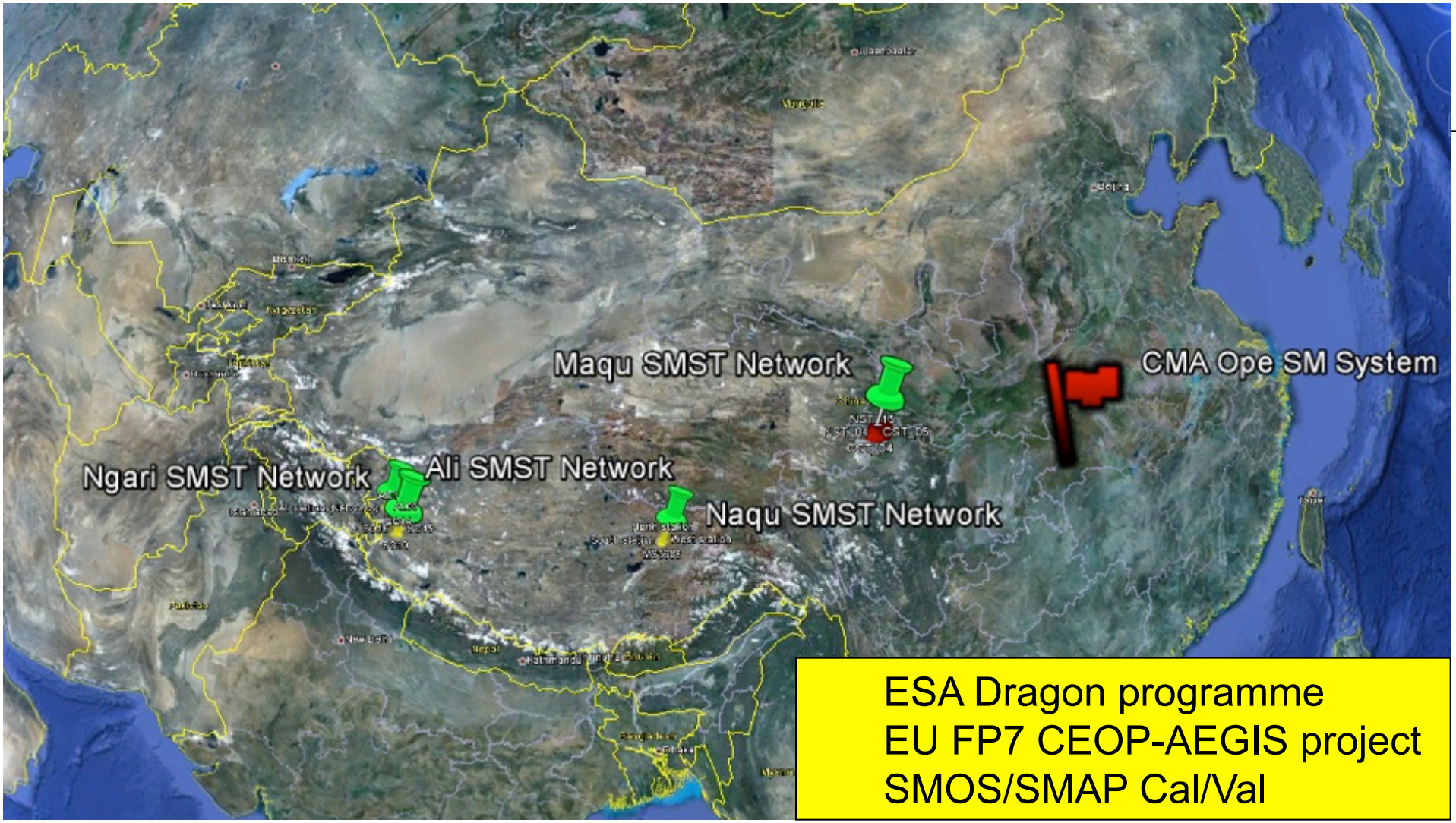
P. Ferrazzoli (UR), M. Schwank (Eth)

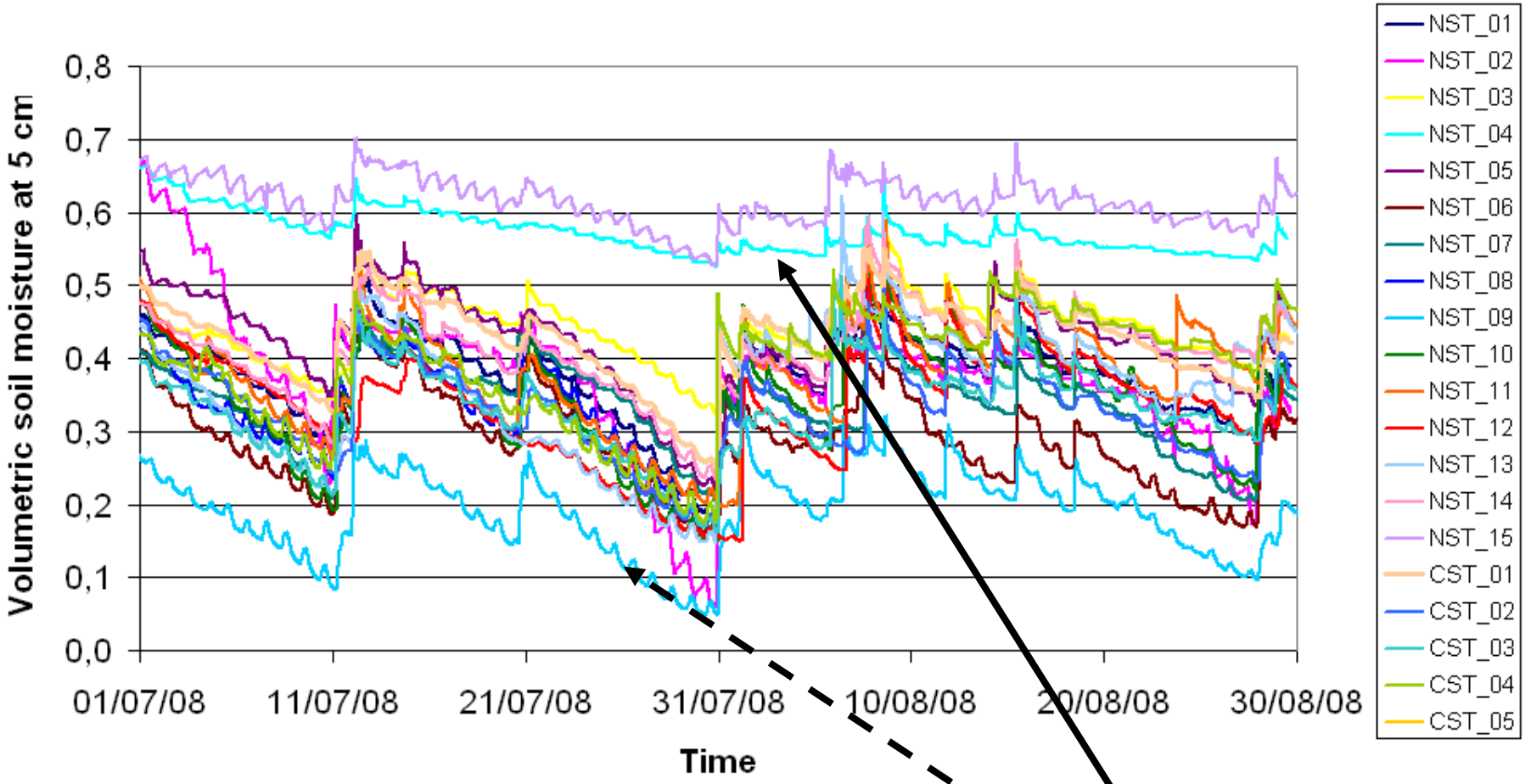
Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs)



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

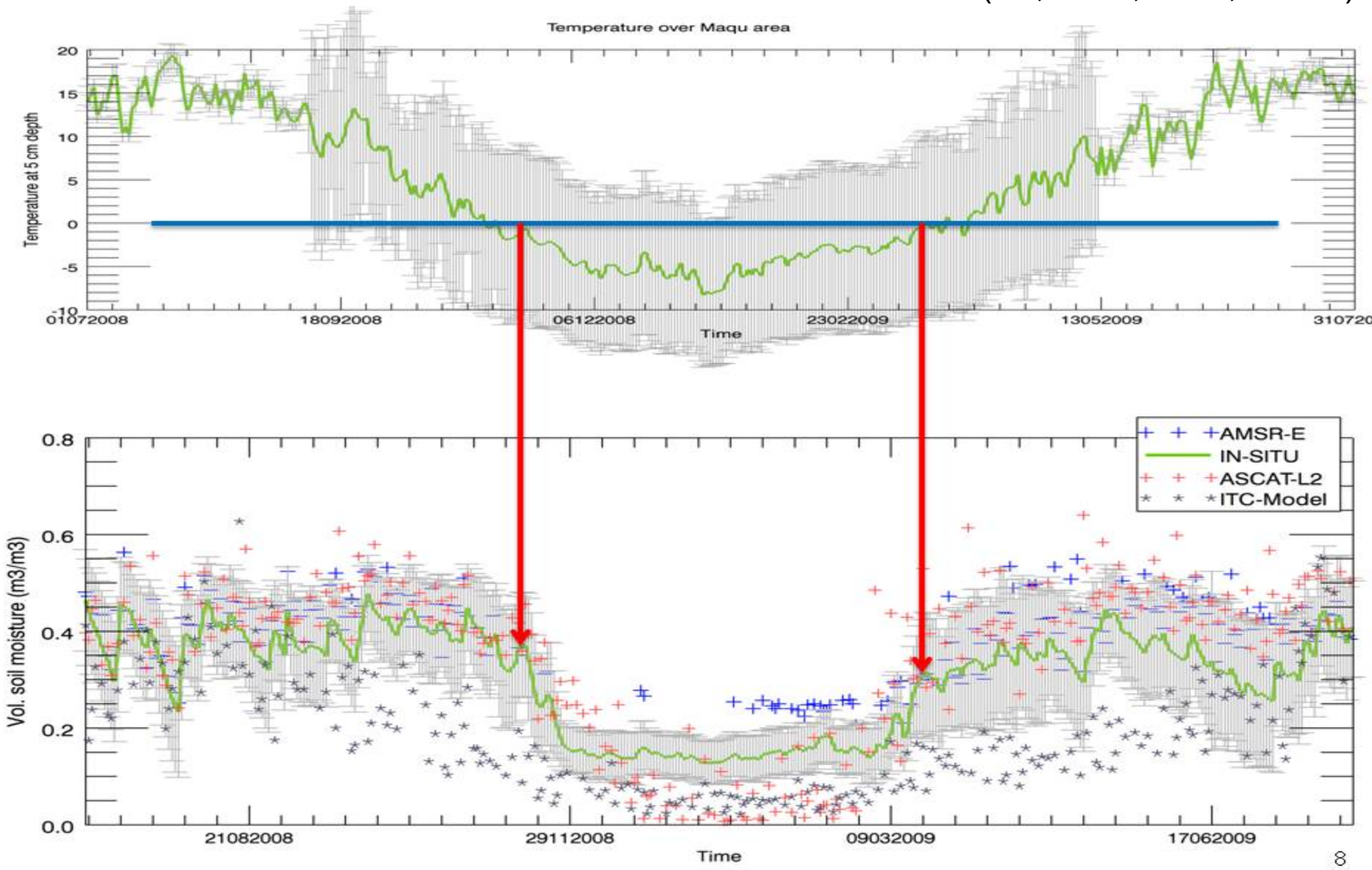
(Su et al. 2011, HESS)

Maqu: Soil moisture at 5 cm depth

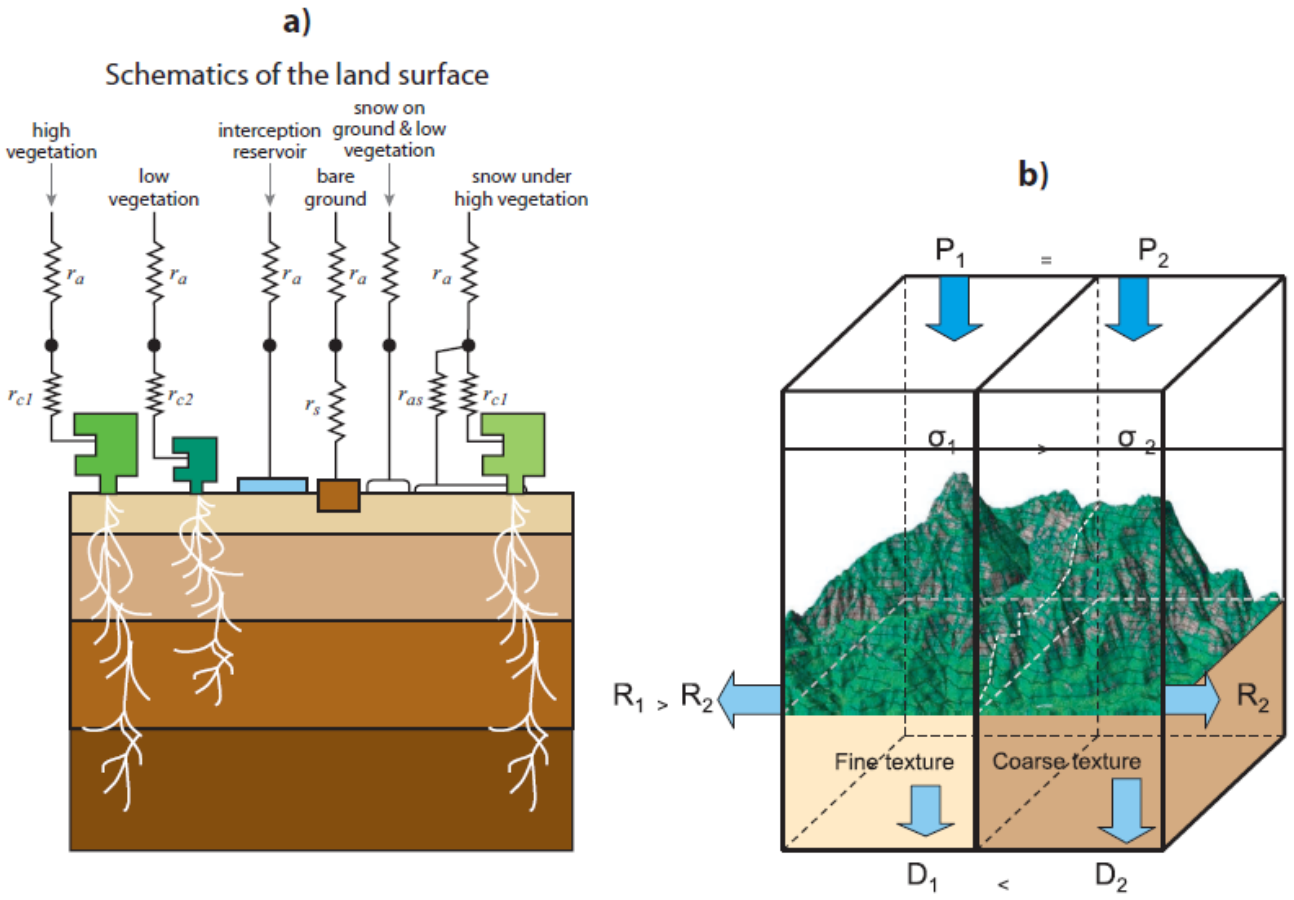


Quantification of uncertainties in global products

(Su, et al., 2011, HESS)



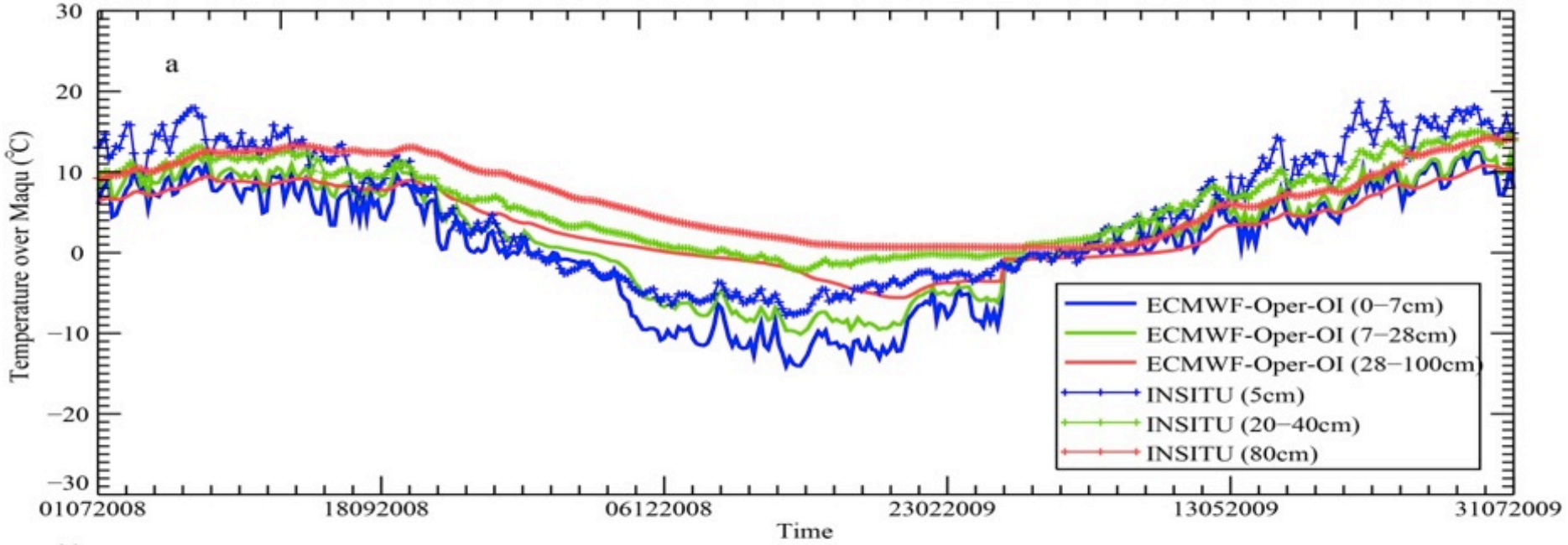
The Tiled ECMWF Scheme for Surface Exchanges over Land (TESSEL) & the HTESSEL (Hydrology TESSEL)

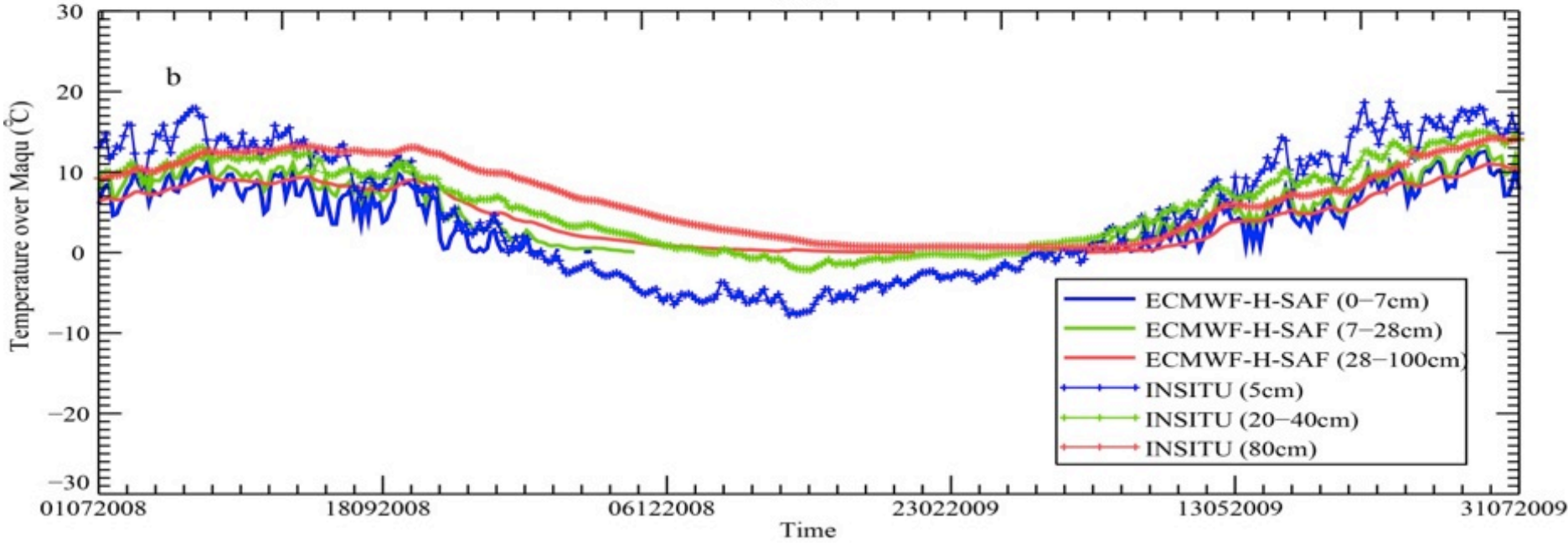


(a) TESSEL land-surface scheme, (b) spatial structure in HTESSEL (for a given precipitation P1 = P2 the scheme distributes the water as surface runoff and drainage with functional dependencies on orography and soil texture respectively) (Balsamo et al., 2006)

How good is soil temperature simulation/analysis?

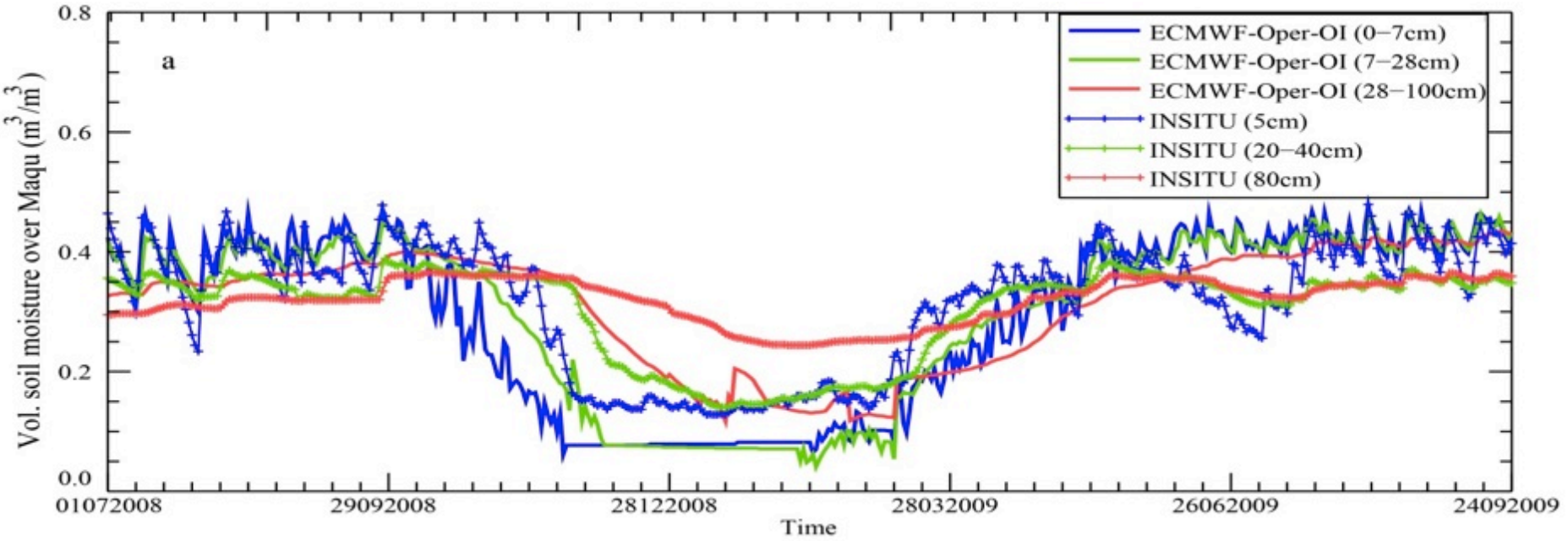
(Su & de Rosnay, et al. 2013, JGR)

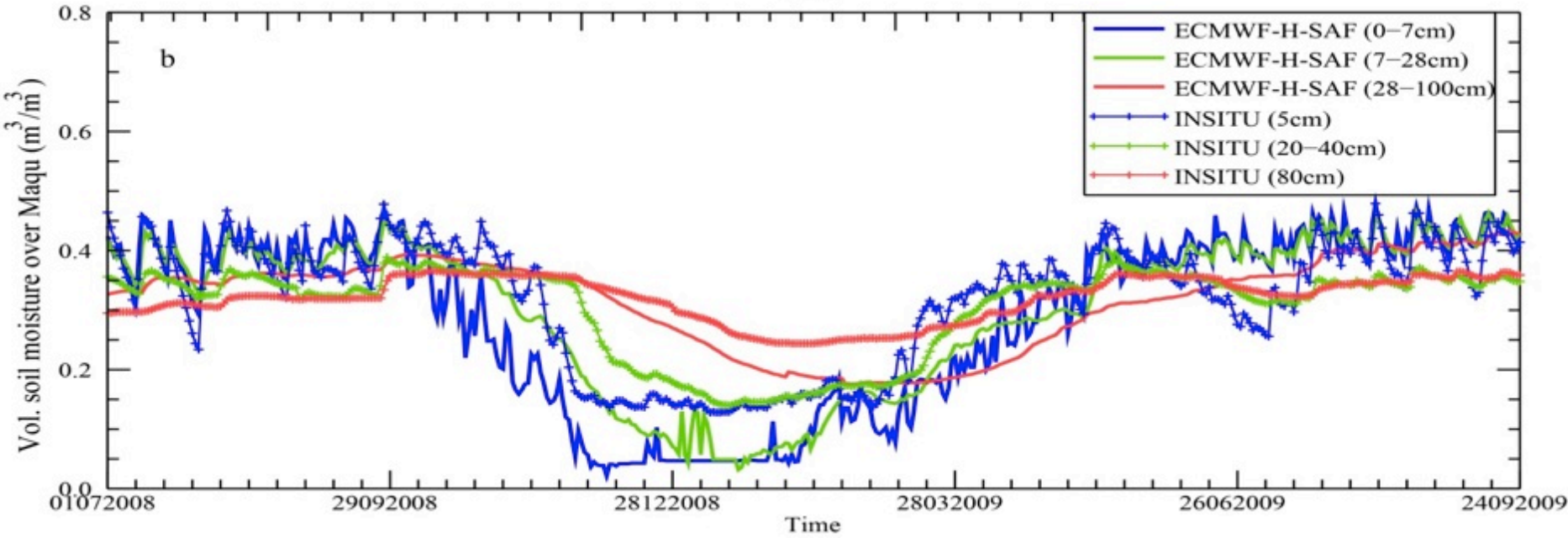




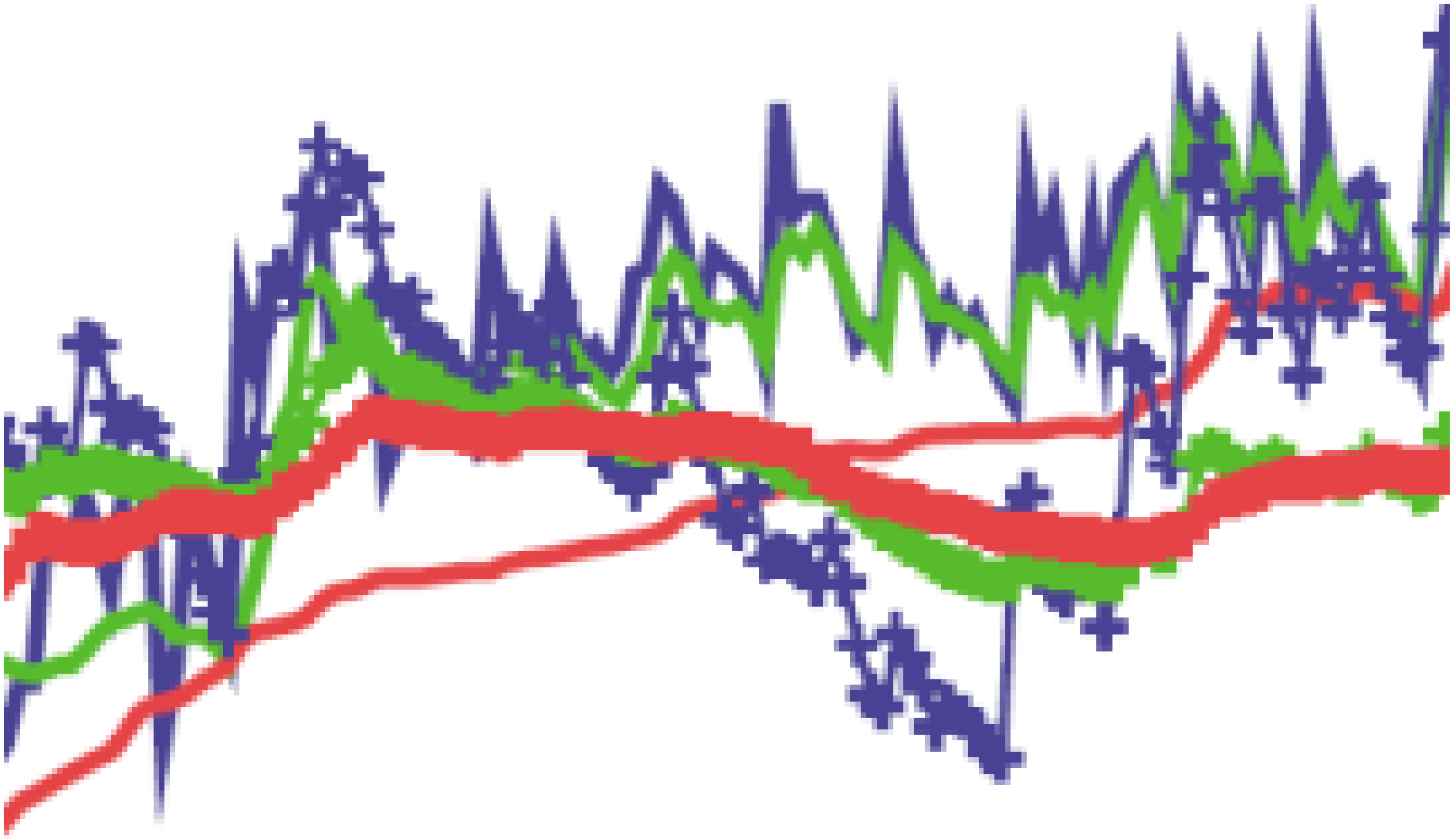
How good is soil moisture analysis/assimilation?

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



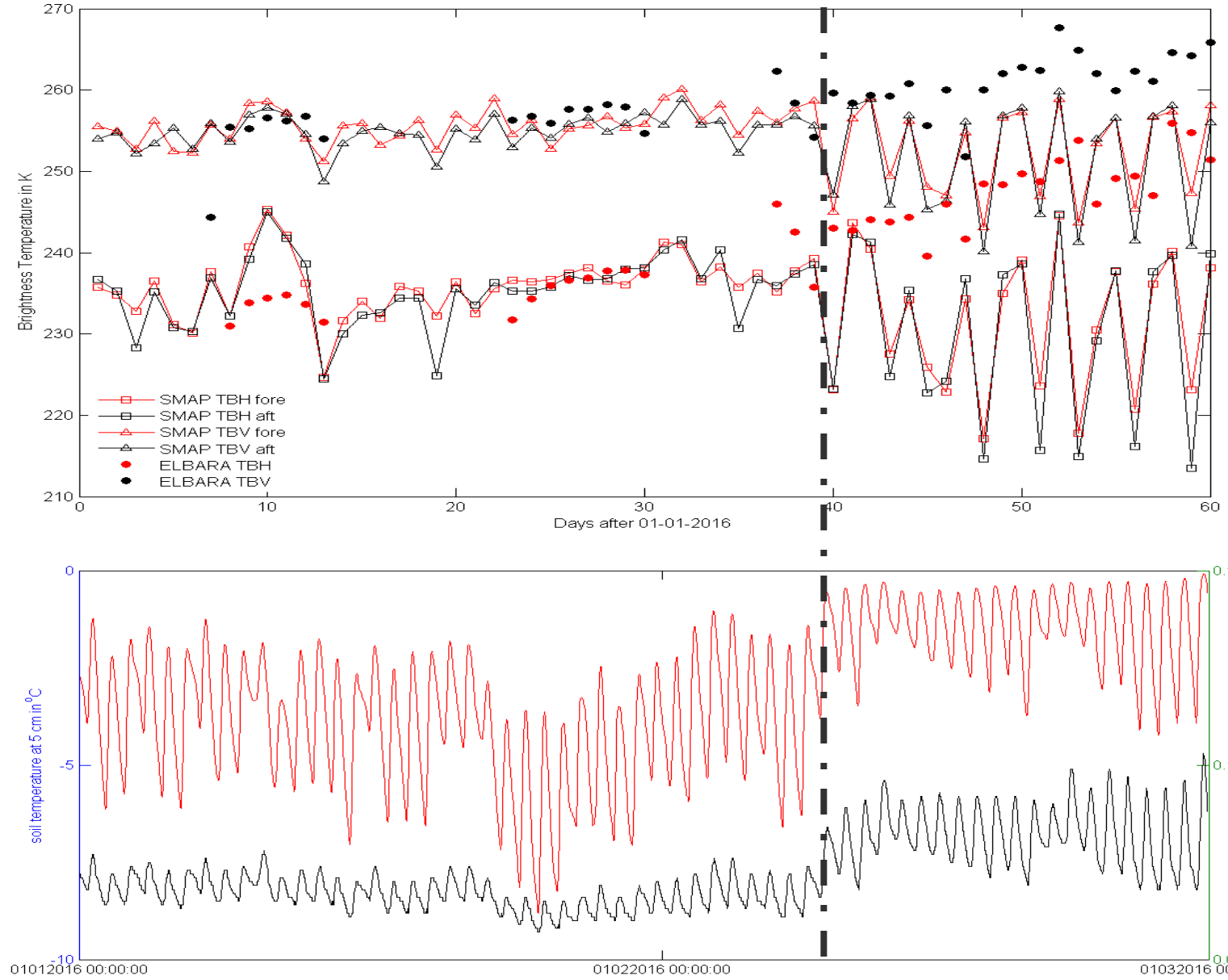


How good is soil moisture assimilation?



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

Why does SMAP underestimate ELBARA Tb?



DOY 1:
01-01-2016

DOY 40:
10-02-2016

DOY 60:
29-02-2016

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;

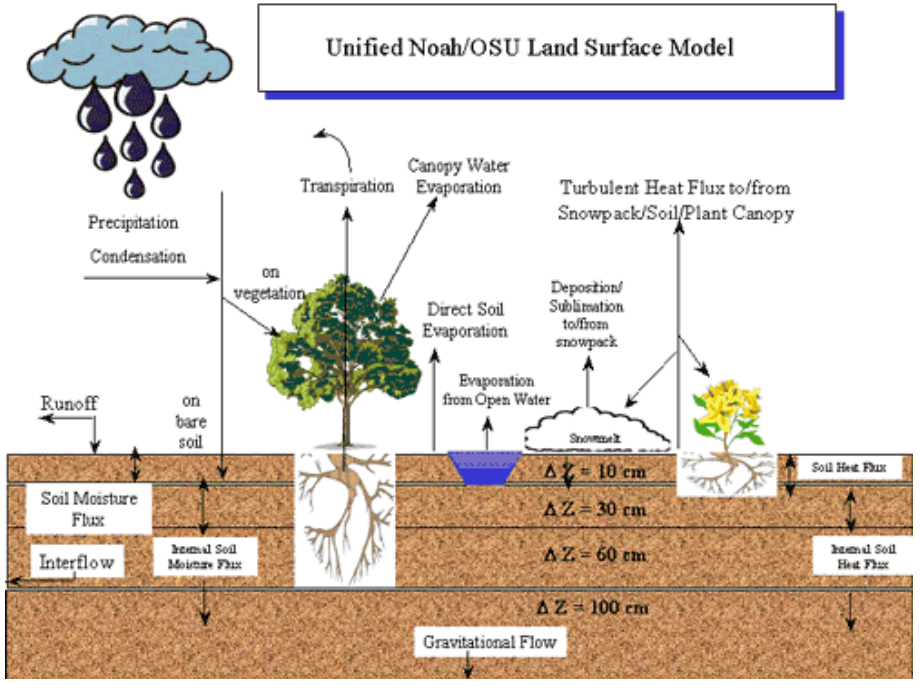
(Zheng et al., 2014, 2015a,b, JHM; Zheng et al. 2016, 2017, JGR)

- Snow pack;

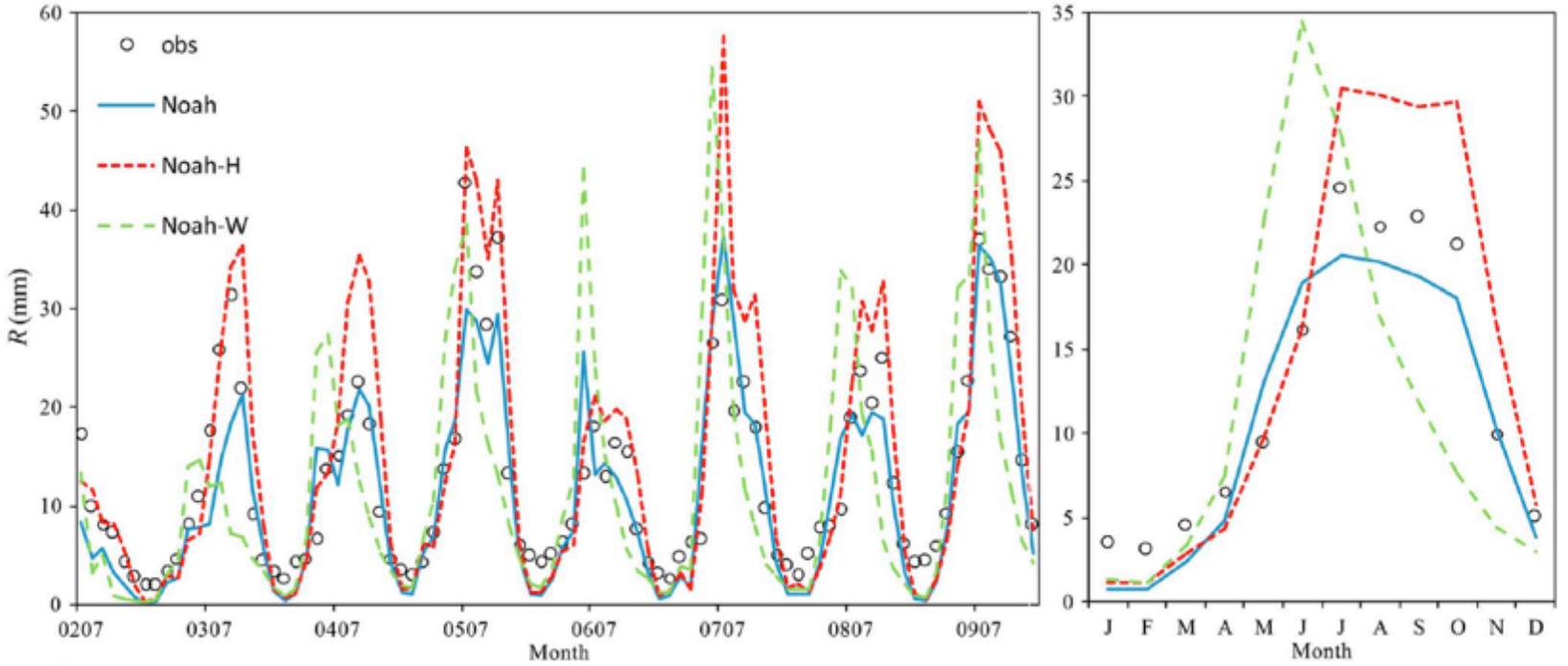
(Malik et al., 2012, JHM; 2013, JGR; 2011, RSE)

- Frozen soil;

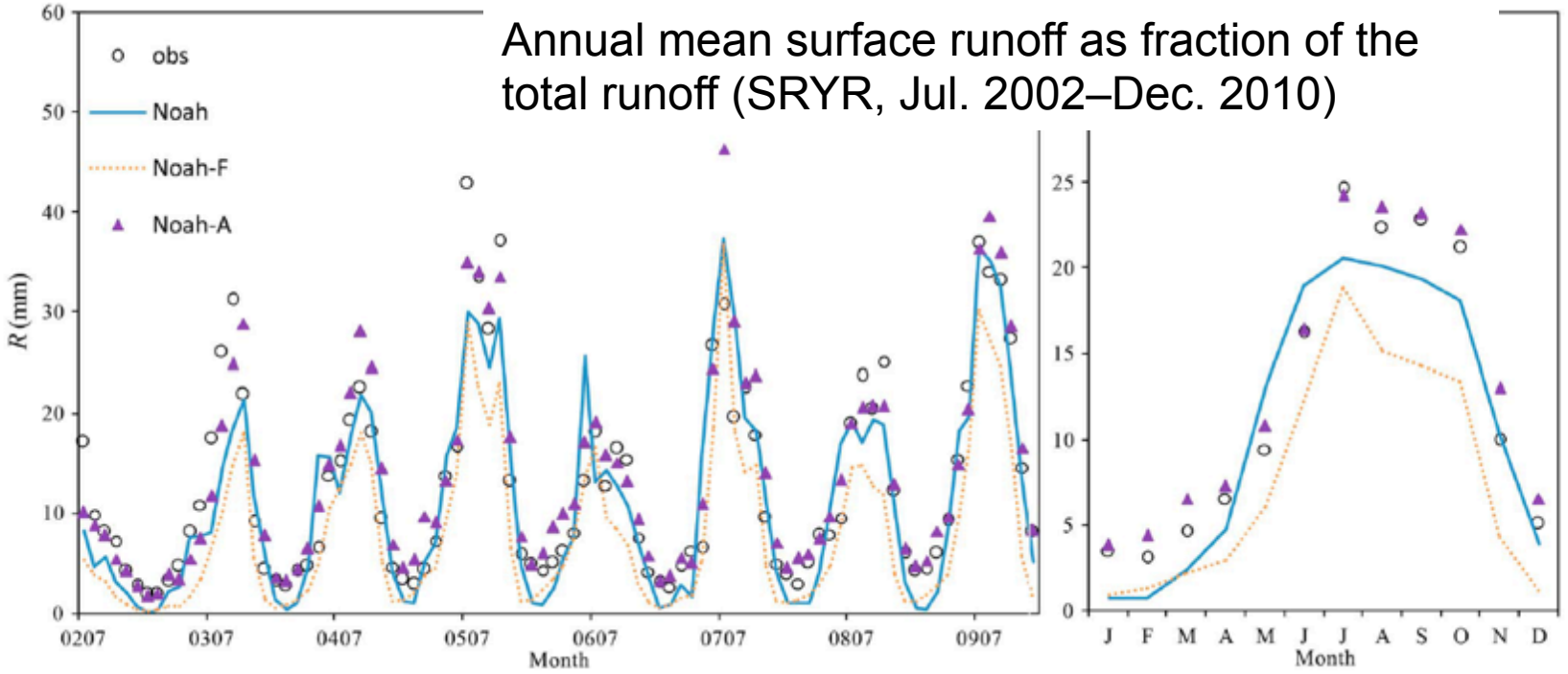
(NWO SMAP freeze/thaw, Zheng et al., 2017 TGRS)



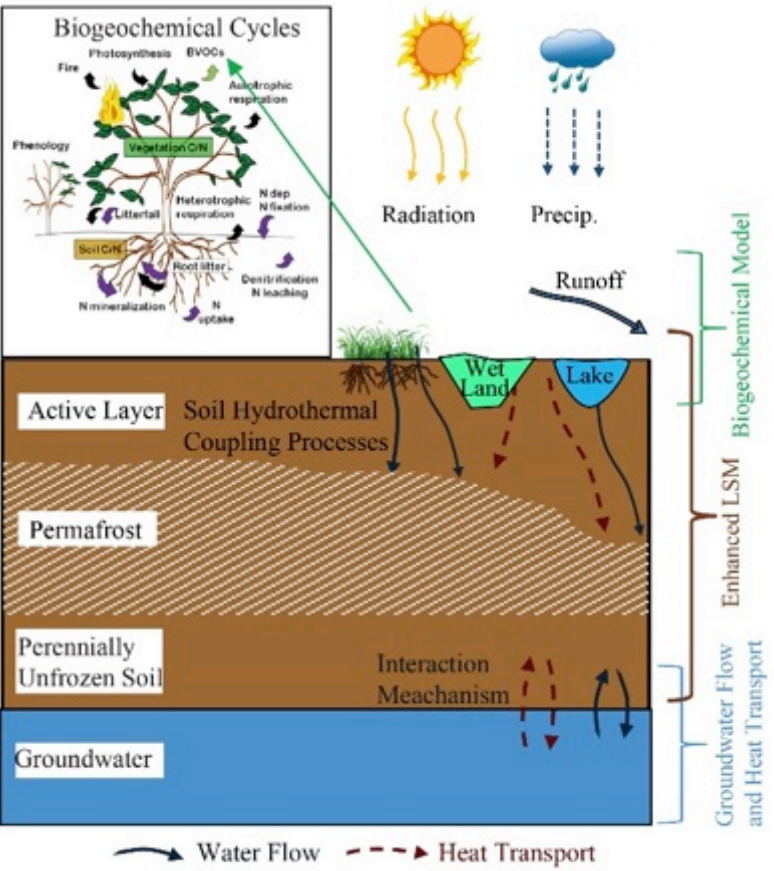
UNIVERSITY OF TWENTE.



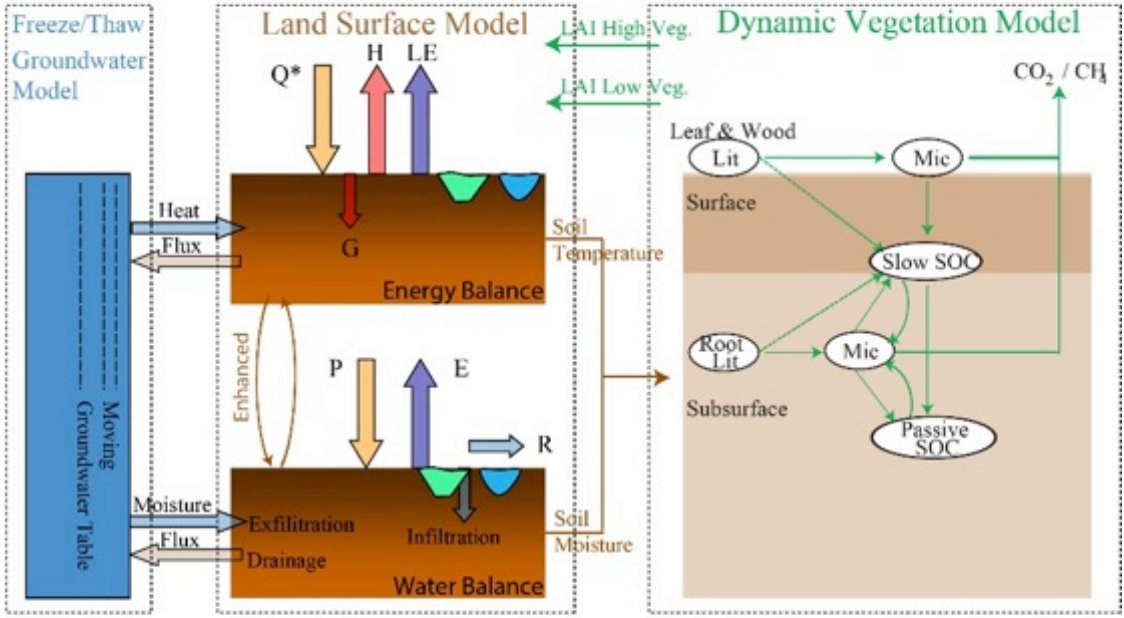
Annual mean surface runoff as fraction of the total runoff (SRYR, Jul. 2002–Dec. 2010)



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



a) Physical processes



Q*– Downward Radiation
H – Sensible Heat Flux
LE– Latent Heat Flux
G – Ground Heat Flux

P – Precipitation
E – Evaporation
R – Surface Runoff

Lit – Litter pool
Mic – Microbial biomass
SOC– Soil organic content

b) Coupling processes

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

STEMMUS-FT (Freezing/Thawing) model

Soil Water Phase Change

Soil Water Transport

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

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

Soil Heat Transport

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

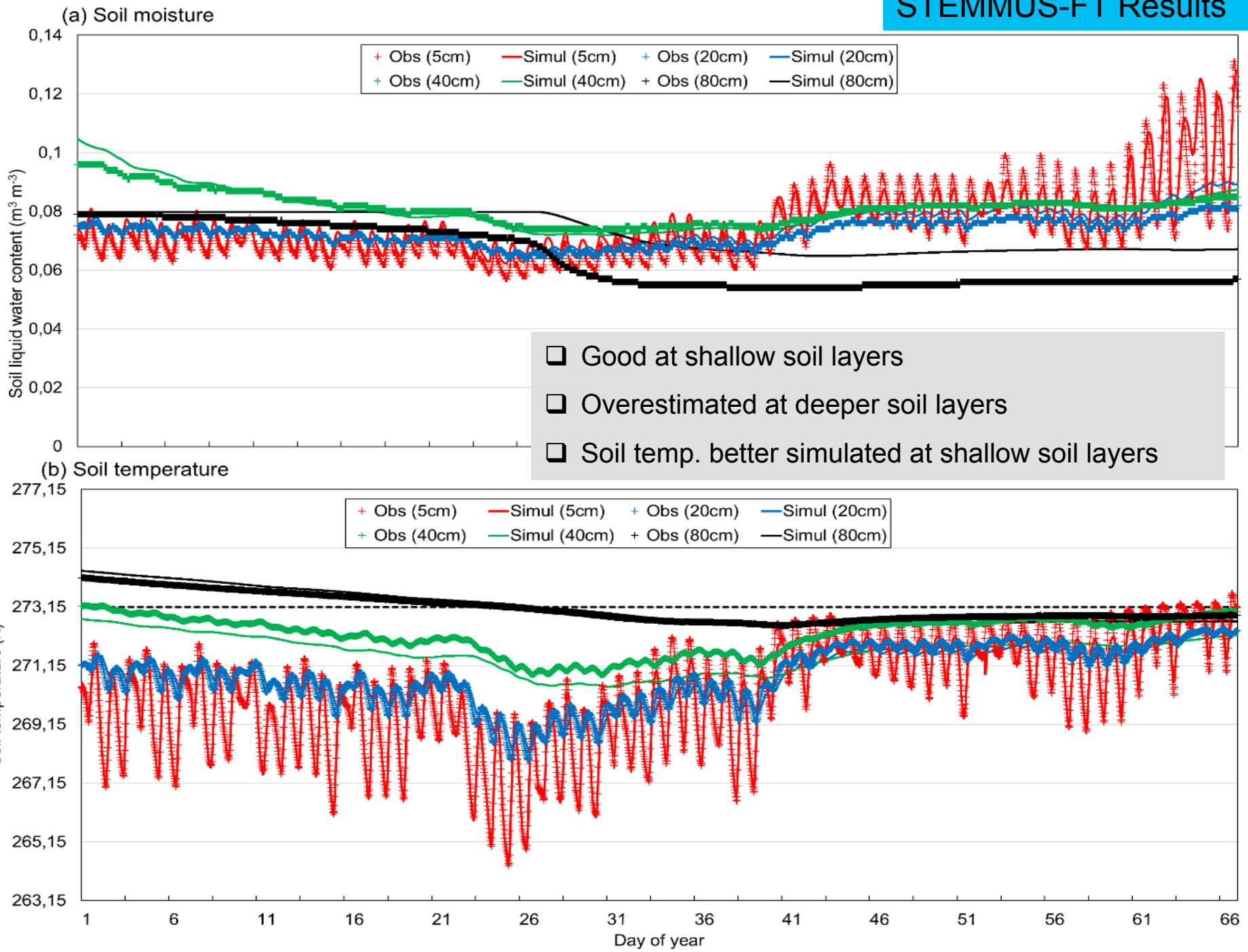
$$= \frac{\partial}{\partial z}(\lambda_{eff}\frac{\partial T}{\partial z}) - \frac{\partial q_L}{\partial z}C_L(T - T_r) - \frac{\partial q_V}{\partial z}[L_0 + C_V(T - T_r)] - C_L S(T - T_r)$$

Soil Dry air Transport

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

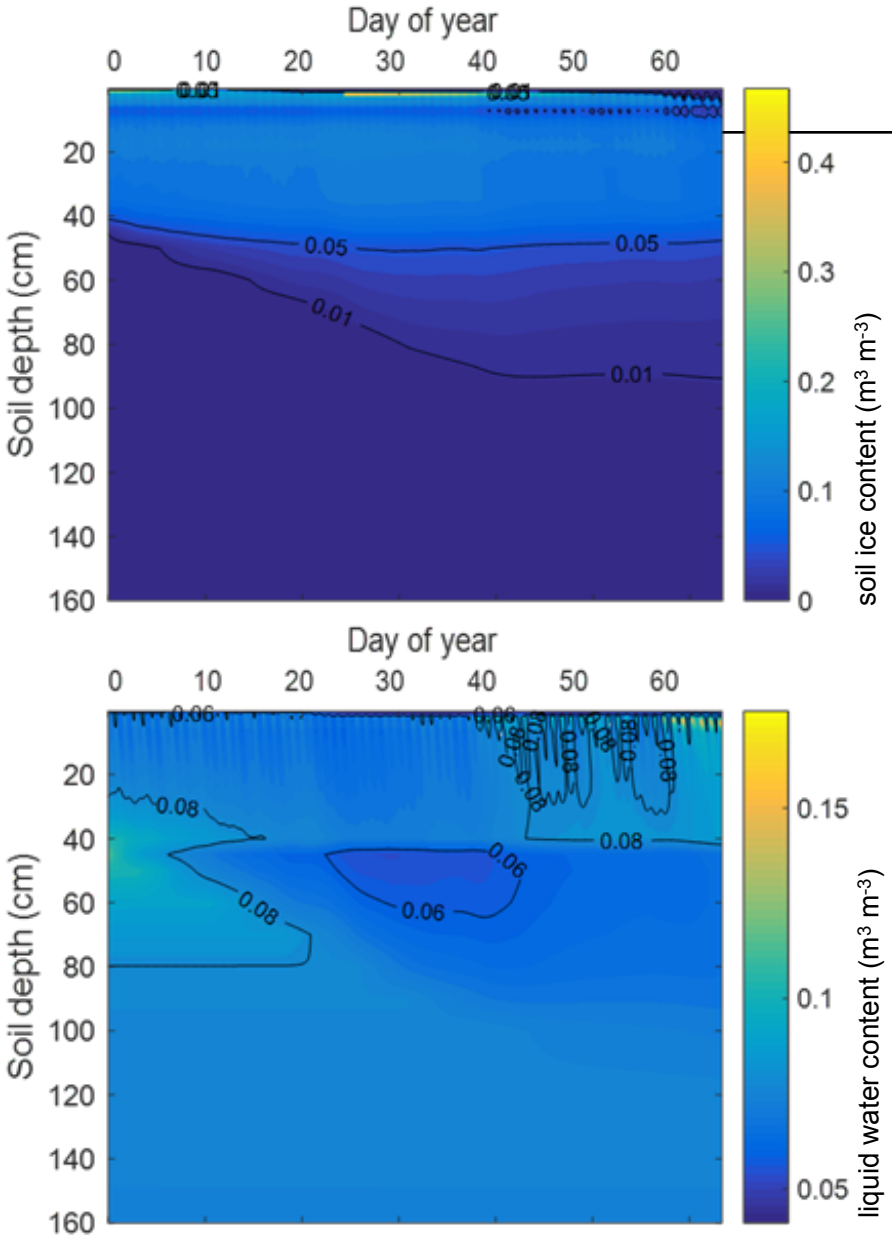
(Zeng et al., 2011 JGR,
Zeng et al., 2011 WRR,
Yu et al., 2016, HESS)

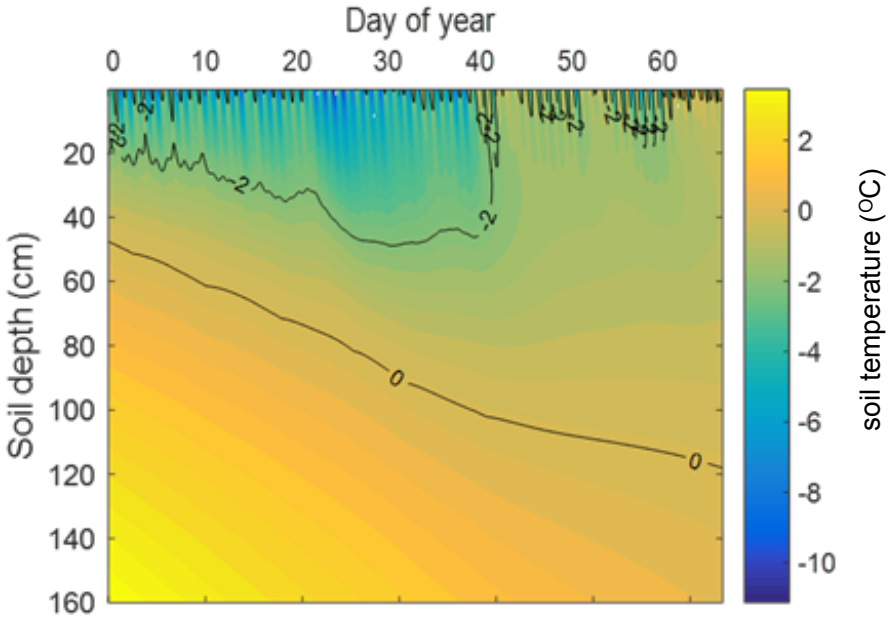
STEMMUS-FT Results



- ❑ Good at shallow soil layers
- ❑ Overestimated at deeper soil layers
- ❑ Soil temp. better simulated at shallow soil layers

STEMMUS-FT
Profile of ice, liquid water and temperature

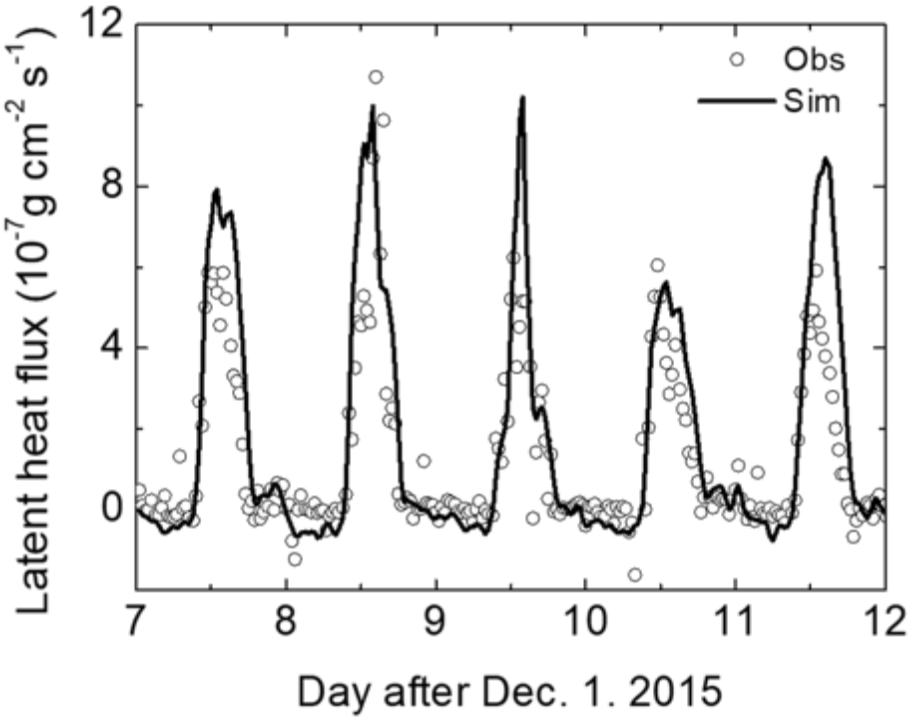




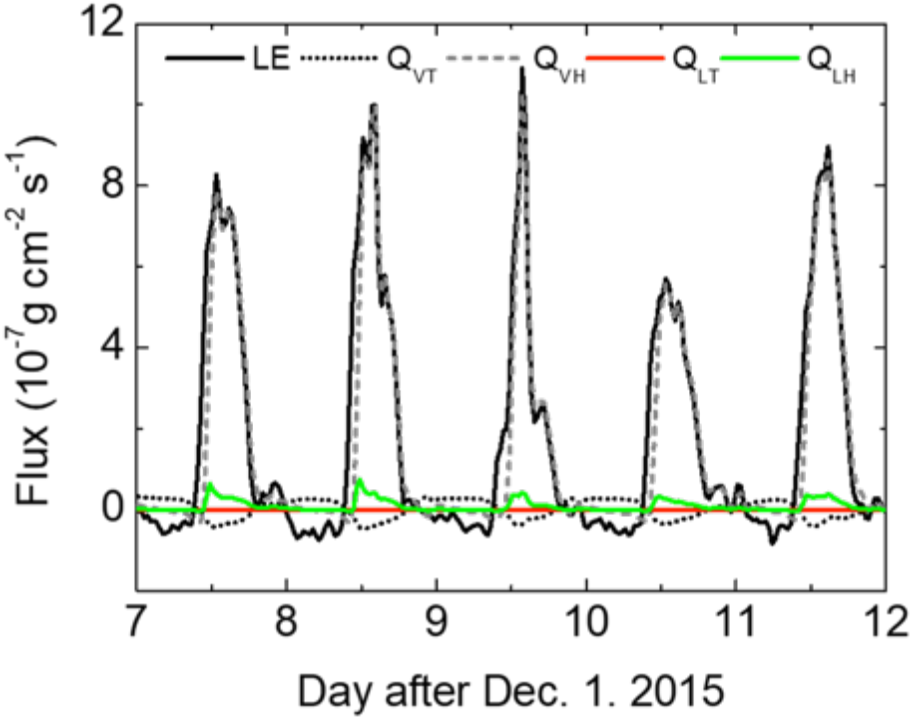
Freezing front increase along with the zero isotherm

Soil liquid water content behave differently

STEMMUS-FT results
Surface fluxes

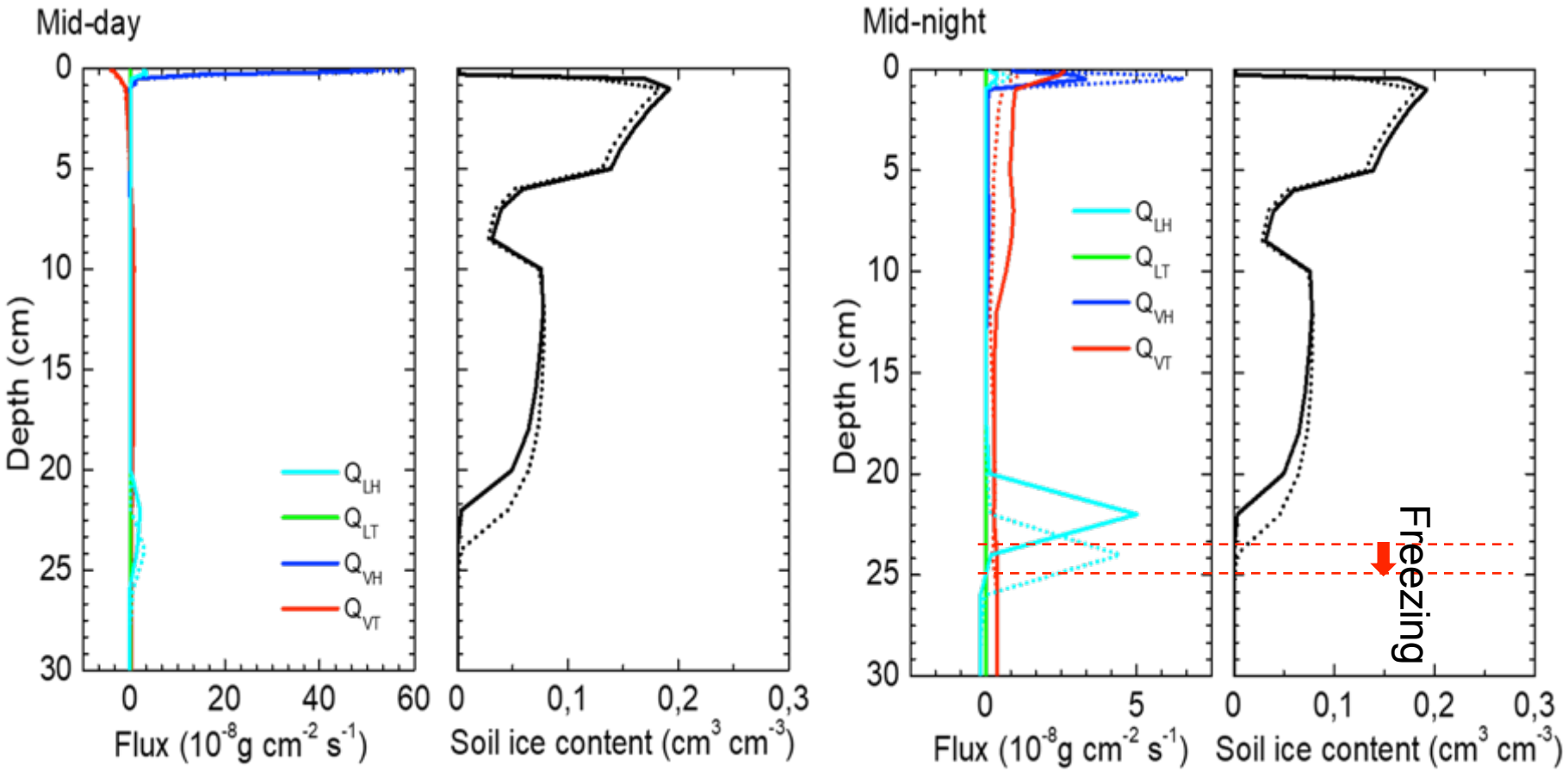


(a)Latent heat flux

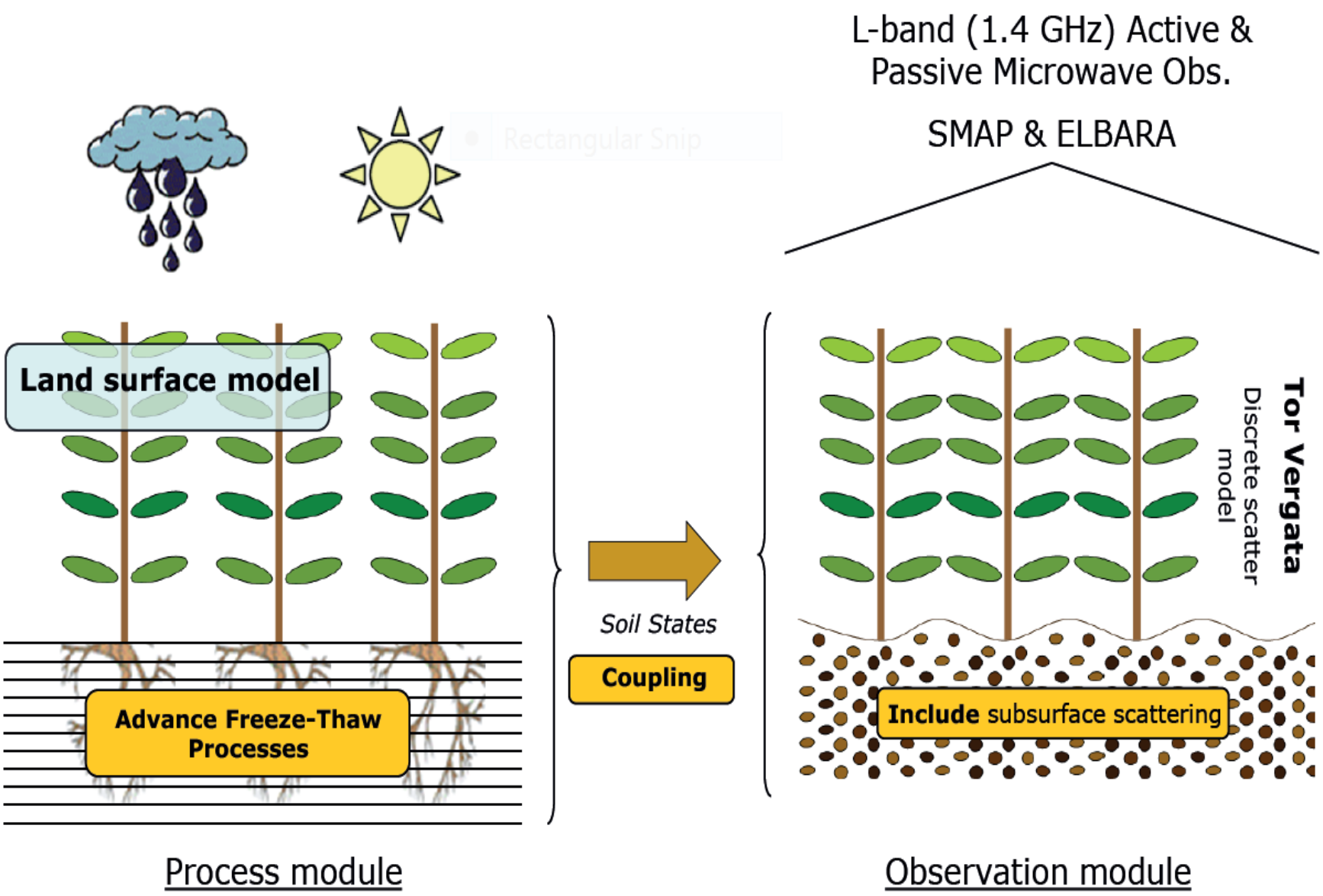


(b) Surface (0.1cm) thermal/isothermal liquid and vapor flux

What STEMMUS-FT model tells us?

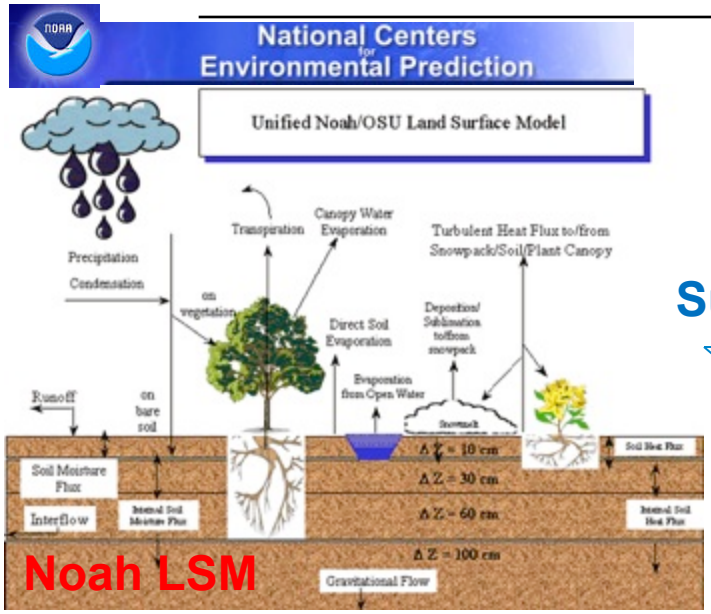


—— Solid lines: Dec. 11 2015 ------ Dashed lines: Dec. 12 2015



5. Coherent process modeling and radiative transfer modelling

Noah-Tor Vergata OSSE (Observation Opearator)



Surface SMST

Four Phase Dielectric Mixing Model

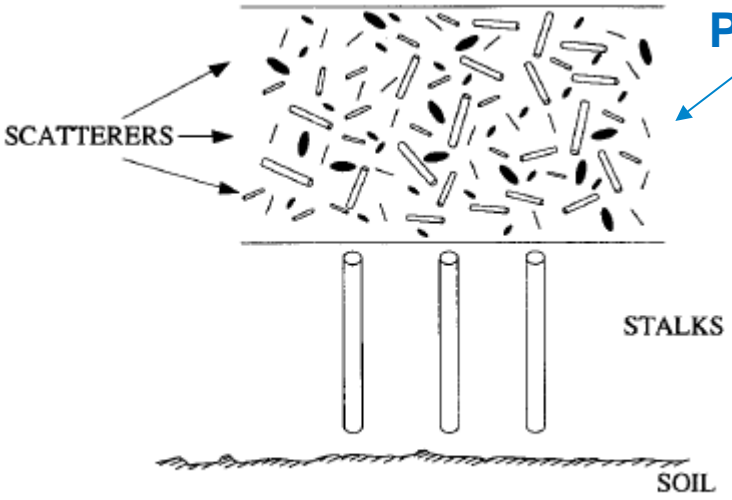
$$\varepsilon^{\eta} = (\theta_s - \theta)\varepsilon_{air}^{\eta} + \theta_{liq}\varepsilon_{w}^{\eta} + (\theta - \theta_{liq})\varepsilon_{ice}^{\eta} + (1 - \theta_s)\varepsilon_{matrix}^{\eta}$$

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

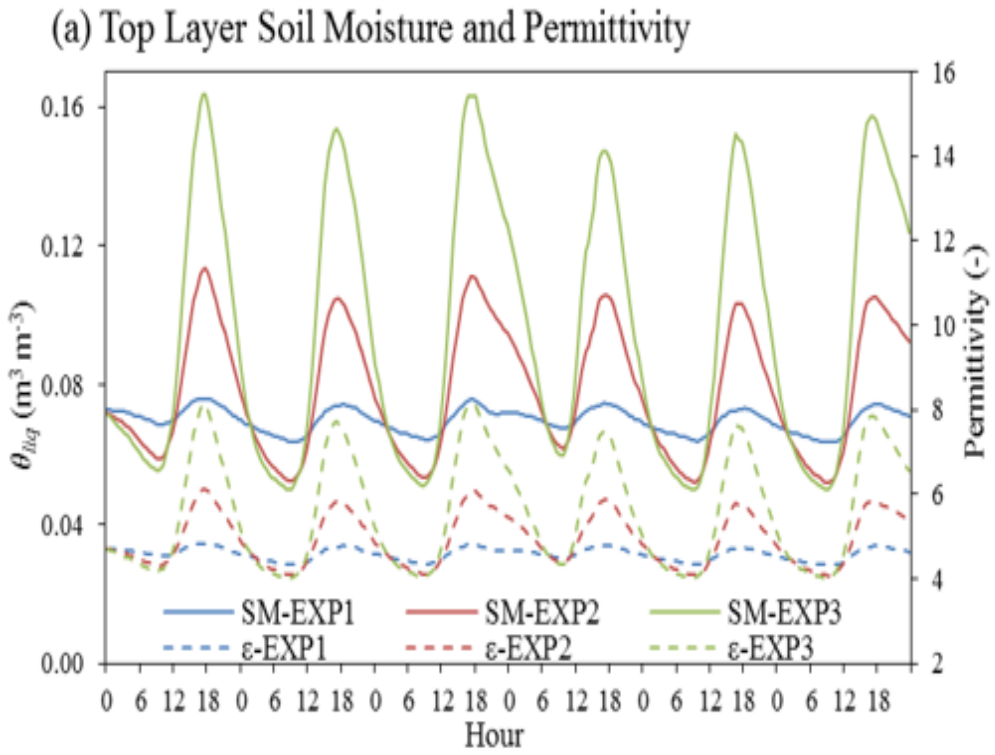
Noah-Tor Vergata Simulations

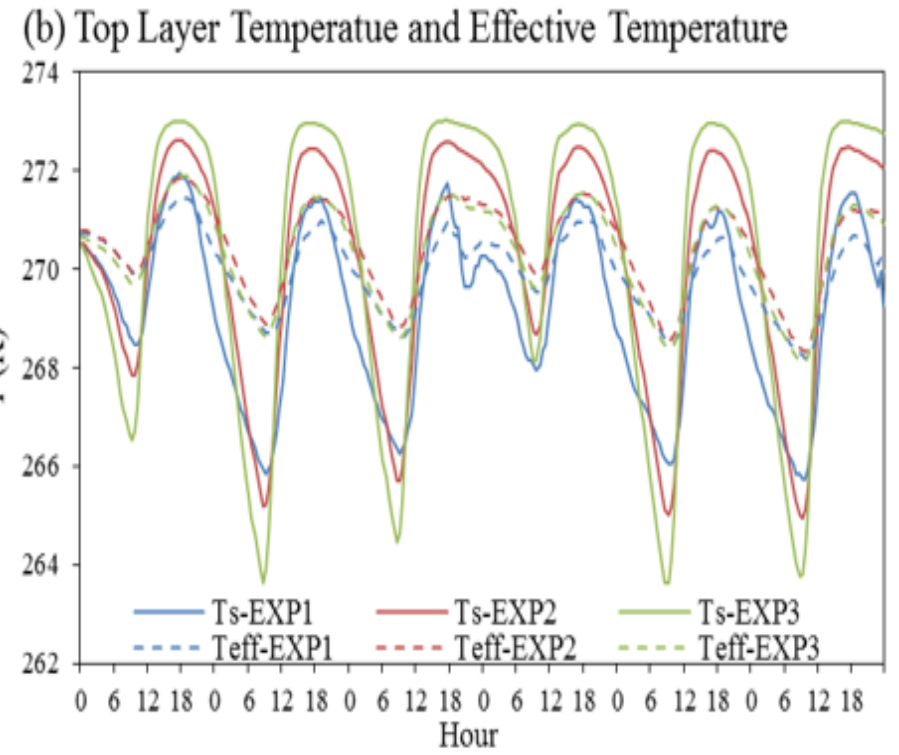
Frozen Period: DOY 1-6

EXP1: SMST in situ measurements at 5 cm

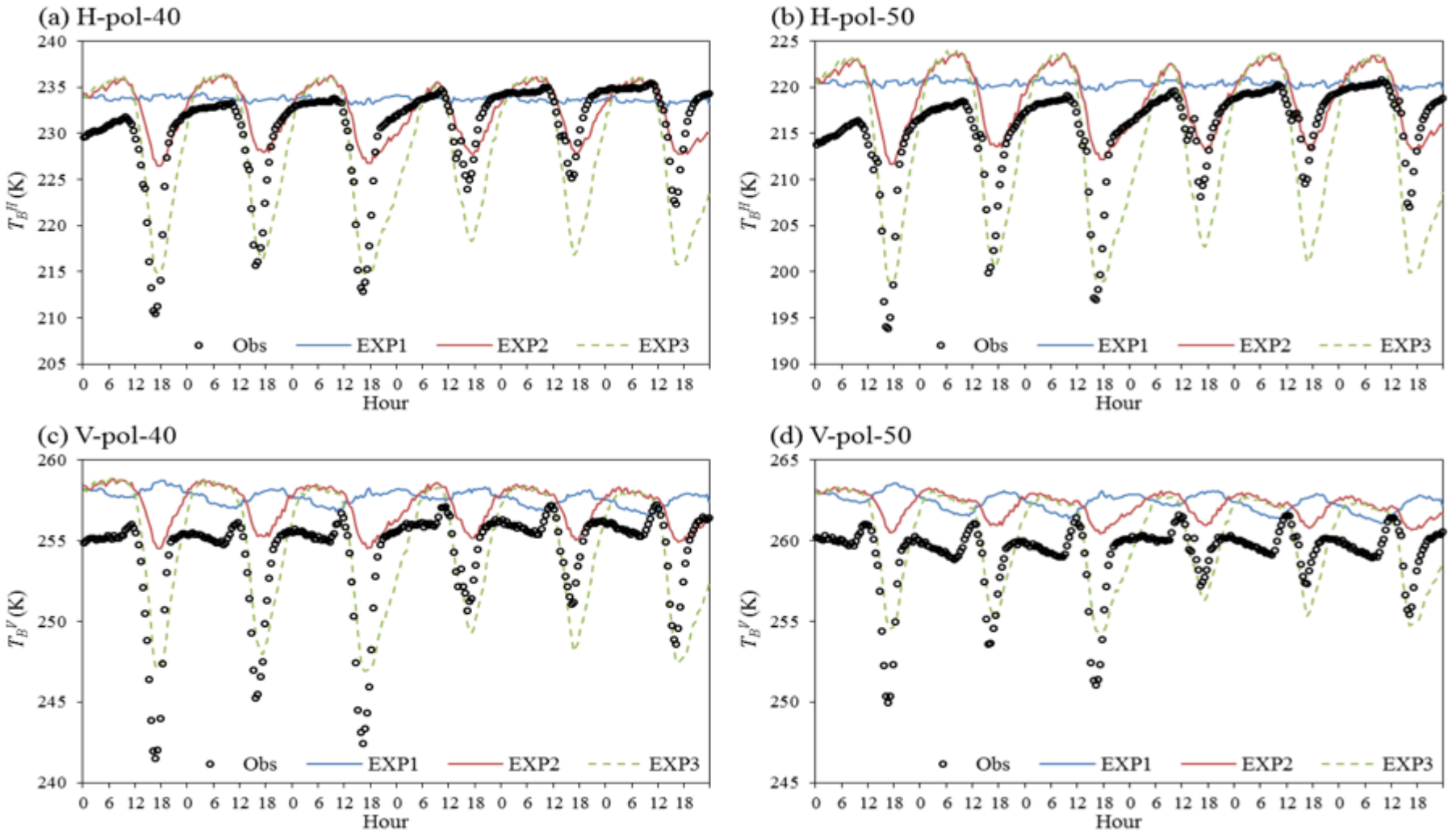
EXP2: SMST Noah 4-layer (0.1, 0.4, 1.0, 2.0) midpoint of top layer at 5 cm

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



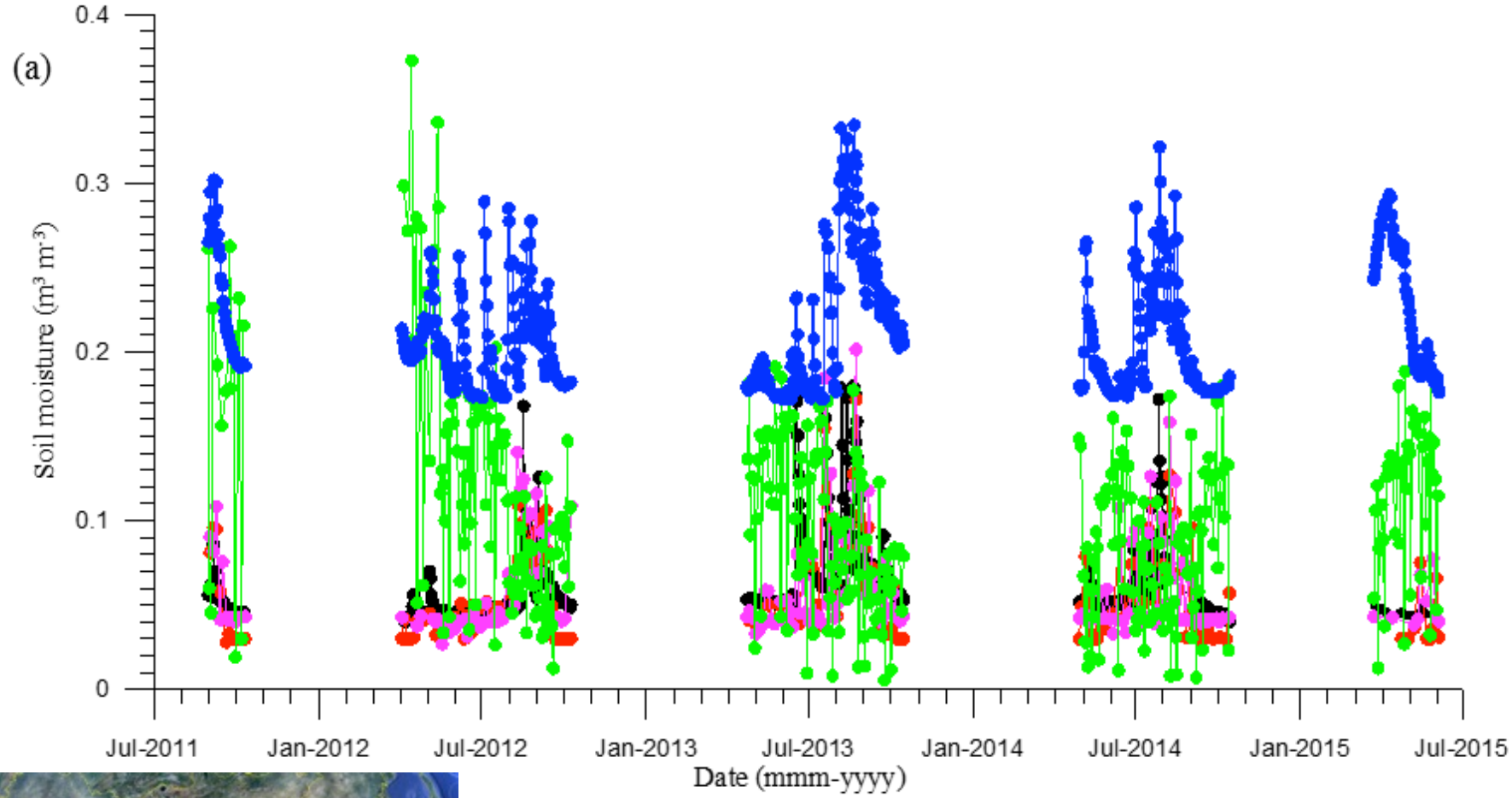


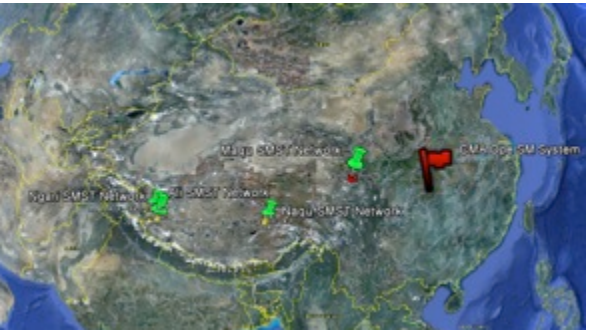
Noah-Tor Vergata Simulations



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

Implication for retrievals (Aquarius A/P)

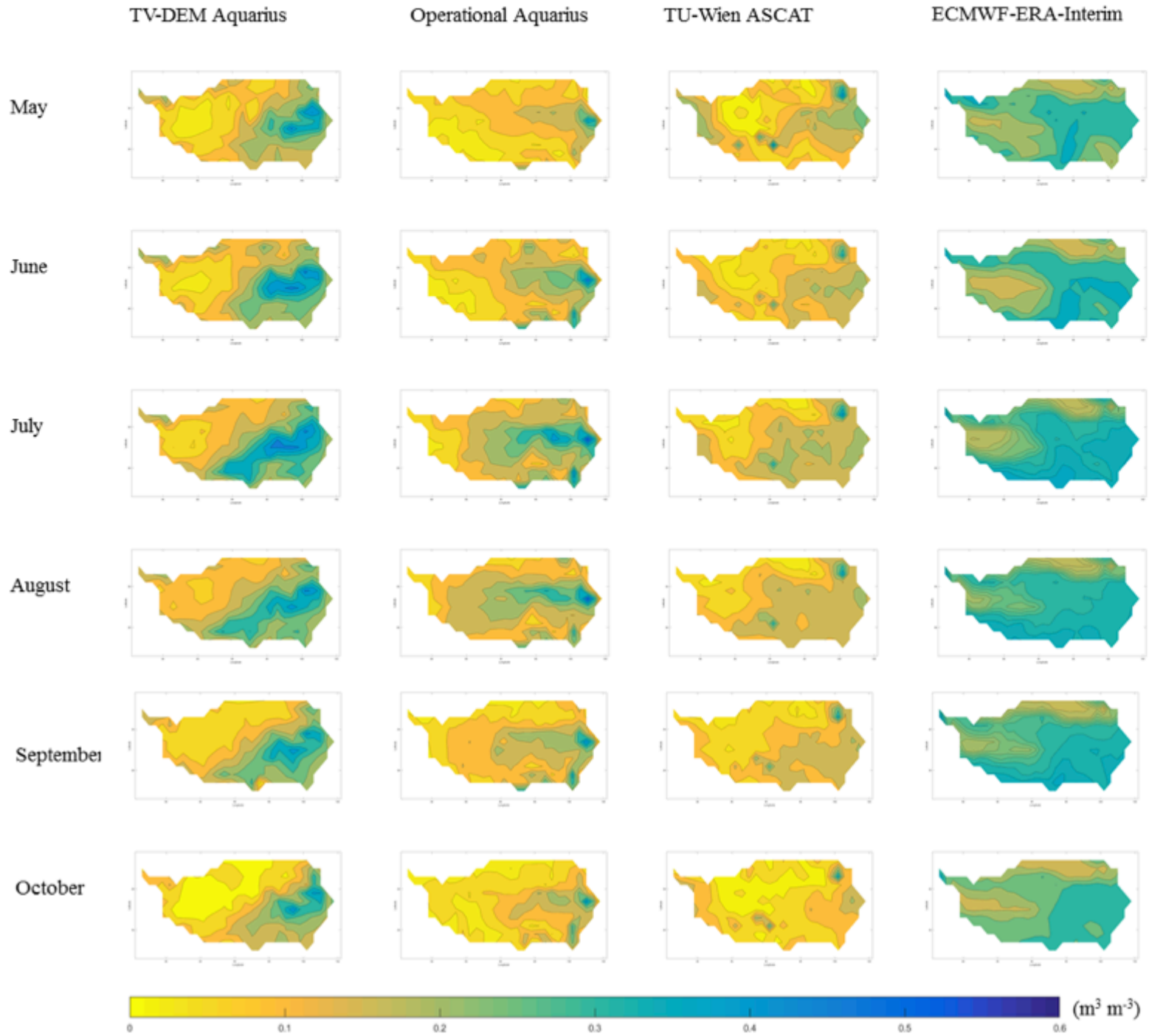




In-situ
TV-DEM Aquarius
Official Aquarius
TU-Wien ASCAT
ECMWF-ERA-Interim

(a) Ngari
(b) Naqu
(c) Maqu

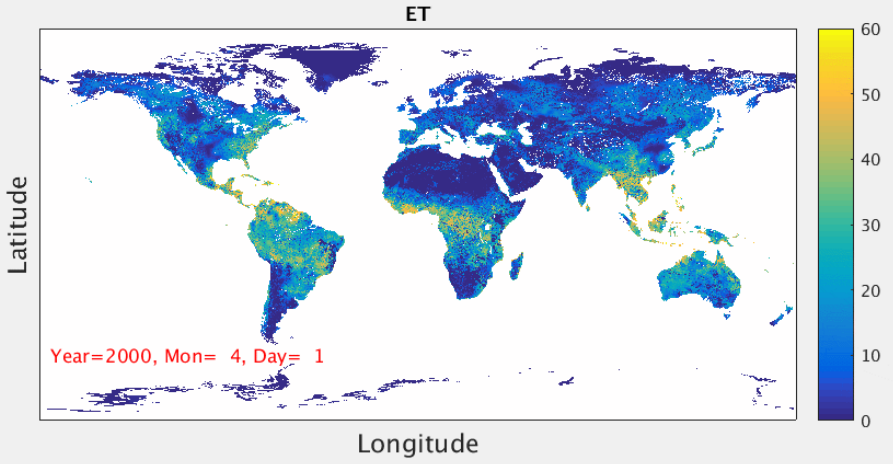
(Wang et al., 2017, RSE)

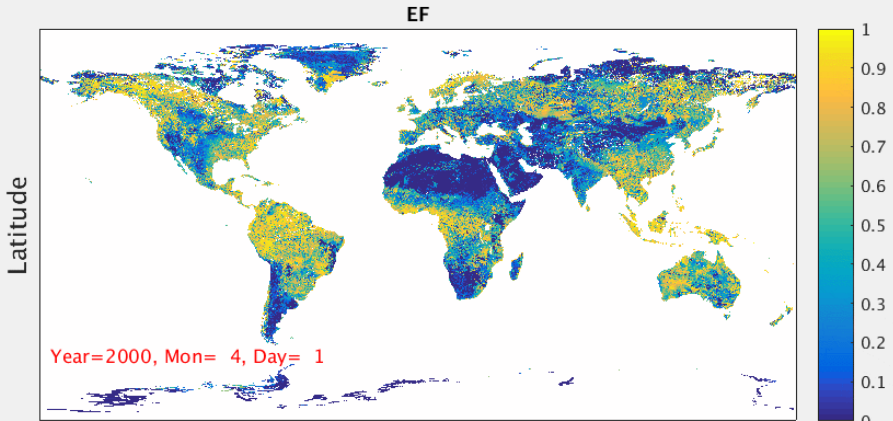


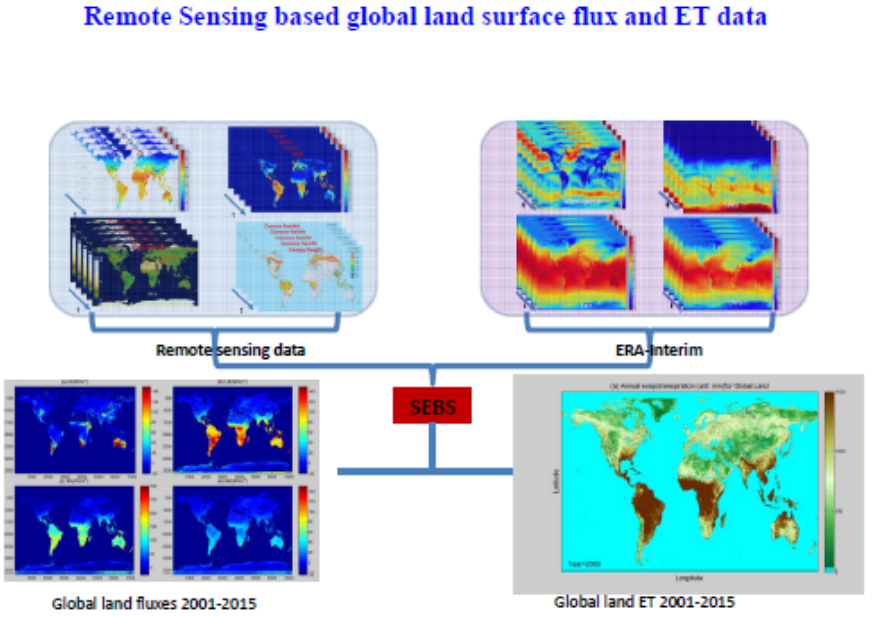
Implication for quantifying monsoon patterns

High Resolution Hydrologic and Ecosystem Fluxes

2000 – Near Present at 5km x 5km Daily

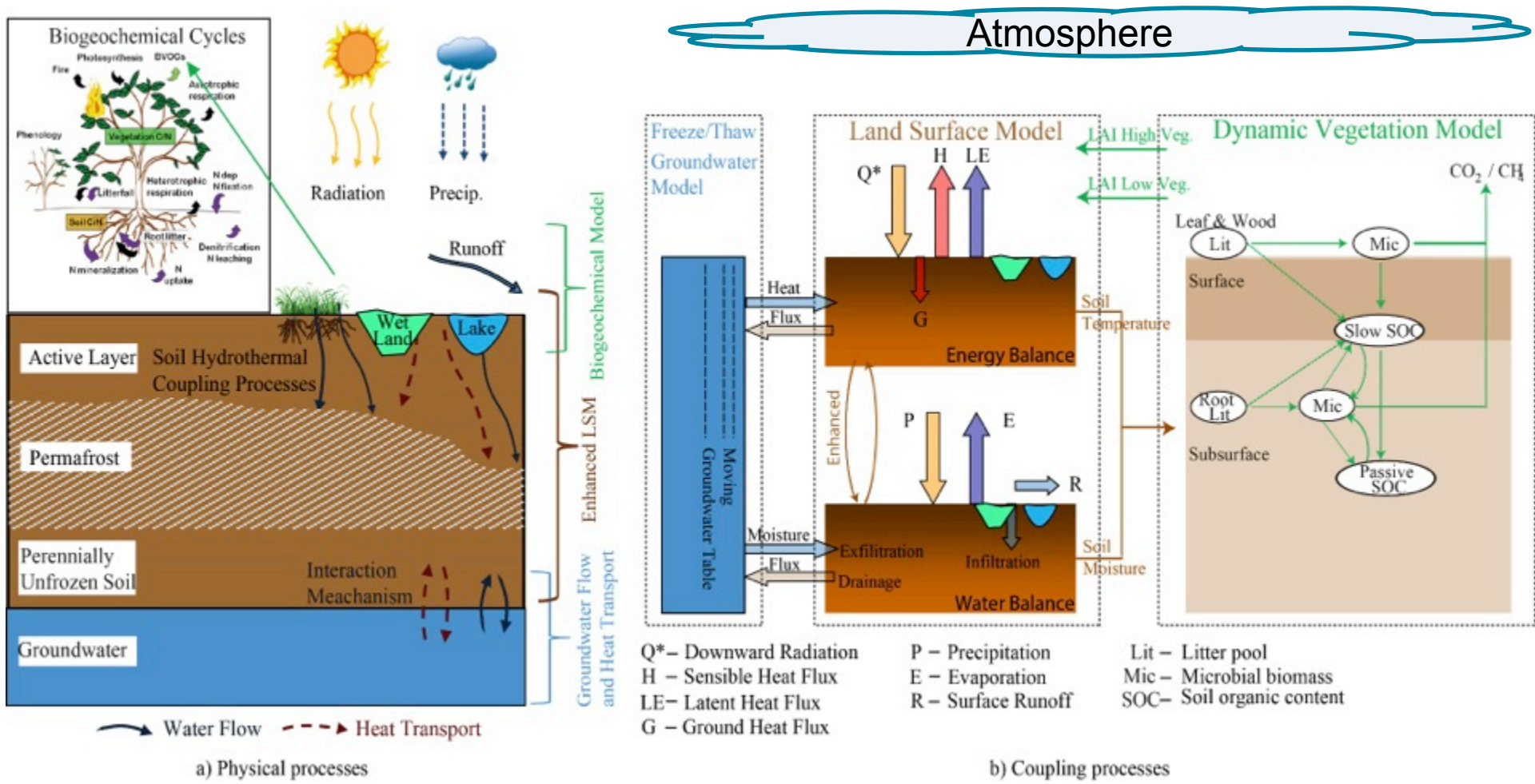






(Su, 2002, HESS; Chen et al., 2013, JAMC; Chen et al., 2014, ACP)

AN INTEGRATED MODELLING SYSTEM



as a contribution to NL EC-Earth System