Calibration and Validation Methodologies for SMOS/SMAP

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ITC GEO Soil Moisture Soil Temperature Networks
Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs) (Su et al. 2011, HESS)
Maqu: Soil moisture at 5 cm depth

- Organic soils
- Sandy loam soil
Validation - Quantification of uncertainties
(Su, et al., 2011, HESS)
How good is the satellite signal? (Tb)
How good is the satellite retrieval? (SM)
What is the spatial-temporal representativeness? (Pixel scale?)
Why does SMAP underestimate ELBARA Tb?

**DOY 1:**
01-01-2016

**DOY 40:**
10-02-2016

**DOY 60:**
29-02-2016
5. Coherent process modeling and radiative transfer modelling
Noah-Tor Vergata OSSE (Observation Operator)

Surface SMST

Four Phase Dielectric Mixing Model
\[ \varepsilon^n = (\theta_s - \theta)\varepsilon_{air} + \theta_{liq}\varepsilon_{w} + (\theta - \theta_{liq})\varepsilon_{ice} + (1 - \theta_s)\varepsilon_{matrix} \]

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

(Zheng et al., 2017, TGRS)
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

(Zheng et al., 2017, TGRS)
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
STEMMUS - Simultaneous Transfer of Energy, Momentum and Mass In Unsaturated Soil

http://blogs.itc.nl/stemmus/
STEMMUS-FT (Freezing/Thawing) model

**Soil Water Transport**

\[
\frac{\partial}{\partial t} \left( \rho_L \theta_L + \rho_V \theta_V + \rho_i \theta_i \right) = \\
\rho_L \frac{\partial}{\partial z} \left[ K \left( \frac{\partial h}{\partial z} + 1 \right) + D_{TD} \frac{\partial T}{\partial z} + \frac{K}{\gamma_w} \frac{\partial P_g}{\partial z} \right] + \frac{\partial}{\partial z} \left[ D_{vh} \frac{\partial h}{\partial z} + D_{vT} \frac{\partial T}{\partial z} + D_{va} \frac{\partial P_g}{\partial z} \right] - S
\]

**Soil Heat Transport**

\[
\frac{\partial}{\partial t} \left[ (\rho_s \theta_s C_s + \rho_L \theta_L C_L + \rho_V \theta_V C_V)(T - T_r) + \rho_V \theta_V L_0 - \rho_i \theta_i L_f \right] - \rho_L W \frac{\partial \theta_L}{\partial t} = \\
\frac{\partial}{\partial z} \left( \lambda_{eff} \frac{\partial T}{\partial z} \right) - \frac{\partial q_L}{\partial z} C_L (T - T_r) - \frac{\partial q_V}{\partial z} [L_0 + C_V (T - T_r)] - C_L S(T - T_r)
\]

**Soil Dry Air Transport**

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

(Zeng et al., 2011 JGR, Zeng et al., 2011 WRR, Yu et al., 2016, HESS)
Freezing front increase along with the zero isotherm

Soil liquid water content behave differently
Latent heat flux (10^{-7} \text{g cm}^{-2} \text{s}^{-1})

Day after Dec. 1. 2015

(a) Latent heat flux

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

Day after Dec. 1. 2015

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

- Process understanding based on measurements and modeling is of primary importance:
  - Cal/Val needed to assure the stability and truthiness of observations and retrievals
  - Spatial scaling remains a challenge – could UAS help?
  - Modeling and DA remains indispensable in understanding and efficient use of observations and retrievals