Optimizing land surface model for improved soil moisture estimation: Bridging the gap between simulation and satellite observations

Ashok Bhandari, Natthachet Tangdamrongsub

Water Engineering and Management(WEM), School of Engineering and Technology (SET), Asian Institute of Technology, Bangkok

Background

Soil moisture (SM) is key parameter for understanding interactions between the atmosphere and Earth's surface through energy and water cycles. The major Source of estimation of SM are land surface Models (LSM) and Satellite observations(SSM). SM estimation is hindered by spatial heterogeneity in soil, atmospheric, vegetation, and land use conditions.

There is a gap between LSM simulations and satellite observations, especially in regions like Southeast Asia like Thailand, affecting SM prediction. So, for the proper representation of land-atmosphere interactions optimization of LSM is important which will be done by adjustment of physics and parameters following satellite observation and checking the performance over other hydrological states.

Optimization

- Model : **Noah-MP 3.6** , Satellite observations : **SMAP**
- Model spin up to 3 times.[2010-2023]
- Forcing Dataset : ERA5
  - ✓ Temporal range: 2010-2023
  - ✓ Resolution = 0.250 x 0.250
  - ✓ Data interval: 3 hourly

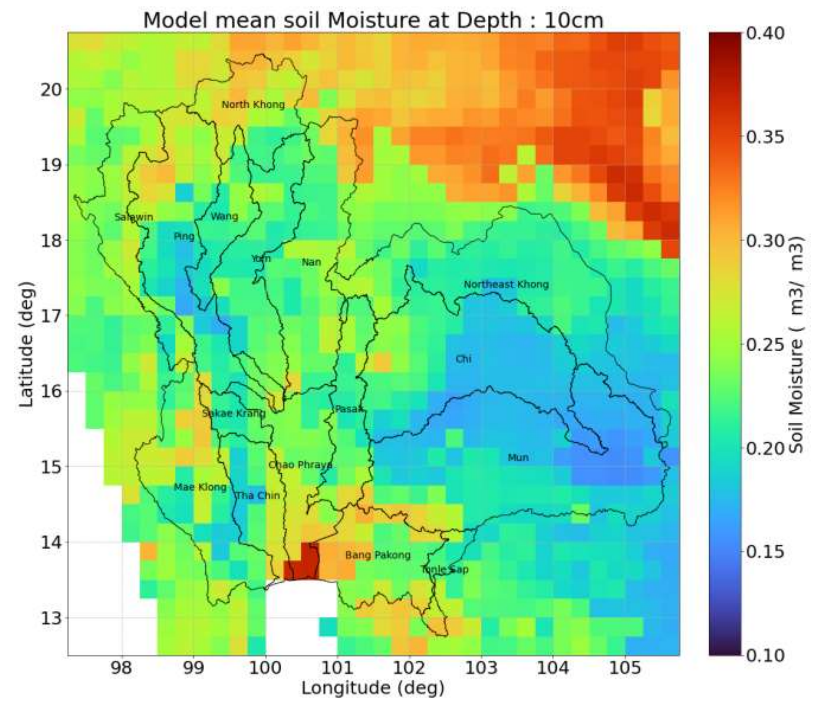
572 experiments to be performed on the following applicable physics options and compare with SMAP on various scenarios.

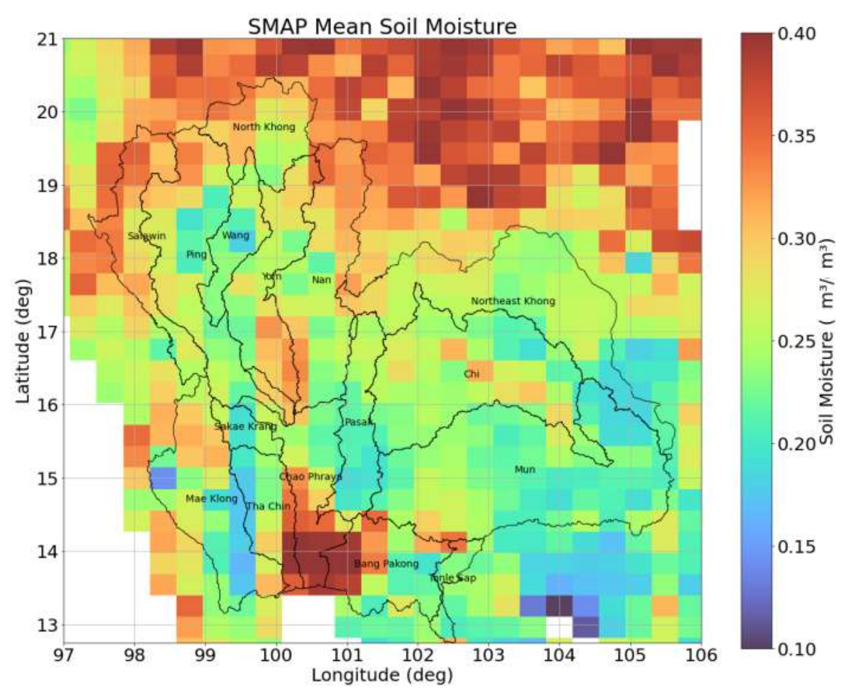
Parameter	Noah-MP 3.6 Physics options
Vegetation Model	1 = Prescribed; 2 = Dynamic; 3 = Calculate; 4 = Maximum
Canopy Stomatal Resistance	1 = Ball-Berry; 2 = Jarvis
Soil Moisture Factor for Stomatal Resistance	1 = Noah; 2 = CLM; 3 = SSiB
Runoff and Groundwater	1 = SIMGM; 2 = SIMTOP; 3 = Schaake96; 4 = BATS
Surface Layer Drag Coefficient	1 = M-O (Monin-Obukhov); 2 = Chen97
Radiation Transfer	1 = Gap=F(3D; cosz); 2 = Gap=0; 3 = Gap=1-Fveg
Lower Boundary of Soil Temperature	1 = Zero-flux; 2 = Noah

Result

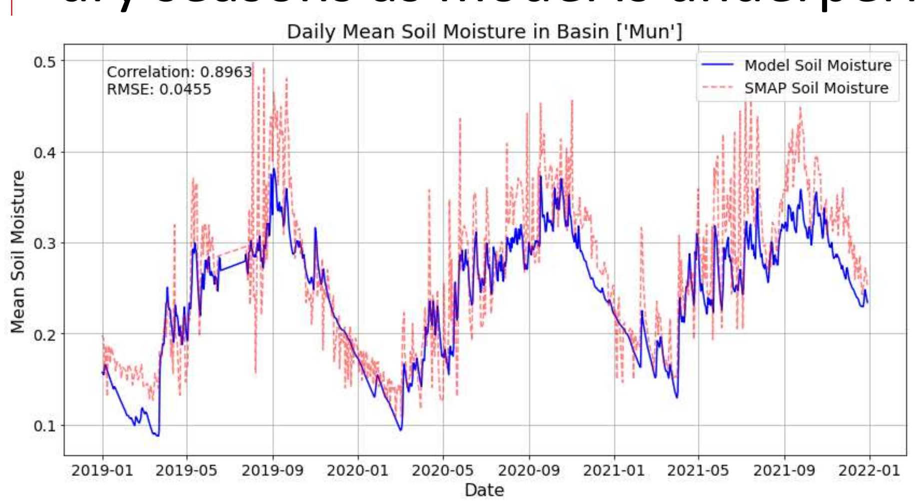
Optimal parametrization scheme with the physics are vegetation model [2], stomatal resistance[1], SM factor [1], drag coefficient [1] , runoff [4] , soil temperature [3]. The improvement on correlation coefficient is overall 10% and vary with scenarios.

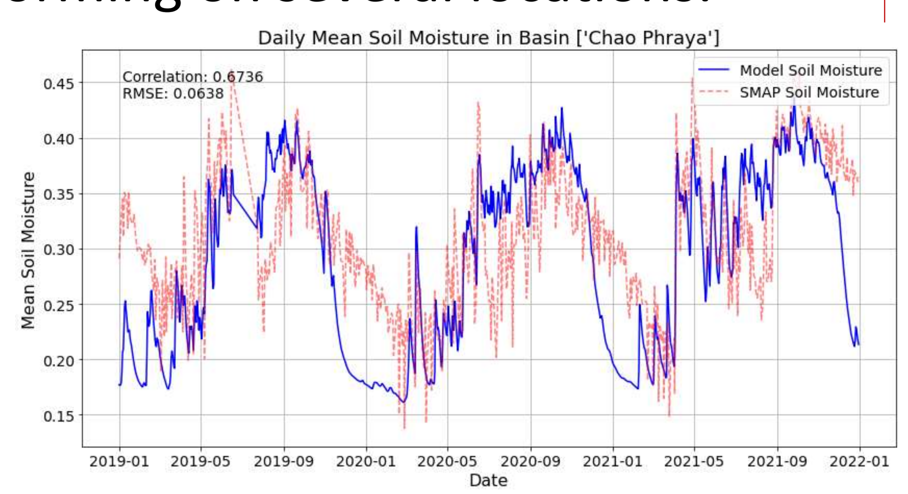
Scenario	Default	Optimized	improvement
pixel wise	0.589	0.648	10%
basin average	0.679	0.795	17%
SM>0.25	0.6	0.678	13%
SM<0.25	0.55	0.59	7%





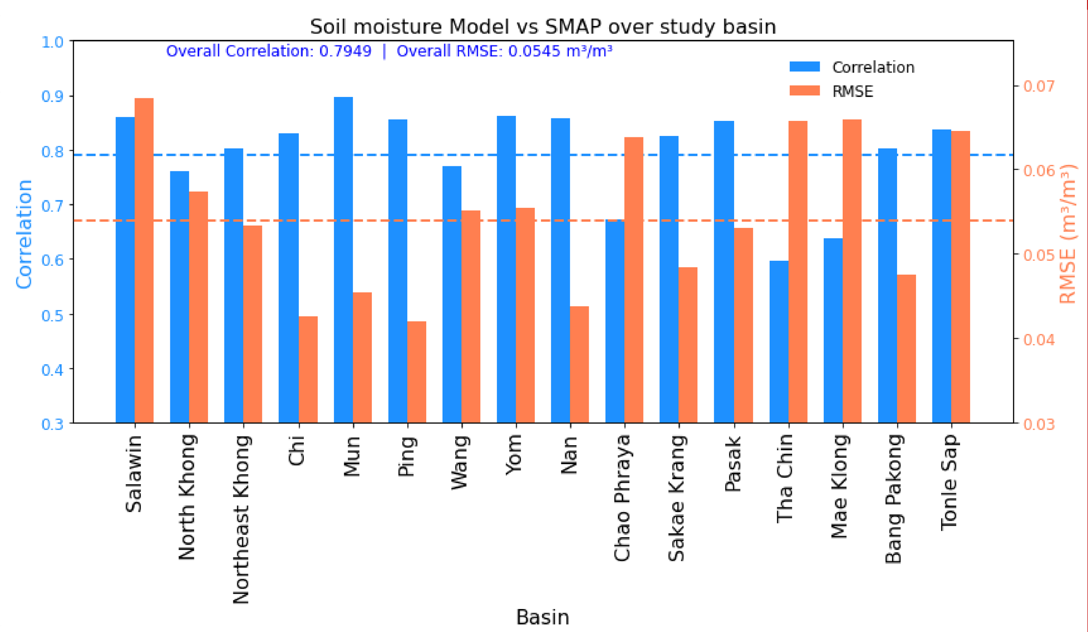
Significant discrepancies in soil moisture estimates during Thailand's dry seasons as model is underperforming on several locations.





Monsoon season have better correlation whereas the rmse error is lowest in the Winter season with overall correlation as 0.79 and rmse as 0.0545m^3/m^3. The performance of the model is better in Mun basin and lowest in Chao-praya basin.

Season	r	RMSE
Summer	0.777	0.06
Monsoon	0.828	0.041
Winter	0.728	0.03
Land use		
Cropland	0.68	0.07
Forest	0.63	0.05
Builtup	0.57	0.07



Conclusion

The model's performance was enhanced by incorporating dynamic vegetation, which accounts for changes in vegetation cover and its impact on soil moisture, evapotranspiration, and overall water use efficiency.

The improvement in soil moisture has limitation in areas with low values, as the irrigation scheme dominates across different regions. The choice of model physics depends on the specific area being studied, considering factors like land use, soil type, seasonal changes, and time variations. Physics configurations are tailored to address these conditions for accurate representation of soil and water dynamics.

Development

Further improvement on soil moisture by updating soil texture parameters and optimal soil depth for simulating surface soil moisture.

Performance evaluation of improved SM parametrization over other hydrological components and respective satellite / observations is underway where the comparison is done as LAI vs GLASS,, Evapotranspiration vs GLEAM, Total water Storage vs GRACE , GPP vs MODIS, water table vs observation well, Streamflow vs Observed station.

Likewise, model's ability to capture the extremes requires to be analyzed for preparing the long-term soil moisture database and evaluate drought severity indices. This kind of database will be used for the preparation of agriculture decision support system.

Contact

Ashok Bhandari
Email: er.ashokbhandari@gmail.com
Current: ME in WEM, AIT