The impact of Land Surface Models (LSMs) change in the Korean Integrated Model (KIM)

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1 Background

- The operational KIM employs the Noah LSM which is relatively simple (bulk form)
- Noah is an efficient model but often hinders explicit computation and the additional land surface processes. It is also known to be improper for middle or long-term predictions
- For better prediction, KIM is necessary to couple with more advanced LSMs such as multi-parameterization option (NoahMP) and Community Land Model (CLM)
- Noah-MP has advanced hydrology, vegetation processes including the big-leaf scheme, and more soil layers. KIM-NoahMP coupling is recently completed and under stabilization
- CLM is known to be a state-of-art LSM having more advanced physics and detailed land surface processes. CLM-KIM coupling is underway.

2 Objectives

1. To compare the performance of three LSMs in the framework of KIM
   - ✓ To test the consequences triggered by replacing Noah with NoahMP. The replacement may significantly affect current KIM's performance
   - ✓ Examine CLM by off-line test to compare with Noah and NoahMP
2. To test the application of CLM physics and sub-data to NoahMP

3 Methods

Model Comparison Method and Setup

- The comparison test used KIM-Noah and KIM-NoahMP coupled models and CLM offline models using forcing data produced by KIM-Noah. This experiment was performed for one year in 2017. KIM model used a NE045 grid which has about 100km grid size.
- CLM used about 1 degree scale (0.9x1.25_gx1v6) and followed GSWP3.0v1 (0.5x0.5) forcing format
- The test simulation for the updated NoahMP considered a few week's time span and a NE180 grid scales (~25km)

Update Case: LAI/SAI

- Noah, NoahMP, and CLM use different LAI/SAI values. CLM LAI data is made based on MODIS but Noah and NoahMP use a table. Noah LAI is unrealistically high and NoahMP has an abnormal seasonal cycle. Noah does not consider SAI and NoahMP set SAI as LAI*0.1 if not use the table but CLM uses MODIS SAI data.
- This Case Study : Apply CLM LAI/SAI scheme to NoahMP

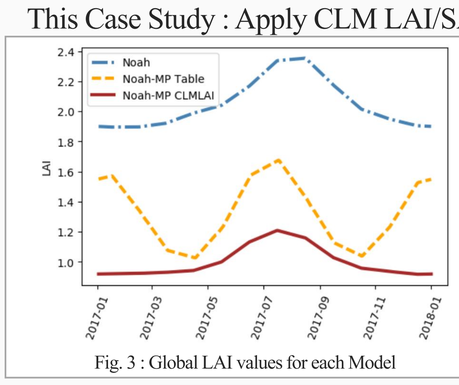

Fig. 3 : Global LAI values for each Model

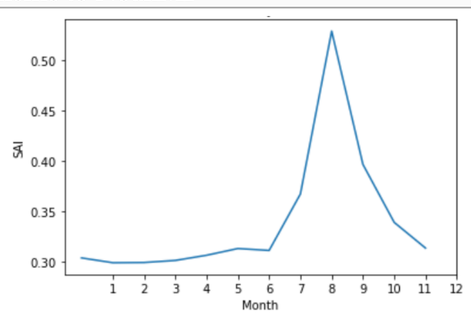

Fig. 4 : Global SAI values for each Model

Update Case: Soil Evaporation

- KIM-NoahMP is known to have a cold bias in T2M in the winter. Updating the soil evaporation model may reduce such errors.
- CLM4.5 and NoahMP employ the same soil evaporation model (Sakaguchi and Zeng [2009]) which still relies on experiment parameters.

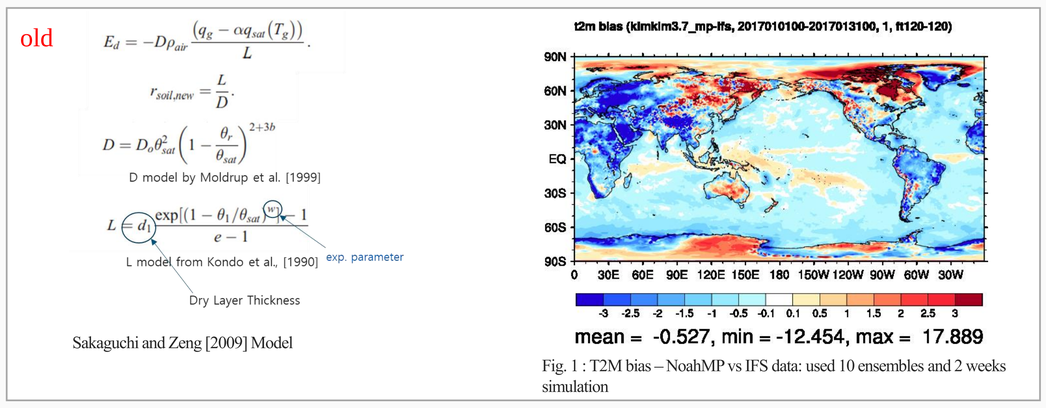

Fig. 1 : T2M bias – NoahMP vs IFS data: used 10 ensembles and 2 weeks simulation

- Swenson and Lawrence [2014] pointed out the soil water loss problem and suggested a new method which is selected in CLM5. How about NoahMP?

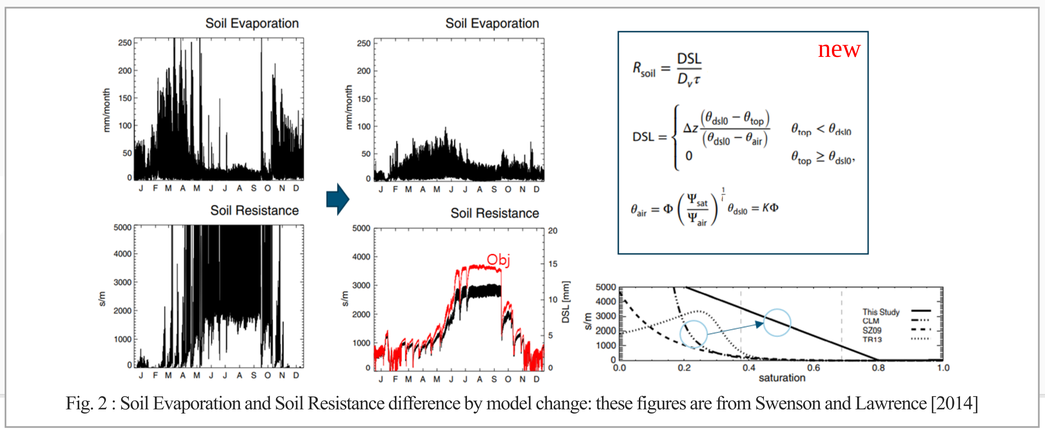

Fig. 2 : Soil Evaporation and Soil Resistance difference by model change: these figures are from Swenson and Lawrence [2014]

Model Comparisons –Surface Fluxes

- Compared to the climatological results of KIM-Noah, the surface albedo is satisfactorily simulated by CLM, while NoahMP highly underestimates it in the global aspect: NoahMP's albedo is about 0.05 lower at high latitudes in the cold season, thereby overestimating the surface temperature in the northern hemisphere.
- Despite the similar surface albedo with KIM-Noah, turbulent heat fluxes are apparently lower than the other models in CLM, which implies that their land surface processes are systematically different.

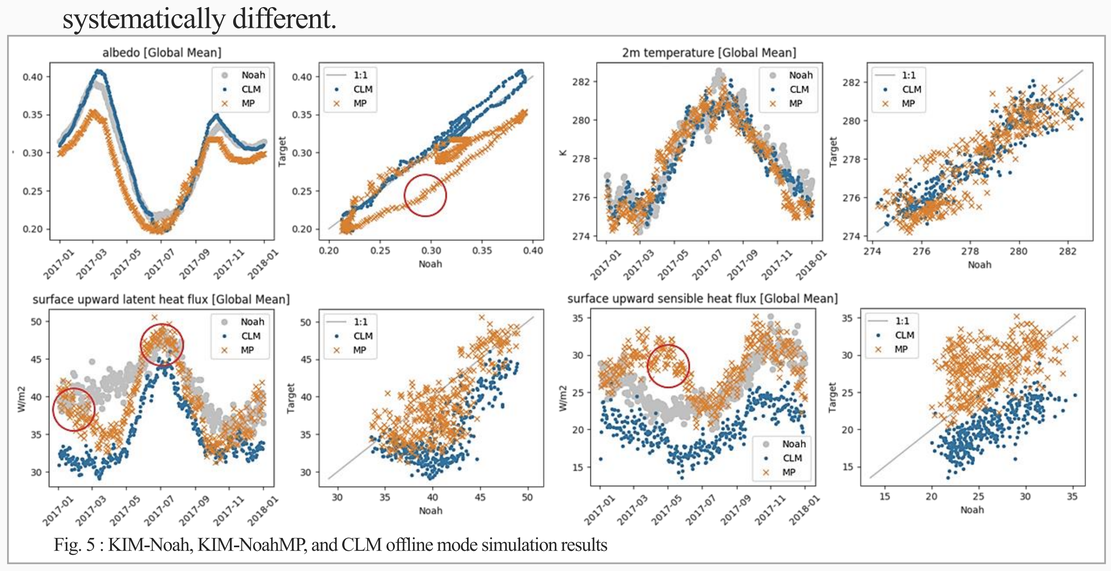

Fig. 5 : KIM-Noah, KIM-NoahMP, and CLM offline mode simulation results

Update Case: LAI/SAI

- Updating the LAI of NoahMP model reduces the bias of albedo significantly. Also, it alleviates abnormal seasonal variation for latent and sensible heat fluxes.

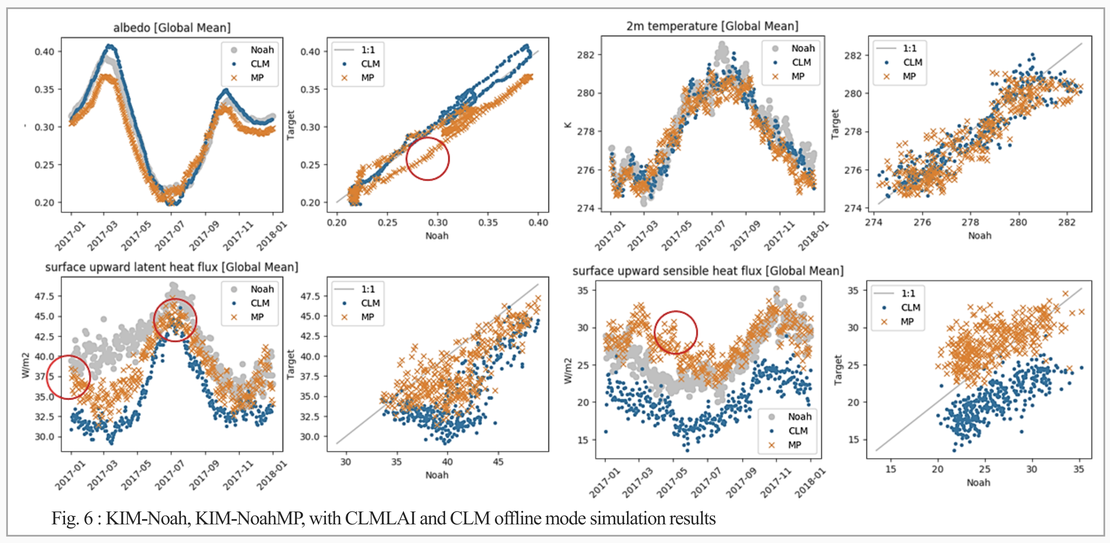

Fig. 6 : KIM-Noah, KIM-NoahMP, with CLMLAI and CLM offline mode simulation results

- Updating the SAI of NoahMP reduces the bias of T2M

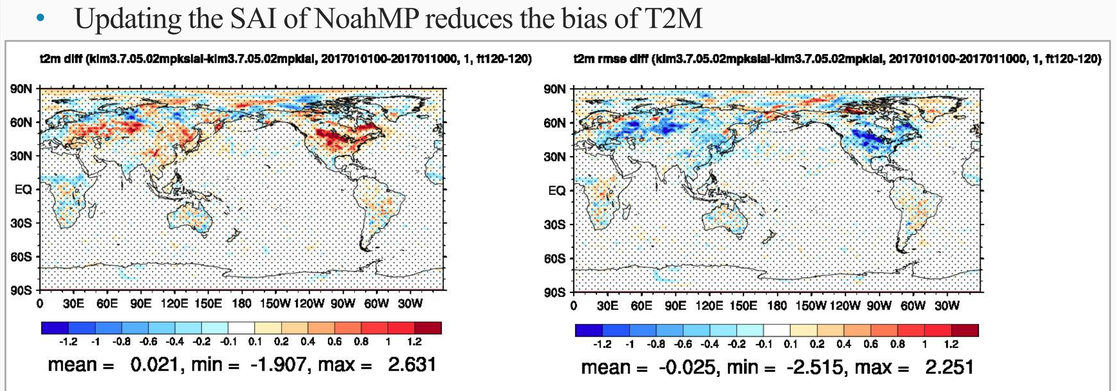

Fig. 7 : T2M difference and bias for original KIM-NoahMP vs KIM-NoahMP with CLM SAI: used 10 ensembles and 10 days predictions

Update Case: Soil Evaporation

- by updating the soil evaporation model, global temperature has been increased which results in reduced cold biases that appeared in the original KIM-NoahMP

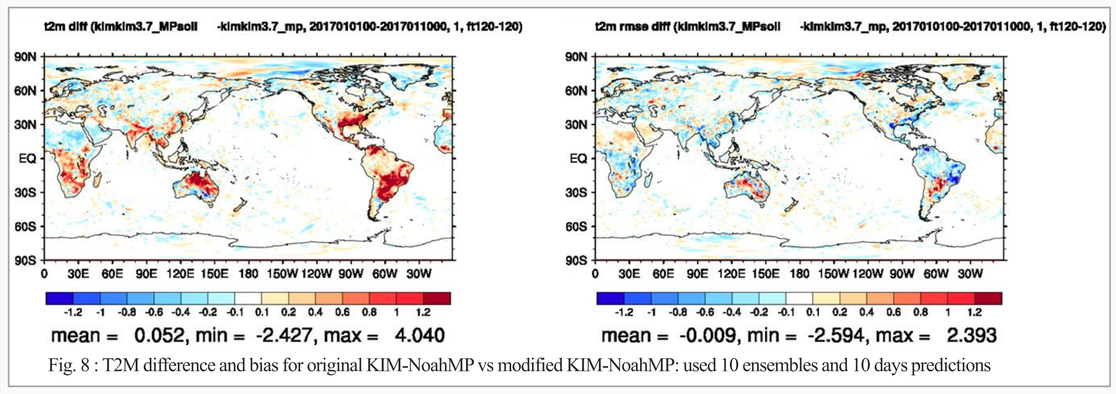

Fig. 8 : T2M difference and bias for original KIM-NoahMP vs modified KIM-NoahMP: used 10 ensembles and 10 days predictions

5 Conclusions

- Replacing KIM's Noah with Noah-MP results in large changes to some variables such as albedo and fluxes due to model system changes. Stabilization is necessary.
- CLM predicts Noah-like albedos, but the latent and sensible heat fluxes differ significantly, meaning that their surface processes are systematically different. Need to test under fully coupled system. The KIM-CLM coupling system will be released soon!
- By adopting the CLM's soil evaporation model and LAI/SAI scheme, KIM-NoahMP shows some improvements. Employing new sub-model or scheme like CLM sub-process to the NoahMP for stabilization is promising

「6th WGNE workshop on systematic errors in weather and climate models」 ECMWF, Reading, October 31 to November 4, 2022