Response to Referee (#2)

Ms. Ref. No: GMD-2022-311

Title: Developing Spring Wheat in the Noah-MP LSM (v4.4) for Growing Season Dynamics and Responses to Temperature Stress
https://doi.org/10.5194/gmd-2022-311

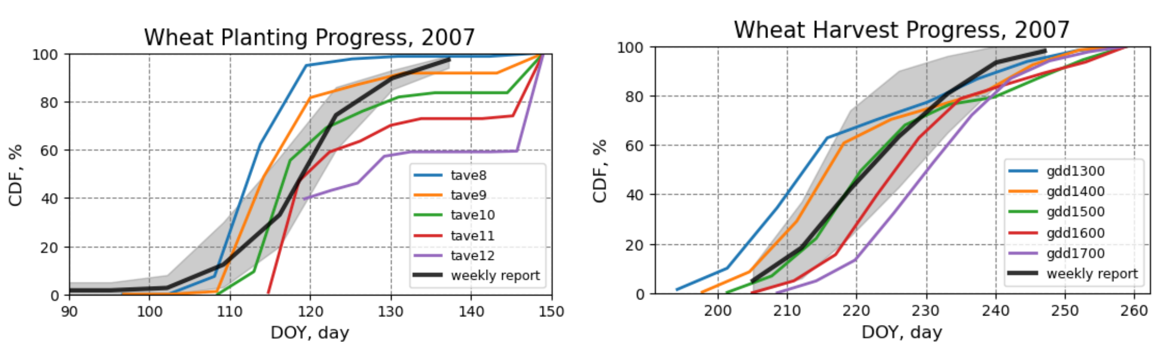
Crop growth and yield simulations in land surface models are crucial for both crop yield projections and the land-atmosphere interactions. Noah-MP is the latest generation of Noah land model. The authors added spring wheat growth (including dynamic planting/harvest and the temperature stress) into Noah-MP which improved its capabilities in application over the area where the spring wheat is the major crop. The manuscript is well written and there are only minor comments before considering for publication.

We gratefully thank the reviewers for their comments and suggestions, which we believe have substantially improved the original manuscript. The original reviewers' comments are reproduced below in black text and the corresponding response is shown in blue text.

Minor Comments:

Even though the authors mentioned that the 10 oC is based on a global synthesis of planting and harvest dates, the thresholds in equation 3 and 4 are quite arbitrary. I suggest to do some sensitivity analysis by adjusting the thresholds and show the current thresholds are reasonable for the region.

This is a great suggestion and we really appreciate it. We conducted sensitivity analyses on these two thresholds, TAVE and GDD, for one year (2007). The model results are compared with the weekly crop progress report provided by USDA, for planting and harvest (see figure below).



Cumulative distribution function (CDF) of the planting and harvest date from five parameter sensitivity analyses (TAVE=8, 9, 10, 11, 12 ℃ for planting and GDD=1300, 1400, 1500, 1600, 1700 for harvest). The weekly progress report from USDA is also presented, with gray shaded areas indicating spatial variation for three states (North Dakota, South Dakota, and Minnesota).

Both parameters demonstrate strong influence on planting and harvest date in the North Great Plains region and indicate that average temperature and cumulative heat unit (e.g. GDD) have strong control of the management process on a large regional scale. These two figures show that the two parameters used in our study (TAVE=10 and GDD=1500), obtained from the global synthesis of Sacks (2010), are reasonable.

In addition, we are currently developing a more comprehensive dynamic planting/harvest model, aiming to address the connections between interannual variability of growing season climate and planting/harvest date and areas. This model will involve not only average temperature and GDD, but also consider water availability, such as soil moisture. We will add this to the discussion of the manuscript.

For the regional simulation, the authors used 4-km resolution atmosphere forcing data. Could you prove the 4-km resolution yield a better LAI and yield simulation than other coarse resolution forcing, such as CRUNCEP? I'm curious for the regional averaged crop LAI and yield, will the coarse forcing showed a similar result as the 4-km high resolution.

Thank you for this great question. As for the CRUNCEP data, the dataset is 0.5° x 0.5° spatial resolution and 3-hourly temporal interval. We didn't perform simulations for coarse resolution forcing but it is an interesting question to explore for those who are interested.

We used the 4-km resolution forcing for two reasons: (1) the high-resolution convection-permitting forcing provides more reasonable precipitation, without using the convection parameterization scheme; (2) the high-resolution model grids better resolve surface representation, such as topography, land use, etc. These two advantages enable the model evaluation with available dataset, such as MODIS LAI at 500-m and USDA NASS crop yield at county-level.

With limited data (for example crop yield) or regional average analysis, the fine-resolution forcing may lose a lot of spatial details and prohibit the evaluation of high-resolution LAI data, as we shown in Figure 8 with the dynamic planting scheme. Thus, the advantages of high-resolution forcing don't stand out.

It is also worth noting that high-resolution dataset allows landowners and agencies to make decisions and policies. It is at this level where high-resolution forcing may provide more detailed information that coarse resolution data cannot. That's why we used 4-km forcing in the beginning.

In figure 5, adding the spring wheat model improved LH, but showed poor soil moisture simulations than the default model. Please comment on how to fix this problem in Noah-MP.

Thank you for this question. Figure 5 shows the new wheat model presents increased LH and reduced SH, but reduced soil moisture compared to default and observation. This could be due to two reasons. The first reason is the initialization of model states, such as soil moisture, snow in spring, etc, i.e. the model is drier than the observation when it starts. However, as the station was established in 2016 and a short period of data was used to initialize the model states. Therefore, discrepancies of soil moisture were found at the beginning of the simulation, in 2016 and SW30-2019. However, these discrepancies vary site by site - in 2019, SE13 site presents better soil moisture results compared to SW30, especially the second layer depth.

The second reason may be due to shallow groundwater aquifers in the Canadian Prairies. There is shallow groundwater less than a few meters deep in the Canadian Prairies, supplying unsaturated soil moisture during the growing season when the ET demand is strong. This shallow groundwater contributes nontrivially to the total water budget in the Canadian Prairies, but is particularly hard to represent in a single-point model. We had a paper discussing the groundwater contribution to the region's water budget under current and potential future climate (Zhang et al., 2020: https://doi.org/10.5194/hess-24-655-2020), and we will add this information in the discussion of this manuscript.