A Point-by-Point Response to Comments of Reviewer #1

Dear Reviewer,

Thank you for the constructive comments. We have carefully studied your comments and carried out revisions accordingly. Below is a point-by-point response (marked as red) to the review comments. We hope you find our responses adequately address your comments and the revisions acceptable.

Sincerely,

Cenlin He (on behalf of all co-authors)

Reviewer #1:

This manuscript describes the modernization and refactoring of the widely-used state-of-art Noah-MP LSM, which was released as Noah-MP v5.0. The mordent Fortran code and data structures and standards are adopted in the refactoring. Five key features, including re-organized model physics inro individual process-level Fortran module files, enhanced data structure, enhanced code structure, self-explanatory variable naming standard, and enhanced interface structure to couple with the host models are introduced. It is introduced that the latest released Noah-MP has been coupled with NCAR/HRLDAS system. Some benchmark simulation results over the CONUS are presented. The work of coupling the Noah-MP v5.0 with the latest NASA/LIS system and the WRF-Hydro/NWM system is on-going. In the future, it is also plan to couple to other weather and climate models.
The original code of the model is lengthy single Fortran file. One has to read through the whole file and locate places interested. The refactoring procedures provide a modernized and interoperated model system, with which users could easily understand, modify or utilize in wide applications. As an open-sourced model, the simulation results should be reproducible with given forcing datasets. It is a substantial contribution to modelling science within the scope of Geoscientific Model Development. The manuscript is logical clearly, concisely, and well-structurally interpreted. In addition, model refactoring is a burdensome but less productive task. Not much people have willingness to do this work. This manuscript describes the refactoring conception and processes of the widely-used land surface model. For this kind fundamental work, encourage and circulate should be deserved. I think it is acceptable with minor revisions.

Response: We thank the reviewer for the positive comments. We have provided a point-by-point response below. The page and line numbers in our responses are referring to the track-change version of the revised manuscript.

The manuscript detailed describes the model structures, and what have been done with the model coupling to HRLDAS. My only concern is about the future plans. It is stated that the Noah-MP v5,0 will be coupled with more host models. It is encouraging. However, every model has its discrepancies. What are the advantages and disadvantages of this model? how about the future plans for model developments and applications? What is the next step in next several years to promote the advantages and makeup the weakness?

Response: Thanks for the constructive comments on the future plans.

(1) We agree that every model has its own disadvantages and advantages, including Noah-MP.

As we stated in the manuscript, the advantages of Noah-MP include (a) a comprehensive treatment of the coupled vegetation-snow-soil-hydrology system, which captures their complex interactions; (b) capabilities for additional critical land processes (e.g., crop, irrigation, tile drainage, groundwater, urban, and carbon cycles); (c) the inclusion of multiple physics options for different land processes, which allows the multi-physics model ensemble experiments for uncertainty assessment and testing competing hypotheses; (d) broad model applicability that allows to be used for various spatial and temporal scales as well as various application cases (e.g., weather prediction, climate projection, data assimilation, extreme weather/climate, hydrology, and agriculture); (e) high computational accuracy and efficiency that leads to the use of Noah-MP in many research and operational coupled modeling systems (e.g., NWM, UFS, LIS, WRF, MPAS).

The disadvantages of Noah-MP include the uncertainties and biases in some processes such as snowpack physics, vegetation dynamics, plant hydraulics, soil infiltration, and coupled carbon-nitrogen cycle, which have been pointed out by some previous studies cited in our manuscript, as well as some missing land surface processes such as accurate representations of blowing snow, wetland, wildfire disturbance, vegetation recovery and replacement. We expect these missing processes will be included in the model gradually in the future. For example, in our on-going work, we are implementing the wildfire disturbance process into Noah-MP.

(2) There are a few future plans for Noah-MP developments and applications based on the recent Noah-MP international workshop (https://ral.ucar.edu/events/2023/noah-mp-annual-users-workshop). Thus, we added the future plans to the revised manuscript in Section 10. "Conclusions and future plans" as follows:

"*The future plans for Noah-MP developments and applications include but not limited to (1) coupling with other widely-used weather/climate models (e.g., WRF, MPAS, NOAA/UFS), (2) enhancing capability of land data assimilation with Noah-MP, (3) enhancing plant hydraulics and soil hydraulics/hydrology schemes, (4) improving accuracy of applications in subseasonal-to-seasonal (S2S) forecasts, food-water security, and extreme weather/climate (e.g., fire, drought, flood, and heatwave), (5) including automated model parameter calibration/optimization algorithms, (6) enhancing modeling capabilities for rapid landscape transformation (e.g., deforestation/reforestation) as well as vegetation recovery and replacement after environmental disturbance, (7) including human management modeling (e.g., groundwater pumping), (8) including interactions with air pollution (e.g., pollutants' deposition and ozone damage to vegetation), (9) enhancing representation of subgrid heterogeneity, (10) improving high-resolution input datasets (e.g., soil properties and groundwater-related inputs), (11) creating a set of packages for code benchmarking and testing, model diagnostic, and better debugging capability.*"

(3) In the next few years, we plan to promote the Noah-MP advantages by enhancing its process representations and application in research and operational coupled weather/hydrology/climate modeling through coupling with various host models, and by enhancing its offline applications particularly in handling weather/climate extremes. In order to mitigate Noah-MP weaknesses, we plan to enhance the representations of key model processes and include missing physics as summarized above.