Response to Reviewer #1

RC1: 'Comment on gmd-2022-283':

General comments

In this manuscript, two physics suites separately coupled in a unified weather-climate model are described. Three field cases are used to understand the difference in model behaviors between the two physics suites within single column model configuration. The authors provide evidence for contribution of convective parameterization scheme to the major discrepancy in the simulated precipitation and clouds. Model sensitivity to time step is attributable to the interaction between microphysics and other processes. Although the discrepancies between the simulations are clearly illustrated, the underlying reasons need further investigation as suggested in the specific comments. Meanwhile, the roles for the two physics suites in unified weather and climate modeling need to be clarified to provide reference for other modeling centers. I would recommend it for publication in GMD after minor revisions in terms of the specific issues below.

Response: The authors thank this reviewer for many helpful suggestions.

Specific comments

L40 and L46: Please briefly describe the distinct formulation of unified weather-climate modeling (e.g., GRIST) that is different from other weather and climate models.

Response: The development of GRIST boosts the creation of a new model architecture that facilitates unified weather and climate modeling. In practice, because global weather and climate modeling differ significantly in terms of their spatial and temporal scales, the unification is realized by maximizing the possibility of constructing weather and climate models using a single model framework and dynamical core. GRIST further pursues to maximize the possibility of using a unified model formulation with minimum application-specific changes for weather-to-climate forecast applications.

L133: The statement "… a clear difference…, that is, dynamics and all the microphysical processes are more closely coupled together" could be more specific. A schematic flowchart of the computational procedure, if possible, could be beneficial to illustrating the difference in coupling strategies of dynamics and physics between PhysC and PhysW.

Response: Done. We add a figure (Figure 1) to show the different coupling strategies and process orders for the two physics suites.

The physical processes of PhysC are sequentially coupled with an order from the wet (deep convection, shallow convection, stratiform cloud condensation, and cloud microphysics) to dry (radiation transfer, surface flux, and PBL turbulence) processes. In contrast, PhysW adopts a coupling order from fast to slow processes. Cloud microphysics is computed first, and it is not specifically tied to those physical assumptions related to large-scale stratiform-like clouds. PBL turbulence, cumulus convection, and radiation transfer are called after the atmospheric state updated by the microphysics. Deep and shallow convection share the same parameterization, but they do not co-occur within one time step.

L172: The mentioned citation for DYCOMS experiment (Table 1) is missing in the reference list. In addition, please check the long name of the experiment in Table 1. And the location (lat, lon) should be precise with direction units.

Response: We have modified Table 1 and complemented the reference.

L221: It is found that the ratio of convective precipitation in PhysC is quite smaller during day 2-4 than that during day 0-2 at the peak value time of each event (Figure 1a). What background environment or treatment in model physics contributes to the difference? Does the difference has influence on the mean state of cloud profile during the convection active period (Figure 1c, e)?

Response: The closure of the parameterized convection for PhysC is based on the convective available potential energy (CAPE). That is, an equilibrium is assumed between the convection (reducing CAPE) and the grid-scale environment (generating CAPE). Due to the large consumption of CAPE at the first two days, the convective precipitation decreases afterwards.

Figure R1 shows the time-averaged cloud fraction for days 0-2 and days 2-4, respectively. The pattern of cloud profiles modeled by PhysC overall resembles the observation. PhysC produces ~0.3 more middle and high clouds than that observed at day 2-4.

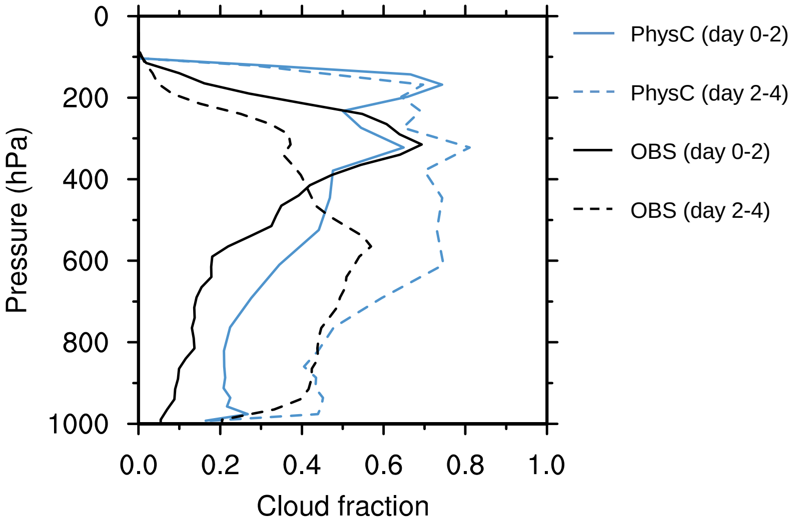

Figure R1: Time-averaged cloud fraction of days 0-2 and days 2-4 for PhysC and IOP observation.

L272: DYCOMS shows consistent marine stratocumulus cloud amount generated by different interactions of the physical processes in PhysW and PhysC. In CGILS, however, difference in stratocumulus cloud fraction at S11 between PhysW and PhysC is apparent. Is this difference primarily attributed to the shallow convection or other processes such as PBL turbulence?

Response: We add a sensitivity experiment for CGILS to examine the role of PBL turbulence on stratocumulus (Supporting Information). The UW wet turbulence scheme is coupled to the PhysW suite and replaces the YSU scheme. Figure S1 compares the time-averaged cloud fraction and cloud liquid water mixing ratio simulated by PhysW (UW) and PhysW (YSU), respectively. Compared with PhysW (YSU), PhysW (UW) increases stratocumulus at CGILS-S11 that more resembles the observation. The UW wet turbulence scheme increases the moisture transport and thus reduces the ventilation of shallow convection (Figure S2). This leads to condensation instead of evaporation occurring in the microphysics. Comparing Figure 7b and Figure S2, shallow convection in PhysW (UW) is still more active than that in PhysC. It confirms that the collaborative effect of shallow convection and PBL turbulence is the key difference of PhysW to PhysC for stratiform cloud process. Changes in the PBL turbulence scheme can notably impact this collaborative effect, leading to improved stratocumulus for PhysW.

L274: Please clarify the “lower levels” with specific pressure layers.

Response: The “lower levels” means a height of 600-1000 m. The specific depth is added in the sentence.

L323: Compared to the convection active period, the increment of middle and low clouds (500-900 hPa) without convection parameterization seems larger in PhysW during the convection suppressed period. Why does the increment become larger when the convection is suppressed rather than active?

Response: The large-scale forcing and precipitation are both weaker in the convection suppressed period than that in the convection active period. Without the vertical transport of convection, moisture tends to accumulate and easily reach saturation. Thus, condensate increases in middle and low levels (below 500 hPa), leading to notable increment of clouds. This increment in clouds is also seen in the "nocu" runs of PhysW for the CGILS case. Their physical mechanisms are consistent.

L417: What roles do the two physics suites play in the current unified weather and climate modeling? The authors may consider linking the main conclusion to future implication of this study for other modeling centers.

Response: PhysW is more optimal for kilometer-scale simulations due to its physical and computational performance. PhysC is, in principle, more optimal for decades-to-centuries scale long-term climate simulations. The two physics suites can do some common work. For instance, PhysW can produce a realistic model climate with close-to-zero top-of-atmosphere radiation budget and well captures the global and regional precipitation patterns. But its net cloud radiative forcing needs further improvement. Looking to the future, it is our hope that a unified model physics suite with minimum application-specific changes can be used (and behaves properly) for both weather and climate modeling. We have provided some concluding remarks in the last two paragraphs of this paper.

Technical corrections

L90: Section 5 explores

Response: Modified.

L142: while using

Response: Modified.

L156: subscript phys

Response: Modified.

L183: Please check the vector symbol in the equation (4).

Response: It is modified as $\vec{V} \cdot \nabla q$.

Please make sure the reference list includes all the citations in the manuscript.

Response: Thanks for your suggestion. the reference list has been complemented.