Review

Technical note: Emulation of a large-eddy simulator for stratocumulus clouds in a general circulation model. K. Nordling et al.

This paper describes the successful implementation of a process emulator for stratocumulus clouds in a general circulation model (GCM). Details reveal both the ability of the emulator to capture the wide range of stratocumulus in the present-day (PD) climate and the impacts of including it on the climate simulation. Updraft velocities, which are critical for aerosol-cloud interactions and microphysics, are simulated with much greater fidelity to LES by the emulator than by the current ECHAM parameterizations. Using emulators in GCMs is potentially powerful in representing unresolved process important for climate and climate change. Publication with revision is recommended.

Major Revisions

1. Although the emulator performs well in the PD climate, with leave-one-out cross validation, an important question remains as to how the emulator would perform in an out-of-sample climate, e.g., globally warmer. Serious problems of this nature have been reported with other emulators, e.g., Rasp et al. (2018, *PNAS*). An experiment in which ECHAM CTRL sea surface temperatures are increased uniformly by 4K, for example, could be run and compared with a corresponding simulation with emulators. Would the CTRL and EMU simulations differ in ways not expected from the PD results? With considerably more effort, the emulators could be trained on both PD and warm climates, and the ability of a model using only PD-trained emulators to reproduce a model using the more broadly trained emulators would provide a sense of the ability of emulators as constructed here to perform well out-of-sample. It may not be feasible to do these experiments in a timely manner for publication of this paper, but the revised version should at least discuss the issues with using the emulators developed here for climate-change experiments.
2. Changes in climate sensitivity between CTRL and EMU are an important issue. In uncoupled models, sensitivity can be assessed using the method of Cess et al. (1990, *J. Geophys. Res.*). This issue should at least be discussed in the revised paper.
3. Fig. 2: Provide correlation coefficient, bias, and RMSE for Emulator vs. LES. Figs. 6 and 7: Provide correlation coefficient and RMSE relative to observations, in addition to bias.

Minor Revisions

1. l. 53: Bretherton et al. (2022) train on a global kilometer-scale model, not a super-parameterized model.
2. ll. 101-104: Setting a lower bound of 40 cm^{-3} CDNC to avoid values “considered too low”: Is that consideration based on CDNC observations or just a necessity to keep within bounds necessary for realistic simulation of the 20th century? If the former, should it be reset to 10?

If the latter, it's worth noting that there remain serious problems with simulating aerosol-cloud interactions requiring a limit not supported by process-level observations and justifying altering it for the emulator experiments.

3. l. 150: The focus in this paper is on a characteristic updraft velocity, as used in some parameterizations for aerosol activation. Activation dependence on vertical velocity is nonlinear, and some parameterizations sample the PDF of updraft velocities. Use of a PDF as opposed to a characteristic value has implications for modeling aerosol-cloud interactions (Golaz et al., 2011, *J. Climate*). Could the emulator approaches described in this paper generate a PDF of updraft velocities from the LES, as opposed to a single characteristic value?
4. l. 155: Clarification of the discussion of the rainfall formation rate would be helpful. The rate appears to be calculated from terms in the rainfall formation budget, instead of from the rainfall itself, and spin-up problems are cited to justify using removal rates. But wouldn't removal rates be problematic also, if autoconversion and accretion rates are? Later in the paper, it becomes evident that the rainfall rate is a major control on modeled clouds, so the question of how the rainfall formation rate is diagnosed from LES results is important.
5. Fig. 4 might convey results more clearly if panel (a) were presented as is, while the other panels showed differences from it.
6. ll. 299-301: How is ECHAM cloud cover obtained from the three-dimensional ECHAM cloud distribution? Are the modeled cloud cover fractions compatible with the observational methods used by Stubenrauch et el. (2013) for comparison?
7. l. 316 and Fig. 5: Between 800 and 850 hPa, CDNC values using EMU-BOTH and EMU-UP differ from CTRL more than the corresponding differences in updraft.
8. l. 423: Question marks appeared on the copy I reviewed where the locations of data from the ECHAM simulations were intended.

Fig. 6 legend: "panels" -> "panel"

l. 330: "extents" -> "extends"