Review of “An update of shallow cloud parameterization in the AROME NWP model” by Marcel et al.

Summary:

This study updated several moist physical parameterization schemes within the AROME NWP model to improve shallow cloud simulation. The work includes evaluations using both Single Column Model (SCM) simulations and Large Eddy Simulationx (LES) simulations across four distinct cloud cases. It also incorporated a semi-automatic parameter tuning tool to enhance model performance. The updated model shows promising improvements in several key variables, such as cloud fraction, cloud and rain water content, and turbulent kinetic energy.

The manuscript presents a thorough account of the modifications and their impacts. To strengthen the paper’s scientific contribution and better align it with the scope of ACP, I recommend restructuring the narrative to more clearly highlight the scientific questions and the novelty of the approach. For instance, the paper could focus on one or two key modifications and deeply explore the underlying physical processes.

Major comments:

The manuscript documents a significant number of modifications across several physical schemes. However, it is challenging for the reader to quantitatively assess the specific contribution of each individual modification to the final simulated improvements. The final evaluation of the new AROME configuration includes the cumulative effect of all physical scheme updates plus the parameter tuning from the HTexplo tool. To help the community better understand the physical mechanisms driving the improvements, I strongly suggest a more detailed breakdown.

Specifically, it would be extremely valuable to see a 'Tuning vs. Physics' analysis. This could be achieved by showing a comparison between the control run, a run with all the physical scheme modifications but without the HTexplo tuning, and the final new configuration. This would clearly separate the contributions of the new physics from the new tuning.

Additionally, to further enhance the paper's scientific impact, consider adding a section or a supplementary figure that systematically shows the impact of one or two of the key modifications on the relevant cloud variables. For example, a "Figure 10-13"-style plot that shows the incremental changes from the control run as each major modification is added would be highly informative. This would make the scientific significance of each update much more apparent and provide a clearer path for other researchers looking to adopt similar techniques.

Other comments:

- Line 5: “the associated precipitation” could be rephrased as “the cloud microphysical scheme” for greater specificity.
- Line 10: “a transition case” could be more clearly described as “a stratocumulus-to-cumulus case.”
- Line 25: It appears “in” is missing before “Wyngaard (2004)”
- Line 30: To provide a broader context, consider including citations for other HOC schemes, such as the CLUBB scheme used in CESM2 and E3SM models
- Line 55: The final sentence in this paragraph appears to shift topics abruptly. To improve the flow, please ensure the discussion of radiation and microphysics is more smoothly integrated or moved to a more suitable section.
- Line 60: between Couvreux et al. (2021) and Hourdin et al. (2021): replace semicolon by comma
- Line 110: It would be helpful to briefly explain what input profiles and large-scale forcings are used and how they are generated.
- Consider adding a table to summarize the four cloud cases, including their cloud type and time period, for easier reference.
- Section 2.2: To clarify the methodology, please explain the difference between the AROME and Meso-NH models as they are used in the study. Additionally, please specify the horizontal and vertical resolutions used for the Meso-NH LES simulations.
- Line 170: “where B_u is strong and detrain…”: please change “detrain” to “detrains”.
- Line 205: in the formula for \bar{s’_{ED}^2}, I believe it should be “\bar{d}^2 * \bar{T’}^2. For clarity, it would also be helpful to show the formulas for CF and \bar{r_c}.
- Figure 2: The LES line shows discontinuous characteristics. A note explaining the cause of this, such as the conditional sampling method, would be helpful to readers.
- Line 305: “fractionnal” → “fractional”
- Line 325: It would be helpful to define the parameters alpha and beta directly within the text rather than solely referring to previous studies.
- Line 330: Using 'w' for both "updraft" and "wet" can be confusing. Consider using a different variable, like 'wet' or 'cld,' to distinguish them.
- Figure 5: Consider directly plotting the TKE to more clearly show the improvement between Equation 24 and Equation 22.
- Line 455: The definition of Max(CF) is unclear. Please provide a clear definition.
- Figure 8’s caption: “HTexplo experience” → “HTexplot experiment”? The same applies to Table 1’s caption.

- Figure 9: The "Remaining space" in the bottom right of the figure could be explained in the figure caption to improve clarity.
- L625: While the model shows improvements, the claim that it "can accurately reproduce" cloud fractions and cloud water content might be overstated. Figure 13, for example, highlights several areas where discrepancies remain. To maintain scientific precision, I suggest revising this sentence to acknowledge both the successes and the remaining limitations.