**ACP paper 2019-937 – revised version "Hectometric scale simulations of a Mediterranean heavy precipitation event during HyMeX SOP1." O. Nuissier, F. Duffourg, M. Martinet, V. Ducrocq and C. Lac**

## REPLY TO THE COMMENTS OF EDITOR

## General comment: lack of clarification and illustration to better understand how the physical involved mechanisms are modified/improved while increasing horizontal resolution from 450 m to 150 m.

As a matter of fact the main purpose of the paper is effectively to assess how the physical mechanisms and convective organization, involved in a real case study of Mediterranean heavy precipitation, are represented from 450 m down to 150 m. The results obtained in this present study confirm the need to use horizontal grid spacing of about a hundred of meters to resolve properly (at least partly explicitly) these eddies containing most of the kinetic energy and thus to better represent in particular the different stages of convection, especially the possible link with cloud-edge entrainment.

One of the main conclusions of the paper is that increase of horizontal resolution does not significantly impact the larger scale forcing in which deep convection is embedded (especially the southwest- to southeasterly low-level moist and converging flow driven by a surface low pressure between Spain and Balearic Islands), and the location of the convective systems themselves (more related to initial and lateral boundary condition issues). However, when focussing at convective cell scale, HR150 appears more realistic in terms of cloud appearance and evolution, whereas deep convection in LR450 could be triggered too abruptly, leading to enhanced microphysical processes and amplified mechanisms (stronger low level cold pools). We fully agree that there was a lack of illustration regarding that point and we are grateful to the editor for his help providing a list of possible fields to be drawn.

For that purpose, a few additional figures (cf. new Figure 12, 13 and 14) have been added in the revised version of the paper, showing horizontal cross sections of vertical velocities, subgrid turbulent kinetic energy (TKE) at 6 km and 8 km height, and both dynamical and thermal contributions in the TKE production at 6 km height, throughout the convective cells displayed in Figure 11, respectively. As one can see in Figure 12a,12c and Figure 13a,13c at 450 m horizontal resolution, the updraft cores are partly resolved, as vertical velocities do not exceed 12 m $s^{-1}$, and are also partly unresolved, with TKE sometimes higher than 30 $m^2 s^{-2}$. This TKE is produced by both dynamical and thermal processes, and is mainly localized in updraft cores. The eddies near the cloud edges, which are subgrid at 450m resolution, are not represented by the turbulence scheme. These results are in a good agreement with those obtained by Verrelle et al. (2017) and Strauss et al. (2019), who have shown that a commonly used eddy-diffusivity turbulence scheme underestimates the TKE at kilometric and hectometric (500m) resolution, especially at the cloud edges but also in the updraft cores where the thermal production is misrepresented because the scheme does not enable the countergradient structures present in the updraft to be reproduced. At 150 m resolution, these eddies, as well as the updraft cores, are becoming better resolved as ascents exceed 12 m $s^{-1}$ over large areas (Figure 12b,12d) . Furthermore, the strongest updraughts are neighboured by strong downdraughts (exceeding 10 m $s^{-1}$) just outside the cloud-edge that might be associated with a subsiding shell (Figure 12b,12d). At 150 m the unresolved flow is mainly located at cloud edges and a significant part of the TKE contribution comes from the 3D dynamical production linked to the entrainment process, with a clear signature visible in Figure 14d . As a consequence, it is possible to argue that the entrainment process, especially along the cloud-edge, is strongly underestimated at 450 m horizontal resolution, that might lead to less entrainment of dryer environmental air in the clouds that could explain why LR450 simulates a too rapid development of the convective system, greater surface rainfall and stronger low level cold pools compared to HR150.

Regarding the cold-pool aspect, Figure 8 already illustrates differences in terms of horizontal low-level flow (moisture advection and low-level flow between 0 and 3 km height) between both 450 m and 150 m horizontal resolution around the cloud complexes. The simulated environmental flow is not significantly different between both simulations. However, we do think that comparison of horizontal motions within the convective systems appear less obvious and more complicated, as clouds are not simulated at the same location and the same time in both simulations that strongly disrupt the flow around. Nevertheless, although other factors could impact the cold-cold, greater surface precipitation simulated at 450 m horizontal resolution lead to more cooling underneath the storms.

References :

- Verrelle, A., D. Ricard, and C. Lac, Evaluation and improvement of turbulence parameterization inside deep convective clouds at kilometer-scale resolution, *Mon. Weather Rev.*, *145*, 3947-3967, 2017.
- Strauss, C., D. Ricard, C. Lac, and A. Verrelle, Evaluation of turbulence parameterizations in convective clouds and their environment based on a large-eddy simulation, *Quart. J. Roy. Meteor. Soc.*, *145*, 3195-3217, 2019.