Review of nhess-2019-321:

The sensitivity of intense rainfall to aerosol particle loading – a comparison of bin-resolved microphysics modeling with observations of heavy precipitation from HyMeX IOP7a

Overview

The authors present simulations of a heavy precipitating event (IOP 7a) that occurred on Sept. 26, 2012, during the HyMeX observation campaign. Simulations are performed using the DESCAM bin microphysics scheme, which provides a detailed representation of hydrometeors, aerosols, and their interactions. The purpose of this paper is first to evaluate the rainfall prediction using this bin scheme, and then to assess the sensitivity of rainfall prediction to the initial aerosol loading taking advantage of the scheme's abilities.

Although we are far from being able to use such a detailed and costly microphysics scheme in operational NWP, this study is interesting both to advance our understanding of rain production processes, and to maybe serve as a reference for the development of simpler, less computationally expensive schemes.

The paper has a usual but efficient structure, and shows that the rainfall predicted using DESCAM agrees well with the observations overall, although some discrepancies remain both on the regional scale (location, intensity and timing of rain) and the raindrops scale (particle size distributions). Results also clearly show that changing the aerosol population has an impact on rainfall forecasts.

However, I think that the paper suffers from the issues raised below as "major comments" (minor comments are listed afterwards).

Major comments

- This study is conducted based on rainfall characteristics at the ground only. This is a deliberate choice from the authors, who mention twice that in-cloud features will be presented in a future work. Following this idea, the paper neither discusses the quality of the simulated convective system macroscopic and microscopic characteristics (cloud height, anvil extension, cloud composition) nor investigates the rain formation processes (eg. warm phase vs. mixed phase formation). This is especially lacking since the bin scheme is not expected to be used in operational NWP in the near future, but instead a very good tool for process studies and understanding. Thus, to me, the paper has more value as an introduction for a detailed cloud composition and processes study, despite being presented as a standalone paper. I can imagine a detailed study of the cloud composition and processes needs a paper by itself, so maybe the two parts could be made into a two-part paper (part 1 for model description and rainfall evaluation, part 2 for microphysics and processes) ?

- The paper sometimes stops short of providing or verifying an explanation for the presented results.
    - <u>P6 l23-27</u>: If the reach of the X-band radar is too short, why don't you use the french radar mosaic instead (especially since the radar is only used to check the large scale characteristics of the convective line) ?
    - <u>P8 l6-10:</u> The three simulations do not represent the precipitating system shift. Other studies of this case are mentioned in the paper (eg p3 l23, Hally et al 2014). How does that (or its consequence on the total rainfall amount slight mislocation) compare to others ? This could hint at the influence of large scale conditions used for coupling.

- P8 l25-30 & p9 l1-5: Various studies of the impact of aerosols on clouds and precipitation show different effects. Sometimes an increase in aerosol concentrations leads to reduced precipitations, sometimes to “convective invigoration” instead. What processes (is the impact on droplets or ice crystals concentrations more important ? More cloud droplets subjected to contact freezing with aerosols ?) are important in this specific case (organized, long-lasting convection, with an orographic forcing), and are they different from what was found for isolated convective cells ?
- P9 & fig 7 : The three simulations show very little differences below 70mm. Is there a physical explanation to the fact that aerosols only impact the occurrence of high precipitation ?
- P10 l11-18: The model resolution can explain some differences with the observations, eg. higher 5-min rainfall in the observations. However, there are differences between figs. 8 (observations) and 9 (models) that probably cannot be explained by the smoothing effect of the model resolution. The progressive increase and decrease in precipitation in the simulations, occurring over 20min to 1h, is more probably linked to differences in the convective system characteristics or dynamics. Is this linked to convective cells dissipating slower in the model ? To convective cores being surrounded by larger regions of moderate precipitation in the model than in the observations ?
- P11 l24+: To explain differences in rain size distributions between the model (at altitudes of 900-1000m) and observations (at 950m), the authors state that the cloud base may have been lower than simulated (1300 to 1400m). Are there no observations from the HyMeX campaign (Lidars ? Cloud radars ? Maybe MRRs ?) to support this, even if they were not located at the same place ?

- The three simulations use realistic aerosol loadings (Table 2) coming from observations for this specific case (*HymRef*), the cleanest HyMeX case (*HymLow*) which still has high aerosol concentrations, and another set of observations to represent cleaner conditions (*Remote*). The total number concentration for these simulations is, as stated by the authors, lowest in the *Remote* case and highest in the *HymRef* case, and therefore conclusions are drawn throughout the paper about the impact of an increase / decrease in aerosol number concentration. However, if we look only at aerosol modes 2 and 3 (because the smallest aerosols from mode 1 with a diameter around 0.05 microns are much harder to activate into cloud droplets or ice crystals), the number concentrations are highest in the *Remote* simulation (which also has the largest diameters for these two modes) and lowest in the *HymRef* simulation, so maybe the conclusions based on aerosol number concentrations could be reversed ? Simulations using the population from *HymRef* but modulated by the same factor for the 3 modes would make this conclusion easier. Maybe this can be clarified in the current simulations, through an analysis of the activation of smaller aerosols in the three simulations (total number of activated aerosols, activation height or temperature or timing for the different modes, …) ?

- Comparisons of raindrop size distributions show that the number of small rain drops at the ground is not very well represented by DESCAM. Although the distance from cloud base changes the shape of the rain PSD, authors state that the decrease in small drops numbers with an increase in rain water content was not observed by disdrometers at lower altitudes. This calls for some more detailed analysis: how is the drop PSD changing with height in the model vs. observations (Micro Rain Radars were deployed during HyMeX and provide the rain PSD at different heights, polarimetric radars can also help assess the rain characteristics) ? Is this really possibly linked to the collisional break-up as suggested, or is this also possibly linked to overestimated collection rates, or errors in the sedimentation process ?

Minor comments

- p1,l19-21: add references for the climatology of extreme events in the region and modelling difficulties

- p1,l22-24: A lot more than just rain gauges and radars were available during the HyMeX campaign.
- P2,l24-27: The first stated objective is to show added value of a bin scheme vs. bulk schemes, however no result in the paper ever discuss the performance of bulk schemes. This should be moderated as there is no evidence of it in this paper → *the first objective of the paper is to evaluate the performance of a 3D mesoscale model including a bin microphysics scheme in predicting heavy rainfall.*
- P4,l30-34: Please precise the aerosol concentration decrease in the first 3km (how many aerosols remain at 3km and above?)
- p5,l1-2: Please precise if soluble aerosols act as CCN only, or can also act as INPs (eg. by immersion freezing)?
- P5,l7 & 13: some characters do not display correctly
- P6,l1-2: this sentence is not necessary as the flight date and location were already mentioned before.
- P6,l18: figure 4 is used in the text before figure 3?
- p7,l29: text mentions precipitation over 10mm, while fig.4a shows reflectivity in dBz.
- P8,l13-15: Is the Taylor diagram necessary for only 3 simulations?
- P9,l6-11: “considerable similarity” is exaggerated. For most precipitation accumulations, there is more difference between any simulation and observations, than between different simulations.
- P10,l19-26: say at the beginning of the paragraph that we are now looking at fig. 10 (I initially thought that the comment was not fitting the figure because I was still looking at fig. 9 that does not show 5min precipitation over 6 or 7mm for *Remote* simulation)
- p11,l6-8: What fraction of observed DSD spectra is ignored?
- P11,l23: between 900~~0~~ and 1000m
- p12,l3-11: mass distributions from fig. 12 are very similar. Can the small differences be explained by the differences on rain water content (especially for *Remote* which has a higher mean RWC, but also for *HymLow* which has the same mean RWC but maybe more extreme values), or is there also a difference in distributions at the same given RWC for the 3 simulations ?
- P14,l15: strange characters around “broken”
- Fig1: legend missing for the gray contours.