Response to Reviewer 1 on the Manuscript wcd-2022-17 entitled "Impact of combined microphysical uncertainties on convective clouds and precipitation in ICON-D2-EPS forecasts during different synoptic control"

by Takumi Matsunobu et al.

1 General comment

This paper examines the contributions of microphysics uncertainties arising from two sources, the cloud condensensation nuclei (CCN) concentration and the shape of the parameter of the cloud drop size distribution (CDSD). These impacts are investigated in 5 cases of precipitation over Germany in Au- gust 2020, including 2 strong forcing and 3 weak forcing situations. The work is performed using the convective-scale ICON-D2-EPS with 180 members. The contributions of microphysical uncertainties and initial and boundary condition uncertainties (IBC) are primarily examined on precipitation fore- casts, with a focus on intensity and spatial variability, and secondly on cloud and rain water contents. While the impact of IBC overall dominates for precipitation forecasts, cloud and rain water contents appear to be more sensitive to the microphysical uncertainties. The paper is well-written and provides a number of new and interesting results. It will surely contribute to a better understanding of model uncertainties, with potential applications for the design of EPS. In addition, the methodology is sound and the in-depth analysis with several diagnostics is valuable. My main comments, detailed below, would recommend a simplification or clarification of some results, and a potential re-organization of the manuscript plan. For that purpose, I consider major revisions are required before publication in Weather and Climate Dynamics.

We would like to thank the reviewers for their constructive comments, which will help to improve further the quality of the manuscript. Note that we changed the title to 'The impact of microphysical uncertainty conditional on initial and boundary condition uncertainty during different synoptic control' and the co-author list due to major modifications and considerable re-writing. The answers to the reviewer's remarks describing the corrections made in the manuscript, are written in blue hereafter.

2 Major comments

- 1. My main concern is about the huge volume of information on some figures, in particular I found the readibil-ity/understanding of Figure 3 particularly challenging (especially the top panel). Would it be possible to think about a new design that would make the interpretation easier ?

We re-designed Figure 3 and reformulated the explanation in Section 4.1.

- 2. Different ensembles are examined in the paper (IBC, MP, CCN, CDSD). It would be very helpful to clearly define these sub-ensembles in a table (rather than in the text), with information on the number and size of the associated sub-ensembles.

  Thank you for pointing that out. We changed the text accordingly at several places (at the beginning of the Experimental desgin and the results sections) to clearly describe our subsampling strategy used to quantify the relative impact of different uncertainties by analysing different sub-ensembles.

- 3. As microphysics perturbations more directly impact cloud and rain water contents than precipitation, I think it would be more natural to start section 4 with the results of 4.3. Such a re-organization would imply a non-negligible work but the resulting manuscript should be more consistent.

  We agree, a process chain like structure of the results would be a sensible approach. However, we put the weather regime dependence of precipitation at the heart of our investigation and start our line of argument very broad and detailed with an illustration of the precipitation difference of all 180 ICON-D2 ensemble members for two different cases. Subsequently, we compress the data and show boxplots to focus on the relative contribution of the various uncertainties. Having found the largest impact during weak synoptic control, we then examine the spatial predictability of precipitation. After that we turn to cloud and rain water contents. We changed the order in Section 4.3 going 'backwards the process chain' from precipitation to cloud water content so that readers can more easily follow the argument from precipitation at the ground to microphysical impacts within clouds.

- 4. The study is based on the in-depth analysis of 2 cases, and more statistically robust results are computed with 5 situations. This is a small sample to draw conclusions, however I understand that running additional cases is beyond the scope of the paper for computational reasons. At least I seems important to underline this limitation in the conclusions.

  We understand your concern on the limited data base. We added a sentence in the conclusions mentioning the limitation of this study as follows:

  > We caution the limited dataset covering five days in August 2020 only. More robust results require a larger data base containing more cases that comprise different synoptic conditions. Based on the five cases we cannot draw general conclusions.

3 Specific comments

- 1. L37-39 "The impact of parameter perturbations ... using a variety of NWP models and schemes" : add references to studies

  We agree and added the following text:

The impact of parameter perturbations in microphysical parametrisations has been studied extensively in mostly single deterministic idealized (e.g. Grant and van den Heever, 2015; Glassmeier and Lohmann, 2018; Heikenfeld et al., 2019; Chua and Ming, 2020; Wellmann et al., 2020) or realistic (e.g. Bryan and Morrison, 2012; Barthlott and Hoose, 2018; Schneider et al., 2019; Baur et al., 2022) simulations using a variety of NWP models and schemes.

– 2. Figure 6 : add Time [utc] as x-axis legend.

Added.

– 3. Section 4.2 : add the definition of FSS somewhere.

We added the definition of the FSS in Sect. 4.2 with its mathematical interpretation.

The definition of the FSS is given by

$$FSS = 1 - \frac{\sum (f_A - f_B)^2}{\sum f_A^2 + \sum f_B^2} \quad (1)$$

where f_A and f_B represent the fraction of rainy grid points in fields A and B, respectively, at which the precipitation amount is exceeding a certain threshold value. The second term on the right hand side represents the ratio of the mean squared error (MSE) of the fraction fields A and B to their maximum possible MSE.

– 4. L267-268 : do you think the differences of sampling size for the different ensembles can impact the results ?

Thank you for pointing this out. To check the sample size effect, we computed the FSS with different sample sizes (Fig. R1.1, as in Fig. 6 in the manuscript). The impact of different sample sizes is very small for sample sizes used in this study (n=1710, 720, 180, top row in Fig. R1.1), only for two-digit (and smaller) sample sizes there are slight modifications of the FSS and believable scales. Therefore we conclude that the differences caused by the sample size are negligible in this study.

Note that there was a typo on the sample size of combined microphysical perturbations in the manuscript. 720 is the correct value (was falsely 7200). This is corrected.

– 5. L342-344 : is it only a spin-up and/or the nature of precipitation that explain the differences between nighttime and daytime rainfall ?

We believe that the differences are mainly caused by spin-up effects. A similar discussion was raised in Barthlott et al. (2022, ACP), in which the impact of CCN and CDSD perturbations on precipitation was addressed and a smaller impact of microphysics perturbations at short lead times was found. They write that "The comparably small spread in precipitation intensities for both the CCN and shape parameter runs during the nighttime precipitation maximum on 2 June 2016 could be explained by the fact that this maximum occurs during the first hours of the simulation. In that time, the spin-up effects and the adjustment to the driving coarser-scale model are still in effect, which could dampen

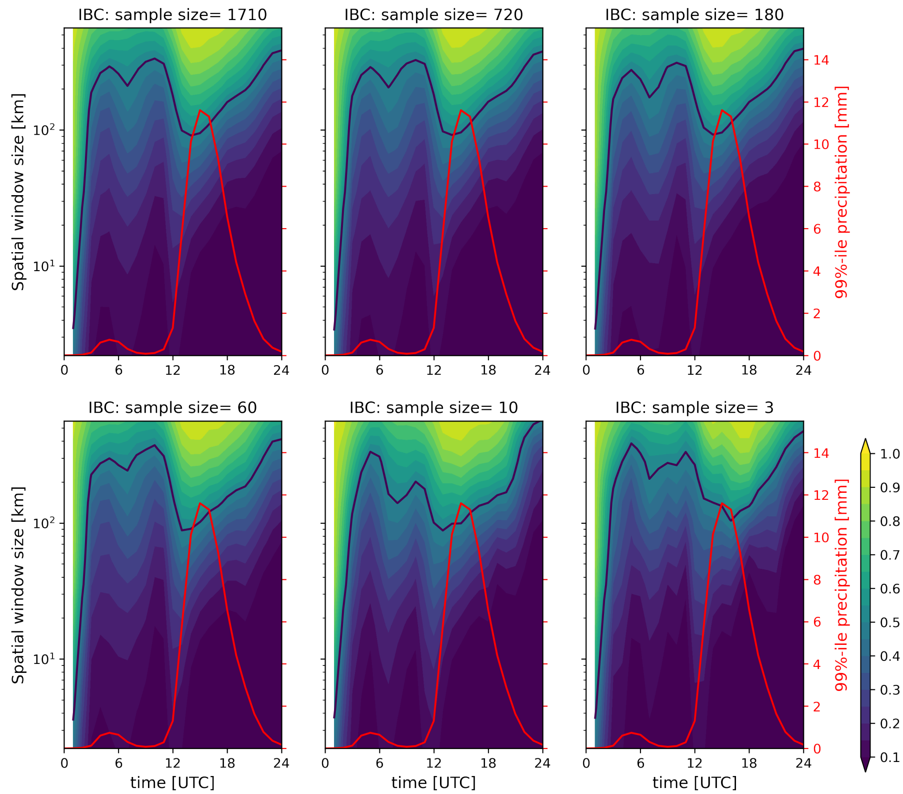

Figure R1.1. Time series of FSS values of hourly precipitation calculated on scales ranging from 2 to 560 km across the German domain for the weak forcing case 11 August. Each panel shows the mean of re-sampled data with different sample sizes (from 1710 to 3). The black lines show believable scales of mean FSS. The red lines (right axis) show the time series of the entire IBC sub-ensemble mean 99th percentile value of hourly precipitation. All valid for of the IBC sub-ensemble.

the impacts of the microphysical uncertainties assessed here. A similar, smaller impact of microphysics perturbations at short lead times was found in further sensitivity experiments for 11 June 2019, initializing the model at 18:00 UTC (not shown)." We added a citation to our manuscript.

In addition we compared hourly precipitation maps showing nighttime and daytime precipitation to examine if the nature of precipitation is completely different (Fig. R1.2). Both nighttime and daytime precipitation fields show clear rain bands across Germany with intermittent strong precipitation. Both snapshots represent convective precipitation events that are driven by synoptic-scale flow thus sharing a similar nature of precipitation.

We therefore conclude that the small impact on nighttime precipitation is largely due to spin-up effects. The similar precipitation characteristics of nighttime and daytime precipitation hint towards the same nature of precipitation.

– 6. Figure 9 legend : (c) domain-averaged total column rain water content.

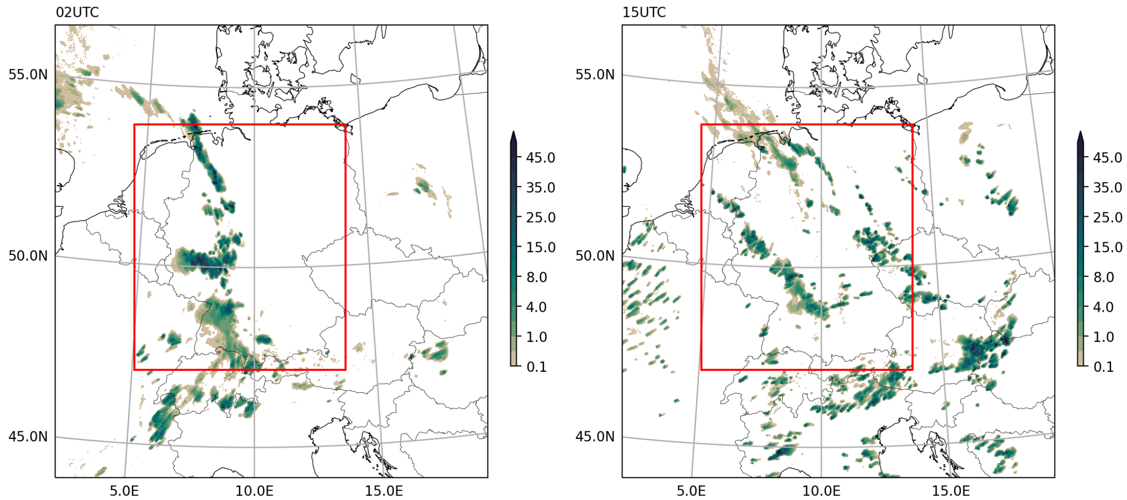

Figure R1.2. Two snapshots of hourly precipitation rates valid at 02 UTC (nighttime precipitation, left) and at 15 UTC (daytime precipitation, right). Data of member 1 of a nu0c ICON-D2 simulation on 17 August 2020 (strong-forcing case) is shown.

Corrected.

– 7. Figure 10 : It would be interesting, for each variable, to discuss the statistical significance of differences observed between the 3 sub-ensembles, and between weak and strong forcing situations

We agree. However, as mentioned above in major comment 4, robust results including a statistical significance test necessitate a larger data base that is beyond the scope of the present study but is planned in future work.