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Interactive comment on "Observational operators for dual polarimetric radars in variational data assimilation systems" *by* Takuya Kawabata et al.

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General comments:

In this manuscript, the authors propose forward operators together with their tangent linear (TL) and adjoint (AD) operators for observational data from dual polarimetric radar. This investigation was done by following their previous work on developing forward operators (Kawabata et al. 2018, JMSJ). To my knowledge, the development of theoretically-based TL and AD codes for polarimetric parameters is the first attempt. Operators were derived in appropriate manners, and they could be useful in a framework of variational data assimilation. The results, however, show the low performance in a simple assimilation experiment. The authors have to revise this manuscript mainly

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Discussion paper

the relevant section of this 4DVar assimilation experiment before acceptance for publication. I think the authors need to reconsider the experimental configurations with additional consideration of the results, especially on the performance of FIT and the errors found in differential reflectivity field. My comments are addressed below.

1. The authors had better mention clearly the range of application in abstract and summary. For example, operators can be applicable to C-band radar data (possibly S-band radar using findings of previous works). Another work, however, is needed to perform a statistical fitting of results simulated by a numerical radar simulator in applying to a radar system with a shorter wavelength (e.g., X-band radar). Besides, a dataset of beam-filling (effected by the ground) is required. In terms of a mesoscale model, the use of a two moment microphysical scheme is assumed.

2. The descriptions in Section 2.1 are quite similar to the description found in the previous work of Kawabata et al. (2018). The authors should explain the essence of FIT concisely for the readers to understand that the forward operators have been already proposed in another work. Please revise Section 2.1 carefully avoid double posting. This revise may be reflected to title.

3. The authors have to describe experimental configurations (Section 4.2) in detail, including the domain, the grid spacing of the mesoscale model used, 4DVar timeline, radar data configuration (e.g., resolutions, the number of elevation angles) at least. Which mesoscale model is used, WRF or NHM? In terms of timeline, are several PPI data in one volume scan assimilated at the precise scanning timing during assimilation window? How about a method for preparing the background error?

4. Observational errors are quite large, and, especially, the error for horizontal radar reflectivity seems to be unrealistic. A smaller error of radar reflectivity should be used. The authors may show the data to support the set-up of errors. The sensitivity of errors to the results should be discussed.

5. Why not radial velocities (rv) assimilated in case of KD? Anyway, hail is associated

with the event investigated. How does the authors consider the fall speed of hydrometeor in assimilating rv data?

6. In Figure 2, non-zero differential reflectivity (Zdr) is calculated in non-stormy areas of retrieved and background fields, regardless of the type of operator. A possible reason regarding the axis ratio does not make sense to me. The authors should mention logically the reasons together with plotting smaller radar reflectivity Zh (< 15 dBZ). Assimilation of radar data (Zh, Zdr, Kdp) with quite weak echoes (e.g., clear air echo) is not appropriate in this framework. In operators, quite small Qr can lead to huge contribution in the perturbations of lamda, N0, and Zh (Zv). Therefore, the use of the minimum thresholds for Zh and Qr may remedy the low performance for the retrieval of Zdr, if the authors does not set the thresholds.

7. Although FIT is theoretically more precise than KD, FIT shows the lower performance than KD. The authors jump to conclusions too quickly by regarding the nonlinearity in FIT as the low performance. In the background Zh and Kdp, the mesoscale model cannot resolve convections at all. One possible situation is that it is too dry in the background water vapor field. If so, I guess the adjustment of humidity is needed before assimilation to retrieve larger Zh and Kdp.

Specific and minor comments:

1. (Page 2) Why do the authors address on quantitative precipitation estimation (QPE)? I think QPE is out of the main topic of this manuscript.

2. (Page 2 Line7) Change “is” to “are”.

3. (Pages 2 and 3) Operators proposed consider the relations between variables concerning rain water and radar observables. I feel something wrong with the mention of “cloud water”. Can C-band radar observe cloud water?

3. (Pages 2 and 3) Please check if the WRFDA “(WRF-Var” mentioned in the manuscript) deals with the “perturbation” of rainwater mixing ratio, not dealing with

“the total part”.

4. (Page 4 Line 6) Change “proportional” to “polynomial”.

5. (Page 8 Line 17) Essentially, is Kdp assimilate in KD?

6. (Page 9 Lines 8 & 9) The performance found in a simple assimilation test is far from a successful level.

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