

## Response to the Comments of Referees

### Investigating the assimilation of CALIPSO global aerosol vertical observations using Four-Dimensional Ensemble Kalman Filter

Yueming Cheng, Tie Dai, Daisuke Goto, Nick A. J. Schutgens, Guangyu Shi, and Teruyuki Nakajima

We would like to thank to the two reviewers for giving constructive criticisms again concerning our manuscript. Based on the critical comments and suggestions, we have made careful modification on the manuscript. The referee's comments are reproduced (**black**) along with our replies (**blue**) and changes made to the text (**red**) in the revised manuscript. All the authors have read the revised manuscript and agreed with submission in its revised form.

#### Anonymous Referee #1

**Comment NO.1:** The author has made significant improvements to the manuscripts. I recommend accepting it after modifying several technical corrections as indicated below: Please pay attention to the grammar in the sentences of the manuscript.

**Response:** We are extremely grateful to the referee for the positive assessment of our manuscript.

**Comment NO.2:** Page 4 Line 10, 'Due to' should be changed to 'Because' or 'Since'. Similar situations often occur in the manuscript (Page 7 Line 5; Page 15 Line 3, 29, 37; Page 17 Line 28).

**Response:** Accept.

**Changes in Manuscript:** We have replaced the 'Due to' with 'Because' and 'Since'. Please refer to the revised manuscript, Page 4 Line 11, Page 7 Line 6, Page 15 Line 7, Page 15 Line 33, Page 16 Line 1, and Page 17 Line 29.

**Comment NO.3:** Page 12 Line 33, 'where' should be changed to 'and'.

**Response:** Agree. To make the statement clearer, we have replaced this sentence with 'In order to make the statistics significant, we require at least 10 observations in each selected site'.

**Changes in Manuscript:** Please refer to the revised manuscript, Page 13 Line 1-2.

## **Anonymous Referee #2**

**Comment NO.1:** Satellite derived data is often considered as one of the most important data sources for aerosol DA due to its wide coverage. Many DA algorithms have been developed to assimilate MODIS AOD data to obtain better initial fields for aerosol short forecast and generate the aerosol analyses for research community. However, the MODIS AOD data is just the integration of extinction coefficient that is difficult to improve the vertical profile of aerosol. In this paper, the authors assimilated the CALIPSO vertical extinction coefficients observations to improve the simulations of the aerosol vertical distributions using a global chemical transport model. The assimilation methodology was based on the four-dimensional Local Ensemble Transform Kalman Filter (4D-LETKF), and several experiments were conducted to investigate the impact of the assimilation system parameters and observation data on the assimilation results. The work presented in this study is innovative and significant. The paper is in general well written and the structure is clear and logical. The authors also provided clear explanations of why the results seen may be occurring. I recommend accepting for publication following minor revision.

**Response:** We thank the referee for the valuable feedback of our manuscript.

**Comment NO.2:** Page 6 Line 27, 'implement' -> 'implementation'?

**Response:** Accept.

**Changes in Manuscript:** We have replaced the 'implement' with 'implementation'. Please refer to the revised manuscript, Page 6 Line 28.

**Comment NO.3:** Page 7 Line 8, Please clarify the observation operator to map the aerosol mixing ratio to the optical properties.

**Response:** Done. The observation operators we used to map the model state vector into the aerosol extinction coefficient  $\sigma$  and the AOT observation space at wavelength  $\lambda$  are calculated as  $\sigma_j(\lambda) = \beta(\lambda) \cdot M_j$  and  $AOT(\lambda) = \sum_{j=1}^n (\beta(\lambda) \cdot M_j)$ , where the  $M_j$  represents the simulated aerosol dry mass concentration in each model level  $j$ ,  $\{j = 1, 2, \dots, n\}$  and the  $\beta$  represents the prescribed aerosol mass extinction coefficient.

**Changes in Manuscript:** We have clarified the descriptions of the observation operator in the revised manuscript, please refer to the revised manuscript, Page 7 Line 13-18.

**Comment NO.4:** The assimilation cycle used in Figure 1 is a bit confusing.

**Response:** Accept.

**Changes in Manuscript:** We have replaced the confused 'assimilation cycle' with 'Assimilation Cycle 1 (2016-11-01)', 'Assimilation Cycle 2 (2016-11-02)', and 'Assimilation Cycle 3 (2016-11-03)'. Please refer to the Fig.1 in the revised manuscript.

**Comment NO.5:** Page 8 Line 3, 'are' -> 'is'

**Response:** Accept.

**Changes in Manuscript:** We have replaced the 'are' with 'is'. Please refer to the revised manuscript, Page 8 Line 1.

**Comment NO.6:** Page 10 Line 2, delete 'the' before '0.30'.

**Response:** Accept.

**Changes in Manuscript:** We have deleted the 'the' before '0.30'. Please refer to the revised manuscript, Page 10 Line 8.

**Comment NO.7:** Page 10 Line 5 and Line 29, 'relative larger' -> 'relatively larger'.

**Response:** Accept.

**Changes in Manuscript:** We have replaced the 'relative' with 'relatively'. Please refer to the revised manuscript, Page 10 Line 11 and Page 10 Line 35.

**Comment NO.8:** Page 13 Line 20, 'which in also mentioned in Zhang et al. (2014)' -> 'which is also mentioned in Zhang et al. (2014)'.

**Response:** Accept.

**Changes in Manuscript:** We have replaced the 'which in also mentioned in Zhang et al. (2014)' with 'which is also mentioned in Zhang et al. (2014)'. Please refer to the revised manuscript, Page 13 Line 25.

**Comment NO.9:** Page 15 Line 32, 'With respected to' -> 'With respect to'.

**Response:** Accept.

**Changes in Manuscript:** We have replaced the 'With respected to' with 'With respect to'. Please refer to the revised manuscript, Page 15 Line 36.