Detailed response to Reviewer's comments.

Review of Pagowski et al.
The paper concerns an important aspect of data assimilation, namely development of techniques to assimilate aerosol data. As such it is timely and of interest to the general data assimilation community. The paper is technical, rather than scientific, and its inclusion in GMD/GMDD is warranted. The paper should be suitable for publication in GMD once the authors address the general and specific comments below.

General comments:
Introduce acronyms when first used, both in the abstract and the manuscript, e.g., PM, MODIS. The English needs improving, including avoiding repetition of text.
The paper would benefit from inclusion of references to back statements made. See specific comments.

Authors appreciate Reviewer's attention and comments.

Specific comments:

P. 2484:
L. 2: Introduce NCEP acronym - it is well known in the data assimilation community.

NCEP acronym introduced.

L. 6: Perhaps better to say: "...we present illustrative results...".

Corrected as requested.

P. 2485:
L. 1-2: Many of the references cited concern tropospheric chemical data assimilation (e.g. the Elbern work). There has also been work on stratospheric chemical data assimilation, with a focus on ozone (e,g,, Geer et al., 2006). The authors should also refer to chemical data assimilation within the MACC, MACC-II projects, e.g., Massart et al. (2014).

References on stratospheric assimilation provided.

Regarding the variational and ensemble data assimilation methods introduced, general references could be provided here. Examples include: Bouttier and Courtier, 1999; Talagrand, 2010; Kalnay, 2010.

References on assimilation methods provided.

L. 10: I suggest the authors provide references for air quality forecast systems. One example is Rouil et al. (2009) – PREV'AIR in France; the work of Elbern provides

another example.

We include Rouil et al. (2009) in the text and references.

L. 16+: Indicate here what you will discuss in the paper.

More detailed description provided.

P. 2486:
L. 1+: Is all this detailed information necessary?

Agreed, some information was superfluous and has been removed.

L. 20: I suggest replacing "inaccuracy" with "error". Please specify whether this error is random or otherwise.

Agreed, corrected.

L. 29: Is this error the random error?

Remer et al. (2005) do not discuss distribution of observation errors. They derive error estimates using least-squares which are the best linear unbiased estimator of any linear combination of independent observations. We cannot infer whether observation errors have a normal distribution though it seems to be a justifiable assumption based on the figures in the paper. This paper is the most authoritative reference on MODIS errors (over 1100 citations).

"In most cases, MODIS and AERONET exhibit very similar annual cycles, often with very similar magnitudes of optical thickness. Two- thirds of the differences in optical thickness over land are less than 0.10. There is some indication that MODIS retrievals over land may be systematically biased high, but in most cases the difference is still well within the estimated uncertainty of +/-0.05 +/- 0.15."

"Globally 62%, 66%, and 70% of all retrievals over ocean at 0.55, 0.66, and 0.87 μm, respectively, are falling within the narrowly defined expected uncertainty. Only the 0.55-μm channel is falling outside of the error bars more often than the prelaunch expectations of 66%, albeit slightly. The average at 0.55 μm is 0.18 for the ocean global database at defined AERONET stations, the same as for land. Because the land and ocean databases include many of the same stations, this is not surprising. The percent error between MODIS ocean retrievals and AERONET observations at 0.55 μm is only 1%, showing the same absence of bias exhibited in Fig. 9."

"An extensive validation effort that collocated over 8000 MODIS retrievals with AERONET measurements of optical thickness show that globally, the MODIS products are accurate to within prelaunch expectations, namely, +/-0.05 +/- 0.15 over land and +/-0.03 +/- 0.05 over ocean. In particular, the retrieval of aerosol over oceans consistently shows remarkably good agreement with virtually no offset or bias through the range of optical thickness where most observations occur. Regional analysis, however, shows specific issues for certain locations."

P. 2487:
L. 15: Indicate that H is a non-linear operator. Is it linearized in your system?

H can be non-linear, it is linearized within the inner loop as in the incremental approach of Courtier et al. (1994). We extended description of Eq. (1) to clarify.

L. 16: R typically includes the representativeness error.

Agreed, corrected.

P. 2488:
L. 17: sea salt.

Agreed, corrected.

P. 2490:
L. 24: Define the "increment".

Increment defined.

P. 2492:
L. 4: The subscript should be "2.5".

The edited manuscript incorrectly subscripted PM25/PM10. PM25/PM10 are actual names to be entered in the table, i.e. no dot required in PM25.

L. 5: Please elaborate on what you mean by "regressions", and discuss their purpose here.

We removed reference to regressions as not essential. We believe it would be a distraction from the text to discuss this aspect of data assimilation in the manuscript.

L. 26: Quantify this "improvement". Significant in what sense? Statistical?

Figures clearly show large improvement in correlation, it is statistically significant. We rephrased the sentence.

Figures:
I suggest make the figures bigger, and provide details of the colour scale range in the figure captions.

Agreed, figures were enlarged and corrected to include aerosol name and units.

References:

Bouttier, F., and Courtier, P. (1999). Data Assimilation Concepts and Methods. ECMWF training notes. Available online at: http://www.ecmwf.int

Geer, A. J., Lahoz, W. A., Bekki, S., Bormann, N., Errera, Q., Eskes, H. J., et al. (2006). The ASSET intercomparison of ozone analyses: method and first results. Atmos. Chem. Phys. 6, 5445–5474. doi: 10.5194/acp-6- 5445-2006

Kalnay, E. (2010). "Ensemble Kalman filter: current status and potential," in Data Assimilation: Making Sense of Observations, eds W. A. Lahoz, B. Khattatov, and R.

Ménard (Berlin: Springer), 69–92.

Massart, S., Agusti-Panareda, A., Aben, I., Butz, A., Chevallier, F., Crevosier, C., et al. (2014). Assimilation of stratospheric methane products in the MACC-II system: from SCIAMACHY to TANSO and IASI. Atmos. Chem. Phys.. 14, accepted.

Rouïl, L., Honoré, C., Vautard, R., Beekmann, M., Bessagnet, B., Malherbe, L., et al. (2009). PREV'AIR: an operational forecasting and mapping system for air quality in Europe. Bull. Am. Meteorol. Soc. 90, 73–83. doi: 10.1175/2008BAMS2390.1

Talagrand, O. (2010). "Variational assimilation," in Data Assimilation: Making Sense of Observations, eds W. A. Lahoz, B. Khattatov, and R. Ménard (Berlin: Springer), 40–67.

Above references are included.