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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol optical depth assimilation for a size-resolved sectional model: impacts of observationally constrained, multi-wavelength and fine mode retrievals on regional scale forecasts" *by* P. E. Saide et al.

Anonymous Referee #1

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1 Overview

The manuscript by Saide et al. presents and applies a new 3D-Var assimilation system for AOD using the GSI framework and WRF-Chem. The system is applied to size-resolved aerosol simulations based on the MOSIAC aerosol module over CA. This is likely the most sophisticated and comprehensive work on 3D-Var assimilation of AOD to date, as several versions of AOD remote sensing products are considered

and analyzed. Overall, while clearly the performance of assimilation is subject to data quality, the tool introduced here is a nice advancement for the field of forecasting. What's not as clear, or not taken as further here, is the relevance for furthering our understanding / reducing uncertainty in the impacts of aerosols on health and climate. My broadest request would be to include additional discussion of the implications of the work here in terms of reducing uncertainty in knowledge of aerosol sources, and how 3D-Var, while not explicitly designed to adjust emissions, can be interpreted in that light. The authors do in fact touch lightly on several such issues (issues with NO_x or SO_2 inventories, or dust and sea salt concentrations in the boundary conditions being overestimated); such aspects could be brought out a bit more. Overall, the manuscript is fairly well written and nearly suitable for publication.

2 Specific comments

- Abstract: Possible to add some quantitative aspects of the results to the abstract? At the moment the description is all qualitative.
- Intro: The rational for using 3D-Var to address model uncertainty needs to be made more clear, or the introduction could used revision to focus more directly on the question of aerosol forecasting and the importance of this work in that light.
- 12216.10: Also, Wang et al. (GRL, 2012) and Xu et al. (JGR, 2013), constrain emission using 4D-Var assimilation of AOD.
- 12220: Is choice of the form of the control parameter or observation (linear or log scale) more or less consistent with the implicit assumption in using Eq (1) that x and y are normally distributed?

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- 12220: I follow the explanation of how assimilating concentration vs mass will be different, but the reason for preferring the latter formulation hasn't been explained. Only the consequences of using concentrations are mentioned, and it isn't obvious to me why these consequences would be undesirable. To improve estimates of aerosol on climate, wouldn't we want to target grid cells that have the largest impact on the column AOD?
- 12221.06: Perhaps it will be discussed further later, but it's not clear from here how these values are chosen, or what their uncertainty is, or what their impact on the results might be.
- 12223.14: Could it be explained what are "tangent linear and adjoint tests"?
- 12222.19: Regarding the constant correlation of two size bins, does that mean that aerosol properties within the fine mode are equivalently correlated to two bins spanning the boundary of the coarse and fine modes? Is this physically reasonable?
- 12226.22: Regarding "increase as AOD is lowered" – wouldn't the constant a term prevent this for small AOD?
- 12230.15: Are there any other works evaluating the dust simulations used here?
- A problem with the approach is that the fundamental source of model error, namely emissions, is not improved by the assimilation. This problem is most visible in plots such as Fig 6, where the observations only briefly pull down the model to values in better agreement with observations, only to pop right back up again as soon as the impact of the assimilation has subsided. Fundamentally, this problem required a different assimilation approach, or if keeping with 3D-Var perhaps the error correlation length / time scales need reconsideration.

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- 12232.17: It might be useful to reiterate here that you are discussing (I think) fractional error compared to surface PM2.5 at the AQS sites.
- Mention Xu in intro?
- 12234: It's a bit hard to reconcile the discussion of the persistence of influence of the observations here with the results shown in Fig 6, where it appears that in locations like Trinidad Head and UCSB that the assimilation run relaxes back to the non-assimilation run often within a day or less.

3 editorial comments

- throughout: e.g. → e.g.,
- 12215.23: First sentence is a bit awkward and could use a bit of work. I think it's the "play multiple roles including" part that is odd. Suggest something like "aerosols interact with society and the environment in several important ways – "
- 12215.26: Remove "mass distributions", as the scope of your work, and the impacts being discussed, are broader than aerosol mass.
- 12216.22: versus observationally constrained products
- 12216.24:), and
- 12216.26:), and
- 12217.6: who used
- 12217.6: Not sure what is meant by "performed over models"
- 12223.02: used the Community . . . as the forward

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- 12224.4: bins “of” MOSIAC?
- 12224.17:),
- 12225.15: land
- 12231.8: When considering
- 12235.17: constraint

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