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Geoscientific Model Development Discussions

Interactive comment on "The SPRINTARS version 3.80/4D-Var data assimilation system: development and inversion experiments based on the observing system simulation experiment framework" *by* K. Yumimoto and T. Takemura

Anonymous Referee #1

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The manuscript "The SPRINTARS version 3.80/4D-Var data assimilation system: development and inversion experiments based on the observing system simulation experiment Framework" presents an assimilation system based on 4D-Var assimilation method and the SPRINTARS global aerosol model. The system assimilates aerosol optical depth and seeks to find the emissions and initial concentration that represent the best compromise between the background information and the observations. To reduce the computational costs the authors have divided the system in outer and inner loop with the on-line version of SPRINTARS in the outer-loop and an off-line model

version in the inner loop. The off-line model version was examined in its performance to reproduce the on-line equivalent observations. Finally, the system was applied in a series of experiments to study the feasibility and capability for aerosol inverse modelling. This is a very interesting paper, well written and the methodology as well as the results are clearly presented. However, I consider that important aspects should be addressed before its publication.

General comments:

The cost function in equation 3 includes one term corresponding to the initial concentration and one to the emissions. Therefore in the inversion process the system will use both, initial concentration and emissions, to find the minimum of the cost function. However, after introducing the cost function and the state vector in section 2, no further mention about the initial concentration is given in the manuscript. The authors should explain why the initial concentration and its role in the inversion have been omitted after section 2.

Although the authors present the main parts of the inversion system, additional information not provided to the reader should be included. What is the assimilation window, is it the full 10 days period? The adjoint of SPRINTARS has been derived, but what is its accuracy? The state vector should be better presented. Is just the total dust emission estimated or each one of the their bins separately? How is the initial concentration defined in the state vector? What about the sea salt? Since a scaling factor is applied, I assume the system does not create sources, just increases/ decreases the existing ones, this should be put explicitly.

The definition of the error covariance matrix in equations 4 to 6 is crucial in the minimization of the cost function since it will determine the weight of the different pieces of information in the minimization. The authors present briefly the observation error used but do not present neither of the background error covariance matrices. The authors should not only present how they define these matrices but also explain their choice.

As part of the Monitoring Atmospheric Composition and Climate (MACC) project, the assimilation of aeorosl optical depth from MODIS was included in the Integrated Forecast System from the ECWMF. This work and the results have been presented in Benedetti et al. (2009). Zhang et al. (2008) also assimilate aerosol optical depth in an operational forecast system. The authors should at least include these works in the introduction. Furthermore, additional studies estimating aerosol emissions from inverse methods are Zhang et al. (2005), Huneeus et al. (2012, 2013) and Fu et al. (2012).

Benedetti, A., Morcrette, J. J., Boucher, O., Dethof, A., Engelen, R. J., Fisher, M., Flentje, H., Huneeus, N., Jones, L., Kaiser, J. W., Kinne, S., Mangold, A., Razinger, M., Simmons, A. J., and Suttie, M., Aerosol analysis and forecast in the European Centre for Medium-Range Weather Forecasts Integrated Forecast System: 2. Data assimilation, J. Geophys. Res.-Atmos., 114, D13205, doi:10.1029/2008JD011115, 2009.

Zhang, J. L., Reid, J. S.,Westphal, D. L., Baker, N. L., and Hyer, E. J.: A system for operational aerosol optical depth data assimilation over global oceans, J. Geophys. Res.-Atmos., 113, D10208, doi:10.1029/2007JD009065, 2008.

Fu, T. M., Cao, J. J., Zhang, X. Y., Lee, S. C., Zhang, Q., Han, Y. M., Qu, W. J., Han, Z., Zhang, R., Wang, Y. X., Chen, D., and Henze, D. K.: Carbonaceous aerosols in China: top-down constraints on primary sources and estimation of secondary contribution, Atmos. Chem. Phys., 12, 2725–2746, doi:10.5194/acp-12-2725-2012, 2012.

Huneeus, N., Chevallier, F., and Boucher, O.: Estimating aerosol emissions by assimilating observed aerosol optical depth in a global aerosol model, Atmos. Chem. Phys., 12, 4585-4606, doi:10.5194/acp-12-4585-2012, 2012.

Huneeus, N., Boucher, O., and Chevallier, F.: Atmospheric inversion of SO2 and primary aerosol emissions for the year 2010, Atmos. Chem. Phys., 13, 6555-6573, doi:10.5194/acp-13-6555-2013, 2013.

Specific comments:

- The abstract should include which kind of observation is assimilated and what the state vector is?

Section 2, provide a reference with the theoretical background of variational assimilation

Page 3438, line 20, reformulate “does the dust emission begin to emit”. Replace wit something like “dust is emitted”.

Page 3438, line 23, STD is used but not defined. Define acronym of STD.

Page 3434, lines 24-27, the aerosol species included in the SPRINTAR models are included. Even though the authors provide the reference for further information of the model, the size distribution of the dust and sea salt aerosols (presented in page 3441) should be given here.

Page 3439, lines 26-29, in line 26 lower layer is defined as sigma level <0.8 but then in line 29 the lower layer is defined as sigma level>0.85. Please correct. Furthermore, why use different sigma values in both, why not just use 0.8?

Page 3439 and 3440, What about the overestimation of dust in the upper layers, is it also due to the reasons presented in the last sentence of section 4? Please clarify.

Page 3441-3442, section 5.1, in experiments E4 and E5 the authors use fine and coarse mode AOT over land emulating Terra and Aqua satellite. The authors should be aware that even thought a fine mode product exist over land it has not been validated up to this day and is therefore not recommended to be used (Huneeus et al., 2012). A total AOT is provided over land that has been validated and that can be used in the inversion. To assess the real capability of the inversion system in inverse modelling applications realistic synthetic observations need to be used.

Page 3442, line 5, An observational error of 0.05 was used for the experiments. Why

use the same error over land than over ocean. The errors characterizing the MODIS product over ocean and over land are defined differently reflecting the higher accuracy over ocean than over land. Zhang et al. (2008), Benedetti et al. (2009) and Huneeus et al. (2012, 2013) define the errors differently over ocean than over land. The reference provided by the authors is a study conducted over ocean and therefore does not apply to justify applying the same error over land. I strongly recommend repeating the experiments with larger errors over land than over ocean or otherwise justify why you decide not to.

Page 3445, lines 2-5, which "AOTs for sulphate and carbonaceous aerosols" were directly assimilated? Please elaborate and explain or remove the sentence.

Page 3445 lines 28-29 and page 3446 lines 1-2, the authors conclude from the difficulties to obtain larger improvements in cases where different aerosol species coincide, the inadequacy of fine and coarse mode AOT to identify major tropospheric aerosol species. The problem is not the classification of aerosols as presented by the authors but the amount of information that is provided to differentiate between species. In regions where sulphate aerosols coincide with carbonaceous and dust ones, as can be the case in Easter Asia, the system is provided with one piece of information to constrain all three species, clearly not enough. Additional information is needed, such as the Angström exponent as suggested by the authors. I suggest to reformulate the sentence and do so accordingly in the conclusions and in the abstract.

Page 3470, Figure 10, Figure caption should include the units of the emission in each sub-figure. It is difficult to read.

Interactive comment on Geosci. Model Dev. Discuss., 6, 3427, 2013.