Geosci. Model Dev. Discuss., 5, C687–C690, 2012
www.geosci-model-dev-discuss.net/5/C687/2012/

Geoscientific Model Development Discussions

Interactive comment on "A simulation study of the ensemble-based data assimilation of satellite-borne lidar aerosol observations" *by* T. T. Sekiyama et al.

Anonymous Referee #3

Received and published: 17 September 2012

General comments

In this interesting paper, the authors present Observing System Simulation Experiments (OSSEs) to assess a four-dimensional ensemble-based data assimilation system. A synthetic CALIPSO satellite observation set is assimilated with an ensemble Kalman filter (EnKF) methodology. The observation operator used allows them to use attenuated backscatter and depolarization ratio, avoiding the retrieval process. An improvement in the representation of the aerosol concentration is demonstrated using Object-Based Diagnostic Evaluation (MODE). Several sensitivity experiments are run although the variability found was less than expected. The paper also describes an

optimized rescaling of the emission fluxes. While the optimization process reduces the large overestimation of the Free Run respect to the Nature Run, the quality of the spatial distribution is degraded. This may be due to the assumptions related to diagonality of the covariance matrix of the flux parameters. In contrast with the thorough validation of aerosol plumes, only episodic comparisons of fluxes are presented instead of a systematic assessment. A more thorough assessment of the error covariances of the flux parameters as well as a more systematic evaluation of the spatio-temporal distribution of fluxes would be required in order to support the claim that the system is capable of flux estimation. Otherwise, a caveat should accompany the claimed ability of the model to improve aerosol emissions.

Specific comments

1878, l16: Figure 16 does not visibly support an improvement in the estimation of dust emission spatial patterns.

1881, l23: An additional phrase on the previous OSSEs literature would be useful.

1885 A better description of 'filter divergence' would improve the readability of this section.

1886 l1 'which is mathematically equivalent to an Ensemble Kalman Smoother (EnKS).' Include a reference or better explain the EnKS.

1887, last paragraph and 1888, l1: In EnKF, if the unknown parameters are not forecast by the model, in contrast with state variables, does the ensemble add new information regarding the parameters' probability distribution? If not, does such probability distribution need to be added as an additional assumption?

1888, l3: How do the authors justify the claim that that the spatial correlation between surface dust concentrations and the dust emission is equivalent to the background error covariance distribution? Is it assumed that error correlation and variable correlation are proportional?

1888, l11: How does the spatial distribution indicating the response pattern of the dust concentrations as an increase in the dust emission within the square area provide information regarding actual cross correlation of errors in the emission scaling factors?

1888, l15: Is this simplified assumption consistent with the EnKF requirement that the ensemble represents the actual error statistics?

1888, l16: "This is a typical approach to parameter estimation," please include a reference.

1888, l17: "the error information of the dust emission is not propagated during forward forecasting". In addition to the mean and variance it is necessary to introduce the error covariances of the emission scaling factors or assumptions thereof.

1888, l19 : Does inflation also take into account non-diagonal terms in the error covariance matrix?

1888, l22: How is this random Gaussian noise defined? How is it related to the error covariance of the fluxes and the 'emission factors'?

1891, l25: 'It is assumed that only dust particles are nonspherical in this study': is this assumption reasonable?

1892, l14: 'Correlations among the observation errors were neglected; namely, the observation error covariance R is a diagonal matrix': is this a reasonable assumption? Is this also true for real satellite data?

1893, l2: Was the covariance inflation parameter fixed for all variables, regardless if they were parameters or state variables?

1893, 6-9: 'The deviations of these additive perturbations' only the standard deviation was quoted for the perturbations. What is the treatment of non-diagonal terms (especially for dust emission factors)? 1893, l12: What is meant by 'the unlikely subspace of the chaotic atmosphere system'?

1893, l16: The presence of negative emission and overlarge emission may be connected with the degradation in spatial patterns for emission estimation shown in Fig. 16.

1896, l10: 'results are less likely to be influenced by the initial conditions.' Are the authors referring to the dynamical wind fields? Do meteorological reanalysis contain aerosol concentration?

1896, l15: Can SO2 and DMS then be negative?

1900, Sect 4. There is no mention of any evaluation of the aerosol flux.

1900, l7: is the assumed random Gaussian noise uncorrelated? In the real world, it is expected that at least the representation errors are correlated within a given model grid cell. Interesting experiments could be devised if the true error correlations and the estimation mismatch were known.

1908 l11. A more careful assessment of spatial error covariances may improve this.

1909 l25 The use of error correlations could have an impact here.

1914: 'Consequently, we found better experimental settings of the 4D-LETKF data assimilation system.' How would the same setting translate for real observations?

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