Response to Reviewer 2's comments on “The GRAPE aerosol retrieval algorithm” by Thomas et al.

The authors thank the reviewer for their comments and recommendation, which we believe we have addressed, as detailed below. The reviewers comments are included in italic text, with our responses in regular font.

General Comment

The manuscript describes an aerosol retrieval algorithm developed for application to nadir observations by the ATSR-2 sensor. When applied to the ATSR-2 observational record the proposed algorithm will contribute aerosol optical depth data to the period 1995-2000 prior to the deployment of the MODIS and MISR instruments.

The most serious limitation of the algorithm is the use of the Lambertian approximation to characterize the surface reflectance in a spectral region where the need to accurately account for surface effects is well known. The chosen approach is rather puzzling taking into account that the dual viewing capability of the ATSR-2 can be advantageously used to carry out a more realistic and accurate surface reflectance characterization. Given the availability of a multi-view algorithm already documented in the literature by the same author one wonders what is then the purpose of this manuscript, describing a technically limited retrieval approach.

The authors acknowledge that the Lambertian surface reflectance approximation is a limitation of the algorithm presented in this paper, along with the use of only the nadir view of ATSR-2. These two limitations stem from the fact that the GRAPE analysis is primarily concerned with retrieving cloud properties, with the aerosol retrieval essentially filling the gaps. This paper details an algorithm that has already been applied to the ATSR-2 record, and from which data is publicly available. The authors feel that the existence of this dataset warrants a paper describing the algorithm used to produce it. The application of an optimal estimation approach is novel and demonstrates how much information can be retrieved from a single view of the atmosphere.

The manuscript has been modified to provide more information about the providence of the algorithm and the reasons for its configuration. Details of where the dataset produced using the algorithm can be obtained have also been included.

Another serious shortcoming of this paper is the failure to use actually observed ATSR-2 data to evaluate the robustness of the proposed algorithm. The authors have carried out a detailed sensitivity analysis using synthetic data. The results are clearly very useful but not conclusive. A more useful analysis could have been produced making use of actual observations out of the ATSR-2 1995-2001 record instead of synthetic data.

We repeat the point made to the first referee:

The description of satellite products is achieved by publishing papers describing the instrument calibration, the retrieval algorithm and product validation before publishing science results. This best practice approach is taken by many instrument teams (e.g. those on the UARS and AURA platforms such as MLS and ISAMS). An advantage of this approach is to decouple the analysis of the algorithm from real data — a sensitivity analysis is not possible with real remote sensing data, since it isn't possible to know the true state of the atmosphere.

As mentioned above, this algorithm has been applied globally to ATSR-2 data from 1995-2001. Since the submission of this paper, another paper detailing the validation of this dataset has now been submitted to Atmos. Chem. Phys. References to this paper have now been added to the manuscript.

Specific Comments:

-Page 982: The authors need to provide a rationale for the application of a technically limited algorithm to a sensor capable of providing data to be used in a more robust and accurate retrieval approach taking advantage of the dual viewing capability.

Remote sensing of atmospheric properties involves a compromise between computational accuracy and speed. While the referee is correct that a second view can provide more information it does so at a computational cost. In the GRAPE data set we have produced a long term record of aerosol and cloud properties along with their uncertainties. The algorithm described in this paper is state-of-the-art in the sense that applies optimal estimation to the retrieval of aerosol properties from imager data. As computational speed increase so we will increase the complexity of our forward model – however what we have presented here represents a baseline for aerosol retrieval from imager sensors.

-Page 983: The Lambertian surface approximation breaks down rapidly at the wavelengths of the observations. This is especially true over land. The use of actual ATSR-2 observations for the evaluation of this approximation will probably yield a more realistic assessment of the inadequacy of the proposed surface treatment approach.

The fact that the Lambertian surface breaks down is a concern but it is accounted for. The advantage of optimal estimation is that approximations in the radiative transfer are expressed as forward model errors. In consequence our aerosol optical depths over land are very noisy and we do not recommend their use.

-Page 984: The authors need to define what 'sufficient accuracy' is. I agree with the authors that the ATSR-2 sensor could provide a valuable data set on aerosol optical depth during the 1995-2000 period. It can be even more valuable if one takes advantage of the full observational capabilities of the sensor.

In this context sufficient accuracy means an uncertainty in aerosol optical depth of less than 0.1. This is sufficiently accurate to identify significant aerosol events such as Saharan dust storms, biomass burning, polluted air and perform scientific investigations with the data e.g. Bulgin et al. 2008.

The Thomas et al paper (2009) documents an existing algorithm that seems to make use of the sensor's dual viewing geometry. If such algorithm has been developed, why is a nadir-only algorithm needed?

So that the algorithm can be applied to sensors that do not have a dual view capability (MODIS, MERIS, SEVIRI). The results from those instruments can be compared with those from ATSR so that potential algorithm difference between the sensor results can be decoupled from differences due to sampling.

-Page 985: The authors rely heavily on the OPAC data set for the aerosol model representation. Are the resulting atmospheric-column model representations consistent with AERONET derived aerosol columnar properties of particle size distribution and refractive index?

This question is outside the scope of this paper. The authors acknowledge that OPAC is far from the final word in aerosol microphysical and optical properties, especially when it comes to absorbing aerosols such as particulates from biomass burning. Nevertheless we attempt to quantify the errors in the aerosol microphysics and optical properties in the retrieval by including a forward model error.

-Page 987: It is not clear where the mixing ratio of the ith component comes from. Please explain.

The mixing ratio of the components in each aerosol class is varied from that specified in OPAC to obtain a specific effective radius.

The expectation that large changes to the effective radii are not needed to match the observed radiances is clearly unrealistic in the retrieval of dust plumes blowing over the oceans. (See comment on Figure 1 below).

This is correct. However, if grossly inaccurate assumptions are made about the type of aerosol being retrieved, the size distribution and composition will be wrong in any case.

-Page 989: I do not understand the need to report the retrieval results at a wavelength other than the ones of the observations. It makes more sense to report retrievals at 0.67 or 0.87 microns. A converted value to 0.55 micros can also be reported but making clear that it is a converted rather than retrieved value.

It is essential to present results at 0.55 microns as this is the standard wavelength at which instruments compare optical depths.

The normalization channel should be one of the actual ATSR channels. Any extension to other channels is a modeling exercise beyond the scope of the retrieval algorithm

An explanation of this has been added to this section of the paper. Essentially, the inclusion of the 550 nm channel wouldn't greatly affect the retrieval of AOD and surface reflectance at this wavelength, since optimal estimation retrievals all state parameters from all channels, constrained by the assumed aerosol properties. The retrieval is not calculating the AOD at some other instrument wavelength and then extrapolating it to 550 nm.

-Page 992: A more extensive discussion of the geographical distribution of aerosol types shown in Figure 1 necessary. For instance, figure 1 shows the desert dust type only over the continents. Does it mean that the algorithm does not expect desert dust in the middle of the Atlantic and Pacific Oceans as it is often seen by MODIS, MISR and OMI observations? The same can be said about the smoke plumes that frequently flow from the continents to the oceans. Are the optical properties of the continental aerosol type used in the forward model consistent with what is known today (AERONET) for carbonaceous aerosols? It is not clear if aerosol mixtures are considered.

The discussion of the assumed geographical distribution of different aerosol types has been expanded to address these points.

- *The reported sensitivity analysis is very useful but not conclusive. The use of actually observed ATSR-2 data will allow the testing of the assumed spatial distribution of the different aerosol types.*

See the response to the reviewers second general point above.

Page 995: In discussing Figure 5 the authors refers to precision. I believe the concept they refer to is 'accuracy' rather than precision.

Page 996: Again, I believe the authors mean 'accuracy' rather than precision

The reviewer is incorrect here. The uncertainty estimates given by optimal estimation indicate how well constrained the retrieved state is: that is they can be considered to be the 1-sigma width of a PDF of possible states which is constructed from the PDFs of measurement noise (as defined by the measurement error covariance) and the a priori PDF of possible states. Thus, they are a measurement of the precision of the retrieved variable, as opposed to the accuracy of the retrieval, which is defined by how different to the true state it is.

Page 998: The Plane parallel approximation should also be listed as a forward model error.

Agreed.

Page 1002: On the last paragraph the authors refer to the large errors in retrieved effective radius resulting from assuming desert aerosol in place of maritime. The opposite case (i.e, prescribing maritime instead of desert type) is probably likely to occur more often in practice. What is the implication on the accuracy of the retrieval?

The errors introduced by assuming maritime aerosol when desert dust would be more appropriate would be similar in magnitude to the case presented in the paper.