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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Synergetic aerosol retrieval from SCIAMACHY and AATSR onboard ENVISAT" *by* T. Holzer-Popp et al.

T. Holzer-Popp et al.

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Response by the authors to referee number 1

Dear reviewer,

We are thankful for your comments which are in deed very helpful to improve our paper.

Response to GENERAL COMMENTS

Overall scientific objective / organisation of the manuscript: The major original contribution is the improvement of our own method and its application to a new sensor combination, which allows better coverage and thus a clearer demonstration and validation of the potential in the methodology. The new skill in this method is the capability to derive information on the type of aerosols. To mathematically support this new capability we have added the information content analysis. As we consider the capability to retrieve “more than” AOD and Angstrom coefficient a significant step forward, we want to keep both the description of method improvements and first results together with the analysis of the information content of the algorithm part referring to the type of aerosols. In response to your criticism about the focus and organisation of the manuscript we suggest following 2 changes (which we will also discuss with the editor): - change the title of the paper into “Satellite-based estimation of aerosol composition from ENVISAT” - split the paper into 2 parts: o “Part 1: method improvements and application” (which would contain methodology, the 3 improvements, initial validation, and first example results and be extended to discuss impact of the improvements on these results) o “Part 2: analysis of retrieval capabilities for aerosol properties“ (which would contain the information content analysis and state of the art overview on other retrieval methods of aerosol composition)

Information content analysis We only use the information content analysis to assess the capabilities of the retrieval for estimating the aerosol type. The retrieval, itself, is based on the choice of one pre-defined aerosol type with the help of a least square method. We are therefore not using measurement and a priori covariance matrices in retrieval.

As our method comprises of 2 subsequent parts applied to the 2 different sensors with different pixel size, a comprehensive information content analysis for the whole methodology or of the impact of the improvements would be very demanding. We therefore focus on the new element, namely the second retrieval step applied to the spectrometer, which delivers the choice of the most plausible type of aerosols.

Therefore we concentrate our attention on the 40 pre-defined aerosol mixtures when constructing the state vector. We are thus using just another way of definition of the statement vector to answer the main question for us: how many aerosol components can we retrieve from satellite data? We regard this as justified since in the second retrieval step surface type and surface reflectance for each pixel are fixed based on the

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results of the first retrieval step. Consequently, the covariance matrices do now only contain equivalent variables, namely the fraction of each aerosol component (0-100%). As a consequence, the a priori covariance matrix has no longer any diagonal structure.

In summary, the information content analysis has been upgraded to become consistent with the retrieval scheme – the revised manuscript will contain the same setup of aerosol modelling and state vector throughout all parts of the paper: - we now use the same set of 9 aerosol components as in the retrieval - we construct the state vector in the information content analysis solely from the aerosol type (the set of 40 aerosol mixtures) and without the surface contribution in order to exactly repeat the second retrieval step in the information content analysis

We have prepared a comparison of results obtained with these changes in the information content analysis versus the analysis in the original manuscript and found that the major results and conclusions remain the same and DOF values even increased slightly by about 0.3.

We will include these additional explanations and revised figures into the revised manuscript.

Response to SPECIFIC COMMENTS: (our responses are marked by $<$ $>$ 1. Introduction: The introduction is too long. It is not clear why such a long review of existing methods (from p2905 line 3 to p2909 line 26) is relevant in the context of this paper. I would suggest to remove these lines or to create a specific section to host this review. $<$As we have received feedback from other scientists that this review of aerosol type retrieval with other sensors was very helpful we suggest to create a specific section in the proposed Part 2 of the manuscript.$>$

2. Introduction: The paper scientific objective not clearly stated. The relationship between the information content analysis and the algorithm improvement is not clearly established. Is the purpose of this analysis to propose a method to assess the algorithm improvement? $<$When implementing our suggestion to split the paper we will

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adjust the introduction part of the information content analysis to make clear that the role of the information content analysis not to assess the method improvements or to redevelop our retrieval algorithm, but to theoretically establish the principal capabilities for aerosol type retrieval.>

3. Section 2: There is an inconsistency between the retrieval method proposed in Section 2.1 and the DFS analysis proposed in Section 2.2. Error covariance matrices should be the same in both cases. <This inconsistency was corrected – now the same set of aerosol mixtures is used in both parts.>

4. Section 2.2. This type of approach has been developed and used for systems where all the variables have the same physical dimension, eg, number of vertical temperature or humidity values in case of sounding. Hence, it cannot be used as such when variables have different units whose magnitude might be very different. Such method might be applicable if all variables are first scaled for instance between 0 and 1. As it is not the case here, any interpretation of the analysis is meaningless. <Both top-of-atmosphere reflectance as well as surface albedo values have a scale from 0 to 1 and equivalent physical meaning. Thus we think that the condition is met. While making the information content analysis consistent with the retrieval algorithm, we have removed the 12 surface types from the state vector and the covariance matrix, since the second retrieval step is for each pixel only applied to one surface type, which has been selected prior based on the results of the first retrieval step.>

5. Page 2913, line 6. Replace 7 by 10. <While assuring consistency between information content analysis and retrieval this was done (now using the same set of 9 aerosol components).>

6. Page 2914. The measurement vector consists in 10 spectral observations. Why are they simulated? <In the second retrieval step the measurement vector consists in 10 spectral observations – these are then compared (by least square fit) to 40 simulated spectra of each 10 spectral observations based on the results of the first

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retrieval step (AOD, surface albedo) representing the spectra of the 40 aerosol mixtures for this pixel. In the information content analysis, however, the spectra are simulated and then the information content in their differences is assessed with the assessment. We will improve our description of this step.>

7. Page 2914. Considering 40 a priori aerosol mixtures and 12 a priori surface reflectance as state parameters is erroneous. In principle, the state vector is composed of - the four aerosol micro-physical properties listed in Table 1, i.e. the complex refractive index, the mode radius and its standard distribution and the particle density. As these four basic properties can be mixed as can be seen on Table 2, this represent a maximum total of 16 variables (up to four mixing are possible). Note that the extinction coefficient and ssa are derived from the Mie theory and should not be considered as state variables. - The relative humidity - The surface reflectance in each spectral band, ie, 10 values. The information content should thus analysise how much of these 27 or so state variables can be retrieved from the measurement vector and the a priori information. <Our setup is completely different to reproduce exactly the second retrieval step, i.e. the state vector is composed of the aerosol components’ optical characteristics, which are the result of the second retrieval step. A more detailed description will be provided in the revised manuscript.>

8. Page 2915. The accurate determination of the measurement and a priori error covariance matrices is absolutely fundamental for a relevant assessment of the information content. The measurement error covariance matrix should be composed of the total measurement system uncertainty, ie, observation, cloud screening and forward model. A diagonal form for such matrix cannot be justified, eg, co-registration error, inter-band calibration error, approximation in the forward model. As concern the a priori error covariance matrix, it should be composed of the true state variables and in no way might be considered as a diagonal matrix. This matrix should contain information on how the aerosol properties are mixed to generate a pre-defined mixture. The same is true for the surface spectrum. Note that the elaboration of such

matrix is not straightforward. <After eliminating the albedo part from the a priori error covariance matrix, we don’t have any diagonal structure in this matrix. Regarding the measurement error covariance matrix due to the fine spectral resolution of the spectrometer SCIAMACHY (0.2 nm in the visible and thus no band cross-talk between selected wavelengths 20 nm and more apart) we think that a diagonal structure is justified. Inaccuracies of the forward model are not taken into account here, since the same forward model is used for the AOD/surface reflectance retrieval in step 1 and in step 2, where these results of step 1 are used – thus assuring self-consistency of the 2 retrieval steps. To cover realistic retrieval conditions which take into account that the results of step 1 are not error-free (and as we now deleted the surface types from the a priori matrix) we increased the noise term in the measurement error covariance matrix diagonal elements from a constant value of (1e-3)2 for all 10 wavelengths to a 5% value (using the mean reflectance of all 40 simulated spectra for each wavelength). This cautious assumption (versus a 1% instrument error) means also a larger noise level of shorter wavelengths with higher reflectance values. With this new setup we calculate only slightly altered results. We have also made an additional analysis, where we increased the value of the measurement error covariance matrix (i.e. the noise in the spectrometer measurements) by a factor of 2, which showed only a decrease of DOF by a value of 0.15.>

9. Section 3.1. Why only spherical particles are considered for this improvement? <It is clear to us and stated accordingly in the discussions that this means a relevant restriction for our methodology. We chose to limit ourselves to spherical particles, because the setup of the aerosol model in order to capture realistic global atmospheric aerosol variability is already rather complex and also – based on our information content analysis – we can not justify to add another degree of freedom.>

10. Section 3.2. The uncertainty associated to the cloud screening should be included in the measurement error matrix (which is supposed to represent only cloud free observations). <This would require a complete matching of the entire retrieval scheme

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(subsequent steps 1 and 2) in the information content analysis, which is not feasible.>

11. Section 4.1. What is the benefit (reduction) between V1 and V2 in term of RMSE? In other words, what are the bias, stdv and corr values for version 1.0. <In version 1.0 the respective values for 440, 550, 670 nm were (43 pixels of the same period/test orbits): - bias: -0.02, 0.03, 0.03 - stdv: 0.15, 0.18, 0.14 We will add this information for version 1.0 to document the impact of the improvements. >

12. Section 4.2. The purpose of this section is not clear, as it only contains results from version 1.0. It should be remove from the paper. <We have exchanged the seasonal and monthly mean examples, which now contain version 2.0 results; the validation results already contained version 2.0 data. With this upgrade we intend to keep this section in Part 1 of the revised manuscript.>

13. Section 5: This section should be re-organised according to the actual paper objective (see general comments). <When implemnting our suggestion to split the paper the discussion section will also be split and reorganized, accordingly.>

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 2903, 2008.