

Response by the authors to referee number 1

Dear Reviewer,

We are thankful for Your comments which are indeed very helpful to improve the paper.

Detailed comments

1. The present study builds on work by Holzer-Popp et al, 2008, who has already addressed the information content to some extent. It should be stated explicitly in the present manuscript what is new to the present study.

The purpose of the analysis in work by Holzer-Popp et al, 2008 is to establish theoretically the information content of step 2 in SYNAER retrieval, namely the choice of the most plausible aerosol mixture. The information content analysis in Holzer-Popp et al, 2008 estimates degrees of freedom for signal (DFS) for aerosol composition retrieval.

This paper is logical continuation of Holzer-Popp et al. 2008 work and concentrates mostly on the interpretation of the DFS values (derived in previous paper) with respect to understanding the possibility to differentiate between aerosol types using a principal component analysis.

A corresponding explanation will be added in the revised version of the present paper.

2. It should be made more clear what assumptions are made regarding the spectral surface reflectance; is the spectral surface reflectance part of the state vector in the DFS analysis using Rodgers optimal estimation? how is the surface albedo treated in the SYNEAR retrieval?

The SYNAER aerosol retrieval algorithm comprises of two major parts: A dark field method exploiting single wavelength radiometer reflectances (670nm over land, 870nm over ocean) and a least square fit of visible top-of atmosphere reflectance spectra at 10 wavelengths (415, 428, 460, 485, 500, 516, 523, 554, 615, and 675 nm) with the spectrometer.

The focus of information content analysis is on the second retrieval step exploiting the spectrometer measurements. This uses the results of the first retrieval step, namely aerosol optical depth at 550nm and surface reflectance at 550, 670 and 870nm for each aerosol mixture.

So the spectral surface reflectance is considered to be known from the first retrieval step in SYNAER and not included as the part of the state vector in DFS analysis using Rodgers optimal estimation.

The statement will be added to the revised paper.

3. It should be discussed in more detail why two methods are employed for estimating DFS and what the associated advantages or disadvantages are. Also it needs to be made more clear in which context the PCA is applied: is the surface albedo variability included in the set of input spectra? Is the PCA analysis aiming at distinction of aerosol types restricted to cases where the spectral surface reflectance is known?

In SYNAER a look-up table approach is used. Radiative transfer calculations are precalculated for many values of the parameters, then results are compared with measurements until the best "fit" is obtained. There is a problem in such method, that is the lack of uniqueness in the solutions, but this is the problem of all inversions. We used a

classical tool from statistical methods (PCA) to explore this problem, extract the uncorrelated and independent variables and concentrate attention only on main (principal) aerosol type components which should be retrieved. Such an approach has advantages (in comparison with, for example, Factor-analysis) and is useful since it will give us in an unbiased way the number of parameters (and their interpretation) that can be retrieved.

The PCA analysis is aiming only at distinction of aerosol types. The spectral surface reflectance is considered to be known from the first retrieval step in SYNAER and not included as the part of the state vector in the DFS analysis.

Corresponding changes will be added in the revised version of present paper.

4. The text says that an "a priori covariance matrix" is shown in Figure 1. In contrast, Figure 1 shows a covariance matrix of the 40 aerosol models used in the PCA.

As a state vector x for the analysis we consider only 40 different aerosol models. So the a priori covariance matrix S_a is the associated covariance matrix for these a priori values and knowledge about the x vector, i. e. 40 aerosol models

5. The literature list seems incomplete.

Corresponding changes will be added in revised version of present paper.

6. The assumed values for the measurement error should be discussed.

As a starting value of measurement error we took $10e-6$, which is around 0.001% of reflectance spectra from SCHIAMACHY, assuming explicit knowledge of surface type and AOD from the first AATSR step. After that, in order to make some sensitivity studies, we varied measurement error in large-step series of the error ($10e-6$, $6e-7$, $3e-8$) and in small-step series of the observation error ($4e-7$, $5e-7$, $6e-7$). The choice of such values for observation error variance is based on the attempt to explore the dependency of DFS from observation error.

7. A discussion on which kind of information comes from which instrument would be desirable.

The appropriate description of the retrieval method is necessary in order to understand the sources of information from both instruments. The SYNAER aerosol retrieval algorithm comprises of two major parts for two instruments: A dark field method exploiting single wavelength radiometer reflectances (670nm over land, 870nm over ocean) and a least square fit of visible top-of atmosphere reflectance spectra at 10 wavelengths (415, 428, 460, 485, 500, 516, 523, 554, 615, and 675 nm) with the spectrometer. AOD calculation over automatically selected and characterized dark pixels and surface albedo correction at 550, 670, and 870nm for a set of 40 different pre-defined boundary layer aerosol mixtures is done with the radiometer. To characterize surface reflectance R1.6 and NDVI are used. After spatial integration to the larger pixels of the spectrometer these parameters are used to simulate spectra for the same set of 40 different aerosol mixtures with the same radiative transfer code. A least square fit of these calculated spectra to the measured spectrum delivers the correct AOD value and – if a uniqueness test is passed – the plausible aerosol mixture. The entire method uses the same aerosol model of basic aerosol components, each of them representing optically similar aerosol species. These basic components are externally mixed into 40 different aerosol types meant to cover a realistic range of atmospheric aerosol masses.

We assume 2 DFS from the first step of algorithm (regarding AOD and surface reflectance). And up to 2-3 DFS for second step (regarding aerosol type), as shown in Holzer-Popp, et al. 2008.

Corresponding changes will be added in revised version of present paper.

8. It is recommended to discuss the results of the present study also in context of the findings of Hasekamp et al JGR 2005.

The Hasekamp et al study presents an analytical linearization of vector radiative transfer with respect to physical properties of spherical aerosols. It is quite close to the analysis of information content discussed in ACP paper by Holzer-Popp et al., 2008. There, we also use linearization of radiative transfer around some point of state space with respect to different aerosol type properties. The present paper concentrates on PCA analysis applied for aerosol type in order to understand the separation of the aerosol types.

9. It is recommended to refer also to Tanre et al JGR 1996 for the PCA.

Corresponding changes will be added in revised version of present paper.