Executive Summary

Aeolus/EarthCARE Aerosol Assimilation Study (A3S)

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ABSTRACT:

The objective of the Aeolus/EarthCARE Aerosol Assimilation Studies (A3S) project was to allow assimilation of the Aeolus L2A lidar backscatter data also paving the way for the assimilation of EarthCARE products. Since the Aeolus and EarthCARE missions were not yet launched, demonstration datasets based on model data (MOCAGE model for the aerosols and the IFS for the clouds) and a one-day dataset based on CALIPSO data (reprocessed at the UV wavelength and with the Aeolus orbit data) was created. Technical developments were undertaken at ECMWF to extend the observation operation for lidar backscatter which had been used for CALIPSO data and to enable the use of different datasets. In particular, the backscatter lidar operator was adapted to the 355nm wavelength, including the tangent linear and adjoint routines. An operator for extinction was also developed, but is not yet tested. It is expected that the aerosol extinction product from Aeolus will not be of high enough quality for assimilation. The existing data quality control and screening was adapted for the Aeolus/EarthCARE products. The demonstration datasets were encoded into the Observation Data Base (ODB) which allowed inclusion in the IFS's 4D-VAR system.

The final report provides a detailed description of the aerosol model, observation operator, aerosol analysis and structure of the ECMWF's incremental 4D-Var. Functional tests of the assimilation system are presented and discussed. **These tests showed that it is technically possible to assimilate Aeolus L2A data into the ECMWF system.**

Several 4D-Var assimilation experiments were performed to assess the assimilation of the L2A lidar backscatter demonstration datasets. From the technical point of view the assimilation of L2A backscatter data was completely successful. From the scientific point of view, however, some issues were highlighted. In particular, the MOCAGE aerosol + IFS cloud was shown to have large, possibly unrealistic values of low level/low backscatter clouds which were not screened by the cloud screening based on thresholds on height and backscatter values. Experiments were also conducted with the one-day L2A demonstration dataset derived from CALIPSO. These experiments showed the technical feasibility of the assimilation of L2A backscatter data and less problems for the clouds screening. The impact of the error assumptions on the L2A data was also investigated showing a large reduction in bias with a corresponding increase in standard deviation when the reported errors were down-scaled. This indicates an imbalance in the error assumptions for the background and the observations. When using the native errors from the L2A product, better results were achieved. Further investigation into the errors is needed.

Finally, verification using independent datasets from AERONET was also performed. Two experiments including the L2A aerosol-only demonstration dataset with and without MODIS data were compared. The experiment with the L2A data only is of comparable quality to the experiment which includes both L2A and MODIS data. While it is not possible to draw conclusions on what impact the actual L2A data will have, due to the use of synthetic datasets, it is nonetheless encouraging that the L2A synthetic data have a positive impact on the analysis. In view of the recent launch of the Aeolus satellite, when the actual L2A data will become available it will be possible to apply all the tools developed in A3S and investigate the impact of this type of observations on the aerosol analysis and forecast.

The work described in this report was done under ESA contract. Responsibility for the contents resides in the author or organization that prepared it.

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Executive Summary

Started in February 2016, the Aeolus/EarthCARE Aerosol Assimilation Studies (A3S) project covered 2 years of research to allow assimilation of the Aeolus L2A lidar backscatter data with the view to pave also the way for the assimilation of EarthCARE products. Since no actual data were available a big cornerstone of the project was the creation of demonstration datasets based on model data (MOCAGE model for the aerosols and the IFS for the clouds). A one-day dataset based on CALIPSO data reprocessed at the UV wavelength and with the Aeolus orbit data was also created. Technical developments were undertaken at ECMWF to extend the observation operation for lidar backscatter which had been used for CALIPSO data and to enable the use of different datasets. In particular, the backscatter lidar operator was adapted to the 355nm wavelength, including the tangent linear and adjoint routines. An operator for extinction was also developed, although it was not possible to test it with the demonstration datasets. It is expected that the aerosol extinction product from Aeolus will not be of high enough quality for assimilation. The existing data quality control and screening was adapted for the Aeolus/EarthCARE products. The demonstration datasets were encoded into the Observation Data Base (ODB) which allowed inclusion in the IFS's 4D-VAR system. All project tasks were complete successfully with the exception of the refinement of the online variational bias correction which has been deferred to a follow-on activity.

This document provides a detailed description of the aerosol model, observation operator, aerosol analysis and structure of the ECMWF's incremental 4D-Var. The procedure to convert L2A data from the native Earth Explorer format to the Observational Data Base format is also described in detail. Functional tests of the assimilation system are presented and discussed. **These tests showed that it is technically possible to assimilate Aeolus L2A data into the ECMWF system.**

Several 4D-Var assimilation experiments were performed to assess the assimilation of the L2A lidar backscatter demonstration datasets. From the technical point of view the assimilation of L2A backscatter data was completely successful. From the scientific point of view, however, some issues were highlighted. In particular, the MOCAGE aerosol + IFS cloud was shown to have large, possibly unrealistic values, of low level/low backscatter clouds which were not screened by the cloud screening which is based on thresholds on height and backscatter values. Two different thresholds were tested (200.E-07 sr-1 m-1 and 100.E-07 sr-1 m-1). In both cases, the backscatter data from low level clouds were present in the assimilation, even after the screening, and introduced a large bias in the "aerosol" backscatter particularly over the tropical oceans, in areas where the aerosol load is low.

Experiments were also conducted with the one-day L2A demonstration dataset derived from CALIPSO. These experiments showed again the technical feasibility of the assimilation of L2A backscatter data. It appeared also that with the CALIPSO-based dataset, the problem of clouds screening was less severe than with the model-based dataset. The impact of the error assumptions on the L2A data was also investigated. When reduced errors are assumed for the L2A backscatter data, a large reduction in bias is observed with a corresponding increase in standard deviation. This indicates an imbalance in the error assumptions for the background and the observations. When using the native errors from the L2A product, better results were achieved, even if in general the bias was corrected more than the standard deviation in the analysis. Further investigation into the errors is needed.

Finally, verification using independent datasets from AERONET was also performed. Two experiments including the L2A aerosol-only demonstration dataset with and without MODIS data were compared. The experiment with the L2A data only is of comparable quality to the experiment which includes both

L2A and MODIS data. While it is not possible to draw conclusions on what impact the actual L2A data will have, due to the use of synthetic datasets, it is nonetheless encouraging that the L2A synthetic data have a positive impact on the analysis. In view of the recent launch of the Aeolus satellite, when the actual L2A data will become available it will be possible to apply all the tools developed in A3S and investigate the impact of this type of observations on the aerosol analysis and forecast.