ALADIN Aerosol and Cloud retrievals using ATLID-like approaches (an update).

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Abstract: This paper presents recent developments associated with the application of cloud and aerosol retrieval approaches, originally developed for the EarthCARE lidar ATLID, to ALADIN data. These two algorithms are AEL-FM and AEL-PRO. AEL-FM provides a ``feature-mask'' based on ALADIN crosstalk corrected pure particulate (``Mie'') and molecular (``Rayleigh'') attenuated backscatter profiles. These two algorithms have been added to the AEOLUS Level 2A operational processor. In this paper. AEL-FM and AEL-PRO are briefly described, and some representative recent results are presented and discussed.

1. Introduction

The Atmospheric Laser Doppler Instrument (ALADIN) was the world's first space-based Doppler wind lidar [1]. ALADIN operated at 355nm and its main product was line-of-sight wind profiles. ALADIN used a variation of the High Spectral Resolution Lidar (HSRL) technique to directly detect the Doppler shift of the return signal.

ATLID (Atmospheric Lidar) is the lidar carried by the Earth Clouds and Radiation Explorer (EarthCARE) mission. EarthCARE is a joint ESA-JAXA mission and will carry a cloud/aerosol lidar (ATLID) [2] as well as three other instruments. ATLID is a HSRL system optimized exclusively for cloud and aerosol sensing, unlike ALADIN which is optimized for wind measurements. Aerosol and cloud products were considered secondary for ALADIN, however, useful aerosol and cloud information is present in the products and purpose built cloud/aerosol algorithms have been formulated and deployed e.g. [3,4].

A-FM [5] and A-PRO [6] are two algorithms, developed for ATLID for cloud and aerosol retrievals. A-FM provides a featuremask that identifies significant targets at high resolution. This information is used by other processors to guide binning/smoothing and classification procedures. A-PRO uses A-FM as input and performs a two-pass procedure to estimate both cloud and aerosol properties. The first pass is based on selectively smoothing the data (guided by A-FM inputs) so that direct methods for estimating weak feature (e.g. aerosol) extinction and backscatter can be applied. The second pass uses the first pass results a-priori input and a high resolution forward modelling optimal estimation retrieval procedure is used to retrieve both cloud and aerosol optical properties. A target classification and an aerosol type estimation procedure are also implemented within A-PRO.

A-FM and A-PRO have been developed and tested mainly on simulated data [7]. The availability of ALADIN data provided a means to test many of the concepts used by A-FM and A-PRO. This resulted in the creation of AEL-FM and AEL-PRO. Significant differences between the ATLID algorithms and their ALADIN counterparts exist due to, for example, the varying range-gate structure of ALADIN and the fact that ALADIN did not detect cross-polar backscattered radiation (e.g thus limiting the potential of ALADIN to classify targets). After dealing with several issues (including the formulation of accurate calibrated attenuated backscatter (ATB) profiles [8]), AEL-FM and AEL-PRO were added to the ALADIN operational processing chain.

In this paper, AEL-FM and AEL-PRO are briefly introduced and illustrative examples are shown and discussed.

1.1. AEL-FM

AEL-FM provides an index that corresponds to the probability of a target being present and additionally identifies clear-air and attenuated regions. The product is reported at the Aeolus native resolution (about 3 km horizontal resolution and 0.25-3 km vertical resolution). The procedure combines a hybrid-median edge preserving filter (to identify strong returns) and an iterative adaptive Gaussian smoothing (which is targeted towards weaker extended features). AEL-FM is described in more detail in [5] and [8].

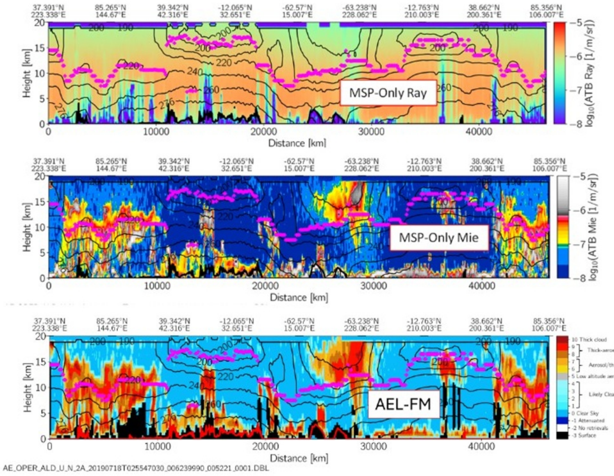

Figure 1: Example AEL-FM data as well as corresponding Ray and Mie ATBs. The Magenta lines show the tropopause height.

Example AEL-FM output is shown in Figure 1. Here several features are seen to be present. High altitude clouds associated with tropopause heights above 16 km are seen to be present in the tropics. In the summer mid- and high-latitudes aerosol (forest fire smoke) is present in the lower stratosphere and upper-troposphere. In the winter Antarctic stratosphere, Polar Stratospheric Clouds (PSCs) are present.

1.2. AEL-PRO

AEL-PRO uses a two-pass optimal estimation approach to retrieve (primarily) extinction and lidar-ratio. More details may be found in [8]

Example extinction and lidar ratio retrievals corresponding to the same orbit as for Figure 1 are shown in Figure 2. Both results from the SCA mid-bin algorithm [4] and AEL-PRO results are shown. Data where the estimated SNR is greater than 1 was aggregated to a resolution of 0.5 km (vertically) by 90 km (horizontally). There is a large degree of correspondence between the SCA and AEL-PRO results, however, the AEL-PRO results are more precise and sensitive, particularly with regards to the lidar-ratio retrievals. This difference is due to the combined effects of both more precise ATB profiles estimates as discussed earlier and the regularization (or stabilization) effect afforded by the optimal estimation approach used by AEL-PRO.

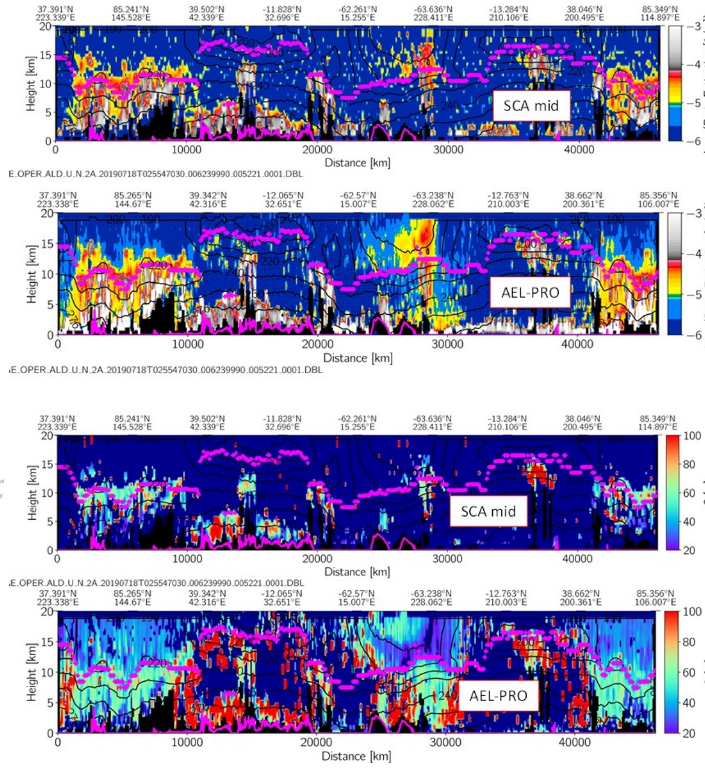

Figure 2: SCA and AEL-PRO retrievals of particulate extinction and lidar-ratio for the same orbit as previously presented. The black areas correspond to attenuated or below surface altitudes.

2. Comparisons with CALIPSO

AEL-FM data has been compared with the CALIPSO Vertical Feature Mask (VFM) data by van Zadelhoff et al. [5] for dust plumes in cloud-free scenes. Figure 4 shows the comparison of Aeolus and CALIPSO feature mask products on 10 October 2018 for the orbit depicted in Figure 3. CALIPSO measured dust between 37–12º N and biomass burning aerosols between 5.54 –24º S.

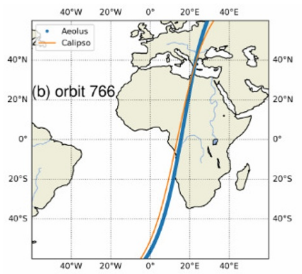

Figure 3: Aeolus orbit 766 on 10 October 2018 with collocated CALIPSO orbit at 00:27:07 UTC on 10 October.

The Aeolus feature mask exhibits a similar shape and altitude compared to the CALIPSO feature mask for both clouds and aerosols. The aerosol plumes are from the ground surface up to 5 km, with some small, scattered clouds present above the aerosols.

In ``homogeneous'' aerosol fields, CALIPSO derived extinction profiles and AEL-PRO results compare well quantitatively. An example is shown in Figure 5. Here the aerosol type was dust and the 532nm CALIPSO extinction values were extrapolated to 355nm using an Angstrom coefficient of 0.55. In Figure 6, a comparison of AEL-PRO and CALIPSO extinction coefficients for a month for the indicated region is shown. The comparison exhibits a high degree of consistency.

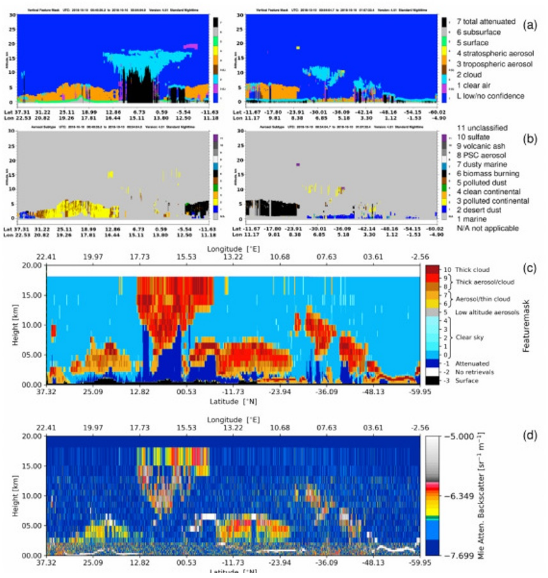

Figure 4: Comparison of Aeolus orbit 766 on 10 October 2018 (Figure 3) and collocated CALIPSO orbit for feature masks, (a) CALIPSO vertical feature mask, (b) CALIPSO aerosol subtypes, (c) Aeolus feature mask, (c) Aeolus Mie attenuated backscatter.

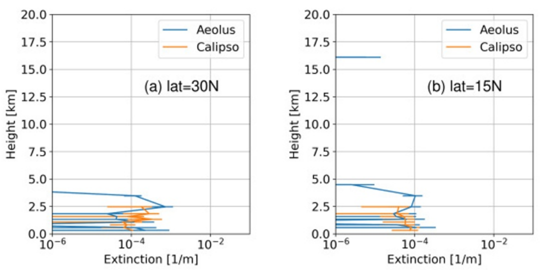

Figure 5: Comparison of AEL-PRO and CALIPSO extinction profiles for orbit 766 on 10 October 2018.

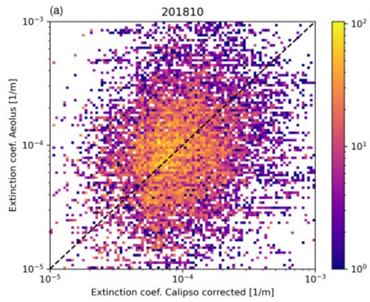

Figure 6. Scatter plots of Aeolus tropospheric aerosol extinction coefficients versus CALIPSO tropospheric aerosol extinction coefficients for October 2018, -10 to 50 ºE, l0 - 30 ºN. The colorbar indicates the number of data points.

3. Monthly averages

AEL-PRO results can be used to estimate AOD. Example AOD estimated by integrating the AEL-PRO extinction profiles in cloud-free conditions aggregated for a period of one month are shown in Figure 7. Here several expected features are observed, for example, lower AOD values over Greenland and elevated levels over Southern-central Africa and the Indian sub-continent.

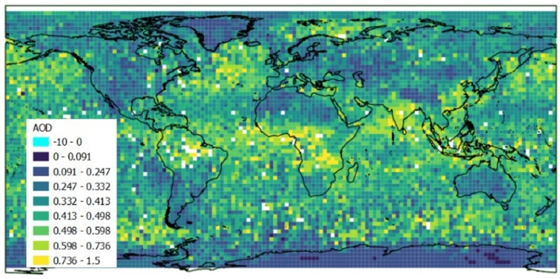

Figure 7: AOD estimated from the AEL-PRO profiles for the month of 2018-11.

Average profile can also be computed. An example of a time series of cloud-screened monthly average profiles of extinction and lidar-ratio for a region off the coast of N-W Africa is shown in Figure 8. Here the dotted line indicates the mean freezing level, above this, the results may be affected by imperfect screening of thin ice cloud. The evolution of the profiles is dominated by the seasonal transport of dust from the Sahara. The response in the lidar-ratio around 4-6 km is particularly striking, with the lidar-ratio response being more visible than the response in the extinction itself.

4. Summary

The adaptation of cloud and aerosol retrieval methods developed for ATLID to ALADIN has proven to be a successful endeavor. Useful new

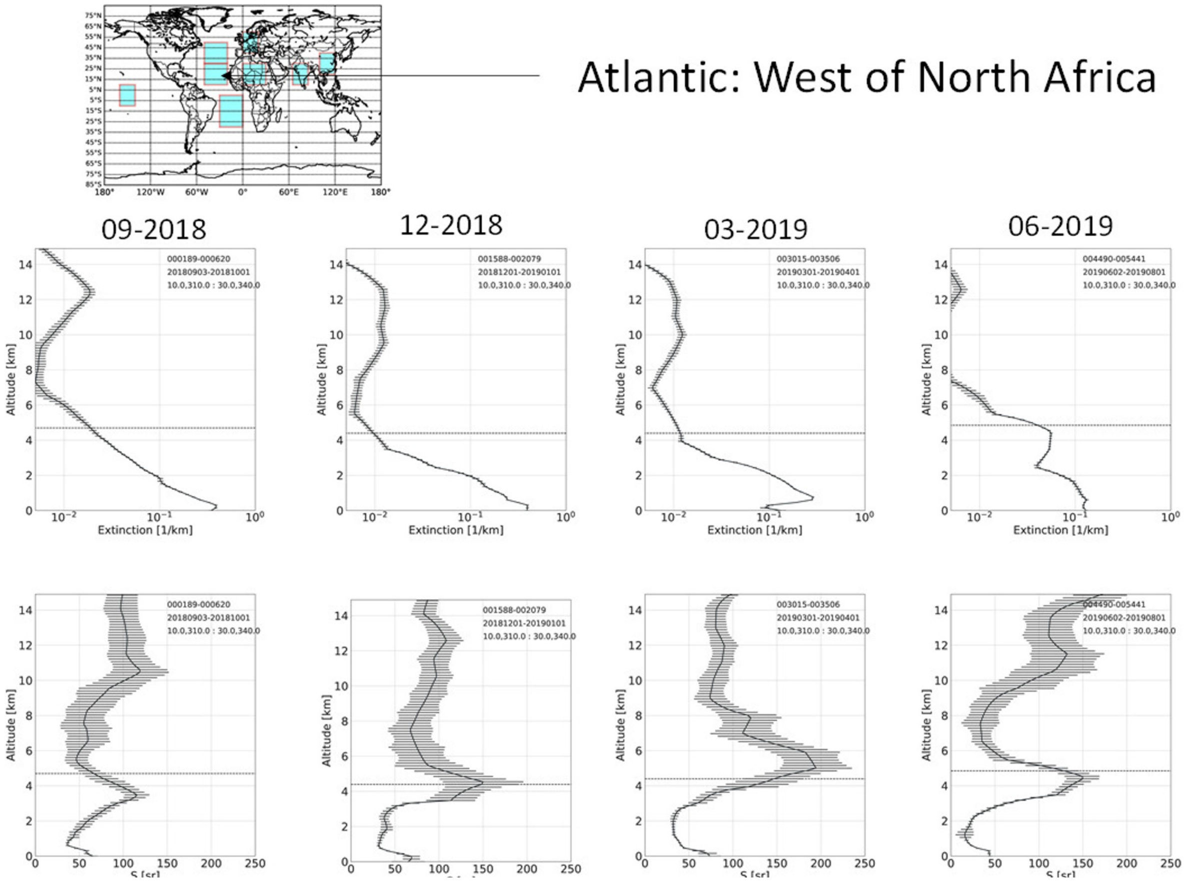

Figure 8: Average profiles of aerosol extinction and lidar ratio for the indicated region in the for the labelled months.

ALADIN products have been created and more insight and confidence in the ATLID approaches has been gained.

The evaluation of the AEL-FM and AEL-PRO products continues. However, it is already clear that ALADIN aerosol/cloud products are reaching a level of confidence where they can be used by the community for numerous applications.

5. References

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