EARTHCARE ATLID EXTINCTION AND BACKSCATTER RETRIEVAL ALGORITHMS

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ABSTRACT

ATLID stands for "ATmospheric LIDar" and is the lidar to be flown on the Earth Clouds and Radiation Explorer (EarthCARE) platform in early 2019. ATLID is a High-Spectral Resolution (HSRL) system operating at 355nm. This presentation will introduce the ATLID level-2 retrieval algorithms being implemented in order to derive cloud and aerosol optical properties

1 INTRODUCTION

EarthCARE[1] is an upcoming ESA/JAXA mission expected to fly in 2019. The EarthCARE instruments are:

- A 94 GHz, Doppler Cloud Radar supplied by Japan (CPR)
- An advanced 355 nm High-Spectral Resolution Lidar (ATLID)
- A Multispectral Cloud/Aerosol imager for narrow-band TOA radiances (MSI)
- A 3-view Broad-Band Long- and Short-Wave Radiometer for TOA radiance (BBR)

EarthCARE is a cloud-aerosol-precipitation-radiation process oriented mission for which a comprehensive suite of retrieval algorithms is being developed. As outlined in [1], both (primarily) single-instrument (L2a) and multi-instrument algorithms are being developed. The results of the algorithm chain will be used in an ongoing radiative closure assessment in which the derived aerosol and cloud properties will be used as input to broad-band radiative transfer models which will, in turn, generate TOA flux and radiance estimates which will be compared to the actual BBR measurement. The assessment results will be used to assess the retrieval products, guide scientific and technical improvements and lead to a high-quality set of data suitable for process studies.

ATLID is a polarized three channel lidar operating at 355nm. The lidar delivers profiles of the parallel, so-called, Mie (or particulate) attenuated backscatter, the parallel Rayleigh (molecular) attenuated backscatter and the corresponding total (Mie+Rayleigh) cross-polarized return.

The development efforts are spread over a number of cooperating development teams. In this paper we will describe the ATLID L2a algorithms responsible for target detection, aerosol and cloud optical property retrievals and target classification. Examples of other related developments involving ATLID and MSI can be found in [2].

2 Algorithm overviews

The L2a ATLID algorithms/procedures described here are:

-The Featuremask (A-FM). This algorithm uses a combination of image processing inspired techniques in order to, respectively, detect regions of clouds/aerosols, surface returns, clear air or regions where the lidar return is completely attenuated. At this stage, the valid targets are not classified into different type (e.g. water, ice). This is accomplished in subsequent processing steps.

-The aerosol oriented extinction and backscatter retrieval routine (A-AER). This procedure uses relatively conventional HRSL retrieval methods for determining extinction and backscatter at the 50km+ horizontal scale (e.g. deriving the extinction based on the log derivative of the Rayleigh signal). In order to do this the lidar signals must be appropriately averaged to achieve a target SNR. The averaging mask is based (mainly) on the A-FM produce which is used to avoid averaging intervals which would mix "strong" and "weak" features together which would lead to invalid retrievals.

-The cloud and aerosol extinction, backscatter and depolarization procedure (A-EBD). This routine retrieves the aerosol and cloud extinction and backscatter at the 1-km horizontal scale. At this scale the SNR of the molecular scattering channel return is too low to enable the techniques employed by the A-AER approach. Instead, the method relies on finding the optimal profile of the extinction-to-backscatter ratio (S) that allows one to invert the total lidar signal to produce an extinction profile consistent with the observed Rayleigh channel signal. Multiple-scattering (MS) effects which are important for accurate cloud (and in some cases aerosol) retrievals are included in the procedure which is cast in an optimal-estimation framework [3]. As a-priori information, the S estimates produced by A-AER are used.

-The ATLID Target classification procedure (A-TC). This procedure uses extinction, backscatter and depol. ratio, as well as auxiliary inputs such as temperature and geographic location in order to classify targets into classes such as water or ice cloud or aerosol type. The aerosol typing scheme is based primarily on using the S and depol. ratio to assign a class to the aerosol [4]. The cloud phase determination scheme uses backscatter and depolarization in a manner similar to that employed for the CALIOP retrievals [5].

3 Algorithm Development and Testing

The algorithm development process is being aided by simulated data produced using the EarthCARE Simulator (ECSIM) [1]. One such `scene' has been built using ECMWF MACC data [6] corresponding to a simulated orbit track from sub-Sahara Africa to southern Europe on 2015/01/13, a distance corresponding to a single EarthCARE processing fame (6200 km).

Fig. 1 shows the 355 nm nadir extinction field derived from the MACC data. The corresponding observed CALIOP attenuated backscatter exhibits strong correlation in terms of aerosol and cloud features indicating that the MACC forecast for this time period exhibited a high degree of realism.

The MACC output is at a low resolution (0.5x0.5 Deg.). The cloud and aerosol fields were interpolated to a resolution of 500mx100m. Structure was added by perturbing the mass fields using suitably correlated pseudo-random deviates.

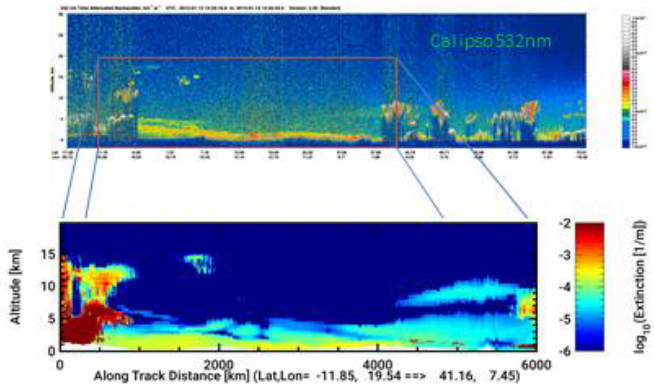

Figure 1: (Bottom Panel) MACC ECSIM scene derivied extinction field. Ice and water clouds as well as aerosol regions (including extensive desert dust) are visable. (Top-Panel) the corresponding observed CALIOP 532 attenuated backscatter image is shown.

3.1 Example Simulations and Retrievals

Example simulated ATLID observations are shown in Fig. 2. Here the observations are plotted with an effective horizontal resolution of 1-km and a vertical resolution of 100m. ECSIM is capable of performing 3-D Monte-Carlo lidar radiative transfer calculations. However, in this case the fast semi-analytical model described in [7] with a physically based parameterization of the depolarized return due to MS in water clouds, was used.

The scene contains regions of ice cloud, water cloud and various types of aerosols. Realistic ice crystal phase functions were used with an adjusted backscatter peak following [8]. The aerosol regions contain mixtures of 4 distinct basic types following [4], namely, Coarse-Dust, Coarse-Marine, Fine-Weakly-absorbing, and Fine-Strongly-absorbing. Mie phase functions were used in the case of the later 3 types while T-matrix spheroids have been used to model the dust aerosols (which are mainly present between 10 and 25 Deg N).

Noise levels corresponding to the expected instrument performance characteristics and background light levels have been included. Cross-talk between the Mie and Ray channels for ATLID is significant and the effect of the cross-talk on the SNR ratio of the cross-talk corrected attenuated backscatters has been accounted for.

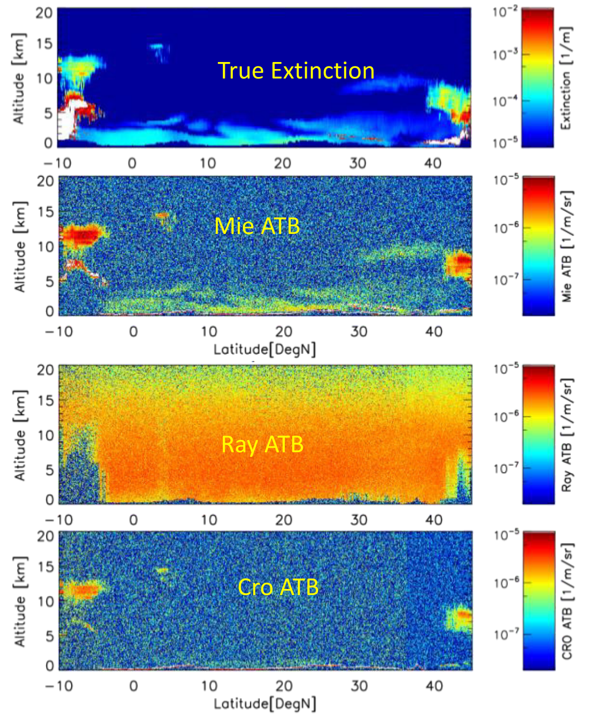

Figure 2: (From Top to bottom) The ECSIM scene extinction and the corresponding ATLID simulated Mie (Particulate), Rayleigh (molecular), and cross polarized attenuated backscatter fields.

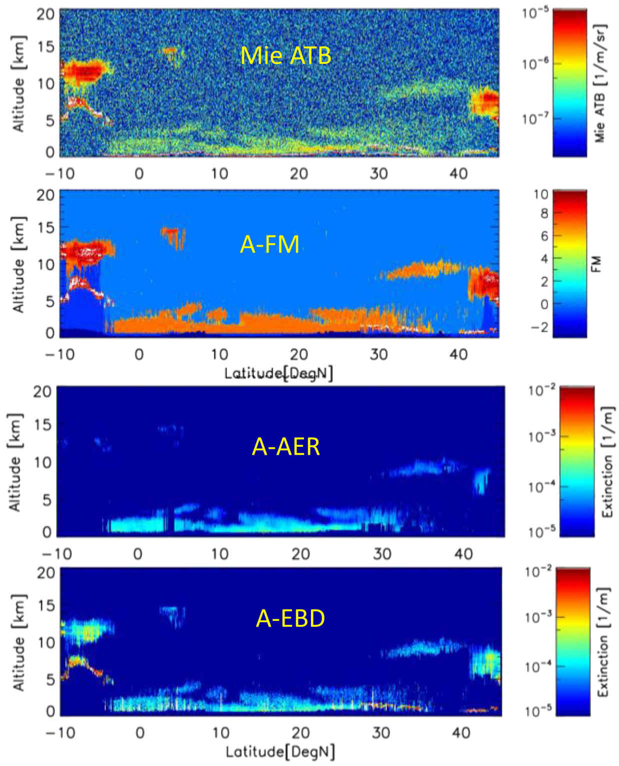

Figure 3: Featuremask, A-AER and A-EBD retrieval results.

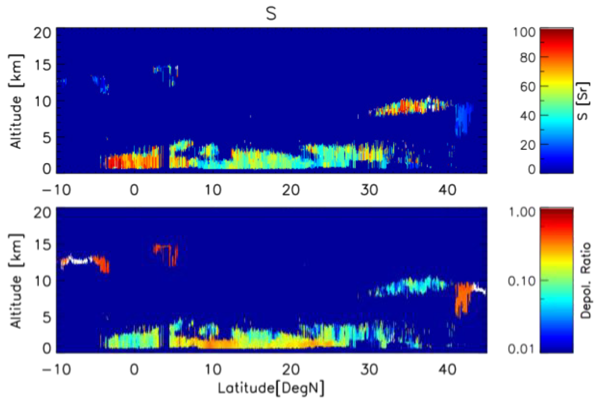

Figure 4: Retrieved A-AER lidar ratio (S) and depolarization ratio.

Sample retrieval results for the Feature mask (A-FM) as well as A-AER extinction and A-EBD extinction are presented in Fig 3. Here it can be seen that the A-FM output (an integer field where higher values correspond to higher detection confidence, negative values correspond to surface returns (-2) and attenuated regions (-1)) does an impressive job of detecting features at high resolution. However, some deficiencies are also noticeable. Namely, there are some issues near the surface in areas of variable surface-height and between about 30 and 40 N between 0 and 5 km in an attenuated region with very low extinctions.

The A-AER and A-EBD extinction fields are also presented in Fig. 3. The A-AER algorithm distinguishes between weak and strong features and horizontally averages the ATB fields avoiding the strong features. Areas below `thick enough' ice clouds are also avoided due to the possibility of multiple-scattering induced tails [3] extending below the cloud into the aerosol regions. This strategy is reflected in the results which mainly correspond to thin ice cloud regions and aerosol fields. The corresponding higher resolution A-EBD extinction field is seen to be more complete (i.e. Extinction is provided for both cloud and aerosol regions) however, in the case of aerosols, it is considerably noisier than the A-AER product.

The corresponding A-AER extinction-to-backscatter ratio (S) retrievals as well as the depolarization ratio are shown in Fig. 4. Here it can be seen that even though the depolarized signals were not so distinct in the high resolution Cross-ATB presented in Fig. 2., that with appropriate smoothing a usable depolarization ratio can be estimated.

Fig. 5 depicts the aerosol classification for a height of 400 meters above surface based on the data shown in Fig. 4. Here, in general, the aerosol type is reasonably well retrieved.

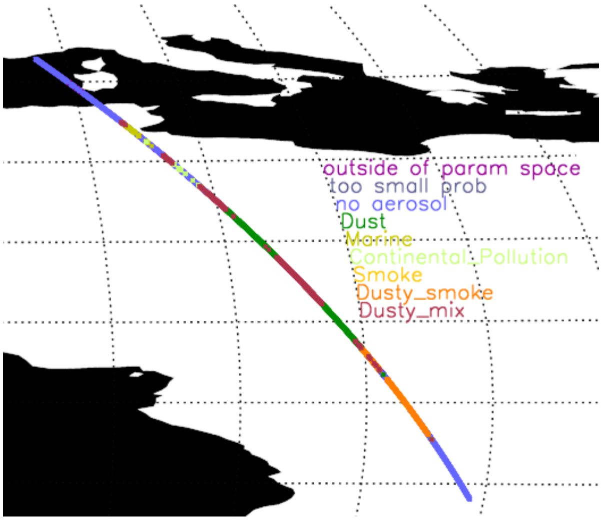

Figure 5: Aerosol type at an altitude of 400 m derived using the S and depolarization data presented in Fig. 4. Here the dark areas correspond to ocean/sea areas. The "no aerosol" regions correspond to areas where high thick clouds prevent lower level aerosols from being detected.

4 CONCLUSIONS

The lidar algorithm development for EarthCARE is well underway. Full-frame data sets have only just recently been generated but already, the use of realistic ECSIM simulations is proving to be an effective means to develop the scientific and technical aspects of the algorithms. This is of particular importance, since for ATLID, suitable proxy sources of actual data are not available (e.g. CALIOP observations cannot be used due to the change in wavelength, different instrument characteristics and the lack of HSRL capability).

In the coming year the algorithms and related codes will continue to be developed with the aim, that when EarthCARE is launched, useful well-understood data products will be able to be rapidly generated and made available to the scientific user community.

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