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OVERVIEW OF THE EARTHCARE L2 LIDAR RETRIEVAL CHAIN

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ABSTRACT

In this paper an introduction to the planned L2 retrieval algorithms for the Earth Clouds and Radiation Explorer (EarthCARE) lidar ATLID is given. The ATLID instrument is a high spectral resolution lidar which will provide independent retrievals of extinction and backscatter profiles and will be launched in 2018. A short description of the intended operational ESA products is given together with the logic behind the choices made.

1. INTRODUCTION

The interactions between clouds, aerosols and solar and terrestrial radiation play key roles in the Earth's Climate. As stated in the most recent assessment report of the Intergovernmental Panel on Climate Change, clouds and aerosols are two of the largest causes of uncertainty in climate prediction: aerosols because of their uncertain direct and indirect radiative forcing of climate, and clouds because the way they change in response to a warmer world is one of the more poorly understood climate feedbacks.

It has been recognized that, despite a long history of satellite observations, novel high-quality novel observations are needed for atmospheric model evaluation and process studies. In particular, the importance of true height-resolved global observations of cloud and aerosol properties has been recognized as being essential to making progress. Currently-, elements of the A-Train satellite constellation, namely CloudSAT (carrying a 94 GHz cloud radar; [1]) and CALIPSO (carrying a 532/1064 nm lidar; [2]) continue to produce many exciting results and have demonstrated the value of multi-sensor cloud/aerosol observations including active instruments (i.e. lidar and radar).

EarthCARE[3] is an upcoming ESA/JAXA mission to fly in 2018. The instruments that will be carried onboard EarthCARE 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 may be thought of as selected components of the A-Train. However, whereas CloudSAT and CALIPSO are separate platforms, EarthCARE is a single platform designed from the ground-up in order to maximize the benefit that may be realized by combining the different sensors. By combining the lidar and radar observations with the imager and radiometer radiances the production of a suite of self-consistent synergistic products will be possible.

APRIL is one of the ESA sponsored L2 algorithm development projects. The focus of APRIL is the development and implementation of ATLID and MSI L2 algorithms. Within this work the planned stand-only ATLID L2 algorithms and products are discussed.

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2. The ATLID instrument

ATLID is an example of a High Spectral Resolution Lidar [4]. ATLID emits a linearly polarized spectrally narrow beam (FWHM for ATLID is around 30 MHz) and the return is detected by 3 different receiver channels. First the return is separated into components which are either the same (co-polar) or perpendicular (cross-polar) to the transmitted beams plane of polarization. Subsequently the co-polar channel is spectrally separated into 2 channels. The Mie channel is dominated by light scattered by aerosol or cloud particles whereas the Rayleigh channel is dominated by the thermally broadened molecular return from the atmosphere itself

ATLID provides atmospheric echoes with a vertical resolution of about 100 m from ground to an altitude of 20 km and 500m from 20km to 40km altitude and is designed to retrieve profiles of particle extinction and backscatter coefficients, lidar ratio, and linear depolarization ratio as well as the aerosol optical thickness (AOT) at 355 nm.

A Fabry-Pėrot (FP) etalon is used to (imperfectly) spectrally separate the two channels resulting in Rayleigh signals ending up in the Mie channel and vice versa (cross-talk). A cross-talk correction procedure is implemented as part of the L1 processing to ensure that the L2 algorithms are supplied with corrected Rayleigh and Mie signal profiles.

Due to this measurement capability, in contrast with the case of an elastic backscatter lidar, one can retrieve the aerosol/cloud extinction and backscatter profiles independently.

3. ATLID retrievals

The design of the retrieval chain is driven by expected signal-to-noise ratio [SNR] of the ATLID instrument and the EarthCARE requirements [5]. The instrument design will not provide sufficient single-shot SNR to enable an extinction retrieval using the Rayleigh signals directly, instead it is expected that at least 1 km binning is required for the thicker ice clouds and 10-150 km horizontal binning for regions consisting of aerosols only. Three separate (but interdependent) processors, as shown in Figure 1, have been proposed in order to retrieve the atmospheric state. As a first step, a feature mask algorithm (A-FM) has been created to separate regions with particle return from molecular backscatter regions only. This will enable the development of binning strategies to minimize the number of shots to bin to achieve a given SNR. The second processor will provide the best possible profile information (A-Prof) and the third derives the layer information (A-Layer), which is a direct input to the synergistic MSI-ATLID algorithms.

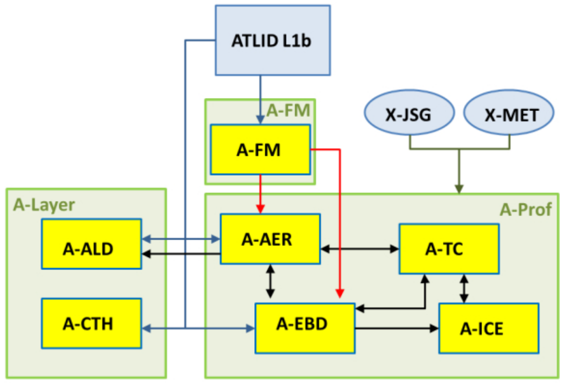

Figure 1:Flow diagram of the ATLID only algorithms. The blue boxes and arrows depict the input to the algorithms. The green boxes show the three ATLID only processors, while the yellow boxes depict the individual algorithms. Black arrows show data streams between algorithms, while green arrows indicate that all products within the processors use the same input stream. The X-MET input reflects the ECMWF meteorological information along the EarthCARE track while X-JSG (joint standard grid) defines the collocated grid, used within the synergistic algorithms, with the horizontal grid defined by the CPR and the vertical grid by ATLID.

The A-FM algorithm returns the probability of particle return, between 0 (molecular) and 10 (particles), detection at native resolution (horizontal approx. 0.2-km and vertical approx.100 m) based on the correlation of the data without focusing on a number of hard coded or input dependent thresholds. For this a combination of image reconstruction techniques has been employed. In Figure 2 an example of the Feature Mask is shown using CALIOP 1064nm data. The 1064nm data is used in preference to 532 nm data since the lower Rayleigh scattering contribution better matches ATLID's Mie channels.

The retrieval of the extinction and backscatter at a horizontal resolution of 1 km will be achieved using an optimal estimation (OE) technique [A-EBD]. This requires a reasonable a-priori input value of the local extinction to backscatter (lidar or S) ratio.

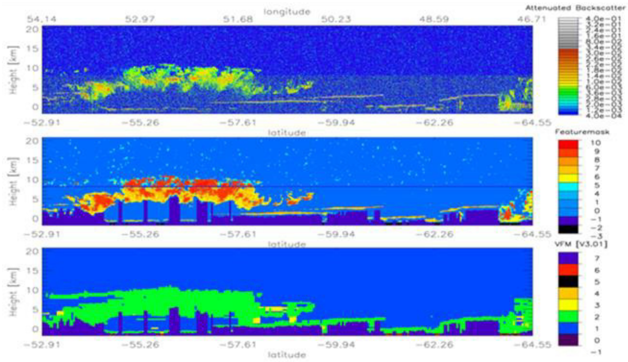

Figure 2: CALIOP night time data on 18-04-2010, the top panel represents the raw 1064nm data, the center panel the ATLID featuremask and the bottom panel the VFM (V3.01) mask.

This is in general, no problem for the ice clouds but S values can be very different for different types of aerosols. In order to deal with this issue, a separate routine will be used to derive the lidar ratio for aerosols at low horizontal resolution [A-AER]. These data will then provide the *a priori* estimate necessary for the high resolution OE procedure. The low-resolution approach will use a conventional direct retrieval using the Rayleigh signals, which requires a horizontal binning between 10 and 150 km. The OE procedure uses these retrieved lidar ratios as an *a priori* input along with both the Rayleigh and Mie channel signals to in order to produce extinction and backscatter profile retrievals at 1 km horizontal scales Both these algorithms require a target classification [A-TC] to enable the correct retrieval and binning strategies. Finally, based on the high resolution extinction, backscatter, depolarization and target classification the higher order retrieval algorithm like the synergistic classification and ice microphysical retrieval can be performed [A-ICE]. In Figure 3, an example is shown for the retrieval of the extinction at 1 km scale using a scene and modeled signals created using the EarthCARE simulator (ECSIM). The retrieved profile information can be used as a direct input to the synergetic lidar+radar retrievals.

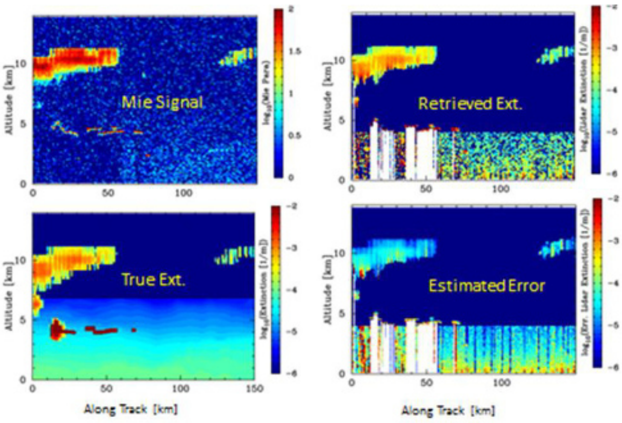

Figure 3: Simulated Mie Signals (top left) with true extinction (bottom left). The two images on the right depict the retrieved extinction and estimated errors at 1km resolution.

The third processor (A-Layer) defines the layer products for clouds and aerosols, respectively. Cloud and aerosol layers appear as regions of increased backscatter signal compared to aerosol-free and cloud-free atmospheric regions. Layers can be identified by gradients in the Mie signal measured by ATLID, or combined gradient/threshold methods. The ATLID stand-alone layer products A-CTH and A-ALD are pre-requisites for the corresponding synergistic layer products. The A-CTH algorithm makes use of a

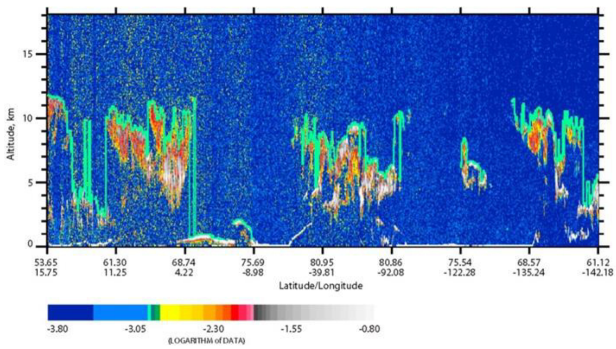

Figure 4: CTH determined with the WCT algorithm (green line) plotted on top of the 1064-nm attenuated backscatter signal along a CALIPSO daytime orbit on 1 August 2006, 1156-1213 UTC.

combined wavelet covariance transform (WCT) and threshold approach (e.g., [6], [7]) to determine the uppermost cloud top height along the ATLID track with a resolution of 1 and 10+ km. The latter, coarser resolution is needed to identify optically thin clouds, e.g., subvisible cirrus. An example of the CTH is shown in Figure 4 using CALIOP 1064nm data.

For the determination of aerosol layer boundaries a WCT algorithm with thresholds has been developed. The WCT is the same as for CTH determination, but the thresholds are adapted for aerosols, and a multi-layer search for base and top heights is performed. For each layer the aerosol optical depth and its error are calculated, in addition, the stratospheric AOT and the column AOT, both with errors, are computed.

4. CONCLUSIONS

With the launch of EarthCARE the active remote sensing of clouds and aerosols from space, as started by CloudSAT and Calipso, will continue for at least another three years. Since the precise instrument designs are very different from, the A-TRAIN instruments novel retrieval techniques have been defined and are currently being coded for implementation in the future ground segment. The major difference between CALIOP and ATLID is the possibility to retrieve directly and independently the cloud and aerosol extinction and backscatter profiles.

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