MERLIN Level 0-1 Processing and Calibration Concept

G. Lichtenberg[1], B. Aberle[1], M. Meringer[1], T. Trautmann[1], G. Ehret[2], M. Wirth[2], A. Amediek[2]

[1]Remote Sensing Technology Institute (IMF), German Aerospace Center (DLR), Oberpfaffenhofen, Wessling, Germany
[2]Institute for Atmospheric Physics, German Aerospace Center (DLR), Oberpfaffenhofen, Wessling, Germany

Introduction

The new generation space borne Lidar mission MERLIN (Methane Remote Sensing Lidar Mission) will make measurements of the CH_4 distribution with a precision of $< 2\%$ and an unprecedented low systematic error $< 0.2\%$. The latter is a prerequisite for reliable emission estimates by inverse modeling. After its launch, MERLIN will track down sources and sinks of methane on a global scale. MERLIN is an active spaceborne instrument using a IPDA (Integrated Path Differential Absorption) LIDAR. The difference in atmospheric transmission between a laser emission with a wavelength placed around the center of a CH_4 absorption line ($\lambda_{on} \approx 1.6\mu m$) and a reference wavelength, λ_{off}, slightly shifted from λ_{on} by a few tenths of a nm is used to derive the differential absorption optical depth (DAOD) and ultimately the CH_4 mole fraction.

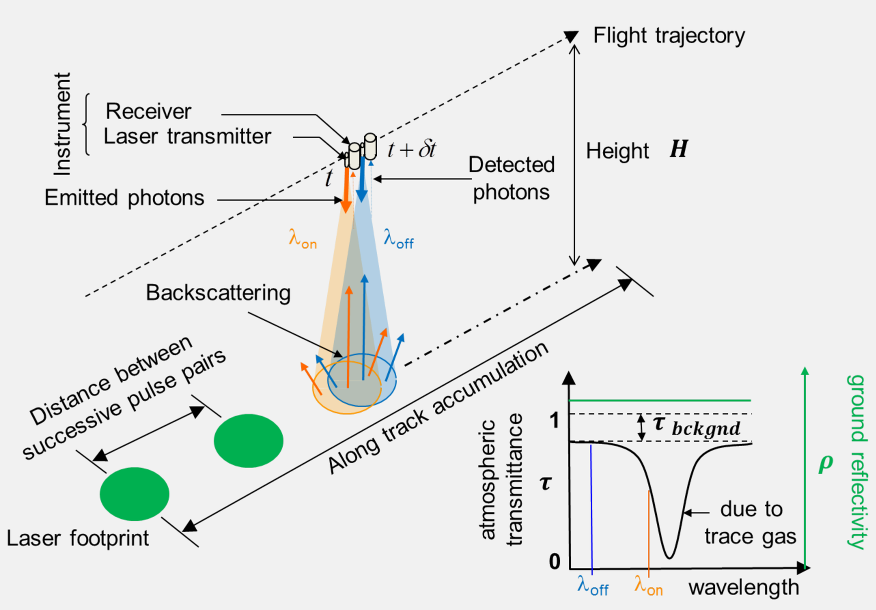
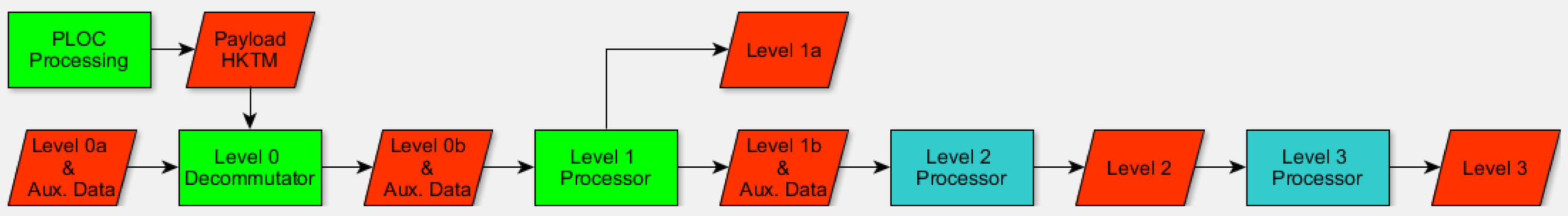


Figure 1: *Measurement principle.*

MERLIN Products & Processing Chain

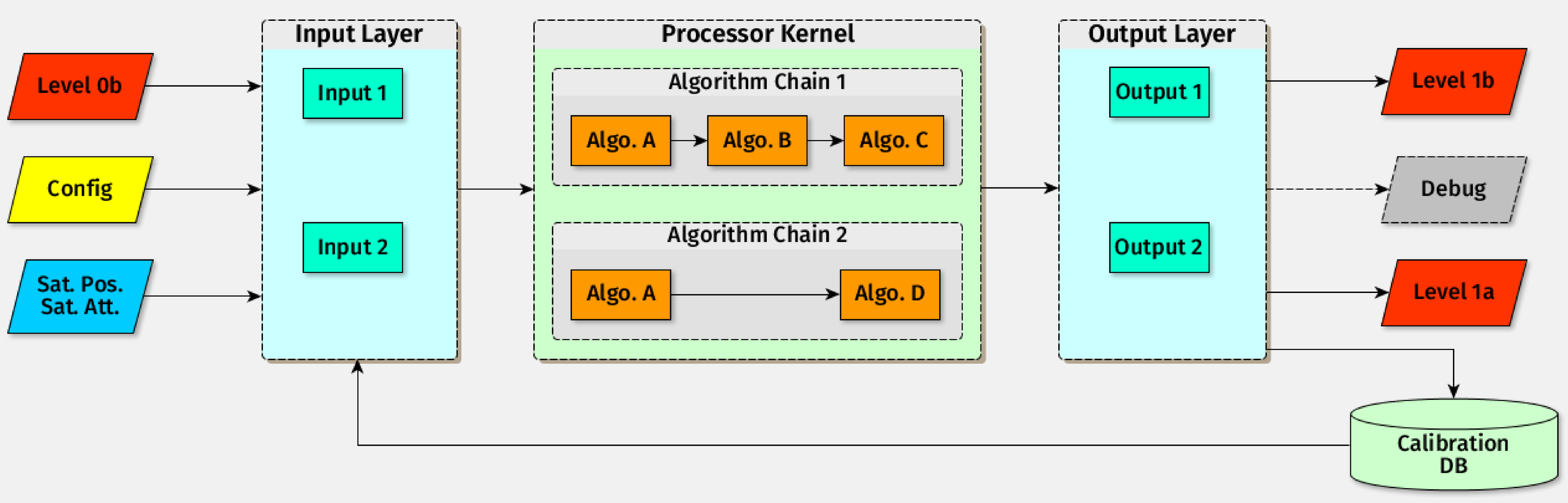


The algorithms are developed together by DLR and CNES. DLR has the main responsibility for the Level 0 and Level 1 processing and the instrument monitoring; CNES has the main responsibility for Level 2 and Level 3 processing. The products are:

Level 0a:	Time ordered raw data containing the backscatter signal of the shot pairs
Level 0b:	L0a parameters converted to physical units and added satellite attitude and position data
Level 1a*:	Pulse energy corrected, vertically resolved single shot data
Level 1p:	Calibration parameter file
Level 1b*:	DAOD for averaged shot data and single shot data
Level 2*:	CH_4 dry air mole fraction
Level 3*:	(Regridded) maps of CH_4

* distributed to the public

GCAPS Framework



The DLR developed Generic Calibration & Processing System GCAPS is used as framework for the Level 0 decommutator and the Level 1 processor. The framework provides a generic kernel, I/O layers and database interfaces. Processors for specific purposes and/or instruments are realised by adding plug-ins to the framework using the framework API. The user can define different calibration chains and can enable or disable plug-ins via a simple XML configuration file without the need of recompilation. The framework is also used in the operational Level 1 processing for SCIAMACHY.

In-flight Calibration

MERLIN has several in-flight calibration options to ensure the data quality during the mission. Calibration measurements are either analysed off-line by instrument experts leading to adjusted parameters to be used by the Level 1 processor or directly used in processing. At the moment the following in-flight calibrations are planned:

- Calibration of the pointing system to align the receiver telescope LoS with the laser footprint on-ground ($\approx$ every few months).
- The seed laser of the YAG laser might show a slow drift. The wavelength of the seeder has to be scanned occasionally while checking the YAG output power to determine the optimal set value for the seeder wavelength.
- CH_4 gas cell scan to check degradation of the cell that is part of the wavelength control loop.
- The Frequency Reference Unit (FRU) provides the seed laser for various laser frequencies and ensures the correct wavelength of the outgoing pulses. The FRU provides a 1064nm seed laser to give preference to a defined harmonic of the pulsed 1064nm oscillator frequency and to be able to control the 1064nm cavity in a continuous closed loop manner. It provides the seeds for λ_{on} and λ_{off} to the OPO. An additional task of the FRU is the measurement of the outgoing pulses with respect to the desired wavelengths.
- Laser energy is measured for each shot in order to calculate the ratio between λ_{on} and λ_{off} pulses.

References & Further Information

G. Ehret et al, MERLIN: A French-German Space Lidar Mission Dedicated to Atmospheric Methane, Remote Sensing 2017, 9(10), doi:10.3390/rs9101052

Processing & Auxiliary Data

The raw signal consists of signal values $P_{on,off}$ vs. time for $\lambda_{on,off}$ and the corresponding energy monitoring signals $E_{on,off}$. From these signals we

- remove instrument effects and calculate the noise
- calculate the backscatter signal and the range
- finally calculate the DAOD

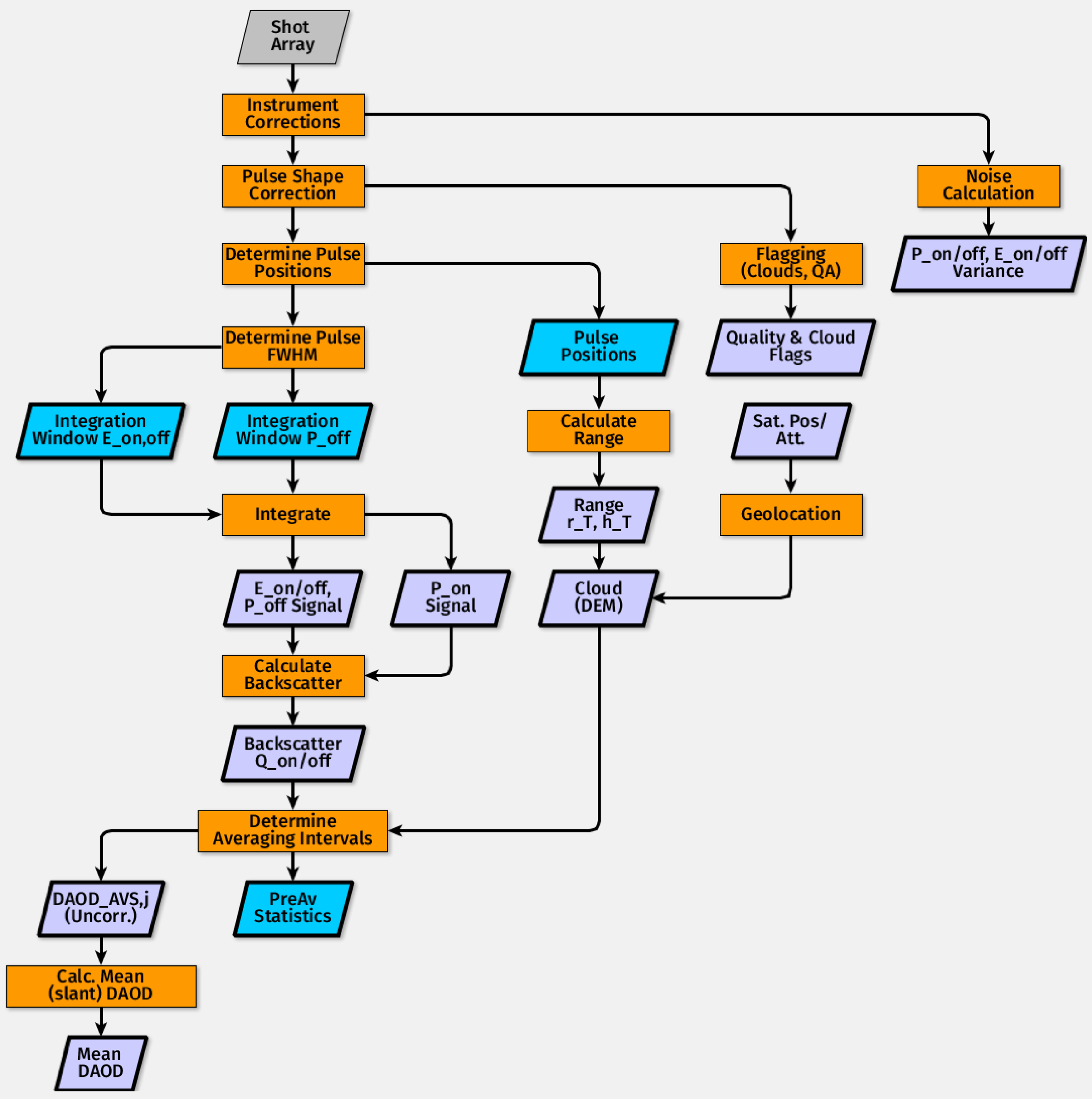
The current baseline is to provide DAOD for cloud free scenes and also for all scenes. Additionally auxiliary data and quality flags are provided such as

- cloud flag (from range/DEM comparison) and possibly from pulse shape (TBC)
- Signal noise and signal-to-noise ratio
- Averaging parameters (which shots, quality of individual shots, weighting)
- Results of in-flight calibration by FRU and APC to be used in long term monitoring to detect instrument degradation or drifts

Processing Flow (Main Blocks)

The main processing steps are shown below

1. Removal of instrument effects: Background subtraction, non-linearity correction and pulse shape correction.
2. Determination of integration windows and pulse positions for $P_{on,off}$ and $E_{on,off}$, taking into account possible jitter.
3. From this the range and the backscatter $Q_{on,off} = \frac{P_{on,off} \cdot r^2}{E_{on,off}}$ is calculated.
4. The range is also used to determine if a cloud was in the FoV for a given shot.
5. The backscatter signal of the single shots is then averaged and converted to uncorrected DAOD. Further corrections needed to go from DAOD to CH_4 mole fractions are applied in Level 2 processing.



Outlook

The processors will be continuously developed during phase C/D and new requirements that emerge during the instrument building and calibration will be incorporated. At the moment we foresee 3 Level 01 processor versions with an increasing feature set. Version 3 will be the launch ready version. Another update incorporating lessons from the commissioning phase is foreseen 3 months after launch, with 2 further updates during the mission. The road-map for the immediate future is

- Review and optimisation of the GCAPS framework (this is regularly done to keep the framework lean and performant)
- Consolidation of the Level 0a format and start of Level 0 Decommutator coding
- Study and develop missing algorithms.
- Consolidation of algorithms (updates of ATBD) and in-flight calibration procedures
- Implementation of Level 0-1 processor

One critical item still to be developed in detail is the averaging strategy. This does not only include the classification of measurements along signal quality and cloud presence and the derivation of a proper weighting of the individual shots, but also the calculation of the most representative coordinate for the averaged DAOD. The algorithm must be able to adapt to different observed scenes (e.g. broken clouds).

Contact Information

If you like to have further information, you can reach me at guenter.lichtenberg@dlr.de