THE NEW MERLIN INSTRUMENT FOR ATMOSPHERIC CH_4: QUALITY AND PERFORMANCE MONITORING

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ABSTRACT:

After water vapor and carbon dioxide, methane is the most abundant greenhouse gas in the Earth atmosphere. The new generation space borne Lidar mission MERLIN (Methane Remote Sensing Lidar Mission) will make very sensitive measurements of the CH4 distribution with unprecedented quality, with a precision <2%. After its launch in 2021, MERLIN will track down sources and sinks of methane (CH_4) on a global scale. We present our approach and strategy to perform a key ground segment work component that supports MERLIN scientific activities which is the long-term monitoring of the Lidar instrument and its measurements. This function includes tracking the behavior of the instrument and its subsystems over time as well as the verification and validation of the scientific data over the mission lifetime.

1 MERLIN:

MERLIN (Methane Remote Sensing Lidar Mission) is an active space-borne instrument– IPDA (Integrated Path Differential Absorption) LIDAR that will measure the atmospheric column content of methane. The difference in atmospheric transmission between a laser emission with a wavelength placed around the center of a CH_4 absorption line ($\lambda_{on} \approx 1.645$ µm) and a reference one, λ_{off}, slightly shifted from λ_{on} by a few tenths of a nm. The reference is located where CH_4 absorption is relatively smaller than λ_{on}, but yet it is close enough to have a nearly identical interaction with the atmosphere and the reflecting surface (Figure 1).

The mission is a joint space science project of the DLR (German Aerospace Center) and the CNES (French National Center for Space Studies). After its launch in 2021, MERLIN will track down the methane sources and sinks on a global scale. Its Lidar instrument will be mounted on a satellite platform flying at ~500 km altitude in a Sun synchronous orbit. It will continuously - every 50ms - send and receive the pulses pair λ_{on} and λ_{off}. MERLIN will provide 50km averaged CH_4 column measurements with better than ~2% precision [ref. 1].

2 LONG TERM MONITORING:

During both the commissioning and the operation phase, the instrument long term monitoring (LTM) component will track the measurements quality and the performance of the instrument and its subsystems on a daily up to a monthly basis. This includes monitoring their behavior in response to planned or unexpected operational situations, changing in-orbit environment, and/or natural events. The long term monitoring task obtains the necessary information to perform the task from various channels including housekeeping telemetry, scientific data, and calibration models.

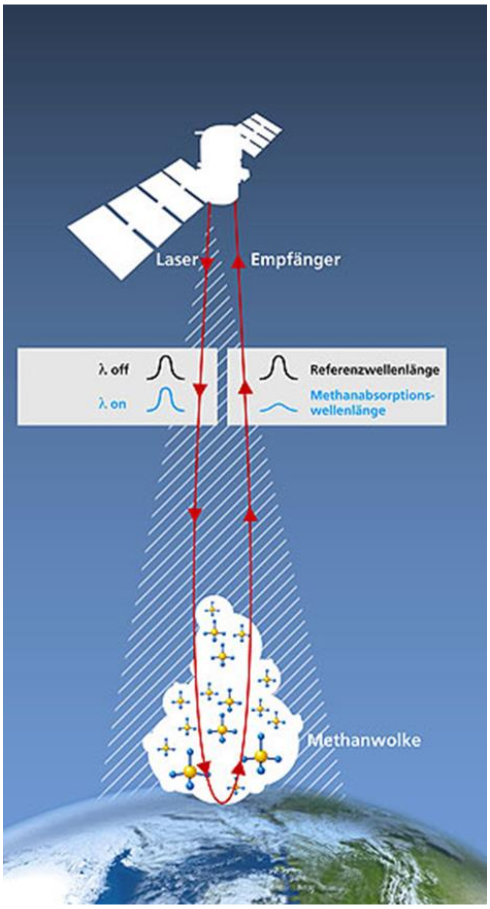

Figure 1 **: MERLIN Lidar space mission with its double pulses (on/off) principle.**

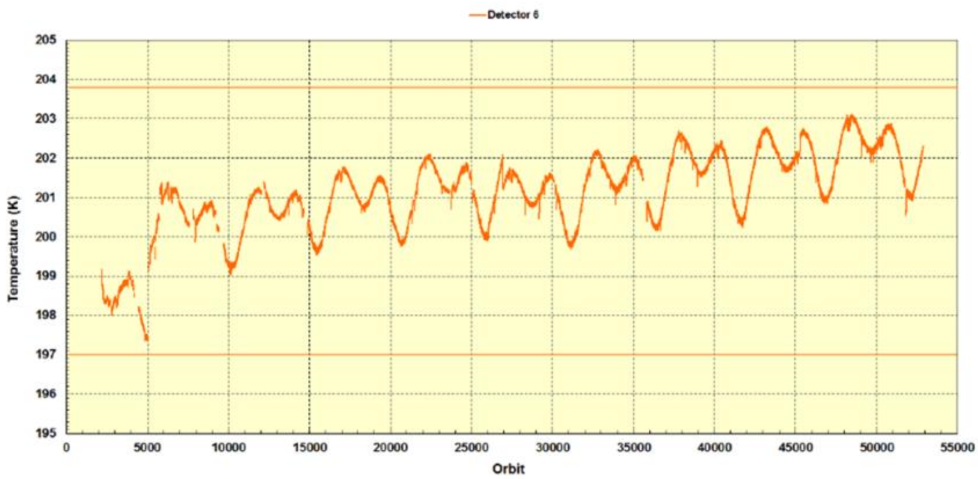

Figure 2: **Long term monitoring of the detector's temperature in the IR Channel 6 of SCIAMACHY as a function of orbits. It shows a variation of 0.29K/year and a seasonal variation of 2.3K**

3 KEY MONITORED COMPONENTS:

One of the motivation for the monitoring is to probe and analyze the instrument behavior during operation and its response to expected and unexpected events. Additionally, the instrument performance should be monitored over the mission lifetime to pro-actively anticipate any aging effects on the instrumment. Figure 2 shows an example of a LTM result of SCIAMACHY. It shows the detector temperature in channel 6 [ref. 2] where a variation of 0.29K/year can be perceived. In MERLIN, similar trends might occur in any of the instrument's subsystems. When they do, they should be detected and analyzed as one of LTM tasks.

Two of the main monitored components are the following:

3.1 The Laser Component:

One of the main components of the instrument is the laser. Some of its parameters that require long term monitoring are the emitted (T_x) and returned (R_x) pulses. One of LTM tasks will be making analytical models to check the emitted pulse's shape, i.e. the center position, width, peak, energy, and noise level. This will also help us to deduct any return delay and to monitor the repetition rate.

The signal to noise ratio (SNR) will be monitored to allow the user to detect any peculiarity that could, perhaps, even benefit the science team in their interpretation of the measurements. The SNR can also help us to keep track of aging effects. For consistency, we will also compare and correlate it with R_x's.

Furthermore, R_x is another key quantity to monitor in both level 0 and level 1. In fact, over water (sea or lakes), the ground is considered relatively stable (reflectance & height) for back-scattering measurements; and thus, the estimated energy at level 0 over water will be "relatively" close to the actual energy obtained in level 1 products. When measuring over water, we expect to find a nearly linear correlation between the two over time. Otherwise, the reason of the divergence should be investigated.

By selecting regions where the backscattered signal is both strong and relatively constant, or with an identified variation over time, we would be able to monitor the R_x *SNR* variation over these regions in order to track the mission performance.

3.2 Footprint and Geolocation:

Footprint positioning (or pointing) will validate several key parameters such as the Instrument sub-system alignments, geolocation, Satellite position - including their corrections- and eventually CH_4 column density measurements due to possible Doppler changes. The footprint position will be another key parameter that we will monitor and track as part of LTM.

In practice, MERLIN Lidar signal is expected to show sudden drops and rises while passing and "*transiting*" into or out of specific Earth regions such as land/water or desert. When its line of sight crosses such geographical areas, we will compare its signal variation over the "*transiting*" area against the expected one. Similarly, MODIS surface reflectance data at CH_4 wavelength in Band 6 [ref. 3] will also be used for relative comparisons with the collected MERLIN one. Detected inconsistencies would mean that the footprint might have shifted from its expected position. This would be investigated by LTM in collaboration with the science teams. Nevertheless, the pointing data will still be recorded to probe any long term deviations or jittering over MERLIN's lifetime.

4 SCIENTIFIC RESULTS

The long term monitoring component allows a close follow up of the mission scientific results to assure high quality data acquisition as well as the instrument's consistent performances with mission planning. Some of the important components in this task are the laser pulses and the pointing. When precise knowledge of the pulse's properties and energy as well as the geolocation are accomplished, a reliable and accurate measurement of the relative signal (on/off) can be achieved, and thus the deduced CH_4 column density.

Ultimately the long term monitoring component allows us to avoid measurements' biases and to differentiate between scientific conclusions or discoveries from any other effects that might be due to unpredicted instrument behavior, sudden technical issues, or unexpected space events (e.g. solar flares), since such effects might affect the interpretation of CH_4 column density measurements.

REFERENCES

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