ATMOSPHERIC METHANE WITH SCIAMACHY: OPERATIONAL LEVEL 2 DATA ANALYSIS AND VERIFICATION

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ABSTRACT

SCIAMACHY is a passive imaging spectrometer mounted on board ESA's ENVISAT satellite to probe a large number of atmospheric trace gas species, such as methane, and their global distribution and evolution. Methane (CH_4) is particularly interesting as it is one of the most abundant greenhouse gas in the Earth atmosphere. To analyze SCIAMACHY methane measurements, we used the DLR BIRRA (Beer InfraRed Retrieval Algorithm) to retrieve nadir methane concentrations from its infrared spectra in channel 6.

By integrating the DLR BIRRA code into ESAs operational Level 2 processor, we expanded it to include atmospheric CH_4 column measurements. We have therefore performed an extensive test and verification operation. Our tests are based on separate comparisons with existing space and ground-based obtained measurements of methane column density. We present here our strategy for quality check of this first version of a CH_4 product. We will further discuss specific geographical areas we used to validate the products.

Key words: Methane (CH_4); SCIAMACHY; Operational processor.

1. INTRODUCTION

SCIAMACHY (SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY) is an imaging absorption spectrometer that probed a large number of atmospheric trace gases over its lifetime (2002 - 2012) such as methane (CH_4). Methane is an important gas as it is one of the most abundant greenhouse gas in the atmosphere and it contributes significantly to the climate change. This makes it a key gas to study and to probe both its geographical distribution and its temporal variation. The goal of this study is to present the first operational processor's CH_4 measurements and to verify their validity.

2. ESA LEVEL 2 OPERATIONAL PRODUCTS: METHANE

2.1. The operational processor

Since the beginning of the mission, DLR has been developing and updating the ESA Level 1-2 operational processor for the retrieval of most trace gases measured by Sciamachy from the UV to the infrared. The processing of Level 1 to 2 generates the atmospheric gases profiles and column densities from the Level 1b data. These are calibrated geolocated radiances that were derived from the Level 0 to 1b processing. The overall steps of the processor are shown in the flow chart (Figure 1).

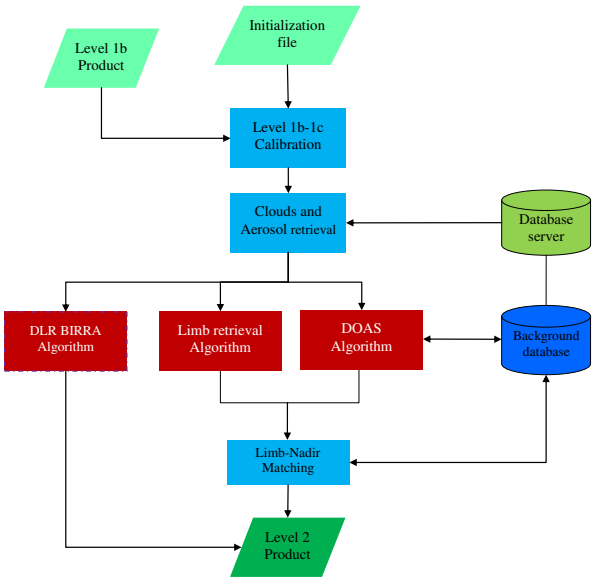

Figure 1: *The Level 2 processor design and description: The chart shows the main processing steps; CH_4 measurements are calculated from the BIRRA algorithm.*

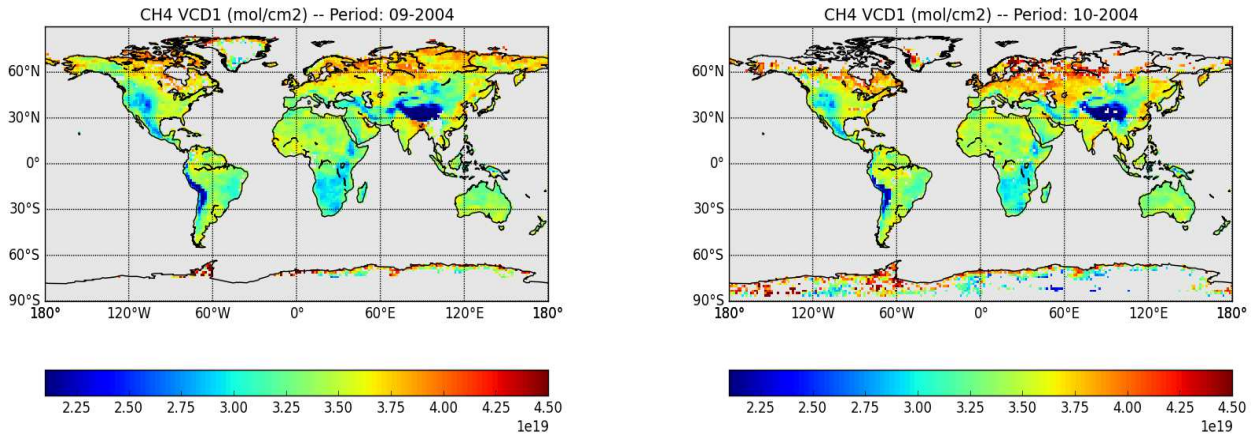

Figure 2: *Monthly averaged maps of the operational CH_4 product with a spatial resolution of $1.5^o \times 1.5^o$. The maps show CH_4 VCD distribution overland for September and October 2004. The units are in molecules/cm^2.*

As shown in figure 1, the processor includes the following:

- The database server which contains the auxiliary data (e.g. reference spectra, albedo).
- The initialization file that contains the input for the algorithms (e.g. calibration settings) and the fitting methods.
- DLR BIRRA algorithm that retrieves CO_2 and CH_4 column densities and their corresponding mixing ratios xCH4 and xCO2 respectively.
- Level 2 product which includes both the vertical column density (VCD) and the mixing ratio.

2.2. Level 2 operational products: Methane

In the latest released Level 2 data product, methane measurements were introduced for the first time. These were generated from the Level 1 - 2 processor version 6.0 using Level 1 version 8 data. CH_4 gas measurements at 1.6μm are retrieved from SCIAMACHY SWIR channel 6 of spectral range [917-1773 nm]. The core of the processor for nadir CH_4 concentrations retrieval is based on the DLR BIRRA (Beer InfraRed Retrieval Algorithm) algorithm.

In order to derive the gas dry air mixing vertical ratio xCH4, one needs to correct for cloud effects as well as transmission changes. This is done by normalizing the gas by a relatively more stable and homogeneous and yet measured simultaneously gas (see also [1]). In this case, CO_2 is the gas that is used for xCH4 retrieval, which is also retrieved from Channel 6 and is close to CH_4 band. The mixing ratio is then calculated as shown in equation 1.

$$xCH4 = \frac{\alpha CH_4}{\alpha CO_2} \times refVCD_{CH_4} \qquad (1)$$

By integrating the DLR BIRRA code into the operational SCIAMACHY Level 1-2 processor as described above, the operational products will include atmospheric CH_4 column measurements.

3. TESTS AND VERIFICATION

3.1. Strategy

The presented study is a prerequisite for the verification and validation of methane data from the operational processor. The tests are based on two separate comparisons first with existing Level 2 SCIAMACHY methane data that are produced by the SRON (Netherlands Institute for Space Research) institute as well as with ground-based retrieved methane measurements with TCCON (Total Carbon Column Observing Network) and ESRL (Earth System Research Laboratory) Global Monitoring Division (GMD). This first validation study uses Level 2 methane data from the year 2004 for testing.

3.2. Results

Examples of monthly maps of the VCD of CH_4 Level 2 processor product are shown in Figure 2. These maps display the expected values and consistency of methane global distribution.

Figure 3 shows monthly averaged xCH4 ESRL GMD data in a North African Assekrem site in the Sahara desert compared to SCIAMACHY values over the same geographical location (over a $4^o \times 4^o$ area around the ESRL site). Both SRON and DLR operational processors generated SCIAMACHY data are shown for comparison and consistency. The figure shows that DLR operational CH_4 product measurements are relatively variable over this time frame, but

are on average consistent with ESRL data by up to 3% and with SRON's by up to 4%.

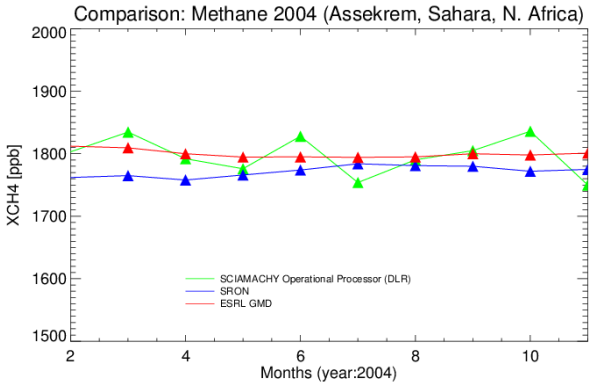

Figure 3: *Monthly averaged xCH4 comparison between ESRL at Assekrem site in N. Africa, SRON SCIAMACHY Level 2, and DLR operational SCIAMACHY Level 2.*

A further comparison is run against TCCON data. Yet, there are not many available methane TCCON measurements taken in 2004. The Parkfalls TCCON site that is located in North America measured only six months of data which were from June until November.

Figure 4 shows the corresponding xCH4 monthly averaged values compared against the DLR processor SCIAMACHY ones. The comparison is made over a $4^o \times 4^o$ region around Parkfalls geographical site. The figure shows that overall the values are consistent and slightly deviate from each other by up to 6%.

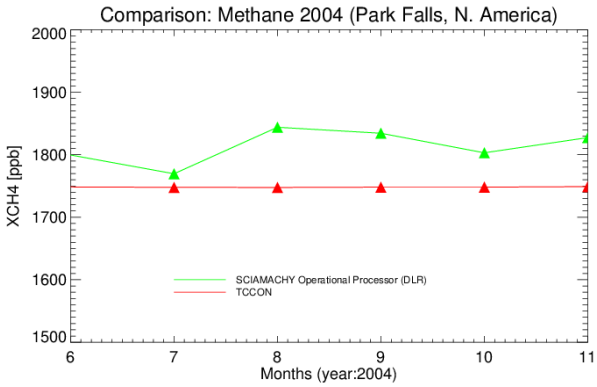

Figure 4: *Monthly averaged xCH4 comparison between TCOON at Parkfalls01 site in N. America and DLR operational SCIAMACHY Level 2.*

4. SUMMARY

The first DLR's operational CH_4 products show an overall agreement with ground based measurements. The deviation between SCIAMACHY data and ground based corresponding values are not significant and lie within a few percent only from each other.

ACKNOWLEDGMENTS

We used in this study CH_4 data that were provided to us by the SRON institute as well as the publicly available CH_4 ground based data from TCCON and ESRL sites. We thank all these institutions for either providing us access to their data or for making them available to the public.

REFERENCES

[1] Gimeno García, S., Schreier, F., Lichtenberg, G., Slijkhuis, S., 2011, Atmospheric Measurement Techniques, vol 4, issue 12