Linking SCIAMACHY time series to follow-on sensors

SCIAMACHY Quality Working Group Project 3
WP 3260

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1. Introduction

This document contains the results of WP 3260 of the SCIAMACHY Quality Working Group Project (Part 3). The aim of this work package was to check which SCIAMACHY products can be used for the generation of long-term time series in combination with previous and forthcoming sensors. A generation of these combined data sets is not covered by this task.

2. Nadir data sets

2.1. Available nadir data sets

Table 1: Overview of products from past, present and future missions which can be combined with SCIAMACHY nadir time series. Instruments with an asterisk are in afternoon orbits. Green shading indicates areas where currently funded projects work on merged / homogenized data sets. Brackets indicate products which are possible in principle but need to be demonstrated or further developed.

	TOMS	GOME	GOME2	OMI*	OMPS	S5P*	S5	S4	OCO-2*	GOSAT*	GOSAT-2*	FLEX	MICROCARB	MERLIN	TANSAT
O_3 strat	x	x	x	x	x	x	x	(x)							
O_3 trop		x	x	x		x	x	x							
NO_2 strat		x	x	x	x	x	x	(x)							
NO_2 trop		x	x	x	(x)	x	x	x							
HCHO		x	x	x	x	x	x	x							
H_2O		x	x	(x)		(x)	x	(x)	(x)	(x)	(x)		(x)		(x)
CO						x	x								
CH_4						x	x			x	x		x	x	x
CO_2							(x)		x	x	x		x		x
BrO		x	x	x	(x)	x	x								
OClO		x	x	x		x	x								
SO_2	(x)	x	x	x	x	x	x	(x)							
Glyoxal			x	x		(x)									
IO		(x)	(x)	(x)		(x)	(x)	(x)							
SIF		x	x			x	x		x	x	x	x	x		x

For nadir data, there was already heritage data available at EnviSat launch from the TOMS and GOME instruments. After SCIAMACHY, the GOME2 instruments, OMI, and OMPS continued many of the SCIAMACHY nadir observations. The upcoming S5P and S5 satellites will also provide further continuation opportunities for SCIAMACHY nadir data. For CO_2, there is some possible link to OCO data. The geostationary S4 satellite has a large overlap in products but due to its limited spatial coverage, the use of S4 data in long-term time series is limited.

When merging nadir satellite data from different instruments, several complications need to be considered:

- Differences in observation time need to be considered, in particular for photochemical active gases such as OClO, NO_2 or BrO. This is of particular importance for merging of time series from instruments in morning orbits such as SCIAMACHY and data from instruments in afternoon orbits (OMI, S5P). Approaches which can be taken to overcome these differences include the use of atmospheric models as transfer standards between the different observation times. This works well in the stratosphere but is more difficult in the troposphere where time variations in emissions, illumination and chemistry interact in complex ways.
- Differences in spatial resolution are of large importance in particular for trace gases having short atmospheric lifetimes such as NO_2, SO_2, or BrO. Direct comparison of measurements from instruments having different spatial resolution are not meaningful unless averaging over sufficiently large areas is performed. As an alternative, explicit resolution corrections have been derived and applied in the past, but they are based on the assumptions on consistent spatial patterns which limits their applicability to longer time series. The most straight forward solution of this problem is the reduction of spatial resolution of the merged data set to that of the instrument having the lowest spatial resolution.

- Differences in sampling can be relevant for trace gases having short atmospheric lifetimes and, therefore, have large horizontal inhomogeneities (NO_2, SO_2, BrO). Although temporal averaging over, for example, months helps to reduce this effect, it can still bias the time series for instruments having incomplete global coverage (GOME, SCIAMACHY, OMI after row anomaly)
- Instrumental biases and temporal drifts cannot be excluded and may have to be accounted for.

There are to our knowledge only very few funded activities to produce merged data sets of measurements from SCIAMACHY and other space sensors. In the context of the European QA4ECV project, a consistent data set of GOME, SCIAMACHY, GOME-2 and OMI NO_2 and HCHO data is being produced, but the focus is on consistent retrievals and less on merged time series. In the framework of ESA cci merged datasets of total ozone, tropospheric ozone, and GHGs are produced.

2.2. Recommendations for nadir data

SCIAMACHY nadir data cover several different areas of current atmospheric research: stratospheric ozone chemistry (O_3, NO_2, OClO, BrO), tropospheric air pollution (NO_2, HCHO, SO_2, CO, CHOCHO, O_3), climate change (O_3, CO_2, CH_4, H_2O), and tropospheric halogen chemistry (IO, BrO). In all these areas there is a clear need for consolidated merged time series in order to have the necessary data base for trend estimates and evaluation of policy actions taken such as the Montreal Protocol or NOx emission controls.

For stratospheric ozone and climate gases some efforts have been taken in the context of the CCI projects, and within the QA4ECV project, there was preparatory work for NO_2 and HCHO. For the future, it is recommended to continue these efforts taking into account data from the new European Sentinel missions.

In particular, for reactive tropospheric gases, merging of data from morning and afternoon platforms is a challenge and has not yet been fully addressed and this will become even more pressing with data from S5P. This aspect should therefore be a priority for tropospheric reactive gases.

3. Limb data sets

3.1. Available limb data sets

Table 2: Overview of products from past, present and future missions which can be combined with SCIAMACHY limb time series

	SAGE II on ERBS	OMPS on NPP/Suomi	OMPS on JPSS-2	SAGE III on ISS	Altius on PROBA
Ozone	Mergeable directly, Ozone-CCI	Mergeable either directly or with a transfer function, Ozone-CCI	Mergeable with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet
NO_2	Mergeable directly, no funding yet	Not available	Not available	Mergeable with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet
Water vapour	Mergeable directly, no funding yet	Not available	Not available	Mergeable with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet
Aerosols	Mergeable directly, no funding yet	Mergeable either directly or with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet	Mergeable with a transfer function, no funding yet
BrO	Not available	Not available	Not available	Not available	Mergeable with a transfer function, no funding yet

Products from present and future occultation and limb missions which can be combined with time series obtained from SCIAMACHY limb measurements are summarized in Table 2. Concurrent missions which have a strong overlap with SCIAMACHY operation time and already are beyond their expected operation times (e.g. MIPAS/GOMOS on ENVISAT, MLS on Aura, ACE-FTS/MAESTRO on SCISAT, OSIRIS/SMR on Odin) are not included in the list because they are already merged within the ESA ozone CCI. Table 2 lists all missions that can be used to extend the SCIAMACHY limb data record into the past and future. The SAGE II instrument (1984-2005) is considered to be the best choice for merging applications as it offers a long time series with a substantial overlap with SCIAMACHY operation time and is known to be of high quality. OMPS/NPP-Suomi has a very short overlap period with SCIAMACHY (transfer function may be needed via other available missions) Future occultation and limb missions are rather rare and the quality of their data could not yet be assessed as they have not been launched yet (SAGEIII/ISS, OMPS/JPSS-2) or have not been mission approved yet (ALTIOUS). The latter instruments are also listed in Table 2

Vertically resolved ozone, NO_2, and BrO products from SCIAMACHY are available both as operational and as scientific products. To make a proper choice, which of the products is better suitable for merging activities, results of previous validation studies need to be analysed to compare the quality of the products and select the best one. If necessary, additional validation activities should be performed.

Currently, funding is only available for merging activities related to the OMPS NPP/Suomi and SAGE II ozone data set within the ESA ozone-CCI project.

3.2. Recommendations for limb data

As essential climate variables, ozone and aerosols are most important to deal with when combining data sets into long-term records. While the ozone data records from most instruments are generally of very good quality and can be merged without much additional efforts, a lot of uncertainties are still present in the aerosol data sets. Nowadays, aerosol extinction coefficients are generally used to characterize stratospheric aerosol abundancies. Beside a significant dependence on the wavelength, the derived quantities are affected by assumptions about the stratospheric aerosols during the retrieval process. This is especially an issue for measurements of scattered light (e.g. as done by SCIAMACHY, OMPS and Altius). Thus, combining aerosol data sets requires major preparatory work to homogenise the available products.

After the halogenated species have been banned by the Montreal Protocol and its amendments the role of NO_x as ozone depleting substance became more important. Up to now, emission of N_2O, a major source of NOx, is not efficiently regulated by any international agreements. This is why continuous monitoring of NO_2 and a creation of long-term time series becomes as much important as monitoring of stratospheric ozone.

Long-term monitoring of stratospheric water vapour is one of the key issues in climate related studies. As stratospheric water is observed in all aggregate phases, it is an important tracer of climate related circulation changes as well as relevant for ozone chemistry and their changes in a future climate.

As a major ozone depleting species, BrO is still important to be monitored on a long term basis. Due to its weak spectral signature, BrO measurements are however rare and very difficult to retrieve. Generally, time series of BrO obtained from measurements of scattered solar light are associated with large uncertainties and the agreement between measurements from different instruments is rather moderate. A major preparatory work on the quality assessment needs to be done when merging BrO time series.

4. Overall Conclusions

SCIAMACHY data with their broad range of species measured and the combination of limb and nadir data are an essential part of the global atmospheric data set from space which is available so far. This data set can be linked to data from some past sensors and many current and future instruments to create long-term records of stratospheric and tropospheric composition. However, merging of instrumental data sets is always difficult because subtle differences in observation geometry, instrument, and retrieval algorithms can lead to substantial differences in the products which in turn can lead to inconsistent long-term data sets. This is well known for stratospheric ozone observations but is similarly true for tropospheric species where spatial resolution of instruments is an important factor. Combining time series from satellite sensors is a task which is necessary and important but it also requires careful and thorough analysis to provide useful data sets. As new instrumental records become available over time, this remains an ongoing task.