# EVIDENCE FOR LONG-RANGE TRANSPORT OF CARBON MONOXIDE IN THE SOUTHERN HEMISPHERE FROM SCIAMACHY OBSERVATIONS

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## ABSTRACT

This paper gives an overview of the results published by [1],[2], and [3]. The precision of the SCIAMACHY carbon monoxide (CO) total columns depends on the random instrument-noise error and is generally within 10% for monthly means. SCIAMACHY CO total columns agree well with chemistry-transport model simulations using the GFEDv2 biomass-burning emission data base. Enhanced CO columns are seen with SCIAMACHY over Australia during its biomass-burning season in local Spring. It is shown that the enhancements over Australian biomass-burning areas contain a large contribution of CO from South American biomass-burning regions. The results indicate that SCIAMACHY can be used to study both longe-range transport and emission sources of CO.

Key words: SCIAMACHY; CO; long-range transport.

## 1. INTRODUCTION

With a lifetime of weeks to months carbon monoxide (CO) is an excellent tracer of atmospheric transport processes. It is also the major sink of OH and an important pollutant. One of its major sources is seasonal biomass burning (hereafter: BB). The SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) on board the ENVISAT satellite, allows the measurement of global distributions of CO down to the Earth's surface. SCIAMACHY observations show significant CO total column enhancements over well-known BB areas [e.g. 4, 5, 6, 1, 2].

The SCIAMACHY satellite instrument provides the first solar reflectance measurements of CO, and is uniquely sensitive down to the boundary layer. This is in contrast to thermal measurements as currently performed by MOPITT (Measurements Of Pollutants In The Troposphere [7]), AIRS (Atmospheric InfraRed Sounder [8]), and TES (Tropospheric Emission Spectrometer [9]) which are mostly sensitive to the middle and upper troposphere. Thus, the near-infrared SCIAMACHY observations can be used to study both local emissions and CO transported from overseas emission areas. This allows us to determine their relative contributions over emission areas as well as over more remote regions on a global scale for long time periods.

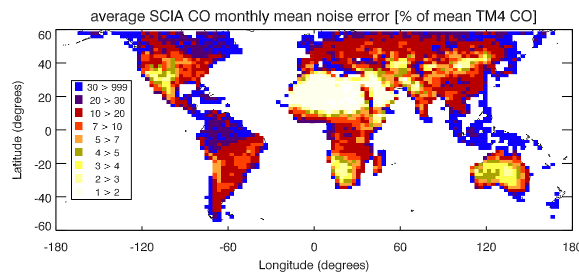
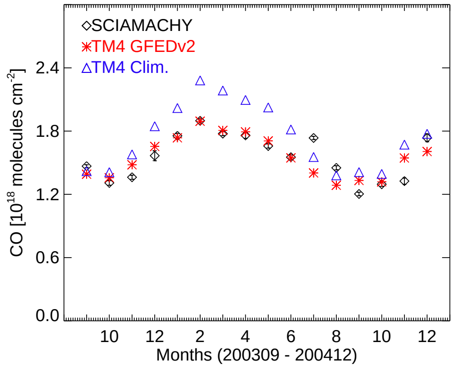



*Figure 1. Geographical distribution of the average SCIAMACHY CO total column monthly mean instrument-noise errors for the period September 2003 – August 2004. The noise errors are shown as a percentage of the mean CO from the TM4 model simulation (From:[3]).*

## 2. SCIAMACHY CO MEASUREMENTS

The SCIAMACHY CO total columns presented here have been retrieved with the Iterative Maximum Likelihood Method (IMLM) version 6.3 between 2324.5–2337.9 nm [10, 1, 2]. The continuous growth of an ice layer on the detector and an increasing number of radiation-damaged detector pixels over time complicate the near-infrared retrievals. Detailed corrections are now available to account for these complications [10].
A detailed statistical analysis of one year (September 2003 to August 2004) of global SCIAMACHY Carbon Monoxide (CO) total column retrievals from the IMLM algorithm (v6.3) has been performed by [3]. This analysis shows that differences between single SCIAMACHY CO



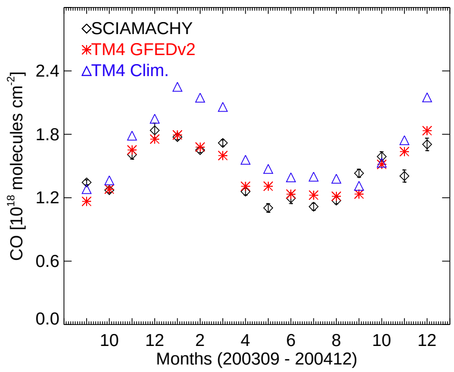




*Figure 2. Comparison of seasonal cycles for two locations outside biomass-burning regions for the period September 2003 – December 2004. Top panel: northern Sahara. Bottom panel: Ethiopia. In both cases the agreement between the monthly mean SCIAMACHY CO total columns (black) and the TM4 model with the GFEDv2 emissions (red) is much better than with the TM4 model including the climatological emissions (blue) (From:[3]).*

total column measurements and corresponding model results are primarily explained by random instrument-noise errors. This strongly suggests that the random instrument noise-errors are a good diagnostic for the precision of the SCIAMACHY CO measurements. The analysis also indicates that noise in single SCIAMACHY measurements is generally greater than actual variations in total columns. It is thus required to average SCIAMACHY CO data over larger temporal and spatial scales to obtain valuable information. Fig. 1 shows that a large spatial and temporal variation in instrument-noise errors exists which shows a close correspondence with the spatial distribution of surface albedo and cloud cover [3]. This large spatial variability is important for the use of monthly and annual mean SCIAMACHY CO total column measurements. The smallest instrument-noise errors of monthly mean SCIAMACHY CO total columns measurements are found over high surface albedo areas such as the Sahara.
SCIAMACHY measurements and chemistry-transport model results have been compared on a monthly mean basis. Significant improvements in agreement occur of up to ∼30%, when the new Global Fire Emissions Database version 2 (GFEDv2) from [11] is used with the chemistry transport model TM4 instead of climatological emissions [3]. The largest improvements are seen near biomass-burning regions, but even outside biomass-burning regions the agreement between SCIAMACHY and the TM4 model improves significantly (Fig. 2).
Globally, the seasonal variation of the model is very similar to that of the SCIAMACHY measurements. A small bias of ∼0.05–0.1 x $10^{18}$ molec/cm$^2$ (or about 5%) is found between the TM4 model and the SCIAMACHY observations which includes retrieval uncertainties as well as model errors. This thus provides a best estimate of the currently achievable measurement accuracy for SCIAMACHY CO monthly mean averages. Analyses of monthly averaged SCIAMACHY measurements thus indicates that they are of sufficient accuracy to reveal valuable information about spatial and temporal variations in CO columns.

## 3. SOUTHERN HEMISPHERIC BIOMASS-BURNING

Biomass burning is the major source of CO in the southern hemisphere. The peak of the biomass-burning season in South America and southern Africa is around September whereas in Australia most of the burning occurs around October. SCIAMACHY CO observations show enhanced carbon monoxide (CO) columns over all three regions during the 2003 and 2004 biomass-burning seasons in local spring [1]. Chemistry-transport model simulations using the new independent satellite-based GFEDv2 biomass-burning emission data base show a similar temporal and spatial CO distribution, indicating that the observed enhancements are due to biomass burning (Fig. 3).
Outside the biomass-burning season, the TM4 model and SCIAMACHY agree well with an average difference $<5\%$. During the 2004 biomass-burning season, i.e. about August to November, South America and Australia show much larger CO enhancements than in 2003, with higher values in South America than in Australia. In southern Africa the 2003 and 2004 maxima seem comparable. The observed enhancements are generally larger than the model simulations. These differences are significant compared to those found outside the BB season. Possible biases in the retrievals or due to modeling assumptions are also much smaller. This indicates that, although the timing of the BB emissions seems correct in the GFEDv2 database, the absolute magnitude may be too low. CO emissions in South America may be high because of deforestation as well as maintenance fires, but frequent cloud cover hinders satellite observation of these fires. Therefore, the satellite-based GFEDv2 emissions probably underestimate real emissions [11].

The Australian locations are particularly interesting since long-range transport from South America and Africa has been shown to affect CO concentrations over remote ar-

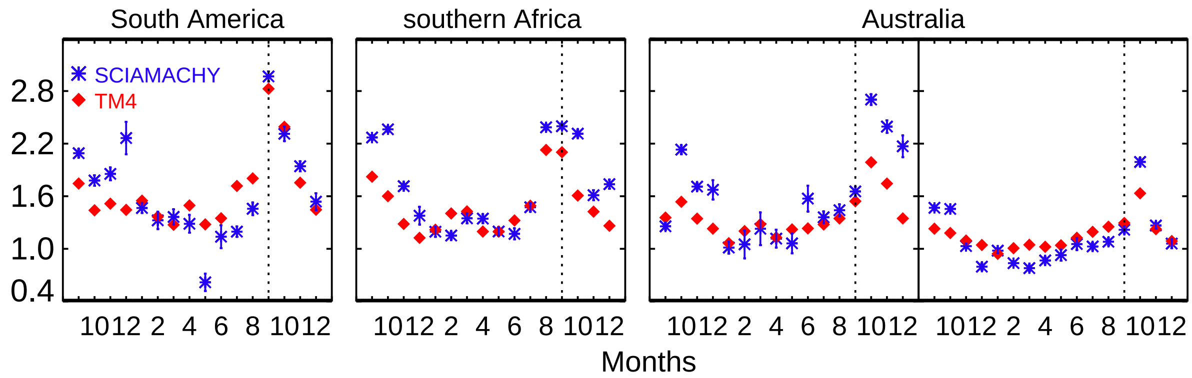



*Figure 3. Comparison of SCIAMACHY (blue) and TM4 (red) monthly mean variability for 4 southern hemisphere locations between September 2003 and December 2004. Error bars denote the 1$\sigma$ noise errors (From:[1]).*

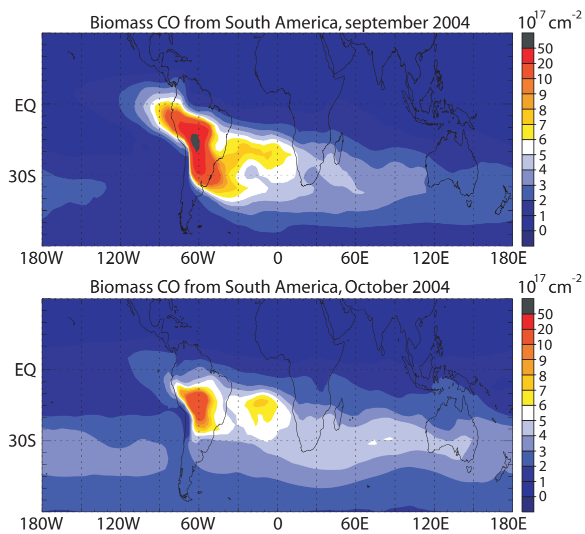



*Figure 4. CO column results for September (top) and October 2004 (bottom) from the tracer model including only biomass-burning emissions in South America. Transport of CO from South America to South Africa and Australia is clearly visible (From:[1]).*

eas in the South Pacific and over southeast Australia [12, 13, 14]. The third panel in Fig. 3 shows CO enhancements over the biomass-burning region in northern Australia. But even over central Australia (fourth panel in Fig. 3) clear CO enhancements are seen. In order to investigate the origin of the CO enhancements over central Australia [1] have used a tracer model. The rationale is that interannual variability in CO emissions is dominated by biomass burning rather than other CO sources. Fig. 4 shows that the high South American CO emissions in 2004 lead to accumulation over the southern Atlantic. Part of this accumulated CO enters the westerlies and is transported to Australia.

Fig. 5 shows the CO contribution of the different tracers and their sum for the same southern hemispheric locations as in Fig. 3. A large contribution of CO from South American biomass-burning regions to observed CO total columns over Australian biomass-burning regions is found during the 2004 fire season of up to ∼30–35% and up to 55% over central Australia. During the 2003 biomass-burning season, South America and Africa each contribute ∼35–40%. The results also indicate that differences between SCIAMACHY CO and the model simulations over Australian biomass-burning areas are not only due to uncertainties in local emissions but also in overseas emissions followed by efficient long-range transport.

## 4. SUMMARY AND OUTLOOK

The three papers mentioned in the abstract show the potential of the SCIAMACHY CO total column data. Future studies will involve combining SCIAMACHY near-infrared CO data with thermal-infrared CO measurements from MOPITT, AIRS, and TES which are mostly sensitive to middle and upper tropospheric CO. This will allow a better quantification of the contribution of local and overseas emissions in order to improve current emission estimates.

Three years of SCIAMACHY CO total columns from the IMLM algorithm (v6.3) are now available (2003-2005). Data can be requested through the website: http://www.sciamachy.org/products/ . A first impression of the data can also be obtained using the Google Earth tools described on the website: http://www.sron.nl/google_earth .

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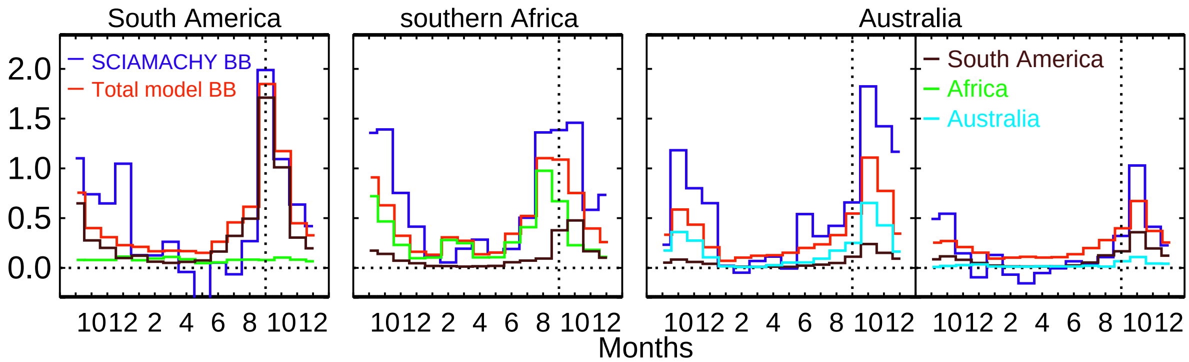


*Figure 5. Contribution of different CO biomass-burning sources to the SCIAMACHY CO columns for the same southern hemispheric locations as in Fig. 3 as derived from the tracer model used in [1], which is sampled in the same way as SCIAMACHY CO. The black dashed line shows the zero level. The large contribution of South American biomass-burning CO over central Australia (fourth panel) is clearly seen (From:[1]).*

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