SCIAMACHY simultaneous measurements over the biomass burning source regions

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Overview

The spectra of reflected and backscattered solar radiation as measured by SCIAMACHY in nadir observation mode in the UV/visible/near-infrared/short-wave-infrared (UV/vis/NIR/SWIR) spectral region contain information on the vertical columns of the air pollutants like carbon monoxide (CO), formaldehyde (HCHO), and nitrogen dioxide (NO_2). The information about the concentration of gases is retrieved using DOAS and WFM-DOAS retrieval algorithms [1,5,6]. Because SCIAMACHY measurements are made simultaneously, this information is of special interest for studying the chemistry of the atmosphere. Measurements of atmospheric columns are however have relatively high uncertainty. Additionally, several effects on the light path (e.g., clouds) do not allow to use the value of column directly for quantitative estimations. Here we show how the widely used bottom-up method of excess mixing ratios could be applied for quantitative analysis of pollutions sources with the help of SCIAMACHY simultaneous measurements of trace gases.

Method of excess mixing ratios

To express the emission of trace gases from fires quantitatively, the concept of emissions ratios and emission factors is widely used. Those parameters relate the emissions of a particular compound of interest to that of a reference compound, usually CO_2 or CO – emission ratios (ER), or to the amount of fuel burned - emission factor (EF). This method is especially suitable for airborne and local measurements, where the usage of these relative quantities helps to overcome the dilution problem.

The satellite measured values of vertical column could be applied directly for quantitative analysis, because they are already contain the amount of molecules in the volume of interest. However, due to a high uncertainty of the single satellite measurement, and because the averaging need to be made for any quantitative application of satellite retrieved data, the bottom-up method could be useful here as well. Additionally this method provides the possibility to compare quantitatively the values originated from a different measurements techniques. From the other hand, being used with the satellite measurements, the method could provide the emission ratio values globally, even for those sources unreachable for the local or airborne measurements.

To obtain the "excess" concentrations, the ambient background concentration must be subtracted from the values measured over the source (ΔHCHO, ΔNO2). Emission ratios are then obtained by dividing the excess trace component concentration measured in a fire plume by excess concentration of a simultaneously measured reference trace gas, here CO (i.e., ΔCO).

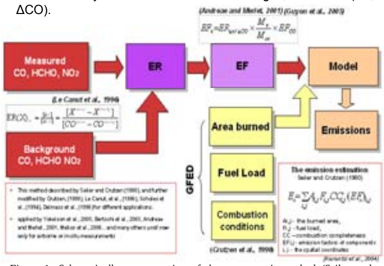


Figure 1: Schematically representation of the excess ratio method (Seiler and Crutzen, 1980) shows how the simultaneously measured gas concentrations could be converted into the emission quantities.

SCIAMACHY CO, NO_2 and HCHO over large biomass burning events

Generally, emissions from fires occurring in natural vegetation are a mixture of components from flaming and smouldering combustion, with different proportions being typical for of the various types of fires. For example, the major part of savannah and domestic fuels is consumed in the flaming stage, while the forest biomass is combusted about equally by both processes - flaming and smouldering. Over the evergreen forests with high fuel moisture burning are mostly defined by smouldering processes. Lobert et al., (1991) summarized the composition of emissions released during the different burning stages. Relatively oxidized components, such as CO_2, NO, NO_2, SO_2, and N_2O and elementary carbon particles are emitted during the flaming stage, whereas the emissions of more reduced components like CO, CH_4, and HCHO, NH_3, HCN, H_2S, CH_3CN, PAH, COS, DMS and organic particles occur during the smouldering stage (Lobert, et al, 1991; Yokelson et al, 2003; Yokelson et al., 2007).

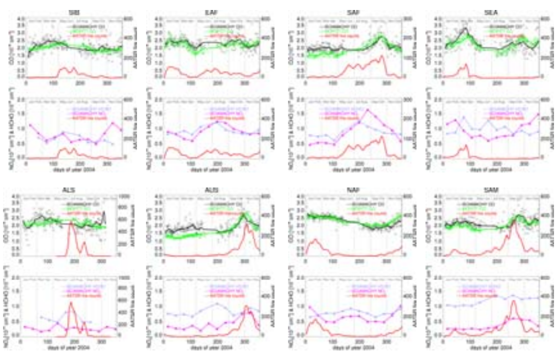


Figure 2: Time series of SCIAMACHY CO, NO_2 and HCHO, as well as the AATSR fire counts.

Fires are a major source of CO. Different types of fires or burning processes result in different relative amounts of emitted or chemically generated CO, HCHO, and NO_2. We aim at taking advantage of the capability of SCIAMACHY to simultaneously measure all three gases to learn more about their surface sources [3].

Figure 2 on the left shows the regional time series for three gases measured by SCIAMACHY over each selected region (selection shown on the posters right most panel). Together with SCIAMACHY CO (in black) the MOPITT CO series are shown (in green). On the bottom part of each regional graph, the time series of SCIAMACHY NO2 tropospheric column (purple), and HCHO (violet) total column, are plotted. Te red line denotes AATSR fire counts.

SCIAMACHY ΔCO/ΔHCHO and ΔCO/ΔNO_2

During the various field experiments, and in other studies in the past, a large number of emission ratios/emission factors have been determined. Afterwards, these data have been compiled into a coherent set of recommended emission factors (Andreae and Merlet 2001). Most recent studies over several selected regions of large Biomass burnings events provided extended references over Southern African savannah areas (Yokelson et al, 2003; Bertschi et al, 2003) over south America (Yokelson et al., 2007) Australian bush fires (Grifith et al., 2008), and some other regions.

The selection of CO or CO_2 as reference gas is determined by the ultimate objective of the analysis and on the fire phase (flaming or smouldering) during which the component is preferentially released. For components predominantly released in the smouldering phase of fire, CO is a suitable reference gas as it is also released predominantly during this phase.

ER	ΔCO/ΔHCHO			ΔCO/ΔNO_2		
	Reference	SCIAMACHY		Reference	SCIAMACHY	
Tropical Forest Fires	74±14(A) 22-37(S)	27±39	SAM	65±12(A) 143 – 609(S)	540±536	SAM
		68±71	EAF		706±530	EAF
		69±51	SEA		862±493	SEA
Extra tropical Forest Fires	49±17(A)	179±200	ALS	35±12(A)	6511±5562	ALS
		37±29	SIB		1318±690	SIB
Other / mixed sources*	66 - 600(A)			37 - 1759(A)		
Savannas Fires	250±77(A) 41 – 233(S)	71±38	NAF	17±6(A) 20 – 57(S)	426±148	NAF
		148±96	SAF		520±243	SAF
		90±41	AUS		436±146	AUS

Table 1: The SCIAMACHY measured ratios values and the reference from the literature (description – see main text). Symbol (A) denotes the summary from (Andreae and Merlet 2001), and symbol (S) denotes the SAFARI 2000 measurements (Yokelson et al., 2003, Bertschi et al., 2003).

In the Table 1, the reference values were taken for comparison with the SCIAMACHY measurements based ratios. The values of EFs reported in (Andreae and Merlet, 2001) were recalculated back into the ER and denoted in the Table 1 by symbol (A). The values from SAFARI 2000 campaign were denoted by symbol (S).

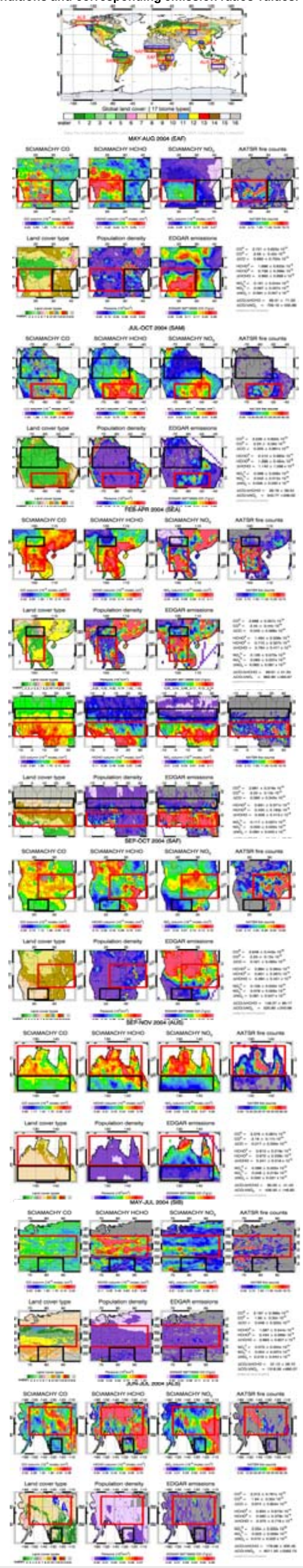
Eight regions were identified, over the regions where similar spatial pattern have been observed over the large fires in South America (SAM) during the July-October; in the Evergreen forest of Equatorial African (EAF) during the dry season, from May till August; the savannas burnings in northern equatorial Africa (NAF) in time form January until May; South Africa savannas fires (SAF) during September – October; the Boreal forests fires in Alaska (ALS) in June and July; and Siberian (SIB) forest fires during May-July 2004. MODIS ecosystem type dataset based on the estimated middle fuel load and mean moisture condition was used, and the position and size of the regions was adjusted in order to include only the areas with equal ecological system type (and thus, with almost equal fuel conditions).

Regional values presented in the Table 1 are also presented on the most right panel of the poster to demonstrate the regional conditions. On each of these figures, the CO, HCHO, NO2 columns as well as the ecosystem type, EDGAR 2K spatial CO emissions distribution (Olivier, 2000), and the AATSR fire count maps are presented. Corresponding values of excess and emission ratio are depicted separately for each region.

The values presented in the Table 1 are discussed in the corresponding conference paper (Khlystova et al., 2009) and in the reference, denoted as [7] in the list of selected references (see below).

Calculated values over eight selected regions

Eight regions were selected (selection show on the land cover type map). For each of the selected regions similar figure were plotted to show the source and background conditions and corresponding emission ratios values.



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ACCENT

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