SCIAMACHY AND FTS CO_2 RETRIEVALS USING THE OCO RETRIEVAL ALGORITHM

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ABSTRACT

The Orbiting Carbon Observatory (OCO) mission will make the first global, space-based measurements of atmospheric CO_2 with the precision and coverage needed to characterize CO_2 sources and sinks on regional scales. OCO will acquire spectrally and spatially highly resolved measurements of reflected sunlight in the O_2 A-band and two near-infrared CO_2 bands. To test the OCO retrieval algorithm, SCIAMACHY and ground-based Fourier Transform Spectrometer (FTS) measurements at Park Falls, Wisconsin have been analyzed. Good agreement between SCIAMACHY and FTS CO_2 columns has been found with SCIAMACHY showing a much larger scatter than FTS measurements. Both, SCIAMACHY and FTS, overestimate the surface pressure by a few percent which significantly impacts retrieved CO_2 columns.

INTRODUCTION

The current knowledge about the temporal and spatial variability of CO_2 is based mainly on highly accurate in-situ measurements from a network of surface stations. Due to the sparseness of these measurements the inferred sources and sinks of CO_2 have significant uncertainties. *Rayner and O'Brien* [2001] showed that these source/sink retrievals will benefit from space-based measurements of the column-averaged dry-air mole fraction, X_{CO2}, if acquired globally and bias-free with a precision of better than 2.5 ppm for a monthly mean on regional scales (~10^6 km^2).
OCO is a mission solely dedicated to the precise and accurate measurement of X_{CO2} by acquiring spectra of reflected sunlight in the O_2 A-band at 0.76 μm and in the CO_2 bands at 1.61 μm and 2.06 μm with high spatial (3 km^2) and spectral resolution (resolving power of ~ 20000). The three spectral bands will be analyzed simultaneously with an algorithm that incorporates the radiative transfer (RT) model Radiant [*Christi and Stephens*, 2004], an instrument simulator model, and an inverse method using the optimal estimation technique [*Rodgers*, 2000]. A validation program will allow verifying and improving the space-based CO_2 measurements. This is based on ground-based FTS measurements of the OCO spectral bands in direct sunlight, which will be analyzed with the same retrieval algorithm as the space-based measurements. More details about OCO can be found in *Crisp et al.* [2004].

The SCIAMACHY instrument on ENVISAT [*Bovensmann et al.,* 1999] provides space-based near-infrared measurements which are similar to OCO measurements, but with much lower spectral (resolving power of 1700 ,1150 and 10000) and spatial resolution (30 x 60 km^2). These measurements allow critically testing of the OCO retrieval algorithm under real atmospheric conditions.

In this paper we present results obtained using space-based SCIAMACHY measurements over Park Falls, Wi (46^0N, 90^0W). This site allows validation of the space-based measurements with ground-based FTS (Bruker 125 HR) measurements and to compare the results obtained from both instruments using the OCO retrieval algorithm.

RESULTS

We have selected SCIAMACHY nadir measurements of the O_2 A-band and of the 1.58 μm CO_2 band for overpasses over Park Falls between June and October 2004. The 2.0 μm CO_2 band in channel 7, with much higher spectral resolution, has not been used due to calibration problems caused by a build-up of an ice-layer on the detector. All SCIAMACHY radiances have been calibrated using a tool developed at University Bremen.

The SCIAMACHY and the FTS spectra have been analyzed using the OCO retrieval algorithm, which simultaneously retrieves a CO_2 profile on 12 atmospheric levels (SCIAMACHY), or a CO_2 scaling factor (FTS), a H_2O and temperature scaling factor, surface pressure, surface albedo (SCIAMACHY), and instrumental parameters. The absorption cross sections for O_2 and H_2O have been taken from HITRAN 2004 and for CO_2 from *Toth el al.* [personal communication]. A fixed aerosol profile with a total optical depth of 0.1 has been used. X_{CO2} has been calculated after convergence from the retrieved CO_2 profile by applying a pressure weighting operator. All spectra with a retrieved surface pressure of less than 925 mbar have been assumed to be cloudy and have been discarded.

Figure 1 shows spectral fits of the SCIAMACHY O_2 A-band and 1.58 μm CO_2 band. The residuals show some distinct systematic structures which are most likely caused by uncertainties in the calibration or in the instrument function The presence of the systematic structures is also reflected by the value of the root mean square (rms) of the fit of 0.5 – 1 % which is by a factor of 5 larger than the noise.

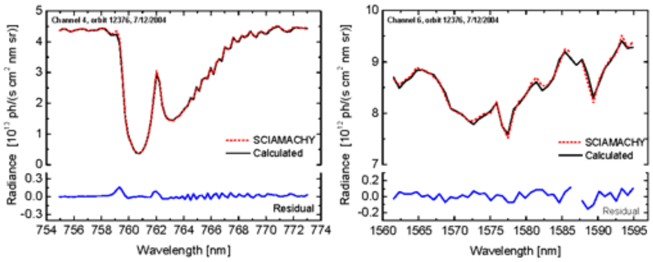

Fig. 1. Spectral retrieval of the O_2 A-band and the 1.58 μm CO_2 band of a SCIAMACHY nadir measurement over Park Falls, Wi on July 12, 2004 (SZA = 30.7^0). The discontinuity at 1.587 μm is caused by a dead detector pixel.

The retrieved X_{CO2} from SCIAMACHY and FTS measurements is shown in the upper panel of figure 2 (solid symbols). The precision of SCIAMACHY X_{CO2} has been inferred from rms considerations and is ~8 ppm. Consequently, SCIAMACHY X_{CO2} shows a substantially larger scatter than the precise FTS X_{CO2} measurements (1σ ~0.3 ppm). With few exceptions, X_{CO2} retrieved by both instruments agrees within the error bars. The comparison of the retrieved surface pressure from SCIAMACHY and FTS with a pressure sensor measurement at the FTS site is shown in the lower panel of figure 2. Both remote sensing measurements overestimate the pressure sensor measurements by a few percent. Some outliers can be found in the SCIAMACHY retrievals which are very likely caused by a partly cloudy scene. This overestimation of surface pressure was studied in detail by *Yang et al.* [2005]. They found that the surface pressure retrieval can be significantly improved by using super-Lorentz spectral functions for strong O_2 lines. This approach, however, has not been adopted in the present study. The surface pressure retrieved from SCIAMACHY also shows a tendency to increase towards fall 2004. This feature is presumably related to the increasing SZA but seems to cancel for X_{CO2}, which is the ratio of the retrieved CO_2 and the O_2 columns. To demonstrate the effect of overestimating surface pressure on the retrieved X_{CO2}, the surface pressure measured by the pressure sensor has been used to calculate X_{CO2} from the FTS measurements (Fig. 2, open symbols). In this case X_{CO2} is systematically larger by approx. 10 ppm.

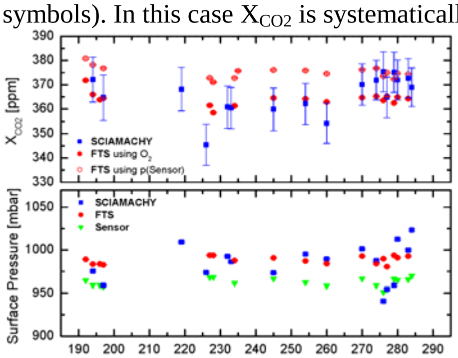

Fig. 2**.** Comparison of X_{CO2} retrieved from SCIAMACHY and ground-based FTS measurements for Park Falls, Wi (upper panel). The solid symbols show X_{CO2} calculated from the retrieved CO_2 profile and the retrieved surface pressure. Also shown is X_{CO2} generated from the FTS measurements using the surface pressure measured by a pressure sensor (open symbols). A comparison of the surface pressure retrieved from the O_2 A-band measurements of SCIAMACHY, FTS and the pressure sensor is given in the lower panel.

SUMMARY

The retrieval algorithm being developed for the OCO mission has been tested using space-based SCIAMACHY and ground-based FTS measurements at Park Falls, Wi. Good agreement between SCIAMACHY and FTS X_{CO2} has been found with SCIAMACHY showing a much larger scatter than FTS measurements, as expected from the much weaker reflected sunlight and the sensitivity to aerosol. Spectroscopic uncertainties for the strong O_2 lines in the A-band lead to an overestimation of the surface pressure which significantly impacts the retrieved X_{CO2}. New lab measurements of O_2 with very long light paths will be needed to resolve this problem. As a dedicated CO_2 instrument with much higher spectral and spatial resolution OCO should achieve much higher precision and accuracy than SCIAMACHY.

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