Evaluation of simulated clear sky O_2 A-band measurements from GOSAT over different surfaces - a sensitivity study

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Motivation

The motivation of the presented study arises from the results of investigations of photon path length distributions in clouds using O_2 A band measurements from the GOSAT satellite **[1]**. For different cloudy sky measurements over ocean, radiance spectra of the O_2 A band were simulated with the radiative transfer code McArtim **[2]** and fitted to the measurement by allowing slight variations in the wavelength and the simulated O_2 absorption. The results suggested a systematic overestimation of the simulated O_2 absorption. In order to further understand the results, it was decided to analyze a large dataset of clear sky measurements, test dependencies of selected measurement parameters and use different configurations of the fit function.

Dataset and Simulation

All radiance measurements originate from the Fourier Transform Spectrometer TANSO-FTS on the Greenhouse Gases Observing Satellite GOSAT **[3]** (2009 - 1020+). The spectral resolution is 0.2 nm for the O_2 A band and the instantanious field of view diameter is 10.5 km. The high spectral resolution of the data products allows to almost completely resolve the individual absorption lines. The Cloud- and Aerosol Imager TANSO-CAI measures pixel radiances of the observation region and thus provides information on cloud and aerosol coverage.

The simulations are performed with the Monte Carlo model McArtim, using a precision of 1% and including effects of polarization and rotational Raman scattering. They are then compared to the averaged P- and S-polarized TANSO-FTS spectra.

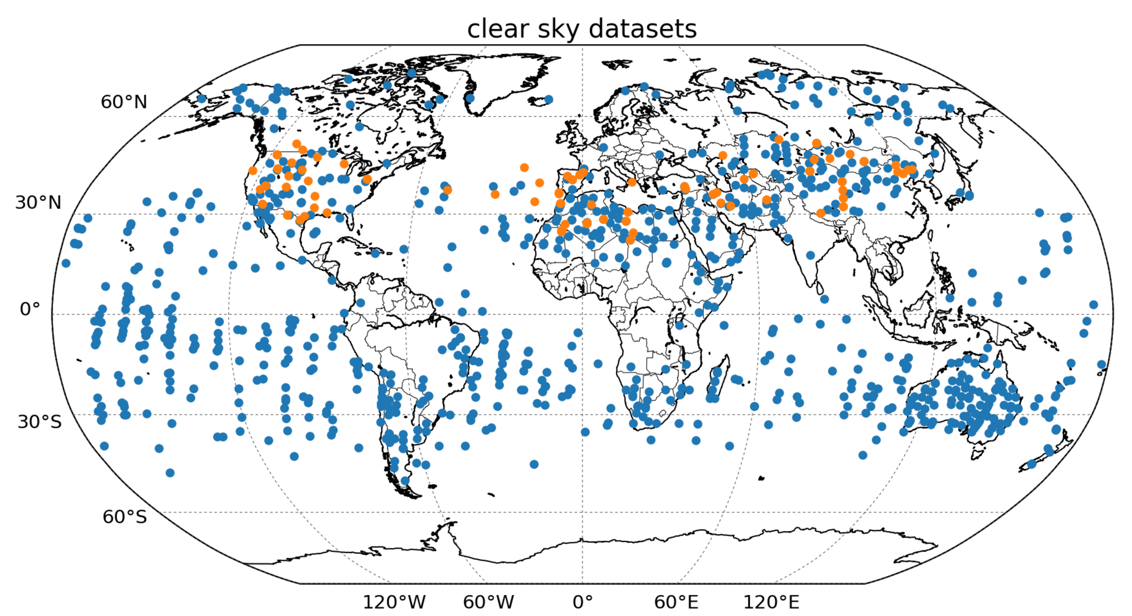

Figure 1: Measurement coordinates of (collocated) dataset 1 in orange and (non-collocated) dataset 2 in blue.

Two different datasets are used in the study and shown on the worldmap in figure 1. Dataset 1 (4.2009 - 10.2015) has additional collocated (Δt $\leq$ 20 min. and FOV coincidence) lidar measurements from CALIOP onboard the CALIPSO satellite [3] which are used to exclude measurements with cloud or aerosol presence. Dataset 2 contains non-collocated measurements from TANSO-FTS from 2010 to 2014. All measurements are screened for clear sky status and quality criteria using different TANSO-FTS (V220.220) and TANSO-CAI datasets provided by the GOSAT teams.

Data analysis and fit results

Prior to the simulation of the entire radiance spectrum, the surface albedo is determined by comparison of measured and iteratively simulated continuum radiances I_c. Two spectral regions, left (758.9 nm) and right (770.9 nm) of the strong absorption lines, are used. The comparison to the surface albedos from GOSAT analysis and MODIS is good although our values are slightly higher than those derived by from the GOSAT teams.

After calculation of the radiance spectrum, the comparison to the measurement is performed via a fit function allowing small variations of the wavelength and the simulated O_2 absorption.

$$I_{FTS}(\lambda) = I_{sim}(\lambda + \delta_\lambda)^B$$

For perfect measurement and simulation conditions, a parameter of B=1 is expected. B < 1 indicated an overestimation of the simulated O_2 absorption, B > 1 indicates an underestimation.

Fig. 3 displays the fit results for the B parameter (dataset 2) as a histogram also including Gaussian distribution fits. While the land measurement results are close to B=1, the water measurement results are centered near 0.95 and thus indicating an overestimation of simulated O_2 absorption. The same conclusions are found for dataset 1.

For dataset 2, many of the surface albedos found for the water measurements are higher than expected. Although most cases can be explained by effects from sun glint geometries (see fig. 4), the remaining high values are not yet understood.

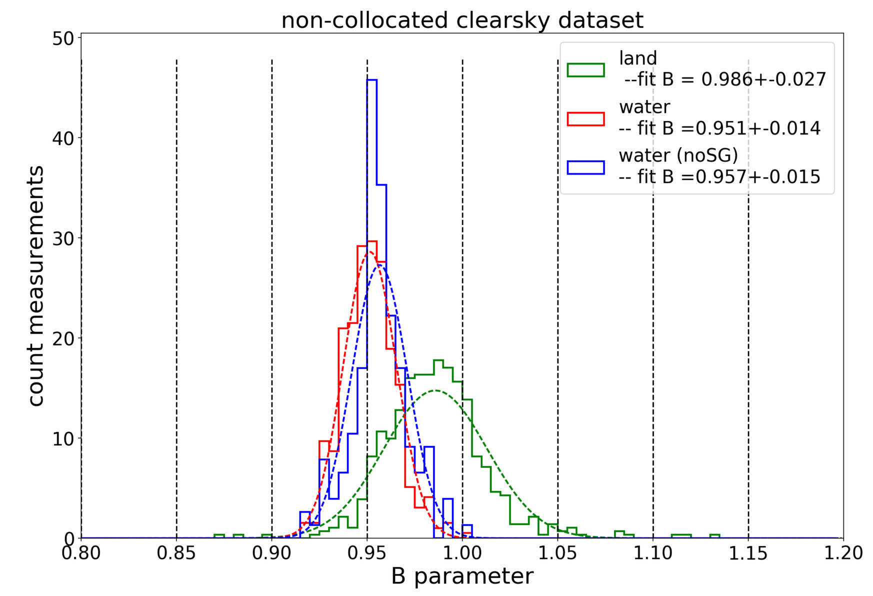

Figure 3: Fit results of dataset 2 for different surfaces.

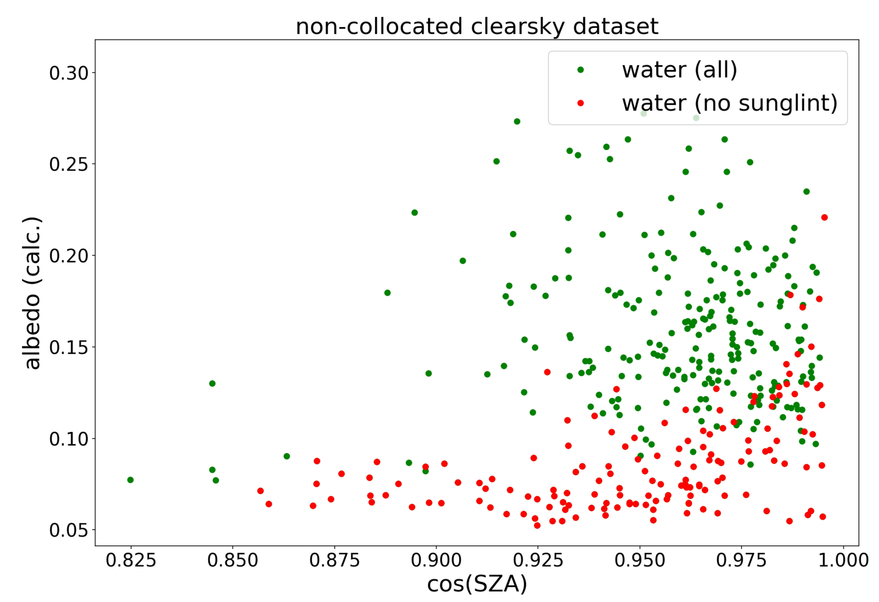

Figure 4: Cosine of SZA vs. albedo for all water measurements and sunglint cases.

Influence of simulation parameters

Effects of observation geometry, surface parameters, radiance polarization and the use of different continuum regions for the albedo determination were investigated. The distributions of fitted B values increase with higher SZA, and also with lower NDVI values. For higher SZA values, a difference between P- and S-polarized spectra can be observed. Using different continuum regions during the analysis only influences the results for land surfaces. Including an aerosol layer (g = 0.7, τ = 0.05, 0.1) between 0 and 1 km in the model atmosphere does not show any significant effect on the fit results.

In contrast to the land measurements, the water observations are sensitive to the used continuum value during the analysis, suggesting a wavelength dependence of the water albedo (see also **[4]**). Including a wavelength dependence in our algorithm for three example ocean measurements shows a potential improvement of 1% for B. This effect may thus contribute to but not fully explain the observed deviation of B from unity.

Intensity offset investigation

In a next step, an additive offset C is added to the fit function. Using polynomial orders $C(n)$ with n=0-5, it was observed that it has the potential to "shift" the mean of the resulting B distribution (see fig. 5) towards unity by decreasing the fit residual at the same time. As for C(n>3), the residual is not significantly reduced, the complete dataset 2 was fitted using polynomial degrees of 0 for B and of 3 for C.

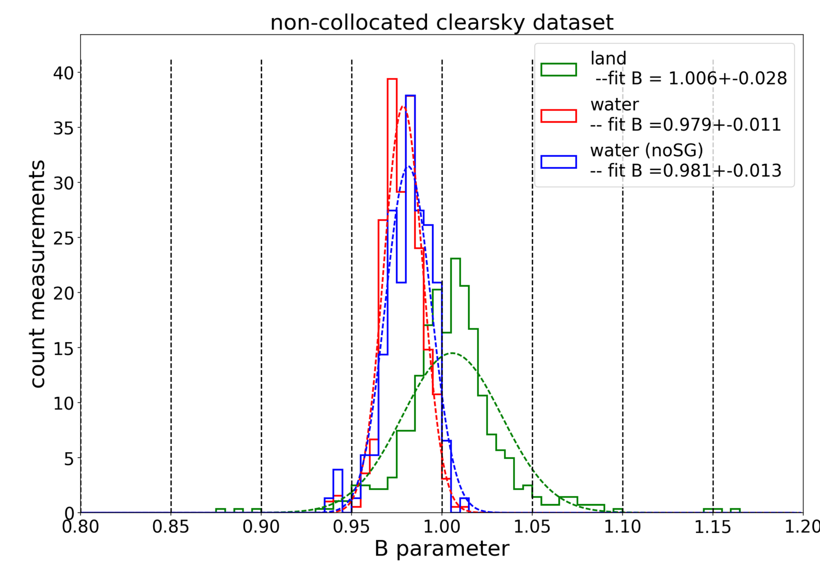

Figure 5: Fit results of dataset 2 for different surfaces using a fit parameter B and an additive offset C.

The averaged determined offset is in the order of 10^{-4} W/m^2/sr/nm. Orders of magnitude agree with the (constant) zero-level offset of the TANSO-FTS data **[5]**.

Conclusions and Outlook

Datasets of clear sky TANSO-FTS measurements were selected and compared to radiative transfer simulations. The used fit function allows wavelength alignment and a variation of the simulated O_2 absorption (fit parameter B). While for land measurements, B is near the expected value of 1, systematically lower B values are found for water measurements. Influence of simulation parameters on the results are found for SZA, NDVI and the wavelength dependence of the water albedo. By including an additive offset in the fit, the deviation of the B parameter from unity and the fit residual were significantly reduced.

This study was intended to complete the understanding of the analysis of clear sky scenarios before continuuing the investigation on clouds and photon path length distributions.

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