



Initial CO₂ And CH₄ Retrievals From GOSAT: Comparisons To Model And Ground-Based Data

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Abstract

With the launch of the Japanese Greenhouse gas Observing SATellite (GOSAT) on 23 January 2009, the first observations from a dedicated greenhouse satellite sensor have become available. GOSAT provides global measurements of total column CO₂ and CH₄ from its shortwave infrared (SWIR) bands and of mid-tropospheric sub-columns from its thermal-IR bands.

Specifically, observations of total column CO₂ and CH₄ are well suited to improve our knowledge of sources and sinks. However, to infer the total columns with the required precision and accuracy is a major challenge for the applied retrieval algorithms mainly due to the presence of atmospheric aerosols and cirrus clouds.

We will present first results of CO₂ and CH₄ retrievals from GOSAT spectra using the retrieval algorithm developed for OCO. We will compare our results against model calculations and ground-based column data.

Keywords: GOSAT, CO₂, CH₄

1. Introduction

The dramatic increase of atmospheric carbon dioxide (CO₂) from a pre-industrial level of ~280 parts per million (ppm) (IPCC, 2007) to more than 385 ppm presently due to human activities is one of the main drivers of climate change. Atmospheric levels of methane (CH₄) have also risen dramatically over the last 300 years from 400-700 parts per billion (ppb) to 1774 ppb (IPCC, 2007).

In situ surface networks provide accurate measurements of global CO₂ concentrations and their large scale variations. However, they are limited by the number of sensors and their low spatial coverage, leaving key carbon cycle science questions to be unresolved such as where are the sinks that absorb over 40% of emitted CO₂, what is driving the variations in the atmospheric build-up and how will CO₂ and CH₄ sources and sinks respond to climate change?

Satellite observations such as those of SCIAMACHY and now of GOSAT can provide data with dense spatial and temporal coverage over regions poorly sampled by surface networks which can lead to large improvements in estimates of carbon surface flux.

The Japanese Greenhouse gases Observing SATellite (GOSAT) is the first dedicated greenhouse gas sensor and was launched on the 23rd January 2009. The payload consists of two main instruments; the TANSO Fourier Transform Spectrometer (FTS) and the Cloud Aerosol Imager (CAI). TANSO-FTS provides spectrally resolved radiances in the shortwave infra-red (polarised) and thermal infra-red ranges, allowing coverage of several absorption bands of CO₂, CH₄, H₂O and O₂. TANSO-CAI observes in 4 broadband channels with high spatial resolution, providing aerosol and cloud information required for the greenhouse gas retrieval.

2. Methodology

The OCO "Full Physics" Retrieval Algorithm was developed for the NASA Orbiting Carbon Observatory (OCO) mission, now the ACOS (Atmospheric Carbon Observations from Space) project. The algorithm retrieves XCO₂ (dry air, column averaged, mole fraction of CO₂) from a (simultaneous) fit of SWIR O₂ and CO₂ bands using Optimal Estimation. The algorithm retrieves typically profiles of CO₂, CH₄, H₂O, temperature and aerosol optical depth for several aerosol/cloud types as well as surface pressure, surface albedo and spectral dispersion (Boesch, 2006). XCO₂ is computed from the retrieved state after the iterative retrieval has converged. In collaboration with the NASA ACOS team we have modified the OCO algorithm to operate on GOSAT data in order to provide global retrievals of XCO₂ and XCH₄.

For the CO₂ retrievals the O₂ A Band and the 1.61µm and 2.06µm CO₂ absorption bands were simultaneously retrieved as well as water vapour, surface pressure, dispersion, albedo and aerosols. The a priori used ECMWF surface pressure, H₂O profile and temperature profile, CO₂ from the LSCE model and CH₄ from S. Houweling's climatology. Additionally, four aerosol profiles with a total optical depth of 0.2 were used for all retrievals.

For the CH₄ retrievals, the CH₄ at 1.67µm is jointly fitted along with the weak CO₂ band at 1.61µm. This approach allows the ratio of CH₄/CO₂ to be calculated which is capable of removing many of the effects of aerosols on the retrieval. This ratio is then scaled by modelled CO₂, in this case the CarbonTracker CO₂.

4. Results

GOSAT retrievals of XCO₂ have been performed for observations between April 2009 and February 2010 using the OCO retrieval algorithm. Cloud screening was achieved by comparing the difference between the retrieved surface pressure from the O₂ A Band retrievals against ECMWF surface pressure. Data was determined to be cloud-free if the difference was below 20 hPa, otherwise the scene was deemed to be cloudy and no XCO₂ retrieval was attempted.

To validate our retrieved XCO₂, comparisons with in-situ ground based observations made by the Total Carbon Column Observation Network (TCCON) have been performed (Figure 1). The retrieved XCO₂ was filtered for only converged retrievals with an aerosol optical depth less than 0.3.

As can be seen, whilst the XCO₂ values are currently offset from the TCCON data by approximately 7 ppm, potentially due to calibration effects, the seasonality is being well-captured with a similar overall trend.

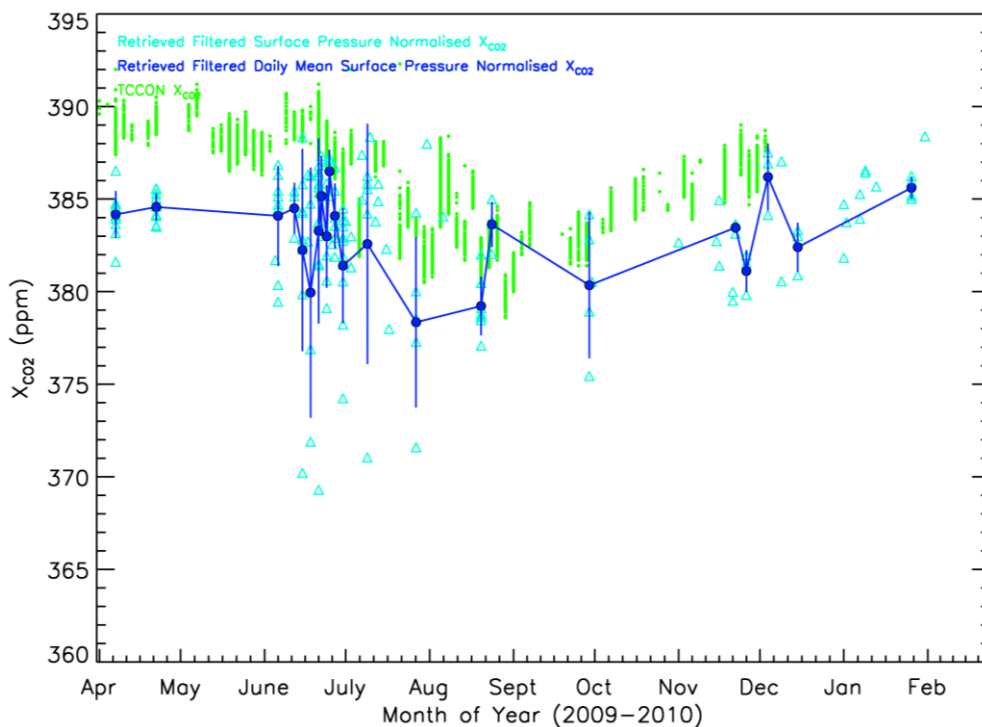


Figure 1: Retrieved XCO₂ from GOSAT over Lamont (US) between 01/04/2009 – 06/02/2010 filtered and normalised with surface pressure, compared to retrieved XCO₂ from the Lamont TCCON ground-based FTS. The daily mean of the retrieved XCO₂ from GOSAT is only calculated when at least 3 measurements pass the filter for that day.

In addition to retrievals over validation sites, preliminary global retrievals have been performed. Our results are compared to modelled data, specifically the GEOS-Chem model. GEOS-Chem is a global 3-D transport model that has been extensively evaluated using ground-based, aircraft and satellite measurements of CO₂ and CH₄, and is used in conjunction with a data assimilation algorithm to infer surface fluxes.

In Figure 2 we present the preliminary XCH₄ retrievals from GOSAT compared against GEOS-Chem model runs for 1st-6th June 2009. As can be seen, using the CH₄/CO₂ ratio proxy approach discussed above appears to provide reasonable XCH₄ values which compare well to the modelled data. A comparison of the zonal mean for both datasets is provided in Figure 3 which demonstrates how well the GOSAT retrieval is capturing the XCH₄ distribution and hemispheric gradient.

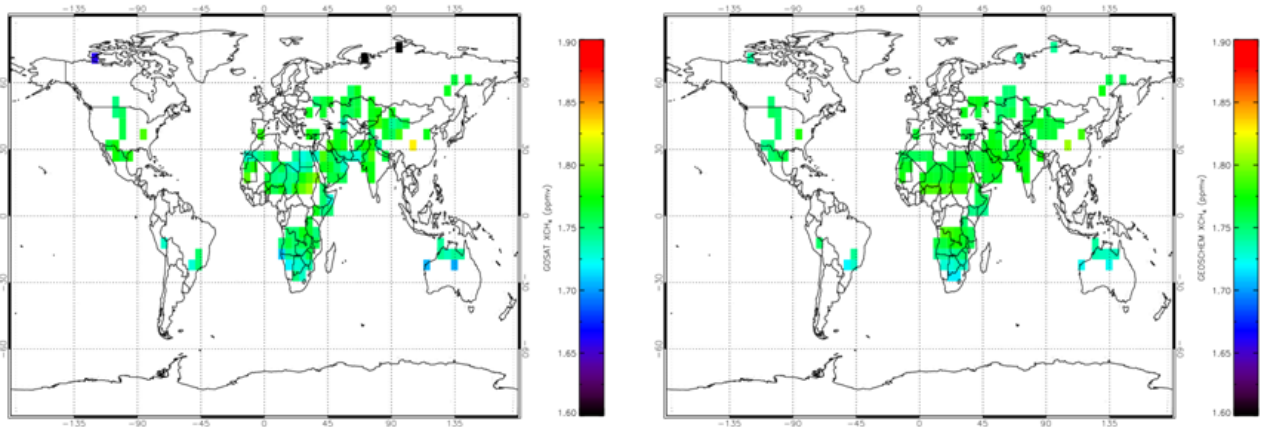


Figure 2: Initial retrievals of XCH₄ from GOSAT spectra measured 1st – 6th June 2009 and averaged into 5° boxes (left) and GEOS-Chem modelled XCH₄ sampled for the same time period (right).

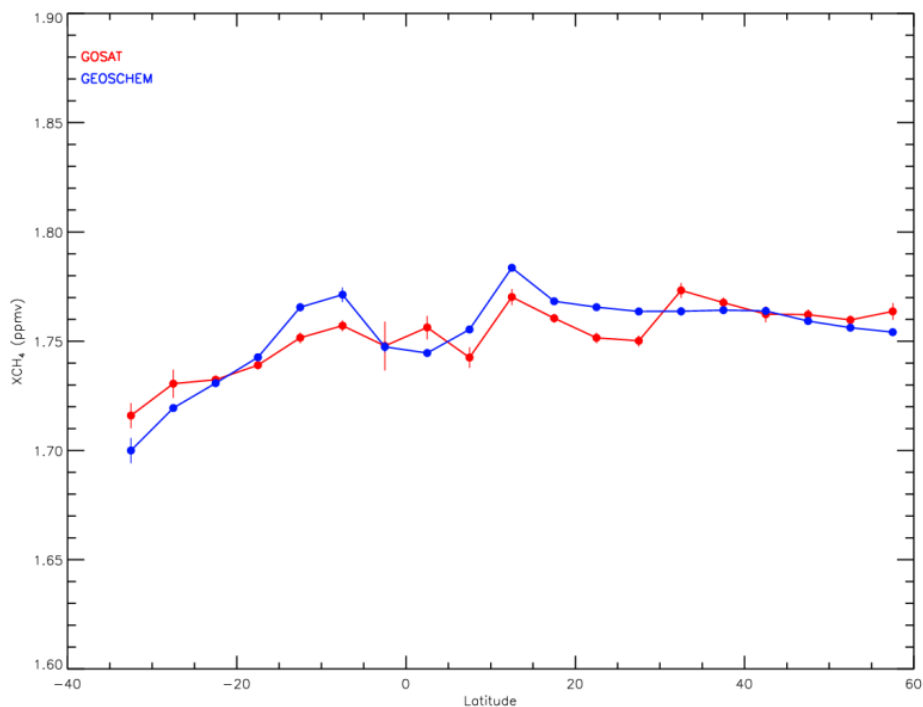


Figure 3: The zonal mean of the XCH₄ from Figure 2 for both the GOSAT retrieval (red) and the GEOS-Chem model data (blue). A strong agreement in the zonal mean between the retrieved and modelled data is shown, suggesting that the GOSAT XCH₄ is capable of providing valuable results relating to the CH₄ global distribution.



4. Conclusions

The first dedicated greenhouse gas satellite, GOSAT, was launched in early 2009 and is successfully acquiring data, ensuring that continuation of observations of CO₂ and CH₄ from space.

Observations of total column CO₂ and CH₄, in particular, are well suited to improve our knowledge of the surface fluxes of these two gases. However, inferring the surface fluxes from these total columns requires stringent levels of measurement precision and accuracy, representing a major challenge for the trace gas retrieval algorithms mainly due to spectral interference from atmospheric aerosols and clouds.

If carefully validated and characterised, the data presented here has the potential to significantly improve our understanding of the global carbon cycle. Initial XCO₂ and XCH₄ retrieval tests at Leicester show promising results and we expect further improvements once more data has been processed and analysed.

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7. References

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