Combining chlorophyll fluorescence and column water vapour retrievals from GOSAT data

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Abstract

Previous work by Guanter et al. [2012] provides an extremely fast chlorophyll fluorescence (F_s) retrieval from GOSAT SWIR spectra. This is currently in the process of being extended, with the aim of soon providing a complementary water vapour product.

Fluorescence is a good proxy for plant photosynthesis, and gross primary production. Combined with water availability and CO_2 concentration information, it should be of greater use to plant scientists than a fluorescence product alone. Initial simple retrievals of water vapour column are shown, and compared to ECMWF water vapour column fields. The aim of the project is to provide a fast algorithm for co-located water vapour and F_s values.

GOSAT

The FTS on GOSAT is has a high resolution (0.2 cm^{-1}) SWIR and TIR bands, and is designed to measure greenhouse gas concentrations The two shortest wavelength bands are used to obtain fluorescence and water vapour column respectively.

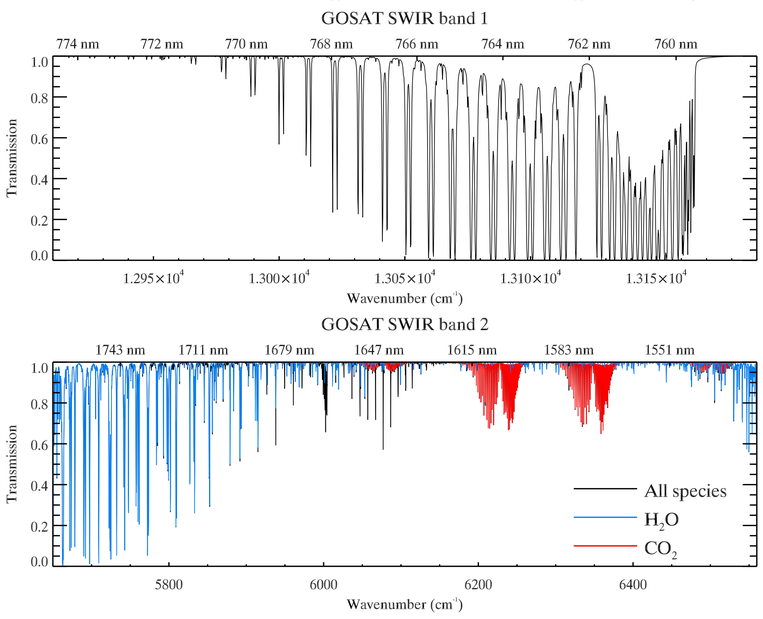

Figure 1: Modelled transmission for GOSAT SWIR. A standard mid-latitude reference atmosphere is used.

Absorption in band 1 is from the O_2 A-band. Signals from H_2O and CO_2 in band 2 have been highlighted, but there are also CH_4 lines present.

Fluorescence retrieval

Details for retrieving F_s have been described by Guanter et al. [2012]. The method uses singular vector decomposition of F_s-free GOSAT spectra from a narrow spectral band (e.g. 755–759 nm). These are then fitted in a linear retrieval with a constant F_s term which is non-neglegible within solar Fraunhofer lines.

Results from July 2009 are shown in Fig. 2. Due to the simplicity of the method, the computational expense (once a training set of singular vectors has been obtained) is very low.

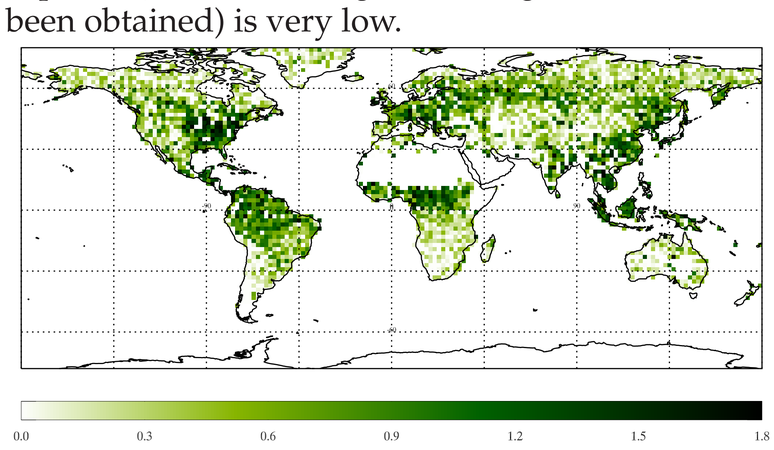

Figure 2: Retrieved F_s from July 2009 using the S-polarization of a narrow spectral window at 755 nm.

Water vapour retrieval method

In order be useful alongside the F_s product, it is desirable for a fast water retrieval method. As such, a fast linear retrieval, assuming a constant CO_2 profile is used instead of a full-physics retrieval. Deviation in the expected absorption of H_2O relative to the CO_2 absorption is then used to calculate a water vapour column.

Atmospheric transmission, $\mathbf{T}$, (as shown in Fig. 1) is calculated with the Reference Forward Model [RFM]. A standard mid-latitude atmosphere is used; two small spectral windows from GOSAT band 2 are selected, one containing mainly water vapour lines (5710–5950 cm^{-1}), and a one containing mainly CO_2 lines (6170–6390 cm^{-1}). The differential transmission with respect to a small change in the water vapour column, $\partial\mathbf{T}/\partial U$, is then calculated. At this time, a single inflection point in H_2O is used.

The linear combination of these two values, a quadratic (to simulate broadband features), and a wavenumber offset, $\mathbf{\Psi}$, (to model misalignment of GOSAT spectral data) is solved for the state vector $\mathbf{x}$ for each GOSAT spectra, $\mathbf{S}$:

$$\mathbf{S} = x_0\mathbf{\Psi} + x_1 + x_2\boldsymbol{\nu} + x_3\boldsymbol{\nu}^2 - x_4\left(1-\mathbf{T}\right) - x_5\frac{\partial\mathbf{T}}{\partial U}.$$

To recover a water vapour column amount, U_{wv}, the linearized difference in transmission is added to the standard atmosphere H_2O column:

$$U_{\mathrm{wv}} = U_{\mathrm{wv},0} + \delta U = U_{\mathrm{wv},0} + \frac{x_4}{x_5}.$$

Comparison with ECMWF profiles

Comparisons of the preliminary retrieval with ECMWF interim fields for total column water vapour (TCWV) are shown in Fig. 3. Overall, spatial paterns are encouraging, although pixel-by-pixel comparisons are not often close. Several explanations for this are possible:

1. The coarse resolution of the ECMWF profiles will not be able to pick up fine structure in the TCWV.
2. The is at the moment no cloud screening (although data points with bad retrieval statistics are thrown away before the comparison.
3. The method only uses a single value of TCWV about which to linearise.
4. A mid-latitude atmospheric profile has been used for all points on earth. No care has been taken to vary CO_2 column based on climatology.

Improvements to the methods are currently being implemented, and will lead to a future colocated H_2O and F_s product from GOSAT measurements.

References

ECMWF: data portal. data-portal.ecmwf.int/data/d/interim_full_daily

Guanter, L., C. Frankenberg, A. Dudhia, P. E. Lewis, J. Gómez-Dans, A. Kuze, H. Suto, and R. G. Grainger, 2012: Retrieval and global assessment of terrestrial chlorophyll fluorescence from GOSAT space measurements. *Remote Sensing of Environment*, **121**:236–251, doi: 10.1016/j.rse.2012.02.006.

RFM: Reference forward model, A. Dudhia. www.atm.ox.ac.uk/RFM

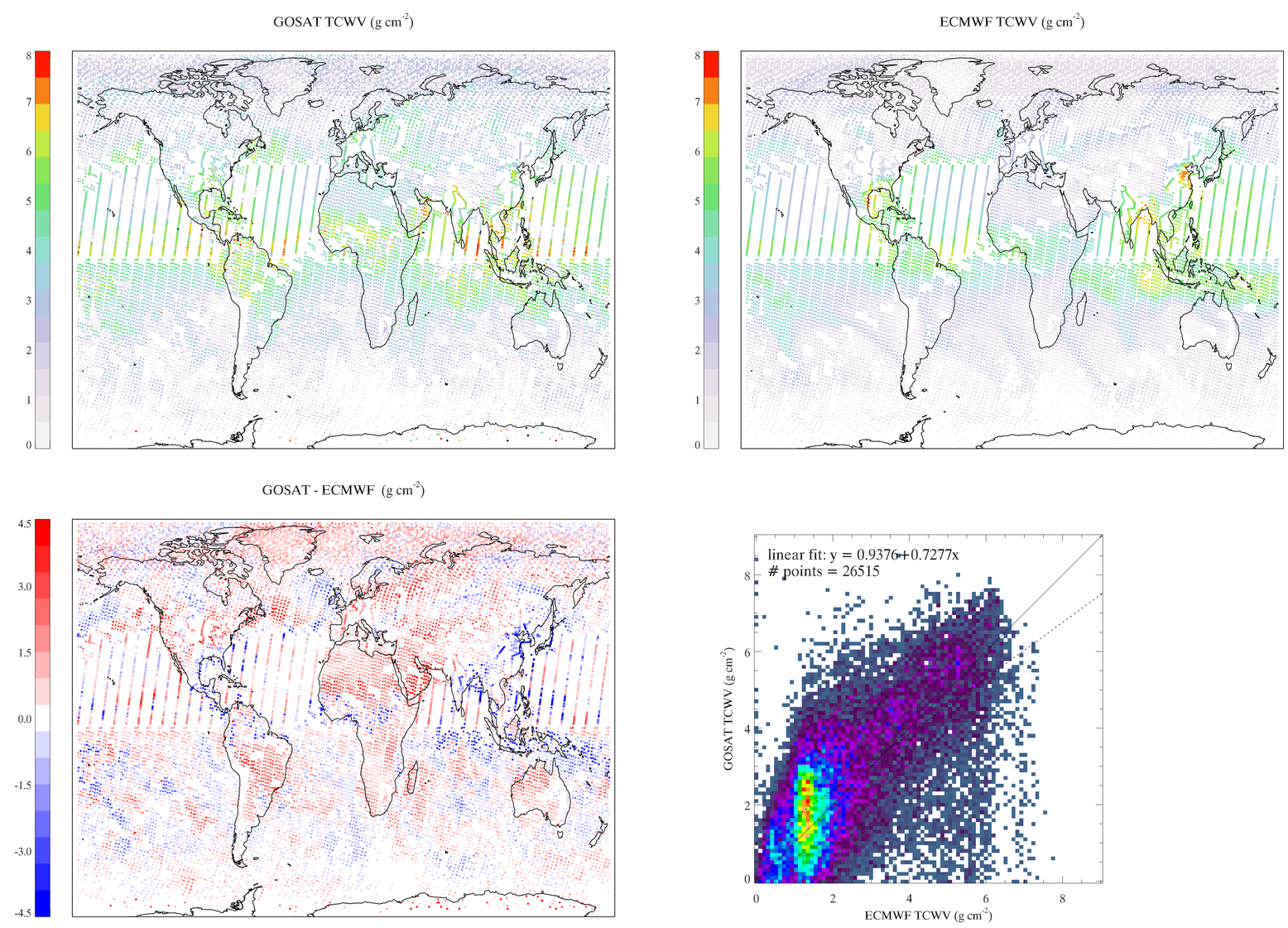

Figure 3: Comparing linear retrieval of column H_2O with ECMWF profiles. Data is from 9th–11th July, 2009. The first panel shows the GOSAT water vapour, as retrieved using the linear method described above. The second panel shows ECMWF interim total column water vapour, interpolated onto the GOSAT measurement grid from 6 hour, $1.5^\circ \times 1.5^\circ$ resolution fields. The third panel is the absolute difference between the two, positive values implying that the retrieved value is higher than the ECMWF. The final plot is a histogram comparing the two data sets, with a linear line of best fit overplotted.