# Retrieval of Chlorophyll Fluorescence from GOSAT-760nm measurements

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## Introduction

Solar-induced chlorophyll fluorescence (Fs) is a weak electromagnetic signal emitted in the red and far-red spectral regions by vegetation chlorophyll under excitation by solar radiation. The fluorescence emission occurs in two broad peaks in the red (685 nm) and far-red (740 nm) regions of the spectrum. A number of laboratory and field experiments have demonstrated that chlorophyll fluorescence is directly linked to the instantaneous plant photosynthesis, as opposed to traditional reflectance-based vegetation parameters which are only indicators of the potential photosynthetic activity of the plant.

Measurements of backscattered sunlight in atmospheric absorption features overlapping the Fs emission (Fig. 1) can serve for Fs retrieval (Guanter et al, 2010). The different atmospheric optical paths crossed by the fluorescence and reflected signals provide the information required to decouple these two components from the radiance measured at the top-of-atmosphere (TOA) level.

According to this, the entire GOSAT's band 1 measurements around the O2-A absorption feature in 760nm could in principle be used for Fs retrieval. However, the relatively narrow spectral range covered between 755-770 nm may cause the retrieval to be strongly biased by uncertainties in the atmospheric state, especially in aerosol concentration and type and surface pressure, which have a spectral impact on TOA radiance very similar to that of fluorescence (Fig. 2).

However, the very high spectral resolution of GOSAT measurements enable individual Fraunhofer lines present in the exo-atmospheric solar spectrum to be resolved (Fig. 3). As demonstrated by Frankenberg et al (2011) and Joiner et al. (2011), the modeling of the changes in the fractional depth of these Fraunhofer lines, which is not affected by atmospheric absorption and scattering, can be used to disentangle Fs from the radiation reflected by the surface-atmosphere system at the TOA level.

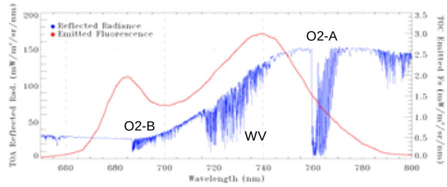


*Fig. 1 – Real top-of-canopy (TOC) chlorophyll fluorescence spectrum superposed to a top-of-atmosphere (TOA) radiance spectrum simulated for a green vegetation target.*

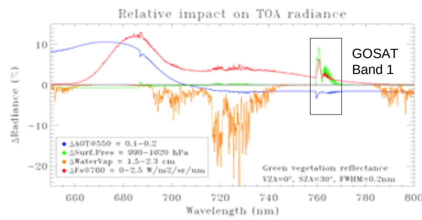


*Fig. 2 – Impact of aerosol optical thickness, water vapor column surface pressure and fluorescence on TOA radiance for a green vegetation target. The impact of Fs on the Fraunhofer lines around 760nm is not visible due to the coarse spectral resolution of the simulation.*

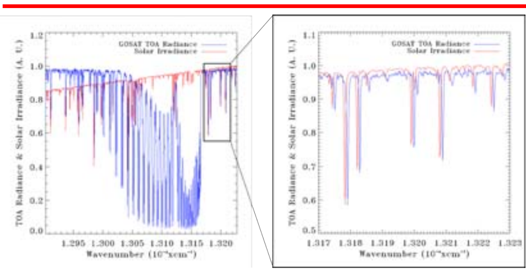

*Fig. 3 – (Left) TOA radiance spectrum measured by GOSAT compared with the Chance & Kurucz solar irradiance spectrum. (Right) Zoom over a spectral window several Fraunhofer lines and free from oxygen features.*

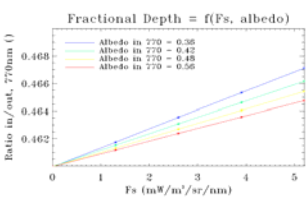


*Fig. 4 – Change in the fractional depth of the Fraunhofer line in 770.1nm as a function of Fs and background albedo. The log-based approach to decouple Fs from the background signal minimizes the effect of background albedo.*

## Methodology

The method proposed by Frankenberg et al (2011) has been adapted to GOSAT data in two fitting windows (around 755 and 770nm). The main steps of the approach which has been implemented are:

•Estimation of the spectral shift between GOSAT measurements and the input solar irradiance spectrum convolved with the GOSAT's ILS (Fig. 3). The resulting shift is used to resample the solar irradiance onto the GOSAT spectral grid.

•Estimation of surface pressure (SPR) and upward atmospheric transmittance in order to account for residual oxygen absorption in the fitting window and to correct for continuum atmospheric absorption in the retrieved Fs signal. A LUT giving SPR=f(Lin/Lout, air mass) with Lin, Lout being pseudo channels of 3nm width inside and outside the O2-A feature generated through spectral binning is used.

•Retrieval of Fs by means of the inversion of TOA measurements using the forward operator

$$\vec{f}(F_s^{rel}, a) = \log(< \tilde{I}_0 + F_s^{rel} >) + \sum_{i=0}^{n} a_i \cdot \lambda^i$$

which is reproduced here as described in Frankenberg et al. (2011). $I_0$ is an effective solar transmittance spectrum calculated by removing the continuum from the Chance and Kurucz (2010) spectrum, and $a_i$ represents the coefficients of a 2nd order polynomial accounting for low-frequency variations within the spectral window which compensates for changes in the fractional depth related to deviations from linearity in the relationship between TOA radiance and surface reflectance (Fig. 4).

## Preliminary Results

Two months of global GOSAT data, November 2009 and May 2010, have been processed to test the algorithm. An exemplary fit is shown in Fig. 5 and the resulting global fluorescence maps are displayed in Fig. 6. Data acquired under illumination angles >65° are not shown. Consistently with Joiner et al. (2011), the highest Fs levels are detected in tropical forests, and a seasonal trend between May and November is observed. The fact that Fs in 755nm is higher than in 770nm as expected (Fig. 1) is a good test of the consistency of the retrievals.

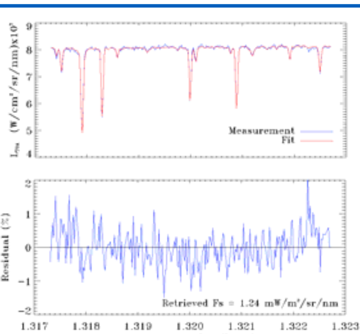


*Fig. 5 – Example of fit and residual in the 755nm fitting window.*

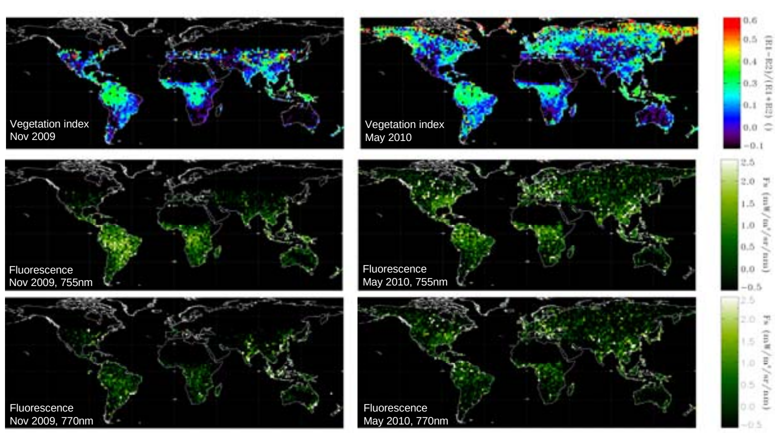


*Fig. 6 – Global fluorescence maps in Nov 2009 and May 2010 in the 755 and 770nm spectral windows compared with an estimation of vegetation amount as given by the ratio of TOA reflectance (R1-R2)/.(R1+R2), with 1 and 2 being the continuum reflectance in GOSAT bands 1 and 2, respectively. All data correspond to S polarization.*

## References

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