FLUORESCENCE EXPLORER (FLEX): A NEW TECHNIQUE FOR THE OBSERVATION OF GLOBAL VEGETATION PHOTOSYNTHESIS

Jose F. Moreno
Dept. Earth Physics and Thermodynamics, Faculty of Physics, University of Valencia
Dr. Moliner, 50 - 46100 Burjassot, Valencia, Spain.
Tel. +34 96 3543112, Fax +34 96 3543385, Email: Jose.Moreno@uv.es

Yves Goulas [1], Elizabeth Middleton [2], Franco Miglietta [3], Peter North [4], Wout Verhoef [5], Uwe Rascher [6], Sune Svanberg [7], Michael Berger [8], Matthias.Drusch [9], Ferran Gascon [9], Bernardo Carnicero [9], Jean-Loup Bezy [9], Luis Guanter [10], Federico Magnani [11]

[1] LMD, CNRS, Palaiseau, France
[2] NASA-GSFC, Greenbelt, MD, USA
[3] IBIMET-CNR, Florence, Italy
[4] University of Swansea, United Kingdom
[5] NLR, Emmeloord, The Netherlands
[6] Research Centre Jülich, Germany
[7] Lund University, Sweden
[8] ESA / ESRIN, Frascati, Italy
[9] ESA / ESTEC, Noordwijk, The Netherlands
[10] GeoForschungsZentrum Potsdam, Germany
[11] University of Bologna, Italy

Email list:
yves.goulas@lmd.polytechnique.fr
Elizabeth.M.Middleton@nasa.gov
f.miglietta@ibimet.cnr.it
p.r.j.north@swan.ac.uk
verhoef@nlr.nl
u.rascher@fz-juelich.de
sune.svanberg@fysik.lth.se
Michael.Berger@esa.int
Matthias.Drusch@esa.int
Ferran.Gascon@esa.int
Bernardo.Carnicero.Dominguez@esa.int
Jean-Loup.Bezy@esa.int
luisguan@gfz-potsdam.de
federico.magnani@unibo.it

ABSTRACT

Fluorescence is a powerful non-invasive tool to track the status, resilience, and recovery of photochemical processes and moreover provides important information on overall vegetation photosynthetic performance with implications for related carbon sequestration, allowing to measure planetary photosynthesis by means of a global monitoring of steady-state chlorophyll fluorescence in terrestrial vegetation. The early responsiveness of fluorescence to atmospheric, soil and plant water balance, as well as to atmospheric chemistry and human intervention in land usage makes it an obvious biological indicator in improving our understanding of Earth system dynamics. The amenability of fluorescence to remote, even space-based observation qualifies it to join the emerging suite of space-based technologies for Earth observation.

The FLuorescence EXplorer (FLEX) mission proposes a set of instruments for the measurement of the interrelated features of fluorescence, hyperspectral reflectance, and canopy temperature, selected by ESA as a candidate Earth Explorer Core Mission. FLEX will be the first mission designed to observe the photosynthetic activity of the vegetation layer, for a better understanding of the carbon cycle, by using a completely novel technique measuring the chlorophyll fluorescence signal that originates from the core of the photosynthetic machinery, i.e. the 'breathing' of the vegetation layer of the living planet. This will provide a completely new possibility to assess the dynamics of actual vegetation photosynthesis and subsequently Gross Primary Production (GPP) at a global scale. The primary objectives are: to quantify the

photosynthetic efficiency of terrestrial ecosystems at the global scale, to improve the predictability of dynamical vegetation models on scales comprising canopies and biomes, and to provide an improved estimate of GPP for a better understanding of the global carbon cycle. Secondary objectives are: to improve understanding of the role of vegetation in the coupled global carbon / water cycles, the global assessment of the vegetation health conditions and vegetation stress and the support the development of future crop production strategies in a changing climate.

Spectral coverage includes two windows from 677 to 697 nm and from 750 to 770 nm with a spectral sampling of 0.1 nm, to measure fluorescence in the two oxygen absorption bands. A secondary imaging spectrometer covers from 400 to 1200 nm at 5 – 10 nm spectral resolution, plus additional six bands in the SWIR (1350 – 2300 at 20 - 30 nm bandwidth) and four channels in the TIR (8.5 – 12.5 µm at 0.5 µm bandwidth). All above instruments look at nadir with the same swath and spatial resolution (300 m). An additional off-nadir imager (3 bands with 1 km resolution and 50° along-track looking) is dedicated to aerosols retrievals for improved atmospheric corrections. The mission will provide global coverage of land masses (-56° to +75° latitude) with 7 days revisit time, at 10:00 LTDN. Mission duration is 3.5 – 5 years, with a potential launch in 2016.

The recent developments in the context of the airborne simulator AirFLEX, and the use of MERIS data (in standard mode and in spectral calibration campaign mode) have clearly demonstrated the feasibility of the measurements of canopy fluorescence from space. Moreover, recent model developments and data processing tools have made possible to guarantee the capability to retrieve the needed information from fluorescence measurements and the proper use of such information in monitoring vegetation photosynthesis at global scales. New type of field instruments and airborne sensors are also in development in support of the activities related to advance the use of chlorophyll fluorescence in vegetation monitoring. A joint effort in support of basic science and derived applications is needed to achieve the expectations created with such new powerful technique.

The measurement techniques proposed in FLEX are highly innovative and represent a challenge for atmospheric corrections and cloud screening of such very high spectral resolution data. Moreover, the weak fluorescence signal is masked by the reflected background radiance, and accurate compensation of all perturbing effects (changes in surface pressure with elevation changes, changes in illumination with topographic variations) becomes essential. The algorithms being developed for the processing of FLEX data are expected to be of high relevance for other missions providing also high spectral resolution measurements, that can benefit from the techniques and tools put in place in the context of FLEX preparatory studies.

The incorporation of vegetation fluorescence as a new remote sensing tool fits perfectly into the main research objectives of ESA and related international programmes, with impact on global carbon cycle studies and vegetation photosynthesis, water resources research and anthropogenic impacts associated to land-use changes and varying spatial patterns of vegetation species. All these research objectives are of high relevance for international research programmes, such as the World Climate Research Programme and the International Geosphere-Biosphere Programme.

This paper will review recent developments in the field and summarise achievements, perspectives and research to be done in the near future.