Let's exploit available knowledge on vegetation fluorescence

The potential to measure vegetation fluorescence from space (1) and to derive from it direct information on the gross primary productivity (GPP) of terrestrial ecosystems is probably the most thrilling development in remote sensing and global ecology of recent years, as it moves Earth observation techniques from the detection of canopy biophysics (e.g., fraction of absorbed radiation) and biochemistry (chlorophyll and nitrogen content) to the realm of ecosystem function.

The existence of a functional relationship between fluorescence and photosynthesis has been elucidated over the last decade by several laboratories, notably as part of the preliminary studies of the European Space Agency Fluorescence Explorer (FLEX) Earth Explorer Mission.

The empirical observation presented by Guanter et al. (2) of a linear relationship between fluorescence radiance and GPP, however, provides the first experimental confirmation of the feasibility of the approach—already thoroughly tested at leaf level—at the desired scale, despite the confounding effects associated with the satellite detection of such a faint signal.

A word of clarification is needed here. The use of fluorescence as a probe of leaf photochemistry has been a staple of plant ecophysiology for decades, rooted in a sound understanding of photosynthetic energy dissipation. However, most past studies had to rely for the interpretation of results on active (pulse-saturated) techniques, making them unsuitable for remote-sensing applications. Over recent years, however, novel process-based models have been developed for the interpretation of steady-state, solar-induced fluorescence at the leaf to canopy scale (3). We are therefore in a position to move beyond the mere empirical observation of an association between GPP and fluorescence radiance.

In particular, Guanter et al. (2) base their analysis on the assumption of a constant ratio between photosynthetic and fluorescence light use efficiencies (equation 3 in ref. 2). We know, however, that the ratio is not constant, but changes widely in response to light, CO_2, stomatal limitations, and extreme stress (4, 5). What's more, we can make sense of such changes, thus extracting valuable information from the very scatter that is apparent in their data.

However, this process will require the availability of more tailored instruments, such as the one planned for the FLEX mission. As already stressed by Guanter et al. (2), the spatial resolution of the Global Ozone Monitoring Experiment-2 sensor (40 × 80 km) makes it difficult to compare meaningfully the fluorescence signal with ground measurements, when only 60–70% of the footprint consists of the desired land-cover type (table S1 in ref. 2), suggesting that this could be largely responsible for the low signals observed in European grasslands. Moreover, the overpass time of the MetOp-A satellite (9:30 AM) implies that fluorescence is generally measured under light-limiting conditions, when fluorescence is only marginally affected by stomatal closure even under stress conditions. This result could explain the seasonal mismatch with daily GPP observed in natural ecosystems in the absence of irrigation (figure 4 in ref. 2).

We hope, therefore, that this welcome contribution to this fast-advancing field will help demonstrate the potential of the new technique, and pave the way for more refined studies under both a technological and scientific point of view.

***Federico Magnani*[a,1], *Sabrina Raddi*[b], *Gina Mohammed*[c], *and Elizabeth M. Middleton*[d]**

[a]*Department of Agricultural Sciences, University of Bologna, Bologna 40127, Italy;* [b]*Department of Agricultural, Food and Forest Systems Management, University of Florence, Florence 50145, Italy;* [c]*P&M Technologies, Sault Ste. Marie, ON, Canada P6A 6S7; and* [d]*Biospheric Science Laboratory, Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, MD 20771*

1 Joiner J, et al. (2011) First observations of global and seasonal terrestrial chlorophyll fluorescence from space. *Biogeosciences* 8:637–651.
2 Guanter L, et al. (2014) Global and time-resolved monitoring of crop photosynthesis with chlorophyll fluorescence. *Proc Natl Acad Sci USA* 111(14):E1327–E1333.
3 van der Tol C, Verhoef W, Timmermans J, Verhoef A, Su Z (2009) An integrated model of soil-canopy spectral radiances, photosynthesis, fluorescence, temperature and energy balance. *Biogeosciences* 6:3109–3129.
4 Meroni M, et al. (2009) Using optical remote sensing techniques to track the development of ozone-induced stress. *Environ Pollut* 157(5):1413–1420.
5 Damm A, et al. (2010) Remote sensing of sun-induced fluorescence to improve modeling of diurnal courses of gross primary production (GPP). *Glob Change Biol* 16(1):171–186.

Author contributions: F.M., S.R., G.M., and E.M.M. designed research; and F.M. wrote the paper.

The authors declare no conflict of interest.

[1]To whom correspondence should be addressed. E-mail: federico.magnani@unibo.it.