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Anisotropic properties of solar induced chlorophyll fluorescence signals at canopy level

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BACKGROUND & OBJECTIVE

- Excess energy dissipation pathways (heat and chlorophyll fluorescence) have been successfully monitored at leaf and canopy level as indicators of plant physiological status with field spectrometry.
- Stress detection in natural environment using such indicators is expected to be complicated by canopy structure, view and illumination geometry.
- In this paper we investigate the anisotropic properties of solar induced chlorophyll fluorescence signal and PRI index at canopy level.

MATERIALS & METHODS

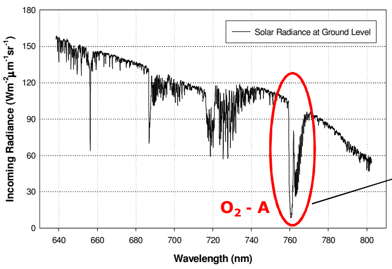
EXPERIMENTAL SETUP

Field goniometer set up over the Lolium perenne field

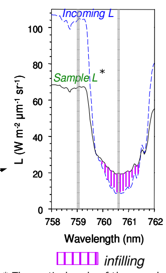
- **Multiangular measurements** of a dense uniform soccer lawn (Lolium perenne) were acquired on 14th December 2006 at solar noon (solar zenith angle = 68°) using a portable field goniometer device (Giardino & Brivio 2003).
- The experiment was carried out by using a **subnanometer resolution spectroradiometer** featuring full width at half maximum (FWHM) of 0.13 nm and spectral range of 716-805 nm. It allowed the detection of **solar induced fluorescence** at 760 nm.
- The **full VIS-NIR spectrum** was observed by an additional spectroradiometer (0.3 nm FWHM, 400-1050 nm spectral range).
- Spectral measurements were acquired with a FOV of 6°. The **sampling geometries** are reported in the table. Each set of measurements required approximately 30 minutes.

	from	*to*	*sampling rate*
VZA (θ_v)	0°	75°	15°
VAA (φ_v)	0°	315°	45°
Spotsize	84 mm	1300 mm	---

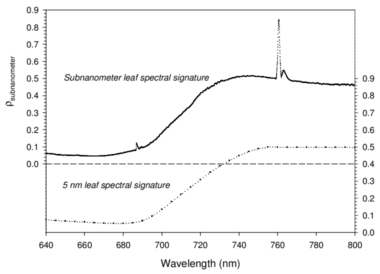
PASSIVE MEASUREMENT OF SOLAR INDUCED FLUORESCENCE



Ground level incident solar radiance. The "well" – dark line positioned at 760 nm is outlined.



* The vertical scale of the sample is exaggerated to facilitate FLD comprehension.



Comparison of a subnanometer leaf spectral signature (FWHM of 0.13 nm) and a reference green leaf reflectance recorded by a traditional spectrometer with a FWHM of 5 nm.

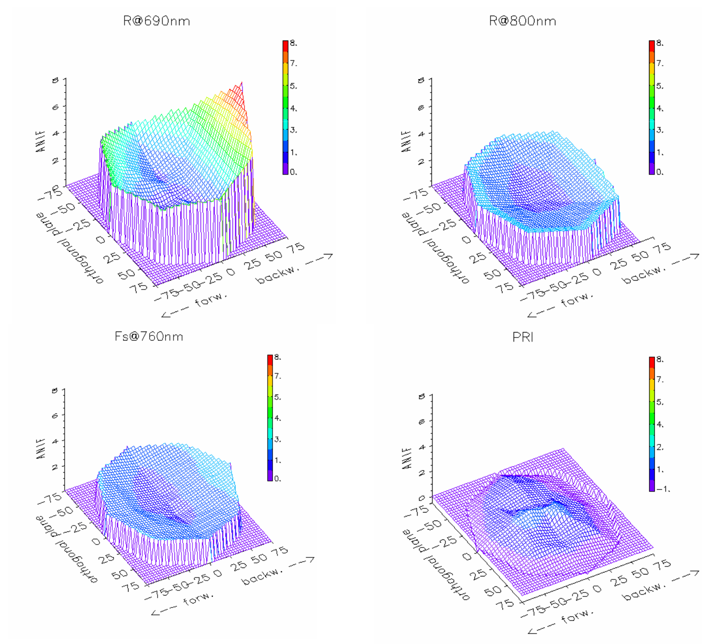
- A variation of the **Fraunhofer line depth (FLD)** principle was used to measure emitted fluxes due to chlorophyll fluorescence at 760 nm (Fs) (Meroni & Colombo 2006).
- This method relies on the use of a **very high spectral resolution spectroradiometer** (FWHM of 0.13 nm).
- Such spectral resolution enables the detection of Fs signal in very narrow dark lines of the spectrum in which solar incident irradiance is strongly reduced (Fraunhofer lines) due to molecular oxygen absorption by terrestrial atmosphere. The chlorophyll fluorescence is detected by exploiting the **infilling** of these "wells".

ESTIMATION OF HEAT DISSIPATION USING PRI

- The full VIS-NIR data were used to calculate the **Photochemical Reflectance Index** PRI connected to the xanthophylls cycle and to heat dissipation.

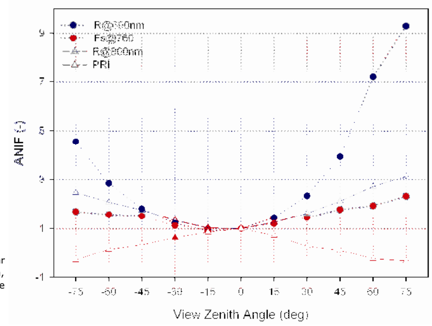
  PRI = (R531-R570)/(R531+R570)

RESULTS



Plots of the anisotropy factor (ANIF) for the reflectance at 690 and 800 nm, Fs estimated at the 760 nm oxygen absorption line and PRI index.

- The anisotropic properties of R and Fs were analyzed by evaluating the **anisotropy factors (ANIFs)**, calculated by normalizing R/Fs directional data to NADIR R/Fs.
- **Fs@760** and reflectance factor were affected by sun-target-sensor sampling geometry as showed by ANIF. The Fs@760 was greater in the backward direction where the sensor saw the sunlit leaves. The ANIF surface of Fs@760 was flatter than the one of reflectance (**R@690, R@800)** in agreement with the fact that fluorescence is an emitted flux originated within the medium.
- ANIF of **PRI** should be carefully interpreted since PRI has no true zero point and therefore ANIF strongly depends on PRI value at NADIR. Lower PRI values (hotspot) were found in the backward direction where the observed leaves were directly illuminated and had a lower PRI. Maximum PRI was found in the forward direction while the reduction around NADIR may be due to the contribution of soil in PRI wavelengths.



Plot of the anisotropy factor (ANIF) in the solar principal plane for the reflectance at 690 and 800 nm, Fs estimated at the 760 nm oxygen absorption line and PRI index

CONCLUSIONS

This study shows that solar induced fluorescence was less affected than reflectance by view and illumination geometry in agreement with the fact that fluorescence is an emitted flux originated within the medium. We expect that the presented experiment may be useful for applications that needs the interpretation of the signal reflected/emitted from vegetated canopies. In particular for the understanding of those models where both fluorescence signals and sun-target-sensor geometries may be crucial parameters.

REFERENCES: Giardino, C. & Brivio, P.A. 2003. The application of a dedicated device to acquire bidirectional reflectance factors over natural surfaces, International Journal of Remote Sensing 24: 2989-2995.
Meroni, M. & Colombo, R. 2006. Leaf level detection of solar induced chlorophyll fluorescence by means of a subnanometer resolution spectroradiometer, Remote Sensing of Environment 103: 438-448.

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