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Detection of steady-state fluorescence and PRI for early ozone injury assessments at canopy level

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BACKGROUND & OBJECTIVE

- The research activities are addressed to find optical signals of the oxidative stress linked to ozone exposure of plants. The connection of ozone damage to remote sensing (RS) is motivated by the interest in developing a rapid and non-intrusive way of evaluation of plant physiological status (ground level RS) and by the appealing possibility of monitoring large areas (airborne and satellite RS).

MATERIALS & METHODS

PLANT MATERIAL & TREATMENT

- Plants of O_3-sensitive white clover (Trifolium repens L. cv. Regal) were grown from cuttings originally supplied by the ICP Vegetation Coordination Centre at the Centre for Ecology and Hydrology, Bangor (UK). Cuttings were grown in a greenhouse in pots containing sterilized soil.

- Plants were exposed to chronic O_3 fumigation (100 ppb O_3, 5 h d^{-1}) for 3 weeks in a controlled environment fumigation facility. Control plants were maintained under the same experimental conditions as O_3-treated plants, but exposed to charcoal-filtered air. O_3 exposure was expressed in terms of AOT40.

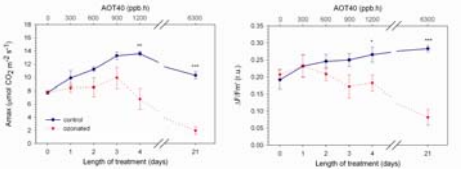
MEASUREMENTS

- Six diurnal cycles of optical properties were acquired under natural solar illumination, together with leaf physiological measurements (i.e. gas exchange, CIRAS PP-System, active chlorophyll fluorescence, Walz PAM-2000 and chlorophyll content, Minolta SPAD 502) and meteorological variables (i.e. PPFD, Delta-BF3; air temperature and relative humidity).
- Spectral measurements were acquired on one canopy per thesis, while physiological measurements were acquired on 6 leaves per thesis.
- A circular area of the canopy with a diameter of 140 mm was observed by the spectrometers through a fibre optic with an angular field of view of 25°.
- Visual assessments of ozone injuries were recorded daily.
- Furthermore, LAI was destructively measured at the end of the experiment.

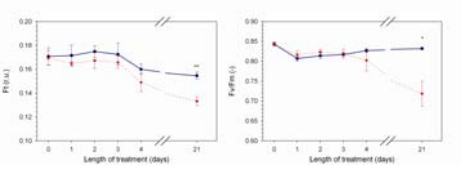
RESULTS

LEAF PHYSIOLOGICAL MEASUREMENTS

Measurements of control and ozonated plants were taken 0, 1, 2, 3, 4 and 21 days after the start of fumigation; results are reported in the graphics below. Values represent means ± S.E. Comparison between means was performed according to Student's t-test (* : P≤0.05; ** : P≤0.01; *** : P≤0.001).

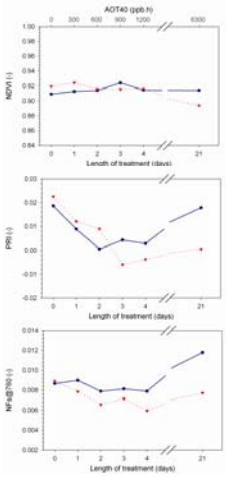


- Both **photosynthetic activity under maximum solar irradiance (Amax)** (around midday) and **fluorescence quantum yield (ΔF/Fm')** were significantly reduced by O_3 treatment from day 4 on.



- **PAM-2000 steady-state fluorescence (Ft)** and **photochemical efficiency of PSII (Fv/Fm)** were able to detect a difference on day 21.

CANOPY PROXIMAL SENSING

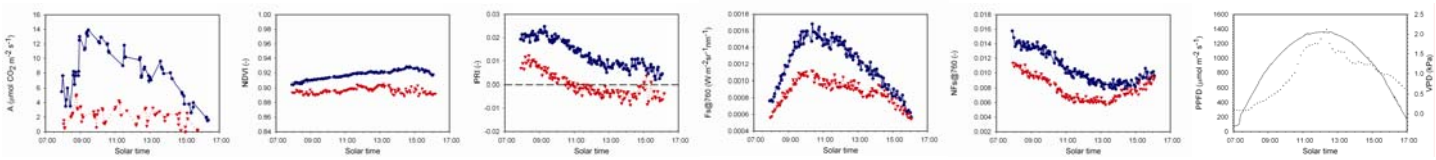


- **Traditional RS techniques (NDVI)** detected differences between control and treated samples on day 21 only. At the end of the experiment **LAI** was the same in control and ozonated canopies (LAI = 2 m^2/m^2). Differences in NDVI may be explained by a decrease in **chlorophyll content** in treated samples, as confirmed by SPAD measurements.
- **PRI index** was lower in treated samples (greater de-epoxidation of xanthophyll-cycle pigments) from day 3 on.
- **Normalized fluorescence (NFs@760)** was lower in treated samples from day 1 on.

Time course of RS measurements. Blue and red lines refer to control and ozonated canopies, respectively.

DAILY COURSES

- As an example, the last diurnal cycle measurements regarding assimilation, NDVI, PRI, Fs@760, NFs@760 and incident PPFD are reported. Blue and red dots refer to control and ozonated canopies, respectively.



- On day 21 the different physiological status between healthy and fumigated samples was separated in terms of A, passive fluorescence, PRI and NDVI.

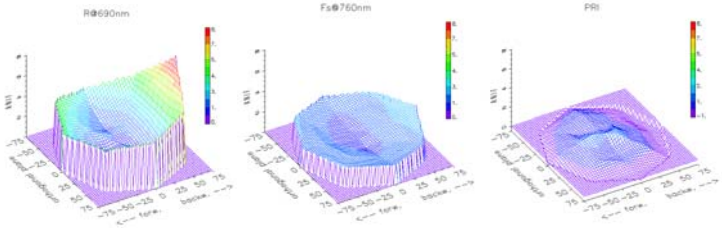
CONCLUSIONS

This study shows that solar-induced fluorescence and xanthophyll de-epoxidation state can be detected from the near-range distance and can be linked to plant physiological status. Plants subjected to O_3 exposure demonstrated lower fluorescence and higher use of the xanthophyll cycle than their counterparts provided with filtered air.

MULTIANGULAR MEASUREMENTS OF FLUORESCENECE AND PRI. PRELIMINARY RESULTS

- The anisotropic properties of Fs@760 and PRI of a dense uniform soccer lawn (Lolium perenne) were investigated: multiangular measurements were acquired on 14 Dec 2006 at solar noon (SZA = 68°) using a portable field goniometer device (Giardino and Brivo, 2003, Int. J. Remote Sens., 2989-2995). Spectral measurements were acquired with a FOV of 6°. The sampling geometries are reported in the table.

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



- Fs@760 and reflectance factor at 690 nm were affected by sun-target-sensor sampling geometry as showed by the Anisotropy Factor (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 R@690 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 backscatter direction where the observed leaves were directly illuminated and had a lower PRI. Maximum PRI was found in the forward direction while the decrease around NADIR may be due to the contribution of soil PRI.

ACKNOWLEDGEMENTS

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