Methanol emissions from grassland: a role of ozone stress ?

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BACKGROUND

The exchange of biogenic volatile organic compounds (BVOC) between plants and the atmosphere provides an important feedback to the climate system. BVOC are, for example, involved in the generation of tropospheric ozone (O_3), which is known to reduce plant photosynthesis and growth, BVOC affect the life time of the greenhouse gas methane (CH_4) in the atmosphere, and act as nucleation centres for precipitable water and thus have the potential to change the amount and timing of precipitation.

Methanol (CH_3OH, abbreviated MeOH) is a BVOC that is emitted by plants through a large variety of processes – for example during cell wall elongation and thus more generally speaking during growth and in response to stress, such as hypoxia, low temperatures or high O_3 concentrations.

Here we investigate what has been demonstrated in leaf-level laboratory experiments – that plants respond to oxidative stress caused by the stomatal uptake of O_3 by emitting MeOH [1]. To this end we report concurrent MeOH and O_3 flux measurements made above a temperate mountain grassland in Tyrol/Austria during the vegetation period 2008.

METHODS

Fluxes of MeOH (and several other BVOC) and O_3 were estimated by means of the eddy covariance method employing a sonic anemometer for the measurement of the vertical wind speed and a proton-transfer-reaction mass spectrometer (PTR-MS) and a O_3-analyser for the quantification of the respective scalar concentrations.

As a measure of plant oxidative stress we use the time-integrated stomatal O_3 uptake, calculated on a daily basis in a cumulative fashion (from sunrise) based on a resistance scheme [2].

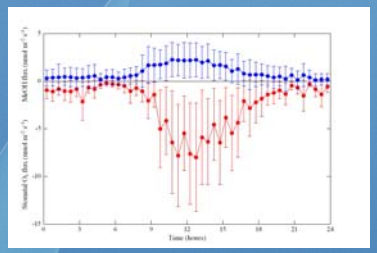

Fig. 1 Bin-averaged diurnal course of the **MeOH** flux and the stomatal O_3 flux.

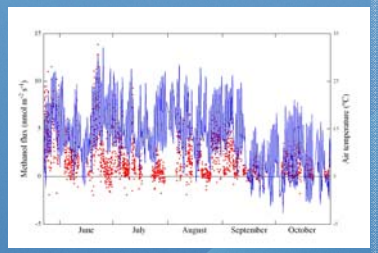

Fig. 2 Seasonal course of the **MeOH** flux and air temperature.

	F_MeOH	GAI	LWS	VPD	TA	TS	SWC	[O3]	NEE	PAR	GS	FO3S	FO3SCUM	dGAI
F_MeOH		-0.11	-0.28	0.52	0.54	0.30	-0.30	0.37	-0.33	0.56	0.26	-0.35	-0.13	0.24
GAI	-0.11		0.05	0.02	0.20	0.29	-0.31	0.29	-0.24	0.06	0.21	-0.29	-0.29	-0.04
LWS	-0.28	0.05		-0.50	-0.40	-0.12	0.25	-0.28	0.31	-0.43	-0.20	0.29	0.21	-0.02
RH	-0.50	0.06	0.61	-0.94	-0.74	-0.28	0.31	-0.65	0.50	-0.72	-0.28	0.55	0.45	-0.08
VPD	0.52	0.02	-0.50		0.84	0.44	-0.40	0.69	-0.49	0.70	0.26	-0.58	-0.48	0.19
TA	0.54	0.20	-0.40	0.84		0.75	-0.62	0.70	-0.41	0.60	0.19	-0.53	-0.45	0.43
TS	0.30	0.29	-0.12	0.44	0.75		-0.64	0.57	-0.05	0.13	-0.02	-0.34	-0.44	0.77
SWC	-0.30	-0.31	0.25	-0.40	-0.62	-0.64		-0.51	0.05	-0.19	0.06	0.30	0.33	-0.44
[O3]	0.37	0.29	-0.28	0.69	0.70	0.57	-0.51		-0.42	0.50	0.24	-0.74	-0.69	0.38
NEE	-0.33	-0.24	0.31	-0.49	-0.41	-0.05	0.05	-0.42		-0.76	-0.71	0.63	0.21	0.03
PAR	0.56	0.06	-0.43	0.70	0.60	0.13	-0.19	0.50	-0.76		0.66	-0.67	-0.23	0.03
GS	0.26	0.21	-0.20	0.26	0.19	-0.02	0.06	0.24	-0.71	0.66		-0.61	-0.04	0.00
FO3S	-0.35	-0.29	0.29	-0.58	-0.53	-0.34	0.30	-0.74	0.63	-0.67	-0.61		0.49	-0.20
FO3SCUM	-0.13	-0.29	0.21	-0.48	-0.45	-0.44	0.33	-0.69	0.21	-0.23	-0.04	0.49		-0.22
dGAI	0.24	-0.04	-0.02	0.19	0.43	0.77	-0.44	0.38	0.03	0.03	0.00	-0.20	-0.22	

Table 1 Results (correlation coefficients) of linear regression analysis (bold letters indicate p<0.05; n=1450).

The field site: Neustift, Stubai Valley

RESULTS

While the time-integrated stomatal uptake of O_3 caused an increase in MeOH emission, it explained only around 2% of the variability in MeOH emissions (Table 1), indicating that oxidative stress through stomatal uptake of O_3 (Fig. 1) may not be playing a major role in controlling MeOH emissions at this site.

Interestingly, MeOH emissions were also poorly correlated with daily changes in the amount of green plant area (dGAI, Table 1), a surrogate for plant growth, contrasting other studies which were able to relate MeOH emissions to cell wall elongation and thus plant growth.

By far the best predictors for MeOH emissions were the amount of incident photosynthetically active radiation (PAR) and air temperature (TA), which together explained 37% of the variability in MeOH emissions (Table 1, Fig. 2).

CONCLUSION

Environmental controls (PAR and air temperature) were by far better predictors of MeOH emissions than oxidative stress through the time-integrated stomatal uptake of O_3.

These results indicate that relatively simple modelling frameworks may be successful for simulating MeOH emissions from this grassland.

The strong temperature sensitivity of MeOH emissions might provide a positive feedback to climate change. The validity of this short-term response for ongoing and anticipated increases in air temperature remains to be determined.

References

[1] Beauchamp *et al.*, 2005, *Plant Cell Environ.*, 28, 1334-1343; [2] Grünhage et al., 2000, Environ. Pollution, 109, 373-392.

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