How trees respond to stress: Isoprene emissions in black locust during heat waves and drought

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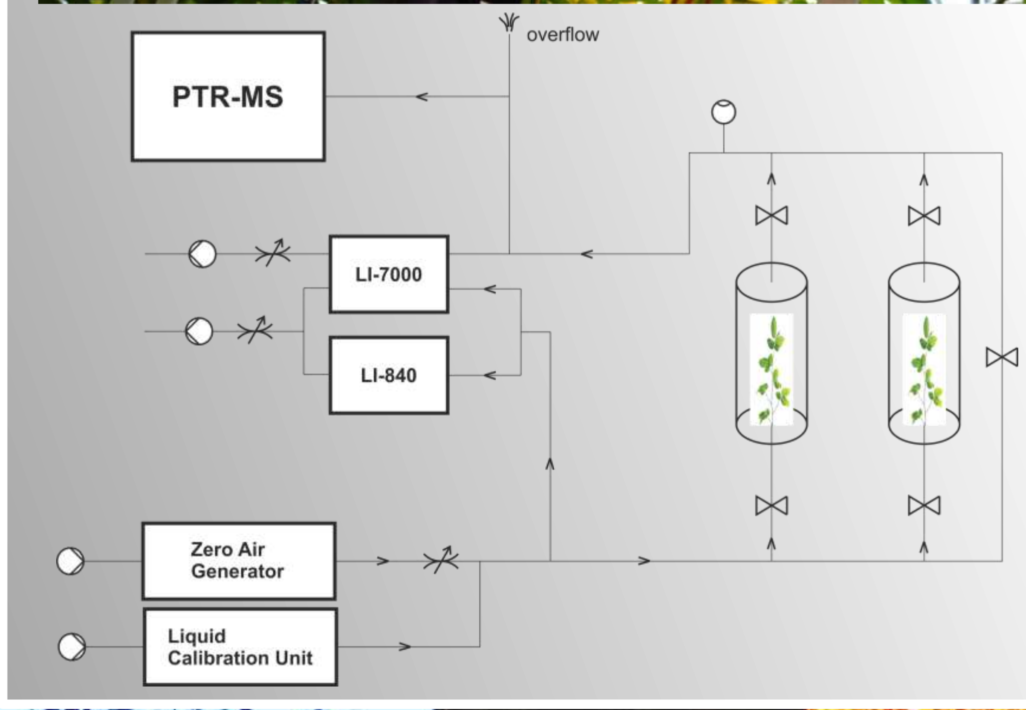
Motivation

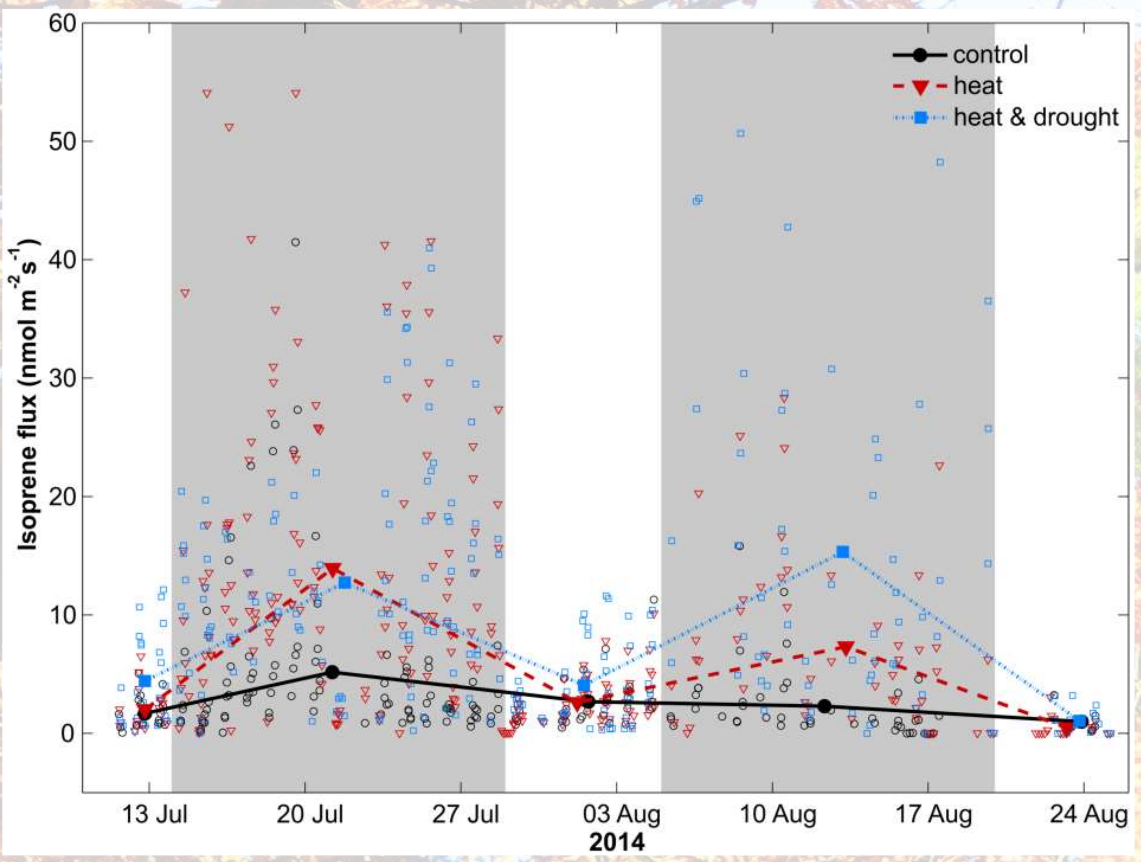
Biogenic volatile organic compounds (BVOCs) influence tropospheric ozone levels [1], contribute to the formation of secondary organic aerosols [2] and affect atmospheric chemistry.
Forested ecosystems contribute a substantial amount to the global emissions of volatile organic compounds (VOCs) to the atmosphere. Under a future climate, extreme weather conditions, like heat waves and drought stress, can affect the quantity and quality of VOC emission from trees dramatically. To date, however, there is only limited understanding of VOC emission patterns during prolonged heat and heat & drought stress including post-stress recovery.
Since, on a global scale, isoprene is the most important biogenic VOC we studied how isoprene emissions in black locust trees respond to heat and combined heat & drought stress.

Material and Methods

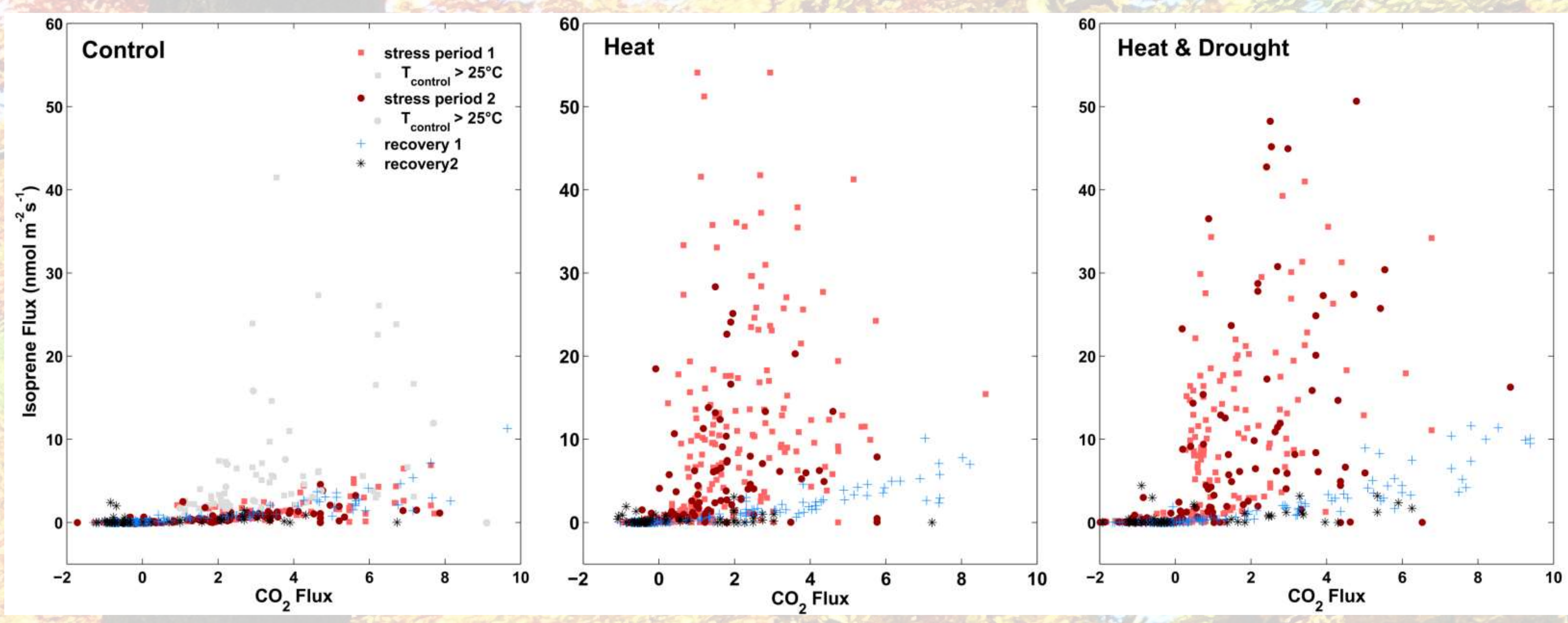


The heat and combined heat & drought stress experiment was conducted under controlled environmental conditions in a greenhouse. Trees in the heat treatments were exposed to repeated heat waves of 14 days at 10°C above ambient temperatures, followed by a recovery period of at least 7 days. In the combined heat-drought treatment irrigation was additionally reduced by 60-80% compared to the control trees, which were exposed to ambient temperatures. VOC emissions of black locust trees were quantified in branch chambers on three different trees per treatment (control, heat and combined heat & drought) using a proton-transfer-reaction mass-spectrometer (PTR-MS). CO_2 and H_2O gas exchange was simultaneously measured by means of an infrared-gas analyzer.

Results, Discussion & Conclusions



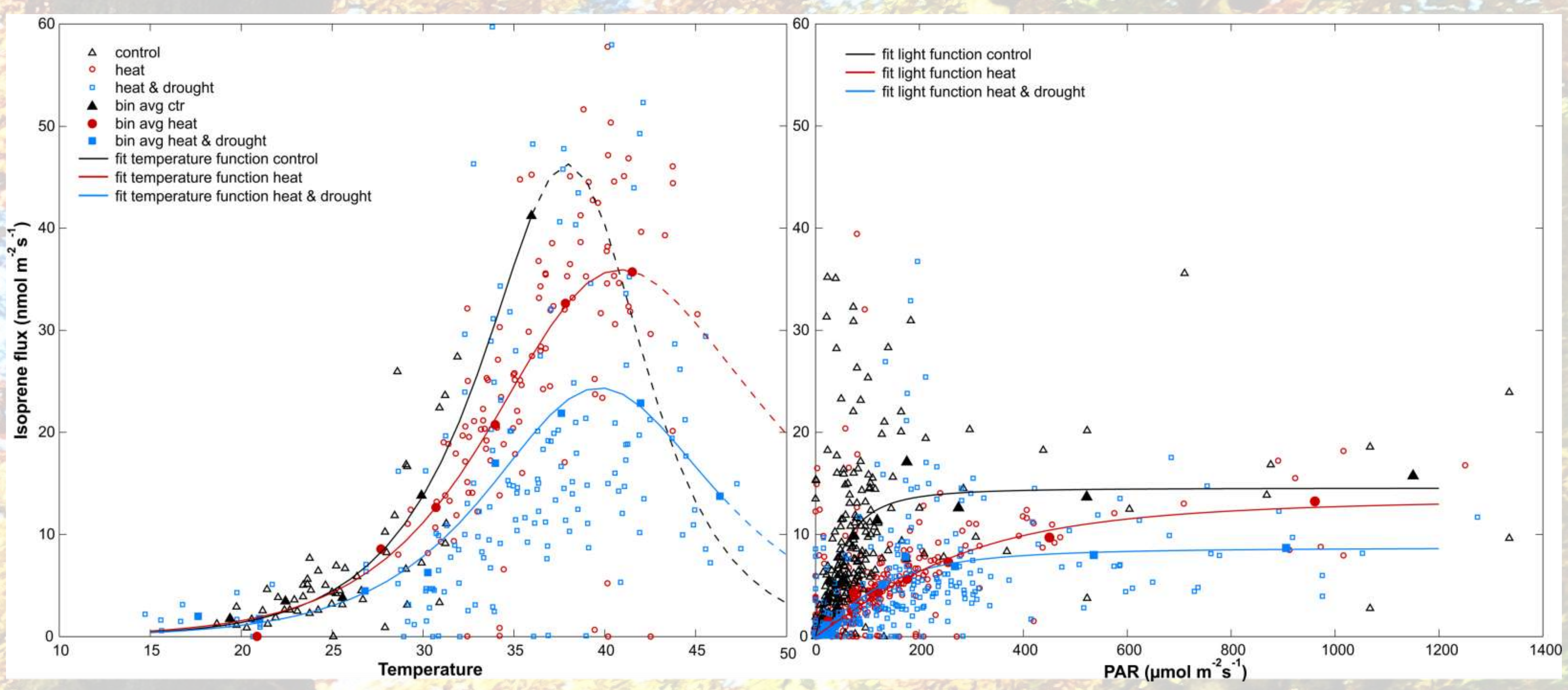
Measured Isoprene fluxes during in the control, heat and heat & drought treatment during the experiment. Heat and heat & drought time periods are highlighted in grey.



Scatter plot of isoprene fluxes against CO_2 exchange in black locust trees exposed to ambient temperatures (left panel), heat stress (centered panel) and combined heat & drought stress (right panel) for different time periods of the experiment.

Results of a linear mixed-effects model evaluating isoprene emission interactions between treatment and time-period relative to before stress control conditions.

Treatment vs time Period	Isoprene	SE	t-statistics	p-value
Intercept	0.78	1.13	0.69	0.49
Heat	0.06	1.06	0.06	0.96
Heat & drought	1.51	1.06	1.42	0.16
Stress period 1	1.16	1.14	1.02	0.31
Recovery period 1	0.21	1.24	0.17	0.87
Stress period 2	0.11	1.14	0.1	0.92
Recovery period 2	-0.49	1.25	-0.39	0.7
Heat x stress_1	**4.37**	**0.92**	**4.74**	**3.30E-06**
Heat & drought x stress_1	**3.45**	**0.94**	**3.69**	**2.70E-04**
Heat x recovery_1	0.15	1.01	0.15	0.88
Heat & drought x recovery 1	-0.64	1.01	-0.64	0.52
Heat x stress_2	**1.69**	**0.92**	**1.85**	**0.07**
Heat & Drought x stress_2	**3.39**	**0.92**	**3.7**	**2.60E-04**
Heat x recovery_2	-0.11	0.99	-0.12	0.91
Heat & drought x recovery 2	-1.36	0.99	-1.38	0.17



Temperature and light response curves of isoprene for control (black triangles), heat (red circles) and heat & drought (blue squares) trees during the stress periods.

Average isoprene emissions of the heat and heat & drought stressed trees were significantly increased compared to fluxes of unstressed black locust trees. This emission increase however was clearly attributed to increased temperatures in the stress treatments. Normalized to the same temperature and light conditions, heat or heat & drought stressed trees emitted less isoprene than unstressed trees.

[1] R. Atkinson, Atmospheric chemistry of VOCs and NOx, Atmos. Environ., 34, 2063-2101, 2000
[2] M. Hallquist et al., The formation, properties and impact of secondary organic aerosol: current and emerging issues, *Atmos. Chem. Phys.*, 9, 5155-5236, 2009