Secondary aerosol formation from stress-induced biogenic emissions and possible climate feedbacks

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Keywords: biogenic SOA , stress induced emissions, climate feedback

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Secondary organic aerosols (SOA) are an important component of tropospheric aerosols. A large fraction of secondary organic aerosols has biogenic sources. The contribution of monoterpenes (MT), isoprene, and sesquiterpenes (SQT) to BSOA formation after atmospheric oxidation are well known. Since aerosols play a role for climate by direct (light scattering and absorption) and indirect effects (cloud albedo, rain probability, cloud lifetime), SOA provides couplings between vegetation, air chemistry and climate. Currently these couplings are believed to provide overall a negative feedback (Kulmala et al., 2004, Goldstein et al., 2009).

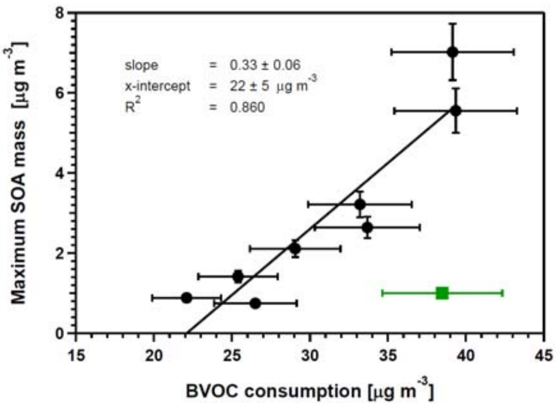

Figure 1, Maximum SOA mass versus consumption of C_{17}–BVOC dominated emissions. Black circles: data obtained at low contribution of GLV. Green square data point obtained on day 0 at high GLV emissions.

However, already SQT indicate that it is probably not sufficient to only consider the constitutive MT and isoprene emissions (Arneth and Niinemets, 2010). Plants tend to change emission patterns and strength, when they are facing stress (insect and pathogen attacks, heat, drought). Typical stress induced emissions are SQT, methylsalicylate (MeSa), and green leave volatiles (GLV). It is not unlikely, that fractions of forests always are exposed to biotic stress e.g. by insect or pathogen attacks, causing latent or episodic SIE emissions. On top heat or drought periods will modify the emissions. This would modify constitutive and SIE emissions episodically.

We determined the incremental mass yields of SOA formation from SIE caused by biotic stressors (Table 1). To simulate future climate effects we applied heat and drought on top. The experiments were performed with individual trees or small stands in the Jülich Plant Atmosphere Chamber JPAC (Mentel et al., ACPD 2013). Before the experiments trees were stored outside, near a forest, to simulate natural (stress) conditions. The trees were transferred to the JPAC for studies under controlled conditions (T, r.h.).

The SOA formation potential of SIE from common trees of Temperate and Boreal forests (Pine, Spruce, Birch, and Beech) were larger than those due to constitutive MT emissions: 17 ± 1% for SQT, 20 ± 3% for MeSa, and 30 ± 4% for C_{17}-BVOC.

Table 1. Incremental SOA yields for SIE and MT.

BVOC source	Action	Major BVOC	Mass yield
Boreal Stand	Aphids	SQT/MeSa	22 ± 2%
Diff. source		MeSa	20 ± 3%
Spruce	Aphids & heat	SQT	17 ± 1%
Temperate Stand	Aphids& drought	C_{17}-BVOC GLV	33 ± 6 %
Grey poplar	Ozone pulse	SQT/MeSa	20 ± 6%
Pine	None	MT 80%	5.3 ± 0.5%
Spruce	None	MT 90%	4.2 ± 0.7%
Diff. source		α-pinene	5.2 ± 0.5%
Holm oak	Heat	MT	6.0 ± 0.6%

In contrast to these SIE classes, GLV emissions have the potential to decrease SOA mass and number (Fig. 1), similar to isoprene (Kiendler-Scharr et al., 2009). Increased GLV emissions support positive feedback in case GLV emissions are related to heat, however exert a potential negative feedback when related to drought. Our results clearly indicate that different stress conditions can affect biogenic SOA production: Stress induced changes of BVOC emission patterns and strength strongly impact SOA formation causing increased (SQT, MeSa, C_{17}-BVOC) or decreased (GLV) SOA formation.

Results of our study indicate the importance of SIE for the existence of feedbacks between climate and vegetation via SOA formation. Biotic stress supports negative feedback and this may be effective already today. But heat and drought can turn the negative feedback proposed by Kulmala et al. (2004) and Goldstein et al. (2009) into a positive feedback in Temperate Forests dominated by *de-novo* emitters. Since it is likely that climate change will affect SIE from vegetation, SIE and their SOA formation potential have to be considered in future climate scenarios.

This work was supported by the integrated EU projects EUCAARI (Contract No. 036833-2) and PEGASOS (Contract No. 265307.). YR acknowledges support from the US-Israel bi-national science foundation (BSF) contract number 2008/146 and support by the Helen and Martin Kimmel Award for Innovative Investigation.

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Mentel, Th. F., Kleist, E., Andres, S., Dal Maso, M., Hohaus, Th., Kiendler-Scharr, A., Rudich, Y., Springer, M., Tillmann, R. Uerlings, R., Wahner, A., Wildt, J., (2013) Atmos. Chem. Phys. Disc. submitted