



# Deposition of terpenes to vegetation – a paradigm shift towards bidirectional VOC exchange?

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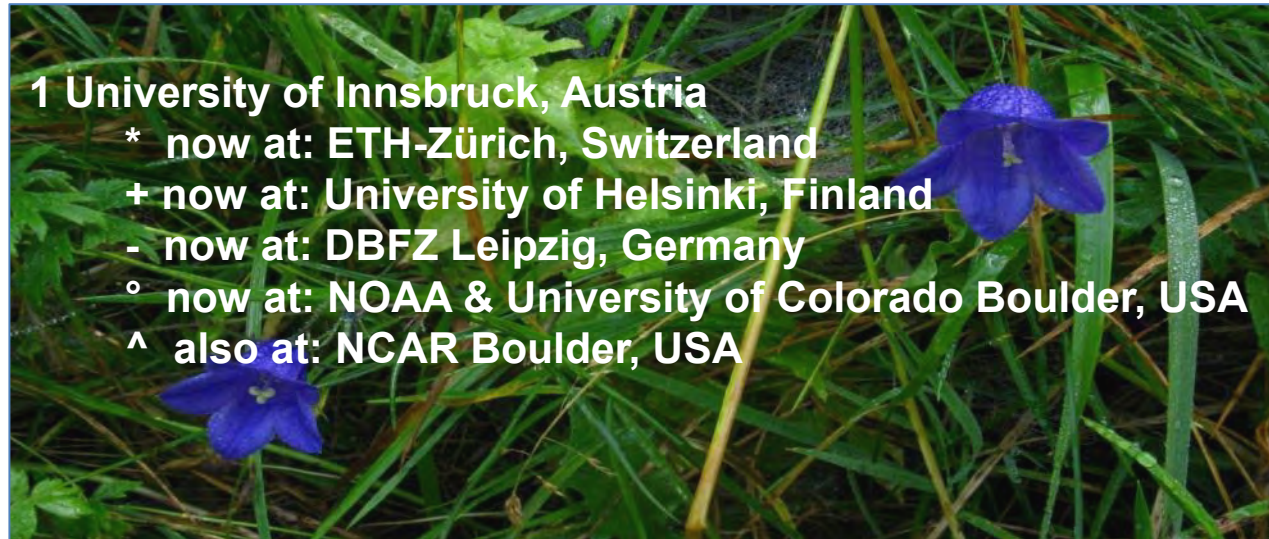
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+ now at: University of Helsinki, Finland

- now at: DBFZ Leipzig, Germany

° now at: NOAA & University of Colorado Boulder, USA

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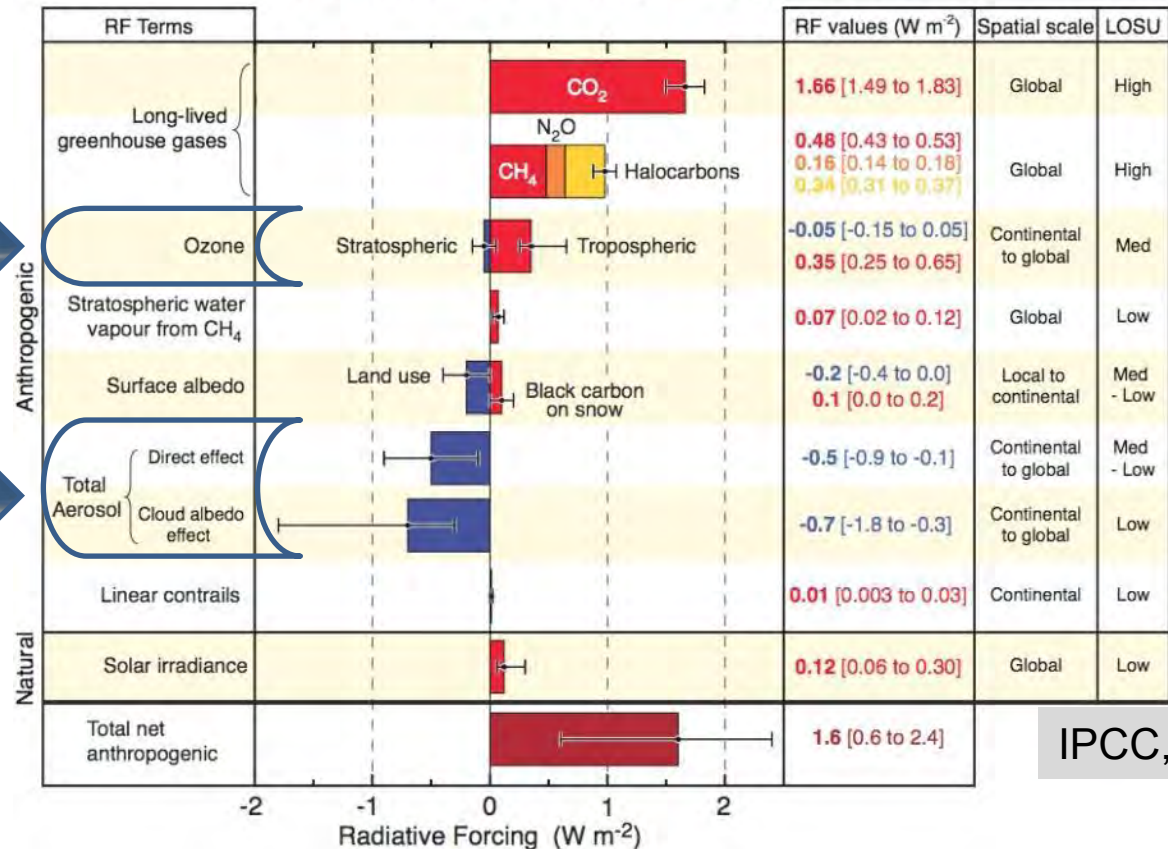


# Introduction

## Radiative Forcing Components

VOC, OH, NO, NO<sub>2</sub>,  
O<sub>3</sub>

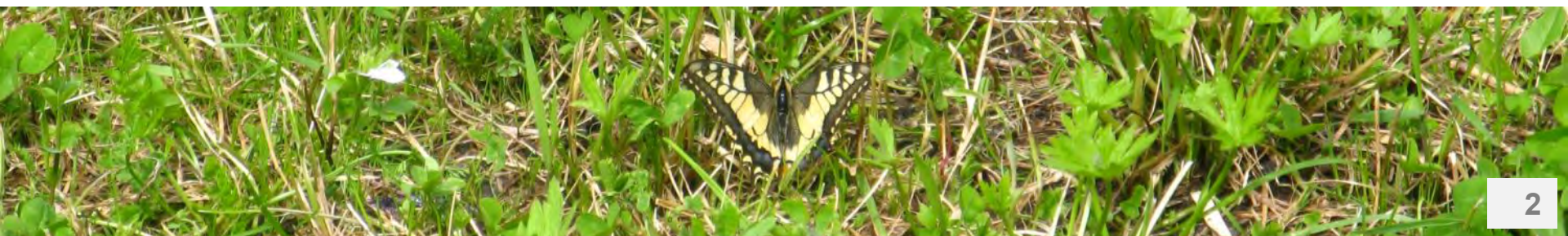
VOC, SVOC, CCN



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IPCC, (2007)

VOCs are involved in the production of tropospheric ozone (Atkinson, 2000) and the formation of SOA (Hallquist et al., 2009).





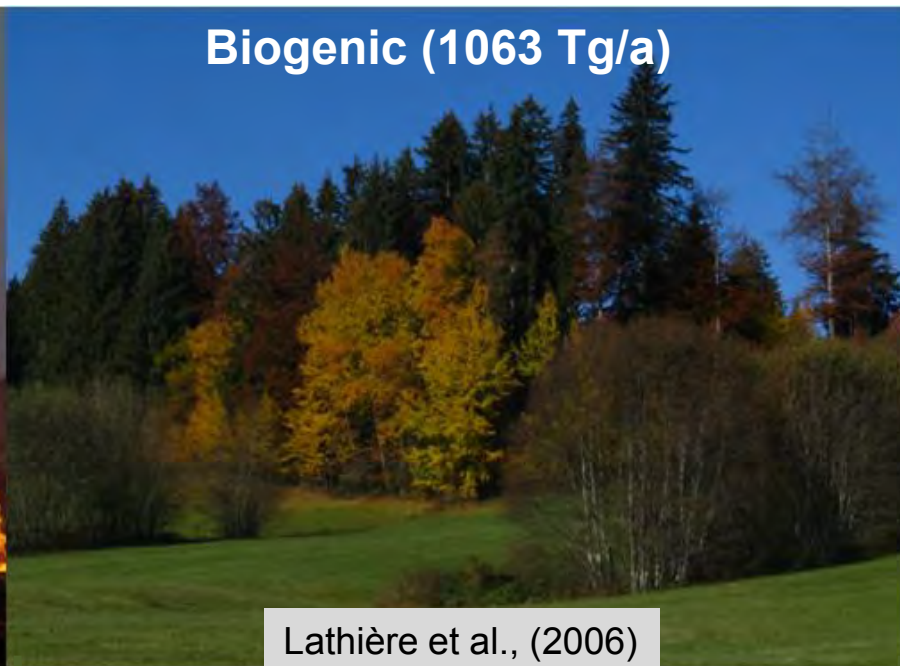
# Sources of VOCs

**Biomass burning  
(97 Tg/a)**



Merlet & Andreae, (2001)

**Biogenic (1063 Tg/a)**



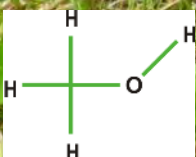
Lathière et al., (2006)

**Urban, Industrial  
(178 Tg/a)**



EDGAR

- during plant growth & maintenance
- in response to stress conditions
  - abiotic stress (environmental stress)
  - biotic stress (cutting, herbivore)

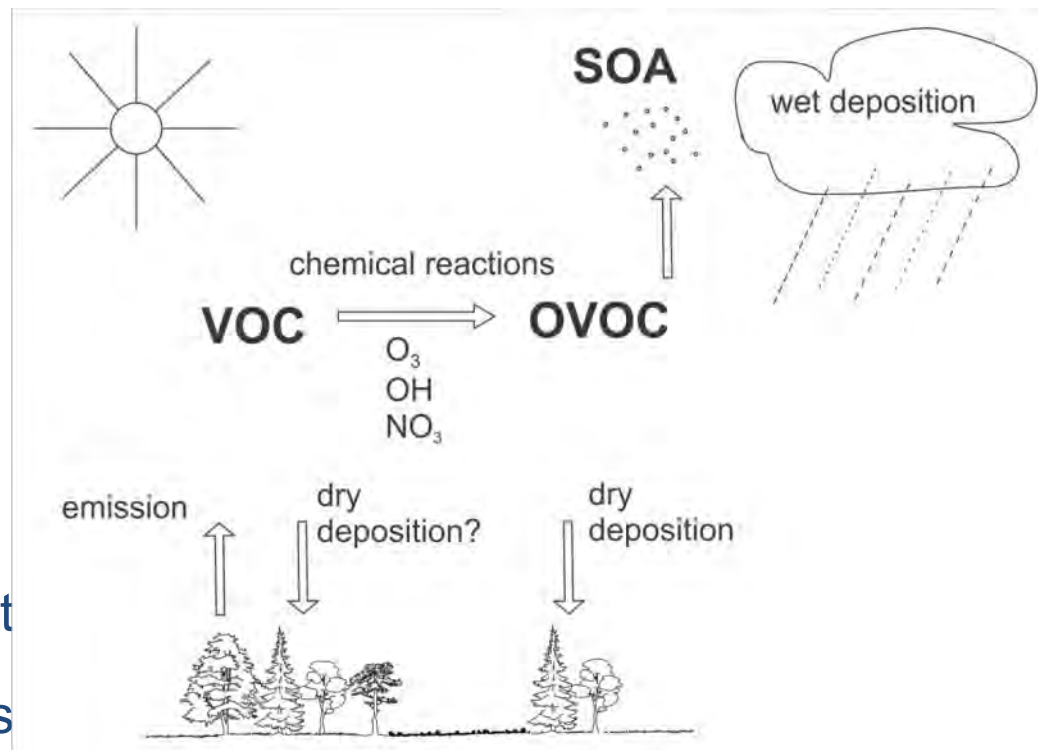


# Sinks of VOCs

Volatile organic compounds are associated with sources rather than sinks

## Dry deposition

- Might be underestimated (Karl et al., 2010)
- Up to now dry deposition is established only for some oxygenated species, e.g. acetaldehyde, (Jardine et al., 2008)
- Should be possible for all compounds as long as plant internal concentrations are below ambient levels (Fick's law of diffusion)

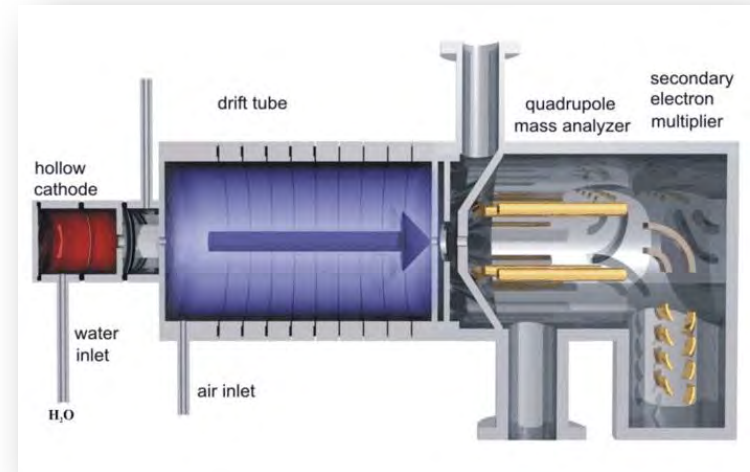




# Instruments & Flux calculation

## VOC measurements

- PTR-MS (only selected VOCs with repetition rates around 2.6 s)
- PTR-TOF-MS (full range mass spectra with repetition rates of 0.1 s)



## 3 D wind measurements

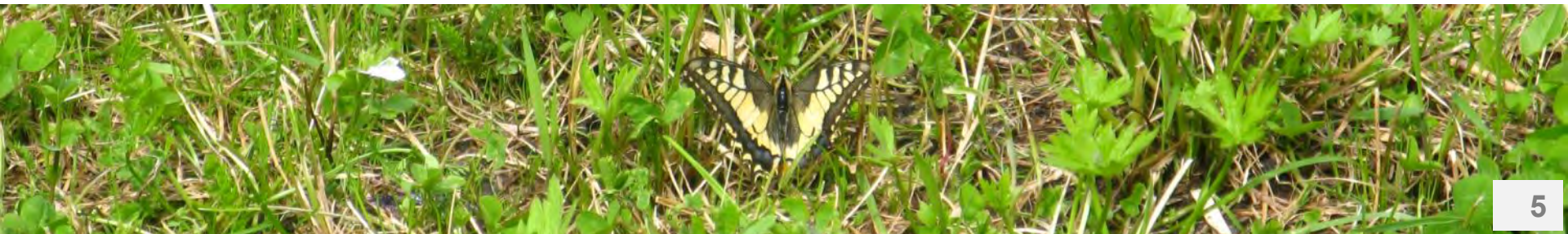
- Sonic anemometer (20 Hz)



## Flux calculation

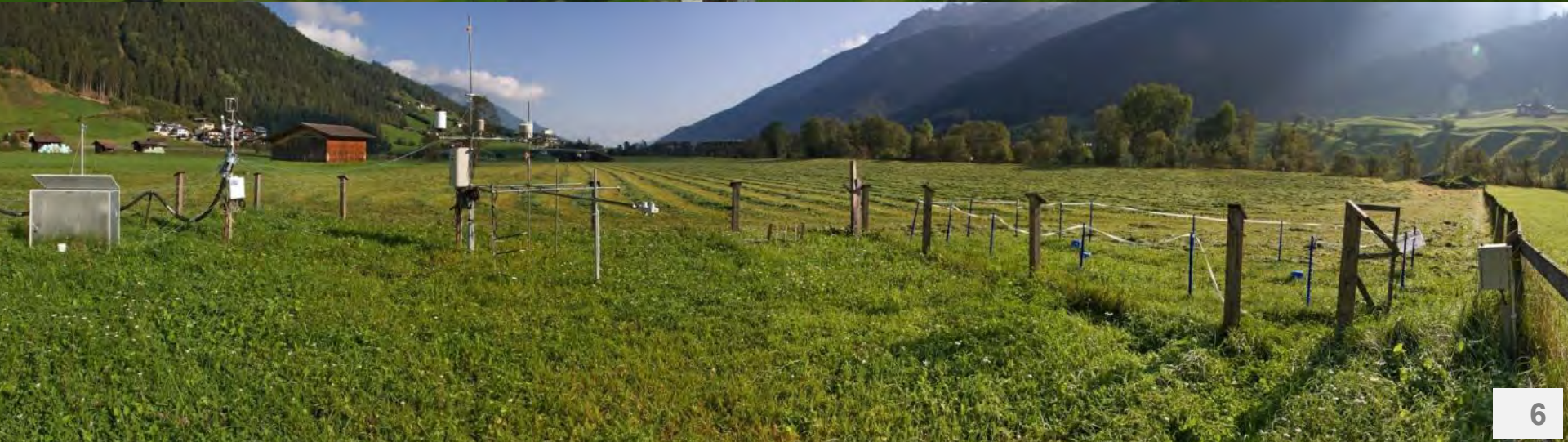
- Net vertical flux is calculated from turbulent departures of the vertical wind ( $w$ ) and the VOC mixing ratios ( $c$ )

$$F_c \approx \overline{\rho_a w' c'}$$



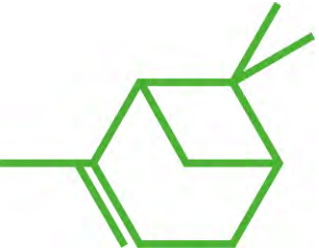
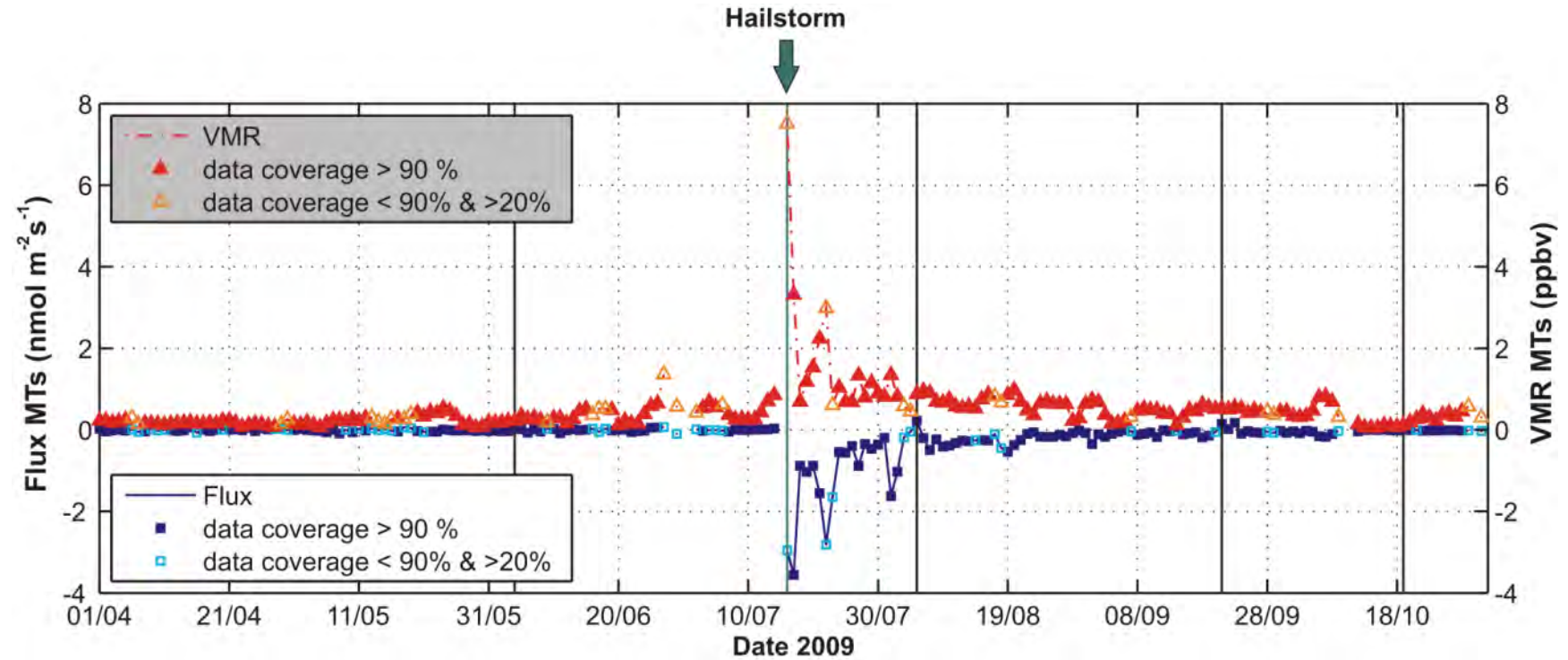


# Measurement Site

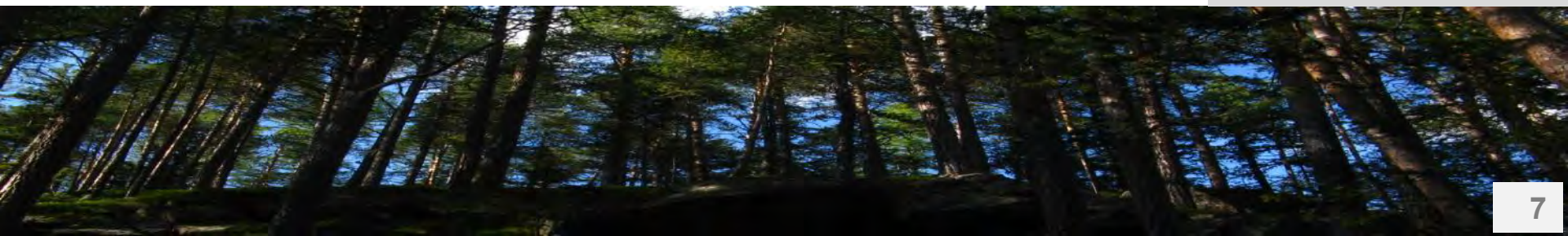




# Results – monoterpene uptake



Bamberger et al., (2011)



# Results

As a consequence of a severe hailstorm in July 2009 needles and small twigs of coniferous trees at the mountain slopes were damaged and terpenes were released from the storage pools

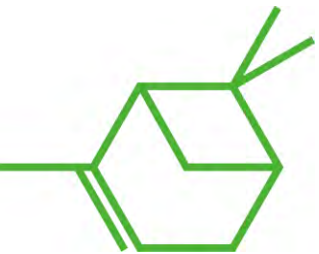
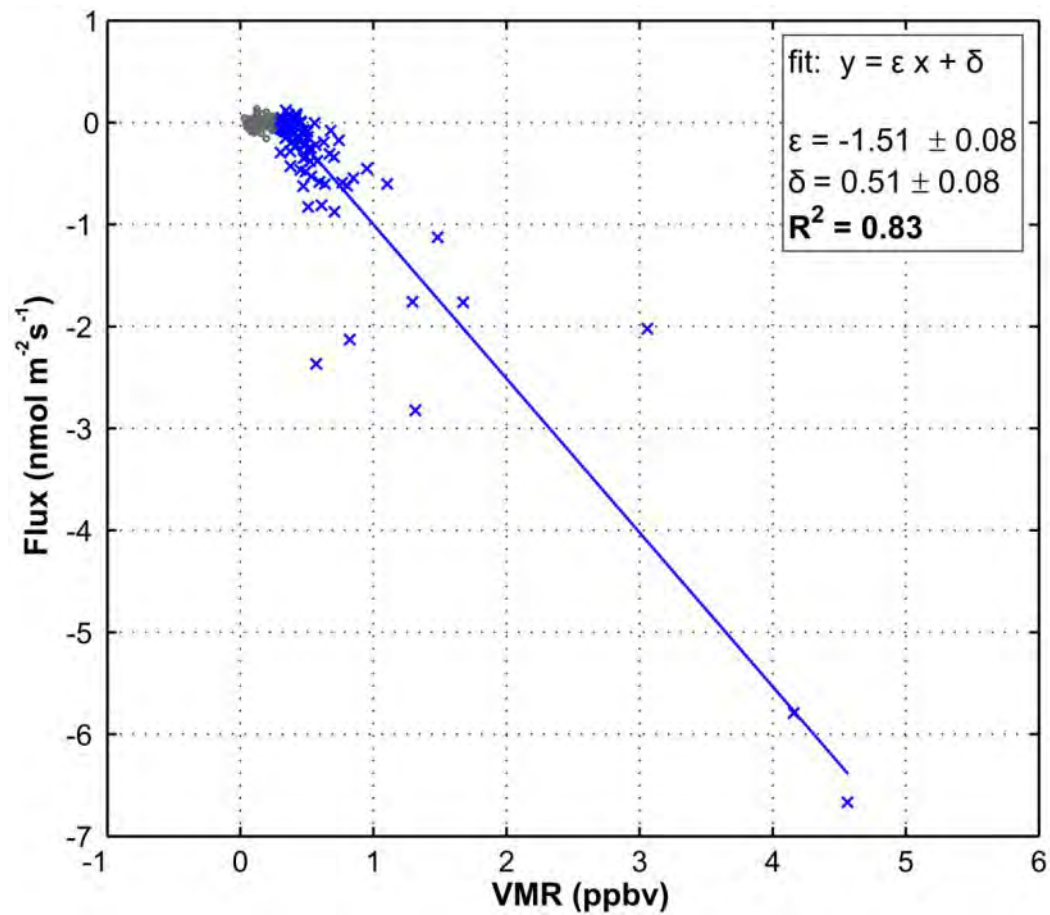


enhanced MT volume mixing ratios

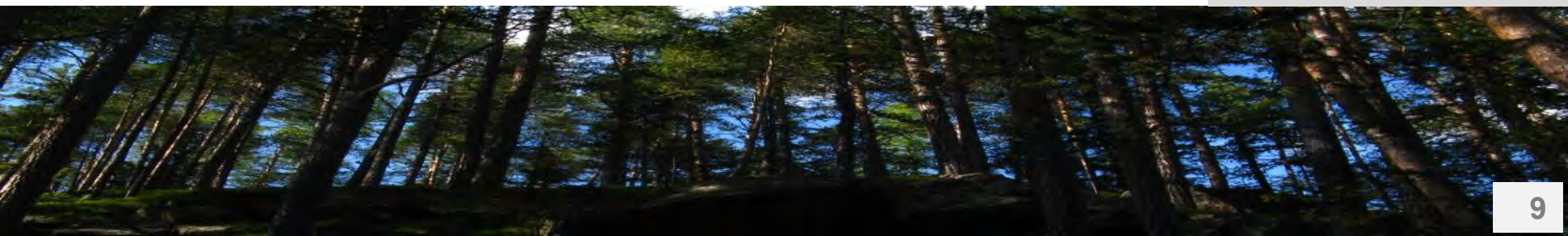




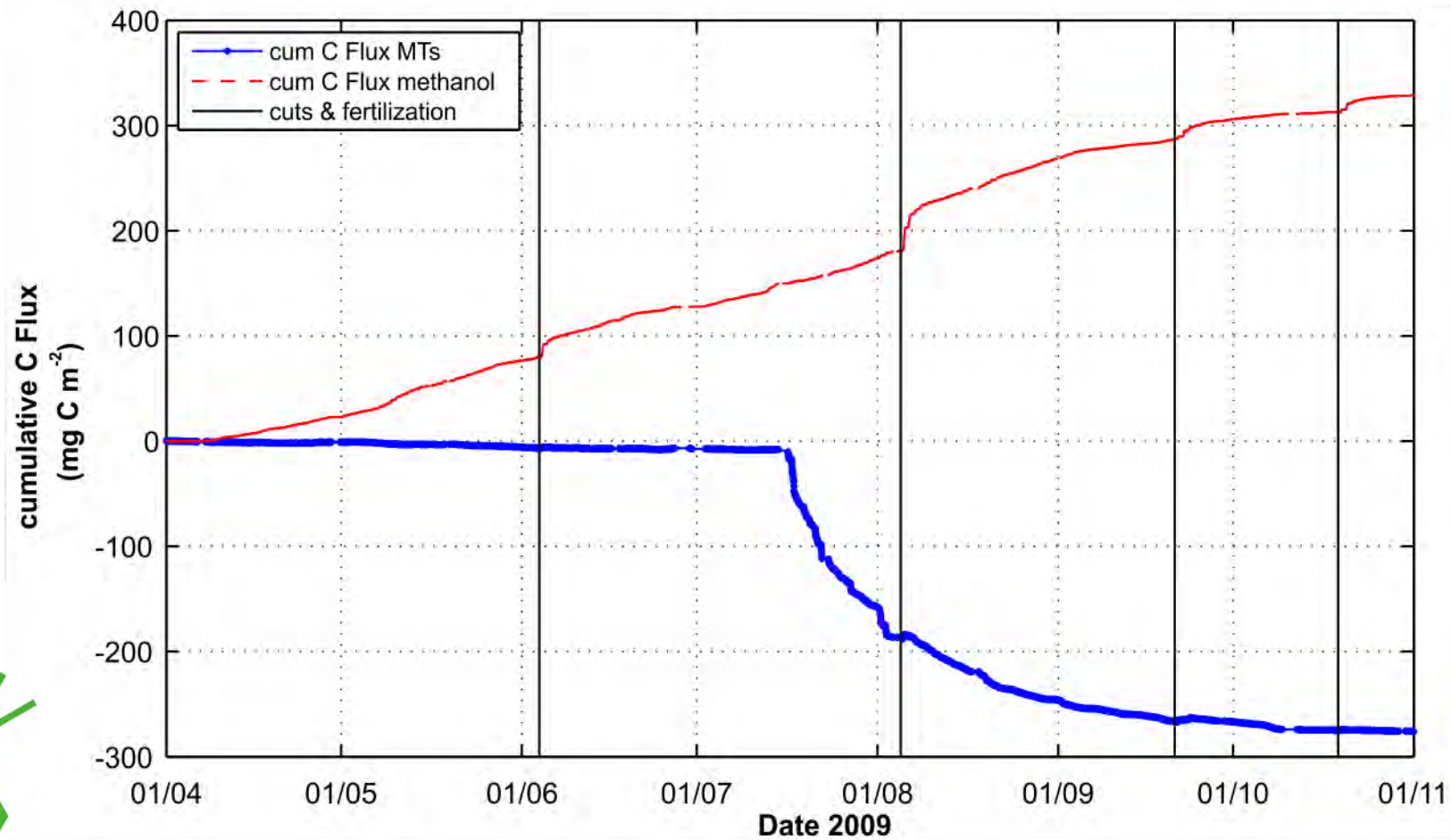
# Results – MT fluxes versus VMRs



Bamberger et al., (2011)



# Results – MT cummulative fluxes

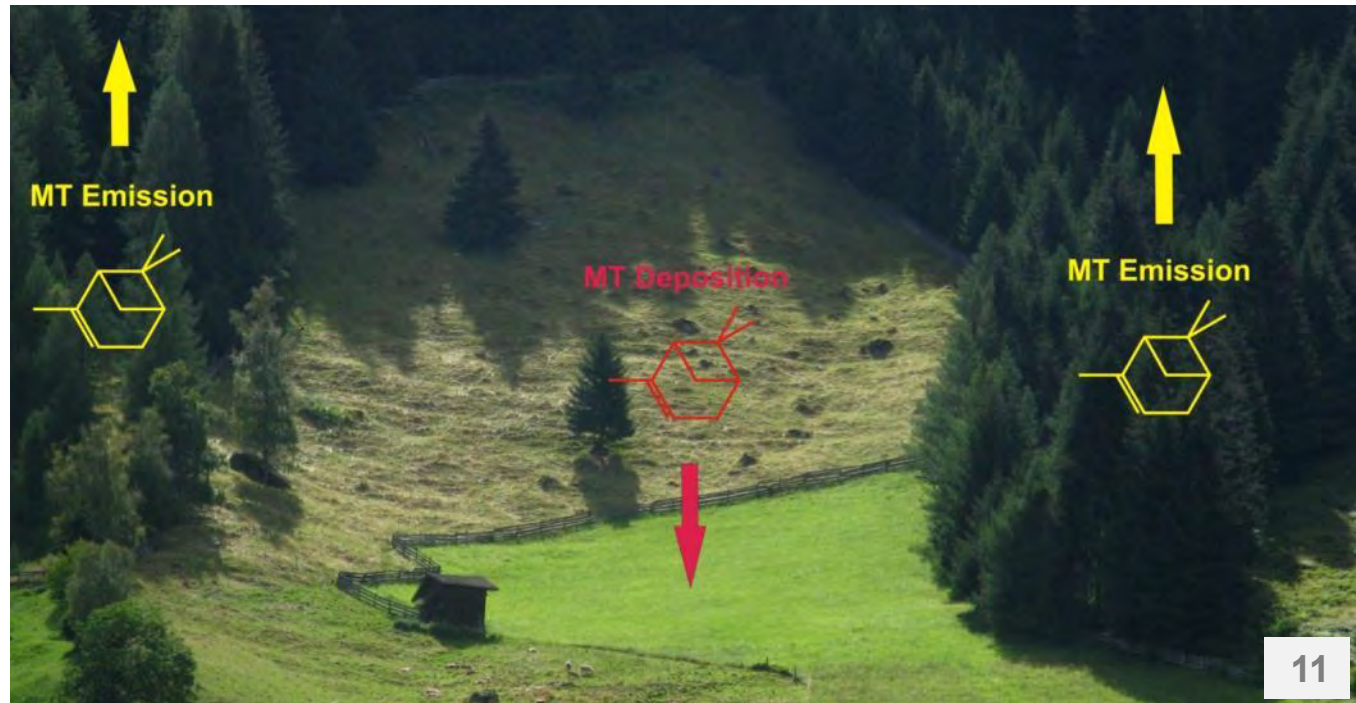


Bamberger et al., (2011)



# Discussion

- Monoterpenes were up to know strongly linked to emissions. On a laboratory scale however an **uptake of terpenes** by plants was already observed (Noe et al., 2008)
- Does MT deposition occur only at rare events or could it also be present for non emitting plants growing intermixed with emitting plant species? First allusion for that was given by Himanen et al., (2010).
- Karl et al., (2010) reported that the deposition sink for oxygenated VOCs is probably underestimated so far
- Our findings propose that dry deposition processes could be important at least for some non-oxygenated species as well



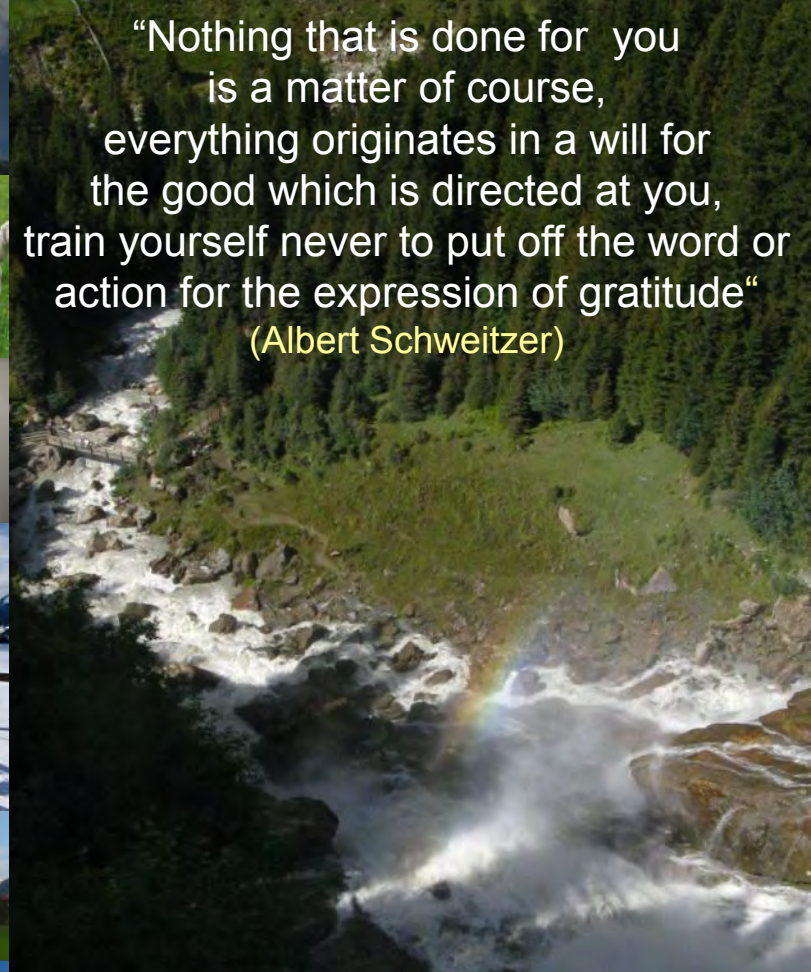
# Conclusions



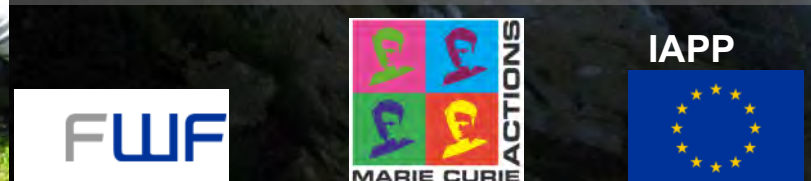
- Terpenes are taken up by grassland (and/or soil?) if ambient volume mixing ratios exceed a certain level
- The uptake of terpenes can be quite significant
- Does bidirectional exchange occur for many more compounds than thought?
- Change of terminology from VOC emission to VOC exchange
- Incorporation into global models might be necessary







**THANK YOU**  
 Georg Wohlfahrt, Armin Hansel, Martin Graus, Taina Ruuskanen, Lukas Hörtnagl, Ralf Schnitzhofer, Markus Müller, Martin Breitenlechner, Irina Herdinger-Blatt, Lisa Kaser, Stephan Langebner, Mario Walser



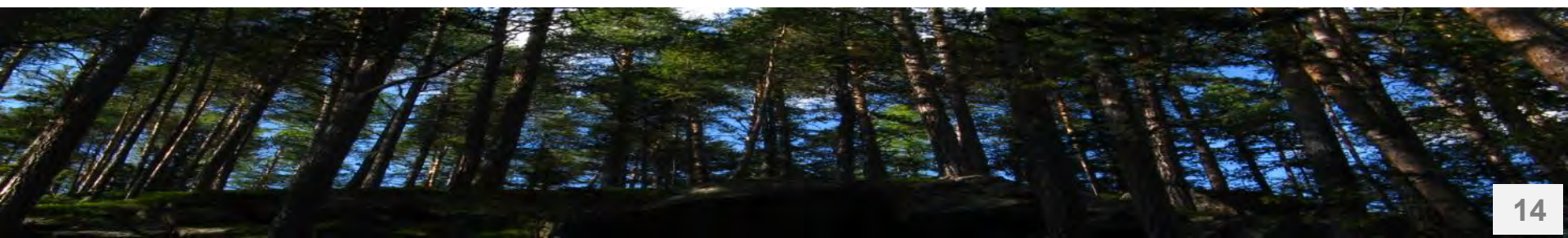


## Deposition fluxes of terpenes over grassland

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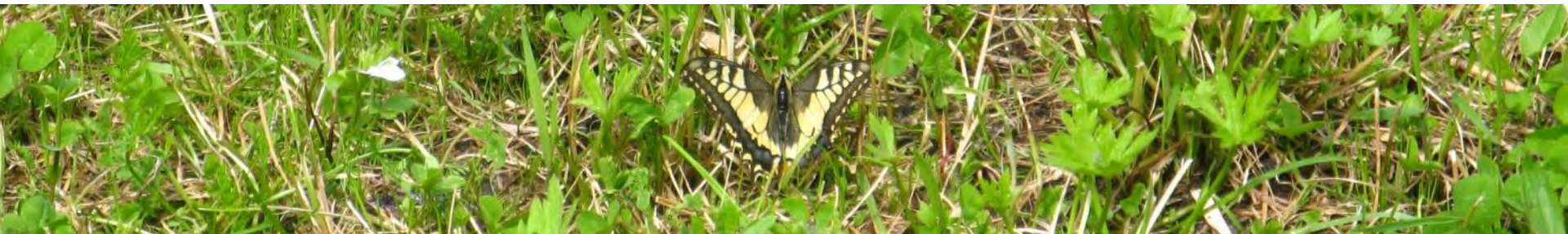
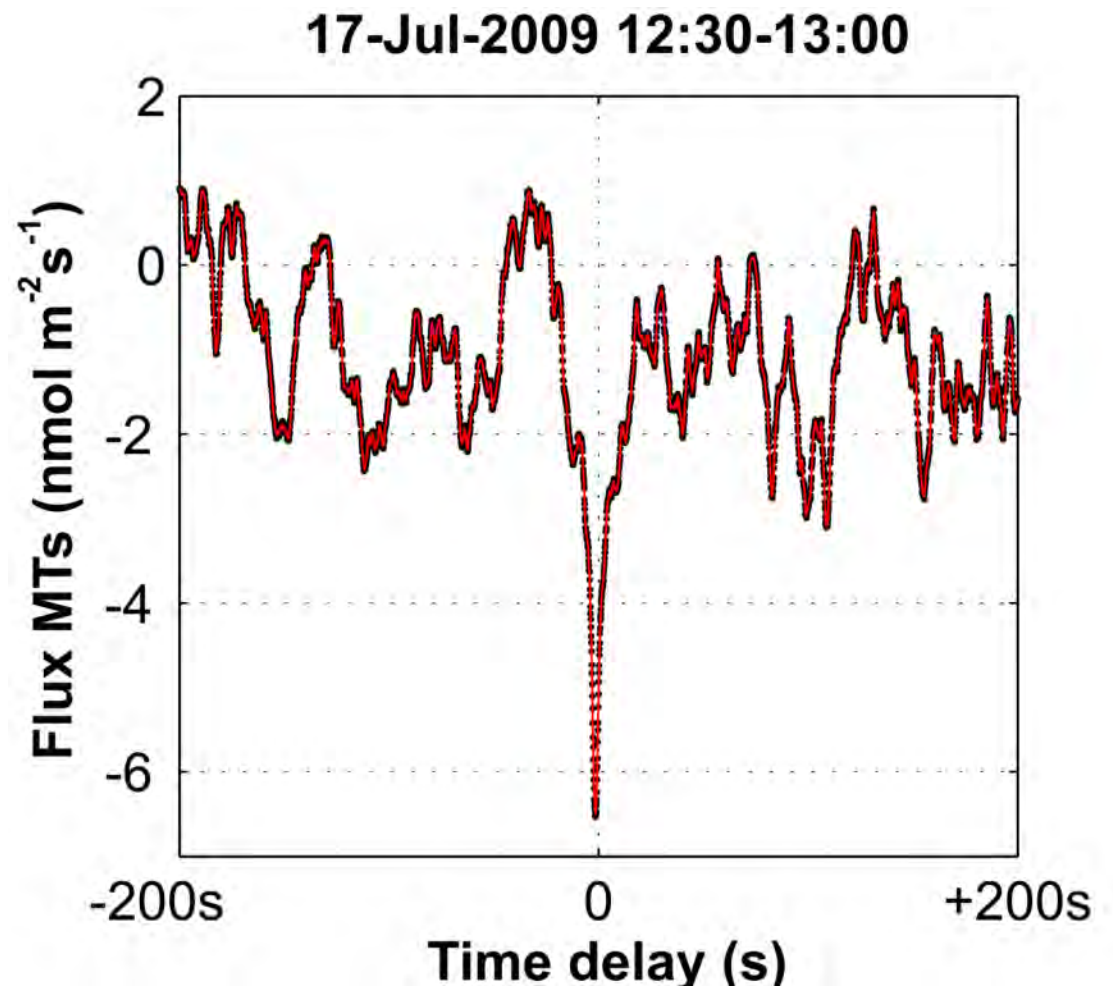
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[1] Eddy covariance flux measurements were carried out for two subsequent vegetation periods above a temperate mountain grassland in an alpine valley using a proton-transfer-reaction-mass spectrometer (PTR-MS) and a PTR time-of-flight-mass spectrometer (PTR-TOF). In 2008 and during the first half of the vegetation period 2009 the volume mixing ratios (VMRs) for the sum of monoterpenes (MTs) were typically well below 1 ppbv and neither MT emission nor deposition was observed. After a hailstorm in July 2009 an order of magnitude higher amount of terpenes was transported to the site from nearby coniferous forests causing elevated VMRs. As a consequence, deposition fluxes of terpenes to the grassland, which continued over a time period of several weeks without significant reemission, were observed. For days without precipitation the deposition occurred at velocities close to the aerodynamic limit. In addition to monoterpene uptake, deposition fluxes of the sum of sesquiterpenes (SQTs) and the sum of oxygenated terpenes (OTs) were detected. Considering an entire growing season for the grassland (i.e., 1 April to 1 November 2009), the cumulative carbon deposition of monoterpenes reached  $276 \text{ mg C m}^{-2}$ . This is comparable to the net carbon emission

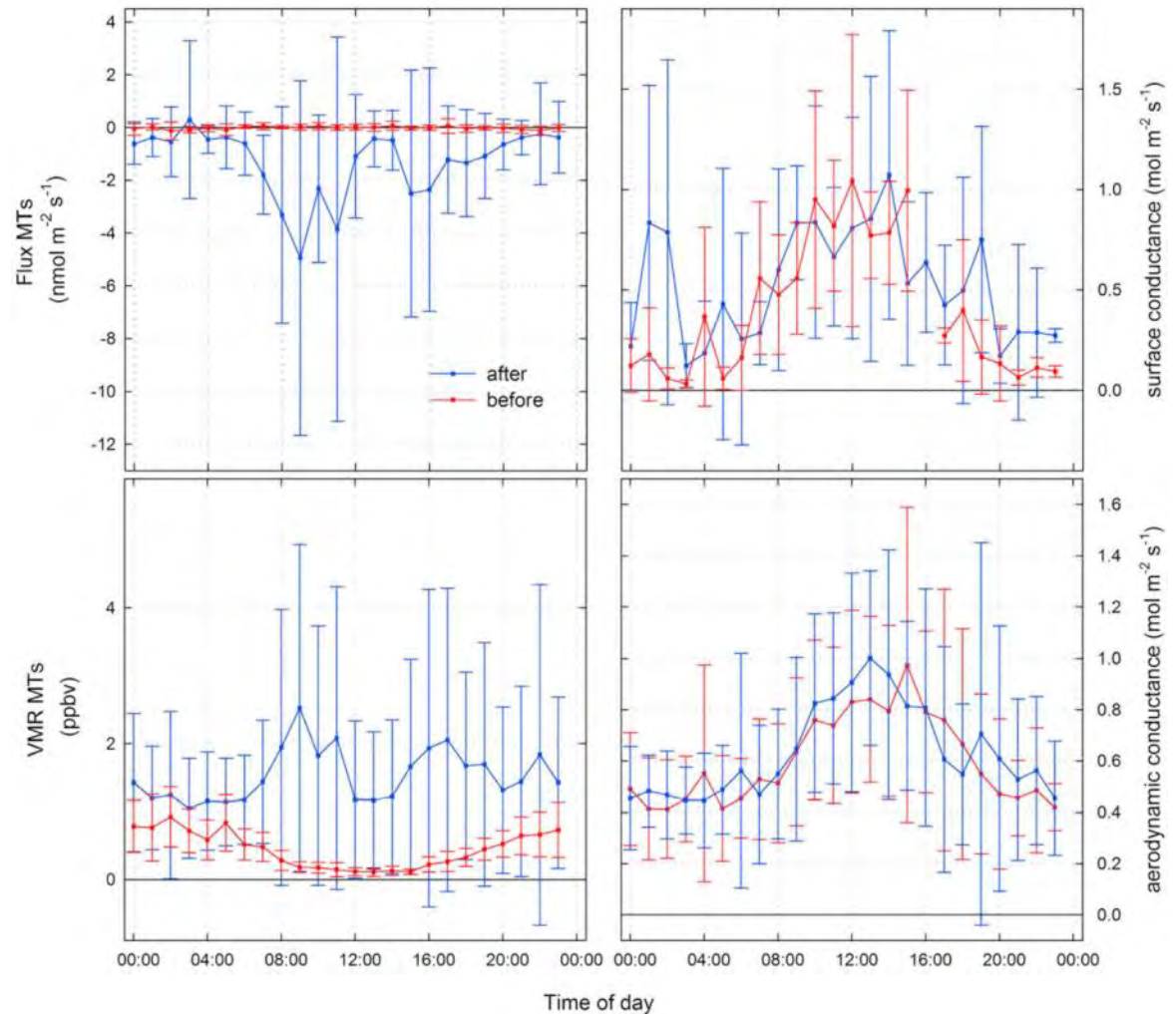




# Additional information

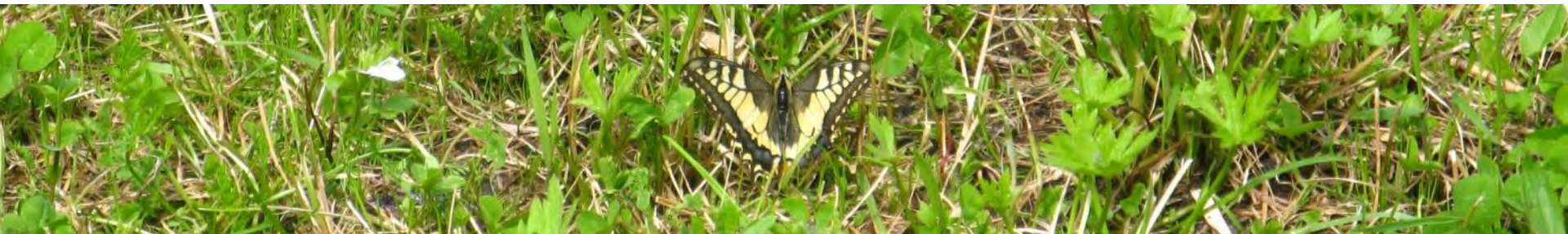
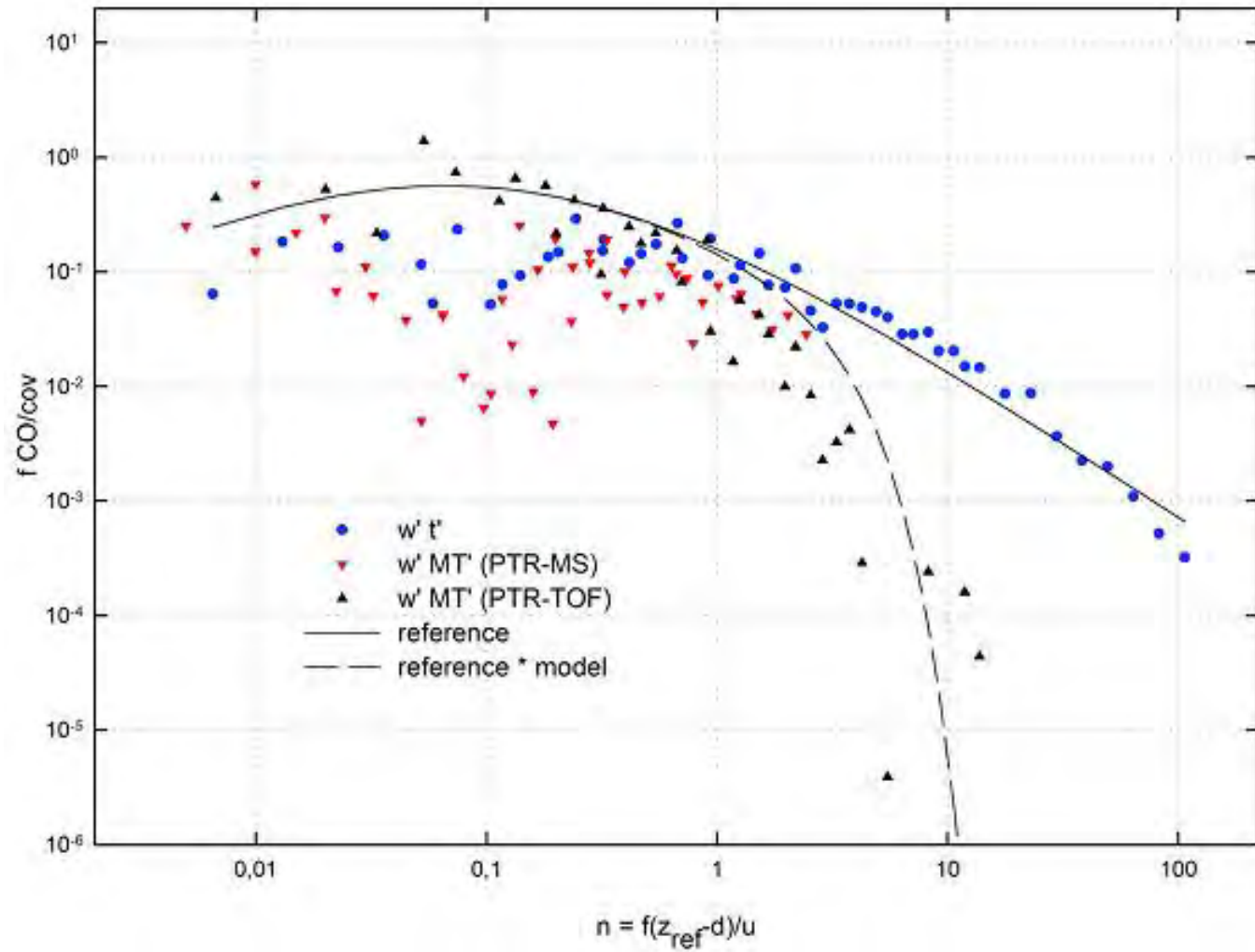


# Additional information





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