Isoprene measurements in an oak-dominated forest during the 2018 heatwave in the UK

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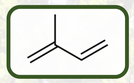
Isoprene in a changing world

- Isoprene (C_5H_8) is one of the most important biogenic non-methane volatile organic compounds (NMVOCs) emitted into the atmosphere
- Estimated emissions ~300-700 TgC year^{-1} (*cf.* 500 TgC year^{-1} for methane): a third of all NMVOCs emitted into the atmosphere
- Highly reactive, source of tropospheric ozone and SOA
- Emissions mainly driven by incoming solar radiation (photosynthetically active radiation, PAR) and temperature
- Current emission estimates vary by up to a factor of 2
- Long-term continuous measurements are few and far apart
- Isoprene emissions impacted by global change (increasing *T*, [CO_2], land use change), and by extreme weather events (heatwaves, droughts) that will become more frequent in the near future

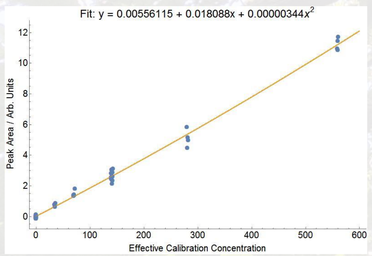


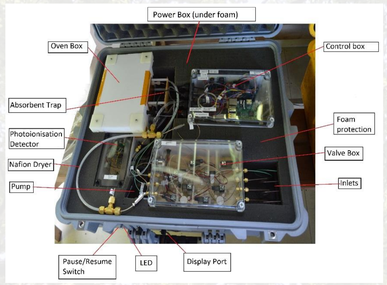
AIMS

- Profile isoprene concentrations in a temperate forest canopy over a full growth season
- Characterise isoprene transport across the canopy to inform canopy-atmosphere exchange
- How are isoprene emissions affected by leaf development, changes in temperature and soil moisture?

iDirac – an overview

- Autonomous portable gas chromatograph with photoionisation detector (GC-PID) for long-term field measurements of isoprene
- Low power (12 W) and low gas consumption
- Limit of detection ~40 ppt
- Precision ~10 %

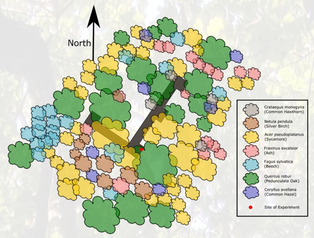


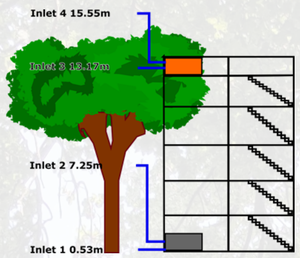


- 3-12 min time resolution (environment dependent)
- Arduino-controlled system with a Raspberry Pi user interface
- Frequent calibration runs for maximum accuracy
- Successfully deployed in Malaysian Borneo and the Southern Ocean

WIsDOM: Wytham Isoprene iDirac Oak Tree Measurements

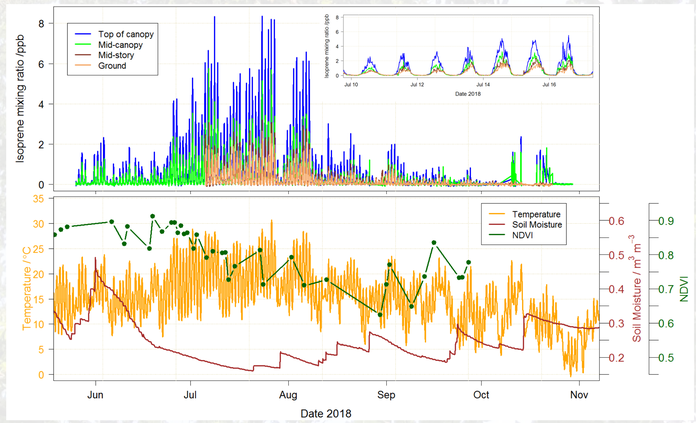
- Wytham Woods (Oxfordshire, UK), mixed temperate woodland
- *Quercus robur* (pedunculate oak) dominant isoprene emitter
- No mains power on site. Long-term, low-power, unmanned deployment - unsuitable for traditional instrumentation





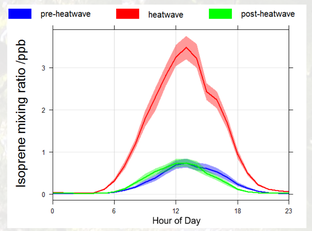
- Canopy walkway allows sampling at different heights
- Isoprene and temperature at four heights in the canopy
- Nearby PAR, wind and soil moisture from met station (200 m from walkway)
- Periodic leaf gas exchange, foliage VOC emissions and whole air samples
- Satellite retrievals of normalised difference vegetation index (NDVI)

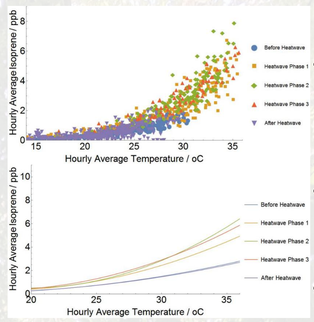
Observations

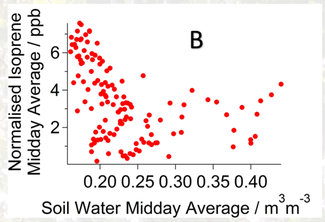


- 5-month continuous monitoring of isoprene at 4 heights in the canopy
- Heatwave (22 Jun-08 Aug 2018): one of the hottest summers on record, combined with prolonged drought
- Mean temperature during the heatwave 4 °C higher than before or after; 3 °C higher than the 1992-2017 mean over the same period
- Soil moisture decreased significantly through heatwave/drought
- NDVI shows drought stress increased through heatwave/drought

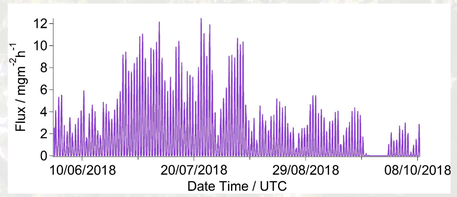
Data Analysis







- Diurnal mean isoprene during heatwave up to 4-5 times greater than non-heatwave
- Expected response of isoprene to temperature seen in early part of summer and after the heatwave
- Unexpected enhancement in response to temperature during the heatwave
- Pre- and post-heatwave response curves overlap
- Normalising isoprene concentrations (with respect to *T* and PAR) shows a clear correlation between soil moisture and enhanced isoprene during drought stress
- No isoprene shutdown observed following drought stress – soil moisture remained above wilting point (~0.15 m^3 m^{-3})
- Tightly constrained canopy models show isoprene flux into boundary layer is ~4 times higher during heatwave



Conclusions & Future work

- iDirac ran autonomously in a logistically difficult environment
- 5 months of uninterrupted isoprene concentration measurements across the canopy before, during and after heatwave
- Isoprene emissions from *Quercus robur* did not exhibit seasonality
- Response of isoprene to temperature enhanced during heatwave apparently as a result of drought stress
- Our data in combination with canopy models provide an alternative method to derive forest VOC fluxes into the lower atmosphere
- Exceptionally hot summer, expected to be typical around 2050
- Need to establish impact of greater isoprene emissions on tropospheric oxidising capacity, ozone and SOA production in future climate scenarios

References

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