SAFARI 2000 Leaf-Level VOC Emissions, Maun, Botswana, Wet Season 2001

Abstract

Trace gases are important constituents of our atmospheric environment. Of these, biogenic volatile organic compounds (VOCs) comprise a significant proportion and play an important role in the formation of secondary air pollutants. Emissions of monoterpenes from *Colophospermum mopane* were studied at adjacent sites in Botswana as part of the SAFARI 2000 (Southern African Regional Science Initiative). Using a LI-COR leaf cuvette, VOC emissions were measured from the dominant tree species (*Colophospermum mopane*) and other vegetation near Maun, Botswana. The aims of this work were to: (1) determine the VOC emission potential of *C. mopane;* (2) investigate any differences in VOC emission potential between the tall and short *C. mopane* morphology types; (3) investigate environmental controls of VOC emissions from *C. mopane;* and (4) screen other non-dominant vegetation for high VOC emission potential. All measurements were made during February of 2001.

Background Information

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Project: SAFARI 2000

Data Set Title: SAFARI 2000 Leaf-Level VOC Emissions, Maun, Botswana, Wet Season 2001

Site: Maun, Botswana
Westernmost Longitude: 23° 33' E
Easternmost Longitude: 23° 33' E
Northernmost Latitude: 19° 54' S
Southernmost Latitude: 19° 54' S

Data Set Citation:

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Data File Information

Data files contain records of biogenic VOC measurements from sites in the Maun area during the wet season campaign of 2001. The data are contained in the ASCII text file **maun_leaf-level_voc.csv** which contains the columns described below, in comma-delimited format with column headers. A zero means that a measurement was made, but was under the detection limits. Blank fields mean there are no data for that cell. Either it was not measured, did not exist, the instrument failed for that particular measurement, or any other circumstance that resulted in missing data.

Column	Description	Units/Format
date	date sample was taken	dd-mon-yy
time	local start time of sample	hh:mm
site	orc = mopane tree outside Harry Oppenheimer Okavango Research Centre (orc); short/pan = mopane growing on "pan"; tall mopane = mopane growing near tower; orc-wh = behind research centre-wild hog	character field
species	plant species investigated	genus species

experiment	the type of experiment associated with measurement (preliminary light dependency, emission potential, tall/short and water potential, light dependency, screening)	character field
leaf	usually a 2-letter code with prefix T=tall or P=pan and a letter (A-V) that labels a different leaf on the same plant (a different tree was sampled each day) or single leaf, which means it was a different tree, not used before, and the same leaf used for all measurements. Also see note below table.	character field
par	photosynthetically active radiation	µmol m^{-2} s^{-1}
tleaf	leaf temperature	degrees C
tcham	temperature inside leaf cuvette	degrees C
P	atmospheric pressure	mb
Leaf area	area of leaf enclosed by leaf cuvette	cm^2
Leaf dry weight	dry weight of that part of leaf enclosed in leaf cuvette	g
isoprene_l	leaf area based emission rate of isoprene	µg cm^{-2} h^{-1}
a-pinene_l	leaf area based emission rate of alpha pinene	µg cm^{-2} h^{-1}
camphene_l	leaf area based emission rate of camphene	µg cm^{-2} h^{-1}
b-pinene_l	leaf area based emission rate of beta pinene	µg cm^{-2} h^{-1}
myrcene_l	leaf area based emission rate of myrcene	µg cm^{-2} h^{-1}
3-carene_l	leaf area based emission rate of 3-carene	µg cm^{-2} h^{-1}
limonene_l	leaf area based emission rate of limonene	µg cm^{-2} h^{-1}
isoprene_d	dry biomass based emission rate of isoprene	µg gdw^{-1} h^{-1}
a-pinene_d	dry biomass based emission rate of alpha pinene	µg gdw^{-1} h^{-1}
camphene_d	dry biomass based emission rate of camphene	µg gdw^{-1} h^{-1}
b-pinene_d	dry biomass based emission rate of beta pinene	µg gdw^{-1} h^{-1}

myrcene_d	dry biomass based emission rate of myrcene	µg gdw^{-1} h^{-1}
3-carene_d	dry biomass based emission rate of 3-carene	µg gdw^{-1} h^{-1}
limonene_d	dry biomass based emission rate of limonene	µg gdw^{-1} h^{-1}

NOTE: In the leaf column, there are a few measurements not defined in the description above, used only once, and are samples of different leaves of the same tree. These are:

Tdark1   leaf 1, which was darkened with a black bin-liner over the cuvette
Tshade2 leaf 2, which was growing naturally in the shade
Tdark2   leaf 3, which was darkened with a black bin-liner over the cuvette (i.e., dark leaf 2)
Tsun2   leaf 4, which was growing naturally in the sun

Site Information

Most of the VOC and soil measurements were made at a *C. mopane* woodland situated approximately 20 km from Maun, Botswana. This site has been used extensively for ecological and plant physiological studies (Mantlana, 2002; Midgley et al., 2004; Veenendaal et al., 2004). The soil type at the site comprises fine Kalahari sand with clay. The vegetation is dominated by *C. mopane* with understorey species such as *Acacia* and *Combretum* sp.

All measurements were made during the wet season in February of 2001. Maun is located in a semi-arid climate with a mean annual rainfall of 464 mm. During the wet season (October-April), long-term mean monthly temperatures normally range between 30-34°C (max.) and 15-19°C (min.) with rainfall normally attaining its annual peak in January (110 mm). Intermittent dry spells during the rainy season are common and, in fact, the measurements made during this wet season campaign were conducted near the end of a 2-month spell of dry weather, with monthly rainfall of 30 and 50 mm in November and December 2000, respectively (Midgley et al., 2004). The winter months, May-September, are particularly dry, with long-term mean monthly rainfall ranging from 0.1 to 3 mm.

Maun Climatic Variables					
Time Period	**Rainfall (mm)**	**Max Rainf. (mm)**	**Max Temp (°C)**	**Min Temp (°C)**	**P.E.T. (mm)***
July	0.1	5.4	25.3	7.1	111
August	0.3	9.6	28.5	9.9	147
September	3	31.9	32.5	14.7	185
October	17	101.1	33.6	18.6	211
November	50	169.6	33.3	19.5	197
December	79	262.2	32.7	19.2	196
January	110	395.9	32.1	19.6	180
February	100	365.7	30.8	19.2	155
March	73	273.8	31.2	18.2	165
April	25	120.4	30.1	15.1	139
May	6	62.3	27.8	7.1	123
June	1	17.1	25.1	7.1	101
Annual	**464**	**1183.9**	**30.3**	**14.9**	**1910**

*Potential Evapotranspiration according to Penman. Source: Bhalotra (1987).

VOC samples were taken from trees growing in two adjacent areas of the same woodland to investigate the effects of light, temperature and water status on VOC emissions. The two study areas have distinctly different soil profiles, which profoundly affect the morphology of the trees. The first sample area was typical of the major part of the woodland. Here, a tall form of *C. mopane* grows, with an average tree height and crown diameter of 5.5 m (Midgley et al., 2004). The second sample area was within a "pan", where the soil profile is considerably shallower. Here, the trees are notably shorter, averaging only 1.6 m in tree height and crown diameter (Midgley et al., 2004) but are the same age as the taller *C. mopane*. Trees from these two sites will be referred to as "tall" and "short" *C. mopane*, respectively. The two sampling sites were approximately 300 m apart and therefore it is assumed that the macro-meteorological conditions and rainfall at each site are identical.

A further study took place to determine whether the VOC emissions from *C. mopane* exhibit light dependency. This research was conducted at the Harry Oppenheimer Okavango Research Centre (HOORC), Maun, Botswana with a mature tree within the campus grounds. The soil type was similar to that at the *C. mopane* woodland with the trees exhibiting morphology akin to that of the tall *C. mopane*. The light dependency and screening measurements contain some 'leaf' column values that are not defined in the table above. These are Tdark1, Tshade2, Tdark2, Tsun2. Dark1 means that leaf was covered and the PAR was 0, shade2 means that the leaf was in low PAR conditions at the time of measurement, sun2 means that the leaf was in full sunlight at the time of measurement. Additional samples (shade1 and sun1) were either lost (leaked) or had bad chromatography.

VOC Sampling

VOC emission samples from both tall and short *C. mopane* were taken using a portable 1 L LI-COR leaf chamber. A representative leaf was carefully placed within the chamber to minimize mechanical stress. Physiological measurements were recorded immediately using a Portable Gas Exchange System (LI-6200, LI-COR, Lincoln, NE, USA) adapted for VOC sampling.

Environmental parameters (PAR, temperature, relative humidity and CO_2 concentration) were recorded, together with assimilation rate and stomatal conductance in the normal closed configuration for this system. The cuvette was then switched to an open configuration to prevent depletion of CO_2 and static build-up of emitted VOC concentrations within the chamber. A 30-minute equilibration period was deemed sufficient to allow emission rates to recover from any cuvette installation stress. After equilibration, a sample of chamber air was collected in 2 or 5 L Teflon sample bags via the internal pumping system of the LI-6200 Portable Photosynthesis System. Immediately following the VOC sample collection, the system was closed again and an additional record of physiological and environmental parameters were recorded. The Teflon sample bags were sealed and stored in dark bags to prevent subsequent photochemical degradation of the samples prior to analysis.

For the light dependency experiment, VOC samples and physiological measurements were taken from the same leaf throughout the day at the HOORC site. Light levels were artificially decreased from ambient by using neutral cumulative filters to shade the chamber. The leaf was allowed to equilibrate for 30 minutes after each change of PAR before emitted VOCs were sampled. Sampled leaf areas and dry weights were recorded.

Sample Analysis

VOC samples were analyzed within 1 hour in the nearby research center laboratory. Full details of the analytical procedure are described by Greenberg et al. (2003). Briefly, gas chromatography was used with flame ionization detection. VOCs within the samples were pre-concentrated onto a Tenax TA trap and cooled to -10°C, with subsequent cryofocusing at -30°C onto the gas chromatograph (GC) column. The GC oven was initially held at 40°C for 2 minutes, before increasing at a rate of 15°C/min to 150°C, which was held for 5 minutes. An isoprenoid standard was analyzed regularly throughout the procedure, thus allowing identification of the samples by retention time comparison. 2,2-dimethyl butane in N_2 was used for quantification of identified VOCs. The detection limit of this system was in the region of 50 ppt. An identical analytical and calibration system has been used to quantify canopy-scale fluxes at Maun (Greenberg et al., 2003).

Emission Rate Calculations

Emission rates (E) are expressed as µg per g leaf dry weight per hour (µg gdw-1 h-1), and were calculated using:

$$E = \{(F * C * M_r) / [(22400 * (T_{std} + T_{cham}) * P_{std}) / (T_{std} * P_{cham})]\} / W$$

where:

F = air flow rate through the cuvette ($L\ h^{-1}$)
C = concentration of emitted compound in the cuvette (ppb)
M_r = molecular mass of monoterpenes ($g\ mol^{-1}$)
T_{std} = standard temperature (°C)
T_{cham} = cuvette temperature (°C)
P_{std} = standard pressure (mb)
P_{cham} = cuvette air pressure (mb)
W = dry leaf biomass (g)

Additional Sources of Information

Related Data Sets

Otter, L. 2004. SAFARI 2000 Estimated BVOC Emissions for Southern African Land Cover Types. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

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