SAFARI 2000 Estimated BVOC Emissions for Southern African Land Cover Types

Abstract

Improved vegetation distribution and emission data for Africa south of the equator were developed for the Southern African Regional Science Initiative (SAFARI 2000) and combined with biogenic volatile organic compound (BVOC) emission measurements to estimate BVOC emissions for the southern African region. Volatile organic compounds (VOCs) consist of a wide variety of chemical species that can be emitted into the atmosphere, where they react with other compounds. These reactions have significant consequences for the chemical composition of the atmosphere. VOCs play an important role in the global carbon budget and radiation balance, regional oxidant balance, and distribution of ozone and other reactive gases. VOCs are emitted into the troposphere by a vast number of sources that can be divided into 2 categories: anthropogenic and biogenic. Major anthropogenic sources include combustion of fossil fuels and solvent evaporation. Many trees and plants emit a wide variety of biogenically emitted volatile organics compounds. BVOC emissions are extremely important, with vegetation producing more than 90% of the total global VOC budget (Guenther et al., 1995).

Background Information

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Project: SAFARI 2000/SAVE

Data Set Title: SAFARI 2000 Estimated BVOC Emissions for Southern African Land Cover Types

Site: Southern Africa
Westernmost Longitude: 5° E
Easternmost Longitude: 60° E
Northernmost Latitude: 5° S

Southernmost Latitude: 35° S

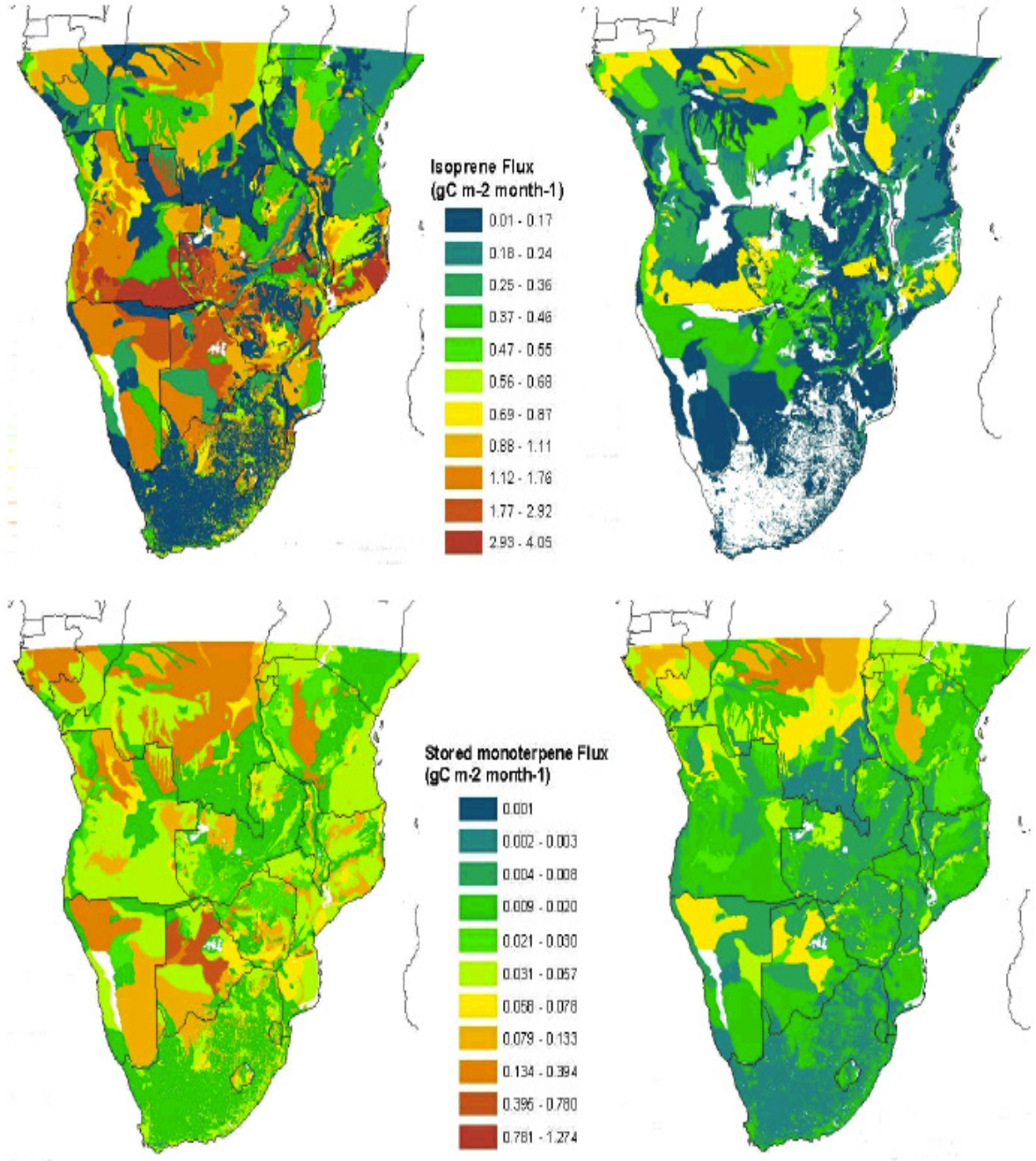
Data Set Citation:

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.

Results of BVOC Emissions Modeling

Reasonable estimates of BVOC from Africa are necessary for our improved understanding of global and regional atmospheric chemistry. A detailed land cover data set for southern Africa has been developed for the specific purpose of modeling biogenic emissions. Canopy and leaf-level fluxes measured during SAFARI 2000 and past studies are interpolated to the regional scale in southern Africa. By combining detailed species composition and emissions data with climatic and leaf area index (LAI) data, new and more accurate regional BVOC emissions were estimated for the area of Africa south of the equator on a monthly basis over a one-year period.

In the figure shown below, average monthly isoprene emissions (top) and 'stored' monoterpene emissions (bottom) (gC m^{-2} $month^{-1}$) over southern Africa decline from January (left) to July (right), particularly in the southern parts as July is very dry. White areas on the map indicate land areas that do not show any emissions.



Data File Information

Model output includes files of isoprene, light-dependent monoterpene, stored monoterpene, and other VOC emissions by land use category and vegetation type. Emissions were modeled for a summer (January) and a winter (July) month. Annual and monthly estimates were also calculated. The data files are ASCII

comma-delimited files. This data set includes the following files:

annual_monthly_emissions.csv
bvoc_emissions_by_landcover.csv
land_use_emissions.csv

The "annual_monthly_emissions.csv" data file contains the following columns of data. In addition, it contains the annual total emissions per constituent.

Column	Description	Units
Month	Month of Estimate	month
Iso	Isoprene Emissions	g C m^{-2} mo^{-1}
LDMT	Light-dependent monoterpene emissions	g C m^{-2} mo^{-1}
SMT	Stored monoterpene emissions	g C m^{-2} mo^{-1}
OVOC	Other VOC emissions	g C m^{-2} mo^{-1}
LAI	Leaf Area Index	m^2 m^{-2}
Temp	Air Temperature	degrees C

The "bvoc_emissions_by_landcover.csv" data file contains BVOC emissions estimates for the different vegetation types on the NBI vegetation map (Rutherford et al., 2000) for the study area. The following table describes the contents of the data file:

Column	Description	Units
Code	Vegetation type code	numeric
NBI Code	Code from NBI map	alphanumeric
Description	NBI Map Description of Vegetation	ASCII
Ann Iso	Annual Emissions of Isoprene	g C m^{-2} yr^{-1}
Ann LDMT	Annual Emissions of Light-dependent monoterpenes	g C m^{-2} yr^{-1}
Ann SMT	Annual Emissions of stored monoterpenes	g C m^{-2} yr^{-1}

Ann OVOC	Annual Emissions of other VOCs	g C m^{-2} yr^{-1}
Iso Jan	Isoprene Emissions January 2001	g C m^{-2} mo^{-1}
LDMT Jan	Light-dependent monoterpene emissions January 2001	g C m^{-2} mo^{-1}
SMT Jan	Stored monoterpene emissions January 2001	g C m^{-2} mo^{-1}
OVOC Jan	Other VOC emissions January 2001	g C m^{-2} mo^{-1}
Iso Jul	Isoprene Emissions July 2001	g C m^{-2} mo^{-1}
LDMT Jul	Light-dependent monoterpene emissions July 2001	g C m^{-2} mo^{-1}
SMT Jul	Stored monoterpene emissions July 2001	g C m^{-2} mo^{-1}
OVOC Jul	Other VOC emissions July 2001	g C m^{-2} mo^{-1}

The "land_use_emissions.csv" file contains contains BVOC emissions estimates for generalized land use and land cover categories in the study area. The following table describes the contents of the data file:

Column	Description	Units
Land cover	Generalized land use categories	ASCII
Iso Jan	Isoprene Emissions January 2001	g C m^{-2} yr^{-1}
LDMT Jan	Light-dependent monoterpene emissions January 2001	g C m^{-2} yr^{-1}
SMT Jan	Stored monoterpene emissions January 2001	g C m^{-2} yr^{-1}
OVOC Jan	Other VOC emissions January 2001	g C m^{-2} yr^{-1}
Total BVOC Jan	Total Biogenic VOC emissions January 2001	g C m^{-2} yr^{-1}
Iso Jul	Isoprene Emissions July 2001	g C m^{-2} yr^{-1}
LDMT Jul	Light-dependent monoterpene emissions July 2001	g C m^{-2} yr^{-1}
SMT Jul	Stored monoterpene emissions July 2001	g C m^{-2} yr^{-1}
OVOC Jul	Other VOC emissions July 2001	g C m^{-2} yr^{-1}

Total BVOC July	Total Biogenic VOC emissions July 2001	g C m^{-2} yr^{-1}

Additional graphics are included with the data:

File Names	Description
bvoc_fig1.jpg	Distribution of light dependent monoterpene emissions across southern Africa during January (g C m^{-2} $month^{-1}$). White areas indicate no emissions.
bvoc_fig2a.jpg	Average monthly isoprene emissions (g C m^{-2} $month^{-1}$) over southern Africa in January.
bvoc_fig2b.jpg	Average monthly isoprene emissions (g C m^{-2} $month^{-1}$) over southern Africa in July.
bvoc_fig2c.jpg	Average monthly 'stored' monoterpene emissions (g C m^{-2} $month^{-1}$) over southern Africa in January.
bvoc_fig2d.jpg	Average monthly 'stored' monoterpene emissions (g C m^{-2} $month^{-1}$) over southern Africa in July.

Methodology

Biogenic VOC emissions (isoprene, light-dependent monoterpenes, "stored" monoterpenes, and other VOCs) were estimated for Africa south of the equator by combining GIS layers of vegetation, LAI, and climate with a biogenic emissions model, GLOBEIS (Guenther et al, 1993; Guenther, 1999). This model used vegetation data, species emission capacity data, LAI data, cloud cover, and temperature data as input.

GLOBEIS Model Input

Data Set	Source
vegetation data	NBI vegetation map; Rutherford et al., 2000

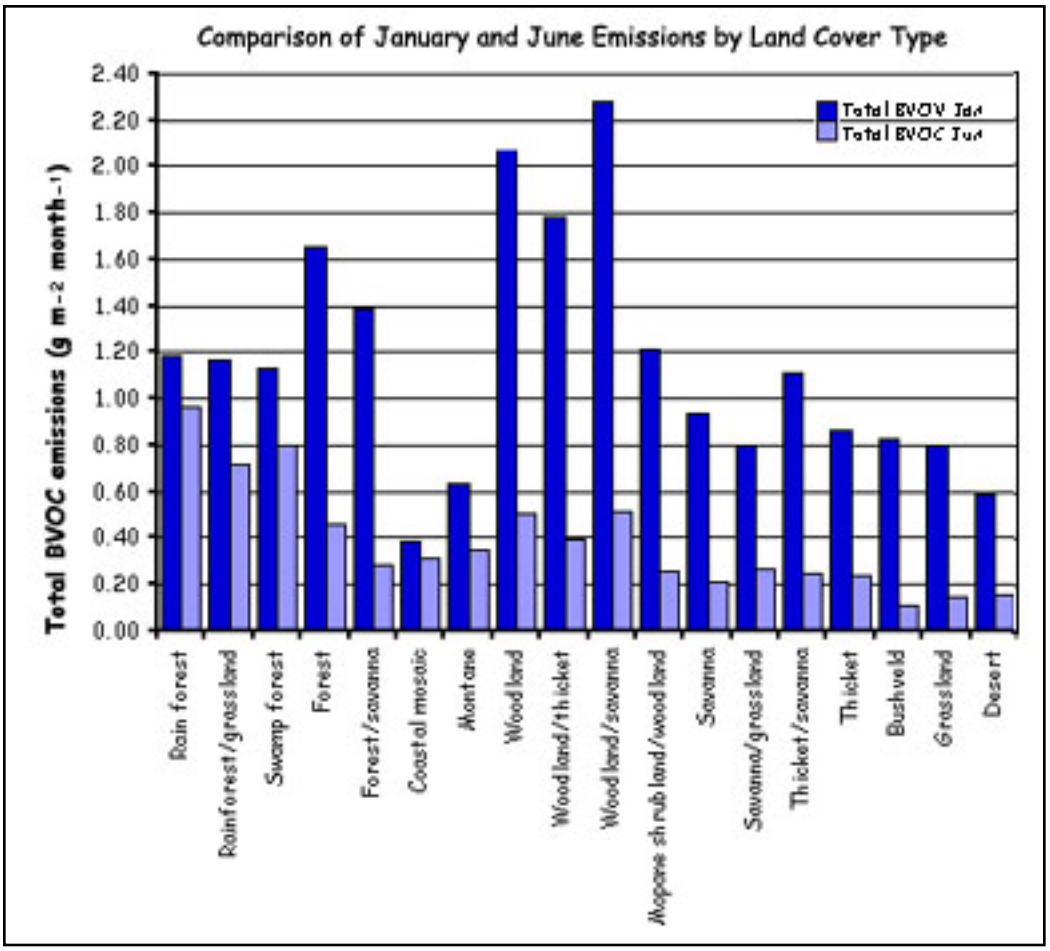
species emission capacity	Greenberg et al., 2003; Guenther et al., 1996; Harley et al., 2003; Klinger et al., 1998; Otter et al., 2002; Serca et al., 2001; Wiedinmyer et al., 2004
LAI data	1987-88 ISLSCP LAI; Sellers et al., 1994
cloud cover	MODIS LAI cloud mask
temperature data	NOAA NCDC data

Model Description

The vegetation characteristics data (LAI, specific leaf mass, emission capacity) were used with temperature and cloud cover data to estimate biogenic isoprene, monoterpene and other VOC emissions from southern Africa for the course of one year. The emissions were calculated using the algorithms described by Guenther (1999) and the following formula:

Emissions = epsilon **D** gamma**L** gamma**T** gamma**a** [1]

where Gamma is the basal emission capacity for a given species or land use classification, **D** is the foliar density , and gamma**L**, gamma**T**, and gamma**a** are emission activity factors that depend on light intensity, temperature, and leaf-age, respectively. The light dependent emission algorithm of Guenther et al. (1993) and Guenther (1999) was used for describing the effects of light on isoprene emissions. Light dependent monoterpene emissions have recently been shown to be important in southern Africa (Greenberg et al., 2003). Therefore, the light dependent emission algorithm was also used to describe the effects of light on those specific monoterpene emitters. The temperature dependent emission algorithm of Guenther et al. (1993) and Guenther (1999) was used to describe the influence of temperature on emissions of isoprene, monoterpenes, and other VOCs.



Species Composition Data

Detailed vegetation mapping of land cover and vegetation distribution is necessary to accurately model the BVOC emissions in southern Africa. The vegetation species composition map used for this study was developed by the South African National Biodiversity Institute (SANBI) [formerly, the National Botanical Institute (NBI)] in South Africa (Rutherford et al., 2000). This vegetation map consists of six independent sub-regional maps, namely: Low and Rebelo (1998) covering South Africa, Lesotho, and Swaziland; Giess (1971) covering Namibia; Wild and Barbosa (1968) covering Botswana, Zimbabwe, Zambia, Malawi, and Mozambique; Barbosa (1970) covering Angola; White (1983) covering Tanzania, Kenya, Uganda, and Somalia; and White (1983) covering Ruanda, Burundi, Congo, and Gabon. Each base map consists of a wide variety of land cover categories (such as *Brachystegia* woodland, *Combretum* savanna, *Miombo* woodland, forest, desert) that differ from region to region. Vegetation discontinuities still exist along some of the regional borders.

The NBI species composition map only defines the vegetation of the region, and has very few non-woody vegetation categories (such as urban and agriculture) identified. This mapping assumes the whole region is covered in vegetation. To create a more realistic mapping of the land cover, the NBI map was overlaid with the national land cover database of South Africa (Fairbanks et al., 2000; Thompson, 1999). This map of South Africa identifies the land cover and land use types in South Africa, including urban and agricultural areas. Due to lack of available data, urban and agricultural maps in other countries of the study domain were not included in this study. However, they will be incorporated in the future as they are made available.

Emission Capacities

The EC (epsilon) is defined as the rate of emission under specific light and temperature conditions. For this study, the ECs used have been standardized for a light intensity of 1000 μmol m^{-2} s^{-1} and a leaf temperature of 30° C. Thus, measured VOC emission rates from vegetation are corrected for light and temperature using the algorithms or activity factors (gammaL, gammaT) derived by Guenther et al. (1993).

Even though the EC database used to estimate BVOC emissions for this study is much larger than any other used in past modeling studies of Africa, it still only provides information about a small portion of the total species in the region. Only about 10% of species- or genus-level ECs used in this study were assigned based on actual emission measurements.

Leaf Area Index (LAI) and Leaf Mass Density

Monthly Leaf Area Index (LAI) and leaf mass density were estimated and assigned to each parcel in the study domain. LAI assignments can be obtained from satellite measurements. Therefore, for the purposes of calculating initial emission estimates, an older LAI data set spanning two years (1987-88), from the ISLSCP LAI database, was applied. The MODIS LAI product was not used because the data set for 2000 and 2001 was found to be missing data for a significant number of our mapping units. LAI (m^2 leaf/m^2 ground) is combined with an estimate of specific leaf mass (SLM), in grams of leaf per m^2 of leaf area,

to estimate the foliar density used in equation 1.

Cloud Cover and Temperature

Photosynthetically active radiation (PAR) data are required for estimating light dependent BVOC emissions. This information was estimated from available cloud cover data as described in Guenther et al. (1996). Cloud cover fraction was obtained by extracting the cloud cover bit field from the MODIS LAI QA product and coding this as either zero cloud, 50% cloud cover, or 100% cloud cover for each pixel.

Daily temperature data were obtained from the NOAA NCDC data set and joined with the temperature data from climate stations within the world climate station database. Daily maximum and minimum temperature surfaces (covering the SAFARI study region) were created using a kriging routine within ArcINFO. The monthly means of these surfaces were then calculated for a 1-year period. Hourly temperatures were calculated from the minimum and maximum temperature and solar elevation using the methods described by Guenther et al. (1996).

Model Uncertainties

As with all models, there is a degree of uncertainty associated with each input variable. Calculating an exact value for the uncertainty is extremely difficult, due mainly to limited data. Therefore error assessments for regional BVOC emissions are usually qualitative rather than quantitative. The uncertainty of regional BVOC emission models is often stated to be a factor of two to three, and the error in this study most likely is in this range. See Otter et al. (2003) for additional uncertainty information.

Additional Sources of Information

Related Data Sets

Related data sets collected by other participants in the 2001 wet season field campaign are archived by ORNL DAAC. A list of these data sets is available at: http://www.daac.ornl.gov/S2K/safari.html.

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