Supplement for "A comprehensive emission inventory of biogenic volatile organic compounds in Europe: improved seasonality and land-cover"

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Supp1 Detailed description of temperature adjustment in the canopy

The temperature correction in the canopy proceeds in two steps: first, the air temperature is corrected using a quadric fit to measurement data. Then, this corrected air temperature is converted to a leaf temperature using a linear relationship involving the radiation level in the layer under consideration. The functions used here are based on unpublished measurement data of Ulrich Joss determined at Riggstäfeli in Switzerland and Hartheimer Wald in Germany (Joss, 1996).

First, the coefficients a, b, c of the quadric fit are selected from Table Supp12 according to the time of day. Then the difference of the air temperature in the canopy compared to the top of the canopy is calculated:

$$\Delta\vartheta_i = a + b \times z_i + c \times z_i^2 \tag{1}$$

where a, b and c are the coefficients from Table Supp12 and z_i is the normalised tree height $\in [0, 1]$ of layer i where $z = 1$ represents the top of the tree (Niinemets, 2010).

Then, the air temperature is corrected using this difference scaled with the ratio of the integrated radiation input h_g and a reference radiation input $h_{g,ref}$ of 7 $\mathrm{kWh\,m^{-2}\,day}$. This reference radiation input represents a cloud-free sky at the measurement sites of Riggstäfeli and Hartheimer Wald (Joss, 1996).

This ratio scales the temperature effect with the local conditions:

$$\vartheta_{air,corr,i} = \vartheta_{air,i} + \Delta\vartheta_i \times \frac{h_g}{h_{g,ref}} \tag{2}$$

And finally, the leaf temperature is derived from this corrected air temperature using this empirical relation (derived from data by (Jones, 1992) and (Lamb et al., 1993)):

$$\vartheta_{leaf,i} = \vartheta_{air,corr,i} - 2.3\,\mathrm{K} + (6.7 \times 10^{-3}\,\mathrm{K}\,\mu\mathrm{mol}^{-1}\mathrm{m}^2\mathrm{s} \times G_i) \tag{3}$$

where G_i is the global radiation in layer i.

This approach neglects, among other things the cooling effect of the evaporation of water. However, it is in reasonable agreement with literature data (Leuzinger and Körner, 2007) suggesting that leaf temperatures may exceed temperatures by up to 9 K at the top of the canopy.

A typical ϑ and PAR profile within a canopy is shown in Fig. Supp20 for a broadleaf and a conifer forest for a summer afternoon. The shapes of the PAR and the temperature profile are similar because they are linked via Eq. 3. The leaf temperature at the tree top is about 3.5 K above air temperature, which drops within the uppermost 20% of the trees height to air temperature and finally reaches a level of about 1.5 K below air temperature at the bottom of the tree. The model predicts that PAR drops below a level of e^{-1} within the uppermost 20% of the trees height and is completely depleted at the bottom of the tree due to extinction. Note that around 25% of the foliage mass of a model tree (irrespective of the tree type) is contained in the upper 20% of the tree.

Supp2 Metrics to assess model performance

We used the *Pearson product-moment correlation coefficient* (r) (Wilks, 2011):

$$r = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{O_i - \bar{O}}{s_O}\right)\left(\frac{M_i - \bar{M}}{s_M}\right) \tag{4}$$

As a measure of accuracy, the *root-mean-square error* (RMSE) (Wilks, 2011):

$$\mathrm{RMSE} = \sqrt{\overline{((O_i - M_i)^2)}} \tag{5}$$

and the *coefficient of variation of the RMSE* (CV(RMSE)) (Wilks, 2011):

$$\mathrm{CV(RMSE)} = \frac{\mathrm{RMSE}}{\bar{O}} \tag{6}$$

are used.

In these equations, M refers to the modelled and O is the observed value and s is the standard deviation and $\bar{x}$ is the mean over all x.

The range of r is $[-1, +1]$ where 1 indicates full positive correlation (the ideal value) and -1 indicates full anti-correlation (Wilks, 2011).

A perfect model has $RMSE$ and $CV(RMSE)$ of 0, whereas for non-perfect models, these quantities may grow unbounded (Wilks, 2011).

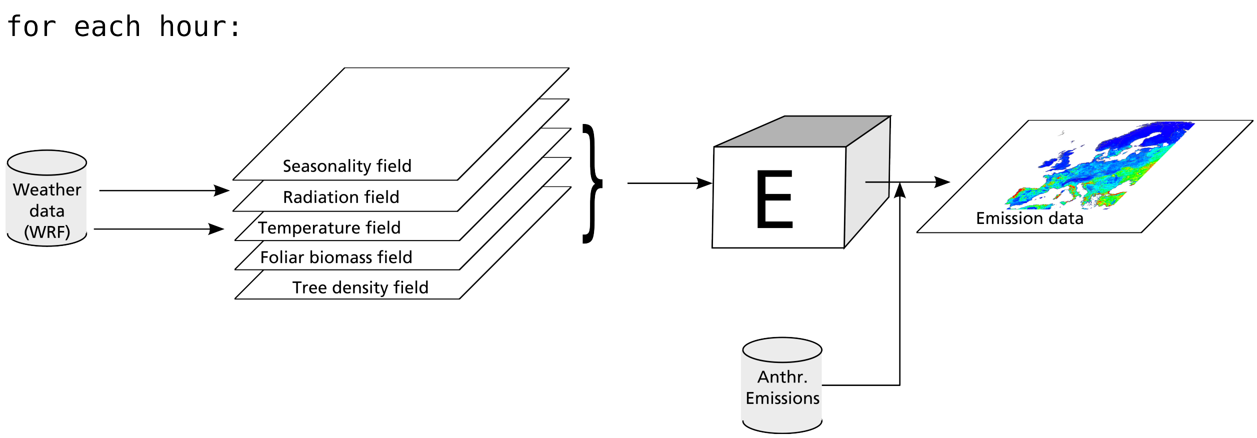


Figure Supp1: Schematic of the modular emission model

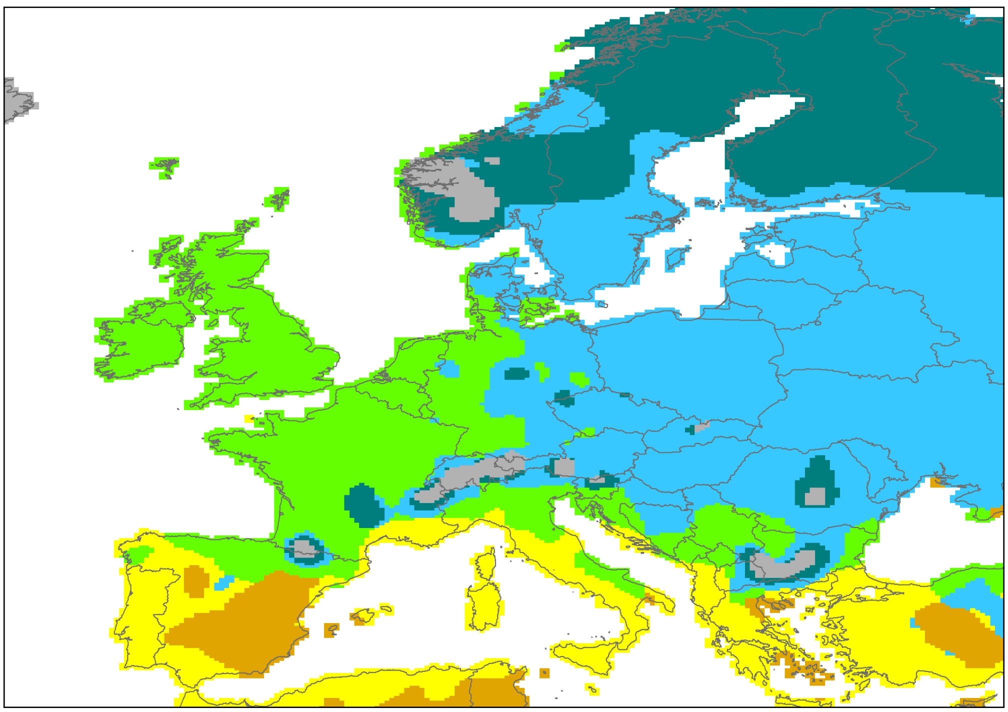


Figure Supp2: The six climatic zones of Europe under consideration. Blue: cold except summer, Dark Green: cold, yellow: temperate with dry summer, green: temperate without dry season, orange: arid, grey: polar, aggregated from Peel et al. (2007)

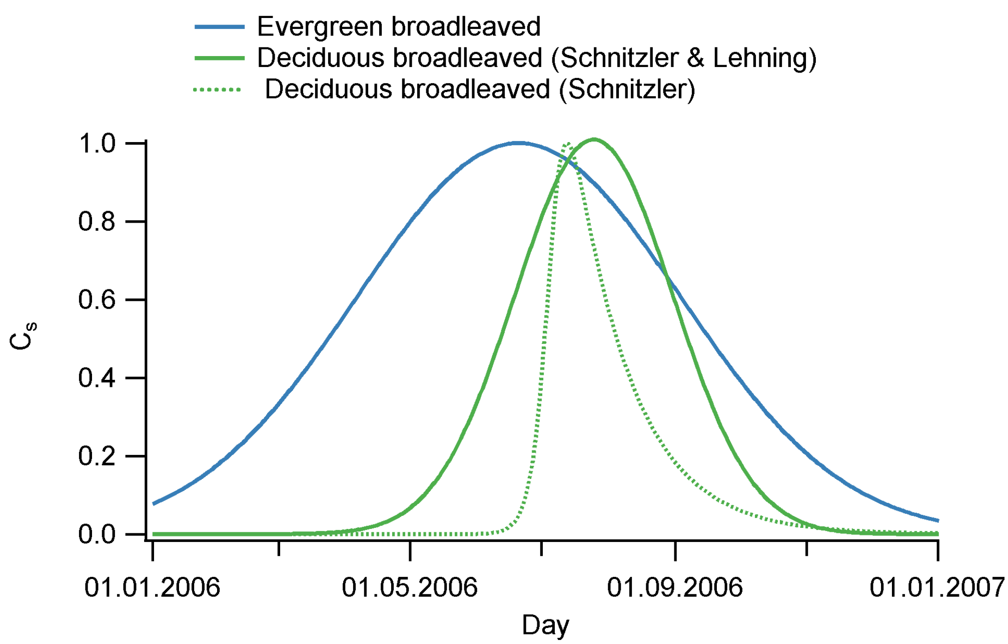


Figure Supp3: Temporal evolution of C_s for isoprene and monoterpenes synthesis emissions of broad-leaved trees (deciduous derived from (Schnitzler et al., 1997) and (Lehning et al., 2001), evergreen after (Ciccioli et al., 2003)). For deciduous broad-leaved trees, $C_s = a \times \exp(-.5 * ((doy - d0)/b)^2)$ where doy is the day of the year and the empirical factors $a = 1.0091, d0 = 205.2055, b = 36.5647$. For reference, the dotted line represents the original function given by (Schnitzler et al., 1997). For evergreen broad-leaved trees, $C_s = \exp(-((a - doy)^2/(2 \times b^2)))$, with the empirical factors $a = 170.538, b = 75.033$. Note that in the original publication by Ciccioli et al. a minus sign in this equation is missing.

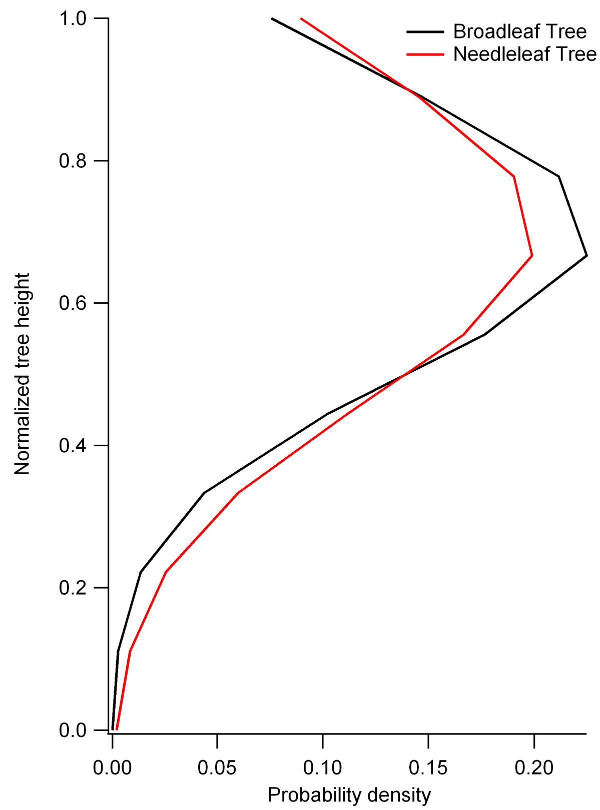


Figure Supp4: Probability density function of the vertical distribution of foliar biomass for needle-leaved and broad-leaved trees as used by the canopy correction for ten layers. Distributions obtained from data by Joss (1996)

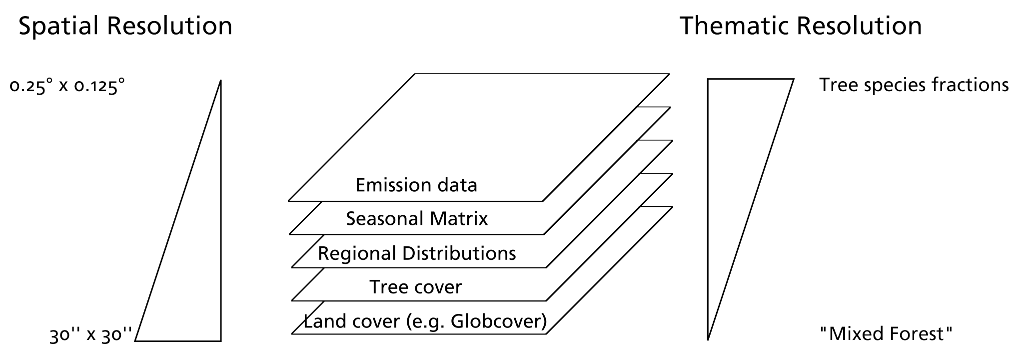


Figure Supp5: Illustration of the work flow to prepare the input data for the emission model. Raw data is at the bottom (land-cover inventory), final data at the top (vegetation inventory).

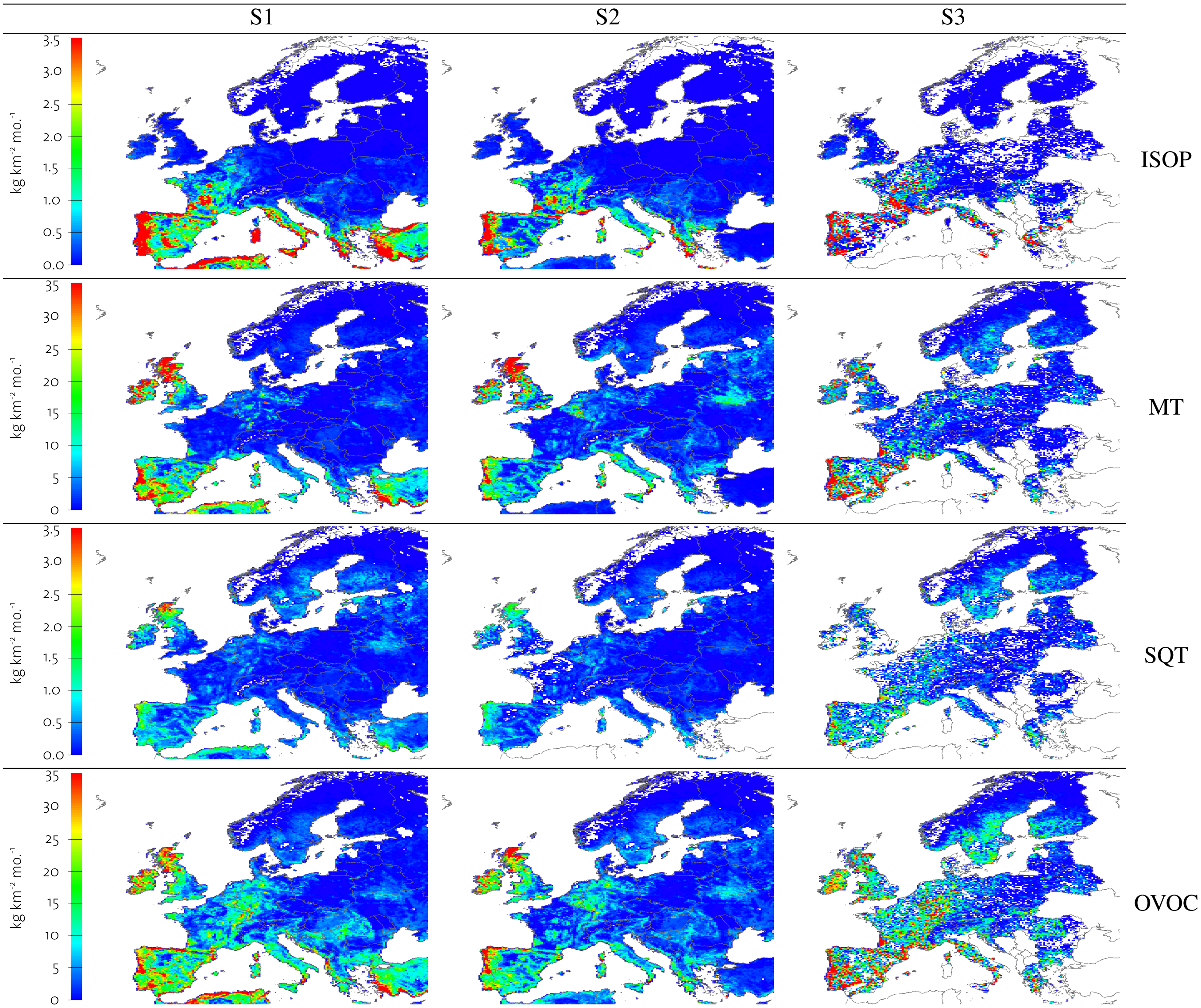
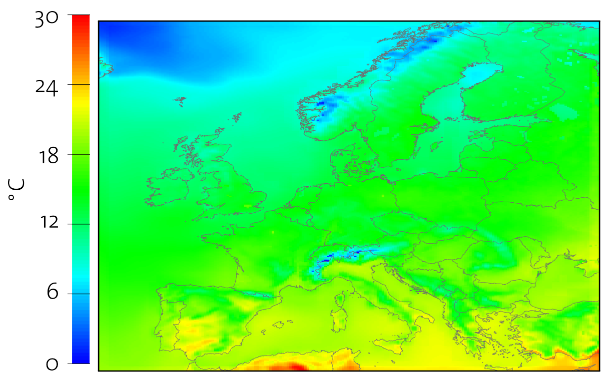
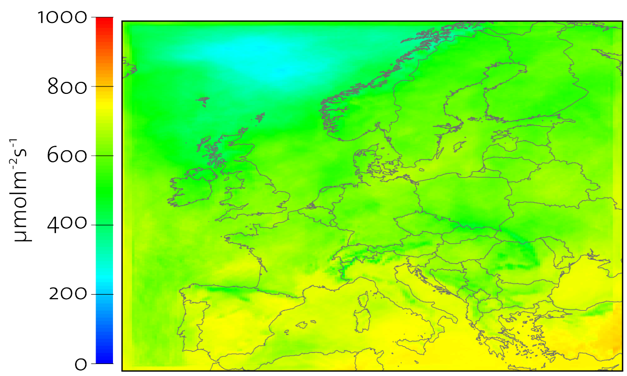


Figure Supp6: Total Emissions in January 2006 for the inventories S1-S3. From top: isoprene, monoterpenes, sesquiterpenes and oxygenated VOC. Note that the maximum of the colour scale is 1% of the scale in the corresponding figure for June 2006 (Figure 8) for isoprene and 10% for all other species.



(a) Temperature



(b) Photosynthetically active radiation (PAR)

Figure Supp7: Average temperature and irradiance fields for June 2006. The artifacts on the eastern and western boundaries of PAR can be explained by a spatial leapfrog effect (numerical diffusion) at the boundary.

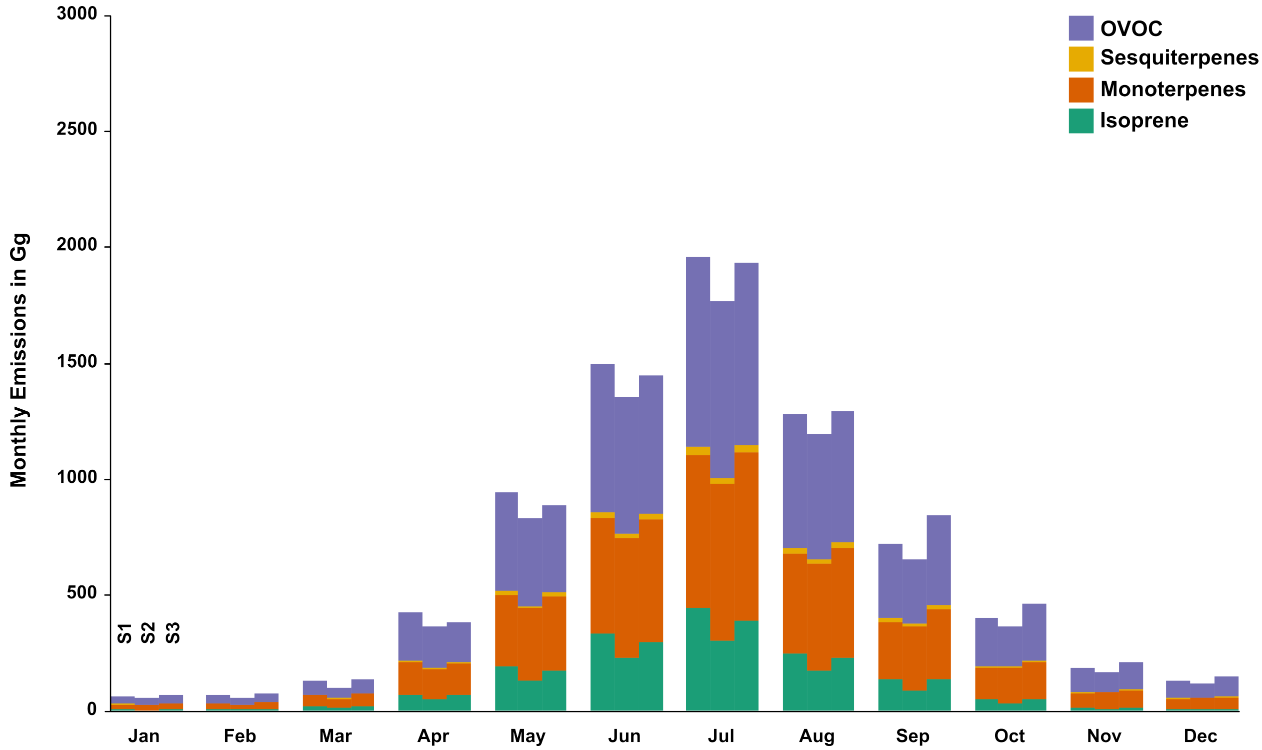


Figure Supp8: Yearly cycle of emissions in Europe (common countries). S1 and S2 are based on Globcover 2.2 using average f_c land-cover correction factors. Only biomass seasonality was applied for all inventories.

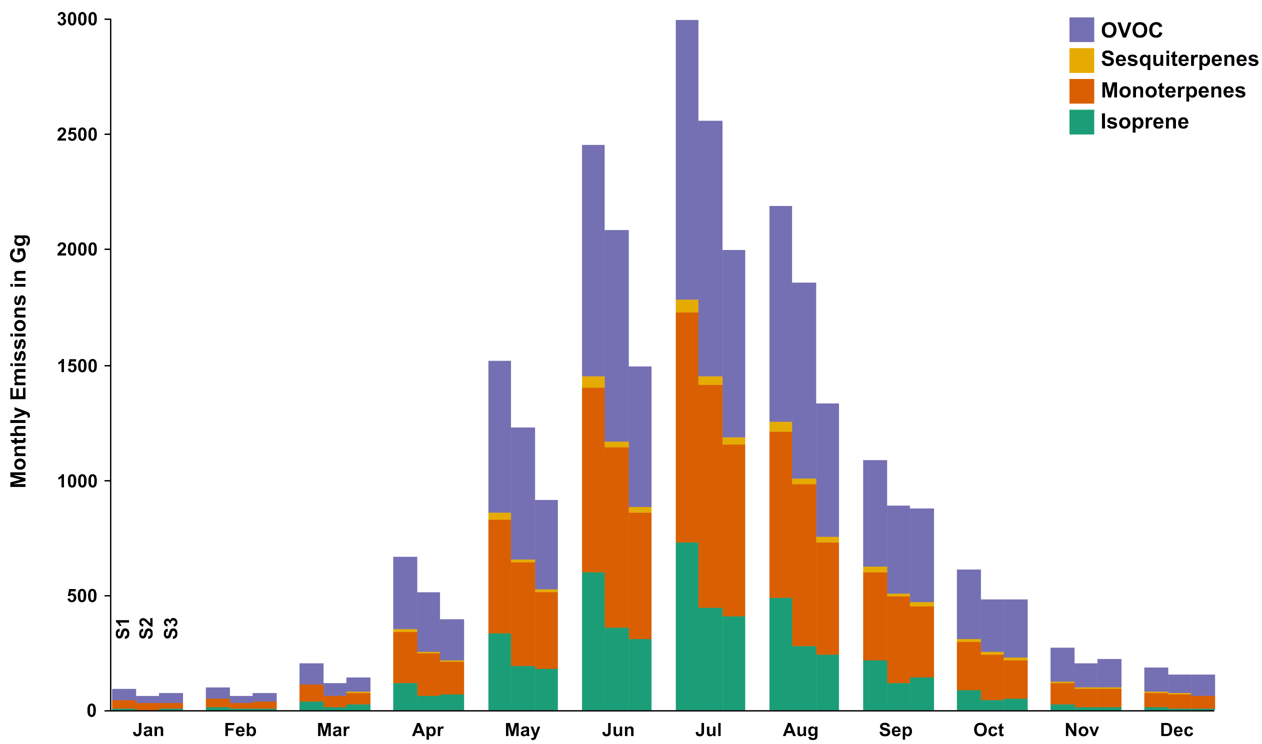


Figure Supp9: Yearly cycle of emissions in Europe (original countries). S1 and S2 are based on Globcover 2.2 using average f_c land-cover correction factors. Only biomass seasonality was applied for all inventories.

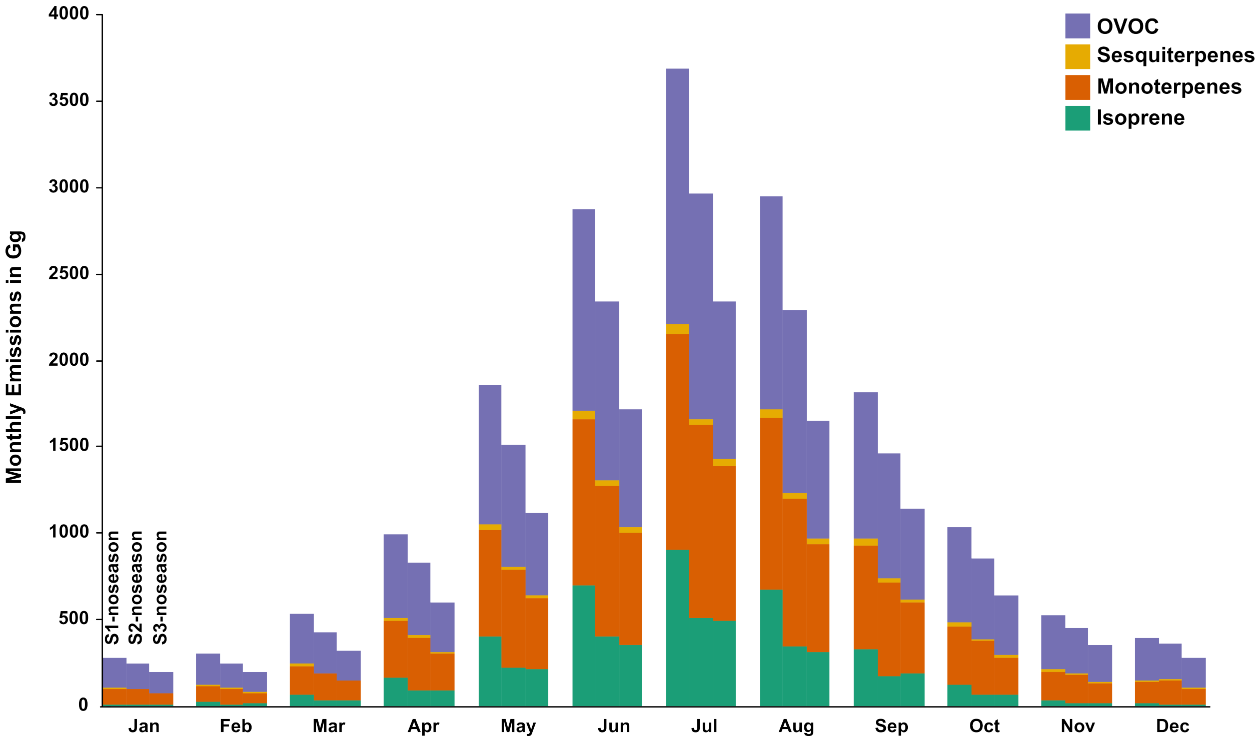


Figure Supp10: Yearly cycle of emissions in Europe (original countries) without any seasonal correction. S1 and S2 are based on Globcover 2.2 using average f_c land-cover correction factors.

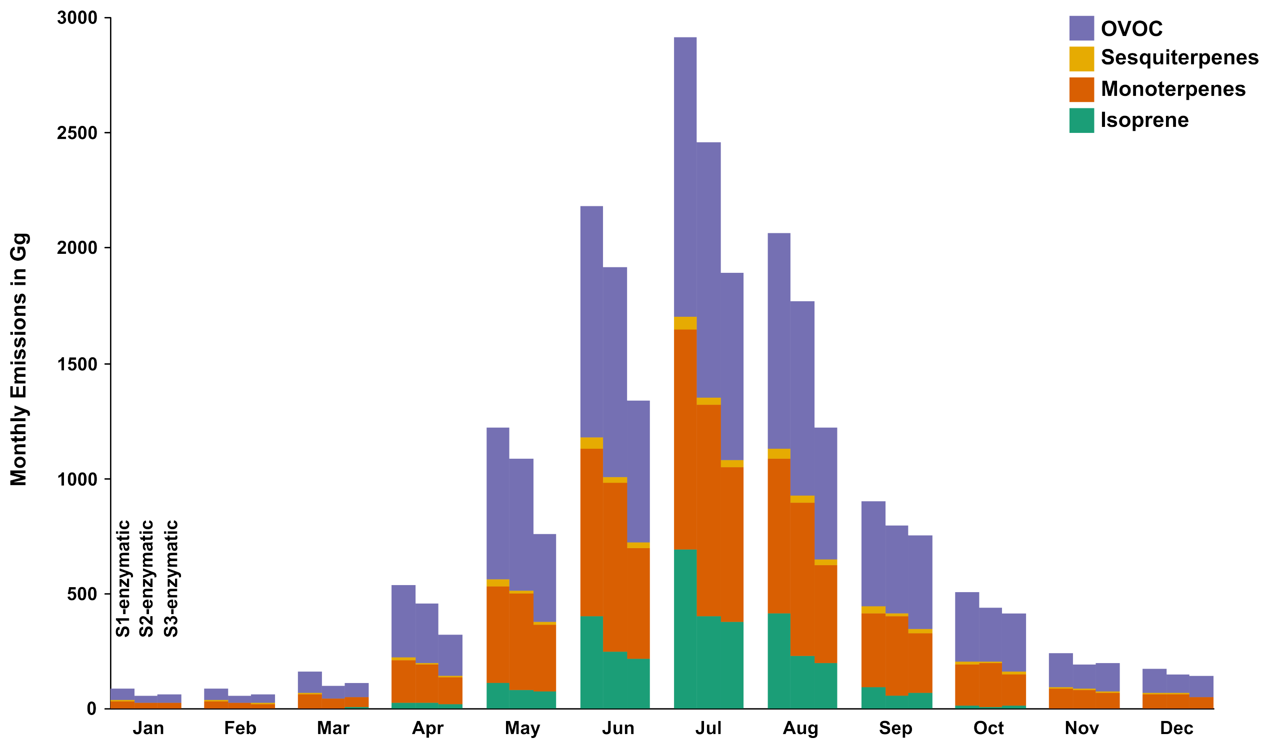
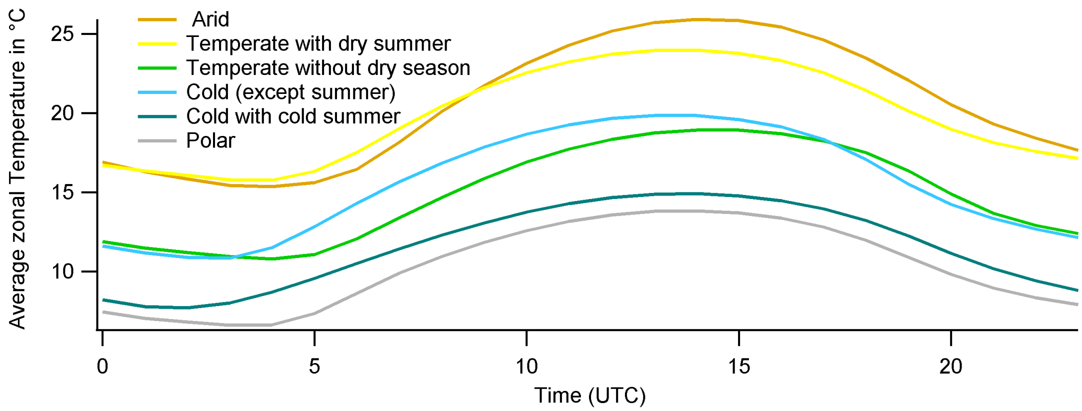
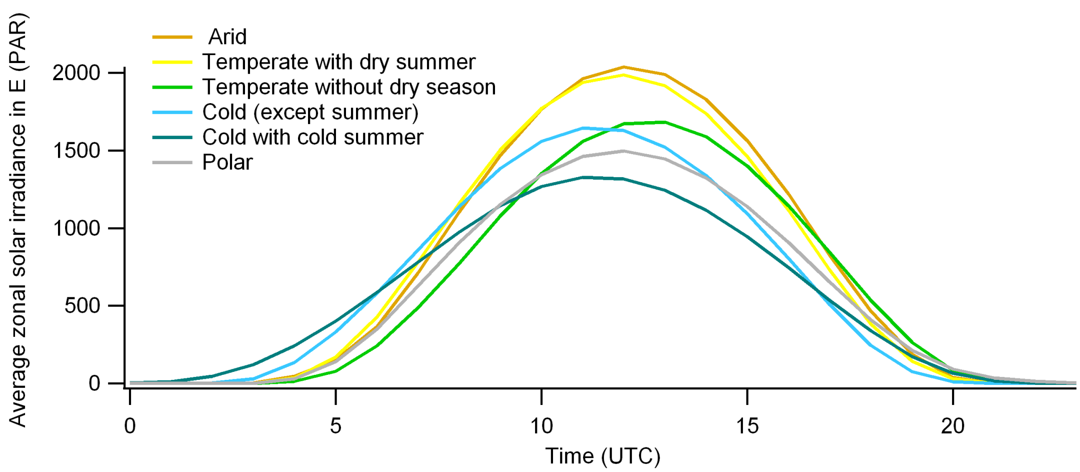


Figure Supp11: Yearly cycle of emissions in Europe (original countries). S1 and S2 are based on Globcover 2.2 using average f_c land-cover correction factors. Biomass and enzyme seasonality was applied for all inventories, which strongly affects isoprene and to a lesser extent monoterpenes.

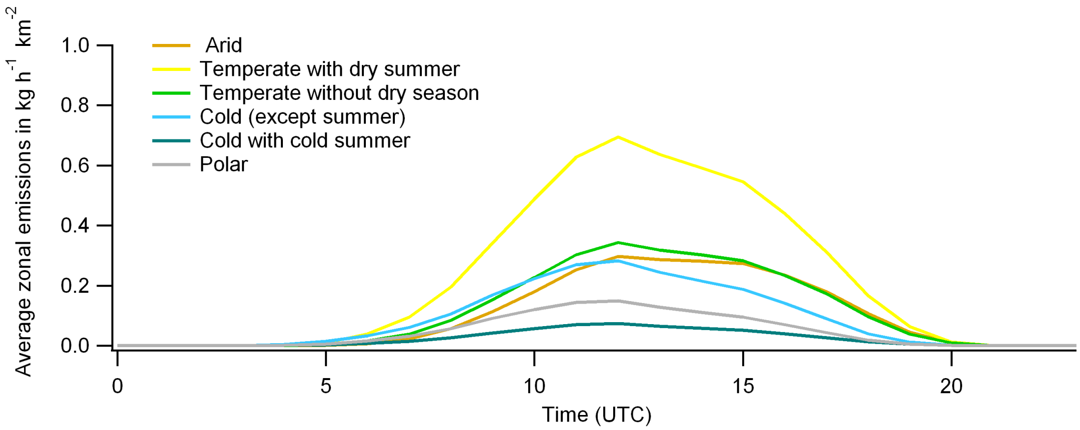


(a) Temperature

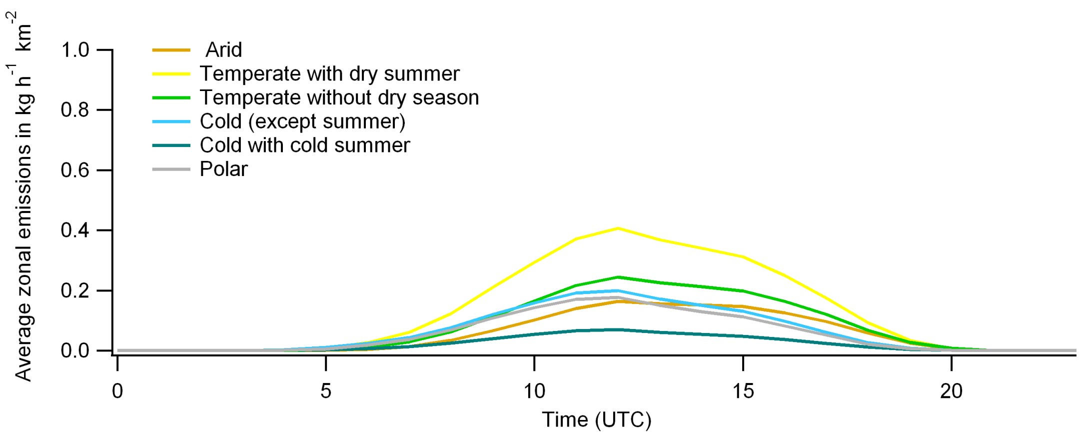


(b) Photosynthetically active radiation (PAR)

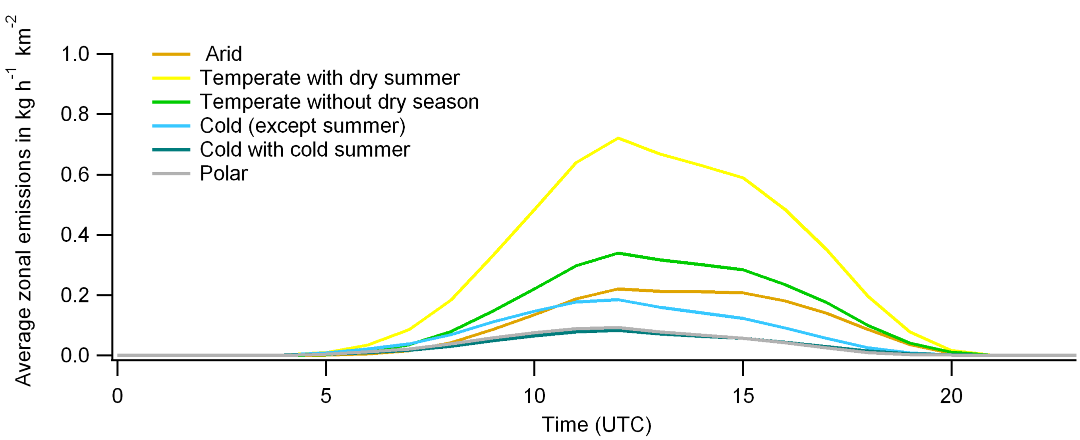
Figure Supp12: Average diurnal cycles of the environmental conditions in the climatic zones for June 2006. Since the time given is in UTC, a clear time shift is visible (for example between cold except summer and temperate without dry season). For consistency, the area of each climatic zone is restricted to the countries common to all vegetation inventories.



(a) S1

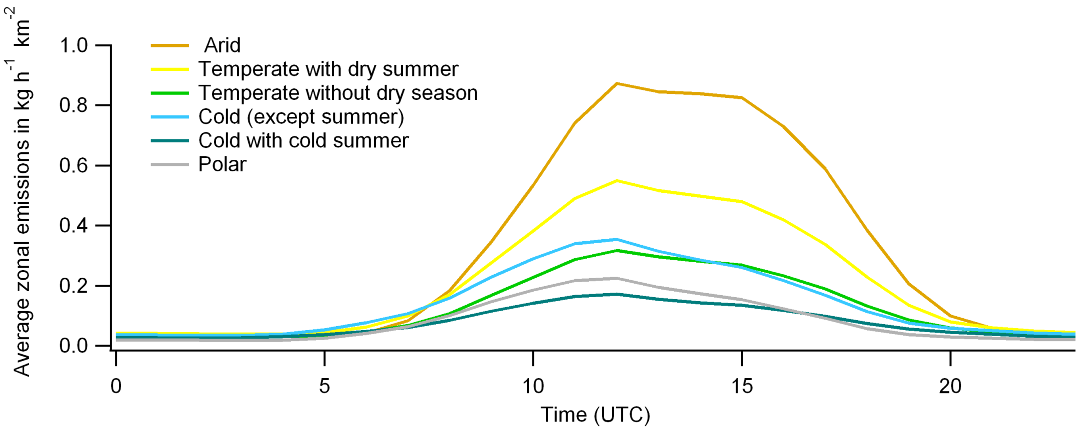


(b) S2

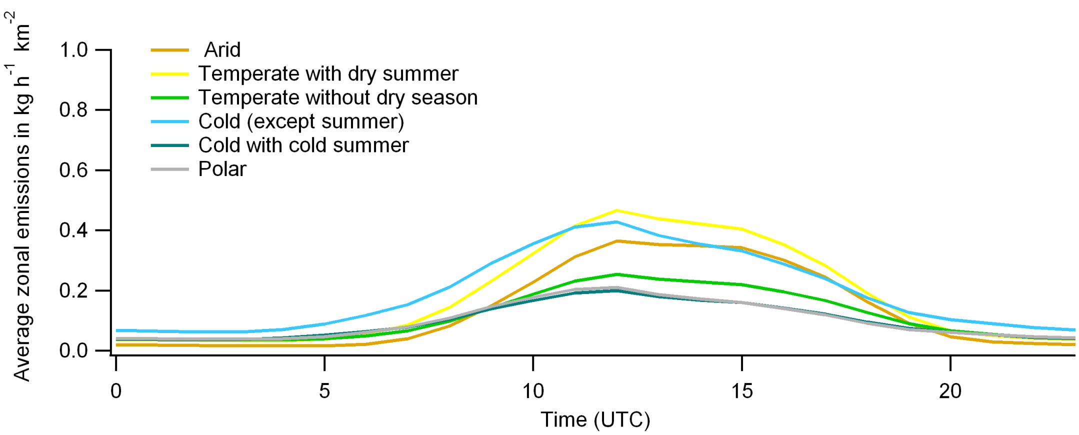


(c) S3

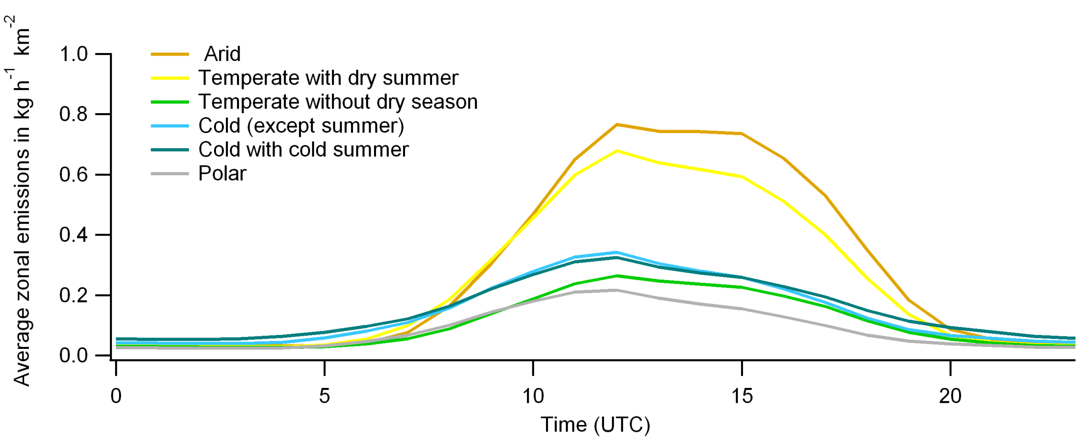
Figure Supp13: Average diurnal cycles for the climate zones (Isoprene in June 2006, common countries)



(a) S1

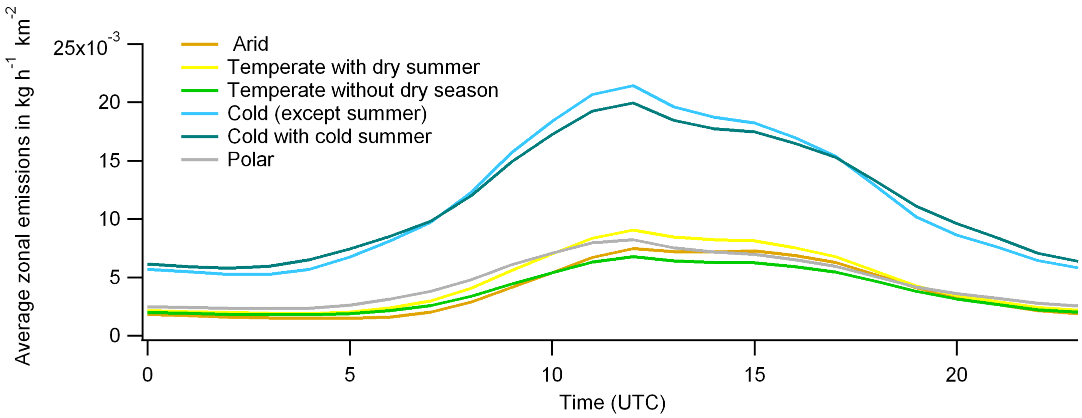


(b) S2

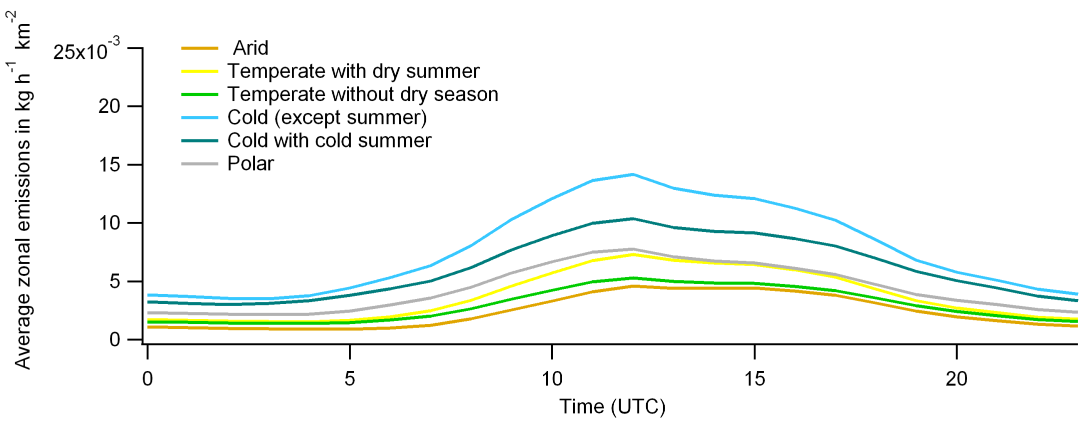


(c) S3

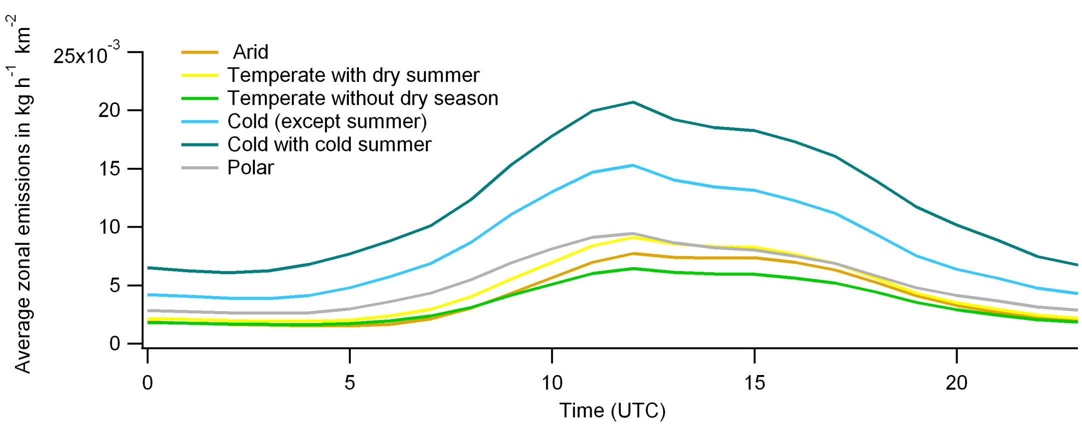
Figure Supp14: Average diurnal cycles for the climate zones (Monoterpenes in June 2006, common countries)



(a) S1



(b) S2



(c) S3

Figure Supp15: Average diurnal cycles for the climate zones (Sesquiterpenes in June 2006, common countries)

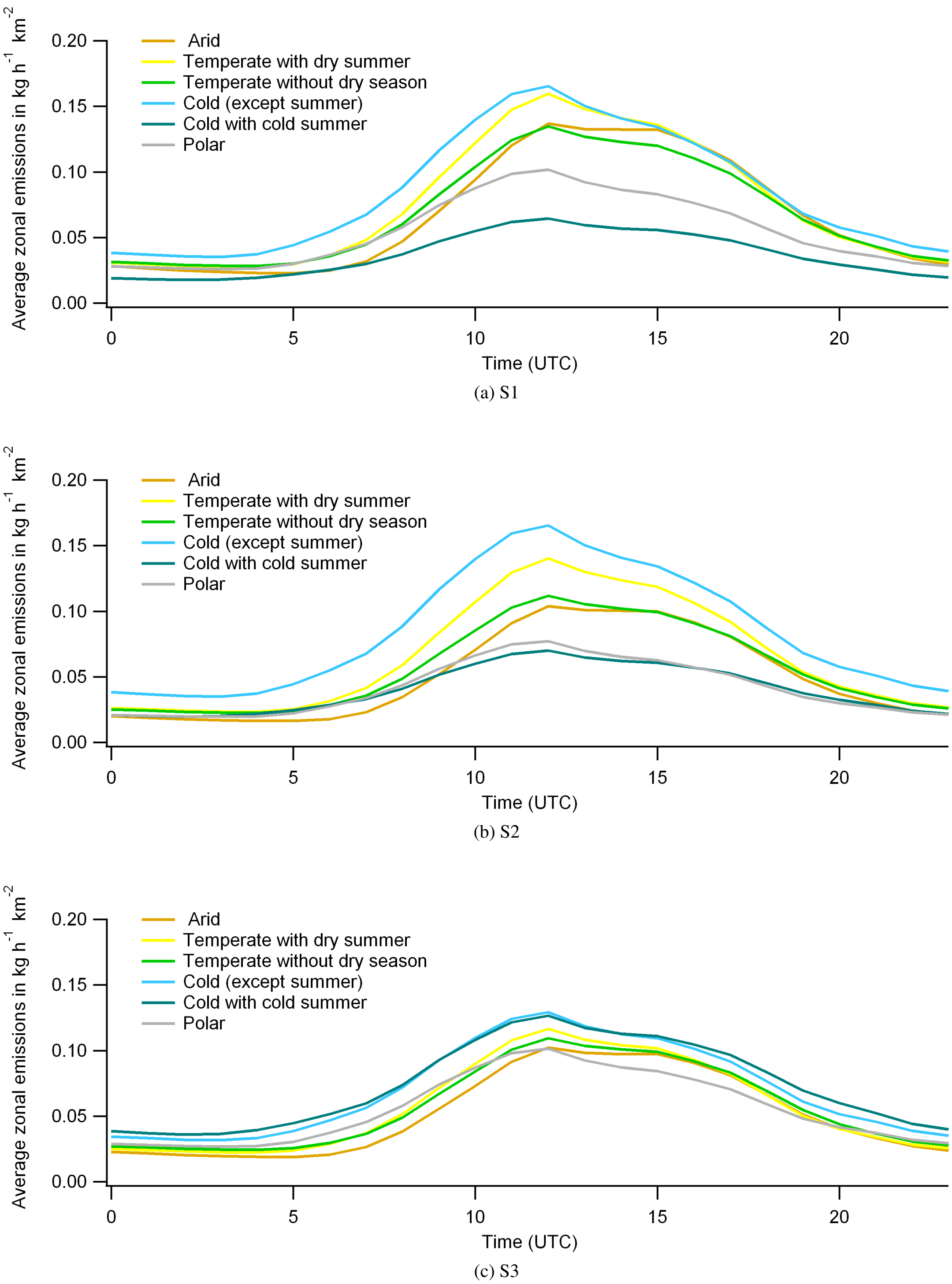


Figure Supp16: Average diurnal cycles for the climate zones (OVOC in June 2006, common countries)

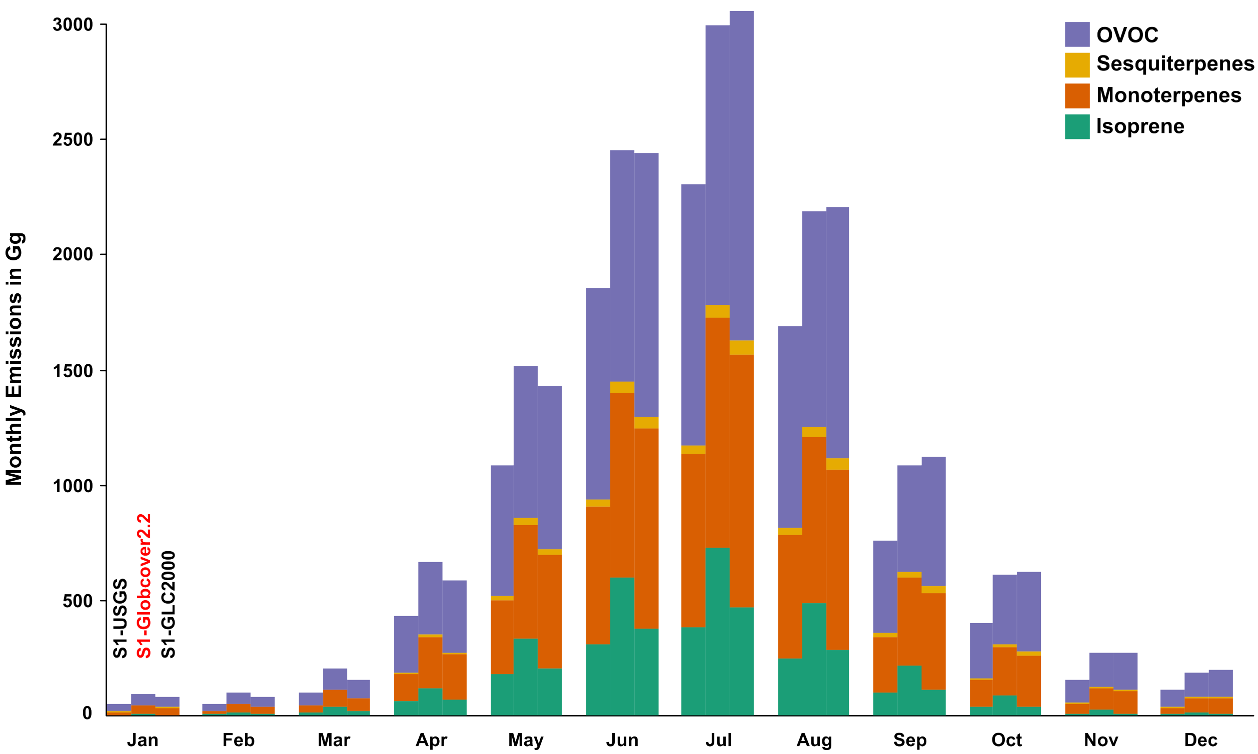


Figure Supp17: Yearly cycle of emissions in Europe using different land-cover data to construct S1. Left: USGS, Middle: Globcover 2.2, Right: GLC2000 (original countries)

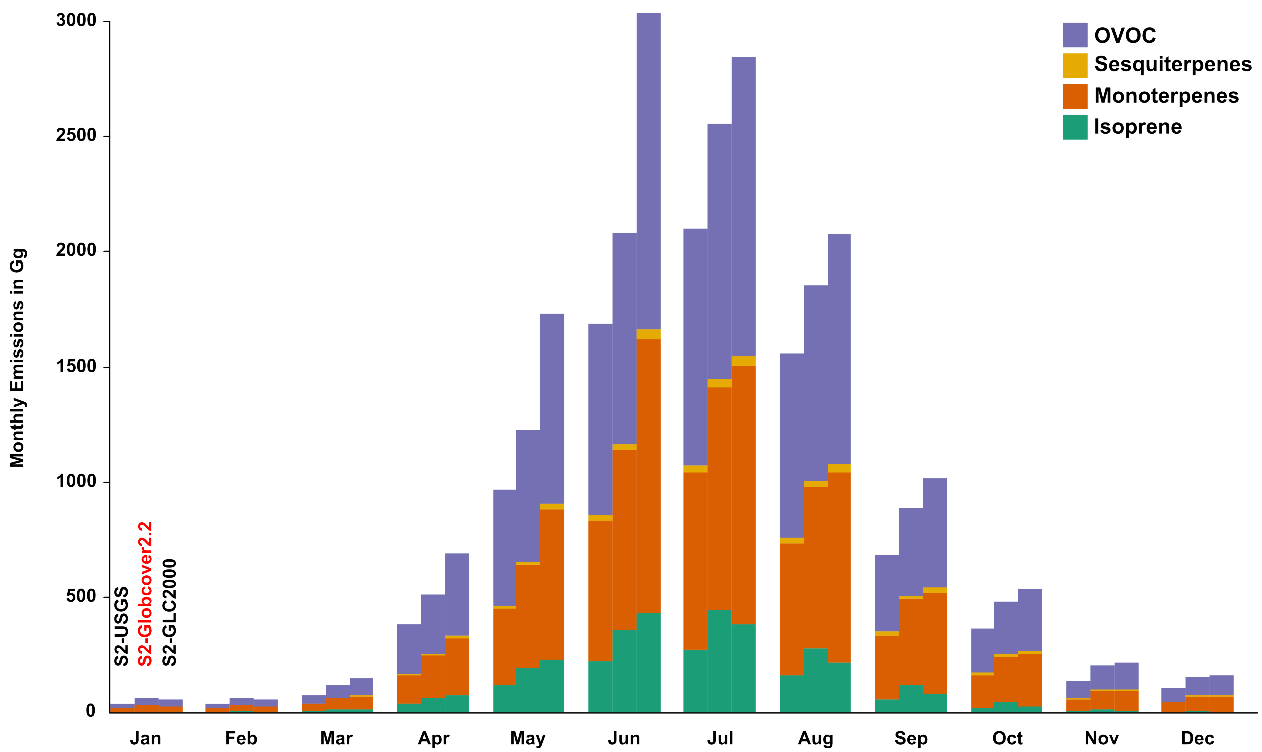
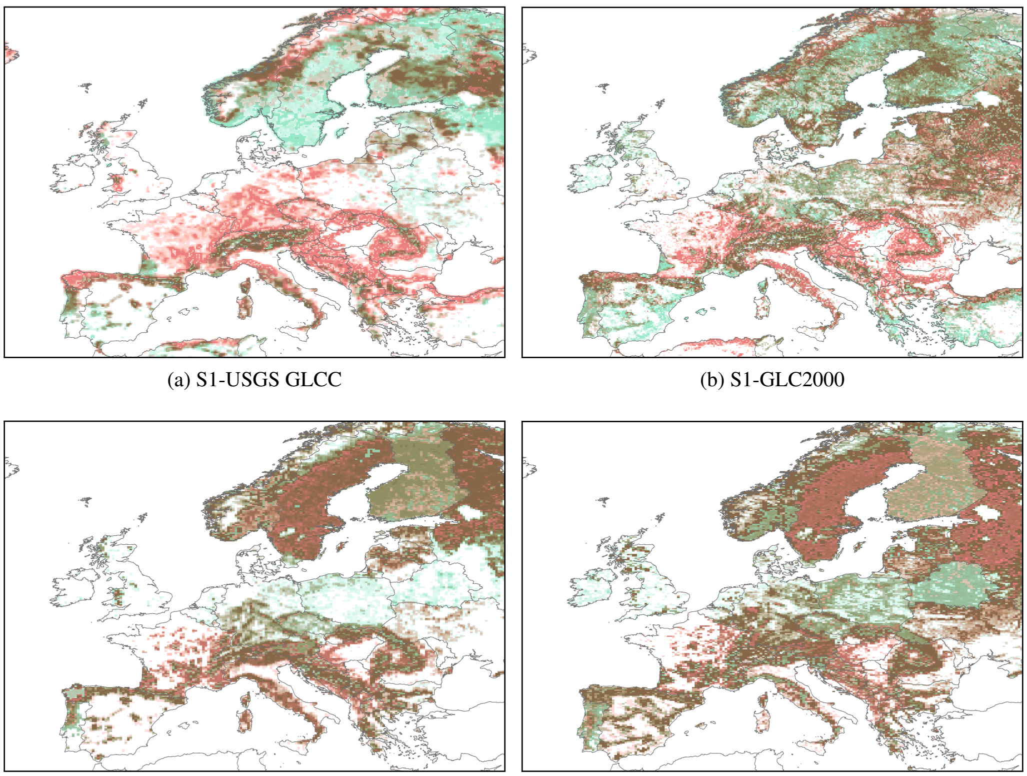


Figure Supp18: Yearly cycle of emissions in Europe using different land-cover data to construct S2. Left: USGS, Middle: Globcover 2.2, Right: GLC2000 (original countries)



(a) S1-USGS GLCC

(b) S1-GLC2000

(c) S2-USGS GLCC

(d) S2-GLC2000

Figure Supp19: False colour image of tree distribution of S1 and S2 based on USGS GLCC and GLC2000. Green channel: density of evergreen species, Red channel: density of deciduous species. The intensity of the colour is proportional to the fraction of the cell area covered by the given tree type.

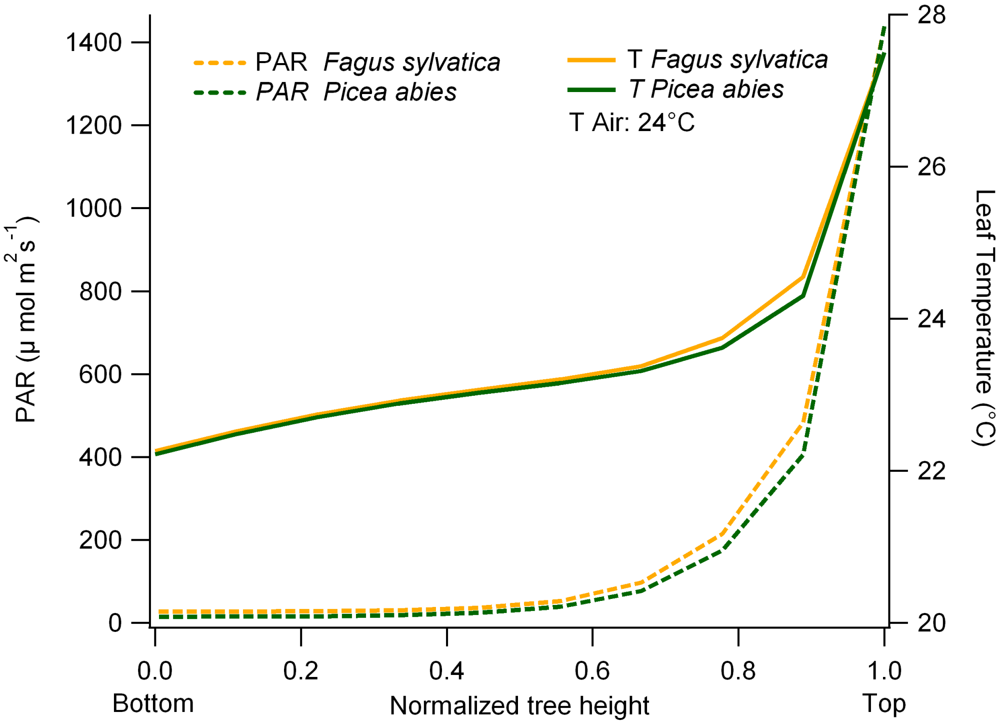
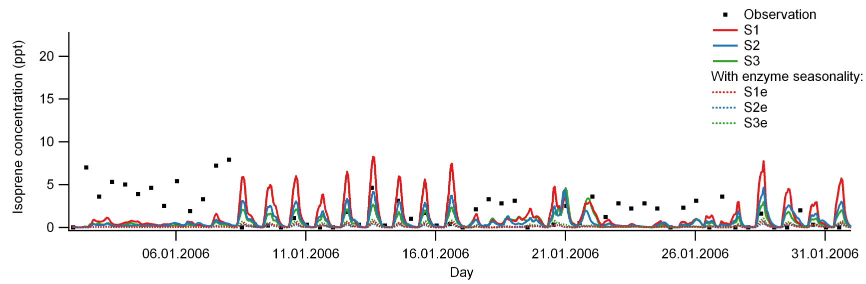
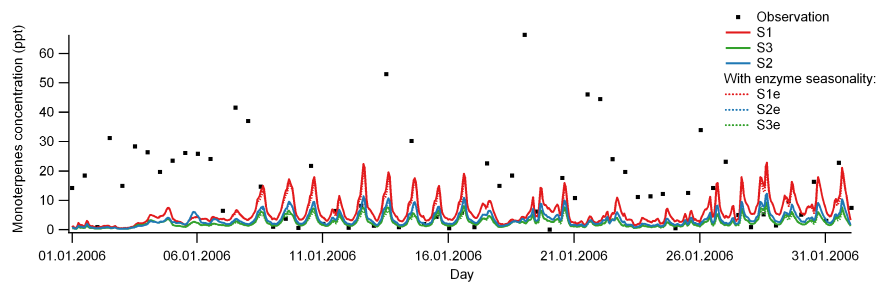


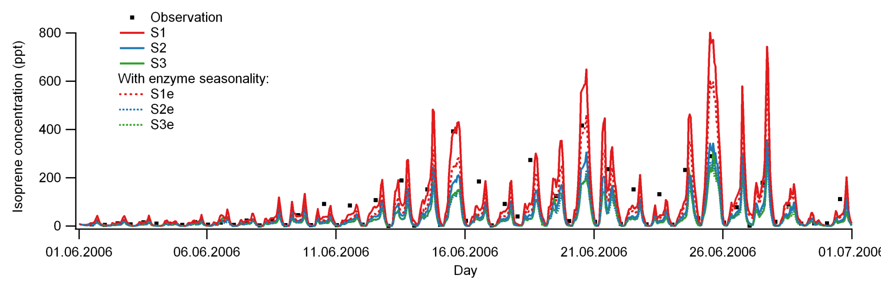
Figure Supp20: Plot of the model profiles of radiation and temperature in a canopy of *Picea abies* (LAI: 8.7) and *Fagus sylvatica* (LAI: 7.5) on the 15. June 2006 15:00 UTC near Payerne, Switzerland. Modelled air temperature is 24 °C.



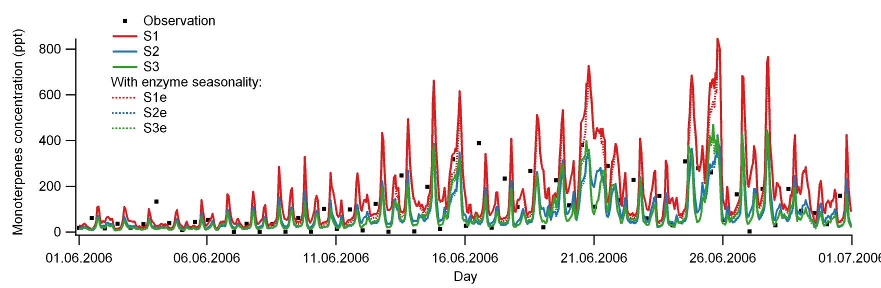
(a) Isoprene January 2006



(b) Monoterpenes January 2006

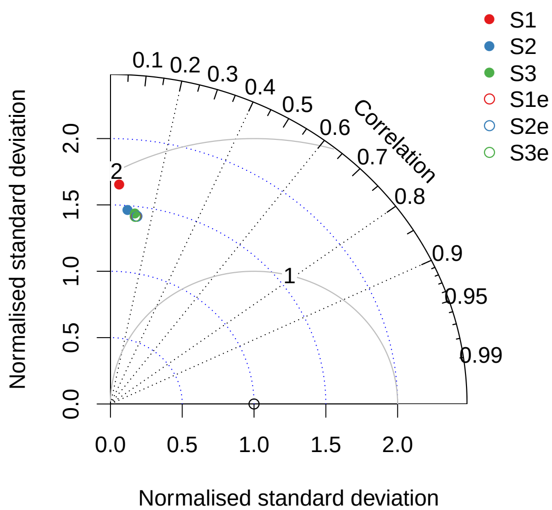


(c) Isoprene June 2006

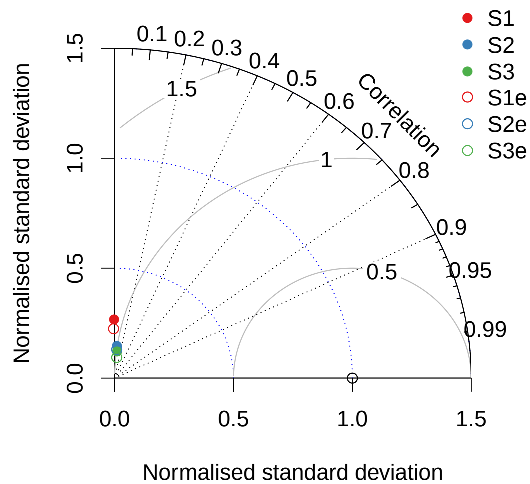


(d) Monoterpenes June 2006

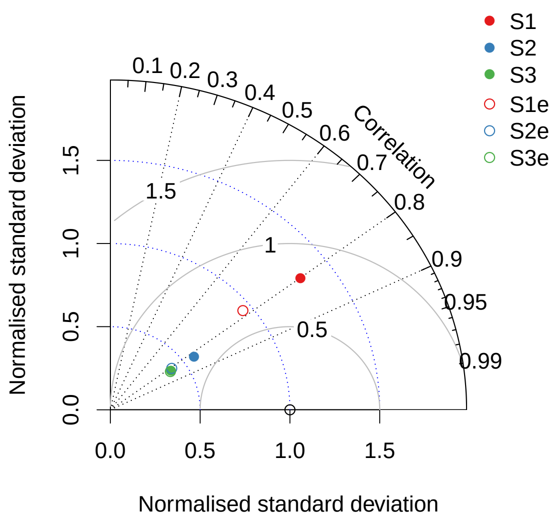
Figure Supp21: Timeseries of observed and modelled concentrations of target compounds at Hohenpeissenberg



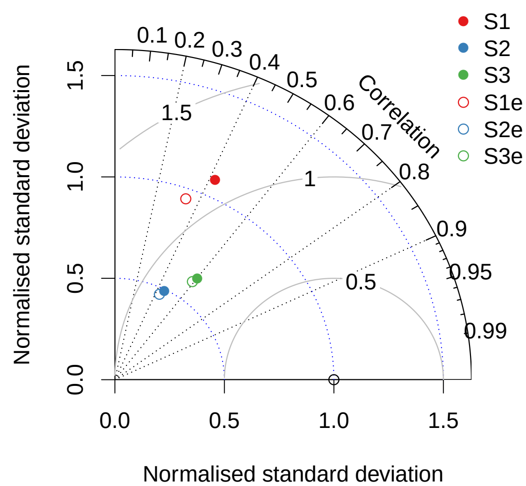
(a) Isoprene January 2006



(b) Monoterpenes January 2006



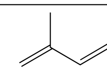
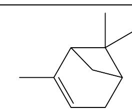
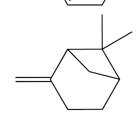
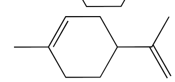
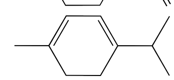
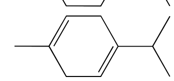
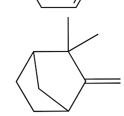
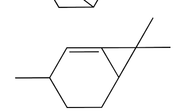
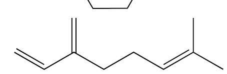
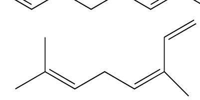
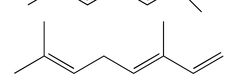
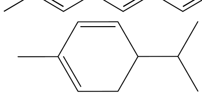
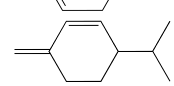
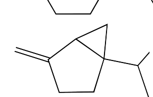
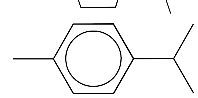
(c) Isoprene June 2006



(d) Monoterpenes June 2006

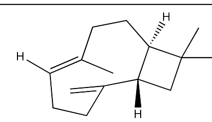
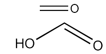
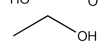
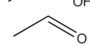
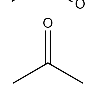
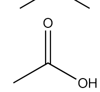
Figure Supp22: Taylor diagrams (Taylor, 2001) of observed and modelled concentrations at Hohenpeissenberg. The measured values are represented by the open circle on the x-axis, S1 by the red, S2 by the blue and S3 by the green filled circle. The corresponding scenarios with enzyme seasonality are represented by the coloured open circles. These diagrams encode three metrics: the distance of a point to the origin represents the standard deviation of a pattern, which is normalised to the standard deviation of the observation. The RMS difference between modelled values and observation is encoded in the distance between the models point and the point representing the observation. The correlation of modelled values and the observations is visualised by the angular position of the point representing the model.

Table 1: Most important known compounds emitted by plants. Hydrogen atoms are not explicitly shown, vertices indicate covalent bonds. Structure data from Linstrom et al. (2011). Species measured at Hohenpeissenberg are marked with *, species used as surrogates for a class in CMAx are printed **bold**. Fraction indicates the contribution of a substance to its class in the default splits given by Steinbrecher et al. (2009). Unless stated otherwise, lifetime data is from (Atkinson and Arey, 2003). Assumed oxidant concentrations: OH: 12-hour average of 2×10^6 molec.cm^{-3}, O_3: 24-hour average of $7 \times 10^1 1$ molec.cm^{-3}, NO_3: 12-hour average of 2.5×10^8 molec.cm^{-3}

Class	Name	Half-life due to			Fraction	Structure
		OH	O_3	NO_3		
Hemiterpenes (C_5H_8)	**Isoprene***	1.4 h	1.3 day	1.6 h	–	
Monoterpenes ($C_{10}H_{16}$)	***α*-Pinene***	2.6 h	4.6 h	11 min	29%	
	β-Pinene*	1.8 h	1.1 day	27 min	21%	
	Limonene	49 min	2.0 h	5 min	8%	
	α-Terpinene	23 min	1 min	0.5 min	1%	
	γ-Terpinene	47 min	2.8 h	2 min	1%	
	Camphene*	2.6 h	18 day	1.7 h	2%	
	Carene*	1.6 h	11 h	7 min	10%	
	Myrcene*	39 min	50 min	6 min	4%	
	Trans-Ocimene	33 min	44 min	3 min	2%	
	Cis-Ocimene	33 min	44 min	3 min	2%	
	α-Phellandrene*	27 min	8 min	0.9 min	0%	
	β-Phellandrene	50 min	8.4 h	8 min	5%	
	Sabinene*	1.2 h	4.8 h	7 min	7%	
	Cymene*[a]	9.2 h	$>$ 330 day	$>$ 93 day	4%	

[a]Rate constants from Corchnoy and Atkinson (1990) and Atkinson et al. (1990)

Table 1: Continued.

Class	Name	Half-life due to			Fraction	Structure
		OH	O_3	NO_3		
Sesquiterpenes ($C_{15}H_{24}$)	***β*-caryophyllene**	42 min	2 min	3 min	–	
Oxygenated VOC	Methanol	12 day	> 4.5 yr	2.0 yr	60%	
	Formaldehyde[a,b]	1.2 day	> 4.5 yr	160 day	2%	
	Formic acid[c]	12 day			2%	
	Ethanol[a]	3.5 day		52 day	11%	
	Acetaldehyde[a]	8.8 h	> 4.5 yr	34 day	11%	
	Acetone[a]	61 day	> 4.5 yr	> 8 yr	12%	
	Acetic acid[a]	7.8 day			2%	

[a]Lifetime data from Atkinson (2000) (adjusted to the same NO_3 concentration).
[b]Lifetime due to photolysis ≈ 4 h
[c]Rate constant from Atkinson et al. (2006)

Table 2: Derivation of molar mass of OVOC and molar fraction of its components. All masses are given in $\mathrm{g\,mol^{-1}}$. Mass fractions from (Steinbrecher et al., 2009)

Compound	Mass fraction	Molar mass
Methanol	0.60	32.04
Formaldehyde	0.02	30.03
Formic acid	0.02	46.03
Ethanol	0.11	46.07
Acetaldehyde	0.11	44.05
Acetone	0.12	58.08
Acetic acid	0.02	60.05
Surrogate molar mass of OVOC		38.83

Table 3: List of vegetation types used for the three inventories. D is the biomass density in g dryweight per per m^2 projected area, LAI is the leaf area index m^2 leaves per m^2 projected area, Type number describe the class of tree: (0) deciduous broad-leaved, (1) deciduous needle-leaved, (2) evergreen broad-leaved, (3) evergreen needle-leaved. $e_{0,ISOP}$, $e_{0,MTS}$, $e_{0,MTP}$, $e_{0,SQT}$ and $e_{0,OVOC}$ are the reference emission factors in µg h^{-1} $\mathrm{g}_{\mathrm{dryweight}}^{-1}$ for isoprene (ISOP), monoterpene synthesis (MTS), monoterpene pool (MTP), sesquiterpenes (SQT) and oxygenated VOC (OVOC), respectively. Crosses in S1, S2 and S3 indicate the presence of this tree in the respective inventory. Sources: A - (Steinbrecher et al., 2009), B - estimation of this study, C - (Smiatek and Steinbrecher, 2006)

Latin Name	Common Name	D	LAI	Type	$e_{0,ISOP}$	$e_{0,MTS}$	$e_{0,MTP}$	$e_{0,SQT}$	$e_{0,OVOC}$	S1	S2	S3	Source
Abies alba	White fir	1200	5	3	1	0.5	1	0.1	2	x		x	A
Abies borisii-regis	Bulgarian Fir	1260	5	3	18.4	2.5	0.2	0.1	2			x	A
Abies cephalonica	GreekFir	1200	5	3	0	0.26	0.63	0.1	2			x	A
Abies grandis	Grand Fir	1200	5	3	0	0.26	0.63	0.1	2			x	A
Abies Normanniana	Caucasian fir	1200	5	3	1	0.5	1	0.1	2	x			B
Abies procera	Noble fir	1200	5	3	1	0.5	1	0.1	2	x			B
Abies sp.	Fir	1200	5	3	1	0.5	1	0.1	2	x	x		B
Acer campestre	Field Maple	270	5	0	0	1.5	1.5	0.1	2			x	A
Acer monspessulanum	Montpellier Maple	270	5	0	0	1.5	0	0.1	2			x	A
Acer opalus	Italian Maple	270	5	0	0.1	1.5	0	0.1	2			x	A
Acer platanoides	Norway Maple	270	5	0	0.1	1.5	0	0.1	2			x	A
Acer sp.	Maple	270	5	0	0.1	1.5	0	0.1	2	x	x	x	A
Alnus cordata	Italian Alder	270	5	0	0	1.5	0	0.1	2			x	A
Alnus glutinosa	Black Alder	270	5	0	0	1.5	0	0.1	2			x	A
Alnus incana	Grey Alder	270	8	0	0	1.5	0	0.1	2			x	A
Alnus sp.	Alder	270	5	0	0	1.5	0	0.1	2	x	x		B
Alnus viridis	Green Alder	270	5	0	0	1.5	0	0.1	2			x	A
Arbutus andrachne	Greek Strawberry Tree	270	5	2	0	0	0	0.1	2			x	A
Arbutus unedo	Strawberry Tree	300	5	0	0.1	0	0.2	0.1	2			x	A
Betula pendula	Silver Birch	230	5	0	0	0	3	2	2			x	A
Betula pubescens	Downy Birch	230	5	0	0	0	3	2	2			x	A
Betula sp.	Birch	230	5	0	0	0	3	2	2	x	x		B
Buxus semperviridis	Common Box	400	5	2	10	0	0.2	0.1	2			x	A
Carpinus betulus	European hornbeam	300	5	0	0	0	0.1	0.1	2			x	A
Carpinus orientalis	Oriental Hornbeam	300	5	0	0	0	0	0.1	2			x	A
Carpinus sp.	Hornbeam	300	5	0	0	0	0.1	0.1	2	x			B
Castanea sativa	Chestnut	380	6	0	0	10	0	0.1	2	x	x	x	A
Cedrus atlantica	Atlas Cedar	700	5	3	0	0	1	0.1	2			x	A
Cedrus deodara	Deodar Cedar	700	5	3	0	0	1	0.1	2			x	A
Ceratonia siliqua	Carob tree	300	5	2	0	0	0	0.1	2			x	A
Cercis siliquastrum	Judas Tree	300	5	0	0	0	0	0.1	2			x	A
Corylus avellana	Common Hazel	300	5	0	0	0	0	0.1	2			x	A
Cupressus sempervirens	Mediterranean Cypress	700	5	3	0	0	0.7	0.1	2			x	A
Erica arborea	Tree Heath	700	5	2	13	0	0	0.1	2			x	A
Erica manipuliflora	autumn heath	700	5	2	0	0	0	0.1	2			x	A
Erica scoparia	Besom Heath	700	5	2	0	0	0	0.1	2			x	A
Eucalyptus sp.	Eucalyptus	650	5	2	50	0	5.41	0.1	2	x	x	x	A
Fagus moesiaca	Subspecies of European Beech	320	5	0	0	0	0	0.1	2			x	A
Fagus orientalis	Oriental beech	320	5	0	0	0	0	0.1	2			x	A
Fagus sp.	Beech	330	5	0	0	0	0	0.1	2	x	x		B
Fagus sylvatica	European beech	341	7.5	0	0	21.14	0	0.1	10	x		x	A
Fraxinus angustifolia	Narrow-leafed Ash	270	5	0	0	0	0	0.1	2			x	A
Fraxinus excelsior	European ash	270	5	0	0	0	0	0.1	2			x	A
Fraxinus ornus	Manna Ash	270	5	0	0	0	0	0.1	2			x	A
Fraxinus sp.	Ash	270	5	0	0	0	0	0.1	2	x	x		B
Ilex aquifolium	Holly	600	5	2	0	0	0	0.1	2			x	A
Juglans nigra	Eastern Black walnut	300	5	0	0	0	1	0.1	2			x	A
Juglans regia	Persian walnut	300	5	0	0	0	1	0.1	2			x	A
Juniperus communis	Common Juniper	700	5	3	0	0.3	0.6	0.1	2			x	A
Juniperus oxycedrus	Prickly Juniper	700	5	3	0	0	1.5	0.1	2			x	A
Juniperus phoenicea	Phoenicean Juniper	700	5	3	0	0	1.5	0.1	2			x	A
Juniperus sp.	Juniper	700	5	3	0	0.075	0.9	0.1	2	x			B
Juniperus thurifera	Spanish Juniper	700	5	3	0	0	0	0.1	2			x	A
Larix decidua	European larch	300	5	1	0	0	5	0.1	2			x	A
Larix kaempferi	Japanese Larch	300	5	1	0	0	5	0.1	2			x	A
Larix sp.	Larch	300	5	0	0	0	5	0.1	2	x	x		B
Laurus nobilis	bay laurel	300	5	2	0	0	0	0.1	2			x	A
Malus domestica	Apple	300	5	0	0	0	0	0.1	2			x	A
	Mixed forest	850	5	1		5	1.5	0	0			x	C
Olea europaea	Olive	300	5	2	0	0	0.1	0.1	2			x	A
Olea sp.	Olive	300	5	2	0	0	0.05	0.1	2	x			B
Ostrya carpinifolia	Hop Hornbeam	300	5	0	0	0	0	0.1	2			x	A
	Other broad-leaved	320	5	0	5	0	0	0.1	2	x		x	A
	Other needle-leaved	700	5	3	1	1	2	0.1	2	x		x	A
Phillyrea latifolia	Green Olive Tree	300	5	2	0	0	0.5	0.1	2			x	A
Picea abies	Norway spruce	1400	8.7	3	1	2.1	0.4	0.1	2.3	x	x	x	A
Picea sitchensis	Sitka spruce	1400	9.8	3	4.75	0	6.46	0.1	2.89	x	x	x	A
Picea sp.	Spruce	1400	9	3	3	1	3	0.1	2.5	x	x		B

Table 3: Continued.

Latin Name	Common Name	D	LAI	Type	$e_{0,ISOP}$	$e_{0,MTS}$	$e_{0,MTP}$	$e_{0,SQT}$	$e_{0,OVOC}$	S1	S2	S3	Source
Pinus brutia	Turkish pine	700	5	3	0	0	2	0.1	2		x	x	A
Pinus canariensis	Canary Island Pine	700	5	3	0	0	6	0.1	2			x	A
Pinus cembra	Swiss pine	700	5	3	0	0	2.5	0.1	2		x	x	A
Pinus contorta	Lodgepole Pine	700	5	3	0	0	6	0.1	2		x	x	A
Pinus halepensis	Aleppo pine	700	4.6	3	0	0	2.7	0.1	2	x	x	x	A
Pinus leucodermis	Bosnian Pine	700	5	3	0	0	6	0.1	2			x	A
Pinus mugo	Mountain Pine	700	5	3	0	0	6	0.1	2			x	A
Pinus nigra	Black pine	700	5	3	0	3	3	0.1	2	x	x	x	A
Pinus pinaster	Maritime pine	700	2.3	3	0	0	2	0.1	2	x	x	x	A
Pinus pinea	Stone Pine	700	5	3	0	3	3	0.1	1.8			x	A
Pinus radiata	Monterey Pine	700	5	3	0	3	3	0.1	2			x	A
Pinus sp.	Pine	700	5	3	0	1.2	4	0.1	2	x	x		B
Pinus strobus	EasternWhite Pine	700	5.7	3	0	2.5	2.5	0.1	2			x	A
Pinus sylvestris	Scots pine	700	3.8	3	0	2.5	2.5	0.1	2	x	x	x	A
Pinus uncinata	Mountain Pine	700	5	3	0	2.5	2.5	0.1	2			x	A
Pistacia lentiscus	Mastic	320	5	2	0	0	0.6	0.1	2			x	A
Pistacia terebinthus	Turpentine Tree	320	5	2	0	0	0.1	0.1	2			x	A
Platanus orientalis	Oriental Plane	260	5	0	18.5	0	0.1	0.1	2			x	A
Populus alba	White Poplar	260	5	0	60	0	0	0.1	2			x	A
Populus canascens	Grey Poplar	260	5	0	70	0	0	0.1	3.46			x	A
Populus hybrides	Poplar Hybrid	260	5	0	70	0	0	0.1	2			x	A
Populus nigra	Black Poplar	260	5	0	70	0	0	0.1	2			x	A
Populus sp.	Poplars	260	5	0	66	0	0	0.1	2.3	x	x		B
Populus tremula	Common Aspen	260	7	0	60	0	0	0.1	2			x	A
Prunus avium	Wild cherry	270	5	0	0	0	0.1	0.1	2			x	A
Prunus padus	Bird Cherry	270	5	0	0	0	0.1	0.1	2			x	A
Prunus serotina	Black cherry	270	5	0	0	0	0.1	0.1	2			x	A
Pseudotsuga menziesii	Douglas fir	1000	10	3	1	0	2	0.1	2	x		x	A
Pyrus communis	European Pear	300	5	0	0	0	0	0.1	2			x	A
Quercus cerris	Turkey oak	320	5	0	0.1	0	0.6	0.1	2	x	x	x	A
Quercus coccifera	Kermes Oak	500	3	2	0.1	25	0	0.1	2			x	A
Quercus faginea	Portuguese Oak	320	5	0	111	0	0	0.1	2	x	x	x	A
Quercus frainetto	Hungarian Oak	320	5	0	85	0	0	0.1	2			x	A
Quercus fructosa		500	5	2	0.1	20	0	0.1	2			x	A
Quercus ilex	Evergreen Oak	600	5	2	0.1	43	0	0.1	4.08	x	x	x	A
Quercus macrolepsis	Valonia Oak	320	5	0	0.2	0	0.7	0.1	2			x	A
Quercus petraea	Sessile Oak	320	5.5	0	45	0	0.3	0.1	2	x	x	x	A
Quercus pubescens	Downy Oak	320	5	0	70	0	0.3	0.1	2	x	x	x	A
Quercus pyrenaica	Pyrenean Oak	320	5	0	59	0	0.3	0.1	2			x	A
Quercus robur	Pedunculate Oak	320	5.5	0	70	0	1	0.1	2	x	x	x	A
Quercus rotundifolia	Holm Oak	600	4	2	0.2	14.6	0	0.1	2			x	A
Quercus rubra	Red oak	320	4	0	35	0	0.1	0.1	2	x		x	A
Quercus sp.	Oak	380	5	0	32	8	0.2	0.1	2	x	x		B
Quercus suber	Cork oak	500	5	2	0.2	20	0	0.1	2	x	x	x	A
Quercus trojana	Macedonian Oak	320	5	2	0.2	0	0.2	0.1	2			x	A
Robinia pseudoacacia	Black locust	300	5	0	12	0	0.1	0.1	2	x		x	A
Salix alba	White Willow	300	5	0	37.2	0	1.1	0.1	2			x	A
Salix caprea	Goat Willow	300	5	0	18.9	0	0.1	0.1	2			x	A
Salix cinerea	Grey Willow	300	5	0	28	0	0.8	0.1	2			x	A
Salix eleagnos	Rosemary Willow	300	5	0	28	0	0.8	0.1	2			x	A
Salix sp.	Willows	300	5	0	28	0	0.8	0.1	2		x	x	A
Sorbus aria	Whitebeam	300	5	0	0	0	0	0.1	2			x	A
Sorbus aucuparia	Rowan	300	5	0	0	0	0	0.1	2			x	A
Sorbus domestica	Service Tree	300	5	0	0	0	0	0.1	2			x	A
Sorbus torminalis	Wild Service Tree	300	5	0	0	0	0	0.1	2			x	A
Taxus baccata	European Yew	300	5	3	0	0	0	0.1	2			x	A
Thuya sp.	Thuja	700	5	3	0	0	0.6	0.1	2			x	A
Tilia cordata	Small-leaved Lime	300	4.5	0	0	0	0	0.1	2			x	A
Tilia platyphyllos	Large-leaved Lime	300	5	0	0	0	0	0.1	2			x	A
Tsuga sp.	Tsuga	1200	5	3	0.1	0	0.2	0.1	2			x	A
Ulmus glabra	Scots elm	300	5	0	0.1	0	0.1	0.1	2			x	A
Ulmus laevis	European White Elm	300	5	0	0.1	0	0.1	0.1	2			x	A
Ulmus minor	Field Elm	300	5	0	0.1	0	0.1	0.1	2			x	A
Ulmus sp.	Elm	300	5	0	0.1	0	0.1	0.1	2	x			B
	Agriculture	500	5	0	0.5	0.5	0.5	0	2	x	x	x	C
	Grassland	250	5	0	0.5	0.5	0.5	0	2	x	x	x	C
	Uncategorized tree	500	6	0	10	3	3	0.1	2			x	A

Table 4: Formulas used for the environmental correction factors γ_P and γ_S Guenther (1997). PAR is the photosynthetically available radiation in $\mu\text{mol}\,\text{m}^{-2}\,\text{s}^{-1}$ (see section "canopy model" of the main text for a detailed discussion), T is the temperature in K and R is the gas constant (8.314 J mol^{-1} K^{-1}). The empirical coefficients have these values: $\alpha = 0.0027, \beta = 0.09, T_0 = 303.15\,\text{K}, T_M = 314\,\text{K}$,
$L_0 = 1000\,\mu\text{mol}\,\text{m}^{-2}\,\text{s}^{-1}, C_{T1} = 95000$ J $\text{mol}^{-1}, C_{T2} = 230000$ J mol^{-1}

Factor		Formula
γ_S	=	$\frac{\alpha\times(\sqrt{(1+\alpha\times PAR_0^2)/(\alpha\times PAR_0^2)}))\times PAR}{\sqrt{1+\alpha^2\times PAR^2}} \times \frac{\exp\frac{C_{T1}\times(T-T_0)}{R\times T\times T_0}}{(1-\exp(\frac{(C_T2\times(T_0-T_M)}{R\times T_0\times T_0}))+\exp\frac{C_{T2}\times(T-T_M)}{R\times T\times T_0}}$
γ_P	=	$\exp(\beta\times(T-T_0))$

Table 5: Regional Globcover codes (Id) and land-cover correction factors f_c used to derive area density of needle-leaved and broad-leaved trees in Europe for S1 and S2. B=broad-leaved, N=needle-leaved

Id	Category	Class	f_c S1	f_c S2
40	Closed to open (>15%) broadl. everg. or semi-decid. forest (>5m)	B	0.43	0.43
41	Closed (>40%) broadl. decid. forest (>5m)	B	0.70	0.70
42	Open (<40%) broadl. deciduous forest (>5m)	B	0.20	0.20
50	Closed (>40%) broadl. decid. forest (>5m)	B	0.70	0.70
60	Open (15-40%) broadl. decid. forest/woodland (>5m)	B	0.28	0.28
134	Closed to open (>15%) broadl. decid. shrubland (<5m)	B	0.43	0.43
160	Closed to open broadl. forest regularly flooded	B	1.00	1.00
161	Closed to open broadl. forest (semi-)permanently flooded	B	1.00	1.00
162	Closed to open broadl. forest temporarily flooded	B	1.00	1.00
170	Closed (>40%) broadl. forest or shrubland permanently flooded	B	0.70	0.70
70	Closed (>40%) needl. everg. forest (>5m)	N	0.70	0.70
90	Open (15-40%) needl. decid. or everg. forest (>5m)	N	0.28	0.28
91	Open (15-40%) needl. decid. forest (>5m)	N	0.28	0.28
92	Open (15-40%) needl. everg. forest (>5m)	N	0.28	0.28
16	Rainfed shrub or tree crops	N/B	0.50	1.00
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	N/B	0.18	0.35
22	Mosaic cropland/Forests	N/B	0.25	0.50
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	N/B	0.30	0.60
32	Mosaic forest (50-70%) / cropland (20-50%)	N/B	0.30	0.60
100	Closed to open (>15%) mixed broadl. and needl. forest (>5m)	N/B	0.30	0.60
101	Closed (>40%) mixed broadl. and needl. forest (>5m)	N/B	0.35	0.70
102	Open (<40%) mixed broadl. and needl. forest (>5m)	N/B	0.10	0.20
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	N/B	0.30	0.60
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	N/B	0.18	0.35
130	Closed to open (>15%) (broadl. or needl., everg. or decid.) shrubland (<5m)	N/B	0.21	0.43
131	Closed to open (>15%) broadl. or needl. everg. shrubland (<5m)	N/B	0.21	0.43
180	Closed to open (>15%) grassland or woody vegetation regularly flooded	N/B	0.21	0.43
181	Closed to open woody vegetation regularly flooded	N/B	0.21	0.43

Table 6: Comparison of the forest area (km^2) in the three inventories with data given by Skjøth et al. (2008) (based on GLC2000) and Simpson et al. (1999) (based on (Organization, 1997)). N/A indicates not available.

	Skjoeth, 2008	Simpson, 1999	S1	S2	S3
Albania	4594	10460	28581	14260	N/A
Algeria	21348	10461	109058	48102	N/A
Austria	58624	32270	47263	33639	46246
Belarus	116026	73834	158602	89168	80561
Belgium	6239	6170	13847	6328	15090
Bosnia & Herzegovina	19735	23724	43571	25618	N/A
Cyprus	N/A	N/A	199	N/A	N/A
Bulgaria	35180	38710	72074	42654	38919
Croatia	21354	20776	38005	19200	19545
Czech Republic	31421	26421	58974	31818	35912
Denmark	4836	4930	20131	6906	6571
Estonia	25331	18692	26225	19874	24277
Finland	265245	232220	125970	122926	207656
France	146021	148500	259710	112411	288270
Germany	111639	104030	183467	100220	157319
Greece	30459	26200	54767	31241	35252
Hungary	14240	17010	61866	22142	26290
Iceland	N/A	1200	N/A	N/A	N/A
Ireland	3124	3450	32386	9579	41774
Italy	116542	67520	164562	80447	107133
Kosovo	N/A	N/A	8107	N/A	N/A
Latvia	30655	28032	39607	29082	40393
Lithuania	21087	19677	38175	21870	29270
Luxembourg	792	886	1425	849	1985
Macedonia	8100	10790	20048	11935	N/A
Moldova	1794	3570	30475	10172	N/A
Montenegro[a]	N/A	N/A	8837	N/A	N/A

[a]Montenegro is independent since 2006

Table 6: Continued.

	Skjoeth, 2008	Simpson, 1999	S1	S2	S3
Morocco	1507	N/A	8404	5291	N/A
Netherlands	2336	3000	14935	6258	20694
Norway	155707	83300	55629	52985	160869
Poland	100144	87810	185108	87035	140617
Portugal	46865	29680	41690	26710	30069
Romania	85134	66900	138138	67569	72036
Russian Federation	1161884[a]	1446420[a]	270548	221833	N/A
Serbia	N/A	N/A	63662	N/A	N/A
Serbia & Montenegro[b]	28215	41196	72499	35697	N/A
Slovakia	25251	19400	28357	16379	18191
Slovenia	15492	10140	11431	8962	13766
Spain	164795	158580	243311	131347	156688
Sweden	341412	280200	157168	150512	293941
Switzerland	23933	10520	18839	12449	16487
Tunisia	4686	N/A	32747	11854	N/A
Turkey	155830	N/A	324869	167791	N/A
Ukraine	130012	92930	391876	155204	N/A
United Kingdom	10425	24100	119645	45485	99811

[a]European part
[b]Montenegro is independent since 2006

Table 7: Total annual emissions in Gg for the tree inventories in each climatic zone (original countries).

Compound	Zone	S1	S2	S3
ISOP	Arid	191	62	68
	Temperate with dry summer	835	306	510
	Temperate without dry season	538	383	458
	Cold except summer	982	660	325
	Cold with cold summer	80	87	75
	Polar	24	29	14
MT	Arid	481	168	293
	Temperate with dry summer	1022	513	611
	Temperate without dry season	749	663	590
	Cold except summer	1486	2060	951
	Cold with cold summer	336	439	467
	Polar	49	63	51
SQT	Arid	9	3	5
	Temperate with dry summer	28	11	14
	Temperate without dry season	29	21	23
	Cold except summer	138	81	63
	Cold with cold summer	50	24	41
	Polar	3	3	3
OVOC	Arid	363	222	160
	Temperate with dry summer	1020	631	419
	Temperate without dry season	1133	863	877
	Cold except summer	2310	2375	1361
	Cold with cold summer	405	455	658
	Polar	96	72	95

Table 8: Total annual emissions in Gg for the tree inventories in each climatic zone (common countries).

Compound	Zone	S1	S2	S3
ISOP	Arid	88	47	66
	Temperate with dry summer	429	247	469
	Temperate without dry season	448	312	448
	Cold except summer	471	337	318
	Cold with cold summer	64	61	74
	Polar	22	26	14
MT	Arid	321	133	290
	Temperate with dry summer	497	409	568
	Temperate without dry season	631	592	568
	Cold except summer	878	1246	935
	Cold with cold summer	238	302	460
	Polar	46	60	50
SQT	Arid	5	3	5
	Temperate with dry summer	13	10	13
	Temperate without dry season	24	18	22
	Cold except summer	83	56	62
	Cold with cold summer	38	20	40
	Polar	3	3	3
OVOC	Arid	193	135	156
	Temperate with dry summer	467	393	386
	Temperate without dry season	943	746	852
	Cold except summer	1469	1451	1340
	Cold with cold summer	329	350	649
	Polar	90	67	94

Table 9: Temperature sensitivity of S1 by climatic zone. Emissions in Gg/month

		January			June		
		-3 K	S1	$+3$ K	-3 K	S1	$+3$ K
ISOP	Arid	0.43	0.64	1.02	27.47	38.14	50.97
	Temperate with dry summer	2.42	3.60	5.75	117.03	164.52	222.95
	Temperate without dry season	0.78	1.16	1.90	83.25	121.45	173.40
	Cold except summer	0.21	0.31	0.51	171.31	249.31	354.40
	Cold with cold summer	0.06	0.09	0.15	12.76	18.87	27.44
	Polar	0.02	0.03	0.04	3.59	5.28	7.64
MT	Arid	3.99	5.28	7.47	60.37	82.38	109.94
	Temperate with dry summer	11.12	14.40	19.97	128.30	173.55	230.69
	Temperate without dry season	8.02	10.30	14.04	103.04	141.75	193.34
	Cold except summer	3.13	4.02	5.47	238.38	324.41	438.06
	Cold with cold summer	0.66	0.84	1.17	52.78	71.23	96.03
	Polar	0.14	0.18	0.25	6.71	9.37	13.00
SQT	Arid	0.16	0.20	0.28	0.99	1.30	1.70
	Temperate with dry summer	0.51	0.65	0.88	3.08	4.03	5.28
	Temperate without dry season	0.47	0.59	0.80	3.37	4.42	5.79
	Cold except summer	0.43	0.55	0.74	20.49	26.84	35.16
	Cold with cold summer	0.12	0.15	0.21	7.44	9.75	12.77
	Polar	0.02	0.02	0.03	0.39	0.52	0.68
OVOC	Arid	4.62	5.86	7.92	46.61	61.06	79.98
	Temperate with dry summer	13.40	16.99	23.00	131.28	171.97	225.28
	Temperate without dry season	12.17	15.47	20.88	155.41	203.59	266.69
	Cold except summer	6.42	8.17	11.02	363.54	476.22	623.84
	Cold with cold summer	1.47	1.84	2.52	58.37	76.46	100.16
	Polar	0.48	0.60	0.82	12.24	16.04	21.01

Table 10: Relative change of monthly emissions when average f_c values are replaced with minimal or maximal factors to derive forest-cover for S1 or S2.

S1		ISOP	MT	SQT	OVOC	Total
January	S1-Globcover-min	-53%	-19%	-21%	-34%	-54%
	S1-Globcover-max	14%	80%	93%	43%	56%
June	S1-Globcover-min	-26%	-18%	-30%	-26%	-60%
	S1-Globcover-max	57%	68%	88%	24%	48%
S2		**ISOP**	**MT**	**SQT**	**OVOC**	**Total**
January	S2-Globcover-min	-60%	-28%	-35%	-22%	-27%
	S2-Globcover-max	26%	88%	104%	90%	87%
June	S2-Globcover-min	-29%	-22%	-37%	-6%	-16%
	S2-Globcover-max	67%	77%	96%	67%	71%

Table 11: Performance metrics of the inventories compared to GC-MS/FID measurements at the DWD Observatory in Hohenpeissenberg, Germany. Top: only seasonality of the biomass, bottom: seasonality of the biomass and enzymes

		S1		S2		S3	
		ISOP	MT	ISOP	MT	ISOP	MT
January	RMSE	3.8	18.1	3.5	19.1	3.5	19.6
	CV(RMSE)	1.95	1.16	1.79	1.22	1.76	1.25
	r	0.04	-0.01	0.08	0.07	0.12	0.09
June	RMSE	78.0	119.5	72.6	108.2	83.7	101.3
	CV(RMSE)	1.14	1.12	1.06	1.01	1.22	0.95
	r	0.80	0.42	0.83	0.46	0.82	0.60

		S1e		S2e		S3e	
		ISOP	MT	ISOP	MT	ISOP	MT
January	RMSE	3.6	18.3	3.6	19.2	3.6	19.7
	CV(RMSE)	1.84	1.17	1.84	1.23	1.82	1.26
	r	0.13	-0.02	0.13	0.07	0.12	0.09
June	RMSE	68.0	118.7	83.5	109.9	84.4	103.0
	CV(RMSE)	0.99	1.11	1.22	1.03	1.23	0.97
	r	0.78	0.34	0.81	0.43	0.82	0.59

Table 12: Coefficients used for temperature correction in the canopy for Equation Supp1

Time (UTC)	a	b	c
1	-2.53E+00	1.60E-02	1.12E+00
2	-1.83E+00	-4.12E-01	1.09E+00
3	-1.76E+00	-1.75E+00	1.94E+00
4	-1.84E+00	-1.08E+00	1.54E+00
5	-1.97E+00	-1.14E+00	1.64E+00
6	-1.59E+00	-1.25E+00	1.54E+00
7	-1.89E+00	-1.30E-01	9.28E-01
8	-2.01E+00	7.96E-01	3.65E-01
9	-3.53E+00	4.84E+00	-1.66E+00
10	-2.82E+00	8.12E+00	-4.16E+00
11	-1.11E+00	7.52E+00	-4.52E+00
12	1.06E+00	3.94E+00	-3.10E+00
13	1.38E+00	5.38E+00	-4.20E+00
14	1.76E+00	2.52E+00	-2.46E+00
15	3.00E-02	2.38E+00	-1.60E+00
16	5.22E-01	3.42E+00	-2.51E+00
17	3.78E-01	2.52E+00	-1.85E+00
18	6.15E-01	2.92E+00	-2.22E+00
19	7.47E-01	1.37E+00	-1.25E+00
20	5.64E-01	-6.34E-02	-2.08E-01
21	-2.39E-01	-2.40E-01	2.66E-01
22	-2.10E-01	8.00E-01	-4.40E-01
23	-9.27E-01	-6.78E-01	8.64E-01

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