Calculations of annual ethanol fluxes from experimental data

Kirstine et al. (1998) (pasture in Australia)

	Value	Min	Max	Units	Comments
Total VOC flux	1.9			g(C) m^{-2} y^{-1}	
Percentage of ethanol		6	21		
Ethanol flux		0.22	0.76	g(eth) m^{-2} y^{-1}	mult by 46/24

Fukui and Doskey (1998) (grassland in USA)

	Value	Min	Max	Units	Comments
Mean ethanol flux	206			µg(eth) m^{-2} h^{-1}	=5760.9/28 (from Table 2)
No.of daylight hours per yr	1500	1000	2000		
Mean ethanol flux		0.21	0.41	g(eth) $m^{-2}$$y^{-1}$	

Schade & Goldstein (2001) (pine plantation in California) - Pinus ponderosa

	Value	Min	Max	Units	Comments
Average daily emission	0.27			mg(C) m^{-2} h^{-1}	from Table 3
Length of day	12			hr	from Fig 7
Average daily emission	3.24	2.59	3.89	mg(C) m^{-2} d^{-1}	+/- 20% based on Fig 7
Average nightly emission	0.10			mg(C) m^{-2} h^{-1}	from Table 3
Length of night	12			hr	
Average nightly emission	1.2	0.96	1.44	mg(C) m^{-2} d^{-1}	
Average total emssion	4.44	3.55	5.33	mg(C) m^{-2} d^{-1}	(day + night)
No of emitting days per yr	160	140	190	days	
Annual emission flux		0.36	0.74	g(C) m^{-2} y^{-1}	
Annual emission flux		0.70	1.42	g(eth) m^{-2} y^{-1}	mult by 46/24

Grabmer et al. (2006) (spruce forest in Germany) - Picea abies

	Value	Min	Max	Units	Comments
Midday max emission	0.40			µg(C) g(dm)$^{-1}$ h^{-1}	
Daily integrated emission	2.7	2.16	3.24	µg(C) g(dm)$^{-1}$ d^{-1}	from Fig 3(b), +/- 20%
Foliage density	900	750	1000	g m^{-1}	Guenther et al. (1994) for northwest conifers +
Daily integr.emission flux	2430	1620	3240	µg(C) m^{-2} d^{-1}	Kellomaki et al. (2001) for Finnish spruce
No of emitting days per yr	120	100	130	days	
Annual emission flux	0.29	0.16	0.42	g(C) m^{-2} y^{-1}	
Annual emission flux	0.56	0.31	0.81	g(eth) m^{-2} y^{-1}	mult by 46/24

Holzinger et al. (2000) (Holm oak) - Quercus ilex

	Value	Min	Max	Units	Comments
Midday max emission	200	100	275	nmol m^{-2} min^{-1}	average midday values from Fig 3
Midday max emission	552	276	759	µg(eth) m^{-2} h^{-1}	(x 46*60/1000)
Daily integrated emission	3726	1863	5123	µg(eth) m^{-2} d^{-1}	using integration factor of Grabmer (2.7/0.40)
No of emitting days per yr	150	120	180	days	
Annual emission flux	0.56	0.22	0.92	g(eth) m^{-2} y^{-1}	

Helmig et al. (1999) (Tulip poplar in Fernbank Forest, Georgia) - Liriodendron tulipifera

	Value	Min	Max	Units	Comments
Midday max emission	0.5			µg(C) $g(dm)^{-1}$ h^{-1}	Table 2 +/- 20%
Daily integrated emission	3.38	2.7	4.1	µg(C) $g(dm)^{-1}$ d^{-1}	using integration factor of Grabmer (2.7/0.40)
Foliage density	670	500	700	g m^{-1}	Guenther et al. (1994) for southeast mixed
Daily integr.emission flux	2261	1350	2835	µg(C) m^{-2} d^{-1}	
No of emitting days per yr	150	120	180	days	
Annual emission flux	0.34	0.16	0.51	g(C) m^{-2} y^{-1}	
Annual emission flux	0.65	0.31	0.98	g(eth) m^{-2} y^{-1}	mult by 46/24

Helmig et al. (1999) (White oak in Fernbank Forest, Georgia) - Quercus alba

	Value	Min	Max	Units	Comments
Midday max emission	0.2			µg(C) $g(dm)^{-1}$ h^{-1}	Table 2 +/- 20%
Daily integrated emission	1.35	1.1	1.62	µg(C) $g(dm)^{-1}$ d^{-1}	using integration factor of Grabmer (2.7/0.40)
Foliage density	670	500	700	g m^{-1}	Guenther et al. (1994) for southeast mixed
Daily integr.emission flux	905	540	1134	µg(C) m^{-2} d^{-1}	
No of emitting days per yr	150	120	180	days	
Annual emission flux	0.14	0.065	0.204	g(C) m^{-2} y^{-1}	
Annual emission flux	0.26	0.12	0.39	g(eth) m^{-2} y^{-1}	mult by 46/24

Helmig et al. (1999) (Gambel oak at Temple Ridge, Colorado) - Quercus gambelii

	Value	Min	Max	Units	Comments
Midday max emission	0.4			µg(C) $g(dm)^{-1}$ h^{-1}	Table 4 +/- 20%
Daily integrated emission	2.70	2.2	3.24	µg(C) $g(dm)^{-1}$ d^{-1}	using integration factor of Grabmer (2.7/0.40)
Foliage density	330	200	400	g m^{-1}	Guenther et al. (1994) for oak scrub

Daily integr.emission flux	891	432	1296	μg(C) m^{-2} d^{-1}
No of emitting days per yr	150	120	180	days
Annual emission flux	0.13	0.052	0.233	g(C) m^{-2} y^{-1}
Annual emission flux	0.26	0.10	0.45	g(eth) m^{-2} y^{-1} mult by 46/24

Rottenberger et al. (2008) (mixed rainforest species)

Flooding period = 210 days

	Units	S.martina	L.corym.	T.juruana	P.glomer.	Mean	Comments
Total for the 6-days following flooding	μmol m^{-2}	60.9	242.1	678.9	85.5	266.9	from Figure 4 (a-d)
Total for the 6-days following flooding	g(eth) m^{-2}	0.0028	0.0111	0.0312	0.0039	0.0123	*46/1E6
Min. annual emission flux calculated assuming 4 flood events per 210 day season interspersed with background fluxes of 0.1 μmol m^{-2} d^{-1}							
Minimum annual emission flux	μmol $m^{-2}y^{-1}$	262	987	2734	361	1086	
Minimum annual emission flux	g(eth) m^{-2} y^{-1}	0.012	0.045	0.126	0.017	**0.050**	
Max. annual emission flux calculated assuming the 6-day cycle of Fig. 4 is repeated throughout the 210 days of the flooding period.							
Maximum annual emission flux	μmol $m^{-2}y^{-1}$	2131	8474	23763	2993	9340	
Maximum annual emission flux	g(eth) m^{-2} y^{-1}	0.098	0.390	1.093	0.138	**0.430**	210 days per year
Daily emission for the 6-day flooding period	μmol $m^{-2}d^{-1}$	10.1	40.4	113.2	14.3	44.5	

Calculation of Annual Ethanol Loss by OH Oxidation in the Troposphere

Ethanol Loss in the Continental Boundary Layer through OH oxidation

Cell	Units	1	3	5	7			
Latitude		**90N-30N**	**30N - 0**	**0 - 30S**	**30S-90S**			
Pressure	mbar	1000-900	1000-900	1000-900	1000-900			
Ocean fraction		0.505	0.721	0.783	0.821	Duxbury and Duxbury (1984)		
Land Fraction		0.495	0.279	0.217	0.179			
Air mass in CBL	kg	6.36E+16	3.58E+16	2.79E+16	2.30E+16			
Moles of air in CBL	moles	2.19E+18	1.24E+18	9.62E+17	7.94E+17			
[OH] in CBL	molec. cm^{-3}	1.10E+06	1.10E+06	1.10E+06	1.10E+06	Galbally and Kirstine (2002)		
$[OH]_{max}$ in CBL		1.40E+06	1.40E+06	1.60E+06	1.60E+06			
Temperature	K	282	288	288	282	mean = 285 (Seinfeld and Pandis 2006)		
k_{OH}(ethanol)	cm^3 $molec^{-1}$ s^{-1}	3.18E-12	3.20E-12	3.20E-12	3.18E-12			
$k_{OH}(ethanol)_{max}$		3.93E-12	3.95E-12	3.95E-12	3.93E-12			
Ethanol loss coefficient	s^{-1}	3.50E-06	3.52E-06	3.52E-06	3.50E-06			
Ethanol conc. in CBL	mol mol^{-1}	1.00E-09	1.00E-09	1.00E-09	1.00E-09	Estimated from observations		
Ethanol mass (CBL)	moles	2.19E+09	1.24E+09	9.62E+08	7.94E+08			
Ethanol loss in CBL	mol s^{-1}	7.68E+03	4.36E+03	3.39E+03	2.78E+03	Total loss=	1.82E+04	mol s^{-1}
Ethanol loss in CBL	Tg y^{-1}	11.2	6.3	4.9	4.0		**26.5**	Tg y^{-1}
NH ethanol loss	Tg y^{-1}	**17.5**						
SH ethanol loss	Tg y^{-1}	**9.0**						

Ethanol Loss in the Marine Boundary Layer through OH oxidation

Cell	Units	1	3	5	7	
Latitude		**90N-30N**	**30N - 0**	**0 - 30S**	**30S-90S**	
Pressure	mbar	1000-900	1000-900	1000-900	1000-900	
Ocean fraction		0.505	0.721	0.783	0.821	Duxbury and Duxbury (1984)

Air mass in MBL	kg	6.48E+16	9.26E+16	1.01E+17	1.05E+17	
Moles of air in MBL	moles	2.24E+18	3.20E+18	3.47E+18	3.64E+18	
[OH] in MBL	radicals cm^{-3}	5.79E+05	1.29E+06	1.53E+06	5.47E+05	Prinn et al. (2001) for 1000-500 mbar
$[OH]_{min}$ in MBL		4.49E+05	9.97E+05	1.21E+06	4.33E+05	
$[OH]_{max}$ in MBL		7.03E+05	1.56E+06	1.85E+06	6.59E+05	
Temperature	K	282	288	288	282	mean = 285
kOH(ethanol)	$cm^3\ mol^{-1}\ s^{-1}$	3.18E-12	3.20E-12	3.20E-12	3.18E-12	Jiménez et al. (2003)
$kOH(ethanol)_{(max)}$		3.93E-12	3.95E-12	3.95E-12	3.93E-12	
Loss rate	s^{-1}	1.84E-06	4.12E-06	4.90E-06	1.74E-06	
$Loss\ rate_{(max)}$		2.76E-06	6.17E-06	7.29E-06	2.59E-06	
Ethanol conc in MBL	$mol\ mol^{-1}$	1.50E-10	1.50E-10	7.50E-11	7.50E-11	(Singh et al. 1995, 2004)
Ethanol conc in MBL	$nmol\ mol^{-1}$	0.150	0.150	0.075	0.075	

Assuming NH and SH have same ethanol concentration

Latitude		**90N-30N**	**30N - 0**	**0 - 30S**	**30S-90S**	
Ethanol conc in MBL	$mol\ mol^{-1}$	1.50E-10	1.50E-10	1.50E-10	1.50E-10	(Singh et al. 1995, 2004)
Ethanol loss in MBL	$Tg\ y^{-1}$	0.90	2.87	3.71	1.38	
NH ethanol loss	$Tg\ y^{-1}$	**3.77**				
SH ethanol loss	$Tg\ y^{-1}$	**5.09**				
Total ethanol loss	$Tg\ y^{-1}$	8.87				

Assuming ethanol concentration in SH is half that in the NH

Latitude		**90N-30N**	**30N - 0**	**0 - 30S**	**30S-90S**
Ethanol conc in MBL	$mol\ mol^{-1}$	1.50E-10	1.50E-10	7.50E-11	7.50E-11
Ethanol loss in MBL	$Tg\ y^{-1}$	0.90	2.87	1.86	0.69
NH ethanol loss	$Tg\ y^{-1}$	**3.77**			
SH ethanol loss	$Tg\ y^{-1}$	**2.55**			

Total ethanol loss	Tg y^{-1}	6.32

Assuming ethanol concentration in SH is 0.2 that in the NH

Latitude		**90N-30N**	**30N - 0**	**0 - 30S**	**30S-90S**
Ethanol conc in MBL	mol mol^{-1}	1.50E-10	1.50E-10	3.00E-11	3.00E-11
Ethanol loss in MBL	Tg y^{-1}	0.90	2.87	0.74	0.28
NH ethanol loss	Tg y^{-1}	**3.77**			
SH ethanol loss	Tg y^{-1}	**1.02**			
Total ethanol loss	Tg y^{-1}	4.79			

Ethanol Loss in the Free Troposphere through OH oxidation

Cell	Units	1	2	3	4	5	6	7	8
Latitude		**90N-30N**	**90N-30N**	**30N - 0**	**30N - 0**	**0 - 30S**	**0 - 30S**	**30S-90S**	**30S-90S**
Pressure	mbar	900-500	500-200	900-500	500-200	900-500	500-200	900-500	500-200
Ocean fraction		0.505	0.505	0.721	0.721	0.783	0.783	0.821	0.821
Tropospheric air mass	kg	6.42E+17	3.85E+17	6.42E+17	3.85E+17	6.42E+17	3.85E+17	6.42E+17	3.85E+17
Air mass in FT	kg	5.14E+17	3.85E+17	5.14E+17	3.85E+17	5.14E+17	3.85E+17	5.14E+17	3.85E+17
Moles of air in FT	moles	1.77E+19	1.33E+19	1.77E+19	1.33E+19	1.77E+19	1.33E+19	1.77E+19	1.33E+19
[OH] in FT	radicals cm^{-3}	5.79E+05	5.20E+05	1.29E+06	1.13E+06	1.53E+06	1.32E+06	5.47E+05	5.72E+05
$[OH]_{min}$ in FT		4.49E+05	4.03E+05	9.97E+05	8.77E+05	1.21E+06	1.05E+06	4.33E+05	4.52E+05
$[OH]_{max}$ in FT		7.03E+05	6.31E+05	1.56E+06	1.38E+06	1.85E+06	1.59E+06	6.59E+05	6.89E+05
Temperature	K	261	230	276	242	276	242	261	230
kOH(ethanol)	cm^3 mol^{-1} s^{-1}	3.11E-12	2.97E-12	3.16E-12	3.03E-12	3.16E-12	3.03E-12	3.11E-12	2.97E-12
$kOH(ethanol)_{(max)}$		3.85E-12	3.72E-12	3.91E-12	3.77E-12	3.91E-12	3.77E-12	3.85E-12	3.72E-12
Loss rate	s^{-1}	1.80E-06	1.54E-06	4.07E-06	3.42E-06	4.84E-06	4.00E-06	1.70E-06	1.70E-06
Loss $rate_{(max)}$		2.71E-06	2.35E-06	6.11E-06	5.19E-06	7.22E-06	6.02E-06	2.54E-06	2.56E-06

Ethanol conc in FT	mol mol^{-1}	**5.00E-11**		Singh et al. (1995), (2004) at altitude of 5-10 km (540 - 260 mbar)					
Ethanol conc in FT	nmol mol^{-1}	**0.050**							

Assuming NH and SH have same ethanol concentration

Latitude		**90N-30N**	**90N-30N**	**30N - 0**	**30N - 0**	**0 - 30S**	**0 - 30S**	**30S-90S**	**30S-90S**
Pressure	mbar	900-500	500-200	900-500	500-200	900-500	500-200	900-500	500-200
Ethanol conc in FT	mol mol^{-1}	5.00E-11	5.00E-11	5.00E-11	5.00E-11	5.00E-11	5.00E-11	5.00E-11	5.00E-11
Ethanol loss in FT	Tg y^{-1}	2.32	1.49	5.25	3.31	6.24	3.87	2.19	1.64
NH ethanol loss	Tg y^{-1}	**12.37**							
SH ethanol loss	Tg y^{-1}	**13.95**							
Total ethanol loss	Tg y^{-1}	26.32							

Assuming ethanol concentration in SH is half that in the NH

Latitude		**90N-30N**	**90N-30N**	**30N - 0**	**30N - 0**	**0 - 30S**	**0 - 30S**	**30S-90S**	**30S-90S**
Pressure	mbar	900-500	500-200	900-500	500-200	900-500	500-200	900-500	500-200
Ethanol conc in FT	mol mol^{-1}	5.00E-11	5.00E-11	5.00E-11	5.00E-11	2.50E-11	2.50E-11	2.50E-11	2.50E-11
Ethanol loss in FT	Tg y^{-1}	2.32	1.49	5.25	3.31	3.12	1.93	1.10	0.82
NH ethanol loss	Tg y^{-1}	**12.37**							
SH ethanol loss	Tg y^{-1}	**6.97**							
Total ethanol loss	Tg y^{-1}	19.34							

Assuming ethanol concentration in SH is 0.2 that in the NH

Latitude		**90N-30N**	**90N-30N**	**30N - 0**	**30N - 0**	**0 - 30S**	**0 - 30S**	**30S-90S**	**30S-90S**
Pressure	mbar	900-500	500-200	900-500	500-200	900-500	500-200	900-500	500-200
Ethanol conc in FT	mol mol^{-1}	5.00E-11	5.00E-11	5.00E-11	5.00E-11	1.00E-11	1.00E-11	1.00E-11	1.00E-11
Ethanol loss in FT	Tg y^{-1}	2.32	1.49	5.25	3.31	1.25	0.77	0.44	0.33
NH ethanol loss	Tg y^{-1}	**12.37**							
SH ethanol loss	Tg y^{-1}	**2.79**							
Total ethanol loss	Tg y^{-1}	15.16							

Ethanol Loss by OH Oxidation in Clouds

		NH	SH		
Mass of cloudwater	g	3.80E+16	4.22E+16		
Volume of cloudwater	L	3.80E+13	4.22E+13		
Mean cloud temperature	K	276	276		Lelieveld & Crutzen (1991)
Pressure at cloud height	atm	0.8	0.8		
Henry's Law constant	mol L^{-1} atm^{-1}	968.7	968.7		
k_{OH_aq} (ethanol)	L mol^{-1} s^{-1}	1.29E+09	1.29E+09		Ervens et al. (2003)
[OH_aq]	mol L^{-1}	7.0E-14	7.0E-14		Leriche et al. (2000) and Herrmann et al. (2000)
Ethanol loss coefficient	s^{-1}	9.05E-05	9.05E-05		
Ethanol loss rate	mol s^{-1}	133.43	147.89		H*Ca*P*V*(k_{OH}*[OH])
Ethanol loss rate	Tg y^{-1}	**0.19**	**0.22**	total =	0.41
Ethanol conc in clouds	mol L^{-1}	3.87E-08	3.87E-08		
				TOTAL	
Total ethanol loss by OH	Tg y^{-1}	**33.83**	**18.70**	**52.53**	