Supplement of Atmos. Chem. Phys., 14, 10363–10381, 2014
http://www.atmos-chem-phys.net/14/10363/2014/
doi:10.5194/acp-14-10363-2014-supplement

Atmospheric Chemistry and Physics Open Access

Supplement of

Worldwide biogenic soil NO_x emissions inferred from OMI NO_2 observations

G. C. M. Vinken et al.

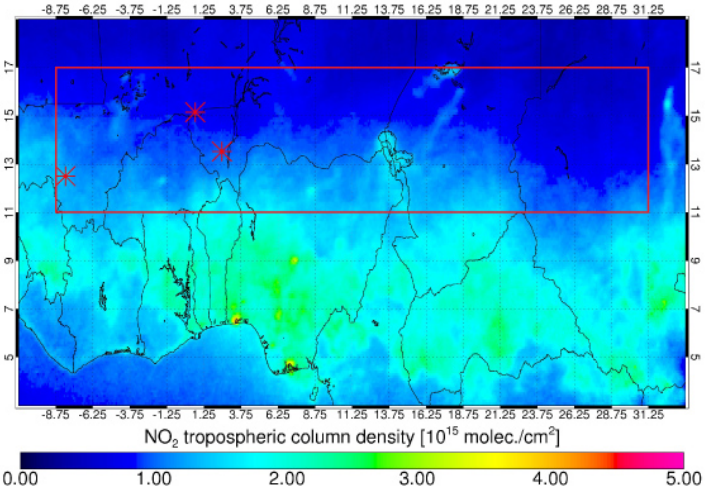
Correspondence to: G. C. M. Vinken (g.c.m.vinken@tue.nl)

Supplement

1. Locations of IDAF, EMEP, and EPA surface monitoring stations

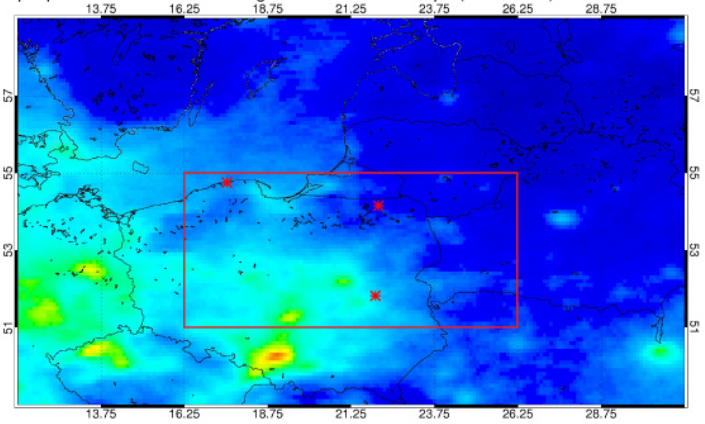
In this study we use NO_2 measurements from surface monitoring stations in Africa, Europe and the USA. Locations of the measurement stations are shown in Fig. S1a for IDAF in Afria, in Fig. S1b for EMEP in Poland, and in Fig. S1c for the mid-USA. OMI tropospheric NO_2 columns averaged over 2005-2008 show that measurement stations are located in rural areas, away from large anthropogenic sources.

(a) OMI tropospheric NO2 columns averaged over Sahel region (2005-2008) & IDAF measurement stations



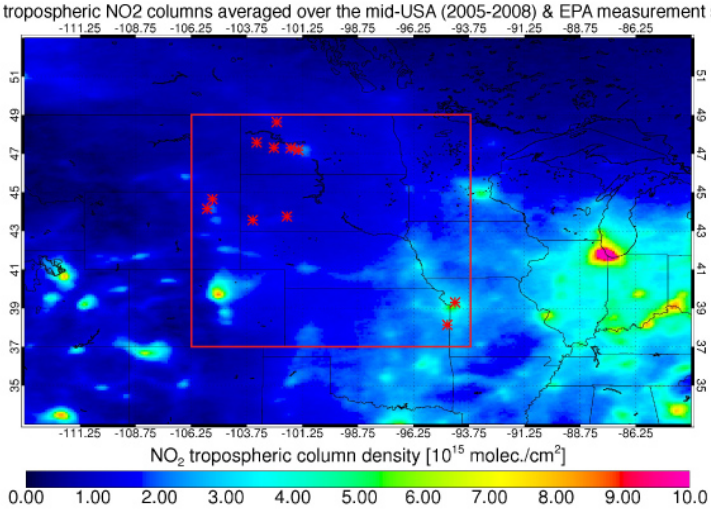
Station	Location
Banizoumbou, Niger	13°31'N, 2°28'E
Katibougou, Mali	12°30'N, 8°5'W
Agoufou, Mali	15°09'N, 0°40'E

(b) OMI tropospheric NO2 columns averaged over Eastern Europe (2005-2008) & EMEP measurement stations



Station	Location
Leba, Poland	54°45'N, 17°32'E
Diabla Gora, Poland	54°9'N, 22°4'E
Jarczew, Poland	51°49'N, 21°59'E

(c) OMI tropospheric NO2 columns averaged over the mid-USA (2005-2008) & EPA measurement stations



Site ID	Location
20-107-0002	38°8'N, 94°44'W
29-047-0005	39°18'N, 94°23'W
38-013-0004	48°39'N, 102°24'W
38-025-0002	47°35'N, 103°18'W
38-025-0003	47°19'N, 102°32'W
38-057-0004	47°18'N, 101°46'W
38-065-0002	47°11'N, 101°26'W
46-033-0132	43°33'N, 103°29'W
46-071-0001	43°45'N, 101°56'W
56-005-0123	44°39'N, 105°17'W
56-005-0456	44°9'N, 105°32'W

Figure S1: OMI NO_2 observations averaged over 2005-2008 on a 0.1°x0.1° resolution (selection criteria as in Sec. 3.1). Note that (a) has a different color bar than (b) and (c). Overplotted are the IDAF (a), EMEP (b), and EPA (c) monitoring stations used in this study, with specific locations indicated next to the Figures.

2. Regression statistics of GEOS-Chem NO_2 columns versus soil NO_x emissions

Statistics of the Reduced Major Axis (RMA) fit of GEOS-Chem NO_2 columns and soil NO_x emissions are given in Table S1. All simulated NO_2 columns were filtered following the filtering scheme of section 3.1. We highlighted months that are included in our constraints in green ($R^2 > 0.2$).

Table S1: Statistics of RMA fit of GEOS-Chem NO_2 columns versus soil NO_x emissions.

		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Argentina (56.3°-66.3°W; 23°-39°S)	slope; intercept	0.11;0.49	0.14;0.36	0.15;0.32	0.25;0.21	-0.48;1.6	0.32;0.27	0.55;0.26	0.51;0.07	0.23;0.28	0.16;0.37	0.11;0.45	0.09;0.41
	R^2; N	0.62; 31	0.22; 23	0.37; 24	0.02; 16	0.0; 10	0.12; 14	0.62; 22	0.05; 13	0.05; 22	0.20;30	0.30; 32	0.38; 30
Mid-USA (93.8°-106.3°W; 37°-49°N)	slope; intercept					0.21;0.47	0.20;1.02	0.16;1.01	0.12;1.02	0.18;0.85			
	R^2; N					0.81; 18	0.77; 15	0.80; 26	0.69; 25	0.71; 25			
West-USA (113.8°-123.8°W; 37°-49°N)	slope; intercept					0.33;0.03	0.16;0.33	0.19;0.31	0.13;0.55	0.16;0.51	0.25;0.41		
	R^2; N					0.76; 6	0.70; 8	0.08; 20	0.25; 19	0.35;15	0.51; 7		
Spain-France[a] (1.3°-6.8°W; 39°-43°N & 1.3°W-3.8°E; 43°-47°N)	slope; intercept				0.30;0.65	0.18;0.83	0.10;1.13	-0.06;2.1	-0.12;2.5	0.25;1.09			
	R^2; N				0.13; 4	0.34; 7	0.46; 8	0.07; 8	0.05; 8	0.02; 8			
Eastern Europe[a] (16.3°-26.3°E; 51°-55°N)	slope; intercept					0.41;0.57	0.23;0.95	0.16,0.94	0.26;0.85	0.50;0.77			
	R^2; N					0.88; 4	0.85; 8	0.82; 8	0.75; 8	0.72; 7			
Sahel (8.8°W-31.3°E; 5°S-1°N)	slope; intercept	0.18; 0.5	0.21;0.45	0.11;0.63	0.13;0.52	0.13;0.57	0.14;0.70	0.15;0.59	0.13;0.58	0.09;0.67	0.15;0.50	0.23;0.36	0.26;0.36
	R^2; N	0.74; 17	0.62; 38	0.71; 37	0.69; 41	0.50; 44	0.43; 40	0.47; 40	0.38; 26	0.70; 25	0.56; 29	0.78; 28	0.84; 29
Namibia-Botswana (16.3°-26.3°E; 19°-25°S)	slope; intercept	0.14;0.44	0.10;0.50	0.05;0.59	0.05;0.62	0.12;0.54	0.17;0.62	0.09;0.71		0.18;0.65	0.10;0.91	0.07;0.72	0.17;0.56
	R^2; N	0.04; 7	0.49; 12	0.65; 12	0.55; 12	0.12; 12	0.22; 12	0.73; 11		0.62; 5	0.03; 11	0.50; 12	0.73; 9
India (71.3°-88.8°E; 18°-23°N)	slope; intercept	0.49;0.39	0.15;1.07	0.25;0.56	0.13;1.23	0.16;0.81	0.11;0.72	0.07;0.75				0.23;1.10	0.38;0.71
	R^2; N	0.36; 16	0.56; 16	0.42; 20	0.82; 20	0.67; 21	0.62; 21	0.98; 3				0.44; 5	0.95; 5
Australia (143.8°-148.8°E; 29°-37°S)	slope; intercept	0.07;0.69	0.06;0.62	0.14;0.48	0.15;0.59	0.48;0.25	0.53;0.12			0.11;0.32	0.06;0.35	0.06;0.51	0.07;0.50
	R^2; N	0.77; 8	0.66; 7	0.64; 8	0.54; 8	0.59; 6	0.81; 5			0.66; 5	0.22; 6	0.64; 7	0.66; 8
Brazil (41.3°-56.3°W; 15°-23°S)	slope; intercept		0.12;0.35	0.09;0.56	0.13;0.48	0.21;0.14	0.16;0.47	0.20;0.54	0.39;0.00	0.23;0.53	0.15;0.67	0.05;0.81	0.14;0.27
	R^2; N		0.07; 13	0.19; 12	0.29; 13	0.19; 20	0.16; 14	0.14; 18	0.48; 11	0.34; 10	0.12; 18	0.22; 12	0.00; 8
South Kazakhstan (46.3°-83.8°E; 35°-49°N)	slope; intercept				0.06;0.42	0.07;0.62	0.06;0.87	0.06;0.95	0.06;0.95	0.12;0.64	0.19;0.50		
	R^2; N				0.27; 18	0.25; 30	0.18; 30	0.48; 28	0.05; 30	0.37; 30	0.56; 28		

[a] regression done on data filtered for soil fraction larger than 0.2

3. Regression statistics of GEOS-Chem NO_2 columns versus OMI NO_2 columns

Statistics of the Reduced Major Axis (RMA) fit of GEOS-Chem and OMI tropospheric NO_2 columns are given in Table S2. All simulated and observed NO_2 columns were filtered following the filtering scheme of section 3.1. We highlighted months that are satisfy our correlation criteria ($R^2 > 0.35$ in this regression, and $R^2 > 0.2$ between GEOS-Chem NO_2 columns versus soil NO_x emissions).

Table S2: Statistics of RMA fit of GEOS-Chem and OMI tropospheric NO_2 columns. Regions as defined in Fig. 3 and Table S1.

		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Argentina	slope; intercept	0.75;0.23	0.88;0.06	0.97;0.04	1.14;-0.2	0.91;-0.1	1.07;-0.2	0.91;0.17	1.12;-0.2	2.01;-0.7	1.68;-0.3	1.33;-0.1	1.26;-0.1
	R^2; N	0.59; 31	0.35; 23	0.34; 24	0.52; 16	0.45; 10	0.14; 14	0.50; 22	0.79; 13	0.38; 22	0.74; 30	0.28; 32	0.27; 30
Mid-USA	slope; intercept					0.90;0.31	0.77;-0.3	0.57;0.16	0.84;0.0	1.04;-0.5			
	R^2; N					0.38; 18	0.77; 15	0.67; 26	0.66; 25	0.71; 25			
West-USA	slope; intercept					1.38;-0.1	0.91;0.18	1.41;-0.4	1.61;-0.9	1.57;-0.6	1.04;0.02		
	R^2; N					0.89; 6	0.31; 8	0.87; 20	0.47; 19	0.72; 15	0.82; 7		
Spain-France[a]	slope; intercept				1.01;0.11	1.01;0.19	1.64;-0.8	2.26;-2.1	1.43; -1.0	2.14;-1.9			
	R^2; N				0.76; 4	0.54; 7	0.51; 8	0.39; 8	0.72; 8	0.12; 8			
Eastern Europe[a]	slope; intercept					1.56;-0.5	1.42;-0.5	0.78;0.36	1.52;-0.6	1.28;-0.3			
	R^2; N					0.92; 4	0.86; 8	0.33; 8	0.95; 8	0.89; 7			
Sahel	slope; intercept	0.50;0.28	0.94;0.06	1.17;-0.2	1.41;-0.4	1.48;-0.4	1.32;-0.4	1.07;0.05	1.28;-0.1	0.98;0.09	0.81;0.16	0.66;0.27	0.69;0.17
	R^2; N	0.77; 17	0.75; 38	0.60; 37	0.70; 41	0.71; 44	0.62; 40	0.60; 40	0.51; 26	0.52; 25	0.74; 29	0.70; 28	0.90; 29
Namibia-Botswana	slope; intercept	2.56;1.12	0.87;0.12	1.06;-0.1	1.50;-0.5	0.75;-0.2	0.77;0.08	2.49;-1.3		1.13;-0.2	0.87;0.37	1.62;-0.5	1.23;0.0
	R^2; N	0.02; 7	0.35; 12	0.22; 12	0.47; 12	0.20;12	0.15; 12	0.02; 11		0.36; 5	0.72; 11	0.82; 12	0.72; 9
India	slope; intercept	1.45;-0.8	1.45;-0.8	1.25;-0.4	1.06;-0.5	1.23;-0.8	1.15;0.20					1.13;-0.2	-0.33;2.6
	R^2; N	0.16; 16	0.05; 16	0.39; 20	0.27; 20	0.71; 21	0.64; 21					0.80; 5	0.00; 5
Australia	slope; intercept	1.41;-0.3	2.25;-0.8	1.18;-0.1	1.49;-0.1	0.99;0.15	0.68;0.38			1.15;0.40	2.93;-0.5	3.28;-1.2	1.14;0.25
	R^2; N	0.60; 8	0.66; 7	0.76; 8	0.88; 8	0.47; 6	0.92; 5			0.01; 5	0.23; 6	0.09; 7	0.70; 8
Brazil	slope; intercept		1.08;-0.2	-1.3;-0.38	0.74;-0.2	1.02;-0.1	1.29;-0.7	1.51;-0.9	0.71;0.06	1.30;-0.4	1.06;0.03	-0.78;1.8	1.44;-0.3
	R^2; N		0.45; 13	0.38; 12	0.75; 13	0.59; 20	0.43; 14	0.43; 18	0.28; 11	0.77; 10	0.46; 18	0.12; 12	0.16; 8
South Kazakhstan	slope; intercept				-4.4;2.9	2.66;-1.2	1.84;-0.8	1.46;-0.4	1.65;-0.8	1.28;-0.5	1.02;-0.2		
	R^2; N				0.03; 18	0.39; 30	0.26; 30	0.59; 28	0.26; 30	0.02; 30	0.00; 28		

[a] regression done on data filtered for soil fraction larger than 0.2

4. Regression statistics of GEOS-Chem NO_2 columns (using top-down soil NO_x emissions) versus OMI NO_2 columns

Statistics of the Reduced Major Axis (RMA) fit of GEOS-Chem and OMI tropospheric NO_2 columns are given in Table S3. All simulated and observed NO_2 columns were filtered following the filtering scheme of section 3.1.

Table S3: Statistics of RMA fit of GEOS-Chem (using top-down soil NO_x inventory) and OMI tropospheric NO_2 columns. Regions as defined in Fig. 3 and Table S1.

		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Argentina	slope; intercept	0.92;0.18	0.94;0.06					0.93;0.18			1.31;-0.3		
	R^2; N	0.57; 31	0.34; 23					0.49; 22			0.48; 30		
Mid-USA	slope; intercept					0.95;0.30	0.84;-0.3	0.77;0.08	0.94; -0.1	1.05;-0.5			
	R^2; N					0.36; 18	0.78; 15	0.76; 26	0.68; 25	0.67; 25			
West-USA	slope; intercept					1.14;-0.1			1.17;-0.8	1.18;-0.6	1.02;0.02		
	R^2; N					0.89; 6			0.23; 19	0.56; 15	0.82; 7		
Spain-France[a]	slope; intercept					1.00;0.19	0.84;0.09						
	R^2; N					0.54; 7	0.46; 8						
Eastern Europe[a]	slope; intercept					1.30;-0.4	1.16;-0.3		1.19;-0.5	1.16;-0.3			
	R^2; N					0.92; 4	0.85; 8		0.91; 8	0.87; 7			
Sahel	slope; intercept	0.88;0.18	0.99;0.05	0.99;-0.1	1.10;-0.3	1.10;-0.3	1.15;-0.4	1.02;0.05	1.04;0.0	1.00;0.08	0.94;0.13	0.88;0.22	0.88;0.15
	R^2; N	0.69; 17	0.74; 38	0.56; 37	0.55; 41	0.69; 44	0.59; 40	0.59; 40	0.45; 26	0.52; 25	0.76; 29	0.74; 28	0.90; 29
Namibia-Botswana	slope; intercept		0.96;0.11		0.57;0.05					1.07;-0.2		0.91;-0.1	1.08;0.00
	R^2; N		0.45; 12		0.37; 12					0.31; 5		0.78; 11	0.68; 9
India	slope; intercept			1.11;-0.3		1.12;-0.8	0.97;0.37					1.08;-0.1	
	R^2; N			0.29; 20		0.72; 21	0.64; 21					0.79; 5	
Australia	slope; intercept	0.98;-0.1	0.82;-0.1	1.04;-0.1	1.00;0.1	0.99;0.15	0.93;0.33						1.00;0.29
	R^2; N	0.60; 8	0.39; 7	0.69; 8	0.85; 8	0.47; 6	0.93; 5						0.69; 8
Brazil	slope; intercept				0.81;-0.2					0.96;-0.2			
	R^2; N				0.79; 13					0.76; 10			
South Kazakhstan	slope; intercept					0.88; -0.3		0.96;0.0					
	R^2; N					0.00; 30		0.35; 28					

[a] regression done on data filtered for soil fraction larger than 0.2

5. Additional beta values

We present β' values calculated without the filtering scheme of Sec. 3.1 in Table S4 (note that GEOS-Chem was sampled on days with valid OMI observations). We found that the influence of boundary effects (as discussed in Sec. 3.2) resulted in 10% lower β' values, by calculating β' values for smaller regions (subsets of the existing regions, not shown). To enable comparision with Lamsal et al. (2011), we present β values calculated without applying the averaging kernel on GEOS-Chem simulated columns in Table S5.

Table S4: β' values calculated by perturbing surface emissions in the 11 regions by 10 % (Eq. 3). Regions are as defined in Fig. 3 and Table S1.

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual average
Argentina	2.2	2.1	1.9	1.9	1.7	1.7	1.8	2.1	1.8	2.1	2.1	2.1	2.0
Australia	3.4	3.4	3.0	3.0	2.7	2.9	3.9	3.8	3.8	3.7	3.2	3.3	3.3
Brazil	3.0	2.6	2.7	2.3	2.1	2.2	2.3	2.3	2.4	2.5	2.8	3.0	2.5
Eastern Europe			1.5	1.6	2.3	2.8	2.4	2.4	2.2	2.3	4.4		2.4
India	1.6	1.7	1.8	1.5	1.9	2.0	2.9	2.6	2.6	2.8	2.1	1.8	2.1
Mid-USA	1.5	1.4	1.4	1.8	2.1	2.7	2.4	2.4	2.1	1.5	1.5	1.6	1.9
Namibia-Botswana	3.6	3.5	2.9	3.0	3.1	3.6	3.6	3.6	4.3	4.7	2.7	3.4	3.5
Sahel	2.2	2.2	2.0	2.1	2.2	2.4	2.4	2.6	2.4	2.1	2.1	2.3	2.3
South Kazakhstan		4.3	4.0	3.0	2.5	2.5	2.3	2.4	2.1	2.2	2.8	4.4	3.0
Spain-France	2.1	2.1	1.7	2.2	2.2	2.4	2.4	2.6	2.3	1.9	2.4	2.7	2.2
West-USA	1.3	1.2	1.2	1.7	2.0	1.9	2.2	1.9	1.6	1.3	1.4	1.3	1.6

Table S5: Similar to Table S4, but now calculated using simulated columns without applying the OMI averaging kernel. Regions are as defined in Fig. 3 and Table S1.

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual average
Argentina	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.7	1.5	1.6	1.6	1.6	1.5
Australia	2.5	2.6	2.5	2.4	2.3	2.5	3.0	3.0	2.9	2.7	2.5	2.4	2.6
Brazil	1.7	1.7	1.7	1.6	1.6	1.5	1.7	1.8	1.8	1.8	1.9	1.7	1.7
Eastern Europe			1.4	1.5	1.8	2.0	1.7	1.8	1.8	1.9	3.5		1.9
India	1.4	1.5	1.5	1.3	1.6	1.6	2.2	1.9	1.9	1.8	1.6	1.5	1.7
Mid-USA	1.4	1.3	1.3	1.6	1.7	1.9	1.8	1.8	1.7	1.3	1.4	1.5	1.6
Namibia-Botswana	2.1	2.3	2.0	2.1	2.3	2.7	2.6	2.8	3.3	3.3	1.9	2.0	2.5
Sahel	1.7	1.7	1.5	1.6	1.7	1.6	1.7	1.7	1.6	1.5	1.6	1.7	1.6
South Kazakhstan		3.1	3.2	2.4	1.9	1.8	1.8	1.8	1.7	1.7	2.0	3.1	2.2
Spain-France	1.8	1.9	1.6	2.0	1.9	2.0	1.9	2.0	1.9	1.6	2.0	2.3	1.9
West-USA	1.1	1.0	1.1	1.5	1.7	1.6	1.7	1.5	1.3	1.1	1.1	1.1	1.3