On the contribution of biomass burning to POPs in air in Africa

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1. Introduction

Forest, savannah and agricultural debris fires in the tropics and subtropics are sources for wide spread pollution and release many organic substances into air and soil [1], including persistent organic pollutants, i.e. polychlorinated dibenzodioxins and -furanes (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs). The significance of this source for the exposure of humans and the environment is unknown. Does biomass burning constitute eventually a significant source for dioxins in the tropics?

2. Materials and methods

We used the global multicompartment chemistry-transport model MPI-MCTM [2-3] to predict the gaseous and particle-associated atmospheric concentrations of selected PCDDs and PAHs. The model large-scale meteorology was constrained by nudging the atmospheric sub-model to re-analysis data (i.e., the historic weather; ECMWF).

Global emissions of PAHs and PCDDs into air are based on recommended (PCDDs, e.g. [4]) and selected (PAHs) emission factors applied to fire distributions. Daily real-time fire data are based on satellite-observed fire radiative power measured from satellite (MODIS instrument) [5]. No other primary sources are considered. Photochemistry with the hydroxyl radical and ozone in the gas-phase and absorption in the particulate matter organic phase and adsorption to black carbon (PAHs [6]) are considered.

Model-predicted near-ground concentrations of PCDDs and PAHs are compared with observations during January-June 2008 at a number of stations across Africa [7]. Back-trajectory analyses (HYSPLIT [8]) suggest that some of these had been influenced by fire episodes in the region.

2.1. Results and discussion

Continental half-year (Jan-June 2008) mean near-ground atmospheric concentrations are 0.0076, 0.51 and 3.25 fg m^{-3} of 2,3,7,8-TCDD, 1,2,3,4,6,7,8-HpCDD and OCDD, respectively. Maxima are in the range 10-

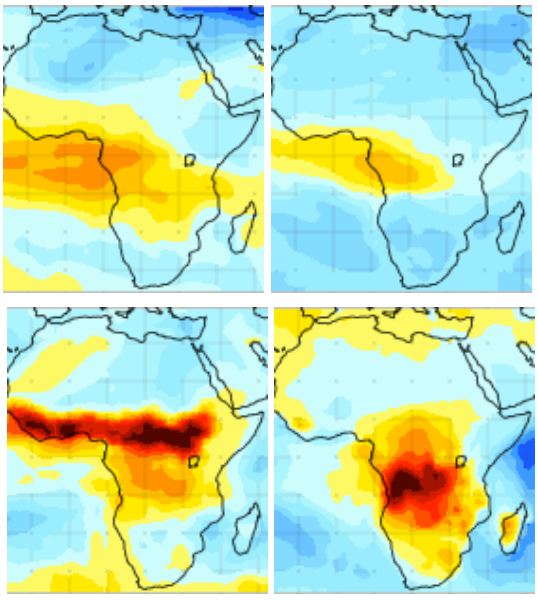

Figure 1: Model-predicted distributions of 1,2,3,4,6,7,8-HpCDD from open fires in January (left column) and June (right column) at ≈1500 m height (upper row) and ground-level (lower row).

100 fg m^{-3} for 1,2,3,4,6,7,8-HpCDD and OCDD, one order of magnitude lower for 2,3,7,8-TCDD. It is found that open fires can explain a major fraction of the air pollution by PCDDs in the background of west, central and southern Africa.

Open fire predicted levels of all PAHs exceed the observed levels at some of the stations by up to one order of magnitude, in rare occasions by up to two orders of magnitude. Exceedances can be explained by too high emission factors and/or neglect of photochemical degradation in the particulate phase.

Highest concentrations of PCDD and PAH are predicted in 1-4 km altitude throughout most of the time, sometimes even higher and sometimes near the ground (Fig. 1). Biomass burning plumes are reportedly transported high, higher than industrial emission plumes [9]. Aloft, they are dislocated downwind, stretching far into the Gulf of Guinea (Fig. 1). Predicted open fires related PAH concentrations sometimes exceed observed levels. This can be explained by model input data uncertainties, namely PAH emission factors and chemical kinetics data for both the gas and particulate phases.

3. Conclusions

Open fires contribute significantly to the exposure of the African environment to PCDDs. The results support an at least regional long-range transport potential of PCDD/Fs, and also of PAHs (as suggested earlier [3]).

The incomplete knowledge of chemical kinetics of gaseous and particle-associated PAHs is severely limiting source attribution and understanding of transport and fate [3,10]. Furthermore, PAH emission factors from biomass combustion sources should be better established, based on field and open burning facilities studies.

4. References

[1] Andreae MO. 1991. Biomass burning: Its history, use, and distribution and its impact on environmental quality and global climate, in: Global Biomass Burning (Levine JS, ed.), Cambridge (MA), USA: MIT Press, pp. 3-21.

[2] Semeena VS, Feichter J, Lammel G. 2006. Significance of regional climate and substance properties on the fate and atmospheric long-range transport of persistent organic pollutants – examples of DDT and γ-HCH. Atmos Chem Phys 6:1231-1248.

[3] Lammel G, Sehili AM, Bond TC, Feichter J, Grassl H. 2009. Gas/particle partitioning and global distribution of polycyclic aromatic hydrocarbons – a modelling approach. Chemosphere 76:98-106.

[4] UNEP. 2005. Standardized toolkit for identification and quantification of dioxin and furan releases, UNEP Chemicals, Genève, Switzerland: UNEP, ed. 2.1, 253 p.

[5] Heil A, Kaiser JW, van der Werf GR, Wooster MJ, Schultz MG, Denier van der Gon H. 2010. Assessment of the real-time fire emissions (GFASv0) by MACC. Tech. Memo No. 628, Reading, UK: ECMWF.

[6] Lohmann R, Lammel G. 2004. Adsorptive and absorptive contributions to the gas-particle partitioning of polycyclic aromatic hydrocarbons: state of knowledge and recommended parametrization for modeling. Environ Sci Technol 38:3793-3803.

[7] Klánová J, Čupr P, Holoubek I, Borůvková J, Přibylová P, Kareš R, Tomšej T, Ocelka T. 2009. Persistent organic pollutants in Africa – 1. Passive air sampling across a continent-wide network 2008. J Environ Monit 11:1952-1963.

[8] Draxler RR, Rolph GD. 2003. Hybrid Single-Particle Lagrangian Integrated Trajectory Model http://www.arl.noaa.gov/ready/hysplit4.html. Accessed 01 02 2011.

[9] Ancellet G, Orlandi E, Real E, Law KS, Schlager H, Fierli F, Nielsen JK, Thouret V, Mari C. 2011. Tropospheric ozone production related to West African city emissions during the 2006 wet season AMMA campaign, Atmos Chem Phys 11:6349-6366.

[10] Dvorská A, Lammel G, Klánová J. 2011. Use of diagnostic ratios for studying source apportionment and reactivity of ambient polycyclic aromatic hydrocarbons over Central Europe. Atmos Environ 45:420-427.

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