Record High Peaks in PCB Concentrations in the Arctic Atmosphere due to Long-Range Transport of Biomass Burning Emissions

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Abstract

We have clear evidence from a number of measurements and model results that the Zeppelin station was strongly influenced by biomass burning (BB) emissions during two episodes in July 2004 and May 2006 [1,2].

The concentrations of many "classical" BB emissions and their products (e.g. aerosols, ozone) reached record high levels in the Arctic. Surprisingly this event also led to significant enhancement of many POPs.

It was found, that during both episodes many PCB congeners were significantly enhanced. During the two episodes different transport leads to different patterns in the congener profile. While in 2006 the transport time was only several days, in 2004 it took three weeks and scavenging occurred on the way, which lead to removal of higher chlorinated congeners.

Figure 1: Emissions from biomass burning in Eastern Europe in May 2006 reach the Arctic and reduce visibility. The right picture shows the view from Zeppelin mountain on Svalbard under clear condition. Picture: Courtesy Ann-Christine Engvall, University of Stockholm.

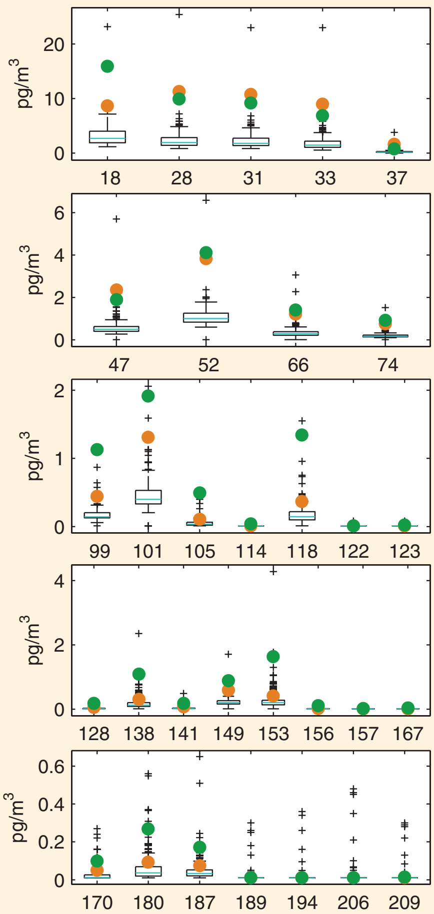

Figure 3: Box and whisker plots showing the frequency distributions of all PCB congeners [pg/m³] sampled at the Zeppelin station during the period from January 2002 to May 2006. The line shows the median, the box delineates the 25 and 75 percentiles, the whiskers are drawn at the 1.5 folded inter quartile range and the crosses mark outliers. The orange dots indicate the sample from 26 to 28 July 2004, the green dots indicate the sample from 1 to 3 May 2006.

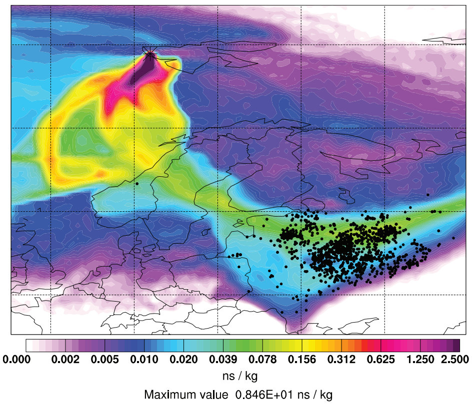

Figure 2: May 2006 episode: Transport pathway (backward in time) of the emission released during agricultural fires in Eastern Europe. The transport time up to the Zeppelin station in Spitsbergen was around 3 days. The colours show the potential emission sensitivity (PES) footprint map (0-100 m) for air arriving at Zeppelin between 1 May 2006 at 10:14 UTC and 3 May 2006 at 8:38 UTC 2006. Black dots show MODIS fire detections.

Method

We present weekly measurements from the research station Zeppelin (11.9° E, 78.9° N, 478 m a.s.l.).

The station is situated in an unperturbed Arctic environment on a ridge of the Zeppelin mountain on the western coast of Spitsbergen. For sampling of a variety of POPs, a combination of glass fiber filter and two polyurethane foam plugs was used. A sample volume of about 1000m³ was taken using a high volume sampler for 48 hours. Simulations of atmospheric transport were made using the Lagrangian particle dispersion model FLEXPART[3] (see *http://zardoz.nilu.no/~andreas/flextra+flexpart.html*). FLEXPART releases so-called tracer particles at emission sources and calculates their trajectories. FLEXPART was driven with operational analyses from the European Centre for Medium-Range Weather Forecasts with 1° x 1° spatial and 3 hourly temporal resolution.

Emission and Transport

In spring 2006 smoke from agricultural fires in Eastern Europe intruded into the Arctic and caused the most severe air pollution episodes ever recorded there. Fig. 2 shows the footprint PES map from a retroplume simulation calculated 20 days back from the time period when the PCB sample was taken. During summer of 2004, about 2.7 million hectare of boreal forest burned in Alaska, the by far largest annual area burned on record, and another 3.1 million hectare burned in Canada. It was shown that smoke from these fires filled large parts of the Arctic. At Zeppelin, the influence was relatively weak – compared to the rest of the Arctic – since the station is 4000 km away from where the fires burned and the air mass transport took about 3-4 weeks.

PCB Concentrations

The forest fire episode during 2004 shows the clearest signal in the less chlorinated PCBs. For instance, for PCBs 52, 28 and 101, the values are 4.8, 4.3 and 3.4 times the standard deviation above the mean, respectively. In contrast, during the agricultural waste burning episode in 2006, the lighter as well as the heavier PCBs are significantly elevated (from 2.6 up to 6.6 times the standard deviation). The concentrations of most congeners were strongly enhanced during the BB episodes. The two elevated samples compared to the long term mean are shown in Fig 3.

Conclusion

In this study, we show that biomass burning has the potential to boost re-emissions of POPs from terrestrial reservoirs, and that biomass burning is a significant, yet overlooked, source of these chemicals into the atmosphere on a hemispherical scale. Moreover, our results illustrate that this leads to significantly elevated levels in the Arctic, several thousands of kilometres away from the regions being subject to such fires. As the prevalence of biomass burning events are expected to increase as a result of climate change, climate change may even mitigate the efficiency of contemporary control strategies for POPs that were motivated to protect vulnerable ecosystems of remote areas.

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