The impact of North American emissions on carbon monoxide and ozone concentrations over Europe

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Motivation

While there exist many model and case studies of intercontinental transatlantic transport, to date no statistical analyses of measurement data over Europe exist, which analyze the influence of North American emission sources. In particular, the influence of the large emissions of the North American East coast megapolis (Boston, New York, Washington, named Bosnywash in the following) on atmospheric composition over Europe has never been assessed. In this study, we used a large data set of carbon monoxide (CO) and ozone (O_3) measurements to examine the influence of Bosnywash emissions on the chemical composition of the atmosphere over Europe.

MOZAIC Dataset

We analyzed 15 years of CO and ozone measurements from the MOZAIC programme taken during ascent and descent from European airports of commercial airliners equipped with instruments measuring meteorological parameters as well as some trace gases. All data points available over Europe (in total 250 000) were averaged over a height of 1 km.

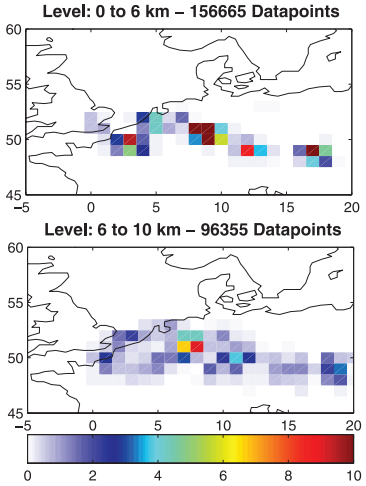

Figure 1 Distribution of the frequency of data points from the MOZAIC dataset used in this study. The upper panel shows the level up to 6 km, the lower panel the distribution above 6 km height.

FLEXPART Dispersion Model

We determined the source regions influencing the measurements with the Lagrangian particle dispersion model FLEXPART. CO and O_3 data were averaged over 1 km high layers during ascent and descent and for each individual 1-km-averaged measurement, 40000 particles were released and followed 20 days backward in time.

Using the EDGAR emission inventory and the FLEXPART backward calculation, CO concentration as predicted by the model could be derived. Comparing the modeled and simulated CO values shows that measured CO and modeled CO enhancement are well correlated and, thus, that the model captures the relevant transport processes.

Screening the dataset for all observation, which had an influence higher than 40% from the Bosnywash area, it was found, that while 22% of the observations were dominated by North American emission, only 3% are coming from the Bosnywash area. European emission dominate with 66.5%, while the contribution of modeled CO from Asia is 10%.

Comparing the signature of North American dominated airmasses to all samples (Figure 3) it can be seen, that influence from North America is related to low and medium CO Concentration. The Bosnywash Emission have compared to the average North American CO lower O_3 Values. In Summer the highest frequency of observations influenced by the Bosnywash area can be found.

Case study:Transport pathway from BOSNYWASH

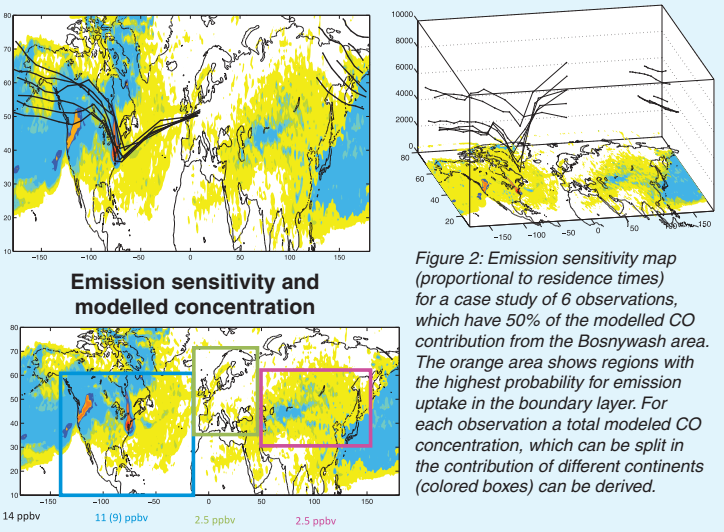

Figure 2: Emission sensitivity map (proportional to residence times) for a case study of 6 observations, which have 50% of the modelled CO contribution from the Bosnywash area. The orange area shows regions with the highest probability for emission uptake in the boundary layer. For each observation a total modeled CO concentration, which can be split in the contribution of different continents (colored boxes) can be derived.

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Scatterplots for Ozone and CO

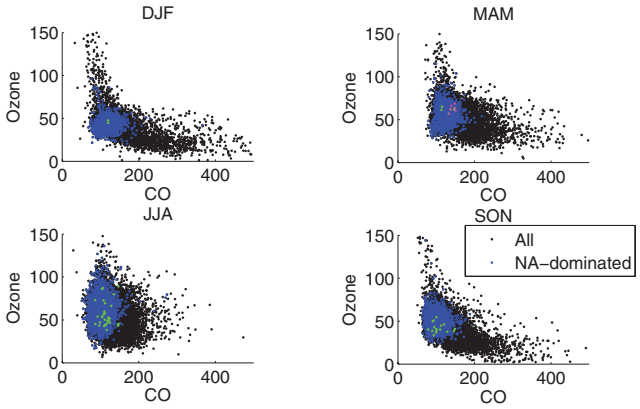

Figure 3: Scatterplot of measured ozone and CO concentrations for all observation, where the modelled stratospheric contribution is less than 5 percent (black dots). Observation, where model results indicate, that more than 70% of the modeled CO concentration origins in the North American boundary layer are shown as blue dots. Samples with contributions of more than 40% of the Bosnywash area are colored green.

Average Profiles of CO and Ozone, classified by the Air Masses Source Region

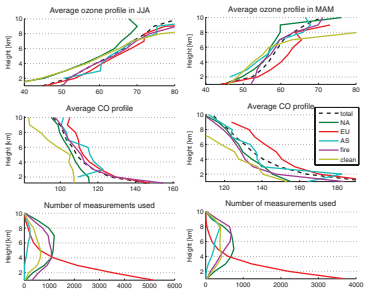

Figure 4: Vertical profiles (for spring and summer) of measured ozone (upper panel) and CO (middle panel) grouped by the continent they were dominated (i.e. if more than 70% of the emissions originating in the North American, European or Asian boundary layer). Additionally the average profile, a clean air profile and averaged values dominated by biomass burning emissions are shown. The lowest panels show the number of ozone observations used for the respective height level.

We grouped the MOZAIC measurements according to the dominant source regions, distinguishing between European, North American and Asian dominated measurements as well as clean air and biomass burning influenced samples, Profiles of ozone and CO (Figure 4) show up to 4 km a clearly domination by Europe, between 4 and 8 km altitude a strong North American influence, and even higher up Asian influence. In both seasons elevated CO concentration around 6 km where transport from Asia occurred can be seen. Biomass burning emission in summer have a clear influence on CO concentrations.

Conclusion and Outlook

- From all observations 22% where dominated by North American emissions, but only 3% show a significant contribution from the Bosnywash area.
- Transport events from the Bosnywash region show a summer maximum and have a higher CO/ozone ratio compared to average North American air masses
- Biomass burning emissions have a great contribution during summer
- Over most levels European dominated air masses have the highest concentrations in CO and ozone, but on some levels North American/Asian influence is clearly visible.
- The study will be extended by using climatology of European surface and mountain stations.

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