Project: **1260**

Project title: **Megacity Aerosol Composition by Satellite: A tool to study anthropogenic Emissions, Climate change and human Health**

Principal investigator: **Adrien Deroubaix**

Report period: **2022-11-01 to 2023-10-31**

The allocated resources were used for the analysis of the two EMeRGe aircraft campaigns conducted in Europe from July 11 to 28, 2017, based in Munich, Germany, and in East Asia from March 8 to April 9, 2018, based in Taipei, Taiwan.
The results were presented at the International Global Atmospheric Chemistry (IGAC22) project (https://www.icacgp-igac-2022.org/scientific-program/) and at the American Meteorological Society AMS 2023 conference (https://ams.confex.com/ams/103ANNUAL/meetingapp.cgi/Paper/413688).
An article has been prepared for the Atmospheric Chemistry and Physics (ACP) journal and will be submitted in the coming weeks (https://acp.copernicus.org/).

Article abstract for ACP

The processes that lead to the formation of carbonaceous aerosols, organic carbon (OC) and black carbon (BC), in the atmosphere are related to trace gases. We have investigated the proportional relationships between both OC and BC with the following trace gases: carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide (NO2), ozone (O3), and sulfur dioxide (SO2). One motivation for selecting these gases is the potential to predict OC and BC because they are also observable using remote sensing measurements from satellite instrumentation.

Measurements performed during campaigns using research aircraft are optimal for the analysis of both the composition of aerosols and trace gases in different environments, ranging from unpolluted oceanic air masses to those in heavily polluted agglomerations. The EMeRGe aircraft campaigns have created a unique database, with flight plans dedicated to studying city plumes in two regions of Europe (2017) and East Asia (2018).

The relative amounts between carbonaceous aerosol and trace gases are analyzed in air masses sampled by the aircraft, which have different environmental conditions, and by focusing on the heavily polluted air masses sampled in the city plumes. Using linear regression analyses to determine the proportional relationships, the results show that the most relevant relationships are:

(i) **The BC/OC ratio is three times higher for the Asian campaign (approximately 0.3) than for the European one (≈≈ 0.1), whereas the correlation between BC and OC is much higher in Europe (R ≈ 0.8) than in Asia (R ≈ 0.6).**

(ii) The CO/BC ratio is also higher for the Asian campaign (≈ 240) than for the European one (≈ 170), and the linear agreement between CO and BC is similar for both campaigns (R ≈ 0.7).

(iii) The HCHO/OC ratio is similar for both campaigns (≈ 0.32), even if the linear agreement is stronger for the European campaign compared to the Asian one (R ≈ 0.7 compared to ≈ 0.3).

The difference between the European and Asian campaigns seems to be related to the larger emissions from shipping and/or the greater number of fires in Asia. By focusing on heavily polluted air masses sampled in city plumes, the proportional relationships between the observed carbonaceous aerosols and the five trace gases are modified because the linear agreements of both BC and OC with O3 increase.

An air quality model ensemble is constructed to represent the state of the art of atmospheric modeling, which includes two global and two regional simulations. **The air quality model ensemble is evaluated and the proportional relationships of carbonaceous aerosols and trace gases compared to those observed**. The evaluation shows that the modeled CO is well correlated with the observations (R ≈ 0.8), whereas the correlation is reasonable for HCHO, NO2, O3 and BC (R varies between 0.5 and 0.7), and low for SO2 and OC (R less than 0.3).

The proportional relationships of BC and OC with the five trace gases are not well reproduced by the air quality model ensemble neither in the different environments sampled by the plane, nor in the city plumes. This analysis of the statistical links between carbonaceous aerosols and trace gases implies that, firstly the

most relevant proportional relationships could be used to constrain the models, and in particular the **anthropogenic emission inventories**, and secondly information on the amount of carbonaceous aerosols in the lowest troposphere could be inferred from satellite retrievals of trace gases, especially in megacities.

Comparison of aircraft measurements and modeling outputs for the proportional relationships of Black Carbon to Organic Carbon

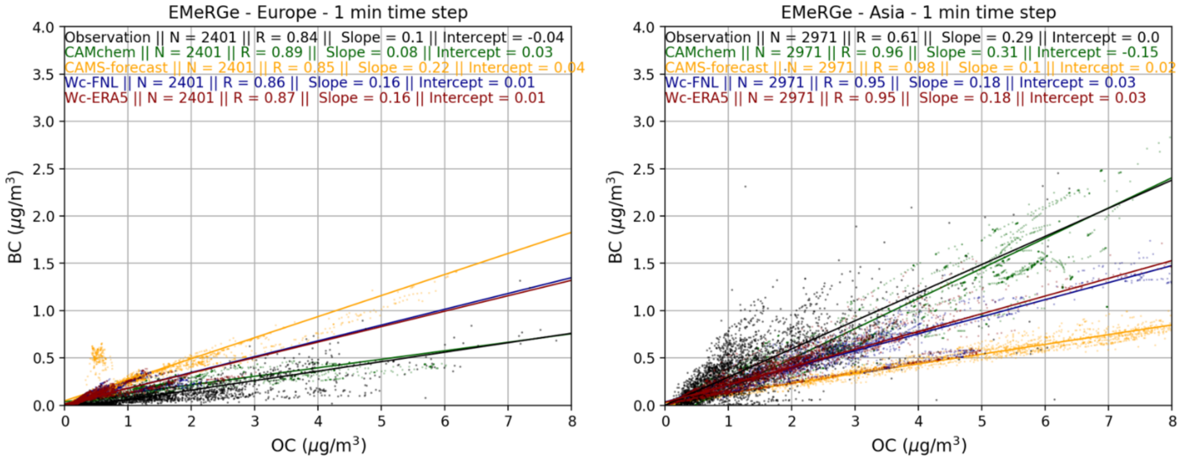

Figure 8. *Comparison of black carbon concentrations (BC in $\mu g.m^{-3}$) with organic carbon (OC in $\mu g.m^{-3}$) during the two EMeRGe campaigns: scatter plots of the concentrations of BC against OC for the observations at 1 step min time realized (a) in Europe and (b) in Asia, and for an air quality model ensemble composed of two global simulations, NCAR–CAMchem (orange line) and ECMWF–CAMS (orange line) and two regional simulations, IUP–WRFchem-FNL (blue line) and IUP–WRFchem-ERA5 (red line). Statistics of linear regression analysis (using reduced major axis regression) are given at the top for each simulation.*

Comparison of anthropogenic emission inventories

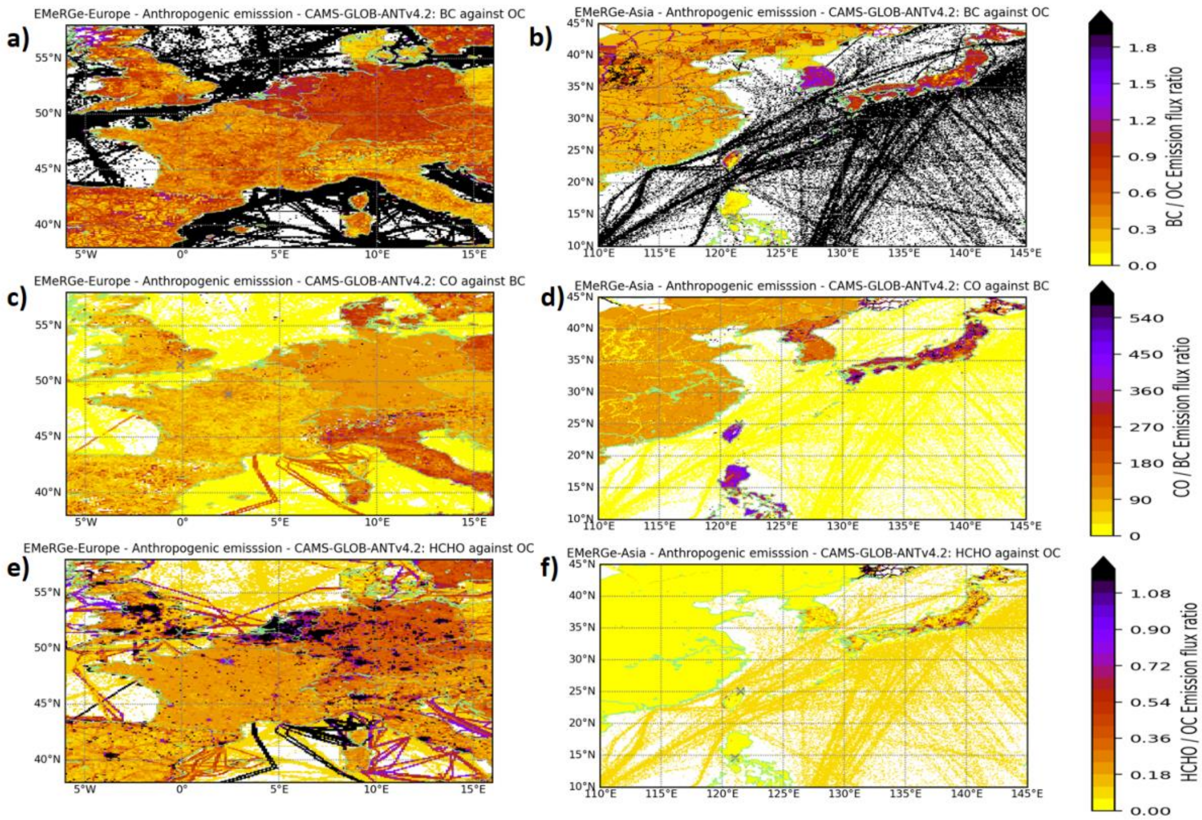

Figure 11. *Maps of emission flux ratios from the anthropogenic inventory CAMS-GLOB-ANT v4.2 (sum of all sectors): a) for BC/OC in Europe for July 2017, b) for BC/OC in Asia for April 2018, c) for CO/BC in Europe for July 2017, d) for CO/BC in Asia for April 2018, e) for HCHO/OC in Europe for July 2017, and f) for HCHO/OC in Asia for April 2018.*