MECO(n) based CO_2 and CH_4 forecast system for aircraft measurement campaign in Stuttgart and Berlin

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I) Abstract

The greenhouse gas budgets of cities are still highly uncertain. In order to understand these budgets better, detailed measurements are important, including not only ground-based, but also aircraft-based measurements. Such aircraft-based measurements took place in July 2018 as part of the BMBF project UC2 (Urban Climate Under Change) over Berlin and Stuttgart with the DLR research aircraft Cessna Caravan. The main focus of this measurement campaign were CO_2 and CH_4, but other trace gases such as NO_x and meteorological variables have been measured as well. All together the measurements can not only help to evaluate the individual greenhouse gas budgets of these cities, but they are also very valuable for evaluating high resolved chemistry climate models.

To provide highly resolved forecasts of CO_2 and CH_4 for Berlin and Stuttgart for the flight planning, a forecast system has been developed. A challenge for such a forecast system is the long lifetime of CH_4 and CO_2. Therefore, not only the regional emissions should be considered, but also the global background must be modelled adequately in order to forecast if the city plumes stand out from the background concentrations. Therefore, the forecast system is based on the MECO(n) model system, which couples the global chemistry climate model EMAC on-line with the regional chemistry climate model COSMO-CLM/MESSy. This forecast system allows for forecasts of CO_2 and CH_4 from the global scale down to 1 km resolution over Berlin and Stuttgart.

II) Forecasting products

The total mixing rations of CO_2 and CH_4 and the mixing ratios resulting only from Stuttgart/Berlin emissions (e.g. excluding the background, called PCO_2 and PCH_4) have been forecasted. For Berlin further also PNO_x has been forecasted. Figures and animations (also for Google Earth) of the forecasted fields have been provided via a website, showing mixing ratios of the forecasted species at specific pressure levels, along specific transects and the total column.

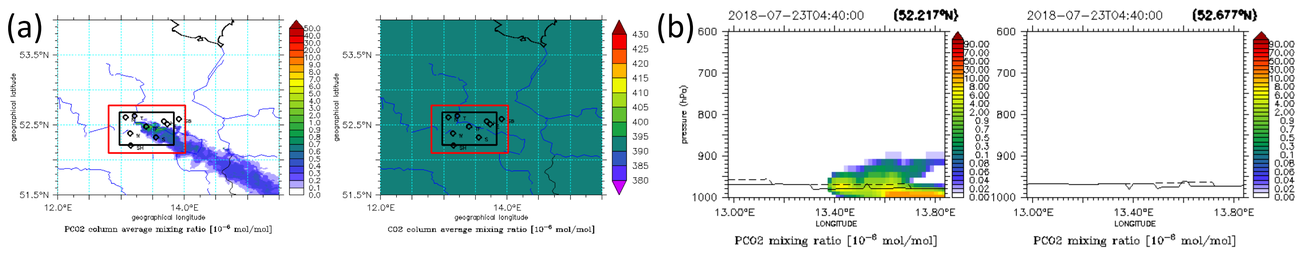

Fig 1: Snapshot of the forecast for Berlin (23-Jul-2018 at 04:40) . (a) shows the total column mixing ratios of (left) PCO_2 and (right) CO_2. (b) shows vertical cross-sections of PCO2 at 52.21°N (left) and 52.67° N (right).

III) Technical realisation

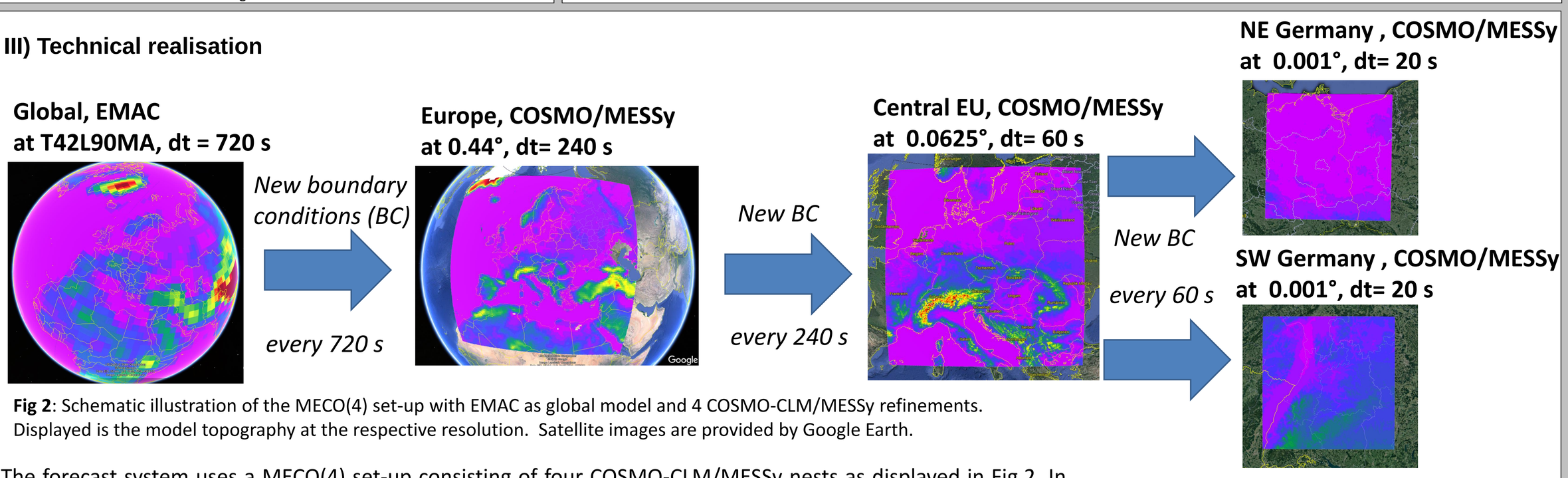

Fig 2: Schematic illustration of the MECO(4) set-up with EMAC as global model and 4 COSMO-CLM/MESSy refinements. Displayed is the model topography at the respective resolution. Satellite images are provided by Google Earth.

The forecast system uses a MECO(4) set-up consisting of four COSMO-CLM/MESSy nests as displayed in Fig.2. In every nest as well as in the global model the MESSy submodel CH4 is applied, calculating a simplified methane chemistry based on climatological OH concentrations.

Emissions:

- *EMAC, Europe and Central Europe*
  - CO_2 mixing ratios near ground level relaxed towards zonally averaged values
  - Global CH_4 emissions from emission inventory created by EMPA with EMAC OH concentrations
- *Berlin*
  - CO_2, CH_4 and NOx emissions from „Berliner Emissionskataster“ (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin and preprocessed for COSMO by D. Brunner and G. Kuhlmann, EMPA)
- *Stuttgart*
  - Most important sources for CO_2 and CH_4 as point sources based on E-PRTR (https://prtr.eea.europa.eu)

In the ongoing analysis phase various sensitivity studies with different emissions will be performed to optimize the model and the emissions.

Analysis and forecast simulations:

The forecast system consists of one continuous analysis simulation as well as several forecasts (see Fig. 3). For the analysis simulation, EMAC is nudged towards the ECMWF operational analysis. Every day one 5-day forecast (simulation time at 00 UTC) is branched from the analysis simulation. For these forecasts EMAC is nudged towards the ECMWF forecast data.

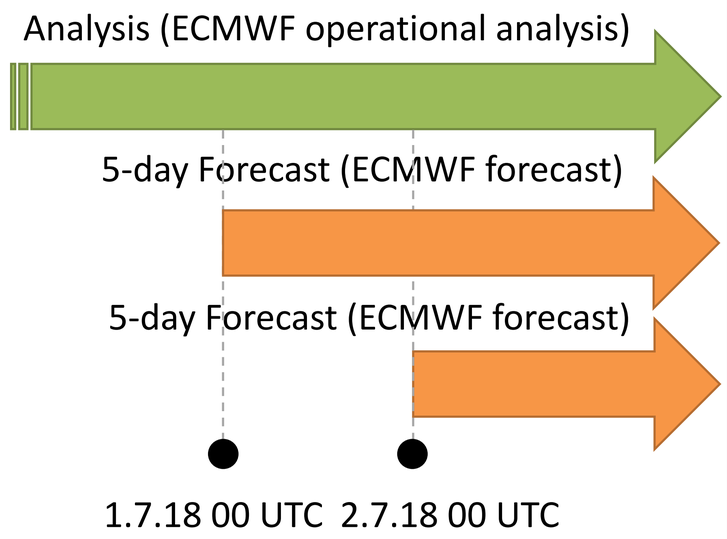

Fig 3: Schematic illustration of the forecast system consisting of one analysis simulation and several 5-day forecasts.

IV) Comparison between measurements and analysis simulation

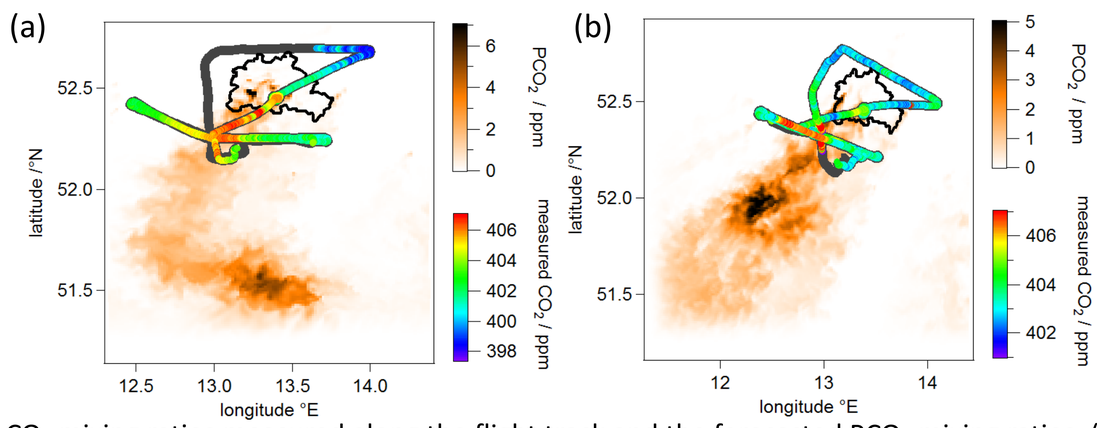

Fig. 4) CO_2 mixing ratios measured along the flight track and the forecasted PCO_2 mixing ratios. (a) Measurements for the 24. July (downwind wall 13:30 and 14:30), model data for 14:00 at 930 hPa. (b) Measurements for 25. July (11:30 – 14:00) and model data for 13:00 at 910 hPa.

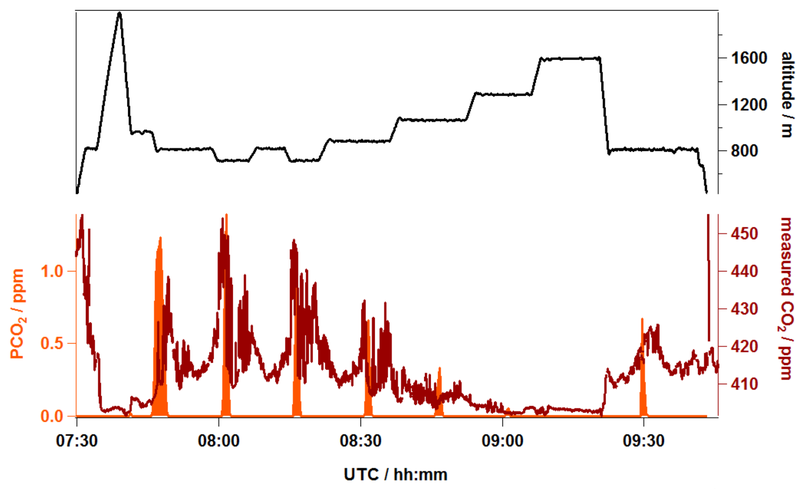

Fig. 5) Comparison between measured CO_2 mixing ratios at 9. July (Stuttgart region) and the forecasted mixing ratios of the PCO_2 tracer.

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