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Geoscientific Model Development Discussions

Interactive comment on "Current status of the ability of the GEMS/MACC models to reproduce the tropospheric CO vertical distribution as measured by MOZAIC" *by* N. Elguindi et al.

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The authors are grateful to the valuable comments by the reviewer. We think that this manuscript is suitable for GMD because it presents work that was carried out for a project whose main goal is to develop an operational data assimilation system for chemically reactive gases. The validation results presented in this study were used in developing such a system. We have made the following changes in the manuscript to better reflect this,

We changed the title of the manuscript to "A global evaluation of the GEMS/MACC ECMWF-IFS model coupled to the CTM MOZART with 4DVAR data assimilation"

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and the abstract to,

“Vertical profiles of CO taken from the MOZAIC aircraft database are used to globally evaluate the performance of the GEMS/MACC models, including the ECMWF-Integrated Forecasting System (IFS) model coupled to the CTM MOZART with 4DVAR data assimilation for the year 2004. This study provides a unique opportunity to compare the performance of three offline CTMs (MOZART, MOCAGE and TM5) driven by the same meteorology as well as one coupled atmosphere/CTM model run with and with data assimilation, enabling us to assess the potential gain brought by the combination of online transport and the 4DVAR chemical satellite data assimilation.

First we present a global analysis of observed CO seasonal averages and interannual variability for the years 2002–2007. Results show that despite the intense boreal forest fires that occurred during the summer in Alaska and Canada, globally the year 2004 had comparably lower tropospheric CO concentrations. Next we present a global validation of CO estimates produced by the MACC models for 2004, including an assessment of their ability to transport pollutants originating from the Alaskan/Canadian wildfires. In general, all the models tend to underestimate CO. The models perform best in Europe and the US where biases range from 0 to –25\% in the free troposphere and from 0 to –50\% in the surface and boundary layers (BL). Using the 4DVAR technique to assimilate MOPITT V3 CO data is shown to reduce biases by up to 25\% in some regions. However, even the IFS/MOZART coupled model with assimilation is not able to reproduce well the CO plumes originating from the Alaskan/Canadian wildfires at downwind locations in the eastern US and Europe. Suggestions regarding the improvement of the assimilation technique, such as the use of averaging kernels, are given. Sensitivity tests also reveal that deficiencies in the fire emissions inventory and injection height also play a role.”

We have also added the following paragraph discussing issues regarding data assimilation to the end of section 4,

GMDD

3, C173–C177, 2010

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“The fact that in many of the cases during the summer biases from the ASSIM simulation are better than from the CTRL simulation suggests that the assimilation is improving the simulation. However, it is still difficult to explain how valid this improvement is because there are many influencing factors, such as sensitivity of the MOPITT sensor, the method to assimilate CO MOPITT tropospheric columns into vertical profiles, and the 4DVAR procedure itself. Firstly, MOPITT CO data have been generally regarded as not very sensitive to the boundary layer. The MOPITT data products used for assimilation are based on thermal-infrared measurements near 4.7∼microns, and its sensitivity to the lower troposphere is debatable (Deeter, 2007). Hence, changes in the PBL can not be efficiently constrained by MOPITT data assimilation. However, recent studies have shown that MOPITT sensitivity varies considerably depending on the thermal contrast conditions (Deeter, 2007,Clerbaux, 2008). These studies show that to a certain degree, MOPITT is sensitive to the lower atmosphere in conditions where there is a strong temperature gradient between the surface and lower atmosphere. This may well be the case during summers in the northern hemisphere and it emphasizes the need to evaluate the impact at all seasons, and explore the difference of impact in using either day- or night-time data. Secondly, as MOPITT’s averaging kernels are not used in the assimilation process, the information on the vertical distribution of CO is lost and the low sensitivity in the lowest troposphere is not taken into account. This may allow the 4DVAR technique to change the concentration profile predominantly in the PBL where the CO variability is largest. Thirdly, in the 4DVAR context, a simplified model (but something still “physical”) is used to make sure that the profiles are modified in a way that their total column (i.e. vertical integral) better fits the MOPITT total columns. The freedom of the 4DVAR technique to change the concentration profiles depends on the assumed background errors statistics. The higher this error is the bigger are the allowed changes. The background error is often linked to the variability, and because variability is often high in the PBL the values in this region are more likely to be changed.”

In addition, we have made modifications throughout the manuscript (as suggested by the reviewers) that emphasize better the 4DVAR assimilation technique, such as a more thorough description in section 2.2.

Below is our response to your other concerns.

MOZART-V3 was used for all the simulations, however there were some minor upgrades/changes that were made specifically for the GEMS/MACC project. We agree that the model versions referred to in the paper are really only relevant to the GEMS/MACC community, therefore we have changed all references to MOZART-V1 and MOZART-V10 to MOZART-V3, while specifying the differences between the models in Section 2.2 as follows,

"Note that the stand-alone version of MOZART is a later version than that which was coupled to the IFS model. The main upgrades are that the RETRO ship emissions have been replaced by estimates based on Corbett et al (2003) and the East Asian anthropogenic emissions have been replaced by the REAS inventory (Ohara et al, 2007) but keeping the original RETRO seasonality. In addition, several chemical reaction rates have been updated to JPL-06 (Sander et al, 2006)."

Regarding the assimilation scheme, we have add the following brief description in Section 2.2 and added the url where one can find a copy of the technical report in the reference section,

'MOPITT V3 total column data (Deeter et al, 2003) are assimilated using ECMWF's 4D-VAR data assimilation system. The data are thinned to a resolution of 0.5 deg x 0.5 deg and are only assimilated over land between 65N and 65S. Averaging kernel information from the MOPITT data is not used, because it was not available at the time the GEMS simulations were run. The model equivalent of the observation is calculated as vertical integral. The background errors statistics for the CO assimilation were determined with the NMC method (Parrish and Derber 1992). For this, 150 days of 2-day forecasts were run with the coupled system initialized from fields produced by the free running MOZART CTM, and the differences between 24-h and 48-h forecasts valid at the same

GMDD

3, C173–C177, 2010

time were used as a proxy for the background errors.'

While we agree with the reviewer that averaging kernels would have clearly been a better option, unfortunately they were not available at the time, and we still feel that the preliminary assimilation technique used here does improve the models simulations, albeit not in all respects such as the LRT of biomass burning emissions. Therefore we would like to keep the ASSIM results in the study and have tried to be more clear about the shortcomings of our paper. For example,

in the Conclusion section we add the following to the second to last paragraph,

"...., showing that the method used for assimilation does not provide enough information about the vertical profiles and is therefore not sufficient to compensate for other model inadequacies."

and to the last paragraph,

'One possible shortcoming of using the MOPITT V3 data without averaging kernels is that the assimilation could be biased to the a-priori profile. Therefore, in the current MACC (follow up project to GEMS) reanalysis, that will cover the period 2003-2010, averaging kernel information is used for MOPITT V4 data. This allows one to separate the contributions of measurement and a-priori information in forming the total column and should lead to improvements in the CO analysis.'

Interactive comment on Geosci. Model Dev. Discuss., 3, 391, 2010.

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