Reply to Reviewer comments for Manuscript ACPD-10-26361-2010

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We are grateful to the constructive and thorough comments of the reviewers. In our revision, we took into account all specific and technical comments by the reviewer as detailed below. In addition, we performed a number of minor technical/semantic corrections to improve the overall readability of the manuscript.

Anonymous Referee #2

[…]

Specific comments:

The majority of the plumes encountered had a fire origin. Authors compare simulations from different models that have different fire emissions. It is therefore difficult to estimate if differences between models are due to differences inherent to the models themselves or to differences in the fire emissions. Authors should try to estimate the differences coming from the fire emissions used. There are of 2 orders : ground emissions and fire injection height. Indeed WRF-CHEM (the only model using a parametrisation of fire injection height) simulates an injection height of 4.6 km when TOMCAT and FLEXPART emit BB fire emissions in the lower layers. Authors should at least show a map of total CO fire emission over the analysed period to estimate ground emissions differences. More interestingly, they could compared simulations (averaged over the analysed period) with the different models just over the emission regions. A comparison between WRF-CHEM simulation and the others would show differences arising from different injection height, and comparison between TOMCAT and FLEXPART would help to distinguish between differences coming from model formulation and emissions.

According to the comments by reviewer 1, the WRF-Chem simulation has been largely removed from the manuscript. We compare the total emission amounts of CO in a new Table 1, as described in the reply to reviewer 1 above.

Abstract: You should perhaps mention the origin of smoke plumes (anthropogenic plumes from Asia and biomass burning plumes)

The second sentence of the Abstract has been changed to:
"The two cyclones had extensive smoke plumes from Siberian forest fires and anthropogenic sources in East Asia embedded in their associated air masses, creating an excellent opportunity to use satellite and aircraft observations to validate the performance of atmospheric transport models in the Arctic, which is a challenging model domain due to numerical and other complications."

Section 2:

Can you mentioned the time-step used for ECMWF input data, for both FLEXPART and TOMCAT ?

We amended Sec. 2.1:
"Six-hourly analysis data were supplemented by 3-hour forecast data to increase the time resolution of the meteorological fields. "
In Sec. 2.2, we added the time step information for TOMCAT:
"The model is forced using 6-hourly ECMWF operational analyses of wind speed, temperature and humidity. The model was run at a horizontal resolution of ~2.8°x2.8° with 31 vertical levels up to 10 hPa."

Pg 26368 section 2.1: What is the horizontal and vertical resolution of the FLEXPART output grid ? Is it the same than ECMWF data? Depending on these resolutions will the narrower structures appear or not.

We added a sentence to Sec. 2.1:
"Output data from the FLEXPART calculations were stored at 0.5°x0.5° horizontal resolution and on 15 vertical levels."

Pg 26369 line 10-12: What is the altitude of the surface layer in TOMCAT? It is useful in order to compared with FLEXPART that distribute the emissions in the first 150m.

The TOMCAT model uses a sigma-pressure level coordinate system in the vertical discretisation (Chipperfield, 2006). We added this information to Sec. 2.2:
"These daily emission fluxes are regridded to the TOMCAT grid and emitted every timestep and distributed throughout the lowest level gridbox (up to ~86m)"

Section 3:

Pg 26374 line 20: different color scales are mentioned in the text but only one is shown in Figure 2.

corrected

Pg 26376 line 20 : It would be useful to give an estimation of mean OH concentrations during this period of the year in the Arctic and then evaluate the mean CO life time.

As mentioned in the reply to reviewer #1, we briefly discuss OH concentrations and the impact on CO lifetimes.

Pg 26378 line 12 : It was not easy for me to understand where is the small plume that is shed east of the main plume in the TOMCAT simulation (when it is clear in FLEXPART and WRF-CHEM simulation). May the feature be circled in Figure 6g ?

We added an arrow pointing to the feature to Fig. 6g and changed the text accordingly

Pg 26378 line 29-28: You suggest that differences in model TCO maximum may come from differences in anthropogenic emission inventories. You also mention differences in fire emissions. I though it was possible with FLEXPART simulations to know the origins of air masses? In that case, this would help to know which differences are more likely to dominate.

As requested by reviewer 1, we removed the WRF simulation results from the manuscript. The discussion is thus no longer part of the manuscript.

Pg 26380 line 10: Is it easy for you to estimate the width of this narrow filament? This could be interesting for further studies to know how small can be the feature well represented by FLEXPART.

The filament in Fig. 7g was measured to be ~220-300 km wide, at an elongation of 2500 km. Another filament extending from the pole to the Canadian Arctic on the same image only ~100 km wide. The TOMCAT plots show good correspondence when the plume is 850-1600 km wide (Fig. 7q,r). We edited Sec. 3.2 accordingly.

Pg 26384 section 3.4: Model simulations are interpolated along the flight and compared with data. Are data averaged along the flight ? If this is 1 second data and if we consider that aircraft flew at 250 m.s-1, then aircraft data represent features with characteristic length down to 250m. Depending on model resolution (or output resolution for FLEXPART), some of the variability observed in data cannot be reproduced even if the model perfectly transport the plume. You can mention it in the paper.

We used a merged dataset of the DC-8 at 10s resolution, which allows to resolve features larger than ~2-5 km at typcial airspeeds of the DC-8. This was already mentioned in Sec. 2.5. In backward run mode, particles are released from every few seconds (when the aircraft position has changed more than 0.3° horizontally or 150 m vertically). At 75° latitude, the resolution of features in the backward run FLEXPART data is thus between 10-30 km. Aircraft data at higher time resolution (1s) are available for some instruments, but have not been used in this study. By means of those data, smaller features could be resolved, that are not represented by FLEXPART in the current model configuration. We extended the discussion in Sec. 3.4:
"Air parcels were tracked backwards from locations along the flight track of the aircraft when its position has changed more than 0.3° horizontally or 150 m vertically."
and

"At 75° latitude and typical airspeed of the DC-8, the backward run FLEXPART data resolves features of about 10-30 km width. The 10 s averaged CO data from the DC-8 can resolve features of up to 2.5 km length. Thus, even with perfect advection of the plume, FLEXPART would miss some of the variability measured by the aircraft."

Section 4:

Pg 26388, line 4-6. You first suggest that the low bias of FLEXPART compared to IASI may be due to a "wrong" background CO. Is not background CO taken from measurement (and therefore "true")? But maybe measurement chosen for establishing CO background are too "local" compared to area where FLEXPART and IASI are compared. Can you explain this a bit in your paper ?

We added a sentence on this aspect to the discussion:
"A reason for a low bias could be that the aircraft data used to construct the background profile was only from a limited domain, that was not representative for the whole Arctic (see Sec. 2.6)"

Conclusion: Conclusions seems to me too general. If you manage to evaluate a minimum width of filament that are resolved with FLEXPART simulations, I think it is worthwhile to mention it in the conclusion.

We revised the conclusions to appear less general and to be more closely connected to the results in our manuscript. A sentence was added to mention the ability of the models to resolve horizontal features:
"In the configuration applied here, the FLEXPART model could realisticly resolve pollution features up to a horizontal size of ~250 km. While the coarser-grid model TOMCAT could not resolve such narrow features, correspondence between both models and the satellite data was excellent for structures of ~850 km width or more."

Technical corrections

Pg 26377, line 9 : No need for brackets for "Rastigejev et al., 2010)

done

Pg 26378, line 6 : "towards higher altitudes, the and a singularity". "the" is probably supposed to be place before "higher"

corrected

Pg 26382, line 11: FLEPXART instead of FLEXPART

corrected

Pg 26386 line 7: "The dynamical tropopause from the ECMWF analysis confirms that the aircraft sampled in the stratosphere at around 15:30 UTC." Something is missing in this sentence.

We changed the sentence to
"The dynamical tropopause from the ECMWF analysis confirms that the aircraft was located within the stratosphere at around 15:30 UTC."

Figure 7 : There is a problem in the colorbar of the first column (FLEXPART). Figure 9 : Caption and figures order do not correspond

corrected

Figure 11 : caption: c) black solid line is defined as FLEXPART anthopogenic CO, when figure legend defines it as anthropogenic + biomass burning

corrected