Review of "Assimilation of IASI satellite CO fields into a global chemistry transport model for validation against aircraft measurements" by Klonecki et al.

This paper discusses the assimilation of CO retrievals from the IASI instrument into the chemical transport model LMDz-INCA. The authors give a careful description of the techniques used and present an evaluation of the impacts of data Assimilation on modeled CO fields through comparison to aircraft observations of CO during the POLARCAT campaign. The sub-optimal Kalman Filter assimilation technique is well established and has been applied in previous studies.

The work described is generally sound and the manuscript well written, but it includes little scientific content and, in my opinion, might be more suited for GMD than ACP unless the authors find a way to increase the scientific significance.

The main scientific result presented in the article, which in our opinion justifies the publication of the manuscript in ACP, is the validation of the IASI CO product. In order to improve the scientific presentation, the updated version of the manuscript was reorganized:
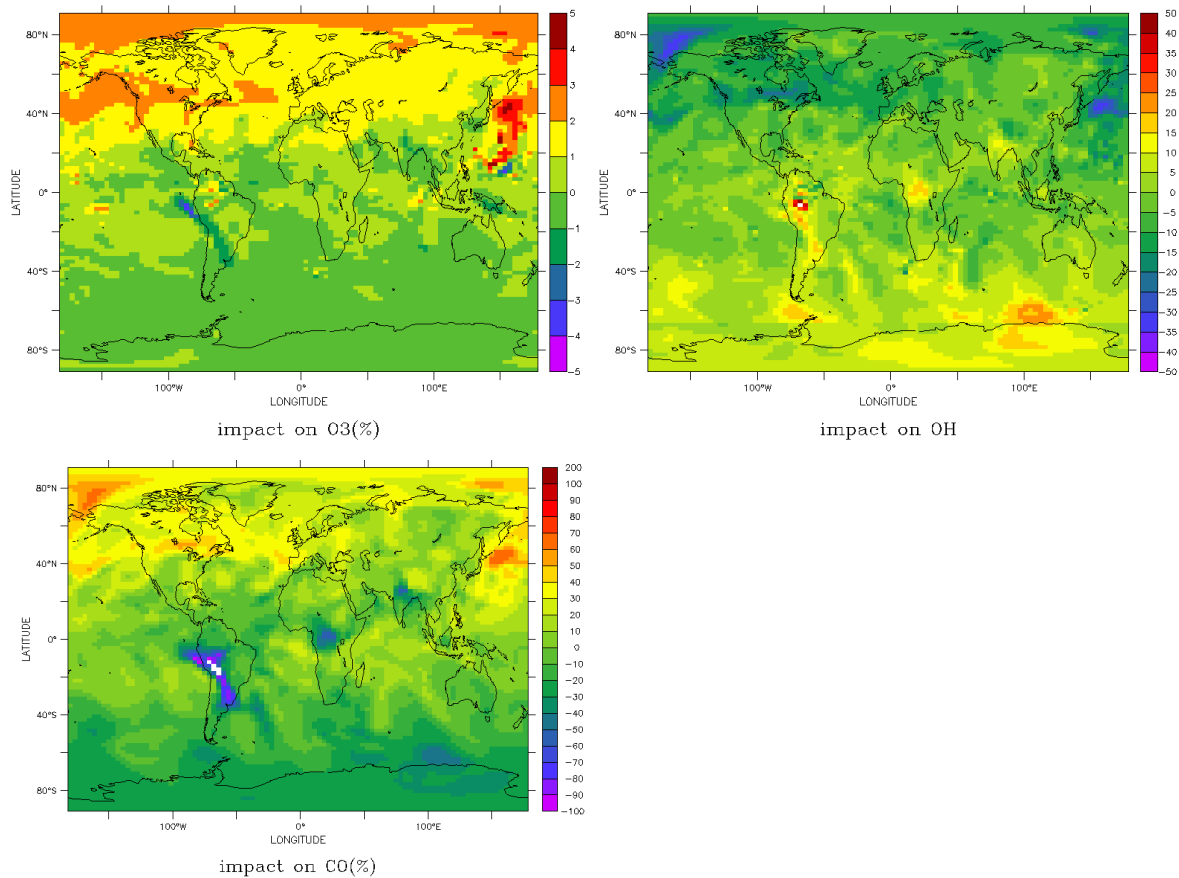
- o The abstract was rewritten
- o The sections on comparison with in-situ data was put into a separate section
- o The summary was shortened

In addition the article is part of the POLARCAT effort (and hence belongs to the POLARCAT special issue). It discusses the improvement of the modeling of CO transport into the Arctic when assimilation is used.

General comments:

The authors discuss the impact of assimilation of CO on modeled CO fields, but it would be interesting to see if and how other chemical species changed.

The figures below show the impact of assimilation of CO on O_3 and OH at 550 hPa for July 7th, which is the day with strong cross-pole transport. The figures show the change in percentages in daily averaged values of O_3 and OH. (e.g. (O_3(with assim)-O_3(control))/O_3(control)*100%). For comparison the corresponding figure is shown for CO. For O_3 the biggest increased is of 5%, and is correlated with higher CO fields and higher rate of chemical production. For OH the change in the daily averaged values is higher and can reach 50% in the strongest CO plumes (decrease of OH). The background values of OH are reduced as well in the northern hemisphere with a decrease of about 10%. In the Southern Hemisphere, where assimilation leads to a reduction in CO concentration, the OH levels increase by 5-10%.

impact on O3(%)

impact on OH

impact on CO(%)

The quality of the figures could be improved. Many of them are fuzzy and labels are often too small to read.
The quality of the figure has been improved. The following figures have been modified: figure 6, 7, 8, 9, 10, and 12.

Specific comments:

Section 2, page 31694, line 25
Do I understand correctly that there are only two profiles used as a priori, one for polluted and one for unpolluted cases? And the model is used to geographically separate these cases?
A single profile is used as a priori in the FORLI-CO retrieval algorithm. The error covariance matrix was constructed to encompass the variability for both clean and polluted conditions.

Section 2.3
Does the assimilation include both daytime and nighttime retrievals?
Yes, we assimilate both day and nighttime data.
It is now specified in the text (section 2.2): Both day (local time for equator crossing – 9:30 A.M.) and night time data (local equator crossing time –9:30 PM) are assimilated.

Section 2.3, page 31699, equation 4
If the variability is considered in the error and also added to the superobservations, isn't it counted for twice then?
We believe that the variability is not counted twice as it is added to final formulas for superobservation and its error. The variability is added to the superobservations in order to have a consistency between the superobservations and their error. Not adding the variability to the superobservations leads in certain cases

(such as for most of the Southern Hemisphere) to a situation in which the superobservations are very stable spatially and temporally, and the error levels are too high with respect to the variability in the superobservations.

Section 2.3, page 31700, line 8
Is there a reason behind the Nobs >=4 or is this threshold chosen arbitrarily?
Yes, this value was chosen somewhat arbitrarily in order to avoid cases with too few observations that were judged not to be representative of the whole model grid box.

Section 3.1
Why was climatology used for the emissions and not the emission inventory that was developed specifically for the POLARCAT time period? It can be expected that model output using climatological emissions is not able to capture measured patterns well, especially in the presence of fires.

One of the main objectives of this study was the validation of the IASI CO columns. The choice of using climatological GFEDv2 emissions was done in order to test if assimilation of IASI derived CO columns was able to bring model CO mixing ratios closer to in-situ observations.
Nevertheless, we have also performed tests with FLAMBE emission inventories developed specifically for the ARCTAS campaign. These tests indicate that the assimilation is a more powerful tool to simulate the CO plumes in the Arctic free troposphere than the use of the FLAMBE emission inventory. Moreover Fisher et al. (2010) show that the FLAMBE inventory overestimated the CO emission from the forest fires by a factor of 2.

Section 4.3.1
It would be helpful to specify the number of data points available for each bin in Figures 8 and 9. I assume most data points will be at the cruise altitude and few below? I also suggest adding horizontal error bars on the mean difference plots to show if the improvement with assimilation is within the variability.

The figures were updated: in figure 8 the right column with the number of measurements per pressure bin was added and the horizontal error plots were added on the mean difference plots. Indeed, most of the points are at the cruise altitude, but the number of measurements in the lower and mid troposphere is still relatively high. The number of measurements was also added in Figure 9. New Figures 8 and 9 are shown below.
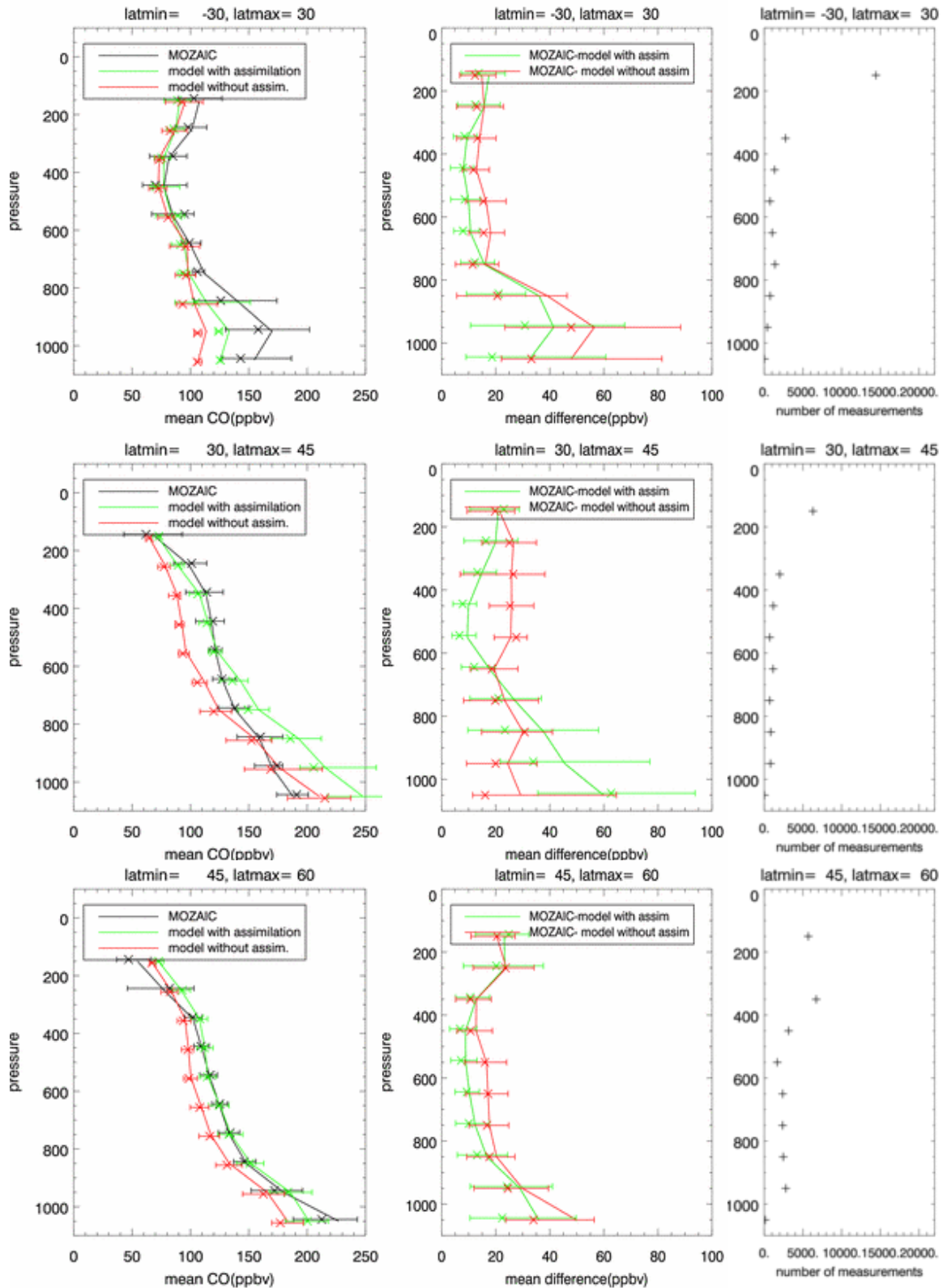
latmin= -30, latmax= 30 (top row); latmin= 30, latmax= 45 (middle row); latmin= 45, latmax= 60 (bottom row). Left column: mean CO(ppbv) vs pressure showing MOZAIC, model with assimilation, model without assim. Middle column: mean difference(ppbv) showing MOZAIC-model with assim, MOZAIC- model without assim. Right column: number of measurements.
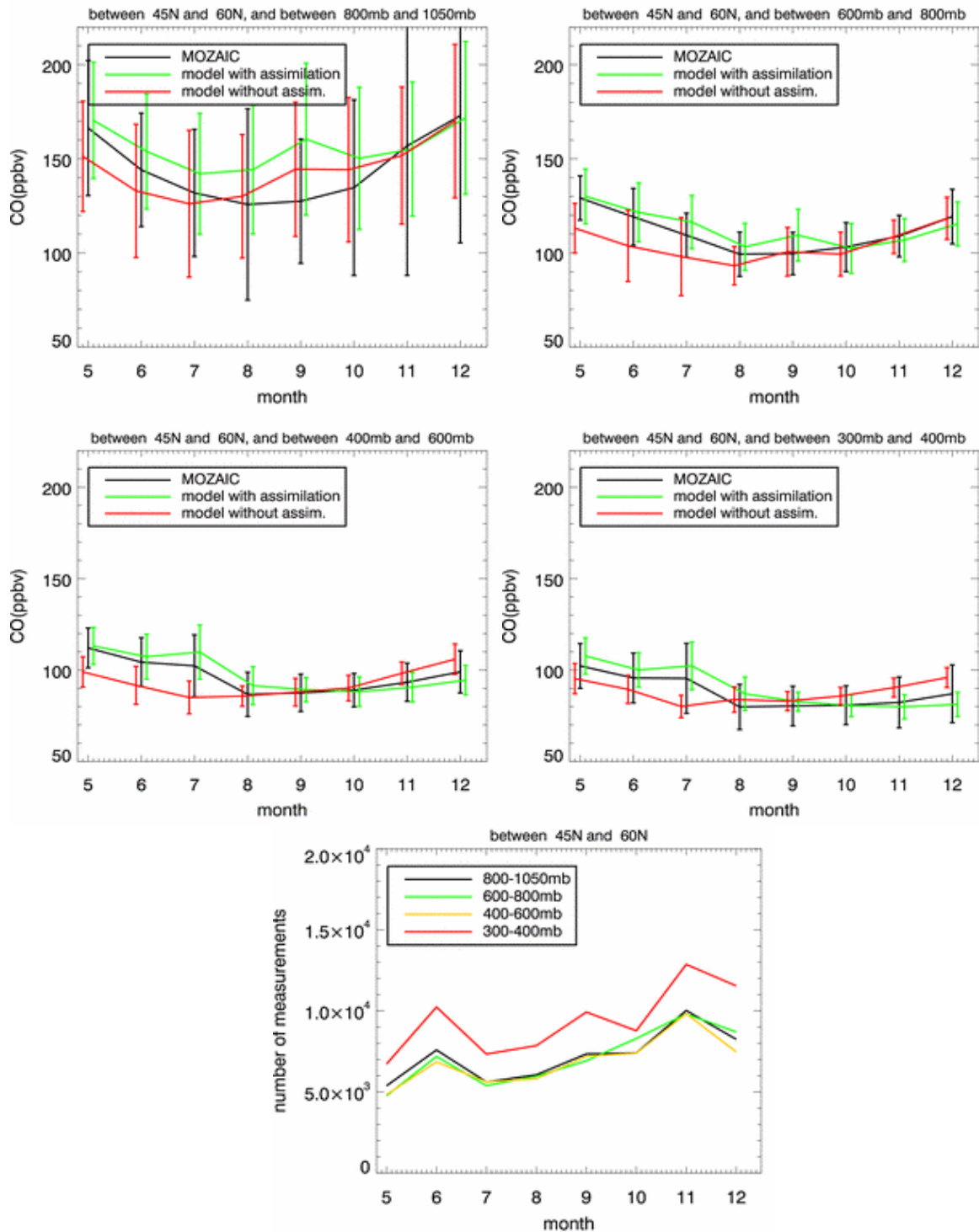
Figure 8. Left column: solid lines indicate monthly averaged CO for: MOZAIC (black curve), LMDz-INCA with assimilation of IASI CO products (green curve) and LMDz-INCA control run (red curve). Centre column: mean absolute differences between: MOZAIC data and assimilation run (green curve) and MOZAIC and control run (red curve). The horizontal bars in the left and centre column panels indicate the 25 and 75 percentiles, and the symbol x indicates the median. The right column indicates the number of MOZAIC measurements. The number of measurements in the 200-300mb bin is off the scale of the figure. The results are shown for May 2008, for data in three latitude bands: 30°S-30°N (top figure s), 30°N-45°N (centre figures), and 45°N-60°N (bott om figures) and 100 hPa pressure bins.
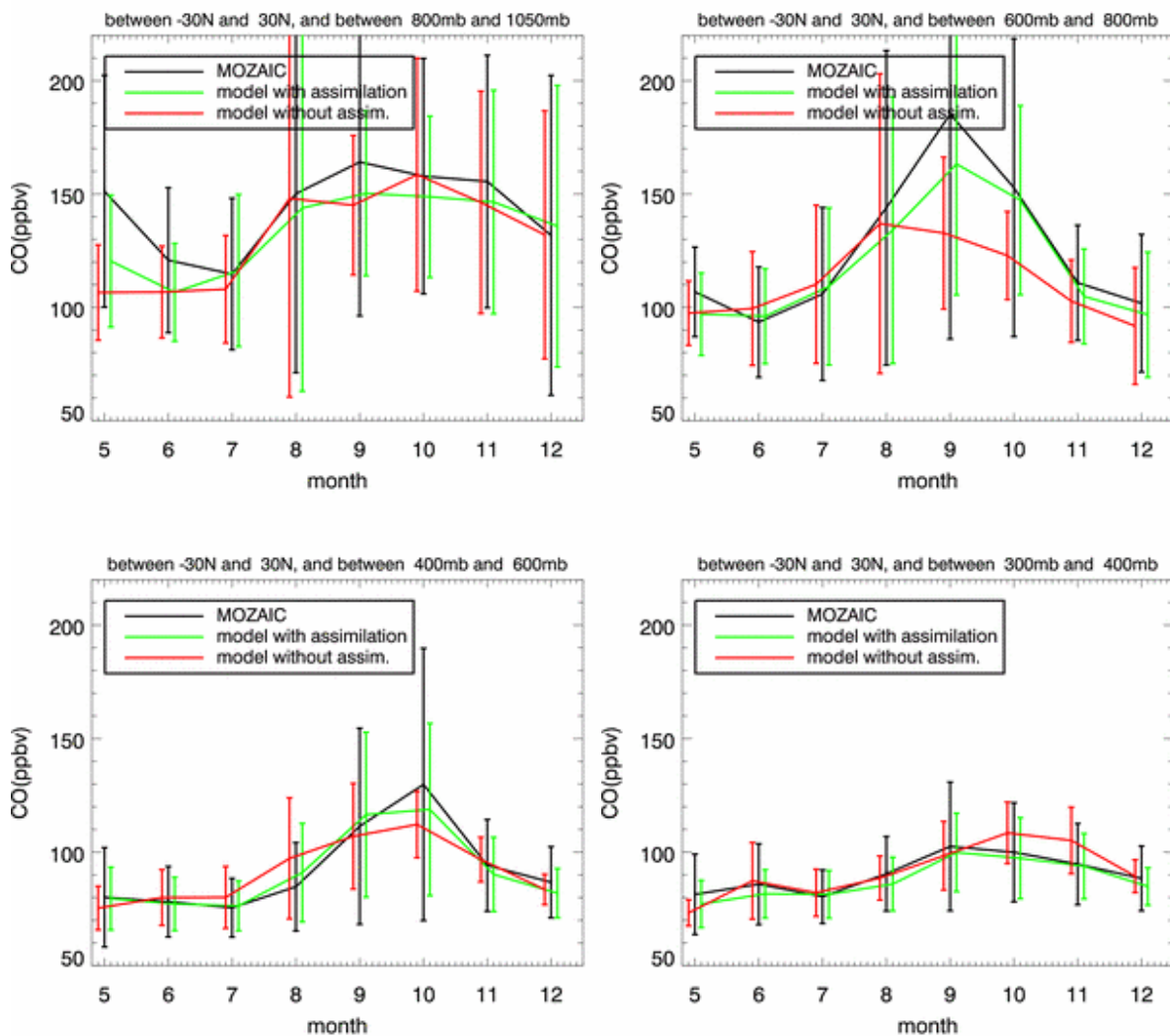
Figure 9. Monthly averaged CO data for: MOZAIC (black curve), LMDz-INCA with assimilation of IASI CO products (green curve) and LMDz-INCA control run (red curve). The plotted data represent the means and standard deviations (error bars) for one latitude band (45-60°N), for data in four pressure bins: below 800 mb (upper left), between 800 and 600 mb (upper right), between 600 and 400 mb (centre left) and between 400 and 300 mb (centre right) and from May to December 2008. The data in the lowest panel shows the number of measurements in each pressure bin as a function of month.
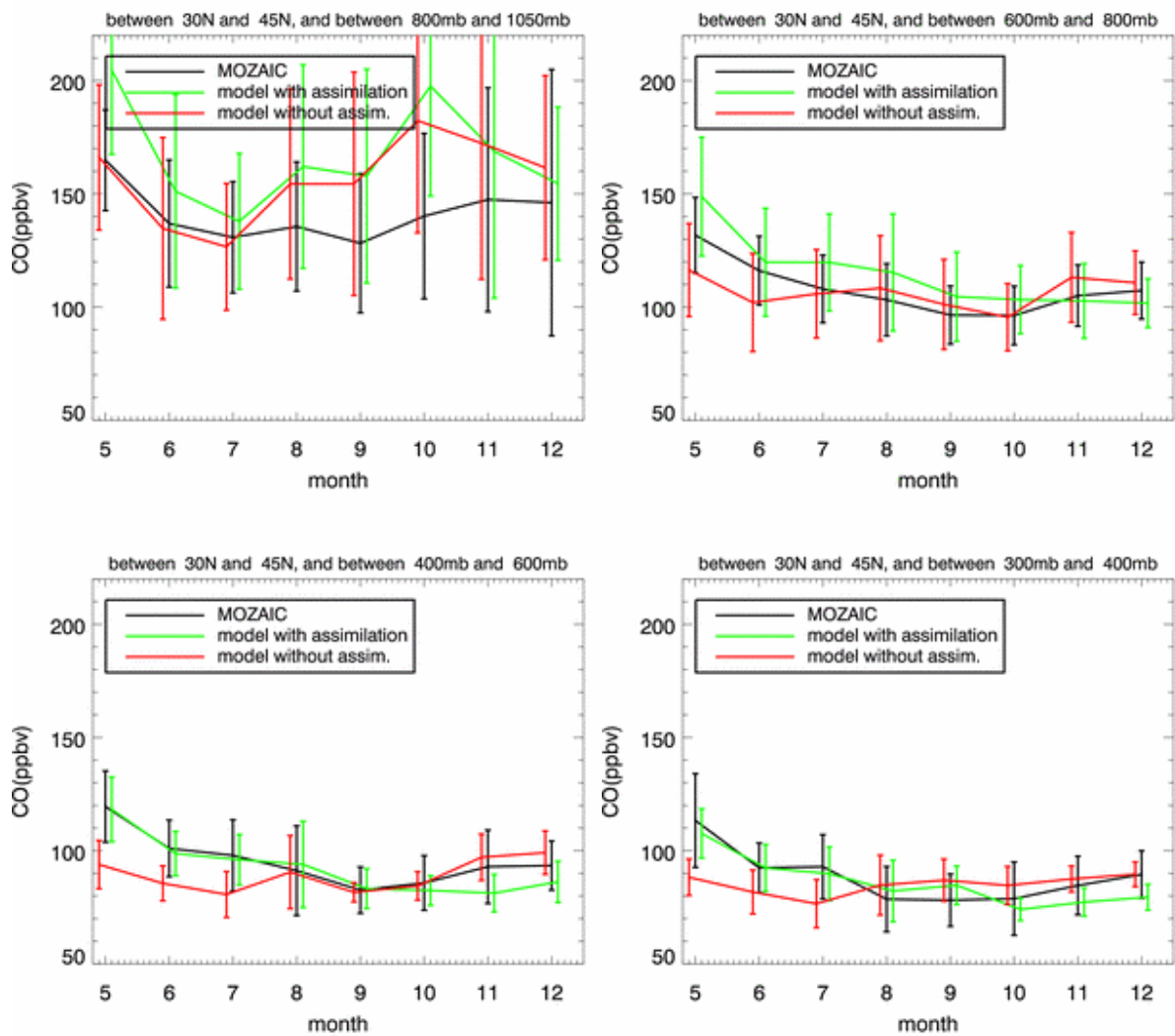
Line 15: I would not say that assimilation seems to increase the mean bias, it clearly does. Could there be an issue with the vertical correlation length?

When assimilation leads to an increase in CO levels in the middle troposphere, the levels near the surface are also increased. This could indeed be due to the correlation lengths being too long; however sensitivity tests with lower correlation lengths also show similar bias near the surface. A more likely explanation is the vertical mixing which might be too fast in the current version of the model.

Figure 9: Does the seasonal cycle also improve for the other latitude bands?

Yes, it improves also for other latitude bands (with some minor exception, e.g. Nov-Dec, 30-45°N, 400-600 mb), see the figures below. In addition, the following sentence was added to the manuscript:
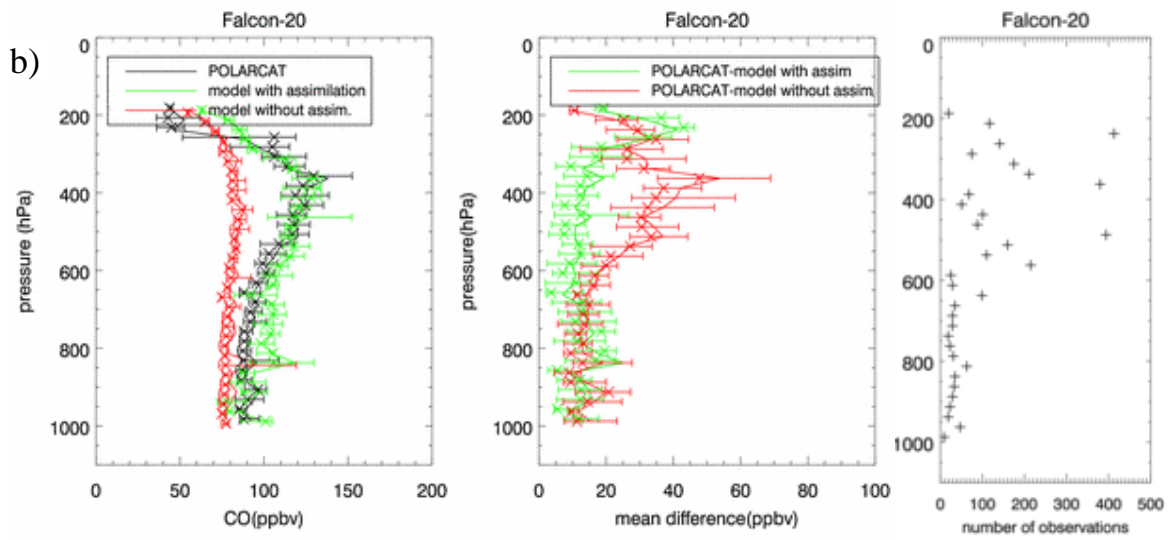Similar improvements are also observed for the other latitude bands: 30°S-30°N and 30°N-45°N (figures not shown).
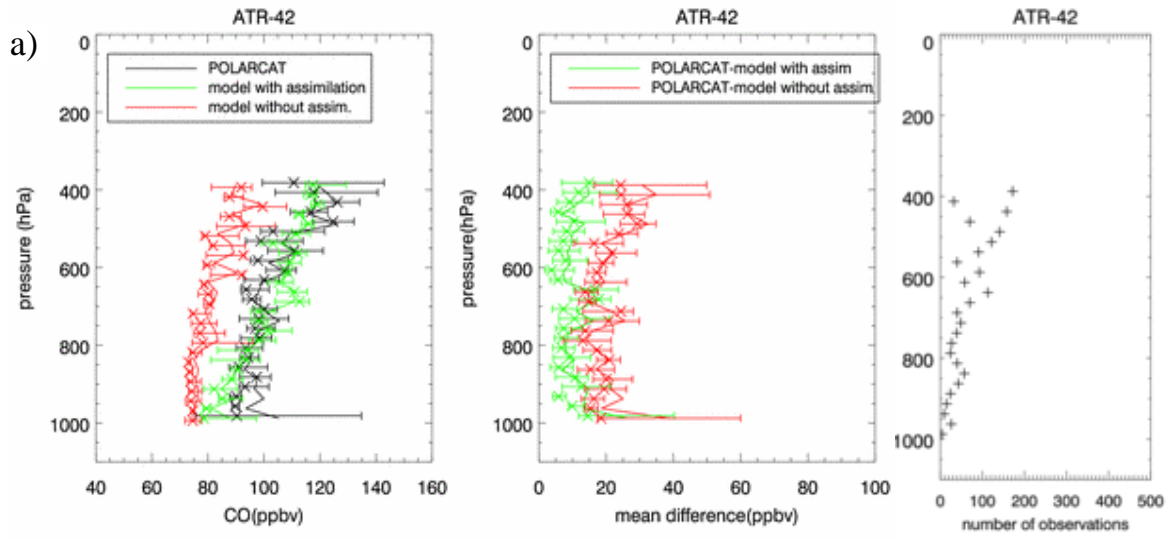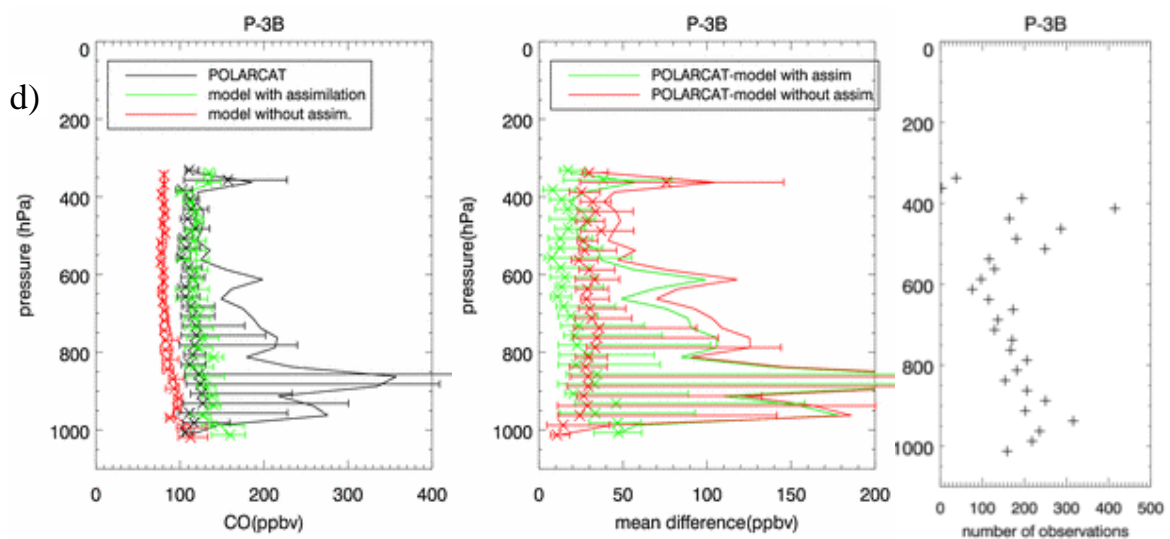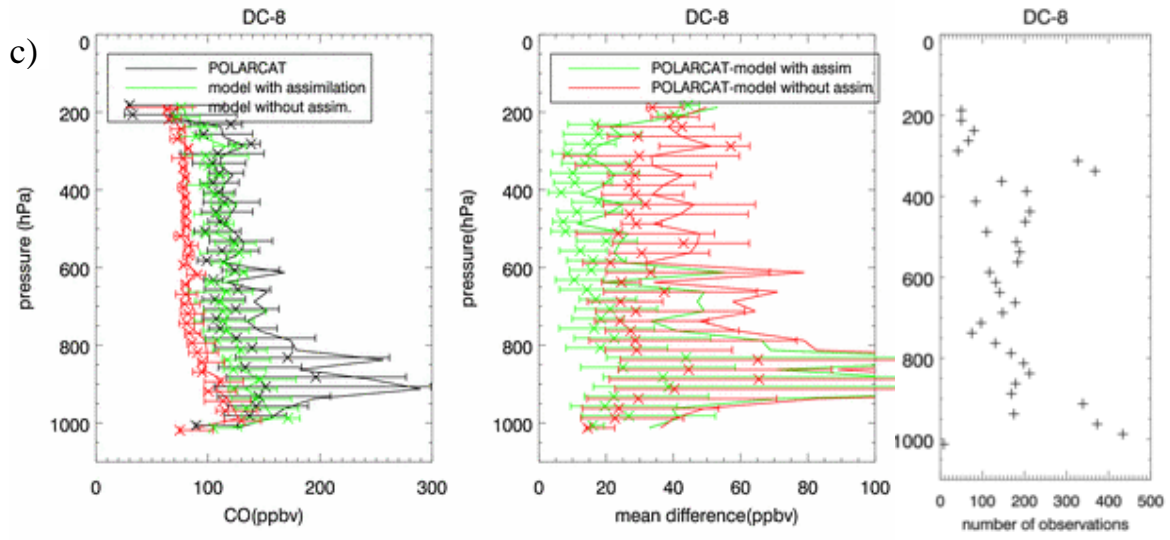
Section 4.3.2
Figure 12: I suggest also adding here the number of data points per bin and including error bars in the difference plots.

The panels showing the number of measurements per bin and per aircraft was added. The new figure 12 is shown below.

a)

| ATR-42 | ATR-42 | ATR-42 |

b)

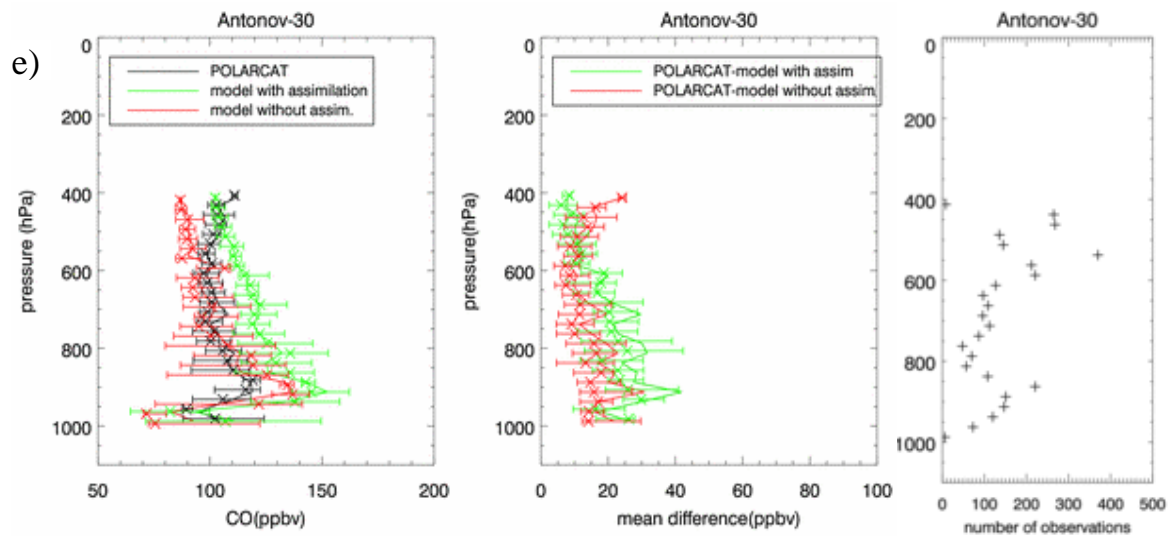| Falcon-20 | Falcon-20 | Falcon-20 |

c)

d)

Figure 12. Left column: solid lines show mean CO profiles for simulation with assimilation (green), control run (red) and in situ measurements (black). Centre column: mean absolute difference between CO data from POLARCAT observations and model with assimilation (green), and observations and control model run (red). The horizontal bars in the left and centre column panels indicate the 25 and 75 percentiles, and the symbol x indicates the median. The right column indicates the number of POLARCAT measurements for each aircraft. Data are plotted for July 2008 for the ATR-42 (row a), the Falcon-20 (row b), the DC-8 (row c), the P-3B (row d) and the Antonov-30 (row e).

Section 5: I would label this section Summary as it does summarize the findings discussed previously but does not present any more discussions.
The suggestion from the reviewer was followed and now the final section is named Summary. The manuscript was reorganized with the discussion present in section 5.3 (5.3 Discussion of the validation results), and the summary in section 6 (6. Summary).