Interactive comment on "Global Distribution of CO$_2$ in the Upper Troposphere and Stratosphere" *by* Diallo et al.

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Dear Editor, Dr. Gabriele Stiller

We have made modified the manuscript in order to seriously consider the reviewers suggestions and comments. These changes include: a new figure 4.b concerning the discrepancies between the reconstructed CO$_2$ profile in 9 October 2001 and the balloon observations. The language of the manuscript still has been improved by native speaker. The abstract has been entirely rewritten. The initial mean error from CarbonTracker has been added in the text.

Best regards,
Mohamadou Diallo (on behalf of the co-authors)

Answer to anonymous referee #1

We thank referee #1 for his comments and suggestions. Comments by the referee are highlighted and followed by our answers.

Minor points:

1. *The paper has improved a lot. This paper is ready for publication now. There is only one (still open) point which I have raised in my first report:*
   page 16, line 7 (and following): Why do you use a asymmetric (with respect to the equator) latitudinal band (10S-20N)? And it does not fit with American Samoa (14S)!?

   We wanted to have the same latitude bin 10S-20N for both timeseries (Fig.5 (a,b)) because the CONTRAIL data have less observations in latitude bin 10S-20S and extending to 4-10 degrees in the south does not change the inter-comparison in Fig.5b at least at that level 16-17km.

Another minor point:

There are some typos which I found during reading the manuscript
  The manuscript was corrected by a native speaker and also sent for English correction service.

  page 5, lines 14 and 20: brackets with respect to Shia et al.
  Done
  page 8, line 6: CO-2
  Done
  page 8, line 20: vortex .
  Done
  page 9, line 23: TRACZILLA. (Legras...
  Done
  page 15, line 24: Fig.4 also

Done

Answer to anonymous referee #2

We thank referee #2 for his comments and suggestions. Comments by the referee are highlighted and followed by our answers.

1. *Awkward sentence structure still needs to be addressed.*

   The manuscript was corrected by a native speaker and also sent for English correction service.

Specific comments:
Abstract: some awkward wording in here
The abstract has been rewritten.
p 1 L14: more readily than what
Corrected
p3:
L16 represents is redundant
L18-20 grammar (Despite its potential ... our knowledge) (should modify Co2, not knowledge)
Corrected
p5 L7 - specify "major disagreements between the model and observations occur in winter"
Corrected
p6 L20 section
Corrected
p7 how many and which sites? aircraft obs used at all? specify quantitative criteria for choosing sites ("high enough elevation to neglect variability..." is not quantitative). This was raised by reviewer 4 and was not addressed in the first round. The boundary condition could be shown or over time at given latitude, showing the condition as it goes from 1999 to 2000.

As mentioned in the text page 7, we used only ground stations which are selected depending on their location (height, near city, Island, Ocean). There are 61 sites distributed in 30 latitude

bins: 6 stations in 60-90S, 7 stations in 30-60S, 8 stations in 0-30S, 10 stations in 0-30N, 23 stations in 30-60N and 7 stations in 60-90N. The selection criteria is not quantitative because it depends on which station is considered. In the main land close to the big cities like in China we only considered stations (Lulin: 2867m, Mt. Waliguan: 3810) with altitude above 2867m. For some stations located on Island and near the coast (Guam: 2m, Mauna Loa: 3397m, Black Sea: 3m, ...), the criteria based on altitude of the station is not necessary because these stations are far from strong local sources.

p7 L21 Is there a discontinuity in time from switching between the two initialization products?

There is not a discontinuity in time from switching between the initialization products because our trajectories integrate the contribution of sources over time.

p8 L5-9. This is a good explanation of what effect the pre-2000 initialization might have. Although this section notes that the uncertainty prior to 2005 should then be higher, later on in the paper (p19) this is not mentioned - this should be incorporated somehow in the uncertainty analysis. I would recommend an uncertainty be placed on the initialization values that is based on uncertainties in carbon tracker and in the confidence of the pre-2000 initialization method. Then it could be added (in quadrature) to the uncertainty from the spread of the trajectories.

The initial errors from the CarbonTracker (CT) are not included in the standard error estimated here. We consider CT as truth and its initial error will constitute additional error bar for final product. As demanded, here we estimate the monthly uncertainty (Fig. 6c) induced by the lagrangian model calculations. As shown, the model errors are quite small then any additional errors will be the CT errors during the initialisation. The mean error of CT on initial value is less tha 1.25 ppmv and should be added in quadrature to the standard error of the mean.

p13 L16: the mean value over what location? I was under the impression that a single particle was released (for the ER-2 flights) at every one location (one particle per location)? Or are there multiple particles launched per flight measurement?

L17 how is the Confidence interval estimated? Presumably from the standard deviation of

the particle sampling over some number of particles - how many per location?

The zonal mean value of CO2. Not a single particle was released but ensemble of particles: 200 for ER-2 at every one location. The confidence interval was estimated from the dispersion of the ensemble of air particles.

Fig3. This is a big improvement over the previous version of the comparison. Note in caption that the dashed line is the 1:1 line. I don't see why both the correlation coefficient and R^2 are needed if one is just the square of the other?

Yes. It's repeating. We have remove the correlation coefficient and keep the R^2.

Fig 4. What does EI mean in the legend? Perhaps it should be CO2-model or reconstruction. In the caption as well, I would describe the black line as the vertical profiles from the model-reconstructed CO2.

EI mean ERA-Interim. We modified the legend and corrected the caption.

p14 and figures 3& 4: how is the CI calculated? Is only the scatter of particles considered, or is there a different error analysis being done here to account for additional possible sources of uncertainty?

The confidence interval was estimated from the dispersion of the ensemble of air particles.

p14-15 units should be on Delta throughout this section - this must be in ppm. Also in caption of Fig 3.

Corrected in the caption and text.

p19: uncertainty. line 5: why average over 11 years? Shouldn't each point in the global distribution, which is monthly, have its own uncertainty? I see that this average is used in the figure, but for the product, the uncertainty should exist for every month for every year, yes? Also clarify if this is a standard error or standard deviation (i.e. did you divide by the square root of the number of trajectories or not?). I believe this should be the standard error. See comment above about incorporating a second error by assigning an uncertainty on the initialization values as well.

Yes it's the standard error of the mean. We averaged the uncertainty in the paper to have only one additional panel instead of 11x12 panels. Of course, the uncertainty exists for every month for every year. Yes, it is the standard error of the mean.

Do the longer transit times have higher standard deviations because the trajectories have more time to spread out more essentially, so they hit the 500 hPa boundary at different latitudes and times, giving larger spread? I might add a sentence to explain this.

Larger mean transit times (mean age) indeed mean also a larger variance of the transit and spread of the origin.

fig 7a caption: black triangles, not orange. Approximately how many CONTRAIL profiles were averaged here? (over the whole month and latitude band?).

The CONTRAIL data are given along the flight track no as flight. For 2007 there are 733 305 points over whole flight track. The profile construction is based on sampling for each given month, altitudes and latitude (here, May and Aug., 50-60N, 5-13km) all points available and averaged it. As the plane flies longer in cruiser it's natural to find more point in the altitude 10-13km than 4-5km for examples. Just to give an idea the sampling variations for May at 4-5km we have 427 points and at 11-12km we have 3638 points. The altitude sampling is 1km.

p21 L4: uniformise

Rephrased

Answer to anonymous referee #3

We thank referee #3 for his comments and suggestions. Comments by the referee are highlighted and followed by our answers.

Major Comments:

1. *Your introduction is too long. E.g. the detailed description of all in situ campaigns/satellite observations and their results (which are not used in the paper) is not necessary, e.g. P3/L27 - P4/L28 - here is some potential to shorten your introduction.*

   These sentences have been removed from the manuscript.

Minor Comments:

1. *P2 /L1*

   ...a new 3D data database...of carbon dioxide (CO2) extending from...

   Done

2. *P3/L3-6*

   satellite validation, inverse modeling - you are almost not talking in your paper about these points. However, you talking much more about the circulation, inverse gradients, seasonal cycle. Please reformulate this sentence.

   Done

3. *P3/L2*

   ...can also be diagnosed...

   Done

4. *P3/L12*

   ...anthropogenic emissions, deforestation, biomass and fossil fuel burning...

   Rephrased

5. *P3/L14*

   Tans and Keeling, 2015 - I did not find this citation in your literature list

   Corrected

6. *P3/L15*

   that represent x2

   Rephrase

7. *P320*

   ...were hold...

   Rephrase

8. *P328*
   The SPURT campaigns were...

   Rephrased

9. *P621*
   ...section section...

   Corrected

10. *P74-5*
    ...to assign CO2 to air parcels transported along the backward trajectories. During the 1989-1999 time period, data from...are applied. The WDCGG is an international...

    Rephrased

11. *P714-20*
    Remove some repetitions. This part of the text should be reformulate

    Done

12. *P8/L6*
    CO2 is not correctly written

    Done

13. *P8/L19*
    ...in the northern polar regions

    Done

14. *P8/L19*
    ...in the northern polar regions

    Done

15. *P9/L17*

    ...in the Northern Hemisphere...

    Done

16. *P9/L19*

    air particles or air parcels (please unify this notation everywhere, I would prefer air parcels)

    We have replaced by air parcels everywhere.

17. *P9/L20*

    ...and integrated backward in time

    Corrected

18. *P10/L7*

    ...the whole stratosphere at any latitude and longitude, 30 levels...

    Rephrase.

19. *P10/11-14*

    Trajectory starting - you consider backward trajectories. Please reformulate this part with too much technical jargon.

    First we integrate backward the air parcels. After the backward integration, the trajectories are initialized depending on their position compared to the boundary condition. That is why we use the term "Trajectory starting" instead of "Trajectory ending".

20. *P10/L19*

    is impacted - it does not sound good. Maybe was hit during the backward integration

    Corrected

21. *P11/L8*

    ...and that remain within... - and staying within

    Corrected

22. ***P11/L11-12***
    I do not understand your sentence with standard deviation. Maybe 2 sentences would be better.

    Rephrased

23. ***P12/3.3***
    Instead of evaluation I would recommend to use validation in the title and everywhere in the text

    The reviewer-4 suggestion in the previous reviewing: "Chapter title: The term "validation" is used, but one can not validate the results, since agreement can be reached for the wrong reasons. Therefore I suggest the term "evaluation" ".
    We have changed again "evaluation" to the initial wording "validation.

24. ***P12/L22***
    ...that a single trajectory processed by... - sounds very strange. Maybe: ...that a single probe can be understood as a mixture of sub-parcels...

    There is same mixing as we average in longitude the contribution of many air parcels.

25. ***P13/Formula (3)***
    You should also explain u(X,t)

    Done

26. ***P13***
    The reconstruction of CO2 observations is with mixing and the global reconstruction is without mixing. I think you should explain it little bit.

    Done

27. ***P14/L6 and L10***
    same sentences

    Done

28. ***P14/L19***

    ...the two curves almost superimpose but for small-scale fluctuations... - you probably mean: ...the two curves agree fairly well even for small-scale fluctuations...

    Rephrase

29. ***General For the sub-panels of the figures you sometimes use (a) or a. Please unify your notation***

    Corrected

30. ***P16/L16***

    ...and we recover a delay of 2 months... - ...and we diagnose a delay of 2 month...

    Done

31. ***P17/5.1***

    ...and lowermost stratosphere (please unify large and small characters in titles)

    Done

32. ***P20/L2 and 4***

    inherited - please replace by a different verb

    Rephrased

33. ***P21/L4***

    to uniformise - to be uniformly mixed at isentropic surfaces

    Done

34. ***P21/L9***

    in opposition - opposite

    Done

35. ***Fig 1***
    The upper green line is shifted

    Figure corrected.

36. ***Fig 4***
    Black curves, Green squares without brackets. You write 17 September but in your figure I see 1th September, please correct

    Corrected

37. ***Fig 5/L5***
    average of what

    Done

Answer to anonymous referee #4

We thank referee #4 for his comments and suggestions. Comments by the referee are highlighted and followed by our answers.

Minor Comments:

1. ***The only remaining (minor) point is the discussion of the balloon profile in the vicinity of an upper level trough (which indeed might be linked to a surface cold front), which shows a deviation between reconstruction and measurements. In the manuscript, the whole stratospheric column up to 35 km shows differences between observations and reconstruction. If a mismatch of the exact location of simulation versus observation is the reason for this (as in Pisso et al., 2008), this should be evident in vertical cross sections of CO2 (or other quantities). I still doubt that a PV gradient at 70 hPa affects the stratosphere up to 35 km. Is it possible, that the data have a problem? The case in Pisso et al., 2008 is different since it shows, that a layered (eventually filamentary structure) of approx 1-2 km vertical extent is not correctly captured.***

In the absence of error bar on this balloon profile, it is not straight forward to state what is creating this spread on the Fig.4b. To do so, we have created a square box around this profile and reconstruct 8 vertical profiles which surrounded the initial profile. We have not found any big scatter among these reconstructed profiles which can explain the spread. In addition, for this balloon profile we have reconstructed the mean age and compared with SF6 and CO_2 mean age derived from this balloon observation. The mean age derived from CO_2 measurement show same dispersion as in CO_2 profile but the SF6 mean age does not show such scatter. This suggests that this CO_2 profile is questionable.

2. *In general (as I stated in my first review), a data set like the one which is presented here, is of great importance and highly appreciated. Therefore I see a strong need to correct for an appropriate use of the English language.*

   The manuscript was corrected by a native speaker and also sent for English correction service.