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Interactive Comment

Interactive comment on "Anthropogenic CO_2 flux constraints in the Tokyo Bay Area from Lagrangian diffusive backward trajectories and high resolution in situ measurements" *by* I. Pisso et al.

Anonymous Referee #2

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The paper entitled "Anthropogenic CO2 flux constraints in the Tokyo Bay area from Lagrangian diffusive backward trajectories and high resolution in situ measurements" presents a Bayesian inversion of CO2 emissions from the Tokyo Bay area using surface tower measurements and a coupled Eulerian-Lagrangian modeling framework. The inversion uses measurements from 3 towers and compared the results using different prior emission inventories. In addition, the introduction of additional measurements from the CONTRAIL aircraft program showed an important impact on the inverse emissions.

The present study requires several major revisions and additional tests which are all critical elements of the inverse system. The two main concerns listed hereafter are key elements in the inverse systems, i.e. the observation and prior flux error covariance matrices. In addition, posterior uncertainties are not presented, and only sensitivity tests provide a crude approximation of the uncertainty from one component of the inversion, i.e. the prior fluxes. Finally, the boundary conditions, which are one of the major source of uncertainties at fine scale, are provided by a station in the middle of the Pacific Ocean. Considering the amplitude of the CO2 plume from large urban areas, and the presence of large sources in North East Asia, the boundary inflow can be highly influential and become even more important than in larger scale studies.

1. Transport errors: Several studies have shown the importance of transport error characterization in mesoscale inversions. It includes systematic and random errors, due to physical parametrizations, driver data at the boundaries, and initial conditions. Here, the comparison between the two models is limited to the sum of the absolute values. A more careful comparison is required, especially in the context of fine plume structures which are difficult to simulate correctly in the atmospheric model. In addition, the Planetary Boundary Layer, responsible for large systematic errors, has not been evaluated. Tokyo is located in a complex terrain, including mountains, the Ocean, and the Bay with local circulation patterns which are challenging to simulate correctly. The present modeling system has to be evaluated with meteorological measurements, and the performance of the model has to be tested in the context of plumes and sporadic emission signals, affected by local atmospheric processes. The modeling performances should be presented including the ability of the model to capture the city plume.

2. Prior flux errors: The use of emissions as unknowns implies that the errors associated with them, and the various correlations in time and space, are estimated carefully before being used in the inverse system. This information is not even available in the present study. The sensitivity tests are secondary, and cannot be considered as a quantification of the errors due to the prior emissions. Here, the authors need to describe precisely how they defined prior error variances and covariances. The assump-

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tion of 200% variance is based on a study at global scale, trying to infer large scale fluxes using low resolution General Circulation Models affected by severe model errors and under-constrained eco-region fluxes. This number is unrelated to the present mesoscale inversion.

3. The posterior uncertainties are not even shown. The inverse fluxes are not an absolute value, but the combination of the mean fluxes and their uncertainties. In fact, the posterior uncertainties are even more important than the posterior emissions themselves. If the method is to bring any significant result, the posterior uncertainty is the only quantity that can provide information on the emissions. An inversion is an optimization system using both prior and observation information combined to generate the posterior fluxes and errors.

4. Absence of boundary conditions: As explained above, the boundary inflow is a critical element in inversions over limited domains. The uncertainties associated with it and the potential biases affect the posterior fluxes at continental, regional, and local scales. Several studies have evaluated the potential impact of the boundary inflow on the inverse fluxes. Here, the authors used a surface station located in the middle of the Pacific Ocean to constrain the signals from distant sources. Tokyo is surrounded by other large sources of emissions, as well as synoptic systems and latitudinal circulation systems conveying large CO2 signals from lower latitudes. Considering the amplitude of urban emissions (not shown in the paper, but in the order of 6-10ppm depending on the PBL), the distant sources can easily affect the simulated concentrations by several ppm as well. The inverse fluxes can be affected seriously if the boundary inflow is not correctly constrained.

Technical corrections:

Abstract: Use more classic units as umol.m-2.s-1.

Introduction: The introduction is incomplete. Many references are missing in the first and second paragraphs. Past studies over urban areas have tried to constrain urban

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emissions using aircraft or surface tower data. Add these references. Describe also meteorological modeling studies over urban surfaces.

2-25: "... record the effect of CO2 sources on the earth's surface...": please re-phrase

2-2: Incorrect statement. Eddy-flux technique is a direct approach, not inverse.

2-11: this is true at global scale, not at regional scale.

4-1: "...with varied topography surrounded by mountainous terrain...": please re-phrase

4-26: Seibert et al., 2004 is an example. Source-receptor relationships have been used since the 1980's and before.

5-4: This is a physical reality due to turbulence in the lower atmopshere. One single particle could be used with a statistical approach (e.g. plume model with Gaussain distribution).

5-10: Explain what is a "data block" more precisely.

7-Eq: the equation is not used later in the paper. Just delete it or refer to it in the description of the Jacobian and the fluxes.

8-24: This layer represents the Surface Boundary Layer, and not the PBL. During the day, the convective conditions distribute the particles homogeneously which allow you to use an over-estimated height. But this definition cannot be used at night.

9-19: Please use the Ide et al., (1997) convention on data assimilation (H, R, B)

10-2: As explained above, the 200% variance assumption was applied at global scale. In addition. you use identity function which is limited to the uncorrelated prior flux errors. Knowing that emissions are using parameters and common statistics, it seems very unlikely.

Figure 1: the 3D does not seem very informative, and makes the figure harder to read. A statistical distribution of the data density over the vertical would be more interesting.

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in addition, measurements over the PBL bring little information to constrain the local emissions. Have you used the column data up to 3km?

12-3: "... fluxes [the] represent..."

12-Section Models: Show the domain of simulation for WRF, and the domain used for the inversion.

14-8: "necessary" but not sufficient. The analysis is very limited. The absolute mean difference does not provide the required information to build the observation error co-variance matrix. You should develop this section consequently and show that you have performed a careful assessment of model errors.

14-25: This statement implies that the prior flux errors were carefully adressed, and that the inventories are reliable estimates of the interannual variability. These two points have not been adressed and past literature has shown little confidence in high resolution inventories in both time and space.

14-27: Is the additional spatial information corresponding to noise or signals? "adding information" is also depending on the spatial structures in the flux errors. If the pixels are independent, the signals will affect singular pixels. But if spatial correlations exist, the prior flux structure will remain unchanged. You need to refine your prior flux errors before concluding.

Fig 2: the figure is hard to understand, and finally provides very little information. The statistical distribution of SSR in time would be easier to read and as informative. Caption: "...WRF [of=or] with ERA Interim winds..."

16-6: Aircraft data are more sensitive to vertical mixing errors and may be affected by different errors than surface measurements. This result should be discussed in the paper.

Fig 4: caption: Retrieved fluxes...

17-10: re-phrase the sentence

17-14: this point is not clear. or maybe this is due to the y-axis in figure 5 (time)? CDIAC is lower than EDGAR. If the retrieved fluxes arer larger than EDGAR, it seems very logical that they are larger than CDIAC as well. Explain your point more clearly.

17-18: this sentence is unrelated and beyond the scope of the paper in general.

17-25/27: This sentence is very confusing. Are you comparing an urban iversion to a transport comparison using global scale inversions? "Regional inversions" was used to describe global scale inversions using large eco-regions at sub-continental scale. The reference used here is unrelated to the present study in scale.

20-20: Are you comparing a park in Essen Germany with the averaged emissions from Tokyo? This comparison does make any sense. It could be used to provide a range of a priori fluxes in mixed urban areas, but not as a comparison.

20-25: the fluxes at the surface are rapidly mixed on the vertical at very short time scales compared to the mesoscale model. The introduction of a 2D flux is a formulation that is valid in this case because the transfer of mass from the surface to the first layer of the atmosphere is almost instantaneous. Many tests have shown the applicability of the SSR for tracking tracer release, even at small scales. At your scale, other issues have more impact on your results than this problem.

21-6: Several studies have shown the potential of PBL height measurements in atmospheric modeling applied to mesoscale inversions. Complete your discussion.

21-8/12: Is your time step sufficient? Have you missed some information by using one hour back trajectories?

21-2/8: This paragraph is lmited to references and statements. What are you trying to discuss here?

21-9: twice "that"

21-9/18: this paragraph is very confusing as well. An inverse system being over-constrained by observations is a very well-known issue in meteorology where millions of observations are assimilated into single model runs. In your case, you have to demonstrate if the system is over-constrained by comparing prior flux errors, the number of unknowns, the number of observations, and their dimension. A chi-sqaure test can be used to evaluate the relative constraint from each component. If the system is not well-balanced, you can filter observations or add more confidence in your prior.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 10623, 2012.

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