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Interactive comment

Interactive comment on "Carbon Dioxide and Methane Measurements from the Los Angeles Megacity Carbon Project: 1. Calibration, Urban Enhancements, and Uncertainty Estimates" *by* K. R. Verhulst et al.

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Response to Referee #1 Comments

1. Overview

We would like to thank the reviewer for insightful comments on the manuscript. Overall, the reviewer's comments on the background analysis and background uncertainty generated some internal discussion and prompted us to make edits that improved the content and clarity of the paper. Below we provide a summary of our responses to each comment and relevant changes made to the manuscript.

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2. Minor Comments:

2.1 IRV site

Author response: The modeling study conducted by Feng et al., (2016) focused on modeled CO_2 pseudo-data from during May/June 2010. We began collecting observations from the IRV site in Nov. 2014. While it is not possible to do a direct comparison with the results of Feng et al., we do expect the IRV site to experience less trace gas variability due to stronger onshore flow conditions during spring/summer months. The text has been edited to further clarify this point.

MS Changes: We edited the text beginning on P.11 (line 28) as follows: "Feng et al. (2016) used a forward modelling framework to explore variability in modelled CO_2 mole fractions during the CalNex period (May-June 2010). Their results, based on modelled CO_2 pseudo-data, are generally in agreement with the observations from the SCI and VIC sites. Feng et al. (2016) also showed that the IRV site was relatively clean with respect the modelled pseudo-CO_2 data. As shown in Figure 2, during spring/summer months, sites such as IRV and LJO typically show less trace gas variability relative to winter months due to more persistent onshore flow. However, during the rest of the year, the IRV site shows CO_2 and CH_4 mole fractions in the same range as other suburban sites, such as GRA and FUL (Figure 2, Tables 2 and 3). The LJO site is outside the innermost model domain used Feng et al. (2016) and was not discussed as part of that study. Future work should focus on comparing modelled and observed CO_2 and CH_4 mole fractions during different meteorological conditions, but using periods with overlapping model and measurement results from the same time period."

2.2 Background values

Author response: The background selection criteria were designed to select observations with a small degree of variability. Overall, the selection criteria are based on the assumption that "clean" background air masses (i.e., those that are not impacted by local sources) exhibit small variability within one hour, with stable conditions persisting for several hours. A site sampling marine or continental background air is not expected to exhibit significant changes in trace gas variability due to small shifts in meteorology (i.e. wind speed or direction, PBL growth, etc.). By contrast, the same changes in meteorology may lead to increased trace gas variability if the site is influenced by nearby emissions sources. Although not described previously, we have considered possible impacts of PBL growth on the background analysis when preparing this manuscript. Based on this comment (and other reviewer comments) we decided to add a section to the Supplementary materials to provide more details about the background selection criteria. In this new section, we also specifically address the topic of diurnal variability (see below).

MS changes: New text added to the Supplementary materials, P. 4 (beginning on line 29): “We have considered possible impacts of PBL growth on the background analysis. As described in the main text, we use only nighttime flask samples for the MWO background estimate because this site is more sensitive to the LA Basin during daylight hours due to growth of the PBL and upslope winds. However, our filtering criteria for SCI, LJO, and VIC do not account for diurnal variations, e.g., due to variations in the planetary boundary layer height or due to potential daytime drawdown of CO2 due to photosynthetic uptake. Initially, we made plots of the monthly average diurnal variability for the SCI, LJO, and VIC sites. However, it was not apparent how the diurnal cycle would aid in the interpretation of background because most of the time the diurnal changes at these sites are dominated by impacts from local emissions (especially at LJO and to a lesser extent at the other two background sites due to outflow). At the marine background sites (LJO and SCI), it is the growth the marine boundary layer (MBL) rather than the PBL over the land, that is relevant to the interpretation of background. However, the MBL growth effect is most relevant when a site located very far off-shore, such that nighttime continental outflow is not present. Under these conditions, changes in the MBL with time of day are likely to be very small. The LJO is near sea level and is within the MBL, but is frequently impacted by local sources. The SCI site can be either within or above the MBL due to its elevation (∼489 m asl), but is still occasionally impacted by continental outflow. For these reasons, we do not limit the background consideration to certain times of day. The agreement between the SCI and LJO marine background estimates (within ∼±1 ppm CO2 and ∼±10 ppb CH4) suggests that there is not a large gradient between the CO2 and CH4 levels in the surface MBL and above the MBL. In summary, for the SCI, LJO, and VIC background sites, our underlying assumption is that if the PBL (or MBL) grows, it will not further dilute the CO2 or CH4 levels or cause additional large variations if the site is truly sampling background conditions. . . . Overall, we have achieved a reasonable level of convergence between the background estimates for three sites with very different variability in CO2 and CH4 mole fractions. A metric of success exhibited by our results is that the background reference curve estimates agree within ∼±1 ppm CO2 and ∼±10 ppb CH4 for the marine sites (LJO and SCI) and continental sites (MWO and VIC, see Figures 4 and S10)."

2.3 Background uncertainty:

Author response: We have significantly revised the method to quantify a time-dependent background uncertainty estimate for each site based on this comment and our internal review. As shown in Figure 3 in the manuscript, the blue curves are the background estimates and the red points are used to calculate the blue curve. During periods when the curve is constrained by observations, we assign the uncertainty based on the monthly average residual between the observations and the smooth curve. Due to filtering, there were some large gaps in the observations (red points) that were used to calculate the background curves. The CCGCRV curve fitting algorithm interpolates over these gaps, resulting in an additional interpolation uncertainty. We now assign a larger uncertainty during data gaps such that the uncertainty will default to the maximum annual average residual during periods with gaps. Finally, it is worth mentioning that based on a comment from Reviewer #3, we revised our filtering criteria such that the largest gaps are now ∼1 month (see our response to Reviewer #3's comments). Overall, we feel these changes have significantly improved the discussion of background and uncertainty.

MS changes: We changed the text in Section 6.2, P. 28 (lines 1-13) as follows (note "..." was inserted where equations are given: "We define the time-varying uncertainty in the background estimate as ...(Eq. 13), where ... is the absolute value of the monthly average residual of the selected background observations (red points, Figure 3) from the smooth curve result. Due to the method used to filter the observations, there are some gaps in the background observations. The background reference curves interpolate over observation gaps, however, the portions of the curve that are not constrained by observations are more uncertain relative to other periods. For data gaps longer than one month, it is not possible to estimate .... Since there are no observations to constrain the curve, we assign an interpolation uncertainty based on the maximum annual average residual. In other words, if there are long observation gaps, the interpolation uncertainty will default to the maximum residual based on periods when observations were available. The time-varying uncertainty estimates for the SCI, VIC, and LJO reference curves are shown in Figure S10. During 2015, the annual average uncertainty in the SCI smooth curve estimate is 1.4 ppm CO2 and 11.9 ppb CH4 (Table 6). This amounts to roughly 10% and 15% of the median midday enhancement near Downtown LA (i.e., at the USC site) for CO2 and CH4, respectively."

We also added Figure S10 to the Supplementary materials, which shows the background and time-dependent uncertainty estimates for SCI, VIC, and LJO. All the other text related to background uncertainty was also updated, including the annual average U_BG estimate from SCI in the abstract and in Table 6. Figure S10 will be attached to this review as a separate PDF file.

3. Specific comments

Page 2, Line 25: The reference was added to the Introduction.

Page 11, Line 30: A shallower nighttime PBL will lead to higher CO2 and CH4 enhancements and higher sensitivity to local surface emissions. We edited the text (now on P.12, lines 11-13) as follows: "Many of the CH4 spikes throughout the GRA record

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occur at night, suggesting contributions from a nearby source. Shallower PBL heights at night will lead to higher trace gas enhancements and higher sensitivity to local surface emissions (e.g., Djuricin et al., 2010; Turnbull et al., 2015)."

Page 18, Line 10: Yes, the converse is also true that SCI and LJO would not be relevant choices for background when flow is from the continent. We modified the text on P. 18 (now on lines 1-4) as follows: "Overall, the VIC and MWO sites may not be relevant choices for background during summer, when onshore flow patterns dominate. Conversely, SCI and LJO may not be relevant choices for background when flow is from the continent. In future studies, background data could also be selected based on the prevailing flow patterns in the region of interest (e.g., McKain et al., 2015)."

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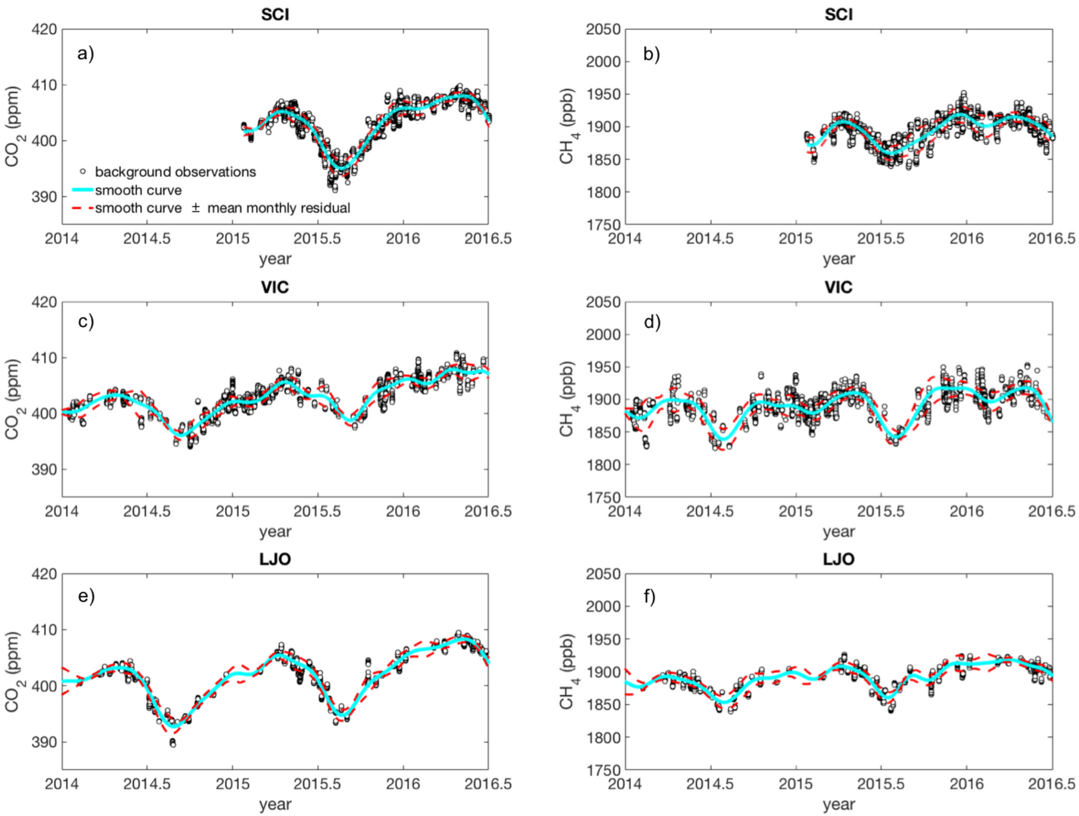

Fig. 1. Fig S10. Background observations (black circles), smooth curve estimates (cyan lines) and uncertainty estimates (red dashed lines) for San Clemente Island (a-b), La Jolla (c-d), and Victorville (e-f).