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Atmospheric Measurement Techniques Discussions

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Interactive comment

Interactive comment on “Determination of the Emission Rates of CO_2 Point Sources with Airborne Lidar” *by* Sebastian Wolff et al.

Anonymous Referee #2

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I have reviewed the following paper which is now available for discussion on Atmospheric Measurement Techniques as amt-2020-390:

“Determination of the Emission Rates of CO2 Point Sources with Airborne Lidar,” by Sebastian Wolff, Gerhard Ehret, Christoph Kiemle, Axel Amediek, Mathieu Quatrevalet1, Martin Wirth, and Andreas Fix

General comments: The paper describes the use of measurements from the airborne CHARM-F IPDA lidar to estimate the CO2 emission rates from a large European fossil fuel power plant. The measurements were made during the 2018 airborne CoMET campaign. Multiple overflights of the emission plume from the plant were performed,

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Discussion paper

and the increase in the DAOD of the lidar's XCO2 measurements were determined during the crossings over the plume. From these measurements the authors used the cross-sectional flux method to estimate the power plants rate of CO2 emission. The paper gives overviews of the CHARM-F lidar, the cross-sectional flux method and computes the emission rates from four plume overpasses made on one day. It also describes the impact of turbulent boundary layer mixing on the plume caused by daytime solar heating of the Earth's surface.

To investigate the impact of turbulence further, the authors performed a time-resolved simulation of a modelled plume, which showed the plume's 3-D structure as a function of time of day. These results are quite interesting and clearly show the impact of daytime turbulence on the emission plume structure. The authors discuss the airborne measurement results in the context of the simulations, and the implication of the simulation results on estimates of emission rates for those made using IPDA lidar and those using passive spectrometers.

This paper addresses an important topic, given the importance of remotely sensing CO2 and CH4 emissions to monitor drivers of climate change. Both the airborne measurement results and simulation results are quite interesting. However, there are several issues and questions in the present version that are either unclear or need to be addressed in a revised version. These are briefly discussed below.

Specific Comments: 1. The simulations show that daytime turbulence randomly changes the 3-D velocity field of the plume on short spatial and time scales. Is the cross-sectional method used to compute fluxes still viable under these conditions? The authors need to discuss this point, and if they feel it is, please address how the value and direction of the velocity vector is obtained for overpasses during turbulent conditions. 2. It seems the precision of the lidar estimate of A depends on how many lidar measurements occur during the plume crossing. Since the laser pulse rate is fixed, it seems crossing the plume at an oblique angle (rather than at right angles) should allow more lidar measurements to be used in computing A, hence should increase the precision of A's estimated value. Please discuss. 3. Several places in the paper state that the differential absorption cross section of CO_2 for CHARM-F is constant with altitude. For these measurements CHARM-F used the online wavelength locked to the peak of the CO_2 line. Due to the decreasing atmospheric pressure with altitude, the absorption cross section of the CO_2 line and vertical weighting functions of airborne IPDA lidar which uses this approach is not uniform with altitude. It instead peaks at the aircraft altitude. (For example, see Figure 6 in Bell et al. (2020) "Evaluation of OCO-2 XCO_2 variability at local and synoptic scales using lidar and in situ observations from the ACT-America campaigns." Journal of Geophysical Research: Atmospheres, https://doi.org/10.1029/2019JD03140.) Please address this point in the revision. 4. The simulations clearly show the transition of smooth flow of the plume during and nighttime and at low sun angles, to a more chaotic/random dispersed structure caused by turbulence at higher sun angles. This dispersal of the plume's structure seems an important limitation to using passive remote sensing to estimate power plant emissions. Can the authors expand on this point in the revised version? 5. Please add the local sun angles to the figures of the simulated plumes. 6. Equation 1 uses a mixture of laser power and laser energy, and obviously the optical power changes during the pulse. Isn't the DAOD computed from measurements of the on- and off-line laser energies (not power)? 7. In general it seems that the emission plume adds CO_2 to an air mass that already has some variability in CO_2. Hence the background also has variability in XCO_2. As shown in equation 5, the enhancement from the plume is computed from the total DAOD minus that of the background (non-plume region). Hence variability in the background DAOD will cause variability in computed enhancement. More discussion of about the variability in the background is needed for the region measured near the plumes and on its impact on the computed enhancement from the plume. 8. In Figure 3, please inform the reader how many lidar measurements are used in the running means values, and the approximate standard deviations of DAOD for the lidar measurements with and without averaging. 9. In line 238, it is stated the primary error in the flux estimate is from uncertainty in wind speed. This is an important point and should be emphasized in the paper's abstract and conclusion. 10. Line 238 gives a reported value for power plant's Co2 emission mass flow rate. Please clarify the source of the estimate. Is this some sort of average or is it based on the fossil power plant's operating conditions at the time of the overflights? 11. The caption of Figure 6 states DAOD enhancements < 0.008 cannot be distinguished. It is unclear if the authors mean in the simulation, in the color plot, or in the CHARM-F lidar measurements – please clarify in the text. 12. The LH plot in Figure 6 shows a stable linear plume extending to the edge of the plot for nighttime conditions. It would benefit the readers to know from the simulations typically how far these linear flow conditions extend in distance. 13. In the paragraph of line 285, please explain in the simulation how the plume's velocity values and directions were estimated for the turbulent conditions. 14. Line 330 – Please be more quantitative than "mid-day" please clarify the sun angle limits or time of day limits for avoiding turbulent mixing. 15. In the discussion section, please address how more accurate estimates of the wind vector in the plume could be attained in the future. For example, could co-aligned wind and IPDA lidar be used for this? 16. Several aspects of the last paragraph in the Conclusion section don't seem to apply to the main findings of the paper. Please reexamine and edit for relevance. 17. Figure A2 – please include the sun angles for the plumes shown in daytime hours.

Minor points/technical corrections: 1. The manuscript will benefit from a check of consistency of tenses. The airborne campaign was performed in the past, while the analysis may described in the present tense. 2. In the title, would the word "estimation" perhaps be a more appropriate word than "determination"? 3. Line 17 – Consider changing "we suppose." Did not the simulations show the variability was clearly driven by turbulent mixing ? 4. Line 30: consider perhaps "assessment" instead of "stocktake" 5. Line 43 – this sentence is many lines long. Please break it into logical pieces. 6. Page 2 and elsewhere. There are many adjectives used in the lidar description and elsewhere (e.g. on page 2: most sophisticated, small divergence, dense sequence, sophisticated, high-power etc,) whose meanings are subjective. Please either delete or replace these type of adjectives with quantitative descriptors. 7. Line 60. The term “adaptive averaging “does not appear to be not defined or described 8. Line 199 – the distances listed in the text are slightly different than in Table 1 9. Table 1- 2nd column – please check, are the crossing dimensions km or in m? 10. Table 1 – is the mean q listed for all crossings? – please clarify 11. Figure 3 would be easier to interpret if the 3 boxes were labelled. 12. Line 365 – please delete the word “high” and replace with the approximate accuracy attained.

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