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Optimizing airborne emission rate retrievals with sub-hectometre resolution numerical modelling

Sepehr Fathi et al.

Correspondence to: Mark Gordon (mgordon@yorku.ca)

Supplementary Materials

S1. Ground-vehicle Sampling

Here, we investigate the potential improvement to the emissions estimate through ground-based mobile vehicle concentration sampling. For the case of the Aug 20 (starting at 16:20) flight set downwind of the stack sources, we simultaneously sample concentrations at the lowest model level beneath the flight path. Although vehicle path locations are typically limited to roadways, we investigate here the highly idealized case where a car or truck can drive directly beneath the flight path of the aircraft for the duration of the flight. We assume a constant vehicle speed of 60 km/hr (16.7 m/s) and drive a single transect south-eastward from the most NW location. These values are then used in the interpolation of the screen (at $z = 1$ m) without the need to assume a profile below a height of 150 m.

Figure 4 demonstrates that there can be considerable error associated with the assumed concentration profile below the lowest flight path of 150 m. As discussed in Section 2.4, in some situations, it may be possible to measure concentrations at ground level with a mobile measurement platform on a car or truck. With these surface-level measurements, the assumption of a constant profile below the height of 150 m is no longer necessary, and the screen can be interpolated using these additional measurement values. Resulting emissions estimates for the Aug 20, 16:20 flight set augmented by ground-based vehicle measurements are shown in Figure 3a. The horizontal advective flux with ground-based measurements consistently overestimates the emission rate for all downwind distances, with values of E_H/E_S ranging from 1.14 to 1.30 for $2 \leq D \leq 12$ km. This demonstrates that the underestimation of the horizontal advective flux close to the stacks ($D < 6$ km) with an assumed constant concentration below 150 m is predominantly due to a large amount of the plume being below the lowest flight path, as was shown in Figures 4 and 5. Further, the variability between flights is consistently reduced by between 1% and 6%. The results demonstrate significant value is obtaining surface-level measurements where possible, so that extrapolation below the lowest flight path is not required.

S2. Sensitivity to Random Offsets

As discussed in Section 2.4, at each 1-s timestep of the flight, the horizontal aircraft speed is randomly offset by a Gaussian random number with a standard deviation of 3 m/s, and the vertical position is offset by a Gaussian random number with a standard deviation of 1 m. To assess the sensitivity of the results to the scale of the offsets, we rerun the analysis for the set of flights on Aug 20 flight (at 16:20) at $D = 6$ km with both horizontal speed and vertical position offsets (3 m/s and 1 m respectively) simultaneously modified by a factor of 0 (i.e. no offset), 1/3, and 2/3. The resulting changes in estimated E_H/E_S and the variability (σ) are shown in Figure S1 (in addition to the 3 m/s and 1 m offsets used throughout the study). Using an evenly spaced, elevation-following grid with no offsets give a value of $E_H/E_S = 1.10$ with σ =28%. Adding a small amount of random offset (a factor of 1/3) to the grid increases E_H/E_S to 1.15. The offsets higher than that (factors of 2/3 and 1) both give $E_H/E_S = 1.17$. The difference in variability between flights within the flight set is < 1%. Hence, although there is a slight difference between no random offsets (even grid spacing) and the inclusion of random offsets (E_H/E_S of 1.10 versus 1.15), the results are not sensitive to the size of the offset over the range of values investigated here.

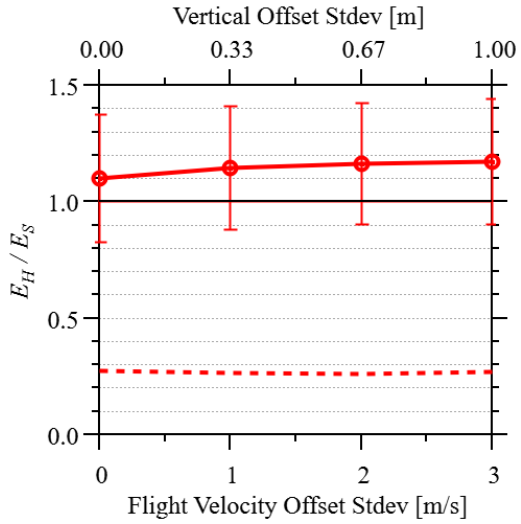

Figure S1. The variation in the ratio of horizontal advection flux (E_H) to the known emission rate (E_S) with change in the random offsets along the flight path for the Aug 20 flight set starting at 16:20. Error bars show one standard deviation (σ) calculated from 10 flights and the dashed lines show σ as absolute values.