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TITLE: Uncertainties in the CO2 budget associated to the diurnal variability of the boundary layer dynamics

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ABSTRACT BODY: The relationship between boundary layer dynamics and carbon dioxide (CO2) budget in the convective boundary layer (CBL) is investigated by using mixed-layer theory. We derive a new set of analytical relations to quantify the uncertainties on the estimation of the bulk CO2 mixing ratio and the inferred surface flux. This analysis of the uncertainties is done as a function of boundary layer depth, morning vertical CO2 distribution, which also includes the CO2 vertical gradient in the free atmosphere (FA) and the carbon dioxide horizontal advection. We apply these relations for two prototype convective boundary layers observed at the Cabauw tower in The Netherlands: one CBL is near the free convective regime and the other is largely influenced by advection of CO2.

We find that at midday CO2 mixing ratio in the boundary layer and CO2-inferred surface flux are mainly sensitive to the early morning CO2 mixing ratio in the boundary layer and in the FA, just above the inversion. From the sensitivities the actual errors of CO2 mixing ratio and inferred surface flux are calculated by assuming typical errors on the variables considered. Notice that the contribution of the error of each analyzed variable on the CO2 budget depends on the sensitivity and on the uncertainty of the variable understudy. Consequently, although CO2 mixing ratio or the inferred surface flux have small sensitivity to some of the analyzed variables, errors in these variables can have a non-negligible contribution to the errors in the CO2 mixing ratio and in the inferred CO2 surface flux. This is the case of the CO2 vertical gradient in the FA.

Focusing on the CO_2 advection, we find that errors lead to notable uncertainties in the simulated CO_2 mixing ratio even on diurnal time scales. This is due to the fact that these errors are of the order of the advection rates. This finding is very relevant since CO_2-horizontal advection is a contribution to the CO_2 budget characterized by large uncertainty in its quantification either by using measurements or modeling. Furthermore, CO_2 mixing ratio errors due to advection are history dependent and hence even small systematic errors can increase to cause substantial errors in the CO_2 mixing ratio. Similar conclusions can also be drawn regarding to the inferred CO_2 surface flux. Our findings stress the fact that advection plays an important role on the CO_2 budget even when diurnal time scales are studied.

We complete the analysis of the uncertainties in the CO_2 budget by studying the role of large-scale subsidence on the CO_2-budget. We will show as an example that by introducing a deviation of approximately 1 cm/s in the subsidence velocity, we obtain differences of 4 ppm in the CO_2 mixing ratio and 50% of the inferred CO_2 surface flux.

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