Response to the Second Review of "Drone CO_2 Measurements During the Tajogaite Volcanic Eruption" by Ericksen et al. (2024)

The manuscript by Ericksen et al. (2024) applies Unpiloted Aerial System (UAS) platforms to measure carbon dioxide (CO_2) concentrations and carbon isotope ratios during the 2021 eruption of the Tajogaite Volcano in Spain. This study used a Dragonfly UAS outfit with systems for measuring CO_2 concentrations and carbon isotopic ratios for 10 transects through volcanic plumes during the eruption. Using measured CO_2 concentrations and winds, applying gaussian assumptions, led to emission rate estimates of $4.6 \pm 0.46 \times 10^3$ to $2.8 \pm 0.28 \times 10^4$ t day^{-1} (4.6 to 28 kt day^{-1}). These emission rates are much more consistent compared to recent literature estimates compared to what was presented in the first version of the manuscript. Overall, the authors did a decent job in addressing my initial comments. The only major concern that remains is the author's minimal effort to estimate uncertainty in the CO_2 flux estimates. Please see my comment below. I think an improved uncertainty estimate, following other recent research cited below, would make this publication suitable for publication.

<u>Response:</u>
We thank the reviewer for their second review of our manuscript. We have addressed the major concern raised by increasing our effort to estimate the uncertainty in the flux measurements. We have taken into account the works proposed by the reviewer and followed some of their methods. We show that the main uncertainty lies in the plume direction and we now state the modeled plume directions in Table 1. After accounting for all errors and summing them we obtain an error of ± 11.6%. This is quite close to our initial error estimate of ±10%.

Major Comments

1. The uncertainty estimates of the CO_2 fluxes in this study are likely much too conservative. Many studies have shown that modeled winds (this study uses ERA5 model predicted wind speeds) are much larger than 10% (e.g., Nassar et al., 2017, 2021; Reuter et al., 2019; Johnson et al., 2020; Lin et al., 2023). Especially when you consider model wind speed and direction. Also, studies have shown it is not safe to assume a linear impact of wind speed on model prediction uncertainties (Nassar et al., 2017)? While wind speed/direction likely does have a majority impact on the overall uncertainty, it is not safe to neglect the other sources of uncertainty (e.g., measurement error, background concentration error, vertical distribution. etc.). It would be easy for this study to follow methods from recent research which quantify uncertainties from point-sources (.g., Nassar et al., 2017, 2021; Reuter et al., 2019; Johnson et al., 2020; Lin et al., 2023) to calculate more representative uncertainty values for this study.

<u>Response:</u>

We have re-evaluated our ERA5 output and have included the wind directions in Table 1. The range of wind-directions based on this model during our transect flights is ±15°. This results in a flux estimate error of ± 3.4% based on our method to obtain linear distance of the transect: cos

($heading_{UAS} – heading_{wind}$), as described in the methods section. We have also included a 1% error of our CO_2 sensor measurement and a 1% error on the background measurement. Our estimated total error calculated by the root sum square method (following approaches of related work) results in an overall error of ±11.61% on our flux measurements for each transect.

We have described this in the revised version in particular at the end of section 2 (methods):
"Uncertainty in the flux calculation is given by the following root sum of squares method which combines the uncertainties in wind velocity ϵv, wind direction ϵd sensor error ϵs, and background CO_2 ϵb. ϵ is calculated similar to uncertainty calculation techniques described in Nassar et al. (2021); Lin et al. (2023); Nassar et al. (2017); Johnson et al. (2020)"

We also describe this in section 3.1 (plume transect wind measurements):
"The wind direction given by the ERA5 model yielded results ranging from 38◦ to 68◦ with an average of 53◦. These ranges contribute to the overall uncertainty ϵ_d "

and in section 4.1, the discussion of the CO_2 flux uncertainty:
"We used our wind estimates during the time of each flux calculation. This variation in wind velocity ϵv is ± 11% which is calculated from the wind velocity range measured over the experiments (Table 1). The range of wind directions is ±15° from Table 1, which gives an error in the flux estimate based on $\epsilon d = 1 - \cos(\text{angle})$, thus ±3.40%. The SBA-5 documentation reports sensor error ϵs is 1% in the range of CO_2 we measured. Finally, background ambient CO_2 ϵb adds 1% to the uncertainty model which we calculated from the uncertainty in ambient CO_2 readings. Therefore, our estimated flux uncertainty given by the root sum of squares method is $\epsilon = \pm$ 11.61%."

References

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