Reply to Referee 2

We would like to thank Referee 2 for bringing important details of the proposed method to our attention. Below we address the comments, grouping them by their close relationship to each other and aligning some of them with the comments of Referee 1.

Response to main comments

Referee: I find the method section is difficult to follow. I would suggest the authors to re-construct this section in a manner that: you first see a co2 concentration map (raw data); second, a pre-setup of the boundaries/masks, and basic information about your study region (topography, carbon ecosystem dynamics); third, how you apply your algorithm to detect sources and sinks by steps, and show intermediate figures to help the audience understand.

Referee: Limitations of your methods need to be addressed. A big part of the work that I think is missing is the uncertainty and limitations of your method. For example, some regions are low-hanging fruit for detection, but some regions might be really difficult (topography, complex ecosystem). Also look at the CO2 concentration dataset, some regions show sufficient enhancement to be easily detected but some regions might look really uniform, how can these different scenarios be handled by your method? All of these need to be at least discussed in detail, so the readers can know how widely this method can be applied.

Replies: We agree with the Referee that the mathematical material describing the proposed method can be complex. However, according to the ESD Idea Paper format, authors should present a comprehensive analysis and justification in a few pages. We thank the Referee for the idea to restructure the paper, which can be applied in a full paper in the following stages of our research, and will add the algorithm for CO_2 sources and sinks detection to the *Anticipated changes* below.

We also agree with the comments on the specific challenges related to the characteristics and limitations of the method. However, we have stated in the paper that the CO_2 sinks and sources have been preliminary detected and that additional tools are needed to obtain more accurate results. The proposed digital filtration method is based on multiplication, difference and sum operations. All three operations can be applied to any CO_2 concentration value without mathematical limitations. A specific limitation of the digital filtration is described in lines 58-62. To avoid repetition, we will not include it in the *Anticipated changes*. Technical limitations in the resolution of satellite datasets (the resolution of a sensor) can pose an indirect challenge to preliminary detection, which can be partially overcome by matching the resolution of a dataset to the expected sizes of the areas to be detected.

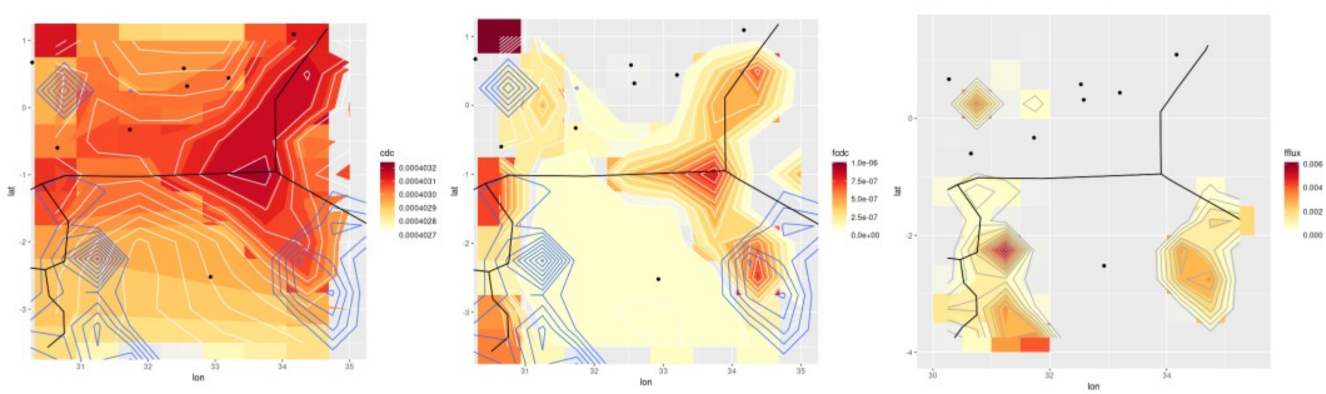
Another challenge is the nature of the area of interest, which includes many individual characteristics, e.g. topography, complex ecosystem, natural or industrial origin, etc. These are more important in the following stages, which depend on the objectives and do not affect this preliminary stage. At the current stage of our work, we are exploring the ability of digital filters to capture and detect changes in various characteristics of natural processes, using CO_2 sinks and sources as an example, and focusing on the fact that these changes occur in near real-time and on their sign.

Anticipated changes: We will change the following sentence in the abstract (lines 6-8): "Here, we detect ecosystem areas with weighty changes in the CO_2 concentration using digital filtration, similar to image processing techniques, to identify terrestrial CO_2 sources and sinks" to: "Here, we propose digital filtration with a Laplacian filter for preliminary detection of areas with different changes in the characteristics of natural processes, using CO_2 sinks and sources as an example".

We will also add the following sentences to the manuscript after line 18: “Applying digital filtration to CO_2 sinks and sources preliminary detection can be challenging due to their nature and behaviour. Industrial objects have more stable emission characteristics. Natural objects have a clear seasonal and also daily periodic dependence. This leads to the need for continuous observations in near real-time mode. Another potential challenge for satellite datasets are technical limitations in the resolution of satellite datasets (the resolution of a sensor), which indirectly challenge the preliminary detection. At the current stage of our work, we do not focus on the reasons that may affect the accuracy of detection, but aim to explore the ability of digital filters to capture and detect changes in various characteristics of natural processes, for example, for the preliminary detection of CO_2 sinks and sources”.

We will add the following detection algorithm at the beginning of the Appendix: “According to the proposed method, the preliminary detection of CO_2 sources and sinks involves the following steps: 1. Digital filtration of the CO_2 concentrations in the area of interest and identification of the area as a source or sink by the sign ("+" is a source, "-" is a sink). 2. Comparison of the superimposed filtered CO_2 concentrations with fire fluxes in the area of interest. 3. Finding the area where two parameters are closely superimposed at their maximum intensities”.

For a better understanding of the algorithm, we propose to include another figure showing the distribution of the CO_2 fire fluxes with both colours and isolines. The proposed Fig. A1(c) is shown below, together with the distributions of the CO_2 parameters in the fire area in Fig. A1(a) and the obtained results in Fig. A1(b).



(a) CDC distribution in the fireplace area and CO2 fire fluxes data

(b) The obtained results and their verification by CO2 fire fluxes data

(c) Verifying CO2 fire fluxes data

Figure A1: Spatial distributions of the CO_2 parameters and the obtained results of the CO_2 source area detection

We will also change the sentence “The flux data are presented in Fig. A2a with isolines showing the rate of CDC changes” in line 138 to: “These data are presented in Fig. A1c, which shows the CO_2 flux rate with colour intensity and isolines, and in Figs. 1a, 1b with isolines only. The density of the isolines is related to the rate of flux intensity change – higher density corresponds to higher rate, and lower density corresponds to lower rate of change”.

Referee: Studies of CO2 point source quantification is well developed in the last couple years. This makes me wonder the meaning of only detecting sources or sinks but not quantifying them. Existing datasets like GPP or NPP are great proxies for this purpose and they serve many more scientific meaning. I would encourage the authors to describe in detail how this detection technique could uniquely provide more information, and if there is potential to further quantify the sources and sinks. I believe that would be a more appealing method to be used by our carbon community.

Reply: Functional indices such as GPP or NPP can be good proxies for detecting long-term continuous sources and sinks of CO_2, assessing long-term CO_2 processes, and quantifying the effects of changes in CO_2 after these changes have occurred. These and similar indices are more integral and reflect the cumulative result over a period of time with large measurement inertia. For example, it is rather difficult to use them to determine how CO_2 fixation changes during the day (this is one of the tasks of our main project), which, in our opinion, is easier to do by analysing fluctuations in atmospheric CO_2. Also, the detection of CO_2 sources and sinks can be more meaningful than their quantification for near real-time decision making based on CO_2 dynamics. For example, detecting a short-term CO_2 source in the forest area without quantification may help stop a forest fire in its early stages. Near real-time detection of a CO_2 sink area can help understand the time frames of different sink activity periods and capture transitions between periods. These are potential applications of the proposed method.

Anticipated changes: We will add the following sentences to line 29: "In our paper, we do not quantify CO_2 sources and sinks, because quantification is valuable for understanding the consequences of CO_2 changes after these changes have occurred. Our focus is on short-term (e.g., hours) CO_2 changes, which can help detect CO_2 sources and sinks and their different phases of development in near real-time, until further analyses can be performed".

Response to minor comments

Referee: Lines 11-12: No this is clearly not your research focus of this work.

Reply: In this idea paper, we propose and justify the applicability of the algorithm for the preliminary detection of CO_2 sources and sinks, which is one of the tasks of the new method. Another feature of this algorithm is the possibility of using it in near real-time.

Anticipated changes: We will specify that the proposed detection algorithm is part of a new method for CO_2 reduction and make the following changes to lines 11-13: "Our primary research therefore focuses on the development of a new method for CO_2 reduction. As part of this method, we propose an algorithm for the near real-time preliminary detection of CO_2 source and sink areas. This algorithm can help to facilitate the monitoring, reporting and verification of CO_2 source and sink areas".

Referee: Line 15: why a co2 concentration dataset is abbreviated as CDC?

Reply: The abbreviation CDC stands for Carbon Dioxide Concentration, used first in the line 15.

Anticipated changes: none.

Referee: Line 72: Eqs. (2) and (3) are identical.

Reply: Equation 2 is a mathematical interpretation of the dependence of the CO_2 data on Figure 1b. Equation 3 is an initial set of relationships that ground the relationships in Equation 4. They therefore had different functional aims.

Anticipated changes: We will delete Equation 3, retain Equation 4 (#3 in the new numbering) and change the text of the explanatory paragraph after Equation 2 to: "If, at $t_1 > t_0$, the concentrations change according to (2) while all internal environmental conditions remain stable, this will result in a simultaneous multi-point (X-Z) increase in CDC as shown in (3)".