First of all, we wish to thank both the reviewers for going through the manuscript carefully, appreciating the actual content of the manuscript and providing constructive comments/suggestions for the improvement of the manuscript content. Point-to-point replies to each of the comments/suggestions made by both reviewers are provided below.

Replies to reviewer-1 comments

General comments:

- With the best will in the world, the grammar and general sentence structure in this manuscript is not amazing. I would recommend the authors conduct a detailed review into the language they have used here—particularly in the first two sections—since it was hard to interpret in places. I understand, however, that it is unfair when English is not your first language, so I leave my comment with good intentions.

Reply: Grammatical mistakes and typos are minimized to the maximum possible extent in the revised manuscript. The language used is also revised thoroughly. We hope the revised manuscript is better readable now.

- This manuscript presents the results of several field campaigns conducted using a synergy of aerosol instrumentation, including balloon-based sensors and remote sensing apparatus. The authors correctly note that the characterisation of aerosol cloud interactions is important and ongoing research. They also make the point that multiple instruments must be used in a field campaign to play to their respective advantages and disadvantages.

Reply: We thank the reviewer for making positive remarks about our manuscript.

- It is difficult to understand the exact purpose of this manuscript. The authors appear to focus on many different topics but not go into too much detail on each one. It would be better if the authors were clearer on whether this is for instrument validation/inter-comparison, presenting a novel data analysis technique, or presenting a dataset. A paragraph at the end of the introduction would be nice.

Reply: The purpose of the manuscript is to introduce the BACIS Campaigns to the reader and show the data obtained from these campaigns helps to quantify the aerosol-cloud interactions. We focused on relevant topics to the extent required for emphasizing the scope of this manuscript. For example, the discussion on the campaign approach and instruments/sensors employed is detailed. A section is given on discrimination of aerosol/cloud in a profile before going to the quantification of aerosol-cloud interaction. We have also gone into the details of data and analytical methods. The comparison of sensors is qualitative. The following paragraph is written at the end of the introduction section to highlight these aspects of the manuscript.

"The purpose of this manuscript is to introduce the motivation and objectives of the BACIS Campaigns for quantifying aerosol-cloud interactions. In order to do this, we have discussed most related topics, such as the campaign approach, sensors/instruments employed, analytical methods and comparison of balloon features. Results from selected campaigns focus on discrimination of aerosol/cloud in a profile. Overall, the methods presented in this paper for the data analysis/processing are novel. Using these methods aerosol-cloud interaction is

estimated in liquid clouds."

- The authors create the narrative that this measurement campaign type is "unique", however there are many studies into atmospheric aerosol using both balloons and remote sensing apparatus (Kezoudi *et al* 2021 for example). This narrative needs to be weakened, and the relevant literature needs to be cited. I have made a few specific comments to this aim. Generally, I find the techniques used for data analysis and processing in this research more novel than the measurements themselves; if this is what the authors meant then it needs to be stressed more specifically because it was not clear to me.

Reply: We removed the word 'unique' in the places of the revised manuscript. The revised manuscript cites the relevant literature. We thank the reviewer for the positive remarks on the techniques used in the manuscript for data analysis and processing. We have included the following statements in the last paragraph of the introduction section.

"The purpose of this manuscript is to introduce the motivation and objectives of the BACIS Campaigns for quantifying the aerosol-cloud interactions. In order to do this, we have discussed most related topics, such as the campaign approach, sensors/instruments employed, analytical methods and comparison of balloon features. Results from selected campaigns focus on discrimination of aerosol/cloud in a profile. Overall, the methods presented in this paper for the data analysis/processing are novel. Using these methods aerosol-cloud interaction is estimated in liquid clouds."

- In Sect. 2.1, can you detail the method by which the sensors are aspirated, and the relevant sample flow rates. Also, can you detail how you have mounted the instruments to the balloon package, and how you have ensured isokinetic flow. Also, attention to how platform-based sampling biases affect your measurements is required in this section, particularly since you have correctly pointed out in your introduction that aircraft suffer from these disadvantages too.

Reply: COBALD sensor illuminates the air in the vicinity. Therefore does not require any flow to operate. For CPS, the sample flow depends on the balloon ascent rate. Fujiwara et al. 2016, (Appendix B) measured the flow rate within the duct of the CPS by using hot-wire anemometers and estimated that the flow rate in the detection area is about 0.7 times the balloon ascent rate. We used the value of 0.7 (of balloon ascent) for this paper.

As shown in fig.2a, the ozonesonde at the centre serves as the support for the balloon payload. COBALD sonde with a slight upward-looking angle is attached to one side of the ozonesonde and the CPS on another side. Radiosonde (Meisei and iMet) connected to the remaining two sides. All the sondes are tightly packed using adhesive tapes. At the base of the ozone sonde, a wide thick thermocol sheet is arranged to protect the entire payload at the time of ground contact during descent. A couple of GPS/GSM based trackers are also attached to the payload along with a power bank for safe recovery.

For CPS, the flow (i.e., 0.7 of the balloon ascent rate) inside the duct and the detection area would be more or less turbulent, meaning that the flow has a minor component of a complicated function of time and space, but for example, taking a sort of averaging e.g. for 5 seconds, 10 seconds, 1 minute, etc. would dump the impacts of such a turbulent component.

The entire payload is hung to an inflated balloon with the help of a nylon thread. The length of the thread between the inflated balloon and parachute is 5 m.

Similarly, the length of thread between the parachute and payload is 10 m. In this paper, CPS and COBALD data are shown at actual resolution (5 m). But in the estimation of the aerosol-cloud index sensor data is averaged over the thickness of the cloud which is about 300 m. Therefore, the sampling biases would be nullified.

- Generally some of the subsections under Sect. 2 can be merged. The current structure of this entire section is confusing, and much of the information is repeated. I am not entirely sure what the purpose of Sect. 2.3 is, since much of this content is also present in the introduction and other subsections of Sect. 2. Overall this section needs to be more information dense.

Reply: Thank you for your suggestion. We wish to inform you that the structure of the Sect.2 was arranged in response to the suggestion made by one of the reviewers during the review process before the manuscript appeared as a preprint.

- It would be nice to have a figure in Sect. 3 somewhere to show measurement context—that is, a map of the campaign area showing the balloon launch site, the location of remote sensing apparatus, wind direction, and relevant mesoscale parameters.

Reply: Thanks for the suggestion. We have included a map of the campaign area in the supplementary file of this manuscript.

- The authors conclude that the remote sensing and in-situ instruments "agree well", but this statement means nothing. The results of basic statistical tests—even a percentage difference would be better than nothing— followed by an explanation of why this means they "agree well", needs to be stated in Sect. 3 as well as the summary.

Reply: What we mean by "agree well" is that the broad features of the remote sensing and in-situ measurements are matching/reasonably agreeing. But, it is possible that some of the sharp/short-time/localized features may not appear in all. We have discussed these details in sec.3.1.1. As the balloon drifts away from the measurement location with time, one can't expect both profiles to match exactly. Our intention of comparison is to qualitatively observe the features of aerosol/cloud in multi-instrumental observations. In the abstract, the statement is changed to *"Aerosol/cloud profiles obtained from the multi-instrumental observations are found similar".*

Specific Comments:

- Page 1, title. The title is misleading. It appears to either incorrectly present the paper as a review paper, or somehow claim that these are the first balloon-based aerosol measurements. You could fix this by changing it to something along the lines of:
  "The results of Balloon borne Aerosol-Cloud Interaction Studies (BACIS)—a set of campaigns to understand and quantify aerosol effects on clouds."

Reply: We have slightly modified the title to
"*Balloon-borne Aerosol Cloud Interaction Studies (BACIS): Field campaigns to understand and quantify aerosol effects on clouds*"

- Page 2, line 34. An important aspect of what?

Reply: The word 'aspect' is now removed in the revised manuscript and rewritten as follows,

"Better understanding of aerosol-cloud interaction process is important to quantify the role of aerosol and clouds on the climate system".

- Page 2, line 37. I struggle to see what is unique specifically regarding the measurements presented here, Kezoudi *et al* 2021. Combined balloon-based aerosol measurements with remote sensing.

Reply: The word 'unique' is now removed in the revised manuscript. Please note that Kezoudi et al., 2021 and the present manuscript are two different approaches to measurements for aerosol/cloud.

- Page 2, line 44. Can you quantify the agreement and how "good" it is please? Standard deviations? Correlation coefficients?

Reply: The physical quantities assessed among the different sensors/instruments are different. Independently the balloon-borne sensors have been proven (Fujiwara et al., 2003; Vernier et al., 2015) but for the first time, a combination of COBALD and CPS is used in the BACIS Campaigns. Retrieval of physical quantities also involves assumptions. Hence, our intention is to assess the features of aerosol/cloud among different instruments. The wording 'A good agreement' is now removed in the revised manuscript.

- Page 2, line 52-53. "Paving the way for further investigations using this approach" is overly emotive language, especially considering campaigns involving similar instrumentation and platforms have been conducted before (for example A-LIFE and DETECT in the eastern Mediterranean).

Reply: In this sentence, we are referring to BACIS campaigns only. Please note that it is not a generalised statement. We mean to say, the results obtained here (BACIS), give us the confidence to conduct similar campaigns in future to explore the process of aerosol-cloud interaction in detail.
In the revised manuscript we have removed the portion of the statement starting with "and paves the way for …..".

- Page 3, line 65. Sentence starting "All these effects…", I'm not sure what the authors are saying here, please revise phrasing.

Reply: Cloud modifications due to aerosol are multifold. They depend on cloud type and the surrounding meteorological, and dynamical conditions. The sentence is rewritten in the revised manuscript as below,
"*All aerosol-cloud effects are found to act specifically to cloud type, background meteorological and dynamical conditions.*"

- Page 3, lines 80-81. Please cite some UAV examples here too since you mentioned them as a platform, for example Mamali *et al* 2018, Girdwood *et al* 2020, Girdwood *et al* 2022.

Reply: The suggested references are now added to the revised manuscript.

- Page 3, line 82-83. A balloon will also perturb the atmosphere while sampling. In fact, there is less information and data on balloon-based aerosol sampling artefacts than conventional aircraft. This is important to state.

Reply: The suggestion is included in the revised manuscript as stated below,
"*There is less information and data on balloon-based aerosol sampling artefacts than on conventional aircraft*"

- Page 6, line 133. I am unclear as to whether this instrument measures the scattering from single particles like the UCASS (smith *et al* 2019), or ensemble scattering properties, could you clarify this?

Reply: It does not measure the single-particle scattering but the backscattered light from an ensemble of particles in the atmosphere from 0.5(overlap region) to ~10 m of distance. The word 'ensemble of particles is brought into the statement in the revised manuscript as shown below

"The light emitted by the sonde illuminates the air in the vicinity; backscattered light from the ensemble of particles is detected using a silicon photodetector"

- Page 6, line 134. The acronym "FWHM" is undefined.

Reply: The acronym is defined in the revised manuscript.

- Page 6, line 141. "also delivered in cps", do you mean "also conducted with the CPS? Also the acronym must be capitalised.

Reply: Sorry for that. We mean to say 'counts per second' not CPS sonde. The acronym is defined in the revised manuscript.

- Page 6, lines 141-142. I am not sure what you mean by "the sonde is passed", do you mean launched? Also, explain what "the return signal data is within 15% of the reference value" means.

Reply: We mean to say 'The sondes is launched'. The word 'passed is changed in the manuscript.
The COBALD sonde is supplied along with blue and red channel checkout values. Usually, COBALD is operated for about 15 minutes at the surface before every launch. If the blue and red monitor values of the sonde are within ±15% of check-out values, then the sonde is ready for launch (passed).

- Page 9, line 216. Operated, not operational.

Reply: Thanks for the suggestion. Changed the word to 'operated' in the revised manuscript.

- Page 30, line 744. Remove "we noticed".

Reply: Removed.

- Page 31, lines 771-772. I'm not convinced that this study "paves the way for future campaigns to understand aerosol-cloud process". Please remove this line or soften the concluding statement.

Reply: Removed the sentence as suggested.

- Figure 5, left panel. Counts per second data is not necessary because it does not mean anything without information regarding flowrate through the instruments.

Reply: Please note that, cloud particle concentration is also used and shown in the manuscript. However, cloud particle concentration is estimated assuming the ascent rate as the flow rate. This approach may induce uncertainty in the estimates of cloud particle concentration. Therefore to minimise the propagation of error in the estimation of aerosol-cloud interaction index, we used the cloud particle counts as

a cloud proxy instead of cloud particle concentration. Please note that cloud particle count is the direct measurement. Hence, the cloud particle count is shown in Figure 5.

- Figure 10a. dn/dlog(Dp) is a more standard method for displaying particle size distribution data, since counts on its own doesn't really mean much.

Reply: Thank you for the suggestion. Please note, fig.10a shows cloud particle number concentration (dN, #/cc) but not counts. The former parameter is estimated assuming balloon vertical ascent as air flow rate. Fujiwara et al., 2006 also used the same parameter while reporting the first cut results from CPS Sonde observations.

- Figure 11a. Can you state what the box and whiskers represent? Is it mean, interquartile range, and range?

Reply: Box and Whisker representation is stated in the figure caption. The horizontal line in the centre of the box represents the median. The Upper and lower edges of the box represent the third quartile (Q3), and first quartile (Q1) respectively. Similarly, the upper and lower whiskers represent Q3+1.5*(Q3-Q1) and Q1-1.5*(Q3-Q1). The data points beyond the whiskers (outliers) are shown with red star symbols.

- If the red crosses are outliers, then there is a lot of outliers in these data, can you explain why this is?

Reply: As pointed out, we see large outliers in the 1st, 2nd and 6th campaigns only. In the rest of the campaigns they are below 10 (in Colour Index). From Table.3, ice clouds from these campaigns were found to be very thick (2.5, 5.5 and 6.7 km respectively). Therefore, there might be more outliers due to the extended distribution of CI values.

- Figure 11b. The results shown here are near illegible, I think a line plot with bin centres on the x-axis would be better. Also a key is needed here to indicate what the different colours mean.

Reply: Thank you for the suggestion. In the revised manuscript Fig.11b is replotted. Hope it is legible.

- Figure 12. The figure caption states that the data are from 100, 200, 300, 400, and 500 m below the cloud base but only the latter 3 are shown on the graph. You state in the text that 100 and 200 m lack enough data points for a statistically significant result, but the caption is wrong.

Reply: Thank you for the suggestion. Figure.12 caption is corrected. "Scatter between logarithm values of COBALD median blue backscatter (x-axis) from 300, 400 and 500 meters below the cloud base and the corresponding CPS median cloud particle count (y-axis) obtained from five balloon soundings, with a linear fit (different coloured lines). The table inside shows detailed statistics."

- Figure 12. Only 5 balloon sounding results are shown, but in Sect. 3.4 it is mentioned that 6 launches were observed with aerosol and cloud layers, why did you omit these results?

Reply: As rightly pointed out, aerosol-cloud layers were observed in 6 launches (see Sect 3.4). However, due to abnormal values found in the COBALD

measurements, the data from the launch held on 04 Feb 2020 was not considered in the analysis. This was already mentioned in the original manuscript. The same sentence is slightly modified in the revised manuscript as follows.
“Data obtained on 04 Feb.2020 was not considered in the analysis due to high values of COBALD”.

References:

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Reply: Thanks for providing additional references which are included in the revised manuscript.

We thank once again the reviewer for going through the manuscript carefully, appreciating the actual content of the manuscript and for providing constructive comments/suggestions which made us improve the manuscript content further.

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