Response to Reviewers

The authors would like to express our deep appreciation to the three reviewers who invested so much time and thought into their question, comments and suggestions. We have tried to address each of these and implement all changes that we considered valid and helpful for improving the manuscript. All responses are indented and placed in italics.

Reviewer 1

At several places in the text where the non-uniformity of the beam is addressed only the across-beam variation in mentioned (e.g. 7383/5, 7384/25,7388/5) yet along the beam variation is referred to at 7385/15, and Fig. 4 clearly illustrates it. This is confusing.

> *This has been clarified in the text to explain that this is a 2 dimensional map and we are taking into account the width and length variation.*

The sample volume is quoted as 0.18 mm2. In Fig. 4 the beam is mapped over a larger area. Clearly, the sample volume is dependent on the detector threshold setting. Could the area used in the analysis be shown in Fig. 4?

> *This section has now been modified extensively showing how the sample area is diameter dependent because of the Gaussian intensity distribution of the laser beam. This is now included in Fig. 4 as suggested by the reviewer.*

The comparison of the size distributions in Fig. 12 is for a long averaging period (20 minutes) and the conclusion of good match is based on this. Is such a long period needed for good statistics? How good is the agreement for shorter periods?

> *Four time period that show different characteristics of the size distributions are now presented. More discussion of the shapes and differences has been added.*

Are there signatures in the size distributions that would allow periods with ice crystals to be screened out?

> *No, without the polarization method that we use in the CAS-POL and the new BCP with polarization, we can't screen for ice crystals.*

Reviewer 2

Concentration comparison data should be plot for only channels above 5 um. The sampling frequency is not given for the research flight comparison. I expect that the sampling frequency is too large and that in and out of cloud areas are being sampled and confusing the interpretation of the data plots presented. A sampling frequency of 1 second or at most 5 seconds should be used.

Sampling was at 1 hz and time series are shown at 10 second averaging. We have redrawn the time series at 5 seconds averaging, all probes at ≥ 5 µm and provided the appropriate discussion in the text of this sampling and averaging.

The paper should present information that the CDP and CAS were working correctly. When were they calibrated? When were bead size performance checks done? Was the same True Air Speed (TAS) used for the concentration of all probes? Does the CDP have an optical mask so that droplet coincidence is not a problem for concentration values? How was the data processed?

We have expanded the discussion to clarify that we are not asserting that either the CDP or CAS are correct, but that it is a basic check of a new instrument to compare against other instruments that have a longer performance record. We have now added the information now of the relative positions of the instruments to one another, how often calibrated (before each flight with glass beads) and that the CDP did not have the additional optical mask to improve the reject coincident particles.

Details:

Line 77: Suggest paper or article instead of presentation.

"Presentation" is replaced with "article" throughout.

Line 78: Remove first "for"

Changed as suggested

Line 79: Suggest "clouds" instead of cloud.

Changed as suggested

Line 82: Suggest "on" instead of "from"

Changed as suggested

Line 88-90: Suggest “The laser beam is transmitted through a silicate glass window and focused on a small region approximately 4 cm from the fused.” Currently, second part is just stuck onto the first and does not flow.

Changed as suggested

Line 90: “this region” Be direct and state what this region is. In focused region???

“Region” is replaced with “sample volume”.

Line 93-94: Suggest breaking up sentence because doesn't flow well. New sentence instead of the and. “The collecting lenses focus light onto an avalanche photodiode (APD).

*Modified: “*The fraction of light that is scattered backward at a solid angle of 144°-156° is collected by a set of lenses that are located behind the window. These focus the collected light onto an avalanche photodiode (APD).”

Line 100: Is there not a minimum transient peak that is needed for the first channel? To be above the noise level? What about the maximum of transient signal? Hence, does every peak value end up in a channel?

The text has been edited to reflect that the noise threshold has to be exceeded to do a peak detection and particles that saturate the detectors are also rejected.

Line 104: “size histogram” is a confusing term to me. Histogram is typically a type of plot. It is really the counts in each of the channels that is transmitted. Should it not be then “channel counts” instead of “size histogram”. No size information is transmitted.

“Size histogram” has been changed to “frequency distribution”.

Line 105: For the commercial aircraft measurements, please state the serial sampling rate of the channel counts. 10 Hz, 1 Hz or ???

As discussed in the text, the sampling rate is determined by the data system. In the section where the commercial airline measurements are discussed, we now state that the sampling rate was 0.25 Hz..

Line 113: Another example of adding a comma and putting a sentence fragment on the end of another sentence. Construct new sentence for stuff after “, illustrating ...”. Check over rest of paper for this mistake.

Changed as suggested

Line 118-122: Paragraph only two sentences. Could you add something about if the BCP has to be mounted through a pressurized bulk head? I know on the Citation

Research Aircraft, it was within the cable. What about on the other aircraft. Does the pressure and temperature range of the BCP allow it to be mounted in an unpressed location? Also, may want to talk about wiring requirements here, 3 wires for RS232 data, what is required for power, just two wires for A/C?????

Added "A pressurized bulkhead is not required as the instrument is designed to operate up to 20 km altitude, ±40℃ and 100% humidity. The optical head and processing electronics are separate units connected by a cable. Interfacing to the data logger is via a standard RS-232 serial cable. The BCP can operate on 110/220 AC or 24V DC."

Line 125-127: Long sentence with lots of clauses. Suggest ending at "simple indicator for the presence of clouds". New sentence, "Knowing when the aircraft is flighting through clouds is an important parameter when analyzing IAGOS measurements, i.e. water vapor, ozone, carbon monodixe, etc.

Changed as suggested

Line 129: "estimate cloud particle sizes" cloud and particles are both nouns in this context and is not correct. "cloud particle" is like saying "car vehicle". Suggest using "estimate droplet sizes" or "estimate hydrometer sizes"

*The authors respectfully disagree. For example the SPEC CPI is a Cloud Particle Imager, and in a recent Heymsfield et al paper in JAS, "*Ice Cloud Particle Size Distributions and Pressure-Dependent Terminal Velocities from In Situ Observations at Temperatures from 0° to −86".

Line 130: Delete "by the particle"

Changed as suggested

Line 132: Be direct, what does "its" refer too. The particle, the cloud, ??? Suggest "provide additional information about cloud micro-physical properties such as the droplet number concentration.

Changed as suggested

Line 133: A well organized paper does not need to state what will be talk about, just talk about it.

Removed as suggested

Delete line 133-138

Removed as suggested

Line 141-145: A pagagraph is not one sentence, combine with next paragraph.

Modified..

Line 141: It is not the diode laser that has a Gaussian intensity distribution but the laser beam's crosssection that has a Gaussian intensity distribution. Need to talk about the cross-section here because the laser beam would be two dimensional and where as the cross-section would be one dimensional.

Reworded as suggested

Line 153: Having to state that something will be described later is a clear indication that an article is not ordered correctly. Move lines 141-153 to end of section 2.2 and then remove line 153 since it will not be needed when reordered. Furthermore, Line 141-142 follows from discussion of figure 4 later in section 2.2 and anthoer reason to move this material.

Reorganized as suggested

Line 164: Assume 22 um droplets is 22 um diameter droplets. Should state.
Line 164: Why was 22 um droplets used? Accuracy of the map would increase with smaller droplets;however, the intensity would decrease. Would not 10 um droplets provide sufficient intensity? Or even 5 um droplets. Could these small sizes be produced?

Clarification is added to the text. Ideally, every BCP should be mapped with droplets over the entire range of droplet diameters; however, this is several days work with the current setup that requires manual operation. A diameter of 22 µm was selected as being in the mid-range.

Line 165: Should include the length and width values used to come up with this area. Maybe label these values on Figure 4.

The area is not calculated from the length and the width but by adding up the number of grid points included in the scan. This is now clarified.

Line 186: Poor name for this section, you can not just retrieving data but doing a droplet size inversion; hence suggest “Droplet Size Inversion”

Reworded “Size distribution retrieval by inversion”

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Line 188: “ambient”???? Ambient means surrouding area or environment. Not very useful word here.

Removed

Line 191: Suggest “real” instead of “ambient”. If not “real” then “Atmospheric” has the same letter for equations that follow.

Replace “ambient” with “actual” throughout.

Line 192: You do not describe what i and j represent. Suggest “Mathematically, the atmospheric size distribution is represented by the row vector A, with bins (i) of from 1 to n. The measured size distribution is represented by the column vector M, with bins (j) from 1 to m.”

On line 195 and 196 “I” and “j” are explicitly defined.

Line 253: Change to “with a real refractive index of 1.33 (liquid water)”.

Added as recommended.

Line 255: Transformation matrix is not for an individual BCP but for an individual set of samples or time interval. There is not a single T for a BCP but for a set of measurements. Believe this need to be made clear here.

Modified to “The transformation matrix that describes the response of an individual BCP…”

Line 256: Why 5 to 90 um and not 5 μm to 75 μm which is the size interval of the BCP line 229.

We can estimate the concentration of particles larger than the maximum size range because a large fraction of them are undersized and the inversion puts them back into their correct size class.

Line 256: Why start at 5? Anything smaller doesn't scatter sufficient light to have a peak about the noise level?

The size range of the BCP is determined by the dynamic range of the amplifiers and the range of scattering cross sections. We selected 5 to 75, instead of 2-50 in order to measure to larger sizes at the expense of the small particles.

Line 260: “particles” Should probably use drops or droplets since you are using refractive index of 1.33 (water). Likewise, further on use droplet if you are making assumption of 1.33 refractive index.

Modified as recommended

Line 264: Why do the distribution cut off at 12 um for a 40 um particle. Seem that this may be related to a limitation of your software. Should there not be some probability of sizing between 5-12 um? Please explain.

If the Mie scattering function was linear and monotonic then this would be the case but it is not and leads to the type of behavior seen in Fig. 6. .

Line 272-274: Delete. No need to tell me what is in the next section, I'll just read it.

Deleted as recommended.

Line 307: Why is 100 m conservative. 1 second sampling interval and slow jet would give you 100 m.

We are referring to cloud depth in the vertical, not along a horizontal flight path.

Line 334-343: Here you talk about particles with reflective index of 1.33 and should be called droplets and not simply particles.

Modified as recommended..

Line 360: I don't understand about the nose being the best location. Further back on the fuselage the airflow streamlines should be less affected by the aircraft.

The issue is boundary layer growth. Since the sample volume of the BCP is only 4 cm from the window, it is important that the sample volume is outside the boundary layer, otherwise it could find itself in a shadow zone..

Line 366: Where was the detection threshold of 0.1 cm^-3 previously stated? I see online 308 a value of 0.03 cm^-3. Are the units correct here. Doesn't really matter, if the TAS is only know to within a factor of two, then sample value is only this good and so is the concentration and optical depth.

The 0.1 should be 0.03.

Line 375: 250 ms^1??? Should be 250 m/s or 250 m s^-1.

Corrected.

Line 384: Factors 1 and 2 are labeled but not 3.

Corrected.

Line 386: Should it be “over a range of values”

Corrected.

Line 386-391: Very long sentence that is difficult to understand, please shorten and rephase.

Rewritten into three sentences.

Line 420: Be direct and state what “This” refers to.

Rewritten into two sentences.

Line 445: Need comma after “aircraft”

Added.

Line 447: Delete “to measure size distributions” repetitive since you state that you compare with other spectrometers.

Deleted

Line 447-451: No need to state what is in the next sections. Suggest not having subsections. Just Flight Results or if you want to section, then “Research Flights” and “Commercial Flights”

Deleted. Renamed as recommended.

Line 453-454: Delete/combine with other sentences.

Modified as recommended..

Line 456: “on flights” instead of “in flights”
Line 457: No need for comma before and Check document for correct use of commas

Corrected.

Line 466-467: Even on wing pylons, probes can be affected by the aircraft and hence not in free air? Delete.

Deleted

Line 467-470: Delete, leave this until the discussion section.

Deleted

Line 473: “during a four hour flight” Be direct and state what flight (day, flight id).

Flight information has been added.

Line 474: Delete “Also shown with the .. temperature.” This describes the figure and should be in the figure caption.

Deleted

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Line 475-477: Not the way I would think about this. I would calculate the sample volume using the best information and then say that the concentration was multiplied by 0.5 to adjust the concentration to be similar to the other probes.

We have done a reanalysis without using a scale factor to highlight that even though there is uncertainty in the sample volume, the BCP measurements have the same trends as the CDP and BCP.

Line 478-483: Place description about the figure in the caption and provide the interpretation here. Revise.

This entire section has been rewritten after removing the scale factor and constraining the calculation of concentration, LWC and MVD of the three instruments to the same size range..

Line 482-483: What about breakup of water droplets on leading edges. I would not talk about possible fragmentation here. Enough to say that you are sampling a liquid cloud during this period.

Revised as recommended.

Line 487-488: Speculation about measuring accumulation mode aerosols is incorrect. First, there are very few accumulation mode aerosols from 0.5-3 um, second this is an in cloud measurement and all large aerosols would be in cloud droplets. Furthermore, the CAS has is a spectrometer so just plot the concentration from 5-50 um. Likewise for the CDP, just plot concentration above 5 um. If you plot this concentration then there is no need for any speculation.

Now removed after reprocessing.

Line 493-499: Not clear what parameter the author thinks is affecting the airspeed. Yaw angle would not be related to altitude. Typically, the yaw angle doesn't change much. Are you talking about attach angle?

Now removed after reprocessing.

Line 493-502: I don't believe that this speculation is correct. The sampling period is too long and in cloud and out of cloud data are being sampled. Have you looked at high resolution data? I would suggest plotting 1 Hz data for this comparison.

Now removed after reprocessing.

Line 504-511: I see no reason to do a LWC comparison. Do a comparison of the mean diameter and standard deviation of the mean. This is what has been talked about previously.

The LWC time series was requested by a reviewer who reviewed the paper prior to acceptance as a discussion article..

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Line 513-520: 100 seconds is too long of a period. I suggest showing the spectrum every 10 seconds. Put each spectrum in a different color and use different line types for the different probes.

Multiple spectra are shown in different figures to illustrate different time periods..

Line 523: Do not use acronym (BCP) in section headers.
Line 525-531: Repeating previous material. Delete, combine figure 13 with Figure 3 and move text there.

Modified as recommended.

Line 533: Be direct and state what "this instrument package is"

Modified as recommended..

Line 542: 20 second at what concentration, is it a 20 second average?

No, 20 seconds of data all in cloud just as a way to filter small clouds. This is clarified now in the text.

Line 542-547: Delete, this is just describing what is in the figure which should be in the figure caption. Text should present interpretation of the data.

Deleted.

Line 549-553: Delete should be in table caption.

Deleted.

Section 3.2: Delete this section and move material to other section or to captions.

We have left it in and expanded the discussion.

Line 573: State a number for how good. “qutie good” is not scientific.

This sentence has been deleted.

Line 575: Delete “Expanding ... 2.4,”

Deleted

Line 577: Boundary layer of what? The atmosphere????

Of the flow around the aircraft. This has been clarified..

Line 578: Reference, here.

References added.

Line 579: “all” have you checked? Best to reference one and go from there.

“all of them” has been removed.

Line 581: Again reference, why 20 um. Doesn't this depend on air speed?

References added.

Line 592: Why 100% and not 50% or 150%? Seems like just pulling a number out of the air.

Removed the estimate as we don’t have enough information to quantify..

Line 594: Have you checked with the aircraft manufacturer for air flow information. Lot of commercial aircraft have extensive flow modeling to find thing like static port points.

Airbus doesn’t release that information.

Line 594-599: Are you sure, the small particles could be following stream lines and large particles have sufficient are sampled because they do not follow the streamlines. High resolution, detailed comparison of the mean volume diameter (MVD) on the research flight should indicate if this is an issue. Do the commercial flights have MVD over all size ranges, similar to the research flights?

Not sure what the reviewer is asking about here. The point of this discussion was to emphasize that there are uncertainties that still remain unknown. The commercial flights have MVDs that are within the size range of the BCP.

They also most likely encounter MVDs outside this range but without other instruments, we can't comment on this.

Line 663: Define cloud encounter, concentration averaged over what time.

Edited to define clouds as concentrations > 0.01 cm^{-3} (10 L^{-1}) for more than 20 seconds.

Line 669-670: I don't understand the four layers. Looks like two layers. Again, higher resolution data.

These are the highest resolution recorded, i.e. 0.25 hz. The wording as been edited to explain why these look like 4 layers, i.e. where the concentrations peak at values greater than 100 cm^{-3}

Line 682-683: Present the conclusion of this paper, not other papers.

Reference is removed.

Line 779: Provide a caption not just a title for the figure. What defines a region? How is cloud encounter define?

Modified to change "Region" to "Geographical Region". Edited to define cloud encounters as clouds with concentrations > 0.01 cm^{-3} (10 L^{-1}) for more than 20 seconds

Figures:
Figure 1 - Text, items in () are not read as part of the sentence, which would make the caption not make sense. Suggest "The principal optical components of the BCP are shown in the top section and the bottom pictures shows the BCP with dimension and total weight.

Edited as recommended

Figure 1 – Assume the 500 gm is 500 grams so shouldn't this be 500 g? Also, in Figure 2, the weight of the CDP is given in kg. Use either g or kg but don't switch between them.

Edited as recommended

Figure 1 – Please add the third dimension in the picture, the height of the probe, looks like 3-4 cm. Also, would be good to give the diameter of the outside plate the is mounted to the fuselage, either in the picture or in the text.

Edited as recommended

Figure 1 – Can you label the Blue Arrow as “Air Flow”. Also, What is the line or number 1 for next to the laser beam lines and next to “4 cm”. Can these be deleted? Also, should not “skin” and “optics” be capitalized?

Edited as recommended

Figure 1 – Figure captions should be independent of the text. Hence, all acronyms like BCP need to be defined in the text. Likewise for other figures.

Edited as recommended

Figure 1 – I don't get what the blue circles are indicating in Fgiure 1A. This can't be the area that droplet are confined to. It can't be the area over which droplets are detected because it is in the beam. I would suggest removing the circle and puting in a blue section of the laser beam to indicate the area over which droplets are detected by the Photo-detector.

Replaced and added legend.

Figure 1 – In this figure, the detector is called a photo-detector but in the text it is a “Avalanache photodiode”. Please use the same term in the figure and in the text.

Changed on figure

Figure 1-17 – Suggest removing the blue box. The box just adds a lot of white space. Better to just make the figures larger.

Removed.

Figure 2 – How about labeling the width of the CDP?

Added.

Figure 2 – Use either g or kg but not both.

All now in kg.

Figure 2 – Figure captions should only describe the figure and interpretation of the figure discussed in the text. The text sentence does not make sense. Suggest “Picture showing the Backscatter Cloud Probe (BCP), the Cloud Droplet Probe (CDP) and the Forward Scattering Spectrometer Probe (FSSP). The size and weight of each probe are given by the labels.

Modified as recommended.

Figure 2 – I would suggest using different cloud fonts for the text of each instrument. Also, if you want, include the year introduced as a label in the figure.

Dates are added to figure.

Figure 3b – Description for the Citation (CE-550) could be better. The BCP was not mounted inside the radio compartment, no compartment at this location. The BCP was mounted on one of the hard points that has been added to the Citation for research purposes. Also, might be best to say that the BCP was behind the co-pilot's seat and ahead of emergency exit door.

Modified as recommended

Figure 4 – Units on the y-axis. Assume the unit is mm.

Modified as recommended

Figure 4 – The resolution is not 10 um. The spacing of the droplets was 10 um. The droplets themselves were 22 um.

This has been removed and discussed in the text.

Figure 4 – Why smooth the image? I would like to see an unsmoothed image. If you have to provide a smoothed image, what is the smoothing factor. Can't reproduce image or make a compare one without this informaiton.

With respect to the reviewer's opinion, we prefer to leave the figure as is as it better depicts visuallythe intensity distribution of the laser beam. Had we had a digital mapping system, this is close to what would have been measured. Gaussian smoothing is used. We also use the higher resolution, smoothed data to calculate sample areas and the inversion probability matrix.

Figure 4 – Provide a color bar legend at least in terms of digital number. Is there no way to easily transfer the color to a scattering intensity?

New image with color bar

Figure 5 Line 900-902 Text refers to water and assumes 1.33. Also, inversion is only for droplet larger than 5 um. Hence, your red line example should be for water of 5 um or larger. Which does not have nearly the difference in optical diameter as the one you illustrate.

Good point. Modified on graph and in text, accordingly.

Figure 6 Line 906-910 Use droplet here because you are talking about water and not any particle.

Modified as recommended.

Figure 7: The color lines can't be Atmospheric (ambient) distribution but the BCP measured distributions that need to be inverted. Labeling them as Atmospheric distribution would infer that they have been inverted. Please correct or explain how I am misunderstanding the figure.

Modified using more clear terminology.

Figure 8: Fonts are very small. Should be approximately the same size as the caption text. I don't see why we need three examples. Suggest only showing A and B.

Fonts have been increased in size. The three figures demonstrate the three different ways that the inversion can be improved so we left all three.

Figure 8: Distribution are not very realistic when compared to real cloud observations. Suggest a peak at 12 or 15 um and not 20 um. Remove figure C you would only have to go up to 40 um. Most real clouds have standard deviations of 2-4 um.

The point of the figure is to highlight aspects of the inversion and are not meant to replicate exactly cloud distributions. They are only unrealistic in the Gaussian tails that are not normally seen in clouds.

Figure 9: Caption Need space between 10 and um. Figure text needs to define chnls and dbar.

Modified as recommended.

Figure 10b: Use linear scale 0-500 for concentration. Will make the comparison look a lot worst.

Modified as recommended

Figure 10b: Use temperature scale of 10 to 20 C.

Modified as recommended

Figure 10b: What is the blue box for?

Boxes are now described in the caption.

Figure 10: Provide a description of the figure. Data for what day, for what aircraft, for what location. Define acronyms. Fonts too small. What is the sampling frequency being presented? What is the approximate speed of the aircraft?

Modified as recommended

Figure 11: Define IWC, MVD in caption. Like figure 10, provide a description of the text. You state in the caption that plot A is liquid water content but the y-axis label is IWC which I assume is ice water content. Which is it.

Modified as recommended

Figure 11: I would like to see the standard derivations comparison instead of liquid water content (LWC). If there is really a need of LWC, add a standard deviation plot. Having a standard deviation plot would put would Figures 8 and 9 in the context of real cloud observations.

A reviewer of the paper, prior to publication as a discussion paper, asked for the LWC. Adding standard deviation bars to all the MVD plots would obscure the trends, so we have only included a better discussion in the paper. In addition, we no longer use the scale factor, preferring illustrate the differences then discuss the probable sources.

Figure 11: Describe the data, what day, location/field project.

Modified as recommended

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Figure 12: Use “liquid cloud” or pure liquid cloud instead of all water cloud.

Modified as recommended

.

Figure 12: Is the time period the full interval or just what is in the blue box in Figure 10? State in figure caption what seconds the interval is over, even if it is defined in figure 10.

This figure has been changed tothree figures of shorter averaging time to illustrate different time periods.

Figure 12: What frequency data was averaged?

Now labeled on the figures.

Figure 13: Suggest combining this figure with Figure 3 and deleting this figure.

Combined as recommended.

Figure 14: Text in figure is too small. Just label a few key cities and make the text larger.

Several key cities have been enlarged.

Figure 14: The x-y ratio of the map has been changed (stretch vertically). Use a standard map project and don't change the x-y ratio.

The ratio has been kept as is in order better visualize the flight tracks

Figure 14: The yellow diamonds for the arrival/departure airport are confusing. Suggest leaving them off or using a color that is not part of the particle concentration scale. Use black.

Figures have been redrawn

Figure 14: What averaging time was used for this data?

No averaging other than the 4 second accumulation times.

Figure 15: Similar comments as on Figure 14.

Figures have been redrawn

Figure 17: Delete
Figure 18: I don't understand how there are four layers here, Looks like two layers what a break at 1500 m.

See response above.

Figure 18: Again what is the sampling frequency? Can you provide higher solution data?

See response above

Figure 18: Provide sufficient information (details) so someone else could create this figure. For example what day?

More information has been added to figure.

Reviewer 3

Page 7381 “The need for 3-D global data sets is increasing. . . Use of commercial aircraft now allows the collection and transmission of highly relevant observations on a scale and in numbers impossible to achieve using normal research aircraft. . .” This section fails to mention the limitations of using commercial aircraft to map out the cloud statistics. The first, most glaring, limitation is the bias against convective systems (commercial aircraft typically go out of their way to avoid these). Commercial aircraft also spend most of their time at cruise altitude, and only descend (often into more polluted conditions surrounding airport hubs) during landing. Modelers and other researchers need to keep this type of (biased) pattern in mind when trying to tease out statistical information from, for example, BCP measurements of cloud droplet concentrations as a function of altitude.

This section has been modified to explain that the majority of the data will be taken from flight cruise altitude where the majority of the clouds will be cirrus. In addition the vertical profiles through clouds are also highlighted

Page 7383 “The fraction of light that is scattered backward at a solid angle of 144-156-deg is collected by a set of lenses . . .” I suspect these angles were used simply as a practical measure (i.e. to keep the instrument package small). It should be mentioned that the backscattered light is generally greater for ice particles than for liquid cloud droplets of the same size.

Yes, this was determined by the geometry of the design and is justified now in the text, along with words regarding the fact that backscattered light from ice crystals is somewhat greater than equivalent droplets.

Page 7385 “. . .in which a linear, mono-dispersed droplet stream is producted by a piezoelectric oscillator that breaks up a narrow stream of water into droplets. . .” Was the droplet generator operated in the ‘Rayleigh breakup’ mode, meaning that a continuous stream of water is streamed under pressure through the orifice while the orifice vibrates (similar in operation to the vibrating orifice aerosol generator)? Or was the droplet generator operated in ‘on demand’ mode, where a capillary wave is induced within the tip of the droplet generator nozzle? I suspect the former, since the droplet size in this paper is only 22um, whereas my understanding from MicroFab (the droplet generator manufacturer) is that the ‘Rayleigh breakup’ mode of operation is used for generating much larger droplets. If that is the case, then the description for how droplets are generated is not accurate.

We operated in the “demand mode” and have edited the text accordingly.

Page 7388
“The transformation matrix for an individual BCP is generated by stepping through 85 diameters, in 1 um steps. . .” It is never explained how the droplet size is varied. If drop size is varied in the same manner as used by Lance et al (2010), i.e. changing the residence time of the droplets in an evaporation flow tube by moving an impinger

connected to the droplet generator device, then it is not clear how perfect 1 um increments in the droplet size could be achieved.

> *There is confusion here that is now clarified in the revision. The stepping through referred to here is not with the droplet generator but mathematically. We have changed "stepping" to "incrementing" and explain that this is not with the droplet generator.*

Page 7391
"Thus, droplets 22um and larger will have a sampling area of . . ." This does not follow. With a constant threshold voltage, droplets larger than 22um will have a greater effective sample area than for 22 um droplets. I think some of the confusion behind this statement lies in misunderstanding Fig 4. Figure 4 does not show the laser beam intensity, as stated throughout the text, but rather a combination of beam intensity, particle scattering phase function and efficiency of the collection optics (including the max aperture of the optical system and the sensitive photodetector area). If, for instance, a 50um droplet intercepts the 'edge' of the 22um sample area, the signal will register with amplitude larger than the amplitude of a 22um droplet moving through the same position. Moving just outside of this 'edge', although the 22um droplet will no longer be detected, the scattered light from a 50um droplet will still be sufficient to trigger a counting event. If the authors believe that I am incorrect about this, they should demonstrate that I am wrong by performing another sample area calibration with a much larger droplet (say 50 um). Smaller droplets will have a smaller sample area, as stated in the text. These are a several instances within the text where the laser intensity distribution was indicated as the only reason for the shape of the BCP response map (i.e. Figure 4), e.g.:Page 7388, ln 5 ". . . as a result of the Gaussian intensity distribution of the laser beam"

> *This section has been rewritten to clear up the confusion pointed out by the reviewer. The description of the sample area in the figure is rewritten to point out what the reviewer has correctly described,*

Page 7390 "The counting efficiency of the BCP is 100% as long as there are no coincident particles in the beam since these would be counted as a single particle. Given the very small sample area of the BCP this is a very low probability event unless concentrations exceed 500 cm-3. . . . with measured sample area of 0.18mmˆ2" First of all, I don't understand how the sample area can only be 0.18 mmˆ2. Looking at the map in Fig. 4 the sample area spans a longitudinal range > 2.5 mm (presumably constrained by the DOF of the collection optics) and the beam width is 0.2mm, which means the sample area must be at least 0.5 mmˆ2, unless most of that plot is below the counting threshold of the electronics. I would also like the authors to provide a calculation of the expected undercounting error due to coincidence at 500 cm-3 droplet concentrations, for whatever the sample area truly is. The beam width parallel to the droplet trajectory should also be stated, since the coincidence error depends on the volume of the sensitive region of the laser beam, not just on the sample area perpendicular to the airflow.

We have expanded on the current discussion of what the sample area actually is, i.e. that since it depends on the size of the particles it is variable. Figure 4b now shows the sample area as a function of droplet diemeter. Estimates are now provided for coincidence losses for the different drop diameters because they have different sample area.

Page 7391 “This accuracy estimate is a good approximation for the case of the 22um droplets that were used to map the area because, even near the edges of the beam where the intensity is only 15% of the maximum intensity, the scattered light will still exceed the minimum detection threshold.” I do not see how the 15% factors in to the question of sample area. For this particular case (22um droplets) the ‘minimum detection threshold’ is set such that it happens to be 15% of the maximum of scattered and collected light. However, the important constraint here is not the 15%, but rather the constant ‘minimum detection threshold’. Thus I do not follow this assertion: “Dividing 0.7x10-8 cmˆ2 by 0.15 results in a scattering cross section of 4.6x10-8 cmˆ2, the scattering cross section through which a particle would have to pass and still scatter sufficient light to be detected.” Line 25 “. . .the sample area for a 10um particles is 0.12mmˆ2 so the correction factor is 1.5” Is this sample area for 10um particles measured? Or is it calculated by “. . .multiplying by the intensity map of the laser beam” (as described on page 7388, Ln 22)?

We have removed this section since we have discussed size sensitive sample area in a previous section related to mapping the sample area.

Page 7392 “. . .the accuracy in the measurement of the number concentration is dominated by the uncertainty in airspeed” In the Error analysis section, there is no mention of the ‘shadow’ of the aircraft fuselage, which can lead to both depletion or concentration of cloud particles depending on the distance from the airframe, especially when the cloud particles are large or have significant aerodynamic drag (e.g. hexagonal plates) and are therefore not able to follow the streamlines of the airflow perfectly around the curvature of the fuselage. Since the BCP sample volume is only 4 cm away from the outer surface of the airframe, I expect this could have an important effect on the observations.

This is discussed in the discussion section.