Review of “Characterization of a self-sustained, water-based condensation particle counter for aircraft cruising pressure level operation” by Weber et al.

The paper details the performance of a COTS water CPC for use on the IAGOS aircraft. Instrument performance was compared to another butanol-based CPC and an electrometer throughout the pressure range of anticipated flight conditions for two different aerosol species.

The manuscript requires some clarification, added details, corrections, and further editing for grammar and punctuation. However, the discussion is suitable for the publication in AMT.

##########
##########

Remarks/Questions

Abstract:

You say "simulated aircraft operational environment", but no temperature characterization across ambient range. Is instrument sensitive to ambient temperature changes affecting sample temperature, and thus, supersaturation and cut size?

Saying "excellent agreement" between the instruments is misleading when you have performance differences in pressure for soot particles.

ANSWER:

Measurement data from a separate instrument running in an IAGOS package shows, that the temperature in the package is around room temperature (22-27 °C).

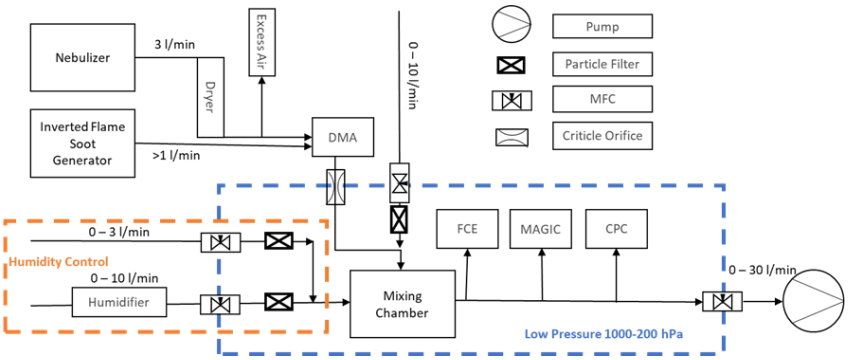
We will rephrase that statement.

Figure 1:

Poorly drawn diagram. Uneven spacing, crooked lines, random box sizes, critical orifice gap and protrusion.

ANSWER:

The Figure is updated



Low pressure section incorrectly defined at Flow Control filter. Flow control and "dry side" of the humidity section are redundant.

With 4 flow controllers, do you have any measure of stability of the system? How steady was the sample flow, pressure, and humidity control?

ANSWER:

The measured standard deviation for 600 s is 0.24 hPa (100s 0.07 hPa) at 200 hPa. The reported flow data shows a standard deviation of 0.0017 l/min for the "main" flow controller

92-95:

Why constant 30 second steps? What were your statistics? Your particle size distribution concentration is varying >3 orders of magnitude across the size range (fig 5), why hold constant DMA steps. Increase time at small sizes to reduce massive error bars in counting statistics.

ANSWER:

Earlier experiments have shown that this time is sufficient to flush the system. The "error" bars shown in the figures are the sig+ and sig- values. We will mention this in the manuscript and change it to the variance.

Why is no data shown above 60 nm if upper limit was 140 nm?

ANSWER:

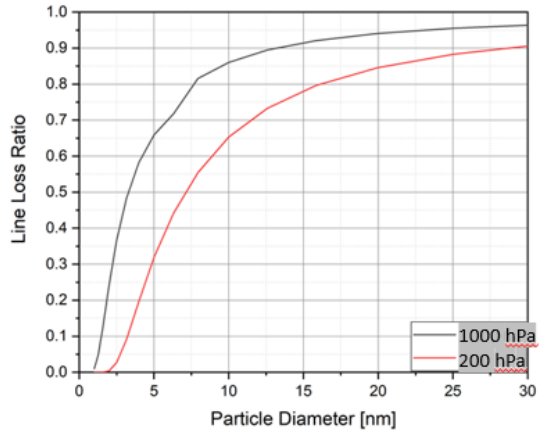
After 60 nm was no gain of knowledge. The Ratio reached its relatively stable plateau and we wanted to show a clear picture of the graphs at the D50 diameter.

Is 2.5 nm lower limit corrected for diffusion losses changing distribution shape asymmetrically, and shifting peak upwards? Any line loss analysis to approximate what the actual peak was when DMA is set to 2.5 nm?

ANSWER:

The FCE has the roughly same distance (instrument flow is accounted) from the DMA as the CPC. All measurement instruments got the same aerosol particles.

The line loss (DMA-> Line + Line -> Instrument) can be viewed here:



What is your mixing chamber volume and flowrate to show that 15-seconds between samples is enough flush time? Show flush time is at least 3-5*Tau.

ANSWER:

The Volume of the mixing chamber is approximately 550 ml. The mixing chamber is flushed with 10 l/min. Therefore, after 15sec, the chamber is flushed more than 4 times. We tested this by putting a filter in between the DMA and the Mixing Chamber and reached Zero particles within this time.

101-125:

Section labeling? Whole section needs to be explained more thoroughly and clearly.

How is ksi determined? Is it calculated, determined experimentally? Where is the equation for it? How can one reproduce your correction method with the information provided here?

ANSWER:

We moved this section to the supplementary and expanded it. The theory behind it with full explanation is written in Bundke et al. 2015. Using a diffusion charger, the particles may carry multiple charges passing the DMA and may then be counted multiple times by the FCE. To correct the FCE count, the number concentrations are multiplied by a size-dependent correction factor calculated by using the size distribution measurement.

Figure 2: What flowrate and offset corrections? Why and how are they performed? You have them listed in Figure 2 but never address. Figure 2 does not add value.

ANSWER:

An FCE measures a zero count. Those were subtracted from the reported particle counts. The Flowrate correction is necessary to address the changing mass flow rates at different pressures.

148-163:

CPC operating parameters should be mentioned earlier (first introduction of the instrument).

This is your first use of the term "offset" without defining what it is or how it differentiates from the detector threshold.

You stated only two parameters are adjusted, laser power and detector threshold. Now you're adjusting the offset too?

Move definition of offset at its first usage, and first introduce it when you're defining what parameters you adjust.

Move last sentence (162-163) to where you're talking about threshold set points. You jump from threshold set, to laser power adjust, back to threshold set.

ANSWER:

This section will be moved into the supplementary. The manufactures produces now an updated version (MAGIC- LP 250).

Figure 1 shows an idealized signal from the optics electronics. The analog signal is compared to the "detector threshold" (normally 250mV) which produces a digital pulse that increments a counter in the microcontroller.

The "baseline voltage", i.e. the signal with no particles present, could be above or below 0 volts due to imperfection in the optics and electronics, as shown in Figure 2. There is always some stray light that reaches the photo detector, and all operational amplifiers have some non-zero offset. To compensate, a "detector offset" is add to the analog signal to adjust the baseline voltage to zero.

Since the stray light reaching the photodetector is proportional to laser power, the firmware automatically adjusts both the laser power and detector offset with pressure. The specific relationship between laser power and detector offset are set at the factory and vary from instrument to instrument.

To operated the MAGIC 210-LP at pressures lower than then it was designed for, voltage offset and detector thresholds had to be determined experimentally below 300 hPa. At 250 hPa, we found that the required laser power was so high that the electronics was incapable of zeroing out the baseline voltage. To compensate the detector threshold was increased above the factory setting of 250mV (figure 3).

Note: due to specifics of the electronics a larger firmware setting for the detector lowers the baseline. Also the digital pulse are 0-5V; the height was reduced in the figures for clarity.

Based on this study, Aerosol Dynamics Inc. has updated their low pressure CPCs to operate down to 200 hPa.

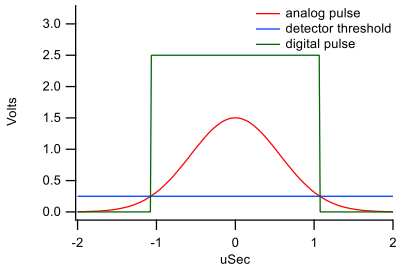


Figure 1: Ideal signal from one particle passing through the optics detector

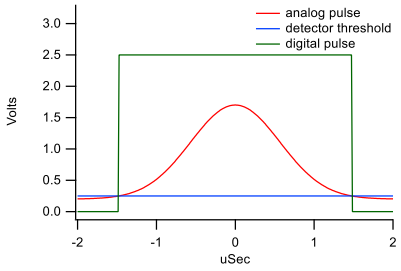


Figure 2: Effect of imperfections in optics and electronics on the baseline voltage.

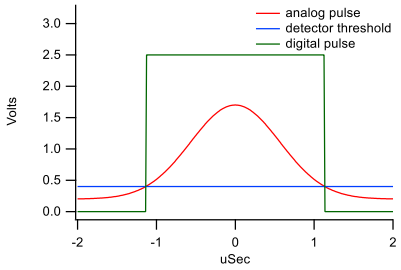


Figure 3: Detector threshold is increased to compensate for inability of the electronics to completely cancel out the baseline signal at lowest pressure.

165:

State the aerosol types in the text. Also why you used them as your reference aerosols.

ANSWER:

Ammonium sulphate is an omnipresent aerosol in the atmosphere. Fresh combustion soot is interesting, because the MAGIC should be able to measure non-volatile particle matter emissions from aircraft engines while operating on IAGOS.

Figure 5 and associated text should be in the Methods section.

ANSWER:

Acknowledged

Since your data is most significant in the 3-10 nm cut size range, use log y-scale so the concentrations used during the tests are more apparent.

ANSWER:

Great suggestion

Figure 6: No horizontal error bars accounting for DMA transfer function width. What were your DMA flows? Sizing accuracy analysis?

ANSWER:

The DMA sheath flow was set to 6 L/min , whereas the sample flow was 1 l/min. This narrows the horizontal error down to 1/6 of the mobility according to DMA theory.

222-225:

If log-normal fit is inappropriate, don't use a log-normal fit. Use the measured size distribution in your calculations.

Error between log-normal fit and measured size distribution affecting your multiple-charge correction can be calculated. If you're using this as your explanation, prove it.

ANSWER:

We used the measured size distribution for all calculations. We could not measure the complete combustion soot particles size distribution with without changing to the L-DMA; The approximation could be an issue; nevertheless, it gave consistent results when checked at the lower pressure ranges.

281-284: This is your first time discussing uncertainty. This should be discussed in detail in the results section, then summarized in conclusions.

ANSWER:

We tried to make a statement, that for the operation on IAGOS, the reported total number concentration might have a higher "dark number" therefore uncertainty compared to butanol CPC.

##
#################

Minor remarks/corrections

11: Remove "and more"

OK

26: Punctuation

Thanks

31-33: nm particles can be detected via charging and electrometer, as you've used. Suggest changing to "... growing them to optically-detectable droplets..."

Acknowledged

38: Replace "by" a photodiode with "with" or "using"

OK

51-53: Wordy. "However, butanol's flammability property strongly hinders..." Also, flammability does not hinder the operation, it hinders the desire to operate it.

We got no permission to operate butanol CPC on a passenger aircraft. The reason was: flammability. We add this phrase: "Because of it's flammability the use of butanol on passenger aircraft requires special permission which we were unable to attain."

54-59: Unbalanced parentheses and wordy.

We will rephrase it, by adding semicolons:

This study is part of the development of a new air quality package for IAGOS, in response to these flight safety aspects. The package consists of a modified Portable Optical Particle Spectrometer (POPS, (Gao et al., 2016) originally developed by NOAA which measures of the particle size distribution in the diameter range from 125 nm to 4µm; four Cavity Attenuated Phase Shift (CAPS, Aerodyne Research Inc., Billerica, MA, USA) to measure the particle extinction coefficients at different wavelengths as well as the NO_2 concentration; and the water-based MAGIC 210-LP CPC characterised in this work to measure the total particle number-concentration.

60: define "low-pressure" range. Can it be used in a balloon? High-altitude aircraft?

We tested it down to 200 hPa. I forgot that low-pressure could be relative.

63-64: Incomplete sentence by itself. No subject.

Acknowledged

64-65: define "broad pressure range" and define "aerosol types" and why.

Acknowledged

71-73: Avoid using "it". Define. Rework sentence.

OK

77: Why is RH controlled to 30%. Explain significance. State where RH and temperature are measured.

Acknowledged. We wanted to test, if "low" (up to 30%) humidity can have an impact on aerosol activation for particle counters. RH, T , P, are measured at the mixing chamber and in the instrument.

102: Change to "multiply-charged particles". What do you mean by measurement? DMAs do not measure particle size, they size-select based on particle mobility. The issue is using a mobility-based selector as an equivalent to a size-selector.

Thanks, I will use this wording

103: Replace "these" to avoid being ambiguous. Hyphen singly-charged.

Acknowledged

104: "this effect" is ambiguous.

Acknowledged

105-106: "this artifact" ambiguous. To address multiply-charged particles biasing the concentration discrepancy...

Acknowledged

111: Why is Multiple capitalized?

Because I made a mistake.

113: Why is Electrometer capitalized?

electrometer it is

119-125: Mixture of fonts, inconsistent throughout text. Assume document is printed B&W and can't refer to "red line". Describe what the first order approx. means.

OK

123: efficiency of what?

Counting rate efficiencies compared to electrometer

130-132: Confusing.

Will be rephrased, expanded and put into the supplementary

132-134: Merge sentences.

OK

134: Compared to what temperature values at normal operation?

We will add this information. During normal (ambient, 1000hPa) operation, the conditioner is maintained at 18 K below and the initiator at 17 above, the heat sink temperature, which is typically a few degrees above ambient. The moderator is temperature is normally set as a function of input dew point to minimize water used. Note: if the input and output dewpoint are equal, no water is used in the instrument. Water evaporated in the initiator is condensed in the moderator and flows through the wick back to the moderator. MAGIC is an acronym for Moderated Aerosol Growth with Internal water Cycling). The user has the option of changing these temperature or setting fixed temperatures

144-147: This section should be merged within the paragraph above

OK

149: Remove: initial. Replace "to" with "at".

OK

150: Missing comma, missing "is"

Acknowledged

151: insert "and is shown..."

Acknowledged

152: efficiently

Acknowledged

153: comma after pressure. "as a function"

Acknowledged

154: lowered

OK

157-158: merge sentences

OK

158-159: Be specific and mention for the 250 hPa case...

Acknowledged

159-160: redundant

OK

174: suggest replacing "concerning" to "with reference to"

OK

175: Comma after 7.

Acknowledged

183: Not necessary to have "as illustrated in Figure 7". You've already stated you're referring to Fig 7. Sentences seem redundant with message.

ok

194-195: This sentence seems out of place here... remove?

We will rephrase it

197: Explain why the second test aerosol case is necessary. What are you exploring with the second choice of aerosol?

We used the second type to show the behavior of an aerosol, that does not dissolve in a liquid.

214: State this earlier in motivating your methods on why you chose this second case.

OK

215: Source? There are many flights and missions targeting fresh combustion. On commercial flight, you're flying in a corridor route that follows other aircraft.

Good Point, I was speaking of the overall likelihood. We rephrase it

217: Refer back to Eqn 1 to remind the reader. What is derived vs Exp?

OK. Derived: With the EQ and EXP: read from the data

218: As can be seen where?

We rephrase that

220-221: Are you saying that your method is incorrect?

We rephrase it

222: remove "full-size"

OK

234: reference.

Table 1 & 2: Why is Table 2 Bb when Table 1 is B? Exp. stands for experimental or exponential? Unclear.

Acknowledged. It should be B as in the Equation. EXP for experimental. We rephrase it

243: Refer back to Eqn 1.

OK

249: "agreement... is high". Be quantitative. e.g. "agreement within 10% throughout the range..." "R^2 of ..."

OK

253: Formatting

OK

260: remove comma

OK

261: insert comma after hPa. Change ot "as necessary"

OK

262: "We were able to have a look at 5 units." Relevance?

This was not an artefact of one unit.

267: remove "well-engineered". You're not in marketing.

OK

270: change "was" to "were", since you're comparing 2 objects.

OK

272: "Approved" is a strange word choice. Revise?

Acknowledged Changed to "Verified"

277-278 Awkward. Change to ….for ambient pressure levels down to 250 hPa the linearity is within 95%

279: Should "below" be "above"? You didn't test below 200 hPa.

Acknowledged, Down to