**A reply to https://doi.org/10.5194/amt-2022-208-RC3**

**Original referee comments in blue, with author response in black.**

General comments:

I found this to be a clearly written paper, well-structured and systematic. It is a little long for the content so an attempt to shorten some sections would be welcome.

We will reduce the length of the manuscript, in particular in Section 4.1. Additionally, upon the recommendation of Referee #1, the manuscript focus will shift slightly to be a presentation of a "field **profiling** system" rather than as a "field **deployment** system". In this regard, we will also shift the focus of the discussion to the reliability of the profiles, from which the performance of the CRDS analyzer naturally follows. We will also now be including details on an alternative profiling frame that we used while at the Fjord measurement site.

It provides a detailed account of the design and testing of a well engineered set of enclosures for the isotope analyser and some peripheral equipment. It looks to be quite costly - please provide the cost of the parts to build this. Many users of these instruments would look for low-cost solutions to building enclosures and peripherals and in many cases sensible cost cutting can be made without substantially affecting performance.

Upon the recommendation of Referee #2, we will be providing a detailed purchase list of more components in the Supplemental "builder's guide", including the amount of each item for each module. We will also include the approximate cost of each item. We do already put forward some alternative connectors in the Supplemental.

The paper would benefit from a better justification of the need for this design, i.e the advantages of this design compared to other solutions to obtain such data. For example, given that a power source must be nearby (presumably within a few 10's of meters) why couldn't instruments be installed indoors with inlet tubing to the outdoors? Long inlet tubings are routinely used on tall masts with an appropriate pump rate? Are there particular problems regarding lag time? Or memory effects? Or disturbance of the air stratification? Why couldn't an existing mast be used with multiple inlet heights and the use of a manifold? A nearby EC tower is mentioned in the paper.

We see these questions underline the value of shifting focus in the revised manuscript, as recommended by Reviewer #1. Thereby, we will specifically highlight our aim of making in-situ profiles of the near-surface exchange between the surface and overlying air. Therefore, we required response time faster than provided by long inlet lines. At the Snow site, we tied into the power supply of the nearby EC site, but the nearest building that could adequately house the Picarro was on the order of 300 m away, which we deemed to not be a viable option. As a result, it follows that we needed a Picarro housing that would minimize disturbance to the measurement site (albeit not eliminate as mentioned in a comment below), while being as close as possible. In regards to the advantages that the arm provided us over a manifold setup, we briefly touch upon these on L.464 & 483, but we will expand upon both points earlier in the revised manuscript.

The publication could be seen as premature given the preliminary and incomplete parts (cold trap, pivot arm and standard gas supply module). However, it may be that the authors had limited opportunities to test the device in this remote location.

While we don't agree that the manuscript is premature, we do recognize that our initial scope as an all-around Picarro deployment platform might be seen as overreaching. However, we do assert that the capability that the system provides for making near-surface profiles in polar environments is novel and worthy of a publication.

The paper is mainly an account of environmental measurements (T and P, spectral characteristics etc) of the analytical instrument when placed inside the housing under cold and windy conditions, rather than a more complete account of a test of actual isotopic measurements. Ultimately the most critical isotope test, i.e. a comparison of one or more constant gas supplies both in the field and the laboratory, could not be carried out due to the lack of a working standards gas supply module. Also, there seems to have been a missed opportunity to compare the real time isotope data with isotope data obtained from the cold trap sampling, why wasn't this done (or presented) here?

Yes, we do agree that exposing the instrument to standard gas while deployed would provide for a definitive proofing of the system. However, no such standard gas supply module was available for field deployment under such extreme ambient conditions. Therefore, we instead focus on the analyzer metrics related to spectroscopy, the most critical being the cavity temperature and pressure, which we do readily have. Then, by comparing these metrics to analogous operation inside a controlled laboratory environment, we can discuss the impact the deployment made on the isotopic measurements.

We don't believe that the cold trap can currently provide fair insight into the accuracy of the CRDS. The design is proven in Peters and Yakir (2010), but we are deploying it under very different conditions as a test. In that sense, we will revise our statement on P.5 L.105 to put forward that discrete sample analysis gives the option for calibration, rather than with the intention of using our particular samples for that purpose. We will edit this section to better reflect this intention. In the revised manuscript, we will be including analysis of select cold trap samples for a first comparison. Thereby, we will maintain the cold trapping module as an "expansion" to the overall profiling system.

Given the anticipated degradation of isotope ratio precision at low $H_2O$ mixing ratios (typical of polar regions), and the possible instrument drift due to the changing environmental conditions, it would be important to check standard gasses a regular interval (likely several times daily) in an actual measuring campaign, hence the need for a standard gas supply device. As mentioned, this has not been demonstrated in the current manuscript.

While the low concentration does negatively impact the measurement precision of the instrument, we anticipate minimal drift in the instrument over our deployment timespan. Older models of Picarro instruments (L1102i) have shown a much stronger tendency to drift during previous studies (Steen-Larsen et al., 2013). Leroy-Dos Santos (2021) has shown no measurable drift in an L2130i over a 3-week period at quite low humidities. However, longer (profiling) deployments with our system that would start to approach this timescale would require an in-field calibration system, which we mention in Section 5. We will further expand on this discussion in the revised manuscript.

A more thorough explanation of the stratified air column data obtained would benefit the paper as it would demonstrate the useful application of the enclosure and pivot arm. The need for an operator to use the pivot arm seems to risk disturbing the stratified air column, depending on wind direction (creating turbulence)

Yes, we agree, which is why the manuscript will now shift focus. For this reason, Figure 12 will change to show a profiling period from 9 March.

Yes, the potential for site disturbance is an argument for the remote/automated operation of the arm, which would be great to develop further. However our deployment orientation at the Snow site ensured that we were downwind of the arm for the vast majority of the deployment period.

Specific comments:

P1 L12: I don't think you can claim it would be satisfactory in all environments, e.g. in the tropics, overheating, condensation of humidity may be a different challenge, in environments with high day – night temperature contrast drift may be problematic

We did not intend for this sentence to make such a claim. We will rephrase it to more accurately describe the potential we see in the system.

P2 L41: What are the conventional approaches?

Conventional deployments inside tents or person-sized enclosures, which are on the order of 5 cubic m or larger. We will make this comparison clear in the text.

P2 L49: But you have a nearby power source so why not house the instrument there?

The nearby power source is the EC mast, which does not have any adequate housing for the Picarro.

P2 L52: But long inlet lines (fluorinated plastics) are routinely used in tall towers

As mentioned in a comment above, our aim was to minimize instrument response time, which involved shorter lines.

P3 L64: Is it pneumatic? Maybe just gas or airtight connectors?

Yes, pneumatic isn't quite the right word. We will find a different term.

P4 L85: Isn't a lower flow rate preferable to increase precision in dry air? Especially since there's a separate high-flow pump to deliver the air sample close to the inlet?

This is a very interesting point, and one that we did not consider in our planning. Our aim was to minimize response time, which meant increasing flow. We will be mentioning this potential setup in our the newly added Discussion section.

P5 L106: So why wasn't this done when there was no available standard gas module available?

As we mention above, we will rephrase this paragraph to better communicate our expectations from the cold trapping module.

P6 L144: Does the presence of an operator disturb the stratification?

There was no discernable disruption of the stratification at the sampling site. Additionally, we positioned the operator to be downstream of the sampling inlet.

P7 L161: This would have been the most complete test of the system

As in a comment above, yes, it would have been the most complete test. However, in its absence, we maintain that the analyser diagnostics provide adequate proof of operation.

P10 L211: Please state if these are liquid or vapour values

These are values of the liquid standards used in the Picarro SDM.

P10 L220: This sentence is unclear – does it mean that measurements were within +/- 1 sigma?

The total calculated measurement drift during the campaign was smaller than the standard deviation of the 17 calibrations. This standard deviation across the 17 calibrations was also similar in size to the standard deviation of any individual calibration.

P10 L229: Not sure this is correct, there are numerous field applications documented on the Picarro web site.

Very much agreed, however the form of the CRDS analyser is *designed* for use on a laboratory bench, which is where it should be operating at its best. We certainly did not mean to imply that no one else had used Picarro's in the field. This possible misunderstanding is why we have decided to switch focus to emphasize the system's holistic profiling capacity.

P11 L247: Don't think 'minutely' is a word (?)

Quite correct; we will fix this phrasing at this and all other points in the manuscript

P11 L259: Please specify where DAS is measured

The DAS temperature is measured inside the exterior housing of the analyzer, on an internal circuit board. It is taken to represent the overall temperature of the analyser circuitry (not including components in controlled casings).

P16 L355: As mentioned above, wouldn't the normal low flow setup have been preferable?

As mentioned above, we will be discussing this possible setup in the newly added Discussion section.

P22 L454: add 'for d18) and dD, respectively

Yes, we will change this accordingly.

References


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