Interactive comment on “Comprehensive laboratory and field testing of cavity ring-down spectroscopy analyzers measuring H2O, CO2, CH4 and CO” by C. Yver Kwok et al.

Anonymous Referee #2

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Yver Kwok et al. 2015 present the testing results of a large number of CRDS instruments (47 in the laboratory and 15 in the field) in terms of short-term and long-term repeatability, temperature and pressure dependence, linearity, and instrument longterm stability, which is very useful for deploying the CRDS instruments in the field. It is particularly useful that the paper has discussed the potential source of the long-term stability, suggesting that the stability of the cavity pressure may be the cause. Furthermore, the authors formulated recommendations for use of the CRDS instruments in the field. The test results are comprehensive, and the paper is well organized. I recommend publication after addressing the comments below.

We would like to thank the reviewer for having reviewed the paper and formulated helpful comments.
We answer each of them hereafter and add when needed what will be the modifications in the text.

General
The testing results are no doubt comprehensive, however, a rigorous discussion on the conclusions and recommendations is missing, which makes the recommendations difficult to follow, and/or not justifiable in the paper.

For example For recommendation #1 “Instruments should be tested in the laboratory before being on site”. Why should the instruments be tested, and in what particular sense? The paper shows the testing results from the factory, from the MLab, and from the filed agree well with each other. Why not taking the testing results from the factory and from the field, instead of testing the instruments in the laboratory? What additional information shall we get by testing the instrument in the laboratory?
We have formulated recommendations that can apply to other brands of instruments or other measured species. In these two cases, we do not have a comparison showing an agreement between factory, laboratory and field tests. Moreover, some important tests such as the temperature, pressure and water vapor dependence tests (another paper is in preparation that will describe the water vapor test and emphasize its importance) are only done at the laboratory. Doing the tests at the laboratory also ensure that they are done the same way. As seen, the factory tests have evolved over time and could still change and on the field it is usually not possible to test the instruments with exactly the same settings. It is also convenient to be able to verify with an standardized and recognized protocol that the performances of an instrument are indeed compliant to the specifications of the purchased instrument.
p4244 l6 Indeed, some important tests such as the temperature, pressure and water vapor dependence tests are only done at the laboratory. It is also convenient to be able to verify the performances of an instrument with an standardized and recognized protocol.

For recommendation #2 what is the target precision/accuracy to have the measurement duration of 10 minutes?
The target precision depends of the WMO goals and the expected performances of the instrument. To be able to reach the WMO comparison goals, we need to have biases as small as

possible for every source of biases. Here, we aim for a difference less than 0.05 ppm for CO_2, 0.2 ppb for CH_4 and 1 ppb for CO.
p4244 l9 ***Indeed, to be able to reach the WMO comparison goals, we need biases as small as possible for every source of bias. Here, we aim for a difference less than 0.05 ppm for CO2, 0.2 ppb for CH4 and 1 ppb for CO.***

For recommendation #3 what is the consequence of having the pressure difference between the different samples/standards higher than 0.4 bar? A spike would occur during the switch of course, but does it matter? I would think not.
Experiments showed not only a spike during the switch but a systematic bias when the pressure of the standards was different from the sample pressure with a difference higher than 0.4 bar.
P4244 l11 ***which leads to systematic biases.***

For recommendation #4&#5, I expect to read the recommended frequency of the calibrations, instead of obvious
It is difficult to give a recommended frequency as each setup in a station will be different. We will reformulate to take this into account and recommend higher frequency at the beginning, then decreased frequency if experience shows that it is possible without loss of quality.
P4244 l14 Each station setup being different, we cannot recommend a specific frequency for calibration but we recommend that during the first six months, these calibrations are run at least every two weeks then after analysis of the data, the frequency should be optimized.

Details
All corrections of spelling will be done.
P4226, L17-19: what is the significant inlet pressure influence?
The inlet pressure impacts mainly the CO_2 measurement. We have observed that an increase of 1 bar at the instrument inlet pressure can induce up to 0.03 ppm decrease of CO_2. We did not find any convincing explanation (wall effect, leakage, material degassing upstream the Picarro proportional valve?). However, by working around the atmospheric pressure at the inlet, within the range from -0.2 bar to +0.2 bar (0.4 bar pressure difference as specified in the paper), the CO_2 measurement does not show significant bias. This inlet pressure range corresponds to a typical atmospheric station setup using pressurized tanks with pressure regulator adjusted to a pressure slightly above atmospheric pressure (1.2 atm) and a basic system (without pressurization pump) to sample ambient air through a flushed sampling line which results in an instrument inlet pressure slightly below the atmospheric pressure (0.8 atm).

P4228, L4: it is needed to clarify which temperature and pressure values are being discussed, i.e. ambient vs. cavity.
This will be clarified.
P4228 l4 ***Ambient temperature and pressure dependence***
P4232, L19: CO2frac is defined as a function of the slope and intercept, how is CO2frac defined?
CO_{2frac} and CH_{4frac} are defined as the fractional change of CO_2 and CH_4 concentrations compared to the reference mixing ratios.
P4233, L1: replace “intersects” with “intercepts”
P4235, L26: replace “in term of” with “in terms of”
P4236, L7: has the change of the room temperature affected the cavity temperature? What would be the reason of the temperature dependence?
Indeed when there is a dependence, we see that the cavity temperature is affected as well. It is caused by the fact that the cavity cannot regulate its temperature as fast as the outside changes.

As the mixing ratios are calculated assuming a fixed temperature, small changes in this temperature lead to biases.
P4236 l13 ***It is caused by the fact that the cavity cannot regulate its temperature as fast as the outside changes. As the mixing ratios are calculated assuming a fixed temperature, small changes in this temperature lead to biases.***

P4237, L3: Which part has been changed during the upgrade to reduce the temperature dependence?
The upgrade procedure to reduce pressure dependence involved modifications to the optical train that were designed to reduce the effect of stray reflections external to the cavity on the measurement of the ring down time.
We will add this sentence in the text.

P4240, L14: How does the drift rate compare with other available data? e.g. Karion et al., 2013 and Richardson et al. 2012. Is a linear drift correction needed? Noting that in Richardson et al. 2012 "Although it is likely that the slope and zero of the linear calibration drifted over the deployment period, the error associated with correcting with an offset rather than a slope and offset is small (e.g., 0.03 ppm at Kewanee and 0.02 at Mead over a 370–400 ppm range) ".
Richardson et al. found a drift before calibration of 0.38ppm over 30 months, so about 0.15 ppm/yr which compares well with our upper limit for CO_2.
The drifts found in Karion are higher for CO_2 and CH_4 (0.25ppm/yr and 3.4ppb/yr respectively).
P4241 l1 ***These rates are comparable but lower than rates from other studies such as Richardson et al or Karion et al. which found drift rates of 0.15 ppm/yr for CO_2 in the first case and 0.25ppm/yr for CO_2 and 3.4ppb/yr for CH_4 in the second study.***

P4241, L11-12: I see the trend toward both increase and decrease of the concentrations of CH4. Did you mean both?
As said, there is a general trend toward increasing. A few instruments during some period of time show a decrease of the concentrations over time (like OPE91 in 2013) but the majority show an increase.
P4259, Figure 7&8. I suggest adding the number of instruments showing this temperature dependence in the caption, although it has been mentioned in the main text.
This will be added.
P4264, Figure 12, How is exactly the virtual tank with a fixed value after calibration defined? Is the initial laboratory calibration equation used in the calculation?
For each calibration, we use the calibration equation and assume that after applying the equation to the raw data, the reached concentration would be the one of the virtual tank. This allow us to go back to raw values. The first used calibration is the one from the station and not from the laboratory.