

Overview:

Conil, et al., have submitted a manuscript for publication detailing continuous greenhouse gas (CO₂, CH₄, CO) observations at the Observatoire Pérenne de l'Environnement (OPE) station, France. The focus of the manuscript is on multi-analyser (and multi-height sampling system) performance over a 7-year period and subsequent analysis of the resultant quality controlled timeseries. Diurnal cycles, seasonal cycles and inter annual trends are calculated and commented upon in context of air mass back trajectory analysis. The OPE station is an important component of the ICOS network providing high quality data. Such data uses will include national and pan-national 'top down' GHG inventory emission monitoring.

The novelty of this manuscript is that this is the first time that the OPE station instrument performance has been explicitly evaluated along with a preliminary analysis of data. The OPE continuous greenhouse gas observations are conducted under the auspices of the ICOS in situ measurement framework, hence all measurements, performance metrics, auditing techniques and data selection/filtering at OPE must meet ICOS standards. OPE data is centrally processed at the ICOS-ATC. As such, the authors defer to published work by Hazan et al., AMT, 2016 to define OPE station data calibration and quality assurance procedures, thus the manuscript is the standard combination of site and meteorological descriptions, instrument performance and time series evaluation, but with a very minimal section on measurement calibration and data selection filtering.

The manuscript content is in the scope of the AMT journal. This research will be a welcome addition to already published ICOS network literature and long term in situ analyser performance. Unfortunately, the manuscript is let down in multiple critical areas and I do not recommend publication until the issues listed below are addressed; either fixed or with a sufficient logical rebuttal. The language and structure of the manuscript can be improved. Scientific methods and assumptions need to be clarified. I have concerns (or maybe just a lack of detail) about the methodology of combining multiple instrument data into a single timeseries. There is incomplete analysis of datasets (lack of uncertainty estimates). There needs to be more collaborative evidence from peer reviewed literature to support conclusions deduced from analysis.

Specific comments:

S1/ AMT English guidelines and house standards: A major draw-back of the submitted manuscript is that I do not believe the grammar meets the standard required for publication in AMT. The authors are referred to AMT guidelines: https://www.atmospheric-measurement-techniques.net/for_authors/manuscript_preparation.html. There are many instances of incorrect grammar use, such as non-defined subjects (nouns), use of colloquialisms, non-defined acronyms along with simple grammatical errors. All such instances need to be corrected. This is no reflection on the quality of the science presented and doesn't detract (only distracts and introduces ambiguity) from the novelty and importance of the presented subject matter along with the effort the authors have already put into the manuscript. As an example, the majority of the first 18 technical comments (see below) are related to grammatical errors in the abstract and first section of the manuscript. For the remainder of the manuscript review correction of such grammatical errors will be left out (to speed up the review), and only commented upon if scientific clarity is required.

S2/ The term "Afternoon mean residuals" is introduced in the abstract and section 2.2, but the term is not defined until section 4.5. A more detailed description is required early in the manuscript, or a reference to later sections (i.e. see section XX for the definition of 'Afternoon mean residuals').

S3/ Page 4, Line9 (pg4, L9). The criteria used to define the six clusters needs to be included.

S4/ The section detailing the calibration strategy: pg 7, L5 to pg 8, L2 needs to be reorganised. The section starts by explaining the cylinder measurements, then details the reference scale then back to the routine operating sequence (including flushing). I suggest the routine operating sequence (sample measurements, flushing, injections etc) be moved to the start, followed by the calibration (this will logically allow how the calibration cycles fit into the overall measurement scheme) then describe the reference scale. Maybe include a table like Table 3 from Hazan, et al., AMT 2016 (H16) but specifically for the OPE station operation.

S5/ Concerning the performance and standard cylinders (pg 7 L10 to L15). As the manuscript reads, the measurements made pre and post March 2016 are on difference scales for some species. Are measurements all recalibrated onto the same scale (per species) later? The details are not clear if this is done or not.

S6/ The paragraph starting pg 8 L3 concerning the $^{14}\text{CO}_2$ measurements seems outside the scope of this manuscript. Should it be removed along with the non-continuous GHG measurements listed in Table 1? It seems the manuscript content is solely concerned with the description and data interpretation of the continuous GHG analysers. The scope of the manuscript is stated on pg 2, L26: "Describe the OPE station and measurement system. Present its performance..." I think the scope needs to change to only include the continuous GHG systems, or the manuscript expanded to include performance of all instruments...which could be a lot of work.

S7/ Table 1 has columns of identical naming, i.e. period 1. I assume these are the start and stop dates for each period? Column naming needs to be tidied up. Even if this was done, it is hard to understand. Would the authors consider replacing the period columns with a time line graph, with each instrument a separate bar? This way it would be easy to see dates and overlapping periods.

S8/ Section 2.4 should be renamed 'data processing', (currently section 2.5). The first paragraph in Section 2.5 needs to be put in this, along with the current section 2.4 as data processing should be explained before combining any datasets. The second and third paragraphs in the current section 2.5 need to be moved to section 4.2 as it deals with analysis of a subsection of data. Current section 2.5 is now not needed.

S9/ For section 2.4, there is lot of broad qualitative reasoning for instrument issues. I recommend the authors make more extensive use of H16 by referencing the types of QA/QC practise used and provide a quantitative statistical summary of the OPE site, like that for OPE in table 6 of H16. On pg 10, L18 it states, "Raw data is flagged using a set of parameters defined for the station and instrument". This is where a quantitative statistical summary for OPE specifically would be useful.

S10/ Table 2 is very complicated and hard to understand. The caption is not helpful. Possibly make a bar plot, as in comment S7, or a table per species.

S11/ Combination of instrument time series. Please detail how priority is set, the instrument with the best precision or 'best' QC/QA? Is there an ICOS procedure to follow for the combination of different instrument timeseries at one location? I find figure 4 a very important piece of information in this manuscript. The current figure does not relay much information. It effectively is central to the OPE total timeseries, as such it would be very helpful to either change figure 4 to display statistics, such as box whisker plots or include another table with the bias and spread of instrument overlap differences. Something akin table 4 in Schibig, et al. (2015). In the final instrument combined time series are the time periods of instrument overlap where there are large differences which instrument measurement is kept? Or should such a disagreement exclude both measurements?

S12/ There is no mention of the GAW-recommended compatibility limits (GAW, 2011) in section 3 (it is mentioned in the travelling audit section, pg 16, L30). The authors may want to state the GAW compatibility limits and how OPE CMR and LTR compare to these (such in the paragraph starting at pg 12, L15). Does ICOS have a precision and reproducibility limits that needs to be reached? If so this could also be stated and OPE CMR and LTR statistics compare to this guideline instead of the GAW limits.

GAW: Report no. 194, 15th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques, Geneva, WMO/TD-No. 1553, 2011.

S13/ CMR monthly means of the time series. Again, a very important part of the manuscript. CMR is related to single instrument performance. Calculating and displaying the CMR of combined instruments does not make sense and contradicts the definition of how the time series is constructed, in the sense that data selection is based upon instrument priority, and exclusion of the lower priority instrument data (pg 9, L2)? A combined CMR in Figure 5 (example 379:187) implies that the timeseries includes all overlapping measurement data. Is this correct? Does ICOS allow this practise? If so, then CMR calculation of a combined dataset should not be performed. I suggest that CMR should be calculated for each individual instrument to be displayed in figure 5. This also applies to LTR statistics in figure 6.

S14/ Pg 12, L3, "The time series of CO's CMR o are not shown as the intrinsic properties of the Picarro and Los Gatos Research analysers are very different making it difficult to compare on a same plot.". The performance of the instruments is central to this manuscript; thus, I think it is very important to also present the CO CMRs. CO LTRs are displayed in figure 6. The CO CMRs for the Picarro and Los Gatos can be displayed on separate plots.

S15/ Table 4. In both Picarro's (187 and 728), LTR is significantly less than CMR. There is no mention of this, or interpretation, as in principle LTR (reproducibility) should be greater than CMR (repeatability). Could the author please comment on this. Pg 15, L11 discusses the Los Gatos instruments but neglects to mention which species they are talking about.

S16/ Pg 13, L14: "These two types of analysers have very different internal properties making it difficult to show direct comparison.". I disagree with this comment. CMR and LTR can be directly compared and are defined to be independent of instrument internal properties. This is the idea behind using such statistics. Table 4 indicates that instruments 80 and 478 have better CMR and LTR than instruments 187 and 728.

S17/ Table 2 shows that the combined times series of CO includes measurements from all four instrument timeseries. This means that the CMR and LTR of the timeseries will have step functions. This should be mentioned in the manuscript (indirectly alluded to at pg 15, L8), preferably referencing H16 (as to how uncertainty estimates are delivered in the end user database).

S18/ Pg 15, L25 to pg 16, L11. Just a comment: The audit shows differences. Was there a change in OPE operation due to the audit results?

S19/ Figure 7, A box whisker plot would convey the target tank statistics a lot clearer with a box whisker plot per tank, per instrument. The cucumber tanks can be left as individual points.

S20/ Pg 18, L7. "A trend may be present". Yes, this is interesting, firstly I thought there was a clear trend, but on reflection there could be a step change at each tank. If the time series is a combination of multiple instrument datasets, then could this be the cause of a possible step change? Would the authors like to comment on possibilities of a continual trend or a series of step changes?

S21/ Section 4: Results. The first paragraph in this section mentions that general characteristics will be investigated, then diurnal cycles. There also is a need to state that seasonal cycles and long-term trend analysis will also be analysed and commented upon.

S22/ Section 4.1: General characteristics. Most of this section is about vertical concentration gradients thus should this section be called vertical concentration gradients (or something similar). If this title change is made then 'general characteristics' details can be moved to the appropriate section: diurnal, seasonal or long-term trend. There is also no commentary of the OPE vertical gradients in relation to other tall tower measurements in the same region (or Europe as a whole). Is the drawdown seen at OPE like other measurements? Is it anomalous? This section could use a few more references to contemporary literature to put OPE measurements in context.

S23/ Figure 9: there are no uncertainty, or spread, bars on these plots. Such uncertainty or spread is critical in such plots and must be displayed.

S24/ Figure 9: The caption states that the data is normalised to the 120 metre inlet height measurements. Why is this done? I cannot see the reason why. Wouldn't it be better to display the actual non-normalised data? Maybe I am misinterpreting.

S25/ Figure 9. Are the mean diurnal cycles deseasonalised and detrended? If so (or not) then it should be stated.

S26/ Section 4.1. There is no mention of any diurnal cycle in wind direction or speed. Are night time inversions seen? Is the diurnal cycle in CO₂, CH₄ and CO affected by such inversions or windy nights?

S27/ Section 4.2 As stated in prior comments (S8), pg 11 L3 to L12 should be moved to section 4.2.

S28/ Section 4.2 should be renamed to something other than the generic title of "data selection and time series analysis", as the section is predominantly concerned with well mixed boundary layer conditions. Data selection is a too generic term. The section should state that data is filtered to represent a well-mixed boundary layer, also state that this filtered data is to be used in seasonal and trend analysis.

S29/ The 'openair package' and the 'theilsen method' need referencing.

S30/ In the CCGCRV algorithm please specify how was the npoly and nharm variables are set, i.e. using a geophysical basis or iterative attempts to get the best fit?

S31/ Pg 21, L22. Comparison of CCGCRV residuals with REBS. The sentence on this line states a comparison was made, but no mention of any results of this 'qualitative' comparison. If the comparison was important then results should be mentioned, else maybe leave out the REBS comparison.

S32/ Figure 10. Like Fig 9 comments, no 'spread' (1-sigma?) bars for each month. These need to be included. The caption should also state if the seasonal cycles are detrended or not.

S33/ As in section 4.1, section 4.3 does not mention the seasonal cycle in context of any prior studies. Is the OPE station seasonal cycles anomalous or what is expected. The authors need to put their results into such context.

S34/ Pg 23, L18: "We analysed the residuals from the trend...". Residuals from which measurement height? Could the specific height be stated, or all three? (I'm sure it's 120m but should be explicitly stated).

S35/ Table 6. Uncertainty estimates are needed for all calculated trends parameters. Unlike previous sections, the OPE trends are compared to other sites. W. But no mention of the comparisons in respect to OPE or other station trend uncertainties. Please rectify.

S36/ Figure 11. What is OPE level 3? I gather the 120m height? Maybe remove references to level 3?

S37/ Pg 25, L23. "We presented the GHG measurement system as well as the quality control performed". Quality control (QC) for OPE was not presented. The QC method used was referenced to H16 and a qualitative description of filtering parameters and issues were given. Explicit OPE filtering diagnostics were not displayed. As stated in S9, the authors already have such statistics available through the ATC processing and should be easily incorporated into the paper.

S38/ Section 5 Conclusion: GAW and/or ICOS compatibility limits should be mentioned and referenced when discussing OPE CMR and LTR, travelling standard and target tank results.

Technical comments (no particular order):

T1/ Title: OPE full name should be used.

T2/ In the abstract provide the station coordinates as at pg 2, L30.

T3/ Pg 1, L10, 'several' should be replaced with the exact number.

T4/ Pg 1, L13: 'Thanks' replaced with 'Using the'

T5/ Pg 1, L16, Growth rates need uncertainty estimates.

T6/ Pg 1, L18: 'Afternoon mean residuals', residuals of what?

T7/ Pg 1, L19, what are warm and cold periods? Not defined yet.

T8/ Pg 1 L24, 'largest climate change contributor' can be taken out.

T9 / Pg 1, L26, 'High' placed with 'increased'.

T10/ Pg 1, L27, 'Those' what is this referring too?

T11/ Pg 2, L1, throughout the manuscript are the characters: '<<' and '>>'. These need to be removed.

T12/ Pg 2, L18, 'responsible of the' should be 'responsible for the'

T13/ Pg 2, L19, 'Andra' and 'LSCE' have not been defined. First time these are mentioned, so should be the full title.

T14/ Pg 2, L19. 'OPE' needs to be defined. The full name is only found in the abstract.

T15/ Pg 2, L20. 'It is a....', there is no subject. This should be replaced with 'OPE'

T16 Pg 2, L21, 'actual' not needed.

T17/ Pg 2, L27, 'draw' is a colloquialism and should be avoided.

T18/ Pg 3, L10. What is a "complete set"? A reference to a definition of "complete set" is required. I assume its defined by ICOS.

T19/ Pg 3, L12, ACTRIS and AERONET acronyms need full names.

T20/ Figure 1. Symbol (green house) for OPE station in panel 1 needs to be stated in the legend.

T21/ Pg 3, L23, A reference for 'ICOS AS specifications' is required. Should 'AS' be replaced with 'Atmospheric stations'?

T22/ Pg 4, L6, "96h back trajectories were computed for the OPE station top level (120m) using the NCEP reanalysis fields and HYSPLIT model every 6 hours". I think what the authors mean is "96h back trajectories were computed for the OPE station top level (120m) using the NCEP 6-hourly reanalysis fields and the HYSPLIT model" ...not reanalysis every 6 hours...

T23/ Pg 5, L3: "It was built in order to comply with the Atmospheric Station class 1 stations specifications from ICOS". This needs a reference, or is the reference to T21 sufficient?

T24/ Pg 5, L4: "It includes several continuous analysers for the main GHG CO₂, CH₄ and N₂O, a manual flask sampler as well as specific analysers or samplers for tracers such as radon, CO and 14CO₂". I find it unclear if this refers to the OPE station specifically, or ICOS AS stations in general. Do all ICOS AS stations need several analysers or just the OPE site? For completeness: 14CO₂ should be ¹⁴CO₂.

T25/ Figure 3. This is a detailed schematic. A legend with symbol definitions is required, or components labelled. The figure caption should state this is only for the continuous GHG analysers (it does not include flask sampling details).

T26/ Pg 5, L11: "using 0.5 inches outer diameter Dekabon tubings". The inner diameter is the important specification. Could the inner diameter please be stated?

T27/ Pg 5, L13: A reference for the ¹⁴CO₂ system should be included (if this section kept)

T28/ Pg 5, L18: "At each level, the continuous GHG monitoring system air is flushed from the tower using three flushing pumps". This is unclear. Is it that each line at each level is permanently attached to an independent flushing pump? Could this please be made clearer in the manuscript.

T29/ Pg 5, L23: Could the 'pre-drying' fridge temperature be stated.

T30/ Pg 5, L24: Are the cryo-traps and ethanol bath the same thing? Reading the manuscript, it portrays a cryotrap is in series after the ethanol bath.

T31/ Pg 5, L25 and Figure 3. The Picarro G2301 is given in figure 3, but not mentioned in section 2.3. Please add a sentence or paragraph explaining the G2301 and operation of it.

T32/ Pg 5, L27. PLC: could the make and model be listed.

T33/ Pg 6, L1. Could the model of the Vici Valco be given for completeness?

T34/ Pg 6, L3. 'Avoid' should be replaced with 'reduced', or 'significantly reduced'

T35/ Pg 6, L3. The statement 'According to ICOS rules' needs to be referenced.

T36/ Pg 6, L4. 'global' should be replaced with 'total system'.

T37/ Pg 7, L13, What is 'CAL'? The full title should be given in first instance.

T38/ Pg 11, L18. "Up to now". 'Now' is subjective, please use dates.

T39/ Pg 12, L19. STR is not defined, please define.

T40/ Pg 13, line 4. "MLab" is not defined prior to use, please define.

T41/ Table 3. The authors may want to combine tables 3 and 5, like in table 4.

T42/ Pg 14, L7. "The Figure 6 shows the monthly mean field LTR of the merged time series using the different instruments and sampling systems. This figure shows the uncertainties of the data related to the analysers (not the sampling systems)". The second sentence contradicts the first sentence. Since the tank gas is injected into the analysers downward of the atmospheric sampling system then I suspect the second sentence is more correct. Please correct the statement above.

T43/ Pg 15, L13: "Corrections for these temperature induced biases implied the use of a working standard quite frequently". Please define 'quite frequently'.

T44/ Pg 16, L6: Define "poor performances". A list of "specific hardware problems" would be help help i.e. "specific hardware problems (e.g., XXX, XXXX)"

T45/ Pg 16, L12. "Piccaro G2401 travelling instrument". Please state who owns this instrument. I assume the Finnish Met ICOS mobile lab?

T46/ Pg 16, L13. "FTIR performance was not yet optimised". Remove 'yet'. What is meant by 'not yet optimised'.

T47/ Pg 16, L19: "lightning" to "lightning strikes"

T48/ Pg 16, L21: "Degrading instrument performance", do you mean a decrease in precision or accuracy, or both?

T49/ Pg 16, L21: "The ambient air comparison", of what gases. I presume all (CO₂, CH₄, CO)? if so, it should be stated.

T50/ Pg 18, L12. "over mid latitudes", just mid latitudes?

T51/ Pg 20, L3. "vertical gradients of CO are much stronger in winter and weaker in summer", can this please be quantified.

T52/ Pg 20, L4. "The CO lifetime...". This sentence needs a reference.

T53/ Pg 21, L23, what are REBs? The acronym should be defined before use.

T54/ Pg 23, L12. The sentence "This finding is consistent with recent observations in Europe and in the US" needs to be referenced.

T55/ Figure 11 caption needs to state the box and whisker plot definitions. The sentence on pg 23, L19, "The figure 11..." can be moved to the figure 11 caption. 'Overall data extension' should be replaced with 'overall data range'.

T56/ Pg 25, L6: "...between CH₄ and CO are around 0.75", adding a range would be good, i.e. "correlations between XX to XX are found".

T57/ Pg 25, L7. "large" and significant" need to be defined. Maybe better to state the correlations are greater than XX.

T58/ The last three sentences starting pg 25, L13 all need to be referenced.

T59/ Pg 25, L20. "sampling air masses influence with regional footprints" is not needed. All stations have this, nothing specific to OPE.

T60/ Pg 25, L23. What is 'ICOS-ERIC', please define and what does 'labelled' mean?

T61/ Pg 25, L18. "no significant correlation", define 'no significant'.