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Comment

Interactive comment on “Current systematic carbon cycle observations and needs for implementing a policy-relevant carbon observing system” by P. Ciais et al.

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General comments:

The manuscript aims at presenting the current state of global carbon cycle observations and the needs for a more comprehensive observing system that could not only help researchers to determine carbon fluxes at high spatial and temporal resolution over the continents and oceans, but also to support policy-relevant decision making. To accomplish this overwhelming task is not trivial, due to the many different aspects, which need to be taken into account, and the necessity to include expertise from many different co-authors (i.e., more than 50 on the current manuscript). This difficulty may

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be the reason why the paper, as it currently is, is largely non-digestible, at least for this reviewer. I guess the first question that needs to be posed and answered is: Who are the expected readers of this manuscript? Accordingly, sections 1 and 3 need to be re-written. Section 1, the introduction, is a bit confusing as the authors are jumping from one topic to another and from one scale to another, and back. A clear structuring and shortening could largely help to get a clear idea of the problem and of the aims of the study.

– We thank the reviewer I. Levin for her review of the manuscript. The paper is addressed to scientists, policymakers and funding agencies who need to have a global picture of the current state of the (diverse) carbon observations. We have tried to clarify this in the revised manuscript. Section 1 provides background information about global trends (first paragraph), then highlights the lack of independent verification/estimation of emission inventories (second paragraph). The third and fourth paragraphs describe the rationale for measuring/reducing uncertainty on emissions (not done yet by current observations) and the distribution of variable natural fluxes at appropriate scales, and the following paragraphs describe the relevance of carbon observations for (mitigation)policy in terms of baseline fluxes assessment, trend monitoring and detection of feedbacks. Section 2 poses questions that underline the requirements for future carbon observations, and Section 3 is a state of the art description of current observations, allowing requirements and gaps to be identified and discussed in details for each observation type and their integration. We do not see any logical problem in this ordering, but we agree with the reviewer that sections 1 and 2 are too long. Accordingly, the text of these sections in the revised manuscript has been shortened.

Section 3, which should give the state-of-the art of our current observation system would also very much benefit from focusing and shortening. If it were meant as a real review, the required “educational” part is lacking. Currently, it is more a listing of details, supported by figures which have legends and axes that are literally unreadable, because all fonts are much too small. (I think it is not a good idea to put more than

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two global maps with a lot of detail on one A4 page). Here I would have liked to find dedicated Figures (possibly supported by tables in a Supplement) which would clearly illustrate the (many) gaps in our current observational systems. This would give the readers/researchers, who work on improving the situation, information at hand, that could be shown to funding agencies/stakeholders and help to convince them to invest in the urgently needed much more comprehensive observation system (that is described in Section 4 of the manuscript).

– Section 3 has not been shortened because it is part of the “results” and the diversity as well as detailed capability of current observations is central to be described for the manuscript, since Section 4 is built upon the detailed information given in Section 3. In order to address the reviewer comment about figures, we improved the readability of the global maps axes and legends and hope that the revised figures are clear enough, even if several maps are presented. It is difficult to create dedicated figures to quantify gaps, these gaps being in most instances the regions that are poorly covered by observations. This has been added in the figures caption.

Section 4 is the clearest one in the manuscript. However, here it would help the reader if the acronyms, which have (or have not) been explained somewhere earlier, e.g. in Section 3, would be explained again and if key references would be included (again) (many are completely missing, see below).

– We agree with the reviewer and have added a table with all acronyms in an Appendix, used for reference in Section 3 and Section 4.

Abstract: Line 11: “several orders of magnitude” means to me at least factor 1000: This sounds unachievable. . .

– “Several orders of magnitude” has been removed.

The importance of error assessment for all components should be mentioned in the abstract.

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– This has been added.

General for the whole text: Please explain ALL ACRONYMS when they show up FIRST (not somewhere later or not at all. . .).

– Agreed. A table in Appendix 1 has been added with all acronyms and acronyms are spelled out at their first appearance.

Page 11452, line 12: I guess it is not totally clear that the full increase of CO₂ and CH₄ is man-made.

– The increase of CO₂ and CH₄ is caused by anthropogenic activities. We did not say that the full increase is man-made, but without anthropogenic activity, during the pre-industrial Holocene, CO₂ and CH₄ variations were very small, indicating an equilibrium of the CH₄ and CO₂ cycles (see also IPCC AR5 Chapter 6, Executive summary).

Page 11453, line 2: How to create sinks of CH₄? Line 13: give a number of the reduction target and a respective reference. Line 29 ff: the sentence “For the latter . . .” is unclear.

– Sinks of CH₄ can be created, for instance by processes reducing CH₄ in the atmosphere (de Richter and Caillol, 2011; Kucharczyk, 2011; Stolaroff et al., 2012). The references have been added.

An example of target has been added: the Kyoto Protocol target set by EU15 members of a collective reduction of 8% of during 2008-12 of their emissions below the 1990 level (EEA, 2009, p. 9)

– “for the latter” has been removed.

Page 11454, line 5: exactly 56%? Give uncertainty and reference (i.e. Ballantyne et al., Nature 488, 2012, would be appropriate here). Line 13-14: how long do the time series have to be, appr.?

– Uncertainty and reference added.

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Page 11456, line 17: the topic of “tipping points” has not been discussed later-on (or I over-looked that), why define them here?

– We agree with this remark, as Section 4 mentions “hotspots” but not tipping points. Tipping points has been replaced by hotspot in the revised manuscript and the definition removed.

Page 11458, line 8ff: also negative feedback is possible. How do you know that feedbacks are not yet active? Line 18: give uncertainty on the 93%.

– The sentence has been changed, but large non-linear negative feedbacks are unlikely. We know that negative feedbacks (e.g. defined by deviations from linearity) are not yet active globally or at large scale/magnitude because of the stability of the airborne fraction.

Page 11460, line 9ff: give reference to ICOS, sentence is unclear/incomplete. – Reference to ICOS added.

Page 11461, line 14: why show only France in Figure 2C? IER gives all Europe which should be shown here.

– We have shown only France as an example to better illustrate the high-resolution skewed distribution of emissions between urban and rural areas. The IER European coverage is mentioned in the caption.

Page 11461, Line 18: earlier the uncertainty for industrialized nations was stated as 5% (not 6%)

– Changed in text. The uncertainties stated with 1 sigma.

Page 11462, line 25: are you sure these are exactly 200 observational sites? – Yes, the WDCGG has 212 stations for CO₂.

Page 11463, line 11: are all aircraft sites without long-term funding? Line 23: Give reference to the “Corporate Venture”. Line 24: sounds as if all other CO₂ observations

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are not calibrated. Give reference to ICOS.

– To the best of our knowledge, no research operated vertical sampling program is long-term funded. Name of “Corporate Venture” has been added. Reference to ICOS added. We do not read in L24 that other CO₂ observations that NEON are not calibrated, but since NEON is an ecosystem monitoring network, and flux tower CO₂ usually not calibrated for atmospheric use, it was worth mentioning that NEON data will be calibrated.

Page 11464, line 4: should read “assurance” (unfortunately, there is not insurance for quality ...)

– Changed to “assurance”.

Line 14: include “total” before “column” and mention that only one total column number is currently available from satellite data (am I correct?)

– This is correct, but different satellites have different weighting of CO₂ in the air column (e.g. IR sounders like IASI or AIRS) that do not probe CO₂ near the surface. For this reason, we prefer here not to use “total” before “column.”

Line 15: How can satellite data COMPENSATE for too low surface network density, needs re-phrasing.

– Sentence modified.

Page 11465, line 25: Be careful with nomenclature: ppm could stand for mixing ratio or mole fraction (which is not the same e.g. in the case of CO₂).

– In the case of satellite, XCO₂ is dry air mole fraction.

Page 11468, line 21: what is meant with “transfer standard”?

– It is meant that TCCON data evaluated against in situ vertical profiles calibrated to the WMO scale can indirectly be used to assess the compatibility of satellite data with

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the WMO scale. The sentence revised accordingly.

Page 11469, line 12ff: as far as I understand, fluxes can only be estimated from Delta_pCO₂, not from pCO₂ alone, could be confusing (also in Figure 5 caption).

– This has been changed to delta pCO₂.

Page 11470, line 24ff: sentence/relation unclear.

– The sentence says that surveys also allow to measure ocean temperature and physical parameters, from which the ocean change in heat content can be derived. Sentence has been reformulated.

Page 11471, line 12ff: Delta_pCH₄, same comment as above for Delta_pCO₂, give reference for the ocean CH₄ source.

– Text changed to Delta_pCH₄. One reference has been added.

Page 11472, line 24ff: not clear which data come from satellite or in situ, where do the winds come from?

– The sentence clearly mentions the QuickSCAT satellite wind data. No changes made.

Page 11475, line 7: sounds as if ecosystems otherwise are always sinks. . .

– The sentence explains that after disturbance, an ecosystem gradually become a carbon sink (from recovering pools) which is correct. It does not say that ecosystems are always a sink.

Page 11476, line 3: what is the period of inventories? I guess you mean the time period between two inventories?

– Yes, this has been added.

Page 11483, line 24: what is a global 300m map?

– Changed to “a global map of 300 m spatial resolution”.

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Page 11484, line 1: ditto, perhaps include “resolution”

– Done.

Page 11486, line 23: specify what improves the quality and relative to what.

– The different programs have improved the quality of data relative to the previous situation.

Page 11490, line 12ff: I do not agree that with more meta data bias correction would be possible. Our current InGOS NA2 (www.ingos-infrastructure.eu) exercise to estimate uncertainties (random and bias) for historical CH4 and N2O data shows that the individual PIs need to be involved to estimate uncertainties of their data.

– We did not say that individual PIs do not need to be involved, but state that information about known systematic errors must be documented. This does not contradict the reviewer’s statement, and our statement is also more general than in-situ CH4 and N2O data collected by European laboratories (e.g. satellite bias correction is documented when these biases are characterized).

The representativeness error should also be mentioned in this Section 4.1.

– Good point. This was added, although the representativeness error is model dependent.

Page 11491, line 1.3: I do not understand this point.

– This means that for instance uncertainties on biomass stock estimates, for instance a REDD+ project, should be considered for decisions such as the amount of carbon credit claimed by this project.

Page 11492, line 25: what does it mean in terms of fluxes: factor of two error reduction?

– It means that at the scale of a large region, errors on net annual carbon fluxes can be typically reduced by a factor of two with existing dense atmospheric observations.

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We prefer to give an error reduction, because inversions calculate an error reduction that is independent of the flux magnitude. The sentence has been slightly modified and reference changed to published inversion work by Broquet et al. 2013 using pre-ICOS real data.

Page 11495, line 3: give reference. Line 21: what means “accurate” in a quantitative sense? Line 24: “where possible”? I would say this is really necessary!

– Reference to EDGAR dataset added to line 3. Sentence about accuracy slightly changed (line 21). “where possible” suppressed (line 23).

Page 11497, line 18: give reference to the 14C-CO₂ method. 14C-CH₄ is largely contaminated by nuclear emissions, and thus useless to estimate the fossil component (see Levin et al., 1992, Radiocarbon in atmospheric carbon dioxide and methane: global distribution and trends, in: R.E. Taylor, A. Long and R.S. Kra (Eds.) Radiocarbon After Four Decades: An Interdisciplinary Perspective, Springer-Verlag, New York, 503-517.)

– We added a sentence about contamination of 14C-CH₄ by nuclear plants but there is also a global published study by the peer reviewed study of Lassey et al. ACP 2007 using 14C-CH₄ to provide a very useful constraint on the total fraction of fossil CH₄ emissions.

Line 24: give reference to fossil fuel proxies (i.e. CO, NO_x, other), see also Page 11499, line 21-24.

– References added.

Page 11498, line 25ff: give references.

– Web sites have been added.

Page 11501, line 2-3: why exactly 1 ppm for CO₂ and 5 ppb for CH₄?

– These requirements are from the ESA-CCI-GHG user requirement report. The 5 ppb

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for the CH₄ is now replaced by 9 ppb (Buchwitz et al., 2011). The reference has been added.

Page 11502, lines 5-9: give references to explain the tracers SF₆ and 222Radon.

– References added.

Page 11503, line 3: the term “space-time covariance matrices” has never been explained

– Text changed.

Line 7: should read: ocean “CO₂” sink

– Added.

Lines 12ff: explain how these numbers have been estimated and give references

– Reference added.

Fig 7 is not readable (could go to a supplement, I guess).

– We would like to keep fig 7 in the main text and have improved its readability.

Page 11507, lines 12ff: what is “optimal accuracy”? I guess what is important is compatibility?

– Agreed – text changed.

Page 11509, line 24: give reference to explain BEF, DBH, . . .

– DBH been made explicit, BEF was already explained.

Page 11514, line 3ff: . . . and “organic soil carbon”. . . is this the same as the soil carbon inventories, regularly made?

– No, we talk about DOC in the soil solution. The sentence was slightly modified for clarity.

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Page 11515, line 24-25: “waste management” needs to be included when listing CH4 emissions.

– Added.

Page 11517, line 11: what is MRV?

- Monitoring Reporting and Verification – added in the text.

– I guess, also Megacities are “hot spots”.

Added.

Page 11522, line 11 & 14: include also quality control.

– Added.

Page 11523, line 10: should better read “. . . incomplete data and missing estimates of realistic uncertainties, various . . .”

– Changed.

Page 11526, line 22: explain and give reference to WMO WIS, also to CF-1 and netCDF.

– Added.

Page 11527-8: Include a remark that uncertainty estimates need to be put on existing/historical data sets (e.g. stored in the WDCGG)

– Added.

Figure 1A and 1C: Give two space axes, as for Fig 1B & 1D.

– Done.

Figure 3: Why not show all surface sites with data in the WDCGG?

– Because all surface sites don’t have long enough data useable for flux inversion, and

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some sites have no CO₂, CH₄, N₂O (ex. only O₃) data.

Figure 4: What is the x-scale in 4B.

– X-axis units is the dimensionless weight in each atmospheric layer. It is now explained in figure caption.

Figure 5: See comment above but note that Delta_pCO₂ is plotted in A and B. Figure

6: Chose different color for “Phase 3”

– Done.

Figure 9: Explain acronyms AFOLU, NEE - It is done in text and Appendix.

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