

## Review on „Sixty years of radiocarbon dioxide measurements at Wellington, New Zealand 1954 – 2014” by Turnbull et al. 2016

by Samuel Hammer

Turnbull et al. present a thorough revisit of the entire Wellington atmospheric  $^{14}\text{CO}_2$  record. They re-measured archived samples and include new information from tree samples to better investigate known “noisy” periods of original record. Conceivable flagging criteria are formulated and the Wellington record is compared to independent data sets. Therefore this manuscript is of upmost scientific interest to the radiocarbon community and I definitely recommend publication in ACP.

In addition to the data review the authors revisit and extend the key findings that the Wellington  $^{14}\text{CO}_2$  record provides. For some of the conclusions drawn from the data I would like to ask the authors to reinforce their arguments to overcome my minor concerns.

General comments to the authors:

P5 l212ff       $^{14}\text{C}$  measurements:

Have you investigated if the use of IRMS- $^{13}\text{C}$  in the early AMS measurements introduces a bias? Such a potential bias could originate e.g. from a machine immanent fractionation. I assume you have IRMS- $^{13}\text{C}$  measurements also for the post-2005 samples. Did you compare the effect of offline and online  $^{13}\text{C}$  measurements for the  $\text{D}^{14}\text{C}$  normalization directly? Such an investigation will also quantify the contribution to the scatter which is due to offline  $^{13}\text{C}$  analysis in the earlier AMS results.

P8 l338      Smooth curve fit:

Fitting section by section may introduce problems at each overlap of the sections. Wouldn't it be better to use a fit routine which can deal with a changing phase? Pickers et al. mention that STL per se does not require gap filling, only the current implementation of STL does. Pickers et al. also investigate HPspline which would allow for a change in phase. Why didn't you chose this fitting algorithm?

When you investigate the phase change in the  $^{14}\text{CO}_2$  signal, you find that the seasonal cycle weakens between 1978 and 1980, and then reverses. Could it be that this timing is related to the change in the fitting sections (1966-1979 and 1980 to 1989). The described method for overlap and interpolation between different fits favors the weakening of the seasonal cycle at the section borders if both sections are out of phase. I wonder if you would find the same timing for the phase change if you chose different fitting sections...

P11 l450ff      Hypothesis of reversed seasonal cycles in the early post-bomb era:

The hypothesis behind the changing phase in the seasonal cycle should be backed up by a small (box-) model exercise. This model should include the seasonal cycles of the STE (in NH and SH) and the CEE (cross equator exchange) in the troposphere and the stratosphere. The Mount Pinatubo eruption is a well-studied phenomenon when it comes to stratospheric transport. see e.g. Aquila et al. 2012. They find middle-stratospheric meridional pathways with mixing times of less than a year. The major

stratospheric bomb-peak lasted for about 4-5 years (see HASL data compiled in Naegler et al 2006). Can you show in a (box-) model that with those boundary conditions your hypothesis is valid?

Aquila, Valentina, et al. "Dispersion of the volcanic sulfate cloud from a Mount Pinatubo-like eruption." *Journal of Geophysical Research: Atmospheres* 117.D6 (2012).

P11 l471ff Interpretation of the seasonal cycles since 2005:

I have a couple of questions and comments to the comparison of the Wellington and Cape Grim seasonal cycles:

- The comparison to the Cape Grim seasonal cycle is problematic since both mean cycles do not average the same time period. Figure 4b shows that there are obvious large inter-annual variations in the amplitude (phasing?) of the seasonal cycle.
- What is the origin of the double maxima in the BHD cycle?
- Is the Melbourne influence at Cape Grim detectable in CO<sub>2</sub> or CO?
- Fig 6 does not convince me that BHD is not influenced by anthropogenic emissions. Wellington is in the middle of the "red" area. When reading Pickers et al. they mention that in their data example of the BHD CO<sub>2</sub> data they had to gap fill 10% of the data since they deviated from baseline conditions.... To me this indicates some anthropogenic influence at BHD as well.
- Sure, Melbourne emits 50 times more ffCO<sub>2</sub> than Wellington, however the distance between Melbourne and Cape Grim is 340km, whereas it is around 10km between Wellington and the BHD...
- If STE is the driving mechanism for the seasonal cycle for the periods 1966 to 1979 and 1980 to 1990, how come that the seasonal cycle post 2005, which is also explained via the STE, is not in phase with the earlier once...

Specific comments:

p.2 l.40 Please state the years when the measurements in Norway and Austria started

p2. l.44 The term "exchanges" is a bit too general, consider oxidized or something more specific.

p.2 l.45: Production -> Natural production

p2. L 47: perturbations to  $\Delta^{14}\text{CO}_2$  -> perturbations to natural  $\Delta^{14}\text{CO}_2$  levels

p2. L62: Add year to Lopez et al., and add also early attempts of ffCO<sub>2</sub> emission estimates like e.g:

*Meijer, H. A. J., et al. "Isotopic characterisation of anthropogenic CO<sub>2</sub> emissions using isotopic and radiocarbon analysis." Physics and Chemistry of the Earth 21.5 (1996): 483-487.*

*Gamnitzer, U., U. Karstens, B. Kromer, R. E. M. Neubert, H. A. J. Meijer, H. Schroeder, and I. Levin (2006), Carbon monoxide: A quantitative tracer for fossil fuel CO<sub>2</sub>? J. Geophys. Res., 111, D22302*

- p.2 I77: add citations to the last part of this paragraph
- p4 I128: what do you intend with the term “nominally CO<sub>2</sub>-free”? Did you process blank NaOH solutions? How much CO<sub>2</sub> is in a blank NaOH solution? What is the <sup>14</sup>C activity of this blank?
- p4.I131: “large tray” can you state the surface area of that tray?
- P4.139: Please add the statement about fractionation (supplement S3.I90-92) to the main text.
- P5 I189 “one” sd? In Fig S2 and the text you state 2 sd?
- P6 I259 please include a reference to Fig.2 in this subsection
- P8 I316 I don't see the 2005 EN Tandem improvement mentioned in Zondervan et al 2015.... Maybe I overlooked it?
- P8 I336 Do the measurements from this period carry a special flag (e.g noisy) in the dataset? Reading the supplement I found that you are already doing this. Maybe make a short note in the main text.
- P8 I353 how does cgvu handle data gaps and inconsistent sampling frequencies? Since the paper is (at least for me) not freely available it is worth mentioning this shortly in the supplement.
- P9 I362 what is the unit of the cutoff criteria in the frequency domain?
- P9 I363 is the 2 year overlap a good idea? In terms of transition yes, but don't you have now the influence of end-effects in 4 years?
- P9 I368 “mean residual difference” do you mean RMS of the residuals
- P9 I379 state the “n” of the MC
- P9 I382 where are the 95% conf intervals given? In the data set I see only one uncertainty column, please specify in the data-set if this is the 1 sigma error or the 95% conf interval.
- P9 I384ff the model simulation are not convincingly not used in the paper. See general comments. Consider skipping the subsection 3.7 and Fig 6.
- P9 I388 LAU ??
- P10 I403ff include ref to fig. 2
- P10 I442 30 per mil amplitude for the period 1966-1979? I only see such an amplitude once? A mean amplitude of ca. 7 per mil seem more realistic.
- P11 I456 fig 6 -> fig 5??
- P11 I459 “Between 1978 and 1980 the seasonal cycle weakened”. This is not really seen in fig 4b.
- Unfortunately 1978 to 1980 is a boundary of the fitting sections... since the seasonal cycles for the two sections are opposed and the overlap is linearly interpolate between fits... a weakening can also come from the applied method.

P11 I460 5 per mil amplitude? Maybe two times in this period... 3 per mil on average  
P11 I467 fig 5 -> fig 4  
P12 I 494 fig5 -> fig 4?  
P12 I497 "records that are indicated in figure 1" -> "records where the sampling locations are indicated in figure 1"  
P13 I563 Model results from Levin et al. 2010 already suggest the development of a interhemispheric gradient in the same magnitude for the same time... without changing the southern ocean... although they admit that they are not matching the data...

P21 Table1: include sample no. to NZ/NZA, replace GC with gas counting, change "measurement methods" to "measurement and sampling methods"

Table2: provide the unit to the 14C differences

P22 Figure1: provide scales to the google earth pictures, indicate urban areas in the upper map.

P23 consider vertical grid lines to illustrate the different periods used in the paper.  
Consider indicating graphs with a) and b)

x-label of graph a) is cropped...

p25 Consider indicating graphs with a) and b)

in a) use the same periods as in the text.

b) consider vertical grid lines to illustrate the different periods

p27 Motivate the plot better. Not really used in the paper. Explain the unit.

P28 Consider indicating graphs with a) and b)

Consider usage of open symbols. Especially after 2000 it would be good to see all data.

Supplement:

S2.I74 state the surface area of the pyrex tray

S4 I147 extraction follows -> extraction from 1995 onward follows

S5 I217ff in total after flagging you have 427 targets, if you split them between the machines you have 397 and 102 .... To me this does not add up? What am I missing?

- S6. L262 Please state the main offset for the QC datasets between the two AMS machines.
- S9 I394 What is RLIMS?
- S12.I457 Indicate the figure S1 with a) and b). I assume a) is Eastbourne and b) is Baring Head? Correct?
- S12.I468 Since you cannot decide between “red” or “green” for the Baring Head tree, how can you than state the excellent agreement? Is it excellent for both red and green? Please include a link to the t-test or the mean difference to reinforce this statement.
- S13 I471 Define “NIK”.  
Why is there only one comparison for NIK and 4 comparisons for BHD?
- S13 I473 please specify the t-test: I assume you use a dependent t-test for paired samples? Since the applied formulas are easy it might be clearer if you just explicitly state them.
- S13 I481 what is the mean difference if you use the one year shifted BHD tree (red points in fig S1)?

Technical comments:

In the text please use a consistent ordering (e.g. temporally ascending) when citing multiple papers.