A Simple Method to Correct Carbon Dioxide Concentrations in Ice Core Data for Ice / Gas Age Difference Perturbations.

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ABSTRACT

Presented here is a simple approach for the compensation of perturbations in ice-core carbon dioxide time reconstructions resulting from inadequate adjustments for ice/gas age differences. The method uses the correlation between the ice/gas age difference and measured carbon dioxide concentrations to predict the concentrations at zero ice/gas difference. This prediction is then applied to compensate the data. It significantly reduces the perturbations and effectively references the data to the ice age.

INTRODUCTION

Throughout this paper, the Vostok ice-core is used as an example. In particular the data set originates from J.M. Barnola & N.I.Barkov (January 2003). The mnemonic IGD will be used in place of “ice/gas difference”.

Recent evaluation of this data set highlighted a relatively large degree of correlation between carbon dioxide concentrations and IGD. This spurred an investigation to determine whether it was possible to compensate the data to remove this artefact. However, it seems remarkable that those involved in creating the data sets have not applied such corrections, especially when some have been published smoothed data along side.

In this paper, following assumptions are made:

1. Estimates of the gas age are robust. The methodology behind this has been assumed to have no effect on the process described here.

2. In order to keep the procedure relatively free from mathematical critique, only least squares linear fits have been used, and are considered adequate. This type of equation fitting is standard and can be done readily within most spreadsheet packages. Therefore, the method described here can be easily reproduced. It does not rule out the possibility that other function fits might provide improvements.

3. An extrapolation is used extending beyond a single data set. However, data from additional sources tends to suggest that this is not unreasonable.
METHOD

The first step in the this procedure is to take the data set and calculate the IGD. Quite simply:

\[ \text{IGD} = (\text{age of the ice}) - (\text{age of the gas}) \]

NB: Depending upon the source, the words gas and air are interchangeable.

Next the carbon dioxide concentrations are plotted as a function of IGD. Then a linear fit is added, resulting in a graph:

**Figure 1.**

As can be seen from Figure 1, the scatter approximates to a straight line quite well, with a Correlation Coefficient = 0.8998. The equation of the fit is:

\[ y = (-0.02362 \times x) + 328.25 \]

To state the obvious, for every year increase in IGD the carbon dioxide concentration drops by 0.02362 ppmv. Also, the y-axis intercept, that is where the ice and gas would be the same age (IGD = 0) is 328.25 ppmv. Remember however, that the intercept is a projected value and well outside of the data range.
So is it justifiable to predict the IGD = 0 value? Consider the next graph which shows the same data but adding some more from another source that has points nearer to IGD = 0:

Carbon Dioxide Concentration plotted against Difference in Age between Ice and Air

Extra points near IGD = 0 were obtained from Law Dome. The linear fit has been extended, not recalculated. Clearly the trend does not quite hit the Law Dome data, but is reasonably close considering that it is not related. Incidentally, the Law Dome data is only five points because there are only that many differing IGD available and it is not possible to resolve all them in the plot.
For more reassurance, a third set was added to the plot. This time from the Taylor ice-core:

![Graph](image)

**Figure 3.**

In the same way as earlier, the fit was calculated on the Taylor set and extended to the y-axis. Again, the line does not pass through the middle of the Law Dome points.

Although the trends do not pass through the scatter of the points near IGD = 0, they certainly overlap within the amount of variation observed. A full-blown statistical analysis could be done to mathematically show this, but that is not the purpose of this paper. If there was a will, the survey teams could almost certainly extend the IGD range closer to zero. That would be the best way to settle any disquiet over this point.

Focussing on Vostok once more, the next step is to use the relationship determined earlier to compensate the carbon dioxide measurements. Use the following formula:

\[ A = B - (-0.02362 \times IGD) \]

Where, \( A = \) Compensated CO2, and \( B = \) Original CO2.
For example: IGD = 4000 years and original CO2 = 250 ppmv:

\[
\text{Compensated CO2} = 250 - (-0.02362 \times 4000) \\
= 344.48 \text{ ppmv}
\]

The following graph shows the time series for Vostok in its original form and after applying the compensation described above:

Corrected and Original Carbon Dioxide Concentration plotted against Ice Age.  

![Graph showing corrected and original CO2 concentration over time.](image)

Figure 4.

Clearly, it makes a huge difference. The average level is much higher, the span is less, and much of the original character has disappeared.
To check that the IGD perturbations have been removed, the compensated carbon dioxide was plotted against IGD:

Vostok - Compensated Carbon Dioxide Concentration plotted against Difference in Age between Ice and Air

Figure 5.

The compensation has worked well. The trend caused by IGD has been removed.
DISCUSSION

One of the side effects of this compensation method is the fact that it effectively compensates the date at the same time as the carbon dioxide level. This is because at IGD = 0, the ice and gas are the same age by definition.

The dramatic change in character is also of great interest. The features are generally much smaller with many disappearing and others appearing. There seems to be some correlation, but nothing strong. This is born-out by the following plot of the compensated carbon dioxide levels against the original concentrations:

Vostok - Compensated Carbon Dioxide Concentrations plotted against Original Concentrations.

![Plot of Vostok data](chart.png)

A relationship exists between the two, but it is not very strong. This suggests that a significant proportion of the original data was not the real signal.

This work has also demonstrated that the plots regularly shown in papers associated with Anthropogenic Global Warming are misleading. It strongly suggests that carbon dioxide levels in the twentieth century are not very different to those on Earth over many earlier millennia, Figure 4.
It is interesting to compare the original and compensated carbon dioxide with temperature:

Corrected and Original Carbon Dioxide Concentration plotted against Ice Age.  

![Corrected and Original Carbon Dioxide Concentration](image)

Here the deuterium temperature is from Jouzel et al. (1987, 1993 and 1996) on Jouzel time scale. None of these series are smoothed. As can be seen from Figure 7, there is some apparent correlation between the original CO2 and temperature. However, there does not seem to be any significant relationship between the compensated CO2 and temperature. It is therefore possible that the original carbon dioxide was contaminated via the IGD with a temperature signal. It is conceivable that this corruption was as a result of the methodology.

Of course, if this is the case then maybe other measurements are similarly affected, for example, methane, and other gaseous compounds.
CONCLUSION

The method described in this paper appears to be able to successfully compensate the carbon dioxide data to $IGD = 0$. There are two spin-offs from this process. Firstly, by definition it adjusts the carbon dioxide sample date to that of the ice, and secondly, it appears to eliminate a noise signal related to temperature.

REFERENCES


   http://www1.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/vostok/

   http://www1.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/taylor/