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Evaluation of periodic contributors to climatic temperature fluctuations from historic data

E.F. Jones and P.M. Gore

FM Research Professionals, PO Box 58412, Nashville, TN 37205, USA

Abstract. The purpose of this study is to fit the record of mean global temperature anomalies by using a logarithmic function of the atmospheric carbon dioxide concentration and to determine any periodic contributors to the temperature anomaly record.

1. Mean temperature anomalies

Parametric fitting of the historical global mean temperature anomalies [1] was performed. A logarithmic function of CO_2 concentration was the best fit to the historical data.

The fit of mean global temperature anomaly vs. atmospheric CO_2 concentration yielded the equation

$$\Delta T = (15.999 + 2.7550 \ln(C_{CO_2}))C^{\circ} \quad (1)$$

with a coefficient of determination $r^2 = 0.79068$. A logarithmic dependence of the mean temperature anomaly on CO_2 concentration would result if the primary effect of increased CO_2 concentration is to raise the height to which the atmosphere is relatively opaque to the absorbed bands of infrared radiation from the Earth's surface [2] and thus the temperature is directly proportional to the change ΔF in radiative forcing as a function of changing concentration for carbon dioxide is given by

$$\Delta F = 5.35 \times \ln \frac{C}{C_0} W m^{-z} \quad (2)$$

where C is the CO_2 concentration in parts per million by volume and C_0 is the reference concentration [3]. The radiative forcing due to increased atmospheric CO_2 is proportional to the log of the CO_2 concentration. The increase in mean global temperature anomaly due to the increased CO_2 concentration is linearly proportional to the radiative forcing and thus proportional to the log of the CO_2 concentration.

2. Sinusoidal fits

Adding a sinusoidal function of time with a 21-year period corresponding to the solar cycle improved the fit. Adding another sinusoidal term with a 70-year period further improved the fit.

This could correspond to the Atlantic multidecadal oscillation [4]. The RMS of the errors of the fit from 1850 to 2011 is 0.092 C°.

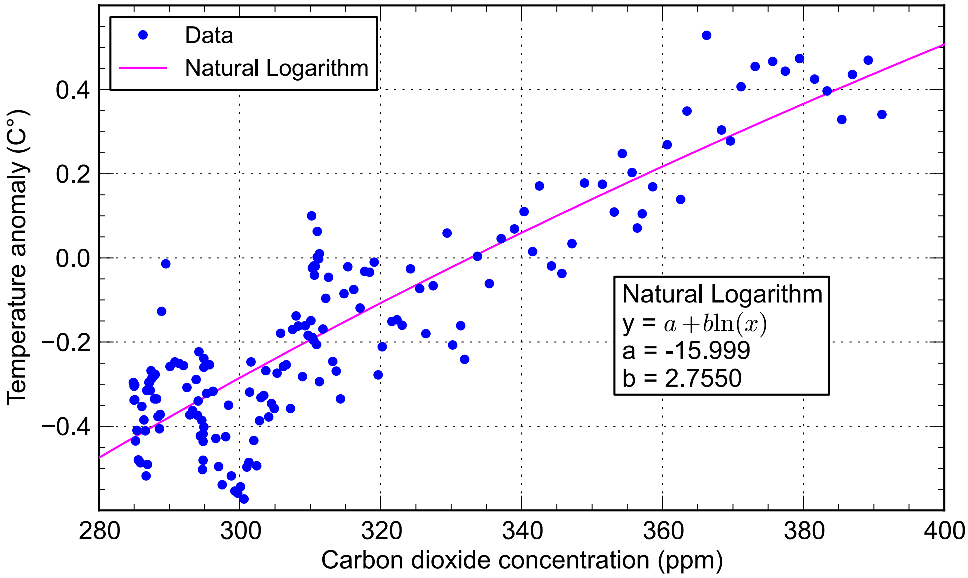

Figure 1. Mean global temperature anomaly vs. atmospheric CO_2 concentration.

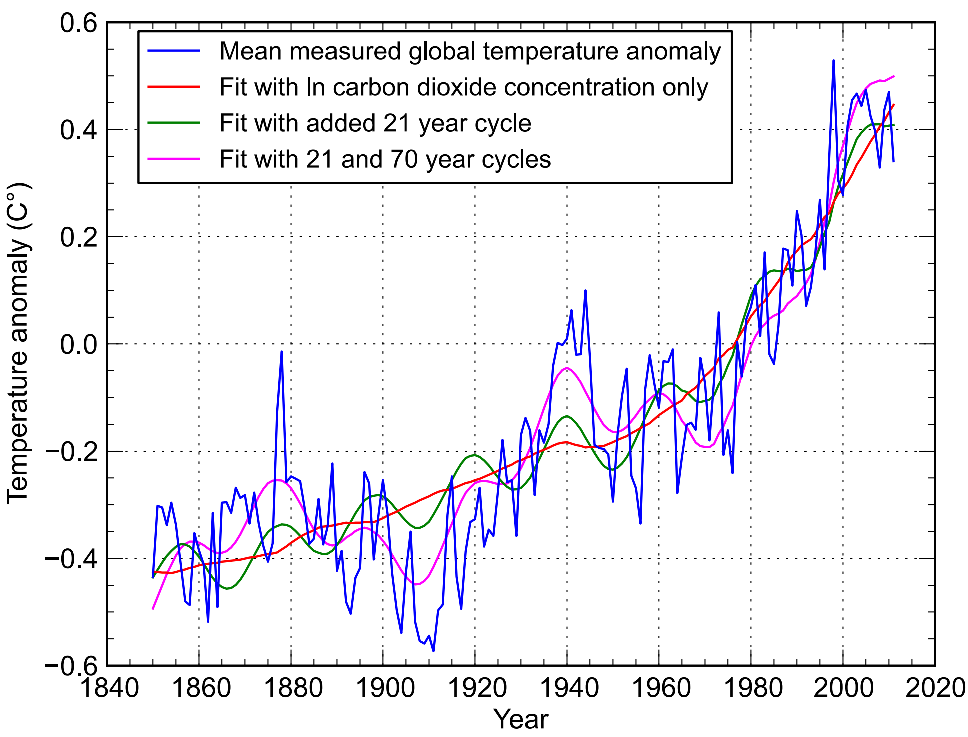

Figure 2. Mean global temperature anomaly vs. year and least squares fits using, respectively, the log of the CO_2 concentration, the log of the CO_2 concentration plus a 21-year cycle oscillation, and the log of the CO_2 concentration plus both 21-year and 70-year oscillations.

The formula resulting in the best fit was

$$\Delta T = \left(2.7712 \ln \frac{C}{333.42} + 0.0503 \sin \frac{2\pi(t - 6.393)}{20.957} + 0.0981 \sin \frac{2\pi(t - 57.715)}{69.167}\right) \mathrm{C}^{\circ} \qquad (3)$$

where C is the atmospheric carbon dioxide concentration in ppm and t is the calendar year C.E. If we assume that the CO_2 linearly increases to 1000 ppm by the year 2100, then we expect the temperature anomaly to be $+3$ C° in the year 2100. This greatly simplified analysis ignores positive feedback mechanisms that may occur as the mean temperature anomaly rises.

3. Summary

In summary, a logarithmic dependence of the historical mean global temperature anomaly to the atmospheric carbon dioxide concentration yielded a good fit. Adding periodic contributions with 11-year and 70-year cycles further improved the fit. With a linear CO_2 increase to 1000 ppm by 2100, the expectation is a $+3$ C° temperature anomaly in 2100.

References

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