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Predicting Seasonal Cycles of Atmospheric Carbon Dioxide from Global Temperature Anomalies

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INTRODUCTION

The well-documented shift in global climate that occurred in 1976-77 altered the balance of the earth's atmosphere-hydrosphere-biosphere system (1). The underlying cause for the change is thought to be the higher sea-surface temperatures observed during and after the climate-shift, which reduced the effectiveness of the oceans as a carbon sink. Relative to the hydrosphere and biosphere, it is likely the atmosphere is now in a state of disequilibrium with respect to carbon dioxide, resulting in a significant change in the interaction between temperature and carbon dioxide. The following were completed in this study:

1. **Applied maximum and minimum daily temperature anomalies derived from an average of observations at 6647 global weather stations to predict daily changes in the concentration of atmospheric carbon dioxide (Figure 1).**
2. **Constructed daily changes in atmospheric CO_2 (from the previous day) from the monthly record of observations collected at Mauna Loa, Hawaii since 1958 (Figure 2).**
3. **Developed a modified temperature anomaly index by incorporating two coefficients into the temperature range equation (Figure 3).**
4. **Regressed the daily change in CO_2 with the temperature index and determined the probable error and correlation of predicting daily CO_2 change from temperature each year of the 1959-2008 period (Figures 4 , 5, 6).**
5. **Determined that the correlation of CO_2 change and the temperature index reversed from mostly positive before the shift to increasingly negative afterward, except following volcanic eruptions and the 97-98 El Nino.**
6. **Predicted the daily change in CO_2 from temperature observations suggesting the possibility of predicting temperatures from CO_2 changes (Figure 7, 8).**

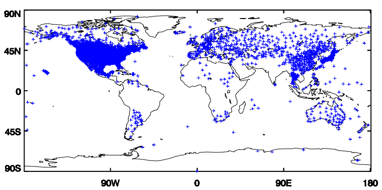

Figure 1: Location of 6647 Met stations used in the study (HadGHCND Data Set, Met Office Hadley Centre & US National Climatic Data Center). Period of record is 1950-2008; anomalies are referenced to the 1961-90 period.

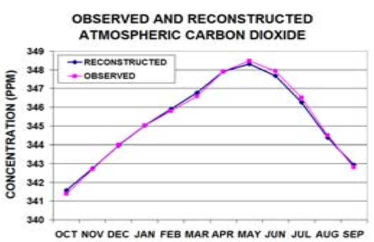

Figure 2: Comparison of the reconstructed monthly concentrations of atmospheric CO_2 with the observed (averaged for 1959-2008) verifies the accuracy of the simulated dailies. The reconstructed monthly averages are calculated by summing the daily changes that were simulated from the initial measurements at Mauna Loa using a 3-point interpolation procedure and 3 coefficients. Based on this analysis the probable error for the daily change in CO_2 is approximately +/- 0.0002 PPM.

LINKING DAILY CO2 CHANGE AND TEMPERATURE

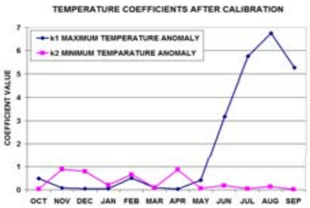

Figure 3. Monthly coefficients calibrated for the modified temperature range,
TR = k_1 (dTx) – k_2 (dTn), regressed against the daily change in carbon dioxide. Initially, k1 = k2 = 1. Final coefficients are determined when the probable regression error of TR versus CO_2 change for the 1959-2008 period is a minimum. Inexplicably, the high summer values of k_1 are much reduced by using 2001-2008 for calibration.

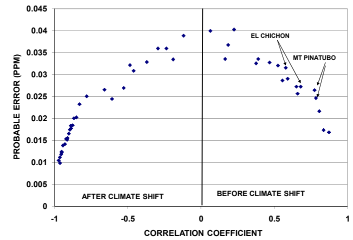

Figure 4. Probable error versus correlation for regression of daily change in carbon dioxide versus modified temperature range (TR). Correlations are generally positive before the climate shift and strongly negative afterward, except for 3-5 years following the El Chichon and Mt Pinatubo eruptions and during the 1997-98 El Nino.

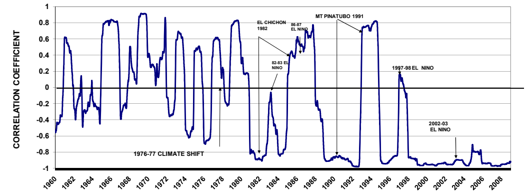

Figure 6. Correlation of the daily change in atmospheric carbon dioxide versus the modified temperature range for each year. Correlations are generally positive or slightly negative before the 1976-77 climate shift and increasingly negative after 1978, except for 3-5 years following two major volcanic eruptions and the 1997-98 El Nino. Aerosols produced by the eruptions lowered global temperatures and impeded vegetation growth reducing the uptake of carbon dioxide from the atmosphere to the biosphere. Warmer oceans during the 1997-98 El Nino tended to reduce the transfer of carbon dioxide from the atmosphere to the hydrosphere. Positive correlations indicate above normal temperatures coincide with positive changes in CO_2, mostly during the winter; negative correlations indicate above normal temperatures coincide with negative changes in CO_2, mostly during the summer and after 1978.

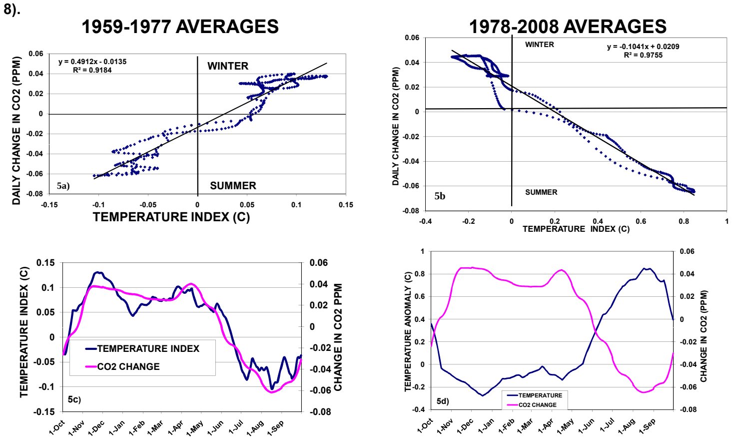

Figure 5 a-d. The daily change in atmospheric carbon dioxide and temperature anomalies averaged for two periods: before and after the 1976-77 climate shift. a) daily change in CO_2 versus temperature anomalies averaged for the 1959-77 period, b) averaged for the 1978-2008 period, c) time series of daily CO_2 change and temperature anomalies averaged for the 1959-77 period, d) time series averaged for the 1978-2008 period. During the 1959-77 period both variables are positive during the winter season and negative during the summer, while during the 1978-2008 period the sign of the temperature variable is reversed. The temperature index is also an order of magnitude greater during the summer of the 1978-2008 period due to the large values of the maximum temperature coefficients (shown in Figure 3). The daily change in CO_2 is more positive during the winter and more negative during the summer after the climate shift.

(1)Miller, A.J., D.R. Cayan, T.P. Barnett, N.E. Graham and J.M. Oberhuber, 1994.

The 1976-77 climate shift of the Pacific Ocean. Oceanography 7:21-26.

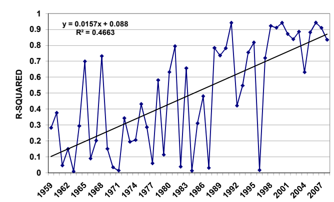

Figure 7. R-Squared for predicting seasonal variations in the concentration of atmospheric carbon dioxide from temperature. The R^2 greater than 0.90 for most of the past decade suggests that the Keeling Curve could now be simulated from global temperature observations.

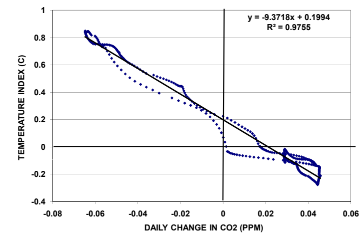

Figure 8. Prediction of global temperature anomaly indices from the daily change in atmospheric carbon dioxide (DCO_2) for 1978-2008, based on the complement of the regression equation in Figure 5b.

ERROR ANALYSIS

There are 18,250 daily changes in atmospheric carbon dioxide regressed against 36,500 daily indices of maximum and minimum temperature anomalies, using 24 coefficients (2 per month) and 102 regression coefficients (2 per year) to predict daily CO_2 changes. The probable error (shown in Figure 4) of the daily CO_2 predictions is equal to: PE = $\sqrt{(\Sigma (S - O)^2) n^{-1}}$
(S = predicted change, O = observed change, n = 18250)

CONCLUSIONS

The reversal in the CO_2-temperature correlation after 1976-77 suggests a critical change in the interaction of atmospheric carbon dioxide and temperature. The strong negative correlation for the past two decades, caused by a significant increase in summer temperature indices and/or increased vegetation growth, suggests global temperatures could now be predicted from daily changes in the concentration of carbon dioxide.