Time Series Analysis of Global Warming Data

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800,000 Year Data

- Source
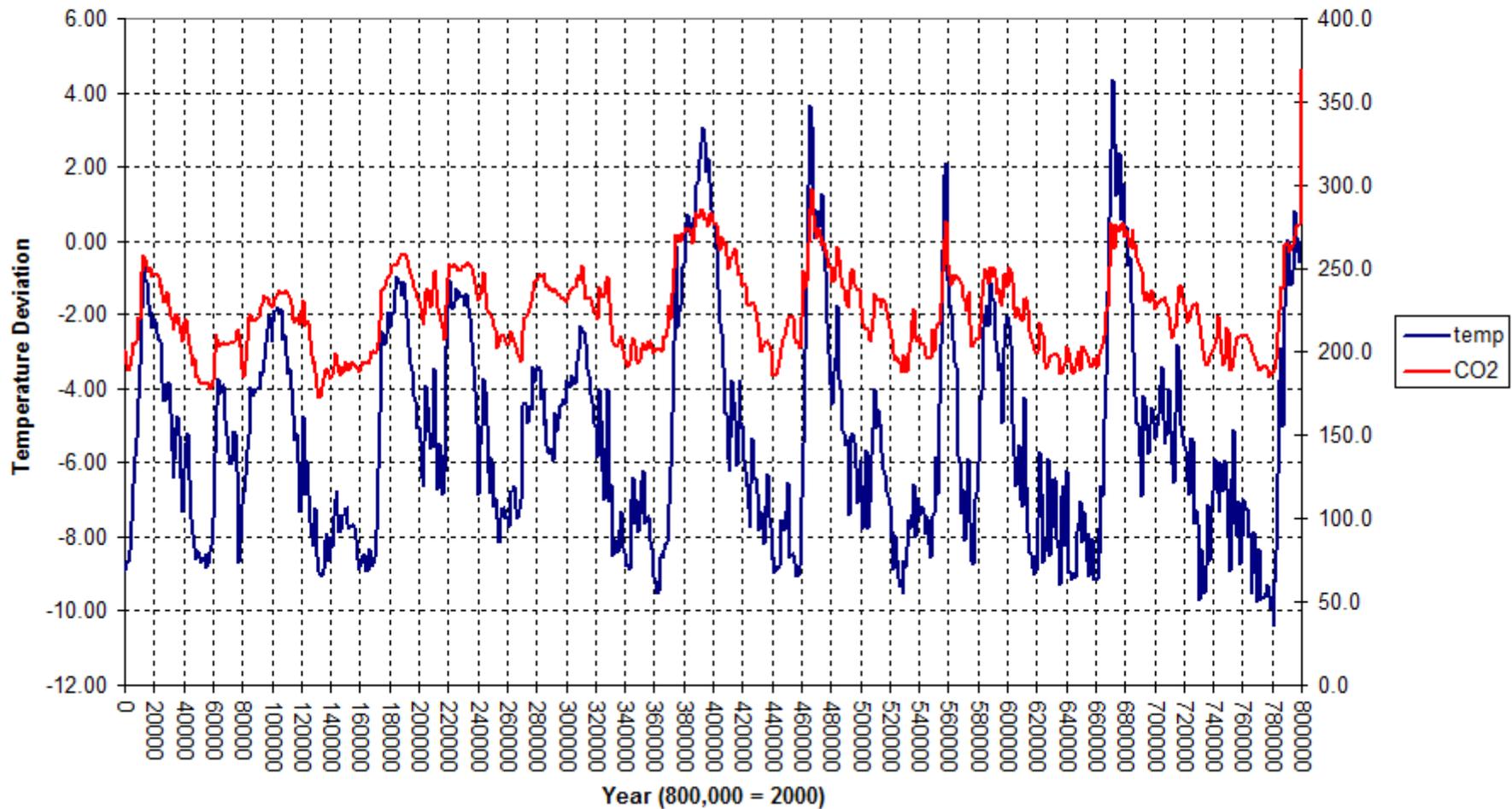 - European Project For Ice Coring In Antarctica
  - Downloaded from BBC website http://news.bbc.co.uk/2/hi/in_depth/sci_tech/2009/copenhagen/8393855.stm
- Contents
  - Global average temperature deviation present every 1000 years
  - Corresponding CO_2 level in parts per million

Temperature Deviation From Present And CO2 Level

800,000 Year Summary Stats

stat	temp	CO2
min	-10.41	172.72
max	4.34	369.50
mean	-5.29	223.96
std	2.92	26.04
current	0.00	369.50

Note that temperature has been much warmer and much colder but CO_2 has never been higher.

800,000 Year Model

- Developed using Autobox
- Autobox automatically finds
  - An ARIMA transfer function model that is both necessary and sufficient - that is:
    - All coefficients in the final model are significant at the .05 confidence level.
    - There is no significant autocorrelation in the errors of the model
  - Outliers in history including:
    - One time outliers (pulses)
    - Level shifts
    - Deterministic time trends
  - Checks for constancy of variance and parameters and adjusts if necessary.

800,000 Year Model
ARIMA and CO_2

Model Component	lag	coefficient	std error	P value	T value
CONSTANT		-1.860	0.369	0.000	-5.030
Autoregressive-Factor	1	0.912	0.016	0.000	58.110
CO2	0	0.071	0.004	0.000	17.940

Years before 2000	value	std	P value	T value
0	-5.890	0.732	0.000	-8.050
13000	-1.870	0.463	0.000	-4.040
29000	1.540	0.463	0.001	3.320
43000	1.270	0.463	0.006	2.740
46000	1.990	0.463	0.000	4.310
48000	-1.970	0.463	0.000	-4.260
50000	-1.700	0.465	0.000	-3.650
52000	1.390	0.464	0.003	3.000
64000	1.490	0.463	0.001	3.220
69000	-1.760	0.463	0.000	-3.790
73000	-1.380	0.463	0.003	-2.980
107000	1.400	0.463	0.003	3.020
126000	-1.670	0.464	0.000	-3.610
128000	1.420	0.463	0.002	3.060

Years before 2000	value	std	P value	T value
137000	-1.310	0.463	0.005	-2.830
150000	1.660	0.465	0.000	3.560
159000	1.740	0.463	0.000	3.750
164000	-1.340	0.463	0.004	-2.890
172000	2.570	0.463	0.000	5.550
188000	1.620	0.463	0.001	3.490
247000	-1.750	0.463	0.000	-3.780
296000	1.750	0.463	0.000	3.780
307000	-1.510	0.463	0.001	-3.270
326000	1.480	0.463	0.002	3.200
349000	1.270	0.463	0.006	2.750
382000	1.260	0.463	0.006	2.730
425000	1.380	0.464	0.003	2.970
679000	1.240	0.463	0.007	2.690

Note that the current temperature is the largest outlier. It implies that if the historic relationship between CO_2 and temperature had not changed, the current temperature would be almost 6 degrees higher

800,000 Year Model Summary Statistics

Number of Residuals (R)	800
Number of Degrees of Freedom	769
Sum of Squares	313.9
Variance	0.392
Adjusted Variance	0.408
Standard Deviation RMSE	0.639
Standard Error of the Mean	0.023
Mean / its Standard Error	0.001
Mean Absolute Deviation	0.488
R Square	0.954

The fit is very good, but root mean square error is still significant implying uncertainty

800,000 Year Model - Actual and fit
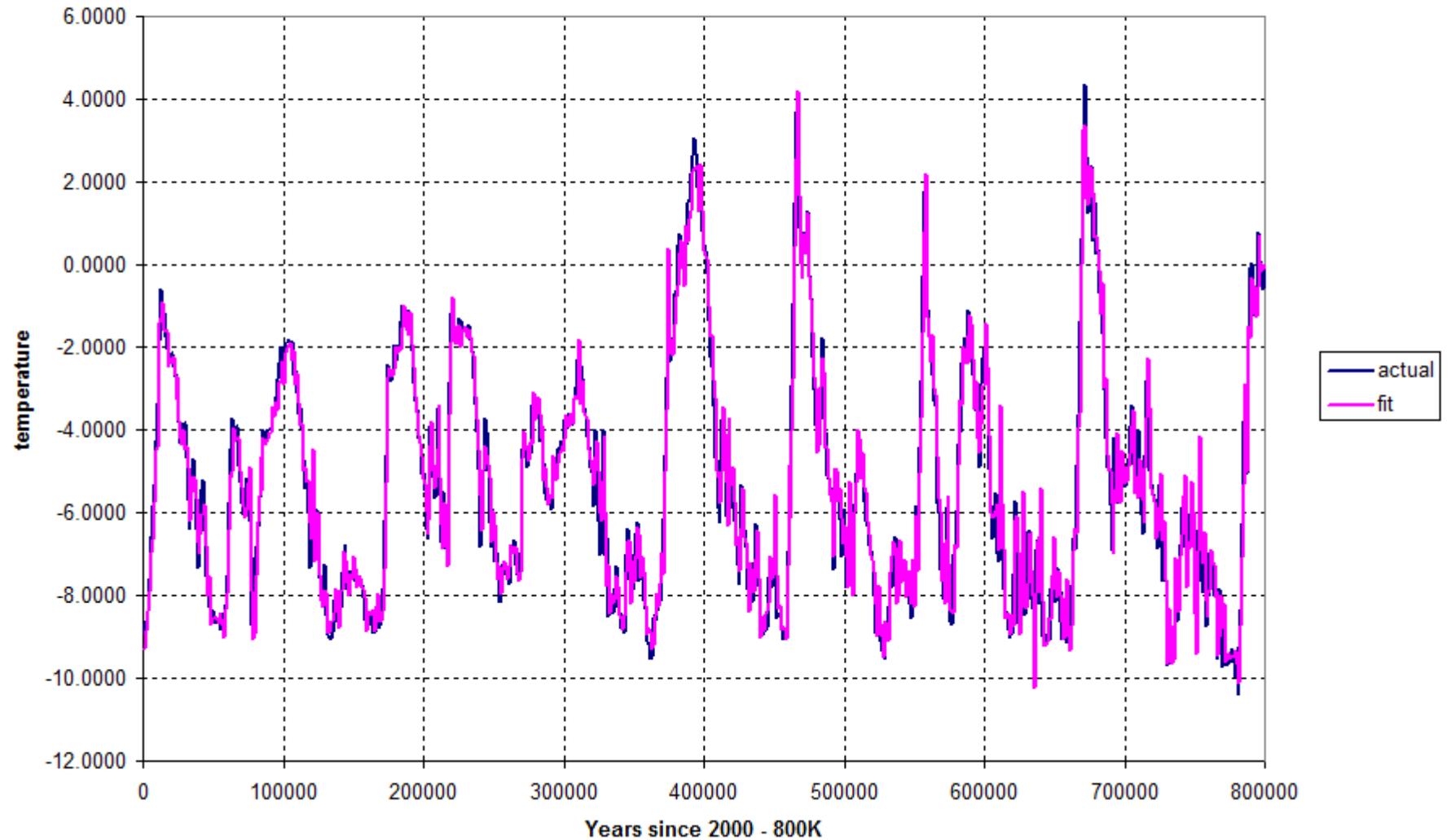
800,000 Year Model
Autocorrelation of Error

lag	Acf	Pacf
1	0.055	0.055
2	-0.034	-0.037
3	-0.020	-0.016
4	0.027	0.028
5	0.072	0.068
6	0.125	0.120
7	0.024	0.017
8	-0.027	-0.019
9	-0.023	-0.020
10	0.042	0.033
11	0.028	0.005
12	-0.074	-0.092

No significant autocorrelations remain

1850 To 2008 Data

- Sources:
  - Temperature – Climatic Research Unit, University of East Anglia
  - CO_2
    - Mauna Loa NOAA station
    - Law dome ice core, Antarctica
  - Downloaded from BBC website http://news.bbc.co.uk/2/hi/in_depth/sci_tech/2009/copenhagen/8393855.stm
- Contents:
  - Temperature by year since 1850
  - CO_2 for selected years since 1850 in parts per million.

1850 to 2008 CO_2 Data

- Used Mauna Loa data from 1959 to 2008
  - 1964 was missing – used average of 1963 and 1965
- Prior to 1959
  - Law Dome Ice core measurements
  - Missing years filled in using linear interpolation.

Temperature and CO2 Since 1850
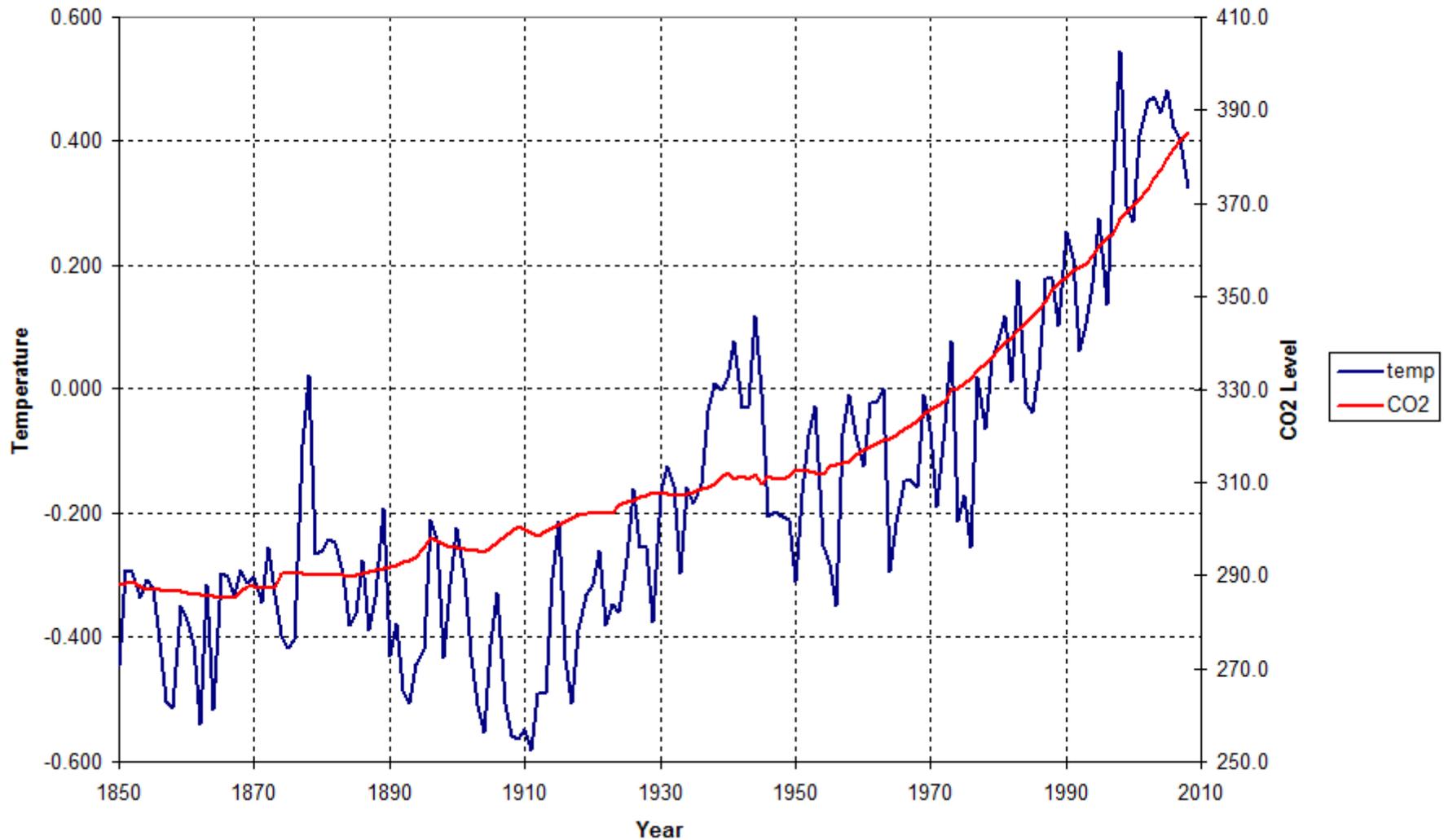
1850 To 2008 Summary Stats

stat	Temp	CO2
min	-0.581	285.2
max	0.546	385.3
mean	-0.172	313.2
std	0.256	26.2
2008	0.325	385.3

Again note that temperature has been warmer and colder but CO_2 has never been higher.

1850 To 2008 Model Same Methodology

- Developed using Autobox
- Autobox automatically finds
  - An ARIMA transfer function model that is both necessary and sufficient - that is:
    - All coefficients in the final model are significant at the .05 confidence level.
    - There is no significant autocorrelation in the errors of the model
  - Outliers in history including:
    - One time outliers (pulses)
    - Level shifts
    - Deterministic time trends
  - Checks for constancy of variance and parameters and adjusts if necessary.

1850 To 2008 Model ARIMA and CO_2

Model Component	lag	coefficient	std error	P value	T value
CONSTANT		-1.980	0.298	0.000	-6.640
Autoregressive-Factor	1	0.399	0.074	0.000	5.410
CO2	0	0.010	0.001	0.000	10.640

Note that the CO_2 coefficient has dropped from .071 in the long term model to .010 in this model.

1850 To 2008 Outliers

type	year	value	std	P value	T value
one time outlier	1877	0.253	0.084	0.003	2.990
one time outlier	1878	0.332	0.084	0.000	3.930
level shift	1890	-0.168	0.033	0.000	-5.130
level shift	1930	0.158	0.034	0.000	4.660
one time outlier	1944	0.156	0.079	0.050	1.980
level shift	1964	-0.171	0.046	0.000	-3.680
one time outlier	1998	0.230	0.079	0.004	2.910

Investigation of other factors that could have caused these outliers could yield important information about causes of temperature change.
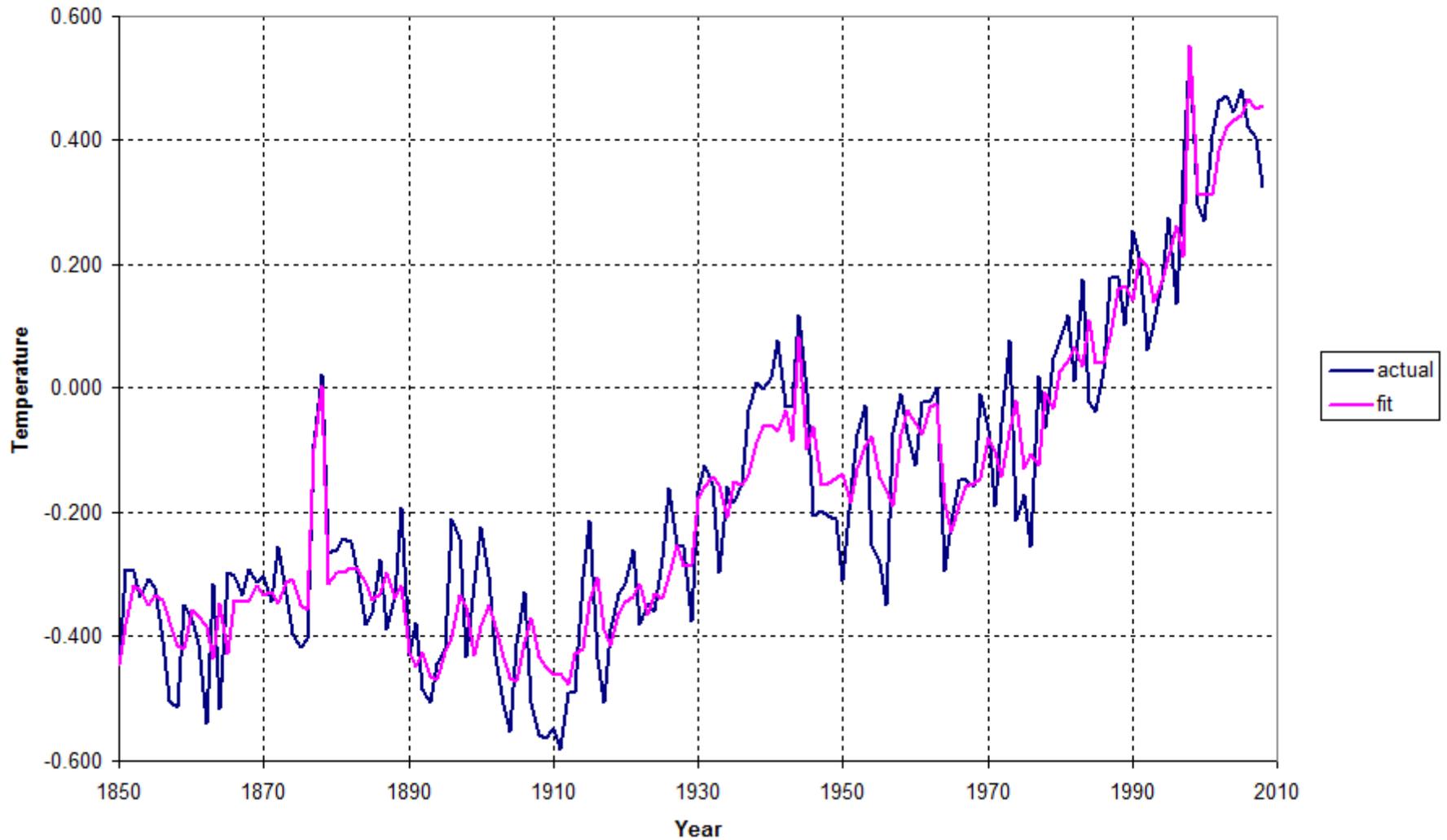
1850 To 2008
Model Summary Stats

Number of Residuals (R)	158
Number of Degrees of Freedom	148
Sum of Squares	1.1
Variance	0.007
Adjusted Variance	0.008
Standard Deviation RMSE	0.087
Standard Error of the Mean	0.007
Mean / its Standard Error	0.002
Mean Absolute Deviation	0.069
R Square	0.890

Again, the fit is very good, but root mean square error is till significant implying uncertainty

1850 To 2008 Model Fit and Actual

1850 To 2008 Model Autocorrelation of Error

lag	Acf	Pacf
1	0.042	0.042
2	-0.018	-0.020
3	-0.096	-0.095
4	0.140	0.149
5	-0.078	-0.098
6	0.009	0.016
7	-0.065	-0.043
8	-0.012	-0.046
9	-0.102	-0.076
10	0.028	0.018
11	-0.077	-0.076
12	-0.098	-0.113

No significant autocorrelations remain

Conclusions

- The relationship between CO_2 and temperature has changed radically in the last century and a half.
- If the previous relationship had held, the current global temperature would be 5.9 degrees warmer.
- This implies that there is at least one if not many other factors that have a huge effect on temperature.
- As a result, it is uncertain whether global temperature will increase or decrease in the future based on CO_2 data alone.

Observations

- Current temperature is nearly the same as it was two and three thousand years ago – Maybe we're just recovering from the little ice age.

- There are numerous times in history where CO_2 went up and temperature went down or visa versa.

- There are many times in history where the temperature was more than 1.5 degrees away from the level predicted by CO_2 alone.

- Studying these outliers and opposites might lead to better knowledge of the causes of world temperature change.