Relationship of Antarctica Temperature to Atmospheric Carbon Dioxide and Methane

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Carbon Dioxide in the Atmosphere

Atmospheric Carbon Dioxide and Antarctica Temperature Data

The data for carbon dioxide (CO_2) concentration in the Earth's atmosphere and for Vostok Antarctica temperature relative to 1990 taken from (**Pettit, 1999**) are shown in Figure 1. Earth average temperature changes are about one-half the polar-regions' temperature changes. (**Houghton, 2004**)

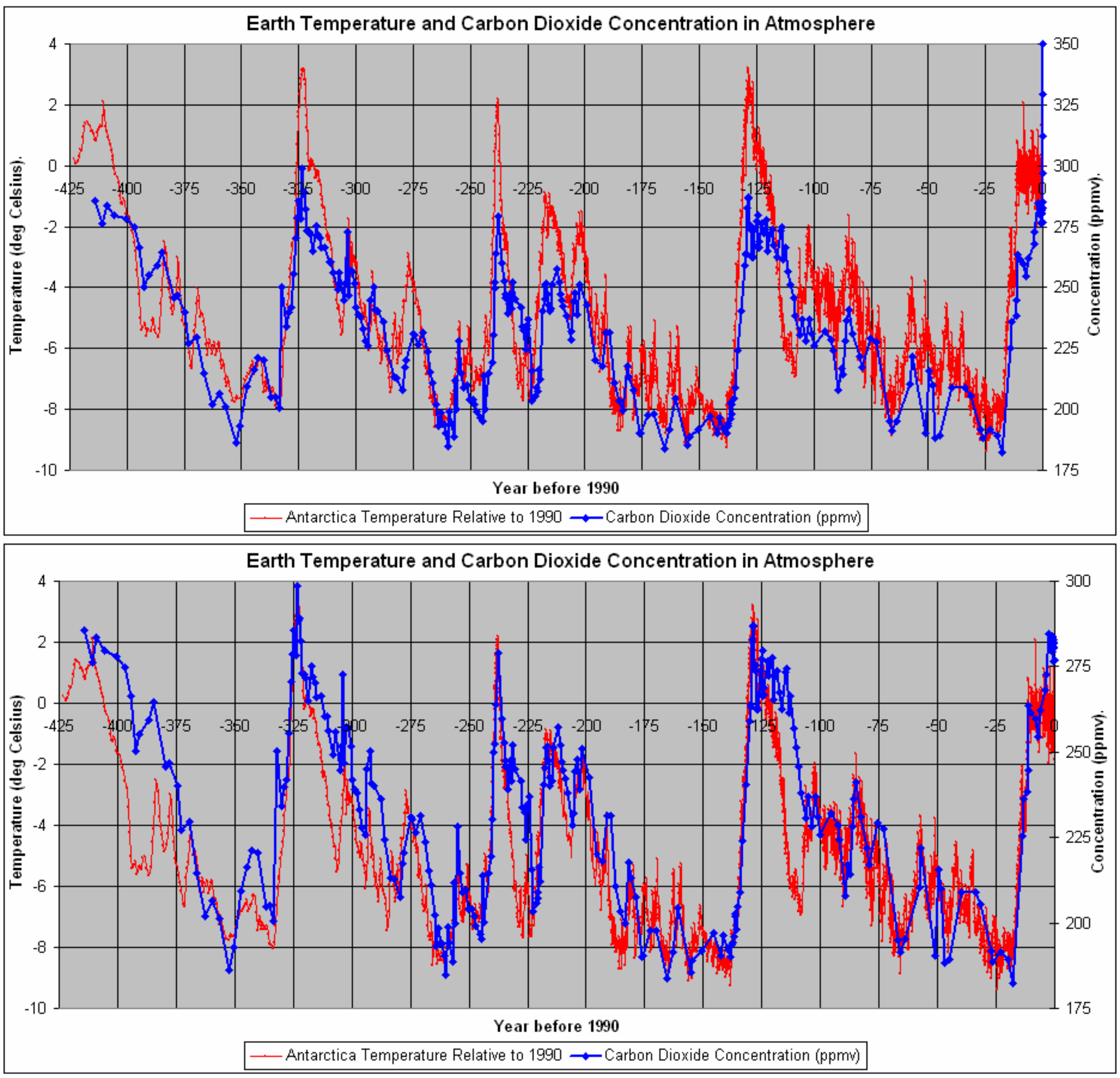


Figure 1. Top: Comparison of Vostok Antarctica temperature for the last 423 kiloyears to carbon dioxide concentration in the atmosphere for the last 414 kiloyears. The temperatures are relative to 1990 at the Vostok site in Antarctica, which is taken as a proxy for about half the Earth's average temperature rise. Note the extreme rise in CO_2 concentration in recent times (near 0 on the horizontal axis. Bottom: The same data sets without the four high CO_2 data for recent times (0 on the right of the time scale).

Notice that the CO_2 concentration shot up from about 280 ppmv (parts per million volume) for most of the current Major Interglacial to 350 ppmv in 1990. In 2005 it was 380 ppm.

Correlation between Antarctica Temperature and Carbon Dioxide Concentration in Upper Atmosphere

A correlation study shows that the Antarctica temperature and CO_2 concentration have the highest correlation (0.869) when the temperature leads the CO_2 by shifting one position in the data array. The data array does not have constant time increments. The median time increment is 920 years. The correlation for no data-array shift is 0.863. Figure 2 shows the correlation coefficients for different values of array shifting for CO_2 concentration lagging the Antarctica temperature.

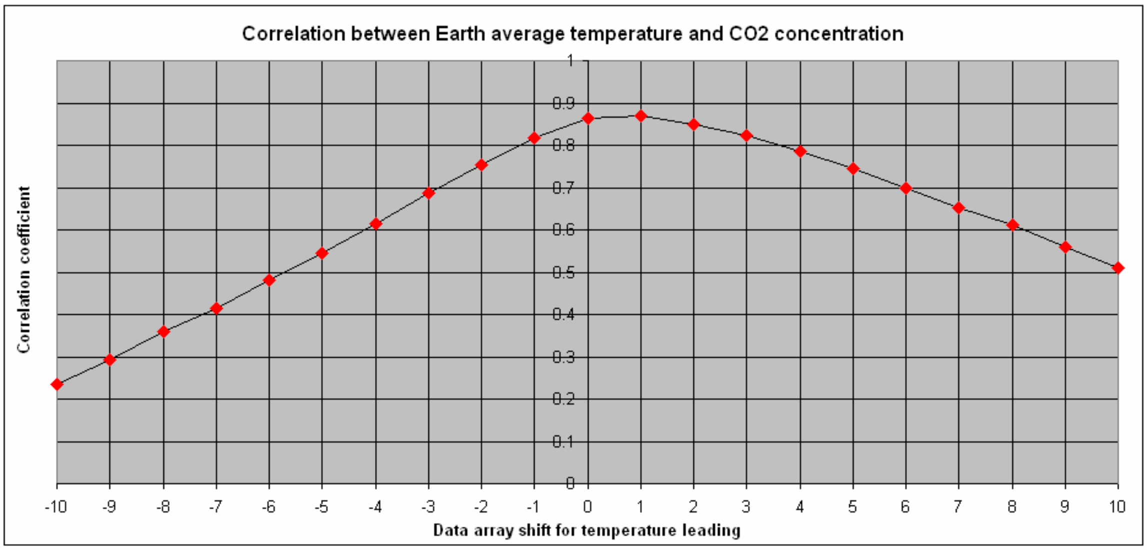


Figure 2. Correlation coefficients for different values of array shifting for CO_2 concentration lagging Antarctica temperature. Since the carbon dioxide concentration data and the Antarctica temperature data are not measured at exactly the same times, I had to pick out Antarctica temperature data as near as possible in time to the carbon dioxide data in order to calculate the correlations.

The high correlation between carbon dioxide concentration in the atmosphere and the Antarctica temperature makes it clear that the two are causally connected. There are many physical reasons why changes in the Antarctica temperature change the CO_2 concentration in the atmosphere and vice versa (**Houghton, 2004**). The causal relationship is a mutual feedback one; that is, when one increases the other increases and when one decreases the other decreases. Although the CO_2 concentration lags temperature changes, the feedback of the greenhouse effect causes the temperature to further change as the CO_2 concentration changes. There is no valid argument against the fact that the projected future high carbon dioxide concentrations will lead to higher Earth average temperatures.

The peak in the correlation coefficient curve is at about 0.6 data-array shifts or about 550 years. So the recent fast rise in CO_2 concentration will probably cause an increase of the Antarctica temperature over several hundred years into the future and future increases in CO_2 concentration will do the same. So Earth's inhabitants have many hundreds of years of increasing temperatures to endure, unless the high temperatures turn off the North Atlantic ocean currents and thereby trigger the next 115,000 year-long Major Ice Age. (See http://www.roperld.com/science/HumanFuture.pdf .)

Just because CO_2 concentration lags temperature in the data does not mean that CO_2 concentration changes do not cause temperature changes. The science of such dependence is well established. A simple model of mutual positive feedback among two variables shows that which one leads or lags depends on which one is changed first after a steady state situation. (http://www.roperld.com/science/feedback.pdf) It appears reasonable to assume that the lag in temperature after an independent change in CO_2 concentration is about 500 years.

Variation of Atmospheric Carbon Dioxide and Antarctica Temperature for the last 414 kiloyears

The Antarctica temperatures relative to 1990 and the atmospheric carbon dioxide concentrations of the five Major Interglacials of the last 423 kiloyears are given in Table 1, along with the current and projected values.

Table 1. Comparison of data for the five Major Interglacials (MI) of the last 425 kiloyears with recent and future years (Houghton, 2004) (ybp = years before 1990).

Major Interglacial	Temperature relative to 1990 (degrees Celsius)	Carbon dioxide concentration in the atmosphere (ppmv)
2100 (business as usual)	?	650
2100 (lowest possible)	?	450
2005	0.3	380
0 (1990)	0	350
0 (1740 before industrialization)	0	280 (before industrialization)
127 ybp (previous MI)	2.7 (Antarctica temperature)	287
238 ybp (2nd previous MI)	2.1 (Antarctica temperature)	279
323 ybp (3rd previous MI)	3.2 (Antarctica temperature)	299
417 ybp (4th previous MI)	1.4 (Antarctica temperature)	286

There is a delay time of the order of centuries after carbon dioxide concentration is raised before the Earth temperature rises to catch up with it. (See Figure 2 above.) For example, if the CO_2 concentration stayed at 380 ppmv, the temperature of the Earth would continue to rise for several centuries; how much will be discussed below.

The “2100 business as usual” scenario would be disastrous for living beings on the Earth! Even the “2100 lowest possible” scenario will be a calamity.

I now will fit linear and quadratic functions to the CO_2 atmospheric concentration versus Antarctica’s temperature. Since the carbon dioxide concentration data and the Antarctica temperature data are not measured at exactly the same times, I had to pick out Antarctica temperature data as near as possible in time to the carbon dioxide data in order to plot the two types of data together, as shown in Figure 3.

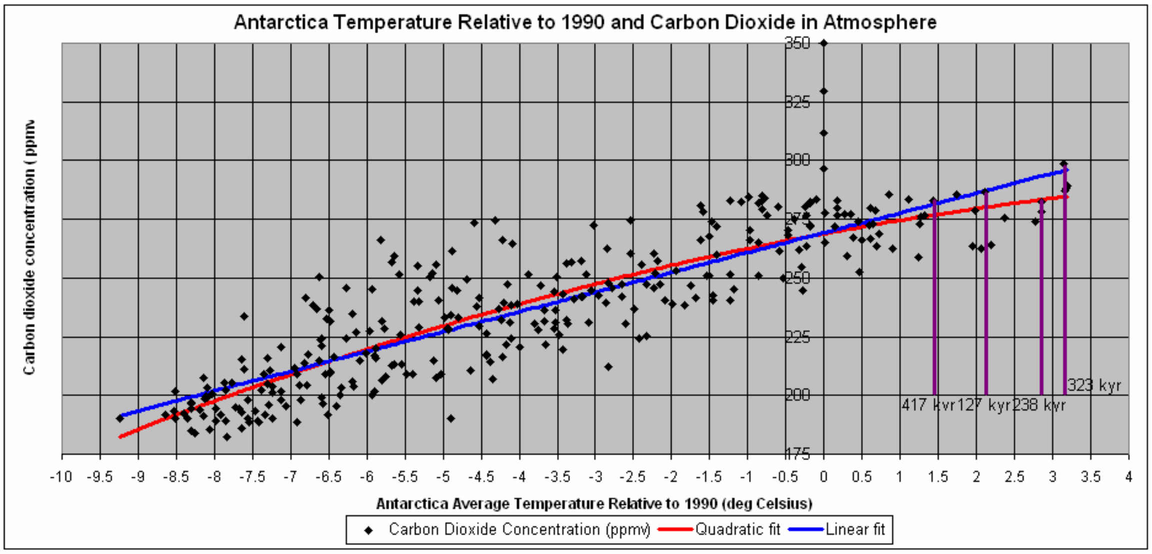


Figure 3. CO_2 data versus Antarctica temperature and linear and quadratic fits to the data excluding the four high recent values up to 1990 (near 0 on the horizontal temperature axis). The four previous Major Interglacials are marked by vertical bars with the times in ybp.

The two curves in Figure 3 show linear and quadratic fits to the data. The quadratic fit is a slightly better fit than the linear fit. One can extrapolate these two fits to higher CO_2 concentrations and read off the predicted Vostok Antarctica eventual temperature change relative to 1990, as shown in Figure 4. (The Earth average temperature change is about one-half the Antarctica temperature change.) (**Houghton, 2004**)

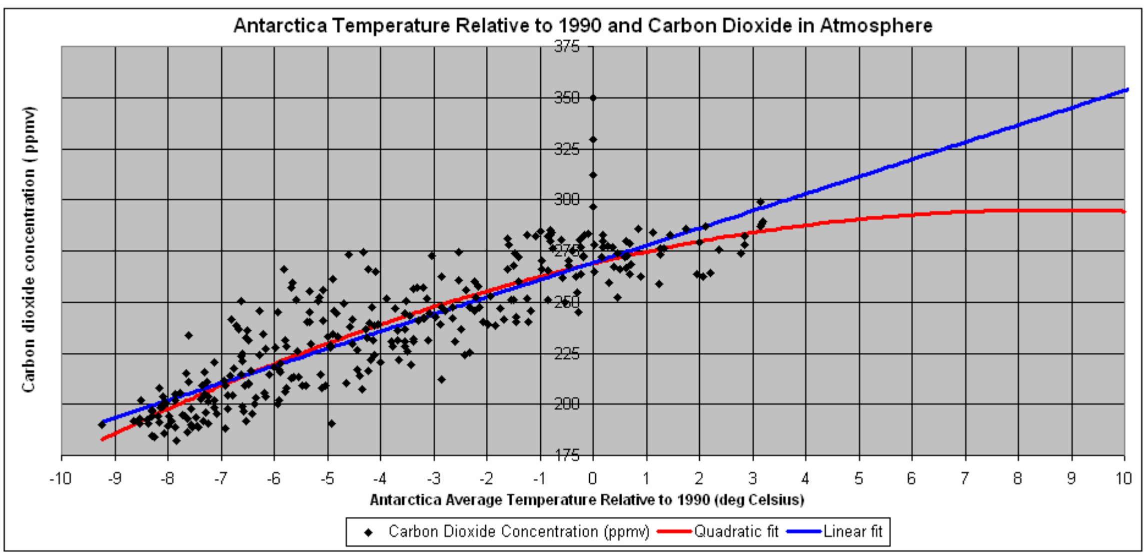


Figure 4. Projection of linear and quadratic fits to higher carbon dioxide concentrations in the upper atmosphere.

We see that the quadratic fit yields a "runaway" global warming scenario; that is, CO_2 concentrations above about 300 ppmv lead to "ever increasing" Earth temperatures.

The linear fit indicates that the 1990 CO_2 concentration of 350 ppmv leads to an eventual Antarctica temperature of about 10 Celsius degrees higher than 1990's. The higher concentrations of 380 ppmv for

2005 and minimum projected 450 ppmv for 2100 would lead to extremely high Antarctica temperatures. I do not try to extrapolate to such high temperatures since many other climate feedback mechanisms will surely come into play for such high temperatures.

Since carbon dioxide concentration in the upper atmosphere will increase due to human activity for a long time into the future and, accordingly, temperatures will increase, in order to project into the future perhaps one should use only data for times when the concentration rises as temperature is rising, as shown in Figure 5.

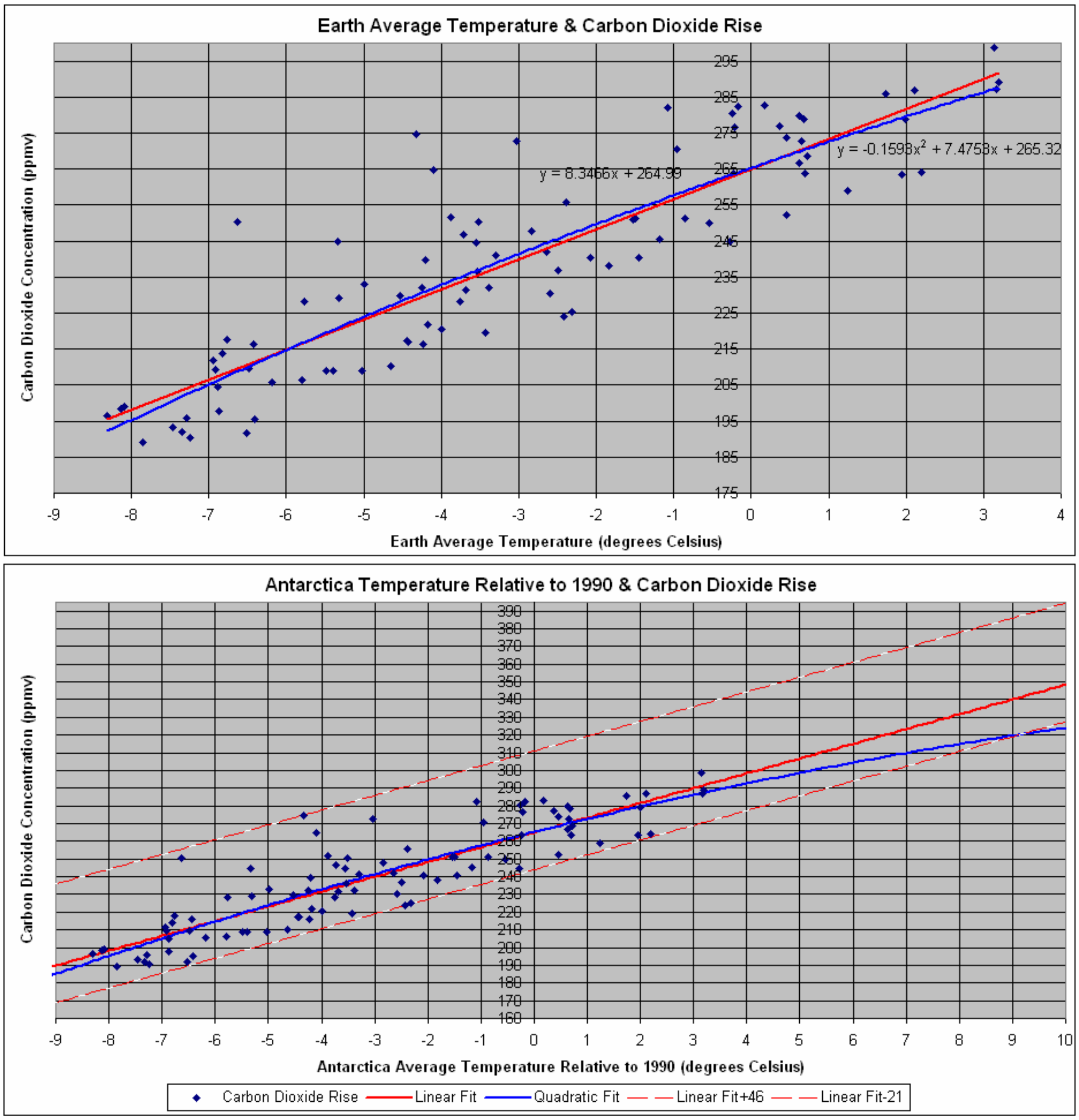


Figure 5. Top: Rising CO_2 atmospheric concentration versus rising Antarctica temperature and linear and quadratic fits to the data excluding the four high recent values up to 1990 (near 0 on the horizontal temperature axis). Bottom: The data and the fits projected out to 10 Celsius degrees more than the 1990 Antarctica temperature. The Two dotted lines are parallel lines to the linear fit drawn through the maximum and minimum concentrations, to give an estimate of possible uncertainties in the projection.

The two dotted lines parallel to the linear fit in the bottom part of Figure 5 are drawn through the maximum and minimum carbon dioxide concentrations in order to give an estimate of possible uncertainties in the projection. It is seen that the 377 ppmv in 2004 would eventually (in a few hundred years) be associated with an Antarctica temperature rise of at least 10 Celsius degrees above the 1990 value.

The linear fit of Figure 5 is extended to include the 1990, 2004 and projected 2100 carbon dioxide concentrations in the upper atmosphere in Figure 6.

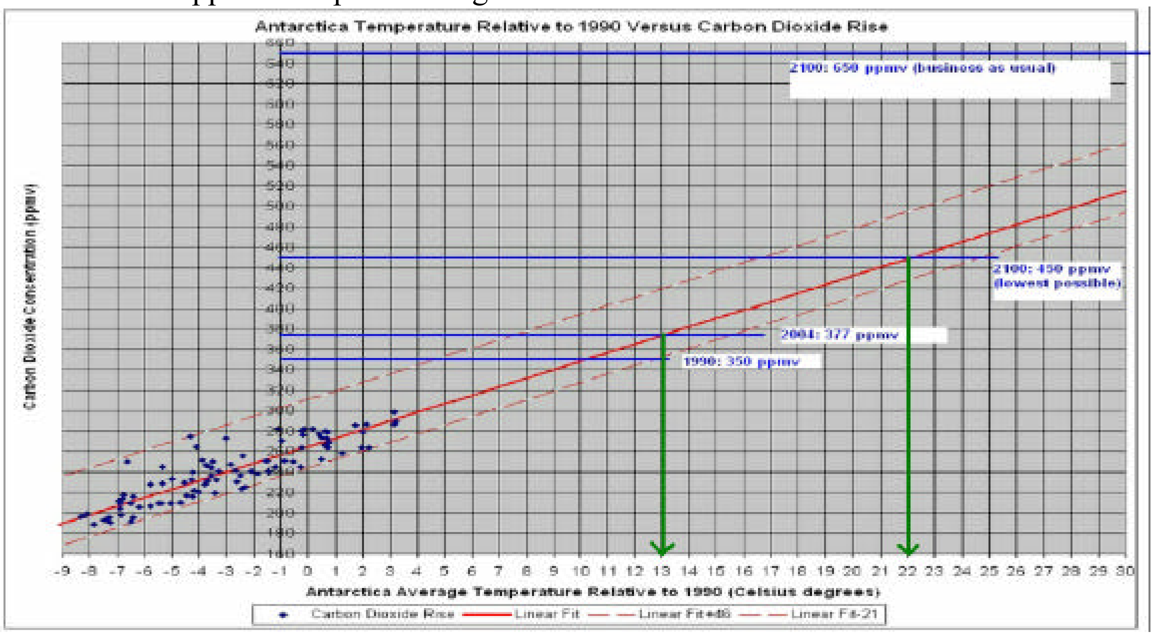


Figure 6. Figure 5 extended to include the 1990, 2004 and projected carbon dioxide concentrations in the upper atmosphere.

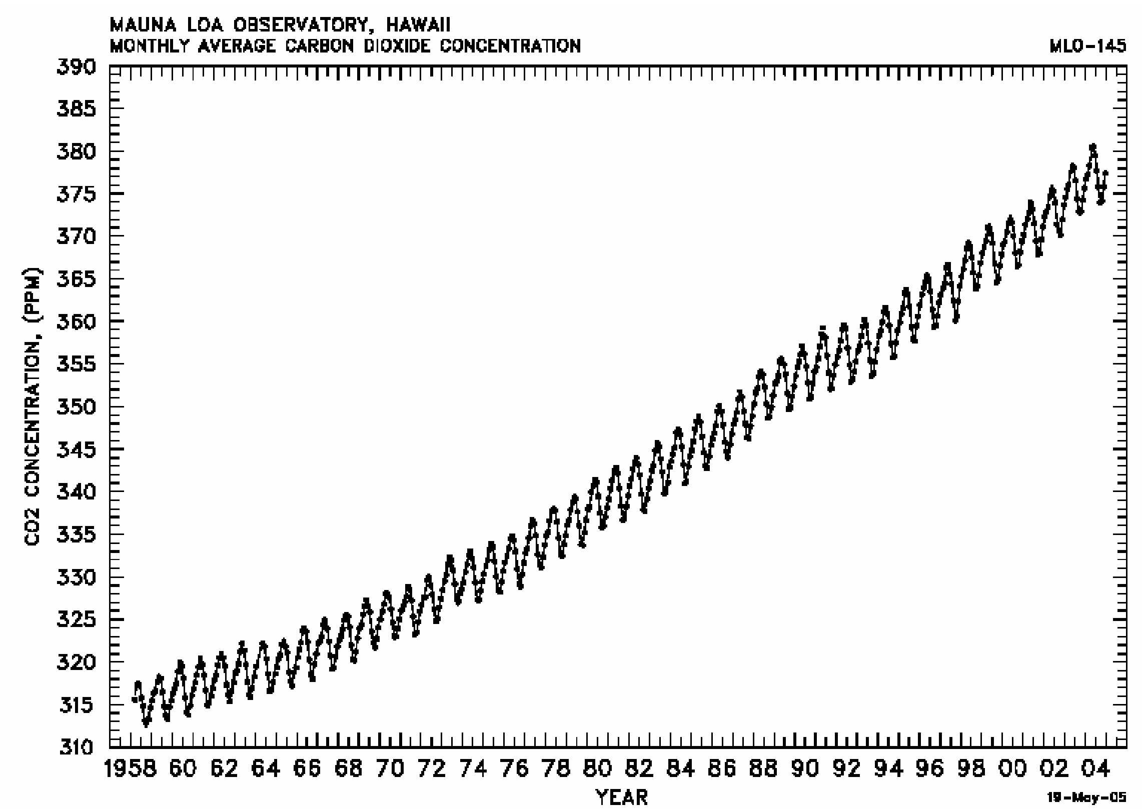
The data points in the lower left corner are from Antarctica ice cores and show how the concentration in the upper atmosphere of carbon dioxide, the major greenhouse gas, has increased along with increasing temperature at different times for Antarctica over the last 423 kiloyears. If this relationship holds for higher concentrations, which is indicated by the red sloping line with parallel dotted uncertainty lines, the second horizontal blue line from the bottom shows what we could eventually expect for Antarctica temperature changes (an increase of about 13 Celsius degrees or 23 Fahrenheit degrees more than 1990) due to the carbon dioxide concentration in 2004. The top two horizontal blue lines bracket indicated temperature changes from 1990 that Antarctica could eventually expect due to the carbon-dioxide concentration in the year 2100 (at least an increase of 22 Celsius degrees or 40 Fahrenheit degrees more than 1990). The bottom of those two top horizontal blue lines is the lowest possible concentration case and the top one is what "business as usual" might bring, a horrible thing to consider.

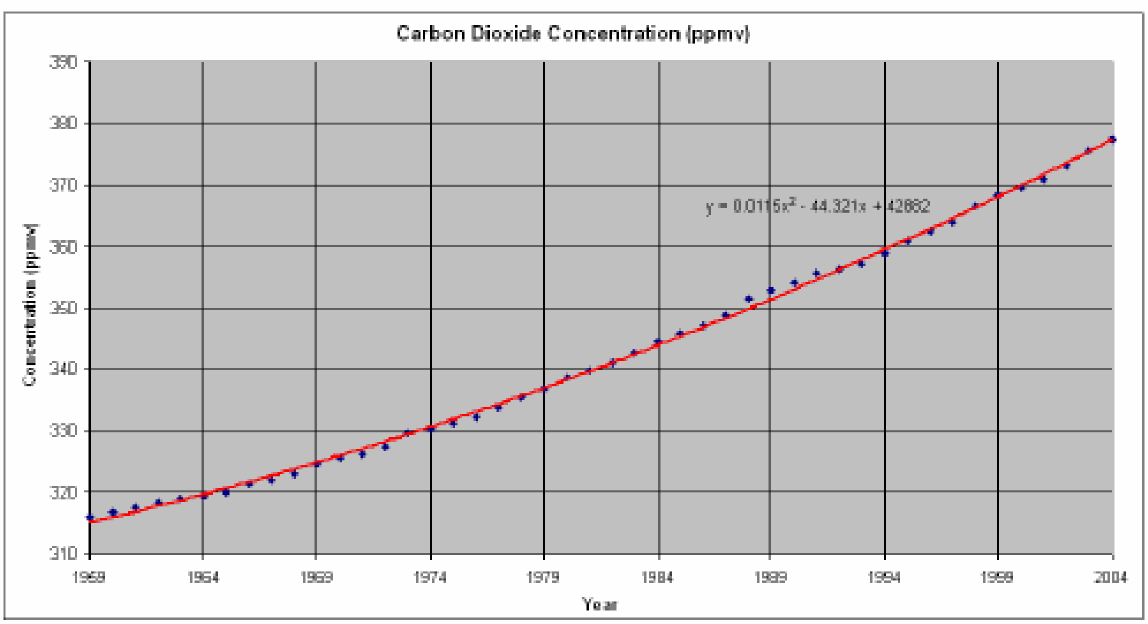
The Earth has never experienced such large temperature changes in such short periods of time, so the many complex feedback interactions may cause even more drastic changes, such as triggering the start of the next Major Ice Age of 100 thousand years duration.

In any case, disaster awaits the World unless we reduce greenhouse gases in the atmosphere.

Recent and Future Carbon Dioxide Concentration in the Earth's Upper Atmosphere

The famous carbon dioxide concentration data graph of Keeling's Carbon Dioxide Research Group at Mauna Loa volcano in Hawaii are shown in the top part of Figure 7. (**Keeling, 2004**)





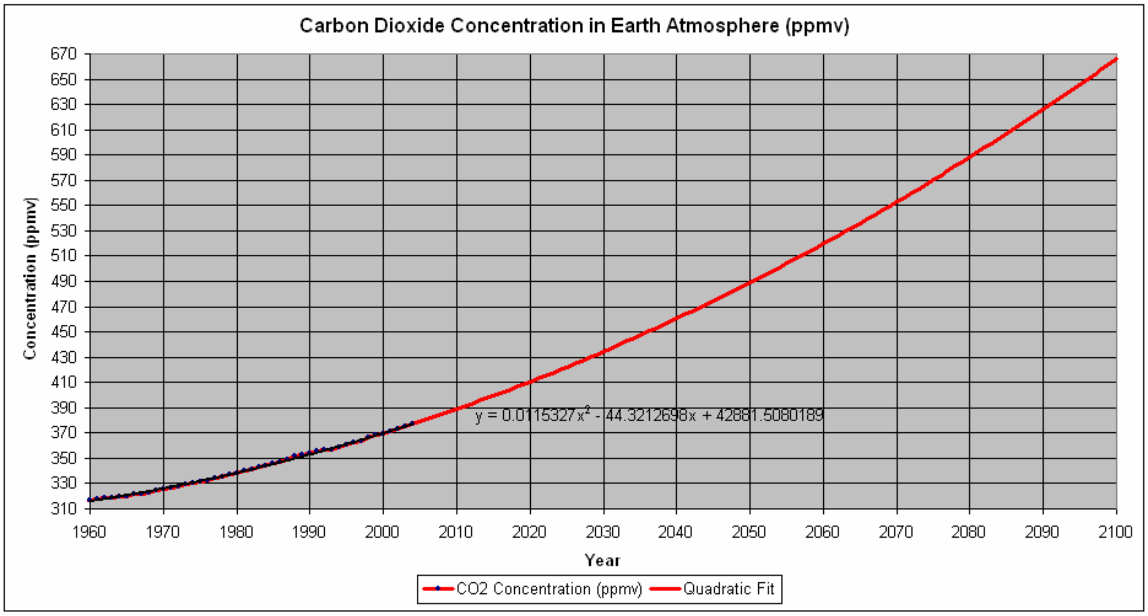


Figure 7. Top: Carbon dioxide concentration data of the Carbon Dioxide Research Group at Mauna Loa volcano in Hawaii. Note the seasonal saw tooth effect. Middle: The average yearly data and a quadratic fit to them. Bottom: The quadratic fit to the data extrapolated to the year 2100.

If the temperature projection curves of Figure 4 are used to project future eventual Antarctica temperatures due to these projected carbon dioxide concentrations, extremely high Antarctica temperatures, much larger than 10 Celsius degrees above the 1990 temperature, are projected.

Figure 8 shows the predicted future Antarctica temperatures if the atmospheric concentration of carbon dioxide continues to grow as shown in Figure 7. It is assumed that there is a 500-year lag of the temperature behind the concentration (via a hyperbolic tangent).

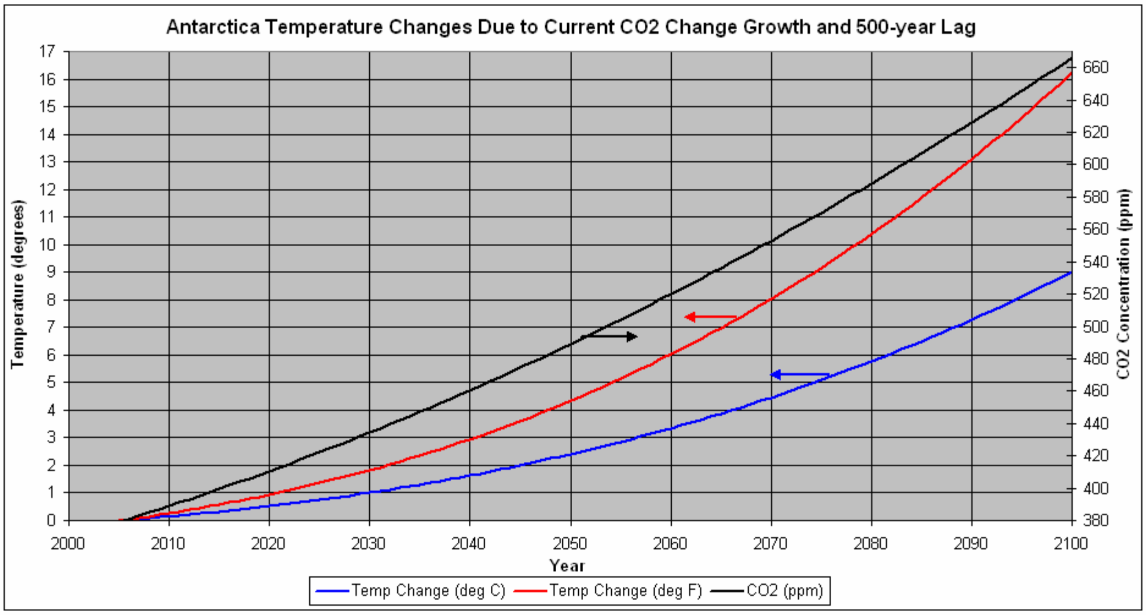


Figure 8. Projected Antarctica temperatures assuming continued growth in carbon-dioxide concentration in the atmosphere as shown in Figure 7 and a lag of 500 years for temperature behind concentration.

Suppose that humans could prevent the increase in growth rate and maintain a steady growth of 2.5 ppmv per year. Then Figure 9 shows the predicted future Antarctica temperatures.

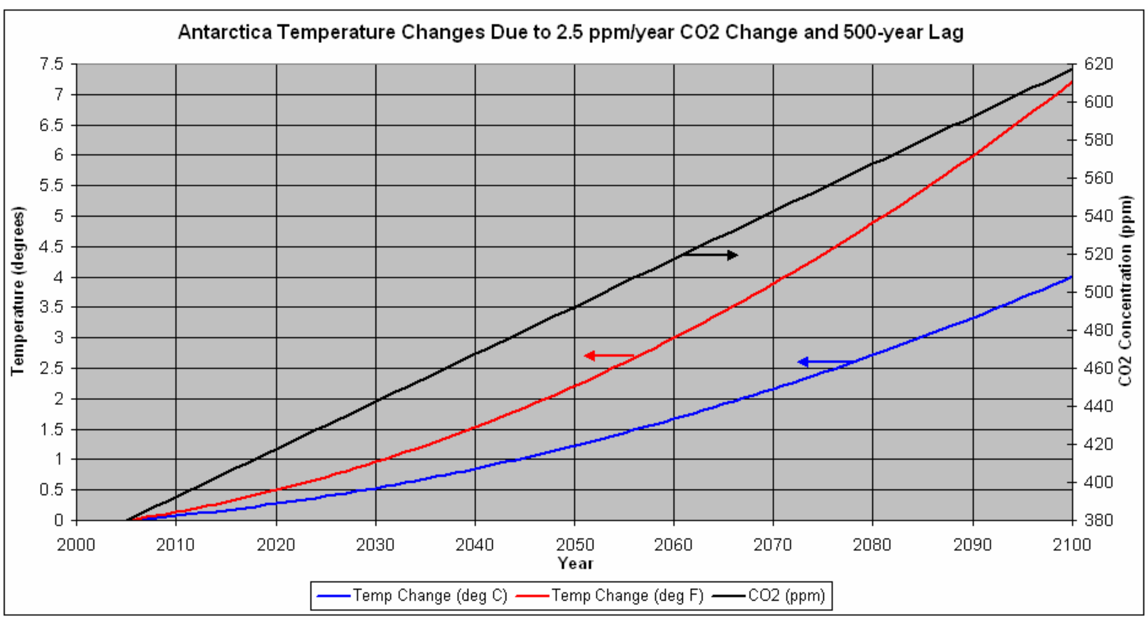


Figure 9. Projected Antarctica temperatures assuming a constant increase in carbon-dioxide concentration of 2.5 ppmv per year in the atmosphere and a lag of 500 years for temperature behind concentration.

Suppose that humans could level off carbon-dioxide concentration in the atmosphere to 500 ppmv in 100 years (via a hyperbolic tangent). Then Figure 10 shows the predicted future Antarctica temperatures.

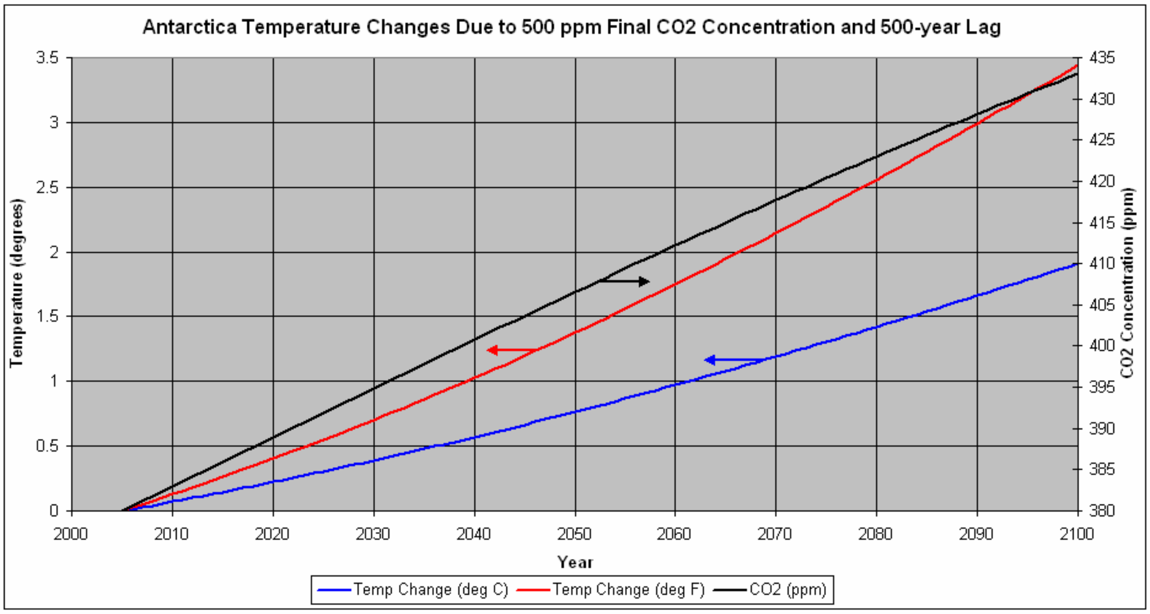


Figure 10. Projected Antarctica temperatures assuming an asymptotic approach to 500 ppmv carbon-dioxide concentration in the atmosphere and a lag of 500 years for temperature behind concentration.

Suppose that humans could keep the carbon-dioxide concentration constant in the atmosphere at the 2005 value of 380 ppmv. Then Figure 11 shows the predicted future Antarctica temperatures.

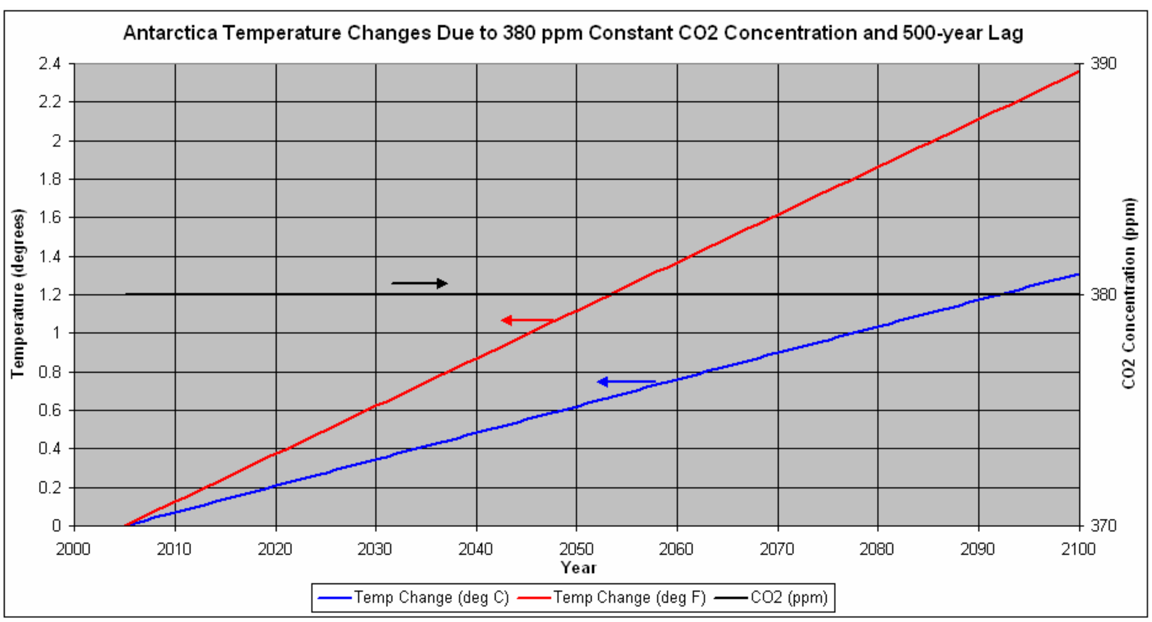


Figure 11. Projected Antarctica temperatures assuming a constant carbon-dioxide concentration of 380 ppmv per year in the atmosphere and a lag of 500 years for temperature behind concentration.

Suppose that humans could cause the carbon-dioxide concentration in the atmosphere to reduce to 300 ppmv in 100 years (via a hyperbolic tangent), the maximum value it had over the last 420 kiloyears before humans started increasing it. Then Figure 12 shows the predicted future Antarctica temperatures.

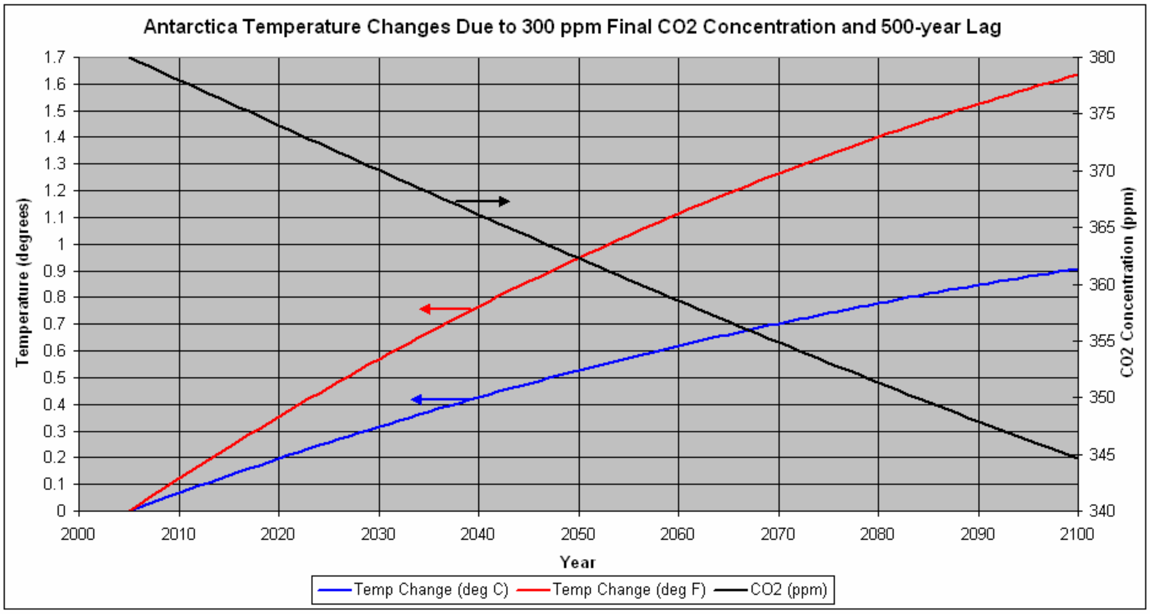


Figure 12. Projected Antarctica temperatures assuming an asymptotic approach to 300 ppmv carbon-dioxide concentration in the atmosphere in 100 years and a lag of 500 years for temperature behind concentration.

Suppose that humans could cause the carbon-dioxide concentration in the atmosphere to reduce to 275 ppmv in 100 years (via a hyperbolic tangent), the maximum value it had over the current Major Interglacial before humans started increasing it. (See Figure 1.) Then Figure 13 shows the predicted future Antarctica temperatures.

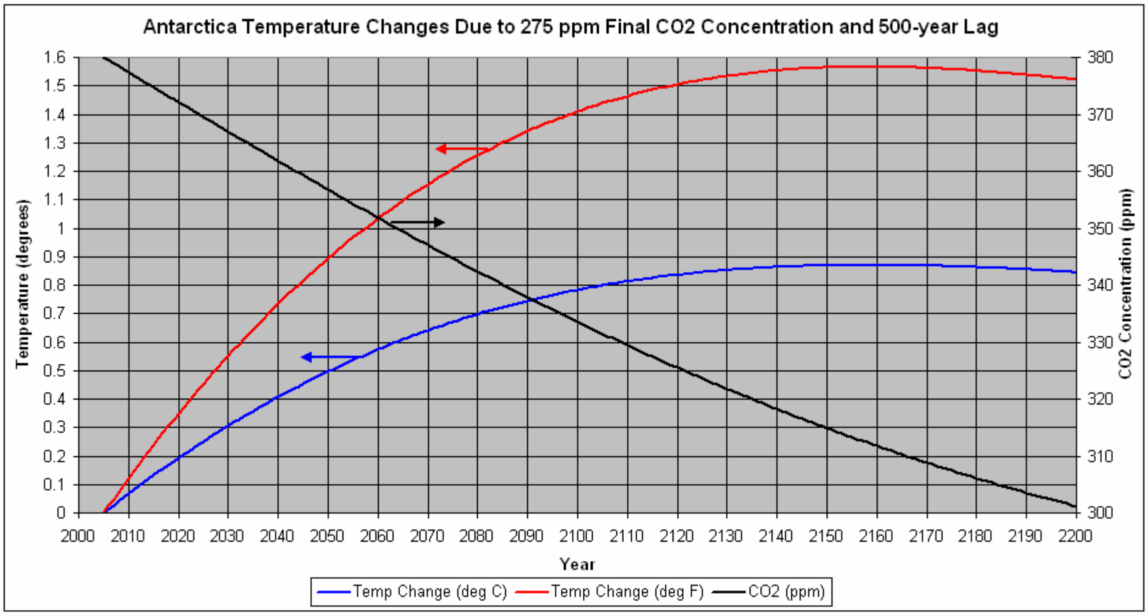


Figure 13. Projected Antarctica temperatures assuming an asymptotic approach to 275 ppmv carbon-dioxide concentration in the atmosphere in 100 years and a lag of 500 years for temperature behind concentration.

Table 2 summarizes the results of the calculations presented in Figure 8 through Figure 13.

Table 2. Antarctica temperature changes from 1990 in (Celsius degrees)/(Fahrenheit degrees) for different scenarios of carbon-dioxide concentration in the atmosphere in the future.

	2050	2100	2200	2300
Business as usual	1.2/2.2	4.6/8.2	21.4/38.6	57.9/1104
Growth 2.5 ppmv per year	1.2/2.2	4.0/7.2	13.9/25.0	29.3/51.7
Asymptotically approach 500 ppmv	0.8/1.4	1.9/3.4	4.7/8.5	7.7/13.8
Constant 380 ppmv	0.6/1.1	1.3/2.4	2.7/4.8	4.0/7.1
Asymptotically approach 300 ppmv	0.5/0.9	0.9/1.6	1.3/2.3	1.5/2.7
Asymptotically approach 275 ppmv	0.5/0.9	0.8/1.4	0.8/1.5	0.7/1.3

Atmospheric concentration of carbon dioxide of 300 ppmv is 21% below the current level of 380 ppmv and 275 ppmv is 27% below the current level of 380 ppmv. It appears that a goal of 25% to 30% reduction of carbon-dioxide concentration in Earth’s atmosphere is what is needed to keep Antarctica’s temperature from rising more than a few degrees.

Methane in the Atmosphere

Atmospheric Methane and Antarctica Temperature Data

The data for Methane (CH_4) concentration (ppbv = parts per billion volume) in the Earth's atmosphere and for Antarctica temperatures taken from (**Pettit, 1999**) are shown in Figure 14.

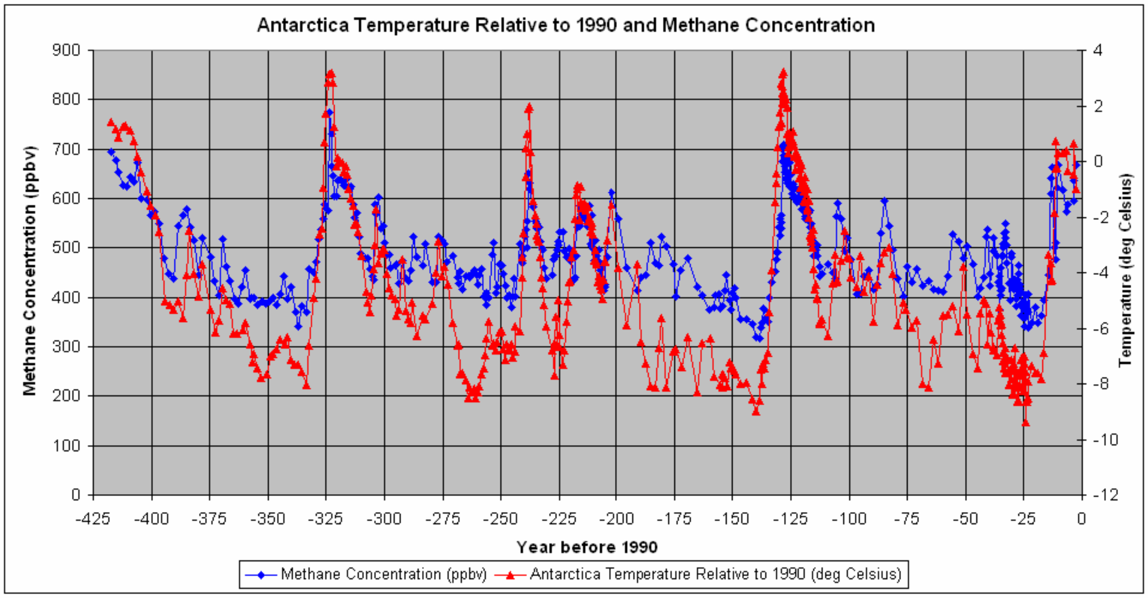


Figure 14. Comparison of Antarctica temperature for the last 423 kiloyears to methane concentration in the atmosphere for the last 417 kiloyears. The temperatures are relative to 1990 at the Vostok site in Antarctica, which is taken as a proxy for the Earth's average temperature rise.

Correlation between Antarctica Temperature and Methane Concentration in Upper Atmosphere

A correlation study shows that the Antarctica temperature and CH_4 concentration in the atmosphere yields the highest correlation (0.864) when the temperature leads the CH_4 concentration in the upper atmosphere by shifting one position in the data array. The data array does not have constant time increments. The median time increment is 714 years. The correlation for no data-array shift is 0.854. Figure 15 shows the correlation coefficients for different values of array shifting for CH_4 concentration lagging the Antarctica temperature.

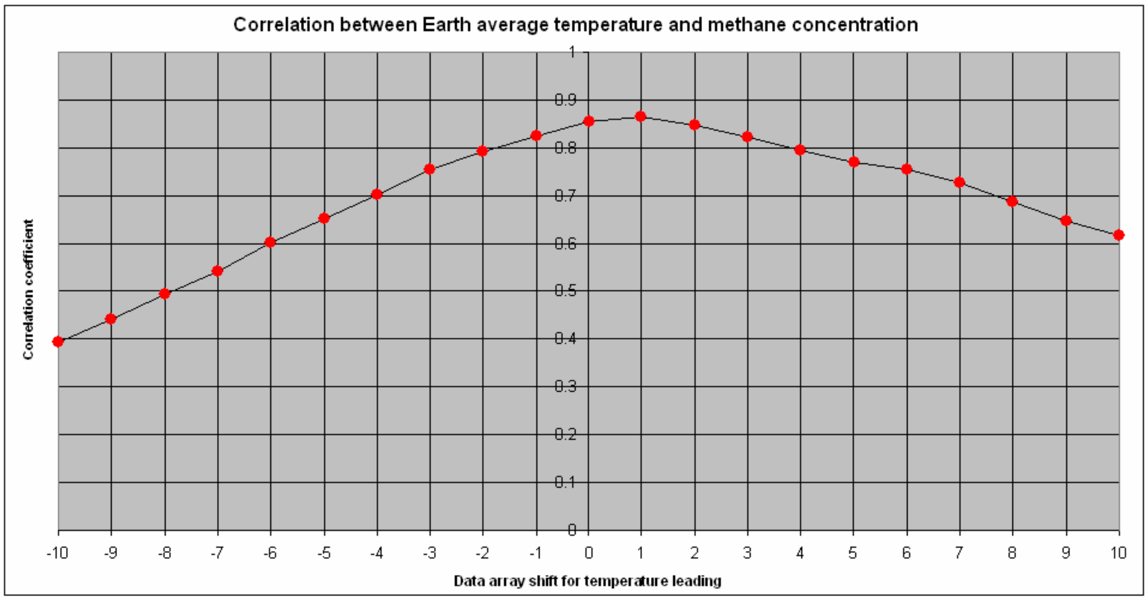


Figure 15. Correlation coefficients for different values of array shifting for CH_4 concentration leading Antarctica temperature. Since the methane concentration data and the Antarctica temperature data are not measured at exactly the same times, I had to pick out Antarctica temperature data as near as possible in time to the methane data in order to calculate the correlations.

The high correlation between methane concentration in the atmosphere and the Antarctica temperature makes it clear that the two are causally connected. There are many physical reasons why changes in the Antarctica temperature change the CH_4 concentration in the atmosphere and vice versa (**Houghton, 2004**). The causal relationship is a mutual feedback one; that is, when one increases the other increases and when one decreases the other decreases. Although the CH_4 concentration lags temperature changes, the feedback of the greenhouse effect causes the temperature to further change as the CH_4 concentration changes. There is no valid argument against the fact that the projected future high methane concentrations will lead to higher Earth average temperatures.

The peak in the correlation coefficient curve is at about 0.6 data-array shifts or about 430 years. So the recent fast rise in CH_4 concentration will probably increase Antarctica temperature over several hundred years into the future and future increases in CH_4 concentration will do the same. So Earth's inhabitants have many hundreds of years of increasing temperatures to endure, unless the high temperatures turn off the North Atlantic ocean currents and thereby trigger the next 115,000 year-long Major Ice Age. (See http://www.roperld.com/science/HumanFuture.pdf .)

Variation of Atmospheric Methane and Antarctica Temperature for the last 414 kiloyears

Figure 16 shows the methane concentration in the Earth's atmosphere versus the Antarctica temperature for the last 417 kiloyears. Linear and quadratic fits to the data are shown, also.

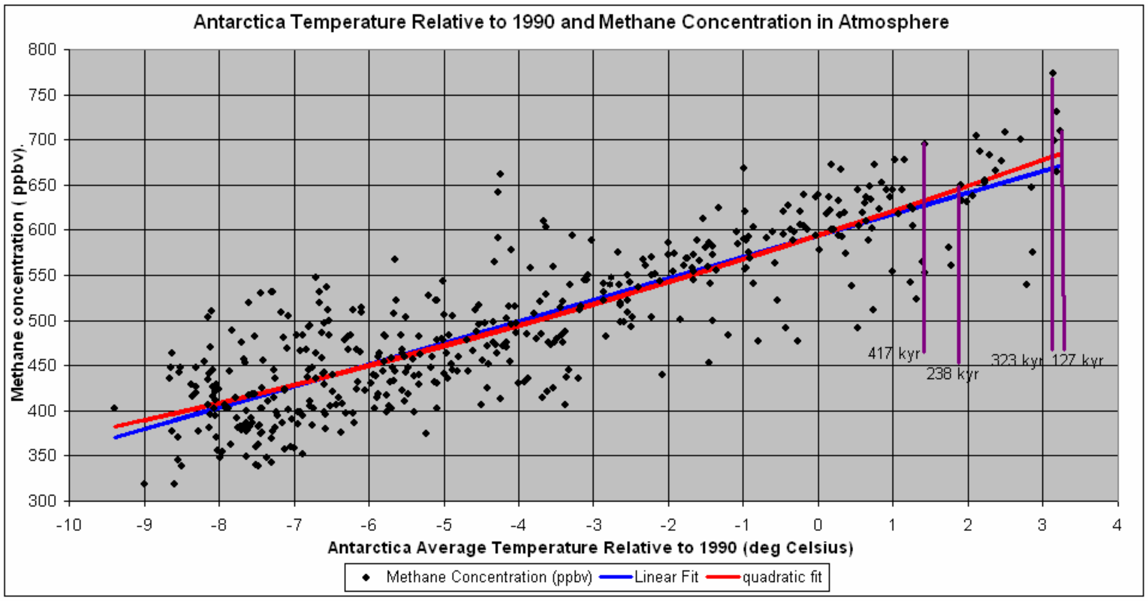


Figure 16. CH_4 data versus Antarctica temperature and linear and quadratic fits to the data. The four previous Major Interglacials are marked by vertical bars with the times in ybp. Since the methane concentration data and the Antarctica temperature data are not measured at exactly the same times, I had to pick out Antarctica temperature data as near as possible in time to the methane data in order to calculate the correlations.

The two curves in Figure 16 show linear and quadratic fits to the data. The quadratic fit is a slightly better fit than the linear fit. One can extrapolate these two fits to higher CH_4 concentrations and read off the predicted temperature, as shown in Figure 17.

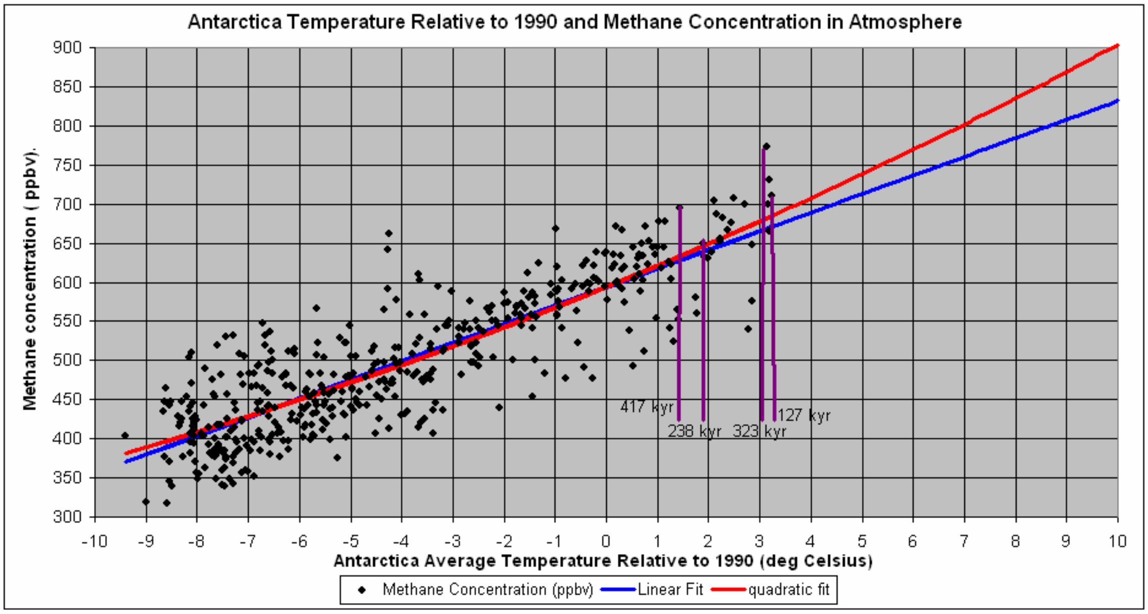


Figure 17. Projection of linear and quadratic fits to higher methane concentrations in the upper.

The linear fit indicates that the 1990 CH_4 concentration of 1720 ppbv, which is way off the chart, leads to an eventual Antarctica temperature much higher than 10 Celsius degrees relative to 1990

Recent and Future Methane Concentration in the Earth's Upper Atmosphere

Recent measurements of methane concentration in the upper atmosphere are shown in Figure 18.

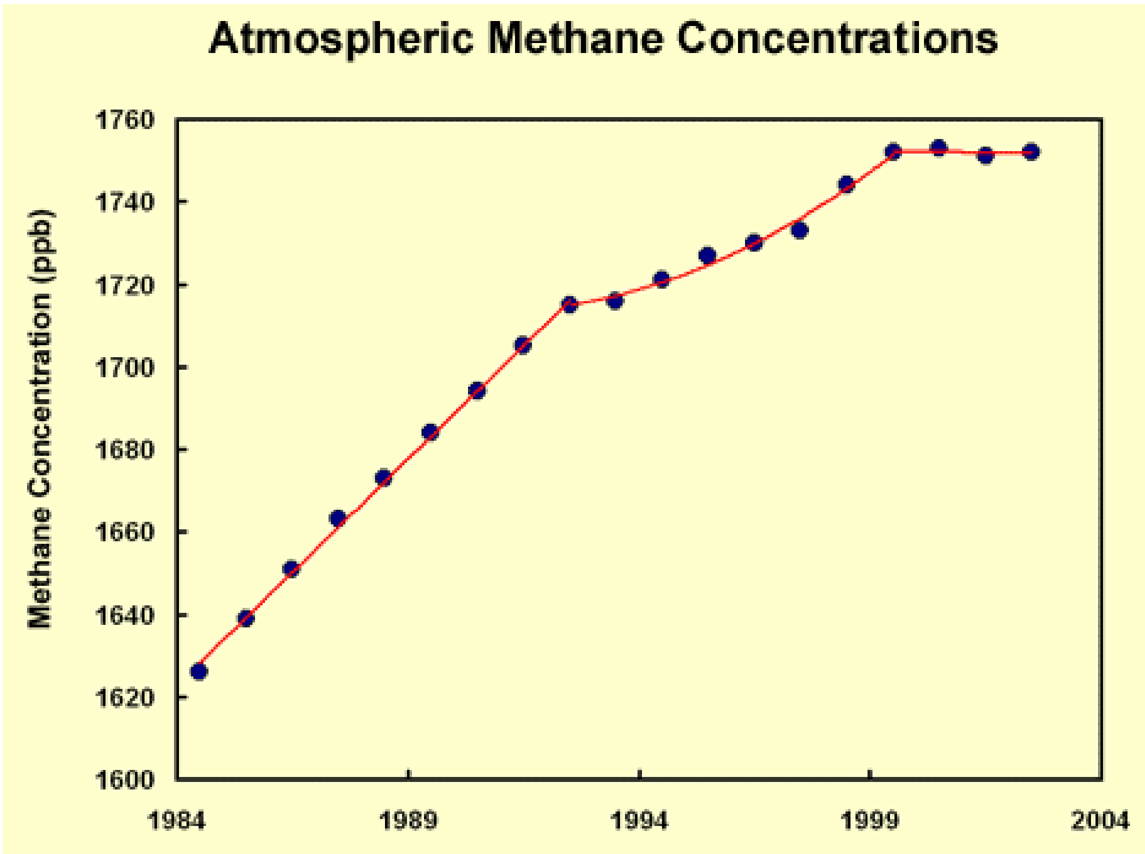


Figure 18. Recent measurements of methane concentration in the upper atmosphere. (http://www.epa.gov/methane/scientific.html)

It appears that the methane concentration is leveling off. Some reasons for that may be:

- Methane's average lifetime in the atmosphere is twelve years, much shorter than for carbon dioxide. Recent higher concentrations of carbon dioxide in the upper atmosphere may speed up the removal of methane.
- Oil wells flare less methane into the atmosphere now than in previous years, since natural gas is a preferred fuel now because of its low pollution emissions and peaking of crude oil extraction. Burning the methane adds to the amount of carbon dioxide in the upper atmosphere.
- More waste dumps are being tapped for the methane gas generated to use as fuel or covered to prevent its release into the atmosphere.
- More methane from animal wastes is being captured for fuel.

Figure 19 shows methane concentration data since the year 1930 and a fit of the following equation to the data:

$$c + a\left[1 + \tanh\left(\frac{t - t_0}{t}\right)\right],$$

where the fit yields $c = 1058$, $a = 376.4$, $t_0 = 1972$ and $t = 21.76$.

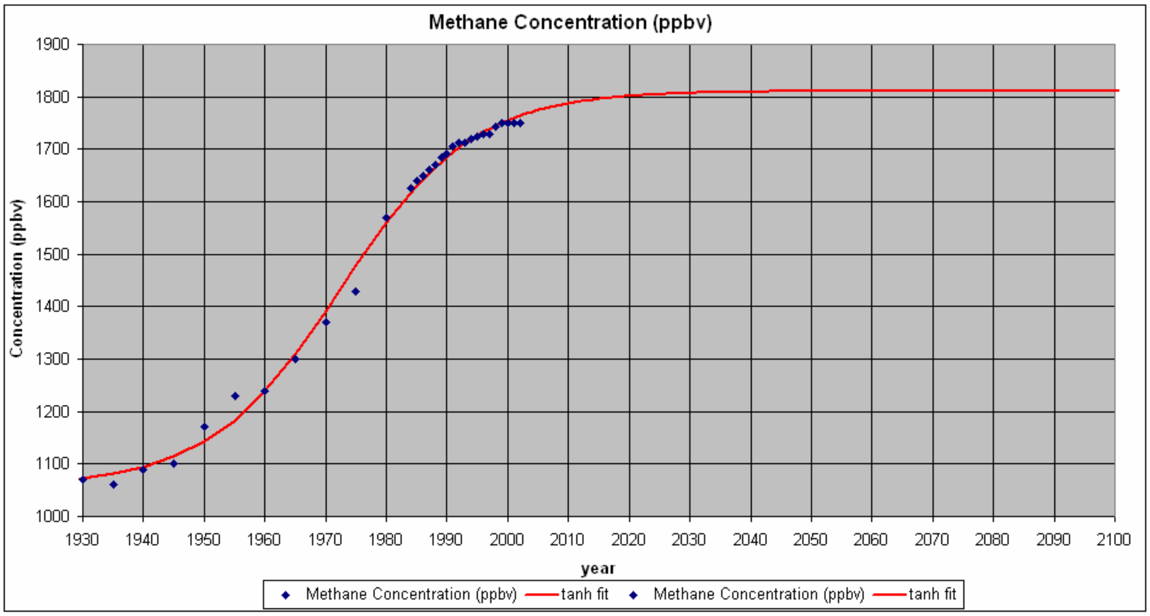


Figure 19. Methane concentration data in the upper atmosphere versus time since the year 1930 and a hyperbolic tangent fit to the data. (http://www.planetforlife.com/gwarm/glob1000.html)

The data appear to be leveling off sooner than the fit. If it only levels off instead of falling, Figure 17 indicates that the final resulting temperature in a few centuries will be extremely high.

However, recent work indicates that methane release is increasing rapidly from melting permafrost in the Arctic: http://www.nature.com/news/2006/060904/full/060904-10.html .

Figure 20 shows the predicted future Antarctica temperatures if the atmospheric concentration of carbon dioxide continues to grow as shown in Figure 19. It is assumed that there is a 500-year lag of the temperature behind the concentration (via a hyperbolic tangent).

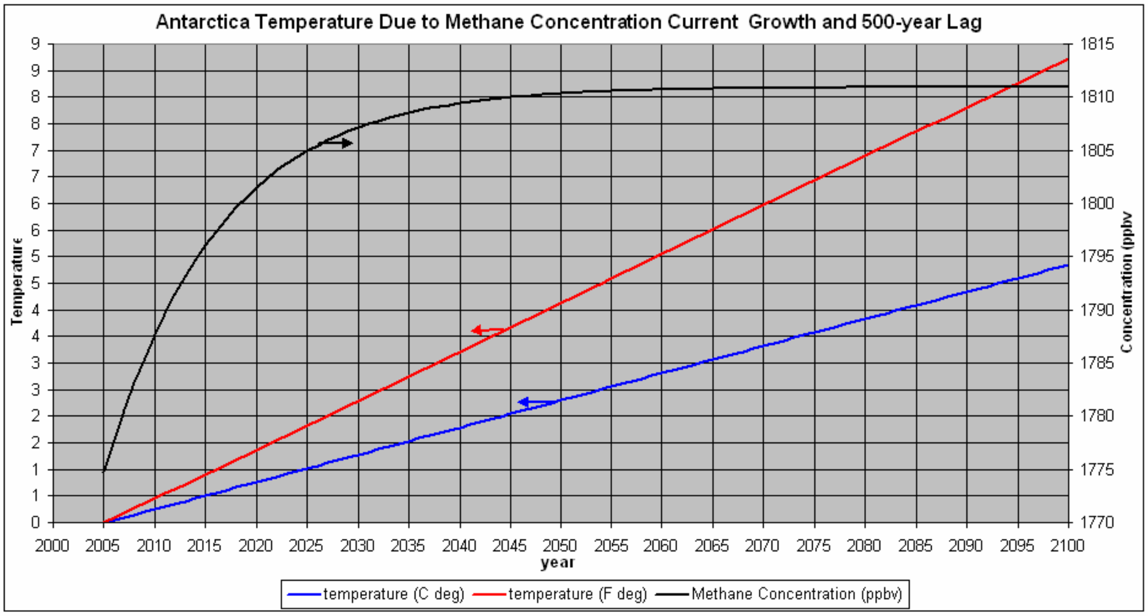


Figure 20. Projected Antarctica temperatures assuming continued growth in methane concentration in the atmosphere as shown in Figure 19 and a lag of 500 years for temperature behind concentration.

Suppose that humans could cause the methane concentration in the atmosphere to reduce to 650 ppbv in 100 years (via a hyperbolic tangent), the maximum value it had over the current Major Interglacial before humans started increasing it. (See Figure 1.) Then Figure 21 shows the predicted future Antarctica temperatures.

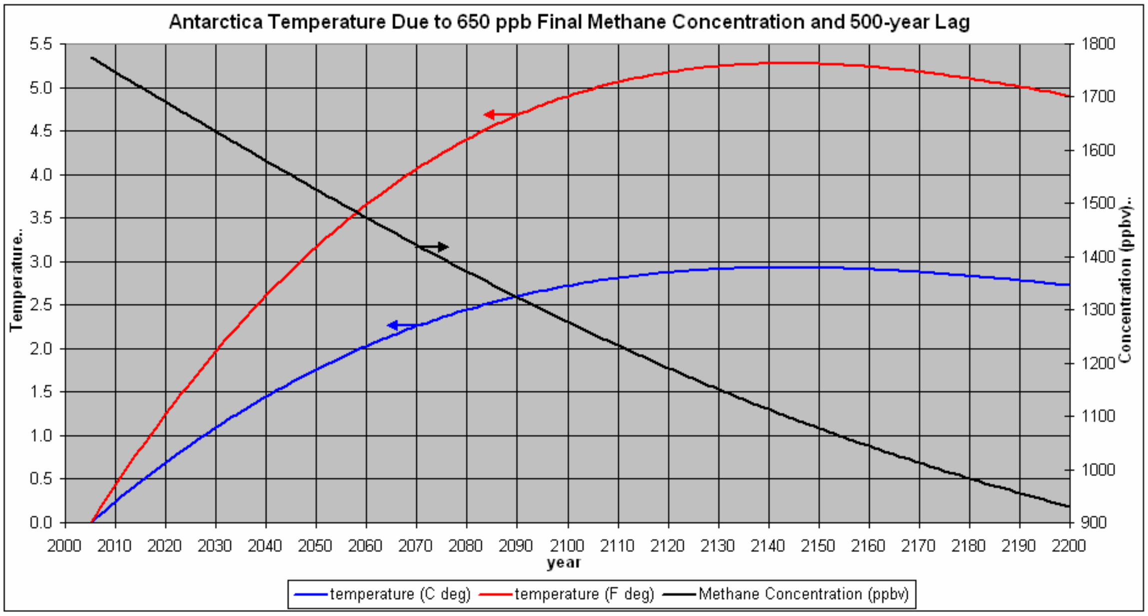


Figure 21. Projected Antarctica temperatures assuming an asymptotic approach to 650 ppbv methane concentration in the atmosphere in 100 years and a lag of 500 years for temperature behind concentration.

Comparing Figure 21 for methane to Figure 13 for carbon dioxide, we see that the methane temperatures are considerably higher than the carbon-dioxide temperatures. We need to include both carbon dioxide and methane together, and add in the effect of solar insolation.

Connecting Antarctica Temperature with Carbon Dioxide and Methane Concentrations

Figure 22 shows the Antarctica temperature, carbon dioxide concentration in the atmosphere and methane concentration in the atmosphere as measured in ice cores at Vostok, Antarctica. It also shows the North Pole summer insolation.

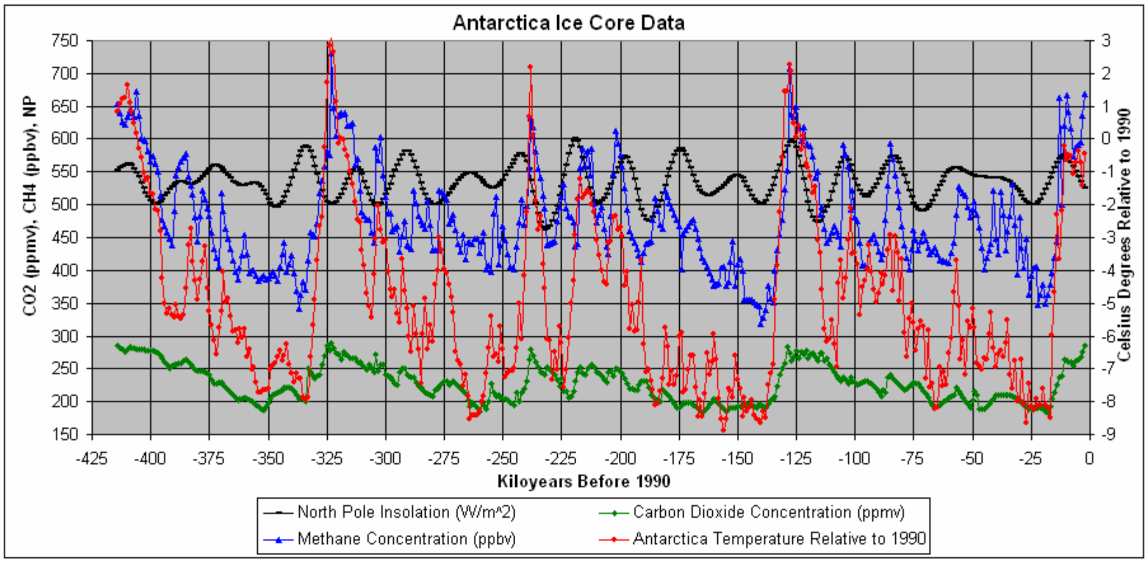


Figure 22. Antarctica temperature (right scale), carbon dioxide concentration, methane concentration and North Pole summer insolation.

Since the three different sets of data for Antarctica are for different times, selection was made from each set to yield values for even thousand-year points from 1990 back to -414 kiloyears.

The following equation was used to fit the temperature to the carbon dioxide and methane concentrations:

$$T = c + d \bullet C + m \bullet M + n \bullet I,$$

where $C = CO_2$ concentration, $M = CH_4$ concentration and I = North Pole summer insolation.

c, d, m and n are parameters to be varied to fit the data.

The parameters for the best fit are:

$$c = -28.22, d = 0.05665\ m = 0.01170 \text{ and } n = 0.008996.$$

The $c^2 = 577$ for a fit to 412 data points.

The fit is shown in Figure 23.

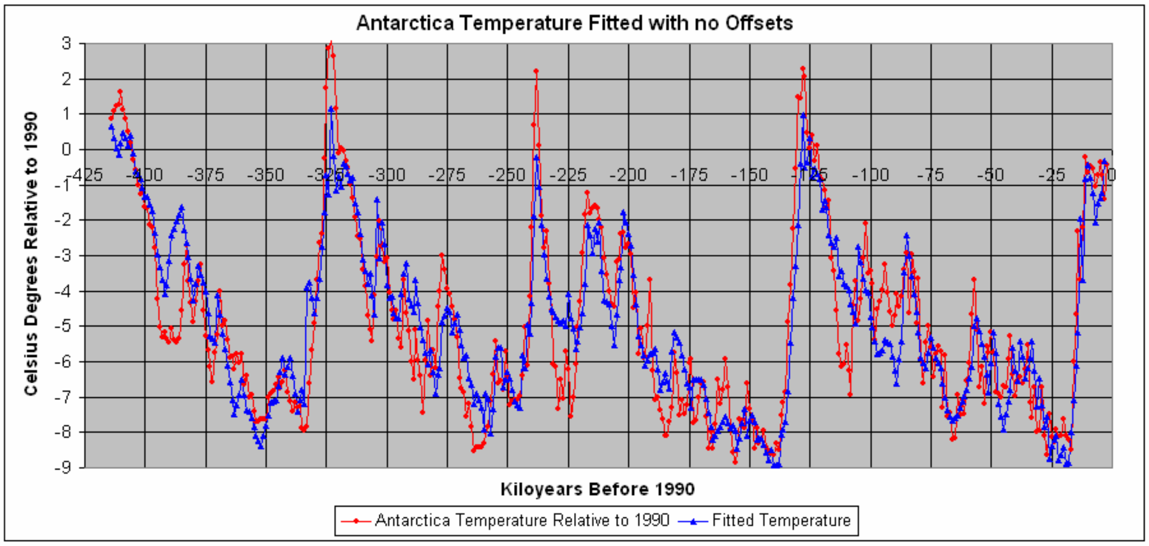


Figure 23. The fit to the temperature data using the carbon dioxide and methane concentrations and North Pole summer insolation.

However, correlation calculations yield the highest correlations when both carbon dioxide and methane lag temperature by 1 kiloyear and when North Pole summer insolation leads the temperature by 5 kiloyears. Putting in those lags and lead a new fit to the temperature data was made, which yielded the parameters:

$$c = -29.22,\ d = 0.05655\ m = 0.01170 \text{ and } n = 0.008996.$$

$$\text{The } c^2 = 471 \text{ for a fit to 412 data points.}$$

Since methane concentration is given in ppbv and carbon dioxide concentration is given in ppmv, the relative strengths of the two gases in producing temperature increases is

$$m(\text{relative}) = m_r = 0.01270 \times 1000 = 12.7 \text{ which is to be compared to } d = 0.05655.$$

$$\text{That is, } \mathrm{m}_r / d = 225\,.$$

The fit is shown in Figure 24.

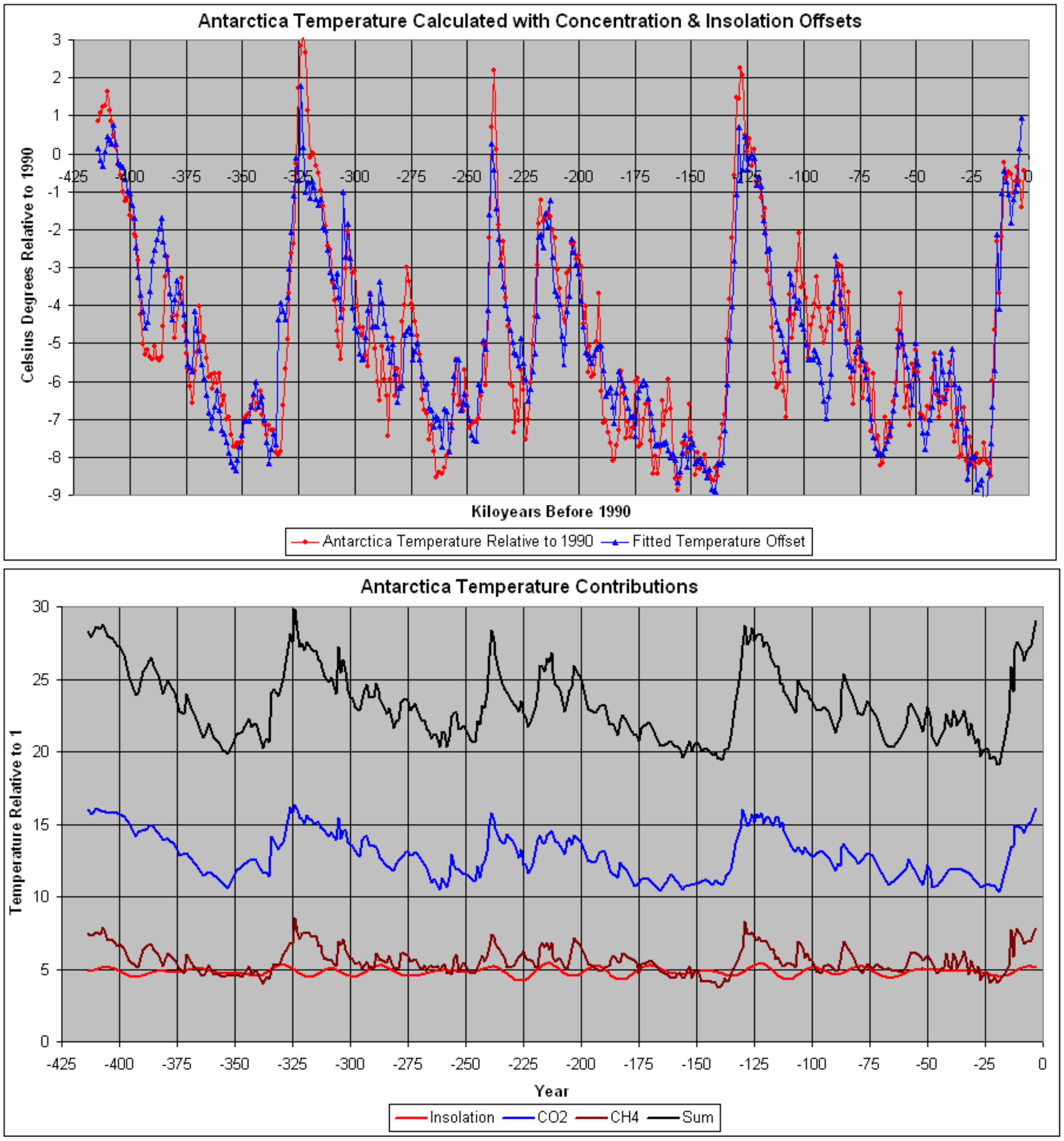


Figure 24. Top: The fit to the temperature data using the carbon dioxide and methane concentrations shifted 1 kiloyear forward in time and North Pole summer insolation shifted backward 5 kiloyears in time. Bottom: The contributions to the temperature, neglecting the constant background temperature.

This equation can now be used to predict future **eventual** Antarctica temperature rise due to future increases in carbon dioxide concentration rise, as shown in Figure 7, and methane concentration rise, as shown in Figure 19. The result for the years 2005 to 2100 are given in Figure 25. It is assumed that it takes 500 years for the temperature to follow the concentrations and the insolation and that the concentrations continue to rise as described above.

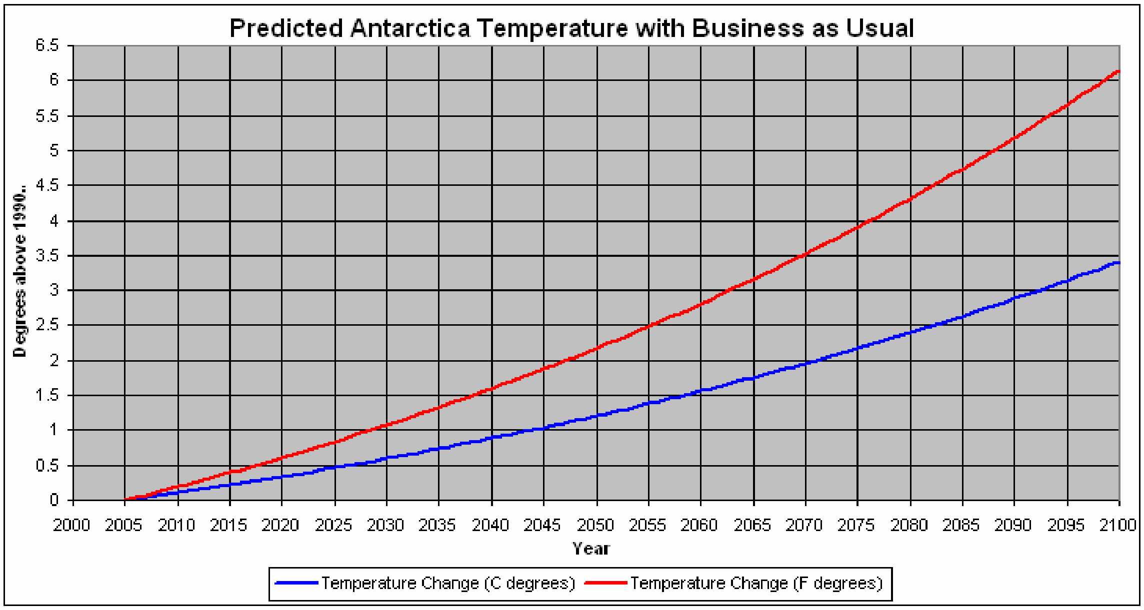


Figure 25. Prediction for Antarctica temperature rise due to future increases in carbon dioxide and methane concentration rises assuming business as usual.

Figure 25, of course, is a prediction of utter disaster.

One could argue that the fit should be done only to the data in the Major Interglacials (-414 kyr to -405 kyr, -325 kyr to -320 kyr, -239 kyr to -237 kyr, -130 kyr to -124 kyr and -11 kyr to present) to predict future Antarctica temperatures. The curve for a fit using only the CO_2 and insolation data gives a curve shaped as in Figure 25 but with a predicted temperature change at year 2100 of 4.5 ºC.

Suppose that humans could keep the carbon-dioxide and methane concentrations constant in the atmosphere at the 2005 values of 380 ppmv and 1775 ppbv, respectively. Then Figure 26 shows the predicted future Antarctica temperatures.

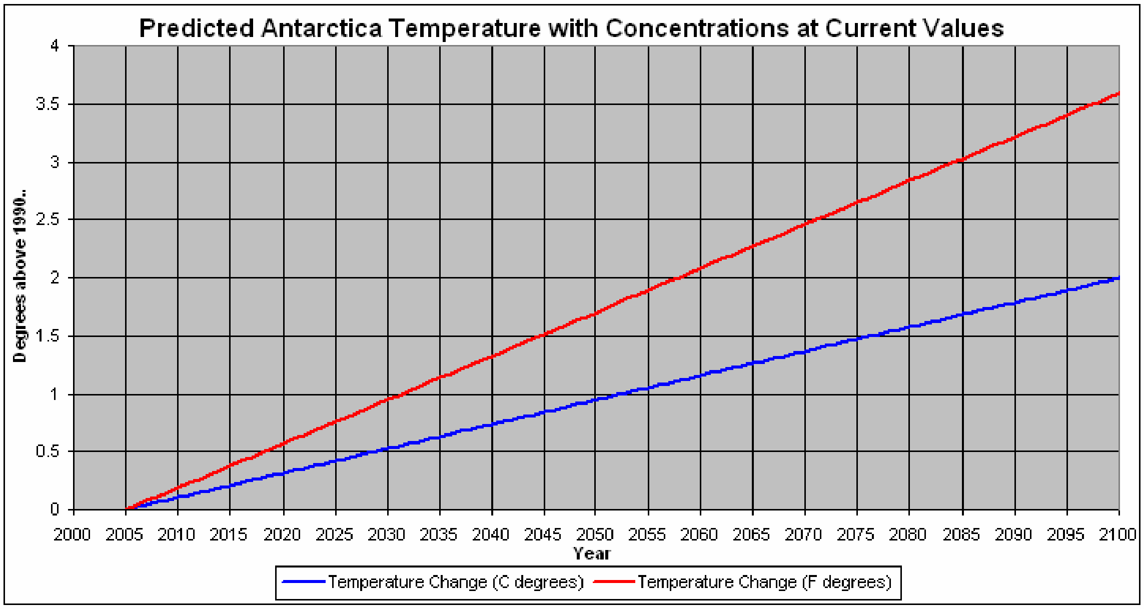


Figure 26. Projected Antarctica temperatures assuming a constant carbon-dioxide concentration of 380 ppmv per year and a constant methane concentration of 1775 ppbv in the atmosphere and a lag of 500 years for temperature behind concentrations.

It is about half as bad as the business-as-usual case of Figure 25 up to year 2100, but much worse beyond then.

One could argue that the fit should be done only to the data in the Major Interglacials (-414 kyr to -405 kyr, -325 kyr to -320 kyr, -239 kyr to -237 kyr, -130 kyr to -124 kyr and -11 kyr to present) to predict future Antarctica temperatures. The curve for a fit using only the CO_2 and insolation data gives a curve shaped as in Figure 26 but with a predicted temperature change at year 2100 of 0.6 ºC.

Suppose that humans could cause the carbon-dioxide concentration in the atmosphere to reduce to 275 ppmv in 100 years (via a hyperbolic tangent) and methane concentration in the atmosphere to reduce to 650 ppbv in 100 years (via a hyperbolic tangent), the maximum values they had over the current Major Interglacial before humans started increasing them. (See Figure 22.) Then Figure 27 shows the predicted future Antarctica temperatures, assuming that it takes 500 years for the temperature to follow the concentrations and the insolation.

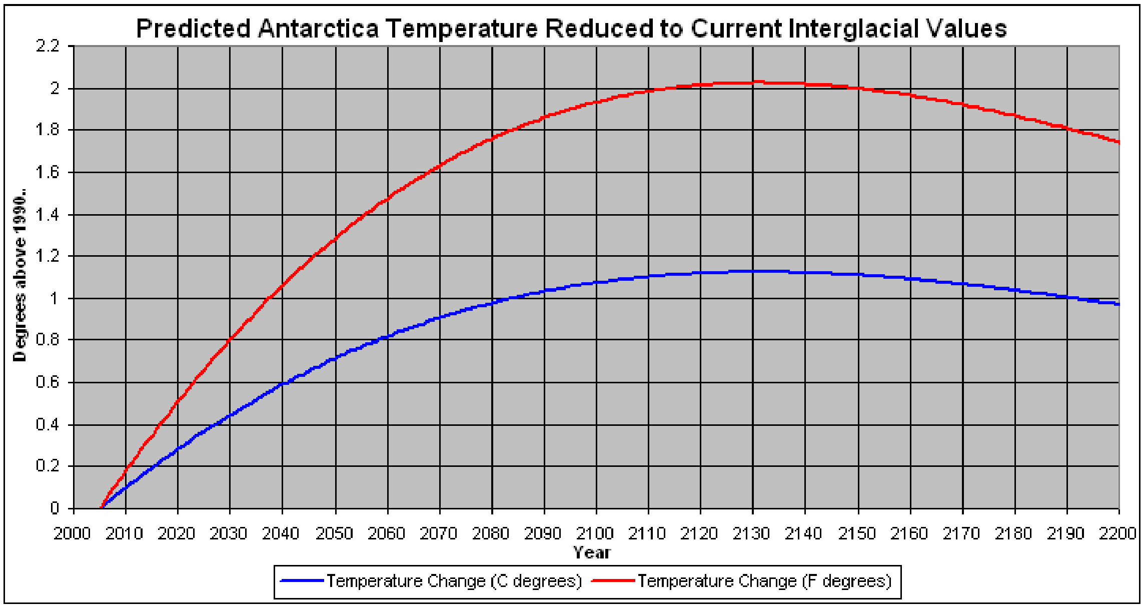


Figure 27. Prediction for Antarctica temperature rise due to future increases in carbon dioxide and methane concentration rises assuming reductions to current Major Interglacial values.

There would be some difficulties for about one-hundred years, but then the temperatures would reduce to a reasonable asymptote in a few hundred years.

One could argue that the fit should be done only to the data in the Major Interglacials (-414 kyr to -405 kyr, -325 kyr to -320 kyr, -239 kyr to -237 kyr, -130 kyr to -124 kyr and -11 kyr to present) to predict future Antarctica temperatures. The curve for a fit using only the CO_2 and insolation data gives a curve shaped as in Figure 27 but with a predicted temperature change at year 2100 of 0.6 ºC.

Previous predictions above were made for future Antarctic temperature using only carbon-dioxide (Figure 13) and only methane (Figure 21). The prediction using both and solar insolation of Figure 27 is probably a better prediction.

Conclusion

This study has shown that drastic changes need to be made in the amount of carbon dioxide and methane gases that reside in the atmosphere. Already the 380 ppmv of carbon dioxide and 1775 ppbv of methane in the atmosphere will lead, after some time delay, to disastrously high Earth temperatures. See Figure 25.

The best goal for reducing these green house gases is to reduce them to the levels of the values they had in the current Major Interglacial before humans started increasing them: 275 ppmv for carbon dioxide and 650 ppbv for methane. See Figure 27.

Any intermediate goal between the present concentrations and the current Major Interglacial concentrations would be better than increasing them above what they are now, which is the immediate prospect.

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