FUN PLOTTING YOUR OWN GLOBAL WARMING CURVES

In almost every course you take during your education, they assign homework problems. Originally, I guess this was thought of as a way to supplement the limited time an instructor has with the students. (You had to work at home _too_.) Later we found that it was more like the notion of "getting your hands dirty".   For most, it really is the best way to actually learn and retain ideas. Even decades from student status, we are often admonished to "do your homework".

The subject variously known as "Global Warming" and/or "Climate Change" is, to say the least, controversial. Many people are content, or must be content for lack of technical training, with the evaluation of so-called experts. Rarely do we find experts in climate science.   Is it ever the title of an official degree – and would that mean anything?

Those of us who are engineers, physicists, or the like, really are quite capable of evaluating the climate science evidence ourselves – or at least working toward that goal.   Because the area is ripe with politics and polemics, it is exceptionally difficult to separate wheat and chaff. Yet it really is the engineers and physicists who are best able to say if a study or model about climate MIGHT be right, or if it is suspicious. As always, a little "hands on" is extremely valuable.   Here we show some easy things to try yourself, as an example of what we can do ourselves..
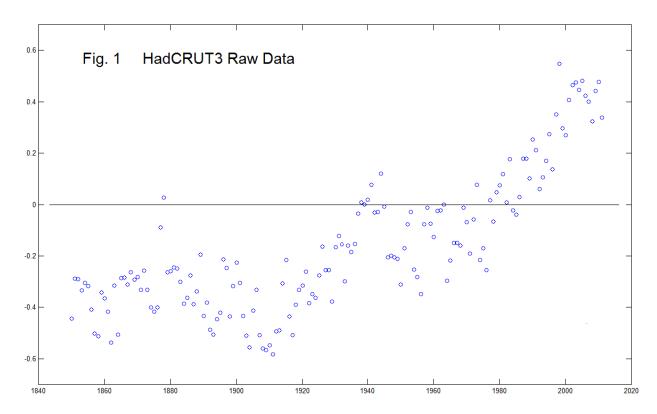
BACKGROUND:

Likely the largest controversies and misunderstandings about the "climate change" issue are due to the limits on the information we put into our discussions.   This includes the near-impossible task of obtaining from available instruments a meaningful notion of a "Global Temperature" at any one instant. And there are also our very real human limits – a failure to appreciate the earth's dimensions in terms of space, time, dynamic range, and complexity.

A major issue is: are we in the midst of Catastrophic Anthropogenic Global Warming (CAGW) due to the burning of fossil fuels? Necessarily the evidence on which we must make a guess about this is at the level of what, anywhere else, would be considered "Noise".

While we can talk about an amount of global warming of ½°C (about 1°F) per century, we know this is against daily variations of at least 10°C, seasonal variations of

perhaps 30°C, and far greater variations in geological time.   So ½°C is tiny.   A somewhat more serious matter is the time window. We all know that climate does change – at least on time scales of thousands or millions of years. Observations over shorter periods may well be meaningless. Yet if we are to consider the CO_2-driven Anthropogenic terms in CAGW, we must necessarily restrict ourselves to a time period which, at the very most goes back 100 years, more realistically, perhaps 65 years. We weren't burning fossil fuels before that. This is too short, but it is all we have.

   In attempting to obtain knowledge from uncertain information, it is often useful to just take a "dry run" using whatever we have, perhaps making arbitrary choices of input (not to suggest reckless choices).   In addition to a very recent window of time, we must also make choices of temperature records and locations with no real justification except our sincere desire not to choose anything obviously excessively biased.   We are talking "typical" and <u>not</u> definitive.

<u>UNPROCESSED</u>

Fig. 1   HadCRUT3 Raw Data

   Fig. 1 shows a generally respected data set known as HadCRUT3 [1] This is totally unprocessed data.   Here I have plotted, as open circles, the original data from 1850 to 2011. This is often plotted along with certain smoothed curves. Soon enough I will add some trend lines of my own.   For the moment, we see that the horizontal axis is

ordinary dates from 1850 – 2011. The vertical axis is temperature – of a sort. The units are in Centigrade degree, so the entire vertical range is 1.4°C   This is not temperatures as you might read it on a thermometer, but rather "temperature anomaly" or a change in temperature from some agreed-upon reference. Since we have no idea what global temperature is even today, it makes far more sense to talk about what we suppose temperature <u>changes</u> have been over time. But the zero reference here is essentially arbitrary. We are concerned with the slopes and peaks in the data.

Here we shall assume that these data are meaningful and correct.   This really is not true – there are probably a dozen things we could list that are problematic with this data. But what can we see. First of all there is an upward trend. Second, there is a lot of noise – no smooth curve here. Thirdly, there are some apparent "ripples" (probably you can see three ripples). Fourthly, a region of interest, say from 1970-2000 shows an apparently sharper than average upward slope.   (Recall that time span of increased CO_2 emissions is from about 1946- present.) This sharp upturn is pretty much what a notion of "global warming" is based on. Beyond 2000 (2001 – 2011) we see what many would call a cooling, or at least a leveling off. This is a hallmark of the <u>anti</u>-CAGW case.
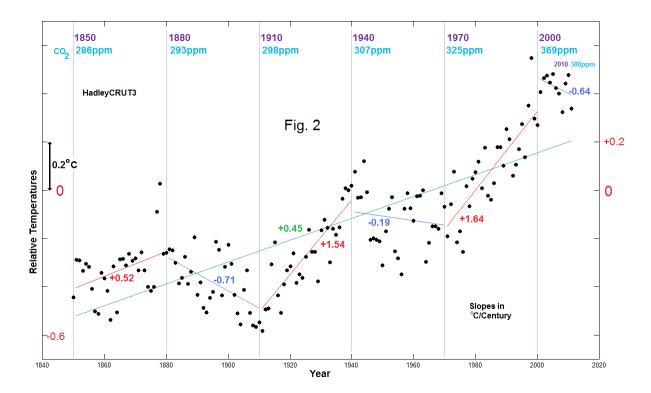
ADDING TREND LINES

Because of the "noise" we tend to do some smoothing or averaging with the notion that we somehow will see more.   Sometimes this helps – sometimes it makes us see things that aren't there.   In Fig. 2 we have added some least square trend lines in what turns out to be a systematic way (Program 1).   To overplot a trend line, we choose a range of dates and temperature values and fit a straight line (minimizing the squared error) to this selected range of circles. In Fig. 2, we show first of all the trend line for all 162 points. It is the green line sloping upward with a slope of +0.45°C/century. To a crude approximation, this tells the story: the whole global warming boils down to a warming, 1850 to present, of less than a full Centigrade degree (about 0.7°C or 1.25°F).

We have also shown six shorter trend lines. These were chosen in a manner that may seem eminently fair – equal length segments. In fact, these were chosen specifically to dig out possible trends which the reader may have already seen in Fig. 1, and which have been described in nearly every discussion of this data. Specifically, a rise from 1850-1880, a decline from 1880-1910, a rise from 1910-1940, a fall from 1940-1970, a rise from 1970-2000, and a fall from 2000-present. These lines, and their corresponding slopes, are plotted in Fig. 2.

Now, there is nothing really wrong with fitting a trend line to a range of data where a trend seems apparent as seen by eye. This case however is certainly fortuitous in seeming to work for segments all of length 30 years (except the last one of course). Note of course that such an occurrence is expected if something had a periodic component of length 60 years. That is, having the segments (at least approximately)

all the same length would indicate an oscillation. Having them exactly at decade boundaries is of course just by chance. We also show in Fig. 2, some general CO_2 values for reference.

Fig. 2

Here are the things that are immediately remarkable: First, there is the rapid rise (slope 1.64°C/century) from 1970-2000. That is a slope 3.64 times greater than the 1850-2011 average. This coincides pretty well with a time period (1970-2000) over which CO_2 levels were rising rapidly (from about 325ppm to 369ppm, or 13.5%). Focusing on this 30 year period, we might suppose we have a good case to prove CAGW. But there are lots of problems.

Most apparent there is the period from 1910-1940 where the slope is almost as sharp (1.54°C/century) where CO_2 emissions rose by a much smaller amount (298ppm – 307ppm, or 3%) than during 1970-2000. So this relatively equivalent slope is problematic to the CAGW argument. Even worse is the cooling trend from 1940-1970 (-0.19°C/century). Famously, a number of prominent news and science magazines were, about 1970, featuring stories on the "coming ice age". Certainly the CO_2 levels were not decreasing during this period.

We see, overall, segments of temperature increase greater than the average (segments about 30 years long) interspersed with segments of cooling (again about 30 years). The average slope (with 2000-2011 proportionally weighted) of the six segments comes out to +0.45 as it must. The cooling segments mean that there must be some heating segments greater than average, and there are. The appearance of the two upward slopes (1.54 and 1.64), the first of which must be non-CO_2, suggests that the recent segment (1970-2000) could or should also be non-CO_2 caused. The segment from 2000 to 2011 is problematic because it is only 11 years long. In fact, if one earlier point is included, it is a very slight increase looking more like a flattening rather than a cooling.

Nevertheless, this 2000-2011 segment is devastating for the CAGW case.   It corresponds to an additional increase in CO_2 of about 5%, and we do not see a temperature increase. It further suggests that the oscillatory component actually is in play, and that this is a downturn following exactly the patterns we see at 1880 and at 1940.   It is further devastating for a reason to be described just below.

LOGARITHMIC RELATIONSHIP

We know the changes of CO_2 concentration over recent time intervals (particularly for the last 40 years or so), and we have fairly good and agreed-upon physics (agreed by both CAGW proponents and skeptics) that this increase in CO_2 should correspond to a known amount of warming. The additional warming of CO_2 is understood (by ALL) to be logarithmic [see Note 2], with any doubling of CO_2 concentration increasing temperature by 1.1°C. (This 1.1°C is often called the "climate sensitivity".) That is:

$$\Delta T = 1.1 \log_2(C_1/C_0) \tag{1}$$

Here C_1 and C_0 are two values of CO_2 concentration. Note that the change in temperature ΔT can be positive for $(C_1/C_0)>1$ or negative for $(C_1/C_0) < 1$. Equation (1) is to be regarded as a good to very good estimate. Shortly we shall see how CAGW modelers modify this.

For the moment, we can look carefully at the interval from 1970-2000, the "smoking gun" interval of CAGW. The CO_2 increased by a factor of 1.135. C_1 is 369ppm (for 2000) and C_0=325ppm (for 1970). Thus we would have expected a temperature change, due to CO_2, of roughly:

$$\Delta T = 1.1 \log_2(C_1/C_0) = 1.1 \log_2(1.135) = 0.2°C \tag{2}$$

But what we see in Fig. 2 is more like 0.5°C, 2.5 times the predicted value.   That is, there is not enough added CO_2 to account for the observed heating!

Notice that this discrepancy is a problem only if we restrict ourselves to CO_2 as the only possible cause. Inasmuch as the evidence with regard to the relationship between CO_2 and temperature, by the experimental data, is extremely poor, failing completely

from 1940-1970, and even more spectacularly post 2000, it would seem best to identify other (natural or non-CO_2 man-made causes) rather than do what the CAGW modelers attempt.

POSITIVE FEEDBACK

The professional climate modelers claim that the effect of CO_2 warming is amplified by positive feedback. They propose that the mechanism of this positive feedback is increased water vapor (a powerful greenhouse gas) and the amplification factor is somewhere (variously, according to modeler) from 2 to 5. It would need to be 2.5 for our example (from 0.2°C to 0.5°C from 1970-2000).There are many reasons why positive feedback is very very unlikely to be an explanation here. However, when it is included, it is generally as an added factor K to equation (1):

$$\Delta T_{(PF)} = K \, (1.1) \, \log_2(C_1/C_0) \tag{3}$$

For the moment, note that once we assume a positive feedback (K>1), we kind of have to stick with it (in the spirit of real science). It should not have been a law of physics that just came into effect in 1970! First of all, CO_2 concentration has been virtually a monotonic rise for something like 100 years. From the viewpoint of 1970-2000, we expected the temperature to continue rising, and it apparently does not. What we see is a flattening, or a downturn. Perhaps more to the point, when we look back before 1970, if we insist on this positive feedback, we find the older temperatures were <u>nowhere near cold enough!</u> Several bloggers, including Warren Meyers [3], have made this point before.

Here is the situation. Assuming positive feedback, we would have a multiplicative constant K = 2.5 added to equation (1):
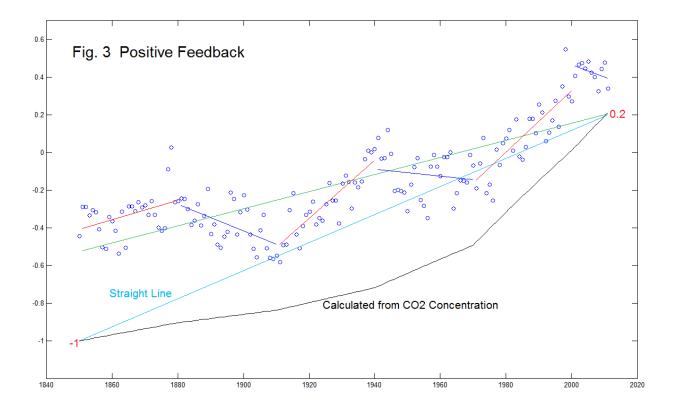
$$\Delta T_{(PF)} = (2.5) \, (1.1) \, \log_2(C_1/C_0) \tag{4}$$

where based on 1970-2000, the K should be 2.5 (for all time!). Once we have established this amplification, we can't just turn it off for previous times. This means that the backward rush to cooling (looking backward, that warming is cooling) would necessarily be lower that the observed value by the time we get to 1850. Yet, this is not a simple matter of extending the slope in the 1970-2000 region back to 1850. (This would be well below the bottom of the graph of Fig. 2.) That would be too simple, and wrong.

Here we have probably been thinking that time is the independent variable (the years) while temperature is the dependent variable. But the theory is now that temperature depends on CO_2 concentration, according to equation (2). From 1970 to 2000, the CO_2 concentration increased 13.5% (C_1/C_0=1.135) and if K=2.5, we get the stated result of 0.5°C. Now remember, we can't change K any more. So what happens from 1850-2011? The CO_2 concentration (our independent variable) went from 286ppm to 388ppm (or 36%). Using equation (2) WITH K=2.5, we get:

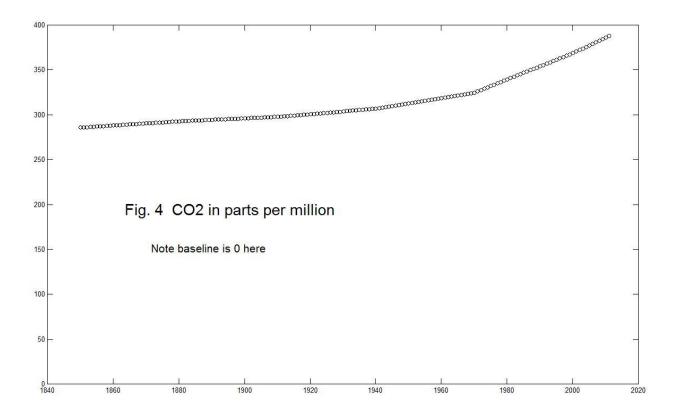$$\Delta T_{PF} = 2.5 \ (1.1) \ \log_2(1.36) \ = 1.22°C \tag{5}$$

So let's make some room at the bottom of the graph, and plot this point. But where should we start. Well, we are dealing with changes, so we can rather freely choose a reference. It seems very reasonable to choose the end of the least square trend line (green) at 2011, and this is about 0.2°C. So back in 1850 it should have been about 0.2 – 1.22 or about -1°C. In Fig. 3, we plot some of the same data as in Fig. 2, but add this point.   Further, with no justification, we connect the point -1 at 1850 with +0.2 at 2011 with a straight line (light blue). This we compare with the green straight line, but must keep in mind that they are of fundamentally different origin. The blue line is just a line between two points – the green line is a least squares fit to 162 data point. But, the light blue line does dip much colder (about 0.5°C) going back to 1850.

Fig. 3 Positive Feedback

As mentioned, the light blue line is bogus – we really don't think the temperature is linear with time (the green least square line is not real either – look at the six shorter trend lines).   Remember that we wanted CO_2 concentration to become the independent variable. For out purposes, it will have to be sufficient to estimate the CO_2 concentrations for each year from the 30 year values in Fig. 2, using linear interpolation. We are only doing ballpark anyway. Fig. 4 shows this result, although we don't intend to use this graph. It does look like most CO2 graphs available

(except we set the baseline at 0 where it belongs – and accordingly it looks less alarming). We could now plot the temperature data vs. the CO2, but this scatters just as much as Fig. 1, and does not lead to the point we want to make here.

Fig. 4 CO2 in parts per million

Note baseline is 0 here

What we do want to do here (to get the black line of Fig. 3) is to use the interpolated values of CO_2 to calculate the values of ΔT for each year. That is, we use equation (4) for each year. In finding the point at 1850, using equation (5), we worked backward. It is perhaps more fun to instead, work forward from 1850. That is, put ourselves in the position of a worried scientist in 1850 considering what will happen 160 years later. So start at a temperature anomaly of -1°C in 1850, and assume positive feedback of K=2.5.

Initially, not much happens, as seen from the black curve. Indeed, from about 1850 to 1910, the CO_2 concentration only goes up about 4% and the temperature increase expected from that is only about 0.1°C. In fact, it wouldn't have mattered much if K was 2.5 (positive feedback) or K=1 (no feedback) at this point. Eventually, as we move on toward 2011, we do see sharper increases in CO_2 concentration and in temperature anomaly. Without the positive feedback, K=2.5, we would not have made it to +0.2°C at 2011. The black curve is thus explained, and the resemblance to Fig. 4 is clearly a matter of even a logarithmic relationship being near linear for a limited range (and the pinning of the endpoints).

What we do see that is remarkable is that while the (bogus) light blue curve did project through some of the lower data, the black curve swings well below every data point. That is, assuming positive feedback for 1970-2000 necessarily meant that the past needed to be much cooler than the data shows.

CONCLUSIONS

The study here has concentrated on one small window into the "Global Warming" debate, with the view of pointing out that the "ordinary engineer" is able to correctly do a few simple calculations the may test a particular claim.   There are probably a dozen or more similar efforts that could have been made, particularly in the area of "renewable alternative fuels" [4].

To say that we find the CAGW theory wanting would be accurate, but really isn't the main point we need to understand.

The main point is one of arrogance. First there is the arrogance of any self-proclaimed climate scientist who would be inclined to exclude persons who are not "professionally" in the game. There is the arrogance of any one group claiming a consensus for themselves. There is the arrogance of people (such as policy-makers and politicians) claiming that they are uniquely in touch with those "in the know". And there is an arrogance to having a hidden agenda and feeling good about it (or not even realizing it).

There is nothing wrong, in science, and possibly everywhere, with a person making the demand: "On what information, exactly, do you make that claim"? Engineers do this automatically as a way of getting to the truth. And if someone's comment or complaint is really silly, we benefit from explaining our own defense of the actual situation – possibly providing a simpler explanation as well. .

But in climate science, all this quotidian arrogance pales under the extreme overarching arrogance of supposing that first, we can understand the workings of the earth's climate, and second, that if we do detect something in the climate system that is not to our liking, that we humans could do anything about it. Nature always wins. Possibly any extreme efforts expended would lead at best to no result at all. Who would be surprised if, in addition to the obvious lost opportunity costs, we made whatever we were trying to manipulate worse.

The call is for engineers and physicists to ask questions and hold feet to fires. Too many in these professions jump on the bandwagon without even looking. We too often assume that someone smarter than ourselves must have worked out the details, and if it does not make sense to us, that is our failing. In may well not be our failing.

REFERENCES

[1] You can get this data by Googling HadCRUT3, or you can get the stored Matlab *.mat* file from (or text file) our website as:

http://electronotes.netfirms.com/gt.mat
http://electronotes.netfirms.com/gt.txt   (text file)

[2] Finding an explanation for the logarithmic dependence between CO_2 concentration and temperature change is not difficult. Below are three links, or you can just Google "CO2 logarithmic" of something like that. The equation in this note numbered (1) is essentially that of Svante Arrhenius from 100 years ago.

I have had success explaining the diminishing effectiveness of adding more CO_2 by an analogy with a baseball game. There are only so many fly balls hit to the outfield during a typical game. Let's guess 16. The traditional three outfielders will catch many of them – perhaps half – I don't know. What if a manager finds a loophole in the rulebook and finds he can have as many extra outfielders as he want – so he adds three more. Now, more balls will be caught, but not all of them. A sharply hit line drive will still sometimes still get through (by luck – by probability if you wish). So the extra fielders may haul in four of the eight the three fielders missed. So the manager doubles the number of outfielders again (that's 12 now) and finds they too may get half the remaining four. Clearly doubling the number of outfielders is becoming less and less productive. And so on.

Here is something you can actually do. Using Matlab or some other program, generate a random image of 1's and 0's with a probability of either choice being 1/2. Print this with 1's being black and 0's being white pixels. Half the pixels will be black. Now generate a second image, and run the same sheet of paper through the printer. Now 3/4 of the pixels (not all of course) will be black. Keep doing this until you are convinced.

Finally, think of yourself as a photon on the earth's surface planning to escape to space if you can make it past CO_2 molecules. Further assume your energy is within the bandwidth CO_2 likes to capture. As you zoom past consecutive shells of CO_2 molecules, there's a chance of being captured. In fact, the first 20 ppm of CO_2 will get you half the time. Doubling this to 40 ppm will get half that remain. Now, 80 ppm (not 60 ppm) will get half again, and so on. If you are keeping score, when you double to 320 ppm you are getting all but 1 in 32. So, at a current CO_2 concentration of about 390 ppm, we only have a couple of percent left to turn back. It's called SATURATION.

Oh – and a lot of phenomenon in physics – like half-life of radioactive decay are similarly logarithmic (or exponential depending on the direction you are looking).

Here are some pretty good links

http://wattsupwiththat.com/2010/03/08/the-logarithmic-effect-of-carbon-dioxide/

http://knowledgedrift.wordpress.com/2011/09/07/co2-is-logarithmic-explained-3/

http://clivebest.com/blog/?p=2241

[3] Here is Warren Meyer's presentation that is outstanding – another engineer:

http://www.climate-skeptic.com/2010/01/catastrophe-denied-the-science-of-the-skeptics-position.html?gclid=COScy_W9mqUCFdV95QodjR3PHQ

[4] The notion of renewable alternative energies (as a choice) has a rather nice touchy-feely air to it. Who would not embrace an alternative energy source (though always ask – alternative to what!) that is cleaner, offers more energy independence, and was not more expensive, or at least not much more. Oh – but <u>if it HAS to be subsidized</u> by the taxpayers, it is bogus from square one.

   Who can figure in all the contributing factors to success or failure? Is it technologically even feasible on <u>any</u> scale? Does the economics work? What are the unseen drawbacks?   Over what time scale could it be implemented (how many decades)? How reliable? What are maintenance issues?

   I think only engineers can handle this evaluation. Certainly not climate scientists or worse, politicians. Engineers have to think about how to make something <u>really</u> work in the first place, and in the long run. They have to think the full thing through.

   I believe that it was our friend and contributor, Thomas Henry, who offered the correct scenario in the simpler context of building an electronic project.   Tom was talking about how to actually build something – how to avoid overlooking a problem or inconvenience. He advocated building the entire project, completely <u>in your imagination</u>, as though you were actually directing conscious actions.   If I recall you were to do this in bed at night, in the dark, just thinking everything through. So, for example, if you had to drill a hole to mount some part, you had to think about where your power drill was, and recall perhaps that in the drill bit box there were three empty holes, bits not put back – almost certainly the size you need.   That sort of thing.

So-called "renewable" Alternative energies fall into three main categories: wind, solar, and bio-fuels. Wind and solar suffer from similar handicaps/unknowns . Both have a relatively low load factor (perhaps 60-80% of the time, they don't work – by definition – the wind does not blow, or the sun does not shine). Both require new infrastructure (transmission lines) and access facilities. Both are relatively fragile (as compared to hydro-electric for example). Maintenance must be factored in. Bio-fuels are a bit different – their production/distribution need not be continuous – resembling food production/distribution for obvious reasons. With bio-fuels, the issues are mainly economics and unintended side consequences.

All these multi-discipline issues are things an engineer is best qualified to recognize and assess as a whole. After all, the engineer's job is to make thing work. Engineers are at least capable of seeing this big picture, because they will generally think of themselves as not being responsible for just a single element, but fitting in to make the whole system work. Like they will speak up and say "Hey, Hey, Hey, what about……..."   If there is a flaw elsewhere, they will likely point it out.

PROGRAM

```
% plotgt.m

clear
load gt

% This is Fig. 1 of AN-379
figure(1)
plot(y,A/1000,'bo')
axis([1840 2020 -.7 .7])
title('HadCRUT3 Raw Data')




% This is Marked Up to become Fig. 2 of AN-379
figure(2)  % trend lines
plot(y,A/1000,'bo')
hold on

% trend 1850-2011 green
ys=1851
ye=2011
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'g')
```

```
% trend 1850-1880
ys=1851
ye=1880
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'r')

% trend 1880-1910
ys=1881
ye=1910
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'b')

% trend 1910-1940
ys=1911
ye=1940
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'r')

% trend 1940-1970
ys=1941
ye=1970
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'b')
```

```
% trend 1970-2000
ys=1971
ye=2000
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'r')

% trend 2000-2011
ys=2001
ye=2011
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'b')


axis([1840 2020 -.7 .7])
hold off
title('HadCRUT3 With Trend Lines')
figure(2)
% end Fig. 2



% Now linearly interpolate 30 year CO2 values

%1850-1879 286-293
s=7/30
for k=0:29
  CO2(k+1)=286+k*s;
end
%1880-1909 293-298
s=5/30
for k=0:29
  CO2(k+31)=293+k*s;
end
%1910-1939 298-307
s=9/30
for k=0:29
  CO2(k+61)=298+k*s;
end
%1940-1969 307-325
s=18/30
for k=0:29
  CO2(k+91)=307+k*s;
end
```

```
%1970-1999 325-369
s=44/30
for k=0:29
  CO2(k+121)=325+k*s;
end
%2000-2011
s=19/11
for k=0:11
  CO2(k+151)=369+k*s;
end
% Interpolation done



% Now plot positive feedback results
% begin by replotting Fig. 2 as Fig. 3
figure(3)
plot(y,A/1000,'bo')
hold on
% trend 1850-2011 green
ys=1851
ye=2011
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'g')
% trend 1850-1880
ys=1851
ye=1880
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'r')
% trend 1880-1910
ys=1881
ye=1910
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'b')
```

```
% trend 1910-1940
ys=1911
ye=1940
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'r')
% trend 1940-1970
ys=1941
ye=1970
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'b')
% trend 1970-2000
ys=1971
ye=2000
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'r')
% trend 2000-2011
ys=2001
ye=2011
is=ys-1849
ie=ye-1849
p=polyfit([ys:ye],A(is:ie),1)
p1=p(1)
p2=p(2)
ts=p1*ys+p2;
te=p1*ye+p2;
plot([ys ye],[ts te]/1000,'b')

% plot light blue curve
plot([1850 2011], [-1 0.2],'c')
% black line
plot([1850:2011],[-1+(2.5)*(1.1)*log2(CO2/286)],'k')
axis([1840 2020 -1.2 .7])
hold off
title('HadCRUT3 With Positive Feedback Curves')
% end Fig. 3
```

```
figure(4)
plot([1850:2011],CO2,'ok')
axis([1840 2020 0 400])
title('CO2 Concentration')
figure(4)

% temp as function of CO2 - not used here
figure(5)
plot(CO2,A)
figure(5)
```