Global Warming

A Look at the Data

We look at temperature changes against three variables:

Sunspots - the El Niño / La Niña cycle - Carbon Dioxide levels

- **Just** about all energy entering the earth system enters as radiant energy from the sun – the *solar flux*, for which sunspots are a proxy.

- **At** the surface of the earth, temperature is moderated by the cycling of warm and cold water in the oceans – the *El Niño / La Niña* cycle seems to be a good measure of the moderation.

- **Just** about all energy leaving the earth system leaves as radiant energy – *Carbon Dioxide* in the atmosphere slows the radiant cooling.

Temperatures have been increasing over many years now.

In the slides that follow, we show the *temperature anomaly* (temperature difference) from the *temperature average of the years 1951 to 1980.*

(That is, the average of the values of the temperature for the years 1951 to 1980 is set to zero and the temperature anomaly is the difference between the temperature for any given month and the actual average.)

The *data series* in the following plot is a monthly measure of **temperature over both ocean and land**, and is measured in degrees centigrade.

(There are 1.8 degrees Fahrenheit for each degree centigrade.)

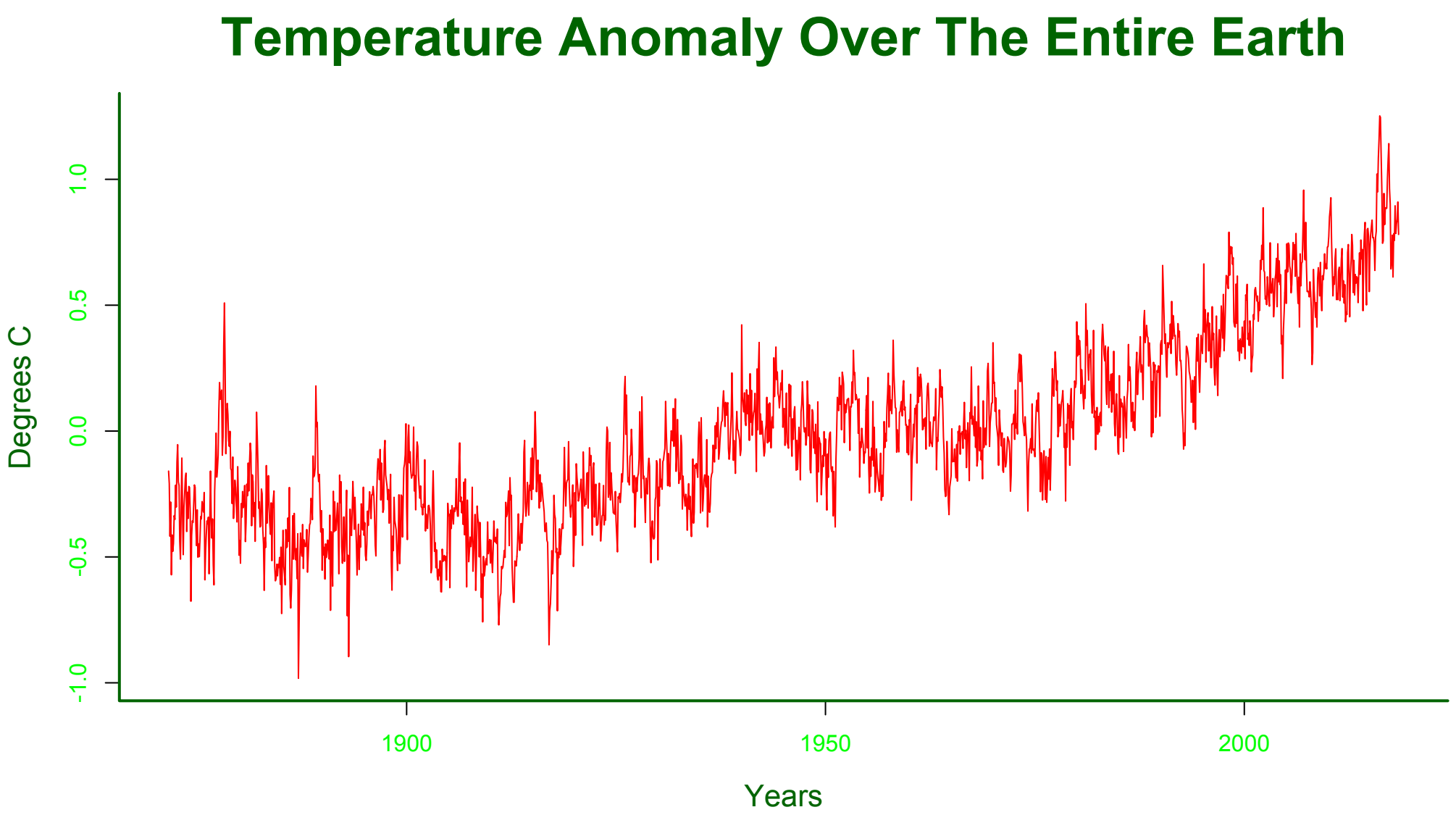
The data in this slide show is from the years **1871 to 2018**.

Temperature against Time

Average Land and Ocean Temperature

Data From Berkeley Earth (at the University of California Berkeley)

Temperature Anomaly from the Average of Years 1951 to 1980


Temperature Anomaly Over The Entire Earth
Degrees C
1.0
0.5
0.0
-0.5
-1.0
1900
1950
2000
Years

Scientists have observed that as the *number of sunspots* increases, the *solar flux* (the density of the energy from sun – which is mainly light) increases.

If the energy entering the earth system increases, temperature should increase, all other things being equal.

Does the energy associated with sunspots cause the increase in global temperature?

There is an increase in temperature as sunspots increase - as can be seen in the following plot. But, **the increase is not enough** to explain the change we see in the data.

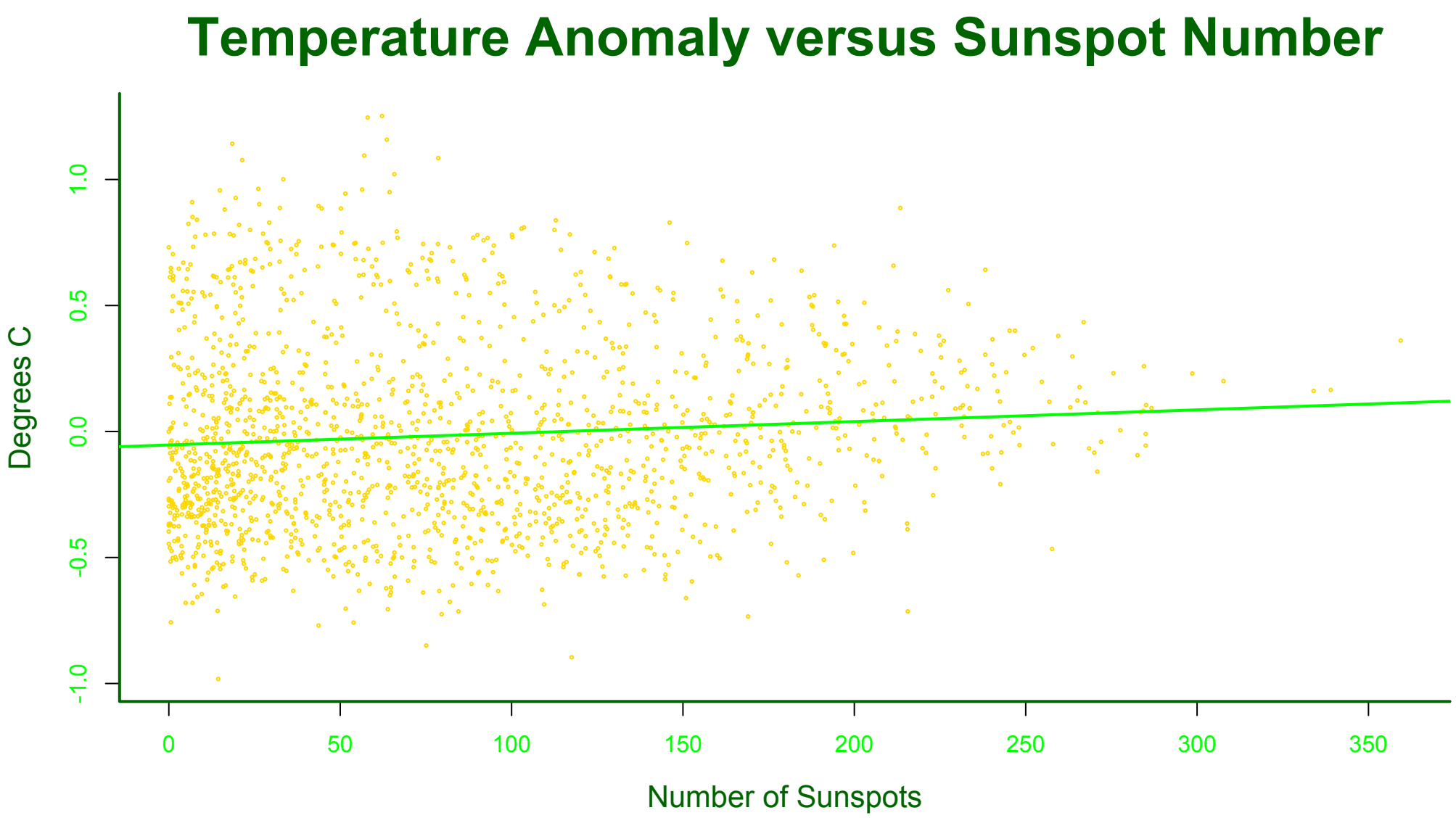
The sunspot data is from the Solar Influence Data Analysis Center (SIDC) at the Royal Observatory of Belgium and is monthly data of the number of sunspots per day (the number of sunspots seen each day averaged over a month.)

Temperature against Sunspot Number

Average Daily Sunspot Numbers

Averaged over Months

Data from the SIDC at the Royal Observatory of Belgium


Temperature Anomaly versus Sunspot Number
Degrees C
1.0
0.5
0.0
-0.5
-1.0
0
50
100
150
200
250
300
350
Number of Sunspots

The *El Niño/La Niña cycle* in the tropical eastern Pacific Ocean - also known as the *El Niño Southern Oscillation (ENSO)* - is a cycle known to affect weather patterns and temperature.

Does the ENSO cause the increase in global temperatures?

One measure of the size of the ENSO is the *Multivariate ENSO Index (MEI)*, which is estimated by the *National Oceanic and Atmospheric Administration (NOAA)*.

Temperature increases as the MEI increases, as can be seen in the following plot, but the index is **barely growing over time** and is cyclical.

(The MEI may be a proxy for all such cycles in the oceans. For my analysis, I smoothed the index using a twelve month running average to remove seasonal influences, since global temperature is global – that is, season free.)

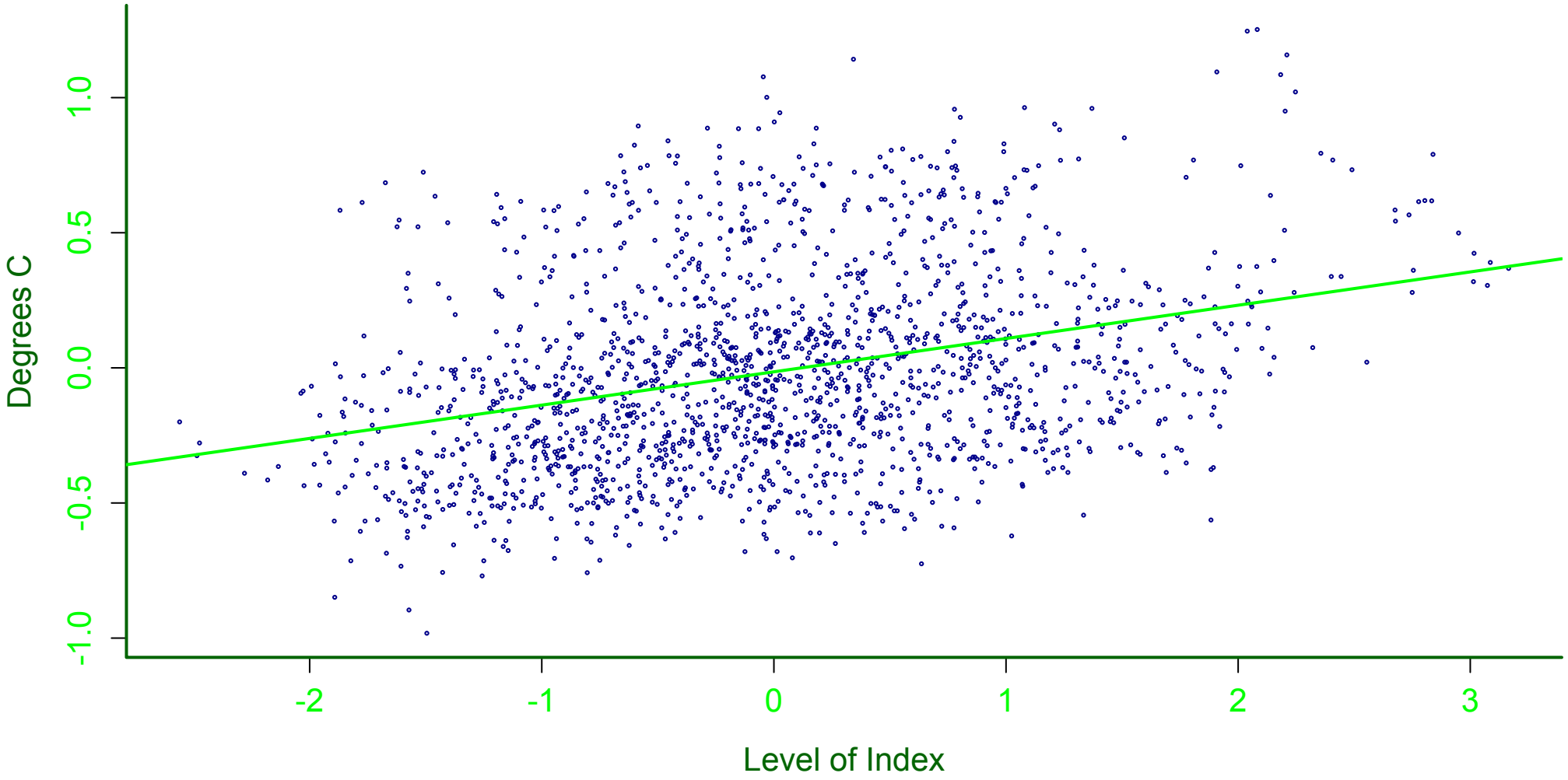
Temperature against ENSO Index

El Niño and La Niña Cycle: ENSO (MEI) Index

(Temperature Differential in the Eastern Pacific Ocean)

Data from the ESRL at NOAA and Wrangled a Bit

Temperature Anomaly versus ENSO: MEI Index



Carbon Dioxide levels are more strongly related to temperature than *sunspots* or the *ENSO index*, as can be seen in the following plot.

Does Carbon Dioxide cause the increase in temperature we see?

The answer is **probably** (there is a good physical reason why), but the *carbon dioxide* we use in this study is likely a proxy for *all greenhouse gases*.

The carbon dioxide numbers that I use in this analysis are a combination of the monthly averages of measurements of carbon dioxide levels at the *Mauna Loa Observatory* in Hawaii – taken since 1978 - and yearly carbon dioxide levels estimated from ice core samples at the Law Dome in Antarctica - from the *Carbon Dioxide Information Analysis Center (CDIAC)* at the *Department of Energy*. I wrangled the CDIAC data into a monthly index using the seasonal pattern in the Mauna Loa data. The combined data was smoothed using a 12 month running average to remove the seasonal pattern.

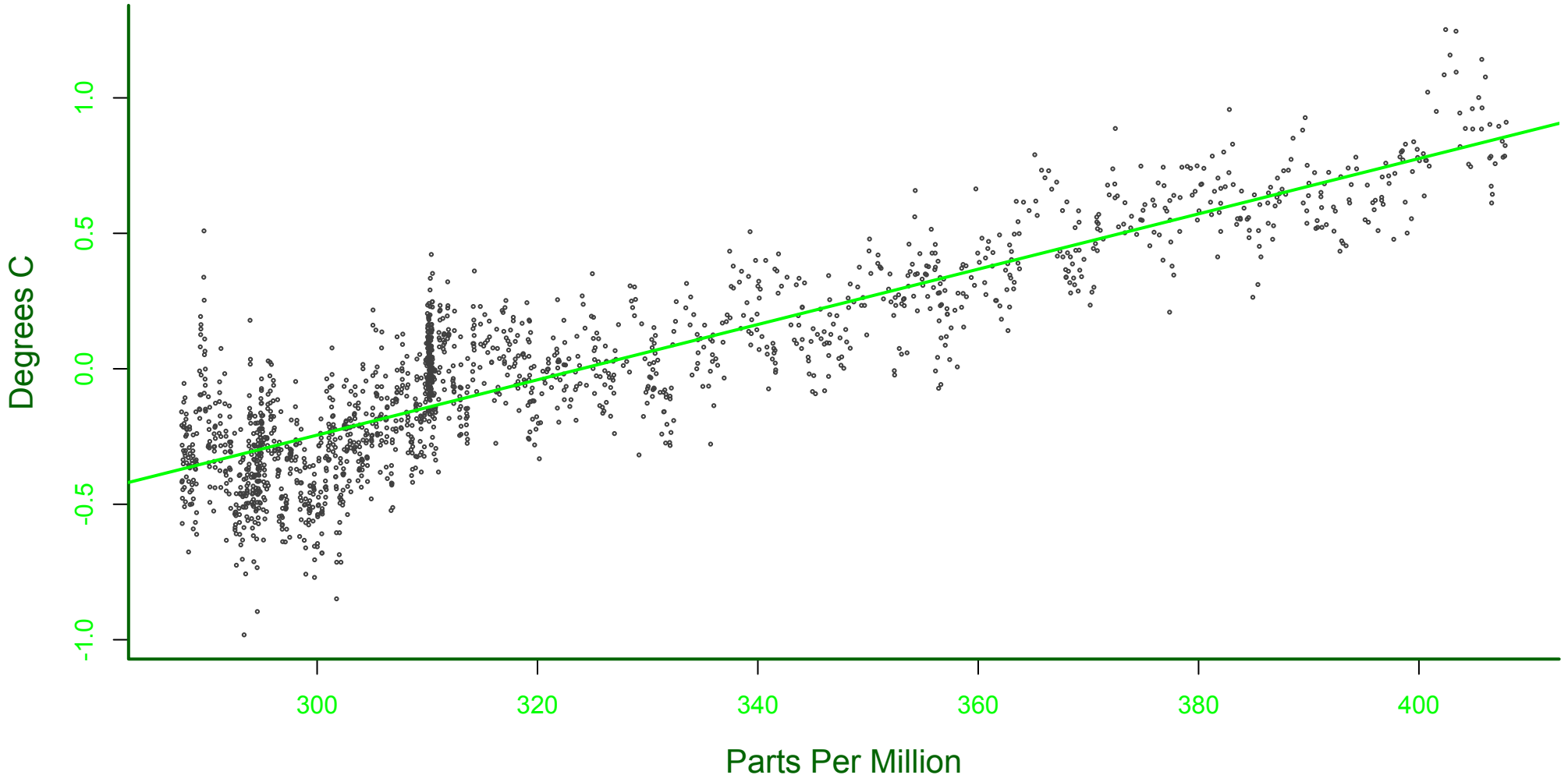
Carbon Dioxide Levels

Estimated Smoothed Carbon Dioxide Levels

From the ESRL at NOAA and the CDIAC at DoE - Wrangled a Bit

Two Series – Mauna Loa and Antarctic Law Dome Ice Cores

Temperature Anomaly versus Carbon Dioxide Level

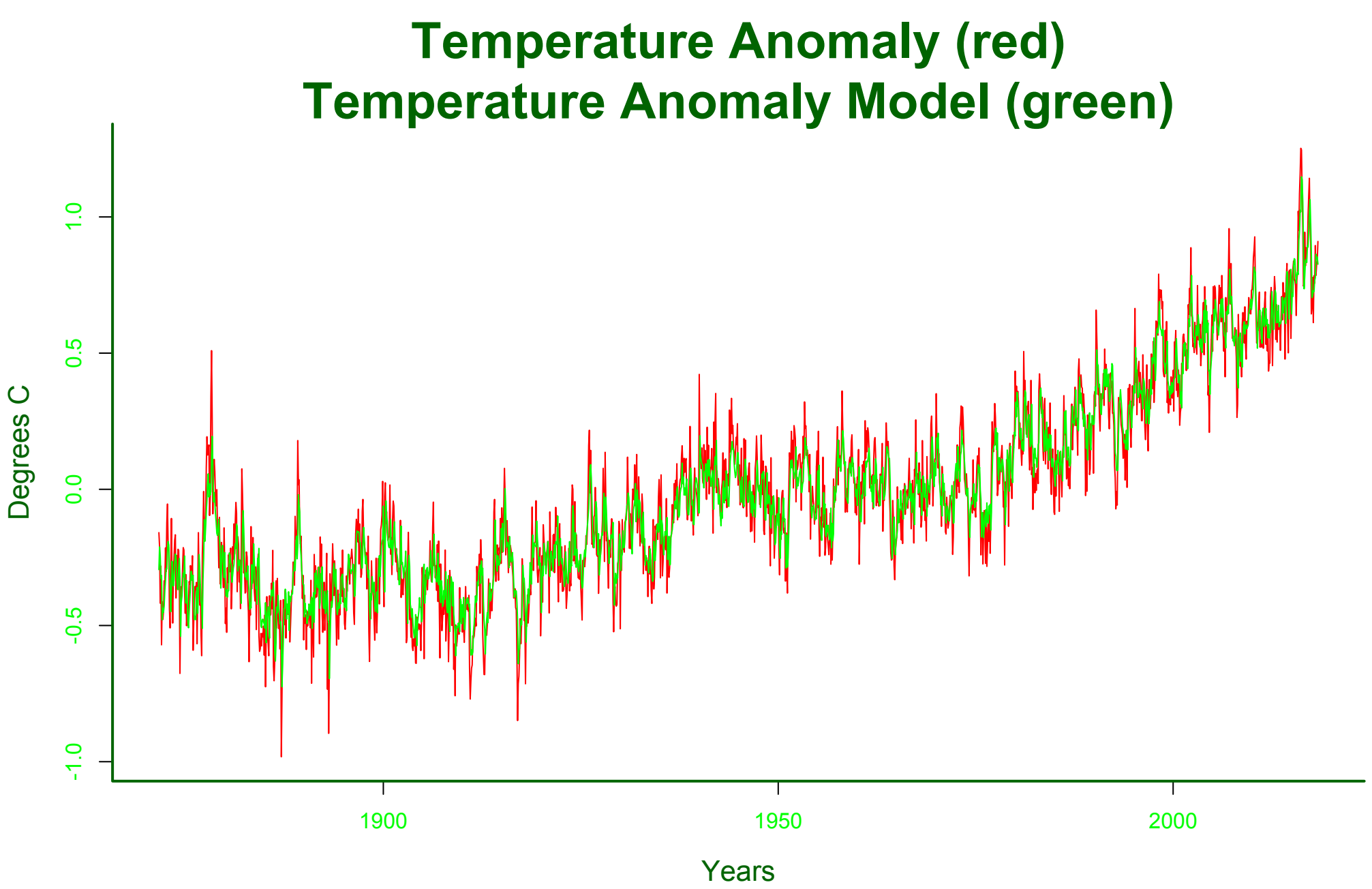


While *carbon dioxide* has the **strongest relationship** with temperature, *sunspots* and the *ENSO Index* are **also important**.

I fit a model, using all of *the three variables* against the *temperature anomaly*, by doing a **multiple linear regression** with **correlated times series errors** (using arima() in R.)

(For *correlated time series errors*, the value of a *temperature point* depends in the values of *past points* - in this case, the **three past months** and **twelve** and **twenty-four months back**. The *sunspot data was* from three months before the *temperature data.)*

In the following graph, the **actual data** is in **red** and the **estimated line** is in **green**. (The good fit is more a result of modeling the correlated time series errors than a result of using the sunspots, the MEI, and the carbon dioxide level.)


Temperature Anomaly (red)
Temperature Anomaly Model (green)
Degrees C
1.0
0.5
0.0
-0.5
-1.0
1900
1950
2000
Years

Putting Them All Together: The Model

The Temperature Has Memory

The Model Contains

3 Months of Past Temperatures and

Temperatures at *12 Months* and *24 Months* Back

The Rest of the Model

Intercept: *-3.2 Degrees* Centigrade

Sunspots: *0.03 Degrees* Centigrade per *100 Sunspots*

ENSO Index: *0.06 Degrees* Centigrade per *1 Level* of the Index

Carbon Dioxide: *0.99 Degrees* Centigrade per *100 ppm CO2*

The Intercept

The intercept is what the model would predict for the temperature anomaly given zero sunspots, an ENSO index of zero, and a carbon dioxide level of zero.

This model has an intercept of **-3.2 degrees** centigrade.

Since this is observational data we would not extrapolate to zero for the carbon dioxide, since zero is far outside the range of the carbon dioxide values.

Coefficient for Sunspots

The increase in sunspots *correlates* with an increase in temperature. For every increase of ***100 sunspots*** there was an average increase of ***0.03 degrees*** centigrade.

Over the years **1871 to 2018** the number of sunspots varied from ***close to zero*** to ***close to 370***.

Coefficient for ENSO Index

The ENSO Index also *correlates* with temperature. For every increase of ***one in the MEI*** there was an average increase of ***0.06 degrees*** centigrade in temperature.

The MEI varied from **about *-3.0* to *3.0*** during the years ***1871 to 2018*** (indices do not have units).

Coefficient for Carbon Dioxide

Carbon Dioxide *correlates* with temperature even better than sunspots or the ENSO index. For every increase of ***100 parts per million*** of carbon dioxide in the atmosphere, the was an average increase of ***0.99 degrees*** centigrade in the temperature.

Over the years ***1871 to 2018***, the carbon dioxide level increased from ***about 280 ppm*** to ***about 420 ppm***.

Disclaimer

This Analysis is of **Observational** Data

So The Analysis **Does Not Imply Causation**

But **Supports** What We Know about **Physical Reality**

Acknowledgments

This analysis was made possible by the, I would guess, millions of hours of labor by government and academic technicians, researchers and scientists and the persons who kept temperature logs on ships and on land over many decades - whose work resulted in the datasets I used.

Also, I credit what I believe to be the work of the researchers of the fossil fuel industries for suggesting that global warming is caused by sunspots and, later, the El Niño Southern Oscillation (ENSO), from whence I chose the variables I used.

Thanks to Kathy Getting and Julie Ehresmann for their help and advice.

By Margot Tollefson, PhD

For the

Hamilton County Going Green Town Hall

April 23, 2019 at Webster City, IA