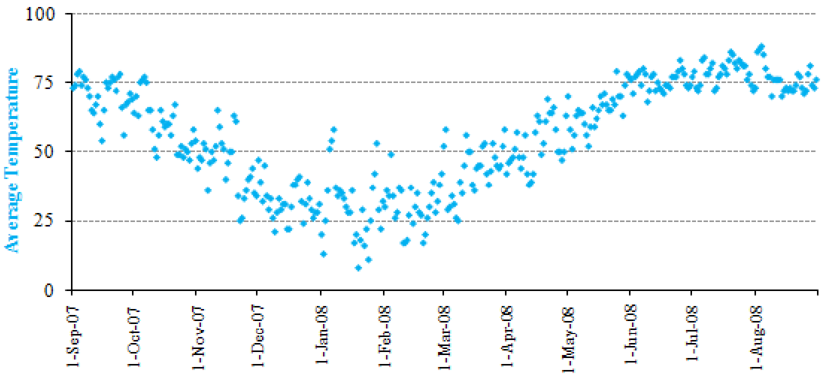
THE WEATHER

and Other Interesting Things

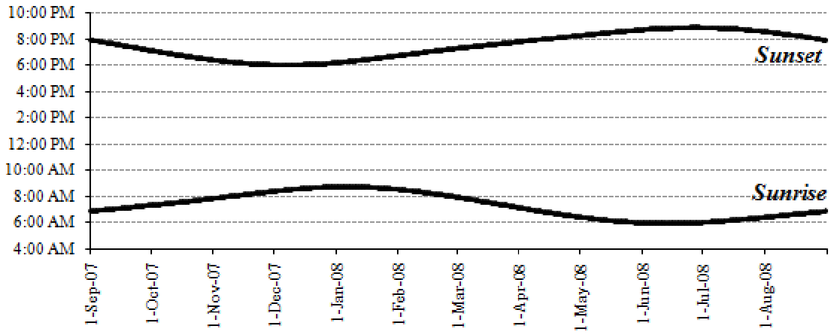
It gets cold in the winter and hot in the summer. We know that. Have you ever looked at it – visually? Let's take a look:



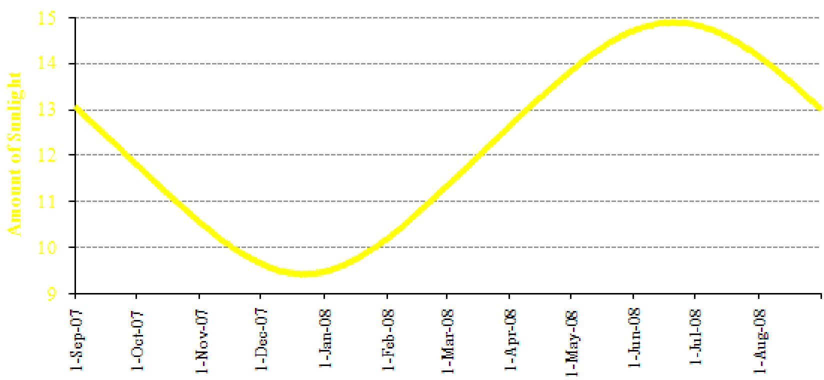
We were right, of course. We also know this is the case – for us. In other parts of the world, the graph is reversed. It's also flat – where the weather is constant.

But let's talk about us.

Why does this graph look like this? Sunlight? The fall equinox just passed, meaning we're going to start having less and less sunlight. Less sunlight should mean colder temperatures. It makes sense. Let's see if it's true, by graphing sunrise and sunset for the same annual period:

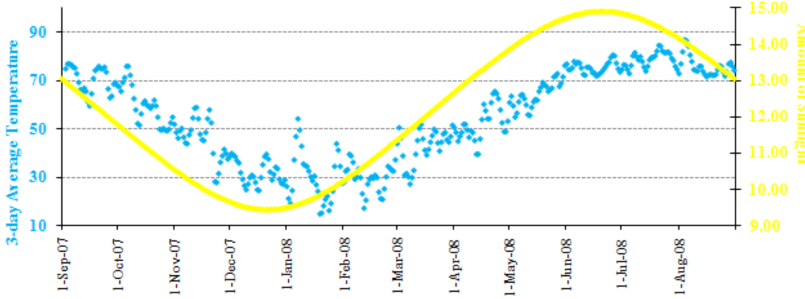


Indeed, exactly as we thought. As there's more sunlight, there's higher temperatures – and vice versa. But how much sunlight? Let's just graph that:



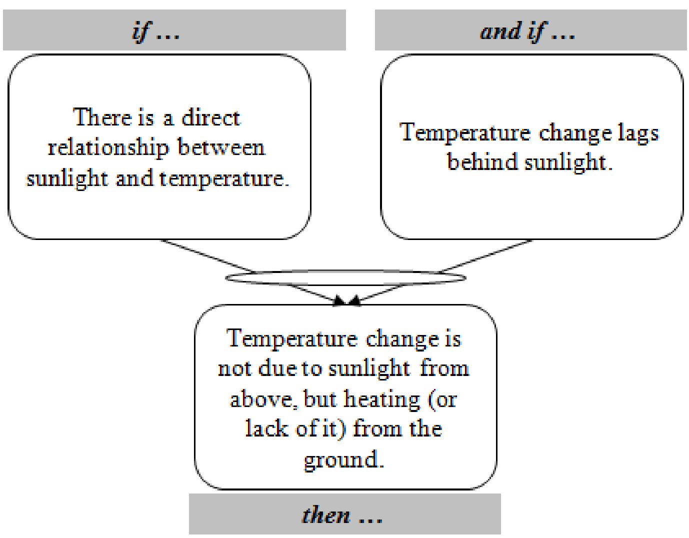
Temperature and Sunlight look remarkably similar. How similar? Let's put one on top of the other and see.

But there's something about the "temperature" graph that bothers me. The temperature can rise – and fall – significantly, over a short period of time. I'm not interested in that amount of variability – I just want to see trends. Therefore, rather than graphing each day, let's graphing the rolling average of the temperature over a certain period of time. To start, let's just try 3-day rolling average:



Lots of things stand out. Our thought was there was a direct link between temperature and sunlight. That seems true – but not quite. There's a delay between the minimum sunlight, for example, and the lowest temperature.

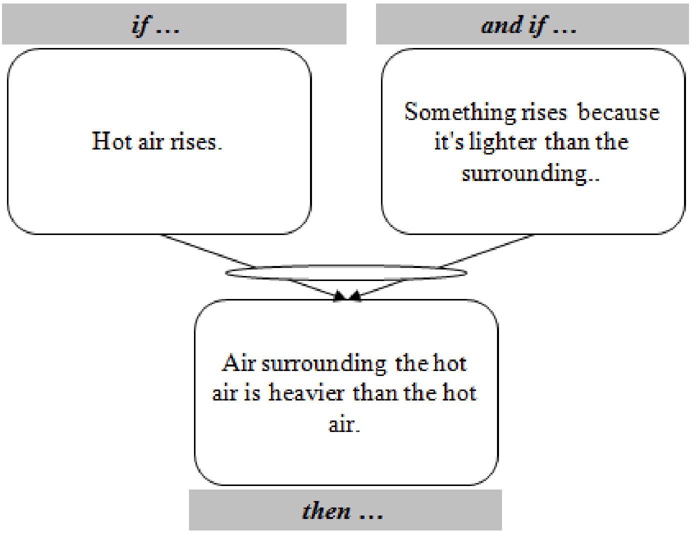
Why is this? Here's a reasonable guess:



The sunlight (or lack of it) warms the ground (or keeps it cool). What else can a bunch of weather data tell us? Let's look at atmospheric pressure. What does this look like – over time? But before I look at this graph, let's throw out a guess: what would I expect it to look like?

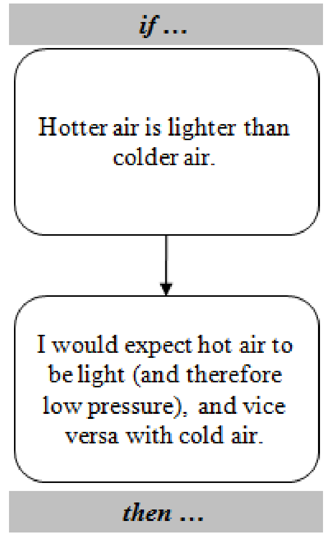
Where would we start?

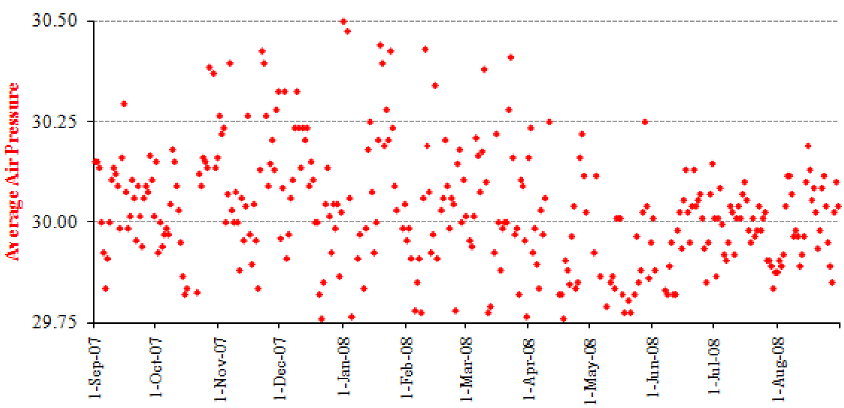
Let's start with a cliché: hot air rises. Is this true? Let's assume it is. It seems true for hot air balloons, after all! Why does hot air rise? Why does anything rise? It's lighter than – than what? The surrounding air. That is:



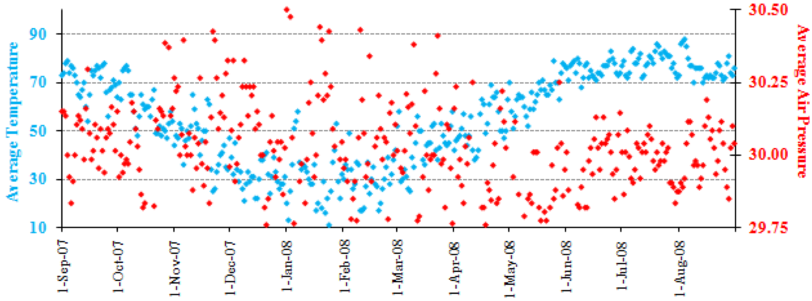
What about air pressure? It seems, then, if hotter air is lighter than colder air, then I would expect hot air to be light (and therefore, have low pressure), and vice versa for cold air. In fact, it seems I should be able to exchange one for the other: if it's hot, the pressure is low. If the pressure is low, then it's hot.

Let's graph the data and see:

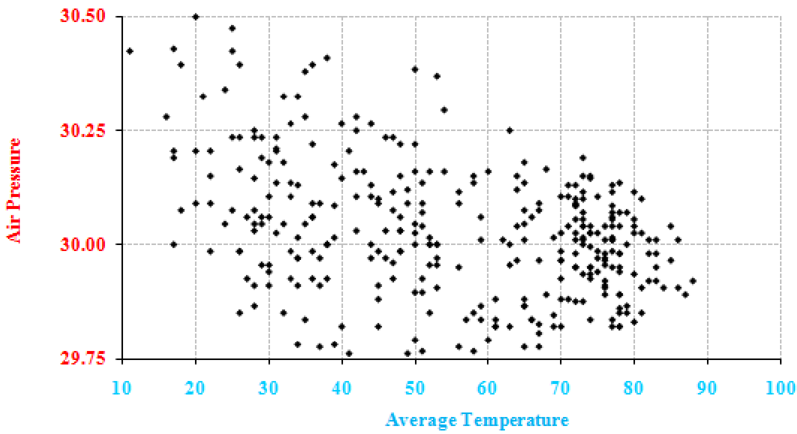




Where's the seasonal patterns we saw above with temperature? Sure, the pressure is low in the summer – as expected. And the highest pressures are during the winter. We expected to see that as well. But why are there extremely low pressures – in the winter? Let's put air pressure and temperature on the same graph, just to make sure:



What a mess! And what happens if we do a scatter plot of temperature versus air pressure?



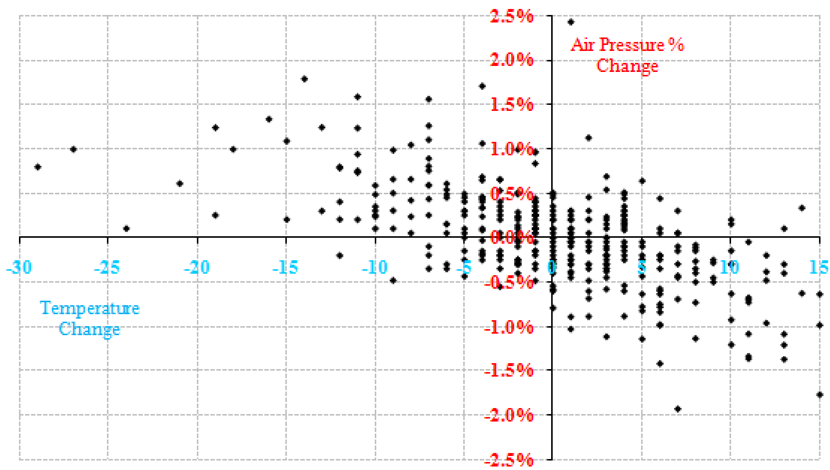
What is going on here? There seems a general relationship: as temperature goes up, air pressure goes down, but I was expecting a *direct* relationship!

Additional Thoughts

One mistake I might be making is this: let's suppose the temperature is 42° with a pressure of 30.00. We get a day of sunlight that warms the ground, and excites the air molecules. This air is just a bit lighter than the surrounding air, and is pushed up. The new pressure – at that moment – may slightly go down, let's say to 29.75, as the temperature rises, let's say to 43°. It's still cold, though the pressure is pretty low.

The relationship between air pressure and temperature, then, depends on the conditions on a day-by-day basis.

Let's graph the data, then, on a changing basis: How does temperature change, one day versus the prior, on a pure temperature basis? How does air pressure change, on a percent basis?



That's a little better, but still not the direct relationship I'm looking for.

An additional thought comes to mind. I'm taking single numbers – air pressure and temperature – for the entire day. Both, of course, change throughout the day. By hour. By minute. Every single second, the atmosphere is changing! Everything is changing!

A meteorologist's job is to predict the weather. Here, I'm wondering if it's even possible to recreate the weather?

And that brings me to Edward Lorenz.

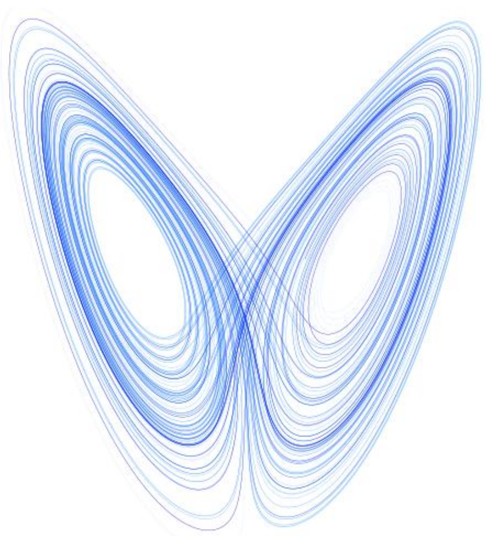
He came upon a similar question – by accident.

In trying to create a model, in the 1960s, to simulate weather patterns, he found he couldn't even recreate his own model.

Why?

He was rounding his data to six decimal points, but ultimately, this rounding manifested itself in huge errors that meant he couldn't even predict his own weather data!

He called this phenomena "The Butterfly Effect". Small changes in the inputs can lead to dramatic effects in the outputs. This is the Lorenz Attractor



How can I recreate this image? By these three equations:

$$\frac{dx}{dt} = \sigma(y - x)$$
$$\frac{dy}{dt} = x(\rho - x) - y$$
$$\frac{dx}{dt} = xy - \beta x$$

I honestly don't know what these mean, particularly with respect to a spreadsheet. However, I did find these:

$$x_{n+1} = x_n + t(\sigma(y_n - x_n))$$
$$y_{n+1} = y_n + t(x_n(\rho - x_n) - y_n$$
$$z_{n+1} = z_n + t(x_n y_n - \beta x_n)$$

What do *they* mean? Each *x*, *y*, and *z* depends on the previous value of *x*, *y*, and *z*. '*t*' represents "time", so as time moves forward, the values change. And what about the three variables:

$$\sigma,\ \rho,\ \beta$$

We set these! OK – let's create a spreadsheet and see what we've got. And for the three parameters? What values should I use? The figure above was with

$$\sigma = 10,\ \rho = 28,\ \beta = 8/3$$

so I'll try these, and see if I can re-create the diagram. But first, the table of data points to graph:

THE LORENZ ATTRACTOR

PARAMETERS

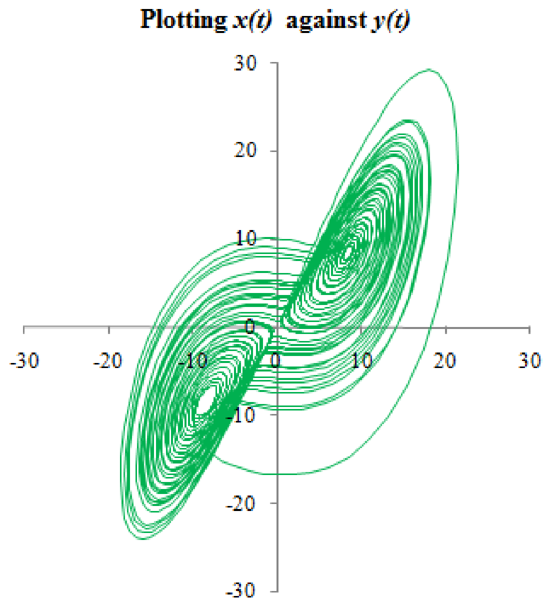
sigma:	10
rho:	28
beta:	2.667
Show Elapsed Time:	50
delta t:	0.01

Based on Initial Conditions

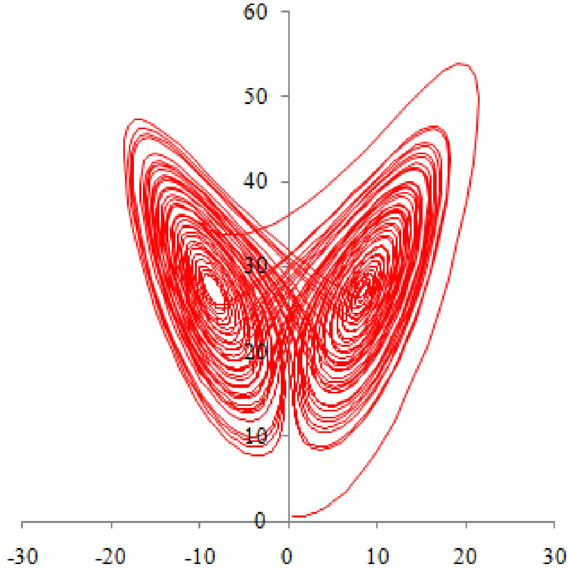
at Time t = 0.00

t	x(t)	y(t)	z(t)
0.00	0.5000	0.5000	0.5000
0.01	0.5000	0.6325	0.4892
0.02	0.5133	0.7637	0.4793
0.03	0.5383	0.8973	0.4704
0.04	0.5742	1.0366	0.4627
0.05	0.6204	1.1843	0.4563
0.06	0.6768	1.3434	0.4515
0.07	0.7435	1.5164	0.4486
0.08	0.8208	1.7061	0.4479
0.09	0.9093	1.9151	0.4499
0.10	1.0099	2.1465	0.4553
0.11	1.1235	2.4032	0.4649
0.12	1.2515	2.6885	0.4795
0.13	1.3952	3.0061	0.5003
0.14	1.5563	3.3597	0.5289
0.15	1.7366	3.7536	0.5671
0.16	1.9383	4.1925	0.6172
0.17	2.1638	4.6814	0.6820
0.18	2.4155	5.2256	0.7651
0.19	2.6965	5.8312	0.8709
0.20	3.0100	6.5045	1.0049

What can I do with this data? It's hard to create a 3-d scatter plot in Excel, but I can plot the coordinates against one another. Let's see what this looks like:



Plotting *x(t)* against *z(t)*



Plotting *y(t)* against *z(t)*