Sunny and Shady Math

The Light Probe

It was Friday afternoon, around 4PM toward the end of February - the 24th, to be exact. I looked out my office window at Seattle University. It wasn't yet dark but it was a little dreary. I was cleaning up a few things, getting ready to go home and I came across a glass tube with a wire extending out one end and a shielded sensor staring out the other. I followed the wire through a couple of junctions to a USB plug. It was a light sensor, one of several data probes I got a few years back. While I have used the temperature and sound probes a good deal, the light sensor has been less useful. It seems I don't really have a need to quantify light; it's just there insufficient quantity or it's not, in which case I flip a switch or I stumble around in the dark. Nevertheless I plugged in the probe, fired up the data logger software and recorded a 20 second swing around my office, starting by pointing toward the book cases on the south wall and gradually rotating 360° so that I ended facing the south wall again. Figure 1 shows the record produced by the software. The x-axis is time (20 seconds) and the y-axis is lux (think of it as light intensity). Can you guess which wall is mostly window? To do this you have to understand how the progression of time from left to right on the x-axis is associated with the change in the dependent variable, lux, represented on the y-axis. That is, you need to really understand how an X-Y graph works.

Before I left that afternoon, I set the probe up, aimed out the window at a point low on the southeastern horizon. I set the software to record ten times per minute for 124 hours (five days and 4 hours), turned off the lights and left. Returning Monday morning I found an interesting record of the weekend. Saturday had been overcast but Sunday had seen a few brief sunbreaks in the morning before the clouds rolled back around noon. The next few days

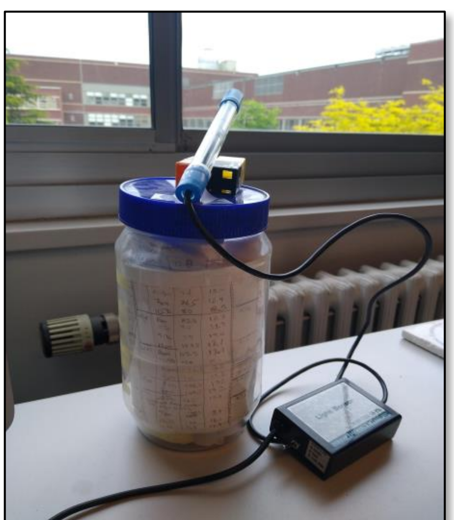

Image 1 - Light Probe

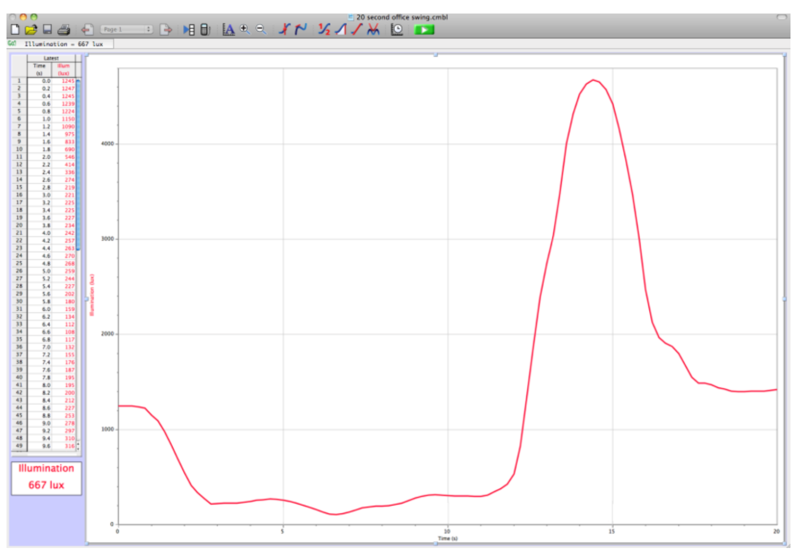

Figure 1 - Twenty second swing around my office

brought several sorts of weather including wind, sun, periods of overcast and even some light snow on Wednesday morning. Figure 2 is the record of those 5 days. As in Figure 1, time is on the x-axis and light intensity (lux) is on the y-axis.

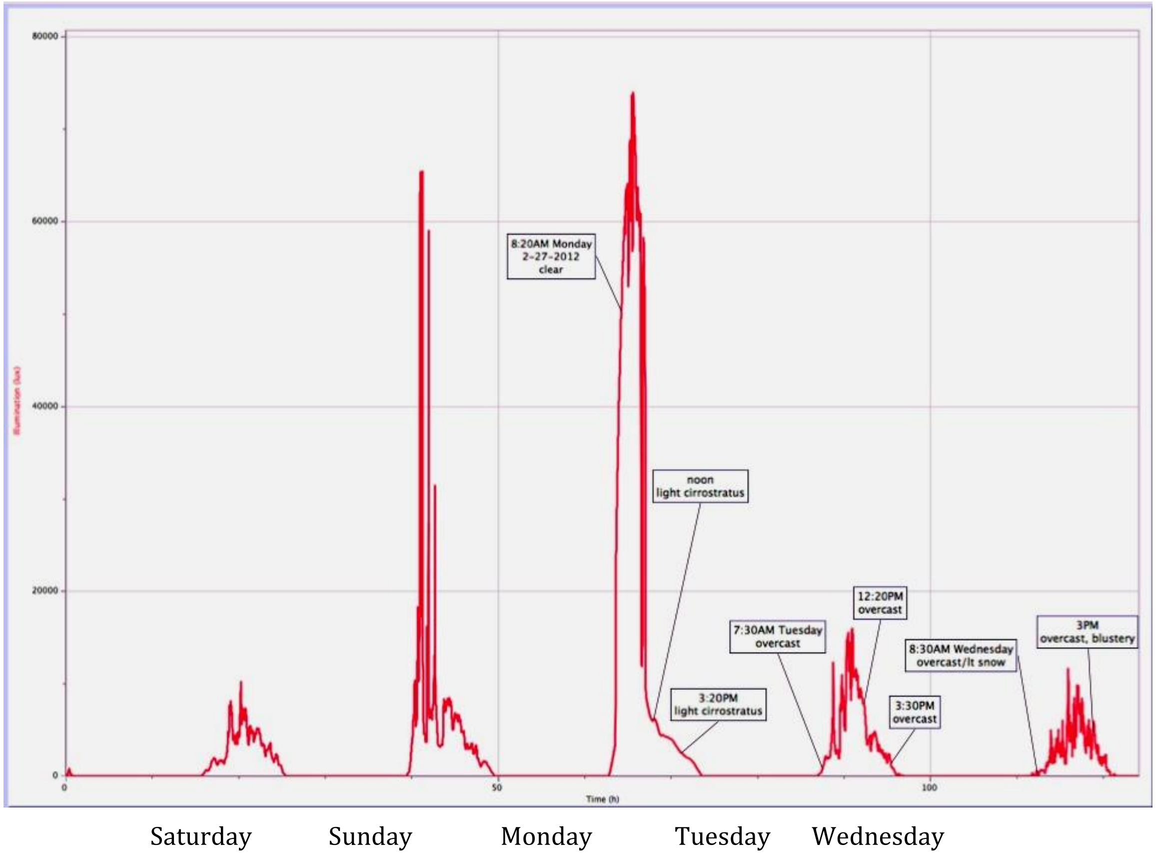

Figure 2 - Time (124 hours) vs. lux (light intensity)

Light Comes and Goes

A closer look at the graph, the units and the scale make me wonder about the probe's sensitivity to direct sunlight as well as the range settings, which I chose haphazardly on that Friday afternoon, and the subsequent accuracy of the measurements. Nevertheless, the experience of sunlight over these five days is represented graphically and there is a remarkable difference in the records of Sunday and Monday (the second and third days on the record) versus Saturday (the first day), and the last couple of days, Tuesday and Wednesday. While Monday morning had been clear and sunny, by noon we had a layer of cirrostratus, often a forerunner to an approaching weather system, and the next two days were overcast and windy with rain and even a little snow Wednesday morning.

Thinking further about the graph, it seems clear that the area between the curve above and the x-axis below tells us something about how much sunlight we received each day. Those with a little calculus under their belts will recall that you can use integrals to find that area. The data logger software comes with an "integral" tool that allows me to select a range on the x-axis and estimate an integral over that period. Doing so allows me to compare in a rough way, the amount of sunlight received. Table 1 shows the results of these calculations for each of the five days.

Saturday	Sunday	Monday	Tuesday	Wednesday
30,200 h*lux	61,900 h*lux	211,000 h*lux	45,100 h*lux	27,900 h*lux

Table 1 - Light (lux) under the curves for the five days

I can see that according to these measurements we went from a high of over 210,000 units of light on Monday to a low of only about 28,000 units on Wednesday, the last day of the record and one with an overcast thick enough to produce snow and rain. The record of just these few days encourages me to infer that a solid and persistent layer of clouds can reduce by a factor of at least seven the amount of sunlight we receive on any given day. The simple math serves to underscore the fact that though we complain to our friends who live in sunnier climes, we don't actually live under a sodden blanket of drizzling grey clouds that stretches from October through late June. There is variation, even in Seattle and the simple mathematics represented in the graph and the summarizing table help us to clarify the situation.

The extraordinarily useful Web site, *Gray Skies*, created by and hosted at the University of Washington's Atmospheric Science department allows me to investigate extensive records of a number of intuitive and interesting weather variables for locations all over the northwestern U.S. While "lux" is not one of them, the closely related Solar Radiation, measured in watts per square meter is available

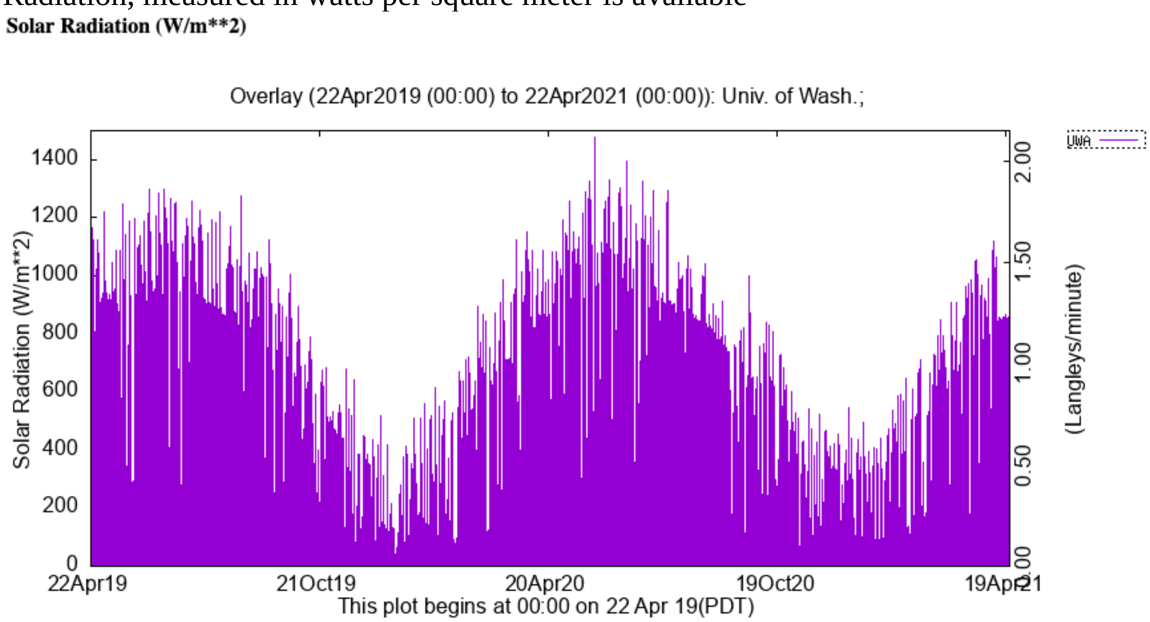

Figure 3 - Two years of solar radiation at the University of Washington

at a few stations including one at the University of Washington in Seattle. Figure 3 shows two years-worth of these data, from 22 April of 2019 to the same date in 2021. From this graph it is clear that the amount of sunlight received shows a strong trend over the course of a year. The shape of the curve reminds me of a sine (or cosine) function and I wonder if I could get students who are learning about basic trigonometry to model the seasonal coming and going of the light with one or another of these functions. With the right parameters the model would allow learners to input an x value corresponding to a calendar date and calculate a y value, a prediction of the light to be expected on that date.

Counting on Rain

Of course sunlight or its absence in the Northwest is just one variable that we encounter on a daily basis and mostly take for granted. Some others include temperature, wind, and rain. Figure 4 shows the record of cumulative rain amounts over one year from 24 April 2020 to the same date in 2021.

Cumulative Rain

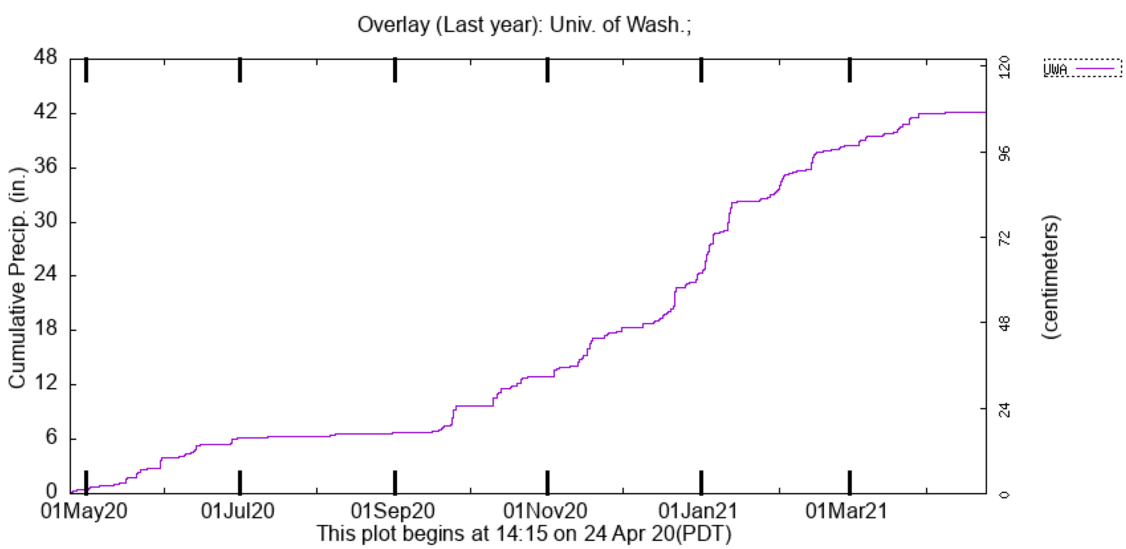

Figure 4 - Cumulative rain April 2020 - April 2021 - Seattle, WA

What does it mean when the graph is flat? How about those sudden steep rises? Why does the graph never fall as we look from left to right? These questions, posed at the right time by a caring and interested teacher, might prompt a 7th grader just developing her understanding of x-y graphs and slope to make connections between real life, her daily experiences of the weather, and fundamental constructs of mathematical representation.

When we engineer situations in which learners construct understanding through active engagement, we do them a service that can transfer beyond the immediate circumstances.

If we can help our students see math as a way of making sense of the world, we have done them a service that can last a lifetime.

Lesson Plan

Learn more about implementing Sunny & Shady Math in your classroom by exploring the Illuminations lesson here! Then, share your experiences using Math Sightings on social media with the hashtag #MathSightings.

References

Gray Skies: http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html

An interesting weather visualization tool on the web is Ventusky:
https://www.ventusky.com/

Note: One **lux is** equal to one lumen per square meter.