A Meteorology Package for Eclipse Observation

David Snyder

Introduction

For the upcoming total eclipse of the Sun on April 8, 2024, I would like to propose a package of instruments that have a high probability of giving at least some results. As I live near Cleveland OH, and a recent Sky & Telescope article [1] suggests a 60% chance of clouds, photographs of the Sun's Corona, or nearby starfields [2] are not likely, nor are daytime observation of planets or bright stars, though they may be useful to prepare for, just is case the skies are clear.

We can be assured that it will get dark. So quantitative measurements of the sky illumination should be possible, whether covered by clouds or not. Reduced Solar energy should result in falling temperatures.

I expect falling temperatures to cause a change in pressure. One could argue that from the ideal gas law this causes a drop in pressure. However, the pressure is caused by the weight of the atmosphere. And instead, from the ideal gas law the density increases, and the collapsing atmosphere may cause additional air to flow into the eclipse region, raising the pressure.

Presumably the absolute moisture content would not change much, so the relative humidity may rise with falling temperature.

This suggests four basic measurements: illumination, temperature, pressure and humidity. Additional measurements might include a collimated illumination from the Sun (if it is visible), wind speed and direction, as well as alternative temperature measurements. And maybe [nearly] full sky photographs.

This paper is my first cut at proposing sensors for an eclipse meteorological. I intend to use them for developing a prototype hardware and software. However, there may be better choices.

Time intervals

At early stages of the eclipse fairly course measurement intervals of 5 min should be acceptable. As the eclipse gets deeper, 1 min intervals might be desirable. During the total eclipse which may last up to 4 minutes, 20 s interval should be OK to detect the final changes.

Instruments/Sensors (Basic)

To run this system I am trying the Raspberry Pico. I have used Raspberry Pi Zero's for a few projects, including High Altitude Balloon projects. However, they are getting difficult to find. In fact, I have not yet seen the Raspberry Pi Zero 2. I have gotten a hold of a Pico and a Pico-W ($6.99), from the local MicroCenter. The Pico is more like an Arduino than a Zero. It does not include as much memory as the Zero, for data logging. It does not support the Pi camera interface, or, as far as I know support, a web server. But it does support analog inputs, which would be nice for making photocell measurements, wind direction, and analog temperature measurements. It is possible to program it in python.

The power requirements for the Pico are a flexible 1.8 to 5.5V. While a USB source is preferable, a two or three cell AA battery pack ($2.00) should work.

I choose I2C compatible instruments, preferably with Sparkfun's Qwiic Interface. A BME280 [3] ($16.50) provides temperature, pressure and humidity measurements. Some preliminary tests should be made to determin the response time of the Temperature sensor, perhaps by moving the sensor from indores to outdores, or vis versa.

A VEML7700 [4] ($5.95) provides an ambient light measurement. (I am assuming it can handle direct sunlight). It looks like there are adjustments for sensitivity and integration time, with a 16-bit readout so it ought to work from from direct sunlight into the dark sky of the eclipse. It appears to have a 60 degree field of view, to 50% response, so I would consider it to be a nearly full sky sensor. I would consider this to be a "full sky" reading. My first choice would be to mount it facing up. My second choice, if I got a second sensor, would be to orient it to the sun. Direct sunlight may be up to 100 kLx. At one point in the Datasheet, it states it can read up to 167 kLx. At another point it gives the range as 0-167 lx. My assumption is that it can handle a little more than direct sunlight, which is a reasonable limitation.

Options

Additional meteorological measurements might be useful. Wind Speed and direction sensors run about $15 each. A change in pressure may result in a wind change, but in past eclipses I don't remember the wind.

It may be useful to spend a little more effort in illumination measurements. Two possible photodiodes may be the VTP1188SH as a (nearly) full sky sensor, directed upward. This has a case lens that acts as a fish eye lens. A VTP9812FH might be used as a collimated sensor. A drinking straw, with the interior painted flat black (Krylon flat black) to minimize reflections may be used as a collimating tube. The sensor gets inserted at one end and pointed at the sun. It might be taped to a tripod, with a shadow card in back. The idea is that when the shadow of the tube minimized, the tube should be pointed at the sun. a LM358 op amp might be used to amplify the signal to a reasonable level. But the circuitry still needs to be worked out.

Adafruit offers a small I2C display that might be used to indicate the status of the sensors and measurement. But timestamped measurements should be logged for later retrieval.

A Camera operated as an Intervalometer may be used to record the sky conditions. It is fairly easy to use a Raspberry Pi with a picam, as a relatively inexpensive intervalometer. Probably 10 minute intervals would be acceptable as I don't see how the sky could change rapidly. But several pictures during Totality may be useful. It may be possible to translate the photograph into luminosity measurements.

Conclusion

It should possible to build a relatively inexpensive instrument package to monitor the 2024 solar eclipse, possibly in the $40-$70 price range.

References

[1] Espenak, F. and Anderson, J., “Get Ready for Totality in ‘24”, Sky and Telescope, April 2023, pp26-35 (2023).

[2] *Dyson, F. W.; Eddington, A. S.; Davidson, C. (1920). "A Determination of the Deflection of Light by the Sun's Gravitational Field, from Observations Made at the Total Eclipse of May 29, 1919". Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences.* ***220*** *(571–581): 291–333.*

[3] BME280 Atmospheric Sensor

https://www.sparkfun.com/products/15440

Data Sheet - https://cdn.sparkfun.com/assets/e/7/3/b/1/BME280_Datasheet.pdf

[4] Ambient Light Sensor (VEML7700)

https://www.sparkfun.com/products/18981

Data Sheet - https://cdn.sparkfun.com/assets/a/2/b/a/4/VEML7700_Datasheet.pdf

Raspberry Pico data sheet
https://datasheets.raspberrypi.com/pico/pico-datasheet.pdf

This article
https://stratohio.wordpress.com/2023/03/02/a-meteorology-package-for-eclipse-observation/