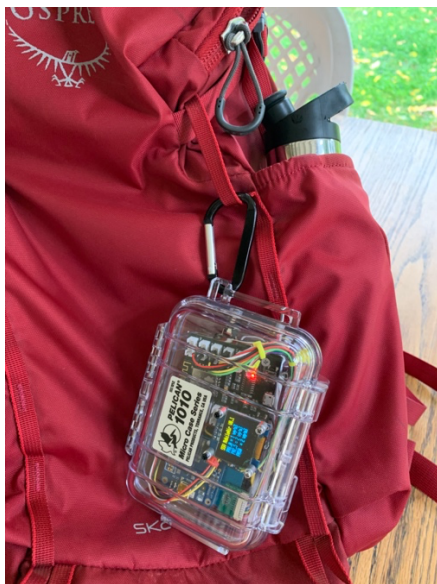




## BackpAQ Mobile *Personal* Air Quality Monitor

V2.0

[User's Guide V0.88](#)



Source: [BackpAQ User's Guide](#)

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## Introduction

The BackpAQ project is an essential part of a middle and high school STEM curriculum that promotes learning about and experience with the monitoring of air quality (AQ) particularly in disadvantaged communities, and drives engagement among underrepresented youth in STEM activities.

Key to the program is deployment of a suite of community-based mobile air quality monitors that leverage new low-cost sensors. These handheld units can be readily assembled by advanced middle-school and high school students and other STEM-oriented youth who are motivated by interest in obtaining, understanding and sharing hyper-local air quality data.

### What we'll build

For this project we are going to build a BackpAQ personal air quality (AQ) monitor. As you can see from the accompanying photos, BackpAQ is designed to be easily carried, clipped to a backpack, or placed in a mobile scenario such as a vehicle or other transport. As BackpAQ utilizes GPS positioning technology, the AQ information we collect will be geo-positioned no matter where the monitor goes.

These student-built monitors, encased in a lightweight polycarbonate box, weigh less than a pound and are powered by rechargeable LiPo batteries. They feature carabineers and nylon straps for easy fastening to a backpack or bicycle frame.

### What we'll measure

As designed, the monitors will measure and display criteria pollutants PM<sub>1</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> concentrations in ug/m<sup>3</sup>, as well as display the US EPA Air Quality Index (AQI). Gases such as TVOC and CO<sub>2</sub> are also easily monitored with BackpAQ and can be optionally built in. Monitoring of additional pollutants, such as CO, O<sub>3</sub>, NO<sub>2</sub> and SO<sub>2</sub> are possible future enhancements. The latest version pairs with a smartphone app to provide an interactive user experience and allow customization and personalization of monitored data and how it's displayed. BackpAQ automatically uploads data to the Thingspeak cloud where it can be visualized using powerful analytics, and shared with other students or local community officials.

### What we'll learn

To begin with, we'll learn design, build and fabrication techniques - along with some pretty powerful electronics, Internet-of-Things (IOT), and sensor technology skills. Perhaps most importantly, we'll learn how to curate and analyze data we capture from the monitors. Learning how to develop and apply critical judgement to the data and subsequent reporting and sharing of findings and implications are key outcomes of this project.

### Outcomes

The intended outcome of this project is twofold: one, obtain a richer, deeper understanding of air pollution, where it comes from, how to measure it, how to harness powerful analytics to responsibly report and share findings, and (hopefully) gain some insight that will enable ordinary concerned people to do something about it. And two, build a monitoring device - BackpAQ - to better understand the science and engineering behind sensors, IOT, the Maker Movement, and have hands-on involvement with one of the more critical challenges facing communities today.

## Quick Review of What We're Measuring

Before we get started building, let's take a look at the science behind air quality, sensors and monitoring.

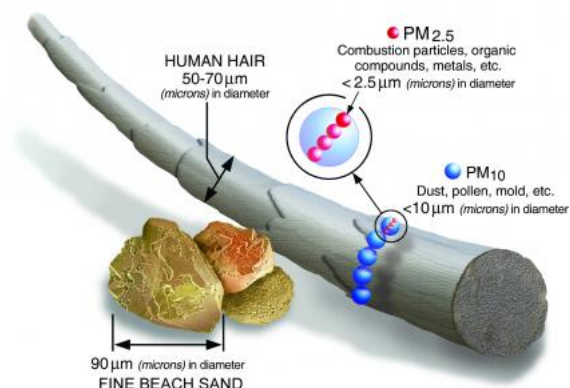
"I've got one word, just one word....Particulates! (see movie "The Graduate" for why I have paraphrased here.)

So, what are "Particulates" (PM), and how do they get into the air?

### Size comparisons for PM particles

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye.

Others are so small they can only be detected using an electron microscope. Particle pollution includes: PM<sub>10</sub>: inhalable particles, with diameters that are generally 10 micrometers and smaller; and PM<sub>2.5</sub>: fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller. How small is 2.5 micrometers? Think about a single hair from your head. The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle. See this:



### Sources of PM

These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

### What are the Harmful Effects of PM?

Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or PM<sub>2.5</sub>, pose the

greatest risk to health. Fine particles are also the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas. Learn more about health and environmental effects.

### The PM Sensor for BackpAQ

The particulate sensor we have chosen for this project is the Plantower PMS7003. It is able to measure the concentration of fine particles of less than  $1\mu\text{m}$  (PM1); less than  $2.5\mu\text{m}$  (PM2.5) and less than  $10\mu\text{m}$  (PM10). The operating principle of the PSM5003 sensor is as follows: a laser illuminates airborne particles. An optical sensor captures the laser light and generates an electrical signal proportional to the rate and size of the particles in the air. This block diagram shows what's going on inside the sensor. Note that there is a microprocessor that does some computation and digitization of the signal so that we can read the data in our own hardware.

### What are ATM and CF1?

The CF\_ATM and CF\_1 values are calculated from the particle count data with a proprietary algorithm developed by the laser counter manufacturer, Plantower. The specifics of the calculation are not available to the public (or us for that matter). However, to convert the particle count data ( $\mu\text{m}/\text{dl}$ ) to a mass concentration ( $\mu\text{g}/\text{m}^3$ ) they must use an average particle density. They do provide 2 different mass concentration conversion options; CF\_1 uses the "average particle density" for indoor particulate matter and CF\_ATM uses the "average particle density" for outdoor particulate matter.

Depending on the density of the particles you are measuring the sensor could appear to read "high" or "low". Some groups have developed conversion factors to convert the data from the sensor to match the unique average particle density within their airshed.

### What are TVOCs?

VOCs, or volatile organic compounds, are a group of thousands of organic chemicals that evaporate at low temperatures. So, TVOC is just "total volatile organic compounds", right? It's "all the VOCs added up together." Unfortunately, the answer isn't quite that simple.

Most pollutants are extremely easy to define - ozone is three oxygen atoms.  $\text{SO}_2$  is a molecule composed of one sulfur atom and two oxygen atoms. Even particulate matter, with all its different flavors can be defined in one simple phrase (particulate matter with an aerodynamic diameter less than  $2.5\mu\text{m}$ ). But what exactly is TVOC?

Wikipedia dedicates an entire subsection JUST to the definition of TVOC. The simple answer is that there is no consensus around how TVOC should be defined. There are literally thousands of VOCs, and countless national bodies, governments and organizations have created their own lists of VOCs to be included in their TVOC definition.

Luckily, several standards have emerged based upon research on the VOCs typically found in indoor environments. For example, ISO 16000-29 defines a "VOC mixed gas" comprised of 40

individual compounds. This is a standardized gas mixture used to simulate typical indoor air. Mølhave et al. defines a “Typical IAQ Mix” of 22 VOCs at concentrations similar to those determined on average in residential indoor environments.

### How is TVOC measured?

There are a number of ways to measure VOCs, with pros and cons based on the situation, budget available, etc. Historically, laboratory techniques such as flame ionization detectors or gas chromatography–mass spectrometry were used, providing an accurate way to identify specific gases within a sample.

While lab-based measurements may be highly accurate, they are unable to provide a continuous measurement of TVOC, which is incredibly important and, some may even argue, more important than having a perfectly accurate value for a specific gas.

For the continuous monitoring of TVOC, MOS sensors are generally used. This is a broad category, and sensors across this category provide varying degrees of quality in their readings - not all MOS sensors are built equal. Similar technology is used throughout, however, which is what we will explore below.

MOS (metal oxide semi-conductors) work by heating a thin film, or surface, of metal-oxide particles. For BackpAQ, our sensor employs a thin film of metal-oxide nanoparticles. This film is heated to around 300°C, so a brief warm-up period is needed after turning on a BackpAQ device).

During operation, oxygen particles will be adsorbed on the surface, and these in turn will react with the target gas. This reaction causes a release of electrons from the oxygen present on the surface, which in turn leads to a change in electrical resistance of the metal-oxide layer.

Chemical reactions within the MOS sensor creates a change in electrical resistance. What the sensor is actually measuring is the electrical resistance of this metal-oxide layer. This real time measurement and output of resistance is the first step in obtaining our TVOC reading.

Finally, it's important to remember that the sensor we use will be sensitive to a wide variety of VOCs, rather than to one specific individual VOC.

### An Important Caveat

The data that the Plantower (and other optical counters) produce is an *estimation* of particulate mass concentration that relies on several assumptions for shape, diameter and density. The quality of your data will depend on those assumptions as well as environmental considerations such as humidity, light and temperature.

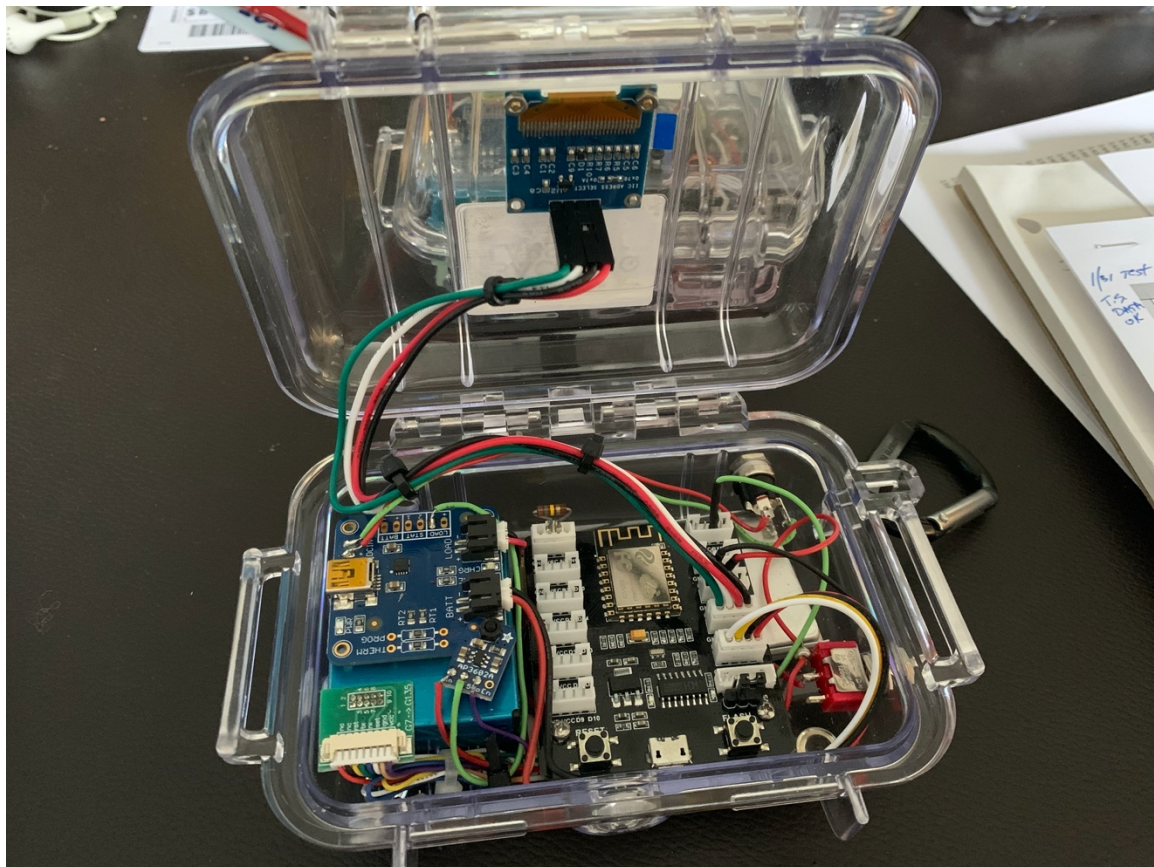
Because of the fact that optical counters rely on these assumptions, the data produced by them are not FRM or FEM certified.



## BackpAQ Specifications

### Specifications

- Size: 5" x 2" x 4"
- Weight: 10 OZ
- Case Material: Polycarbonate
- Measured particles: PM1, PM2.5 and PM10
- Optional: TVOC, eCO2
- Processor: ESP32 (240MHz Tensilica LX6 dual core)
- Communication: WiFi, 802.11 b/g/n + Bluetooth V4.2 and Bluetooth LE
- Battery Life: around 9 hours, depending on sampling frequency
- Battery: 3.7V LiPoly- 2000/2500 mAh rechargeable
- Sampling period: adjustable 1 - 60 minutes
- Display: Multicolor OLED interface for local data display and control
- Smartphone Interface (Android, iOS) via Wifi and Blynk
- Regular OTA software updates (roadmap)



## Configuring your BackpAQ (Version 2) Device

Congratulations on completing the build of your BackpAQ kit, or, if using an already-complete monitor, let's get started configuring your unit for use. You'll need your laptop, tablet or other Internet-connected device for this next step.

When you first power up your BackpAQ unit, after a few seconds you'll see the following display on the top of the case:



This is BackpAQ prompting you to connect your WiFi (on your laptop, tablet or phone) to BackpAQ's own SSID, which is "BackpAQ" + a set of unique hex characters that represent the id of the processor contained within the unit.


Next, depending on what kind of device you are using, and what operating system & browser you use, your browser should automatically pop up with the BackpAQ Configuration webpage displayed. If this does not happen automatically with about 5 seconds, just launch your browser manually and go to address 192.168.4.1 and the Configuration page will appear.

You will see a page that looks like this:

Join "BackPAQ\_B485AABC"

## Configuration

[NETGEAR96](#)

 14%

SSID

Your WIFI SSID from your smartphone Hotspot

password

Your password for this Hotspot

BackPAQ Userid

xxxxxxxxxx

Blink auth token

zaOlhbXU0xo0aXnluRiCa1jY7E-ID-aS5

☒ Run BackPAQ in mobile mode

Default GPS Position



Fill in the required fields, scrolling down to complete all. Most should be pre-filled for you if you are participating in a class or study. **The “SSID” and “Password” fields should be filled in with the WiFi SSID and password from your smartphone’s Hotspot.** If you need help with this step be let your instructor or me know and we’ll help you get connected.

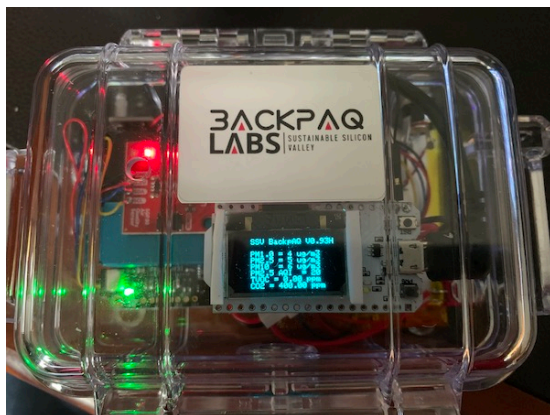
Also, be sure to check “mobile” if you intend to use BackpAQ for mobile monitoring, and ignore the “GPS Location” box.

Once connected and configuration is complete, the device will



continue its setup sequence and should look like the image above. If you don’t see “BLYNK Connected!” then something has mis-fired and you’ll need to click the switch off and restart. Sometimes there are timing or Internet issues...usually it only takes an additional try to get it working.

Finally, once the sensor has warmed up (about 30 seconds), you should see this screen:



You should see the PM readings displayed. If there are no TVOC or CO2 readings check to see if you have that sensor installed. On many devices it is optional, so these readings will be zero. You can quickly test to see if the sensor is working...try bringing the left-side opening near a source of particles, say, a candle, a match that's been lit and extinguished (be careful!), or other source. You should see the readings climb quickly and stay up for a time. Don't worry if the readings don't jump immediately – there is some processing delay to properly read and process the input from the sensor so there is usually a delay of several seconds until you see it on the display or on your smartphone.

## Using the BackpAQ app

The BackpAQ app has been designed to be useful and engaging to aid you in pursuing your AQ monitoring activities and investigations. However, please recognize that it's a work-in-progress and while highly functional, there are bound to be some bugs, glitches and not-quite-yet functions. Indeed, we hope that you will help refine this design or, better yet, help design something better! Consider this app a starter set of capabilities that you can build on + refine + share.

### Starting the app

**(Note: This section assumes that you have an email account configured and provisioned with the Blynk software. If not, stop and talk to your instructor where to download the Blynk software and which account to use.)** Also, if this is your first time you might have to enter your userid and password. To start the app, scroll your phone to the Blynk icon and click to activate.



(Here's a [link to Blynk](#) if you want to learn more about this tool.)

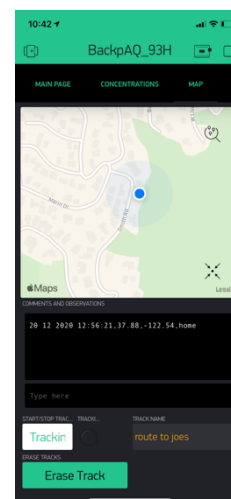
Now, let's go through each of the BackpAQ app screens in detail.



Main Screen



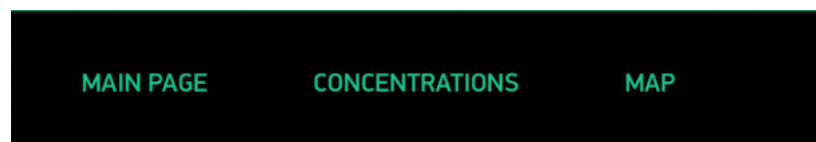
Detailed Data



Map & Tracking

## Basic Functions

In the photos above you can see that the current app has three screens: left to right is the main screen, the detailed data screen, and finally the map and tracking screen. To navigate between screens, just click on the tabs at the top (like this):

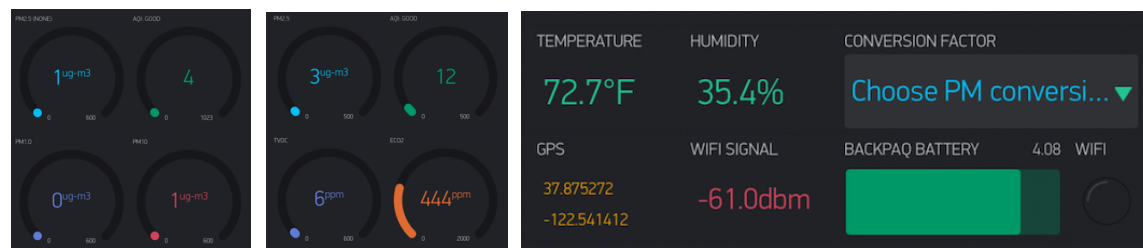


Next, we'll go briefly through each screen, from left to right:

### Main Screen

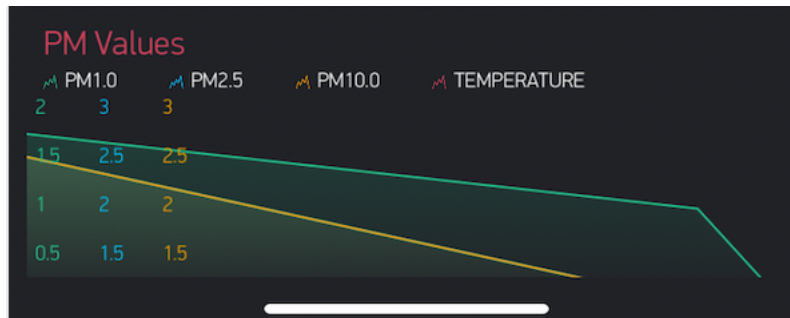
The screen you see when you open BackpAQ . There is a lot of data on this panel but it's (hopefully) organized well and fairly self-explanatory:

- (Top) Gauges showing PM2.5, AQI based on PM2.5 measurement
- (Second Row) Gauges showing TVOC, and CO2 measurements -- **if TVOC installed, OR**
- (Second Row) Gauges showing PM1.0 and PM10 measurements



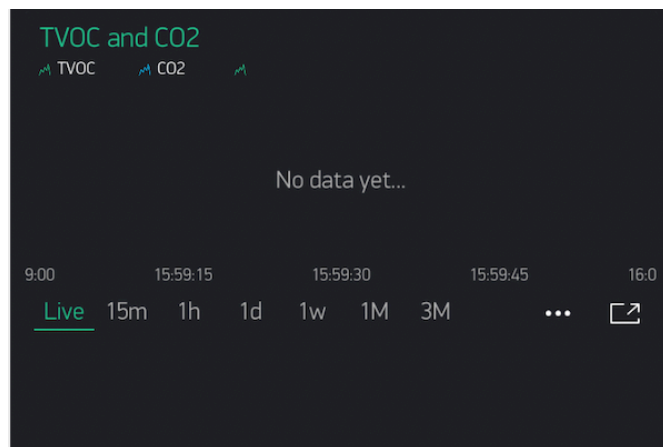
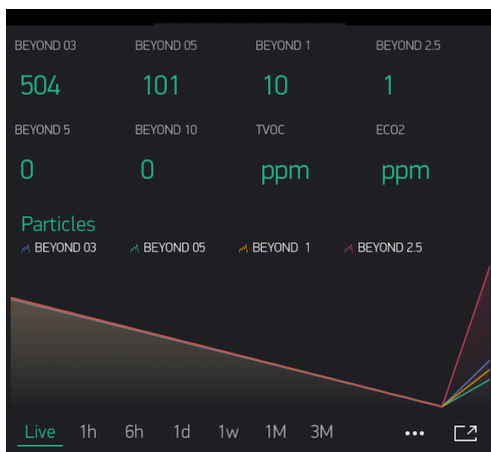
- Temperature (in degrees F) and Relative Humidity (in %) measurements
- Latitude and Longitude of your current position (see Map below)
- WiFi Signal Strength shows the strength of the WiFi connection between your BackpAQ device and your WiFi router or smartphone Hotspot.
- Estimated battery voltage for the BackpAQ device - when do I need to recharge? You should expect around 8-9 hours of battery life, depending on usage. Plan to recharge overnight as you would for a phone or tablet.
- PM correction selection menu, allowing you to correct the data from the sensor for woodsmoke, according to three well-known factors: US EPA, LRAPA, and AQandU. More detail on these corrections is in the appendix.

- (Bottom) Multi-graph showing these concentrations in Live and various timed intervals



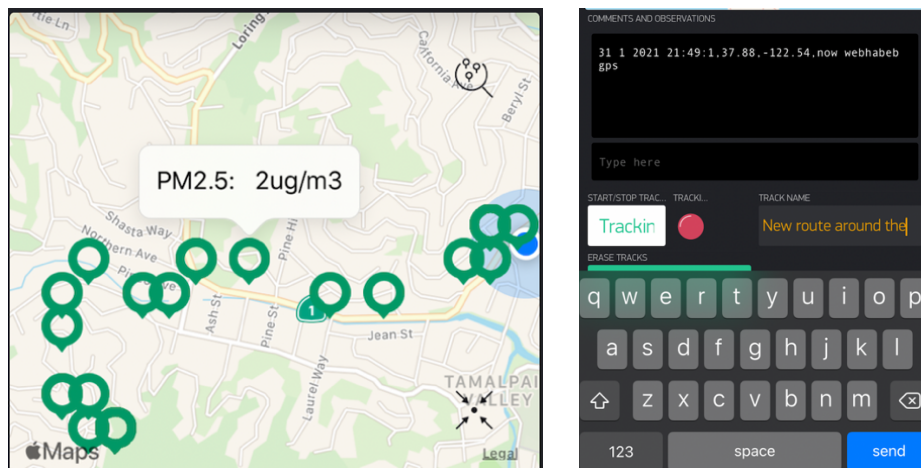
### Detailed Data

The Detailed Data screen displays the various particle concentrations from the PM sensor, eg, Number of Particles Beyond 5.0 ug/mL. Also displayed is a graph showing these counts in Live and various timed intervals. If TVOC sensor is installed, you'll also see TVOC and CO2 readings displayed in a graph.



Again, see Thingspeak and AQView for details and some cool tools to further process and visualize your data, and make it meaningful and actionable.

## Map and Track

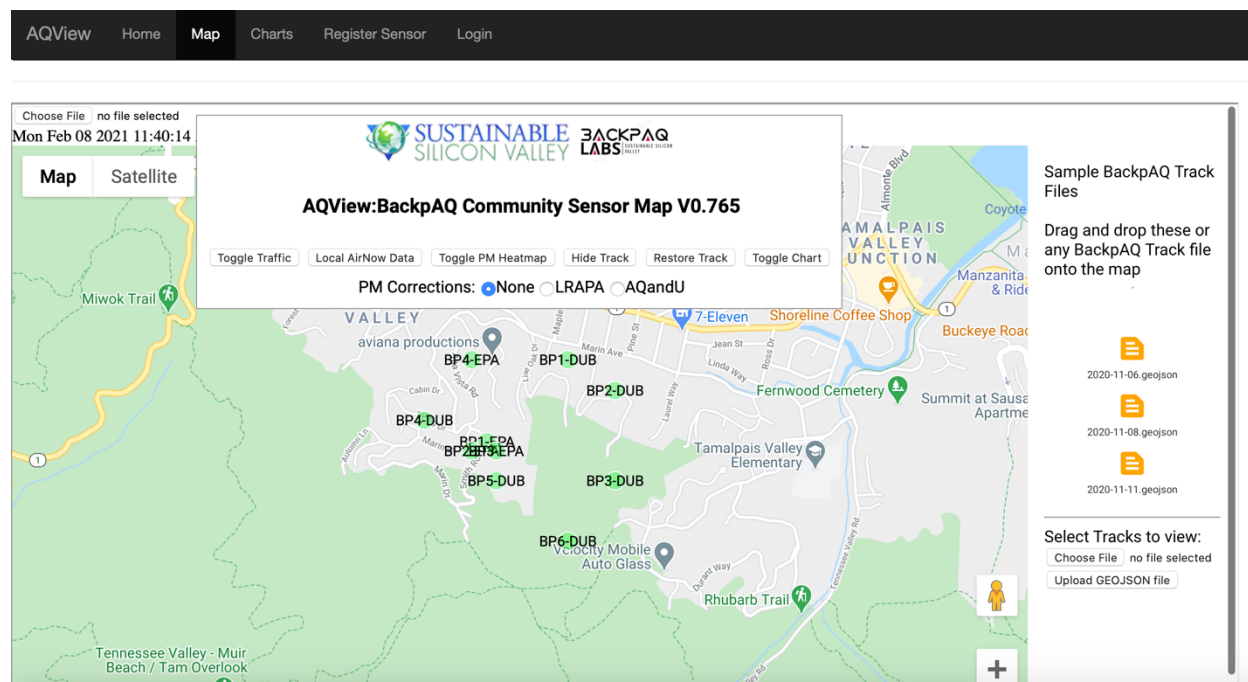


The Map screen displays your current position and the last 60 positions based on 1 minute intervals (this is adjustable). You can click on any position icon to see the PM reading captured at that position. Note that the color of the track marker reflects the “PM AQI-equivalent” value at the time it was recorded.

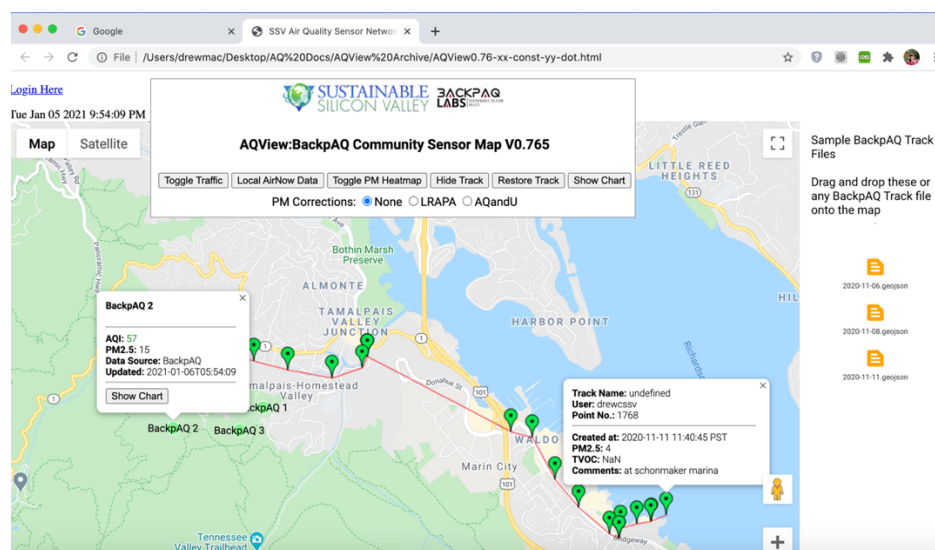
There are also buttons to turn tracking on and off, and assign a “track name” to this track. You can also attach comments as you move about. The comments will be tagged along with your current position and will also be recorded in the ThingSpeak data. And you can elect to erase the current track data from the phone screen (the data is still kept in the ThingSpeak database.)

## AQView Community Air Quality Map

All BackpAQ users are automatically entitled to use the AQView Community Air Quality portal. Simply point your web browser to [www.backpaqlabs.com](http://www.backpaqlabs.com) to get started. This is the main window you'll see:



The main page is the Map itself, and where you'll probably spend the most time and get the biggest value. These maps are highly interactive: click around on the various tabs, options, and markers to see more detailed data.

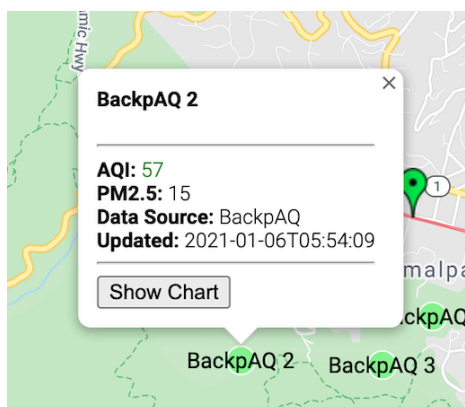




There are several additional functions we can utilize to better understand the data we have collected.

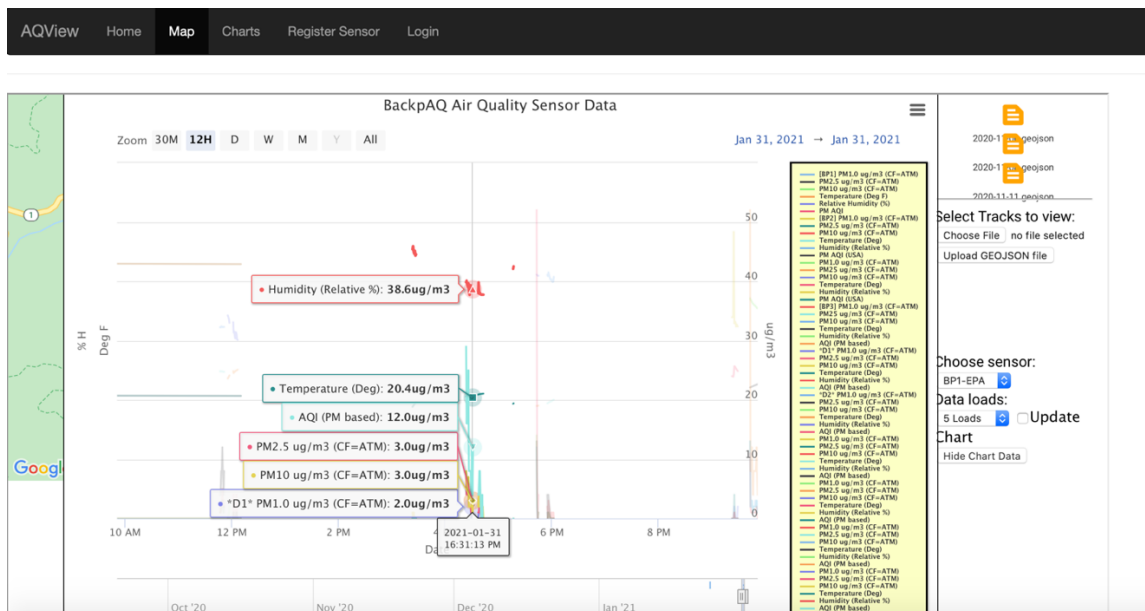
## BackpAQ Sensor Data

To see **your** BackpAQ data live on the map, click on the name of your BackpAQ device (example: BP1-DUB) and you'll see a popup window appear with the current sensor readings. Note that it may not be positioned where you are actually located because it may not have been updated with your current GPS location. You can re-click this periodically to see the current reading refresh.



## Mega-Chart

You can also click over to “**Toggle Chart**” on the front panel menu and you’ll see this mega-chart appear:



This powerful chart will display up to all of the BackpAQ devices participating in your study or class. To better focus on your BackpAQ data, click “Hide Chart Data” and then re-select only the data pertaining to your device, for example, “BP1-DUB”, in the yellow box. Or, load all of the data and see how yours compares to your classmates. Note that you can select or de-select data simply by clicking on the fields in the yellow box. Have fun! Oh, and one more feature...you can download the data for sharing or further analysis by clicking the “hamburger” icon in the upper right corner of the chart. There are options for downloading PDFs, JPEGs, CSV and other formats.

## Using Track Data

### A Brief Intro

Since BackpAQ is aimed at mobile air quality monitoring, the most useful data is probably the data that is collected and stored in time-sequence form, as you walk around. This is one of the reasons we chose ThingSpeak to store and manage the data, as it’s primarily a time-sequence data store. But we’ve also come up with some data visualizations that should help you interpret your data using the same *temporal* cues and visual representations that were there when you first collected the data. You’ve already no doubt seen and used the “Map” function on the BackpAQ app. Here are a few additional ways to get the most out of your AQ monitoring wanderings.

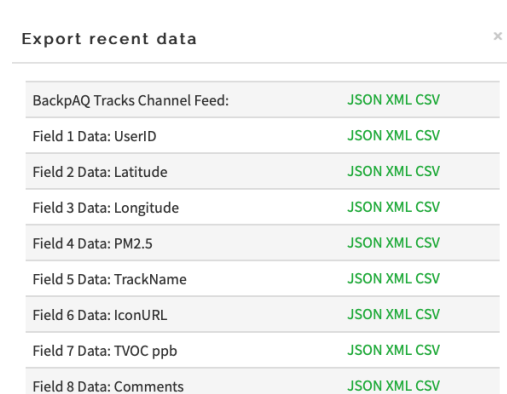
### Accessing your BackpAQ Tracks

Here is how you can download your Track data from the ThingSpeak database to your local laptop.

**Step 1** Logon to your ThingSpeak account using your assigned email and password.

**Step 2** Open “My Channels” and then click on channel 3, “BackpAQ Tracks”

Here you will have access to and see all of your track data. Click on “Export Recent Data”.



**Step 3** Click on the top line, “CSV” to download a .csv file which contains your recent track data. The file will appear in your “Downloads” folder on your laptop.

**Step 4** Go to your “Downloads” folder on your laptop to verify that you have received the file, and note the file name.

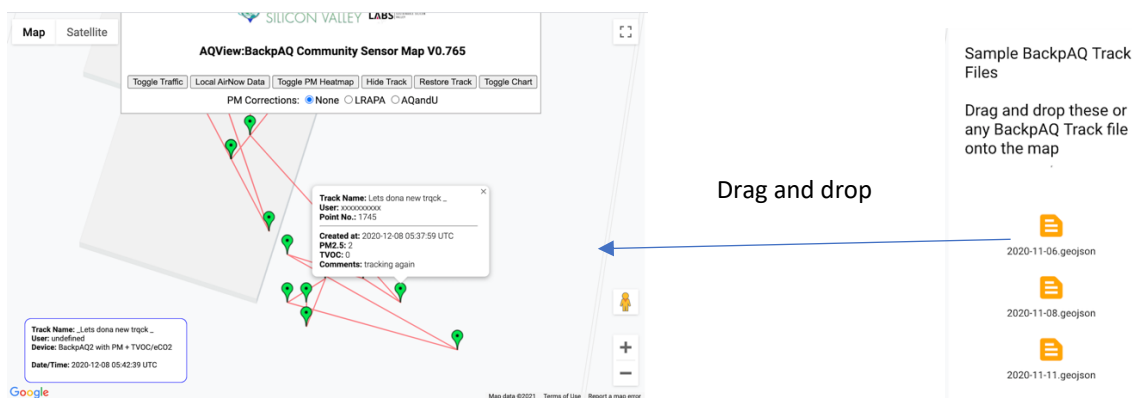
**Step 5** From the file entry dialog in AQView, use the dialog to select this file (“Choose File”) and press “Upload GeoJSON file” to load the Track file into the map.

### How to see your Tracks on the map

Once you have the file(s) downloaded on your laptop, you can simply drag them onto the map window, or use the dialog box on the right-hand side to select the file. If you use the box you need to select **.csv** files. For drag and drop, they are **.geojson** files.

Select Tracks to view:  
Choose File feeds-28.csv  
Upload GEOJSON file

You can try the sample *Tracks* located in the “dock” on the right-hand side of the window.

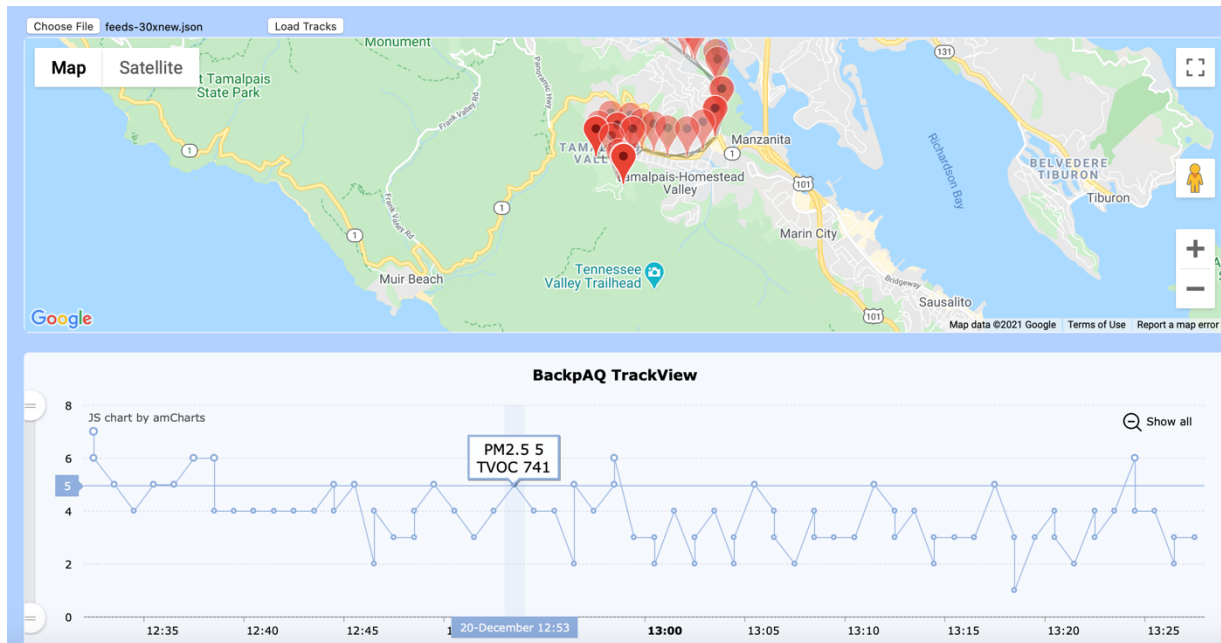


Grab by clicking and hold the button done while dragging over the main map. Then drop onto the map by letting go of the (mouse or scroll) button. You should then see a series of color markers which represent a time-sequenced based visual of the track data you’ve collected and submitted. Notice that they also might appear in different colors, mapping to the US AQI color scheme we’ve grown familiar with. You can then click on any marker to see the sensor data that was captured at that location, along with the *Track Name* you gave it, and any *comments* you entered at that moment.

### Using TrackCharts

There is one more function you might want to try. It’s the newest so least tested, but offers some capabilities not present in the one’s we’ve just discussed.

If you click on “Charts” on the main menu bar you can enter your tracks file name. You should then see something like this:



Here, in the upper window, you’ll see the familiar map with your track data displayed. But a new chart now sits below this, with a time-sequenced representation of your journey that’s linked to the map above. You can **click on the marker** in either window and see the corresponding location or time sequence. This should help greatly in providing important *context* to your data analysis.

If you have questions or comments about the BackpAQ devices or program, contact your instructor/study facilitator or email us at SSV: [dclark@sustainable.v.org](mailto:dclark@sustainable.v.org).

Good luck and good data!

## Safely Using Your BackpAQ

Your BackpAQ has been designed and tested to work safely with the internal LiPO battery, charging circuit, and supplied charger. But, to keep things on the safe side, it is important to follow these rules:

- Use only the supplied charger! It is unsafe to plug anything else into the charging connector
- Charge your BackpAQ at night in a safe place, preferably outside, a garage, or in a metal enclosure
- Do not overcharge! It is ok to charge until the green light comes on, indicating full charge. Then disconnect the charger. Usually about 5-6 hours will do it
- If you see or smell something unusual coming from the BackpAQ device or it seems to be warm, immediately disconnect the charger and take it outside

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## Appendices

### AQI, Air Quality Index

The AQI is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health effects might be a concern for you. The AQI focuses on health effects that you may experience within a few hours or days after breathing polluted air. EPA calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health. Ground-level ozone and airborne particles are the two pollutants that pose the greatest threat to human health in this country.

#### How Does the AQI Work?

Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA has set to protect public health. AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy-at first for certain sensitive groups of people, then for everyone as AQI values get higher. Here is what it looks like:

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
<i>When the AQI is in this range:</i>	<i>...air quality conditions are:</i>	<i>...as symbolized by this color:</i>
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

#### How is AQI Calculated?

Consult the above figure (1) for the actual AQI calculation.

See [AQI Calculation](#) for more detail on how the AQI is calculated.

**NOTE:** By definition, the AQI is calculated using data from a 24-hour period. That's because the science we have about air pollution exposure and health is based on 24 hours and therefore EPA's air quality standards are based on 24 hours average of sampled AQ. **It is not valid to use shorter-term (e.g. hourly) data to calculate an AQI value.**

### **Making AQI More Useful Now: Nowcasting**

The AQI is used to deliver a daily air quality report which means at the end of the day, we attain an effective reading for the air quality, but this also means that we defeat the purpose of the AQI in the first place. The AQI is intended to help users take immediate actions if air is of harmful quality. This is where the Nowcasting algorithm comes into place. A mixture of the words “now” and “forecasting”, Nowcasting in air quality is a method to give readings for concentrations of harmful substances in the air in a form that immediately usable.

Obviously, simply giving a reading for a harmful concentration in an environment of frequently changing air would be misleading as the immediate reading would in most cases present just an anomaly to an overall cleaner air than what is depicted. This means that even on days when the AQI forecast at the end of the day predicts unhealthy conditions, it is possible that pollution levels might be lower during some parts of the day and vice versa.

Thus the NowCast allows current condition maps to *align more closely with what people are actually seeing or experiencing*. The technique of Nowcasting is to take a weighted average instead of taking the average of the last relevant span of time. The equation (2) above is used to Nowcast a concentration at any given time.

So to separate the two, for momentary AQI readings, Nowcasting is used; for a daily report the general formula is practiced. [Here](#) is an excellent overview of where AQI and Nowcasting are headed.

### Sensor: Plantower PMS-A003i

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## TECHNICAL DETAILS

#### Sensor module specifications:

- Particle Range of measurement: 0.3~1.0, 1.0~2.5, 2.5~10 Micrometer
- Particle Counting Efficiency: 50% @ 0.3 $\mu$ m 98% @  $\geq 0.5 \mu$  m
- Particle Effective Range (PM2.5 standard): 0~500  $\mu$  g/m<sup>3</sup>
- Particle Maximum Range (PM2.5 standard):  $\geq 1000 \mu$  g/m<sup>3</sup>
- Particle Resolution: 1  $\mu$  g/m<sup>3</sup>
- Particle Maximum Consistency Error (PM2.5 standard):  $\pm 10\%$  @ 100~500  $\mu$  g/m<sup>3</sup>  
 $\pm 10 \mu$  g/m<sup>3</sup> @ 0~100  $\mu$  g/m<sup>3</sup>
- Particle Standard Volume 0.1 Liter
- Single Response Time < 1 second
- Total Response Time  $\leq 10$  seconds
- DC Power Supply Typ: 5.0V Min: 4.5V Max: 5.5V
- Active Current  $\leq 100$  mA
- Standby Current  $\leq 200 \mu$  A
- Interface Level: 3.3V logic, L < 0.8V, H > 2.7V
- Working Temperature Range -10 ~ 60 °C
- Working Humidity Range 0~99%
- Storage Temperature Range -40 ~ 80 °C
- MTTF  $\geq 3$  Year
- I2C address 0x12 (cannot be changed)

Product Dimensions: 51.0mm x 35.5mm x 13.6mm / 2.0" x 1.4" x 0.5"

Product Weight: 28.0g / 1.0oz

### Quirks, Bugs, and Not-quite-working, ...

As mentioned above this app is at a Beta stage of maturity and naturally has some quirks and bugs, as well as some functions that are still being developed. Here's a list of what's known (help us find the rest!)

- The sensor *readings* will not be accurate until the sensor has warmed up and various connections are complete. Wait for at least 30 seconds until things settle down. This is particularly true with the TVOC/CO2 sensor (if installed) as proper use requires a brief "burn-in" period prior to using.
- The *Map* occasionally misbehaves and places position markers in strange countries. Not sure what's going on but it does seem to know where you currently are and have been.
- The *Battery Level* indicator is approximate...best practice is to just recharge nightly as you would your smartphone. You should get about 8-9 hours of battery life.
- The *PM sensor* is obviously directional in this application as it depends on pulling in air through the intake hole in the BackpAQ case. So, best to orient the device so that the intake has a "view" of where you wish to monitor and is not impeded or blocked.
- The *PM sensor* is either the larger PMS5003 or the more *svelt* PMS7003, depending on which unit we shipped with your kit. Future versions will utilize only the 7003.
- The BackpAQ V2 monitors utilize a new chip (Heltec ESP32) and new code base to go with it. There may be some hiccups with the new software so appreciate your patience as we get a feel for how this chip will perform.
- The *BackpAQ software* running on the device is still young and fragile. This means it may crash occasionally or need to be restarted when it "bogs down". The prototype units have been run successfully for 12-15 hours at a time without problems but things do happen in software, especially when handling several temperamental sensors with a low-cost processor, on a small battery.
- The *AQI gauge* and values are slightly controversial in the way they are calculated here and in most other portable devices. The NowCast function (code included but not invoked) is designed to handle this. We will discuss this in class and hopefully come up with a better way to calculate and use it in this context.
- The AQView tool is brand new and will need several more iterations before the functions and interfaces settle down. We hope you find it useful and appreciate your feedback and comments!

