



User Manual

May 2020

Introduction

Thank you for your help with the Citizen-Enabled Aerosol Measurements for Satellites (CEAMS) Project! The data you gather will help scientists understand the link between local air quality on the ground and air quality observed by satellites.

Please note: This manual is directed at CEAMS network participants in Denver; thus, some instructions may only be applicable to them.

Purpose

In this manual, you will be shown:

1. Requirements for participation
2. A description of the AMOD device
3. How to care for the AMOD device
4. A description of the CEAMS mobile application
5. How to use the AMOD and mobile application to take measurements
6. How to access your measurements on the internet

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Requirements for Participation

In order to participate in the CEAMS Denver network, you will need to apply and be accepted into the network. The application process determines participant eligibility based on several criteria:

- (1) You must have a smartphone that can install mobile applications and has Bluetooth capabilities
- (2) You must have Wi-Fi at your place of residence
- (3) You must be available to come to a training event
- (4) You must be willing to commit to 10-15 minutes per week for the campaign period (up to 10 weeks)
- (5) You must live in metro Denver and have a space in your yard or on your deck that gives a clear view of the sun for at least 3 to 4 hours of the day

Description of the AMOD device

For definitions of any of the terms in this section, please see the Glossary at the end of the manual.

What is the AMOD?

AMOD stands for “Aerosol Mass and Optical Depth”. The AMOD sampler measures air quality by three different methods:

1. It measures $PM_{2.5}$ mass on a filter. This will give the average concentration for the full sampling session (5 days).
2. It measures $PM_{2.5}$ by an optical laser. This will give sub-hourly $PM_{2.5}$ concentrations.

3. It determines the Aerosol Optical Depth (AOD) at multiple wavelengths every 20 minutes during daylight by tracking the sun and taking a direct sun measurement. This is a measure of the total amount of aerosols in the atmospheric column.

In order to get these values for the sampled air, the AMOD has several different components.

Components

Most of the Aerosol Mass and Optical Depth (AMOD) components are housed in the box. CEAMS participants **should not open** the lid of the box at any time. Components on the outside of the box are shown in the picture below. The three main components for taking air quality measurements in the AMOD are:

1. The PM_{2.5} mass filter system
2. The real-time (optical) PM_{2.5} sensor
3. The AOD sensor

Both the filter and real-time PM_{2.5} measurements rely on a pump that draws in air. The filter is placed behind the filter cap (see section [Changing the filter](#) for information on how to change out the filter for each sampling session). AOD is calculated using measurements taken by four filtered diodes. These are located on the AOD turret. Also on the AOD turret is an alignment window. While the AMOD will automatically find and align with the sun, the alignment window can be used to check that it indeed centered directly on the sun.

In addition to these components, the AMOD also includes a 120 watt-hour lithium battery. When sampling, the battery should last about 5 days. At the end of a sampling session, participants should take the AMOD indoors and leave it to charge (using the charging port and provided wall charger) overnight.

The handle should be used to carry the AMOD at all times. Please see section [Carrying the AMOD](#) for instructions on how to carry the AMOD. The AMOD is turned on using the

button on the front of the AMOD. This power button is also an LED light. Please see the section [What do the LED light colors mean?](#) for a list of what the different color LED lights indicate.

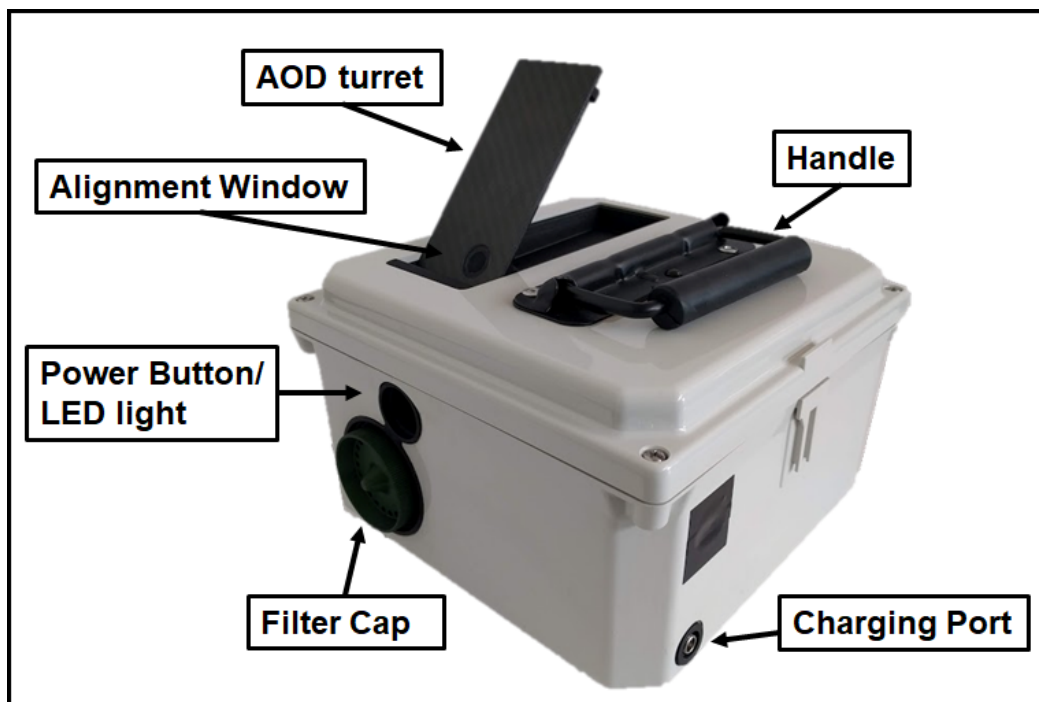


Image: Diagram of AMOD external components.

Caring for the AMOD device

Turning on the AMOD

Turn the AMOD sampler on using the power button (with LED light) on the AMOD. You should hear a click and then the LED light will cycle through different colors (pink, blinking orange, blue). It will turn blue when it is ready to be paired (connect) with your mobile phone, and stay blue when it has paired.



Image: CEAMS sampler showing the power button before (left) and after (right) it is pressed and paired with a mobile phone.

Charging the AMOD

The AMOD includes a 120 watt-hour lithium battery that allows the device to operate for approximately 5 days without charging. You can check the status of the battery charge in the menu of the CEAMS mobile application (Note: AMOD sampler needs to be turned on and connected in the mobile application to see the battery level). We ask that you charge your device overnight after each sampling session (a sampling session lasts 5 days) in order to guarantee that there is no interruption to the following sampling period (because the filter is continually collecting mass, a sampling period cannot be restarted once it has stopped).

To charge the AMOD, you will need to use the wall charger that is provided to you. The charging port is on the side of the box (see picture below). Remove the cover, insert wall charger firmly into the charging port, and leave the AMOD to charge overnight.



Image: View of the AMOD charging port

There are two charging modes. In the first mode, the LED light will be blue, and in the second mode, the LED light will be pink. Charging will take 6-8 hours, but we recommend leaving the AMOD to charger overnight. After the AMOD is finished charging, replace the cover over the port before setting the AMOD out for a sampling session.



Image: When charging, AMOD LED light will be blue (left) or pink (right).

Carrying the AMOD

We suggest always using both hands to carry the AMOD instrument. The best method to hold the AMOD is by holding the handle in your left hand and placing your right hand flat on the bottom of the AMOD so the instrument is held horizontally. .



Image: How to hold the AMOD sampler.

What to do in inclement weather

The AMOD box is very durable and the AOD turret contains a drain to remove moisture. However, the AOD turret could be damaged by severe hail. The AMOD will not be able to take an AOD measurement when there are storm clouds blocking the sun; thus, if you expect severe weather, you can move the AMOD under a table or porch (so it can still sample $PM_{2.5}$ in the air). Please set the AMOD back out in the sun once the severe weather has passed. If you do not have a way to leave the AMOD out unexposed during severe hail, please stop the AMOD sampling session (by pressing the power button), remove the filter and put it in its clear plastic cartridge (do not reuse for another sampling session), and bring the AMOD indoors.

Storing Filters and handling the “Blank” filter

At the training session, you will pick up an AMOD device and filters. You will be provided with six (6) filters. Five (5) of these filters will be used for sampling, and one (1) is a blank filter.

What is a blank filter? A blank filter is not used for sampling, but is used to correct your sample measurements. Each filter, including the blank, is

pre-weighed before sampling and then weighed after sampling to determine the amount of particle mass collected from the air. Ideally, the blank would have the same pre and post weight, but sometimes the process of removing from the cartridge or transporting the filters could alter that. The blank will help us correct for these other processes that might affect the collected mass that are not from the air sample.

When filters are not being used for sampling, they need to be kept in their clear plastic cartridges. We suggest also keeping them in the box in your refrigerator. A cooler storage area helps protect the sample.



The blank should be stored along with the other filters and treated in the same manner, except that it should **NOT** be removed from the clear plastic cartridge. Participants will mail the blank filter back with the other five filters once the five filters have all been used for sampling sessions. Information on mailing is under the section “Returning Filters.” Once a participant has completed a fourth sampling session, we will mail another set (five filters for measuring and a blank filter) to the participant.

The CEAMS mobile application



In order to take measurements for the CEAMS network, participants are required to have a smartphone or tablet (running Android or iOS [Apple iphone/ipad]) that is able to install applications (apps). The CEAMS mobile application will allow you to:

1. Connect your phone to the AMOD by Bluetooth

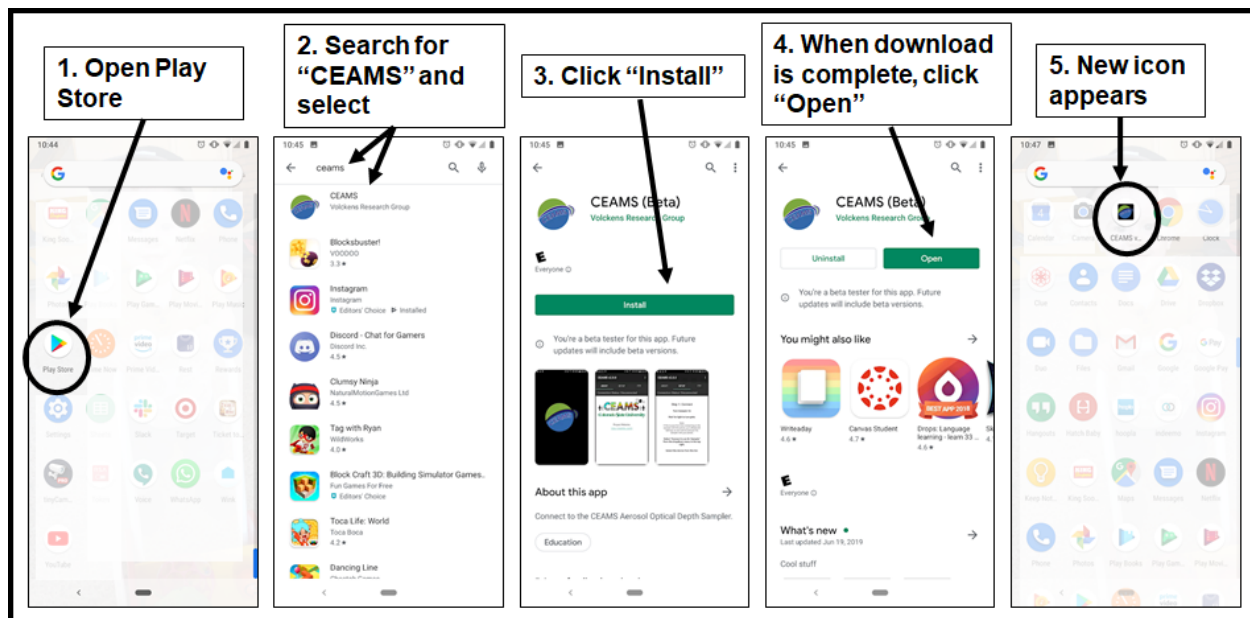
2. Connect the AMOD to your home Wi-Fi in order to send measurement data
3. Set up your Device ID
4. Set up your API key in order to send your measurement data to the website

The mobile application will provide a menu to help ensure that you have completed all of these steps before starting a sampling session.

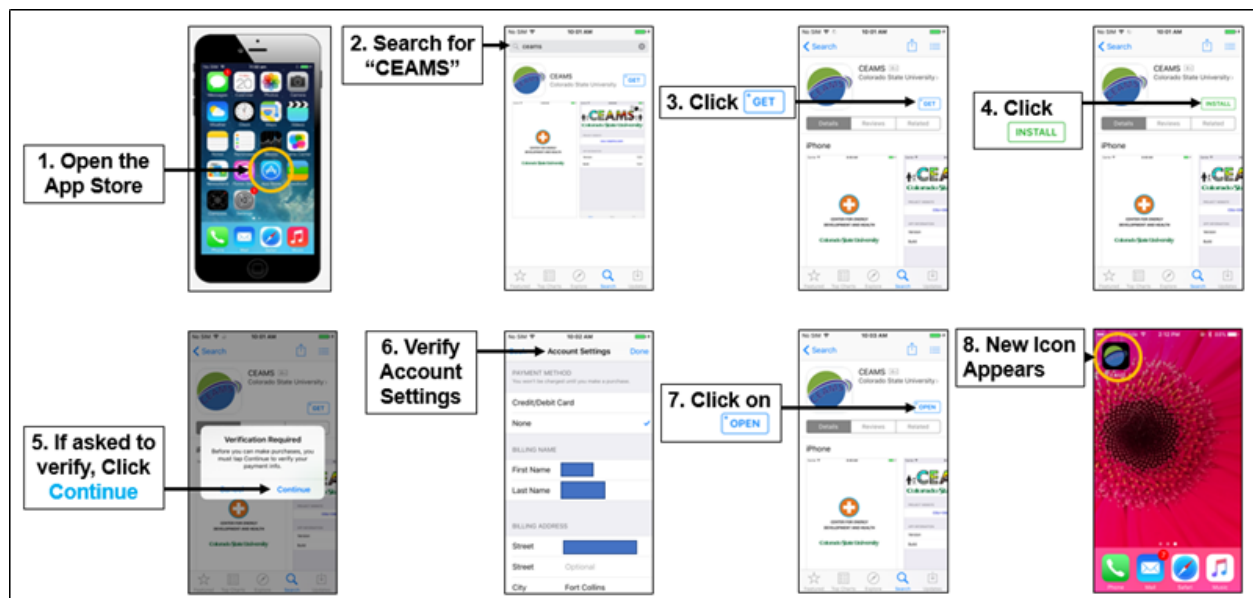
Downloading the mobile application

The mobile application can be downloaded either from the Google Play Store () or the iOS (Apple) store (). Directions for each are detailed below.

Google Play Store



iOS Store



Preparing to take measurements

Where to set up the AMOD

You want to set up the AMOD in a location that will give a representative measurement of your local air quality. Your AMOD will measure higher concentrations if you set it next to your bbq grill while you cook or next to your fire pit while you have a fire. Similarly, AOD values will be high if there is an object blocking direct sun to the instrument (tree branches, roof line, etc.). It is best to set the AMOD elevated off the ground in a space that has a clear view of the sun for at least 3 to 4 hours of the day, as the AMOD will track the movement of the sun throughout the day.



Example: This would **not** be a good place for the AMOD because there are tree branches obstructing the view of the sun.

Changing the filter

The AMOD uses a filter to measure particle mass concentrations. Similar to your HVAC system, air (that contains particles) is brought into the AMOD device where the particles are collected on a filter and the air passes back out of the device. We weigh the filter before and after a sampling session in order to determine the concentration of particles in the air that was sampled by the device. Because of this process, each filter is used for only one (1) sampling period. **DO NOT REUSE A FILTER.**

Filters should also only be taken out of their containers immediately before starting the sampling period (after scanning the QR code) and then returned to the case at the end of the sampling period. Extra handling could cause contamination and lead to an inaccurate estimate of pollution.

Each filter has a unique QR code (shown in figure). This QR links the filter to the data that is sent to the server.

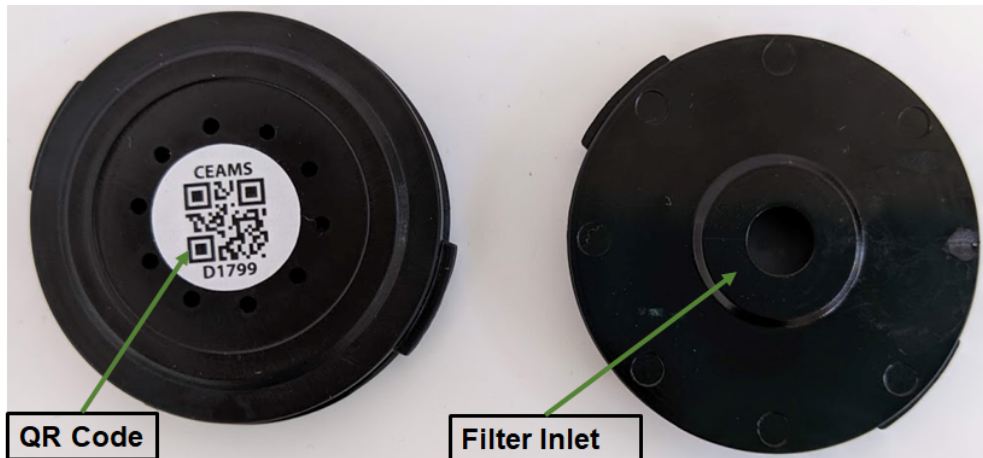


Image: QR Code on the back of a filter (left) and the filter inlet (right).

Changing the filter is easy. On the front of the device, twist the green filter cap (see picture) counter-clockwise to take it off the AMOD. Place a filter on the inside of the green filter cap (filter inlet side down on the cap with QR code facing up). Screw the cap with the filter back on (clockwise) to the AMOD device.

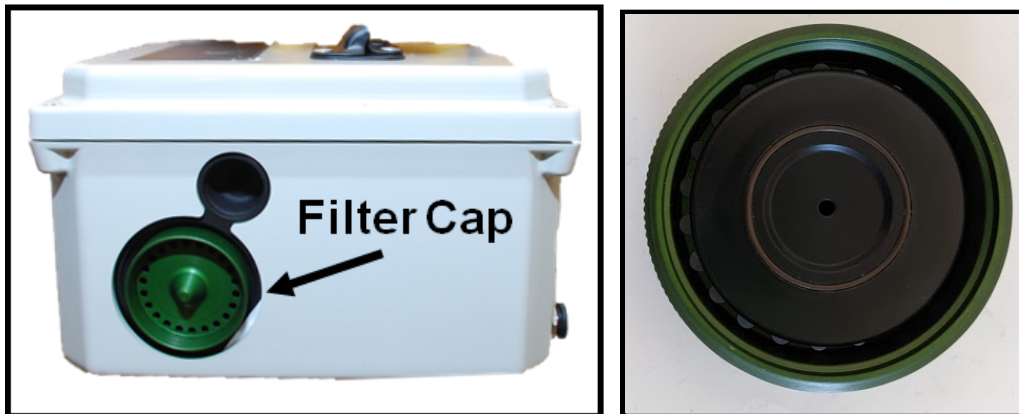


Image: Location of filter cap on the AMOD (left) and inside of filter cap (right).

Using the mobile application

In order to start a sampling period, you must have the CEAMS mobile application installed on your phone. Please see section [Downloading the mobile application](#) for instructions on installing the CEAMS mobile application.

Setting up for first measurement


This section will explain how to set your Device ID and Wi-Fi before starting a sample. If you have already set these, please proceed to “Starting a sample.”

You will be using the CEAMS mobile application to set the Device ID and Wi-Fi for your AMOD device. Thus, you will need the AMOD and a mobile phone with the CEAMS app. You will also need Wi-Fi access for the AMOD. Note that, although you are using the mobile application on your phone, you are setting these values on the AMOD. The AMOD will store these values (thus, you can start a sampling session with different phones/devices that have the CEAMS application).

For the following sections, the AMOD will need to be turned on. See section [Turning on the AMOD](#) for how to turn the AMOD on.

Connecting your phone to the AMOD

Note: the AMOD device is ONLY connected to your phone during the sampling setup process in the mobile application. It will NOT stay connected to your phone.

The AMOD will connect to your phone through Bluetooth (). Therefore, you will need to turn on Bluetooth on your mobile phone (under Settings or from the dropdown menu on your phone) in order to start a sampling session.

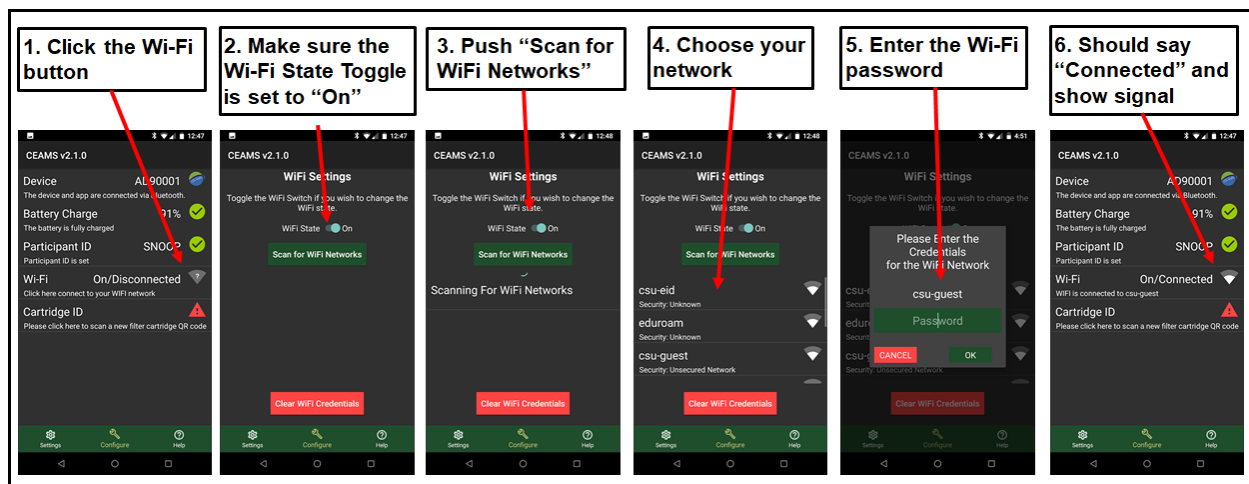
Once you have started a sampling session, the AMOD will no longer be connected to your phone. You may turn Bluetooth off on your phone, but it will need to be turned on before starting the next sampling session.

Setting up Wi-Fi for the AMOD device

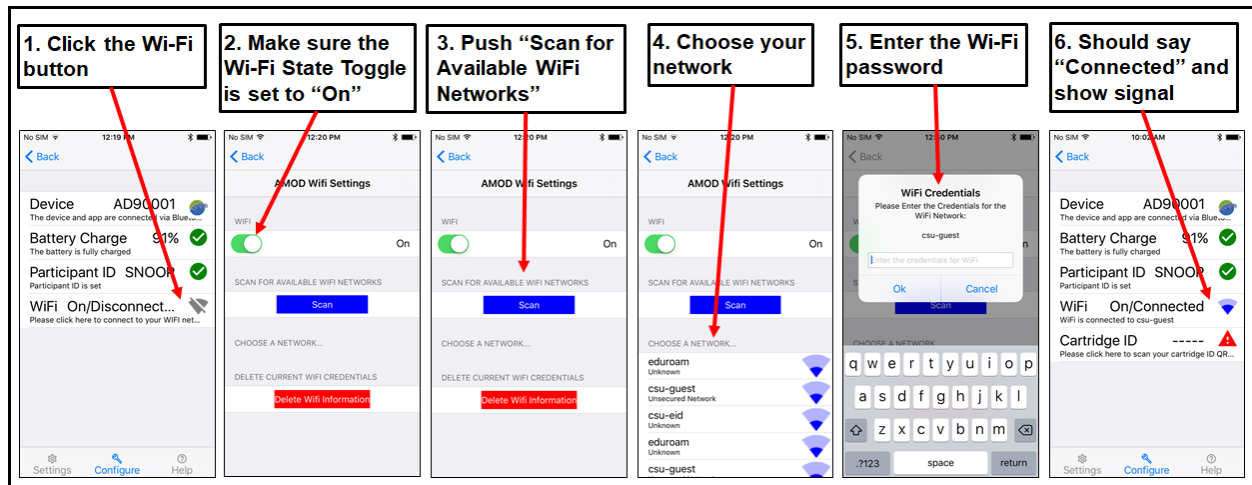
Turning on Wi-Fi is not required to start a sampling session. However, the AMOD will need to be connected to your home Wi-Fi in order to send your data files to the server. Thus as a requirement for participation, we ask you to turn on Wi-Fi and set up the AMOD to connect to your home Wi-Fi. You will use the CEAMS mobile application to set up the Wi-Fi credentials for the AMOD. The AMOD will be connected to your Wi-Fi during the sampling session. It is best to do the initial Wi-Fi set-up when you are inside your home.

Make sure the AMOD is turned on and connected to your mobile phone. You will also need to make sure Wi-Fi is turned on your phone.

For Android:



For iOS:



Once the instrument shuts down after a sampling session or is manually turned off, it will no longer connect to your Wi-Fi. The device, however, will remember these credentials (as shown in the mobile application), so that you will not have to set them up for each sampling session. You may tell the device to forget your Wi-Fi credentials (if you set up a new Wi-Fi network, change your password, or are returning the AMOD) by Clicking on the "Clear WiFi Credentials".

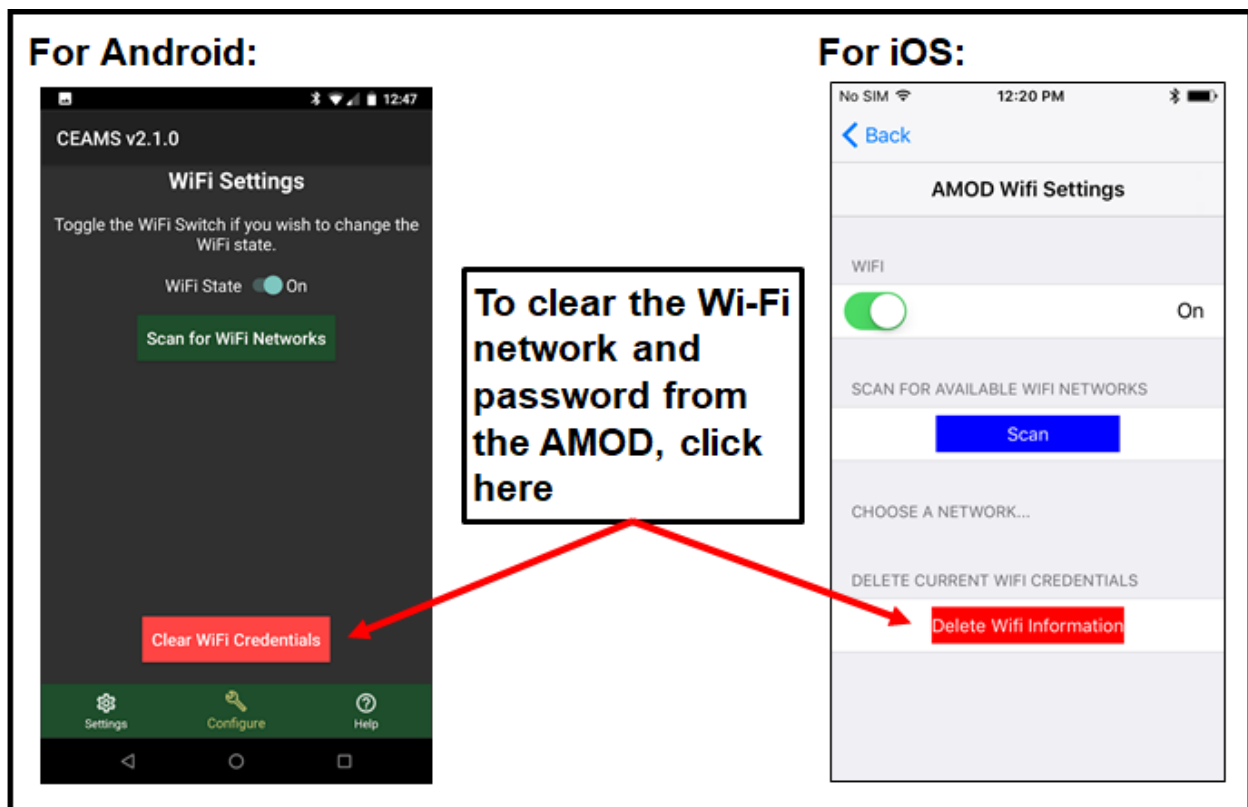


Image: How to clear Wi-Fi credentials from AMOD device.

Tip: If you are having difficulties connecting to Wi-Fi, you may start the set-up process in your home (closer to your router), and then move the AMOD outside for sampling.

Starting a sample

You should have set up your Device ID during the training session. These will be stored on the AMOD device and will automatically be filled in on the mobile application when you connect to the device. If these do not appear in the menu, please see the previous sections. The following is a narrative for starting a sample. Please see the following pictures for a simplified guide. You may choose to do steps 1-7 inside your house but will have to go to your backyard for steps 8 and 9.

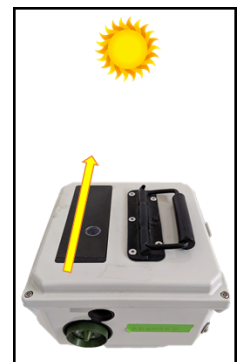
1. Turn the device on. Press the Power Button/LED light for three seconds. The LED light will go through a series of colors (orange then blue). Wait for it to turn blue before trying to pair it with your phone.
2. Open the mobile application. This should already be installed on your phone or tablet.
3. Click “Scan” if device does not automatically appear.
4. Select Device (AD00***). The LED light on the AMOD will turn blue when it is paired to your phone. The app will bring up the menu screen with the device information.

(If Wi-Fi is not set, please see section [Setting up Wi-Fi](#)).

5. Click on the Cartridge ID option in the app.
6. Open the filter cartridge and scan the QR code (this will happen automatically).
7. Take the filter cap off the front of the AMOD. Put the filter into the filter cap and screw it back on to the AMOD device.

(If you completed Steps 1-7 inside, please now take the AMOD outside for sampling location.)

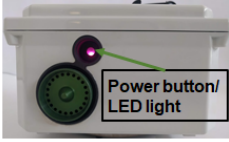
8. Position the AMOD so that the turret will be directed towards the sun when it starts (see picture to right).
9. Click “Start the Sample!” You will receive a message congratulating you for starting the sample. Click “Clear Message” (Android) or “Ok” (iOS). The device is no longer paired to your phone.



The following are quick picture guides for the sampling process.


For Android:

1. Turn on AMOD. Wait for pink light.

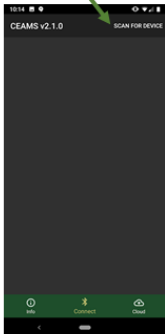


Power button/LED light

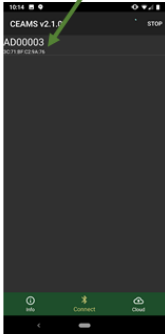
2. Open CEAMS app.




3. Click SCAN



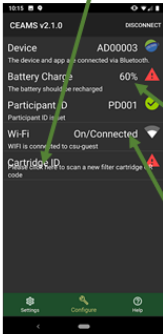
4. Select Device.



Light will turn blue when connected.





5. Click Cartridge ID.



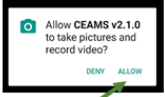
If battery is too low, please charge before starting the sample.

To set Wi-Fi, please see section "Setting up for first measurement".


6. Hold filter under the camera. The app will automatically capture the QR code.

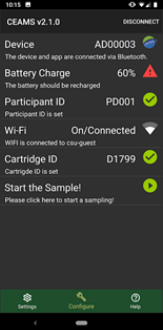
If this pops up, select **ALLOW**



7. Put filter in AMOD.



8. Push Start the Sample!

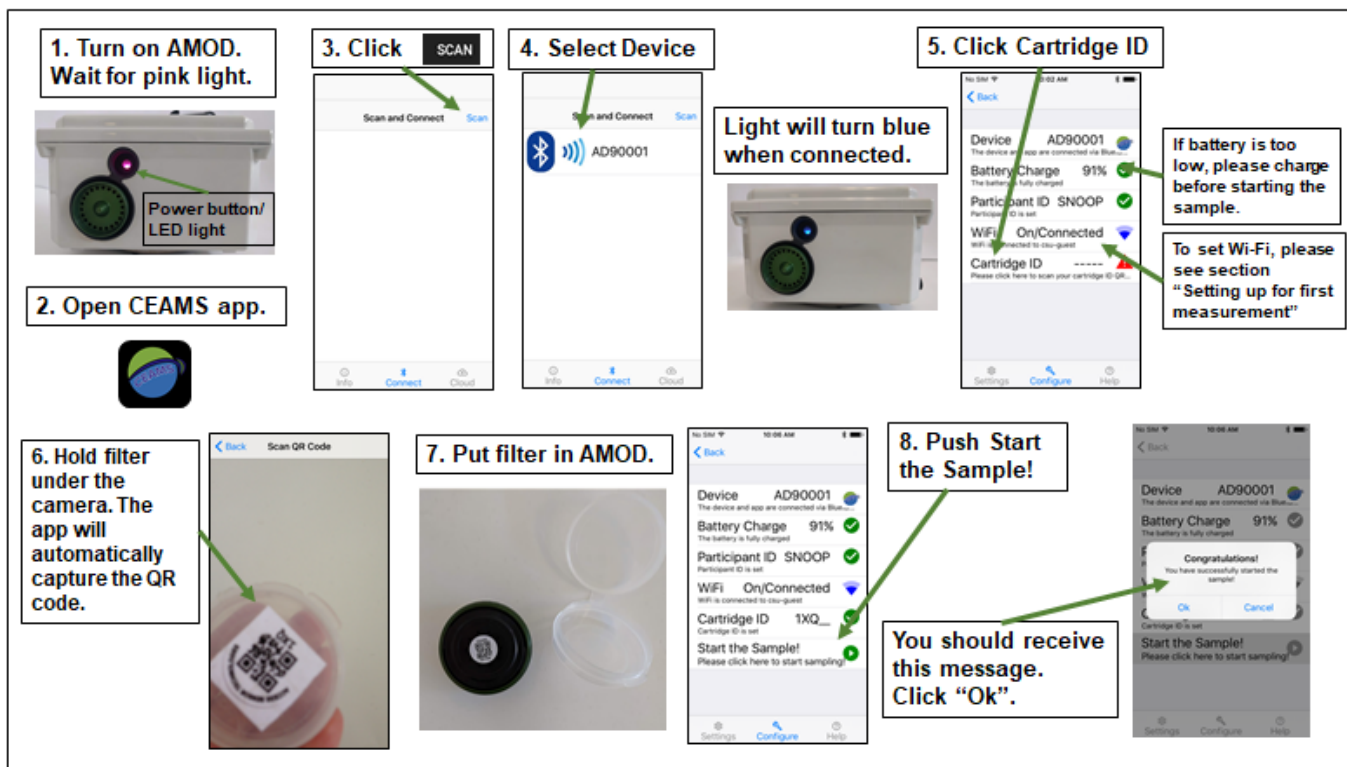


Congratulations!
You have successfully started the sample!

CLEAR MESSAGE

You should receive this message.

For iOS:



Note: DO NOT turn off the AMOD once a sampling period has started.

Please do not turn off the AMOD while it is sampling. It cannot automatically start sampling again. You will need to use the app to start a new sampling period. Additionally, the filter is collecting mass and can only be used for one sampling period. Thus, if you do stop the sampling session, you will need to remove the filter and use a new one.

What to do when a measurement/sampling period is finished

A sampling period will last, at most, five days (120 hours). The LED light will turn off when the sampling period has ended. Once the sampling period is finished, please remove the filter and put it back in the clear plastic cartridge (make sure to keep this separated from your other filters so as not to reuse a filter). Take the AMOD into your

home or garage and recharge the battery. It will take approximately 6-8 hours to charge the battery from 0% to 100%. We suggest leaving the battery to charge overnight. Once the battery is charged, you may set up the AMOD for another sampling period.

Returning Filters

After five (5) weeks of measurements, you will send back the used filters from each week of measurements. These filters (INCLUDING the blank filter given to you to start at the training session) will go into a prepaid envelope given to you at the beginning of the project. There will be one envelope with your sampler. You will receive a second envelope with your second round of filters.

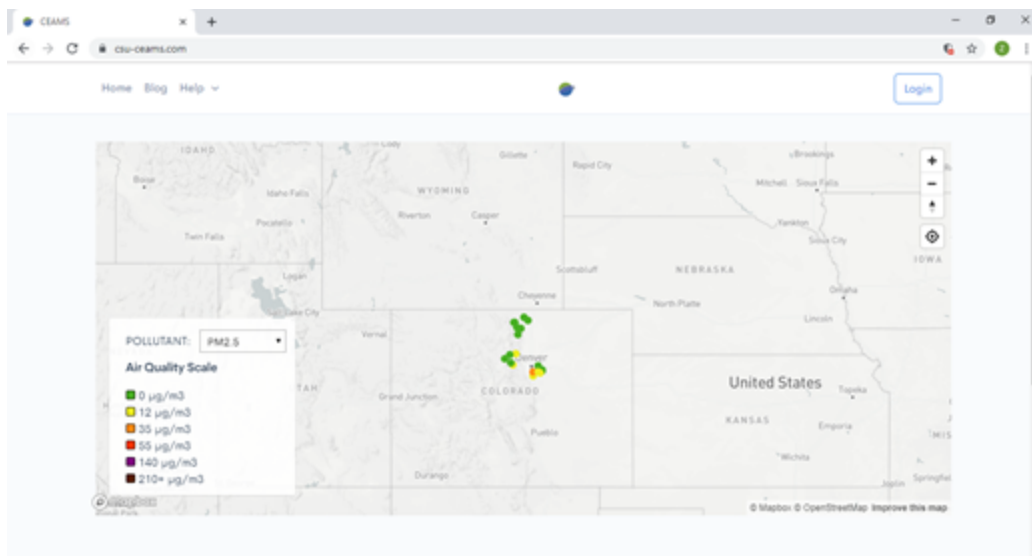


You can drop off your envelopes at the US Post Office, or where you normally mail your letters. If you run into issues with this process, please contact us at csu-ceams@gmail.com.

Viewing your measurement data on the internet

If you have connected the AMOD to your Wi-Fi network, it will automatically send your measurement data to the CEAMS server. Your measurements should be available to view within two (2) hours or less. Your measurement data will be viewable on csu-ceams.com.

On the homepage of csu-ceams.com, you will see the map of all participants in the CEAMS network and the most recent measurements. In order to see a graph of your measurements over time, you will need a login.



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How to get a username and password for login

You should have signed up with a username and password at your training session. The CEAMS team will verify your account and link your account to your User ID and Device ID. Once you have submitted your username and password, an email verification will be sent to your email address with your username. If you do not immediately receive an email, please check your "Spam" folder.


If you did not sign up at a training session, an email invite must be sent to you in order to sign up and create a login for the CEAMS website. The email invite will include a link

that will allow you to create a username and password. Once you have submitted your username and password, an email verification will be sent to your email address with your username. You must validate your email account through this email in order to login to the website. If you do not immediately receive an email, please check your "Spam" folder.

Where to view your measurements


Your measurements will be available on the csu-ceams.com website. The website will allow you to see a map of all participant locations in the CEAMS network (on the homepage) and all your measurements (on your device page). You will need to login to see your specific measurements. Use the following directions to login.

1. Go to csu-ceams.com in your internet browser



2. Click "Login"

3. Sign in using your username and password
(please email csu.ceams@gmail.com if you have lost your username)



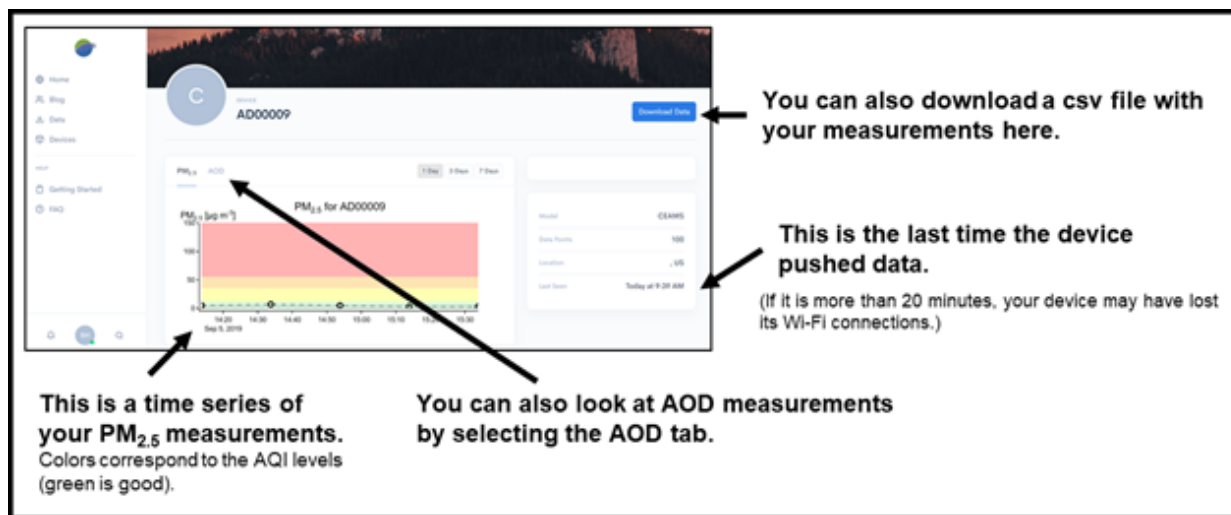
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Use the following directions to go to your data page.



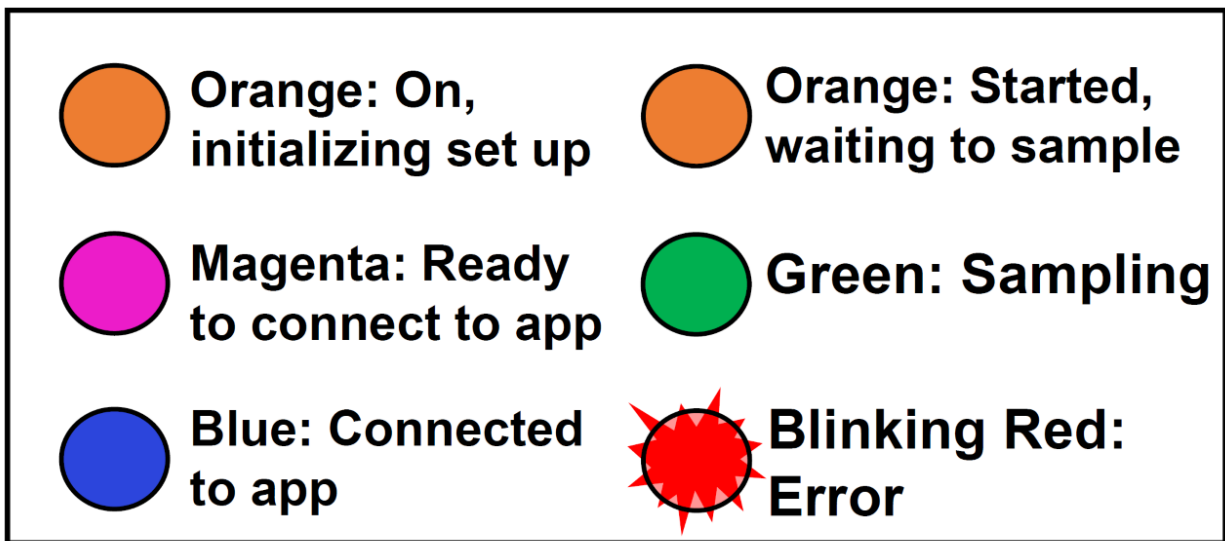
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The following diagram explains some of the features of your data page.



What do the LED light colors mean?

The AMOD LED lights will change colors during different processes. Listed below are what each color means:



This sticker is also on your AMOD for quick reference. There are also two other colors which correspond to the two charging modes (blue and pink).

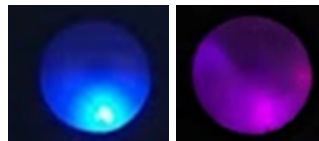


Image: Two charging modes for the AMOD. First mode is blue (left) and the second mode is pink (right).

If you get a flashing red light, please contact the CEAMS Team (csu.ceams@gmail.com). This is indicative of an error. We will attempt to help you diagnose the problem.

Troubleshooting

My device will not turn on.

First check if it is just the LED light that is out. Does the LED light come on when it is charging (plugged in)? If not, try pressing down on the button (for at least 3 seconds), and determining if the device moves in response? If it does, then only the LED light is out. You can still pair the device. If nothing happens, try leaving the device charging overnight. Again, check if the LED light is on while it is charging. If the LED light is not coming on when charging, you have already left it charging overnight, and it still will not turn on, please contact the CEAMS team.

When I turn my AMOD on and try to pair it, the LED light flashes.

Your device likely had a complete battery drain. Thus, it lost GPS clock time. Please take the AMOD outside and let it reconnect to GPS in order to reset the clock. Then you may proceed to connect to the device. The LED light will stop flashing once it has reestablished GPS clock time.

The LED light stays red when I push “Start Sampling” and is unable to find the sun.

This is likely because the AMOD GPS has not synced. Therefore, it does not know where it is and cannot calculate the angle for the sun. Occasionally, it will have to wait until the second scan (20 minutes after the start time) to locate itself and find the sun.

The AMOD will not connect to my Wi-Fi.

If you are outside, go back into your house and try to connect while inside. Then go back outside and check if your Wi-Fi signal is strong enough in your backyard (is your phone able to connect?). If not, you may need to move the AMOD closer to your house. If this is not possible, you may have to let the AMOD run with Wi-Fi turned off. In this case, you will not be able to see your data on the website in real time. After the sample period is done, you can take the device back inside to charge and connect to Wi-Fi. The device will push some of the missed data to the website (alternatively, at the end of the campaign, we can download data from the device and upload to the website). If the

AMOD will not connect to Wi-Fi in your house, please contact the CEAMS Team (csu.ceams@gmail.com).

The AMOD does not show up when I push “Scan” in the CEAMS mobile application.

First, check that you have Bluetooth enabled on your phone (check if your phone is able to connect to ANY Bluetooth device). Second, make sure that the AMOD is turned on and that the LED light is pink. If the device still does not appear, you may need to try restarting your phone or using another mobile device with the CEAMS application.

My device is on, but my data is not showing up on the website.

Your device may have lost connection to Wi-Fi. Wait until the sample period is over. When you take the AMOD inside to charge, try to connect the device to Wi-Fi again.

Why are there gaps in my timeseries on the website?

Your device may have temporarily lost Wi-Fi and was therefore unable to send data to the server. All the data is stored on the device; we will be able to retrieve any missing data once the devices are returned.

Glossary of Terms

AMOD: Aerosol Mass and Optical Depth device

PM_{2.5}: small particulate matter

CEAMS: Citizen-enabled aerosol measurements for satellites, a citizen-science network that measures air quality

Filter: collects mass while still allowing air to pass through

Optical: uses light (specifically, the visible part of the light spectrum)

Bluetooth: Short-range wireless interconnection. Bluetooth often connects mobile phones, computers, and other electronic devices

API: Application Programming Interface

Blank filter: Pre-weighed, unused filter. This will be used as a comparison to used filters to make sure the measurements are valid

Further Questions?

Feel free to contact us at csu.ceams@gmail.com or go to our website www.csu-ceams.com if you have any additional questions.