Magee Scientific Aethalometer® Model AE33
Standard Operation Procedures Reference Manual

This manual is for users of the AE33 Aethalometer, and is intended to provide and encourage standard operating procedures for the instrument. This manual is not intended to replace the Magee Scientific Aethalometer® Model AE33 Users Manual, and is not meant to be a comprehensive document. Rather, the protocols in this document are a simplified guide for use in the field to help optimize instrument performance and minimize instrument downtime. The hope is that comparable operation of and care for the instruments at different sites will lead to a similar high quality of Aethalometer performance and data output regardless of instrument location.

SUMMARY

This summary page is a quick reference guide for key items that are described in detail throughout the SOP reference manual.

GENERAL

- ➔ NEVER tamper with AE33 inlet while instrument is on
- ➔ **Double check calibrations** before changing instrument settings
- ➔ **Maintain a detailed log** of instrument operation and maintenance

SETUP and OPERATIONS

- ➔ Inlet tubing to the Aethalometer must be **conductive**
- ➔ Instrument flow reporting standard should be set to 'NIST' (101325 Pa and 0°C)
- ➔ Instrument **flow rate** should be set to **5 slpm**
- ➔ Instrument **timebase** should be set to **1 second**
- ➔ Tape roll is set to advance when maximum attenuation is reached
- ➔ Maximum attenuation should be set to $\mathbf{ATN_{max} = 120}$
- ➔ Instrument date and time should be set to (GMT) Universal Coordinated Time
- ➔ External Device should be **Com1** and set to **'Datalogger_AE33_protocol'**
- ➔ Null modem serial cable should be attached to **Com1** on back of instrument

MAINTENANCE

- ➔ **Daily**: check instrument status, check percentage of filter tape left
- ➔ **Monthly**: inspect sample line tubing for kinks or breaks, review log file, inspect and clean insect screen, verify time and date, delete data from compact flash card
- ➔ **Biannually:** overnight filtered air check, inspect optical chamber, verify flow, manual clean air test, stability test, leakage test
- ➔ **Annually**: lubricate optical chamber sliders, check bypass cartridge filter

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AETHALOMETER THEORY

The Aethalometer measures light transmitted through a filter on which particles are deposited and interprets the change in transmittance, or the attenuation of light through the filter, as the atmospheric concentration of black carbon (BC) particles. The attenuation of light is roughly proportional to the amount of BC on the sample filter (ignoring filter loading and other effects), and attenuation is defined by the equation

$$ATN = -100*\ln(I/I_o)$$

where I_o is the intensity of light transmitted through an unloaded reference portion of the filter and I is the intensity of light transmitted through a loaded filter. As the instrument produces a time series of attenuation values, an attenuation coefficient is calculated using the change in attenuation with time, along with the spot size and flow rate using the following equation

$$b_{ATN} = A/Q *(1/100) * (\Delta ATN/\Delta t)$$

where A is the spot size area, ΔATN is change in attenuation over time Δt, Q is flow into the instrument and Δt is change in time. An uncompensated absorption coefficient can then be calculated from the attenuation coefficient by dividing attenuation coefficient by the multiple scattering parameter, C (Weingartner et al., 2003), which accounts for multiple scattering of the filter material, as in the following equation

$$b_{abs} = b_{ATN}/C$$

Finally, the raw mass equivalent black carbon concentration [BC] is calculated by dividing the absorption coefficient by the mass absorption cross section of black carbon in air (σ_{air}).

$$[BC] = b_{abs}/\sigma_{air}$$

The σ_{air} values are a function of wavelength, and are stored in instrument AE_SETUP.txt files that can be downloaded from the Aethalometer onto a USB stick. Manufacturer settings for σ_{air} values in the AE33 are as follows: σ_{370}= 18.47 m^2/g, σ_{470}= 14.54 m^2/g, σ_{520}= 13.14 m^2/g, σ_{590}= 11.58 m^2/g, σ_{660}= 10.35 m^2/g, σ_{880}= 7.77 m^2/g, σ_{950}= 7.19 m^2/g. These σ_{air} values, which are multiplied by the multiple scattering parameter C=1.57, are used by the instrument to convert attenuation coefficient to equivalent black carbon; however, other σ_{air} values found in literature may be used for a more site-specific conversion (Bond et al., 2013).

The Aethalometer manufacturer uses the term “black carbon” to describe the measurements by the instrument. However, note that the term “equivalent black carbon” (EBC), as recommended by Petzold et al. (2013), should be used when reporting quantitative results from the measurements, and that convention is used here.

SETUP

Installation & Sampling System

The Aethalometer should be installed on a sampling system and inlet that meets the appropriate international World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) standards for aerosol sampling and analysis (ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw153.pdf). **Conductive tubing must be used** to provide air flow from the sampling system to the inlet of the Aethalometer, and the inlet tubing should be kept at a minimal length in order to minimize particle losses in the tubing. Bends and long horizontal stretches of tubing should also be avoided. If the instrument is being installed at sites where bugs interfere with the sampling system, the instrument insect screen can be installed in the sampling line before air is pulled into the Aethalometer. The arrow on the side of the bug screen should align with the direction of flow.

To start making measurements, the instrument can be turned on using the ON/OFF switch on the back of the instrument, as well as the ON/OFF switch immediately inside the door of the instrument on the bottom right (see Figure 1). Once on, the instrument will automatically start measuring after a warm-up period of a few minutes.

Figure 1. Back view of instrument (left) and view inside the front of the instrument (right) with corresponding labels of instrument components

Connection to a Data Acquisition System

Although data can be exported from the instrument onto a USB stick and uploaded and stored onto a computer that way, a data acquisition system is often an easier way to acquire and store data. Any data acquisition system may be used to log data from the AE33 Aethalometer. The instrument can be connected to a data acquisition system in one of two days: (1) through the RS-232 serial cable port using a null modem cable connecting to, for example, a datalogger, or (2) through the Ethernet port on the instrument, allowing the Aethalometer network access for remote batch or streaming data acquisition, retrieval of instrument status and control of instrument operation.

Communication through the RS-232 port can be established using the following values:

- ➔ BaudRate = 115200
- ➔ DataBits = 8
- ➔ StopBits = 1
- ➔ Parity =None
- ➔ Handshake =None
- ➔ DtrEnable = True
- ➔ RtsEnable = True

For logging with cpd3 the external device setting option (on the Operations/Advanced tab) should be set to Com1 and the option 'Datalogger_AE33_protocol' should be chosen. The null modem cable should be connected to the Com1 serial port on the back of the instrument.

Spare Materials

It is advisable to have extra instrument supplies at stations that operate the AE33 Aethalometer. If the necessary spare materials are not included in the initial shipment of the instrument, it is recommended to order the following parts to have on hand, especially at stations that may be seasonally inaccessible:

- ➔ 2 extra tape rolls
- ➔ 1 extra bypass cartridge filter
- ➔ 1 extra compact flash card (initiated and bootable in case of instrument failure)
- ➔ 1 extra flow calibration pad
- ➔ 1 extra USB stick
- ➔ Extra inlet/outlet plumbing connection material

SAFETY CONSIDERATIONS

The AE33 instrument uses light at wavelengths in the visible and UV/IR to make EBC measurements, and care should be taken not to look directly at the light source in the optical chamber in order to avoid injury to the eyes.

Since the Aethalometer has moving parts, care should be taken to avoid getting fingers pinched between any of the operational pieces, especially when lifting and locking the optical chamber, when removing the optical chamber for inspection, and when removing and replacing the transparent covers from the filter tape roll spools.

The user should NEVER tamper with the electrical insides of the instrument (under the back and top covers) while the instrument is plugged in and turned on. Additionally, the user should NEVER obstruct the inlet while the AE33 is on and air is flowing.

OPERATION

The following section outlines recommended operational settings and procedures for AE33 Aethalometers. Operational settings addressed here include: flow rate, timebase, maximum attenuation value, date and time, and downloading data and setup files.

Flow rate

There are two settings that need to be addressed when considering the flow rate on the AE33- the flow reporting standard and the flow rate. The AE33 is equipped with a built-in mass flow meter, the reading from which is either converted to volumetric units using a standard preset temperature and pressure (or a set temperature and pressure of the user's choosing), or using ambient temperature and pressure readings from an external probe connected to one of the AE33 serial ports. The user can choose from many different flow reporting standards from the OPERATIONS menu under the GENERAL tab. It is recommended to **set the mass flow reporting standard to 'NIST'** in order to best homogenize flow rates across instruments at different stations, and to meet recommendations for submission to the World Data Center for Aerosols. This will set the **standard temperature to 0°C** and set the **standard pressure to 101325 Pa**.

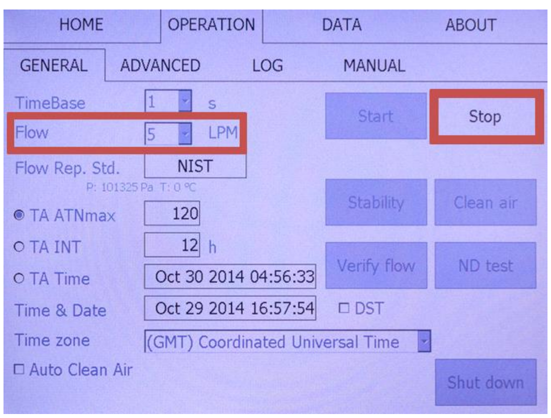

Figure 2. Flow rate can be set in the OPERATION menu under the GENERAL tab

Furthermore, the AE33 has pre-set flow rate options of 2, 3, 4, and 5 liters per minute (lpm). Because there are no scientific disadvantages to having a high flow rate, it is recommended to **set the flow rate to 5 lpm**, unless the site is so contaminated that excessive tape usage becomes cost prohibitive, or if the system configuration requires a lower flow rate. Flow rate can be set under the OPERATIONS menu in the GENERAL tab, as shown in Figure 2. AE33 measurements must be stopped before changing flow rate and restarted again after a new flow rate is set. If it is deemed necessary to change the flow rate at some time after installation and operations have begun, record the change in the log record.

NOTE: At high altitude sites where pressure is low, an external supplemental pump may be needed in order to maintain an operational flow rate of 5 slpm. Alternatively, a lower flow rate can be used at high altitude sites.

Timebase

The timebase indicates how often the instrument records data. A faster timebase means the instrument will report more readings, providing better time resolution, but more noise. A slower timebase means the instrument fails to capture fine time details, but the data have less noise. The optimal timebase setting depends on the data recording system. If the data recording system does its own averaging to synchronize multiple instruments, a **timebase of 1 second** is desirable. This setting will generate large quantities of data, filling the CF card in approximately 1 year. The "delete oldest if full" setting in the DATA menu under the EXPORT tab should be selected.

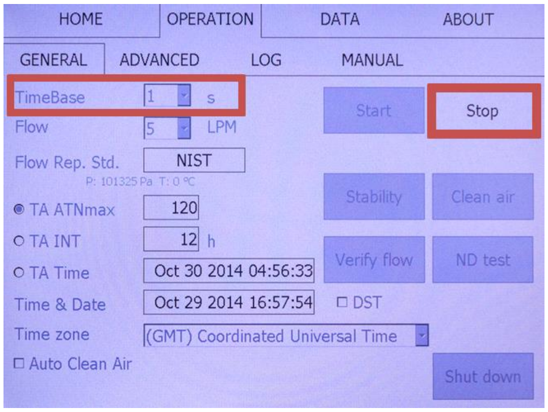

Figure 3. Timebase can be set under the OPERATION menu under the GENERAL tab

If the data recording system logs all data sent to it, and if its capacity is limited compared to the data sent by the AE33, then **a timebase of 1 minute** makes more sense.

Timebase can be set under the OPERATIONS menu in the GENERAL tab, as shown in Figure 3. AE33 measurements must be stopped before changing the timebase and started again after setting the new timebase. To stop AE33 measurements press the *Stop* button in the OPERATION menu under the GENERAL tab.

Maximum attenuation value

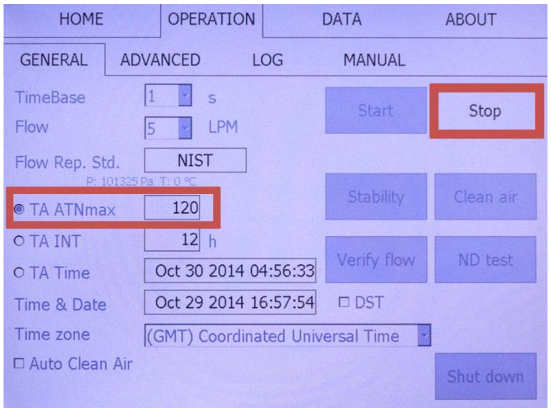

Figure 4. The maximum attenuation value that determines when the tape advances can be set in the OPERATION menu under the GENERAL tab

The AE33 Aethalometer uses a maximum attenuation value, a set time, or a time interval to indicate when to advance the filter tape. It is recommended to **use the maximum attenuation value to specify when the filter tape advances** to a new loading spot. Setting a low maximum attenuation value, e.g., ATN_{max} = 75, is conservative in that filter loading correction is greater at higher ATN values, but means the filter tape will advance more often. A higher attenuation value, of say ATN_{max} = 150, means the tape will not advance until a much higher particle loading on the filter, so the filter tape will advance less often, but the filter loading correction will be more significant at the high ATN values. It is recommended to **keep the setting at the manufacturer default maximum attenuation value of ATN_{max} =120**, which is an appropriate balance between a conservative filter tape advance and one that saves filter tape resources. The maximum attenuation value can be set in the OPERATIONS menu in the GENERAL tab. Measurements must be stopped before changing the maximum attenuation value setting, and restarted after the new value is entered.

Date and Time

The instrument's **date and time should be set to (GMT) Coordinated Universal Time**. The date and time can be set under the OPERATIONS menu in the GENERAL tab. Alternatively, the date and time can be set by sending a command through the serial port ($AE33:TyyyyMMddHHmmss, where yyyy is year, MM is month, dd is day, HH is hour (24), mm is min and ss is second). Ensuring that the date settings are accurate is important in case data need to be downloaded directly from the instrument as a supplement to data logged on the data acquisition system.

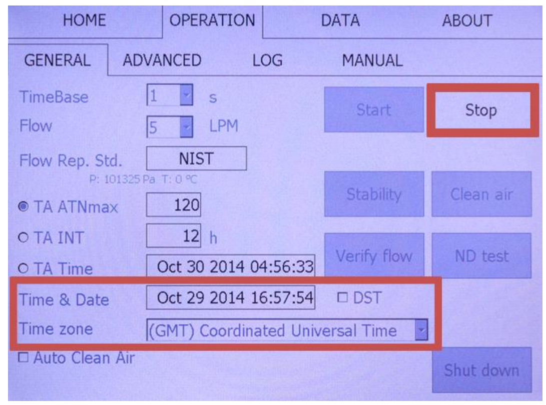

Figure 5. Date and time are set in the OPERATION menu under the GENERAL tab

Downloading data and setup files

If the AE33 is connected to a data acquisition system, there should rarely be a need to manually download data from the instrument and send it for data storage and analysis; however, in the event that a data acquisition system is not being used or is not functional, it might be necessary to get data from the instrument manually. Furthermore, the instrument's setup file (AE_SETUP.txt) is not automatically transmitted through a serial cable connection, and thus should be downloaded periodically (or retrieved remotely through the serial from the command line; see manual version 1.53 for more information) and saved for recordkeeping. Data and setup files are manually downloaded in the same way, as described below.

The Aethalometer AE-SETUP.txt file contains comprehensive information about the instrument's operational settings. To extract the setup file and/or data manually, go to the DATA menu and EXPORT tab. There, set the *From:* and *To:* dates as desired. If the user wants the setup file but not necessarily other data, then set both dates to the current date. This way, only one day's worth of data will be downloaded with the AE_SETUP.txt file, which will save time. The *Copy Log, Copy ND test results,* and *Copy flow verification results* boxes can be checked if that information is desired. Selecting *Copy Log* will output the instrument's status log, *Copy ND test results* will output all neutral density test results, and *Copy Flow verification results* will output result tables from all flow verification tests.

Put a USB memory stick into the USB port and press *ExportToUSB* under the DATA menu and EXPORT tab. This will put data from the selected time period and the current setup file onto the USB stick. The setup file can now be uploaded and saved wherever data are typically stored. **The setup file should be downloaded and saved at least once per year, plus every time a change to the instrument configuration or calibration is made.**

Figure 6. Files can be downloaded from the AE33 onto a USB stick by inserting a USB stick into the USB port on the front panel, and choosing 'ExportToUSB' in the DATA menu under the EXPORT tab

The most current version of the AE33 hardware and software (as of August 2015) now includes the ability to access the AE_SETUP.txt file remotely through the serial port from the command line. This process can theoretically be automated so that manual download is not necessary- check with the AE33 manual version 1.53 for more information.

DATA CORRECTION AND REPORTING

As with any filter-based aerosol absorption measurement technique, unwanted artifacts arise in the AE33 due to the deposition of the sample in the filter matrix. The effects in the filter matrix include: multiple scattering in the filter, scattering by aerosols, and/or filter loading. The first effect (multiple scattering by the filter fibers) is actually desirable, as it increases the sensitivity of the measurements, and the effect itself is accounted for in the instrument algorithm. Many Aethalometer correction schemes exist that try to account for one or all of these artifacts (Collaud Coen et al., 2010; Drinovec et al., 2015), but there is currently no agreed upon and widely accepted correction scheme. The AE33 does have an internal that provides a real time 'loading compensation parameter', k, that corrects instantaneously for the spot loading effect (i.e., when instrumental sensitivity decreases as filter loading increases).

It is recommended that site scientists carefully consider all available correction schemes, including the internal AE33 compensation scheme, to evaluate how best to determine the absorption coefficient from the Aethalometer data before scientific analysis.

AE33 data from WMO/GAW stations should be submitted annually to the WMO World Data Center for Aerosols in the format described at http://www.gawwdca.org/SubmitData/AdvancedDataReporting-/Level0/FilterAbsorptionPhotometerlevel0/MageeInstrumentslevel0.aspx. At present, WDCA requests that GAW stations submit raw Aethalometer data, so that a consistent correction scheme can be applied to all Aethalometer measurements in the GAW network.

DATA QUALITY CONTROL

The integrity of the AE33 data should be maintained with periodic data editing. In general, the goals of data editing are to flag any instances where: (1) The instrument or peripherals (e.g., a pump) malfunction, making the data invalid, or (2) A local contamination source has created a spike in the data that is not representative of the regional aerosol population. More detailed information on Aethalometer data editing can be found in the data editing manual included in the Appendix.

MAINTENANCE

The Aethalometer needs to be maintained regularly through instrument performance checks and calibrations. These maintenance tasks will help ensure that the instrument is running properly and output data are not being affected by instrument malfunction. Table 1 presents a list of maintenance tasks, as well as how often each check should be done. Maintenance task procedures are described in the Aerosol d.o.o. AE33 User's Manual, and also in the AE33 Maintenance Procedures document.

Table 1. AE33 maintenance tasks

Maintenance Check	Frequency of Check
Check instrument status	Daily
Check percentage of filter tape left (Install new filter tape roll if needed)	Daily
Inspect sample line tubing for kinks and bends	Monthly
Inspect and clean insect screen	Monthly
Verify time and date (correct if necessary)	Monthly
Delete data from compact flash card	Monthly
Download and save AE_SETUP.txt file	Biannually
Inspect optical chamber (clean if necessary)	Biannually
Flow check (always a flow verification, flow calibration if necessary)	Biannually
Manual clean air test	Biannually
Stability test	Biannually
Leakage test	Biannually
Inlet leakage test	Biannually
Overnight filtered air check	Annually
Tape sensor calibration	Annually
Neutral density filter test	Annually
Lubricate optical chamber sliders	Annually

Check bypass cartridge filter (change if necessary)	Annually

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Photo Credits: Will von Dauster, NOAA, Boulder, CO, USA

APPENDIX

Aethalometer Data Editing Guide

This guide is intended to provide a reference for anyone responsible for quality control and editing of Aethalometer data for different Aethalometer models, including the AE33, AE31, AE16, AE22, and AE42. General Aethalometer data editing techniques, as well as commonly encountered Aethalometer data editing issues, are presented here.

Quick Reference Guide

After reading the entirety of the Aethalometer data editing document, these basic steps can be used as a quick reference guide during the Aethalometer data editing process:

1. View instrument log- invalidate any data where there was a documented instrument malfunction or issue at the monitoring station affecting Aethalometer data
2. Check Aethalometer status- flow should be constant and close to the desired operating value, attenuation should be increasing (except for during a filter change), and temperature should be constant. If flow, attenuation, or temperatures look erratic, consider invalidating data and contacting station tech for instrument maintenance.
3. Check Aethalometer intensities- sense beam intensity values should decrease slowly and reference values should be more or less constant. If the sense or reference values are noisy or erratic, consider invalidating data and contacting station tech for instrument maintenance.
4. Check Aethalometer zero- sense and reference zeros should be constant near zero. If zero values look erratic, consider invalidating data.
5. Look for Aethalometer filter spot changes- spikes or erratic EBC data immediately before, during or after a filter spot change need to be invalidated.
6. Check for strange data behavior occurring in only one channel- if data in only one wavelength channel has a spike, for example, all data can be invalidated because the spike in one channel may be indicative of a short-lived instrument malfunction. Or it could be a failure with just that light source in which case only that channel should be invalidated.
7. Look for spikes in EBC concentration- large positive or negative spikes in equivalent black carbon concentration data that can otherwise not be explained by instrument malfunction or periods of contamination should still be invalidated, if the spikes are of short duration and well above or below reasonable values for the region.
8. Inspect data for periods of contamination- data may be contaminated if the wind is blowing from a pre-determined contaminated air sector (e.g., from a nearby town) or if there is construction or other disruptive activities happening on site. Contaminated data may have large anomalous spikes indicative of higher aerosol levels, even though housekeeping parameters show that the instrument is performing fine.
9. Save all edits- after completing all edits for Aethalometer data, be sure to save the edited dataset.

General editing goals

In general, the goals of data editing are to flag or remove any instances where:

1. The instrument or peripherals (e.g., a pump) malfunction, making the data invalid
2. A local contamination source has created a spike or change in the data that is not representative of the regional aerosol population

Generally, instances where there is a problem with an instrument or the sampling system, or instances where system maintenance is being carried out, should be invalidated. On the other hand, instances of short contamination spikes (see the next section for information on defining a data spike) should be marked as contaminated. Being able to separate contamination and invalidation edits is important, since there may be instances where including contaminated data are useful for a scientific analysis.

The goal of editing is for the final edited data set to be representative of the regional aerosol. One way to confirm that data edits were successful is to look at the calculated hourly averages of the variables after the edited dataset has been saved. The hourly averages should show values within the ranges typically expected of the aerosol variables at that station for that season of the year.

The NOAA/ESRL/GMD Aerosol Group acquisition and visualization software- CPD/CPX- is utilized to display the examples used throughout the document. All stations within the NOAA/ESRL/GMD Federated Aerosol Network already use the CPD/CPX system for data acquisition and visualization; more information about editing within CPX can be found here: ftp://aftp.cmdl.noaa.gov/data/aer/doc/software/Using_CPX2.pdf. The guide in the link outlines in detail the basics of the CPX interface, how to log edits, and general editing techniques. However, this document will proceed assuming the user does not use CPD/CPX, and general editing guidelines for Aethalometer data, which can be implemented using any editing system, are presented here.

What is considered a data spike?

When editing data, it can be tricky to determine a data spike caused from local contamination sources (or from instrument error) and what is a real flux in the regional aerosol. Typically, an increase in the regional aerosol appears as a broader bump in the data that persists for more than 15 minutes, while a local contamination spike (or spike from instrument error) typically lasts less than 15 minutes and is a sharp increase or decrease in magnitude of the aerosol variable. A spike from instrument error is often accompanied by spikes or anomalous behavior in other ‘housekeeping’ (e.g., temperature, pressure, flow, lamp intensity) parameters.

There is certainly subjectivity in deciding whether an observed increase is a real regional aerosol increase or a local contamination spike. Sometimes, for example, a sharp increase in aerosol in the data record for longer than 15 minutes should still be marked as contamination. Expert knowledge of the monitoring site, as well as data editing experience, help clarify tough editing decisions.

Methods

It is advisable to edit a week of Aethalometer data at a time, as soon as that week of data are received by the editor. This way, if the data show instrument malfunctions, the issue can be addressed quickly in order to minimize poor data and instrument downtime.

In addition, it is useful to edit Aethalometer data along with any other instrument that may be running concurrently with the Aethalometer at the monitoring site. This can help the editor distinguish time periods of instrument malfunction from contamination. For example, if all aerosol instruments show anomalous behavior, it is likely contamination or a system-wide malfunction (e.g., pump failure). On the other hand, if the Aethalometer has anomalous spikes, while a concurrently running absorption instrument does not, it may indicate issues with the Aethalometer operation itself.

Station technicians should maintain a log of site activities and instrument behavior. Reading through the message log is a good first indication of any issues the Aethalometer might have had that week. The following log entries are examples of message that indicate the Aethalometer data might need editing:

1. The station tech performed a maintenance procedure on the Aethalometer instrument (*Example: "The AE33 Aethalometer chamber was found to contain insects. Optical chamber cleaned and advanced tape"* – the insects created a large spike in the data, which needed to be invalidated since it was due to instrument contamination)
2. Communications were lost to the Aethalometer (*Example: "Instruments, AE31; Comms lost"* - sometimes lost communications can create spikes on either side of the missing data, which need to be invalidated since it is due to instrument error)
3. There was a power outage at the monitoring station (*Example: "Overnight power outage at station"* - if spikes or strange data behavior occur on either side of the power outage, those data should be invalidated, perhaps due to improper instrument shutdown or startup on either side of the power outage)
4. There was an annual maintenance visit to the station (*Example: "PJS on site now for annual maintenance visit. Invalidate all aerosol data. Work with system would have caused many spikes"* - be sure to invalidate all data that could have been contaminated throughout the duration of the site visit)

The next step is to view a time series of the week of Aethalometer data (including EBC concentrations, absorption coefficient, flow, lamp intensities (sense and reference values), and attenuation values). This is also the time to view any concurrent aerosol measurements by other instruments. This will provide a good overview of any time periods that need attention when editing, and provide information about the status of the instrument and its housekeeping parameters that affect data quality.

After getting a good overview of that week's worth of data, the editor can proceed to zoom in on a time period that might need editing, and add an edit. The next section provides details regarding commonly encountered Aethalometer edits.

Commonly Encountered Aethalometer Data Edits

The following table outlines common Aethalometer data edits, and how they could be noted in the editing system. Any variation of these comments could be implemented; however, it is worthwhile to maintain some level of consistency with editor comments. This way, it is easy to search a specific subset of edits if they need to changed or separately analyzed after the editing process.

Table 2. Common data issues and corresponding mentor edits for Aethalometer data editing

Editor Comment	Data Issue
Positive spike	EBC concentration value spikes much above reasonable level
Negative spike	EBC concentration value spikes much below reasonable level
Positive/negative spike	EBC concentration value spikes much above reasonable level, followed subsequently by a spike much below reasonable level
Noisy EBC data	EBC concentration values are noisier than usual for the station
Noisy ATN	ATN values are noisy (dipping up and down) and making the Aethalometer data noisy and/or erratic as well
Noisy reference values or beam intensity	Reference intensity is noisy and making the Aethalometer data noisy and/or erratic as well
Noisy sense values or beam intensity	Sense intensity is noisy, or increasing at a time other than during a filter change, affecting the Aethalometer data
Power outage	Aethalometer data on either end of a power outage are erratic, likely from improper instrument shutdown or startup
Filter change spikes	Aethalometer data immediately before or after a filter spot advance are erratic, likely an artifact from filter change
One noisy wavelength channel	A spike or strange data behavior is observed in only one wavelength channel of the Aethalometer, and might be indicative of a short-lived instrument malfunction
Automatic clean air test	During an automatic clean air test, or immediately after, data can erroneously have erroneous black carbon or absorption data
Contamination	Data are influenced by contaminated air

Aethalometer Data Editing Checks

The following section outlines Aethalometer parameters that should be checked during the data editing process, and provides examples of Aethalometer data that would require editing.

Aethalometer Status

Aethalometer status refers to parameters like flow, attenuation, and/or temperature, depending on the instrument model at the station. In the example below, the AE31 Status tab shows instrument flow and attenuation. The example shows a week of normal Aethalometer status.

- **Flow** values should always remain more or less constant. If flow suddenly drops much below the set value, consider invalidating data for that time period, and the Aethalometer might need maintenance.
- **Attenuation** should monotonically increase or stay level - generally it should not decrease (with the exception of a filter spot change, or if desorption of previously adsorbed VOCs occurs and creates a 'real' negative signal at lower wavelengths). If the attenuation values get noisy, this can cause large jumps in EBC concentrations, so the editor should make note of any time periods where the attenuation values are not smoothly increasing. The larger the wiggle in attenuation, the noisier the EBC data.
- **Temperature** should be more or less constant, with special attention being paid to check that temperature never gets too high. Typically temperature is only output for AE33 instruments.

If any of these parameters are behaving erratically, it is an indication that a data edit might be needed, and a technician at the monitoring station may need to check the instrument's operation.

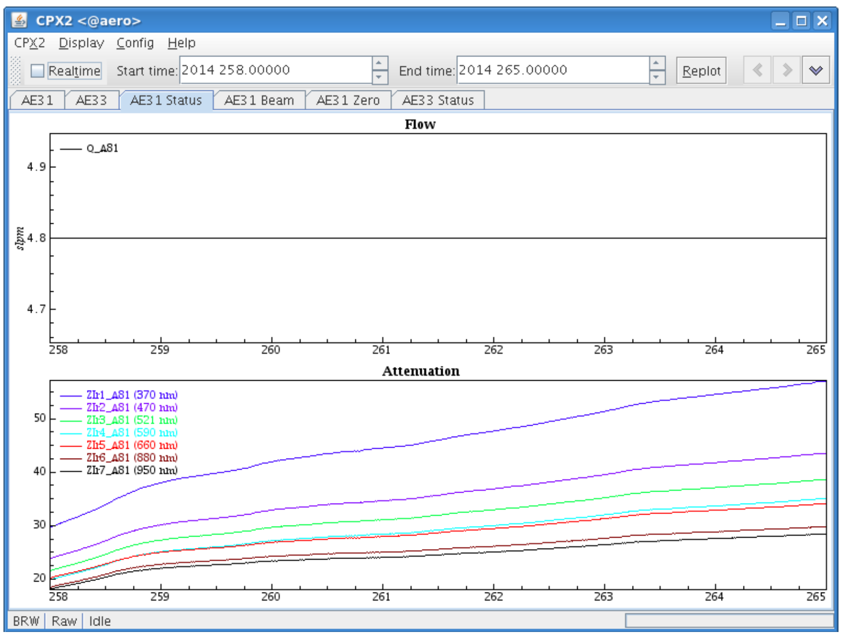

Figure 7. Aethalometer status should show constant flow, and increasing attenuation over time (with the exception of filter changes), as seen here

Aethalometer Intensities

The Aethalometer beam refers to the sense and reference lamp intensities in the legacy Aethalometers and to the digitized intensity values in the AE33 –the main thing to check is the stability of the intensities.

- During normal sampling the **sense beam** should be slowly decreasing with time (as the aerosol particles load the filter, the sense beam intensity decreases). The exception is when the filter tape advances for a filter spot change, at which point the sense beam value should increase almost instantaneously. You will know it is a filter spot change if the sense intensity increase coincides with an instantaneous drop in attenuation to near zero (legacy Aethalometers) and or a status indicating a filter change (Aethalometer AE33).
- The **reference beam** should be more or less constant over time.

If the sense or reference beams are noisy, then data should likely be invalidated, since EBC concentrations will also be unnecessarily noisy. In the example below, the data before (to the left of) the filter change are invalidated because of noisy sense and reference beam intensities, while the data after the filter change are acceptable, indicated by the smoothly decreasing sense beam intensity and the constant reference beam intensity.

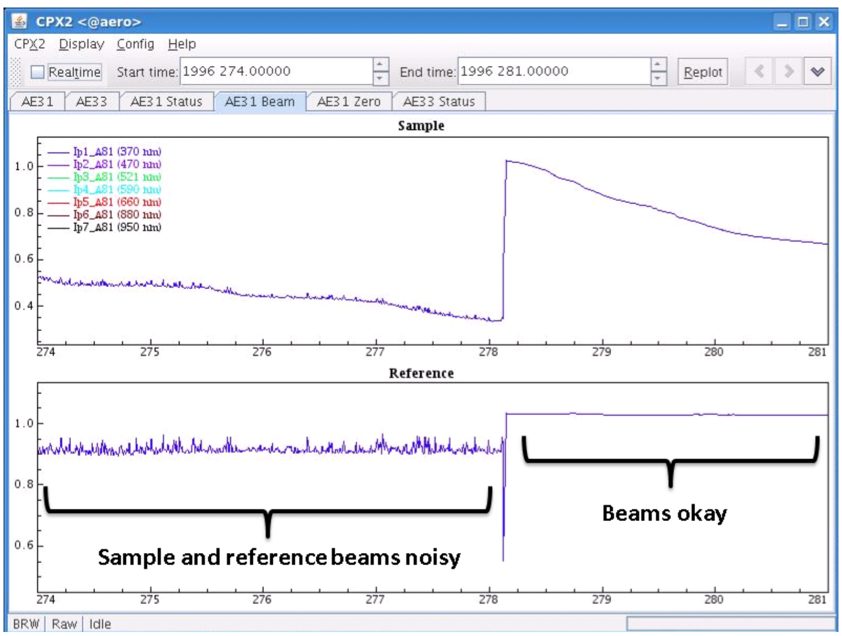

Figure 8. An example of noisy sense and reference beams before a filter change, and stable sense and reference beams after a filter change. The time periods with noisy sense and reference beams likely need to be invalidated

Aethalometer Zeros (legacy Aethalometers only)

The Aethalometer zeros (signal beam zero and reference beam zero) represent the values of the beam detector outputs when the lamps are turned off. These zero values are then subtracted from the response when the lamps are on in order to correct for the 'dark response signal'. These zero values should be more or less constant, and near zero. In the example below, the sense and reference zero spikes correspond to a filter spot change, and data at this time should be invalidated.

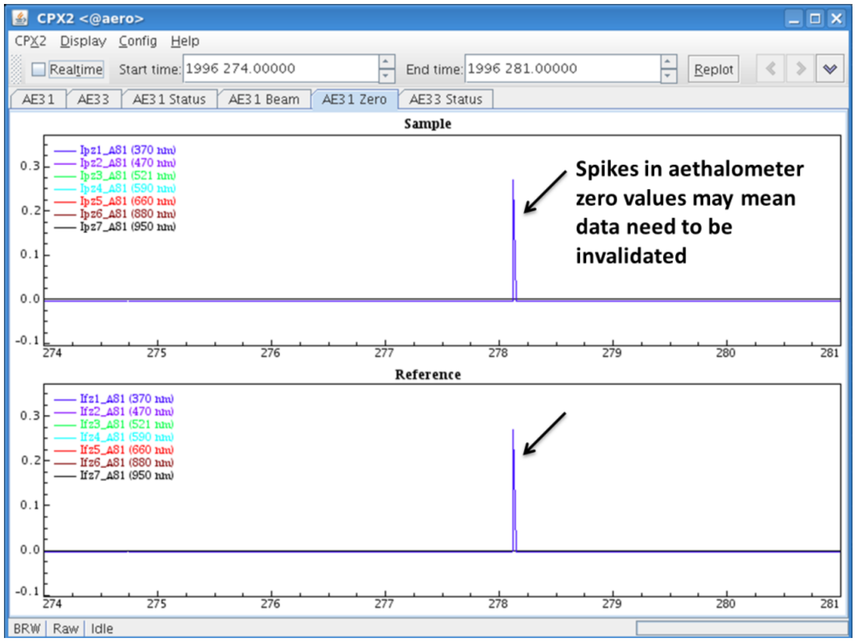

Figure 9. The large spikes in sense and reference beam data seen here may indicate that Aethalometer data need to be invalidated during that time period

Aethalometer Filter Spot Change

When the Aethalometer filter tape advances, many things happen to the Aethalometer variables. The attenuation drops back to zero, the sense intensity beam increases as a step function, the Aethalometer zero value may spike, and the EBC concentration data may look erratic (this happens when legacy Aethalometer data are being reprocessed through a data logger). Generally these data need to be invalidated, as the erratic values are not representative of real aerosol.

In the example below, an extreme positive spike occurred in the EBC data right after a filter change. This data spike was invalidated, noting that the spike was likely related to the filter spot advance.

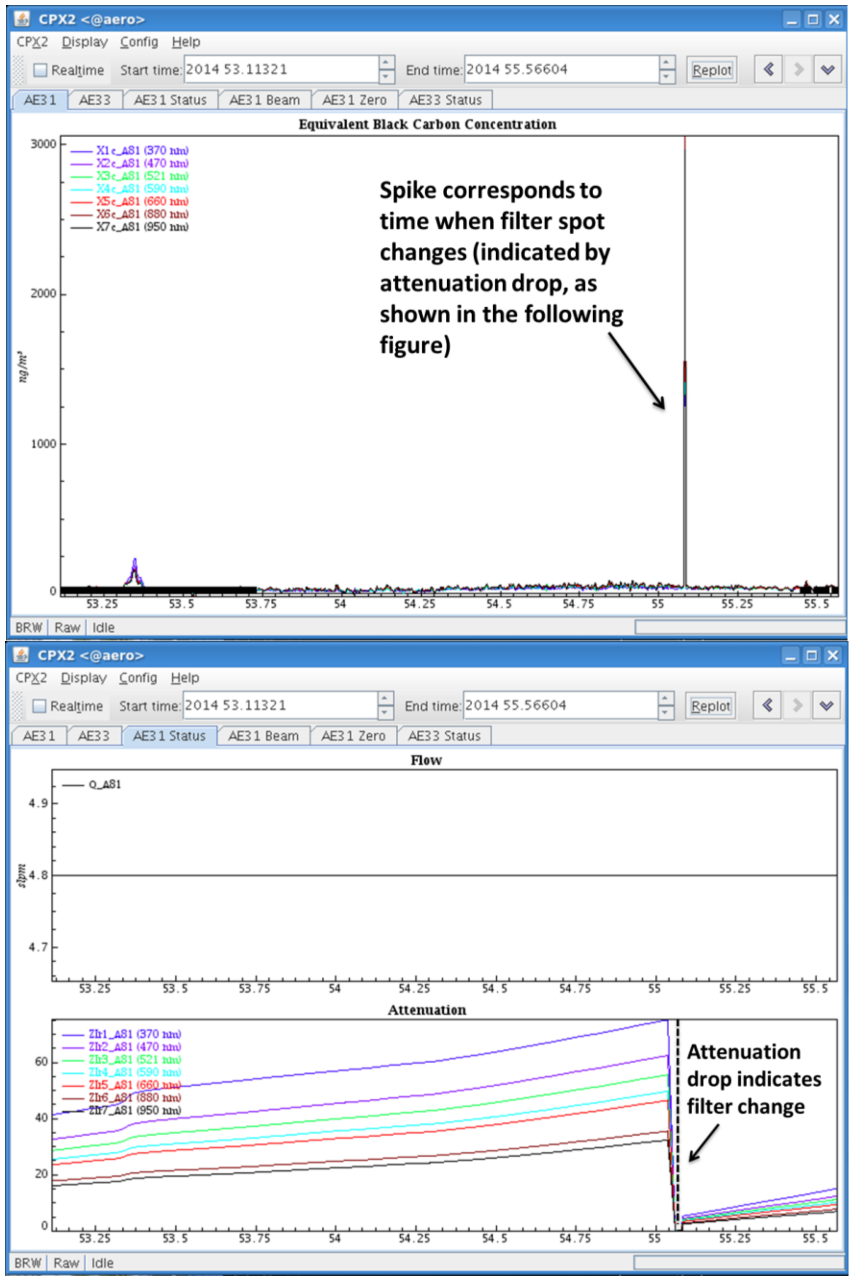

Figure 10. A large spike in EBC concentration corresponding to a filter change (indicated by drop in attenuation to zero) needs to be invalidated, since it is likely an artifact of the filter advancing process in the instrument

Strange behavior in one channel

Sometimes, Aethalometer data are only erratic in one channel. In the example below, only the 470nm wavelength channel sees a deep negative spike. The editor needs to decide if the spike in the one channel is indicative of a brief instrument malfunction, and if data from all channels need to be invalidated. Alternatively, the editor could decide that only the one channel needs invalidating, and the rest of the data are acceptable.

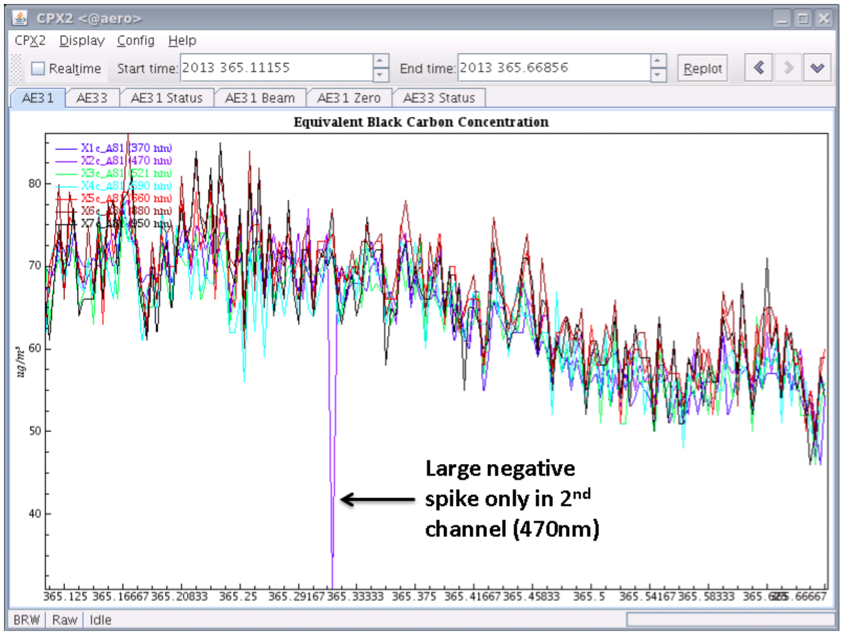

Figure 11. If only one channel exhibits noisy behavior or spikes, then just the single channel's data need to be invalidated

Spikes in EBC concentration data

Sometimes there are spikes in EBC concentration data for no immediately apparent reason- the housekeeping parameters are stable, there is no indication of contamination, and there is no log message indicating system maintenance, but the EBC data still spike. This could just be an artifact of the Aethalometer being a filter-based instrument. These large spikes in EBC data that are not representative of regional aerosol or local contamination need to be marked as invalid. Unreasonably high or low spikes that fall outside the normal noise of the instrument can affect the hourly average of EBC concentration in a false way.

Spikes should be invalidated and commented with a note like 'positive spike', 'negative spike', or 'positive/negative spike'. The only reason to specify in the comments whether the spike is positive or negative is so there is a record over time of *how* the data that were invalidated are erratic- recurrent spikes may be indicative of a larger problem, say, with the signal or reference lamps, that could be fixed. It is important to take care to only invalidate the data spike, and not too much of the valid data surrounding the spike. Examples of positive, negative, and positive/negative spikes are shown in the examples below.

The case below shows an example of an extreme positive spike that is not characteristic of the region and should be edited as invalidated and noted as 'positive spike'.

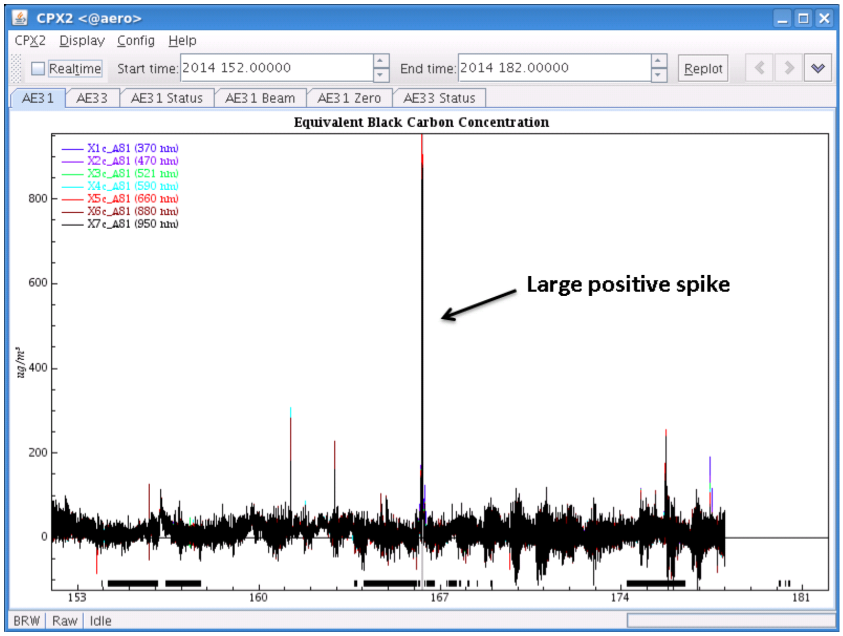

Figure 12. Substantial positive spikes in EBC concentration data, like the one shown here, should be removed

In this case, the negative spike is so extreme that all of the other days of data are barely visible. This data spike needs to be invalidated, and noted with a comment like ‘negative spike’.

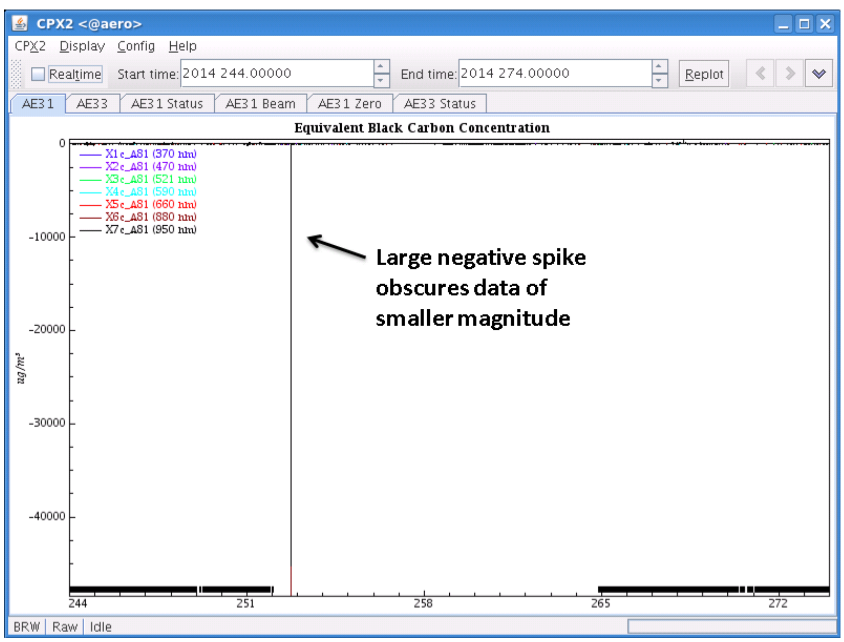

Figure 13. Extreme spikes, like the negative spike shown here, should be invalidated. In the case shown here, this needs to be the first edit done so that data of smaller magnitudes become visible by the editor

This final example shows a positive/negative spike, when the EBC concentration data first spikes way up, and then subsequently spikes way down. Both spikes should be marked as invalid, but can be done so using just one edit with a comment like ‘positive/negative spike’. These positive/negative spikes are common in the Aethalometer- since the Aethalometer uses a difference measurements, a single high spike in sense beam intensity will result in a low spike in EBC concentration followed immediately by a high spike in EBC concentration of similar magnitude. The spikes should be removed if data at high time resolution are being used. Otherwise these spikes average out.

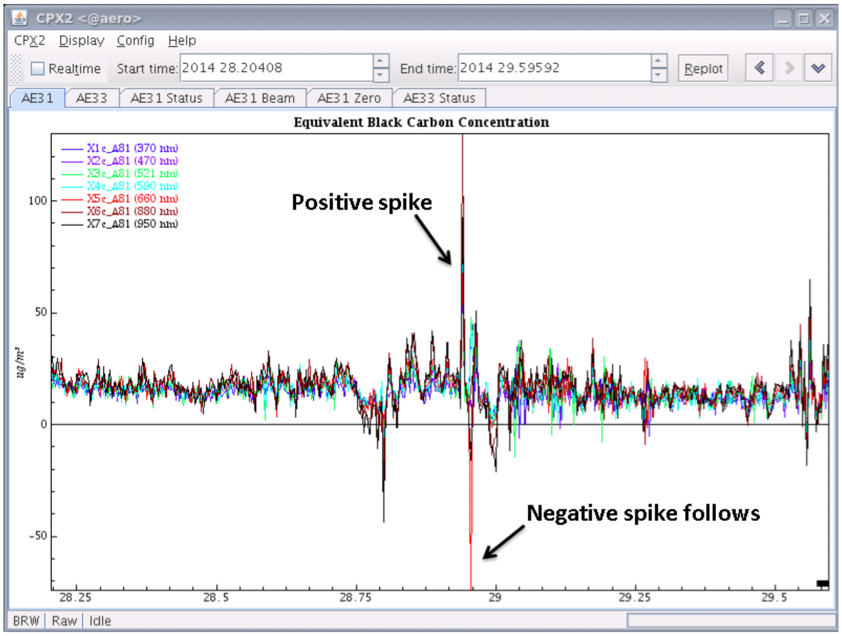

Figure 14. Often the Aethalometer exhibits large spikes in one direction, followed by a compensating large spike in the other direction, like the positive/negative spike shown here. These data should be invalidated.

Automatic clean air test

When an automatic clean air test is performed, data during and after the clean air test can be erratic and should be removed. The figure below shows data during an automatic clean air test, the test roughly marked by the vertical black lines, as well as the data after the appropriate time period of erratic data has been removed.

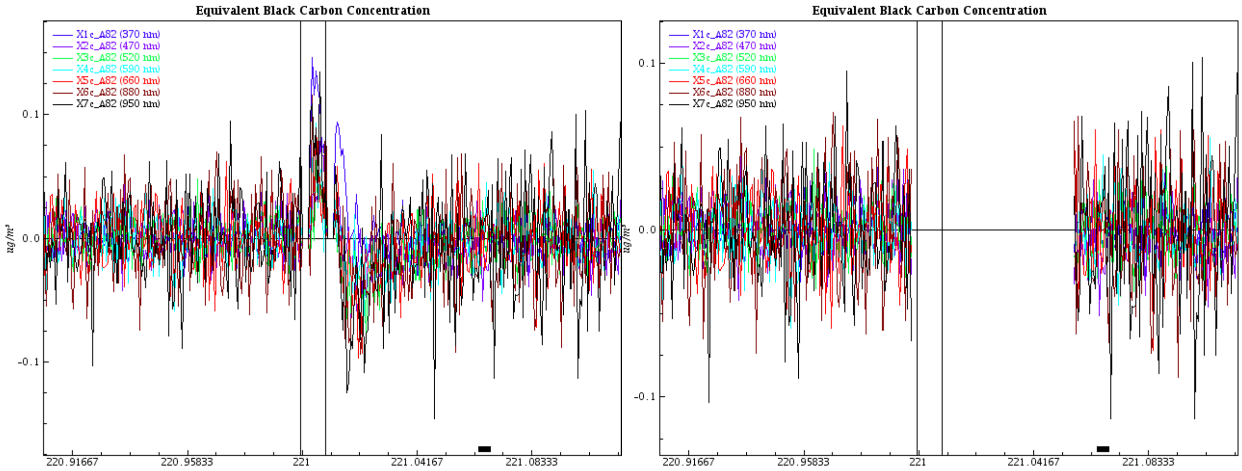

Figure 15. Clean air test is marked by the two vertical black lines, where data is higher than expected during the test, and lower immediately after. The figure on the left shows data before editing, and the figure on the right shows the data after proper editing

Contaminated data

Contaminated data are measurements made when the instrument is performing as expected, but the aerosol being measured is not representative of typical regional aerosol in that location. At some stations, there is a pre-determined clean air sector and contaminated air sector. In this case, data are typically edited and marked as contaminated if the wind direction is from the contaminated air sector. Two types of local contamination that are particularly problematic include trash burning, and people driving vehicles up to instrument locations. Contaminated data may also occur if there are construction activities onsite at the monitoring station, or if there are maintenance activities being performed at the station. Typically, these disruptive activities will be communicated by the station technicians or documented in a log file, so the editor can use the information to edit and mark as contaminated the corresponding data. Expert knowledge on the monitoring site, the climatology of aerosols at that location, and expected magnitudes of Aethalometer measurements is especially key when identifying periods of contamination.

Saving and Reviewing Aethalometer Edits

It is important that edits are saved often, so that if the editing system goes down in the middle of an editing session, all edits are not lost. After all of the Aethalometer edits are completed and saved, it is prudent to go back and view the week that was just edited and check a few things. It is smart to ensure that the new edited data do not have any residual strange behavior. Furthermore, make sure that the hourly averages look reasonable based on what you would expect to see at that station. If something looks strange, it is worthwhile to re-visit the raw data and see if there is an anomaly that was missed the first time around that needs to be edited. Remember, if you make any additional edits at this point, the data need to be resaved again.

Miscellaneous Notes

When there are two Aethalometers running in parallel at a station, extra care needs to be taken when completing the data editing. If a data spike is observed in the record of only one instrument, be sure to mark only the instrument that had troubles and needs the data to be invalidated. Also, when commenting the edit, it is advisable to specify which Aethalometer you are editing (e.g., AE31 or AE33) - this way, the subset of edits for only one of the Aethalometers can be viewed later if necessary.

It is important that data edits are reviewed periodically on longer time scales (e.g., many months or years). This is because patterns in data edits may be indicative of a larger station or instrument issue. For example, if Aethalometer data are invalidated every Thursday around the same time due to excessive noise in the EBC data, perhaps there is a recurrent but preventable activity at the station (e.g., cleaning of the inlet stack, arrival of station techs onsite by diesel truck) that explains the data problems. Additionally, long time periods of issues with Aethalometer housekeeping parameters (e.g., noisy reference beam or inconsistent flow rates) could indicate that the instrument needs to return for the manufacturer for servicing, or the sampling line to the Aethalometer needs to be checked for problems.