STANDARD OPERATING PROCEDURES

Nephelometer Data Acquisition and Processing

Dalhousie University
Halifax, Nova Scotia, Canada

Prepared by: Crystal Weagle
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1.0 SCOPE AND APPLICATION

This SOP describes the practices for acquiring data from nephelometers and conducting nephelometer performance checks and calibrations. A set of performance checks are performed to check the state of the nephelometer under normal operating conditions, without special preparation or adjustment. These permit the Site Manger to determine if maintenance and/or repairs are necessary, if recalibration is warranted, or if adjustment to operation should be made. On-site calibrations are performed when nephelometers are operating as expected, but to correct excess baseline drift in scattering measurements and to prolong the normal, on-site operation of the nephelometer. As material is accumulated on the walls of the nephelometer tube, cleaning of the nephelometer tube becomes necessary. When this point is reached, the nephelometer is sent to the SPARTAN Central Lab at Dalhousie University for maintenance, cleaning, and recalibration before being returned to the site. The ultimate aim of this protocol is to ensure the integrity of the SPARTAN scattering data and to assess the data for accuracy.

REVISION HISTORY			
Revision No.	Change Description	Date	Authorization
2.0	General reorganization and clarification; update to performance checks and on-site calibration timelines; addition of data acquisition information	August 13, 2018	Crystal Weagle
3.0	Additional details added to calibration instructions	March 4, 2019	Brenna Walsh
3.1	Updated the performance checks and linked the SOP version to data version	December 19, 2023	Haihui Zhu

2.0 DATA ACQUISITION

A vital part of ensuring the normal operation of nephelometers while deployed at sampling sites is regular transfer of data files from the nephelometer. These files are then sent to the site manager, who performs a series of performance checks to ensure the nephelometer is operating properly. The data files that contain nephelometer light scattering measurements are saved on a memory card as .csv files. Under normal operation (one data point every 15 seconds) approximately 10 MB of data is accumulated during 1 week of continuous sampling.

The data files are transferred from the nephelometer memory card to a secure computer at least once every two weeks. This allows the site operator to ensure the nephelometer is still powered on and functioning on a regular basis, and to minimize the potential loss of sampling time. After the files are transferred from the memory card, they are shared with the site manager by email and/or a shared folder to which both parties have access. Once this is complete, the data files are cleared from the memory card and the memory card is reinserted into the nephelometer.

NOTE: The nephelometer should be turned off prior to removal of the memory card and subsequently powered back on when the memory card is reinserted.

3.0 PERFORMANCE CHECKS

The site manager coordinates with the site operator to receive nephelometer data from the site operator. When new data is received, the site manager analyzes the data file(s) to ensure the nephelometer is operating properly and producing quality scattering measurements. Performance checks provide the necessary information to:

- Assess the timeline for nephelometer calibration
- Direct appropriate corrective action as indicated by the performance checks
- Review and flag scattering data as appropriate due to failed performance check

There are a number of variables that are recorded by the nephelometer that are used in calculating scatter. Therefore, it is necessary to assess the stability of the sensors used to measure these variables as well as the resulting scatter measurements. *NOTE:* the absolute values of sensor signals (e.g. reference sensors and PMTs) vary significantly between nephelometers and are not compared. Rather, there is an initial data file for each nephelometer that provides a baseline for the signal.

- There is a natural variation in the reference sensor signal, however the variance should not be more that 10 %. If the variance is found to be greater than 10 % there may be an issue with the reference sensor or its power supply.
- Dark reference sensor values and dark PMT values are significantly lower than reference measurements at all wavelengths (not higher than 80%) and have little variation (not more than 15%).
- PMT signals with LED on should be at least 10% higher than the PMT dark signal.
- Time series plots of temperature, relative humidity, and pressure should be compared to that of the dark reference sensor measurements. Dark reference measurements should not show a similar signal/pattern to ambient conditions.
- Check that there is variation in the scatter measurements; scatter should not remain at a given number with no variation for more than a few minutes. Lack of sensitivity in scattering is indicative of a larger issue with the nephelometer and requires immediate investigation by the site manager.

This SOP corresponds to data version 1.1 of the Nephelometer data.

4.0 NEPHELOMETER CALIBRATION

Nephelometer calibration is fundamental to obtaining accurate scatter data. Whenever a calibration is performed, it is compared to the previous calibration conducted at Dalhousie University to evaluate the validity of the recently performed calibration. Calibrations can be performed at the sampling site as well as at the Central Lab at Dalhousie University.

4.1 Calibration Equipment

There is a minimal amount of equipment required for the calibration of a nephelometer, whether on-site or at the central SPARTAN Lab at Dalhousie University. The following two gases (> 99% purity) are required for every nephelometer calibration:

- N_2 or clean air (Clean Air Reference system can be used as clean air source)
- CO_2

Additional equipment required:

- Regulator for gas cylinders
- Clean plastic tubing with in-line HEPA filter (for CO_2)
- Inlet for gases to run into nephelometer, such as a copper tube with diameter of XX (same as black tube used for CR system
- AirPhoton program for determining calibration configuration variables (NephCal1.1.htm)

4.2 Calibration Frequency

Nephelometers sample continuously, making them prone to accumulation of dirt inside the nephelometer tube where scatter measurements are made. When possible, on-site calibrations are performed to maintain and assess the condition of the nephelometer and correct for accumulation of dirt inside the nephelometer, even when a clean air reference system (CR) is installed at the site. However, over time the amassing of dirt inside the nephelometer will be too much for on-site calibrations and the nephelometer will require detailed maintenance, cleaning, and calibration at the SPARTAN Central Lab at Dalhousie University. The ability to conduct on-site calibrations are an ideality, many SPARTAN sites do not have easy access to the gases required for calibration of the nephelometer. In the case that a site does have a clean air reference system and easy access to CO_2 (and N_2 if no clean air reference system), then on-site calibrations will be conducted.

Determining the frequency of on-site and central lab calibrations is an ongoing process. It is the responsibility of the site manager to continually assess the need for calibration during performance checks. There are various metrics that are used to determine the frequency of nephelometer recalibration but generally,

- On-site calibrations are recommended when the baseline drift reaches 15 % of the average total green scatter ($< B_{sp,532} >$) at the site.

- When on-site calibrations are not possible, detailed cleaning and calibration are required when the baseline drift reaches 30 % of $< B_{sp,532} >$ at the site.
- If on-site calibrations are possible, detailed cleaning and recalibration will be conducted after 2 on-site calibrations have been performed. Therefore, three consecutive on-site recalibrations should not be performed, rather when the third is due the nephelometer will be returned to the SPARTAN Central Lab.

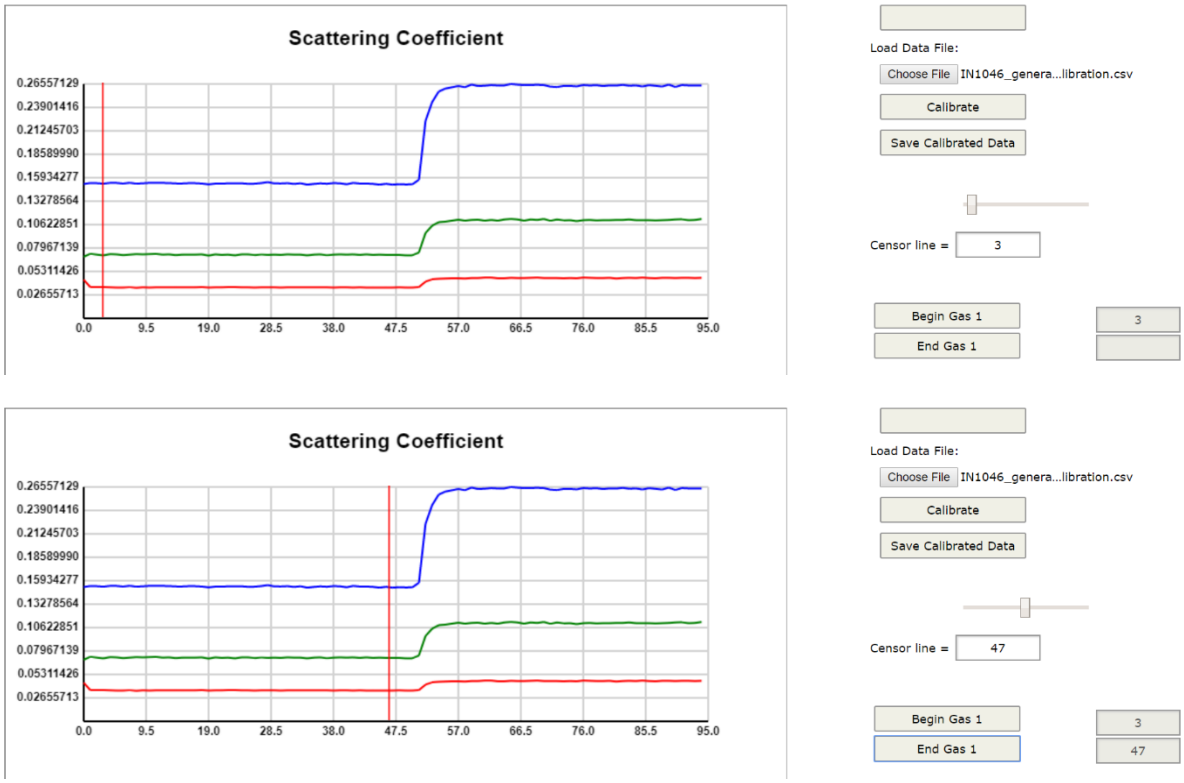
Every SPARTAN site operates with a clean air reference system that is programmed to perform a clean air reference (for baseline drift correction) once every 24 hours. Therefore, the correction values calculated from clean air reference periods are used to determine the magnitude of baseline drift. For sites where the clean air reference is not automatically applied to the scatter measurements the baseline drift can also be determined by inspection of the baseline in the $B_{sp,532}$ time series.

4.3 Calibration Procedure

Whether a calibration is conducted on-site or at the central SPARTAN lab at Dalhousie University, the procedure is the same with the exception of sections ***in bold italic font*** as a few extra steps are required for on-site calibrations. The steps to be taken are as follows:

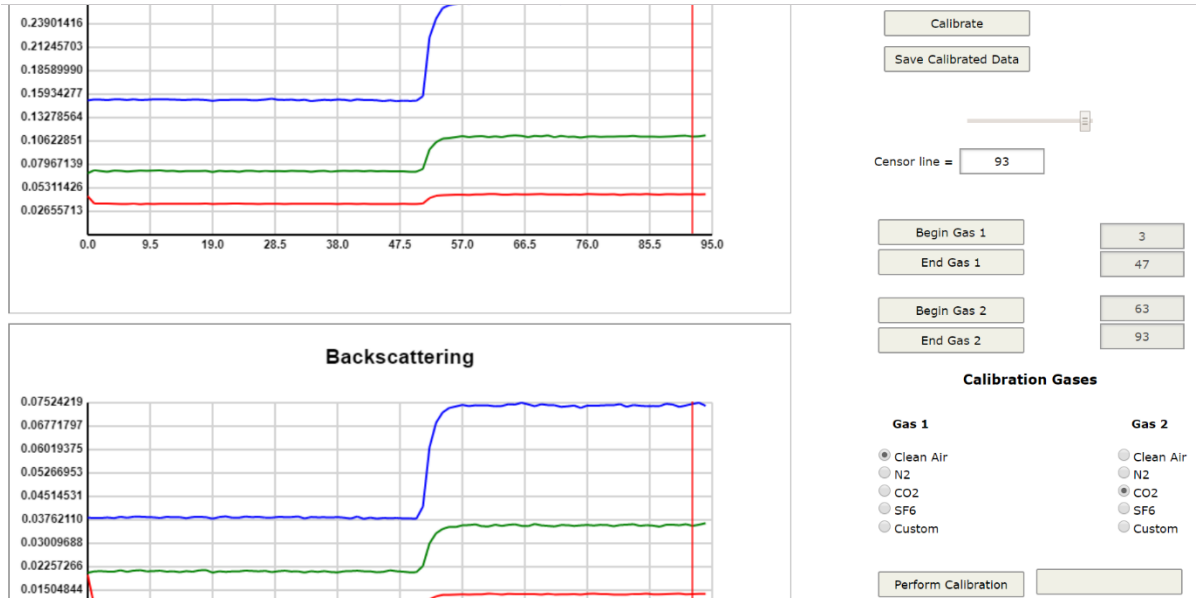
- Remove the cyclone inlet, metal plate and inlet tube from the nephelometer. Seal the hole where the inlet tube connects to the nephelometer with a red stopper.
- Turn off the nephelometer and transfer any data on the nephelometer memory card to a computer ***for transfer to the Site Manager***.
- Be sure that the nephelometer fan is OFF. This can be done by creating a configuration file (config.txt) which contains the following command “fan=0”.
- Reinsert the memory card in the nephelometer
- Turn nephelometer ON and listen for the sound of the fan. The fan SHOULD NOT turn on during a calibration.
- Turn CR system ON in MANUAL mode and let run for 10 minutes
- Turn off CR system but leave the nephelometer ON; the scatter from the clean air and CO_2 need to be in the same file for processing.
- Open CO_2 cylinder and test flow, CO_2 should be flowing just strong enough to feel on your hand.
- Disconnect the clean air reference tube from the nephelometer, then connect CO_2 to nephelometer and let run for 10 minutes
- Turn OFF nephelometer
- Remove nephelometer memory card and transfer file with CR and CO_2 data to computer.
- Scatter from N_2, or clean air, and CO_2 are compared to the scatter values from the previous calibration to guarantee consistency. ***On-site exception: the site operator will send the data file to the site manager to assessment.***
    - Open NephCal1.1.htm and load in data file
    - `Click calibrate`

- For both gas one and gas two, the goal is to use the longest possible section of the 10 minutes of data collected that is flat for the calibration. Values will be selected by placing the censor line, then selecting this value for beginning and end of particular gases.
- Type in value for censor line when data begins to flatten for first gas. Press Begin Gas1. Type in value for censor line before gases are changed(inversion point in plot)selecting a point as far from Begin gas 1 value as possible. Click End gas 1.



- Repeat on the other section of data for gas 2.

- Select gases used for calibration under Calibration Gases in order they were used.



- Click perform calibration.

  - Get configuration numbers from NephCal program and transfer to config.txt file. ***On-site exception: site manager will send the new config.txt file to the site operator.***

- Set CR values to zero in the config.txt file by copying the following lines into the config.txt file below the new calibration values. A fan=1 command was added to turn the nephelometer fan back on.

```
fcrroffset=0
fcrgoffset=0
fcrboffset=0
bcrroffset=0
bcrgoffset=0
bcrboffset=0
fan=1
```

- Insert the memory card back into the nephelometer.
- Turn the nephelometer ON and wait 10 seconds for the nephelometer to set the new calibration values
- Turn the nephelometer OFF and remove the memory card to confirm that the config.txt file is no longer on the card.
- Create a new config.txt file to dump the configuration information on the nephelometer
  - In a blank config.txt file use the following command: DUMP=1. ***On-site exception: site manager will send this config.txt file to the site operator.***
- Save the new config.txt file to the memory card and reinsert in the nephelometer.
- Turn the nephelometer ON and wait 10 seconds for the nephelometer to take the new config.txt file
- Turn the nephelometer OFF and remove the memory card to copy the resulting DUMP.txt file on the memory card to your local device for saving in the SPARTAN nephelometer database
- Return the nephelometer to normal operation
  - Reconnect the nephelometer inlet tube and, if applicable, clean air reference system.
  - Turn the nephelometer ON and the clean air reference system to AUTO to resume normal operation. Make sure you can hear the sound of the fan running following the initial clean air reference cycle (upon start up).

4.4 Cleaning the Nephelometer Tube

Upon receiving the nephelometer from the sampling site, a physical condition check of the outer nephelometer body needs to be conducted and all information recorded. After external physical check is finished the cleaning of the nephelometer tube is to be completed. This requires removing the nephelometer tube from the body. Supplies required for removing the tube from the body and cleaning the nephelometer tube are:

- Clean cloth
- Lint-free tissue wipes (e.g. Kim-wipes)
- Methanol
- Water
- Hex-keys
- Screwdriver
- Wrench
- Compressed air

After cleaning of the nephelometer tube is complete, any remaining dust or lint needs is removed using compressed air. Following successful cleaning of the nephelometer tube, the nephelometer is reassembled and calibrated following the procedure outlined in section 4.3. The new calibration values are compared against the last calibration conducted at the Central SPARTAN Lab to ensure a good cleaning and calibration before redeployment of the nephelometer.