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Section 5 : Nephelometer data processing

General summary: Here we outline some basic shipping information, nephelometer specs, and converting raw data to condensed .csv file outputs. A short section on a novel inlet shows a possible solution to curtail the cleaning frequency. Maintenance details include cleaning the nephelometer while Section 5b and 5c (via AirPhoton) explain nephelometer configuration and calibration procedures, respectively.

Delivering the nephelometer to sampling site:

Because of the high volume of air sampled monthly (~ 140 m^3), nephelometers cavities are prone to becoming dirty or rusted. We estimate nephelometer will require detailed maintenance every ~12 months. For site address deliveries, please refer to Appendix B.

If the nephelometer needs to be returned to Halifax, we provide the following shipping address

[Your Name, e.g. Graydon Snider]
6310 Coburg Rd. room 218
Dalhousie University
Department of Physics and Atmospheric Science
Sir James Dunn bldg.
Halifax, NS
B3H 4R2
Phone: 902-494-1820

The cost of shipping is between $250 and 500 CAD and one week to ship (save for a customs-related delay).

Background details on nephelometer and recorded data

Raw neph data contains the following information: Unit#, Date/Time,Temp ,Pressure, RH%, PMT DARK, Back scatt Red, Back scatt Green, Back scatt Blue , Total scatt Red, Total scatt Green, Total scatt Blue, Fan RPM

Air enters the inlet of nephelometer passing through a bug screen (wire mesh diameter ~1mm). Flow rate into the neph is 3.4 lpm, and neph volume is approximately 40cm x 8cm x 8cm = 2.5 litres, therefore air lifetime is < 1 min. Data is recorded every 15 seconds (approx.), and files tend to be about 10 MB per week of continuous data. We encourage site operators to run nephelometers continuously unless strong reason not to (even dust events are acceptable). LED wavelengths are 632 nm, 532 nm, 450 nm for red, green, and blue, respectively.

Nephelometer scatter (Back scatt Red, Back scatt Green, Back scatt Blue , Total scatt Red, Total scatt Green, Total scatt Blue) is reported in Mm^{-1}. Minimum baseline values for dry nitrogen are around 4, 8, 16, 11, 18, 28 Mm^{-1}, respectively, for the six scatter measurements. Maximum scatter before saturation and/or nonlinear effects occur is near 1300 Mm^{-1} for green.

Data files are sent by site operators via email or share Dropbox/Google drive folder.

Processing raw nephelometer data

Save raw neph files e.g. **IN210014.csv** neph into Stetson folders

Data1/gsnider/SPARTAN/neph_condensing/[Site name_Code]/Neph/[Neph files]

On Stetson, run the following Matlab program:

Data1/gsnider/SPARTAN/neph_condensing/reading_neph_files.m

Inputs parameters:

foldername=[appropriate site folder, e.g. Beijing_CHTS]';
Neph_Num=24; %neph # used at that site
toffset=0; %<=== used for older nephs (.TXT files) that obey UTC time, otherwise zero

MinNeph=105; %first file to scan
MaxNeph=106; %last file to scan

Program screens out RH values less than 0 and greater than 80%. Also removes scatter values below 0 and > 1300 Mm^{-1}.

Output parameters:

Output Neph data is saved into three files
1) Mean hourly neph data
2) Mean daily neph
3) Mean daily, satellite-only hours

In each of these files, new columns include

1) Green scatter at 550nm
2) Volume growth factor f(RH)
3) Dry scatter at 550nm
4) Angstrom exponent
5) Backscatter-to-total scatter ratio BR_632, BR_532, and BR_450

On Stetson, the files are saved as:

Data1/gsnider/SPARTAN/neph_condensing/[Site name_Code]/Neph/[Neph output file names]

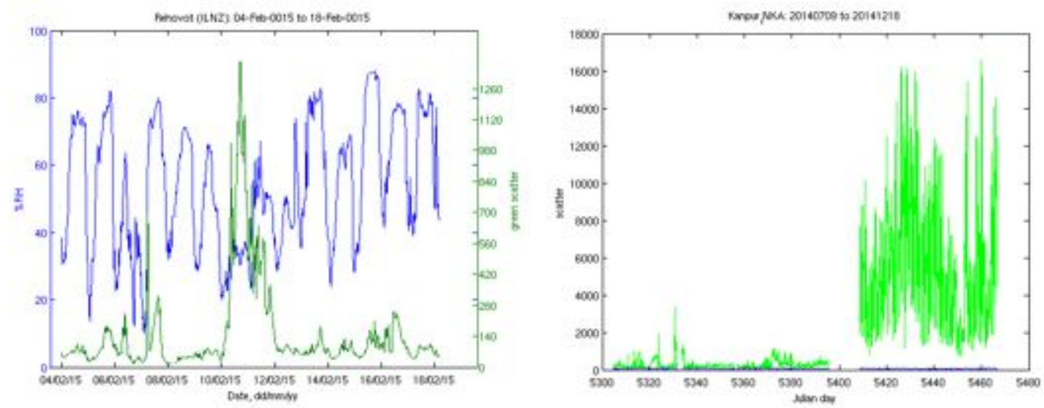


Figure 1: Two sample files, one successful, one not (saturated signal due to too much dirt).

Where **[Neph output file names] =**
Neph#_startdate_enddate_[site code]_hourly.csv
Neph#_startdate_enddate_[site code]_Daily.csv
Neph#_startdate_enddate_[site code]_Daily_sat.csv

These files are then later used in conjunction with AERONET AOD data (**section 4**) and processed $PM_{2.5}$ data (**section 3**).

Cleaning the nephelometer

Figure 2: View inside nephelometer. Top: excess aerosol deposited, Bottom left: pollen visible, Bottom right: Dead insects

Broadly speaking, there are four types of interference of the signal.

1. Insects
2. Pollen
3. Water damage
4. Excessive aerosol loading

Example case when there was pollen in the neph:

Whether the nephelometer contains significant amounts of pollen, soil, or insects the result it usually the same: a very high background signal of total scatter (red, green and blue all continuously above 1000 Mm^{-1}). The backscattering is less sensitive to this issue but still might raised by some factor. The first option is to clean the instrument and later recalibrate. Only with water contamination do we potentially see more dire results, such as a shorting of the signal, possibly causing permanent damage.

With enough time, any nephelometer will suffer some degree of contamination, therefore It is important for SPARTAN personnel to learn how to maintenance required for any nephelometer.

Note: We are considering installing filters with 140-micron mesh ahead of the nephelometer to screen out very large debris, pollen, and insects.

Here are a few questions to consider:

1- Was the instrument run with an inlet or bug screen? It only takes a single piece of debris or insect inside the chamber to cause additional stray light.

2- Look for any indication of large debris close to the inlet of the nephelometer like grass, spider webs, bugs, etc. Remove the fan and check if there are plant debris or any other sign of contamination there.

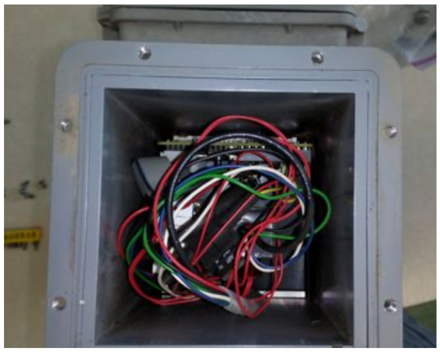
3- There is a remote possibility that the lens in front of the detector got loose (this happened during shipment to Kanpur, India). You can easily check this by gently moving the nephelometer around and listening for any rattling components inside.

How to clean a nephelometer

You will need
1. Kimwipes
2. Methanol
3. Water
4. Hex keys, set of screwdrivers (Phillips and Robertson), and wrench

Turn off the sampler. Unplug the fan, and remove the four screws it is attached to. Clean the fan separately by scraping of all excess debris and wiping with a damp Kimwipe.


Next, using a wrench, remove the brass-colored bolt between the inlet and the fan exit port. Unscrew the four side screws with a Phillips head. Be careful not to lose the four rubber orings around the threads. Finally, with a hex key, remove the 8 screws covering the top and bottom of neph.


The base of the neph has only a black sheet of metal under the exterior plate. The top is full of wiring. Pushing the base of the neph, sliding out the wiring half of body first.


Disconnect the cable ribbon as seen above left before sliding the body out more than a few inches. Once the ribbon is disconnected, the body should slide very easily. Remove the silver-colored sheet metal plate off held by two screws, and you now have access to the nephelometer light-scattering cavity. In this instance the insides are quite dirty. All surfaces must be wiped carefully with Kimwipes lightly dabbed in water or methanol.

Clean the inside of the optical bench with a small vacuum cleaner and/or by blowing clean air over the dirty components. Be careful because some of the baffles are very sensitive.

Once cleaned the surface will be a dull black, without much brown coloring visible.

Once all signs of debris are removed, re-assemble the instrument (as it had been before opening). Then run N_2 (or clean air) and CO_2 for 30 min apiece.

Prevention of dust entering sampler:

NB 1: Ideally there should be no size cut to the instrument, however this remains a small point of discussion/debate.

NB 2: Pantyhose is too water absorbent, so we have scrapped this option

NB 3: We are currently experimenting with Teflon-coated mesh wire from www.twpinc.com/. See below for details.

Nephelometer Humidity Wetting Test

Graydon Snider
March 30th, 2015

Goal: To determine whether a wicking fabric will retain too much water in headspace between Teflon-coated wire mesh and copper inlet. The face of Teflon inlet is 2.7" and is positioned facedown when added to AirPhoton IN100 nephelometer (very much in the shape of a shower head).

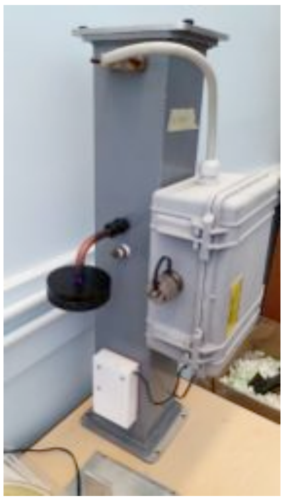


Figure 1: Inlet screen (facing down) installed on nephelometer

Background: Flow of $PM_{2.5}$ and PM_{10} will not be impeded by placing a Teflon wire screen in front of nephelometer inlet (pore diameter 140 or 40 microns). Undesired airborne items such as insects, large water droplets, pollen, and other large debris are prevented from entering the neph. We anticipate the Teflon mesh is either replaceable or easy to clean. A test using a graphite pencil shows little to no adhesion of the graphite flakes to the surface.

Challenge: Water may get trapped inside the faceplate during heavy rainfall. Teflon mesh is water repellant but not waterproof. Water, once inside, may persist.

Figure 2: Inlet screen with water beading on surface. Water passes through pores once surface tension is broken (sufficient buildup).

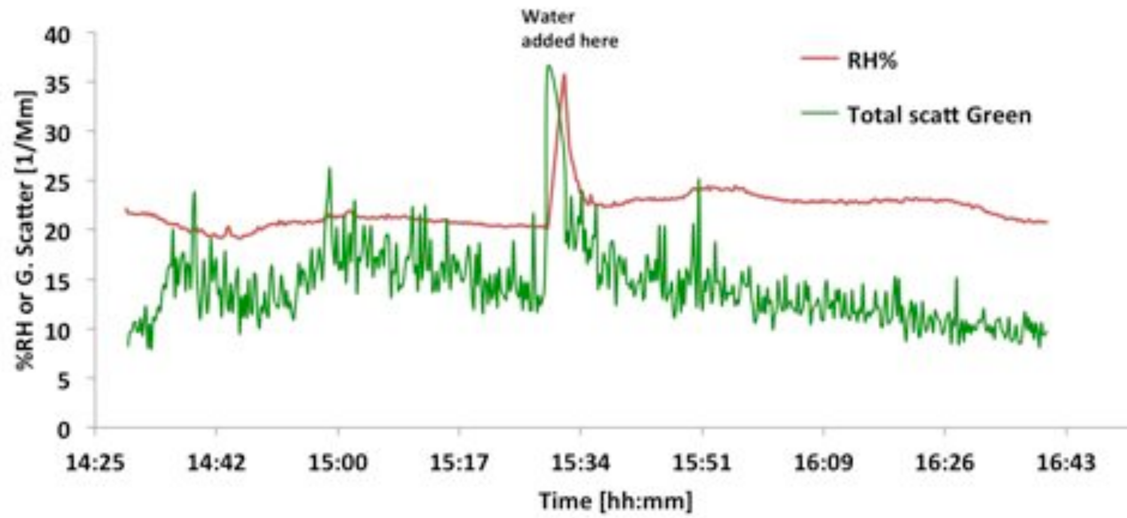
Solution: Add a wicking material around inside inlet perimeter to draw out water from headspace. A circular piece was cut to the same diameter as the ring. Fabric used for this test came from a 'quick dry' polyester running t-shirt. Water is removed gravitationally downwards and outwards. Two indents are cut around edge of Teflon screen and two additional pieces of fabric are wrapped around to exterior of faceplate. It is clear large quantities of water (beyond what is expected in downpour rainfall) will pass through fabric mesh in < 60 seconds. Fabric ring stays wet but away from center air stream.

Figure 3: Frontside view with fabric wick exits visible (left) and inside view with cap face removed (right).

Test: We are concerned with the water left behind after a rainstorm. Hence we ran the nephelometer for 60 min without inlet cover, then added cover after it had been drenched with water.

Figure 4: Wetting the filter as much as possible. Water was added from splashing upwards and from deliberately adding water inside.

Results: A two-hour test showed an initial spike in %RH (from RH = 20% to 35%), then a fast decrease to 22% thereafter. Excluding the RH spike at 15:32, the mean RH before the inlet was place was 20.7 ± 0.6, and after 22.8 ± 0.8. The RH decreased to its original value at 16:38, 66 minutes after the original "wet" event.



Concluding remarks: The facedown Teflon screen is water resistant and prevents undesired particulates, insects, and excess moisture from entering nephelometer. Inlet holes are 42 or 140 microns in size, so there is no impedance of flow or of breathable fraction of aerosols. The wick appears effective in preventing water buildup in Teflon filter head. It may cause a small RH increase for about an hour. The wick is a synthetic, UV resistant material hence should have a long lifetime.

It is unknown whether wicking fabric will attract mold over long periods of outdoor use. Also unknown is how clogged the Teflon screen will become. Surface area is 36 cm^2 so should take some time to clog. Teflon scree is also very dirt repellant and we expect readily cleanable by a small brush. Since the design is low cost (< $50) it is easily replaceable. We will provide spare screens to given sites in case eventual clogging occurs.

This new inlet design has the potential of extending instrument lifetime without significant changes to its response to PM_{10} or $PM_{2.5}$