Perspectives on SPARTAN from Rehovot, Israel: Insights about the Nephelometer

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Our station

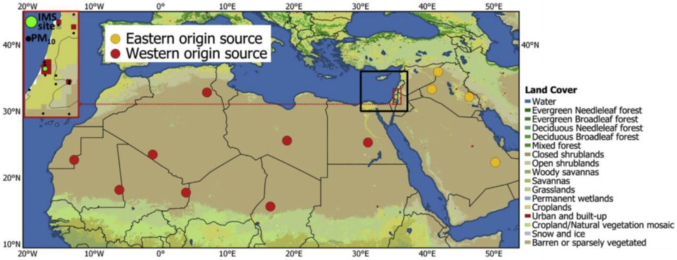
Location of Sussman building on campus

Location of the Rehovot SPARTAN station (ILNZ)

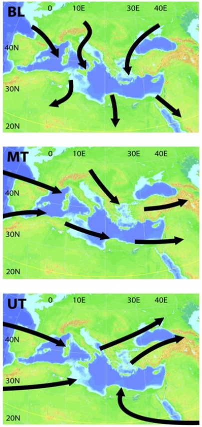
The mediterranean as a global pollution crossroads

Aerosols in Israel

Israel's coarse mode aerosol composition is heavily affected by dust from nearby, and far away arid lands, and also by sea aerosols from the Mediterranean.



Regional dust sources



Air mass trajectories[1]

[1] Lelilveld, Science 2002

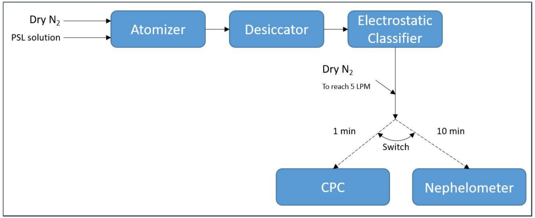
Air photon nephelometer

- The AirPhoton (AP) **Integrating Nephelometer** (Neph), model IN-102, is a workhorse of the SPARTAN program.
- It measures **particulate matter** (PM) **optical scattering** in 3 wavelengths: 450, 532 and 628 nm.
- By using a fan with variable speeds and a cyclone, it has **interchangeable cutoffs** of $PM_{2.5}$ and PM_{10}.

Nephelometer, AirPhoton IN-102

Calibration with PSL

- If difficulties arise while calibrating with the standard operating procedure (SOP), one can calibrate the AP neph by using non-absorbing **Polystyrene Latex** (PSL) spheres.
- Calibrate by exposing the nephelometer to known concentrations of PSL spheres of set diameter and refractive index (RI) and compare to the theoretical Mie scattering.

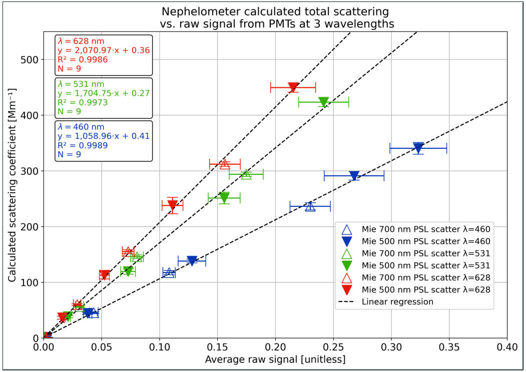


Nephelometer PSL calibration experiment scheme

Calibration with PSL

- A successful calibration will have different diameters PSL converging on a linear curve.
- Use the raw data from the Neph's photomultipliers (PMT) to calculate the raw signal with the equation[1]:

$$\text{Signal}^{\text{reported}} = \frac{PMT - PMT_{\text{Dark}}}{Ref - Ref_{\text{Dark}}} \text{ [unitless]}$$



[1] *PMT* – is the photomultiplier value for a certain channel, e.g., "green – backscattering", "blue – total scattering", etc.
$PMTD_{\text{Dark}}$ – is the PMT channel's corresponding reference.
PMT_{Ref} – is a reference clean air PMT
Ref_{Dark} – is the corresponding dark clean air reference PMT

Truncation error

- All nephelometers suffer from non-idealities. Due to the large aperture, the IN-102 measure only scattering angles between 7° and 172° instead of 0° and 180°. This is called **truncation error**.
- Not to be confused with truncation error in computer science.
- Effect on scattering readings can vary between **5–30%**.
- Common practice suggests adding a flat 7% truncation error correction.
- **Dusty locations** (like Israel) with larger size PM are more prone to be affected.

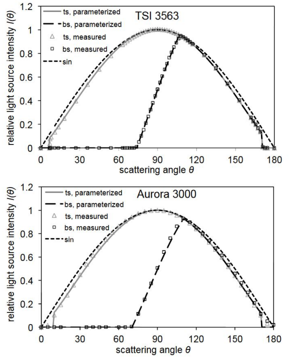
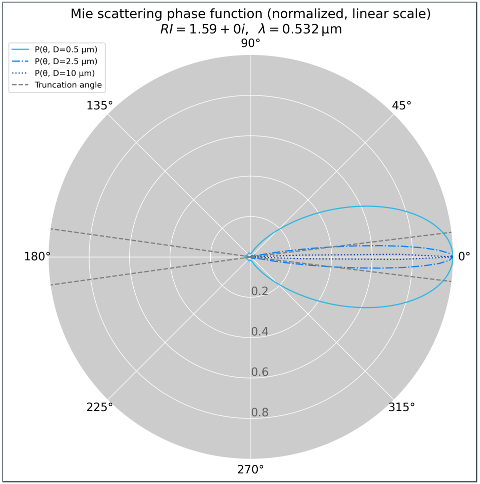


Fig. 3. Measured and parameterized angular intensity functions, $f(\theta)$, including forward and backward truncation for the TSI 3563 (upper panel, data are taken from Anderson et al., 1996) and Aurora 3000 (lower panel). For the Aurora 3000 the average of all three wavelengths is shown. For comparison purposes, the total scattering illumination function (ts) has been normalized to unity at 90° scattering angle. The backward scattering illumination function (bs) was adjusted to match the total scattering function at 110°.

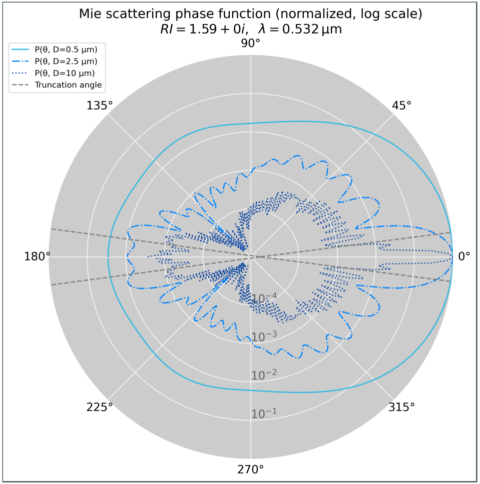
From: Müller, T *et al.* 2011 https://doi.org/10.5194/amt-4-1291-2011.

Truncation error – polar plots



Non-truncated angle ranges for the AP IN-102 are 7°–172° (and 92°–172° for backscattering).

Truncation error – polar plots



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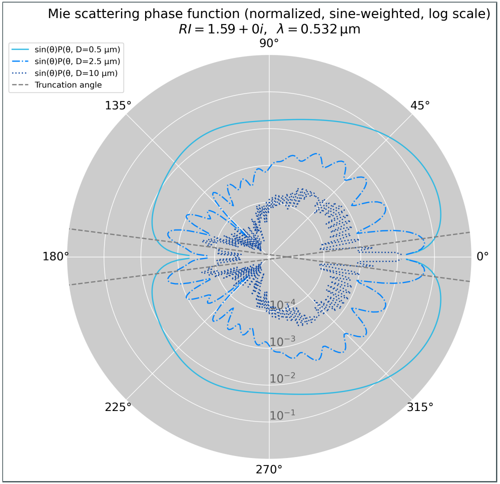

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Truncation error correction by Ångström exponents

- A scheme for the estimation of truncation error for two nephelometers (TSI 3563 and Aurora 3000) was proposed by Anderson and Ogren (1998) and reapplied by Müller *et al.* (2011).
- The scheme involves calculation of the factor through **scattering ångström exponents** (SAE). The Ångström exponent correlates scattering (or extinction, absorption) to wavelength.
- For the Neph, an example calculation of the SAE of the green (532 nm) wavelength:

$$SAE_{ts,\ \mathrm{Green}} = -\frac{\log\left(\frac{\alpha_{ts,\ \mathrm{Blue}}}{\alpha_{ts,\ \mathrm{Red}}}\right)}{\log\left(\frac{\lambda_{ts,\ \mathrm{Blue}}}{\lambda_{ts,\ \mathrm{Red}}}\right)}$$

Where,
$SAE_{ts,\ \mathrm{Green}}$ is the SAE for total scattering of the green wavelength, and is unitless.
$\alpha_{ts,\ \mathrm{Blue}}$ is the light total scattering coefficient of the blue wavelength in inverse megameters (Mm^{-1})
$\lambda_{ts,\ \mathrm{Red}}$ is the red wavelength in nanometers.

Truncation error correction by Ångström exponents

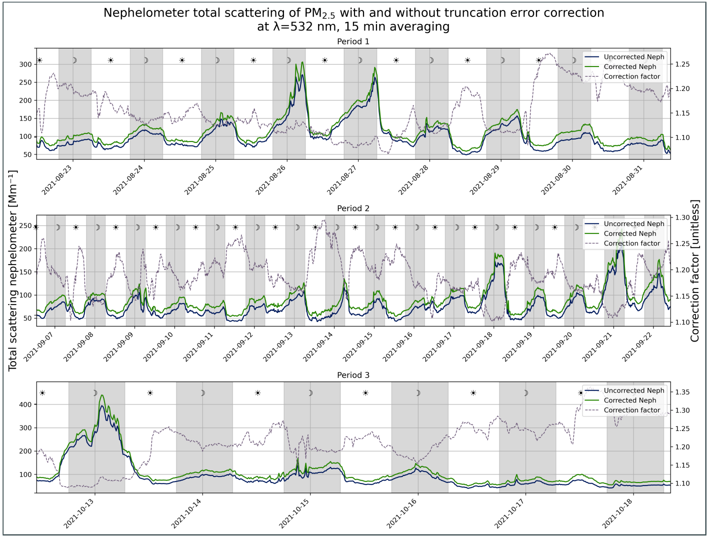
- The SAE is then plugged into the equation: $C_{ts} = a + b \cdot SAE_{ts}$
  Where a and b taken from the table[1]:

	wavelength	B		G		R	
	Ångström exponents	α^*_{ts}(B/G)		α^*_{ts}(B/R)		α^*_{ts}(G/R)	
	parameters	*a*	*b*	*a*	*b*	*a*	*b*
TSI 3563	no cut	1.345	−0.146	1.319	−0.129	1.279	−0.105
	sub-µm	1.148	−0.041	1.137	−0.040	1.109	−0.033
Aurora 3000	no cut	1.455	−0.189	1.434	−0.176	1.403	−0.156
	sub-µm	1.213	−0.060	1.207	−0.061	1.176	−0.053

- AirPhoton recommends applying the same parameters as proposed for the Aurora 3000.
- This method does not apply to backscattering.
- As of today, there is no published truncation correction scheme made specifically for the AirPhoton nephelometer.

[1] Müller T *et al.*, 2011

Truncation correction ambient example



Take home message

The AP Neph is a capable instrument for measuring PM scattering:

- An advantage of the Neph is its multi-wavelength measurement capabilities that allow for SAE calculations.
- The Neph also has a wide aperture, allowing for minimal truncation losses.

However,

- If the standard calibration is insufficient, users may look for other methods, such as with PSL.
- Care should be taken when applying truncation correction to the data. Stations that are exposed to bigger PM may be more vulnerable to this effect.
- An ad-hoc truncation correction scheme should be developed for the SPARTAN's network use of the AP Neph.

In addition:

- Adhere to the AP's recommendation to install a small roof over your station, otherwise, the Neph and sampling station may get water penetration and damaged.

Thank you for listening!

I would like to thank, in particular:

- From WIS: Ofir Shoshanim and Yinon Rudich.
- From Spartan: Brenna Walsh, Chris Oxford and Randall Martin.
- From AirPhoton: Rich Kleidman and J. Martins Vanderlei.

Nephelometer, filter station and meteorological station in Rehovot

References

Anderson, Theodore L., and John A. Ogren. "Determining Aerosol Radiative Properties Using the TSI 3563 Integrating Nephelometer." Aerosol Science and Technology 29, no. 1 (January 1998): 57–69. https://doi.org/10.1080/02786829808965551.

Müller, T., M. Laborde, G. Kassell, and A. Wiedensohler. "Design and Performance of a Three-Wavelength LED-Based Total Scatter and Backscatter Integrating Nephelometer." Atmospheric Measurement Techniques 4, no. 6 (June 29, 2011): 1291–1303. https://doi.org/10.5194/amt-4-1291-2011.