Co-Location Laser Egg in Shanghai

Results from data analysis
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During November 2016 four Laser Eggs were co-located with a TEOM at the Shanghai Qingpu Environmental monitoring station. During the co-location, data from the Laser Eggs and the TEOM were collected. This document summarizes the results from the data analysis.

1. Background information

The measurement principle of the Laser Egg is laser based Mie scattering. A laser with 650 nm wavelength is used. Particles are pulled into the sensor by a fan, where they pass the laser beam. The scattered light is detected by a photodiode placed in a 90° angle to the beam. The peaks of the diffracted light are used to count the particles. By analyzing the intensity of the scattered light, the particles' size and mass is estimated.
The intensity of the scattering is influenced by various properties like shape and composition of the particle. Furthermore, the density of the particle needs to be known in order to correctly estimate the particle's mass. These characteristics can vary depending on the measured aerosol. By temporal and spatial specific calibration these effects can be taken in account and accurate mass concentrations can be performed.

At high relative humidities, particles experience hygroscopic growth. If not controlled, optical sensors will overestimate the particles mass, as the particle diameter of a hygroscopic grown particle is bigger than the diameter of a dry particle. This has been discussed in literature before (Lundgren et al., 1969, Chakrabarti et al., 2004, Day et al., 2004). In order to be able to perform reliable and accurate measurements in environments with increased humidities, it is required to either have a heated inlet which reduces relative humidity or correct the data for the humidity effect.

2. Set-up

Four Laser Eggs were co-located next to a TEOM at the Shanghai Qingpu Environmental Monitoring Station. Following the co-located Laser Eggs:

- "Bumblebee" (8CA9)
- "Megatron" (824B)
- "Defensor" (3C72)
- "Humidity sensor" (167E)

One Laser Egg was equipped with a humidity and temperature sensor ("Humidity sensor"). Plastic bins with holes were used as a simple weather protection (wind and rain) and the Laser Eggs were slightly elevated using plastic boxes (see Figure 1).

Figure 1: Weather protection for the Laser Egg.

Figure 2 shows the set-up in Shanghai at the Qingpu Environmental Monitoring Station next to the TEOM. The Laser Eggs were connected to Wi-Fi using a 4G hotspot.

Figure 2: Co-location set-up at the Qingpu Environmental Monitoring Station.

The Laser Eggs were co-located for over a month, beginning from the 25th of October. There are some data gaps, as the 4G hotspot sometimes broke down. The data was analyzed using the statistical software R.

3. Results and Discussion

Figure 3 shows the course of the raw Laser Egg PM2.5 mass concentration and the TEOM PM2.5 mass concentration. They all follow the same trend, but some deviations can be observed.

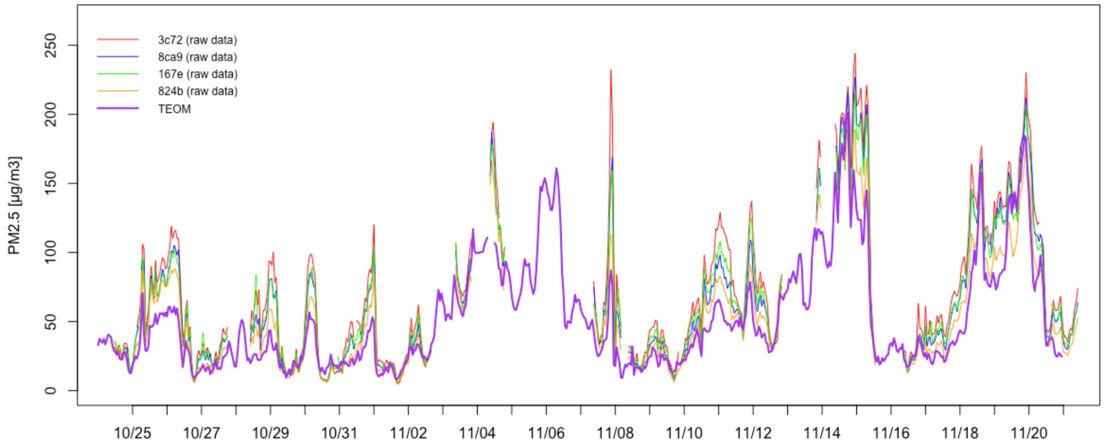

Figure 3: Time series of the raw Laser Egg PM2.5 mass concentration and the TEOM PM2.5 mass concentration.

Figure 4 shows the correlation between the raw PM2.5 mass concentration of the four co-located Laser Eggs and the TEOM monitor. R^2-values range from 0.86 to 0.92. A difference in slope can be observed between the devices, which we believe is the result of using devices that were not new, but had already been through a significant amount of testing in extreme environments. Should this co-location test be performed again, we would use brand new Laser Eggs to ensure the same slope between devices.

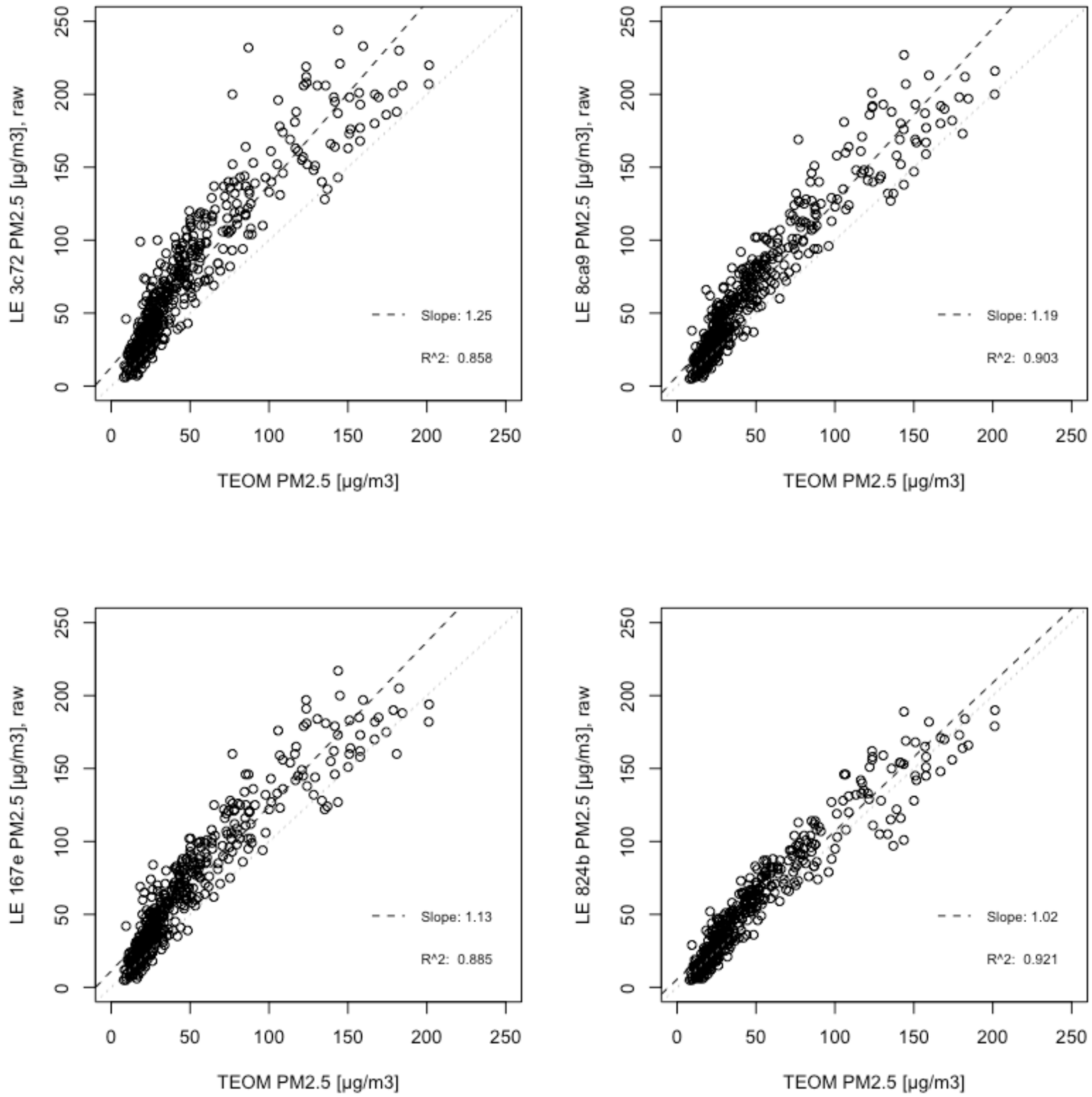

Figure 4: Linear correlation between the raw Laser Egg PM2.5 mass concentration and TEOM PM2.5 mass concentration.

The effect of relative humidity on the raw readings from the Laser Egg can be seen in Figure 5. The ratio of the raw PM2.5 mass concentration to the TEOM mass concentration is plotted against the relative humidity inside the Laser Egg. Due to heat release of different components in the Laser Egg (screen, laser sensor, electronics), the temperature inside the Laser Egg is [illegible] outside. This leads to a reduction of the relative humidity inside the Laser Egg compared to the ambient relative humidity. The dotted lines represent the model used in Chakrabarti et al.,2004.

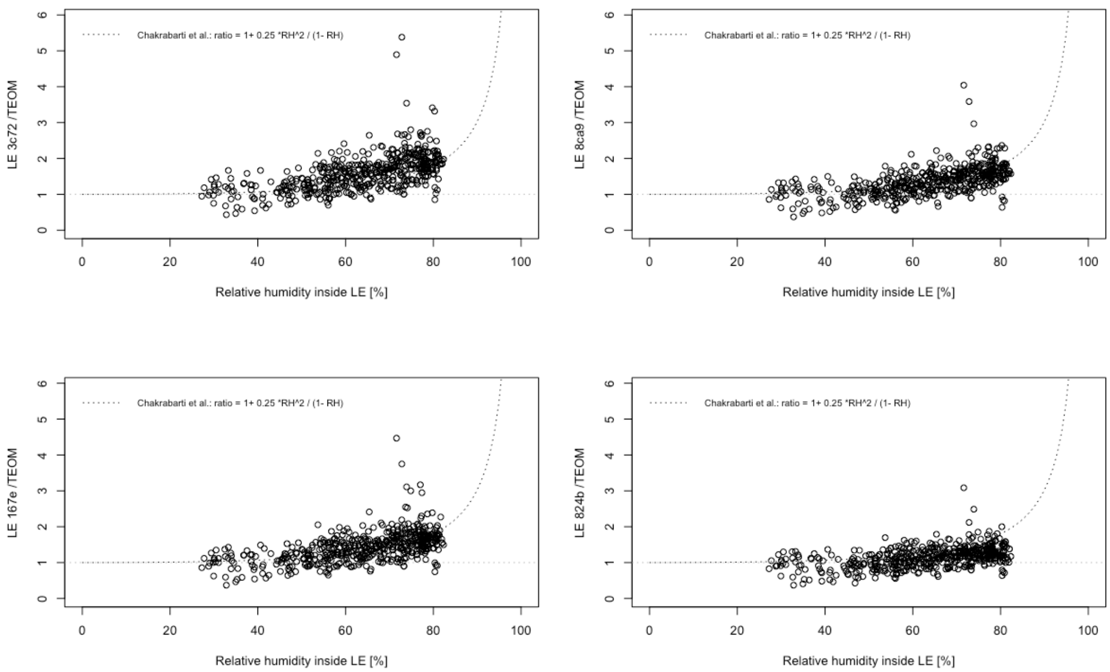

Figure 5: LE to TEOM ratio in dependence of relative humidity inside the LE.

The raw data from the Laser Egg was corrected for the effect of relative humidity using a [redacted] In order to take in account for the different optical properties of the aerosol present in Shanghai, the data was calibrated using a Shanghai specific calibration function. Figure 6 shows the course of PM2.5 concentration, corrected for RH effects and calibrated. The Laser Egg's measurement and the TEOM's measurement correspond well.

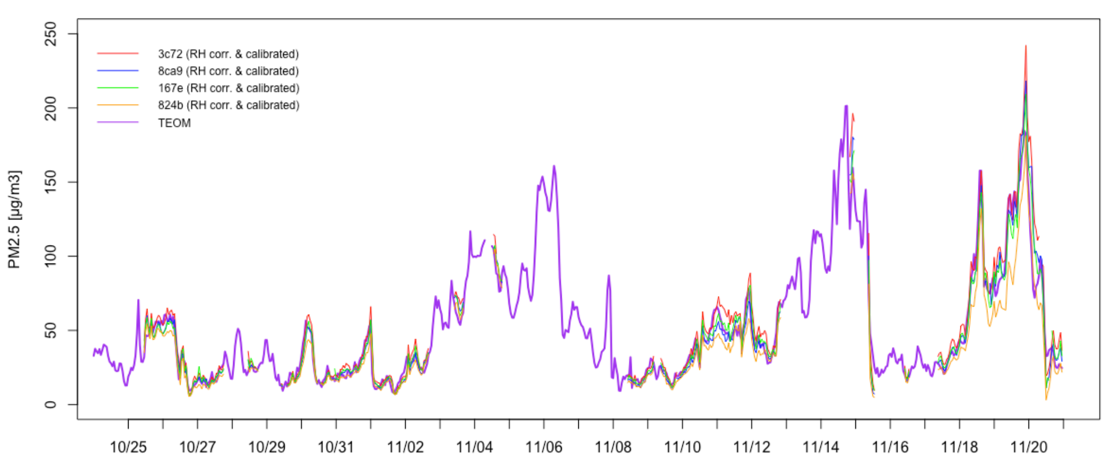

Figure 6: Time series of the RH corrected and calibrated Laser Egg PM2.5 mass concentration and the TEOM PM2.5 mass concentration.

In Figure 7 the correlation between the TEOM PM2.5 mass concentration and the Laser Egg PM2.5 mass concentration (RH corrected and calibrated) is shown. The R^2 values vary from 0.924 to 0.946. A substantial increase of the R^2 coefficient was be achieved by correcting the data for RH and calibration. The slopes still vary, as the same calibration was applied for all the devices. As discussed before, we believe this results from using Laser Eggs which have been used in extreme testing conditions before.

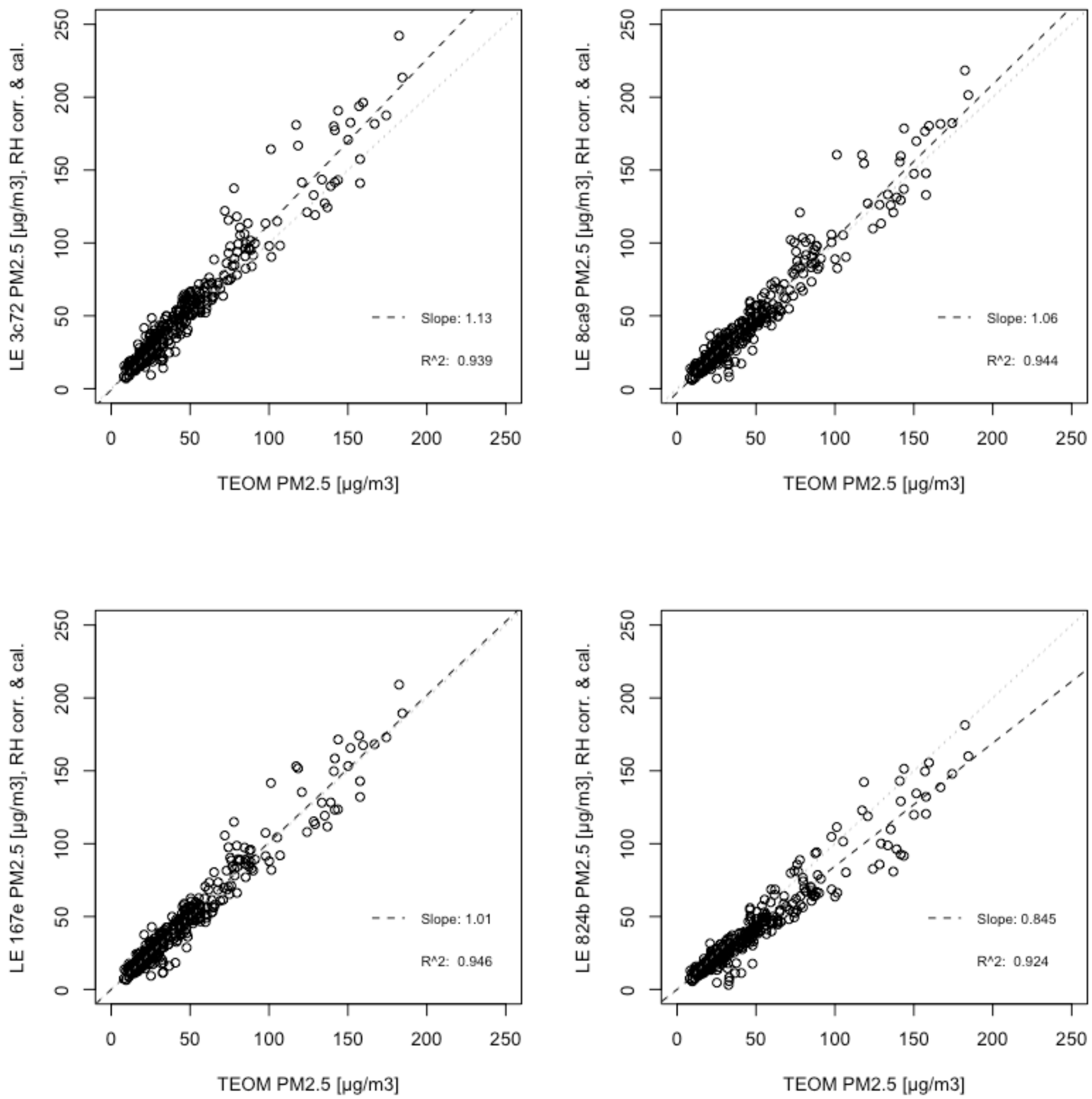

Figure 7: Linear correlation between the RH corrected and calibrated Laser Egg PM2.5 mass concentration and TEOM PM2.5 mass concentration.

References

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