Audit report for the GAW station Bukit Koto Tabang, Indonesia

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Summary: From July 4 to 6, 2008 Alfred Wiedensohler and Thomas Tuch performed a site audit of physical aerosol measurements at the global GAW station Bukit Koto Tabang (BKT). They were accompanied by Drs. Jörg Klausen (EMPA, QA/QC, Switzerland) and Christoph Zellweger (EMPA, WCC Surface Ozone, Carbon Monoxide and Methane) representing the twinning partners of the Indonesian GAW program.

The global GAW station Bukit Koto Tabang is located in West Sumatra, Indonesia (0° 12' 9" S –100° 19' 3.9" E) (Figure 1) at an altitude of 864.5 m a.s.l. The station is roughly 17 km north of the town Bukittinggi situated in the equatorial zone on the ridge of a high plateau 40 km off the western coastline. The prevailing wind directions are either south-south-easterly (December to May) or north-north-westerly (May to October). The temperature varies from 16 to 25 °C with only slight annual variation, and the relative humidity is usually above 80%. The vegetation of the surrounding area (30 km) consists mainly of tropical forest. Local sources of pollution have been reported previously (http://www.empa.ch/gaw/audits/BKT_2001.pdf).

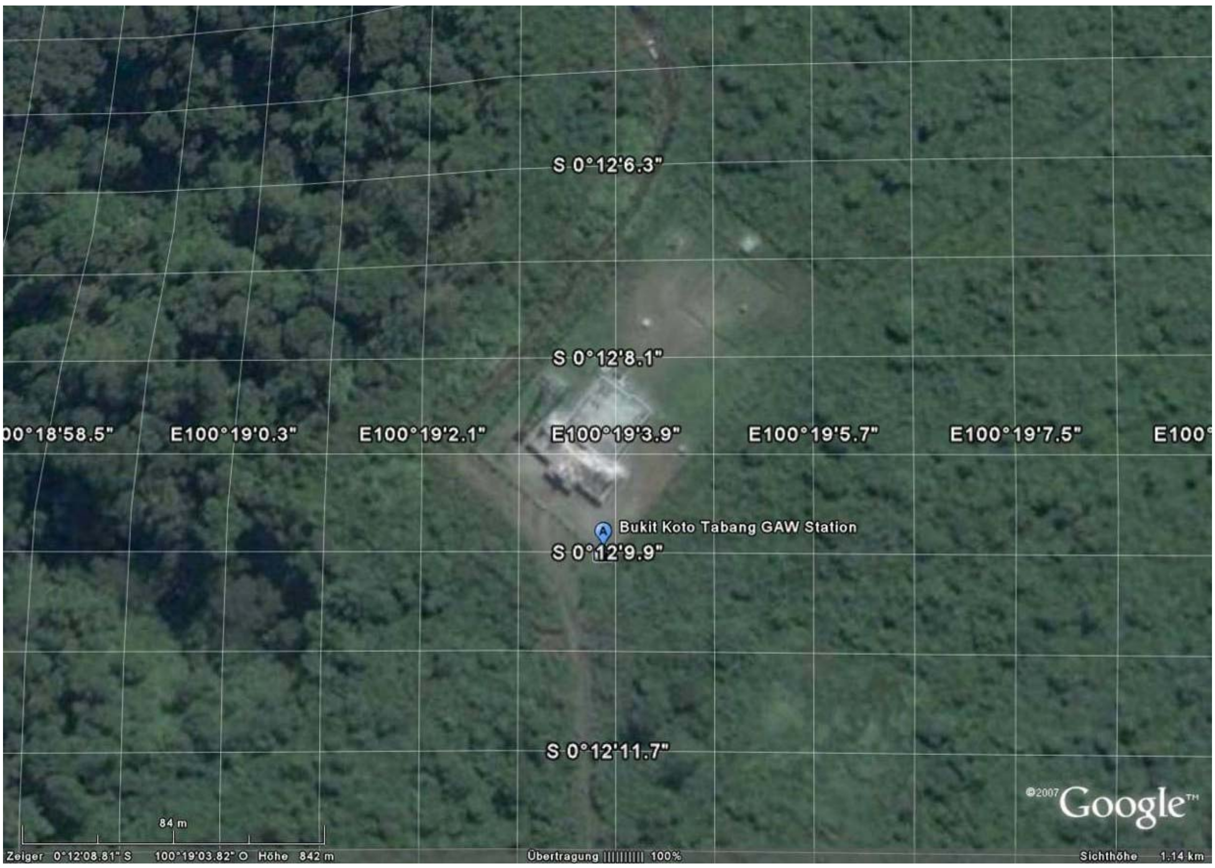

Figure 1: Google Earth view of the GAW station Bukit Koto Tabang.

A large one-story building (Figure 2) provides space for offices, laboratories and a meeting room and a 300 m^2 flat roof suitable for deployment of measurement instruments and inlets. The facilities are very adequate for their purpose. The bandwidth of the internet access could, however, be improved. Dry powder fire extinguishers should be replaced by CO_2 extinguishers to preserve non affected instruments in case of fire.

Figure 2: Laboratory building at Bukit Koto Tabang.

It needs to be noticed that currently smoking is only prohibited in the laboratories inside the building. Smoking is, however, tolerated in the other rooms of the building and in the fenced perimeter. Furthermore access to the fenced perimeter by combustion engine equipped vehicles is not restricted and not logged. Both smoking and unrestricted access to the site by car or motorcycle are a potential source for local pollution affecting aerosol measurements.

Smoking and unrestricted access by motor vehicles is usually not permitted at GAW global stations!

A designated smoking area at least 100 m off wind of the inlets should be provided for smokers. Cars should only be admitted to the fenced perimeter for material transport purposes. Such access should be filed in a logbook. Motorcycles may be pushed into the fenced perimeter.

The station is manned 7 days per week during office hours and guarded during nighttime. Sufficient dedicated staff is available for operation and trouble shooting. Several persons are assigned to one instrument. This yields the opportunity to maintain expertise if one person leaves for another assignment. Unfortunately results and problems are not perfectly communicated between the individual groups assigned to one instrument. Such communication would help to identify instrument problems earlier!

We recommend at least a weekly meeting of the individual groups assigned to one instrument and a crosscheck of individual measurement results to improve error detection and data quality.

Aerosol measurements at Bukit Koto Tabang comprise measurements of mass concentrations in two size fractions, chemical analysis of $PM_{2.5}$ and light scattering coefficient. Observed problems with these measurements are described in detail later in this report.
WMO/GAW AEROSOL MEASUREMENT PROCEDURES GUIDELINES AND RECOMMENDATIONS (WMO/GAW Rep. #153, http://www.wmo.ch/pages/prog/arep/gaw/documents/gaw153.pdf, page 2) suggests measurement of the following parameters:

Table 1: List of comprehensive aerosol measurements with a subset of core variables (identified in bold) that are recommended by the GAW Scientific Advisory Group on Aerosols for long-term measurements in the global network.

Continuous Measurement
Multiwavelength optical depth
Mass in two size fractions
Major chemical components in two size fractions
Light absorption coefficient
Light scattering coefficient *at various wavelengths*
Hemispheric backscattering coefficient at various wavelengths
Aerosol number concentration
Cloud condensation nuclei at 0.5% supersaturation
Intermittent Measurement
Aerosol size distribution
Detailed size fractionated chemical composition
Dependence on relative humidity
CCN spectra (various supersaturations)
Vertical distribution of aerosol properties

With respect to the quantification of the influence of local biomass burning, we suggest the addition of measurement of the absorption coefficient (preferably by MAAP) to the instrumentation at Bukit Koto Tabang. The old Aethalometer had to be removed previously because data were not reliable.

Although we did find some room for improvement during our audit we are confident that aerosol data from the global GAW station Bukit Koto Tabang will be very valuable to achieve the goals of GAW. Dedication of station staff, funding BMG (Indonesian Meteorological and Geophysical Agency -Badan Meteorologi dan Geofisika) and twinning partnership by EMPA provide a stable fundament for this purpose.

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Documentation and data handling: All manuals for the instruments, service documentation and detailed routine service logs for the instruments were available at the site. All data are locally stored in an Access database. Data are regularly transferred to EMPA for quality control. We expect that controlled data sets will be made available at the WDCA in the near future.

Documentation and data handling comply with GAW requirements.

Primary flow standard: A TSI 4100 mass flow meter SN 4146 0514 006 has been recently provided to BKT for QA of BAM measurements. This instrument is internally referenced to 21.1 deg C and 101.3 kPa. An Excel spreadsheet is available to convert flow meter readings to STP. After correction for ambient temperature and pressure the WWCAP reference Gilibrator (Cell S/N 0302113H) and the local TSI standard differed by less than 0.5 %.
It needs to be noticed that prior to our audit this flow standard has only been used to verify the flow of the BAM.

We suggest using this instrument to verify flow rates of all volume based aerosol parameters.

The primary flow standard is in good agreement with the WCCAP reference.

Inlets: BAM and Nephelometer use separate inlets on the roof. The BAM is equipped with a commercially available PM_{10} sampling head whereas the Nephelometer inlet has no defined cutoff size (figure 3).

The Nephelometer inlet head needs to be replaced by an omni-directional inlet with a cutoff size of 10 µm, this inlet will be provided by WCCAP.

Figure 3: BAM (left) and Nephelometer inlet (right).
Furthermore the height of the Nephelometer inlet above the roof is not sufficient to avoid effects of the roof on the local wind field. Both inlets should be at least 2 meters above the top of the roof.
All aerosol ducts are made of conductive material. They are heated inside the laboratory building for humidity conditioning.

After modifications the inlets will comply with GAW recommendations

Nephelometer: An Eccotech single wavelength Nephelometer type M9003 S/N 03-0287 is used to measure aerosol light scattering coefficient at 525 nm (figure 4).

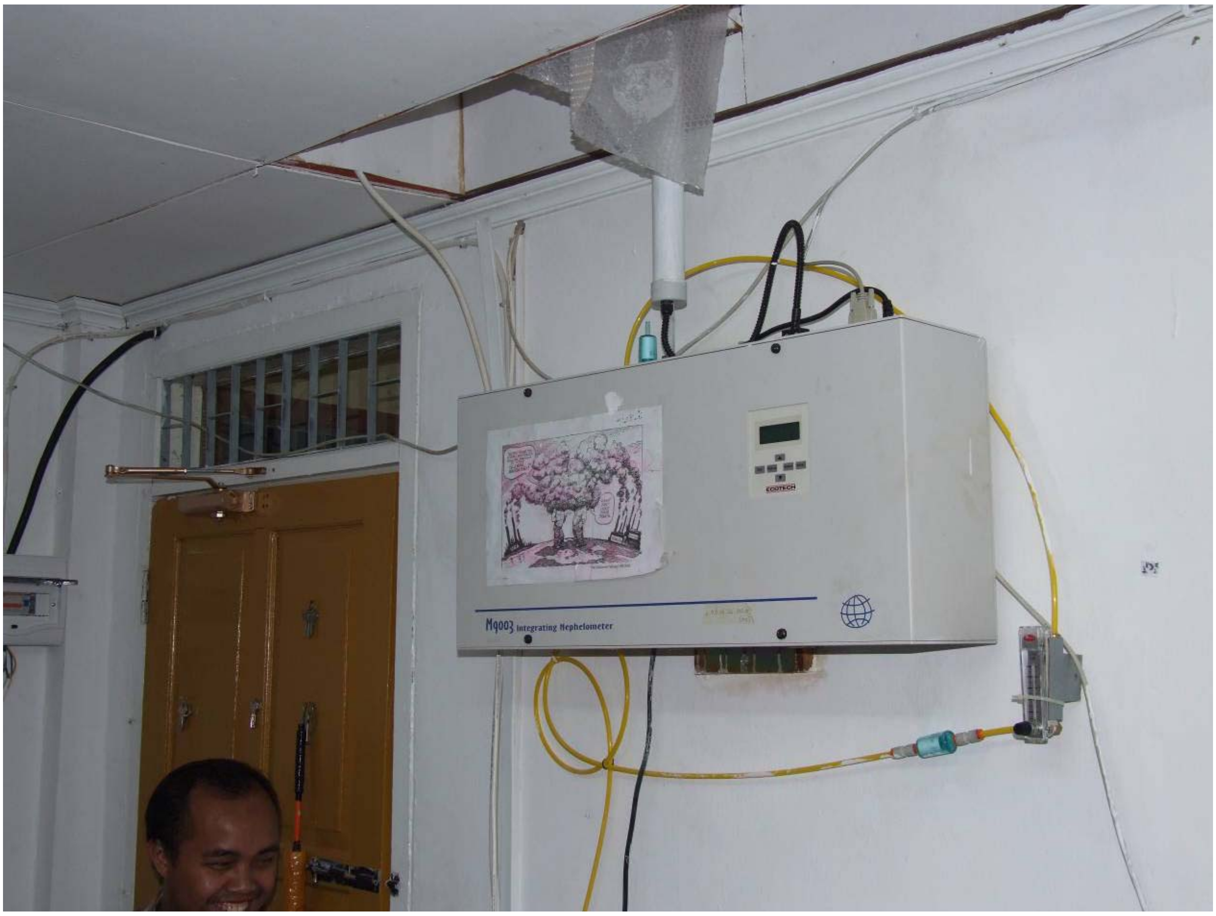

Figure 4: Eccotech Nephelometer.

Calibration of this instrument was unstable prior to our audit. A standard calibration during the audit did yield 21.2 m^{-6} for CO_2 and -17 m^{-6} for clean air after two zero/span cycles. This behavior started about 2 weeks prior to our audit.

The maintenance schedule described in the service manual of the instrument suggests cleaning of the measurement cell every two weeks. The instrument seems to require more attention than comparable instruments produced by other companies. We opened the measurement cell and did find a white spot directly under the aerosol inlet and some scratches in the black coating of the walls of the measurement cell (fig.5). After cleaning of the walls (use only mild soap solution for this purpose) and covering the scratches with black waterproof pen the instrument worked again according to specifications.

Figure 5: White deposits on the edges of the Nephelometer measurement cell and bright area close to the aerosol inlet.

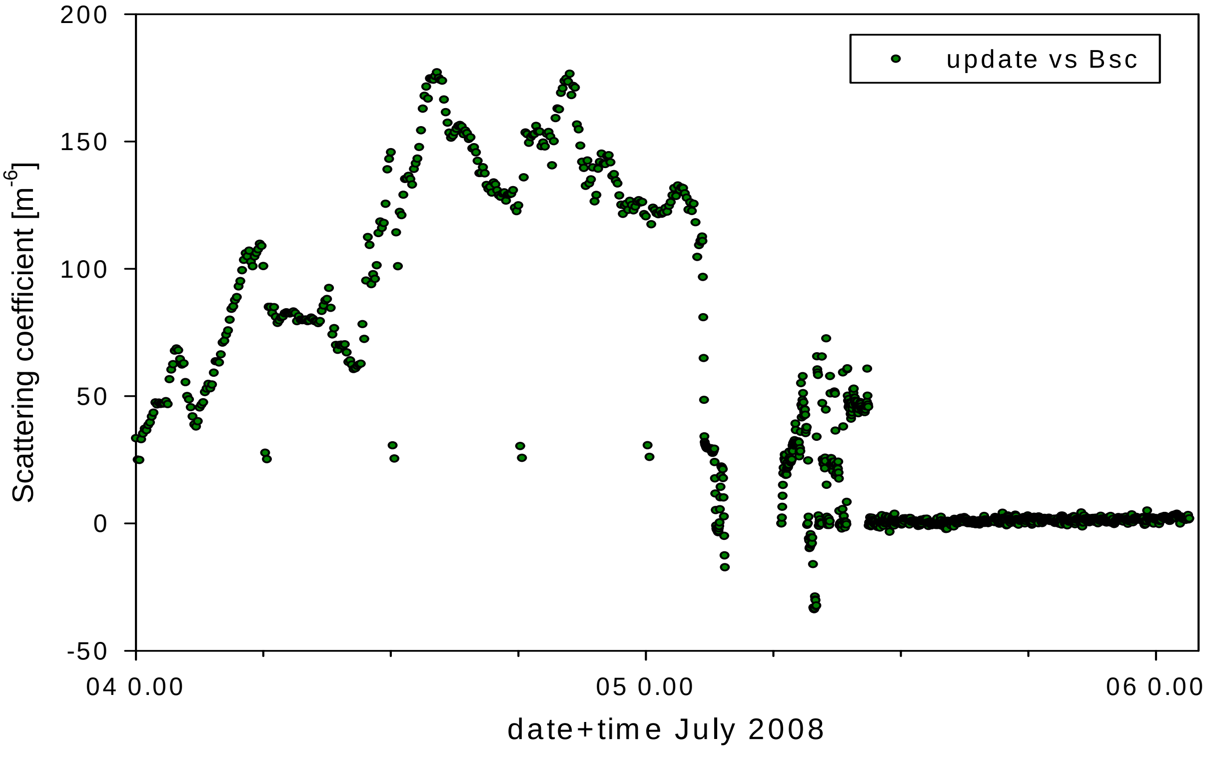

Figure 6: Time series of Nephelometer data after repair, zero filter attached at about 10 am on july 5th.

A time series of the Nephelometer after repair is shown in figure 6. Note that an absolute filter was attached to the instrument during the night.

We did observe a zero drift (0.096 m^{-6} /hour) of the instrument during measurements with an absolute filter. This seems to be rather typical for Eccotech Nephelometers (figure 7).

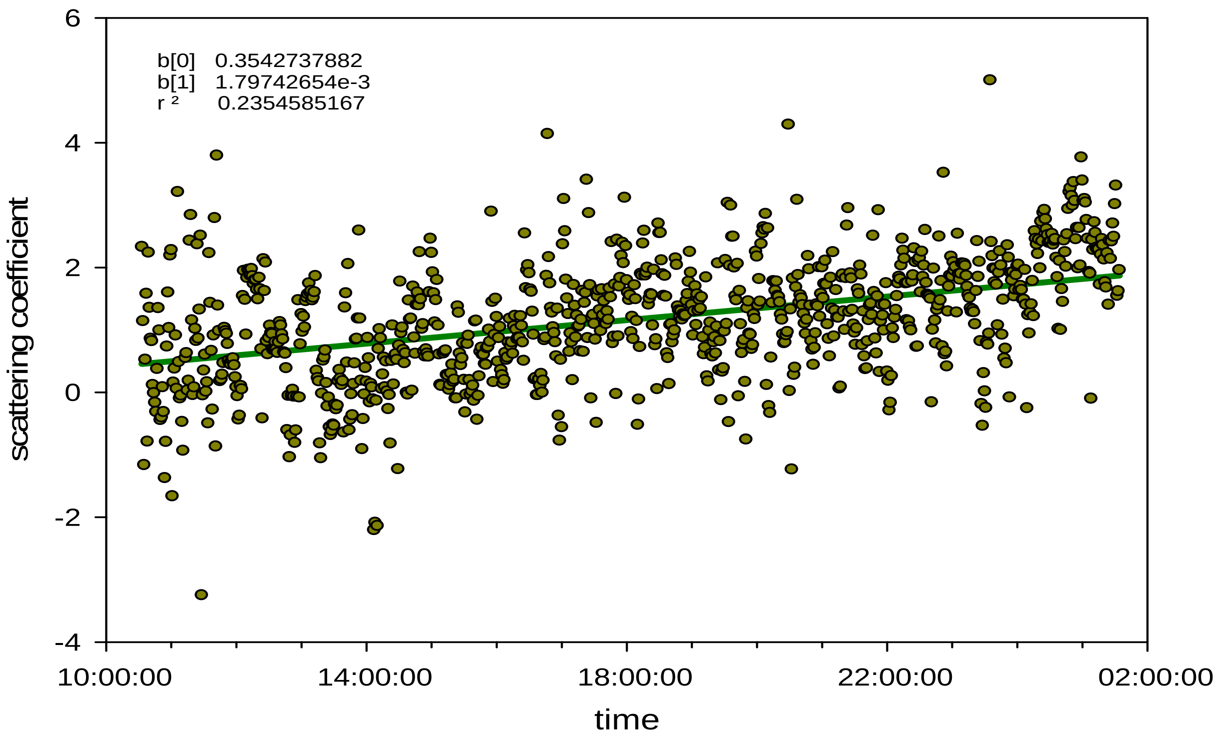

Figure 7: Zero drift of the Nephelometer at BKT.

Statistical parameters of the instrument during absolute filter measurements are summarized in table 2, the frequency distribution of measured values during this run is shown in figure 8.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SC	896	-3.249	5.003	1.16604	.960887
AT	896	26.908	30.994	29.96637	.454076
CT	896	26.433	141.441	30.21003	3.760098
RH	896	43.196	50.774	49.72428	.780813
AP	896	838.312	916.912	914.70640	3.682133
Valid N (listwise)	896				

Table 2: Statistical parameters of Nephelometer measurements with an aboslute filter attached to the inlet oft he instrument.

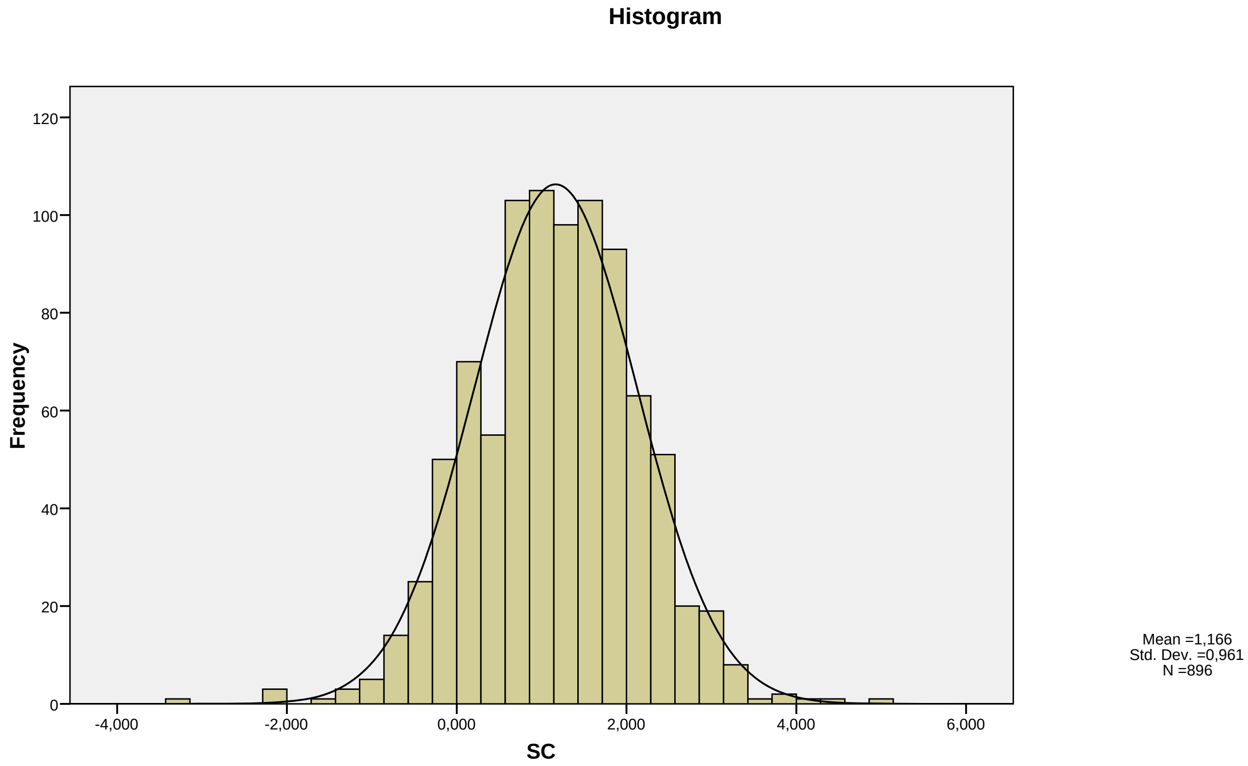

Figure 8: Frequency distribution of Nephelometer measurements with absolute filter.

After repair the Nephelometer at BKT is in good working condition. Zero and span checks must be performed at least weekly to avoid artifacts due to zero and span drift.

Mass concentration measurement: A MetOne PM10 Monitor BAM 1020 S/N C3763 is available at BKT for continuous monitoring of aerosol mass concentration with a time resolution of 1 hour. Comparing data from this instrument with filter measurements we did observe that $PM_{2.5}$ seemed to contribute less than 15% to PM_{10}. This ratio is much lower than expected from experience (typically $PM_{2.5}$ contributes about 70% to PM_{10}). Because the BAM uses an absorbing material for calibration of the instrument once per hour PM_{10} readings from the BAM seem to be correct. Unfortunately a zero check like the one performed above for the Nephelometer is not possible for the BAM because the inlet is (by factory design) not leak tight. Correlation of Nephelometer measurements with BAM PM_{10} concentrations suggests, however, that BAM measurements are correct within instrument specifications.

BAM PM_{10} mass concentrations are apparently correct, BAM data should be frequently crosschecked against Nephelometer data and $PM_{2.5}$ mass concentrations from filter measurements to ensure good data quality.

Filters for chemical analysis are sampled using a Rupprecht&Patashnick Partisol sampler S/N 2010-20042-9407. This sampler samples at a nominal flow rate of 10 l/min with a cutoff size of 2.5 µm. The current sampling schedule of one filter for 24/7 causes frequent filter overloads. An overloaded filter causes false indicated total volumes (for example total volumes measured by a gas-meter were by a factor of 5 higher than those calculate from measured flow rate during the audit) and losses of volatile particles. GAW aerosol procedures suggest:

It may not be possible to analyze all daily samples for chemical concentration. If, due to financial constraints, not all samples can be analyzed, the following alternatives should be considered: (1) sample every day of the week and every other sample is archived, hence effectively reducing the sample analysis by half; or (2) sample every day of the week and only one sample every week are analyzed; or (3) take a daily sample every 6th day and analyze them. These 3 alternatives are preferred to a weekly integrated sample which is difficult to relate to meteorological transport conditions. In all cases, unanalyzed samples should be archived in separate, clean, dry, cool containers for possible later analysis in case of unusual events. To ensure the quality of the sampling and subsequent handling procedures, 5-10% of the samples should consist of field blanks.

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Unfortunately volumes read from the gas-meter have not been crosschecked against theoretically possible volumes. The maximum possible volume would have been:

10 l/min x 1440 min x 7 = 100.8 m^3

Most of the time more than 200 m^3 have been reported from gas-meter readings.

$PM_{2.5}$ mass concentrations and chemical analysis are not usable.

Sampling time must be reduced to avoid filter overloading. The gas-meter must be exchanged. Flow rates must be measured at least once per day with the TSI mass flowmeter to ensure correct measurement of the sample volume.

There are two more problems with the current sampling for chemical analysis:

1: Filters are shipped by regular air freight to BMG. They are not cooled. This procedure may cause losses of aerosol on the filters due to filter handling by the airlines. Furthermore particle mass may be lost during transport due to evaporation of volatile components of the aerosol.

Filters need to be shipped to BMG by personal transport. They need to be frozen until transport to avoid particle losses due to evaporation.

2: Aerosol particles may adsorb water up to more than 100% of their original mass. Filter weighing needs therefore to be done under standardized conditions:

The net mass on the filter sample is determined from the weight difference of the filter before and after sampling. To maintain a constant T and RH, the weighing must be done with a balance in a T and RH-controlled environment. Prior to weighing, the filters should be equilibrated at the controlled constant T and RH for 24 hours.
For the GAW network, a constant temperature and RH of 20°C ± 1°C and 45% ± 5% are recommended.
While balances with ≤100 µg sensitivities are adequate for weighing high-volume samples where 10s of milligrams of net mass are expected, electro-balances with sensitivities below 1 µg are required for the recommended Teflon filter collection at the GAW stations. The same applies to samples collected using other low volume devices (air flow rate ≤30 L min^{-1}), especially if cascade impactors are used. Calibration of the balance must be carried out using standards of similar weights at the same microenvironment as the samples. The standards must be traceable to primary standards, e.g., those of the US NIST, or BMPI.
Static electric charge on filters is especially significant for filters with high dielectric constants such as Teflon. Charge can accumulate on filters during the manufacturing process as well as the sampling and handling processes. The charges can result in handling difficulties,

enhanced or diminished particle collection, and weighing errors. Weighing error is magnified when the collected mass is small. Under the recommended GAW sampling protocol, the collected aerosol particle mass is expected to be in the range of 10s to 100s of µg. The sensitivity of the balance must be sufficient to accurately determine this. To remove any electric charge, the filter should be exposed to a corona discharge device or a low-level radioactive source such as Po-210 or Am-241 prior to and during weighing.

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Currently above mentioned requirements are not met at BMG. Filter weighing is done in a room used by several persons and open for visitor groups. There is no temperature and rH conditioning available. Balance resolution is not according to GAW recommendations (figure 9).

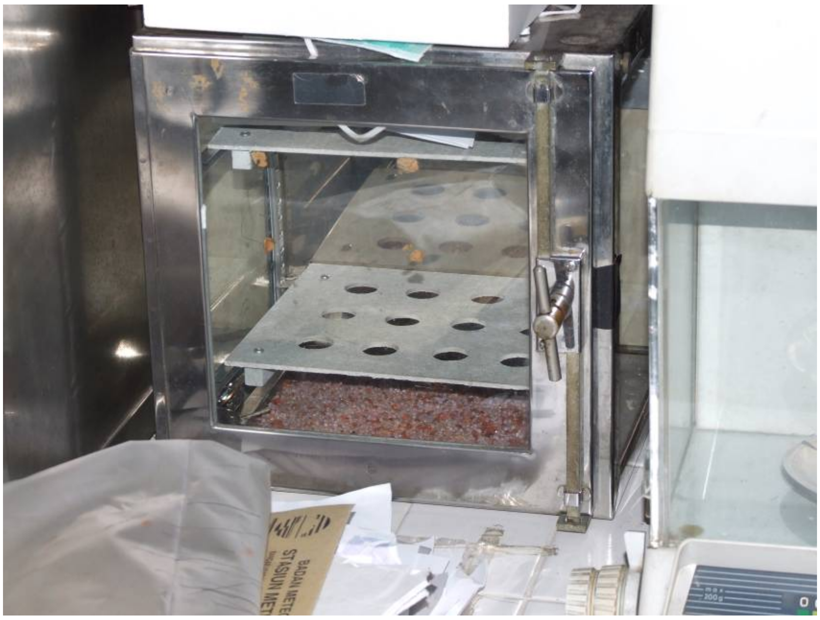

Figure 9: Balances and “filter conditioning” at BMG.

Filter handling and conditioning does not comply with GAW requirements

Final remarks: Although some things need to be improved we are confident that this site will yield valuable data for GAW. We wish to thank everybody supporting us during our audit for their great hospitality. Special thanks to Jörg and Christoph for their dedicated twinning partnership for this site.