Quantification and Intercomparison with Aircraft HR-ToF-AMS: Results from CU-Boulder

Hongyu Guo, Pedro Campuzano-Jost, Jose-Luis Jimenez et al.
Presented by Manjula Canagaratna
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Intro: CU Aircraft HR-ToF-AMS

CU Aircraft HR-ToF-AMS Data Products:
- 1 Hz (up to 10 Hz on request) and 60 s (higher S/N) products
- Submicron aerosol mass: Organic aerosol (OA), SO4, NO3, NH4, Chl
- OA chemical markers: f44 (Secondary OA), f57 (hydrocarbon-like OA), f60 (biomass burning OA), f82 (isoprene epoxide-SOA)
- Above products are available in real-time
- 1 s DLs about 400 ng sm^-3 for OA, 5-50 ng sm^-3 for other species

Advanced products:
- O/C, H/C, OA/OC, organic nitrates (pRONO$_2$), MSA, Br(p), I(p)
- Chemically-speciated size distributions
- Aerosol density and acidity
- OA source apportionment by PMF

An integrated thermal denuder also allows investigation of bulk volatility
Q: What is the cut size of AMS?

- Field calibration of the transmission is critical for accurate quantification and intercomparisons
- Complete cal at start and end (green), then many spot checks with IE cals (gray)

Jimenez group (Guo et al., in prep)
CU AMS Size Cut vs. URG PM$_1$ cyclone

\[ d_a = d_{ve} \frac{\rho_p C_c(d_{ve})}{\sqrt{\rho_0 C_c(d_a)X_c}} \]

\[ d_{va} = \frac{\rho_p d_{ve}}{\rho_0 X_v} \quad (DeCarlo et al., 2004) \]

- AMS transmission could change after transportation or lens alignment (e.g. better in ATom-4 compared to ATom-2).
- AMS transmission is normally characterized in $d_{va}$ and URG PM$_1$ cyclones in $d_a$.
- In $d_{va}$, AMS is a PM$_{0.75}$ (ATom-2) or PM$_{0.96}$ (ATom-4) measurement.
- In $d_{ta}$ (a more commonly used scale to select particles), AMS is a PM$_{0.6}$ (ATom-2) or PM$_{0.76}$ (ATom-4) measurement.
- The sharpness of AMS lens transmission is similar to that of a standard cut URG PM$_1$ cyclone.

Jimenez group (Guo et al., in prep)
How much of nominal PM$_1$ was captured?

- Accurate NOAA volume measurements allow quantifying this.
- Despite of being a PM$_{0.6}$ cut in $d_{ta}$ (in ATom-1 &-2), $\sim$80% of the PM$_1$ volume/mass was captured by AMS.
AMS transmission curve: remote vs. “oil” aerosols

Using ATom-2 density of 1.70 g cm$^{-3}$

- ATom-2: $\text{PM}_{0.6}$
- ATom-4: $\text{PM}_{0.76}$

Assuming a density of 1.0 g cm$^{-3}$

- ATom-2: $\text{PM}_{0.75}$
- ATom-4: $\text{PM}_{0.96}$
What fraction of remote aerosols does AMS see?

Averages and transmissions

Particle Counters (everything)

CU AMS

PALMS (laser ablation, scaled to counters)

Jimenez group (Guo et al., in prep)
A good transmission curve enables meaningful comparisons

- NOAA volume is combined from NMASS (0.003-0.06 µm), UHSAS (0.06-1 µm), and LAS (0.12-4.8 µm).
- NOAA sees much higher volume at times, but once the AMS transmission curve is applied, good agreement is observed.
- Note that *even for direct comparisons with the UHSAS alone*, the transmission curve made a large difference, both at the high and at the low end (particle growth events). Also Hayes et al., JGR 2013.

NOAA volume from (*Williamson et al., 2018; Kupc et al., 2018; Brock et al., 2019*)
A good transmission curve enables meaningful comparisons

Another example: ATom-3 RF308

The same story despite of the large removal in the NOAA volume

NOAA volume from (Williamson et al., 2018; Kupc et al., 2018; Brock et al., 2019)
Volume comparison: AMS vs NOAA size spectrometers

- Consistent agreement in ATom-1&-2
- Applying the AMS transmission curve to volume distributions (prev. slide) was critical
- Independently analyzed and published by the (very rigorous) NOAA group (right plot)

Jimenez group (Guo et al., in prep)
Sulfate: AMS vs SAGA Mist Chamber (IC-based)

- SAGA Mist Chamber has strong tailing due to liquid sampling and analysis (carryover from sample to sample)
- ATom sampling strategy (constantly up and down) requires adding fairly heavy tails to the AMS SO$_4^-$ to simulate the smearing of the SAGA MC. This leads to better agreement.
A campaign-wide smearing of the AMS data leads to good agreement
Slopes are well within the stated uncertainties, but with a larger spread than usual due to the correction for the SAGA time-smearing
• PALMS sulfate is based on single particles, then scaled to the NOAA Volume
  • May be less accurate for AMS range, due to extrapolation of composition to smaller particles than it can see
• Remarkably consistent across both deployments
• In summary, SAGA-IC, PALMS and AMS agree well, with PALMS reporting the largest values

Sulfate: AMS vs PALMS

![Graphs showing the comparison of AMS vs PALMS sulfate measurements for ATom-1 and ATom-2 deployments.](chart)

Slope=1.04, $r^2=0.82$
Slope=0.87, $r^2=0.85$
OA: AMS vs PALMS

- PALMS does not see Aitken mode
- Good agreement when Aitken mode is not important
- PALMS biased low when OA-containing Aitken mode is important
  - It is extrapolating the composition from larger particles, which has more $SO_4$ and less OA
Submicron seasalt: AMS vs PALMS/UHSAS

- Good agreement on average
- More scatter, but this is expected
  - Due to applying transmission function to AMS and PALMS data on a very steep tail of the sea salt size distribution

Method of Ovadnevaite et al. JGR 2012
Summary

• A well characterized and calibrated AMS can deliver quantitative data
  • No evidence of biases (outside the stated uncertainties) for remote data
  • *But this requires a lot of very careful work.* Further analysis in progress

• AMS Transmission curve
  • Critical to characterize & verify in the field
    • Avoids confusing transmission differences with CE or RIE errors
  • AMS transmission can vary $\text{PM}_{0.6}$ to $\text{PM}_{0.96}$ in $d_{ta}$ as $f(\text{lens, particles})$

• Comparison to volume from optical counters
  • Very good once transmission curve is taken into account

• Comparison to chemistry instruments
  • Good for sulfate, OA, sea salt
  • Size transmissions and non-AMS instrument idiosyncrasies need to be taken into account