Comparison of Automated versus Manual Mass Measurements

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IMPROVE Steering Committee Meeting
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Background and motivation

- Samples may absorb and adsorb water

- EPA procedure for mass measurements requires
  - RH of 30 – 40%, change <5% over 24 hours
  - Temp of 20-23°C, change <2°C over 24 hours
  - 24 hour equilibration time prior to measurements

- IMPROVE mass measurements
  - Prior to 2018, IMPROVE mass measurements performed manually on a balance in lab environment
  - In 2018, robotic chamber enclosed balance with controlled T & RH for mass measurements implemented

*40 CFR Appendix L to Part 50
Manual vs automated balance setups

Since inception through Fall 2018, various balances in various rooms with various HVAC units
Subject to change in room RH and temperature
Hereinafter referred to as “manual” balance

MTH AH500 in service since 2018
RH controlled 39 % ± 2 %
Temp controlled 21.5 ± 1 ºC
Minimum 4 hour equilibration time
2nd MTL AH500 deployed in 2021
Hereinafter referred to as “automated” balance

Images from mtlcorp.com and aqrc.ucdavis.edu
AQRC Laboratory RH Historical Records

Note: only included records on weekdays from 8 am to 5 pm

Liu et al. In preparation
Comparative gravimetric study

- Investigate mass differences from manual versus automated balance setups
- Weighed IMPROVE samples on both balances
  - Both pre-weights and post-weights
    - \( M_{\text{manual}} = M_{\text{manual,post}} - M_{\text{manual,pre}} \)
    - \( M_{\text{automated}} = M_{\text{automated,post}} - M_{\text{automated,pre}} \)
PM mass difference ($\Delta M$) vs post RH difference ($\Delta R_{H_{\text{post}}}$)

Error of each net weight:

$$\sqrt{1.20^2 + 1.20^2 + 1.94^2 + 1.94^2} = 3.2 \text{ ug}$$

Points between dashed lines are considered insignificant.

PM mass difference ($\Delta M$)

$$\Delta M = M_{\text{manual}} - M_{\text{automated}}$$

$\Delta R_{H_{\text{post}}} = R_{H_{\text{manual, Post}}} - R_{H_{\text{automated, Post}}}$

Liu et al. In preparation
PM mass difference ($\Delta M$) vs ion concentrations

- Only module A samples have collocated ion data
- 283 points in each plot
- $\Delta M = M_{\text{manual}} - M_{\text{automated}}$

Did not capture widest range of possible RH in these experiments

Liu et al. In preparation
Conclusions from comparative gravimetric study

• RH was only moderately different between balances for these experiments
• No strong relationship between $\Delta M$ and $\Delta RH_{\text{post}}$
  • Weak relationship when ion content is high
• No significant difference in gravimetric/reconstructed ratio
• But
  • RH differences in experiment were small
  • What about historical data?
Historical data

All data median ratio:
Manual 1.05
Automated 0.99

Significant difference

Liu et al. In preparation
New exploration—equilibration time in chamber

- Laboratory RH can be > 50% in summer and <25% in winter
- Chamber RH is 39 ± 2%
- Equilibration time necessary for filter media and sample after loaded into chamber?
- Experiment: Store samples in laboratory, load into chamber and weigh repetitively for hours/days
Net Weight
Relative Percentage Difference (%)

Net Weight
Absolute Difference (µg)

Previous equilibration data

- Measure ~6,000 network samples twice
  - First is routine network measurement
  - Second is a replicate measurement 6 – 46 hours after routine measurement
- RPD is small
  - 75 % of RPD within ± 1.6 %
  - 75 % of AD within ± 1.0 µg
Blank filter equilibration

Green lines are ± 1.2 µg, 1 standard deviation measurement error of balance
Network samples equilibration

Masses dropping throughout “equilibration times”
New exploration - different RHs in chamber

• How will mass change when chamber RH changes?
• Tuned chamber RH to 39 %, 44 % and 53 %
  • Repetitively weighed samples.
Blank filter mass at different chamber RH

Green lines are ± 1.2 µg, measurement error of balance.
Network sample mass at different chamber RH

![Graph showing net weight difference from database (µg) vs. chamber RH. The graph includes data points from various locations and dates, such as FRES-1/13/2021_Nitrate, BIBE-6/9/2021_Sulfate, SACR-2/18/2021_Sulfate, and more. The X-axis represents weighing date and time, ranging from October 10 to October 11, while the Y-axis shows net weight difference from database (µg). The graph also indicates the percentage of chamber RH, ranging from 40% to 55%. The line colors and markers correspond to different locations and dates, highlighting trends and variations in sample mass over time.]

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Weighing date and time

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<th>Date</th>
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<th>Chamber RH (%)</th>
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<tr>
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<tr>
<td>Oct 11</td>
<td>06:00</td>
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</table>
Observations from equilibration and RH experiments

• Blank filter mases stable during equilibration and with RH changes

• Samples show changes in mass
  • Higher the loading, bigger the change
  • Equilibration process: samples with
    • High loading showed 10 – 70 µg of change
    • Medium loading showed 2 – 5 µg of change
    • All changes below 6% of total mass
  • RH change: samples with
    • High loading showed 6 – 70 µg of change
    • Medium loading showed 2 – 7 µg of change
    • All changes below 11 % of total mass
Thank you!