IMPROVE Network Technical System Audit Report

Overview of completed audits and results for 2022.

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Derek Day

Introduction

Technical System audits (TSAs) are conducted to ensure the Interagency Monitoring of Protected Visual Environment (IMPROVE) sampling sites are being operated in accordance with the Quality Assurance Project Plan (QAPP): http://vista.cira.colostate.edu/improve/wp-content/uploads/2017/01/IMPROVE-QAPP-Signed_3_2016.pdf and all relevant standard operating procedures (SOPs) :http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/.

The complete TSA consists of verifying the site's coordinates and elevation, sampler's date/time, vacuum pressure, temperature, and the flow rate of each module. The sampler stand is checked for safety, integrity and configured for proper sample collection. Pictures of the sampler modules, sampler stand/building, and surroundings are taken. When the operator is available, their sample change technique is observed to ensure that (s) he has adequate sampler and sample change knowledge. The site operators are asked about sampling safety concerns and about whether the current IMPROVE Operations Contractor (UC Davis) is providing adequate support to help the operator maintain high quality sampling at the site. The sampler siting criteria is reviewed; which ensures the samples collected represent local ambient background conditions as outlined in SOP 126: http://vista.cira.colostate.edu/Improve/particulate-monitoring-network .

Review of Audit Program and Completed Audits

In 2016 personnel from the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University began conducting and overseeing the TSA program for the IMPROVE network. In addition to conducting audits, CIRA personnel have also conducted auditor training/certification of other auditors from EPA Region 2, CO, AZ, MO, WY, and DE. This training program has helped to ensure consistency of audits throughout the network. Some of these people now conduct audits for their respective states/regions. Since 2016, an audit has been conducted at all but 5 IMPROVE sites in the U.S.; the unaudited sites are: Montgomery, Atlanta, Virgin Islands, Toolik Lake, and Carlsbad Caverns. Figure 1 below shows a map of the IMPROVE sites which have been audited to date (colored in blue) and the unaudited sites (colored in red). There were no audits conducted during 2020 by CIRA personnel because the University did not allow travel during the pandemic. However, auditors from Colorado and Missouri did conduct a few audits.

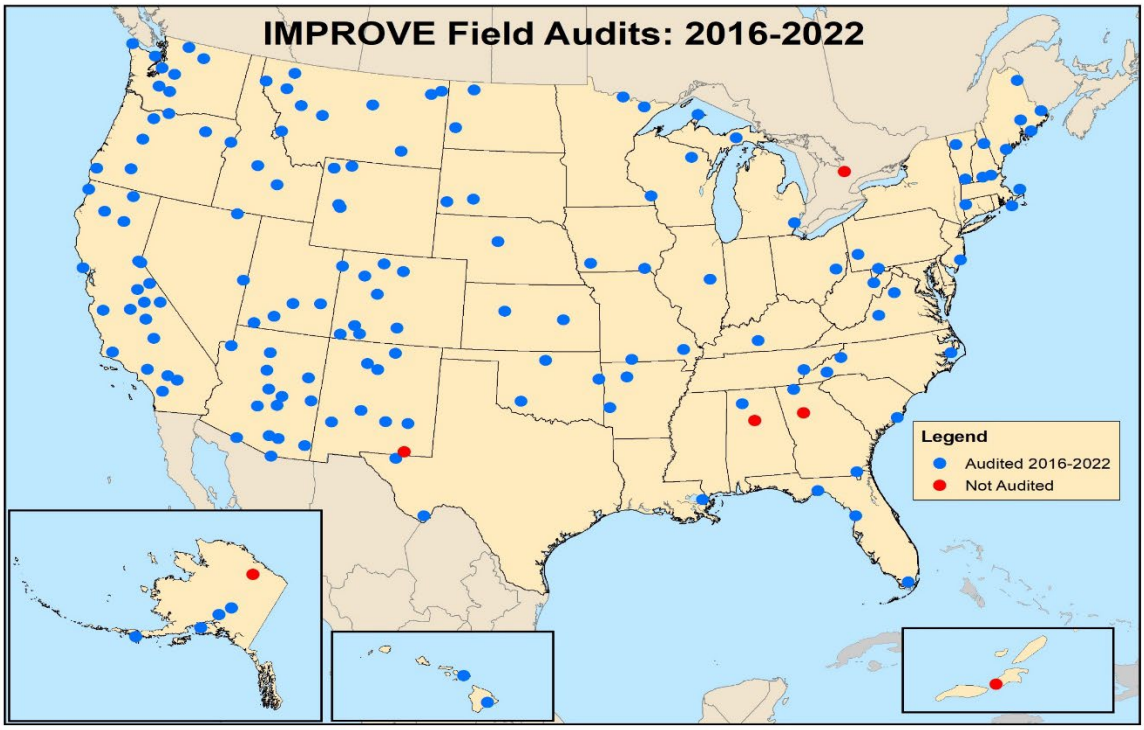

Figure 1. Map showing IMPROVE sites which have been audited (blue dots) and sites which have not been audited (red dots).

Results

This report presents the results of audits performed during 2022. They include: sampler flow rate, sampler vacuum pressure, sampler temperature, sampler time, and sampler siting criteria.

Sampler Flow Rate

The IMPROVE sampler consists of four separate channels which are commonly referred to as modules A, B, C, and D. Modules A, B, and C operate at a nominal flow rate of 22.8 liters/minute (lpm) and utilize a cyclone to achieve a 2.5 micron size cut. Module D operates at a nominal flow rate of 16.9 lpm and utilizes an impactor at the inlet to achieve a 10 micron size cut. Pressure transducers are used to measure the pressure drop across the cyclone (Modules A,B, and C)and across a critical orifice/needle valve (Module D). A calibration curve, relates the measured pressure drop to sampler flow rates for each module. During an audit the IMPROVE sampler flow rate is compared to a NIST traceable reference standard. Most auditors are using trical or tetraCal flow meters. For audits conducted by CIRA the flow rates were measured using

a tetraCal flow meter which had been calibrated and certified by Mesa Labs. All audit devices undergo certification annually. Modules A, B, and C fail the flow rate test if the audit device flow rate differs from the nominal flow rate by more than 10% as shown by the equation below.

$$failure\ when: \frac{(22.8\ -\ \text{Audit Flow Rate})}{22.8} * 100\% > 10\%$$

Module D also fails the flow rate test if the audit device flow rate differs from its nominal flow rate by more than 10%

$$failure\ when: \frac{(16.9\ -\ \text{Audit Flow Rate})}{16.9} * 100\% > 10\%$$

Module flow rates can also fail the audit test if calculated sampler flow rates differs from the audit device flow rate by more than 10%

$$failure\ when: \frac{(\text{Sampler Flow Rate}\ -\ \text{Audit Flow Rate})}{\text{Audit Flow Rate}} * 100\% > 10\%$$

Results of audit flow rate checks are shown in Tables 1-4 and Figures 2-5. These figures show the nominal flow rate (solid red lines), the allowed deviation from nominal flow rate (dashed red lines), and a 1:1 line between the audit device and the IMPROVE sampler flow rates.

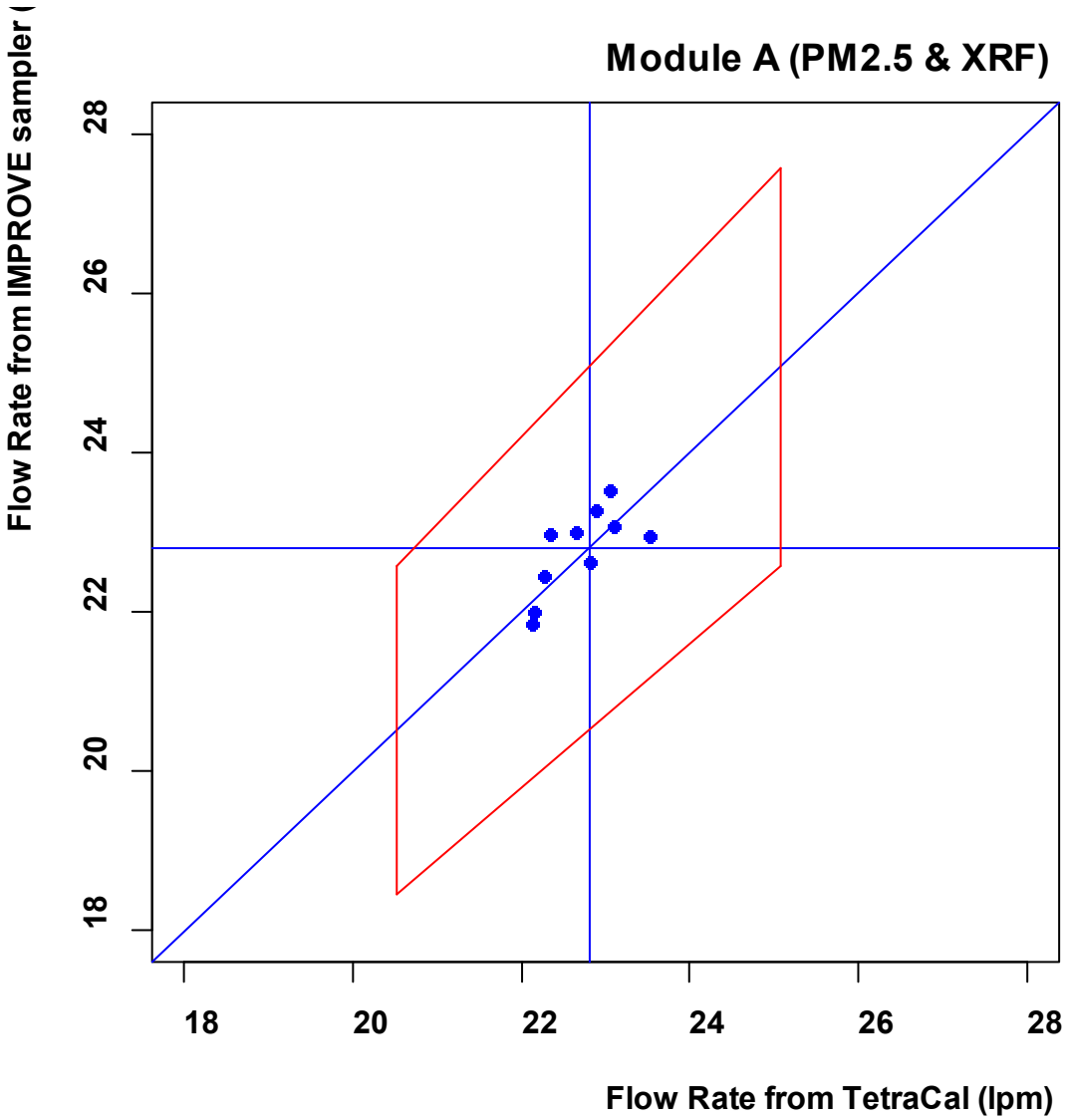

Figure 2. Plot showing flow rate comparison between Module A and audit devices.

Table 1. Summary statistics of Module A and audit device flow rates in liters per minute (lpm). The "% difference" is the percent difference in flow rates between the audit device and the IMPROVE sampler.

Statistic	Audit Flow	IMP Flow	% diff
Min.	22.12	21.86	0.06357
1st Qu.	22.29	22.50	0.78250
Median	22.73	22.96	1.38730
Mean	22.69	22.78	1.41193
3rd Qu.	23.01	23.06	1.99432
Max.	23.51	23.53	2.86159

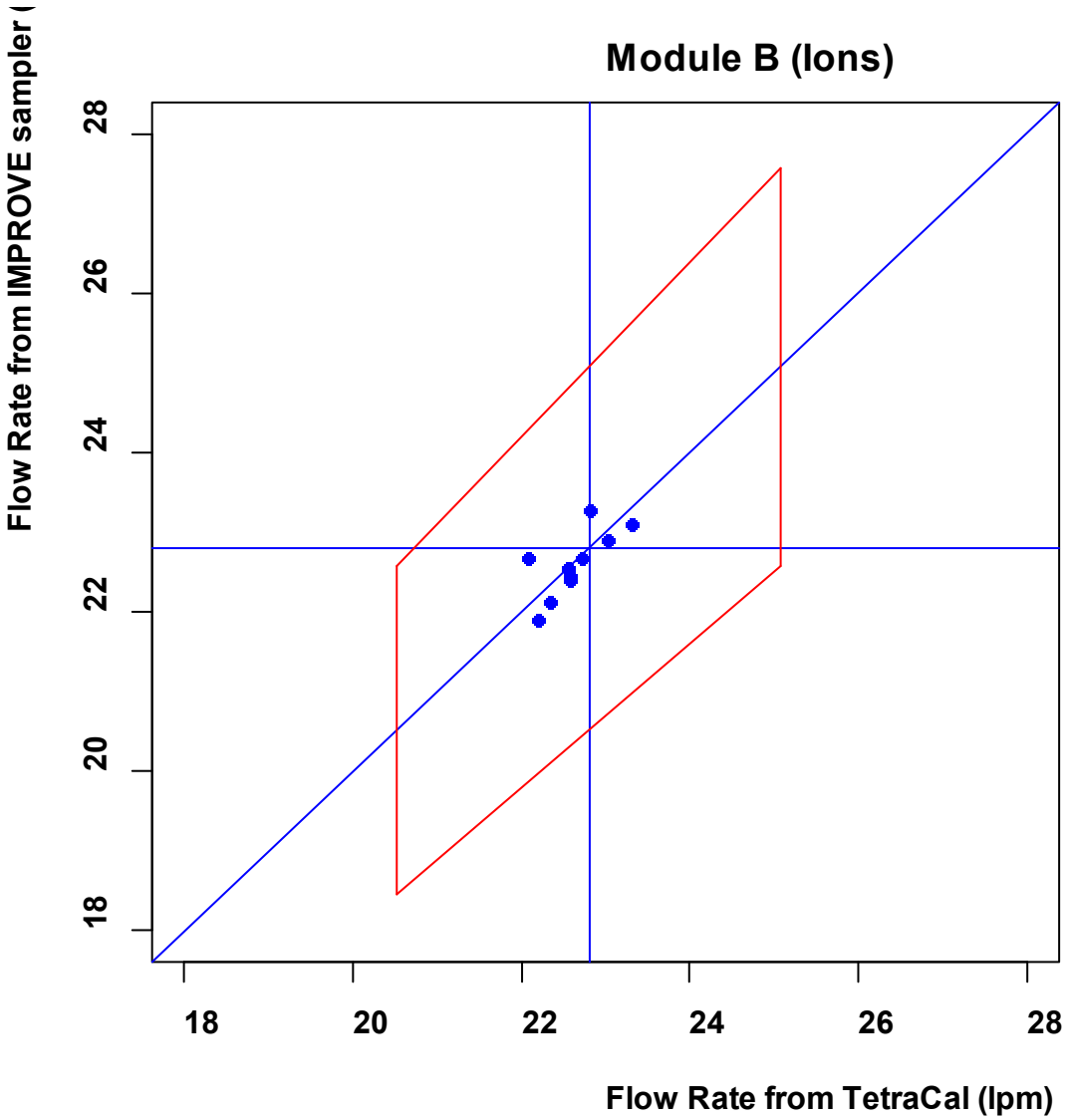

Figure 3. Plot showing flow rate comparison between Module B and audit devices.

Table 2. Summary statistics of Module B and audit device flow rates in liters per minute (lpm). The "% difference" is the percent difference in flow rates between the audit device and the IMPROVE sampler.

Statistic	Audit Flow	IMPROVE Flow	% Difference
Min	22.07	21.90	0.04806
1st Qu.	22.39	22.41	0.49555
Median	22.57	22.61	0.82034
Mean	22.61	22.61	0.99208
3rd Qu.	22.79	22.85	1.21700
Max.	23.30	23.28	2.79493

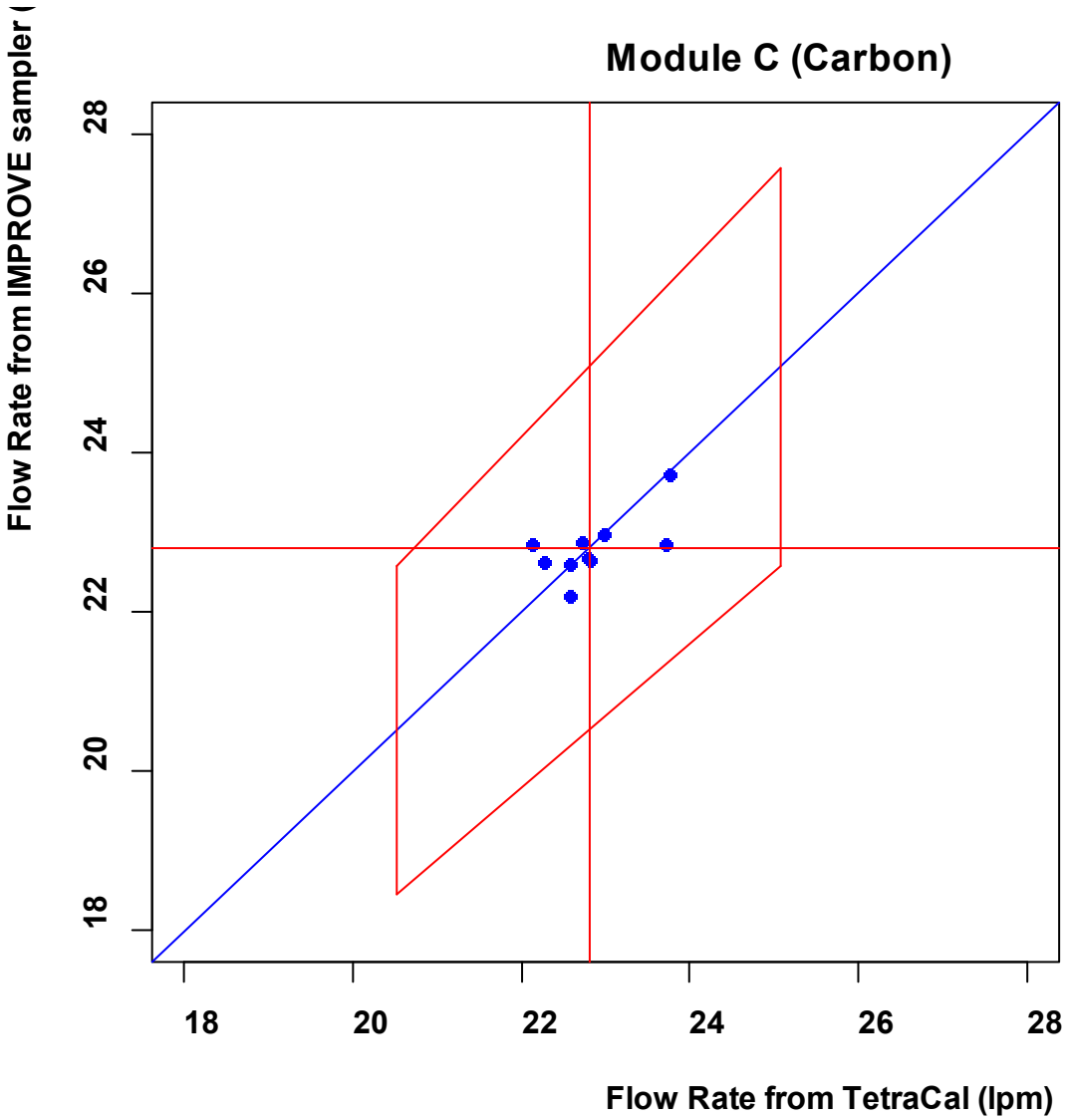

Figure 4. Plot showing flow rate comparison between Module C and audit devices.

Table 3. Summary statistics of Module C and audit device flow rates in liters per minute (lpm). The "% difference" is the percent difference in flow rates between the audit device and the IMPR OVE sampler.

Statistic	Audit Flow	IMPROVE Flow	%diff
Min	22.13	22.20	0.004784
1st Qu.	22.57	22.63	0.243040
Median	22.75	22.76	0.701982
Mean	22.83	22.80	1.231770
3rd Qu.	22.94	22.87	1.658354
Max.	23.75	23.71	3.605342

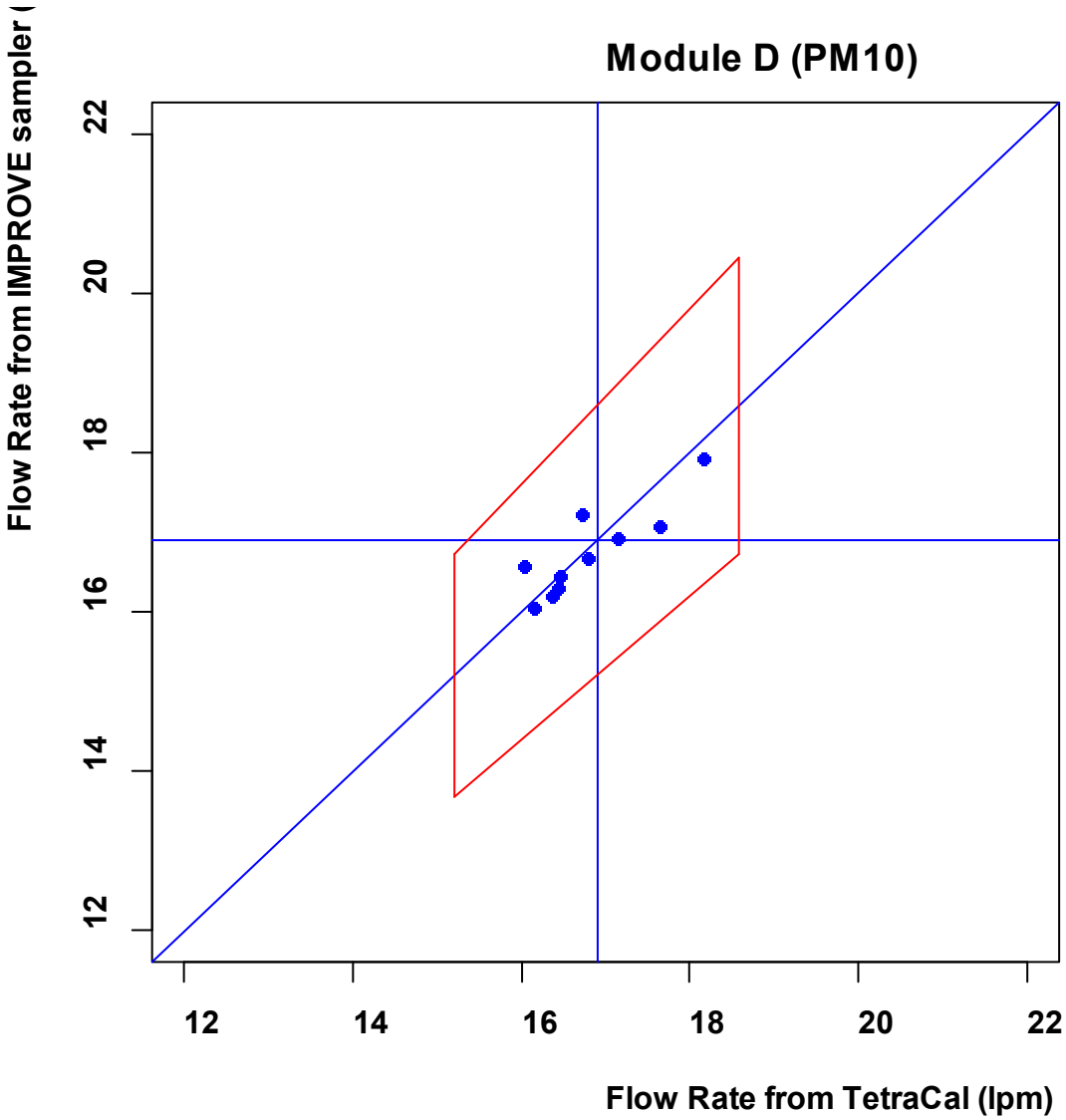

Figure 5. Plot showing flow rate comparison between Module D and audit devices..

Table 4. Summary statistics of Module D and audit device flow rates in liters per minute (lpm). The "% difference" is the percent difference in flow rates between the audit device and the IMPR OVE sampler.

Statistic	Audit Flow	IMPROVE Flow	%diff
Min.	16.02	16.04	0.05473
1st Qu.	16.39	16.34	0.74340
Median	16.58	16.63	1.20523
Mean	16.79	16.74	1.55139
3rd Qu.	17.06	17.05	2.64375
Max.	18.16	17.92	3.42241

Sampler vacuum

The sampler vacuum is measured to ensure minimal air leakage throughout the sample train. All vacuum tests passed.

Sampler temperature

Temperature impacts air density and hence sample flow rate, therefore air temperature is monitored by the IMPROVE sampler. The IMPROVE temperature is compared to a reference standard during audits. All audit temperatures checks passed.

Sampler time

All sampler clocks were in agreement with audit times.

Sampler integrity

There were a couple sampler issues found during audits. At Trapper Creek (TRCR1) the roof was leaking and water was running down the inlet tube and was dripping onto the sampler. A tube of silicon was purchased and applied to the roof around the inlet to mitigate this issue. The second issue was at Great Sand Dunes (GRSA1) where two sampler inlet stacks (channels B & C) were not seated into the sampler. The tubes were seated after the audit. The site operator and UCDavis were notified of the issue. UCDavis subsequently sent a note to all network operators to check that their samplers' inlet tubes were properly seated.

Summary

Ten IMPROVE sites were audited in 2022. All flow rate, temperature, time, and vacuum tests passed for all modules. There were problems with a leaking roof at Trapper Creek and inlet tubes not inserted at Great Sand Dunes.