Overview of 2021 IMPROVE Sampler Technical System Audits

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CIRA

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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/2020/02/IMPROVE-QAPP-Signed_3_2016_updated.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 date and time, vacuum pressure, temperature, and the flow rate of each module. The sampler stand is checked for safety, structural integrity and that it is 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 to ensure 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 (CSU) 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 those who completed the training now conduct audits for their respective states/regions. Since 2016, an audit has been conducted at all but 11 IMPROVE sites in the U.S.; the unaudited sites consist of five sites in Alaska, two sites in Hawaii, Montgomery, AL, Atlanta, GA, and Carlsbad Caverns in New Mexico. It is expected that the remaining sites will be audited within the next two years. Sites at the U.S. Virgin Islands and Egbert, Canada have not been audited since 2016. Figure 1 below shows a map of the IMPROVE sites. The year in which each site was audited is color coded on the map. There were no audits conducted during 2020 by CIRA personnel because CIRA/CSU did not allow travel during the pandemic. However, auditors from Colorado and Missouri did conduct a few audits.

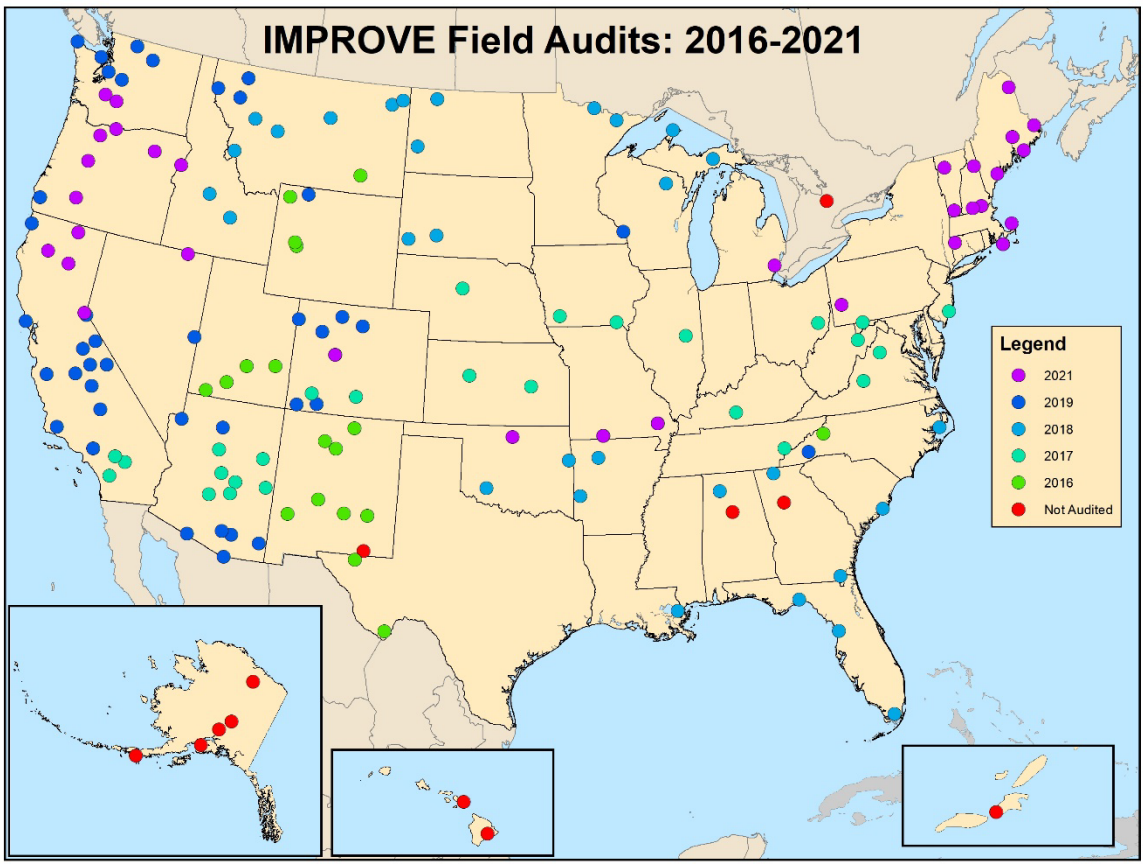

Figure 1. Map of all IMPROVE sites. Shown are the year each site was audited by CIRA personnel and the unaudited sites.

Results

During 2021 CIRA personnel audited 34 sites. The results of these audits are discussed in the following sections.

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 for modules A, B, and C and across a critical orifice/needle valve for module D. A calibration curve relates these measured pressure drops 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 use 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 calculated using the following equation:

$$failure\ when: \frac{|22.8 - audit\ device\ flow\ rate|}{22.8} \times 100\% > 10\%$$

Module D fails the flow rate test if the audit device flow rate differs from its nominal flow rate by more than 10% as calculated using the following equation:

$$failure\ when: \frac{|16.9 - audit\ device\ flow\ rate|}{16.9} \times 100\% > 10\%$$

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

$$failure\ when: \frac{|sampler\ flow\ rate - audit\ device\ flow\ rate|}{audit\ device\ flow\ rate} \times 100\% > 10\%$$

Results of audit flow rate checks from the 2021 audits are shown in Tables 1-4 and Figures 2-5. These figures show the allowed deviation from nominal and measured flow rate (red lines), and a 1:1 line between the audit device and the IMPROVE sampler flow rates.

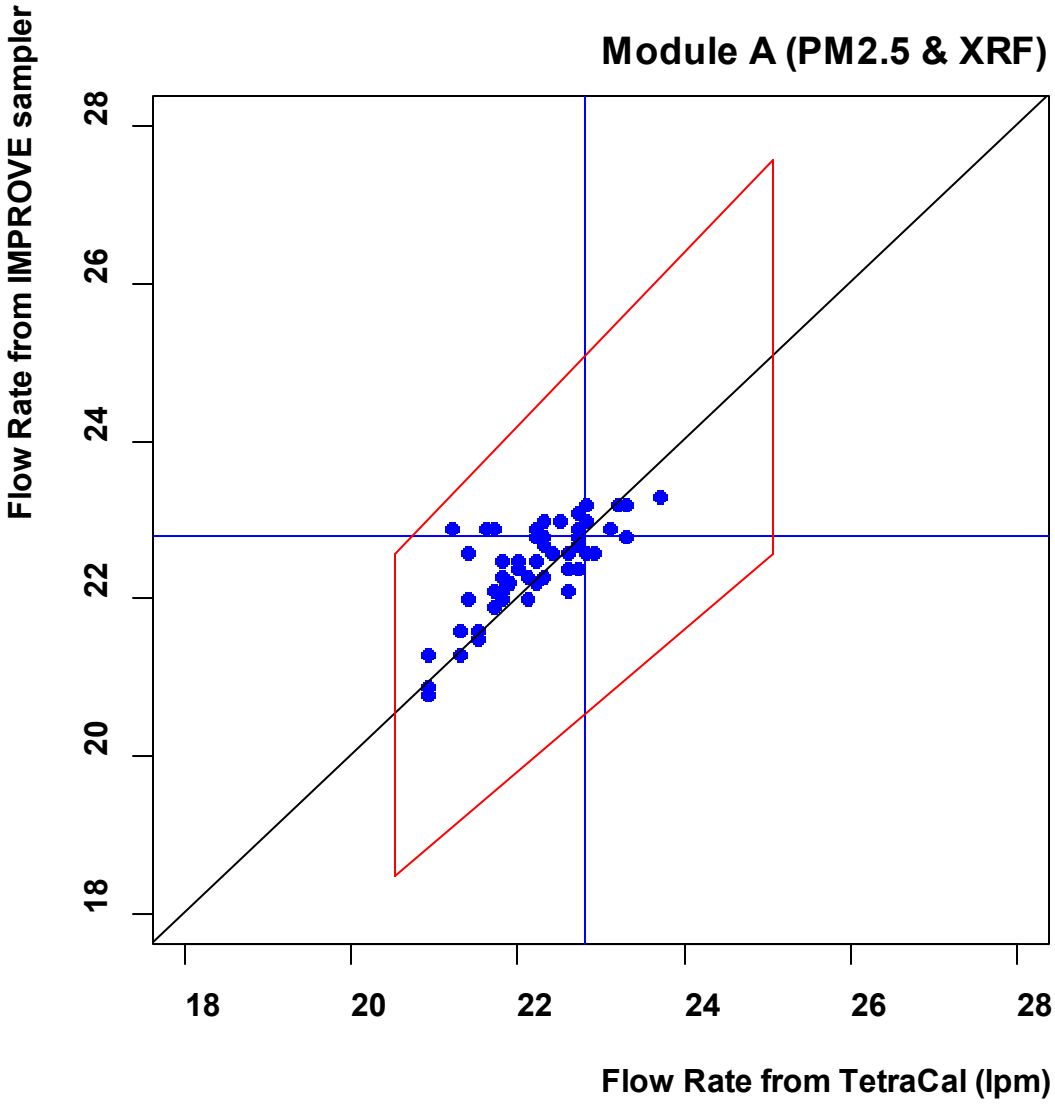

Figure 2. Flow rate comparison between IMPROVE sampler and audit devices.

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. The "Nominal difference" is the percent difference between audit device and nominal sampler flow rate (22.8 lpm).

Statistic	Audit (lpm)	IMPROVE (lpm)	% difference	Nominal difference
Min.	20.90	20.80	0.0000	0.000
1st Qu.	21.73	22.12	0.8686	1.425
Median	22.20	22.55	1.3606	2.632
Mean	22.17	22.43	1.6667	3.208
3rd Qu.	22.68	22.88	2.2198	4.715
Max.	23.70	23.30	8.0189	8.333

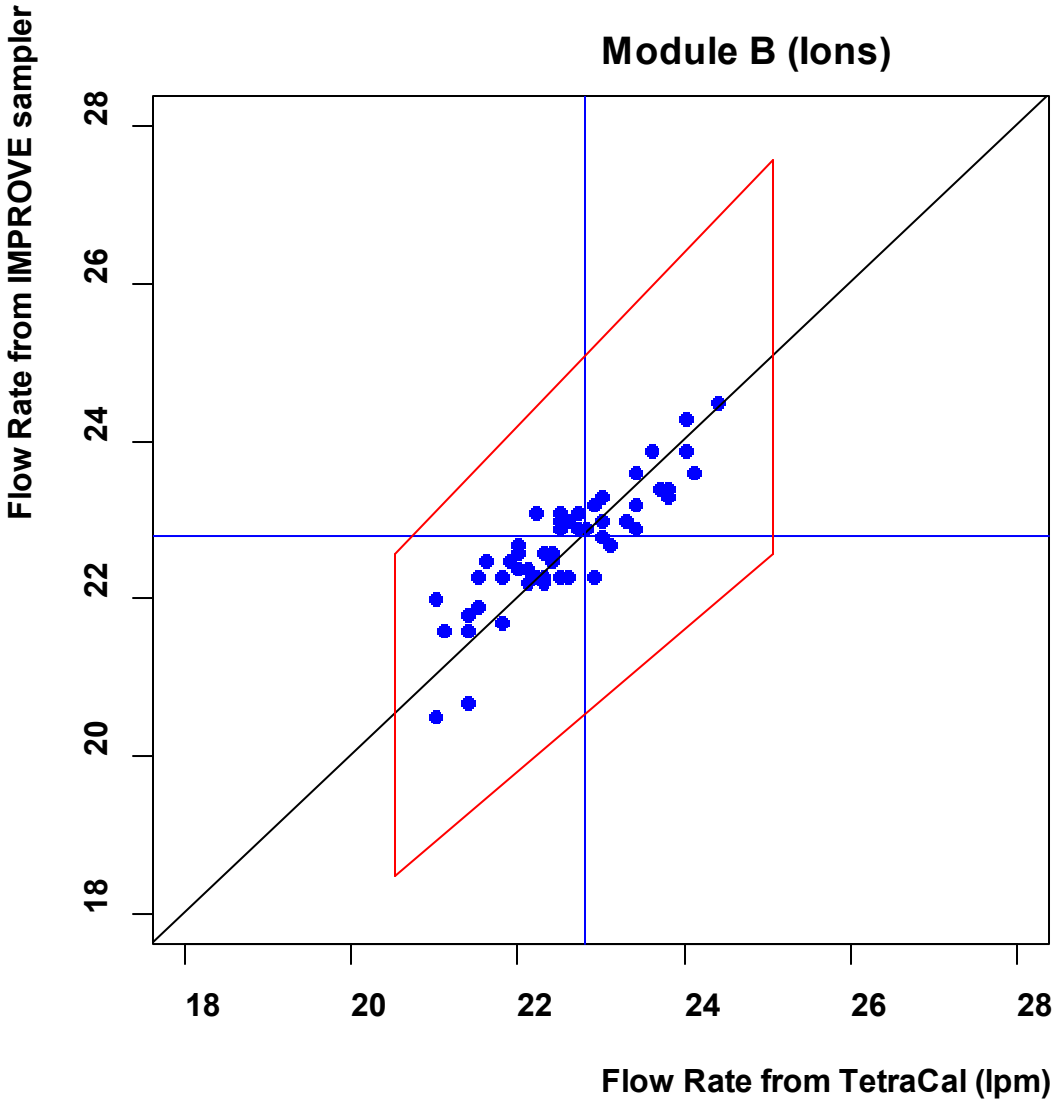

Figure 3. Flow rate comparison between IMPROVE sampler and audit devices.

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. The "Nominal difference" is the percent difference between audit device and nominal sampler flow rate (22.8 lpm).

Statistic	Audit	IMPROVE	% difference	Nominal difference
Min	21.00	20.50	0.0000	0.000
1st Qu	22.00	22.30	0.8724	1.316
Median	22.50	22.65	1.3453	2.632
Mean	22.54	22.69	1.6353	3.143
3rd Qu.	23.00	23.10	2.2009	4.386
Max.	24.40	24.50	4.7619	7.895

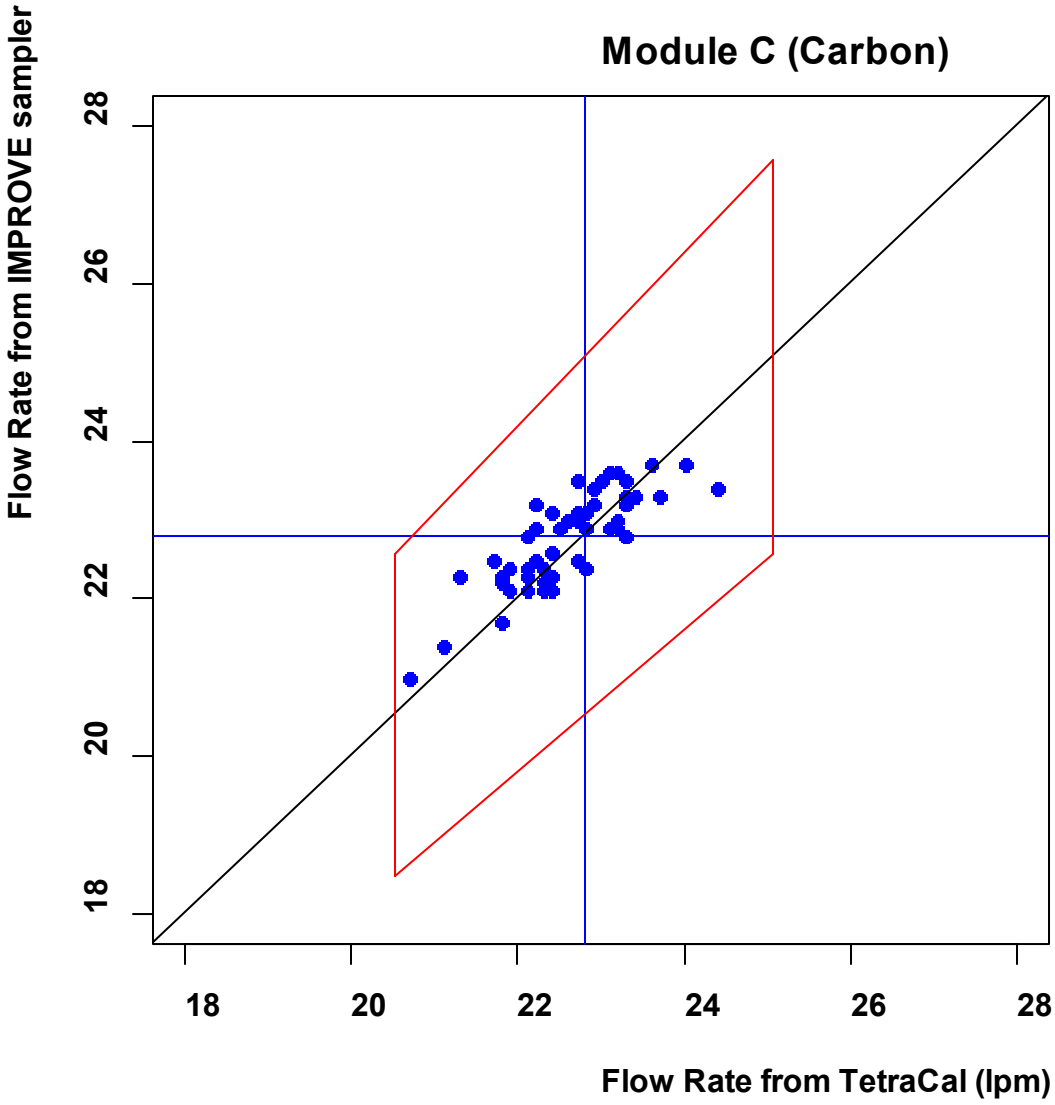

Figure 4. Flow rate comparison between IMPROVE sampler and audit devices.

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 IMPROVE sampler. The "Nominal difference" is the percent difference between audit device and nominal sampler flow rate (22.8 lpm).

Statistic	Audit	IMPROVE	% difference	Nominal difference
Min	20.70	21.00	0.0000	0.000
1st Qu	22.15	22.40	0.8658	1.316
Median	22.60	22.90	1.3514	2.193
Mean	22.59	22.78	1.5995	2.464
3rd Qu	23.10	23.20	2.1552	3.289
Max.	24.40	23.70	4.6948	9.211

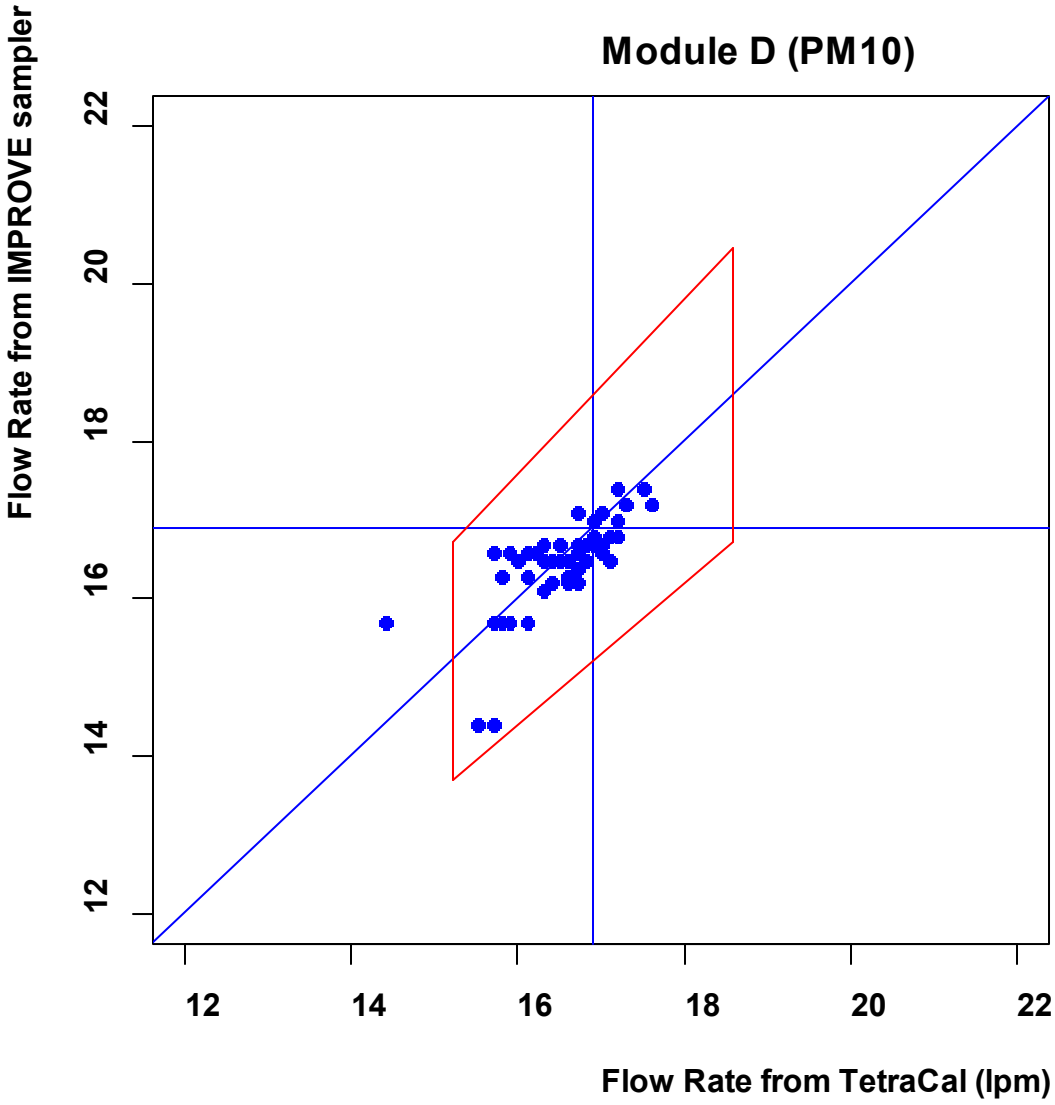

Figure 5. Flow rate comparison between IMPROVE sampler and audit devices.

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 IMPROVE sampler. The "Nominal difference" is the percent difference between audit device and nominal sampler flow rate (16.9 lpm).

Statistic	Audit	IMPROVE	% difference	Nominal difference
Min	14.40	14.40	0.0000	0.000
1st Qu.	16.10	16.30	0.6098	1.183
Median	16.70	16.50	1.7647	1.775
Mean	16.53	16.46	2.1028	3.031
3rd Qu.	16.90	16.70	2.4691	4.734
Max.	17.60	17.40	9.0278	14.793

Sampler Vacuum

The vacuum pressure is measured by starting the module's pump, closing a ball valve, which prevents air flow through the system, and subsequently reading the orifice pressure transducer. This measurement is labeled vac on the TSA form. It is indicative of pump strength, air leakage through the system, and proper transducer operation. The TSA test fails if the vac pressure is greater than 3.5psi; vacuum pressures below 1psi are not uncommon. The TSA measurement is different from the MaxORI readings obtained during routine sample changes because the TSA test measures pressure drop through the entire sample train while during routine sample changes the pressure drop is measured from the solenoids to the pump. There were instances when the IMPROVE MaxORI passed, while the TSA vac test failed. An overview of these results is given in Table 5.

Temperature

The IMPROVE sampler temperature is monitored to accurately calculate sampler flow rates. During TSAs the sampler temperature is compared to the NIST traceable temperature of the tetraCal. The TSA temperature fails if the temperature of the sampler and the tetraCal differ by more than 10 ˚C. There were no temperature failures for the 2021 TSAs.

Sampler time

The sampler time is compared to cell phone time and adjusted if the difference is greater than 5 minutes. There have been no failures of the sampler clock at any site since the new controllers were installed.

Sampler Integrity and Siting Criteria

The TSAs ensure the sampler stands are maintained such that routine access does not pose a risk to the operator, the IMPROVE modules are protected from direct sunlight, and sample changes are protected during inclement weather. The IMPROVE modules are checked to ensure they are fastened securely to the structure, and inlet stacks are seated properly into each module. Electrical wiring and connections are visually examined and photos are taken. Problems are reported to the proper regional personnel and noted in the TSA notes section. The IMPROVE sampler siting criteria are thoroughly explained in SOP 126 (http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/) and are not reiterated here. In general, the TSA process notes and documents site properties which could impede sampling aerosol of a regional background nature. Impediments include significant local sources of particulates (automotive, wood smoke, dust, etc.) or obstructions such as trees or buildings which could hamper air flow to the sampler inlet. Problems are reported on the TSA form and the site operator is notified if corrective action is needed (trees trimmed or brush cleared).

Summary

Thirty-two IMPROVE sampling sites were audited during 2021. Three of these sites, Three Sisters, Bliss State Park, and Lyebrook did not have the D channel flow rate checked because the stack could not be removed. The stack could not be removed at Three Sisters because an active wasp nest was present, at Bliss State Park (a temporary site) the stack physically could not be removed, at Lyebrook there was a severe thunderstorm with lightning and access to the roof was extremely difficult. Trees were found to be encroaching at Mt Hood and at Lyebrook (tree trimming was discussed with the site operators). Leak checks of at least one Module failed at 8 of these sites. The flow rate failed at White River. Table 5 below summarizes these results.

Table 5 Audit Result Overview

Site	Date	Issues/Notes	Follow up Required	Priority (H,M,L)	Actions Taken
Jarbidge Wilderness, NV	7/20/2021				
Hells Canyon, OR	7/21/2021	All Pass			
Starky, OR	7/22/2021	All Pass			
Columbia River Gorge	7/23/2021	Module A leak check fail	Y	L	report to UCD
White Pass, WA	7/26/2021	All Pass			
Mt Rainier, WA	7/27/2021	All Pass			
Mt Hood, OR	7/28/2021	All modules pass; trees are encroaching on inlets	Y	L	report to USFS
Three Sisters, OR	7/29/2021	Could not audit D channel because of wasps; everything else passed			
Crater Lake, OR	8/2/2021	All Pass			
Lava Beds, CA	8/2/2021	All Pass			
Trinity, CA	8/3/2021	All Pass			
Lassen Volcano, CA	8/5/2021	All Pass			
Bliss State Park. CA	8/5/2021	Could not remove D channel stack; everything else passed; temp site			
White River, CO	8/8/2021	D module flow rate failure measured 14.4 should be 16.9	Y	M	report to UCD
Southern Great Plains, OK	10/19/2021	Module D leak check fail.	Y	L	report to UCD
Hercules Glades (Rueter), MO	10/20/2021	Module A leak check fail			
Mingo NWR, MO	10/21/2021	All Pass			
Pittsburg, PA	10/25/2021	All Pass. Roof is rotted away			
Mohawk Mountain, Conn	10/26/2021	D module leak check failure	Y	L	report to UCD
Marthas Vineyard, MA	10/28/2021	All Pass			
Cape Cod, MA	10/29/2021	All Pass			
Casco Bay, ME	11/1/2021	Modules A&B leak checks failed	Y	L	report to UCD
Acadia, ME	11/2/2021	Module B leak check failed	Y	L	report to UCD
Penobscot, ME	11/2/2021	All Pass			
MooseHorn NWR, ME	11/3/2021	All Pass			
Presque Isle, ME	11/4/2021	Modules A&C leak checks failed	Y	L	report to UCD
Great Gulf, NH	11/8/2021	Modules B&C leak checks failed	Y	L	report to UCD

Proctor Maple Research, VT	11/9/2021	All Pass			
Londonderry, NH	11/10/2021	All Pass			
Pack Monadnock, NH	11/10/2021	All Pass			
Lybrook, VT	11/12/2021	Modules A,B and C passed. Trees encroaching on inlets.	Y	M	report to USFS
Detroit, MI	11/15/2021	All Pass			