UC Davis Status Report to IMPROVE Steering Committee

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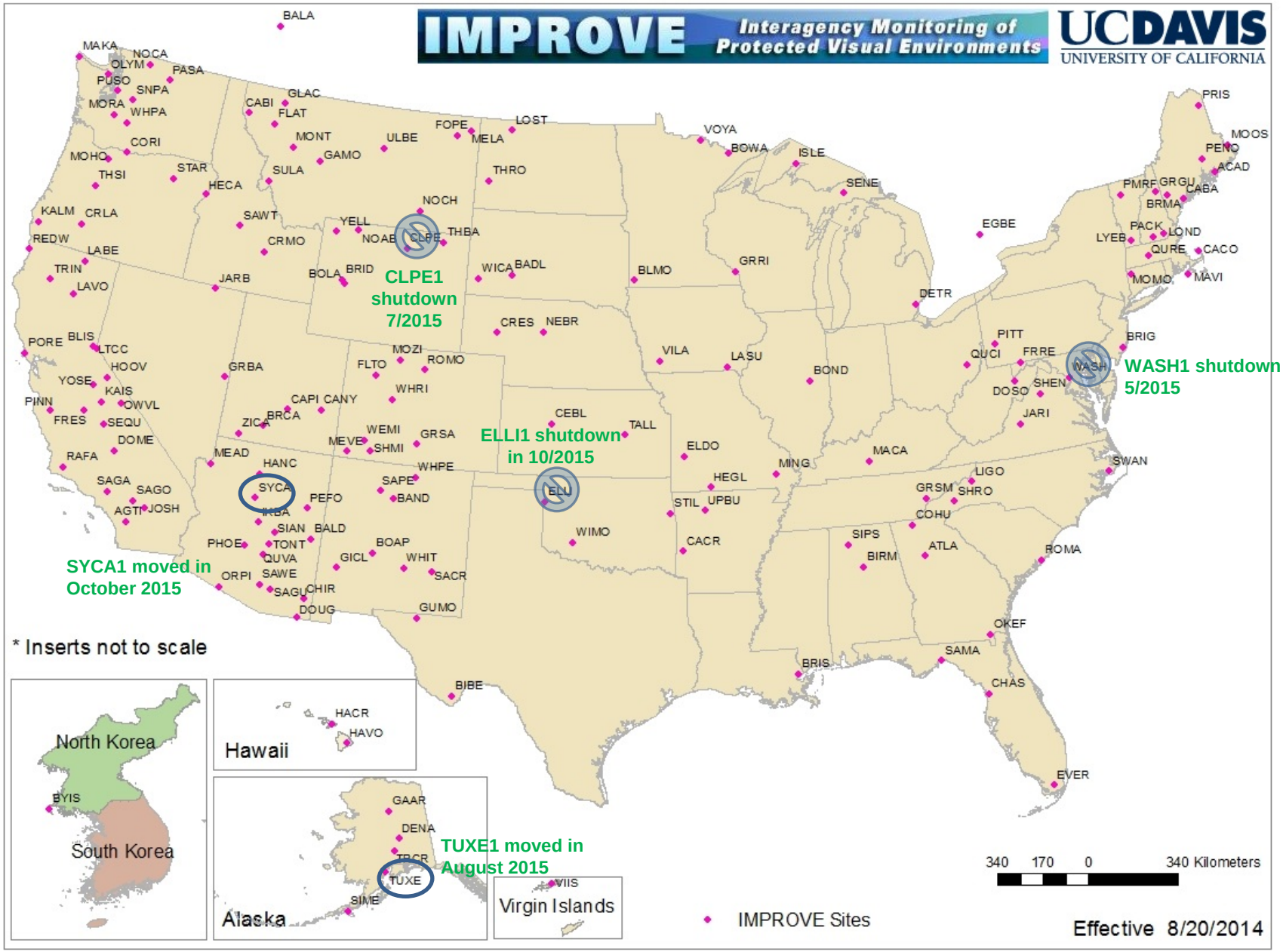
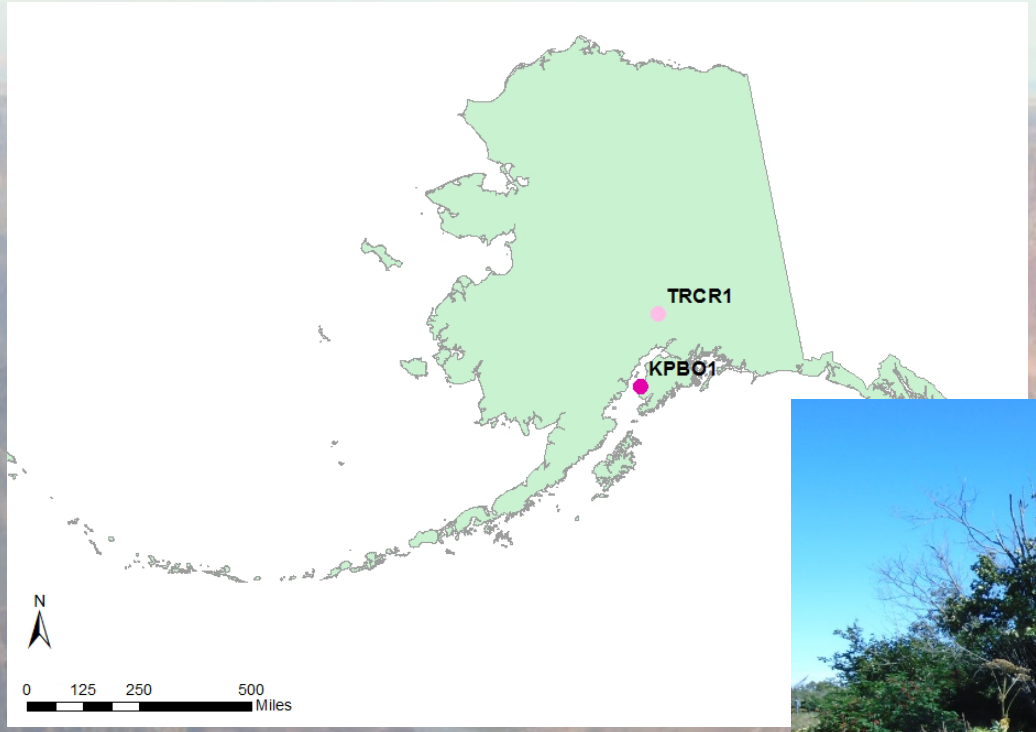
University of California, Davis
Presented at Grand Canyon National Park, AZ
November 3, 2015

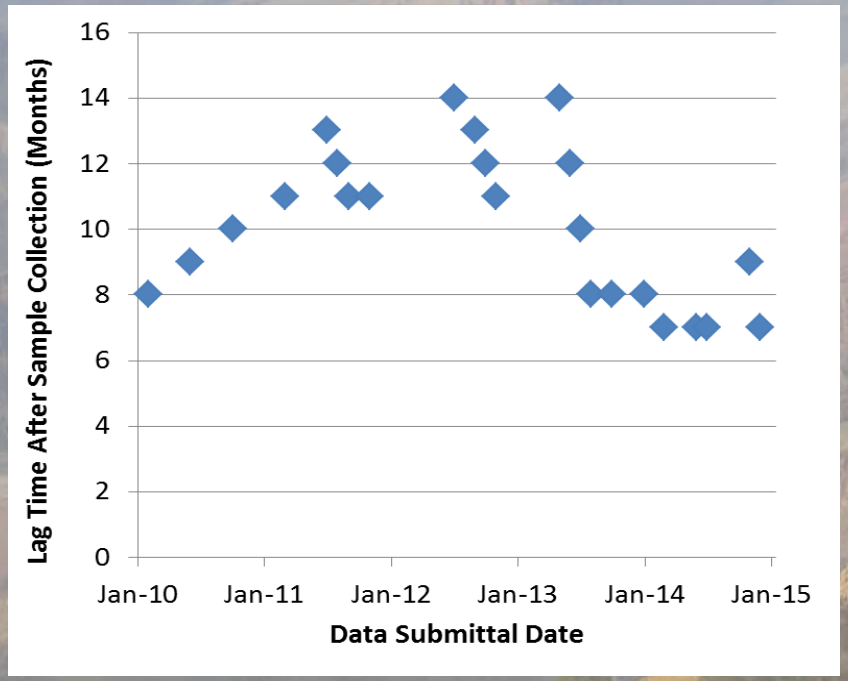

IMPROVE
Interagency Monitoring of Protected Visual Environments
UCDAVIS
UNIVERSITY OF CALIFORNIA
CLPE1 shutdown 7/2015
ELLI1 shutdown in 10/2015
WASH1 shutdown 5/2015
SYCA1 moved in October 2015
TUXE1 moved in August 2015
* Inserts not to scale
North Korea
South Korea
Hawaii
Alaska
Virgin Islands
340 170 0 340 Kilometers
IMPROVE Sites
Effective 8/20/2014

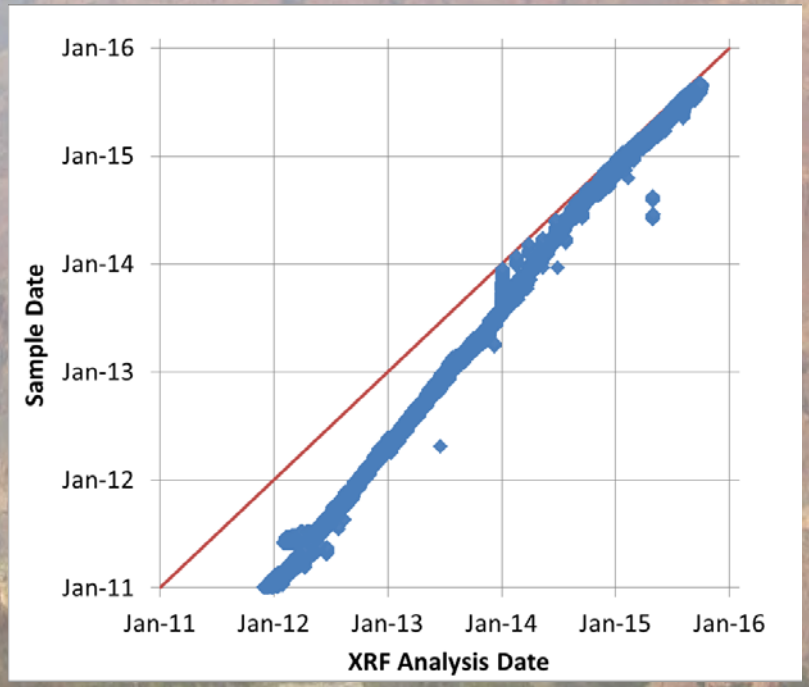
Kenai Peninsula Borough (KPBO1), AK
Replaces Tuxedni Site
August 2015



Data Submittal Status

- Data have been reported through March 2015
  - Data deliveries are 7-10 months after collection for past couple years
  - Data are being delivered 2-3 weeks after receipt of analysis data
- XRF analysis occurs within a month of filter receipt
  - Even with FTIR analysis performed prior to XRF





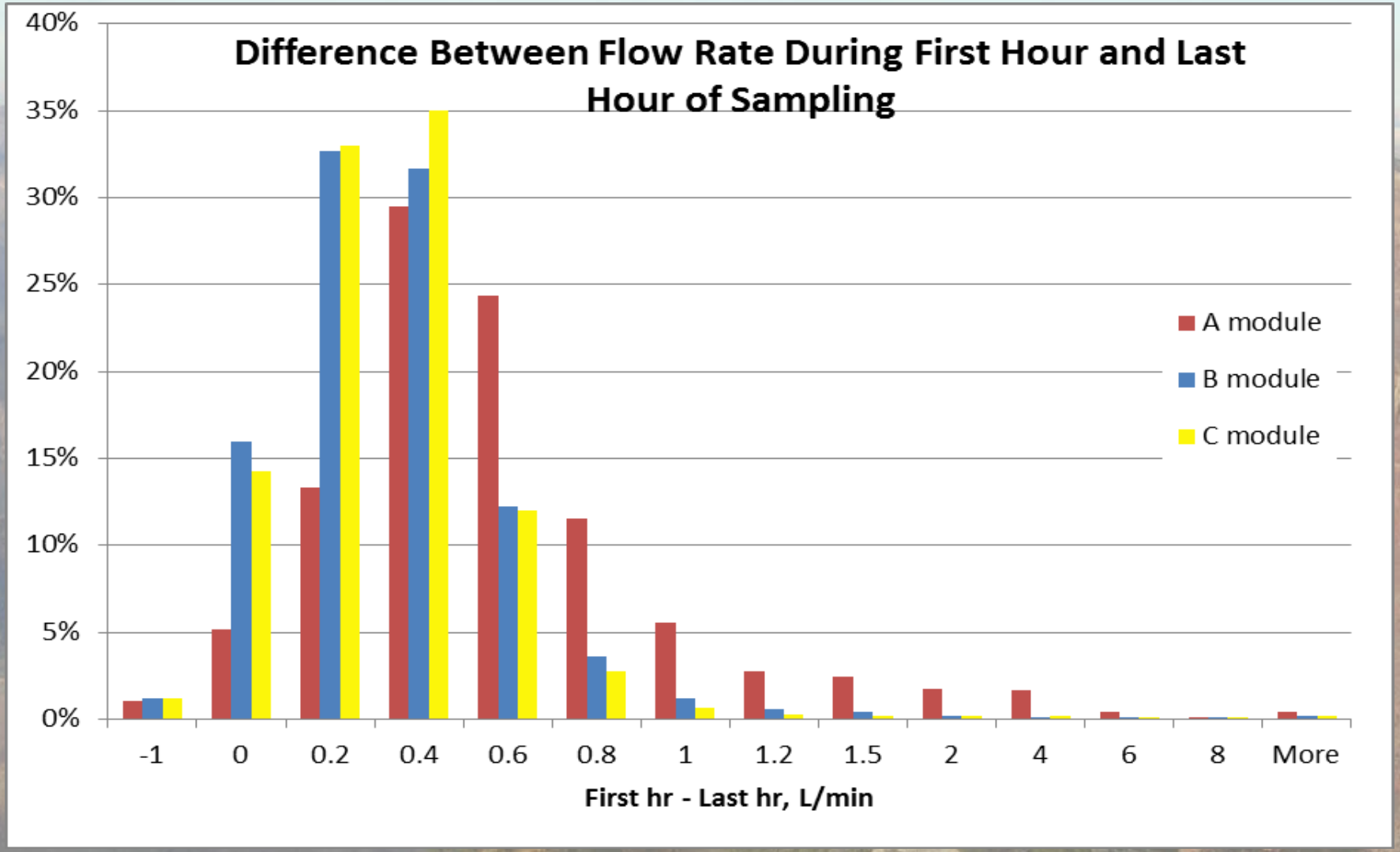
Data Resubmittal: 2005 thru 2013

- Re-delivered to CIRA/FED in April 2015
- Re-delivered back to 2007 on AQS
  - Having difficulties with data prior to 2007
- TOR artifact corrections by field blanks (FB), not backup (secondary) filters
- Calculates filter light absorption (Fabs from HIPS) using new calibration algorithm. Replaces LRNC
- Applies corrected temperature equation to calculate flow rates (usually <1% change)
- Corrects flow rates for some low-concentration samples incorrectly flagged as clogged (CL)
- New formulations for uncertainty and MDL based on collocated measurements
- Three Data Advisories summarizing these changes were submitted and posted

Reasons for Sample Losses

Year	ABCD recovery	Operator no-show	Bad installation	Equipment problem	Power outage	Destroyed/ No filter
2005	93%	1.3%	1.1%	2.9%	0.9%	0.8%
2006	92%	1.9%	1.0%	2.8%	1.4%	0.9%
2007	92%	2.1%	1.0%	2.5%	1.4%	1.0%
2008	90%	2.1%	1.3%	4.5%	1.5%	0.6%
2009	91%	1.9%	1.1%	3.6%	1.8%	0.6%
2010	92%	2.3%	0.9%	3.1%	1.4%	0.5%
2011	91%	2.4%	0.9%	3.1%	1.8%	0.6%
2012	94%	1.9%	0.9%	1.6%	1.4%	0.6%
2013	94%	2.0%	1.1%	1.5%	1.2%	0.5%
2014	94%	2.3%	1.2%	1.0%	1.1%	0.3%

Passive Flow Control



Lightning Damage

- # and dates of equipment shipments following electrical storm activity since 2007 for sites with more than two incidents of equipment damage
- Would like to move forward with lightning protection for NOAB in 2016

NOAB1	18	8/8/07	8/21/07	6/23/09	9/1/09	9/30/09	6/15/10	7/19/11	7/26/11	8/23/11	8/15/12
		7/18/13	10/17/13	7/16/14	8/7/14	11/12/14	5/21/15	8/11/15	9/2/15		
SULA1	10	8/11/11	9/20/11	5/8/12	8/21/12	11/13/12	9/18/13	7/16/14	8/13/14	11/7/14	5/20/15
SHRO1	8	7/11/07	8/21/07	10/3/07	6/9/09	7/26/11	1/17/12	7/31/12	7/14/15		
COHU1	8	8/6/08	6/23/09	8/4/09	8/17/10	6/23/11	4/30/13	7/5/13	9/10/14		
KAIS1	7	3/26/07	7/13/07	9/21/07	5/19/09	9/22/11	7/22/14	9/2/15			
UPBU1	6	4/1/08	1/6/09	12/3/09	5/18/10	4/18/12	4/9/14				
GAMO1	5	6/26/07	8/7/07	8/10/10	7/24/12	9/26/12					
VIIS1	5	7/25/07	9/10/08	7/23/09	11/24/09	11/26/13					
FRRE1	4	11/27/07	6/23/09	6/1/10	7/26/11						
GUMO1	4	7/3/07	7/16/07	7/13/10	9/28/11						
CACR1	3	5/20/08	8/18/10	10/18/11							
CHIR1	3	6/16/09	8/25/09	8/18/10							
VOYA1	3	8/26/09	5/23/12	6/5/12							
WHRI1	3	8/20/08	1/15/09	7/13/11							

Regional Haze Rule (RHR) Completeness Criteria

- RHR requires for all modules:
  - >75% annual recovery
  - >50% recovery in each quarter
  - <11 consecutive missed samples
- Number of Sites failing RHR completeness criteria
  - 2008 13 sites
  - 2009 11 sites
  - 2010 9 sites
  - 2011 7 sites
  - 2012 6 sites
  - 2013 5 sites Best in recent history – Party!!!
  - 2014 4 sites Best in recent history – Party!!!
  - 2015 We've already lost 5

Sites Not Meeting RHR Criteria

2014

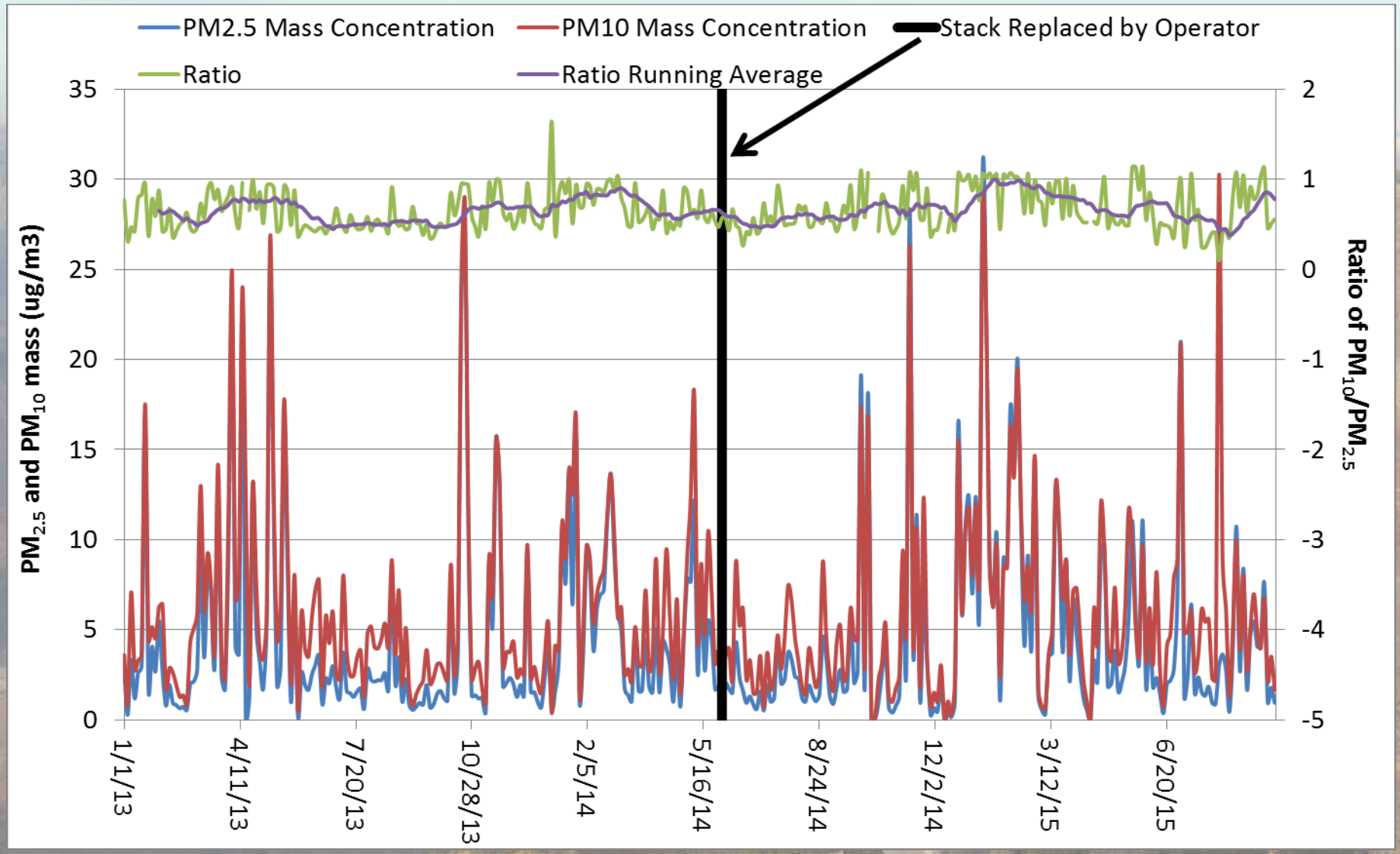
- Bosque Del Apache, NM (FWS, IMPROVE)
  - Failed to meet annual completeness criteria by losing 32 samples
  - Combination of lost boxes of sampling supplies (7 samples), equipment problems (5), and missed sample changes (16)
- Sierra Ancha, AZ (FS, IMPROVE)
  - Failed to meet annual completeness criteria by losing 36 samples
  - No backup operator at the site, and primary operator has many other responsibilities
- Atlanta, GA (EPA, Protocol, Carbon-only site)
  - Failed to meet the quarterly completeness criteria
  - Site operator quit without notifying us and we couldn't reach anyone at the site for weeks
- Monture, MT (FS, IMPROVE)
  - Data review suggested a problem at the site and follow-up led to discovery of an obstruction in the inlet that was left over by our maintenance crew. Affects data from 7/31/14 till 5/4/2015.
  - Implemented immediate review of sulfur/sulfate ratios

Sites Not Meeting RHR Criteria

2015

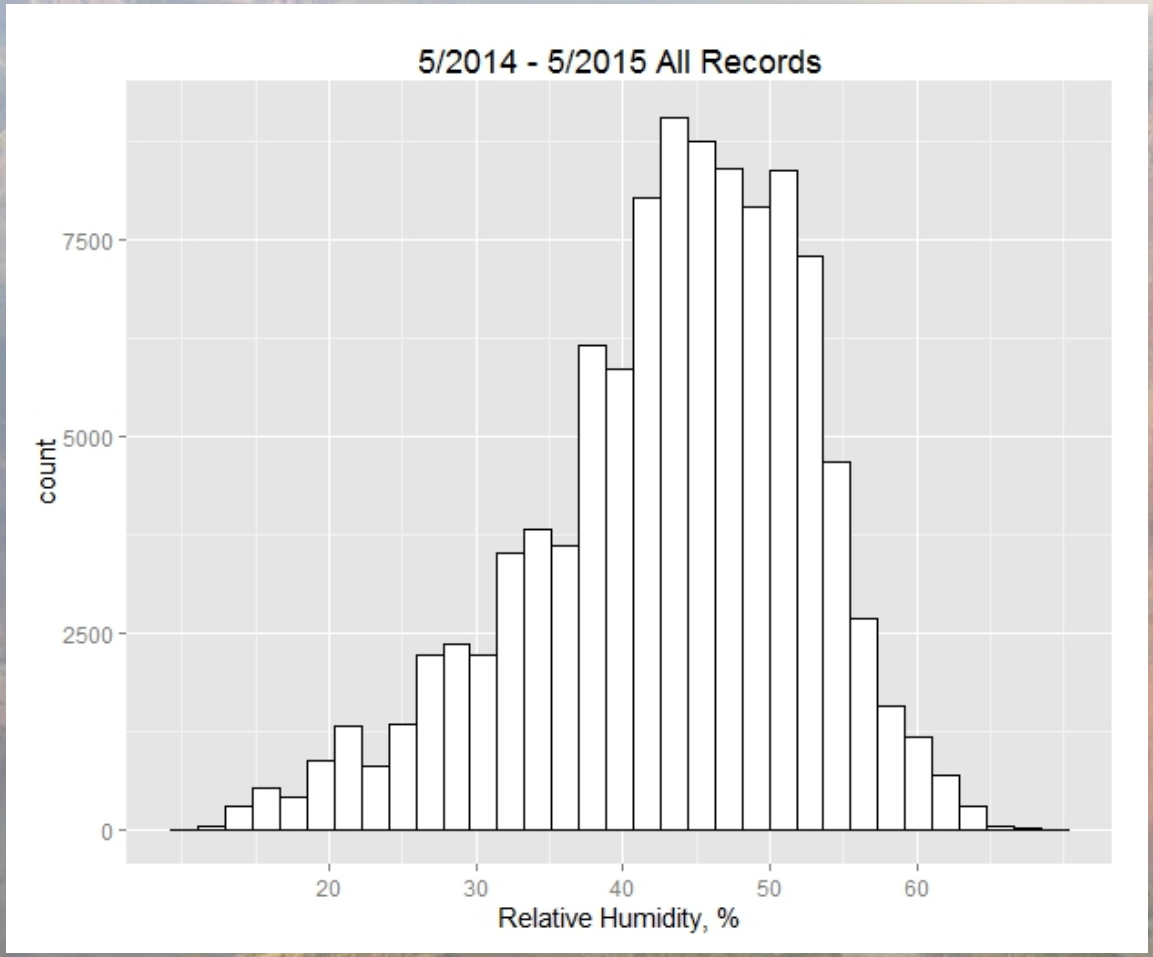
- Monture, MT (FS, IMPROVE)
  - Obstruction in the inlet was removed on 5/4/2015
- Sierra Ancha, AZ (FS, IMPROVE) ALSO LOST IN 2014
  - Failed to meet annual completeness criteria by losing 36 samples
  - No backup operator at the site, and primary operator has many other responsibilities
- Pittsburgh, PA (EPA, Protocol, Carbon-only site)
  - Failed to meet the quarterly completeness criteria
  - Sampler offline for construction from 5/9/15 to 8/10/15
- Sula Peak, MT (FS, IMPROVE)
  - On August 28, 2015, maintenance crew found the A module cyclone throat loose in the cyclone
  - Shift in $PM_{2.5}/PM_{10}$ ratio suggests the throat fell out between December 28th and 31st, 2015
- Trinity Alps, CA (FS, IMPROVE)
  - Operator contract expired in July 2015. No operator since then.

Hawaii Volcanoes D Module Problem



Relative Humidity in Lab

- RH is within EPA weighing criteria of 30-40% about 20% of the time



Sampler Electronics Redesign

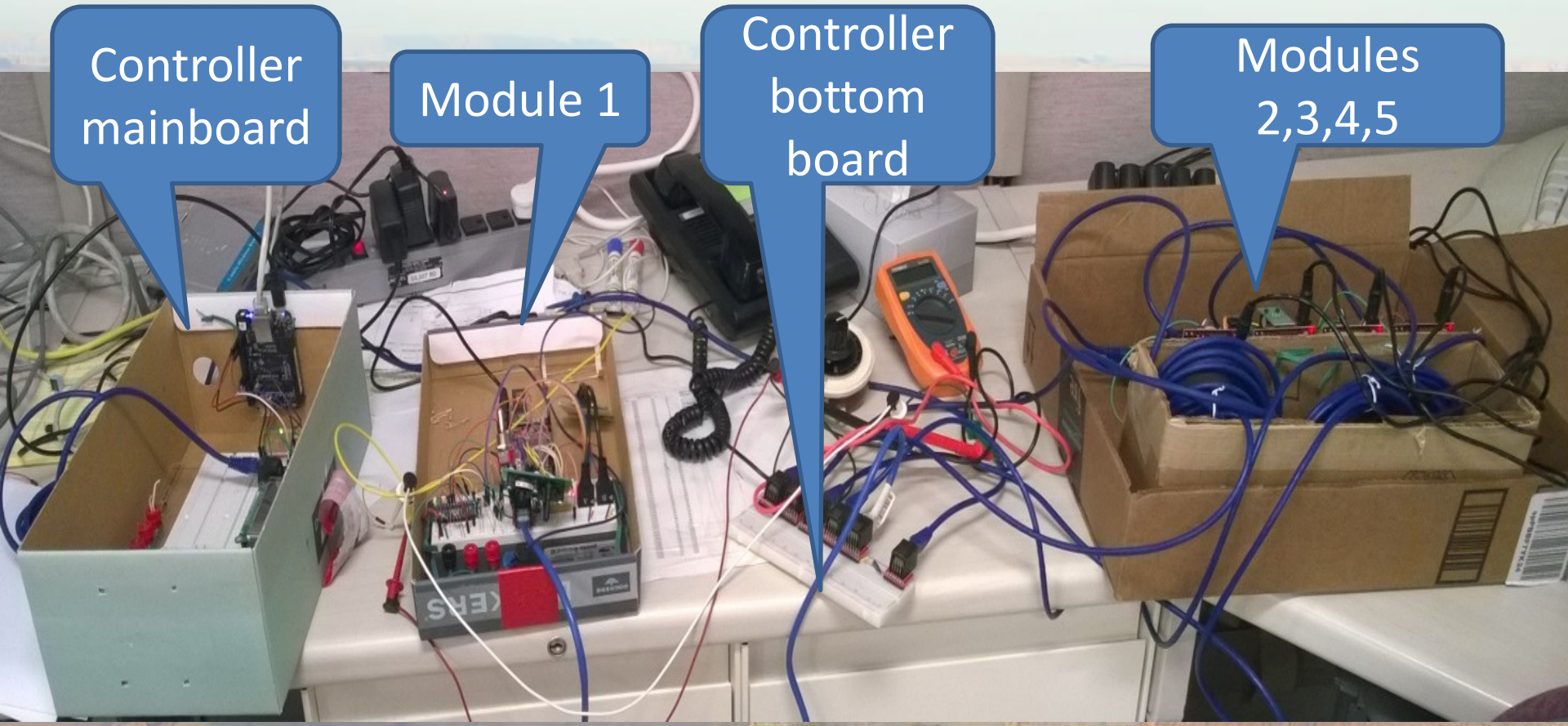
- Progress on this project was inadequate over the last two years, so more engineers were assigned to get the project back on track
  - Jose Mojica – Project management and mechanical design
  - Brian Trout – Programming (100% for last year)
  - Chris Wallis – Component testing
- Excellent progress was made this year
  - Field-ready prototype will be operating on roof by end of 2015
  - First systems will be installed at easily accessible sites in Spring 2016

Sampler Electronics Redesign

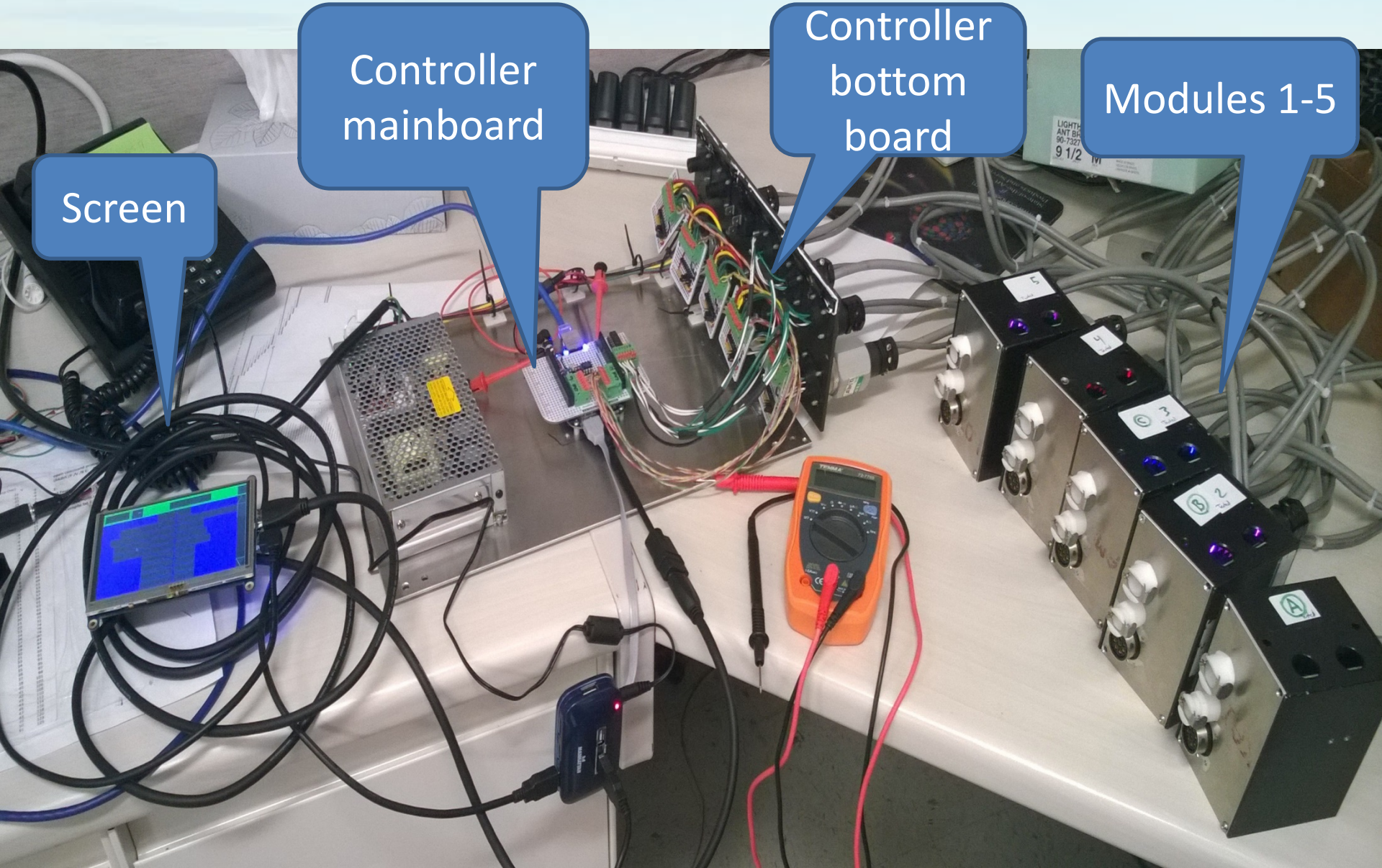
Status

- Module electronics boxes (e-boxes)
  - 2nd round of prototype boards manufactured
  - Data acquisition code complete
- Controller
  - Completed design and manufactured 1st round of main board
    - Main board is designed around a Beaglebone Black hobbyist board
  - Completed design and manufactured 1st round of bottom connector board
  - Completed design of auxilliary board, will be manufactured in next week
  - Need to complete designs of back connector plane and power supply boards
  - 7” touch screen display selected
  - Minimum viable code is almost complete. In the process of
    - Making aesthetic changes to user interface
- Hardware casing designed
  - Two prototypes have been machined and assembled in-house

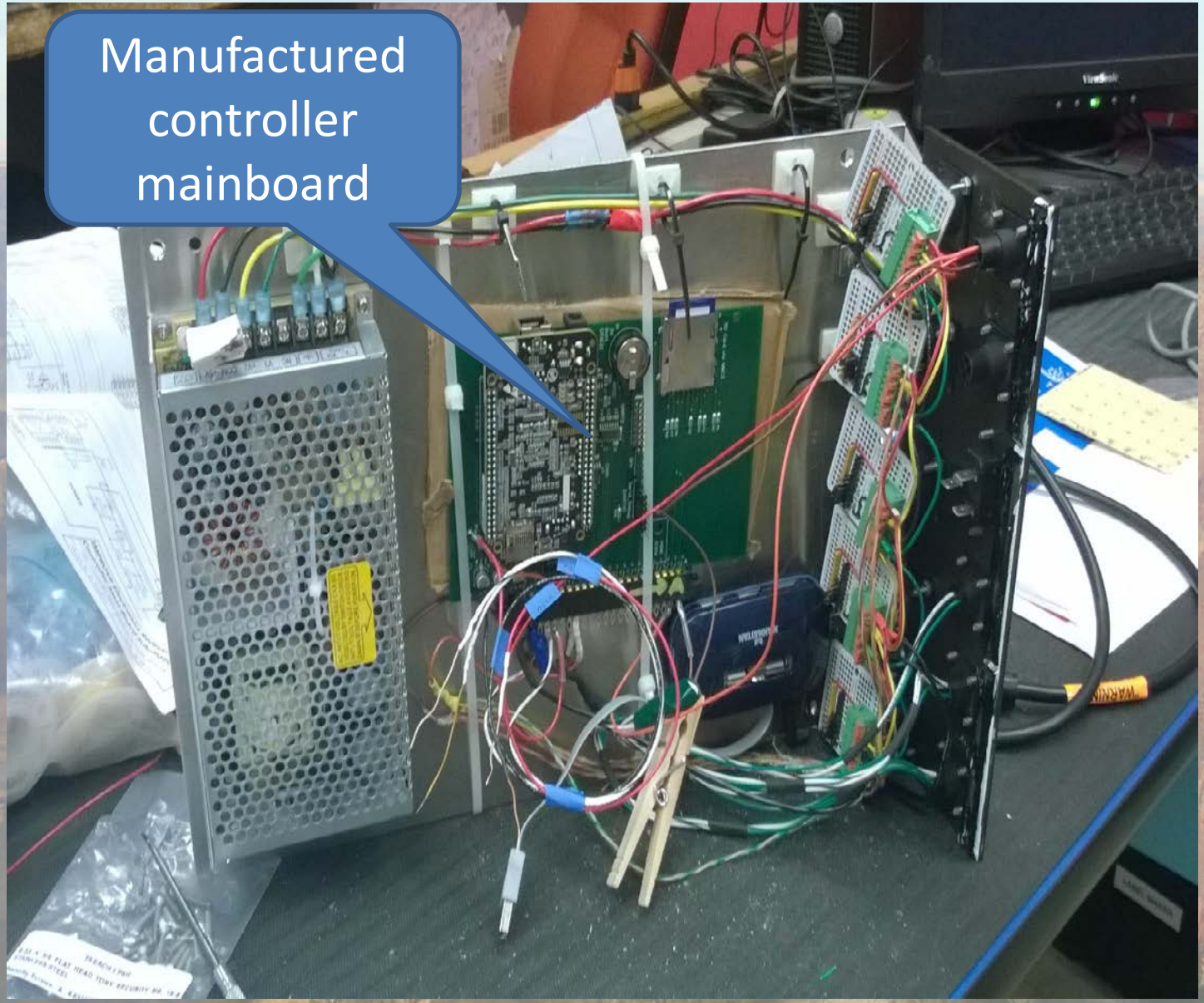
Shoebox Controller: December 2014



Proto-Controller V1: May 2015



Proto-Controller V2: August 2015




Menu
Settings
Quick Checks
Equipment Change
Advanced Menu
Page:
MENU1

Data Management Transition – Legacy System

- 2 large FoxPro applications, SQL database, spreadsheets, scripts, and macros
- LabApp and SWAP (FoxPro)
  - Last version discontinued in 2007
  - Difficult to find developers to support
  - No support for newer operating systems/hardware
  - Rigid and convoluted code that is difficult to modify
- Database warped to work with existing code
  - Wide format matching FoxPro outputs
  - Numerous workarounds for things like collocated sites
- Excel spreadsheets galore!
  - Difficult to maintain and track
  - Too easy to accidentally mess up the spreadsheet

Data Management Transition - Goals

- Produce a more maintainable, secure, flexible, and supported system
  - Eliminate any dependencies on FoxPro
  - Redesign the database
  - Build professionally engineered software using modern technologies
- Provide tools to the internal team for lab, network, and data management; outreach; and analysis

Data Management Transition – New System

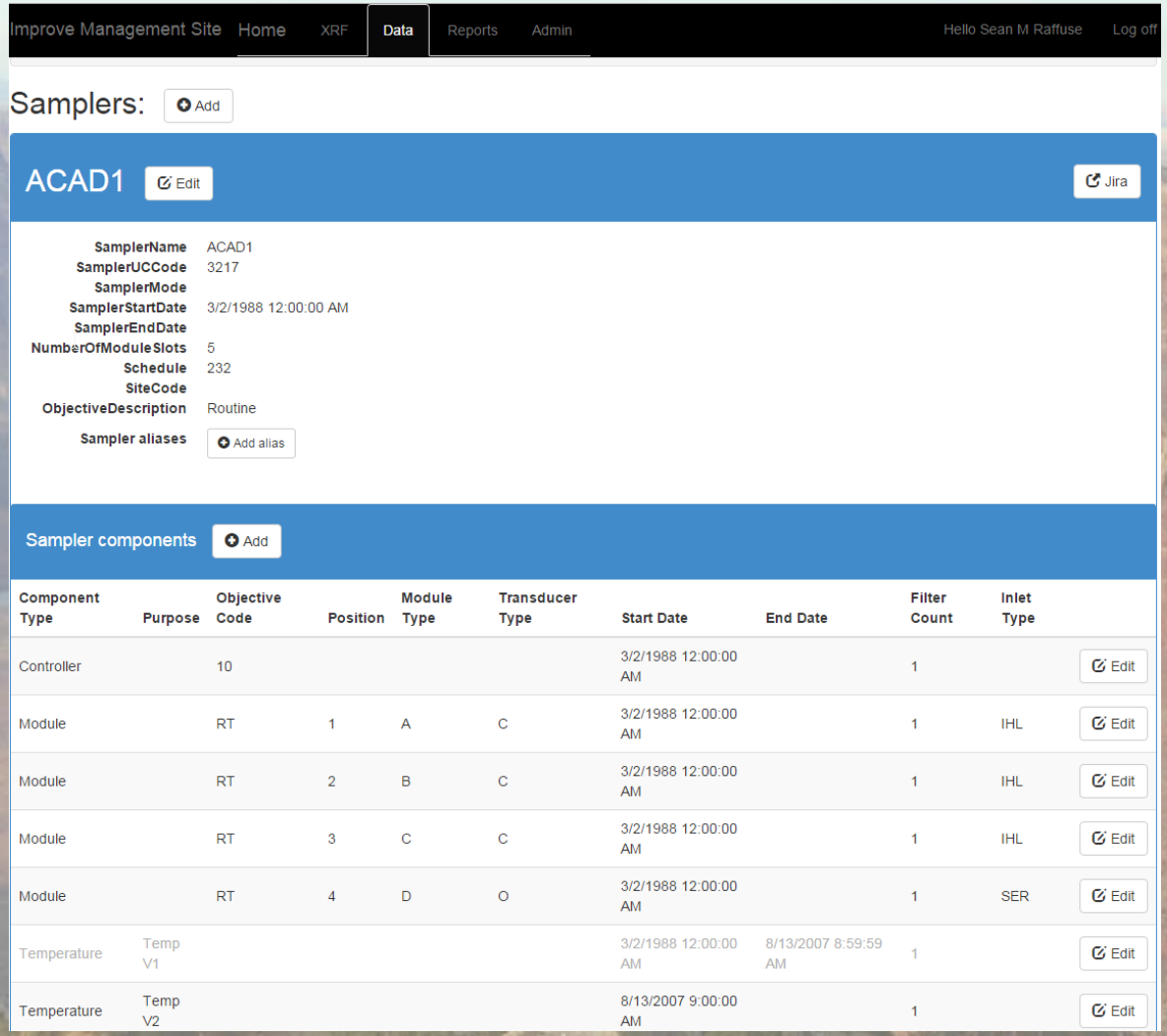
- New, normalized SQL database
- .NET applications for laboratory management
- R Shiny applications for data visualization

Data Management Transition – Timeline

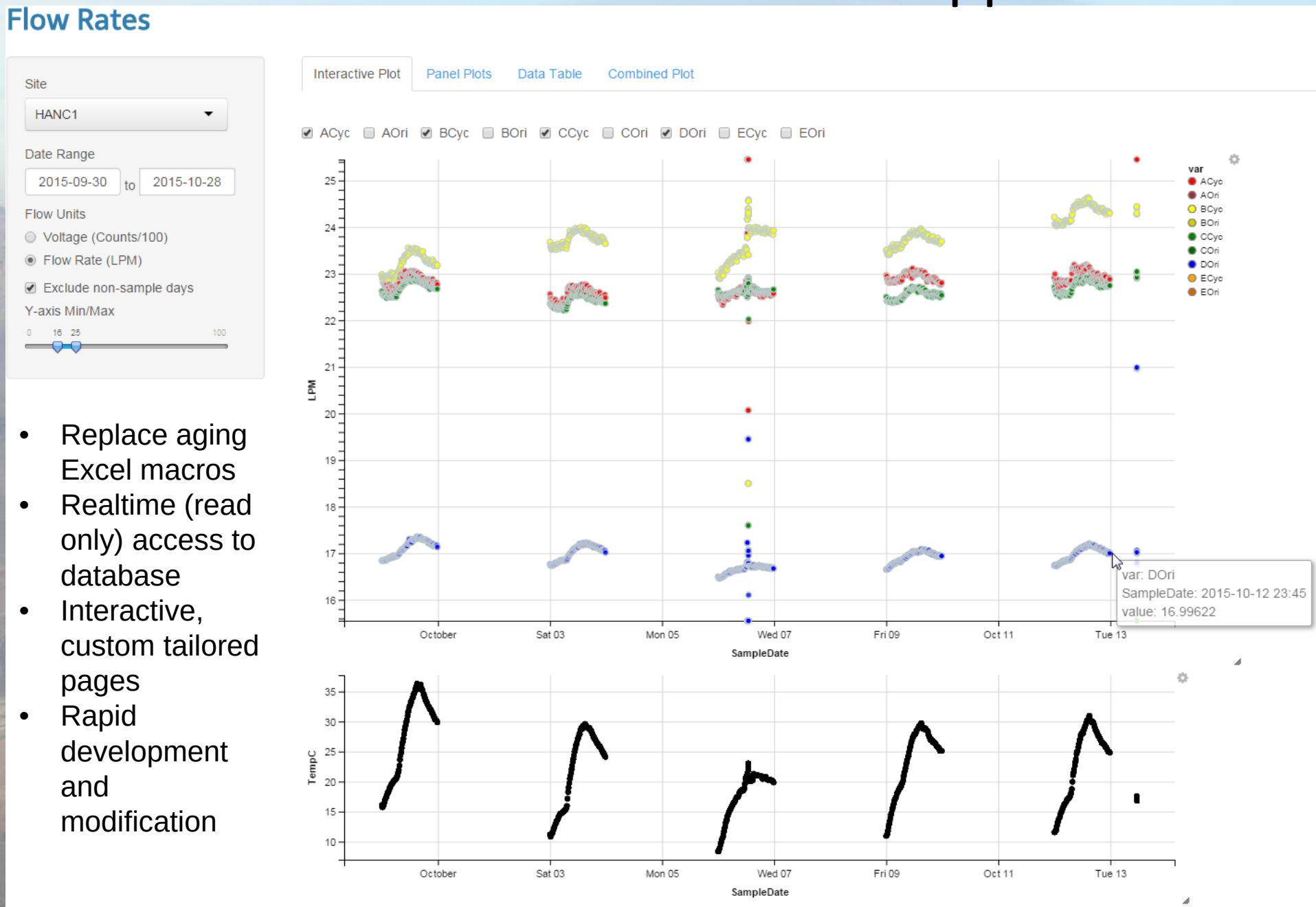
- Last year
  - Gravimetric lab application into production
  - XRF processing application into production
- This year
  - Data management web application into production
  - Data visualization web applications into production
  - Database redesign now in testing
- Next year and continuing
  - Transition to new database (all existing and new applications)
  - New data processing, data validation, delivery
  - Improvements to production applications

Data Management Web Application

- Database driven
- Modern software architecture
- Role-based permissions for editing of specific fields
- Flexible and expandable



Data Visualization Web Apps



- Replace aging Excel macros
- Realtime (read only) access to database
- Interactive, custom tailored pages
- Rapid development and modification

Data Visualization Web Apps

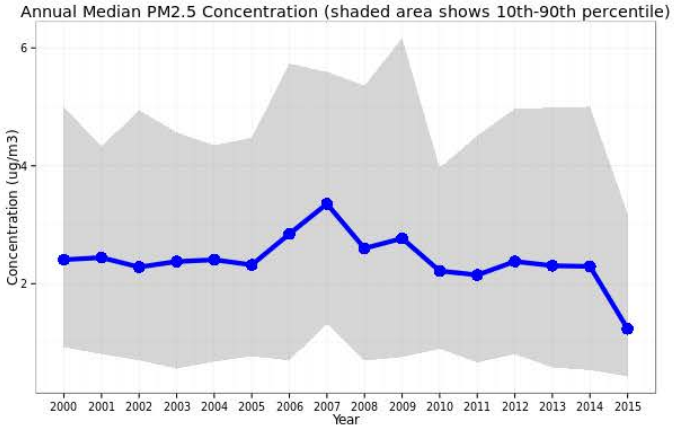
Site

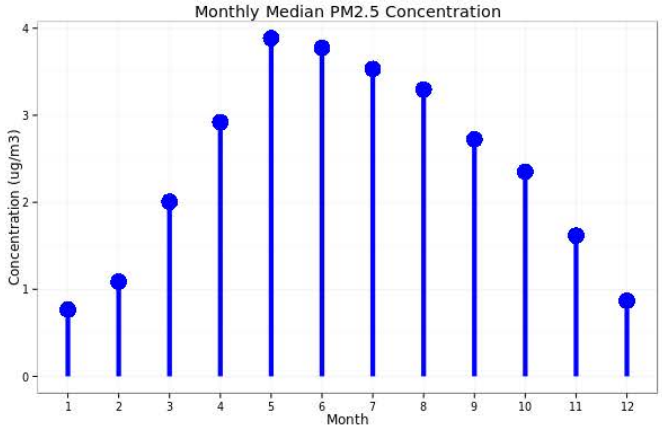
HANC1

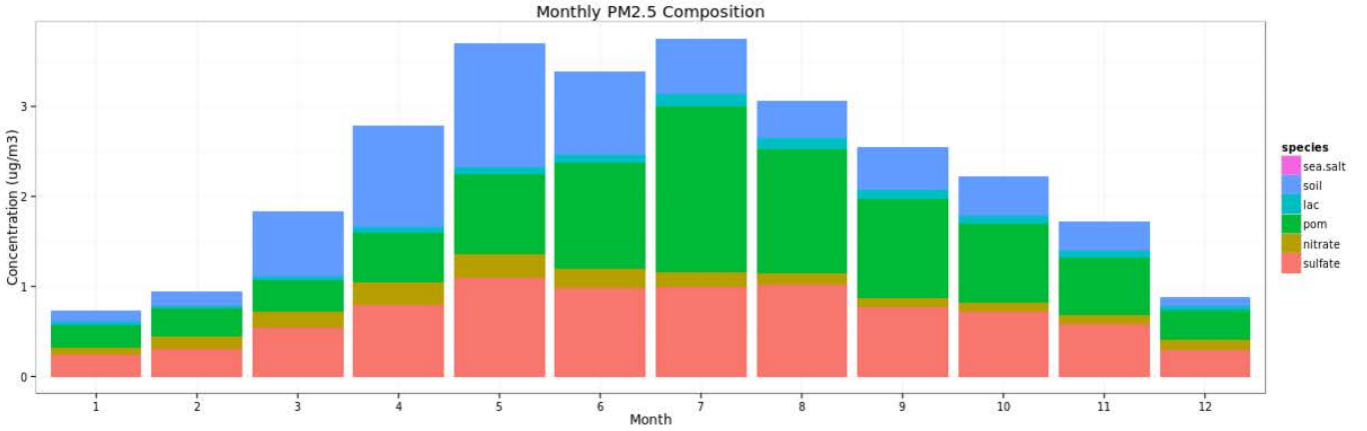
Site: Grand Canyon (AZ)
Start Date: 1988-03-02
Latitude: 35.9731085
Longitude: -111.9840835
Elevation (m): 2267

Grand Canyon

Last Year's Rank: 44 of 163

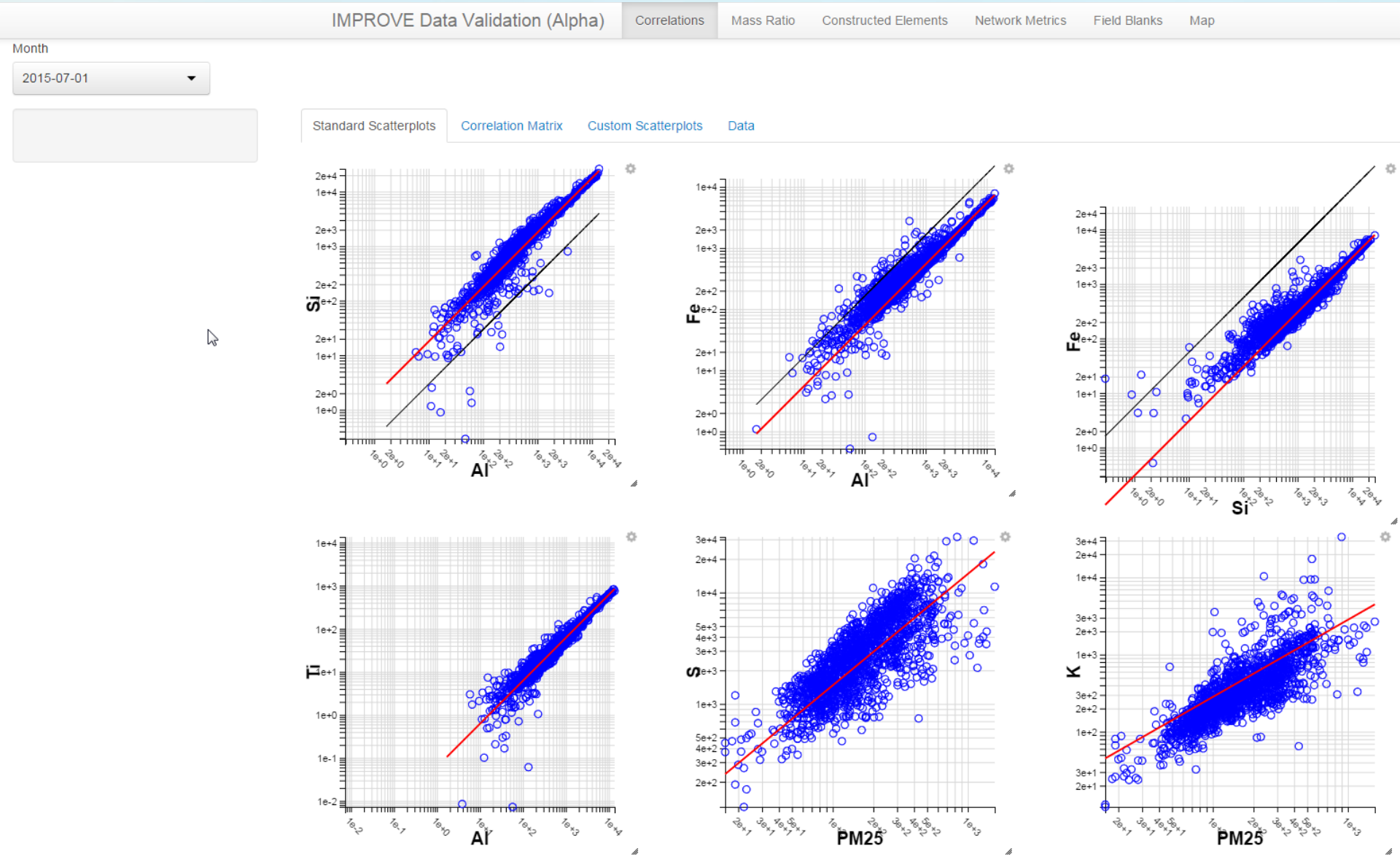






Data Visualization Web Apps

Data Visualization Web Apps



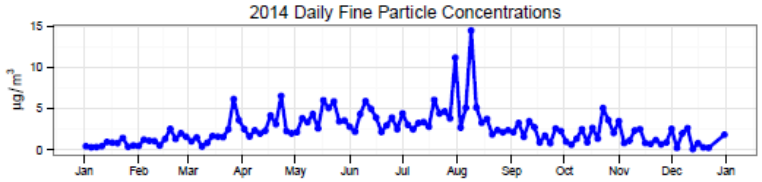
Annual Site Summary

- Goal: create more invested and reliable operators through outreach
- Automatically generated through R Markdown
- Delivered to operators this year during maintenance visits
- Received positive feedback
- Looking for comments for improvement
- What goes on the back?

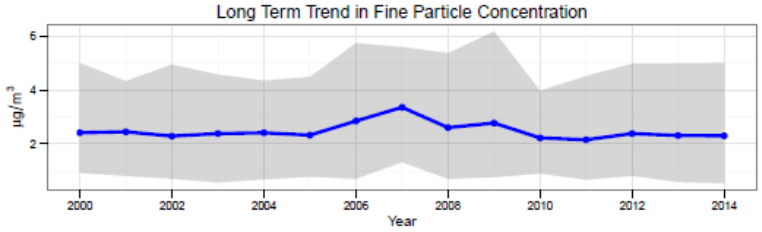
UCDAVIS
UNIVERSITY OF CALIFORNIA

IMPROVE is a long-term monitoring program designed to understand visibility conditions in protected areas. IMPROVE measures particles in the air, which reduce visibility.

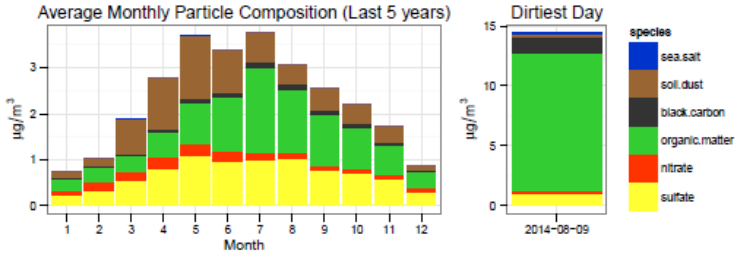
Grand Canyon (HANC) 2014 Site Report Compared to other sites in the IMPROVE network, HANC ranked **49** of **163** in average fine particle concentration for last year (the cleanest site is ranked 1).



The plot below shows the trend in annual average fine particle concentrations over the lifetime of the site. The shaded area indicates the range between the 10th and 90th percentile for the site.



The plots below show the composition of particle pollution at HANC on a monthly average basis (left) and for the day with the highest measured level of particle pollution for last year (right).



Species	Common Sources
sea.salt	Ocean spray
soil.dust	Construction, agriculture, wind
black.carbon	Diesel engines, fires
organic.matter	Vehicles, fires, wood stoves
nitrate	Fertilizer, livestock
sulfate	Coal-fired power plants, volcanism

Data Management Transition - Detail

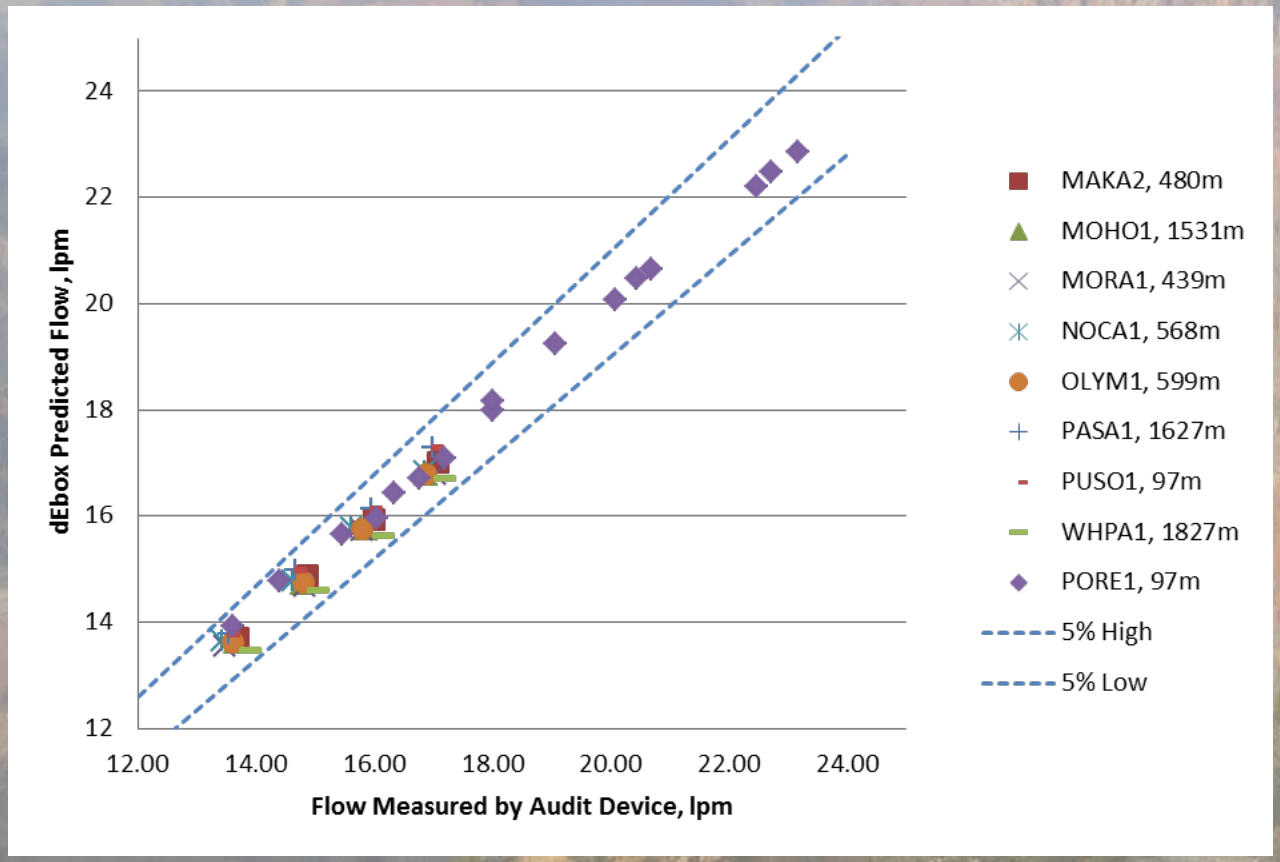
Lab Function	Legacy Method	Updated Method	Status
Sample Prep and Receiving	FoxPro application	.NET application	Production
Filter lab automation	FoxPro application	.NET application	Production
Tracking late boxes	Excel spreadsheet	SQL Server Reporting Services	Production
XRF queue management and processing	Mix of stored procedures and manual intervention	.NET application	Production
Editing of data	Mix of direct editing in database and FoxPro application	.NET web application	Production
Flow rate review and monitoring	Excel spreadsheet	Shiny web application	Production
Site flow calibration data entry	Direct entry to database	.NET web application	Production
Central data storage	Wide-format SQL database	Redesigned skinny-format database	Testing
XRF blanks and controls monitoring	Excel spreadsheets	Shiny web application	Testing
Calculating concentrations, uncertainties, MDLs	FoxPro application	R processing script	Testing
XRF routine data viewing	Excel spreadsheets	Shiny web application	Testing
Sample Completeness Report	Manually prepared quarterly	Shiny web application	Development
Data validation	FoxPro application, stored procedures, Excel spreadsheets	TBD	Design
AQS and FED delivery	FoxPro application	TBD	To do
Managing contractor filters/files	Excel spreadsheet	.NET web application	To do

Flow Rate Measurement

- Motivation: PM_{10} flow rate measurement was insensitive
  - Sometimes hard to tell if flow is on or off
- Flow measurement redesign - decided on fixed critical orifices
- During testing, realized that fixed orifices offer another advantage – fixed calibration for flow rate
  - May install fixed orifices in all modules
  - Has potential to improve data quality and reduce maintenance time

Ruby Orifice Installation Complete

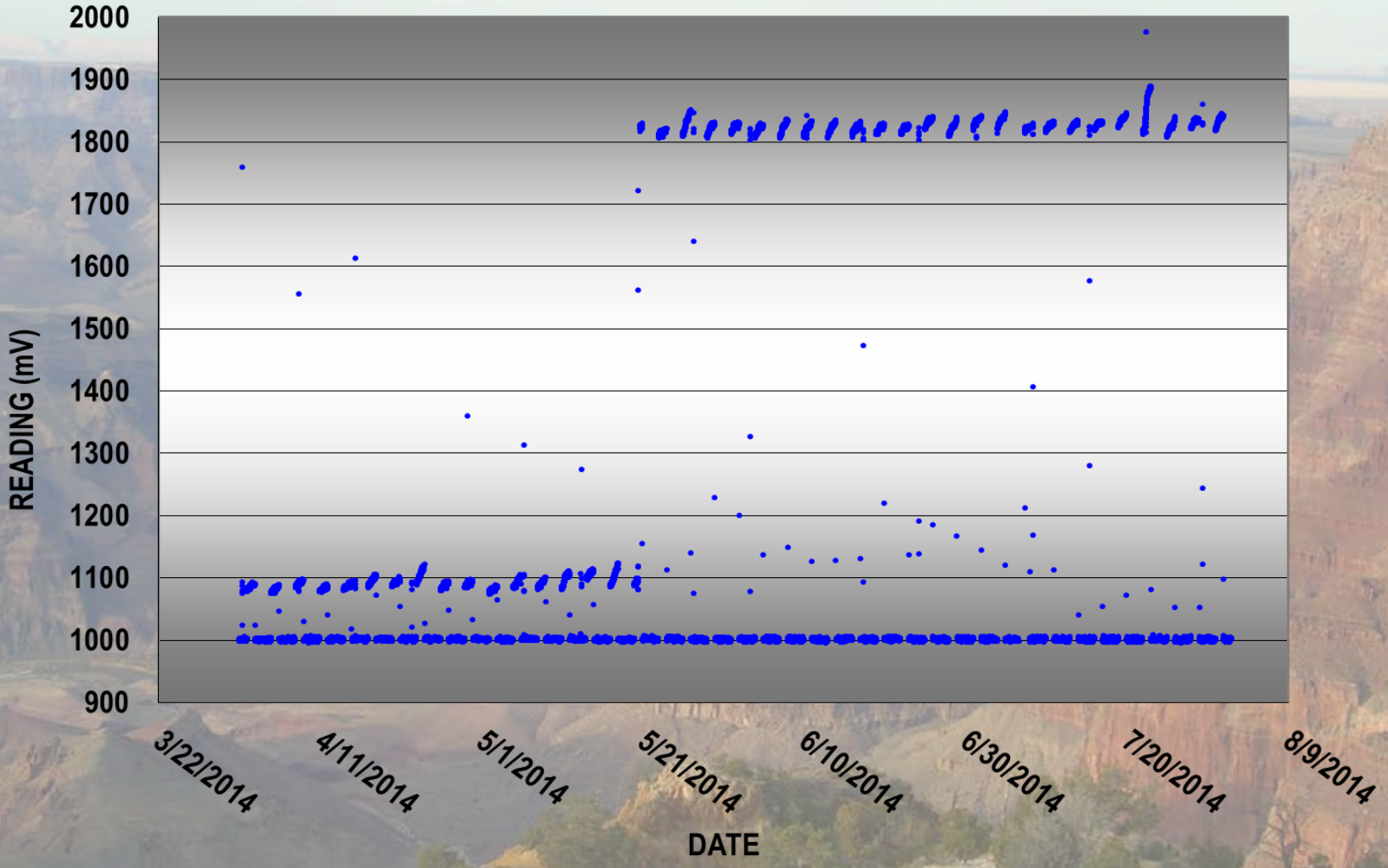
- 0.062” diameter sharp-edge ruby critical orifices installed in PM_{10} modules during 2014 maintenance (half of sites now have ruby orifices)
- Provides fixed parameter for flow equation, independent of valve setting
- Allows prediction of flow without site-specific calibration



Average abs error: 0.99%

Standard deviation: 0.87%

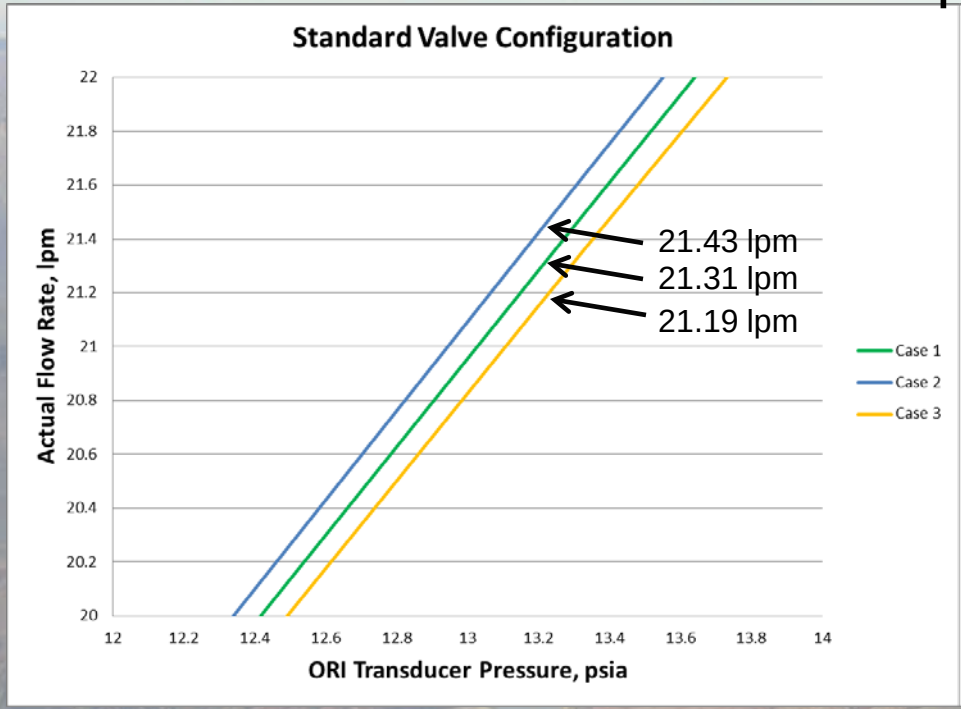
Ruby Orifice Setup Provides More Sensitive Flow Measurement

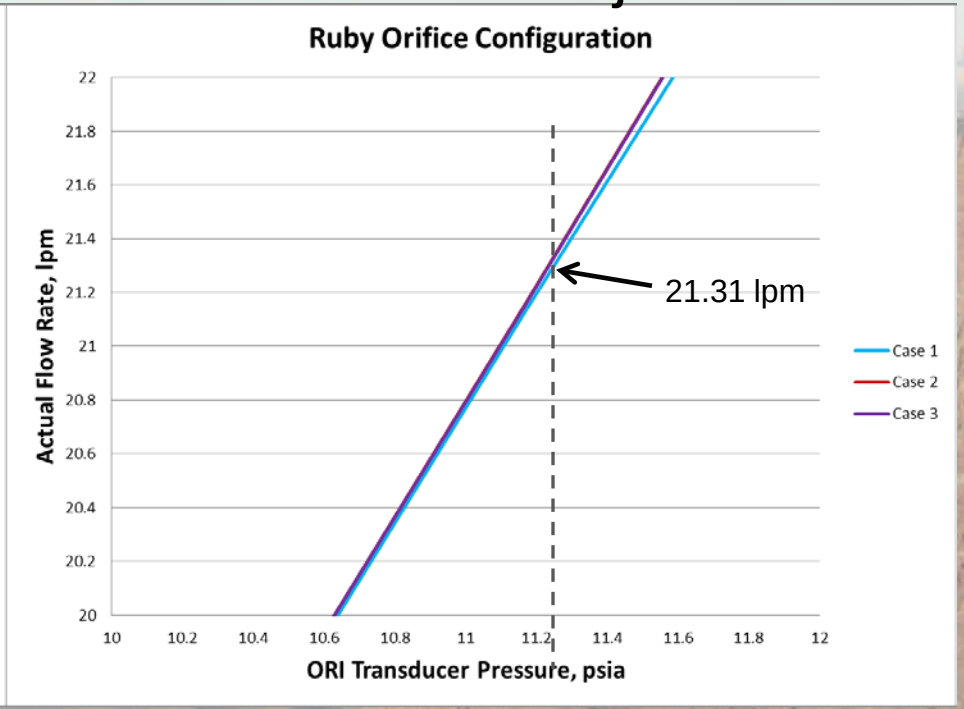


Valve Issues Do Not Affect Calibration

$$Q = 0.58k\gamma^{\frac{1}{2}}(A_{ori}/\rho_{ambient})(\rho_{ori}P_{ori})^{\frac{1}{2}}$$

Test Case: Valve variations equivalent to 0.0002” adjustment

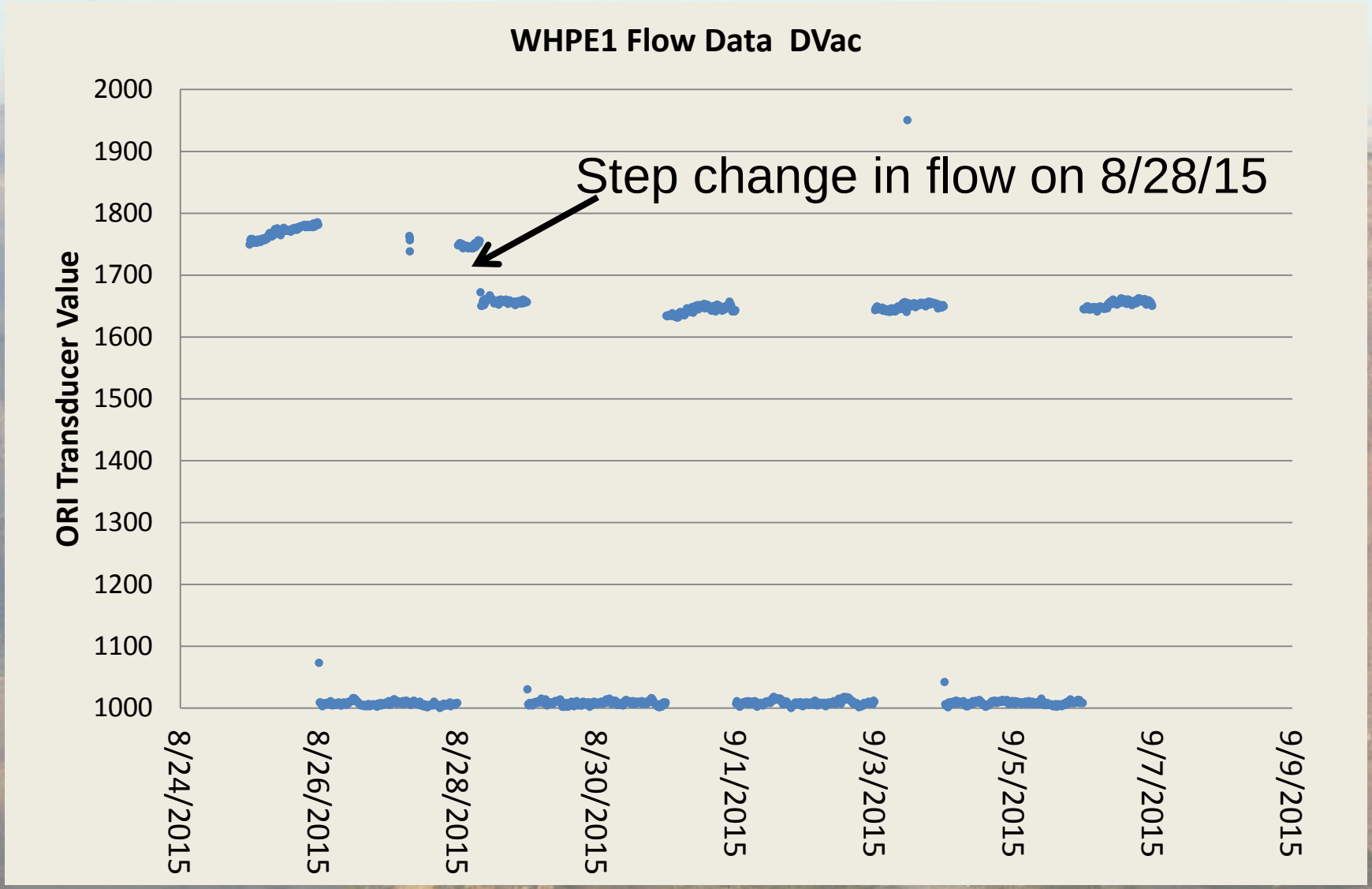




- Tiny valve adjustments produce different flows for the same ORI pressure.
- Impossible to know which calibration to use

- The same valve adjustments do not change the equation
- If ORI pressure is known, flow is known

Example – Wheeler Peak

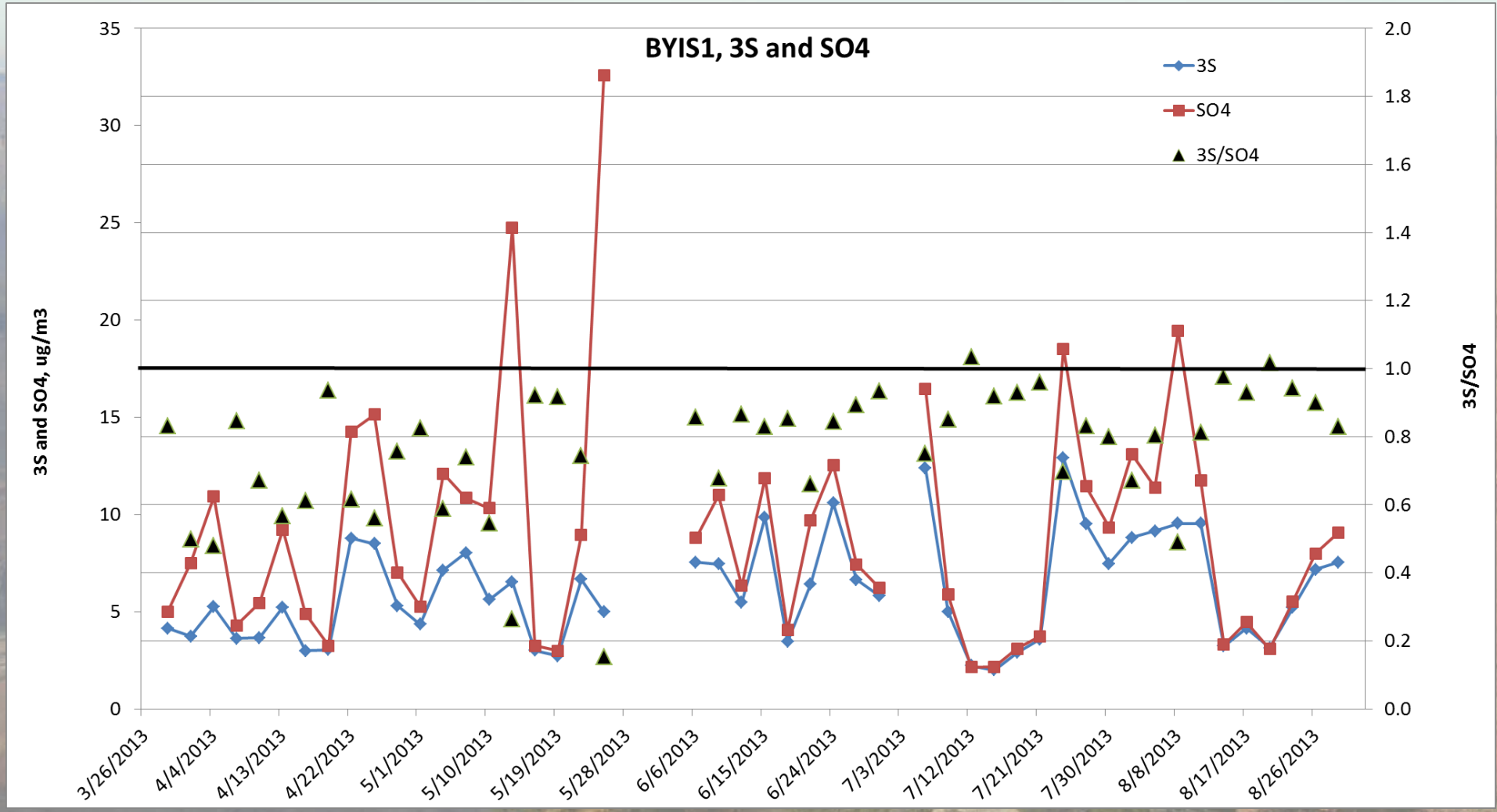


Instructional Videos

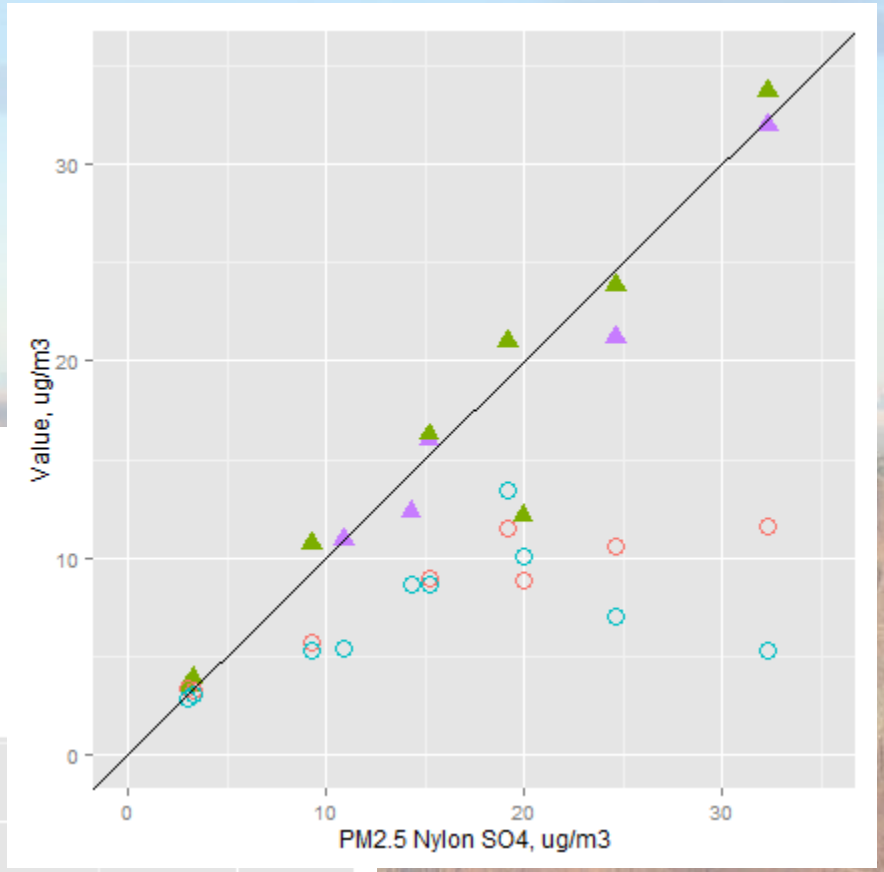
- Weekly sample change for both site schedules
- Performing flow check
- Performing flow calibration
- Disengaging motor for manifold
- Replacing sampling manifold

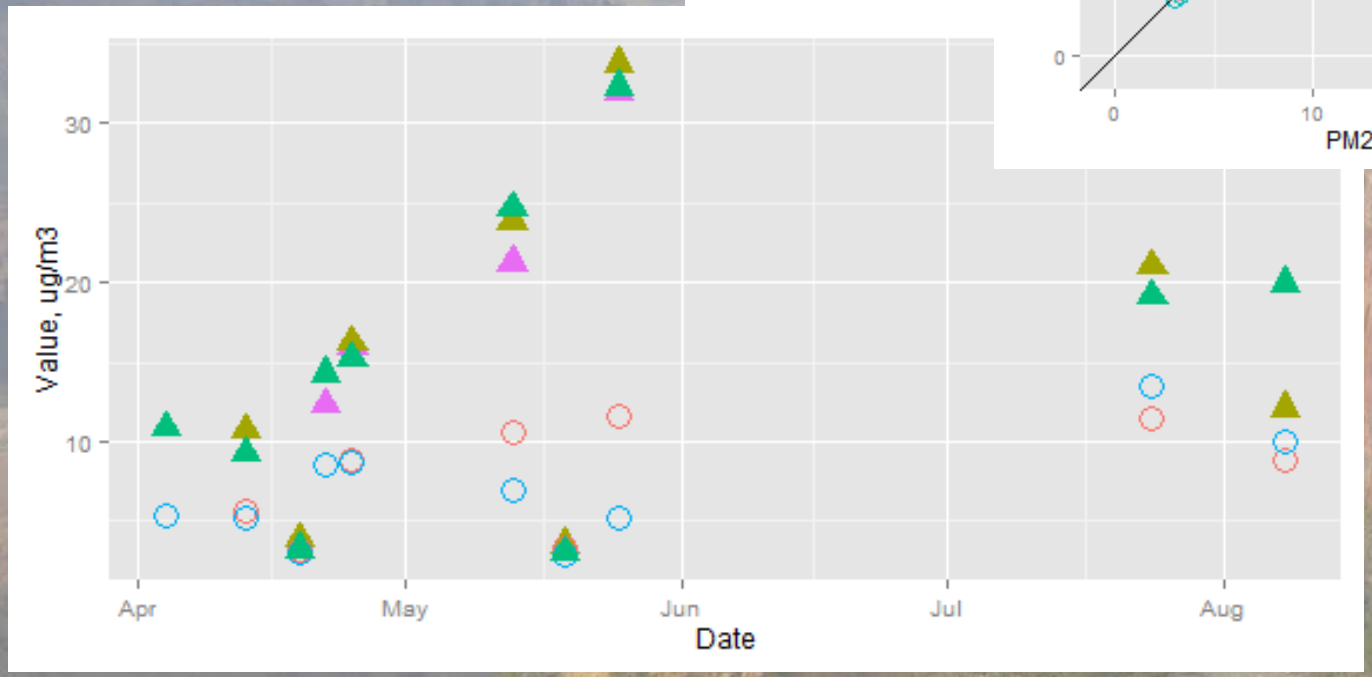
Sampling in South Korea

Poor agreement between S and SO_4^{2-} in first year

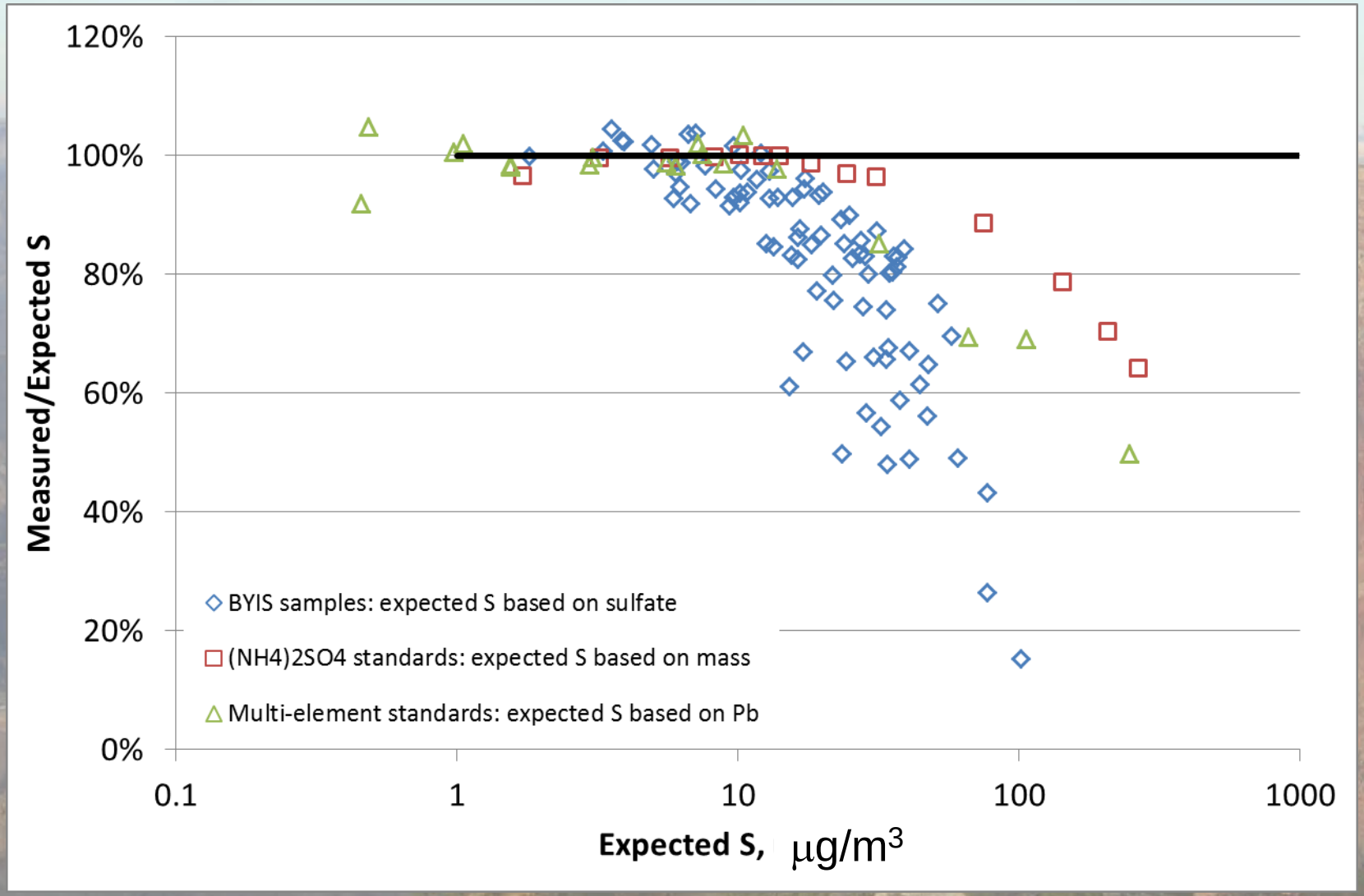


Additional Measurements on the BYIS Filters



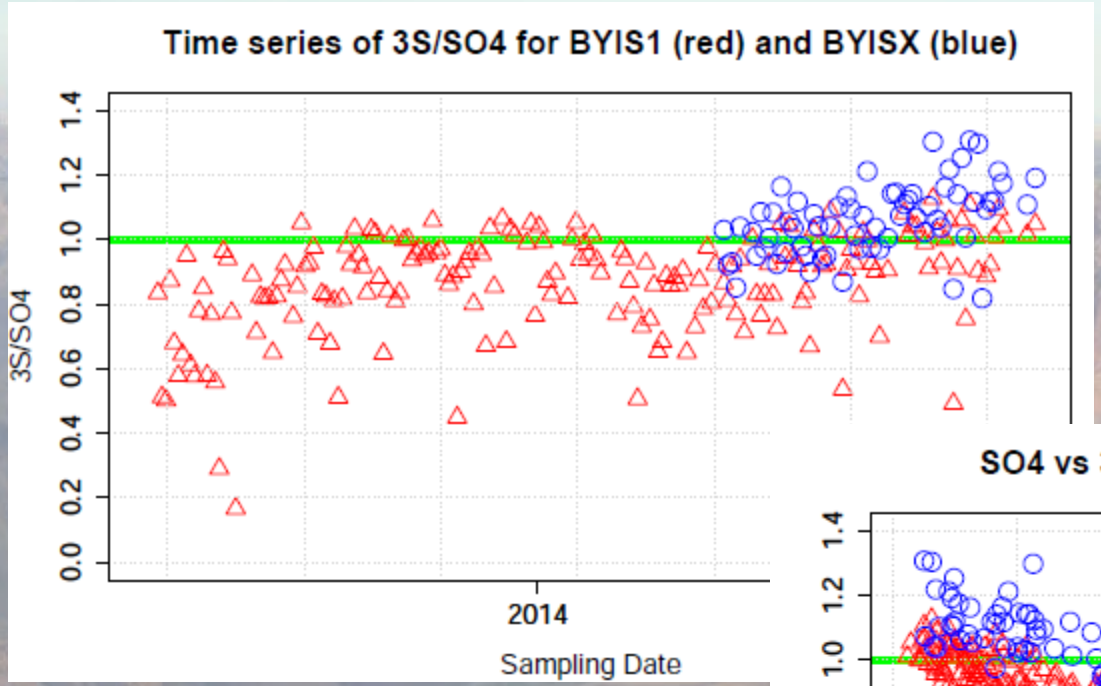


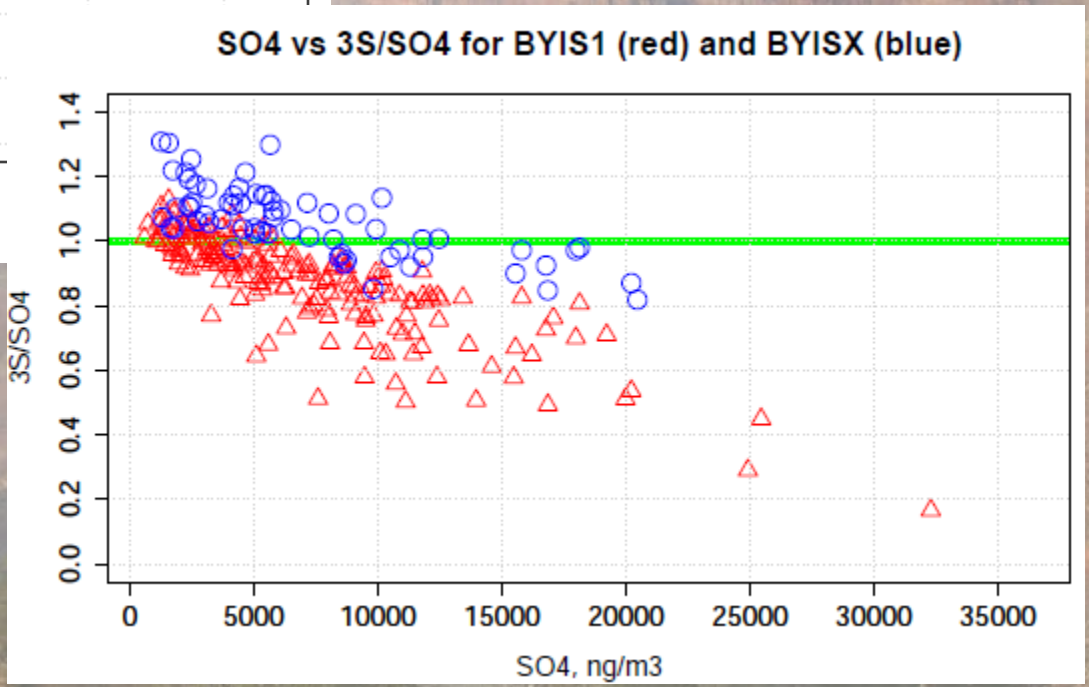
XRF Matrix Effects



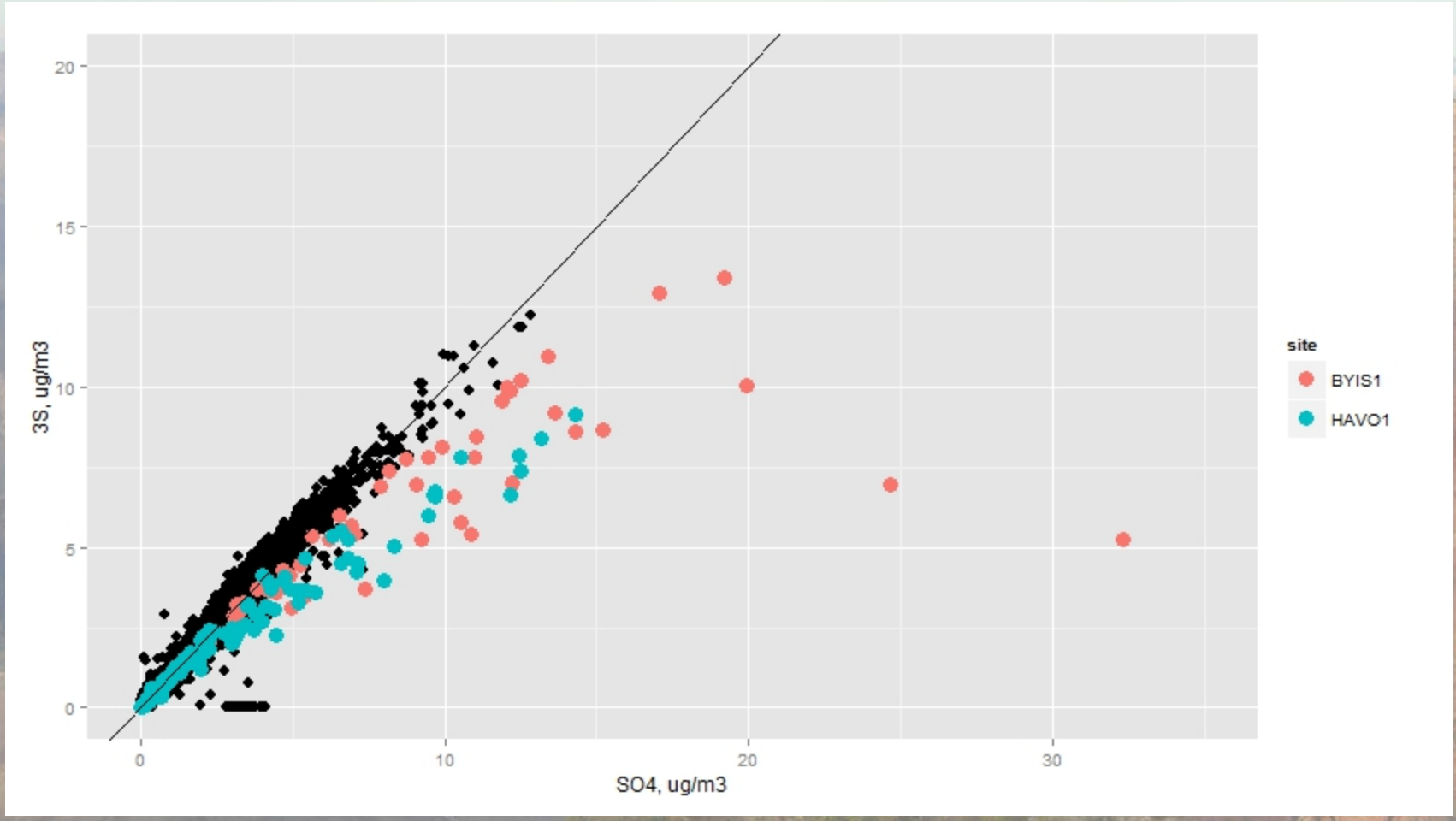
Added a 5th Module to BYIS1

BYISX: A module with 37mm PTFE filters





Should we add a 5th module with larger diameter to HAVO1 also?

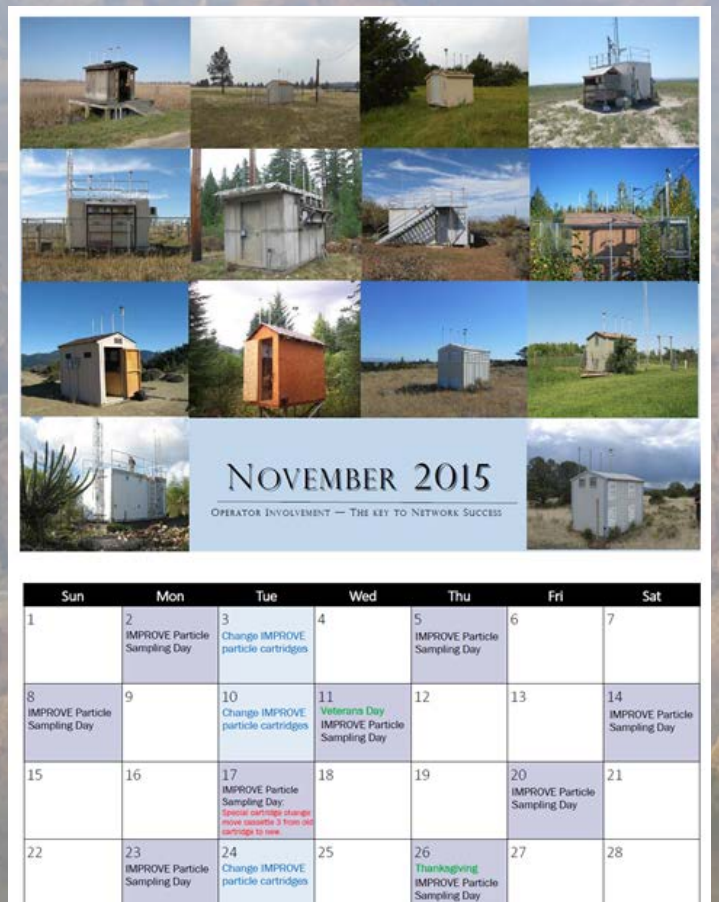


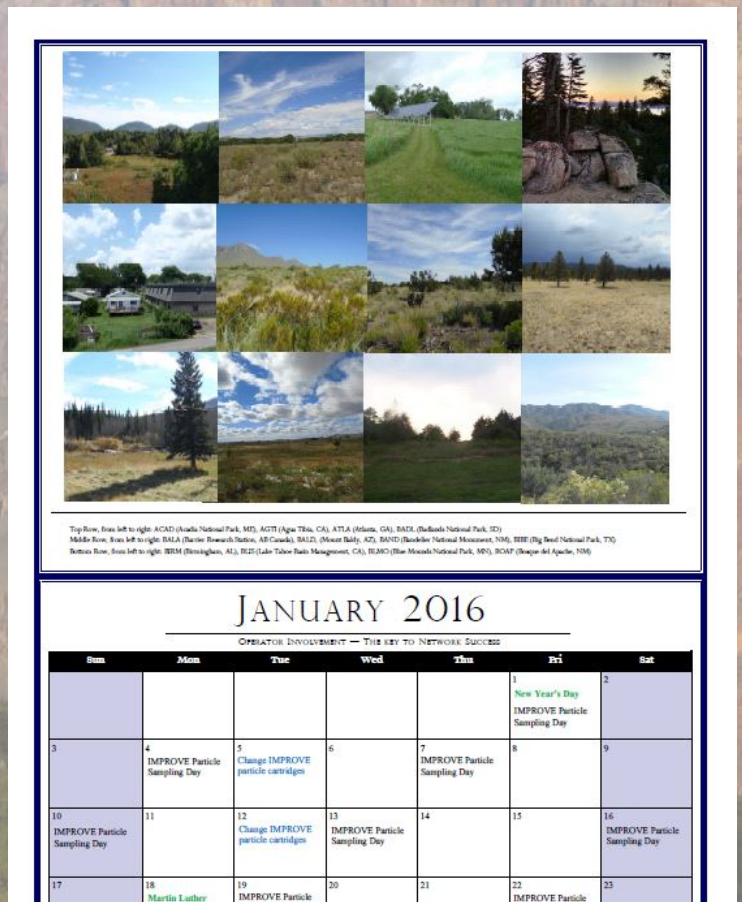
QAPP Revised in 2015

- First revision since 2002
- Incorporates current organizational structure and operating procedures
- Shorter than 2002 QAPP; references details in SOPs
  - Provides an overview of the program without the inclusion of technical details
  - Technical details can be revised in the SOPs without the need to revise the QAPP

IMPROVE Calendar

- UCD created 2015 calendar and currently working on 2016 calendar
- Planning a photo contest for 2017





Concerns about Not Sampling a Week at End of Year

- If we don't sample week of 12/29, will lose two samples from 2016, not 2015
  - This is a bad way to start 2016!
- We prefer to collect as many valid samples as possible and then decide which ones will not be analyzed.

DECEMBER 2015

OPERATOR INVOLVEMENT — THE KEY TO NETWORK SUCCESS

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1 Change IMPROVE particle cartridges	2 IMPROVE Particle Sampling Day	3	4	5 IMPROVE Particle Sampling Day
6	7	8 IMPROVE Particle Sampling Day: Special cartridge change: move cassette 3 from old cartridge to new	9	10	11 IMPROVE Particle Sampling Day	12
13	14 IMPROVE Particle Sampling Day	15 Change IMPROVE particle cartridges	16	17 IMPROVE Particle Sampling Day	18	19
20 IMPROVE Particle Sampling Day	21	22 Change IMPROVE particle cartridges	23 IMPROVE Particle Sampling Day	24	25 Christmas Day	26 IMPROVE Particle Sampling Day
27	28	29 IMPROVE Particle Sampling Day	30	31	Jan 1, 2015 IMPROVE Particle Sampling Day	Jan 2

NOVEMBER 2015

- IMPROVE operator training videos: http://aqmalpha.crocker.ucdavis.edu/improve/resources_operators/
- Compare current log sheet values with those of the sample log sheet pasted inside the sampler door. If values are out of range, please call UC-Davis.
- Correct the time on your sampler if it deviates by more than 5 minutes from the time on a calibrated clock.

For questions regarding the IMPROVE equipment or samples, please call:

UC Davis:
General Lab
(530) 752-1123

JANUARY 2016

Photo Locations: from left to right: VOYA, WASH, WEMI, WHIT (top row) WHPA, WHPE, WHRI, WICA (second row) WIMO, YELL, YOSE, ZICA (third row)

UC-Davis Planned Operational Changes

- **2014-2015**
  - Laboratory management software Version 2.0 ✓
  - Complete development of sampler controllers ✓
  - In-field testing of new sampler controllers ✓
  - Deployment of new PM_{10} flow rate measurement ✓
  - Data processing & delivery software Version 1.0 ✓
  - ~~Temperature & RH control for weighing chamber~~
- **2015-2016**
  - Deployment of new sampler electronics
  - ~~Deploy BITS for routine analysis~~
  - Data processing & delivery software Version 2.0

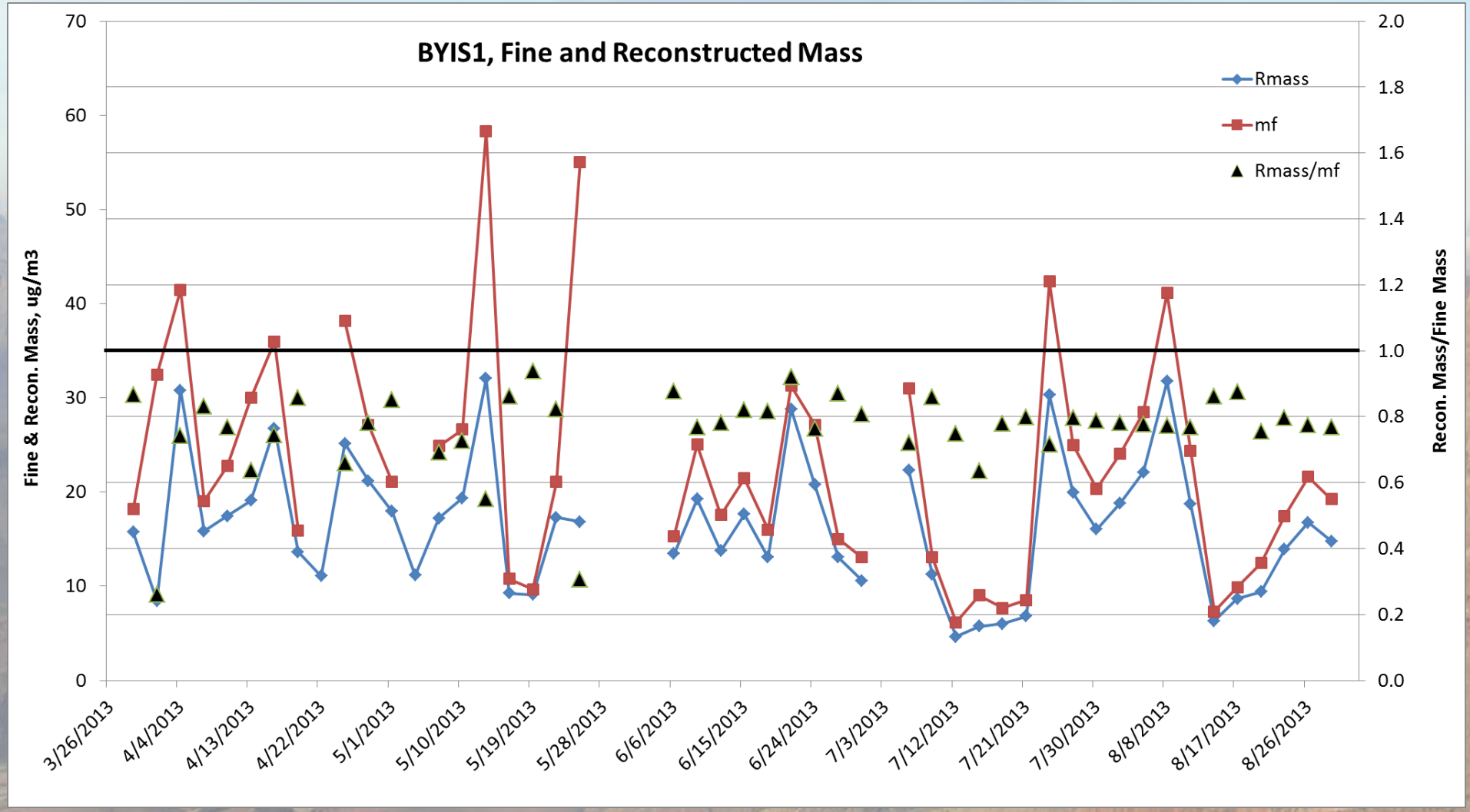
UC-Davis Planned Operational Changes

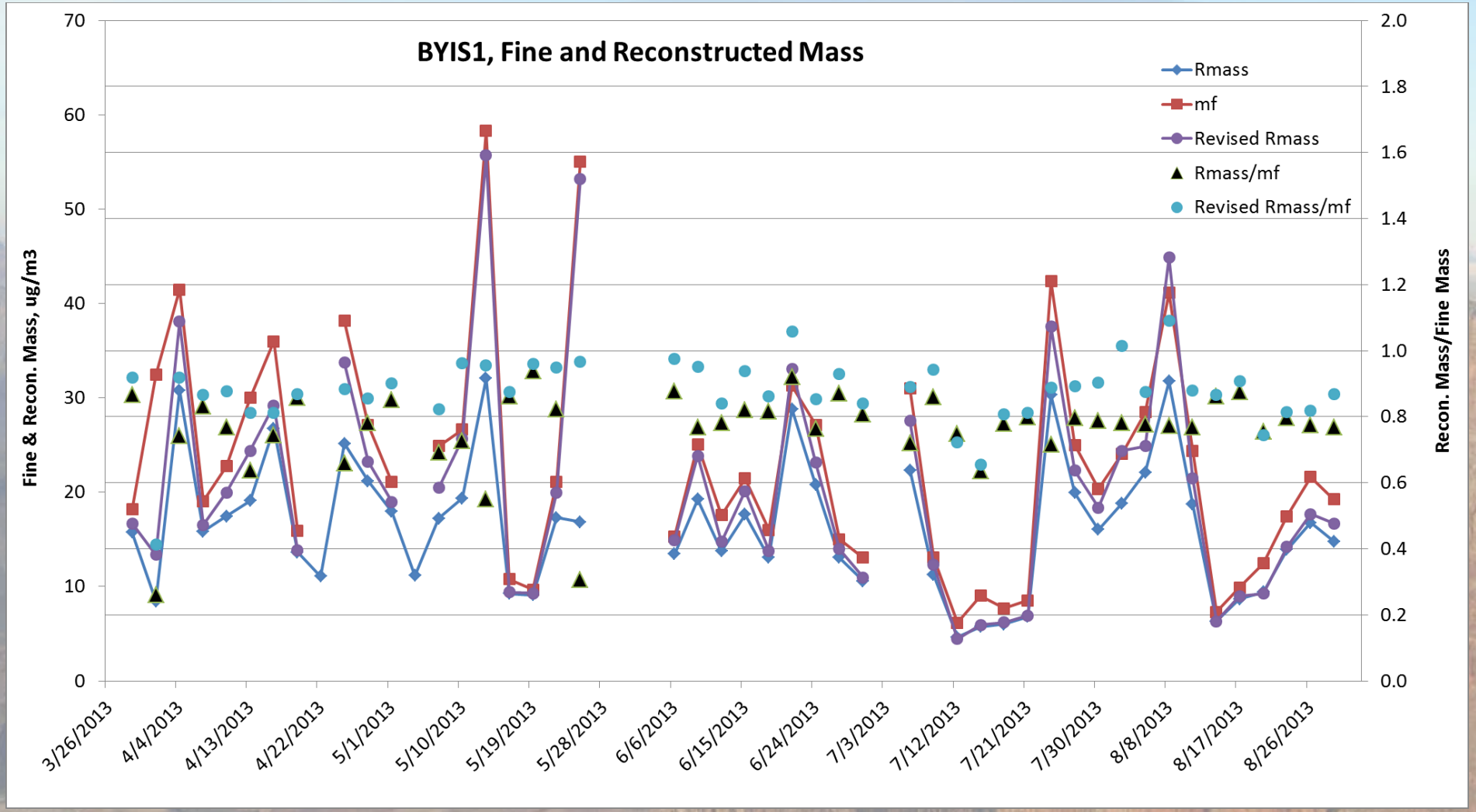
- **2015-2016**
  - In-field testing of new sampler electronics at select sites
    - If testing goes well, will start deploying in late summer 2016
  - Data processing & delivery software Version 1.0
  - Normalized relational database
    - Ability to easily add parameters to the CIRA delivery files and to deliver data to AQS in XML format
  - Laboratory management software Version 3.0
- **2016-2017**
  - Deployment of new sampler electronics
  - Data processing & delivery software Version 2.0

THE END

IMPROVE Sampling at Baengnyeong Island, South Korea

Nicole Pauly Hyslop
Xiaoya Cheng
Chuck E. McDade
Crocker Nuclear Laboratory
University of California at Davis


BYIS1, Fine and Reconstructed Mass
Rmass
mf
Rmass/mf
Fine & Recon. Mass, ug/m3
Recon. Mass/Fine Mass
70
60
50
40
30
20
10
0
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3/26/2013
4/4/2013
4/13/2013
4/22/2013
5/1/2013
5/10/2013
5/19/2013
5/28/2013
6/6/2013
6/15/2013
6/24/2013
7/3/2013
7/12/2013
7/21/2013
7/30/2013
8/8/2013
8/17/2013
8/26/2013


BYIS1, Fine and Reconstructed Mass
Rmass
mf
Revised Rmass
Rmass/mf
Revised Rmass/mf
Fine & Recon. Mass, ug/m3
Recon. Mass/Fine Mass
70
60
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20
10
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1.4
1.2
1.0
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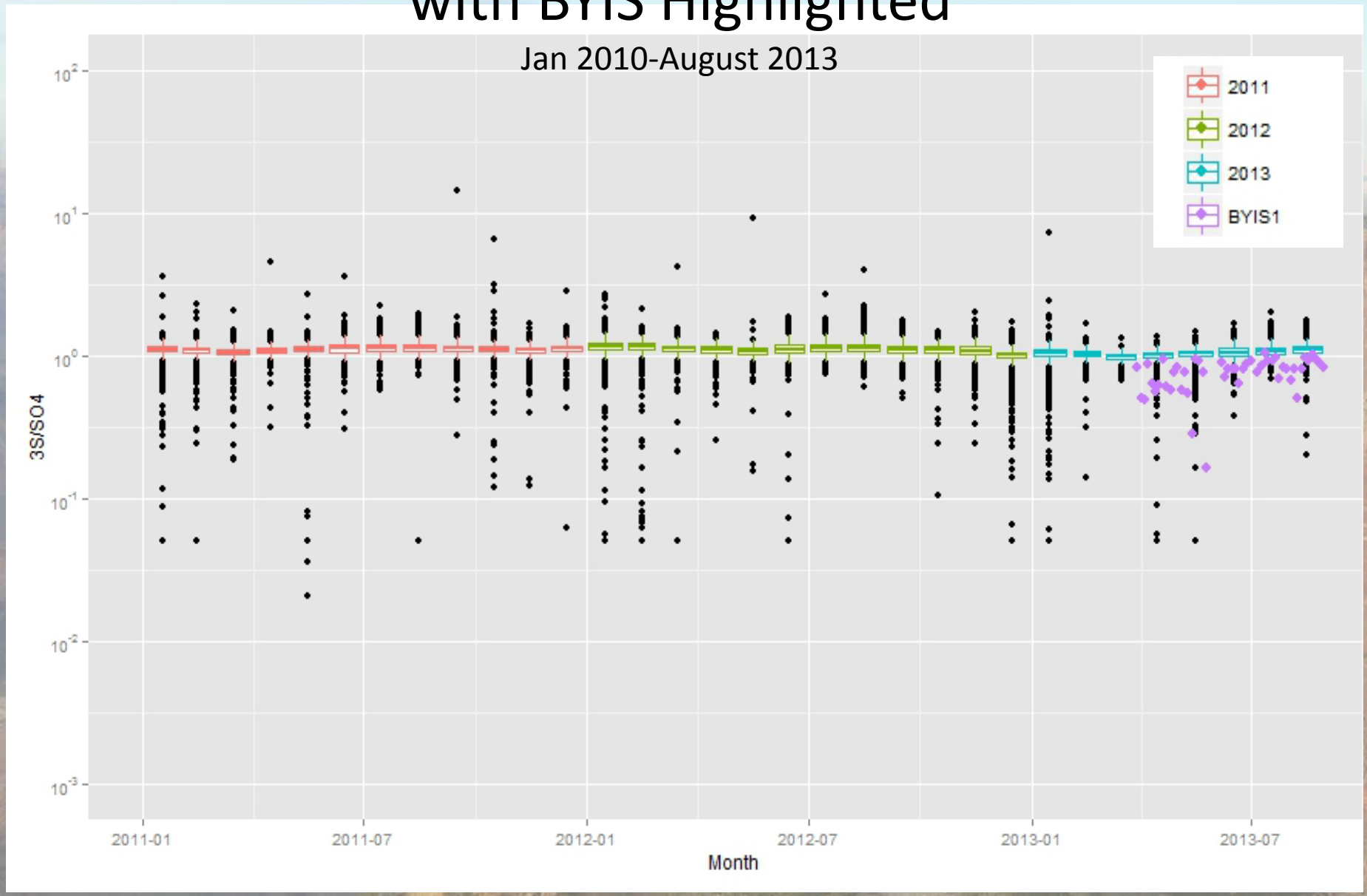
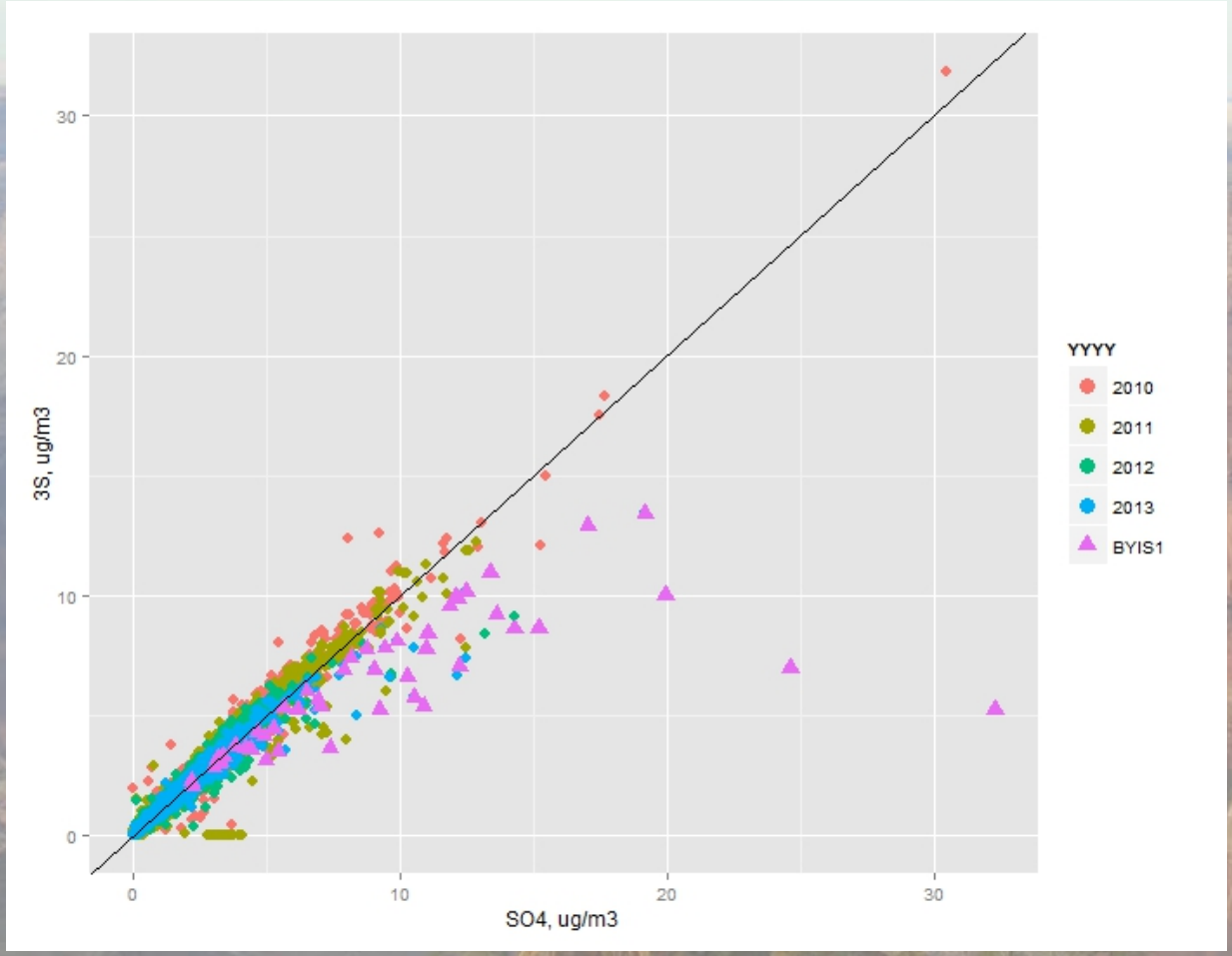
3/26/2013
4/4/2013
4/13/2013
4/22/2013
5/1/2013
5/10/2013
5/19/2013
5/28/2013
6/6/2013
6/15/2013
6/24/2013
7/3/2013
7/12/2013
7/21/2013
7/30/2013
8/8/2013
8/17/2013
8/26/2013

Network-wide Sulfur/Sulfate Ratio Comparison with BYIS Highlighted



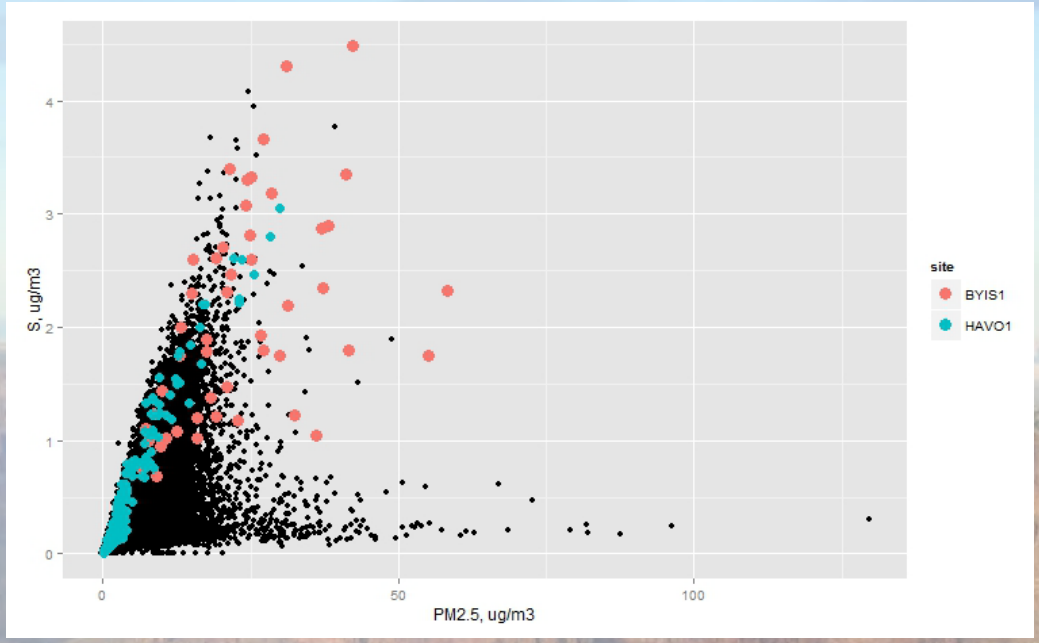
Network-wide S versus Sulfate with BYIS highlighted

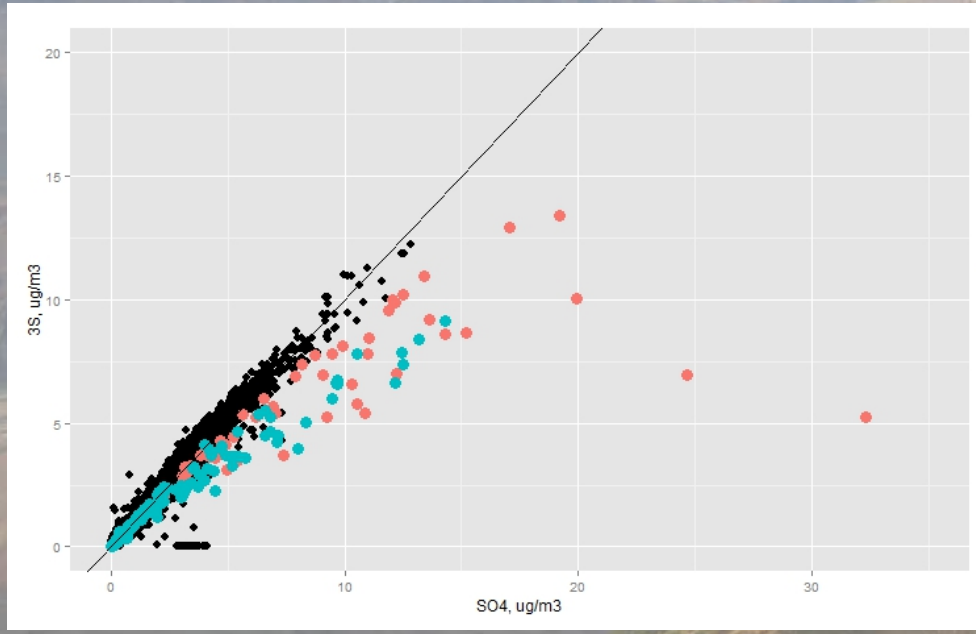
Jan 2010-August 2013

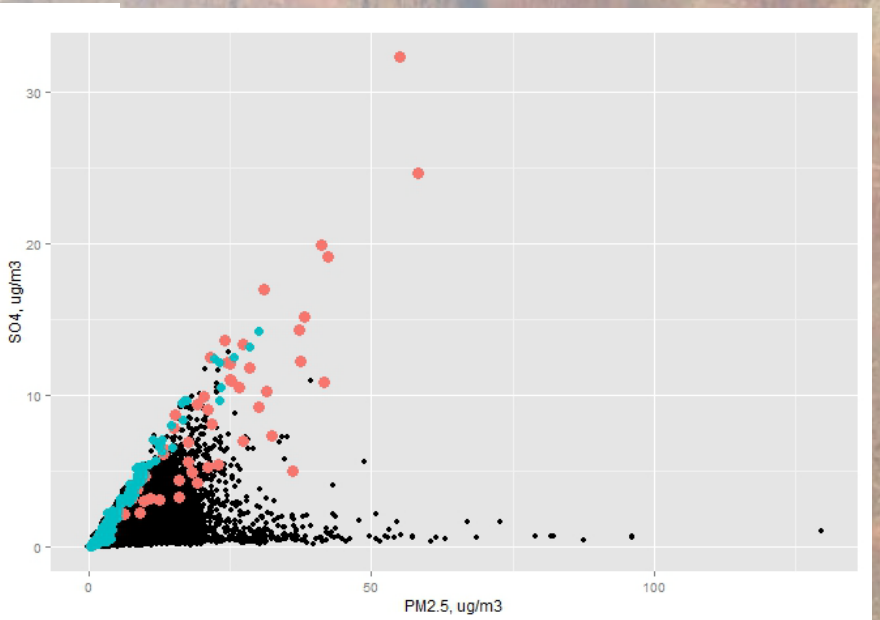


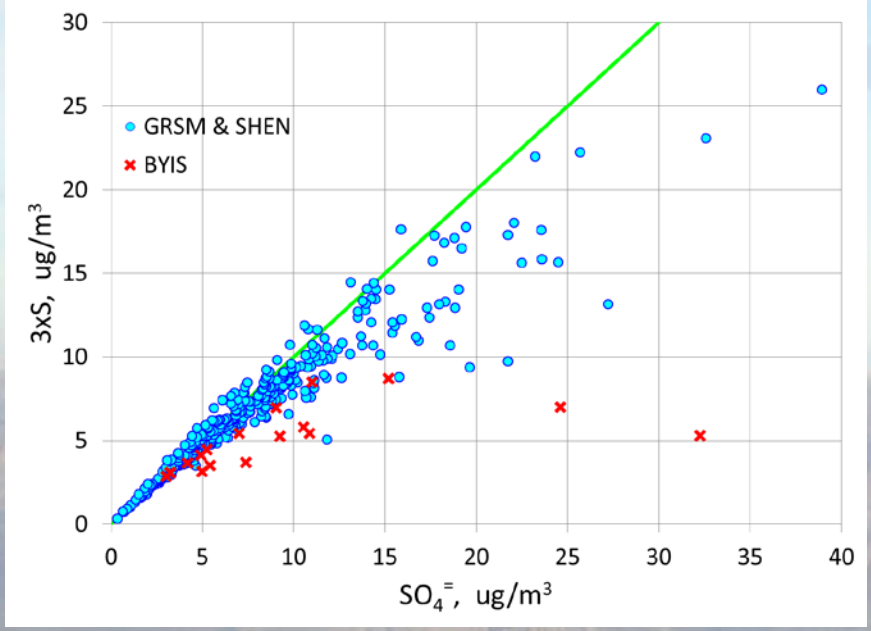
Network-wide Sulfur, Sulfate, and $PM_{2.5}$ mass Measurments with BYIS and HAVO Highlighted

Jan 2011 - August 2013








GRSM & SHEN
BYIS
3xS, ug/m3
SO4=, ug/m3
0
5
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30
35
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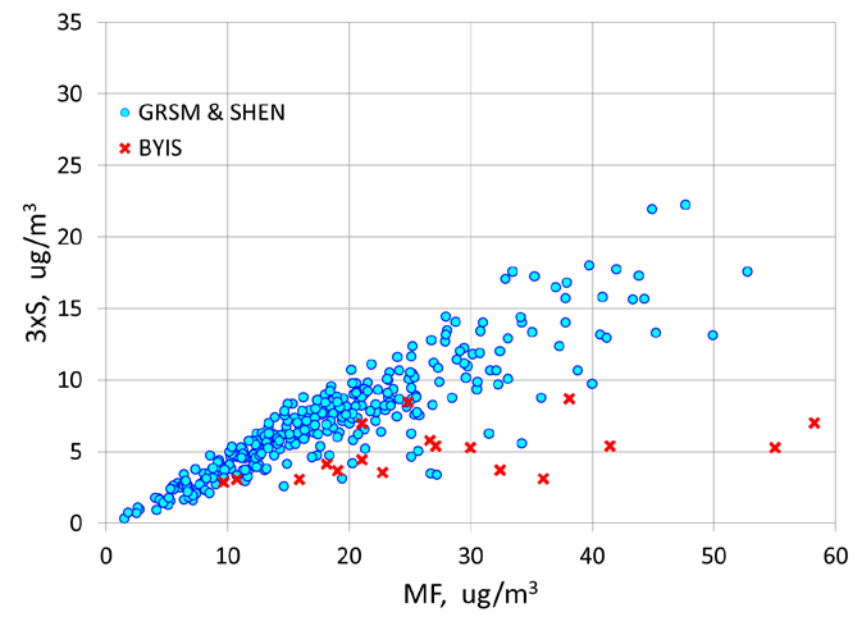
GRSM & SHEN
BYIS
3xS, ug/m3
MF, ug/m3
0
10
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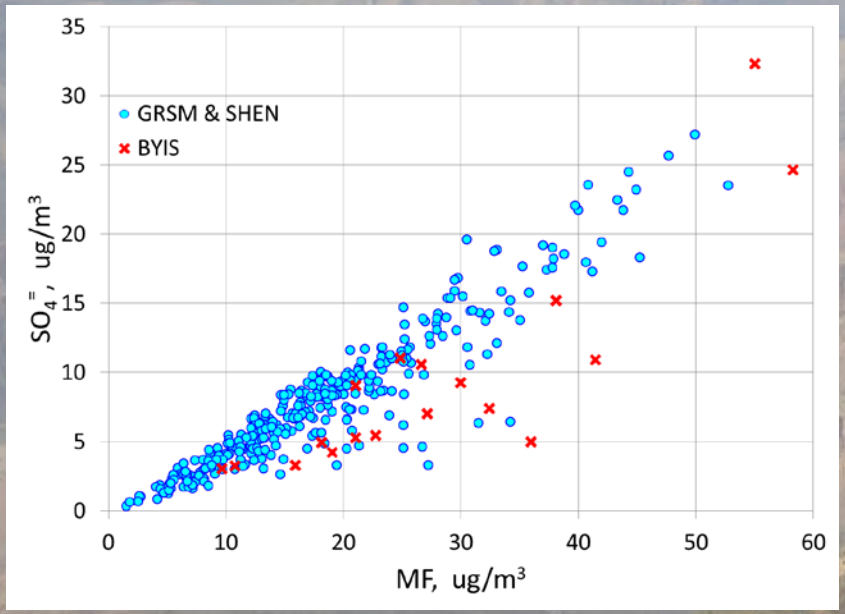
GRSM & SHEN
BYIS
SO4=, ug/m3
MF, ug/m3
0
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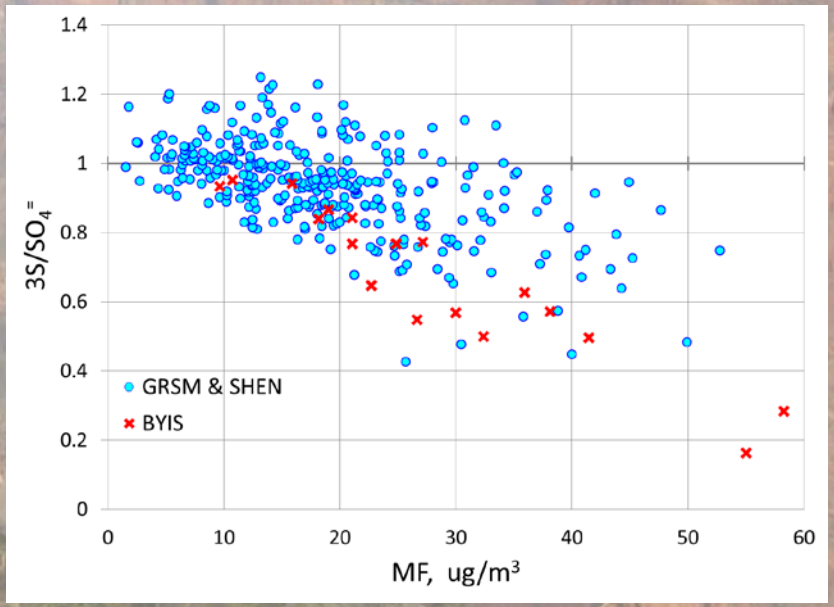
GRSM & SHEN
BYIS
3S/SO4=
MF, ug/m3
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0.2
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By Warren