QA Statistics and the DASC Tool

National Air Monitoring Conference
November 4, 2009

Louise Camalier & Jonathan Miller
EPA - Office of Air Quality Planning and Standards

What We Will Cover

- Data Quality Indicators (DQI's)
  - The Statistics
  - Proper Aggregation of the Data
- Tools
  - Data Assessment Statistical Calculator (DASC)
  - AQS Report (AMP255)
  - Annual Box and Whisker Plots
- What to Look For
- Reconciliation with the DQO's

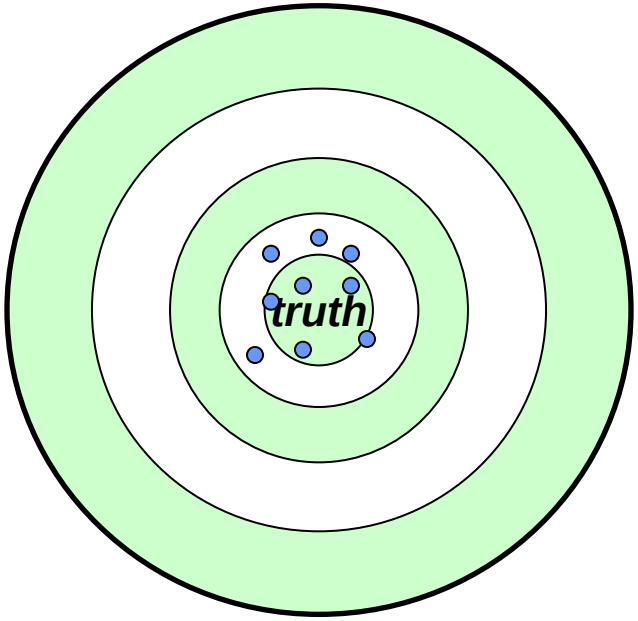
What is Performed

Method	Pollutants	Frequency	MQO	
One-Point QC	SO_2, NO_2, O_3, CO	Every 2 Weeks	O_3 : Precision = 7% Bias = 7%	SO_2, NO_2, CO : Precision = 10% Bias = 10%
Annual Performance Evaluation	SO_2, NO_2, O_3, CO	Once per Year	<= 15% for each audit concentration	
Flow Rate Verification	PM_{10}, $PM_{2.5}$, PM_c	Once per Month	<= 4% of Standard & 5% of Design Value	
Semi-Annual Flow Rate Audit	PM_{10}, $PM_{2.5}$, PM_c	Every 6 Months	<= 4% of Standard & 5% of Design Value	
Collocated Sampling	PM_{10}, TSP, $PM_{2.5}$, PM_c	15% of Network Every 12 Days	$PM_{2.5}$, TSP, PM_{10} : Precision = 10%	PM_c: Precision = 15%
PM PEP Program	$PM_{2.5}$, PM_c		$PM_{2.5}$: Precision = 10%	PM_c: Precision = 15%

Using What Was Acquired

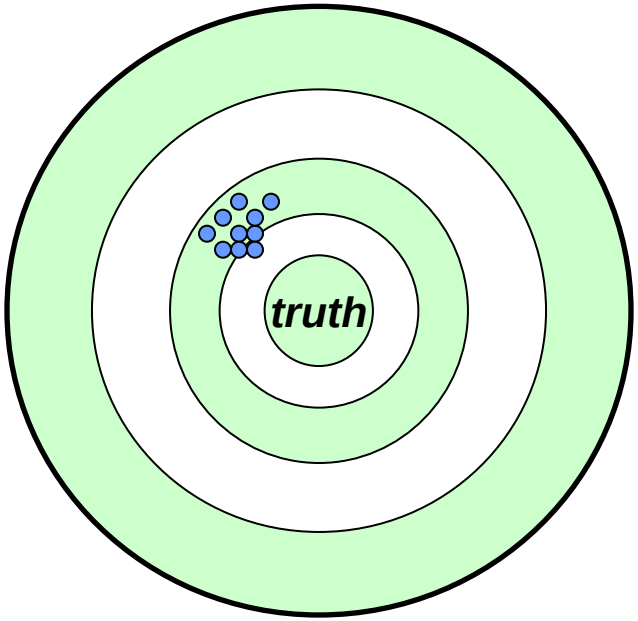
Method	Pollutants	What is Assessed	How?
One-Point QC	SO_2, NO_2, O_3, CO	Precision & Bias	Annual @ Site Level
Annual Performance Evaluation	SO_2, NO_2, O_3, CO	Validation of Bias	Annual @ Site Level or 3-Years @ PQAO Level
Flow Rate Verification	PM_{10}, $PM_{2.5}$, PM_c	Bias	Annual/3-Year @ Site/PQAO Level
Semi-Annual Flow Rate Audit	PM_{10}, $PM_{2.5}$, PM_c	Bias	Annual/3-Year @ PQAO Level
Collocated Sampling	PM_{10}, TSP, $PM_{2.5}$, PM_c	Precision	Quarterly/Annual/3-Year @ PQAO Level
PM PEP Program	$PM_{2.5}$, PM_c	Bias	Annual/3-Year @ Site/PQAO Level

What Are We Trying to Determine?



Precision

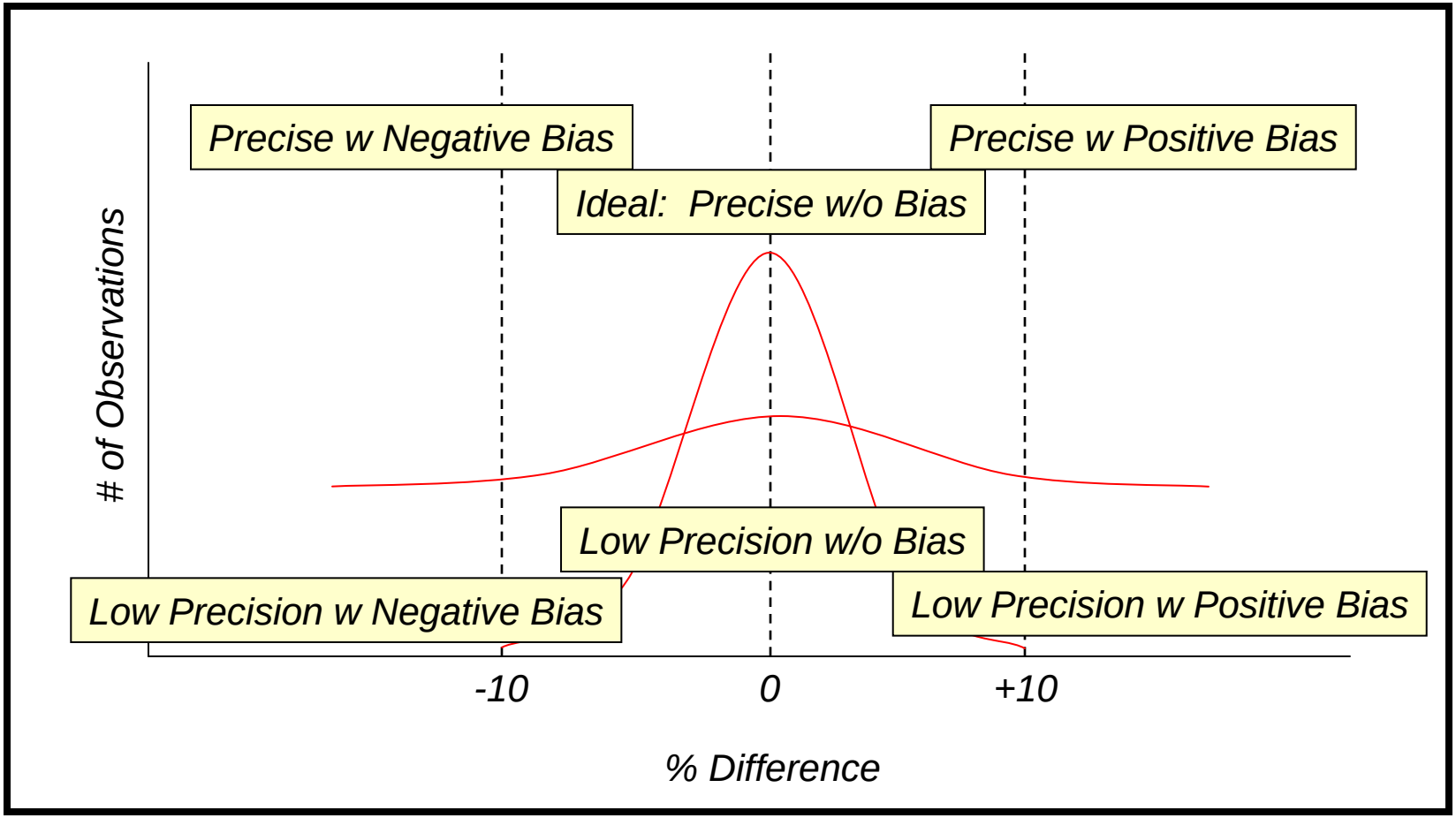
"A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions"



Bias

"A systematic or persistent distortion of a measurement process which causes errors in one direction"

Another Way of Looking at It…



Percent Difference & Relative Percent Difference

Basis for All Statistical Calculations

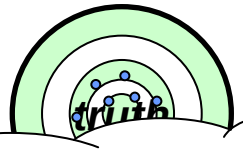
- For standard gas

$$d_i = \frac{meas - audit}{audit} \times 100$$

- For Collocated Samples,

$$d_i = \frac{X_i - Y_i}{(X_i + Y_i)/2} \bullet 100$$

Precision



Defines the "Width" of the Bell Curve

90th Percentile of a Chi-Squared Distribution → ***<u>More Conservative</u>***

Gaseous Estimate

$$Precision_Estimate = \sqrt{\frac{n \bullet \sum_{i=1}^{n} d_i^2 - (\sum_{i=1}^{n} d_i)^2}{n(n-1)}} \bullet \sqrt{\frac{n-1}{\chi^2_{0.1,n-1}}}$$

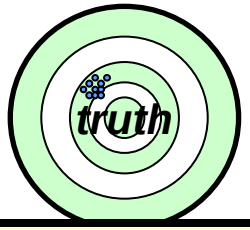
Collocated Estimate

$$Precision_Estimate = \sqrt{\frac{n \bullet \sum_{i=1}^{n} d_i^2 - (\sum_{i=1}^{n} d_i)^2}{2n(n-1)}} \bullet \sqrt{\frac{n-1}{\chi^2_{0.1,n-1}}}$$

Denominator changes because we do not have "truth"

Precision is more conservative when evaluated at the 90% one-sided upper confidence level

Bias



$$Bias_Estimate = |AB| = AB + t_{0.95,n-1} \bullet \frac{AS}{\sqrt{n}}$$

Central Tendency

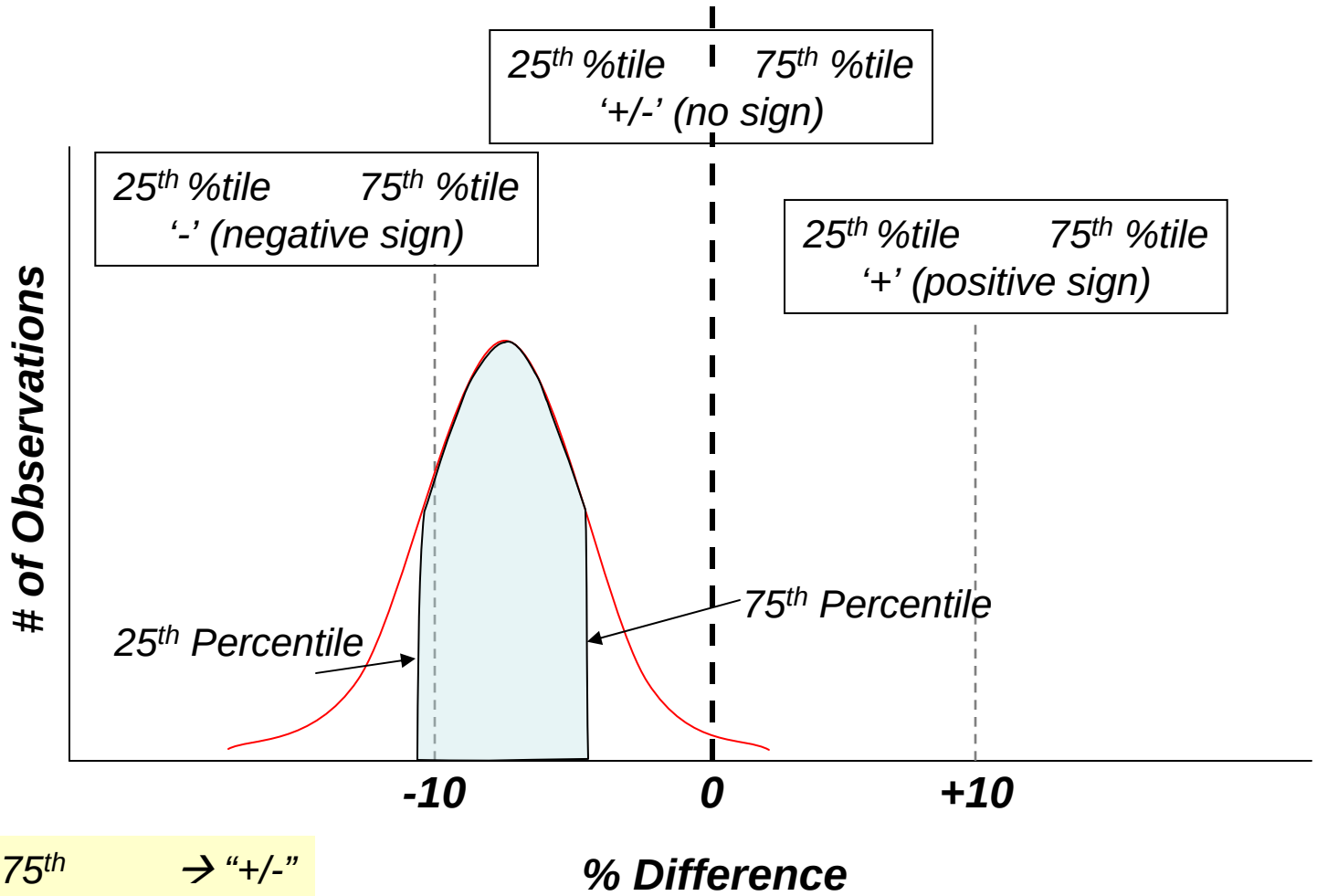
95th Quartile of a Student-t Distribution w/ n-1 df

Standard Error

$$AB = \frac{1}{n} \bullet \sum_{i=1}^{n} |d_i|$$

$$AS = \sqrt{\frac{n \bullet \sum_{i=1}^{n} |d_i|^2 - (\sum_{i=1}^{n} |d_i|)^2}{n(n-1)}}$$

Assigning a Sign to Bias



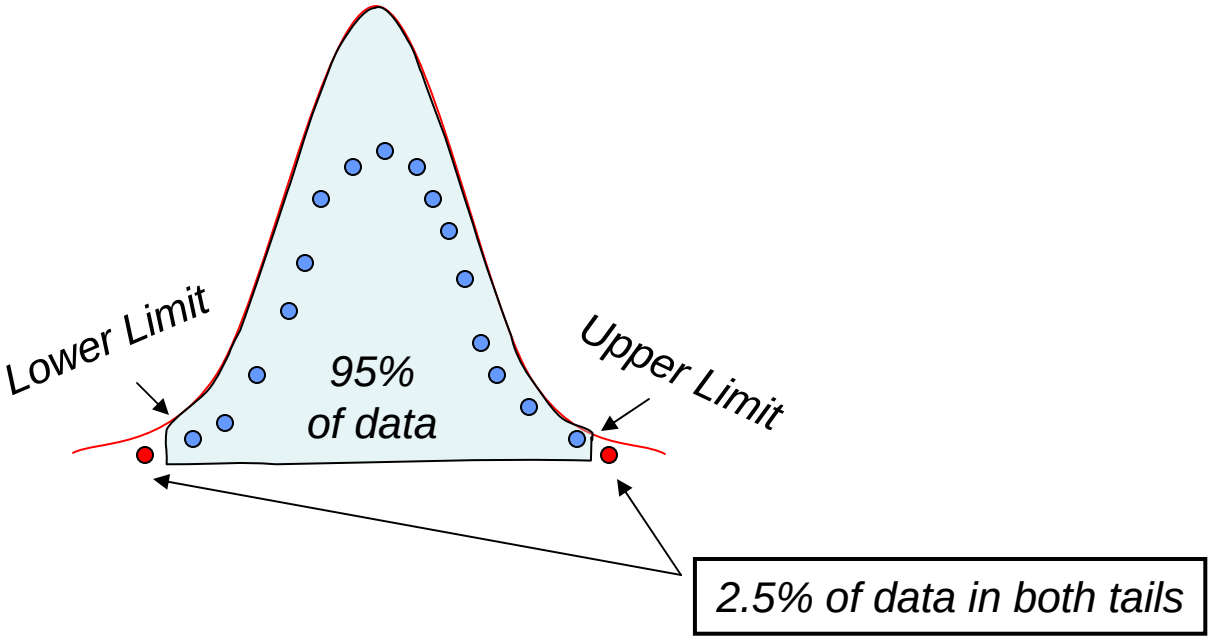
$25^{th} < 0 < 75^{th}$ → "+/-"
25th Percentile is >0 → "+"
75th Percentile is <0 → "-"

Validation of Bias

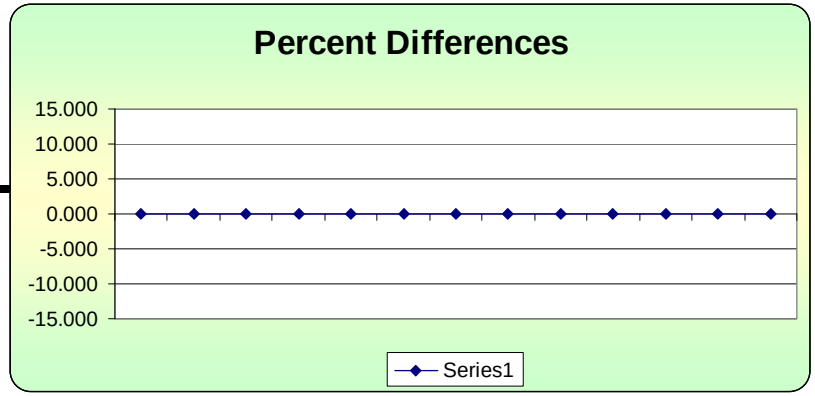
*Upper Probability Limit = m + 1.96*S*

*Lower Probability Limit = m + 1.96*S*

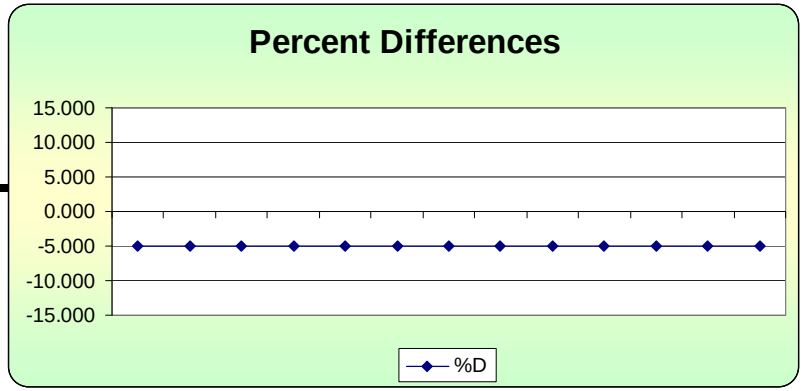
- *"d"s for the Results of the Annual Performance Evaluation*



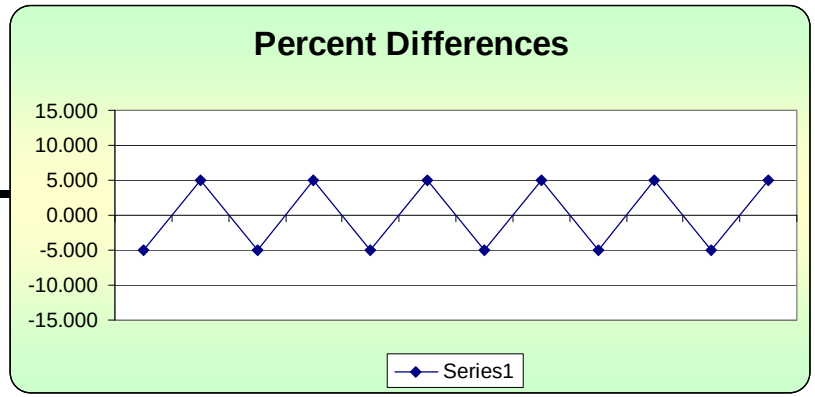
CV= 0%
Signed Bias= 0%
Upper Probability Limit= 0%
Lower Probability Limit= 0%



CV= 0%
Signed Bias= -5%
Upper Probability Limit= -5%
Lower Probability Limit= -5%



CV= 7.3%
Signed Bias= +/- 5%
Upper Probability Limit= 10.24
Lower Probability Limit= -10.24



The DQI's

- The Statistics
  - Gaseous Precision & Bias Assessments
  - Precision Estimate from Collocated Samples
  - $PM_{2.5}$ Bias Assessment
  - $PM_{2.5}$ & PM_c Absolute Bias Assessment
  - One-Point Flow Rate Bias Estimate
  - Semi-Annual Flow Rate Audits
  - Lead Bias Assessments

Evaluation Tools

- DASC (Data Assessment Statistical Calculator)
  - “Lightweight”
  - Easy to Use
  - Can be Used With Anything (If You Know What to Apply)
- AQS: Data Quality Indicators Report (AMP255)
  - Covers all of the Requirements
  - “Official Copy”
- Annual Box Plot Evaluation
  - Convenient (Let Someone Else Generate it)
  - Interesting Method of Assessment

DASC Tool

- Where to Access
  - Downloadable Excel Spreadsheet Available on the TTN
  - http://www.epa.gov/ttn/amtic/parslist.html
- When to Use
  - Need a Quick Answer and You Have Data Pairs in Hand
  - Want to do an Assessment for Non-Criteria Pollutants

DASC Tool

Holds Up to 500 Pairs of Values

References Equations in Appendix A

Graphs & Stats Automatically Updated

P&B DASC

Insert Format Tools Data FlashPaper Window Help

90% Arial

=IF(C44="","",ABS(C44)^2)

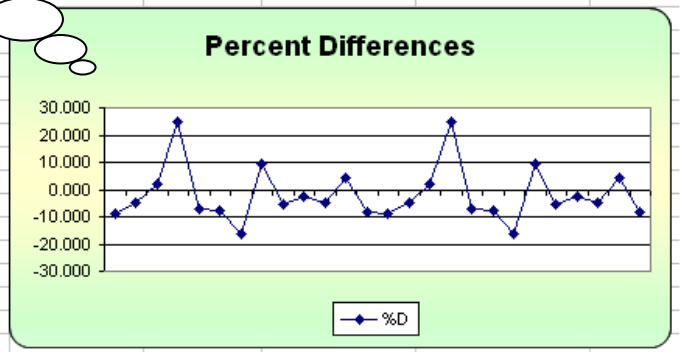
$PM_{2.5}$ Absolute Bias

2	Site ID: {E	ite ID}	Pollutant type: $PM_{2.5}$ (Absolute Bias)							Bias (%)	
3	Meas Val (Y)	udit Val (X)	d (Eqn 1)	25th Percentile	d^2	|d|	$\|d\|^2$				
4	5.05	5.55	-9.009	-7.509	81.162	9.009	81.162				
5	12.35	13	-5.000	75th Percentile	25.000	5.000	25.000	n	$\Sigma\|d\|$	$\Sigma\|d\|^2$	
6	14.67	14.35	2.230	2.230	4.973	2.230	4.973	26	213.332	2660.956	
7	9.59	7.68	24.870		618.507	24.870	618.507	n-1	Σd	Σd^2	
8	10.51	11.3	-6.991		48.876	6.991	48.876	25	-51.502	2660.956	
9	12.44	13.45	-7.509		56.389	7.509	56.389				
10	3.78	4.51	-16.186		261.995					Bias (%) (Eqn 3)	Both Signs Positive
11	18.56	16.99	9.241							10.23	FALSE
12	12.56	13.32	-5.706							Signed Bias (%)	Both signs Negative
13	7.68	7.89	-2.662							+/-10.23	FALSE
14	14.56	15.32	-4.961								
15	17.45	16.76	4.117								
16	12.34	13.44	-8.185								
17	5.05	5.55	-9.009								
18	12.35	13	-5.000								
19	14.67	14.35	2.230								
20	9.59	7.68	24.870		618.507		618.507				
21	10.51	11.3	-6.991		48.876	6.991	48.876				
22	12.44	13.45	-7.509		56.389	7.509	56.389				
23	3.78	4.51	-16.186		261.995	16.186	261.995				
24	18.56	16.99	9.241		85.391	9.241	85.391				
25	12.56	13.32	-5.706		32.555	5.706	32.555				
26	7.68	7.89	-2.662		7.084	2.662	7.084				
27	14.56	15.32	-4.961		24.610	4.961	24.610				
28	17.45	16.76	4.117		16.949	4.117	16.949				
29	12.34	13.44	-8.185		66.986	8.185	66.986				

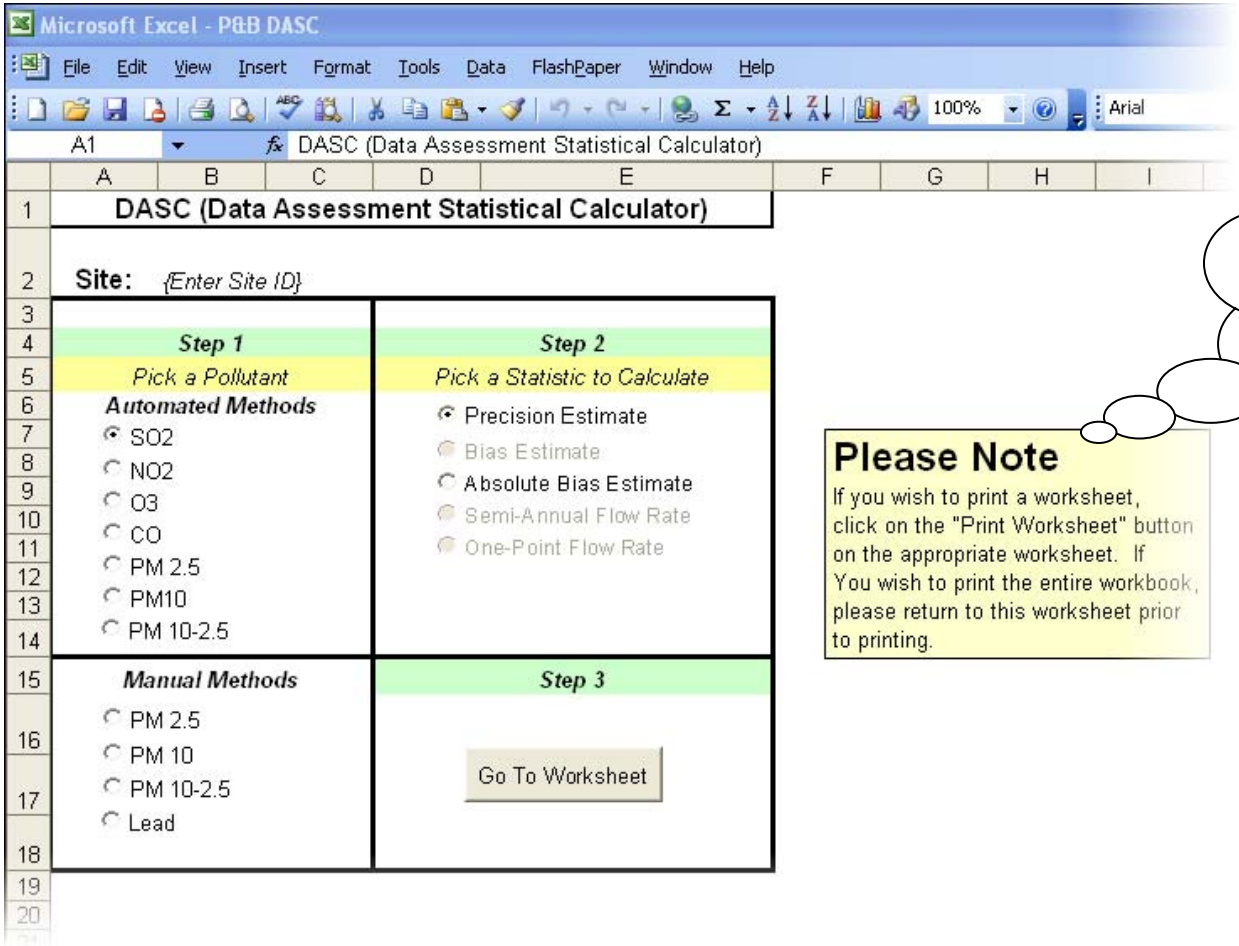
"AB" (Eqn 4)
8.205
"AS" (Eqn 5)
6.035

Return to Main Menu

Print Worksheet



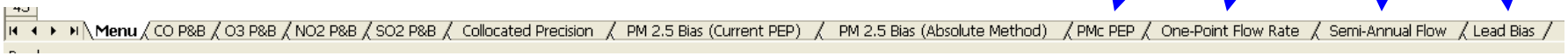
DASC Tool (Cont'd)



Easy to Use Navigation to Find the Stats You Need

Please Note

If you wish to print a worksheet, click on the "Print Worksheet" button on the appropriate worksheet. If You wish to print the entire workbook, please return to this worksheet prior to printing.



AMP255

- Where to Access
  - AQS Standard Reports
- When to Use
  - Submit for Annual Certification of Data
  - Compare Your Results for What HQ Will Refer to as “The Answer”

AMP255 Examples

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
AIR QUALITY SYSTEM

DATA QUALITY INDICATOR REPORT

Oct. 27, 2009

1-Point Quality Control

Pollutant: CO **PQAO:** 1188 (Wyoming Air Quality Division, Dept Of Environmental Quality) **App A?:** Yes

Year	Region	State	Site ID	POC	MT	Begin Date	End Date	# Req	# Obs	% Complete	CV	Bias
2008	08	WY	56-041-0101	1	SP	01-JAN-08	31-DEC-08	26	98	100	7.18	+/- 5.68
2008	08	WY	SUMMARY					26	98	100	7.18	+/- 5.68
SUMMARY	08	WY						26	98	100	7.18	+/- 5.68

Pollutant: NO2 **PQAO:** 1188 (Wyoming Air Quality Division, Dept Of Environmental Quality) **App A?:** Yes

Year	Region	State	Site ID	POC	MT	Begin Date	End Date	# Req	# Obs	% Complete	CV	Bias
2008	08	WY	56-005-0123	1	SP	01-JAN-08	31-DEC-08	26	39	100	4.72	+/- 3.89
2008	08	WY	56-005-0456	1	SP	01-JAN-08	31-DEC-08	26	40	100	4.39	+ 5.08
2008	08	WY	56-013-0099	1	SP	01-JAN-08	31-DEC-08	26	31	100	3.13	+ 3.01
2008	08	WY	56-035-0098	1	SP	01-JAN-08	31-DEC-08	26	34	100	4.19	- 4.68
2008	08	WY	56-035-0099	1	SP	01-JAN-08	31-DEC-08	26	29	100	3.65	- 3.86
2008	08	WY	56-035-0100	1	SP	01-JAN-08	31-DEC-08	26	26	100	15.79	- 12.65
2008	08	WY	56-037-0200	1	SP	01-JAN-08	31-DEC-08	26	49	100	6.41	+/- 5.36
2008	08	WY	56-041-0101	1	SP	01-JAN-08	31-DEC-08	26	117	100	4.73	+ 5.48
2008	08	WY	SUMMARY					208	365	100	6.45	+/- 4.87
SUMMARY	08	WY						208	365	100	6.45	+/- 4.87

PQAO: 1347 (Anadarko, WY) **App A?:** Yes

POC	MT	Begin Date	End Date	# Req	# Obs	% Complete	CV	Bias
1	SP	01-JAN-08	31-DEC-08	26	28	100	17.78	+/- 11.69
				26	28	100	17.78	+/- 11.69
				26	28	100	17.78	+/- 11.69

PQAO: 0908 (Rhone Poulenc) **App A?:** Yes

POC	MT	Begin Date	End Date	# Req	# Obs	% Complete	CV	Bias
1	ID	01-APR-08	31-OCT-08	15	0	0		
				15	0	0		

Statistics Shown on a per Site and Per PQAO Level as Appropriate

RECAP: What is Performed

Method	Pollutants	Frequency	MQO	
One-Point QC	SO_2, NO_2, O_3, CO	Every 2 Weeks	O_3 : Precision = 7% Bias = 7%	SO_2, NO_2, CO : Precision = 10% Bias = 10%
Annual Performance Evaluation	SO_2, NO_2, O_3, CO	Once per Year	<= 15% for each audit concentration	
Flow Rate Verification	PM_{10}, $PM_{2.5}$, PM_c	Once per Month	<= 4% of Standard & 5% of Design Value	
Semi-Annual Flow Rate Audit	PM_{10}, $PM_{2.5}$, PM_c	Every 6 Months	<= 4% of Standard & 5% of Design Value	
Collocated Sampling	PM_{10}, TSP, $PM_{2.5}$, PM_c	15% of Network Every 12 Days	$PM_{2.5}$, TSP, PM_{10} : Precision = 10%	PM_c: Precision = 15%
PM PEP Program	$PM_{2.5}$, PM_c		$PM_{2.5}$: Precision = 10%	PM_c: Precision = 15%

AMP255 Examples (Cont.)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
AIR QUALITY SYSTEM

DATA QUALITY INDICATOR REPORT

Oct. 27, 2009

Performance Evaluation Program (PEP)

Pollutant: PM2.5 **PQAO:** 0520 (Indiana Depart Of Environ Management/Office Of Air Management) **App A?:** Yes

Year	Region	State	# Sites	#PEP Required	# PEP Collected	# Collocated PEP Req	# Collocated PEP Coll.	% Complete	Bias	Conf. Limits Lower	Conf. Limits Upper
2008	05	IN	32	8	7	0	0	88	- 3.22	-10.32	3.88
SUMMARY	05	IN						88	- 3.22	-10.32	3.88

Pollutant: PM2.5 **PQAO:** 0523 (Indianapolis Office of Environmental Services) **App A?:** Yes

Year	Region	State	# Sites	#PEP Required	# PEP Collected	# Collocated PEP Req	# Collocated PEP Coll.	% Complete	Bias	Conf. Limits Lower	Conf. Limits Upper
2008	05	IN	5	5	5	0	0	100	- 8.70	-17.06	-0.34
SUMMARY	05	IN						100	- 8.70	-17.06	-0.34

Page 6 of 6

Notes About the AMP255

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
AIR QUALITY SYSTEM
DATA QUALITY INDICATOR REPORT

Oct. 27, 2009

Semi-Annual Flow Rate Audits

Pollutant: PM2.5 **PQAO:** 0523 (Indianapolis Department Of Environmental Management/Office Of Air Management) **App A?:** Yes

Year	Region	State	Site ID	POC	MT	Begin Date	End Date	# Req	#Q w/ Data	% Complete	Criteria Met?	Obs / Q Q1	Q2	Q3	Q4	Avg %d	Flow Rate Conf. Limits Lower	Upper	% Between Conf. Limits
2008	05	IN	18-157-0008	2				2	4	100	N	1	1	1	1	3.5			
2008	05	IN	18-163-0006	1				2	4	100	Y	1	1	1	1	-0.3			
2008	05	IN	18-163-0006	2				2	4	100	Y	1	1	1	1	0.0			
2008	05	IN	18-163-0012	1	S	01-JAN-08	31-DEC-08	2	4	100	Y	1	1	1	1	-0.2			
2008	05	IN	18-163-0016	1	S	01-JAN-08	31-DEC-08	2	4	100	Y	1	1	1	1	-1.4			
2008	05	IN	18-167-0018	1	S	01-JAN-08	31-DEC-08	2	4	100	Y	1	1	1	1	0.4			
2008	05	IN	18-167-0023	1	S	01-JAN-08	31-DEC-08	2	4	100	Y	1	1	1	1	1.1			
2008	05	IN	SUMMARY					73	145	100	84	36	35	37	38	0.5			
SUMMARY	05	IN						73	145	100	84	36	35	37	38	0.5			

Pollutant: PM2.5 **PQAO:** 0523 (Indianapolis Office of Environmental Services) **App**

Year	Region	State	Site ID	POC	MT	Begin Date	End Date	# Req	#Q w/ Data	% Complete	Criteria Met?	Obs / Q Q1	Q2	Q3	Q4	Avg %d	Flow Rate Conf. Limits Lower	Upper	% Between Conf. Limits
2008	05	IN	18-097-0043	1							Y	1	1	1	1	0.4			
2008	05	IN	18-097-0066	1							Y	1	1	1	1	-1.2			
2008	05	IN	18-097-0078	1							Y	1	1	1	1	-1.2			
2008	05	IN	18-097-0081	1							Y	1	1	1	1	-1.0			
2008	05	IN	18-097-0081	2							Y	1	1	1	1	-1.8			
2008	05	IN	18-097-0083	1							Y	1	1	1	1	-1.6			
2008	05	IN	SUMMARY								100	6	6	6	6	-1.1			0
SUMMARY	05	IN									100	6	6	6	6	-1.1			0

Understanding The Rules Is Key!

Data Is Grouped By Whether it Applies to Appendix A Regulations Or Not (Defined by the Monitor Type)

Summaries are Computed Per Year within the Group And then Summarized Across Years

How Can This Be?!?!?!

# Req	#Q w/ Data	% Complete	Criteria Met?
2	4	100	N

- Rule Says:
  - Must Have at Least 2 Samples if the Monitor was Operational at Least 7 Months in the Year
  - Samples Must be Between 5 and 7 Months Apart

Audit Date	Months Since Last Audit
March 16, 2008	n/a
June 19, 2008	3.10 Months
July 22, 2008	1.10 Months (4.20 Months Since 1st Sample)
November 4, 2008	3.42 Months (4.42 Months Since 2nd Sample; 7.61 Months Since 1st)

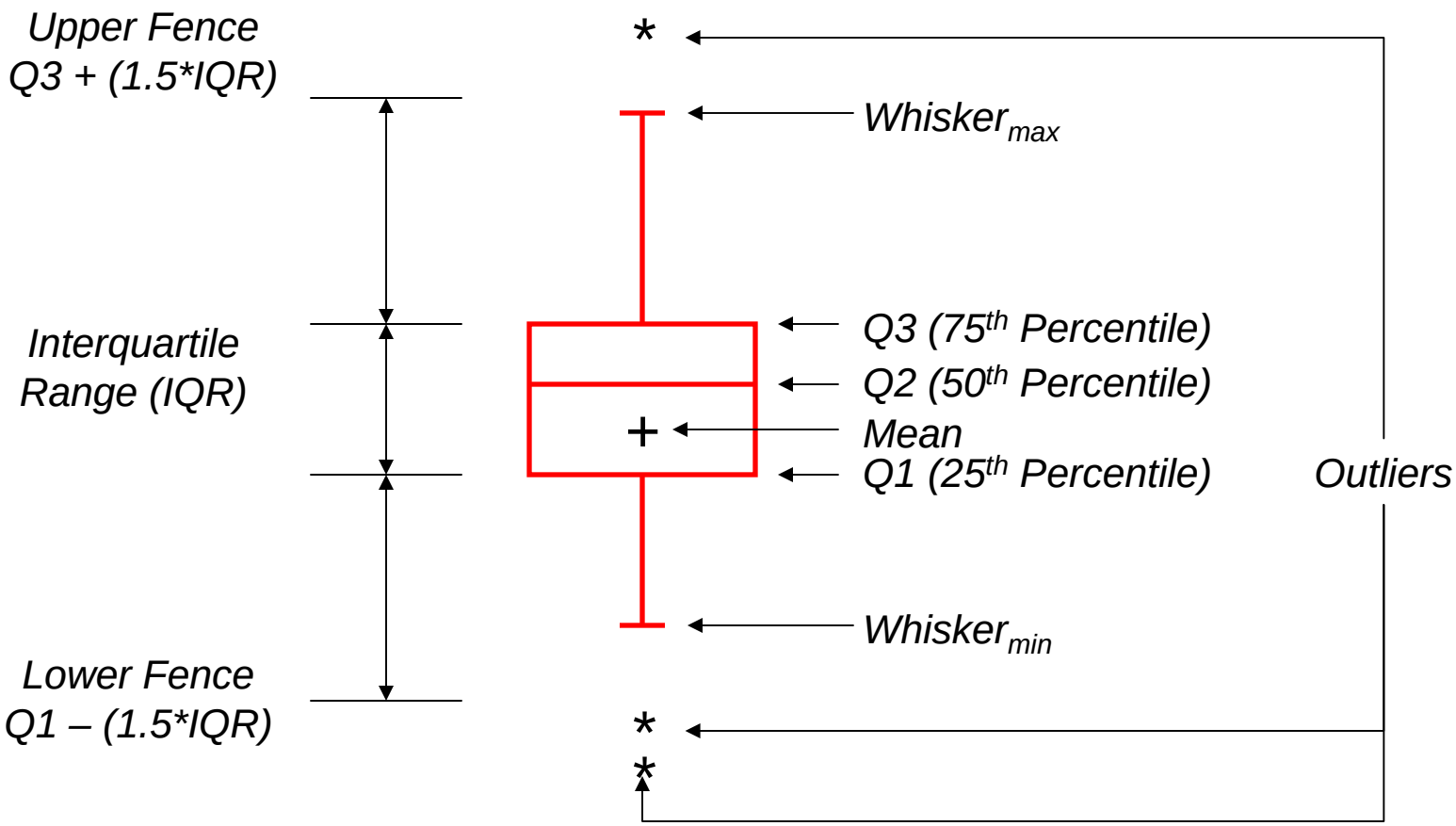
Practical Interpretations of the AMP255

- Provides and INDICATION of Quality… Not the Final Answer
  - Data Will Not be Invalidated / Not Certified Because the “Criteria Met” Column Says “N”
- Flow Rate Verifications Are Not Required to Be Entered in AQS
  - Interpretation of Results Provided for Those Agencies that Choose to Report These Values
- Rules of the AMP255 Are Documented on the TTN (http://www.epa.gov/ttn/amtic/files/ambient/qaqc/AMP255FAQ.pdf)

Annual Box and Wisker Plots

- Where to Access
  - http://www.epa.gov/ttn/amtic/parslist.html
- When to Use
  - Provides Interesting Graphical Displays of Previous Year's Data
  - Use in Historical Trends of Quality of Data

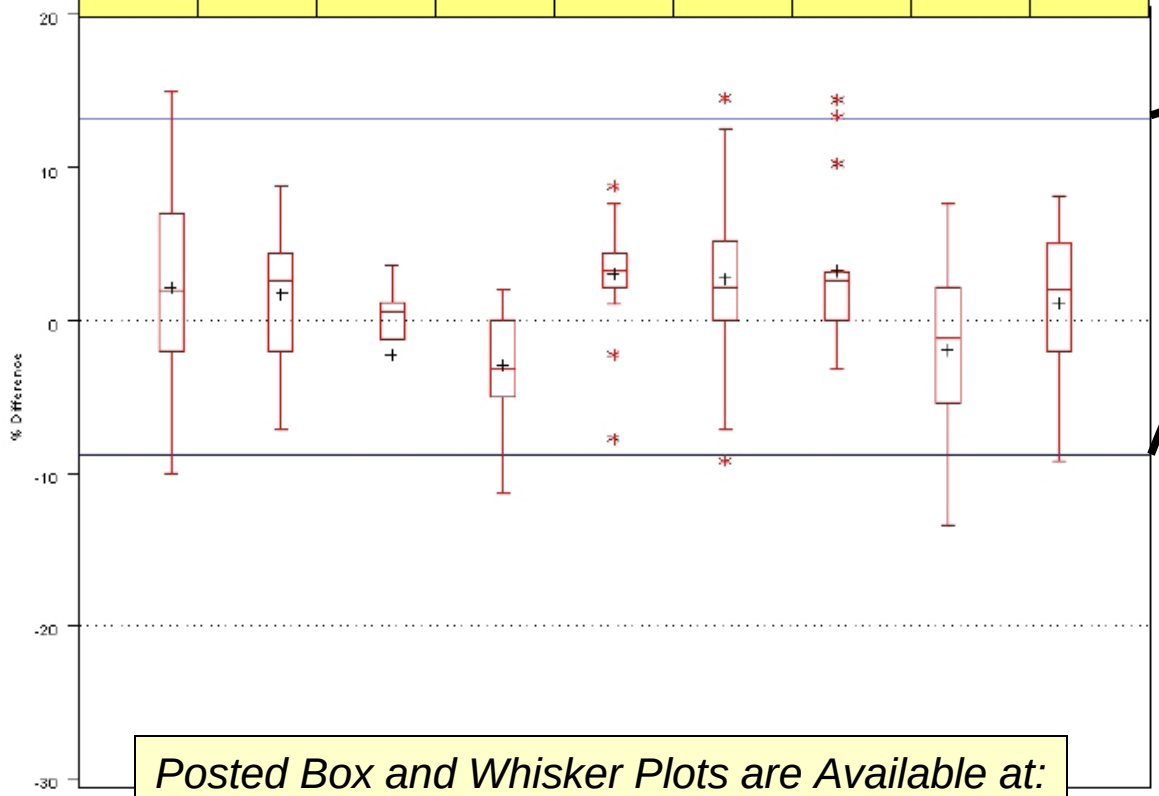
Box and Whisker Plots

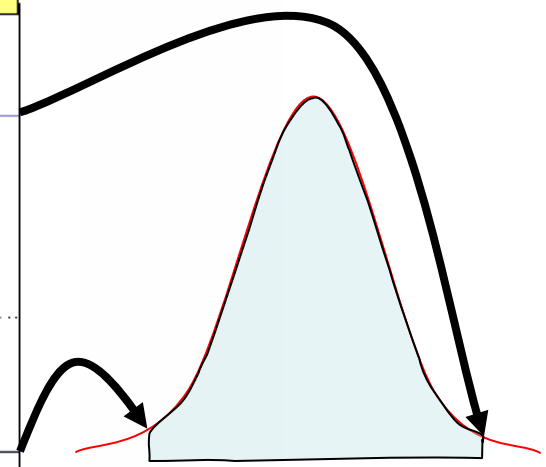


Box and Whisker Plots

Region	State	Agency	Parameter	Monitor Type
[illegible]	[illegible]	[illegible]	SO_2	SLAMS

AQS ID	[illegible]								
CV	7.77	4.83	14.36	4.11	3.99	7.54	5.73	7.31	6.37
Bias	6.66	4.39	9.41	-4.36	+4.59	+6.63	+5.27	6.19	5.34
# Obs	28	26	10	26	25	26	26	26	26





Remember Me?

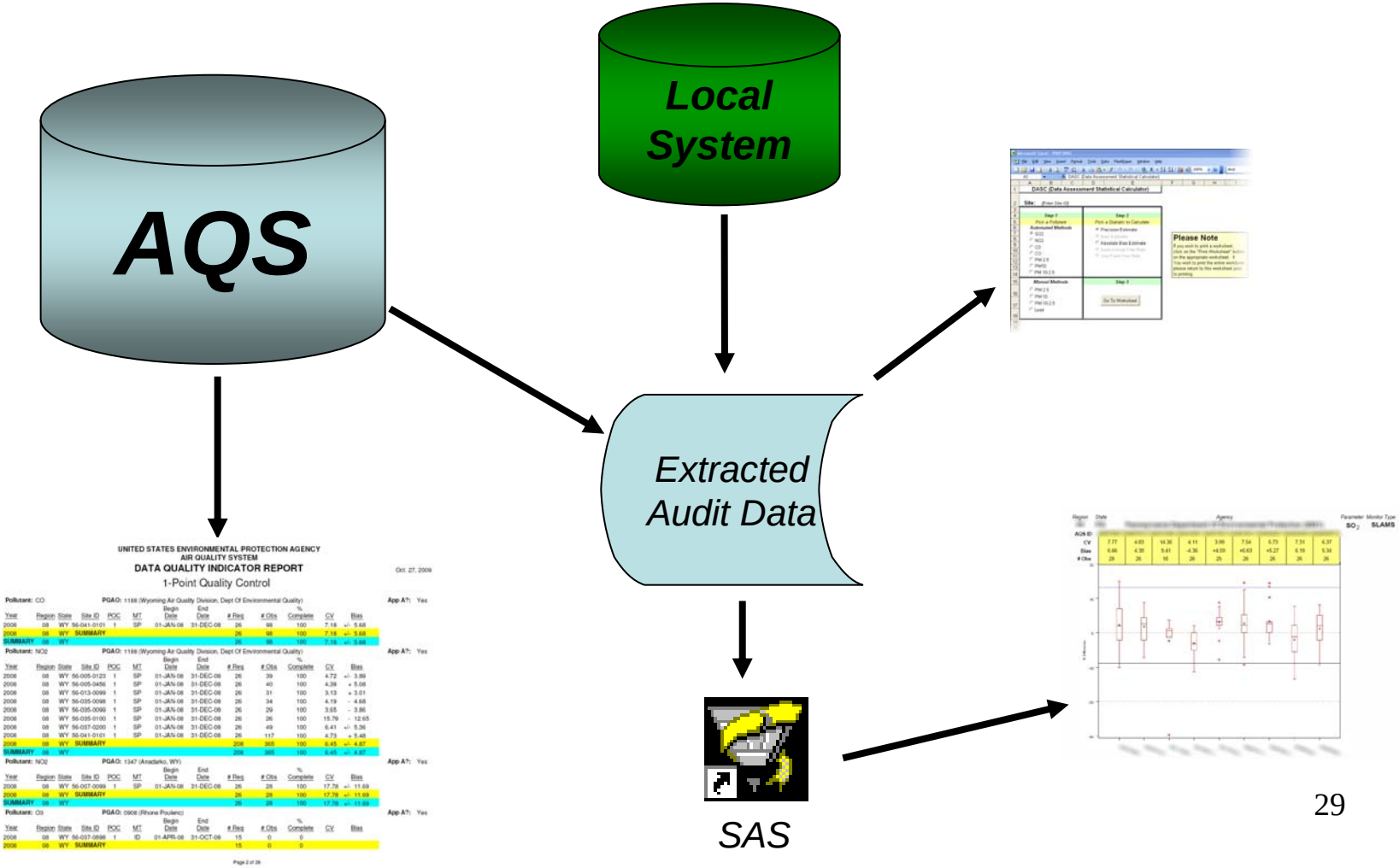
Posted Box and Whisker Plots are Available at:
www.epa.gov/ttn/amtic/parslist.html

What Data is in AQS?

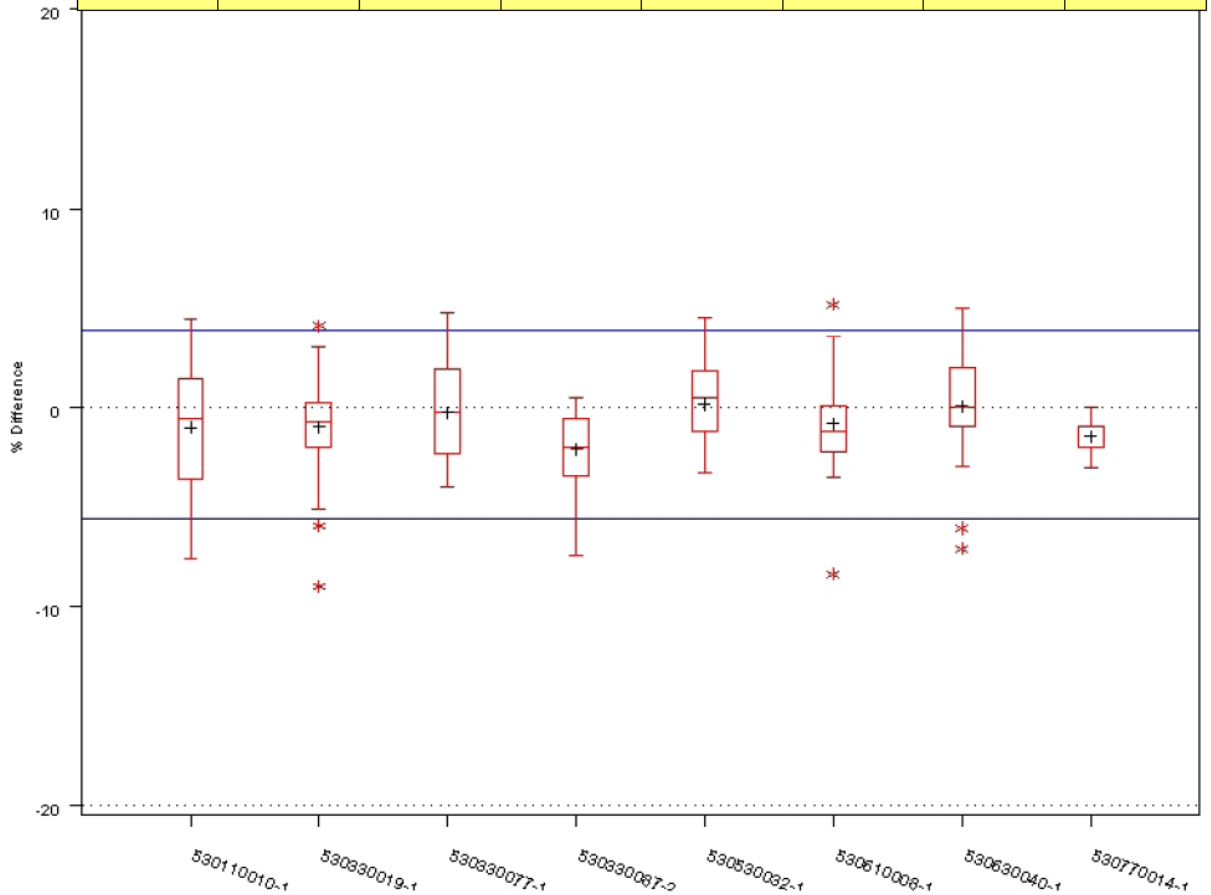
- Collocated Data
- Flow Data
- Annual Performance Audits
- NPAP Data
- *Technical Systems Audit Information???*

"Where the Rubber Meets the Road"

An Example of Output of the Tools for a Common Dataset



Box Plot Output

Region	State	Agency	Parameter	Monitor Type
10	WA	Washington State Department Of Ecology (1136)	CO	SLAMS

AQS ID	530110010-1	530330019-1	530330077-1	530330087-2	530530032-1	530610008-1	530630040-1	530770014-1
CV	3.43	2.58	3.21	2.11	2.69	3.30	3.19	1.35
Bias	2.94	2.12	2.64	-2.67	2.21	2.72	2.38	-1.96
# Obs	35	55	22	28	26	26	25	13