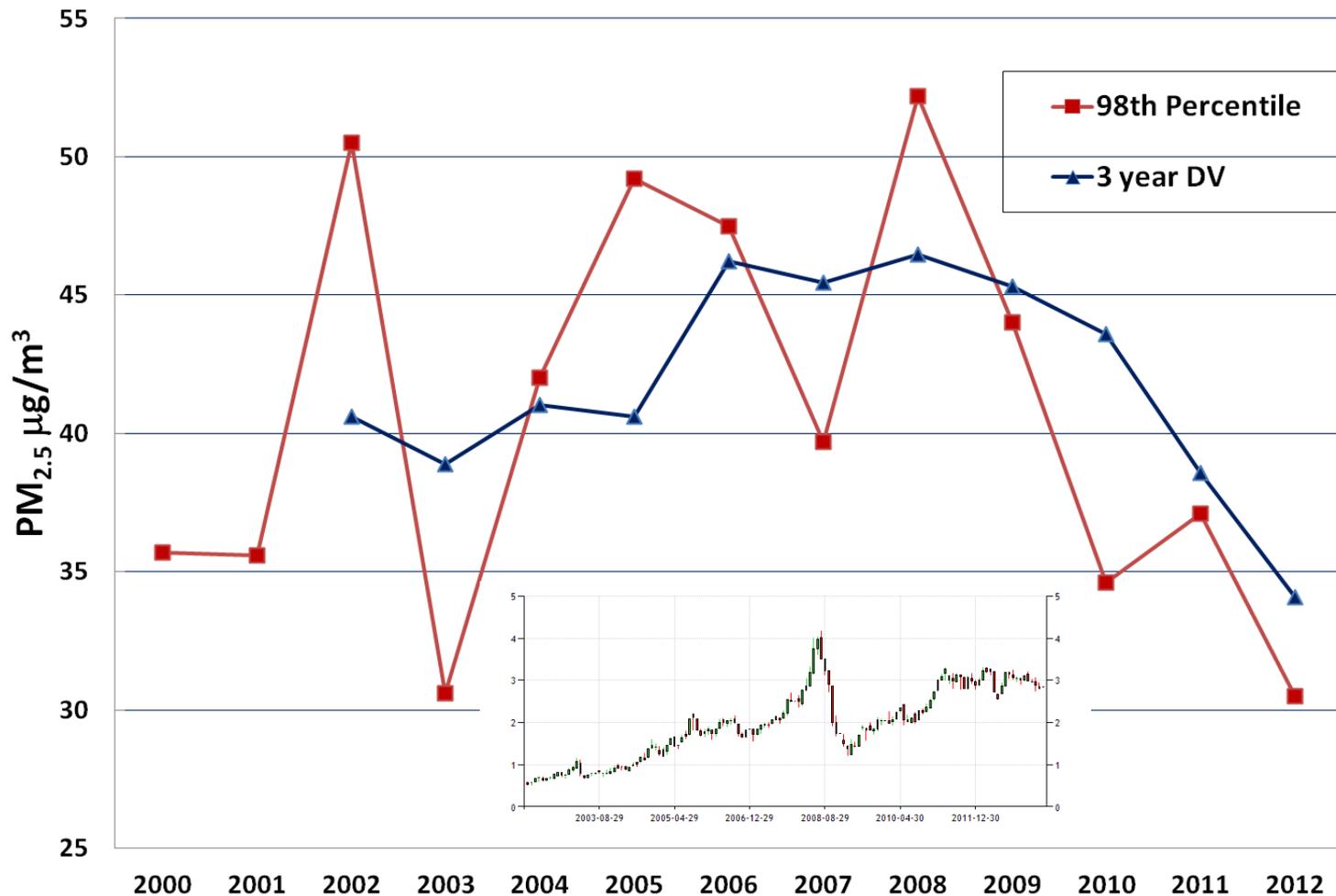# A look at PM$_{2.5}$ Meteorological and Sampling Luck

Robert Elleman
EPA Region 10
Presented to 2013 NW-AIRQUEST Meeting
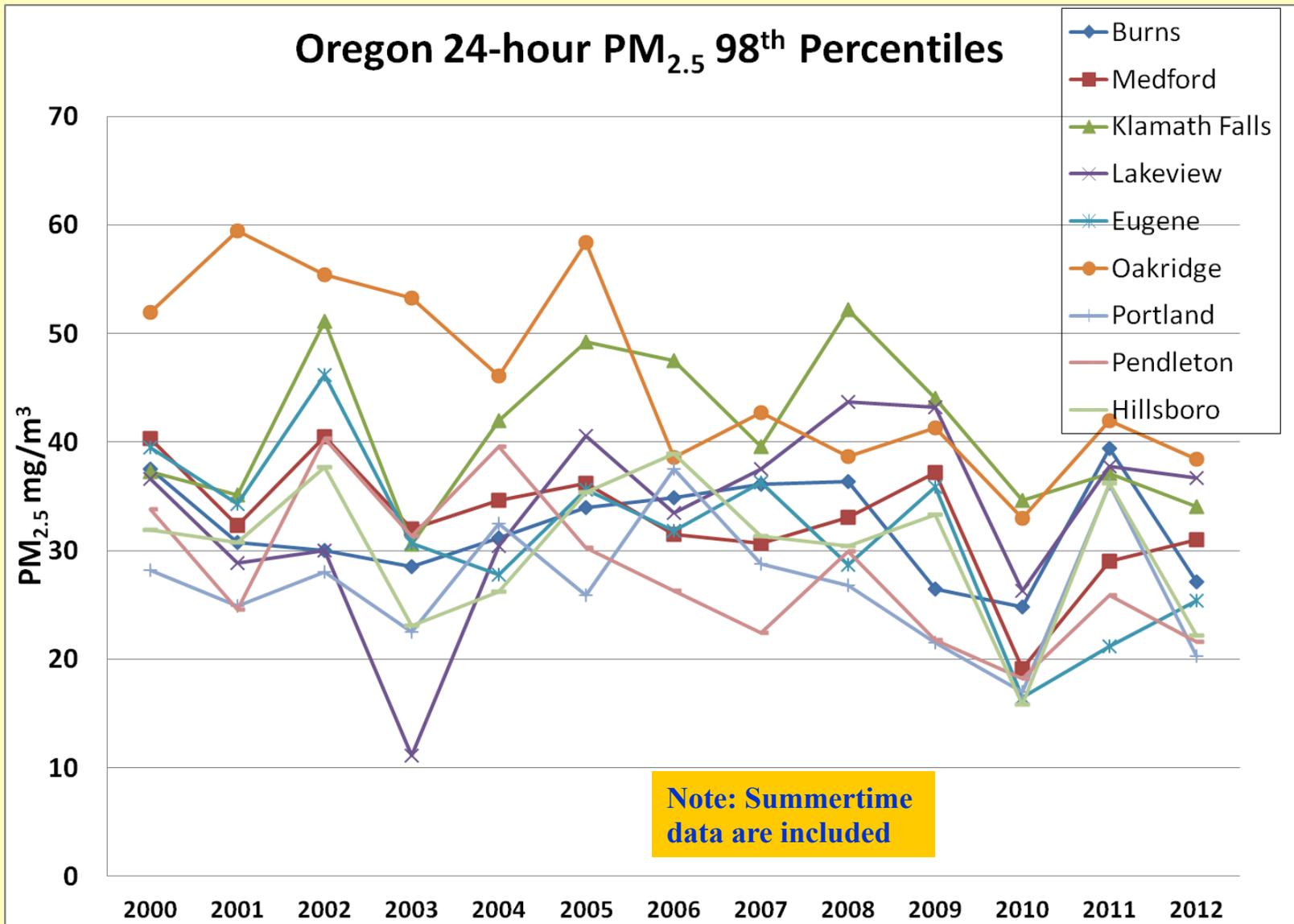
Example of Interannual Variability

24-Hour PM$_{2.5}$ at Klamath Falls

Note: Summertime data are excluded
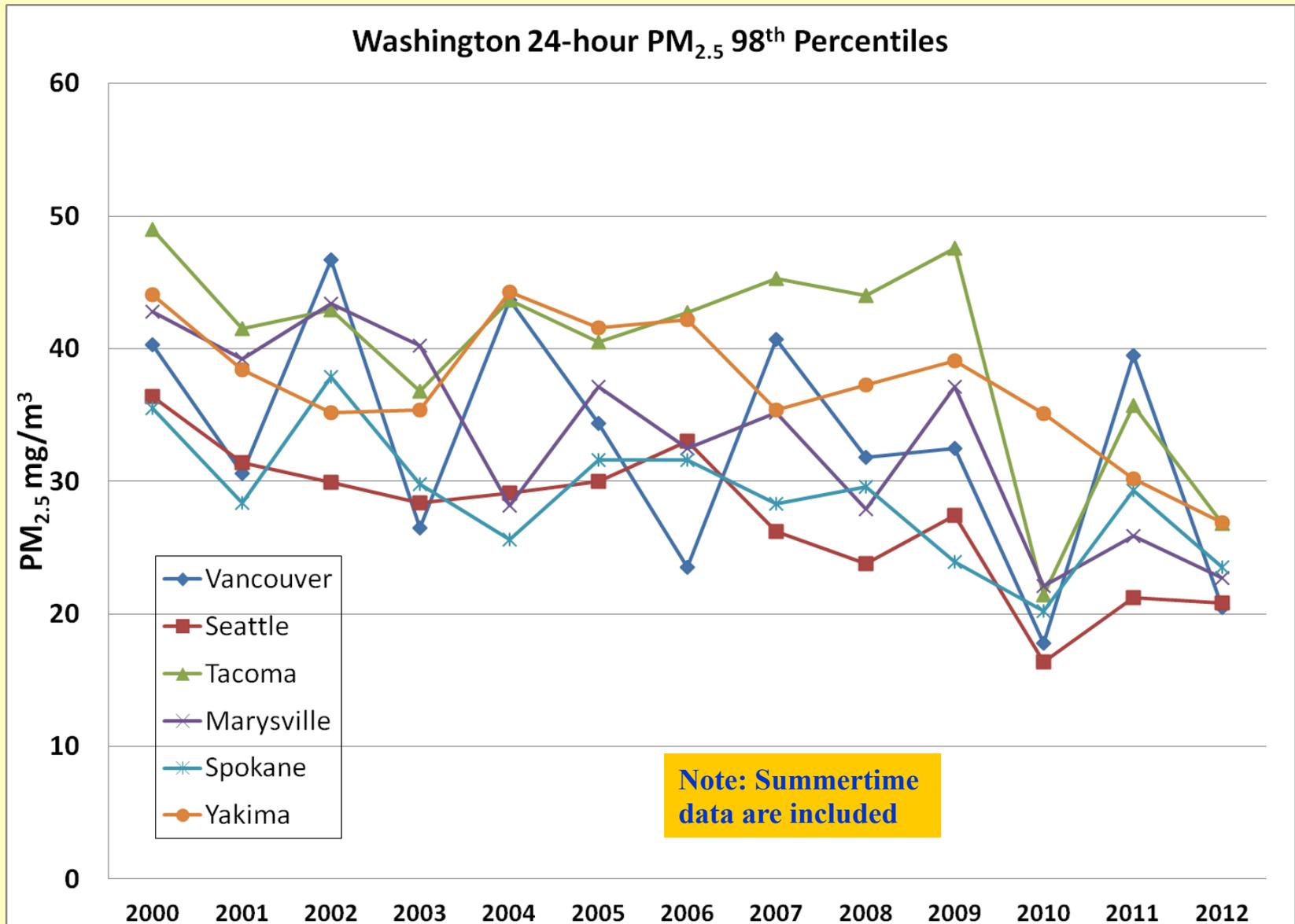
Interannual Variability

Oregon 24-hour PM$_{2.5}$ 98th Percentiles

Note: Summertime data are included

Interannual Variability

Washington 24-hour PM$_{2.5}$ 98th Percentiles

Note: Summertime data are included

What Causes Interannual Variability?

- **Meteorological variability**
- **Sampling luck**
- **Real variations in emissions**
  - **Recession**
  - **Energy costs**
  - **Stochasticity near monitors influenced by just a few sources**
  - **Inconsistent compliance with policies to reduce pollution**

Meteorological Adjustment

- **Regression techniques**
  - **Multiple linear regression**
  - **Factor analysis**
  - **Principal Component Analysis (PCA)**
  - **Singular Value Decomposition (SVD) or Canonical Covariance Analysis**
- **Classification and Regression Trees**
  - **e.g., Idaho DEQ ozone forecasting**
- **Non-linear regression and cluster analyses**
- **Time series filtering**
- **Spatial Analysis**

Analysis of 2012 Meteorological Luck

- **Started with yearly 98th percentiles from AQS data**

  - compared 2007-2011 average 98th %tile to 2012 for sites in Washington and Oregon

  - If one site in 2012 varies from the 2007-2011 average much more than the others did, something other than meteorology is probably going on

Washington

West Side	2012 / [2007-2011]	East Side	2012 / [2007-2011]
Bellingham	0.58	Winthrop	0.73
Darrington	0.71	Twisp	0.88
Port Angeles	0.95	Wenatchee	0.80
Marysville	0.77	Ellensburg	0.76
Lynnwood	0.71	Yakima	0.74
Lk Forest Park	0.74	Toppenish	0.93
Duwamish	0.84	White Swan	0.70
Beacon Hill	0.62	Walla Walla	0.67
Kent	0.89	Spokane Augusta	0.58
Puyallup 128th	0.91	Clarkston	0.73
Tacoma Alex	0.80		
Tacoma L	0.66		
Shelton	1.02		
Lacey	1.03		
Yacolt	0.78		
Vancouver	0.75		
Average	0.81	Average	0.75
Standard Deviation	0.13	Standard Deviation	0.10
Statewide	Average	0.78	
	Standard Deviation	0.12	

Oregon

West Side	2012 / [2007-2011]	East Side	2012 / [2007-2011]
Portland	0.76	The Dalles	0.73
Hillsboro	0.72	Pendleton	0.84
Beaverton	0.79	LaGrande	1.00
Salem	0.68	Baker City	0.70
Albany	0.68	John Day	0.65
Sweet Home *	0.57	Prineville #	0.83
Eugene	0.75	Bend *	0.59
Oakridge	0.82	Burns	0.69
Roseburg	1.01	Klamath Falls	0.76
Grants Pass	0.63	Lakeview	0.84
Medford	1.00		
Average	0.76	Average	0.76
Standard Deviation	0.14	Standard Deviation	0.12
Statewide	Average	0.76	* 2008-2011
	Standard Deviation	0.13	# 2009-2011

Analysis of 2012 Meteorological Luck

- **Started with yearly 98th percentiles from AQS data**
    - Perhaps can conclude that Tacoma L Street was anomalously clean for 2012, but not Kfalls and Oakridge
- **Then I got a better dataset from Anthony Barnack at Oregon DEQ**
    - Data since 2000 with AQS data when available and filled with continuous monitor data for days when AQS was not available
    - 29 sites with at least five years of data (31 sites total)
    - I used the *wintertime only*

Compare Klamath Falls 98th %tile to Oregon Across Time

- **Assumes that interannual meteorological variability is on the scale of the state or significant portions of the state**

	Klamath Falls	Klamath Falls Attainment Plan	Average of statewide (No Kfalls)	Average of Eastside (No Kfalls)	Average of Southern (No Kfalls)
2000	37.3	37.3	30.7	27.2	31.9
2001	35.1	35.1	26.7	25.5	26.9
2002	51.1	51.1	28.3	28.8	28.2
2003	32.4	32.4	27.0	25.8	28.7
2004	42.0	42.0	27.9	27.4	25.7
2005	46.4	46.4	27.2	28.2	26.3
2006	51.2	51.2	23.5	24.6	25.2
2007	51.6	51.6	26.1	23.2	24.4
2008	49.4	33.0	24.0	25.6	25.1
2009	35.8	33.0	25.7	25.0	25.8
2010	33.2	33.0	18.5	20.6	18.2
2011	37.8	33.0	24.4	27.3	28.1
2012	34.5	33.0	19.5	21.5	21.7

# Compare Klamath Falls to Oregon Across Time

	Kfalls/State		Kfalls/State for Attainment Plan	Kfalls/Eastside	Kfalls/Eastside for Attainment Plan	Kfalls/South	Kfalls/South for Attainment Plan
2000	1.22		1.22	1.37	1.37	1.2	1.17
2001	1.32		1.32	1.38	1.38	1.3	1.30
2002	1.81		1.81	1.77	1.77	1.8	1.81
2003	1.20		1.20	1.26	1.26	1.1	1.13
2004	1.50		1.50	1.53	1.53	1.6	1.63
2005	1.70		1.70	1.64	1.64	1.8	1.76
2006	2.18		2.18	2.08	2.08	2.0	2.03
2007	1.97		1.97	2.22	2.22	2.1	2.11
2008	2.06		1.37	1.93	1.29	2.0	1.31
2009	1.40		1.29	1.43	1.32	1.4	1.28
2010	1.80		1.79	1.61	1.60	1.8	1.81
2011	1.55		1.35	1.38	1.21	1.3	1.17
2012	1.77		1.70	1.60	1.53	1.6	1.52
Average 2000-2007	1.61		1.61	1.66	1.66	1.62	1.62
Average 2008-2012	1.71		1.50	1.59	1.39	1.62	1.42
T-test (needs to be <0.05 to be significant)	0.283		0.249	0.342	0.046	0.495	0.139

Analysis of 2012 Meteorological Luck

- **Started with yearly 98th percentiles from AQS data**
  - Perhaps can conclude that Tacoma L Street was anomalously clean for 2012, but not Kfalls and Oakridge

- **Then I got a better dataset from Anthony Barnack at Oregon DEQ**
  - Not possible to see emission reductions among the meteorological variability with this relatively simple technique

1-in-3 Sampling Luck

Klamath Falls 2007 Sampling Luck
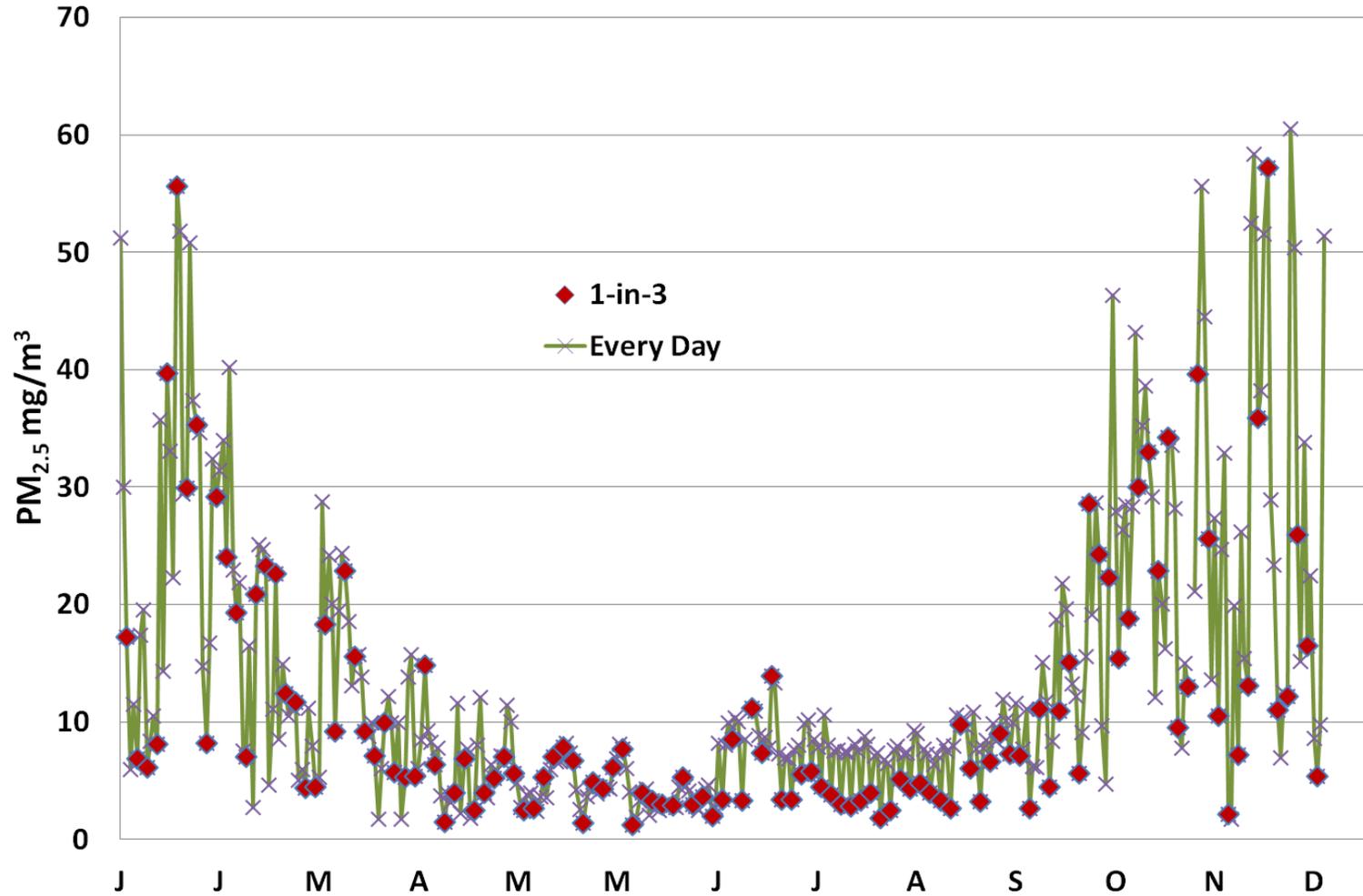
98th Percentile Based on 8th Highest of Every Day:	51.6
98th Percentile Based on 3rd Highest of 1-in-3:	39.7

Sampling Luck

- **Used Oregon DEQ 13-year dataset to create synthetic 1-in-3 datasets**
  - *In many cases this is reverting to 1-in-3 FRM filter method, in other cases it is not*
  - *Summertime data excluded*

- **Also, created two hypothetical 1-in-3 datasets for unchosen sampling schedules**
  - *e.g., if schedule is Jan 1/4/7/[…], also created dataset using Jan 2/5/8/[…] and using Jan 3/6/9/[…]*

Distribution of Sampling Luck
Annual 98th Percentiles

Samples: 330

+: 134

-: 155

Mean = -0.3 µg/m^3

Median = 0 µg/m^3

Stdev = 3.2 µg/m^3

<-1.8 µg/m^3 : 57

>1.8 µg/m^3 : 76

<-3.5 µg/m^3 : 35

>3.5 µg/m^3 : 30

Sampling Luck for Oregon 98th %Tile, 2000-2012
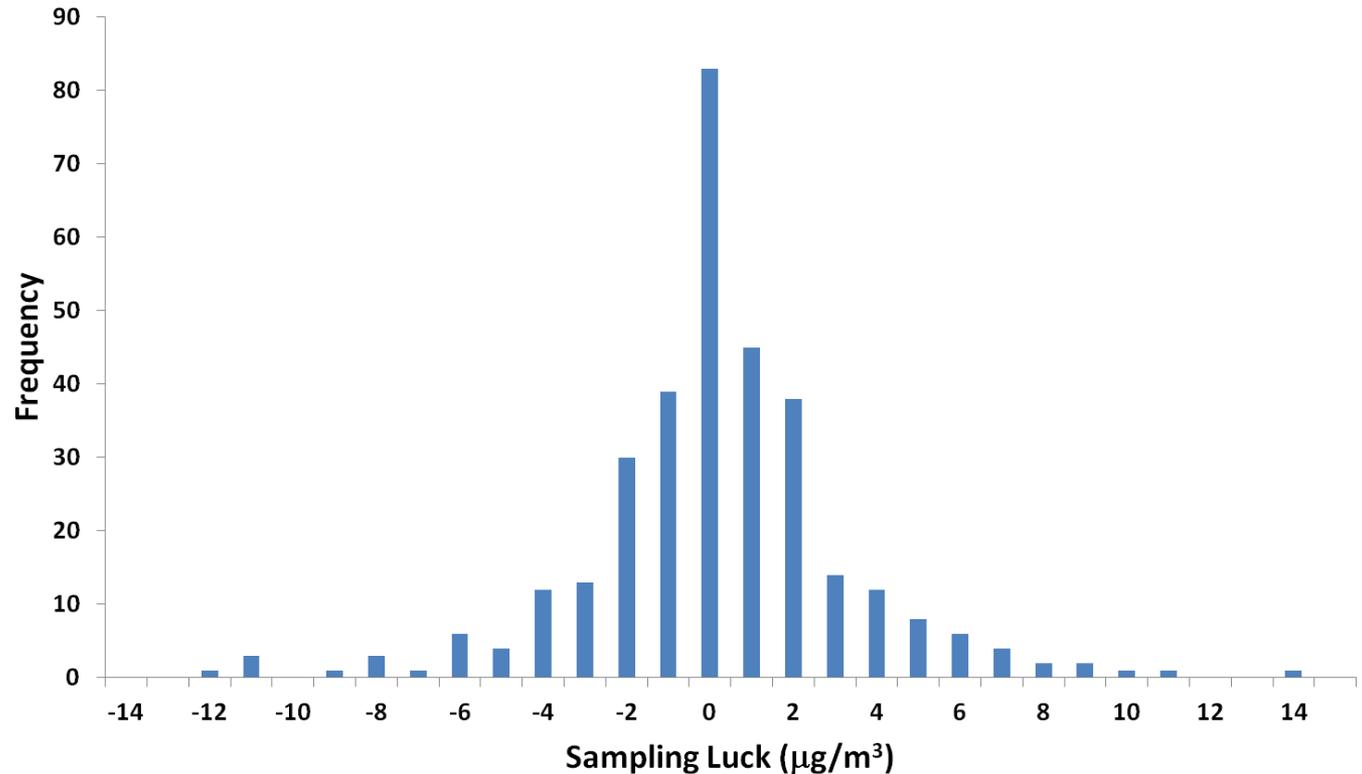
Good Luck   Bad Luck

Distribution of Sampling Luck
3-Yr Design Values

Samples: 269

+: 119

-: 149

Mean = -0.3 µg/m³

Median = -0.2 µg/m³

Stdev = 1.9 µg/m³

 # <-1.8 µg/m³ : 52

 # >1.8 µg/m³ : 29

 # <-3.5 µg/m³ : 12

 # >3.5 µg/m³ : 6

Sampling Luck for Oregon DV, 2000-2012
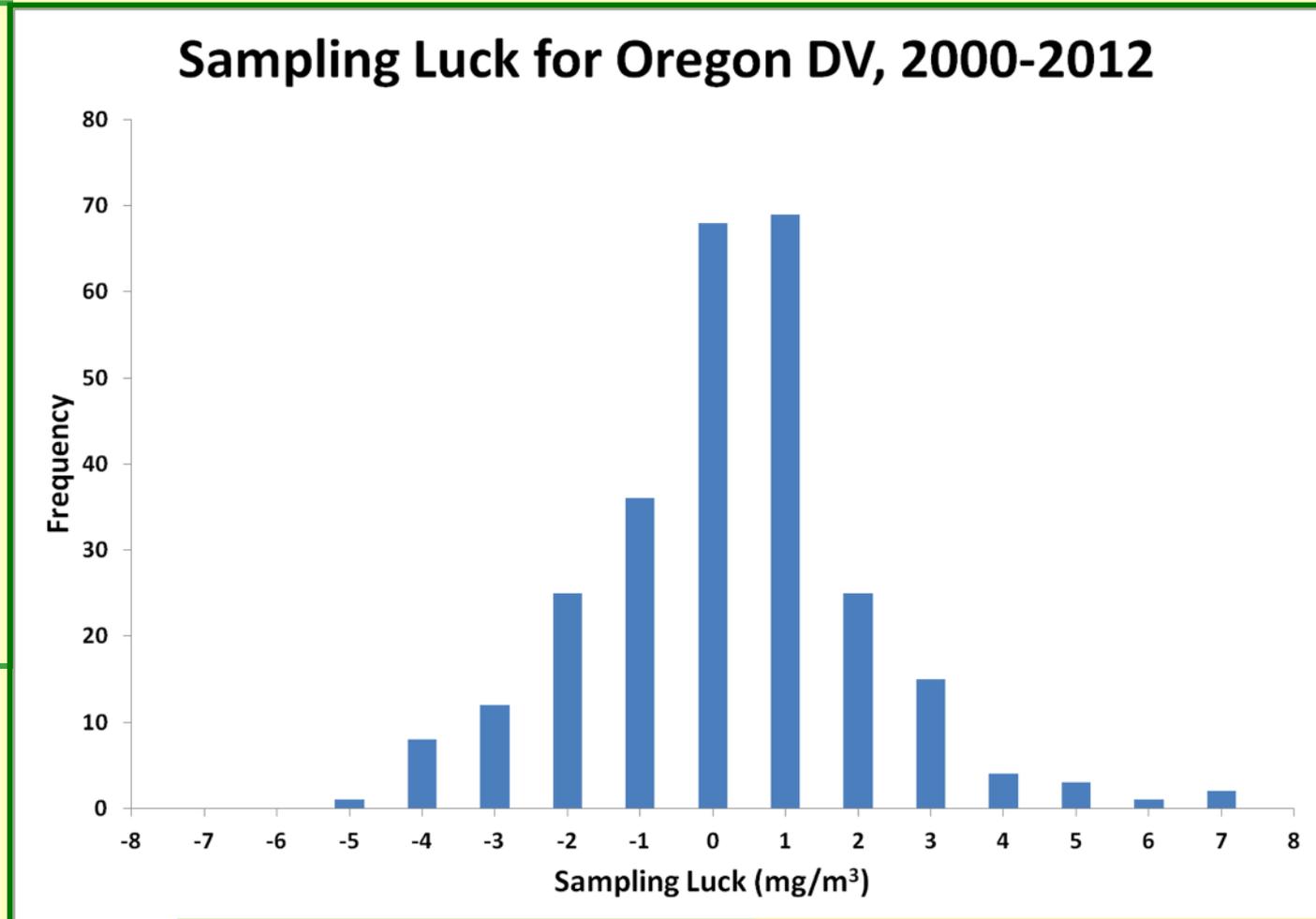
Good Luck **Bad Luck**

Sampling Luck Example
Lakeview, Oregon

98th Percentiles in μg/m^3	1-in-1	1-in-3	1-in-3 +1	1-in-3 +2
2000	36.6	35.1	33.4	38.6
2001	30.0	34.7	26.8	28.9
2002	32.0	32.0	33.9	29.6
2003	33.2	20.5	28.4	26.2
2004	29.2	28.2	31.1	24.6
2005	40.7	44.1	41.9	37.3
2006	33.5	31.4	26.4	43.6
2007	29.6	28.8	28.7	31.7
2008	38.1	43.7	37.4	38.3
2009	44.2	57.7	44.2	42.2
2010	26.0	26.3	23.1	23.1
2011	48.1	43.6	52.2	39.5
2012	36.3	36.3	30.1	31.1
Average Difference from 1-in-1	0	0.4	-1.5	-1.7

3-Yr Design Values in μg/m^3	1-in-1	1-in-3	1-in-3 +1	1-in-3 +2
2000-2002	32.9	33.9	31.4	32.4
2001-2003	31.7	29.1	29.7	28.2
2002-2004	31.5	26.9	31.1	26.8
2003-2005	34.4	30.9	33.8	29.4
2004-2006	34.4	34.6	33.1	35.2
2005-2007	34.6	34.8	32.3	37.5
2006-2008	33.7	34.6	30.8	37.9
2007-2009	37.3	43.4	36.8	37.4
2008-2010	36.1	42.6	34.9	34.5
2009-2011	39.4	42.5	39.8	35.0
2010-2012	36.8	35.4	35.1	31.2
2006-2010 Baseline Design Value	35.7	40.2	34.2	36.6

Recent Sampling Luck at Key Oregon Monitoring Sites

	Difference from 1-in-1 98th Percentile or Design Value								
	1-in-3	**1-in-3 +1**	**1-in-3 +2**	**1-in-3**	**1-in-3 +1**	**1-in-3 +2**	**1-in-3**	**1-in-3 +1**	**1-in-3 +2**
	Medford			**Oakridge**			**Hillsboro**		
2010	-0.3	3.0	-1.1	1.3	-4.9	0.0	0.0	2.9	-1.2
2011	-2.4	3.5	-0.2	-3.1	-5.2	2.9	1.4	2.1	-9.4
2012	2.6	-3.2	0.0	6.1	0.3	-1.4	-1.2	-0.3	1.2
2010-2012 DV	0.0	1.1	-0.4	1.5	-3.2	0.5	0.1	1.6	-3.1
	1-in-3	**1-in-3 +1**	**1-in-3 +2**	**1-in-3**	**1-in-3 +1**	**1-in-3 +2**	**1-in-3**	**1-in-3 +1**	**1-in-3 +2**
	Klamath Falls			**Burns**			**Lakeview**		
2010	1.4	-2.8	-4.1	-4.3	-2.7	2.0	0.3	-2.9	-2.9
2011	-0.7	5.3	-4.0	1.0	1.0	-3.4	-4.5	4.1	-8.6
2012	-4.0	0.0	0.7	-3.0	3.8	-4.6	0.0	-6.3	-5.2
2010-2012 DV	-1.1	0.8	-2.4	-2.1	0.7	-2.0	-1.4	-1.7	-5.6

+ means dirtier than every day sampling

- means cleaner than every day sampling

Klamath Falls Adjusted for Sampling Luck But Not Meteorology Luck

24-Hour PM$_{2.5}$ at Klamath Falls

Note: Summertime data are excluded

Legend:
- 98th Percentile
- 98th Percentile Adjusted for Sampling Luck
- 3 year DV
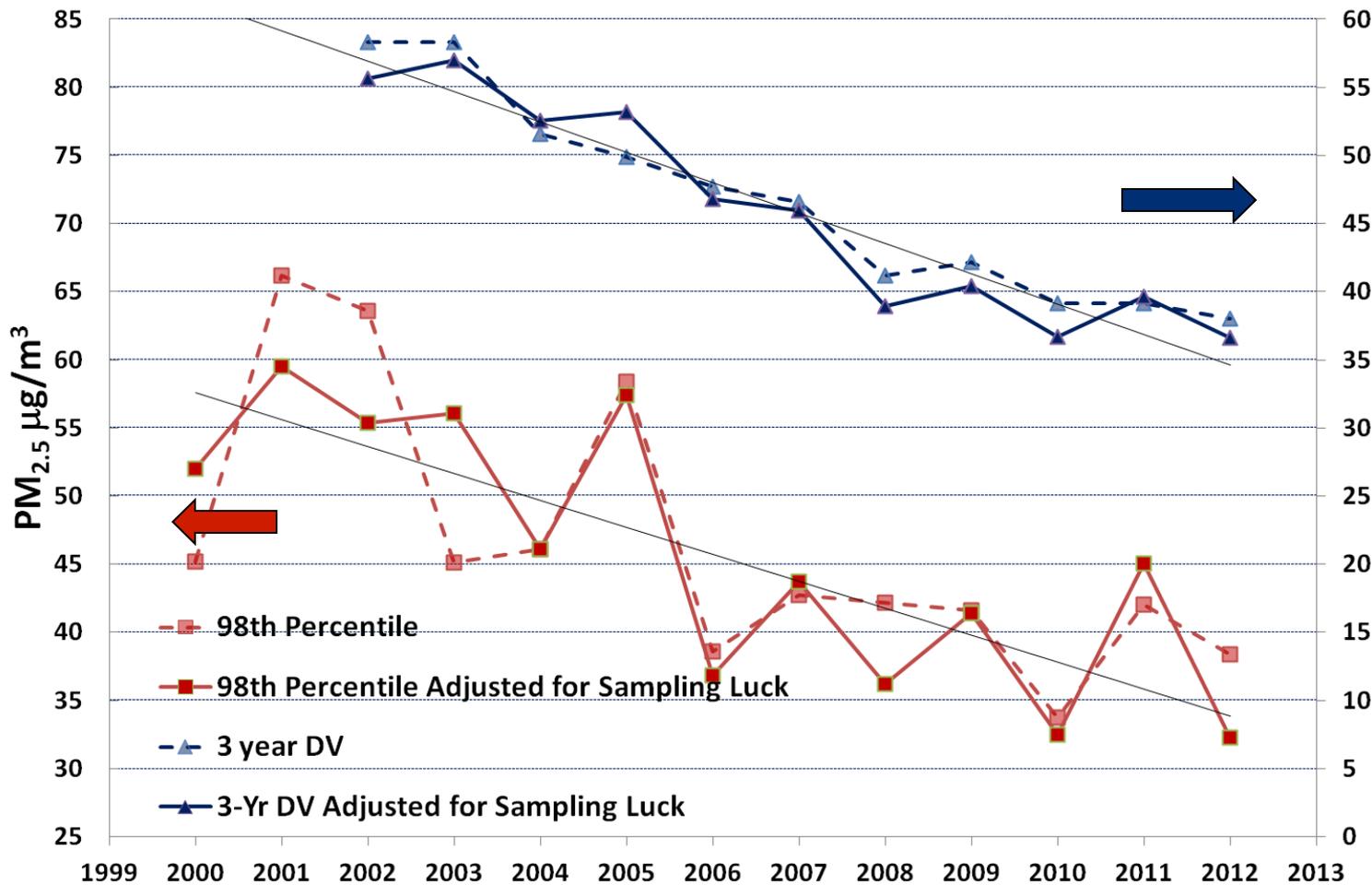- 3-Yr DV Adjusted for Sampling Luck
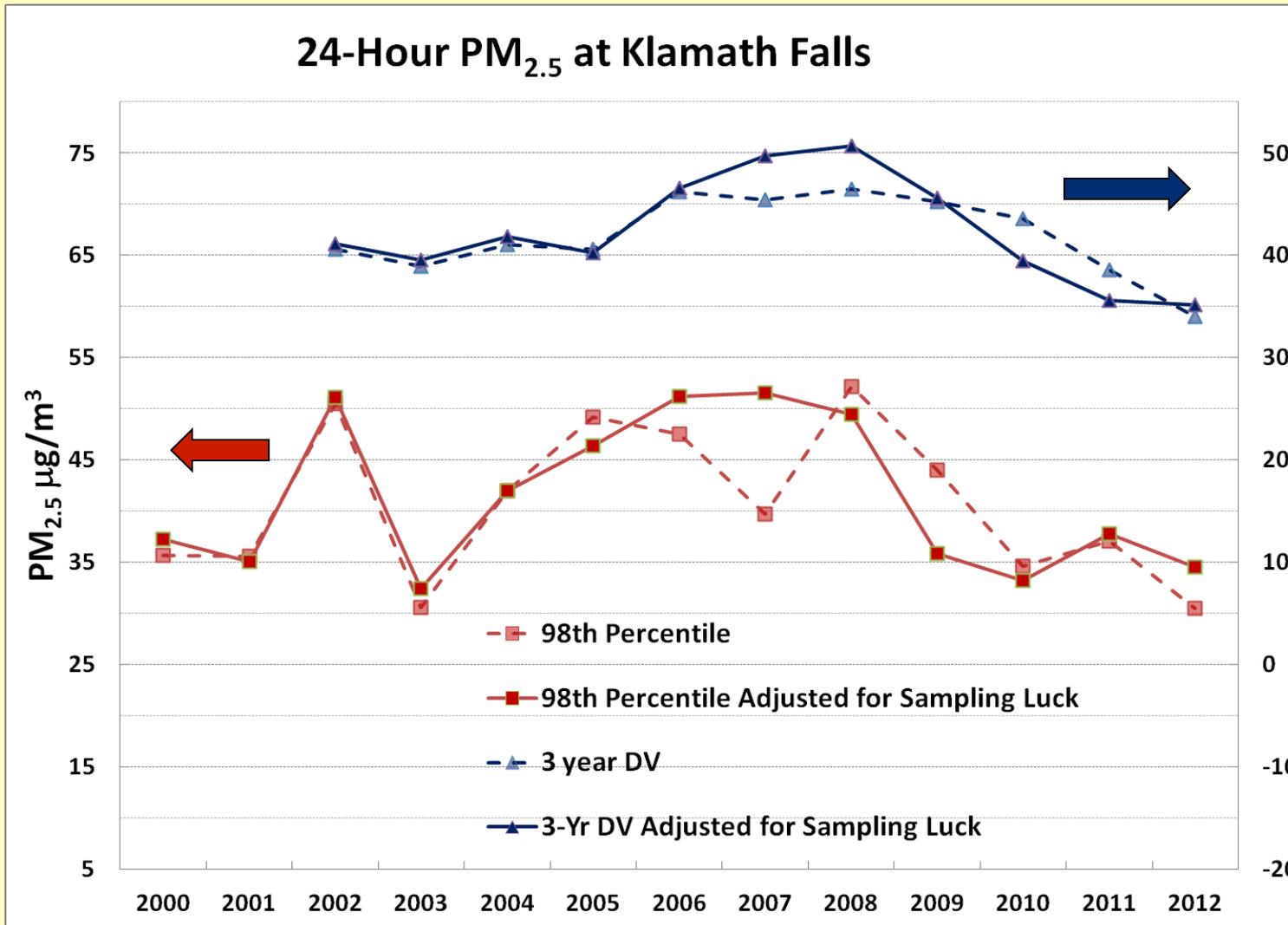
Conclusions

- **Cannot rule out meteorology as a cause for low 2012 98th percentiles or 2010-2012 design values**
  - **Harder for Oregon sites, easier for Tacoma L Street**
  - **It would take a rigorous location-by-location analysis to determine this (PSCAA?)**
  - **Generally not enough years in dataset to account for meteorological variability**
- **Sampling luck is a considerable issue**
  - **>3.5 μg/m^3 variations in 98th %tile are common (20%)**
  - **>1.8 μg/m^3 variations in 3-Yr DV are common (29%)**
- **Wintertime PM$_{2.5}$ pollution is more susceptible to meteorological and sampling luck**
  - **Short episodes and more driven by meteorology**

Good Luck to You!

Oakridge Adjusted for Sampling Luck But Not Meteorology Luck

24-Hour PM$_{2.5}$ at Oakridge

Note: Summertime data are excluded

Legend:
- 98th Percentile
- 98th Percentile Adjusted for Sampling Luck
- 3 year DV
- 3-Yr DV Adjusted for Sampling Luck

Design Value Variability

24-Hour PM$_{2.5}$ at Portland SE Lafayette