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AERMOD Experiences during the Birmingham Area Particle Study (BAPS)

EPA 9th Modeling Conference
October 9, 2008

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Background

- EPA designated Jefferson, Shelby, and a small portion of Walker counties as nonattainment for the annual standard effective April 5, 2005.
- Current PM2.5 Design Values – 2005-2007:
  - North Bham – 18.9 ug/m^3 (*18.7*)
  - Wylam - 17.7 ug/m^3 (*17.5*)
- NAAQS = 15 ug/m^3

State Implementation Plan

- Contracted with ENVAIR to help identify causes of high PM2.5.
- Based on the conclusions of the ENVAIR study, the SIP focuses on reduction of emissions of fine particles in the area surrounding the North Birmingham and Wylam monitors.
- The plan also relies on reductions from national programs such as CAIR, and cleaner cars, diesels and fuels.
- Base Case 2002/2009/2012 modeling to help develop attainment plan is being completed using a CMAQ/AERMOD integrated approach in accordance with EPA implementation guidance.

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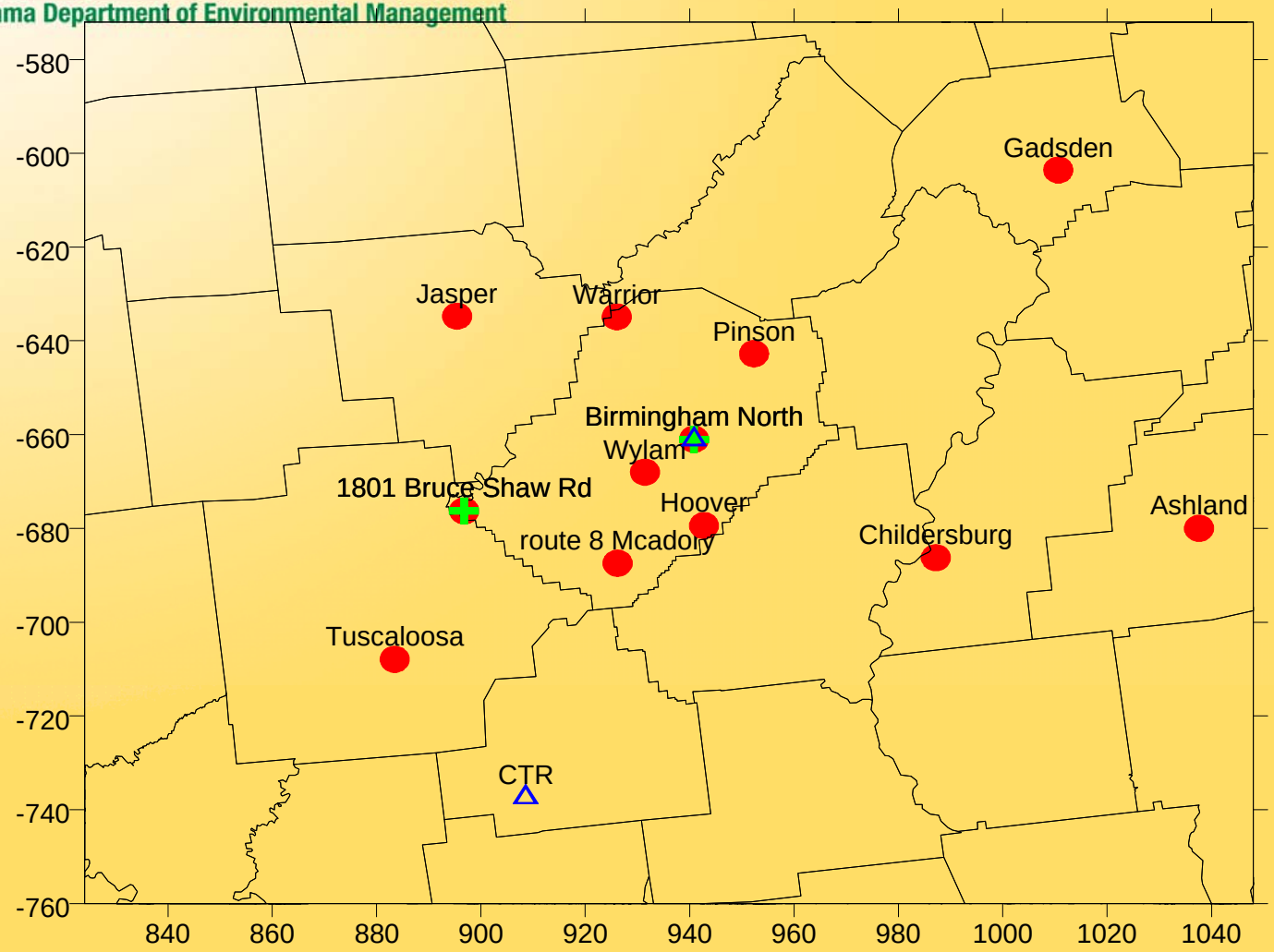
Measurement Sites



Birmingham PM2.5 Observation Sites

FRM
STN
SEARCH

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Birmingham Area Design Values

Site	3 Year Avg. 2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007
North Bham	19.63	18	17.53	18.24	18.56	18.67
Wylam	18.43	16.74	16.05	16.49	17.28	17.45
Hoover	16.18	14.73	14.33	14.76	15.14	15.12
McAdory	15.65	14.73	14.59	15.01	15.49	15.60
Pinson	14.72	13.72	13.57	14.18	14.45	14.60
Corner	14.95	13.87	13.53	14.22	14.52	14.59
Providence	14.08	12.63	12.30	13.07	13.46	13.75
Leeds					15.60	15.92

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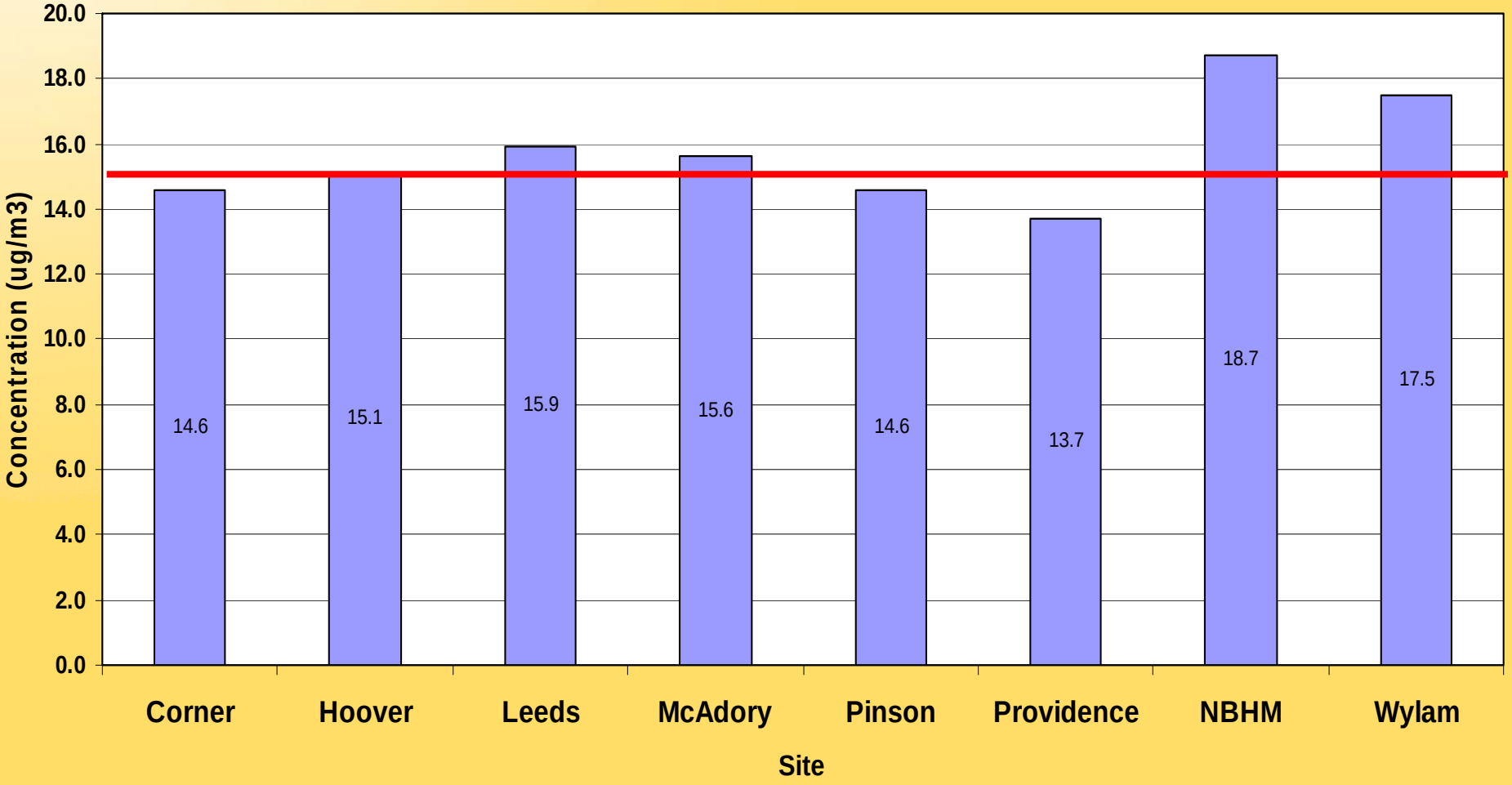
Annual PM2.5 Design Values 2005-2007



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VISTAS/CAIR Modeling

Modeling predicts that EPA's adopted regulations for mobile sources and electric utilities will reduce regional and general urban PM by about 1 $\mu g\ m^{-3}$.

Additional modeling suggests this may be higher, i.e. 1 – 1.5 $\mu g\ m^{-3}$

This reduction will help, but is not likely to bring Wylam and North Birmingham into attainment by 2010

Are reductions of local PM possible? Need to understand what local PM is and where it comes from.

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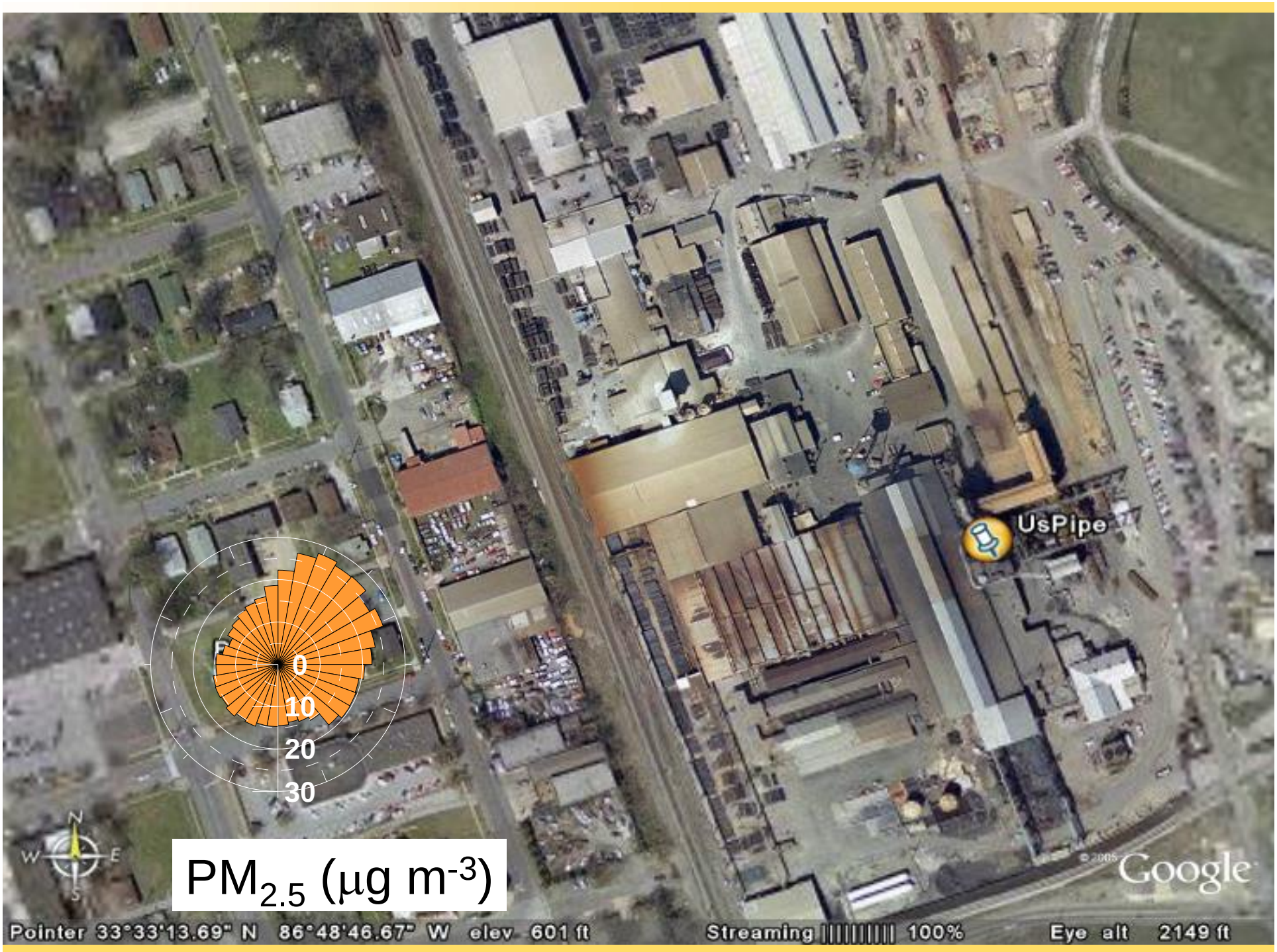
Major Findings of ENVAIR Study

- Nonattainment due to N. Birmingham & Wylam
- Local and urban PM contributions are superimposed on regional component
  - Regional - ~12-14 $\mu g/m^3$
  - General urban - ~2 $\mu g/m^3$
  - Local - ~3-4 $\mu g/m^3$
- Multiple lines of evidence link local excess PM at Wylam and North Birmingham to several geographical source complexes
- Evidence includes wind directions, carbon compounds, elements (metals), day-of-week variations, fence-line samples, & PM spikes

Major Findings of ENVAIR Study

- With moderate decreases projected in regional PM, local emission reductions will likely be needed to attain the standard
- Since Wylam and N. BHM drive nonattainment, first attention to source complexes surrounding those sites
- Many sources are intermittent or semi-continuous processes in open buildings
- Very high infrequent PM concentrations
- Transportation – rail and trucking – contribute
- What to do now? Model and see….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PM2.5 (μg m-3)
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Pointer 33°33'13.69" N 86°48'46.67" W elev 601 ft
Streaming 100%
Eye alt 2149 ft


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PM2.5 (µg m-3)
Pointer 33°33'33.59" N 86°48'15.64" W elev 591 ft
Streaming 100%
Eye alt 7734 ft
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ENVAIR to ENVIRON/AG

- Taking the findings from the monitoring study, JCDH and ADEM contracted with ENVIRON/Alpine Geophysics to conduct a model attainment demonstration
  - Contract awarded in Fall 2006
  - Using the CMAQ platform with MM5/SMOKE to model the regional and urban signals
  - Using the AERMOD model to evaluate local source impacts
  - Integration of modeling platform results

What doesn't kill you….

- This has been a learning process
- Many different stakeholders
- New territory for modeling
- Uncertainty in emissions inventories
- Uncertainty in modeling integration
- Highly variable emissions from many types of sources, many of whom have never been involved in a modeling study of this magnitude
- Sheer number of sources

Emissions Inventory Development

- Multiple 2002, 2009, and 2012 CMAQ and AERMOD inventories have been developed to identify direct, inert PMfine emissions
  - Much bigger challenge than expected
  - Many sources never modeled with this much detail and scrutiny
  - Emissions factors for PM2.5 poorly defined, if even available
  - Needed to weigh a perfect inventory against time and resource constraints
  - Known errors in emissions are being corrected in the final runs
  - Small sources may have significant impacts

Emissions Inventory Issues

- Mistakes were made by both the regulatory agencies as well as the facilities. This is due in large part, to the lack of understanding of what is needed to model at this level
  - For transparency, we insisted on active involvement of facilities.
  - If we had known how difficult it would be, we might have contracted for the inventory development.
- This led to **multiple** revisions of the 2002, 2009 and 2012 SMOKE runs
- SMOKE outputs were run through CAMx to produce consistent hourly emissions profiles to be input into AERMOD

AERMOD Modeling

- Our studies showed a clear “local sources” signature, especially for primary PM2.5.
- CMAQ, even with 4 km grid spacing, was not considered adequate to resolve impacts due to local emission controls.
- AERMOD selected as the best way to model the significant industrial contributors.
- Which local sources should be modeled?

AERMOD Modeling Local Source Criteria

- No established criteria- all new territory.
- Based on the results of the ENVAIR study, it was assumed that every source identified by the study would be included.
- Any source within 5 km of either monitor with $PM_{2.5}$ emissions greater than 1 tpy (~1/4 lb/hr) was included.
- Between 5 – 10 km of either monitor, any source with $PM_{2.5}$ emissions greater than 4 tpy (~1 lb/hr) was included.
- A Q/d and Q/d^2 analyses supported the above criteria fairly well.
- Total of 46 facilities identified; roughly 1200 individual emitting sources. Included point, area, volume and buoyant lines.

AERMOD Modeling Grid

- Initial discussions with EPA and among the study participants led to a 1 km X 1 km AERMOD receptor grid with 100 meter spacing
    - Plant property issues
- Additional discussion led to agreement on a 300 m X 300 m Cartesian grid with 100 meter spacing.
    - For the attainment demonstration, concentrations will be averaged across all receptors
    - For culpability and RACT, concentrations at the monitor were used

AERMOD Met Data

- Used 2002 met data – same as base case emission data year.
- Options
  - Conventional NWS ASOS data at Birmingham airport (BHM) – 7 – 18 km from key monitors.
  - SEARCH site wind data at North Bham monitor.
  - Hourly-averaged ASOS data at BHM.
- Choice – hybrid of hourly ASOS data augmented by conventional ASOS data as necessary. SEARCH data had too many holes and quality questions. OAQPS invaluable in developing the hybrid data set.

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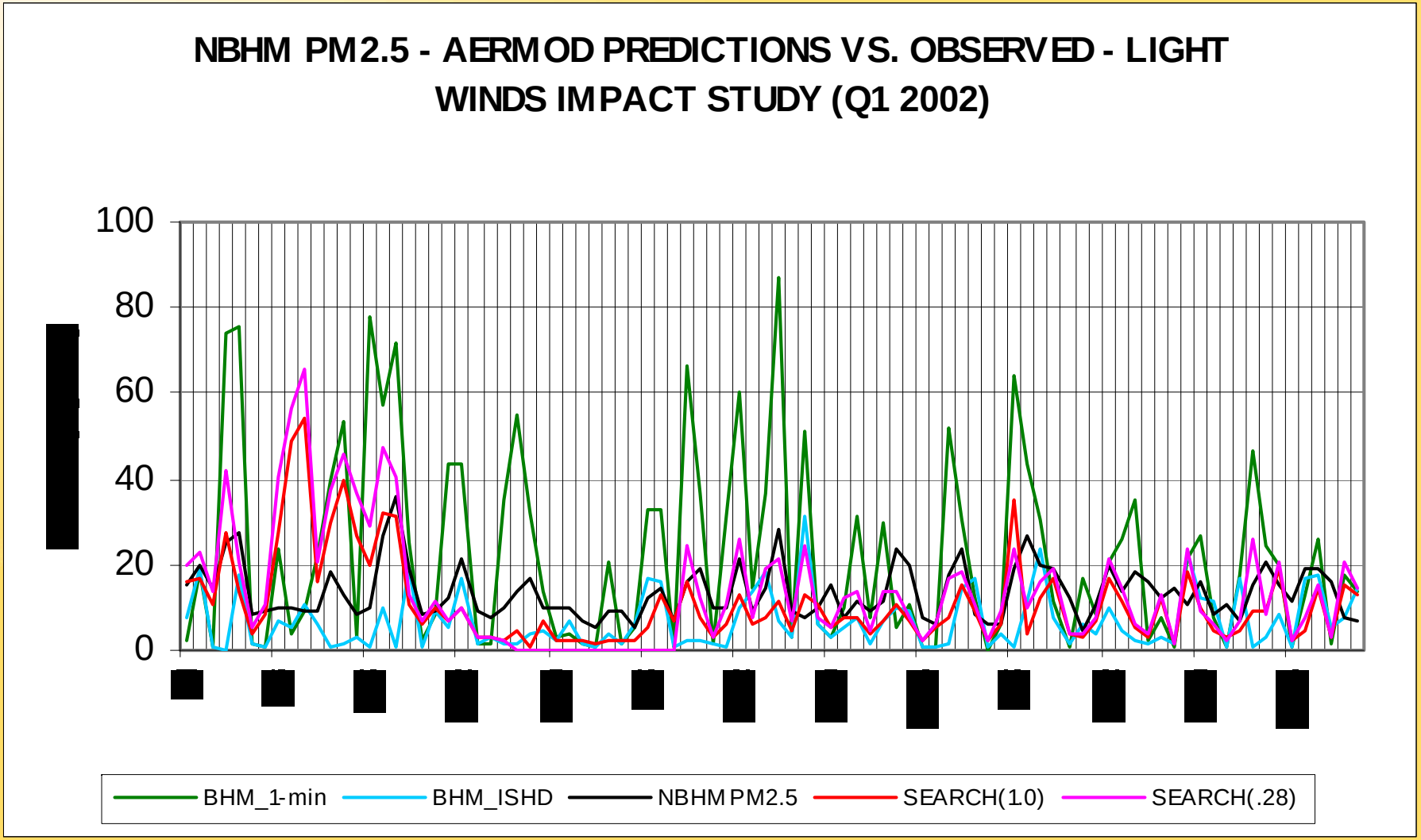
AERMOD Met Data



AERMOD Overview

- AERMOD run for local significant facilities
  - ADEM assessed “significance” and determined facility list for AERMOD
  - Only primary PM2.5 was simulated
  - Wind inputs generated using draft EPA 1-minute ASOS data methodology
  - For 2002 MPE, 24-hr concentrations saved at WYLM and NBHM monitor coordinates

AERMOD Overview

Thus, we expect AERMOD to predict lower concentrations than daily FRM observations

- Observation-based analyses (ENVAIR Study) suggest annual local industrial contribution is
  - ~3 ug/m3 at NBHM
  - ~2 ug/m3 at WYLM

But we recognize AERMOD is considered a "conservative" (high) model

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AERMOD Results

Monitor	Quarter	2002 Quarterly $PM_{2.5}$ Concentration	2009 Quarterly $PM_{2.5}$ Concentration
NBHM	1st	25.74	15.02
	2nd	34.69	20.16
	3rd	37.66	22.18
	4th	35.87	21.33
	Annual	33.49	19.67
WYLM	1st	6.27	5.4
	2nd	7.02	5.73
	3rd	6.48	5.17
	4th	6.09	4.93
	Annual	6.47	5.31

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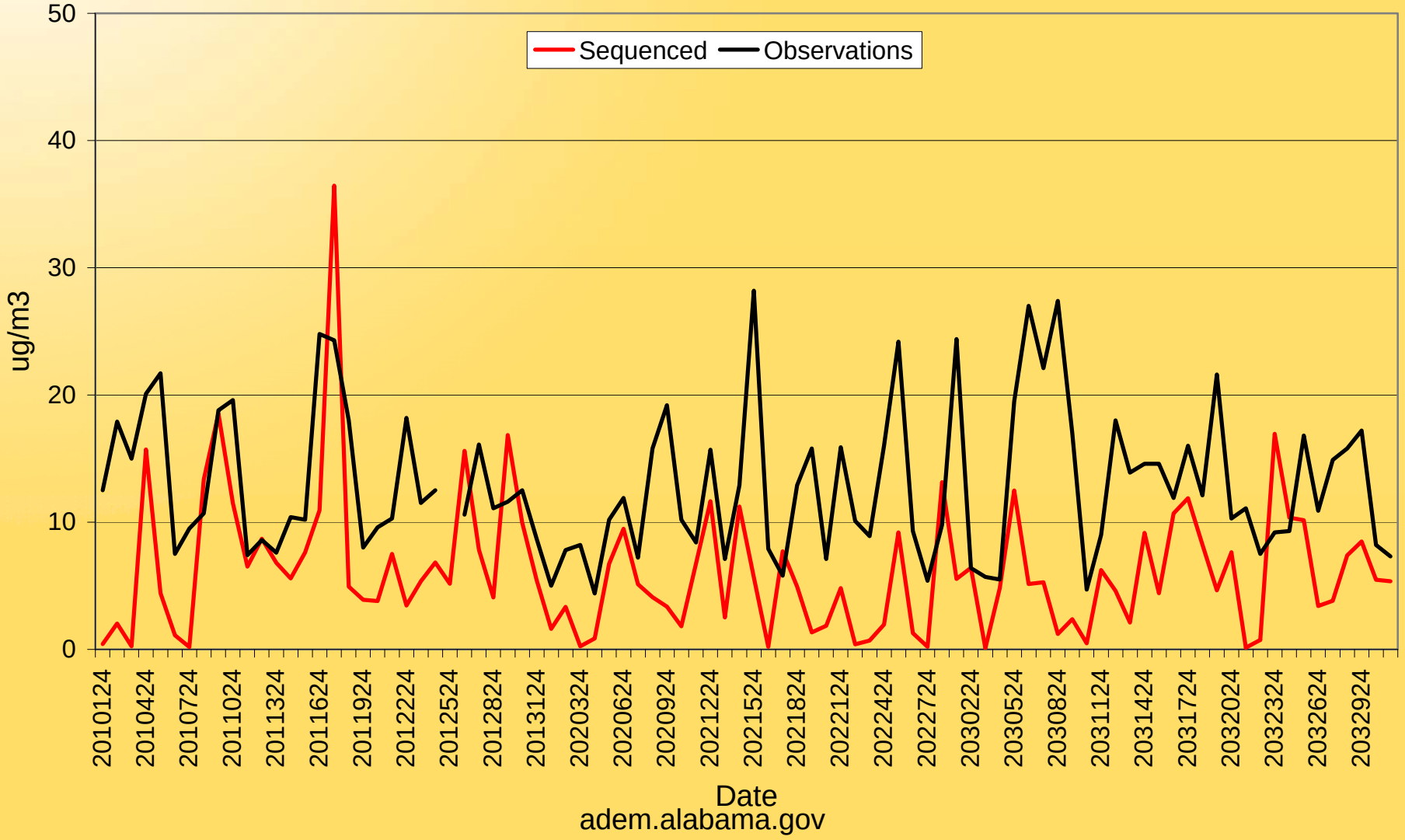
2002 by Quarter at Wylam

Sequenced 24 hour PM2.5
1st Quarter, WYLM Monitor



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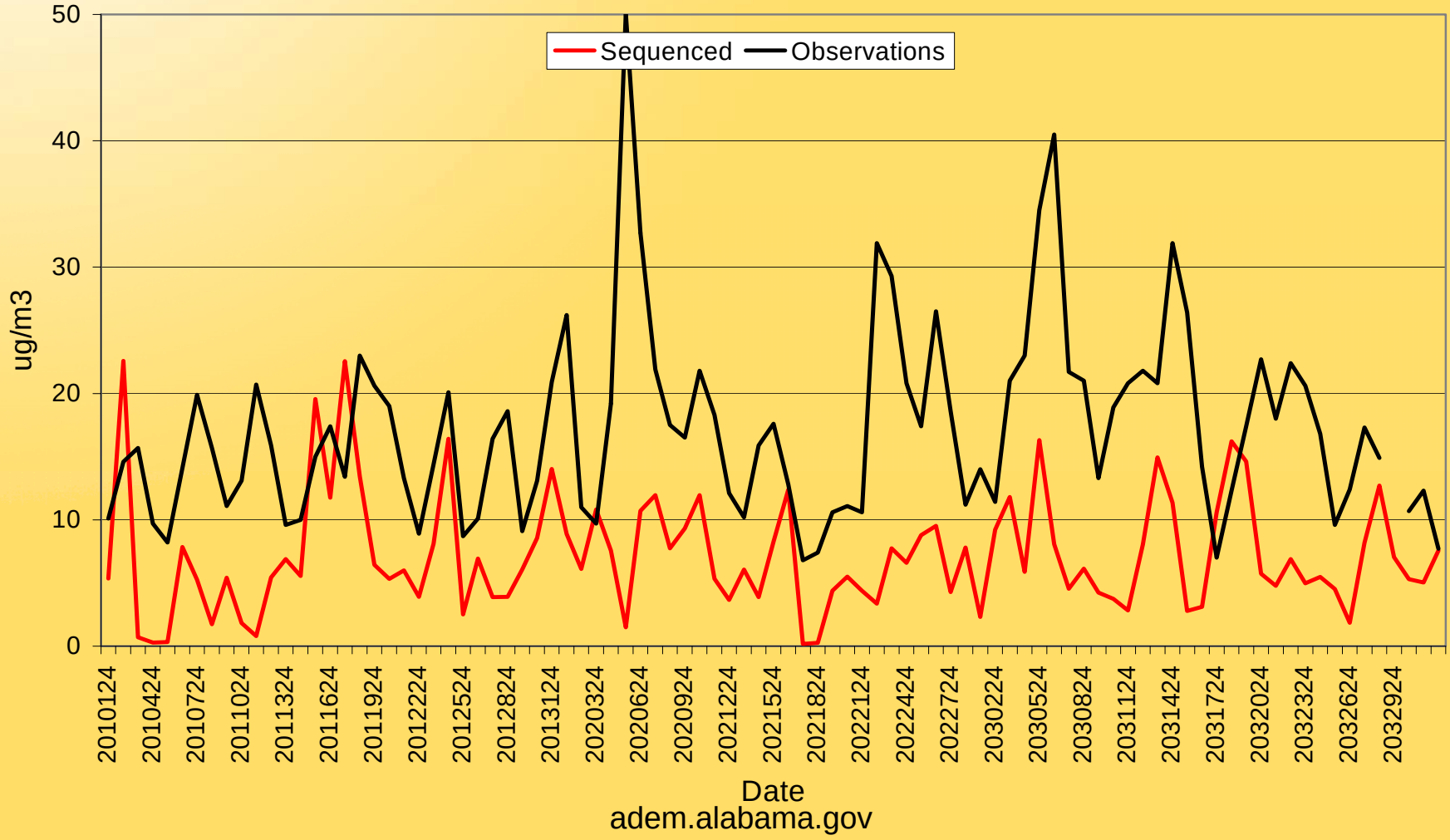
2002 by Quarter at Wylam

Sequenced 24 hour PM2.5
2nd Quarter, WYLM Monitor



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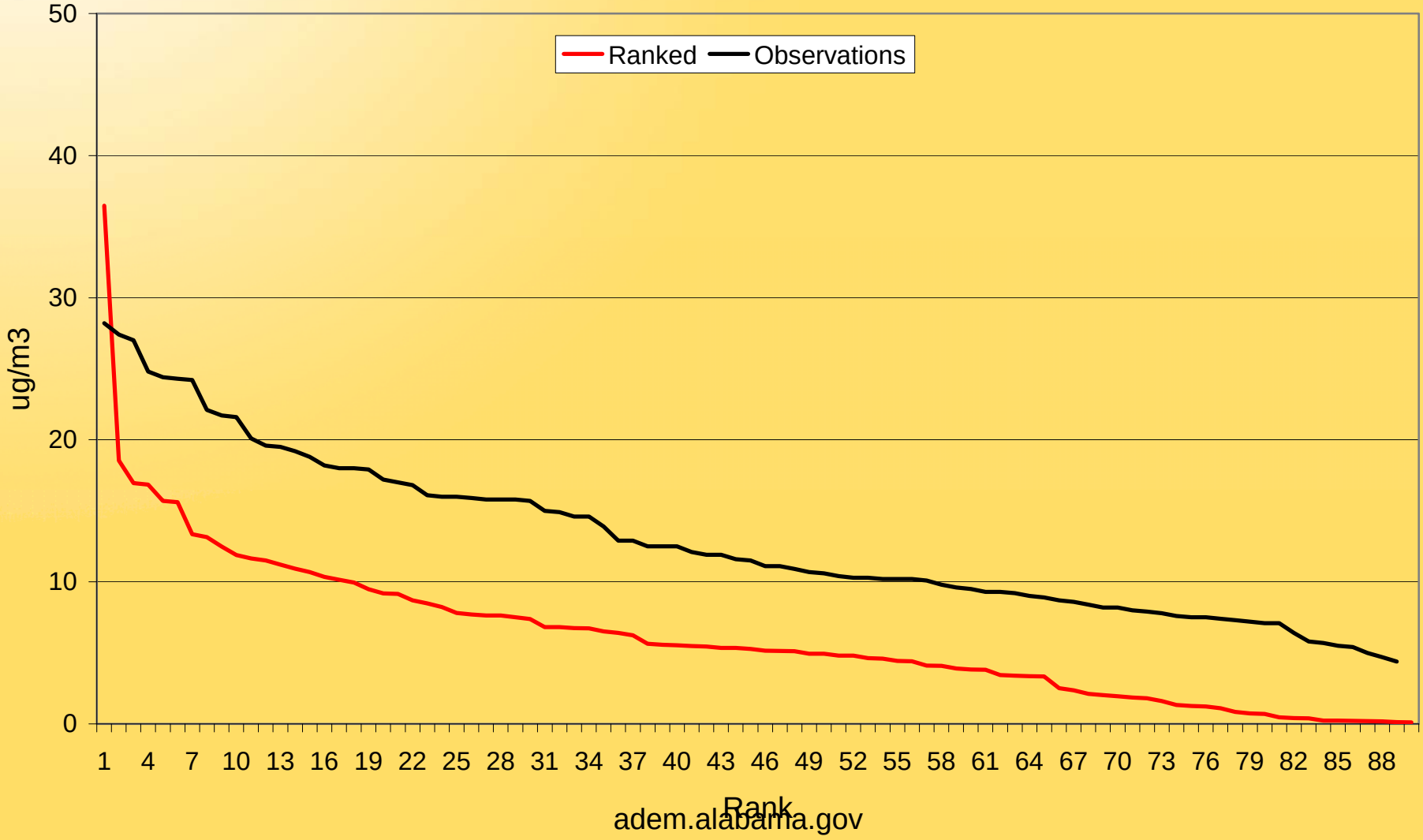
2002 by Quarter at Wylam

Ranked 24 hour PM2.5
1st Quarter, WYLM Monitor



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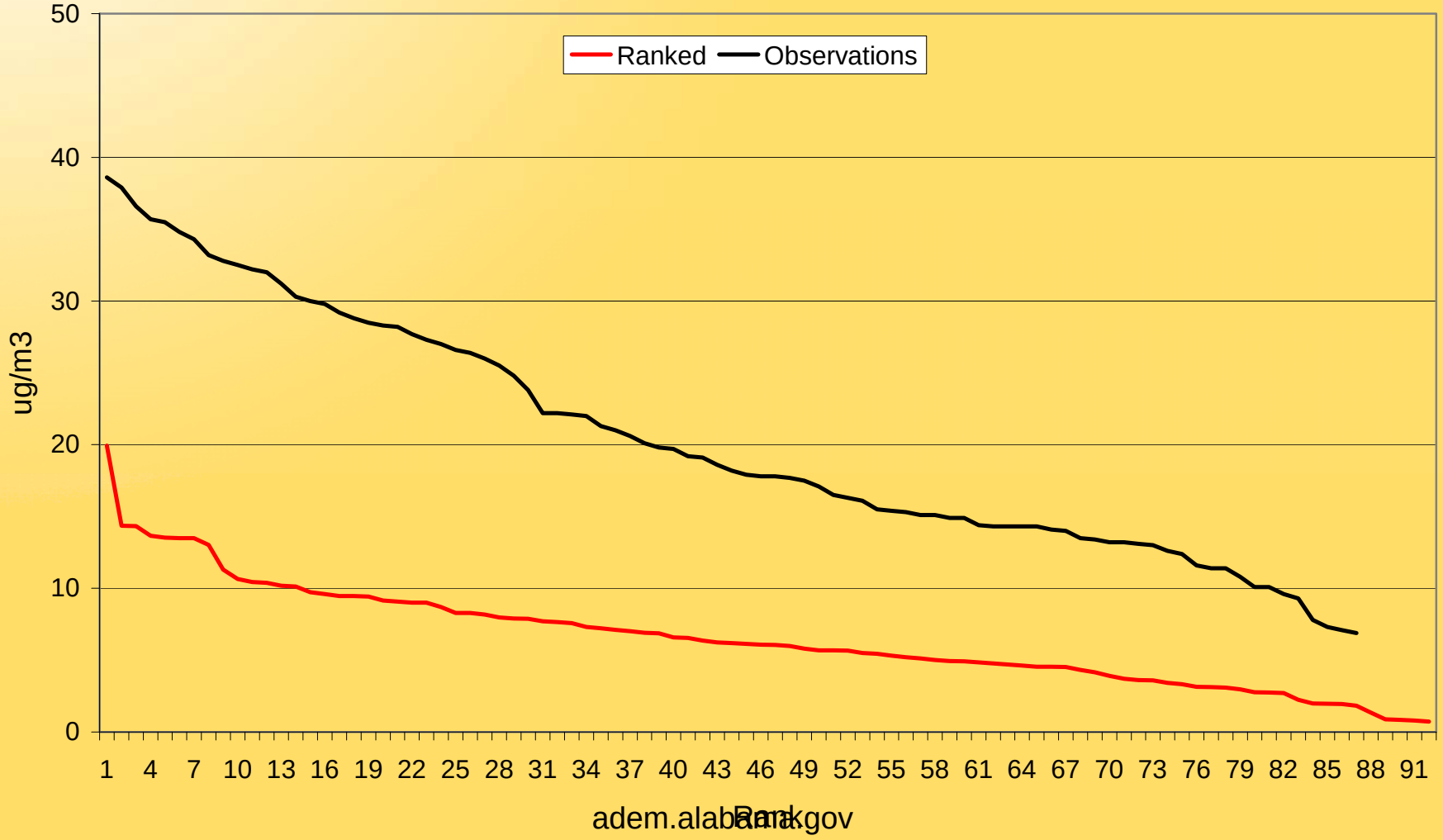
2002 by Quarter at Wylam

Ranked 24 hour PM2.5
3rd Quarter, WYLM Monitor



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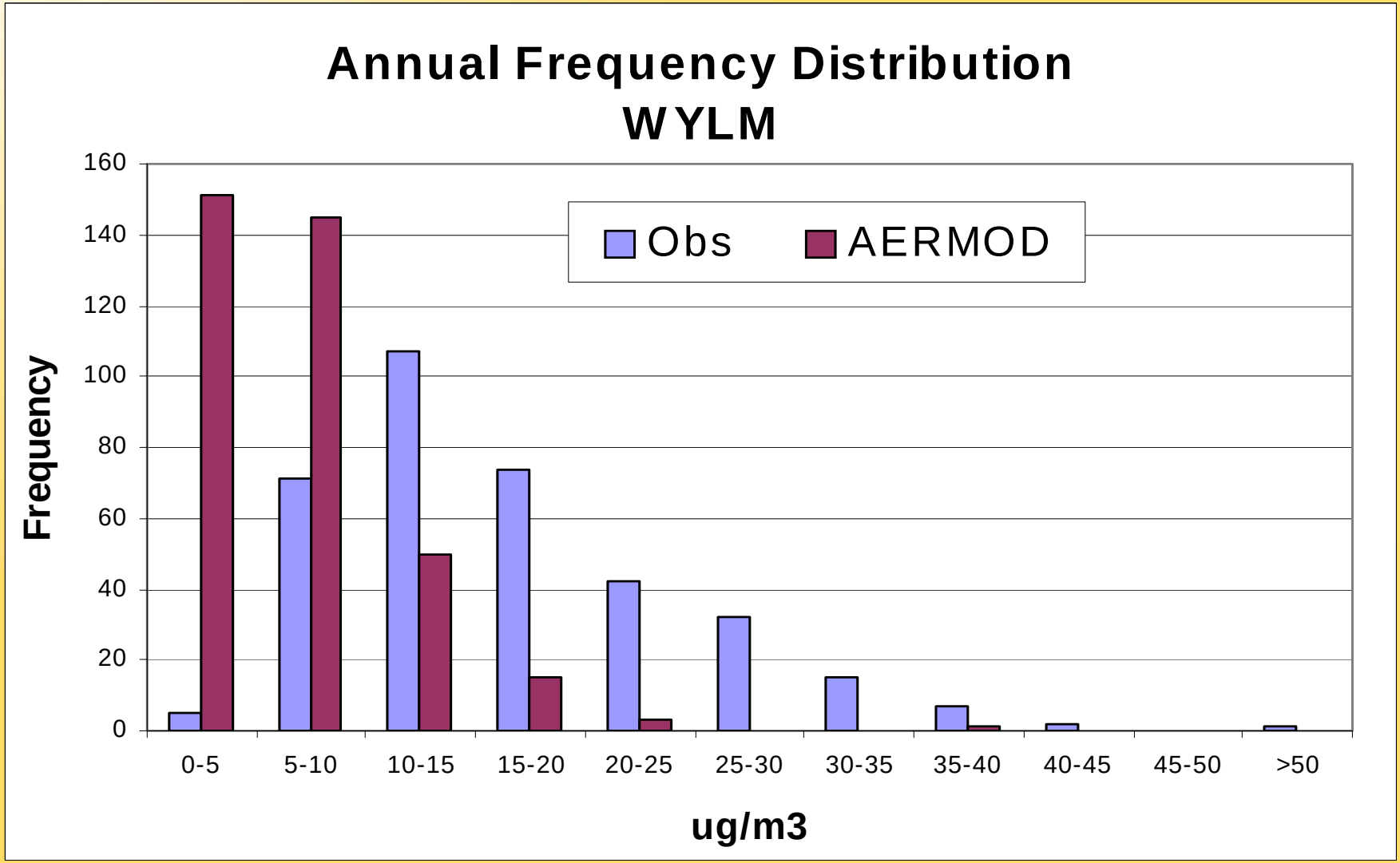
2002 Wylam Frequency Distribution



WYLM Results

Agrees with expected patterns (good)

- Always lower than daily FRM total obs
  - Expected local industry contributions are ~2 ug/m3
  - AERMOD annual mean is ~ 6.5 ug/m3
- AERMOD is rarely >10x the assumed local component (4 days)
  - >5x local component 20% of the year
- Annual frequency distribution is heavy in the 0-10 ug/m3 range

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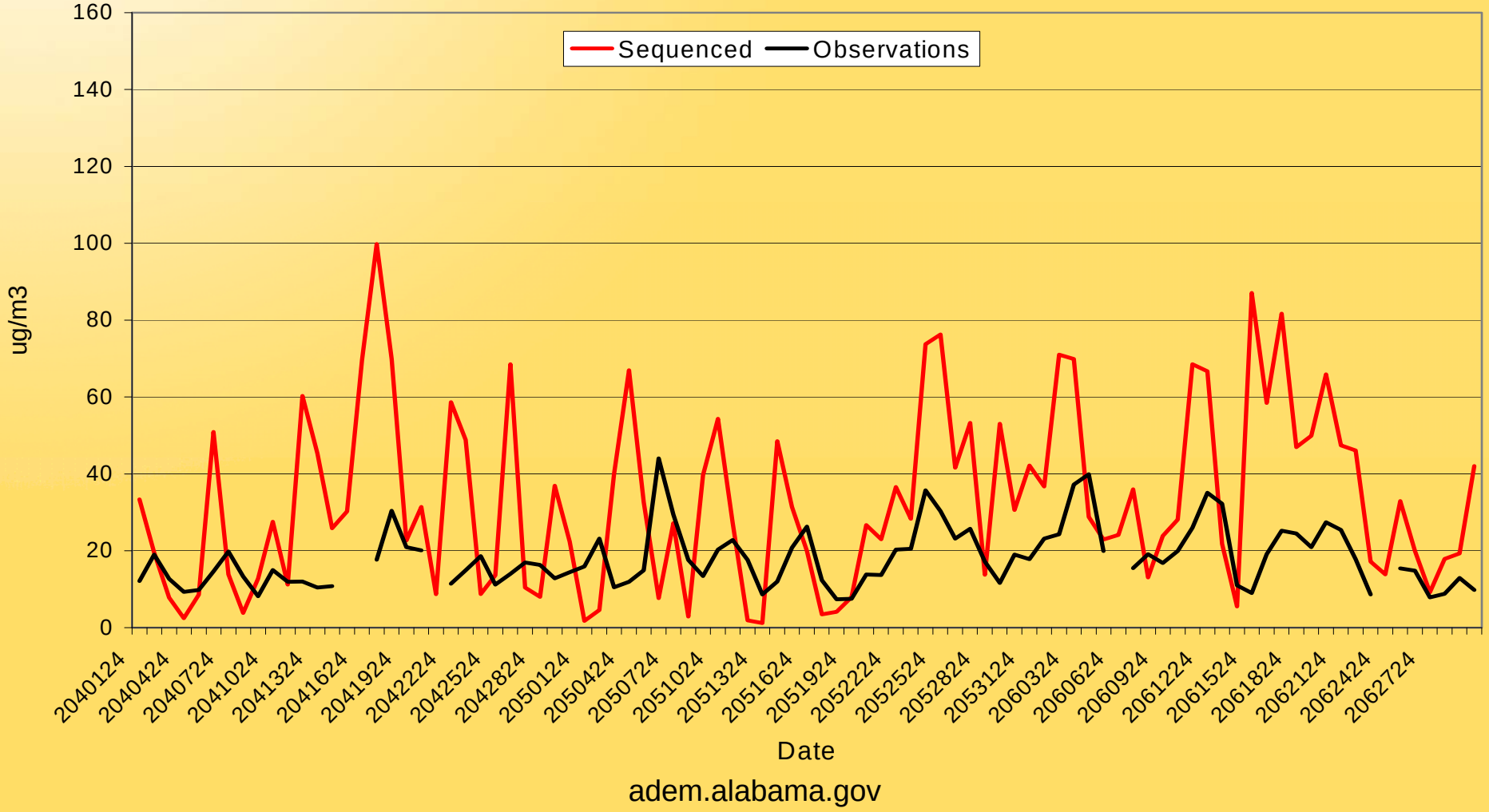
2002 by Quarter at NBHM

Sequenced 24 hour PM2.5
2nd Quarter, NBHM Monitor



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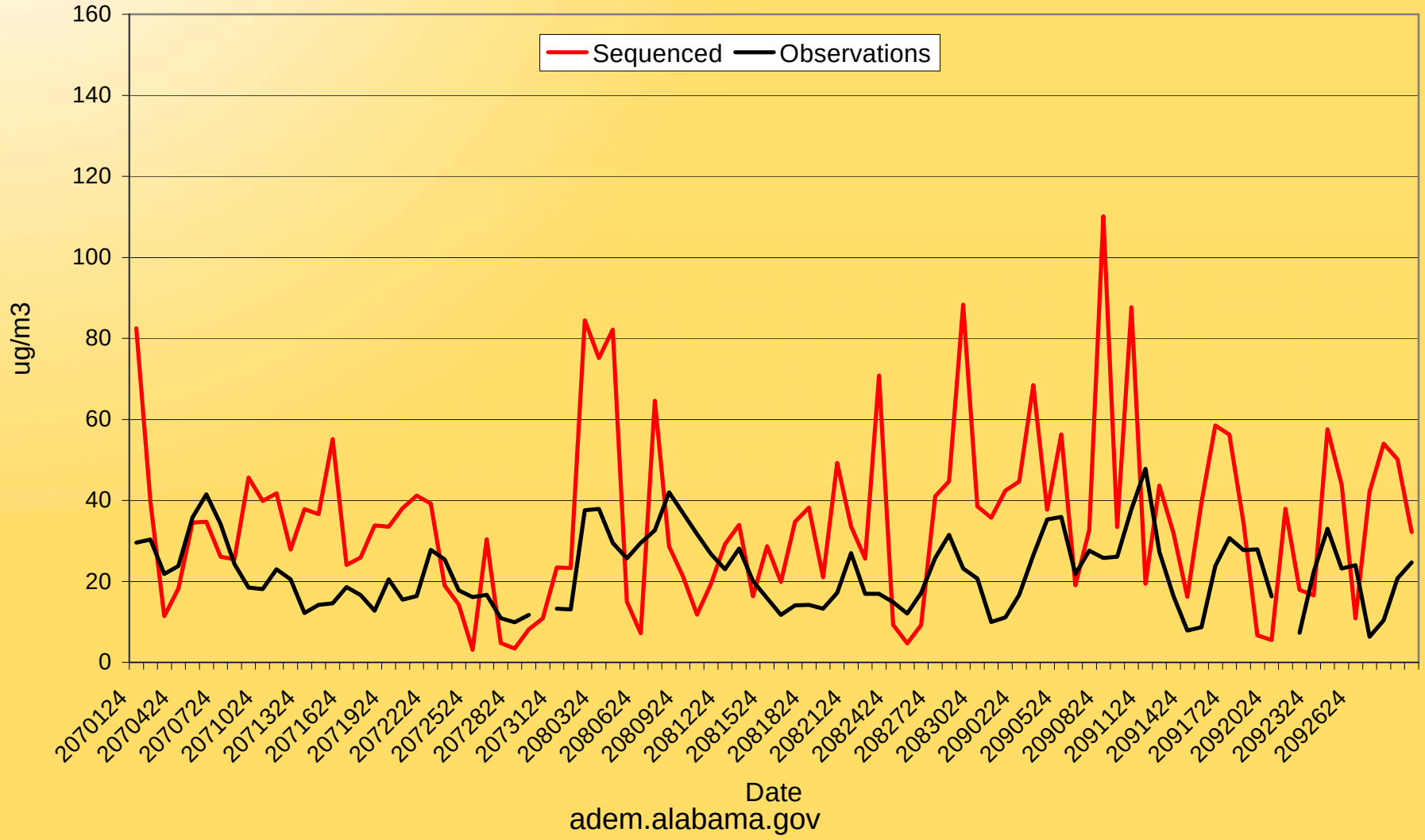
2002 by Quarter at NBHM

Sequenced 24 hour PM2.5
3rd Quarter, NBHM Monitor



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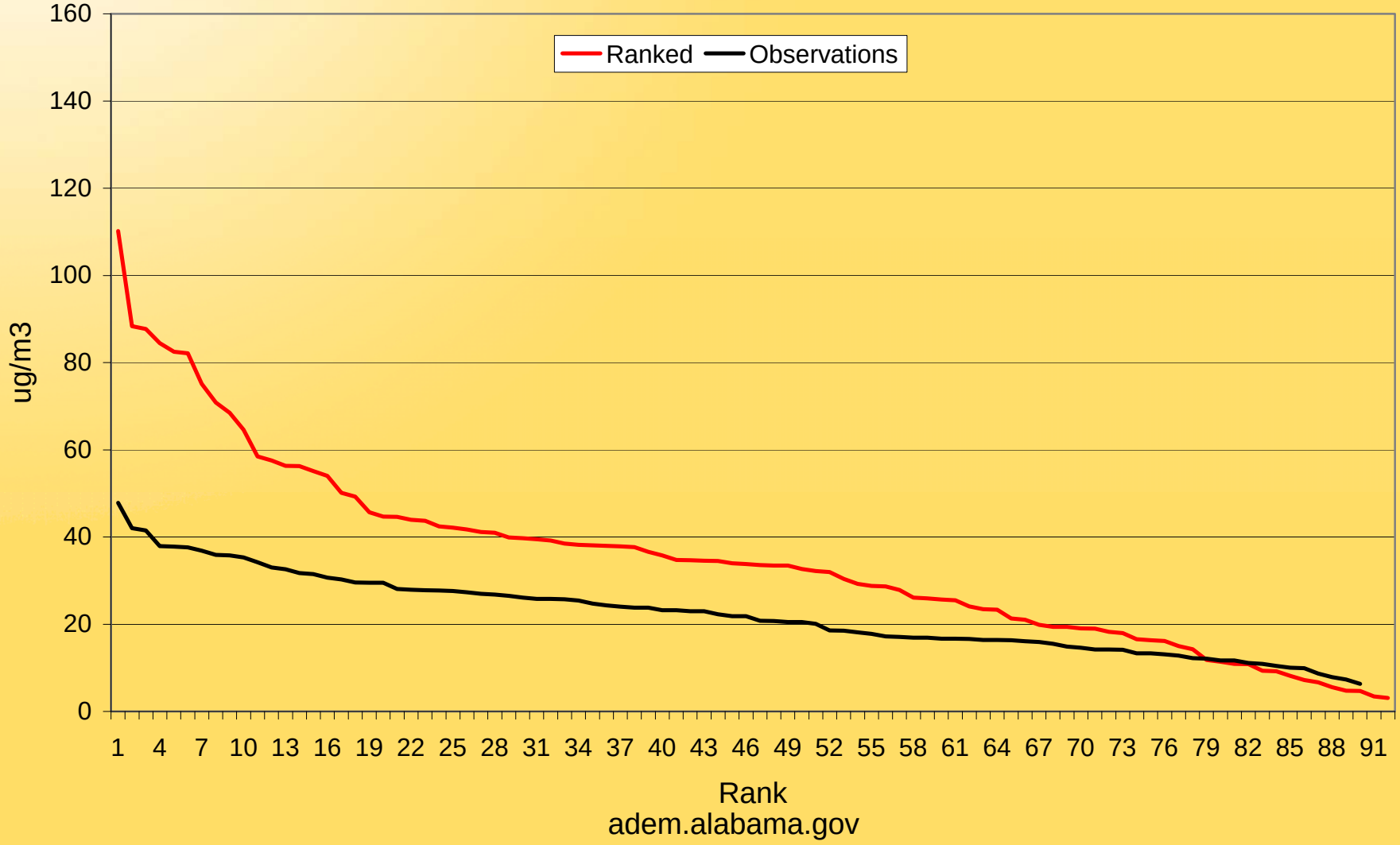
2002 by Quarter at NBHM

Ranked 24 hour PM2.5
3rd Quarter, NBHM Monitor



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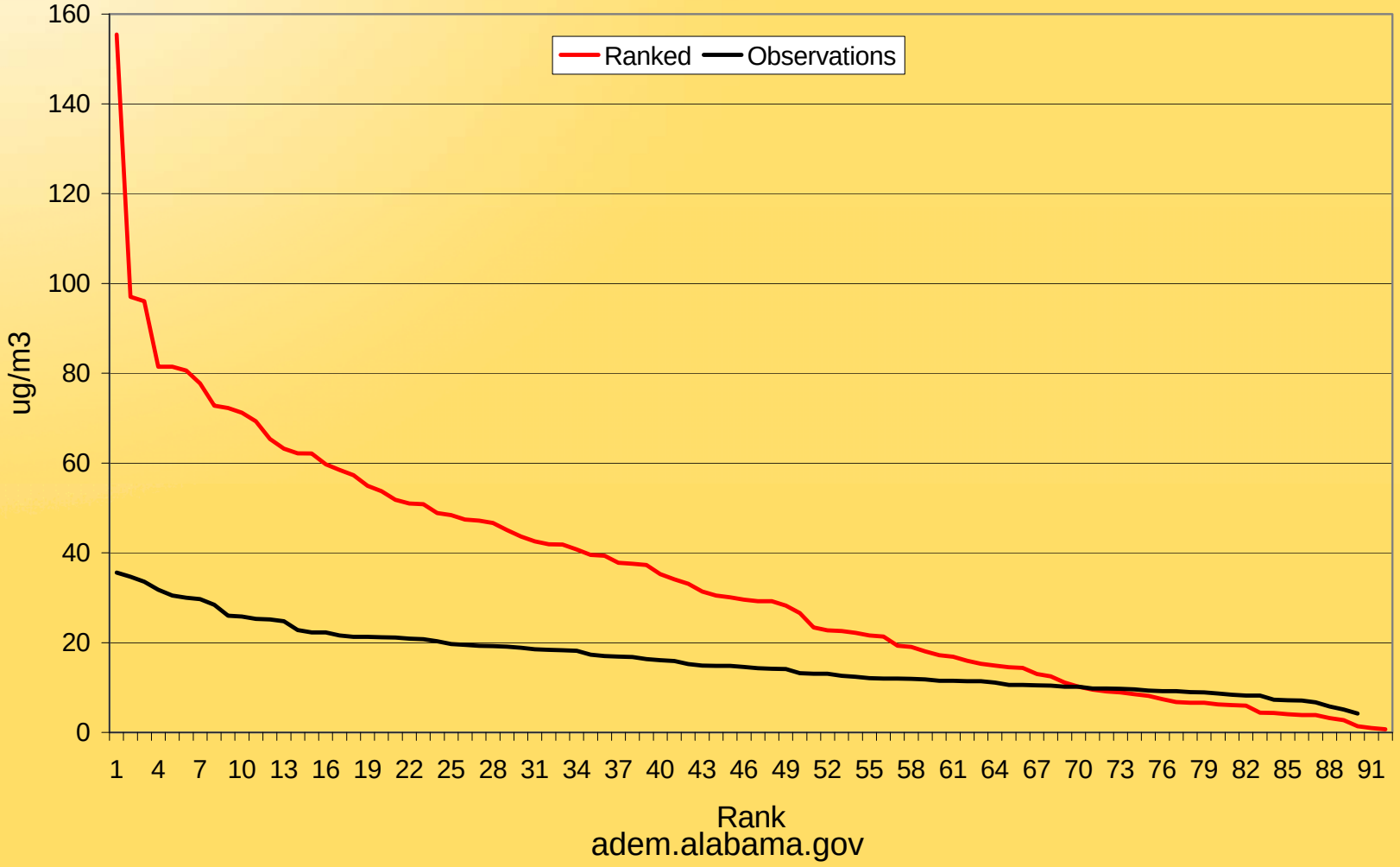
2002 by Quarter at NBHM

Ranked 24 hour PM2.5
4th Quarter, NBHM Monitor



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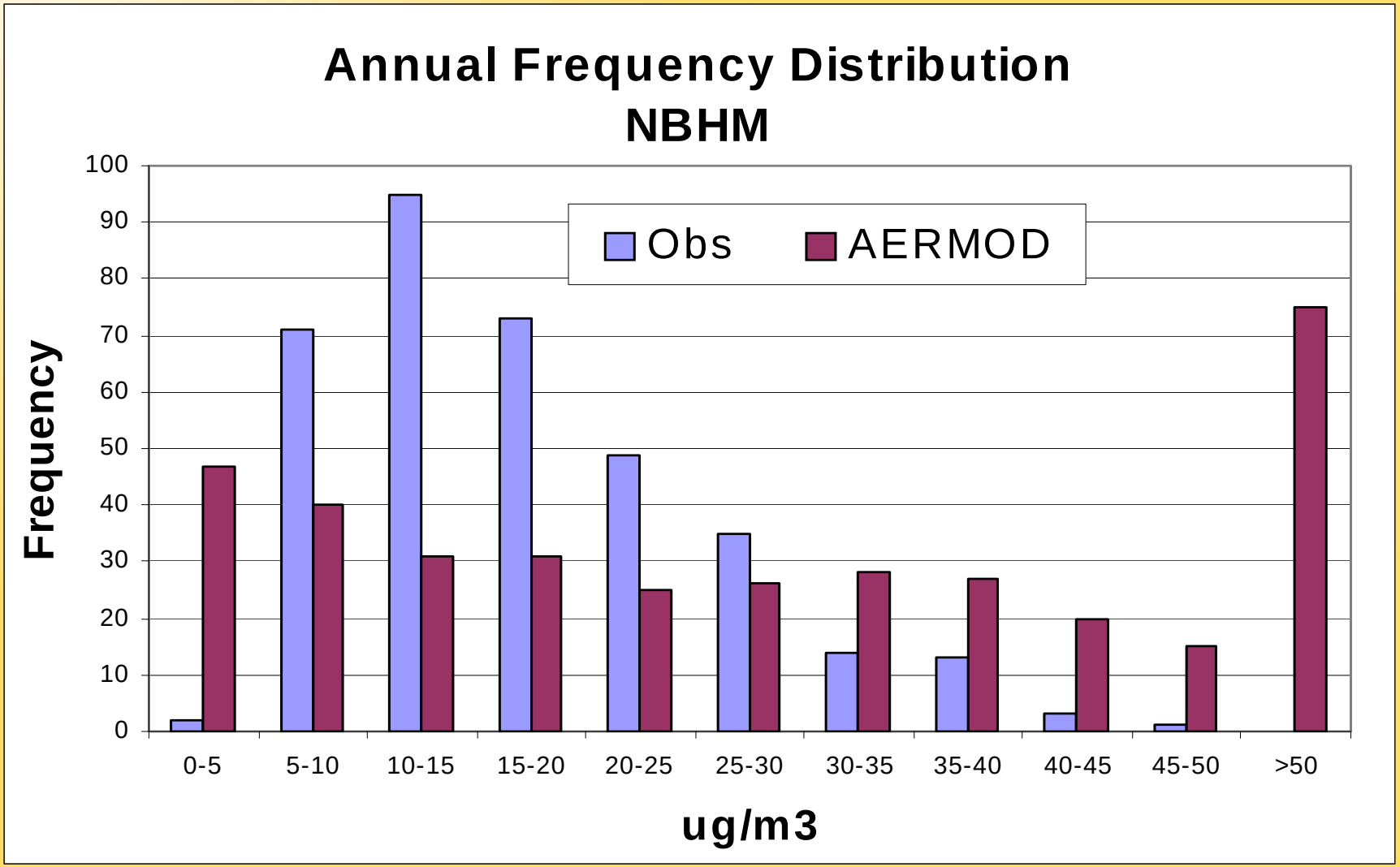
2002 NBHM Frequency Distribution



NBHM Results

Dramatic over predictions (bad)

- Usually higher than daily FRM total obs
  - Expected local industry contributions are ~3 ug/m3
  - AERMOD annual mean is ~ 5x higher
- AERMOD is >10x the assumed local component ~1/2 of year
  - >5x local component 2/3 of the year
- Annual frequency distribution is heavy in the >30 ug/m3 range

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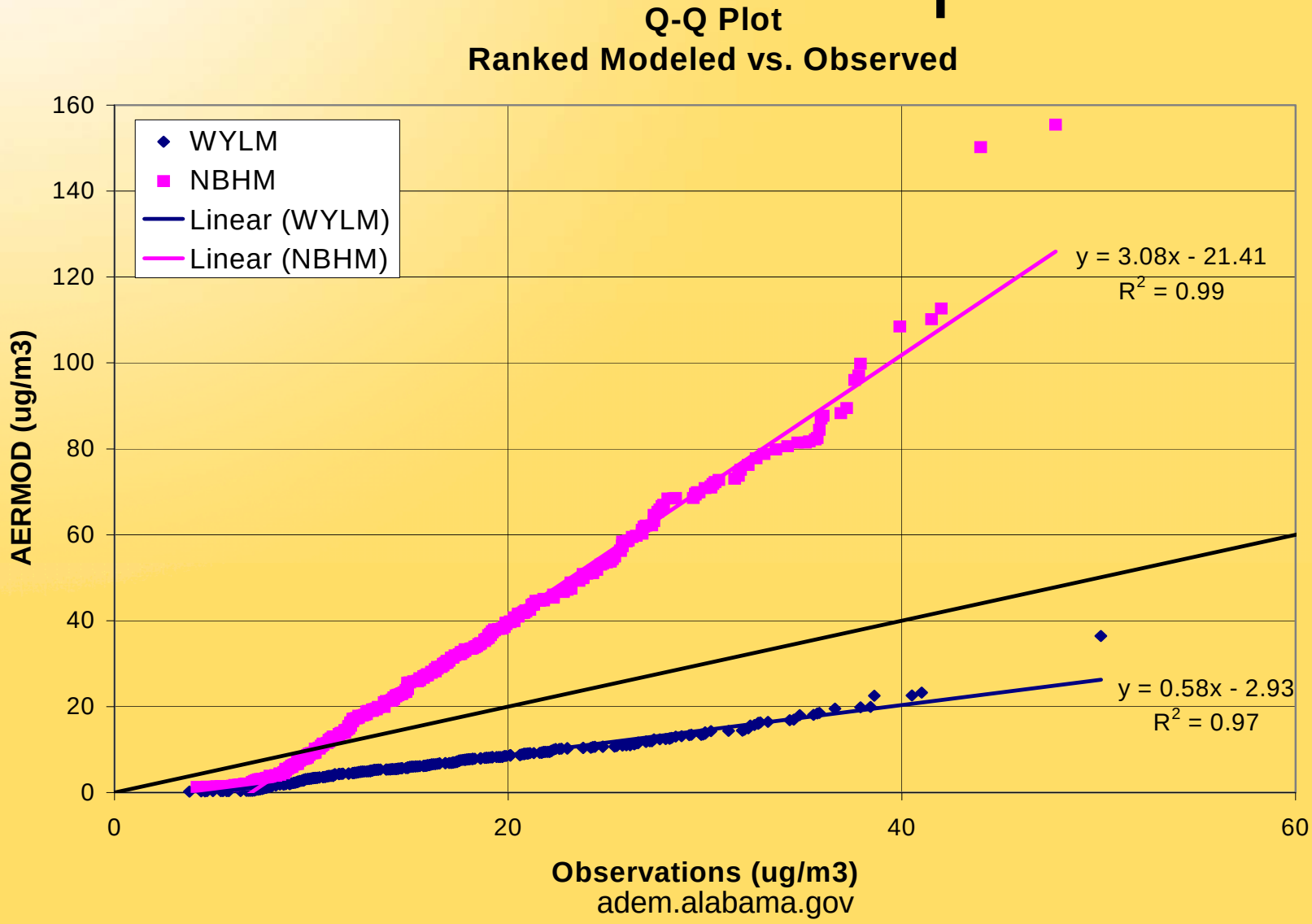
Quantile-Quantile Comparison



Conclusions

- Q-Q plot shows a marked difference in the character of AERMOD prediction between NBHM and WYLM
  - NBHM shown to be dominated by facilities in very close proximity
  - Are sources characterized adequately?
  - Should we expect AERMOD to perform poorly for certain source configurations?
  - What are our expectations from AERMOD?

Conclusions, cont.

- Additional revisions to source characterizations have been made, and emission rates have been revised
- Will these changes affect AERMOD performance?
    - Unknown
- Hope to show compliance with CMAQ alone
- Think that future modeling exercises like this should focus on refining photochemical models to handle at very small grid scales
  – Don’t feel this is the best use of these models

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CMAQ - AERMOD Integration

- AERMOD was run for selected local sources for the 2002 and 2009 bases to simulate the dispersion of primary inert PM2.5.
- CMAQ was run to simulate the dispersion of urban and regional scale primary as well as secondary emissions of PM.
  - Secondary and gaseous PM from all facilities
- CMAQ was run twice for the 2002 and 2009 bases
  - Each base year was run once with all sources and once without the AERMOD sources
  - Additional runs, including alternate future years, are being considered
- The results of the combination of CMAQ and AERMOD were used to obtain the future year projections of $PM_{2.5}$.

CMAQ - AERMOD Integration

- Followed EPA's modeling guidance
- EPA's involvement has been invaluable
  - Met data
  - Modeling assistance
  - Discussion on issues such as source characterization, policy implications and model performance
- Even with this involvement, it is still difficult to determine whether this is an appropriate application of the model for this situation.

2009 DV Projections
Circa Spring 2008

- CMAQ “all-source” runs
  - 1x1 and 3x3 grid cell averaging around NBHM and WYLM
- CMAQ + AERMOD runs

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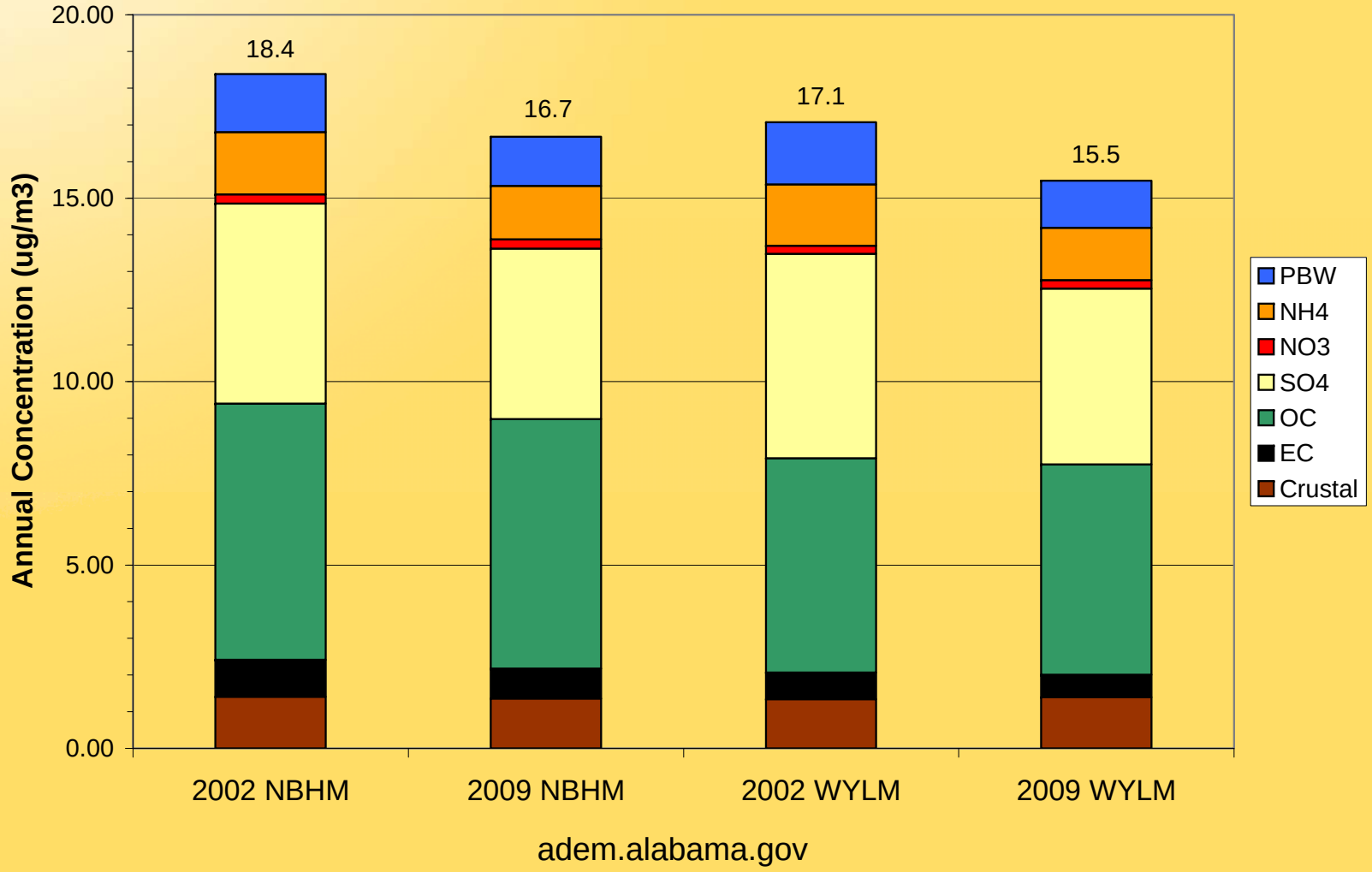
CMAQ "All Source" 2009 DV Projection (3x3 cell average)



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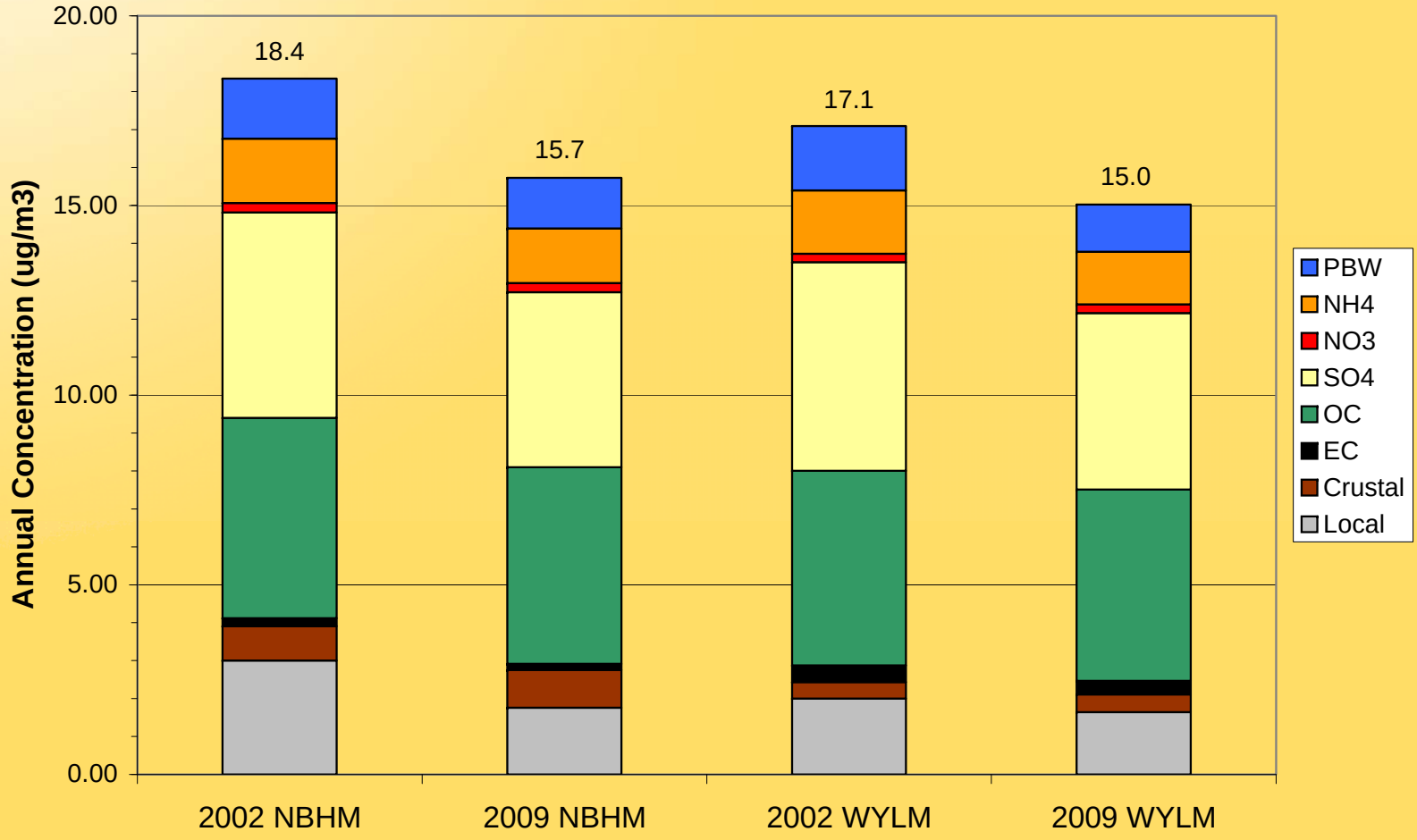
CMAQ + AERMOD 2009 DV Projection (3x3 cell average)



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2009 CMAQ "All-Source" Projection 3x3 averaging

	2002	2009	Reduction
N. Bham.	18.4	16.7	-1.7
McAdory	15.0	13.8	-1.2
Providence	13.0	11.7	-1.3
Wylam	17.1	15.5	-1.6
Hoover	15.1	13.7	-1.4
Pinson	14.0	12.6	-1.4
Corner	14.1	12.6	-1.5

ASIP Modeling Results

- **Updated modeling for 2012 (12km) accomplished by ASIP in July/August for GA and AL SIPs**

- **All states provided updated emissions inventories**
  - **Alabama rolled in the "to-date" 2002 BAPS inventory**
  - **CAIR controls assumed**

ASIP Modeling Results

- The 2012 results are promising
  - It's important not to look to closely at the number per se, but rather the reduction
  - 2002/2009 results used different emissions inventories than the 2012 (VISTAS vs. BAPS)
  - Still, we think the results show that controls in GA and AL will help bring the area into attainment
- The following chart illustrates the 2002 Base, 2009 Best and Final, 2012 Initial, 2018 Best and Final results for Alabama assuming CAIR implementation.

ASIP RESULTS- AL

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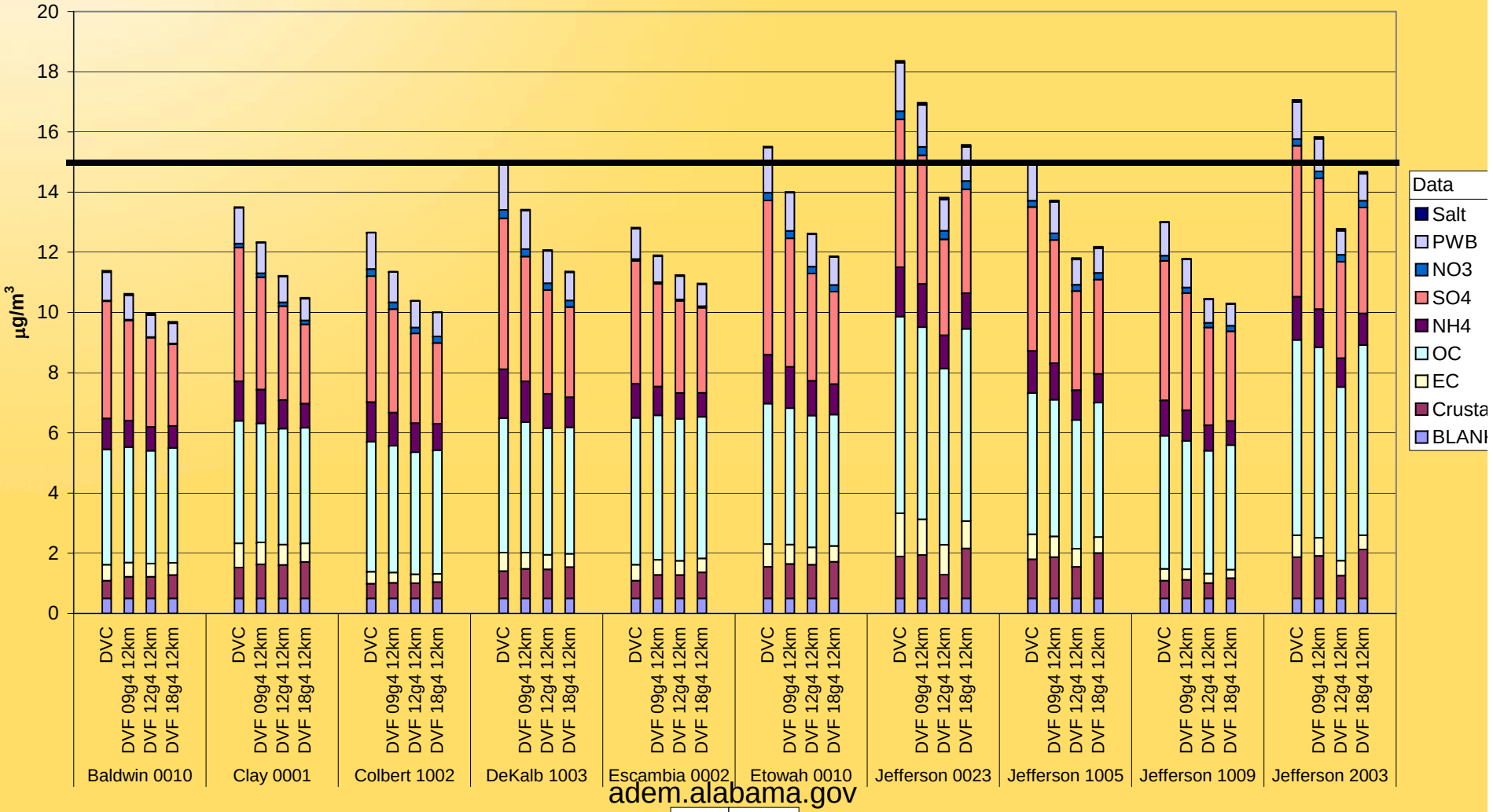
State | Alabama set 1

Alabama, 2002 Design Value, 2009 base G4a 12km and 36km,
2012 base G4a 12km and 36km, and 2018 base G4a 12km and 36km Projected DVF



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Name | dataset

Determination of Attainment Year

- ADEM will propose an attainment date that represents attainment as expeditiously as practicable based on implementation of existing Federal and State measures and all new reasonable local measures.
  - •We believe that 2012 will represent the best future year for the Birmingham NAA
  - •However, we will model both future years and develop RRF's (2009 and 2012)
- In our 2009 basecase, we will account for controls already on the books such as CAIR and mobile source controls, as well as local industry controls implemented between 2002 and 2009.
- Same for 2012

Final Attainment Plan

- The process of identifying significant contributors and candidate control strategies will continue until an emissions reduction plan is developed that demonstrates attainment.
- JCDH will modify permits to reflect final emission controls.