NO_2 Modeling - PVMRM and OLM Evaluation using a New Data Set

Steven Hanna Hanna Consultants
Elizabeth Hendrick and Vincent Tino Epsilon Associates, Inc.
Bruce Egan Egan Environmental, Inc

March 13-15, 2012
10th EPA Air Modeling Conference – RTP, NC

Sponsored by API

PVMRM
Plume Volume Molar Ratio Method

- Developed by Hanrahan (1999)
- Evaluated with a few limited data sets (Empire Abo, Palaau, Arellano/Bange Neth. power plant plumes)
- Assumes simplified chemistry and:
  - Initial in-stack NO/NOx ratio
  - Instantaneous reaction (conversion of NO to NO_2) based on amount of entrained ozone at distance x
  - Originally uses ISC3 dispersion estimates, revised to use AERMOD estimates of NOx concentration and plume spread. Uses relative dispersion estimates for ozone entrainment and reactions
  - Can simulate multiple sources

OLM
Ozone Limiting Method

- Compares the estimated $[NOx]_{max}$ and the ambient O_3 to determine which is the limiting factor to NO_2 formation

- If $O_3 > [NOx]_{max}$, then total conversion is assumed

- If $[NOx]_{max} > O_3$ the formation of NO_2 is limited by the ambient O_3

Evaluation Objectives

- Identify existing dataset that could be used to evaluate AERMOD and the PVMRM and OLM options for predicting 1-hour NO_2 concentrations

- Evaluate:
  - AERMOD predictions of NOx
  - OLM and PVMRM predictions of NO_2/NOx ratio
  - AERMOD/PVMRM and AERMOD/OLM predictions of NO_2 concentrations

Wainwright, AK Data Set

- Single monitoring station sited 500 m from the local power plant
- Observes NO_2, NO, and ozone concentrations, as well as meteorological variables
- 12 ½ months of observations

Wainwright, Alaska

Source Information

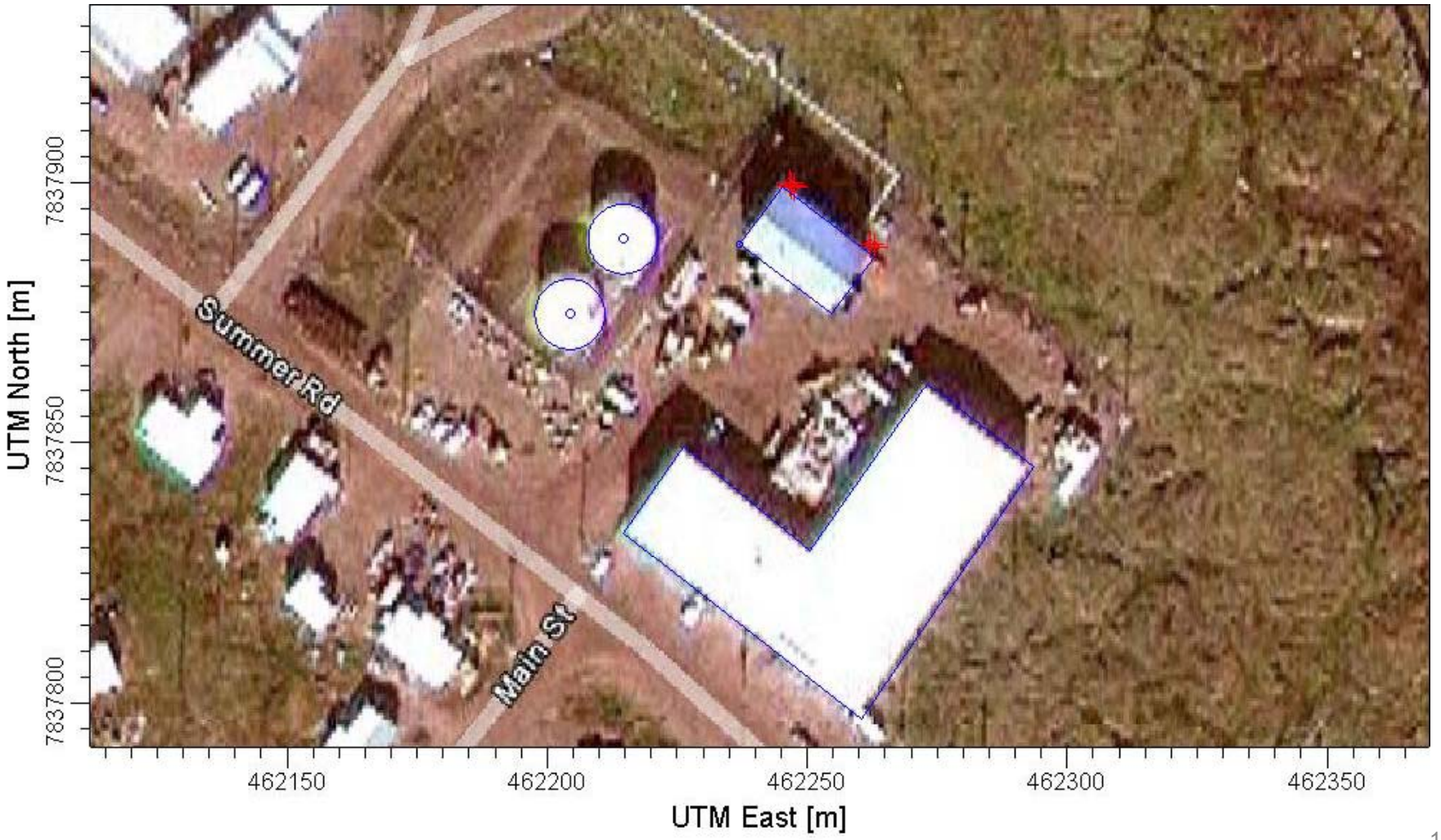
- Five diesel-fired generators and stacks
- Hourly operating logs, listing engine runtimes and kW output
- Stack emissions rate, exit flow and exit temperature have been interpolated from engine design capacity data
- In-stack NO_2/NOx ratio estimated at 0.2

Wainwright Power Plant Building

Model Options Tested

- AERMOD version 11103 runs:
  - OLM option
  - PVMRM option
  - PVMRM algorithms, but with modified relative dispersion parameters
  - PVMRM, but with initial ambient ozone = monitored ozone plus monitored NO_2
- BPIP-Prime was run for downwash for all runs

Stacks shown in red; shop building and storage tanks shown in blue outline



Meteorology and Land Use

- Monitoring station provided primary meteorological data; ASOS data used when monitoring station data missing

- No AERSURFACE land use data available for Wainwright, so land use values assigned manually:

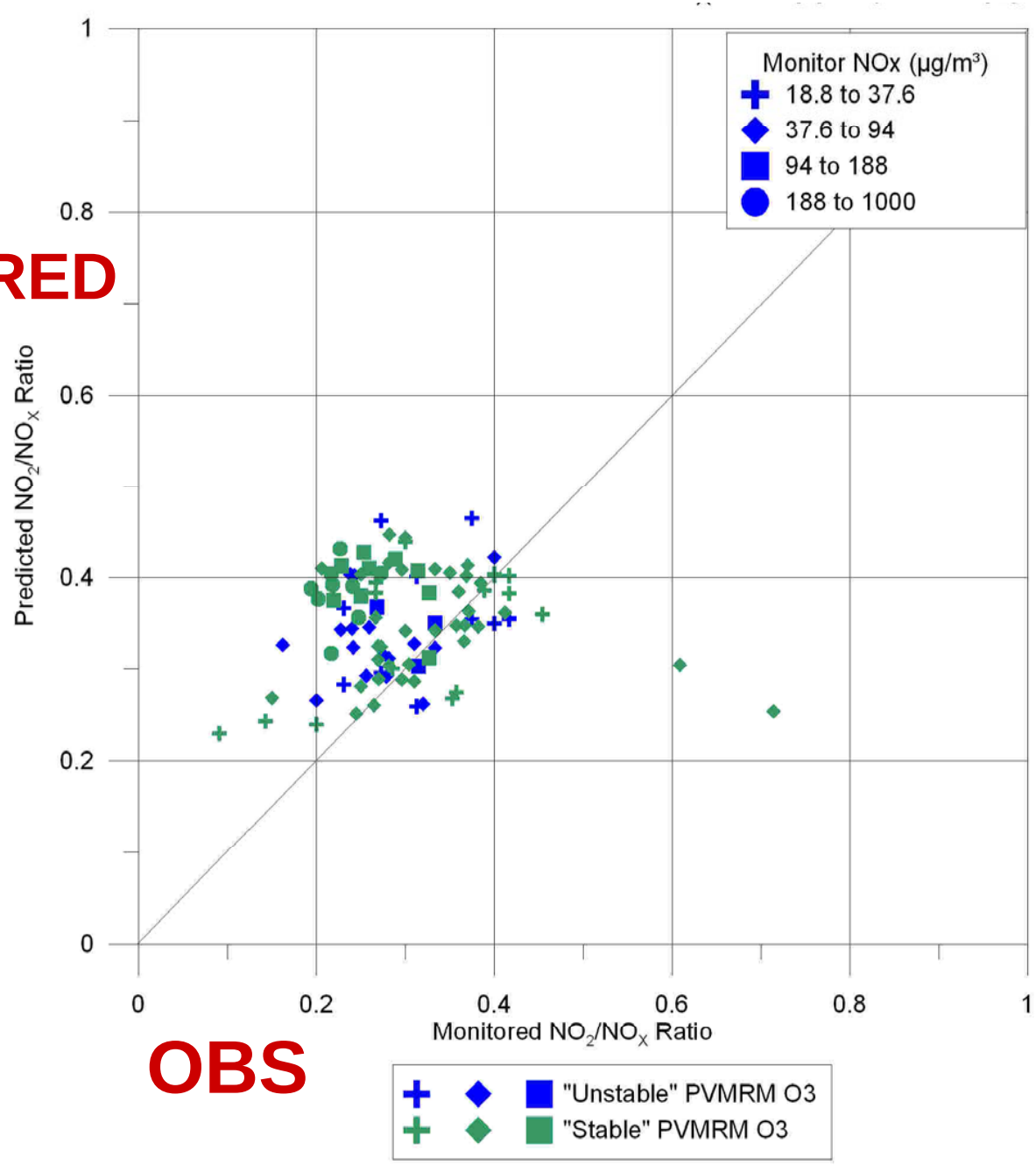
  37° - 218° "desert shrubland"

  218° - 37° "water"

Evaluation Methodology

- Use hours when wind direction is blowing from power plant towards the 60° sector containing the monitor
- Paired NO_2/NOx ratio evaluations use data with NOx > 10 ppb
- BOOT software applied to observed and predicted NOx and NO_2 concentrations paired in time and space
- Also list top-10 and present Q-Q plots

PRED



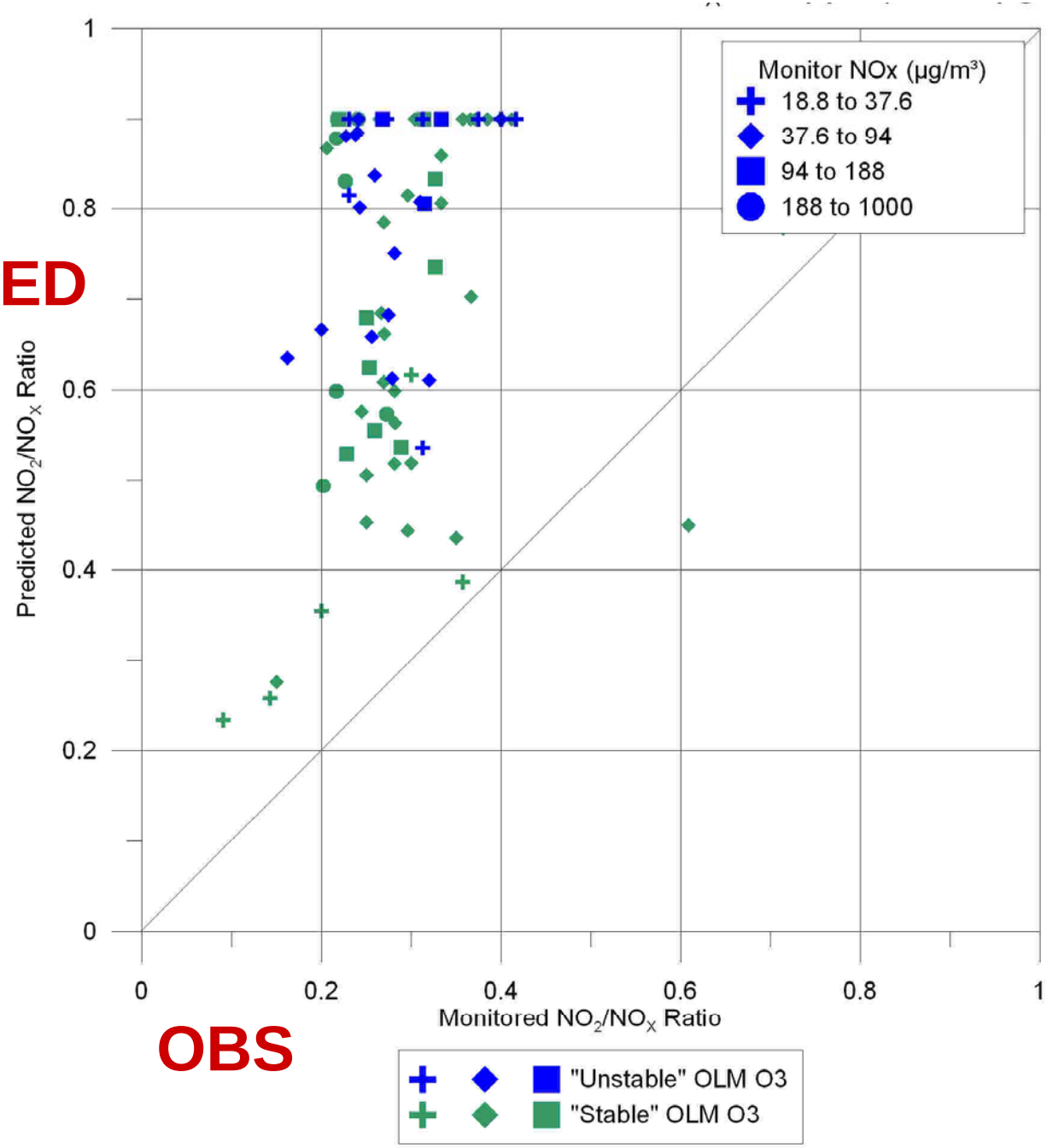
OBS

AERMOD/ PVMRM NO_2/NOx

Green – Stable

Blue - Unstable

PRED



OBS

AERMOD/ OLM NO_2/NOx

Green- Stable

Blue - Unstable

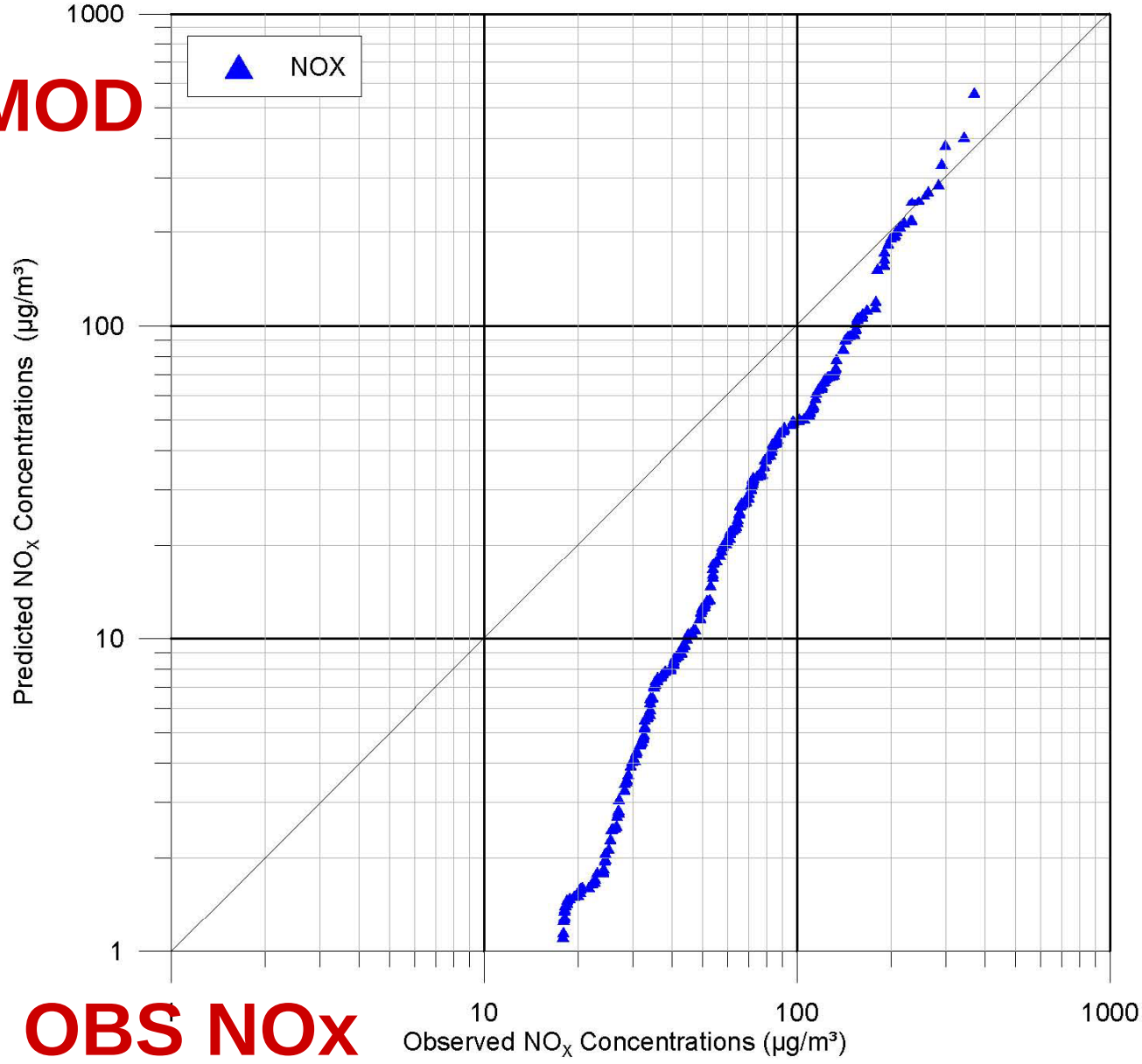
Some BOOT Results for NO_2

PERFORMANCE MEASURE	OBS	AERMOD/ OLM	AERMOD/ PVMRM
Highest NO_2 ($\mu g/m^3$)	73	158	130
Mean	13	21	13
Fractional Mean Bias FB		-0.50	0.01*
Normalized Mean Sq Error NMSE		3.6	3.1
FAC2		0.40	0.47

* Not significantly different from 0.00 (no mean bias) at 95% confidence level

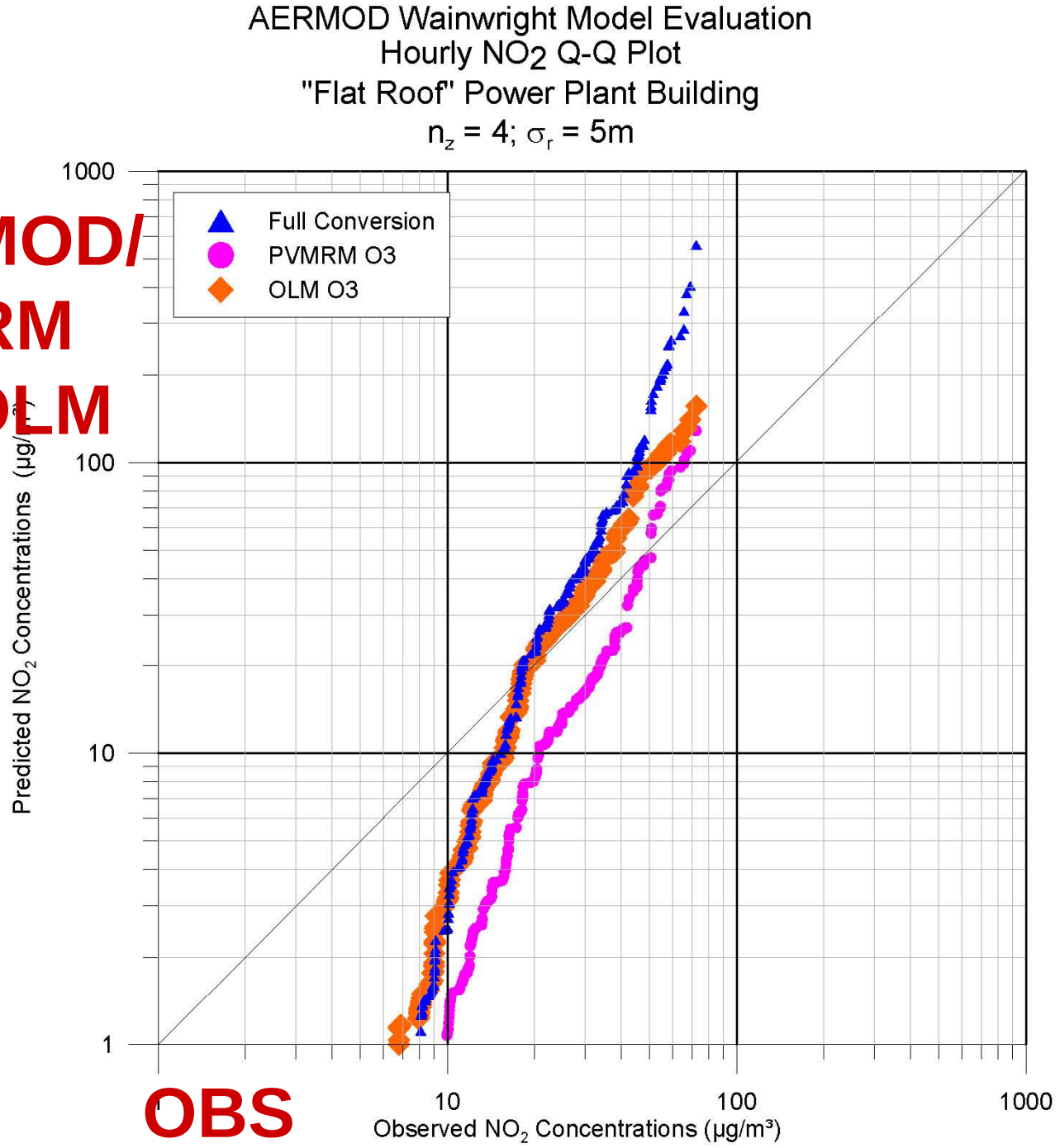
AERMOD Wainwright Model Evaluation
Hourly NOX Q-Q Plot
"Flat Roof" Power Plant Building

AERMOD NOx



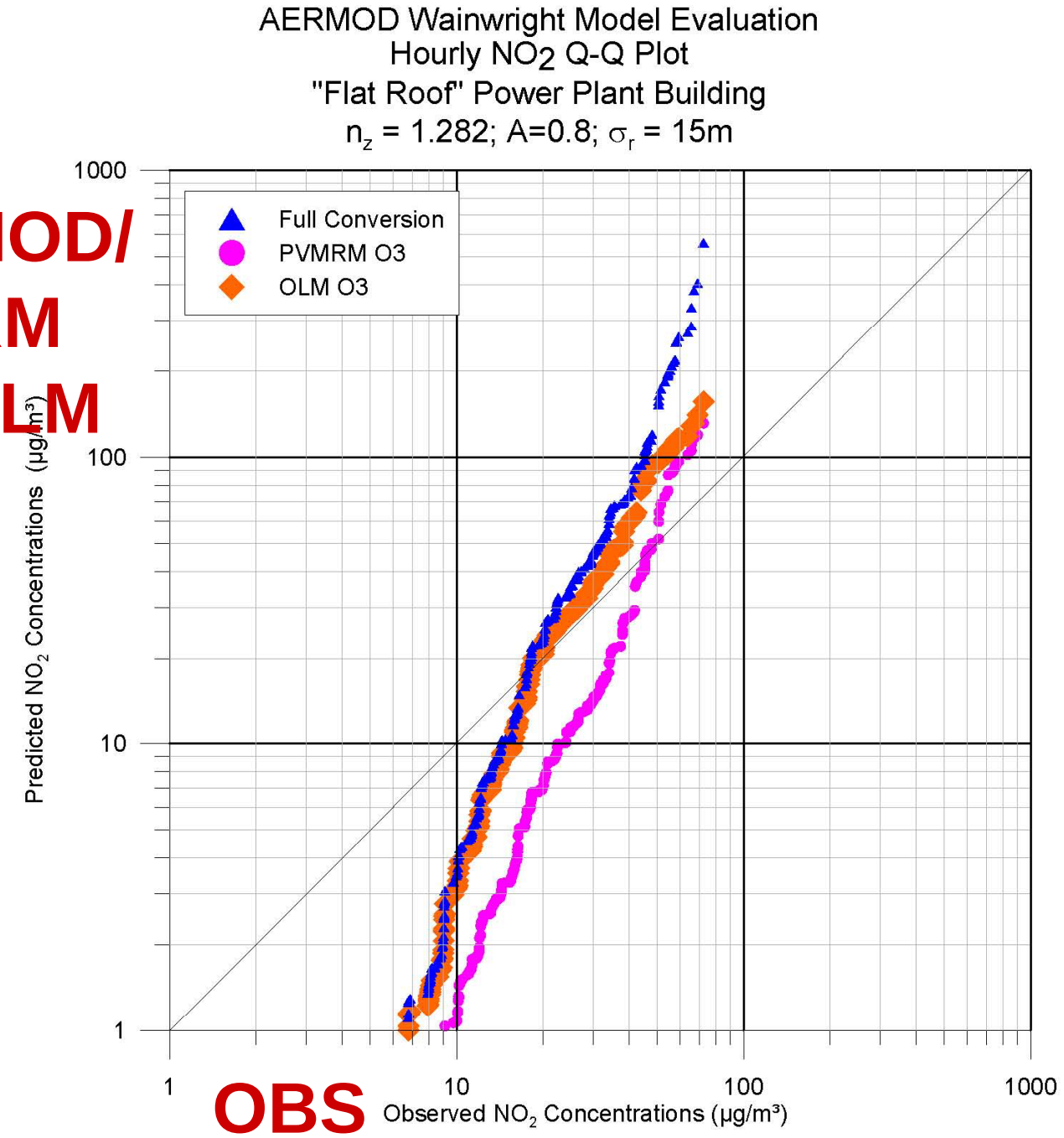
OBS NOx

AERMOD/ PVMRM and OLM



OBS

AERMOD/ PVMRM and OLM



Key Limitations

- Hourly emissions and stack parameters were estimated using operating logs and vendor performance data
- Ambient O_3 was observed only at a single monitoring location. That O_3 may have been affected by scavenging by NO in the plume to form NO_2
- Ambient NOx and NO_2 concentrations were relatively small

Conclusions

- PVMRM is doing well at predicting the NO_2/NOx ratio (minimal bias, with most ratios from 0.2 to 0.4).
- OLM has a general 70 % overprediction tendency for the NO_2/NOx ratio.
- Both AERMOD/OLM and AERMOD/PVMRM overpredict the high end NO_2 concentrations by about a factor of two (OLM by more) (But this may be caused by the fact that AERMOD overpredicts the high end NOx concentrations).
- There was little skill (correlations) evident in both AERMOD/PVMRM or AERMOD/OLM.

This Evaluation in the Context of all PVMRM and OLM Comparisons

To be robust, many data sets should be used in a model evaluation so that a multitude of conditions, source data, etc. can be included.

This evaluation using the Wainwright data set should be considered an additional piece of information to supplement the limited number of data sets used by EPA to date to evaluate the PVMRM and OLM options in AERMOD for predicting 1-hour NO_2.

A detailed field experiment is needed.