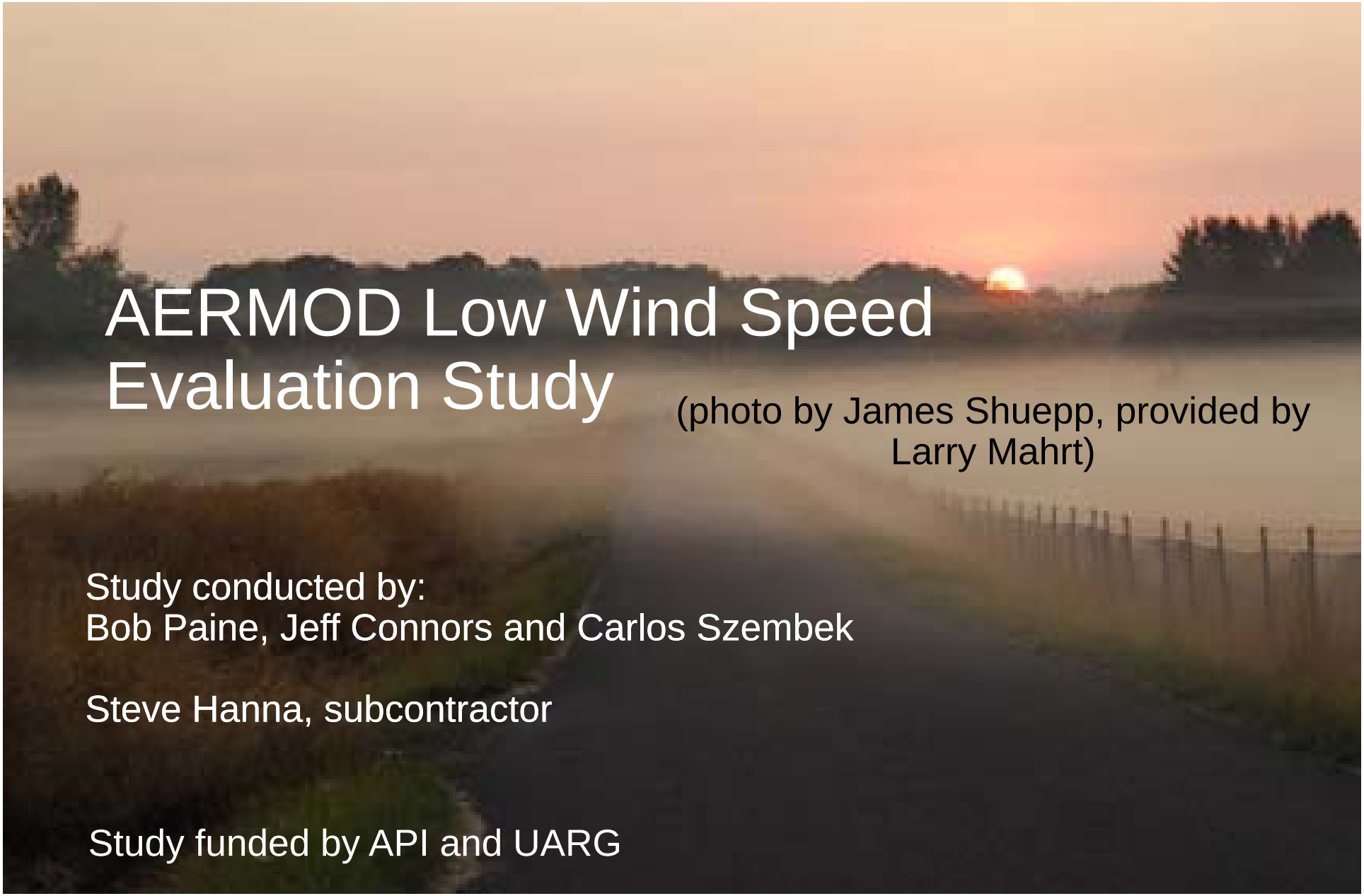

AERMOD Low Wind Speed Evaluation Study

(photo by James Shuepp, provided by Larry Mahrt)

Study conducted by:
Bob Paine, Jeff Connors and Carlos Szembek

Steve Hanna, subcontractor

Study funded by API and UARG

For Presentation at the 10th EPA Modeling Conference, March 13, 2012

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Outline of Presentation

- **Why are low wind speeds a concern?**
- **Review of current AERMOD formulation**
- **Evaluation study approach**
- **Meteorological evaluation results**
- **Tracer study evaluation results**
- **Findings and recommendations**

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Concerns Noted by EPA and the Modeling Community

- **Brode USEPA 2007 Modeling Workshop from AERMOD Implementation Workgroup Highlights**
  - **"Mandatory Work: Light winds. Revise AERMOD's treatment of light winds to avoid unrealistically high concentrations"**
- **Reported at USEPA's 9th Modeling Conference - Air & Waste Management Association Comments**
  - **Many investigators report that the worst-case AERMOD impacts occur for very low wind speeds at night, especially for low-level sources**
- **AERMOD has limited evaluation for these conditions – very few hours with wind speed < 1 m/s**

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Current AERMET/AERMOD Approach

- **AERMET computes the friction velocity (u_*), which is an important parameter for nocturnal hour estimates of mixing height, sigma-z, and sigma-y**
- **AERMOD approach in low winds is reasonably simple, and involves a combined solution of a coherent plume (traditional Gaussian shape) and a random (pancake) plume**
- **Weighting of the two solutions depends upon wind speed and turbulence provided to AERMOD**

Approach for this Study (2009)

- **We initiated a new evaluation study to understand AERMOD's performance under low wind speeds**
- **The evaluation study featured existing research-grade meteorological and low wind speed tracer databases**
- **Guideline and alternate versions of AERMET/AERMOD were tested in this study**
- **Collaboration with USEPA and AERMIC review was important for this study**
- **However (to my knowledge), AERMIC has provided limited review to date**

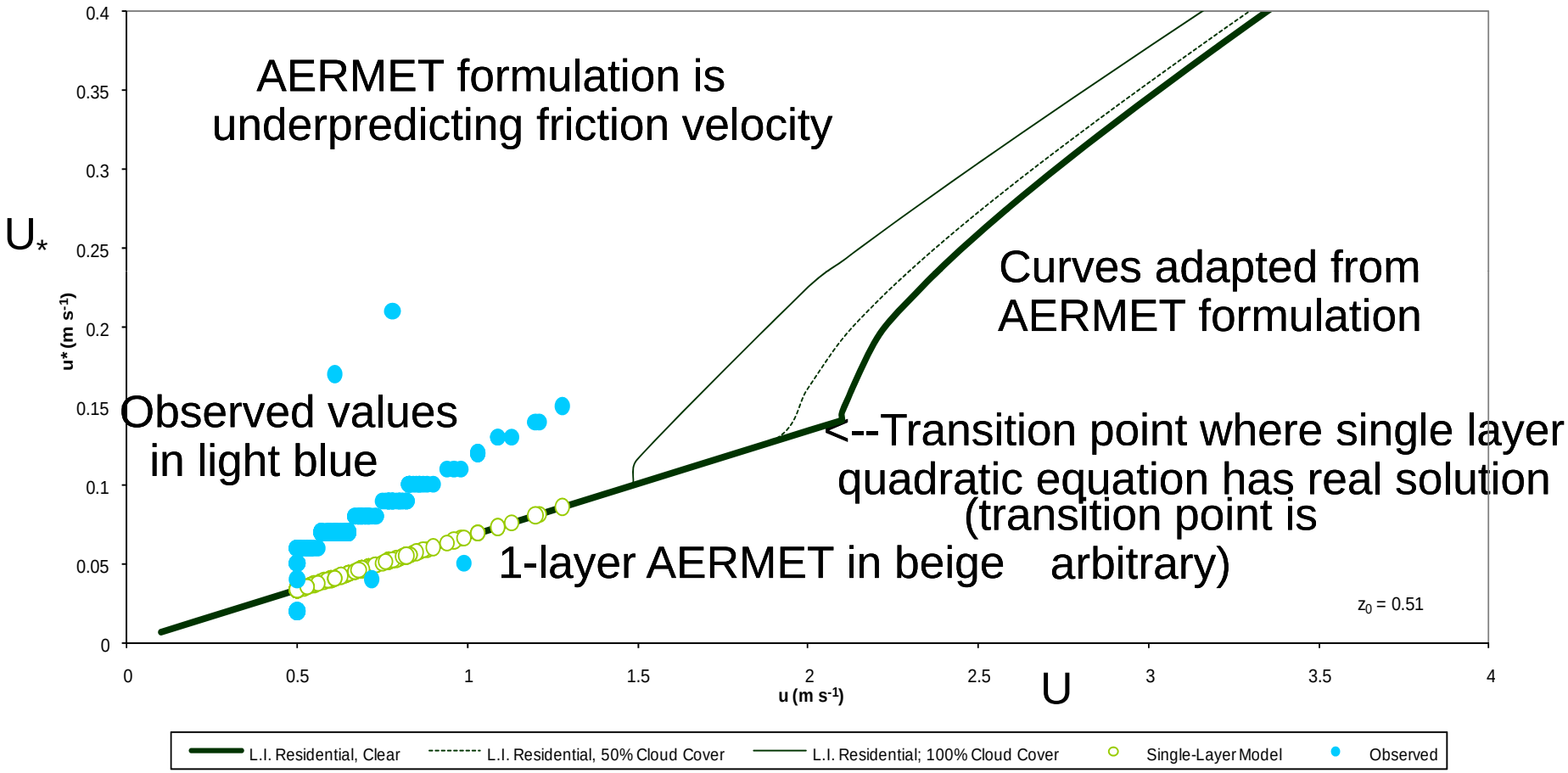
Phase 1: Meteorological Evaluation Study

- **Requested by EPA; evaluation focused upon u_***
- **Research-grade databases were selected for low wind speeds and sonic anemometer to get observed u_***
- **Evaluation focused upon nocturnal, low wind conditions**
- **Cardington (flat, grassy site in the UK) was included in the evaluation**
- **Other met databases (USA) were:**
  1. **Bull Run (mixed land use/terrain Tennessee site)**
  2. **FLOSS II (Fluxes Over Snow Surfaces, Phase 2: flat open site in northern Colorado)**

Meteorological Evaluation Results

- **Single-level friction velocity predictions by AERMET were found to be too low for low wind, stable hours**
- **An adjustment to the formulation was suggested by the data, and appeared to greatly improve the AERMET single-layer performance**
- **This adjusted formulation was tested all three met databases**

u* (y axis) vs. u for Bull Run Nocturnal Stable Hours



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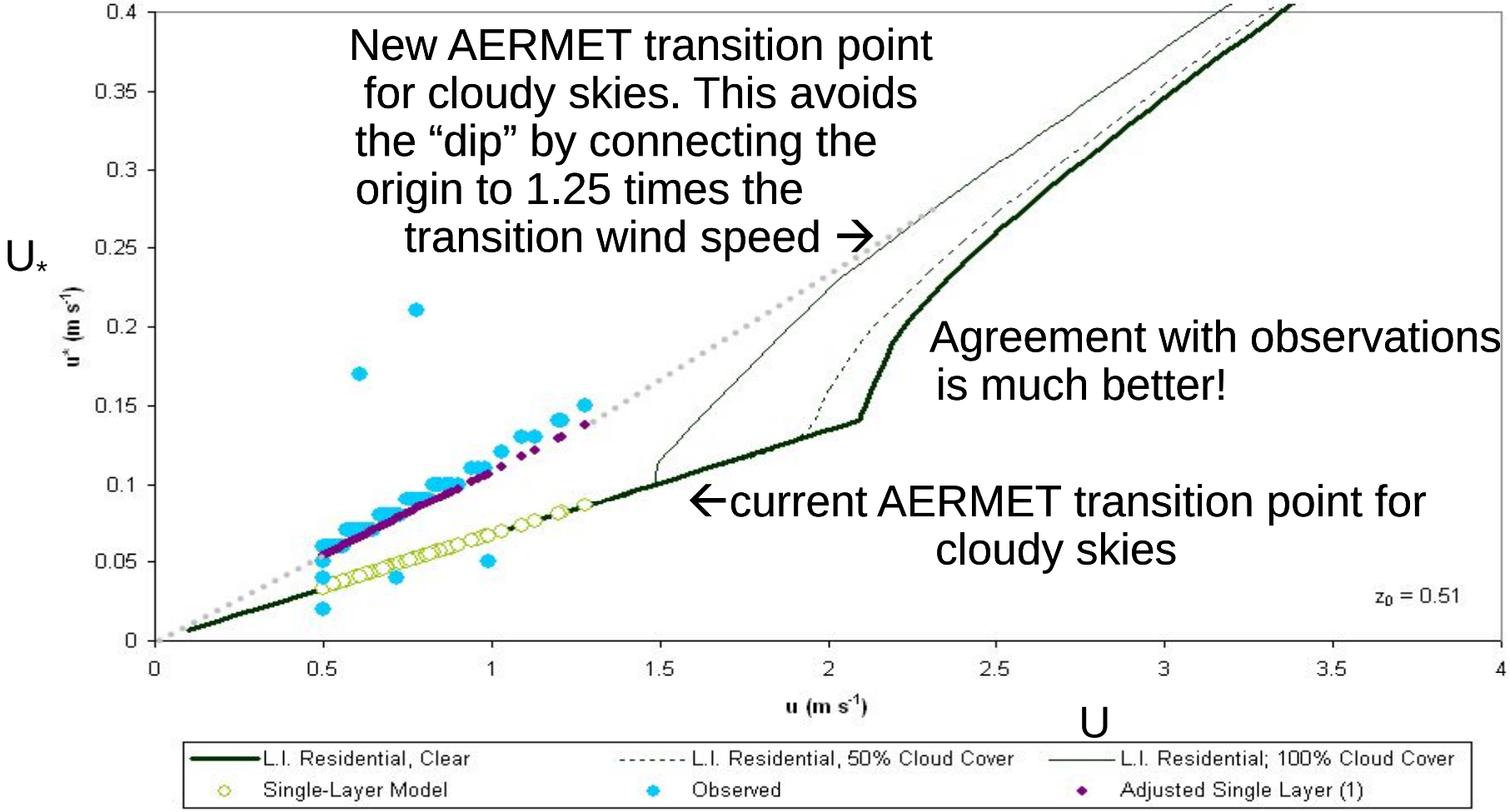
Improvement to Single-Layer Method



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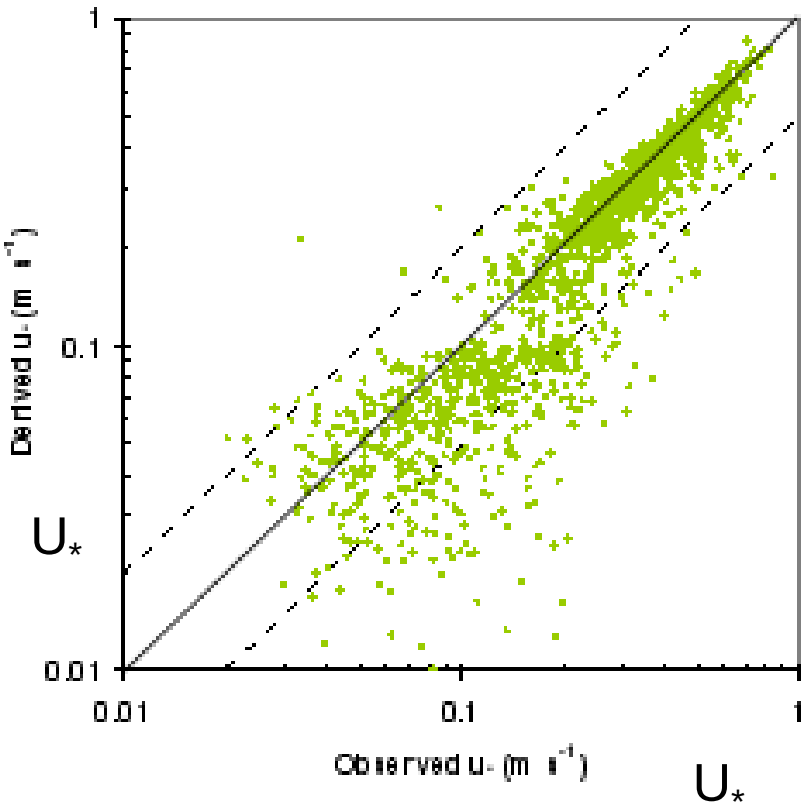
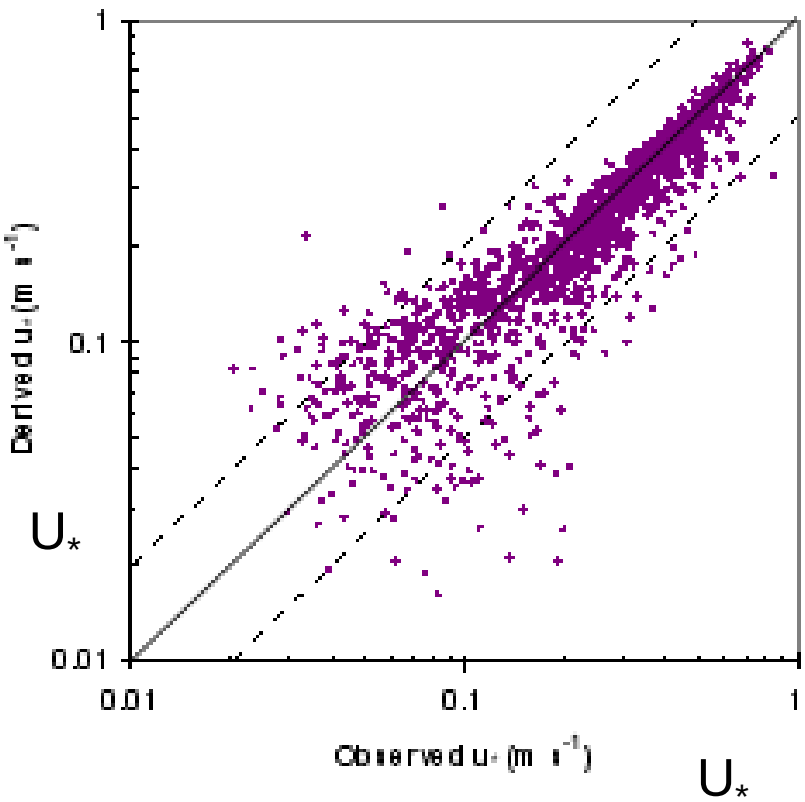
Comparisons for u* with Cardington data (low wind speed, stable hours)

Current AERMET



Modified AERMET



Single layer

Conclusions from Met Evaluation

- **Current AERMET formulation will likely underpredict u* in low wind speed, stable conditions**
- **This would be expected to result in higher predicted concentrations (lower dilution speed and dispersion rate)**
- **This happens for both the single-layer and 2-layer (Bulk Ri) methods**
- **Met model performance with the suggested improvements is better overall**
- **These changes were carried forward into the tracer evaluation phase of the study**

Phase 2: Tracer Database Evaluation

- **Study focused on 3 databases:**

1. **Bull Run, TN (tall stack, buoyant plume)**
2. **Idaho Falls, ID (low-level releases)**
3. **Oak Ridge, TN (low-level releases)**

Candidate Models

- **Candidate models based on changes to AERMET/AERMOD**
- **Results presented for 3 cases:**

1. Base AERMET

2. Modified stable u* formulation in AERMET

3. AERMET/AERMOD with minimum sigma-v = 0.4 m/s

  – **Current minimum sigma-v = 0.2 m/s**

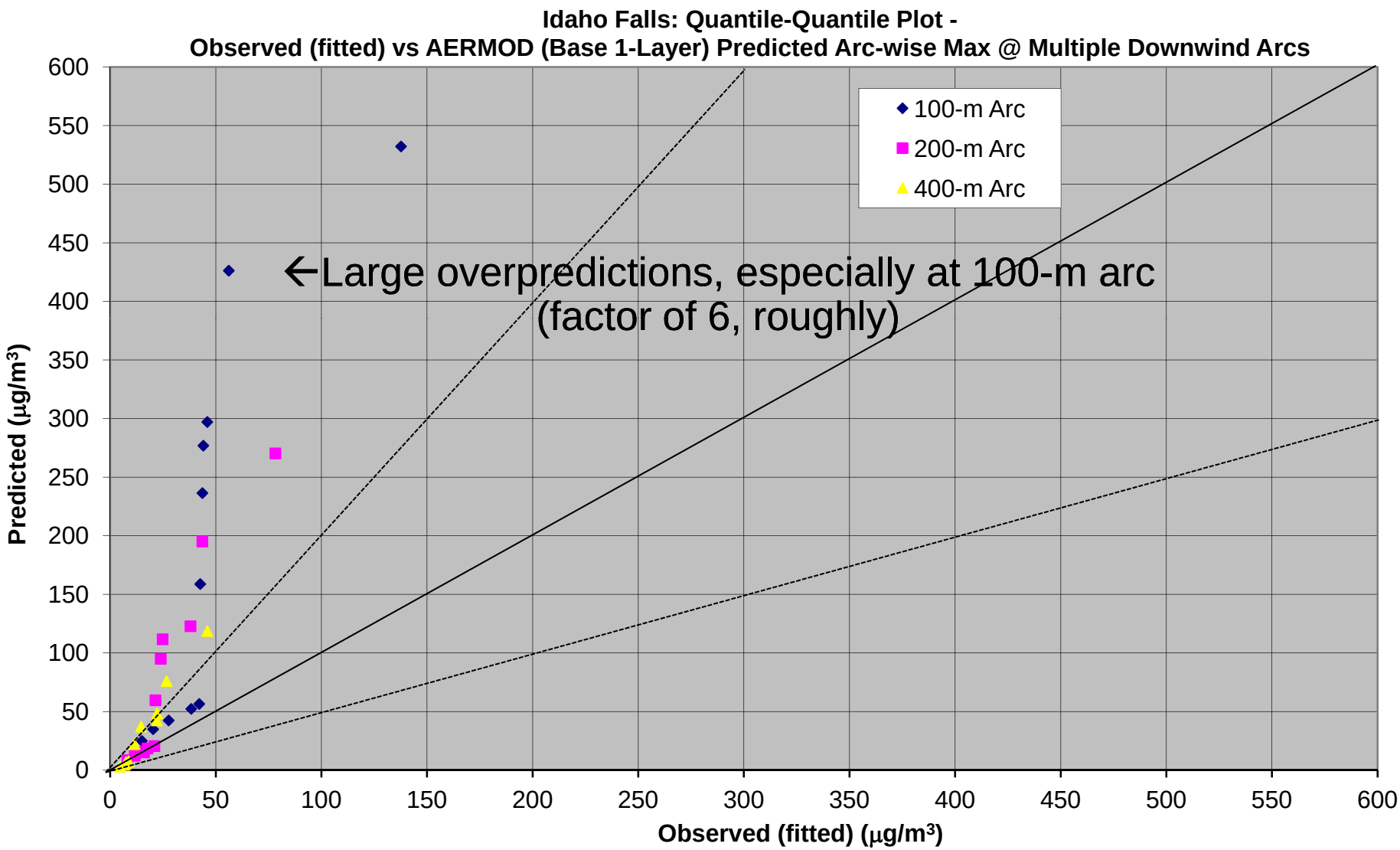
Why Adjustments to Minimum Sigma-v?

- **After running AERMOD with current AERMET, we constructed Excel spreadsheet to replicate AERMOD predictions during stable hours (Oak Ridge and Idaho Falls) w/ model debug output**
- **Found sigma-v becomes very important under low-wind speed conditions when sigma-theta data is not available because it helps define:**
  - **lateral dispersion (sigma-y)**
  - **fraction of the random plume used to calculate total concentration**
- **AERMOD was underestimating the lateral dispersion and fraction of the random plume**
- **This was causing the model to overpredict significantly for light winds**

Why Adjustments to Minimum Sigma-v?

- **Model debugging showed the following:**
  - **Random plume fraction is too low for very low winds**
  - **Coherent plume component dominates the total prediction**
  - **Availability of observed sigma-theta helps to increase lateral dispersion for the coherent plume**
  - **Without sigma-theta measurements, the minimum sigma-v needs to be increased from the current value of 0.2 m/s**
- **Key databases showing model overpredictions were near-surface releases (Idaho Falls and Oak Ridge)**
- **Tall stack evaluation study for Bull Run showed acceptable model performance for convective conditions**

Idaho Falls Q-Q plot – 1 met level, no sigma-theta with current AERMET



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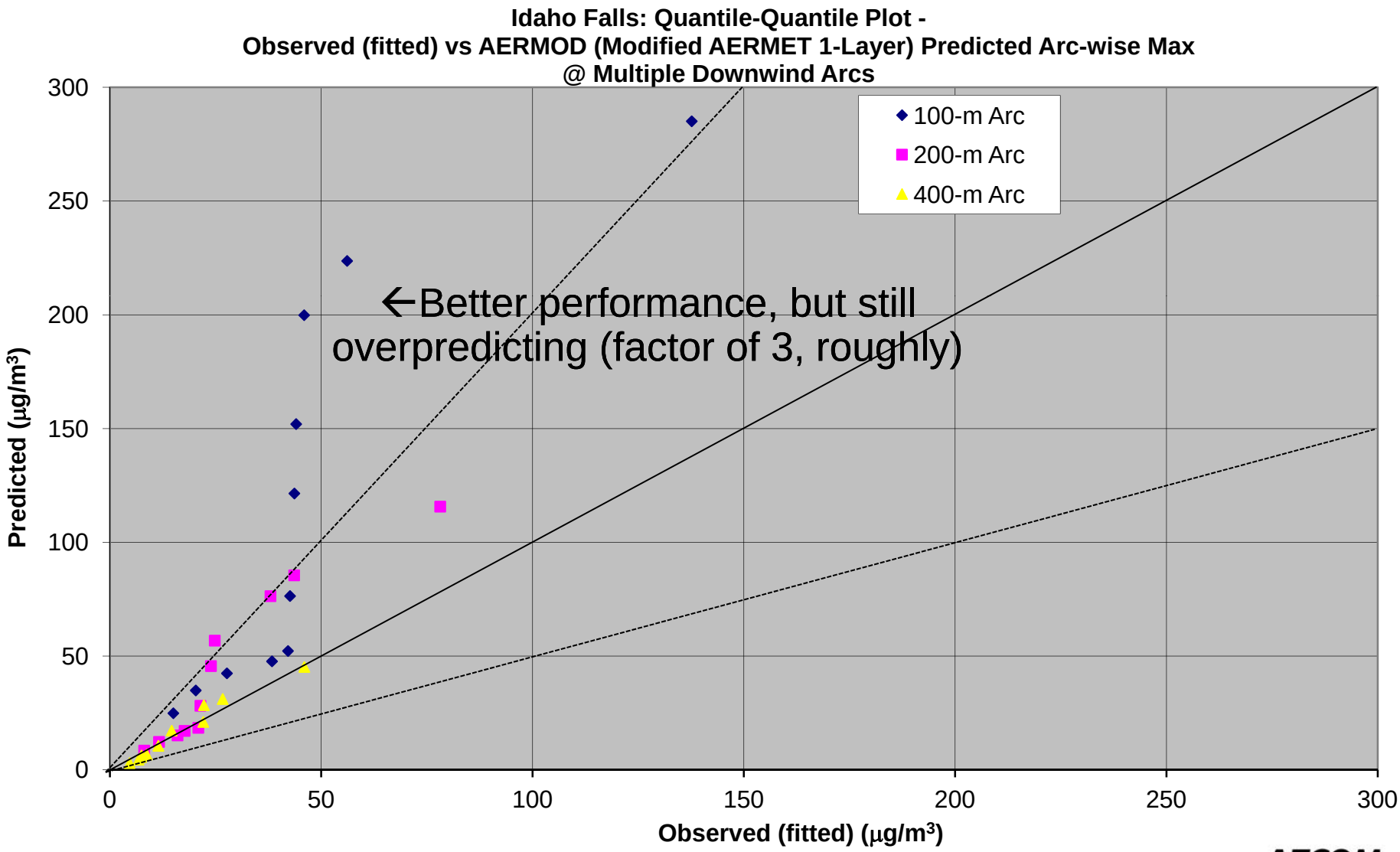
Idaho Falls Q-Q plot – 1 met level, no sigma-theta with new AERMET processing (improved u_*)



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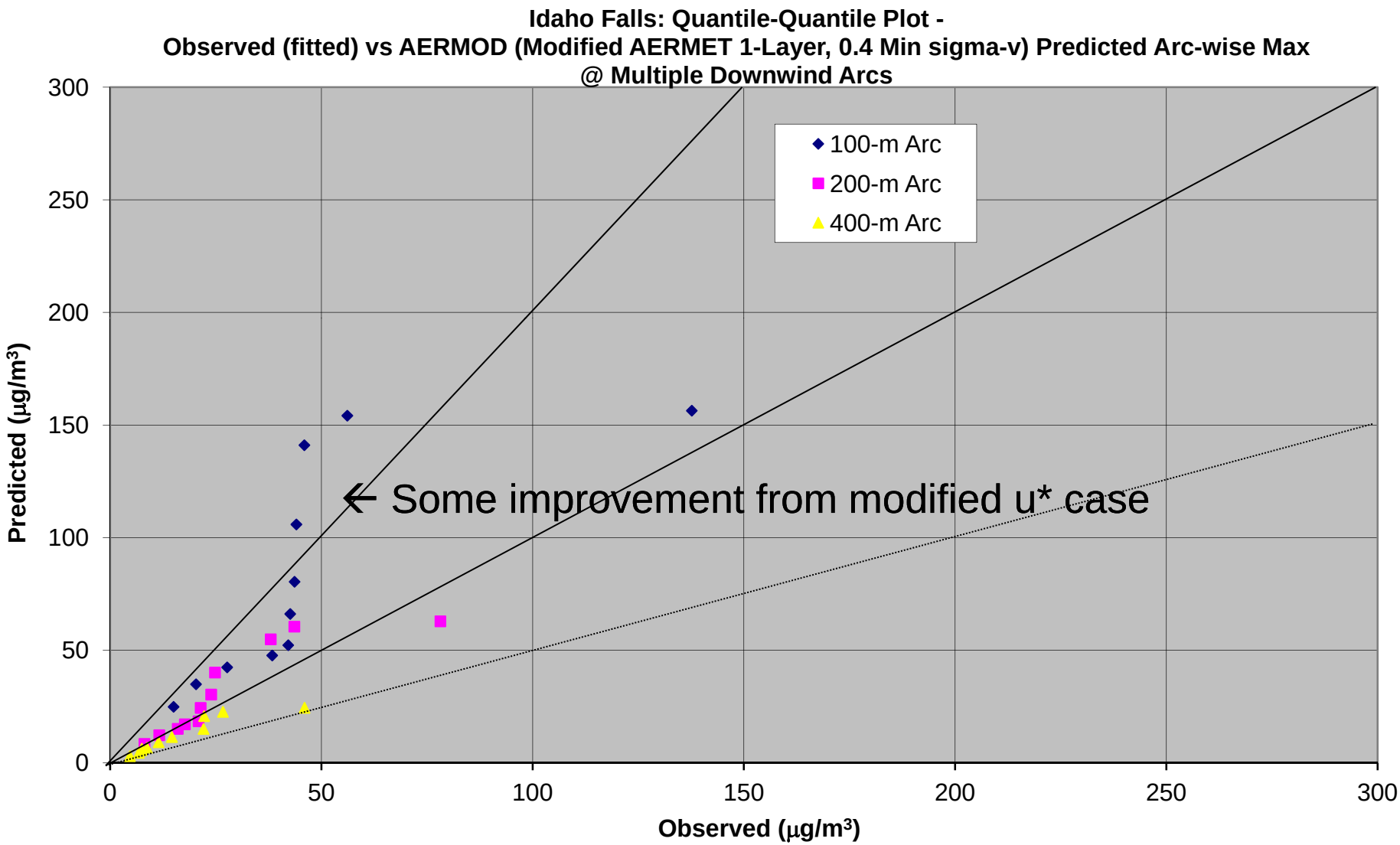
Idaho Falls Q-Q plot – 1 met level, no sigma-theta with new AERMET processing (improved u_* and min sigma-v)



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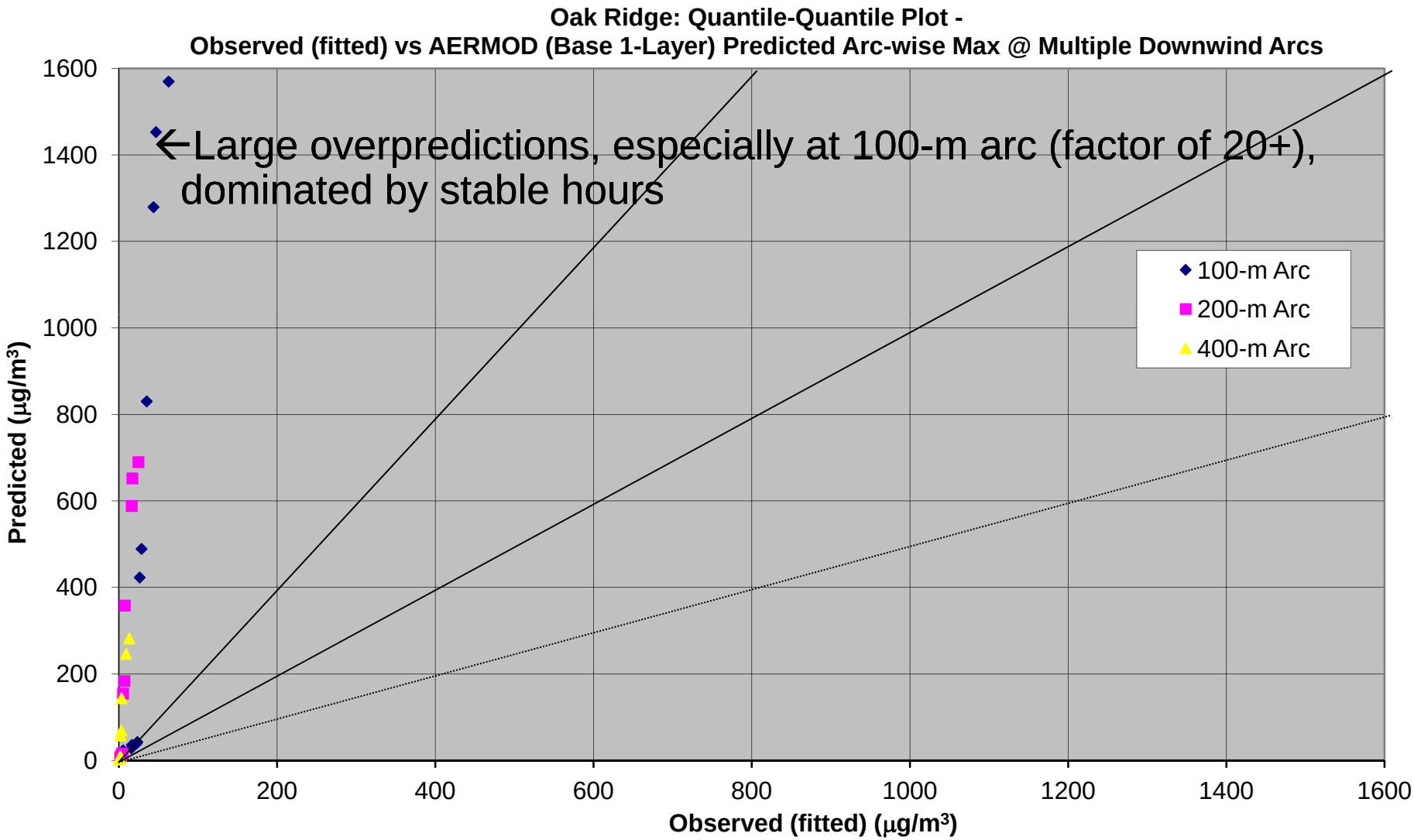
Overall Results for Idaho Falls

- **Overpredictions clearly evident at 100 m, better model performance further out**
- **Sigma-theta observations reduced overpredictions (better depiction of lateral plume spreading)**
- **Use of better AERMET (higher u_*) reduced overpredictions by about a factor of 2**
  - **Higher effective dilution wind speed**
  - **Higher turbulence levels in vertical and horizontal**
- **Biggest improvement to model performance → reformulated u* in AERMET when lacking sigma-theta**
- **Increased minimum sigma-v resulted in additional performance improvements**
- **Single-level AERMET works as well as 2-level AERMET**

Oak Ridge Q-Q plot – 1 met level, no sigma-theta with Current AERMET



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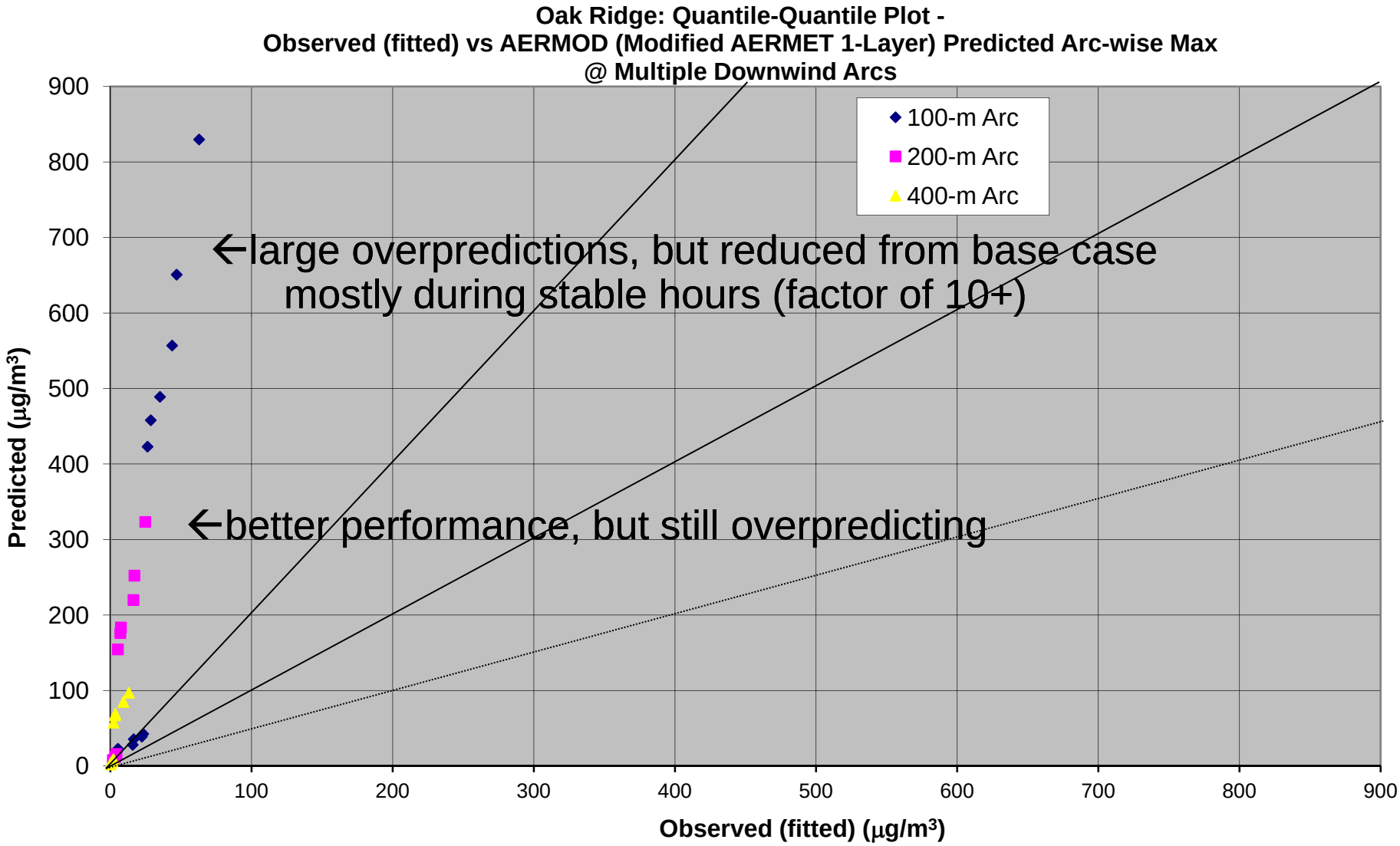
Oak Ridge Q-Q plot – 1 met level, no sigma-theta with new AERMET processing (new u_*)



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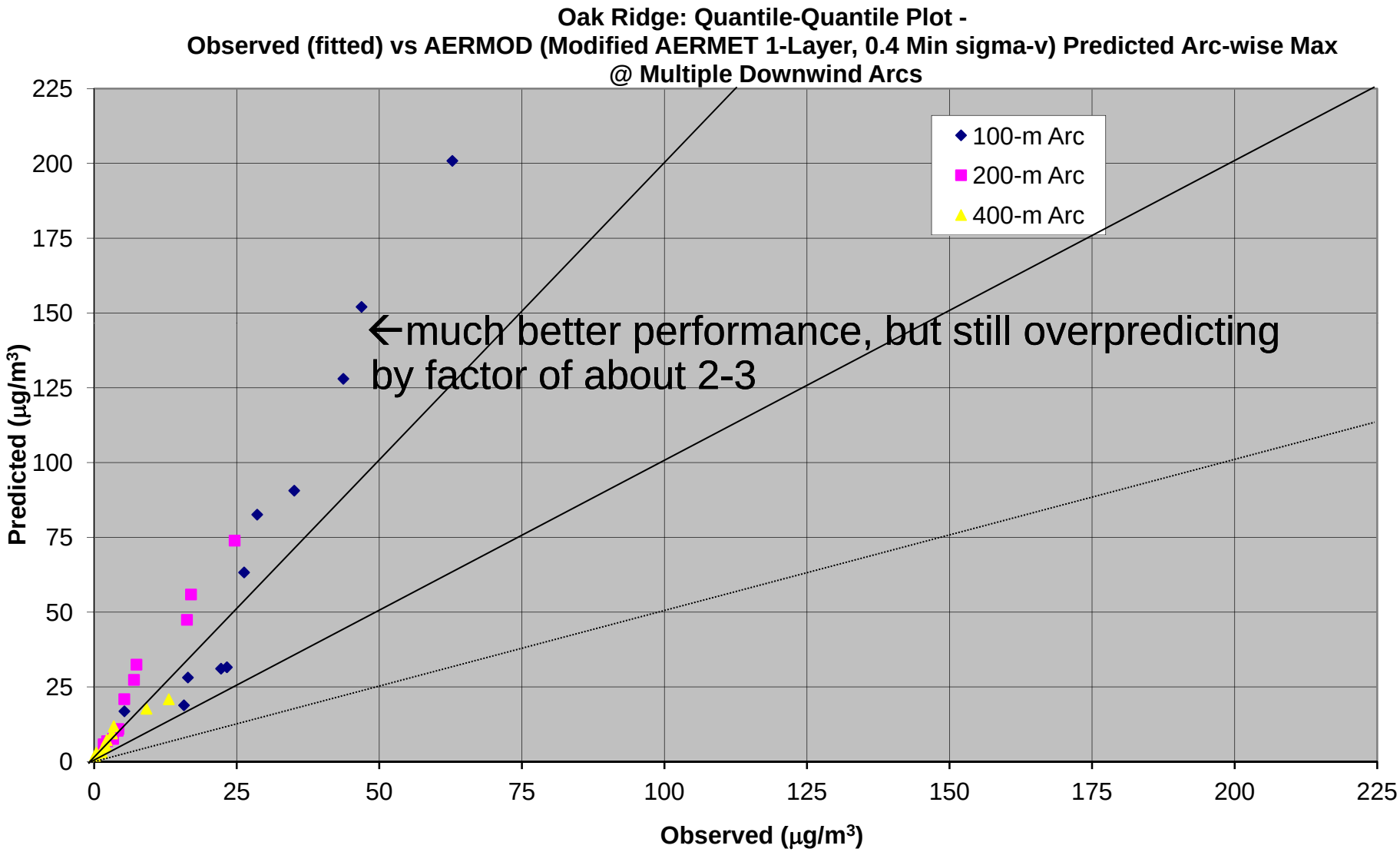
Oak Ridge QQ-plot – 1 met level, no sigma-theta with new AERMET processing (improved u_* and min sigma-v)



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Overall Results for Oak Ridge

- **Substantial overpredictions occur, especially at closest distances**
- **Overpredictions mostly due to model's poor performance during stable hours**
- **AERMOD does reasonably well for unstable conditions**
- **There is a need to predict a larger lateral spread of the plume for stable conditions (no sigma-theta data available here)**
- **Use of enhanced AERMET (higher u_*) reduces overpredictions**
  - **Higher effective dilution wind speed**
  - **Higher turbulence levels in vertical and horizontal**
- **Minimum sigma-v of 0.4 m/s substantially improves model performance**

Findings and Recommendations

- **API provided results, code, and modeler's archive to EPA for review 2 years ago**
- **We encouraged EPA to add our code changes as a beta option to an AERMET/AERMOD release:**
    1. **Set minimum sigma-v = 0.4 m/s instead of 0.2 m/s**
    2. **Use alternative u* formulation for both single-level and 2-level approaches**
- **Low u* has other implications – results in very low mechanical mixing heights which leads to extremely low plume spreading for releases above the mixing height**