AERMOD Low Wind Speed Evaluation with Tall-Stack Databases

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Outline of Presentation

• Background for this study
• Description of evaluation databases
• Modeling options evaluated
• Evaluation results
• Overall results and conclusions
Background for this Study

• Before AERMOD, model input wind speeds were never allowed to go below 1 m/s in EPA models
• In light winds, steady-state plume model assumptions tend to break down
• AERMOD allows arbitrarily low wind speed input, and attempts to account for plume meander with a random plume and coherent plume weighting scheme
Depiction of AERMOD Coherent and Meander Plume Components

LOWWIND3 removes the upwind part of the meander impact

Basic Over-Prediction Issues for Previous AERMOD Versions in Low Winds

• Friction velocity (u*, related to mechanical wind shear) was underestimated in AERMET by a factor of 2 in low winds
• This resulted in turbulence and mixing height being underestimated for stable conditions in AERMOD
• Plume meander weight was possibly underestimated - this could result in a plume that is too concentrated
• AECOM study in 2010 recommended a change in the u* formulation to fix that underestimation problem
• That study also recommended an increase in the minimum lateral plume spread (tied to sigma-v) to help account for additional meander in very light winds
EPA’s Low Wind Improvements

- In 2012, EPA updated AERMET and AERMOD to implement an approach similar to that proposed by AECOM.
- This was implemented in AERMOD version 12345, and then updated in versions 13350, 14134; also updated in version 15181 with LOWWIND3.
- EPA has also discussed these updates in various webinars (January 14, 2014 and August 12, 2014), available at www.epa.gov/scram001 and at this conference.
- The new AERMOD release should make these improvements a permanent part of the model (default).
- The study reported here, funded by EPRI and the Lignite Energy Council, provides additional low wind evaluation findings for tall stacks.
Tall-Stack Evaluation Databases

- North Dakota Mercer County – rolling terrain and 5 monitors (4 years)
- Gibson Generating Station (SW Indiana) – flat terrain and 4 monitors (3 years)
- Each site featured data from a 10-m tower to evaluate a standard airport-type meteorological input
AERMOD (v. 14134) Options Tested

- AERMET and AERMOD in default mode
- Low wind beta option for AERMET and default options for AERMOD (minimum sigma-v value of 0.2 m/s)
- Low wind beta option for AERMET and the LOWWIND2 option for AERMOD (minimum sigma-v value of 0.3 m/s)
- Low wind beta option for AERMET and the LOWWIND2 option for AERMOD (minimum sigma-v value of 0.5 m/s)
Evaluation Statistical Results Produced

- 99th percentile peak daily 1-hr max, averaged over all years modeled
- Quantile-quantile (Q-Q) plots for each monitor (plotted pairs of ranked values) – not shown here due to time constraints
- Review of meteorological conditions associated with peak predictions and observations
Terrain Near SO$_2$ Monitors Used in the North Dakota Study

Contour interval is 10 m
Design Concentration Results for North Dakota

![Bar chart showing concentration results for different sites in North Dakota. The chart compares different models and wind conditions.]

- **DGC #12**: Default AERMET, Default AERMOD
- **DGC #14**: Beta AERMET, Default AERMOD
- **DGC #16**: Beta AERMET, AERMOD with LOWWIND2 Sigma V = 0.3 m/s
- **DGC #17**: Beta AERMET, AERMOD with LOWWIND2 Sigma V = 0.5 m/s
- **Beulah**: Default AERMET, Default AERMOD

The chart illustrates the model predictions compared to monitor data, with varying wind speed conditions affecting the concentration results.
Low Wind Performance Improvements

• For the four monitors in relatively low terrain, AERMOD LOWWIND2 option improved performance
• DGC #16 was the closest monitor, and showed higher over-predictions than the other monitors
• AERMET ADJ $u_*$ had little effect because the peak predictions were during daytime hours
• For the monitor in high terrain (DGC #17), both the ADJ $u_*$ and the LOWWIND2 options resulted in performance improvements
Comparison of Meteorological Conditions for Peak Observed and Modeled Impacts

- Peak obs. for DGC #17 monitors were mixed between daytime and nighttime conditions with a large range of wind speeds.
- AERMOD with default options for DGC #17 predicts peak conc. mostly for hours featuring stable, light winds.
- This result changes substantially with the ADJ $u_*$ option employed, for which many more peak prediction hours are daytime periods with light to moderate wind speeds – much more consistent with the peak observed concentration conditions.
Overall Evaluation Results: North Dakota Database

• AERMOD default predicts the highest, and over-predicts substantially at the elevated DGC #17 monitor.
• Low wind options significantly improve the matching of meteorological conditions between predictions and observations at DGC #17.
• Low wind options (both ADJ $u_*$ and LOWWIND2) improve AERMOD performance, and LOWWIND2 with minimum sigma-$v$ of 0.5 m/s has the least bias while still over-predicting.
Gibson Generating Station Monitoring Network
Design Concentration Results for Gibson

- Default AERMET, Default AERMOD
- BETA AERMET, Default AERMOD
- Beta AERMET, AERMOD with LOWWIND2 Sigma V = 0.3 m/s
- Beta AERMET, AERMOD with LOWWIND2 Sigma V = 0.5 m/s
Overall Evaluation Results: Gibson Database

• Results are generally insensitive in this flat terrain setting to the low wind options (especially ADJ $u_*$) because most predicted (and observed) impacts are during the daytime

• Results are relatively insensitive to the AERMOD low wind options (although there was a slight improvement) because the key conditions are generally not extremely low wind speeds

• In this type of application, default use of the low wind options would not degrade AERMOD performance

• AERMOD (v. 14134) model options still consistently over-predict between 10 and 50% for Gibson
Overall Conclusions

• The AERMOD v. 14134 low wind speed options have a minor effect with tall stacks for flat terrain locations.
• These options have a significant effect with AERMOD modeling for elevated terrain locations.
• The use of the LOWWIND2 option with a minimum sigma-v up to 0.5 m/s consistently performs well.
• The low wind options improve the consistency of meteorological conditions associated with the highest observed and predicted concentrations.
• Initial quick look at EPA’s proposed adoption of the ADJ-u* and LOWWIND3 options in v. 15181 indicate general consistency with our findings for v. 14134.
• Applications with these proposed options should result in more accurate AERMOD predictions.

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