AERMOD Low Wind Speed Evaluation with Tall-Stack Databases

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Study sponsors: EPRI and Lignite Energy Council

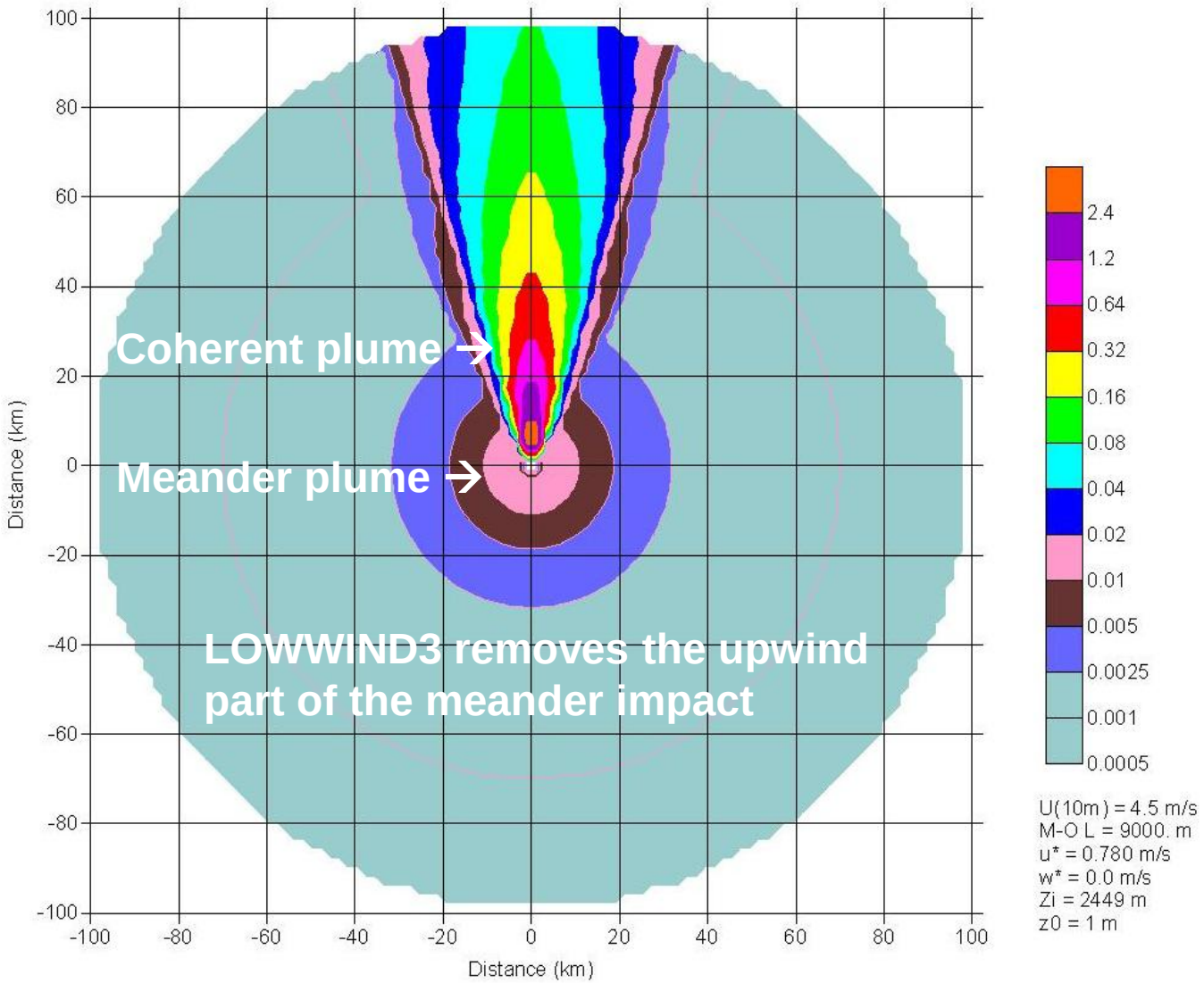
Outline of Presentation

- 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



*source: slide #48 presented by Joe Scire at EPA's Ninth Modeling Conference, available at http://www.epa.gov/ttn/scram/9thmodconf/scire_calpuff.pdf

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

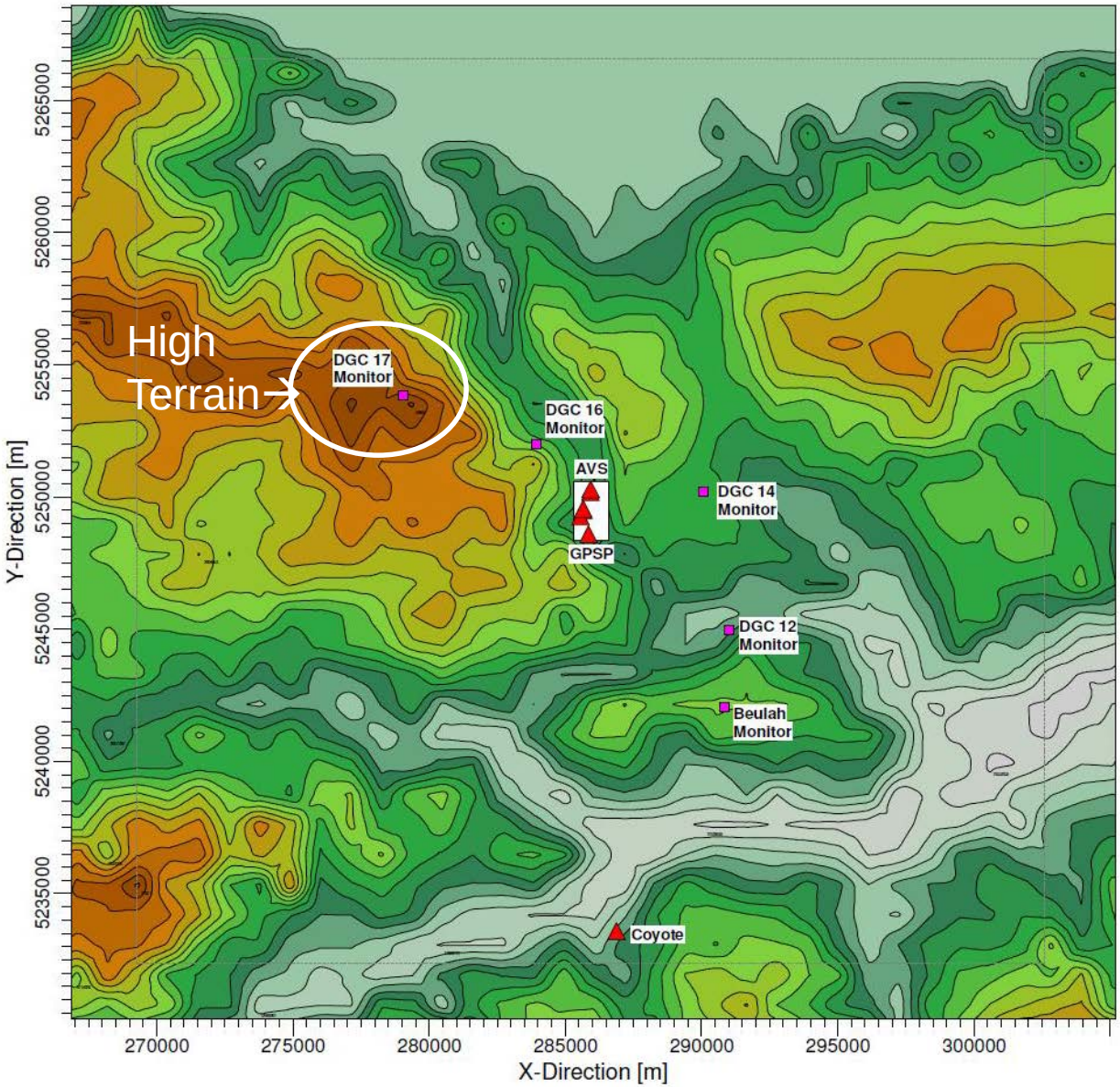
- AERMET and AERMOD in default mode
- Low wind beta option for AERMET and default options for AERMOD (minimum sigma-v value of 0.2 m/s)
- Low wind beta option for AERMET and the LOWWIND2 option for AERMOD (minimum sigma-v value of 0.3 m/s)
- Low wind beta option for AERMET and the LOWWIND2 option for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

Evaluation Statistical Results Produced

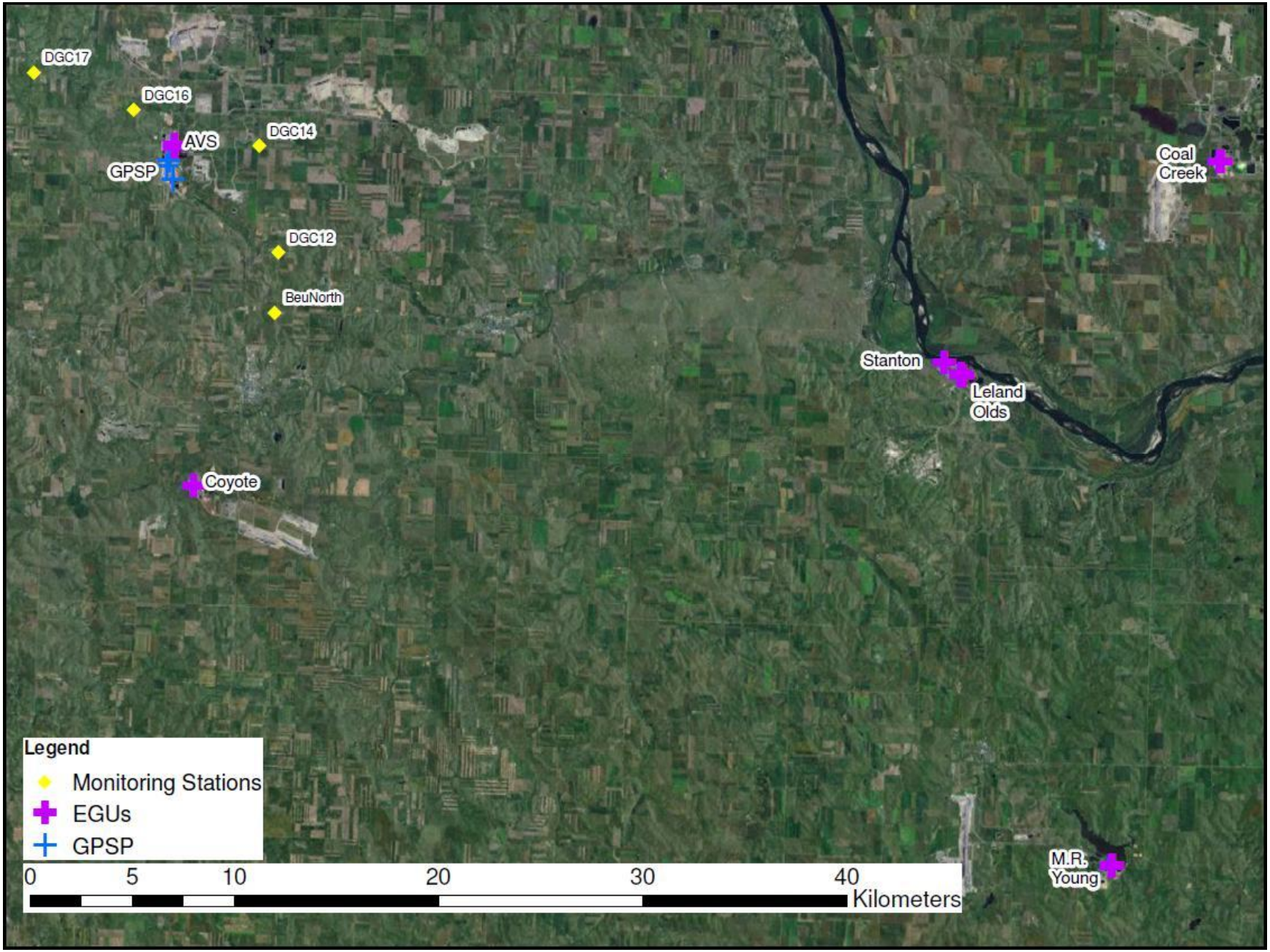
- 99th percentile peak daily 1-hr max, averaged over all years modeled
- Quantile-quantile (Q-Q) plots for each monitor (plotted pairs of ranked values) – not shown here due to time constraints
- Review of meteorological conditions associated with peak predictions and observations

Terrain Near SO_2 Monitors Used in the North Dakota Study

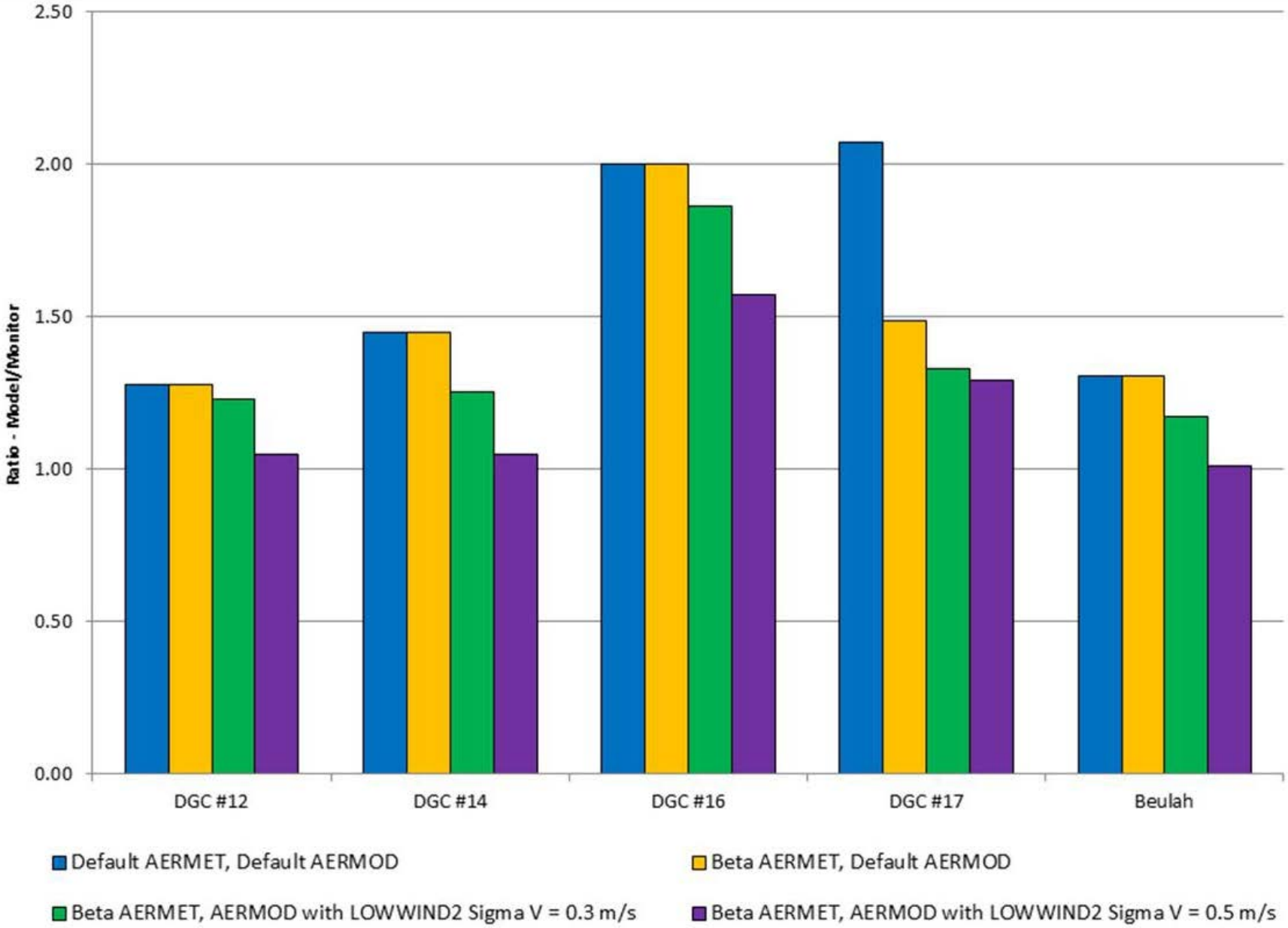
Contour interval is 10 m



North Dakota Sources Modeled Within ~50 km



Design Concentration Results for North Dakota



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

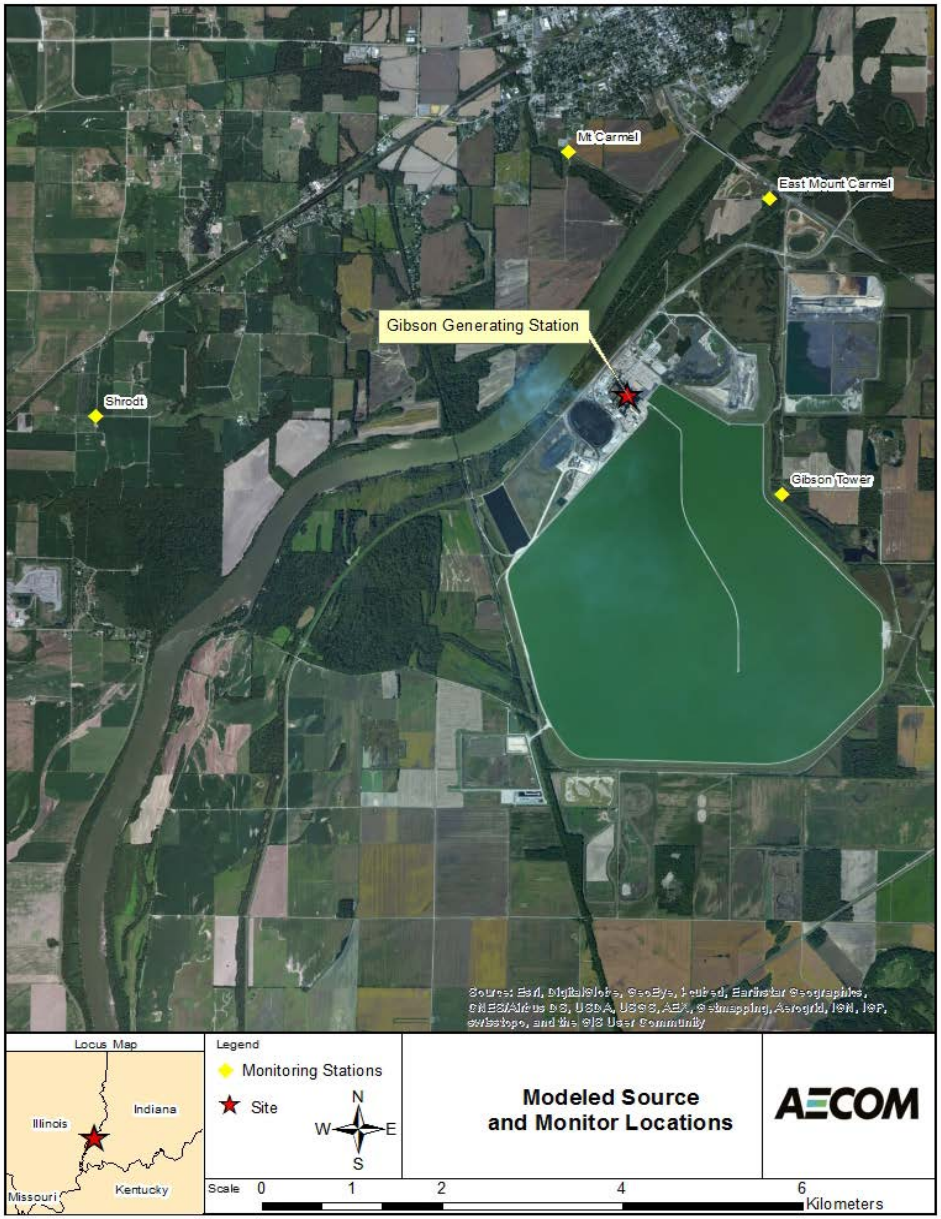
Comparison of Meteorological Conditions for Peak Observed and Modeled Impacts

- 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

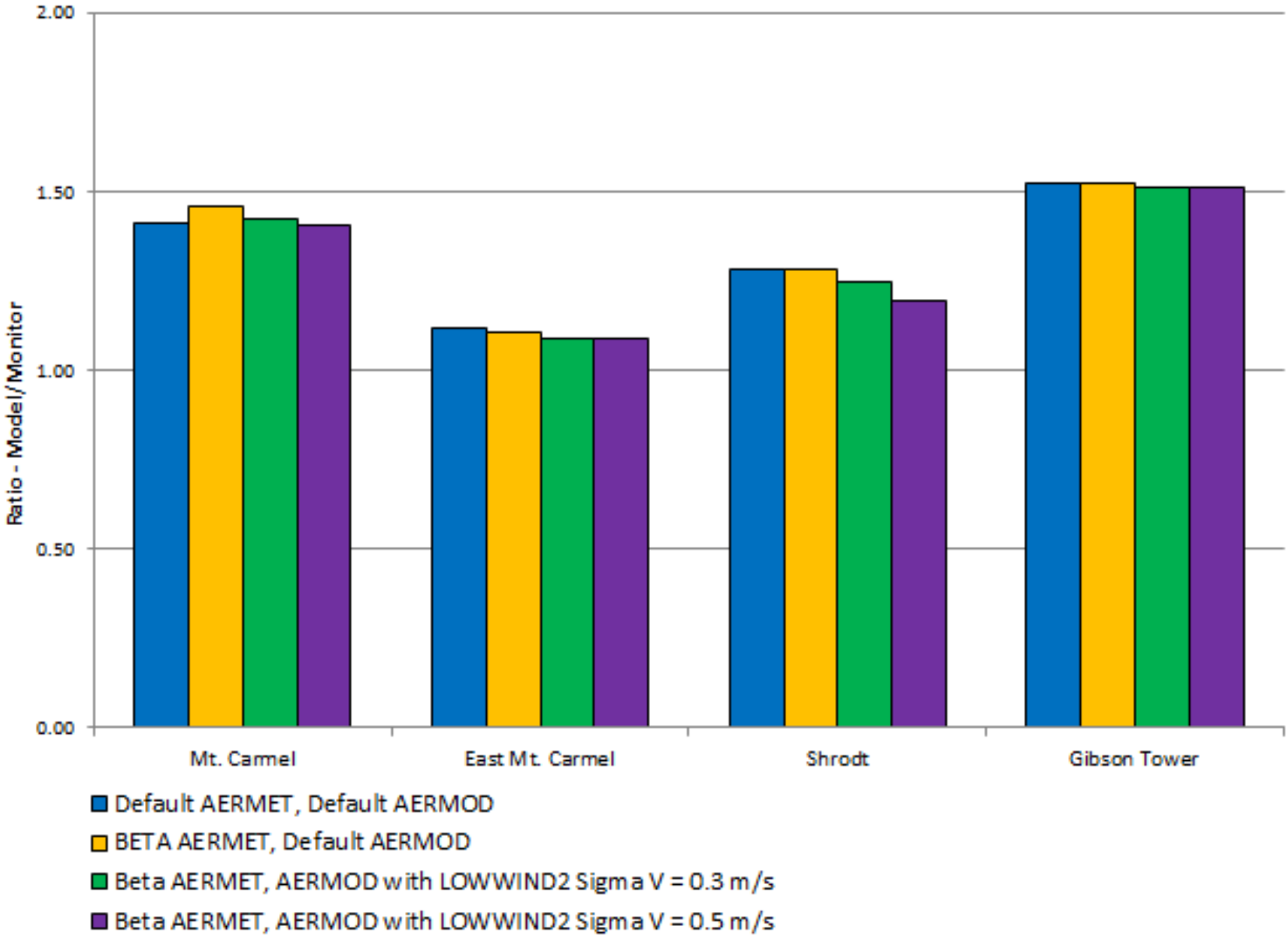
Overall Evaluation Results: North Dakota Database

- 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



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.