Model Evaluation of AERMOD at a Monitoring Network in North Dakota

Bob Paine, AECOM

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Outline of Presentation

- Motivation of the study
- Database description
- Modeling results using EPA-proposed approach for 1-hour SO_2 NAAQS compliance
- Results from refinements in modeling approach
- Problem with low-wind stable conditions
- Conclusions

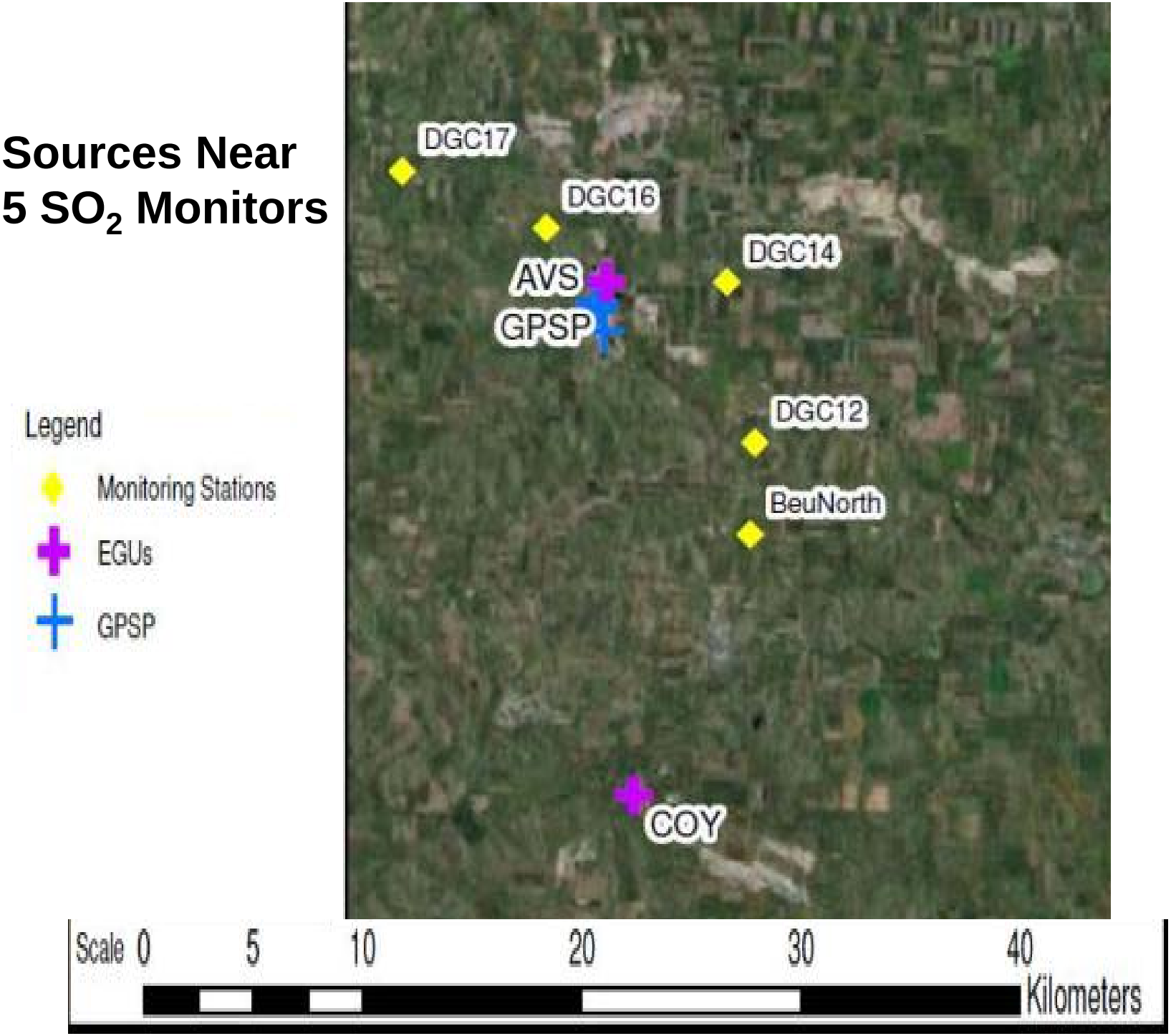
Motivation for the Study

- AERMOD evaluations focused upon single sources
- Actual hourly emissions were evaluated
- Background concentrations were not considered
- Typical AERMOD applications use allowable emissions and multiple sources
- EPA proposal to replace monitoring with modeling should replicate monitoring data where available

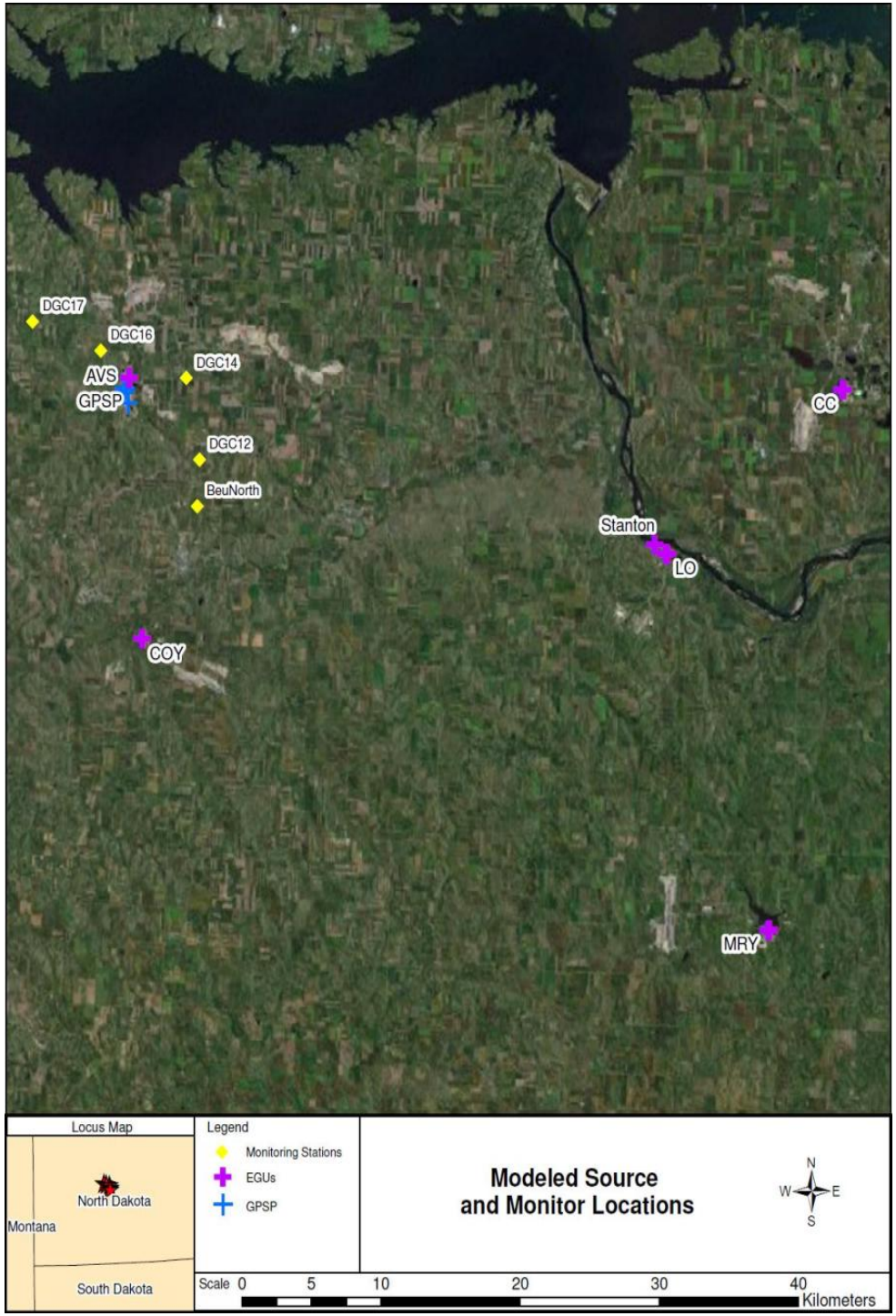
Evaluation Opportunity in North Dakota

- Electrical generating unit sources dominate SO_2 emissions – have hourly data
- Five SO_2 monitors in area within about 10 km of two nearby "central" sources: Antelope Valley Station and Great Plains Synfuels Plant
- Site-specific PSD quality meteorological data years were available (10-m tower)
- Major SO_2 sources within 50 km were modeled
- Five recent years of data were used

Sources Near 5 SO_2 Monitors



All Sources Modeled out to 50 km

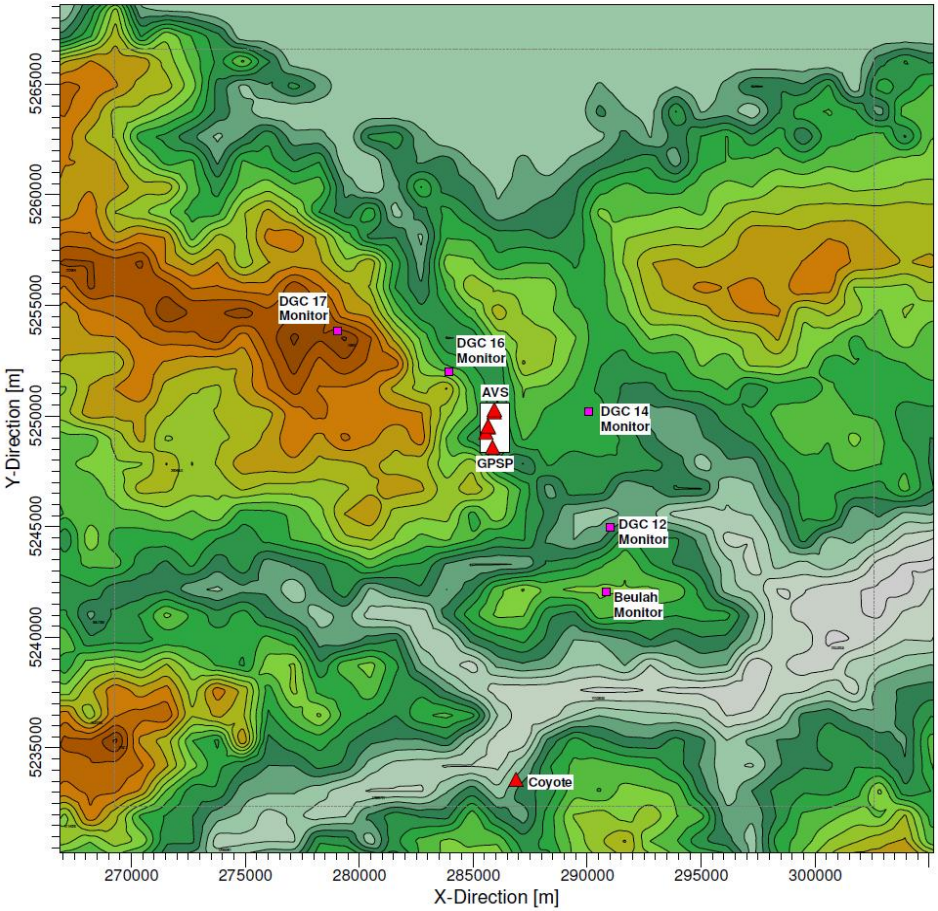


Initial Modeling Done Using EPA Guidance

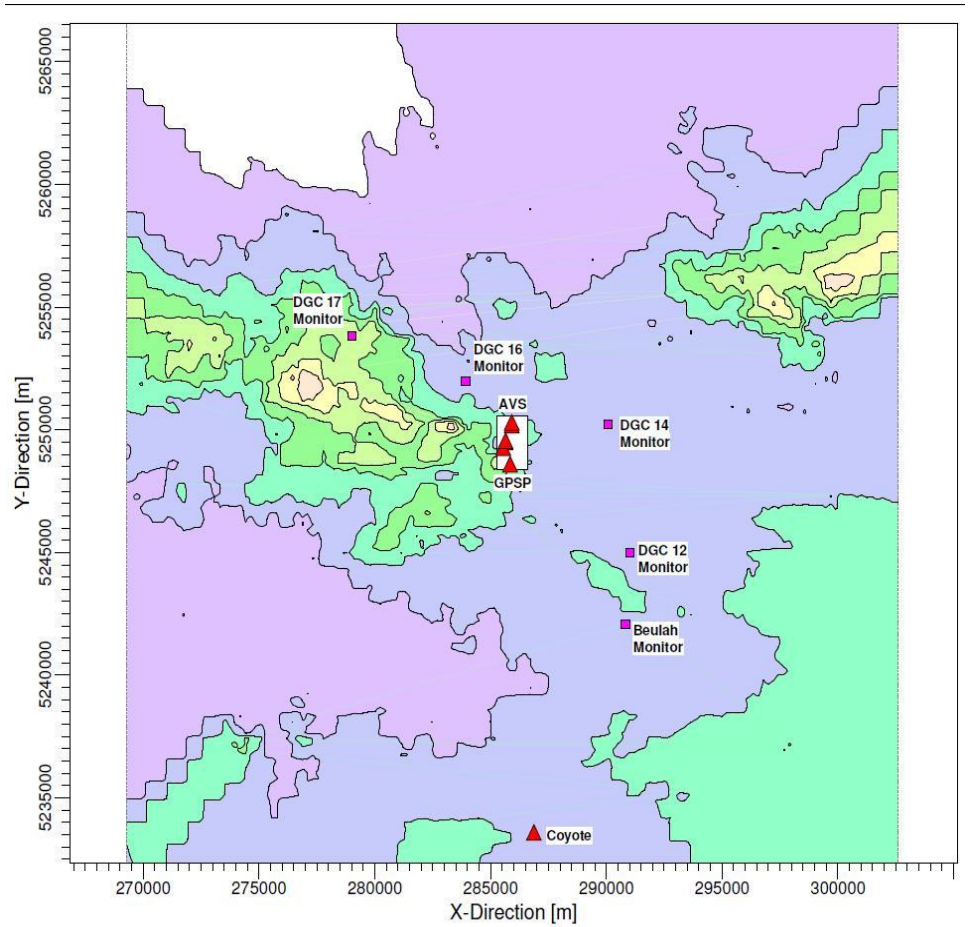
- Allowable emissions used for all sources, assumed to be constantly at peak rates
- Receptors placed at monitor sites only, using actual terrain (even though slopes are < 2%), except to characterize the spatial concentration pattern
- Four of the five monitors were at elevations near local stack base, a fifth monitor was about 100 m higher

AERMOD Concentration vs. Terrain Pattern

Terrain Pattern



AERMOD Concentration Pattern



Initial AERMOD Evaluation Results

Monitor	Elev. (m)	Observed Monitor Values: 5-yr Avg 99th Percentile Daily Max	AERMOD 5-yr Avg 4th High Daily Max w/ No Background Added (Terrain)	Ratio (Terrain)
DGC #12	593.2	93.2	227.5	2.44
DGC #14	604.0	92.0	227.7	2.48
DGC #16	629.1	88.5	215.8	2.44
DGC #17	709.8	86.9	392.8	4.52
Beulah	627.1	92.3	222.5	2.41

AERMOD Performance with Flat Terrain

Monitor	Elev. (m)	Observed Monitor Concentrations 5-yr Avg 99th Percentile Daily Max	Ratio (Flat)
DGC #12	593.2	93.2	2.49
DGC #14	604.0	92.0	2.50
DGC #16	629.1	88.5	2.39
DGC #17	709.8	86.9	2.41
Beulah	627.1	92.3	2.41

AERMOD Evaluation with Actual Hourly Emissions and Flat Terrain

Monitor	Observed Monitor Concentrations 5-yr Avg 99th Percentile Daily Max	AERMOD 5-yr Avg 4th High Daily Max w/ No Background Added (Flat)	Ratio (Flat)
DGC #12	93.2	104.4	1.12
DGC #14	92.0	104.6	1.14
DGC #16	88.5	151.8	1.72
DGC #17	86.9	107.5	1.24
Beulah	92.3	107.7	1.17

Overall Conclusions

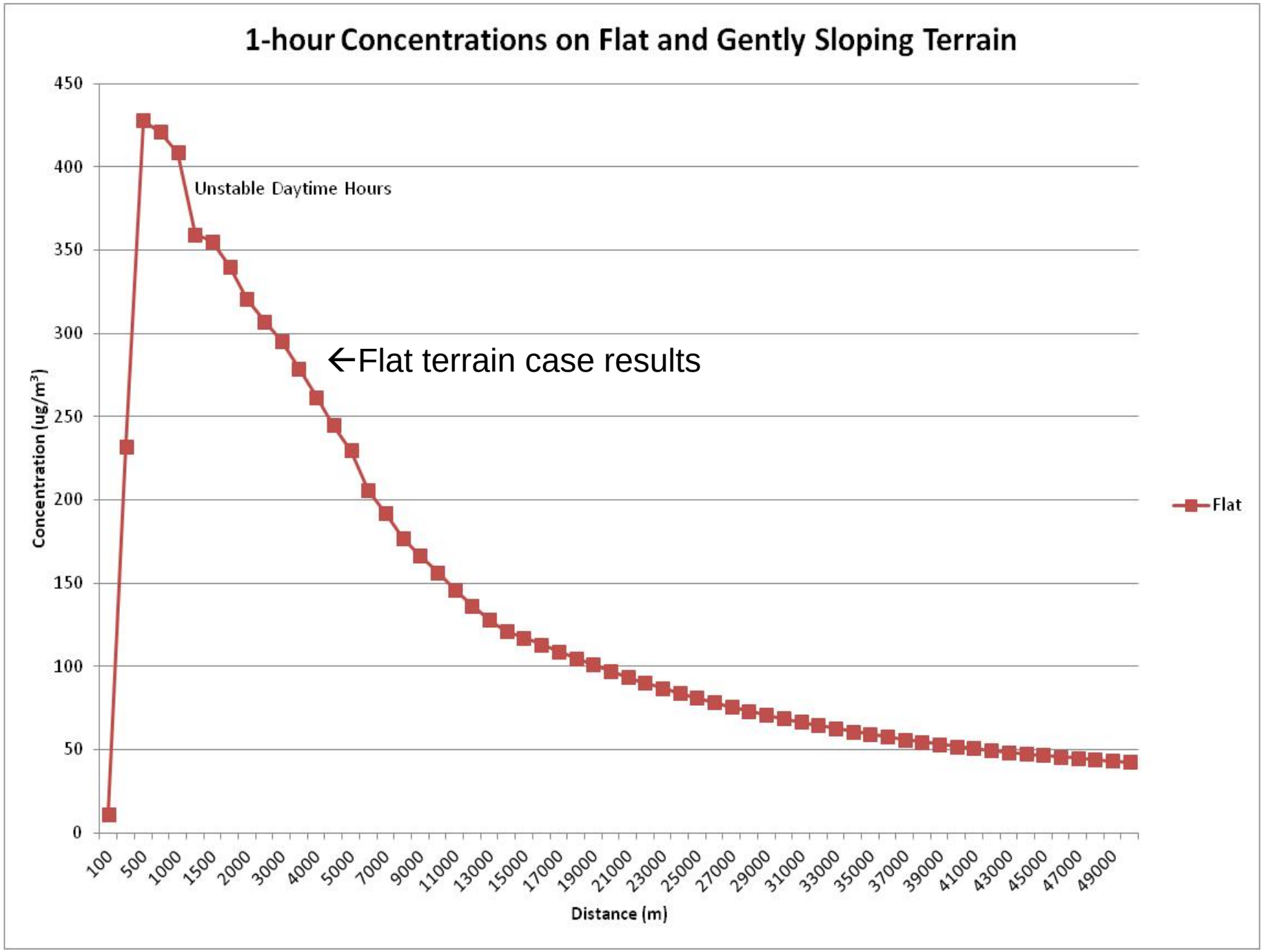
- At one monitor (#DGC 16), remaining overprediction may be associated with uncertainty of exhaust parameters during bypass stack condition at GPSP
- AERMOD performance improves with use of actual hourly emissions and flat terrain
- Since terrain slope is gentle (< 2%), use of flat terrain appears to be justified

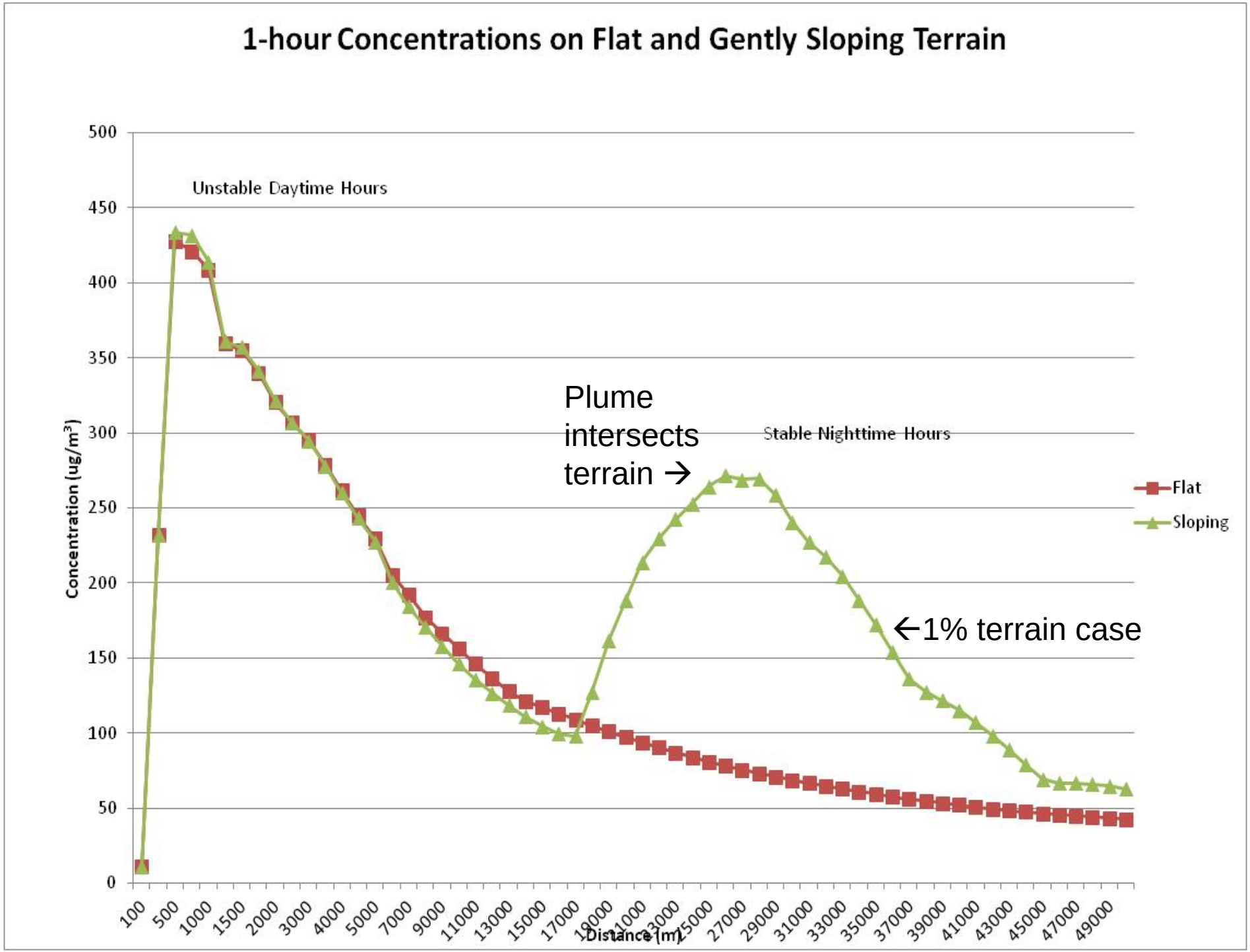
One Significant AERMOD Problem

- In very light winds, mechanical mixing height is much less than plume height
- Plume is assumed to be perfectly level, no matter how slight the slope
- Plume dispersion is very restricted
- Result is plume intersection with terrain when plume intersects terrain
- This condition is avoided with assumption of flat terrain

Test of Terrain Problem for Gentle Slope

- Used generic tall stack buoyant source
- Modeled both flat and very gentle terrain
- Terrain case was uniformly sloped upward 1% in all directions
- Modeled entire year of meteorology
- Obtained peak concentration on each ring of receptors out to 50 km
- Plots follow for flat and gently sloping terrain


1-hour Concentrations on Flat and Gently Sloping Terrain
Unstable Daytime Hours
←Flat terrain case results
Concentration (ug/m³)
450
400
350
300
250
200
150
100
50
0
100
500
1000
1500
2000
3000
4000
5000
7000
9000
11000
13000
15000
17000
19000
21000
23000
25000
27000
29000
31000
33000
35000
37000
39000
41000
43000
45000
47000
49000
Distance (m)
Flat


1-hour Concentrations on Flat and Gently Sloping Terrain
Unstable Daytime Hours
Stable Nighttime Hours
Plume intersects terrain →
←1% terrain case
Flat
Sloping
Concentration (ug/m³)
Distance (m)
0
50
100
150
200
250
300
350
400
450
500
100
500
1000
1500
2000
3000
4000
5000
7000
9000
11000
13000
15000
17000
19000
21000
23000
25000
27000
29000
31000
33000
35000
37000
39000
41000
43000
45000
47000
49000

Conclusions from Gentle Slope Test

- AERMOD has unusual prediction result for very low wind, stable conditions and low slope
- Problem is, in part, caused by very low mixing height that leads to very compact plume
- Mixing height is below building obstacles, which the model does not know about
- Plume stays perfectly level; terrain should not be considered in these cases
- With terrain, result is an unexpected plume impact "bulge" at point of terrain impact