11TH CONFERENCE ON AIR QUALITY MODELING

OPTIMIZED USE OF MMIF FOR AERMOD IN COMPLEX TERRAIN

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RAMBOLL ENVIRON

INTRODUCTION TO MMIF

NWP Models

MM5
WRF

MMIF

Dispersion Models

CALPUFF
AERMOD
SCICHEM

INTRODUCTION TO MMIF FOR AERMOD

MMIF supports AERMOD in three ways

1. WRF + MMIF + AERMOD

   "Direct" or "AERMOD Mode"

2. WRF + MMIF + AERMET + AERMOD

   "AERMET Mode"

3. WRF + MMIF + AERCOARE + AERMOD

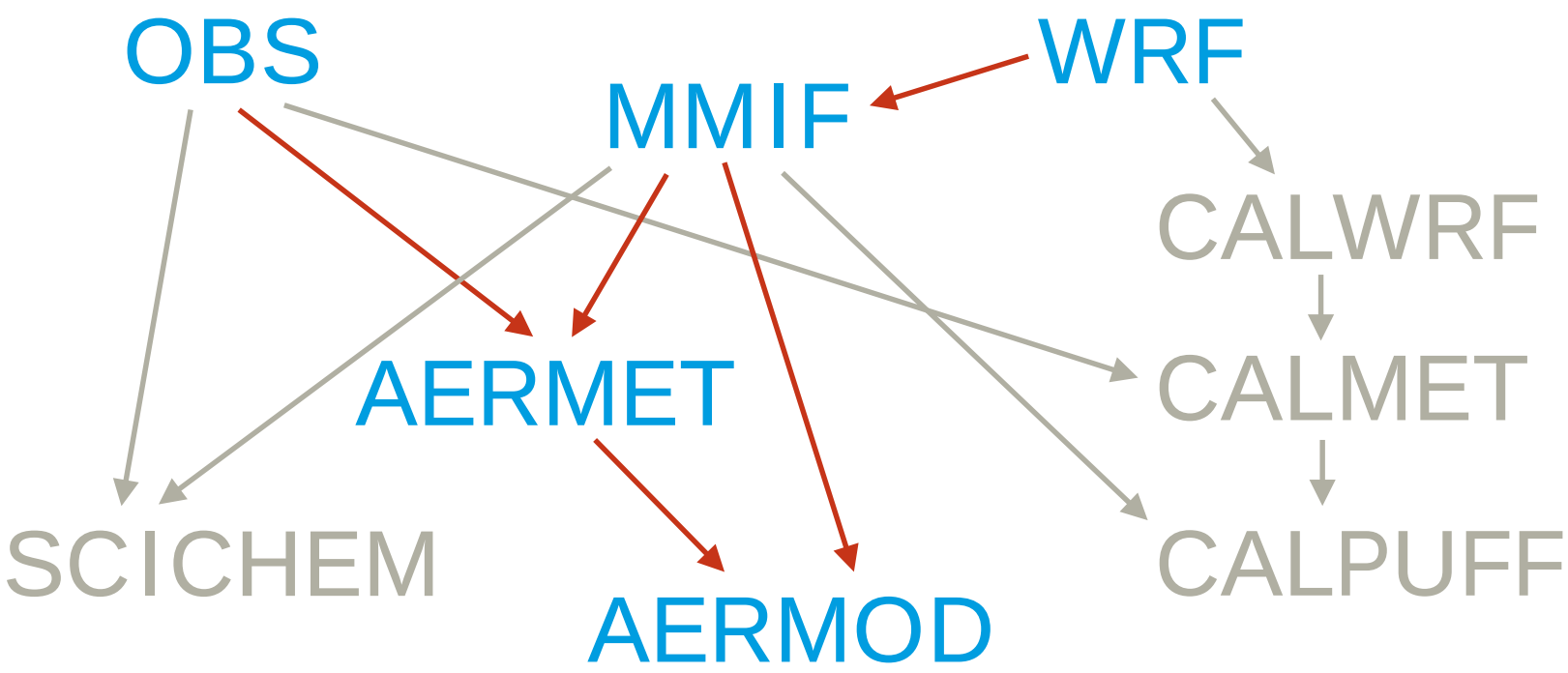
   For use over water

THE SITUATION

- The Monongahela River Valley in Allegheny County, SE of Pittsburgh
- Several sources of SO_2 in the area, mostly near the valley floor
- Liberty SO_2 monitor (on hill) measured 1-hr SO_2 NAAQS violations
- Non-attainment area (NAA) designated, SIP revision required

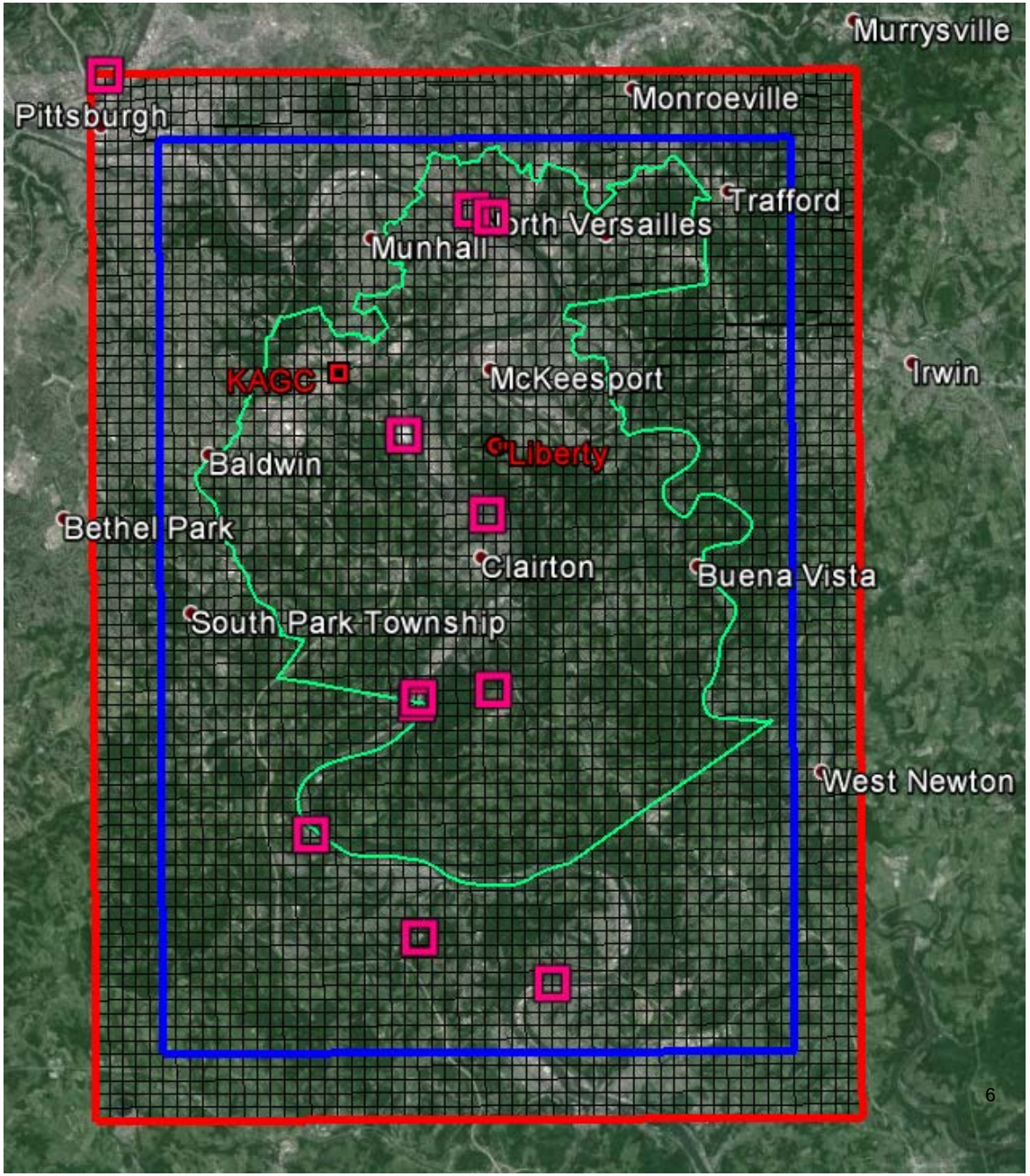
THE APPROACH – A "MODEL SHOOT-OUT"

- Test many dispersion models against SO_2 observations
  - Hope for a clear winner



WRF DOMAIN

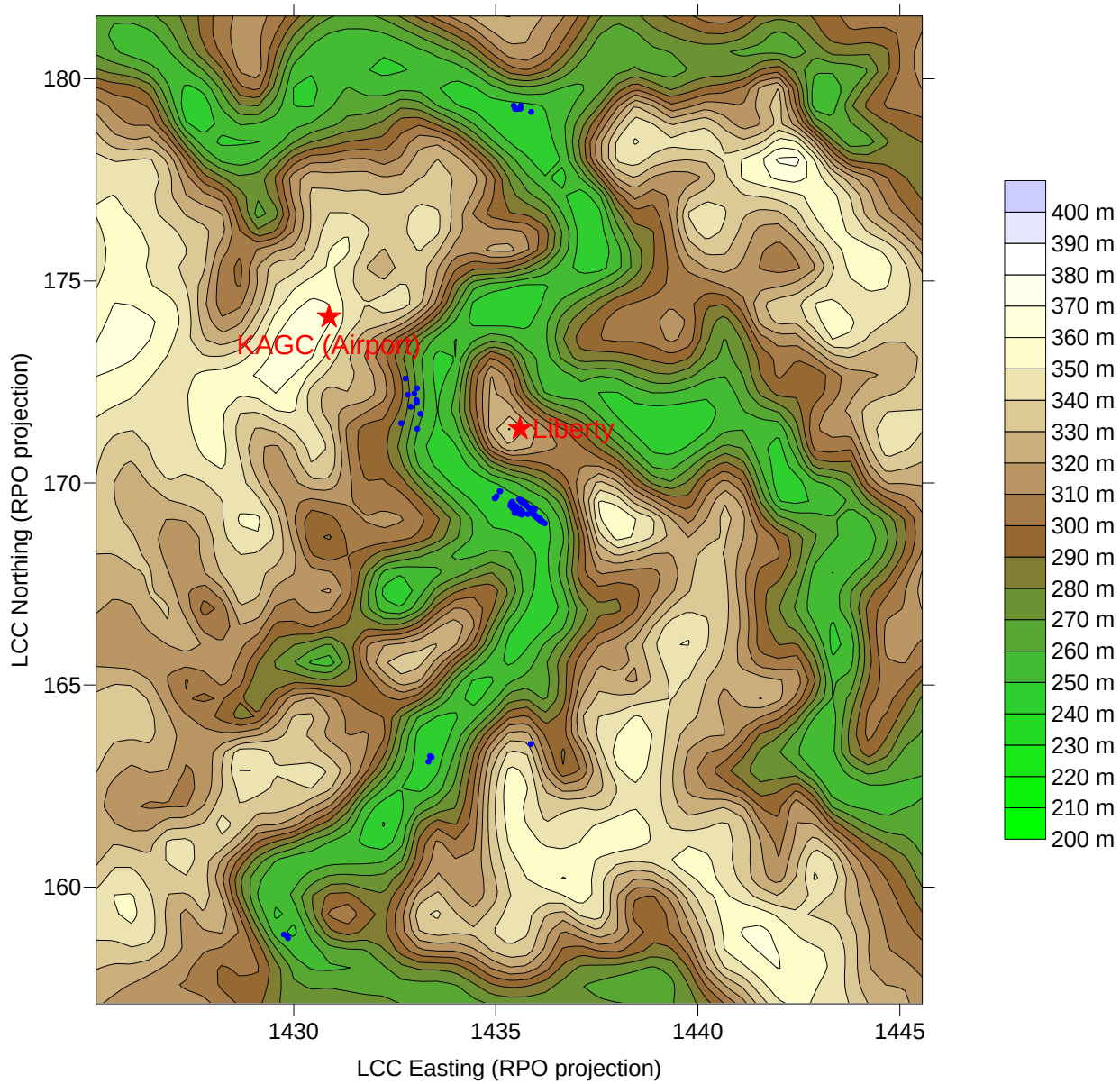
- Five nested domains: 36, 12, 4, 1.333 and 0.444 km spacing
- Useable domain spans NAA plus some Sources outside NAA
- One year used for Model Shoot-Out
- Three-year WRF production run



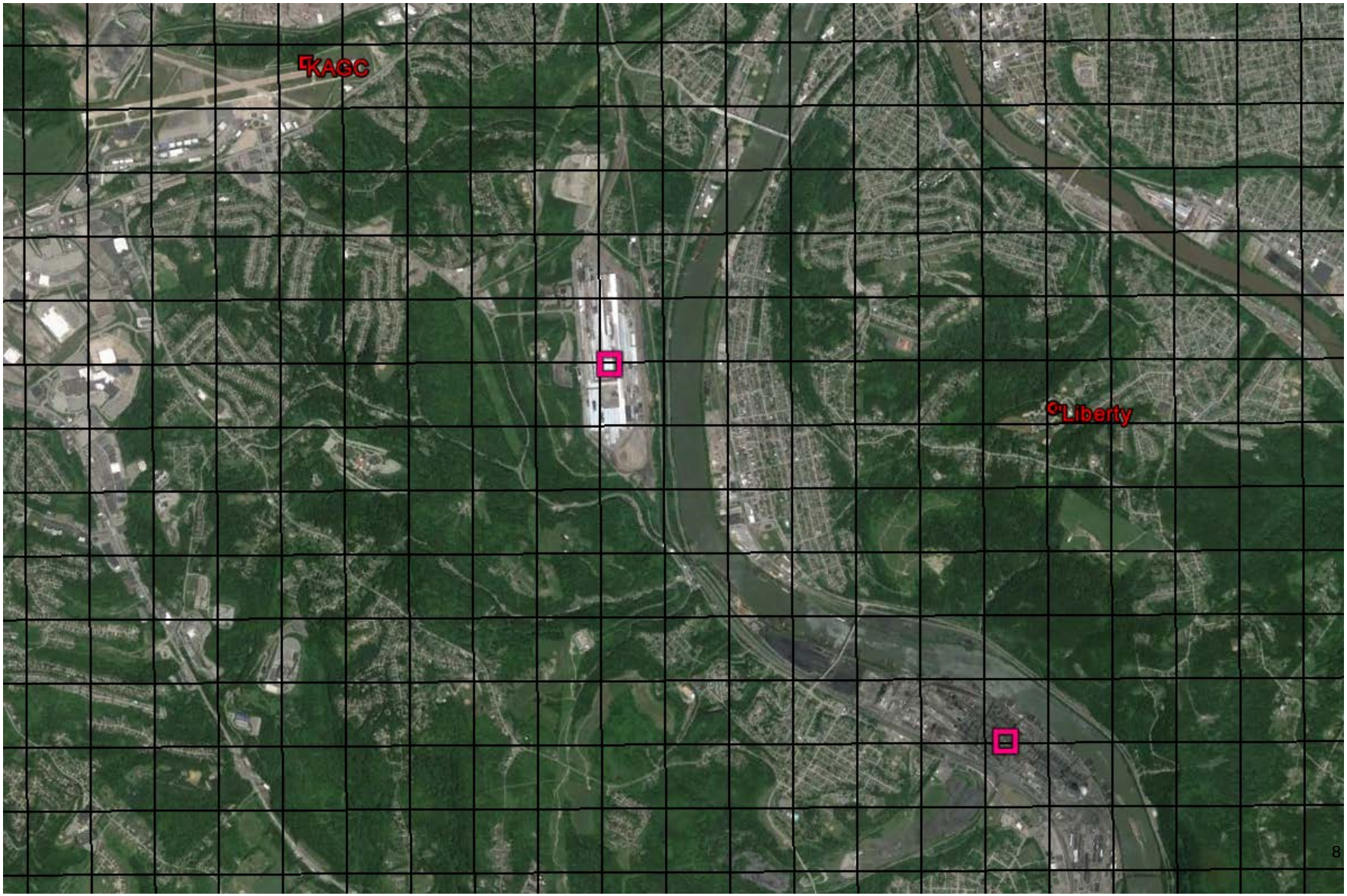
RAMBOLL ENVIRON

444m WRF TERRAIN

- WRF terrain is smoothed for numerical stability reasons
- Approximately 130m difference between valley floor and Liberty site



TWO MET SITES, TWO SOURCES, & 444m GRID



KEY FEATURES OF THE APPROACH

- Receptors at SO_2 Site, plus rings at 100, 200… 500m
- One MMIF extraction point and AERMOD run for each facility
  - Run MMIF
    - Optionally run AERMET
  - Run AERMOD
    - Output to POSTFILEs
  - Sum POSTFILEs, perform Cox-Tikvart-style statistics
    - Hourly and Max-Daily statistics

Sensitivity Runs:

- How tall a MET "tower"?
  - Emulate a 10m tower
    - Not much in each PFL file
  - Emulate a tall multi-level tower
    - 10 levels: FLM CALPUFF levels
    - 17 levels: WRF levels to 250m
    - Not (yet) MMIF Guidance levels
- WRF domain resolution
  - 4km, 1.3km, or 444m
- WRF vs. re-diagnosed PBL

COLOR-CODED STATISTICAL PERFORMANCE

Observations	OBS	257	5																243		
CALPUFF_CALMET	Liberty	211	1	-0.85	0.13	0.66	44.96	0.78	27.66	1.16	-16.21	0.49	-0.26	-0.39	1.49	15.49	3.21	0.72	4.70	115	0.30	0.49
CALPUFF_CALMET	Mean	140	0	-0.87	0.14	0.67	46.17	0.79	28.03	1.03	-21.42	0.29	-0.36	-0.51	1.29	13.85	2.81	0.64	4.58	79	0.30	0.45
CALPUFF_CALMET	95th	269	1	-0.78	0.17	0.67	42.71	0.75	27.92	1.77	-0.70	1.37	0.15	-0.02	2.37	25.54	3.36	1.18	4.33	156	0.31	0.51
CALPUFF_CALMET	Max	333	4	-0.77	0.17	0.79	48.99	0.78	32.89	2.28	12.03	1.99	0.34	0.29	2.99	32.26	3.59	1.49	5.15	233	0.32	0.48
CALPUFF_Base	Liberty	118	0	-0.85	0.19	0.67	45.90	0.80	27.93	0.80	-22.85	-0.01	-0.46	-0.55	0.99	12.14	2.97	0.56	4.55	95	0.37	0.45
CALPUFF_Base	Mean	87	0	-0.90	0.18	0.70	48.12	0.83	29.43	0.79	-25.97	-0.09	-0.53	-0.62	0.91	11.10	2.67	0.51	4.92	63	0.37	0.40
CALPUFF_Base	95th	166	0	-0.81	0.20	0.61	41.13	0.70	25.34	1.16	-11.51	0.63	-0.09	-0.27	1.63	19.14	3.21	0.88	3.56	126	0.36	0.53
CALPUFF_Base	Max	217	2	-0.79	0.21	0.65	41.92	0.71	27.07	1.52	-0.46	1.12	0.12	-0.01	2.12	24.39	3.52	1.13	3.84	196	0.36	0.54
CALPUFF_HiRes	Liberty	183	1	-0.91	0.12	0.69	47.41	0.81	28.68	0.83	-22.82	0.01	-0.46	-0.55	1.01	12.01	2.99	0.56	4.76	94	0.36	0.45
CALPUFF_HiRes	Mean	125	0	-0.91	0.14	0.71	48.44	0.84	29.77	0.80	-25.71	-0.08	-0.53	-0.61	0.92	11.07	2.70	0.51	5.04	69	0.36	0.39
CALPUFF_HiRes	95th	206	1	-0.82	0.17	0.62	42.46	0.71	25.84	1.17	-11.82	0.63	-0.10	-0.28	1.63	18.80	3.21	0.87	3.63	127	0.36	0.54
CALPUFF_HiRes	Max	254	2	-0.79	0.17	0.66	43.31	0.71	27.42	1.50	-1.57	1.09	0.10	-0.04	2.09	23.79	3.50	1.10	3.87	189	0.36	0.54
CALPUFF_BestSci	Liberty	78	0	-0.92	0.10	0.74	50.50	0.88	30.82	0.80	-28.16	-0.14	-0.61	-0.67	0.86	9.82	2.51	0.45	6.66	52	0.30	0.38
CALPUFF_BestSci	Mean	74	0	-0.92	0.09	0.76	51.59	0.92	31.81	0.80	-29.53	-0.19	-0.66	-0.71	0.81	9.22	2.36	0.43	7.47	46	0.28	0.35
CALPUFF_BestSci	95th	90	0	-0.90	0.12	0.68	47.56	0.80	28.67	0.96	-23.49	0.19	-0.37	-0.56	1.19	13.49	2.53	0.62	4.54	73	0.29	0.42
CALPUFF_BestSci	Max	99	0	-0.90	0.14	0.66	45.92	0.77	27.65	1.04	-20.73	0.36	-0.27	-0.50	1.36	15.40	2.59	0.71	4.11	89	0.29	0.48
CALPUFF_High	Liberty	232	1	-0.90	0.13	0.65	45.77	0.76	27.31	0.85	-18.43	0.13	-0.34	-0.44	1.13	13.86	3.15	0.64	4.18	138	0.37	0.49
CALPUFF_High	Mean	123	0	-0.90	0.17	0.66	45.71	0.77	27.57	0.84	-21.96	0.08	-0.40	-0.52	1.08	13.06	2.85	0.60	4.16	100	0.37	0.47
CALPUFF_High	95th	302	3	-0.76	0.21	0.67	43.85	0.70	27.84	1.51	1.57	1.12	0.13	0.04	2.12	24.59	3.59	1.14	3.75	213	0.38	0.53
CALPUFF_High	Max	520	10	-0.64	0.21	0.94	63.16	0.78	39.48	2.25	22.35	1.99	0.37	0.53	2.99	33.16	4.05	1.53	4.98	357	0.38	0.46
AERMET_AERMOD	95th	241	5	-0.66	0.22	0.75	47.07	0.74	31.58	2.12	10.45	1.85	0.36	0.25	2.85	33.79	2.85	1.56	3.58	218	0.41	0.49
AERMET_AERMOD	Max	283	14	-0.54	0.24	0.96	59.14	0.80	40.34	2.70	24.63	2.50	0.52	0.59	3.50	41.51	2.99	1.92	4.52	302	0.42	0.45
AERMET_AERMOD	Mean	119	0	-0.79	0.23	0.60	41.10	0.71	25.25	1.15	-13.80	0.60	-0.10	-0.33	1.60	19.49	2.56	0.90	2.88	107	0.41	0.50
AERMET_AERMOD	Liberty	112	0	-0.74	0.27	0.59	40.44	0.71	24.80	1.09	-14.70	0.52	-0.12	-0.35	1.52	19.05	2.57	0.88	2.86	102	0.42	0.51
MMIF_AERMET	95th	289	25	-0.91	0.10	1.37	81.62	0.94	57.39	5.34	39.03	5.08	0.55	0.93	6.08	46.29	3.35	2.14	11.45	307	0.18	0.35
MMIF_AERMET	Max	524	30	-0.91	0.09	1.94	117.91	1.03	81.31	7.12	66.10	6.92	0.73	1.58	7.92	59.66	3.51	2.76	19.17	495	0.18	0.28
MMIF_AERMET	Mean	147	0	-0.92	0.10	0.74	46.36	0.81	31.02	2.26	-4.03	1.76	0.05	-0.10	2.76	23.87	2.88	1.10	5.16	155	0.20	0.45
MMIF_AERMET	Liberty	195	2	-0.92	0.06	0.84	52.18	0.85	35.18	2.20	-1.04	1.66	0.05	-0.02	2.66	23.60	3.14	1.09	5.67	220	0.20	0.42
MMIF_AERMET_1.3km	95th	367	29	0.04	0.18	1.56	91.35	0.94	65.45	4.76	52.69	4.56	0.65	1.26	5.56	51.32	3.78	2.37	10.54	351	0.30	0.35
MMIF_AERMET_1.3km	Max	538	31	0.11	0.16	2.24	132.95	1.04	93.72	6.43	83.19	6.27	0.80	1.99	7.27	64.55	4.05	2.99	18.02	556	0.30	0.29
MMIF_AERMET_1.3km	Mean	174	0	-0.50	0.17	0.74	45.20	0.77	31.13	2.16	3.28	1.75	0.16	0.08	2.75	26.76	3.22	1.24	4.51	161	0.29	0.49
MMIF_AERMET_1.3km	Liberty	204	7	-0.75	0.15	0.87	53.06	0.80	36.40	2.57	10.09	2.16	0.20	0.24	3.16	28.14	3.54	1.30	5.36	254	0.27	0.47
MMIF_AERMET_4km	95th	109	0	-0.84	0.26	0.59	41.36	0.68	24.84	0.92	-16.37	0.32	-0.18	-0.39	1.32	17.36	2.69	0.80	2.78	99	0.45	0.56
MMIF_AERMET_4km	Max	150	0	-0.62	0.30	0.56	38.79	0.66	23.62	1.02	-11.90	0.52	-0.07	-0.28	1.52	19.83	2.79	0.92	2.68	139	0.45	0.58
MMIF_AERMET_4km	Mean	57	0	-0.89	0.26	0.68	46.88	0.80	28.49	0.76	-25.32	-0.07	-0.48	-0.60	0.93	12.01	2.42	0.56	3.82	53	0.43	0.42
MMIF_AERMET_4km	Liberty	71	0	-0.88	0.28	0.66	45.19	0.78	27.50	0.77	-23.58	-0.03	-0.44	-0.56	0.97	12.62	2.58	0.58	3.61	75	0.44	0.46
MMIF_AERMET_TOWERS	95th	301	20	-0.70	0.18	1.12	66.67	0.86	46.85	3.13	28.73	2.84	0.44	0.69	3.84	37.90	3.78	1.75	6.22	287	0.33	0.40
MMIF_AERMET_TOWERS	Max	417	28	-0.44	0.20	1.55	92.15	0.95	65.04	4.22	52.80	4.01	0.63	1.26	5.01	49.47	4.00	2.29	9.60	357	0.33	0.34
MMIF_AERMET_TOWERS	Mean	126	0	-0.86	0.16	0.66	43.00	0.77	27.79	1.40	-10.69	0.82	-0.11	-0.26	1.82	18.97	3.08	0.88	3.81	142	0.33	0.44
MMIF_AERMET_TOWERS	Liberty	208	2	-0.72	0.19	0.69	43.89	0.77	28.92	1.54	-5.25	0.98	-0.06	-0.13	1.98	20.10	3.42	0.93	4.03	193	0.33	0.46
MMIF_AERMET_TOWERS_1.3km	95th	283	17	0.11	0.29	1.12	66.56	0.85	47.01	2.77	32.98	2.51	0.44	0.79	3.51	36.39	4.29	1.68	5.75	305	0.39	0.39
MMIF_AERMET_TOWERS_1.3km	Max	388	30	0.51	0.31	1.63	94.88	0.96	68.39	3.74	57.26	3.52	0.61	1.37	4.52	46.06	4.60	2.13	8.42	406	0.39	0.32
MMIF_AERMET_TOWERS_1.3km	Mean	121	0	-0.56	0.27	0.60	39.02	0.71	25.31	1.26	-8.32	0.74	-0.09	-0.20	1.74	19.16	3.38	0.89	3.52	148	0.38	0.52
MMIF_AERMET_TOWERS_1.3km	Liberty	211	2	-0.53	0.24	0.68	42.94	0.75	28.45	1.50	-1.45	0.99	-0.03	-0.03	1.99	20.46	3.79	0.95	4.17	191	0.36	0.51
MMIF_AERMET_TOWERS_4km	95th	195	1	-0.66	0.21	0.60	41.94	0.65	25.29	0.97	-9.29	0.46	-0.10	-0.22	1.46	19.03	3.16	0.88	2.78	181	0.46	0.58
MMIF_AERMET_TOWERS_4km	Max	234	3	-0.59	0.21	0.65	44.54	0.66	27.17	1.19	-1.49	0.77	0.04	-0.04	1.77	22.58	3.33	1.04	2.79	263	0.47	0.60
MMIF_AERMET_TOWERS_4km	Mean	88	0	-0.86	0.21	0.66	46.21	0.77	27.83	0.72	-23.85	-0.08	-0.47	-0.57	0.92	12.15	2.66	0.56	3.82	79	0.43	0.44
MMIF_AERMET_TOWERS_4km	Liberty	99	0	-0.79	0.25	0.63	44.18	0.74	26.38	0.71	-21.96	-0.06	-0.43	-0.52	0.94	12.64	2.84	0.58	3.75	96	0.43	0.48
MMIF_AERMET_TOWERS_WRF_MIXHT	95th	298	18	-0.72	0.15	1.14	67.93	0.87	47.68	3.30	29.02	3.01	0.45	0.69	4.01	38.76	3.71	1.79	6.64	304	0.31	0.41
MMIF_AERMET_TOWERS_WRF_MIXHT	Max	408	28	-0.50	0.17	1.57	93.24	0.95	65.92	4.39	52.92	4.18	0.64	1.26	5.18	50.60	3.92	2.34	10.28	386	0.31	0.37
MMIF_AERMET_TOWERS_WRF_MIXHT	Mean	128	0	-0.86	0.13	0.68	44.05	0.78	28.41	1.51	-9.98	0.94	-0.09	-0.24	1.94	19.46	3.07	0.90	4.03	148	0.30	0.44
MMIF_AERMET_TOWERS_WRF_MIXHT	Liberty	195	2	-0.74	0.14	0.72	45.48	0.78	29.96	1.67	-5.24	1.12	-0.05	-0.13	2.12	20.40	3.40	0.94	4.30	190	0.31	0.45
MMIF_AERMET_TOWERS_AER_MIXHT	95th	320	19	-0.76	0.16	1.08	67.10	0.84	45.17	2.94	25.14	2.63	0.40	0.60	3.63	35.95	3.67	1.66	5.74	359	0.32	0.42
MMIF_AERMET_TOWERS_AER_MIXHT	Max	421	28	-0.59	0.17	1.47	90.87	0.92	61.66	3.97	47.67	3.75	0.60	1.14	4.75	46.85	3.89	2.17	8.51	407	0.33	0.37
MMIF_AERMET_TOWERS_AER_MIXHT	Mean	131	0	-0.87	0.14	0.67	43.91	0.77	28.11	1.40	-11.40	0.80	-0.13	-0.27	1.80	18.55	3.04	0.86	3.88	145	0.32	0.45
MMIF_AERMET_TOWERS_AER_MIXHT	Liberty	198	1	-0.78	0.16	0.69	45.37	0.77	29.03	1.56	-6.91	0.99	-0.09	-0.17	1.99	19.34	3.34	0.89	4.07	212	0.32	0.47
MMIF_AERMOD	95th	301	24	-0.66	0.12	1.38	80.80	0.93	57.58	5.57	41.47	5.34	0.59	0.99	6.34	48.91	3.31	2.26	11.58	316	0.20	0.37
MMIF_AERMOD	Max	491	31	-0.59	0.11	2.04	122.62	1.04	85.23	7.73	72.91	7.54	0.78	1.74	8.54	64.06	3.53	2.96	21.02	496	0.20	0.28
MMIF_AERMOD	Mean	131	0	-0.92	0.11	0.73	45.23	0.79	30.57	2.33	-3.82	1.85	0.07	-0.09	2.85	24.54	2.83	1.13	5.00	134	0.20	0.47
MMIF_AERMOD	Liberty	188	1	-0.92	0.07	0.82	50.63	0.83	34.28	2.26	-0.19	1.76	0.08	0.00	2.76	24.82	3.07	1.15	5.37	209	0.21	0.45
MMIF_AERMOD_1.3km	95th	351	27	-0.26	0.16	1.61	92.84	0.95	67.44	5.21	55.31	5.03	0.68	1.32	6.03	54.08	3.73	2.50	11.60	355	0.29	0.36
MMIF_AERMOD_1.3km	Max	494	31	0.26	0.16	2.37	138.36	1.05	99.40	7.21	90.13	7.07	0.84	2.15	8.07	69.32	4.03	3.21	21.40	545	0.29	0.28
MMIF_AERMOD_1.3km	Mean	152	0	-0.60	0.17	0.74	44.66	0.75	30.94	2.38	4.04	1.99	0.19	0.10	2.99	28.00	3.16	1.29	4.53	150	0.29	0.49
MMIF_AERMOD_1.3km	Liberty	200	6	-0.81	0.16	0.85	51.56	0.78	35.53	2.68	9.99	2.29	0.21	0.24	3.29	28.88	3.46	1.34	5.26	237	0.27	0.47
MMIF_AERMOD_4km	95th	102	0	-0.81	0.29	0.57	39.64	0.65	23.85	0.92	-13.47	0.39	-0.12	-0.32	1.39	19.03	2.78	0.88	2.40	104	0.52	0.58
MMIF_AERMOD_4km	Max	126	0	-0.64	0.33	0.55	37.33	0.63	23.02	1.00	-9.93	0.54	-0.02	-0.24	1.54	21.22	2.83	0.98	2.32	129	0.52	0.59
MMIF_AERMOD_4km	Mean	69	0	-0.86	0.26	0.63	44.22	0.74	26.58	0.79	-21.53	0.04	-0.37	-0.51	1.04	13.96	2.63	0.65	3.00	68	0.48	0.49
MMIF_AERMOD_4km	Liberty	72	0	-0.84	0.29	0.62	43.02	0.73	25.85	0.78	-20.43	0.06	-0.35	-0.49	1.06	14.27	2.74	0.66	2.93	74	0.49	0.51
MMIF_AERMOD_TOWERS	95th	235	7	-0.70	0.22	0.89	52.80	0.81	37.32	2.51	17.04	2.18	0.32	0.41	3.18	32.38	3.67	1.50	4.92	253	0.34	0.44
MMIF_AERMOD_TOWERS	Max	335	24	-0.43	0.24	1.27	75.03	0.88	53.01	3.50	39.71	3.27	0.54	0.95	4.27	42.76	3.95	1.98	7.17	320	0.34	0.39
MMIF_AERMOD_TOWERS	Mean	111	0	-0.86	0.19	0.64	42.78	0.77	26.80	1.16	-15.94	0.50	-0.23	-0.38	1.50	16.36	2.95	0.76	3.77	106	0.34	0.45
MMIF_AERMOD_TOWERS	Liberty	200	1	-0.72	0.24	0.64	41.10	0.77	26.73	1.22	-10.76	0.60	-0.18	-0.26	1.60	17.42	3.31	0.81	3.84	175	0.35	0.46
MMIF_AERMOD_TOWERS_1.3km	95th	237	5	-0.66	0.27	0.91	54.05	0.81	38.08	2.35	20.07	2.03	0.31	0.48	3.03	31.12	4.05	1.44	4.94	237	0.37	0.46
MMIF_AERMOD_TOWERS_1.3km	Max	349	25	-0.55	0.28	1.31	76.92	0.90	54.96	3.17	40.51	2.90	0.48	0.97	3.90	39.07	4.38	1.81	6.77	284	0.37	0.35
MMIF_AERMOD_TOWERS_1.3km	Mean	96	0	-0.85	0.27	0.60	40.19	0.72	25.16	1.13	-14.02	0.52	-0.20	-0.34	1.52	16.72	3.16	0.77	3.61	95	0.37	0.52
MMIF_AERMOD_TOWERS_1.3km	Liberty	167	0	-0.85	0.21	0.66	42.86	0.75	27.48	1.33	-7.55	0.75	-0.14	-0.18	1.75	18.02	3.55	0.83	4.11	179	0.35	0.50
MMIF_AERMOD_TOWERS_4km	95th	125	0	-0.85	0.32	0.59	41.38	0.68	24.61	0.73	-19.30	0.06	-0.33	-0.46	1.06	14.54	2.81	0.67	2.84	124	0.50	0.57
MMIF_AERMOD_TOWERS_4km	Max	161	0	-0.58	0.36	0.56	38.48	0.64	23.41	0.80	-15.33	0.21	-0.22	-0.37	1.21	16.61	2.90	0.77	2.57	178	0.51	0.59
MMIF_AERMOD_TOWERS_4km	Mean	56	0	-0.92	0.29	0.69	47.53	0.82	28.90	0.67	-26.99	-0.25	-0.60	-0.64	0.75	10.31	2.55	0.48	4.35	64	0.48	0.41
MMIF_AERMOD_TOWERS_4km	Liberty	81	0	-0.89	0.31	0.66	45.95	0.79	27.79	0.66	-25.71	-0.23	-0.58	-0.61	0.77	10.63	2.70	0.49	4.22	80	0.47	0.46
MMIF_AERMOD_TOWERS_LOWWIND2	95th	235	7	-0.70	0.22	0.89	52.80	0.81	37.32	2.51	17.04	2.18	0.32	0.41	3.18	32.38	3.67	1.50	4.92	253	0.34	0.44
MMIF_AERMOD_TOWERS_LOWWIND2	Max	335	24	-0.43	0.24	1.27	75.03	0.88	53.01	3.50	39.71	3.27	0.54	0.95	4.27	42.76	3.95	1.98	7.17	320	0.34	0.39
MMIF_AERMOD_TOWERS_LOWWIND2	Mean	111	0	-0.86	0.19	0.64	42.78	0.77	26.80	1.16	-15.94	0.50	-0.23	-0.38	1.50	16.36	2.95	0.76	3.77	106	0.34	0.45
MMIF_AERMOD_TOWERS_LOWWIND2	Liberty	200	1	-0.72	0.24	0.64	41.10	0.77	26.73	1.22	-10.76	0.60	-0.18	-0.26	1.60	17.42	3.31	0.81	3.84	175	0.35	0.46
MMIF_AERMOD_TOWERS_D05_no5m	95th	204	7	-0.68	0.24	0.89	52.67	0.81	37.34	2.46	18.47	2.15	0.35	0.44	3.15	33.39	3.65	1.54	4.96	237	0.35	0.44
MMIF_AERMOD_TOWERS_D05_no5m	Max	296	28	-0.44	0.26	1.27	74.26	0.90	53.17	3.43	40.57	3.20	0.56	0.97	4.20	43.74	3.91	2.02	7.31	296	0.35	0.39
MMIF_AERMOD_TOWERS_D05_no5m	Mean	100	0	-0.85	0.18	0.64	43.01	0.77	26.78	1.14	-15.88	0.48	-0.22	-0.38	1.48	16.58	2.93	0.77	3.71	99	0.34	0.44
MMIF_AERMOD_TOWERS_D05_no5m	Liberty	162	0	-0.71	0.23	0.64	41.21	0.78	26.98	1.22	-10.18	0.60	-0.16	-0.24	1.60	17.79	3.31	0.82	3.84	163	0.35	0.45
MMIF_AERMOD_TOWERS_AER_layers_1	95th	211	5	-0.55	0.25	0.88	51.95	0.80	36.71	2.48	17.78	2.17	0.33	0.42	3.17	32.86	3.66	1.52	4.97	234	0.34	0.46
MMIF_AERMOD_TOWERS_AER_layers_1	Max	296	28	-0.07	0.28	1.26	74.08	0.89	52.71	3.54	40.61	3.31	0.55	0.97	4.31	43.52	3.94	2.01	7.47	296	0.34	0.39
MMIF_AERMOD_TOWERS_AER_layers_1	Mean	101	0	-0.81	0.18	0.65	43.11	0.78	27.05	1.16	-16.22	0.49	-0.23	-0.39	1.49	16.34	2.93	0.76	3.80	101	0.34	0.44
MMIF_AERMOD_TOWERS_AER_layers_1	Liberty	140	0	-0.62	0.24	0.64	40.95	0.77	26.85	1.23	-10.33	0.61	-0.17	-0.25	1.61	17.66	3.33	0.82	3.85	156	0.35	0.46
MMIF_AERMOD_TOWERS_LOWWIND1	95th	235	7	-0.70	0.22	0.89	52.80	0.81	37.32	2.51	17.04	2.18	0.32	0.41	3.18	32.38	3.67	1.50	4.92	253	0.34	0.44
MMIF_AERMOD_TOWERS_LOWWIND1	Max	335	24	-0.43	0.24	1.27	75.03	0.88	53.01	3.50	39.71	3.27	0.54	0.95	4.27	42.76	3.95	1.98	7.17	320	0.34	0.39
MMIF_AERMOD_TOWERS_LOWWIND1	Mean	111	0	-0.86	0.19	0.64	42.78	0.77	26.80	1.16	-15.94	0.50	-0.23	-0.38	1.50	16.36	2.95	0.76	3.77	106	0.34	0.45
MMIF_AERMOD_TOWERS_LOWWIND1	Liberty	200	1	-0.72	0.24	0.64	41.10	0.77	26.73	1.22	-10.76	0.60	-0.18	-0.26	1.60	17.42	3.31	0.81	3.84	175	0.35	0.46
MMIF_AERMOD_TOWERS_AER_layers_1	95th	198	2	-0.79	0.19	0.80	48.87	0.77	33.50	2.38	11.43	2.05	0.29	0.27	3.05	31.17	3.36	1.44	4.50	219	0.33	0.48
MMIF_AERMOD_TOWERS_AER_layers_1	Max	277	22	-0.74	0.21	1.12	66.88	0.85	46.71	3.30	31.19	3.06	0.49	0.75	4.06	40.53	3.64	1.87	6.38	272	0.33	0.43
MMIF_AERMOD_TOWERS_AER_layers_1	Mean	87	0	-0.91	0.15	0.65	43.94	0.77	27.20	1.26	-16.38	0.61	-0.21	-0.39	1.61	16.86	2.77	0.78	3.72	102	0.33	0.44
MMIF_AERMOD_TOWERS_AER_layers_1	Liberty	134	0	-0.92	0.20	0.63	42.16	0.76	26.56	1.28	-12.53	0.66	-0.17	-0.30	1.66	17.74	3.02	0.82	3.64	153	0.35	0.46
MMIF_AERMOD_TOWERS_aerminSpeed	95th	301	25	-0.66	0.11	1.45	84.52	0.95	60.74	6.13	46.46	5.94	0.67	1.11	6.94	55.32	3.08	2.56	13.14	322	0.20	0.36
MMIF_AERMOD_TOWERS_aerminSpeed	Max	491	31	-0.59	0.10	2.13	126.86	1.06	89.03	8.39	78.26	8.24	0.84	1.87	9.24	71.40	3.28	3.30	24.25	518	0.20	0.27
MMIF_AERMOD_TOWERS_aerminSpeed	Mean	131	0	-0.92	0.10	0.75	45.48	0.79	31.29	2.63	-1.11	2.19	0.16	-0.03	3.19	27.96	2.66	1.29	5.07	135	0.20	0.46
MMIF_AERMOD_TOWERS_aerminSpeed	Liberty	188	1	-0.92	0.07	0.82	50.38	0.83	34.49	2.44	1.50	1.99	0.16	0.04	2.99	27.61	2.86	1.28	5.20	209	0.21	0.44
MMIF_AERMOD_TOWERS_WRF_MIXHT	95th	221	3	-0.72	0.20	0.87	51.22	0.80	36.48	2.50	15.36	2.17	0.32	0.37	3.17	32.21	3.59	1.49	4.93	232	0.33	0.46
MMIF_AERMOD_TOWERS_WRF_MIXHT	Max	309	20	-0.50	0.23	1.22	71.32	0.87	50.90	3.43	36.99	3.21	0.54	0.88	4.21	42.70	3.84	1.97	7.02	309	0.34	0.42
MMIF_AERMOD_TOWERS_WRF_MIXHT	Mean	107	0	-0.86	0.17	0.65	43.46	0.78	27.15	1.20	-16.63	0.53	-0.24	-0.40	1.53	16.15	2.91	0.75	3.94	104	0.32	0.43
MMIF_AERMOD_TOWERS_WRF_MIXHT	Liberty	185	1	-0.74	0.20	0.65	42.22	0.77	27.10	1.33	-12.26	0.71	-0.19	-0.29	1.71	17.20	3.21	0.80	4.15	156	0.32	0.45

RAMBOLL ENVIRON

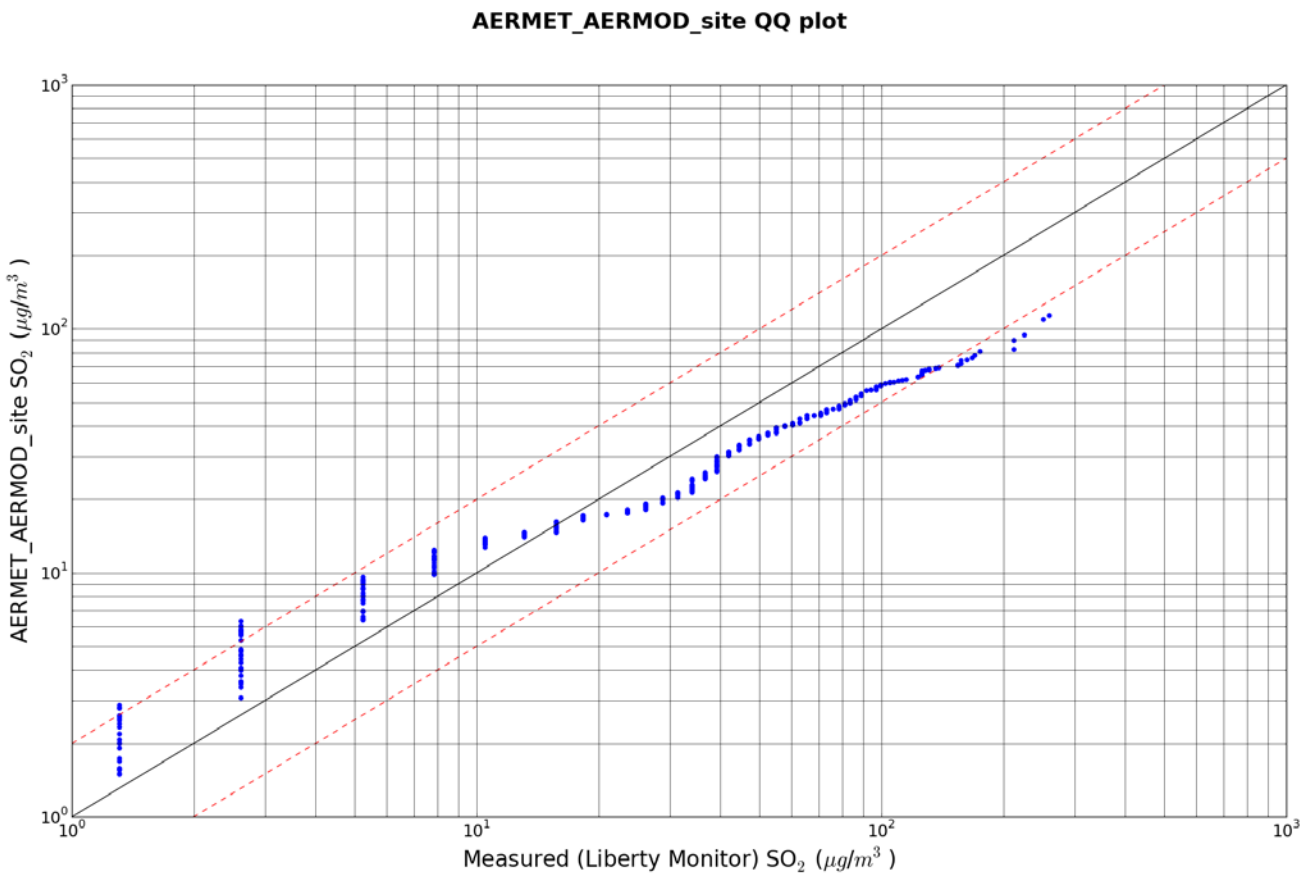
SELECTED STATISTICS – MAX DAILY VALUES AT LIBERTY SITE (ug/m³)

Model	Rec	99th Percentile	Num NAAQS Exceedences	Accuracy of paired peak	Coefficient of determination	Normalized Mean Error	Root Mean Square Error	Fractional Gross Error	Mean Absolute Gross Error	Mean Normalized Gross Error	Mean Bias	Mean Normalized Bias
		2										
Observations	OBS	**257**	**5**									
AERMET_AERMOD	Liberty	112	0	-0.74	0.27	0.59	40.44	0.71	24.80	1.09	-14.70	0.52
MMIF_AERMET_10m	Liberty	195	2	-0.92	0.06	0.84	52.18	0.85	35.18	2.20	-1.04	1.66
MMIF_AERMET_TOWERS	Liberty	208	2	-0.72	0.19	0.69	43.89	0.77	28.92	1.54	-5.25	0.98
MMIF_AERMOD_10m	Liberty	188	1	-0.92	0.07	0.82	50.63	0.83	34.28	2.26	-0.19	1.76
MMIF_AERMOD_TOWERS	Liberty	200	1	-0.72	0.24	0.64	41.10	0.77	26.73	1.22	-10.76	0.60

Model	Rec	Mean Fractional Bias	Normalized Mean Bias	Bias Factor	Geometric Mean	Geometric Standard Deviation	Geometric Mean Bias	Geometric Mean Variance	Robust Highest Concentration (N=26)	Geometric Correlation Coefficient	Fraction Inside Factor of Two	N
					0				2			3
Observations	OBS								**243**			358
AERMET_AERMOD	Liberty	-0.12	-0.35	1.52	19.05	2.57	0.88	2.86	102	0.42	0.51	358
MMIF_AERMET_10m	Liberty	0.05	-0.02	2.66	23.60	3.14	1.09	5.67	220	0.20	0.42	358
MMIF_AERMET_TOWERS	Liberty	-0.06	-0.13	1.98	20.10	3.42	0.93	4.03	193	0.33	0.46	358
MMIF_AERMOD_10m	Liberty	0.08	0.00	2.76	24.82	3.07	1.15	5.37	209	0.21	0.45	358
MMIF_AERMOD_TOWERS	Liberty	-0.18	-0.26	1.60	17.42	3.31	0.81	3.84	175	0.35	0.46	358

QQ PLOTS: OBS + AERMET + AERMOD

- Traditional AERMET + AERMOD under-predicts the high range



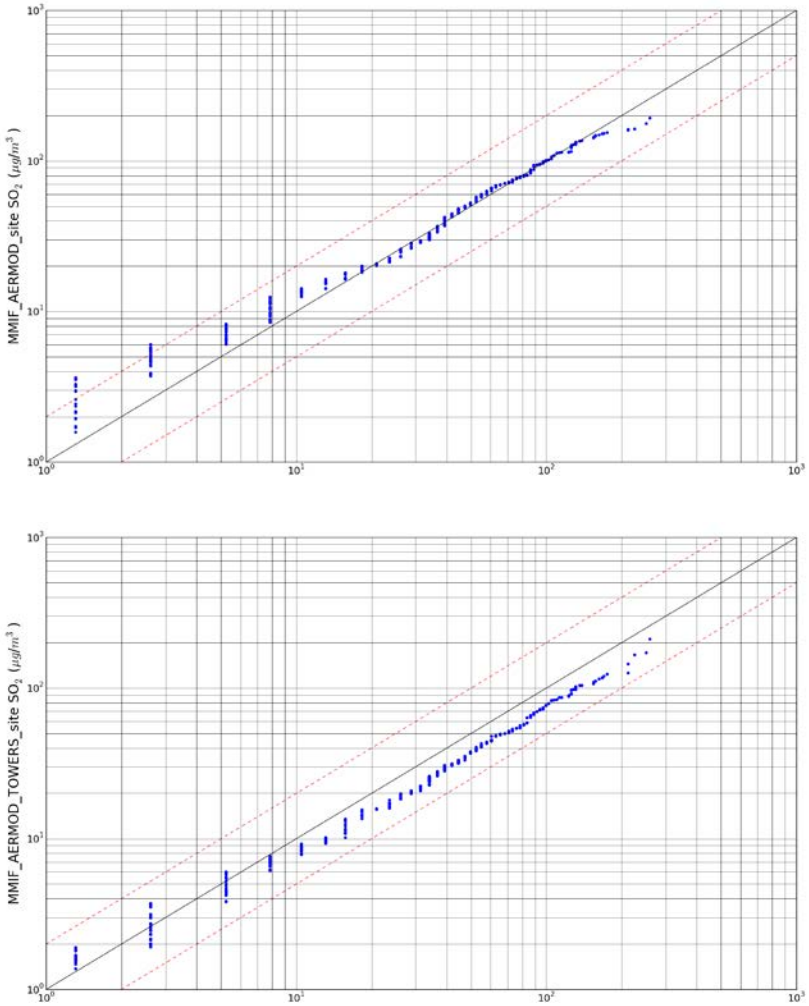
QQ PLOTS USING MMIF 10m & 250m TOWERS

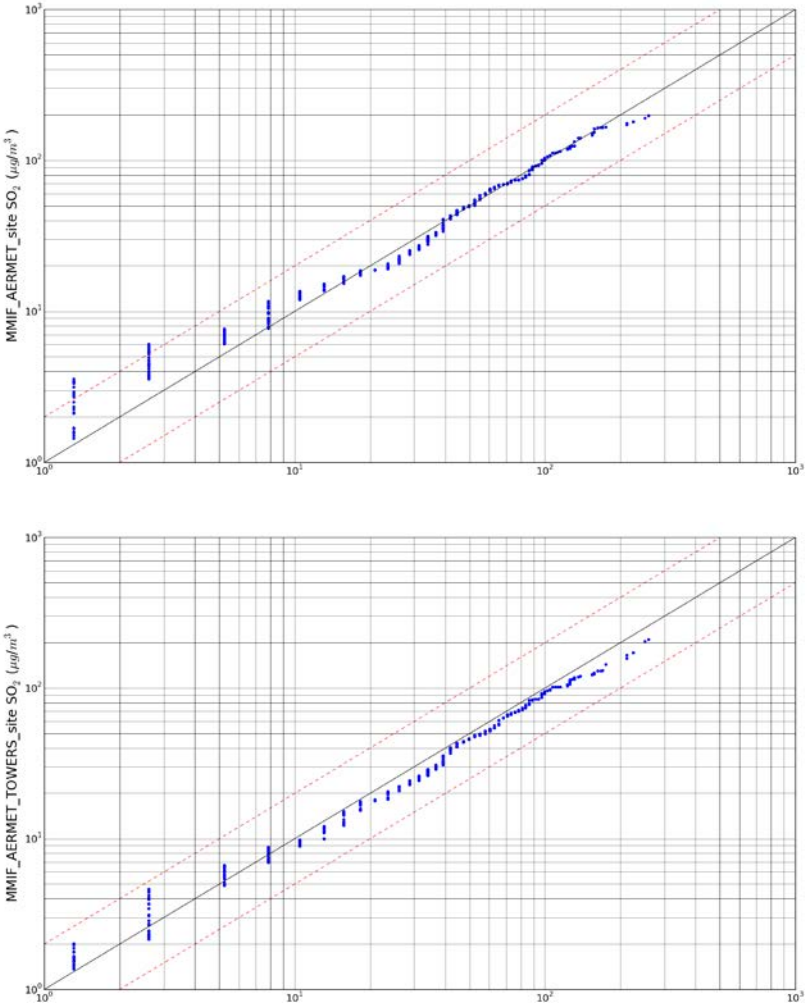
MMIF + AERMOD

MMIF + AERMET + AERMOD

10m Tower

250m Tower





SELECTED STATISTICS – MAX DAILY VALUES WRF RESOLUTION (ug/m³)

Model	Rec	99th Percentile	Num NAAQS Exceedences	Accuracy of paired peak	Coefficient of determination	Fractional Gross Error	Mean Bias	Mean Fractional Bias	Normalized Mean Bias	Geometric Standard Deviation	Robust Highest Concentration (N=26)	Geometric Correlation Coefficient
		2									2	
Observations	OBS	**257**	**5**								**243**	
AERMET_AERMOD	Liberty	112	0	-0.74	0.27	0.71	-14.70	-0.12	-0.35	2.57	102	0.42
MMIF_AERMET_444m	Liberty	195	2	-0.92	0.06	0.85	-1.04	0.05	-0.02	3.14	220	0.20
MMIF_AERMET_1.3km	Liberty	204	7	-0.75	0.15	0.80	10.09	0.20	0.24	3.54	254	0.27
MMIF_AERMET_4km	Liberty	71	0	-0.88	0.28	0.78	-23.58	-0.44	-0.56	2.58	75	0.44
MMIF_AERMET_TOWERS_444m	Liberty	208	2	-0.72	0.19	0.77	-5.25	-0.06	-0.13	3.42	193	0.33
MMIF_AERMET_TOWERS_1.3km	Liberty	211	2	-0.53	0.24	0.75	-1.45	-0.03	-0.03	3.79	191	0.36
MMIF_AERMET_TOWERS_4km	Liberty	99	0	-0.79	0.25	0.74	-21.96	-0.43	-0.52	2.84	96	0.43
MMIF_AERMOD_444m	Liberty	188	1	-0.92	0.07	0.83	-0.19	0.08	0.00	3.07	209	0.21
MMIF_AERMOD_1.3km	Liberty	200	6	-0.81	0.16	0.78	9.99	0.21	0.24	3.46	237	0.27
MMIF_AERMOD_4km	Liberty	72	0	-0.84	0.29	0.73	-20.43	-0.35	-0.49	2.74	74	0.49
MMIF_AERMOD_TOWERS_444m	Liberty	200	1	-0.72	0.24	0.77	-10.76	-0.18	-0.26	3.31	175	0.35
MMIF_AERMOD_TOWERS_1.3km	Liberty	167	0	-0.85	0.21	0.75	-7.55	-0.14	-0.18	3.55	179	0.35
MMIF_AERMOD_TOWERS_4km	Liberty	81	0	-0.89	0.31	0.79	-25.71	-0.58	-0.61	2.70	80	0.47

THREE SOURCES FOR MIXING HEIGHT

1. WRF produces PBLH
   - Quantized to WRF levels
   - Each PBL scheme gets to define PBLH – no common method or diagnosis
2. MMIF (optionally) re-diagnoses Mixing Height
   - Critical bulk Richardson number method
3. AERMET's model
   - Mechanical at night, Convective during the day

Comment:

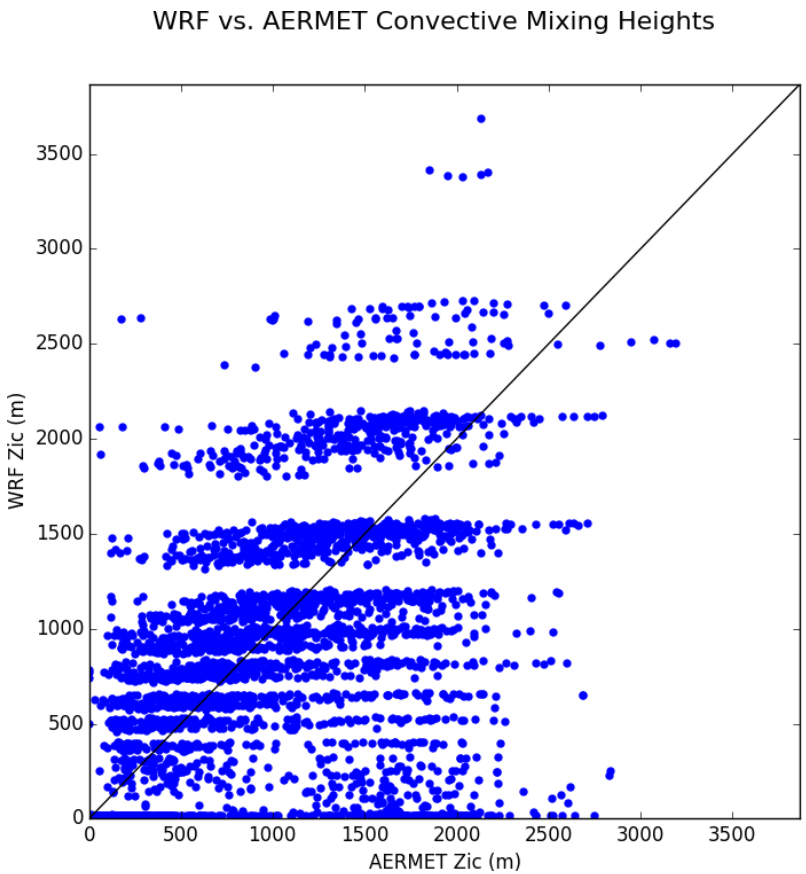
Draft MMIF Guidance (EPA-HQ-OAR-2015-0310-0008) doesn't mention which mixing height should be used.

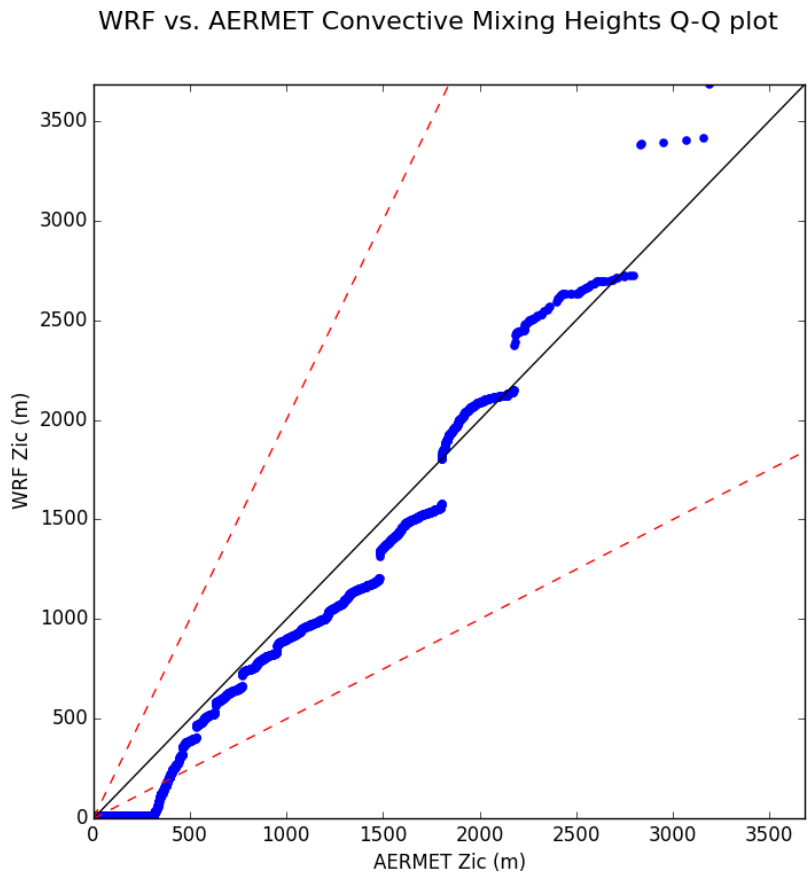
Draft MMIF Evaluation (EPA-HQ-OAR-2015-0310-0009) doesn't mention which mixing height was used (it was WRF).

The following plots should tell us if more work is needed.

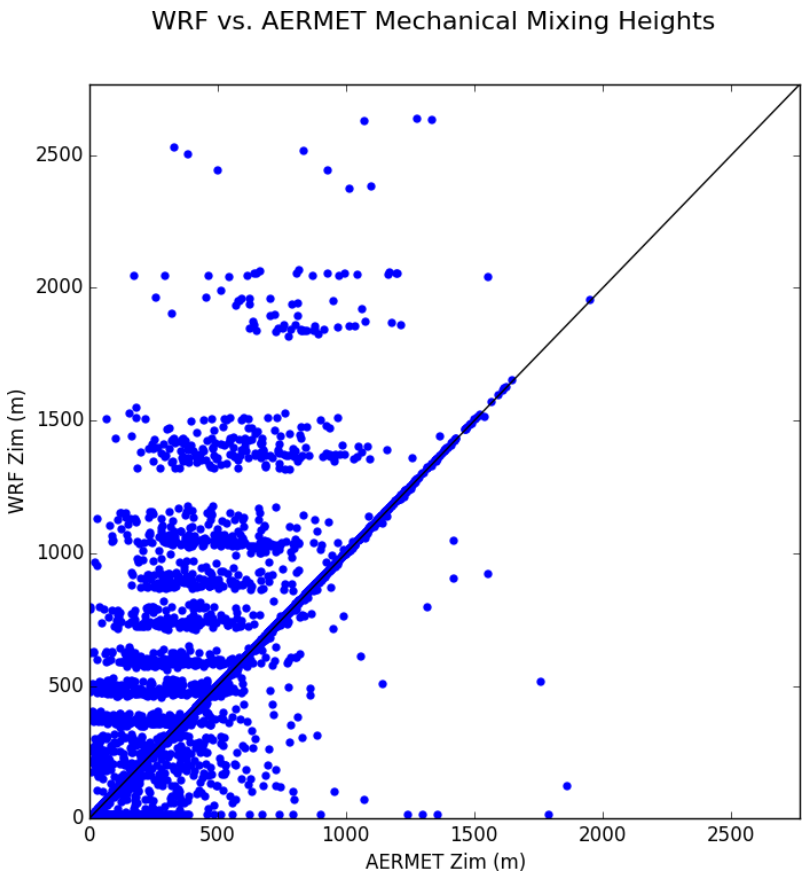
Note: No OBS here, just models…

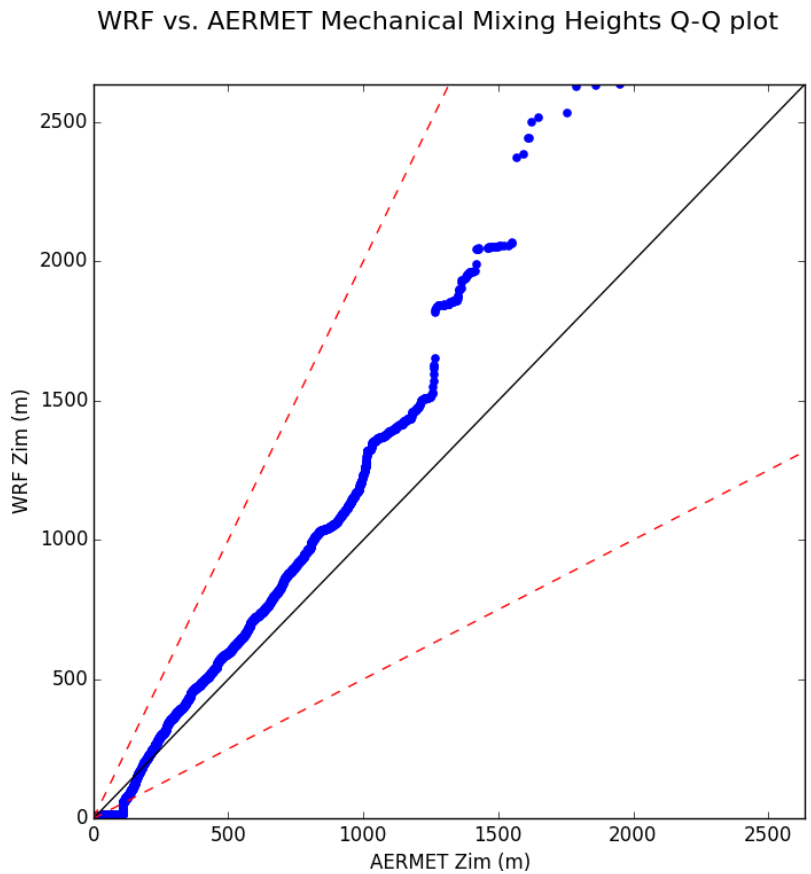
WRF VS. AERMET CONVECTIVE MIXING HEIGHTS



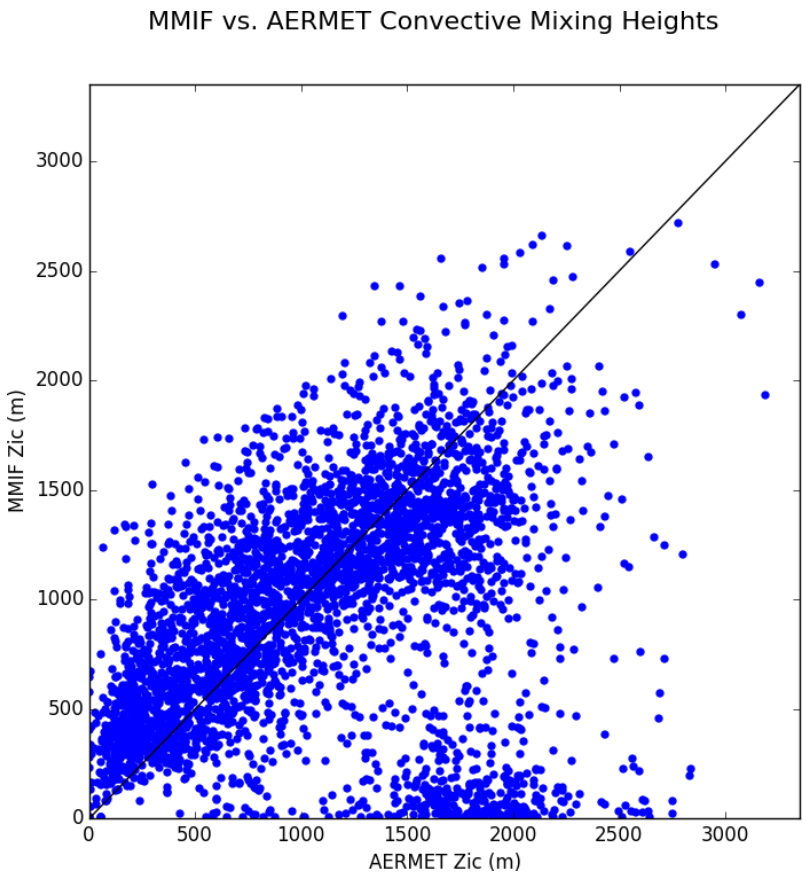


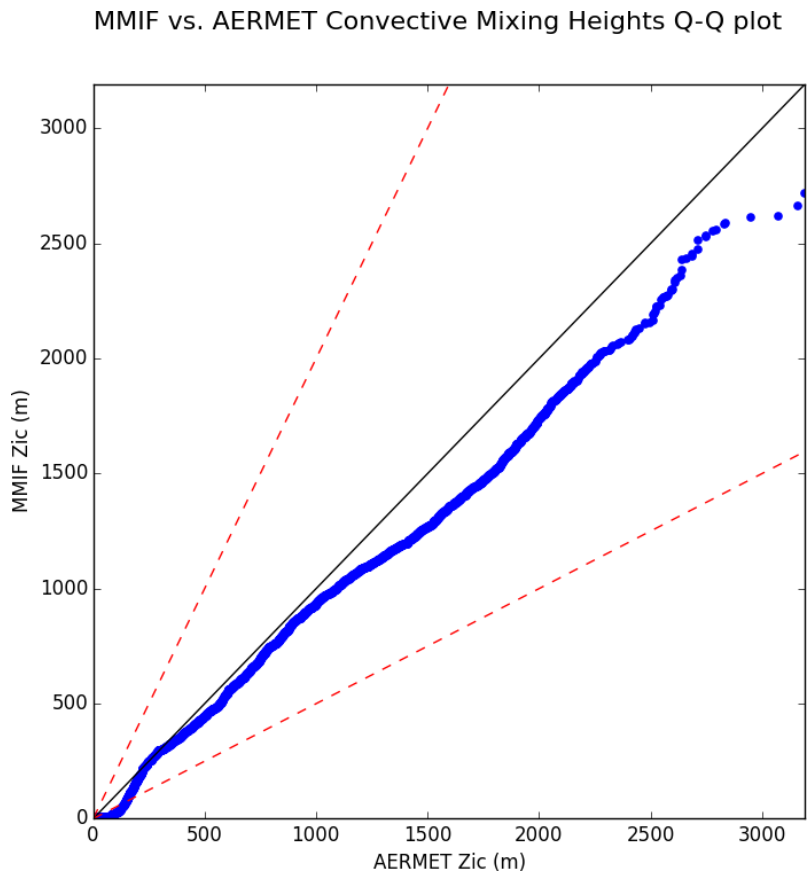
WRF VS. AERMET MECHANICAL MIXING HEIGHTS



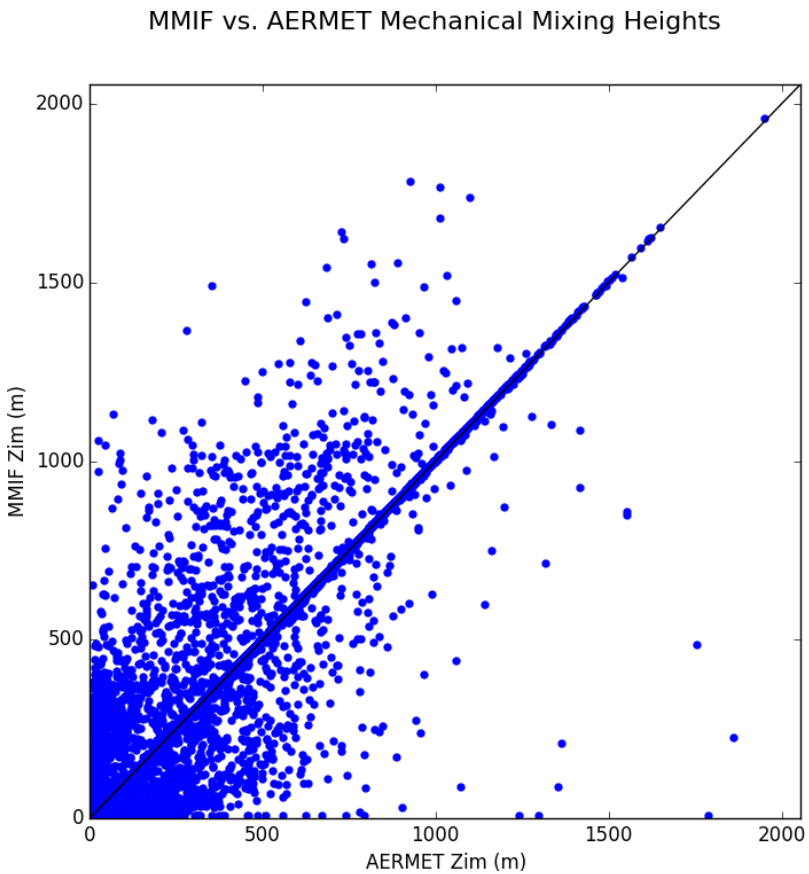


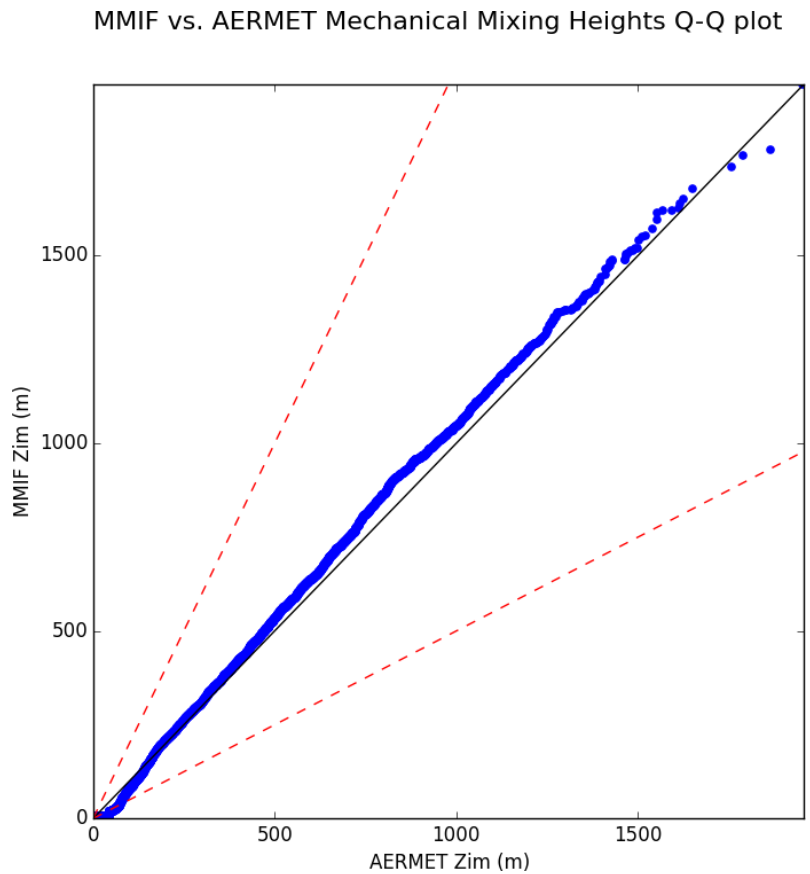
MMIF VS. AERMET CONVECTIVE MIXING HEIGHTS





MMIF VS. AERMET MECHANICAL MIXING HEIGHTS





SO2 DISTRIBUTION STATISTICS FOR DIFFERENT MIXING HEIGHTS (ug/m³)

Model	Rec	99th Percentile	Num NAAQS Exceedences	Accuracy of paired peak	Coefficient of determination	Normalized Mean Error	Root Mean Square Error	Fractional Gross Error	Mean Absolute Gross Error	Mean Normalized Gross Error	Mean Bias	Mean Normalized Bias
		2										
Observations	OBS	257	5									
MMIF_AERMET_TOWERS_MMIF_MIXHT	Liberty	208	2	-0.72	0.19	0.69	43.89	0.77	28.92	1.54	-5.25	0.98
MMIF_AERMET_TOWERS_WRF_MIXHT	Liberty	195	2	-0.74	0.14	0.72	45.48	0.78	29.96	1.67	-5.24	1.12
MMIF_AERMET_TOWERS_AER_MIXHT	Liberty	198	1	-0.78	0.16	0.69	45.37	0.77	29.03	1.56	-6.91	0.99
MMIF_AERMOD_TOWERS_MMIF_MIXHT	Liberty	200	1	-0.72	0.24	0.64	41.10	0.77	26.73	1.22	-10.76	0.60
MMIF_AERMOD_TOWERS_WRF_MIXHT	Liberty	185	1	-0.74	0.20	0.65	42.22	0.77	27.10	1.33	-12.26	0.71

Model	Rec	Mean Fractional Bias	Normalized Mean Bias	Bias Factor	Geometric Mean	Geometric Standard Deviation	Geometric Mean Bias	Geometric Mean Variance	Robust Highest Concentration (N=26)	Geometric Correlation Coefficient	Fraction Inside Factor of Two	N
					0				2			3
Observations	OBS								243			358
MMIF_AERMET_TOWERS_MMIF_MIXHT	Liberty	-0.06	-0.13	1.98	20.10	3.42	0.93	4.03	193	0.33	0.46	358
MMIF_AERMET_TOWERS_WRF_MIXHT	Liberty	-0.05	-0.13	2.12	20.40	3.40	0.94	4.30	190	0.31	0.45	358
MMIF_AERMET_TOWERS_AER_MIXHT	Liberty	-0.09	-0.17	1.99	19.34	3.34	0.89	4.07	212	0.32	0.47	358
MMIF_AERMOD_TOWERS_MMIF_MIXHT	Liberty	-0.18	-0.26	1.60	17.42	3.31	0.81	3.84	175	0.35	0.46	358
MMIF_AERMOD_TOWERS_WRF_MIXHT	Liberty	-0.19	-0.29	1.71	17.20	3.21	0.80	4.15	156	0.32	0.45	358

CONCLUSIONS FOR THE LIBERTY SITE

- MMIF + AERMOD can give results on par with OBS + AERMOD
- A 250m MET tower is not necessarily better than a 10m tower
  - Depends on which statistic you value
- Finer WRF resolution doesn't necessarily give better statistical performance (1.3km vs. 444m, 4km was too coarse in this case)
- Using too coarse of a WRF resolution under-predicts maximum SO_2 concentrations
- Using WRF, MMIF, or AERMET mixing heights gave similar statistical performance of SO_2 distributions
- MMIF in AERMET and AERMOD modes give similar results

COMMENTS

- Overall, this work supports proposed changes to Appendix W regarding MMIF
- Requiring that MMIF use AERMET mode (vs. AERMOD mode):
  - Assumes AERMET's surface layer similarity is better than WRF's
  - Precludes the use of MMIF in locations where AERMET's assumptions aren't appropriate (e.g. over water)
  - Would benefit from more testing, e.g. sites in MMIF Eval. document
- Suggestion: expand MMIF Guidance document about when MMIF in AERMOD mode would be acceptable
- Suggestion: more clarity in MMIF Guidance document on MMIF's PBL_recalc setting
  - Would benefit from more testing, e.g. sites in MMIF Eval. document

THANK YOU