Ensemble MM5 Simulations: AMET Evaluation

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AD-HOC METEOROLOGICAL MODELING MEETING
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Outline

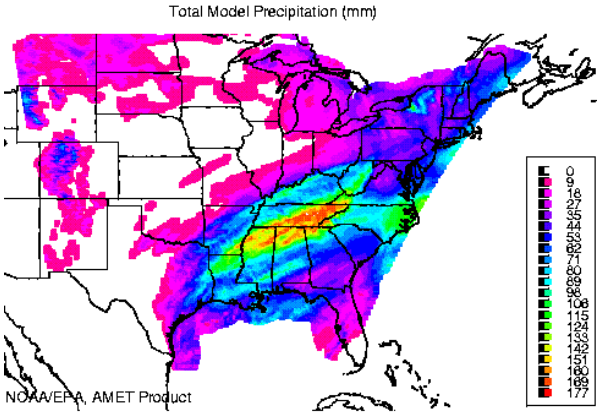
- Project overview
- Model configurations
- Surface-based evaluation and comparison
- Precipitation
- Insolation
- Upper-air (wind profiles, rawindsonde)
- Future plans

Project Overview

- Examine the spread in meteorological solutions and link to spread in CMAQ
- Examine the accuracy of various meteorological options in MM5
- Highlight areas of good and poor model performance to aid model development

Model Configuration

- 12 km East US domain
- Executed for Jan and Jul, 2002
- 5-day run segments with FDDA analysis nudging (T not in PBL)



Project Overview

Simulation Matrix

Simulation	ENS1	ENS2	ENS3	ENS4	ENS5	ENS6
Physics						
LSM	P-X	NOAH	NOAH	P-X	NOAH	NOAH
PBL	ACM	M-Y-J	MRF	ACM	M-Y-J	MRF
Convective	K-F	K-F	K-F	Grell	Grell	Grell
Micro-physics	Reisner II	Reisner II	Reisner II	Reisner II	Reisner II	Reisner II
Radiation	RRTM	RRTM	RRTM	RRTM	RRTM	RRTM

Statistical Analysis

Surface-Based

Subset Statistics

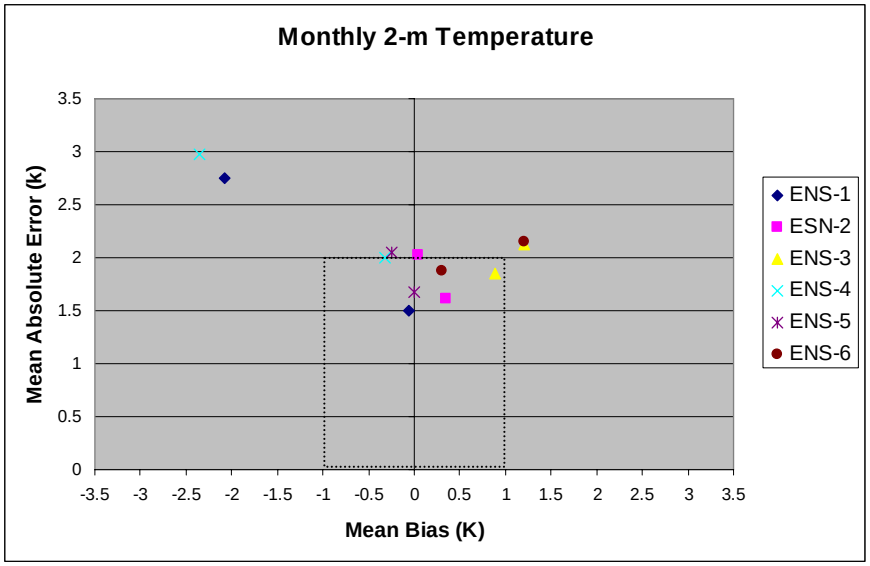
Monthly Temperature

Collective Monthly Temperature Bias (K)

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Month	T	T	T	T	T	T
january	-2.08	0.04	1.21	-2.35	-0.25	1.2
july	-0.06	0.35	0.89	-0.32	0	0.3

Collective Monthly Temperature MAE (K)

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Month	T	T	T	T	T	T
january	2.75	2.02	2.13	2.98	2.05	2.15
july	1.5	1.61	1.85	2	1.67	1.87



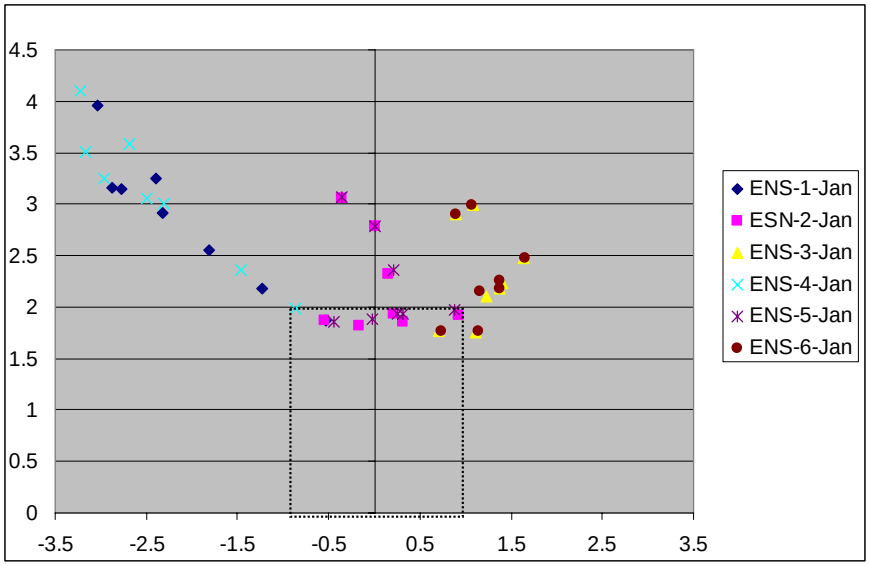
Regional Temperature, Jan., 2002

January Temperature Bias

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	T	T	T	T	T	T
florida	-0.86	0.93	1.23	-0.86	0.88	1.16
midatlantic	-2.32	0.21	1.37	-2.3	0.25	1.37
northeast	-3.28	-0.54	0.71	-3.16	-0.44	0.73
south	-1.44	0.32	1.41	-1.46	0.31	1.38
greatlakes	-3.07	-0.17	1.12	-2.96	-0.02	1.14
midwest	-2.51	0.15	1.64	-2.5	0.21	1.65
lowerrockies	-2.75	0.01	1.08	-2.68	0.01	1.07
upperrockies	-3.24	-0.36	0.9	-3.22	-0.36	0.89

January Temperature Mean Absolute Error

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	T	T	T	T	T	T
florida	1.87	1.92	2.1	1.99	1.97	2.15
midatlantic	2.55	1.94	2.18	3.01	1.94	2.18
northeast	3.14	1.87	1.77	3.51	1.86	1.77
south	2.18	1.86	2.23	2.36	1.93	2.26
greatlakes	3.16	1.82	1.75	3.25	1.88	1.77
midwest	2.92	2.32	2.47	3.05	2.36	2.47
lowerrockies	3.25	2.78	2.99	3.59	2.79	2.99
upperrockies	3.96	3.06	2.9	4.1	3.07	2.9



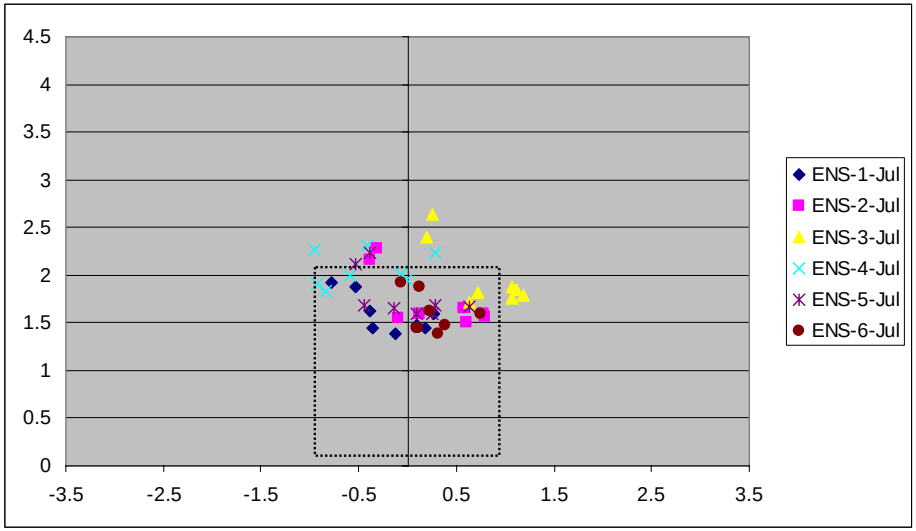
Regional Temperature, Jul., 2002

July Temperature Bias

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	T	T	T	T	T	T
florida	-0.39	0.78	1.12	-0.92	0.63	0.23
midatlantic	-0.13	0.8	1.19	-0.59	0.26	0.32
northeast	0.27	0.58	1.07	0.29	0.28	0.75
south	-0.35	0.6	1.07	-0.84	0.09	0.11
greatlakes	0.18	-0.09	0.63	0	-0.45	0.1
midwest	0.1	0.13	0.72	-0.06	-0.14	0.38
lowerrockies	-0.78	-0.38	0.2	-0.95	-0.53	-0.07
upperrockies	-0.53	-0.31	0.25	-0.41	-0.38	0.12

July Temperature Mean Absolute Error

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	T	T	T	T	T	T
florida	1.63	1.6	1.85	1.91	1.67	1.85
midatlantic	1.38	1.57	1.79	1.99	1.6	1.78
northeast	1.6	1.65	1.88	2.24	1.68	1.89
south	1.44	1.51	1.76	1.83	1.59	1.75
greatlakes	1.44	1.55	1.72	1.95	1.68	1.8
midwest	1.47	1.59	1.82	2.01	1.66	1.82
lowerrockies	1.92	2.16	2.4	2.27	2.12	2.41
upperrockies	1.88	2.28	2.63	2.31	2.23	2.58



BIAS

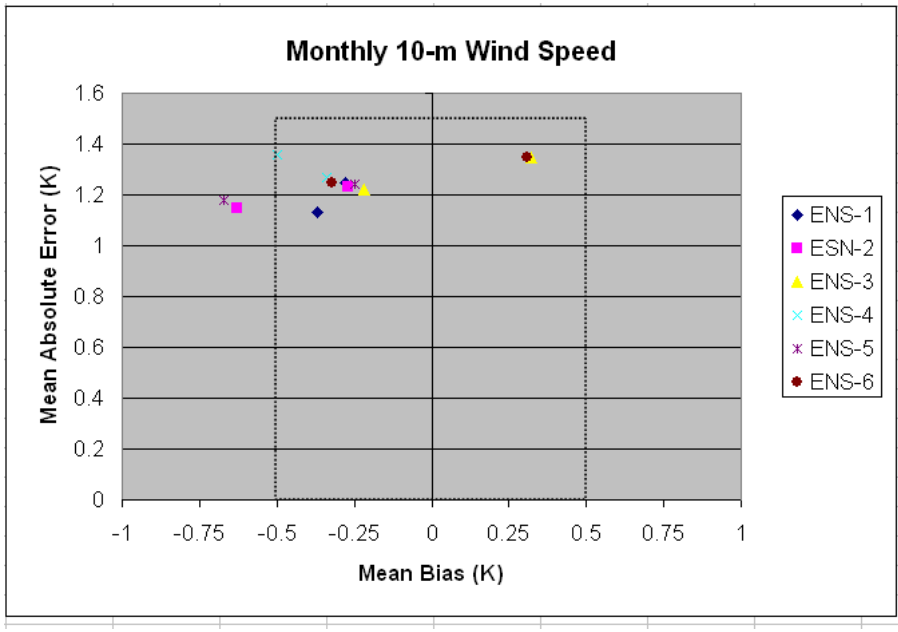
Monthly Wind Speed

Collective Monthly Wind Speed Bias (m/s)

Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Month	WS	WS	WS	WS	WS	WS
january	-0.28	-0.27	0.32	-0.34	-0.25	0.31
july	-0.37	-0.63	-0.22	-0.5	-0.67	-0.32

Collective Monthly Wind Speed MAE (m/s)

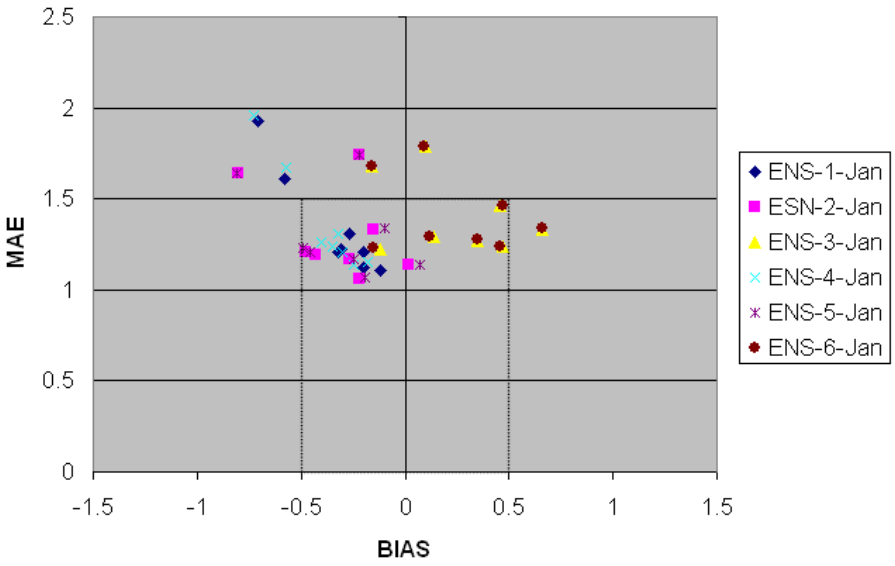
Ensemble Run	ENS -1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Month	WS	WS	WS	WS	WS	WS
january	1.25	1.23	1.35	1.27	1.24	1.35
july	1.13	1.15	1.22	1.36	1.18	1.25



Regional Wind Speed, Jan., 2002

January Wind Speed Bias						
Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	WS	WS	WS	WS	WS	WS
florida	-0.2	-0.43	-0.12	-0.3	-0.46	-0.15
midatlantic	-0.12	-0.22	0.47	-0.18	-0.19	0.46
northeast	-0.27	-0.15	0.46	-0.32	-0.1	0.47
south	-0.32	-0.48	0.14	-0.4	-0.49	0.12
greatlakes	-0.2	0.02	0.66	-0.25	0.07	0.66
midwest	-0.31	-0.27	0.35	-0.35	-0.25	0.35
lowerrockies	-0.58	-0.8	-0.16	-0.57	-0.81	-0.16
upperrockies	-0.71	-0.22	0.1	-0.73	-0.22	0.09

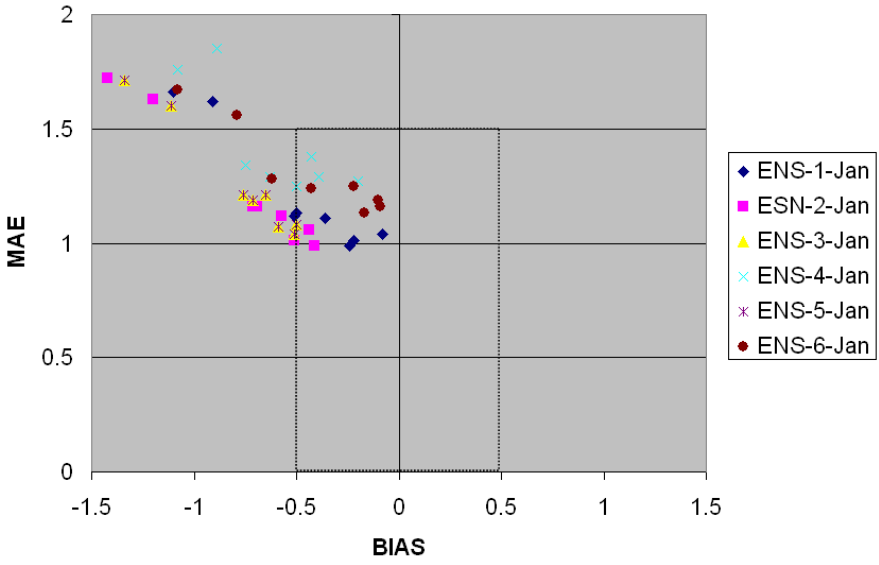
January Wind Speed Mean Absolute Error						
Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	WS	WS	WS	WS	WS	WS
florida	1.21	1.19	1.22	1.21	1.21	1.23
midatlantic	1.11	1.06	1.24	1.15	1.07	1.24
northeast	1.31	1.33	1.46	1.31	1.34	1.46
south	1.21	1.21	1.29	1.26	1.23	1.29
greatlakes	1.12	1.14	1.33	1.14	1.14	1.34
midwest	1.22	1.17	1.27	1.24	1.17	1.28
lowerrockies	1.61	1.64	1.68	1.67	1.64	1.68
upperrockies	1.93	1.74	1.79	1.96	1.74	1.79



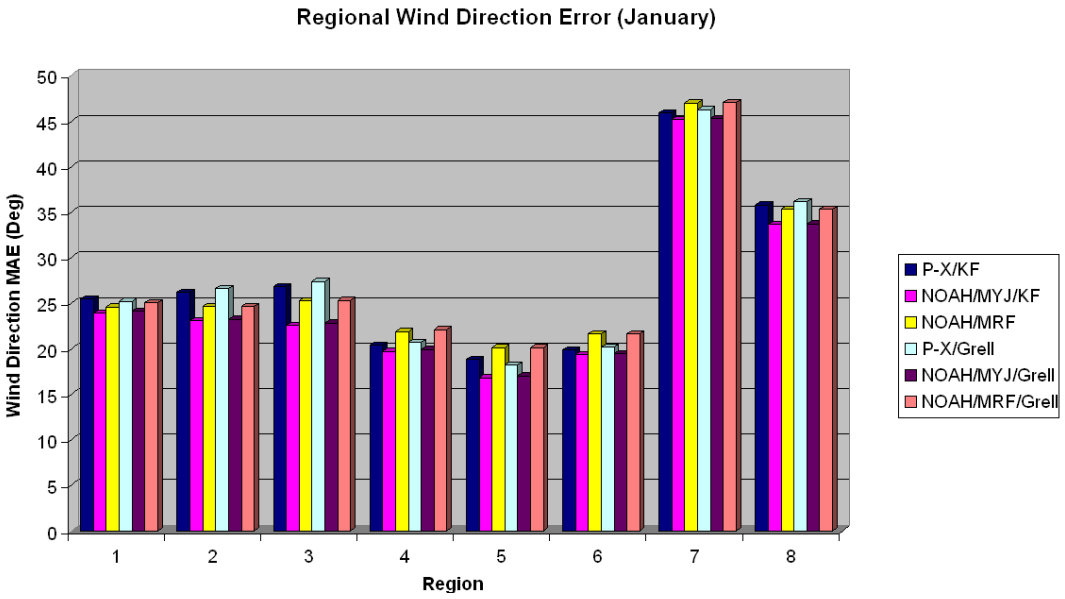
Regional Wind Speed, Jul., 2002

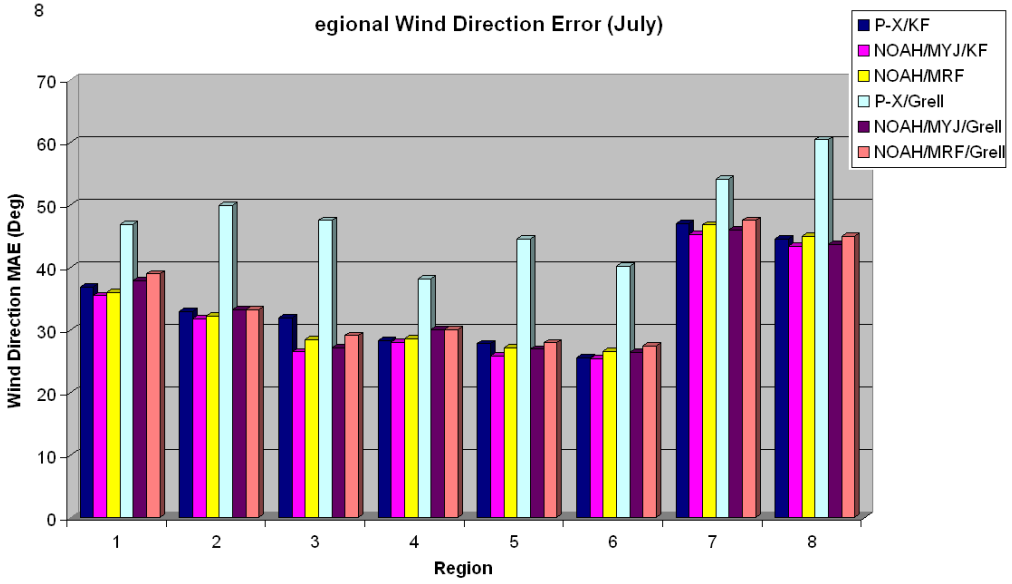
July Wind Speed Bias						
Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	WS	WS	WS	WS	WS	WS
florida	-0.5	-0.57	-0.4	-0.75	-0.65	-0.62
midatlantic	-0.24	-0.41	-0.06	-0.5	-0.51	-0.17
northeast	-0.08	-0.44	-0.02	-0.2	-0.5	-0.09
south	-0.51	-0.71	-0.32	-0.63	-0.76	-0.43
greatlakes	-0.22	-0.51	0.01	-0.39	-0.59	-0.1
midwest	-0.36	-0.69	-0.18	-0.43	-0.71	-0.22
lowerrockies	-1.1	-1.42	-1.09	-1.08	-1.34	-1.08
upperrockies	-0.91	-1.2	-0.83	-0.89	-1.11	-0.79

July Wind Speed Mean Absolute Error						
Ensemble Run	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Region	WS	WS	WS	WS	WS	WS
florida	1.13	1.12	1.17	1.34	1.21	1.28
midatlantic	0.99	0.99	1.1	1.25	1.04	1.13
northeast	1.04	1.06	1.15	1.27	1.08	1.16
south	1.12	1.16	1.19	1.29	1.21	1.24
greatlakes	1.01	1.01	1.16	1.29	1.07	1.19
midwest	1.11	1.16	1.23	1.38	1.19	1.25
lowerrockies	1.66	1.72	1.66	1.76	1.71	1.67
upperrockies	1.62	1.63	1.56	1.85	1.6	1.56



Regional Wind Direction





Precip-based Statistics

Precipitation dependent temperature bias

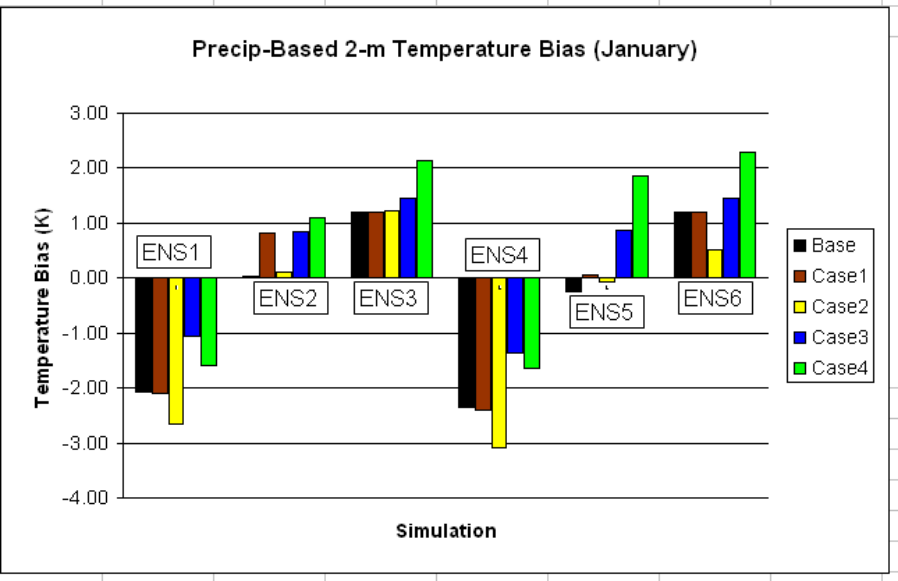
	Model Precipitation	Observed Precipitatio
Case1		
Case2	X	
Case3		X
Case4	X	X

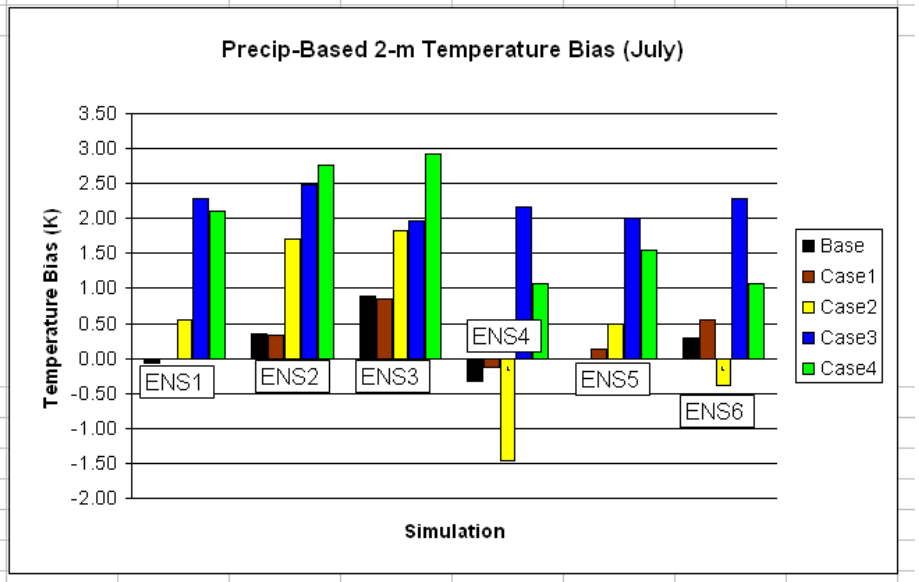
January Temperature Bias

Ensemble	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Base	-2.08	0.04	1.21	-2.35	-0.25	1.20
Case1	-2.11	0.81	1.19	-2.39	0.05	1.19
Case2	-2.65	0.10	1.22	-3.09	-0.07	0.52
Case3	-1.06	0.85	1.46	-1.35	0.86	1.46
Case4	-1.59	1.11	2.15	-1.64	1.87	2.30

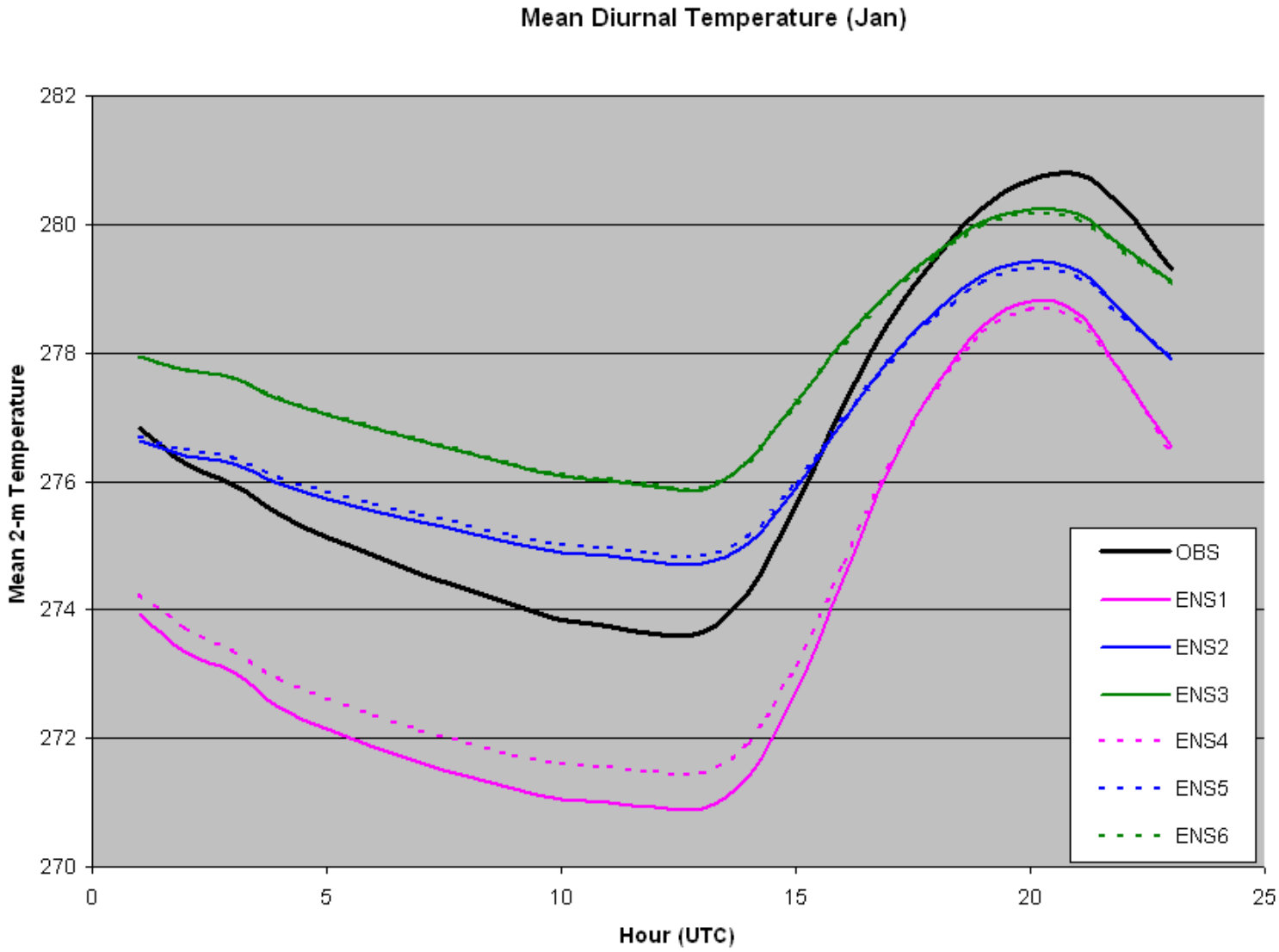
July Temperature Bias

Ensemble	ENS-1	ENS-2	ENS-3	ENS-4	ENS-5	ENS-6
Base	-0.06	0.35	0.89	-0.32	0.00	0.30
Case1	0.00	0.33	0.84	-0.12	0.13	0.56
Case2	0.56	1.70	1.82	-1.46	0.50	-0.38
Case3	2.28	2.49	1.96	2.17	2.01	2.29
Case4	2.10	2.76	2.93	1.07	1.54	1.07

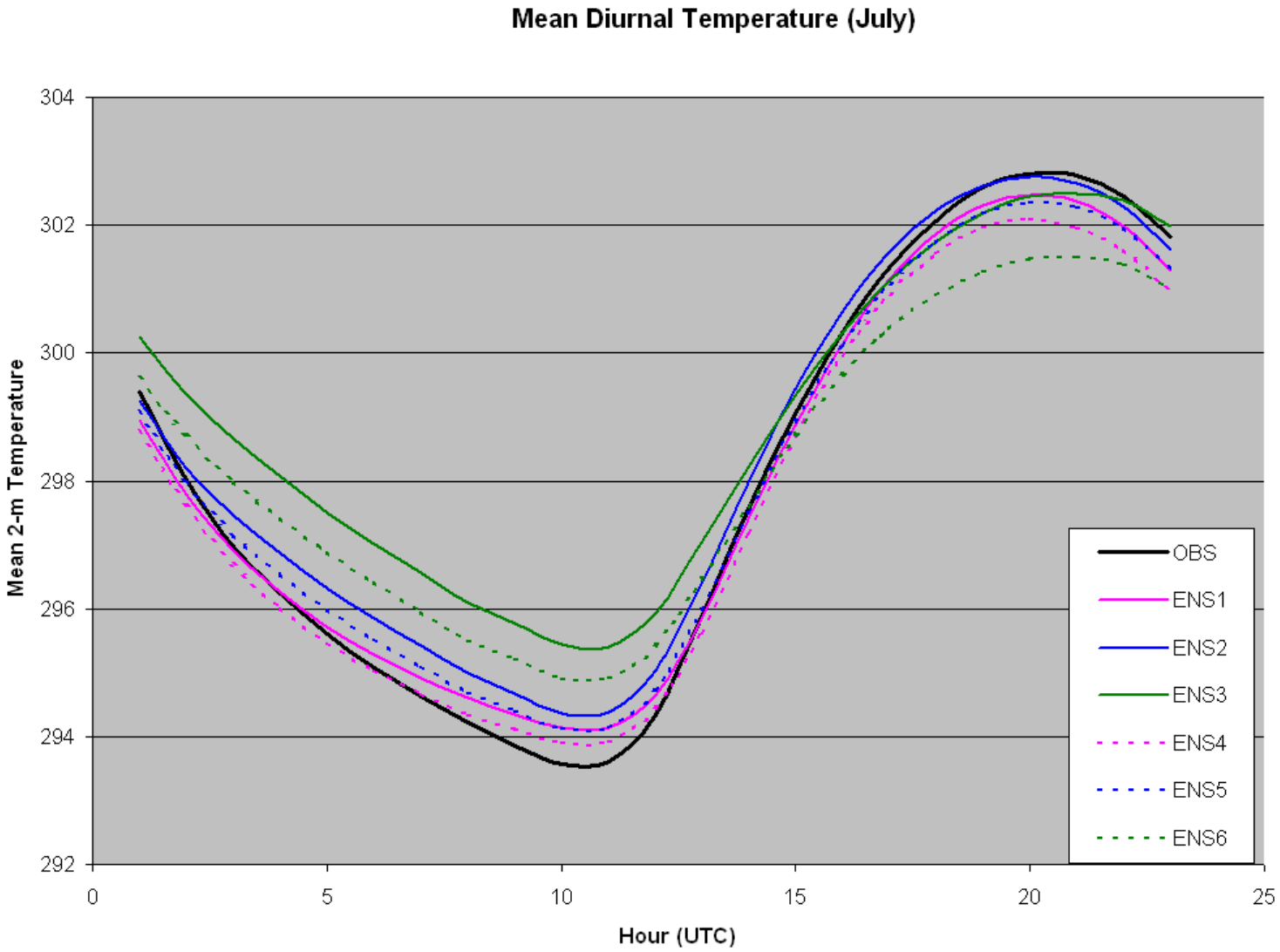




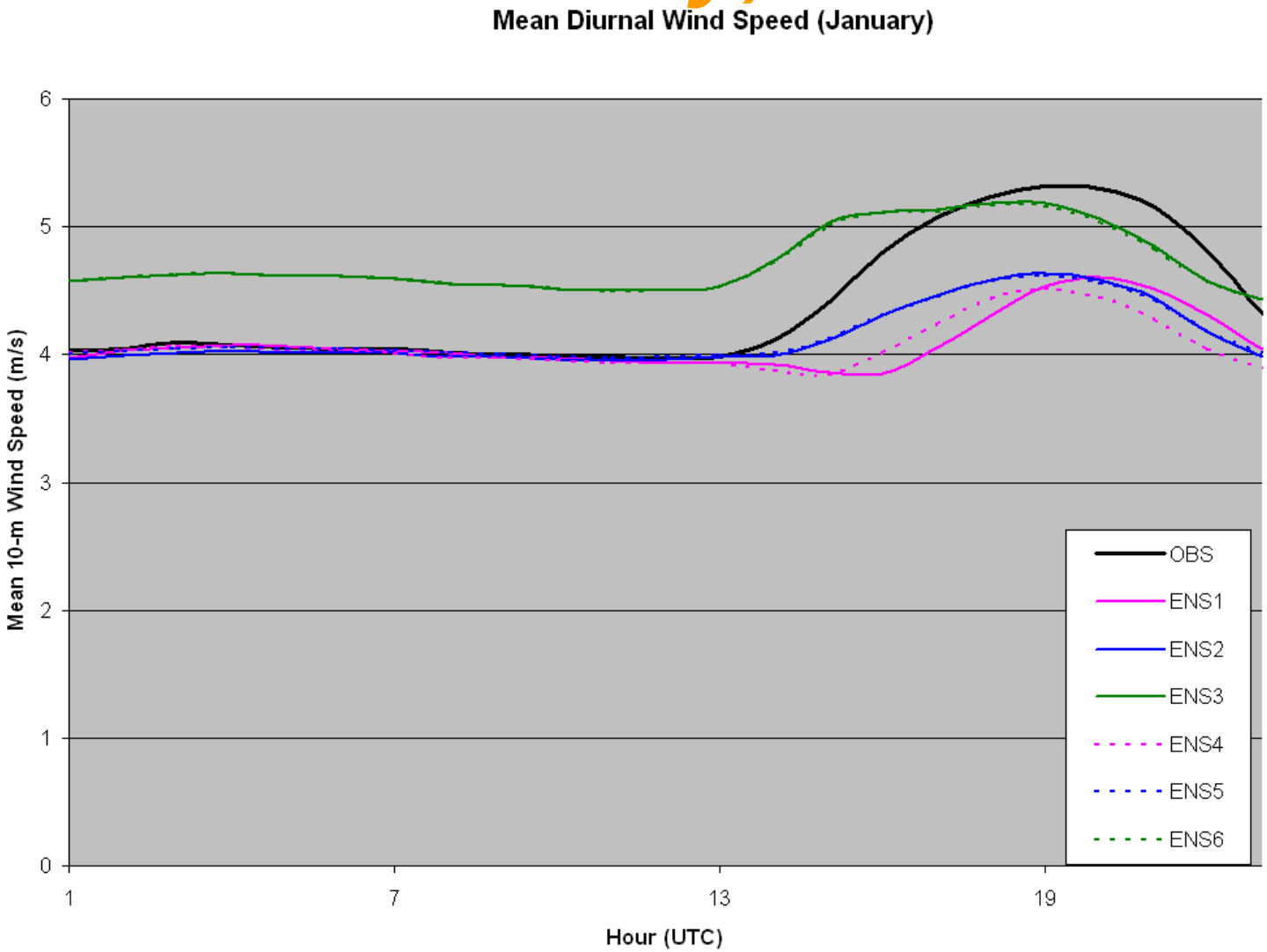
Diurnal Temperature Statistics January, 2002



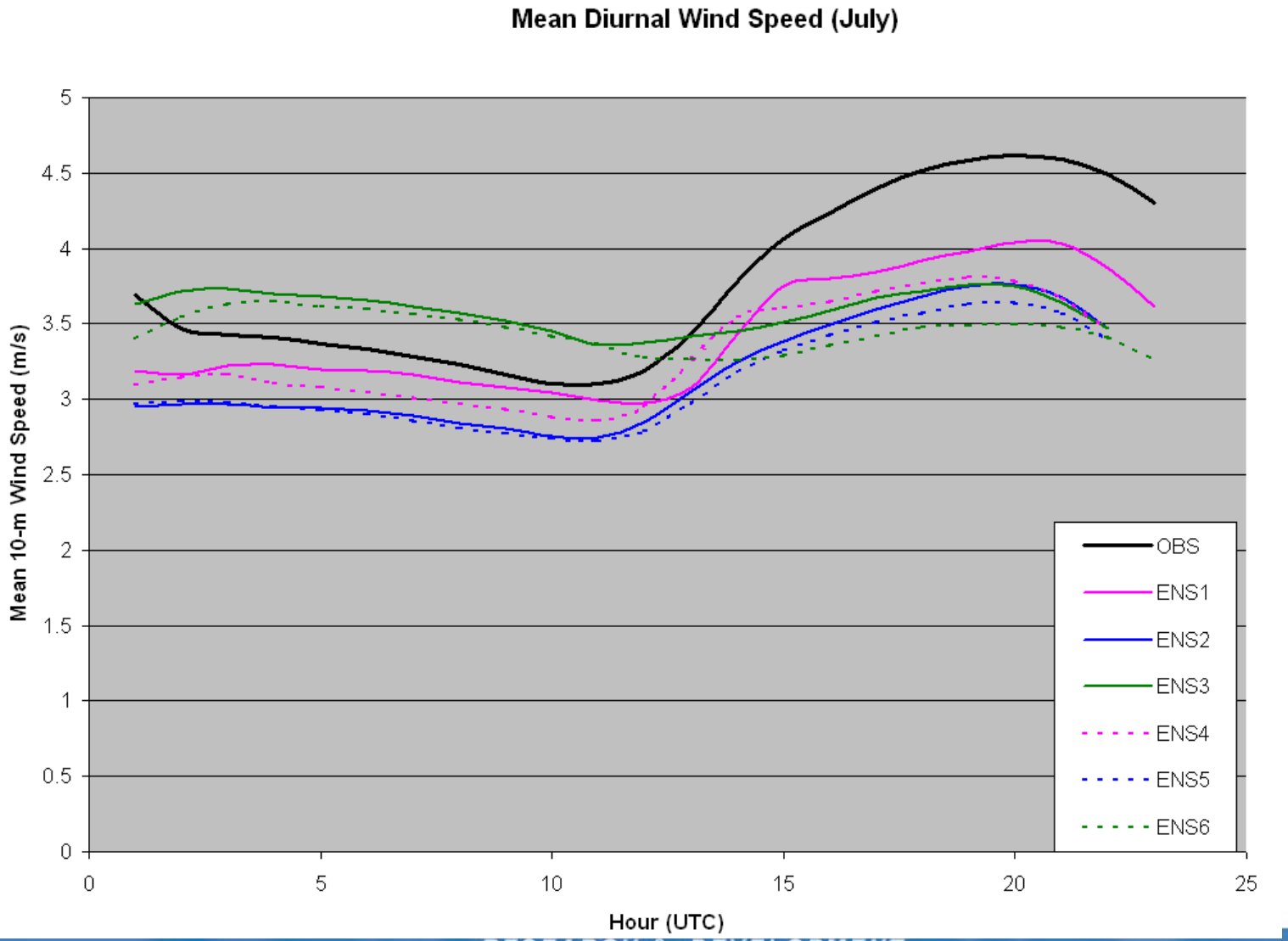
Diurnal Temperature Statistics July, 2002



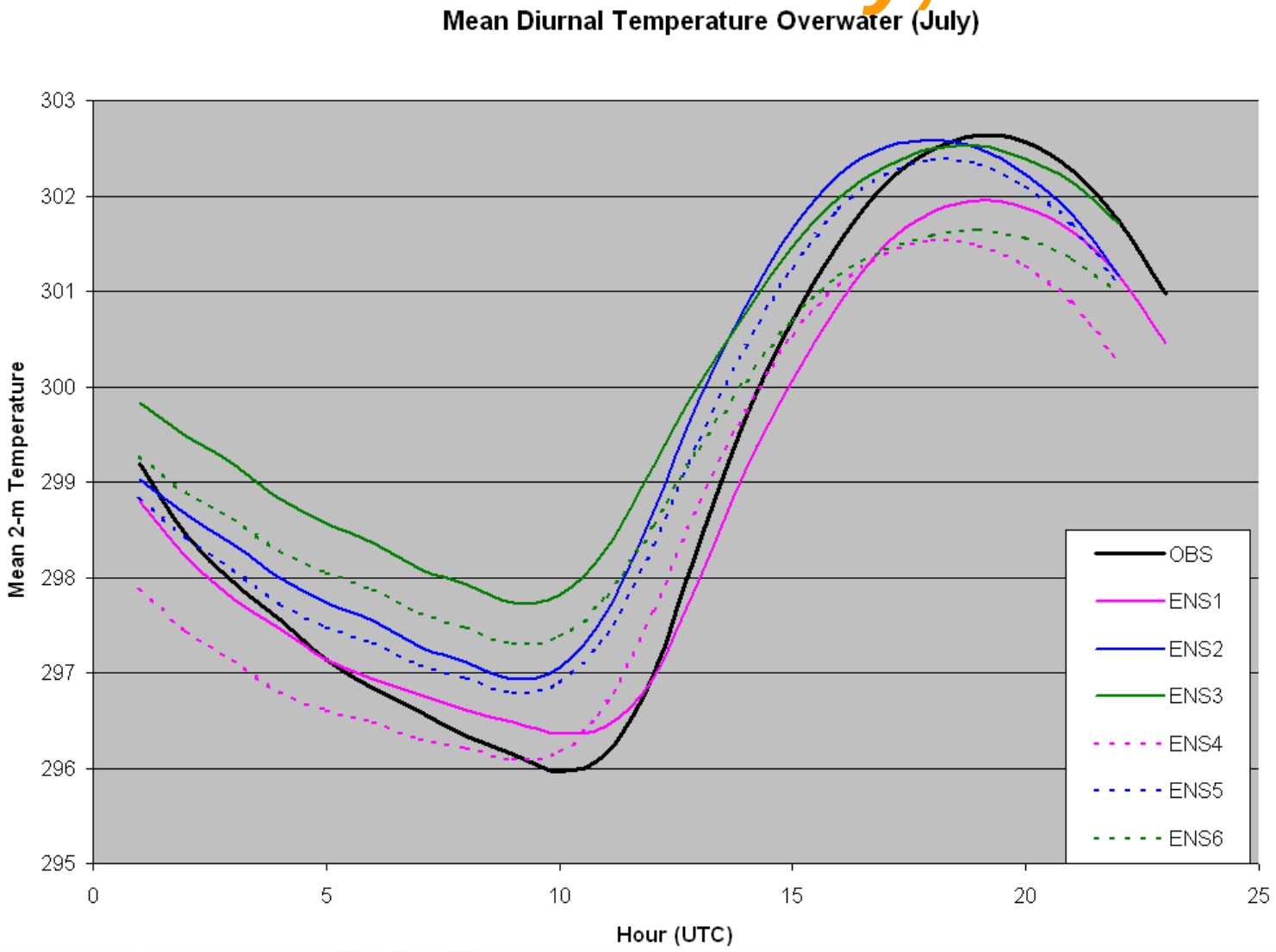
Diurnal Wind Speed Statistics January, 2002



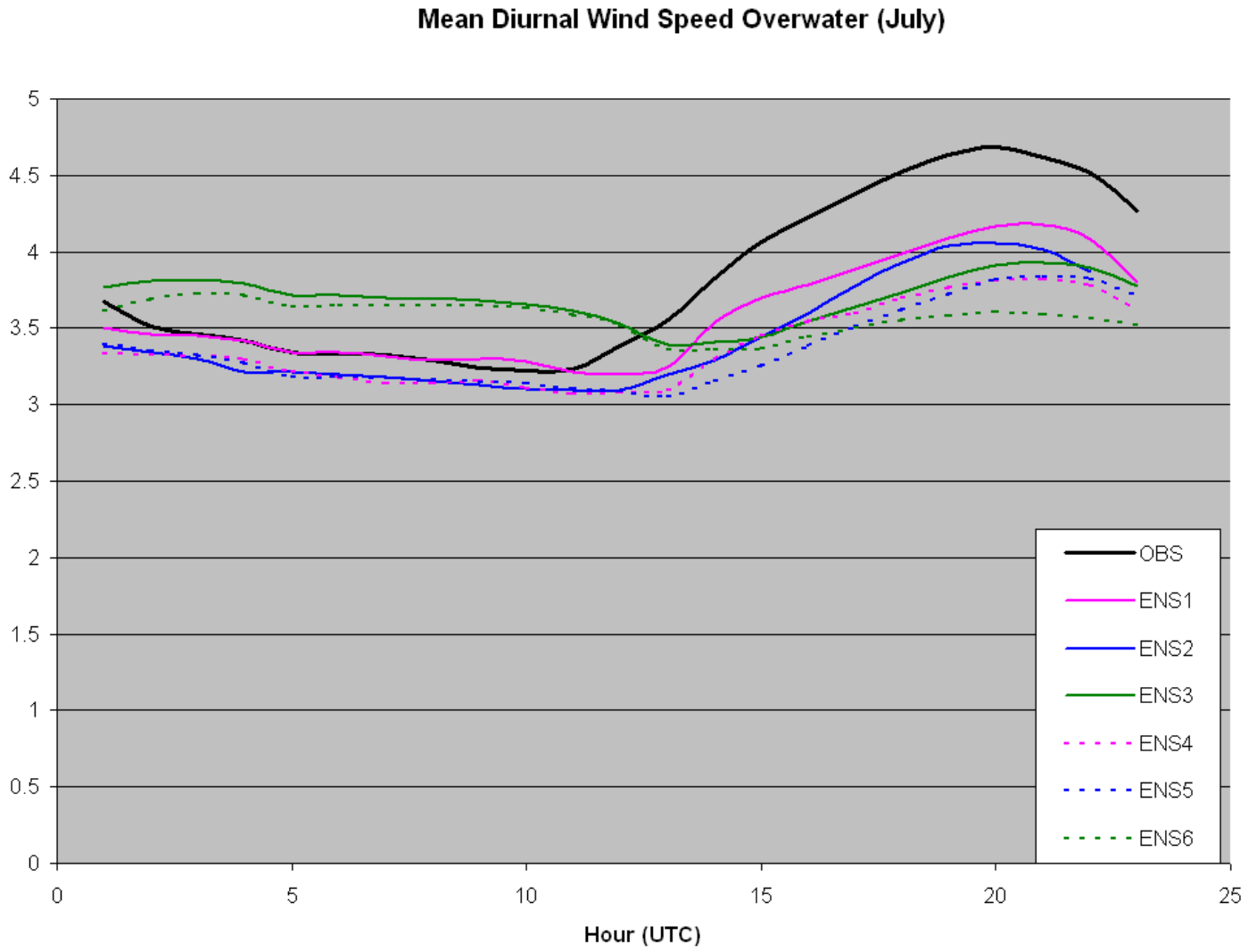
Diurnal Wind Speed Statistics July, 2002



Diurnal Temperature Statistics Over Water July, 2002



Diurnal Wind Speed Statistics Over Water July, 2002



Monthly Spatial Statistics
January, 2002

Absolute Error Scale

Excellent agreement between observations and model

Good agreement between observations and model

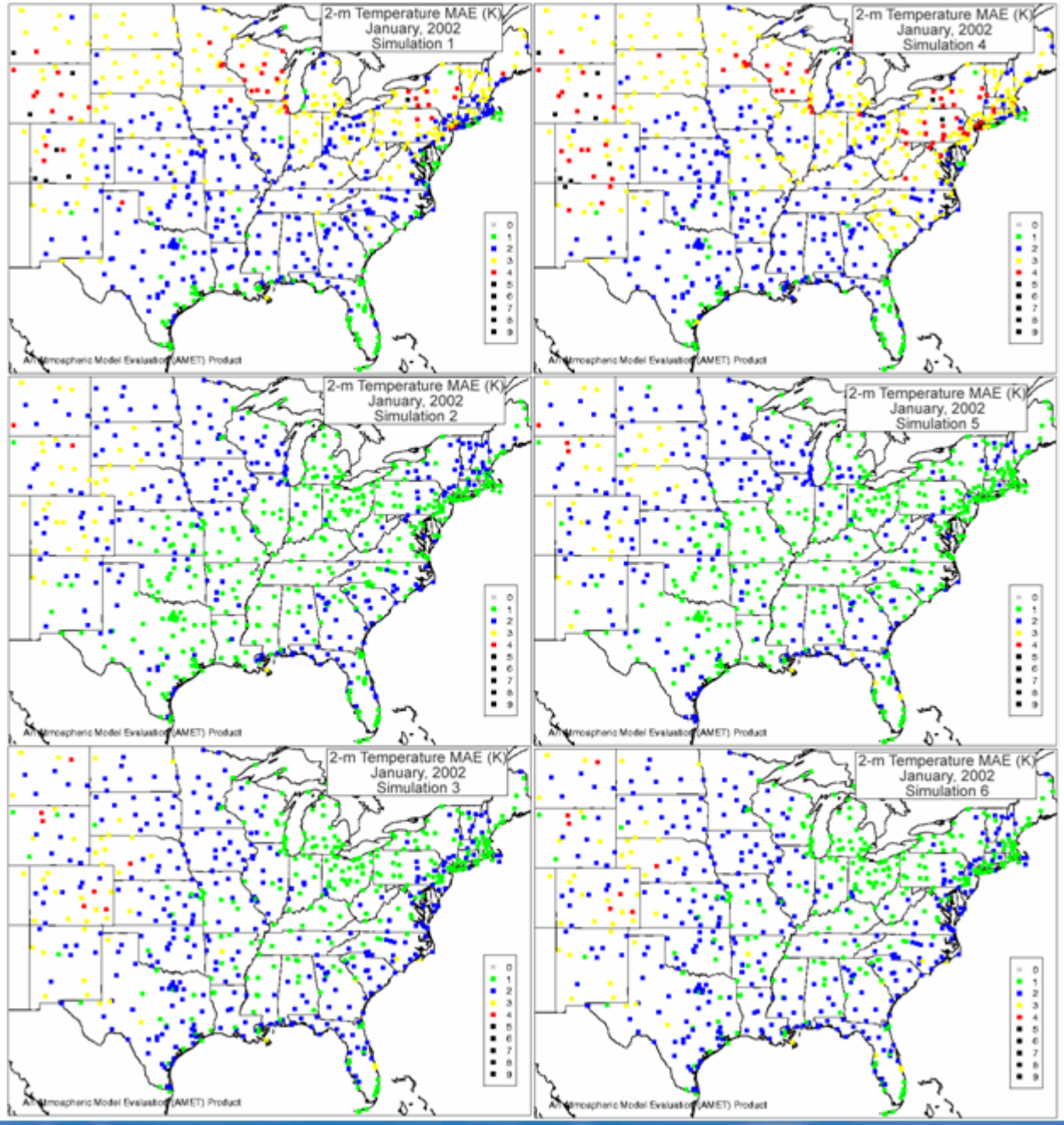
Fair agreement between observations and model

Poor agreement between observations and model

Mean Absolute Error

2-m Temperature (K)

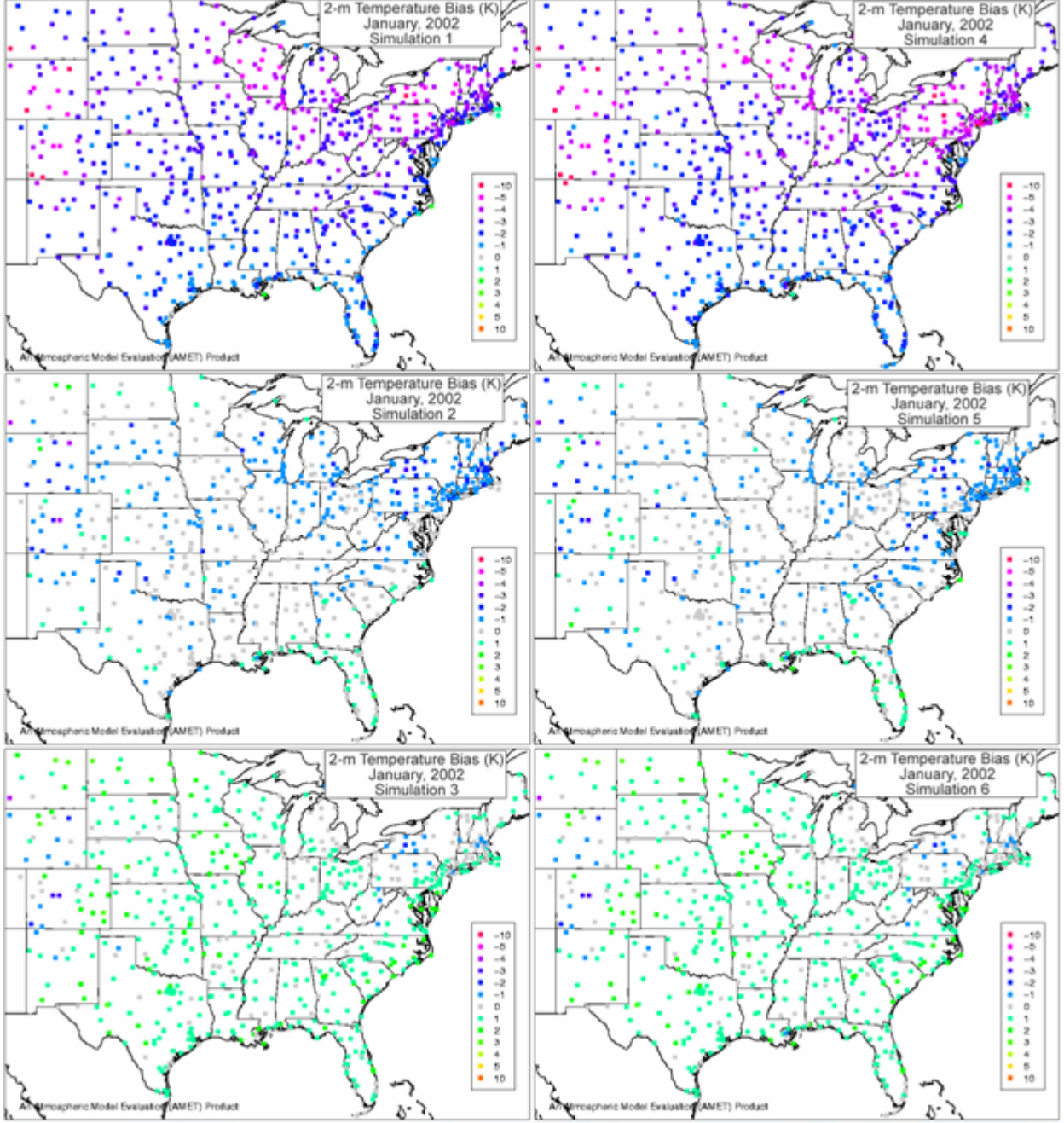
January, 2002



Mean Bias

2-m Temperature (K)

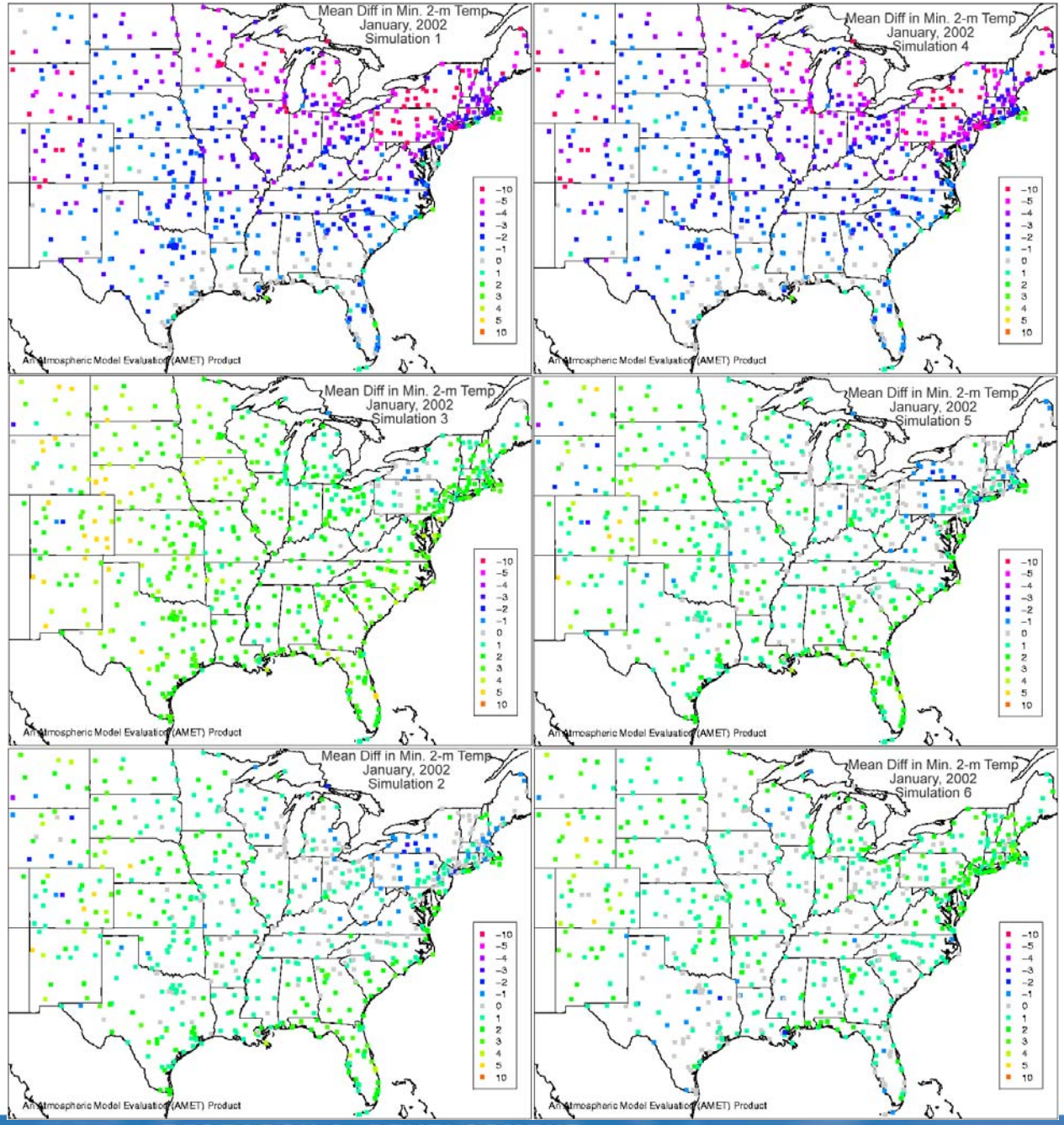
January 2002



Mean Min-Daily Difference

2-m Temperature (K)

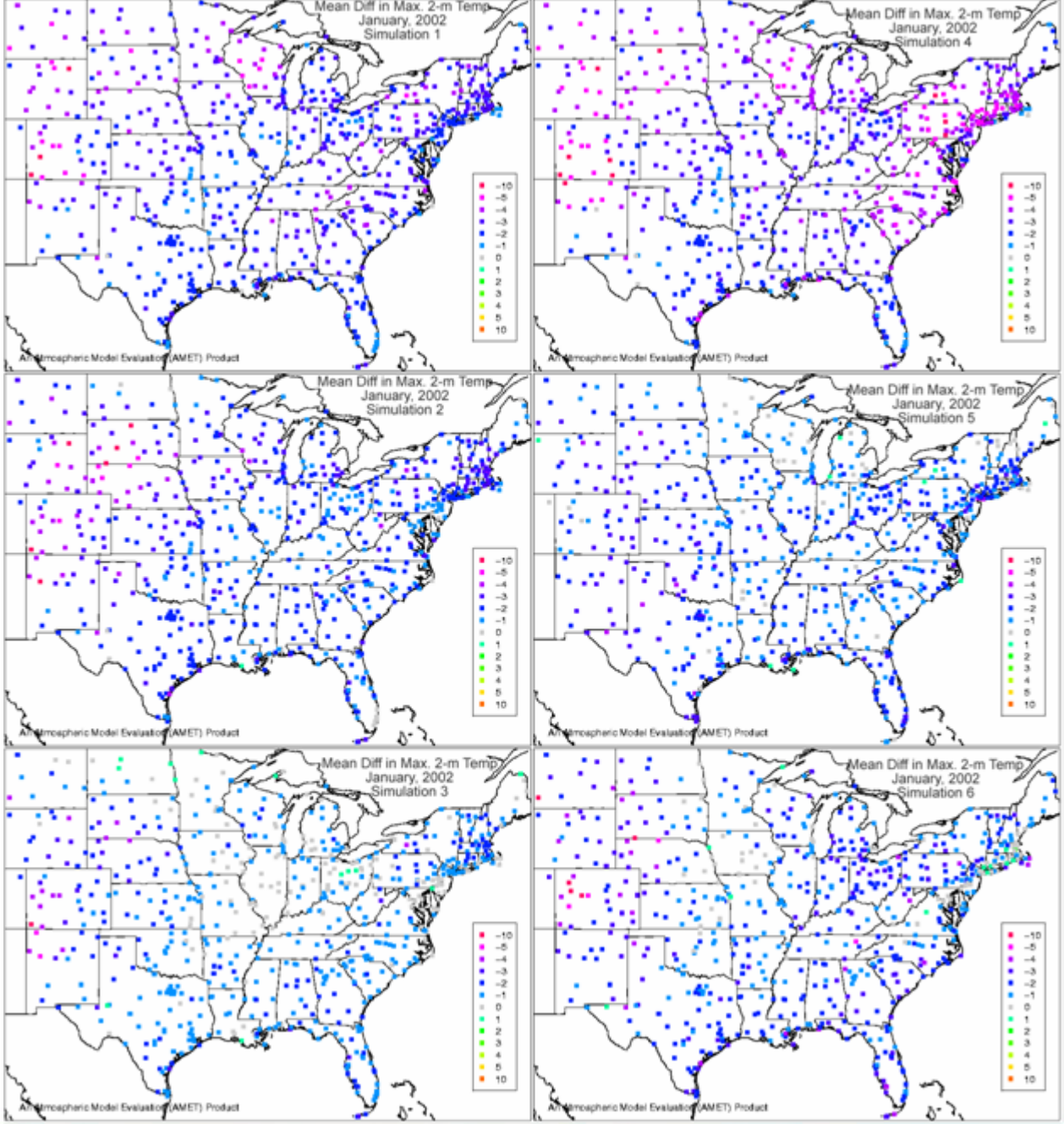
January 2002



Mean Max-Daily Difference

2-m Temperature (K)

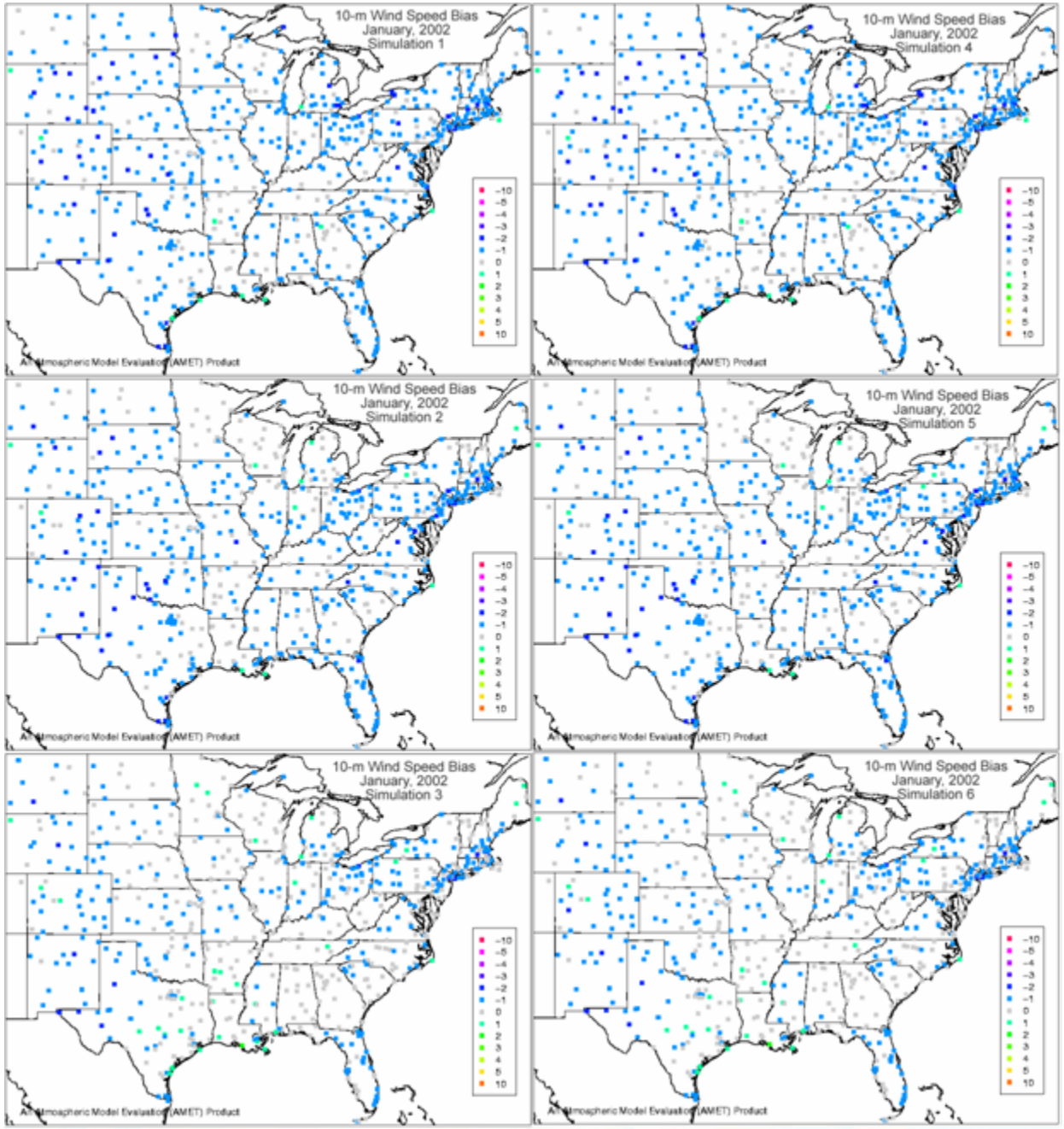
January 2002



Mean Bias

10-m Wind Speed (m/s)

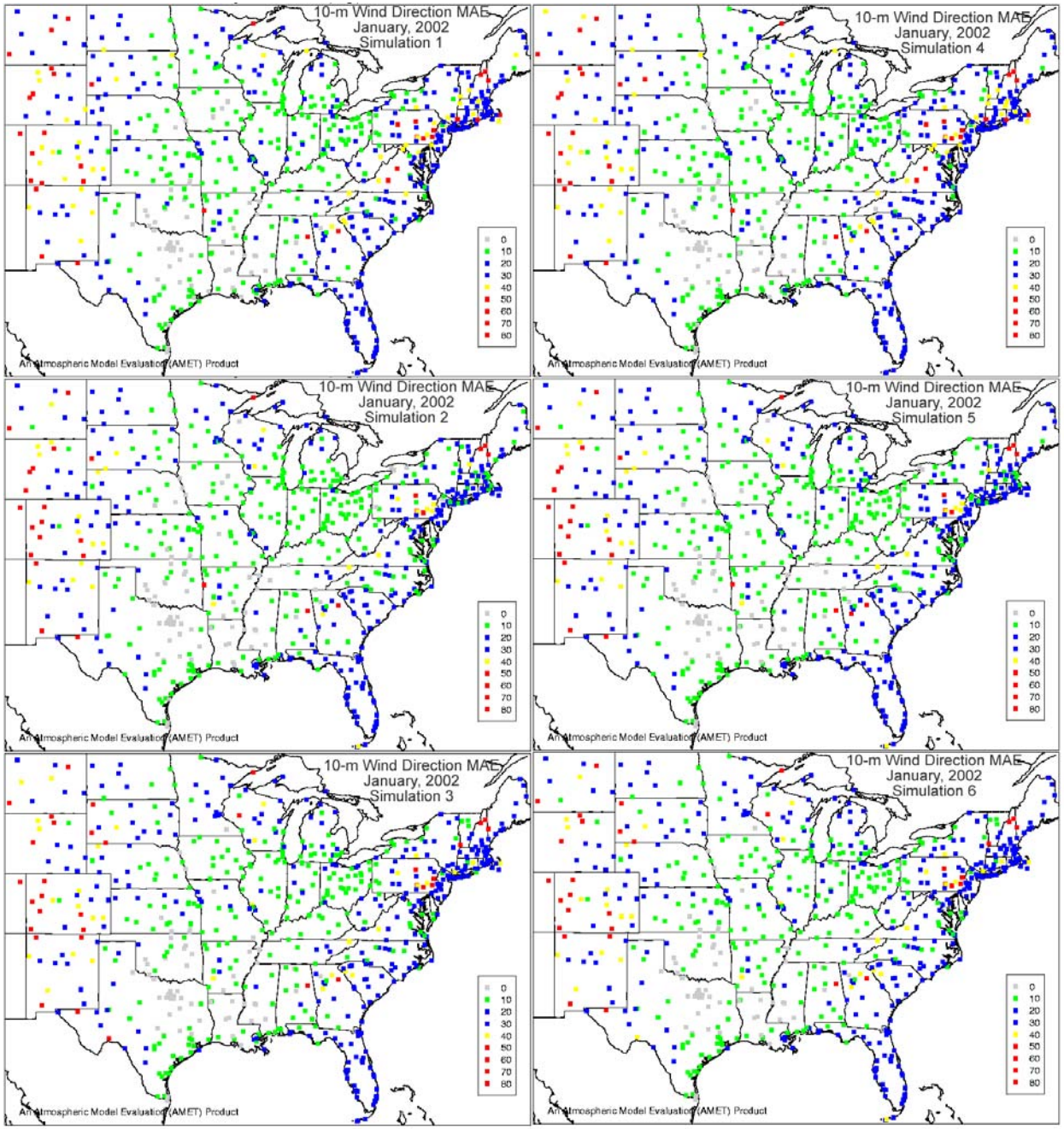
January, 2002



Mean Absolute Error

10-m Wind Direction (deg)

January, 2002

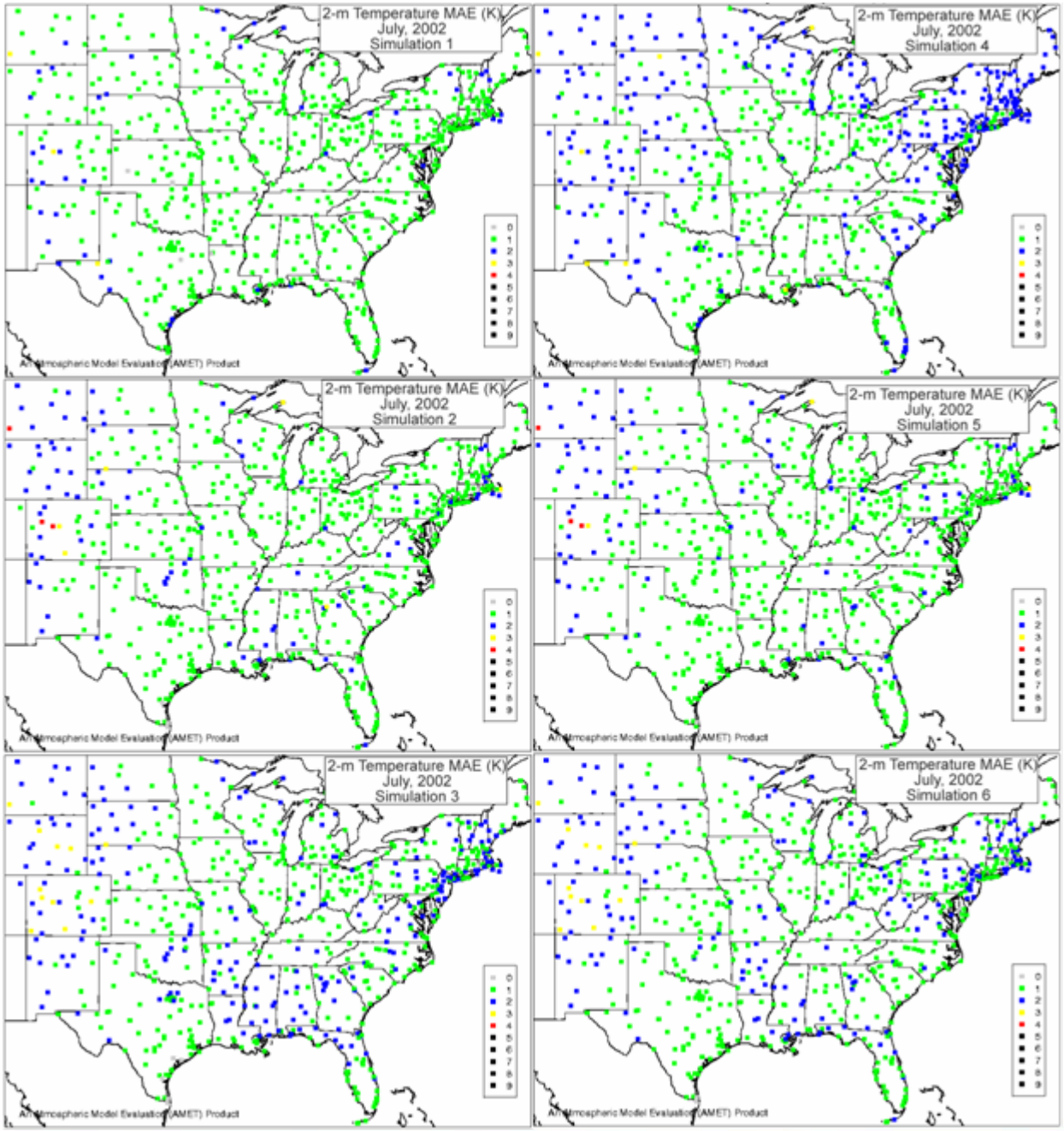


Monthly Spatial Statistics

July, 2002

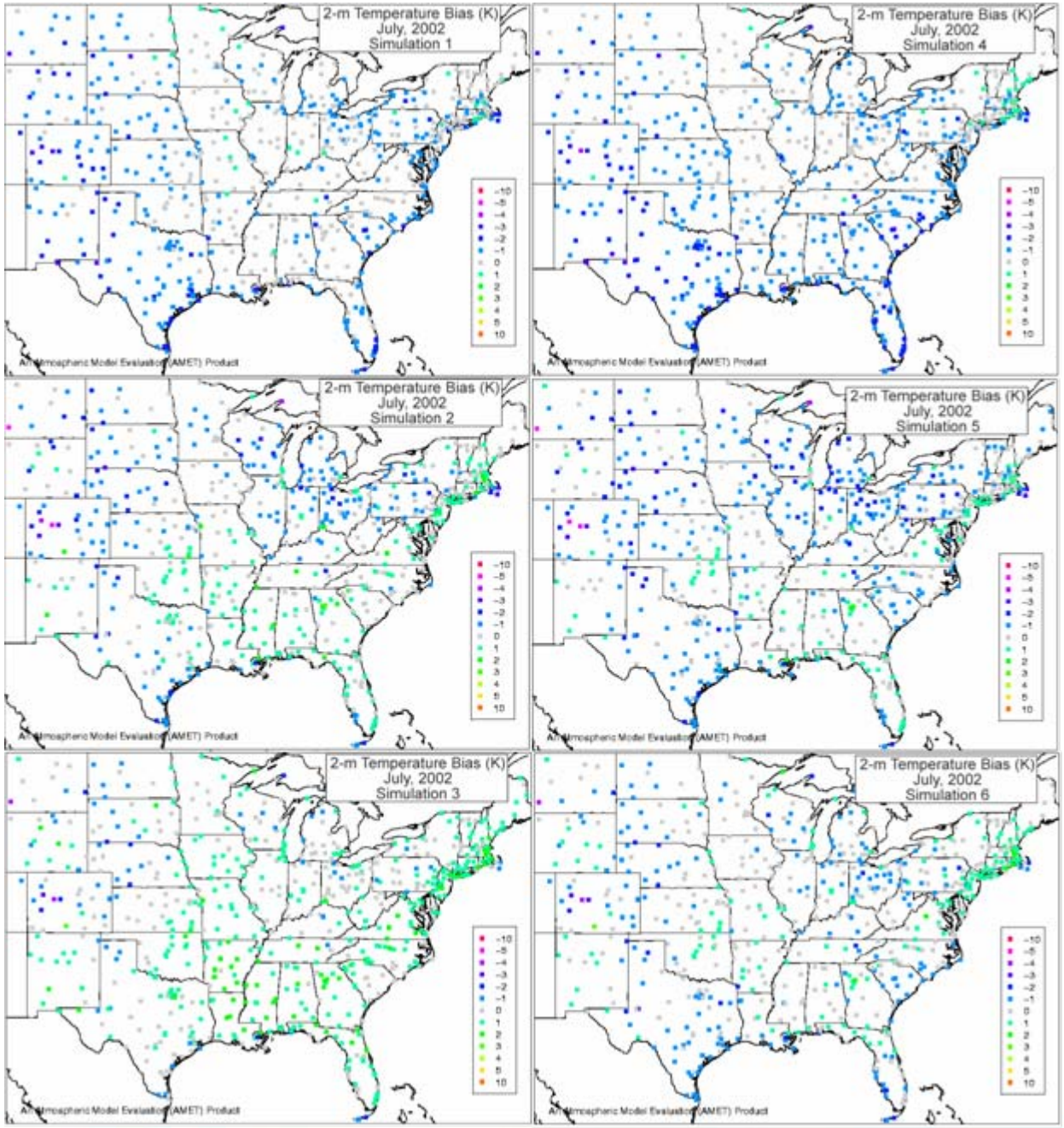
Mean Absolute Error (K)

July, 2002



Mean Bias (K)

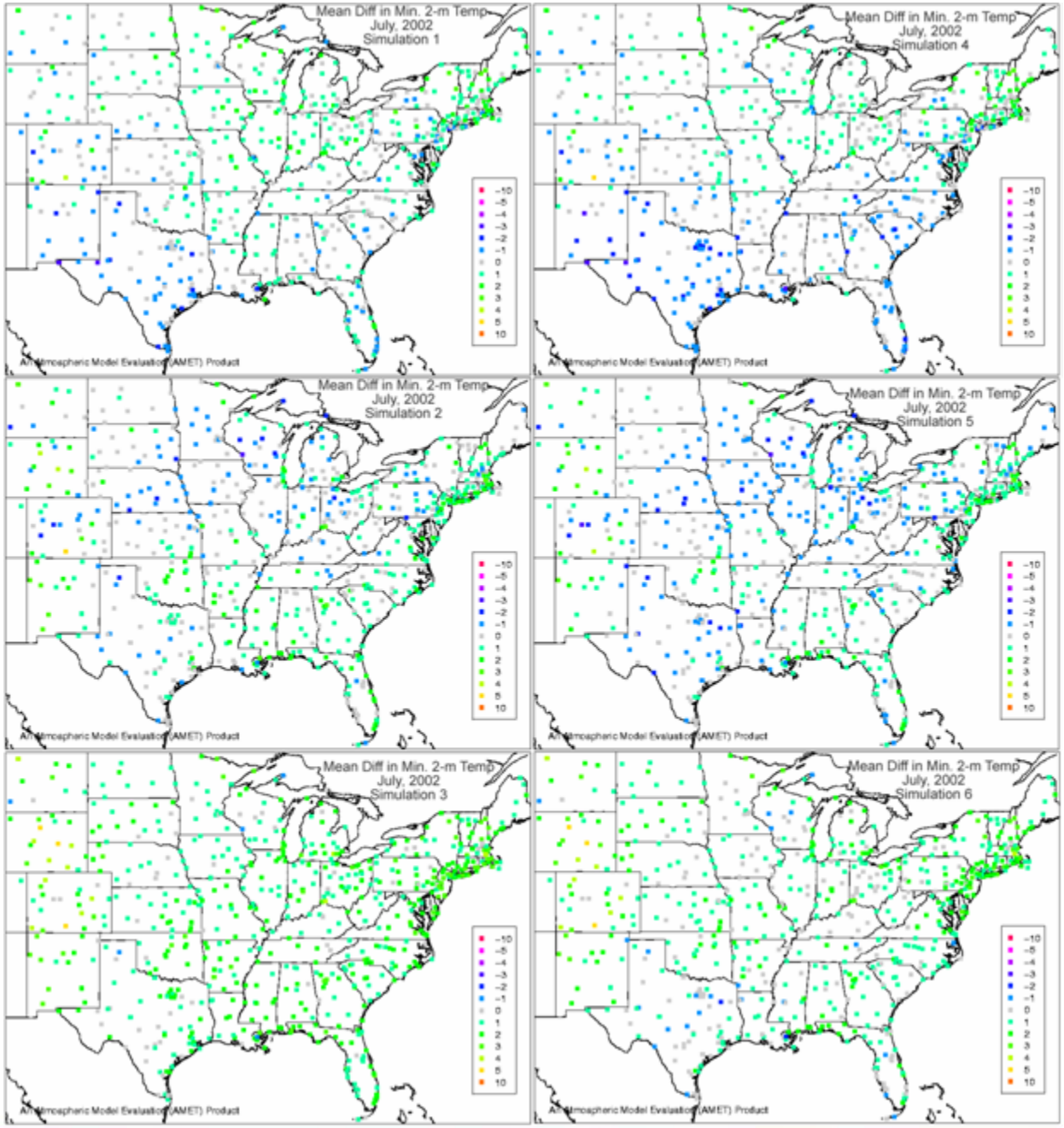
July, 2002



Mean Min-Daily Difference

2-m Temperature (K)

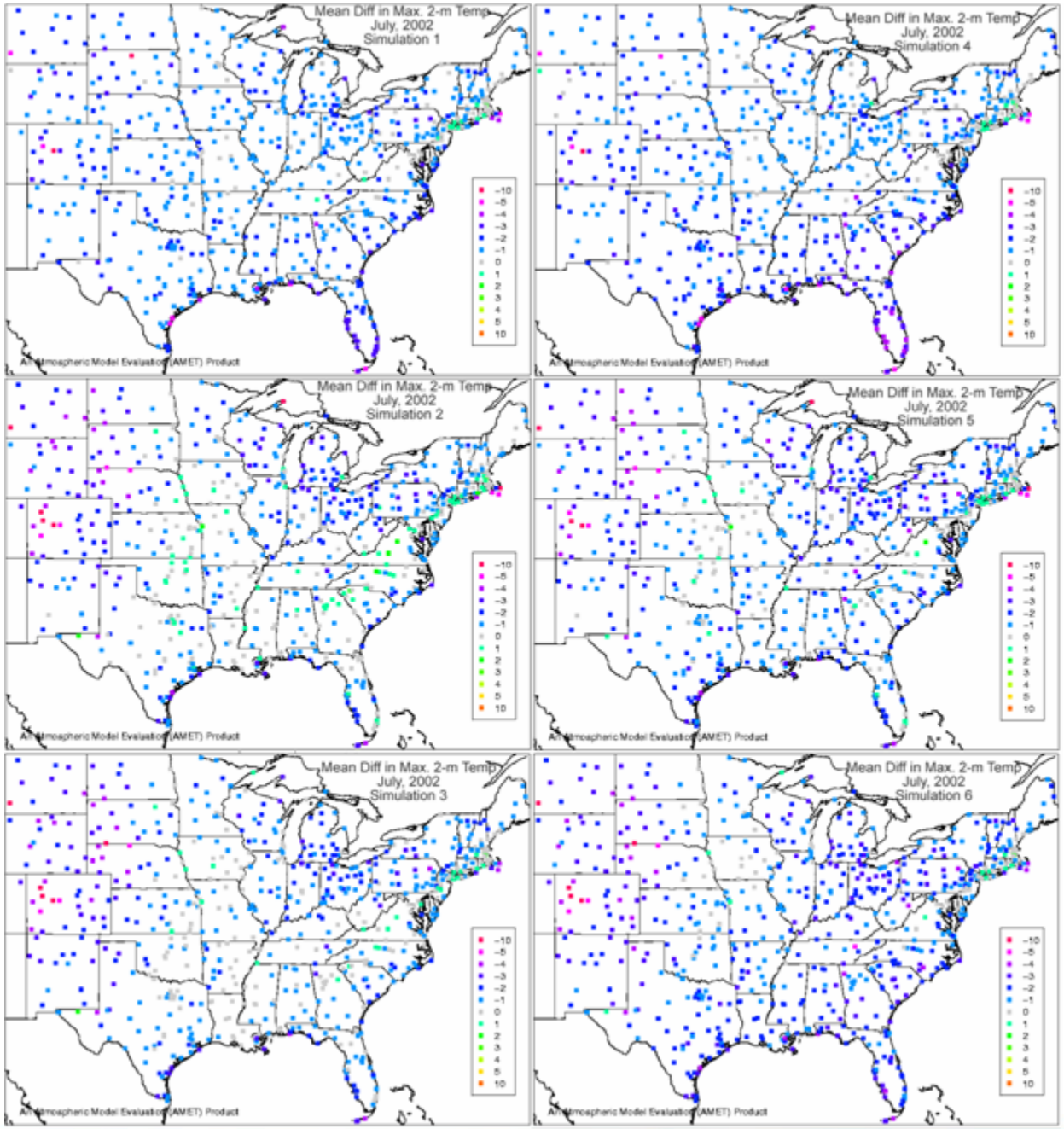
July, 2002



Mean Max-Daily Difference

2-m Temperature (K)

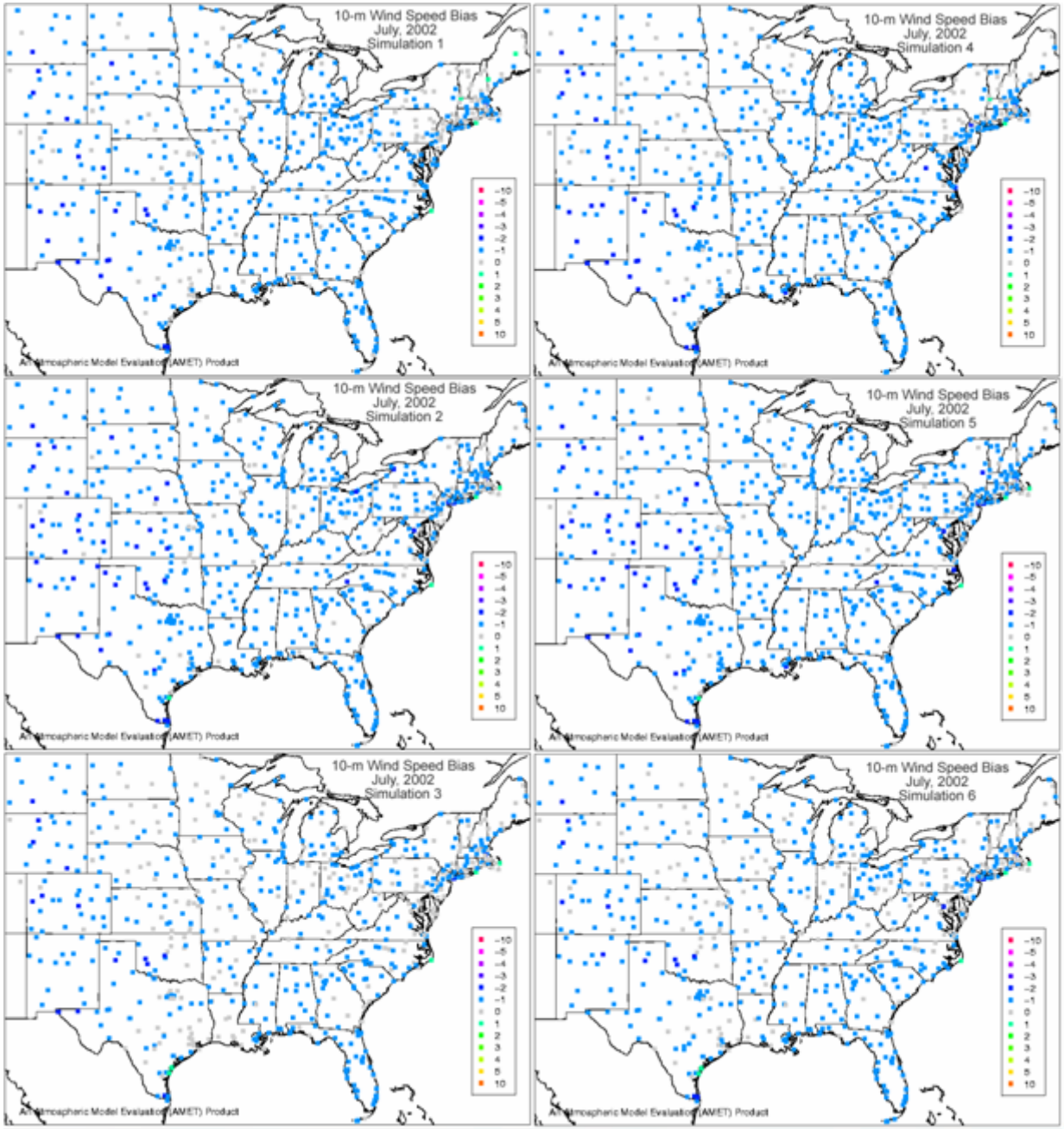
July, 2002



Mean Bias

10-m Wind Speed (m/s)

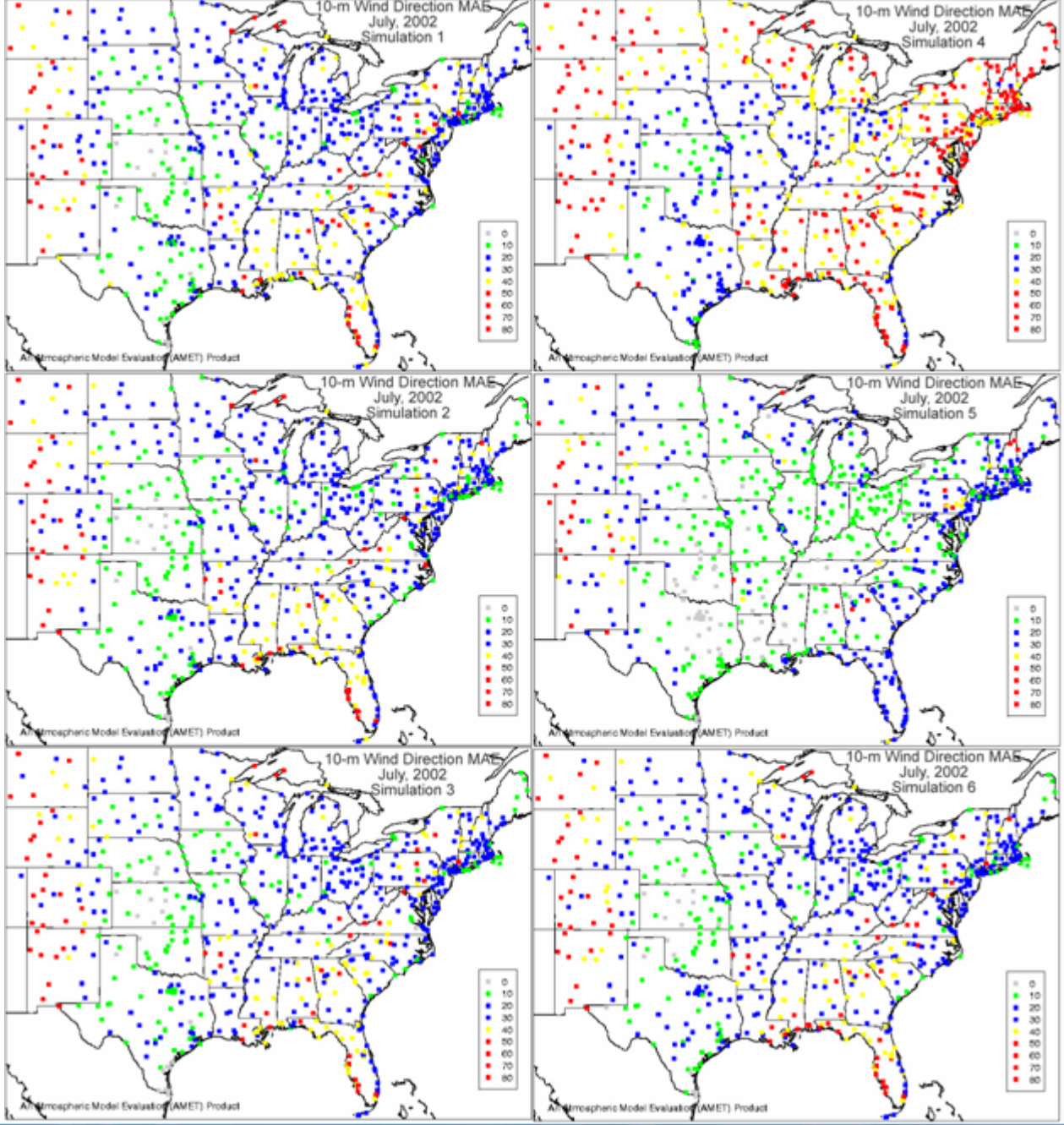
July, 2002



Mean Absolute Error

10-m Wind Direction (deg)

July, 2002



Summary of Surface-Based Statistics

- 2-m temperature predictions in winter contain more error in general than July; should AQ models be considered more uncertain in winter?
- Schemes have diverse diurnal performance and show systematic bias linked with PBL evolution
- Most runs do no capture daytime high temps in winter
- P-X has a large cold-season cold bias, but performs best in warm seasons
- NOAH/MYJ performed best in winter in terms of temp bias, but does have a substantial diurnal bias
- FDDA does constrain simulated wind to observations, although wind speed bias does exist; good for transport.

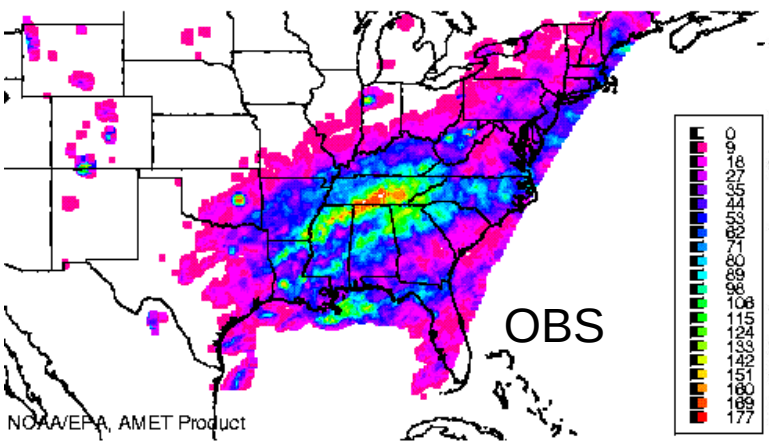
Summary of Surface-Based Statistics

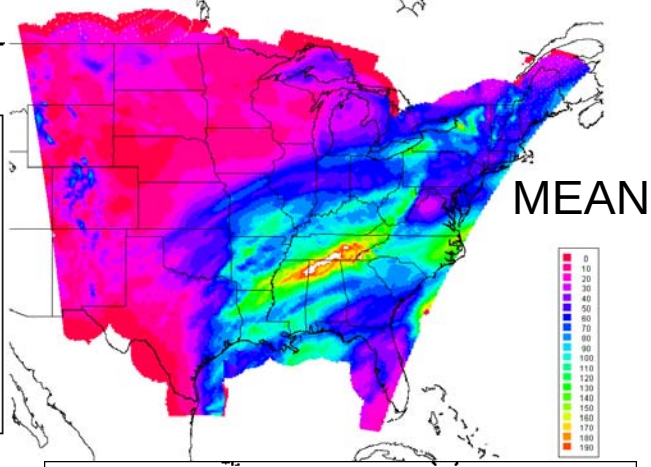
- Place holder

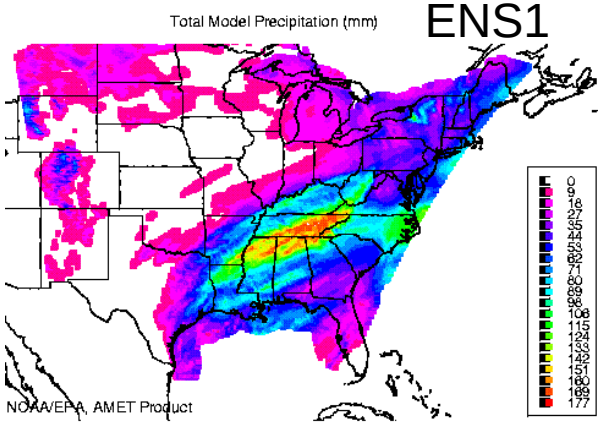
Statistical Analysis

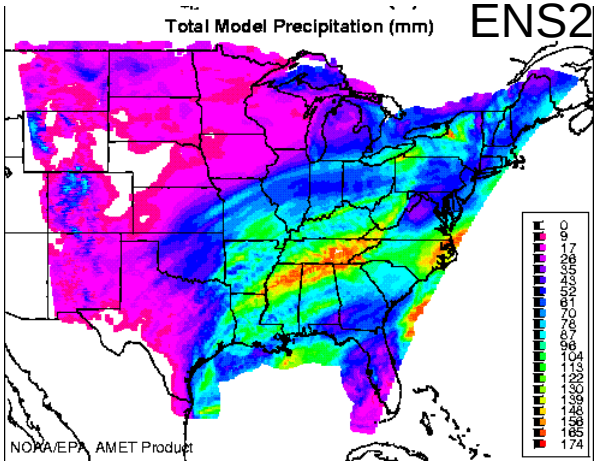
Precipitation

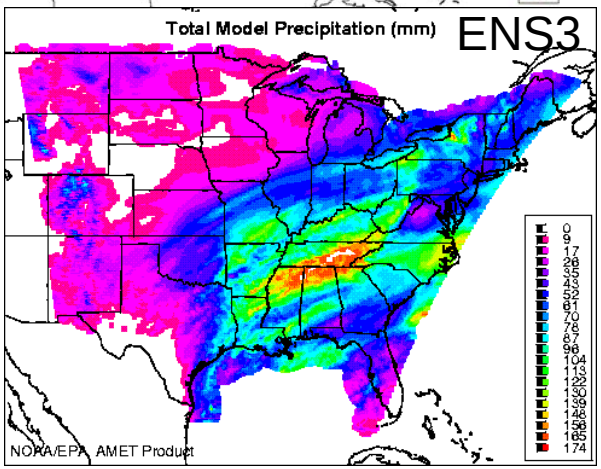
Total Precipitation (mm)
Jan, 2002

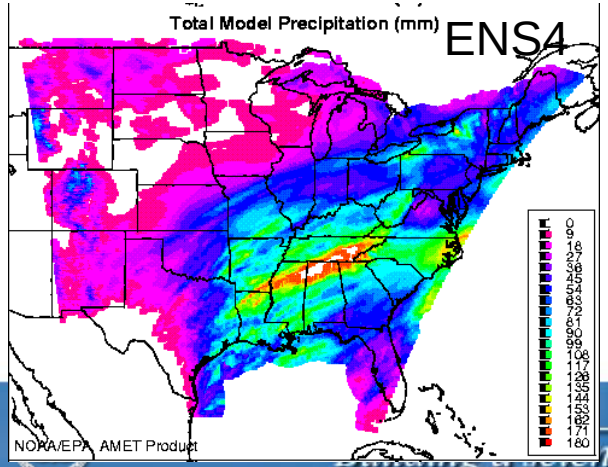


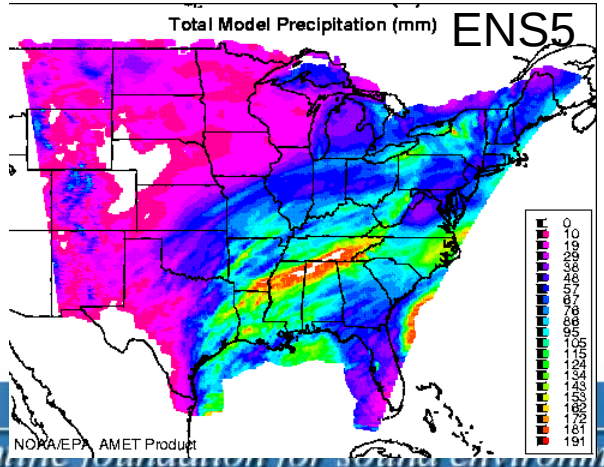


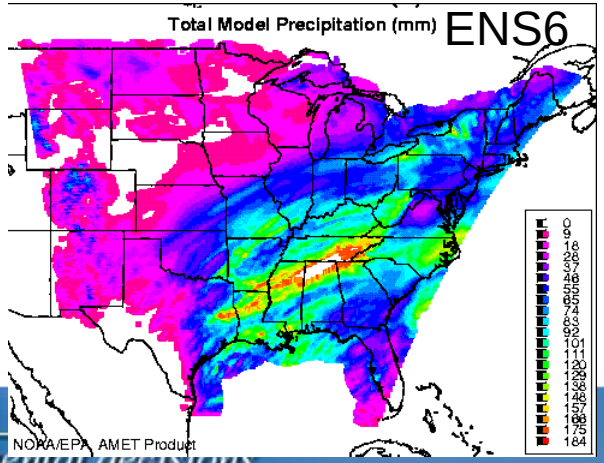




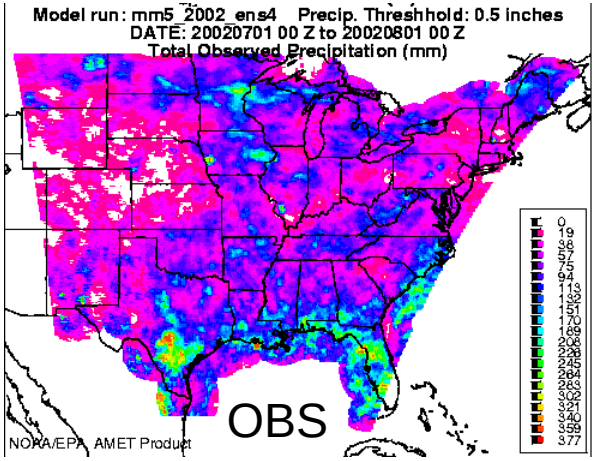


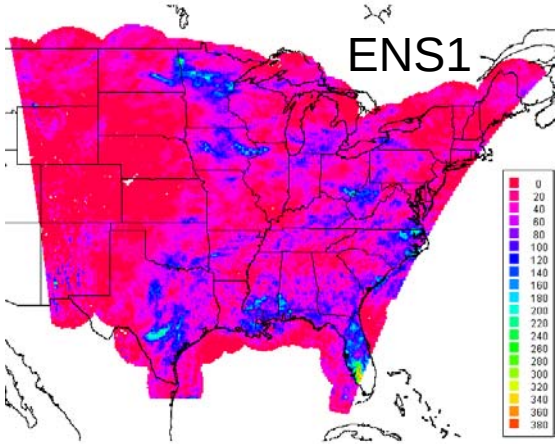


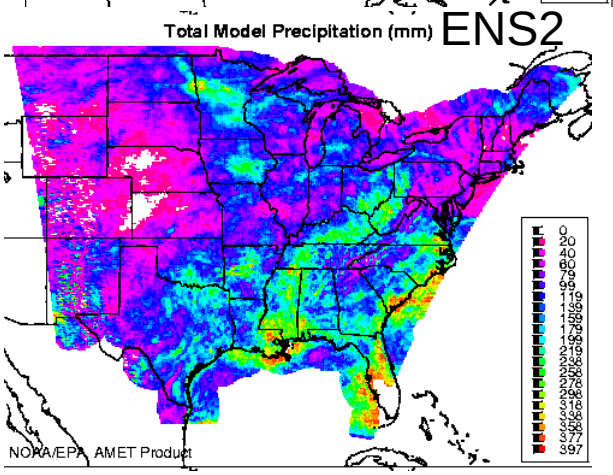


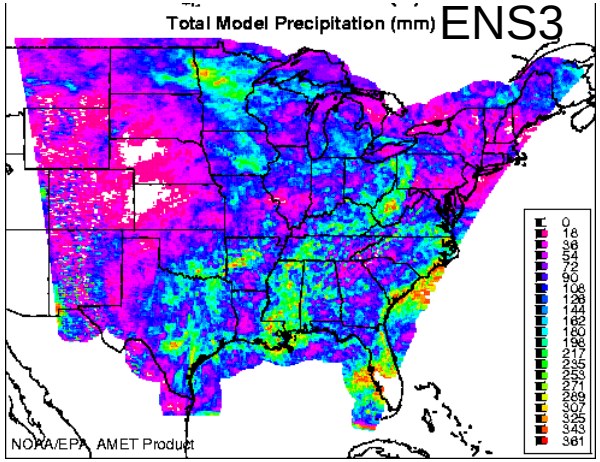


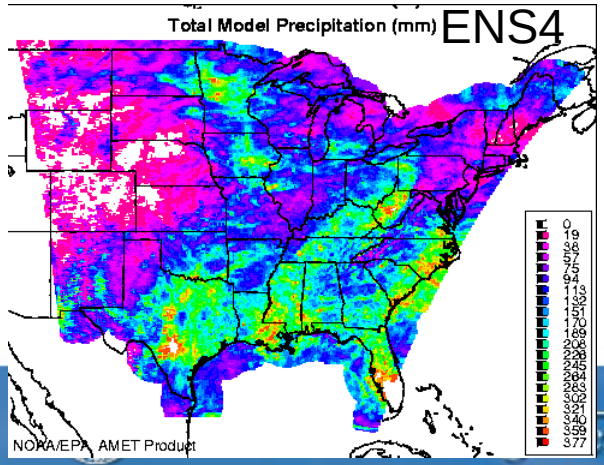
Total Precipitation (mm)
July, 2002

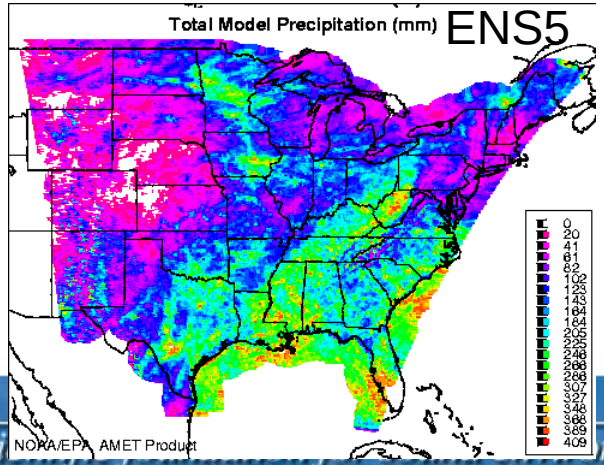


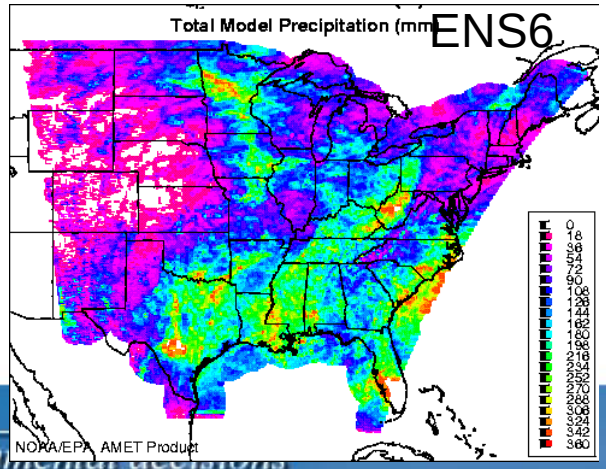








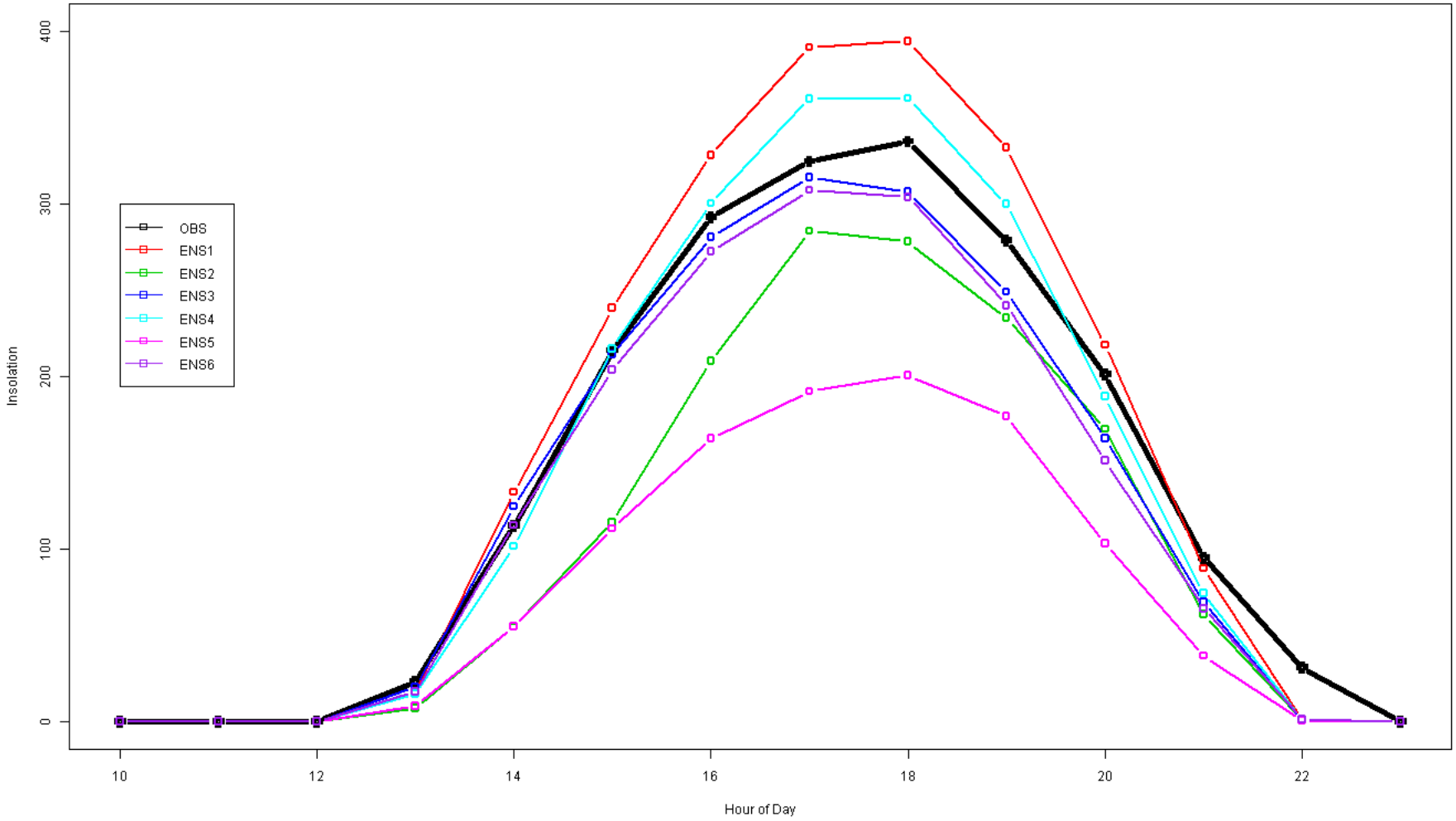




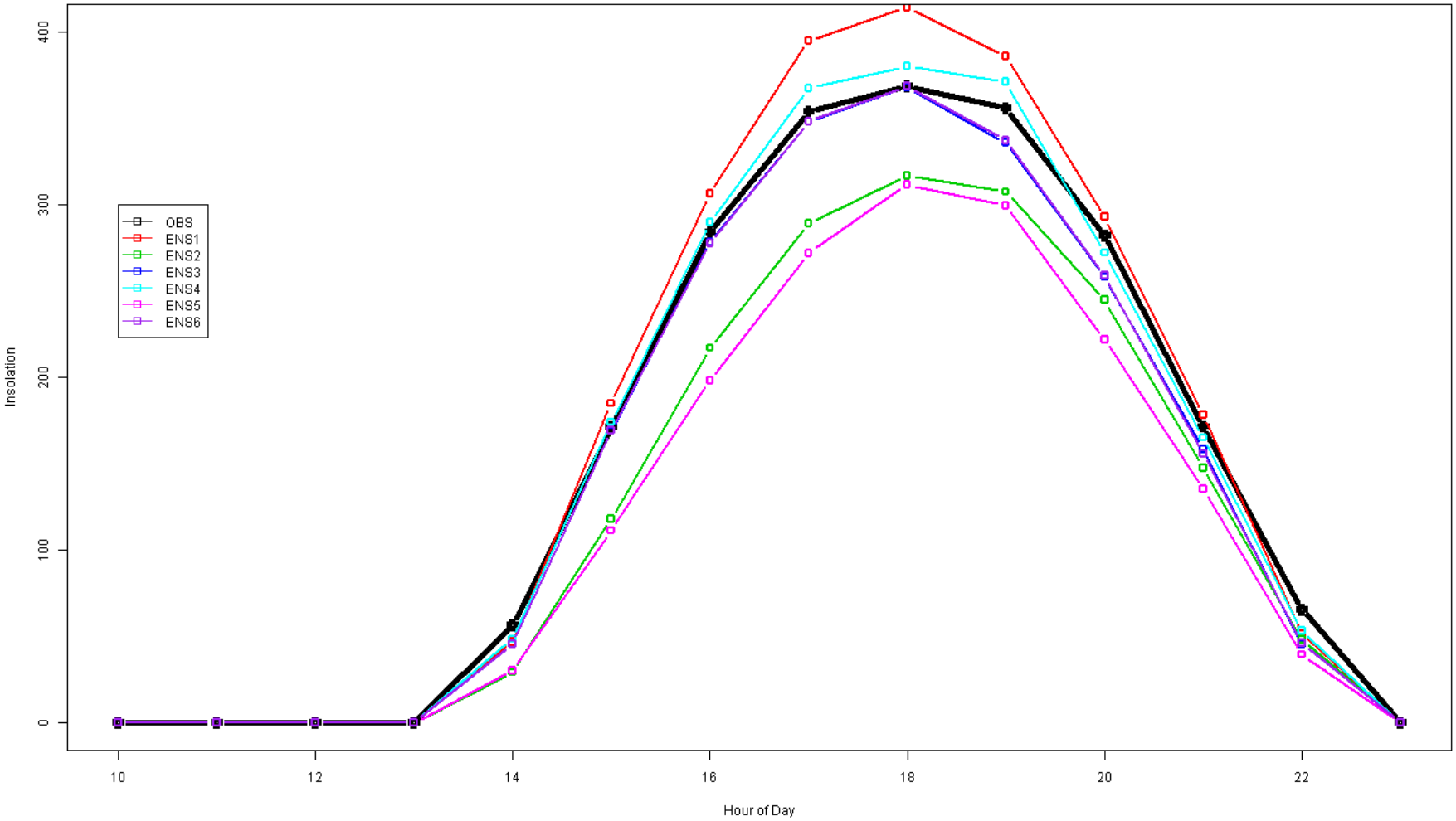
Solar Radiation Analysis

Comparison of model insolation and SurfRAD observations

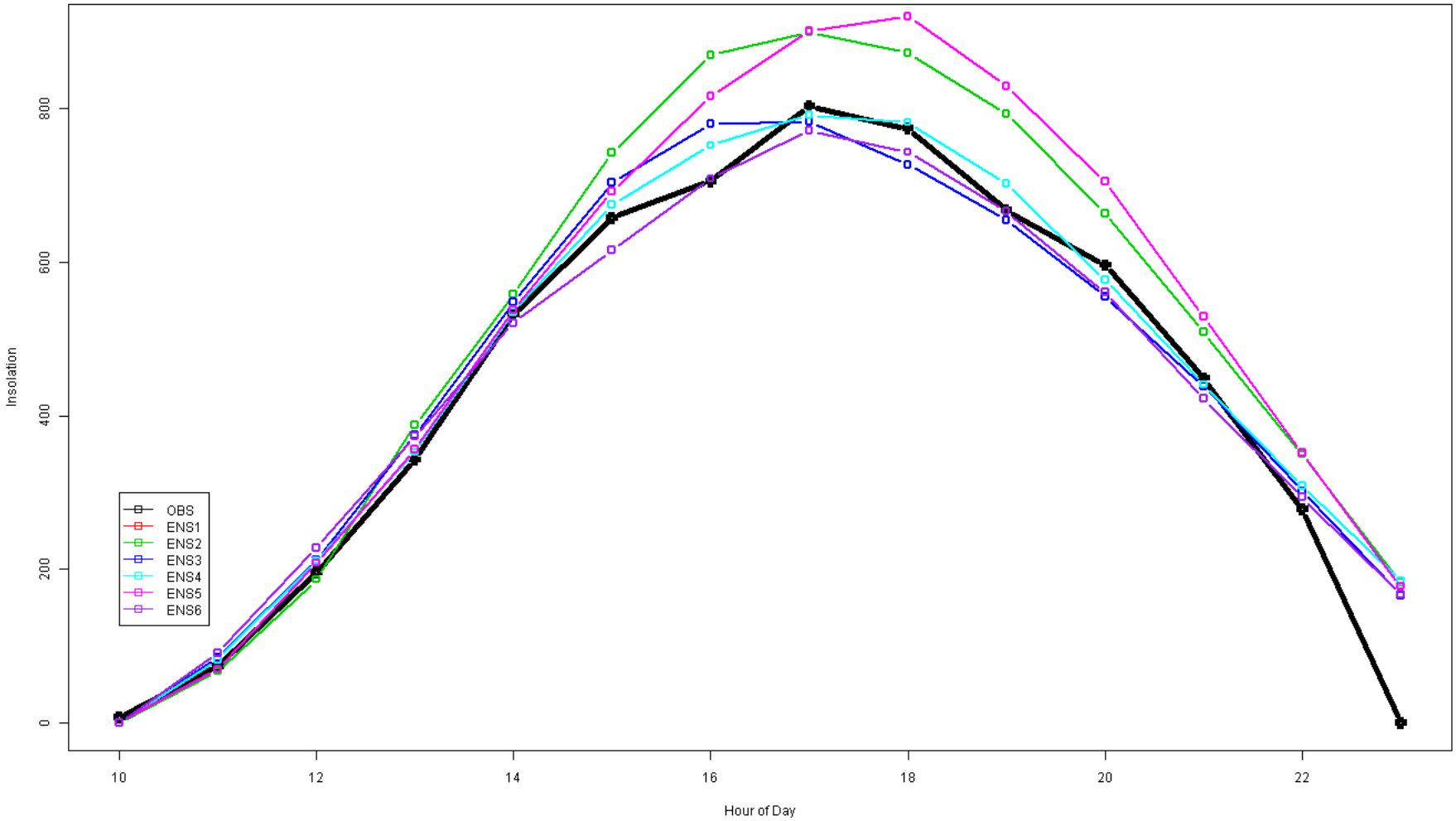
Penn State Jan, 2002



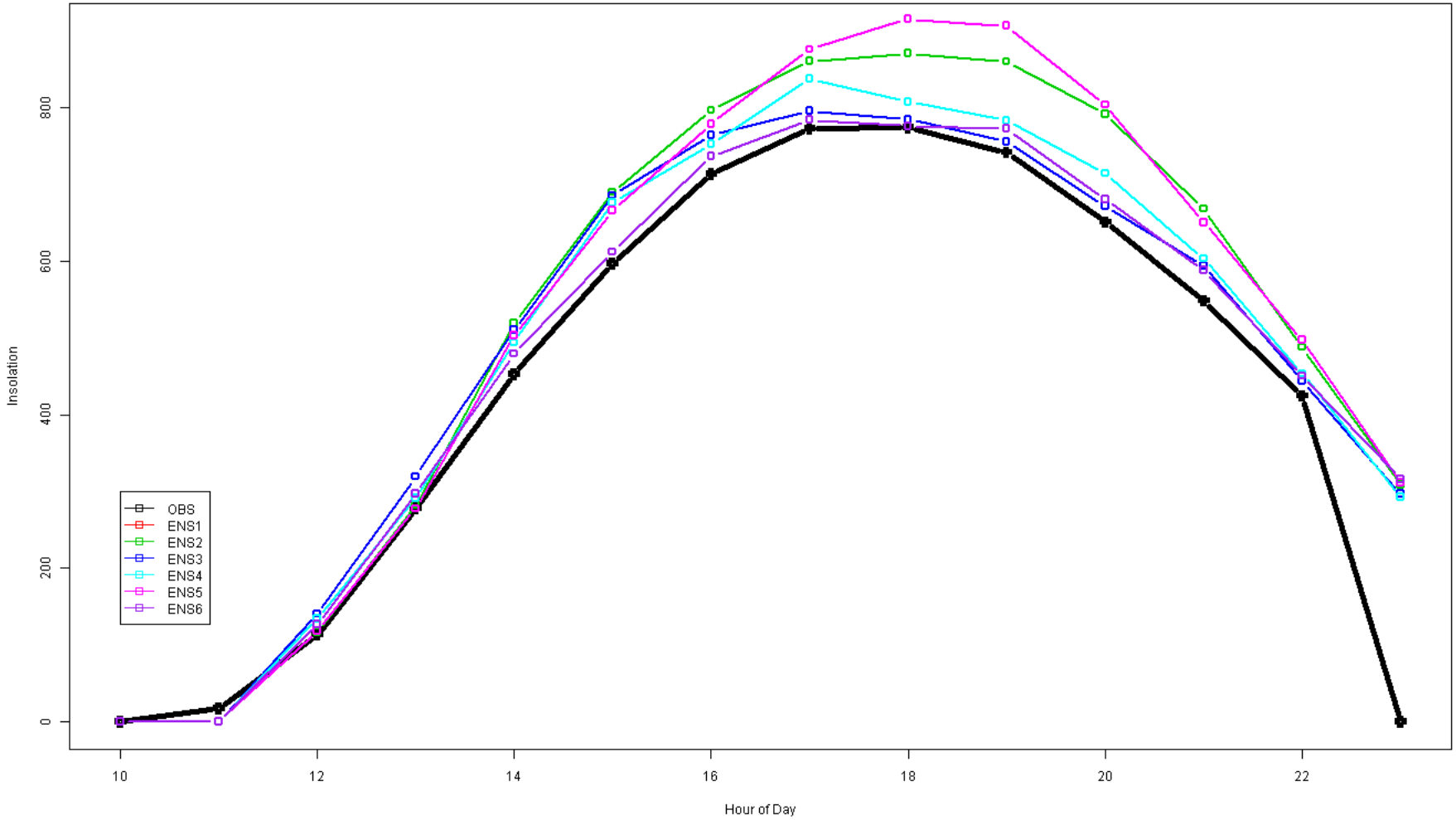
Illinois Jan, 2002



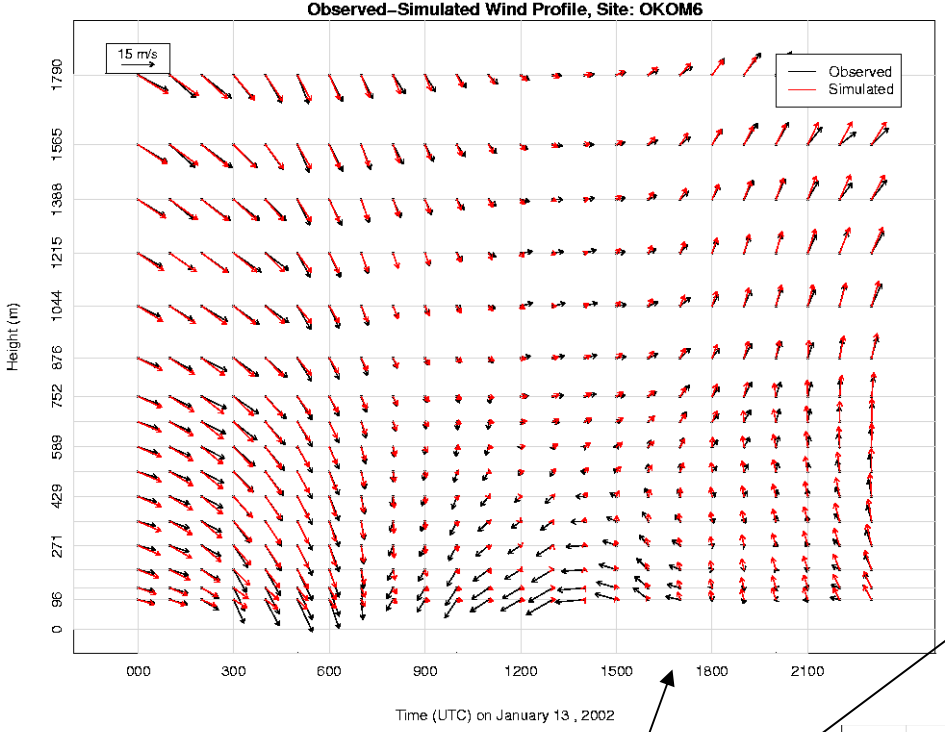
Penn State July, 2002

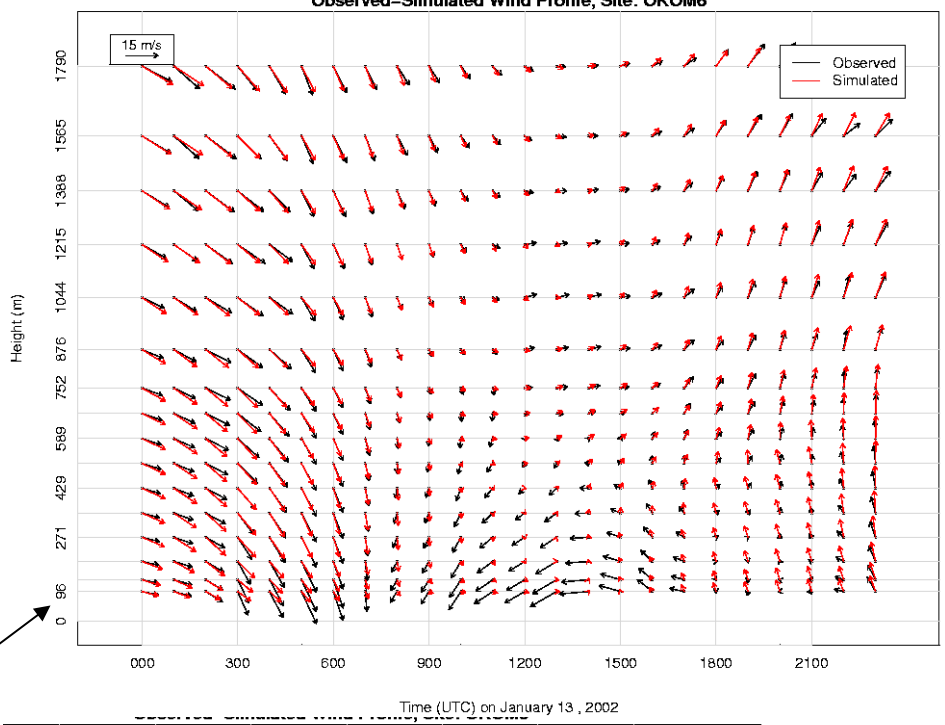


Illinois July, 2002



Daily Wind Profiles Comparisons

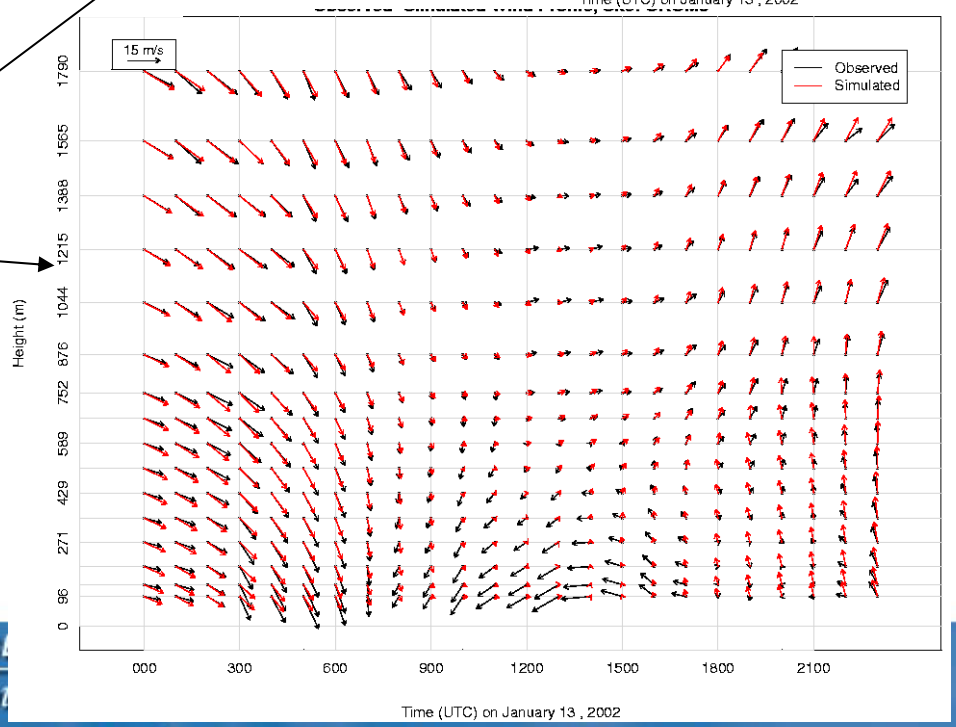




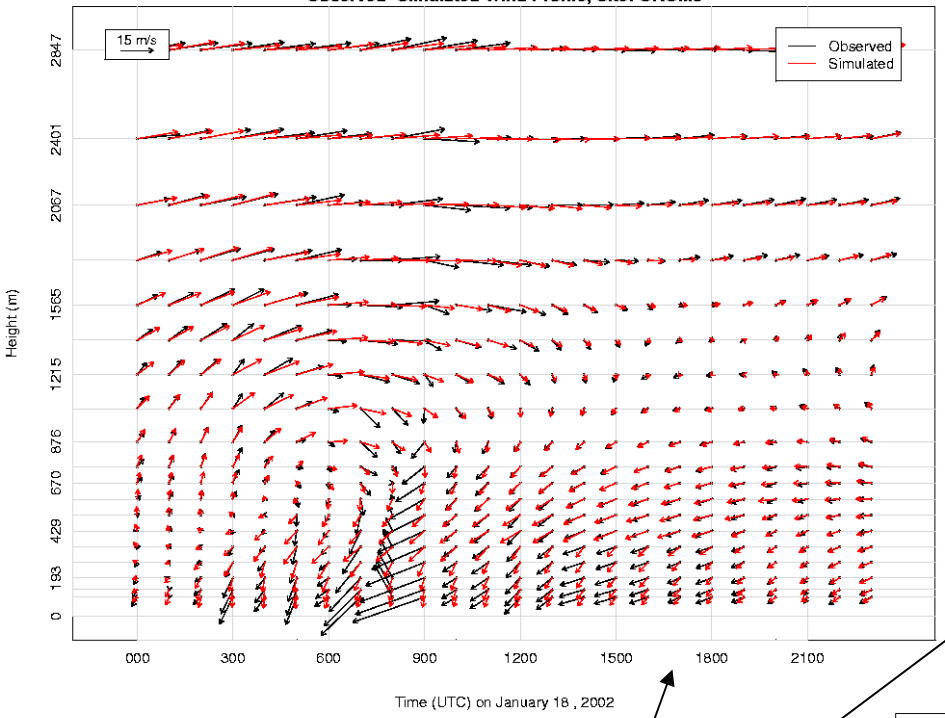
P-X

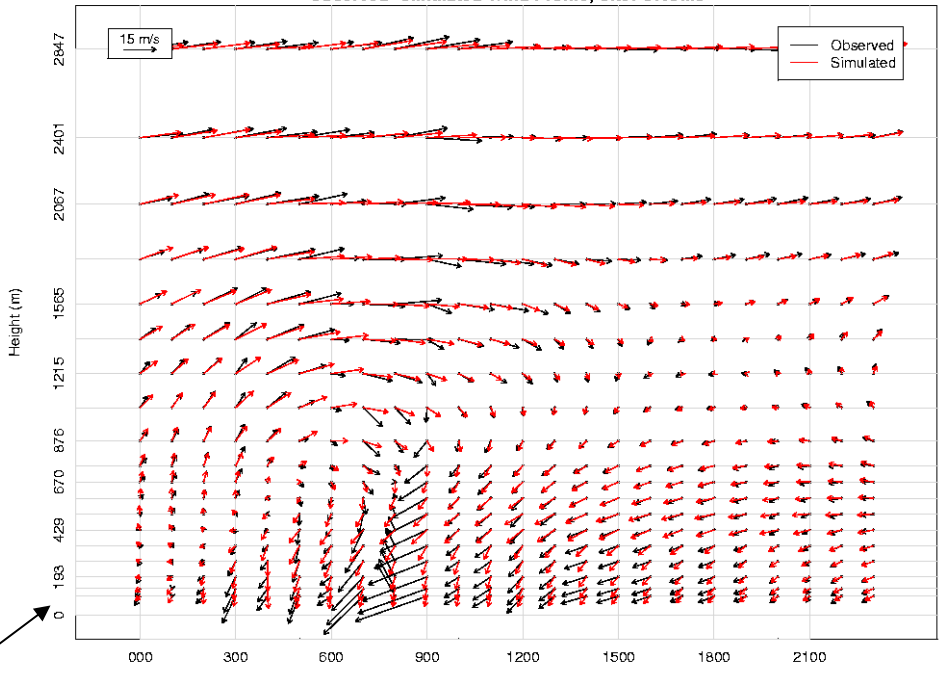
Eta-NOAH

MRF-NOAH



Winter "Fair Weather" Example, Jan. 13, 2002

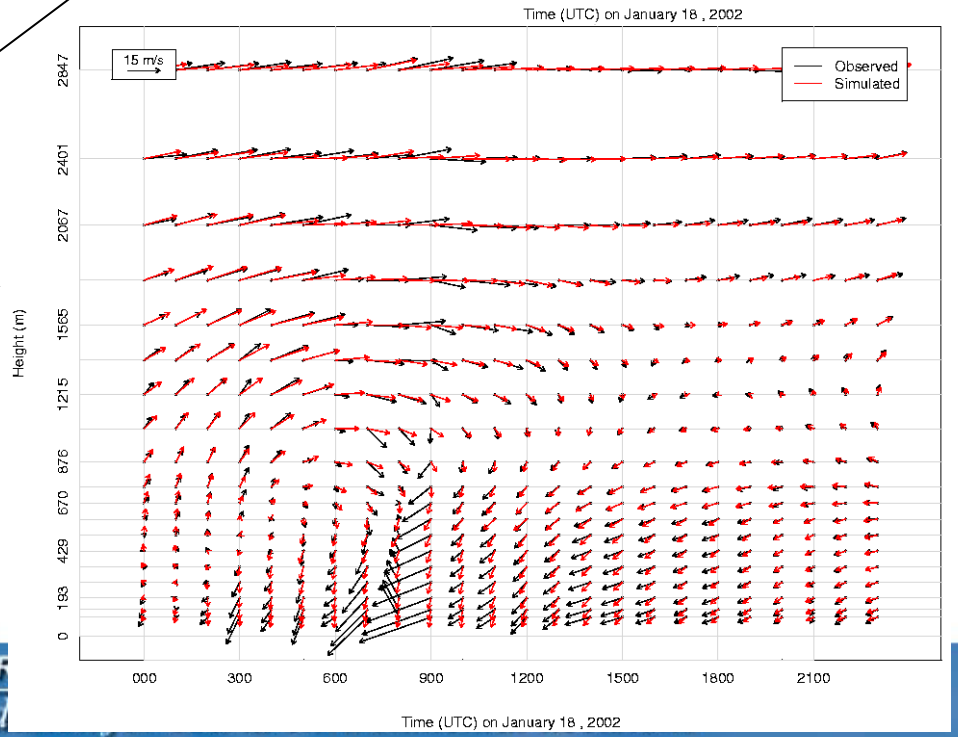




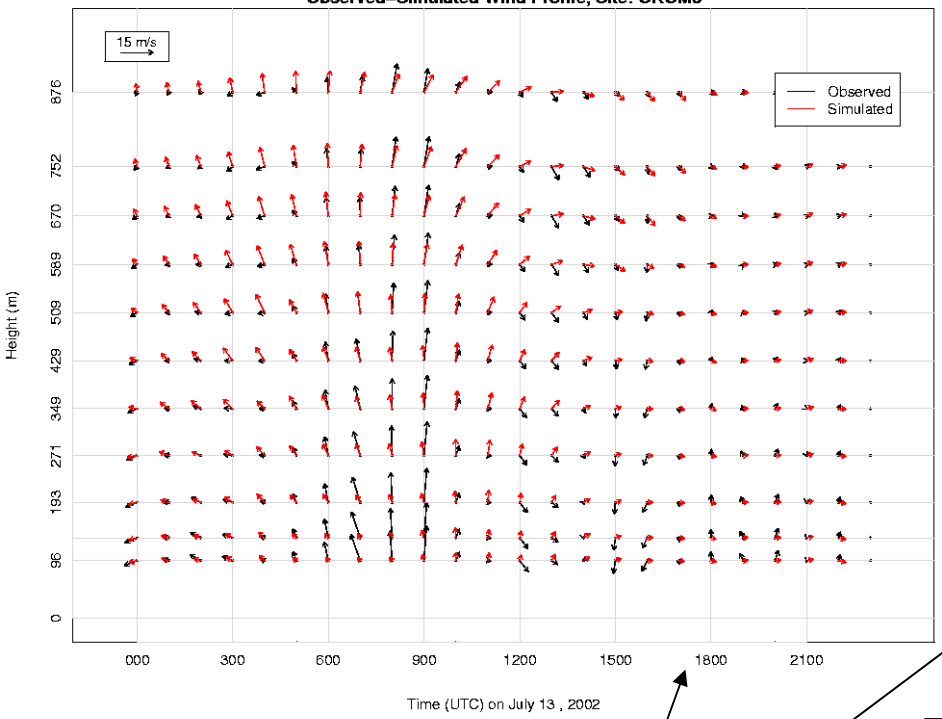
P-X

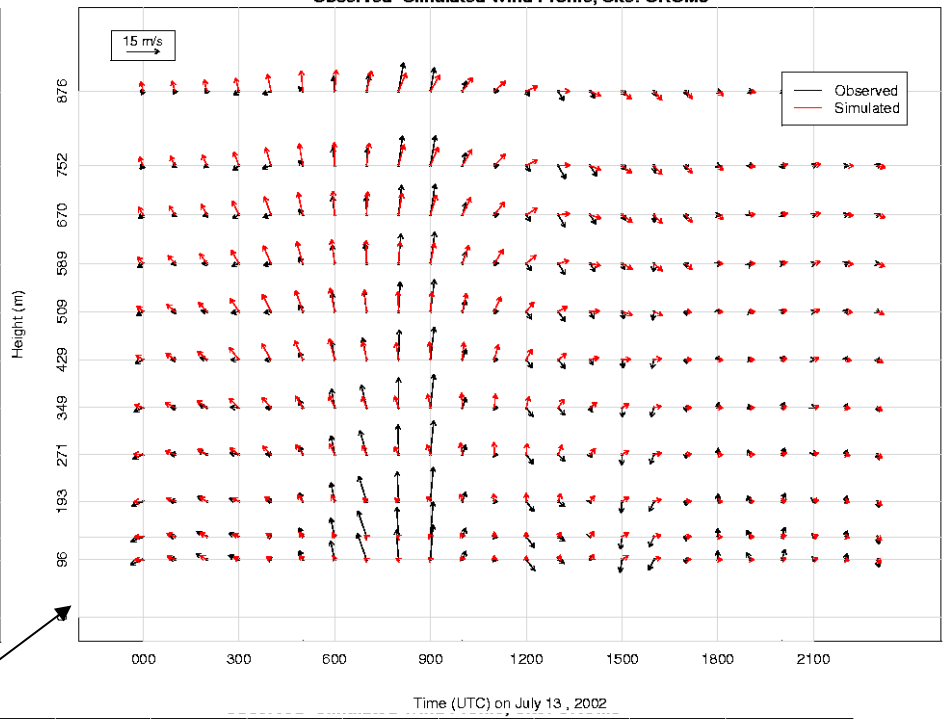
Eta-NOAH

MRF-NOAH



Winter "Disturbed Weather" Example, Jan. 18, 2002

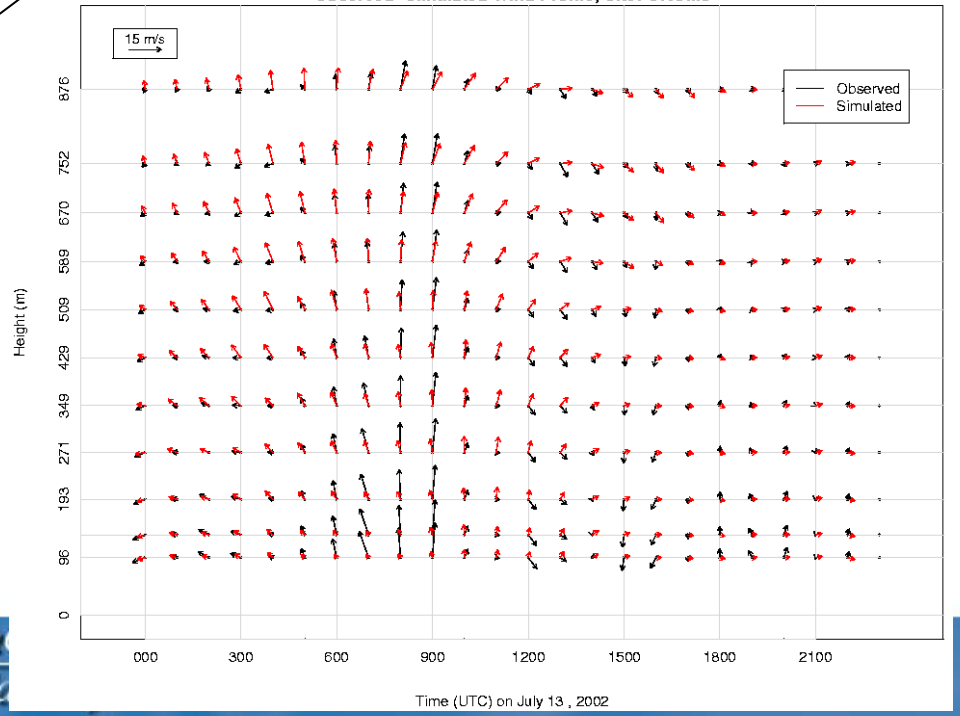




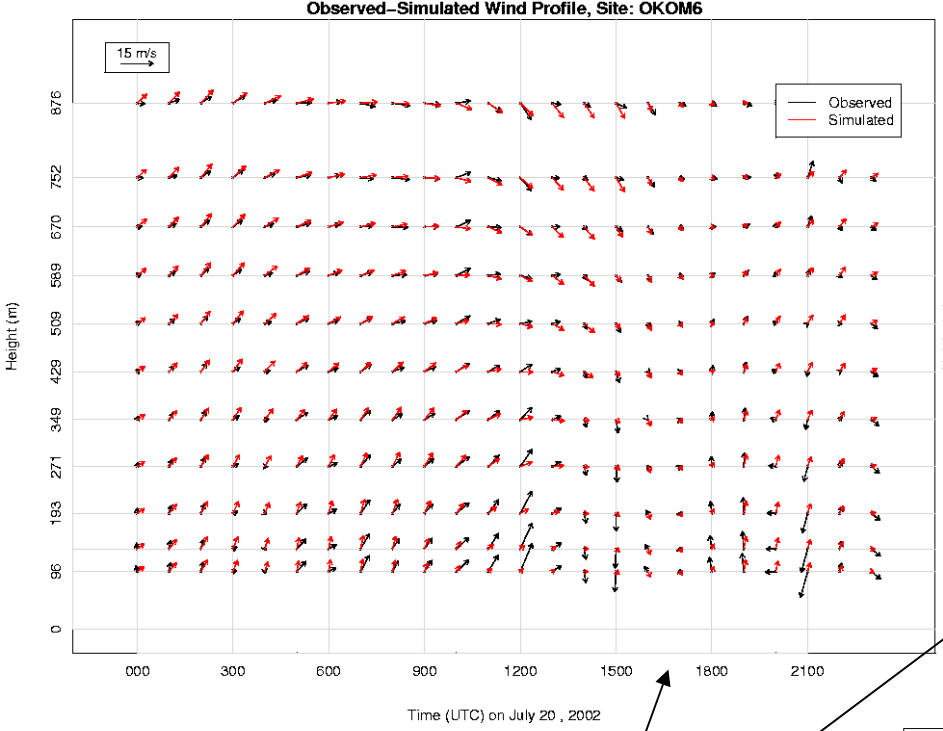
P-X

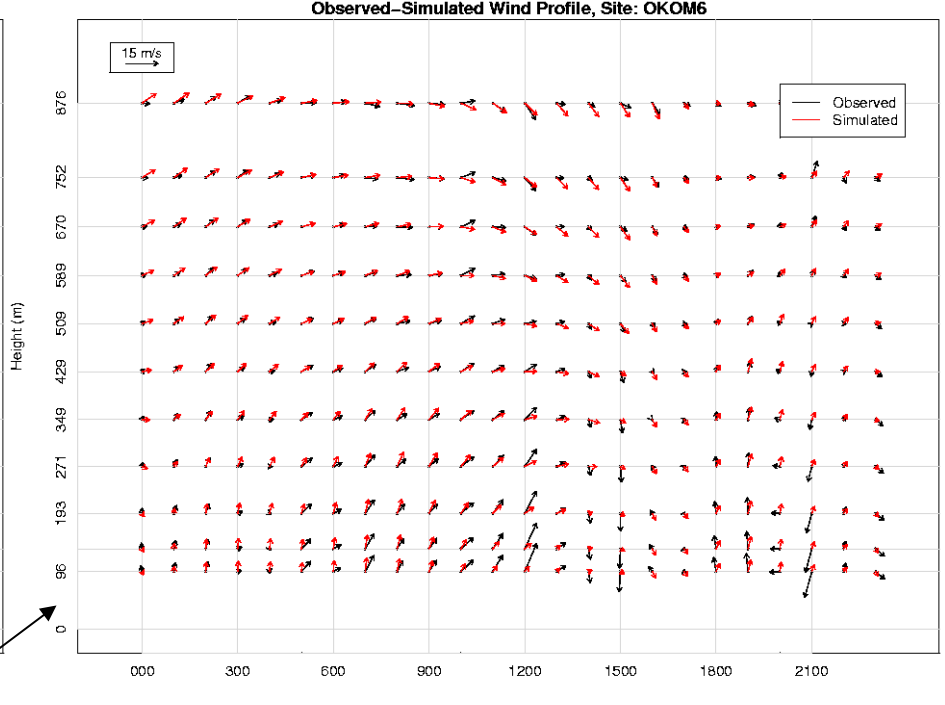
Eta-NOAH

MRF-NOAH



Summer "Fair Weather" Example, July 13, 2002

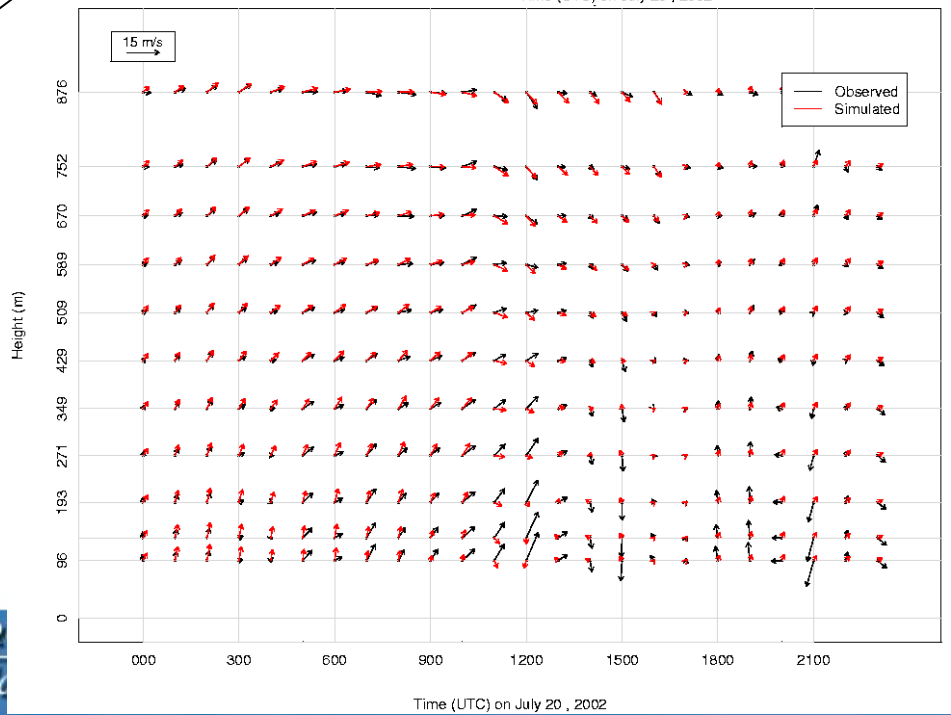




P-X

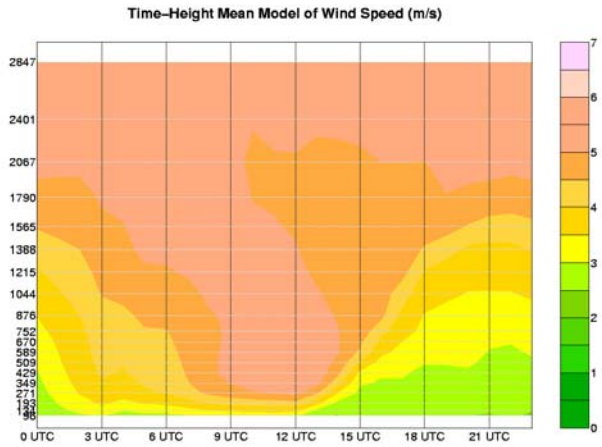
Eta-NOAH

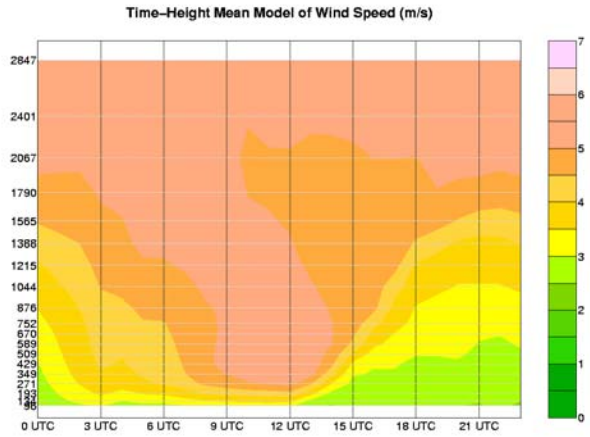
MRF-NOAH

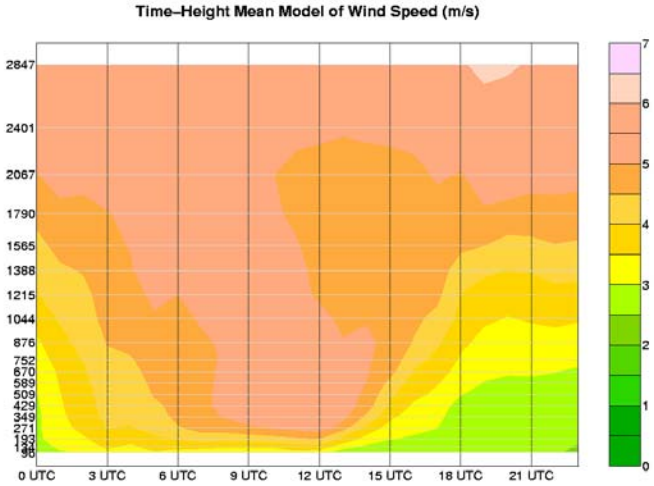


Summer "Disturbed Weather" Example, Jan. 20, 2002

Mean Wind Speed



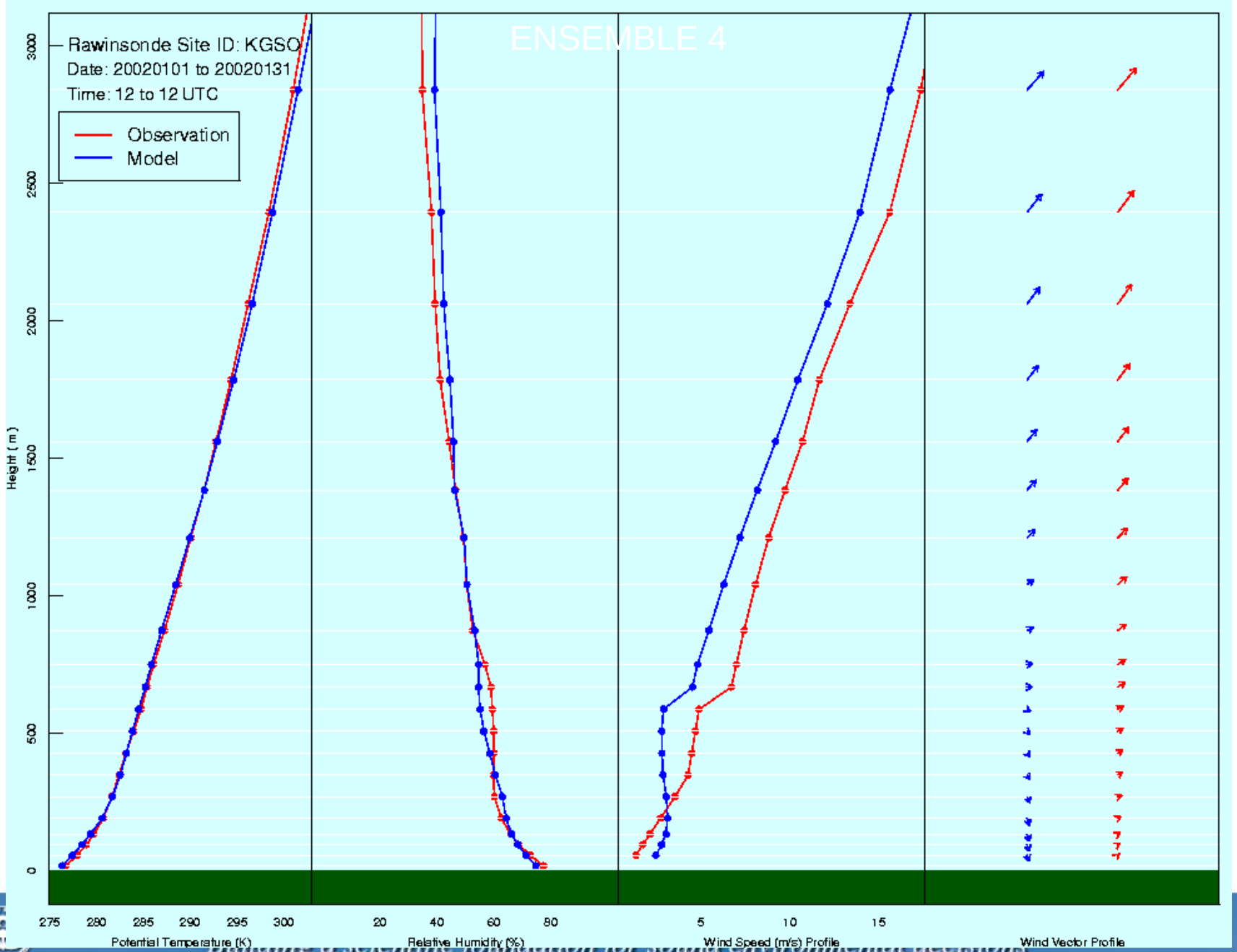




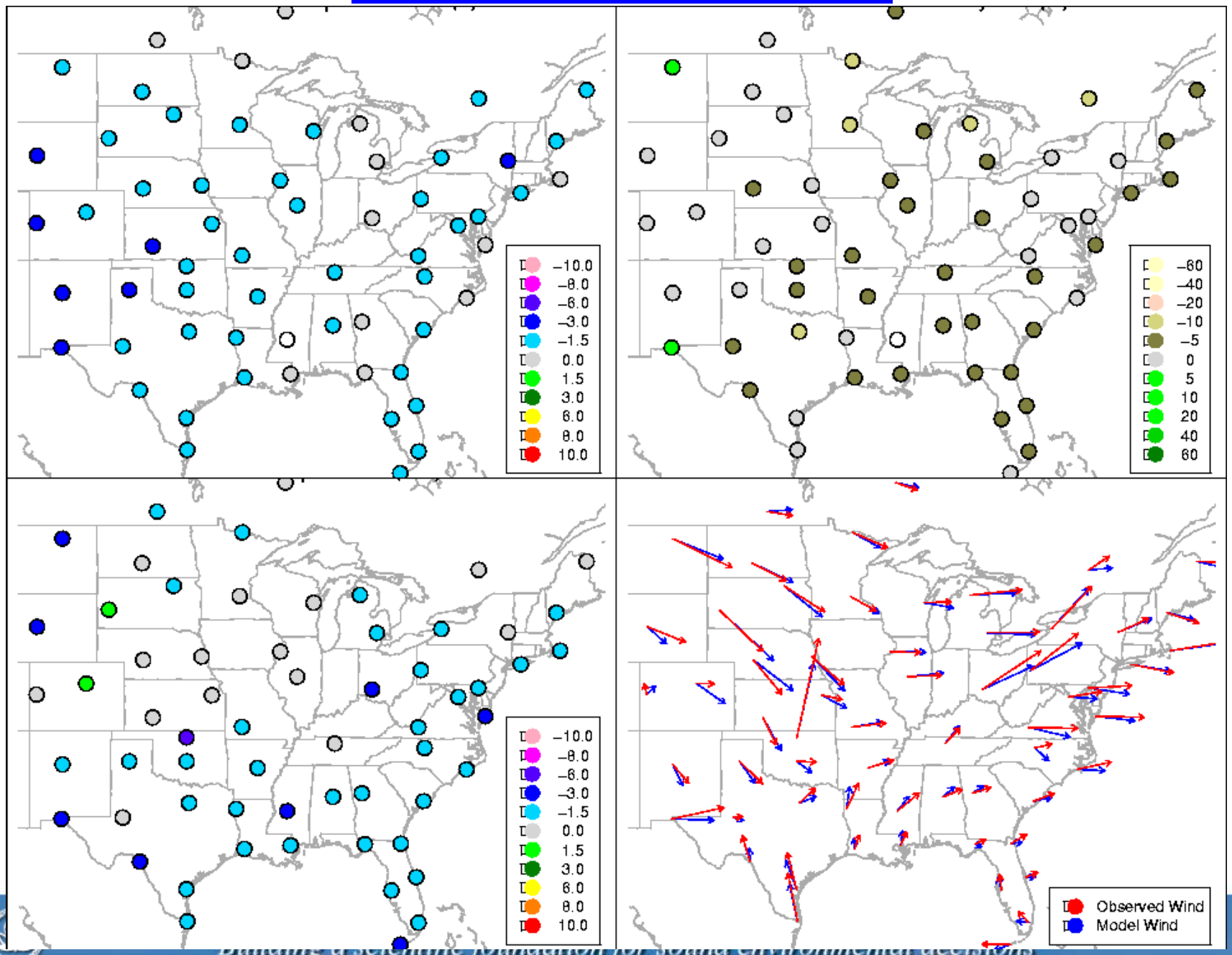
Statistical Analysis

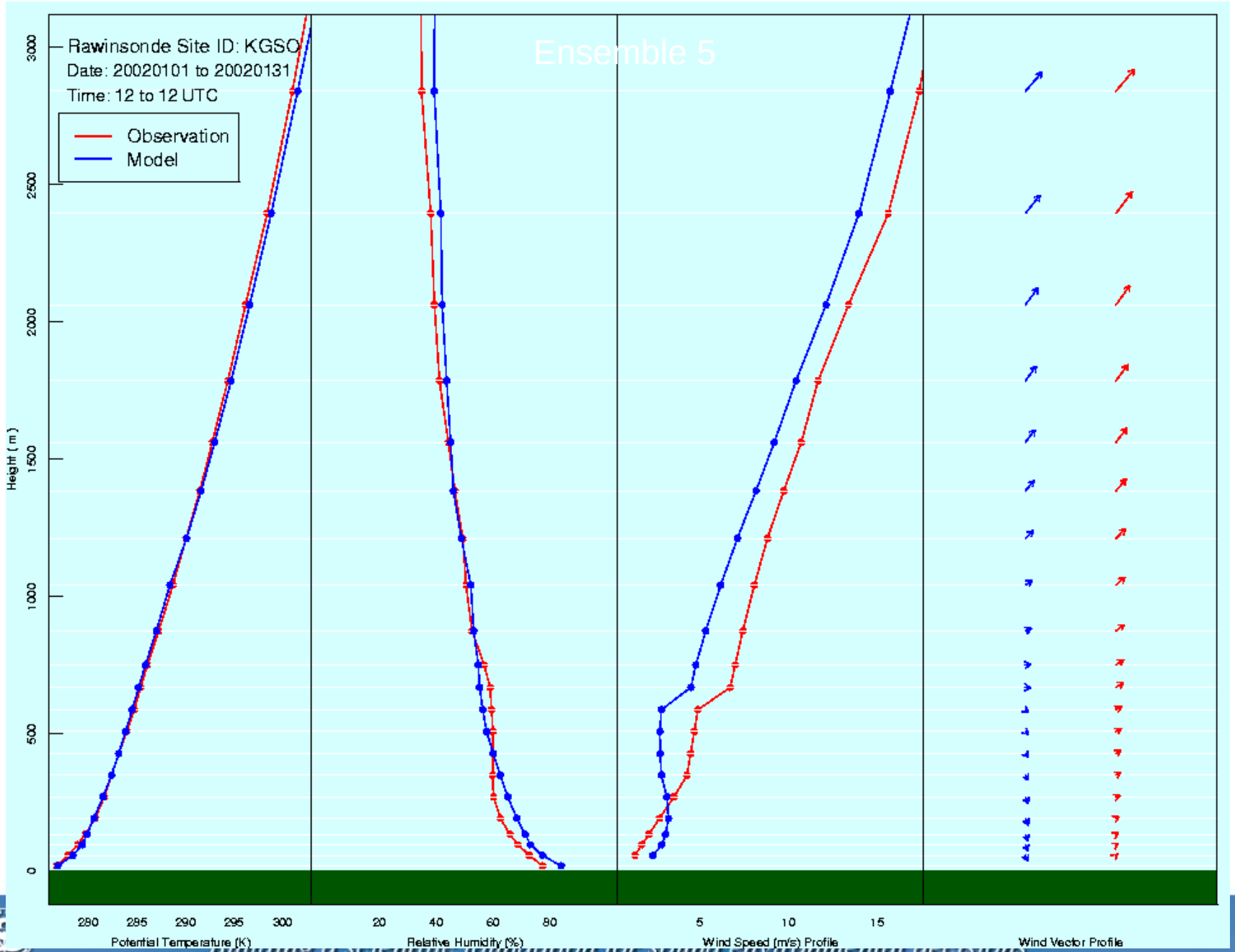
Rawindsonde

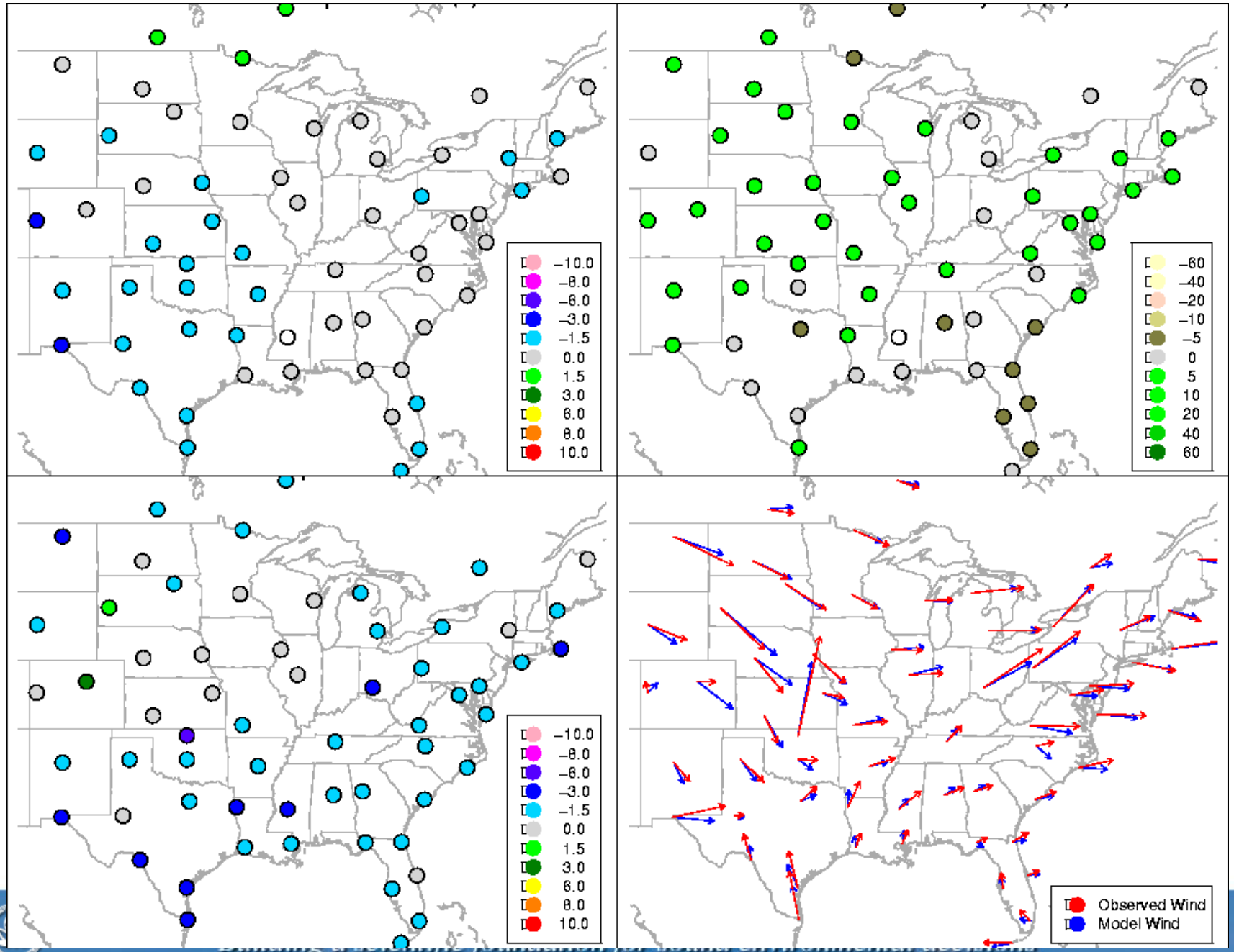
RAOB Profiles and Layer Stats January, 2002

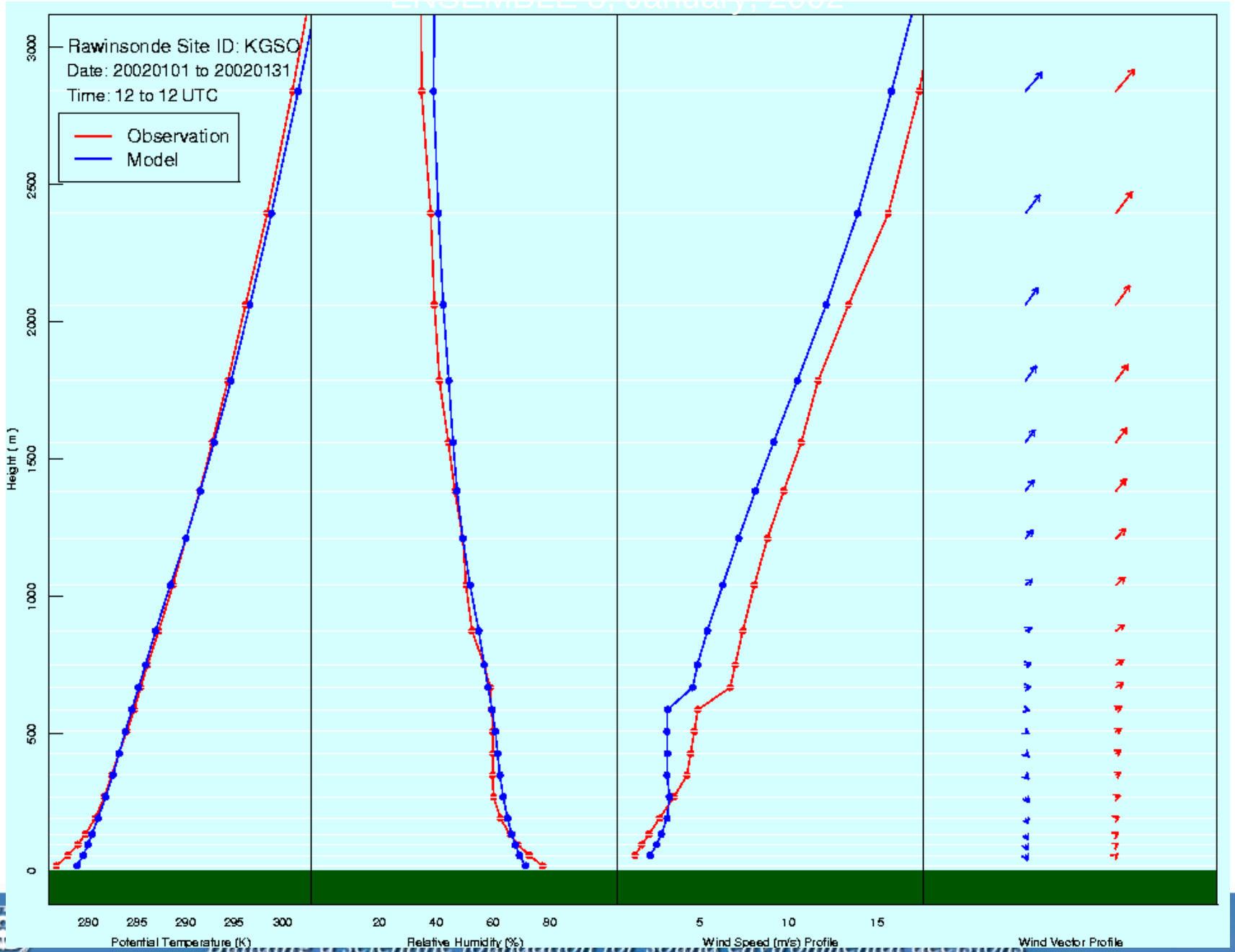

ENSEMBLE 4
Rawinsonde Site ID: KGSO
Date: 20020101 to 20020131
Time: 12 to 12 UTC
Observation
Model
Height (m)
0
500
1000
1500
2000
2500
3000
275
280
285
290
295
300
Potential Temperature (K)
20
40
60
80
Relative Humidity (%)
5
10
15
Wind Speed (m/s) Profile
Wind Vector Profile

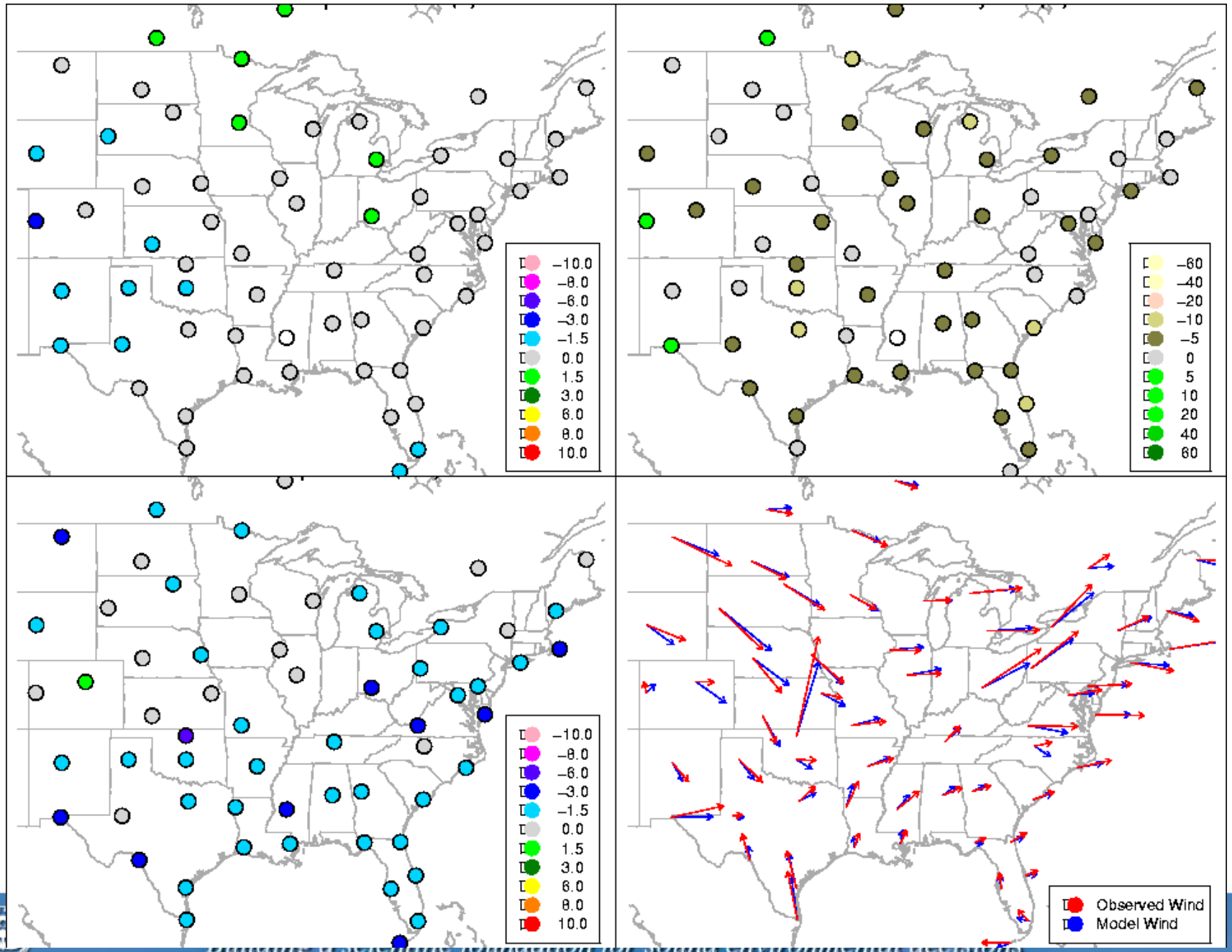
ENSEMBLE 1, January, 2002




Ensemble 5
Rawinsonde Site ID: KGSO
Date: 20020101 to 20020131
Time: 12 to 12 UTC
Observation
Model
Height (m)
0
500
1000
1500
2000
2500
3000
280
285
290
295
300
Potential Temperature (K)
20
40
60
80
Relative Humidity (%)
5
10
15
Wind Speed (m/s) Profile
Wind Vector Profile


−10.0
−8.0
−6.0
−3.0
−1.5
0.0
1.5
3.0
6.0
8.0
10.0
−60
−40
−20
−10
−5
0
5
10
20
40
60
−10.0
−8.0
−6.0
−3.0
−1.5
0.0
1.5
3.0
6.0
8.0
10.0
Observed Wind
Model Wind


Rawinsonde Site ID: KGSO
Date: 20020101 to 20020131
Time: 12 to 12 UTC
Observation
Model
Height (m)
0
500
1000
1500
2000
2500
3000
280
285
290
295
300
Potential Temperature (K)
20
40
60
80
Relative Humidity (%)
5
10
15
Wind Speed (m/s) Profile
Wind Vector Profile


−10.0
−8.0
−6.0
−3.0
−1.5
0.0
1.5
3.0
6.0
8.0
10.0
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−40
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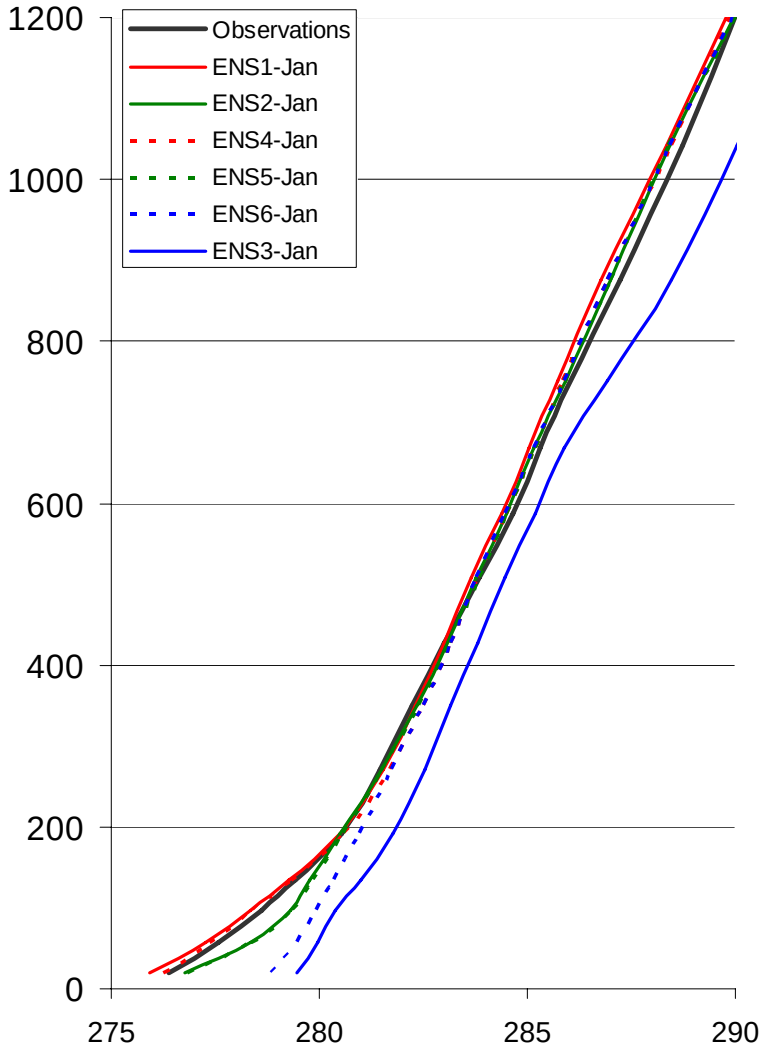
10
20
40
60
−10.0
−8.0
−6.0
−3.0
−1.5
0.0
1.5
3.0
6.0
8.0
10.0
Observed Wind
Model Wind

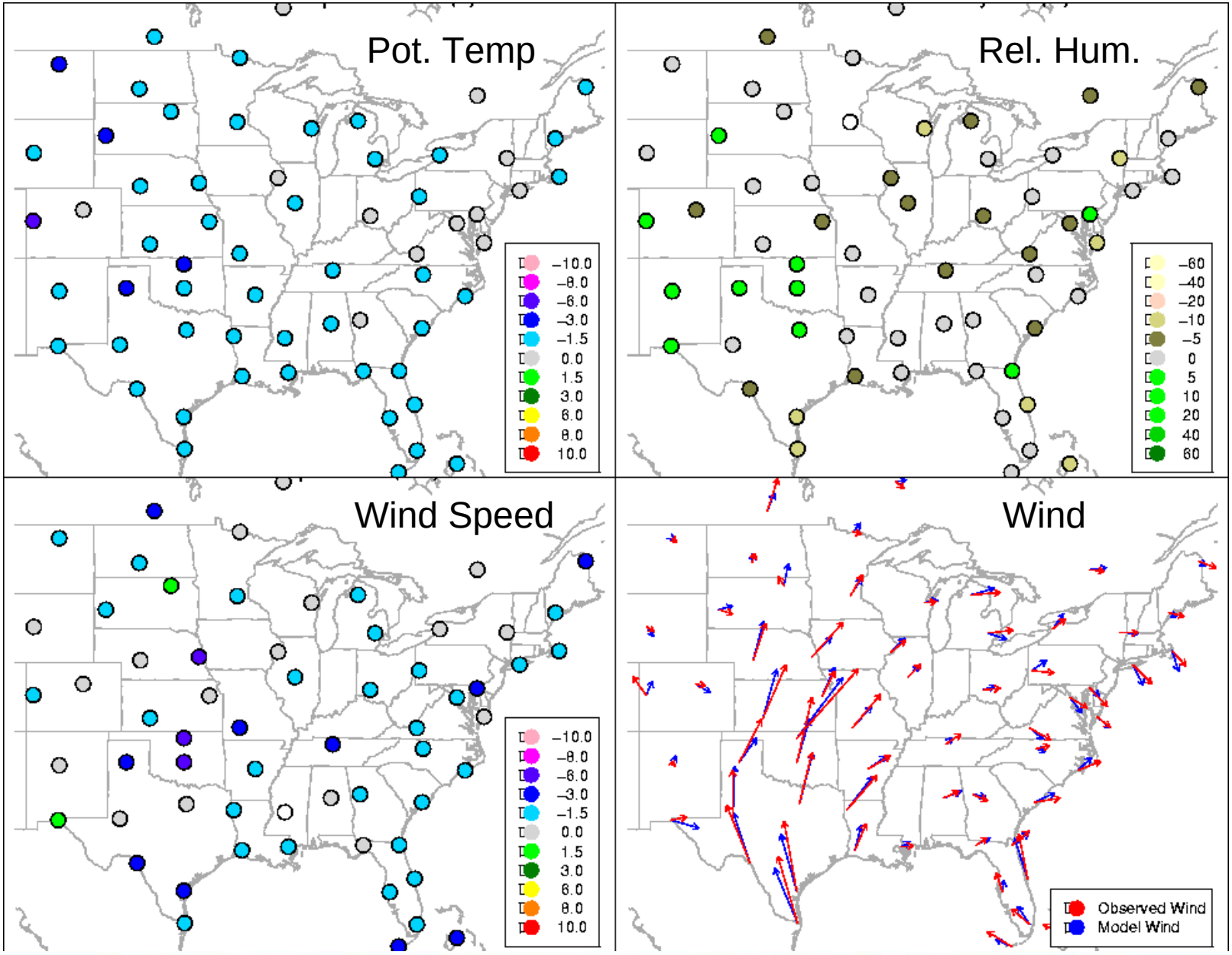
Potential temperature profiles for each MM5 simulation averaged for Jan, 2002 at KGSO at 1200 UTC



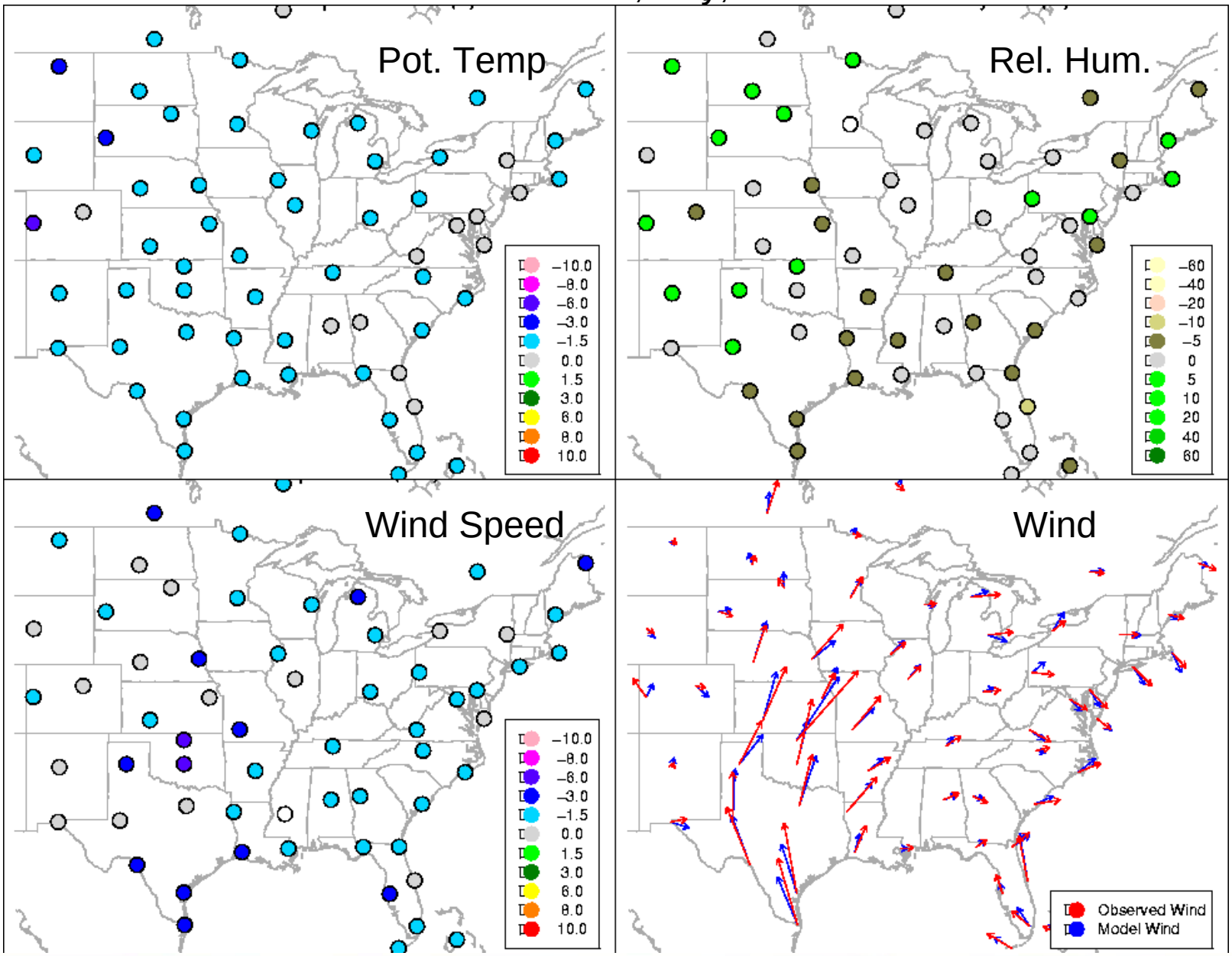
RAOB Profiles and Layer Stats
July, 2002

0-500 m Layer Statistics

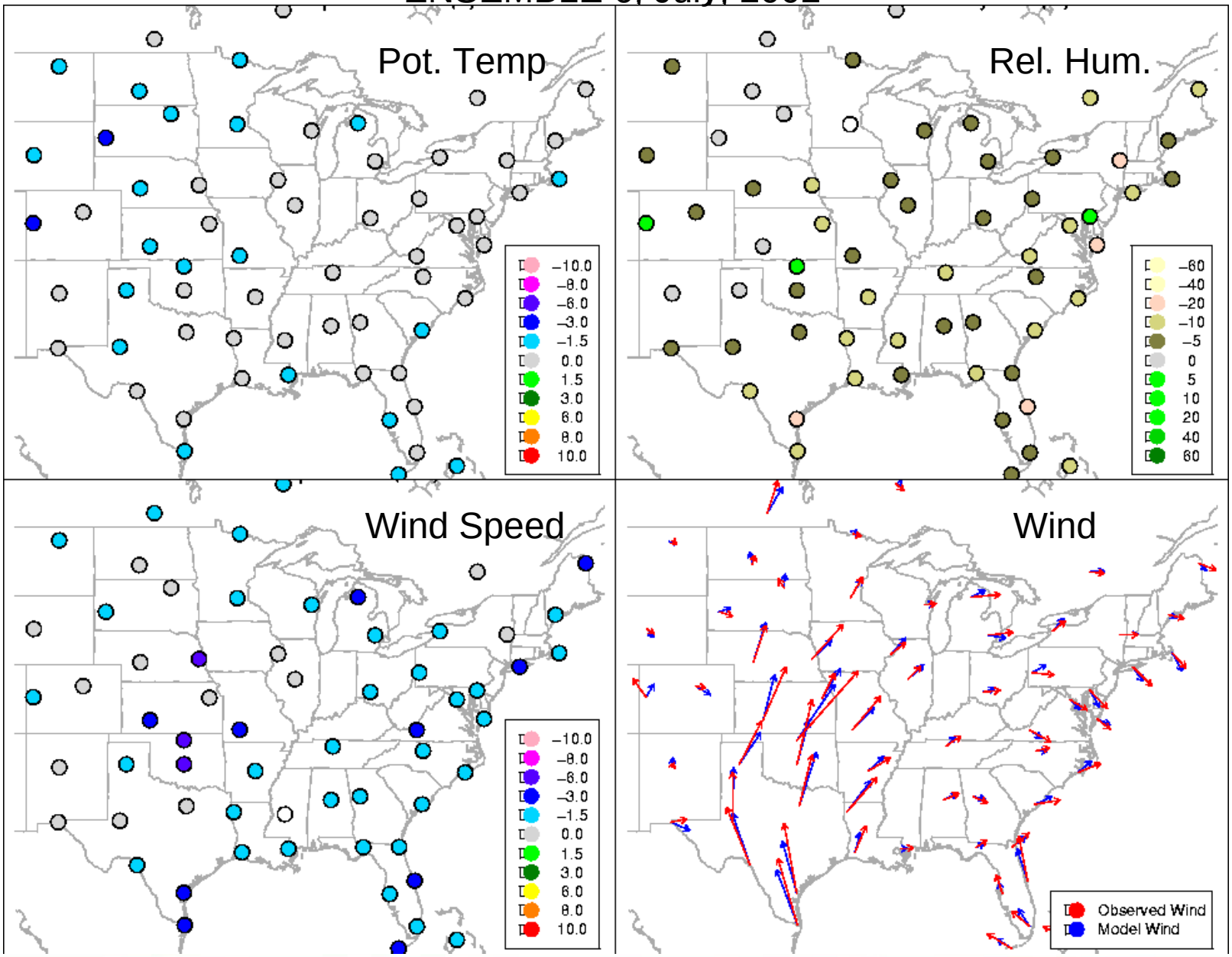
ENSEMBLE 4, July, 2002



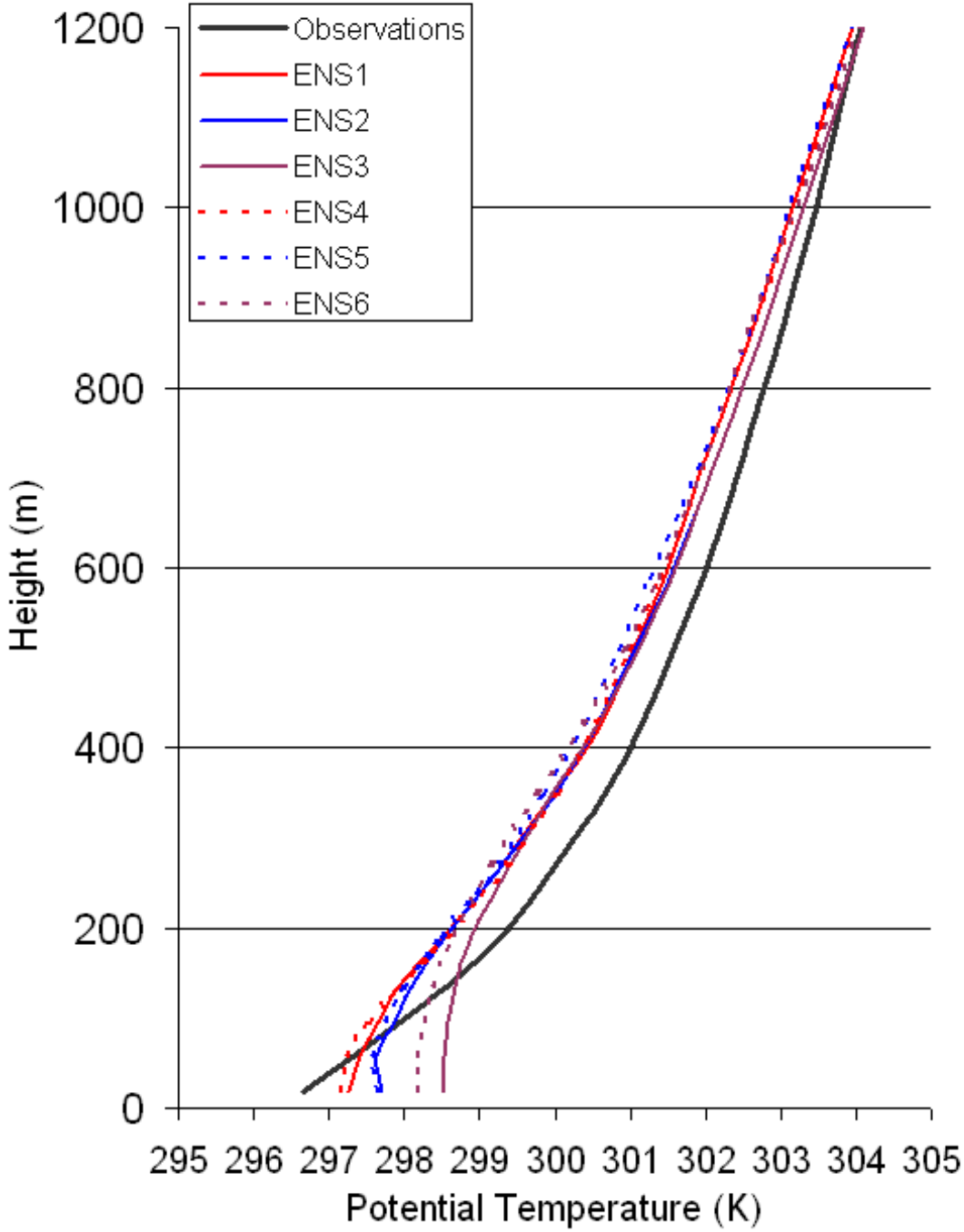
ENSEMBLE 8, July, 2002



ENSEMBLE 6, July, 2002



Potential temperature profiles fo each MM5 simulation averaged for July, 2002 at KGSO



Disclaimer

The research presented here was performed under the Memorandum of Understanding between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and under agreement number DW 13921548. This work constitutes a contribution to the NOAA Air Quality Program. Although it has been reviewed by EPA and NOAA and approved for publication, it does not necessarily reflect their policies or views.