Preliminary Evaluation of EPA 2002 12km MM5 Modeling

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2006 Ad Hoc Meteorological Modeling Meeting

Meteorological Model Evaluation Principles

- Evaluation goal(s)
  - Move toward an understanding of how bias/error of the meteorological data impact the resultant AQ modeling
  - Move away from an “as is” acceptance of met modeling data
- Two specific objectives:
  - Determine if the met model output fields represent a reasonable approximation of the actual meteorology that occurred during the modeling period. (Operational evaluation)
  - Identify and quantify the existing biases and errors in the meteorological predictions in order to allow for a downstream assessment of how AQ modeling results are affected by issues associated with the meteorological data. (Phenomenological evaluation)

Meteorological Model Evaluation Principles

- Operational Evaluation
  - Statistical comparisons of model/obs pairs (e.g., bias, IOA, RMSE, etc.)
  - Assess operational performance for all available met parameters
    - T, q, WS, WD, clouds, rain, solar radiation, etc.
  - Conduct the evaluation on a segmented basis

- Phenomenological Evaluation
  - Tied to AQ conceptual model (e.g., lake breeze in Chicago)
  - Assess performance for all important met phenomena
    - Trajectories, low-level jets, frontal passages, airmass residence time, etc.
  - Different universe of statistics (FAR/POD) or possibly qualitative

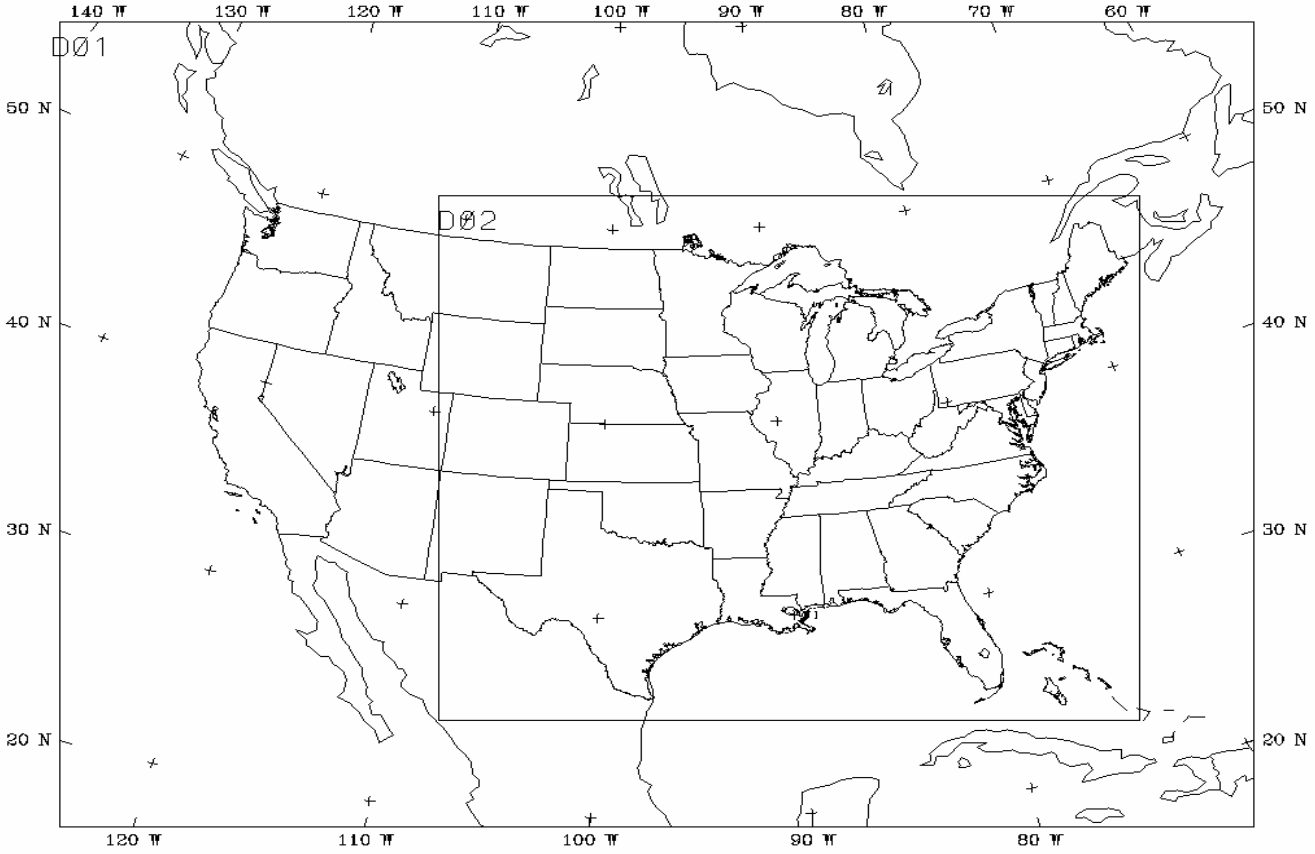
Meteorological Model Evaluation Principles

- Most important evaluation step is to incorporate the meteorological evaluation results into the air quality model evaluation.
  - Identify regions/regimes where model predictions are most uncertain
  - 2002 AQ modeling has not yet started at EPA
    - At this point of process, we attempt to make general “sound bite” conclusions about the MM5 model preformance
- Met issues with 2001 12km MM5
  - Generally, CMAQ model performance for PM2.5 has been good
  - Issues: 36 vs. 12, deposition/precipitation, ozone underpredictions, diurnal O3 patterns, coastal sites

2002 12km EPA MM5 Configuration

- Modeling conducted by CSC (L Reynolds, A. Huffman)
- Model version 3.7.2 (values in red differ from 2001 EPA application)
- RPO 36km domain; 251 x 290 EUS 12km domain
- Physics Options
  - Radiation: RRTMLW
  - Cumulus Parameterization: Kain-Fritsch 2
  - Microphysics: Reisner 1
  - LSM: Pleim-Xiu
  - PBL: Pleim-Chang
  - IFSNOW = 1, snow cover effects considered
  - ISSTVAR =1, SST varying in time
  - RADFRQ = 15, frequency that solar radiation is computed
  - Analysis Nudging (@ 12km):
    - winds (aloft): 1.0E-4, winds (surface): 1.0E-4,
    - temperature (aloft): 1.0E-4, temperature (surface): N/A
    - moisture (aloft): 1.0E-5, moisture (surface): N/A

2002 12km EPA MM5 Configuration



Operational evaluation

Domainwide statistics by subsector

Mean Error	T	Q	WS	WD
january	3.0	0.6	1.3	24.1
febuary	2.5	0.6	1.3	23.6
march	2.7	0.7	1.4	24.9
april	2.3	0.9	1.3	24.9
may	1.8	1.0	1.3	25.8
june	1.5	1.2	1.2	29.2
july	1.5	1.4	1.1	31.4
august	1.5	1.3	1.1	30.5
september	1.5	1.1	1.1	28.1
october	1.6	0.8	1.1	26.7
november	2.0	0.7	1.2	24.3
december	2.5	0.6	1.3	24.5

Mean Bias	T	Q	WS	WD
january	-2.4	-0.2	-0.3	7.4
febuary	-1.3	-0.2	-0.4	7.8
march	-1.5	-0.1	-0.7	7.5
april	-1.5	-0.1	-0.4	6.2
may	-0.5	-0.1	-0.3	6.8
june	-0.5	-0.2	-0.4	6.8
july	-0.1	-0.1	-0.4	7.8
august	-0.1	-0.1	-0.4	7.1
september	0.0	-0.3	-0.3	7.8
october	0.4	-0.2	-0.2	8.3
november	-0.2	0.0	-0.2	8.4
december	-0.6	0.1	-0.5	8.1

Mean Error	T	Q	WS	WD
florida	1.5	1.3	1.2	29.7
midatlantic	1.4	1.2	1.0	30.5
northeast	1.6	1.1	1.1	32.0
south	1.5	1.4	1.1	24.4
greatlakes	1.5	1.1	1.0	26.7
midwest	1.6	1.2	1.2	23.8
lowerrockies	2.2	1.3	1.7	43.7
upperrockies	2.0	1.1	1.6	40.6

Mean Bias	T	Q	WS	WD
florida	-0.5	-0.1	-0.4	5.9
midatlantic	-0.1	-0.1	-0.2	11.5
northeast	-0.2	-0.1	-0.2	18.3
south	-0.3	-0.3	-0.4	1.6
greatlakes	0.0	0.1	-0.2	8.9
midwest	-0.1	-0.2	-0.4	2.0
lowerrockies	-1.1	-0.2	-1.0	0.1
upperrockies	-0.7	-0.3	-0.9	-0.5

Mean Error	T	Q	WS	WD
urban	1.5	1.2	1.2	26.0
ag	1.5	1.2	1.1	25.8
plains	1.9	1.3	1.5	30.9
forest	1.6	1.2	1.1	33.1
desert	1.5	1.4	1.1	25.4
water	1.4	1.2	1.4	28.7

Mean Bias	T	Q	WS	WD
urban	-0.5	-0.3	-0.6	6.0
ag	-0.1	-0.1	-0.3	6.6
plains	-0.7	-0.3	-0.8	-0.4
forest	-0.1	-0.1	-0.2	12.6
desert	0.2	-0.4	-0.3	2.2
water	-0.2	-0.2	0.2	11.9

Mean Error	T	Q	WS	WD
coastal	1.5	1.2	1.2	28.1
inland	1.5	1.2	1.0	28.3
mountains	1.8	1.2	1.4	30.8

Mean Bias	T	Q	WS	WD
coastal	-0.4	-0.2	-0.2	8.7
inland	-0.1	-0.1	-0.2	9.1
mountains	-0.5	-0.2	-0.7	2.6

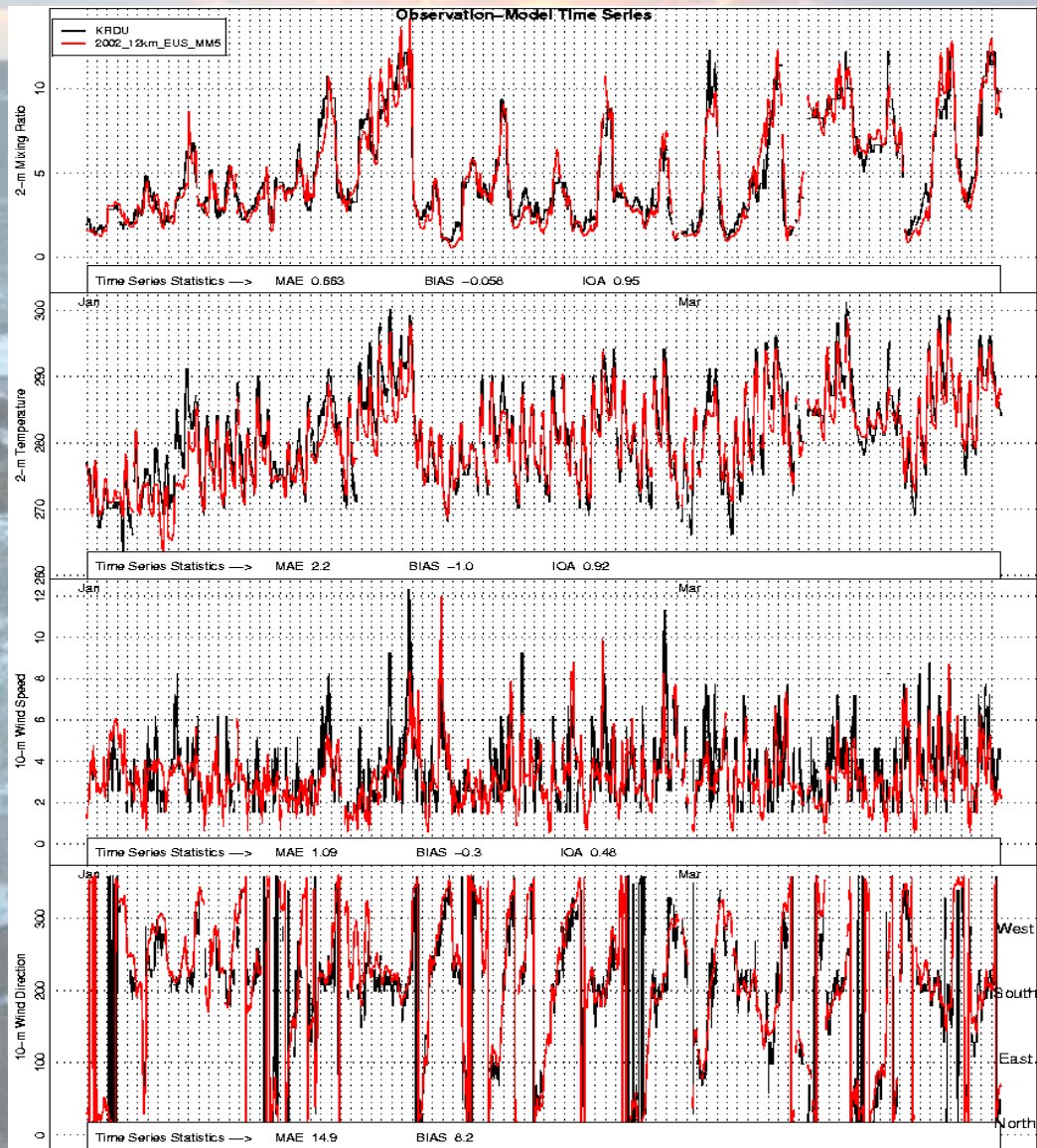
Operational Evaluation at “key” sites

Sample quarterly time series plot

KRDU (Winter 2001)

Observations:

- too many sites to look at individually
- Have chosen 10 “key” sites as snapshot
  - BOS, PNE, DCA, RDU, BHM
  - CVG, DTW, MDW, DFW, DEN
- Synoptic patterns captured (q)
- Cold bias in January
- Peak winds usually underestimated
- Wind speeds appear least correlated
- Model has smaller T range than obs
- **Can look at individual sites, days, hours … as directed by AQM performance issues**



Operational Evaluation at “key” sites

Mean Absolute Error

	2-m temperature				2-m mixing ratio				10-m wind speed				10-m wind direction			
	winter	spring	summer	fall	winter	spring	summer	fall	winter	spring	summer	fall	winter	spring	summer	fall
Boston	3.7	1.8	1.4	1.9	0.5	0.9	1.2	0.6	1.9	1.7	1.3	1.8	11.2	12.7	12.7	9.9
Philadelphia	2.7	1.7	1.4	1.9	0.5	1.0	1.3	0.8	1.2	1.1	0.9	1.1	8.9	8.8	7.3	6.4
Washington DC	2.8	1.6	1.4	1.6	0.6	1.1	1.5	0.8	1.4	1.1	1.1	1.2	11.4	10.6	9.4	7.5
Raleigh	2.2	1.6	1.4	2.0	0.7	1.1	1.3	0.8	1.1	0.9	0.8	0.8	5.9	6.2	6.9	5.4
Birmingham	2.4	1.7	1.3	1.7	0.7	1.1	1.4	0.7	1.1	1.0	0.9	1.0	6.3	6.7	7.1	5.4
Cincinnati	2.6	1.8	1.4	1.8	0.6	1.1	1.3	0.7	1.1	1.1	1.0	1.0	6.1	7.2	7.0	5.0
Detroit	2.8	1.8	1.1	1.6	0.4	0.9	1.1	0.5	1.3	1.1	1.0	1.1	9.8	8.8	7.6	7.4
Chicago	3.4	2.0	1.3	1.5	0.6	1.1	1.4	0.5	1.3	1.1	1.1	1.2	6.4	8.4	8.2	6.5
Dallas	2.2	1.5	1.1	1.7	1.0	1.3	1.3	0.9	1.5	1.3	1.0	1.1	7.0	7.8	7.4	6.4
Denver	4.4	3.5	1.7	3.8	0.5	1.1	1.4	0.6	1.8	1.8	1.7	1.6	17.0	17.1	14.4	14.7

Mean Bias

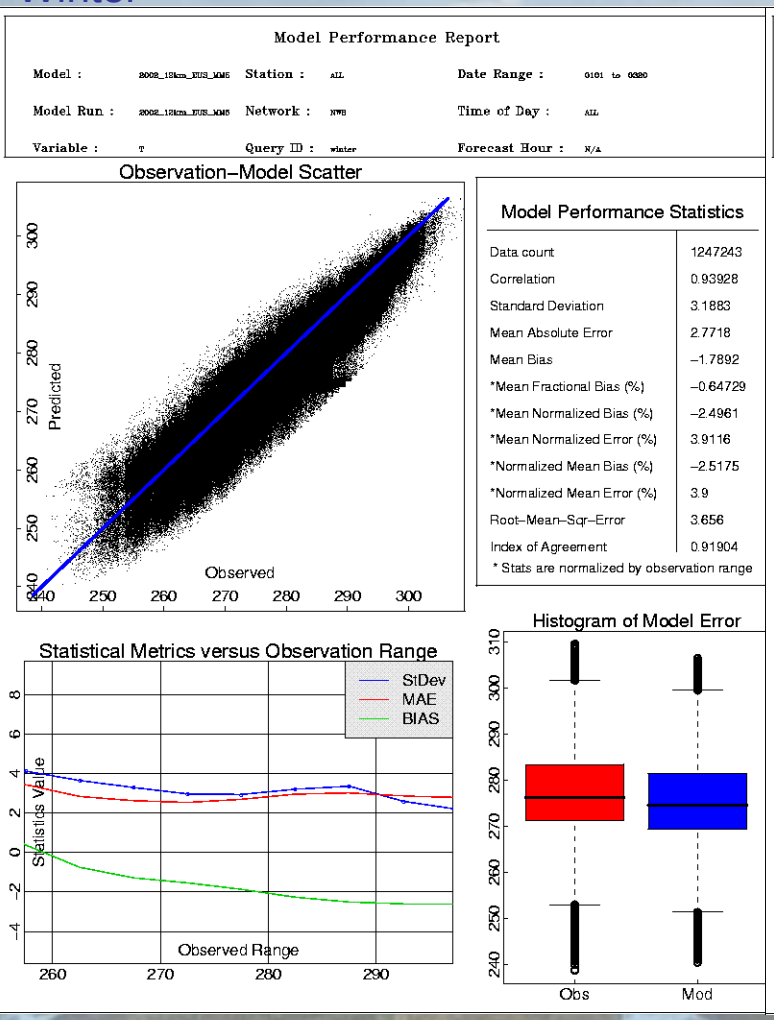
	2-m temperature				2-m mixing ratio				10-m wind speed				10-m wind direction			
	winter	spring	summer	fall	winter	spring	summer	fall	winter	spring	summer	fall	winter	spring	summer	fall
Boston	-3.7	-1.1	-0.3	-1.3	-0.1	0.4	-0.3	0.1	-1.8	-1.5	-1.1	-1.7	7.4	9.1	9.6	8.0
Philadelphia	-2.5	-0.5	-0.1	-0.7	0.0	0.3	0.2	0.4	-0.8	-0.6	-0.5	-0.8	7.3	5.9	5.1	4.9
Washington DC	-2.5	-0.7	-0.7	-1.0	0.2	-0.2	-0.9	-0.2	-0.9	-0.7	-0.9	-0.9	8.7	5.0	1.6	1.8
Raleigh	-1.0	0.1	0.6	0.6	-0.1	-0.2	0.1	0.2	-0.3	-0.2	-0.4	-0.2	3.2	2.3	2.7	3.1
Birmingham	-1.5	-0.3	-0.4	-0.2	-0.2	0.2	0.2	0.1	-0.4	-0.1	-0.2	-0.3	-1.6	0.0	0.5	0.8
Cincinnati	-1.9	-0.3	0.4	0.6	-0.2	0.6	0.6	0.3	-0.7	-0.7	-0.6	-0.6	1.0	1.0	1.1	1.3
Detroit	-2.5	-1.2	0.0	-0.3	-0.1	-0.1	-0.5	-0.2	-0.9	-0.7	-0.6	-0.7	8.6	5.3	4.5	5.7
Chicago	-2.7	-1.2	-0.4	-0.4	-0.4	0.3	0.8	0.0	-1.0	-0.7	-0.7	-0.9	-0.2	0.9	1.1	0.8
Dallas	-1.1	-0.3	-0.4	-0.2	-0.8	-0.5	-0.1	-0.4	-1.2	-0.8	-0.7	-0.8	0.3	0.2	-0.3	1.3
Denver	-3.6	-2.5	-0.3	-2.8	0.1	-0.3	-0.3	0.1	-1.1	-1.4	-1.3	-1.2	-3.8	-1.2	-1.5	-2.2

Observations:

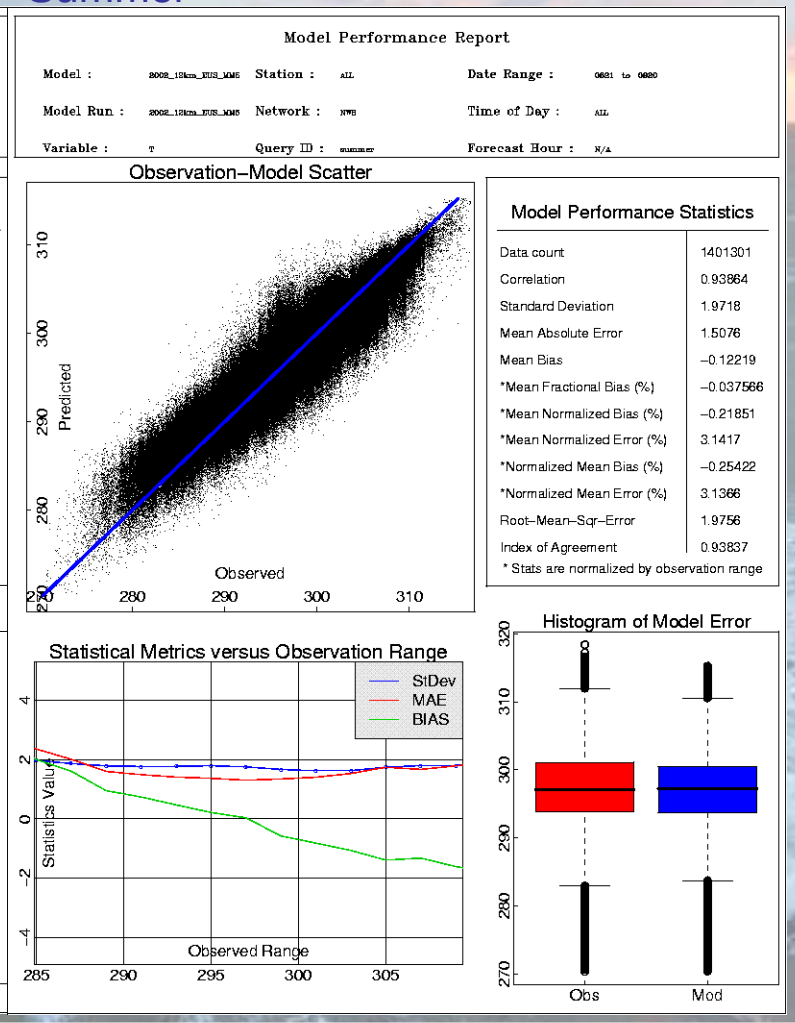
- Winter time cold bias ranges from 1.0 to 3.5 deg C
- Model does particularly poorly at coastal & high-altitude sites
- Model tends to underestimate wind speeds (~0.5 – 1.0)
- Wind direction error is highest at northern sites

Operational evaluation: Temperature

Winter



Summer

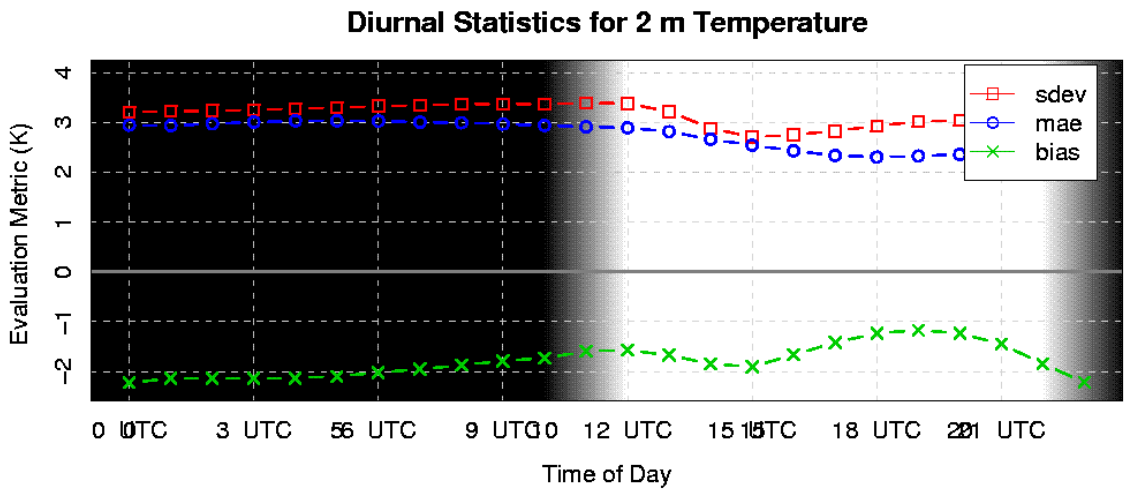


Observations:

- Bias change as a function of temperature is largest in the summer
- AMET software allows for Nearly unlimited subsetting by site-type (region, state, month, value, etc.)

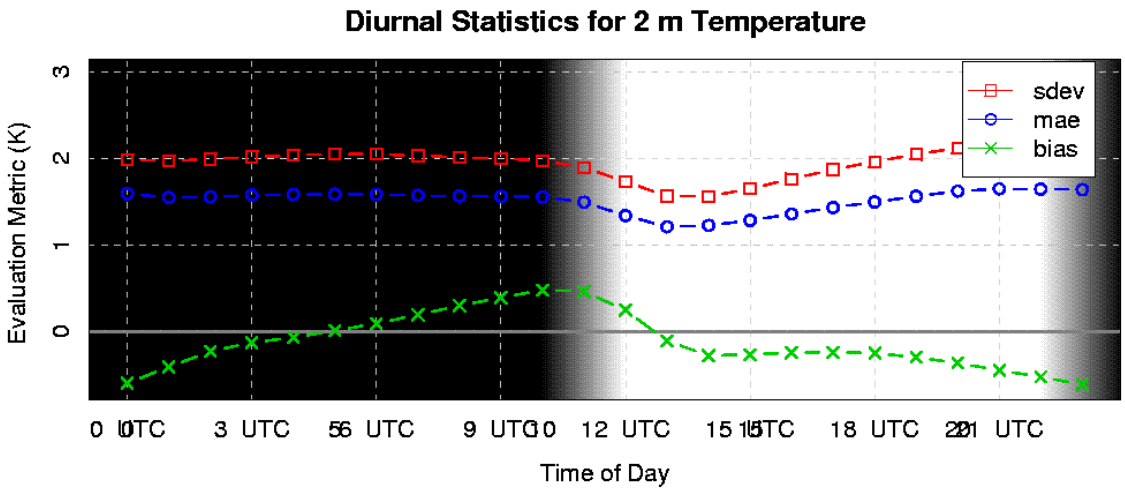
Operational evaluation: Temperature

Winter



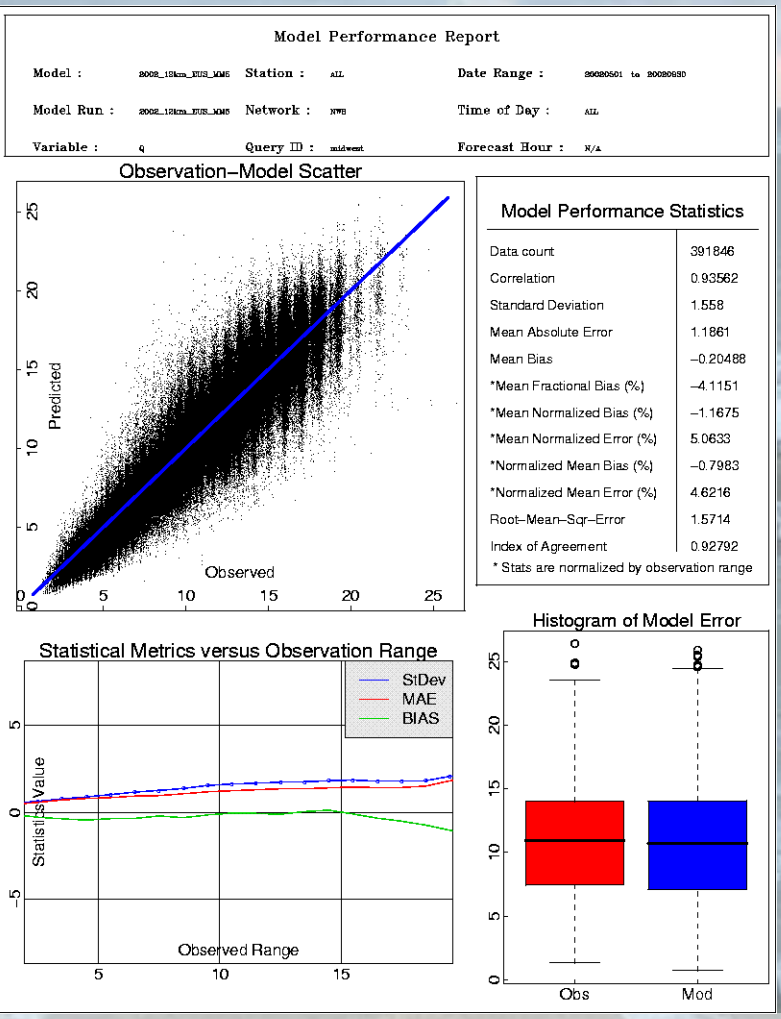
Observations:

- Winter time cold bias is Strongest at Night
- In summer, Model overnight temperatures decrease at a slower rate than observed.
- As nocturnal layer is mixed, Slight warm bias rapidly gives way to small cool bias.

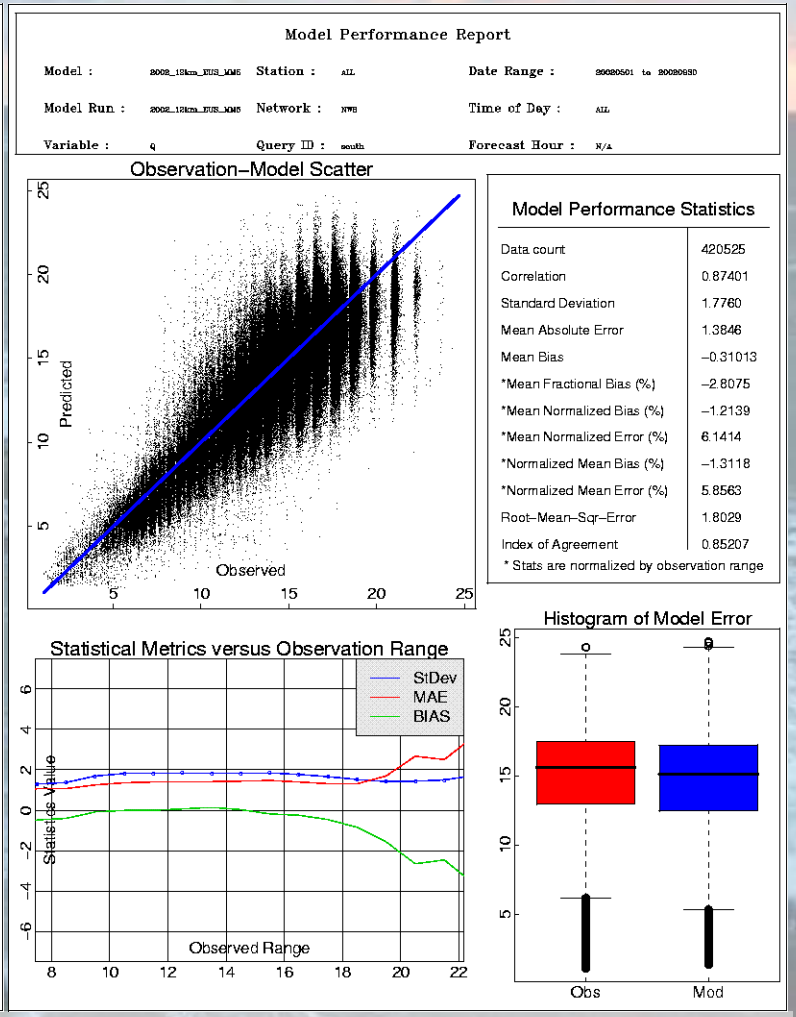


Operational evaluation: Mixing Ratio

Midwest



Deep South

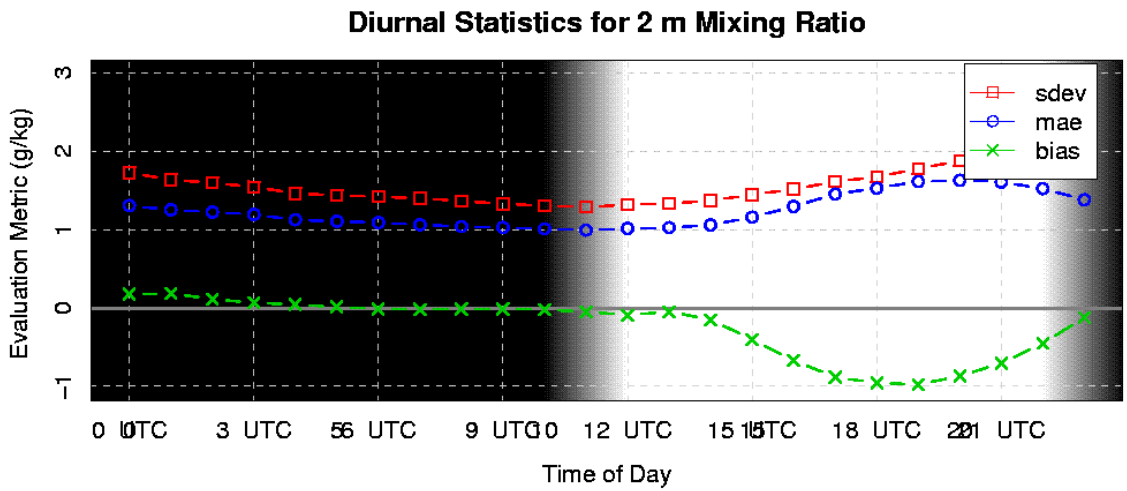


Observations:

- Model performance drops off above 18 g/kg (dry bias)
- Q is generally well-predicted; slightly more scatter in the south

Operational evaluation: Mixing Ratio

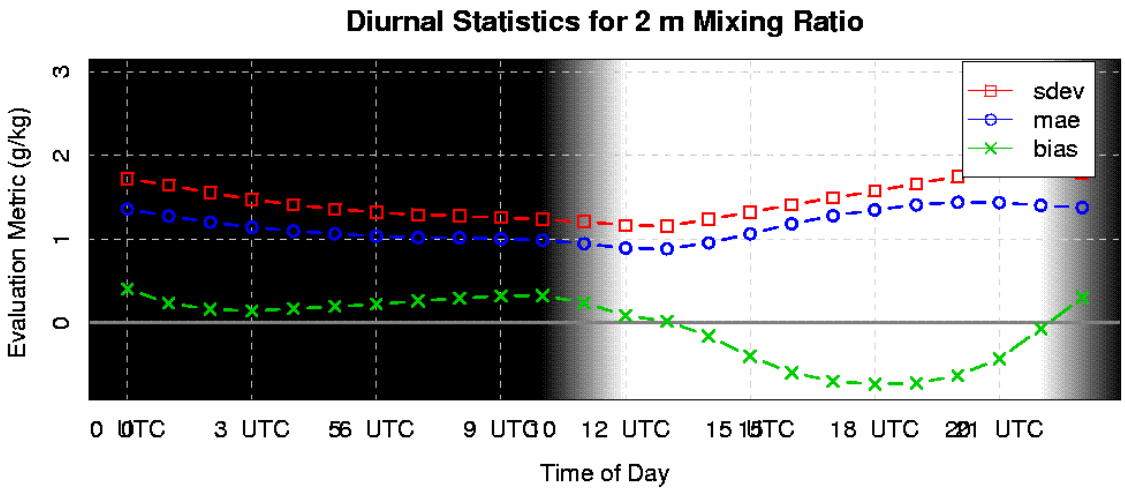
Urban



Forest

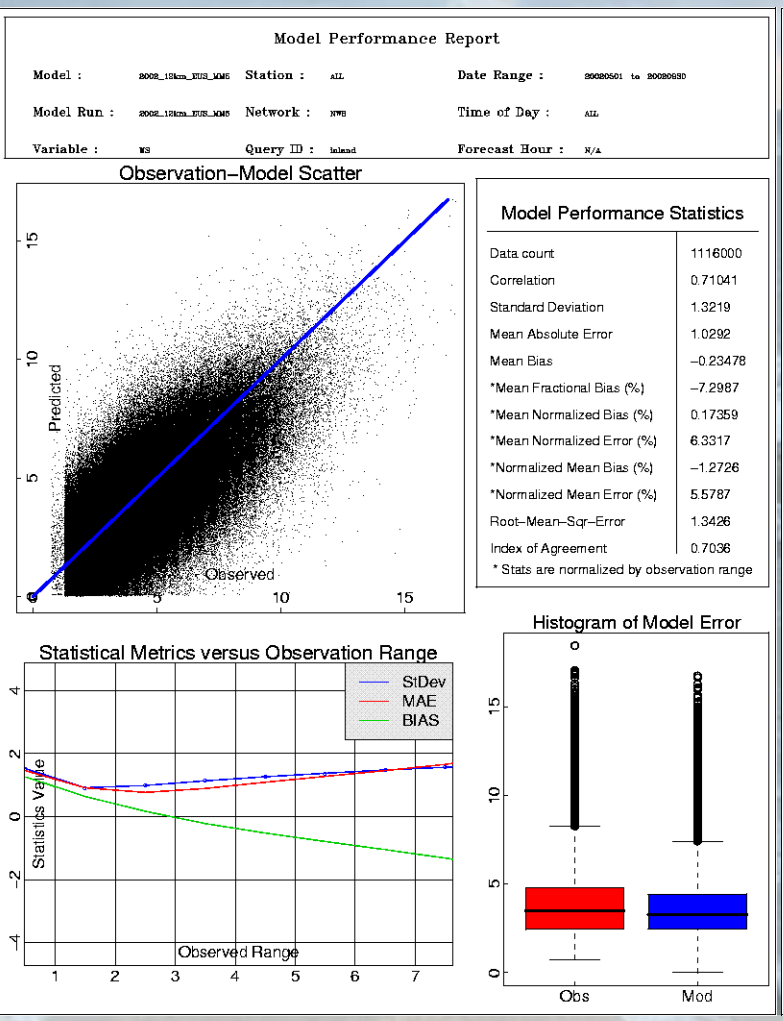
Observations:

- Diurnal pattern is generally Dry during daylight hours; slightly moist overnight
- Diurnal pattern doesn't change greatly as a function of landuse

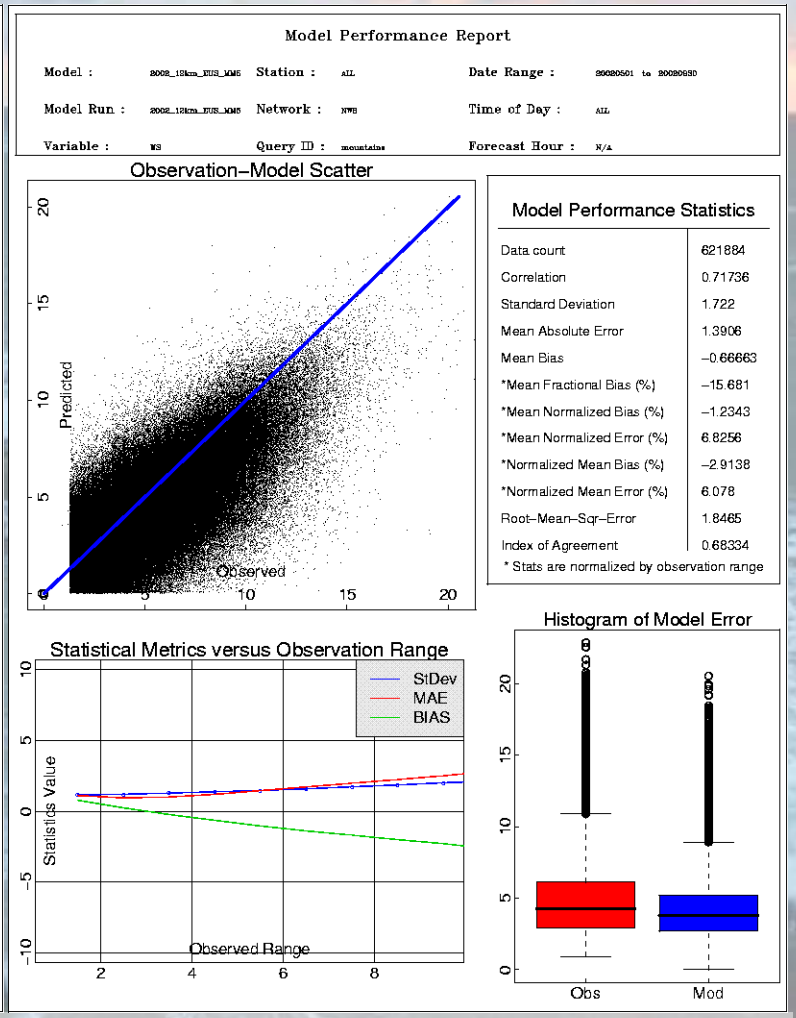


Operational evaluation: Winds

Inland



Coastal

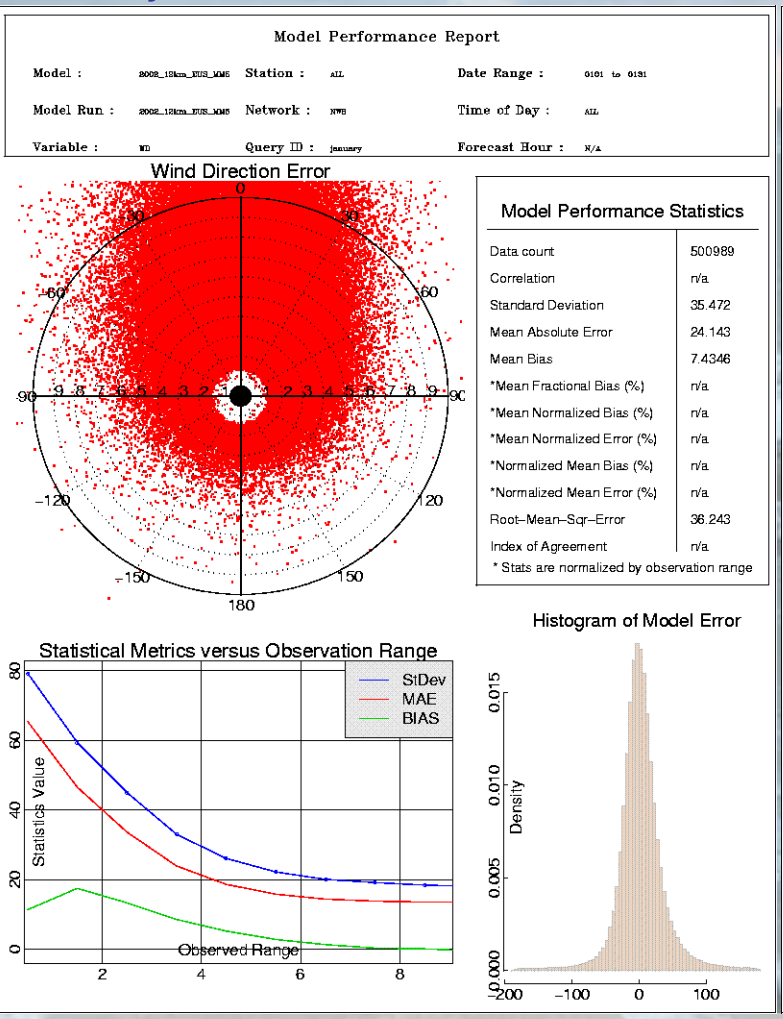


Observations:

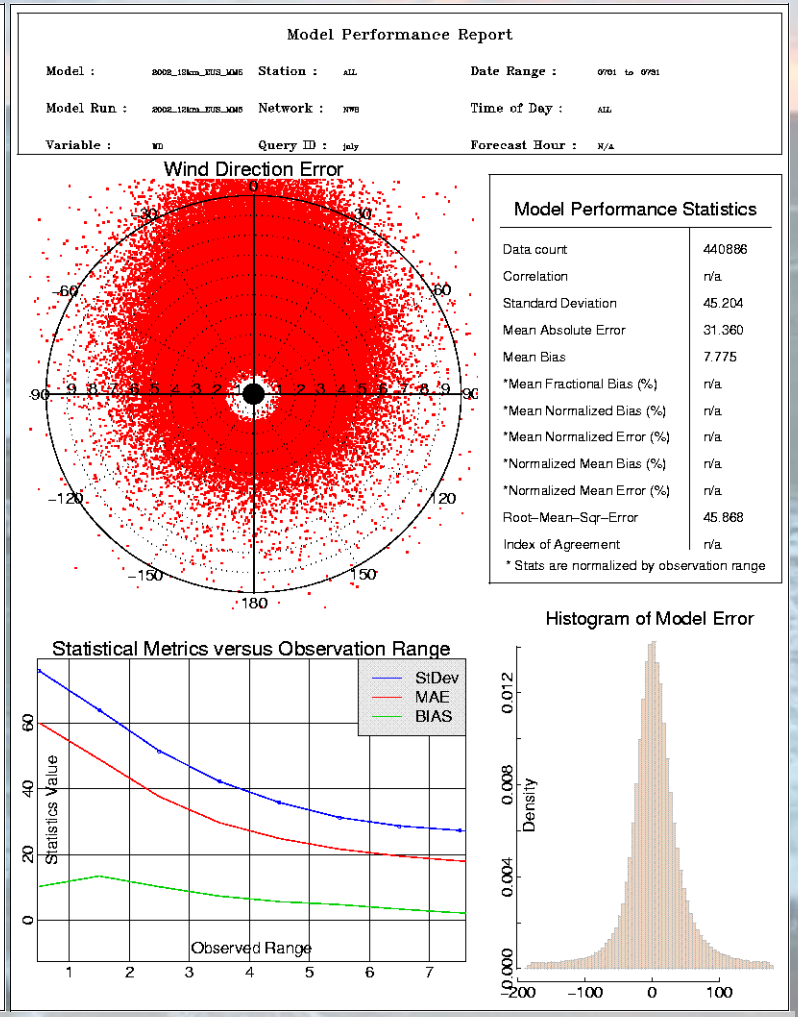
- Performance poorer at coastal sites
- increasing underprediction w/ magnitude

Operational evaluation: Wind Direction

January



July



Observations:

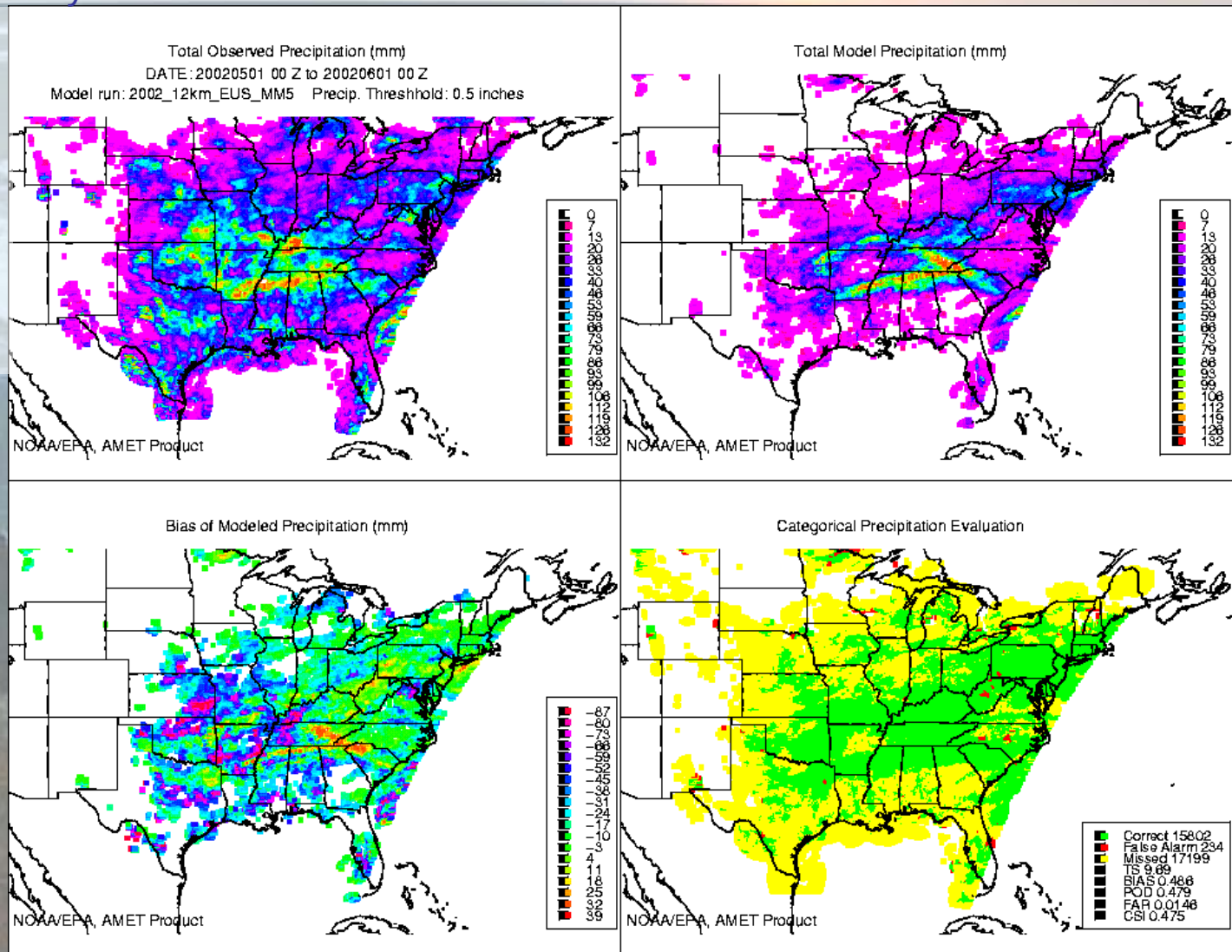
- Considerable scatter in wind direction
- Majority of points w/in 30-60 deg of obs once speeds > 2-3 m/s

Operational evaluation: Precipitation

May 2002

Observations:

- May 2002 was probably the best instance of good model performance for monthly precipitation
- Slight underestimates in KS/AR/OK/TX
- General tendency toward underestimation

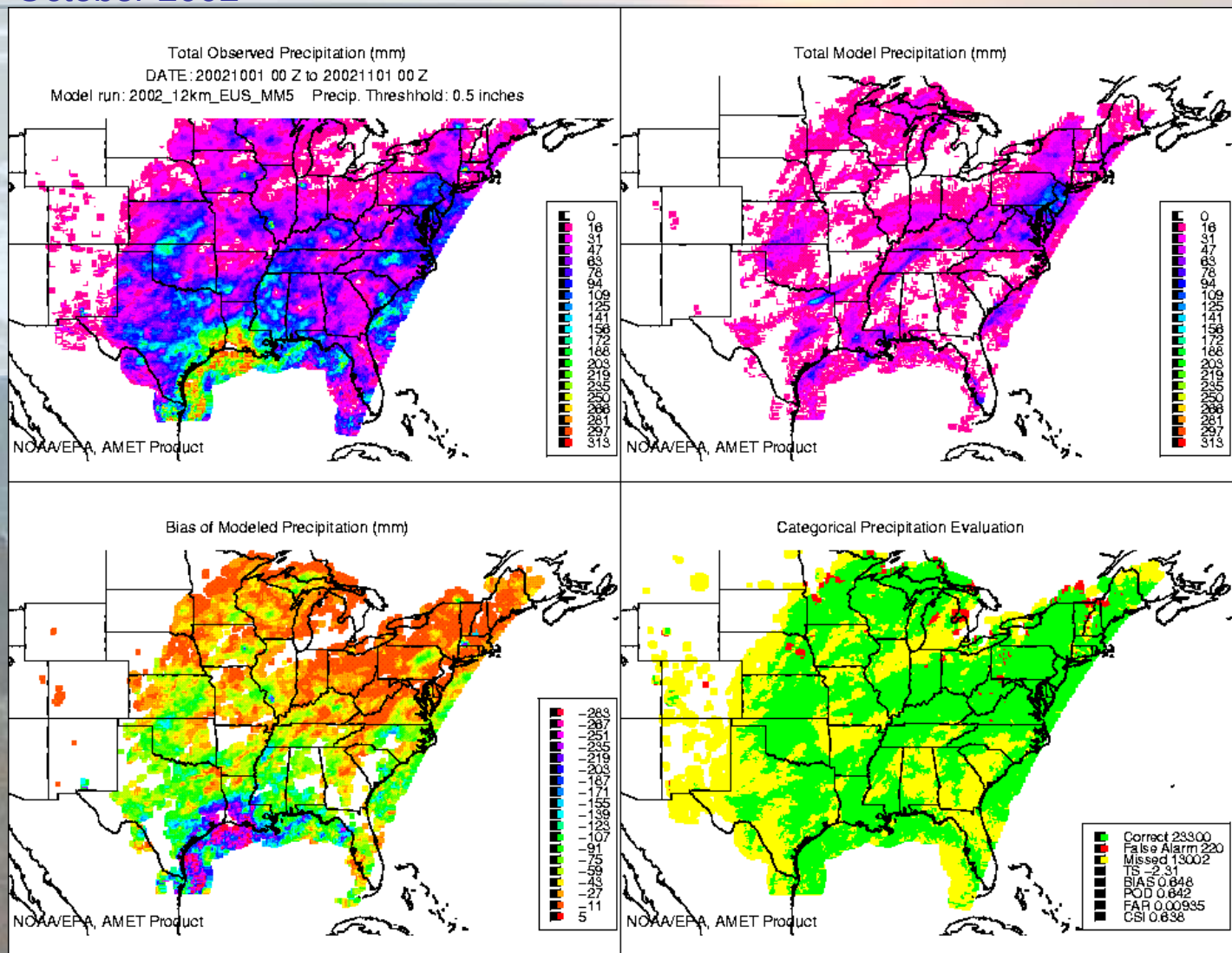


Operational evaluation: Precipitation

October 2002

Observations:

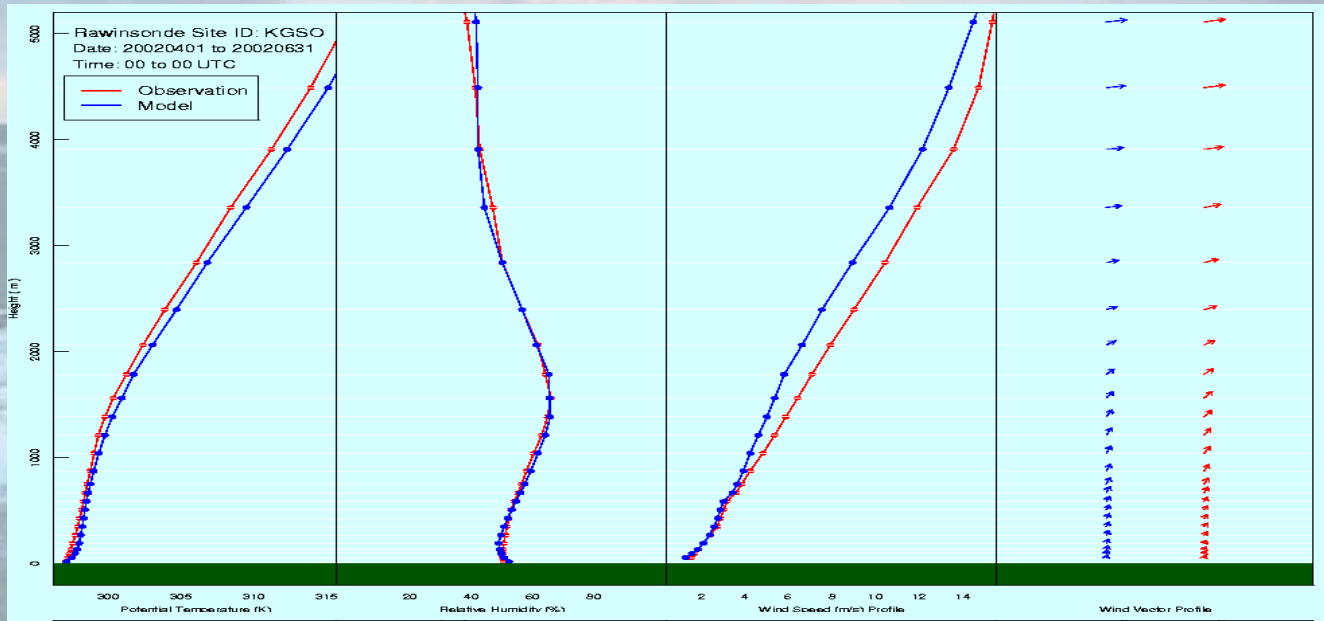
- October 2002 was likely the worst instance of model performance for monthly precipitation
- Large underestimates along western Gulf Coast
- Again, there is a General tendency toward underestimation



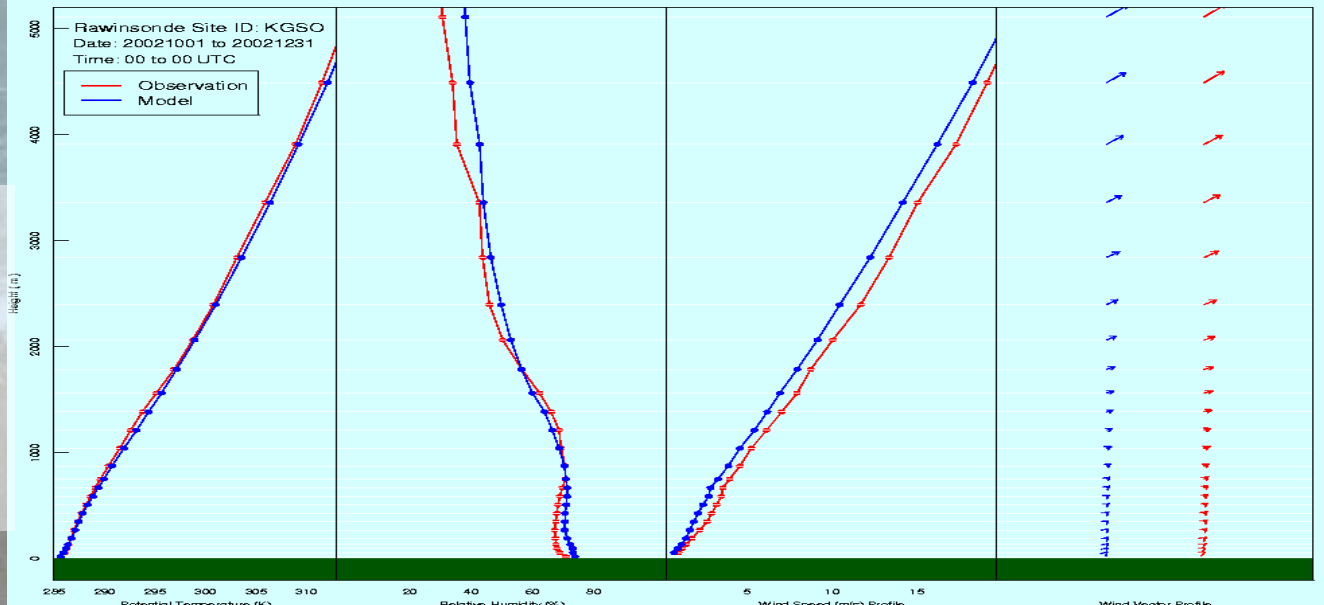
Phenomenological Evaluation

Aloft: “key” sites

Spring



Fall

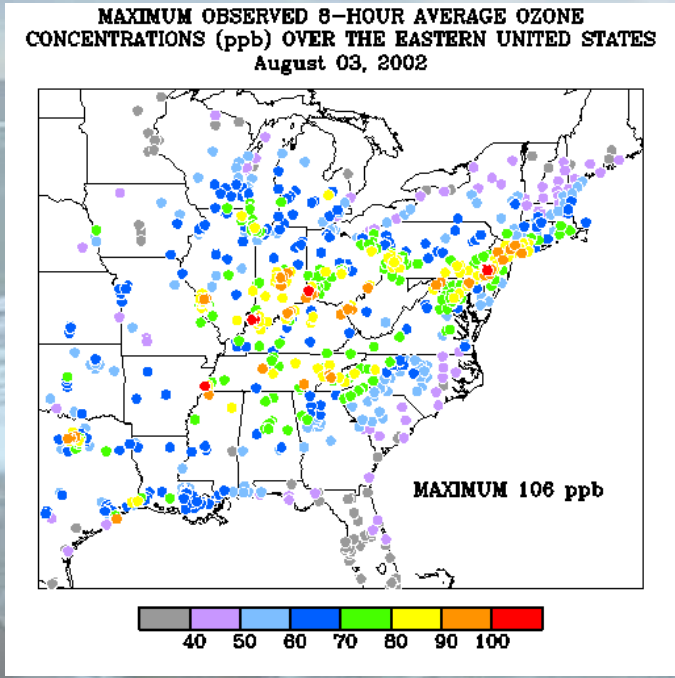


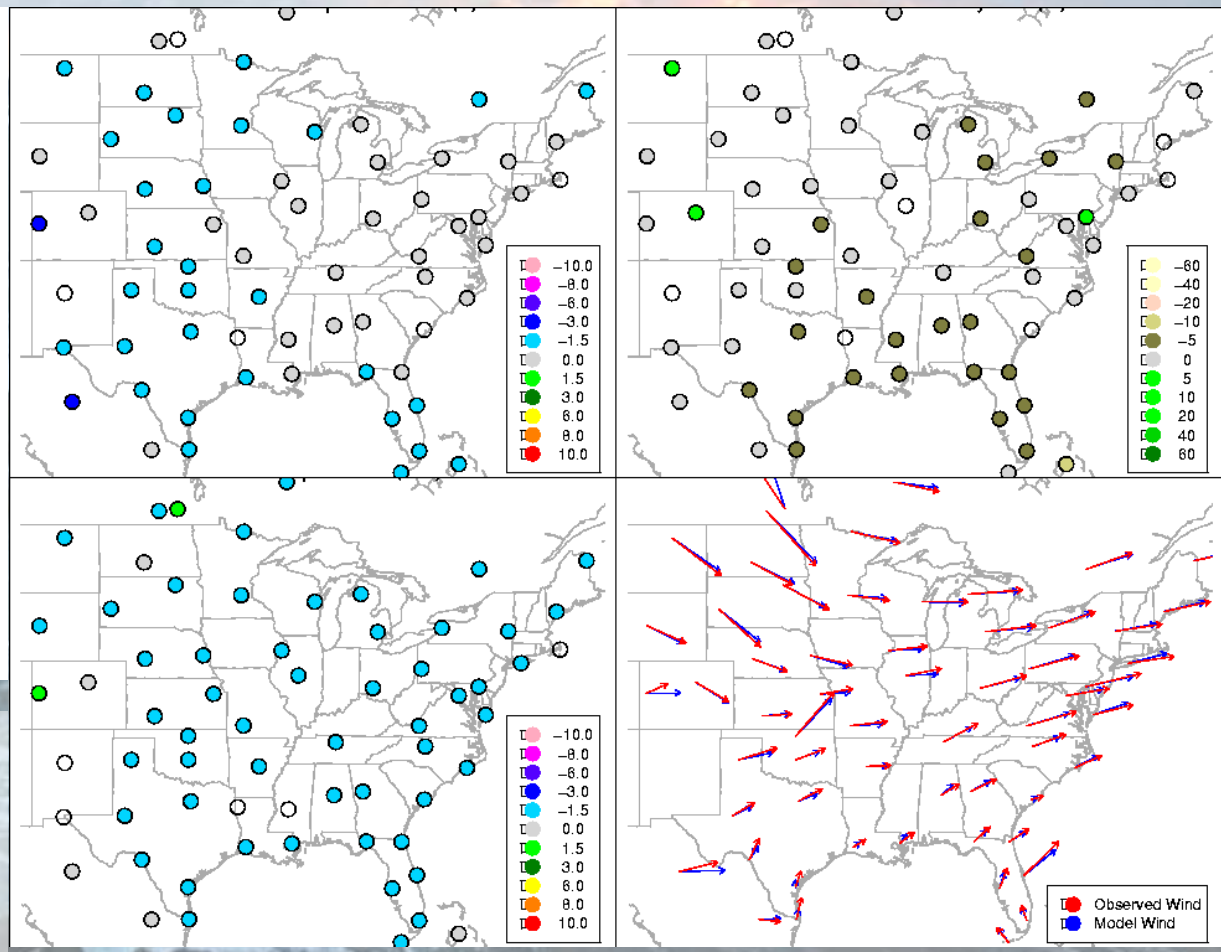
Observations:

- Generally, Avg pot. Temps, RH, and wind vectors are well-captured Vertically
- Wind speeds tend to be underestimated in the lowest 5km.
- IN general, differences are greatest in the lowest 1km.

Phenomenological Evaluation

Aloft: “key” periods, mean diffs lowest 5km



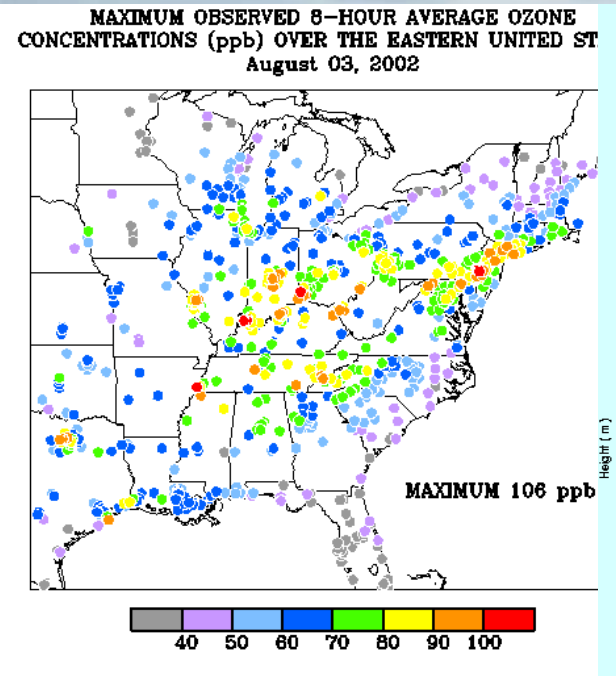


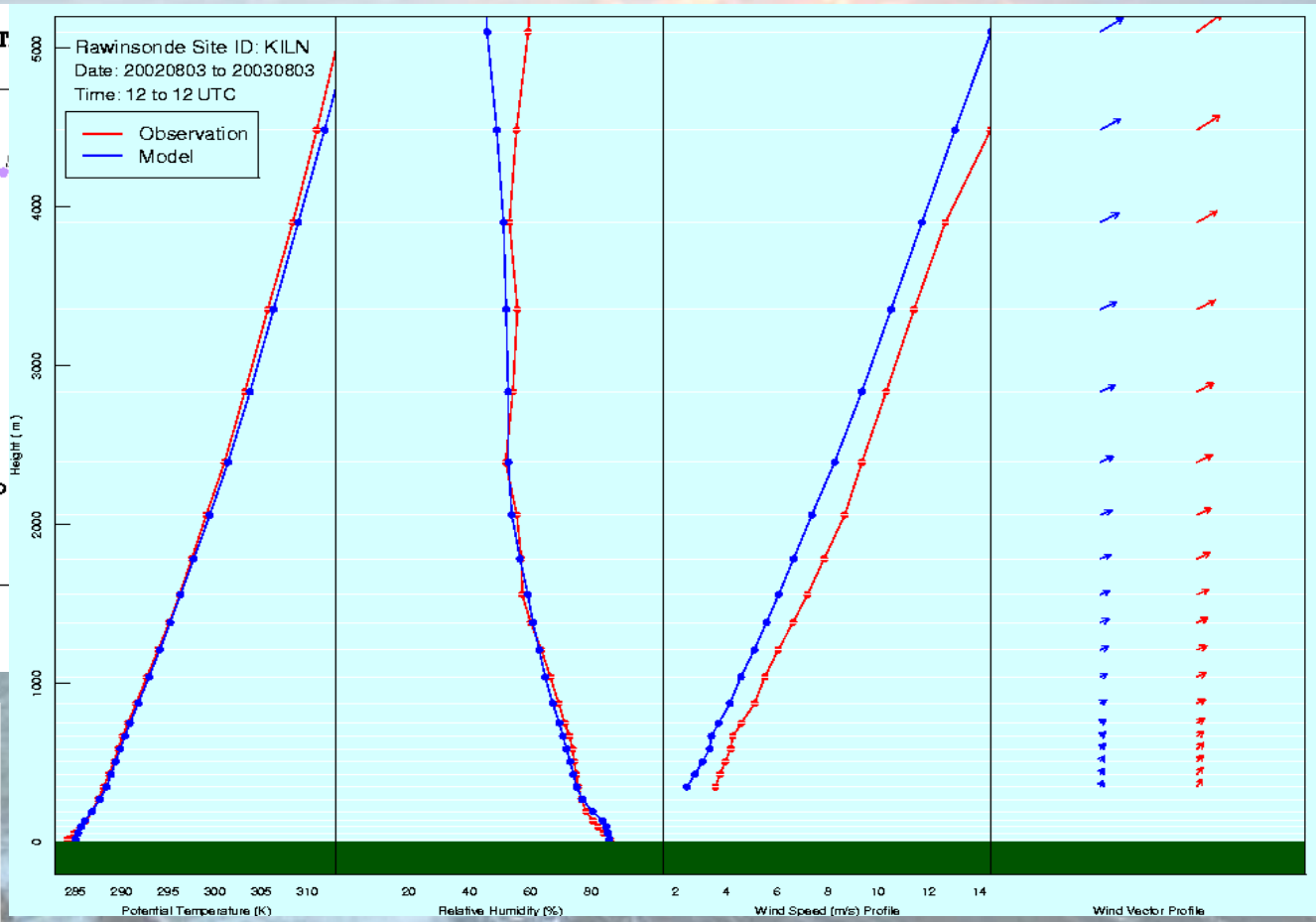
Observations:

- PBL temps are well represented in zone of interest
- Consistent 1-2 m/s bias in BL-average wind speeds will lead to under-representation of transport on this day

Phenomenological Evaluation

Aloft: “key” periods, mean diffs lowest 5km



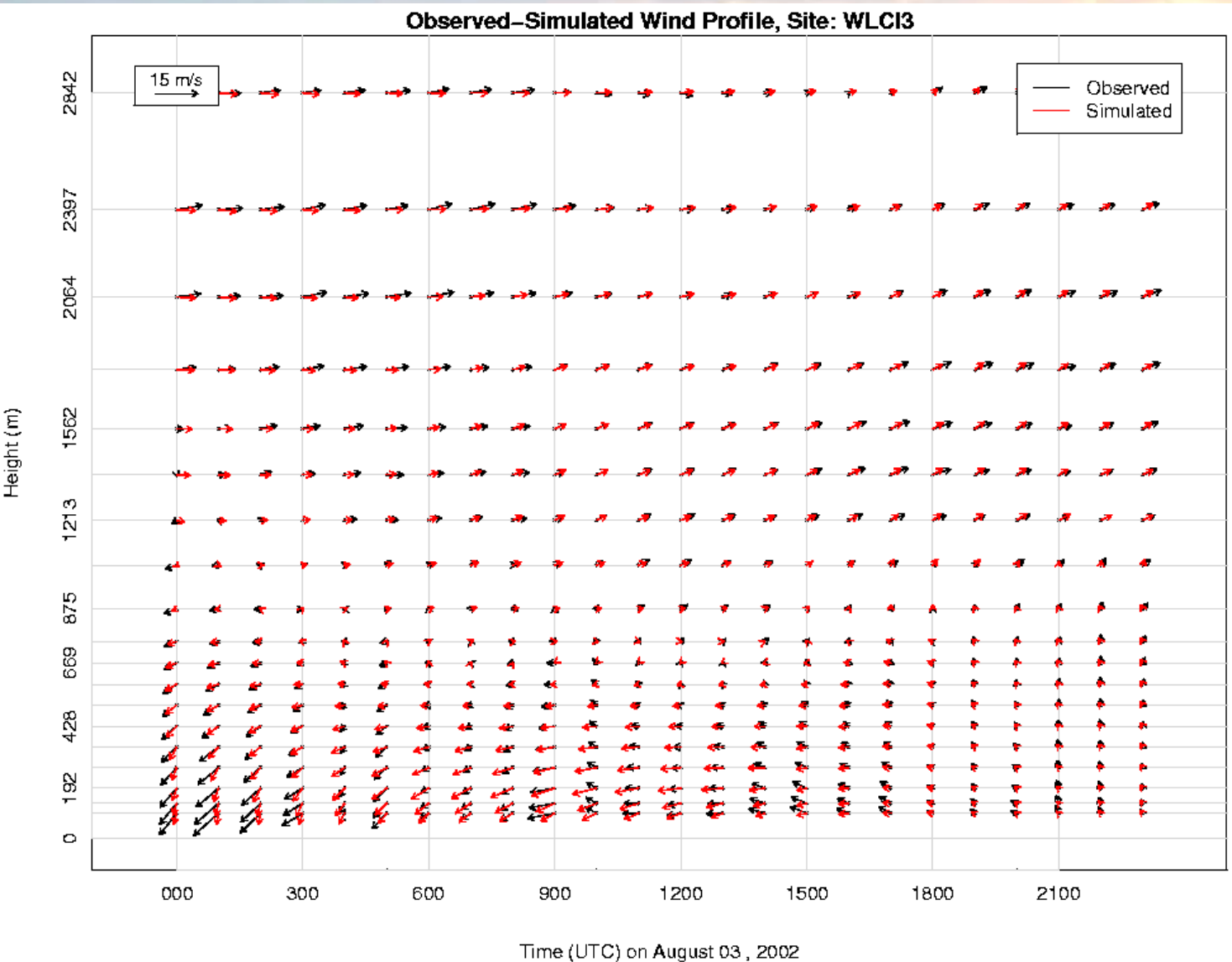


Observations:

- Boundary layer winds are under-estimated at all levels at this Ohio Valley site
- 12Z stability fairly well-captured, model slightly more stable

Phenomenological Evaluation

Aloft: “key” periods, individual profile comparisons

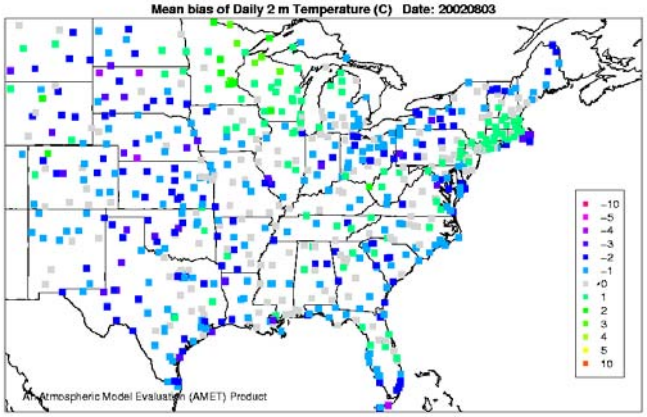


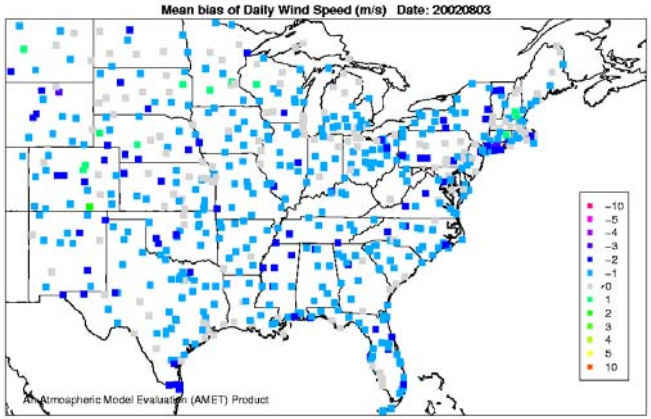
Observations:

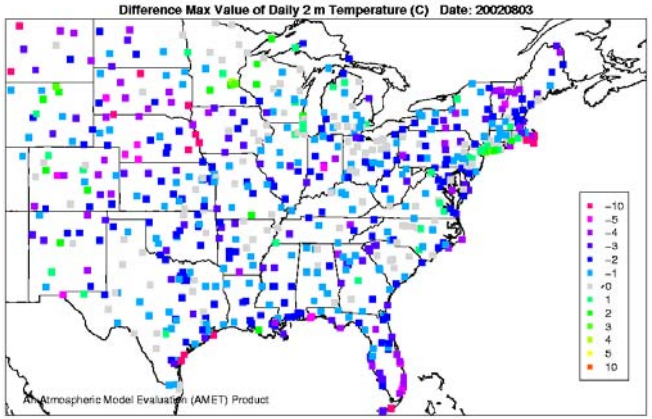
- This profile site is just north of area of high ozone (other side of a stationary front). Model does not capture strong nne flow behind the front
- Model “front” is likely weaker than observed, or misplaced
- Unfortunately, Profiler network has limited spatial coverage in 2002

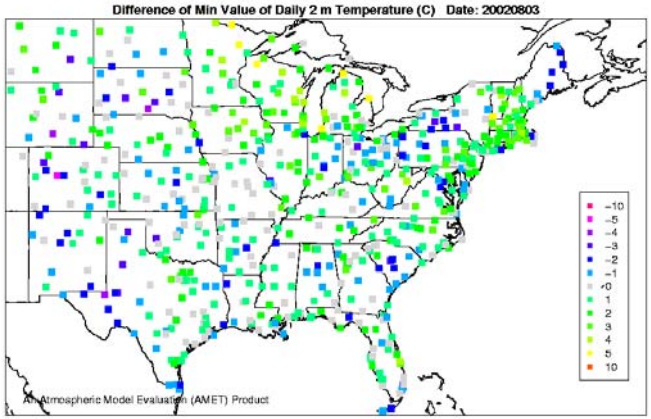
Operational Evaluation

Spatial statistical plots







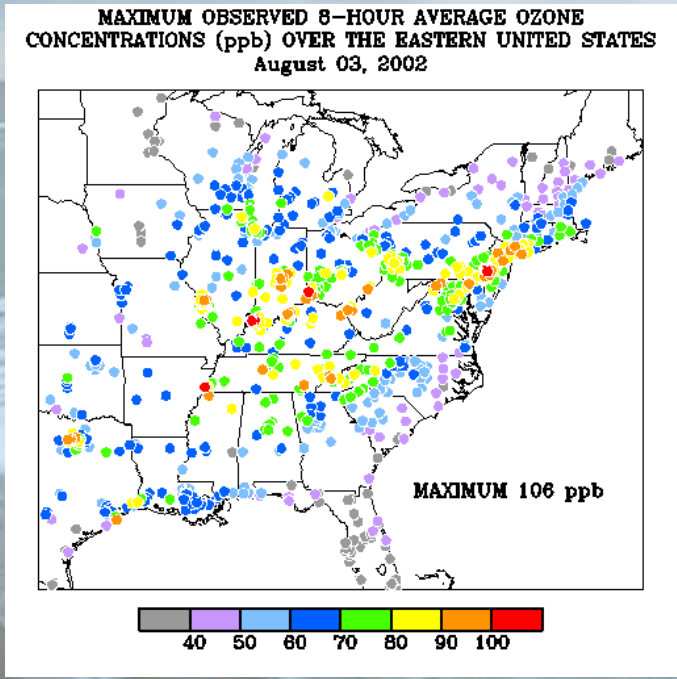


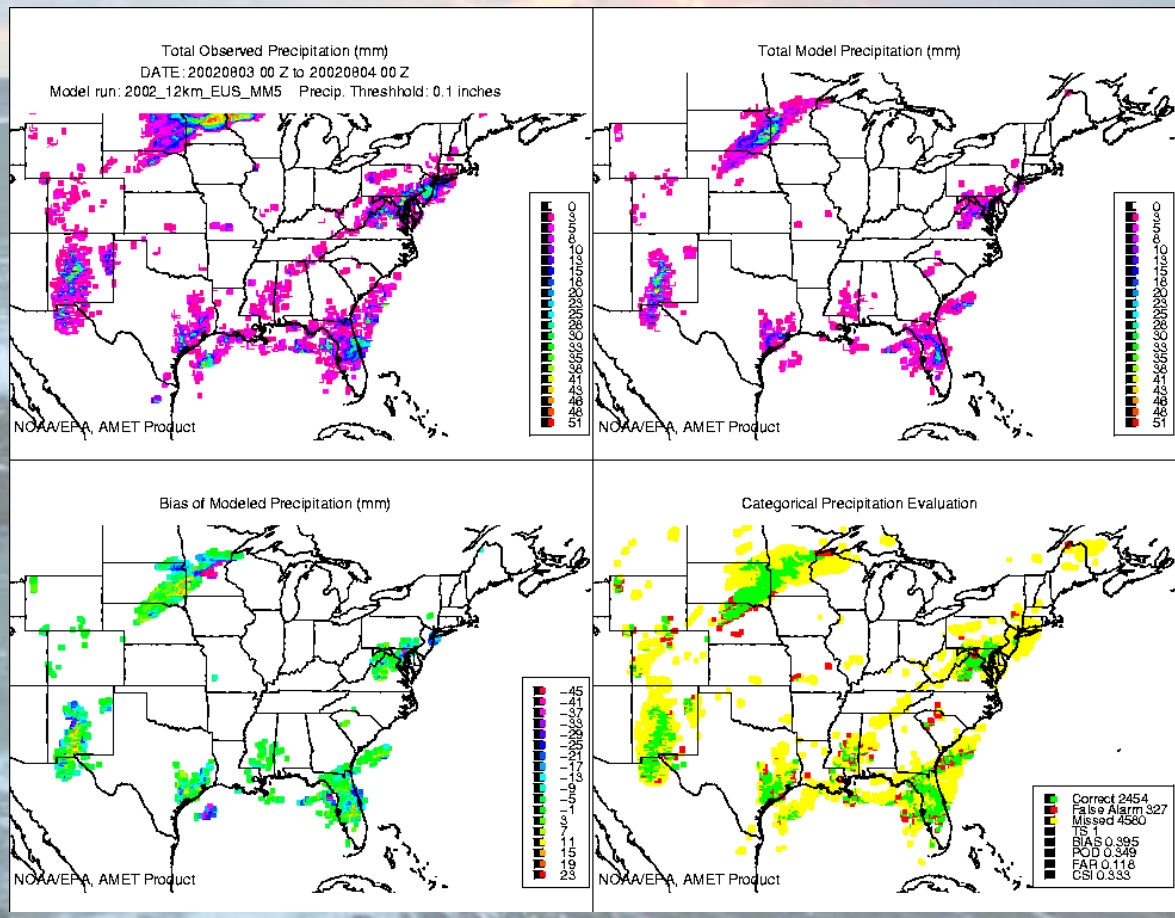
Observations:

- In areas w/ high ozone on this day, model temperatures exhibit a small low bias, but generally good
- As usual, surface wind speeds are underestimated

Operational Evaluation

Daily precipitation





Observations:

- Daily rainfall generally well-captured
- Model rainfall does not extend as far NE as observed, may lead to O3 overpredictions in NYC area

Conclusions (preliminary)

- Major concerns regarding the 2002 modeling are:
  - Cold bias in winter (esp. January)
  - Underestimation of precipitation (esp. in fall months)
  - Underestimation bias of wind speed (transport distance)

- Number of evaluation activities still to be completed
  - Determine model performance for clouds/radiation
  - Some assessment of PBL depth
  - Need work w/ AQ modelers to assess individual time periods, regions, etc. … based on questions arising from AQM evaluation