Evaluation of Multi-Annual CONUS 12 km WRF simulations

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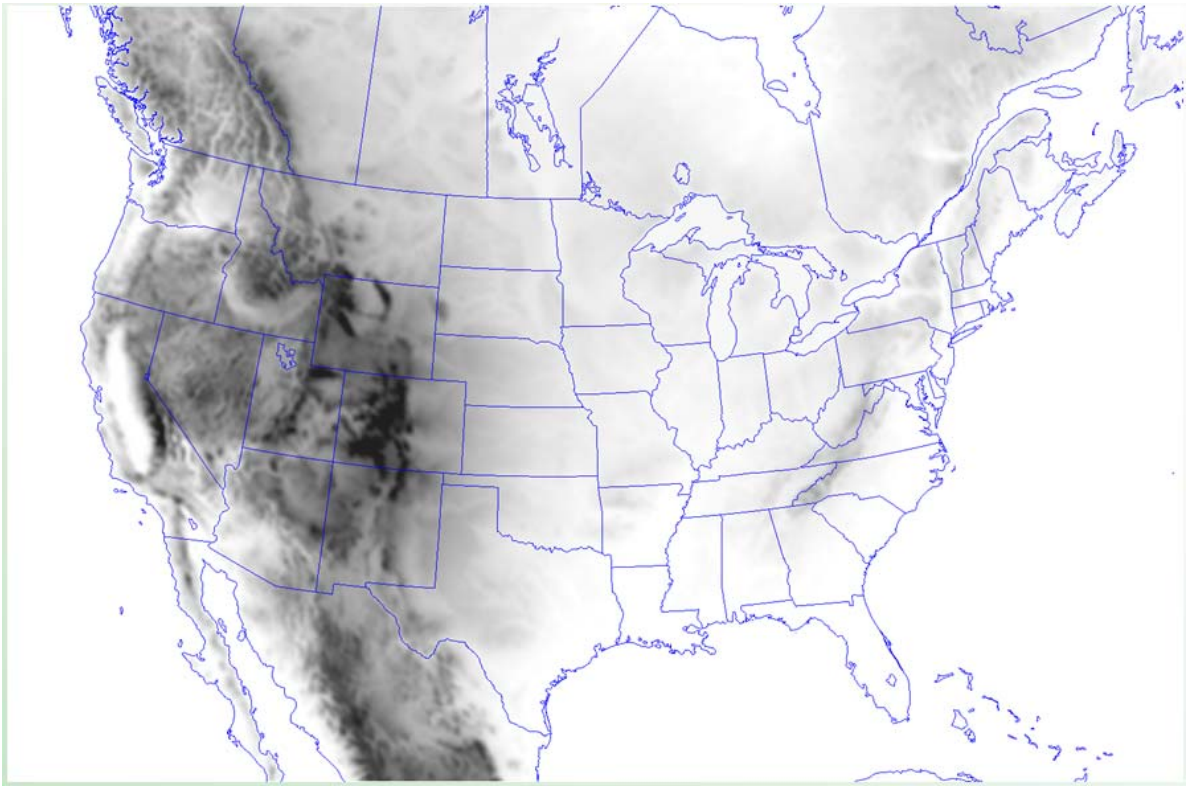

Outline

- Purpose of presentation
- Description of simulations
  - Model configuration
- Operational Evaluation
  - Domain-wide stats
  - Spatial statistics
  - Seasonal precipitation
  - PBL wind assessment using profilers
- Nudging sensitivities

Goals of Presentation

- Examine model performance of across several years and seasons
- Identify major problem areas that may impact air quality model and to direct future research aimed at model improvements
- Compare with “similar” MM5 simulation
  - MM5 physics were similar (PX LSM, ACM2, KF2, nudging, etc)
  - Domain was the eastern US since no CONUS MM5 at 12 km have been run
  - MM5 was for 2005, used out of convenience

Model Configuration

- 12 km North American domain pictured above
- Annual simulations for 2002, 2006 and 2007; 2008 in progress and 2009-2010 are planned
- 472 (nx) x 312 (ny) grid cells with 34 layers; first layer is ~40 m thick with about 17 layers below 2000 m
- High resolution (30 m) National Land Cover Dataset used for landuse; fractional landuse used to derive surface characteristics within the PX LSM
- Time varying sea surface temperature
- 6th order diffusion (opt. 1), w_damping, w-Rayleigh damping, km_opt (opt. 4), positive definite advection for scalars and moisture
- Simulations were split into 5.5 day run segments that overlapped by 12 hours. The 12 hours is used for model spin-up, but not used by the air quality model or in the evaluation
- Analysis nudging of U,V, T and Q was enabled with the specific options provided to the right; no temperature and moisture nudging in the PBL
- Surface analysis nudging was enabled per namelist options to the right
- Pleim-Xiu LSM soil moisture and temperature nudging enabled
- All nudging fields including 3-D wind, temperature and water vapor mixing ratio; 10-m wind, 2-m temperature and 2-m mixing ratio were derived from the ***Obsgrid*** re-analysis program, which used the 12 km NAM as the base analysis and standard surface observations and rawinsonde soundings for the upper air data

Physics	Parameterization
Microphysics	Morrison
Longwave radiation	RRTMG
Shortwave radition	RRTMG
Surface-layer	Pleim
Land-surface	Pleim-Xiu
Boundary-layer	ACM2
Cumulus	Kain-Fritsch 2

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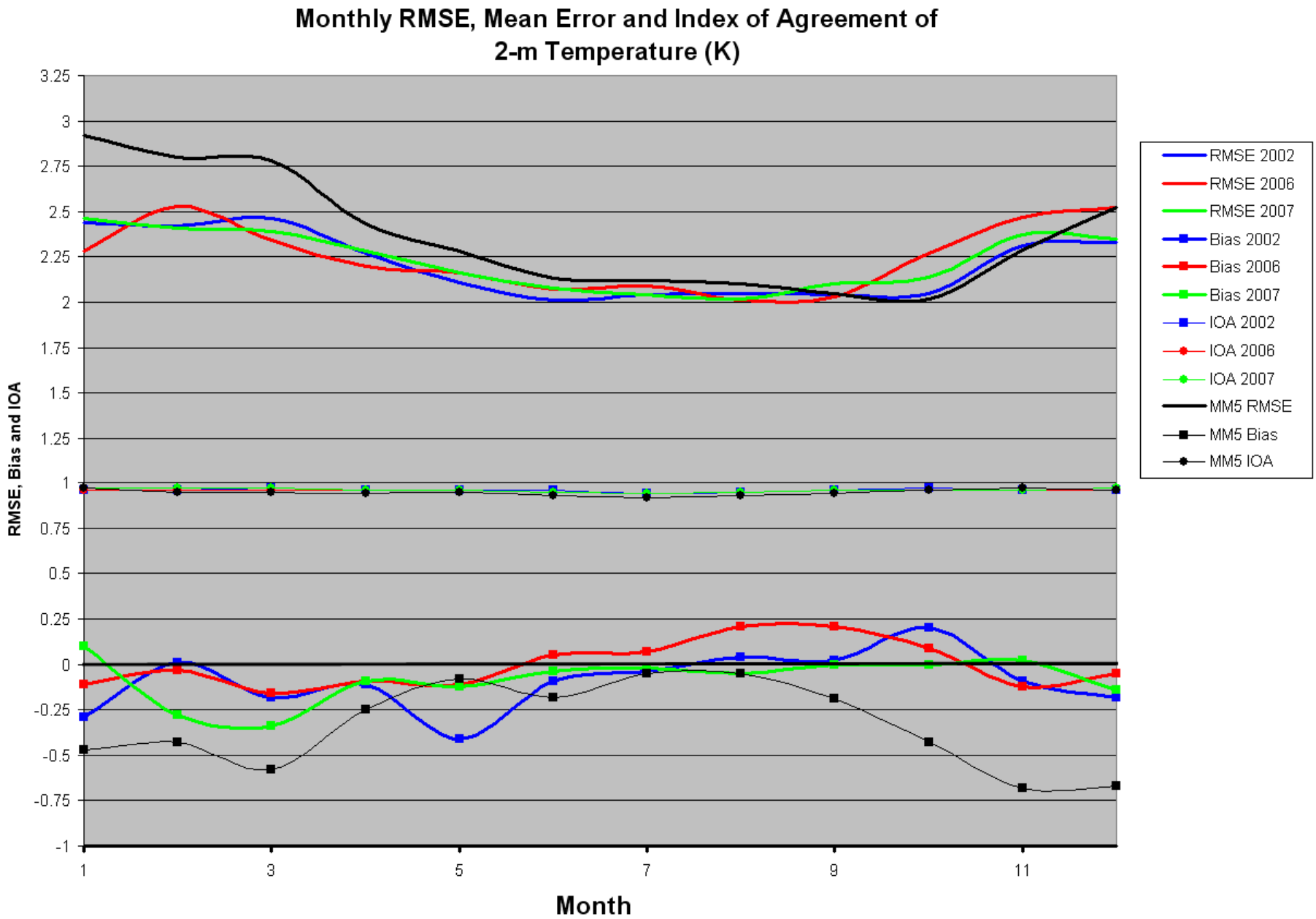
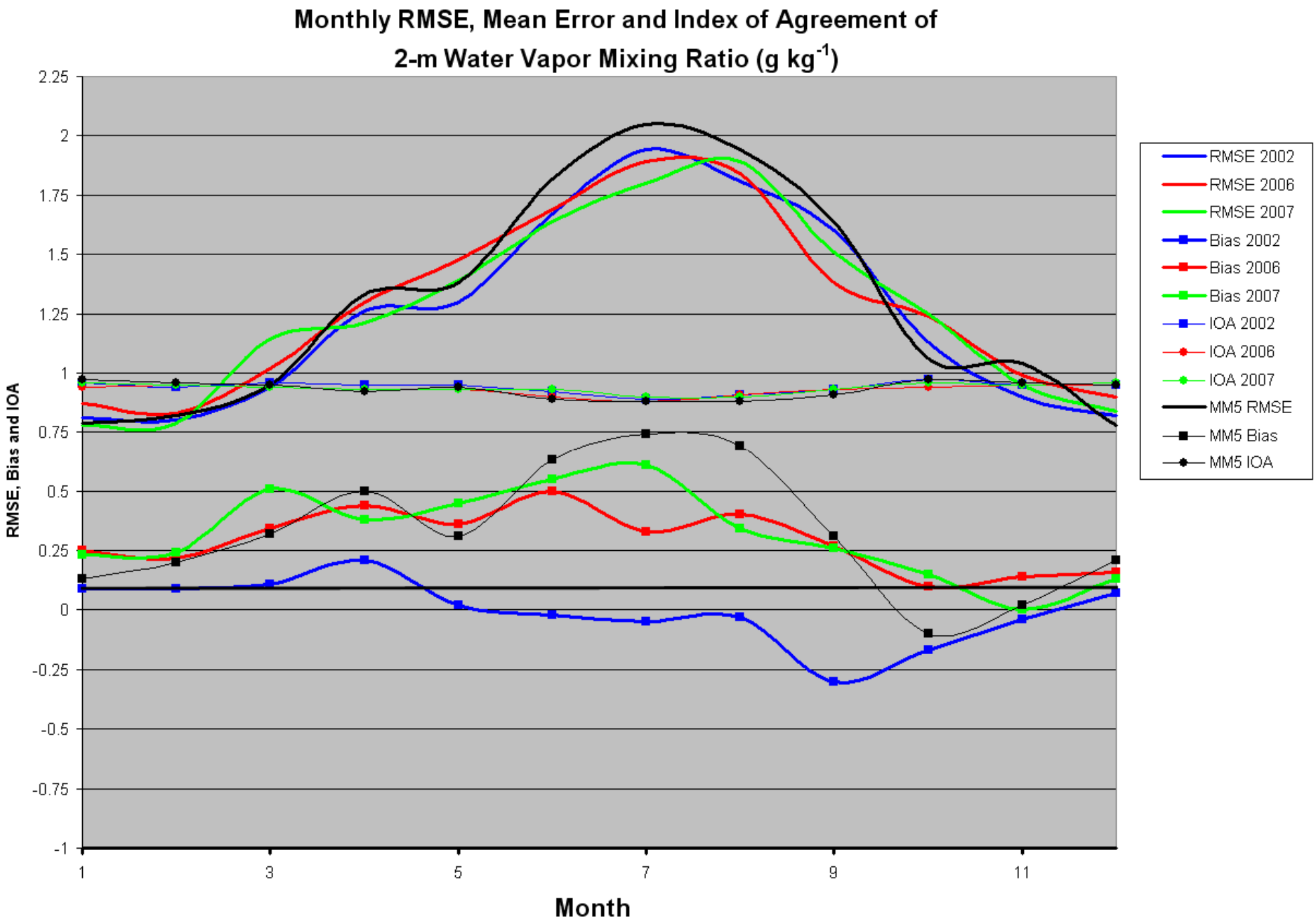
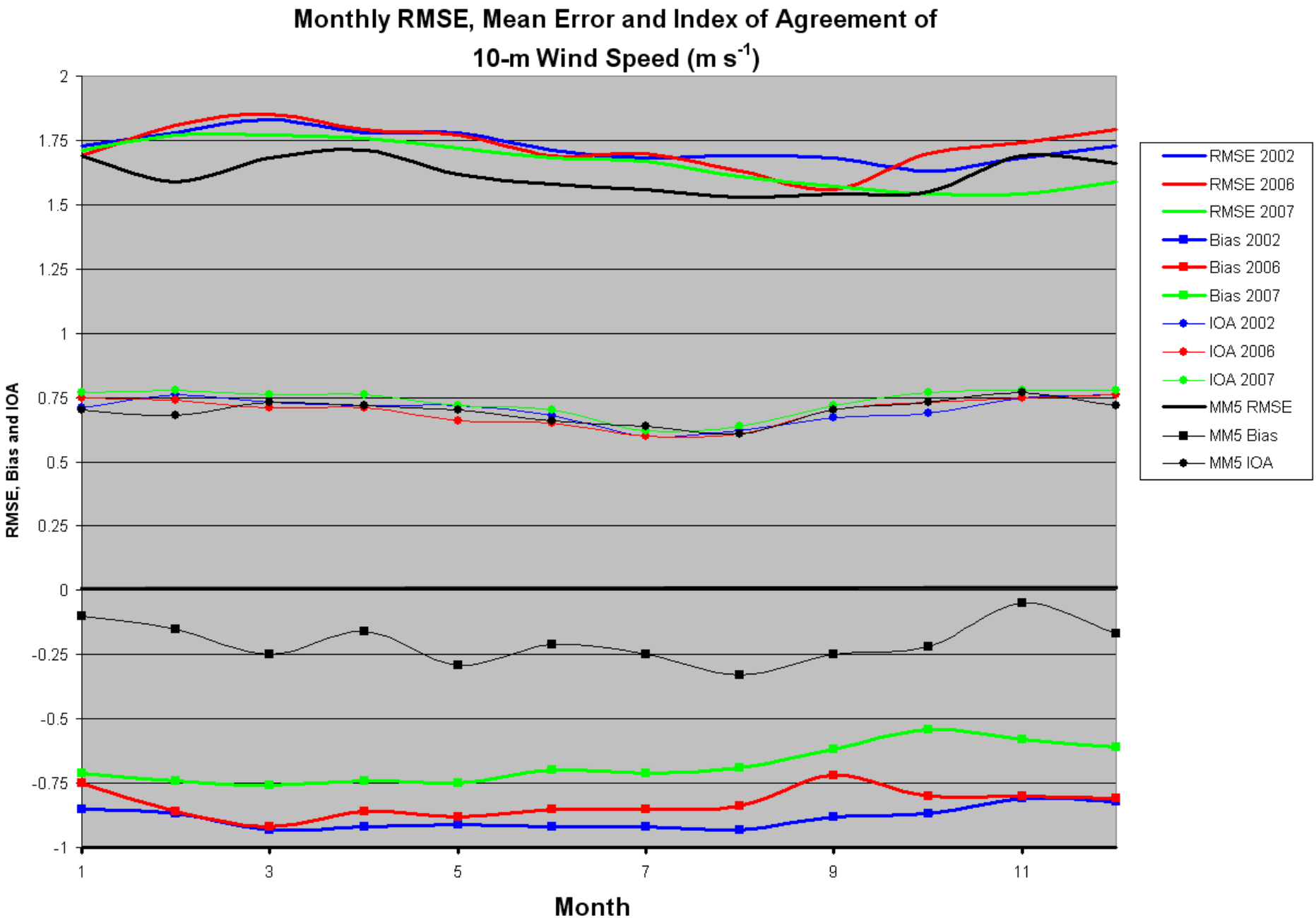
Model Evaluation: The Atmospheric Model Evaluation Tool (AMET), developed by the US EPA and the Univ. of North Carolina's Institute for the Environment, was used to match the annual WRF simulations with point measurements from surface networks and wind profilers. AMET uses the observations collected by the Meteorological Assimilation Data Ingest System (MADIS). For the comparisons to MM5 it must be understood that the MM5 simulation was for a different year (2005) and that domain only covered the eastern US, while the WRF domain covered the difficult to model western US.

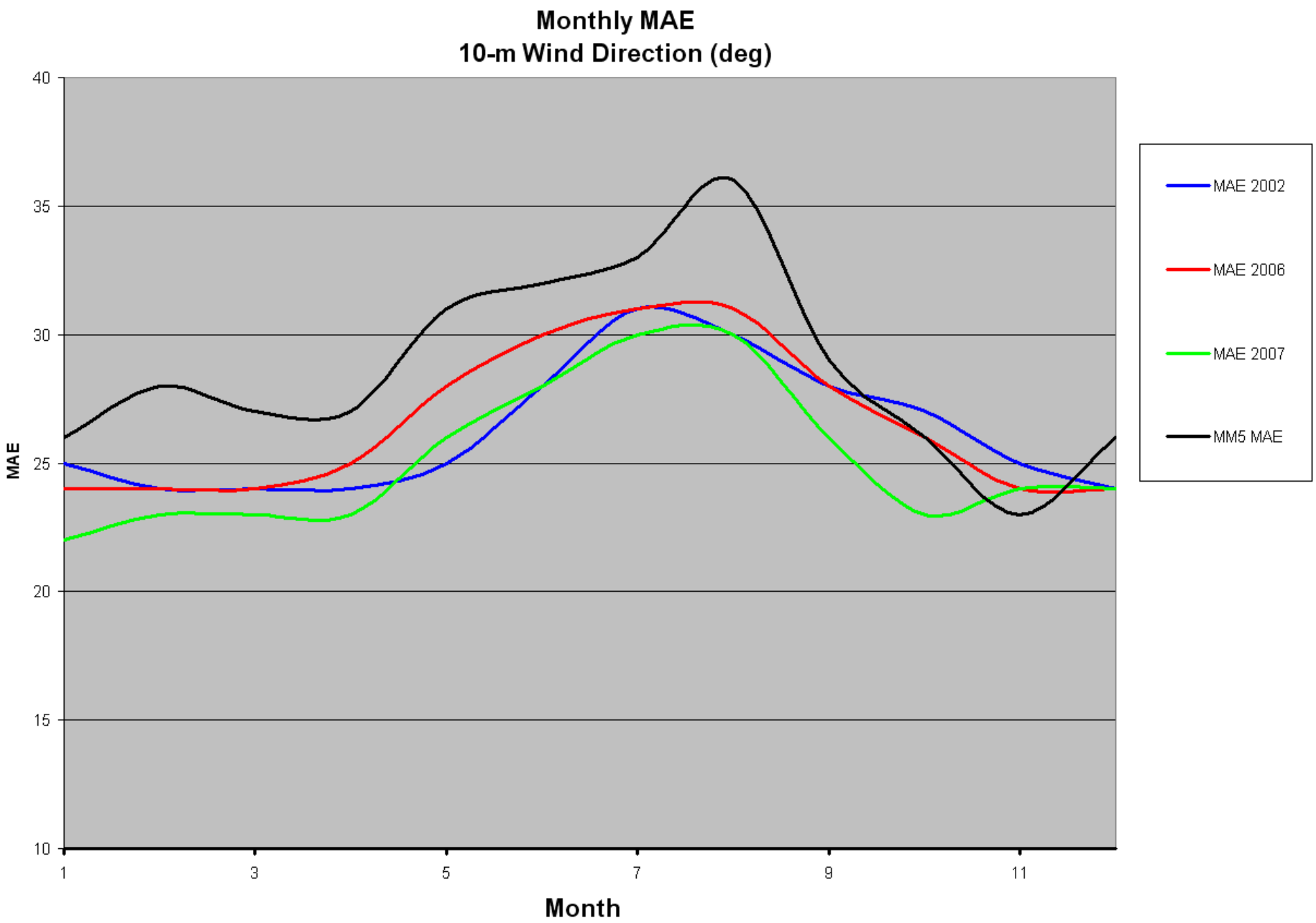
Domain-wide and regional model performance

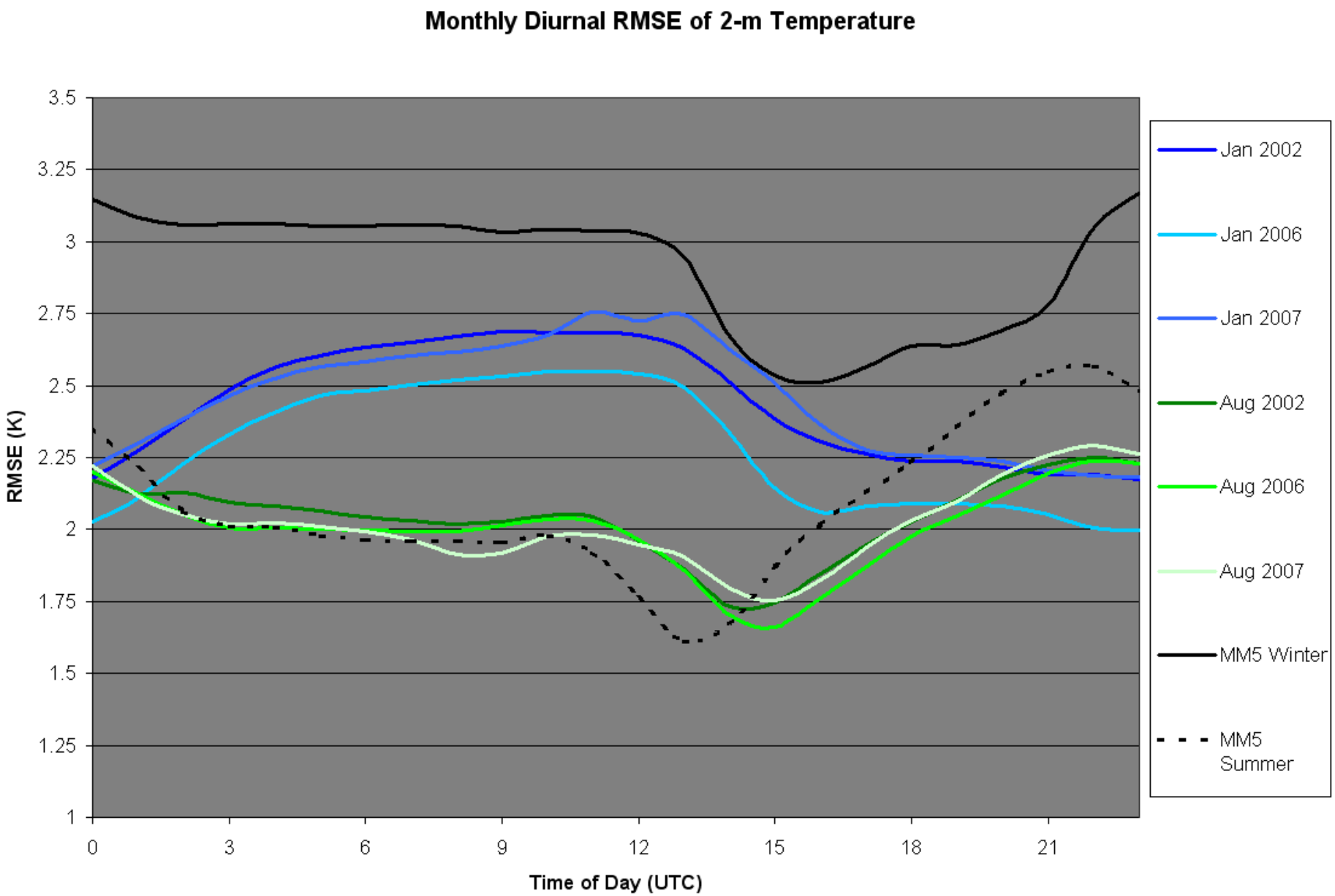
Error and bias of near-surface temperature, moisture and wind grouped by month and time of day

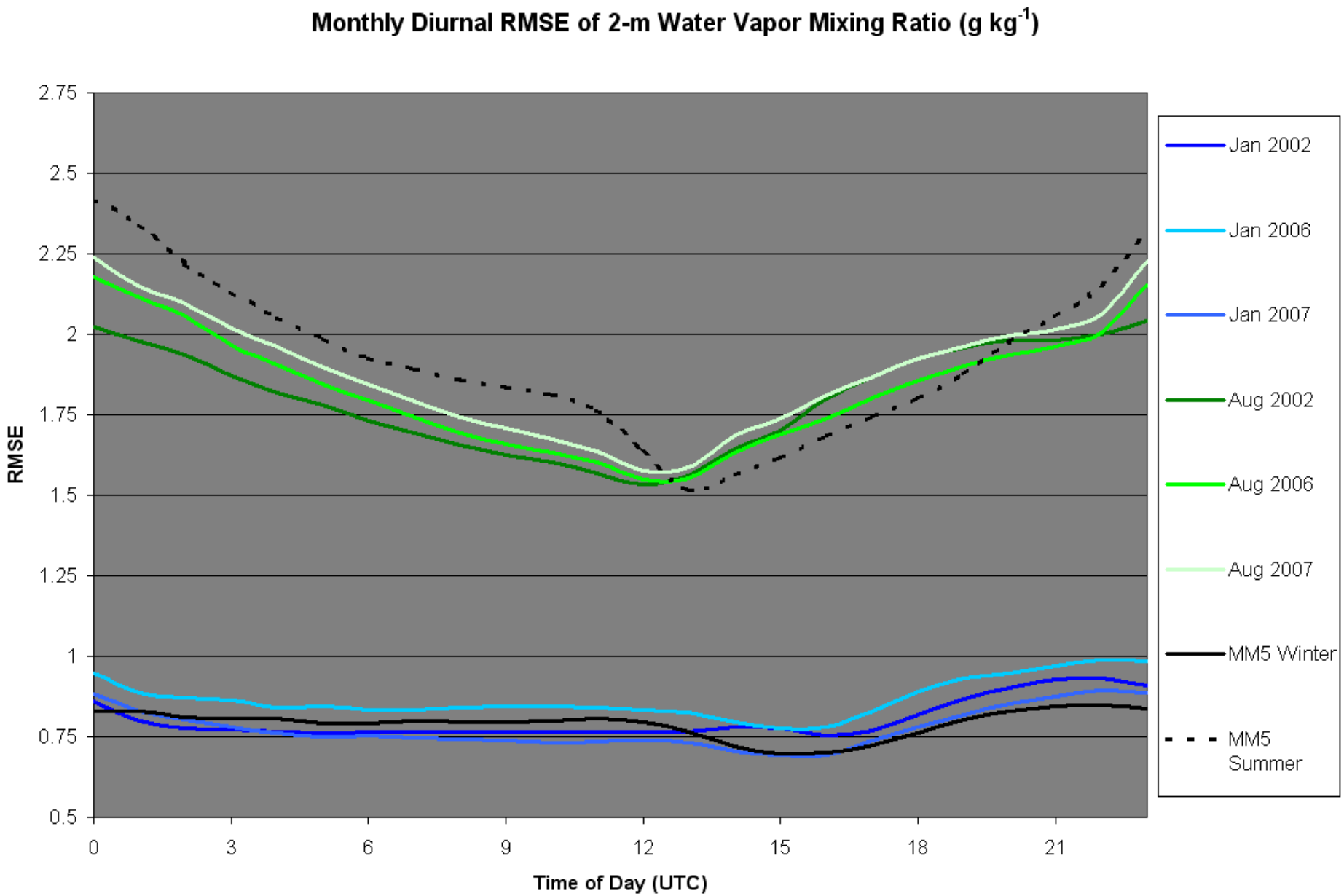

Monthly RMSE, Mean Error and Index of Agreement of
2-m Temperature (K)
RMSE, Bias and IOA
3.25
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
1
3
5
7
9
11
Month
RMSE 2002
RMSE 2006
RMSE 2007
Bias 2002
Bias 2006
Bias 2007
IOA 2002
IOA 2006
IOA 2007
MM5 RMSE
MM5 Bias
MM5 IOA

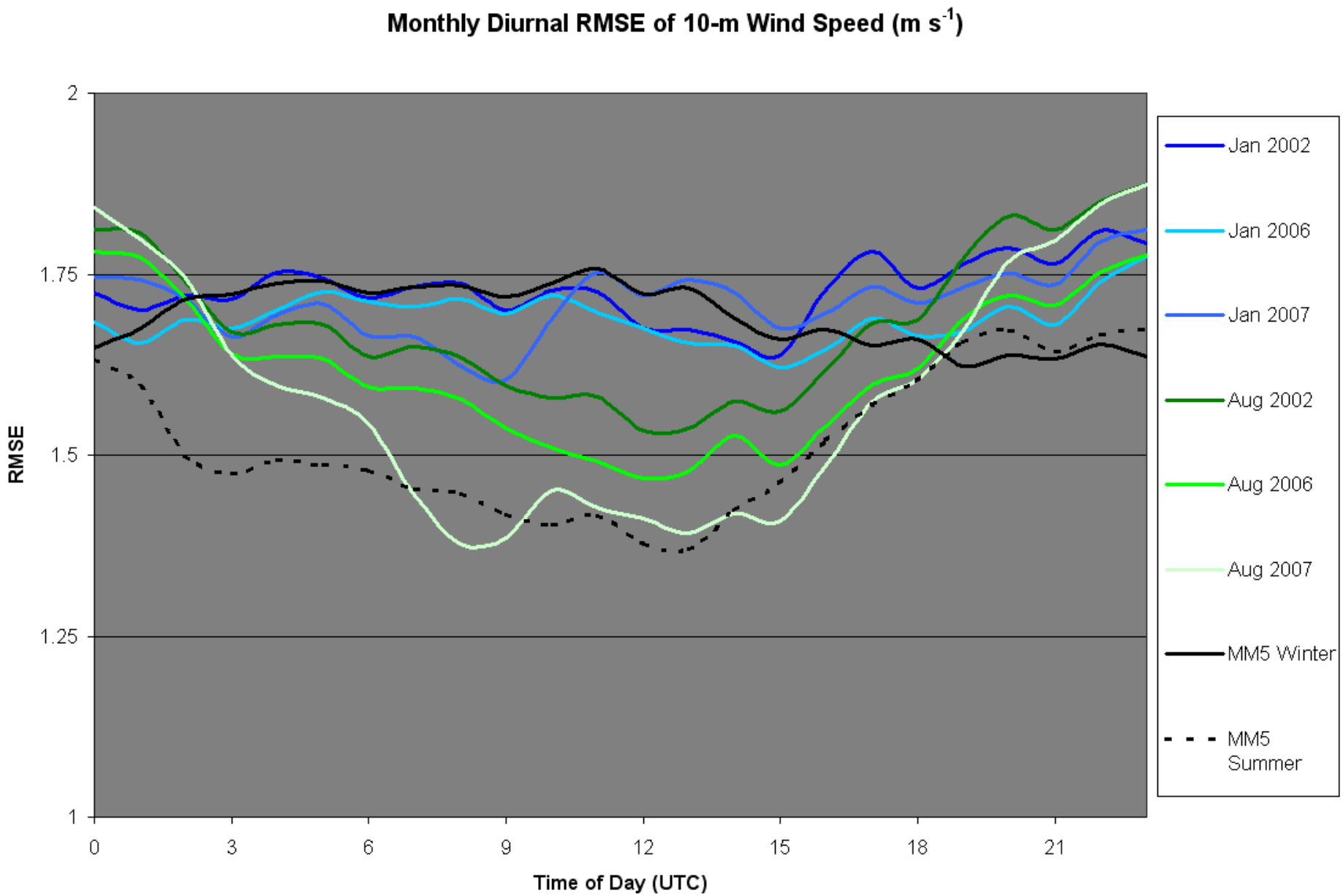

Monthly RMSE, Mean Error and Index of Agreement of
2-m Water Vapor Mixing Ratio (g kg-1)
RMSE, Bias and IOA
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
1
3
5
7
9
11
Month
RMSE 2002
RMSE 2006
RMSE 2007
Bias 2002
Bias 2006
Bias 2007
IOA 2002
IOA 2006
IOA 2007
MM5 RMSE
MM5 Bias
MM5 IOA


Monthly RMSE, Mean Error and Index of Agreement of
10-m Wind Speed (m s-1)
RMSE, Bias and IOA
Month
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
1
3
5
7
9
11
RMSE 2002
RMSE 2006
RMSE 2007
Bias 2002
Bias 2006
Bias 2007
IOA 2002
IOA 2006
IOA 2007
MM5 RMSE
MM5 Bias
MM5 IOA


Monthly MAE
10-m Wind Direction (deg)
MAE
40
35
30
25
20
15
10
1
3
5
7
9
11
Month
MAE 2002
MAE 2006
MAE 2007
MM5 MAE


Monthly Diurnal RMSE of 2-m Temperature
RMSE (K)
3.5
3.25
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0
3
6
9
12
15
18
21
Time of Day (UTC)
Jan 2002
Jan 2006
Jan 2007
Aug 2002
Aug 2006
Aug 2007
MM5 Winter
MM5 Summer

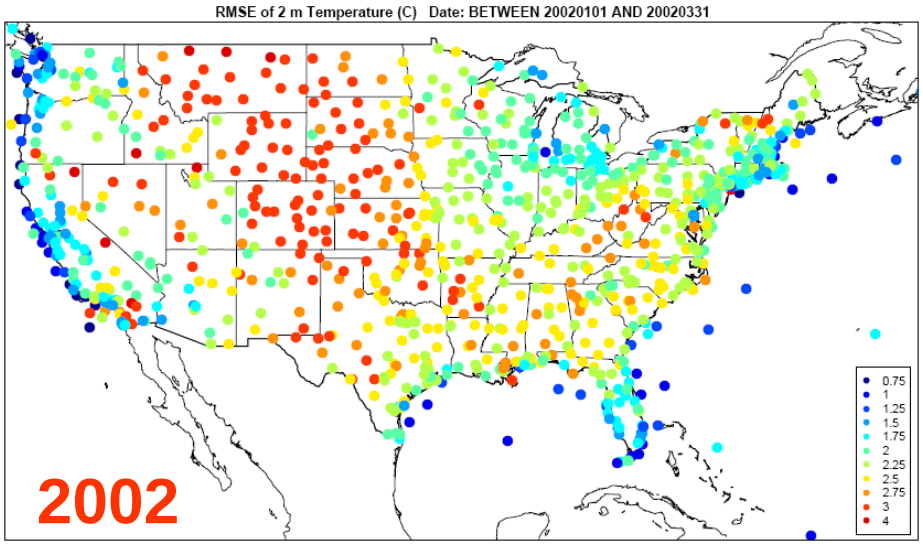

Monthly Diurnal RMSE of 2-m Water Vapor Mixing Ratio (g kg-1)
RMSE
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0
3
6
9
12
15
18
21
Time of Day (UTC)
Jan 2002
Jan 2006
Jan 2007
Aug 2002
Aug 2006
Aug 2007
MM5 Winter
MM5 Summer

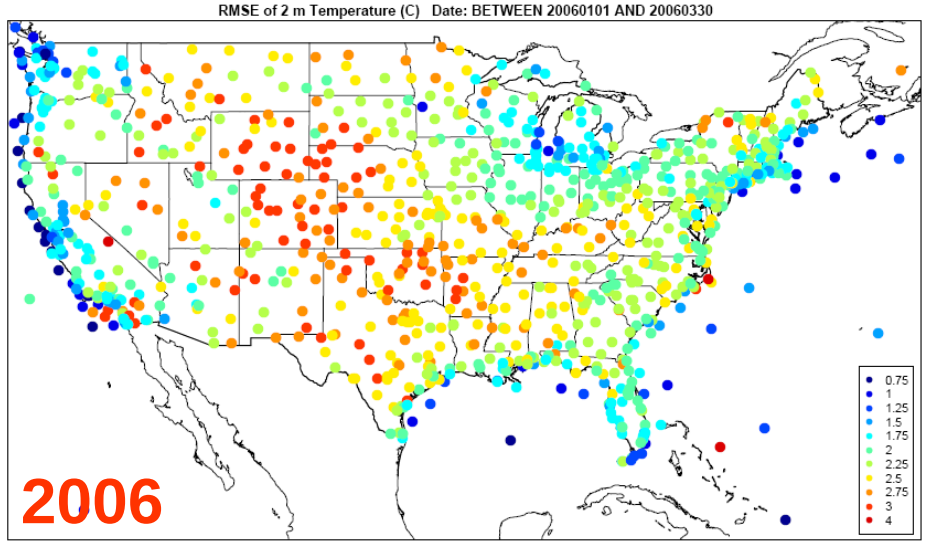

Monthly Diurnal RMSE of 10-m Wind Speed (m s-1)
RMSE
2
1.75
1.5
1.25
1
0
3
6
9
12
15
18
21
Time of Day (UTC)
Jan 2002
Jan 2006
Jan 2007
Aug 2002
Aug 2006
Aug 2007
MM5 Winter
MM5 Summer

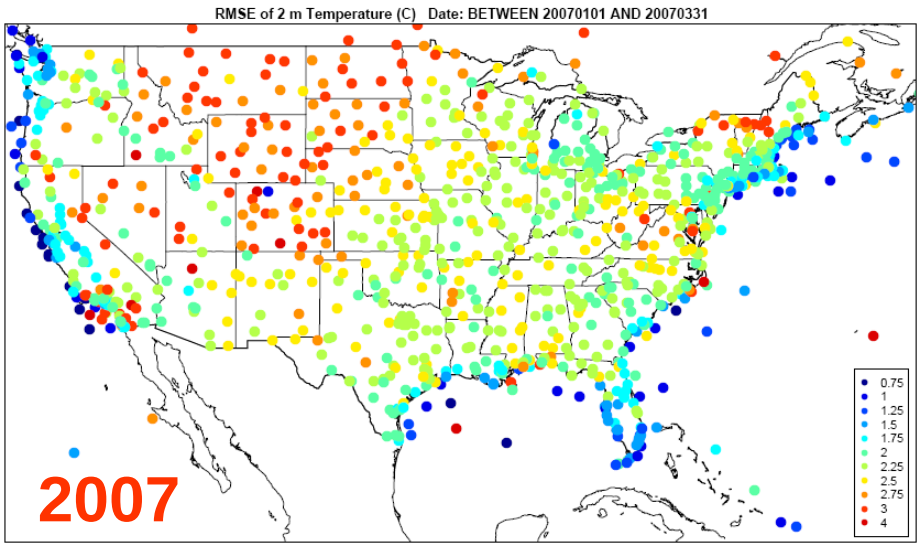
Spatial model performance

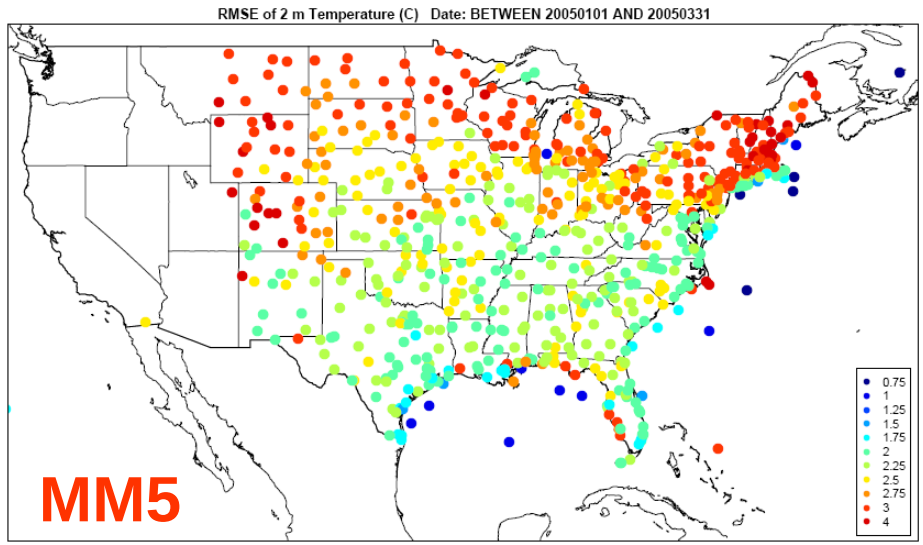
Spatial statistics grouped by season for near-surface temperature, moisture and wind

RMSE 2-m Temperature (Winter)

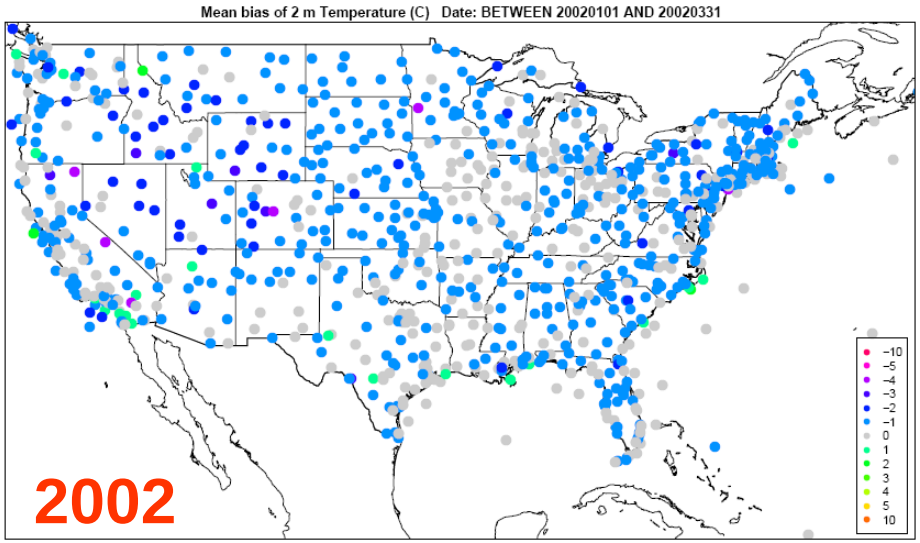


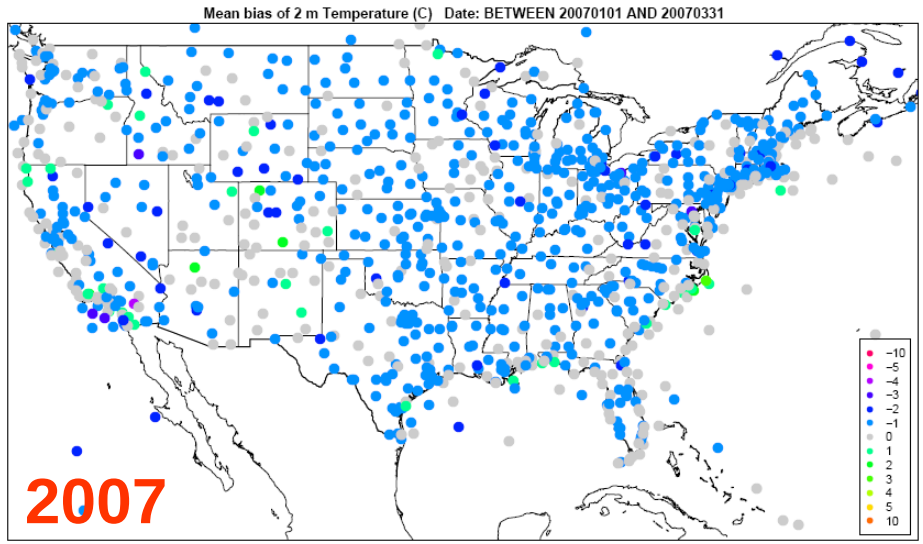


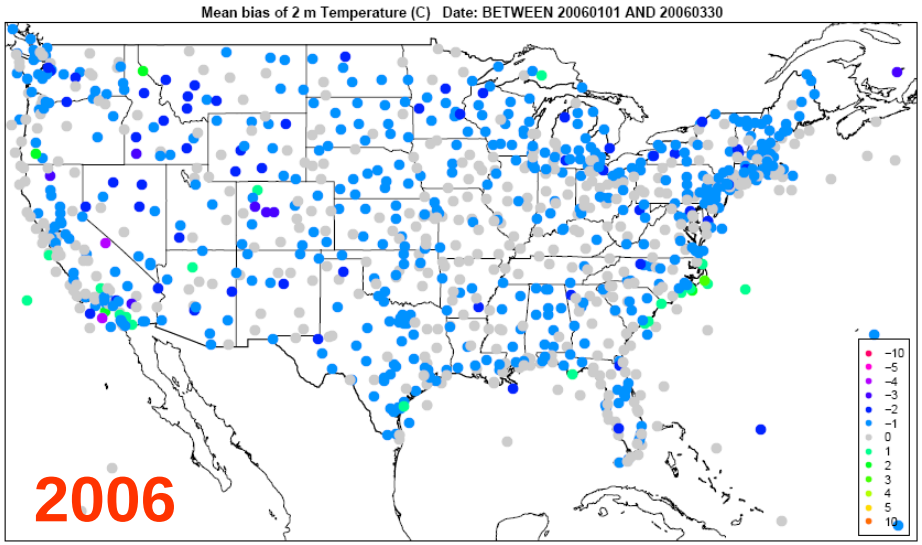


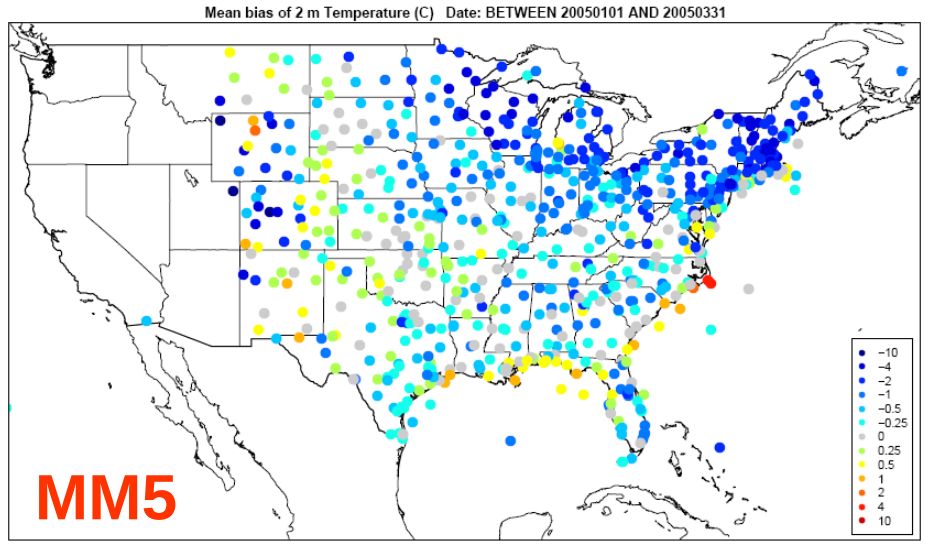


Bias 2-m Temperature (Winter)

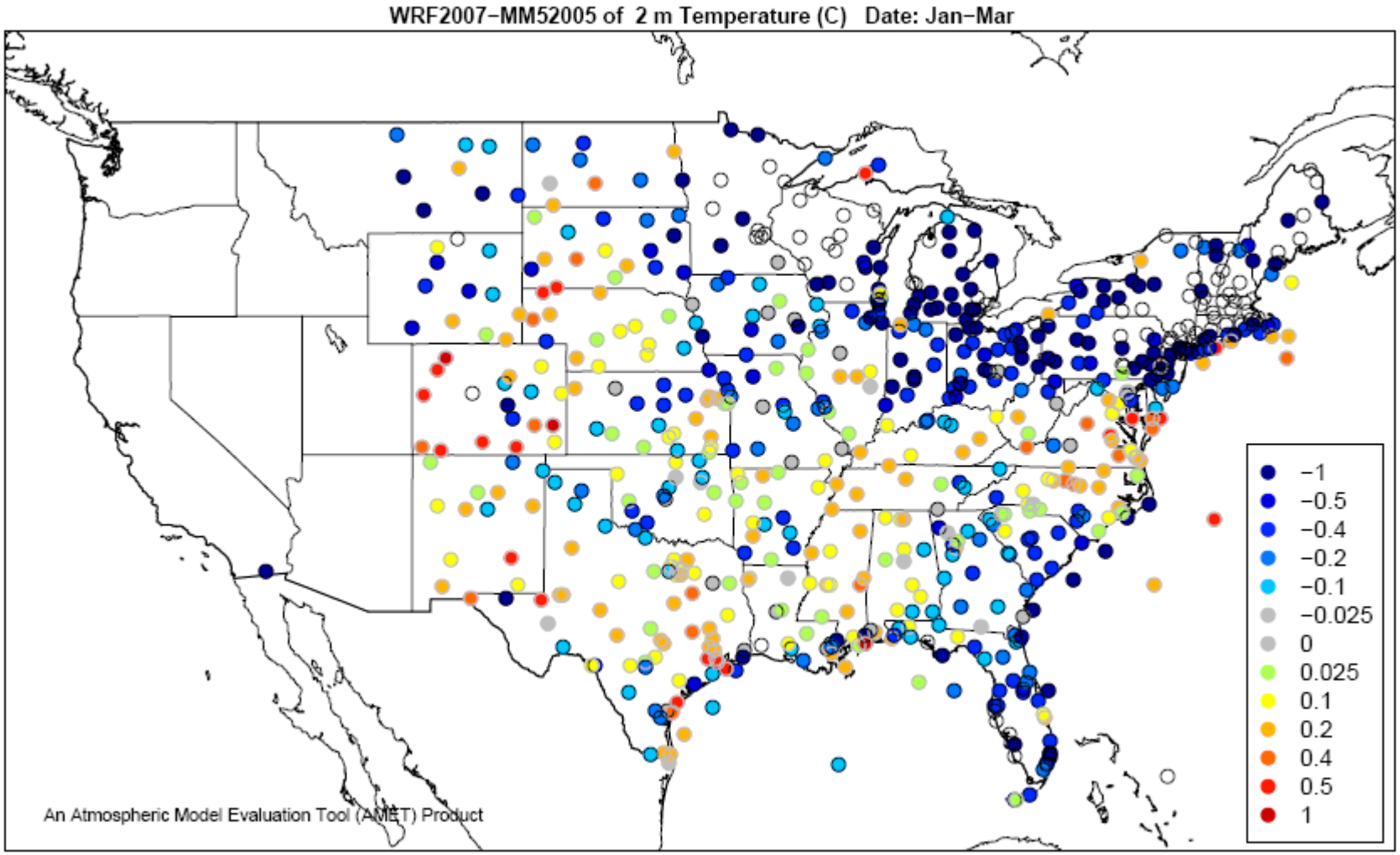




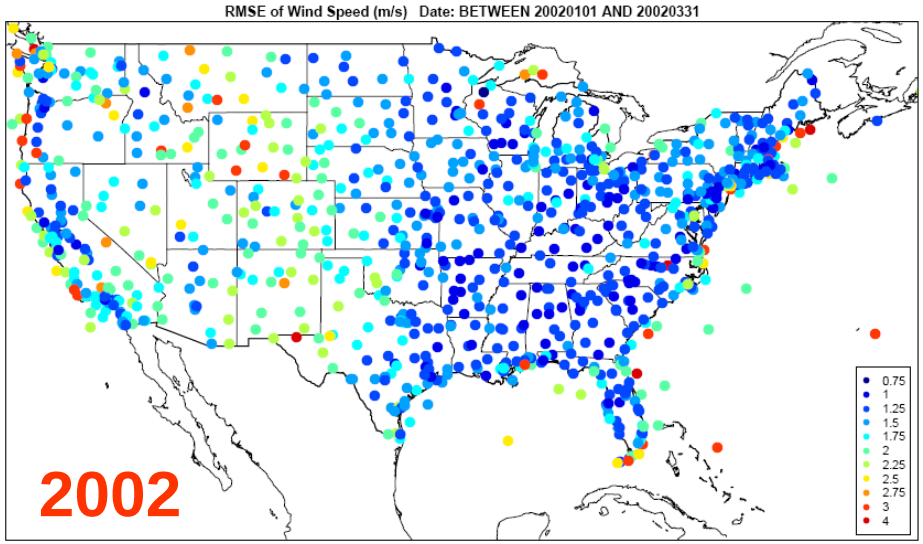


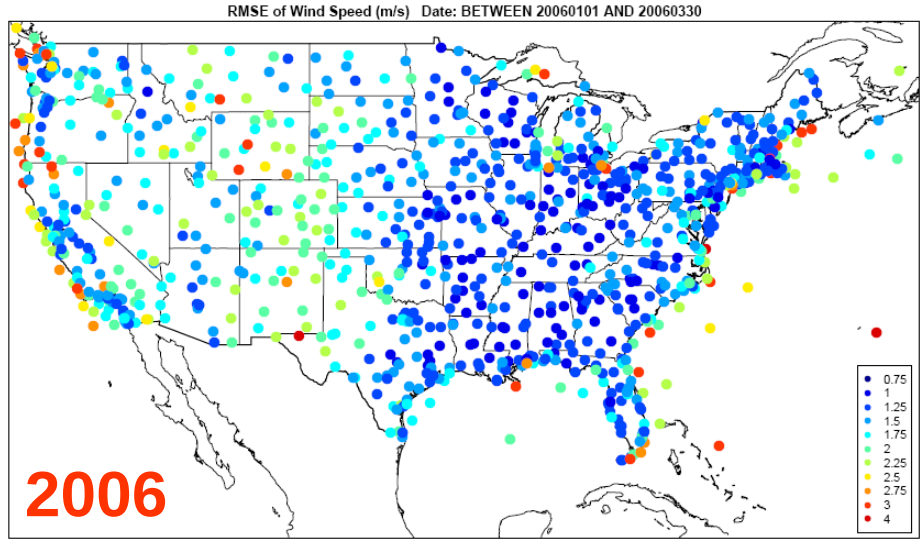


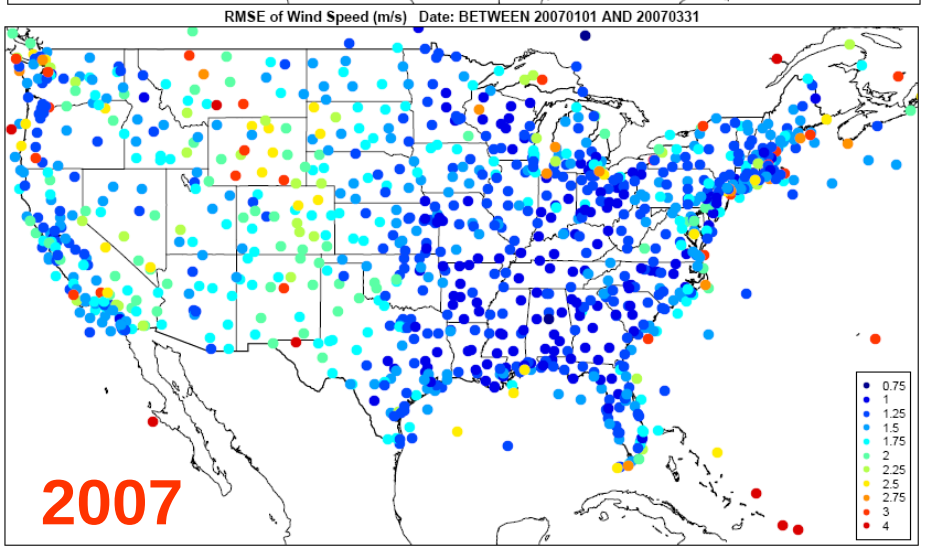
RMSE 2-m Temp Differences (Winter)
WRF – MM5

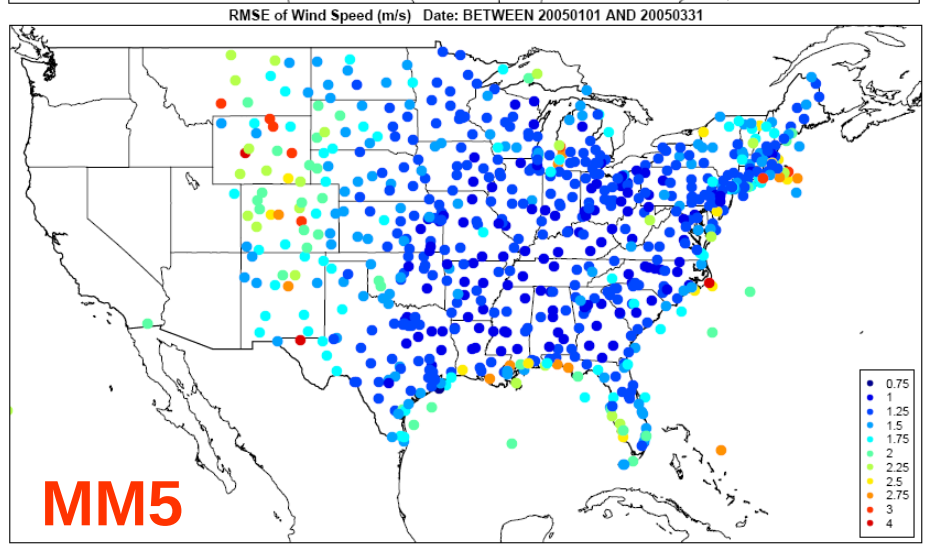


RMSE 10-m Wind Speed (Winter)

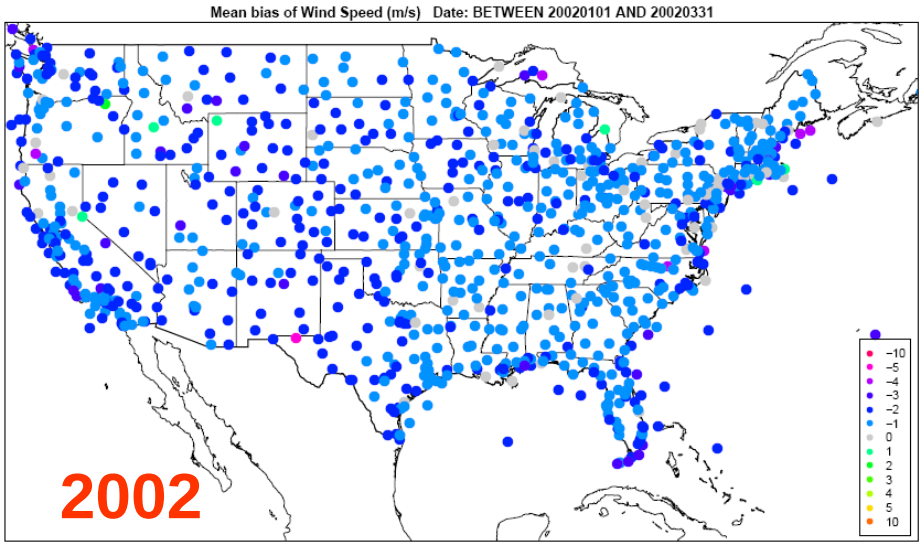


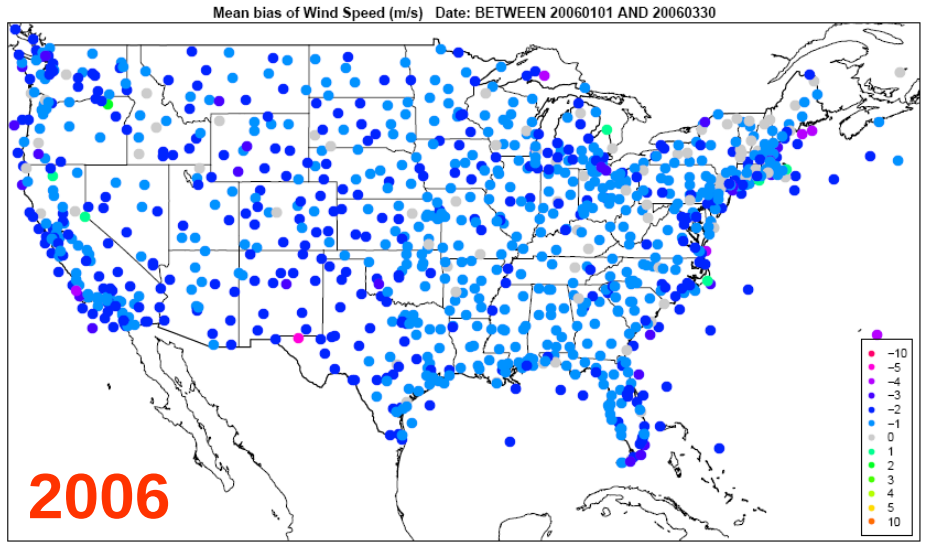


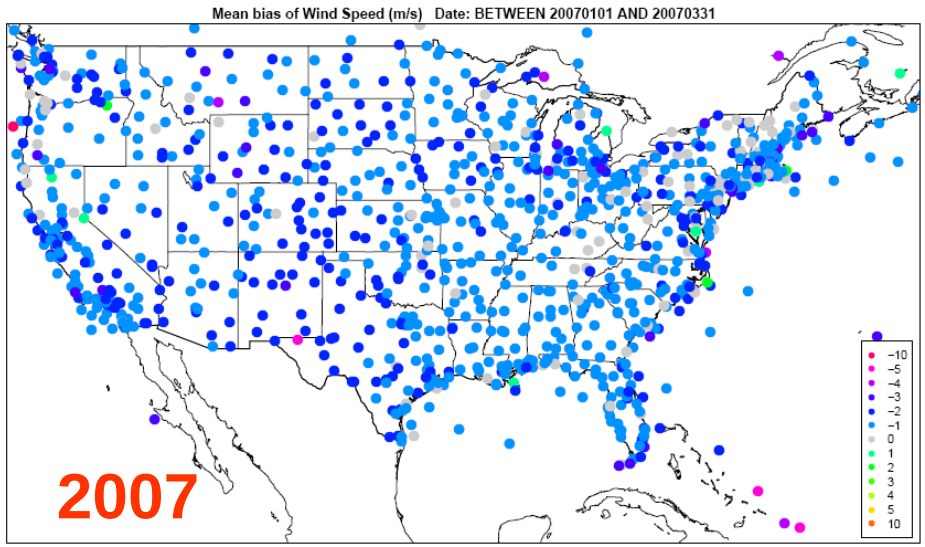


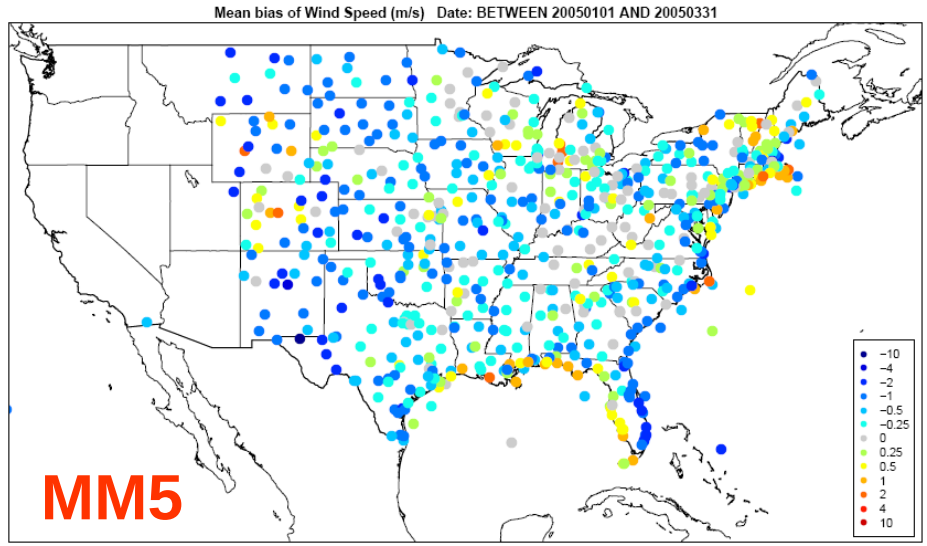


Bias 10-m Wind Speed (Winter)

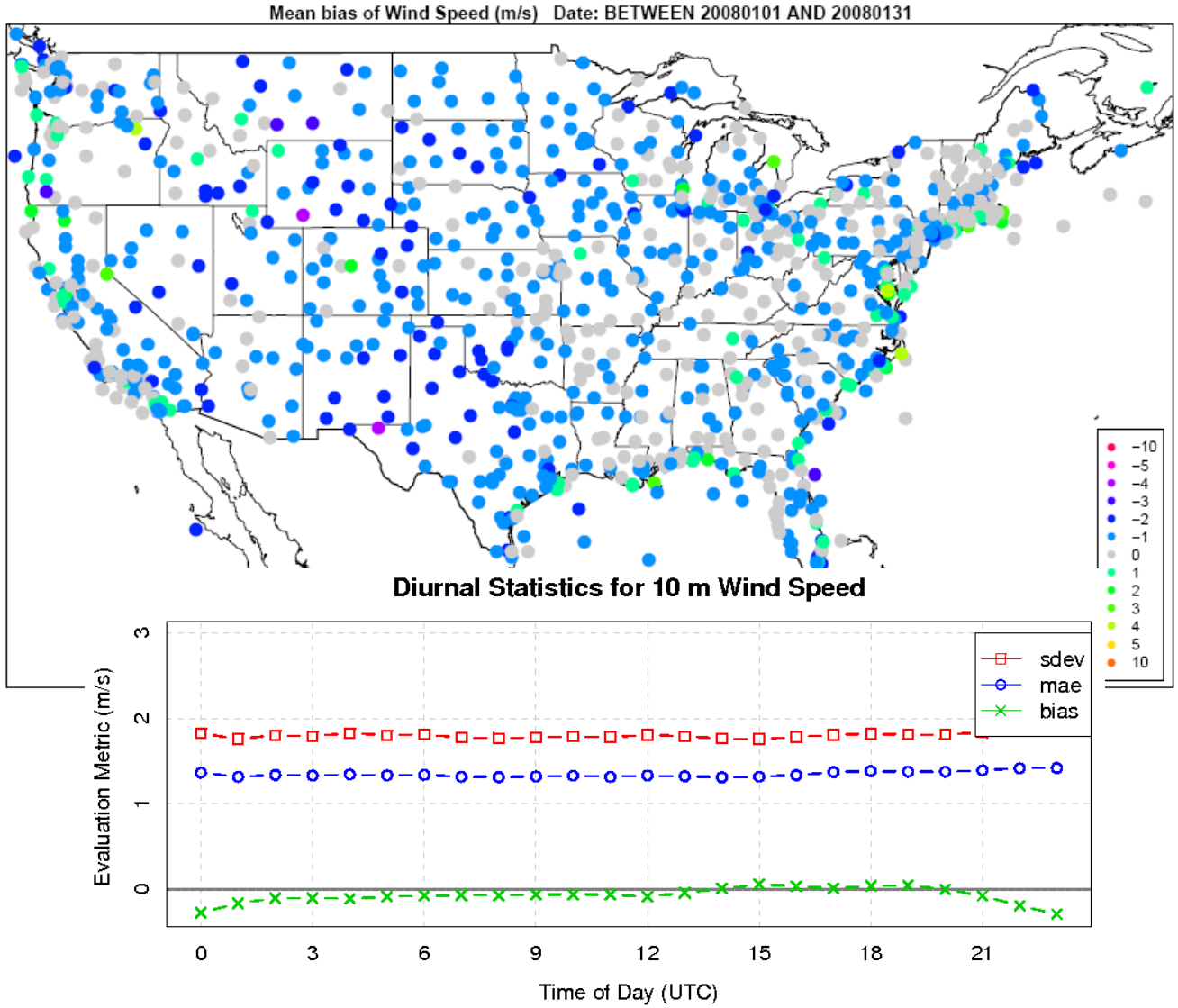




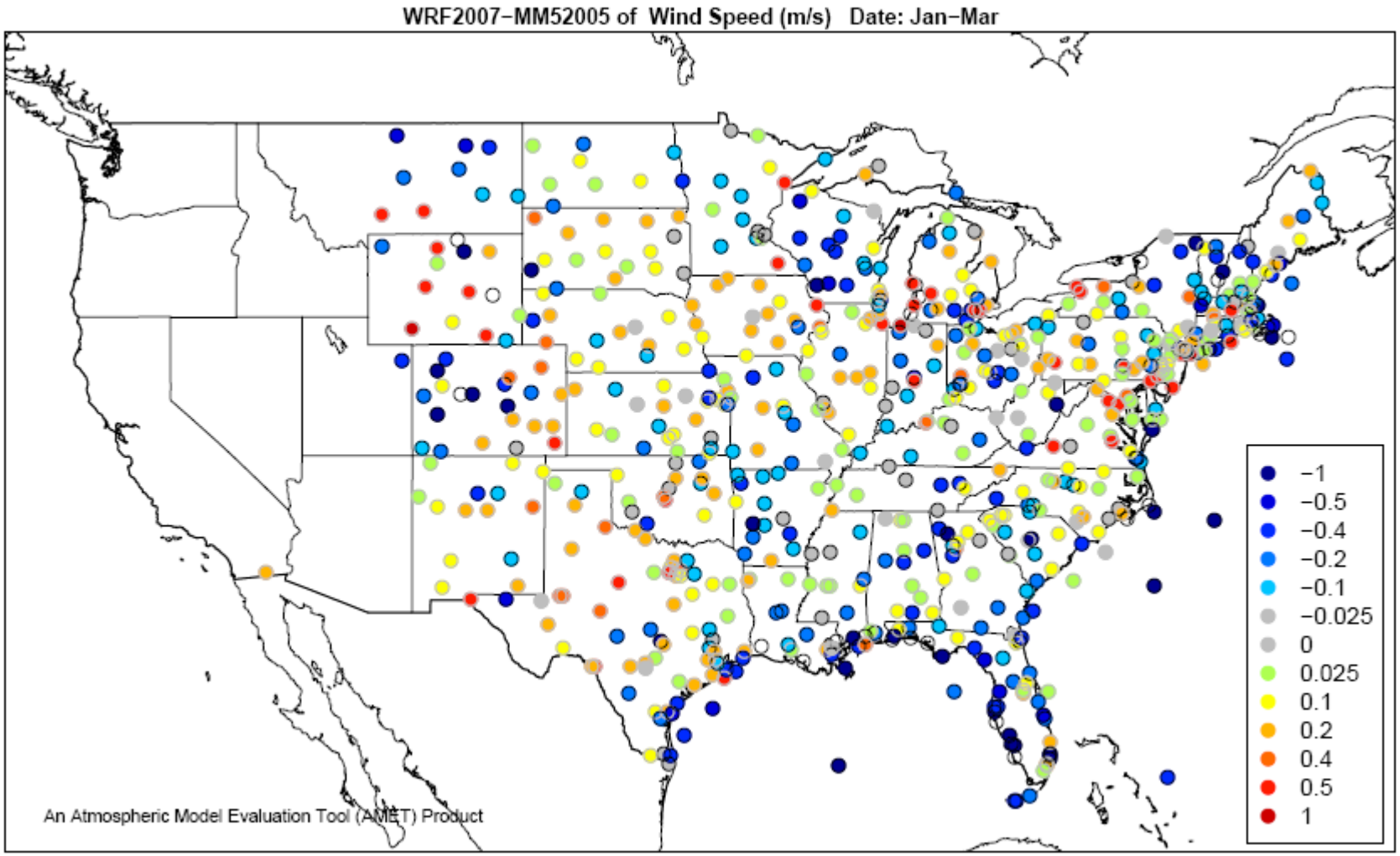




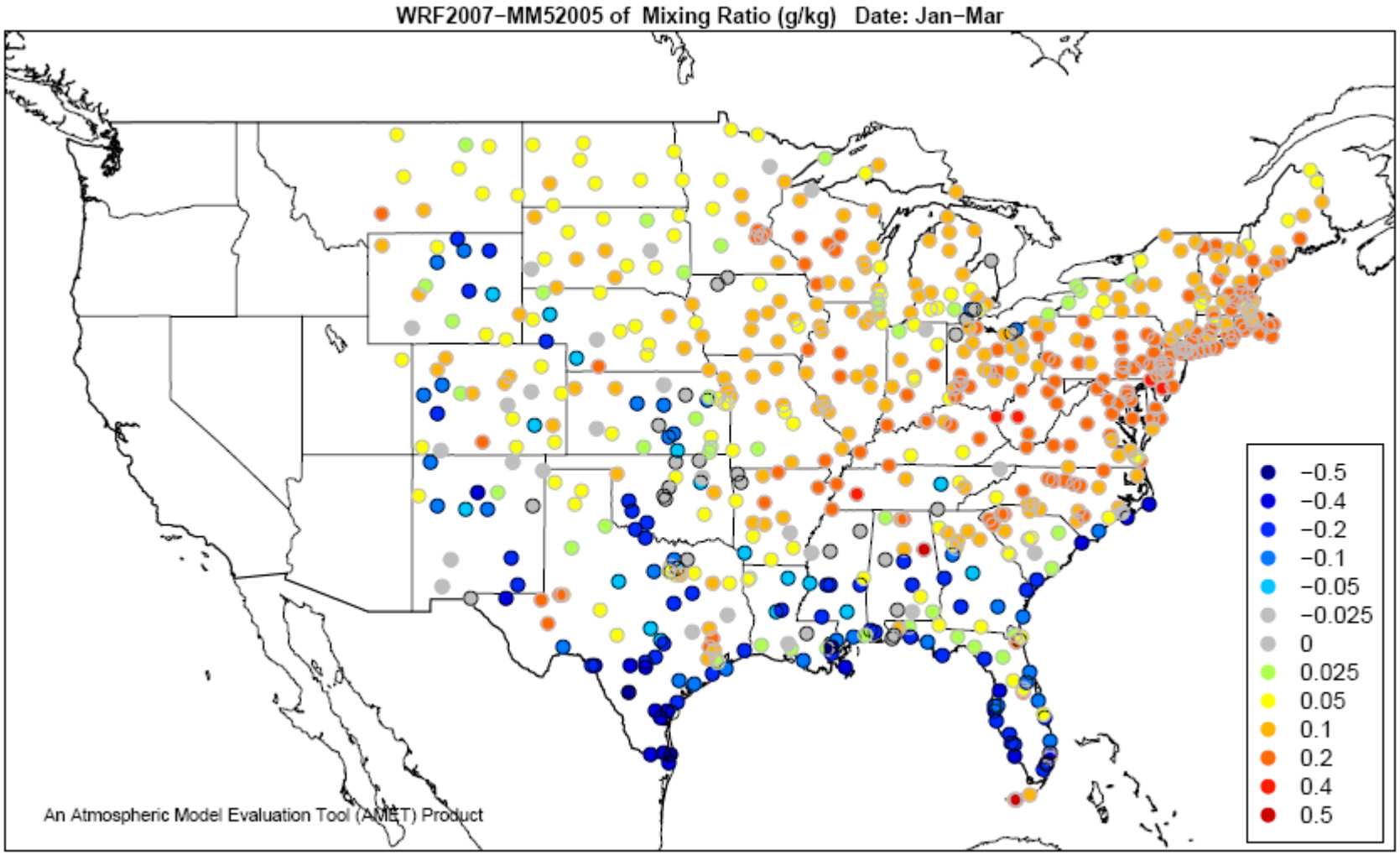
Jan 2008 WS Bias, no sfc nudging or 3-D analysis nudging of wind



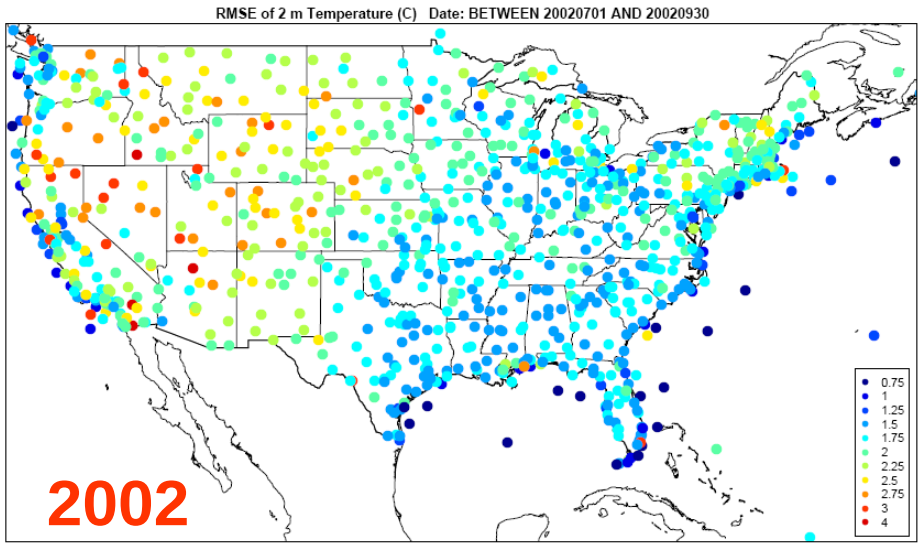
RMSE 10-m Wind Speed Differences (Winter)
WRF – MM5

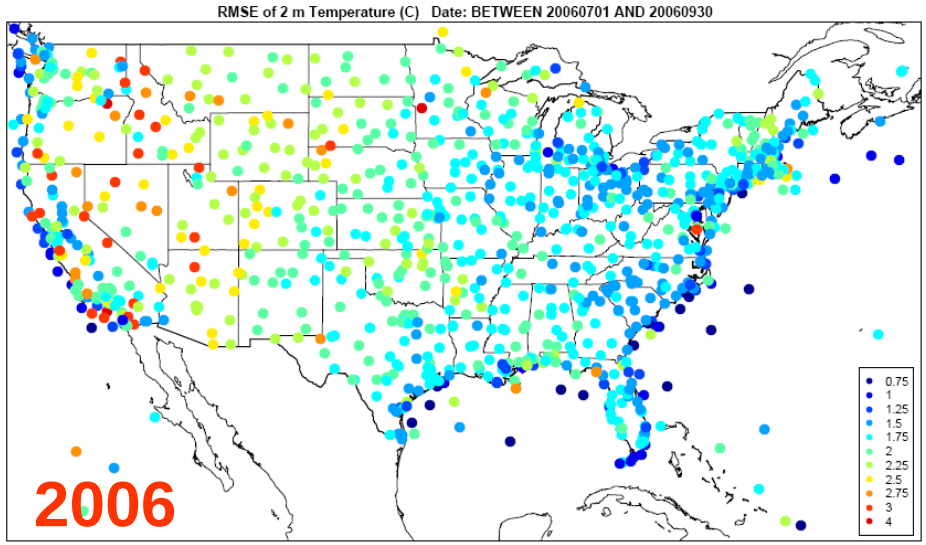


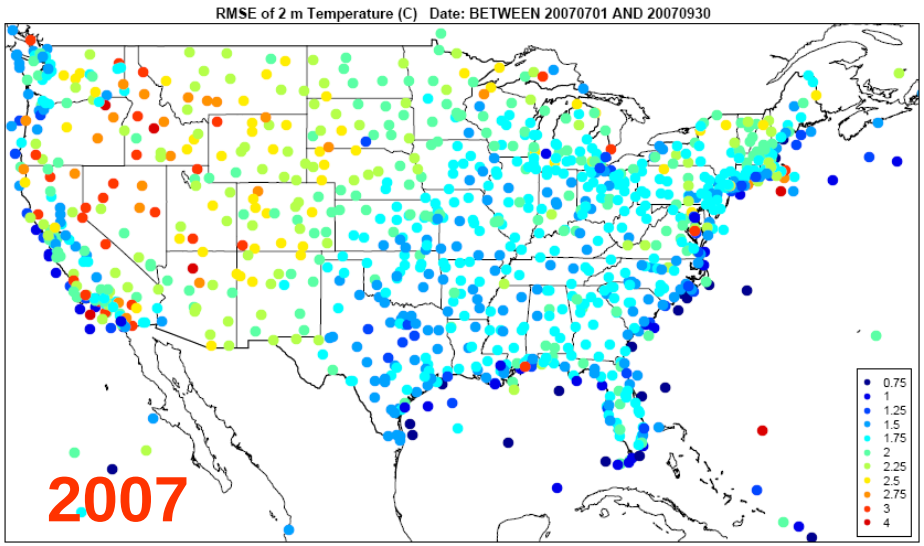
RMSE 2-m WV Mixing Ratio Differences (Winter) WRF – MM5

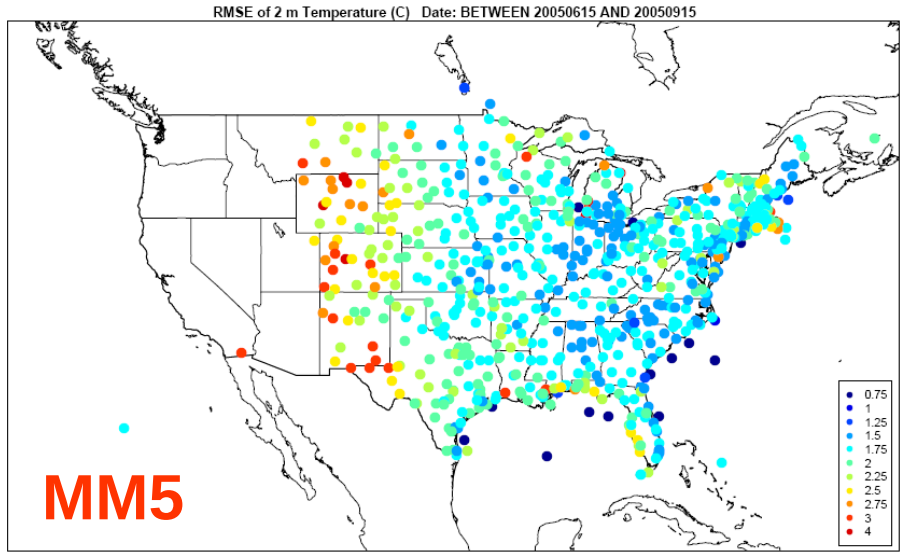


RMSE 2-m Temperature (Summer)

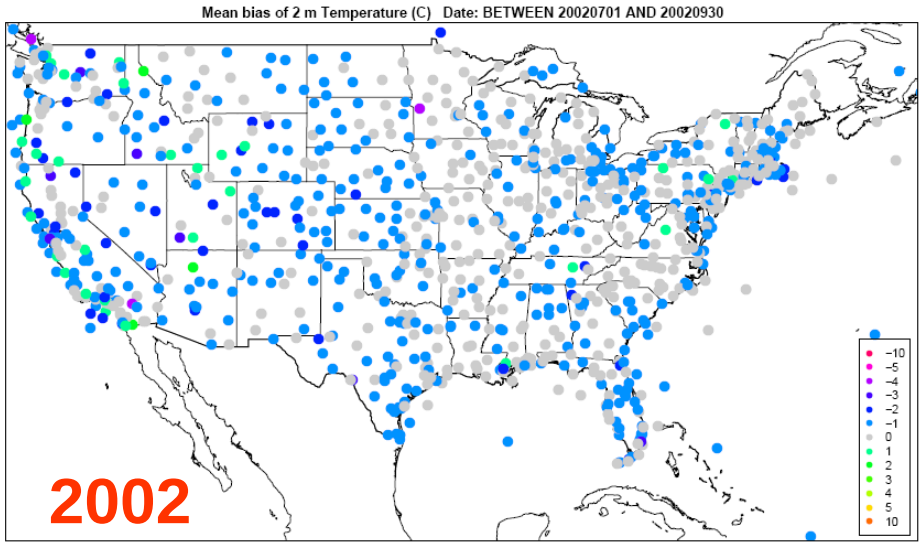


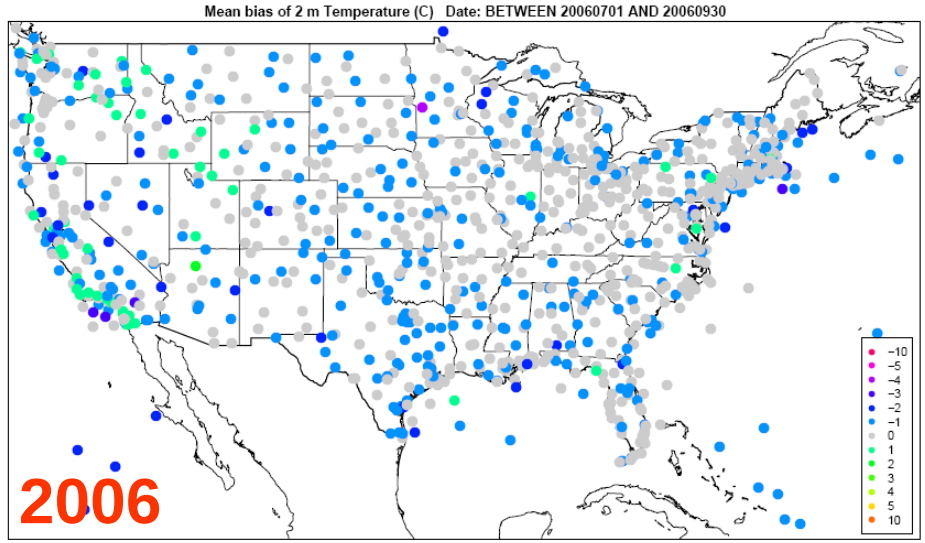


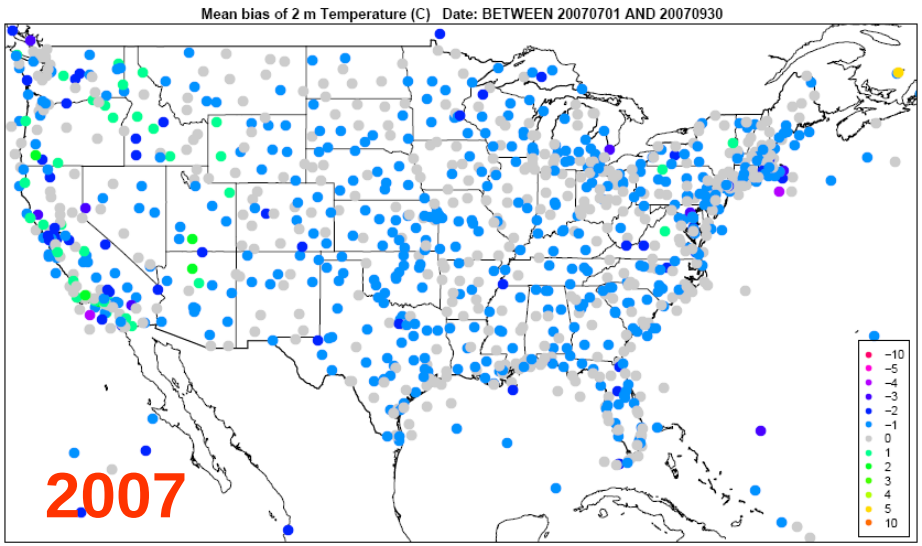


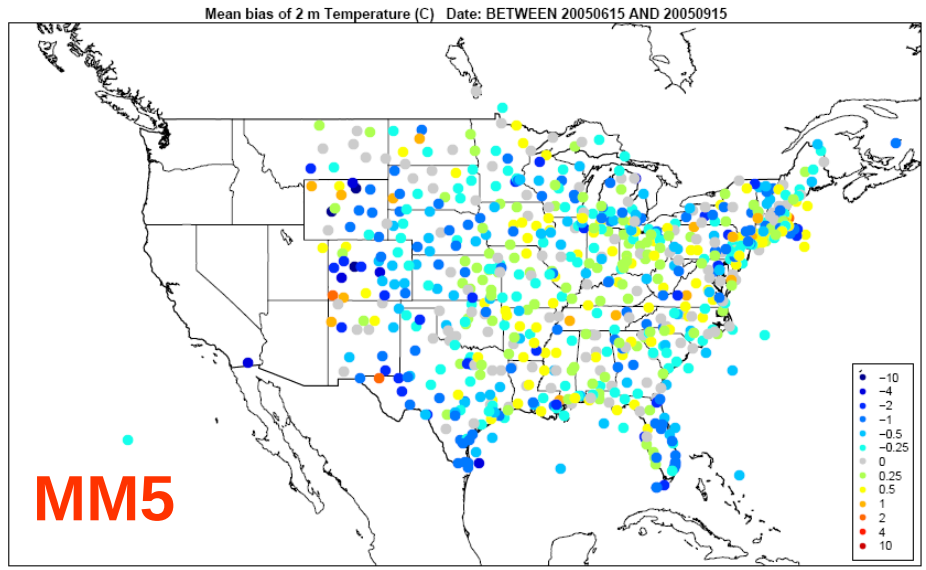


Bias 2-m Temperature (Summer)

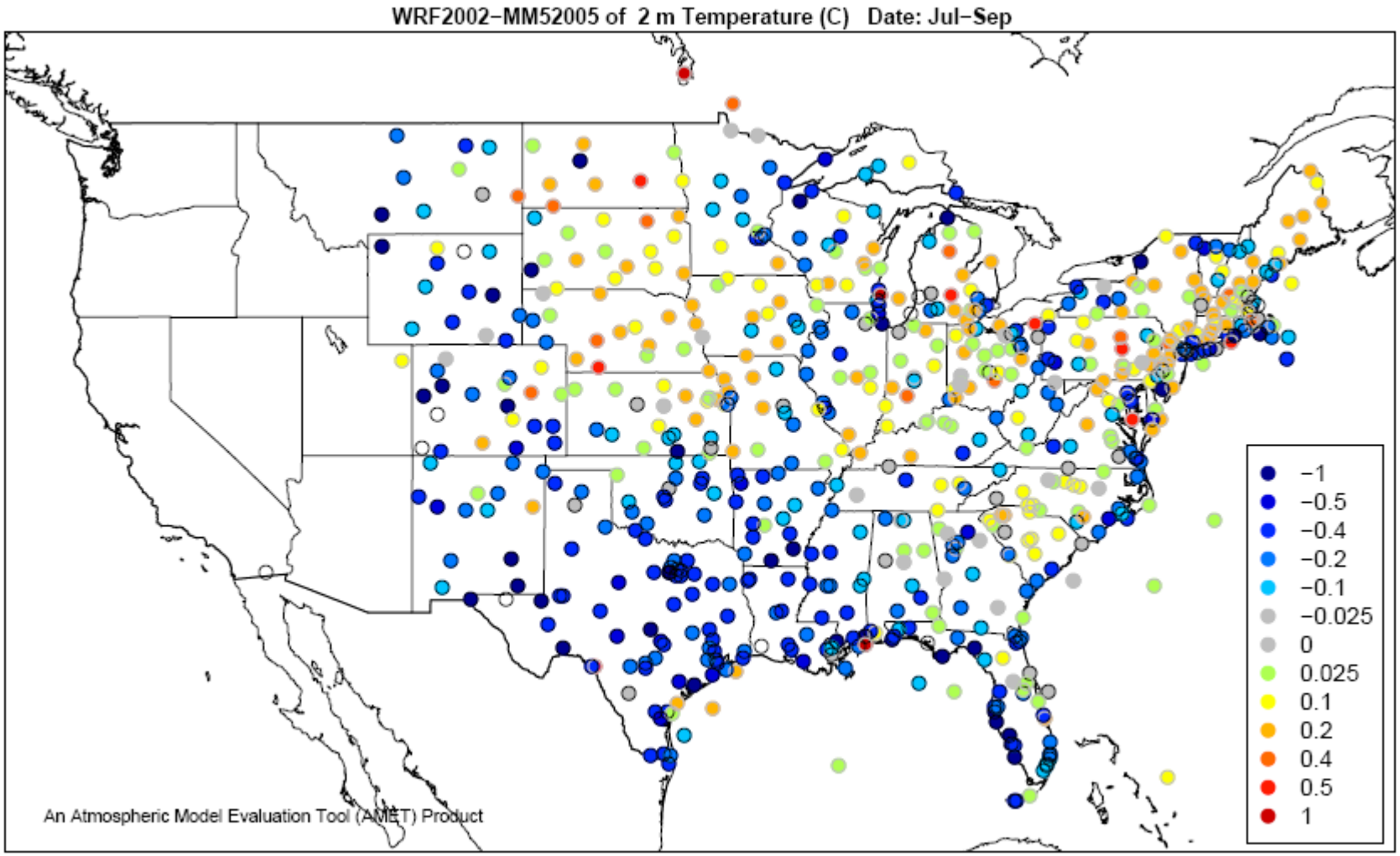




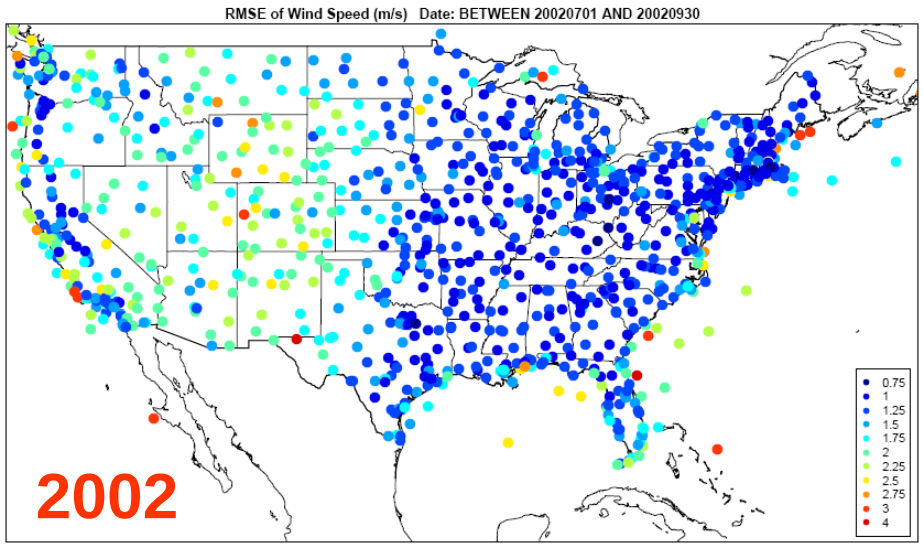


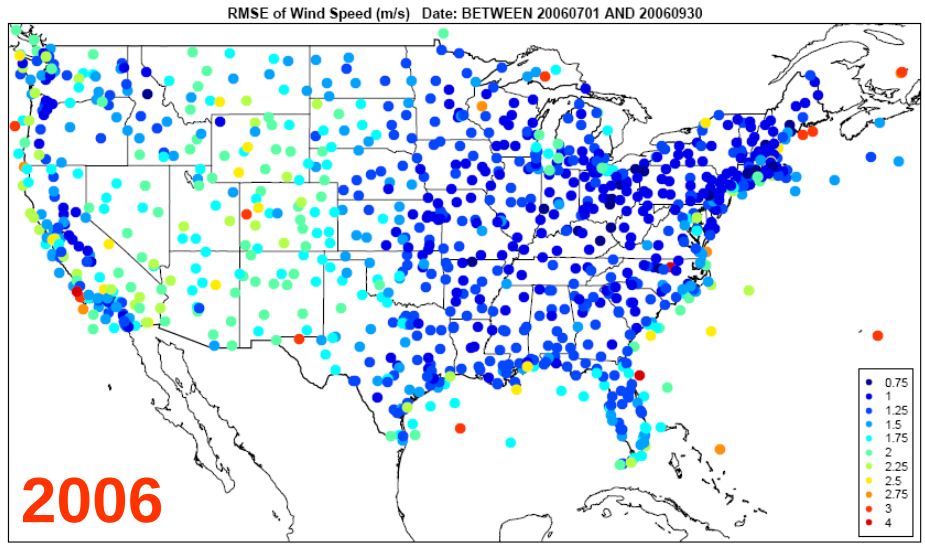


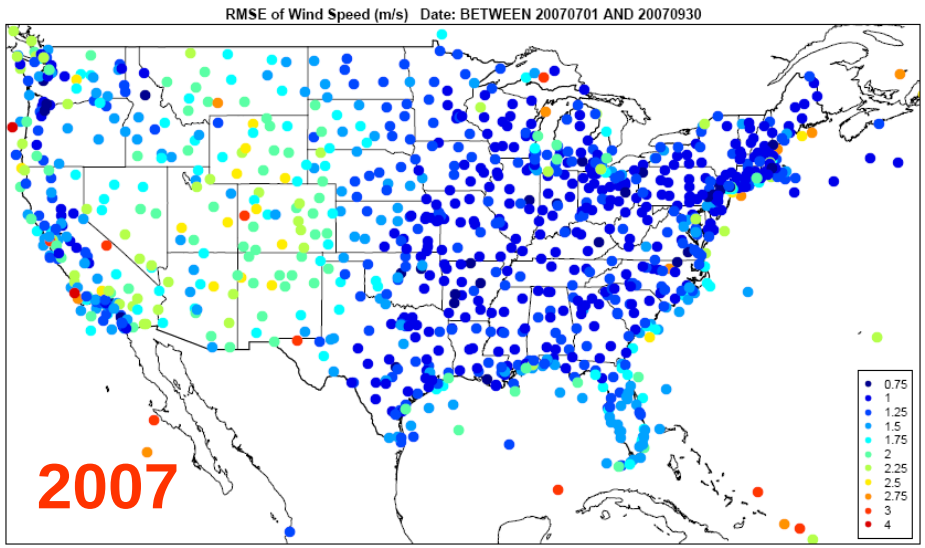
RMSE 2-m Temp Differences (Summer) WRF – MM5

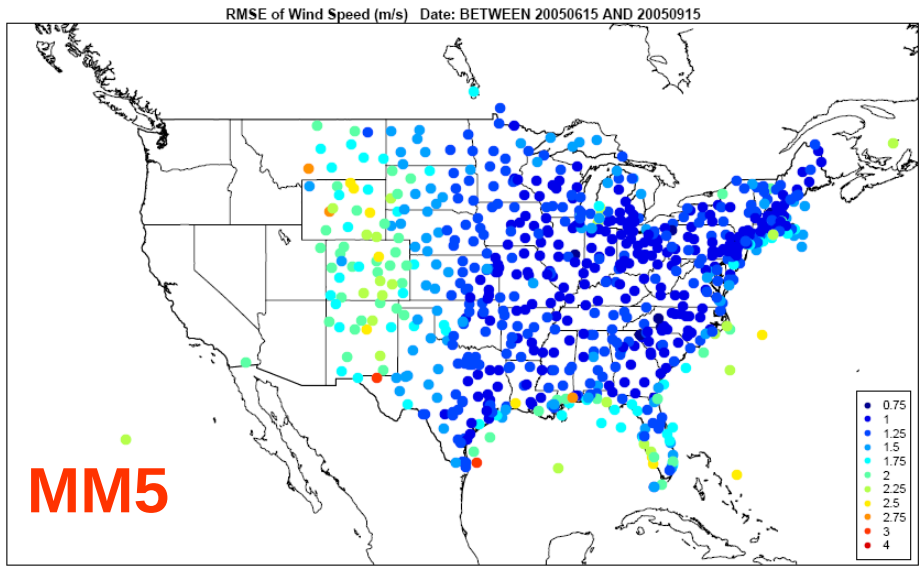


RMSE 10-m Wind Speed (Summer)

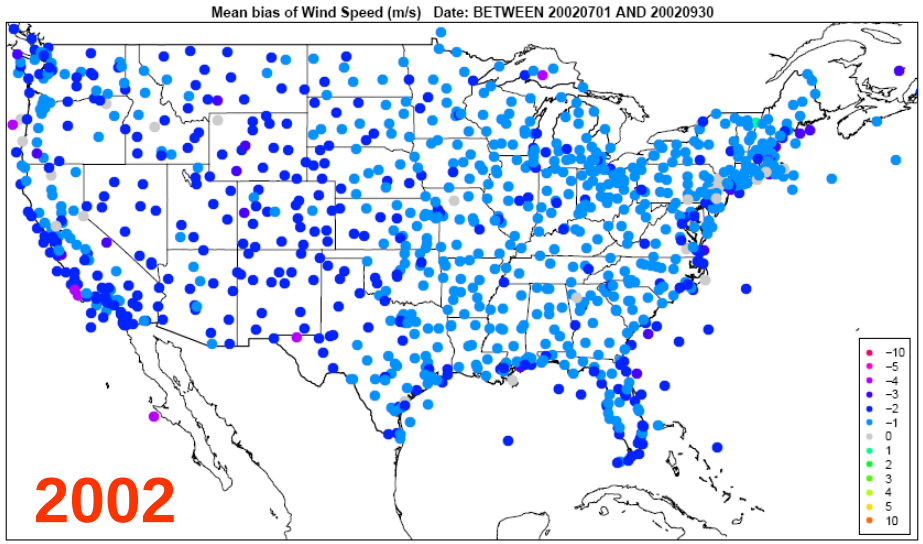


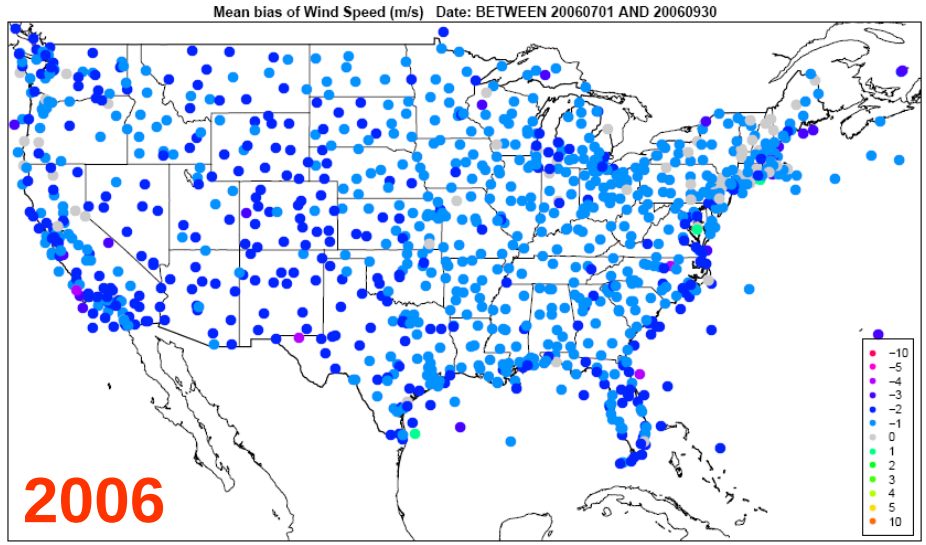


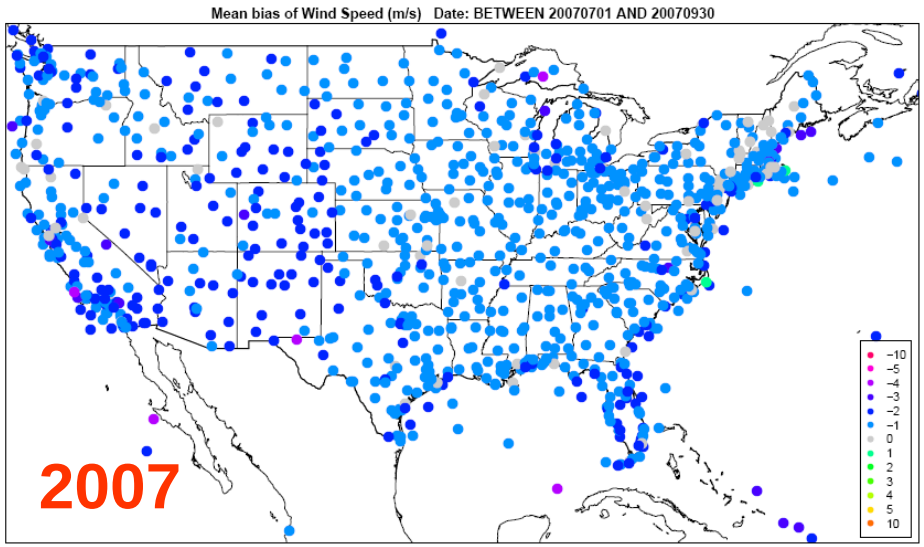


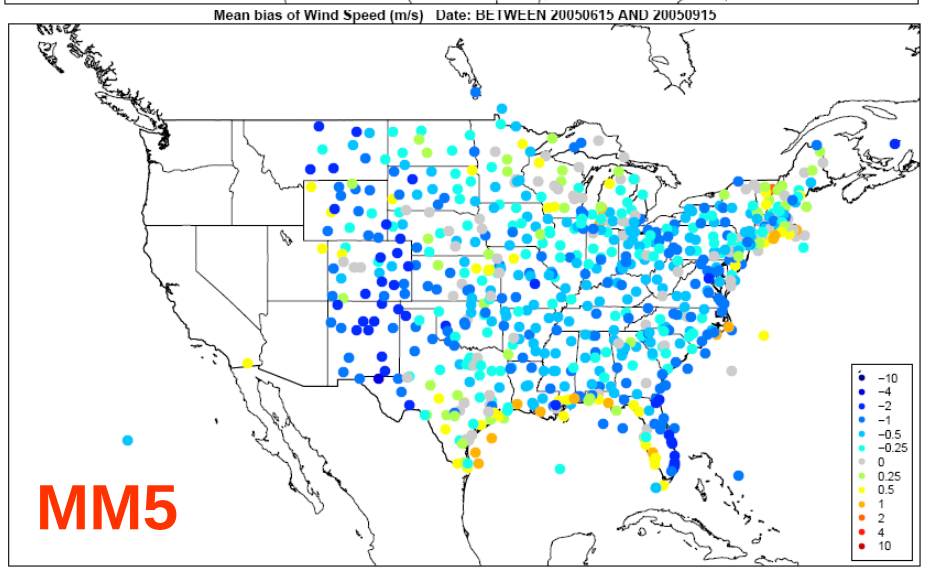


Bias 10-m Wind Speed (Summer)

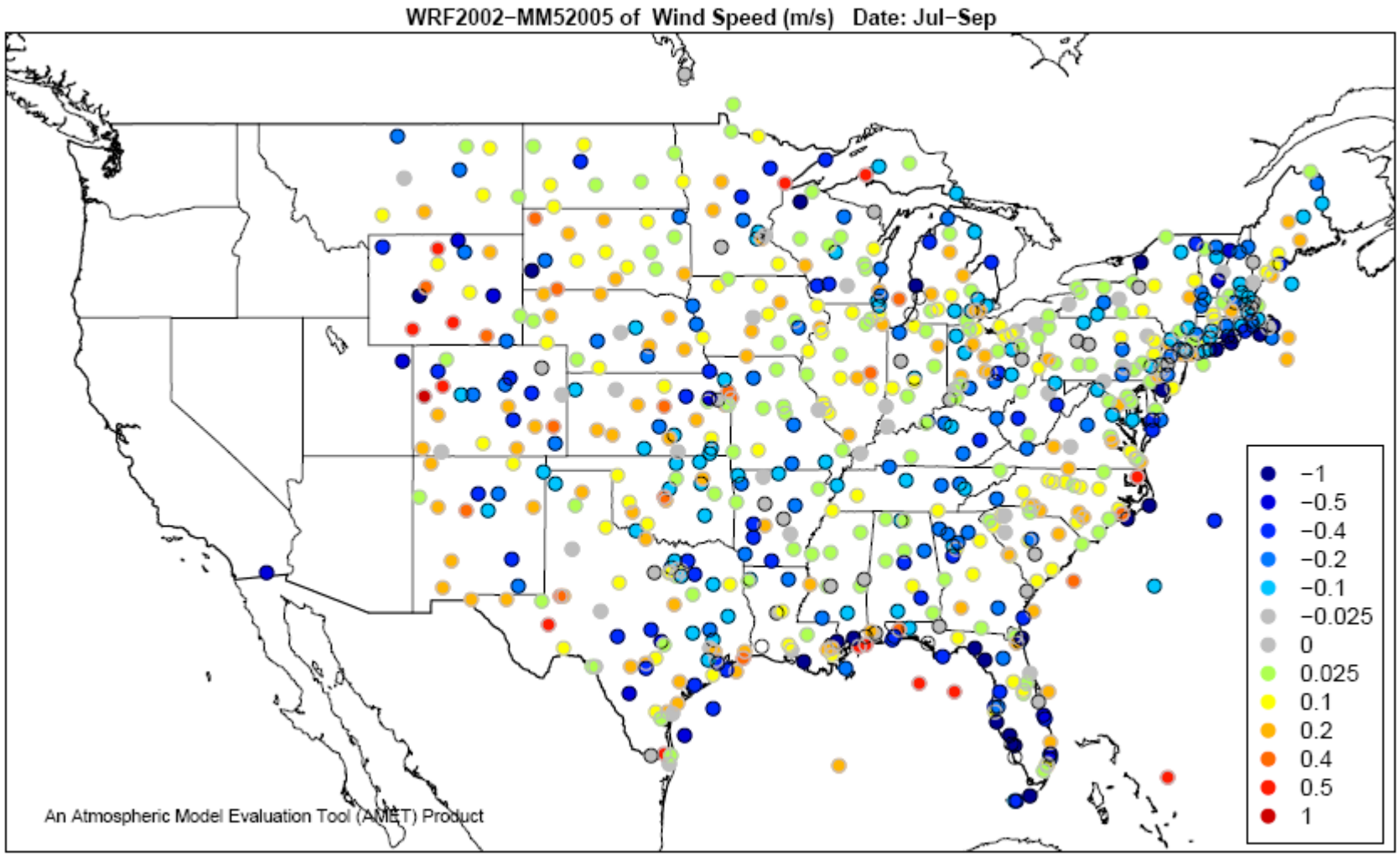




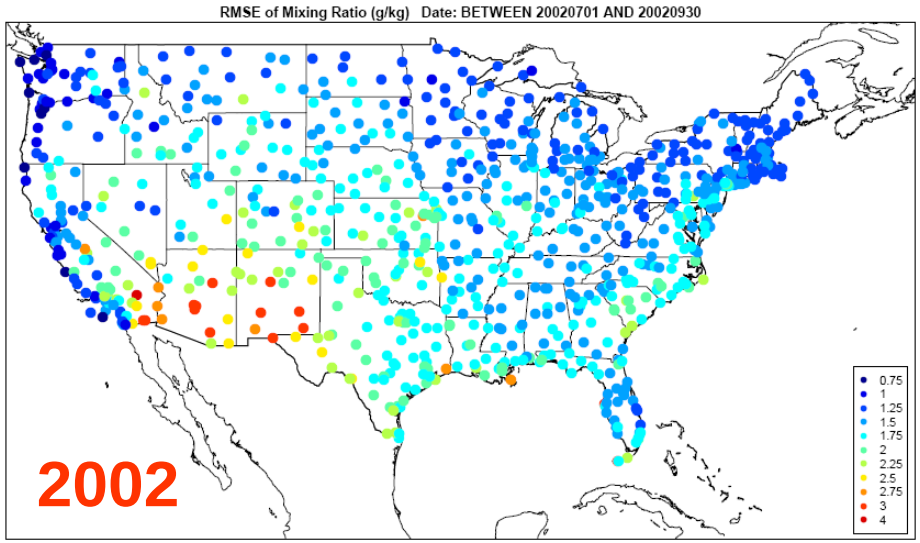


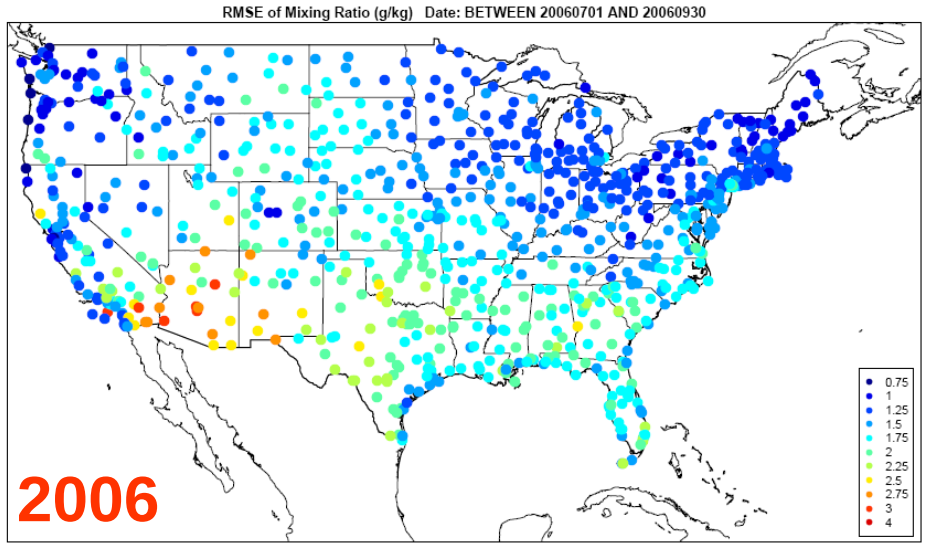


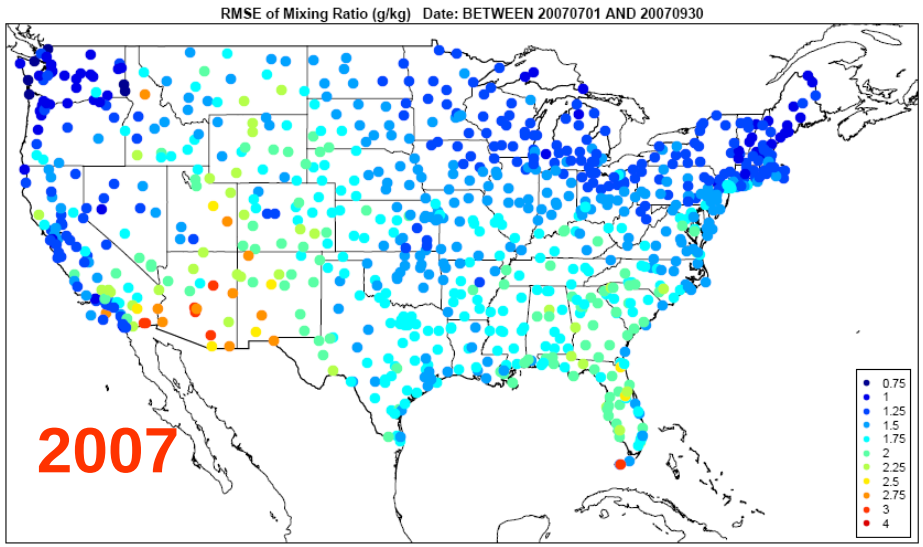
RMSE 10-m Wind Speed Differences (Summer)
WRF – MM5

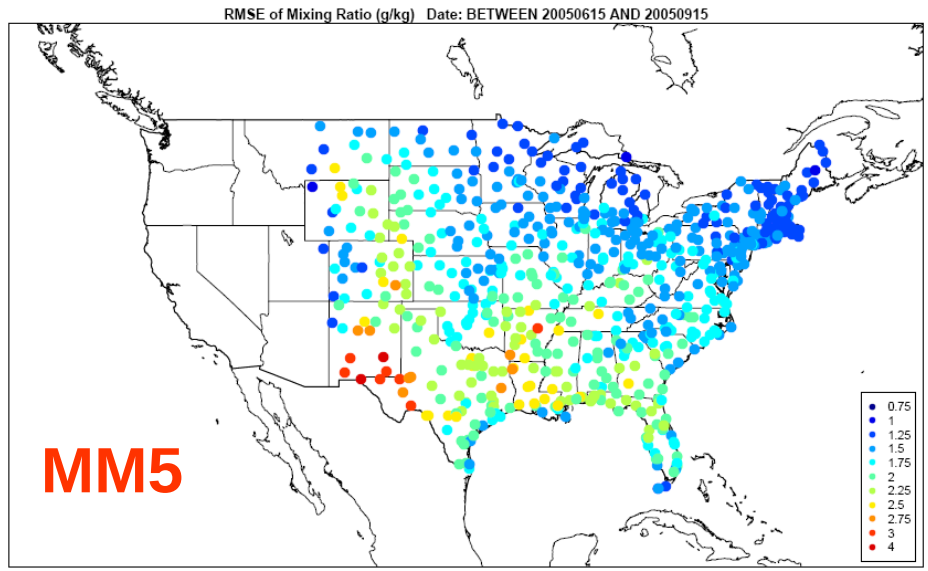


RMSE 2-m Mixing Ratio (Summer)

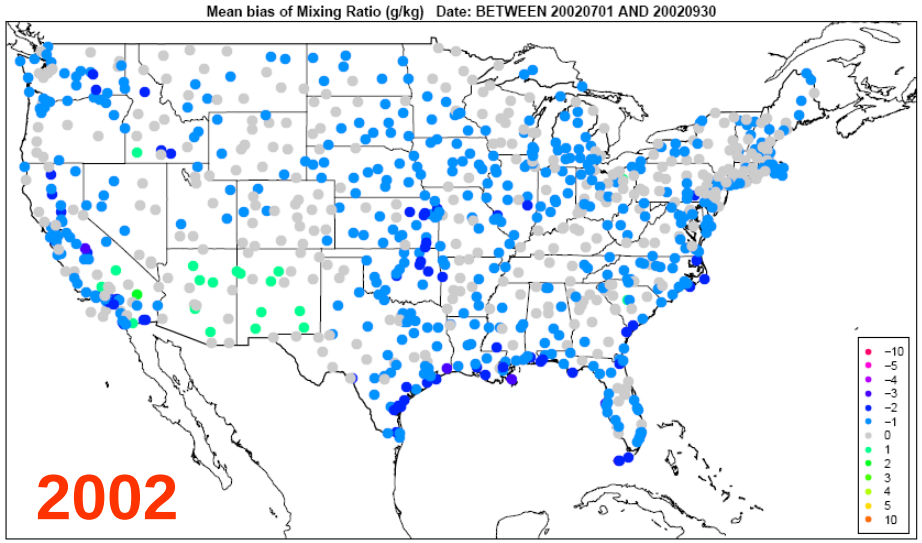


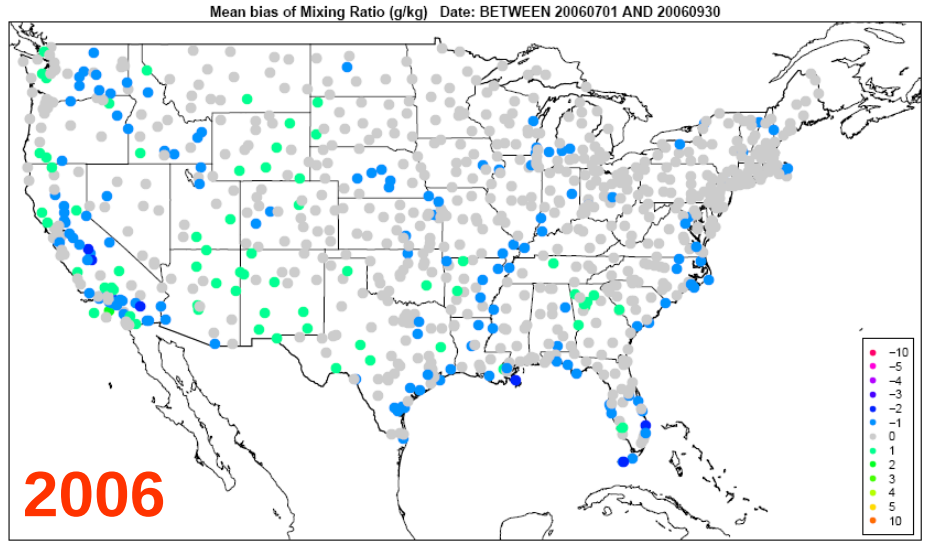


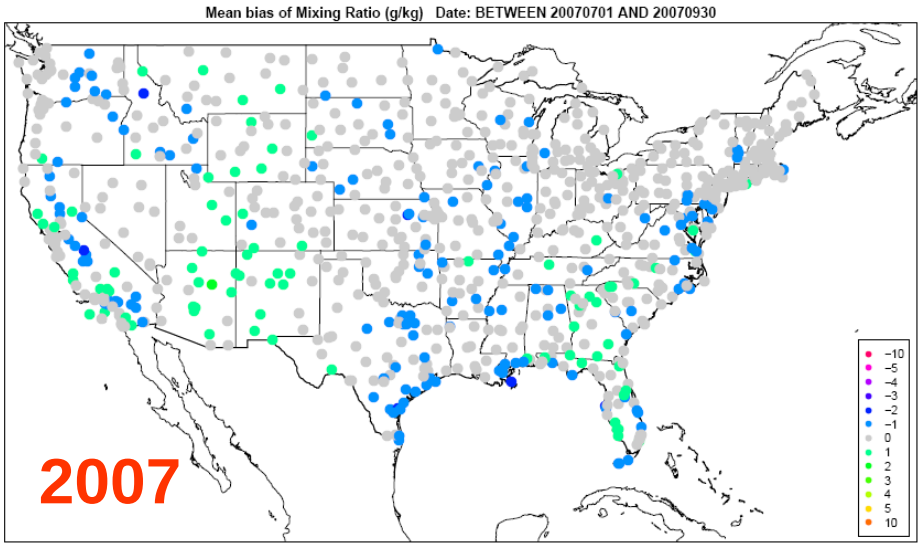


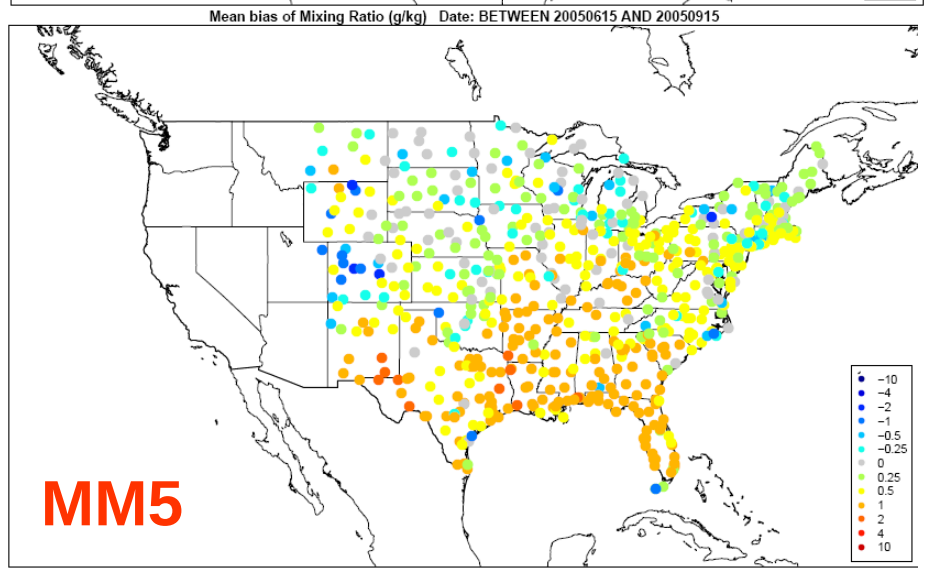


Bias 2-m Mixing Ratio (Summer)

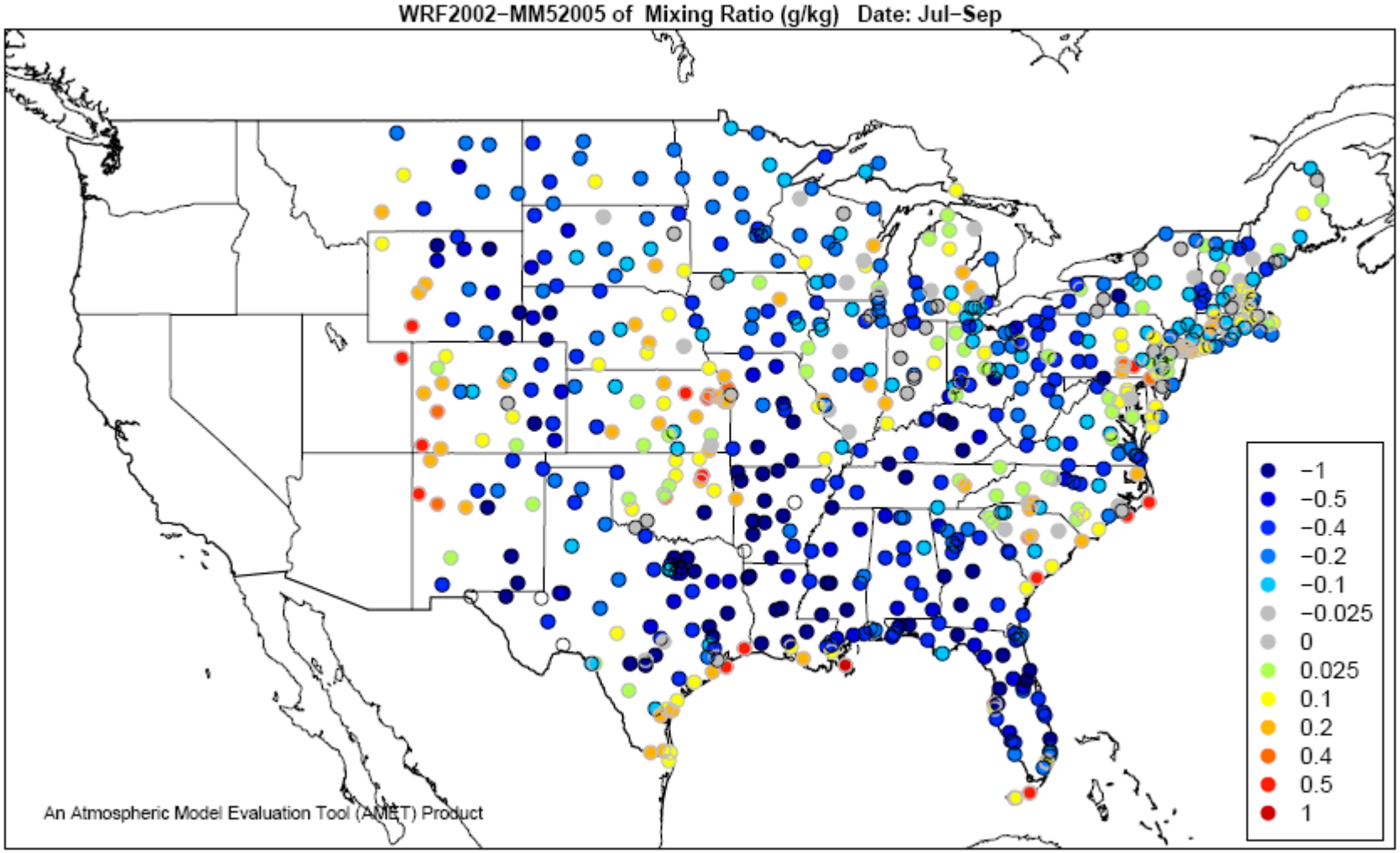








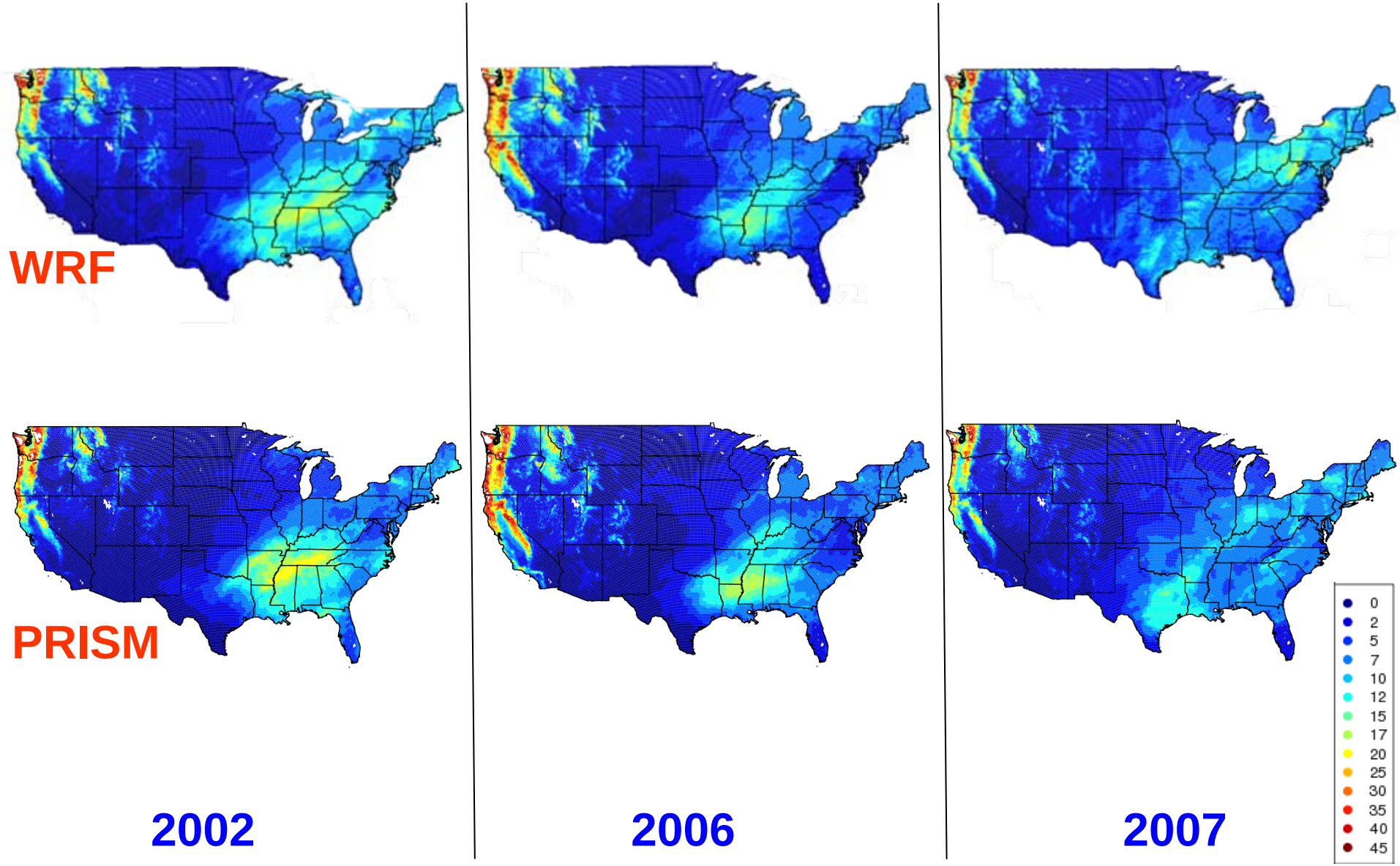
RMSE 2-m WV Mixing Ratio Differences (Summer) WRF – MM5



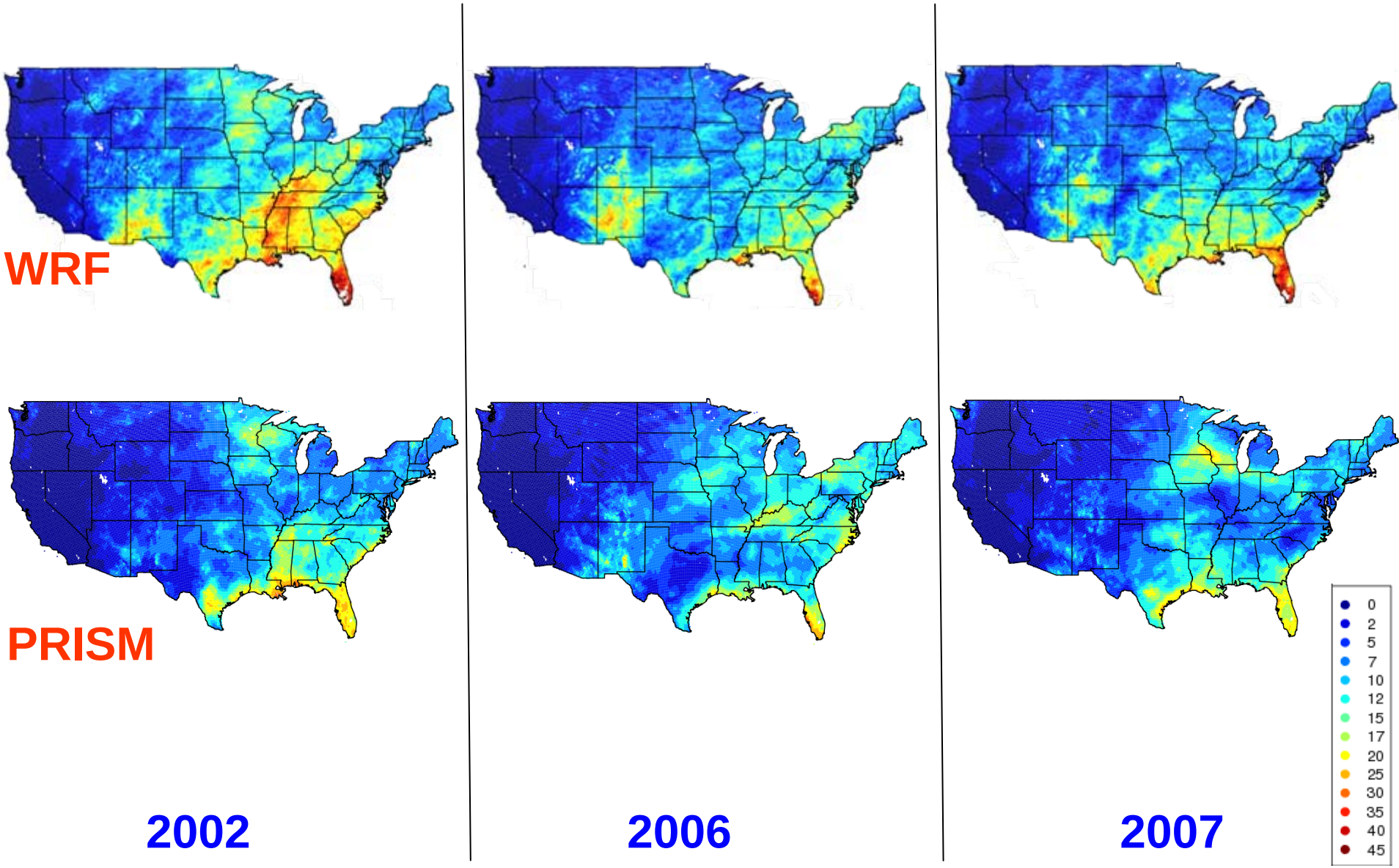
Seasonal Precipitation

Comparison of WRF simulated seasonal precipitation with PRISM

Seasonal Precipitation (inches)
Winter (JFM)



Seasonal Precipitation (inches)
Summer (JAS)

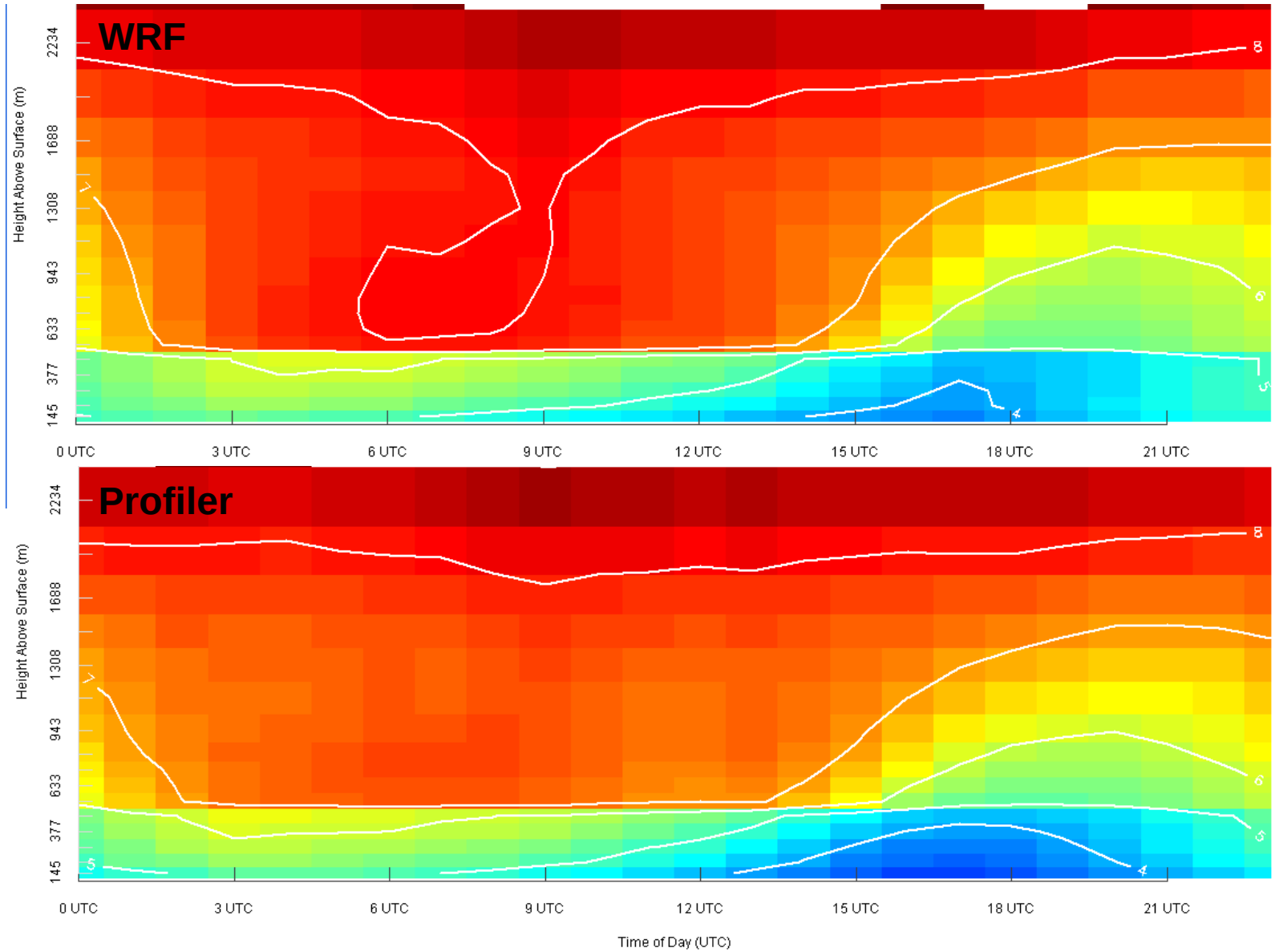


PBL Wind

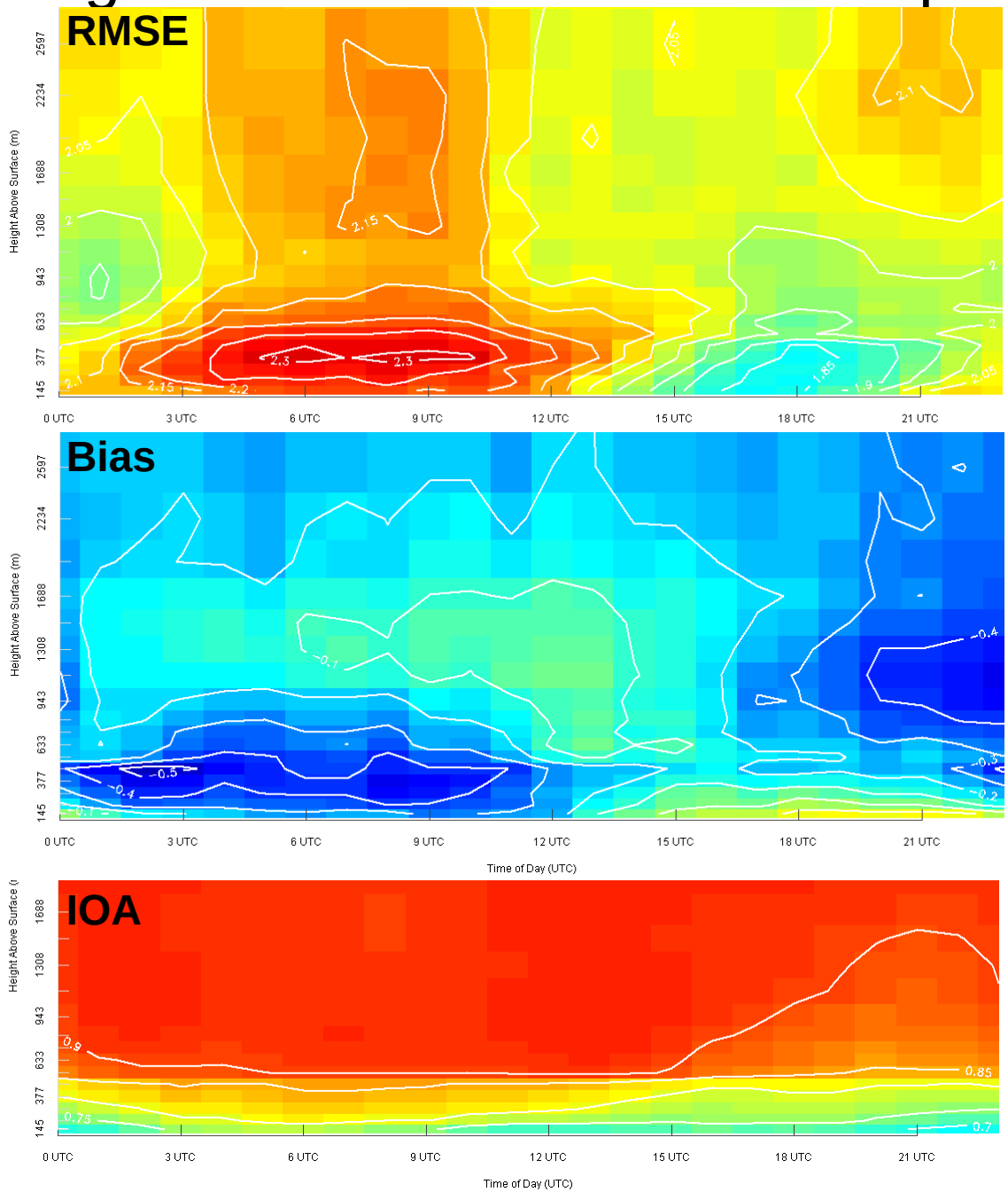
Comparison of simulated PBL wind with ~55 US wind profilers for summer

Time-Height Mean Wind Speed

All US profilers (Winter and summer 2002, Summer 2007, winter 2006)

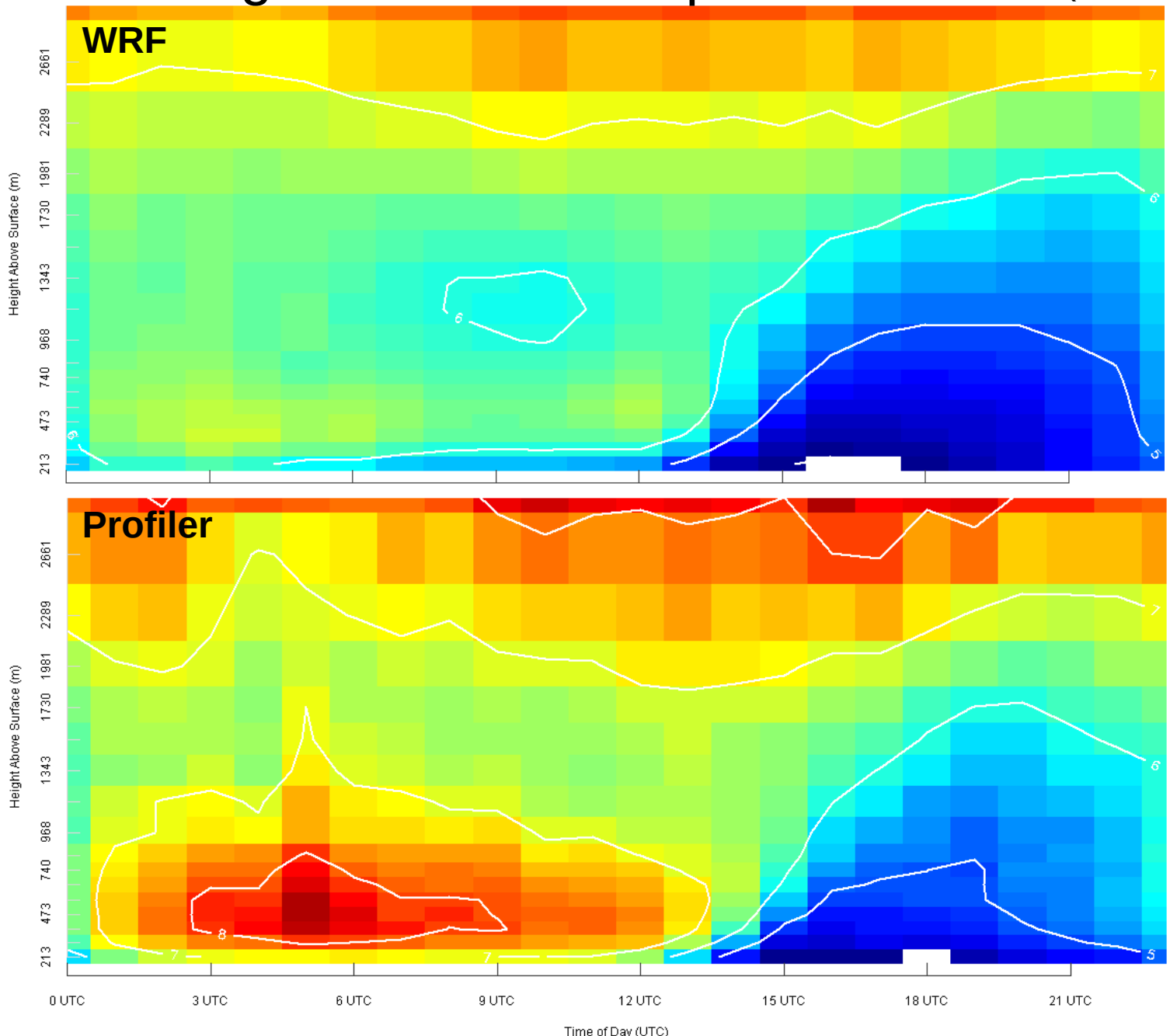


Time-Height RMSE/BIAS/IOA Wind Speed (m s^{-1})

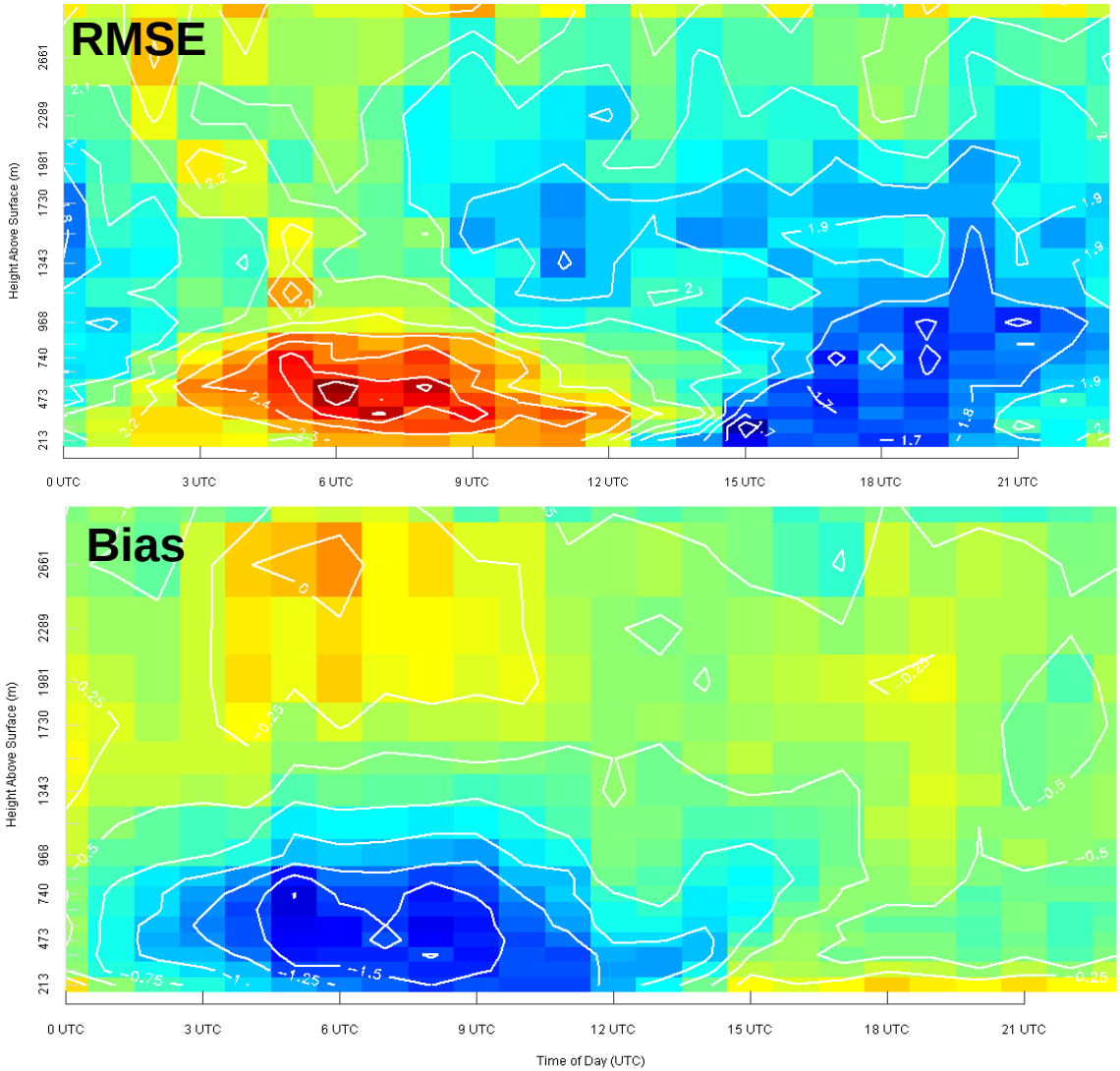


All Profilers

Time-Height Mean Wind Speed Mid-Atlantic (Summer 2002)

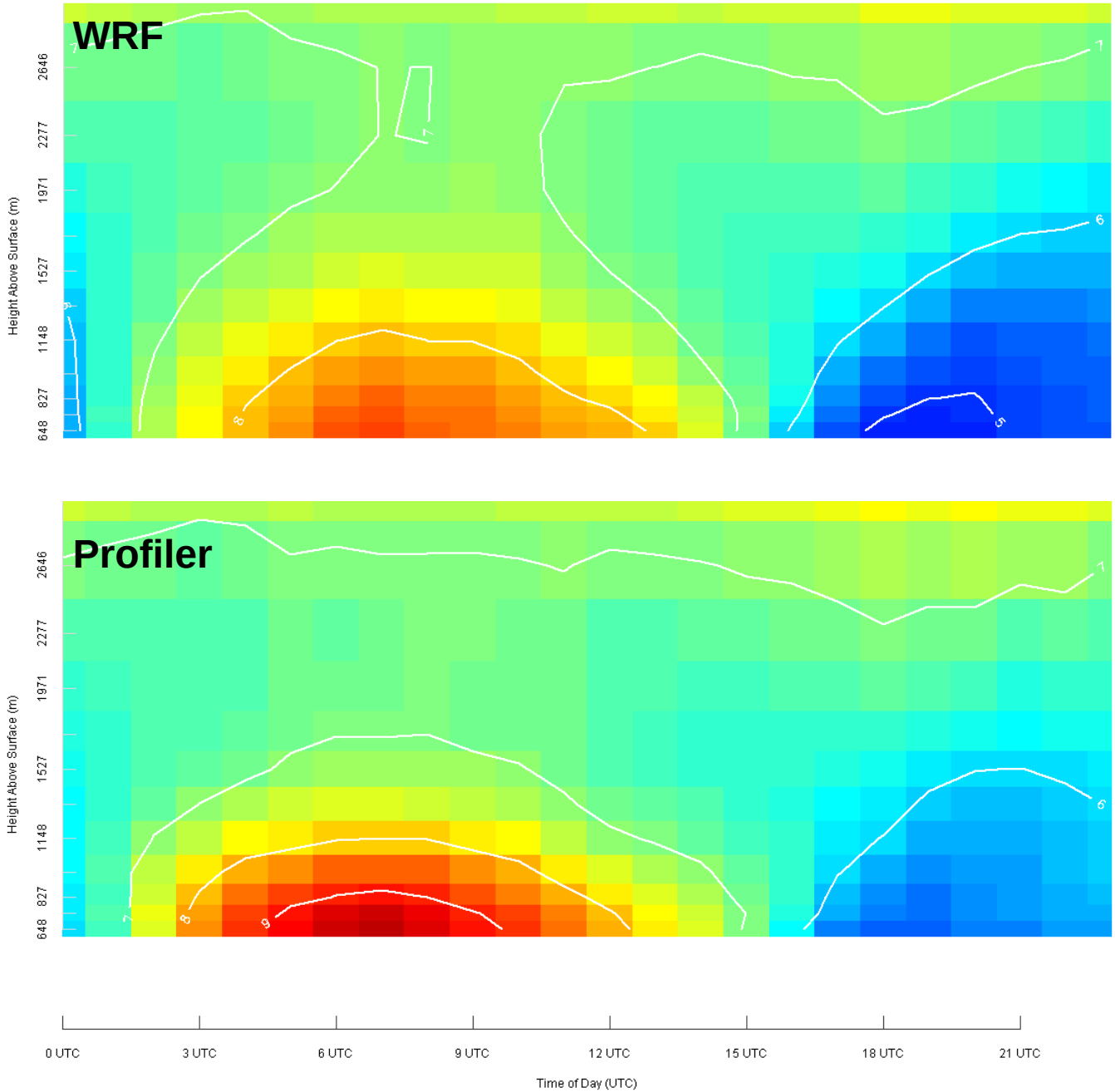


Time-Height RMSE/BIAS Wind Speed

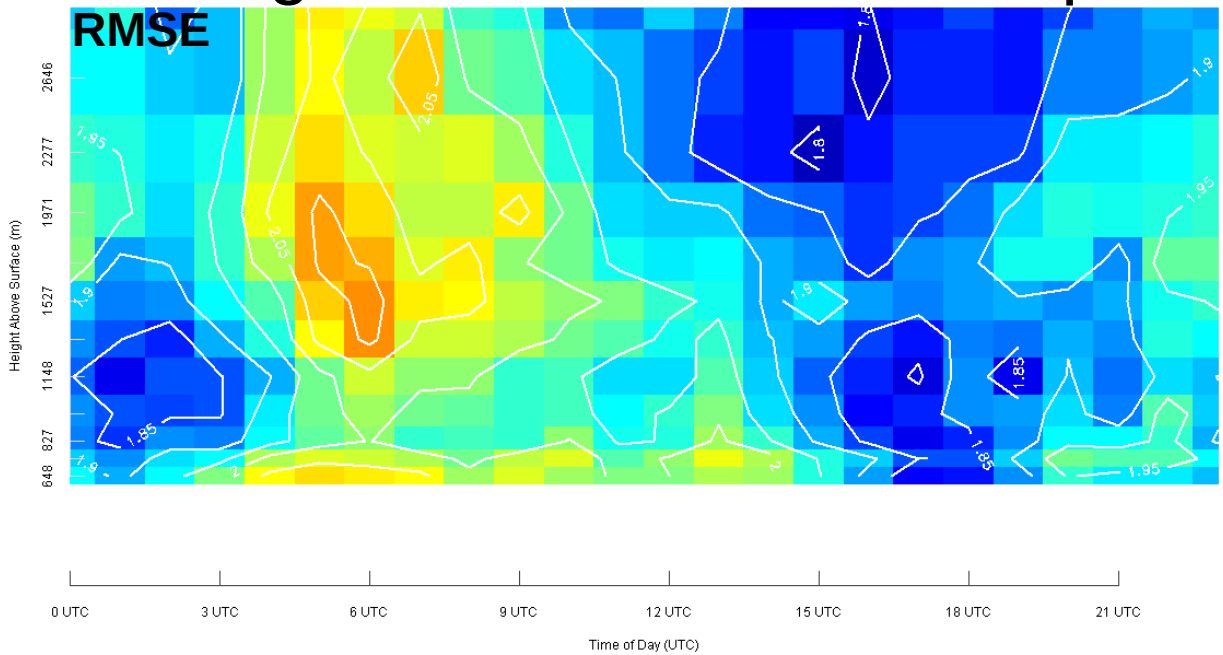


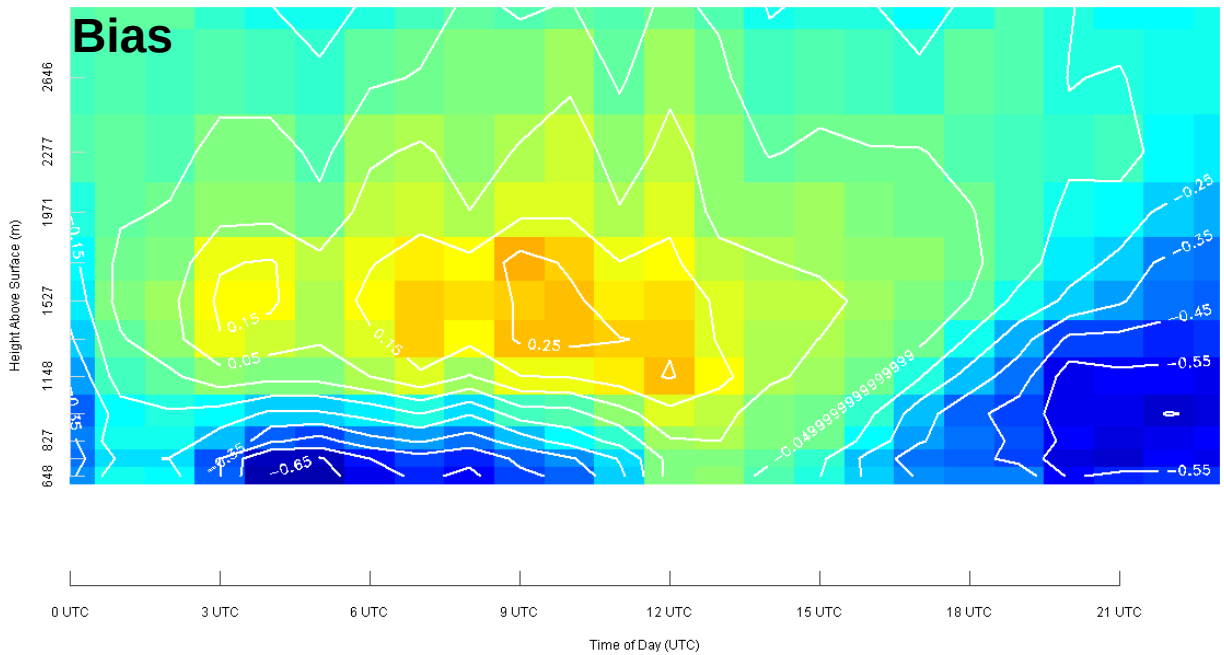
Mid-Atlantic

Time-Height Mean Wind Speed Plains (Summer 2002)



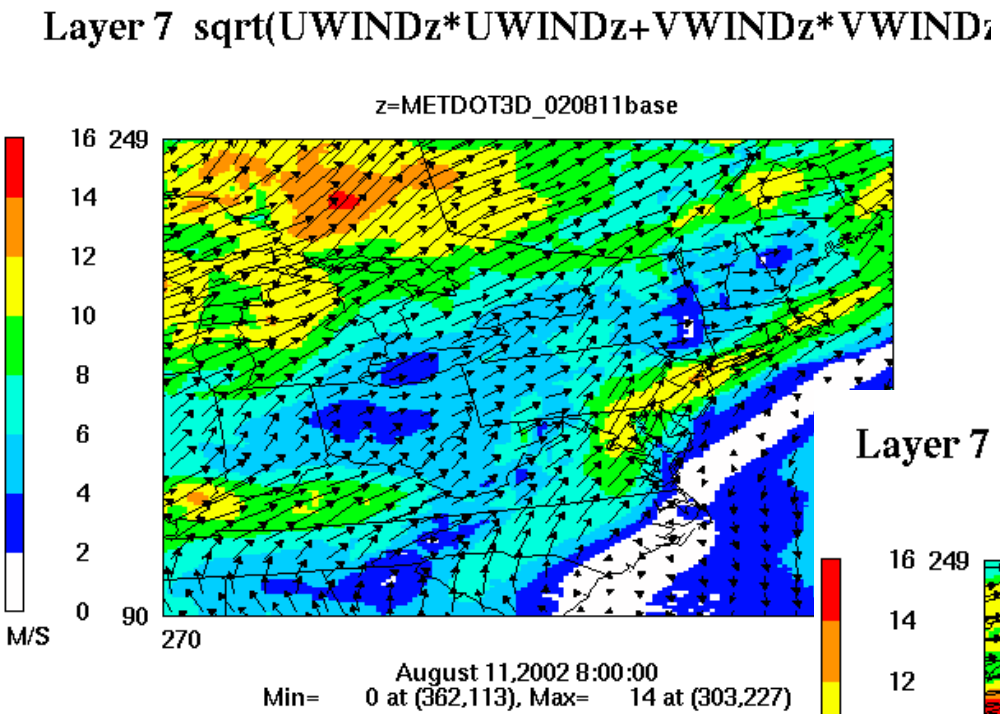
Time-Height RMSE/BIAS Wind Speed

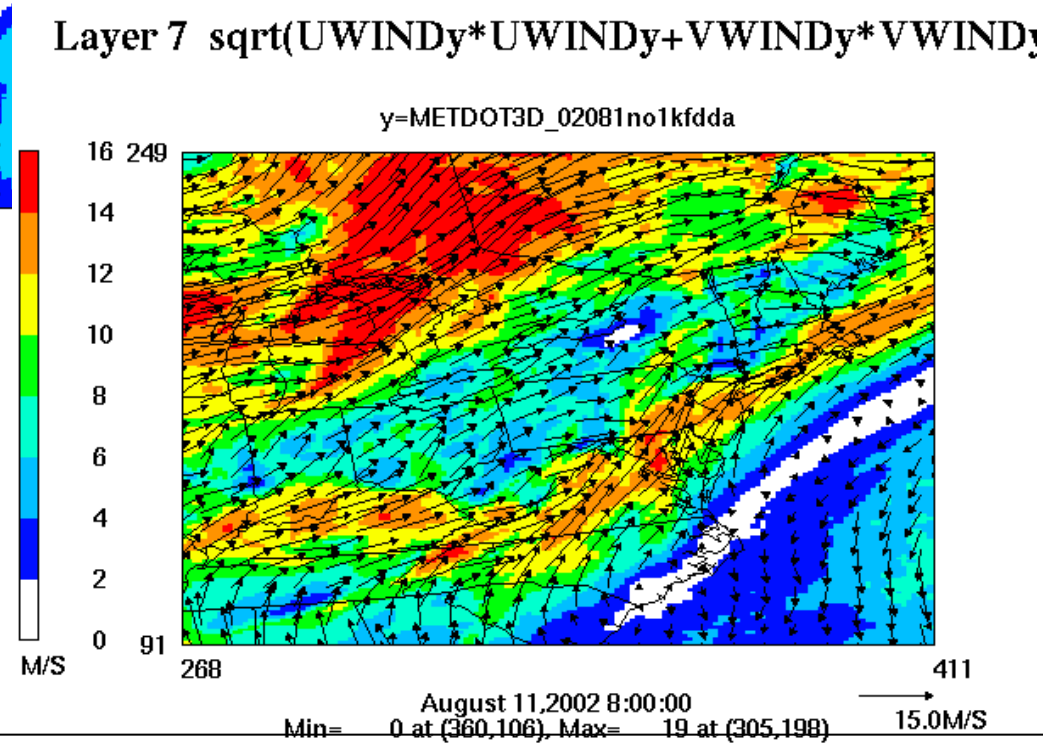




Plains

WRF Wind Flow (with base FDDA)

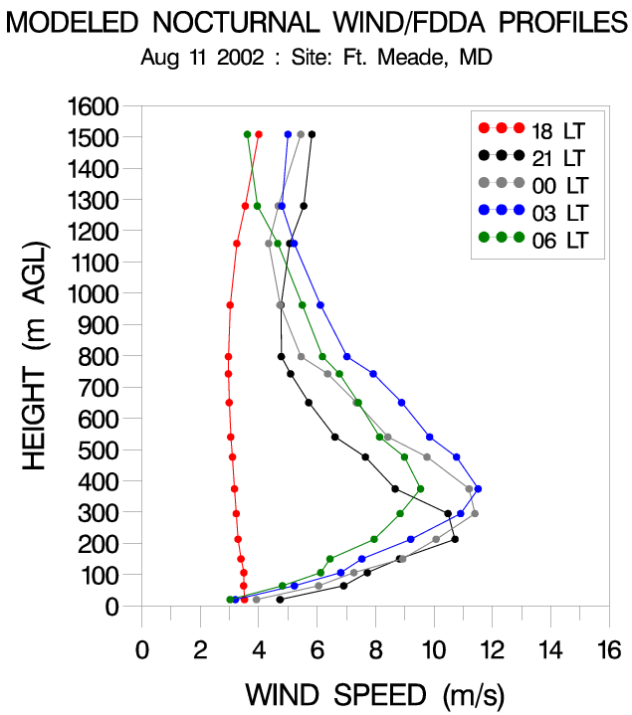




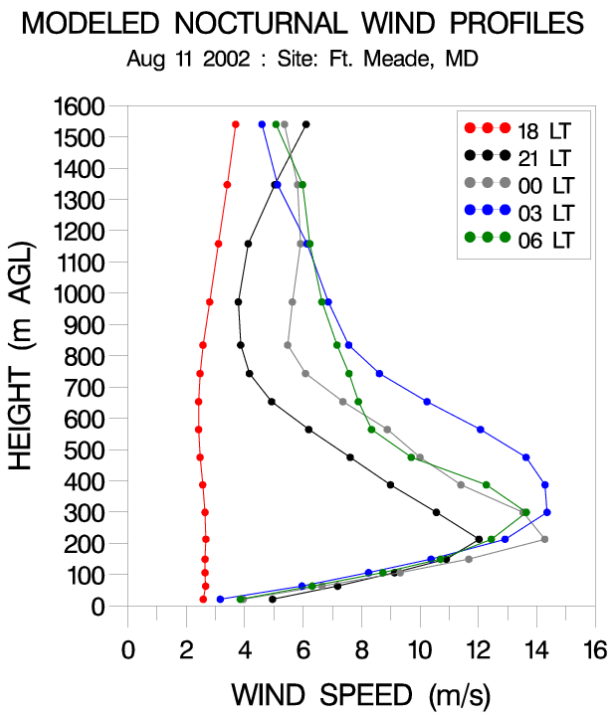
WRF Wind Flow (with NoFDDA < layer 13 [~1-km])

WRF vs Obs Nocturnal Wind Profiles at Different Times at a mid-Atlantic Location

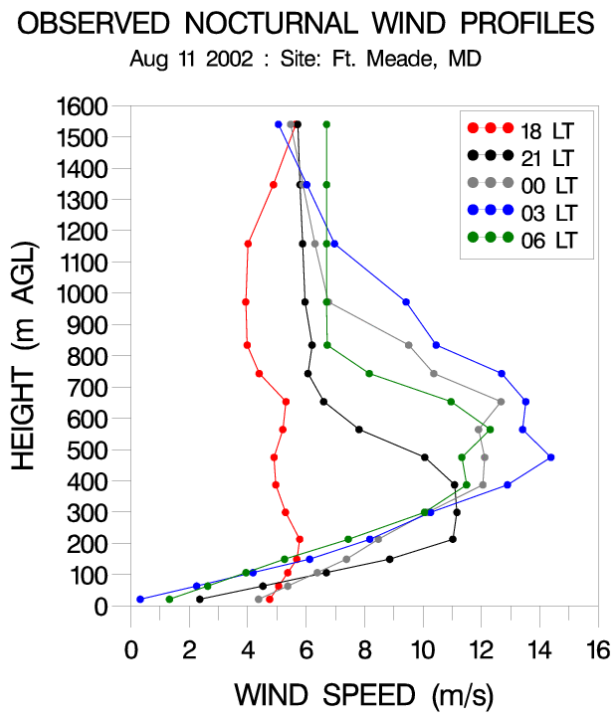
Base FDDA



NoFDDA,< 1 km, new SBL

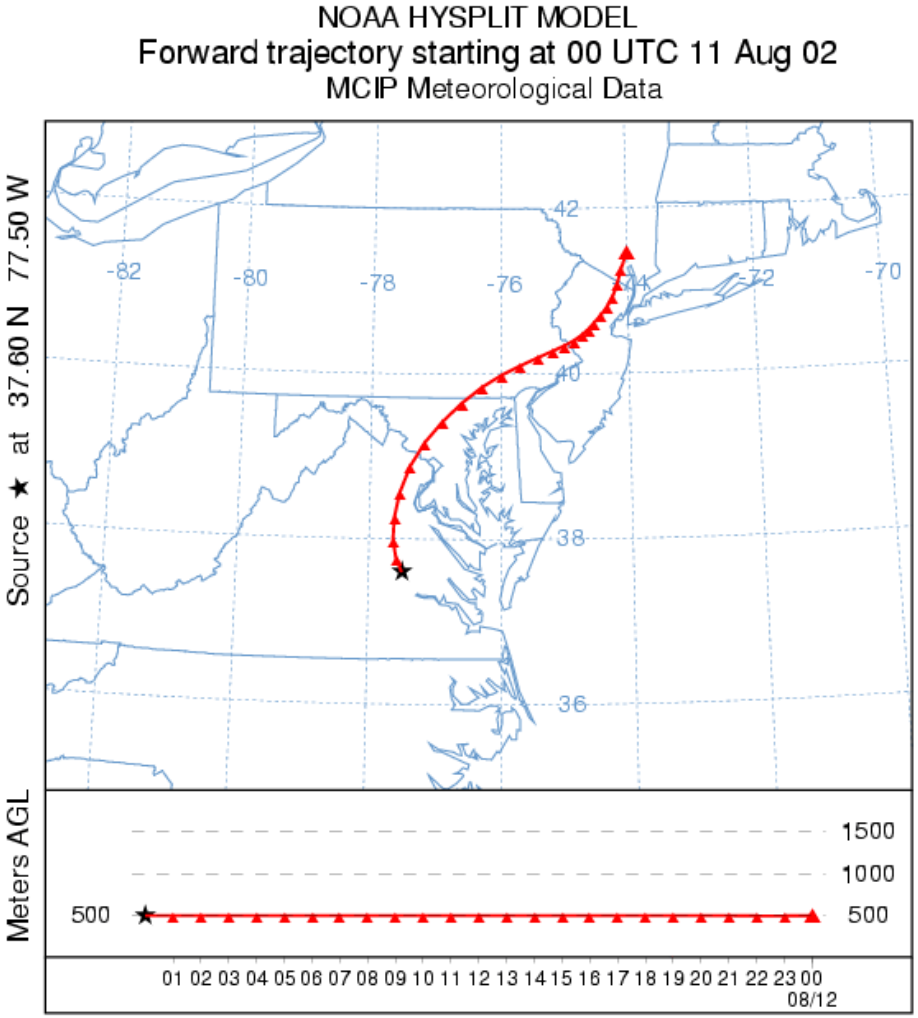


NOAA Profiler Obs

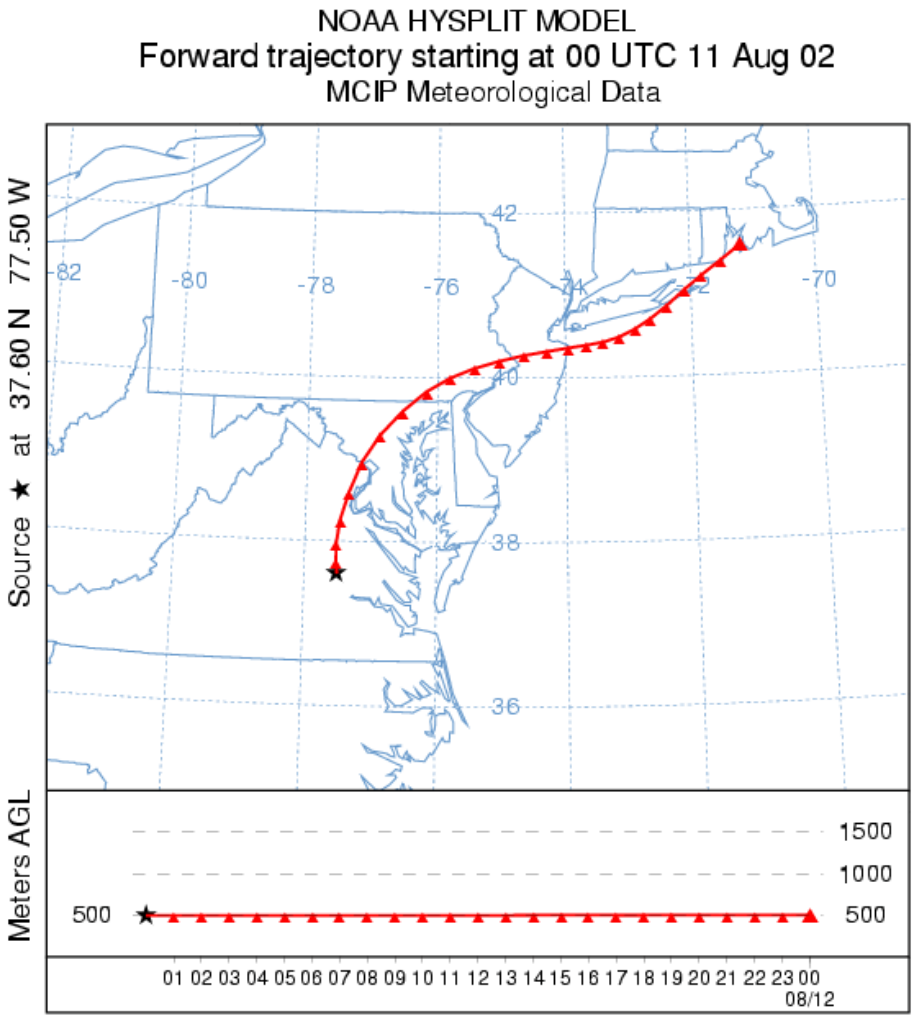


24-hr Trajectory Path with WRF Winds at RCH, VA

Base FDDA

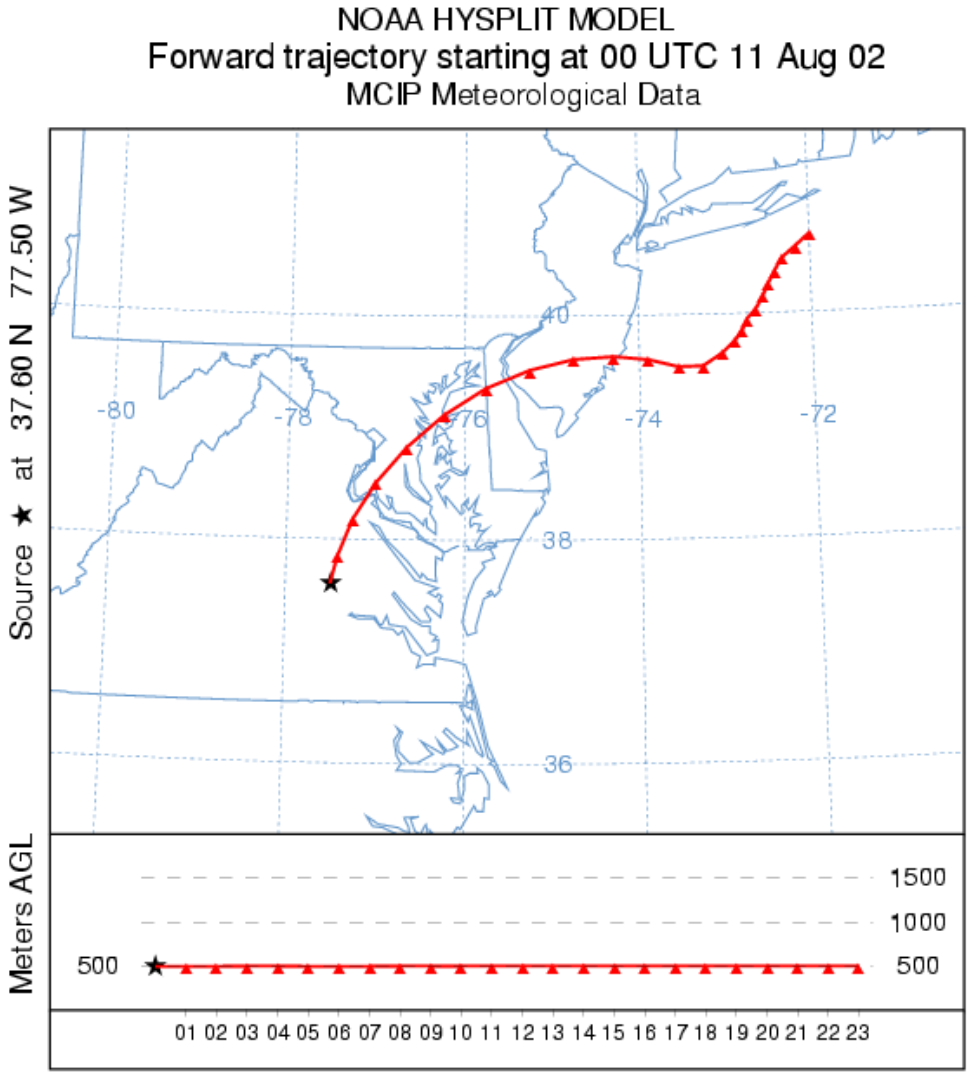


No FDDA < 1 km

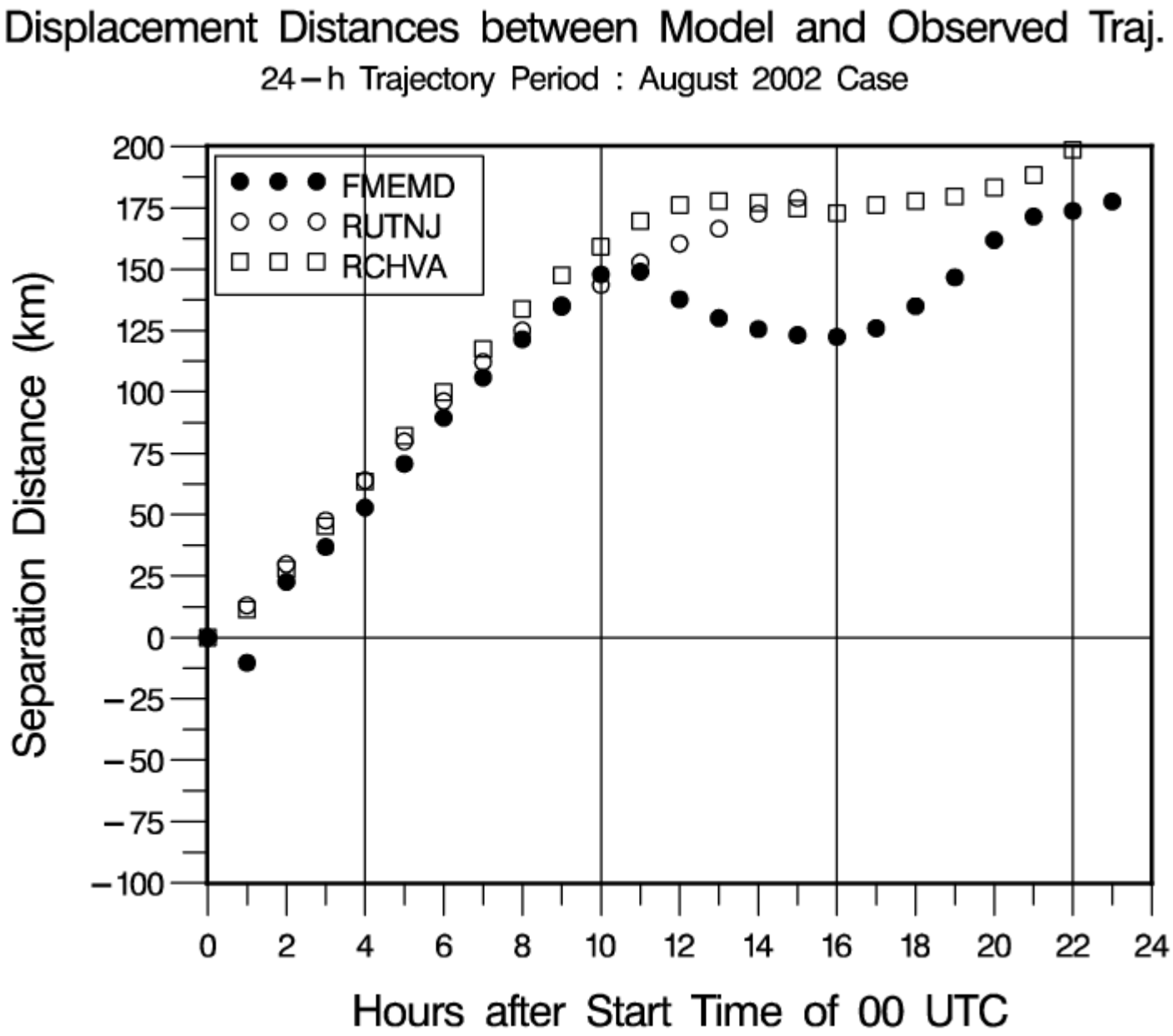


(Hourly averaged wind profiles from 11-15 August, 2002)

24-hr Trajectory Path (NOAA Profiler Obs from RCH, VA)



(Hourly averaged wind profiles from 11-15 August, 2002)


Displacement Distances between Model and Observed Traj.
24 – h Trajectory Period : August 2002 Case
FMEMD
RUTNJ
RCHVA
Separation Distance (km)
200
175
150
125
100
75
50
25
0
– 25
– 50
– 75
– 100
0
2
4
6
8
10
12
14
16
18
20
22
24
Hours after Start Time of 00 UTC

Main Take Home Points

- Model performance varies some from year to year, but that variability is less than differences of performance from winter to summer (T and Q, mainly; wind speed similar throughout the year)
- Wind speed bias at 10 m is a problem that we think has been mitigated with our 2008 simulations. Surface analysis nudging and FDDA in the PBL may not be advisable; groups may want to independently verify.
- Performance (near surface) across the Plains and Rockies is poor in winter. Performance in Rockies may be a systematic modeling issue and not necessarily a model configuration issue.
- Precipitation is generally well simulated in winter, but warm season convective precip, mainly southern US, is not well simulated and should be a main research area in the near future.
- PBL wind is systematically underestimated, both the nocturnal jet magnitude and within the convective PBL

Future Research Plans

- Nudging technique reassessment
  - Grid nudging vs. spectral nudging
  - Nudging strength and vertical distribution
  - Obs nudging with analysis nudging
  - Nudging to 3-D Var analyses that incorporate more non-standard observations