Southeastern Modeling, Analysis and Planning Project

WRF Meteorological Modeling Performance Evaluation and Documentation

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1 Introduction

The purpose of this Contract is for meteorological model performance evaluation and documentation services in support of modeling analyses, control strategy assessments, and other air quality management needs.

Technical air quality analysis projects generally include compilation and analysis of existing ambient air quality monitoring data, collection of additional monitoring data as needed, assessment of air quality trends, preparation of emission inventories, development of emissions control scenarios, modeling of meteorology, emissions, and air quality, and completion of reports revealing the impact of emissions and the air quality benefits of varying emission control levels. This meteorological modeling performance project will support this larger group of tasks.

SESARM intends to concurrently address, to the extent feasible, national ambient air quality standard (NAAQS) requirements and to evaluate progress towards long-term regional haze goals. Because similar pollutant emissions and atmospheric processes control chemical formation and transport for fine particles, ozone, and regional haze, similar technical analyses are necessary to evaluate air quality benefits of emissions controls. SESARM will develop and operate a single integrated, one-atmosphere air quality modeling platform to provide the states with technical analyses that support the required air quality demonstrations.

Prior to this contract, an annual WRF model simulation was performed for 2007. The project supported by this Contract provides a detailed, quantitative and qualitative analysis of these simulated meteorological fields and their suitability for application to air quality modeling.

2 WRF model and Observational dataset descriptions

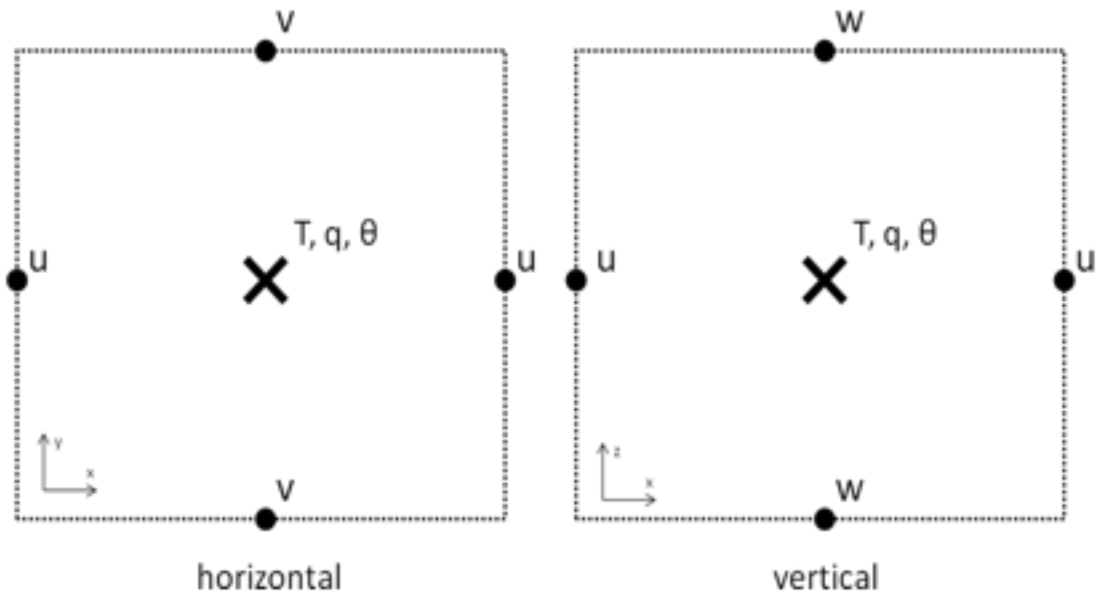
2.1 Model configuration and verification methodology

The WRF v. 3.1 mesoscale meteorology model is a fully compressible, non-hydrostatic model with an Eulerian mass dynamical core [*Skamarock et al*. 2008]. Two dynamical cores are available: the Advanced Research WRF (ARW) core, developed and supported by NCAR, and the Nonhydrostatic Mesoscale Model (NMM) core, whose development is centered at NCEP's Environmental Modeling Center (EMC) and support is provided by NCAR's Development Testbed Center (DTC). The WRF-NMM is designed to be a real-time forecast model so physics schemes are preset. WRF-ARW (hereinafter WRF) was chosen because it includes multiple physics options for turbulence/diffusion, radiation (long and shortwave), land surface, surface layer, planetary boundary layer, cumulus, and microphysics.

Time integration is performed with a 3rd-order Runge-Kutta scheme. WRF has split time integration, which uses smaller time steps used for fast processes like sound waves or gravity waves. WRF was designed to conserve mass, momentum, entropy, and scalars using flux form prognostic equations.

WRF uses Eta (η) as a vertical coordinate, which is defined as the hydrostatic pressure difference from the layer to the top divided by the difference in the entire vertical domain so it is always between 1 (surface) and 0 (top). This vertical coordinate is terrain following hydrostatic pressure system.

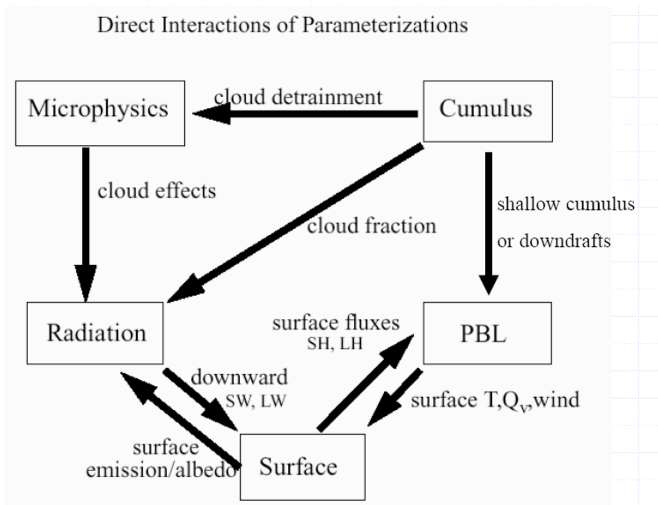
The grid format is Arakawa- C with all variables in the center of the grid except for wind velocity, which is defined on the edges of the grid, and shared between adjacent grids.



The WRF core uses a 3rd-order Runge-Kutta split-explicit time integration scheme, high-order advection scheme, and is scalar conserving. It contains complete Coriolis, curvature, and mapping terms. Domain nesting is possible with one-way and two-way capabilities. Full physics options are available to represent atmospheric radiation, surface and boundary layers, and cloud and precipitation processes. The model contains gridded analysis and observational nudging four dimensional data assimilation (FDDA) capabilities that allow users to perform enhanced retrospective analyses.

The WRF modeling system is divided into two main components: the WRF Preprocessing System (WPS) and the WRF modeling core. WPS contains three processors that define the WRF modeling domain, generate map, elevation/terrain, and land-use data, and generate horizontally interpolated input meteorological fields to the WRF grid. The WRF modeling core interpolates the meteorological fields processed by WPS to the WRF vertical levels and generates initial and lateral boundary conditions. The model solver integrates the atmospheric equations and interfaces with the physics parameterizations to generate forecasts of meteorological variables.

WRF uses physics sub-models to simulate land surface, surface layer, and boundary layer dynamics, along with cumulus convection, microphysics, and radiation. For each of these sub-models, WRF offers from 3 to 9 different parameterizations from which the modeler may select. To make these choices, the modeler must consider not only the individual merits of each parameterization but also how it interacts with the other physics sub-model options. The following flow chart illustrated the interaction of the WRF physics sub-modules.



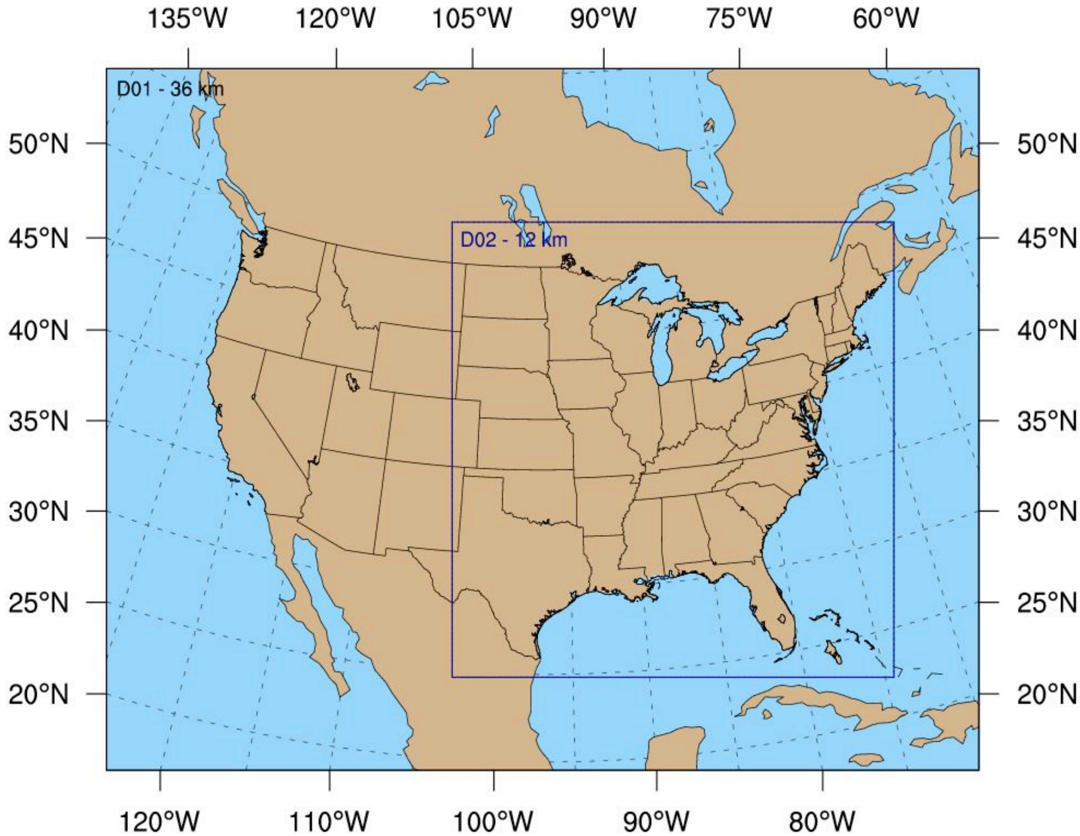
WRF version 3.1.1 (July 2009) was used for the sensitivity tests and the annual simulations. The main update to the model in this release was the addition of objective analysis (OBSGRID) and surface analysis nudging capabilities, an option preferred for generating meteorological data for input to air quality simulations

2.2 Modeling domains

The domain used by the SEMAP has been expanded from the domain used for the 2002 State Implementation Plan modeling. This was done to coordinate with the other members of the WRF Work Group, which including LADCO, SESARM, and the State of Iowa.

2.2.1 Horizontal Grid

The computational domain for this simulation consists of a coarse and fine grid nested domains. The coarse domain consists of a Lambert conic conformal projection with specifications used in previous regional modeling studies, which is centered at 40° N and 97° W with true latitudes of 33 and 45° N. The coarse grid structure consists of an array of 165 cells in the east-west direction and 129 cells in the north-south direction with a grid spacing of 36 kilometers (km). This domain was designed maximize the usage of the Eta analysis region.



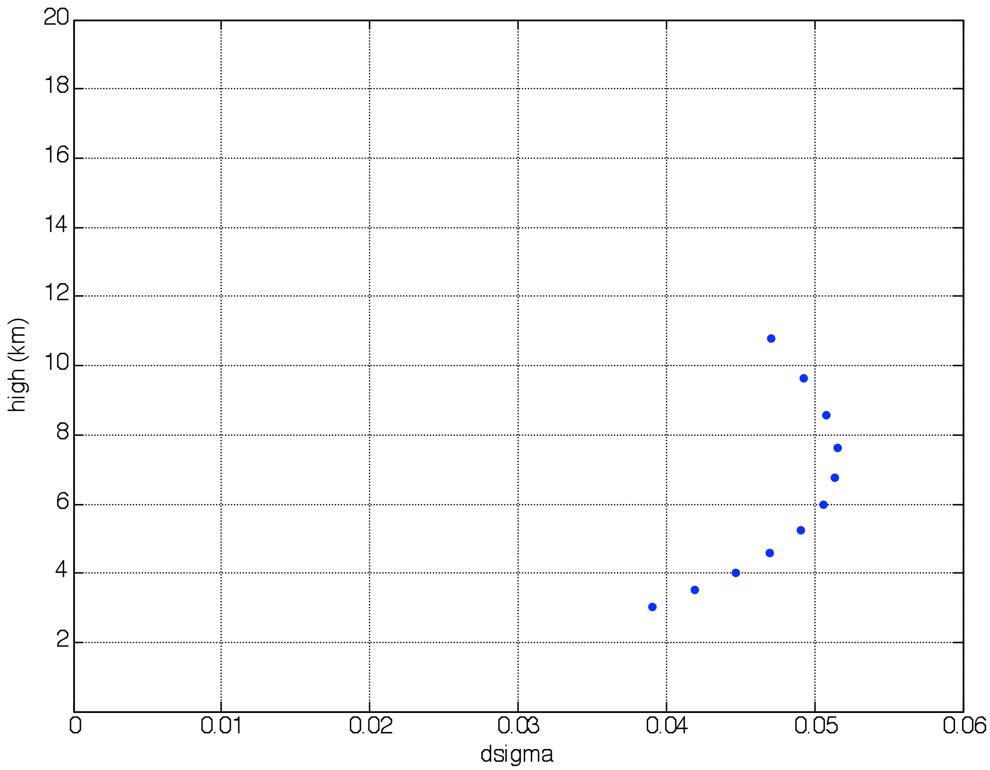
A nested domain is implemented to resolve finer scale meteorological features. The nested domain grid structure is a 250 by 250 array of grid cells with a grid spacing of 12 km. This domain begins at node (66, 18) of the course domain. The nested domain shares the northern, eastern, and southern boundaries of the EPA 12 km Eastern domain and western boundary of the Iowa/LADCO 12 km domain. A summary of the horizontal structure of the modeling domain is given in Table below.

Domains	**Outer (1)**	**Inner (2)**
Resolution (km)	36	12
Starting Location (i,j)	1,1	66,18
nx (E-W)	165	250
ny (N-S)	129	250
SW Coordinate (km)	-2952, -2304	-612, -1692
NE Coordinate (km)	2952, 2304	2376, 1296

Using 12 km horizontal resolution is sufficiently high to simulate mesoscale features and is also in range to use both WRF microphysics and cumulus convection schemes.

2.2.2 Vertical Layers

The vertical grid structure consists of 35 layers (34 layers) as shown below.



Each dot signifies one level. The height of the level is shown on the y-axis and the mass between layers is shown on the x-axis. The number of levels is more concentrated below 1 km.

This vertical structure was designed to provide increased resolution in the boundary layer and near the tropopause. The second level is placed at ~20 meters so that the midpoint of the grid cells in the vertical direction is located at 10 meters and corresponds to the standard National Weather Service (NWS) anemometer height. This avoids the use of a surface layer parameterization to vertically interpolate horizontal wind components to the standard NWS observational height. The top of the model is fixed at 50 mb. A summary of the vertical structure of the modeling domain is given below.

Level	Sigma	Height (m)	Pressure (mb)	Depth (m)
35	0.0000	18663	50	2034
34	0.0332	16629	82	1715
33	0.0682	14914	115	1515
32	0.1056	13399	150	1375
31	0.1465	12024	189	1255
30	0.1907	10769	231	1145
29	0.2378	9624	276	1045
28	0.2871	8579	323	955
27	0.3379	7624	371	870
26	0.3895	6754	420	790
25	0.4409	5964	469	715
24	0.4915	5249	517	645
23	0.5406	4604	564	580
22	0.5876	4024	608	520
21	0.6323	3504	651	465
20	0.6742	3039	690	415
19	0.7133	2624	728	370
18	0.7494	2254	762	330
17	0.7828	1924	794	293
16	0.8133	1631	823	259
15	0.8410	1372	849	228
14	0.8659	1144	873	200
13	0.8882	944	894	174
12	0.9079	770	913	150
11	0.9252	620	929	128
10	0.9401	492	943	108
9	0.9528	384	955	90
8	0.9635	294	965	74
7	0.9723	220	974	60
6	0.9796	160	981	48
5	0.9854	112	986	38
4	0.9900	74	991	30
3	0.9940	44	994	24
2	0.9974	20	998	20
1	1.0000	0	1000	0

2.3 Data Nudging

To minimize the accumulation of model errors and retain as many mesoscale circulations as possible, the Objective Analysis and Four-Dimensional Data Assimilation (FDDA) techniques were used to include observations of the surface winds and upper-level meteorological information. The datasets used are high resolution (in time and space) and the technique has been applied in previous air quality modeling studies. *Gilliam et al.* (2009) found big improvements in WRF results when OBSGRID, was used to lower error of analyses.

2.3.1 Objective Analysis

The OBSGRID option, just introduced in WRF v. 3.1, is used for objective analysis. The goal of OBSGRID is to improve the first-guess gridded analysis by incorporating high-resolution observations with the low-resolution global analysis [*Wang et al.* 2009]. It also prepares the input files for surface nudging.

The Cressman style objective analysis was used, in which several successive scans nudge a “first-guess” field toward each neighboring observed value within a circular radius of influence from each grid point. A distance-weighted average of the difference between the “first guess” and the observations is added to the value of the “first guess” at each grid point. Once all grid points have been adjusted, the adjusted field is used as the “first guess” for another adjustment cycle with a smaller radius of influence.

2.3.2 Four-Dimensional Data Assimilation

In contrast to objective analysis, which is used to improve initial and boundary conditions, FDDA incorporates observations during model integration [*Stauffer et al.* 1991]. The FDDA options chosen for the OTC WRF runs were analysis and surface nudging. The surface FDDA option creates a separate surface analysis that has a higher temporal resolution than full 3D analyses. The analysis nudging uses 3D gridded variables above the surface layer that are used throughout the WRF run to nudge model outputs toward the analysis, which is based on observations [*Wang et al.* 2009].

The input data was set at 3-hour intervals. In the boundary layer, only U and V winds were nudged. Nudging of temperature at the surface was not used because it can cause static instability if it is not consistent with temperature above the surface layer [*Stauffer et al.* 1991]. The water vapor mixing ratio is also not nudged in the PBL because supersaturation may occur when surface temperature is not nudged. In the free troposphere, nudging was used for U and V winds, temperature, and water vapor mixing ratio to help minimize large-scale errors.

2.3.3 Nudging Coefficients

The strength of dynamical nudging depends on the magnitude of the nudging coefficients selected. The nudging coefficient for wind should not exceed that of the Coriolis parameter [*Gupta et al.* 1997]. The nudging coefficients used for the SEMAP WRF runs are listed below.

Domain	Variable Nudged	Nudging Coefficient
Outer Domain	U and V winds	5.0×10^{-4}
Outer Domain	Temperature	5.0×10^{-4}
Outer Domain	Water vapor mixing ratio	1.0×10^{-5}
Outer Domain	Surface U and V winds	5.0×10^{-4}
Inner Nest	U and V winds	3.0×10^{-4}
Inner Nest	Temperature	3.0×10^{-4}
Inner Nest	Water vapor mixing ratio	1.0×10^{-5}
Inner Nest	Surface U and V winds	3.0×10^{-4}

The inner nest nudging coefficients are similar to those used in air quality retrospective studies. *Gupta et al.* (1997) tested various nudging coefficients for wind and found that 2.778×10^{-4} best replicated the energy spectrum. *Mao et al.* (2006) used 2.5×10^{-4} for temperature and wind and 1.0×10^{-5} for water vapor mixing ratio. However, *Gilliam and Pleim* (2010) used a slightly higher nudging coefficient for temperature and wind (3.0×10^{-4}) but the same for moisture (1.0×10^{-5}).

The outer domain nudging coefficients were determined after testing at different levels. Using lower coefficients, the SEMAP found that the 3D analysis and surface nudging had very little impact on surface and upper air variables. As a result, higher settings were chosen for the outer domain to improve WRF performance

2.4 Period of analysis

SEMAP provided AER with WRF model output for domains 1 and 2 from the year-long production run and nine sensitivity runs of the WRF model for selected periods during 2007.

2.4.1 Production Run

Detailed model evaluation of the production run was performed for the 365-day period comprising the entire calendar year of 2007 for both domains. The full year of simulations was pieced together from 73 individual WRF runs of length five and a half days each. To avoid meteorological field contamination due to model spin-up, data from the first twelve hours of each model run were not analyzed. Thus, each five-day model segment contained data with forecast lengths of between 12 and 131 h.

2.4.2 Sensitivity Runs

Detailed model comparison amongst the nine sensitivity runs was carried out for domain 2 for two evaluation periods of 20 days each, hereafter, the ‘Summer’ and ‘Winter’ periods. Respectively, these two sets of four individual WRF runs were valid for the calendar days 28 July 2007 through 16 August 2007, and 5 December 2007 through 24 December 2007. These dates were selected by the WRF Working Group based on known air quality exceedances throughout the Eastern US.

2.5 Observational dataset

The WRF-MET meteorological evaluation software that was used in this study (refer to Section 3.2) was designed to ingest observations in prepBUFR format. A readily available and valuable source of observations in prepBUFR format was obtained from the UCAR web server (http://dss.ucar.edu/datasets/ds337.0/). While the observation types available in the prepBUFR files include the following platforms for 2007, version 2 of WRF-MET does not decode visibility, precipitable water, snow cover, or cloud elements:

Air Temperature	Dew Point Temperature
Atmospheric Pressure Measurements	
Cloud Amount/Frequency	Geopotential Height
Cloud Base	Precipitable Water
Cloud Types	Precipitation Amount
Sea Level Pressure	Surface Winds
Sea Surface Temperature	Upper Level Winds
Snow	Visibility
Station Height	

The following is the general description from the UCAR web server that accompanies this dataset:

NCEP ADP Global Upper Air and Surface (PREPBUFR format) Weather Observations are composed of a global set of surface and upper air reports operationally collected by the National Centers for Environmental Prediction (NCEP). These include land surface, marine surface, radiosonde, pibal and aircraft reports from the Global Telecommunications System (GTS), profiler and US radar derived winds, SSM/I oceanic winds and TCW retrievals, and satellite wind data from the National Environmental Satellite Data and Information Service (NESDIS). The reports can include pressure, geopotential height, temperature, dew point temperature, wind direction and speed. Report time intervals range from hourly to 12 hourly. These data are the primary input to the Global Data Assimilation System (GDAS), which is used to create the NCEP Final Analyses (FNL).

WRF-MET was designed for the direct ingest of this dataset and so use of these data for the entire verification exercise minimized the time-consuming and error-prone task of aggregating and reformatting observations. This dataset spans the time period and geographical region of interest and thus the verification techniques maintained data integrity from a single source across all verification stratifications.

This dataset has undergone quality control procedures as part of preprocessing for NCEP's Grid Point Statistical data assimilation system and, as a result, contains an estimation of the observational error. Below is a description from the UCAR web server of the quality control procedures:

The "PREPBUFR" processing is the final step in preparing the majority of conventional observational data for assimilation into the Global Forecast System and Global Data Assimilation System unified grid-point statistical interpolation analysis (GSI) (the "GFS" and "GDAS" networks). This step involves the execution of series of programs designed to assemble observations dumped from a number of on-line decoder databases, encode information about the observational error for each data type as well the background (first guess) interpolated to each data location, perform both rudimentary multi-platform quality control and more complex platform-specific quality control, and store the output in a monolithic BUFR file, known as PREPBUFR. The background guess information is used by certain quality control programs while the observation error is used by the analysis to weigh the observations. The structure of the BUFR file is such that each PREPBUFR processing step which changes a datum (either the observation itself, or its quality marker) records the change as an "event" with a program code and a reason code. Each time an event is stored, the previous events for the datum are "pushed down" in the stack. In this way, the PREPBUFR file contains a complete history of changes to the data throughout all of the PREPBUFR processing. The most recent changes are always at the top of the stack and are thus read first by any subsequent data decoder routine. It is expected that the data at the top of the stack are of the highest quality.

It should be noted that a software bug in WRF-MET inverted the stack. This resulted in a small number of observations of lower quality being used. Detailed evaluation by the UCAR software developers during their attempt to correct the problem determined that less than 10% of all observations were incorrectly selected and that temperature observations were the most affected. We believe that this is the source of some of the gross outliers, which are often unphysical, that are most readily seen in the scatter plots (Section 5.1.5).

2.6 Meteorological variables and assessment measures

The following six meteorological fields were objectively analyzed by WRF-MET: temperature (degrees Celsius), dew point temperature (degrees Celsius), specific humidity (g/kg), relative humidity (%), wind speed (m/s), and wind direction (degrees). Not all tasks required the evaluation of all fields, however. The following Quantitative Assessment Metrics were considered as important thresholds during the analysis of the errors, including the choice of colors in plot legends:

Quantitative Assessment Metrics		
Wind Speed	RMSE	≤ 2 m/s
	Mean Bias	≤ ±0.5 m/s
Wind Direction	Gross Error	≤ 30 deg
	Mean Bias	≤ ± 10 deg
Temperature	Gross Error	≤ 2 K
	Mean Bias	≤ ±0.5 K
Specific Humidity	Gross Error	≤ 2 g/kg
	Mean Bias	≤ ±1 g/kg

3 Evaluation techniques

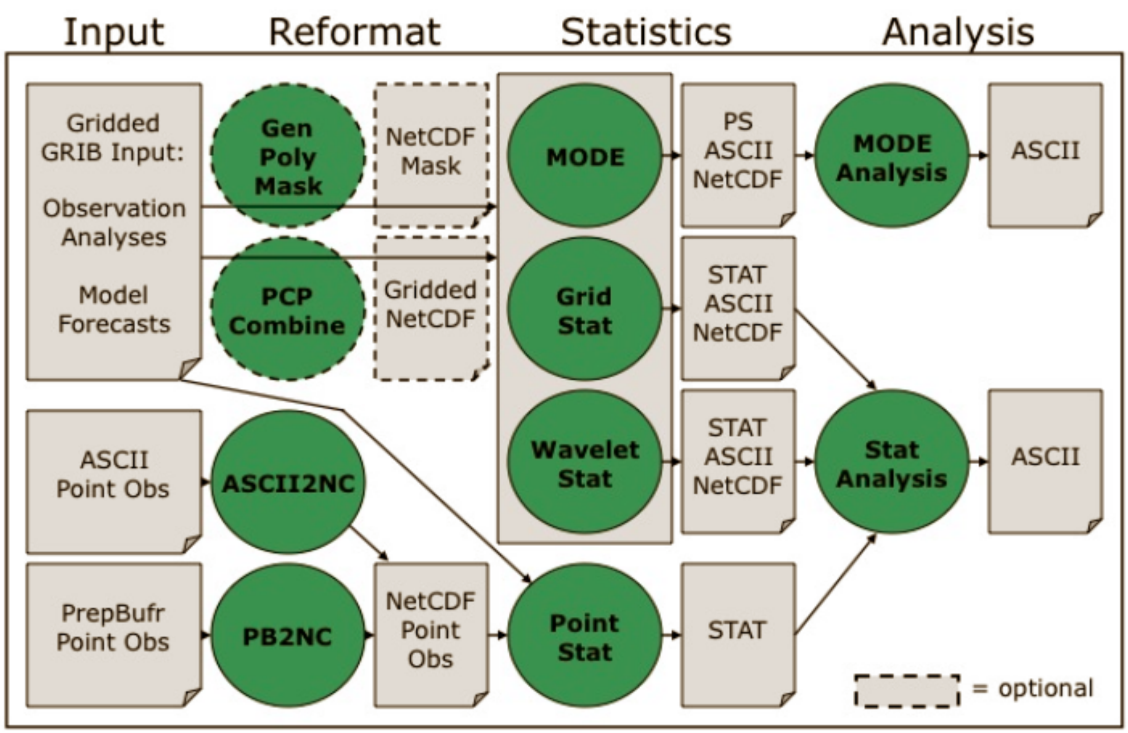
3.1 Subjective

A subset of the production and sensitivity run WRF output files, as well as input namelist files, were subjectively inspected to ensure that the WRF model was configured as intended, and also that the intended configuration is consistent with established combinations of model options. The following aspects of the model configuration were inspected:

- initialization data (horizontal grid spacing, frequency of boundary conditions)
- application of data assimilation
- time step
- placement and number of vertical levels
- one-way or two-way nested grid interaction
- strategy for piecing together coincident model runs
- physical parameterizations for cumulus convection, the planetary boundary layer scheme, explicit moisture, radiation and land-surface scheme.

3.2 Objective

Version 2.0 of the WRF-MET meteorological modeling verification software (available from http://www.dtcenter.org/met/users/) was used to carry out the initial steps of the objective statistical analysis. A logical depiction of the components of the WRF-MET software package is shown below. Green indicates software and modules, and gray represents input and output files.



WRF-MET expects GRIB1 format model data, which was generated by processing all raw model runs received from SESARM in netCDF format through software named WRF-WPP. This is an NCEP-developed post processor that also converts the native model sigma level data to standard pressure levels. This will facilitate generation of statistics at levels typically available from radiosondes.

The WRF-MET software is composed of a number of individual processing steps. The input data – both point and gridded observations - first are converted into internal intermediate formats, and then raw statistics files are generated. These raw statistics are named “STAT” in the above flowchart and ultimately represent top-of-the-hour pairs of modeled and observed values. These take the form of both spatially-averaged modeled and observed values and, more fundamentally, matched pairs of true single-time modeled and observed values. These raw statistics have been provided to SESARM in zipped files on suitable media.

The STAT files were then aggregated and temporally averaged to produce summary statistics presented in the form of plots, charts, maps and tables. The aggregation and plotting steps were carried out through extensive use of shell and Perl scripts. The R analysis and display software was used to generate all graphics.

3.3 Spatial Averaging

Statistics for a number of tasks have been spatially averaged into 27 states and Regional Planning Organization regions (RPOs): Alabama, Arkansas, District of Columbia, Florida, Georgia, Iowa, Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, Mississippi, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, Wisconsin, West Virginia, MANEVU (ME, MA, VT, NH, NY, PA, NJ, MD, DE), CENRAPN (MN, IA, NE, KS, MO), CENRAPS (TX, LA, OK, AR), SEMAP [VISTAS] (VA, WV, KY, TN, NC, SC, GA, AL, MS, FL), MRPO (MI, WI, IN, IL, OH) and FULL (entire model domain)

*Some early plots and tables refer to VISTAS. Subsequently, the term SEMAP has been used.

Computation of statistics inside WRF-MET for different regions is accomplished using grid point masks based on state outlines as defined by the 2000 US Census. Because masking is grid point based, as opposed to observation location based, whether an observation is used in a specific masked region (for instance, a state) depends upon in which state the closest grid point resides. It is thus possible that observations can be used in different states depending on the domain in question. A small number of observations changed states between domains 1 and 2 in this study, but the overall effect on the statistics is negligible.

A second consequence of the grid point method is that statistics are unavailable for domain 1 for the District of Columbia. For domain 1 there are no grid points that lie inside that very small geographic area.

The following illustrates the geographical extent of the five RPOs for which statistics were computed. Note that the red WRAP RPO was not involved in this study:

4 Inspection of model configuration

In our opinion, the WRF model configuration selected by SEMAP for the production run is acceptable for generation of meteorological fields to be input to air quality models. A reasonable mix of physics options and model configuration parameters was selected using an up-to-date release of the ARW-WRF model. Sufficient documentation in the form of log files and namelist files was provided by SESARM to be confident that the WRF model was run in the manner designed and intended.

While the choice in the production run to turn feedback off between nests allows for independent evaluation of forecasts from each of the two domains, ideally feedback would be active in order for the coarser outer domain fields to incorporate the meteorological fields from the innermost domain that have been influenced by the higher-resolution topography. It is noted that feedback between grids was active for all sensitivity runs. This fact contributes, in part, to the different error statistics between the sensitivity run that was chosen for the production run and the actual production run. The difference in statistics is also attributable to the different model initialization times of the run segments between the sensitivity and production runs.

The dependence on model forecast length is considered a relatively minor factor in the overall quality of the forecast fields, though a degradation in the quality of the model 2-m dew point temperature field was noted (reported below in 5.1.1.2). This may be a result of the lack of nudging moisture in the PBL. Considered more important overall, however, is the quality of the individual initialization field for each run. It is hypothesized that any deleterious effects of the use of relatively long segments (132 h), as opposed to 30-h simulations, for instance, was generally negated by the use of nudging.

5 Evaluation of Annual Production Run Meteorological Model Performance

5.1 Statistical analysis of WRF full-year production run

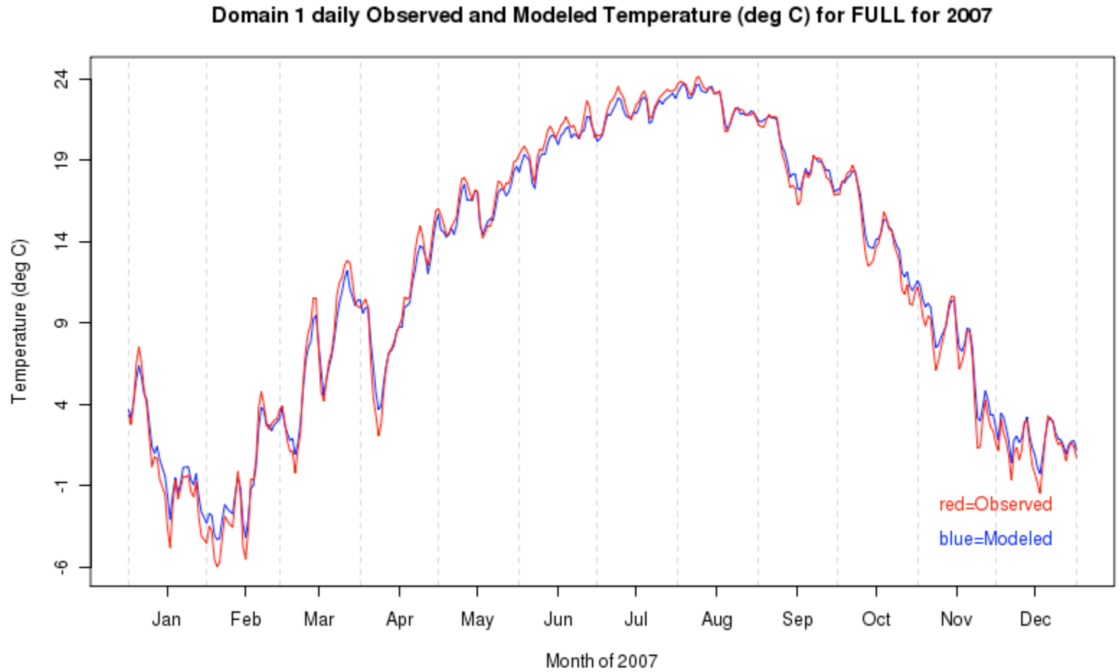
Detailed analysis of each Production Run Task now follows.

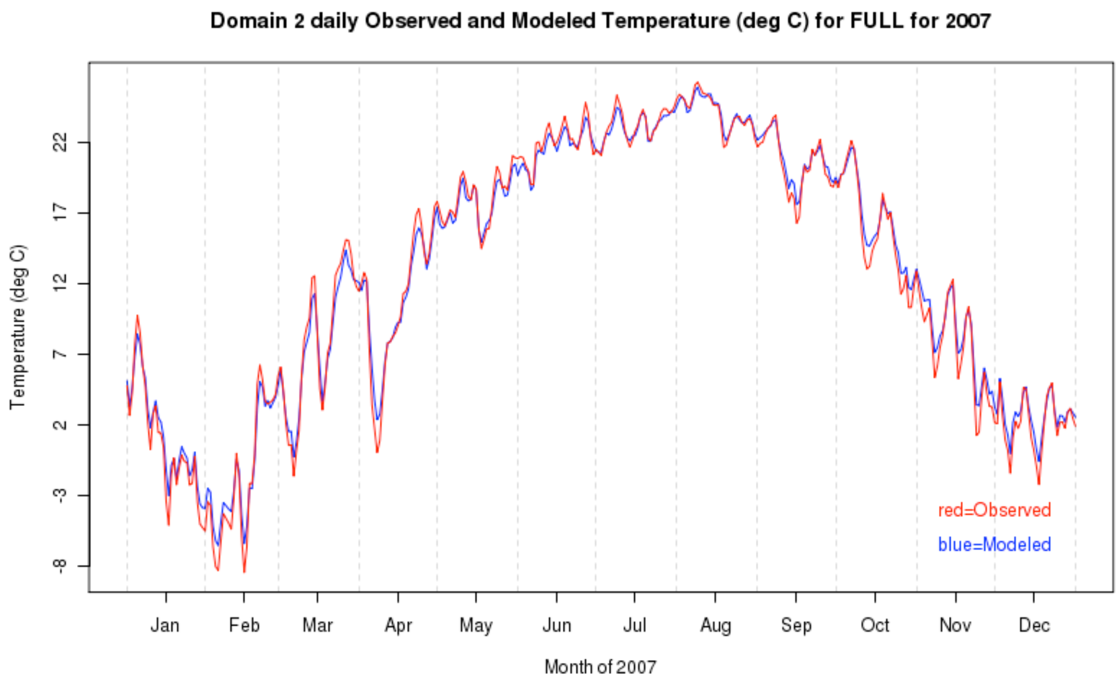
5.1.1 Task 2 A: Time series of spatial averages over all regions

This section discusses verification plots that show time series (of daily averages for annual and monthly plots, and hourly values for plots covering 5-day segments) of spatially averaged forecast and observed values of various surface fields (temperature, dew point, etc). We concentrate here on domain-wide (domain 1 and 2) averages that highlight model performance over the entire model domain. Statements concerning the model performance in this section apply to these domain-wide statistics. The website contains additional plots for averages computed over various geographic regions.

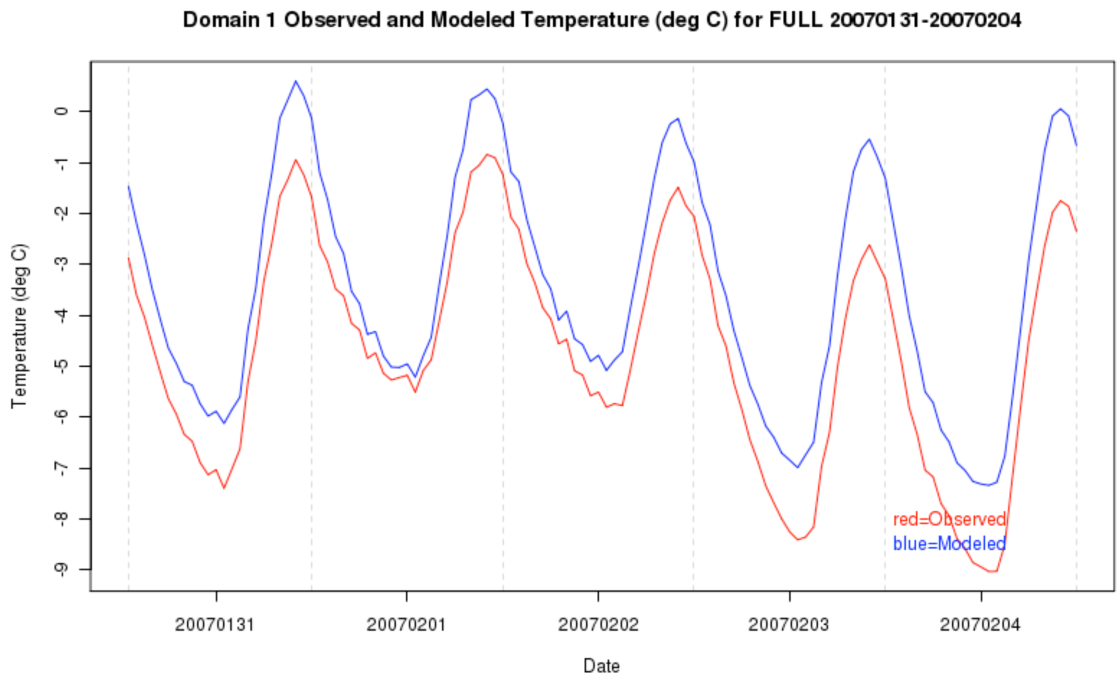
5.1.1.1 Temperature

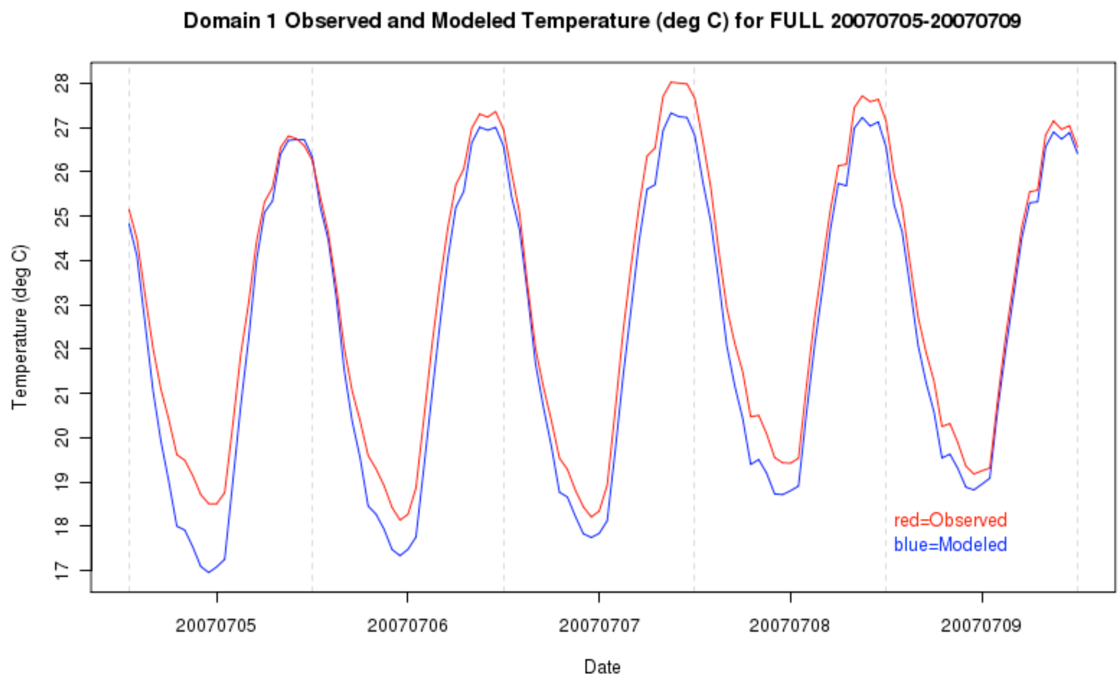
The annual observed and modeled temperature for the FULL region of Domains 1 and 2 shows that temperatures are generally well simulated. The model temperatures track the observations well; however, they have a slight high bias during the cooler portions of the year, in January and February and again in December. A slight negative bias is also found during a portion of the warm season from roughly June through early August. The time series also suggests the model has some difficulty predicting periods of lower temperatures as it tends to not predict temperatures as low as the observed values. Differences in the observed performance of the model between domain 1 and domain 2 were found to be minimal.





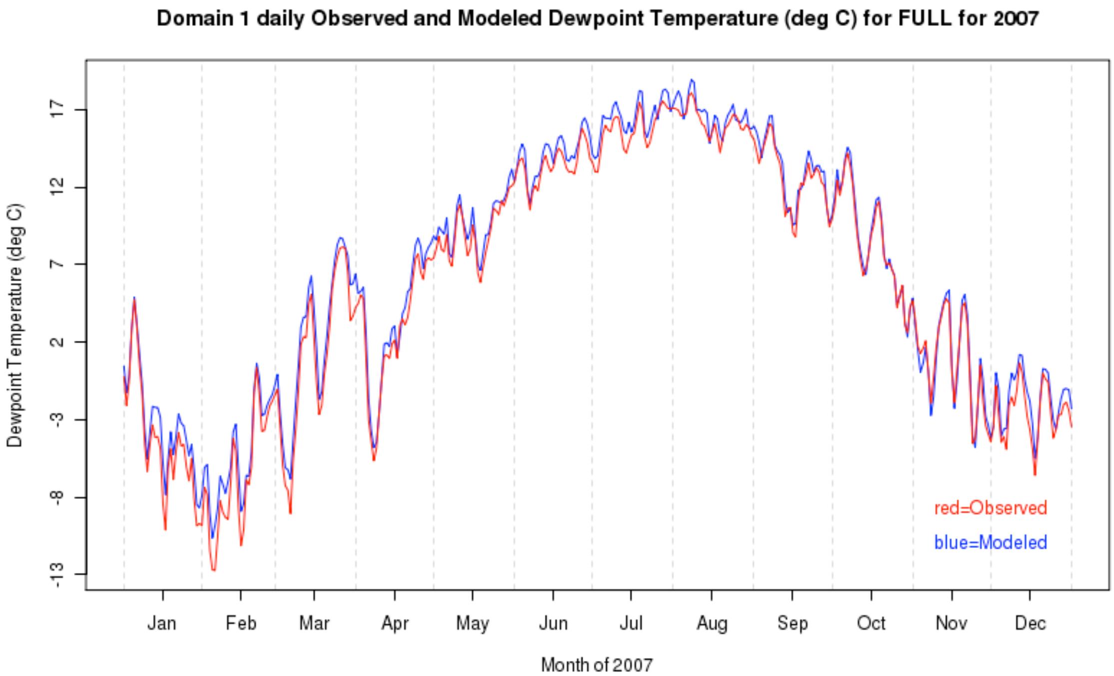
The two plots below demonstrate the different biases of the model prediction of air temperature for two different 5-day runs. The first plot shows an approximate 1-1.5° C high bias in the model prediction for the period January 31 – February 4, 2007. By contrast, a high bias of generally less than 0.5° C is found for the period July 5–9, 2007. The transition from a high bias during the cool season to a negative bias during the warm season highlights the seasonality of the results from the WRF model.



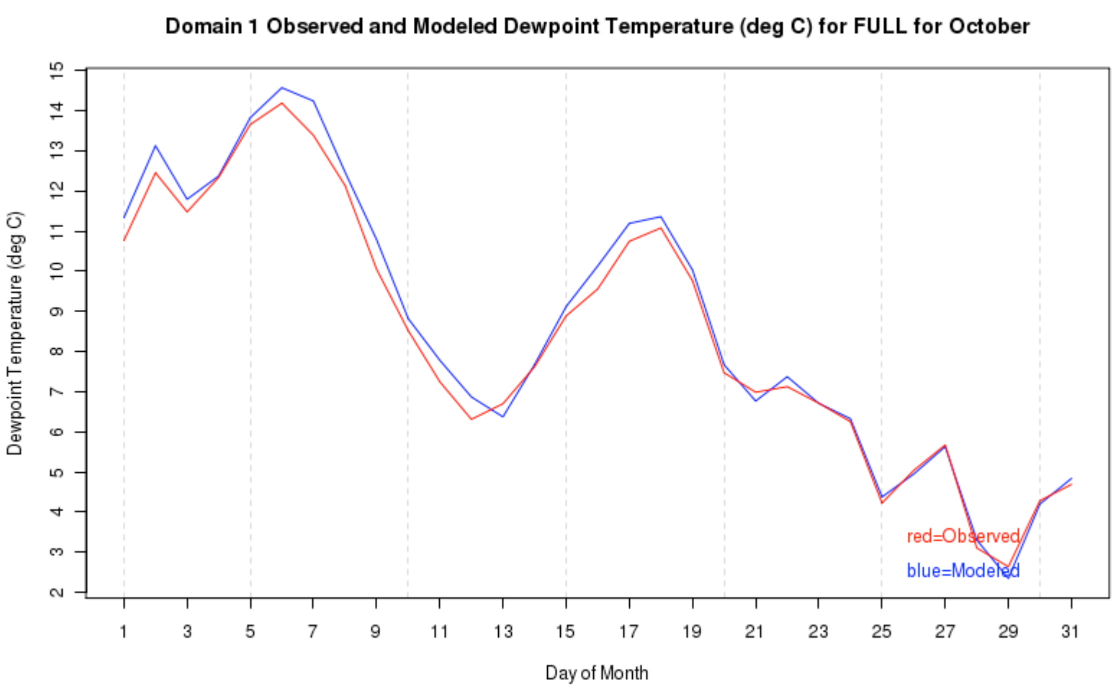


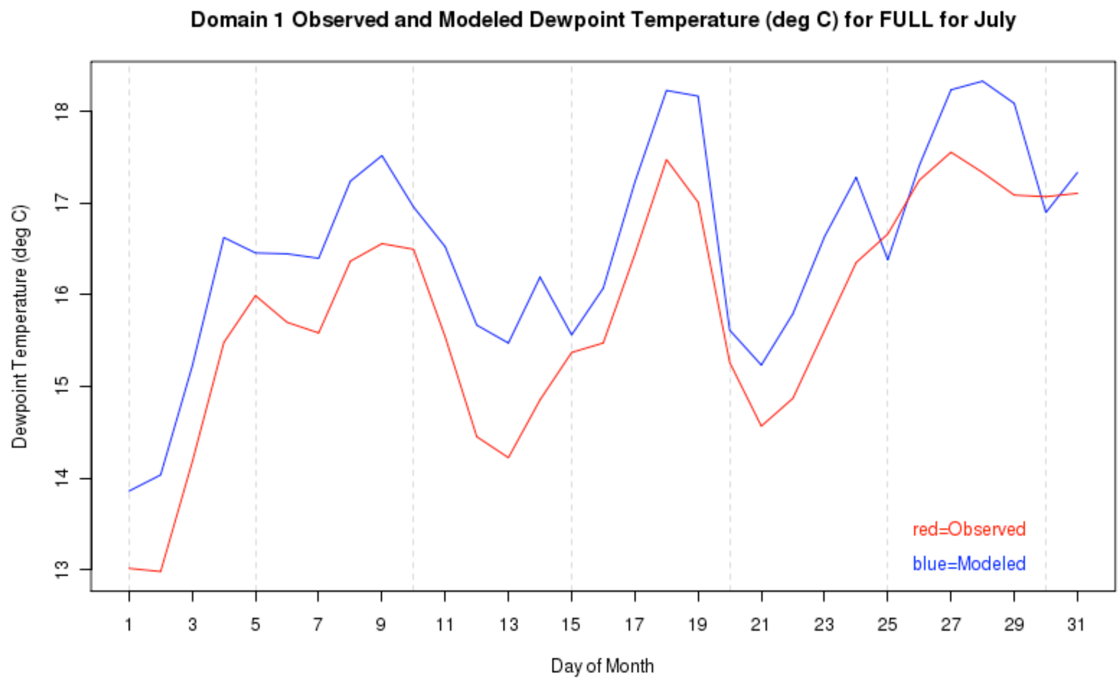
5.1.1.2 Dew point temperature

The observed and modeled dew point temperature time series for domain 1 appears in the plot below. It shows that there is a slight high bias in the dew point temperature throughout most of the year except during the autumn when the simulation more closely matches the observations.

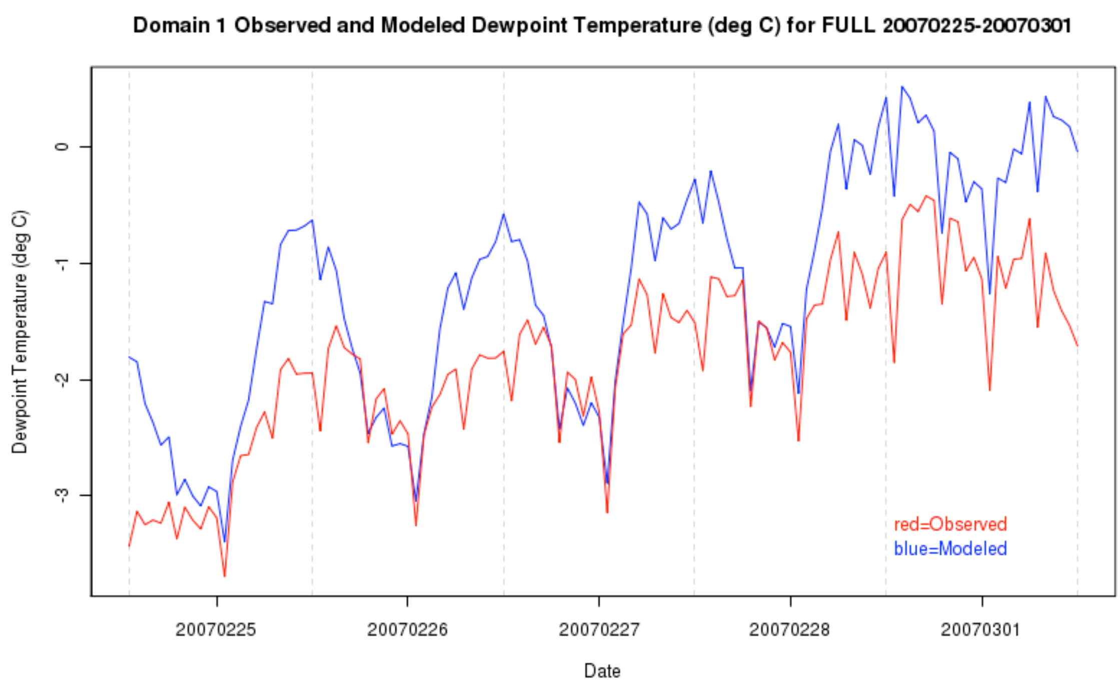


The following plots of monthly dew point temperature further detail the performance of the WRF model. The first plot below shows good performance from the WRF model during the month of October. The plot for the month of July shows that the time series is more disorganized and the model simulation does not track the trends in the observations particularly well. The dew point temperatures in July are forecast about 1° C too warm on average.

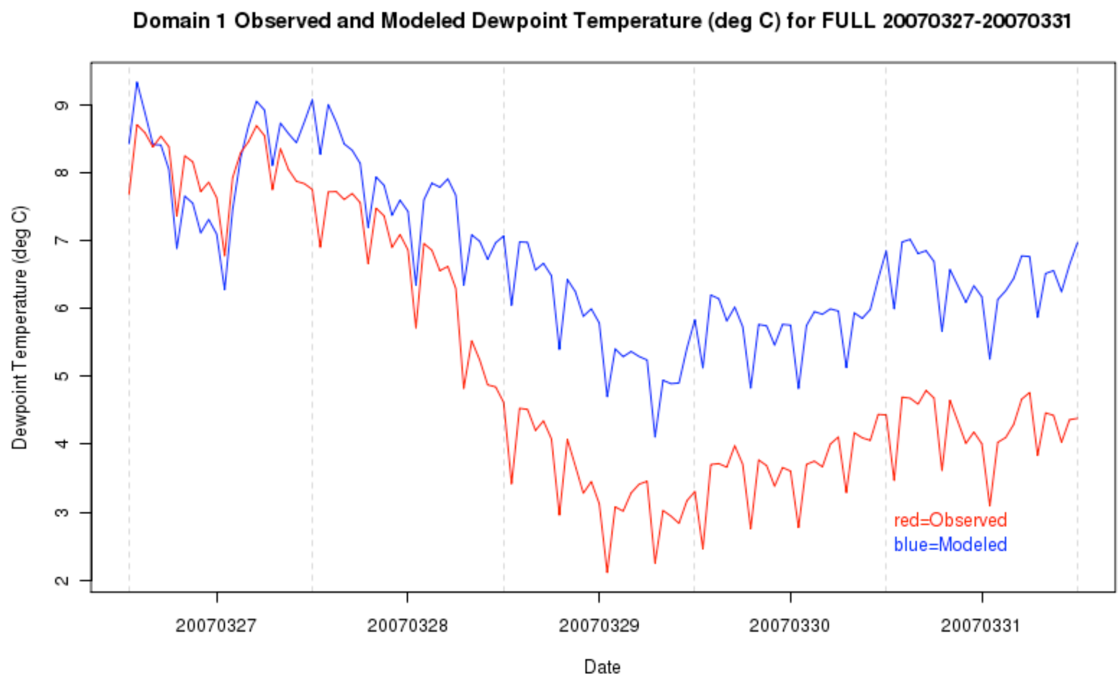




A poor representation of the diurnal cycle appears to be contributing greatly to the observed high bias in the longer time series. The plot below from February 25 – March 1, 2007 shows that the dew point is well simulated during the daytime hours when boundary layer mixing is strongest; however, the WRF simulation predicts the nighttime dew point temperature much too high – on the order of 1° C.

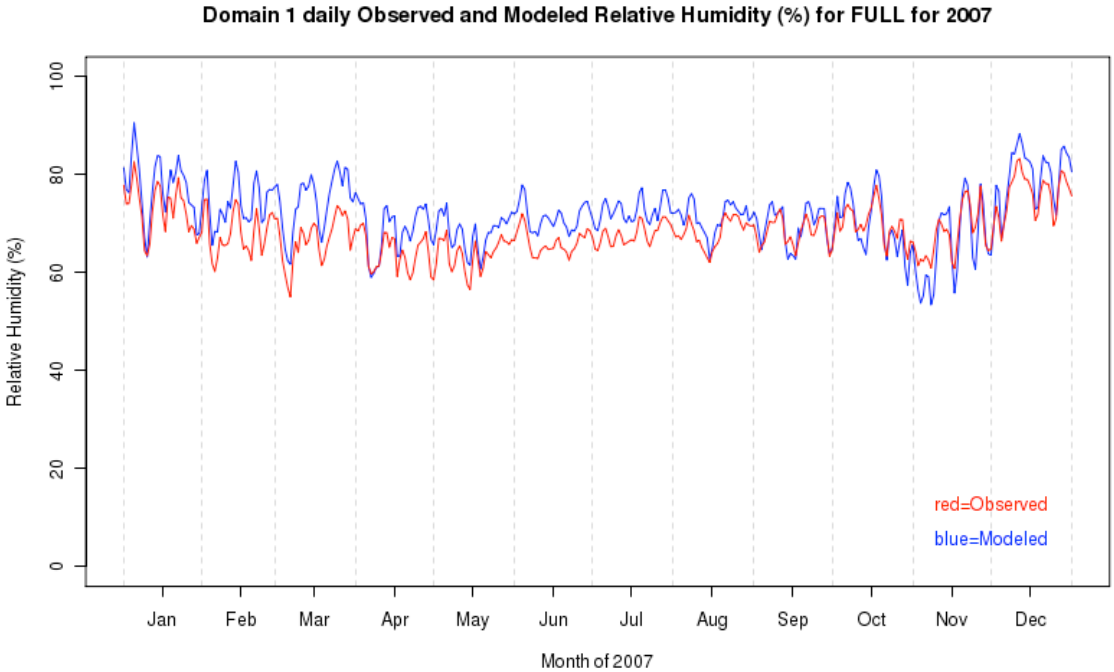


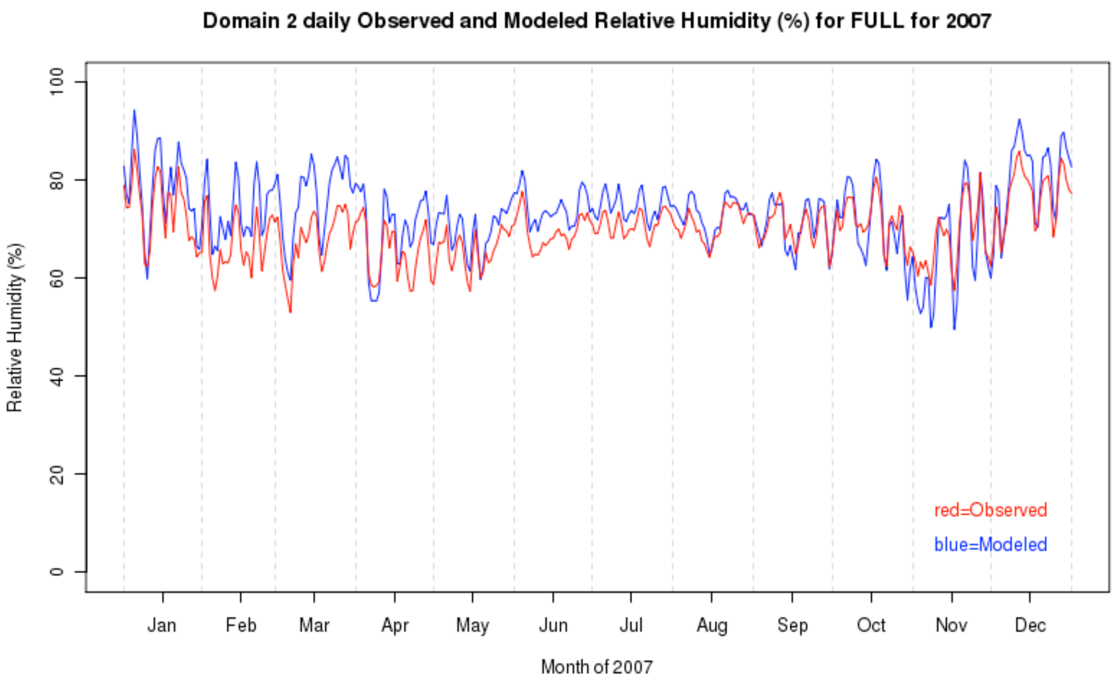
There is also evidence in the 5-day model simulations that the dew point temperature tends to develop a greater spread between the modeled value and the observed value at later forecast times. The plot below shows an example of this tendency. In the first 48 hours of the simulation, the modeled dew point temperature time series follows the observed time series relatively well, but diverges after this time resulting in a significant high bias of approximately 2°C.



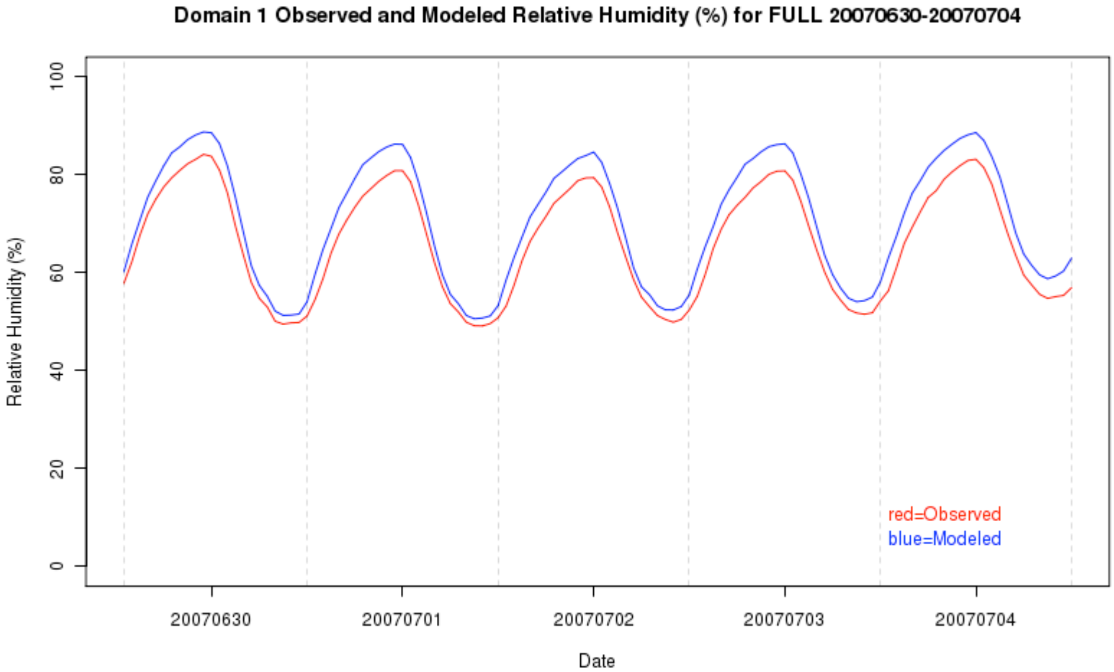
5.1.1.3 Relative humidity

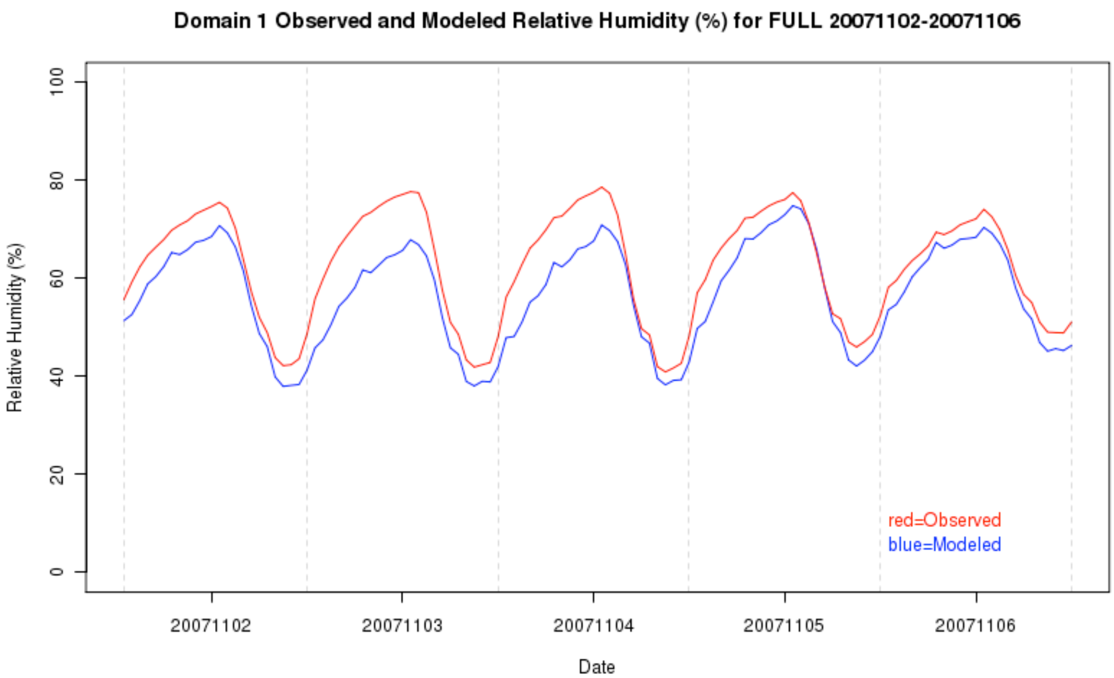
The modeled relative humidity time series displays many of the same characteristics as the dew point temperature time series in that it carries a high bias relative to the observed values for much of the year excluding much of the autumn season. The combination of air temperatures that are simulated near or below the observed values and dew point temperatures that are generally above the observed values is consistent with a heightened relative humidity profile, especially during the January through August time frame. Comparing the two domains in the plots below, the modeled and observed relative humidity increases slightly for domain 2, but the trends are quite similar.





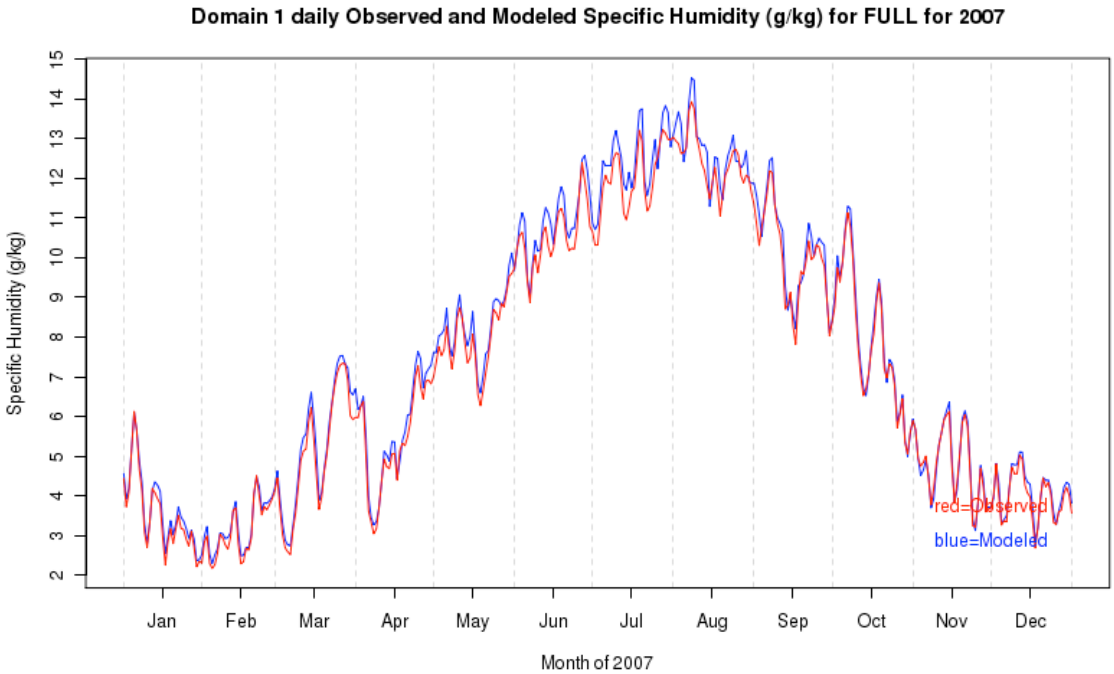
The plots below show 5-day model simulations of relative humidity during the summer and autumn to highlight the differences on a shorter time scale. The top plot shows the relative humidity time series for June 30 – July 4, 2007. The modeled relative humidity is slightly higher than the observed relative humidity with good performance during the daytime hours and poorer performance during the nighttime hours. Similarly in the bottom plot, the model performance is better during the daytime in the autumn. The modeled relative humidity, however, is predicted lower than the observations.

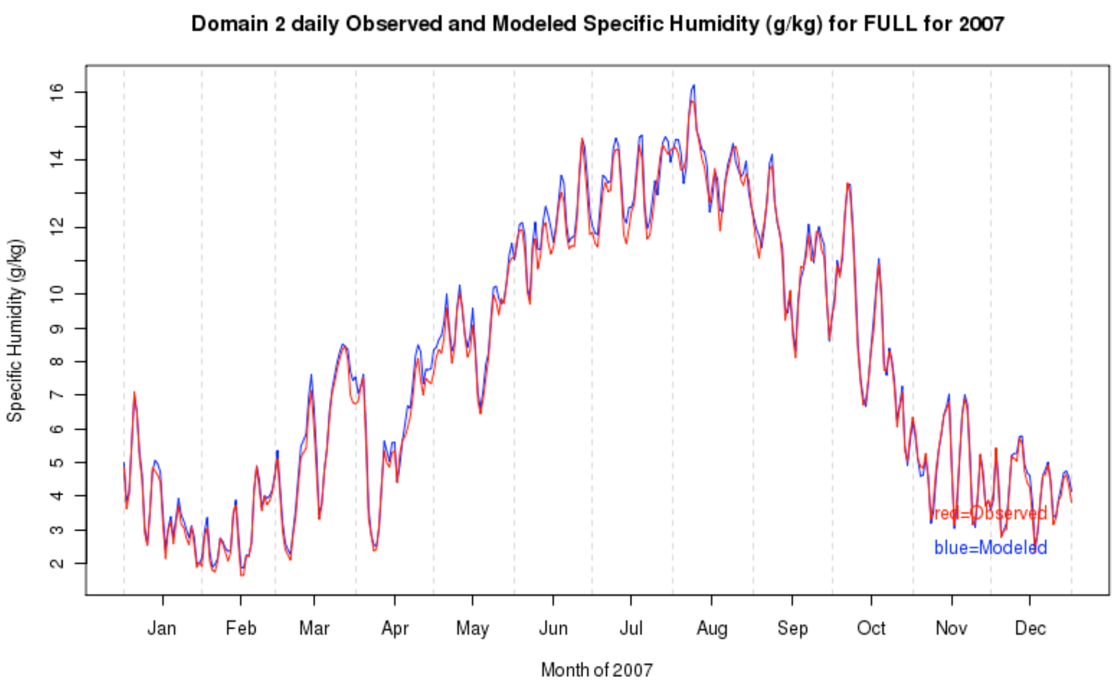




5.1.1.4 Specific humidity

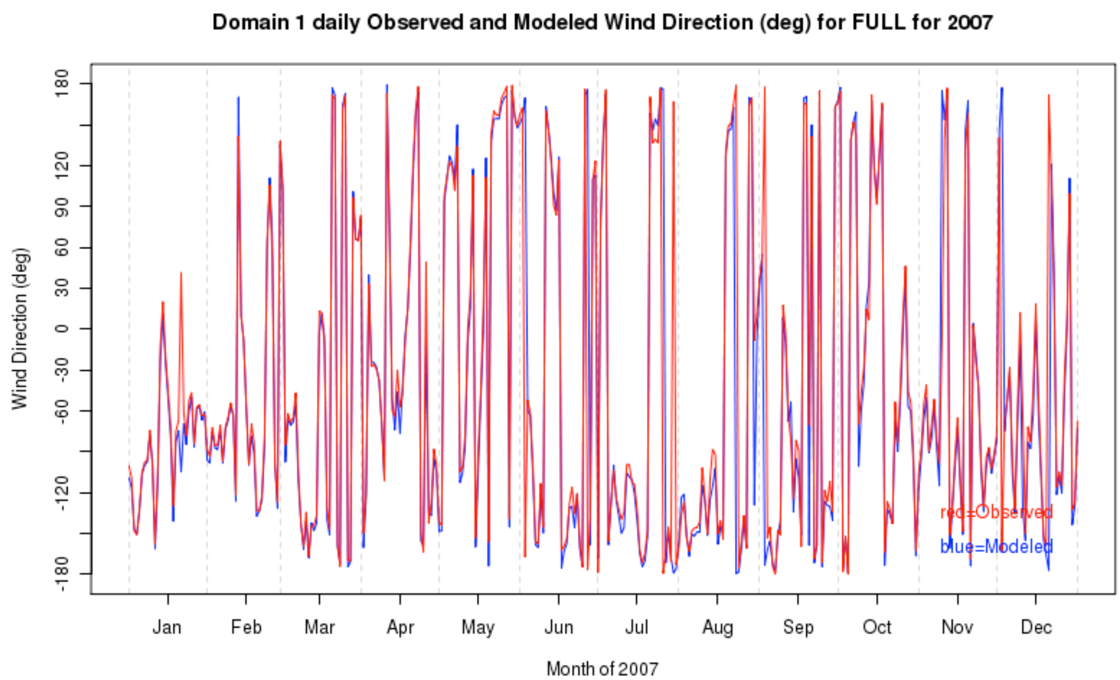
The modeled and observed specific humidity time series is shown in the plot below. The WRF model performs well at predicting the specific humidity especially during the cooler portions of the year, however, there is a slight high bias in the model simulation during the warmer months especially during June and July for domain 1. The performance of the WRF model for domain 2 in the lower plot is significantly better during the warmer months.

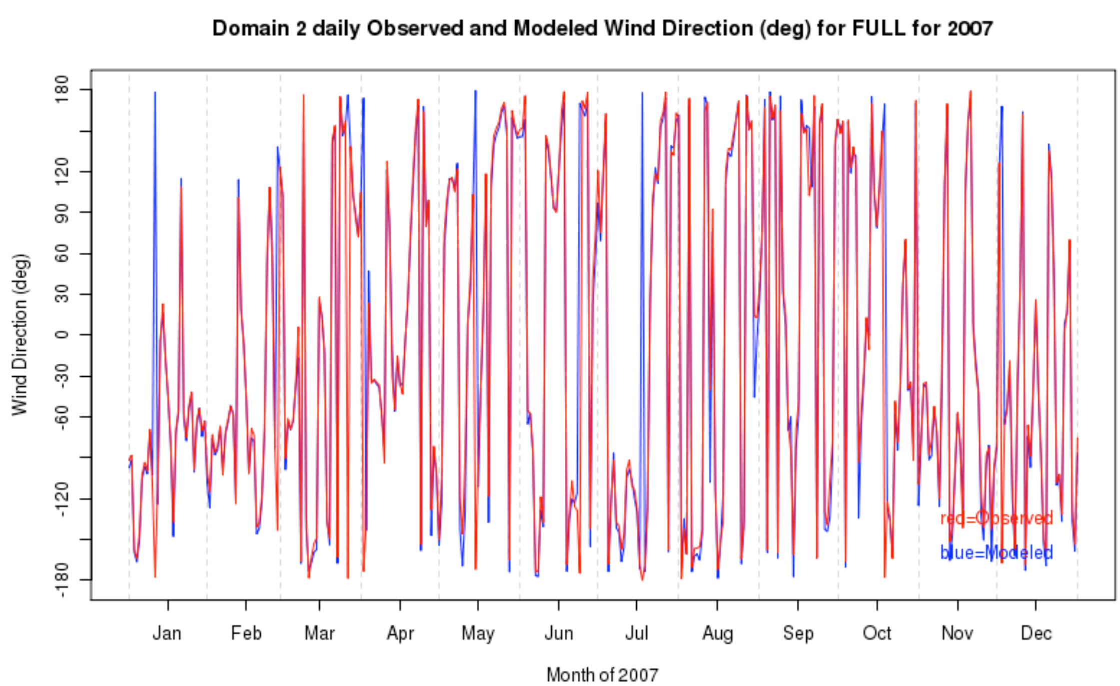




5.1.1.5 Wind direction

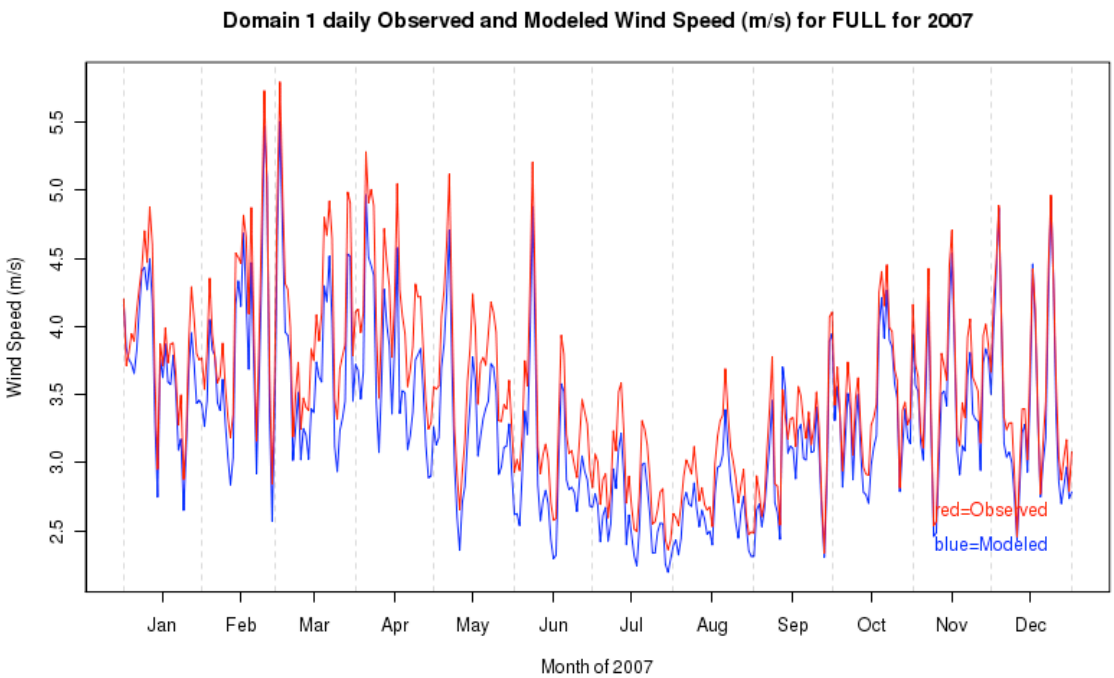
The averaging procedure for wind direction differs from those of the other variables, since a simple arithmetic average of wind direction is not a meaningful quantity; instead, the time series show the wind direction of the averaged (in space and time, if applicable) wind vector. Despite of the somewhat noisy appearance of these plots caused wind direction near south (+/- 180), some general observations are possible. In the plot below it can be seen that the WRF model accurately captures the westerly wind tendency in domain 1 as indicated by the collection of data points between -180° and 0° in the lower portion of the plot which indicates winds with a westerly component. The corresponding plot for domain 2 shows a greater tendency for a southerly component to the wind especially during the warmer months than domain 1.

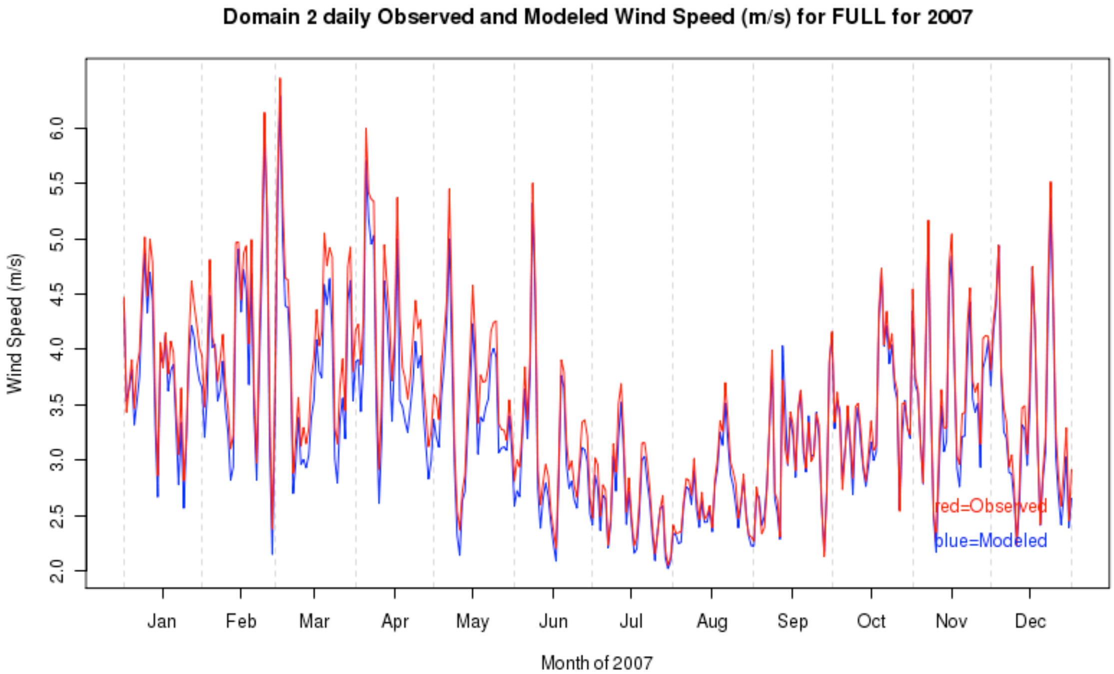




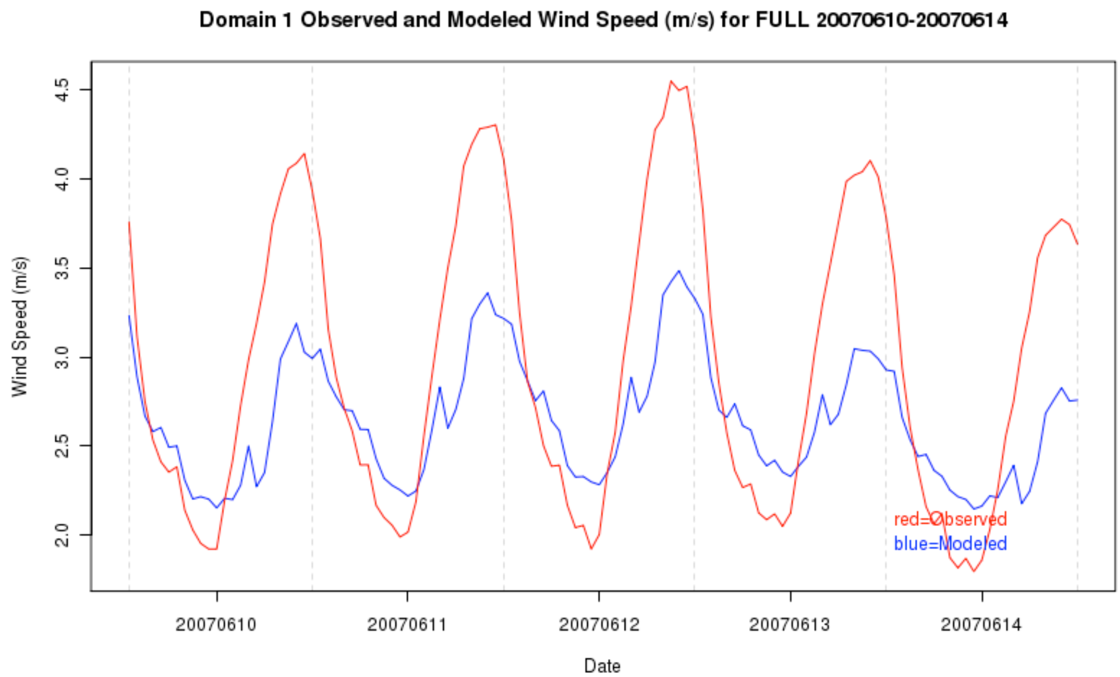
5.1.1.6 Wind speed

The annual plot of wind speed for the observations and WRF model is shown below. There is a consistent negative bias throughout the year in domain 1 and this is similar to the negative bias in wind speed found at many of the individual locations. It appears that the negative bias is most pronounced during the early spring. The lower plot shows the time series for domain 2 and it is apparent that the performance is better with significant improvement during the late winter and spring and excellent simulation of the wind speeds during the warmer months.





A closer examination of a shorter time scale reveals some important diurnal characteristics of the modeled wind speed. First, there is a short period of time when the wind speed decreases in the early afternoon before resuming its increase to an evening maximum. This pattern is observed in a majority of the individual 5-day runs throughout the year and results in the model having a negative bias during the entire year because the negative bias in the afternoon is so significant. Also, in the warmer months there seems to be a high bias during the night as the modeled wind speeds are slightly higher than the observed wind speeds.

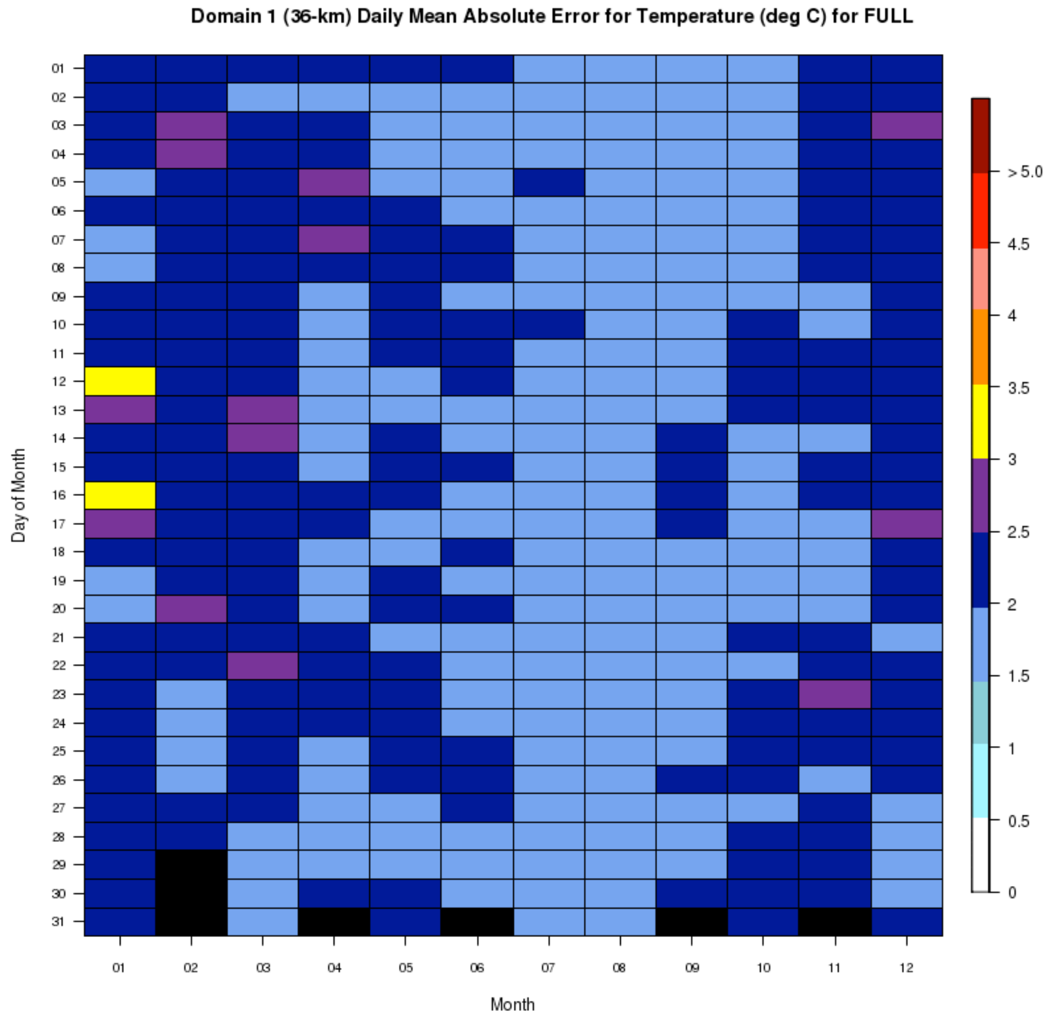


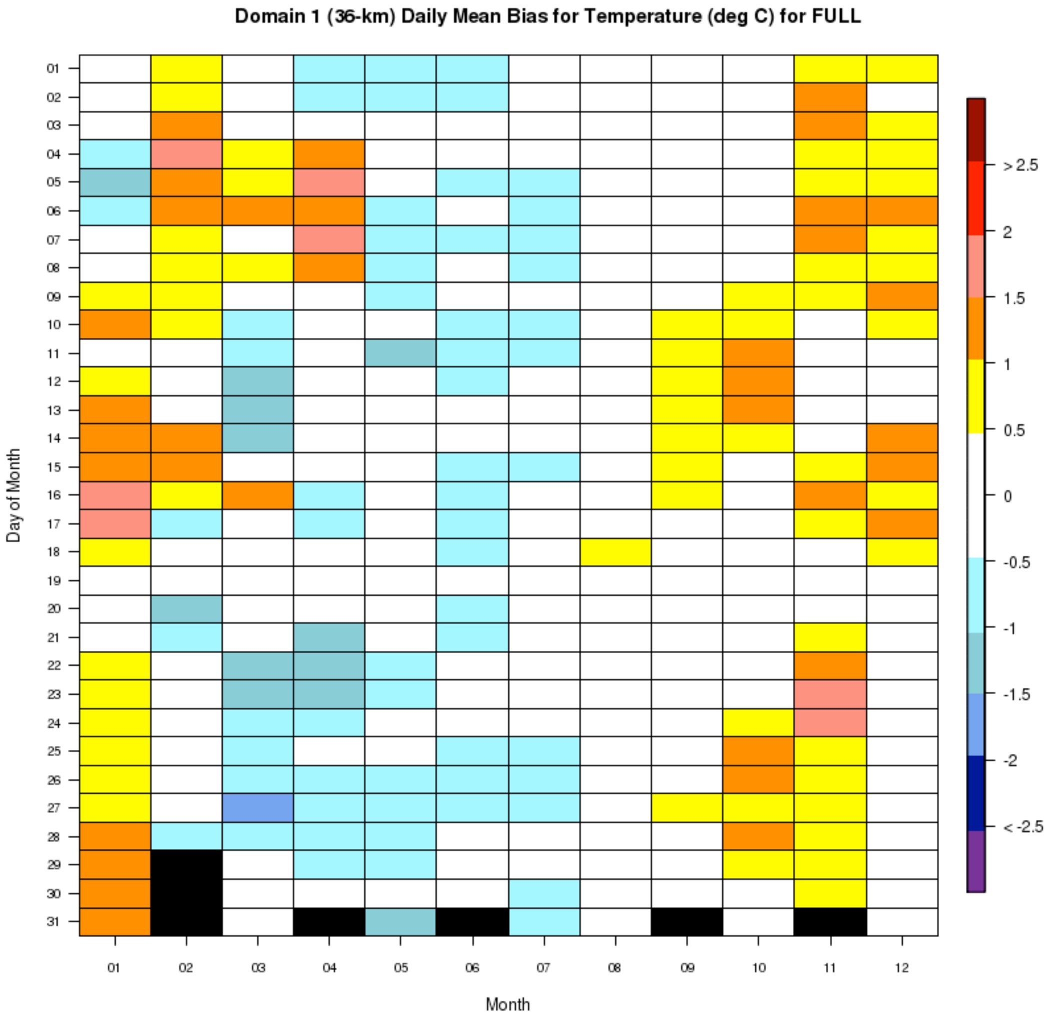
5.1.2 Task 2 B: Monthly Bakergrams

The next section describes the variability of the daily mean absolute error and the daily mean bias for the production run through a series of Bakergrams. The discussion focuses primarily on the "FULL" region (entire model domain) for Domains 1 and 2.

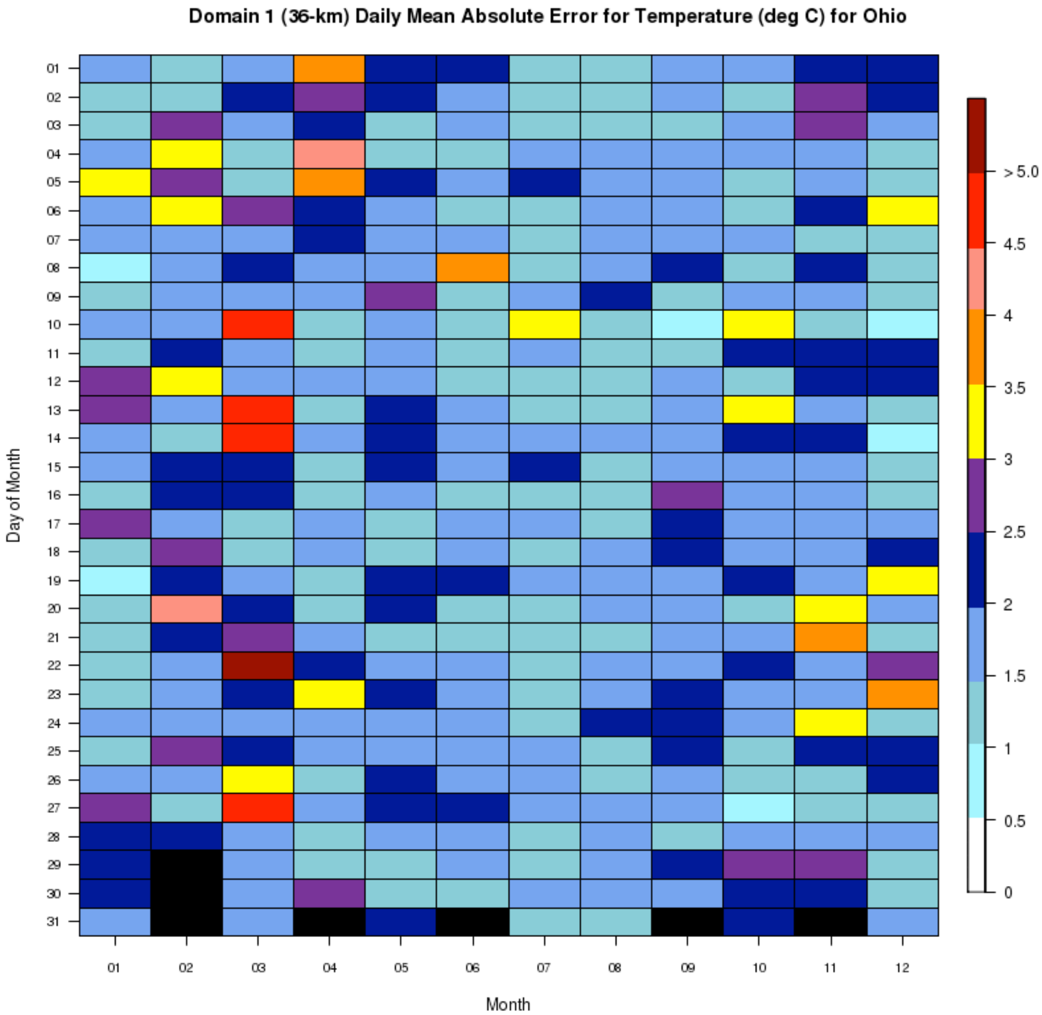
5.1.2.1 Temperature

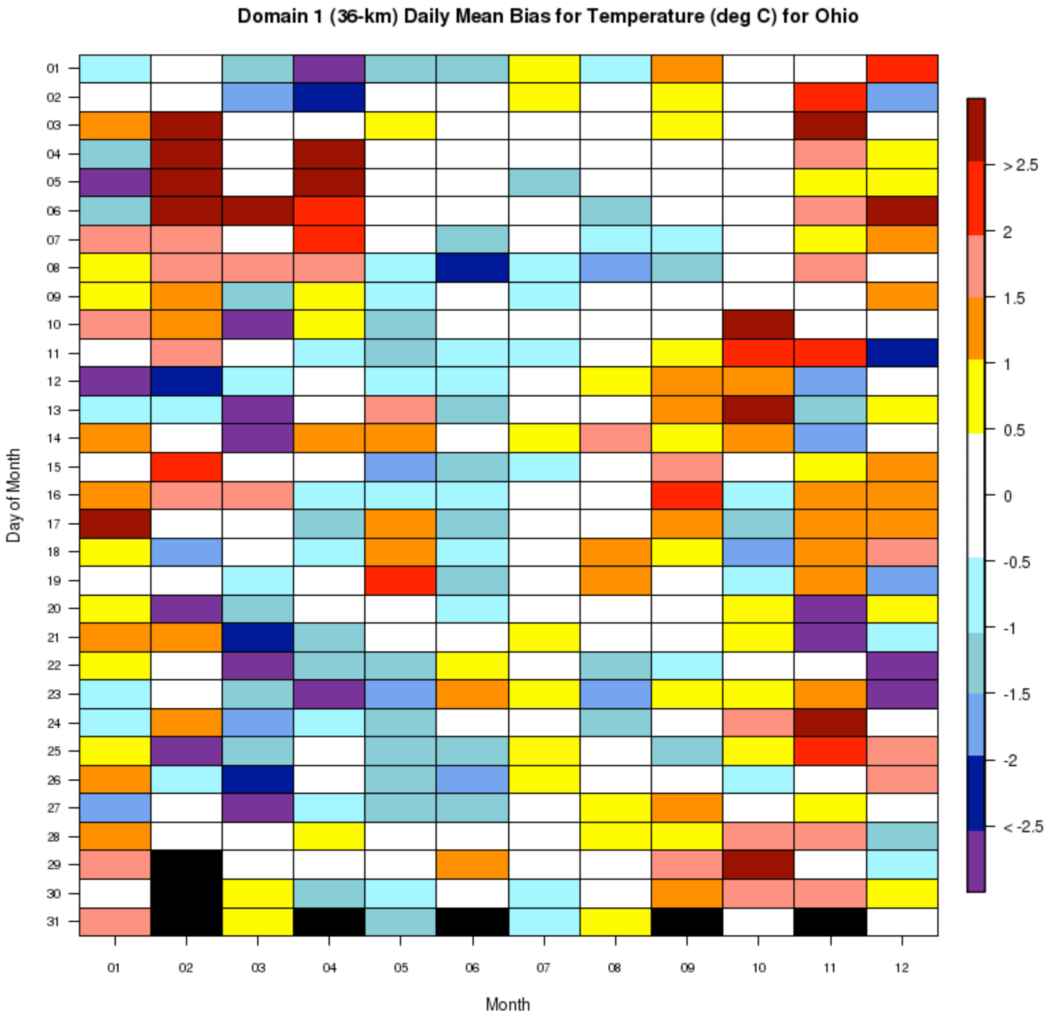
The daily mean absolute errors (MAE) for the production run of the WRF model are greatest during the winter months and are approximately 2-3°C for this period. The errors decrease to roughly 1.5-2°C on average during the summer months. The daily mean bias in temperature shows a similar seasonal pattern to the mean absolute errors. The temperatures have a high bias from the early autumn through about mid-winter. The remaining portion of the year presents a negative bias. The mean absolute error variability is very similar for domain 2 except the mean errors are slightly smaller, perhaps 0.5°C smaller on average; however, the mean bias over domain 2 increases slightly. Additional Bakergrams below of the daily mean absolute errors and mean bias over Ohio are examples of greater variance over the individual states and smaller RPOs in these parameters.


Domain 1 (36-km) Daily Mean Absolute Error for Temperature (deg C) for FULL
Day of Month
Month
01 02 03 04 05 06 07 08 09 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
> 5.0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0



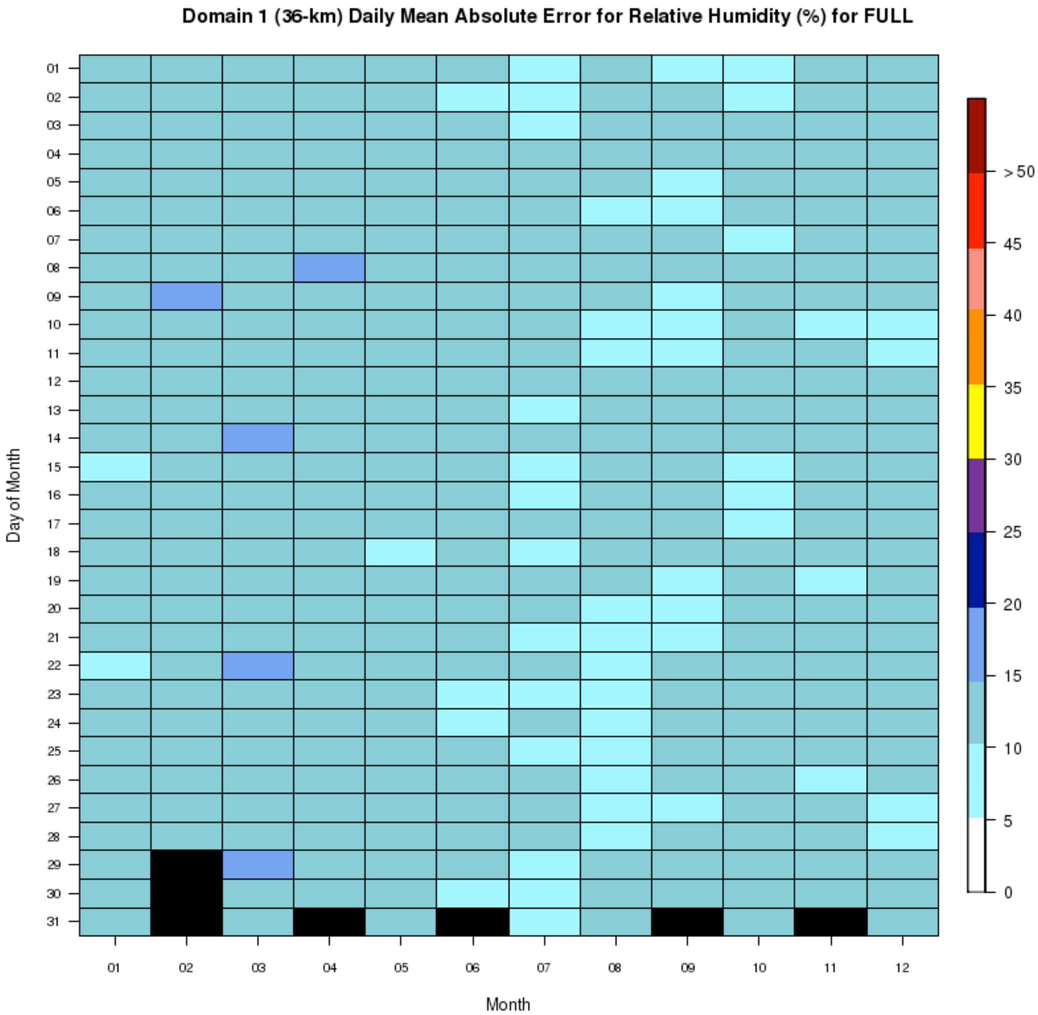
Domain 1 (36-km) Daily Mean Bias for Temperature (deg C) for FULL
Day of Month
Month
01
02
03
04
05
06
07
08
09
10
11
12
> 2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
< -2.5

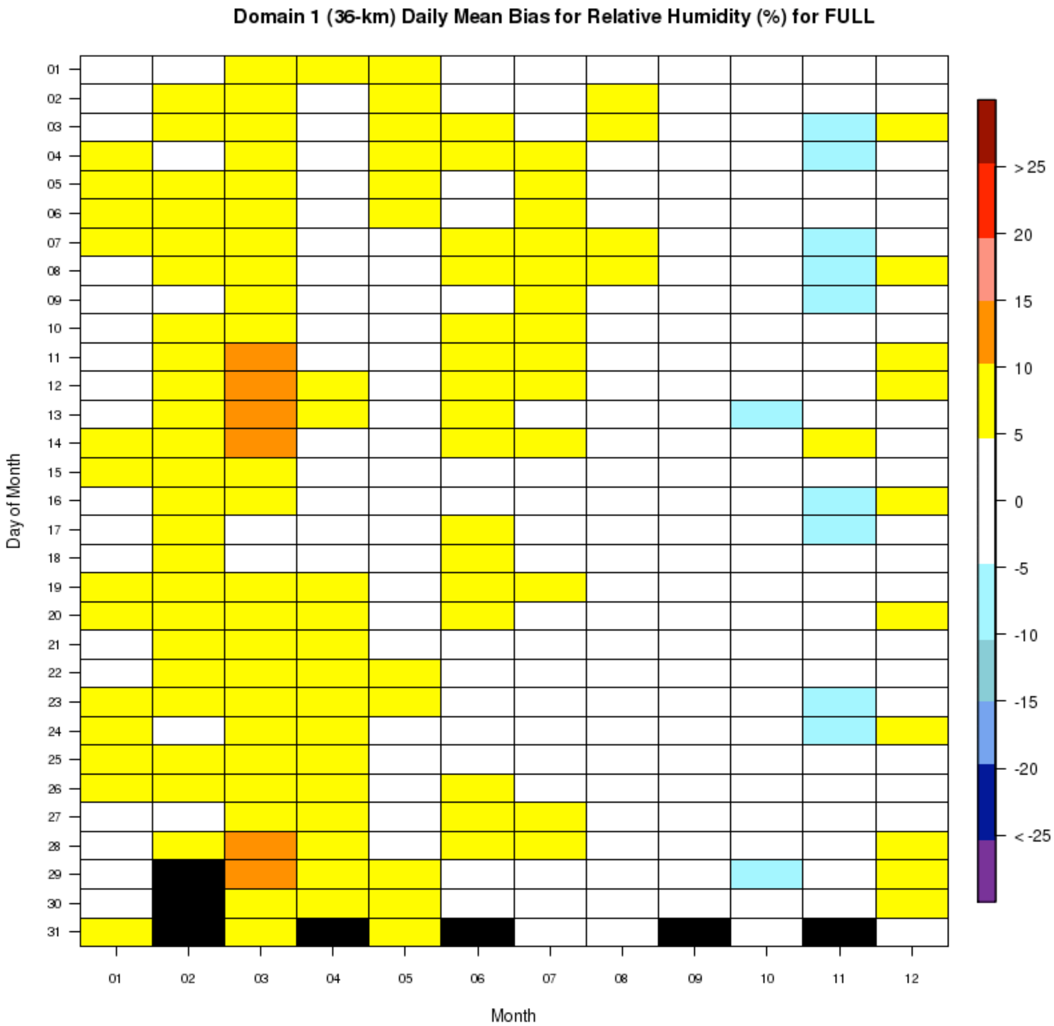

Domain 1 (36-km) Daily Mean Absolute Error for Temperature (deg C) for Ohio
Day of Month
Month
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
> 5.0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

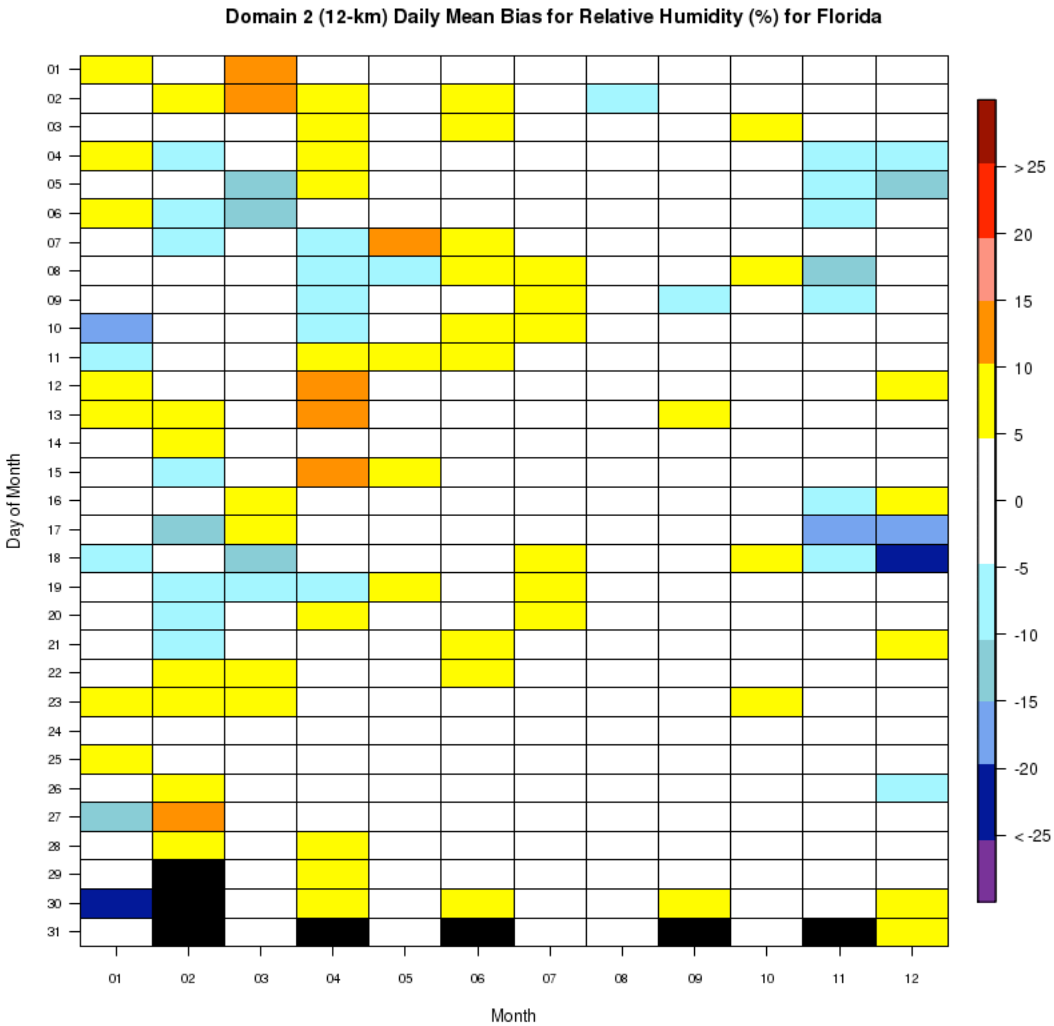


5.1.2.2 Relative humidity

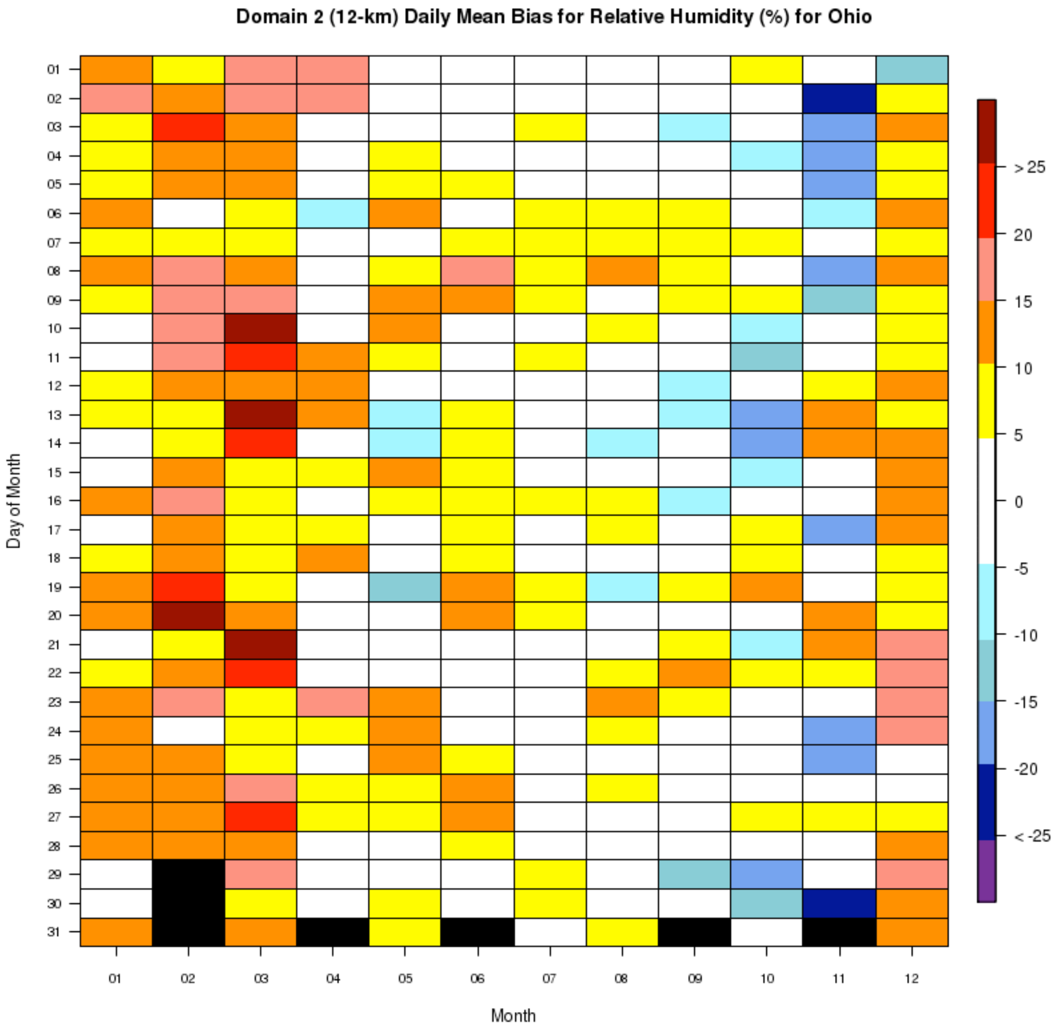
The relative humidity plots below show that the daily mean absolute errors are largest during the late winter and early spring with errors up to 15-20%. The errors are smallest during the summer and early autumn time frame generally around 10%. The relative humidity parameter in the WRF model has a high bias over most of the year in the daily mean except during the autumn when it has a slight negative bias. The daily mean absolute errors and mean biases are slightly increased for domain 2, although they retain a similar seasonal pattern. Comparing the daily mean bias Bakergrams from Florida and Ohio shows that there is a much more significant high bias over Ohio during the winter consistent with the overall pattern from the full domain. In contrast, no obvious bias exists over Florida at any time during the year.


Domain 1 (36-km) Daily Mean Absolute Error for Relative Humidity (%) for FULL
Day of Month
Month
01
02
03
04
05
06
07
08
09
10
11
12
0
5
10
15
20
25
30
35
40
45
> 50


Domain 1 (36-km) Daily Mean Bias for Relative Humidity (%) for FULL
Day of Month
Month
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
> 25
20
15
10
5
0
-5
-10
-15
-20
< -25

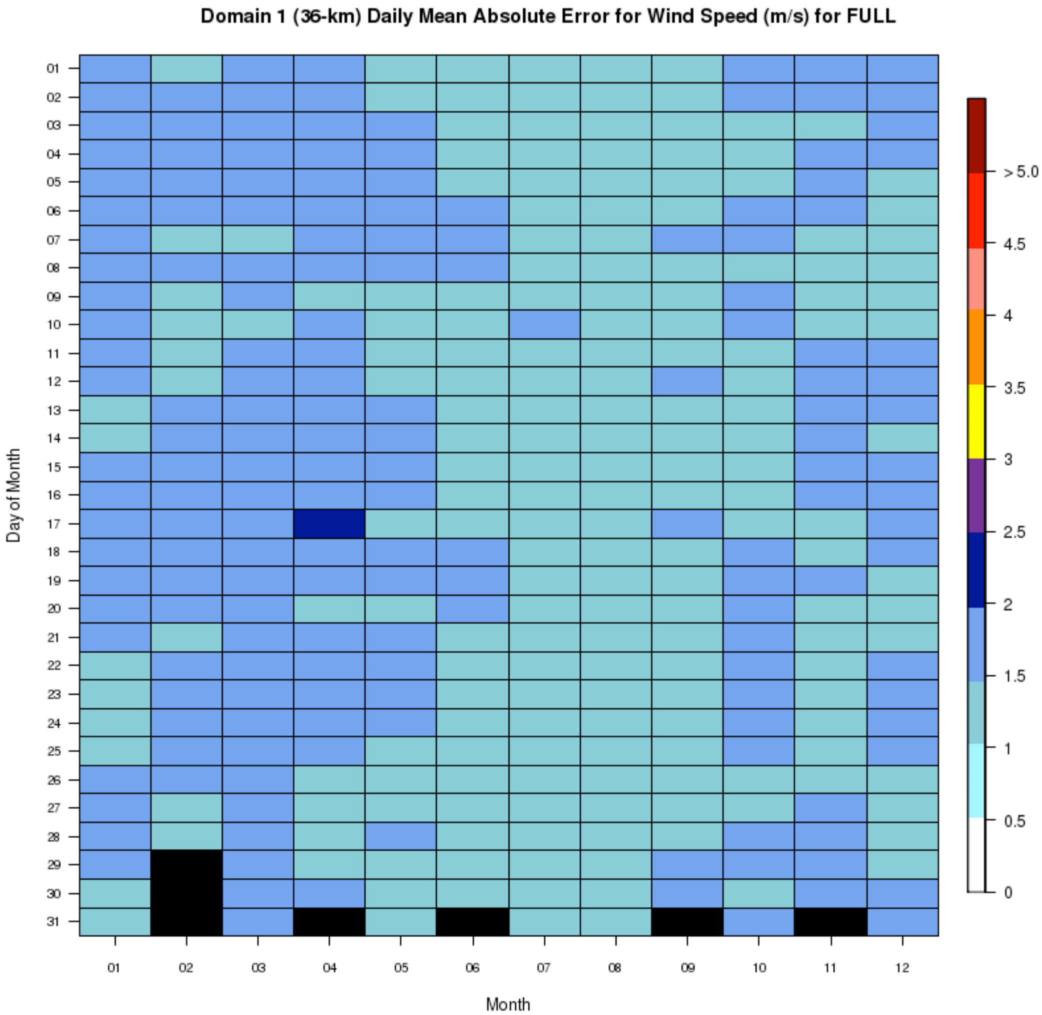


Domain 2 (12-km) Daily Mean Bias for Relative Humidity (%) for Florida
Day of Month
Month
01
02
03
04
05
06
07
08
09
10
11
12
> 25
20
15
10
5
0
-5
-10
-15
-20
< -25

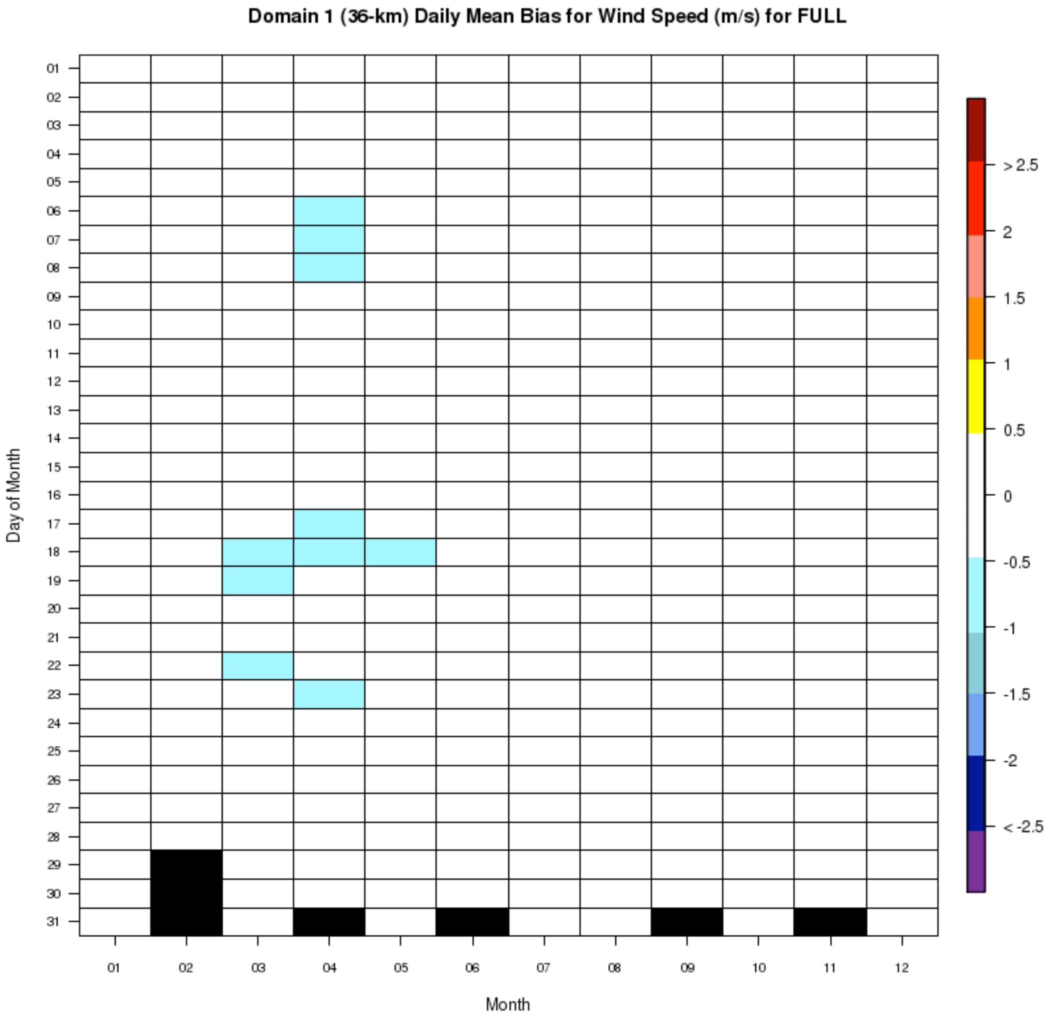


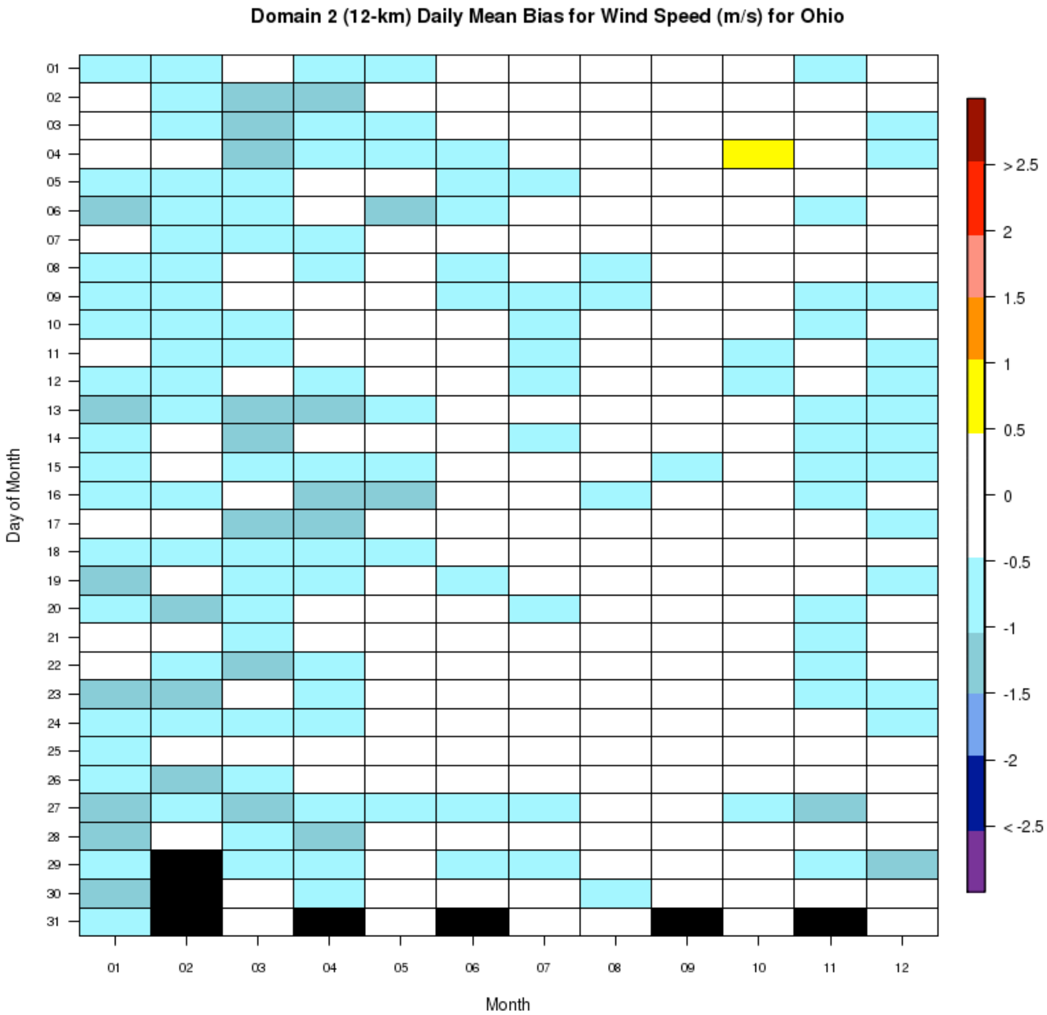
5.1.2.3 Wind Speed

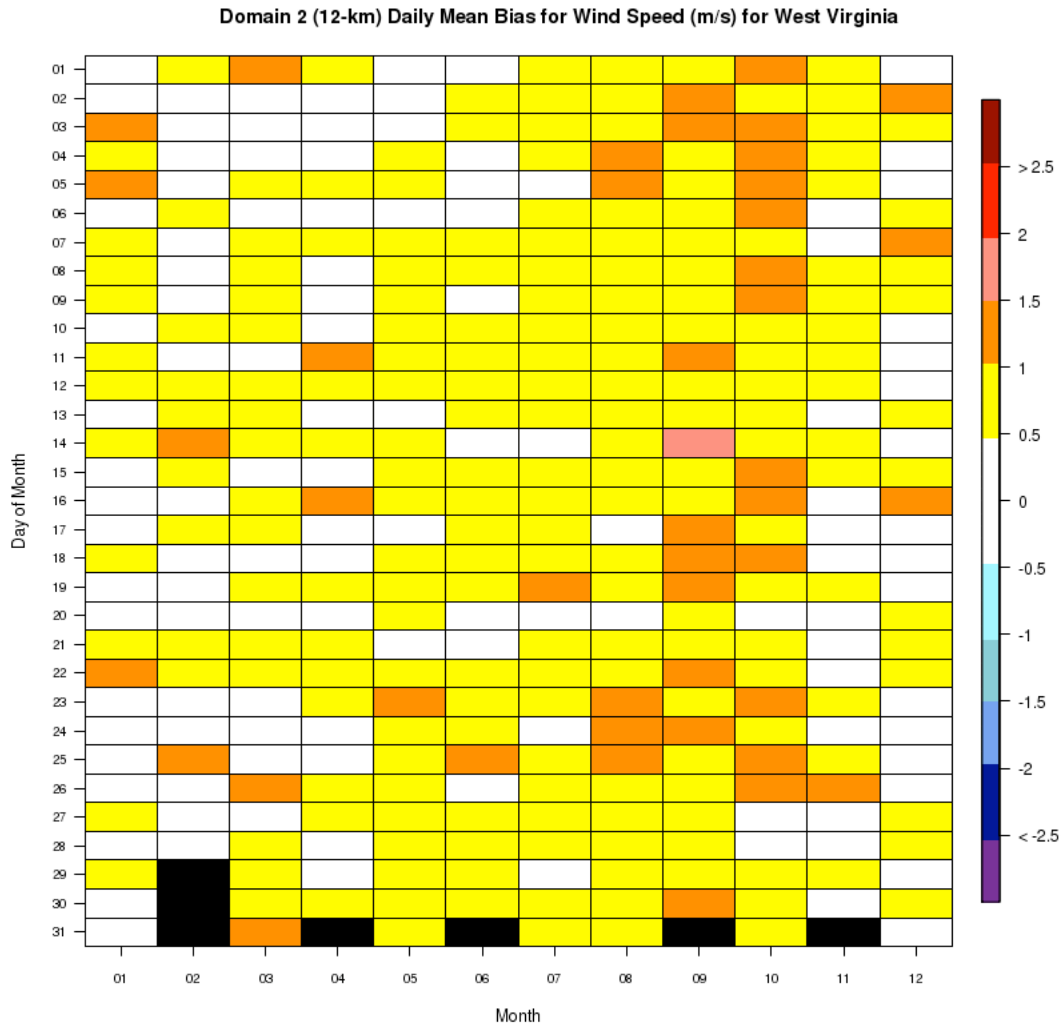
The daily mean absolute error for wind speed in the WRF model is generally higher in the winter and spring than during the warmer months and this is most likely a result of higher average wind speeds that occur at these times of the year. The mean absolute errors are generally under about 2 m/s. The mean bias is quite small (under 0.5 m/s), with the only significant bias to appear on the plot being a negative bias during the spring months. These statistics for domain 2 are very similar to domain 1. Two additional plots below comparing wind speed bias over Ohio and West Virginia highlight the effect of elevated terrain on the WRF model results. There is a consistent positive bias throughout the year over West Virginia (especially during the late summer and early autumn), while over Ohio the wind speed bias is generally negative.



Domain 1 (36-km) Daily Mean Absolute Error for Wind Speed (m/s) for FULL
Day of Month
Month
01 02 03 04 05 06 07 08 09 10 11 12
> 5.0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Domain 1 (36-km) Daily Mean Bias for Wind Speed (m/s) for FULL
Day of Month
Month
> 2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
< -2.5


Domain 2 (12-km) Daily Mean Bias for Wind Speed (m/s) for Ohio
Day of Month
Month
01
02
03
04
05
06
07
08
09
10
11
12
> 2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
< -2.5



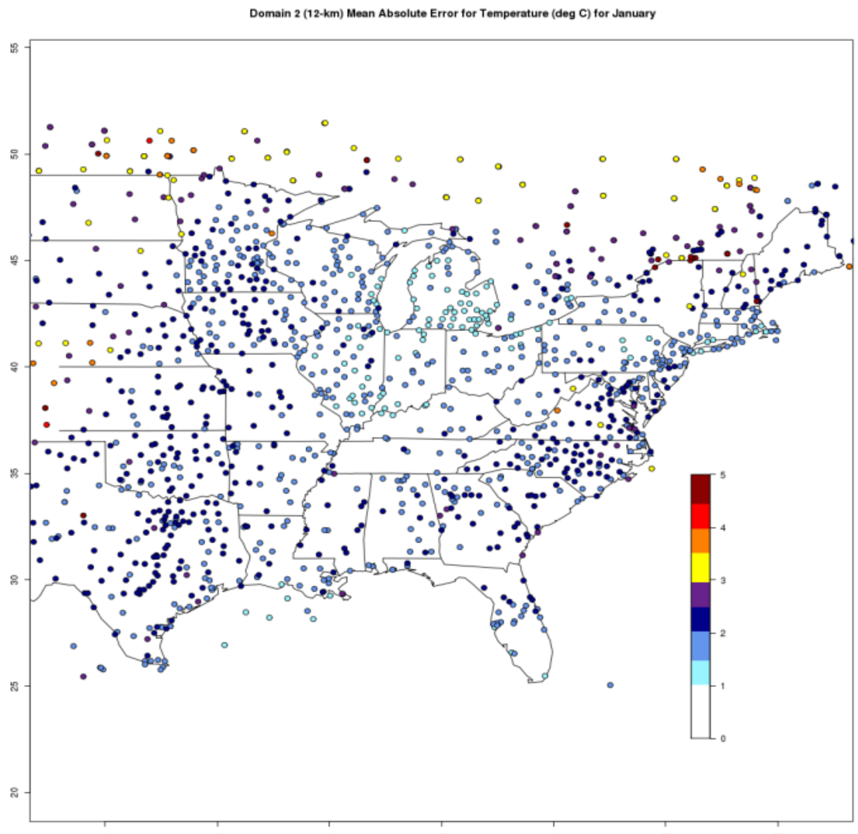
5.1.3 Task 2 C: Bubble spatial plots of error statistics

These plots show maps covering the entire modeling region (domain 1 and 2), with color-coded symbols at surface observation sites. The color-coding corresponds to the value time-averaged error statistics (e.g., mean bias, MAE) at each observations site. These plots help to identify spatial patterns of different error characteristics.

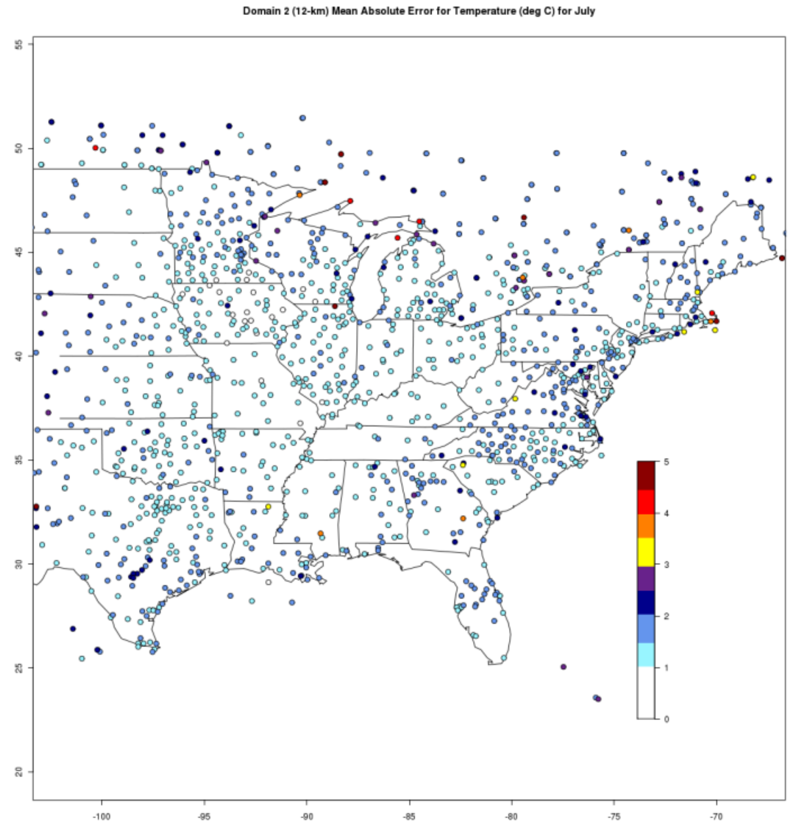
5.1.3.1 Temperature

The 2-meter / surface temperatures simulated by the WRF-MET model were generally accurate to within 3.0 °C of the observations for all U.S. stations within the model's inner domain (12 km). The agreement between the simulated and observed temperatures was somewhat poorer in the cooler seasons than during the summer as the mean absolute error (MAE) for many locations was between 2 – 3 °C in winter, spring, and fall (see Figure below) but decreased to generally < 1.5 °C in all regions during the summer (see Figure below). The MAEs in Southern Canada were notably higher during winter peaking at > 3.0 °C, but of the same magnitude as those in the U.S. during the other seasons. Much of the temperature error during the winter and fall could be explained by warm biases of 1- 2 °C in the U.S., particularly in the Great Plains and Midwest, and 1– 3 °C in Southern Canada. During the spring, biases of -1 to -2 °C were produced for many locations in the Midwest and Northeast. As will be discussed in Section 5.1.4.1, some sites in the South and Southeast, particularly Tennessee and Alabama, showed a tendency towards a negative bias in temperature. The spatial plots, however, did not show evidence of substantial widespread cool biases (< -1.0 °C) across that part of the U.S. during the warm months (see Figure for July mean bias below).

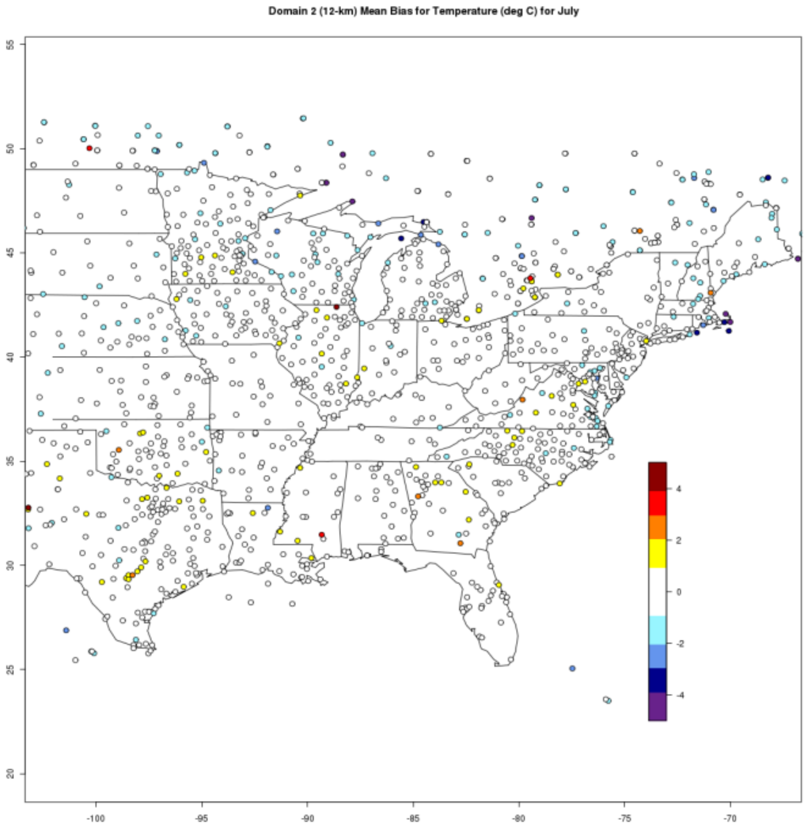
January Temperature MAE for Domain 2:



July Temperature MAE for Domain 2:



July Temperature Mean Bias for Domain 2:

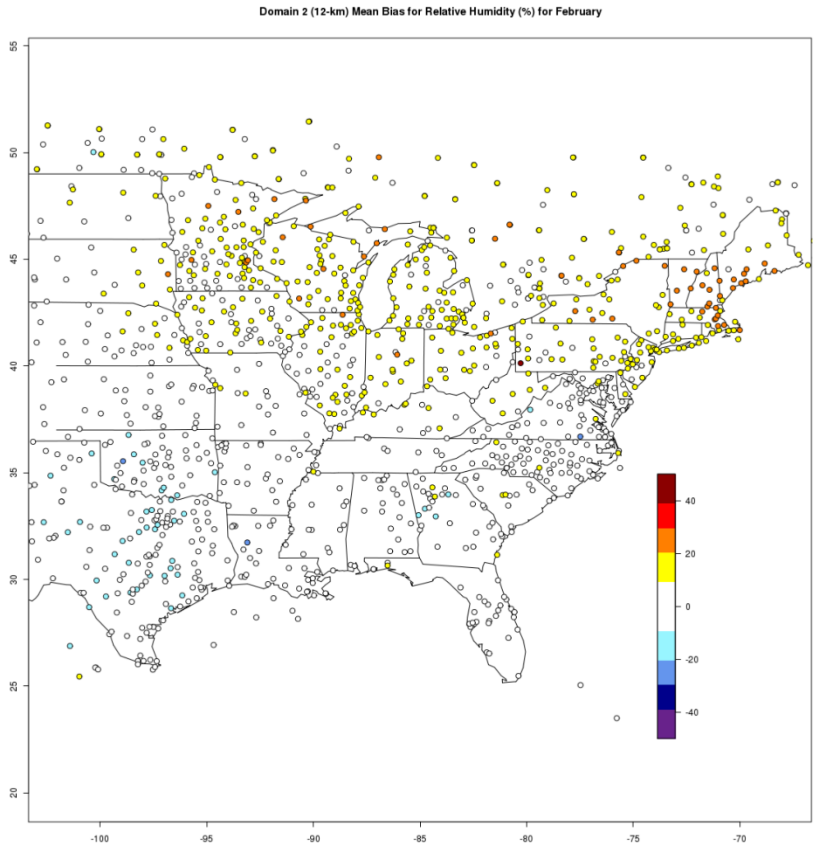


The error characteristics in the portion of the outer domain (36km) that overlapped domain 2 were similar to those in domain 2 but of a slightly greater magnitude (~ 0.5 °C) presumably due to the coarser grid spacing. Domain 1 covered the entire contiguous U.S. and MAEs were generally > 3.0 °C over the Rocky Mountains but < 2.5 °C along the immediate West Coast.

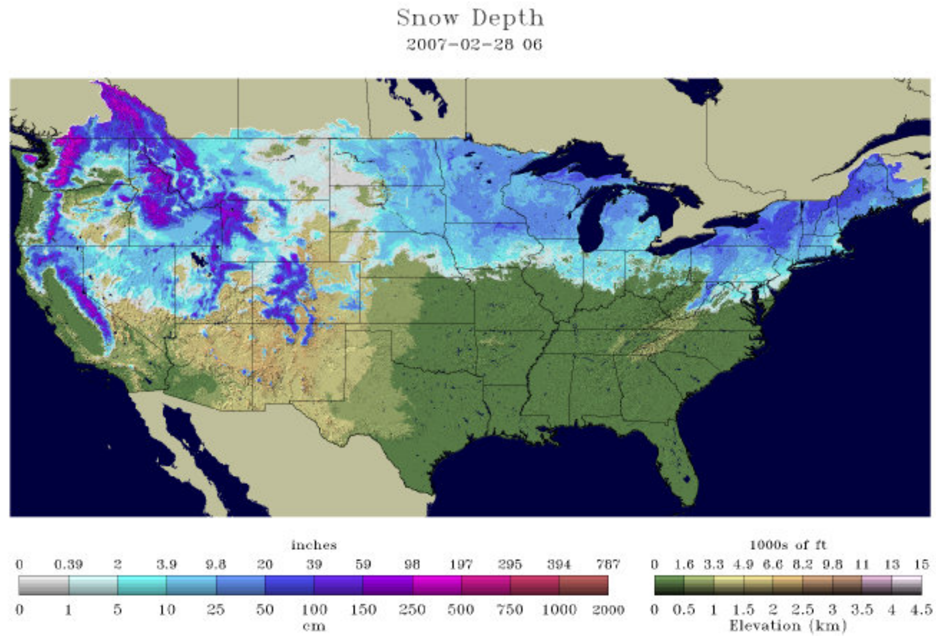
5.1.3.2 Relative humidity and dew point temperature

The WRF-MET 2-meter / surface relative humidity (RH) errors exhibited well-defined seasonal and spatial variability peaking in the northern half of domain 2 during late winter and early spring of 2007. The larger late winter/early spring errors were primarily due to positive biases ranging from 20 - 40 % (see Figure below) and corresponding positive biases in dew point of 2 C to > 4 C indicated that the RH biases were due to an overprediction of absolute moisture content rather than an under prediction in temperature. In addition the locations of the high positive RH biases were mostly over snow-covered areas suggesting that the model may not accurately simulate the moisture flux from snow (see Figure below).

February Relative Humidity Mean Bias for Domain 2:



National Snow Analysis for February 28, 2007 - While the area of snow cover varied in time this plot was representative of the areas of most persistent snow cover during February and early March of 2007**.** (Available from National Weather Service National Operational Hydrologic Remote Sensing Center, http://www.nohrsc.noaa.gov/nsa/.)



The unusually mild early winter of 2006 -2007 (see statewide temperature rankings at http://www.ncdc.noaa.gov) in the Midwest and Northeast caused a delay in the usual spread of snow cover in the region. As temperatures cooled to slightly below normal in February the area of snow cover began to increase substantially. It is interesting to note that the increase in the WRF-MET positive RH biases seemed to follow the increase in snow cover in the region, which provides further evidence that the model may have a tendency to overpredict the surface moisture flux over snow-covered land.

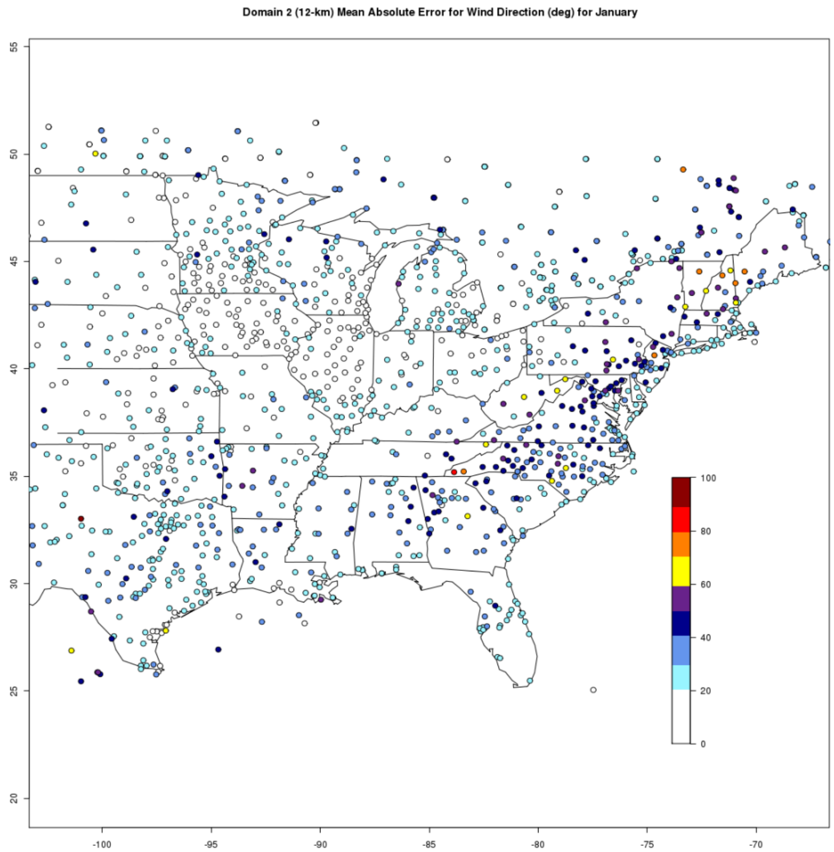
5.1.3.3 Wind speed

The MAEs for the WRF-MET 10- meter / surface wind speed were generally < 1.5 m/s throughout domain 2 with a few exceptions. Along the coast of the northeastern U.S. and in southern Canada during the cooler months of January – April and November – December the MAEs generally ranged from 1.5 – 2.5 m/s with a few locations > 3.0 m/s. The errors seemed random with no consistent biases and were not dependent on the time of day. For domain 1 the wind speed MAEs were similar to those of domain 2 in the eastern U.S, but were generally > 2.5 m/s over the Rocky Mountains.

5.1.3.4 Wind direction

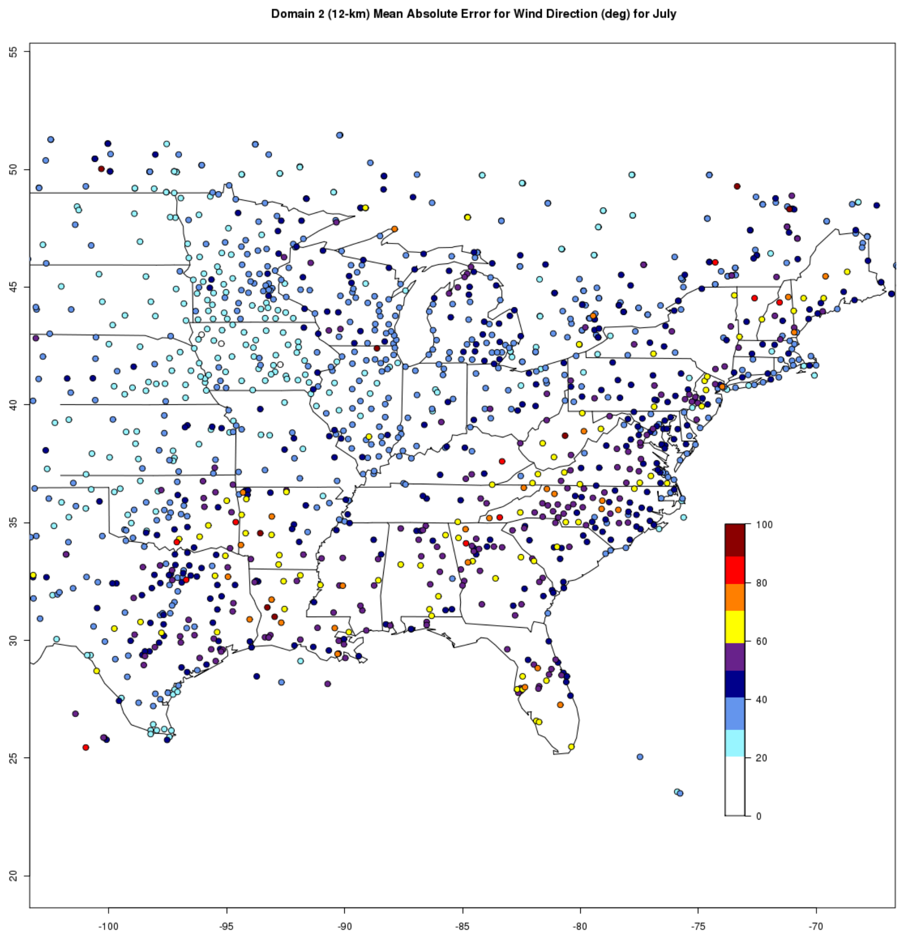
During the winter months substantial directional errors in the WRF-MET 10-meter/surface winds were limited to the lee side of the Appalachian Mountains. In this region the directional errors generally ranged from 40 – 60° (see Figure below). With the juxtaposition of cold continental polar air and the warmer maritime air of the Gulf Stream, this region is an area of frequent cyclone development, and because of these dynamics and the complexity involved in simulating them larger wind errors are not surprising.

January Wind Direction Mean Absolute Error for Domain 2:



During the warmer months the large errors in the lee of the Appalachians persisted, and another area spanning the Gulf Coast states developed with errors exceeding 60° at many locations (see Figure below). It is possible that the large directional errors in the Gulf Coast states were due in part to frequent convective activity that was unresolved at the model grid scale. As with other variables, in domain 1 the Rocky Mountains caused substantial wind directional errors that in most locations exceeded 70 °.

July Wind Direction Mean Absolute Error for Domain 2:



5.1.4 Task 2 E: Time series at individual sites of forecast/observed values

This task focuses on model evaluation at a limited number of individual METAR sites. The sites are identified in the following table.

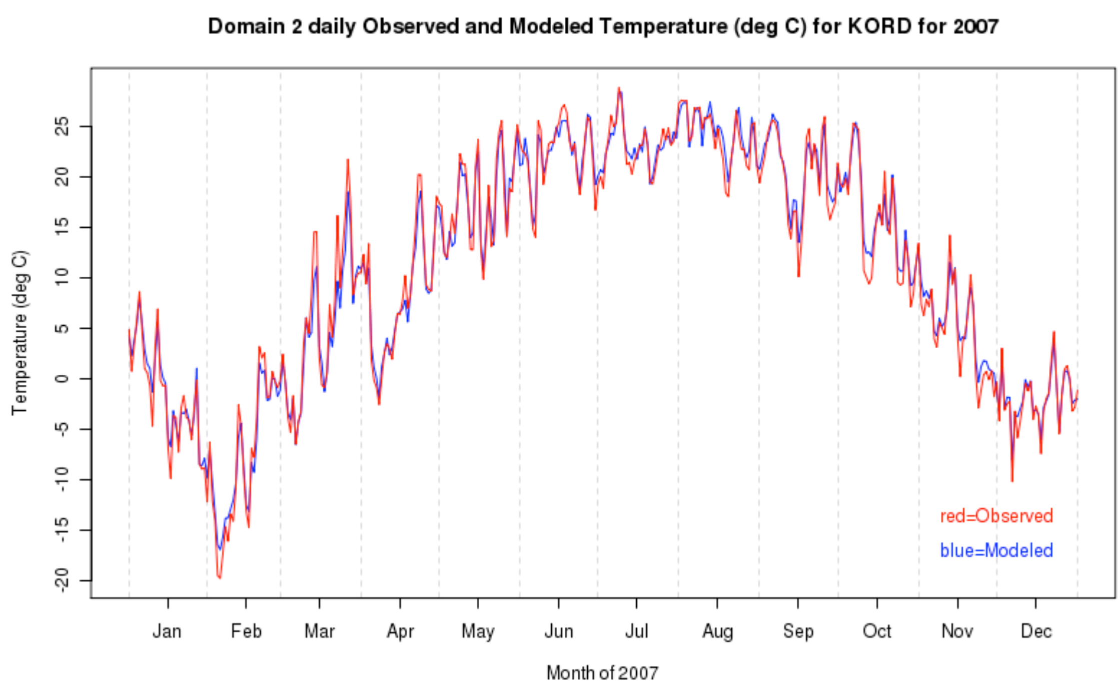
State	City	Observation Station	State	City	Observation Station
AL	BIRMINGHAM	KBHM	MO	ST. LOUIS	KSTL
AL	MOBILE/BATES	KMOB	MN	MINNEAPOLIS	KMSP
AR	LITTLE ROCK	KLIT	MS	JACKSON	KJAN
DC	WASHINGTON/NATL	KDCA	NC	CHARLOTTE	KCLT
FL	ORLANDO	KMCO	NE	NORTH PLATTE	KLBF
FL	TALLAHASSEE	KTLH	OH	CLEVELAND	KCLE
FL	MIAMI	KMIA	OK	OKLAHOMA CITY	KOKC
GA	ATLANTA	KATL	SC	COLUMBIA	KCAE
IA	DES MOINES	KDSM	SC	GREEN/SPARTANSBG	KGSP
IL	CHICAGO O'HARE	KORD	TN	CHATTANOOGA	KCHA
IL	PEORIA	KPIA	TN	KNOXVILLE	KTYS

State	City	Observation Station	State	City	Observation Station
IN	FORT WAYNE	KFWA	TN	MEMPHIS	KMEM
KS	DODGE CITY	KDDC	TN	NASHVILLE	KBNA
KY	COVINGTON	KCVG	TX	DALLAS/FT WORTH	KDFW
KY	LOUISVILLE	KSDF	VA	RICHMOND	KRIC
LA	SHREVEPORT	KSHV	WI	ASHWAUBENON	KGRB
MI	DETROIT/WAYNE	KDTW	WI	WAUSAU	KAUW
MI	HOUGHTON LAKE	KHTL	WV	CHARLESTON	KCRW
MO	KANSAS CITY/INTL	KMCI	WV	HUNTINGTON	KHTS

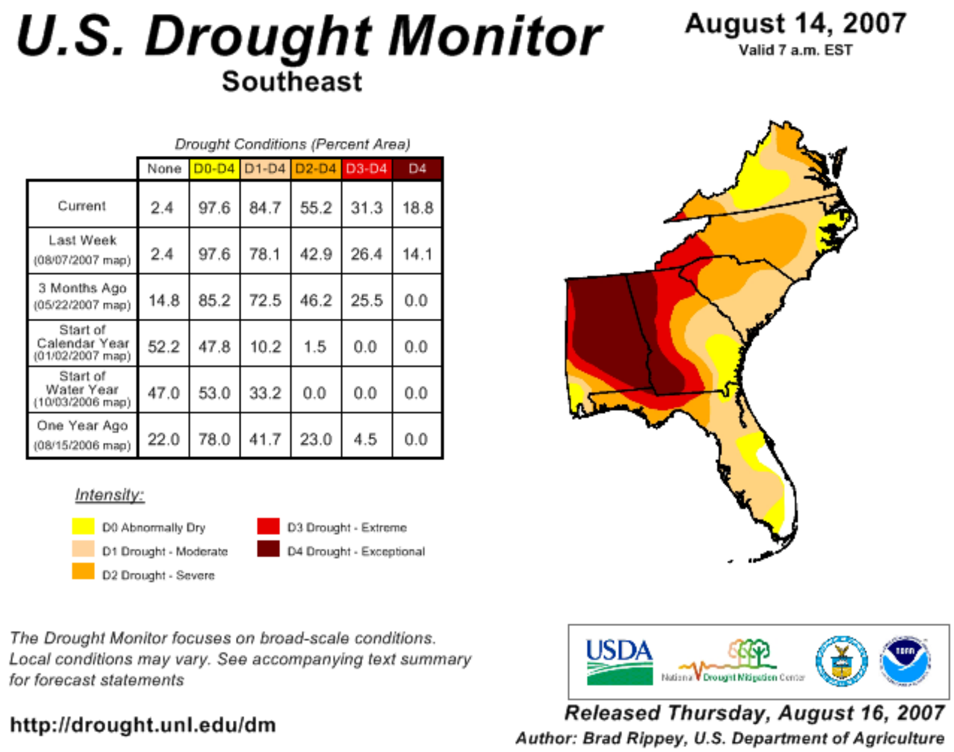
5.1.4.1 Temperature

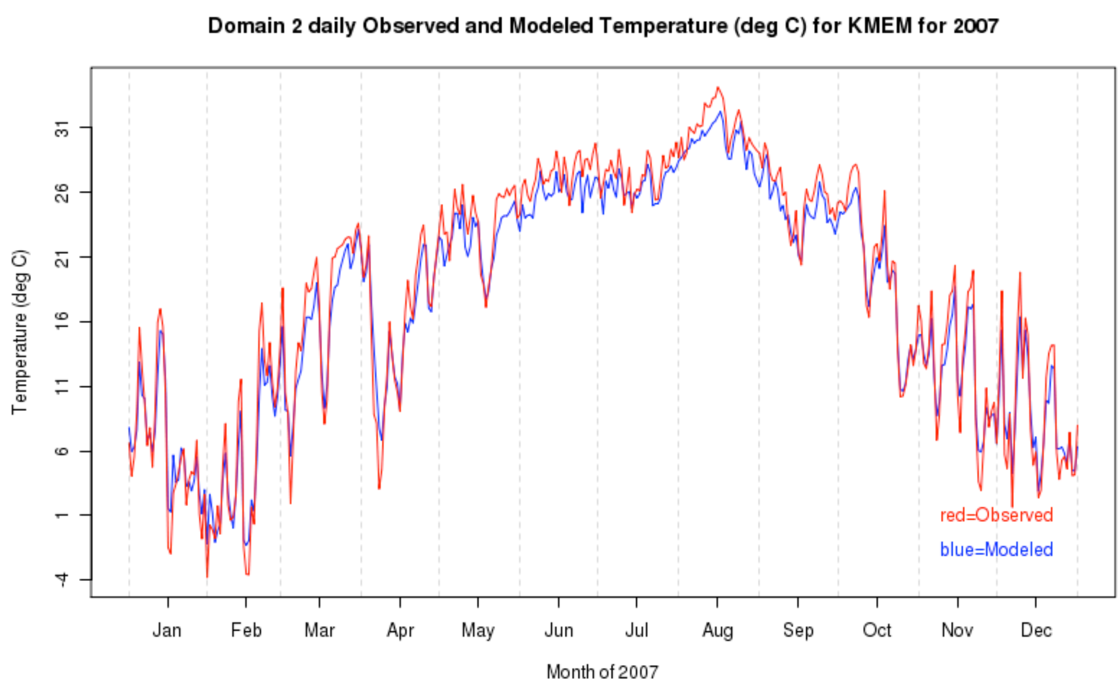
The temperatures produced by the WRF simulations were comparable to the temperature observations at most of the individual METAR locations. The model temperatures track the observations relatively well; however, the variability of the model temperatures is generally lower than the observed values meaning the model simulations have difficulty replicating temperature extremes both high and low.

The WRF model performed the best at simulating temperatures at locations in the Great Lakes, Midwest, and central Plains regions. At the sites in these regions, significant temperature biases were absent as the mean and variability are well represented. For example, at KORD (Chicago, IL) the annual observed temperatures are well predicted by the model and there is no apparent bias at any period of time during the year.

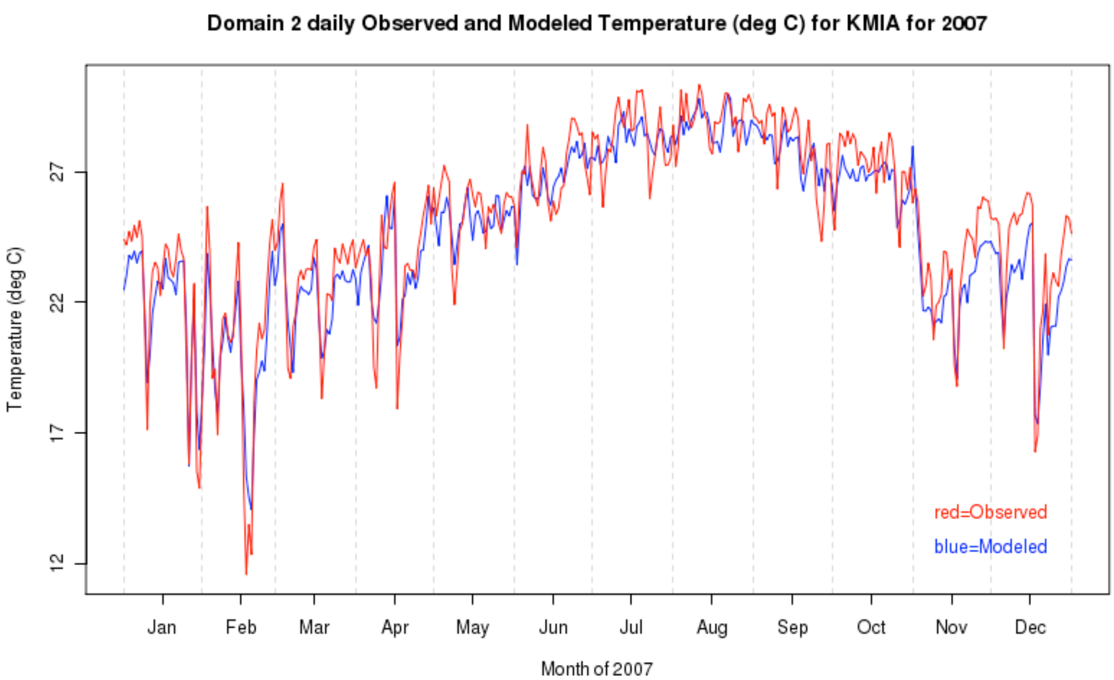


At sites across the South and Southeast, especially during the warmer months, a negative temperature bias appears to be present in the WRF model. This negative temperature bias is most apparent in the KBHM, KCHA, and KMEM annual observed and modeled temperature plots. The KMEM (Memphis, TN) plot appears below. Notice the consistent negative bias from late May through the middle of August in the modeled temperature relative to the observed temperature. The results discussed in Section 5.1.3.1, however, indicate that errors of this magnitude are not typical of most stations in that region. During 2007, a major hydrological drought affected a large portion of the southeastern United States. The drought monitor map (at right, valid 14 August 2007) indicates the expanding moderate through exceptional drought during the summer of 2007. Failure of the WRF model to accurately initialize the surface and boundary layer conditions (e.g., dry soil) could have lead to or contributed further to this error.



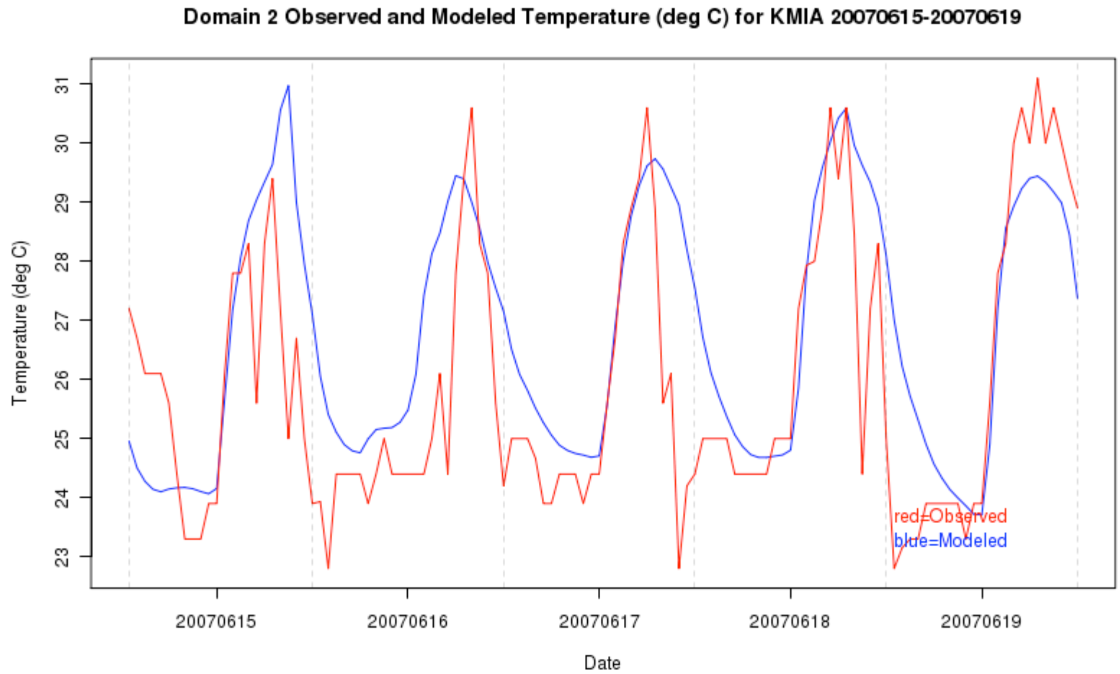


As previously mentioned, the WRF-modeled temperatures tend to exhibit less variability than the observed temperatures. The most obvious example of this is shown in the annual observed and modeled temperature plot for KMIA (Miami, FL) in the plot below. The plot shows that the model has a poor representation of the periodic highs and lows. This poor performance appears to be greatest during the summer and this is likely due to the inability of the model to accurately model the boundary layer moisture characteristics. As will be discussed in a subsequent section, the WRF model grossly over predicts the dew point temperature at KMIA during June through October and this would contribute to a lower modeled diurnal range.



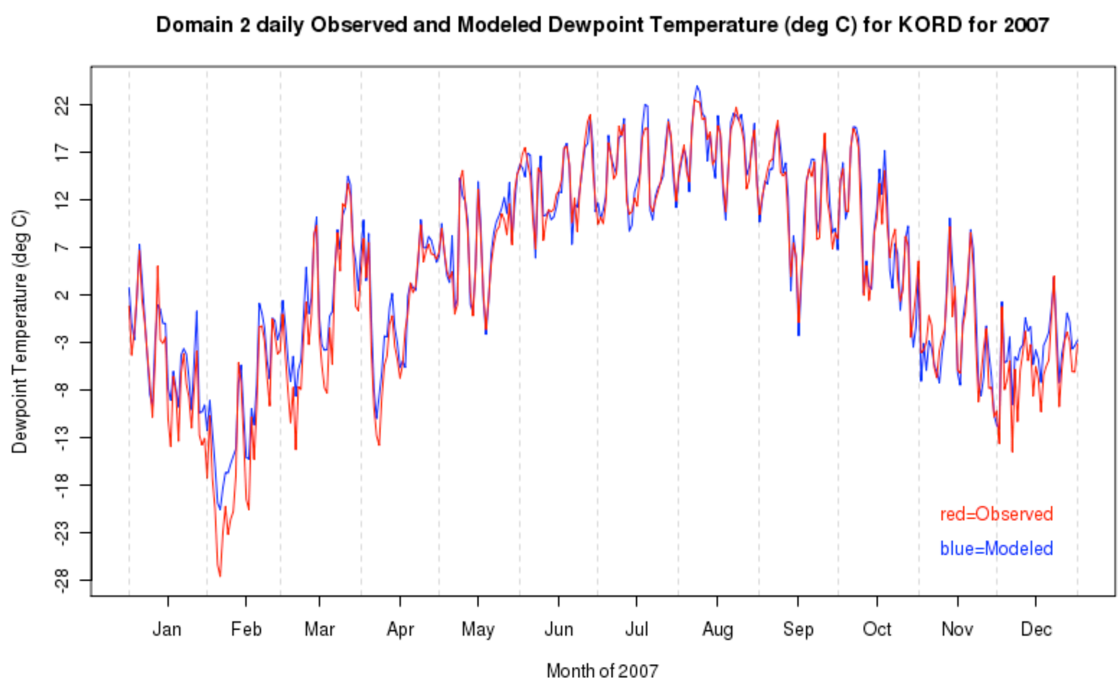
The 5-day model run from June 15-19, 2007 at KMIA shown below exemplifies the problem of modeling the diurnal cycle and summertime air mass convection. With the exception of the first daytime period, the high temperatures are close to the modeled values or under predicted and the low temperatures are over predicted for all days.

The observed diurnal temperature trace is sharply interrupted by the cooling effects of rainfall that are absent in the modeled fields. The related effect on the dew point temperature and relative humidity fields is also not captured by the model (not shown). Convective rainfall occurred on all days during this period except for the 19th. The correct placement and timing of convection is a particularly difficult task for meteorological models and this example does not necessarily suggest a chronic problem in the WRF model. A detailed analysis of precipitation was out of the scope of this project.



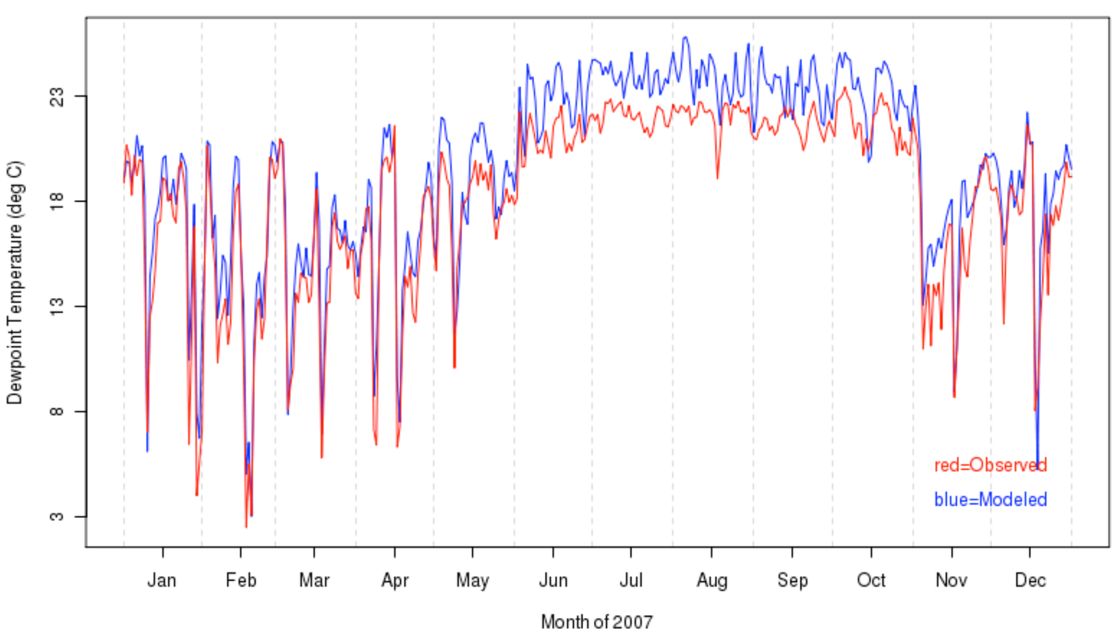
5.1.4.2 Dew point temperature

The WRF model results for the dew point variable generally indicate that it has a slight positive bias across a majority of the individual METAR sites, especially during the warm season. As with temperatures, the best representations of dew point in the WRF simulations were found outside of the southeastern United States. The plot below of the annual modeled and observed dew point at KORD (Chicago, IL) is an example of a particularly good dew point simulation.

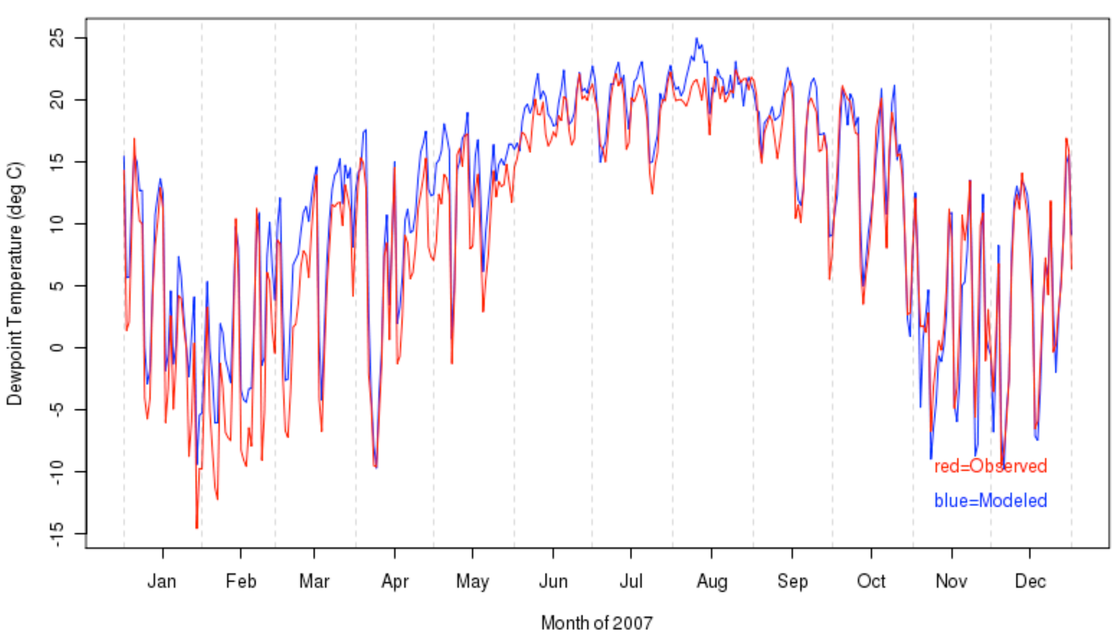


The number of individual METAR sites that have positive dew point biases suggests that the WRF model potentially has an issue with the parameterization of moisture fluxes at the surface. This bias is most noticeable across the Southeast, but also can be seen in the central Plains during the warm season. The annual dew point plots below demonstrate that KMIA (Miami, FL) has a very strong positive dew point bias during the June through October time frame while KCAE also has a consistent positive bias during the late spring and summer.

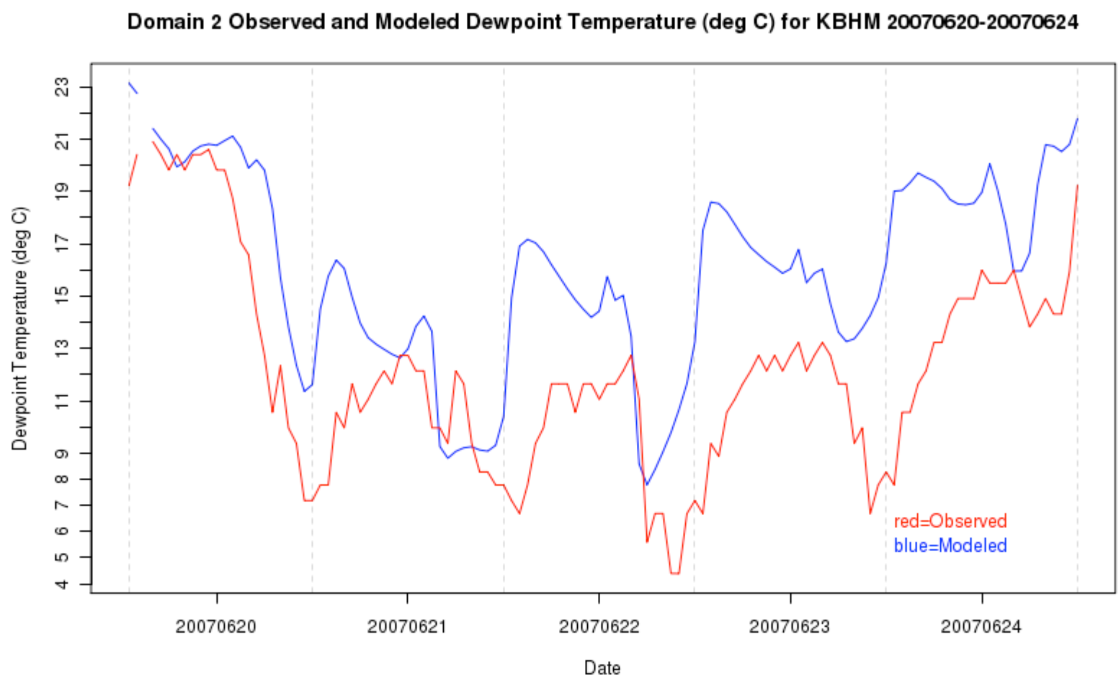
Domain 2 daily Observed and Modeled Dewpoint Temperature (deg C) for KMIA for 2007

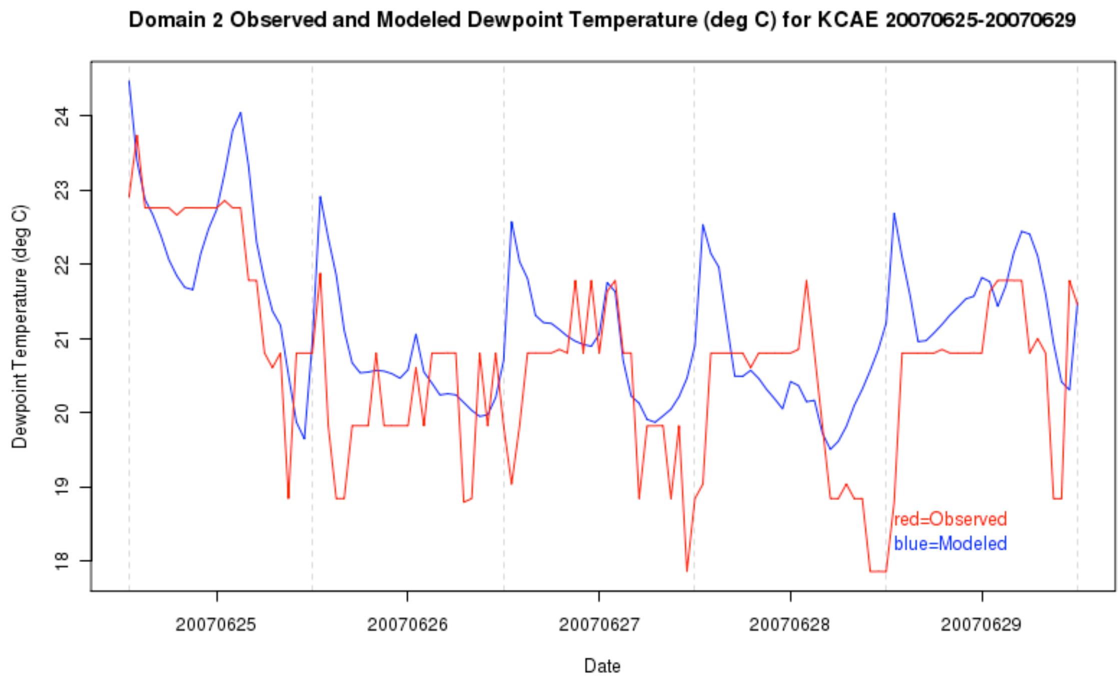


Domain 2 daily Observed and Modeled Dewpoint Temperature (deg C) for KCAE for 2007



A partial reason for the lack of skill in the WRF simulation of dew points during the warm season in the Southeast may be that the baseline model dew point temperature is too high. In both plots below from KBHM (Birmingham, AL) – June 20–24, 2007 – and KCAE – June 25–29, 2007, the nocturnal rise in dew point is quantitatively similar for both the model results and observations; however, the model doesn't simulate the drop in dew point associated with a well-mixed daytime boundary layer resulting in dew points that are generally too high.

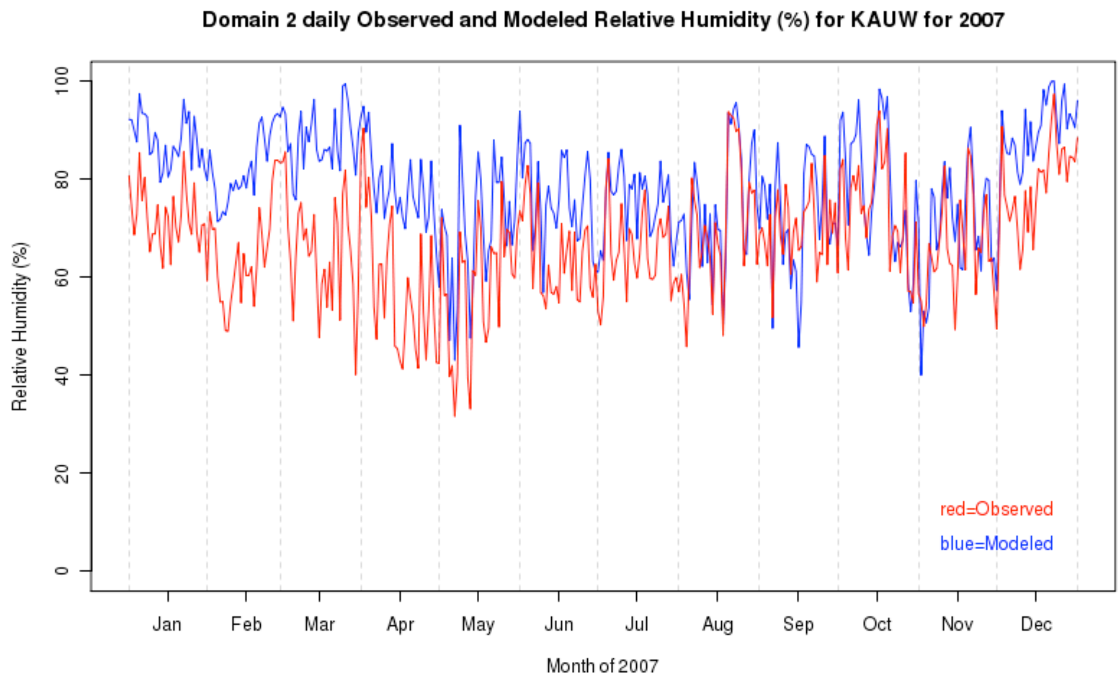


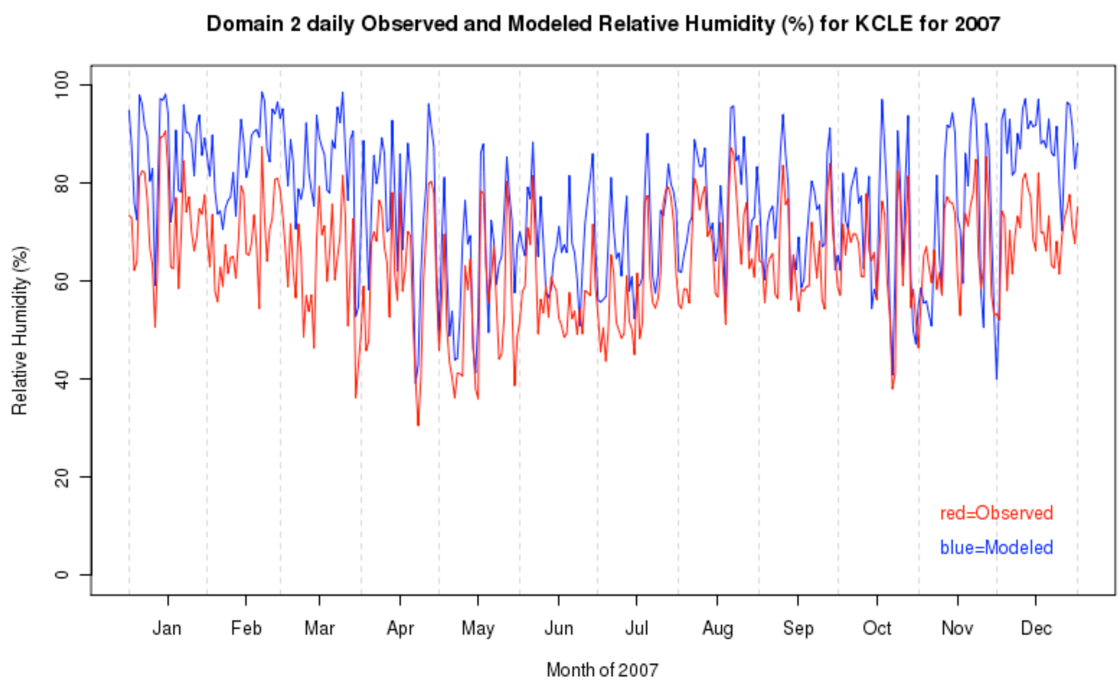


5.1.4.3 Relative humidity

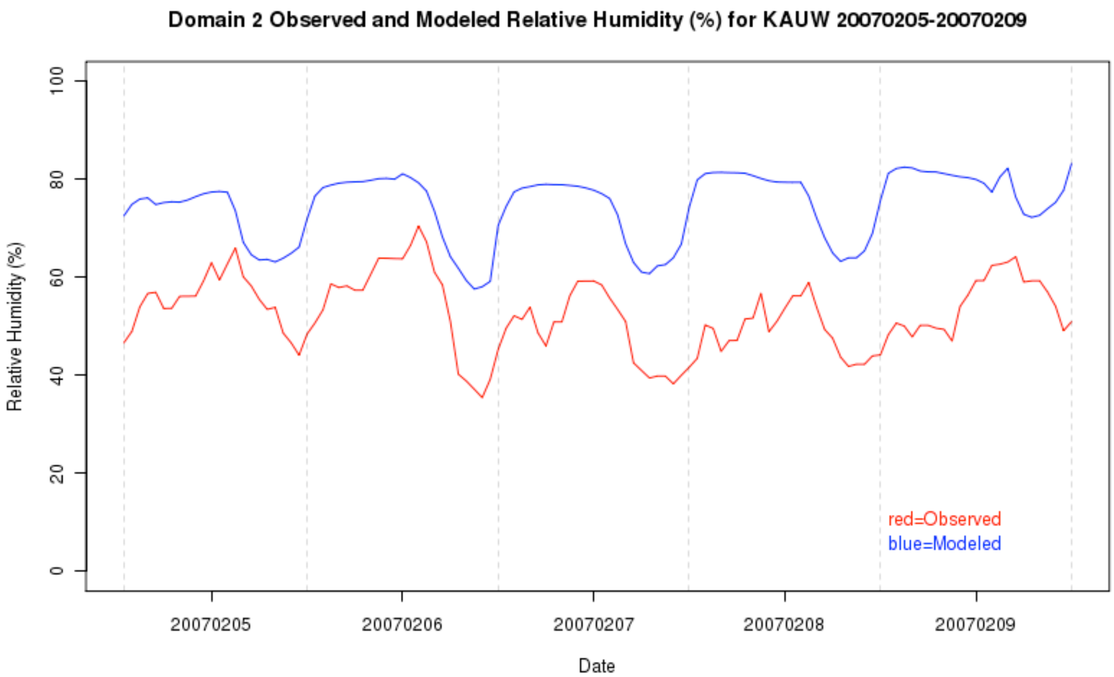
The trends observed in relative humidity for the WRF simulations closely resemble those of the dew point trends. A number of the individual locations exhibit a positive relative humidity bias during the warm season especially over the southeastern portions of the United States. A couple less common observations that differ from the dew point results are also found: a number of sites are associated with a positive bias during the winter or a transition to a neutral or negative bias during the autumn. An example of each case is shown discussed further below. It is also worth noting that the variability in the WRF relative humidity tends to be greater than the variability in the observed values.

The plot below shows the annual observed and modeled relative humidity for KAUW (Wausau, WI). A strong positive bias is noted from January through the end of April and again starting in December. Although it appears that a higher relative humidity as compared with the observations is seen throughout the year, the distinction is most pronounced during the cool season. This effect could possibly be due to how the WRF handles snow cover in its simulation. Another station that exhibits a significant positive bias throughout the year is KCLE (Cleveland, OH), which could be the result of its location along Lake Erie in which poor simulation of the moisture fluxes off of the lake could result in a persistently high relative humidity as compared with observations.

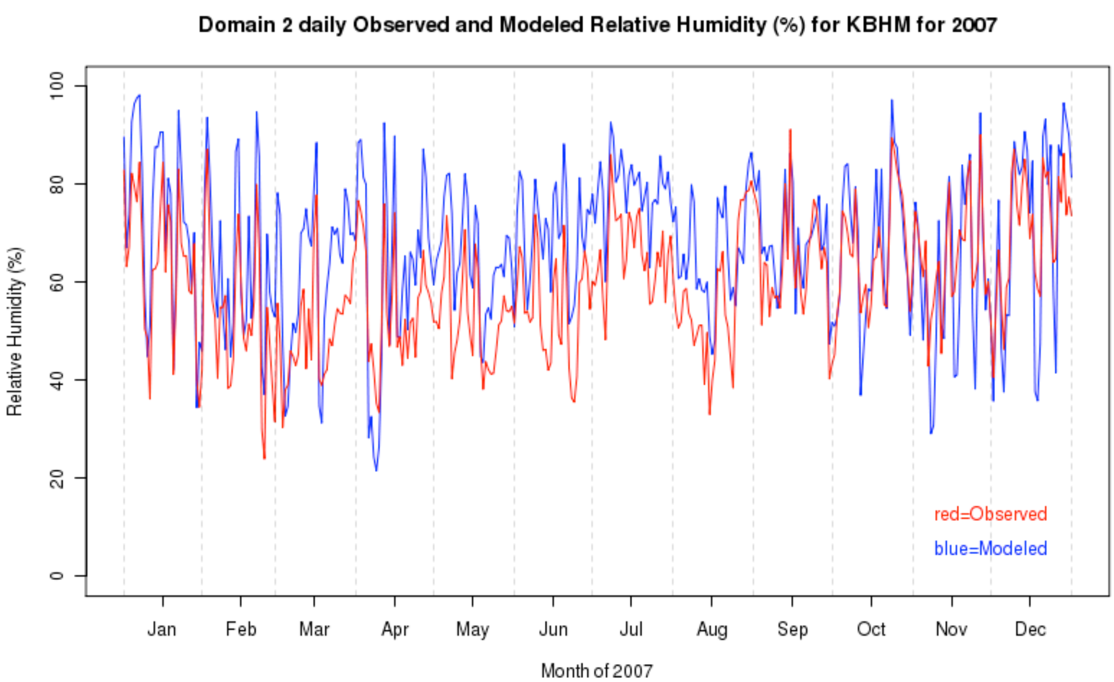




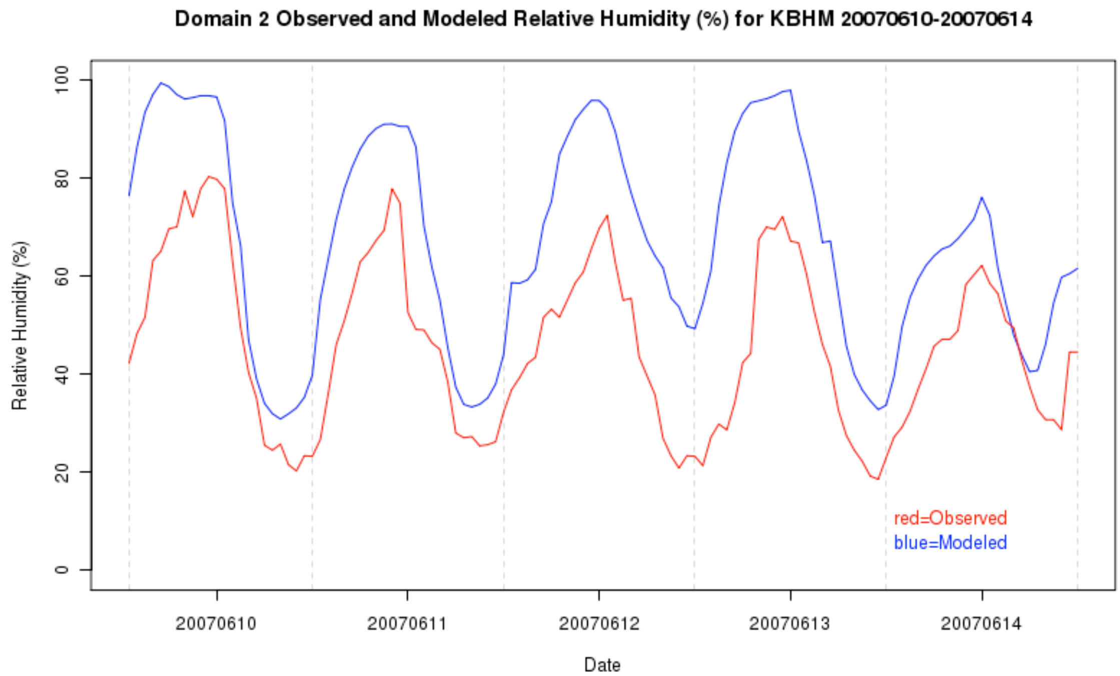
The 5-day run for KAUW during a period of relatively poor performance (Feb 5–9, 2007) shown in the plot below shows that there do not appear to be any problems simulating the diurnal cycle, but the overall relative humidity is forecast too high at all time periods.



The following plot from KBHM (Birmingham, AL) is a prime example of a station that has a positive relative humidity bias during the summer and transitions to a neutral or slightly negative bias during the autumn season. Notice also the relatively large variability in the modeled relative humidity as compared with the observations especially during the winter and later in the fall. It is important to keep in mind KBHM was under a significant drought during 2007, so this may have had an influence on these modeling results.



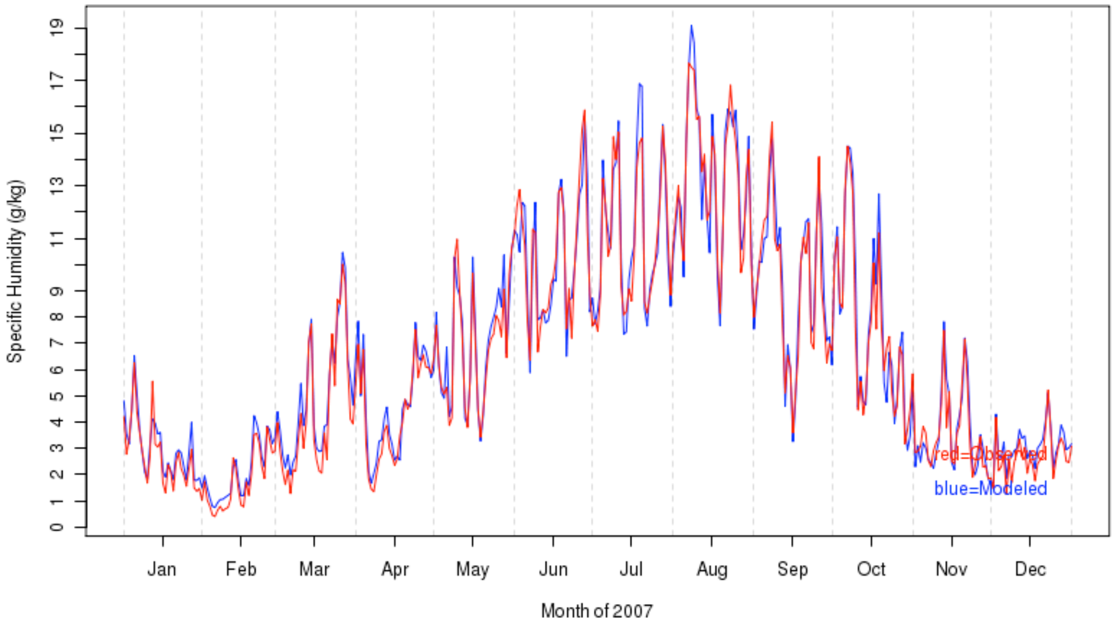
A 5-day model run depicting the modeled and observed relative humidity at KBHM for June 10–14, 2007 is shown in the plot below. There is a noticeable positive bias in the relative humidity in the early morning time period and although the diurnal cycle seems to be well represented, the values remain fairly high because the dew points are modeled too close to the air temperatures resulting in over predicted relative humidity values. This type of behavior is observed at a number of individual stations in the Southeast during the warm season.



5.1.4.4 Specific humidity

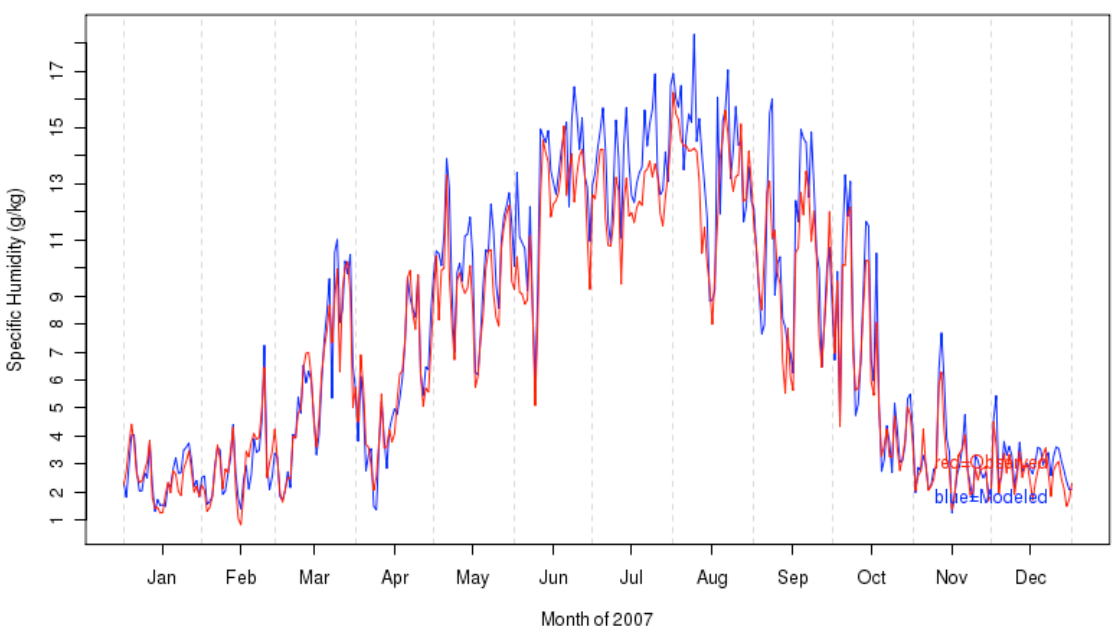
The specific humidity is generally modeled better than the relative humidity in the WRF model; however, it exhibits some of the same biases seen with the relative humidity when compared to the observations. Many locations in the Southeast and the central Plains into the Midwest display a positive bias during the warmer months. A plot of the specific humidity for KORD is shown in the plot below and represents an excellent fit between the model results and the observations.

Domain 2 daily Observed and Modeled Specific Humidity (g/kg) for KORD for 2007



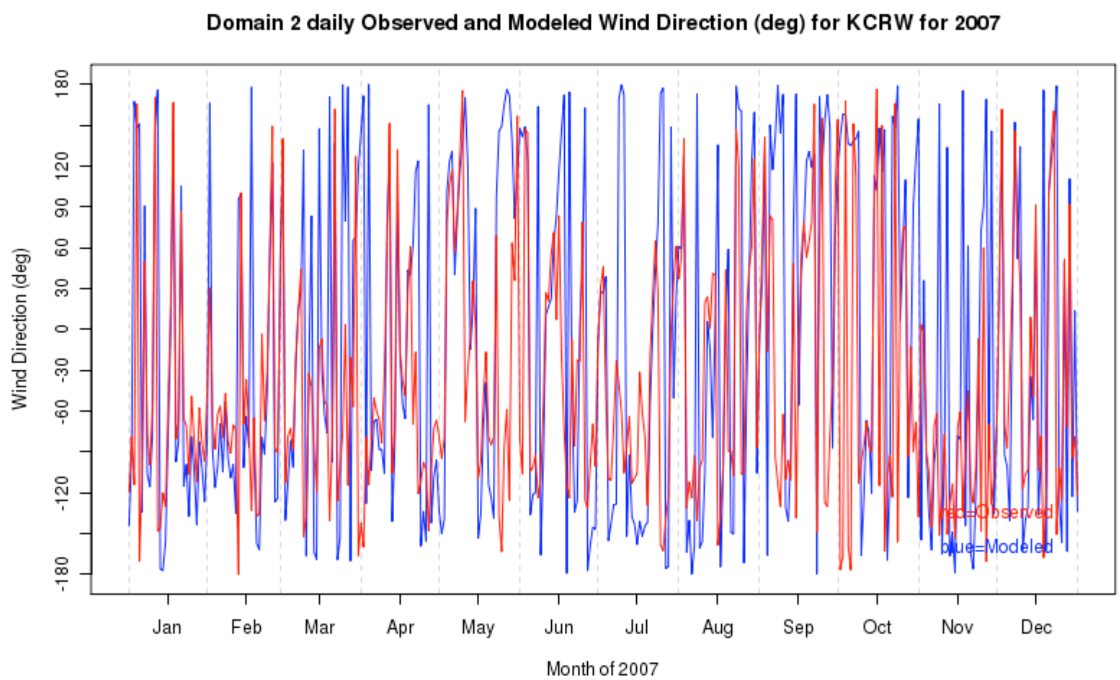
The annual modeled and observed specific humidity plot for KDDC (Dodge City, KS) is shown in the below plot and is representative of a majority of the individual locations especially those in the central Plains and Southeast. Notice how the specific humidity is well modeled in the early portion of the year, but from May to September it shows a positive bias and then from October to December the model results match the observations quite well.

Domain 2 daily Observed and Modeled Specific Humidity (g/kg) for KDDC for 2007

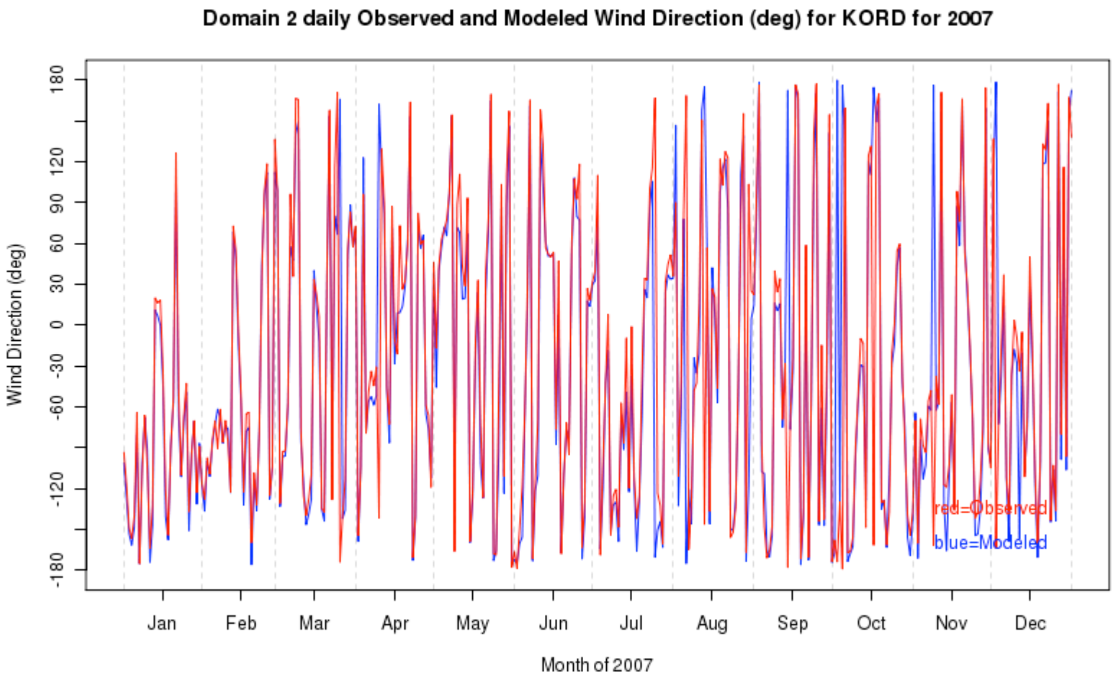


5.1.4.5 Wind direction

The wind direction as modeled by the WRF simulations was good overall, but there were a few locations that had directional biases, one of which was likely related to topography. At KCRW (Charleston, WV) shown below, the mean observed wind direction is generally westerly, between -30° and -150°, but the model simulates too many wind directions that are southerly – near -180° or 180°. As this location is at a higher elevation, it is somewhat likely that terrain effects are contributing to the poor performance of the model.

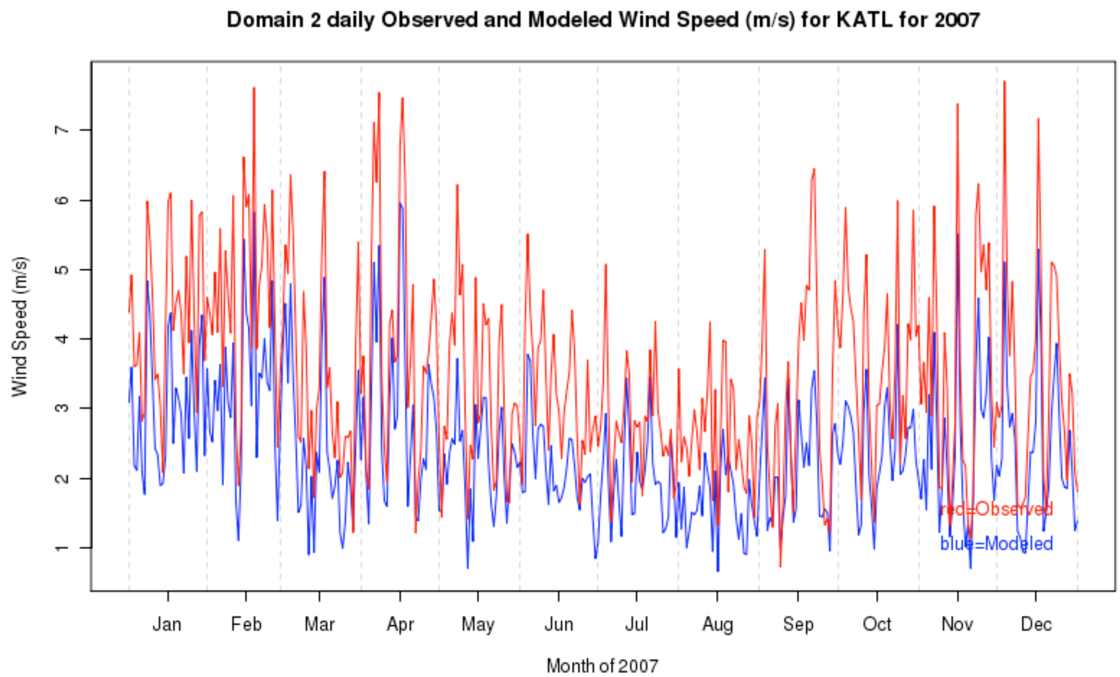


The modeled wind direction at KORD (Chicago, IL) is particularly good, especially during the cool season. The plot below shows that wind direction simulated by the model is very close to the observations from January through June and the model only experiences a slight decline in skill during the late summer and autumn and then recovers during the month of December.

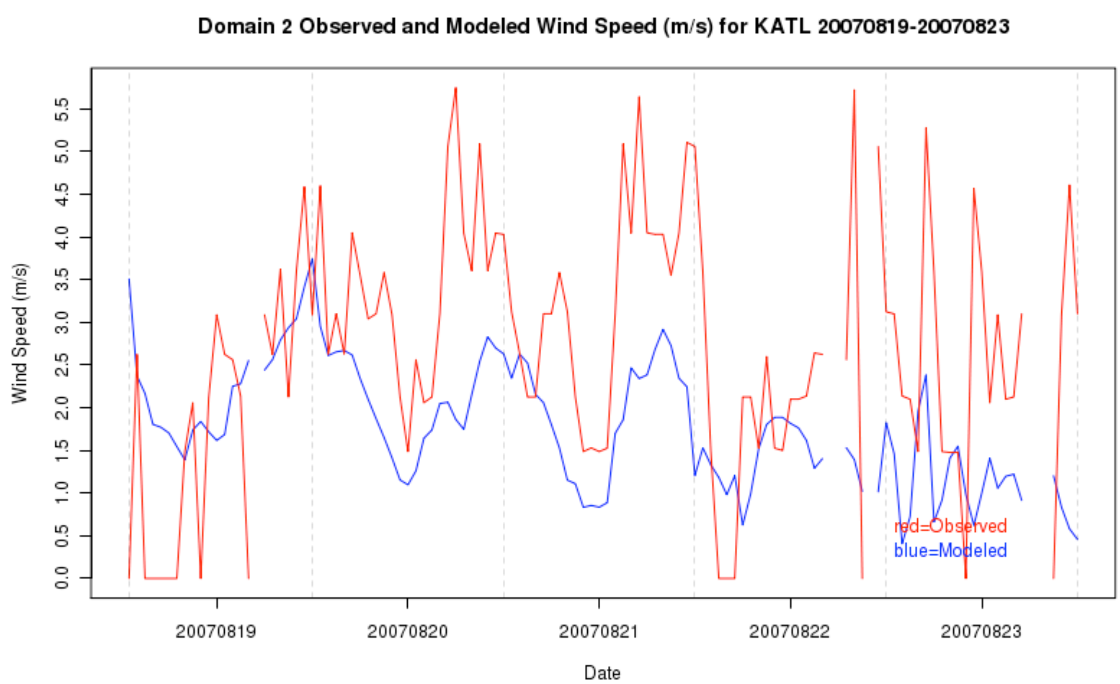


5.1.4.6 Wind speed

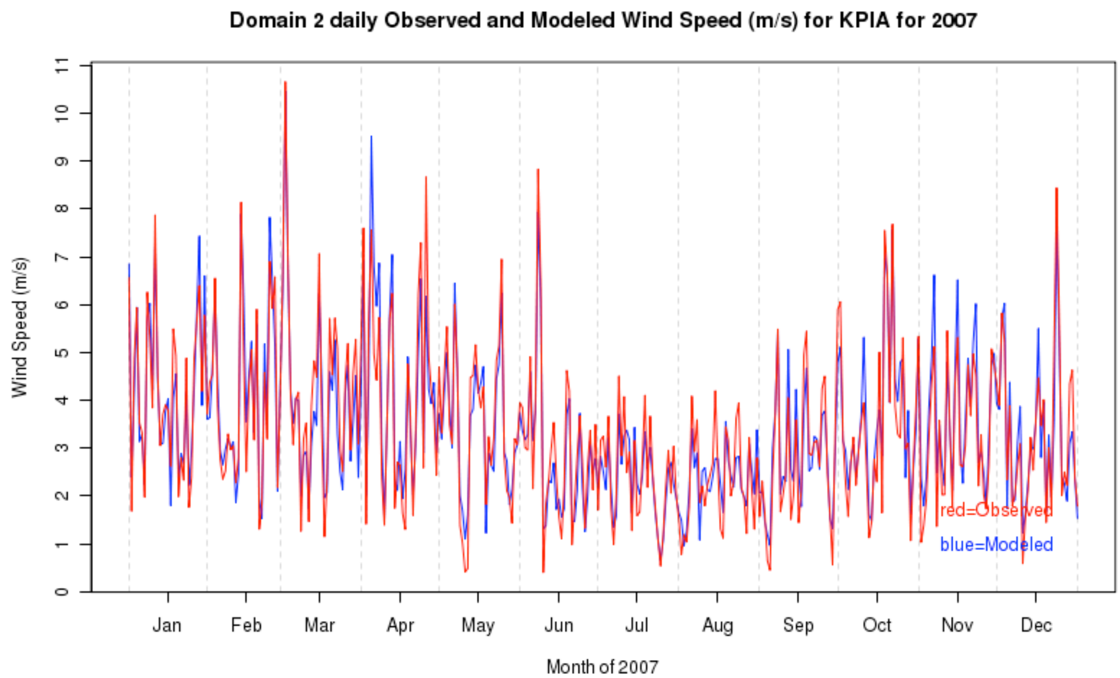
The wind speeds depicted in simulations of the WRF model generally were under predicted by as much as 1–2 m/s relative to the observations of wind speeds at each of the individual METAR locations. There are no particular regional trends observed for this variable, but it appears to be closely linked to local topography. A typical example is shown below from KATL (Atlanta, GA). Notice how the modeled wind speed is approximately 1 m/s below the observations and this is a consistent relationship year round.



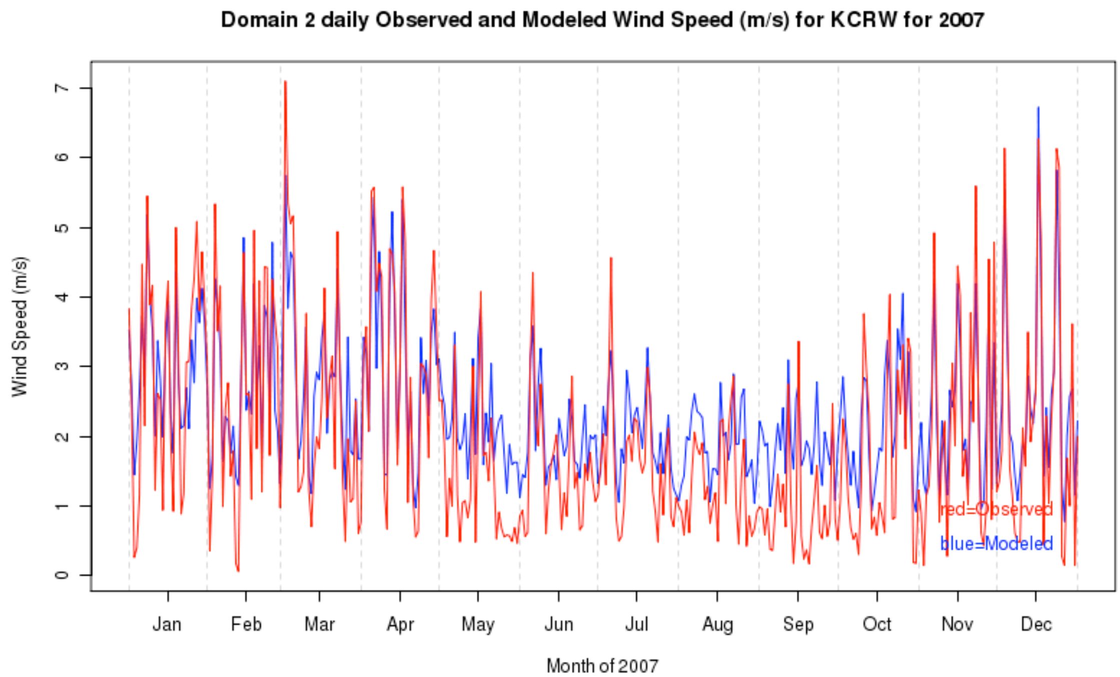
A 5-day run plot below of the wind speed at KATL from August 19–23, 2007 shows in some detail that a possible reason the wind speeds are under predicted at KATL and a number of other locations is that the WRF model fails to capture the higher wind speeds with much accuracy. Notice that over a 3-day period maximum observed wind speeds are near 5 m/s, however, the model predicts a maximum wind speed roughly one half of this value near 2.5 m/s.



The northern and central Plains as well as the Midwest tended to have the best representations of wind speeds in the model as these areas have relatively flat terrain and the presence of tall vegetation is generally less than in other regions. As a result, wind speed observations at METAR sites in these locations are not greatly influenced by small-scale local effects. Below is the plot from KPIA (Peoria, IL), which indicates that the model performed exceptionally at this location with regard to wind speed.



Although most sites conform to the overall 1–2 m/s negative bias in wind speed, a notable exception is KCRW (Charlestown, WV). Figure 13 below indicates that the WRF model simulates wind speeds slightly above the observations, especially during the warm season. Since KCRW is one of the locations at a higher elevation this may play a role in how the model simulates the wind speed at this location.



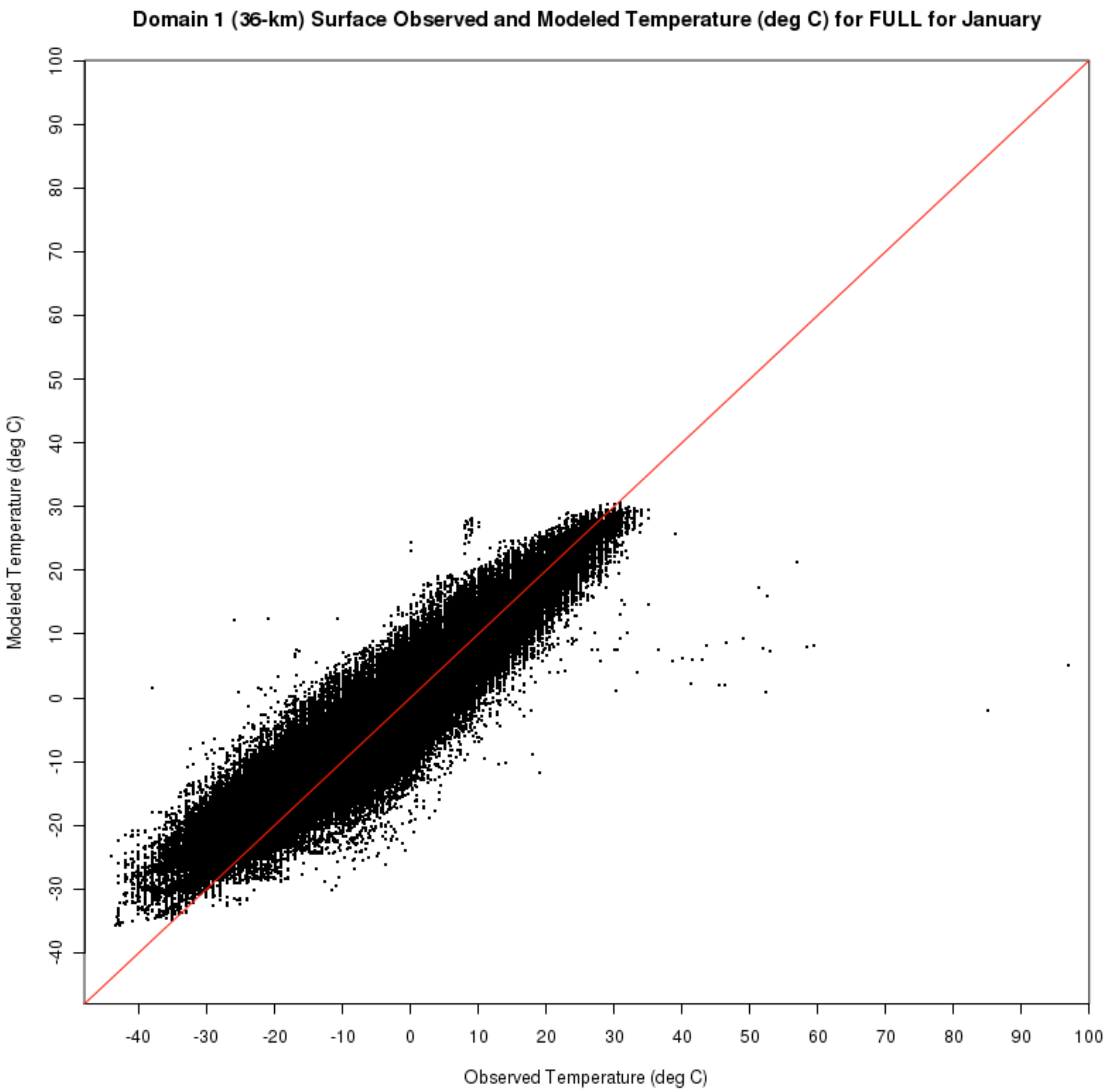
5.1.5 Task 2 G: Scatter plots

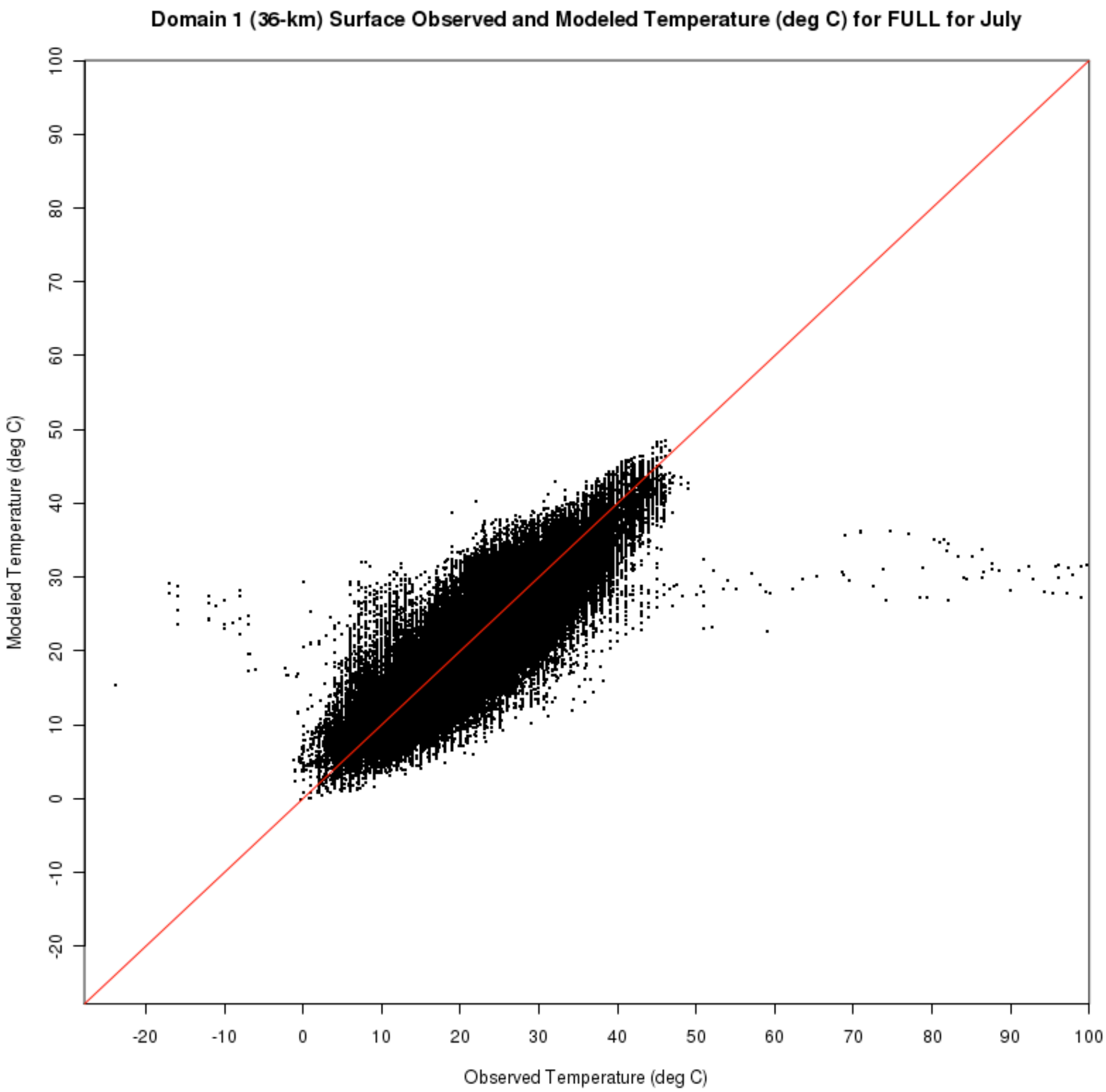
5.1.5.1 Surface

The following scatter plots show the observed value relative to the modeled value of each variable.

5.1.5.1.1 Temperature

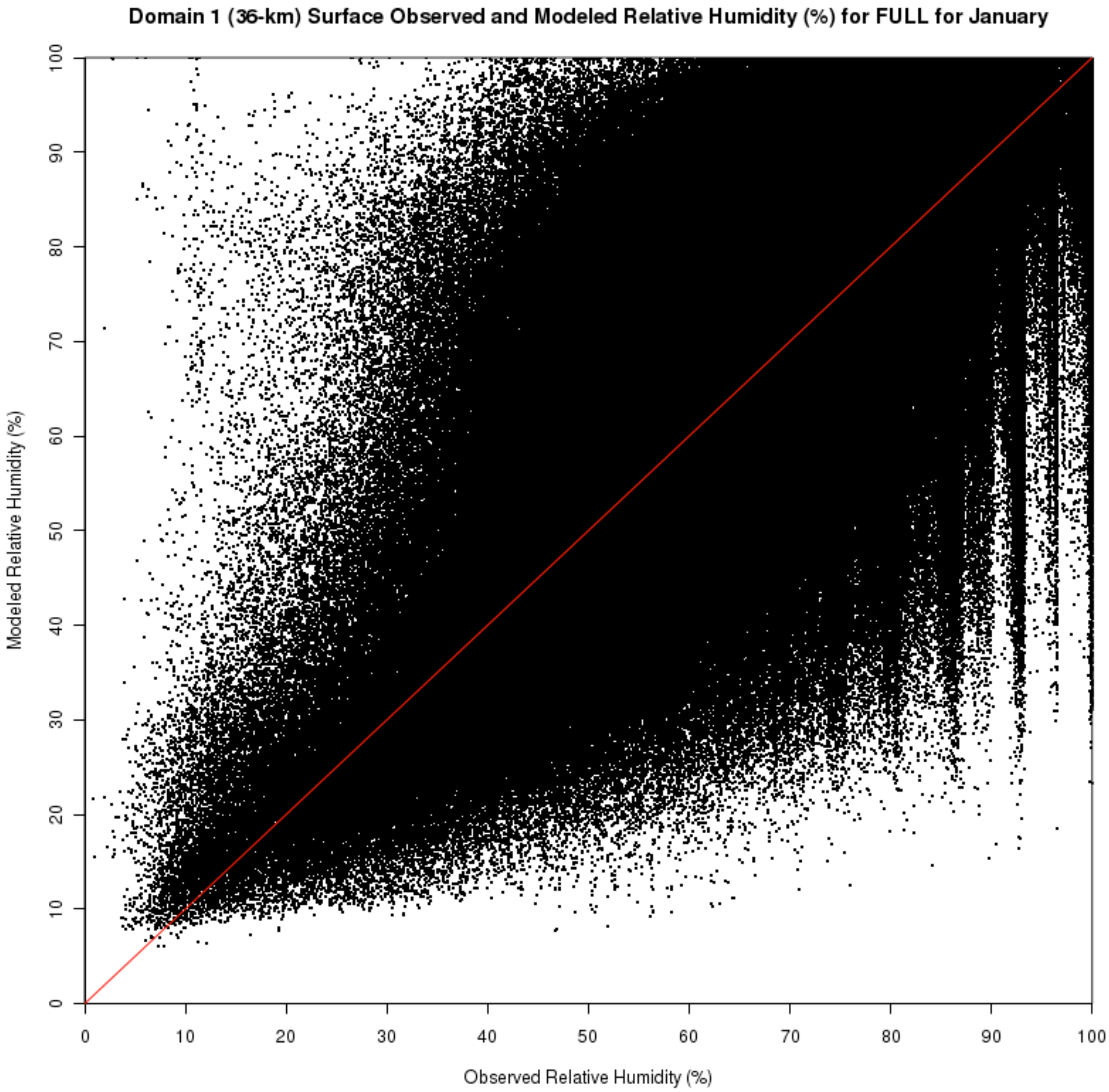
Surface temperatures simulated by the WRF model generally track the observations well and larger errors are often the result of bad observations. In the monthly plot for January below, there is a fairly linear relationship; however, at the coldest temperatures the model simulates the temperature too warm relative to the observations. The monthly plot for July shows no significant bias for the errors at the low end of the temperature scale, but the number of observational errors appears to increase with a greater number of values far to the left and right of the red 1:1 line.


Domain 1 (36-km) Surface Observed and Modeled Temperature (deg C) for FULL for January
Modeled Temperature (deg C)
Observed Temperature (deg C)
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100

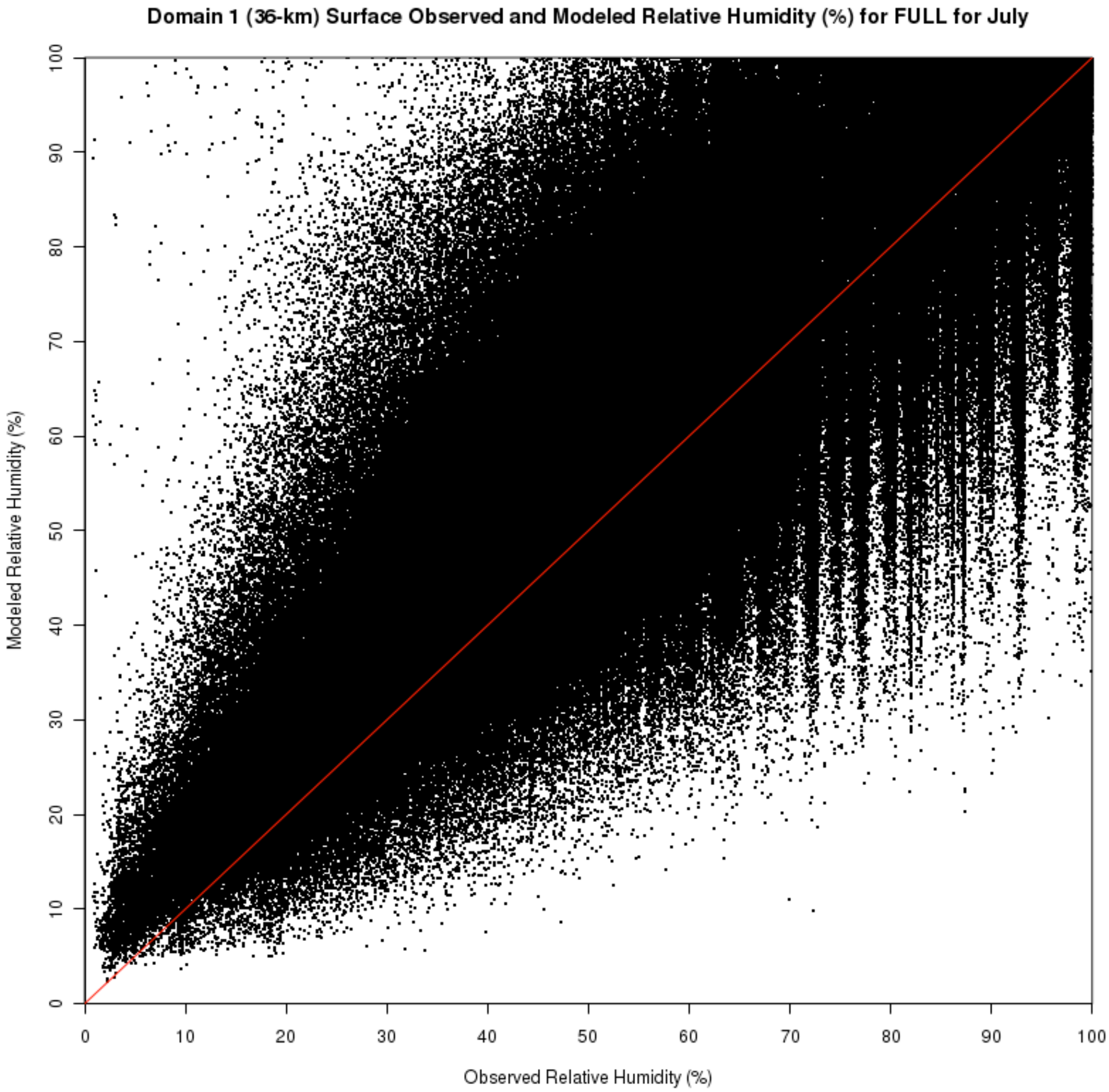


5.1.5.1.2 Relative Humidity

The scatter plots for surface relative humidity show that the observed and modeled values are generally close to each other at low relative humidity. The errors increase significantly above an observed relative humidity of approximately 30%. The plot for July is similar except that the largest errors are reduced and there appears to be more of a bias towards higher modeled relative humidity values versus the observed values meaning a tendency for the value to fall above the red 1:1 line. It is less obvious for the relative humidity data which values are related to errors in the observations and which are related to errors in the WRF model output.

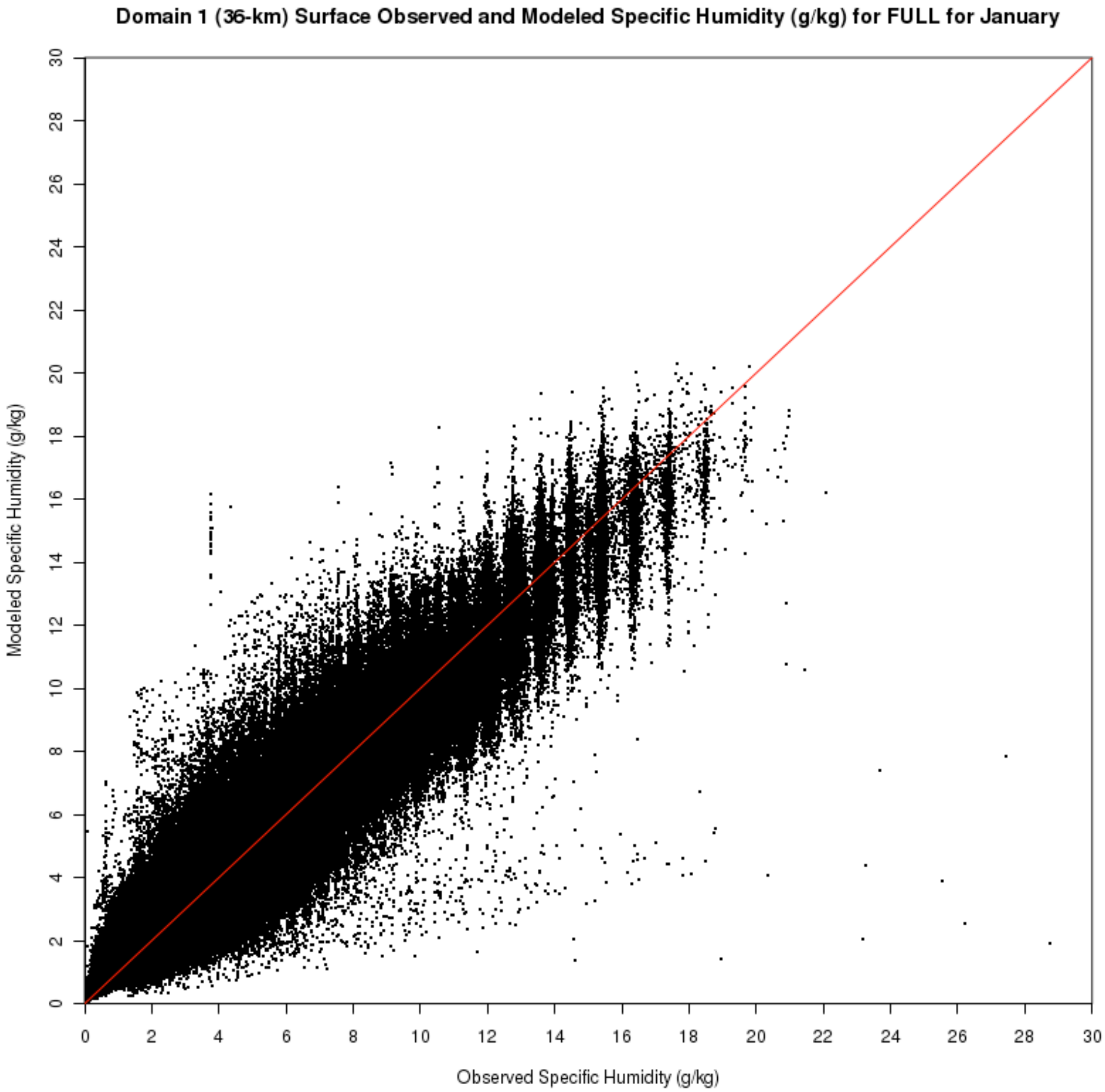


Domain 1 (36-km) Surface Observed and Modeled Relative Humidity (%) for FULL for January
Modeled Relative Humidity (%)
Observed Relative Humidity (%)
0
10
20
30
40
50
60
70
80
90
100



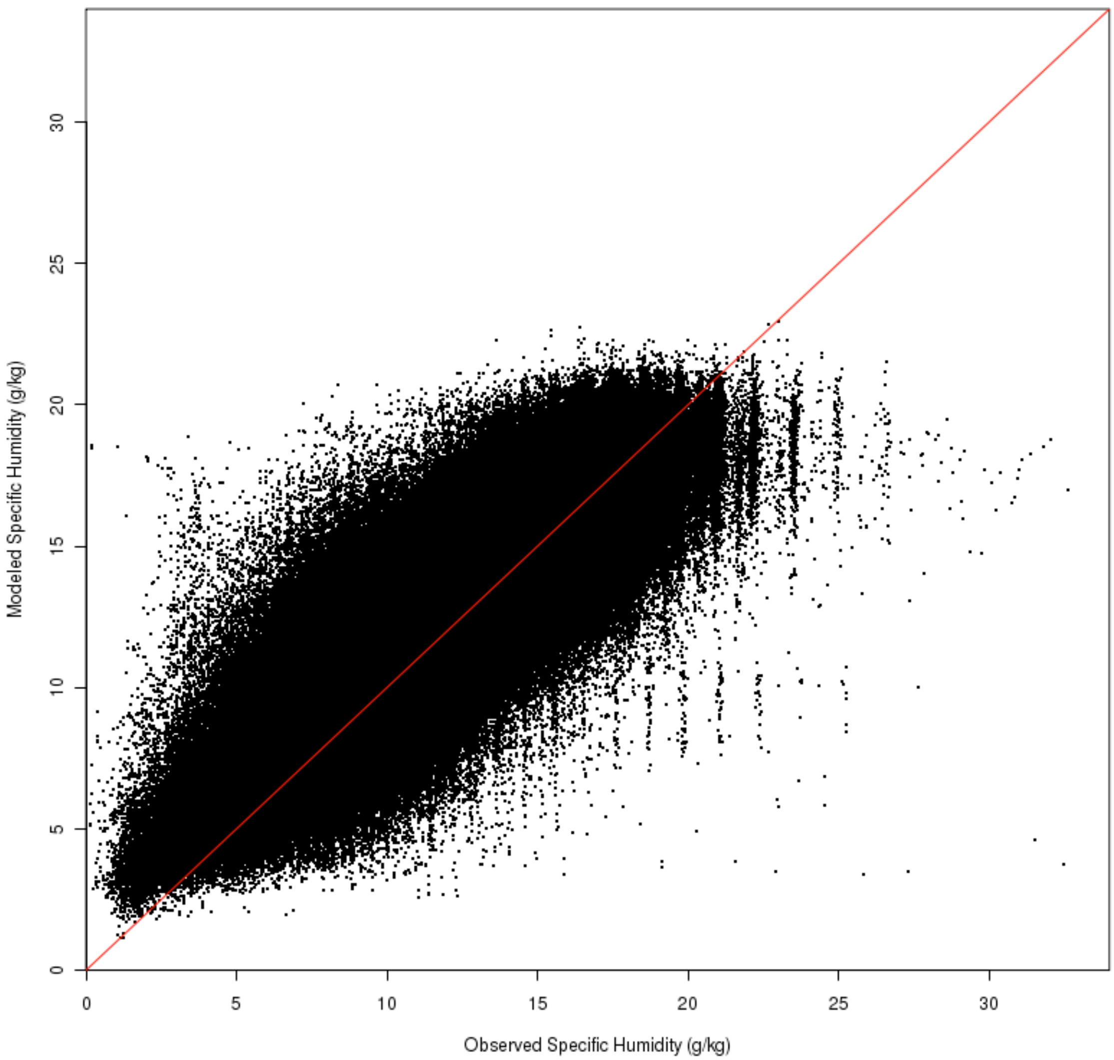
5.1.5.1.3 Specific humidity

The surface specific humidity plots below show a good correlation between the observed and modeled values for the month of January. As with the temperature data, there are a number of outlier observations especially to the right of the red 1:1 line. In the month of July, the correlation between the observations and WRF values weakens and as with the relative humidity there appears to be a slight bias towards higher model values versus the observations.



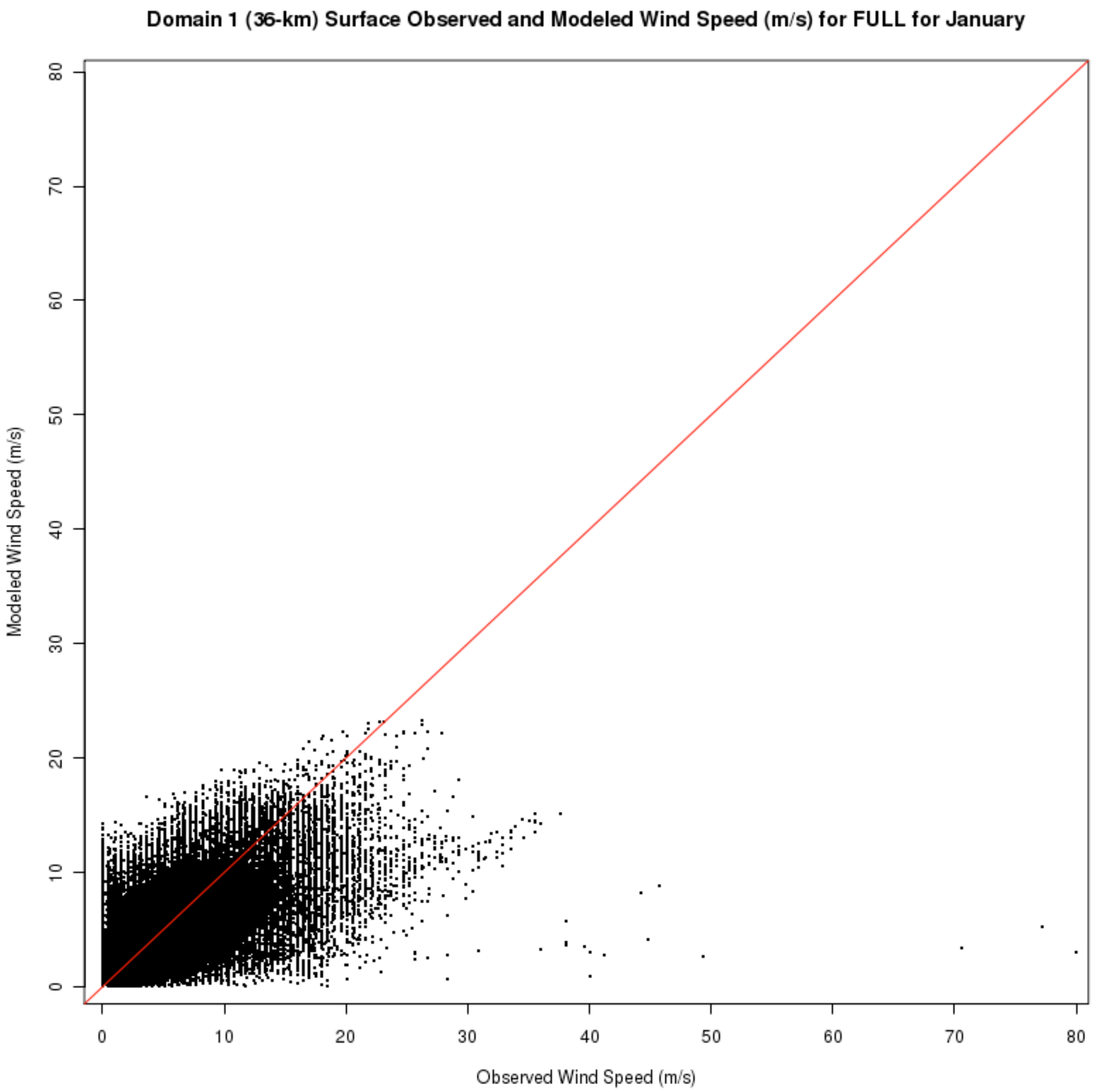
Domain 1 (36-km) Surface Observed and Modeled Specific Humidity (g/kg) for FULL for January
Modeled Specific Humidity (g/kg)
Observed Specific Humidity (g/kg)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

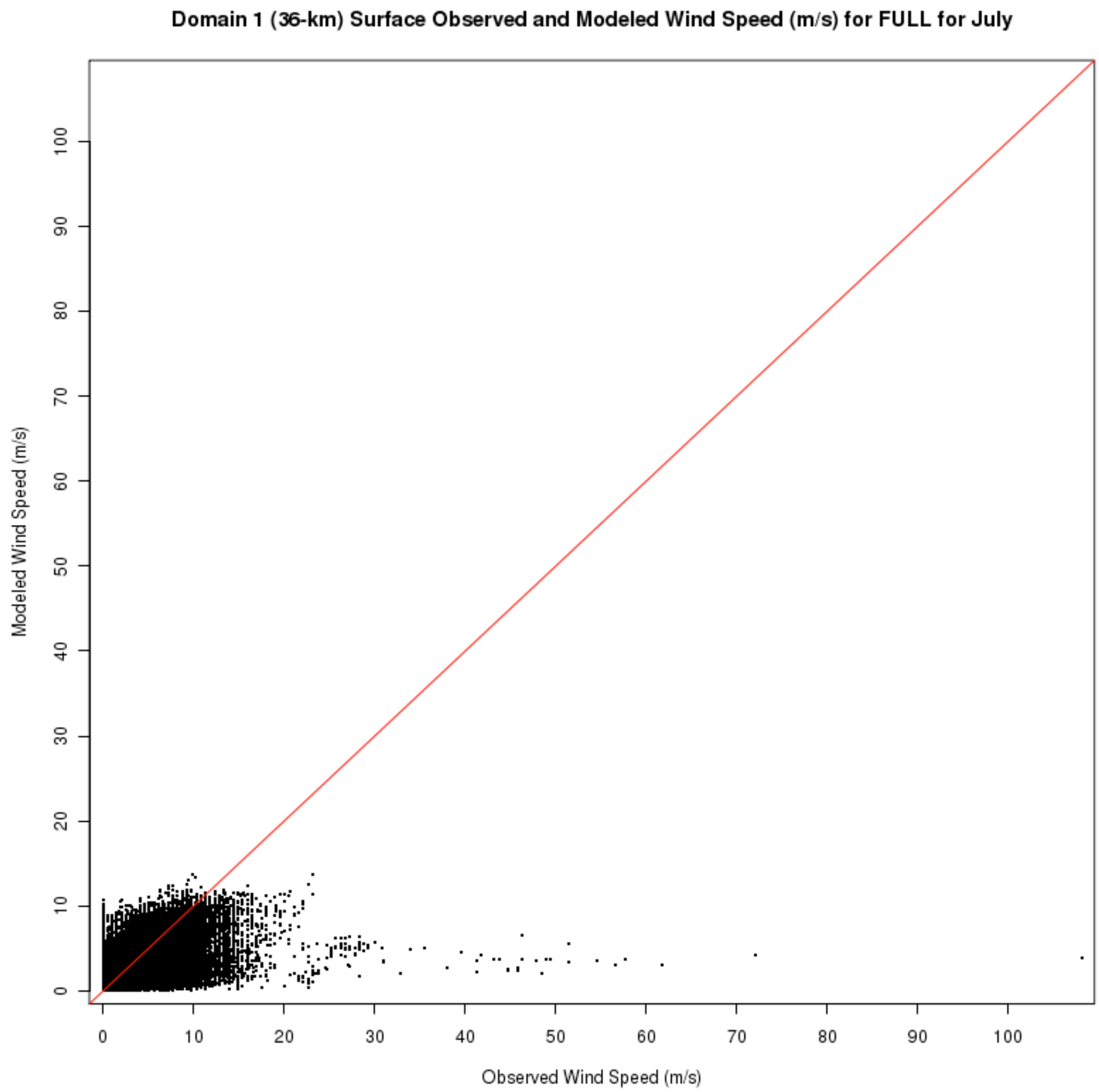
Domain 1 (36-km) Surface Observed and Modeled Specific Humidity (g/kg) for FULL for July



5.1.5.1.4 Wind speed

The wind speed scatter plots for the months of January and July show that the WRF model performs relatively poorly at simulating wind speeds that are near zero as there are modeled values upwards of 10 m/s where the observations indicate calm winds. Conversely, there is a tendency to underpredict wind speeds that are in excess of 10 m/s, as a majority of the points fall to the right of the 1:1 line.


Domain 1 (36-km) Surface Observed and Modeled Wind Speed (m/s) for FULL for January
Modeled Wind Speed (m/s)
Observed Wind Speed (m/s)
0
10
20
30
40
50
60
70
80

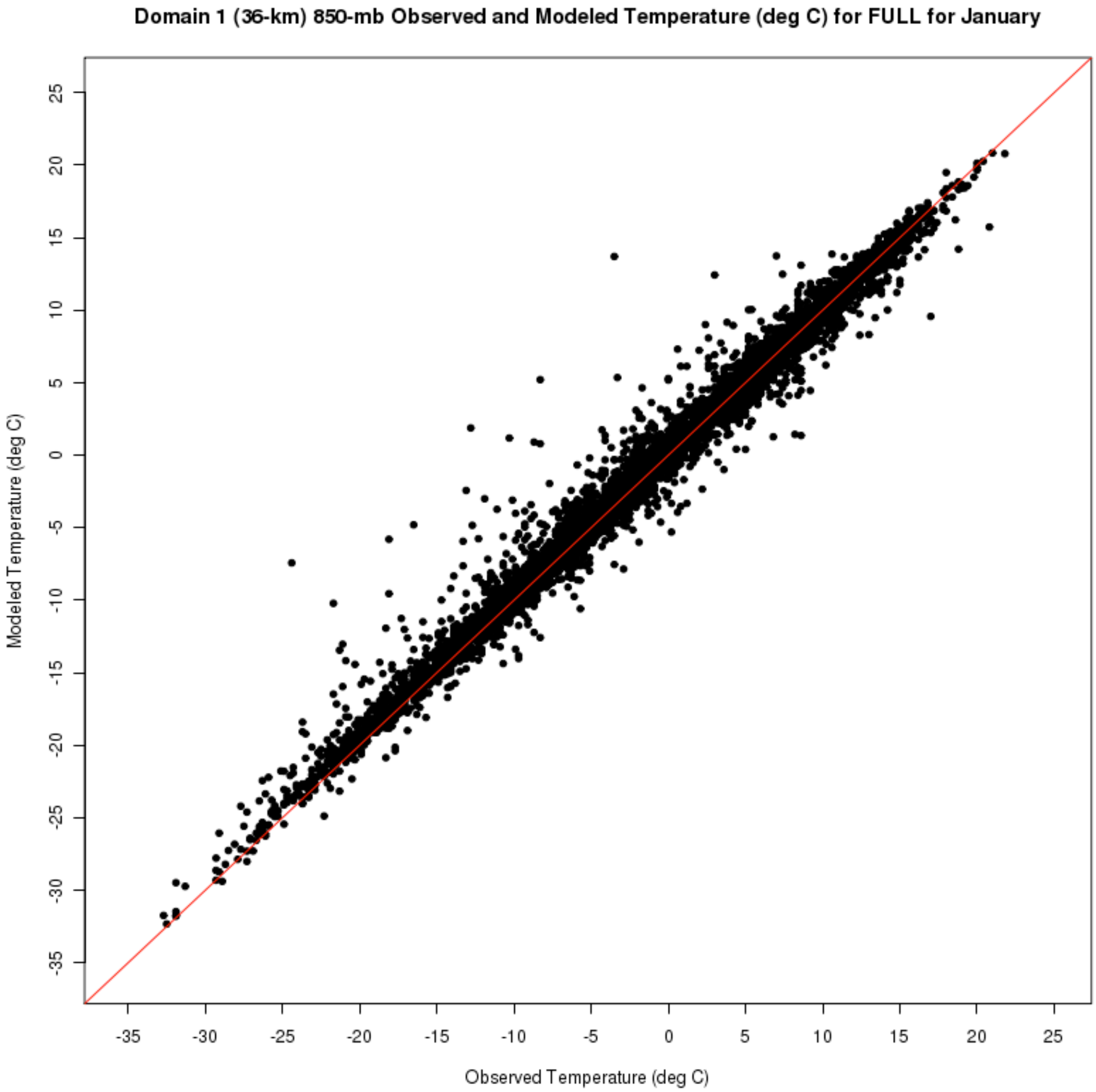


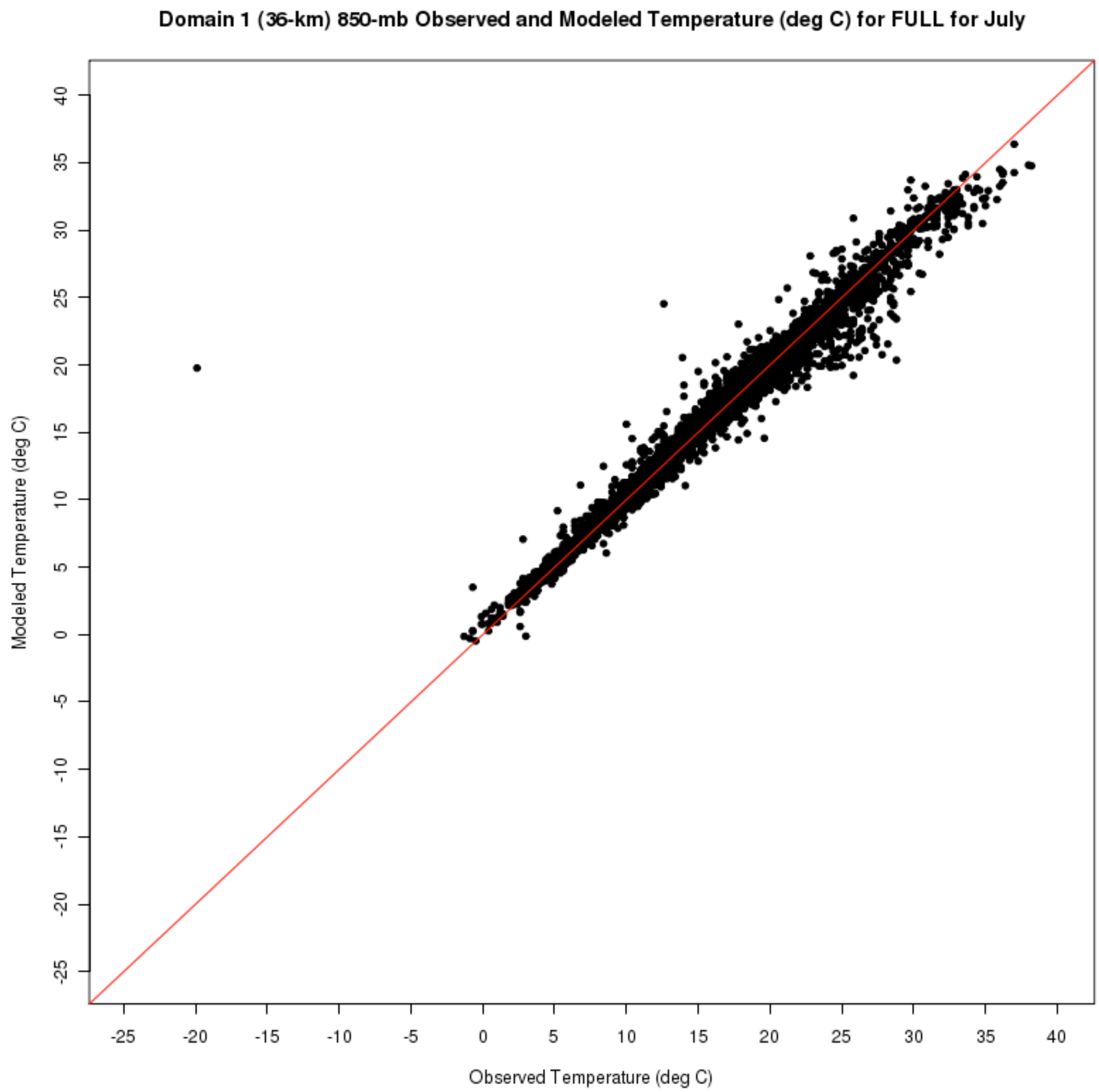
5.1.5.2 850 mb and 700 mb

The following section will only show scatter plots at the 850-mb level as these are representative of the scatter plots at 700 mb.

5.1.5.2.1 Temperature

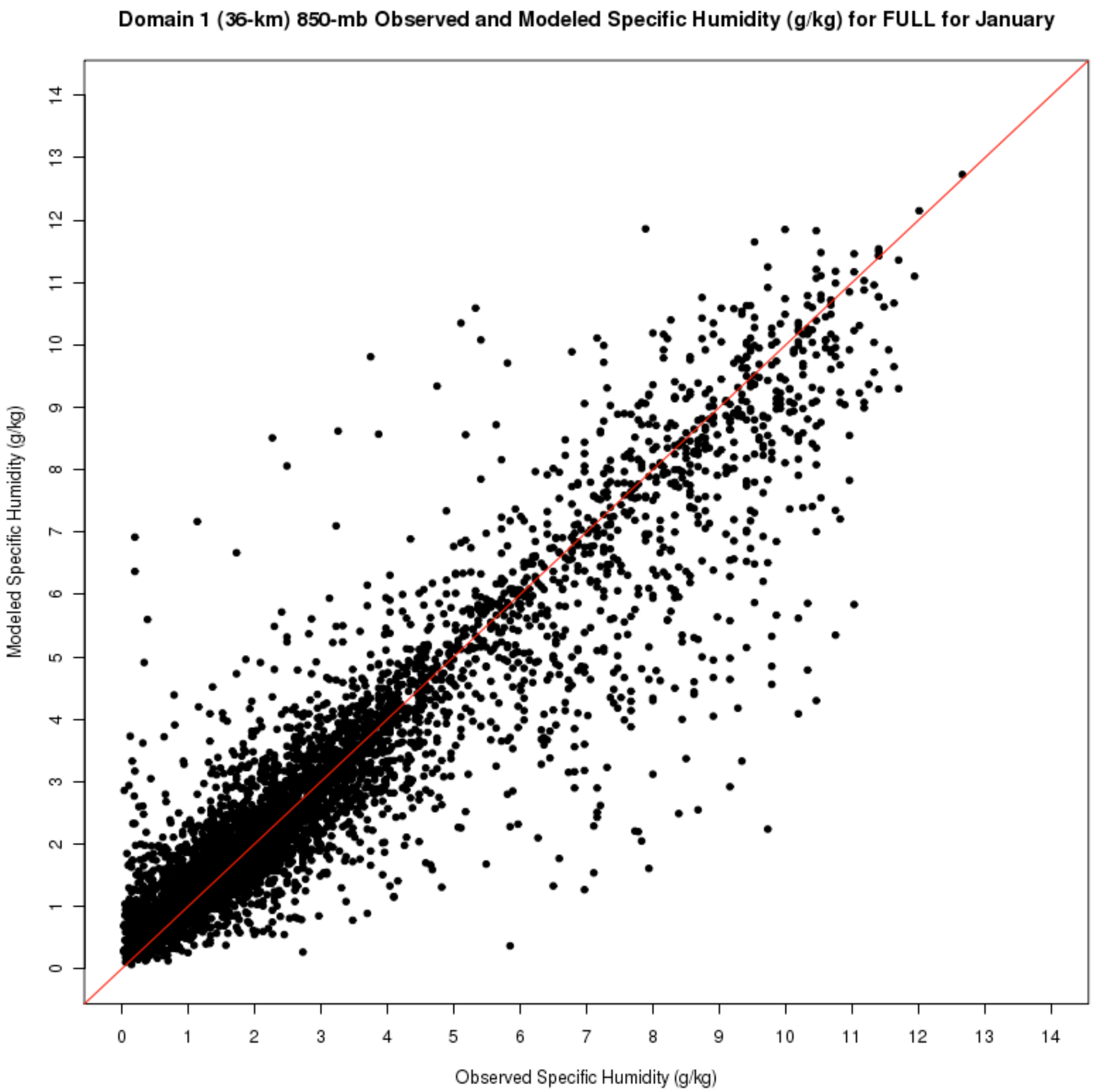
The observed and modeled temperatures are well correlated at the 850 and 700-mb levels. There appears to be a slight tendency for more outliers left of the 1:1 line especially in January most likely indicating that observations are erroneously cold or the WRF simulation is producing temperatures that are too warm.


Domain 1 (36-km) 850-mb Observed and Modeled Temperature (deg C) for FULL for January
Modeled Temperature (deg C)
Observed Temperature (deg C)
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25

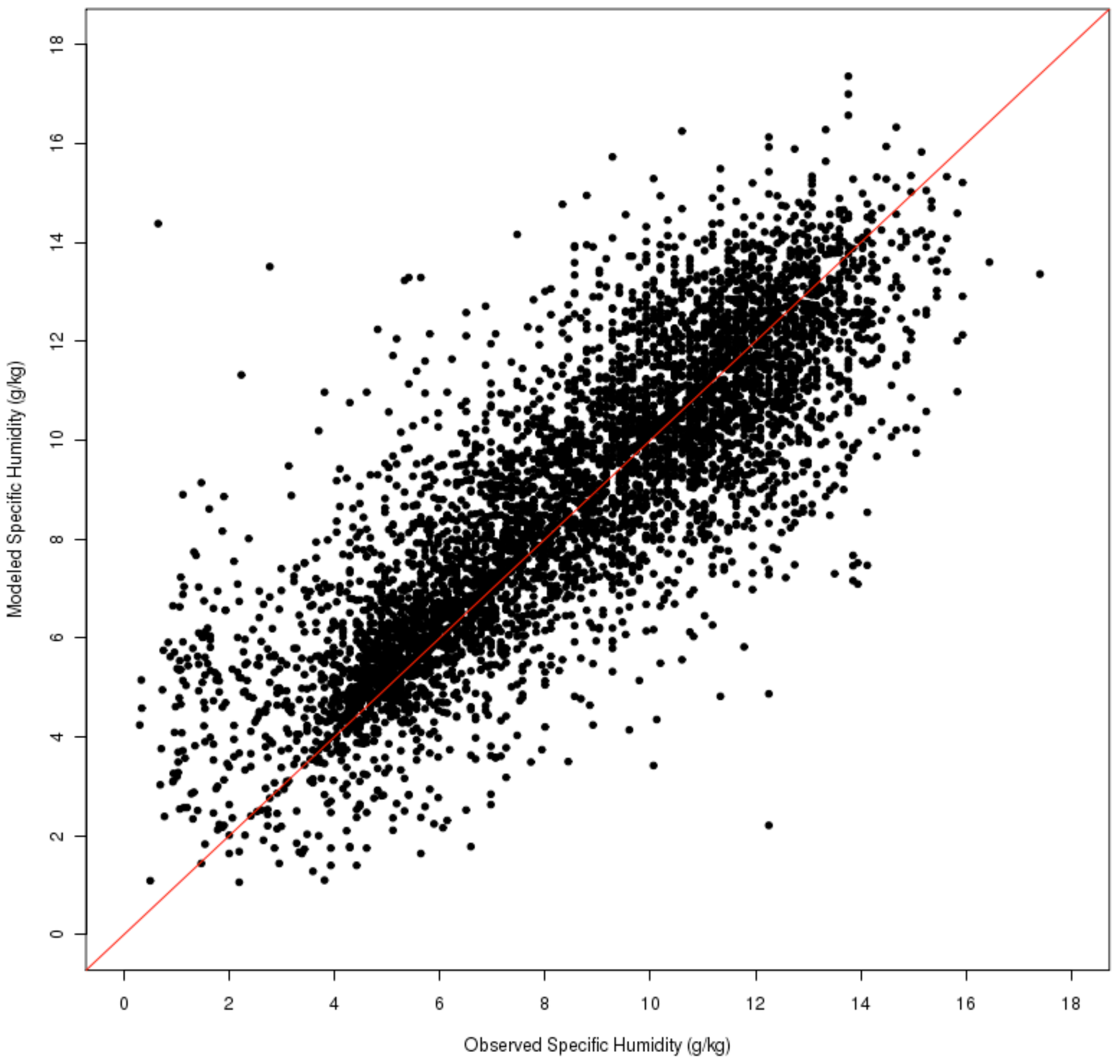


5.1.5.2.2 Specific Humidity

The 850-mb scatter plot for January indicates that the observations and modeled values are more closely related at low moisture levels, generally under 5 g/kg. The correlation between these data becomes weaker at high moisture levels indicated by the large number of outliers especially those to the right of the red 1:1 line suggesting observed values are erroneously high or the WRF simulation is producing values that are too low. The July scatter plot shows that while the correlation appears to be slightly weaker where most of the data lies, there are fewer extreme outliers.

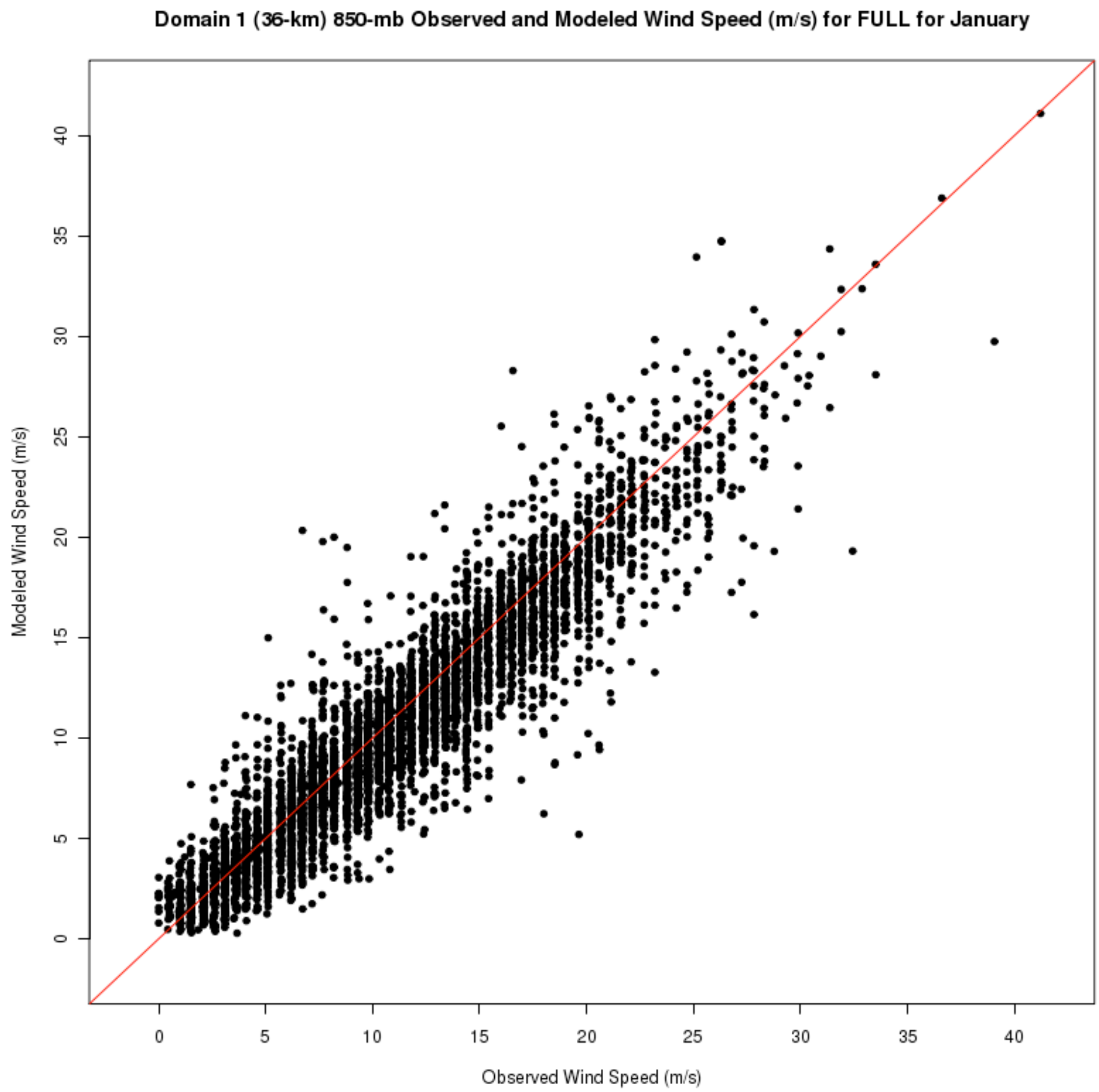

Domain 1 (36-km) 850-mb Observed and Modeled Specific Humidity (g/kg) for FULL for January
Modeled Specific Humidity (g/kg)
Observed Specific Humidity (g/kg)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

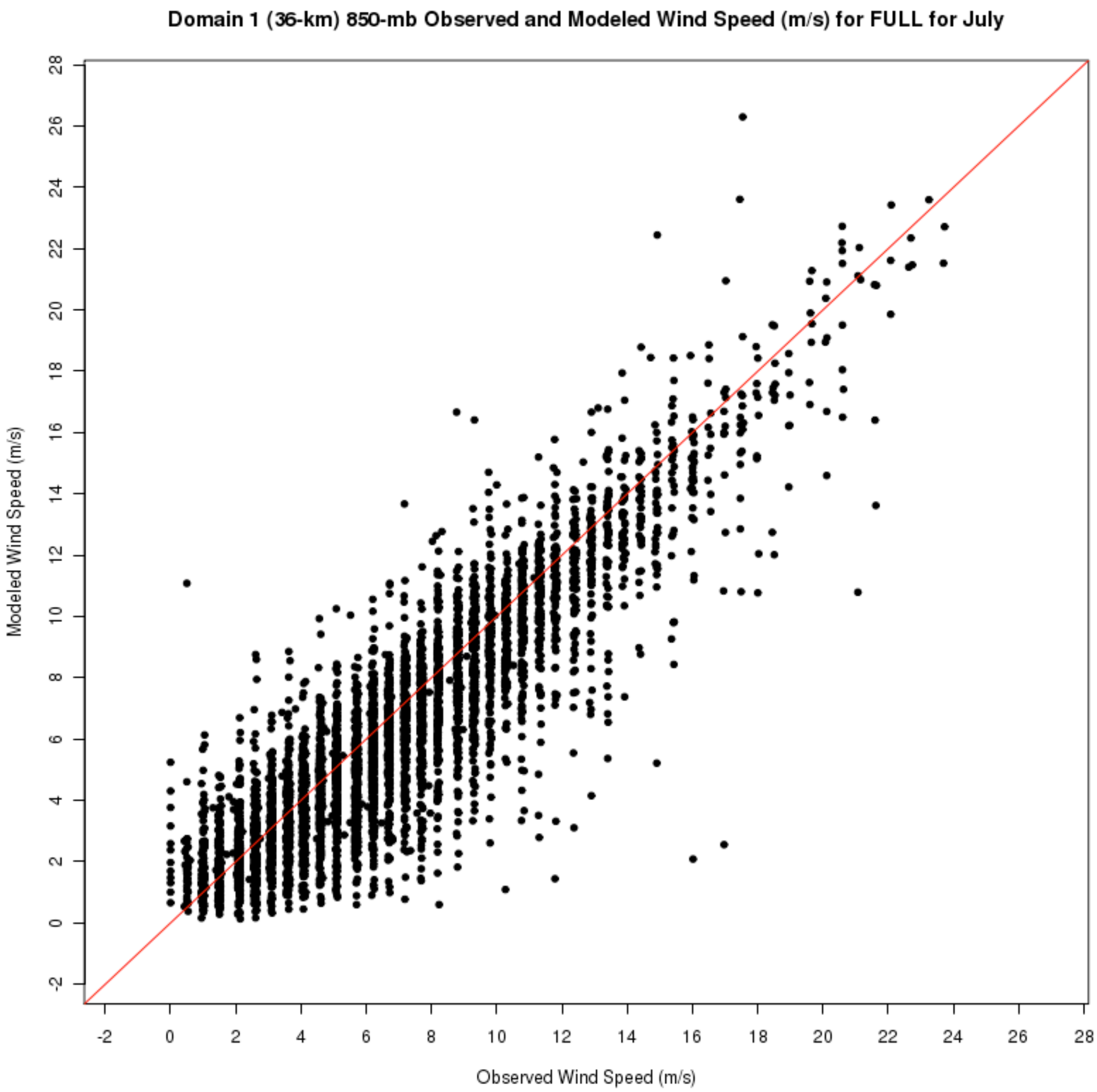
Domain 1 (36-km) 850-mb Observed and Modeled Specific Humidity (g/kg) for FULL for July



5.1.5.2.3 Wind Speed

The 850-mb scatter plots for wind speed show a stronger correlations between the observed wind speeds and the wind speeds simulated by the WRF model with perhaps a slight negative bias indicating that the model slightly underestimates the actual wind speed. The correlation becomes slightly weaker in July as mean wind speeds decrease. There is a larger number of significant outliers to the right of the 1:1 line in July suggesting that the WRF model may have a greater tendency to under predict wind speeds at this level in the warmer months. The 700-mb wind speed scatter plots are similar except the correlation between the observed and modeled wind speeds improves because it is in most cases removed from the influence of the boundary layer.


Domain 1 (36-km) 850-mb Observed and Modeled Wind Speed (m/s) for FULL for January
Modeled Wind Speed (m/s)
Observed Wind Speed (m/s)
0
5
10
15
20
25
30
35
40

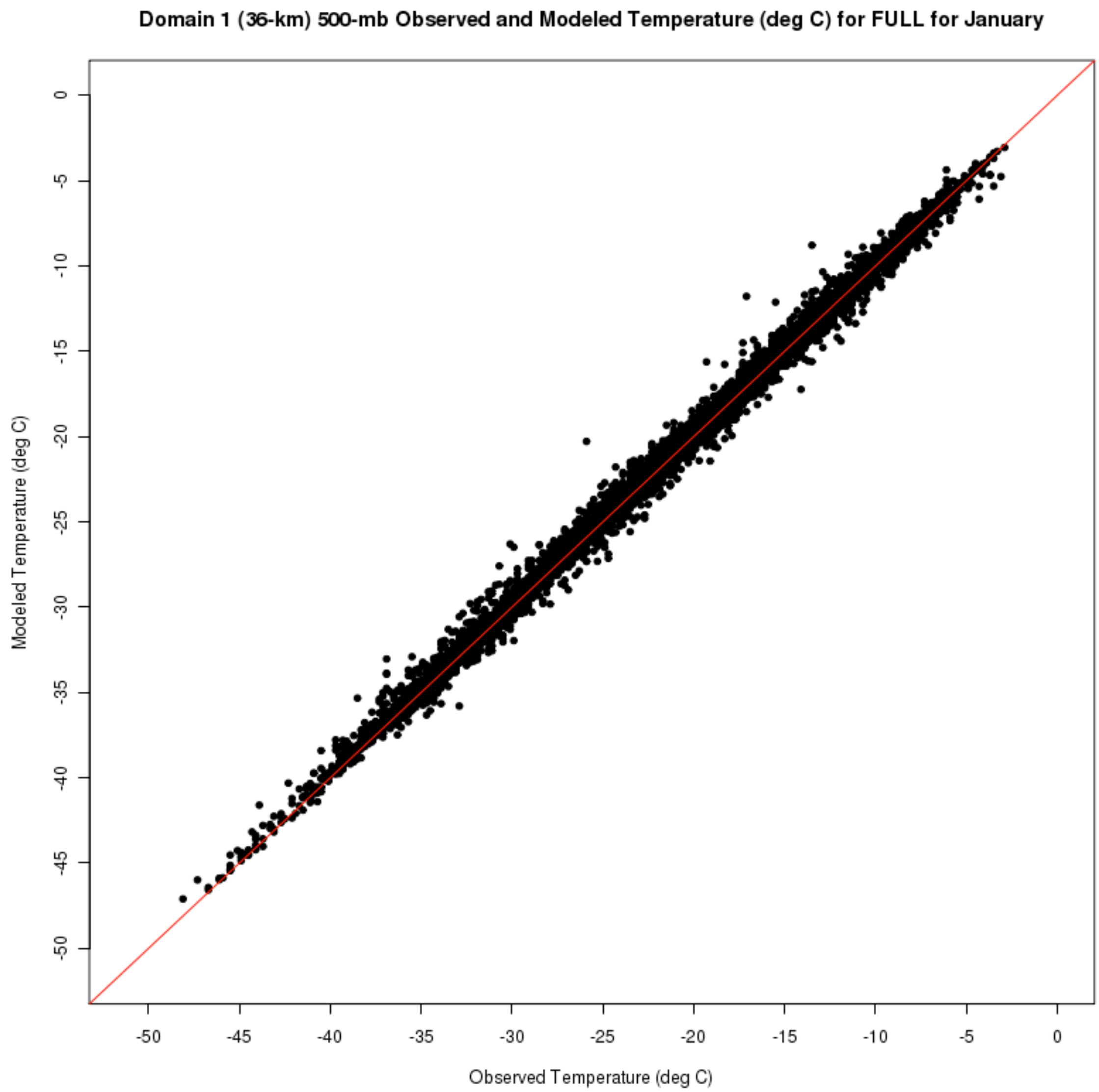


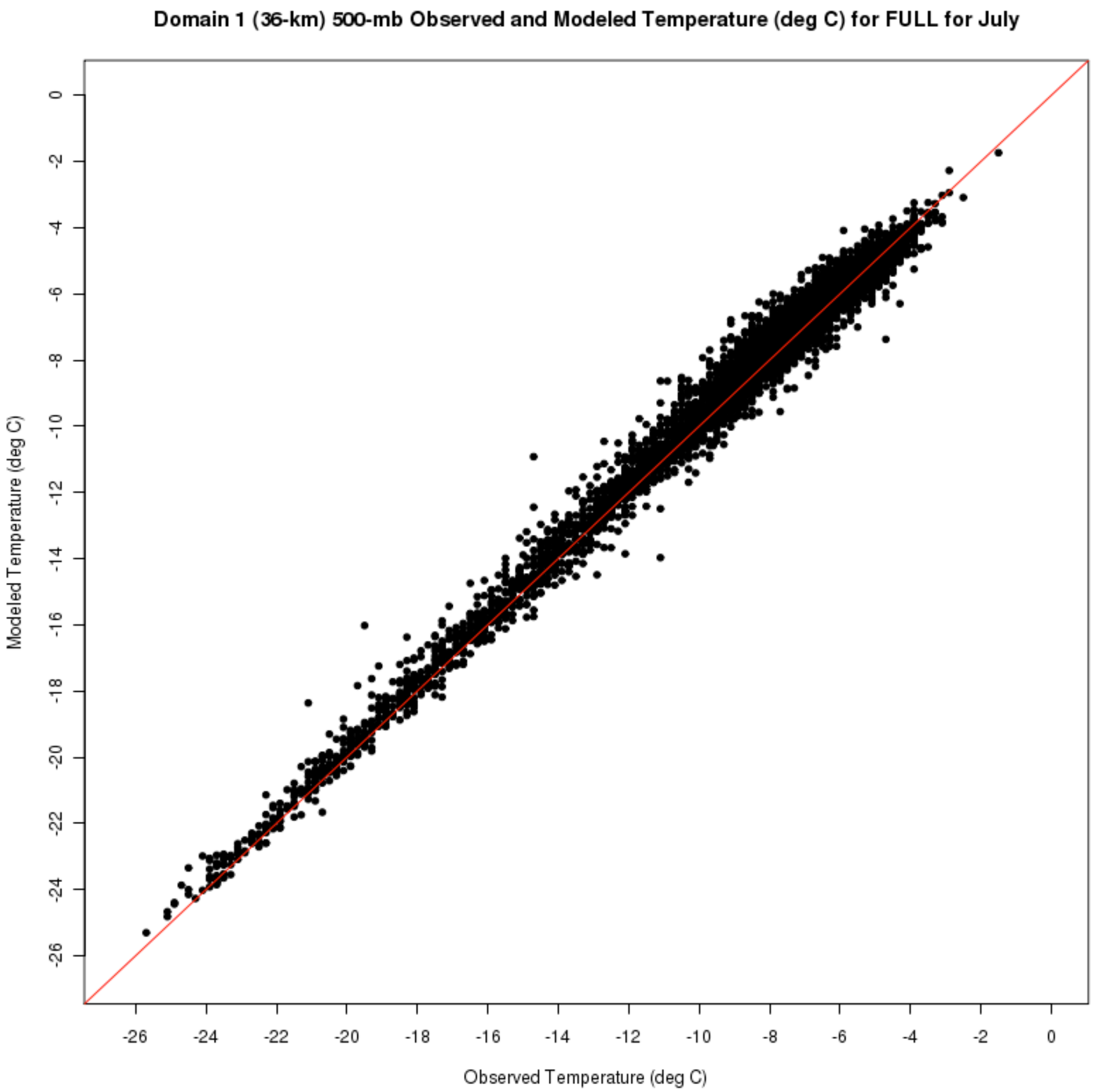
5.1.5.3 500 mb and 300 mb

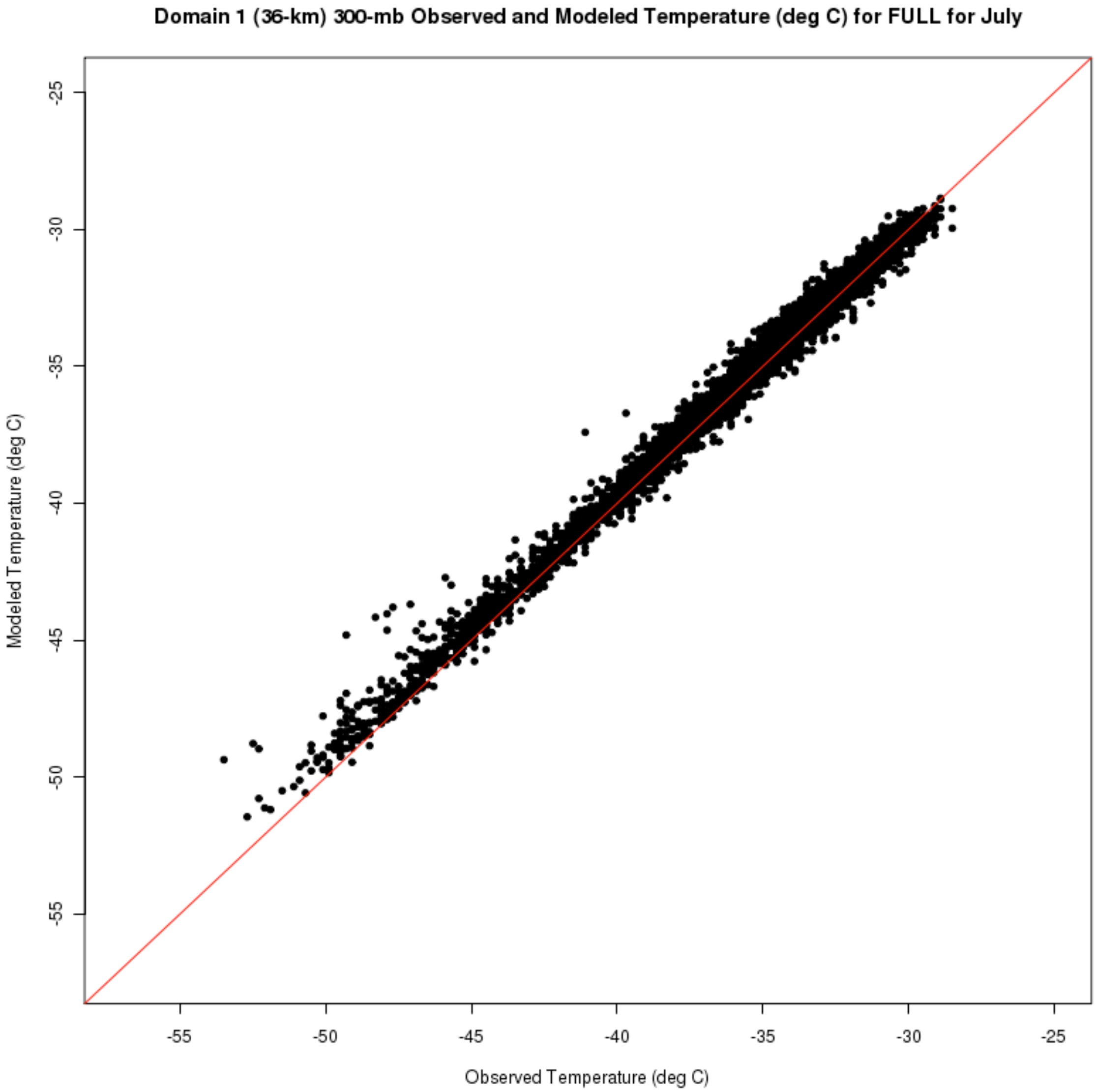
Similarly to the previous section, the following section will mostly show scatter plots at the 500-mb level as these are very representative of the scatter plots at 300 mb.

5.1.5.3.1 Temperature

The scatter plots of temperature for both the 500-mb and 300-mb levels show that the observations and model data are well correlated with just a few significant outliers. The correlation weakens a bit during July especially at locations with colder 500 mb temperatures at the low end of the plot. The last plot shows the 300 mb temperature scatter plot which shows a slight positive bias at the coldest temperatures with observations slightly colder than the WRF simulation.

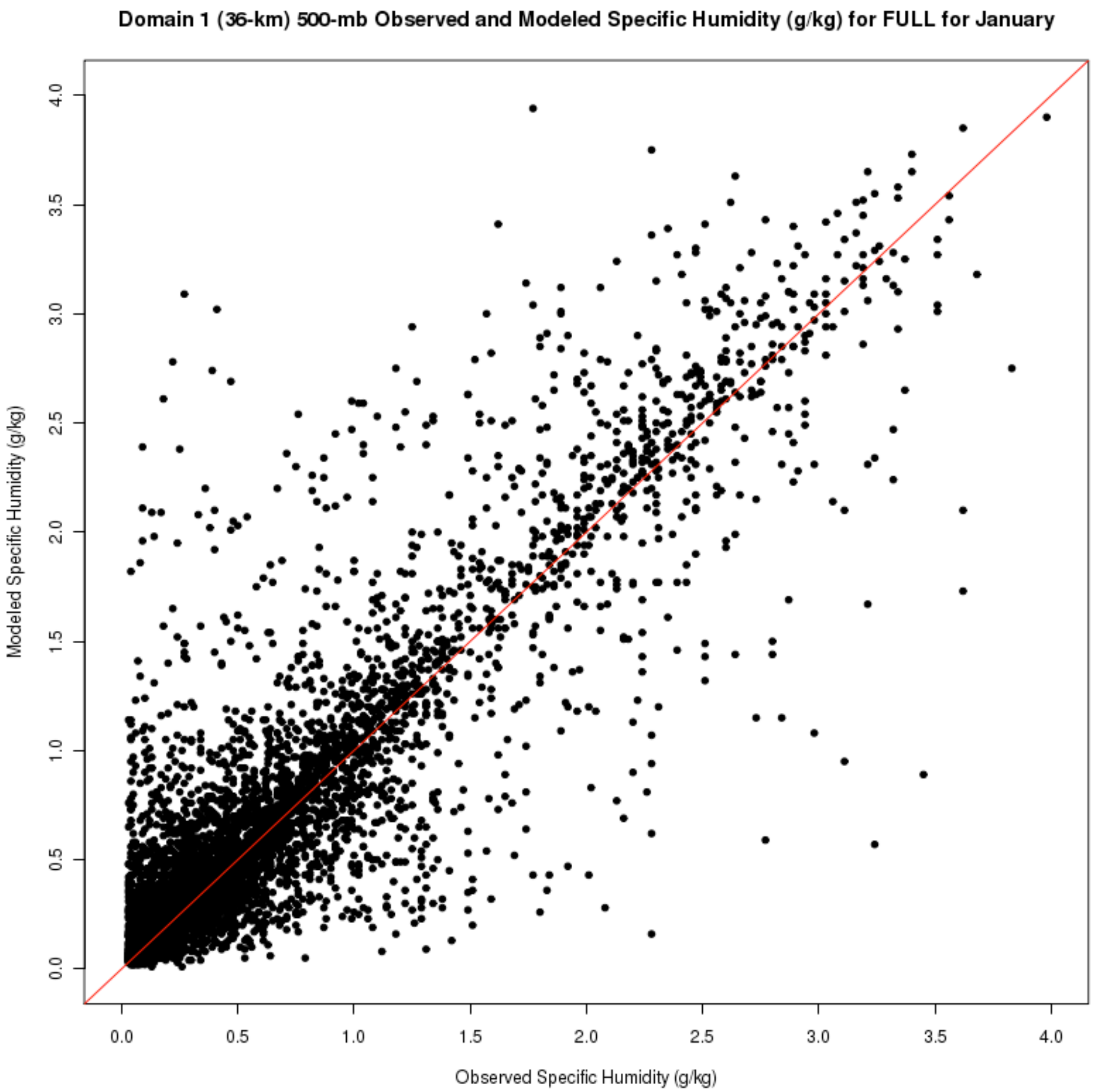

Domain 1 (36-km) 500-mb Observed and Modeled Temperature (deg C) for FULL for January
Modeled Temperature (deg C)
Observed Temperature (deg C)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0


Domain 1 (36-km) 500-mb Observed and Modeled Temperature (deg C) for FULL for July
Modeled Temperature (deg C)
Observed Temperature (deg C)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

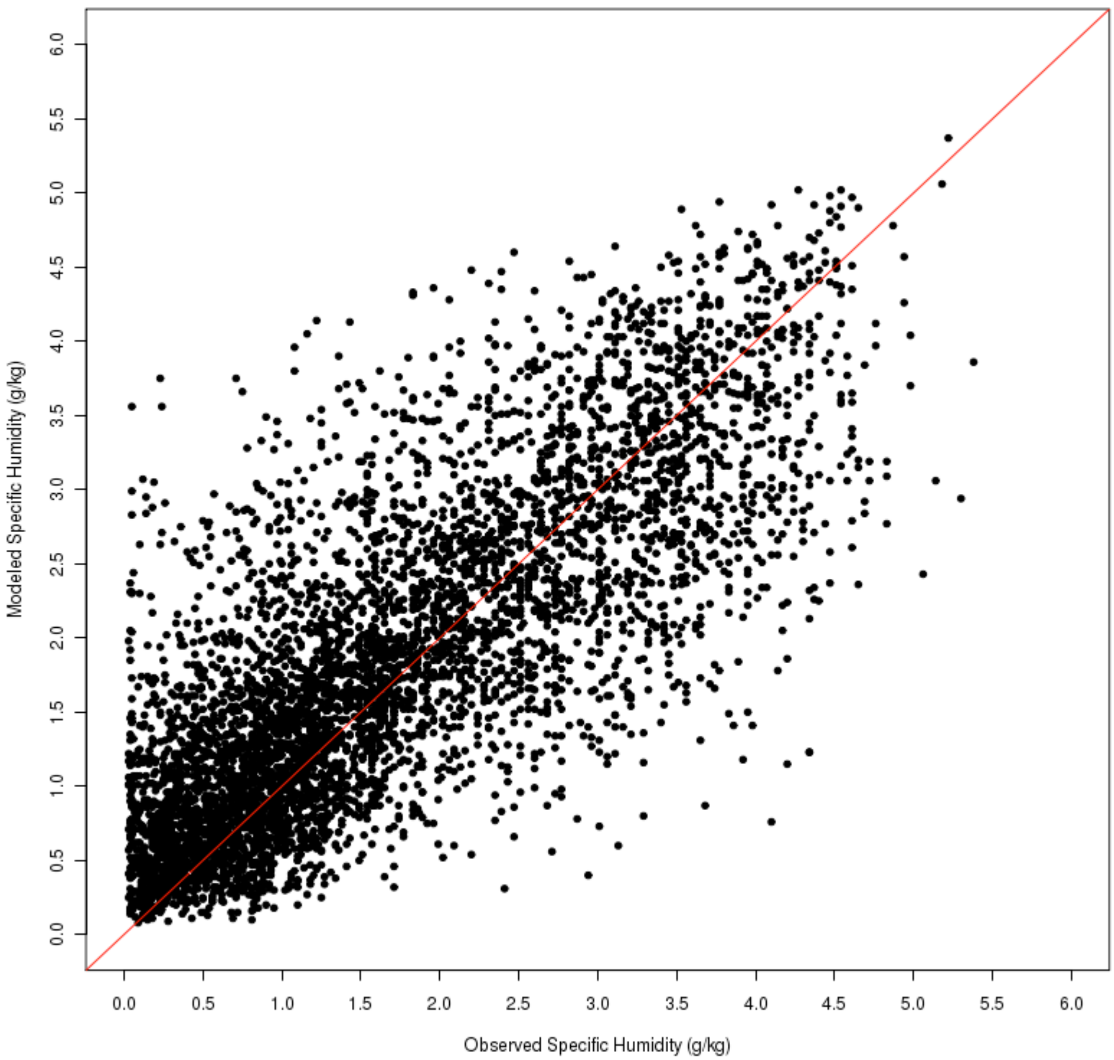


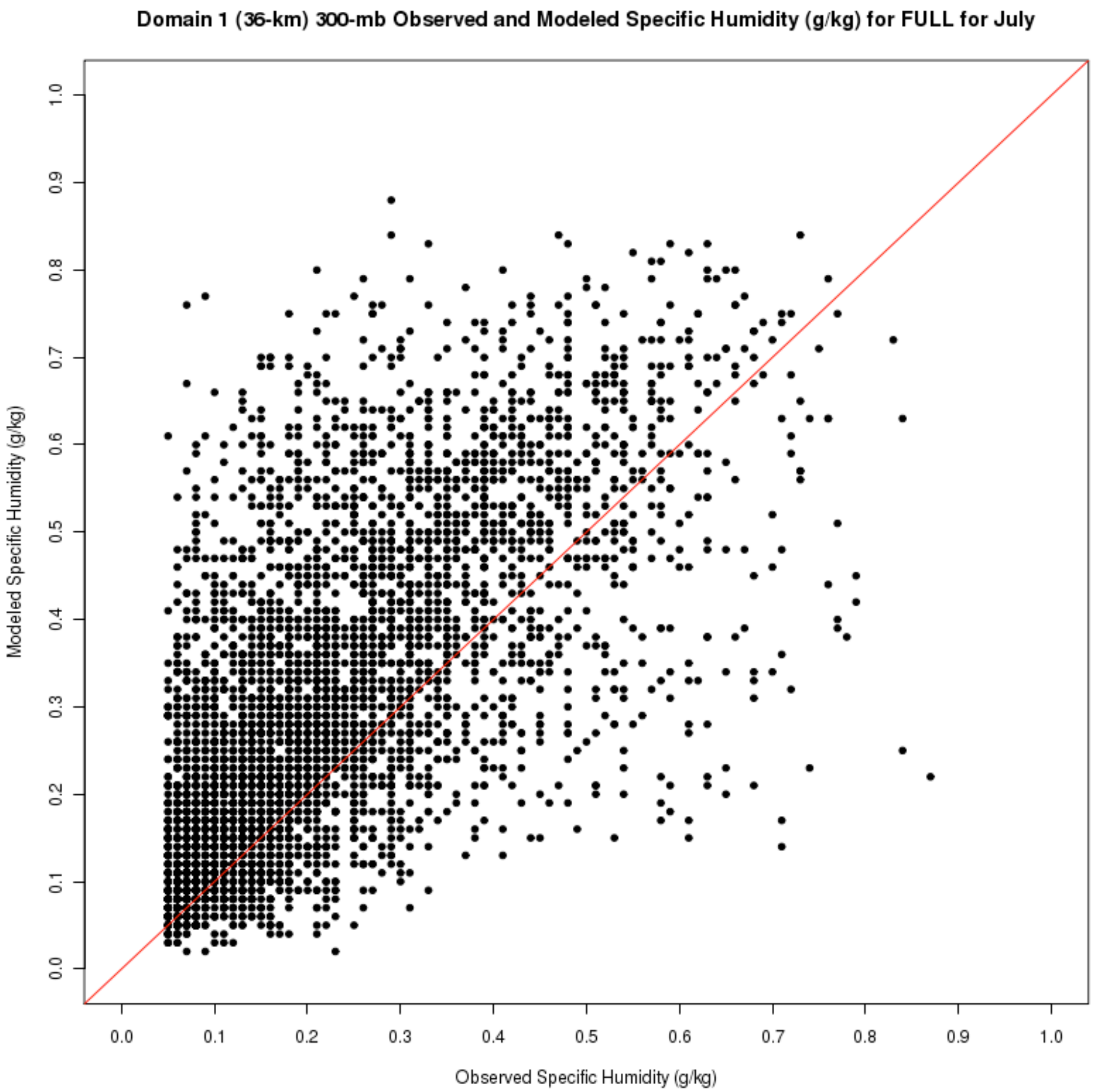
5.1.5.3.2 Specific Humidity

The specific humidity scatter plots for the 500-mb and 300-mb levels similar to the previous section show that the correlation between the observed and modeled data is better at low moisture values, in this case under about 1.5 g/kg. There does not appear to be any significant bias in these data as the points are evenly distributed to the left and right of the red 1:1 line. As with the July scatter plot for 850 mb, the data is more spread out and the correlation appears a bit weaker. At 300 mb, a significant positive bias in the specific humidity is noted for July with a majority of the points left of the 1:1 line indicating that the model is producing values that are higher than the observed values.


Domain 1 (36-km) 500-mb Observed and Modeled Specific Humidity (g/kg) for FULL for January
Modeled Specific Humidity (g/kg)
Observed Specific Humidity (g/kg)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

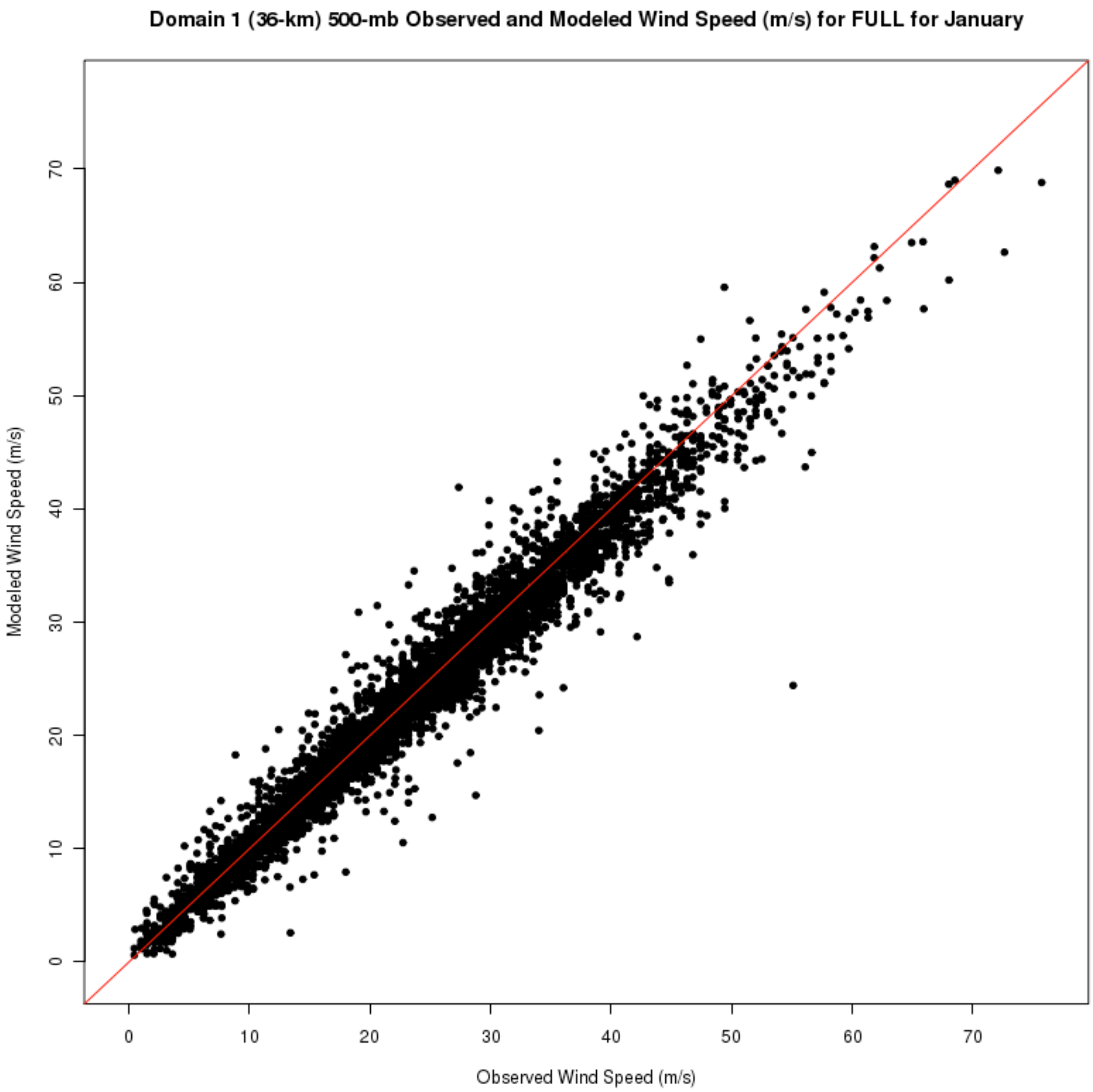
Domain 1 (36-km) 500-mb Observed and Modeled Specific Humidity (g/kg) for FULL for July

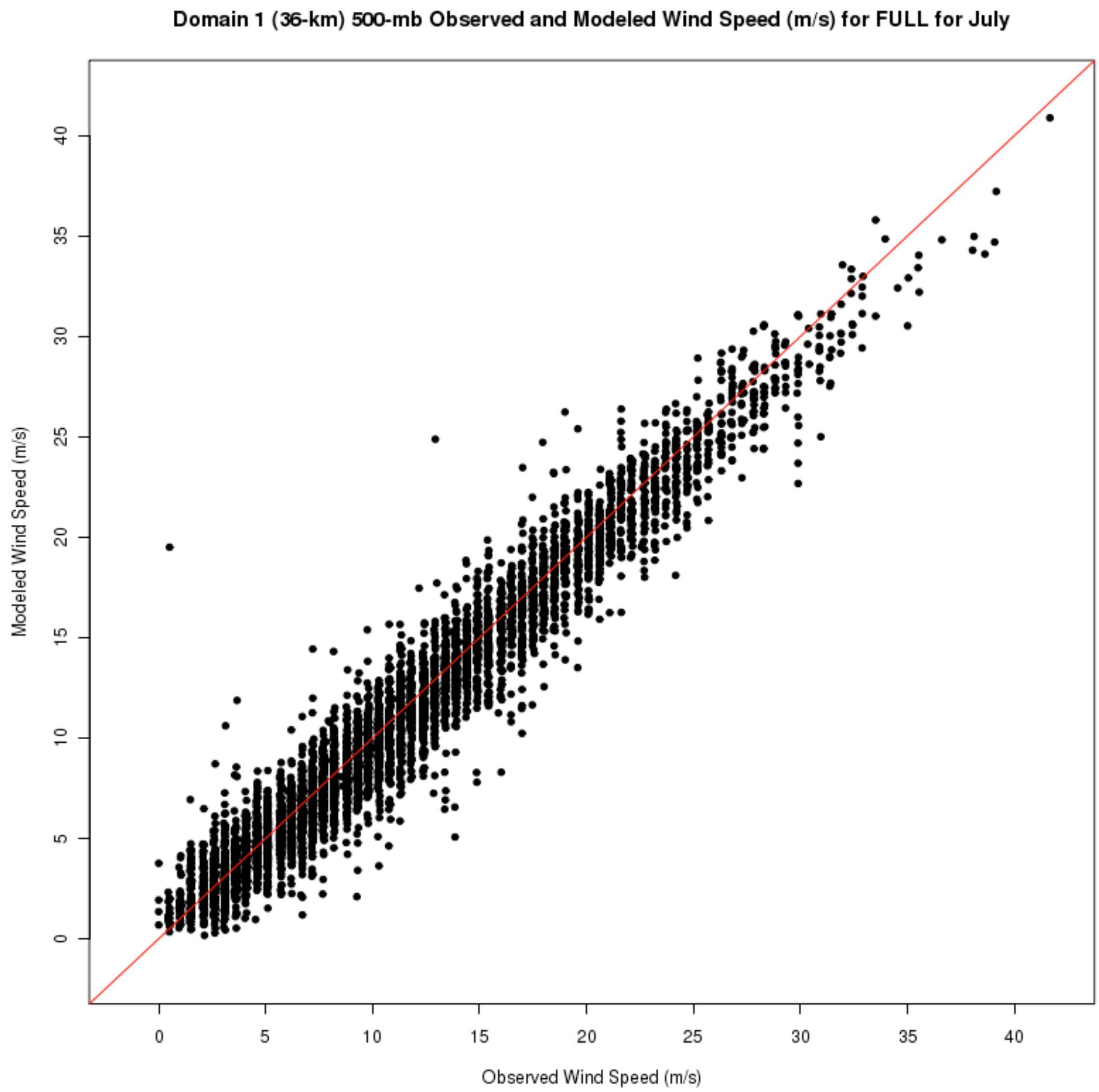




5.1.5.3.3 Wind Speed

At the 500-mb level, the observed and modeled wind speeds are well correlated with perhaps a slight negative bias in the WRF model output at wind speeds in excess of about 50 m/s. This pattern is similar for the month of July with observed wind speeds greater than the modeled wind speeds at the high end of the plot as well.


Domain 1 (36-km) 500-mb Observed and Modeled Wind Speed (m/s) for FULL for January
Modeled Wind Speed (m/s)
Observed Wind Speed (m/s)
0
10
20
30
40
50
60
70



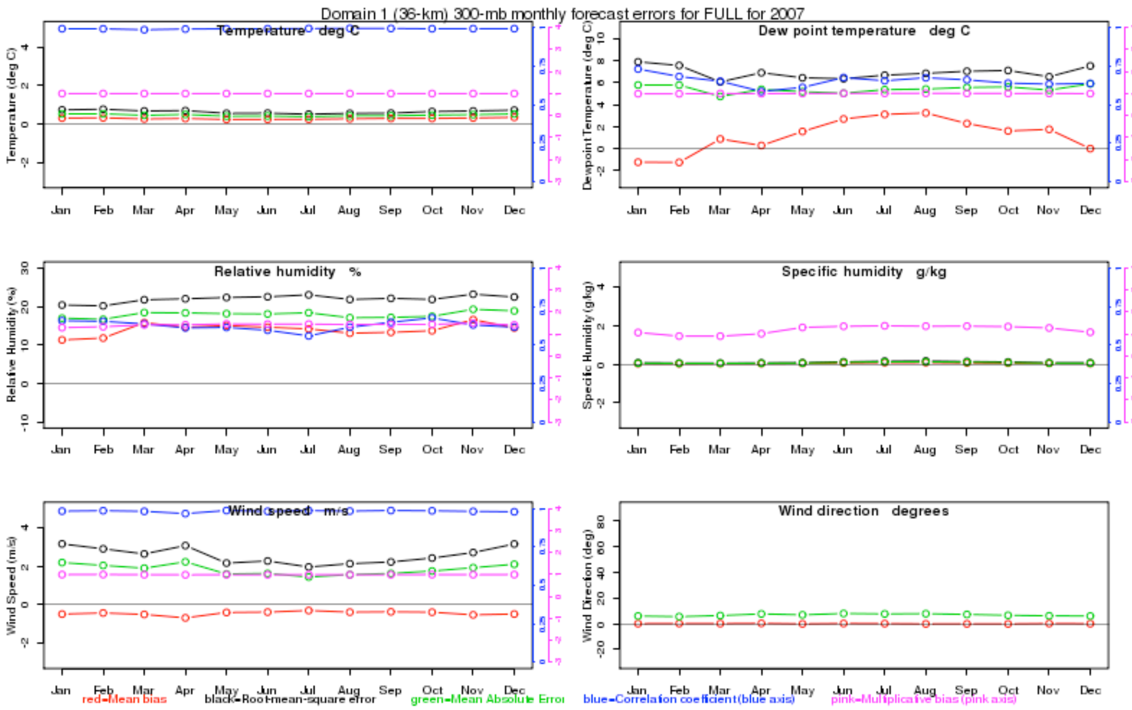
5.1.6 Tasks 2 I and 5 C: Line plots of error statistics

The following section reports on the error statistics of the FULL region (the entire model domains) of both domains 1 and 2. The analysis is conducted on 4 different pressure levels as well as the surface. The pressure levels analyzed with an approximate height levels in parenthesis are: 300 mb (9500 m), 500 mb (5750 m), 700 mb (3000 m), and 850 mb (1500 m). Additional plots for geographic sub-regions are available on the website.

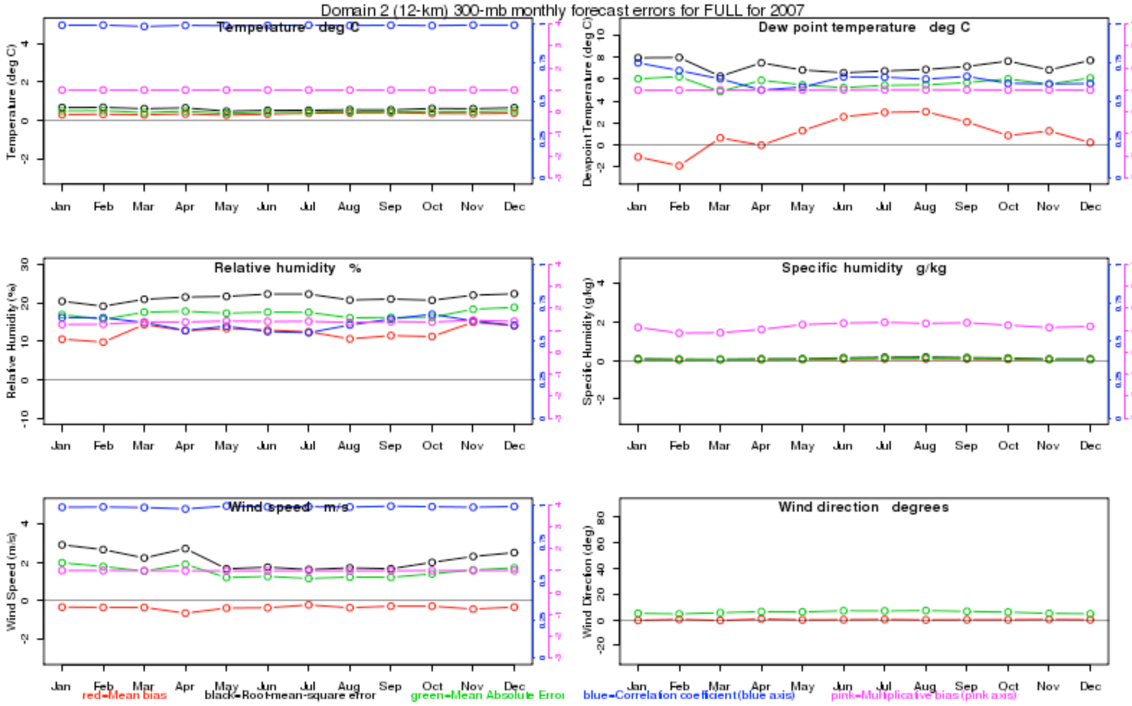
5.1.6.1 300 mb

The temperature time series shows that the WRF model has a slight, but consistent positive bias relative to the observations. The errors for temperature at this level are quite small between 0.5° C and 1.0° C below the 2.0° C maximum error target. The errors for the dew point temperature are quite large with a mean absolute error averaging about 6° C. The dew point temperature profile also shows that the modeled dew point transitions from a negative to neutral bias during the winter to a positive bias from late spring through summer. The error statistics for relative humidity are consistent with those for the dew point temperature. The positive bias in dew point contributes to a positive bias of 15-20% in relative humidity. The specific humidity, wind speed, and wind direction are generally well simulated at the 300 mb level. Correlations between the modeled and observed parameters are very high for temperature and wind speed, but indicate a weakened relationship for dew point and relative humidity. Differences between domain 1 and domain 2 at the 300 mb level were found to be minimal.

Domain 1



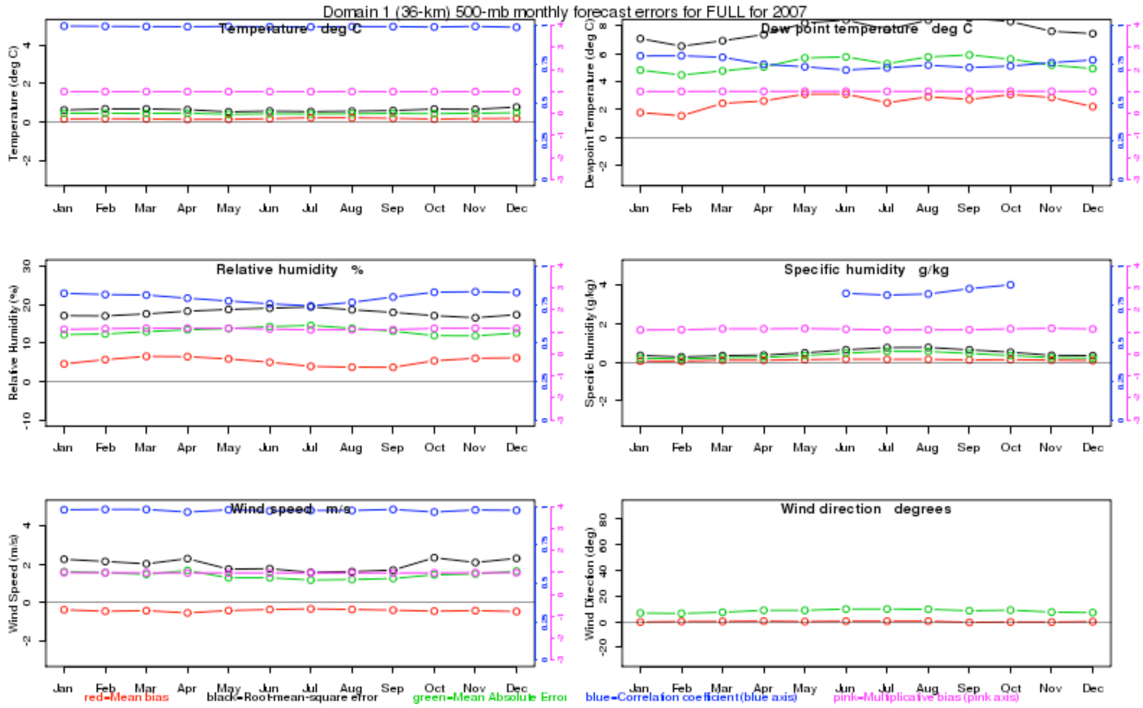
Domain 2



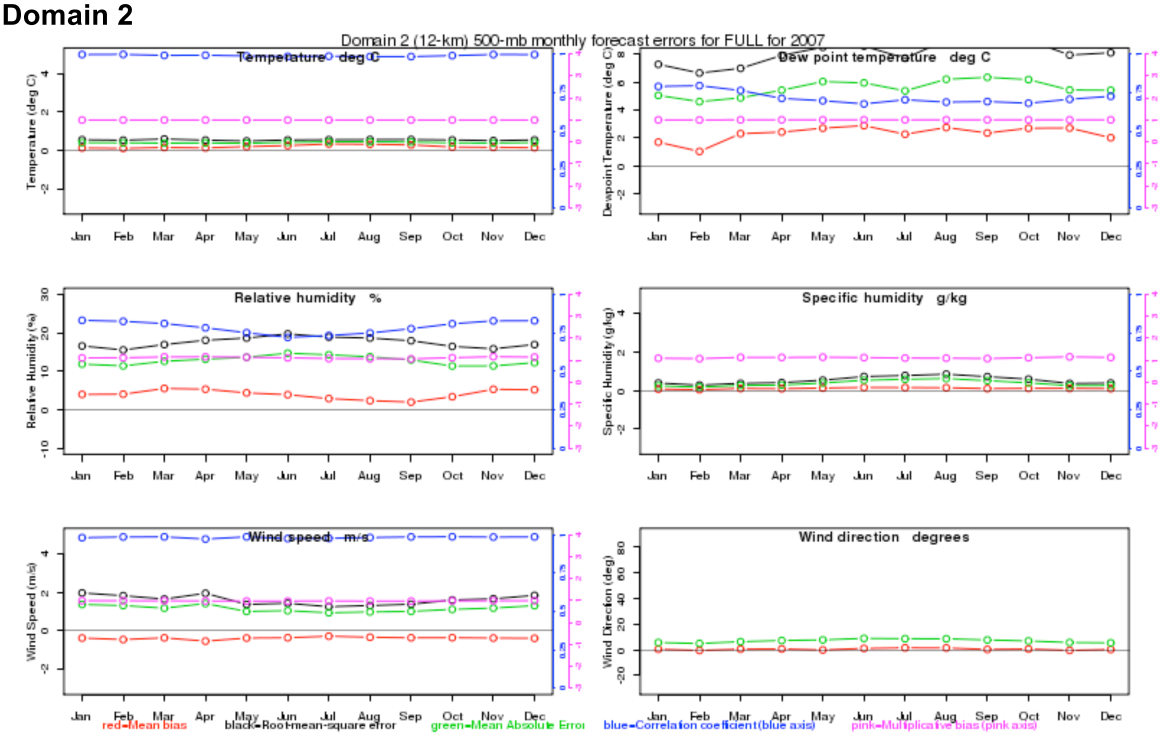
5.1.6.2 500 mb

The error statistics at 500 mb are very similar to those at 300 mb. The temperature is well predicted by the WRF model with errors consistently below the 2° C error metric and the bias at this level is minimal. The mean absolute errors for the dew point temperature are similarly high to the errors at 300 mb averaging near 6° C. The root mean squared error (RMSE) is somewhat higher than at 300 mb suggesting that very large errors in the dew point temperature are possible at the 500-mb level. The mean absolute error of the relative humidity field at the 500-mb level is slightly lower between 10 and 15% and the correlations between the WRF model simulation and the observations are significantly improved over those at the 300 mb. Specific humidity, wind speed, and wind direction continue to be well simulated at this level as well. Differences between domain 1 and domain 2 at the 500-mb level are minimal.

Domain 1



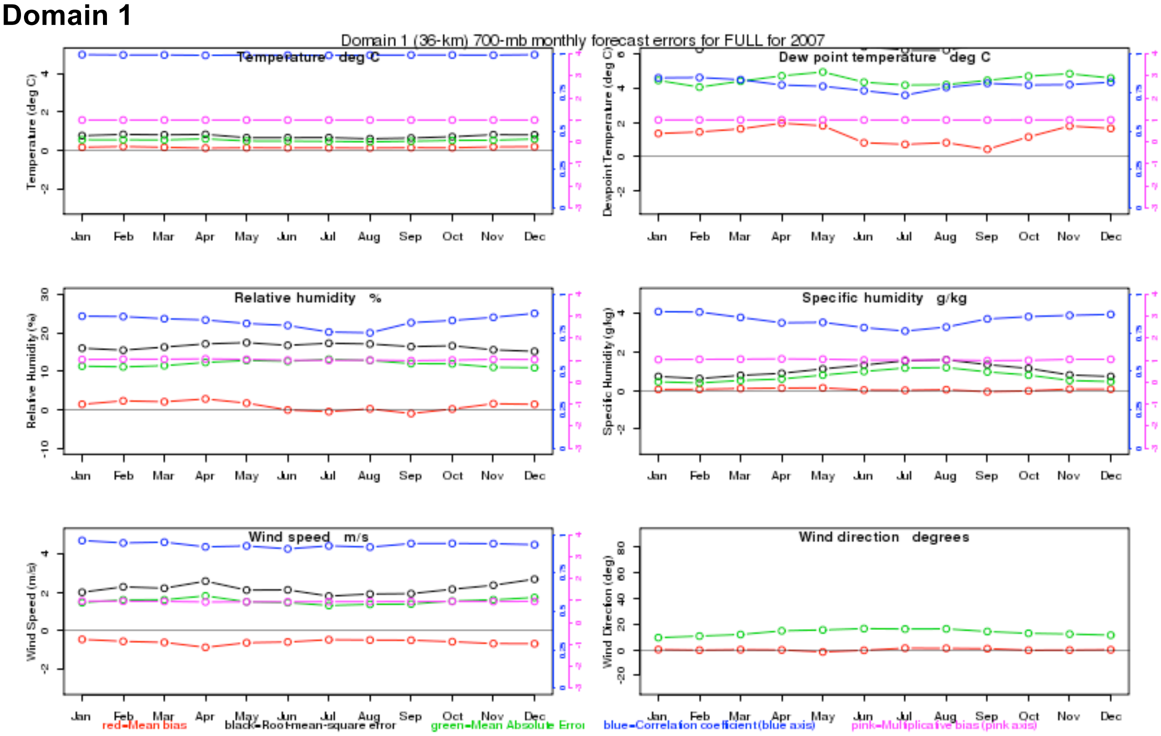
Domain 2



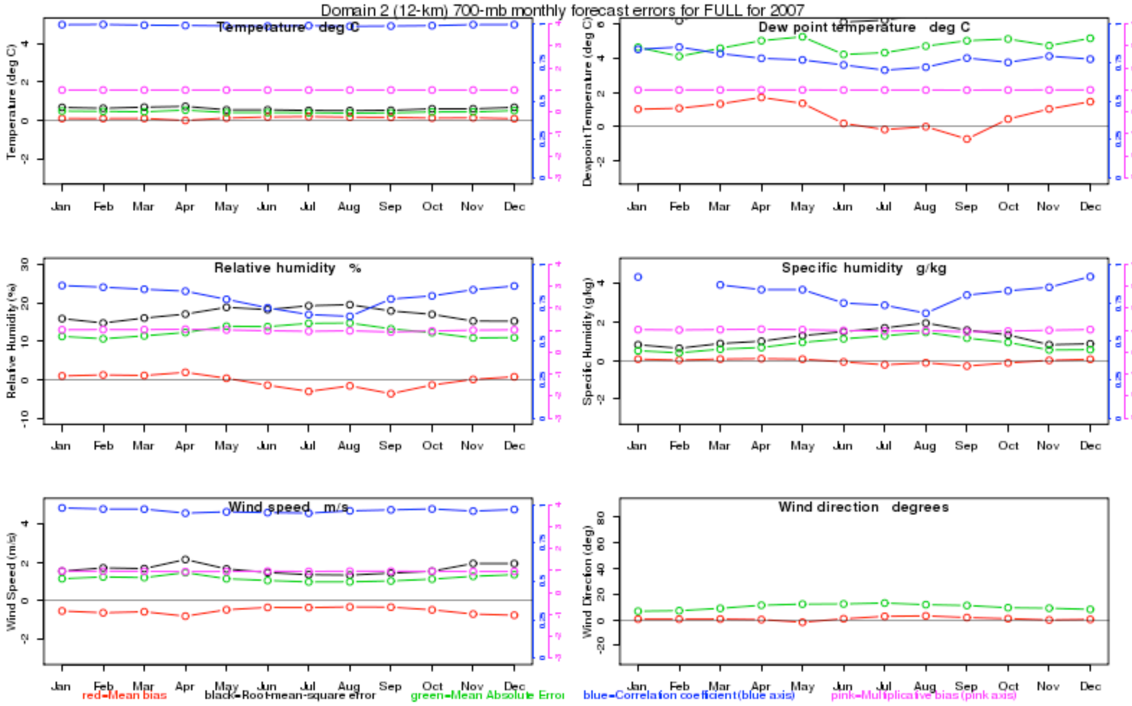
5.1.6.3 700 mb

The error statistics for temperature at the 700-mb level show the parameter to be well simulated by the WRF model. Absolute mean errors generally remain under 1° C and the model results are highly correlated with the observations. The dew point temperature has a positive bias during the cool season with errors that are quite large, generally exceeding 4° C. The observed bias also appears to be more significant for domain 1 than domain 2. The relative humidity has a mean absolute error of near 10% at this level, but the bias is neutral. At the 700-mb level, the specific humidity has nearly a 1 g/kg mean absolute error during the summer months. The modeled wind speed remains highly correlated with the observations at this level although the bias is slightly negative and the RMSE is close to the maximum RMSE target of 2 m/s. The wind direction errors are larger than at higher pressure levels, but have a mean absolute error of less than 20°. The wind parameters are generally modeled better in domain 2 than in domain 1.

Domain 1



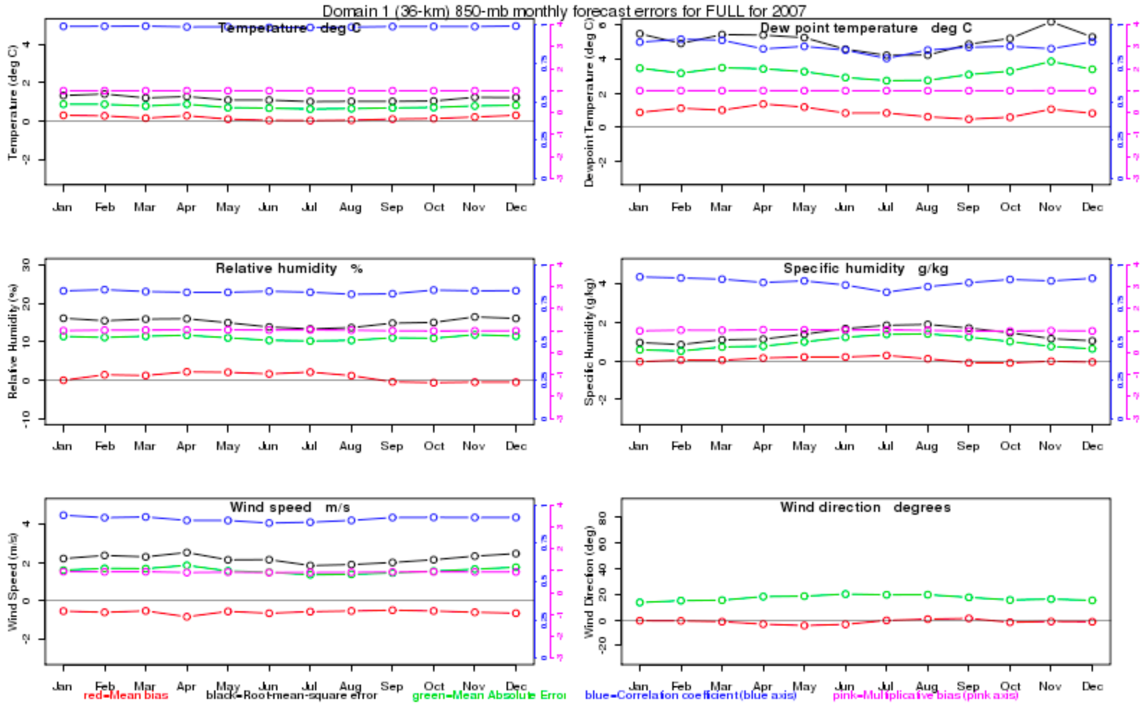
Domain 2



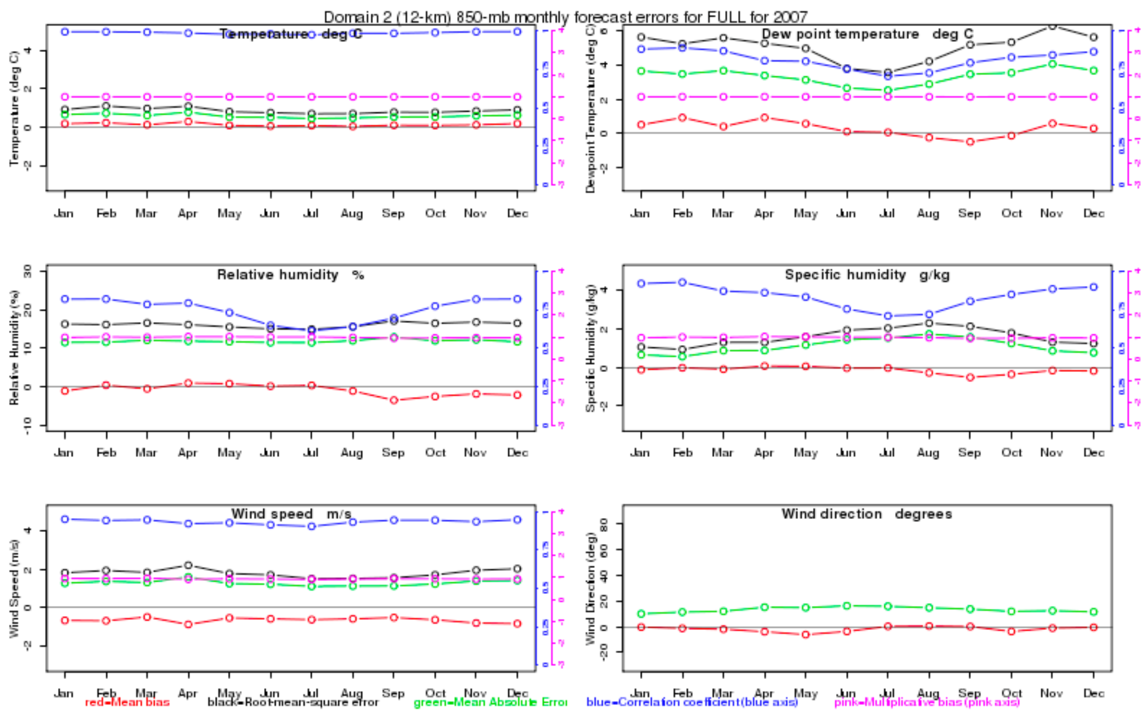
5.1.6.4 850 mb

The 850-mb temperature is well simulated by the WRF model and remains highly correlated with the observations. The 850-mb dew point temperature maintains a slight positive bias in domain 1 that does not appear in domain 2. The mean absolute errors and RMSE are moderately reduced as compared with those at the 700-mb level. The correlation between the modeled dew point and the observations also improves slightly. The relative humidity at this level has small bias and mean absolute errors that are near 10%. Although the bias is small, the mean absolute errors for specific humidity during the summer months approach 2 g/kg. The correlations for relative humidity and specific humidity are much higher during the same period for domain 1 than domain 2. The WRF model wind speed remains highly correlated with the observations at the 850-mb level although the bias is slightly negative and the RMSE is near the maximum RMSE target of 2 m/s. Wind direction errors are near 20° in domain 1, but decrease somewhat for domain 2. The wind parameters are, similar to the 700-mb level, modeled better in domain 2 than in domain 1.

Domain 1



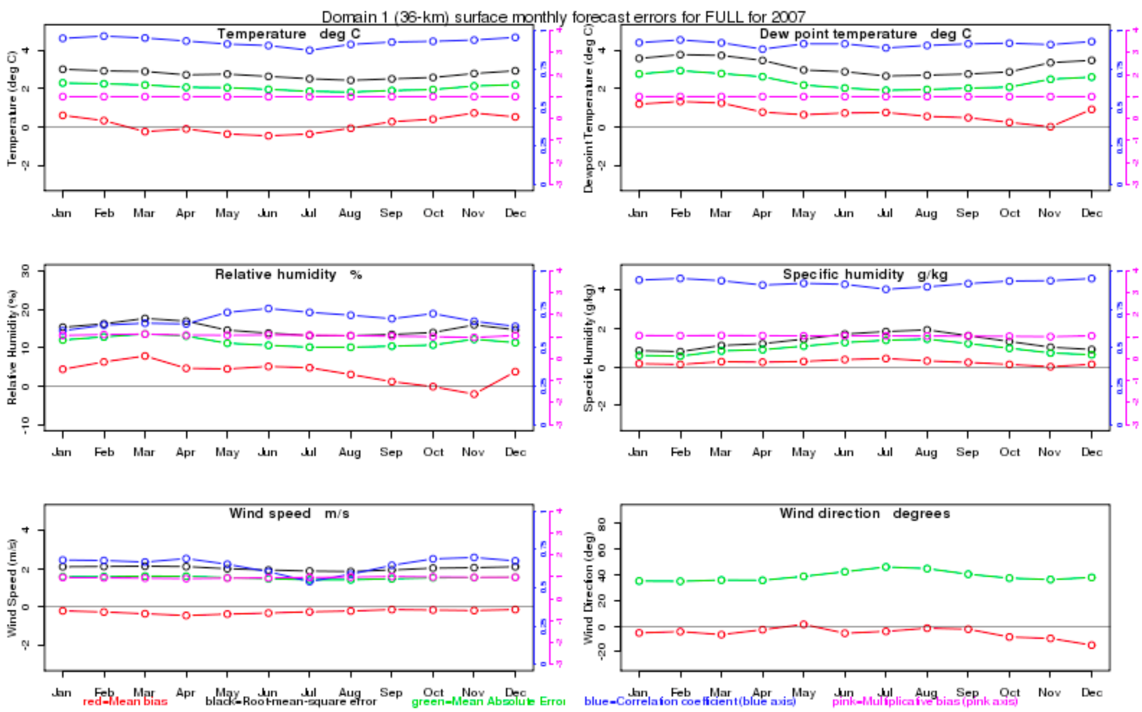
Domain 2



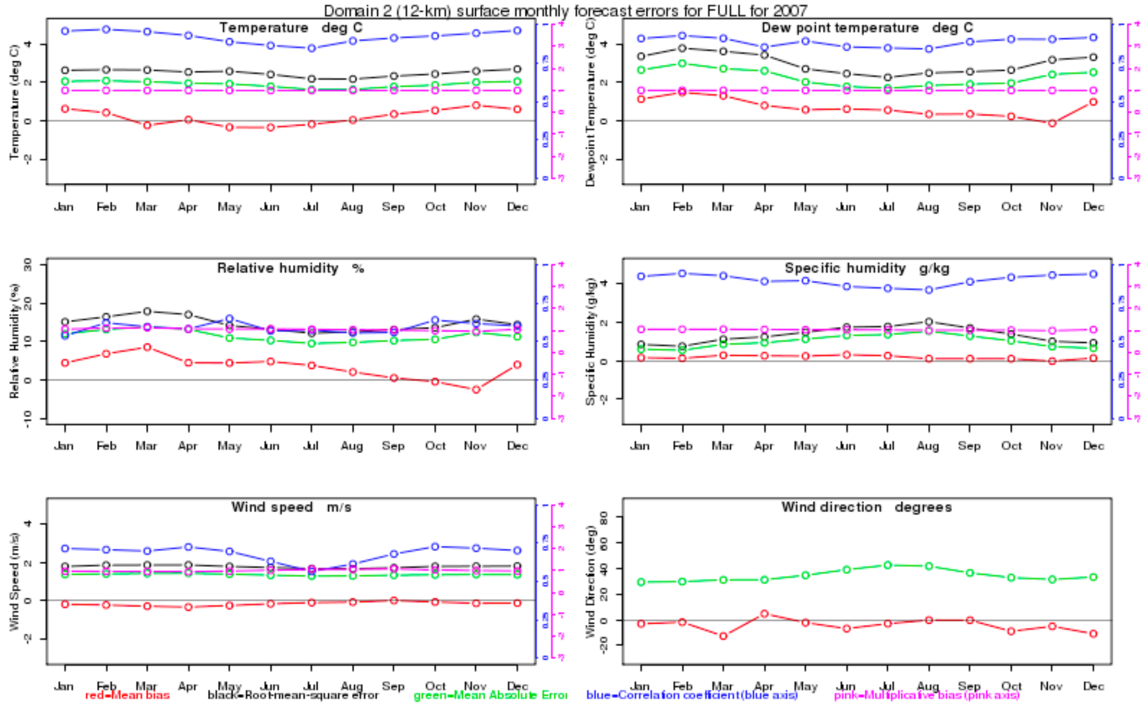
5.1.6.5 Surface

The temperature errors increase significantly at the surface as compared with pressure levels above the surface. Although the bias remains relatively small, the mean absolute errors are close to 2° C, which is very near the maximum error target. The modeled temperatures have slightly better error statistics for domain 2 than domain 1. The dew point temperatures simulated by the WRF model have a positive bias during the winter months, but a more nearly neutral bias the rest of the year. The mean absolute errors are highest during the cool season with values approaching 3° C, larger than the target threshold of 2° C. The biases found in the relative humidity field are similar to the dew point temperature – larger in the winter months and more neutral during the remainder of the year. The correlations for the relative humidity parameters fall significantly for domain 2. The mean absolute errors for specific humidity are largest during the summer and slightly larger for domain 2. The bias in the specific humidity field at the surface is neutral. The surface wind speed mean absolute errors are near 2 m/s, but the bias is minimal. The modeled wind direction at the surface has the largest error of any of the levels that have been examined. There is a mean absolute error of roughly 40° that far exceeds the maximum target given for gross error in wind direction.

Domain 1

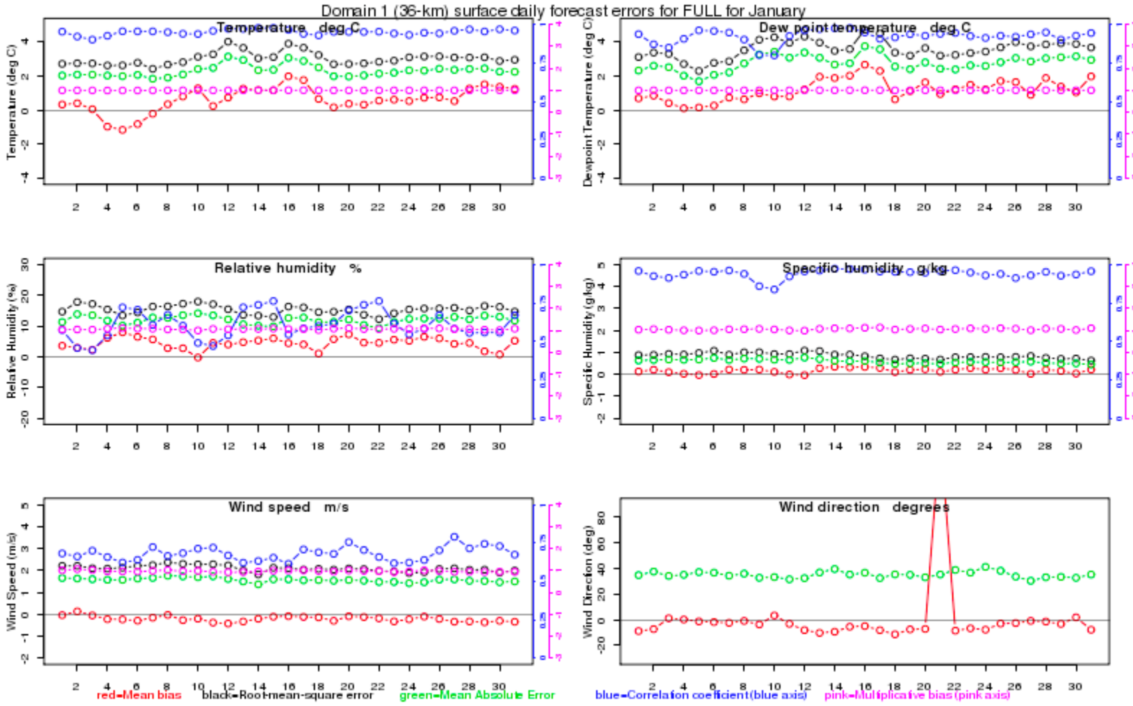


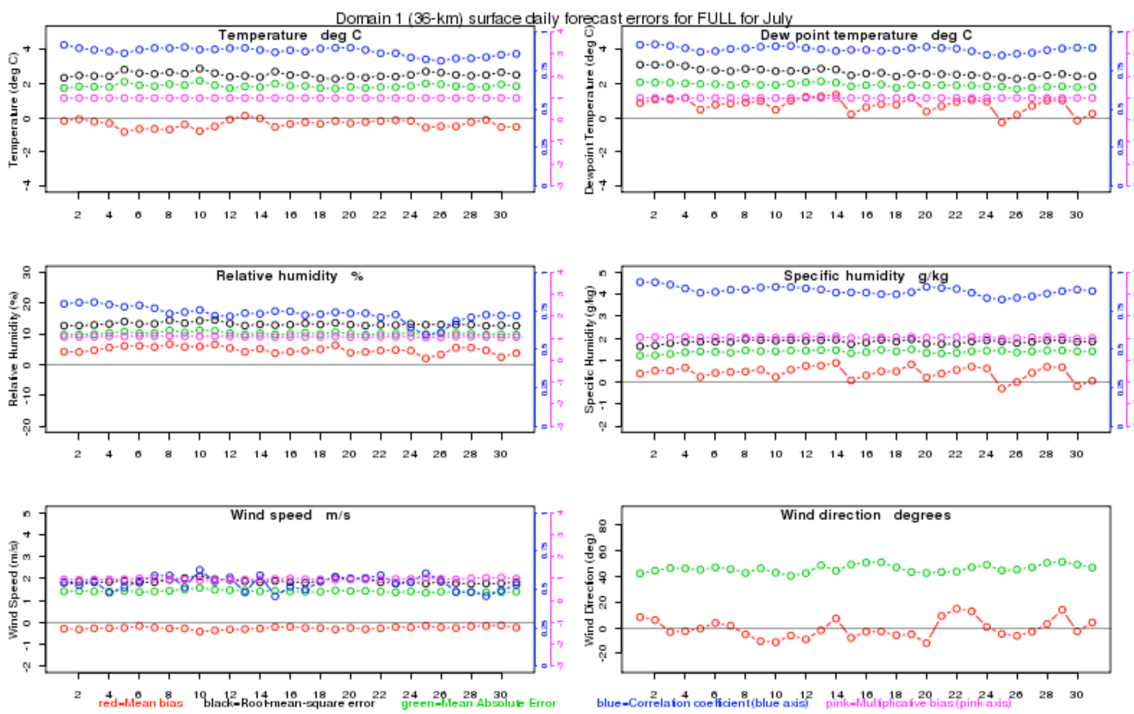
Domain 2



5.1.6.6 Monthly plots (surface)

Monthly plots from January and July in domain 1 are shown below to highlight the seasonality of the WRF model performance at the surface. The January plot shows that temperatures at the surface are more strongly correlated with the observations than in July; however, the mean absolute error remains relatively large near 2° C. The dew point temperature shows a similar pattern except that it runs a more consistent positive bias especially during the month of January. The mean absolute errors in relative humidity are larger in the month of January and, as with dew point temperature, there is a slight positive bias for this period. The correlation coefficient between the relative humidity modeled by WRF and the observations are depressed especially in January, most likely a result of the larger absolute error and observed variability in dew point temperature errors. The mean absolute errors in the specific humidity are slightly larger in July, but this is likely due to higher moisture availability during the warm season. The mean bias data for specific humidity shows that generally the WRF over predicts the specific humidity in July. Wind speeds, consistent with earlier results, have mean absolute errors of under 2 m/s, with very small bias during both January and July. Wind direction errors are quite large around 40° at the surface, as the model is likely not simulating the frictional effects near the surface particularly well.





5.1.7 Task 5 B 4: Tables of Annual Statistics

This section presents summary tables of annual statistics for domain 2 modeled fields for each region. These tables are available on the project web site in Task 5 B 4. Brief discussion is provided for the regions FULL and SEMAP. For the metrics that are compared to the target ranges in Section 2.6, green indicates that the modeled error lies within the target range, while red indicates that is lies outside the target range. This simple color coding is only designed to highlight model performance and should not be construed as a simple pass/fail judgment. The reader should be reminded that the values contained in Section 2.6 are target values from the historical record. Note that rounding may introduce small disagreements between values in different columns.

5.1.7.1 FULL

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature (degrees C)	18082480	12.7	12.6	0.2	1.9	2.5	0.92	1.001
Dew Point Temperature (degrees C)	16272421	7.4	6.8	0.7	2.2	3.0	0.89	1.002
Relative Humidity (%)	16272365	73.2	69.8	3.4	11.4	14.6	0.59	1.049
Specific Humidity (g/kg)	17015610	8.0	7.9	0.2	1.0	1.3	0.90	1.028
Wind Speed (m/s)	17648777	3.4	3.5	-0.2	1.4	1.8	0.68	0.994
Wind Direction (degrees)	17648777			-4.2	34.6			

5.1.7.1.1 Temperature

Annual MAEs for temperature lie within the target value and daily values do not exhibit any unexpected characteristics. Daily MAE values are largest, often upwards of 2.5 degrees Celsius, for a number of days during the cold months of November through April, with summertime values at times below 1.5 degree Celsius. Some of the larger daily errors are clustered together in time, often in five-day segments, which strongly indicates that individual model runs suffered from poor initialization. Annual values of mean bias are small. Daily values during the summer almost exclusively are within 1 degree Celsius, while the most extreme values occurred during the three other seasons. The spring and early summer from March through July produced the vast majority of days with a negative temperature bias. Days with the largest positive bias occurred mostly from October through April. An especially poor period with large (positive) forecast errors occurred in early April.

5.1.7.1.2 Dew Point Temperature

The annual mean bias of 0.7 degrees indicates that, on average, modeled dew point temperatures were higher than observed. Significantly contributing to this domain-wide bias is the widespread over-prediction of dew point temperatures in the northern parts of the modeling domain during the colder months. This problem persists from December through April. The MAEs are notably larger during the winter months, again predominantly in the northern part of the modeling domain. Problems with snow cover in the model may be a contributing factor.

5.1.7.1.3 Relative Humidity

Annual mean bias values also indicate modeled fields with slightly higher levels of relative humidity than observed. The occurrence of days with over-predicted relative humidity is concentrated strongly in December and from January through May and, again, in the northern parts of the modeling domain. March, by far, has the most days with the largest mean bias values. The only months with daily negative mean bias values of magnitude greater than 5% are October and November. The overall annual MAE of 11.4% is generally representative of individual daily MAE values. As might be expected, there is a minimum during the summer months, while maximum winter gross errors exceed 15% on a handful of days.

5.1.7.1.4 Specific Humidity

A small positive mean bias, well within the target range, is seen in the annual specific humidity field, which agrees with the characteristics of the dew point temperature and relative humidity. A positive bias in the Northeastern states is present during March and April. The magnitude, persistence and large-scale nature of this bias, especially during the cold season when absolute values of the atmospheric moisture are at a minimum, again suggests a link to how the model handles snowcover. MAE values overall are very close to the target value and are largest south of 40 ^{o}N latitude during the months of August and September. The lack of a widespread and persistent mean bias signature at this time, indicative of errors all of the same sign, suggests that the larger MAE values may be largely due to the fact that atmospheric moisture content is close to its maximum and thus subject to the largest error.

5.1.7.1.5 Wind Speed

The annual mean bias lies within the target range, and both it and the MAE are quite small and show no significant temporal variability during the course of the year. MAE errors overall are slightly higher in the northern parts of the modeling domain in the winter and spring when overall wind speeds are highest and the passage of synoptic weather systems increases the variability of the wind field. The annual RMSE is slightly less than the target of 2 m/s.

5.1.7.1.6 Wind Direction

(Note that, by convention, wind direction indicates the direction from which the wind is blowing. Here we denote, for instance, zero degrees as a North wind, 90 degrees as an East wind and -90 degrees as a West wind.) While the mean bias is well inside the target range, the MAE is slightly larger than the target value of 30 degrees. Thus, while there are substantial deviations from the observed wind, they do not exhibit a substantial bias in direction. The wind direction field is strongly affected by local topography, and, while there are no expansive and persistent regions of significant mean bias, individual stations for any one day can exhibit large biases. These individual episodes of large bias are likely tied to poor modeling of synoptic features and can be sufficiently persistent to affect monthly averages, especially in mountainous or otherwise elevated terrain. Indeed, such areas suffer from the largest and most persistent MAE values. This is most noticeable in the Appalachian mountains throughout the year. During the summer months with lighter winds, individual sites throughout the modeling domain can suffer at times from large MAE values.

5.1.7.2 SEMAP

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	3250685	17.9	17.6	0.3	1.8	2.3	0.81	1.001
Dew Point Temperature	3104743	10.9	10.6	0.4	2.2	2.8	0.78	1.001
Relative Humidity	3104716	68.9	67.5	1.5	11.2	14.2	0.47	1.021
Specific Humidity	3107904	9.6	9.5	0.2	1.2	1.5	0.76	1.019
Wind Speed	3139180	2.5	2.6	-0.0	1.3	1.6	0.52	1.115
Wind Direction	3139180			-1.5	42.8			

5.1.7.2.1 Temperature

Annual MAEs for temperature lie within the target value and daily values do not exhibit any unexpected characteristics. Daily MAE values are largest, often upwards of 2.5 degrees Celsius, for a number of days during the cold months of October through April, with summertime values mostly below 2 degrees Celsius. Some of the larger daily errors are clustered together in time, often in five-day segments, strongly indicating that individual model runs suffered from poor initialization. As for FULL, an especially bad forecast segment occurred in early April. Annual values of mean bias are small and, again, do not indicate a problem. Daily values during the summer almost exclusively are within 1 degree Celsius, while the most extreme values occurred during the three other seasons. During these cooler seasons, individual days exhibit the largest mean biases, sometimes in excess of 2.5 degrees Celsius.

5.1.7.2.2 Dew Point Temperature

The annual mean bias of 0.4 degrees indicates that, on average, modeled dew point temperatures were higher than observed. Of note are the episodes of poorly predicted dew point temperatures centered over North Carolina during November. Detailed analysis is beyond the scope of this project, but during this month there were a number of consecutive days that exhibited large negative mean bias values. The largest MAEs are found in the mountainous or otherwise elevated regions.

5.1.7.2.3 Relative Humidity

Annual mean bias values also indicate modeled fields with slightly higher levels of relative humidity than observed. The occurrence of days with under-predicted relative humidity is concentrated strongly in November, as noted above for dew point temperature. During the rest of the year, there is a predominance of positive daily mean bias of up to 10-15%. The annual MAE of 11.2% is generally representative of individual daily MAE values. As might be expected, there is a minimum during the summer months, while maximum winter gross errors exceed 15% on a handful of days. These are focused somewhat during the month of November.

5.1.7.2.4 Specific Humidity

A small positive mean bias, well within the target range, is seen in the annual specific humidity field, which agrees with the characteristics of the dew point temperature and relative humidity. A positive bias, with a corresponding increase in MAE, in some individual locations that are mostly located in mountainous terrain or plateaus, develops during the summer, peaks in August, then diminishes during the fall. Mean bias values in the fall and early winter are then near zero or slightly negative. It is hypothesized that the positive bias that peaks in August may reflect inadequate model representation of topography, with model locations being positioned at lower elevations than in reality and subjected to higher values of PBL moisture in an otherwise horizontally-uniform moisture environment.

5.1.7.2.5 Wind Speed

The annual mean bias and MAE both lie within the target range and show no important temporal variability during the course of the year. The annual RMSE is acceptably less than the target of 2 m/s.

5.1.7.2.6 Wind Direction

The mean bias for SEMAP lies within the target range, while, as for FULL, the MAE is slightly larger than the target of 30 degrees. As for FULL, deviations of the wind from observed while large do not exhibit a substantial bias in direction. This meteorological field is strongly affected by local topography, and, while there are no expansive and persistent regions of significant mean bias (since the signs of the individual errors often cancel), regions of mountainous topography do suffer from the largest and most persistent MAE values. Along the spine of the Appalachian mountains, it is commonplace throughout the year to exceed the target MAE value. During the summer months with lighter winds, individual sites throughout the modeling domain can suffer at times from large MAE values.

5.1.7.3 CENRAPN

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	3251073	9.4	9.2	0.2	2.0	2.4	0.82	1.001
Dew Point Temperature	3246133	4.2	3.4	0.8	2.3	2.8	0.74	1.003
Relative Humidity	3246133	74.3	70.4	3.9	11.2	13.8	0.52	1.054
Specific Humidity	3246299	6.9	6.7	0.2	0.9	1.1	0.74	1.052
Wind Speed	3232104	3.8	4.0	-0.2	1.3	1.6	0.63	0.999
Wind Direction	3232104			-5.7	31.0			

5.1.7.4 CENRAPS

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	3034465	18.4	18.0	0.5	1.8	2.3	0.74	1.002
Dew Point Temperature	3014970	11.4	11.7	-0.3	2.1	2.7	0.75	0.999
Relative Humidity	3014970	68.5	70.5	-2.0	10.8	13.6	0.50	0.967
Specific Humidity	3015096	10.1	10.3	-0.2	1.2	1.5	0.70	0.975
Wind Speed	2969315	3.1	3.3	-0.2	1.3	1.6	0.60	1.013
Wind Direction	2969315			-1.0	35.9			

5.1.7.5 MANEVU

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	2002709	9.8	9.9	-0.2	1.8	2.3	0.82	0.999
Dew Point Temperature	1914305	5.2	3.5	1.7	2.6	3.2	0.66	1.006
Relative Humidity	1914304	77.4	68.0	9.4	13.4	16.4	0.44	1.157
Specific Humidity	1923324	6.8	6.3	0.4	0.9	1.2	0.64	1.132
Wind Speed	1895332	3.0	3.1	-0.1	1.4	1.7	0.49	1.049
Wind Direction	1895332			-4.3	41.0			

5.1.7.6 MRPO

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	2919819	9.9	9.8	0.1	1.9	2.5	0.77	1.000
Dew Point Temperature	2750615	5.1	4.0	1.1	2.3	3.0	0.67	1.004
Relative Humidity	2750615	75.6	69.8	5.8	11.8	14.5	0.48	1.085
Specific Humidity	2751158	6.9	6.6	0.3	0.9	1.1	0.69	1.074
Wind Speed	2898290	3.4	3.5	-0.1	1.3	1.7	0.53	1.063
Wind Direction	2898290			-9.3	37.2			

5.1.7.7 AL

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	267984	18.5	18.1	0.4	1.9	2.2	0.54	1.002
Dew Point Temperature	259275	11.5	11.0	0.6	2.2	2.6	0.52	1.002
Relative Humidity	259269	68.4	66.8	1.5	11.1	13.4	0.28	1.029
Specific Humidity	259281	9.9	9.5	0.4	1.2	1.5	NA	1.039
Wind Speed	257290	2.3	2.4	-0.1	1.2	1.5	0.29	1.303
Wind Direction	257290			4.8	47.1			

5.1.7.8 AR

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	329163	16.6	16.3	0.3	1.8	2.2	0.57	1.001
Dew Point Temperature	328968	10.0	9.9	0.1	1.9	2.3	0.53	1.000
Relative Humidity	328968	69.8	69.1	0.7	10.6	12.7	0.33	1.003
Specific Humidity	328984	9.3	9.2	0.1	1.0	1.2	NA	1.006
Wind Speed	316425	2.7	2.7	-0.0	1.2	1.5	0.40	1.164
Wind Direction	316425			-5.4	42.3			

5.1.7.9 DC

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	12369	14.5	14.8	-0.3	1.8	1.9	0.00	0.999
Dew Point Temperature	12369	6.4	6.5	-0.2	2.3	2.3	0.00	1.000
Relative Humidity	12369	63.7	60.4	3.3	11.9	11.9	0.00	1.063
Specific Humidity	12369	7.2	7.4	-0.2	1.0	1.0	NA	1.015
Wind Speed	12342	2.5	3.8	-1.3	1.6	1.6	0.00	0.591
Wind Direction	12342			27.6	32.2			

5.1.7.10 FL

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	677614	22.4	22.1	0.3	1.6	2.0	0.64	1.001
Dew Point Temperature	582110	16.4	16.1	0.3	1.9	2.4	0.48	1.001
Relative Humidity	582110	72.6	71.5	1.1	9.7	11.9	0.36	1.015
Specific Humidity	582161	12.4	12.3	0.1	1.3	1.7	0.51	1.009
Wind Speed	657579	2.6	3.2	-0.5	1.4	1.7	0.41	0.918
Wind Direction	657579			0.2	41.7			

5.1.7.11 GA

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	403666	18.7	18.2	0.4	1.9	2.4	0.57	1.002
Dew Point Temperature	399664	11.3	11.2	0.1	2.4	3.0	0.51	1.000
Relative Humidity	399653	67.1	67.6	-0.5	11.6	14.4	0.29	0.995
Specific Humidity	399751	9.8	9.7	0.1	1.3	1.7	0.65	1.001
Wind Speed	388828	2.4	2.2	0.2	1.2	1.5	0.34	1.589
Wind Direction	388828			-4.5	46.9			

5.1.7.12 IA

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	791648	10.3	10.1	0.2	1.9	2.2	0.65	1.001
Dew Point Temperature	791118	5.0	4.7	0.4	2.2	2.6	0.50	1.001
Relative Humidity	791118	74.5	71.8	2.8	10.6	12.5	0.34	1.034
Specific Humidity	791118	7.2	7.1	0.1	0.9	1.1	NA	1.031
Wind Speed	789918	3.8	4.0	-0.2	1.3	1.6	0.46	1.022
Wind Direction	789918			-4.8	30.9			

5.1.7.13 IL

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	812881	12.5	12.1	0.4	1.9	2.6	0.63	1.001
Dew Point Temperature	810870	6.5	5.6	0.9	2.5	3.4	0.45	1.003
Relative Humidity	810870	71.9	68.0	3.8	11.8	14.3	0.32	1.056
Specific Humidity	810884	7.5	7.2	0.3	1.0	1.4	0.61	1.061
Wind Speed	808417	3.2	3.6	-0.3	1.3	1.8	0.41	0.997
Wind Direction	808417			-7.7	40.4			

5.1.7.14 IN

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	226668	11.9	11.9	0.0	1.8	2.1	0.58	1.000
Dew Point Temperature	211546	6.6	5.6	1.0	2.2	2.5	0.53	1.004
Relative Humidity	211546	74.2	68.3	5.9	11.7	13.5	0.35	1.089
Specific Humidity	211562	7.5	7.1	0.3	0.9	1.1	NA	1.077
Wind Speed	225658	3.2	3.7	-0.5	1.3	1.6	0.36	1.083
Wind Direction	225658			-9.8	36.3			

5.1.7.15 KY

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	185936	14.6	14.6	-0.0	1.9	2.2	0.49	1.000
Dew Point Temperature	185352	8.4	7.4	0.9	2.3	2.7	0.45	1.003
Relative Humidity	185352	70.9	65.3	5.6	12.6	14.8	0.27	1.090
Specific Humidity	185355	8.3	7.9	0.4	1.1	1.3	NA	1.069
Wind Speed	178798	2.5	2.6	-0.1	1.2	1.5	0.30	1.404
Wind Direction	178798			-19.9	44.1			

5.1.7.16 LA

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	340415	20.1	19.8	0.3	1.8	2.2	0.51	1.001
Dew Point Temperature	325728	14.7	14.5	0.2	1.8	2.3	0.43	1.001
Relative Humidity	325728	75.0	74.1	0.8	10.3	12.6	0.26	1.011
Specific Humidity	325736	11.6	11.5	0.1	1.2	1.5	NA	1.010
Wind Speed	326209	2.6	2.6	0.1	1.2	1.5	0.39	1.355
Wind Direction	326209			0.1	41.9			

5.1.7.17 MD

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	244761	13.7	13.8	-0.0	1.9	2.3	0.53	1.000
Dew Point Temperature	227744	7.5	7.1	0.4	2.1	2.5	0.34	1.001
Relative Humidity	227743	69.8	67.4	2.4	11.6	13.8	0.27	1.046
Specific Humidity	227748	7.7	7.7	0.0	1.0	1.2	NA	1.031
Wind Speed	232396	2.9	2.9	-0.0	1.3	1.6	0.32	1.322
Wind Direction	232396			-13.1	42.1			

5.1.7.18 MI

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	838372	8.2	8.4	-0.1	1.9	2.3	0.68	1.000
Dew Point Temperature	719683	4.2	2.9	1.3	2.1	2.6	0.63	1.005
Relative Humidity	719683	77.9	70.7	7.2	11.7	13.9	0.42	1.112
Specific Humidity	720172	6.3	6.0	0.4	0.8	0.9	NA	1.099
Wind Speed	834088	3.7	3.6	0.1	1.4	1.7	0.44	1.164
Wind Direction	834088			-13.1	37.7			

5.1.7.19 MS

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	189575	19.1	18.6	0.5	1.8	2.2	0.54	1.002
Dew Point Temperature	189113	12.7	12.3	0.4	2.0	2.4	0.53	1.001
Relative Humidity	189113	70.7	69.9	0.8	10.5	12.5	0.31	1.011
Specific Humidity	189124	10.5	10.2	0.3	1.1	1.4	NA	1.024
Wind Speed	182594	2.4	2.5	-0.1	1.2	1.5	0.38	1.366
Wind Direction	182594			-2.4	43.7			

5.1.7.20 NC

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	603286	16.8	16.4	0.3	1.9	2.3	0.62	1.001
Dew Point Temperature	594875	9.2	8.8	0.4	2.3	2.9	0.58	1.001
Relative Humidity	594875	65.8	64.7	1.0	11.5	13.9	0.37	1.024
Specific Humidity	594968	8.8	8.5	0.3	1.1	1.4	0.68	1.029
Wind Speed	583869	2.5	2.3	0.2	1.3	1.6	0.40	1.518
Wind Direction	583869			-1.2	45.5			

5.1.7.21 OH

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	339806	11.4	11.3	0.1	1.8	2.1	0.59	1.000
Dew Point Temperature	335165	6.0	5.2	0.8	2.2	2.6	0.38	1.003
Relative Humidity	335165	74.1	69.0	5.1	12.1	14.2	0.30	1.076
Specific Humidity	335177	7.2	6.9	0.2	0.9	1.1	NA	1.066
Wind Speed	333355	3.0	3.4	-0.4	1.3	1.5	0.43	1.038
Wind Direction	333355			-10.1	37.8			

5.1.7.22 PA

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	371524	10.5	10.7	-0.2	1.8	2.1	0.72	0.999
Dew Point Temperature	365735	6.1	4.0	2.1	2.8	3.6	0.39	1.008
Relative Humidity	365735	77.9	67.3	10.6	14.1	17.3	0.33	1.181
Specific Humidity	365743	7.2	6.5	0.7	1.0	1.3	NA	1.162
Wind Speed	353747	2.8	2.9	-0.2	1.3	1.6	0.41	1.133
Wind Direction	353747			-4.4	42.2			

5.1.7.23 SC

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	177570	18.2	17.9	0.3	1.7	2.1	0.44	1.001
Dew Point Temperature	168137	10.3	10.1	0.2	2.2	2.6	0.62	1.001
Relative Humidity	168128	65.3	64.5	0.8	10.7	12.7	0.35	1.019
Specific Humidity	168145	9.3	9.1	0.2	1.1	1.3	NA	1.018
Wind Speed	170346	2.6	2.9	-0.3	1.2	1.5	0.33	1.148
Wind Direction	170346			-0.2	41.2			

5.1.7.24 TN

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	167722	16.3	16.1	0.1	1.8	2.2	0.64	1.001
Dew Point Temperature	167612	9.2	8.6	0.6	2.1	2.5	0.52	1.002
Relative Humidity	167612	67.7	64.4	3.3	11.4	13.6	0.35	1.052
Specific Humidity	167631	8.7	8.4	0.3	1.1	1.3	NA	1.043
Wind Speed	160097	2.4	2.4	-0.0	1.3	1.5	0.34	1.440
Wind Direction	160097			-15.0	46.4			

5.1.7.25 VA

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	403095	14.7	14.7	-0.0	2.0	2.4	0.62	1.000
Dew Point Temperature	384814	7.4	7.5	-0.1	2.2	2.8	0.54	1.000
Relative Humidity	384813	66.5	65.9	0.5	12.0	14.6	0.31	1.008
Specific Humidity	387698	7.9	8.0	-0.1	1.1	1.3	0.75	0.987
Wind Speed	391915	2.6	2.5	0.1	1.3	1.6	0.43	1.289
Wind Direction	391915			-1.9	47.0			

5.1.7.26 WI

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	702092	7.3	7.5	-0.1	1.9	2.3	0.62	1.000
Dew Point Temperature	672962	3.2	2.0	1.2	2.3	2.7	0.54	1.004
Relative Humidity	672962	78.1	71.0	7.1	12.0	14.2	0.33	1.114
Specific Humidity	672975	6.2	6.0	0.2	0.8	0.9	NA	1.097
Wind Speed	696772	3.6	3.3	0.3	1.2	1.6	0.42	1.277
Wind Direction	696772			-2.3	36.0			

5.1.7.27 WV

Field	Number of Obs	Model Mean	Obs Mean	Mean Bias	Mean Absolute Error	Root-Mean-Squared Error	Correlation Coefficient	Multiplicative Bias
Temperature	174258	12.1	12.2	-0.1	2.0	2.4	0.54	1.000
Dew Point Temperature	174172	7.0	5.7	1.3	2.4	2.9	0.41	1.005
Relative Humidity	174172	75.1	68.4	6.7	13.6	16.1	0.26	1.116
Specific Humidity	174172	7.8	7.3	0.5	1.1	1.3	NA	1.100
Wind Speed	167864	2.7	2.0	0.6	1.5	1.8	0.26	2.436
Wind Direction	167864			-28.9	53.5			

Disregarding wind direction, there is excellent model performance in the tables above relative to the target metrics. All variables for each region have error values (mean bias or MAE/RMSE) less than or equal to the target metrics, except for the one isolated case of Washington DC's wind speed bias. Note that the sample size for this region is between one and two orders of magnitude smaller than for other regions and oftentimes there is only one available observing site.

Across most regions, wind direction MAE are larger than the target of 30 degrees, though most often this statistic is marginally outside the target range. The mean bias, on the other hand, does not indicate a chronic problem with the modeled wind vectors, thus the large MAE values may be associated in general with poor model representation of topography, including coastlines and perhaps the occurrence and timing of sea breezes.

6 Evaluation of Sensitivity Runs Meteorological Model Performance

6.1 Statistical analysis of WRF sensitivity runs

The model configurations for each sensitivity run, as retrieved from raw WRF netcdf files, are listed in the following table. Note that sensitivity run 7 was not available for the summer period.

CENTER	Sensitivity run number/name	MOIST PHYSICS	LONG WAVE	SHORT WAVE	LAND SURFACE	SOIL LAYERS	PBL	SURFACE LAYER	CUMULUS
IA	1 - px-acm2_wsm5	WSM5(4)	RRTM(1)	Dudhia(1)	PX(7)	2	ACM2(7)	PX(7)	KF (1)
IA	2 - px-acm2_wsm6	WSM6(6)	RRTM(1)	Dudhia(1)	PX(7)	2	ACM2(7)	PX(7)	KF (1)
IA	3 - px_acm2_morr_ rrtmg	Morrison (10)	RRTMG(4)	RRTMG(4)	PX(7)	2	ACM2(7)	PX(7)	KF (1)
IA	4 - px-acm2_morr_ rrtmg_ipxwf	Morrison (10)	RRTMG(4)	RRTMG(4)	PX(7) IPXWRF	2	ACM2(7)	PX(7)	KF (1)
NY/ UMD	5 - myj.wsm5	WSM5(4)	RRTM(1)	Dudhia(1)	Noah(2)	4	MYJ(2)	MO(2)	KF (1)
NY/ UMD	6 - myj.wsm6	WSM6(6)	RRTM(1)	Dudhia(1)	Noah(2)	4	MYJ(2)	MO(2)	KF (1)
NY/ UMD	7 - ysu.wsm5	WSM5(4)	RRTM(1)	Dudhia(1)	Noah(2)	4	YSU(1)	MO(1)	KF (1)
NY/ UMD	8 - ysu.wsm6	WSM6(6)	RRTM(1)	Dudhia(1)	Noah(2)	4	YSU(1)	MO(1)	KF (1)
NY/ UMD	9 - OTC	WSM6(6)	RRTM(1)	Dudhia(1)	PX(7)	2	Blackadar (11)	PX(7)	KF (1)

Based on experience, clearly identifying a single model configuration that minimizes model error for all meteorological fields for large geographical areas and for long periods of time is frequently a futile exercise. Model errors for a specific choice of model parameters can only be minimized over individual runs for short periods of time in limited geographical areas. Results of the objective statistical analysis for the nine sensitivity runs presented to AER bear out the belief that there are simply no clearly identifiable ‘best' model configurations that minimize errors in *all* fields.

AER does not disagree with the method that identified sensitivity run 3 (px_acm2_morr_rrtmg) as the ‘best' one, and therefore the one that should be used as the Production Run. It is important to remember that, in general, the best means to minimize model error is to use a state-of-the-art model with accepted combinations of recent model physics' schemes, since some are not compatible with others either by software design or because of scientific limitations. Acceptance is conveyed by the model and physics algorithm developers and peer-reviewed literature. All configurations above meet these basic requirements, except the modified Blackadar scheme. This scheme from the OTC run is not available as a standard PBL option in WRF and therefore lacks both a long history of use in conjunction with the other options and has not undergone full vetting by the WRF Developers' Committee.

6.1.1 Tasks 2 H 1 and 2 H 7 Statistical tables for FULL model domain

This section describes the performance of sensitivity runs of the WRF model as characterized by tables of their error statistics. The discussion here focuses on statistics computed over the entire model domain ("FULL") for model domain 2, at four pressure levels and at the surface. These analyses are performed for the summer and winter episodes as described above. The pressure levels analyzed with approximate height levels in parentheses are: 300 mb (9500 m), 500 mb (5750 m), 700 mb (3000 m), and 850 mb (1500 m).

6.1.1.1 300 mb

The temperature fields at 300 mb for all of the sensitivity runs including the production run are very similar although the bias and standard errors are smallest for the production run itself. The WRF temperatures are highly correlated with the observations. The statistics are quite similar between the summer and winter episode. The sensitivity runs have a similar bias to the production run in the relative humidity field at 300 mb at roughly a 10% positive bias. The mean absolute error for the production run is slightly larger than the other sensitivity runs, upwards of over 2% larger. The relative humidity field at this level is, however, not well correlated with the observed relative humidity with a correlation coefficient of approximately 0.6. The mean absolute errors are also slightly larger for the winter episode.

Temperature

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1992	-32.5	-32.9	0.4	0.4	0.5	0.99	1.002
px-acm2_wsm5	1992	-32.4	-32.9	0.5	0.5	0.7	0.99	1.002
px-acm2_wsm6	1992	-32.4	-32.9	0.5	0.5	0.7	0.99	1.002
px_acm2_morr_rrtmg	1992	-32.4	-32.9	0.5	0.5	0.7	0.99	1.002
px-acm2_morr_rrtmg_ipxwrf	1992	-32.4	-32.9	0.5	0.5	0.7	0.99	1.002
myj.wsm5	1992	-32.4	-32.9	0.5	0.5	0.7	0.99	1.002
myj.wsm6	1992	-32.4	-32.9	0.5	0.5	0.7	0.99	1.002
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1992	-32.5	-32.9	0.5	0.5	0.7	0.99	1.002
OTC	1992	-32.5	-32.9	0.5	0.5	0.7	0.99	1.002

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2033	-43.2	-43.6	0.4	0.5	0.7	0.99	1.002
px-acm2_wsm5	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
px-acm2_wsm6	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
px_acm2_morr_rrtmg	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
px-acm2_morr_rrtmg_ipxwrf	2033	-43.1	-43.6	0.5	0.6	0.8	0.99	1.002
myj.wsm5	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
myj.wsm6	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
ysu.wsm5	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
ysu.wsm6	2033	-43.2	-43.6	0.4	0.6	0.8	0.99	1.002
OTC	2033	-43.2	-43.6	0.4	0.5	0.7	0.99	1.002

Relative humidity

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1607	38.4	28.5	9.9	15.7	20.4	0.59	1.349
px-acm2_wsm5	1607	38.1	28.5	9.6	15.6	20.3	0.58	1.338
px-acm2_wsm6	1607	38	28.5	9.5	15.5	20.2	0.58	1.336
px_acm2_morr_rrtmg	1607	38.7	28.5	10.2	15.9	20.6	0.59	1.358
px-acm2_morr_rrtmg_ipxwrf	1607	39.2	28.5	10.7	16.1	20.8	0.59	1.379
myj.wsm5	1607	38.2	28.5	9.7	15.6	20.2	0.58	1.344
myj.wsm6	1607	38.2	28.5	9.7	15.6	20.2	0.58	1.344
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1607	38	28.5	9.5	15.5	20.1	0.59	1.334
OTC	1607	38.1	28.5	9.6	15.4	20.1	0.59	1.34

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1185	49.9	34.4	15.5	19.5	22.9	0.61	1.447
px-acm2_wsm5	1185	47.1	34.4	12.7	17.3	20.6	0.6	1.364
px-acm2_wsm6	1185	47.1	34.4	12.7	17.3	20.6	0.6	1.364
px_acm2_morr_rrtmg	1185	49.4	34.4	15	19.4	22.9	0.6	1.432
px-acm2_morr_rrtmg_ipxwrf	1185	49.5	34.4	15.1	19.4	22.9	0.59	1.433
myj.wsm5	1185	46.9	34.4	12.5	17.2	20.6	0.6	1.359
myj.wsm6	1185	46.9	34.4	12.5	17.2	20.6	0.6	1.359
ysu.wsm5	1185	47.1	34.4	12.7	17.3	20.7	0.6	1.364
ysu.wsm6	1185	47.1	34.4	12.7	17.3	20.7	0.6	1.364
OTC	1185	47	34.4	12.6	17.3	20.7	0.6	1.363

For the wind field statistics, the production run and the other sensitivity runs display a slight negative bias in their wind speeds relative to observed values. The mean absolute errors for the wind speeds average slightly less than 1.5 m/s for the summer episode, but are slightly larger for the winter episode at just under 2.0 m/s. The wind speeds from the production run have the least error in either season. The WRF wind speeds are highly correlated with the observations at 0.97 and 0.98 for the summer and winter, respectively. For the wind direction, the production and sensitivity runs have very small biases and the mean absolute errors range from 4-5 degrees in the winter episode to 8-9 degrees in the summer episode.

Wind speed

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1970	15.4	15.8	-0.4	1.2	1.7	0.97	0.975
px-acm2_wsm5	1970	15.3	15.8	-0.4	1.4	2	0.97	0.971
px-acm2_wsm6	1970	15.3	15.8	-0.4	1.4	2	0.97	0.97
px_acm2_morr_rrtmg	1970	15.3	15.8	-0.4	1.4	2	0.97	0.97
px-acm2_morr_rrtmg_ipxwrf	1970	15.3	15.8	-0.4	1.4	2	0.97	0.97
myj.wsm5	1970	15.3	15.8	-0.4	1.4	2	0.97	0.971
myj.wsm6	1970	15.3	15.8	-0.4	1.4	2	0.97	0.971
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1970	15.3	15.8	-0.4	1.4	2	0.97	0.97
OTC	1970	15.3	15.8	-0.5	1.4	2	0.97	0.969

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1995	37.1	37.5	-0.4	1.6	2.3	0.99	0.99
px-acm2_wsm5	1995	37.1	37.5	-0.4	1.8	2.6	0.98	0.988
px-acm2_wsm6	1995	37.1	37.5	-0.4	1.8	2.6	0.98	0.988
px_acm2_morr_rrtmg	1995	37.1	37.5	-0.5	1.8	2.6	0.98	0.988
px-acm2_morr_rrtmg_ipxwrf	1995	37	37.5	-0.5	1.9	2.7	0.98	0.988
myj.wsm5	1995	37.1	37.5	-0.4	1.8	2.6	0.98	0.989
myj.wsm6	1995	37.1	37.5	-0.4	1.8	2.6	0.98	0.989
ysu.wsm5	1995	37.1	37.5	-0.4	1.8	2.6	0.98	0.988
ysu.wsm6	1995	37.1	37.5	-0.4	1.8	2.6	0.98	0.988
OTC	1995	37.1	37.5	-0.4	1.8	2.5	0.98	0.989

Wind Direction

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	1970	-64.2	-64.2	0	7.9
px-acm2_wsm5	1970	-64.4	-64.2	-0.2	9
px-acm2_wsm6	1970	-64.4	-64.2	-0.2	9
px_acm2_morr_rrtmg	1970	-64.4	-64.2	-0.2	9
px-acm2_morr_rrtmg_ipxwrf	1970	-64.4	-64.2	-0.2	9
myj.wsm5	1970	-64.4	-64.2	-0.1	9
myj.wsm6	1970	-64.4	-64.2	-0.1	9
ysu.wsm5	0	NA	NA	NA	NA
ysu.wsm6	1970	-64.3	-64.2	-0.1	9
OTC	1970	-64.5	-64.2	-0.3	8.9

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	1995	-95.4	-95.4	0	4.5
px-acm2_wsm5	1995	-95.4	-95.4	0.1	5.1
px-acm2_wsm6	1995	-95.3	-95.4	0.1	5.1
px_acm2_morr_rrtmg	1995	-95.3	-95.4	0.1	5.1
px-acm2_morr_rrtmg_ipxwrf	1995	-95.3	-95.4	0.1	5.3
myj.wsm5	1995	-95.4	-95.4	0	5.1
myj.wsm6	1995	-95.4	-95.4	0	5.1
ysu.wsm5	1995	-95.4	-95.4	0.1	5.1
ysu.wsm6	1995	-95.4	-95.4	0	5.1
OTC	1995	-95.4	-95.4	0	5

6.1.1.2 500 mb

The statistics from the WRF sensitivity runs at 500 mb for temperature are quite similar to those at the 300-mb level. The temperature biases are smaller than at 500 mb and range from 0.1-0.2 °C in the winter episode to 0.3-0.4 °C in the summer episode. The production run has the smallest mean absolute errors of all of the runs. The correlation coefficients for all runs remain very high at 0.98 or above. The relative humidity fields show significant improvement over those at the 300-mb level with mean bias reduced to 2% and 6% above the observed value for summer and winter, respectively. The mean absolute errors and the correlation coefficients are better for the relative humidity than at 300 mb over both the summer and winter episodes.

Temperature

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2002	-6.4	-6.7	0.3	0.4	0.6	0.98	1.001
px-acm2_wsm5	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.001
px-acm2_wsm6	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.001
px_acm2_morr_rrtmg	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.001
px-acm2_morr_rrtmg_ipxwrf	2002	-6.3	-6.7	0.4	0.5	0.7	0.97	1.001
myj.wsm5	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.002
myj.wsm6	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.001
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.001
OTC	2002	-6.3	-6.7	0.4	0.5	0.7	0.98	1.001

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2046	-17.6	-17.7	0.1	0.4	0.5	1	1.001
px-acm2_wsm5	2046	-17.6	-17.7	0.2	0.4	0.6	1	1.001
px-acm2_wsm6	2046	-17.6	-17.7	0.2	0.4	0.6	1	1.001
px_acm2_morr_rrtmg	2046	-17.6	-17.7	0.1	0.4	0.6	1	1.001
px-acm2_morr_rrtmg_ipxwrf	2046	-17.6	-17.7	0.2	0.5	0.6	0.99	1.001
myj.wsm5	2046	-17.6	-17.7	0.2	0.4	0.6	1	1.001
myj.wsm6	2046	-17.6	-17.7	0.2	0.4	0.6	1	1.001
ysu.wsm5	2046	-17.6	-17.7	0.2	0.4	0.6	1	1.001
ysu.wsm6	2046	-17.6	-17.7	0.2	0.4	0.6	1	1.001
OTC	2046	-17.6	-17.7	0.1	0.4	0.6	1	1.001

Relative Humidity

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1988	36.7	34.8	1.9	13.4	18	0.75	1.059
px-acm2_wsm5	1988	36.3	34.8	1.5	13.3	18	0.75	1.046
px-acm2_wsm6	1988	36.3	34.8	1.5	13.3	18	0.74	1.048
px_acm2_morr_rrtmg	1988	36.5	34.8	1.7	13.4	18.1	0.74	1.053
px-acm2_morr_rrtmg_ipxwrf	1988	36.7	34.8	1.8	13.8	18.6	0.73	1.058
myj.wsm5	1988	36.4	34.8	1.5	13.5	18	0.74	1.049
myj.wsm6	1988	36.5	34.8	1.6	13.5	18.1	0.74	1.051
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1988	36.4	34.8	1.6	13.2	17.8	0.75	1.048
OTC	1988	36.1	34.8	1.3	13.5	18	0.74	1.04

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1940	41.6	35.9	5.8	12.3	16.9	0.83	1.16
px-acm2_wsm5	1940	40.6	35.9	4.8	11.9	16.7	0.82	1.133
px-acm2_wsm6	1940	40.6	35.9	4.8	11.9	16.7	0.82	1.133
px_acm2_morr_rrtmg	1940	41.2	35.9	5.4	12.4	17.1	0.82	1.149
px-acm2_morr_rrtmg_ipxwrf	1940	41.3	35.9	5.4	12.4	17.1	0.82	1.15
myj.wsm5	1940	40.4	35.9	4.5	11.9	16.6	0.82	1.126
myj.wsm6	1940	40.4	35.9	4.5	11.9	16.6	0.82	1.125
ysu.wsm5	1940	40.4	35.9	4.5	11.8	16.5	0.82	1.125
ysu.wsm6	1940	40.4	35.9	4.5	11.8	16.5	0.82	1.125
OTC	1940	40.3	35.9	4.5	11.8	16.5	0.82	1.125

The wind speeds at 500 mb are strongly correlated with the observations during both the summer and winter sensitivity runs. The mean absolute error for both periods is slightly reduced as compared with 300 mb, but this may be more due to the lower average wind speed at the 500-mb level. The mean absolute error in the wind direction increases slightly at 500 mb, but of all the sensitivity runs the production run has the lowest errors at 9.8° and 5.4 m/s, respectively, for the summer and winter episodes, respectively.

Wind Speed

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1967	9.2	9.6	-0.3	0.9	1.3	0.97	0.964
px-acm2_wsm5	1967	9.2	9.6	-0.4	1.1	1.5	0.96	0.961
px-acm2_wsm6	1967	9.2	9.6	-0.4	1.1	1.5	0.96	0.961
px_acm2_morr_rrtmg	1967	9.2	9.6	-0.3	1.1	1.5	0.96	0.961
px-acm2_morr_rrtmg_ipxwrf	1967	9.2	9.6	-0.4	1.1	1.5	0.96	0.961
myj.wsm5	1967	9.2	9.6	-0.3	1.1	1.5	0.96	0.962
myj.wsm6	1967	9.2	9.6	-0.3	1.1	1.5	0.96	0.962
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1967	9.2	9.6	-0.3	1.1	1.5	0.96	0.961
OTC	1967	9.2	9.6	-0.3	1.1	1.5	0.96	0.961

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2031	24.1	24.5	-0.4	1.3	1.8	0.98	0.982
px-acm2_wsm5	2031	24	24.5	-0.5	1.4	2	0.98	0.979
px-acm2_wsm6	2031	24	24.5	-0.5	1.4	2	0.98	0.979
px_acm2_morr_rrtmg	2031	24	24.5	-0.5	1.4	2	0.98	0.979
px-acm2_morr_rrtmg_ipxwrf	2031	24	24.5	-0.6	1.5	2.1	0.98	0.977
myj.wsm5	2031	24.1	24.5	-0.5	1.4	2	0.98	0.98
myj.wsm6	2031	24.1	24.5	-0.5	1.4	2	0.98	0.98
ysu.wsm5	2031	24	24.5	-0.5	1.4	2	0.98	0.979
ysu.wsm6	2031	24	24.5	-0.5	1.4	2	0.98	0.979
OTC	2031	24.1	24.5	-0.5	1.4	2	0.98	0.98

Wind Direction

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	1967	-61.5	-63.3	1.8	9.8
px-acm2_wsm5	1967	-61	-63.3	2.3	11.3
px-acm2_wsm6	1967	-61	-63.3	2.3	11.3
px_acm2_morr_rrtmg	1967	-61.1	-63.3	2.2	11.3
px-acm2_morr_rrtmg_ipxwrf	1967	-61.1	-63.3	2.2	11.3
myj.wsm5	1967	-61	-63.3	2.3	11.3
myj.wsm6	1967	-61	-63.3	2.3	11.2
ysu.wsm5	0	NA	NA	NA	NA
ysu.wsm6	1967	-60.9	-63.3	2.4	11.3
OTC	1967	-61	-63.3	2.2	11.3

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	2031	-94.8	-95.3	0.5	5.4
px-acm2_wsm5	2031	-94.8	-95.3	0.5	6
px-acm2_wsm6	2031	-94.8	-95.3	0.5	6
px_acm2_morr_rrtmg	2031	-94.8	-95.3	0.5	6
px-acm2_morr_rrtmg_ipxwrf	2031	-94.8	-95.3	0.5	6.3
myj.wsm5	2031	-94.9	-95.3	0.4	6
myj.wsm6	2031	-94.9	-95.3	0.4	6
ysu.wsm5	2031	-94.8	-95.3	0.5	6
ysu.wsm6	2031	-94.8	-95.3	0.5	6
OTC	2031	-94.8	-95.3	0.5	5.9

6.1.1.3 700 mb

At 700 mb, the temperature field shows a slight positive bias of 0.1-0.2 °C, but the mean absolute errors remain small especially for the production run. The mean absolute errors in temperature are slightly larger during the winter episode, but the correlation coefficients indicate a very good relationship with the observations during both periods. In the relative humidity field, there is a slight positive bias during the winter episode; however, this is significantly smaller than either at 300 mb or 500 mb. A negative bias appears for the summer episode at nearly 3% lower than the observed relative humidity on average. Mean absolute errors are greater than those at 500 mb for the summer episode at over 13%, but are reduced for the winter period. Correlation coefficients are similar in this respect with the values for the summer episode especially poor at around 0.65.

Temperature

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2008	9.4	9.2	0.2	0.4	0.5	0.98	1.001
px-acm2_wsm5	2008	9.4	9.2	0.2	0.4	0.6	0.97	1.001
px-acm2_wsm6	2008	9.3	9.2	0.2	0.4	0.6	0.97	1.001
px_acm2_morr_rrtmg	2008	9.4	9.2	0.2	0.4	0.6	0.97	1.001
px-acm2_morr_rrtmg_ipxwrf	2008	9.4	9.2	0.2	0.4	0.6	0.98	1.001
myj.wsm5	2008	9.4	9.2	0.2	0.4	0.6	0.98	1.001
myj.wsm6	2008	9.4	9.2	0.2	0.4	0.6	0.98	1.001
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	2008	9.3	9.2	0.1	0.4	0.6	0.97	1.001
OTC	2008	9.4	9.2	0.2	0.4	0.6	0.98	1.001

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2050	-2.8	-2.9	0.1	0.5	0.7	1	1
px-acm2_wsm5	2050	-2.7	-2.9	0.1	0.6	0.8	0.99	1
px-acm2_wsm6	2050	-2.7	-2.9	0.1	0.6	0.8	0.99	1
px_acm2_morr_rrtmg	2050	-2.8	-2.9	0.1	0.6	0.8	0.99	1
px-acm2_morr_rrtmg_ipxwrf	2050	-2.8	-2.9	0.1	0.6	0.8	0.99	1
myj.wsm5	2050	-2.7	-2.9	0.1	0.6	0.8	0.99	1
myj.wsm6	2050	-2.7	-2.9	0.1	0.6	0.8	0.99	1
ysu.wsm5	2050	-2.7	-2.9	0.1	0.6	0.8	0.99	1
ysu.wsm6	2050	-2.7	-2.9	0.1	0.6	0.8	0.99	1
OTC	2050	-2.8	-2.9	0.1	0.6	0.8	1	1

Relative Humidity

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2002	49.1	51.8	-2.7	15.4	20.2	0.63	0.957
px-acm2_wsm5	2002	49.2	51.8	-2.6	15.1	19.5	0.65	0.957
px-acm2_wsm6	2002	49.4	51.8	-2.4	15.1	19.6	0.65	0.96
px_acm2_morr_rrtmg	2002	49.5	51.8	-2.3	15.1	19.5	0.65	0.963
px-acm2_morr_rrtmg_ipxwrf	2002	48.5	51.8	-3.3	15.1	19.7	0.64	0.945
myj.wsm5	2002	48.4	51.8	-3.5	15.4	20	0.63	0.942
myj.wsm6	2002	48.4	51.8	-3.4	15.3	19.9	0.64	0.943
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	2002	50.2	51.8	-1.7	15.2	19.7	0.64	0.976
OTC	2002	48.4	51.8	-3.5	15.2	19.6	0.65	0.941

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2044	43	42	1	11	15.2	0.86	1.022
px-acm2_wsm5	2044	42.3	42	0.3	11.2	15.7	0.85	1.006
px-acm2_wsm6	2044	42.3	42	0.3	11.2	15.7	0.85	1.007
px_acm2_morr_rrtmg	2044	42.9	42	0.9	11.4	15.8	0.85	1.021
px-acm2_morr_rrtmg_ipxwrf	2044	42.9	42	0.9	11.4	15.8	0.85	1.021
myj.wsm5	2044	42.3	42	0.2	11.2	15.7	0.85	1.003
myj.wsm6	2044	42.3	42	0.2	11.2	15.7	0.85	1.003
ysu.wsm5	2044	42.3	42	0.2	11.2	15.6	0.85	1.004
ysu.wsm6	2044	42.3	42	0.3	11.2	15.7	0.85	1.005
OTC	2044	42.5	42	0.5	11.1	15.5	0.85	1.01

For the wind speeds at 700 mb, the biases remain less than 1 m/s during the winter episode. The mean absolute errors are also relatively small at 700 mb with the production run displaying the smallest errors of all the sensitivity runs. The modeled wind speeds at this level are still well correlated with the observations for both the summer and winter episodes. The wind direction errors at 700 mb are increased relative to those at 500 mb.

Wind Speed

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1902	7.1	7.4	-0.3	1	1.3	0.95	0.955
px-acm2_wsm5	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.957
px-acm2_wsm6	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.956
px_acm2_morr_rrtmg	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.956
px-acm2_morr_rrtmg_ipxwrf	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.958
myj.wsm5	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.961
myj.wsm6	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.961
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.958
OTC	1902	7.1	7.4	-0.3	1.1	1.5	0.93	0.961

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2023	15.1	15.9	-0.8	1.3	1.9	0.96	0.95
px-acm2_wsm5	2023	15	15.9	-0.9	1.5	2.2	0.96	0.942
px-acm2_wsm6	2023	15	15.9	-0.9	1.5	2.2	0.96	0.942
px_acm2_morr_rrtmg	2023	15	15.9	-0.9	1.5	2.2	0.96	0.942
px-acm2_morr_rrtmg_ipxwrf	2023	14.9	15.9	-1	1.6	2.3	0.95	0.937
myj.wsm5	2023	15	15.9	-0.9	1.5	2.1	0.96	0.945
myj.wsm6	2023	15	15.9	-0.9	1.5	2.1	0.96	0.945
ysu.wsm5	2023	15	15.9	-0.9	1.5	2.1	0.96	0.942
ysu.wsm6	2023	15	15.9	-0.9	1.5	2.1	0.96	0.942
OTC	2023	15	15.9	-0.9	1.5	2.1	0.96	0.945

Wind Direction

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	1902	-66.1	-71.1	5	13.1
px-acm2_wsm5	1902	-64.1	-71.1	7	15.5
px-acm2_wsm6	1902	-64.1	-71.1	7	15.4
px_acm2_morr_rrtmg	1902	-64.3	-71.1	6.8	15.5
px-acm2_morr_rrtmg_ipxwrf	1902	-63.8	-71.1	7.3	15.4
myj.wsm5	1902	-64	-71.1	7.1	15.3
myj.wsm6	1902	-64	-71.1	7.1	15.3
ysu.wsm5	0	NA	NA	NA	NA
ysu.wsm6	1902	-64.7	-71.1	6.4	15.7
OTC	1902	-64.2	-71.1	6.9	15.3

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	2023	-92.7	-93.1	0.4	8.2
px-acm2_wsm5	2023	-92.8	-93.1	0.3	9.1
px-acm2_wsm6	2023	-92.8	-93.1	0.3	9.1
px_acm2_morr_rrtmg	2023	-92.8	-93.1	0.3	9.1
px-acm2_morr_rrtmg_ipxwrf	2023	-92.9	-93.1	0.2	9.6
myj.wsm5	2023	-92.8	-93.1	0.3	9
myj.wsm6	2023	-92.8	-93.1	0.3	9
ysu.wsm5	2023	-92.8	-93.1	0.3	9.1
ysu.wsm6	2023	-92.8	-93.1	0.3	9.1
OTC	2023	-92.8	-93.1	0.3	9.1

6.1.1.4 850 mb

The temperatures at 850 mb have mean absolute errors near 0.5 °C for both the summer and winter episode with the production run observed to have the smallest errors of the sensitivity runs. The mean bias is very small during the summer period, but has a slight positive bias during the winter period. Temperatures remain very well correlated with the observations at the 850-mb level. The relative humidity at this level now displays a consistent negative bias for all of the sensitivity runs during both the summer and winter episodes. Mean absolute errors run just over 11% for both episodes. The sensitivity runs are poorly correlated with the observations during the summer period averaging near 0.6; however, this does improve during the winter up to just above 0.8.

Temperature

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2016	18.8	18.8	0.1	0.5	0.8	0.96	1
px-acm2_wsm5	2016	18.8	18.8	0	0.5	0.9	0.96	1
px-acm2_wsm6	2016	18.8	18.8	0	0.5	0.9	0.96	1
px_acm2_morr_rrtmg	2016	18.8	18.8	0.1	0.5	0.9	0.96	1
px-acm2_morr_rrtmg_ipxwrf	2016	18.7	18.8	0	0.5	0.9	0.96	1
myj.wsm5	2016	18.8	18.8	0.1	0.5	0.8	0.96	1
myj.wsm6	2016	18.8	18.8	0.1	0.5	0.8	0.96	1
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	2016	18.8	18.8	0.1	0.5	0.9	0.96	1
OTC	2016	18.8	18.8	0	0.5	0.8	0.96	1

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2050	2.3	2.1	0.2	0.6	0.9	1	1.001
px-acm2_wsm5	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
px-acm2_wsm6	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
px_acm2_morr_rrtmg	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
px-acm2_morr_rrtmg_ipxwrf	2050	2.4	2.1	0.2	0.8	1.2	0.99	1.001
myj.wsm5	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
myj.wsm6	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
ysu.wsm5	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
ysu.wsm6	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001
OTC	2050	2.3	2.1	0.2	0.7	1.1	0.99	1.001

Relative Humidity

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2009	64.2	64.8	-0.6	11.8	15.3	0.64	0.992
px-acm2_wsm5	2009	63.1	64.8	-1.7	12	15.5	0.62	0.975
px-acm2_wsm6	2009	63.1	64.8	-1.7	12	15.6	0.62	0.975
px_acm2_morr_rrtmg	2009	63.3	64.8	-1.6	12.1	15.7	0.61	0.977
px-acm2_morr_rrtmg_ipxwrf	2009	64.8	64.8	0	12.6	16.4	0.57	1.001
myj.wsm5	2009	62	64.8	-2.8	12.2	15.9	0.6	0.957
myj.wsm6	2009	62.1	64.8	-2.8	12.2	15.9	0.6	0.958
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	2009	63.3	64.8	-1.5	11.2	14.7	0.65	0.977
OTC	2009	61.5	64.8	-3.3	12.3	15.9	0.6	0.949

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2046	57.4	60	-2.6	11.8	16.6	0.81	0.959
px-acm2_wsm5	2046	56.8	60	-3.2	12	16.8	0.81	0.948
px-acm2_wsm6	2046	56.7	60	-3.3	12	16.8	0.81	0.947
px_acm2_morr_rrtmg	2046	57.3	60	-2.7	12	16.7	0.81	0.958
px-acm2_morr_rrtmg_ipxwrf	2046	57.8	60	-2.2	12.1	16.7	0.81	0.967
myj.wsm5	2046	56.6	60	-3.5	11.5	16.1	0.83	0.942
myj.wsm6	2046	56.5	60	-3.5	11.5	16.1	0.83	0.941
ysu.wsm5	2046	57	60	-3	11.7	16.3	0.82	0.952
ysu.wsm6	2046	57	60	-3	11.6	16.2	0.82	0.952
OTC	2046	57.3	60	-2.7	11.6	16.1	0.82	0.956

As with the other pressure levels, the wind speed continues to show a consistent negative bias of between 0.5 and 1 m/s. The mean absolute errors remain small with the production run having the smallest error during the winter episode. The wind speeds remain well correlated with the observed wind speeds; however, the correlation coefficients are not as high as at the other pressure levels. The wind direction errors are larger lower in the atmosphere. The production run has the smallest errors, but these are still above 11° for the winter episode and above 15° for the summer episode with larger values found for each of the other sensitivity runs.

Wind Speed

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1752	6	6.5	-0.6	1.1	1.5	0.91	0.905
px-acm2_wsm5	1752	6	6.5	-0.5	1.1	1.5	0.91	0.915
px-acm2_wsm6	1752	6	6.5	-0.5	1.1	1.5	0.91	0.916
px_acm2_morr_rrtmg	1752	6	6.5	-0.6	1.1	1.5	0.91	0.913
px-acm2_morr_rrtmg_ipxwrf	1752	6	6.5	-0.6	1.1	1.5	0.91	0.913
myj.wsm5	1752	6.2	6.5	-0.3	1	1.3	0.92	0.954
myj.wsm6	1752	6.2	6.5	-0.3	1	1.3	0.92	0.954
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	1752	6	6.5	-0.5	1.1	1.5	0.91	0.92
OTC	1752	6.1	6.5	-0.4	1	1.4	0.92	0.938

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	2001	10.5	11.3	-0.8	1.4	1.9	0.95	0.925
px-acm2_wsm5	2001	10.4	11.3	-0.9	1.5	2.1	0.93	0.917
px-acm2_wsm6	2001	10.4	11.3	-0.9	1.5	2.1	0.93	0.918
px_acm2_morr_rrtmg	2001	10.4	11.3	-0.9	1.5	2.2	0.93	0.917
px-acm2_morr_rrtmg_ipxwrf	2001	10.3	11.3	-1	1.7	2.3	0.92	0.905
myj.wsm5	2001	10.6	11.3	-0.8	1.4	2	0.94	0.931
myj.wsm6	2001	10.6	11.3	-0.8	1.4	2	0.94	0.931
ysu.wsm5	2001	10.3	11.3	-1	1.5	2.1	0.93	0.913
ysu.wsm6	2001	10.3	11.3	-1	1.5	2.1	0.93	0.913
OTC	2001	10.4	11.3	-0.9	1.5	2	0.94	0.917

Wind Direction

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	1752	-104.7	-105.9	1.2	15.9
px-acm2_wsm5	1752	-105.6	-105.9	0.3	17.2
px-acm2_wsm6	1752	-105.7	-105.9	0.2	17.2
px_acm2_morr_rrtmg	1752	-106.2	-105.9	-0.3	17.2
px-acm2_morr_rrtmg_ipxwrf	1752	-106.5	-105.9	-0.6	17.2
myj.wsm5	1752	-105.9	-105.9	-0.1	15.8
myj.wsm6	1752	-106	-105.9	-0.1	15.9
ysu.wsm5	0	NA	NA	NA	NA
ysu.wsm6	1752	-107.4	-105.9	-1.5	17.5
OTC	1752	-105.8	-105.9	0.1	16

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	2001	-96.8	-96.4	-0.4	11.2
px-acm2_wsm5	2001	-97.1	-96.4	-0.7	12.5
px-acm2_wsm6	2001	-97.1	-96.4	-0.7	12.5
px_acm2_morr_rrtmg	2001	-97	-96.4	-0.6	12.5
px-acm2_morr_rrtmg_ipxwrf	2001	-97.5	-96.4	-1.1	13.5
myj.wsm5	2001	-96.3	-96.4	0.1	12.2
myj.wsm6	2001	-96.4	-96.4	0	12.2
ysu.wsm5	2001	-97.6	-96.4	-1.2	12.4
ysu.wsm6	2001	-97.5	-96.4	-1.2	12.4
OTC	2001	-97.2	-96.4	-0.8	12.1

6.1.1.5 Surface

At the surface, temperatures display a slight, but consistent negative bias during the summer episode with a less obvious bias during the winter period although the production run has a positive bias of 0.6°C. The mean absolute errors increase significantly at the surface relative to those at 850 mb to around 1.5°C in the summer episode and 2°C in the winter episode. The majority of the sensitivity runs including the production run have similar performance in this regard. The temperatures are more strongly correlated in the winter episode than during the summer. The relative humidity fields generally have a positive bias for both periods, but somewhat larger for the winter episode. A number of the sensitivity runs perform more strongly than the production run during the winter with mean absolute errors 1-2% lower. The WRF relative humidity fields are poorly correlated with the observations at the surface with the majority of runs falling under a 0.6 correlation coefficient. An additional variable, specific humidity, is also analyzed at the surface. There is a slight, but consistent positive bias in the specific humidity at the surface during the winter period, but the bias varies between the different sensitivity runs for the summer. The mean error is smaller during the winter, but this is likely a result of lower moisture content in the atmosphere at this time of year. As with the relative humidity, the specific humidity modeled by WRF sensitivity runs is more strongly correlated with the observations during the winter than summer.

Temperature

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	973252	24.9	25	-0.2	1.6	2.1	0.86	0.999
px-acm2_wsm5	973252	24.6	25	-0.4	1.7	2.2	0.86	0.999
px-acm2_wsm6	973252	24.6	25	-0.4	1.7	2.2	0.86	0.999
px_acm2_morr_rrtmg	973252	24.8	25	-0.2	1.6	2.2	0.86	0.999
px-acm2_morr_rrtmg_ipxwrf	973252	25.2	25	0.2	1.7	2.4	0.84	1.001
myj.wsm5	973252	24.6	25	-0.4	1.7	2.2	0.86	0.999
myj.wsm6	973252	24.6	25	-0.4	1.7	2.2	0.86	0.999
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	973252	24.9	25	-0.2	1.7	2.3	0.85	0.999
OTC	973252	24.6	25	-0.4	1.6	2.1	0.87	0.999

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1067902	2.4	1.8	0.6	2.1	2.7	0.96	1.002
px-acm2_wsm5	1067902	2.1	1.8	0.3	2	2.7	0.96	1.001
px-acm2_wsm6	1067902	2.1	1.8	0.3	2	2.7	0.96	1.001
px_acm2_morr_rrtmg	1067902	2.3	1.8	0.5	2	2.7	0.96	1.002
px-acm2_morr_rrtmg_ipxwrf	1067902	2.2	1.8	0.4	2.1	2.7	0.96	1.002
myj.wsm5	1067902	1.1	1.8	-0.7	2.1	2.8	0.96	0.998
myj.wsm6	1067902	1.1	1.8	-0.7	2.1	2.8	0.96	0.997
ysu.wsm5	1067902	1.5	1.8	-0.3	1.9	2.6	0.96	0.999
ysu.wsm6	1067902	1.4	1.8	-0.4	2	2.7	0.96	0.999
OTC	1067902	2.3	1.8	0.5	1.8	2.4	0.97	1.002

Relative Humidity

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	877230	72.9	70	2.9	9.7	12.4	0.55	1.042
px-acm2_wsm5	877230	72.7	70	2.7	10.1	12.9	0.55	1.04
px-acm2_wsm6	877230	72.7	70	2.7	10.1	12.9	0.55	1.04
px_acm2_morr_rrtmg	877230	72.8	70	2.8	10	12.7	0.55	1.04
px-acm2_morr_rrtmg_ipxwrf	877230	73	70	2.9	9.8	12.5	0.54	1.048
myj.wsm5	877230	72.5	70	2.5	9.9	12.6	0.55	1.037
myj.wsm6	877230	72.5	70	2.5	9.9	12.6	0.55	1.037
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	877230	66.5	70	-3.5	9.6	12.5	0.61	0.949
OTC	877230	73.1	70	3.1	10.1	12.9	0.58	1.047

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	949432	82	77.7	4.3	11.3	14.3	0.57	1.055
px-acm2_wsm5	949432	82.8	77.7	5.2	11.2	14.4	0.56	1.068
px-acm2_wsm6	949432	82.8	77.7	5.2	11.2	14.4	0.56	1.067
px_acm2_morr_rrtmg	949432	82.8	77.7	5.1	11.3	14.4	0.57	1.066
px-acm2_morr_rrtmg_ipxwrf	949432	83.4	77.7	5.8	11.2	14.3	0.56	1.075
myj.wsm5	949432	84.9	77.7	7.3	10.7	13.6	0.57	1.097
myj.wsm6	949432	85.1	77.7	7.5	10.8	13.7	0.57	1.1
ysu.wsm5	949432	81.7	77.7	4.1	9.6	12.3	0.61	1.055
ysu.wsm6	949432	81.9	77.7	4.2	9.6	12.4	0.61	1.057
OTC	949432	82	77.7	4.3	10.2	13.2	0.62	1.056

Specific Humidity

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	916117	14.3	14.2	0.1	1.6	2	0.81	1.008
px-acm2_wsm5	916117	14	14.2	-0.2	1.6	2.1	0.81	0.989
px-acm2_wsm6	916117	14	14.2	-0.2	1.6	2.1	0.81	0.989
px_acm2_morr_rrtmg	916117	14.2	14.2	0	1.6	2.1	0.81	1
px-acm2_morr_rrtmg_ipxwrf	916117	14.8	14.2	0.6	1.7	2.2	0.81	1.042
myj.wsm5	916117	14	14.2	-0.2	1.6	2.1	0.81	0.988
myj.wsm6	916117	14	14.2	-0.2	1.6	2.1	0.81	0.988
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	916117	13	14.2	-1.2	1.8	2.3	0.82	0.914
OTC	916117	14.2	14.2	0	1.6	2.1	0.81	0.997

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	990050	4.4	4.2	0.1	0.7	0.9	0.93	1.038
px-acm2_wsm5	990050	4.4	4.2	0.1	0.6	0.9	0.94	1.035
px-acm2_wsm6	990050	4.4	4.2	0.1	0.6	0.9	0.94	1.035
px_acm2_morr_rrtmg	990050	4.4	4.2	0.2	0.6	0.9	0.94	1.044
px-acm2_morr_rrtmg_ipxwrf	990050	4.5	4.2	0.2	0.6	0.9	0.94	1.059
myj.wsm5	990050	4.4	4.2	0.1	0.6	0.9	0.95	1.034
myj.wsm6	990050	4.4	4.2	0.1	0.6	0.9	0.95	1.032
ysu.wsm5	990050	4.2	4.2	0	0.5	0.8	0.96	1.003
ysu.wsm6	990050	4.2	4.2	0	0.5	0.8	0.96	1.001
OTC	990050	4.4	4.2	0.2	0.6	0.9	0.95	1.049

The wind speeds are biased negative for the production run in both the winter and summer episodes, but the remaining sensitivity runs are consistently positive although the absolute value of the bias is relatively small in both cases. The mean absolute errors are between 1.2 and 1.4 m/s. The correlation coefficients are generally low indicating that the relationship between the WRF-modeled and observed winds is not particularly strong. The wind direction data shows the largest deviations between the sensitivity runs and the actual observations with mean absolute errors exceeding 30° in the winter episode and 40° in the summer episode.

Wind Speed

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	945601	2.5	2.5	-0.1	1.3	1.6	0.58	1.068
px-acm2_wsm5	945601	2.7	2.5	0.2	1.2	1.6	0.61	1.157
px-acm2_wsm6	945601	2.7	2.5	0.2	1.2	1.6	0.61	1.157
px_acm2_morr_rrtmg	945601	2.7	2.5	0.2	1.2	1.6	0.61	1.164
px-acm2_morr_rrtmg_ipxwrf	945601	2.7	2.5	0.2	1.2	1.6	0.61	1.173
myj.wsm5	945601	2.8	2.5	0.3	1.2	1.6	0.61	1.179
myj.wsm6	945601	2.8	2.5	0.3	1.2	1.6	0.61	1.179
ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
ysu.wsm6	945601	2.7	2.5	0.2	1.2	1.6	0.61	1.16
OTC	945601	2.2	2.5	-0.3	1.2	1.6	0.6	0.924

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	1049252	3.4	3.5	-0.1	1.3	1.8	0.7	0.98
px-acm2_wsm5	1049252	3.7	3.5	0.2	1.3	1.7	0.73	1.071
px-acm2_wsm6	1049252	3.7	3.5	0.2	1.3	1.7	0.73	1.071
px_acm2_morr_rrtmg	1049252	3.7	3.5	0.2	1.3	1.7	0.73	1.072
px-acm2_morr_rrtmg_ipxwrf	1049252	3.7	3.5	0.2	1.3	1.7	0.72	1.07
myj.wsm5	1049252	3.7	3.5	0.2	1.3	1.7	0.73	1.08
myj.wsm6	1049252	3.7	3.5	0.2	1.3	1.7	0.73	1.078
ysu.wsm5	1049252	3.8	3.5	0.3	1.4	1.8	0.72	1.112
ysu.wsm6	1049252	3.8	3.5	0.3	1.4	1.8	0.72	1.112
OTC	1049252	3.4	3.5	0	1.3	1.7	0.72	0.997

Wind Direction

Summer

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	945601	-171.2	-169.5	-1.7	43.9
px-acm2_wsm5	945601	-171.7	-169.5	-2.2	42.5
px-acm2_wsm6	945601	-171.6	-169.5	-2.2	42.5
px_acm2_morr_rrtmg	945601	-172.1	-169.5	-2.6	42.4
px-acm2_morr_rrtmg_ipxwrf	945601	-172.5	-169.5	-3	42.5
myj.wsm5	945601	-171.8	-169.5	-2.3	42
myj.wsm6	945601	-171.8	-169.5	-2.3	42
ysu.wsm5	0	NA	NA	NA	NA
ysu.wsm6	945601	-171.2	-169.5	-1.7	42.3
OTC	945601	-168.1	-169.5	1.4	42

Winter

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	1049252	-95.1	-82.8	-12.3	33
px-acm2_wsm5	1049252	-92.8	-82.8	-10	31.5
px-acm2_wsm6	1049252	-92.8	-82.8	-10	31.5
px_acm2_morr_rrtmg	1049252	-97	-82.8	-14.2	31.6
px-acm2_morr_rrtmg_ipxwrf	1049252	-95.2	-82.8	-12.4	31.8
myj.wsm5	1049252	-87.3	-82.8	-4.6	31.3
myj.wsm6	1049252	-87.3	-82.8	-4.5	31.3
ysu.wsm5	1049252	-98.4	-82.8	-15.6	31.8
ysu.wsm6	1049252	-98.3	-82.8	-15.5	31.9
OTC	1049252	-94.2	-82.8	-11.4	31.6

6.1.2 Tasks 2 H 1 and 2 H 7 Surface Statistical tables for SEMAP region

The following tables summarize the domain 2 Summer and Winter statistics at the surface for each sensitivity run for SEMAP. The discussion is limited to noteworthy aspects of the statistics, with a focus on those metrics that can be compared to the target Metrics from Section 2.6.

6.1.2.1 Temperature

Summer Temperature Celsius

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	176141	27.5	27.6	-0.1	1.5	2.0	0.68	1.000
1-px-acm2_wsm5	176141	27.4	27.6	-0.2	1.5	2.0	0.69	0.999
2-px-acm2_wsm6	176141	27.4	27.6	-0.2	1.5	2.0	0.69	0.999
3-px_acm2_morr_rrtmg	176141	27.5	27.6	-0.1	1.5	1.9	0.69	1.000
4-px-acm2_morr_rrtmg_ipxwrf	176141	27.8	27.6	0.2	1.6	2.1	0.67	1.001
5-myj.wsm5	176141	27.5	27.6	-0.1	1.5	2.0	0.71	1.000
6-myj.wsm6	176141	27.5	27.6	-0.1	1.5	2.0	0.71	1.000
7-ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
8-ysu.wsm6	176141	27.6	27.6	0.0	1.6	2.1	0.70	1.000
9-OTC	176141	27.2	27.6	-0.4	1.5	1.9	0.71	0.999

Winter Temperature Celsius

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	199175	11.4	11.0	0.4	2.1	2.7	0.89	1.001
1-px-acm2_wsm5	199175	11.0	11.0	0.0	2.1	2.7	0.89	1.000
2-px-acm2_wsm6	199175	11.0	11.0	0.0	2.1	2.7	0.89	1.000
3-px_acm2_morr_rrtmg	199175	11.3	11.0	0.3	2.1	2.6	0.89	1.001
4-px-acm2_morr_rrtmg_ipxwrf	199175	11.5	11.0	0.5	2.2	2.8	0.89	1.002
5-myj.wsm5	199175	10.6	11.0	-0.4	1.8	2.3	0.90	0.999
6-myj.wsm6	199175	10.6	11.0	-0.4	1.8	2.4	0.90	0.999
7-ysu.wsm5	199175	10.5	11.0	-0.5	1.8	2.3	0.91	0.998
8-ysu.wsm6	199175	10.5	11.0	-0.5	1.8	2.3	0.91	0.998
9-OTC	199175	11.2	11.0	0.2	1.9	2.4	0.91	1.001

Model performance was generally very good for all sensitivity runs for temperature. Summer correlation values were notably lower than for winter. It is anticipated that correlation values will be lower during periods of more uniform temperature, such as during the summer, with short-term periods of cooling driven largely by less predictable diurnal convection. Mean bias values fell within target values, as did MAE values, except for the winter period for runs that utilized the px-acm2 parameterizations. These runs had gross errors of slightly larger than the target of 2 degrees Celsius.

6.1.2.2 Relative Humidity

Summer RH %

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	167793	72.4	69.3	3.1	9.7	12.3	0.43	1.049
1-px-acm2_wsm5	167793	72.4	69.3	3.1	10.0	12.6	0.45	1.048
2-px-acm2_wsm6	167793	72.4	69.3	3.1	10.0	12.6	0.45	1.048
3-px_acm2_morr_rrtmg	167793	72.4	69.3	3.1	10.0	12.6	0.44	1.048
4-px-acm2_morr_rrtmg_ipxwrf	167793	73.4	69.3	4.1	10.3	12.9	0.38	1.070
5-myj.wsm5	167793	70.2	69.3	0.9	9.5	12.1	0.48	1.015
6-myj.wsm6	167793	70.1	69.3	0.8	9.5	12.1	0.48	1.015
7-ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
8-ysu.wsm6	167793	64.9	69.3	-4.4	9.4	12.2	0.51	0.935
9-OTC	167793	73.6	69.3	4.3	10.5	13.3	0.45	1.069

Winter RH %

6.1.2.2.1.1.1 Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	188866	74.6	75.5	-0.9	12.1	15.2	0.46	0.980
1-px-acm2_wsm5	188866	77.2	75.5	1.7	12.4	15.5	0.44	1.019
2-px-acm2_wsm6	188866	77.1	75.5	1.7	12.4	15.5	0.44	1.019
3-px_acm2_morr_rrtmg	188866	76.0	75.5	0.5	11.8	14.9	0.46	1.000
4-px-acm2_morr_rrtmg_ipxwrf	188866	77.3	75.5	1.9	12.0	15.1	0.41	1.019
5-myj.wsm5	188866	79.3	75.5	3.8	9.6	12.2	0.49	1.056
6-myj.wsm6	188866	79.5	75.5	4.0	9.8	12.4	0.48	1.060
7-ysu.wsm5	188866	76	75.5	0.5	8.9	11.5	0.57	1.010
9-ysu.wsm6	188866	76.2	75.5	0.7	9.0	11.6	0.56	1.013
9-OTC	188866	76.2	75.5	0.8	11.6	14.6	0.50	1.005

Modeled relative humidity forecasts typically exhibited a positive bias of up to 4%, as indicated also by the multiplicative bias scores. It should be kept in mind that relative humidity is dependent not only on the absolute amount of atmospheric moisture, but also the temperature. See the specific humidity tables below for evaluation solely of the amount of moisture. Use of the MYJ planetary boundary layer scheme improved the modeled RH fields in the summer, with the best scores across all statistics. In the winter, on the other hand, this scheme's large positive mean bias values, but relatively small MAE errors, indicate that the sign of the forecast errors did not cancel and RH was generally overpredicted. The YSU PBL scheme had the best error statistics in the winter.

6.1.2.3 Specific Humidity

Summer SPFH g/kg

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	167951	16.1	15.9	0.3	1.7	2.2	0.56	1.017
1-px-acm2_wsm5	167951	15.9	15.9	0.1	1.8	2.2	0.59	1.005
2-px-acm2_wsm6	167951	15.9	15.9	0.1	1.8	2.2	0.59	1.005
3-px_acm2_morr_rrtmg	167951	16.1	15.9	0.2	1.8	2.3	0.57	1.013
4-px-acm2_morr_rrtmg_ipxwrf	167951	16.8	15.9	0.9	2.0	2.5	0.50	1.057
5-myj.wsm5	167951	15.5	15.9	-0.3	1.8	2.3	0.61	0.980
6-myj.wsm6	167951	15.5	15.9	-0.3	1.8	2.3	0.61	0.979
7-ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
8-ysu.wsm6	167951	14.4	15.9	-1.4	2.0	2.5	0.62	0.909
9-OTC	167951	16.1	15.9	0.3	1.9	2.4	0.57	1.016

Winter SPFH g/kg

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	189058	6.7	6.8	-0.1	1.0	1.2	0.83	0.983
1-px-acm2_wsm5	189058	6.8	6.8	0.0	0.9	1.2	0.84	0.997
2-px-acm2_wsm6	189058	6.7	6.8	0.0	0.9	1.2	0.84	0.997
3-px_acm2_morr_rrtmg	189058	6.8	6.8	0.0	0.9	1.2	0.84	0.999
4-px-acm2_morr_rrtmg_ipxwrf	189058	7.0	6.8	0.2	0.9	1.2	0.83	1.027
5-myj.wsm5	189058	6.9	6.8	0.1	0.8	1.1	0.85	1.023
6-myj.wsm6	189058	6.9	6.8	0.1	0.8	1.1	0.85	1.023
7-ysu.wsm5	189058	6.6	6.8	-0.2	0.8	1.1	0.85	0.970
8-ysu.wsm6	189058	6.6	6.8	-0.2	0.8	1.1	0.85	0.970
9-OTC	189058	6.9	6.8	0.1	0.9	1.2	0.84	1.005

All sensitivity runs met the target values for mean bias and mean absolute error (with one exception). Use of the YSU PBL scheme appears to result in the lowest amount of atmospheric moisture, perhaps related to deficiencies in this scheme's amount of vertical mixing. As expected, error statistics for the winter are smaller, due largely to the significantly smaller amount of atmospheric moisture during this time period. It is suggested, therefore, that statistics for the summer period represent a more rigorous evaluation. Of note is the degradation of the model performance (e.g., increased positive mean bias) through introduction of the IPX-WRF (runs number 4). The IPXWRF software is used to initialize soil moisture in the PX land surface model.

6.1.2.4 Wind Speed

Summer WSPD m/s

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	168497	1.9	1.8	0.1	1.3	1.6	0.35	1.319
1-px-acm2_wsm5	168497	2.2	1.8	0.3	1.2	1.5	0.40	1.462
2-px-acm2_wsm6	168497	2.2	1.8	0.3	1.2	1.5	0.40	1.462
3-px_acm2_morr_rrtmg	168497	2.2	1.8	0.3	1.2	1.5	0.40	1.468
4-px-acm2_morr_rrtmg_ipxwrf	168497	2.2	1.8	0.3	1.2	1.6	0.41	1.475
5-myj.wsm5	168497	2.3	1.8	0.5	1.2	1.5	0.42	1.496
6-myj.wsm6	168497	2.3	1.8	0.5	1.2	1.5	0.42	1.496
7-ysu.wsm5	0	NA	NA	NA	NA	NA	NA	NA
8-ysu.wsm6	168497	2.1	1.8	0.2	1.2	1.5	0.41	1.395
9-OTC	168497	1.6	1.8	-0.3	1.2	1.6	0.40	1.015

Winter WSPD m/s

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error	Root Mean Square Deviation	Correlation Coefficient	Multiplicative Bias
production	194801	2.6	2.5	0.0	1.2	1.5	0.57	1.085
1-px-acm2_wsm5	194801	2.8	2.5	0.3	1.2	1.5	0.62	1.194
2-px-acm2_wsm6	194801	2.8	2.5	0.3	1.2	1.5	0.62	1.195
3-px_acm2_morr_rrtmg	194801	2.9	2.5	0.3	1.2	1.5	0.61	1.207
4-px-acm2_morr_rrtmg_ipxwrf	194801	2.9	2.5	0.3	1.2	1.5	0.61	1.209
5-myj.wsm5	194801	3.0	2.5	0.5	1.2	1.5	0.62	1.257
6-myj.wsm6	194801	3.0	2.5	0.5	1.2	1.5	0.61	1.255
7-ysu.wsm5	194801	2.9	2.5	0.4	1.3	1.6	0.60	1.241
8-ysu.wsm6	194801	2.9	2.5	0.4	1.3	1.6	0.60	1.241
9-OTC	194801	2.5	2.5	0.0	1.2	1.5	0.60	1.034

All sensitivity runs for each time period met the target mean bias and RMSE ranges for wind speed. MAE and RMSE differences amongst the runs were unimportant. Overall mean bias errors were small and positive, likely influenced by the models' well-known inability to reproduce coincident observations of calm air. Interestingly, the production run had the smallest overall mean bias, especially when compared against the sensitivity run that used same model configuration. As mentioned above, one factor contributing to this difference in error statistics is the different start times for each 5.5-day run segment. Overall, the correlation coefficient scores were significantly better during the winter, likely a result of the predominance of more robust synoptic-scale flow.

6.1.2.5 Wind Direction

Summer WDIR degrees

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	168497	-128.3	-132.4	4.1	54.7
1-px-acm2_wsm5	168497	-132.1	-132.4	0.3	52.6
2-px-acm2_wsm6	168497	-131.8	-132.4	0.6	52.6
3-px_acm2_morr_rrtmg	168497	-133.6	-132.4	-1.2	52.5
4-px-acm2_morr_rrtmg_ipxwrf	168497	-137.7	-132.4	-5.3	52.3
5-myj.wsm5	168497	-132.1	-132.4	0.3	51.7
6-myj.wsm6	168497	-132.2	-132.4	0.2	51.7
7-ysu.wsm5	0	NA	NA	NA	NA
8-ysu.wsm6	168497	-133.6	-132.4	-1.2	52.0
9-OTC	168497	-130.7	-132.4	1.7	52.1

Winter WDIR degrees

Run	Number of Obs	Model Mean	Observed Mean	Mean Bias	Mean Absolute Error
production	194801	-29.0	-48.0	19.0	40.9
1-px-acm2_wsm5	194801	-13.0	-48.0	35.0	38.2
2-px-acm2_wsm6	194801	-14.1	-48.0	33.9	38.3
3-px_acm2_morr_rrtmg	194801	-26.5	-48.0	21.5	38.4
4-px-acm2_morr_rrtmg_ipxwrf	194801	-31.7	-48.0	16.4	38.5
5-myj.wsm5	194801	-23.6	-48.0	24.4	38.2
6-myj.wsm6	194801	-22.8	-48.0	25.2	38.2
7-ysu.wsm5	194801	-71.8	-48.0	-23.8	38.4
8-ysu.wsm6	194801	-71.7	-48.0	-23.7	38.4
9-OTC	194801	-77.6	-48.0	-29.6	38.2

The production run, and closely-related sensitivity run number three, exhibit two of the smallest mean bias values during the winter when none of the bias values lie within the target of less than 10 degrees. For the summer, given that the observations for METAR sites are provided only to the nearest 5 degrees, we consider the variability in the mean bias values to be unimportant. For both time periods, MAE errors lie outside the target value of 30 degrees. The inter-run variability is very small and there is no clear “best” choice based solely on that metric.

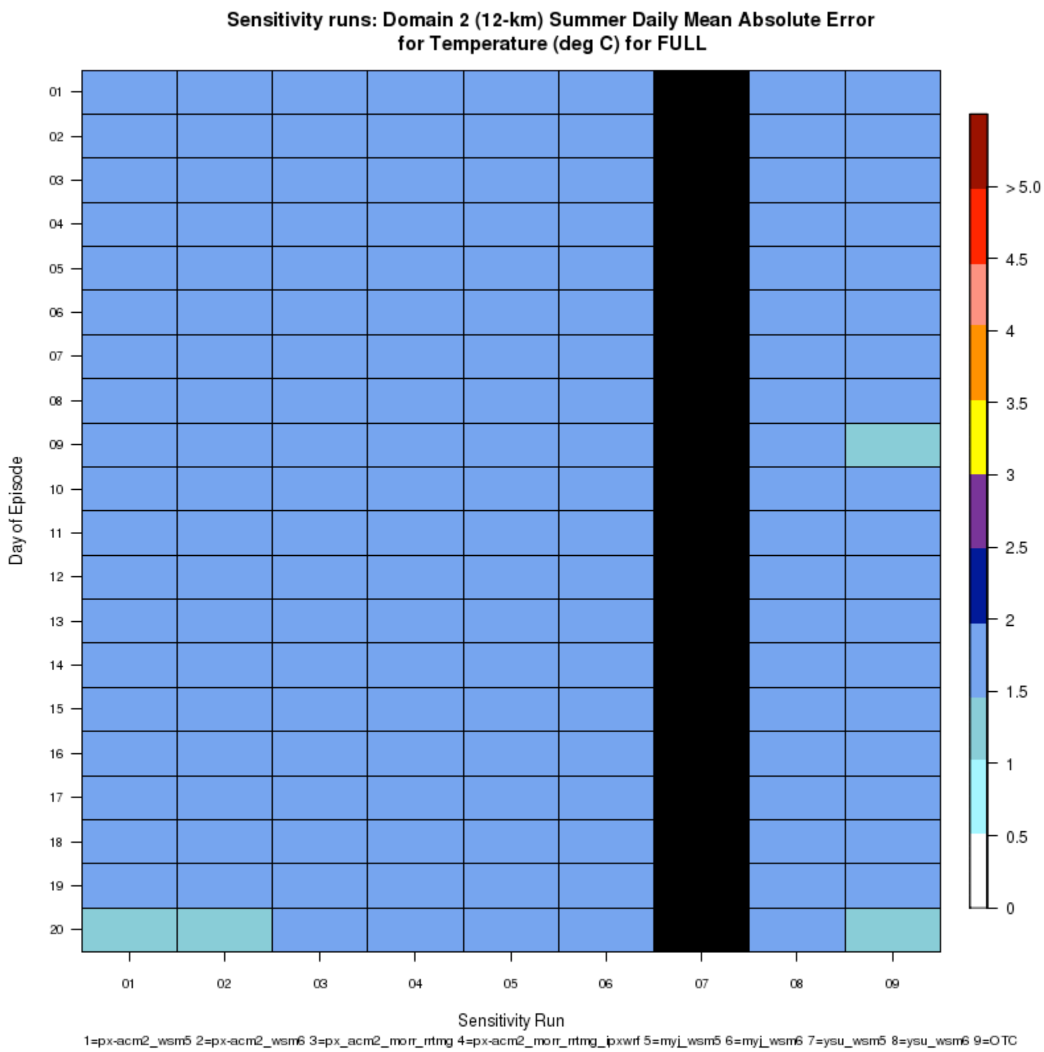
6.1.3 Task 2 H 2: Bakergrams

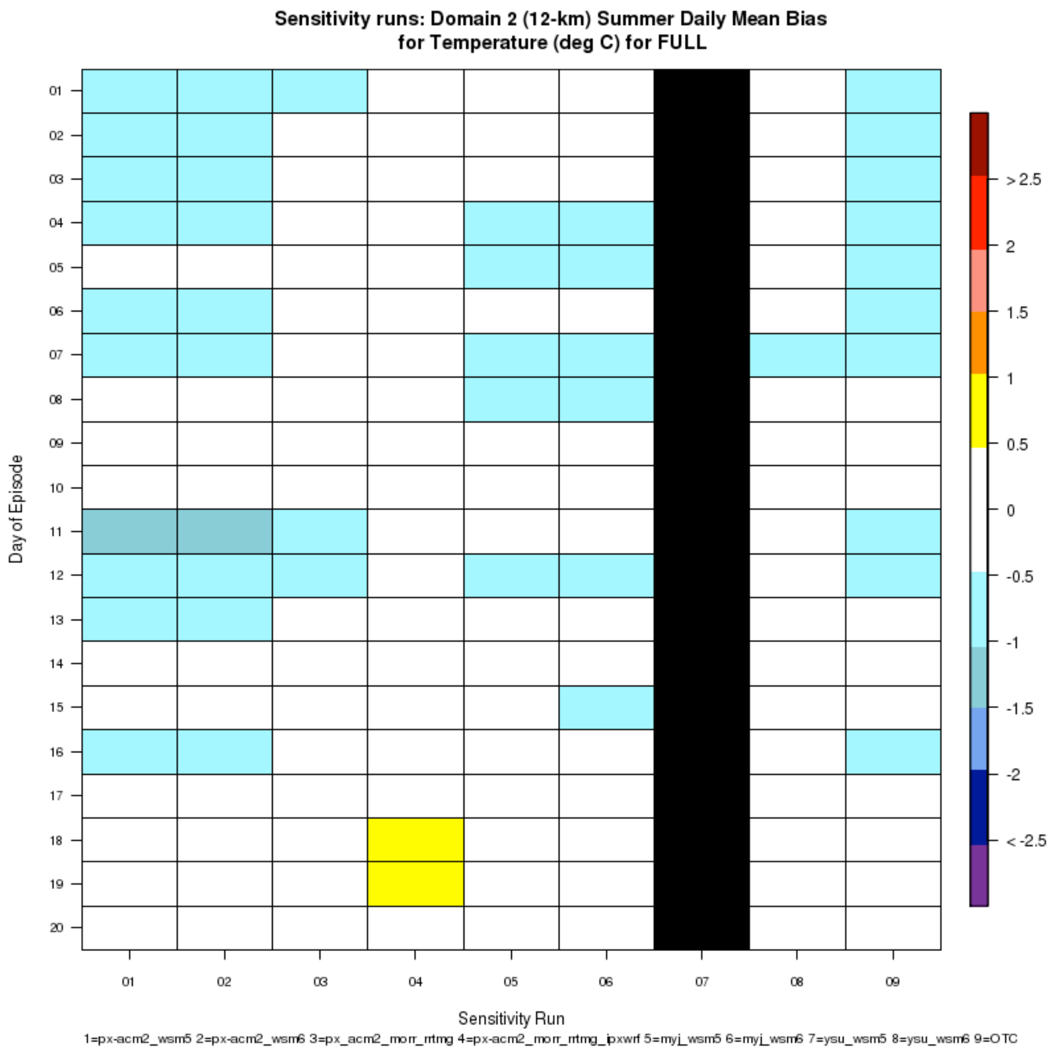
The following section describes the variability of the daily mean absolute error and the daily mean bias for the sensitivity runs through a series of Bakergrams. The discussion will focus primarily on the FULL region for domain 2 only.

6.1.3.1 Temperature

The mean absolute errors of the temperature during summer are indistinguishable for the different sensitivity runs, all showing an MAE between 1.5°C and 2°C. All the sensitivity runs for this period except for the px-acm2_morr_rrtmg_ixpwf demonstrate a consistent negative bias for temperature in their 20-day simulation. The px-acm2_morr_rrtmg_ixpwf has a slight positive bias near the end of the run. For the winter period, the mean absolute errors are somewhat larger overall, ranging from 1.5°C to 3.0°C although there is slightly greater disparity between the individual runs. The OTC run exhibits the lowest mean absolute errors. The sensitivity runs are split in terms of the mean bias in temperature during winter: about half the members show a positive bias, and the other half shows a negative bias.

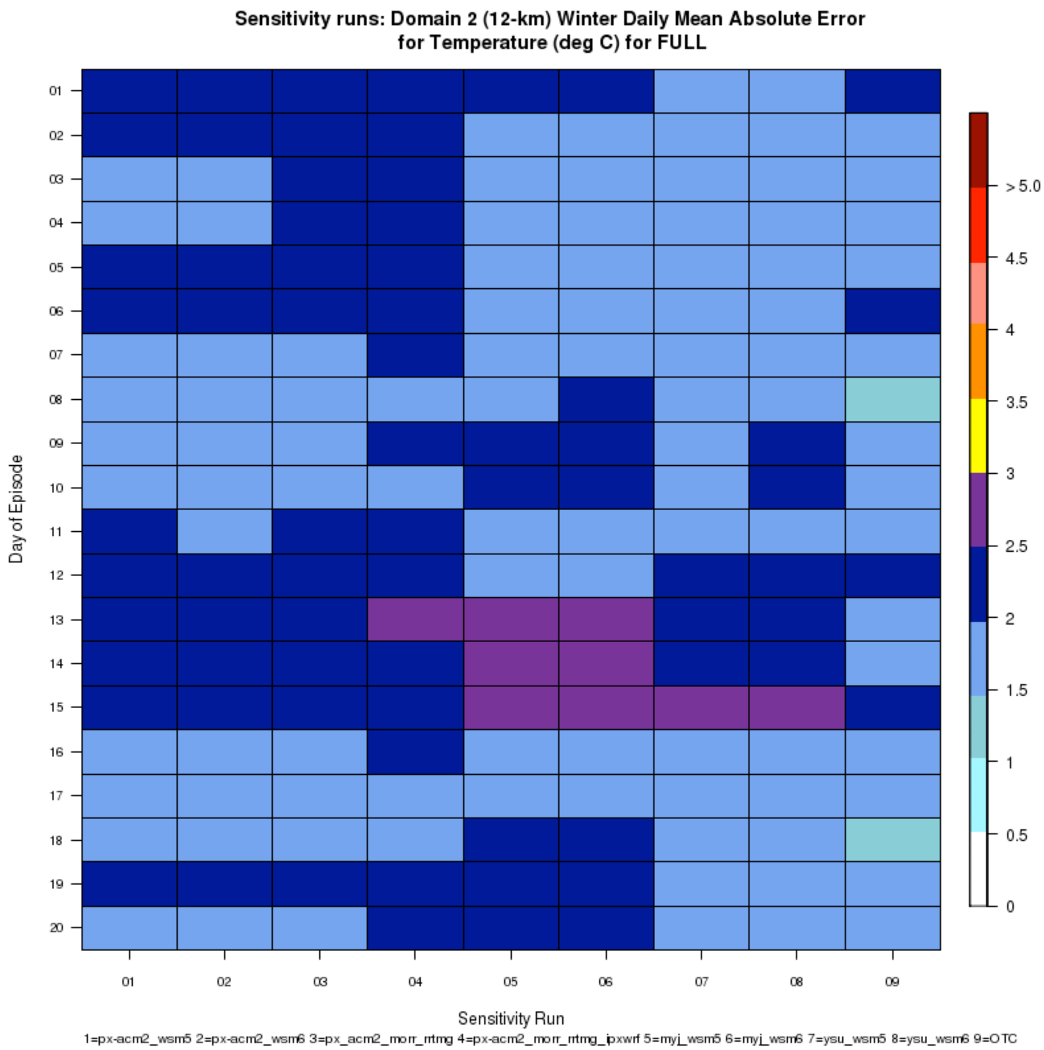
Summer

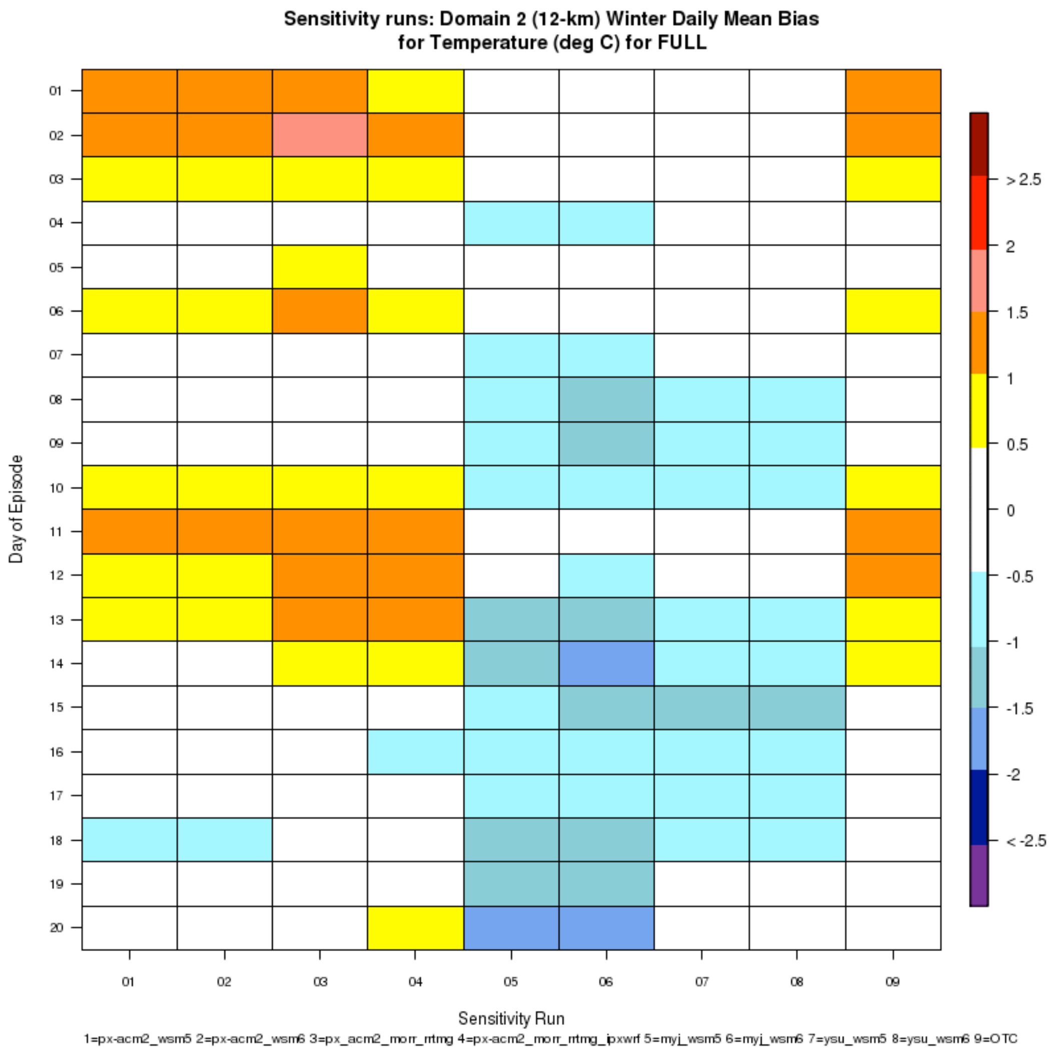




Sensitivity runs: Domain 2 (12-km) Summer Daily Mean Bias
for Temperature (deg C) for FULL
Day of Episode
Sensitivity Run
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC

Winter

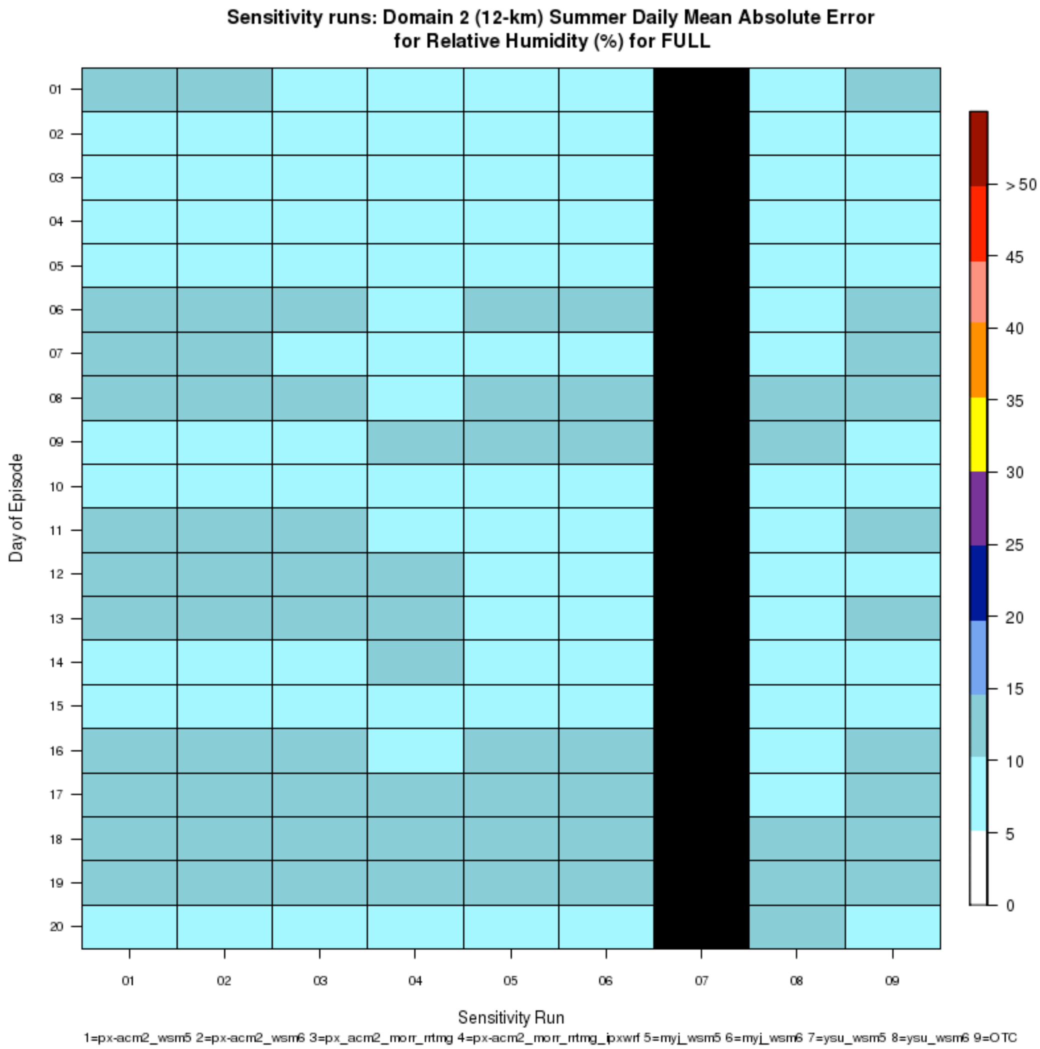

Sensitivity runs: Domain 2 (12-km) Winter Daily Mean Absolute Error
for Temperature (deg C) for FULL
Day of Episode
Sensitivity Run
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC
> 5.0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

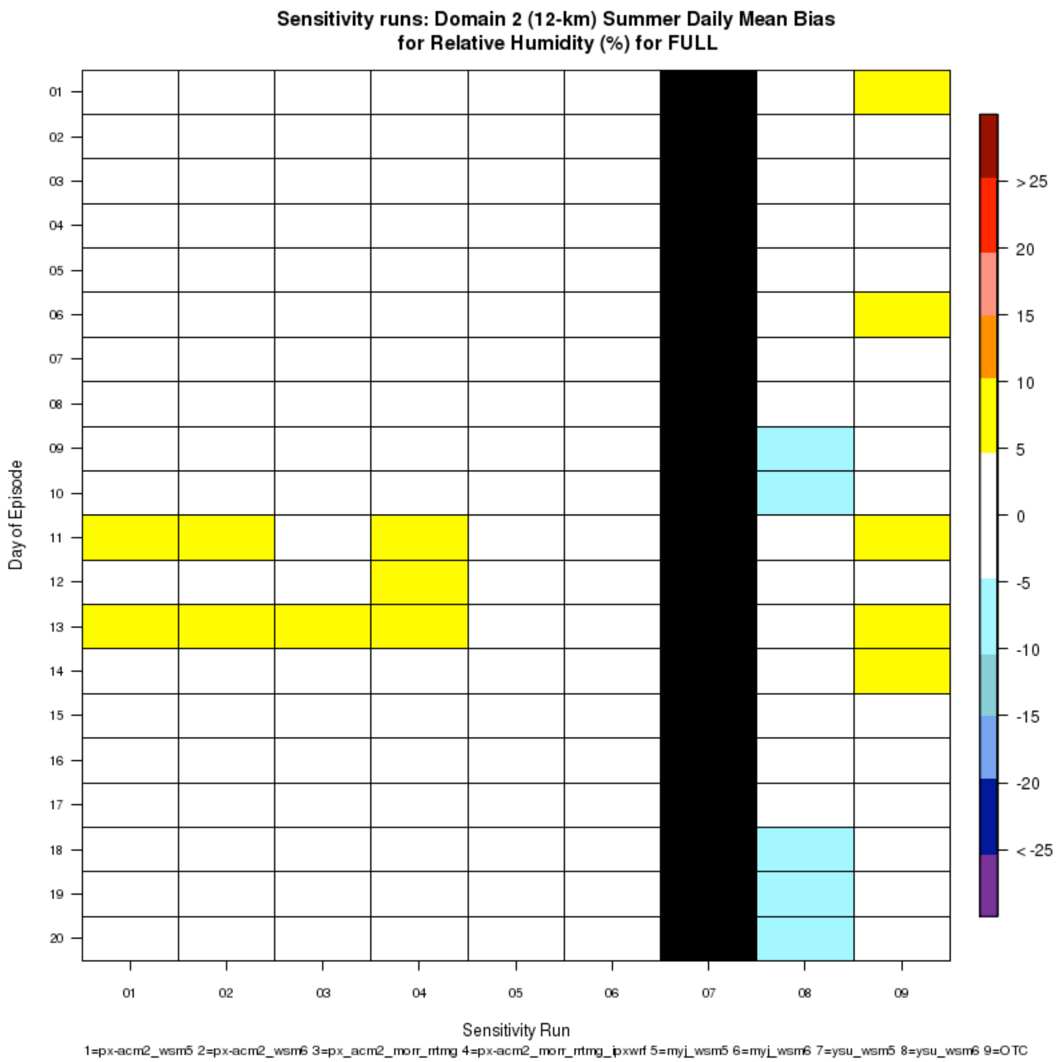


6.1.3.2 Relative Humidity

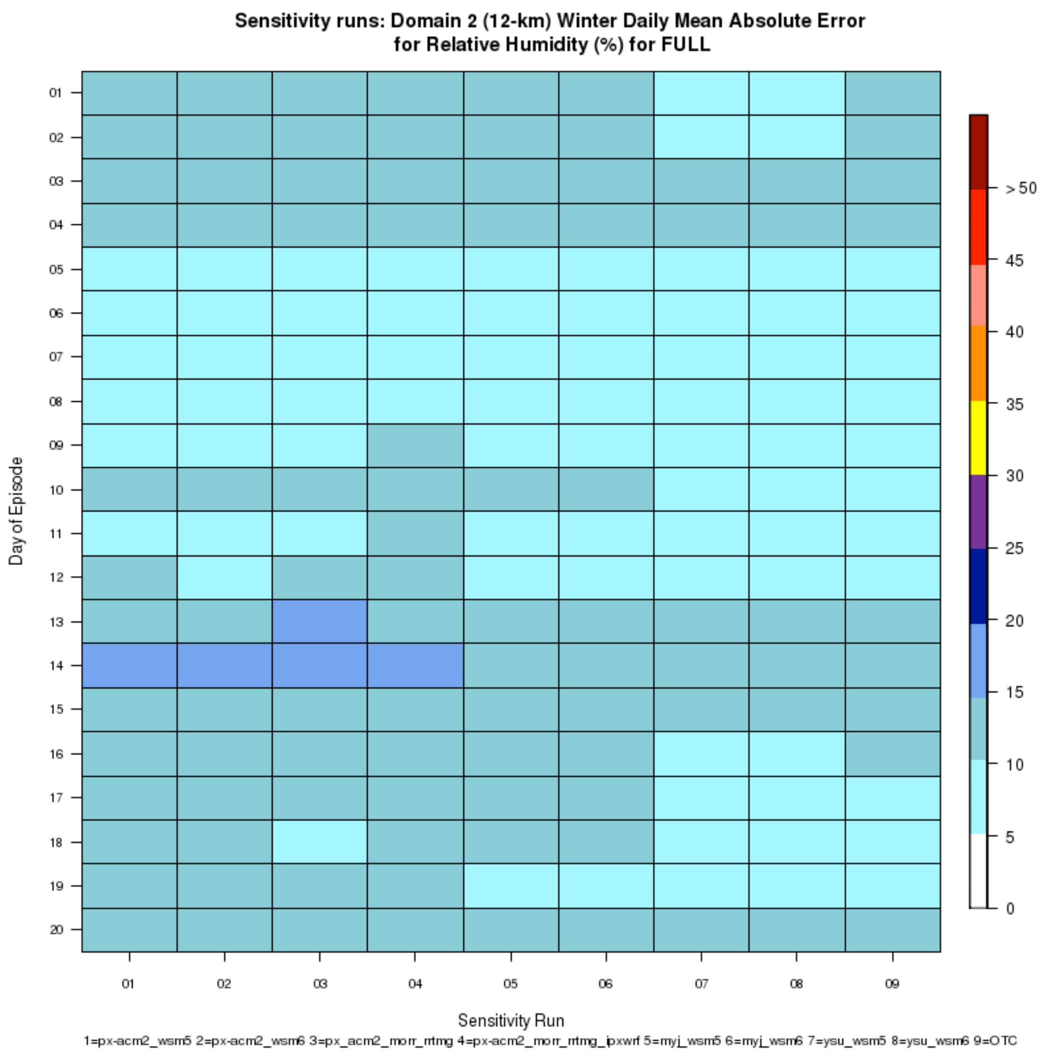
The relative humidity fields in the summer sensitivity runs show that the mean absolute error averages less than 15% for all of the runs. There is some variability among the individual members, but no significant outliers. The mean bias plot for the summer episode indicates that there is a neutral to slight positive bias for all of the runs except for the ysu.wsm6 run which has a few daily values that represent a negative bias. Overall, the winter daily values of the mean absolute errors are slightly larger than during summer, upwards of 15-20% in the first 4 sensitivity runs. The mean bias is fairly uniform, however, with all of the runs showing a consistent 5-10% positive bias in the relative humidity.

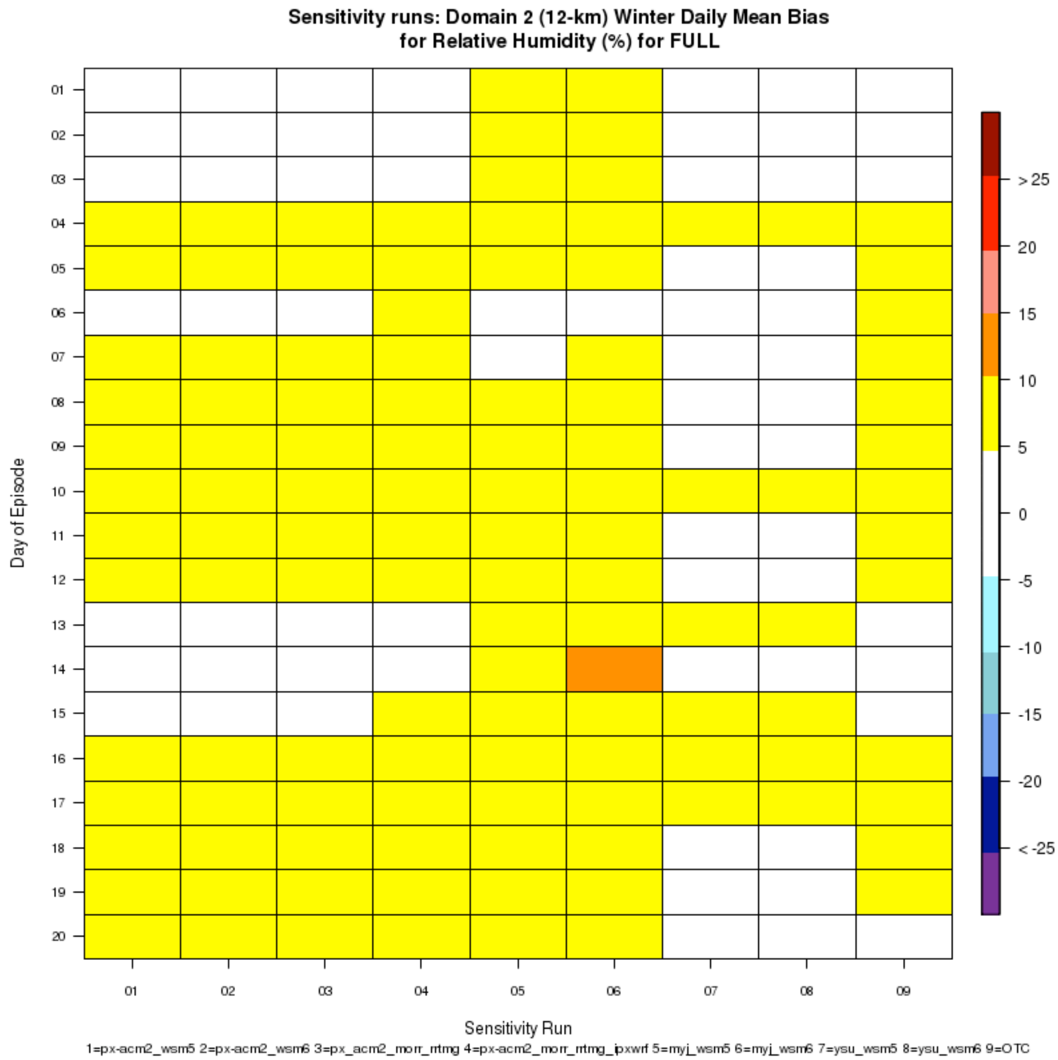
Summer


Sensitivity runs: Domain 2 (12-km) Summer Daily Mean Absolute Error
for Relative Humidity (%) for FULL
Day of Episode
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
Sensitivity Run
01
02
03
04
05
06
07
08
09
> 50
45
40
35
30
25
20
15
10
5
0
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC


Sensitivity runs: Domain 2 (12-km) Summer Daily Mean Bias
for Relative Humidity (%) for FULL
Day of Episode
Sensitivity Run
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC
> 25
20
15
10
5
0
-5
-10
-15
-20
< -25

Winter

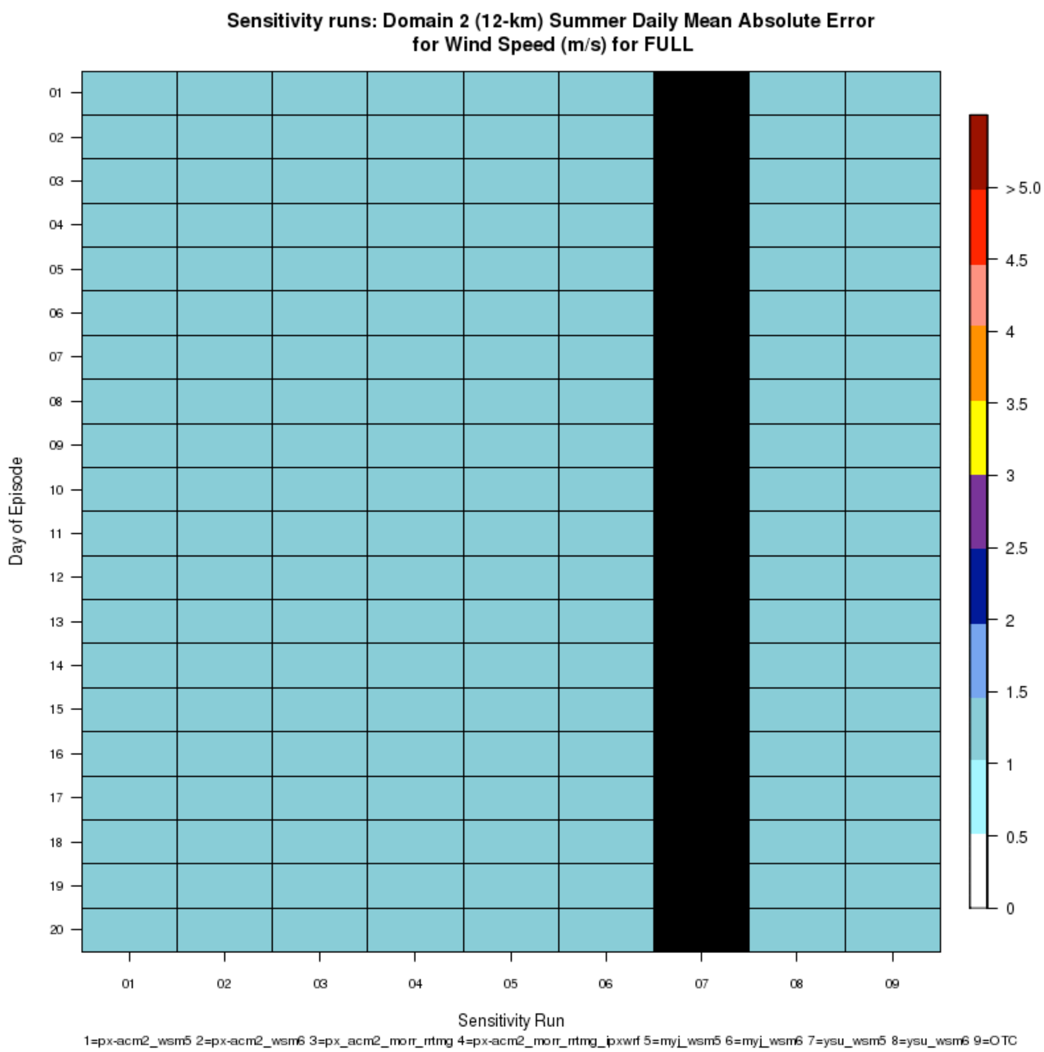

Sensitivity runs: Domain 2 (12-km) Winter Daily Mean Absolute Error
for Relative Humidity (%) for FULL
Day of Episode
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
Sensitivity Run
> 50
45
40
35
30
25
20
15
10
5
0
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC

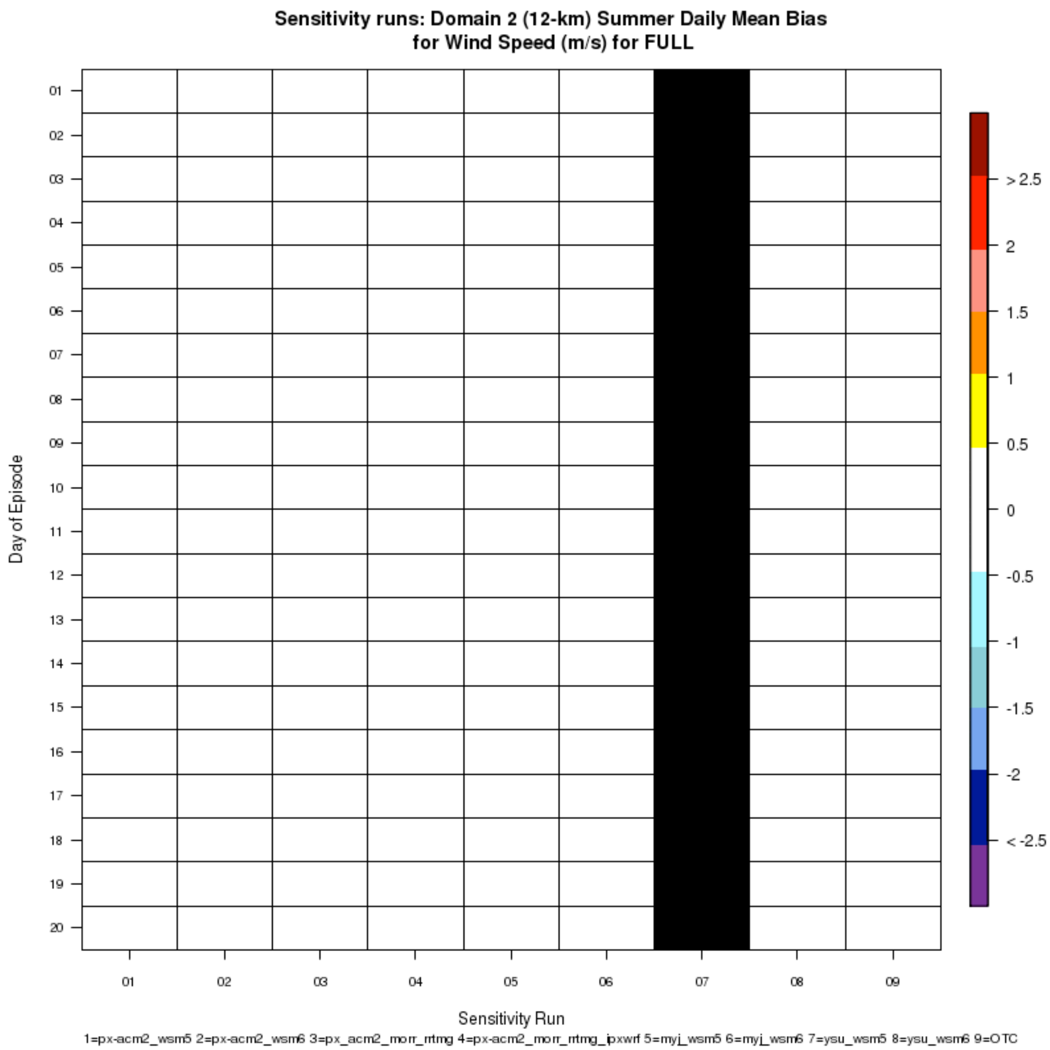


6.1.3.3 Wind Speed

The summer episode of the sensitivity runs shows that the absolute mean error of the wind speed is very uniform among the individual members. An error of 1-1.5 m/s is given for each of the 8 members with wind speed data at all 20 days of the sensitivity run. The Bakergram for the mean bias during the summer period does not show any significant bias for any of the individual runs. The winter sensitivity runs have slightly larger mean absolute errors, but as with the production run this is likely only due to higher average wind speeds during the winter. A few of the daily values for 4 of the sensitivity runs during this period exhibit a slight positive bias, but otherwise the bias appears to be quite small.

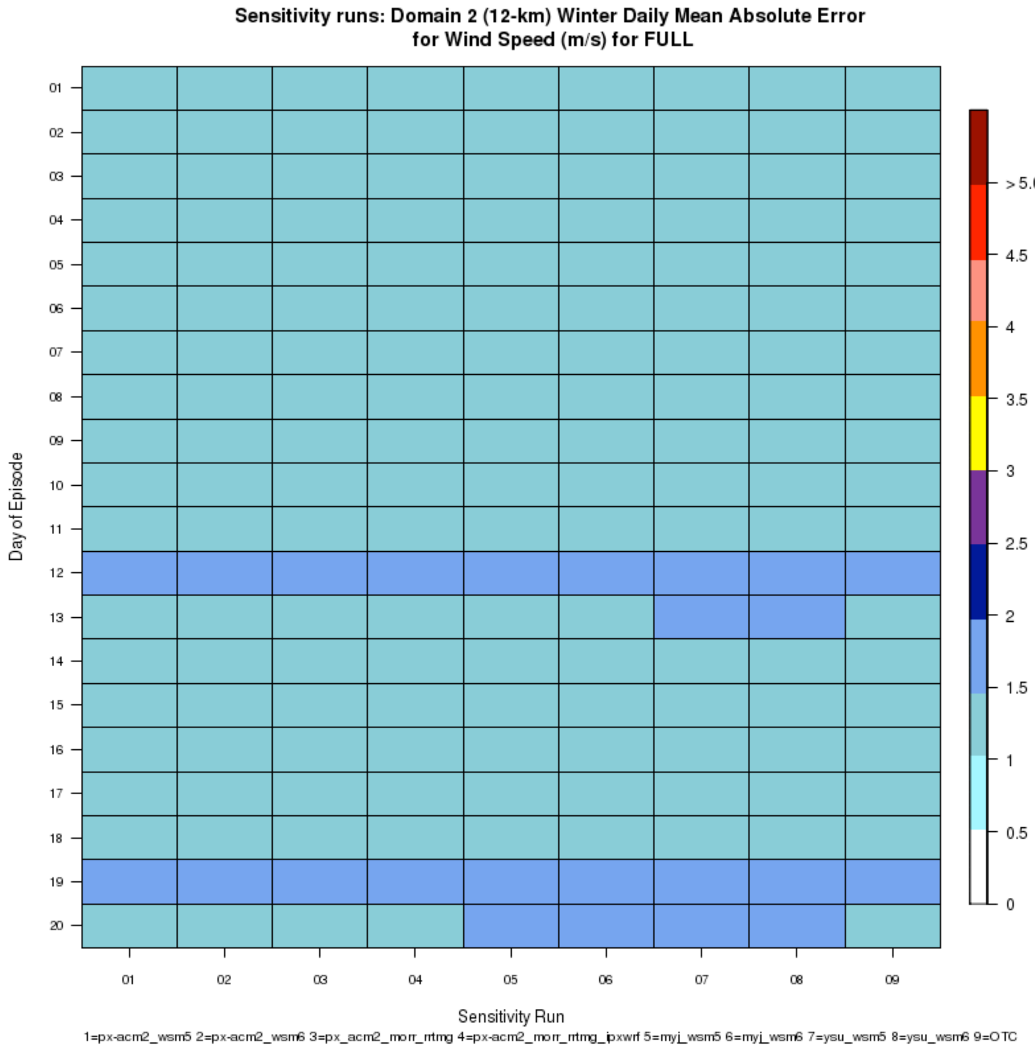
Summer


Sensitivity runs: Domain 2 (12-km) Summer Daily Mean Absolute Error
for Wind Speed (m/s) for FULL
Day of Episode
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
Sensitivity Run
01
02
03
04
05
06
07
08
09
> 5.0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC

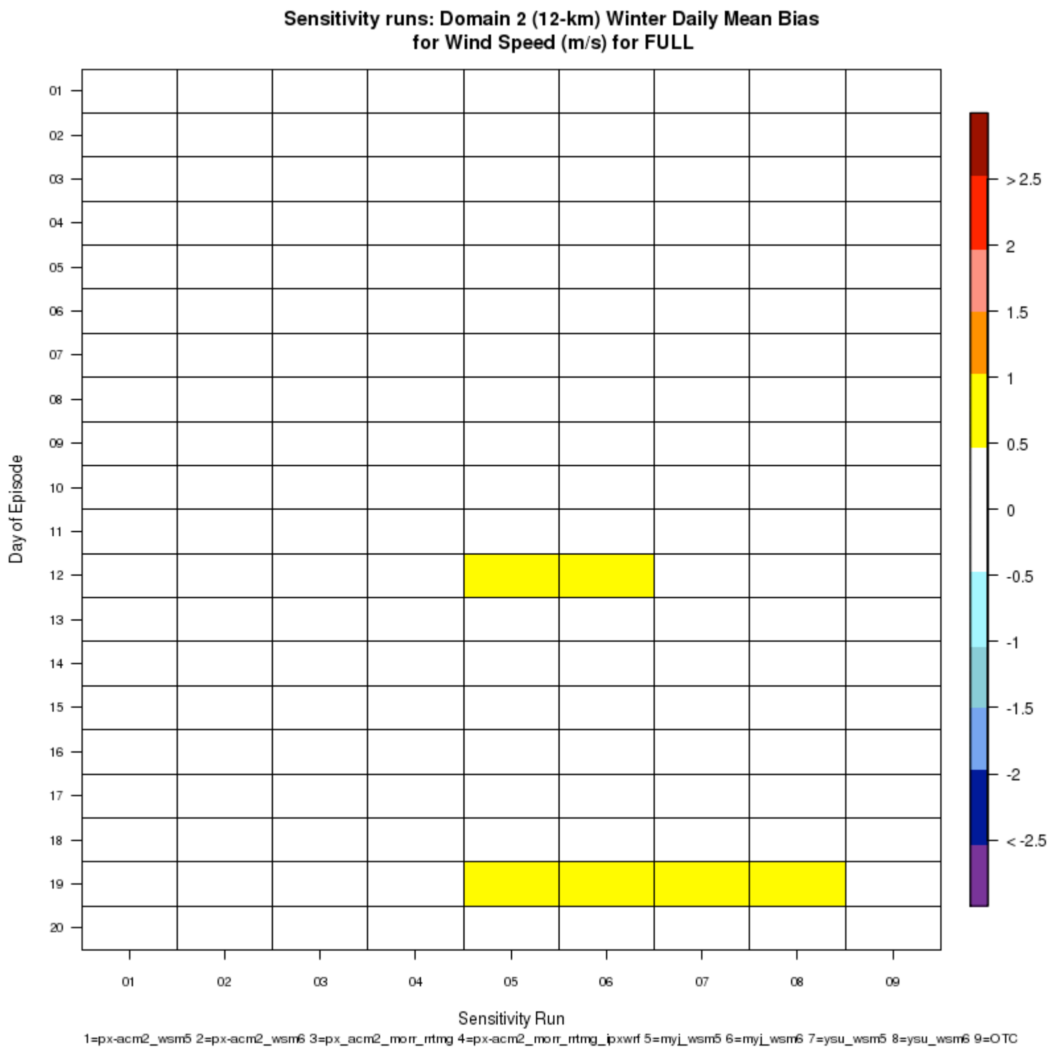


Sensitivity runs: Domain 2 (12-km) Summer Daily Mean Bias
for Wind Speed (m/s) for FULL
Day of Episode
Sensitivity Run
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC
> 2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
< -2.5

Winter



Sensitivity runs: Domain 2 (12-km) Winter Daily Mean Absolute Error
for Wind Speed (m/s) for FULL
Day of Episode
Sensitivity Run
1=px-acm2_wsm5 2=px-acm2_wsm6 3=px_acm2_morr_rrtmg 4=px-acm2_morr_rrtmg_ipxwrf 5=myj_wsm5 6=myj_wsm6 7=ysu_wsm5 8=ysu_wsm6 9=OTC
> 5.0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

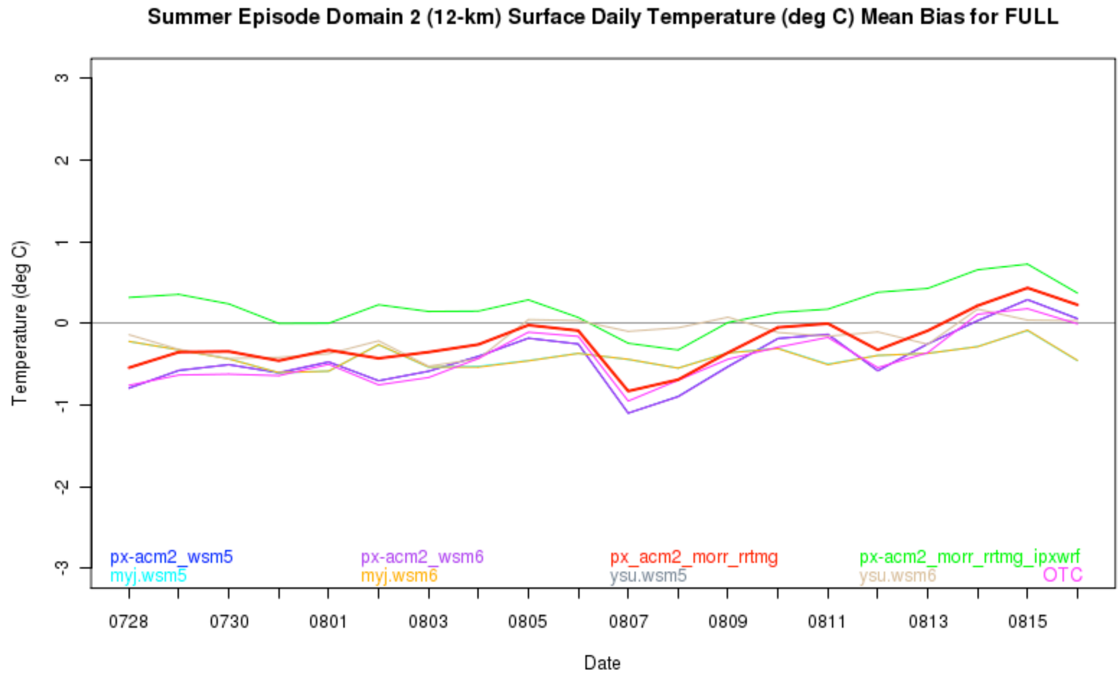


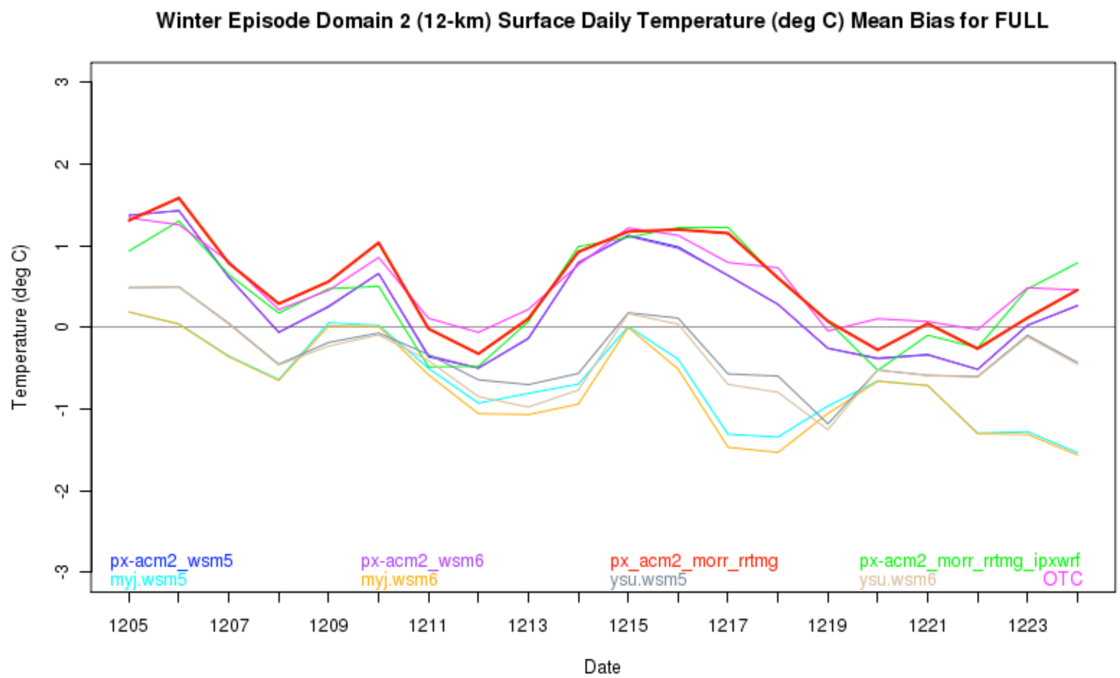
6.1.4 Task 2 H 4: Mean bias plots

This section describes the mean bias for each of the meteorological variables simulated by the WRF model for a summer and winter episode each consisting of 20 consecutive days. The production run, px_acm2_morr_rrtmg, is the red curve in the following plots. The discussion here focuses on the whole domain ("FULL") - plots for geographic sub-regions are available from the website.

6.1.4.1 Temperature

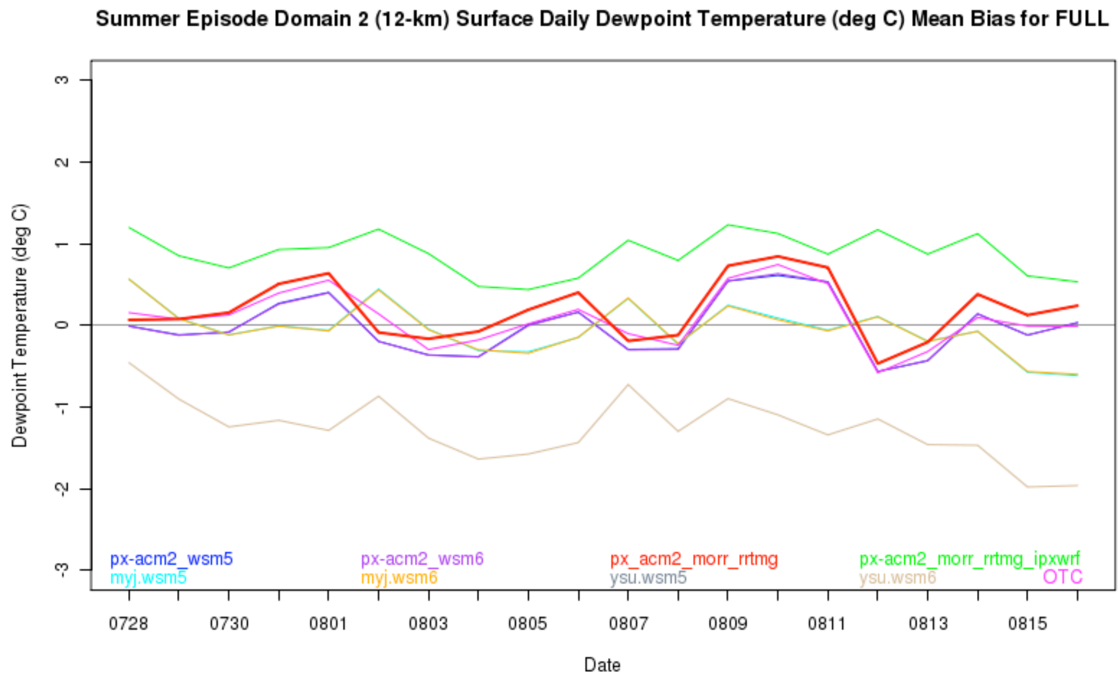
The sensitivity runs are generally in line with the production run for the summer episode with a slightly negative mean temperature bias indicating the simulations were slightly too cold. The px-acm2_morr_rrtmg_ipxwrf run contoured in green was the single outlier, but consistently the best run during this episode with a mean temperature bias near zero except near the end of the 20-day period. For the winter run the sensitivity runs appear to be split into two groups with half of the sensitivity runs, including the production run, slightly too warm and the other half slightly too cold. This difference is especially apparent during the 12-20 December period.

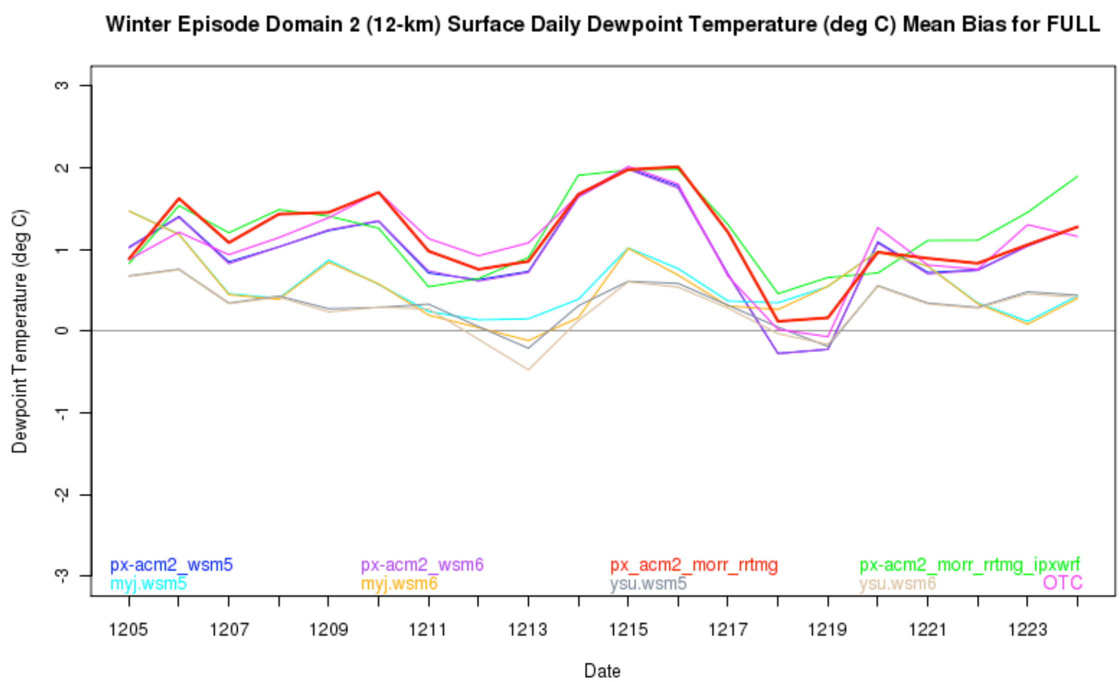


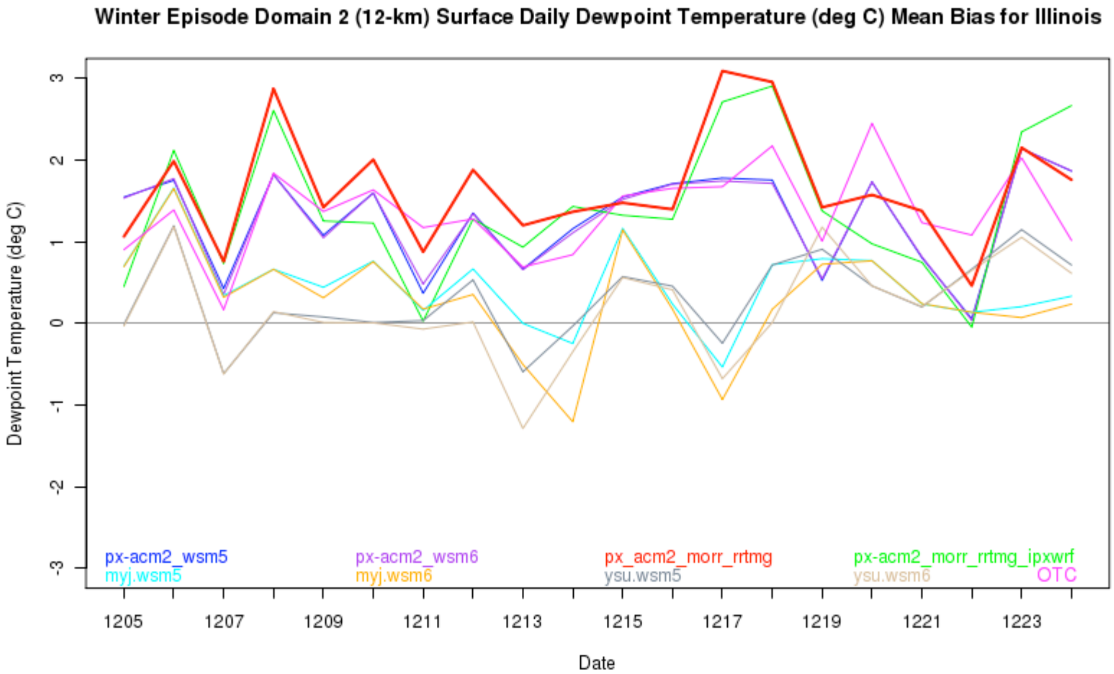


6.1.4.2 Dew point temperature

The sensitivity runs for the summer episode shows that most runs (including the production run) have a dew point temperature bias near zero. The px-acm2_morr_rrtmg_ipxwrf run has a 1°C warm bias and the ysu.wsm6 run a 1-1.5°C cold bias. The winter episode generally displays a positive dew point temperature bias especially from the production run. About half of the sensitivity runs display a smaller bias than the production run. The positive bias during the winter episode tends to be most consistent over the upper Midwest and Ohio Valley possibly due to the presence of snow cover that may affect the ability of the WRF to simulate dew points. A sample plot from Illinois is included to demonstrate the consistent nature of the positive bias.



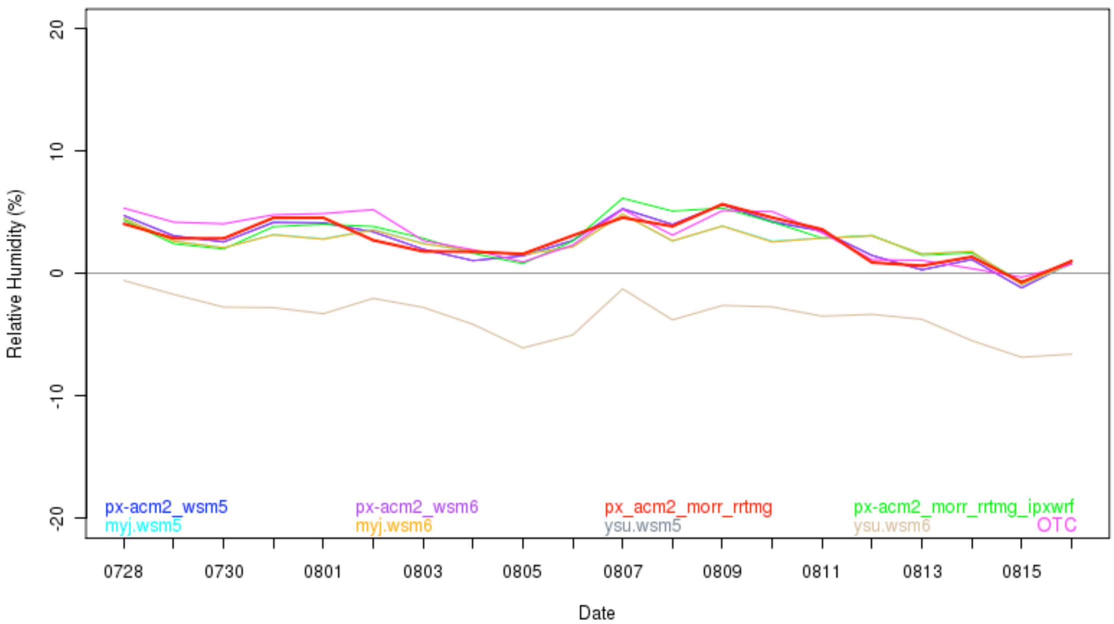




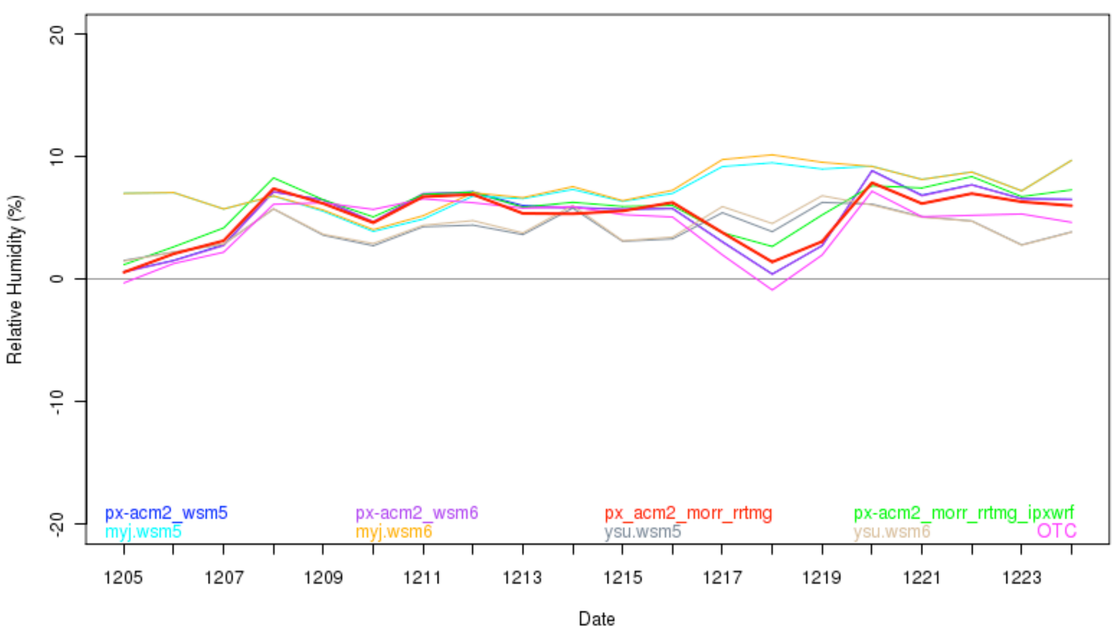
6.1.4.3 Relative Humidity

The sensitivity runs for relative humidity during the summer episode indicate all of the runs except for one significant outlier track closely to the production run and have a positive mean bias of approximately 2-3%. The ysu.wsm6 sensitivity run consistently shows a negative mean bias of roughly the same 2-3%. In the winter episode, all of the sensitivity runs including the production run generally have a positive bias of about 5%. The myj.wsm6 run has the largest bias of the sensitivity runs reaching upwards of 10% during the 16-20 December period when it diverges from the majority of the runs.

Summer Episode Domain 2 (12-km) Surface Daily Relative Humidity (%) Mean Bias for FULL



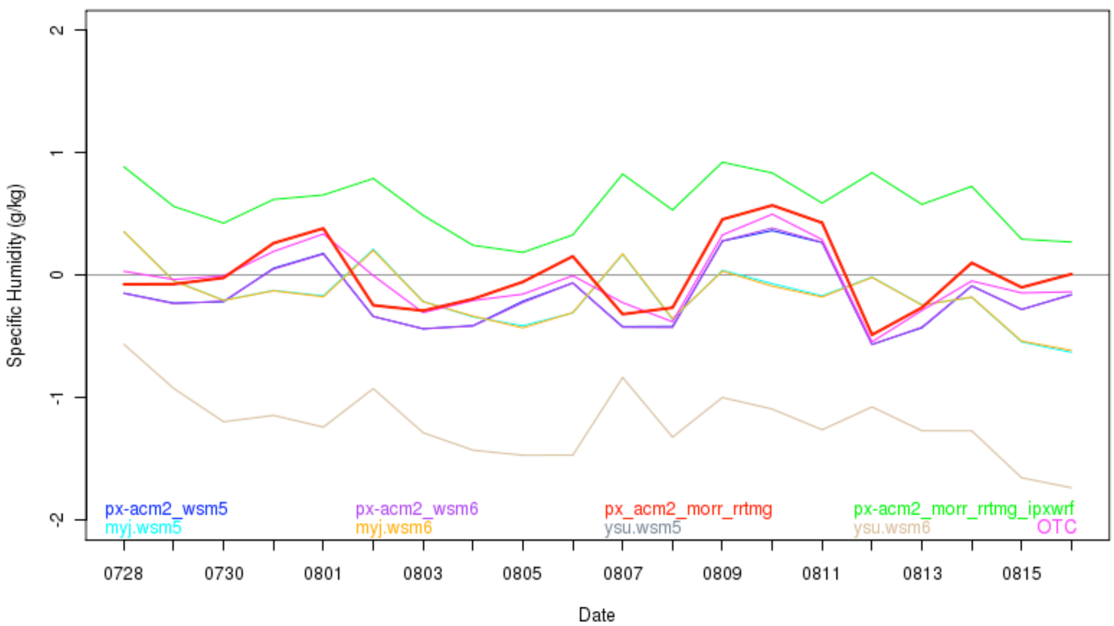
Winter Episode Domain 2 (12-km) Surface Daily Relative Humidity (%) Mean Bias for FULL



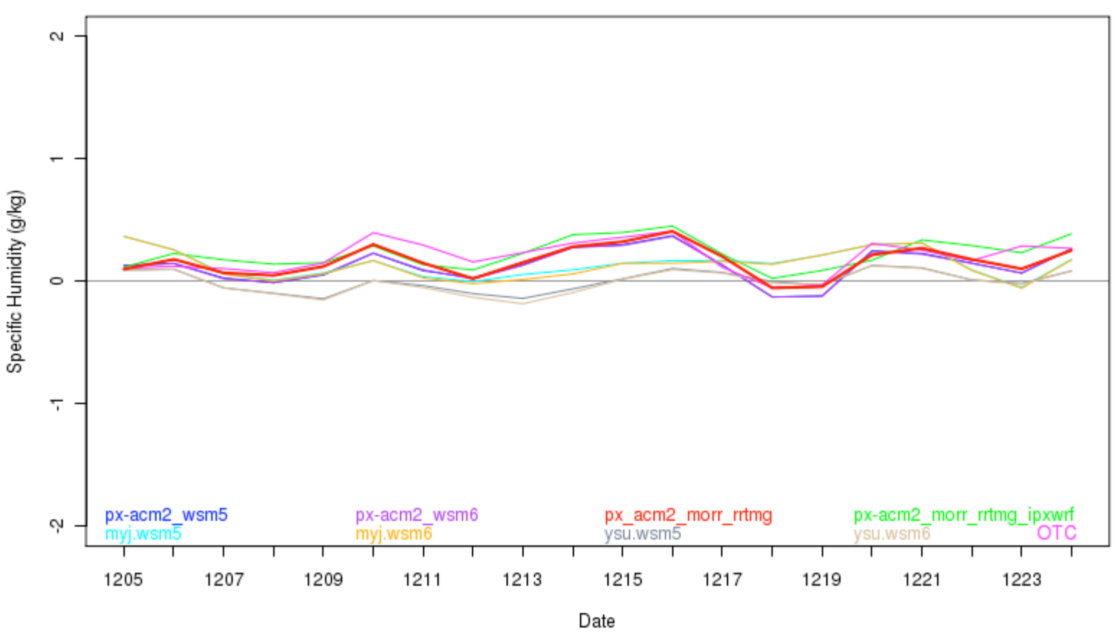
6.1.4.4 Specific Humidity

The summer episode sensitivity runs for specific humidity look qualitatively very similar to the dew point temperature sensitivity runs. The mean specific humidity value is much lower in winter due to lower absolute moisture levels and this is contributing to a perceived lack of a significant bias during the winter episode. However, it appears that as with the dew point temperature the specific humidity has the most significant and consistent positive bias farther to the north over the Upper Midwest and Ohio Valley states. As with the dew point temperature for the summer episode, the px-acm2_morr_rrtmg_ipxwrf run has a positive bias of about 0.5 g/kg and the ysu.wsm6 has about a 1 g/kg negative bias. The majority of the sensitivity runs, however, track closely to the production run.

Summer Episode Domain 2 (12-km) Surface Daily Specific Humidity (g/kg) Mean Bias for FULL



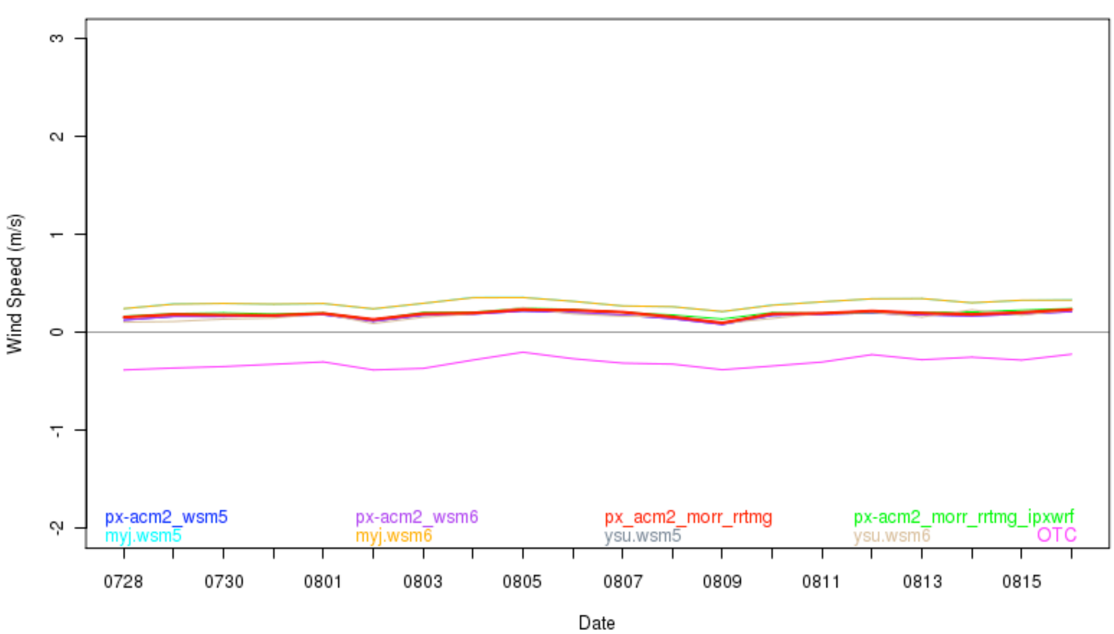
Winter Episode Domain 2 (12-km) Surface Daily Specific Humidity (g/kg) Mean Bias for FULL



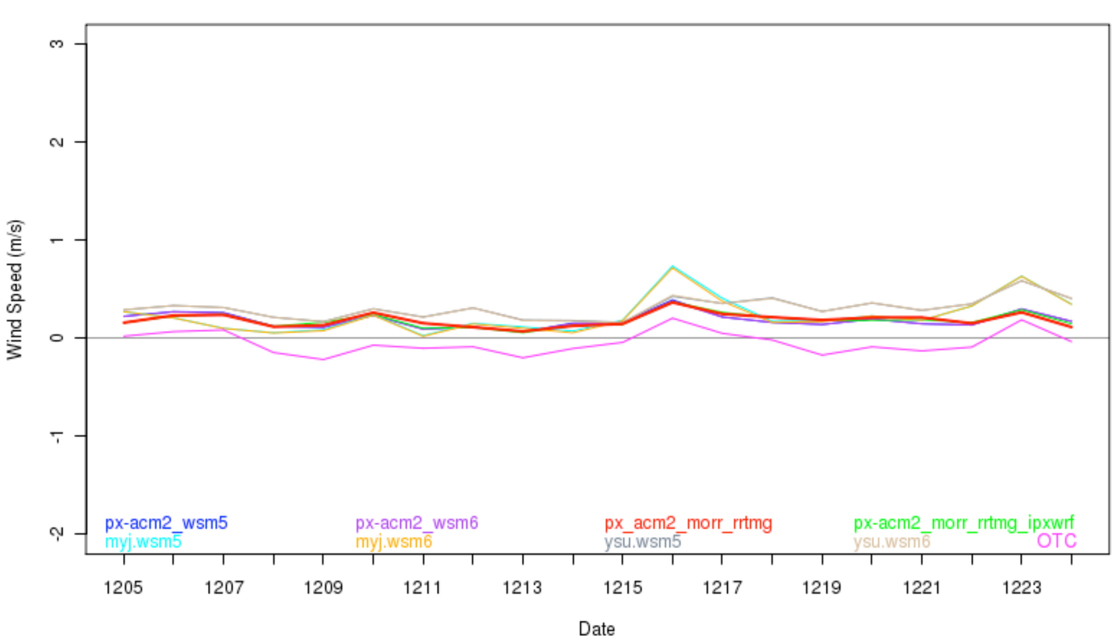
6.1.4.5 Wind Speed

The production and sensitivity runs for the summer and winter episodes are very similar to one another and exhibit only very slight positive biases. The OTC sensitivity run is the single outlier especially during the winter episode when it runs about a 0.5 m/s negative bias relative to the observed wind speed values. Overall, for both episodes the mean bias is small.

Summer Episode Domain 2 (12-km) Surface Daily Wind Speed (m/s) Mean Bias for FULL



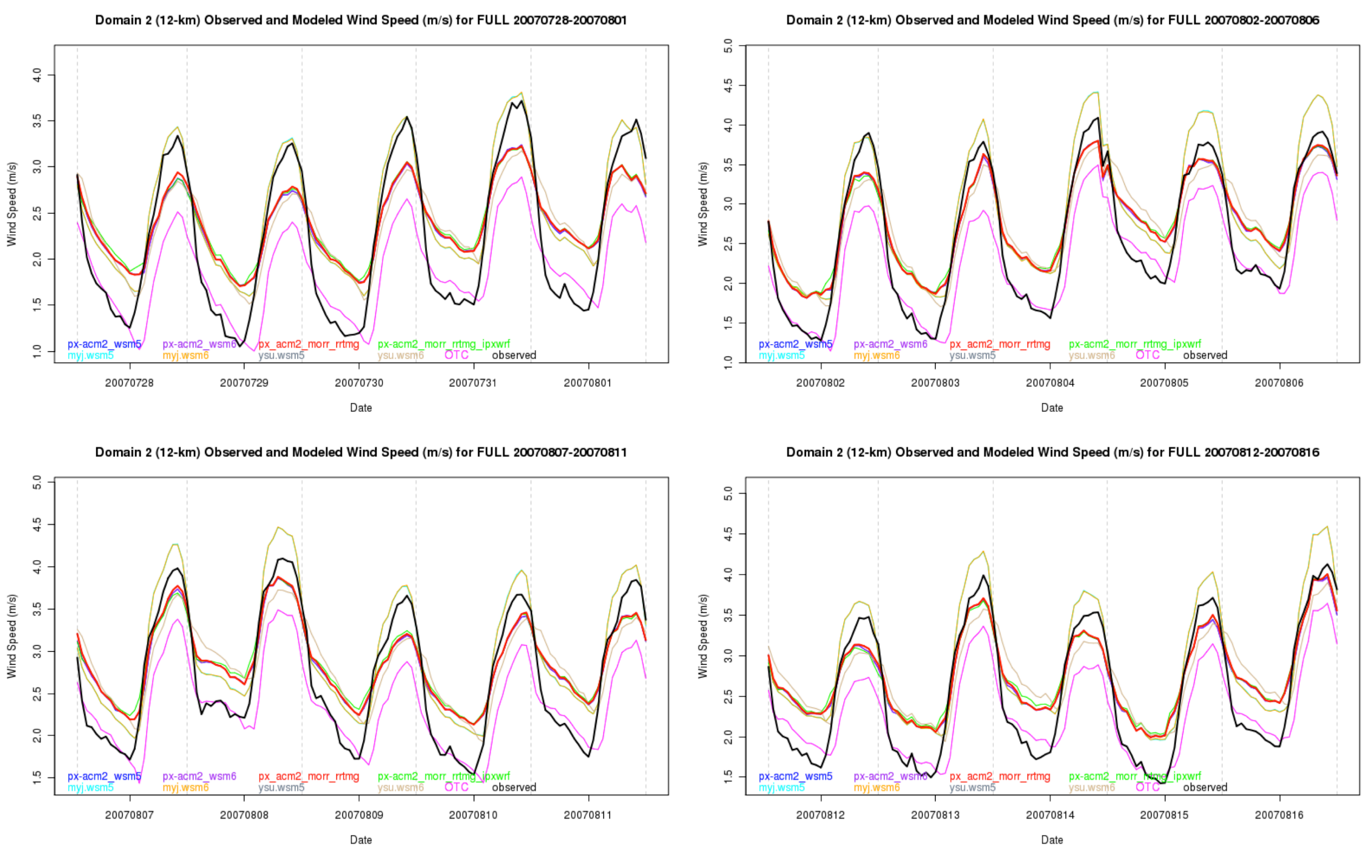
Winter Episode Domain 2 (12-km) Surface Daily Wind Speed (m/s) Mean Bias for FULL



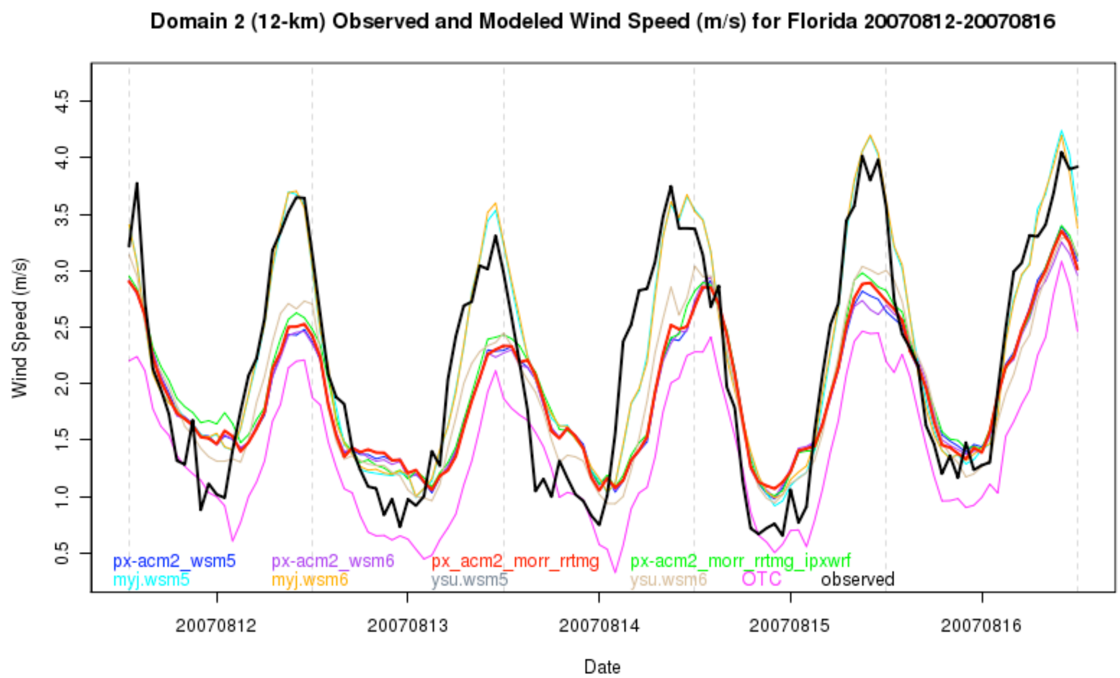
6.1.5 Task 2 H 5: Wind speed plots

The following section shows time series of spatial averages for the surface wind speed from observations (in black) and simulated by the WRF model for 5-day periods for the summer and winter episodes of the sensitivity runs. The production run, px_acm2_morr_rrtmg, is the red curve in the following plots.

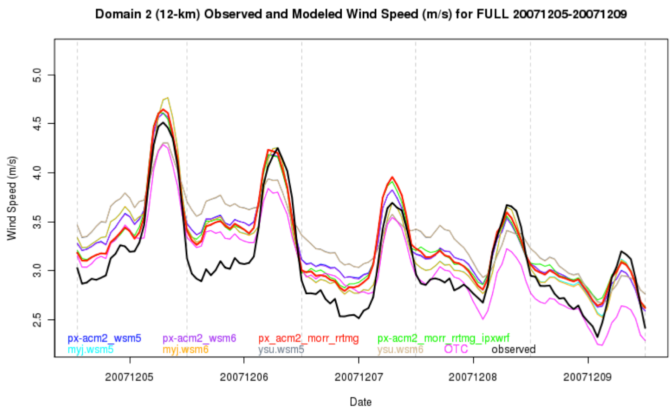
The following plot shows the individual 5-day time series for the summer episode of the WRF sensitivity runs. The production run and most of the sensitivity runs have an under representation of the variability in the observed wind speeds with winds that are simulated too low in the daytime hours and too high during the night. The myj.wsm5 and myj.wsm6 sensitivity runs perform well at simulating the peak wind speeds that occur in the daytime hours although perhaps they show a slight positive bias. The OTC run accurately simulates the wind speed minima that occur during the nighttime and early morning hours, but at other times is the poorest of the sensitivity runs when compared with the observed wind speeds as it predicts the lowest wind speed maxima.

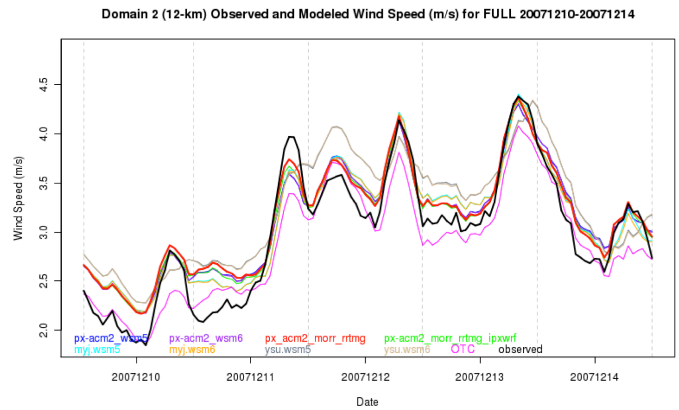


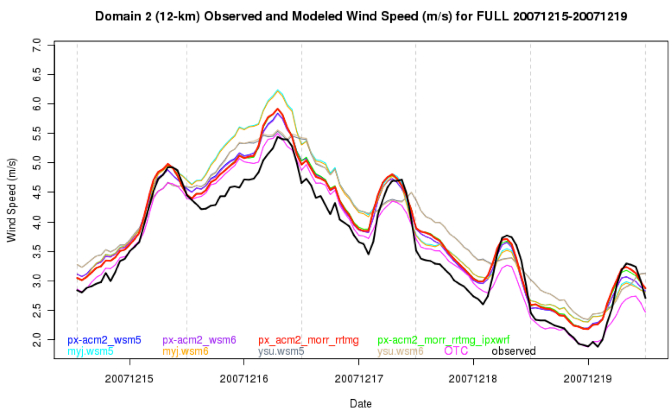
The sensitivity plots for one of the 5-day periods from the summer episode is shown below to highlight one of the regional differences. The plot for Florida is similar to the plot for the entire domain 2, with an under representation of the variability in the observed wind speeds. However, for this the production run and a number of the other sensitivity runs appear to be much better at simulating the wind speed minima (they are within about 0.5 m/s of the observed wind speed minimum).

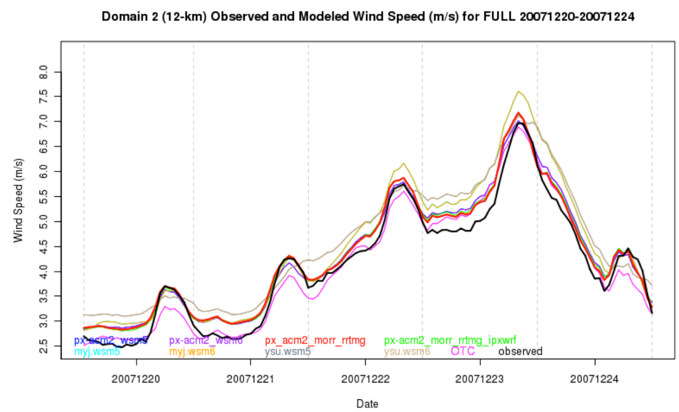


The winter episode shows some considerable differences compared to the summer episode. The observed wind speeds in the winter episode generally have greater variability than during the summer. The production run performs well at simulating the maximum wind speeds, but still appears to overestimate the wind speed during the nighttime and early morning hours when there is a stable boundary layer and the wind speeds are reduced. The ysu.wsm6 has the largest errors of all runs during much of the winter episode and performs the worst during the periods where the boundary layer becomes stable and the observed wind speeds decrease significantly. The OTC sensitivity run consistently has the lowest wind speeds of all the sensitivity runs, similar to what is found for the summer episode.

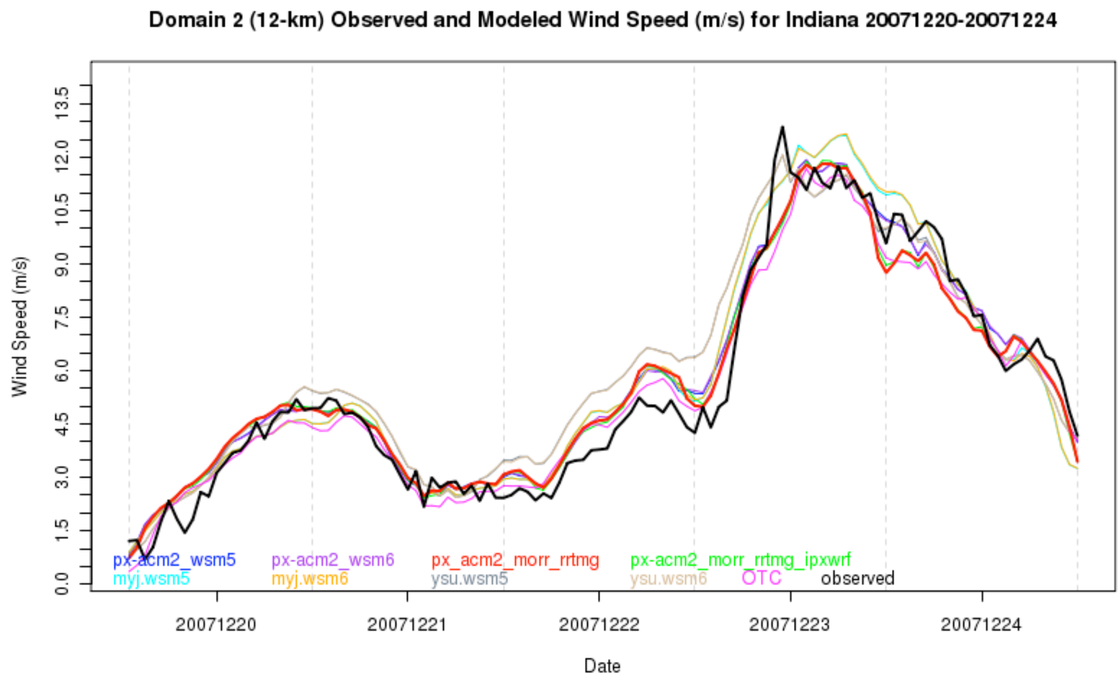


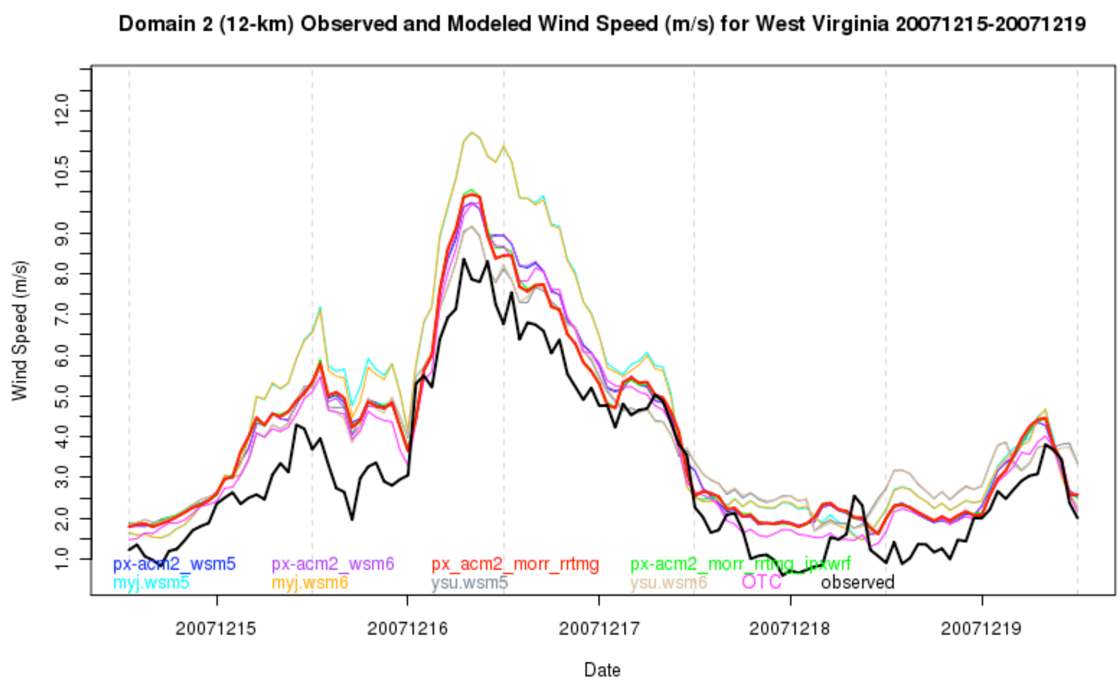






Winter episode plots for separate 5-day periods for Indiana and West Virginia are show below again to highlight some of the regional differences. The production run in the Indiana plot generally tracks the observations well and does not appear to show a systematic bias. A couple of the sensitivity runs (among them myj.wsm5, myj.wsm6, and ysu.wsm6) overpredict the wind speed during maxima in the observed wind speed. In the West Virginia plot there is a tendency for all of the sensitivity runs, including the production run, to overestimate the wind speed. The myj.wsm5 and myj.wsm6 runs had especially strong wind speeds relative to the observed wind speeds. The behavior of the WRF simulation over West Virginia is likely attributable to the higher terrain across much of the state (as was also found for the year-long statistics of the production run).





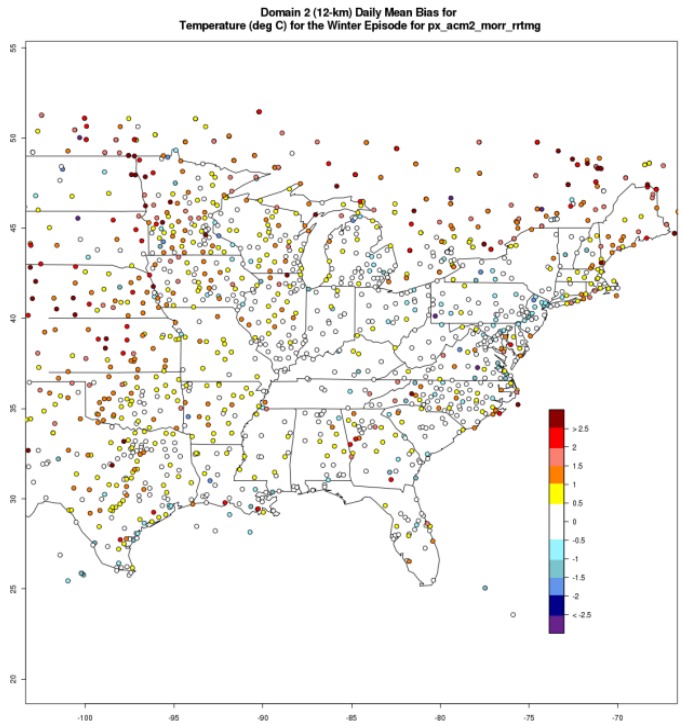
6.1.6 Task 2 H 6: Bubble spatial plots of error statistics

This section discusses the results of the sensitivity runs in terms of the spatial “bubble” plots of bias and MAE. These plots are analogous to those for the production run in Task 2 C.

6.1.6.1 Temperature

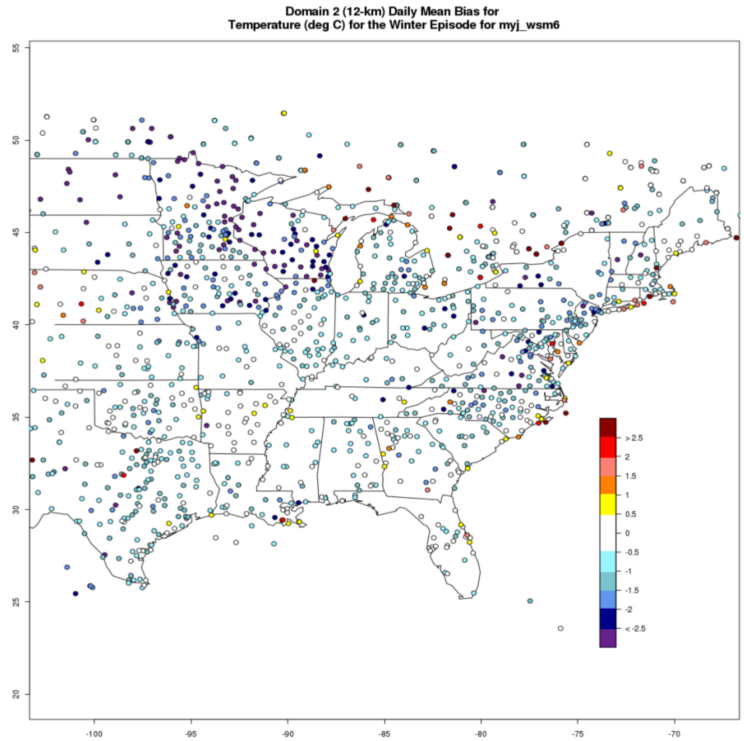
The 2-meter / surface temperature mean absolute errors (MAE) of domain 2 were generally less than 2.5 $^{\circ}$C for both winter and summer for all sensitivity runs. However, there were some differences in the biases between the runs. For winter the OTC, px_acm2_morr_rrtmg_ipxwrf, and px_acm2_morr_rrtmg runs exhibited warm biases > 1.0 C over the Great Plains, southern Canada and many locations along East Coast. The px_acm2_morr_rrtmg run, shown below, was the best of the three as the other two featured more locations with larger biases > 2.0 C.

Winter Temperature Mean Bias for Domain 2 for px_acm2_morr_rrtmg



The runs myj_wsm5, myj_wsm6, ysu_wsm5, and ysu_wsm6 featured a cold winter bias of < -2.0 C over Wisconsin and eastern Minnesota as shown below for myj_wsm6. The cold bias was only present on 4 of the 19 days of the winter runs and interestingly was present for those same days, December 13, 16, 17, 19, in all the sensitivity runs. The fact that the cold bias only shows up as a seasonal bias in these four runs was that much larger positive biases (> 2.5 C) on other days for the other runs negated this cold bias. There were no substantial winter temperature biases for the px_acm2_wsm5 and px_acm2_wsm6 runs.

Winter Temperature Mean Bias for Domain 2 for myj_wsm6

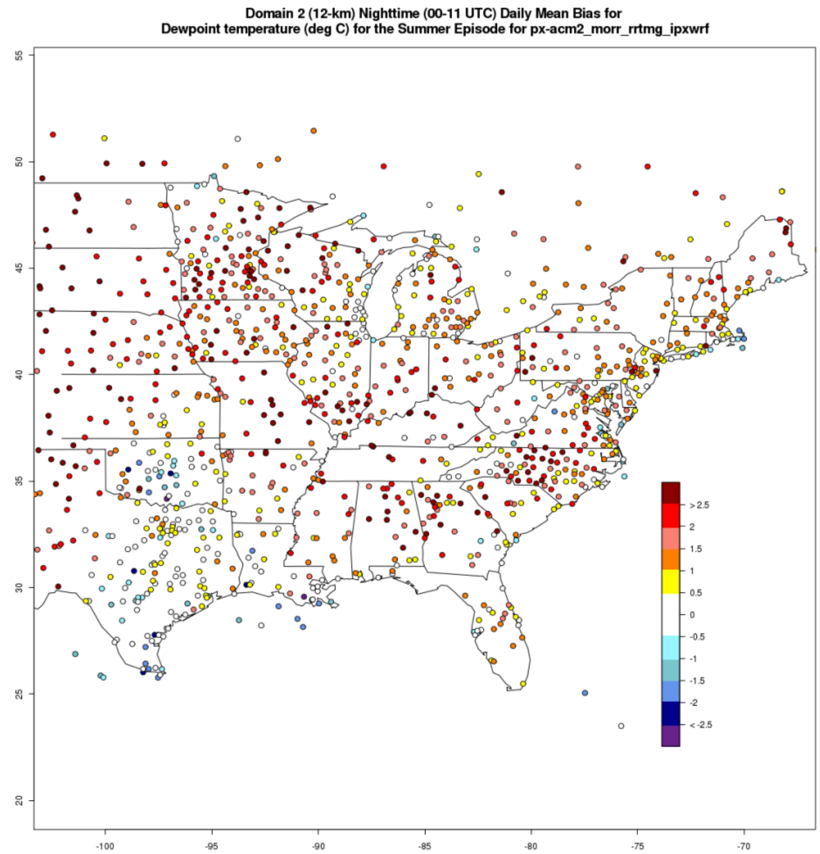


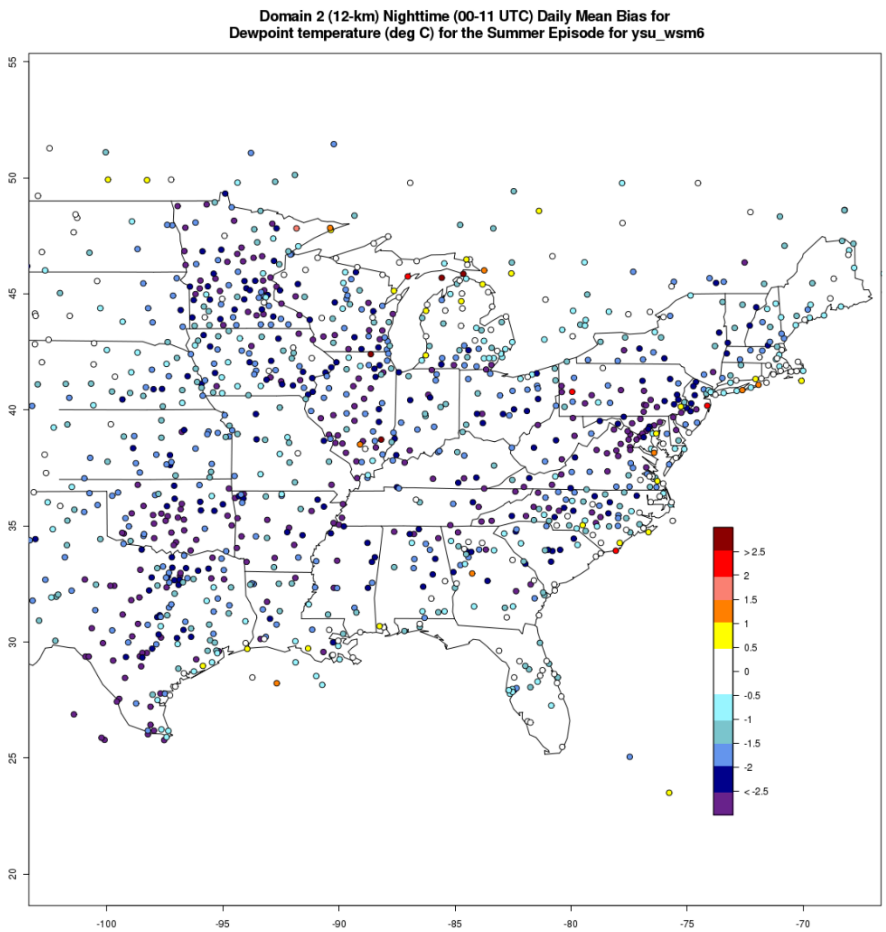
During summer only the px_acm2_morr_rrtmg_ipxwrf run exhibited notable biases. For this run there was a general 0.5 warm bias in the northern half of domain 2 and with an embedded cool bias of < - 2.0 C immediately north of the Great Lakes.

6.1.6.2 Relative humidity and dew point

The WRF-MET 2-meter / surface relative humidity (RH) MAEs were generally < 10 % during the summer and < 15 % in winter for all runs. During winter all runs exhibited a moist bias of 10 – 15 % from the upper Midwest to New England. The 2-meter dew point errors exhibited greater inter-run variability. During winter runs OTC, px_acm2_morr_rrtmg_ipxwrf, px_acm2_morr_rrtmg featured a moist dew point bias of > 1.5 C over much of the northern half of domain 2, while the other runs featured a moist bias < 1.5 C. During summer the biases in the dew point temperature did not seem to have any discernable pattern in all but two runs. For px_acm2_morr_rrtmg_ipxwrf, there was a notable moist bias > 1.5 C over much of the domain and for ysu_wsm6 there was dry bias of < -2.0 C in many locations as shown below. In neither case was the bias dependent on the time of the day, but the cool bias in the latter run seemed to be more persistent.

Summer Nighttime Dew point Mean Bias for Domain 2 for px_acm2_morr_rrtmg_ipxwrf





6.1.6.3 Wind speed

During winter the MAEs for the WRF-MET 10- meter / surface wind speed were generally < 1.5 m/s for all runs over much of domain 2. The exceptions were along the northeastern coast of the U.S. and in southern Canada where the MAEs were > 1.5 m/s with some locations > 2.0 m/s. There did not seem to be any notable differences in the wind errors between the sensitivity runs and biases seemed to be < 0.5 m/s at most locations.

During summer the 10-meter wind MAEs were generally < 1.5 m/s with biases < 0.5 m/s for all runs. There was some inter-run variability in summer as runs OTC, ysu-wsm5 and ysu_wsm6 exhibited MAEs of 1.5 – 2.0 m/s at many locations along coast of the northeastern U.S. and in southern Canada

6.1.6.4 Wind direction

The wind direction errors exhibited the same characteristics as reported in Task 2 C. There were no distinguishable differences between the sensitivity runs.

7 Meteorological modeling website and other technical aspects

7.1 Website development and documentation

The project web site (http://sesarm.aer.com) serves as the primary means for distributing and evaluating the substantial meteorological modeling results/summaries and communicating the corresponding documentation to SESARM. This web site satisfies the requirements for 'Task 5 Technical Meteorological Modeling Web Site' of contract S-2009-09-01. All content on this web site has been approved by the SESARM Project Officer prior to posting. The website presents objective evaluation results as itemized by Amendment 2 of the project Contract, signed 4 August 2011.

7.2 Supplemental Dataset

All WRF-MET point_stat output files (referred to earlier in this document as 'STAT' files) have been provided on an external drive to SESARM. These data represent the raw pairs of modeled and observed values, including spatially-averaged values, that are valid at the top of each hour. Data are available for the full calendar year for the production run, and for each hour during each sensitivity period for the sensitivity runs. Data are available for domains 1 and 2 for the production run, and domain 2 for each sensitivity run.

8 Summary and conclusions

Do the model results fit our conceptual understanding?

Meteorological fields generated during this modeling effort agree with our conceptual understanding of the physical processes of the atmosphere, and, as such, are representative of the observed weather conditions. The WRF-ARW model, when configured in the manner followed by SESARM, ensures that the physical processes of the atmosphere, such as heat and moisture fluxes, interact according to the laws of motion in a manner that is reproducible and verifiable using observations, subject to known, acceptable, model limitations.

Are diurnal features adequately captured?

The WRF model adequately captures the diurnal cycle of temperature, moisture and wind. During periods when the surface flow is forced more strongly by synoptic weather systems, such as during the winter, forecast errors for the wind speeds are minimized. During spring and summer when strong insolation increases the depth of the mixed layer, the model tends to underpredict surface wind speeds during the afternoon. Conversely, the model maintains mixing that is too strong during the overnight hours.

Do the wind fields agree with the observations?

Overall surface wind fields are well represented in the model and provide valuable estimation of the flow fields in the troposphere. Domain-wide wind speed forecasts averaged over full days and for longer timer periods did not exhibit a prolonged or substantial speed bias and wind speed RMSE errors were generally near or slightly exceeded the critical threshold of 2 m/s only for the coarse domain. Values of correlation coefficient are higher than the critical threshold of approximately 0.60. These values do not suggest a systematic problem with the model configuration or performance. Errors values for wind fields above the PBL and removed from the effects of orography were noticeably smaller.

Wind direction forecasts did not exhibit substantial biases, however, mean absolute errors for both domains were at or slightly above the critical threshold of 30 degrees. In combination, these two sets of errors suggest that the direction errors were somewhat random in nature, which is not unexpected when compared with other modeling studies.

Do the temperature and moisture fields generally match the observations?

Overall the temperature and moisture fields generally match the observations. Mean biases in temperature were typically within the critical threshold of 0.5 ^{o}C, with domain 2 values slightly less than those for domain 1. Mean absolute error values during the wintertime were approximately 2 ^{o}C resulting primarily from warm biases. Summertime values were somewhat less. Correlation coefficient values were significantly higher than the critical threshold.

Both mean bias and mean absolute errors for specific humidity were well within acceptable thresholds, even during the summer when levels of moisture in the atmosphere are significantly higher than in the cold winter months. Bias values for all months and both domains were small and positive, with similar characteristics seen in the dew point temperature. A positive bias of moisture may be related to the presence of snow cover in the northern US during the winter and spring, Though a causal relationship is not possible to ascertain, the positive bias of moisture was most pronounced when snow cover was present.

Do the meteorological fields produce acceptable air quality results?

AER recommends the future use of these WRF runs for the following reasons: 1) the fields were generated from the latest version of a state-of-the-art meteorological model, 2) proper configuration of the model was followed, 3) error values are consistent with those in the literature, and 4) there is an absence of obvious, profound, systematic modeling errors. Despite the overall recommendation, it is suggested that future users of subsets of these raw meteorological fields and subsequent air quality fields closely inspect the quality of the individual WRF runs, since the quality of any one run can vary considerably. As well, patterns that seem to emerge from some of the analyses (e.g., time series at METAR sites) are sometimes not representative of broader geographical regions (viz. corresponding bubble spatial plots). The user should make an assessment for their own needs based on the time and region of interest. The individual poor forecasts are often attributed to errors in the initial conditions of the model and may ultimately be linked to failures in the observational network after substantial scientific investigation. Typically these poor model forecasts are limited in space and time.

9 Appendix A

This appendix lists the location details of all Continental US METAR locations whose data are potentially in the prepBUFR observation dataset that was used in this evaluation study. These are observation locations that are generally available over the GTS communication channel that is the standard transmission channel for NCEP. We know of no source that monitors on a site-by-site basis what is available at any observation time. Observations come and go from this set for a number of reasons, including, but not limited to, communications failures, equipment failures, typographical errors and various attempts at quality control. All observations in the prepBUFR files were ingested and used by WRF-MET. There are no known observations that are never used within CONUS and, while a very small number of observations may change states depending on which modeling domain is used, they are never used in multiple states at once for each domain.

This study used Version 2 of WRF-MET, which does not have the capability to assign station IDs to the latitude/longitude pairs associated with each observation.

CD	STATION	ICAO	IATA	SYNOP	LAT	LONG	ELEV (m)
AL	ALABASTER	KEET	EET		33 11N	086 47W	173
AL	ALBERTVILLE MUNI	K8A0	8A0		34 14N	086 15W	315
AL	ALEXANDER/RUSSEL	KALX	ALX		32 55N	085 58W	209
AL	ANDALUSIA/OPP AR	K79J	79J		31 19N	086 24W	94
AL	ANNISTON	KANB	ANB		33 35N	085 51W	183
AL	AUBURN UNIV. (AM	KAUB	AUB		32 36N	085 30W	198
AL	AUBURN OPELIKA A	KAUO	AUO		32 37N	085 25W	236
AL	BIRMINGHAM	KBHM	BHM	72228	33 34N	086 45W	197
AL	OZARK/CAIRNS AAF	KOZR	OZR		31 17N	085 43W	93
AL	CENTREVILLE WSM	K0A8	0A8	72229	32 53N	087 15W	140
AL	COURTLAND	K9A4	9A4		34 40N	087 21W	179
AL	CULLMAN/FOLSOM F	K3A1	3A1		34 16N	086 51W	294
AL	DECATUR	KDCU	DCU		34 39N	086 57W	176
AL	DOTHAN	KDHN	DHN		31 19N	085 27W	113
AL	EUFAULA	KEUF	EUF		31 57N	085 08W	87
AL	EVERGREEN	KGZH	GZH		31 25N	087 03W	78
AL	FAIRHOPE	KCQF	CQF		30 28N	087 53W	28
AL	FLORALA MUNI	K0J4	0J4		31 03N	086 19W	96
AL	FT PAYNE/ISBELL	K4A9	4A9		34 28N	085 43W	267
AL	FT RUCKER/SHELL	KSXS	SXS		31 22N	085 51W	122
AL	FT RUCKER/HANCHE	KHEY	HEY		31 21N	085 39W	97
AL	GADSDEN MUNI	KGAD	GAD		33 58N	086 04W	173
AL	GREENVILLE	KPRN	PRN		31 51N	086 37W	138
AL	GULF SHORES	KJKA	JKA		30 17N	087 40W	5
AL	HALEYVILLE	K1M4	1M4		34 17N	087 36W	284
AL	HUNTSVILLE	KHSV	HSV	72323	34 39N	086 47W	191
AL	HUNTSVILLE/MADIS	KMDQ	MDQ		34 52N	086 33W	230
AL	JASPER/WALKER	KJFX	JFX		33 54N	087 19W	148
AL	LOWE AHP/FT. RUC	KLOR	LOR		31 21N	085 45W	74

AL	MAXWELL AFB/MGM	KMXF	MXF		32 22N	086 22W	51
AL	MOBILE/BROOKLEY	KBFM	BFM		30 37N	088 04W	20
AL	MOBILE/BATES	KMOB	MOB	72223	30 41N	088 15W	63
AL	MONTGOMERY	KMGM	MGM	72226	32 18N	086 24W	63
AL	MUSCLE SHOAL	KMSL	MSL		34 45N	087 36W	164
AL	PHI OIL PLAT	KRAM	RAM		29 03N	088 05W	10
AL	REDSTONE ARSENAL	KHUA	HUA	74001	34 41N	086 41W	209
AL	SCOTTSBORO	K4A6	4A6		34 41N	086 00W	198
AL	TROY	KTOI	TOI		31 51N	086 01W	118
AL	TUSCALOOSA	KTCL	TCL		33 13N	087 37W	49
AL	VIOSCA KNOLL768	KVOA	VOA		29 14N	087 47W	53
AR	ARKADELPHIA	KM89	M89		34 06N	093 04W	56
AR	BATESVILLE	KBVX	BVX		35 43N	091 39W	141
AR	BENTONVILLE	KH00	H00		36 21N	094 13W	395
AR	BENTONVILLE	KVBT	VBT		36 21N	094 13W	395
AR	BENTONVILLE (NW)	KXNA	XNA		36 17N	094 18W	392
AR	BLYTHEVILLE	KHKA	HKA		35 56N	089 50W	78
AR	BLYTHEVILLE	KBYH	BYH		35 58N	089 57W	78
AR	CAMDEN	KCDH	CDH		33 37N	092 46W	35
AR	CLINTON MUNI	KCCA	CCA		35 36N	092 27W	157
AR	CORNING	K4M9	4M9		36 24N	090 39W	90
AR	DE QUEEN	KDEQ	DEQ		34 03N	094 24W	106
AR	EL DORADO	KELD	ELD		33 13N	092 49W	81
AR	FAYETTEVILLE	KFYV	FYV		36 01N	094 10W	379
AR	FLIPPIN (AWOS)	KFLP	FLP		36 17N	092 35W	219
AR	FORT SMITH	KFSM	FSM	72344	35 20N	094 22W	140
AR	HARRISON	KHRO	HRO		36 16N	093 09W	417
AR	HOT SPRINGS	KHOT	HOT		34 29N	093 06W	162
AR	JONESBORO	KJBR	JBR		35 50N	090 39W	79
AR	LITTLE ROCK	KLIT	LIT		34 44N	092 14W	79
AR	LITTLE ROCK AFB	KLRF	LRF		34 55N	092 09W	95
AR	MENA INTERMTN	KMEZ	MEZ		34 33N	094 12W	329
AR	W MEMPHIS MUNI	KAWM	AWM		35 08N	090 14W	65
AR	MONTICELLO	KLLQ	LLQ		33 38N	091 45W	83
AR	MOUNT IDA	KMWT	MWT		34 33N	093 35W	214
AR	MOUNTAIN HOME	KBPK	BPK		36 22N	092 28W	280
AR	N. LITTLE ROCK	KLZK	LZK	72340	34 50N	092 16W	173
AR	NEWPORT	KM19	M19		35 38N	091 11W	73
AR	PINE BLUFF/GRIDR	KPBF	PBF		34 11N	091 56W	62
AR	ROGERS	KROG	ROG		36 22N	094 05W	415
AR	RUSSELLVILLE	KRUE	RUE		35 15N	093 06W	115
AR	SEARCY	KSRC	SRC		35 15N	091 44W	80
AR	SILOAM SPRING	KSLG	SLG		36 12N	094 28W	300
AR	SPRINGDALE MUNI	KASG	ASG		36 10N	094 07W	412
AR	STUTTGART	KSGT	SGT		34 36N	091 34W	68
AR	TEXARKANA	KTXK	TXK		33 27N	093 59W	111
AR	WALNUT RIDGE	KARG	ARG		36 07N	090 55W	83
AZ	PHOENIX/SKY HRBR	KPHX	PHX	72278	33 26N	112 03W	336
AZ	TUCSON	KTUS	TUS		32 08N	110 57W	776
AZ	BUCKEYE	KBXK	BXK		33 25N	112 41W	315
AZ	BULLHEAD CITY	KIFP	IFP		35 09N	114 34W	212
AZ	CASA GRANDA	KCGZ	CGZ		32 57N	111 46W	446
AZ	CHANDLER/MESA	KIWA	IWA		33 18N	111 39W	412
AZ	CHANDLER	KCHD	CHD		33 16N	111 49W	379
AZ	DAVIS/TUCSON	KDMA	DMA		32 10N	110 52W	824
AZ	DOUGLAS BISBEE	KDUG	DUG		31 28N	109 35W	1265
AZ	FLAGSTAFF	KFLG	FLG	72375	35 08N	111 40W	2134

AZ	FORT HUACHUCA	KFHU	FHU	72273	31	35N	110	21W	1438
AZ	GILA BEND (AAF)	KGBN	GBN	74724	32	52N	112	43W	262
AZ	GLENDALE	KGEU	GEU		33	32N	112	18W	325
AZ	LUKE AFB/GLENDAL	KLUF	LUF		33	31N	112	22W	332
AZ	GOODYEAR MUNICIP	KGYR	GYR		33	25N	112	22W	295
AZ	GRAND CANYON	KGCN	GCN	72378	35	57N	112	09W	2016
AZ	GRAND CANYON/VAL	K40G	40G		35	38N	112	09W	1830
AZ	KINGMAN	KIGM	IGM	72370	35	15N	113	56W	1032
AZ	LAKE HAVASU CITY	KHII	HII		34	34N	114	22W	238
AZ	MESA/FALCON FLD	KFFZ	FFZ		33	28N	111	43W	424
AZ	NOGALES	KOLS	OLS		31	25N	110	51W	1184
AZ	PAGE	KPGA	PGA	72371	36	55N	111	27W	1307
AZ	PAYSON	KPAN	PAN		34	15N	111	20W	1572
AZ	PHOENIX/DEER VLY	KDVT	DVT		33	41N	112	04W	443
AZ	PIONEER AIRFIELD	KALK	ALK		31	36N	110	26W	1453
AZ	PRESCOTT	KPRC	PRC		34	39N	112	25W	1524
AZ	SAFFORD	KSAD	SAD		32	51N	109	38W	962
AZ	SCOTTSDALE	KSDL	SDL		33	37N	111	55W	447
AZ	SEDONA	KSEZ	SEZ		34	51N	111	47W	1473
AZ	SHOW LOW MUNICIP	KSOW	SOW		34	16N	110	00W	1954
AZ	ST. JOHNS	KSJN	SJN		34	31N	109	23W	1745
AZ	TUCSON/RYAN FLD	KRYN	RYN		32	09N	111	10W	737
AZ	WILLIAMS CLARK	KCMR	CMR		35	18N	112	12W	2036
AZ	WINDOW ROCK	KRQE	RQE		35	39N	109	04W	2055
AZ	WINSLOW	KINW	INW	72374	35	02N	110	43W	1490
AZ	YUMA INTL	KYUM	YUM	72280	32	38N	114	35W	63
AZ	YUMA MCAS	KNYL	NYL	69960	32	38N	114	37W	65
CA	ALAMEDA NAS	KNGZ	NGZ	74506	37	46N	122	19W	4
CA	ALTURAS	KAAT	AAT		41	29N	120	34W	1331
CA	APPLE VALLEY	KAPV	APV		34	34N	117	11W	934
CA	ARCATA/EUREKA	KACV	ACV		40	59N	124	06W	67
CA	AUBURN MUNI	KAUN	AUN		38	57N	121	05W	467
CA	AVALON	KAVX	AVX	72292	33	24N	118	25W	482
CA	BAKERSFIELD	KBFL	BFL	72384	35	26N	119	03W	151
CA	BEALE AFB/MARYSV	KBAB	BAB		39	07N	121	25W	34
CA	BEAUMONT	KBUO	BUO		33	55N	116	58W	692
CA	BIG BEAR CITY	KL35	L35		34	16N	116	51W	2059
CA	BICYCLE LAKE	KBYS	BYS	74611	35	17N	116	37W	716
CA	BISHOP	KBIH	BIH	72480	37	22N	118	21W	1253
CA	BLYTHE	KBLH	BLH		33	37N	114	43W	119
CA	BURBANK	KBUR	BUR	72288	34	12N	118	22W	217
CA	BURNEY	KBNY	BNY		40	52N	121	40W	957
CA	CALEXICO INTL	KCXL	CXL		32	40N	115	30W	1
CA	CAMARILLO	KCMA	CMA		34	13N	119	04W	23
CA	CAMP PENDLETON	KNFG	NFG		33	17N	117	20W	24
CA	CAMPO	KCZZ	CZZ		32	38N	116	28W	807
CA	CARLSBAD	KCRQ	CRQ		33	08N	117	17W	99
CA	CHICO MUNICIPAL	KCIC	CIC	72497	39	47N	121	50W	73
CA	CHINA LAKE (NAF)	KNID	NID	74612	35	40N	117	40W	696
CA	CHINO	KCNO	CNO		33	59N	117	37W	207
CA	COLUMBIA	KO22	O22		38	02N	120	25W	646
CA	CONCORD	KCCR	CCR		38	00N	122	03W	11
CA	CORONA MUNI	KAJO	AJO		33	54N	117	36W	163
CA	CRESCENT CITY	KCEC	CEC		41	46N	124	13W	17
CA	DAGGETT	KDAG	DAG		34	51N	116	47W	587
CA	DAVIS	KEDU	EDU		38	32N	121	47W	21
CA	EDWARDS AFB	KEDW	EDW	72381	34	53N	117	52W	702

CA EDWARDS N-AUX	K9L2	9L2		34 58N	117 52W	701
CA EL CENTRO NAF	KNJK	NJK	72281	32 49N	115 40W	-13
CA EL MONTE	KEMT	EMT	74704	34 04N	118 01W	90
CA EMIGRANT GAP	KBLU	BLU		39 17N	120 42W	1609
CA EUREKA/MURRAY	KEKA	EKA	72594	40 48N	124 10W	18
CA FRESNO	KFAT	FAT	72389	36 47N	119 43W	104
CA FRESNO CHANDLER	KFCH	FCH		36 43N	119 49W	85
CA FULLERTON	KFUL	FUL		33 52N	117 59W	35
CA HALF MOON BAY	KHAF	HAF		37 31N	122 30W	21
CA HANFORD	KHJO	HJO		36 19N	119 37W	74
CA HANFORD	KO18	O18		36 19N	119 38W	74
CA HAWTHORNE	KHHR	HHR		33 55N	118 20W	18
CA HAYWARD	KHWD	HWD		37 40N	122 07W	21
CA HOLLISTER MUNI	KCVH	CVH		36 54N	121 25W	70
CA HUNTER LIGGET	KHGT	HGT	69002	36 00N	121 13W	310
CA IMPERIAL	KIPL	IPL		32 50N	115 35W	-17
CA IMPERIAL BEACH	KNRS	NRS		32 34N	117 07W	7
CA INYOKERN	KIYK	IYK		35 40N	117 49W	749
CA LA VERNE/BRACKET	KPOC	POC		34 06N	117 46W	308
CA LANCASTER/FOX	KWJF	WJF		34 43N	118 13W	715
CA LEMOORE NAS/REEV	KNLC	NLC	74702	36 19N	119 57W	72
CA LINCOLN	KLHM	LHM		38 55N	121 21W	37
CA LIVERMORE	KLVK	LVK		37 42N	121 49W	117
CA LOMPOC	KLPC	LPC	74606	34 40N	120 28W	27
CA LONG BEACH	KLGB	LGB	72297	33 49N	118 09W	10
CA LOS ALAMITOS AAF	KSLI	SLI		33 46N	118 02W	11
CA LOS ANGELES	KLAX	LAX	72295	33 56N	118 23W	46
CA LOS ANGELES	KCQT	CQT		34 01N	118 17W	56
CA LA / WHITEMAN	KWHP			34 15N	118 25W	306
CA MADERA	KMAE	MAE		36 59N	120 07W	77
CA MAMMOTH/JUNE LAK	KMMH	MMH		37 37N	118 49W	2173
CA MARYSVILLE	KMYV	MYV		39 06N	121 34W	21
CA MATHER FIELD	KMHR	MHR		38 32N	121 17W	29
CA MCCLELLAN AFB	KMCC	MCC		38 40N	121 24W	23
CA MERCED	KMCE	MCE		37 17N	120 30W	47
CA MERCED/CASTLE AF	KMER	MER	72481	37 23N	120 34W	57
CA MIRAMAR NAS/SAN	KNKX	NKX	72293	32 52N	117 08W	146
CA MODESTO	KMOD	MOD		37 37N	120 57W	29
CA MOFFETT NAS/MTN	KNUQ	NUQ	74509	37 24N	122 03W	12
CA MOJAVE	KMHV	MHV		35 04N	118 09W	849
CA MONTAGUE/SISKIYO	KSIY	SIY		41 46N	122 28W	807
CA MONTEREY	KMRY	MRY		36 35N	121 51W	66
CA MOUNT SHASTA	KMHS	MHS	72595	41 19N	122 19W	1078
CA MOUNT WILSON	KMWS	MWS	72289	34 13N	118 04W	1739
CA NAPA	KAPC	APC		38 12N	122 17W	13
CA NEEDLES	KEED	EED	72380	34 46N	114 37W	302
CA NEWHALL	K3A6	3A6		34 22N	118 34W	427
CA NORTH ISLAND NAS	KNZY	NZY		32 42N	117 13W	8
CA NOVATO/GNOSS FLD	KDVO	DVO		38 09N	122 33W	1
CA OAKLAND	KOAK	OAK	72493	37 42N	122 13W	26
CA OCEANSIDE	KOKB	OKB		33 13N	117 21W	8
CA OCEANSIDE/RED-B	KNXF	NXF		33 17N	117 27W	27
CA ONTARIO	KONT	ONT		34 03N	117 35W	274
CA OROVILLE	KOVE	OVE		39 30N	121 37W	58
CA OXNARD	KOXR	OXR		34 12N	119 12W	20
CA PALM SPRINGS	KPSP	PSP		33 49N	116 30W	135
CA PALMDALE	KPMD	PMD	72382	34 38N	118 05W	780

CA	PALO ALTO	KPAO	PAO		37	28N	122	07W	2
CA	PASO ROBLES	KPRB	PRB		35	40N	120	38W	245
CA	PETALUMA	KO69	O69		38	15N	122	36W	28
CA	PLACERVILLE	KPVF	PVF		38	43N	120	45W	789
CA	POINT MUGU NAS	KNTD	NTD	72391	34	07N	119	07W	4
CA	PORTERVILLE	KPTV	PTV		36	01N	119	04W	135
CA	PT. PIEDRAS BLAN	K87Q	87Q	72390	35	40N	121	17W	27
CA	RED BLUFF	KRBL	RBL	72591	40	09N	122	15W	104
CA	REDDING	KRDD	RDD	72592	40	31N	122	18W	155
CA	RIVERSIDE	KRAL	RAL		33	57N	117	27W	252
CA	RIVERSIDE/MARCH	KRIV	RIV	72286	33	52N	117	16W	469
CA	RAMONA	KRNM	RNM		33	02N	116	55W	427
CA	SACRAMENTO	KSAC	SAC		38	30N	121	30W	11
CA	SACRAMENTO/METRO	KSMF	SMF		38	42N	121	36W	6
CA	SALINAS	KSNS	SNS		36	40N	121	36W	30
CA	SAN BERNARDINO	KSBD	SBD		34	06N	117	14W	353
CA	SAN CARLOS AIRPO	KSQL	SQL		37	31N	122	15W	1
CA	SAN CLEMENTE IS.	KNUC	NUC		33	01N	118	34W	55
CA	SAN DIEGO	KSAN	SAN	72290	32	44N	117	11W	12
CA	SAN DIEGO/MNTGMY	KMYF	MYF		32	49N	117	08W	136
CA	SAN DIEGO/BROWN	KSDM	SDM		32	35N	117	00W	159
CA	SAN DIEGO/SANTEE	KSEE	SEE		32	49N	116	58W	117
CA	SAN FRANCISCO	KSFO	SFO	72494	37	37N	122	22W	3
CA	SAN JOSE	KSJC	SJC	74505	37	22N	121	55W	24
CA	SAN JOSE/REID	KRHV	RHV		37	19N	121	49W	41
CA	SAN LUIS OBISPO	KSBP	SBP		35	14N	120	38W	59
CA	SAN NICOLAS ISLA	KNSI	NSI	72291	33	13N	119	27W	154
CA	SANDBERG	KSDB	SDB	72383	34	45N	118	43W	1377
CA	COSTA MESA	KSNA	SNA		33	40N	117	52W	16
CA	SANTA BARBARA	KSBA	SBA		34	26N	119	51W	3
CA	SANTA MARIA	KSMX	SMX	72394	34	54N	120	27W	74
CA	SANTA MONICA	KSMO	SMO		34	01N	118	27W	57
CA	SANTA ROSA	KSTS	STS		38	30N	122	49W	39
CA	SANTA YNEZ	KIZA	IZA		34	36N	120	04W	205
CA	SHELTER COVE	KO87	O87		40	01N	124	04W	21
CA	SOUTH LAKE TAHOE	KTVL	TVL		38	54N	120	00W	1924
CA	STOCKTON	KSCK	SCK	72492	37	53N	121	13W	10
CA	SUSANVILLE MUNI	KSVE	SVE	72584	40	22N	120	34W	1263
CA	THERMAL/PALM SPG	KTRM	TRM		33	38N	116	10W	-35
CA	TORRANCE MUNICIP	KTOA	TOA		33	47N	118	19W	31
CA	TRAVIS AFB/FAIRF	KSUU	SUU	74516	38	16N	121	55W	19
CA	TRUCKEE TAHOE	KTRK	TRK		39	19N	120	07W	1798
CA	TEHACHAPI	KTSP	TSP		35	08N	118	26W	1220
CA	TWENTYNINE PALMS	KNXP	NXP	69015	34	17N	116	10W	626
CA	UKIAH	KUKI	UKI		39	07N	123	12W	187
CA	VACAVILLE	KVCB	VCB		38	23N	121	57W	33
CA	VAN NUYS	KVNY	VNY		34	13N	118	29W	245
CA	VANDENBERG AFB	KVBG	VBG	72393	34	44N	120	35W	112
CA	VANDENBERG RANGE	KXVW	XVW		34	43N	120	34W	100
CA	VICTORVILLE	KVCV	VCV		34	35N	117	23W	876
CA	VISALIA MUNI	KVIS	VIS		36	19N	119	24W	89
CA	WATSONVILLE	KWVI	WVI		36	56N	121	47W	43
CA	WEAVERVILLE	KO54	O54		40	45N	122	55W	717
CO	DENVER (DIA)	KDEN	DEN	72565	39	50N	104	39W	1640
CO	AKRON	KAKO	AKO		40	10N	103	13W	1421
CO	ALAMOSA	KALS	ALS	72462	37	26N	105	52W	2299
CO	ASPEN	KASE	ASE		39	14N	106	52W	2354

CO	BERTHOUD PASS	K0CO	0CO		39 48N	105 46W	4113
CO	BROOMFIELD/JEFFC	KBJC	BJC		39 55N	105 07W	1724
CO	BUCKLEY ANGB/DEN	KBKF	BKF		39 43N	104 45W	1726
CO	BURLINGTON	KITR	ITR		39 15N	102 17W	1279
CO	CANON CITY	K1V6	1V6		38 26N	105 06W	1658
CO	COLORADO SPRINGS	KCOS	COS	72466	38 49N	104 43W	1856
CO	CO SPNGS MEADOW	KFLY	FLY		38 57N	104 34W	2096
CO	CORTEZ	KCEZ	CEZ		37 18N	108 38W	1797
CO	CRAIG	KCAG	CAG	72570	40 30N	107 31W	1887
CO	DENVER/ARAPAHOE	KAPA	APA		39 34N	104 51W	1775
CO	DENVER F. RANGE	KFTG	FTG		39 47N	104 33W	1675
CO	DURANGO	KDRO	DRO		37 09N	107 46W	2035
CO	EAGLE CO. REGION	KEGE	EGE		39 38N	106 55W	1993
CO	FORT CARSON	KFCS	FCS	72468	38 40N	104 46W	1789
CO	FT COLLINS/LOVEL	KFNL	FNL		40 27N	105 01W	1529
CO	GRAND JUNCTION	KGJT	GJT	72476	39 07N	108 31W	1475
CO	GREELEY/WELD	KGXY	GXY		40 25N	104 37W	1420
CO	GUNNISON	KGUC	GUC		38 31N	106 55W	2339
CO	HAYDEN/YAMPA	KHDN	HDN	72571	40 28N	107 13W	2012
CO	LA JUNTA	KLHX	LHX		38 03N	103 31W	1277
CO	LAMAR	KLAA	LAA	72463	38 04N	102 41W	1119
CO	LEADVILLE	KLXV	LXV	72467	39 14N	106 19W	3028
CO	LIMON	KLIC	LIC		39 16N	103 40W	1630
CO	MEEKER	KEEO	EEO		40 03N	107 53W	1930
CO	MONTROSE	KMTJ	MTJ		38 30N	107 54W	1750
CO	NUCLA/HOPKINS F	KAIB	AIB		38 14N	108 34W	1811
CO	PUEBLO	KPUB	PUB	72464	38 17N	104 30W	1420
CO	RIFLE	KRIL	RIL		39 32N	107 44W	1678
CO	SAGUACHE MUNI	K04V	04V		38 06N	106 10W	2385
CO	SPRINGFIELD	KSPD	SPD		37 17N	102 37W	1335
CO	STEAMBOAT SPRING	KSBS	SBS		40 31N	106 52W	2096
CO	MT WERNER SBS	K3MW	3MW		40 27N	106 45W	3241
CO	TELLURIDE REGION	KTEX	TEX		37 57N	107 54W	2769
CO	TRINIDAD/ANIMAS	KTAD	TAD		37 16N	104 19W	1756
CO	USAF ACADEMY/COS	KAFF	AFF	74531	38 58N	104 49W	2003
CO	YUMA	KYMA			40 06N	102 43W	1261
CO	FLAGLER	KFLA			39 17N	103 04W	1507
CO	IDALIA	KIDL			39 42N	102 17W	1209
CO	KIRK	K72C			39 36N	102 34W	1280
CO	STERLING	KSTK			40 37N	103 16W	1231
CO	STRATTON	KSTR			39 18N	102 36W	1345
CO	RED CLIFF PASS	KCCU			39 28N	106 09W	3680
CO	RANGELY	K4V0			40 06N	108 46W	1608
CO	BUENA VISTA	KAEJ			38 49N	106 07W	2422
CO	DELTA/BLAKE FLD	KAJZ			38 47N	108 04W	1583
CO	SALIDA	KANK			38 32N	106 03W	2293
CO	BOULDER MUNI	KBDU			40 02N	105 14W	1612
CO	ELLICOTT-B AFA	KABH			38 45N	104 18W	1840
CO	ERIE MUNI	KEIK			40 01N	105 03W	1564
CO	FORT MORGAN	KFMM			40 20N	103 48W	1393
CO	GRANBY/GRAND CO	KGNB			40 05N	105 55W	2500
CO	HOLYOKE	KHEQ			40 34N	102 16W	1137
CO	LONGMONT/VBRAND	KLMO			40 10N	105 10W	1541
CO	PAGOSA SPRINGS	KPSO			37 17N	107 03W	2334
CO	WOLF CREEK PASS	KCPW			37 27N	106 48W	3584
CO	CORONA PASS	KCRV			40 03N	105 35W	3538
CO	MONUMENT/ELBERT	KMNH			39 13N	104 39W	2152

CO	MONARCH PASS	KMYP			38	29N	106	19W	3667
CO	LA VETA PASS	KVTP			37	30N	105	10W	3114
CO	WALDEN	K33V			40	45N	106	16W	2484
CO	KREMMLING AWOS	K20V			40	03N	106	22W	2259
CO	WILKERSON PASS	K4BM			39	03N	105	31W	3438
CO	SUNLIGHT	K5SM			39	26N	107	23W	3232
CO	COTTONWOOD PASS	K7BM			38	47N	106	13W	2995
CO	WRAY	K2V5			40	06N	102	14W	1118
CT	BRIDGEPORT	KBDR	BDR	72504	41	10N	073	08W	7
CT	CHESTER	KSNC	SNC		41	23N	072	30W	127
CT	DANBURY	KDXR	DXR		41	22N	073	29W	139
CT	GROTON/NEW LONDO	KGON	GON		41	20N	072	03W	3
CT	HARTFORD/BRAINAR	KHFD	HFD		41	44N	072	39W	4
CT	MERIDEN	KMMK	MMK		41	31N	072	50W	31
CT	NEW HAVEN/TWEED	KHVN	HVN		41	16N	072	52W	4
CT	OXFORD/WATERBURY	KOXC	OXC		41	28N	073	08W	222
CT	WILLIMANTIC	KIJD	IJD		41	45N	072	11W	75
CT	WINDSOR LOCKS	KBDL	BDL	72508	41	56N	072	41W	60
DE	DOVER AFB	KDOV	DOV		39	07N	075	28W	9
DE	GEORGETOWN	KGED	GED		38	41N	075	22W	19
DE	WILMINGTON	KILG	ILG		39	40N	075	36W	28
FL	APALACHICOLA	KAAF	AAF	72220	29	44N	085	02W	5
FL	BARTOW MUNICIPAL	KBOW	BOW		27	56N	081	46W	39
FL	BOCA RATON	KBCT	BCT		26	23N	080	06W	4
FL	BONIFAY TRI-CTY	K1J0	1J0		30	51N	085	36W	26
FL	BROOKSVILLE	KBKV	BKV		28	28N	082	27W	20
FL	CAPE CANAVERAL	KXMR	XMR	74794	28	28N	080	32W	3
FL	CECIL FIELD NAS	KNZC	NZC		30	13N	081	52W	25
FL	CRESTVIEW	KCEW	CEW		30	47N	086	31W	55
FL	CROSS CITY	KCTY	CTY	72212	29	38N	083	06W	13
FL	CRYSTAL RIVER	KCGC	CGC		28	52N	082	34W	3
FL	DAYTONA BEACH	KDAB	DAB		29	11N	081	04W	9
FL	DESTIN	KDTS	DTS		30	24N	086	28W	5
FL	DUKE FLD/EGLIN	KEGI	EGI	74778	30	38N	086	31W	59
FL	EGLIN AFB/VALPAR	KVPS	VPS	72221	30	28N	086	31W	26
FL	EVERGLADES CITY	KEGC	EGC		25	51N	081	23W	2
FL	FERNANDINA BEACH	KFHB	FHB		30	37N	081	28W	5
FL	FLAMINGO/MONROE	KFLM	FLM		25	08N	080	55W	2
FL	FT LAUDERD/HOLLY	KFLL	FLL		26	04N	080	09W	3
FL	FT LAUDERD/EXEC	KFXE	FXE		26	12N	080	11W	6
FL	FORT MYERS	KRSW	RSW		26	32N	081	45W	10
FL	FORT MYERS	KFMY	FMY		26	35N	081	52W	4
FL	FORT PIERCE	KFPR	FPR		27	30N	080	23W	13
FL	GAINESVILLE	KGNV	GNV		29	42N	082	17W	45
FL	HOLLYWOOD	KHWO	HWO		26	00N	080	14W	2
FL	HOMESTEAD AFB	KHST	HST		25	28N	080	22W	2
FL	HURLBURT FIELD	KHRT	HRT	74777	30	25N	086	40W	12
FL	INVERNESS	KX40	X40		28	48N	082	19W	15
FL	JACKSONVIL/CRAIG	KCRG	CRG		30	20N	081	31W	13
FL	JACKSONVILLE NAS	KNIP	NIP		30	13N	081	40W	7
FL	JACKSONVILLE	KJAX	JAX	72206	30	30N	081	41W	10
FL	JACKSONVIL/CECIL	KVQQ	VQQ		30	13N	081	53W	25
FL	JACKSONVIL/NAVAL	KNEN	NEN		30	21N	081	53W	30
FL	KEYSTONE HEIGHTS	K42J	42J		29	51N	082	03W	60
FL	KEY WEST NAS	KNQX	NQX		24	34N	081	40W	2
FL	KEY WEST	KEYW	EYW	72201	24	33N	081	45W	5
FL	KISSIMMEE/ORLAND	KISM	ISM		28	17N	081	26W	25

FL	LAKELAND REGIONA	KLAL	LAL		27	58N	082	01W	43
FL	LEESBURG	KLEE	LEE		28	49N	081	49W	23
FL	MACDILL AFB/TAMP	KMCF	MCF	74788	27	51N	082	31W	4
FL	MARATHON	KMTH	MTH		24	44N	081	03W	2
FL	MARIANNA	KMAI	MAI		30	50N	085	11W	32
FL	MAYPORT NAS	KNRB	NRB		30	23N	081	25W	5
FL	MELBOURNE	KMLB	MLB	72204	28	06N	080	39W	11
FL	MERRITT ISLAND	KCOI	COI		28	20N	080	41W	2
FL	MIAMI/TAMIAMI	KTMB	TMB		25	39N	080	26W	2
FL	MIAMI	KMIA	MIA		25	48N	080	17W	3
FL	MIAMI/OPA LOCKA	KOPF	OPF		25	55N	080	17W	16
FL	MIAMI BEACH	KMBF	MBF		25	46N	080	08W	1
FL	MILTON/WHITING S	KNDZ	NDZ		30	42N	087	01W	54
FL	NAPLES MUNICIPAL	KAPF	APF		26	09N	081	46W	3
FL	NASA SHUTTLE FCL	KTTS	TTS		28	37N	080	43W	3
FL	NEW PORT RICHEY	KRRF	RRF		28	11N	082	38W	12
FL	NEW SMYRNA BEACH	KEVB	EVB		29	03N	080	57W	3
FL	OCALA MUNI	KOCF	OCF		29	10N	082	13W	27
FL	OCEAN REEF	KOCR	OCR		25	18N	080	16W	2
FL	OKEECHOBEE CTY	KOBE	OBE		27	16N	080	51W	11
FL	ORLANDO	KMCO	MCO	72205	28	25N	081	20W	29
FL	ORLANDO	KORL	ORL		28	33N	081	20W	37
FL	ORMOND BEACH VOR	KOMN	OMN		29	18N	081	07W	9
FL	PALM COAST	KXFL	XFL		29	28N	081	12W	10
FL	PANAMA CITY	KECP	ECP		30	21N	085	48W	21
FL	PATRICK AFB/COCO	KCOF	COF	74795	28	13N	080	35W	3
FL	PENSACOLA	KPNS	PNS	72222	30	29N	087	11W	38
FL	PENSACOLA NAS	KNPA	NPA		30	21N	087	19W	9
FL	PERRY FOLEY	K40J	40J		30	04N	083	34W	13
FL	PLANT CITY MUNI	KPCM	PCM		28	00N	082	10W	47
FL	POMPANO BEACH	KPMP	PMP		26	15N	080	07W	6
FL	PORT RICHEY	KX41	X41		28	21N	082	37W	12
FL	PUNTA GORDA	KPGD	PGD		26	55N	082	00W	7
FL	QUINCY	K2J9	2J9		30	36N	084	33W	69
FL	SANFORD/ORLANDO	KSFB	SFB		28	46N	081	13W	17
FL	SARASOTA/BRADENT	KSRQ	SRQ		27	24N	082	34W	18
FL	ST AUGUSTINE	KSGJ	SGJ	99441	29	58N	081	19W	3
FL	ST PETERSBURG	KPIE	PIE		27	55N	082	41W	4
FL	ST PETERS/ALBERT	KSPG	SPG		27	46N	082	38W	2
FL	STUART/WITHAM	KSUA	SUA		27	11N	080	13W	6
FL	TALLAHASSEE	KTLH	TLH	72214	30	24N	084	21W	19
FL	TAMPA	KTPA	TPA	72211	27	58N	082	32W	11
FL	TAMPA/O KNIGHT	KTPF	TPF		27	55N	082	27W	3
FL	TAMPA/VANDENBURG	KVDF	VDF		28	01N	082	21W	7
FL	TITUSVILLE	KTIX	TIX		28	30N	080	48W	11
FL	TYNDALL AFB	KPAM	PAM	74775	30	04N	085	34W	5
FL	VENICE	KVNC	VNC		27	04N	082	26W	6
FL	VERO BEACH	KVRB	VRB		27	39N	080	25W	10
FL	THE VILLAGES	KVVG	VVG		28	57N	081	58W	27
FL	WEST PALM BEACH	KPBI	PBI	72203	26	41N	080	06W	6
FL	WHITING FLD NAS	KNSE	NSE		30	43N	087	01W	61
FL	WINTER HAVEN	KGIF	GIF		28	04N	081	45W	43
FL	HURLBERT	KQHY			30	24N	086	39W	8
GA	ALBANY	KABY	ABY	72216	31	32N	084	12W	58
GA	AMERICUS	KACJ	ACJ		32	07N	084	11W	143
GA	ALMA	KAMG	AMG		31	32N	082	30W	59
GA	ATHENS	KAHN	AHN	72311	33	57N	083	20W	244

GA	ATLANTA	KATL	ATL	72219	33	38N	084	27W	296
GA	ATLANTA/FULTON	KFTY	FTY		33	47N	084	31W	263
GA	ATLANTA/PAULDING	KPUJ	PUJ		33	55N	084	56W	393
GA	AUGUSTA/DANIEL	KDNL	DNL		33	28N	082	02W	130
GA	AUGUSTA/BUSH	KAGS	AGS	72218	33	22N	081	58W	44
GA	BAINBRIDGE	KBGE	BGE		30	58N	084	38W	43
GA	BLAIRSVILLE	KDZJ	DZJ		34	51N	084	00W	582
GA	BLAKELY EARLY C	KBIJ	BIJ		31	24N	084	54W	65
GA	BRUNSWICK	KSSI	SSI		31	09N	081	23W	6
GA	BRUNSWICK/GLYNCO	KBQK	BQK		31	15N	081	28W	8
GA	CANTON/CHEROKEE	K47A	47A		34	19N	084	25W	372
GA	CARROLLTON/GRAY	KCTJ	CTJ		33	38N	085	09W	354
GA	CARTERSVILLE	KVPC	VPC		34	08N	084	51W	222
GA	CLAXTON/EVANS CO	KCWV	CWV		32	12N	081	52W	33
GA	COLUMBUS	KCSG	CSG		32	31N	084	57W	135
GA	COVINGTON	K9A1	9A1		33	38N	083	51W	247
GA	DALTON	KDNN	DNN		34	43N	084	52W	216
GA	DOBBINS AFB/MARI	KMGE	MGE	72227	33	55N	084	31W	326
GA	DOUGLAS MUNI	KDQH	DQH		31	29N	082	52W	78
GA	DUBLIN	KDBN	DBN		32	34N	082	59W	94
GA	ELBERTON PATZ F	K27A	27A		34	06N	082	49W	184
GA	FT BENNING/COLUM	KLSF	LSF	72225	32	19N	085	00W	71
GA	FT STEWART/WRIGH	KLHW	LHW	72209	31	52N	081	34W	14
GA	GAINESVILLE	KGVL	GVL		34	16N	083	50W	386
GA	GREENSBORO	K3J7	3J7		33	36N	083	08W	206
GA	HOMERVILLE	KHOE	HOE		31	03N	082	47W	57
GA	JESUP/WAYNE CTY	KJES	JES		31	33N	081	53W	33
GA	LA GRANGE	KLGC	LGC		33	00N	085	04W	211
GA	LAWRENCEVILLE	KLZU	LZU		33	59N	083	58W	323
GA	MACON	KMCN	MCN	72217	32	41N	083	39W	109
GA	MARIETTA MCCOLUM	KRYY	RYY		34	01N	084	36W	317
GA	MCDUFFIE/THOMSON	KHQU	HQU		33	32N	082	31W	152
GA	MILLEDGEVILLE	KMLJ	MLJ		33	09N	083	14W	117
GA	MOODY AFB/VALDOS	KVAD	VAD	74781	30	58N	083	12W	71
GA	MOULTRIE MUNI	KMGR	MGR		31	05N	083	48W	90
GA	MOULTRIE/SPENCE	KMUL	MUL		31	08N	083	42W	89
GA	NEWNAN	KCCO	CCO		33	19N	084	46W	296
GA	PEACHTREE/DEKALB	KPDK	PDK		33	53N	084	18W	302
GA	PEACHTREE CITY	KFFC	FFC	72215	33	21N	084	34W	262
GA	ROME	KRMG	RMG	72320	34	21N	085	10W	193
GA	SAVANNAH	KSAV	SAV	72207	32	07N	081	12W	14
GA	SAVANNAH/HUNTER	KSVN	SVN	74780	32	01N	081	09W	13
GA	STATESBORO	KTBR	TBR		32	29N	081	44W	57
GA	SWAINSBORO	KSBO	SBO		32	37N	082	22W	100
GA	SYLVANIA	KJYL	JYL		32	39N	081	36W	57
GA	TIFTON	KTMA	TMA		31	26N	083	29W	109
GA	THOMASTON UPSON	KOPN	OPN		32	57N	084	16W	243
GA	THOMASVILLE	KTVI	TVI		30	54N	083	53W	80
GA	VALDOSTA REGIONA	KVLD	VLD		30	46N	083	16W	62
GA	VIDALIA MUNI	KVDI	VDI		32	12N	082	22W	84
GA	WARNER ROBINS AF	KWRB	WRB		32	37N	083	35W	90
GA	WASHINGTON	KIIY	IIY		33	47N	082	49W	197
GA	WAYCROSS/WARE CO	KAYS	AYS	72213	31	15N	082	24W	46
GA	WINDER/BARROW	KWDR	WDR		33	59N	083	40W	287
IA	ALGONA	KAXA	AXA		43	04N	094	16W	372
IA	AMES	KAMW	AMW		41	59N	093	37W	279
IA	ANKENY	KIKV	IKV		41	41N	093	34W	275

IA	ATLANTIC	KAIO	AIO		41	23N	095	02W	360
IA	AUDUBON	KADU	ADU		41	42N	094	55W	392
IA	BOONE MUNI	KBNW	BNW		42	02N	093	50W	354
IA	BURLINGTON	KBRL	BRL		40	46N	091	08W	211
IA	CARROLL	KCIN	CIN		42	02N	094	46W	375
IA	CEDAR RAPIDS	KCID	CID	72545	41	53N	091	43W	264
IA	CENTERVILLE MUNI	KTVK	TVK		40	41N	092	54W	314
IA	CHARITON	KCNC	CNC		41	01N	093	22W	320
IA	CHARLES CITY	KCCY	CCY		43	04N	092	37W	343
IA	CHEROKEE	KCKP	CKP		42	44N	095	33W	374
IA	CLARINDA	KICL	ICL		40	43N	095	01W	303
IA	CLARION	KCAV	CAV		42	45N	093	46W	354
IA	CLINTON MUNI	KCWI	CWI		41	49N	090	19W	216
IA	COUNCIL BLUFFS	KCBF	CBF		41	16N	095	46W	382
IA	CRESTON	KCSQ	CSQ		41	01N	094	22W	394
IA	DAVENPORT/QUAD C	KDVN	DVN	74455	41	37N	090	35W	230
IA	DECORAH	KDEH	DEH		43	16N	091	43W	353
IA	DENISON	KDNS	DNS		41	58N	095	22W	388
IA	DES MOINES	KDSM	DSM	72546	41	32N	093	40W	295
IA	DUBUQUE	KDBQ	DBQ	72547	42	24N	090	42W	326
IA	ESTHERVILLE	KEST	EST		43	24N	094	45W	401
IA	FAIRFIELD	KFFL	FFL		41	02N	091	58W	244
IA	FOREST CITY	KFXY	FXY		43	14N	093	37W	375
IA	FORT DODGE	KFOD	FOD	72549	42	32N	094	10W	355
IA	FORT MADISON	KFSW	FSW		40	40N	091	19W	221
IA	GRINNELL REG	KGGI	GGI		41	43N	092	44W	307
IA	HARLAN MUNI	KHNR	HNR		41	35N	095	20W	375
IA	INDEPENDENCE	KIIB	IIB		42	27N	091	57W	298
IA	IOWA CITY	KIOW	IOW		41	38N	091	33W	198
IA	IOWA FALLS MUNI	KIFA	IFA		42	28N	093	16W	347
IA	KEOKUK MUNI	KEOK	EOK		40	28N	091	25W	205
IA	KNOXVILLE	KOXV	OXV		41	17N	093	07W	283
IA	LAMONI	KLWD	LWD		40	38N	093	54W	346
IA	LE MARS	KLRJ	LRJ		42	46N	096	12W	365
IA	MARSHALLTOWN	KMIW	MIW		42	07N	092	55W	296
IA	MASON CITY	KMCW	MCW		43	09N	093	20W	369
IA	MONTICELLO MUNI	KMXO	MXO		42	13N	091	10W	259
IA	MT PLEASANT	KMPZ	MPZ		40	57N	091	31W	224
IA	MUSCATINE	KMUT	MUT		41	22N	091	09W	167
IA	NEWTON MUNI	KTNU	TNU		41	40N	093	01W	290
IA	OELWEN	KOLZ	OLZ		42	40N	091	58W	328
IA	ORANGE CITY	KORC	ORC		42	58N	096	04W	431
IA	OSCEOLA MUNI	KI75	I75		41	03N	093	41W	339
IA	OSKALOOSA MUNI	KOOA	OOA		41	14N	092	30W	256
IA	OTTUMWA	KOTM	OTM		41	06N	092	27W	256
IA	PELLA	KPEA	PEA		41	24N	092	57W	270
IA	PERRY MUNI	KPRO	PRO		41	50N	094	10W	308
IA	RED OAK	KRDK	RDK		41	01N	095	16W	318
IA	SHELDON	KSHL	SHL		43	13N	095	49W	432
IA	SHENANDOAH MUNI	KSDA	SDA		40	45N	095	25W	296
IA	SIOUX CITY	KSUX	SUX	72557	42	23N	096	23W	338
IA	SPENCER	KSPW	SPW	72650	43	10N	095	13W	403
IA	STORM LAKE	KSLB	SLB		42	36N	095	13W	454
IA	VINTON	KVTI	VTI		42	13N	092	01W	255
IA	WASHINGTON	KAWG	AWG		41	16N	091	40W	230
IA	WATERLOO	KALO	ALO	72548	42	33N	092	24W	264
IA	WEBSTER CITY	KEBS	EBS		42	25N	093	52W	342

IA	ADAIR I80	XADA	41	29N	094	43W	450
IA	ALGONA US18	XALG	43	05N	094	23W	337
IA	ALTON IA10	XATN	42	49N	096	05W	430
IA	ALTOONA I80/US65	XALT	41	40N	093	31W	262
IA	AMES I35	XAME	42	02N	093	34W	313
IA	ANKENY I35	XANK	41	46N	093	34W	264
IA	AVOCA I80	XAVO	41	29N	095	17W	377
IA	BURLINGTON US34	XBUR	40	49N	091	05W	218
IA	CARROLL US30	XCAR	42	05N	094	53W	389
IA	CEDAR RAPIDS 380	XCDR	41	49N	091	40W	236
IA	CEDAR RAPID US30	XCID	41	56N	091	41W	246
IA	CENTERVILLE IA2	XCEN	40	44N	093	00W	295
IA	COUNCIL BLUFF 80	XCOU	41	14N	095	52W	268
IA	CRESTON US34	XCRE	41	04N	094	18W	388
IA	DAVENPORT 80/280	XDAV	41	36N	090	41W	206
IA	DECORAH IA9	XDEC	43	14N	091	41W	310
IA	DES MOINES I35	XDSM	41	32N	093	46W	224
IA	DES MOINES I235	XDES	41	35N	093	37W	281
IA	DE SOTO 80/US169	XDST	41	32N	094	06W	291
IA	DE WITT US30/61	XDEW	41	50N	090	34W	240
IA	DUBUQUE US20	XDUB	42	29N	090	44W	250
IA	FORT DODGE US20	XFOD	42	26N	094	11W	286
IA	GRINNELL I80	XGRI	41	41N	092	44W	281
IA	IOWA CITY US218	XIAC	41	38N	091	35W	254
IA	IOWA CITY I80	XIOW	41	41N	091	35W	250
IA	JEFFERSON IA4	XJEF	42	03N	094	23W	310
IA	LEON I35/IA2	XLEO	40	44N	093	50W	349
IA	MANCHESTER US20	XMAN	42	26N	091	26W	309
IA	MAQUOKETA 61/64	XMAQ	42	04N	090	41W	251
IA	MARSHALTOWN US30	XMAR	42	01N	092	58W	291
IA	MASON CITY I35	XMCW	43	02N	093	20W	376
IA	MISSOURI VAL I29	XMIS	41	32N	095	55W	309
IA	MT PLEASANT U218	XMOU	40	53N	091	33W	133
IA	NEW HAMPTON US18	XNEW	43	02N	092	28W	327
IA	ONAWA I29	XONA	41	52N	096	01W	303
IA	OSCEOLA I35	XOSC	41	02N	093	47W	334
IA	OTTUMWA US63	XOTT	41	01N	092	25W	196
IA	PELLA IA163	XPEL	41	23N	092	52W	271
IA	RED OAK US34/71	XRED	40	59N	094	59W	290
IA	SIDNEY I29/IA2	XSID	40	41N	095	47W	287
IA	SIGOURNEY IA92	XSIG	41	20N	092	19W	202
IA	SIOUX CITY I29	XSIO	42	29N	096	23W	364
IA	SPENCER US18	XSPE	43	08N	095	05W	452
IA	STORM LAKE 71/3	XSTO	42	44N	095	09W	405
IA	TIPTON I80	XTIP	41	38N	091	08W	236
IA	URBANA I380	XURB	42	19N	091	59W	302
IA	WATERLOO US20	XWAT	42	27N	092	19W	269
IA	WILLIAMS I35	XWIL	42	32N	093	34W	325
IA	WILLAIMSBURG I80	XWBG	41	41N	092	01W	260
IA	HANLONTOWN I35	XHAN	43	23N	093	20W	333
IA	STEAMBOAT R US20	XSBI	42	27N	093	03W	348
IA	IDA GROVE US59	XIGI	42	21N	095	29W	376
IA	CEDAR RAPIDS U30	XCRI	41	56N	091	33W	232
IA	BEDFORD	XBFI	40	41N	094	43W	357
IA	COLFAX	XCFI	41	41N	093	16W	247
IA	EDDYVILLE	XDYI	41	09N	092	39W	244
IA	SIBLEY	XSYI	43	26N	095	43W	480

IA	TAMA	XTMI	41	58N	092	18W	250
IA	CANTRIL	XCTI	40	40N	092	04W	211
IA	DENISON	XDNI	41	55N	095	20W	426
IA	PLAINFIELD	XPFI	42	50N	092	32W	294
IA	QUAD CITIES	XQCI	41	31N	090	31W	177
IA	STATE FAIR	Q03I	41	36N	093	34W	333
IA	ADAIR	QADI	41	31N	094	35W	417
IA	ADEL	QAEI	41	37N	094	01W	292
IA	AFTON	QAFI	41	02N	094	11W	387
IA	ALGONA	QAGI	43	04N	094	14W	341
IA	ANKENY	QAKI	41	44N	093	37W	310
IA	ALBIA	QALI	41	02N	092	49W	312
IA	AMES	QAMI	42	03N	093	38W	309
IA	ANITA	QATI	41	27N	094	46W	387
IA	AUDUBON	QAUI	41	43N	094	55W	426
IA	BEDFORD	QBDI	40	40N	094	43W	350
IA	BELMOND	QBKI	42	51N	093	36W	372
IA	BLOOMFIELD	QBMI	40	45N	092	25W	260
IA	BOONE	QBOI	42	02N	093	47W	353
IA	BROOKLYN	QBRI	41	44N	092	27W	280
IA	BUSSEY	QBSI	41	13N	092	53W	265
IA	BAXTER	QBXI	41	50N	093	09W	304
IA	BLANK PARK ZOO	QBZI	41	32N	093	37W	294
IA	CARROLL	QCAI	42	04N	094	52W	423
IA	COON RAPIDS	QCBI	41	53N	094	41W	386
IA	CHARLES CITY	QCCI	43	04N	092	40W	304
IA	CORYDON	QCDI	40	45N	093	19W	331
IA	CENTERVILLE	QCEI	40	44N	092	52W	299
IA	CLARION	QCGI	42	44N	093	44W	377
IA	CHARITON	QCHI	41	01N	093	19W	332
IA	CLEAR LAKE	QCKI	43	08N	093	22W	368
IA	CRESCO	QCQI	43	23N	092	06W	390
IA	CORNING	QCNI	40	59N	094	44W	390
IA	COLO	QCOI	42	01N	093	19W	315
IA	CRESTON	QCRI	41	04N	094	22W	417
IA	INWOOD	QCSI	43	19N	096	26W	449
IA	DSM CHRISTIAN	QDCI	41	38N	093	48W	279
IA	SHELDON	QDNI	43	11N	095	50W	433
IA	RIVER WOODS	QDRI	41	34N	093	35W	304
IA	EAGLE GROVE	QEGI	42	40N	093	55W	339
IA	FARNHAMVILLE	QFAI	42	20N	094	25W	374
IA	FOREST CITY	QFCI	43	16N	093	39W	384
IA	FORT DODGE	QFDI	42	31N	094	11W	353
IA	FONTANELLE	QFOI	41	17N	094	34W	423
IA	GLIDDEN	QGLI	42	04N	094	44W	387
IA	GARNER	QGNI	43	05N	093	37W	373
IA	GRIMES	QGRI	41	41N	093	48W	310
IA	HULL	QHII	43	11N	096	08W	436
IA	HAMPTON	QHPI	42	45N	093	11W	328
IA	HUMBOLDT	QHUI	42	43N	094	14W	379
IA	ICA	QIAI	41	35N	093	44W	285
IA	IOWA FALLS	QIFI	42	32N	093	16W	376
IA	INDIANOLA	QINI	41	22N	093	33W	310
IA	JORDAN CREEK	QJCI	41	34N	093	46W	283
IA	JEFFERSON	QJEI	42	00N	094	23W	338
IA	SOUTH HAMILTON	QJWI	42	18N	093	39W	340
IA	KCCI	QKCI	41	35N	093	38W	274

IA	KNOXVILLE	QKNI			41	19N	093	07W	301
IA	KANAWHA	QKWI			42	56N	093	47W	369
IA	LEON	QLEI			40	45N	093	44W	365
IA	LATIMER	QLMI			42	45N	093	22W	398
IA	LAMONI	QLOI			40	38N	093	56W	359
IA	LUVERNE	QLUI			42	55N	094	05W	360
IA	ROCK RAPIDS	QLYI			43	25N	096	10W	410
IA	MARSHALLTOWN	QMAI			42	01N	092	55W	314
IA	MADRID	QMDI			41	53N	093	49W	310
IA	LAKE MILLS	QMII			43	25N	093	32W	393
IA	MALLARD	QMLI			42	56N	094	41W	387
IA	MONTEZUMA	QMNI			41	35N	092	31W	309
IA	MOUNT AYR	QMOI			40	43N	094	14W	396
IA	MANSON-NW	QMSI			42	30N	094	22W	368
IA	MURRAY	QMUI			41	02N	093	57W	365
IA	MASON CITY	QMWI			43	08N	093	14W	357
IA	MASON CITY	QMYI			43	09N	093	10W	335
IA	NEWTON	QNEI			41	42N	093	02W	305
IA	THOMPSON	QNII			43	22N	093	42W	384
IA	NORTHWOOD	QNKI			43	27N	093	12W	371
IA	NORA SPRINGS	QNSI			43	09N	093	00W	332
IA	NEVADA	QNVI			42	01N	093	26W	313
IA	OSAGE	QOAI			43	17N	092	49W	353
IA	OSKALOOSA	QOCI			41	18N	092	39W	245
IA	OGDEN	QOGI			42	02N	094	02W	332
IA	OSCEOLA	QOSI			41	02N	093	46W	353
IA	PANORA	QPAI			41	42N	094	22W	356
IA	PELLA	QPEI			41	25N	092	54W	289
IA	NORTH POLK	QPKI			41	47N	093	43W	286
IA	PERRY	QPYI			41	50N	094	05W	312
IA	MASON CITY	QRMI			43	08N	093	06W	328
IA	ROCKWELL CITY	QROI			42	23N	094	38W	384
IA	ROCKFORD	QRRI			43	03N	092	56W	316
IA	ROCKWELL	QRSI			42	59N	093	06W	351
IA	RUSSELL	QRUM			44	19N	095	57W	466
IA	RICEVILLE	QRVI			43	21N	092	30W	382
IA	ST ANSGAR	QSAI			43	22N	092	55W	358
IA	SIBLEY	QSBI			43	24N	095	45W	462
IA	STUART	QSTI			41	30N	094	19W	367
IA	SULLY	QSUI			41	34N	092	50W	289
IA	TITONKA	QTKI			43	14N	094	02W	348
IA	MESKWAKI SS TAMA	QTQI			41	59N	092	39W	256
IA	UNION	QUNI			42	14N	093	04W	301
IA	VENTURA	QVTI			43	08N	093	29W	386
IA	WALL LAKE	QWAI			42	16N	095	06W	426
IA	WEBSTER CITY	QWBI			42	28N	093	49W	345
IA	WOODWARD	QWGI			41	52N	093	55W	291
IA	WINTERSET	QWII			41	20N	094	01W	356
ID	BOISE	KBOI	BOI	72681	43	34N	116	14W	875
ID	BURLEY	KBYI	BYI		42	33N	113	46W	1264
ID	BONNERS FERRY	K65S	65S		48	44N	116	18W	713
ID	CALDWELL	KEUL	EUL		43	37N	116	37W	740
ID	CHALLIS	KLLJ	LLJ		44	31N	114	13W	1536
ID	COEUR D'ALENE	KCOE	COE		47	46N	116	49W	707
ID	DRIGGS REED MEM	KDIJ	DIJ		43	45N	111	06W	1899
ID	GRANGEVILLE	KGIC	GIC	72687	45	57N	116	07W	1009
ID	HAILEY/FRIEDMAN	KSUN	SUN		43	30N	114	17W	1620

ID	IDAHO FALLS	KIDA	IDA		43	31N	112	04W	1453
ID	JEROME COUNTY	KJER	JER		42	43N	114	27W	1222
ID	LEWISTON	KLWS	LWS	72783	46	22N	117	01W	438
ID	LOWELL/ELK CITY	KP69	P69		46	09N	115	36W	480
ID	MALAD CITY	KMLD	MLD		42	10N	112	17W	1373
ID	MALTA (AWRS)	K77M	77M		42	19N	113	19W	1375
ID	MCCALL	KMYL	MYL		44	53N	116	06W	1533
ID	MOUNTAIN HOME	KMUO	MUO		43	02N	115	52W	913
ID	MULLAN PASS	KMLP	MLP		47	27N	115	40W	1837
ID	NAMPA	KMAN	MAN		43	35N	116	31W	774
ID	POCATELLO	KPIH	PIH	72578	42	55N	112	34W	1359
ID	REXBURG	KRXE	RXE		43	50N	111	48W	1480
ID	SALMON/LEMHI	KSMN	SMN	72686	45	07N	113	52W	1233
ID	SODA SPRINGS	KU78	U78		42	38N	111	34W	1780
ID	SPENCER	KS14	S14		44	21N	112	10W	1800
ID	STANLEY	KSNT	SNT		44	10N	114	56W	1980
ID	TWIN FALLS	KTWF	TWF		42	29N	114	29W	1266
ID	WALL/SANDPOINT	KSZT	SZT		48	18N	116	34W	648
IL	ALTON/ST LOUIS R	KALN	ALN		38	53N	090	02W	166
IL	BLOOMINGTON/NORM	KBMI	BMI		40	28N	088	55W	267
IL	CAHOKIA/ST LOUIS	KCPS	CPS		38	34N	090	09W	126
IL	CAIRO	KCIR	CIR		37	04N	089	13W	98
IL	CARBONDALE/MURPH	KMDH	MDH		37	47N	089	15W	130
IL	CARMI MUNI	KCUL			38	05N	088	07W	118
IL	CENTRALIA	KENL	ENL		38	31N	089	06W	163
IL	CHAMPAIGN/URBANA	KCMI	CMI		40	02N	088	16W	228
IL	CHICAGO	KMDW	MDW	72534	41	47N	087	45W	188
IL	CHICAGO O'HARE	KORD	ORD	72530	41	59N	087	56W	200
IL	CHICAGO/AURORA	KARR	ARR	74465	41	46N	088	29W	215
IL	CHICAGO/DUPAGE	KDPA	DPA		41	55N	088	15W	231
IL	CHICAGO/MEIGS	KCGX	CGX		41	52N	087	35W	181
IL	CHICAGO/LANSING	KIGQ	IGQ		41	32N	087	32W	188
IL	DANVILLE	KDNV	DNV		40	12N	087	36W	212
IL	DECATUR	KDEC	DEC		39	50N	088	51W	207
IL	DE KALB	KDKB	DKB		41	56N	088	42W	279
IL	EFFINGHAM	K1H2	1H2		39	04N	088	32W	179
IL	FAIRFIELD	KFWC	FWC		38	23N	088	25W	133
IL	FREEPORT	KFEP	FEP		42	15N	089	35W	262
IL	FLORA	KFOA	FOA		38	40N	088	27W	144
IL	GALESBURG	KGBG	GBG		40	56N	090	26W	233
IL	HARRISBURG	KHSB	HSB		37	49N	088	33W	121
IL	JACKSONVILLE	KIJX	IJX		39	46N	090	14W	190
IL	JOLIET	KJOT	JOT		41	31N	088	10W	177
IL	KANKAKEE	KIKK	IKK		41	04N	087	51W	192
IL	LACON	KC75	C75		41	01N	089	23W	173
IL	LAWRENCEVILLE	KLWV	LWV		38	46N	087	36W	131
IL	LINCOLN	KAAA	AAA		40	10N	089	20W	182
IL	LITCHFIELD MUNI	K3LF	3LF		39	10N	089	40W	210
IL	MACOMB MUNI	KMQB	MQB		40	31N	090	39W	215
IL	MARION REGIONAL	KMWA	MWA		37	45N	089	01W	144
IL	MARSEILLES	KMMO	MMO	74460	41	22N	088	40W	225
IL	MATTOON/CHARLEST	KMTO	MTO		39	28N	088	16W	214
IL	METROPOLIS	KM30	M30		37	11N	088	45W	117
IL	MOLINE/QUAD CITY	KMLI	MLI	72544	41	27N	090	31W	184
IL	MORRIS-WASHBURN	KC09	C09		41	26N	088	25W	178
IL	MOUNT CARMEL	KAJG	AJG		38	36N	087	44W	131
IL	MOUNT VERNON	KMVN	MVN		38	19N	088	52W	146

IL	OLNEY-NOBLE	KOLY	OLY		38	43N	088	11W	147
IL	PALWAUKEE	KPWK	PWK		42	07N	087	54W	203
IL	PEORIA	KPIA	PIA	72532	40	40N	089	41W	205
IL	PARIS	KPRG	PRG		39	42N	087	40W	199
IL	PERU	KVYS	VYS		41	21N	089	09W	199
IL	PITTSFIELD	KPPQ	PPQ		39	38N	090	47W	216
IL	PONTIAC	KPNT	PNT		40	55N	088	38W	201
IL	QUINCY MUNI/BALD	KUIN	UIN		39	57N	091	12W	234
IL	RANTOUL	KTIP	TIP		40	18N	088	09W	225
IL	ROBINSON MUNI	KRSV	RSV		39	01N	087	39W	141
IL	ROCKFORD	KRFD	RFD	72543	42	12N	089	06W	221
IL	ROCHELLE/KORITZ	KRPJ	RPJ		41	53N	089	05W	238
IL	ROMEOVILLE/CHI	KLOT	LOT		41	37N	088	06W	205
IL	SALEM/LECKRONE	KSLO	SLO		38	39N	088	58W	175
IL	SAVANNA/TRITOWN	KSFY	SFY		42	03N	090	07W	188
IL	SCOTT AFB/BELLEV	KBLV	BLV		38	32N	089	50W	138
IL	SPARTA	KSAR	SAR		38	09N	089	42W	164
IL	SPRINGFIELD	KSPI	SPI	72439	39	51N	089	41W	181
IL	STERLING ROCKFAL	KSQI	SQI		41	45N	089	40W	197
IL	TAYLORVILLE	KTAZ	TAZ		39	32N	089	20W	190
IL	WAUKEGAN	KUGN	UGN		42	25N	087	52W	222
IN	ANDERSON MUNICIP	KAID	AID		40	07N	085	37W	280
IN	AUBURN DEKALB C	KGWB	GWB		41	18N	085	04W	269
IN	BLOOMINGTON	KBMG	BMG		39	09N	086	37W	257
IN	COLUMBUS/BALKALA	KBAK	BAK		39	16N	085	54W	200
IN	ELKHART MUNICIPA	KEKM	EKM		41	43N	086	00W	237
IN	EVANSVILLE	KEVV	EVV	72432	38	03N	087	31W	117
IN	FORT WAYNE	KFWA	FWA	72533	40	59N	085	11W	248
IN	GARY REGIONAL	KGYY	GYY		41	37N	087	25W	180
IN	GOSHEN	KGSH	GSH		41	32N	085	47W	252
IN	GRISSOM AFB/PERU	KGUS	GUS		40	38N	086	09W	247
IN	HUNTINGBURG	KHNB	HNB		38	15N	086	57W	161
IN	INDIANAPOLIS	KEYE	EYE		39	50N	086	18W	248
IN	INDIANAPOLIS	KIND	IND	72438	39	43N	086	18W	241
IN	INDIANAPOLIS EXC	KTYQ	TYQ		40	02N	086	15W	281
IN	KNOX STARKE CTY	KOXI	OXI		41	20N	086	40W	209
IN	KOKOMO	KOKK	OKK		40	32N	086	04W	253
IN	LAFAYETTE	KLAF	LAF		40	25N	086	56W	182
IN	MARION MUNI	KMZZ	MZZ		40	29N	085	41W	262
IN	MUNCIE	KMIE	MIE		40	14N	085	24W	285
IN	RENSSELAER	KRZL	RZL		40	57N	087	11W	213
IN	ROCHESTER	KRCR	RCR		41	04N	086	11W	241
IN	SHELBYVILLE	KGEZ	GEZ		39	35N	085	48W	245
IN	SOUTH BEND	KSBN	SBN	72535	41	42N	086	19W	237
IN	TERRE HAUTE	KHUF	HUF	72437	39	27N	087	20W	179
IN	VALPARAISO	KVPZ	VPZ		41	27N	087	00W	231
IN	WARSAW MUNI	KASW	ASW		41	16N	085	50W	259
KS	BURLINGTON	KUKL	UKL		38	18N	095	44W	358
KS	CHANUTE	KCNU	CNU		37	40N	095	29W	297
KS	COFFEYVILLE	KCFV	CFV		37	05N	095	34W	225
KS	CONCORDIA	KCNK	CNK	72458	39	33N	097	39W	447
KS	DODGE CITY	KDDC	DDC	72451	37	46N	099	58W	789
KS	ELKHART	KEHA	EHA	72460	37	00N	101	54W	1099
KS	EMPORIA	KEMP	EMP		38	20N	096	12W	367
KS	FORT LEAVENWORTH	KFLV	FLV		39	22N	094	55W	235
KS	FT RILEY/MARSHAL	KFRI	FRI	72455	39	02N	096	46W	325
KS	GARDEN CITY	KGCK	GCK		37	55N	100	43W	877

KS	GOODLAND	KGLD	GLD	72465	39 22N	101 42W	1113
KS	GREAT BEND	KGBD	GBD		38 21N	098 52W	575
KS	HAYS MUNI	KHYS	HYS		38 51N	099 16W	609
KS	HILL CITY	KHLC	HLC		39 22N	099 50W	669
KS	HUTCHINSON	KHUT	HUT		38 04N	097 52W	467
KS	INDEPENDENCE	KIDP	IDP		37 10N	095 47W	251
KS	JENNINGS	KJN8	JN8		39 41N	100 18W	762
KS	LAWRENCE	KLWC	LWC		39 01N	095 13W	253
KS	LEOTI/HOARD MEML	K3K7	3K7		38 27N	101 21W	1007
KS	LIBERAL	KLBL	LBL		37 02N	100 58W	879
KS	MANHATTAN	KMHK	MHK		39 08N	096 41W	317
KS	MCCONNELL AFB	KIAB	IAB		37 37N	097 16W	418
KS	MEDICINE LODGE	KP28	P28	72452	37 17N	098 33W	469
KS	NEW ALMELO	KAL8	AL8		39 36N	100 07W	734
KS	NEWTON	KEWK	EWK		38 02N	097 16W	467
KS	OLATHE/INDUSTRIA	KIXD	IXD		38 49N	094 53W	342
KS	OLATHE/EXECUTIVE	KOJC	OJC		38 51N	094 44W	326
KS	PARSONS	KPPF	PPF		37 20N	095 30W	274
KS	PITTSBURG	KPTS	PTS		37 27N	094 44W	290
KS	PRATT INDUST	KPTT	PTT		37 42N	098 45W	595
KS	RUSSELL	KRSL	RSL		38 52N	098 49W	567
KS	SALINA	KSLN	SLN		38 47N	097 39W	385
KS	TOPEKA/FORBES	KFOE	FOE		38 56N	095 39W	320
KS	TOPEKA	KTOP	TOP	72456	39 04N	095 38W	268
KS	WAKEENEY	KWK6	WK6		39 02N	099 53W	752
KS	WICHITA	KICT	ICT	72450	37 39N	097 26W	407
KS	WICHITA/JABARA	KAAO	AAO		37 45N	097 13W	434
KS	WINFIELD/ARKANSA	KWLD	WLD		37 10N	097 02W	350
KS	OBERLIN	KOIN	OIN		39 50N	100 32W	824
KS	SYRACUSE	K3K3	3K3		38 00N	101 45W	1013
KS	NORTON	KNRN	NRN		39 51N	099 54W	727
KS	TRIBUNE	KTRB	TRB		38 27N	101 45W	1103
KS	COLBY	KCBK	CBK		39 26N	101 03W	971
KS	GRINNELL	KGNL	GNL		39 08N	100 37W	887
KS	HOXIE	KHOX	HOX		39 22N	100 26W	833
KS	PHILLIPSBURG	KPHG	PHG		39 44N	099 19W	582
KS	HERNDON	KHD7	HD7		39 55N	100 50W	814
KS	LOGAN	KLG5	LG5		39 40N	099 34W	597
KS	ST FRANCIS	KSYF	SYF		39 46N	101 48W	1025
KS	ABILENE	KK78	K78		38 54N	097 14W	352
KS	ELLSWORTH	K9K7	9K7		38 45N	098 14W	492
KS	EUREKA	K13K	13K		37 51N	096 18W	369
KS	FORT SCOTT	KFSK	FSK		37 48N	094 46W	280
KS	HUGOTON	KHQG	HQG		37 10N	101 22W	956
KS	JOHNSON	K2K3	2K3		37 35N	101 44W	1013
KS	KINGMAN	K9K8	9K8		37 40N	098 07W	490
KS	MCPHERSON	KMPR	MPR		38 21N	097 41W	457
KS	OAKLEY	KOEL	OEL		39 07N	100 49W	929
KS	SCOTT CITY	KTQK	TQK		38 28N	100 53W	904
KS	SMITH CENTER	KK82	K82		39 46N	098 48W	549
KS	ULYSSES	KULS	ULS		37 36N	101 22W	936
KS	WELLINGTON	KEGT	EGT		37 19N	097 23W	390
KY	BOWLING GREE	KBWG	BWG		36 58N	086 25W	168
KY	COVINGTON	KCVG	CVG	72421	39 03N	084 40W	269
KY	DANVILLE	KDVK	DVK		37 35N	084 46W	312
KY	HOPKINSVILLE	KHOP	HOP	74671	36 40N	087 30W	174
KY	FORT KNOX/GODMAN	KFTK	FTK	72424	37 53N	085 58W	230

KY FRANKFORT	KFFT	FFT		38 11N	084 54W	236
KY GLASGOW	KGLW	GLW		37 02N	085 57W	218
KY HENDERSON CITY	KEHR	EHR		37 49N	087 40W	117
KY LEXINGTON	KLEX	LEX	72422	38 02N	084 36W	300
KY LONDON	KLOZ	LOZ	72329	37 05N	084 04W	362
KY LOUISVILLE	KSDF	SDF	72423	38 11N	085 44W	146
KY LOUISVILLE/BOWMN	KLOU	LOU		38 13N	085 40W	164
KY LOUISVILLE/WFO	KLMK	LMK		38 14N	085 40W	166
KY MIDDLESBORO-BELL	K1A6	1A6		36 37N	083 44W	352
KY MONTICELLO/WAYNE	KEKQ	EKQ		36 51N	084 51W	294
KY MURRAY KYLE-OAK	KCEY	CEY		36 40N	088 22W	176
KY NOCTOR/JACKSON	KJKL	JKL		37 36N	083 19W	416
KY OWENSBORO/DAVIES	KOWB	OWB		37 43N	087 10W	124
KY PADUCAH	KPAH	PAH	72435	37 04N	088 46W	119
KY RICHMOND/MADISON	KI39	I39		37 38N	084 20W	306
KY SOMERSET	KSME	SME		37 03N	084 37W	283
LA ABBEVILLE CC MEM	K0R3	0R3		29 59N	092 05W	5
LA ALEXANDRIA	KAEX	AEX	74754	31 20N	092 34W	27
LA ALEXANDRIA	KESF	ESF		31 24N	092 17W	28
LA AMELIA/LAKE PALO	K7R3	7R3		29 41N	091 05W	2
LA AUDUBON PARK	KAUD	AUD		29 56N	090 08W	2
LA BARKSDALE AFB	KBAD	BAD		32 30N	093 40W	51
LA BASTROP MOREHOUS	KBQP	BQP		32 45N	091 53W	51
LA BATON ROUGE	KBTR	BTR		30 32N	091 09W	21
LA BOGALUSA CARR F	KBXA	BXA		30 49N	089 52W	36
LA BOOTHVILLE	KBVE	BVE	72232	29 19N	089 24W	1
LA CAMERON HELIPORT	K7R5	7R5		29 46N	093 17W	1
LA CHENAULT/LK CHAS	KCWF	CWF		30 13N	093 09W	4
LA DERIDDER/FSS	KDRI	DRI		30 50N	093 20W	63
LA EUGENE IS 330	K3B6	3B6		28 14N	091 41W	1
LA FORT POLK FR	KPOE	POE	72239	31 03N	093 12W	101
LA PEASON RIDG/POLK	KAQV	AQV		31 24N	093 18W	111
LA FULLERTON/POLK	KBKB	BKB		31 00N	092 58W	94
LA SELF STRIP/POLK	KDNK	DNK		31 07N	092 58W	114
LA FOURCHON (SAWRS)	K9F2	9F2		29 06N	090 12W	2
LA PORT FOURCHON	KXPY	XPY		29 07N	090 12W	2
LA GALLIANO	KGAO	GAO		29 27N	090 16W	1
LA GALLIANO HELIPRT	K2GL	2GL		29 25N	090 18W	3
LA GRAND ISLE (SAWR	KAXO	AXO	99429	29 15N	089 58W	2
LA GREEN CANYON 184	KXCN	XCN		27 46N	091 31W	1
LA GREEN CANYON 52	K28K	28K		27 53N	091 30W	1
LA HAMMOND	KHDC	HDC		30 31N	090 25W	13
LA HIGH ISLAND 334A	KH02	H02		28 06N	093 24W	30
LA HIGH IS. 264C	KH08	H08		28 28N	093 44W	30
LA OFFSHORE	KH78	H78		28 11N	088 29W	43
LA HOUMA TERREBONNE	KHUM	HUM		29 34N	090 40W	3
LA INTRACOASTAL CIT	K7R4	7R4		29 46N	092 07W	5
LA LAFAYETTE	KLFT	LFT		30 12N	092 00W	11
LA LAKE CHARLES	KLCH	LCH	72240	30 08N	093 13W	4
LA MINDEN	KMNE	MNE		32 39N	093 18W	85
LA MONROE	KMLU	MLU		32 31N	092 02W	29
LA NATCHITOCHES	KIER	IER		31 44N	093 06W	37
LA NEW IBERIA	KARA	ARA		30 02N	091 53W	18
LA NEW ORLEANS/LAKE	KNEW	NEW		30 03N	090 02W	3
LA NEW ORLEANS NAS	KNBG	NBG		29 49N	090 01W	1
LA NEW ORLEANS/INTL	KMSY	MSY	72231	30 00N	090 15W	5
LA OAKDALE ALLEN P	KACP	ACP		30 45N	092 41W	33

LA	RUSTON REGIONAL	KRSN	RSN		32 31N	092 35W	95
LA	PATTERSON MEMORI	KPTN	PTN		29 43N	091 19W	3
LA	SALT POINT	KP92	P92		29 34N	091 32W	1
LA	SHIP SHOAL 207	KGSM	GSM		28 32N	090 59W	1
LA	SHREVEPORT/DWNTN	KDTN	DTN		32 33N	093 45W	53
LA	SHREVEPORT	KSHV	SHV	72248	32 27N	093 50W	83
LA	SLIDELL 22	KASD	ASD		30 21N	089 49W	9
LA	S MARSH ISL 268	KSRN	SRN		29 07N	091 52W	1
LA	S MARSH ISLAND	K7R8	7R8		28 18N	091 58W	1
LA	SOUTH TIMBALIER	KS58	S58		28 31N	090 34W	1
LA	SULPHUR	KUXL	UXL		30 08N	093 23W	4
LA	TALLULAH/VICKSBU	KTVR	TVR		32 21N	091 02W	26
LA	VENICE HELIPORT	K1B7	1B7		29 21N	089 26W	1
LA	E. CAMERON 346	KE12	E12		28 04N	092 42W	1
LA	W. CAMERON 560	KW60	W60		28 09N	093 21W	1
LA	PHI OIL PLATF	KQT8	QT8		27 32N	092 26W	1
LA	PHI OIL PLATF	KQT9	QT9		27 47N	090 38W	1
LA	PHI OIL PLATF	K4CO	4CO		29 47N	093 11W	1
LA	PHI OIL PLATF	K4C0	4C0		29 47N	093 11W	1
LA	GARDEN BANKS172	KGHB	GHB		27 50N	091 59W	30
LA	MISS CANYAN 807	KCYD	CYD		28 10N	089 13W	1
LA	INDEPEDENCE 920	KIPN	IPN		28 05N	087 59W	41
LA	MAGNOLIA OILP	KGBK	GBK		27 12N	092 12W	59
LA	SHIP SHOAL178	KSPR	SPR		28 36N	091 12W	31
LA	MISS CANYON 311A	KMDJ	MDJ		28 39N	089 48W	31
LA	E CAMERON278OILP	KEHC	EHC		28 26N	092 53W	31
LA	SABINE 13B OILP	KVBS	VBS		29 29N	093 38W	31
LA	S MARSH268 OILP	KSCF	SCF		29 07N	091 52W	8
LA	VERMILLION26OILP	KVNP	VNP		29 28N	092 22W	28
LA	EUGENE I 215OILP	KEIR	EIR		28 38N	091 29W	28
LA	ATLANTIS OILP	KATP	ATP		27 12N	090 02W	62
LA	E CAMERON 47JP	KCMB	CMB		29 26N	092 59W	29
LA	GREEN CANYON 338	KGRY	GRY		27 38N	090 27W	58
LA	HIGH IS. 179A	KXIH	XIH		29 11N	094 31W	75
LA	MAIN PASS 289C	KVKY	VKY		29 15N	088 26W	32
LA	MAIN PASS 140B	KMIS	MIS		29 18N	088 51W	32
LA	S TIMBALIER 301B	KSTZ	STZ		28 10N	090 40W	25
LA	VERMILION 331	KVQT	VQT		28 16N	092 16W	25
LA	MISS CANYON 474	KIKT	IKT		28 31N	088 17W	25
MA	BEDFORD	KBED	BED	74490	42 28N	071 18W	50
MA	BEVERLY	KBVY	BVY		42 35N	070 55W	28
MA	BOSTON	KBOS	BOS	72509	42 22N	071 01W	6
MA	CHATHAM	KCHH	CHH	74494	41 40N	069 58W	16
MA	CHATHAM	KCQX	CQX		41 41N	070 00W	19
MA	CHICOPEE/WESTOVE	KCEF	CEF	74491	42 12N	072 31W	75
MA	CHICOPEE/WESTOVE			72491	42 12N	072 31W	75
MA	EAST MILTON	KMQE	MQE		42 13N	071 07W	199
MA	FALMOUTH/OTIS AB	KFMH	FMH		41 38N	070 31W	40
MA	FITCHBURG	KFIT	FIT		42 33N	071 45W	103
MA	HYANNIS	KHYA	HYA		41 40N	070 16W	22
MA	LAWRENCE	KLWM	LWM		42 43N	071 08W	54
MA	MARSHFIELD	KGHG	GHG		42 06N	070 40W	4
MA	MARTHAS VINEYARD	KMVY	MVY		41 24N	070 37W	16
MA	NANTUCKET	KACK	ACK	72506	41 15N	070 04W	16
MA	NEW BEDFORD	KEWB	EWB		41 41N	070 57W	23
MA	NORTH ADAMS	KAQW	AQW		42 42N	073 10W	199
MA	NORWOOD	KOWD	OWD		42 11N	071 10W	19

MA	ORANGE	KORE	ORE		42 34N	072 17W	164
MA	PITTSFIELD	KPSF	PSF		42 26N	073 17W	355
MA	PLYMOUTH	KPYM	PYM		41 55N	070 44W	43
MA	PROVINCETOWN	KPVC	PVC		42 04N	070 13W	2
MA	SOUTH WEYMOUTH	KNZW	NZW		42 08N	070 55W	49
MA	TAUNTON	KTAN	TAN		41 53N	071 01W	7
MA	WESTFIELD	KBAF	BAF		42 10N	072 43W	83
MA	WORCESTER	KORH	ORH		42 16N	071 52W	304
MD	ABERDEEN/PHILLIP	KAPG	APG	74002	39 28N	076 10W	18
MD	ANNAPOLIS/NAVAL	KNAK			38 59N	076 29W	2
MD	ANDREWS AFB	KADW	ADW	74594	38 49N	076 52W	86
MD	BALTO/WASH INTL	KBWI	BWI	72406	39 10N	076 41W	59
MD	BALTIMORE/MARTIN	KMTN	MTN		39 19N	076 25W	7
MD	BALTIMORE/DWNTWN	KDMH	DMH		39 17N	076 37W	5
MD	CAMBRIDGE-DORCH	KCGE	CGE		38 32N	076 02W	6
MD	CAMP DAVID	KRSP			39 39N	077 28W	561
MD	CARROLL CNTY	KDMW	DMW		39 36N	077 00W	241
MD	COLLEGE PARK	KCGS	CGS		38 59N	076 55W	15
MD	CUMBERLAND REG	KCBE	CBE		39 37N	078 46W	236
MD	EASTON/NEWNAM	KESN	ESN		38 48N	076 04W	22
MD	FORT MEADE	KFME	FME		39 05N	076 46W	46
MD	FORT RITCHIE	KJWX	JWX		39 43N	077 25W	84
MD	FREDERICK	KFDK	FDK		39 25N	077 22W	92
MD	GARRETT CO	K2G4	2G4		39 35N	079 20W	894
MD	GAITHERSBURG	KGAI	GAI		39 10N	077 10W	165
MD	HAGERSTOWN	KHGR	HGR		39 42N	077 44W	224
MD	OCEAN CITY	KOXB	OXB		38 19N	075 07W	3
MD	PATUXENT RIVER	KNHK	NHK	72404	38 16N	076 24W	12
MD	RIDGELY	KRJD	RJD		38 58N	075 52W	20
MD	SALISBURY	KSBY	SBY		38 20N	075 30W	19
MD	STEVENSVILLE	KW29	W29		38 59N	076 20W	15
MD	ST MARYS (DUKE)	K2W6	2W6		38 19N	076 33W	44
MD	WEBSTER NAVAL	KNUI	NUI		38 09N	076 26W	7
ME	AUBURN/LEWISTON	KLEW	LEW		44 02N	070 16W	88
ME	AUGUSTA	KAUG	AUG		44 19N	069 48W	109
ME	BANGOR	KBGR	BGR	72607	44 48N	068 49W	57
ME	BAR HARBOR	KBHB	BHB		44 27N	068 22W	26
ME	BRUNSWICK NAS	KNHZ	NHZ	74392	43 52N	069 55W	23
ME	CARIBOU	KCAR	CAR	72712	46 52N	068 01W	191
ME	CLAYTON LAKE	K40B	40B		46 37N	069 31W	314
ME	EASTPORT	KEPM	EPM	72608	44 55N	067 01W	14
ME	FRENCHVILLE	KFVE	FVE		47 17N	068 18W	301
ME	FRYEBURG	KIZG	IZG		43 59N	070 57W	135
ME	GREENVILLE	KGNR	GNR	72619	45 28N	069 33W	427
ME	HOULTON	KHUL	HUL		46 07N	067 48W	150
ME	MILLINOCKET	KMLT	MLT		45 39N	068 42W	123
ME	OLD TOWN/DEWITT	KOLD	OLD		44 57N	068 40W	39
ME	PORTLAND	KPWM	PWM	72606	43 39N	070 18W	15
ME	PRESQUE ISLE	KPQI	PQI	72713	46 40N	068 02W	146
ME	ROCKLAND/KNOX	KRKD	RKD		44 04N	069 05W	17
ME	SANFORD MUNI	KSFM	SFM		43 23N	070 43W	74
ME	WATERVILLE	KWVL	WVL		44 31N	069 40W	101
ME	WISCASSET	KIWI	IWI		43 58N	069 43W	20
MI	ADRIAN	KADG	ADG		41 52N	084 05W	241
MI	ALMA	KAMN	AMN		43 19N	084 41W	230
MI	ALPENA	KAPN	APN	72639	45 04N	083 34W	210
MI	ANN ARBOR	KARB	ARB		42 13N	083 44W	251

MI	BAD AXE	KBAX	BAX		43	47N	082	59W	234
MI	BATTLE CREEK	KBTL	BTL		42	19N	085	14W	290
MI	BELLAIRE	KACB	ACB		44	59N	085	12W	190
MI	BEAVER ISLAND	KSJX	SJX		45	42N	085	34W	204
MI	BENTON HARBOR	KBEH	BEH		42	08N	086	25W	191
MI	BIG RAPIDS	KRQB	RQB		43	43N	085	30W	302
MI	CADILLAC/WEXFORD	KCAD	CAD		44	16N	085	25W	398
MI	CARO/TUSCOLA	KCFS	CFS		43	28N	083	27W	214
MI	CHARLEVOIX	KCVX	CVX		45	18N	085	16W	204
MI	CHARLOTTE	KFPK	FPK		42	34N	084	49W	272
MI	CHEBOYGAN	KSLH	SLH		45	39N	084	31W	195
MI	CHIPPEWA INTL	KCIU	CIU		46	15N	084	28W	244
MI	COLDWATER	KOEB	OEB		41	55N	085	02W	292
MI	COPPER HARBOR	KP59	P59		47	28N	087	53W	190
MI	DETROIT/CITY AIR	KDET	DET		42	24N	083	01W	190
MI	DETROIT/WILLOW	KYIP	YIP		42	14N	083	32W	215
MI	DETROIT/WAYNE	KDTW	DTW	72537	42	14N	083	20W	195
MI	DETROIT/GROSSE I	KONZ	ONZ		42	06N	083	09W	180
MI	DRUMMOND IS	KDRM	DRM		46	00N	083	45W	204
MI	ESCANABA	KESC	ESC	72648	45	45N	087	01W	187
MI	FLINT	KFNT	FNT	72637	42	58N	083	45W	233
MI	FRANKFORT	KFKS	FKS		44	38N	086	12W	193
MI	FREMONT	KFFX	FFX		43	26N	086	00W	236
MI	GAYLORD	KGLR	GLR		45	01N	084	41W	407
MI	GRAND RAPIDS	KGRR	GRR	72635	42	53N	085	31W	237
MI	GRAYLING AF	KGOV	GOV		44	41N	084	44W	353
MI	GWINN/SAWYER	KSAW	SAW		46	21N	087	24W	372
MI	HANCOCK	KCMX	CMX	72744	47	10N	088	29W	326
MI	HARBOR SPRINGS	KMGN	MGN		45	26N	084	55W	209
MI	HILLSDALE	KJYM	JYM		41	55N	084	35W	360
MI	HOLLAND	KBIV	BIV		42	45N	086	06W	208
MI	HOUGHTON LAKE	KHTL	HTL	72638	44	21N	084	40W	351
MI	HOWELL	KOZW	OZW		42	37N	083	58W	293
MI	IONIA	KY70	Y70		42	56N	085	04W	250
MI	IRON MOUNTAIN	KIMT	IMT		45	49N	088	07W	349
MI	IRONWOOD	KIWD	IWD		46	31N	090	07W	375
MI	JACKSON/REYNOLDS	KJXN	JXN		42	16N	084	28W	305
MI	KALAMAZOO	KAZO	AZO		42	14N	085	33W	272
MI	LAMBERTVILLE	KDUH	DUH		41	44N	083	39W	204
MI	LANSING	KLAN	LAN	72539	42	47N	084	35W	264
MI	LUDINGTON/MASON	KLDM	LDM		43	58N	086	24W	197
MI	MACKINAC ISLAND	KMCD	MCD		45	51N	084	38W	226
MI	MANISTEE	KMBL	MBL		44	16N	086	15W	189
MI	MANISTIQUE	KISQ	ISQ		45	58N	086	10W	209
MI	MANISTIQUE	KP75	P75		45	57N	086	14W	178
MI	MARSHALL	KRMY	RMY		42	14N	084	57W	287
MI	MASON	KTEW	TEW		42	34N	084	25W	280
MI	MENOMINEE	KMNM	MNM		45	07N	087	37W	191
MI	MIDLAND BARSTOW	KIKW	IKW		43	40N	084	16W	194
MI	MONROE	KTTF	TTF		41	56N	083	25W	188
MI	MOUNT PLEASANT	KMOP	MOP		43	37N	084	44W	230
MI	MUNISING LAKESH	KP53	P53		46	25N	086	39W	187
MI	MUSKEGON	KMKG	MKG	72636	43	10N	086	14W	191
MI	NEWBERRY	KERY	ERY		46	18N	085	27W	265
MI	OSCODA/WURTSMITH	KOSC	OSC		44	27N	083	24W	193
MI	OWOSSO	KRNP	RNP		43	00N	084	08W	224
MI	PELLSTON	KPLN	PLN		45	34N	084	48W	217

MI	PONTIAC	KPTK	PTK		42	40N	083	25W	299
MI	PORT HOPE	KP58	P58		44	01N	082	48W	179
MI	PORT HURON	KPHN	PHN		42	55N	082	31W	198
MI	ROGERS CITY	KPZQ	PZQ		45	24N	083	49W	204
MI	SAGINAW	KMBS	MBS		43	32N	084	05W	202
MI	SAGINAW/BROWNE	KHYX	HYX		43	26N	083	52W	183
MI	SALEM (LANSING)	KSVM	SVM		42	25N	083	36W	290
MI	SAULT STE MARIE	KSSM	SSM		46	28N	084	22W	221
MI	SAULT STE MARIE	KANJ	ANJ	72734	46	28N	084	22W	218
MI	SELFRIDGE ANGB	KMTC	MTC		42	37N	082	49W	177
MI	SOUTH HAVEN	KLWA	LWA		42	21N	086	15W	203
MI	STURGIS/KIRSCH	KIRS	IRS		41	48N	085	26W	282
MI	THREE RIVERS	KHAI	HAI		41	58N	085	36W	251
MI	TRAVERSE CIT	KTVC	TVC		44	44N	085	34W	190
MI	TROY/OAKLAND	KVLL	VLL		42	33N	083	11W	222
MN	AITKIN NDB	KAIT	AIT		46	32N	093	40W	367
MN	ALBERT LEA	KAEL	AEL		43	40N	093	22W	383
MN	ALEXANDRIA	KAXN	AXN		45	52N	095	24W	433
MN	APPLETON MUNICIP	KAQP	AQP		45	13N	096	00W	311
MN	AUSTIN MUNI	KAUM	AUM		43	40N	092	55W	375
MN	BAUDETTE	KBDE	BDE		48	44N	094	37W	329
MN	BEMIDJI	KBJI	BJI	72755	47	30N	094	55W	420
MN	BENSON MUNI	KBBB	BBB		45	19N	095	39W	317
MN	BIGFORK	KFOZ	FOZ		47	46N	093	39W	411
MN	BRAINERD	KBRD	BRD		46	24N	094	08W	372
MN	BUFFALO MUNI	KCFE	CFE		45	10N	093	51W	295
MN	CAMBRIDGE MUNI	KCBG	CBG		45	34N	093	16W	287
MN	CANBY/MYERS FLD	KCNB	CNB		44	44N	096	16W	364
MN	CLOQUET	KCOQ	COQ		46	42N	092	30W	390
MN	COOK MUNI AIRPOR	KCQM	CQM		47	49N	092	41W	404
MN	CRANE LAKE	KCDD	CDD		48	16N	092	29W	341
MN	CROOKSTON MUNI	KCKN	CKN		47	51N	096	37W	273
MN	DETROIT LAKES	KDTL	DTL		46	49N	095	52W	426
MN	DODGE CENTER	KTOB	TOB		44	01N	092	49W	398
MN	DULUTH (SKY HARB	KDYT	DYT		46	43N	092	02W	186
MN	DULUTH	KDLH	DLH	72745	46	51N	092	12W	435
MN	ELBOW LAKE MUNI	KY63	Y63		45	59N	096	00W	367
MN	ELY MUNI	KELO	ELO		47	49N	091	49W	443
MN	EVELETH MUNI	KEVM	EVM		47	23N	092	30W	421
MN	FAIRMONT MUNI	KFRM	FRM		43	38N	094	25W	354
MN	FARIBAULT MUNI	KFBL	FBL		44	19N	093	19W	322
MN	FERGUS FALLS	KFFM	FFM	72656	46	16N	096	09W	361
MN	FLAG ISLAND	KFGN	FGN		49	19N	094	52W	328
MN	FOSSTON	KFSE	FSE		47	35N	095	46W	389
MN	GLENCOE	KGYL	GYL		44	45N	094	05W	302
MN	GLENWOOD	KGHW	GHW		45	38N	095	19W	425
MN	GRAND MARAIS	KGNA			47	45N	090	21W	185
MN	GRAND MARAIS	KGRM	GRM		47	50N	090	23W	505
MN	GRAND MARAIS/COO	KCKC			47	50N	090	22W	548
MN	GRAND RAPIDS	KGPZ	GPZ		47	13N	093	31W	413
MN	GRANITE FALLS	KGDB	GDB		44	45N	095	33W	319
MN	HALLOCK	KHCO	HCO		48	45N	096	56W	250
MN	HIBBING	KHIB	HIB		47	23N	092	50W	412
MN	HINCKLEY	K04W	04W		46	01N	092	54W	311
MN	HUTCHINSON	KHCD	HCD		44	52N	094	22W	323
MN	INTERNTNL FALLS	KINL	INL	72747	48	34N	093	24W	360
MN	JACKSON MUNI	KMJQ	MJQ		43	38N	094	58W	441

MN	LAKE ELMO	K21D	21D		45 00N	092 51W	285
MN	LITCHFIELD	KLJF	LJF		45 06N	094 30W	348
MN	LITTLE FALLS	KLXL	LXL		45 57N	094 20W	342
MN	LONG PRAIRIE	K14Y	14Y		45 54N	094 52W	406
MN	LONGVILLE	KXVG	XVG		46 59N	094 12W	407
MN	LUVERNE	KLYV	LYV		43 37N	096 13W	436
MN	MADISON	KDXX	DXX		44 59N	096 10W	330
MN	MANKATO	KMKT	MKT		44 13N	093 55W	311
MN	MARSHALL/RYAN	KMML	MML		44 27N	095 49W	359
MN	MAPLE LAKE	KMGG	MGG		45 14N	093 59W	313
MN	MCGREGOR/IVERSON	KHZX	HZX		46 37N	093 19W	374
MN	MINNEAPOLIS	KMSP	MSP	72658	44 53N	093 14W	265
MN	MINNEAPLS/BLAINE	KANE	ANE		45 08N	093 13W	278
MN	MNPLS/FLYING CLD	KFCM	FCM		44 50N	093 28W	280
MN	MNPLS/CRYSTAL	KMIC	MIC		45 04N	093 21W	265
MN	MNPLS/AIRLAKE	KLVN	LVN		44 38N	093 14W	293
MN	MONTEVIDEO	KMVE	MVE		44 58N	095 43W	315
MN	MOORHEAD MUNI	KJKJ	JKJ		46 50N	096 40W	280
MN	MOOSE LAKE	KMZH	MZH		46 25N	092 48W	328
MN	MORA	KJMR	JMR		45 53N	093 16W	309
MN	MORRIS MUNI	KMOX	MOX		45 34N	095 58W	344
MN	CANBY/MYERS FLD	K27D	27D		44 44N	096 16W	363
MN	NEW ULM MUNI	KULM	ULM		44 19N	094 30W	308
MN	OLIVIA	KOVL	OVL		44 47N	095 02W	328
MN	ORR	KORB	ORB		48 01N	092 52W	397
MN	ORTONVILLE	KVVV	VVV		45 18N	096 25W	335
MN	OWATONNA	KOWA	OWA		44 07N	093 15W	350
MN	PARK RAPIDS	KPKD	PKD		46 54N	095 04W	442
MN	PAYNESVILLE	KPEX	PEX		45 22N	094 45W	360
MN	PINE RIVER REGIO	KPWC	PWC		46 43N	094 22W	395
MN	PIPESTONE	KPQN	PQN		43 58N	096 19W	529
MN	PRESTON	KFKA	FKA		43 41N	092 11W	389
MN	PRINCETON MUNI	KPNM	PNM		45 33N	093 36W	298
MN	RED WING	KRGK	RGK		44 35N	092 29W	239
MN	REDWOOD FALL	KRWF	RWF		44 33N	095 05W	311
MN	ROCHESTER	KRST	RST	72644	43 54N	092 30W	403
MN	ST MARY HOSPITAL	K9MN	9MN		44 01N	092 29W	355
MN	ROSEAU MUNI	KROX	ROX		48 51N	095 42W	323
MN	RUSH CITY	KROS	ROS		45 42N	092 57W	281
MN	SAUK CENTRE	KD39	D39		45 42N	094 56W	380
MN	SILVER BAY	KBFW	BFW		47 12N	091 24W	331
MN	SLAYTON	KDVP	DVP		43 59N	095 47W	495
MN	SOUTH ST PAUL	KSGS	SGS		44 51N	093 02W	250
MN	ST. CLOUD	KSTC	STC	72655	45 33N	094 03W	314
MN	ST. JAMES	KJYG	JYG		43 59N	094 33W	325
MN	ST. PAUL	KSTP	STP		44 56N	093 03W	219
MN	STANTON	KSYN	SYN		44 29N	093 01W	280
MN	STAPLES	KSAZ	SAZ		46 22N	094 48W	392
MN	THIEF RIVER	KTVF	TVF		48 04N	096 10W	340
MN	TOFTE (RAMOS)	KP61	P61		47 34N	090 49W	241
MN	TRACY	KTKC	TKC		44 15N	095 37W	408
MN	TWO HARBORS	KTWM	TWM		47 02N	091 45W	328
MN	WADENA MUNI	KADC	ADC		46 27N	095 13W	418
MN	WARROAD	KRRT	RRT	72756	48 56N	095 20W	327
MN	WASECA	KACQ	ACQ		44 04N	093 33W	343
MN	WASKISH MUNI	KVWU	VWU		48 09N	094 31W	360
MN	WHEATON NDB	KETH	ETH		45 47N	096 33W	313

MN	WILLMAR/RICE	KILL	ILL		45	07N	095	04W	344
MN	WILLMAR MUNI	KBDH	BDH		45	07N	095	08W	247
MN	WINDOM MUNI AIRP	KMWM	MWM		43	54N	095	06W	430
MN	WINONA MUNI	KONA	ONA		44	04N	091	42W	200
MN	WORTHINGTON	KOTG	OTG		43	38N	095	34W	480
MN	AUSTIN	QASM			43	40N	092	57W	365
MN	ALBERT LEA	QBLM			43	38N	093	23W	383
MN	PRESTON	QFCM			43	40N	092	00W	318
MN	ROCHESTER	QFMM			44	01N	092	28W	304
MN	GRAND MEADOW	QGMM			43	43N	092	30W	403
MN	HILLS	QHIM			43	31N	096	22W	342
MN	ROCHESTER	QJAM			44	04N	092	29W	317
MN	ROCHESTER	QKGM			44	02N	092	28W	319
MN	LEROY	QLEM			43	31N	092	31W	393
MN	MADISON	QMAM			45	01N	096	11W	340
MN	WORTHINGTON	QMOM			43	38N	095	38W	483
MN	LUVERNE	QMSM			43	40N	096	13W	443
MN	LAMBERTON	QRCM			44	14N	095	16W	349
MN	WEST CONCORD	QTMM			44	08N	092	54W	387
MN	ROCHESTER	QWLM			43	59N	092	26W	312
MO	BOONVILLE	KVER	VER		38	57N	092	41W	218
MO	BRANSON	KBBG	BBG		36	32N	093	12W	397
MO	CAMDENTON	KH21	H21		37	58N	092	41W	324
MO	CAPE GIRARDEAU	KCGI	CGI		37	14N	089	35W	102
MO	CHILLICOTHE	KCDJ	CDJ		39	49N	093	35W	234
MO	CLINTON	KGLY	GLY		38	21N	093	41W	251
MO	COLUMBIA	KCOU	COU	72445	38	49N	092	13W	271
MO	FARMINGTON	KFAM	FAM		37	46N	090	25W	288
MO	FORT LEONARD WOO	KTBN	TBN		37	43N	092	07W	353
MO	GRANDVIEW	KGVW	GVW		38	50N	094	34W	337
MO	JEFFERSON CITY	KJEF	JEF		38	36N	092	09W	168
MO	JOPLIN	KJLN	JLN		37	09N	094	30W	299
MO	KAISER MEM	KAIZ	AIZ		38	06N	092	32W	265
MO	KANSAS CITY/INTL	KMCI	MCI	72446	39	18N	094	44W	320
MO	KANSAS CITY/DNTN	KMKC	MKC		39	07N	094	36W	227
MO	KIRKSVILLE	KIRK	IRK		40	06N	092	33W	293
MO	LEES SUMMIT MUNI	KLXT	LXT		38	58N	094	22W	306
MO	MALDEN	KMAW	MAW		36	36N	090	00W	90
MO	MONETT	KHFJ	HFJ		36	54N	094	01W	401
MO	POPULAR BLUFF	KPOF	POF		36	46N	090	19W	99
MO	SEDALIA	KDMO	DMO		38	43N	093	10W	274
MO	SPICKARD	KP35	P35	72540	40	15N	093	43W	270
MO	SPRINGFIELD	KSGF	SGF	72440	37	14N	093	23W	390
MO	ST. CHARLES	KSET	SET		38	56N	090	26W	134
MO	ST. JOSEPH	KSTJ	STJ	72449	39	46N	094	55W	247
MO	ST. LOUIS/SPIRIT	KSUS	SUS		38	39N	090	39W	141
MO	ST. LOUIS	KSTL	STL	72434	38	45N	090	22W	171
MO	VICHY/ROLLA	KVIH	VIH		38	08N	091	46W	333
MO	WARRENSBURG SKYH	KRCM	RCM		38	47N	093	48W	244
MO	WEST PLAINS	KUNO	UNO	72348	36	53N	091	54W	372
MO	WHITEMAN AFB	KSZL	SZL		38	43N	093	32W	265
MS	BAY ST LOUIS	KHSA	HSA		30	22N	089	27W	7
MS	BILOXI/KEESLER	KBIX	BIX		30	25N	088	55W	10
MS	BROOKHAVEN	K1R7	1R7		31	36N	090	25W	149
MS	CLARKSDALE	KCKM	CKM		34	18N	090	31W	53
MS	COLUMBUS AFB	KCBM	CBM		33	38N	088	27W	67
MS	CORINTH/R TURNER	KCRX	CRX		34	55N	088	36W	130

MS	GOLDEN/COLUMBUS	KGTR	GTR		33	27N	088	34W	80
MS	GREENVILLE	KGLH	GLH		33	30N	090	59W	45
MS	GREENWOOD	KGWO	GWO		33	30N	090	05W	44
MS	GULFPORT	KGPT	GPT		30	25N	089	05W	14
MS	HATTIESBURG	KHBG	HBG		31	16N	089	15W	44
MS	JACKSON/HAWKINS	KHKS	HKS		32	20N	090	13W	108
MS	JACKSON	KJAN	JAN	72235	32	19N	090	05W	91
MS	MCCOMB	KMCB	MCB		31	11N	090	28W	124
MS	MERIDIAN NAS	KNMM	NMM		32	32N	088	34W	97
MS	MERIDIAN/KEY FLD	KMEI	MEI	72234	32	20N	088	45W	89
MS	NATCHEZ/HARDY	KHEZ	HEZ		31	37N	091	17W	83
MS	OLIVE BRANCH	KOLV	OLV		34	59N	089	47W	122
MS	OXFORD	KUOX	UOX		34	23N	089	32W	137
MS	PASCAGOULA	KPQL	PQL		30	28N	088	32W	6
MS	PASCAGOULA	KPGL	PGL		30	24N	088	29W	3
MS	PINE BELT RGNL	KPIB	PIB		31	28N	089	19W	91
MS	RAYMOND	KM16	M16		32	18N	090	25W	76
MS	STARKVILLE	KSTF	STF		33	26N	088	51W	102
MS	TUNICA	KUTA	UTA		34	41N	090	21W	59
MS	TUPELO	KTUP	TUP	72332	34	16N	088	46W	105
MS	INNOVATOR OILP	KMYT	MYT		28	13N	089	37W	23
MS	WEST DELTA 27A	KDLP	DLP		29	07N	089	33W	36
MT	BAKER	KBHK			46	21N	104	15W	902
MT	ENNIS BIG SKY	KEKS	EKS		45	16N	111	39W	1641
MT	BILLINGS	KBIL	BIL	72677	45	48N	108	33W	1091
MT	BOZEMAN	KBZN	BZN		45	47N	111	10W	1361
MT	BROWNING	K8S0	8S0		48	36N	113	07W	1419
MT	BUTTE	KBTM	BTM		45	58N	112	30W	1688
MT	COLSTRIP	KM46	M46		45	51N	106	43W	1044
MT	CUT BANK	KCTB	CTB		48	36N	112	22W	1175
MT	DILLON	KDLN	DLN		45	15N	112	33W	1591
MT	DRUMMOND	K3DU	3DU		46	40N	113	09W	1202
MT	EKALAKA	K97M	97M		45	53N	104	32W	1068
MT	GLASGOW	KGGW	GGW	72768	48	13N	106	37W	694
MT	GLENDIVE	KGDV	GDV		47	07N	104	47W	749
MT	GREAT FALLS	KGTF	GTF	72775	47	28N	111	23W	1119
MT	HAMILTON/RAVALLI	KHMM	HMM		46	15N	114	09W	1110
MT	HARLOWTON	K3HT	3HT		46	25N	109	49W	1268
MT	HAVRE	KHVR	HVR	72777	48	33N	109	46W	787
MT	HELENA	KHLN	HLN	72772	46	36N	111	58W	1182
MT	JORDAN	KJDN	JDN		47	20N	106	57W	801
MT	KALISPELL	KGPI	GPI		48	19N	114	15W	908
MT	LAUREL	K6S8	6S8		45	42N	108	46W	1072
MT	LEWISTOWN	KLWT	LWT		47	02N	109	28W	1270
MT	LIVINGSTON	KLVM	LVM		45	42N	110	26W	1418
MT	MALMSTROM AFB	KGFA	GFA		47	30N	111	10W	1075
MT	MALTA	KM75	M75		48	22N	107	55W	687
MT	MILES CITY	KMLS	MLS	74230	46	26N	105	53W	801
MT	MISSOULA	KMSO	MSO	72773	46	55N	114	06W	975
MT	PLAINS	KS34	S34		47	28N	114	54W	752
MT	ROUNDUP	KRPX	RPX		46	28N	108	33W	1065
MT	SCOBEY	K9S2	9S2		48	48N	105	26W	742
MT	SIDNEY RICHLAND	KSDY	SDY		47	42N	104	12W	605
MT	THOMPSON FALLS	K3TH	3TH		47	36N	115	22W	725
MT	TWIN BRIDGES	K7S1	7S1		45	32N	112	18W	1456
MT	WEST YELLOWSTONE	KWEY	WEY	72676	44	38N	111	05W	2031
MT	WOLF POINT	KOLF	OLF		48	06N	105	35W	604

MT	WEST YELLOWSTONE	KWYS	WYS		44 40N	111 07W	2025
NC	AHOSKIE/TRI COUN	KASJ	ASJ		36 17N	077 10W	21
NC	ALBEMARLE STANLY	KVUJ	VUJ		35 25N	080 09W	186
NC	ANDREWS	KRHP	RHP		35 11N	083 51W	518
NC	WADESBORO/ANSON	KAFP	AFP		35 01N	080 05W	92
NC	ASHEBORO MUNI	KHBI	HBI		35 39N	079 54W	205
NC	ASHEVILLE	KAVL	AVL	72315	35 26N	082 32W	670
NC	BEAUFORT	KMRH	MRH		34 44N	076 39W	3
NC	BOGUE/SWANSBORO	KNJM	NJM		34 40N	077 01W	7
NC	BOONE WATAUGA CT	KTNB	TNB		36 12N	081 39W	911
NC	BURLINGTON	KBUY	BUY		36 03N	079 28W	180
NC	CAPE HATTERAS	KHAT	HAT	72302	35 16N	075 32W	3
NC	CHAPEL HILL	KIGX	IGX		35 56N	079 04W	155
NC	CHARLOTTE	KCLT	CLT	72314	35 13N	080 57W	220
NC	CHERRY POINT	KNKT	NKT	72309	34 53N	076 52W	9
NC	CLINTON	KCTZ	CTZ		34 59N	078 22W	45
NC	CONCORD REG ARPT	KJQF	JQF		35 23N	080 43W	210
NC	CURRITUCK	KONX	ONX		36 24N	076 01W	5
NC	DAVIDSON CTY AP	KEXX	EXX		35 47N	080 18W	223
NC	EDENTON	KEDE	EDE		36 01N	076 34W	6
NC	ELIZABETH CITY	KECG	ECG		36 16N	076 11W	11
NC	ELIZABETHTOWN	KEYF	EYF		34 36N	078 35W	41
NC	ERWIN/HARNETT CO	KHRJ	HRJ		35 23N	078 44W	60
NC	FAYETTEVILLE	KFAY	FAY		34 59N	078 53W	55
NC	FORT BRAGG/SIMMO	KFBG	FBG	74693	35 07N	078 55W	74
NC	GASTONIA	KAKH	AKH		35 12N	081 09W	243
NC	GOLDSBORO/S. J.	KGSB	GSB		35 19N	077 58W	33
NC	GOLDSBORO/WAYNE	KGWW	GWW		35 28N	077 58W	41
NC	GREENSBORO	KGSO	GSO	72317	36 06N	079 57W	275
NC	HATTERAS/MITCHEL	KHSE	HSE		35 14N	075 37W	3
NC	HENDERSON/OXFORD	KHNZ	HNZ		36 22N	078 32W	161
NC	HICKORY	KHKY	HKY		35 45N	081 23W	354
NC	HOFFMAN/MACKALL	KHFF	HFF		35 01N	079 30W	115
NC	JACKSONVILLE	KOAJ	OAJ		34 49N	077 37W	29
NC	JEFFERSON	KGEV	GEV		36 26N	081 25W	969
NC	KENANSVILLE/DUPL	KDPL	DPL		35 00N	077 58W	42
NC	KILL DEVIL HILLS	KFFA	FFA		36 01N	075 40W	4
NC	KINSTON/STALLING	KISO	ISO		35 19N	077 37W	29
NC	LINCOLNTON	KIPJ	IPJ		35 29N	081 10W	267
NC	LOUISBURG/FRANKL	KLHZ	LHZ		36 01N	078 20W	113
NC	LUMBERTON	KLBT	LBT		34 36N	079 04W	37
NC	MACON/FRANKLIN	K1A5	1A5		35 13N	083 25W	616
NC	MANTEO/DARE CO	KMQI	MQI		35 55N	075 42W	4
NC	MAXTON	KMEB	MEB		34 47N	079 22W	67
NC	MONROE	KEQY	EQY		35 01N	080 37W	212
NC	MORGANTON/LENOIR	KMRN	MRN		35 49N	081 37W	387
NC	MOUNT AIRY/SURRY	KMWK	MWK		36 28N	080 33W	380
NC	NEW BERN	KEWN	EWN		35 04N	077 03W	3
NC	NEW RIVER MCAS	KNCA	NCA		34 43N	077 27W	8
NC	PINEY ISLAND	KNBT	NBT		35 01N	076 28W	5
NC	PITT GREENVILLE	KPGV	PGV		35 37N	077 24W	8
NC	POPE AFB	KPOB	POB	72303	35 10N	079 01W	66
NC	RALEIGH/DURHAM	KRDU	RDU	72306	35 52N	078 47W	130
NC	REIDSVILLE	KSIF	SIF		36 26N	079 51W	211
NC	ROANOKE RAPIDS	KRZZ	RZZ		36 26N	077 43W	75
NC	ROANOKE RAPIDS	KIXA	IXA		36 20N	077 38W	44
NC	ROCKINGHAM	KRCZ	RCZ		34 53N	079 46W	109

NC	ROCKY MOUNT	KRWI	RWI		35	51N	077	54W	47
NC	ROXBORO PERSON	KTDF	TDF		36	17N	078	59W	186
NC	RUTHERFORDTON	KFQD	FQD		35	25N	081	56W	329
NC	SALISBURY ROWAN	KRUQ	RUQ		35	39N	080	31W	236
NC	SANFORD	KTTA	TTA		35	35N	079	06W	75
NC	SHELBY MUNI	KEHO	EHO		35	15N	081	36W	258
NC	SOUTHERN PINES	KSOP	SOP		35	13N	079	24W	141
NC	SMITHFIELD JOHNS	KJNX	JNX		35	32N	078	23W	50
NC	STATESVILLE	KSVH	SVH		35	45N	080	57W	294
NC	SOUTHPORT	KSUT	SUT		33	56N	078	05W	8
NC	TARBORO	KETC	ETC		35	56N	077	33W	17
NC	WASHINGTON	KOCW	OCW		35	34N	077	03W	12
NC	WHITEVILLE	KCPC	CPC		34	17N	078	43W	29
NC	WILKESBORO	KUKF	UKF		36	13N	081	06W	396
NC	WILMINGTON	KILM	ILM		34	16N	077	54W	9
NC	WINSTON SALEM	KINT	INT	72319	36	08N	080	13W	291
ND	BEACH	K20U	20U		46	56N	103	59W	840
ND	BISMARCK	KBIS	BIS	72764	46	46N	100	45W	505
ND	BOWMAN MUNI	KBPP	BPP		46	11N	103	26W	902
ND	CANDO	K9D7	9D7		48	29N	099	14W	452
ND	CARRINGTON	K46D	46D		47	27N	099	09W	490
ND	CAVALIER	K2C8	2C8		48	47N	097	38W	272
ND	COOPERSTOWN	KS32	S32		47	25N	098	06W	684
ND	CROSBY	KD50	D50		48	56N	103	18W	595
ND	DEVILS LAKE	KDVL	DVL	72757	48	07N	098	55W	443
ND	DEVILS LAKE	KP11	P11	72758	48	07N	098	55W	443
ND	DICKINSON	KDIK	DIK		46	48N	102	48W	788
ND	FARGO	KFAR	FAR	72753	46	56N	096	49W	277
ND	GARRISON	KN60	N60		47	39N	101	26W	582
ND	GRAFTON	KGAF	GAF		48	24N	097	22W	252
ND	GRAND FORKS AFB	KRDR	RDR		47	58N	097	24W	278
ND	GRAND FORKS	KGFK	GFK		47	57N	097	11W	190
ND	GWINNER	KGWR	GWR		46	13N	097	39W	386
ND	HARVEY	K5H4	5H4		47	47N	099	56W	490
ND	HAZEN	KHZE	HZE		47	17N	101	35W	553
ND	HETTINGER	KHEI	HEI		46	01N	102	39W	828
ND	JAMESTOWN	KJMS	JMS		46	56N	098	40W	455
ND	LANGDON/ROBERTSN	KD55	D55		48	45N	098	24W	491
ND	LIDGERWOOD (RAMO	KP67	P67		46	06N	097	09W	351
ND	LINTON	K7L2	7L2		46	13N	100	15W	543
ND	MANDAN	KY19	Y19		46	46N	100	54W	593
ND	MINOT AFB	KMIB	MIB		48	25N	101	20W	508
ND	MINOT	KMOT	MOT		48	15N	101	16W	519
ND	OAKES	K2D5	2D5		46	10N	098	05W	407
ND	ROLLA	K06D	06D		48	53N	099	37W	556
ND	RUGBY	KRUG	RUG		48	23N	100	01W	472
ND	STANLEY	K08D	08D		48	18N	102	24W	684
ND	TIOGA	KD60	D60		48	23N	102	54W	693
ND	VALLEY CITY	KBAC	BAC		46	56N	098	01W	684
ND	WALHALLA	K96D	96D		48	56N	097	54W	290
ND	WATFORD CITY	KS25	S25		47	48N	103	15W	644
ND	WILLISTON	KISN	ISN	72767	48	10N	103	38W	579
ND	WAHPETON	KBWP	BWP		46	15N	096	37W	295
NE	AINSWORTH MUNICI	KANW	ANW		42	34N	100	00W	789
NE	ALBION MUNI	KBVN	BVN		41	44N	098	03W	551
NE	ALLIANCE	KAIA	AIA		42	03N	102	48W	1196
NE	AURORA	KAUH	AUH		40	53N	098	00W	550

NE	BEATRICE MUNICIP	KBIE	BIE		40 17N	096 45W	403
NE	BLAIR MUNI	KBTA	BTA		41 25N	096 07W	396
NE	BROKEN BOW MUNI	KBBW	BBW		41 26N	099 38W	776
NE	CHADRON	KCDR	CDR		42 50N	103 06W	1010
NE	COLUMBUS MUNI	KOLU	OLU		41 27N	097 19W	440
NE	FALLS CITY/BRENN	KFNB	FNB		40 04N	095 35W	300
NE	FREMONT MUNI ARP	KFET	FET		41 27N	096 31W	367
NE	GRAND ISLAND	KGRI	GRI	72552	40 58N	098 19W	561
NE	HASTINGS	KHSI	HSI		40 36N	098 26W	591
NE	HEBRON MUNI	KHJH	HJH		40 09N	097 35W	447
NE	HOLDREGE/BREWSTR	KHDE	HDE		40 27N	099 19W	705
NE	IMPERIAL MUNICIP	KIML	IML		40 31N	101 37W	998
NE	KEARNEY MUNI	KEAR	EAR		40 43N	099 00W	649
NE	KIMBALL MUNI	KIBM	IBM		41 11N	103 41W	1501
NE	LEXINGTON	KLXN	LXN		40 47N	099 46W	734
NE	LINCOLN	KLNK	LNK	72551	40 51N	096 46W	364
NE	MCCOOK	KMCK	MCK		40 12N	100 35W	782
NE	NEBRASKA CITY	KAFK	AFK		40 36N	095 51W	354
NE	NORFOLK	KOFK	OFK	72556	41 59N	097 26W	470
NE	NORTH OMAHA	KOVN	OVN	72553	41 22N	096 01W	406
NE	NORTH PLATTE	KLBF	LBF	72562	41 07N	100 40W	847
NE	O'NEILL	KONL	ONL		42 28N	098 40W	619
NE	OFFUTT AFB/BELLE	KOFF	OFF	72554	41 07N	095 55W	319
NE	OGALLALA	KOGA	OGA		41 07N	101 46W	999
NE	OMAHA/EPPLEY	KOMA	OMA	72550	41 19N	095 54W	312
NE	OMAHA/MILLARD	KMLE	MLE		41 12N	096 07W	320
NE	ORD/SHARP FIELD	KODX	ODX		41 37N	098 57W	631
NE	PLATTSMOUTH MUNI	KPMV	PMV		40 57N	095 55W	367
NE	SCOTTSBLUFF	KBFF	BFF	72566	41 52N	103 35W	1203
NE	SIDNEY	KSNY	SNY	72561	41 06N	102 59W	1307
NE	TEKAMAH	KTQE	TQE		41 46N	096 11W	312
NE	THEDFORD/THOMAS	KTIF	TIF		41 58N	100 34W	892
NE	VALENTINE	KVTN	VTN	72567	42 52N	100 33W	788
NE	WAHOO	KAHQ	AHQ		41 14N	096 36W	374
NE	WAYNE MUNI	KLCG	LCG		42 15N	096 59W	436
NE	YORK	KJYR	JYR		40 54N	097 37W	509
NE	BENKELMAN-JONES	K42V	42V		40 03N	101 32W	953
NE	CHAMPION	KCHM	CHM		40 23N	101 43W	1029
NH	BERLIN	KBML	BML	72616	44 35N	071 11W	345
NH	CONCORD	KCON	CON	72605	43 12N	071 30W	103
NH	JAFFREY	KAFN	AFN		42 48N	072 00W	313
NH	KEENE/DILLANT	KEEN	EEN		42 53N	072 16W	149
NH	LACONIA MUNI	KLCI	LCI		43 34N	071 25W	166
NH	LEBANON	KLEB	LEB	72611	43 38N	072 18W	171
NH	MANCHESTER	KMHT	MHT		42 56N	071 26W	81
NH	MOUNT WASHINGTON	KMWN	MWN	72613	44 16N	071 17W	1910
NH	NASHUA/BOIRE FLD	KASH	ASH		42 47N	071 31W	61
NH	PLYMOUTH	K1P1	1P1		43 47N	071 45W	154
NH	PORTSMOUTH/PEASE	KPSM	PSM		43 04N	070 49W	31
NH	ROCHESTER	KDAW	DAW		43 17N	070 55W	100
NH	WHITEFIELD	KHIE	HIE		44 22N	071 33W	318
NJ	ANDOVER	K12N	12N		41 01N	074 44W	177
NJ	ATLANTIC CITY	KACY	ACY	72407	39 28N	074 35W	23
NJ	BELMAR/FARMDALE	KBLM	BLM		40 10N	074 07W	48
NJ	CALDWELL	KCDW	CDW		40 53N	074 17W	64
NJ	LAKEHURST NAS	KNEL	NEL	72409	40 01N	074 20W	31
NJ	LINDEN	KLDJ	LDJ		40 37N	074 15W	7

NJ	MILLVILLE	KMIV	MIV		39	22N	075	05W	23
NJ	MORRISTOWN MUNI	KMMU	MMU		40	47N	074	25W	57
NJ	MOUNT HOLLY	KVAY	VAY		39	56N	074	50W	15
NJ	NEWARK	KEWR	EWR	72502	40	41N	074	10W	7
NJ	SOMERVILLE	KSMQ	SMQ		40	37N	074	40W	30
NJ	SUSSEX	KFWN	FWN		41	12N	074	38W	133
NJ	TETERBORO	KTEB	TEB		40	52N	074	03W	7
NJ	TOMS RIVER	KMJX	MJX		39	56N	074	18W	25
NJ	TRENTON	KTTN	TTN		40	17N	074	49W	59
NJ	WILDWOOD	KWWD	WWD		39	01N	074	55W	7
NJ	WOODBINE MUNI	KOBI	OBI		39	13N	074	48W	13
NJ	WRIGHTST/MCGUIRE	KWRI	WRI		40	01N	074	35W	41
NM	GALLUP	KGUP	GUP		35	31N	108	48W	1971
NM	ALAMOGORDO WHITE	KALM	ALM	72269	32	49N	105	58W	1279
NM	ALBUQUERQUE	KABQ	ABQ	72365	35	03N	106	37W	1618
NM	ANGEL FIRE	KAXX	AXX		36	25N	105	17W	2548
NM	ARTESIA	KATS	ATS		32	51N	104	28W	1081
NM	BELEN	KE80	E80		34	39N	106	50W	1582
NM	CANNON AFB/CLOVI	KCVS	CVS		34	22N	103	19W	1309
NM	CARLSBAD	KCNM	CNM		32	20N	104	15W	985
NM	CHAMA (AWRS)	KE33	E33		36	53N	106	34W	2393
NM	CLAYTON	KCAO	CAO	72360	36	27N	103	09W	1514
NM	CLINES CORNERS	KCQC	CQC		35	00N	105	40W	2160
NM	CLOVIS MUNI	KCVN	CVN		34	25N	103	04W	1284
NM	CORONA/LINCOLN	K4CR	4CR		34	06N	105	40W	1981
NM	DEMING	KDMN	DMN		32	16N	107	43W	1311
NM	DOUBLE EAGLE II	KAEG	AEG		35	08N	106	48W	1779
NM	FARMINGTON	KFMN	FMN		36	45N	108	14W	1685
NM	GRANTS	KGNT	GNT		35	10N	107	54W	1987
NM	HOBBS/LEA CO.	KHOB	HOB		32	40N	103	13W	1115
NM	HOLLOMAN AFB	KHMN	HMN	74732	32	51N	106	05W	1248
NM	LAS CRUCES INTL	KLRU	LRU		32	16N	106	55W	1358
NM	LAS VEGAS	KLVS	LVS		35	39N	105	08W	2091
NM	LOS ALAMOS	KLAM	LAM		35	52N	106	16W	2179
NM	MORIARTY	K4MY	4MY		34	59N	106	00W	1890
NM	MORIARTY	K0E0	0E0		34	59N	106	00W	1890
NM	RATON	KRTN	RTN		36	44N	104	30W	1936
NM	ROSWELL	KROW	ROW	72268	33	18N	104	30W	1112
NM	SIERRA B/RUIDOSO	KSRR	SRR		33	28N	105	31W	2076
NM	SANTA FE	KSAF	SAF		35	37N	106	06W	1930
NM	SANTA TERESA	K5T6	5T6		31	53N	106	42W	1253
NM	SILVER CITY	KSVC	SVC	72272	32	38N	108	09W	1659
NM	SOCORRO	KONM	ONM	72362	34	01N	106	54W	1410
NM	TAOS MUNI APT	KSKX	SKX		36	27N	105	40W	2161
NM	TORREON/CUBA	K4SL	4SL		35	47N	107	10W	2106
NM	TRUTH OR CONSEQ.	KTCS	TCS	72271	33	14N	107	16W	1469
NM	TUCUMCARI	KTCC	TCC		35	11N	103	36W	1235
NM	WHITE SANDS TEST	K2C2	2C2	74734	32	22N	106	28W	1244
NM	MCGREGOR RANGE	KQMG			32	03N	106	09W	1283
NV	AUSTIN	KU31	U31		39	30N	117	04W	2014
NV	BATTLE MOUNTAIN	KB23	B23		40	36N	116	52W	1381
NV	BOULDER CITY	KBVU	BVU		35	57N	114	52W	671
NV	CARSON CITY	KCXP	CXP		39	11N	119	43W	1435
NV	DESERT R/MERCURY	KDRA	DRA	72387	36	37N	116	02W	1006
NV	ELKO	KEKO	EKO		40	50N	115	47W	1547
NV	ELY	KELY	ELY	72486	39	18N	114	51W	1906
NV	EUREKA	KP68	P68		39	36N	116	00W	1809

NV	FALLON NAS	KNFL	NFL		39	25N	118	42W	1199
NV	INDIAN SPRINGS	KINS	INS		36	35N	115	40W	955
NV	IND SPRNG RANGE	KL63	L63	69017	36	31N	115	34W	972
NV	LAS VEGAS	KLAS	LAS	72386	36	05N	115	09W	636
NV	LAS VEGAS/NELLIS	KLSV	LSV		36	13N	115	01W	570
NV	VEGAS/HENDERSON	KHND	HND		35	59N	115	08W	749
NV	LOVELOCK	KLOL	LOL	72580	40	04N	118	34W	1189
NV	NORTH LAS VEGAS	KVGT	VGT		36	12N	115	12W	671
NV	RENO	KRNO	RNO	72488	39	29N	119	46W	1342
NV	TONOPAH	KTPH	TPH	72485	38	03N	117	05W	1652
NV	TONOPAH RANGE74	KBJN	BJN	72282	37	37N	116	16W	1756
NV	WELLS	K9BB	9BB		41	06N	114	58W	1723
NV	WILDHORSE RES/EL	KAWH	AWH		41	40N	115	46W	1902
NV	WINNEMUCCA	KWMC	WMC	72583	40	54N	117	48W	1310
NY	ALBANY	KALB	ALB	72518	42	45N	073	48W	92
NY	BINGHAMTON	KBGM	BGM	72515	42	13N	075	59W	490
NY	BUFFALO/CHEEKTOW	KBUF	BUF	72528	42	56N	078	44W	211
NY	CANANDAIGUA	KD38	D38		42	54N	077	19W	248
NY	DANSVILLE	KDSV	DSV	72523	42	34N	077	43W	198
NY	DUNKIRK	KDKK	DKK	99425	42	30N	079	17W	202
NY	EAST HAMPTON	KHTO	HTO		40	57N	072	15W	17
NY	ELMIRA	KELM	ELM		42	09N	076	54W	302
NY	ENDICOTT/TRI-CIT	KCZG	CZG		42	05N	076	06W	254
NY	FARMINGDALE	KFRG	FRG		40	44N	073	25W	21
NY	FORT DRUM/WHEELE	KGTB	GTB	74370	44	02N	075	43W	207
NY	FULTON	KFZY	FZY		43	21N	076	23W	138
NY	GLENS FALLS	KGFL	GFL		43	20N	073	37W	103
NY	HAMILTON MUNICIP	KVGC	VGC		42	51N	075	34W	347
NY	HORNELL	K4G6	4G6		42	23N	077	41W	372
NY	HUDSON/COLUMBIA	K1B1	1B1		42	17N	073	43W	60
NY	ISLIP	KISP	ISP		40	48N	073	06W	43
NY	ITHACA/TOMPKINS	KITH	ITH		42	28N	076	27W	335
NY	JAMESTOWN	KJHW	JHW		42	08N	079	16W	525
NY	MASSENA	KMSS	MSS		44	56N	074	51W	66
NY	MONTAUK	KMTP	MTP		41	04N	071	55W	2
NY	MONTGOMERY	KMGJ	MGJ		41	31N	074	16W	108
NY	MONTICELLO	KMSV	MSV		41	42N	074	47W	428
NY	NEWBURGH/STEWART	KSWF	SWF		41	30N	074	05W	150
NY	NIAGARA FALLS	KIAG	IAG		43	07N	078	56W	182
NY	NORWICH	KOIC	OIC		42	34N	075	31W	312
NY	NYC/JFK ARPT	KJFK	JFK	74486	40	38N	073	46W	9
NY	NYC/LA GUARDIA	KLGA	LGA	72503	40	47N	073	53W	11
NY	NYC/CENTRAL PARK	KNYC	NYC		40	47N	073	58W	11
NY	OGDENSBURG INTL	KOGS	OGS		44	40N	075	28W	91
NY	OLEAN	KOLE	OLE		42	14N	078	22W	651
NY	PENN YAN	KPEO	PEO		42	39N	077	03W	256
NY	PLATTSBURGH	KPLB	PLB		44	41N	073	32W	106
NY	PLATTSBURGH AFB	KPBG	PBG		44	39N	073	28W	72
NY	POTSDAM	KPTD	PTD		44	41N	074	57W	144
NY	POUGHKEEPSIE	KPOU	POU		41	38N	073	53W	46
NY	ROCHESTER	KROC	ROC	72529	43	07N	077	41W	178
NY	ROME/GRIFFISS AF	KRME	RME		43	13N	075	24W	154
NY	SARANAC LAKE	KSLK	SLK		44	24N	074	12W	498
NY	SARATOGA SPRINGS	K5B2	5B2		43	03N	073	52W	132
NY	SCHENECTADY AIRP	KSCH	SCH		42	51N	073	55W	115
NY	SHIRLEY	KHWV	HWV		40	49N	072	52W	21
NY	SIDNEY	KN23	N23		42	18N	075	25W	313

NY	SYRACUSE	KSYR	SYR	72519	43 07N	076 06W	127
NY	UTICA	KUCA	UCA		43 09N	075 23W	228
NY	WATERTOWN	KART	ART		43 59N	076 02W	100
NY	WELLSVILLE	KELZ	ELZ		42 06N	077 59W	646
NY	WESTHAMPTON BEAC	KFOK	FOK		40 51N	072 37W	33
NY	WHITE PLAINS	KHPN	HPN		41 04N	073 42W	121
NY	WILLIAMSON/SODUS	KSDC	SDC		43 14N	077 07W	129
OH	AKRON (FULTON)	KAKR	AKR		41 02N	081 28W	363
OH	AKRON	KCAK	CAK	72521	40 55N	081 27W	377
OH	ASHTABULA	KHZY	HZY		41 47N	080 42W	276
OH	ATHENS	KUNI	UNI		39 13N	082 14W	193
OH	BELLEFONTAINE	KEDJ	EDJ		40 22N	083 49W	342
OH	CINCINNAT/LUNKEN	KLUK	LUK		39 06N	084 25W	155
OH	CLEVELAND	KBKL	BKL		41 32N	081 40W	184
OH	CLEVELAND	KCLE	CLE	72524	41 25N	081 51W	233
OH	CLEVLND/CUYAHOGA	KCGF	CGF		41 34N	081 28W	268
OH	COLUMBUS	KCMH	CMH	72428	40 00N	082 53W	247
OH	COLUMBUS/ST UNIV	KOSU	OSU		40 05N	083 05W	280
OH	COLUMBUS/BOLTON	KTZR	TZR		39 54N	083 08W	276
OH	DAYTON	KDAY	DAY	72429	39 54N	084 13W	305
OH	DAYTON	KMGY	MGY		39 36N	084 14W	289
OH	DEFIANCE	KDFI	DFI		41 20N	084 26W	219
OH	DELAWARE	KDLZ	DLZ		40 17N	083 07W	289
OH	FINDLAY	KFDY	FDY		41 01N	083 40W	247
OH	FLAG CITY	KFBC	FBC		41 01N	083 40W	247
OH	HAMILTON	KHAO	HAO		39 22N	084 31W	188
OH	LANCASTER	KLHQ	LHQ		39 45N	082 40W	260
OH	LIMA	KAOH	AOH		40 42N	084 01W	296
OH	LORAIN/ELYRIA	KLPR	LPR		41 21N	082 11W	241
OH	MANSFIELD	KMFD	MFD		40 49N	082 31W	395
OH	MARION	KMNN	MNN		40 37N	083 04W	301
OH	MARYSVILLE	KMRT	MRT		40 13N	083 21W	312
OH	MIDDLETOWN/HOOK	KMWO	MWO		39 32N	084 24W	198
OH	MT VERNON/KNOX	K4I3	4I3		40 20N	082 32W	363
OH	NEW PHILADELPHIA	KPHD	PHD		40 28N	081 25W	272
OH	NEWARK	KVTA	VTA		40 01N	082 28W	268
OH	RAVENA/PORTAGE	KPOV	POV		41 13N	081 15W	365
OH	RICKENBACKER ANG	KLCK	LCK		39 49N	082 55W	227
OH	SPRINGFIELD MUNI	KSGH	SGH		39 50N	083 50W	321
OH	TOLEDO	KTDZ	TDZ		41 34N	083 29W	189
OH	TOLEDO	KTOL	TOL	72536	41 35N	083 48W	210
OH	VERSAILLES	KVES	VES		40 12N	084 32W	307
OH	WILLOUGHBY	KLNN	LNN		41 40N	081 22W	191
OH	WILMINGTON	KILN	ILN	72426	39 26N	083 48W	322
OH	WOOSTER	KBJJ	BJJ		40 52N	081 53W	343
OH	WRIGHT PATERSON	KFFO	FFO	74570	39 49N	084 02W	251
OH	YOUNGSTOWN	KYNG	YNG	72525	41 15N	080 40W	360
OH	ZANESVILLE	KZZV	ZZV		39 57N	081 54W	268
OK	ADA	KADH	ADH		34 48N	096 40W	308
OK	ARDMORE	KADM	ADM		34 17N	097 01W	232
OK	ARDMORE/EXEC	K1F0	1F0		34 09N	097 07W	257
OK	ALTUS AFB	KLTS	LTS	72352	34 40N	099 16W	420
OK	ALTUS/QUARTZ MTN	KAXS	AXS		34 42N	099 20W	437
OK	ALVA	KAVK	AVK		36 46N	098 40W	449
OK	ATOKA	KAQR	AQR		34 24N	096 09W	189
OK	BARTLESVILLE	KBVO	BVO		36 46N	096 01W	210
OK	BLACKWELL	KBKN	BKN		36 45N	097 21W	314

OK	CLAREMORE	KGCM	GCM		36	18N	095	29W	221
OK	CHANDLER	KCQB	CQB		35	43N	096	49W	300
OK	CHICKASHA	KCHK	CHK		35	06N	097	58W	351
OK	CLINTON	KCSM	CSM		35	21N	099	12W	588
OK	CLINTON	KCLK	CLK		35	32N	098	56W	492
OK	CUSHING	KCUH	CUH		35	57N	096	46W	279
OK	DUNCAN	KDUC	DUC		34	28N	097	58W	339
OK	DURANT	KDUA	DUA		33	57N	096	24W	213
OK	EL RENO MUNI	KRQO	RQO		35	28N	098	00W	432
OK	ENID/VANCE AFB	KEND	END		36	19N	097	55W	398
OK	ENID/WOODRING	KWDG	WDG		36	22N	097	46W	356
OK	FORT SILL	KFSI	FSI	72355	34	39N	098	24W	362
OK	FREDERICK/ALTUS	KFDR	FDR		34	21N	098	59W	386
OK	GAGE	KGAG	GAG		36	18N	099	46W	668
OK	GROVE	KGMJ	GMJ		36	36N	094	44W	254
OK	GUTHRIE	KGOK	GOK		35	51N	097	24W	324
OK	GUYMON	KGUY	GUY		36	41N	101	30W	948
OK	HOBART	KHBR	HBR		34	59N	099	03W	473
OK	IDABEL	K4O4	4O4		33	55N	094	52W	144
OK	LAWTON	KLAW	LAW		34	33N	098	25W	337
OK	MCALESTER	KMLC	MLC		34	53N	095	47W	232
OK	MUSKOGEE	KMKO	MKO		35	39N	095	22W	185
OK	NORMAN/WESTHEIME	KOUN	OUN	72357	35	15N	097	28W	357
OK	OKLAHOMA CITY	KOKC	OKC	72353	35	23N	097	36W	390
OK	OKLA CITY/WILEY	KPWA	PWA		35	32N	097	39W	397
OK	OKLA CITY/PAGE	KRCE	RCE		35	29N	097	49W	413
OK	OKMULGEE	KOKM	OKM		35	40N	095	57W	220
OK	PAULS VALLEY	KPVJ	PVJ		34	43N	097	13W	295
OK	PONCA CITY	KPNC	PNC		36	44N	097	06W	308
OK	POTEAU (R KERR)	KRKR	RKR		35	01N	094	37W	138
OK	SALLISAW	KJSV	JSV		35	26N	094	48W	161
OK	SEMINOLE	KSRE	SRE		35	16N	096	41W	312
OK	SHAWNEE	KSNL	SNL		35	21N	096	57W	327
OK	STIGLER	KGZL	GZL		35	17N	095	06W	183
OK	STILLWATER	KSWO	SWO		36	10N	097	05W	290
OK	TAHLEQUAH	KTQH	TQH		35	56N	095	00W	266
OK	TINKER AFB	KTIK	TIK	72354	35	25N	097	22W	394
OK	TULSA	KTUL	TUL	72356	36	12N	095	53W	207
OK	TULSA	KRVS	RVS		36	03N	095	59W	200
OK	WATONGA	KJWG	JWG		35	52N	098	25W	472
OK	WEATHERFORD	KOJA	OJA		35	33N	098	40W	490
OK	WOODWARD	KWWR	WWR		36	27N	099	31W	667
OR	PORTLAND	KPDX	PDX	72698	45	35N	122	36W	7
OR	HILLSBORO/PORTLD	KHIO	HIO		45	33N	122	57W	68
OR	ASTORIA	KAST	AST	72791	46	09N	123	53W	3
OR	AURORA	KUAO	UAO		45	15N	122	46W	59
OR	BAKER	KBKE	BKE		44	51N	117	49W	1024
OR	BEND	KBDN	BDN		44	06N	121	12W	1055
OR	BROOKINGS	KBOK	BOK	72598	42	04N	124	17W	140
OR	BURNS	KBNO	BNO	72683	43	36N	118	57W	1264
OR	CAPE BLANCO (CGS	K92S	92S	72599	42	50N	124	34W	57
OR	CASCADE LOCKS ST	KCZK	CZK		45	40N	121	52W	46
OR	CLATSOP SPIT	K3CL	3CL		46	14N	124	01W	9
OR	CORVALLIS MUNI A	KCVO	CVO		44	30N	123	16W	75
OR	EUGENE	KEUG	EUG	72693	44	08N	123	13W	114
OR	FLORENCE MUNI	K6S2	6S2		43	59N	124	07W	16
OR	GOLD BEACH	K4S1	4S1		42	25N	124	25W	5

OR	HERMISTON	KHRI	HRI		45	50N	119	16W	195
OR	JOHN DAY STATE	KGCD	GCD		44	23N	118	58W	1127
OR	KLAMATH FALLS	KLMT	LMT		42	09N	121	43W	1246
OR	LA GRANDE	KLGD	LGD		45	16N	118	00W	827
OR	LAKEVIEW	KLKV	LKV		42	10N	120	24W	1441
OR	MCMINNVILLE	KMMV	MMV		45	12N	123	08W	48
OR	MEACHAM	KMEH	MEH		45	31N	118	25W	1136
OR	MEDFORD	KMFR	MFR	72597	42	23N	122	52W	396
OR	NEWPORT	KJNW	JNW		44	34N	124	04W	48
OR	NEWPORT	KONP	ONP	72695	44	34N	124	02W	48
OR	NORTH BEND	KOTH	OTH	72691	43	25N	124	15W	4
OR	ONTARIO	KONO	ONO		44	01N	117	01W	667
OR	PENDLETON	KPDT	PDT	72688	45	42N	118	50W	462
OR	REDMOND	KRDM	RDM		44	15N	121	09W	938
OR	ROME	KP88	P88		42	53N	117	39W	1162
OR	ROME	KREO	REO		42	35N	117	52W	1235
OR	ROOSTER ROCK	KRRK	RRK		45	33N	122	58W	50
OR	ROSEBURG	KRBG	RBG	72690	43	14N	123	21W	154
OR	SALEM	KSLE	SLE	72694	44	54N	123	00W	59
OR	SCAPPOOSE	KSPB	SPB		45	46N	122	52W	14
OR	SEA LION CAVES	K2SL	2SL		44	07N	124	08W	121
OR	SEXTON SUMMIT	KSXT	SXT		42	36N	123	22W	1170
OR	THE DALLES	KDLS	DLS		45	37N	121	10W	71
OR	TILLAMOOK	KTMK	TMK		45	25N	123	49W	11
OR	TROUTDALE	KTTD	TTD		45	33N	122	25W	14
PA	ALLENTOWN	KABE	ABE	72517	40	39N	075	27W	114
PA	ALLENTOWN QUEEN	KXLL	XLL		40	34N	075	29W	122
PA	ALTOONA	KAOO	AOO		40	18N	078	19W	455
PA	AVOCA/WILKES B.	KAVP	AVP	72513	41	20N	075	43W	291
PA	BEAVER FALLS ARP	KBVI	BVI		40	46N	080	24W	382
PA	BRADFORD	KBFD	BFD		41	48N	078	38W	647
PA	BUTLER CO.	KBTP	BTP		40	46N	079	57W	380
PA	CLEARFIELD	KFIG	FIG		41	03N	078	25W	462
PA	COATESVILLE	KMQS	MQS		39	59N	075	52W	201
PA	DOYLESTOWN	KDYL	DYL		40	20N	075	07W	117
PA	DU BOIS	KDUJ	DUJ		41	10N	078	54W	554
PA	ERIE	KERI	ERI	72526	42	05N	080	11W	222
PA	FOUNTAIN DALE	KRYT			39	44N	077	26W	274
PA	FRANKLIN	KFKL	FKL		41	22N	079	52W	469
PA	HARRISBURG	KCXY	CXY		40	13N	076	51W	106
PA	INDIANA/STEWART	KIDI	IDI		40	37N	079	05W	429
PA	JOHNSTOWN	KJST	JST		40	19N	078	50W	694
PA	LANCASTER	KLNS	LNS		40	07N	076	18W	125
PA	LATROBE/WESTMORL	KLBE	LBE		40	16N	079	24W	361
PA	MEADVILLE	KGKJ	GKJ		41	38N	080	13W	428
PA	MIDDLETOWN	KMDT	MDT		40	12N	076	46W	95
PA	MT. POCONO	KMPO	MPO		41	08N	075	23W	577
PA	MUIR AAF/INDIANT	KMUI	MUI		40	25N	076	34W	149
PA	NEW CASTLE MUNI	KUCP	UCP		41	02N	080	25W	327
PA	PHILADELPHIA	KPHL	PHL	72408	39	52N	075	14W	18
PA	PHILADELPHIA/NE	KPNE	PNE		40	05N	075	01W	28
PA	PHILLY WINGS F	KLOM	LOM		40	08N	075	16W	92
PA	PHILIPSBURG/MID	KPSB	PSB	72512	40	52N	078	04W	594
PA	PITTSBURGH/ALLEG	KAGC	AGC		40	21N	079	55W	389
PA	PITTSBURGH	KPIT	PIT	72520	40	30N	080	16W	357
PA	POTTSTOWN	KPTW	PTW		40	14N	075	33W	92
PA	QUAKERTOWN ARP	KUKT	UKT		40	26N	075	23W	160

PA	READING	KRDG	RDG		40	22N	075	58W	109
PA	SELINSGROVE	KSEG	SEG		40	49N	076	52W	134
PA	STATE COLLEGE	KUNV	UNV		40	51N	077	50W	378
PA	WASHINGTON	KAFJ	AFJ		40	07N	080	16W	361
PA	WILLIAMSPORT	KIPT	IPT	72514	41	15N	076	55W	164
PA	YORK	KTHV	THV		39	55N	076	53W	144
RI	BLOCK ISLAND	KBID	BID		41	10N	071	34W	33
RI	N. KINGSTON/QUON	KOQU	OQU		41	36N	071	25W	6
RI	NEWPORT	KUUU	UUU		41	32N	071	17W	51
RI	PAWTUCKET	KSFZ	SFZ		41	55N	071	30W	134
RI	PROVIDENCE/GREEN	KPVD	PVD	72507	41	43N	071	26W	16
RI	WESTERLY	KWST	WST		41	21N	071	48W	21
SC	AIKEN	KAIK	AIK		33	39N	081	41W	161
SC	ANDERSON	KAND	AND		34	30N	082	43W	239
SC	BARNWELL	KBNL	BNL		33	15N	081	23W	75
SC	BEAUFORT MCAS	KNBC	NBC		32	28N	080	43W	12
SC	BEAUFORT CNTY	KARW	ARW		32	25N	080	38W	4
SC	BERKELEY MONCKS	KMKS	MKS		33	11N	080	02W	23
SC	CAMDEN WOODWARD	KCDN	CDN		34	17N	080	34W	92
SC	CHARLESTON	KCHS	CHS	72208	32	54N	080	02W	13
SC	CHARLESTON/EXEC	KJZI	JZI		32	42N	080	00W	6
SC	CHERAW	KCQW	CQW		34	43N	079	57W	73
SC	CHESTER CATAWBA	KDCM	DCM		34	47N	081	12W	200
SC	CLEMSON	KCEU	CEU		34	40N	082	53W	268
SC	COLUMBIA	KCAE	CAE	72310	33	56N	081	07W	70
SC	COLUMBIA-OWENS	KCUB	CUB		33	58N	081	00W	56
SC	CONWAY-HORRY CTY	KHYW	HYW		33	50N	079	07W	11
SC	DARLINGTON CNTY	KUDG	UDG		34	27N	079	53W	59
SC	FLORENCE	KFLO	FLO		34	11N	079	44W	44
SC	GEORGETOWN	KGGE	GGE		33	19N	079	19W	12
SC	GREENWOOD	KGRD	GRD		34	15N	082	09W	185
SC	GREER/SPARTANSBG	KGSP	GSP	72312	34	54N	082	13W	287
SC	GREENVILLE	KGMU	GMU		34	51N	082	21W	315
SC	GREENVILLE	KGYH	GYH		34	45N	082	23W	292
SC	HARTSVILLE	KHVS	HVS		34	24N	080	07W	111
SC	HILTON HEAD	KHXD	HXD		32	13N	080	42W	6
SC	KINGSTREE	KCKI	CKI		33	43N	079	51W	21
SC	LANCASTER	KLKR	LKR		34	43N	080	51W	149
SC	LAURENS	KLUX	LUX		34	30N	081	57W	213
SC	MANNING	KMNI	MNI		33	35N	080	13W	32
SC	MARION	KMAO	MAO		34	11N	079	20W	28
SC	MARLBORO CNTY	KBBP	BBP		34	37N	079	44W	45
SC	MCENTIRE ANG BAS	KMMT	MMT		33	55N	080	47W	77
SC	MOUNT PLEASANT	KLRO	LRO		32	54N	079	47W	4
SC	MYRTLE BEACH	KMYR	MYR	74791	33	40N	078	55W	8
SC	NORTH MYRTLE BEA	KCRE	CRE		33	49N	078	43W	10
SC	NEWBERRY	KEOE	EOE		34	19N	081	38W	174
SC	ORANGEBURG	KOGB	OGB		33	28N	080	51W	59
SC	PICKENS	KLQK	LQK		34	49N	082	42W	309
SC	ROCK HILL	KUZA	UZA		34	59N	081	03W	202
SC	SHAW AFB/SUMTER	KSSC	SSC	74790	33	58N	080	28W	74
SC	SPARTANBURG VOR	KSPA	SPA		35	02N	081	56W	303
SC	SUMMERVILLE	KDYB	DYB		33	04N	080	17W	18
SC	SUMTER	KSMS	SMS		34	00N	080	22W	56
SC	WALTERBORO	KRBW	RBW		32	55N	080	38W	31
SC	WINNSBORO	KFDW	FDW		34	19N	081	07W	176
SD	ABERDEEN	KABR	ABR	72659	45	27N	098	25W	397

SD	BELLE FOURCHE	KEFC	EFC		44	43N	103	52W	982
SD	BROOKINGS	KBKX	BKX		44	17N	096	49W	502
SD	BUFFALO	K2WX	2WX		45	36N	103	33W	915
SD	CHAMBERLAIN	K9V9	9V9	72653	43	46N	099	19W	519
SD	CUSTER	KCUT	CUT		43	44N	103	37W	1725
SD	ELLSWORTH AFB	KRCA	RCA		44	08N	103	05W	999
SD	FAITH	KD07	D07		45	02N	102	01W	784
SD	HURON	KHON	HON	72654	44	23N	098	14W	390
SD	LEMMON	KY22	Y22	72669	45	55N	102	10W	781
SD	MADISON	KMDS	MDS		44	01N	097	05W	524
SD	MITCHELL	KMHE	MHE		43	46N	098	01W	397
SD	MOBRIDGE	KMBG	MBG	72668	45	33N	100	25W	510
SD	PHILIP	KPHP	PHP		44	03N	101	36W	672
SD	PIERRE	KPIR	PIR		44	23N	100	17W	526
SD	PINE RIDGE	KIEN	IEN		43	02N	102	31W	998
SD	RAPID CITY/WFO	KUNR	UNR	72662	44	04N	103	12W	1027
SD	RAPID CITY	KRAP	RAP		44	03N	103	03W	965
SD	SIOUX FALLS	KFSD	FSD	72651	43	35N	096	45W	436
SD	SISSETON	K8D3	8D3		45	40N	096	59W	354
SD	SPEARFISH/CLYDE	KSPF	SPF		44	28N	103	46W	1188
SD	WATERTOWN	KATY	ATY		44	54N	097	09W	532
SD	WINNER	KICR	ICR		43	23N	099	51W	621
SD	YANKTON	KYKN	YKN		42	55N	097	22W	398
SD	BELLE FOURCHE	KBEL	BEL		44	48N	104	03W	971
SD	JCT SD44 US385	KPAC	PAC		44	06N	103	31W	1494
SD	ELLSWORTH I90	KEL0	EL0		44	07N	103	05W	939
SD	WASTA I90	KWTA			44	05N	102	29W	810
SD	SHERIDAN LAKE RD	KSL0	SL0		44	02N	103	26W	1478
SD	EDGEMONT US18	KED0	ED0		43	17N	103	53W	1136
SD	SD-WY BORDR US85	KNE0	NE0		44	11N	104	03W	1940
SD	GLAD VLY SD20	KGLV			45	24N	101	47W	753
SD	BATESLAND US18	KBAT	BAT		43	08N	102	06W	1042
SD	LEMMON US12	KLEM	LEM		45	56N	102	11W	783
SD	ANDOVER	KADR	ADR		45	26N	097	56W	453
SD	BELVIDERE	KBVD	BVD		43	54N	101	08W	728
SD	BRANDT	KBRA	BRA		44	41N	096	51W	564
SD	CACTUS FLATS	KCAC	CAC		43	50N	101	46W	751
SD	KADOKA	KKAD	KAD		43	52N	101	50W	765
SD	FREDERICK	KFED	FED		45	56N	098	34W	427
SD	HARROLD	KHRD	HRD		44	32N	099	42W	547
SD	HERRIED	KHER	HER		45	51N	100	06W	513
SD	RELIANCE	KREL	REL		43	52N	099	34W	542
SD	SUMMIT	KSUM	SUM		45	20N	097	05W	607
SD	TOLSTOY	KTLS	TLS		45	13N	099	40W	596
SD	VICTOR	KVIC	VIC		45	54N	096	52W	329
SD	VIVIAN	KVIV	VIV		44	14N	100	22W	588
SD	ABERDEEN	QABS			45	29N	098	28W	395
SD	ALCESTER	QALS			43	01N	096	38W	342
SD	BALTIC	QBAS			43	46N	096	44W	342
SD	BRANDON	QBRS			43	36N	096	35W	342
SD	FT THOMPSON	QCES			44	04N	099	26W	440
SD	CLARK	QCLS			44	53N	097	44W	342
SD	REDFIELD	QDPS			44	53N	098	31W	397
SD	LEAD	QDSS			44	21N	103	47W	1560
SD	ELKTON	QEKS			44	14N	096	29W	342
SD	PARKSTON	QESS			43	24N	097	59W	426
SD	GETTYSBURG	QETS			45	01N	099	58W	628

SD	GARRETSON	QGAS			43 43N	096 30W	342
SD	CHAMBERLAIN	QHAS			43 48N	099 20W	447
SD	BRITTON	QHHS			45 47N	097 45W	414
SD	HOWARD	QHOS			44 01N	097 32W	342
SD	WINNER	QHSS			43 23N	099 52W	622
SD	HURON	QHUS			44 21N	098 14W	388
SD	KADOKA	QKAS			43 50N	101 31W	749
SD	BROOKINGS	QKGS			44 17N	096 47W	495
SD	MILLER	QLES			44 31N	098 59W	484
SD	CLEAR LAKE	QLKS			44 45N	096 41W	342
SD	COLTON	QLTS			43 44N	096 55W	478
SD	MADISON	QMMS			44 01N	097 06W	510
SD	MILBANK	QMIS			45 12N	096 38W	354
SD	MISSION	QMSS			43 18N	100 40W	784
SD	MOBRIDGE	QOBS			45 32N	100 26W	511
SD	PIERRE	QPIS			44 22N	100 21W	493
SD	ELK POINT	QPJS			42 41N	096 41W	342
SD	RAPID CITY	QRAS			44 04N	103 13W	998
SD	RAMONA	QRMS			44 07N	097 13W	342
SD	FSD PH	QSAS			43 32N	096 43W	440
SD	FSD PAV	QSBS			43 32N	096 44W	449
SD	EUREKA	QSDS			45 46N	099 37W	576
SD	FLANDREAU	QSNS			44 03N	096 36W	478
SD	MITCHELL	QTMS			43 43N	098 02W	395
SD	MARTY	QTYS			43 00N	098 09W	441
SD	VERMILLION	QVMS			42 47N	096 56W	373
SD	WALL	QWAS			43 59N	102 14W	854
SD	WEBSTER	QWES			45 20N	097 31W	342
SD	WATERTOWN	QWTS			44 55N	097 06W	544
SD	YANKTON	QYAS			42 53N	097 23W	382
TN	BOLIVAR/WHITEHST	KM08	M08		35 13N	089 03W	152
TN	BRISTOL	KTRI	TRI		36 29N	082 24W	474
TN	CHATTANOOGA	KCHA	CHA	72324	35 02N	085 12W	210
TN	CLARKSVILLE	KCKV	CKV		36 37N	087 25W	165
TN	COLUMBIA	KMRC	MRC		35 33N	087 11W	208
TN	COVINGTON MUNI	KM04	M04		35 35N	089 35W	85
TN	CROSSVILLE	KCSV	CSV		35 57N	085 05W	570
TN	DICKSON	KM02	M02		36 08N	087 26W	272
TN	DYERSBURG	KDYR	DYR		36 00N	089 24W	103
TN	ELIZABETHTON	K0A9	0A9		36 22N	082 10W	486
TN	FAYETTEVILLE	KFYM	FYM		35 04N	086 34W	300
TN	FRANKLIN WILKINS	KM52	M52		35 39N	088 23W	157
TN	GALLATIN	KM33	M33		36 23N	086 25W	178
TN	HUNTINGDON	KHZD	HZD		36 05N	088 28W	151
TN	JACKSON	KMKL	MKL		35 36N	088 55W	128
TN	KNOXVILLE	KTYS	TYS	72326	35 49N	083 59W	302
TN	LAWRENCEBURG	K2M2	2M2		35 14N	087 15W	286
TN	LEBANON	KM54	M54		36 11N	086 19W	180
TN	LEWISBURG	KLUG	LUG		35 30N	086 48W	219
TN	LIVINGSTON	K8A3	8A3		36 25N	085 19W	419
TN	MCMINNVILLE	KRNC	RNC		35 42N	085 51W	315
TN	MEMPHIS	KMEM	MEM	72334	35 04N	089 59W	86
TN	MILLINGTON/88D	KNQA	NQA		35 21N	089 52W	86
TN	MURFREESBORO	KMBT	MBT		35 53N	086 23W	188
TN	NASHVILLE	KBNA	BNA	72327	36 07N	086 41W	210
TN	NASHV/JC TUNE	KJWN	JWN		36 11N	086 53W	151
TN	OAK RIDGE	KOQT	OQT		36 01N	084 14W	277

TN	PARIS HENRY CTY	KPHT	PHT		36	20N	088	23W	177
TN	PORTLAND	K1M5	1M5		36	36N	086	29W	250
TN	ROCKWOOD	KRKW	RKW		35	55N	084	41W	508
TN	SAVANNAH HARDIN	KSNH	SNH		35	10N	088	13W	144
TN	SHELBYVILLE	KSYI	SYI		35	34N	086	27W	245
TN	SMYRNA	KMQY	MQY		36	01N	086	31W	166
TN	SPARTA	KSRB	SRB		36	03N	085	32W	313
TN	TULLAHOMA	KTHA	THA		35	23N	086	15W	331
TN	UNION CITY	KUCY	UCY		36	23N	088	59W	104
TN	WINCHESTER	KBGF	BGF		35	11N	086	04W	299
TX	DALLAS/FT WORTH	KDFW	DFW	72259	32	54N	097	01W	174
TX	ABILENE	KABI	ABI	72266	32	25N	099	41W	548
TX	ALICE	KALI	ALI		27	44N	098	01W	53
TX	ALPINE-CASPARIS	KE38	E38		30	23N	103	41W	1376
TX	AMARILLO	KAMA	AMA	72363	35	13N	101	42W	1093
TX	ANGLETON	KLBX	LBX		29	07N	095	28W	6
TX	ARLINGTON	KGKY	GKY		32	40N	097	06W	192
TX	AUSTIN	KAUS	AUS	72254	30	11N	097	41W	166
TX	AUSTIN EXEC	KEDC	EDC		30	24N	097	34W	189
TX	AUSTIN/MABRY	KATT	ATT		30	19N	097	46W	201
TX	BAY CITY	KBYY	BYY		28	58N	095	52W	14
TX	BEAUMONT/PORT AR	KBPT	BPT	72241	29	57N	094	02W	5
TX	BEAUMONT	KBMT	BMT		30	04N	094	13W	10
TX	BEEVILLE MUNI	KBEA	BEA		28	22N	097	47W	82
TX	BIG SPRING	KBPG	BPG		32	13N	101	31W	784
TX	BORGER	KBGD	BGD		35	42N	101	24W	927
TX	BOWIE	K0F2	0F2		33	36N	097	47W	336
TX	BRADY	KBBD	BBD		31	11N	099	19W	557
TX	BRECKENRIDGE	KBKD	BKD		32	43N	098	53W	392
TX	BRENHAM	K11R	11R		30	13N	096	22W	94
TX	BRIDGEPORT	KXBP			33	11N	097	50W	260
TX	BROWNSVILLE	KBRO	BRO	72250	25	55N	097	25W	7
TX	BROWNWOOD	KBWD	BWD		31	48N	098	57W	423
TX	BURNET	KBMQ	BMQ		30	44N	098	14W	389
TX	CALDWELL	KRWV	RWV		30	31N	096	42W	119
TX	CANADIAN	KHHF	HHF		35	54N	100	24W	712
TX	DIMMIT	KFTN	FTN		28	13N	100	01W	236
TX	CASTROVILLE MUNI	KCVB	CVB		29	21N	098	51W	235
TX	CHILDRESS	KCDS	CDS		34	26N	100	17W	594
TX	CLARKSVILLE	KLBR	LBR		33	36N	095	04W	134
TX	CLEBURNE	KCPT	CPT		32	21N	097	26W	260
TX	CLEVELAND MUNI	K6R3	6R3		30	21N	095	00W	46
TX	COLEMAN MUNI	KCOM	COM		31	50N	099	24W	517
TX	COLLEGE STATION	KCLL	CLL		30	35N	096	22W	96
TX	COMANCHE	KMKN	MKN		31	55N	098	36W	423
TX	CONROE	KCXO	CXO		30	21N	095	25W	75
TX	CORPUS CHRISTI	KCRP	CRP	72251	27	46N	097	30W	14
TX	C. CHRISTI NAS	KNGP	NGP		27	41N	097	16W	6
TX	CORSICANA	KCRS	CRS		32	02N	096	24W	133
TX	COTULLA	KCOT	COT		28	27N	099	13W	140
TX	CROCKETT	KDKR	DKR		31	18N	095	24W	106
TX	DALHART	KDHT	DHT		36	01N	102	33W	1217
TX	DALLAS/LOVE FLD	KDAL	DAL	72258	32	51N	096	51W	158
TX	DALLAS/REDBIRD	KRBD	RBD		32	41N	096	52W	203
TX	DALLAS NAS/HENSL	KNBE	NBE		32	43N	096	58W	150
TX	DALLAS/ADDISON	KADS	ADS		32	58N	096	49W	196
TX	DECATUR	KLUD	LUD		33	15N	097	35W	319

TX	DEL RIO	KDRT	DRT	72261	29 22N	100 55W	313
TX	DENTON	KDTO	DTO		33 12N	097 12W	196
TX	DRYDEN	K6R6	6R6		30 03N	102 13W	701
TX	DUMAS/MOORE CTY	KDUX	DUX		35 51N	102 01W	1129
TX	DYESS AFB/ABILEN	KDYS	DYS	69019	32 25N	099 50W	545
TX	EDINBURG INTL	KEBG	EBG		26 27N	098 08W	24
TX	EL PASO	KELP	ELP	72270	31 49N	106 23W	1197
TX	FALFURRIAS	KBKS	BKS		27 12N	098 07W	34
TX	FORT BLISS	KBIF	BIF		31 51N	106 23W	1203
TX	FORT STOCKTON	KFST	FST		30 55N	102 55W	918
TX	FORT WORTH	KFTW	FTW		32 50N	097 22W	214
TX	FORT WORTH/88D	KFWS	FWS		32 34N	097 18W	208
TX	FORT WORTH NAS	KNFW	NFW		32 47N	097 26W	198
TX	FREDERICKSBURG	KT82	T82		30 15N	098 55W	517
TX	FT WORTH/ALLIANC	KAFW	AFW		32 58N	097 19W	233
TX	FT HOOD/KILLEEN	KHLR	HLR	72257	31 08N	097 43W	283
TX	GALVESTON	KGLS	GLS	72242	29 16N	094 52W	6
TX	GAINESVILLE	KGLE	GLE		33 39N	097 12W	256
TX	UVALDE/GARNER F	KUVA	UVA		29 13N	099 45W	287
TX	GATESVILLE	KGOP	GOP		31 25N	097 48W	276
TX	GEORGETOWN	KGTU	GTU		30 41N	097 41W	240
TX	GIDDINGS-LEE	KGYB	GYB		30 10N	096 59W	148
TX	GILMER MUNI	KJXI	JXI		32 42N	094 57W	127
TX	GRAHAM MUNI	KRPH	RPH		33 07N	098 33W	342
TX	GRANBURY MUNI	KGDJ	GDJ		32 27N	097 49W	237
TX	GRAND PRAIRIE	KGPM	GPM		32 42N	097 03W	180
TX	GREENVILLE/MAJOR	KGVT	GVT		33 04N	096 04W	163
TX	GUADALUPE PASS	KGDP	GDP	72262	31 50N	104 49W	1692
TX	HAMILTON MUNI	KMNZ	MNZ		31 40N	098 09W	396
TX	HARLINGEN	KHRL	HRL		26 14N	097 39W	10
TX	HEARNE MUNI	KLHB	LHB		30 52N	096 37W	87
TX	HEBBRONVILLE	KHBV	HBV		27 21N	098 44W	202
TX	HENDERSON RUSK C	KRFI	RFI		32 09N	094 51W	135
TX	HEREFORD MUNI	KHRX	HRX		34 52N	102 20W	1154
TX	HILLSBORO	KINJ	INJ		32 05N	097 06W	209
TX	HONDO	KHDO	HDO		29 22N	099 10W	282
TX	HORSESHOE BAY	KDZB	DZB		30 32N	098 22W	334
TX	HOUSTON/DW HOOKS	KDWH	DWH		30 04N	095 33W	46
TX	HOUSTON/HOBBY	KHOU	HOU		29 38N	095 17W	36
TX	HOUSTON	KLVJ	LVJ		29 31N	095 15W	12
TX	HOUSTON EXEC	KTME	TME		29 48N	095 54W	51
TX	HOUSTON/INTNL	KIAH	IAH	72243	30 00N	095 22W	36
TX	HOUSTON/ELLINGTO	KEFD	EFD		29 36N	095 10W	10
TX	HOUSTON/SUGAR LA	KSGR	SGR		29 37N	095 39W	2
TX	HOUSTON/UNIV	KMCJ	MCJ		29 43N	095 24W	69
TX	HOUSTON/SOUTHWST	KAXH	AXH		29 31N	095 29W	21
TX	INGLESIDE/TP MCC	KTFP	TFP		27 55N	097 13W	6
TX	HUNTSVILLE	KUTS	UTS		30 45N	095 35W	104
TX	JACKSONVILLE	KJSO	JSO		31 52N	095 13W	206
TX	JASPER	KJAS	JAS		30 53N	094 02W	65
TX	JUNCTION	KJCT	JCT	74740	30 30N	099 46W	522
TX	KELLY AFB	KSKF	SKF		29 22N	098 34W	210
TX	GRAY/FT HOOD	KGRK	GRK		31 04N	097 50W	309
TX	KERRVILLE	KERV	ERV		29 59N	099 05W	510
TX	KICKAPOO	KCWC	CWC		33 51N	098 29W	305
TX	KILLEEN MUNI	KILE	ILE		31 04N	097 40W	258
TX	KINGSVILLE NAS	KNQI	NQI		27 30N	097 49W	15

TX	LA GRANGE	K3T5	3T5		29 54N	096 57W	99
TX	LAGO VISTA	KRYW	RYW		30 30N	097 58W	376
TX	LAMPASAS	KLZZ	LZZ		31 06N	098 12W	371
TX	LANCASTER	KLNC	LNC		32 35N	096 43W	153
TX	LAREDO	KLRD	LRD	72252	27 33N	099 28W	155
TX	LAUGHLIN AFB	KDLF	DLF		29 22N	100 46W	330
TX	LLANO	KAQO	AQO		30 47N	098 40W	336
TX	LONGVIEW	KGGG	GGG	72247	32 23N	094 43W	107
TX	LUBBOCK	KLBB	LBB	72267	33 40N	101 49W	993
TX	LUFKIN	KLFK	LFK		31 14N	094 45W	88
TX	MARFA	KMRF	MRF	72264	30 22N	104 01W	1481
TX	MARSHALL	KASL	ASL		32 31N	094 18W	109
TX	MC GREGOR	KPWG	PWG		31 28N	097 19W	180
TX	MCALLEN	KMFE	MFE		26 11N	098 15W	38
TX	MCKINNEY	KTKI	TKI		33 11N	096 35W	179
TX	MESQUITE	KHQZ	HQZ		32 45N	096 32W	136
TX	MIDLAND	KMAF	MAF	72265	31 57N	102 12W	874
TX	MIDLAND AIRPARK	KMDD	MDD		32 02N	102 06W	854
TX	MIDLOTHIAN/WAX	KJWY	JWY		32 27N	096 55W	217
TX	MINEOLA/QUITMAN	KJDD	JDD		32 45N	095 30W	132
TX	MINERAL WELLS	KMWL	MWL		32 47N	098 04W	284
TX	MOUNT PLEASANT	KOSA	OSA		33 06N	094 58W	111
TX	NACOGDOCHES	KOCH	OCH		31 34N	094 43W	108
TX	NEW BRAUNFELS	KBAZ	BAZ		29 43N	098 03W	195
TX	ODESSA	KODO	ODO		31 55N	102 24W	902
TX	ORANGE GROVE	KNOG	NOG		27 54N	098 03W	78
TX	ORANGE	KORG	ORG		30 04N	093 48W	4
TX	OZONA	KOZA	OZA		30 44N	101 12W	726
TX	PALACIOS	KPSX	PSX		28 43N	096 15W	5
TX	PALESTINE MUNI	KPSN	PSN		31 47N	095 42W	129
TX	PAMPA	KPPA	PPA		35 37N	101 00W	989
TX	PAMPA M VISTA R	KBPC	BPC		35 53N	101 02W	845
TX	PARIS/COX FIELD	KPRX	PRX		33 37N	095 27W	167
TX	PECOS CITY	KPEQ	PEQ		31 23N	103 31W	797
TX	PERRYTON	KPYX	PYX		36 25N	100 45W	889
TX	PHILLIPS OIL	K25T	25T		26 56N	094 41W	10
TX	PLAINVIEW	KPVW	PVW		34 10N	101 43W	1028
TX	PLEASANTON MUNI	KPEZ	PEZ		28 57N	098 31W	132
TX	PORT ARANSAS	KRAS	RAS		27 49N	097 05W	2
TX	PORT ISABEL	KPIL	PIL		26 10N	097 20W	5
TX	PORT LAVACA	KPKV			28 39N	096 41W	9
TX	RANDOLPH AFB	KRND	RND		29 31N	098 16W	232
TX	REESE AFB/LUBBOC	KREE	REE		33 36N	102 02W	1017
TX	ROBSTOWN/NUECES	KRBO	RBO		27 47N	097 41W	24
TX	ROCKPORT	KRKP	RKP		28 05N	097 03W	6
TX	ROCKSPRINGS	KECU	ECU		29 57N	100 10W	725
TX	SABINE PASS	KRPE	RPE	99426	29 41N	093 57W	3
TX	SAN ANGELO	KSJT	SJT	72263	31 22N	100 30W	576
TX	S ANTONIO/STINSN	KSSF	SSF		29 20N	098 28W	176
TX	SAN ANTONIO	KSAT	SAT	72253	29 32N	098 28W	243
TX	S ANTONIO-BOERNE	K5C1	5C1		29 43N	098 42W	423
TX	SAN MARCOS	KHYI	HYI		29 53N	097 52W	182
TX	SAN MARCOS	KT98	T98		29 53N	097 52W	182
TX	SANDERSON (RAMOS	KP07	P07	74730	30 10N	102 25W	865
TX	SEMINOLE	KGNC	GNC		32 41N	102 39W	1010
TX	SHERMAN/DENISON	KGYI	GYI		33 43N	096 40W	228
TX	SNYDER/WINSTON	KSNK	SNK		32 42N	100 57W	741

TX	SONORA	KSOA	SOA		30 35N	100 39W	652
TX	SOUTH PADRE IS	KSPL	SPL		26 04N	097 09W	4
TX	STEPHENVILLE	KSEP	SEP	72260	32 13N	098 10W	402
TX	SULPHUR SPRINGS	KSLR	SLR		33 10N	095 37W	149
TX	SWEETWATER	KSWW	SWW		32 28N	100 28W	727
TX	TEMPLE/MILLER	KTPL	TPL		31 08N	097 24W	208
TX	TERRELL	KTRL	TRL		32 43N	096 16W	145
TX	TYLER	KTYR	TYR		32 22N	095 24W	165
TX	VERNON WILBARGER	KF05	F05		34 14N	099 17W	386
TX	VICTORIA	KVCT	VCT	72255	28 52N	096 56W	31
TX	WACO	KACT	ACT	72256	31 37N	097 14W	151
TX	WACO/TSTI	KCNW	CNW		31 38N	097 04W	156
TX	WHARTON	KARM	ARM		29 15N	096 09W	31
TX	WICHITA FALL	KSPS	SPS	72351	33 59N	098 30W	308
TX	WINK	KINK	INK		31 47N	103 12W	855
TX	WESLACO MIDVALLY	KT65	T65		26 11N	097 58W	21
TX	ZAPATA	KAPY	APY		26 58N	099 15W	129
TX	BRAZOS 133B OILP	KBBF	BBF		27 50N	096 01W	36
TX	GALVESTON424 OIL	KGVX	GVX		28 35N	094 59W	39
TX	H ISLAND376 OILP	KHQI	HQI		27 58N	093 40W	26
TX	BRAZOS 451 OILP	KBQX	BQX		28 30N	095 43W	34
TX	MUSTANG IS31 OIL	KMIU	MIU		27 17N	096 44W	36
TX	MUSTANG A85A OIL	KMZG	MZG		27 44N	096 11W	29
TX	W CAMERON 368A	KCRH	CRH		28 55N	093 18W	34
TX	E BREAKS BOOMVNG	KVAF	VAF		27 21N	094 38W	46
TX	ALAMINOS CANYON	KHHV	HHV		26 56N	094 41W	25
TX	E BREAKS 165	KEMK	EMK		27 49N	094 19W	26
TX	GUNNISON 668	KGUL	GUL		27 18N	093 32W	30
TX	N PADRE 975	KOPM	OPM		26 50N	096 56W	25
TX	FRIONA 2NE	XFAS			34 39N	102 41W	1222
TX	DIMMITT 2NE	XDMS			34 34N	102 18W	1181
TX	TULIA 2NE	XTIS			34 33N	101 44W	1060
TX	SILVERTON 7E	XSVS			34 27N	101 11W	976
TX	MULESHOE 2S	XMUS			34 12N	102 45W	1160
TX	AMHERST 1NE	XAMH			34 01N	102 24W	1112
TX	PLAINVIEW 1S	XPVS			34 11N	101 42W	1024
TX	FLOYDADA 2NE	XFLS			34 00N	101 20W	969
TX	ROARING S. 3N	XRRS			33 56N	100 51W	797
TX	MORTON 1NE	XMNS			33 44N	102 44W	1144
TX	LEVELLAND 4S	XLDS			33 32N	102 22W	1066
TX	LUBBOCK 12W	XREE			33 36N	102 03W	1020
TX	RALLS 1SE	XRLS			33 40N	101 23W	944
TX	PLAINS 3N	XPPS			33 14N	102 50W	1131
TX	BROWNFIELD 2S	XBWS			33 09N	102 16W	1010
TX	TAHOKA 3NE	XTAS			33 12N	101 47W	946
TX	POST 1NE	XPTS			33 12N	101 22W	792
TX	SEMINOLE 2N	XSMS			32 44N	102 38W	1010
TX	SLATON 2NE	XSLS			33 27N	101 37W	934
TX	ABERNATHY 5NE	XARS			33 53N	101 45W	1016
TX	OLTON 6S	XONS			34 06N	102 07W	1087
TX	O'DONNELL 1N	XOES			32 59N	101 50W	931
TX	SEAGRAVES 1SW	XSGV			32 56N	102 34W	1024
TX	LAMESA 2SE	XLES			32 42N	101 56W	901
TX	HART 3N	XHRS			34 25N	102 06W	1126
TX	GAIL 2SE	XGGS			32 45N	101 25W	778
TX	WHITE R LAKE 6NW	XWVS			33 32N	101 10W	824
TX	GRAHAM 5SW	XGHS			33 05N	101 31W	869

TX	SUNDOWN 8SW	XSDS			33	23N	102	37W	1105
TX	ANTON 6S	XAOS			33	44N	102	11W	1038
TX	FLUVANNA 3W	XFVS			32	54N	101	12W	825
TX	SPUR 1W	XSPR			33	29N	100	53W	697
TX	LUBBOCK 3W	XLBW			33	35N	101	54W	985
TX	GUTHRIE 10W	XPFS			33	34N	100	29W	609
TX	CLARENDON	XCES			34	55N	100	56W	864
TX	PADUCA 10SW	XPAD			33	53N	100	24W	616
TX	SNYDER 3E	XSYS			32	43N	100	52W	741
TX	MEMPHIS 1NE	XMES			34	44N	100	32W	627
TX	JAYTON 1S	XJTS			33	14N	100	34W	613
TX	PAMPA 2E	XPMS			35	32N	100	56W	974
TX	HEREFORD 2NW	XHES			34	50N	102	25W	1182
TX	ASPERMONT 3NE	XASR			33	10N	100	12W	530
TX	GOODLETT 3W	XGDS			34	21N	099	56W	501
TX	MCLEAN 1E	XMCS			35	14N	100	34W	873
TX	DENVER CITY 7W	XDVS			32	59N	102	56W	1113
TX	LAKE ALAN HENRY	XAHS			33	05N	101	03W	705
TX	WOLFFORTH 6SW	XWOS			33	25N	102	03W	1008
TX	ANDREWS 2E	XANS			32	19N	102	31W	966
TX	TURKEY 2WSW	XTUR			34	23N	100	56W	747
TX	CHILDRESS 2NNE	XCXS			34	27N	100	12W	593
NM	TATUM NM 2SW	XTAT			33	14N	103	21W	1225
NM	DORA 2SW	XDR1			33	55N	103	21W	1317
NM	NORTHFIELD 1S	XNOR			34	16N	100	36W	637
TX	SAN ANGELO 7NW	XASU			31	33N	100	31W	597
TX	ST LAWRENCE 5SW	XST1			31	39N	101	36W	821
TX	HASKELL 1NW	XHA1			33	10N	099	45W	488
TX	WALL 1E	XWA1			31	22N	100	17W	572
TX	SEYMOUR 3NW	XSE1			33	38N	099	17W	397
TX	KNOX CITY 3NW	XKN1			33	27N	099	52W	448
TX	PINE SPRNGS GMNP	XGU1			31	53N	104	49W	1698
TX	ODELL 4ENE	XOD1			34	22N	099	21W	418
TX	COYANOSA 2N	XCO1			31	17N	103	04W	783
TX	QUITAQUE 3NNW	XQU1			34	25N	101	04W	808
UT	SALT LAKE CITY	KSLC	SLC	72572	40	47N	111	58W	1286
UT	BLANDING	K4BL	4BL	72472	37	37N	109	28W	1840
UT	BRYCE CANYON	KBCE	BCE		37	42N	112	09W	2312
UT	CEDAR CITY	KCDC	CDC		37	42N	113	06W	1714
UT	DELTA	KU24	U24	72479	39	20N	112	35W	1414
UT	DUGWAY PRVG GROU	KDPG	DPG	74003	40	12N	112	55W	1326
UT	GREEN RIVER RANG	KU28	U28	72477	39	00N	110	10W	1241
UT	HANKSVILLE	K4HV	4HV	72473	38	22N	110	43W	1314
UT	HEBER/RUSS MCDON	K36U	36U		40	29N	111	26W	1718
UT	HILL AFB/OGDEN	KHIF	HIF		41	07N	111	58W	1459
UT	LOGAN	KLGU	LGU		41	47N	111	51W	1355
UT	MILFORD	KMLF	MLF	72475	38	25N	113	01W	1534
UT	MOAB	KCNY	CNY		38	46N	109	45W	1390
UT	OGDEN	KOGD	OGD	72575	41	12N	112	01W	1353
UT	PRICE	KPUC	PUC	72470	39	37N	110	45W	2091
UT	PROVO MUNI	KPVU	PVU		40	13N	111	43W	1369
UT	ROOSEVELT	KU67	U67	74420	40	17N	109	58W	1556
UT	SAINT GEORGE	KDXZ	DXZ		37	05N	113	36W	896
UT	SALT LAKE MUNI	KU42	U42		40	37N	112	00W	1402
UT	TOOELE	KT62	T62		40	19N	112	17W	1628
UT	VERNAL	KVEL	VEL		40	27N	109	31W	1604
UT	WENDOVER (AUT)	KENV	ENV	72581	40	43N	114	01W	1292

VA ROANOKE	KROA	ROA	72411	37 19N	079 58W	362
VA ABINGDON	KVJI	VJI		36 40N	082 01W	631
VA BLACKSBURG/VA T.	KBCB	BCB		37 13N	080 25W	650
VA CHARLOTTESVILLE	KCHO	CHO		38 08N	078 27W	192
VA CHESAPEAKE	KCPK	CPK	99402	36 40N	076 19W	6
VA CULPEPER	KCJR	CJR		38 32N	077 52W	97
VA DANVILLE	KDAN	DAN		36 34N	079 20W	175
VA DUBLIN/NEW RIV	KPSK	PSK		37 07N	080 40W	642
VA EMPORIA	KEMV	EMV		36 41N	077 29W	39
VA FARMVILLE	KFVX	FVX		37 21N	078 25W	125
VA FENTRESS NAVAL	KNFE	NFE		36 42N	076 08W	5
VA FORT BELVOIR/DAV	KDAA	DAA		38 43N	077 10W	21
VA FRANKLIN/J B ROS	KFKN	FKN		36 42N	076 54W	12
VA FREDERICKSB/SHAN	KEZF	EZF		38 16N	077 27W	26
VA FT EUSTIS/FELKER	KFAF	FAF		37 07N	076 37W	4
VA HILLSVILLE/GALAX	KHLX	HLX		36 46N	080 49W	834
VA HOT SPRINGS/INGA	KHSP	HSP		37 57N	079 49W	1156
VA JONESVILLE	K0VG	0VG		36 39N	083 13W	430
VA LANGLEY AFB/HAMP	KLFI	LFI	74598	37 04N	076 22W	3
VA LEESBURG/GODFREY	KJYO	JYO		39 04N	077 34W	119
VA LOUISA	KLKU	LKU		38 01N	077 58W	150
VA LURAY	KLUA	LUA		38 40N	078 30W	275
VA LYNCHBURG	KLYH	LYH	72410	37 19N	079 12W	295
VA MANASSAS MUNI	KHEF	HEF		38 43N	077 31W	59
VA MARION / WYTHEVI	KMKJ	MKJ		36 53N	081 20W	780
VA MARTINSVILLE	KMTV	MTV		36 38N	080 01W	287
VA MELFA/ACCOMACK	KMFV	MFV		37 38N	075 46W	15
VA NEWPORT NEWS	KPHF	PHF		37 08N	076 30W	12
VA NORFOLK NAS/CHAM	KNGU	NGU		36 55N	076 16W	5
VA NORFOLK	KORF	ORF	72308	36 54N	076 12W	14
VA NORFOLK/WAKEFLD	KAKQ	AKQ		36 59N	077 00W	34
VA NORFOLK/HAMPTON	KPVG	PVG		36 47N	076 27W	7
VA OCEANA NAS/SOUCE	KNTU	NTU		36 49N	076 01W	7
VA ORANGE	KOMH	OMH		38 15N	078 03W	142
VA PETERSBURG	KPTB	PTB		37 10N	077 31W	59
VA QUANTICO MCAF	KNYG	NYG		38 30N	077 17W	4
VA RICHMOND/HANOVER	KOFP	OFP		37 42N	077 26W	62
VA RICHMOND/CHESTER	KFCI	FCI		37 24N	077 31W	72
VA RICHMOND	KRIC	RIC	72401	37 31N	077 19W	50
VA SOUTH HILL/MECKL	KAVC	AVC		36 41N	078 02W	135
VA STAFFORD REGNL	KRMN	RMN		38 24N	077 27W	65
VA STAUNTON/SHENAND	KSHD	SHD		38 16N	078 54W	366
VA SUFFOLK	KSFQ	SFQ		36 41N	076 36W	22
VA RICHLANDS	KJFZ	JFZ		37 04N	081 48W	809
VA TAPPAHANNOCK	KXSA	XSA		37 52N	076 54W	42
VA WALLOPS ISLAND	KWAL	WAL	72402	37 56N	075 28W	14
VA WARRENTON	KHWY	HWY		38 35N	077 43W	103
VA WASH DC/DULLES	KIAD	IAD	72403	38 56N	077 27W	93
VA WEST POINT	KFYJ	FYJ		37 31N	076 46W	7
VA WILLIAMSBURG	KJGG	JGG		37 14N	076 43W	15
VA WINCHESTER RGNL	KOKV	OKV		39 08N	078 09W	222
VA WISE/LONESOME PI	KLNP	LNP		36 58N	082 31W	817
VT BENNINGTON	KDDH	DDH	72516	42 53N	073 15W	244
VT BURLINGTON	KBTV	BTV	72617	44 28N	073 09W	105
VT HIGHGATE	KFSO	FSO		44 56N	073 06W	70
VT LYNDONVILLE	KCDA	CDA		44 34N	072 01W	363
VT MORRISVILLE	KMVL	MVL		44 30N	072 37W	234

VT	MONTPELIER/BARRE	KMPV	MPV		44 12N	072 34W	343
VT	NEWPORT STATE	KEFK	EFK	72612	44 53N	072 14W	284
VT	RUTLAND STATE	KRUT	RUT		43 31N	072 57W	240
VT	SPRINGFIELD	KVSF	VSF		43 21N	072 31W	175
VT	ST. JOHNSBURY	K1V4	1V4	72614	44 25N	072 01W	210
WA	ARLINGTON MUNI	KAWO	AWO		48 10N	122 10W	42
WA	BELLINGHAM	KBLI	BLI		48 48N	122 32W	50
WA	BREMERTON NTNL	KPWT	PWT		47 30N	122 45W	147
WA	BURLINGTON/MT V	KBVS	BVS	74200	48 28N	122 25W	43
WA	CHEHALIS CENTRAL	KCLS	CLS		46 41N	122 59W	54
WA	COLVILLE MUNICIP	KCQV	CQV		48 32N	117 52W	572
WA	DEER PARK	KDEW	DEW	72787	47 58N	117 26W	674
WA	EASTSOUND/ORCAS	KORS	ORS		48 42N	122 55W	9
WA	ELLENSBURG	KELN	ELN		47 02N	120 32W	519
WA	EPHRATA	KEPH	EPH		47 18N	119 31W	383
WA	EVERETT	KPAE	PAE		47 55N	122 17W	180
WA	FAIRCHILD AFB	KSKA	SKA		47 37N	117 39W	750
WA	FORT LEWIS/GRAY	KGRF	GRF	74207	47 04N	122 34W	92
WA	FRIDAY HARBOR	KFHR	FHR		48 31N	123 02W	32
WA	HANFORD	KHMS	HMS	72784	46 34N	119 35W	223
WA	HOQUIAM	KHQM	HQM		46 58N	123 56W	7
WA	KELSO LONGVEIW	KKLS	KLS		46 07N	122 54W	5
WA	MOSES LAKE	KMWH	MWH		47 12N	119 19W	362
WA	OAK HARBOR AIRPA	KOKH	OKH	72796	48 15N	122 40W	59
WA	OLYMPIA	KOLM	OLM	72792	46 58N	122 54W	58
WA	OMAK	KOMK	OMK	72789	48 28N	119 31W	395
WA	PASCO	KPSC	PSC		46 16N	119 07W	121
WA	PORT ANGELES	KCLM	CLM		48 07N	123 30W	85
WA	PULLMAN/MOSCOW	KPUW	PUW		46 45N	117 07W	773
WA	PUYALLUP/THUN	KPLU	PLU		47 06N	122 17W	164
WA	QUILLAYUTE	KUIL	UIL	72797	47 56N	124 33W	54
WA	RENTON	KRNT	RNT		47 30N	122 13W	21
WA	SEATTLE/BOEING	KBFI	BFI		47 33N	122 19W	4
WA	SEATTLE/METRO	KSEA	SEA	72793	47 27N	122 19W	136
WA	SHELTON	KSHN	SHN		47 14N	123 08W	82
WA	SPOKANE/FELTS	KSFF	SFF		47 41N	117 19W	609
WA	SPOKANE/METRO	KGEG	GEG	72785	47 37N	117 32W	735
WA	STAMPEDE PASS	KSMP	SMP		47 17N	121 20W	1208
WA	TACOMA	KTIW	TIW		47 16N	122 35W	89
WA	TACOMA/MC CHORD	KTCM	TCM	74206	47 07N	122 28W	98
WA	TOLEDO WINLOCK M	KTDO	TDO		46 28N	122 47W	113
WA	VANCOUVER	KVUO	VUO		45 37N	122 39W	8
WA	WALLA WALLA	KALW	ALW	72788	46 06N	118 17W	363
WA	WENATCHEE	KEAT	EAT		47 24N	120 12W	377
WA	WHIDBEY IS. NAS	KNUW	NUW	69023	48 21N	122 39W	14
WA	YAKIMA	KYKM	YKM	72781	46 34N	120 32W	324
WI	ANTIGO/LANGLADE	KAIG			45 10N	089 07W	464
WI	APPLETON/OUTAGAM	KATW	ATW		44 15N	088 31W	280
WI	ASHWAUBENON	KGRB	GRB	72645	44 29N	088 08W	208
WI	ASHLAND	KASX	ASX		46 33N	090 55W	251
WI	BLACK RIVER FALL	KBCK	BCK		44 15N	090 51W	255
WI	BOSCOBEL	KOVS	OVS		43 09N	090 41W	202
WI	BURLINGTON	KBUU	BUU		42 41N	088 18W	237
WI	CLINTONVILLE	KCLI	CLI		44 36N	088 43W	250
WI	CUMBERLAND	KUBE	UBE		45 30N	091 59W	379
WI	DELLS/BARABOO	KDLL	DLL		43 31N	089 46W	299
WI	EAGLE RIVER	KEGV	EGV		45 55N	089 16W	500

WI	EAU CLAIRE	KEAU	EAU		44	52N	091	28W	276
WI	FOND DU LAC	KFLD	FLD		43	46N	088	29W	240
WI	HAYWARD	KHYR	HYR		46	01N	091	27W	370
WI	JANESVILLE/ROCK	KJVL	JVL		42	37N	089	01W	246
WI	JUNEAU	KUNU	UNU		43	25N	088	42W	285
WI	KENOSHA	KENW	ENW		42	36N	087	56W	219
WI	LA CROSSE	KLSE	LSE	72643	43	53N	091	15W	199
WI	LADYSMITH/RUSK	KRCX	RCX		45	30N	091	00W	377
WI	LAND O LAKES	KLNL	LNL		46	09N	089	13W	520
WI	LONE ROCK	KLNR	LNR		43	13N	090	11W	217
WI	MADISON	KMSN	MSN	72641	43	08N	089	21W	261
WI	MANITOWAC MUNI	KMTW	MTW		44	07N	087	40W	198
WI	MARSHFIELD	KMFI	MFI		44	38N	090	11W	379
WI	MEDFORD	KMDZ	MDZ		45	06N	090	17W	448
WI	MENOMONIE MUNI	KLUM	LUM		44	54N	091	52W	273
WI	MERRILL	KRRL	RRL		45	12N	089	43W	401
WI	MIDDLETON	KC29	C29		43	07N	089	32W	283
WI	MILWAUKEE	KMKE	MKE		42	57N	087	54W	206
WI	MILWAUKEE/LAWREN	KMWC	MWC		43	07N	088	01W	227
WI	MINERAL POINT	KMRJ	MRJ		42	53N	090	13W	359
WI	MINOCQUA/WOODRUF	KARV	ARV		45	55N	089	43W	496
WI	MONROE	KEFT	EFT		42	36N	089	35W	331
WI	MOSINEE/CENTRAL	KCWA	CWA		44	46N	089	40W	389
WI	NEW RICHMOND MUN	KRNH	RNH		45	09N	092	32W	304
WI	OSCEOLA	KOEO	OEO		45	18N	092	41W	275
WI	OSHKOSH	KOSH	OSH		43	58N	088	33W	248
WI	PHILLIPS/PRICE	KPBH	PBH		45	42N	090	24W	449
WI	PLATTEVILLE	KPVB	PVB		42	41N	090	27W	313
WI	PRAIRIE DU CHIEN	KPDC	PDC		43	01N	091	07W	201
WI	RACINE	KRAC	RAC		42	46N	087	49W	203
WI	RHINELANDER	KRHI	RHI		45	38N	089	29W	485
WI	RICE LAKE	KRPD	RPD		45	25N	091	46W	338
WI	SHAWANO MUNI	KEZS	EZS		44	47N	088	34W	248
WI	SHEBOYGAN	KSBM	SBM	99433	43	47N	087	51W	232
WI	SIREN	KRZN	RZN		45	49N	092	22W	301
WI	SPARTA/MCCOY AAF	KCMY	CMY		43	58N	090	44W	256
WI	STEVENS POINT	KSTE	STE		44	32N	089	31W	338
WI	STURGEON BAY	KSUE	SUE		44	51N	087	25W	221
WI	SUPERIOR	KSUW	SUW		46	41N	092	06W	206
WI	TOMAHAWK REGNL	KTKV	TKV		45	28N	089	48W	453
WI	VIROQUA MUNI	KY51	Y51		43	35N	090	54W	394
WI	VOLK/CAMP DOUGLA	KVOK	VOK		43	55N	090	16W	277
WI	WATERTOWN	KRYV	RYV		43	10N	088	43W	254
WI	WAUKESHA CNTY	KUES	UES		43	02N	088	14W	278
WI	WAUPACA	KPCZ	PCZ		44	20N	089	01W	252
WI	WAUSAU	KAUW	AUW	72646	44	56N	089	37W	362
WI	WAUTOMA	KY50	Y50		44	02N	089	18W	262
WI	WEST BEND	KETB	ETB		43	25N	088	08W	270
WI	WISCONSIN RAPIDS	KISW	ISW		44	22N	089	50W	307
WV	BECKLEY	KBKW	BKW	72412	37	48N	081	07W	764
WV	BLUEFIELD	KBLF	BLF		37	18N	081	12W	873
WV	BUCKHANNON	KW22	W22		39	00N	080	16W	499
WV	CHARLESTON	KCRW	CRW	72414	38	23N	081	35W	309
WV	CLARKSBURG	KCKB	CKB		39	18N	080	13W	360
WV	ELKINS	KEKN	EKN	72417	38	53N	079	51W	603
WV	HUNTINGTON	KHTS	HTS	72425	38	22N	082	33W	254
WV	LEWISBURG/GREENB	KLWB	LWB		37	52N	080	24W	702

WV	MARTINSBURG	KMRB	MRB		39	24N	077	59W	164
WV	MORGANTOWN	KMGW	MGW		39	39N	079	55W	378
WV	PARKERSBURG	KPKB	PKB	72427	39	21N	081	25W	262
WV	PT PLEASANT	K3I2	3I2		38	55N	082	06W	196
WV	PETERSBURG	KW99	W99		39	00N	079	09W	293
WV	PINEVILLE	KI16	I16		37	36N	081	34W	544
WV	SUTTON/BRAXTON	K48I	48I		38	41N	080	39W	397
WV	WHEELING	KHLG	HLG		40	10N	080	39W	372
WV	WHITE SULPHUR SP	KSSU	SSU		37	46N	080	19W	549
WY	BIG PINEY	KBPI	BPI	72671	42	35N	110	06W	2117
WY	BUFFALO	KBYG	BYG		44	23N	106	43W	1497
WY	CASPER	KCPR	CPR	72569	42	54N	106	28W	1621
WY	CHEYENNE	KCYS	CYS	72564	41	09N	104	49W	1868
WY	CODY	KCOD	COD	72670	44	31N	109	01W	1553
WY	DOUGLAS	KDGW	DGW	72568	42	48N	105	23W	1499
WY	ELK MOUNTAIN	KEHY	EHY		41	44N	106	28W	2225
WY	EVANSTON	KEVW	EVW		41	16N	111	02W	2177
WY	GILLETTE	KGCC	GCC	72665	44	20N	105	33W	1320
WY	GREYBULL	KGEY	GEY		44	31N	108	05W	1191
WY	HULETT MUNI	KW43	W43		44	40N	104	34W	1300
WY	JACKSON	KJAC	JAC		43	37N	110	44W	1961
WY	LANDER	KLND	LND	72576	42	49N	108	44W	1694
WY	LARAMIE	KLAR	LAR		41	19N	105	40W	2216
WY	NEWCASTLE MONDEL	KECS	ECS		43	53N	104	19W	1273
WY	PINEDALE R WENZ	KPNA	PNA		42	48N	109	48W	2160
WY	RAWLINS MUNICIPA	KRWL	RWL		41	47N	107	12W	2077
WY	RIVERTON	KRIW	RIW	72672	43	04N	108	28W	1697
WY	ROCK SPRINGS	KRKS	RKS	72574	41	36N	109	04W	2060
WY	SHERIDAN	KSHR	SHR	72666	44	46N	106	58W	1202
WY	TORRINGTON	KTOR	TOR		42	04N	104	09W	1277
WY	WORLAND	KWRL	WRL		43	58N	107	57W	1271
WY	YELLOWSTONE LAKE	KP60	P60		44	33N	110	25W	2388
WY	BORDEAUX	KBRX	BRX		41	57N	104	57W	1524
WY	CONTINENTAL DIV	KCTD	CTD		41	43N	107	47W	2146
WY	VEDAUWOO	KVDW	VDW		41	09N	105	24W	2542
WY	PUMPKIN VINE	KPUM	PUM		41	03N	105	28W	2420
WY	ARLINGTON	KARL			41	36N	106	13W	2179
WY	BITTERCREEK	KBIT	BIT		41	39N	108	35W	2160
WY	CEMETERY SEPARA	KCMS	CMS		41	32N	109	28W	1949
WY	FIRST DIVIDE	KFIR	FIR		41	18N	110	46W	2294
WY	I-25 DIVIDE	KIDV	IDV		43	56N	106	39W	1531
WY	20 MILE HILL	KTMH	TMH		43	07N	106	20W	1743
WY	DEAD HORSE	KDHS	DHS		44	13N	106	06W	1241
WY	INYAN KARA	KIKA	IKA		44	18N	104	38W	1319
WY	BELLE FOURCHE	KBFU	BFU		43	56N	105	27W	1422
WY	WHITAKER	KWTR	WTR		41	25N	104	52W	1882
WY	PATHFINDER HILL	KPAT			42	34N	106	51W	1912
WY	BEAVER RIM	KBVR	BVR		42	35N	108	17W	2072
WY	SIBLEY PEAK	KSIB	SIB		42	27N	105	02W	1500
WY	PINEY CREEK	KPIN	PIN		44	34N	106	49W	1392
WY	HILAND	KHLD	HLD		43	06N	107	19W	1846
WY	DEER CREEK	KDRC	DRC		42	50N	105	52W	1543
WY	SKYLINE	KSKL	SKL		41	07N	106	34W	2451
WY	RIM / PINEDALE	KRIM	RIM		43	06N	110	19W	2294
WY	SAGE / JUNCTION	KSGE	SGE		41	47N	110	30W	2354
WY	GUNBARREL	KGUN	GUN		41	26N	104	21W	1695
WY	CHIEF JOSEPH	KCHJ	CHJ		44	45N	109	22W	2512

WY	SHUTE CREEK	KSHC	SHC		41 56N	109 58W	2043
WY	MAMMOTH/YELLOWST	KMMM	MMM		44 59N	110 42W	1902
WY	TOWER FALLS	KTOW	TOW		44 54N	110 23W	1800
WY	MEETEETSE RIM	KMTR			44 16N	108 52W	1803
DC	WASHINGTON/NATL	KDCA	DCA	72405	38 51N	077 02W	18

10 Appendix B

This appendix lists the location details of all Continental US upper air locations whose data are potentially in the prepBUFR observation dataset that was used in this evaluation study.

CD	STATION	ICAO	IATA	SYNOP	LAT	LONG	ELEV
AL	BRMNGHM/ALABASTR	KBMX	BMX	72230	33 10N	086 46W	197
AR	N. LITTLE ROCK	KLZK	LZK	72340	34 50N	092 16W	173
AZ	FLAGSTAFF/BELLEM	KFGZ	FGZ	72376	35 14N	111 49W	2192
AZ	PHOENIX/WFO	KPSR	PSR	74626	33 26N	112 01W	342
AZ	TUCSON/WFO	KTWC	TWC	72274	32 14N	110 57W	752
CA	EDWARDS AFB	KEDW	EDW	72381	34 53N	117 52W	702
CA	MIRAMAR NAS/SAN	KNKX	NKX	72293	32 52N	117 08W	146
CA	OAKLAND	KOAK	OAK	72493	37 42N	122 13W	26
CA	VANDENBERG AFB	KVBG	VBG	72393	34 44N	120 35W	112
CO	DENVER/STAPLETON	KDNR	DNR	72469	39 45N	104 52W	1608
CO	GRAND JUNCTION	KGJT	GJT	72476	39 07N	108 31W	1475
FL	CAPE CANAVERAL	KXMR	XMR	74794	28 28N	080 32W	3
FL	JACKSONVILLE	KJAX	JAX	72206	30 30N	081 41W	10
FL	KEY WEST	KKEY	KEY		24 33N	081 47W	5
FL	MIAMI/WFO	KMFL	MFL	72202	25 45N	080 22W	5
FL	TALLAHASSEE	KTLH	TLH	72214	30 24N	084 21W	19
FL	TAMPA BAY/RUSKIN	KTBW	TBW	72210	27 42N	082 24W	12
GA	PEACHTREE CITY	KFFC	FFC	72215	33 21N	084 34W	262
IA	DAVENPORT/QUAD C	KDVN	DVN	74455	41 37N	090 35W	230
ID	BOISE	KBOI	BOI	72681	43 34N	116 14W	875
IL	LINCOLN	KILX	ILX	74560	40 09N	089 20W	177
KS	DODGE CITY	KDDC	DDC	72451	37 46N	099 58W	789
KS	TOPEKA	KTOP	TOP	72456	39 04N	095 38W	268
LA	LAKE CHARLES	KLCH	LCH	72240	30 08N	093 13W	4
LA	SHREVEPORT	KSHV	SHV	72248	32 27N	093 50W	83
LA	SLIDELL/88D	KLIX	LIX	72233	30 20N	089 50W	7
MA	CHATHAM	KCHH	CHH	74494	41 40N	069 58W	16
ME	CARIBOU	KCAR	CAR	72712	46 52N	068 01W	191
ME	GRAY/PORTLAND	KGYX	GYX	74389	43 53N	070 15W	125
MI	DETROIT/WHITE LK	KDTX	DTX	72632	42 42N	083 28W	327
MI	GAYLORD/ALPENA	KAPX	APX	72634	44 54N	084 43W	446
MN	CHANHASSEN	KMPX	MPX	72649	44 51N	093 34W	288
MN	INTERNTNL FALLS	KINL	INL	72747	48 34N	093 24W	360
MO	SPRINGFIELD	KSGF	SGF	72440	37 14N	093 23W	390
MS	JACKSON	KJAN	JAN	72235	32 19N	090 05W	91
MT	GLASGOW	KGGW	GGW	72768	48 13N	106 37W	694
MT	GREAT FALLS/88D	KTFX	TFX	72776	47 28N	111 23W	1132
NC	GREENSBORO	KGSO	GSO	72317	36 06N	079 57W	275
NC	MOREHEAD/NEWPORT	KMHX	MHX	72305	34 46N	076 52W	9
ND	BISMARCK	KBIS	BIS	72764	46 46N	100 45W	505
NE	NORTH PLATTE	KLBF	LBF	72562	41 07N	100 40W	847

NE	OMAHA/VALLEY/88D	KOAX		72558	41	19N	096	22W	350
NM	ALBUQUERQUE	KABQ	ABQ	72365	35	03N	106	37W	1618
NM	SANTA TERESA/88D	KEPZ	EPZ	72364	31	52N	106	42W	1251
NV	ELKO/WFO	KLKN	LKN	72582	40	52N	115	43W	1608
NV	LAS VEGAS/WFO	KVEF	VEF	72388	36	03N	115	11W	694
NV	RENO/WFO	KREV	REV	72489	39	34N	119	48W	1516
NY	ALBANY	KALB	ALB	72518	42	45N	073	48W	92
NY	BROOKHAVEN/UPTON	KOKX	OKX	72501	40	52N	072	52W	26
NY	BUFFALO/CHEEKTOW	KBUF	BUF	72528	42	56N	078	44W	211
OH	WILMINGTON	KILN	ILN	72426	39	26N	083	48W	322
OK	NORMAN/WESTHEIME	KOUN	OUN	72357	35	15N	097	28W	357
OR	MEDFORD	KMFR	MFR	72597	42	23N	122	52W	396
OR	SALEM	KSLE	SLE	72694	44	54N	123	00W	59
PA	PITTSBURGH	KPIT	PIT	72520	40	30N	080	16W	357
SC	CHARLESTON	KCHS	CHS	72208	32	54N	080	02W	13
SD	ABERDEEN	KABR	ABR	72659	45	27N	098	25W	397
SD	RAPID CITY/WFO	KUNR	UNR	72662	44	04N	103	12W	1027
TN	NASHVILLE	KBNA	BNA	72327	36	07N	086	41W	210
TX	AMARILLO	KAMA	AMA	72363	35	13N	101	42W	1093
TX	BROWNSVILLE	KBRO	BRO	72250	25	55N	097	25W	7
TX	CORPUS CHRISTI	KCRP	CRP	72251	27	46N	097	30W	14
TX	DEL RIO	KDRT	DRT	72261	29	22N	100	55W	313
TX	FORT WORTH	KFWD	FWD	72249	32	49N	097	17W	196
TX	MIDLAND	KMAF	MAF	72265	31	57N	102	12W	874
UT	SALT LAKE CITY	KSLC	SLC	72572	40	47N	111	58W	1286
VA	ROANOKE/BLACKSBG	KRNK	RNK	72318	37	12N	080	24W	648
VA	WALLOPS ISLAND	KWAL	WAL	72402	37	56N	075	28W	14
VA	WASH DC/DULLES	KIAD	IAD	72403	38	56N	077	27W	93
WA	QUILLAYUTE	KUIL	UIL	72797	47	56N	124	33W	54
WA	SPOKANE	KOTX	OTX	72786	47	41N	117	38W	727
WI	ASHWAUBENON	KGRB	GRB	72645	44	29N	088	08W	208
WY	RIVERTON	KRIW	RIW	72672	43	04N	108	28W	1697

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