Western Region Technical Attachment

No. 08-01

March 25, 2008

Evaluation of the Real Time Mesoscale Analysis (RTMA) and the MatchObsAll (MoA) Analysis in Complex Terrain

Mike Soltow and Kirby Cook

National Weather Service, Seattle, WA

Introduction

Temperature analysis systems are a crucial part of forecast operations. These analysis systems serve several purposes, including aiding in the creation and verification of gridded forecasts. In regions of complex terrain that have relatively few surface observations, such as the Cascade Mountains in the Pacific Northwest, it is crucial to have a representative analysis against which a forecast can be verified. At the Seattle weather forecast office (WFO), two analysis systems are currently in use: the MatchObsAll (MoA) analysis developed by Tim Barker and Les Colin of WFO Boise, and the Real-Time Mesoscale Analysis (RTMA; De Pondeca et al. 2007). In order to determine which of these analysis systems is more representative in complex terrain, a data denial experiment was conducted at WFO Seattle in conjunction with the RTMA group at the National Centers for Environmental Prediction (NCEP) and the Global Systems Division (GSD) of the Earth Systems Research Laboratory (ESRL). Data from 14 observation sites in western Washington, including both lowland and mountain locations, were withheld from the MoA run locally at WFO Seattle and the parallel run of the RTMA from 6 July - 31 October 2007. The two analyses were then compared to the withheld temperature data to determine their relative correspondence to the actual observations.

Analyses Background

While there are a few similarities between these two analysis systems, there are many important differences. The RTMA uses 1-h forecasts from the 13-km Rapid Update Cycle (RUC) model downscaled to the 5-km National Digital Forecast Database (NDFD) grid as a background field (Benjamin et al. 2007). For temperature data, the vertical downscaling is carried out using the local lapse rate from the native RUC lowest 25 hPa layer, or in situations where the RTMA topography is higher than the RUC topography, values are interpolated from the native RUC levels to the RTMA surface (Benjamin et al. 2007). In addition, the RTMA ingests surface observations, including METAR, buoy, C-man and various Mesonet data from across the continental United States. The analysis scheme used by the RTMA is based on a 2D Variational (2dVAR) subset of the NCEP Gridpoint Statistical Interpolation (GSI) scheme (De Pondeca et al. 2007). The GSI scheme takes into account errors in the observations as well as the background field, and incorporates anisotropic covariance functions to prevent an observation's influence from stretching across complex terrain, such as a mountain range or ridgeline.

The MoA analysis, uses 12-km GFS-initialized MM5 (MM5gfs) forecasts generated by the University of Washington as its background field. For temperature data, the vertical downscaling in the MoA system uses the local lapse rate from the 12-km MM5gfs forecasts to bring the background field down to the MoA surface. Surface observations used by the MoA also include METAR, buoy, C-man and various Mesonet data. The MoA system is based on a much simpler analysis scheme than the RTMA. This scheme fits observations to the background field using a serpentine curve with simple horizontal and vertical weighting (Foisy 2003). A unique characteristic of the observation correction in the MoA, is the constraint that the analysis match the observation used in that particular grid box exactly.

While both analysis are downscaled and run on the same 5-km NDFD grid, there are significant differences in the topography used by each system. Both systems derive their

5-km topography from the USGS 30 arc second data set, however, this derivation is carried out very differently in each analysis (Jascourt 2008). The MoA system uses the same topography as the Graphical Forecast Editor (GFE) system that creates the NDFD grids at each WFO (Foisy 2003). This 5-km dataset is created by sampling the USGS 30 arc second dataset such that the point value nearest the GFE/NDFD grid point is assigned the elevation at that grid point (i.e. there is no smoothing or averaging carried out over the GFE/NDFD grid box). The RTMA topography is generated by averaging the 30 arc second USGS data over each 5-km gridbox (Benjamin et al. 2007). While this method produces more coherent terrain features in the RTMA, they tend to be smaller in amplitude than the NDFD (and MoA) topography (Jascourt 2008).

Data Denial Methodology

The experiment was conducted by withholding observations from fourteen sites from the two analysis systems. Seven lowland sites and seven mountain sites were chosen (Fig. 1). A program was then run that compared hourly analysis values at the nearest grid points to the corresponding withheld observations at the top of each hour. Over several different time periods, this program calculated the average difference, or bias error (BE), as well as the mean absolute error (MAE). Statistics were generated for the whole period of study from 6 July - 1 November 2007, and over cool sub-period from 1 October - 31 October 2007. For the cool sub-period, statistics were calculated using data valid at the 0900, 1000, 1100, 1200, 1300 and 1400 UTC hours only.

Results

Overall, both analysis systems had similar correspondence to the withheld observations during the period of study. The MoA and the RTMA exhibited MAE values ranging from 3.1 °C to 3.9 °C, respectively, when averaged over all sites for the entire period (Fig. 2). However, when broken down according to mountain and lowland sites, both systems had higher MAE values at the locations in complex terrain (ranging from 4.1 °C for the RTMA to 5.5 °C for the MoA) than those sites at the lower elevations (ranging from 2.1 °C for the RTMA to 2.3 °C for the MoA) (Fig. 2). Furthermore, when evaluated at each specific location, the MAE values for both analyses exhibit much more variability at the mountain sites than at the lowland locations (Fig. 3).

The BE values averaged over the mountain, lowland and all locations for the entire study period are shown in Fig. 4. The overall BE for both analyses is dominated by the large systematic errors at the mountain locations, where the MoA system exhibited a cold bias (-3.21 °C) and the RTMA a warm bias (1.14 °C). Conversely, the BE values over the lowland locations were small for both analysis systems (less than 0.5 °C). When the BE values for both analyses are examined according to site location (Fig. 5), a strong correlation between the systematic error over the period of study, and the disparity between analysis elevation and actual elevation (Fig. 6) can be seen. Sites with warm (positive) BE values correspond to sites where the analysis elevation is lower (negative) than the actual elevation. Conversely, sites with cool (negative) BE values correspond to sites where analysis elevation is higher (positive) than the actual elevation. In other words, the analyses were too cool where they were too high, and too warm where they were too low. This should make sense, given that the period of study occurred mostly during the warm months and the influence of strong, surface based inversions would have been limited. When the BE values for both analyses were examined for the relatively cooler period of 1 October - 31 October 2007, using only the morning hours (0900-1400 UTC) for comparison, the effect of surface based inversions and the disparity between analysis and actual elevation was seen at most of the mountain locations (Fig. 7). Sites that were too high, and generally too cool during the overall period, exhibited BE values that were relatively warmer during the October sub-period. Locations that were too low, and generally too warm over the overall period, exhibited BE values during the October sub-period that were relatively cooler than the longer termed averages. The sole exception to this correlation is site SKKW1, which actually exhibited an even larger cool bias indicating that there is some other factor driving the systematic errors in the analyses at this location.

An additional, and yet unexpected, result of this study was the discovery of a significant flaw in the topography used by the RTMA. While analyzing the data, the RTMA topography was found to be shifted slightly to the northeast (Fig. 8) due to the inadvertent use of non-mass grid points when the initial RTMA terrain was originally configured. This incorrectly shifted topography in the RTMA had potentially large implications, given the impact on the downscaling process and the position of topographically forced features in the RTMA. Indeed, the corrected topography shows significant improvements in the correspondence of the RTMA and actual elevation at several of the mountain sites used in this study (Table 1).

Conclusions

While both analyses performed similarly through the period of study, the differences between their performance at lowland locations and the mountain locations is significant. Both analysis systems exhibited much higher MAE and BE values when compared to the withheld observations at the mountain sites, such that the use of either analysis system in the creation and or verification of gridded forecasts in areas of complex terrain is problematic. The strong correlation between the analysis biases and the disparity between the analysis terrain and the actual terrain highlights the importance of improving the topography in both analysis systems. Better topography will reduce the large systematic errors in both systems that are contributing to the overall errors and improve the correspondence of the analyses to the point observations. It is somewhat reassuring that during this study, even with the incorrect topography, the RTMA performed slightly better than the MoA system relative to the withheld observations. This is true even at the locations in complex terrain. The correction to the RTMA topography should significantly improve its ability to represent temperatures in mountainous areas. In addition, improvements to the MoA topography, such as increased resolution, or a better sampling method for selecting the terrain used by the GFE and NDFD would likely improve the performance of the MoA in complex terrain as well. A second, more complete data denial experiment should be conducted to fully evaluate impact of improved topography on both analyses.

Acknowledgements

We would like to thank Manuel Pondeca (NCEP/EMC) for all of his effort in setting up and managing the observation withholding in the RTMA. Additional thanks are extended to Lee Anderson (OST), Geoff Dimego (NCEP/EMC), Dave Myrick (WRHQ/SSD), Stan Benjamin and the Assimilation and Modeling Branch at ESRL/GSD for their work in identifying and correcting the RTMA topography problem.

References

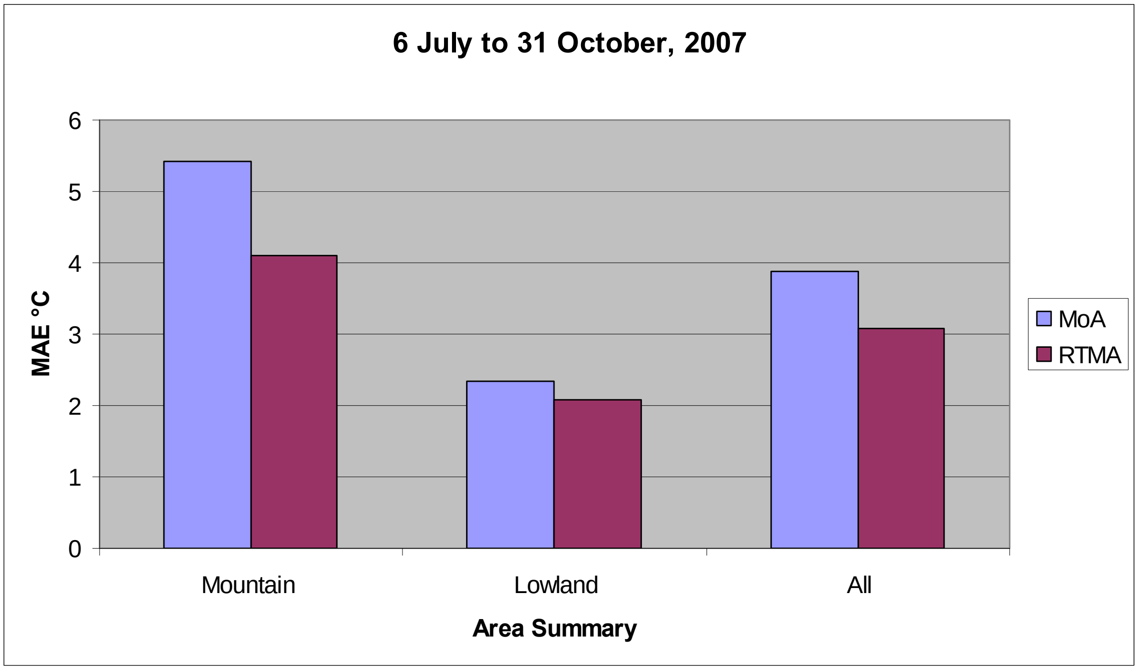
Benjamin, S., J. M. Brown, G. Manikin, and G. Mann. "The RTMA background – hourly downscaling of RUC data to 5-km detail." *23rd Conf. on IIPS,* San Antonio, TX, Amer. Meteor. Soc., P1.4.

De Pondeca, M., and Coauthors, 2007: The status of the Real Time Mesoscale Analysis at NCEP. Preprints, *22nd Conf. on WAF/18th Conf. on NWP*, Park City, UT, Amer. Meteor. Soc., 4A.5.

Foisy, T, 2003: The MatchObsAll Analysis System. Western Region Tech. Attachment 03-02. [Available online at http://www.wrh.noaa.gov/wrh/03TAs/0302/index.html.]

Jascourt, S. A., cited 2008: Real Time Mesoscale Analysis (RTMA). [Available online at http://www.meted.ucar.edu/nwp/RTMA.]

Figure 1: Location of withheld observation sites in Western Washington.



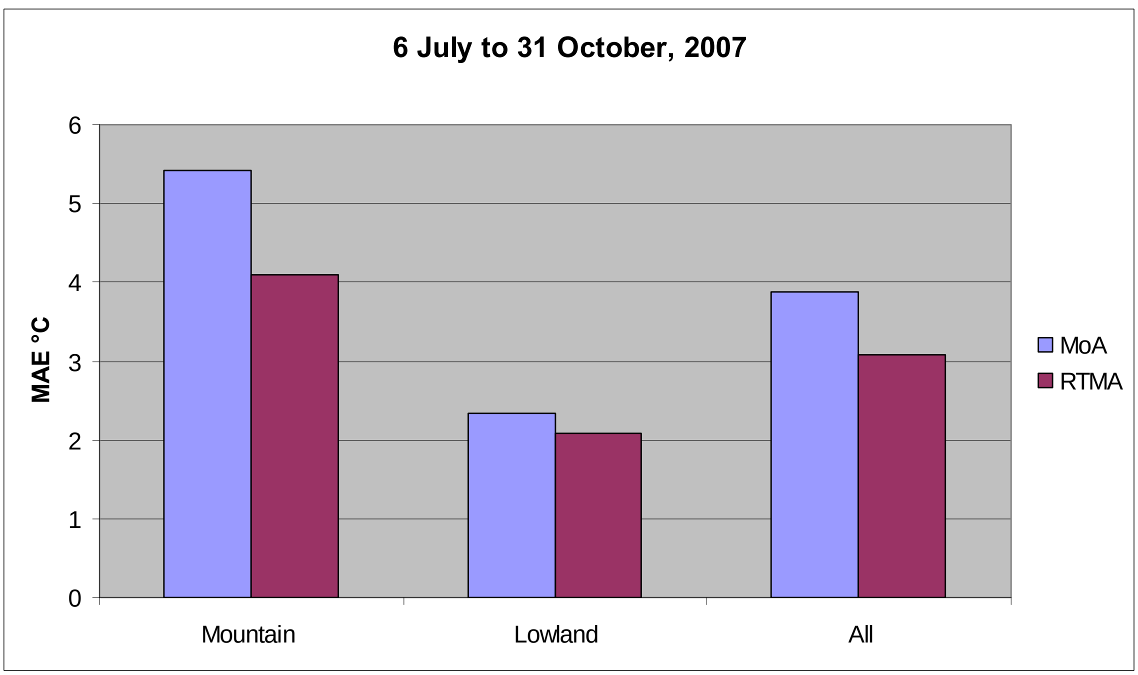


Figure 2: Mean Absolute Errors averaged for the mountain locations, lowland locations and over all the locations.

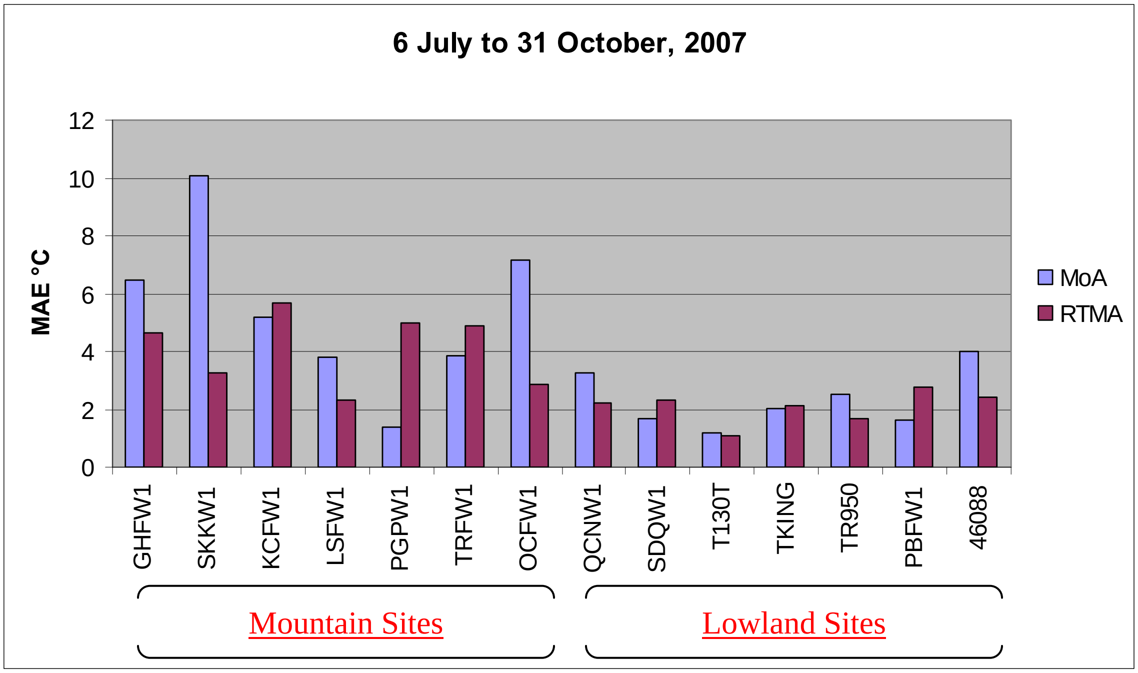


Figure 3: MAE values at each site for the period of 6 July - 31 October 2007

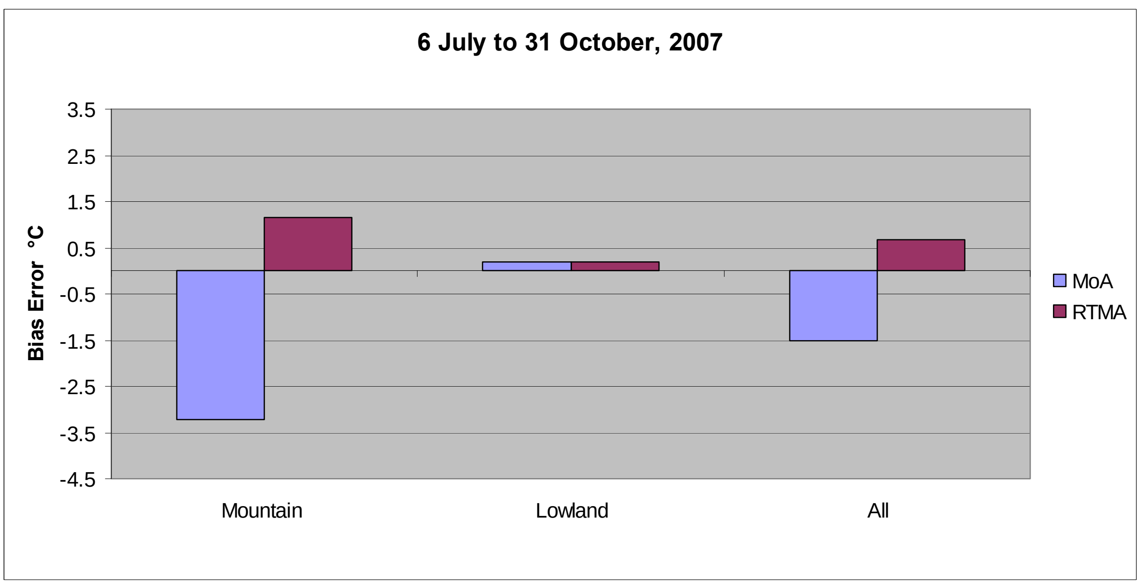


Figure 4: Bias Errors over the mountain locations, lowland locations and all locations for the period of 6 July - 31 October 2007.

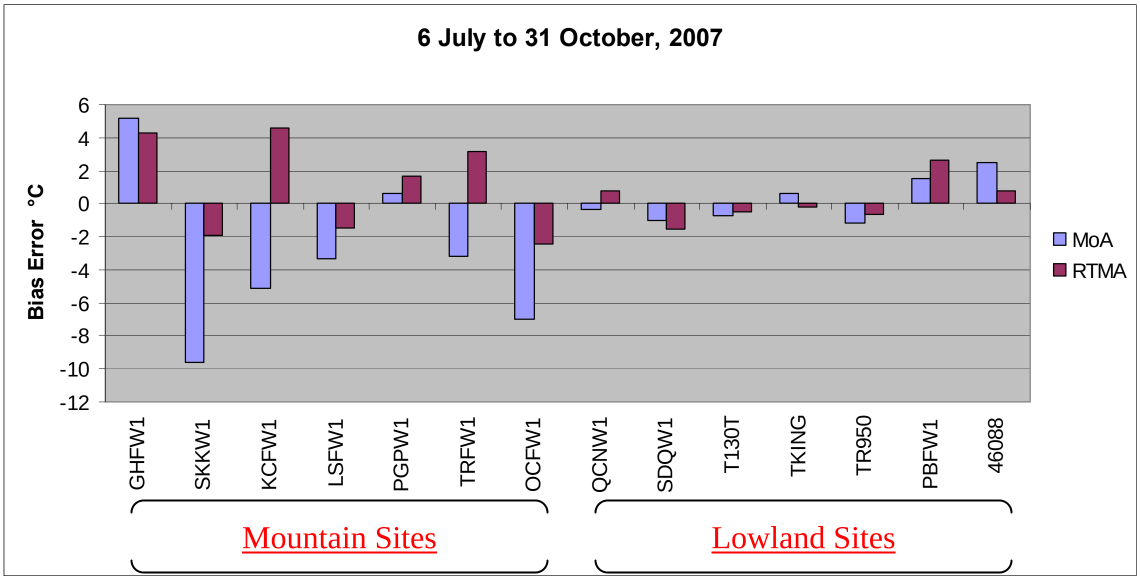


Figure 5: Bias Error for each site generated from the period of 6 July - 31 October 2007.

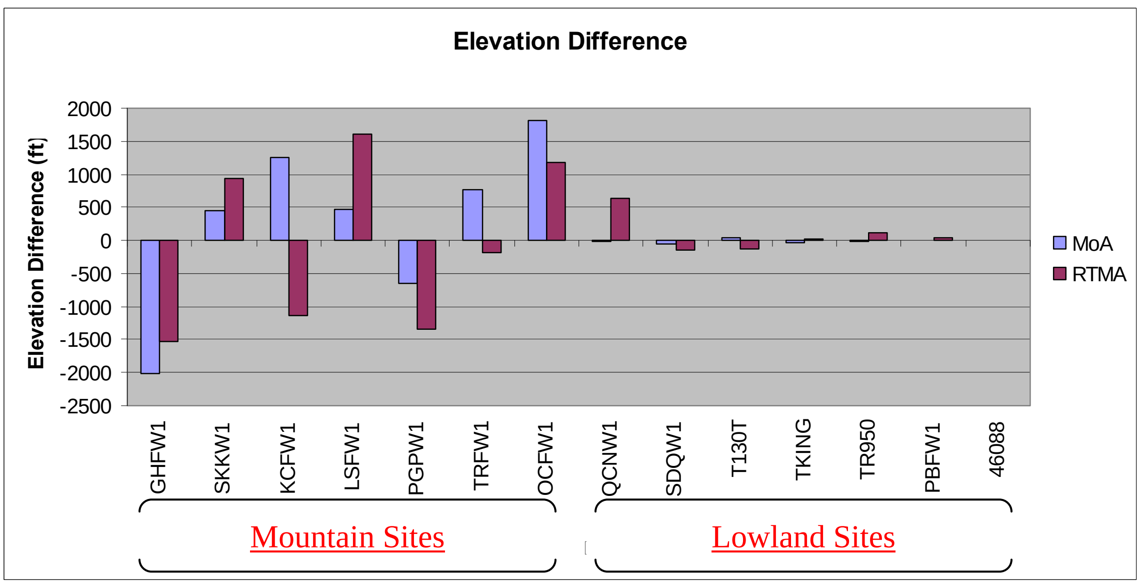


Figure 6: Elevation differences in feet between analysis elevation and actual elevation at each site.

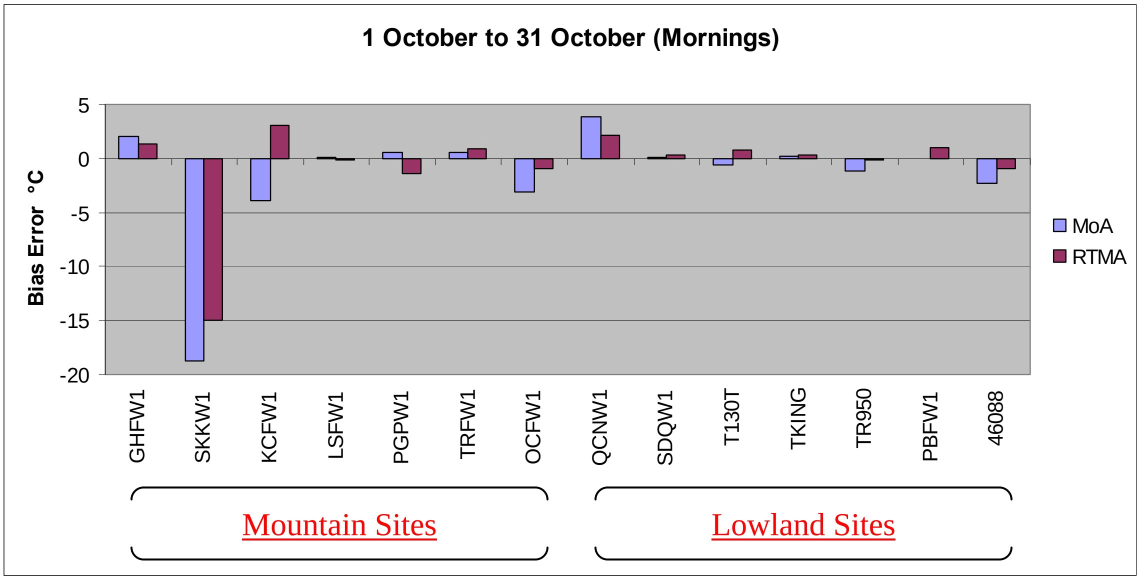


Figure 7: Bias Error for each individual site during the period of 1 October - 31 October 2007, using the 0900, 1000, 1100, 1200, 1300 and 1400 UTC times only.

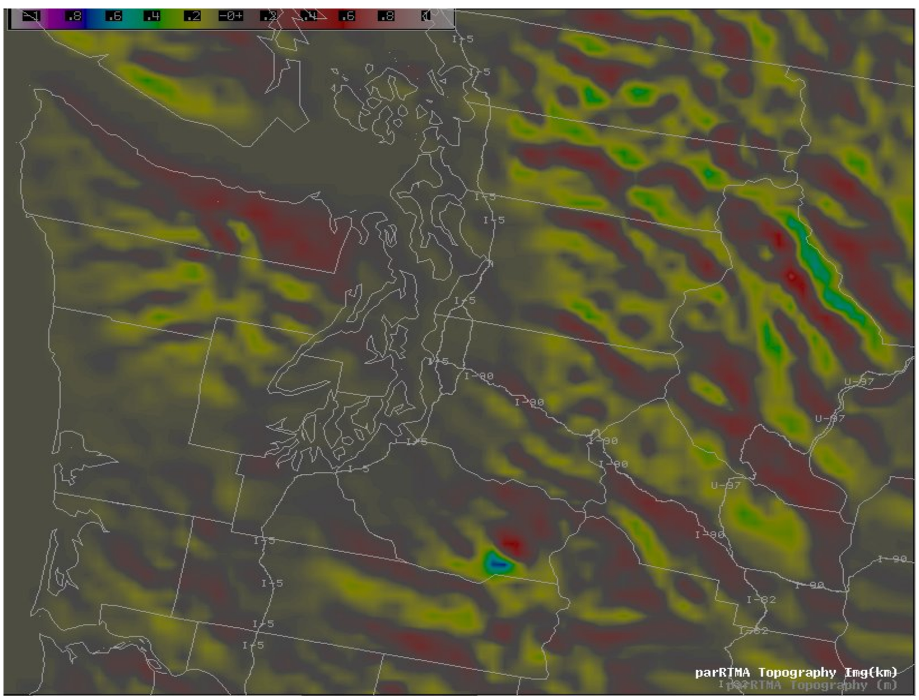


Figure 8: Difference between the incorrect and correct RTMA topography in kilometers. Red represents areas where the incorrect topography is higher than the corrected topography. Yellow and green areas are where the incorrect topography is lower than the correct topography.

Table 1: : MoA, RTMA-incorrect, RTMA-corrected and actual elevations in feet at each of the 14 withheld observation locations. Values shown in red correspond to analysis elevations that are significantly higher than actual, those shown in green are analysis elevations that are significantly lower than actual.

	Site	MoA	RTMA-incorrect	RTMA-corrected	Actual
Mountain Sites	GHFW1	1007	1495	1772	3018
	SKKW1	2444	2943	3198	2001
	KCFW1	4251	1862	3009	2999
	LSFW1	2089	3227	2826	1614
	PGPW1	5255	4557	4615	5899
	TRFW1	4389	3436	3621	3615
	OCFW1	4353	3726	3937	2549
Lowland Sites	TR950	200	324	321	213
	TKING	0	59	37	33
	SDQW1	98	4	110	154
	QCNW1	52	697	346	62
	T130T	400	230	283	354
	PBFW1	0	52	26	7
	46088	0	0	0	0