May 2010

An Inter-Comparison of the NMS and Field Observations for an Orographically Enhanced Precipitation Event at Mt. Werner in Colorado

Daniel Clement

Department of Atmospheric and Oceanic Science, University of Wisconsin-Madison

5 May 2010

ABSTRACT

The inter-comparison of numerical model forecasts and actual observations is an important step in assessing the validity of forecasting systems. This research details an inter-comparison of the UW-NMS and field observations of precipitation for a snowfall event that occurred from April 1st to April 2nd, 2010 at Mt. Werner near Steamboat Springs, Colorado. Measurements and calculations of precipitation in inches of H2O throughout the duration of the event were compared to the NMS predicted values. The results validate the NMS, showing that it accurately predicted the precipitation with an average difference between NMS output and field observations for precipitation of .26 inches of water which equates to about 2.41 inches of snow for this case. The NMS also accurately forecasted the distribution trend of snow throughout the Mt. Werner area with snow heights increasing up the mountain and maximizing at the peak.

---

1. Introduction

Numerical forecast models can be a very useful tool for forecasters. But unless their biases are understood by the forecaster, they can be terribly misleading. That is why it is important to test the model output data against actual observations in order to get a better understanding of the model's biases. This strategy is particularly important in mountainous regions where there is very little radar penetration. In these areas, the precipitation cannot be easily estimated based on radar echoes, making field observations the most effective way to validate a model for an orographic precipitation event. This is certainly the case for Mt. Werner near Steamboat Springs, Colorado. The area of interest on Mt. Werner for this research was oriented in a way where orographically enhanced precipitation will be favored for a northwesterly flow as the complex topography around the region blocks most of the flow out of other directions. Thus, models tend to predict snowfall for Mt. Werner with much more accuracy when there is a uniform flow out of the northwest than when there is a more complex flow out of other directions. Usually between March 26 and April 4, the flow over Mt. Werner is not uniformly out of the northwest. As a result, it was hypothesized that the model would struggle to produce output for precipitation amounts that is consistent with field observations.

2. Methods

A snow board was used to collect fresh snow for each snowfall, and a ruler was used to measure the height of accumulated snowfall. The snow boards consisted of simply a smooth wooden board roughly 12"x18". A Snowmetrics clear snow tube was used to gather the fresh snow. The tube was a 12" long and clear with a corresponding hanging scale. The scale was calibrated to give the inches of water for 12" of snow when the tube was full. In addition, high-resolution NMS model output centered over the area of interest was used for comparison to observations.

Field measurements of inches of water and snow accumulation were recorded. The snowmetrics snow tube and hanging scale were used to measure the equivalent water in inches and millimeters for 12 inches of snow. From these measurements, a ratio between the equivalent water and the height of the snow was calculated. In order to get an accurate ratio for inches of water to inches of snow for the entire depth of the snowfall, snow density measurements were made throughout the column and averaged. Model output of the high resolution NMS model centered over the Steamboat Springs ski area at Mt. Werner in Colorado was collected to be compared to field observations.

3. Procedure

Snow height and equivalent water were measured over a mountain ridge for a single orographically enhanced precipitation event between March 27 and April 3. Measurements were recorded along a Northwest to Southeast axis extending from the valley on one side of the mountain, over the peak and down to the opposite side of the mountain. There were six sites total where measurements were taken. Each snow board was placed at the base of a snow pit. The dimensions of the snow pits varied, but each was about two feet deep with a radius of two to three feet. This allowed for the snow to fall onto the snowboard while the walls of the snow pit would protect the accumulated snow from the drifting effects of the blowing wind.

After the snow event, each site was visited and the accumulated snow height was measured. In addition, the Snowmetrics snow tube was used to measure how many inches of water had fallen during the precipitation event. In order to take into account the effects of the weight of the fallen snow packing down the bottom layer of snow, snow density measurements were taken at the surface and at the bottom layer of the new snowfall. The average of the two values was used as the estimated snow density for the entire snowfall depth. This data was compared to the model output of the high-resolution NMS model in order to verify the model for meso-scale orographically enhanced precipitation. The inter-comparison of the model output and actual observations was analyzed to validate the NMS model.

The snow boards were placed strategically from the valley of Mt. Werner to the Northwest of the peak to the valley southeast of the peak. The first snow board was placed at 8000ft on the northwest side of the mountain. The next snow board was placed at 8410ft up the northwest face of Mt. Werner. The next snow board in line was placed at 9008ft followed by the next site at 9851ft. The next was placed at the peak of Mt. Werner at 10544ft with the final site located southeast of the peak down to 9994ft. The line of snow board sites extended about 3.4 kilometers and is depicted in Figure 1.

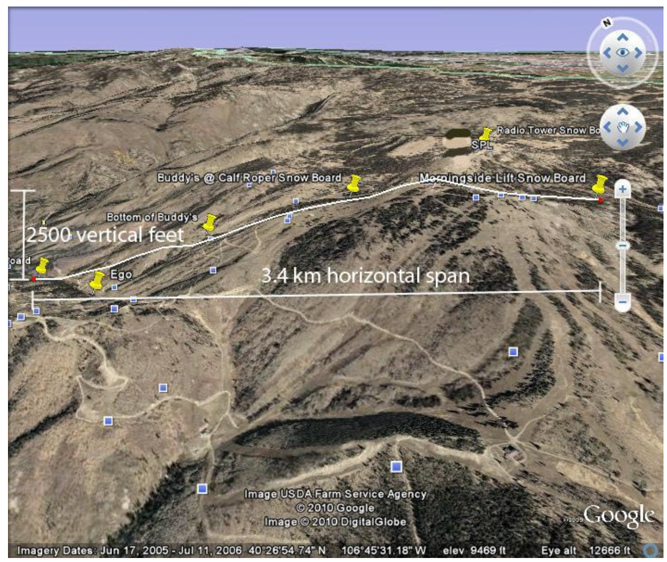

FIG. 1. The line of snow board stations is depicted stretching from the valley to beyond the peak of Mt. Werner. Each site is depicted by a yellow pushpin graphic.

4. Results

Between March 26 and April 4, 2010, there was only one precipitation event. The event occurred beginning around 06UTC on April 1st lasted until roughly 1930UTC on April 2nd when the snowfall amounts were measured. The snowfall amounts are detailed in Figure 2 along with the snowfall density measurements for the top and bottom layers of the fresh snowfall and their average. In addition, figure 2 lists the equivalent H2O in inches.

Figure 2 also contains the snowfall amounts predicted by the NMS model for this precipitation event as well as the difference between the NMS forecasted values and the actual observed values.

Sites/Elevation(ft)	"water/" snow top	"water/" snow bottom	"water/" snow average
1/8000	0.0583	0.1792	0.11875
2/8410	0.0542	0.1875	0.12085
3/9008	0.0333	0.1583	0.0958
4/9851	0.1042	0.175	0.1396
5/10544	0.0392	0.1617	0.10045
6/9994	0.0292	0.14	0.0846

Inches of Snow	Equivalent H2O (in)	NMS Precip (in)	Difference of Values
10.75	1.276562	1.075	0.20156
11.75	1.41998	1.142	0.27798
12	1.1496	1.217	-0.0674
11.5	1.6054	1.276	0.3294
19.5	1.9587	1.358	0.6008
17	1.4382	1.319	0.1192

FIG. 2.

Figure 2 also shows the difference between the NMS forecasted values of precipitation and the recorded observations from the snow board sites for each location.

5. Discussion

The difference between the NMS and the field observations varied from the lower elevations to higher elevations. At the third site, the smallest difference was established at .0674 inches of water which in this case equates to.7 inches of snow. At the summit, the largest difference was recorded at .6 inches of water equating to 6 inches of snow for this case. The average difference between the observations and NMS forecast for new snow fall for the six sites was only 2.41 inches.

Due to their nature, there is room for error associated with the field measurements. Each snow board site was positioned in slightly different ways regarding their relative position to trees, buildings, open areas and exposed areas throughout the ski area. These may have affected the drifting of the snow in ways that the NMS may not have been able to pick up on. As a result, these small scale interactions which affected the way the snow built up in the snow pits introduced error. The manual measurements made using the Snowmetrics snow tube and hanging scale also introduced human error into the field measurements.

The NMS accurately captured the trend of the precipitation amounts. The field observations show that the snowfall increased up the Northwest face of the mountain with the highest value occurring at the peak of Mt. Werner with one outlier in the data. This trend is observed in the NMS output shown in figure 2. The single site down the Southwest face of the mountain received less than the peak site, which is a trend that was picked up NMS. Analysis of figure 2 shows that though the NMS forecasted precipitation varied from site to site, it did capture the dynamics of the flow enough to accurately predict the trend of the snowfall throughout the Steamboat Springs ski area. This observation is significant because the human and procedural errors are assumed to be fairly consistent from site to site, leading to the conclusion that the errors don't affect the trends as much as the snowfall measurements. As a result, the fact that the observed trend matches up with the NMS predicted trend for total precipitation is a concrete finding.

6. Conclusion

The hypothesis for this experiment stated that the NMS would struggle to forecast the precipitation amounts for Mt. Werner because usually the winds are not uniformly out of the favorable Northwest in late March and early April. For this case, the NMS did not struggle to predict the precipitation amounts on Mt. Werner with an average difference between model output and observations of only 2.41 inches of snow. Figure 3 shows that the flow during this event was almost uniformly out of the

Northwest, which is favorable for the NMS predicting precipitation. The hypothesis for this experiment assumed a non-uniform flow and was thus proven invalid for this experiment. Instead, analysis of the NMS output and field observations lead to the conclusion that the NMS is capable of providing an accurate, valid forecast for precipitation amounts for such cases as outlined in this research.

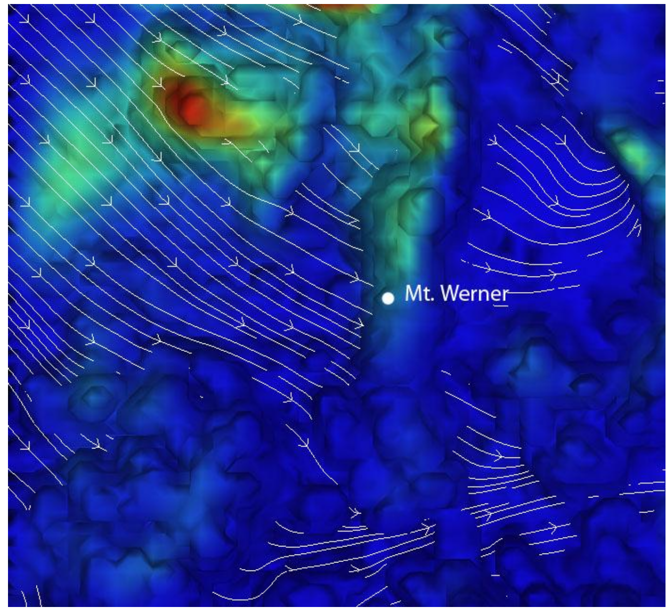

FIG. 3. NMS model output valid 00Z Friday April 2, 2010. Color fills represent precipitation amounts along the topographic surface. White streamlines correspond to the wind field.

REFERENCES

Wetzel, M., et al. 2004: Mesoscale snowfall prediction and verification in mountainous terrain. *Weather and Forecasting*. **19,** 806-823.