The Testing of an Experimental 10% Probability of Exceedance Wind Gust Grid at WFO Elko

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1. Introduction

Since the dawn of the IFPS (Interactive Forecast Preparation System), there has been an increased effort across the National Weather Service (NWS) to produce products in probabilistic format. A number of NWS Weather Forecast Offices (WFOs) have begun experimenting in this area (e.g. WFOs Milwaukee, Tulsa, Pendleton, and Las Vegas). A few years ago, the National Research Council's (NRC) Committee on Estimating and Communicating Uncertainty in Weather and Climate Forecasts published a paper called "Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts" (NRC, 2006). In this paper, the committee recommended that "the entire Enterprise should take responsibility for providing products that effectively communicate forecast uncertainty information," and that the "NWS should take a leadership role in this effort."

Inspired by the call put forth by the NRC, the National Weather Service in Elko, NV (LKN) developed a product called the "Experimental 10% Probability of Exceedance Wind Gust Grid (G10)." G10 displays the upper end of the wind gust spectrum that would be expected 10% of the time for a 12-hour period.

2. Forecast Process

The G10 was intended to capture the highest 10th percentile of wind gusts created primarily by four phenomena: convection, the mixing of the synoptic-scale boundary layer winds down to the surface, strong downslope (leeside) winds, and inversion break-up winds. The product was generated in the IFPS's GFE (Graphical Forecast Editor) by a procedure (G10_Proc) that takes the higher of two elements for each grid point. The first is the highest wind speed in the mixed layer for the forecaster's model of choice, with the depth of the mixed layer determined by forecaster's mixing height grid. The second is the maximum sustained wind speed from the forecaster's wind grids (for a 12 hour period) multiplied by a factor called a "gust multiplier." This creates a gridded first-guess G10 field that the forecaster can then adjust as necessary for downslope winds, convection, and other phenomena. During the cooler season, the "G10_Proc" procedure would use only the gust multiplier to initialize the G10 forecast grid, since mixing heights were not available.

The multiplication factor, or gust multiplier, was developed using empirical data from ASOS and RAWS sites across the forecast area. Observations from April 30th through August 15th, 2008, were compiled to create the multiplier. It was calculated by first finding the highest gust for the 12 hour period (16Z-04Z and 04Z-16Z) and then dividing the highest observed wind gust by the associated sustained wind. This average gust multiplier was plotted versus sustained winds and a best fit curve was then calculated (Fig. 1). The average multiplier ranged from a factor of 5.0 for very low wind speeds to 1.5 for high wind speeds.

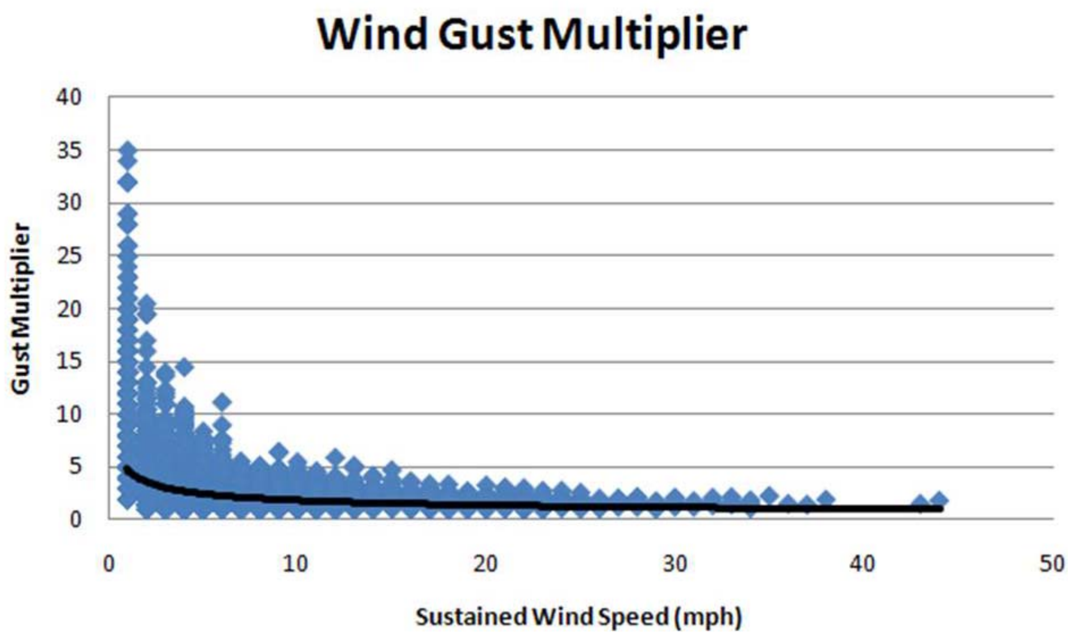

Figure 1: Average wind gust multiplier.

$$Average\ Gust\ Multiplier = 4.238 \times Sustained\ Wind^{-0.3775}$$

The next step was to take the highest 10 percent of gust multipliers for each sustained wind speed and plot this subset of values to create a second best fit curve (Fig. 2), which is the "G10 curve." This is the curve that is used by the procedure "G10_Proc" to help create the first-guess G10 field. Multipliers for G10 range from values greater than 4 for very low sustained wind speeds to 1.5 for very high wind speeds. For wind speeds higher than 30 mph, the multiplication factor was set to 1.5. For wind speeds lower than 4 mph, the actual G10 was set to 11 mph.

G10 forecasts were disseminated at 0006Z and 1206Z, shortly after the primary forecast issuance times. Each forecast (Fig. 3) consisted of a first period grid and a second period grid, each of which covered 12 hours (04Z-16Z or 16Z-04Z) for a total of 24 hours. The G10 grid images (12 and 24 hour forecasts) were sent to the web twice a day as an experimental product from May 4th, 2008 through Oct 31st, 2009. A link was posted on the LKN main web page and a link for comments from users existed on the G10 website.

3. Verification

Verification of the forecast G10 grids was performed several times a week. The forecast grid points that contained RAWS and ASOS sites were compared to the max observed

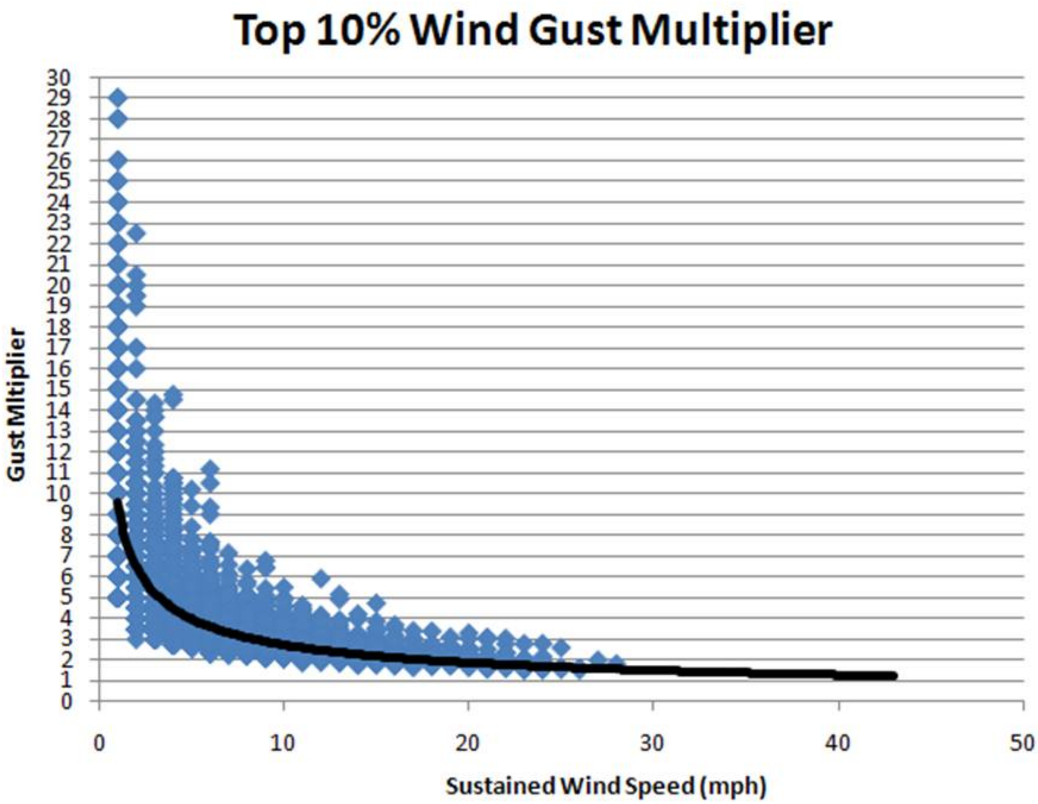

Figure 2: Multiplication factor for the top 10% of wind gusts.
$$\boldsymbol{G10\ Multiplier = 9.6534 \times Sustained\ Wind^{-0.5524}}$$

gusts for the appropriate time period (16Z-04Z or 04Z-16Z). The verification tested overall forecast skill, but only indirectly tested the performance of the G10 multiplier, since: a) the "G10_Proc" procedure would pick the model wind for a grid point if it was higher than the G10 multiplier, and b) the forecaster was able to edit the grid before sending it out.

Overall, we were able to approach the target 10% average exceedance over a period of time. Table 1 shows verification statistics for two to three month periods. However, it is important to note that the data used to derive the multiplication factor were only from April 30th to Aug 15th, 2008. Also, the multiplication factor used changed five times in 2008 before the authors settled on the final version on Jan. 1st, 2009.

Generally, winds exceeded the forecast G10 more during the daytime period (16Z-04Z) than the nighttime period (04Z-16Z). Winds also exceeded the forecast G10 more often during the convective season. After eliminating the top three (RBVN – 42.4%, RLKN – 22.1%, CCRN – 19.6%) and bottom three (BCSN – 0%, CTLN – 1.9%, CEND – 2.8%) sites, the overall exceedance of forecasted gusts was 10.4% over both day and night periods.

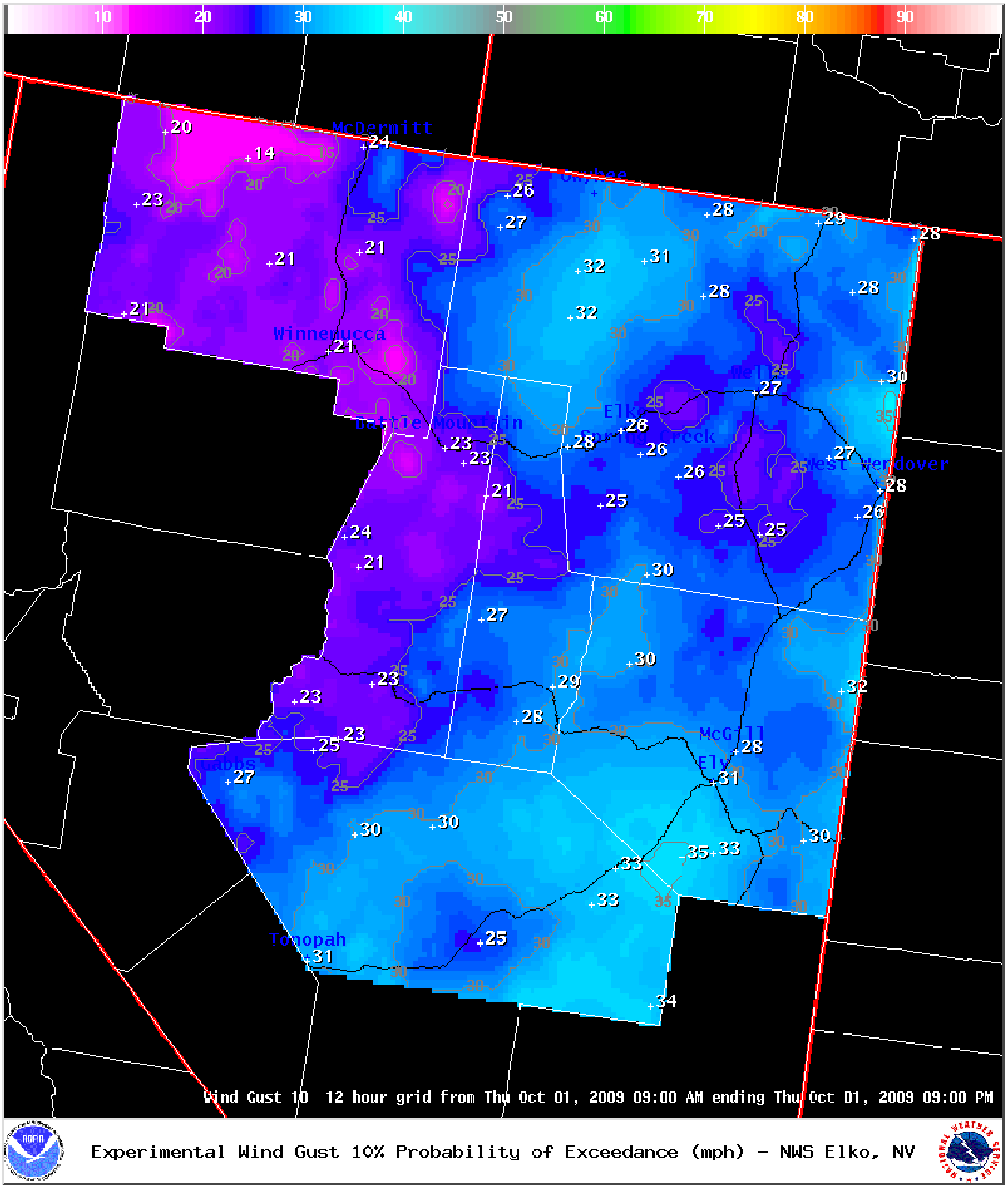

Figure 3: Example G10 forecast grid, valid from 9 AM to 9 PM PDT on Oct. 1st, 2009.

Period	Day (16Z – 4Z)	Night (4Z – 16Z)
July – August 2008	13.5%	14.3%
September – November 2008	9.1%	7.7%
December 2008 – February 2009	8.9%	7.6%
March – May 2009	12.8%	9.2%
June – August 2009	21.1%	8.8%

Table 1: G10 verification statistics (average exceedence of wind gust forecast for the given period).

4. Future Ideas

4.1 Systematic Biases

We quickly realized that some individual sites were consistently under-forecast due to the considerable terrain challenges in our forecast area. Ruby Valley (RBVN2) RAWS site was a classic example of this. This site is located on the lee slopes of the Ruby Mountains (oriented NNE to SSW) and is susceptible to downslope wind events. Alligator Ridge (ALRN2) is another example of a site that was consistently under-forecasted, in this case due to funneling of the winds. Forecasters were asked to try to account for these systematic biases by manually increasing the wind gust grids for these areas when needed. To account for these biases, one possibility would have been to create a bias corrected version of the G10.

4.2 High-resolution Model Data for Convection

Given the abundancy of convection across Nevada during the summer, it would be beneficial to include a mechanism for predicting wind gusts due to convection. The 5-km WRF (NMM or ARW) models, run locally at WFO Elko, can be very helpful in pointing to the possibility of convection. Figure 4 is a screen capture from GFE showing outflow winds from a 5-km WRF NMM forecast for southeastern White Pine County. The forecast is valid at 21Z on May 21, 2009. The winds range from < 10 kts outside of the outflow, to 38 kts inside the strongest outflow winds in the northwestern cell. Figures 5 and 6 show the NMM forecast winds and forecast composite reflectivity, respectively, for the entire LKN forecast area, valid at the same time as Figure 4. The high resolution models may not always be correct on the location of convection, but they do show a signal that there will be gusty winds from convection in the region. So it is possible that this type of forecast output could be used by applying a buffer or area of influence around outflow winds to account for uncertainty. The wind speeds would probably need to be increased slightly as well when using them for a 10% probablity of exceedance. Using a high-resolution WRF ensemble might be another approach.

4.3 High-Resolution WRF ARW Model Output

Another option is to use WRF ARW model output to derive a 10% probability of exceedance wind gust grid. The benefit of this methodology is that the WRF ARW does well at picking up terrain induced winds, i.e. downslope wind events. However, the high amount of wind variability due to convection in the summer would need to be addressed as well.

4.4 Multiple Curves

It would also be possible to calculate multiplier curves for different weather regimes, based on historical data. For example, days could be classified as slightly, moderately, or highly convective; non-convective; downslope; etc.; with the forecaster being able to pick which multiplier curve to use for a give forecast. In addition, edit areas could be used to apply different curves to different portions of the forecast area.

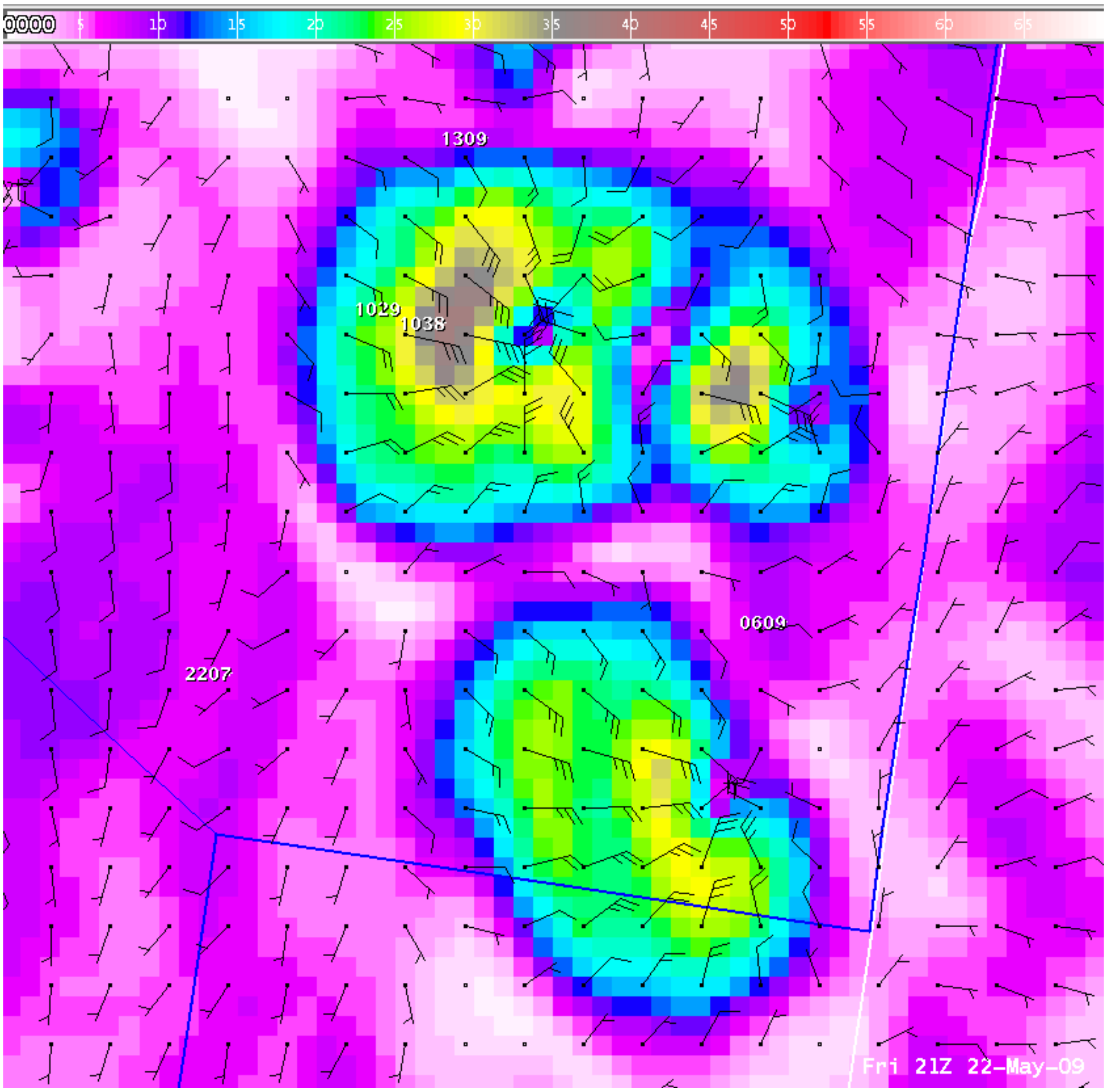

Figure 4: Surface winds predicted by the 5-km WRF NMM at 21Z on May 21, 2009; viewed in GFE.

4.5 Forecaster Subjectivity

During the experiment, the amount of adjustment and modification of the first-guess field changed day-by-day, depending on who was forecasting and what weather regime was in place. On rather stable days, forecasters would usually just run the tool and go with the output. On convective days or days when strong downslope activity was expected, forecasters would increase the G10 values as appropriate. However, as with all forecasting, there was subjectivity, which resulted in some inconsistency from one forecast to the next.

A better plan might have been to keep the forecast in-house for a hands-off test period, during which there would be no forecaster input. This would have allowed for a more objective assessment of the key components of the process, such as the G10 multiplier.

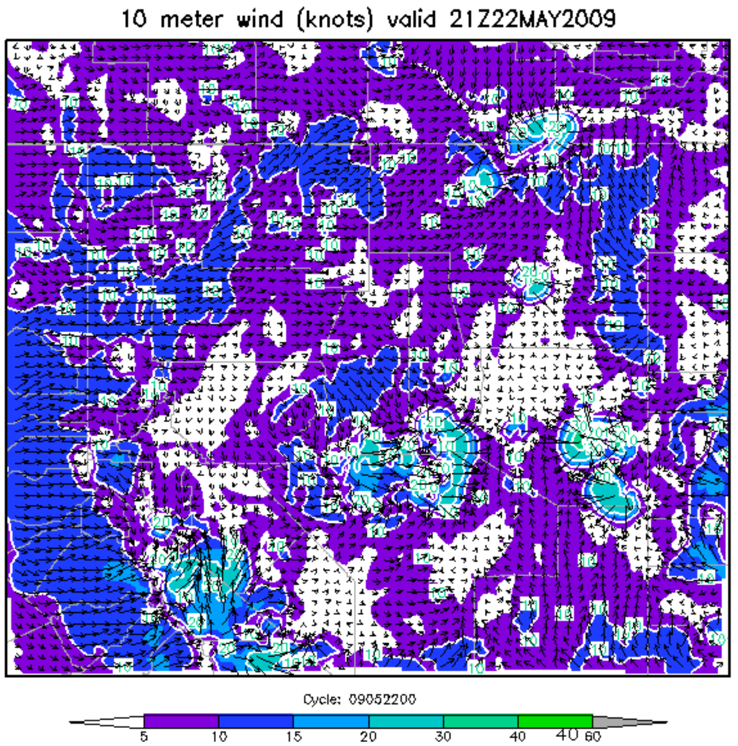

Figure 5: Surface winds predicted by the 5-km WRF NMM, valid at 21Z on May 21, 2009; viewed in GrADS software (Leins, 2009).

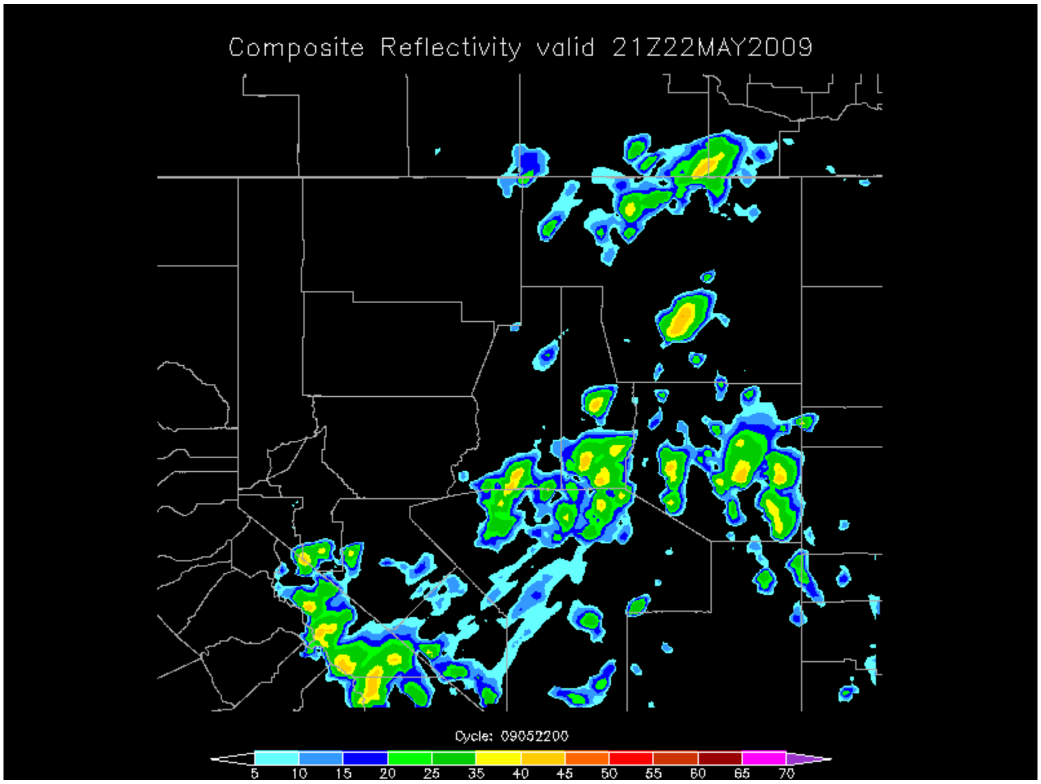

Figure 6: Composite reflectivity predicted by the 5-km WRF NMM, valid at 21Z on May 21, 2009; viewed in GrADS software (Leins, 2009).

These components could then have been tweaked or adjusted as necessary, following which the forecast could have gone public as an experimental product with forecaster input. This methodology would also have the advantage of determining whether or not forecaster input added skill to the product.

4.6 Customer Feedback and Relations

Based on the limited number of survey responses on the G10 product, the primary users were the fire weather community and the general public. For example, one survey response was from a member of the general public who was using the information for transportation purposes. Another response was from a fire weather customer who liked the fact that it "gives a forecast of a worst case scenario for winds" and that it can help predicting fire spread potential. On the negative side, some respondents hoped that there could be a zoom feature or another way to see locations better.

If this product were introduced in a forecast area with a greater population, the number of responses may have been significantly larger, and other user groups may have become more evident. For example, construction and marine interests are two user groups who would probably be interested in the potential for excessive wind gusts.

Based, however, on the limited number of survey responses in the LKN area, it was apparent that the number of users of this product was low. As a result, it was decided to discontinue this product for the time being.

5. Summary and Conclusions

If potential improvements are tested in the future, such as some of those discussed in this paper, it may be appropriate to re-introduce the G10 on a test basis. However, several aspects are important to such an effort. First, the improvements would need to be tested in-house first, *without* forecaster input, to establish a verification baseline. Secondly, the product would need to be tested in-house *with* forecaster input to determine whether or not any additional skill is added. Thirdly, more interaction with users during this test phase would be needed to find out more specifically what their needs are. Fourth, the product would need to be advertised more effectively on the LKN home page. Fifth, forecaster training is essential to providing value-added edits to the product. After all of these steps are undertaken, the G10 could be re-introduced as an experimental forecast product for an additional one-year period of review.

There are many benefits that can be gained from creating an experimental product. It boils down to the generation of new ideas in an attempt to better serve the customer. In addition to the thoughts listed in section 4, there were two other benefits that resulted from the G10 experiment. First, by using GFE to create the gridded probabilistic product, WFO Elko created an innovative way to display experimental probabilistic data. Second, a wind gust curve for calculating the average wind gusts for our daily public forecasts in GFE was also created (Wind Gust Multiplier, Fig, 1). The equation was incorporated into a smart tool, "WindGust_fm_Wind_Eqn", which can be found on the Smart Tool Repository (Knutsvig, 2009).

The purpose of this paper is to document the venture undertaken at WFO Elko in creating a probabilistic product, the G10. The potential value of this product may be sufficient enough that it will be revisited in the future with additional improvements, either here in LKN or at another forecast office.

Hopefully, in the more general sense, this endeavor will serve as a reference to other offices considering the creation of probabilistic products.

6. References

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