Analysis of Ensemble and Gridded Forecast Performance for the 4-5 January 2008 Sierra Blizzard

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I. Introduction

During the period of 4-5 January 2008, a historically strong storm affected the Sierra Nevada Mountains and western Nevada. Snowfall of 3 to 5 feet *in 24 hours* was reported in the Sierra, with heavy rain[1] followed by a period of heavy snow in which 8 to 15 inches of snow fell on the lower elevations of northeast California and western Nevada. The bulk of the heavy precipitation occurred between 12Z 4 January and 12Z 5 January (Fig. 0). While heavy rain on the 4th over western Nevada was exceptional all by itself, winds combined with very heavy snowfall in the Sierra prompted the rare issuance of blizzard warnings for the 4th through early morning of the 5th. Travel was greatly disrupted by very heavy snow (up to 6" per hour) and wind, with Interstate 80 over Donner Pass being closed for almost 18 hours from the evening of the 4th until the morning of the 5th.

This paper will summarize the POP and QPF forecast performance of ensembles and models as well as the gridded forecasts from WFO Reno. Data used includes ensemble fields from the MREF (Medium Range Ensemble Forecast, sometimes referred to as GFS ensemble) and SREF (Short Range Ensemble Forecast), deterministic model runs of the GFS and ECMWF, the BOIverify gridded verification program, and QPE from the CNRFC. The focus of the summary is the Sierra Nevada Mountain range and a portion of far western Nevada (Fig. 1) where the most significant precipitation and perceived impact to the public occurred. The attempt will be to determine the level of certainty among ensembles both at long and short lead times and how that may have affected the forecast from the WFO.

A more in-depth study of this event is ongoing by Chris Smallcomb and Randy Graham, SOO SLC. This research will analyze performance of the ensemble forecasts leading up to this event on a larger scale and how the significant anomalies correlated to observed weather phenomena. It is anticipated that results will be published in the NWA E-Journal of Operational Meteorology this year.

Figures are hosted on the WFO Reno Internet since many contain loops. Click on the hyperlink to view the figures and associated captions.

[1] Including 1.26" of rainfall in 6 hours at the Reno-Tahoe International Airport between 18Z January 4 and 00Z January 5, which is more than the average *monthly* rainfall for January.

II. Ensemble and WFO POP Forecasts (Valid: 12Z 4 January – 00Z 5 January)

a. 5-7 Days Before Valid Time:

The ECMWF forecast via SmartInit indicated a high POP[2] for days 6-7 (valid time mentioned above for the Sierra and far western Nevada (Fig. 2), with the GFS showing a high POP but more confined to near the Sierra Nevada crest. Meanwhile, the GFS ensemble was indicating a significant 500 MB height anomaly and a high POP (probabilistic QPF of .10"/12 hours) for the Sierra at day 7 (Fig. 3). This is especially significant considering the coarse resolution (~105 km) of the MREF members.

In contrast to the ensembles and the deterministic ECMWF and GFS, the gridded forecast from WFO Reno indicated considerably lower POP values until 120 hours (morning forecast issuance on 30 December), by which time the POP was raised to 80% or greater for a large majority of the area of focus. It is unusual for forecasters to indicate high POPs for days 6-7, however given the ensemble data shown thus far, this may have been a case were we could have gotten an extra day or so of "lead time" on this system with high POPs.

By 120 hours or day 5, evidence for heavy precipitation potential had become overwhelming, vastly increasing forecaster confidence. Ensemble data was indicating a 500 MB height anomaly of over 3 standard deviations (SD) above normal along the coast of northern California and Oregon (Fig. 4) and a 250 MB u-wind anomaly of 2 to 3 SD above normal associated with a strong upper jet streak. A significant negative MSLP anomaly developed over northeast California and northeast Nevada valid at 00Z 5 January, with a tight MSLP gradient in the mean fields indicative of vigorous upslope flow impinging on the Sierra Nevada Mountains. As far as deterministic models, the ECMWF continued to show high POPs at day 5 with the GFS finally settling on high POPs after backing off somewhat between days 5 and 7.

By 120 hours, it was clear by all accounts that an exceptionally powerful storm was forthcoming. Potential widespread blizzard conditions began to be noted in special weather statements by NWS Reno on 30 December, as shown below.

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SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE RENO NV
353 AM PST SUN DEC 30 2007

...PROLONGED PERIOD OF WET AND WINDY WEATHER LIKELY LATE WEEK INTO NEXT
WEEKEND...

CONFIDENCE IS INCREASING WITH RESPECT TO SIGNIFICANT SNOWFALL IN THE SIERRA.
LATEST PROJECTIONS SUGGEST STORM TOTALS BETWEEN 5 AND 10 FEET OF SNOW ARE
POSSIBLE ALONG THE CREST WITH MULTIPLE FEET DOWN TO LAKE LEVEL AND HIGHER
ELEVATIONS ALONG THE EASTERN SIERRA. IN ADDITION...WINDS ARE FORECAST TO BE
UNUSUALLY STRONG WITH A POTENTIAL FOR WIDESPREAD BLIZZARD CONDITIONS.
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[2] High POP(s) defined for this paper as 75% or greater, which is considered "categorical" or "definite".

b. 1-5 Days Before Valid Time:

The POP forecast from the GFS ensembles, ECMWF, and WFO Reno changed little inside of 5 days for the Sierra and far western Nevada. Meanwhile, the GFS occasionally wavered on the eastward extent of high POPs during the 48 to 96 hour period, although this was likely a timing issue as GFS POPs valid after 00Z 5 January were consistently high.

Within 3 days of the 12Z 4 January to 00Z 5 January period, the SREF became available. It also showed a 90-100% chance of precipitation in the Sierra and extreme western Nevada on 4 January from the 21Z 2 January SREF run (not shown) all the way until the event.

c. Summary of POP Forecast Bias

Figure 5 shows the WFO Reno POP bias at various forecast hours for the Sierra and far western Nevada. There was an unsurprising movement from a very low POP bias at 168 hours to a significantly smaller bias by 60-84 hours as forecast confidence grew. There is a marked jump towards less bias at 120 hours, which corresponds to the major leap in forecaster confidence by that time, aided significantly by the increasing anomalies and probabilities in the ensemble forecast products.

As opposed to the WFO bias, the ECMWF (not shown) exhibited very little bias as it had high POPs over the Sierra and far western Nevada throughout the forecast period. Meanwhile, the GFS had a low bias persistent through much of the forecast (not shown).

III. Ensemble and WFO QPF Forecasts (Valid: 12Z 4 January – 12Z 5 January)

The period from 12Z 4 January through 12Z 5 January was used for QPF examination as this encompassed the bulk of the precipitation event. The GFS and ECMWF were indicating the potential for a significant precipitation event beyond forecast day 5. By 96 to 108 hours or 00Z 31 December, the GFS ensemble had an expansive *mean* 2.5" bulls-eye along the northern and central Sierra along with a 90% or greater chance of 1.0" of precipitation in 24 hours (Fig. 6). As mentioned earlier, this is an exceptionally strong signal for heavy precipitation in terrain-forced areas given the low resolution of the MREF members.

As the forecast time shortened to less than 84 hours, the SREF mean QPF and WFO QPF became available. Figures 7-12 show the progression of QPF bias and Figures 13-15 show trends in mean absolute error (MAE) from the 12-75 hour forecasts. The black rectangle highlights the general area of interest. Based on this information, WFO Reno performed comparably with most other model forecasts up until 36 hours before trending to a high bias/higher MAE from 18Z 4 January through 12Z 5 January. The ECMWF was the outlier among model bias and MAE, with a more erratic bias and worse overall MAE beyond 12Z-18Z 4 January.

IV. Summary and Conclusions

The blizzard of 4-5 January 2008 was a well forecast event even at days 5-7. Coupled with low spreads between the individual members, the MREF mean was indicating impressive negative anomalies of 3 to 4 SD in the 500 MB height and surface pressure fields at forecast day 5. This, along with similar forecasts from the deterministic ECMWF and GFS at long lead times gave Reno WFO forecasters the confidence to forecast very high POPs and the potential for an anomalously strong and disruptive winter storm many days in advance.

The combination of strong consensus among model forecasts and WFO efforts both in gridded forecasts and with text statements (namely SPS, AFD, and strongly worded WSW products) allowed for excellent overall service to NWS customers and the general public. We feel this storm should be treated as a role model of how to property blend use of ensemble data and forecaster knowledge to anticipate large scale high-impact events well in advance.