CNRFC National Verification Team Case Study
Presented on June 24, 2008 by Alan Takamoto

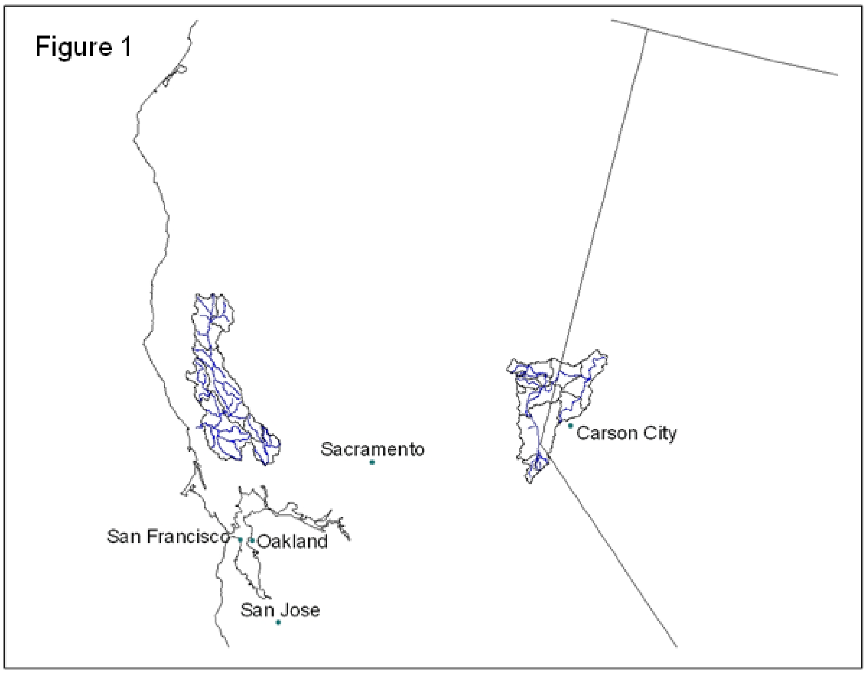
Abstract

This paper describes the implementation of the National Weather Service's Interactive Verification Program (IVP) for two flood events during the New Year's 2006 storm event in California and Northern Nevada. Flooding due to extreme precipitation events were examined for the Russian River basin in Mendocino and Sonoma counties in California and the Truckee River basin whose headwaters start just above Lake Tahoe in California's Sierra Nevada and eventually drains into Pyramid Lake in Nevada. Various statistical display tools are available from IVP, including scatter plots, time series plots, lead time statistics and categorical statistics. Statistical analysis were made for river flow, mean areal precipitation and mean areal temperature forecasts. Initial findings indicate significant under-forecasting of flow in the Truckee basin during the flood event which was brought out quite effectively on the IVP scatter- and time series plots for flow and mean areal precipitation.

Synopsis

This is an expansion of the case study of the 2006 New Year's Flood event on the Truckee River presented to the National Weather Service, Western Region Verification team on December 12, 2007. This study will also examine the flooding that occurred on the Russian River during the same New Years' event.
A rather productive stormy period occurred during December 26, 2005 through January 3, 2006. Soil moisture conditions increased with each passing storm until a large storm around December 28th and a significantly wetter event on New Year's Eve brought forecast points to above flood stage in California's north coast and Russian and Napa Rivers. Forecast points on the lower Truckee River in Nevada also rose above flood stage. Both the Russian and Truckee River basins experienced significant damage during the New Year's event, with about $108 million in damages to businesses and residences in Sonoma County alone. Major flooding occurred in Guerneville and Healdsburg. Northern Nevada experienced about $17 million in damages from the same event. Much of the commercial business area adjacent to the Truckee River in Sparks, Nevada, was 2 to 4 feet under water.

Refer to Figure 1. The Russian River basin drains into the Pacific Ocean and is generally subject to orographically enhanced rainfall events. The headwaters of the basin begin in Mendocino County and flow through Sonoma County. The basin size is in excess of 1300 sq mi. Major communities impacted include Guerneville and Healdsburg. The river forecast points studied include the Russian River at Hopland (HOPC1), the Russian River at Healdsburg (HEAC1) and the Russian River at Guerneville (GUEC1). The headwaters of the Truckee River start just above Lake Tahoe and eventually drain into Pyramid Lake in Washoe County, Nevada. The basin is located just east of the crest of the Sierra Nevada and is subject to "spillover" events, where under the proper meteorological conditions, copious precipitation can spill over the lee side of the Sierra crest into the Truckee basin. The basin size is over 1800 sq mi in size. The major towns affected by flooding events include the town of Truckee CA, and downtown Reno and Sparks, Nevada. Forecast points examined include the Truckee River at Farad (FARC1), the Truckee River at Reno (TRRN2) and the Truckee River at Vista (VISN2).



HOPC1: 362 sq mi
HEAC1: 793 sq mi
GUEC1: 1338 sq mi

FARC1: 932 sq mi
TRRN2: 1067 sq mi
VISN2: 1431 sq mi

This case study will compare the CNRFC performance of forecasting the Russian and Truckee River during the same major flood event.

Flow Scatter plots – Flow was generally under-forecast on the Russian River, at the highest discharge rates (Figure 2a). Flow was also under-forecast at the higher amounts on the Truckee River at Reno (Figure 2b).

Russian Scatterplots - Flow Truckee

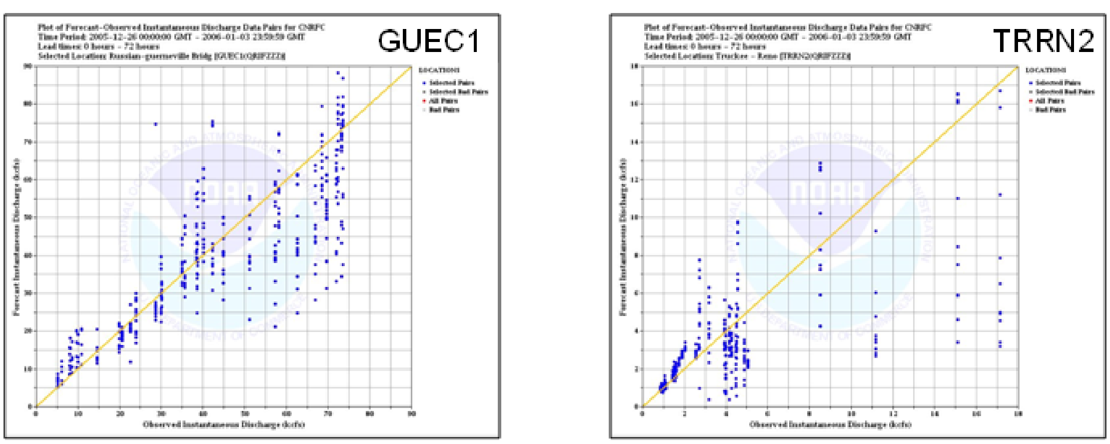


Figure 2a

Figure 2b

Time Series for Flow - The time series for flow reveals over-forecasting at the upstream stream gage on the Russian River at Hopland (HOPC1) during the first peak on 12/29/2005, under-forecasting during the 12/31 peak and over-forecasting during the small peak around 01/02/2006 (Figure 3a). Further downstream, there was over-forecasting at Guerneville (GUEC1) during the 12/29/2005 peak (Figure 3c) and flow was over-forecast during the damaging peak on 01/01/2006 when the river was significantly above Flood Stage. The recession was under-forecast after the 01/01 peak while it was above flood stage. For the Truckee River, the time series for the upstream point at Farad shows a definite under-forecast before the 12/31 peak (Figure 3b), but the river never reached flood stage. It was also under-forecast at Reno (TRRN2) downstream days before the crest on 12/31 (Figure 3d). The hydrologist was able to forecast near the actual peak at the Reno forecast point just a few hours before it occurred.

Time Series - Flow

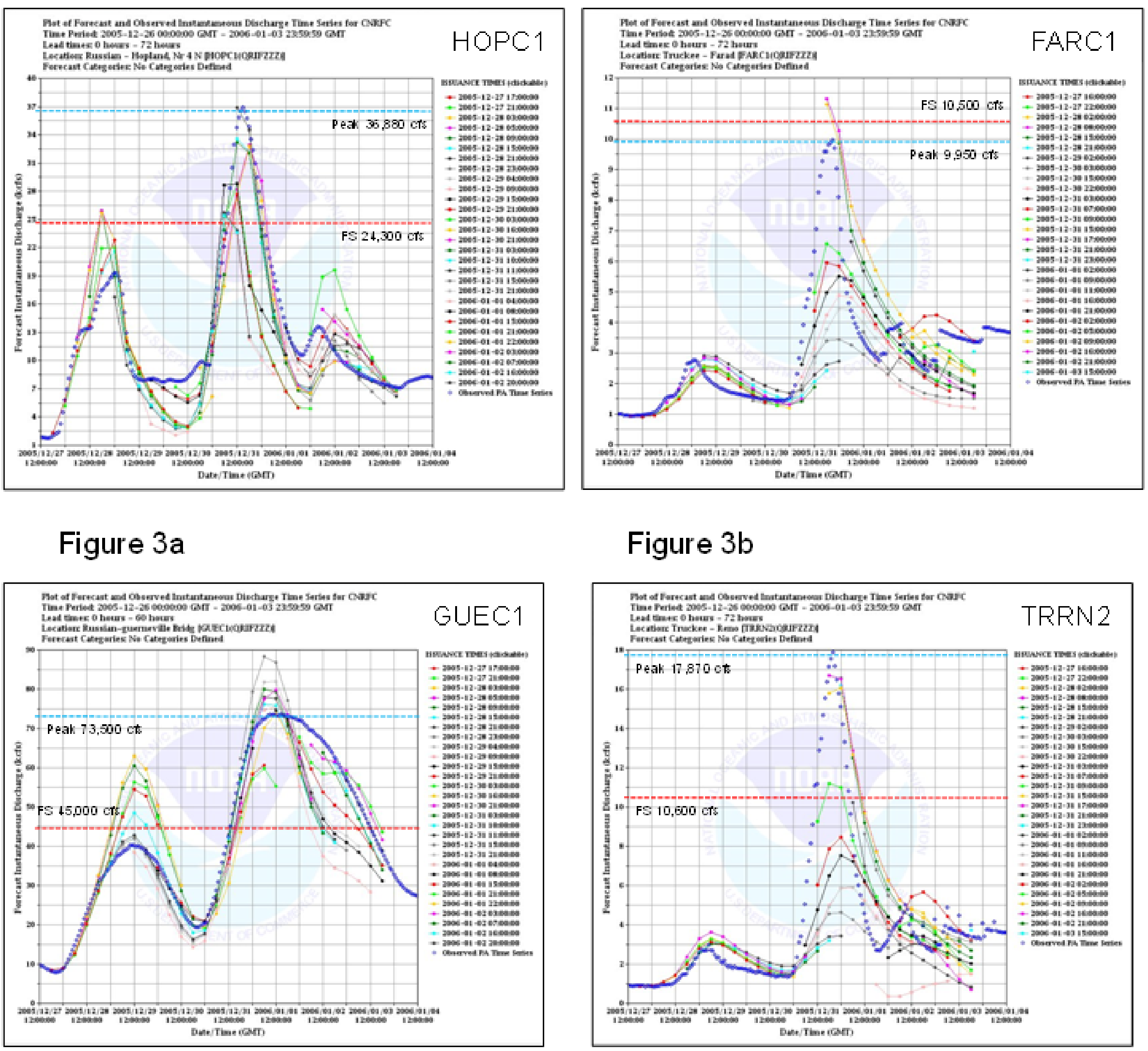


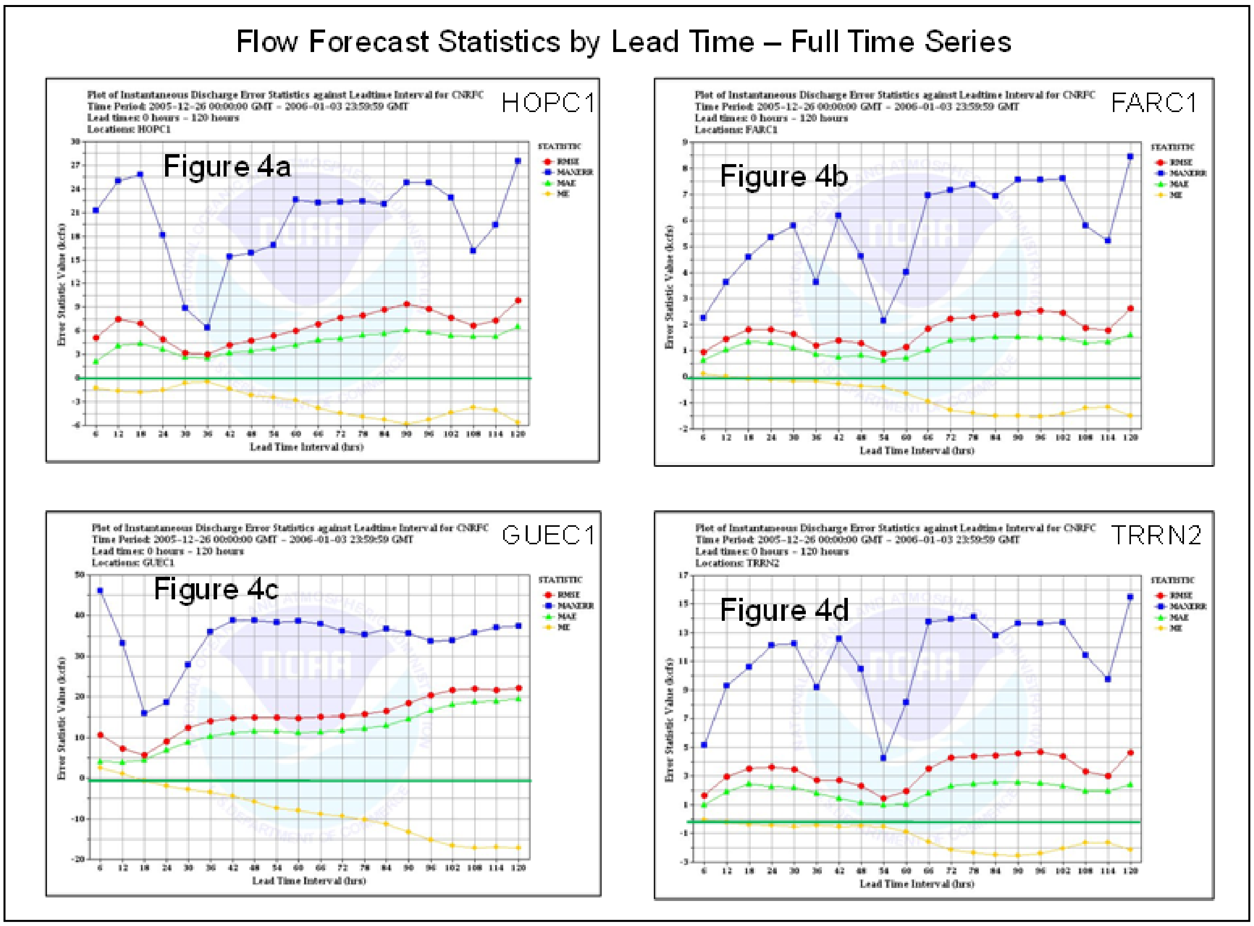
Figure 3a

Figure 3b

Figure 3c

Figure 3d

A plot of instantaneous discharge error statistics was plotted against lead time interval. The Russian basin (Figures 4a and 4c) showed generally the highest MAXERR during the earliest lead time (6 to 12 hours) and RMSE rose slowly from 42 to 120 hours. MAXERR increased gradually on the Truckee, with an unexplainable dip between a lead time at 36 hours and 42 to 60 hours. The dip could be a result of the small sample size. Conversely, RMSE and MAE increased gradually on the Russian, especially at GUEC1 (Figure 4c). There was a gradual increase for the Truckee also (Figures 4b and 4d), except that it also dipped at a lead time of 36 hours and 42 to 60 hours. In general, MAXERR and RMSE increased slowly with increasing lead time. Mean Error was negative for both the Russian and Truckee.



Plot of instantaneous discharge error statistics against analysis interval, computed over lead time interval (Figure 5). The RMSE increased substantially with increasing lead time where the peaks occurred on the hydrograph for both the HOPC1 forecast point on the Russian and FARC1 on the Truckee. This was not the case for the BIAS by Analysis Interval for Flow.

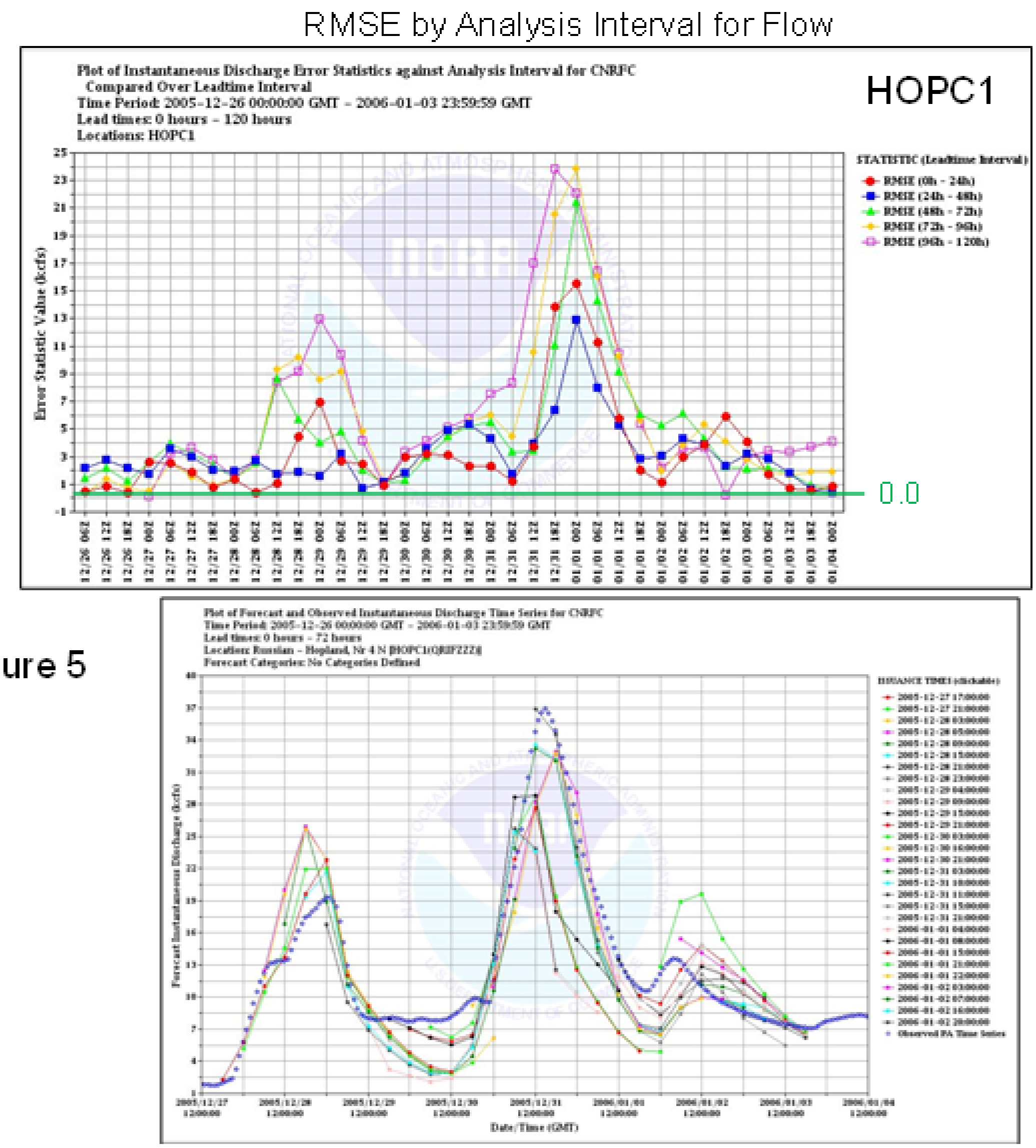
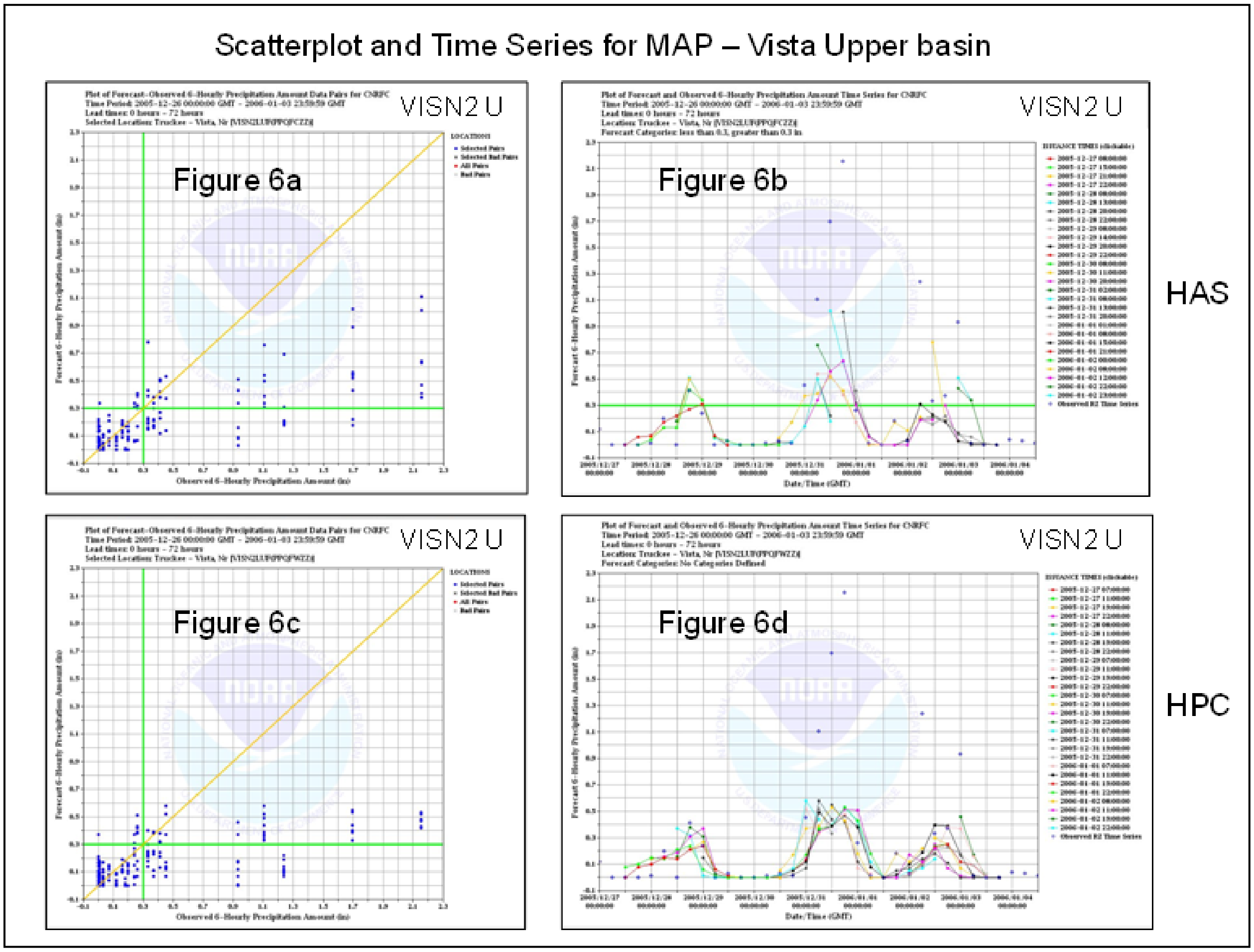


Figure 5

MAP – verification of HAS unit. Quantitative Precipitation Forecasts (QPF) are issued by the CNRFC Hydrometeorological Analysis and Support (HAS) unit. The CNRFC HAS unit is a dedicated unit made up of three meteorologists. Basically, the HAS unit forecasts 6-hourly QPF and freezing level out 0-72 hours (day 1 through 3). For 72-144 hours (days 4 through 6), six-hourly QPF and freezing level forecasts are issued using the Rhea Orographic Aid based on GFS gridded output. The Rhea Orographic Aid enhances the topography as the parcel travels over it to the crest. Generally, most of the effort is put on the day 1 through 3 forecasts by the HAS unit. The 72 to 144 hour QPF forecast was not covered in this case study. For days 1 through 3, the HAS consults the weather models, HPC guidance, collaborate with NWS Weather Forecast Office meteorologists and use other tools such as surface observations and remote data collection available to them on AWIPS and other computers. There is extended coverage by the HAS unit during periods of forecast heavy precipitation. The Mean Areal Precipitation (MAP) observed and forecast data used to generate the statistics for this case study was derived from the HAS and HPC QPF forecasts.

Scatter plots were generated for the upper (VISN2 U) portion of the Truckee Basin at Vista. VISN2 is calibrated in NWSRFS as a split basin with an upper and lower portion delineated by elevation. Note for VISN2 U the relative under-forecast at the higher observed precipitation levels on the scatter plots for both HAS (Figure 6a) and HPC (Figure 6c) and the under-forecast MAP for both on the time series plots (Figures 6b and 6d). It appears that HPC is slightly worse than the HAS forecast for VISN2 at the higher observed values on the scatter plot, but both are well under-forecast.



Moments – MAPs: Figure 7 is a plot of 6-hourly precipitation amount moments (observed mean, forecast mean, observed standard deviation and forecast standard deviation) against analysis interval for GUEC1 and HOPC1. Note that increasing observed and forecast means roughly coincides with the discharge peaks on the time series plot for HOPC1.

Moments – Russian River MAPs

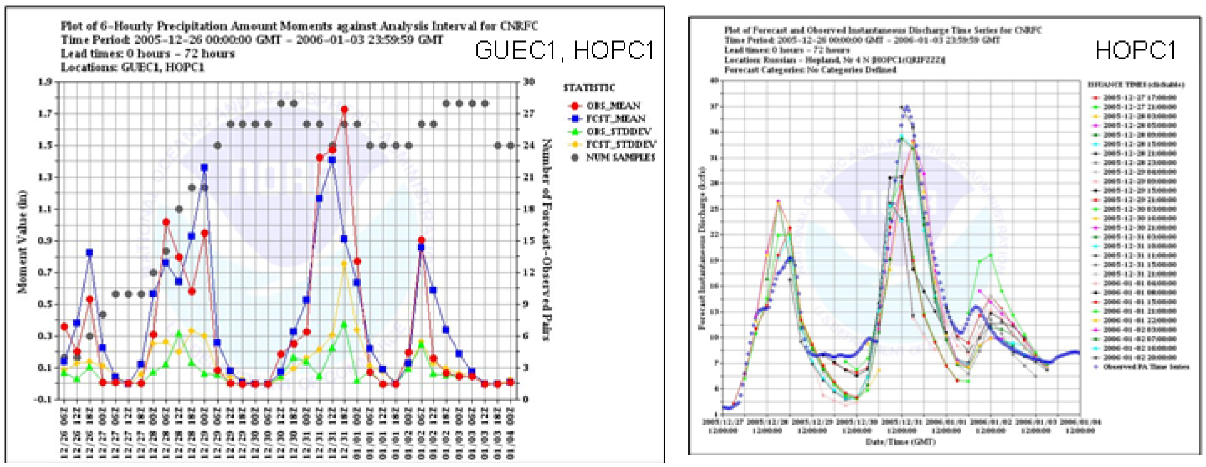
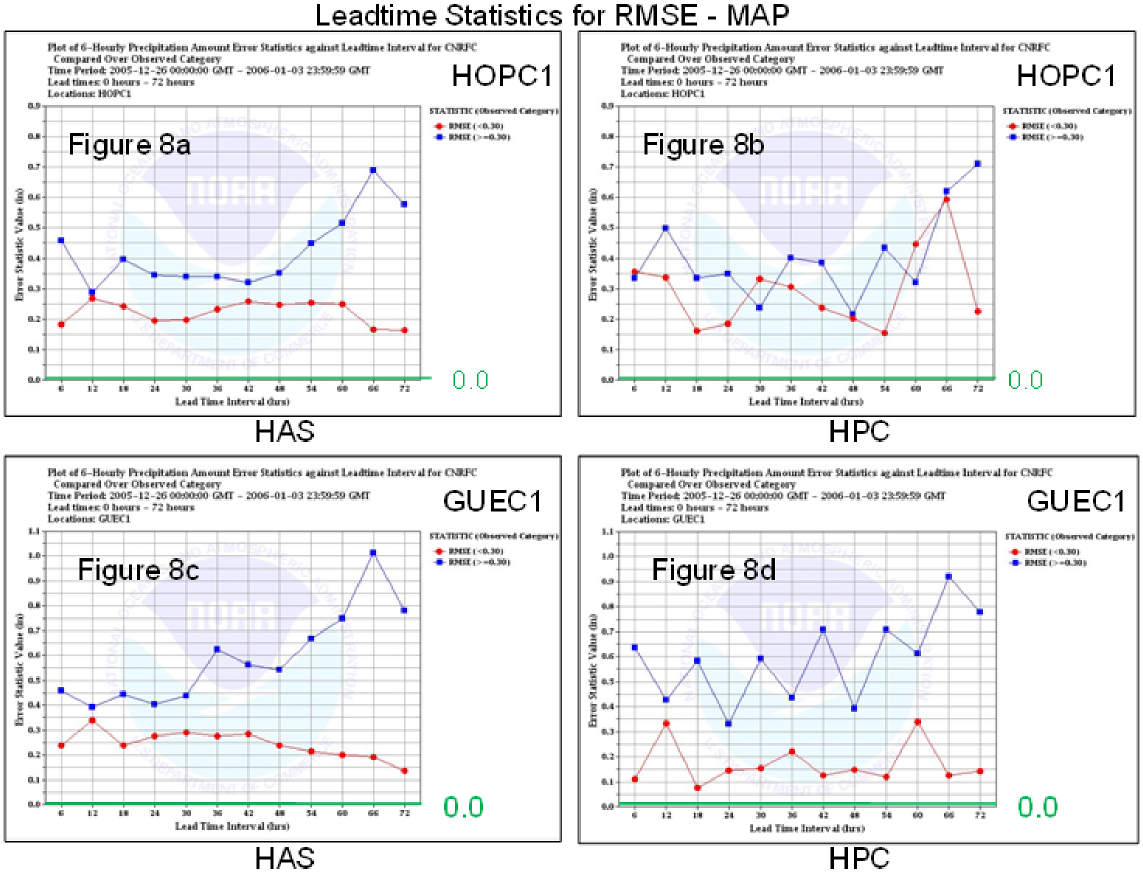


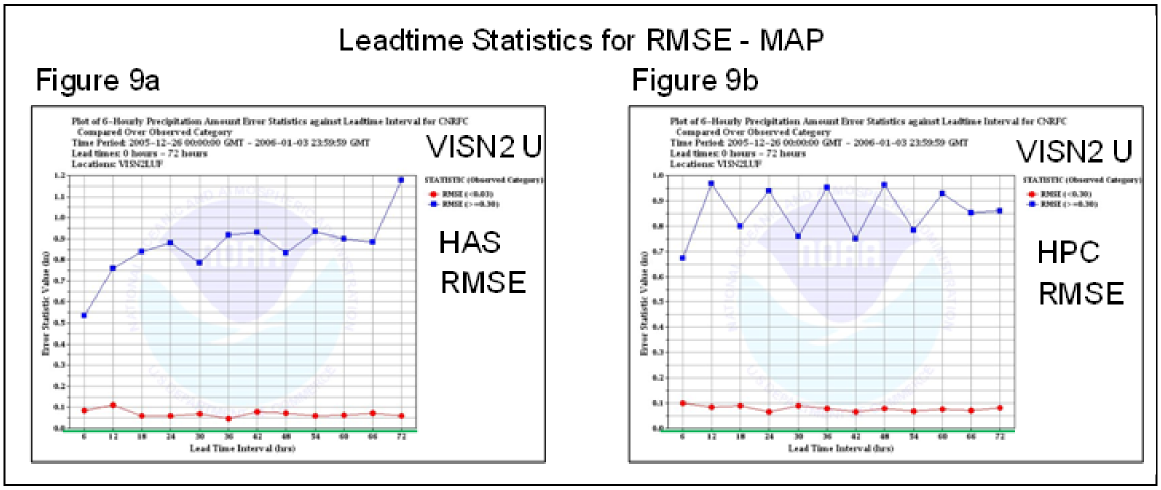
Figure 7

Lead time Statistics – MAP

RMSE appears to increase with increasing lead time for observed category of >= 0.30 inches for HOPC1, GUEC1 and VISN2 - upper basin for both HAS and HPC (Figures 8 and 9). The RMSE is lower for category of <0.30 inches. The HPC plots show fluctuations as lead time increases.

Leadtime Statistics for RMSE - MAP

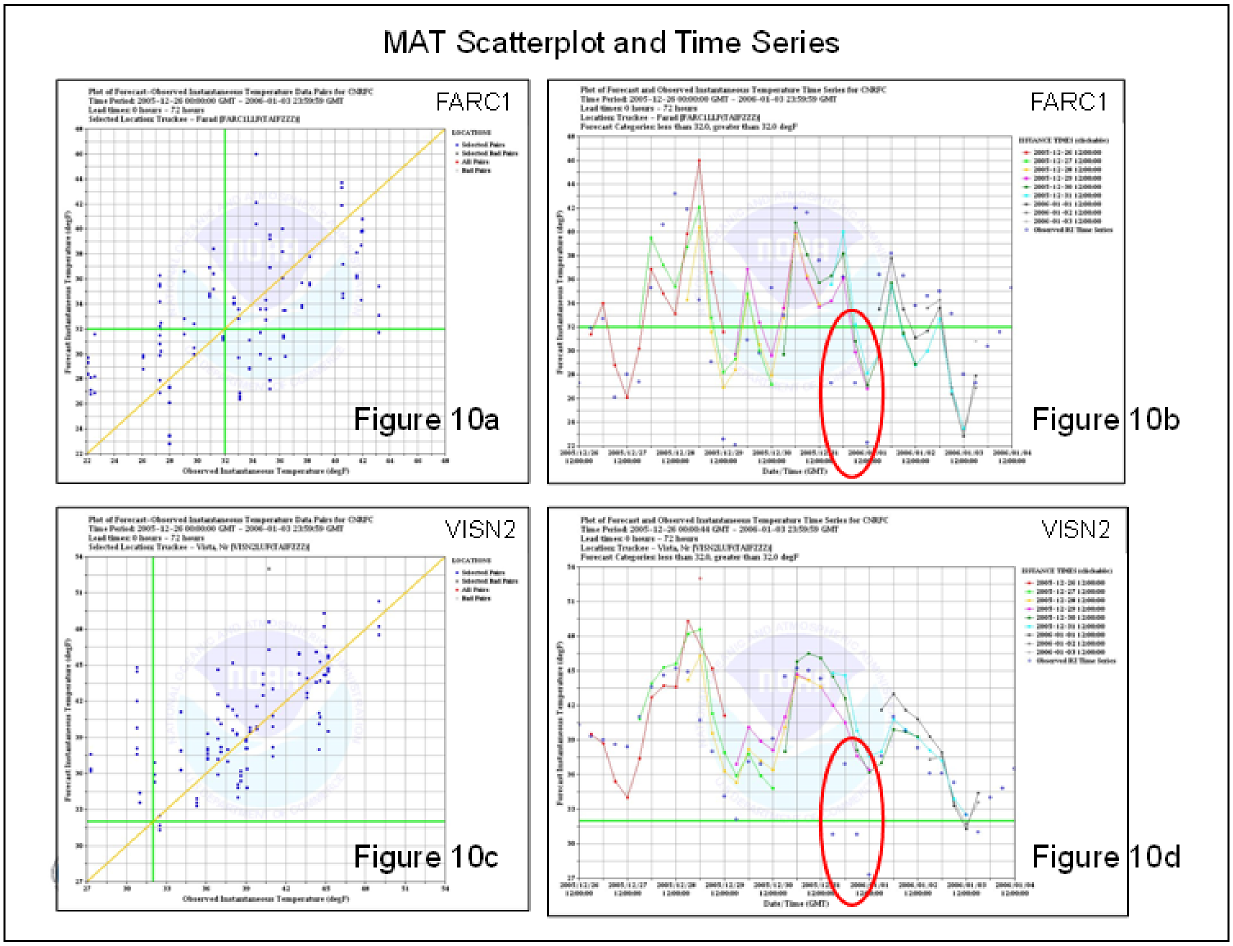




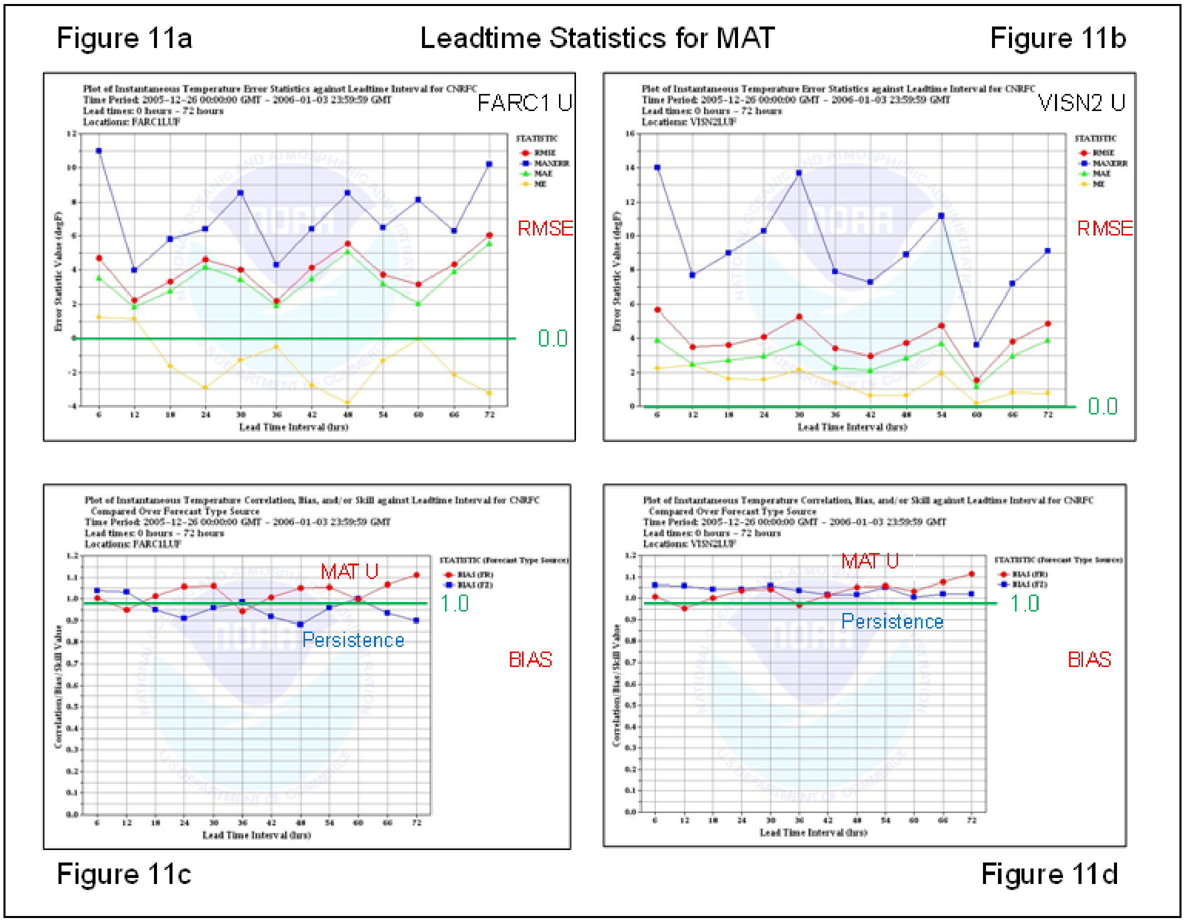
Verification of Forecast Mean Areal Temperature (FMAT): The CNRFC HAS unit produces temperature forecasts using MOS guidance from the GFS model. Forecast MAT were not available for the Russian River drainage for this study. However, temperature may not be a factor in the Russian River basin as all precipitation fell as rain. The following will describe the findings pertaining to the Truckee River FMAT forecasts.

Scatter plots – A scatter plot of observed instantaneous temperature was plotted versus forecast for FARC1 and VISN2 (Figures 10a and 10c). There appeared to be no discernable pattern of over-forecasting or under-forecasting.

Time Series – Time series of forecast instantaneous temperature were plotted versus time for FARC1 and VISN2 on the Truckee River (Figures 10b and 10d). Plots compared favorably with observed temperature except during 18:00Z 12/31/2005 through 12:00Z 01/01/2006 where temperatures were over-forecast. As can be seen from the scatter plots, the temperatures were above freezing at the downstream point (VISN2); only dropping below freezing only at the upstream FARC1 forecast point. Of particular note is that FARC1 crested just 0.2 feet below flood stage while the downstream points TRRN2 crested 1.5 feet and VISN2 over 5 feet above flood stage.



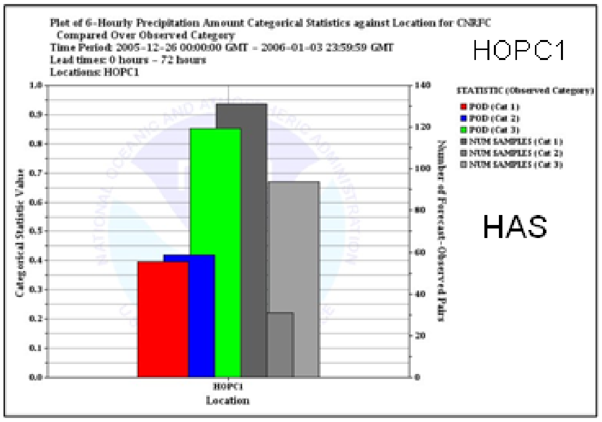
Plots of Instantaneous Temperature Error Statistics against Lead time Interval were constructed for MAT (Figures 11a and 11b). No discernable pattern is seen for RMSE for both FARC1 Upper and VISN2 Upper as lead time increases. VISN2 U has a slightly higher RMSE at the earlier lead times (6 – 52 hours). No definite advantage of FZ (HAS FMAT forecasts for FARC1 and VISN2 upper basins) over FR (persistence) for BIAS (Figures 11c and 11d) although there is a small consistent over-forecast bias for persistence for the downstream forecast point VISN2 U in Figure 11d.

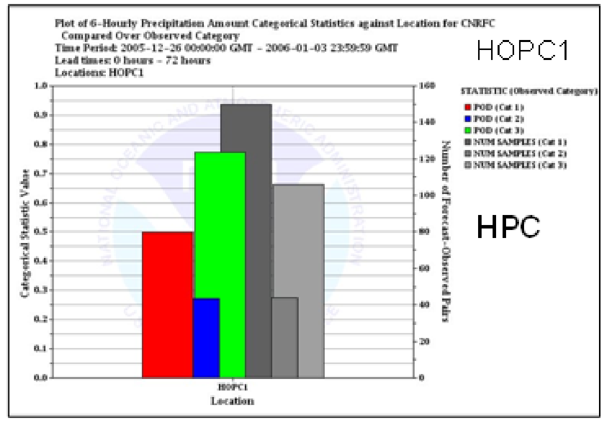


Categorical (POD) for MAP, HAS versus HPC: Probability of Detection is best for category 3 (>= 0.50") for Hopland (HOPC1) for both HAS and HPC forecasts (Figures 12a and 12b). POD is best for category 1 (<0.25") for Vista upper basin (VISN2 U) for both HAS and HPC (Figure 13a and 13b), and relatively poor for category 2 (>=0.25" and <0.50") and 3 (>=0.50") for VISN2 Upper for both HAS and HPC. This could indicate the severe under-forecast of QPF for the higher observed amounts at Vista. However, the computed statistics are compromised by the small sample size.

Categorical based on MAP for precipitation thresholds <0.25” and >=0.25”

Category 1: < 0.25”
Category 2: >= 0.25” and < 0.50”
Category 3: >= 0.50”

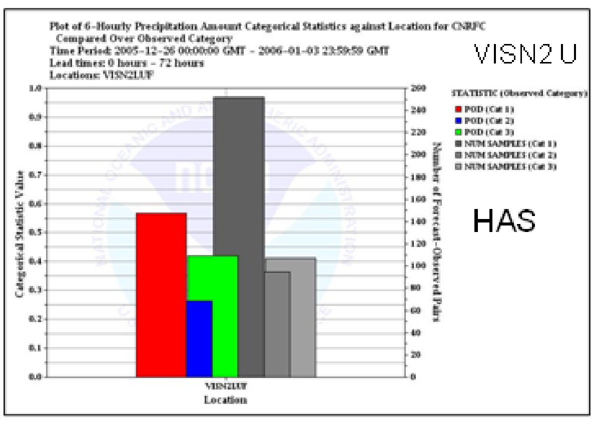


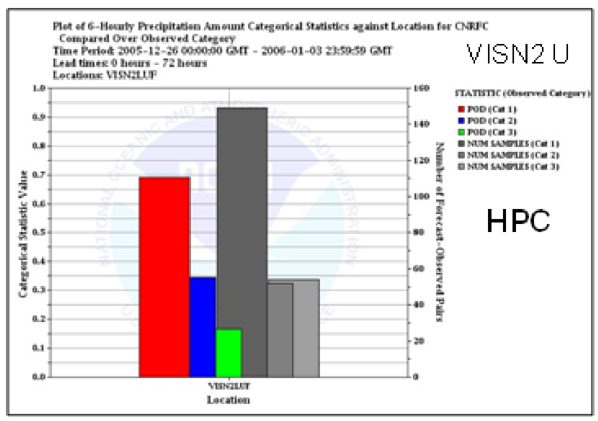


POD: Probability of Detection (discrimination, perfect score 1)

Figure 12a

Figure 12b





POD: Probability of Detection (discrimination, perfect score 1)

Figure 13a

Figure 13b

Bias for MAP based on Type Source (FC: HAS, FW: HPC). There is a tendency for over-forecasting bias for HOPC1, GUEC1 and FARC1 U at the category 1 level (<0.25 inches). VISN2 U has an under-forecasting bias at the category 1 level and a large under-forecasting bias at the category 3 level (>=0.50 inches). No discernable pattern if type source FC-HAS is better than type source FW-HPC. Note the small sample size.

Conclusions

- A limiting factor was the small sample size used in the study. Currently, there is a very small set of historical data available. NWSRFS was not started until 1997 at the CNRFC. The most complete set of data available at the RFC starts after year 2004. The event in the Truckee basin was characterized by copious amounts of rain falling on the lower elevation basins. Extreme lee-side precipitation events are very rare in the case study area. We would have to go back to January 1-2, 1997 to find an event with similar circumstances for the Truckee. However, orographic-type events are more common on the Russian River basin and similar recent historical events would be easier to obtain.

- The most valuable verification plots generated by IVP are the scatter and time series plots. They show quite conclusively that MAPs were under-forecast during the flood event on the Truckee.

- Based on scatter plot and time series output, the Russian River was generally over-forecast and the Truckee River under-forecast.

- There is a need to verify single flood events. It is true that IVP lends itself well to multiple events of similar characteristics and not single events where small sample size could be a limiting factor. Based on data stored in the CNRFC database, multiple events would be easy to verify for the Russian River, as orographic precipitation events are common in that basin. As just mentioned above, it would be difficult to obtain data for the type of event studied for the Truckee.

- There is an advantage of verifying single storm events of limited duration in that zero QPF is generally a small factor that enter into the statistical computations.

- The CNRFC HAS was slightly better than HPC according to the MAP scatter plots and time series and the lead time statistics for MAP. No decision can be made on who is better according to the categorical statistics for MAP that was computed. Obtaining an adequate sample size appears to be the limiting factor in making a determination using the categorical statistics in this case study.

Additional work to be done on the case study

- It was recommended that the forecast-observed pairs not be pooled for all lead times since the forecast performance is likely to vary with lead time.

- Expand this case study to include the Napa and Carson Rivers, which also sustained substantial property damage during the 2006 New Year’s heavy precipitation event.

- Compare the MAP categorical statistics generated by IVP with the ones generated for the NPVU (National Precipitation Verification Unit) QPF verification.

Needs not provided by the IVP software and other unmet needs

- Need to define a raw model to establish baseline statistics in order to assess value added by the forecaster or hindcasting capability to flush out relative error sources in the model.

- The archive database disk size after the “form-fit-function” upgrade is approximately 900 Gigabytes. I used to run a script provided by the MBRFC called “run_PGbkups” which performed a Postgres backup of the archive tables before the upgrade. I cannot run it now. Perhaps we need to consider purchasing another hard drive of sufficient size as a backup.

References

Herr, H., 2007. Interactive Verification Program User’s Manual. NOAA/National Weather Service/Office of Hydrologic Development.

Kozlowski, D. and M. Ekern. December 24, 2005 – January 03, 2006 Southwest Oregon, Northern California and Western Nevada Significant Precipitation Event. NOAA/National Weather Service/California-Nevada River Forecast Center web site, http*://www.cnrfc.noaa.gov.storm_summaries.php*

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