Western Region Technical Attachment
No. 95-18
July 11, 1995

PROBLEMS ASSOCIATED WITH A MOUNTAIN TOP RADAR'S PRECIPITATION PRODUCTS DURING A STRATIFORM PRECIPITATION EVENT

Jesus A. Haro - NWSFO Reno

Introduction

A recent Western Region Technical Attachment, WR-95-08, (Reynolds 1995) documented problems with WSR-88D precipitation underestimation in the San Francisco Bay Area. The author concluded that the underestimation was the result of a combination of the radar siting, the precipitation algorithm, and the precipitation mechanism operating within the cloud system.

Forecasters at the Reno NWSFO experienced similar frustrations this past winter and spring. On several occasions, during stratiform precipitation events, precipitation algorithm output (specifically the Storm Total Precipitation product) from the Virginia Peak WSR-88D (KRGX) yielded cumulative precipitation amounts as much as an order of magnitude below recorded amounts. Subsequently, these products proved almost useless in any operational quantitative precipitation forecast application.

Several factors contributed to the poor precipitation estimates this past winter and early spring, some of which are unique to extreme western Nevada. This Technical Attachment addresses these factors by highlighting a heavy rain and snow event which took place over extreme western Nevada and the Lake Tahoe Basin on March 9-11, 1995.

Synoptic Overview

Conditions were that the upper-level flow was conducive to producing heavy precipitation over the Lake Tahoe Basin. The NGM initial analysis for 0000 UTC 10 March 1995 showed a strong southwest flow at 500 mb across northern California and much of Nevada (Fig. 1a). Vorticity maxima were located over north-central Nevada and along the West Coast approaching the Sierra Nevada. A strong, moist southwest flow was also present at 700 mb (Fig. 1b), with an impressive subtropical tap. Orographic lift was the primary forcing mechanism behind the high snowfall amounts along the Sierra (Table 1). The subtropical nature of the airmass resulted in high initial snow levels (7500-8000 ft east of the Sierra Crest).

Extreme western Nevada, being on the lee of the Sierra, typically experiences a pronounced rain-shadow effect with flow this strong. Thus, other factors had to aid in the development of heavy rain across this area. The placement of the polar jet was among these features. The initial analysis had the 300 mb jet off the West Coast with divergent flow across extreme western Nevada (Fig. 1c). In addition, low-level (850 mb) thickness advection by the ageostrophic wind (Fig. 1d) was concentrated over the same area.

Model forecasts had these features remaining nearly constant through the next 24 hours. The NGM forecast for 0000 UTC 11 March 1995 continued the southwest 500 mb flow across the region with vorticity maxima over western Oregon and approaching northern California (Fig. 2a). A strong and moist flow continued into the area at 700 mb (Fig. 2b). The wind field remained divergent at 300 mb (Fig. 2c), although the area of greatest divergence shifted east into central Nevada. Much like the previous day, an impressive amount of low-level (850 mb) thickness advection by the ageostrophic wind continued into extreme western Nevada (Fig. 2d).

Storm Precipitation Summary

Predictably, heavy snow fell across the Lake Tahoe Basin. Many Lake Tahoe ski areas received between 2-4 feet of new snow during the three-day period (Table 1). Most of the snow did not fall steadily through the period, but in concentrated 6-12 hour bursts during the daytime hours of the 9th and 10th. Accumulations from HYDROMET stations across the Lake Tahoe Basin and extreme western Nevada showed that the heaviest precipitation amount exceeded 7 inches of water.

The Storm Total Precipitation product for the period beginning on 0459 UTC 9 March 1995 and ending 0011 UTC 10 March 1995 (Fig. 3) displayed cumulative precipitation amounts well below what actually occurred. Little change was seen the next day (Fig. 4). Most of the region was covered by radar estimated Storm Total Precipitation values ≤ .10 in. Slightly higher accumulations can be seen over the Lake Tahoe Basin in an area greater than 27 nm from the radar site. The 27 nm distance corresponds perfectly to the location of the arc separating accumulations ≤ .10 in from those ⟩ .10 but ≤ 1.0 in. The arc also corresponds to the distance beyond which the Bi-Scan Maximization procedure selects either 0.5° or 1.5° reflectivity data for inclusion in the Hybrid Scan.

Topography, Winter Weather, and the Precipitation Preprocessing Algorithm

The varied topography of extreme western Nevada and the Lake Tahoe Basin (Fig. 5) poses a challenge not only to forecasters but radar operators as well. KRGX sits atop Virginia Peak (not shown) at an elevation of 8,396 ft, above any significant ground clutter. As a result, few adjustments need to be made due to beam blockage (Fig. 6). The peak is located in the central portion of the Pah Rah Mountains approximately 23 nm northeast of downtown Reno. The Reno/Tahoe International Airport is at an elevation of 4,404 ft. Most of the Reno-Sparks metropolitan area rests in the Truckee Meadows at elevations between 4,500 ft and 5,000 ft although some communities located in the adjoining foothills are at elevations approaching 5,500 ft. Elevations quickly rise and vary west of the area in the adjoining Carson Range and further west into the Sierra Nevada.

The radar's placement becomes a detriment when combined with the precipitation preprocessing algorithm's methodology. Cloud tops during most typical winter stratiform precipitation events are at levels between 13,500 ft MSL and 18,000 ft MSL. The bases of these systems are typically as low as 1,500 ft to 3,000 ft AGL over valley sites (elevations 4,000 ft-5000 ft). Radar calculated elevations at the 0.5° elevation angle slice can vary from approximately 9,500 ft MSL over downtown Reno to near 15,000 ft MSL over Lake Tahoe. The goal during the construction of the Hybrid Scan is to sample 3,000 ft above the ground.

Thus, during the Hybrid Scan construction, the radar is using reflectivity data from elevations close to the tops of these cloud systems and is overshooting most of the moisture as a result.

A side effect of having the beam overshoot the tops of these systems over the area in question is that 0.5° reflectivity data is likely being rejected during the preprocessing algorithm's tilt test a large degree of the time. It is not difficult at these distances from the radar for a 50 percent reduction in echo coverage to occur between the 0.5° and 1.5° elevation scans. Even when the 0.5° data is kept and used in the Bi-Scan Maximization procedure, it is not representative of what is occurring in the lower levels of the cloud systems.

Assumptions made within the default Z-R relationship are also likely contributing to the poor precipitation estimates. Just about all of the precipitation that is sampled during these types of stratiform events is snow. The same assumptions made for rain drops in determining reflectivity (Z) (drop diameter, number of drops of given diameter per cubic meter, etc.) can't be made with frozen precipitation without significantly affecting the resulting dBZ value and subsequent output from the precipitation rate algorithm.

Conclusions

Given the methodology of the precipitation preprocessing algorithm, it is very difficult to expect a radar to give accurate precipitation estimates for locations as much as 4,000 ft lower in elevation during this type of event. It's also evident that modifications need to be made to the existing Z-R relationship in order to yield more representative reflectivity and precipitation products.

One change was made recently that should increase the usefulness of these precipitation products. Approval was gained from the Operational Support Facility (OSF) to increase the default echo coverage decrease percentage used during the tilt test (MXPCT) to 75 percent. This will hopefully ensure that 0.5° reflectivity data is included in the Bi-Scan Maximization procedure more of the time.

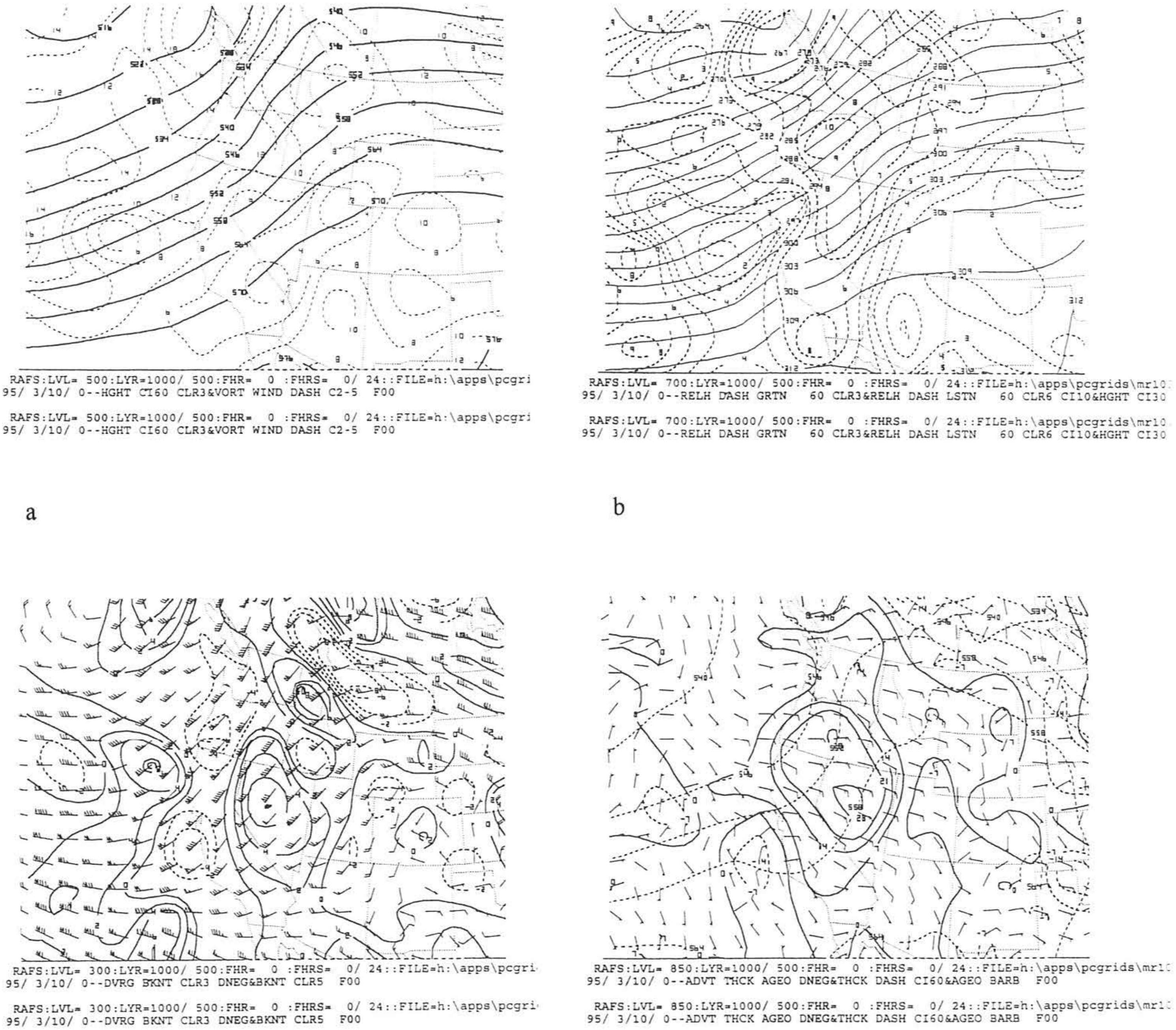
Another change which could be implemented is the use of negative elevation angle scans. This change would require extensive modifications to current hardware and software associated with the WSR-88D. Also, it would introduce beam blockage and ground clutter problems. However, the improved sampling of these lower stratiform layers would greatly aid users of this radar in the form of more accurate reflectivity and precipitation products.

Acknowledgments: The author thanks Mary Cairns, Tom Cylke, Larry Osterman, and Dan Samelson for their helpful contributions to this paper.

References

Operations Training Branch, 1995: WSR-88D Operations Training Student Guide. Operational Support Facility; Norman, OK.

Reynolds, D.W., 1995: The Warm Rain Process and WSR-88D. Western Region Technical Attachment No. 95-08.



a

b

c

d

Fig. 1 NGM Model PCGRIDS initial analyses at 0000 UTC 10 March 1995 of a) geopotential heights and absolute vorticity at 500 mb, b) geopotential heights and relative humidity at 700 mb, c) winds and divergence at 300 mb, and d) thickness advection by the ageostrophic wind at 850 mb.

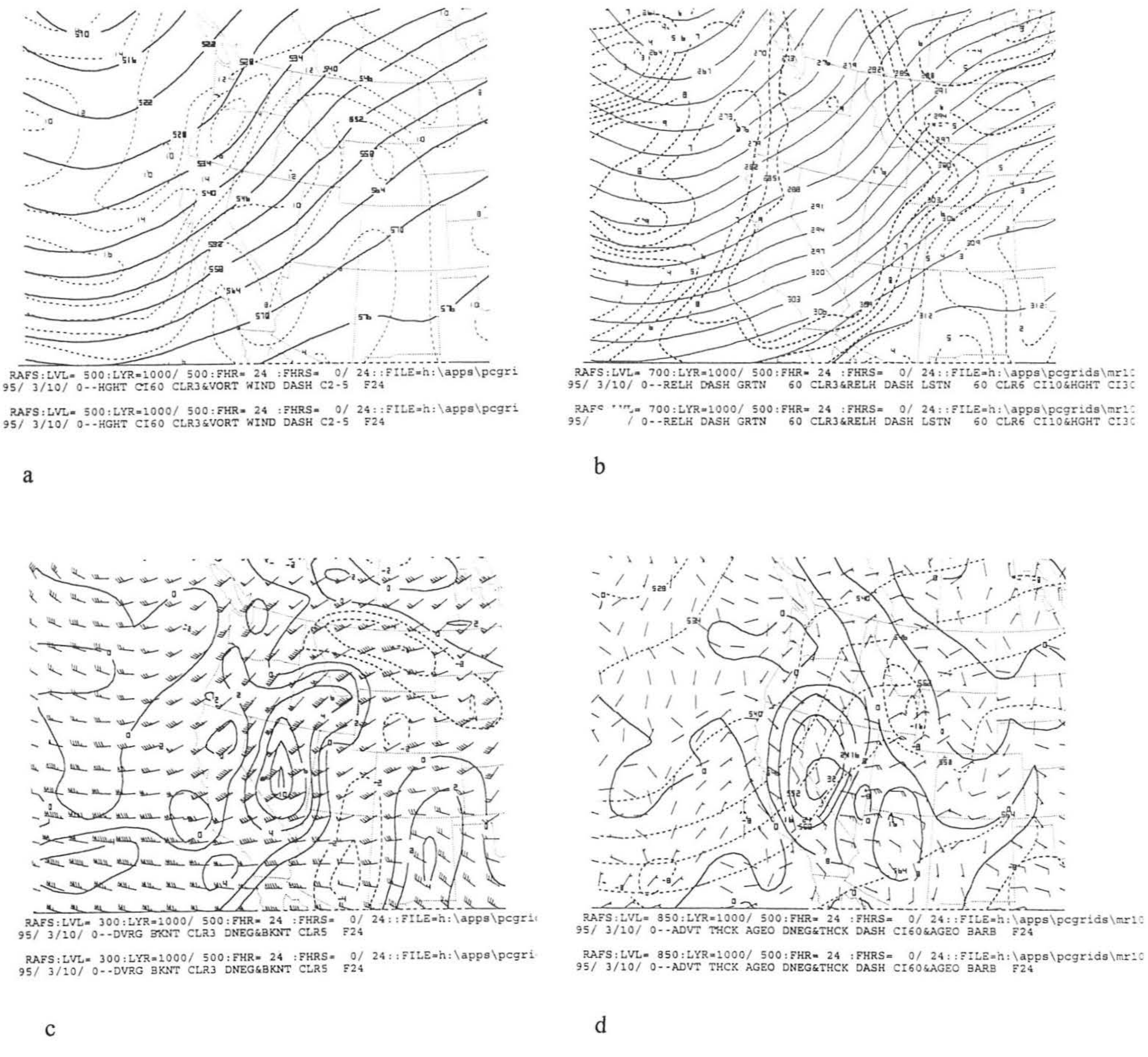
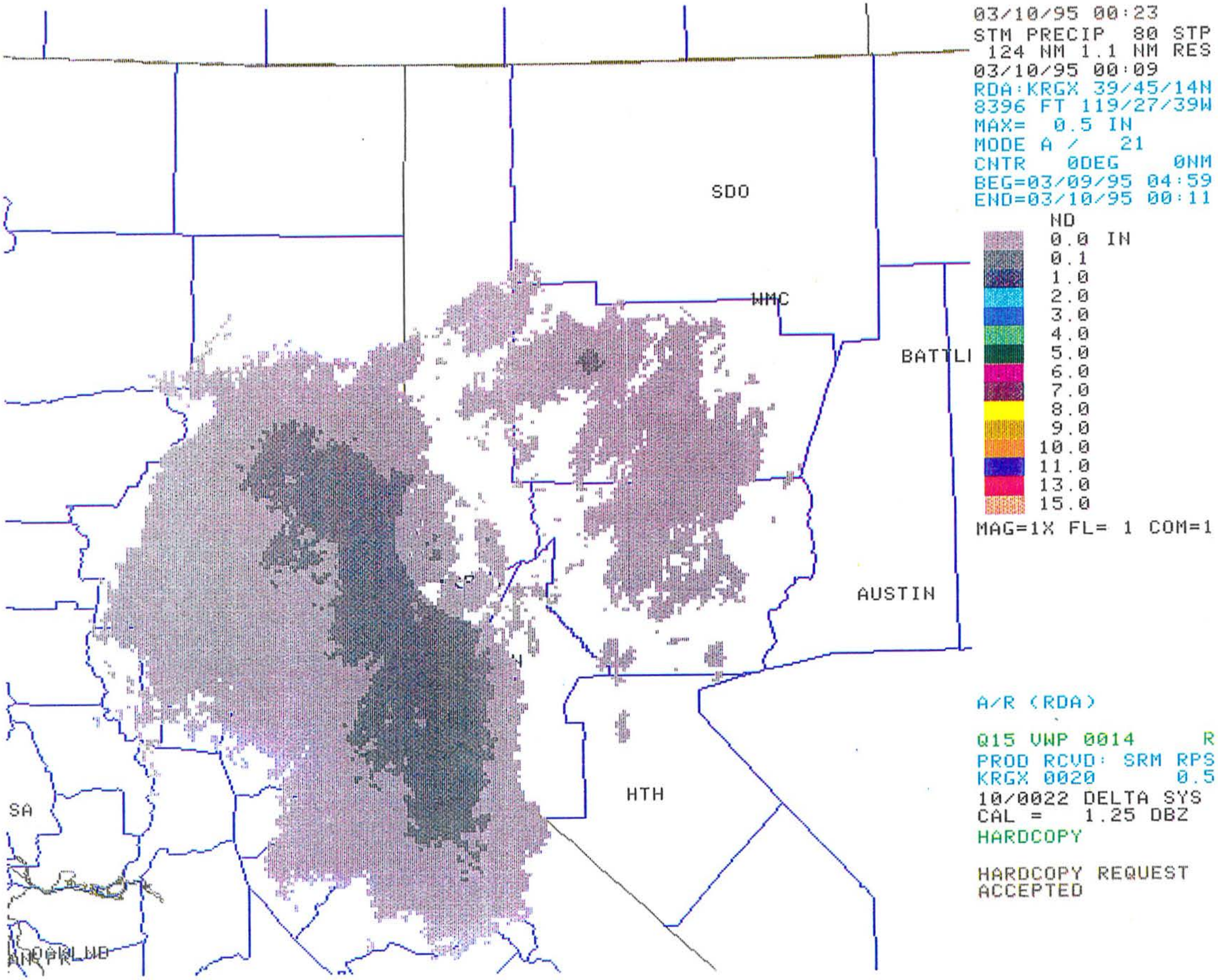


Fig. 2 NGM Model PCGRIDS forecasts valid at 0000 UTC 11 March 1995 of a) geopotential heights and absolute vorticity at 500 mb, b) geopotential heights and relative humidity at 700 mb, c) winds and divergence at 300 mb, and d) thickness advection by the ageostrophic wind at 850 mb.



```
03/10/95 00:23
STM PRECIP  80 STP
 124 NM 1.1 NM RES
03/10/95 00:09
RDA:KRGX 39/45/14N
8396 FT 119/27/39W
MAX=  0.5 IN
MODE A /    21
CNTR   0DEG     0NM
BEG=03/09/95 04:59
END=03/10/95 00:11
        ND
▨       0.0 IN
▨       0.1
▨       1.0
▨       2.0
▨       3.0
▨       4.0
▨       5.0
▨       6.0
▨       7.0
▨       8.0
▨       9.0
▨      10.0
▨      11.0
▨      13.0
▨      15.0
MAG=1X FL= 1 COM=1

A/R (RDA)

Q15 VWP 0014      R
PROD RCVD: SRM RPS
KRGX 0020       0.5
10/0022 DELTA SYS
CAL =    1.25 DBZ
HARDCOPY

HARDCOPY REQUEST
ACCEPTED
```

Fig. 3 KRGX WSR-88D Storm Total Precipitation product valid from 0459 UTC 9 March 1995 to 0011 UTC 10 March 1995.

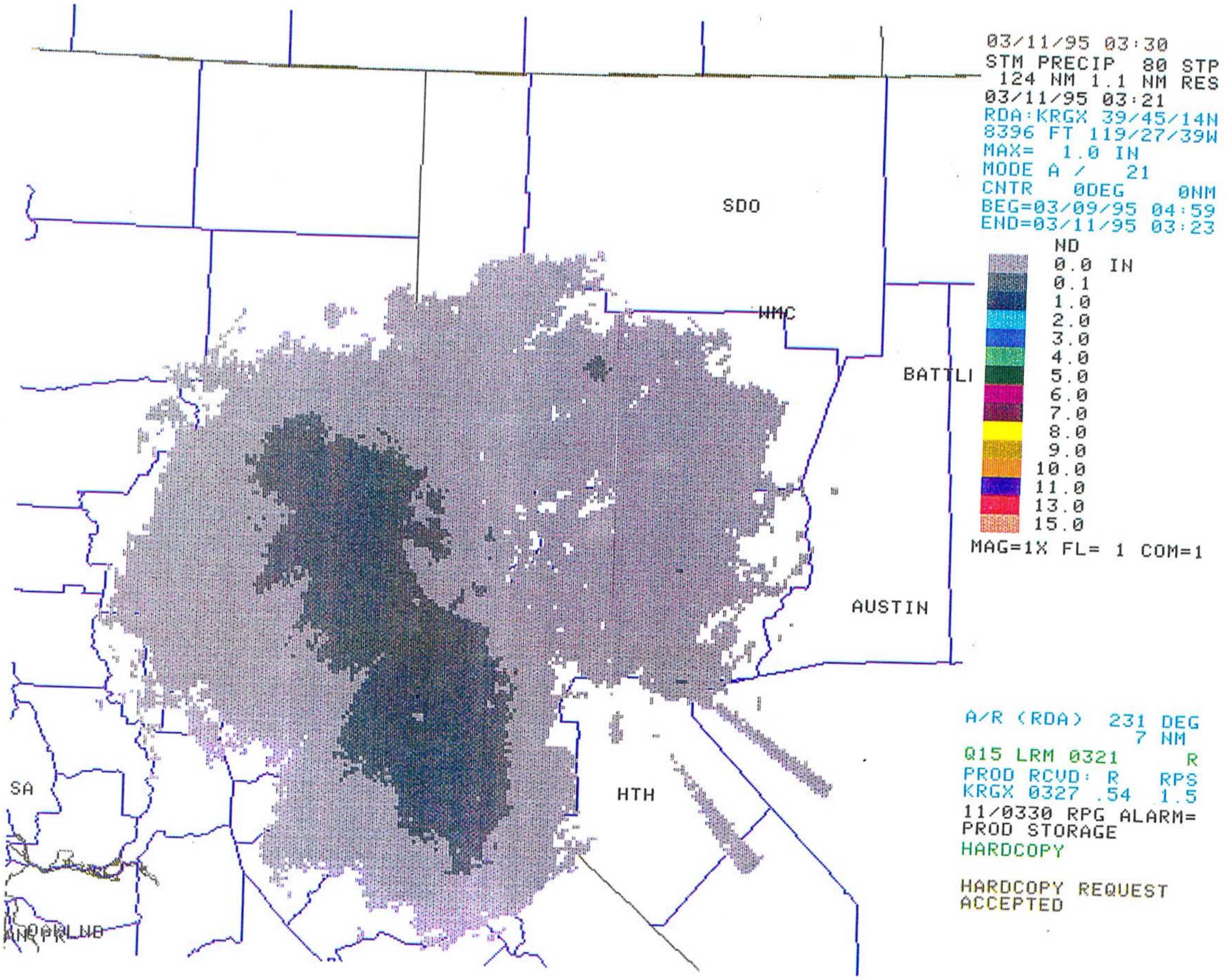


Fig. 4 KRGX WSR-88D Storm Total Precipitation product valid from 0459 UTC 9 March 1995 to 0323 UTC 11 March 1995.

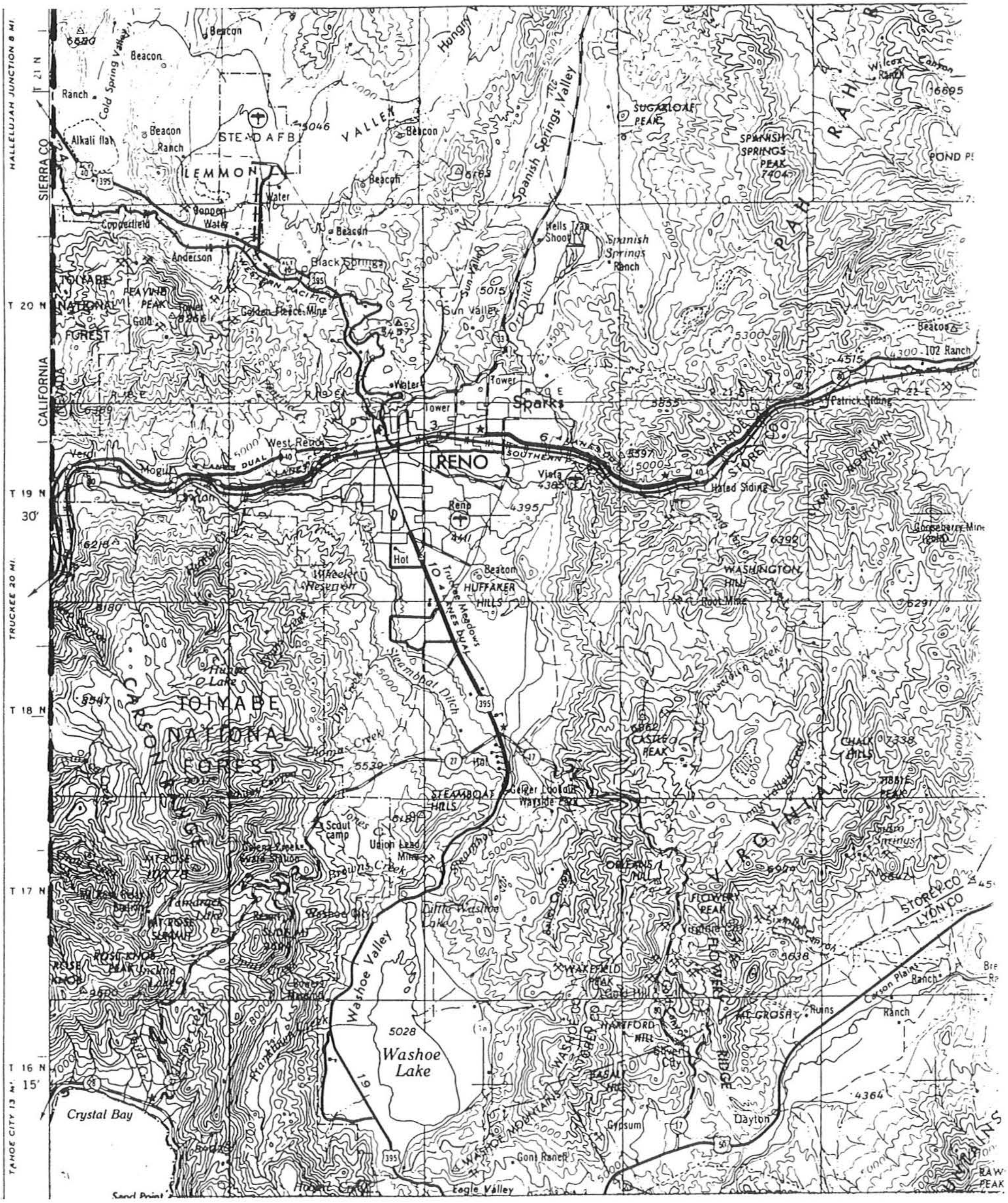


Fig. 5 Topographical map showing portions of extreme western Nevada and the Lake Tahoe Basin.

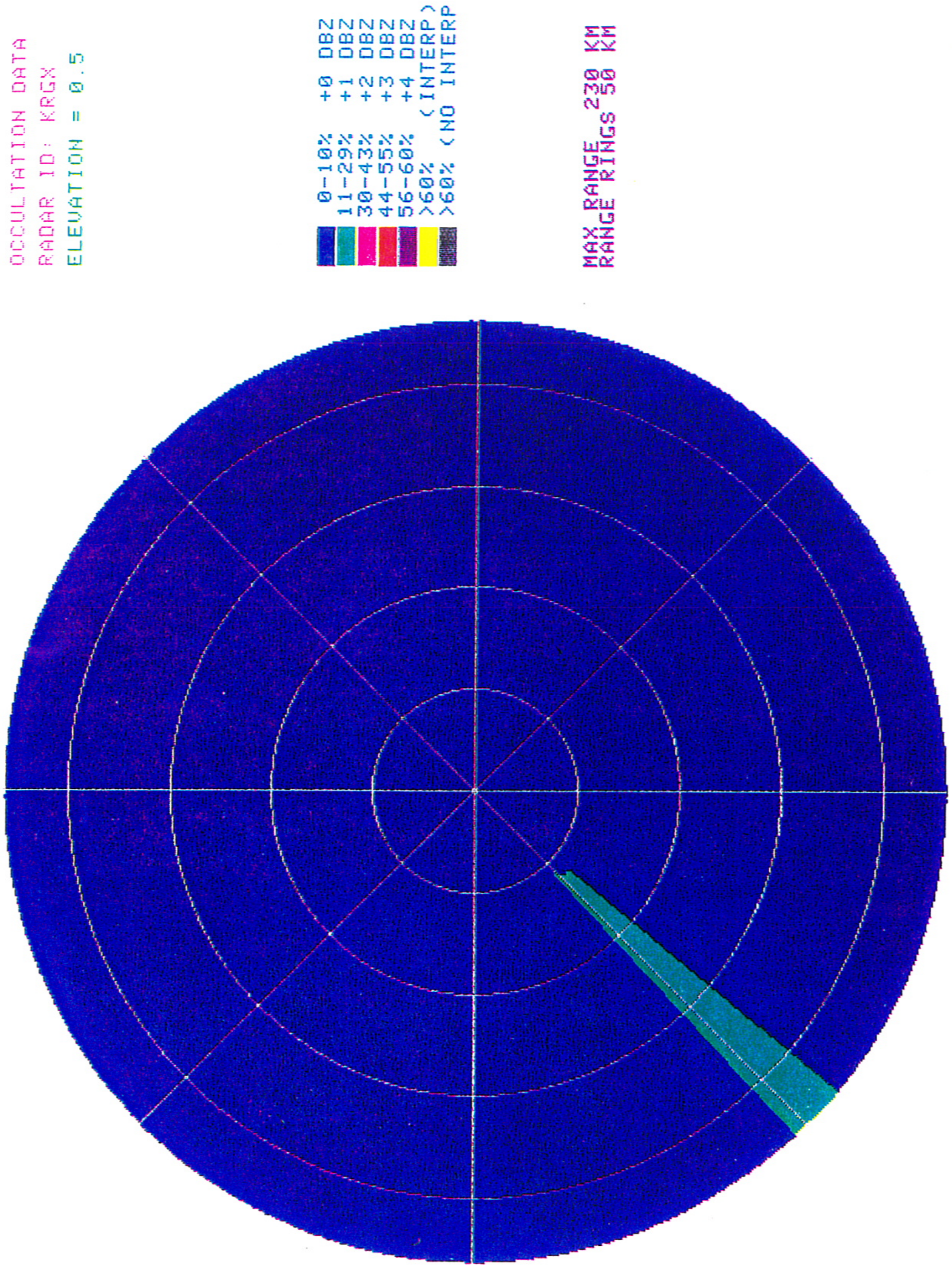


Fig. 6 Occultation Data for KRGX.

Table 1 Snow and rainfall totals for the period 9-11 March 1995 across extreme western Nevada and the Lake Tahoe Basin.

HYDROMET SENSOR PRECIPITATION TOTALS

	3/9/95	3/10/95	3/11/95	Total (in)
Lake Tahoe Basin				
SnowValleyPeak/88	1.22	0.91	0.00	2.13
Stateline/62	1.02	1.73	0.98	3.73
Upper Truckee River Basin				
Gray Creek West/81	2.80	3.11	0.51	6.42
Truckee-RngrStn/60	3.10	3.00	1.20	7.3
Middle Truckee Basin/Truckee Meadows				
Evans Ck-Upper/81	1.65	1.97	0.67	4.29
Alum Ck/62	2.05	1.57	0.79	4.41
Upper Steamboat Creek Basin				
GalenaCkPark/63	2.91	1.02	1.38	5.31
Bailey Ck/57	0.94	2.52	0.00	3.46
Lower Steamboat Creek Basin				
Dry Ck/48	0.91	2.09	0.00	3
Huffaker Hills/45	0.91	1.02	0.24	2.17

SNOWFALL TOTALS

Ski Areas	Total new snowfall (in) 3/9/95 - 3/11/95
Mammoth Mountain	46
Kirkwood	24-48
Alpine Meadows	26
Heavenly Valley	34
Sugar Bowl	44