An Evaluation and Discussion of Overestimated Snowfall Amounts Associated with a Winter Storm in the Northern and Central Sierra Nevada on March 13-15, 2003

Mark Deutschendorf and Brian O'Hara, NWS Reno NV

Introduction

A major winter storm indicated by the GFS model was expected to affect the Sierra Nevada mountain range in northeast California and from Lake Tahoe to Mono county (Figure 1) between March 13 and 15, 2003. Forecasters generally favored this model and issued several Winter Storm Outlooks, Watches and Warnings starting on March 11 with expectations of several feet of snowfall and near-blizzard conditions. However, actual snow amounts were far lower than forecasted (Figure 2). This study takes a closer look at some of the parameters that led to the forecast of heavy snow, followed by a discussion of the storm's results.

Model Data Before the Storm

The 12Z GFS model from Tuesday March 11 showed a shortwave moving into the central Sierra Nevada by 12Z Friday, March 14 2003 with precipitation continuing through 00Z Saturday, March 15 (Figure 3), which is designated in this study as the "first event" for the overall storm. A second shortwave was forecasted to move through the central Sierra by 12Z Saturday, March 15 with precipitation continuing through 00Z Sunday, March 16 2003 (Figure 4), which is designated in this study as the "second event".

QPF amounts were impressive and led to the expectation of significant snowfall totals in the Sierra. The GFS brought 1.0 inch of liquid equivalent into the northern Sierra (Zone 71) during the 24-hour period form 00Z Friday to 00Z Saturday (Figure 3). During the next 12 hours it brought an additional 0.75 to 1.25 inches into Lassen County CA. By 00Z Sunday an additional 1.00 inch of liquid equivalent was expected to move into Lassen County (Figure 4). This gave a total of around 3.00 inches of QPF for Lassen County. At a 10 to 1 liquid- to-snow ratio this would translate into 30 inches (2 ½ feet) of snow.

For the central Sierra (Zone 72) the GFS brought 1.5 inches of QPF into the area from 00Z Friday to 00Z Saturday (Figure 3). By 12Z Saturday an additional 0.75 to 1.25 inches of liquid equivalent was expected to move into the Lake Tahoe area. By 00Z Sunday another 1.25 inches of QPF was forecasted (Figure 4). This was a total of 3.75 inches of liquid equivalent, or approximately 38 inches (over 3 feet) of snow for the Lake Tahoe area.

Mono County CA (Zone 73) had lower (but still impressive) totals from the GFS. From 00Z Friday to 12Z Friday only 0.1 inch of QPF was projected, with an additional 0.5 to 0.75 inches during the next 12 hours from 12Z Friday to 00Z Saturday. By 12Z Saturday a tight QPF gradient was over Zone 73 with 0.25 to 0.75 inches of QPF over Mono County. By 00Z Sunday the largest amount (1.25 inches) was expected to spread into the area (Figure 4). This gave a total of approximately 2.50 inches of liquid equivalent, or 25 inches (around 2 feet) of snow.

These snowfall totals were impressive and the upper level dynamics seemed to agree that significant snowfall could result. The same 12Z GFS model from March 11 showed the left exit region (left front quadrant) of the 300 mb jet maximum entering the Lake Tahoe area by 00Z Saturday (Figure 3). This would generate impressive upward vertical motion over the region below this area of the jet maximum. It was still projected to be over the central Sierra 12 hours later at 12Z Saturday. The left front quadrant of the 300 mb jet maximum moved south into southern portions of the Lake Tahoe basin and Mono county by 00Z Sunday (Figure 4) with the curvature of the jet remaining favorable for enhanced upward vertical motion in the Sierra.

The GFS model from 12Z March 13 maintained a strong 300 mb Pacific jet offshore, with a smaller speed maximum just north of San Francisco Bay by 00Z Saturday (Figure 5). Areas in northeast California from Lake Tahoe northward still remained under the favorable left exit quadrant of this smaller speed maximum.

The jet structure changed by Sunday 00Z March 16 as the left front quadrant shifted farther south into southern California with the speed maximum no longer indicating a curvature that would have favored enhanced vertical motion into the Lake Tahoe basin or Mono county (Figures 6 and 7). Despite the less favorable jet orientation, QPF values for Mono county remained sufficient to reach winter storm criteria. This change in the model data between March 11 and 13 added more uncertainty to the forecast of snow for late Friday night through Saturday.

Snow Level Data for First Event

Snow levels have been derived with the primary calculations at WFO Reno utilizing 700 mb temperatures, 1000-500 mb thickness, and 850-500 mb thickness. For the first shortwave which was expected to arrive between 00Z and 12Z on Friday March 14, a wide discrepancy existed between each derived snow level, which provided an extra challenge in determining snow amounts. The snow levels derived from the12Z GFS model from March 11 are contained in Table 1.

Table 1: Derived Snow Levels in Northeast California (Zone 71) & Lake Tahoe Basin (Zone 72)

Model Valid Time	700 mb Temperature	1000-500 mb Thickness	850-500 mb Thickness
00Z Friday Mar.14	7000-7500 ft (Zone 71)	6000-6500 ft (Zone 71)	6000-7000 ft (Zone 71)

(Prior to onset) .... 7500-8000 ft (Zone 72) .... 6500-7000 ft (Zone 72) .... 7000-7500 ft (Zone 72)

06Z Friday Mar.14 .... 6500-7000 ft (Zone 71) .... +/- 5500 ft (Zone 71) .... 6000-6500 ft (Zone 71)
(Precip expected) .... 7000-7500 ft (Zone 72) .... +/- 6000 ft (Zone 72) .... +/- 6500 ft (Zone 72)

12Z Friday Mar 14 .... +/- 6000 ft (Zone 71) .... 5000-5500 ft (Zone 71) .... +/- 5500 ft (Zone 71)
(Precip expected) .... +/- 6500 ft (Zone 72) .... +/- 5500 ft (Zone 72) .... +/- 6000 ft (Zone 72)

18Z Friday Mar 14 .... +/- 6000 ft (Zone 71) .... +/- 5500 ft (Zone 71) .... +/- 6000 ft (Zone 71)
(Precip tapers off) .... +/- 6500 ft (Zone 72) .... 5500-6000 ft (Zone 72) .... +/- 6500 ft (Zone 72)

While derived snow levels were not available with the 12Z GFS model two days later on March 13, 700 mb temperatures were slightly (1-2 degrees C) warmer for the 00Z and 06Z time periods and slightly (1 degree C) cooler for the 12Z and 18Z time period while thickness values indicated little change from the March 11 GFS model data for the full 12 hours. The forecast issued for Thursday night and Friday morning was likely weighted toward the lower snow levels derived from the 1000-500 mb thickness data, which in combination with the model's QPF, could have produced heavy snow amounts above 5500 feet in Zone 71 and above 6000 feet in Zone 72. In contrast, the snow levels derived from the 700 mb temperature data would have yielded little or no accumulating snow below 6000 feet in Zone 71 or below 6500 feet in Zone 72 through 12Z.

The observed temperature data indicated that the snow levels were actually closer to the higher snow levels derived from the 700 mb temperature data (Table 1). Observed 700 mb temperatures at 12Z March 14 were only 1 degree C warmer than forecasted by the GFS model from 12Z March 11, which converts to about a 500 foot difference in derived snow levels. Weather observations at South Lake Tahoe indicated light snow occurred between 12Z and 16Z, but surface temperatures remained above freezing. The snow changed to rain at 16Z before ending at 18Z. Little or no snow accumulations occurred due to these warmer temperatures. Higher elevations above 6500 feet in the Lake Tahoe basin received only 1 to 3 inches of snow overnight. Conditions for strong downslope winds on the lee side of the Sierra Crest were indicated by a dry adiabatic lapse rate from 750 mb to the surface on the Reno NV sounding from 00Z March 14. Moisture depth upstream of the Sierra was also shallower than expected as the 12Z March 14 sounding at Oakland CA indicated that the moist layer extended up to only 700 mb. As a result of both the downslope winds and shallow moisture, much of the precipitation was cut off at the Sierra Crest. Onset of precipitation occurred up to 8 hours later than expected, resulting in a much shorter duration and reduced snowfall in the Sierra (Figures 8 and 9).

Splitting system for Second Event

Away from the main upper low which remained in the Gulf of Alaska, a secondary upper low pressure center off the northern California coast moved north and remained offshore through Saturday March 15 (Figures 13 and 14). This resulted in a split between the northern and southern branch of the jet stream where the best instability in the north separated from the moisture axis and jet dynamics in the south. This secondary upper level low was not resolved on the GFS model from March 11. Although the split was becoming more evident by March 13, the QPF values associated with the southern moisture axis still supported winter storm criteria with precipitation in the Sierra expected for 15-18 hours between 15/06Z and 16/00Z (Figure 6).

However, the actual southward progression of the main precipitation band accelerated on Saturday, with the back edge exiting southern Sierra and Lassen counties (Zone 71) before 18Z, then exiting the Lake Tahoe basin (Zone 72) between 18Z and 19Z and finally exiting southern Mono county (Zone 73) by 2230Z (Figure 15). This resulted in 3 to 5 fewer hours of snowfall in Mono county with 5 to 8 fewer hours of snowfall in the Sierra from Lake Tahoe northward (Figures 10 and 11). Even though a few higher elevation areas reached minimal winter storm criteria, the shorter duration of the heavy snowfall kept snow amounts up to one foot less than expected in the Sierra above 7000 feet. In addition, snow levels were above 6500 feet for the first 6-8 hours of the heavy precipitation event, so areas around the elevation of Lake Tahoe and Mono Lake received rain followed by only a few hours of snow before the precipitation tapered off, lowering snow amounts by an even greater amount. (Figure 12)

Summary and Conclusions

Several factors contributed to a highly overestimated snowfall forecast for eastern California from March 13 through 15. The derived snow levels exhibited a wide range of values and the coordinated forecast with surrounding WFO's utilized a blend of the data which resulted in snow levels being too low compared to the observed elevation for accumulating snow. Mesoscale processes that modified the air mass to a warmer and drier condition east of the Sierra Crest were not fully captured by the lower resolution GFS model. Moisture depth was shallower than indicated by the model data, resulting is less precipitation being carried over the Sierra Crest. A consolidated 500 mb flow with strong jet dynamics indicated by medium range models evolved into a split flow which reduced instability and convective enhancement within the main precipitation band as it moved across the Sierra. Finally, a southward acceleration of the precipitation band after the air mass became cold enough for snow in lower elevations of eastern California resulted in a shorter duration of moderate to heavy snowfall.

This case highlights the difficulties and challenges that meteorologists face when forecasting winter storms on the east slopes of the Sierra. While a sufficient amount of model data is available, the low spatial resolution of the models fail to fully account for effects of steep terrain in the Sierra. This study was intended to increase situational awareness which can alert forecasters that processes not captured by model data may result in a large difference between expected and actual snowfall amounts. While typical case studies involve strong storms or underestimated snow forecasts, the analysis of storms with overestimated snow amounts also carries substantial benefits to the operational forecasters as they can apply this knowledge to improve future snowfall forecasts in the Sierra.

Acknowledgments

Thanks to Jim Fischer, Science and Operations Officer at NWS Reno for assisting us with this study by archiving the weather data between March 11 and 15 on the Weather Event Simulator (WES), and also for finding the NPVU data from the Hydrometeorological Prediction Center web site which compared forecast QPF by the models to total precipitation amounts estimated by the California-Nevada River Forecast Center.

Figure 1

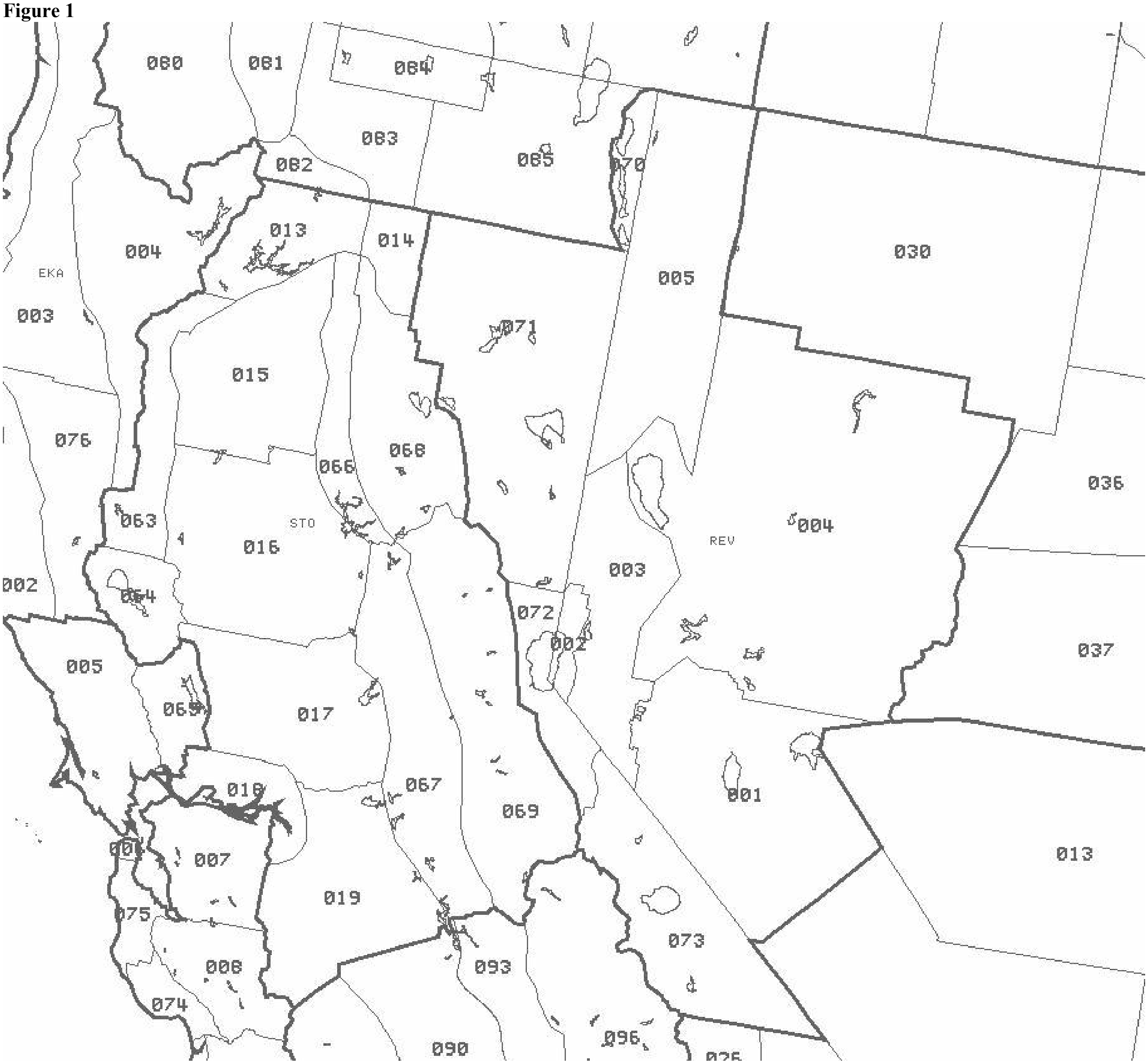


Figure 2

Results from the Snowstorm that Wasn't: March 13-15, 2003

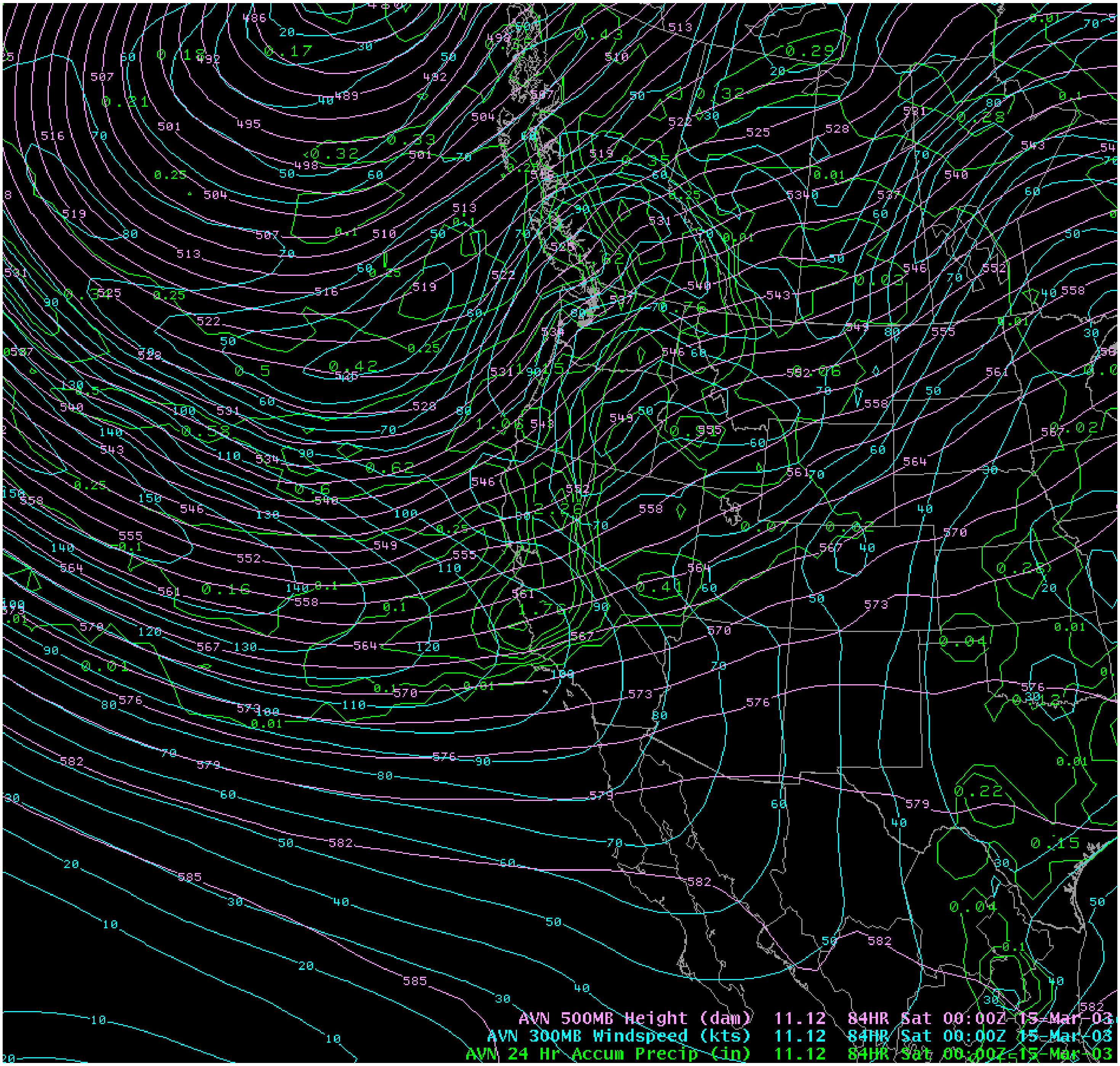
- **Lassen, Eastern Plumas, Eastern Sierra Counties (Zone 71):**
  Expectations: 3-4 feet of snow above 6000 feet.
  12-18 inches of snow 5000-6000 feet.
  Actual Amounts: No reports above 6000 feet.
  Less than 3 inches below 6000 feet.

- **Greater Lake Tahoe Area (Zone 72):**
  Expectations: 3-5 feet of snow above 7000 feet.
  18-30 inches of snow 6000-7000 feet.
  Actual Amounts: Trace-3 inches below 7000 feet.
  6-17 inches above 7000 feet.

- **Mono County (Zone 73):**
  Expectations: 3-4 feet of snow above 7000 feet.
  1-2 feet of snow 6000-7000 feet.
  Actual Amounts: 5-10 inches 7000-9000 feet.
  17 inches above 9000 feet.
  Less than 3 inches below 7000 feet.

Figure 2. Maximum snow amounts forecasted and summary of actual snowfall amounts for each forecast zone in eastern California.

Figure 3



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AVN 24 Hr Accum Precip (in) 11.12 84HR Sat 00:00Z 15-Mar-03

Figure 4

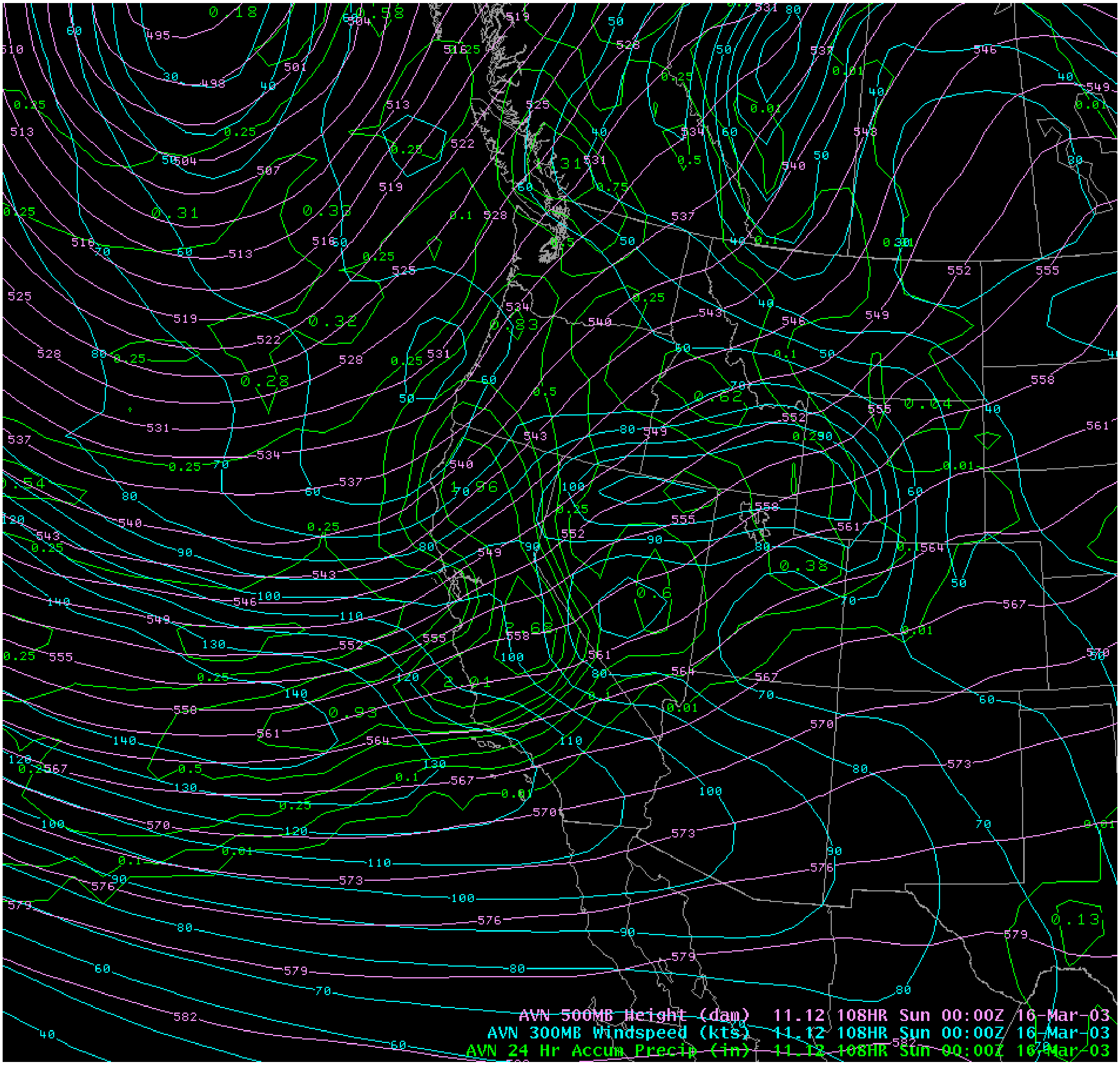
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Figure 5

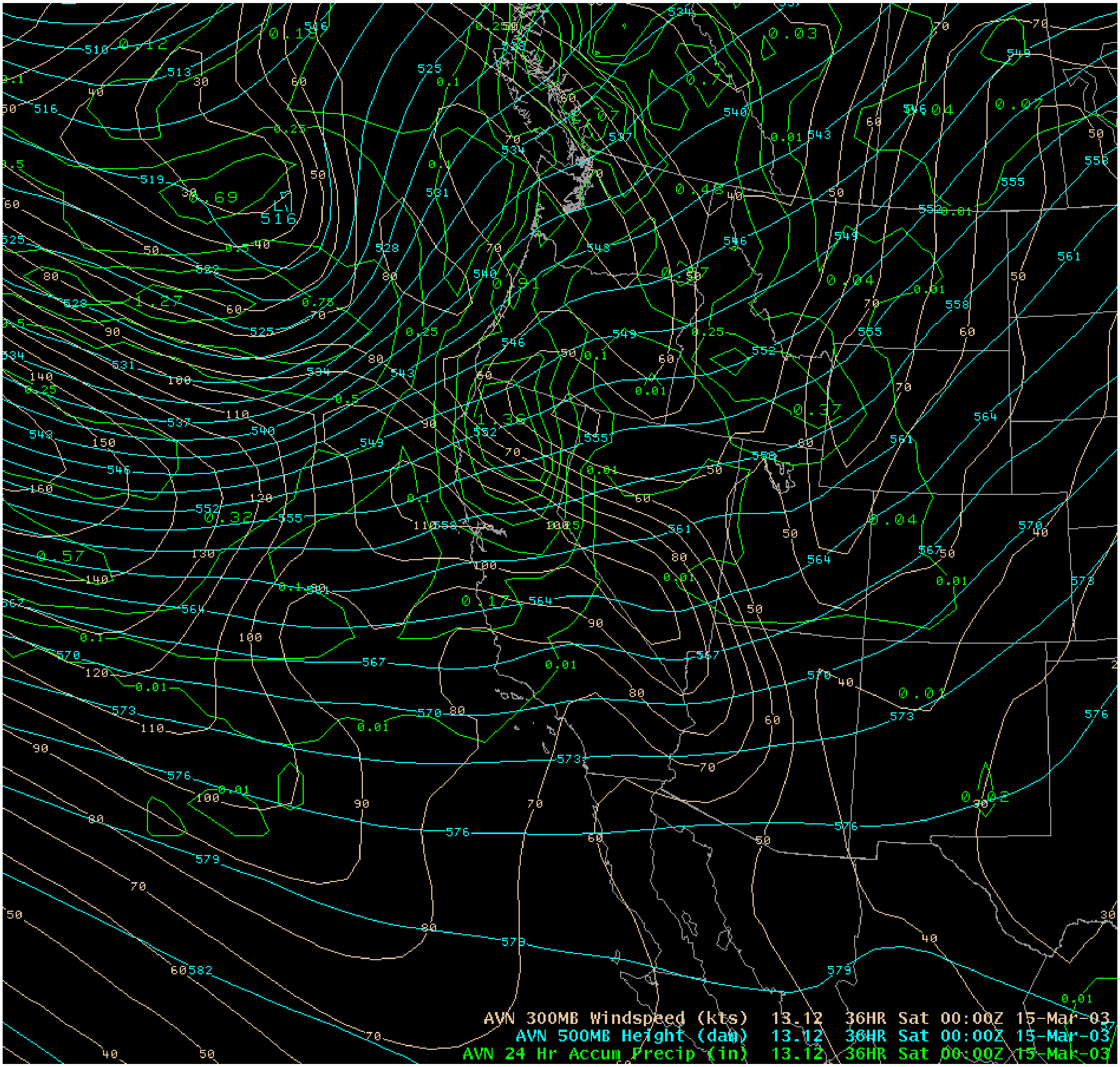
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Figure 6

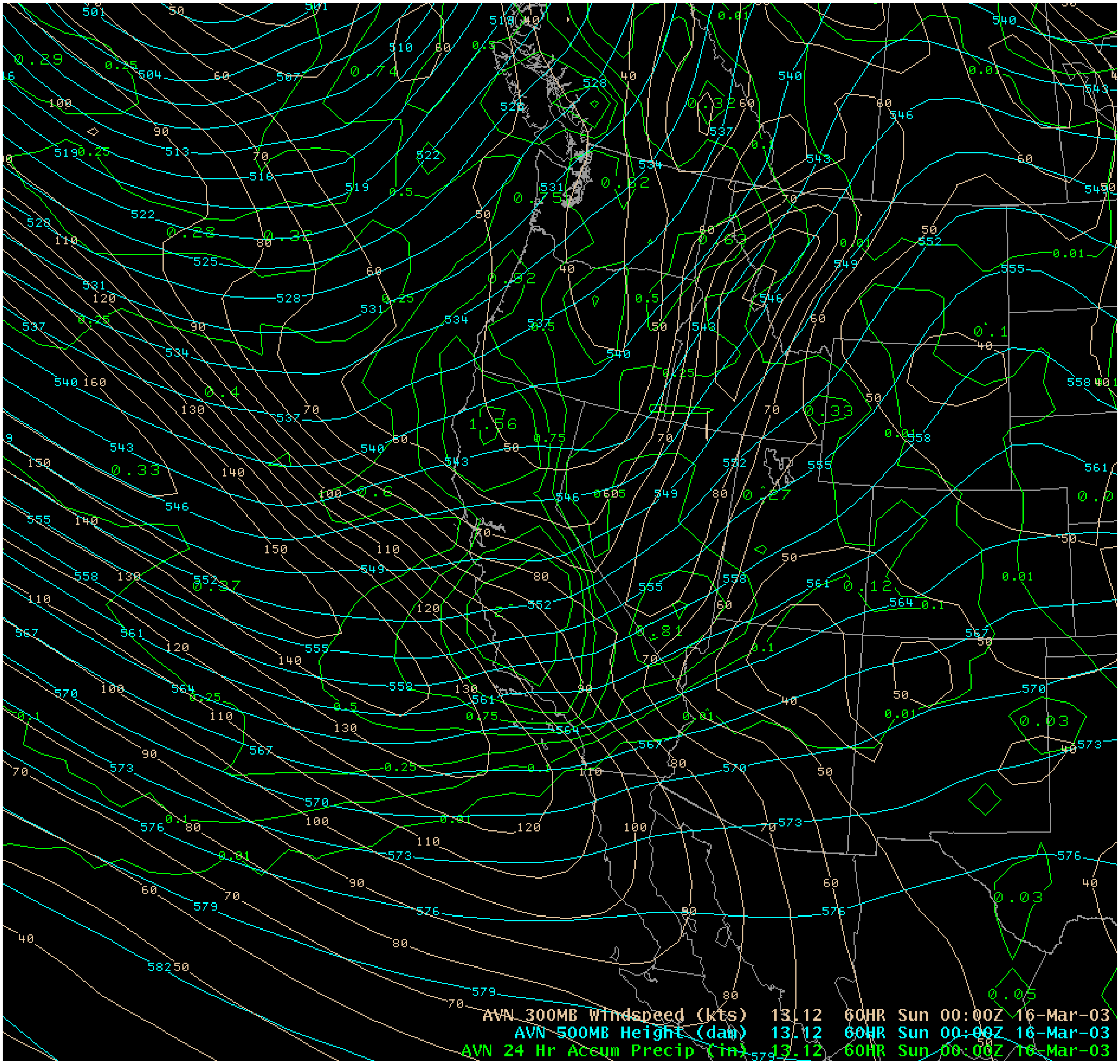
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Figure 7

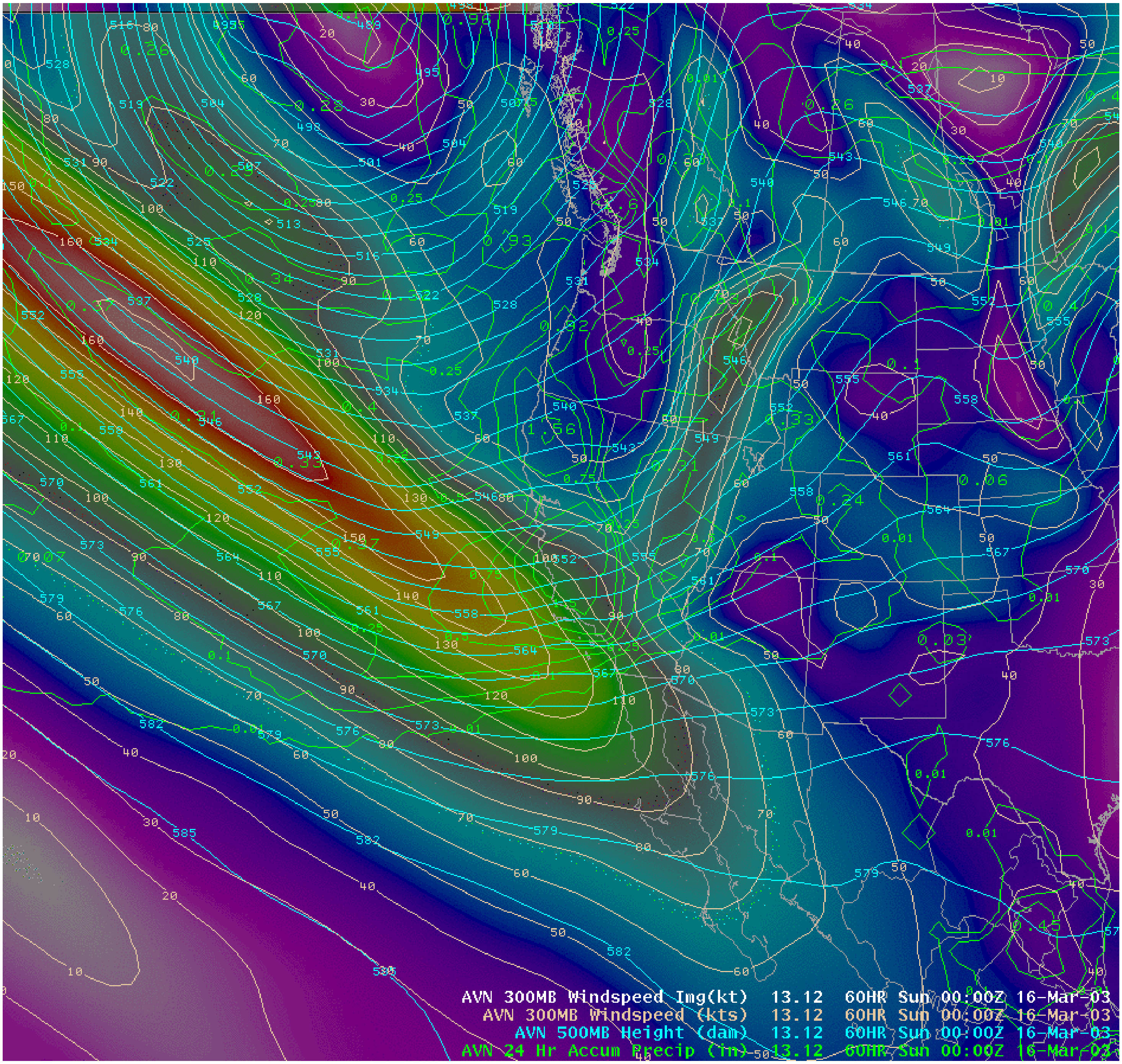
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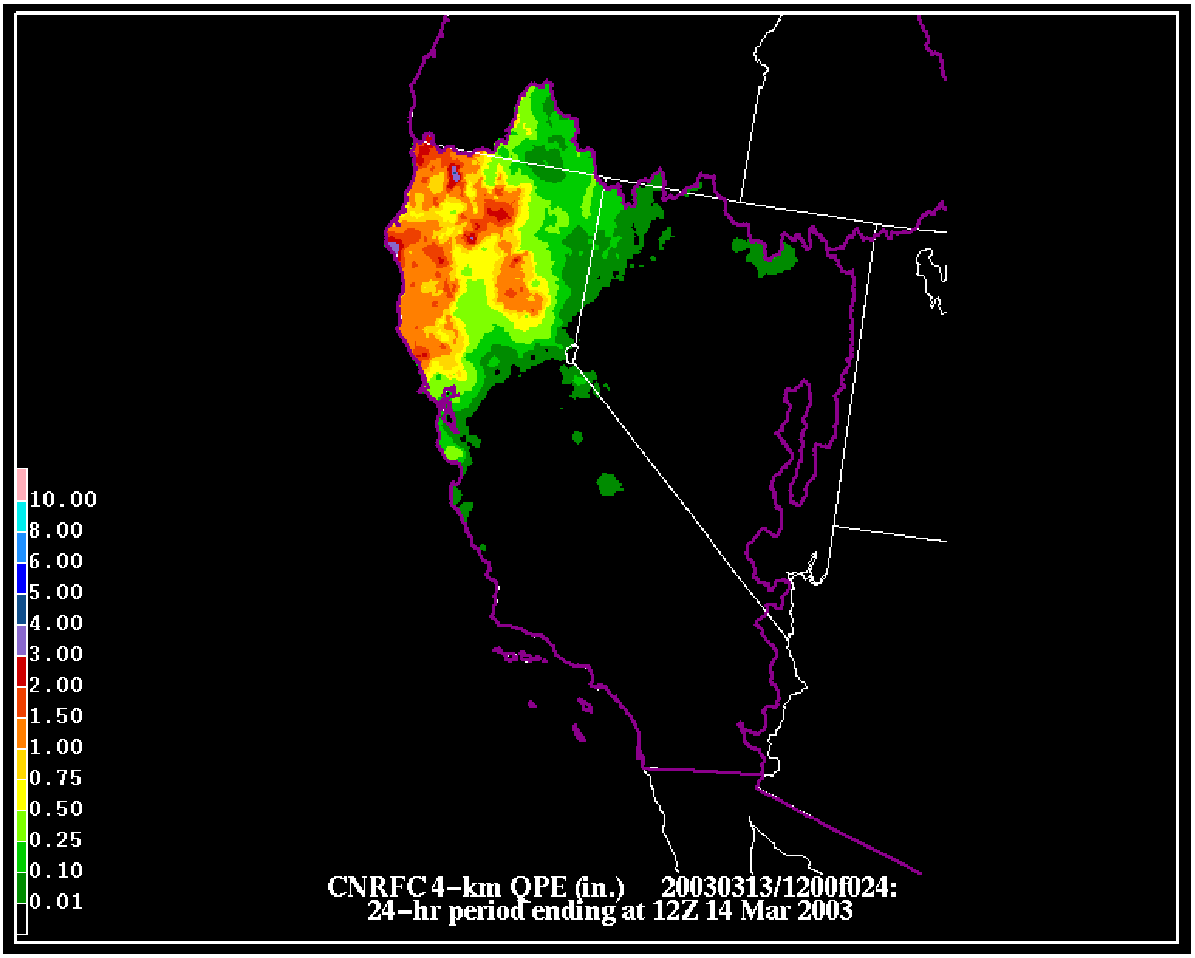
Figure 8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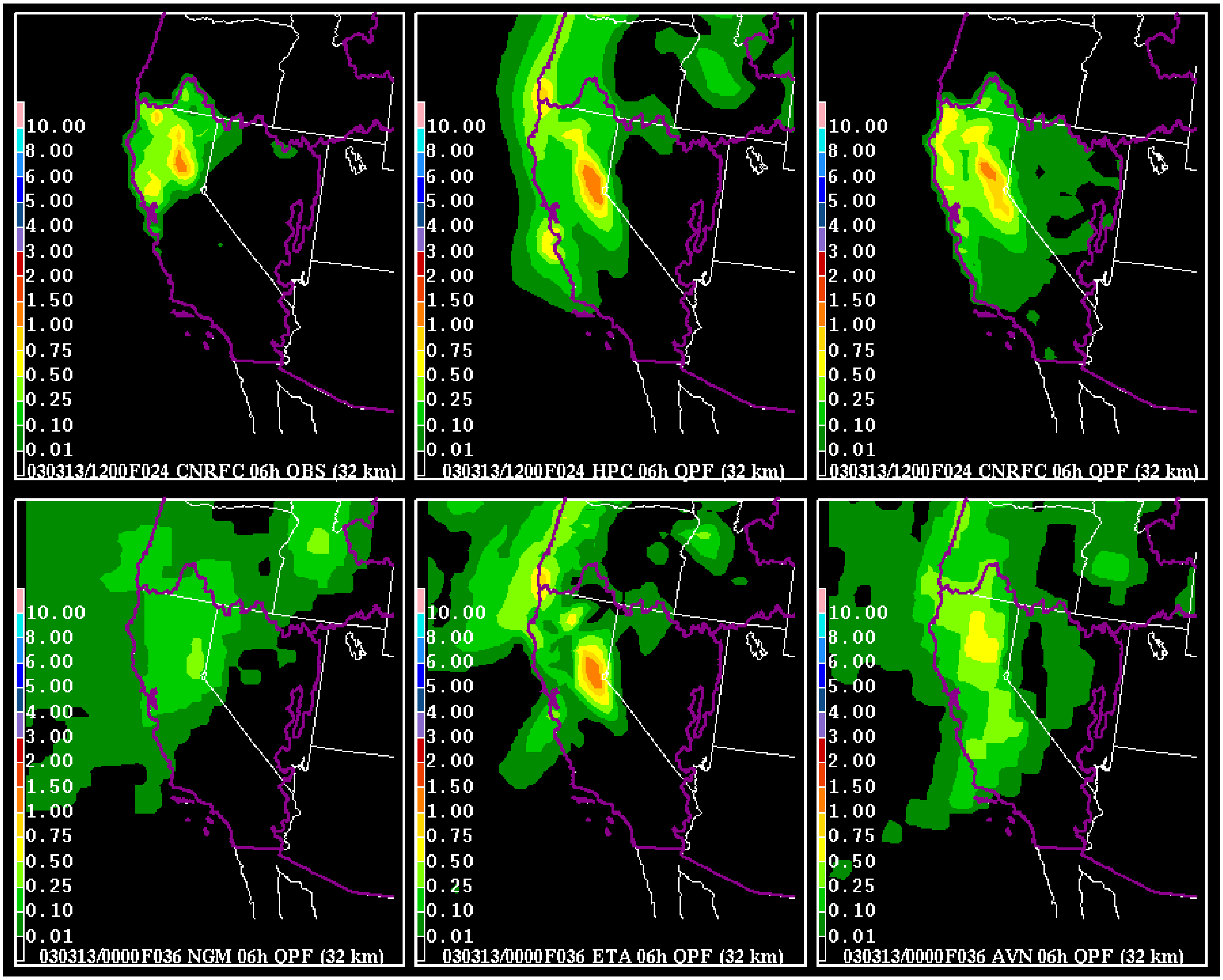
CNRFC 4-km QPE (in.) 20030313/1200f024:
24-hr period ending at 12Z 14 Mar 2003

Figure 9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030313/1200F024 CNRFC 06h OBS (32 km)
030313/1200F024 HPC 06h QPF (32 km)
030313/1200F024 CNRFC 06h QPF (32 km)
030313/0000F036 NGM 06h QPF (32 km)
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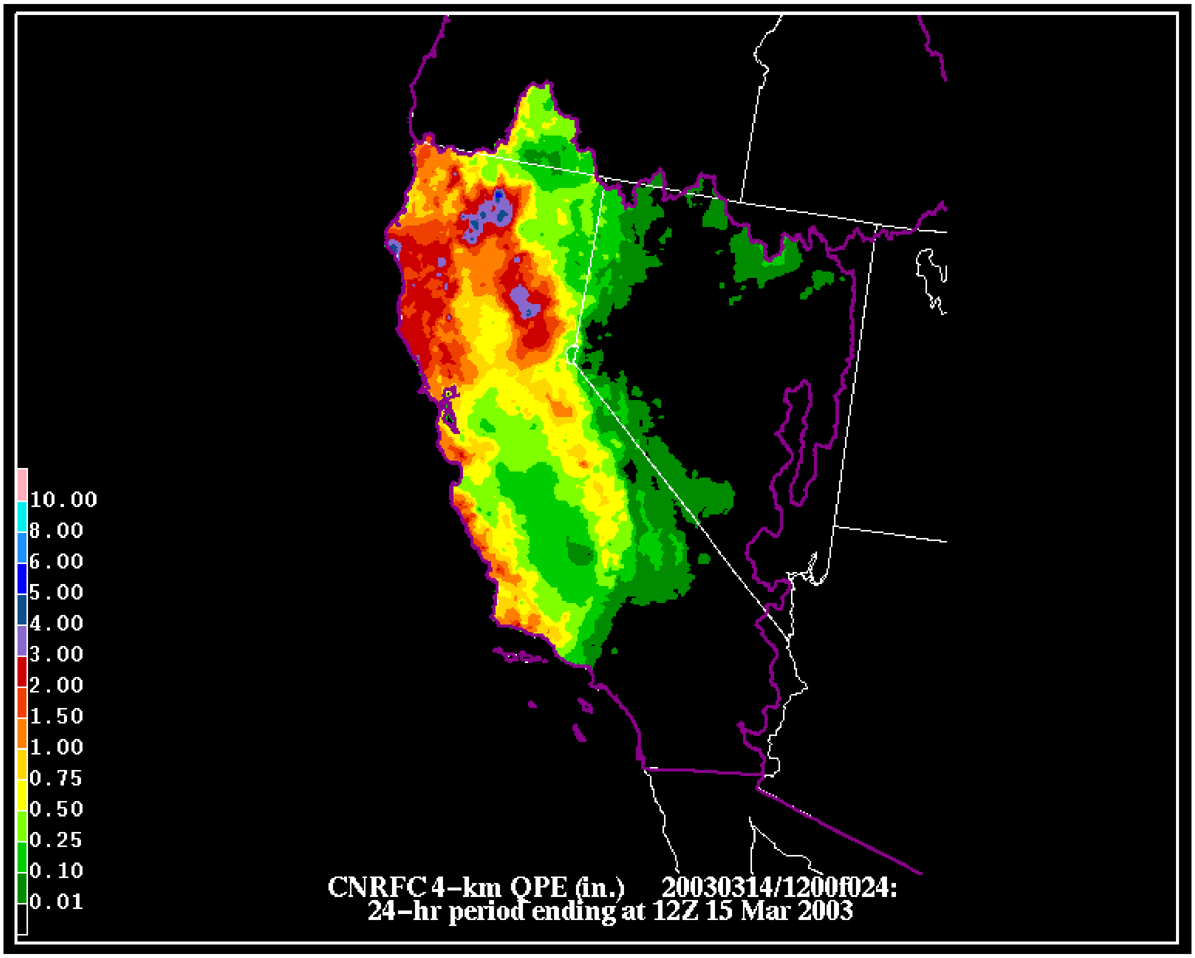
030313/0000F036 AVN 06h QPF (32 km)

Figure 10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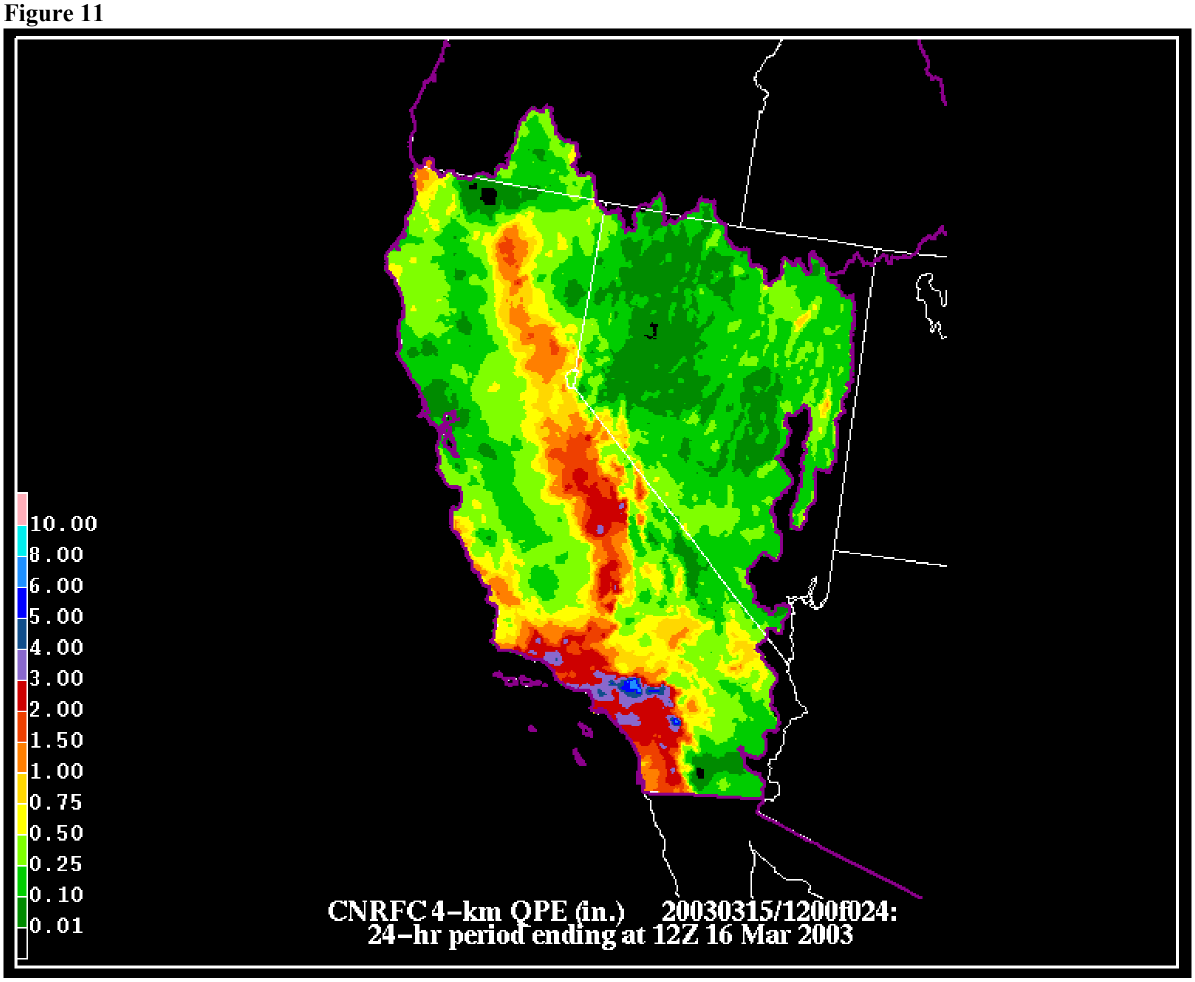
24-hr period ending at 12Z 15 Mar 2003

Figure 11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24-hr period ending at 12Z 16 Mar 2003

Figure 12

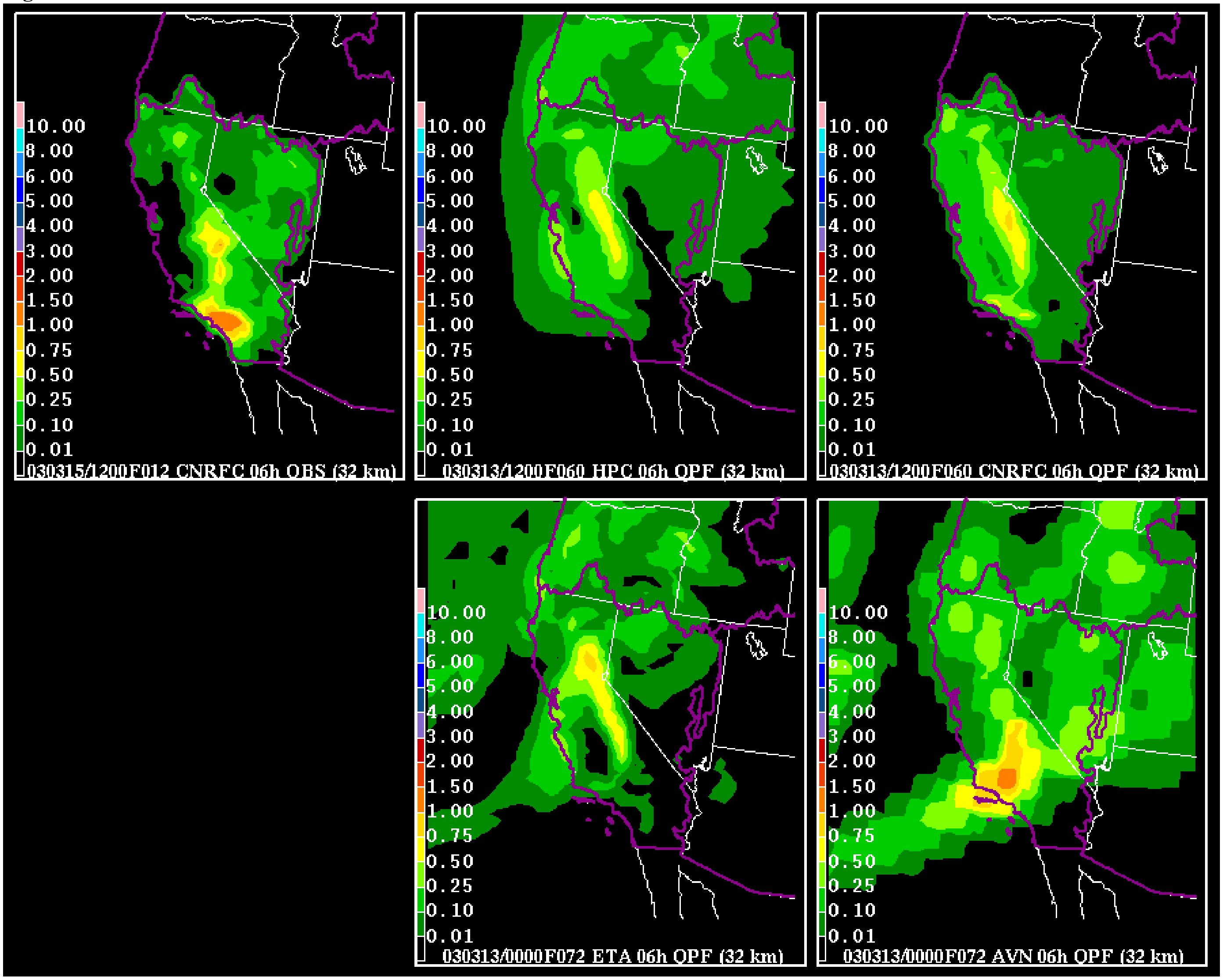
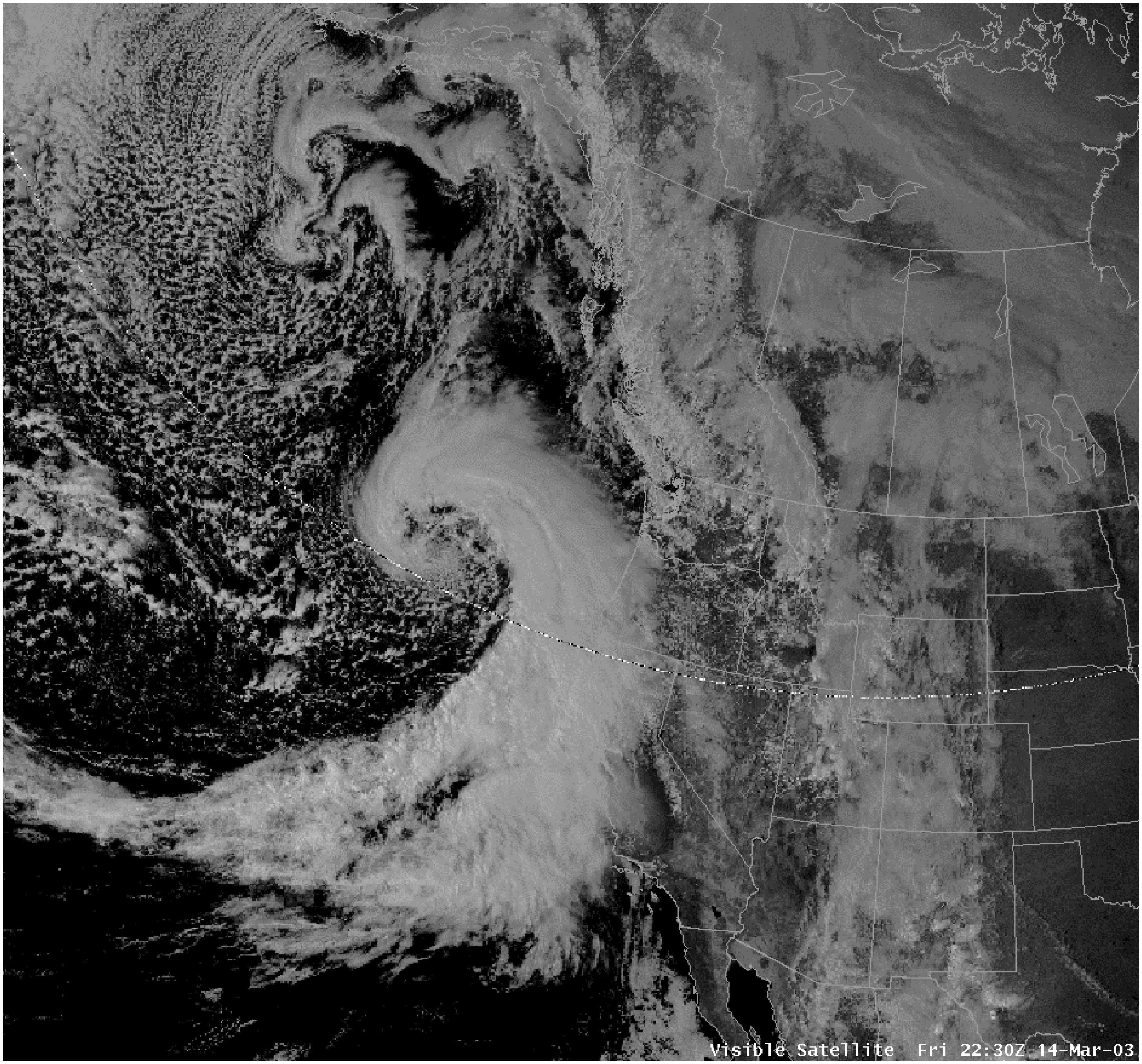


Figure 13



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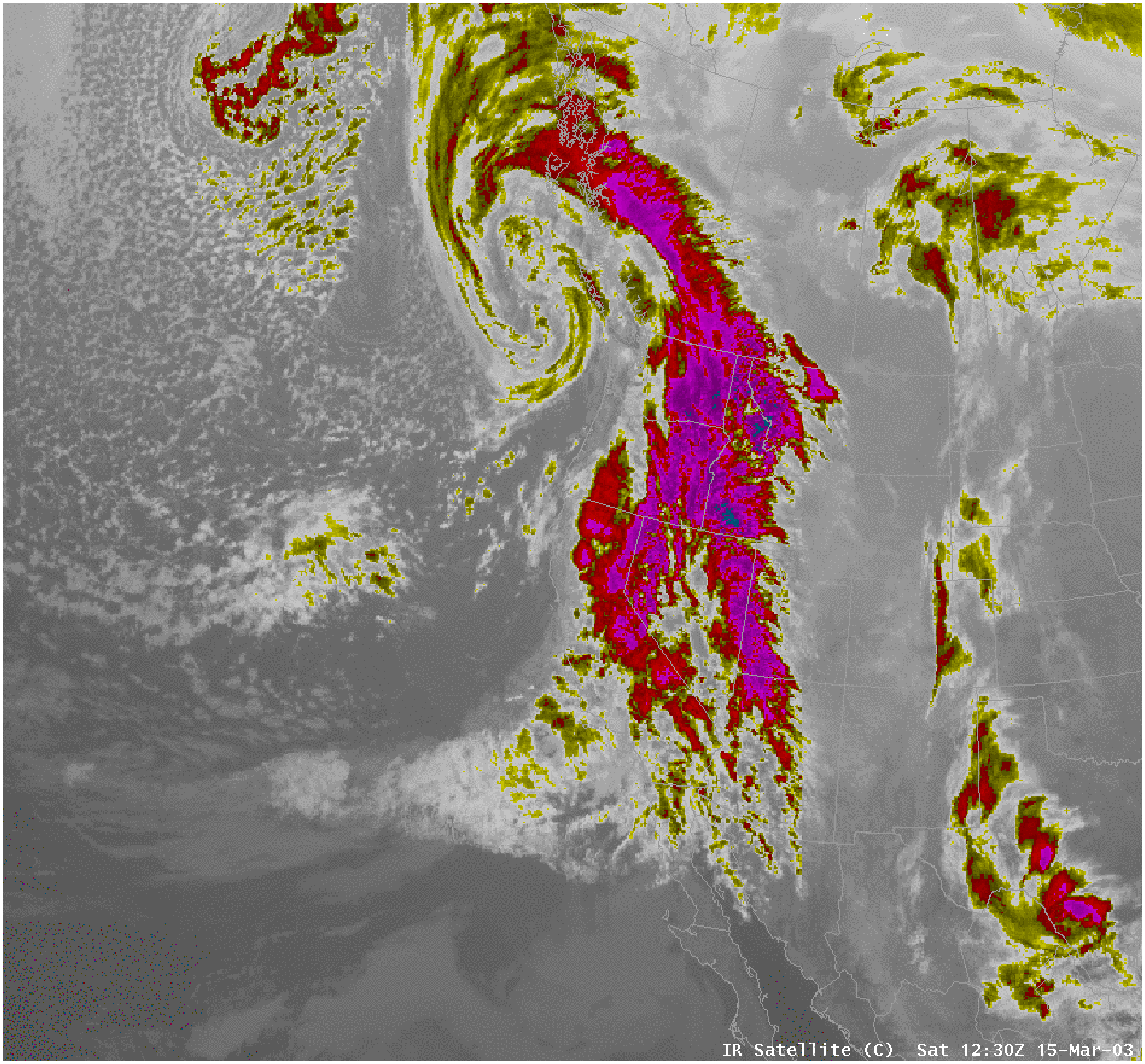
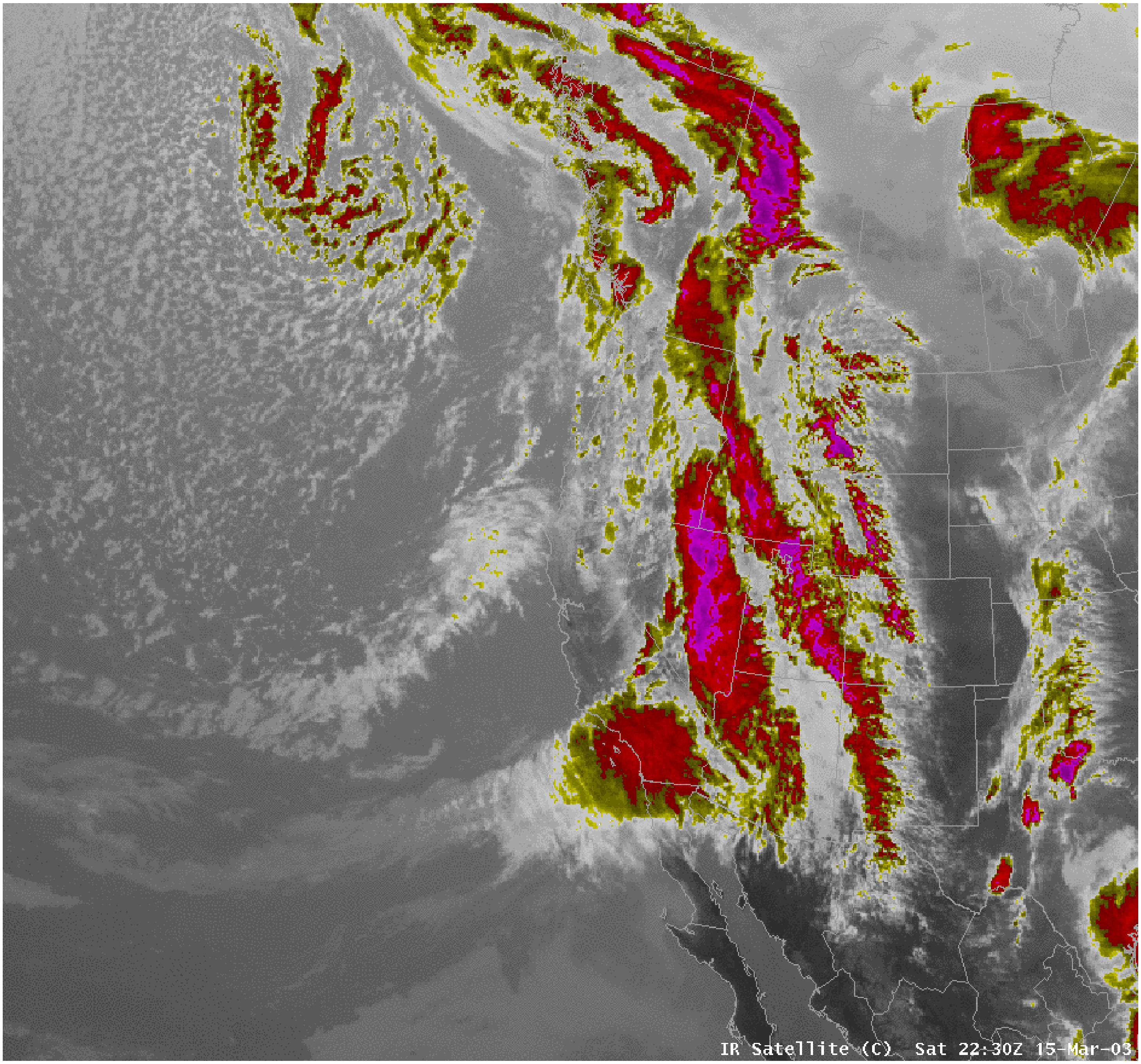


Figure 15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