A Blue Mountain Snowstorm WES Case

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WFO Pendleton
February 3, 2004

Overview

A cold front passage on the 29th of December, 2002 was followed the next day by an 18-hour period of warm air advection and snowfall over the Blue Mountains. This paper will focus on the section of the Blue Mountains located immediately southeast of the Columbia Basin (Fig. 1), and specifically on two Oregon locations:� Meacham (KMEH), elevation 4055 feet on I-84, and Tollgate (KQGT), elevation 4960 feet on state highway 204 northeast of Meacham.� Twenty-four-hour snowfall reports ranged from 10 to 15 inches near Meacham and 18 inches at Tollgate.� A challenging aspect of forecasting this event was the rising snow level at these two locations.� Eta and GFS model forecast soundings at Meacham and Tollgate suggested that the wet-bulb-zero level would rise during the evening of the 30th above 5000 feet.� In reality, wet-bulb temperatures were at or below freezing at Meacham and in the upper 20s at Tollgate throughout the event.

Synoptic Evolution and Model Evaluation

During the day and evening of December 30th, a broad Pacific trough approached the U.S. west coast.� A southwest-to-northeast oriented baroclinic zone progressed eastward from the Oregon coast across the Cascade Mountains while a broad, moist warm sector remained over eastern Oregon and Idaho.� Meanwhile, several short waves moved northeastward along the baroclinic zone.� The two strongest short waves enhanced precipitation across the Blue Mountains: the first between 12 to 18 UTC was embedded in westerly flow (Fig. 2a), and the second between 02 to 08 UTC was the result of cyclogenesis along the Oregon coast (Fig. 2b).

Both the Eta and GFS models initialized on December 29th (1200 and 1800 UTC) captured the timing of the 18-hour period of significant omega/warm air advection and precipitation on December 30th (Fig. 3a and 3b).� Of the two models, only the Eta resolved the enhanced lift, brief cold advection aloft, and precipitation from the two short waves (Fig. 3a).� The Eta also had a superior representation of the southeast pressure gradient across the Blue Mountains (a gradient which trapped colder air and led to lower snow levels southeast of the Blues).� The Eta model was, of course, capable of capturing these smaller-scale features because of its finer model resolution.� Eta grid resolution was (and is) 12 km while the GFS spectral resolution of T254 (out to 84 hours) was (and is) equivalent to about 55 km.

Precipitation Observations and Model Evaluation

The following table shows 6 hour melted snow amounts in inches at the Meacham ASOS and at two SNOTEL Sites:� Emigrant Springs (ESP03), at 3925 feet, 2 miles northwest of Meacham, and High Ridge (HIR03), at 4980 feet, 7 miles south of Tollgate.

Day (PST)	UTC	PST	KMEH	ESP03	HIR03
30	0800	0000	.00	.00	.00
30	1400	0600	.48	.30	.40
30	2000	1200	.83	.50	.50
30	0200	1800	.07	.10	.30
31	0800	0000	.24	.10	.50
31	1400	0600	.09	.05	�.00
31	2000	1200	.05	.05	.20

The strongest observed precipitation rates at the Meacham ASOS were from 1200 to 1800 UTC on the 30th when .98 inches melted precipitation was observed over the 6-hour period.� The cross-terrain flow during the event was moderately strong and from the south to southwest.� A southeast or south surface pressure gradient brought surface flow past Baker City, through the Grande Ronde Valley, and finally past Meacham and Tollgate (Fig. 4).� This flow more or less parallels I-84 through gaps in the mountains and is upslope at Baker City, downslope at La Grande, and then upslope again at Meacham and Tollgate.� Therefore, the forcing for this period of more intense precipitation at Meacham is attributable to the combination of (1) the ongoing warm-air-advection, (2) the first embedded shortwave described above, and (3) upslope surface flow.

Figure 5 shows the 24-hr QPF from 06 UTC on the 30th to 06 UTC on the 31st of December. The Eta model is displayed on a 40-km AWIPS grid (Fig. 5a), and the GFS model on an 80-km grid (Fig. 5b). The Eta model under forecasted amounts by about 50 %, but correctly placed larger amounts on south facing (upslope) aspects.� The GFS QPF amounts were more correct when compared to mountain locations, but it vastly over forecasted amounts for La Grande (.28 inches over 24-hours) and other valley locations.� This over forecast of precipitation is in part due to the coarser resolution of the GFS model and AWIPS display grid, but is probably also attributable to a GFS model bias -- at least in the interior Pacific Northwest � of overestimating QPF.

Snowfall and Microphysics

Both models and regional upper-air soundings suggested a very deep, cold, saturated air mass over the Blues, and no melting layer.� The depth of the -12 to -18 C temperature range was about 4000 feet.� Such a vertical profile should support the activation of ice nuclei, dendrite crystal growth, aggregation of snow, etc., all of which suggest higher snowfall amounts with snowfall to snowmelt ratios of 20:1 or higher.� However, SNOTEL and human observations for this event revealed ratios close to 10:1 at both Tollgate and Meacham.� Lapse rates were in the 4 to 6 C/km range, and perhaps steeper lapse rates are needed to realize higher snow ratios.� In any case, further research into the relationship of microphysics and snow ratios across the interior Pacific Northwest is needed.

Forecasting Snow Level

Both the Eta and GFS models did a fairly good job capturing the timing of the cold front passage on the 29th of December.� However, the models differed with their handling of air mass temperature and moisture within the warm sector on the 30th.� The GFS model was in general a few degrees warmer then the Eta model.� A comparison of model forecast soundings to regional upper air soundings in the warm sector shows that the GFS verified better than the Eta in the 700-500 mb range, where the Eta model was too cold by 1 to 2 degrees C at these locations.� However, these regional upper-air soundings probably do not reflect the influence of the short waves because they traveled mainly in between those locations (Salem, Spokane and Boise).

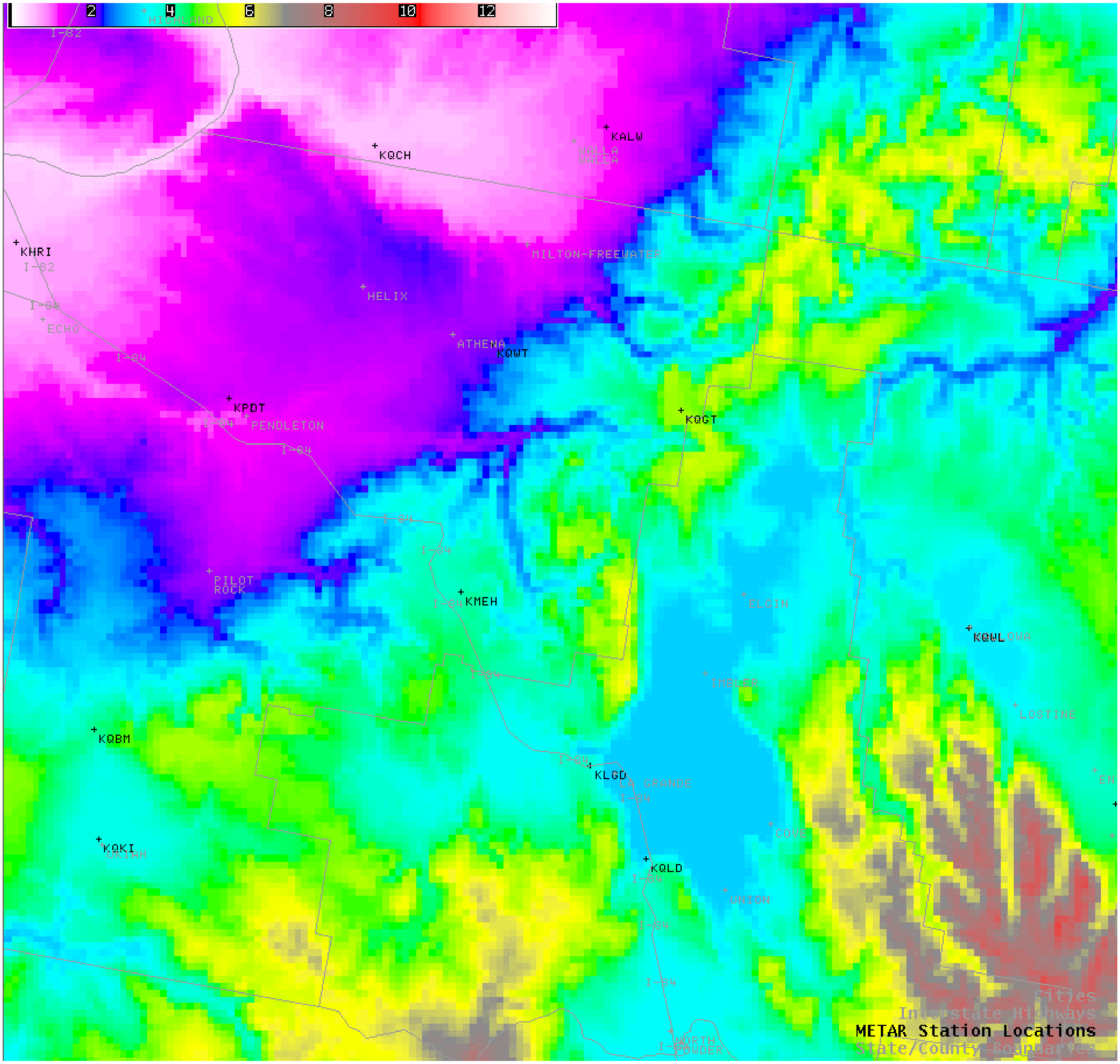
Snow changed to rain overnight on the 29th in the Columbia Basin (northwest of the Blue Mountains).� Snow changed to rain relatively early (9am PST) at La Grande (KLGD, elevation 2755 feet) � where downslope warming probably played a role.� The wet-bulb temperature rose above freezing at noon at Ontario, OR (2188 feet in the Treasure Valley south of the Blues) and not until 11 pm PST at Baker City, OR (3370 feet).� This lower snow level in the valleys south and southeast of the Blues is attributable to upslope flow and trapped cooler air.� The Eta model captured the relatively lower snow levels to the south and southeast of the Blues fairly well, but did not capture the local warming at La Grande.� The GFS model wet-bulb temperatures are too warm in general across the Blues, probably a reflection of its failure to resolve the intensity of the short waves and terrain forcing.

Both GFS and Eta model forecasts from the 29th incorrectly showed that the wet-bulb zero level would rise above the surface at Tollgate (4960 feet) on the 30th (Fig. 6).� The GFS forecast the transition around noon PST (20 UTC, Fig. 6b) and the Eta around 8 pm PST (00 UTC, Fig. 6a).� However, forecaster experience at WFO Pendleton suggests that snow levels will typically be at least 500 feet lower than the model wet-bulb zero forecast, at least during warm-air-advection events.�� Furthermore, a plan view of the Eta wet-bulb temperature (Fig. 7) reveals that at 0000 UTC the grid point at Tollgate is right on the edge of cooler air to the southeast. �This example demonstrates that in addition to model soundings one should use plan views of wet-bulb temperature (or cross sections across mountain ranges) to identify how model terrain forcing is influencing the snow level forecast.� It is also important to note that an error of 500 to 1000 feet in wet-bulb zero can be the result of small temperature and dewpoint errors � say 1 or 2 degrees C at 850 or 700 mb.� Therefore, wet-bulb zero model forecast errors of 500 to 1000 feet in complex terrain should not be considered surprising.

Lessons Learned

1.�� The December 30, 2002 Blue Mountain snowstorm was the result of (a) a prolonged period of warm air advection as a broad, moist warm sector remained over the Blue Mountains, (b) enhanced lift from the passage of two short waves that developed along a baroclinic zone west of the Blue Mountains, and (c) upslope flow.
2.� Smaller scale features important to this event (short waves, surface pressure gradients and upslope flow) required a mesoscale model (such as the 12 km Eta) to be resolved correctly.
3.� An error of 500 to 1000 feet in wet-bulb zero can be the result of small temperature and dewpoint errors � say 1 to 2 degrees C at 850 or 700 mb (yet can have a huge impact on transportation through mountain passes).� As such, wet-bulb zero model forecast errors of 500 feet should not be surprising.
4.� The use of the model cross sections and plan views of surface wet-bulb temperature (with a color table that highlights wet bulb zero centigrade) is recommended to reveal the influence of terrain forcing.

Figure 1


2
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HIGHLAND
I-82
KQCH
KALW
WALLA
WALLA
KHRI
I-82
MILTON-FREEWATER
HELIX
I-84
ECHO
I-84
ATHENA
KQWT
KPDT
I-84
PENDLETON
I-84
KQGT
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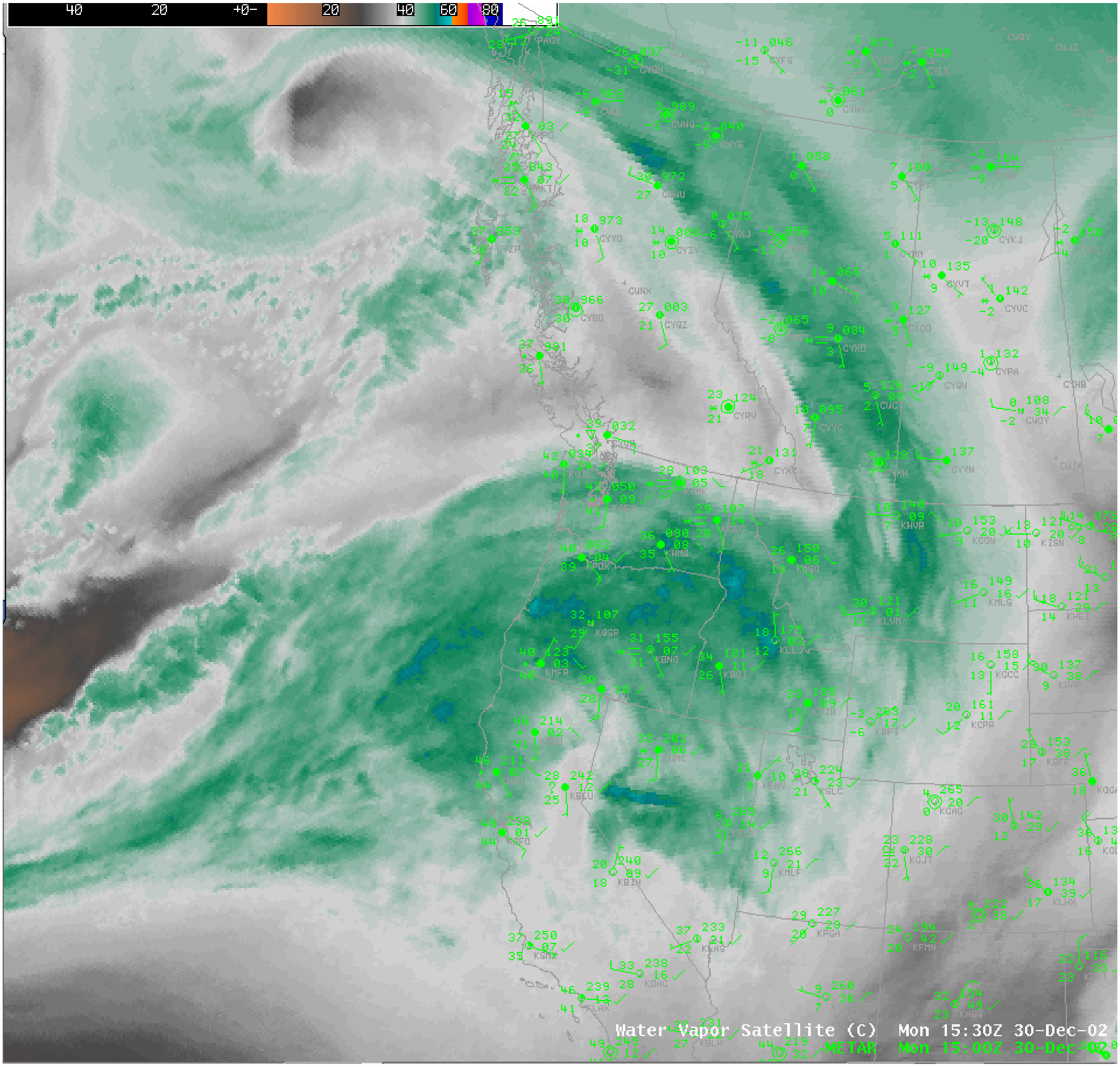
PILOT
ROCK
KMEH
I-84
ELGIN
KQWL
OWA
I-84
IMBLER
LOSTINE
KQBM
I-84
KLGD
LA GRANDE
I-84
EN
COVE
KQKI
UKIAH
KQLD
I-84
UNION
I-84
I-84
NORTH
POWDER
I-84
Cities
Interstate Highways
METAR Station Locations
State/County Boundaries

Figure 2a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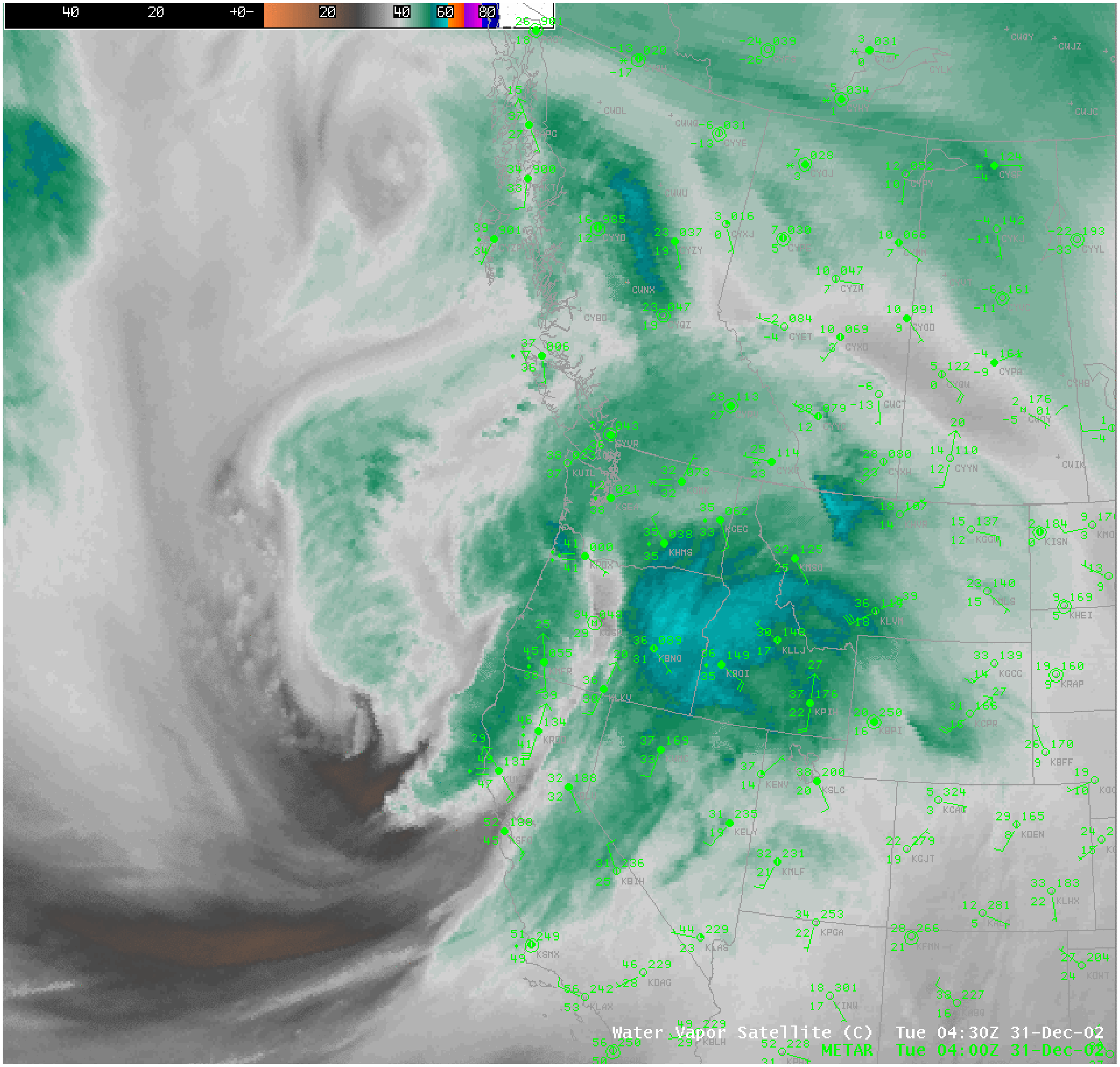
Water Vapor Satellite (C) Mon 15:30Z 30-Dec-02
METAR Mon 15:00Z 30-Dec-02

Figure 2b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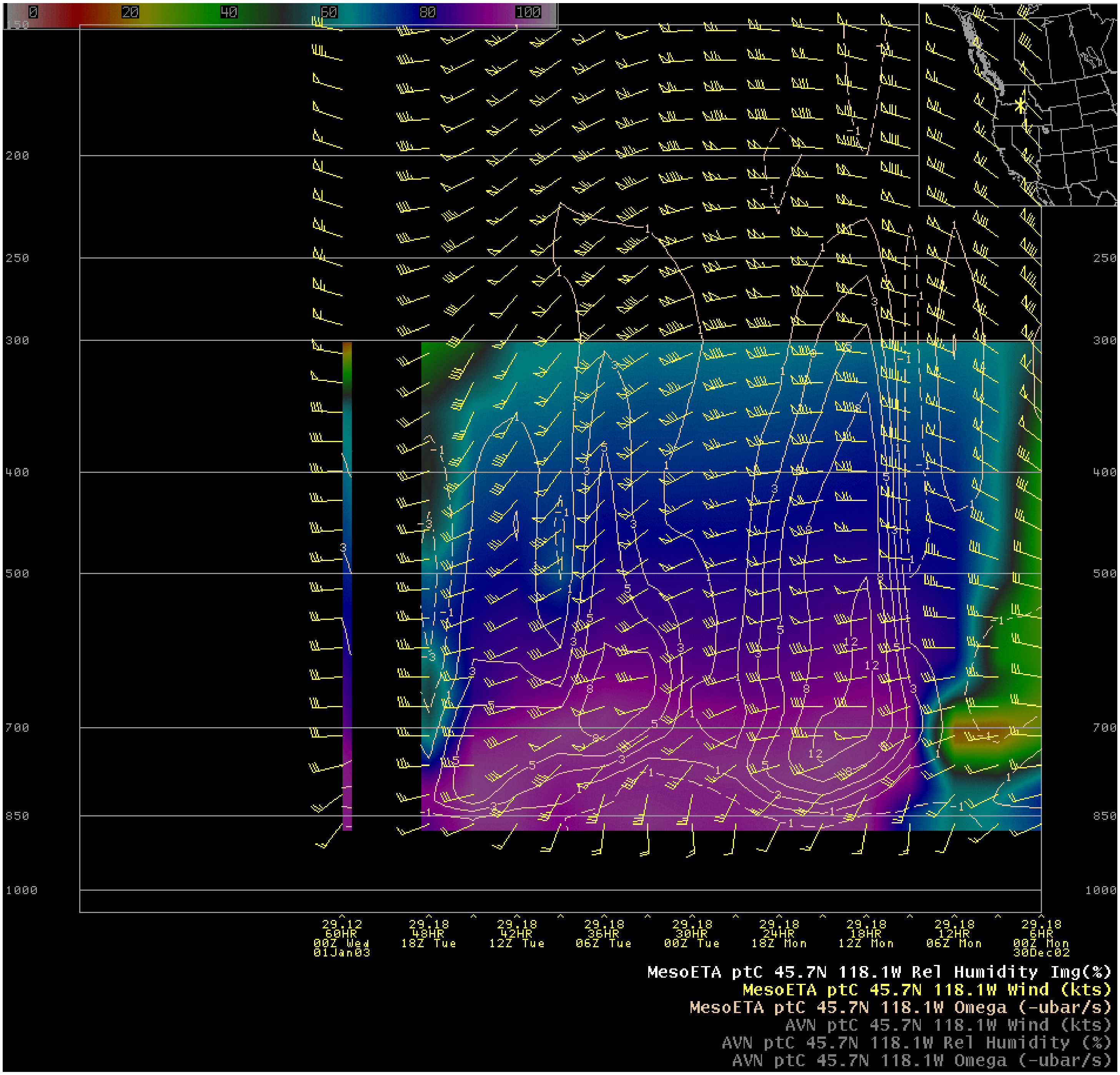
METAR Tue 04:00Z 31-Dec-02

Figure 3a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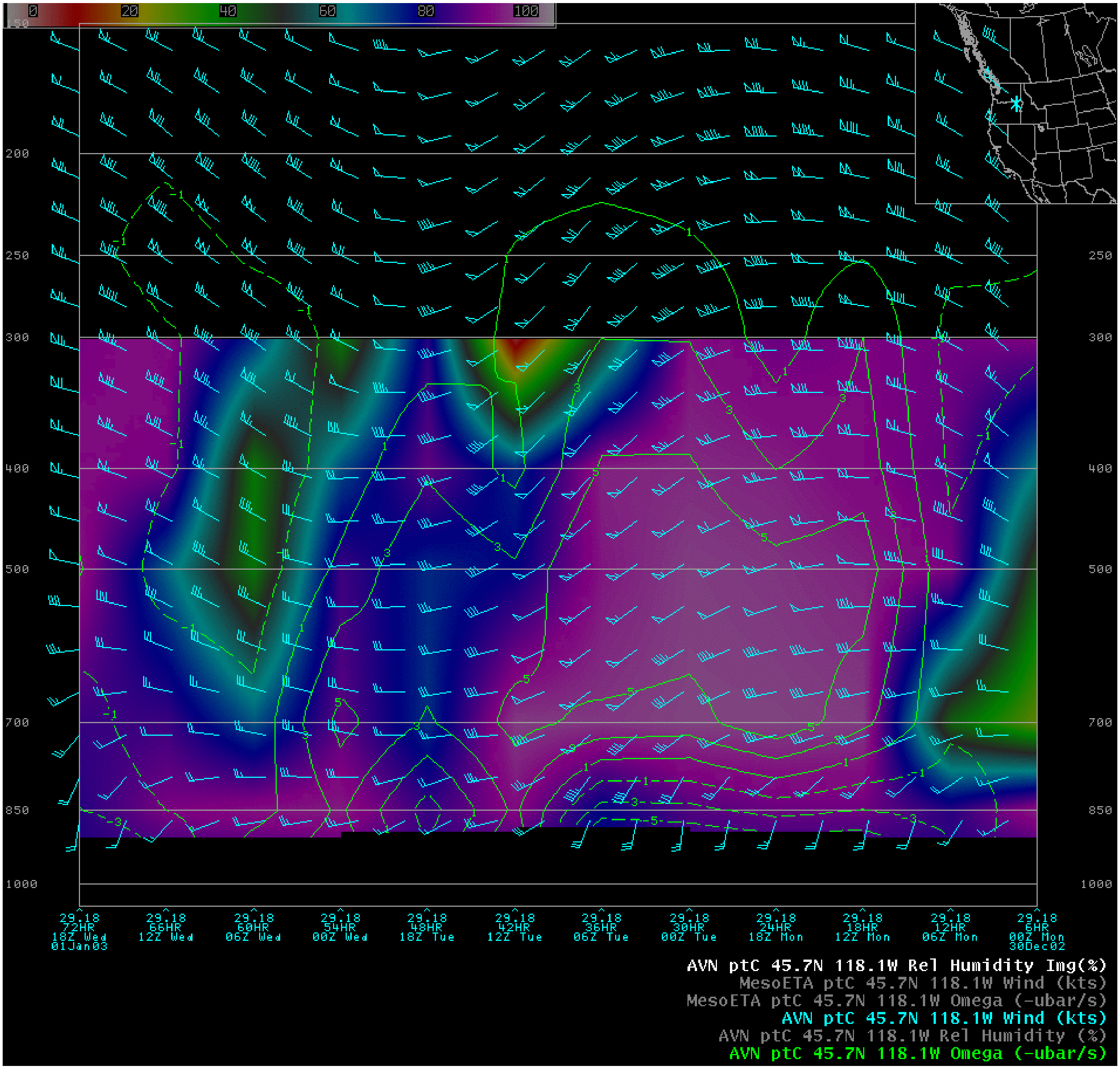
30Dec02
MesoETA ptC 45.7N 118.1W Rel Humidity Img(%)
MesoETA ptC 45.7N 118.1W Wind (kts)
MesoETA ptC 45.7N 118.1W Omega (-ubar/s)
AVN ptC 45.7N 118.1W Wind (kts)
AVN ptC 45.7N 118.1W Rel Humidity (%)
AVN ptC 45.7N 118.1W Omega (-ubar/s)

Figure 3b



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29.18 12HR 06Z Mon
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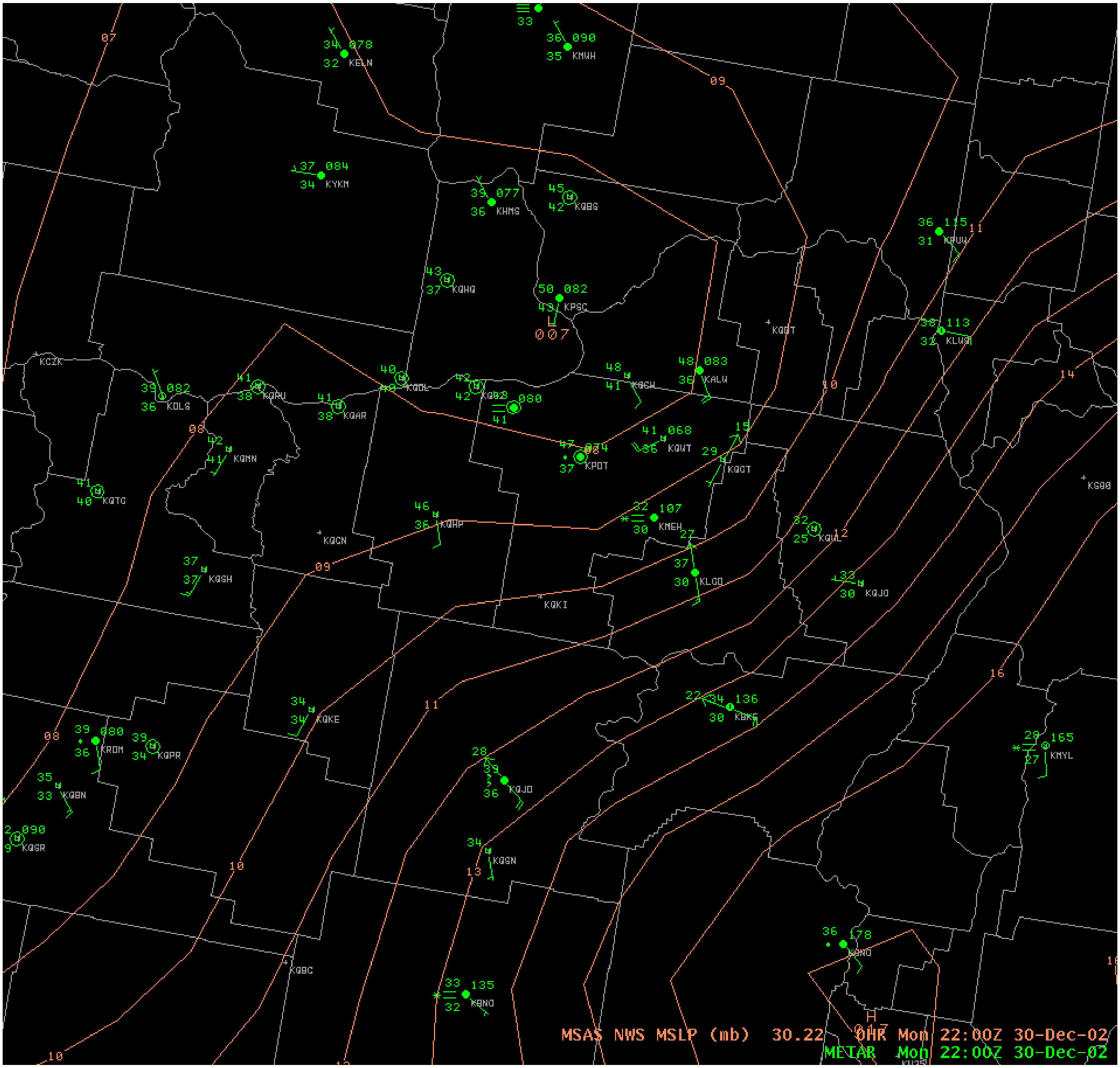
AVN ptC 45.7N 118.1W Rel Humidity Img(%)
MesoETA ptC 45.7N 118.1W Wind (kts)
MesoETA ptC 45.7N 118.1W Omega (-ubar/s)
AVN ptC 45.7N 118.1W Wind (kts)
AVN ptC 45.7N 118.1W Rel Humidity (%)
AVN ptC 45.7N 118.1W Omega (-ubar/s)

Figure 4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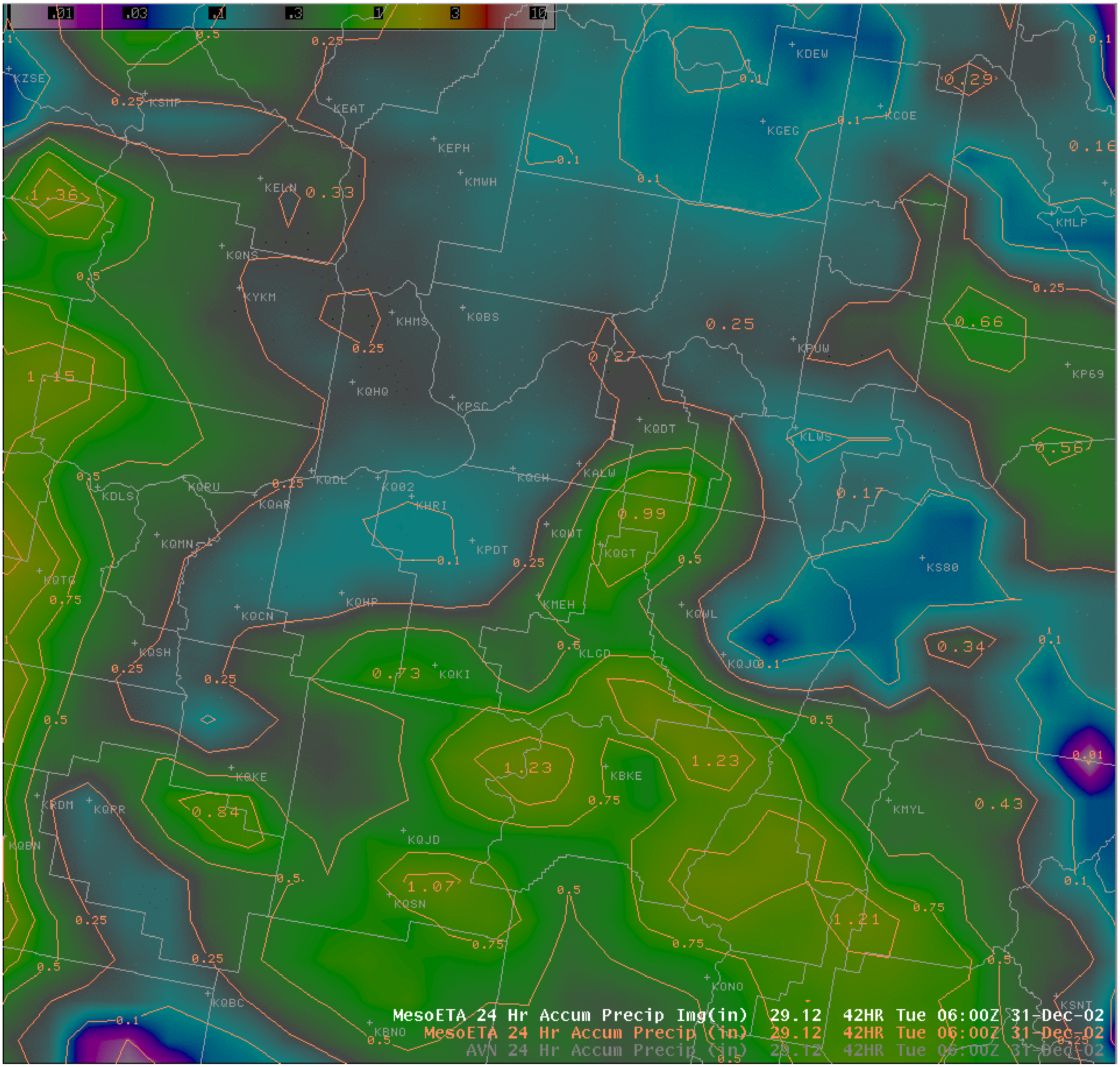
METAR Mon 22:00Z 30-Dec-02

Figure 5a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KP69
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KQHQ
KPSC
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KQRU
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KQCH
KALW
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KHRI
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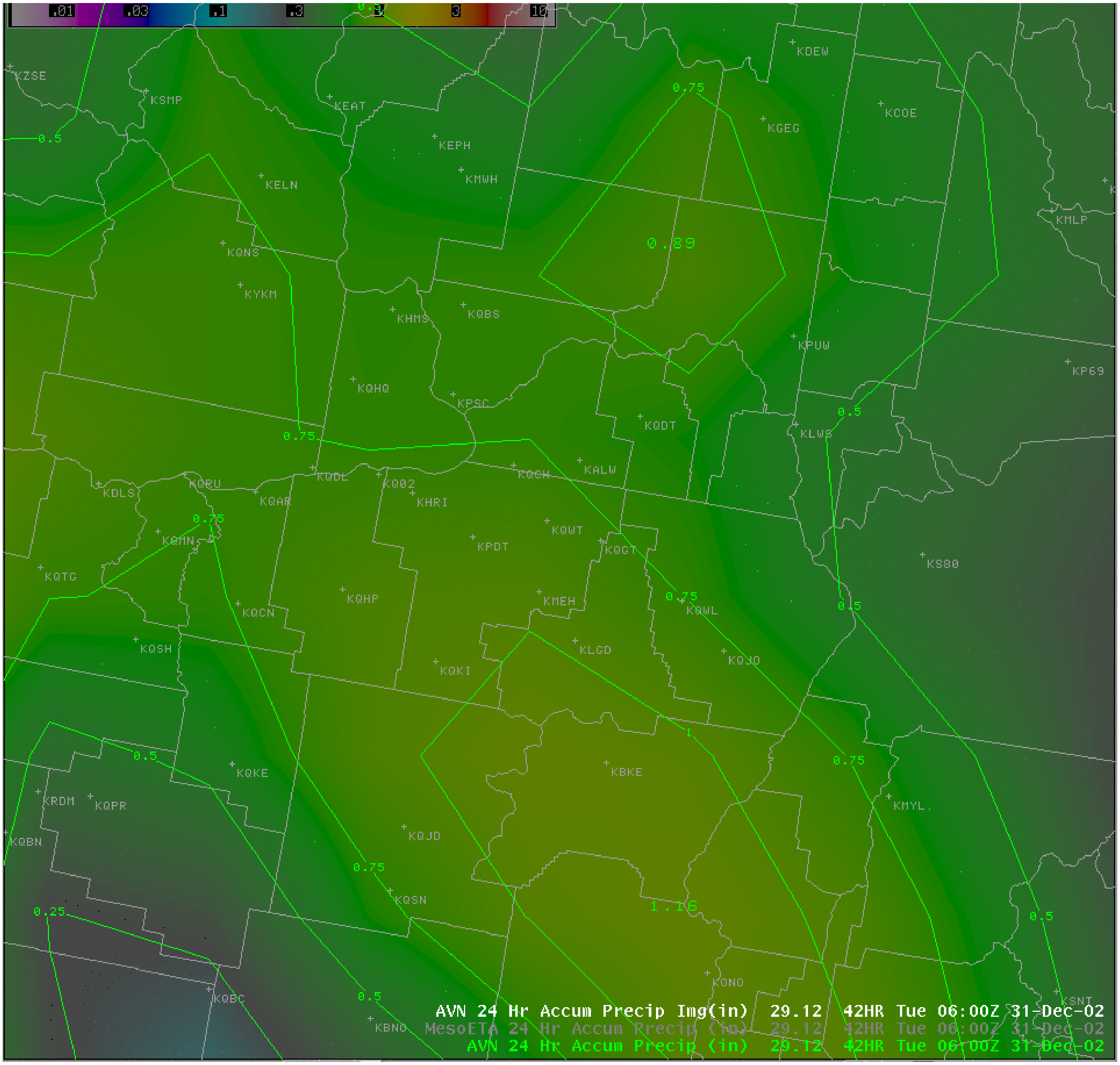
MesoETA 24 Hr Accum Precip Img(in) 29.12 42HR Tue 06:00Z 31-Dec-02
MesoETA 24 Hr Accum Precip (in) 29.12 42HR Tue 06:00Z 31-Dec-02
AVN 24 Hr Accum Precip (in) 29.12 42HR Tue 06:00Z 31-Dec-02

Figure 5b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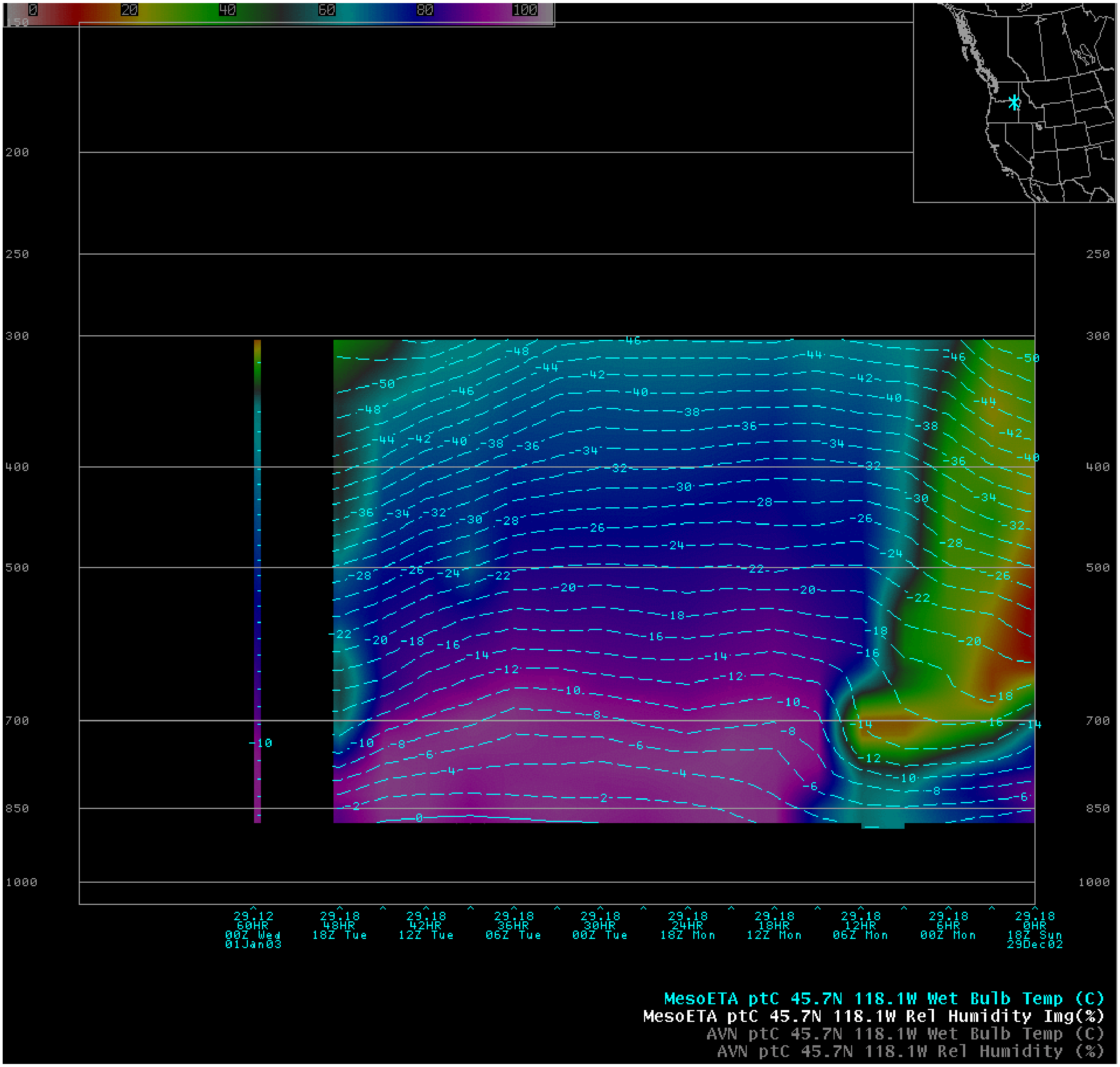
MesoETA 24 Hr Accum Precip (in) 29.12 42HR Tue 06:00Z 31-Dec-02
AVN 24 Hr Accum Precip (in) 29.12 42HR Tue 06:00Z 31-Dec-02

Figure 6a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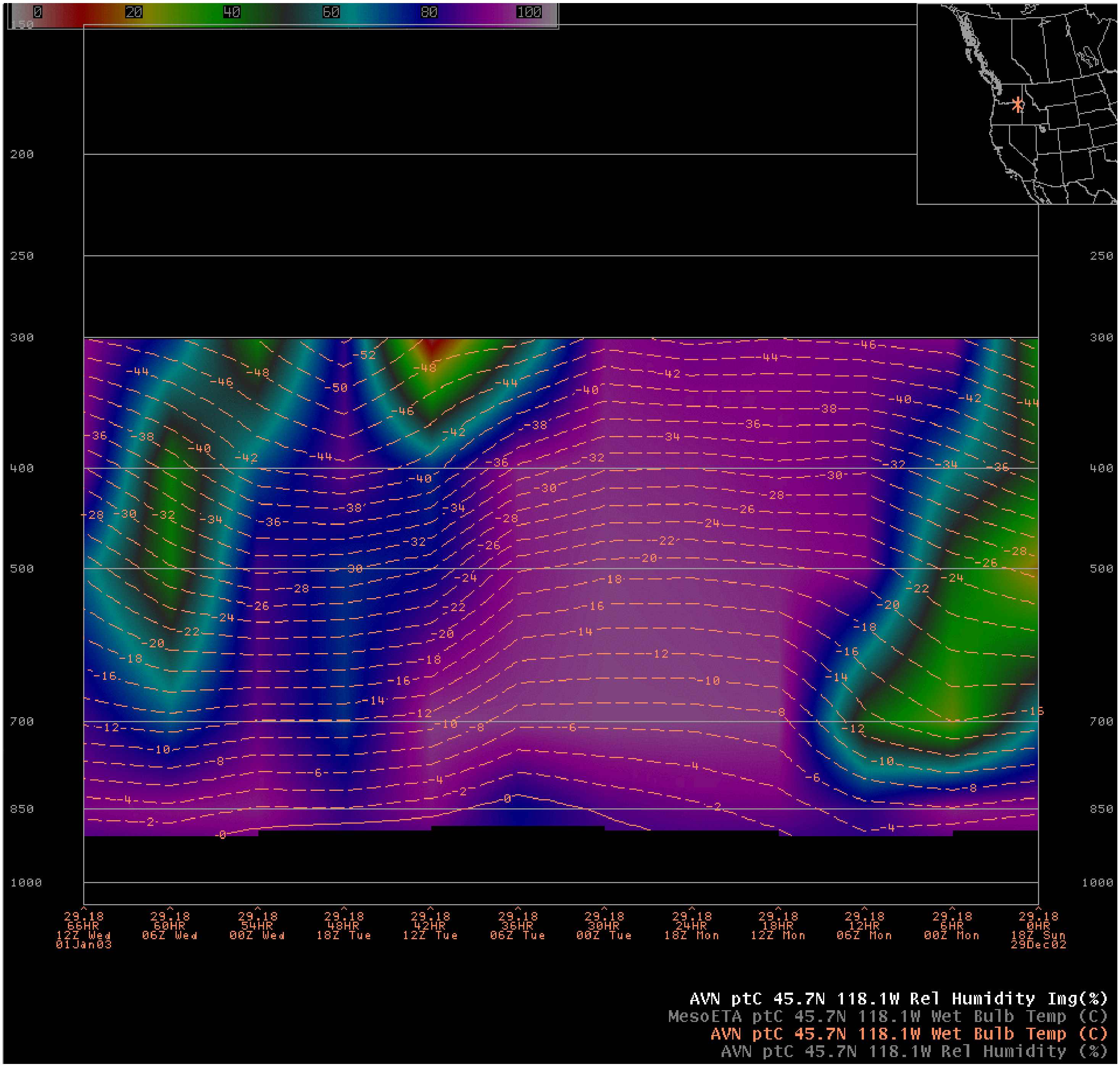
29Dec02
MesoETA ptC 45.7N 118.1W Wet Bulb Temp (C)
MesoETA ptC 45.7N 118.1W Rel Humidity Img(%)
AVN ptC 45.7N 118.1W Wet Bulb Temp (C)
AVN ptC 45.7N 118.1W Rel Humidity (%)

Figure 6b



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MesoETA ptC 45.7N 118.1W Wet Bulb Temp (C)
AVN ptC 45.7N 118.1W Wet Bulb Temp (C)
AVN ptC 45.7N 118.1W Rel Humidity (%)