Gridded Verification of PoPs over the Complex Terrain of Eastern Washington and Northern Idaho

Jonathan Fox & Ronald Miller
WFO Spokane, WA

1. Introduction

The verification of Probability of Precipitation (PoPs) has always been nebulous topic and up until recently has only been done at point locations. While some insight into point biases could be gained from this method, there was always a question as to whether this was representative of a larger area. With the advent of BOIVER, we can now ascertain PoP biases over our entire forecast domain and how it relates to the complex terrain of eastern Washington and north Idaho (Fig. 1).

Figure 1 Topography of the WFO Spokane CWA.

For this study we will take a look at two distinct synoptic patterns and their corresponding PoP biases over the forecast area. One pattern featured a typical wintertime zonal or westerly flow pattern. The other pattern featured a prolonged northwest flow regime more dominated by a long wave ridge centered over the region.

2. Zonal Flow Pattern

The first synoptic pattern evolved over a period extending from 19 December 2007 through 23 January 2008. Figure 2 shows the mean 500mb height pattern over the region. Although there were semblances of a weak ridge over western Canada, the more dominant feature for the Pacific Northwest was a strong westerly jet extending from east of Hawaii and into the Inland Northwest.

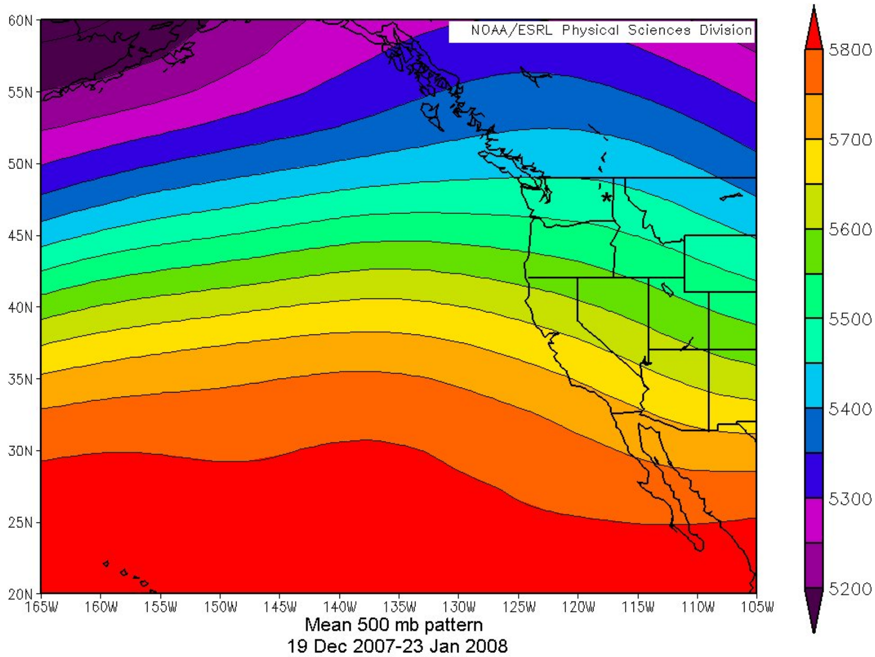

Figure 2 Mean 500mb height 19 Dec 2007-23 Jan 2008

For the WFO Spokane CWA, this westerly flow tends to bring heavier precipitation to the westward facing slopes, including the Cascades and the Clearwater Mountains. Likewise this flow tends to shadow locations in the lee slopes. Table 1 shows a breakdown of the precipitation during this period at some key sites (see locations on Fig. 1).

City	Effect of Westerly Flow	Precipitation	Normal	% of Normal
Spokane	Weak upslope	2.62	2.50	105%
Wenatchee	Strong Downslope	0.95	1.56	61%
Lewiston	Strong Downslope	0.52	1.49	35%
Plain	Upslope	5.81	5.53	105%
Kellogg	Strong Upslope	6.16	4.49	137%
Winchester	Strong Downslope	1.36	5.07	27%

Table 1 Precipitation at selected locations during the 19 Dec 2007-23 Jan 2008 period.

While it can be somewhat useful looking at some key forecast points, a much greater wealth of knowledge can be gathered looking at gridded verification data via bias charts generated from the BOIVER software.

a. MOSGuide PoP Bias

Figure 3 shows the 12-hr MOSGuide PoP bias for the first 12 hour period over the County Warning Area (CWA), with the red (blue) colors indicating a wet (dry) bias. MOSGuide had a large dry bias over most of the CWA with the exceptions occurring in the lee of the Cascades, including Wenatchee and Omak as well as in the lee of the Blues, impacting the Lewiston Area.

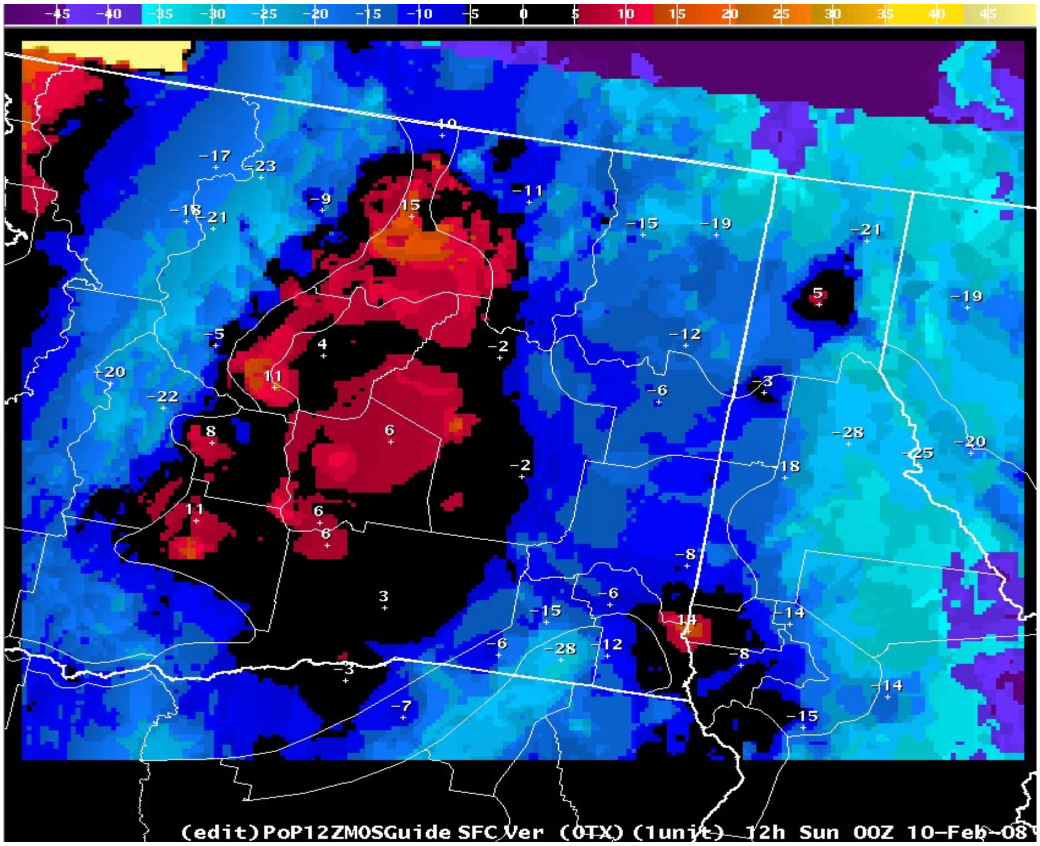

Figure 3 MOSGuide 12-hr forecast PoP bias 19 Dec 2007-23 Jan 2008.

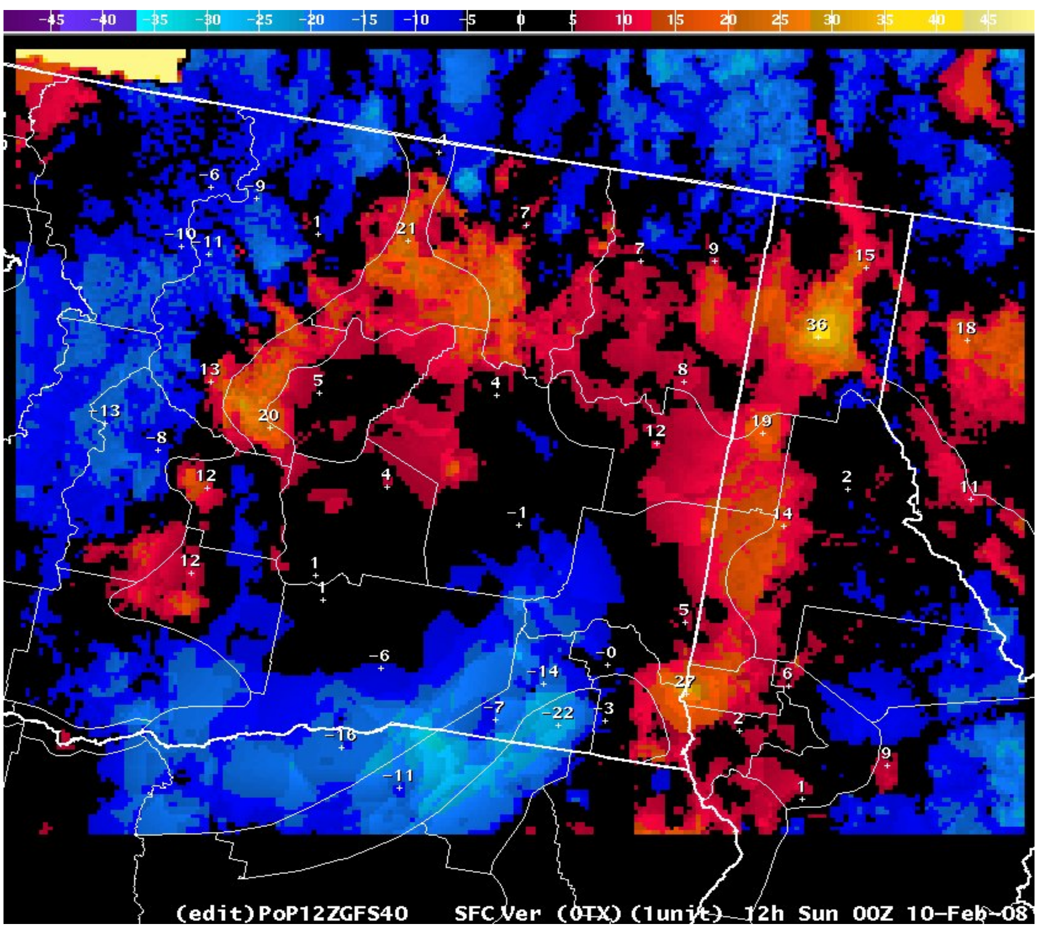

Figure 4 GFS 12-hr forecast PoP bias 19 Dec 2007-23 Jan 2008.

b. GFS PoP Bias

The GFS model (Fig. 4) exhibited a similar pattern to the MOSGuide, however it expanded its wet bias much farther east. Despite the expansion of the dry bias into north Idaho, its overall bias was considerably less than that of MOSGuide. The largest wet bias errors were in the lee of the Cascades, Okanogan Highlands, and Lewiston area (The errors along the Washington/Idaho border are questionable due to faulty observational data at Sandpoint and Coeur d'Alene). Meanwhile the dry bias errors are much more reasonable, with one exception occurring over the Blue Mountains. Most of these errors can be attributed to the poor terrain resolution offered by a 40km model.

It is interesting to compare the GFS with the MOSGuide due to their different methodologies. The MOSGuide is a statistical forecast based on the GFS. Its regression equations were developed using archived observed and GFS model data. The ADJMAV grids (not shown) use a similar methodology, just with fewer observation points. The GFS PoP forecast used in this study was simply derived from the raw GFS QPF grid, modified slightly by the model RH fields. A comparison of Figures 3 and 4 suggests that in a very wet westerly flow pattern the MOSGuide introduces a significant dry bias in the Cascades and Idaho Panhandle mountains that is not found in the raw GFS QPF fields. The MOS PoP equations are derived over a region rather than at individual sites. The Spokane CWA is in the Intermountain MOS region, which includes Salt Lake City, Reno, Las Vegas, El Paso, and Phoenix (Fig. 5 from Sheets 2007). For the GFS MAV/MEX, the only predictors selected for the regression equations in this Intermountain region are model QPF, RH, and K-index. MOSGuide also employs other GIS datasets to resolve complex topography. The results here show that MOSGuide overall does better in the lower elevations, and worse in the mountainous portion of the forecast area, significantly underforecasting the PoP. Since the GFS PoPs perform very well in the upslope region of the Idaho Panhandle, it appears that the MOS dry bias is not due to the raw model precipitation forecast, but rather the MOS equation derivation. The only observation sites used in the derivation of the MOSGuide PoP equations were METARs (Maloney and Gilbert, personal communication). Since nearly all METARs in this region are located in valleys, the main effect of the MOS equations is to downplay the GFS QPF fields, since the model overforecasts precipitation in these areas. However, when these equations are then applied to precipitation-favored areas such as the Idaho Panhandle mountains, the result is a large dry bias in the MOSGuide.

The Cascade crest is the dividing line between two MOS PoP regions (Fig. 5). The distribution of MOSGuide PoP forecasts over the western (Fig. 6) and eastern (Fig. 7) Cascades shows a rather stark difference, with MOSGuide rarely forecasting PoP above 80 percent on the eastern Cascades. Since this is typically a downslope regime, this finding is not too surprising. But the MOSGuide PoP distribution over the Idaho Panhandle (Fig. 8) shows a serious deficiency in the guidance. MOSGuide never forecast a PoP above 72%. This is despite the fact that climatological PoPs over the Panhandle are similar to the western Cascades (Fig. 9).

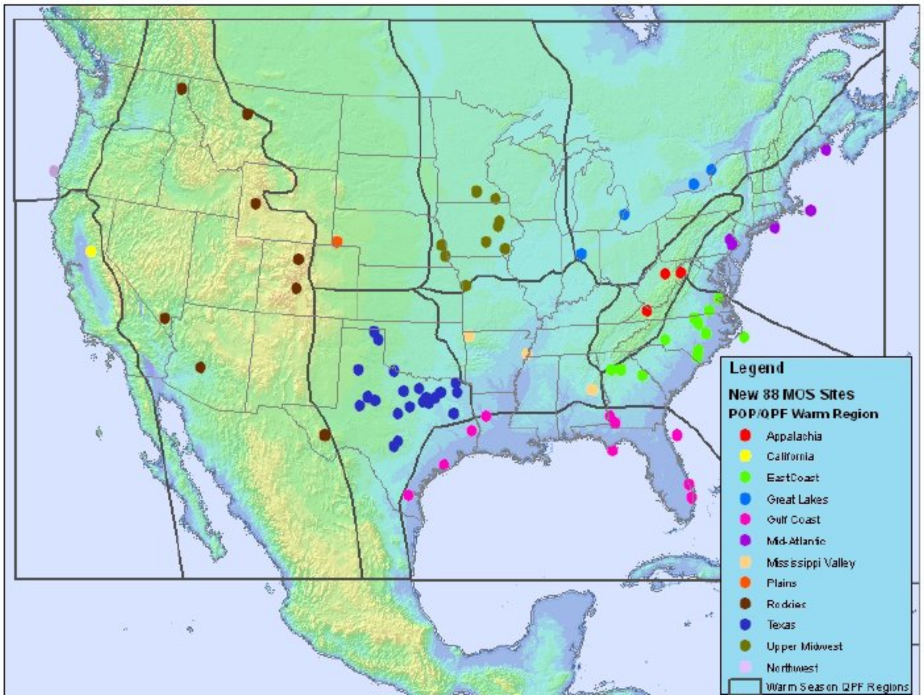

Figure 5 MOS Regions from Sheets 2007. Note Spokane's CWA is entirely contained within the Rockies region, grouping MOS weather regime with arid locations such as west Texas and Arizona.

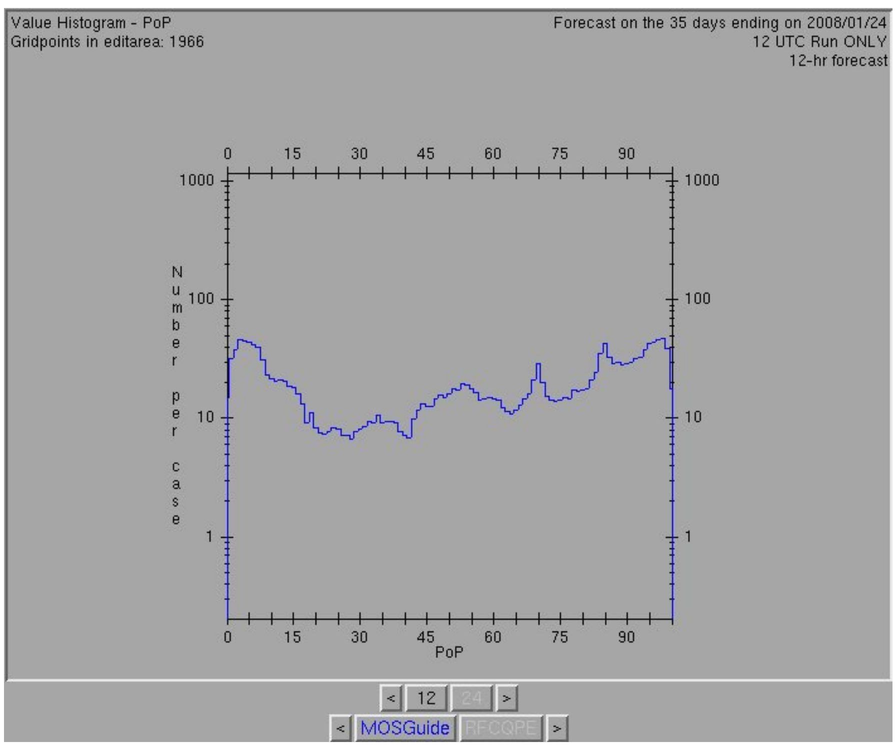

Figure 6 MOSGuide PoP distribution on the west side of the Cascade crest. 19 Dec 2007-23 Jan 2008.

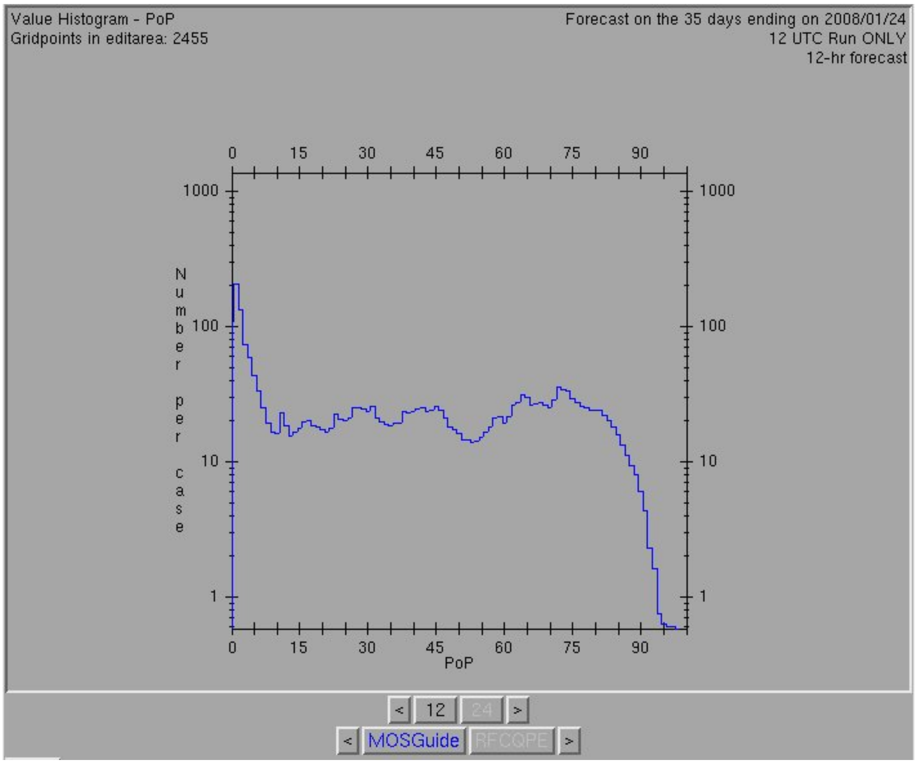

Figure 7 MOSGuide PoP distribution on the east side of the Cascade crest. 19 Dec 2007-23 Jan 2008.

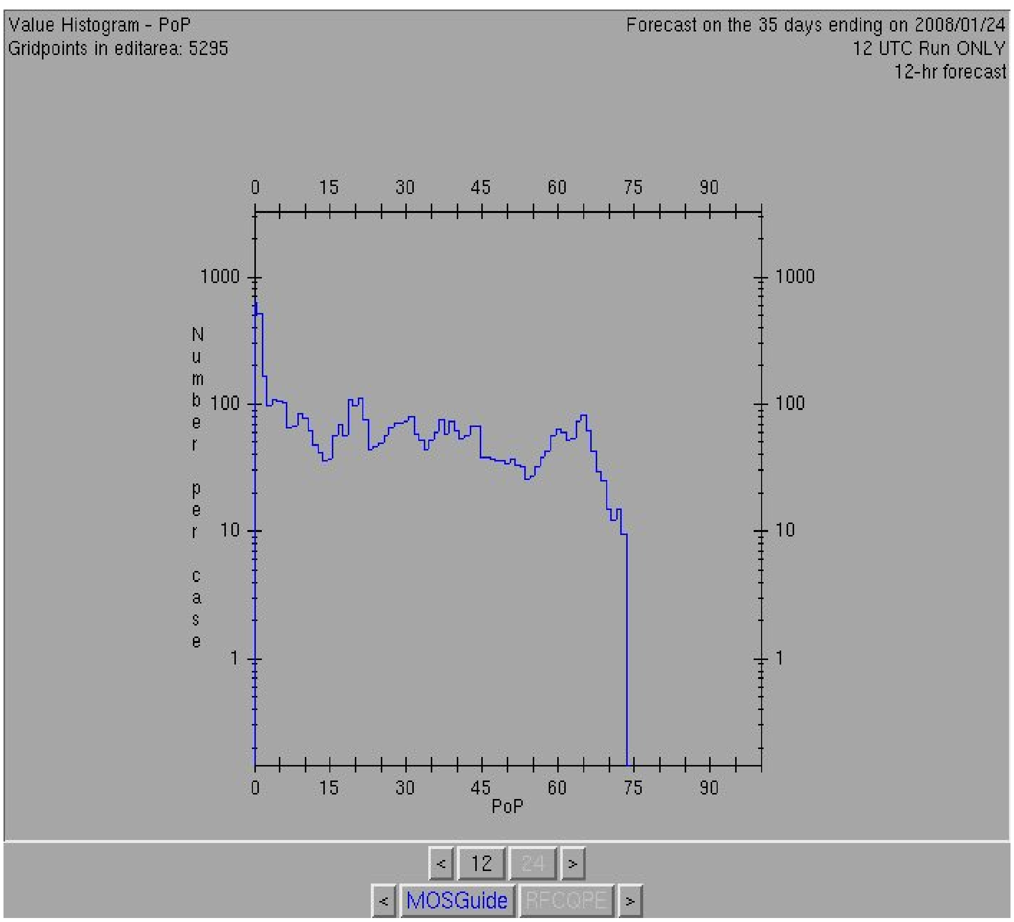

Figure 8 MOSGuide PoP distribution over the Idaho Panhandle. 19 Dec 2007-23 Jan 2008.

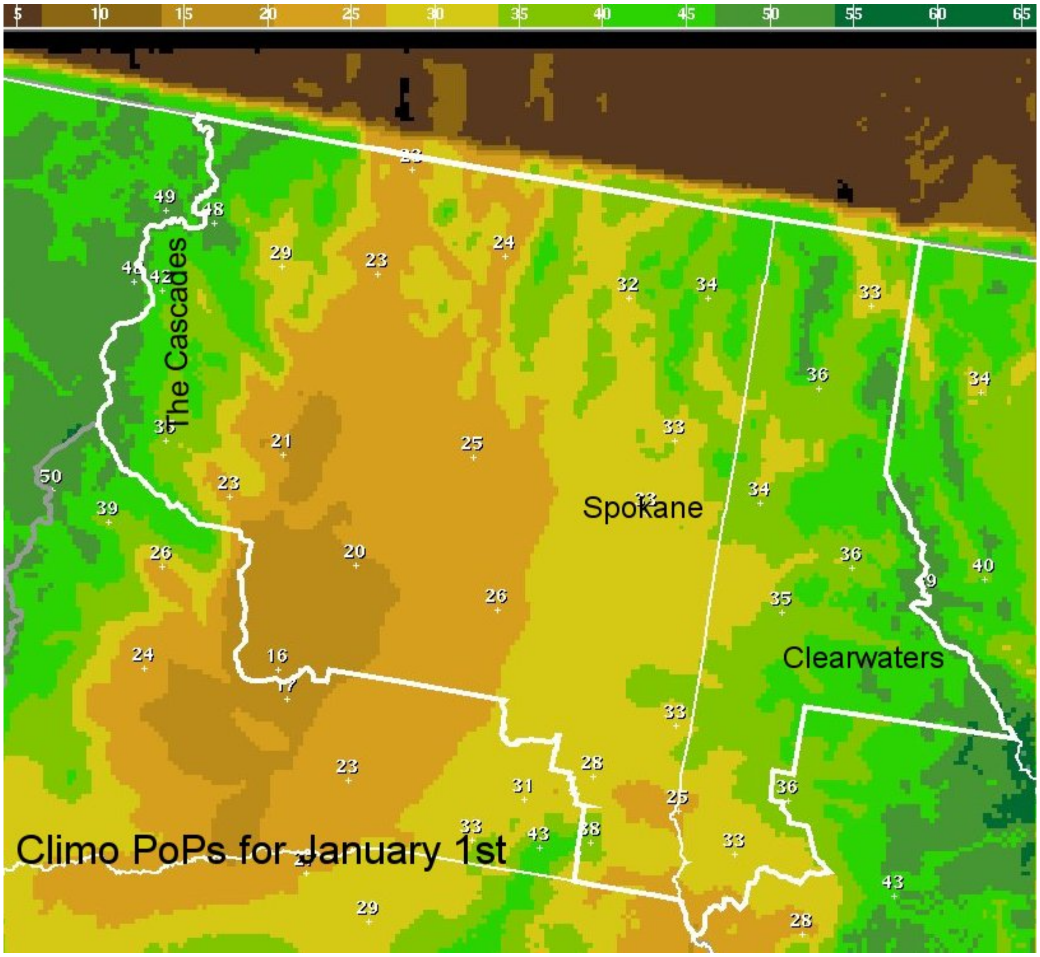

Figure 9 Climotological PoPs for our CWA for January 1st. Notice the PoPs are just as high over the Idaho Panhandle as they are along the Cascade Crest.

c. NAM PoP Bias

The NAM12 had many shortcomings as well, with a pronounced dry bias over most of the CWA (Fig. 10). In fact, the errors were exceedingly large near the Cascade crest and over most of north Idaho. Despite the shortcomings, the model did offer some improvements to the GFS, most notably in the lee of the Cascades from Wenatchee to Omak, as well in the lee of the Blues, impacting the Lewiston area. These improvements are likely due to superior handling of the complex terrain in these regions. Rather than indicating a shallow downslope off the Cascades and Blues, the NAM12 shows a much steeper and refined topographical representation.

d. SREF PoP Bias

The SREF was of little value across the vast majority of the CWA. It was far too wet just about everywhere (Fig. 11), which is rather remarkable considering this was a relatively wet period. The only area it offered a glimmer of skill versus the GFS was at the Cascade crest, where it likely rained or snowed just about every day during the period.

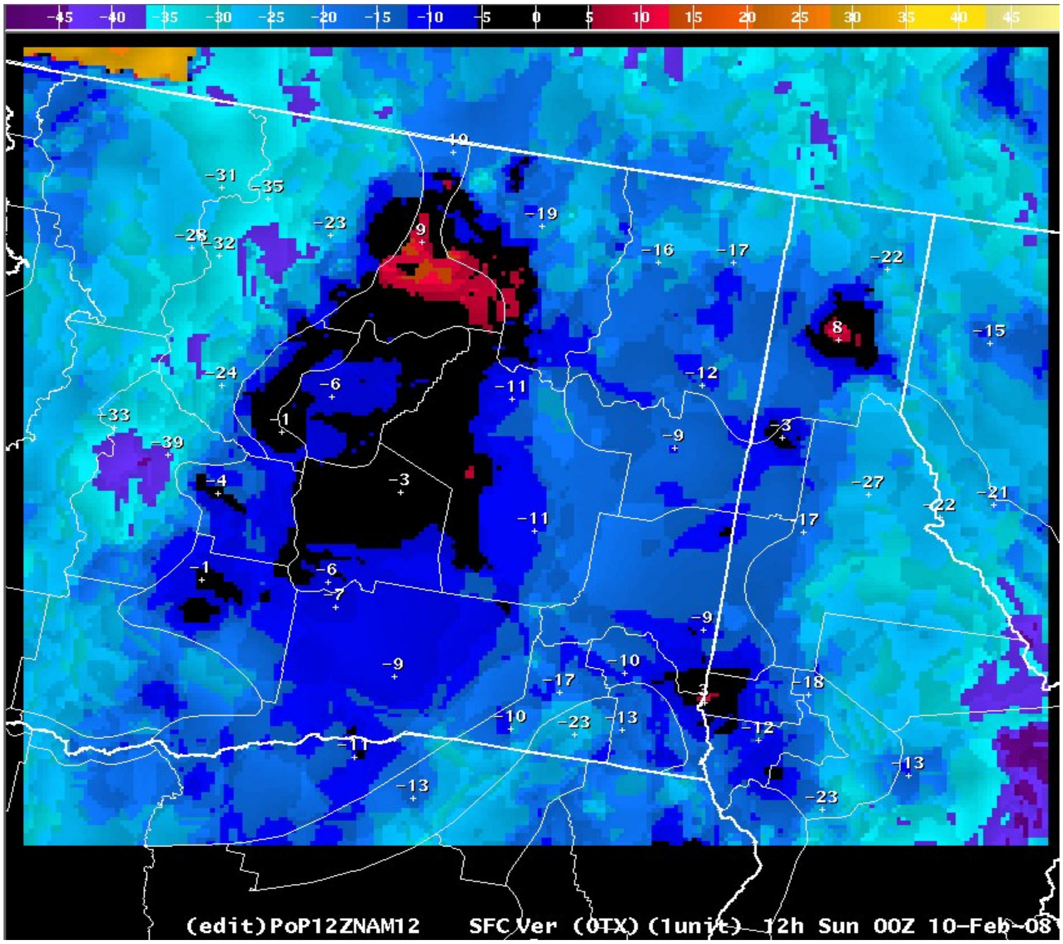

Figure 10 NAM12 12-hr forecast PoP bias 19 Dec 2007-23 Jan 2008.

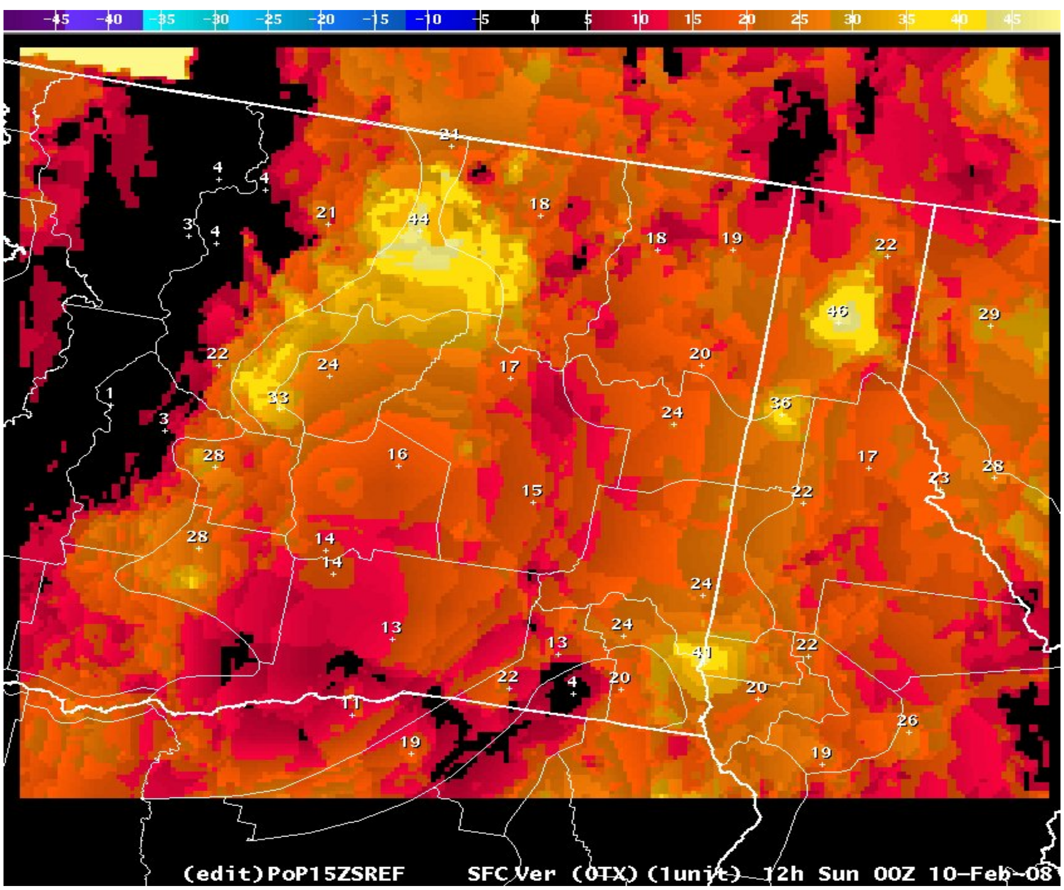

Figure 11 SREF 12-hr forecast PoP bias 19 Dec 2007-23 Jan 2008.

3. Amplified Ridge/Northwest Flow Pattern

A relatively strong ridge dominated the synoptic pattern for the majority of February 2008. The ridge was centered right along the West coast, leaving the eastern half of the Spokane CWA subject to northwest flow.

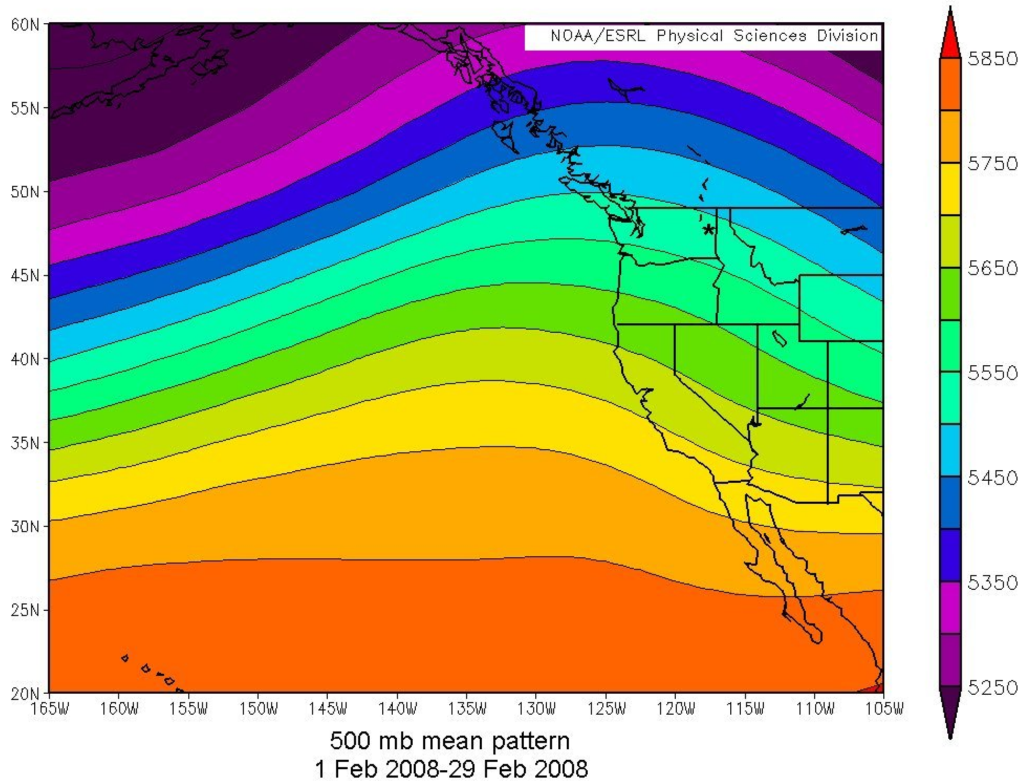

Figure 12 Mean 500mb pattern 1-29 Feb 2008

While typically this is not a very wet pattern for most of the forecast area, weak systems passing over the top of the ridge can become topographically enhanced as they approach the Idaho Panhandle and the Cascade crest (Table 2). This is especially true over the Clearwater Mountains in the central Idaho Panhandle.

City	Effect of NW flow	Precip	Normal	% of Normal
Spokane	Neutral	0.93	1.44	65%
Wenatchee	Strong Downslope	0.53	0.92	58%
Lewiston	Neutral	0.42	1.01	42%
Plain	Weak Upslope	3.63	3.26	111%
Kellogg	Strong Upslope	3.60	2.89	125%
Winchester	Strong Upslope	0.77	1.64	47%

Table 2 Precipitation at select locations 1-29 Feb 2008.

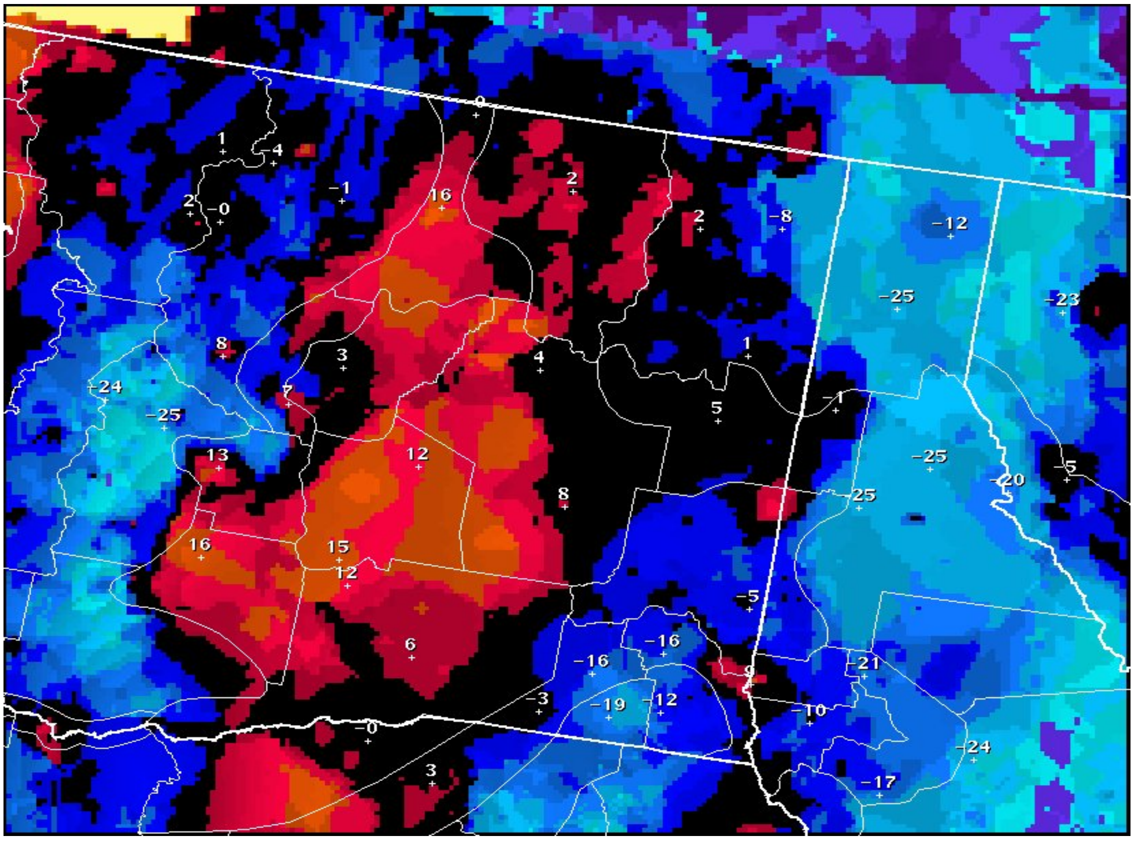

Figure 13 MOSGuide 12-hr forecast PoP Bias 1-29 Feb 2008.

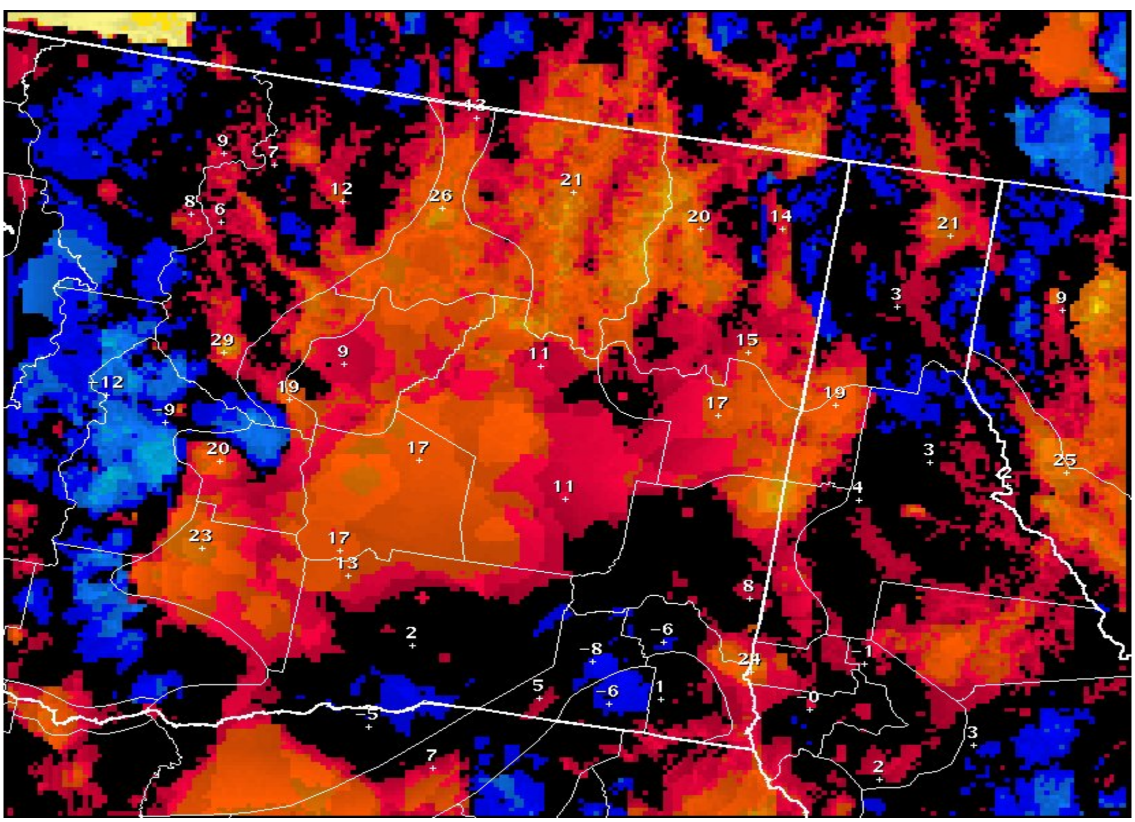

Figure 14 GFS 12-hr forecast PoP Bias 1-29 Feb 2008.

a. MOSGuide PoP Bias

Figure 13 shows the MosGuide 12-hr PoP bias for the first 12 hours over the County Warning Area (CWA). The distribution of biases during this relatively dry period was remarkably similar to the pattern seen during the previous wet pattern (Fig. 3). The main difference was the wet bias spread farther east into most of eastern Washington, including the Spokane area. While the dry bias errors over the Cascades were much smaller compared to the wetter period, there still were very large errors being observed over the Idaho Panhandle. Much of this problem can be attributed to the fact that the MOSGuide never forecast PoPs above 68% in this period (Image not shown), even though this is a relatively wet pattern for this area.

b. GFS PoP Bias

Figure 14 indicated that the GFS had a significant wet bias over most of the Inland Northwest. The distribution pattern was similar to that of the wet period (Fig. 4). However, the bias errors grew significantly, especially over the northern mountains extending from near the Omak area and western Columbia Basin, northeast to the Selkirk Mountain range. Again, a northwest flow regime tends to be relatively dry for these locations, and the poor terrain resolution from the 40km model may have proved to be the major culprit. The model still did fairly well over the Idaho Panhandle.

c. NAM PoP Bias

The overall NAM12 bias during the dry pattern (Fig. 15) looked similar to the distribution during the wet period. The major differences were a better verification in the Cascades and the expansion of the wet bias into western portions of the Columbia Basin and Okanogan Highlands. Even so, the bias values in the Basin were relatively small and compared quite favorably to the large wet bias values offered by the GFS in these areas. Similar gains were also noted in the Lewiston area. While the NAM12 excelled in these locations, it continued to vastly underforecast the PoPs in the Idaho Panhandle.

d. SREF PoP Bias

The SREF PoPs (Fig. 16) continued to offer very little value, which was expected considering this was a relatively dry pattern for the majority of the CWA. It was interesting to note, that the smallest errors (generally around +5% to -10%) were located coincident with the areas that are most favorable to precipitation in a northwest flow regime (Idaho Panhandle, and northern Blue Mountains)

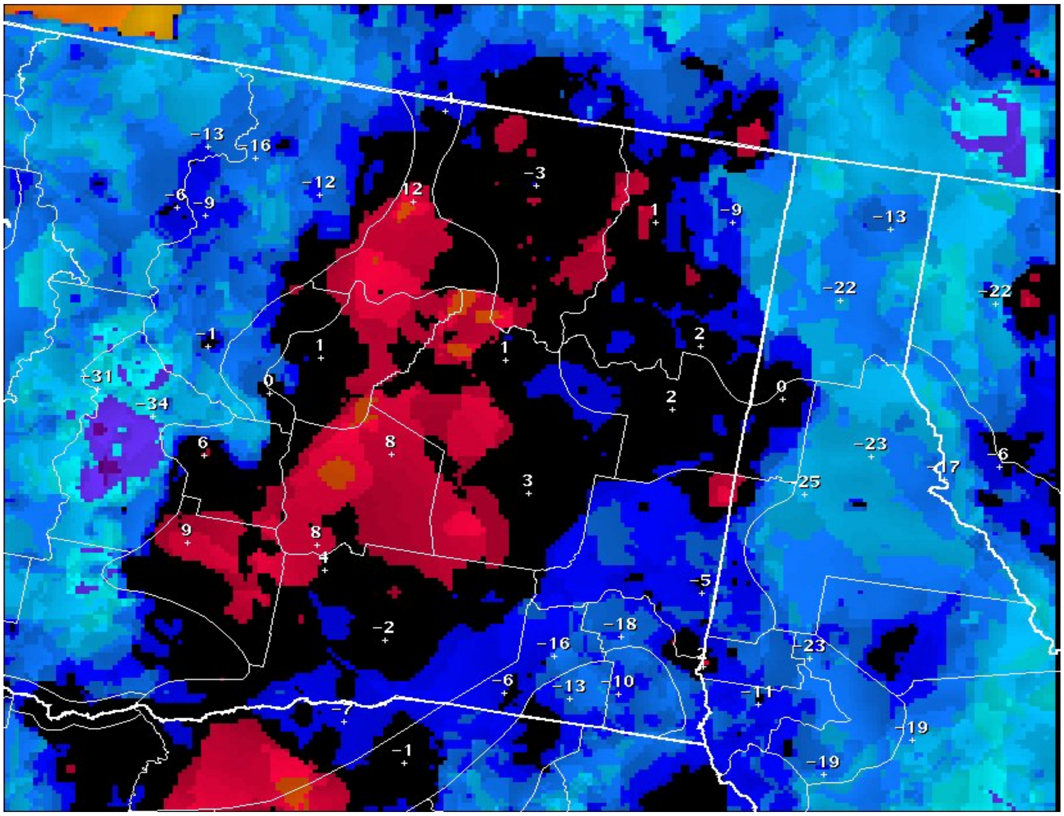

Figure 15 NAM 12-hr forecast PoP Bias 1-29 Feb 2008.

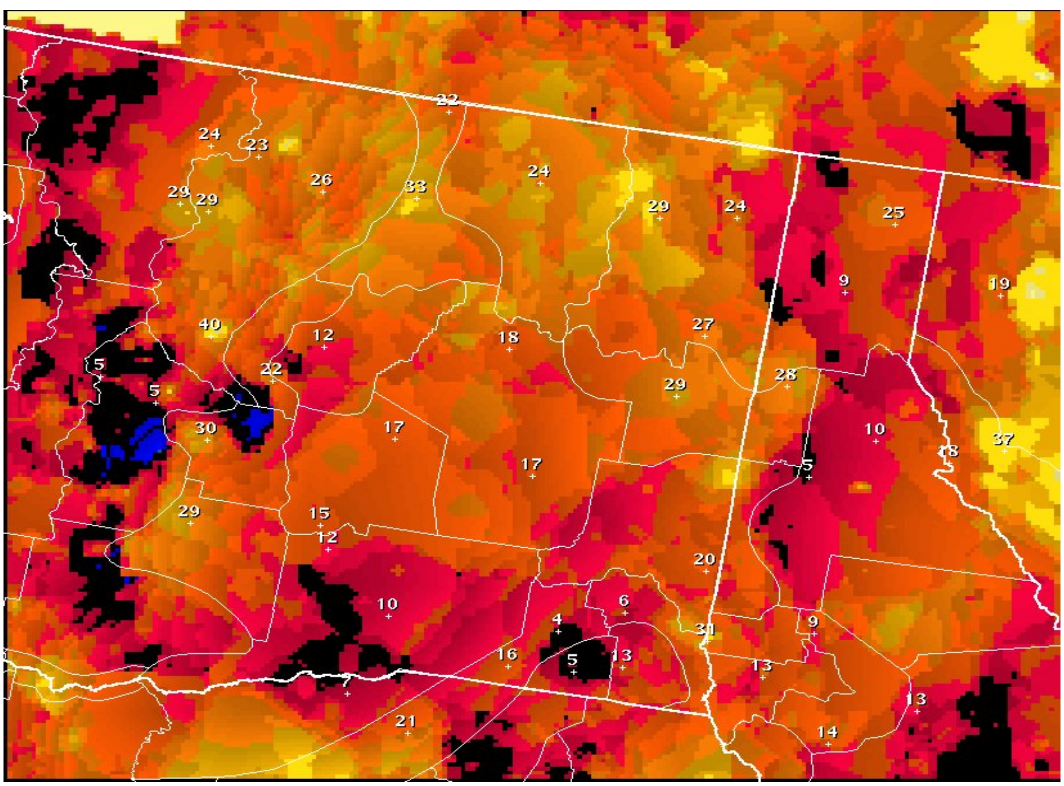

Figure 16 SREF 12-hr forecast PoP Bias 1-29 Feb 2008.

4. Conclusion

The biases indicated in the images above are generally replicated out to 60 hours and shed some insight into typical model biases involved with the complex terrain of eastern Washington and northern Idaho. It is interesting to note that the model bias distributions the models display are rather similar whether we are in a very wet synoptic pattern or a relatively dry one. This being said, it appears each model (aside from the SREF) has certain advantages:

- The superior terrain resolution of the NAM12 allows forecasters to apply more accurate downslope impacts in leeside valley locations such as Wenatchee, Lewiston, and Omak for our typical westerly flow events.
- The MOSGuide (or any MOS-based) grid yields fairly good results over most of our valley locations. This is due to good MOS calibration numbers over our valleys. Meanwhile this method yields much poorer results over the surrounding mountains, particularly those over the Idaho Panhandle and on the east side of the Cascade crest.
- The raw GFS grids perform quite well in areas where the MOSGuide suffers, namely the Cascade crest and the Idaho Panhandle.

The result is there is no clear-cut model which performs best at PoP forecasting. So the question is how can a forecaster take all these strengths and weaknesses into account? One of the best tools found is the ClimoPoPs smart tool (Fig. 17). This tool displays the model PoP at any defined site, and allows the forecaster to adjust their forecast via the use of slider bars. After all the slider bars have been manipulated, the Smart Tool takes these new values and applies climatological adjustments to the surrounding terrain. The tool has been locally modified to display the GFS and NAM PoP and QPF. This tool offers the best method of allowing the forecaster to blend the strengths of the various PoP guidance into one PoP forecast grid.

	FWC	MET	MEX	MEL	MEN	MEH	Climo	OSGuid	NAM	NAM QPF	GFS	GFS QPF	Cur Fcst	New Fcst	Use?
KGEG - Spokane	40	63	25	14	22	35	19	22	22	0.00	8	0.00	54	54	
KCOE - Coeur d'Alene	—	99	24	13	20	33	21	21	32	0.05	5	0.00	60	60	
KSZT - Sandpoint	—	—	23	—	—	—	23	18	40	0.14	6	0.00	61	61	
KPUW - Pullman	—	56	27	16	24	39	22	25	42	0.12	38	0.05	50	50	
KLWS - Lewiston	42	34	28	17	26	40	19	27	32	0.07	55	0.11	26	26	
KEAT - Wenatchee	24	9	28	11	23	36	11	30	9	0.01	19	0.01	15	15	
KMWH - Moses Lake	30	17	26	8	17	29	11	26	5	0.01	0	0.00	16	16	
KEPH - Ephrata	29	13	26	8	18	31	12	26	6	0.01	0	0.00	17	17	
KOMK - Omak	—	21	29	8	18	29	12	29	0	0.00	0	0.00	18	18	
KMLP - Mullan Pass	—	82	27	12	20	35	36	23	34	0.07	16	0.01	80	80	
KSMP - Stampede Pass	—	52	60	49	62	77	42	59	37	0.09	79	0.12	71	71	

Figure 17 ClimoPoPs Smart Tool

5. References

Sheets, K. L., 2007: Supporting gridded model output statistics forecast guidance system. Conference Proceedings, 27th Annual ESRI International User Conference, *San Diego, CA.*