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Evaluation of 9 years of CPC Long Range Precipitation Forecasts in the Northern Sierra Nevada of California

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1. Background

The northern Sierra Nevada is the most important runoff region in California, furnishing much of the water for the two largest water projects in the State – the Federal Central Valley Project and the State Water Project – as well as most of the water for the Sacramento San Joaquin River Delta. Estimated precipitation accumulation during the water year is monitored using eight stations to represent the 15,700 square mile watershed of the four major rivers. See the map of Figure 1 for the locations of the eight stations. The nearly 70 year historical record for the eight station index is shown in Figure 2.

Fig. 1. Location of the 8 northern Sierra index stations.

The Climate Prediction Center (CPC) of the National Weather Service (NWS) has been making long range weather forecasts for over a decade with 0.5 to 12.5 months lead time. For us, the ones with the greatest potential are for the winter season. On average, half the annual precipitation, whether rain or snow, occurs during the December through February period with three-fourths from November through March. See the pie chart in Figure 3. Reliable forecasts during the early part of the rainy season have the most value as many decisions on water delivery and crop planting are made at that time before the halfway point in the accumulation season. Shortly after the first of February, we add the snowpack measurements to the forecasting methodology and the reliability improves.

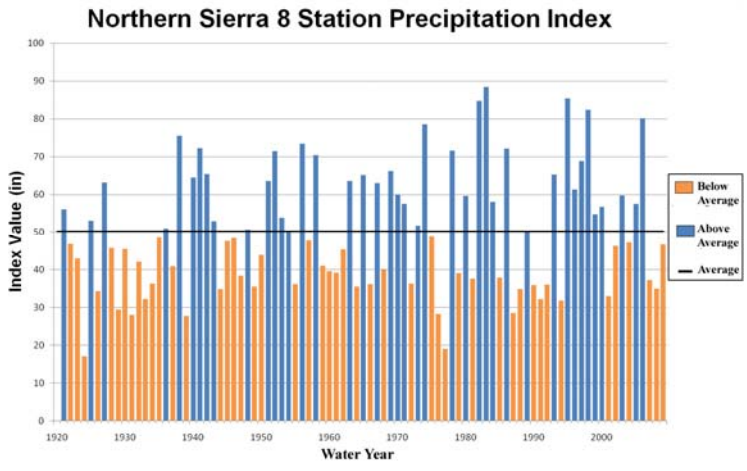

Fig. 2. Northern Sierra precipitation record by water year.

The CPC precipitation forecasts, as you know, use three categories: more than chance probability of being wetter or drier and no slant either way (equal chances). Once in a while they indicate a zone where the probability is such that the area will be near normal. Usually only small portions of the country will be marked as more likely to be wet or dry with the larger space being without a signal. Figure 4 is a recent precipitation forecast map showing how the information is presented. Most of the time a precipitation shift is fairly modest. The edges of the shaded areas are 33 percent and increase to 40 or 45 percent and rarely 50 percent chance of being in the wet or dry tercile.

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2. Evaluation

We tested with the northern Sierra eight station record of monthly or 3 month period precipitation for 9 water years (WY) from 2000 through 2008 and the early portion of WY 2009. We looked at the 0.5 month lead for the 1 month outlook, the 1-3 month outlook, and the 4-6 month outlook. To do this we reviewed all the forecasts, noting which ones showed all or part of the northern Sierra watershed in one of the shaded forecast areas. We made a judgment on the strength of the shift away from normal. These ranged from a slight 1 percent shift to a shift of 9 percent. To test the skill we then checked whether the measured precipitation was more or less than median for the month or the 3 month period. The skill is when the actual precipitation was in the same direction as the forecast. If it went the opposite way, the forecast was wrong. For example, if the forecast was shaded toward a wetter condition, a hit would be when the actual precipitation was above median – the right direction. Slightly over half of the forecasts for the region showed EC, equal chances, that is no signal. The EC forecasts were not counted in computing skill.

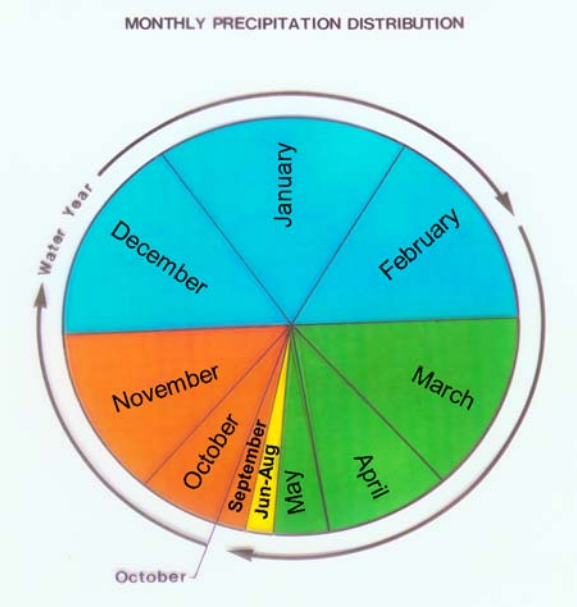


Fig. 3. Average monthly distribution of northern California precipitation.

Results are shown on the first table. They show some skill: the 0.5 month lead one month forecast Heidke skill was 24 percent, the 1-3 month forecast skill was 23 percent, and the 4-6 month skill was a surprising 18 percent. However, when we looked at just the 5 wet months, for November through March (Table 2), the skill fell apart with more wrong than right except for the 4-6 month which only had 5 cases, with an apparent 60 percent skill, but too small a sample. So what this shows is that the skill is in the drier months which don't matter as much in water supply.

Another evaluation approach was to examine just the months where a stronger confidence of wetter or drier was indicated, using at least a 5 percent shift as a threshold. The sample size was small and this did not show any consistent skill either (Table 3).

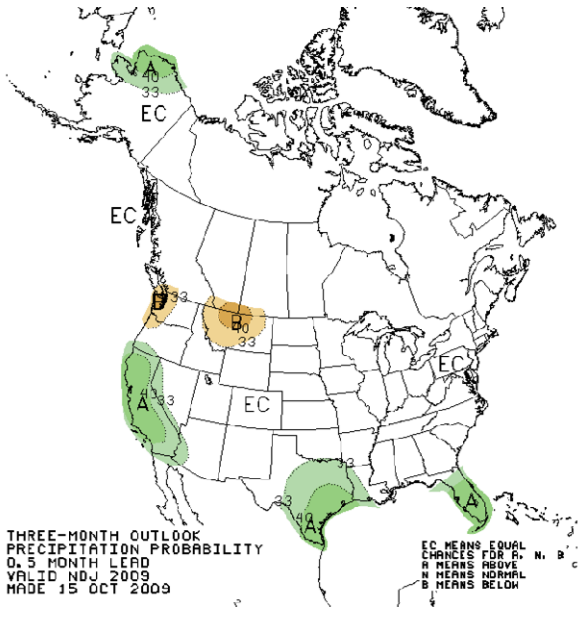


Fig. 4. Sample of CPC seasonal precipitation forecast (Made in October 2009)

Another way to look at forecast results is to see how often the actual precipitation fell in the upper or lower tercile and to use how often their direction, either wet or dry, was indicated in the forecasts. Skill could be shown if the actual precipitation during those calls were slightly higher than the 33 percent expected from chance. Again no skill was shown except marginally in the 4-6 month outlook (see Table 4).

In 2004, CPC started revising the 1 month forecast at the end of the month. This did help quite a bit with the skill for that period rising from 27 percent for the 0.5 month lead forecast to 61 percent for the end of month revised outlook. A major factor is that forecasters can look at end of month weather patterns then and so improvement would be expected.

The last table, Table 5, shows the directional skill each year of the 9 years for each of the three forecasts evaluated. The two best years were 2006 and 2008. But results in the intervening 2007 year were poor, more wrong than right.

	Number with Signal	Right Direction	Wrong Direction	Approx Skill
1 Month	42	26	16	.24
1-3 Months	52	32	20	.23
4-6 Months	34	20	14	.18

Table 1. Evaluation of CPC 0.5 month lead northern Sierra precipitation forecast (2000-2008).

	Number with Signal	Right Direction	Wrong Direction	Approx Skill
1 Month	17	7	10	- .18
1-3 Months	18	8	10	- .11
4-6 Months	5	4	1	.60

Table 2. Same as Table 1 but for 5 wet months and for November through March only.

	Number with Signal	Correct Tercile	Approx Skill
1 Month	8	4	0
1-3 Months	18	5	- .44
4-6 Months	18	4	- 1.1

Note: A strong signal is one with a 5 percent of more shift.

Table 3. Same as Table 1 but for the months where a stronger confidence of wetter or drier condition was indicated. A stronger signal is one with a 5 percent of more shift.

	Number with Signal	Correct Tercile	Approx Skill
1 Month	43	8	- .22
1-3 Months	56	16	- .07
4-6 Months	35	13	.06

Table 4. For observed northern Sierra precipitation falling in the upper or lower tercile, evaluation of CPC forecast according to the direction indication (wet or dry).

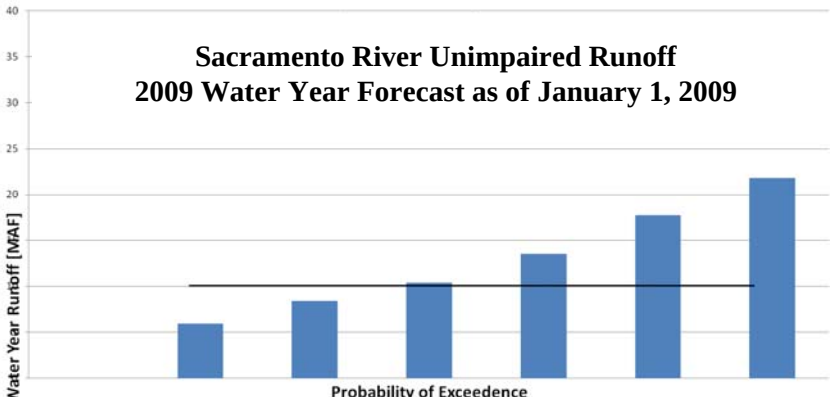
Year	One Month			1-3 Months			4-6 Months		
	EC	Right	Wrong	EC	Right	Wrong	EC	Right	Wrong
2000	4	4	4	7	2	3	6	4	2
2001	7	3	2	9	2	1	10	1	1
2002	7	3	2	4	5	3	8	2	2
2003	8	2	2	4	6	2	9	1	2
2004	7	4	1	6	4	1 (1M)	10	1	1
2005	9	1	2	6	3	3	9	2	1
2006	8	4	0	8	3	1	6	4	2
2007	9	1	2	4	3	5	7	2	3
2008	7	4	1	7	4	1	9	3	0
Total	66	26	16	55	32	20	74	20	14

Table 5. Evaluation of directional skill for 2000-2008.

3. Use of the forecast

For early season water project operations, the owner agencies are quite conservative. They are always worried that the season could turn dry and they would be unable to deliver amounts promised early in the season. Therefore, initial estimates of delivery are based in water in storage in the reservoirs and the amount of runoff anticipated for dry future conditions, either at the 90 or 99 percent probability level. Figure 5 shows a sample of last season's January 1 Sacramento River system runoff forecast and how it changed during the course of December. Project operators (and the bankers who make crop loans to farmers) want to be very sure the water is there before promising delivery. For the State Water Project (SWP), that means the first allocation, usually shortly after December 1, is often less than 50 percent supply. Last year, in WY 2009, it was only 10 percent, which eventually was raised to 40 percent in the third year of drought. At the same time estimates of delivery amounts to users to be expected with normal future weather conditions and 75 and 25 percent

probabilities are provided to guide water users in planning for the ensuing year. Because of the emphasis on dependability, a potentially important forecast product would be for forecasters to be able, with high confidence, to rule out future dry conditions in the forecast period, a more difficult task.



Date of Forecast	99%	90%	75%	50%	25%	10%
Dec 1, 2008	5.1 (27%)	8.2 (44%)	10.8 (58%)	14.8 (79%)	19.9 (107%)	24.8 (133%)
Jan 1, 2009	**5.9 (32%)**	**8.4 (45%)**	**10.4 (56%)**	**13.5 (73%)**	**17.7 (95%)**	**21.8 (117%)**

Fig. 5. Sample of water supply forecast.

Probability shifts in future precipitation can be worked into runoff forecasts. But, so far, there shifts are small on the order of 5 percent. Near median probabilities, a 5 percent shift translates into fairly small quantitative amounts. See Figures 6 and 7 for charts of the one month December and the 3 month December through February winter season historical probabilities of precipitation amounts. For example, a 5 percent shift near median conditions works out to only about 1 and ½ inches in the 3 month winter season precipitation. As long as the climatological dry end of the spectrum is possible, these small shifts don't really change a seasonal runoff forecast much. Reliability, especially in precluding future dry conditions, will have to improve a lot before significant changes in water operations are likely. There is a better chance to make use of small shifts in outlook if an agency has a good backup supply, such as groundwater, to take up the slack if the forecast is wrong. Some of the water customers do have multiple water supplies and are able to use the probability products to guide their operational planning.

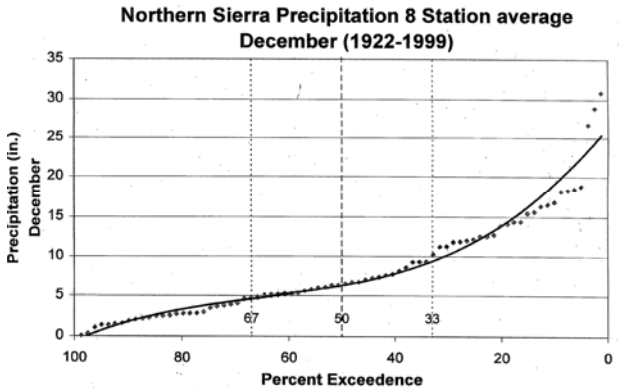


Fig. 6. Probability distribution of northern Sierra 8 station average precipitation for December (1922-1999).

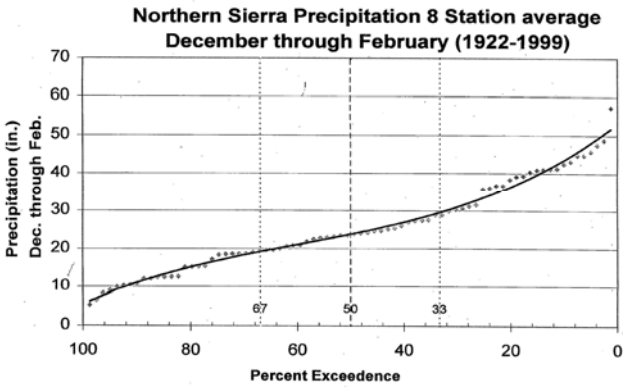


Fig. 7. Same as Figure 6 except for December-February 3 month precipitation.

Some of the CPC long range skill in the past is due to strong El Nino years. There were no strong El Ninos in this 9 year period; the best was a moderate warming event in late 2002. We were coming out of a strong cold La Nina event in water year 2000 at the start of this evaluation and the first portion of 2008 also saw a significant La Nina. Skill did seem a little better in 2008 but since it was not good in 2000 I hesitate to think that the cool events help much in signaling northern California winter precipitation. But we need to keep trying.