The Seasonal Hindcast Precipitation and Snow pack Study for the Sacramento River Basin Stream flow during 1981-1999

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Abstract

Mountainous regions, such as the Sierra Nevada's, become greatly dependent on snow pack for water supply. The regions in the valleys of the mountains are the ones greatly affected by this. The region we chose is depicted in figure A. The latitude and longitude are 39.32 ° N and 120.23 ° W respectively. We chose the Sacramento River basin because most of the precipitation is assumed to be from the snow pack of the Sierra Nevada mountain range. Therefore we could look at the relationships between these parameters. We chose snow pack data starting from October and going through March, since these are the main months in which snow would fall. For our stream flow data we used September through August. We were looking for possible lags of maximum precipitation compared to maximum stream flow. We were also looking at the hindcast precipitation compared with the snow pack that actually fell.

Figure. A Study area, meteorological and river gage sites.

Introduction

The discharge to the Sacramento River in California by the snowmelt runoff from the Sierra Nevada mountain range, is a large component of the stream flow and contributes greatly to the California water supply. Our studies mainly focused on the investigation of the seasonal hindcast precipitation and snow pack telemetry (SNOTEL), particularly during the winter season from October to March, impacts on the stream flow in the Sacramento River. “The depth and water content of the snow pack is measured using SNOTEL stations. These stations measure the weight of snow accumulated through the use of a weight-sensitive snow pillow, as well as collecting daily high, low, and average temperatures. From these data it is possible to determine an estimate of the amount of snowfall each month given model estimates of precipitation and monthly average temperature. Summing these estimates over an entire winter will give an estimate of the total depth of the winter snow pack, which can in turn be employed by water users to determine if water conservation measures will likely be necessary in the coming year.”(Hobbs et al).

Some previous studies have been done about the seasonal precipitation and snow pack effect on the stream flow in the river basin. It was found by Peterson et al. that a change in atmospheric circulation could accompany with the basic evolution of a spring snowmelt cycle in the West. For example, if a strong and expanding high-pressure pattern and high air temperature replace a low-pressure pattern in winter, a snowmelt-driven discharge would be caused. Cayan et al. stated that a spring runoff pulse makes the transition from low stream flow conditions in winter to the high stream flow conditions in the later spring-early summer period. The timing of the pulse might be delayed with greater seasonal accumulation of snow pack. Our study investigated the relationship of the SNOTEL precipitation and hindcast precipitation output during the winter season with the stream flow at the Sacramento River basin from the year 1980-2003.

Data

For this study, we used the monthly stream flow statistics from 1980 to 2003 from the surface water data for California provided by Department of the Interior, U.S. Geological Survey (USGS) water resources of California. The SNOTEL precipitation was used for the measurement of the depth and water content of the snow pack. The SNOTEL precipitation data was gathered from the Natural Resources Conservation Service. Two SNOTEL sites at the upstream of the Sacramento River, Tahoe city and Truckee, were picked to get the averaged data. The precipitation data during the same period used by our study is the output from the hindcasts produced along with the forecasts. We used the hindcast precipitation data of Sep. 2003 at latitude and longitude 39.32 ° N and 120.23 ° W as the input to get the results during Oct. to March from 1979-2003.

Results

The precipitation and SNOTEL precipitation for each year in figure 1 are the total from October to March, while the stream flow for each year is the sum of October to September. The figure showed that there are 3 large peak years with 2 small peak years for the hindcast precipitation during 1981 to 1999. The peaks of stream flow matched well with the precipitation line, particularly during the first 4 years and last 4 years. During most years the averaged SNOTEL precipitation was only a little less than the stream flow and varied almost the same as the stream flow as SNOTEL precipitation is the majority of the precipitation during winter season that contribute to the stream flow.

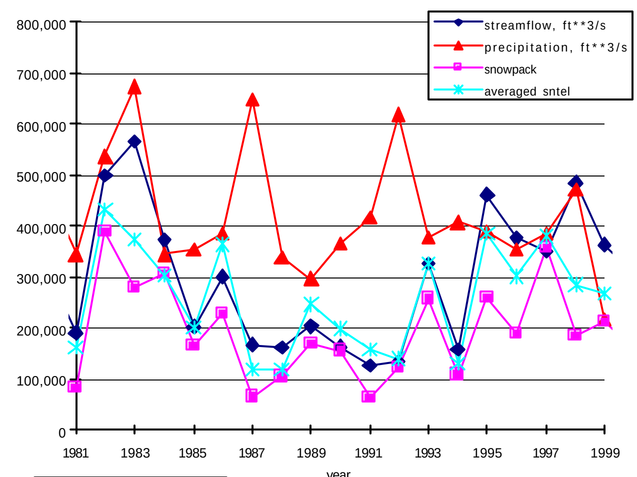

Figure 1

We compared the stream flow with the precipitation in the same year in figure 2. Most of high precipitation years are accompanied with the high stream flow. It was found that 1983 was the highest precipitation year and 1999 was the lowest precipitation year during the investigation period. The year of 1983 stands out in this plot because it has the greatest stream flow and precipitation. 1999 also sticks out due to it having the lowest precipitation year although the stream flow is not the lowest. The reason for this will be discussed later in the paper.

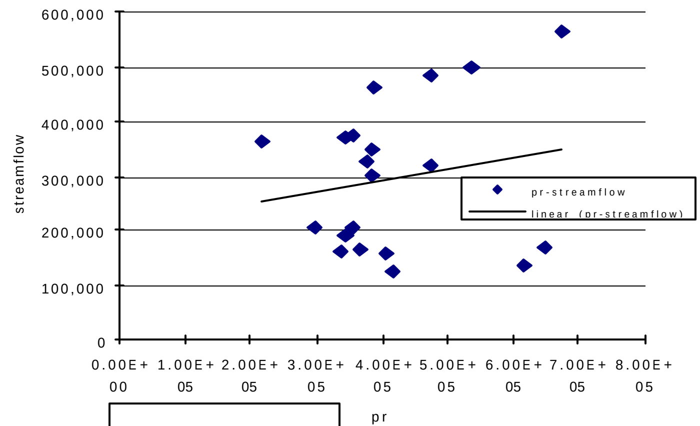

Figure 2

Figure 3 is the comparison of precipitation from October to March between these two years. As we can see the greater amount of precipitation in October, November and December in 1983 than 1999 contributed to the difference of these two years. There were not obvious differences of precipitation in last three month during these two years. The precipitation monotonously decreased from October until March.

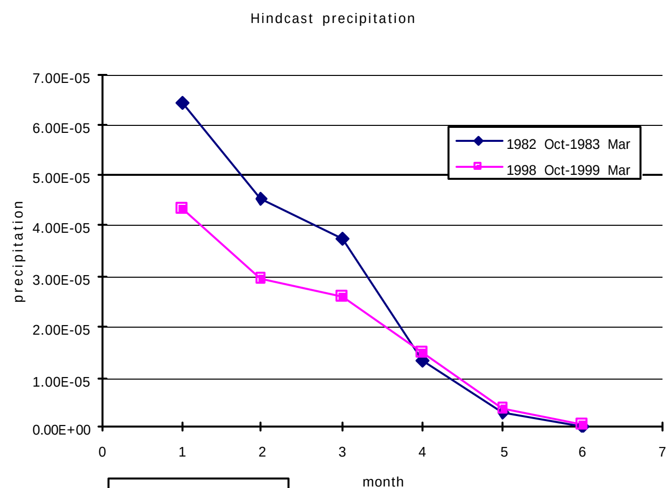

Figure 3

As a result of high precipitation in 1983, there was more stream flow in 1983 than 1999 (As seen in figure 4). Unlike the precipitation, both of the years showed that the maximum stream flow happened during February. For the high precipitation and stream flow year, 1983, there were 3 peaks for the stream flow. The first peak appeared in December. The second and maximum peak was in February and the last peak occured in May. This might due to the long winter and large amount of the snow because the heavier the total annual flow, the more likely that there is a long winter. As the major component of discharge for the Sacramento River is snowmelt, especially in spring, there will be one main peak of stream flow and possibly other peaks due to short snowmelts. The first peak in December can be associated with an early winter thaw. This would cause the snow to melt and create stream flow. The second and main peak in February can be associated with the expected early spring thaw. And the third peak in May can be associated with the main spring thaw. This main spring thaw was later than usual due to a long and cold winter in 1983 with more snow meaning it would take longer to thaw. During 1999, the first and main peak occurring in February is from the main spring thaw. There was a second, weak peak for stream flow in July. This can be explained by the

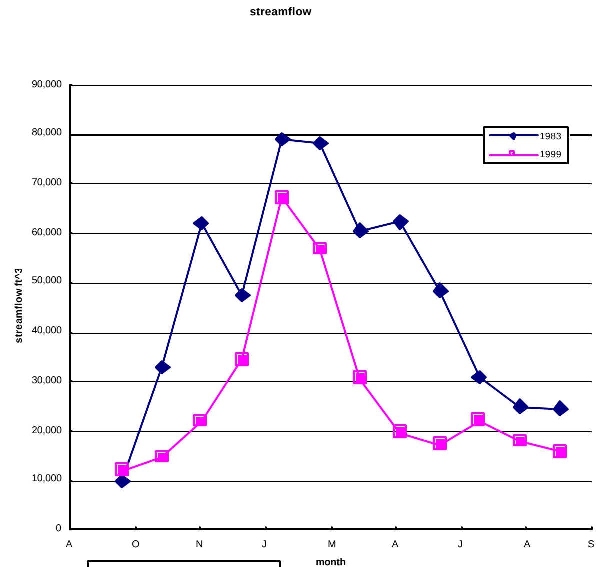

Figure 4

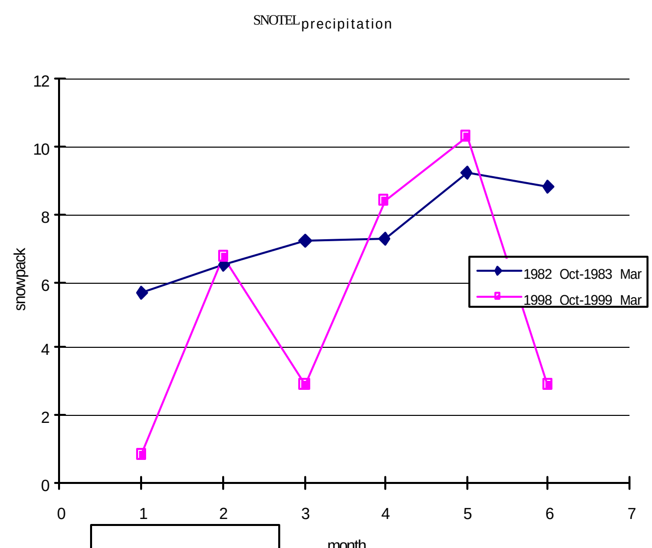

Figure 5

North American monsoon affects in the southwest.

The SNOTEL precipitation increased gradually from October to March in 1983 (see figure 5). However, during the year 1999, there was abnormaly less SNOTEL precipitation in October, December and March. This causes the stream flow during following months in 1999 to be relatively less than in 1983.

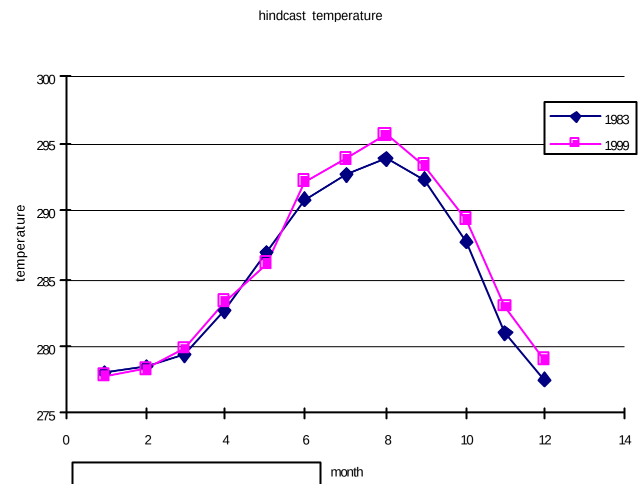

Figure 6

Furthermore, the temperature hindcast (see figure 6) results for 1983 and 1999 tells us that these three months in the year 1999 were relative warmer than the year 1983. That's why it had less snow fell down during the three months in 1999.

"The snow pack index (SI) is an indication of change in the factors that effect the sequestration of winter precipitation in the form of snow pack, beyond precipitation change" (Losleben, Hartman and Lowry).

The SI is the percent of average snow water equivalence (SWE) divided by the percent of average precipitation on any given date. An index value of less than one indicates that less of the winter precipitation is being stored in the snow pack, and a value greater than one indicates more of the winter precipitation is in the snow pack. As showed in Table 1, which has the snow pack index in the 1983, high precipitation year, and 1999, low precipitation year. In 1999, during early to mid winter (Jan-Mar), an increased SI suggests that more of the winter precipitation was sequestered in the snow pack. In early spring (Apr-May), the SI declines suggesting that less of the winter precipitation is banked in the snow pack. While in 1983, the increase lasted until May, and then decreased. The greater the snow pack, the longer the period of heating that is required to bring it to the melting state. This can be explained that the winter in 1983 was longer than usually and thus the SWE was larger than other years. This supports that the high precipitation year, 1983, had more stream flow than usual. Furthermore, the timing of the pulse was delayed with greater seasonal accumulation of snow pack.

Table 1

SI	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
83	0.004425	0.214615	1.181944	2.009589	2.525946	3.577841	7.103226	23.24286	1.475	0	0	0
99	0.025	0.16	1.862069	1.02619	1.981553	9.148276	8.384746	6.029412	0	0	0	0

Furthermore, it was found by Andrade and Sellers that stronger ENSO events have a direct positive effect (increase) on precipitation received in the Southwest United States, especially during the autumn season from Sep. to Nov. at the onset of an ENSO event, and also during the following spring from March to May. We found that the category of ENSO event in 1982 and 1983 was 4. The category 4 event suggests that it was a very strong ENSO season. During strong ENSO season's there is an increase in precipitation as stated above but especially during the following spring. This supports our data for 1983 bye having a greater amount of

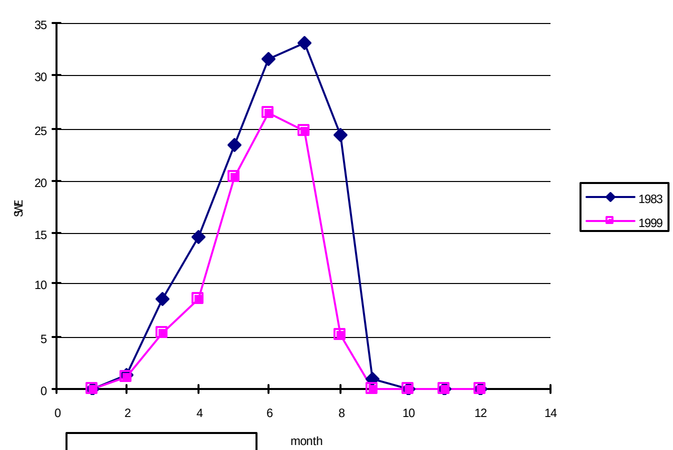

Figure 7

snow pack. La Nina is the only ENSO phase to have a positive effect on the SI (snow pack conductive), due to an increase is SWE, not precipitation. The Southeast and southwest regions have their highest SI during El Nino.

Summary and discussion:

Rajagopalan and Barros found that North American Monsoon is a very important impact on the high precipitation of southwest US. We found two years in which we looked farther into this relationship. We looked at 1999 which was our minimum precipitation year and 1983 which was our maximum precipitation year.

Due to there being a higher amount of precipitation in 1983 we found that there was a greater amount of stream flow. The large difference of stream flow between these two years is due to the greater amount of precipitation in October, November, and December during 1983 than 1999. Also, when looking at the SI in both of these years 1983 showed an increased SI from January to May which indicates winter precipitation. And in 1999 the increased SI only lasted from January to March. Therefore because there was more winter precipitation for longer amounts of time in 1983 there was more stream flow due to melting of the snow pack than in 1999. This supports the greater precipitation year being 1983.

Throughout the years the hindcast precipitation trended towards being greater than actual precipitation and this greater than the stream flow. The hindcast precipitation seemed to have the general trends of the actual precipitation during the months between October and March. The hindcast would not be a very accurate tool for correct amounts of precipitation. Though, it would be useful to see an approximate trend of the season.

The SNOTEL data matches very well with the stream flow data especially during the years of 1992-1994. They are very common throughout by following similar peak and minimum trends. As stated earlier a change in the weather pattern such as a normal low pattern to a high pressure pattern can cause snowmelt runoff. As shown above runoff greatly affects stream flow. Therefore if you have a late snow melt case such as in our study of the winter of 1983 it will provide a later increase in stream flow and also will provide a greater amount due to more snow available to melt.

References

D.R. Cayan, D.H. Peterson, L. Riddle, M.D. Dettinger, and R. Smith: The Spring Runoff Pulse From the Sierra Nevada, the Interagency Ecological Studies Program for the Sacrameto-San Joaquin Estuary Newsletter, Summer 1997, p. 25-28

Mark Losleben, Michael Hartman and Benjamin Lowry: Using a Snowpack Index to Evaluate Non-Precipitation Changes in Snowpack in the Western United States

Jinwon Kim, Norman L. Miller, John D. Farrara and Song-You Hong: A Seasonal Precipitation and Stream Flow Hindcast and Prediction Study in the Western United States during the 1997/98 Winter Season Using a Dynamic Downscaling System, Journal of Hydrometemorology, vol. 1, No. 4, pp. 311-329.

Andrade, E.R., and W.D. Sellers. 1988. El Nino and its effects on Precipitation in Arizona and Western New Mexico. Journal of Climatology, 8, 403-410.

Rajagopalan, B and A. Barros, North American Summer Monsoon: Understanding Its Interannual and Intra-annual Variability and Implications to Water Resources Management.

Hobbs, John; Guimond, Steve; Snook, Nate : Prediction of Snow Water Equivalent in the Snake River Basin. Past reports

http://www.meteor.iastate.edu/classes/mt455/Seas_Fcst/Reports_2004/SnakeRiverSWE.pdf