HyMet Streamflow Forecasting Model for the Sacramento River above Shasta Dam, California

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Introduction

A new seasonal forecasting model has been developed to forecast natural inflow to Lake Shasta, California. The model is similar in structure and operation to the Columbia River forecasting system that has been in operation since the 1999-2001 season (a detailed description of the Columbia model can be viewed at: www.hymet.com).

Model Input

Input to the Shasta model are daily precipitation and temperature observations collected at cooperative weather stations located in or near the basin. Figure 1 is a topographic map of the 6421 mi^2 (16,630 km$^{2)}$ area basin, constructed from a 30 m resolution DEM (19,063,091 pixels). The nine weather stations that provide the daily meteorological observations used in the forecasting model are also shown. Precipitation station selection is based on split-sample testing of all stations in the region to determine which stations have the highest probability of producing the lowest forecast errors in the future. Consequently, some stations within the drainage divides are eliminated and others outside the basin are used. Two temperature stations, one high and one low-elevation, are selected by a similar technique. The distribution of watershed area as a function of altitude is also

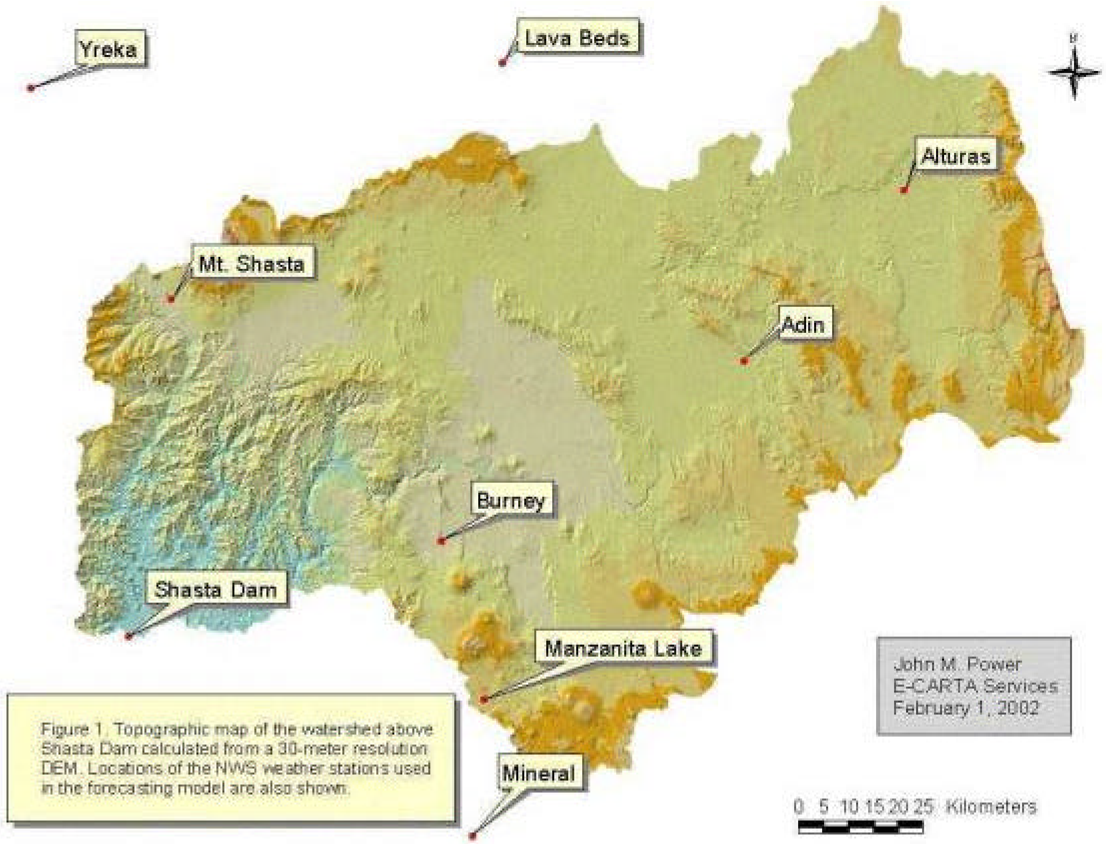

Figure 1

required for optimum forecast accuracy. Figure 2 is a histogram of area for each 165 foot (50 m) altitude increment. The reconstructed Shasta Lake inflow record, required for model development and for operational forecasting, begins in 1987. It was extended to 1949 by daily correlation of the existing record with streamflow records from stations upstream of Lake Shasta that are nearly unimpaired by regulation. However, due to the lower reliability of the earlier records, only the simulated 1980-86 record was used for calibration.

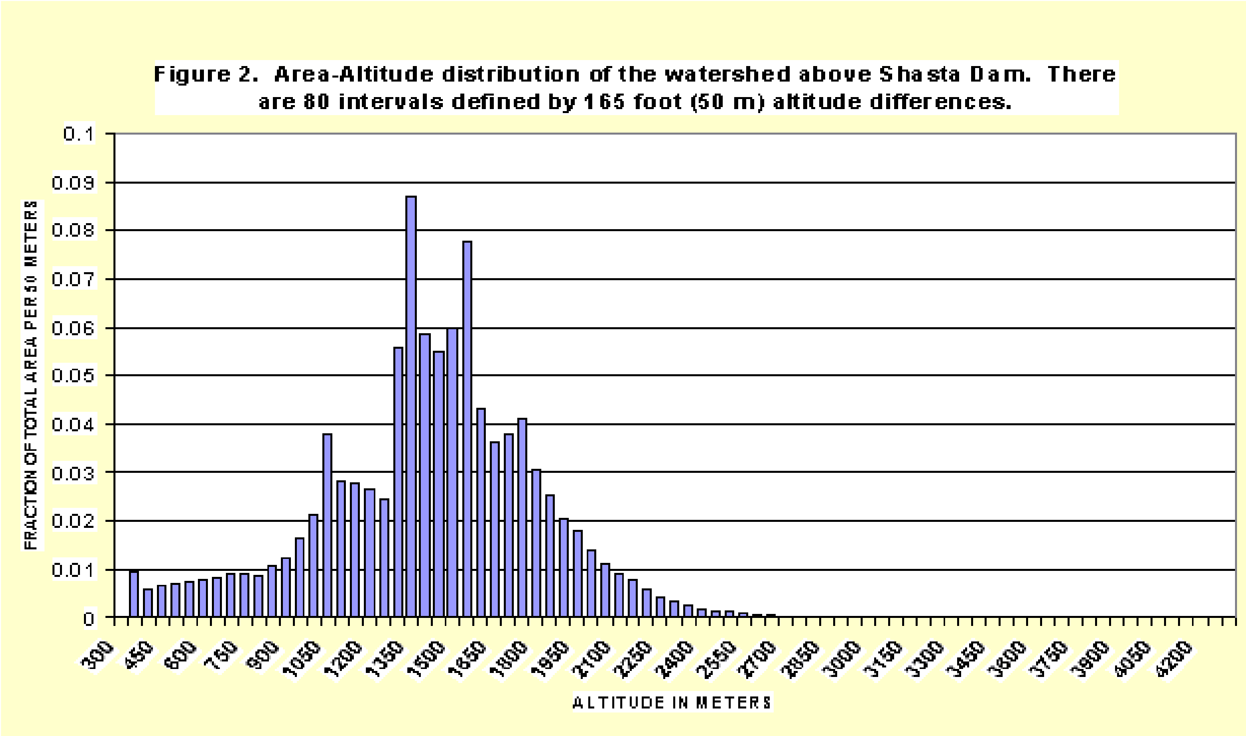

Figure 2. Area-Altitude distribution of the watershed above Shasta Dam. There are 80 intervals defined by 165 foot (50 m) altitude differences.

Figure 2

Model Structure

The model's computer program, written in Fortran 77, applies a set of algorithms that convert daily meteorological observations to such hydrologic variables as snow accumulation and melt, soil moisture, evapo-transpiration, groundwater inflow, outflow and storage. The seasonal forecast is based on the amount of water, both in the snowpack and as groundwater, which is stored in the basin on the day the forecast is made. The distribution of the snowpack as a function of altitude, which determines the time distribution of runoff as a forecast hydrograph, is calculated for each of the 80 altitude intervals. The basin water storage (the snowpack plus groundwater) averaged daily for the 1980-2001 period is shown in Figure 3. Also shown is the basin water storage for the 2001-2002 season, up to January 27. The distribution of the snowpack's water content versus altitude is demonstrated in Figure 4. Both the 1980-2001 mean and the snowpack on January 27, 2002 are shown, along with the altitude distribution of the percent of normal for the current snowpack.

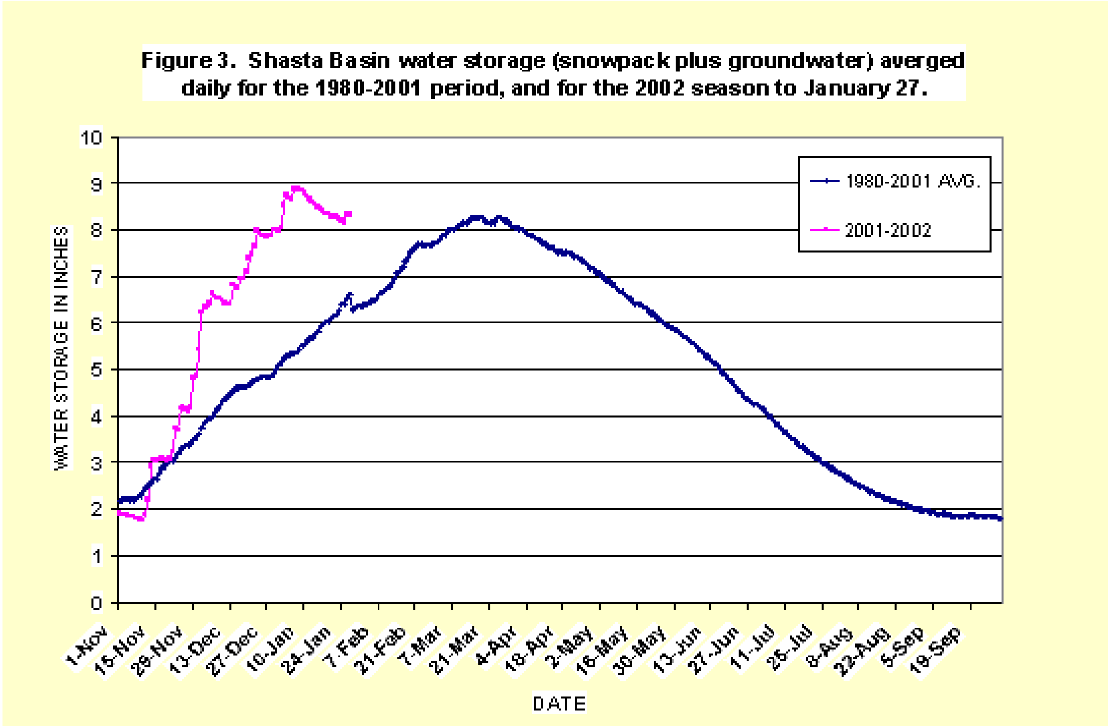
Figure 3. Shasta Basin water storage (snowpack plus groundwater) averged daily for the 1980-2001 period, and for the 2002 season to January 27.
WATER STORAGE IN INCHES
10
9
8
7
6
5
4
3
2
1
0
1980-2001 AVG.
2001-2002
1-Nov
15-Nov
29-Nov
13-Dec
27-Dec
10-Jan
24-Jan
7-Feb
21-Feb
7-Mar
21-Mar
4-Apr
18-Apr
2-May
16-May
30-May
13-Jun
27-Jun
11-Jul
25-Jul
8-Aug
22-Aug
5-Sep
19-Sep
DATE

Figure 3

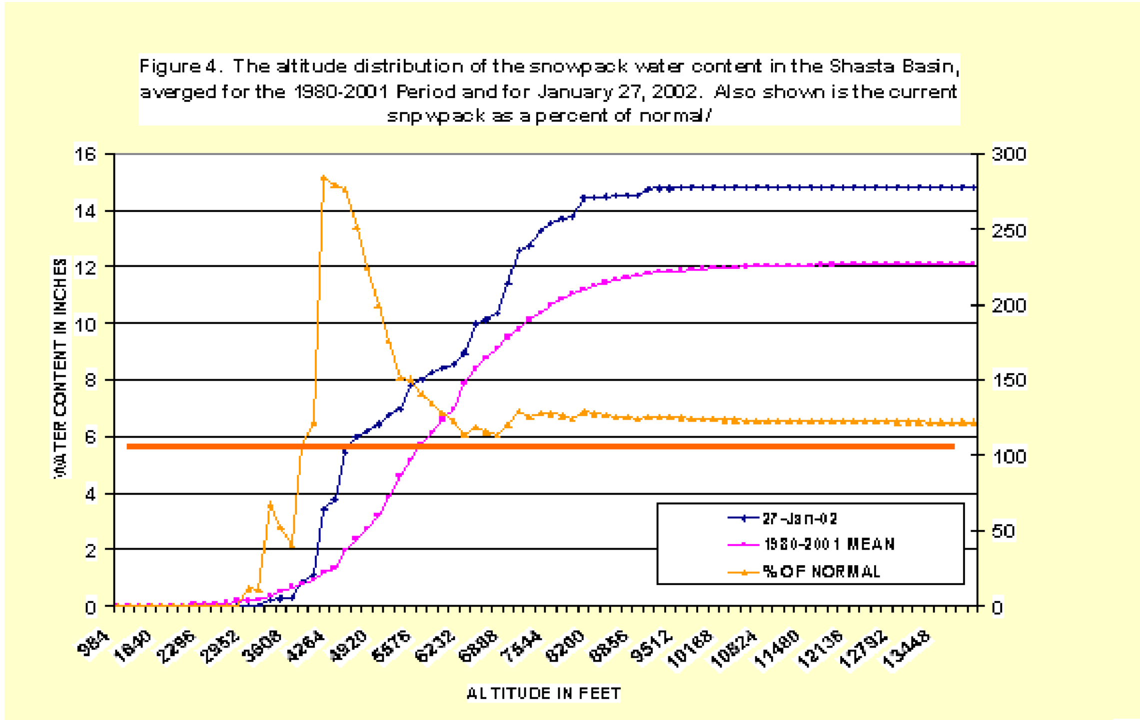

Figure 4

Forecast Accuracy

The expected forecast accuracy of the model, based on retrospective forecasts made each day from November 1 to July 1, for the 1980-2001 period, is shown in Figure 5. The R^2, a measure of model accuracy compared to using the historical mean runoff as a forecast, reaches nearly 0.90 in the spring. The mean error fraction, which is the root mean error divided by the average runoff for the forecast season, reaches a minimum of about 0.20 in early spring. The reason for the relatively high error (the Columbia River at Grand Coulee minimum is about 0.065) is likely due to the high natural variability of the inflow to Lake Shasta (the discharge coefficient of variation averages about 0.60, compared to 0.20 for the Columbia River). The high variability makes accurate forecasting more difficult because the influence of subsequent (and unpredictable) precipitation is unusually strong in this region.

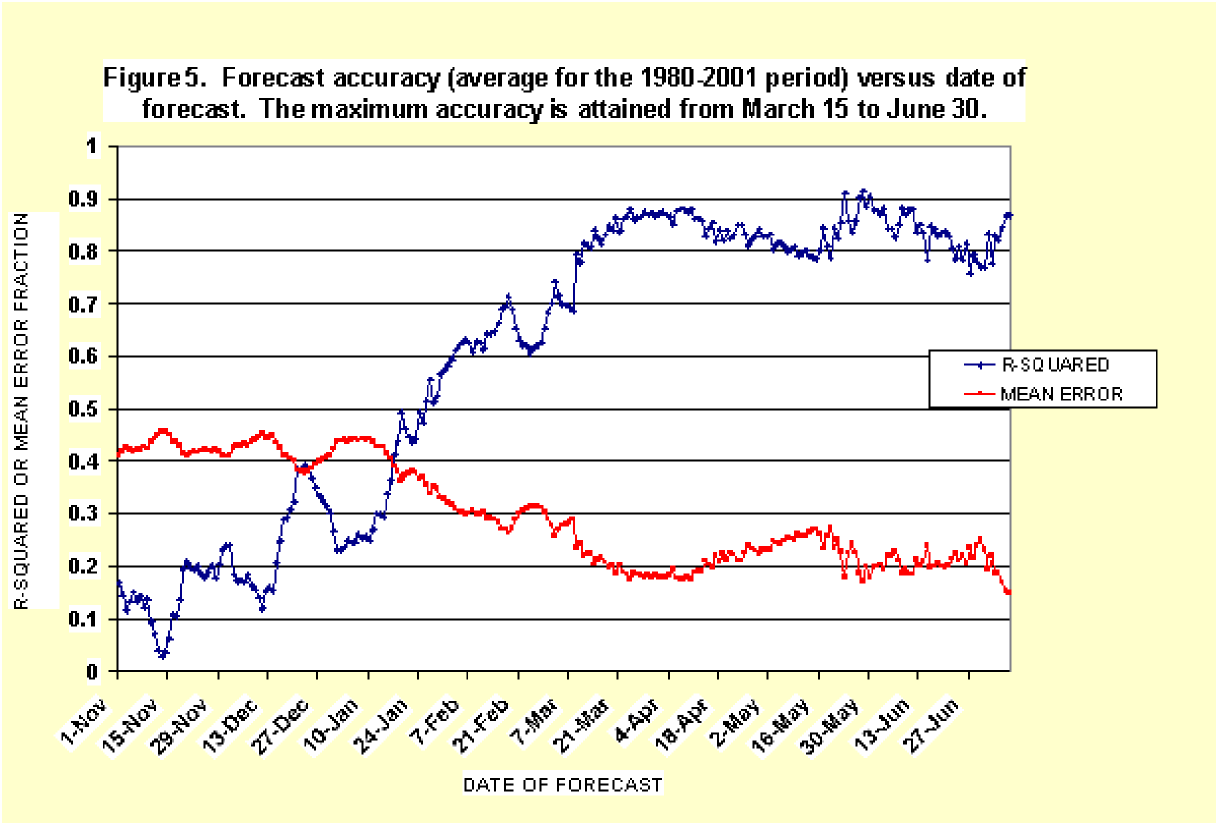

Figure 5

Hydrograph Forecast

The amount and altitude distribution of the snowpack determines the time-distribution of runoff. A low-altitude snowpack will melt rapidly early in the season and a heavy snowpack located at higher altitudes will tend to produce high flows later in the season. By comparing the current year's snowpack with those of previous years, the time-distribution of runoff during the forecast season can be estimated. A forecast hydrograph for the March 1-July 31, 2001 season is shown in Figure 6. The 2001 runoff season was one of the lowest on record and mean daily flows during the March-June period were a historic minimum, but were predicted with fair accuracy on March 1.

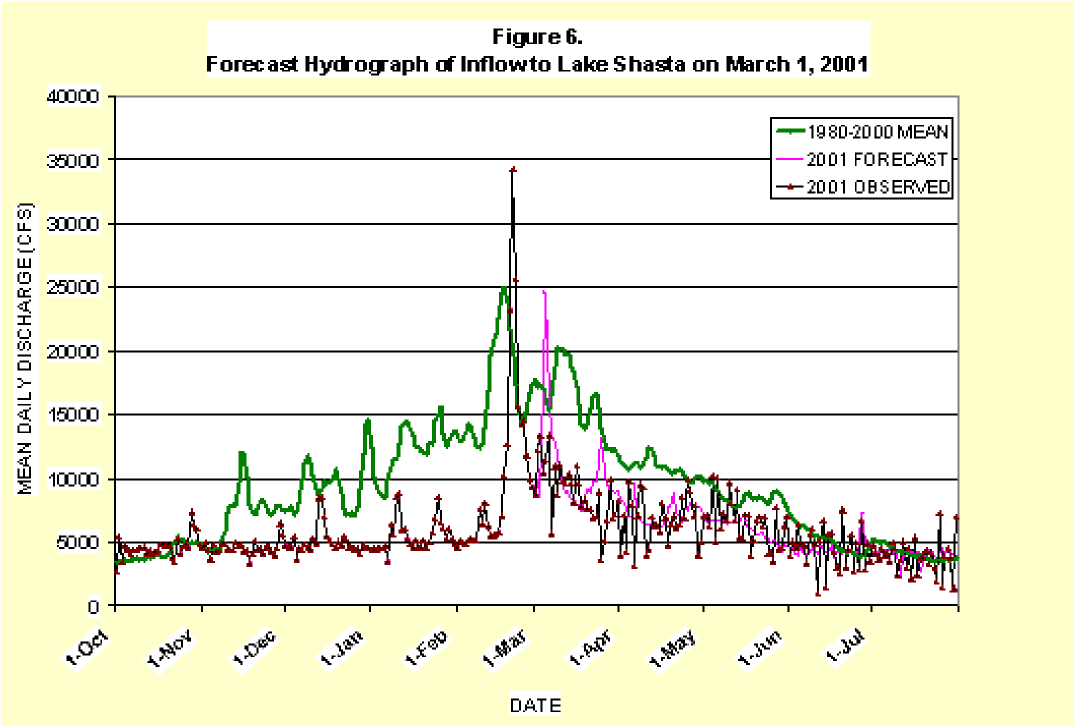

Figure 6

Forecast Example

A history of the forecasts that were made daily from November 1 to the current day are shown graphically in Figure 7 as percent of inflow for seasons ending July 31. A recent real-time forecast made for the season ending July 31 is provided in a separate file. In addition to the forecast, an alternative set of forecasts based on a range of precipitation and temperature scenarios is included, plus a statistical summary of precipitation for each of the nine stations and the weighted basin average, temperature deviations from normal for the two stations, and for reconstructed inflows. These summaries are given for both the season of October 1 to the date of the forecast, and for the week previous to the forecast.

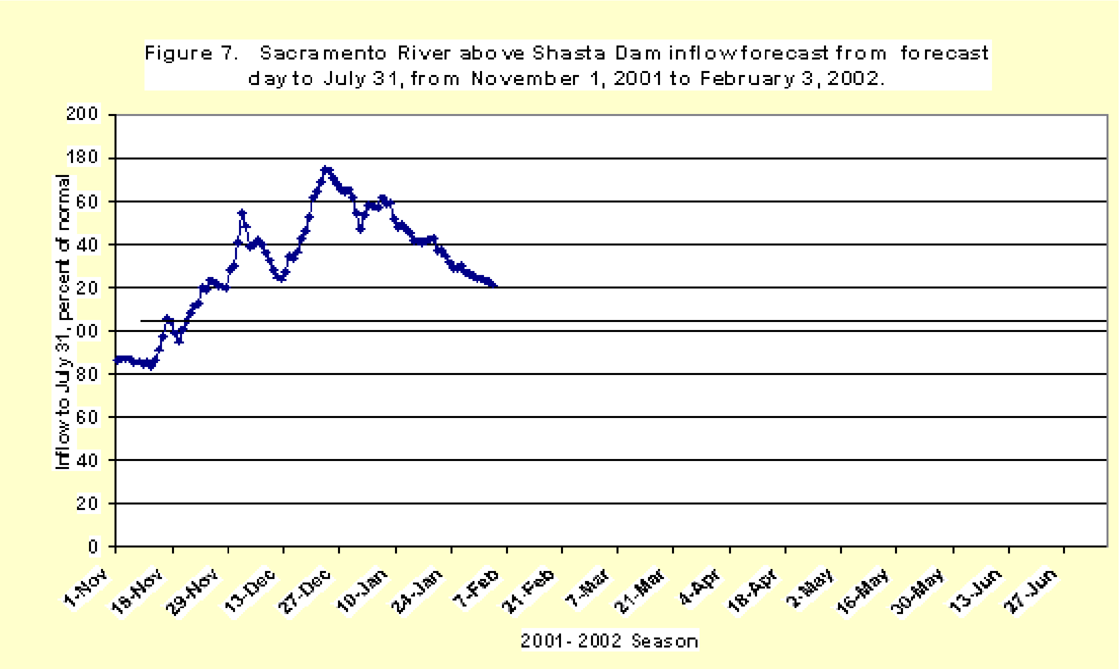

Figure 7

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