# UPPER AIR DATA AS A PARAMETER IN ESTIMATING SNOWMELT RUNOFF 1/

By

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## Introduction and Background

Since the snowmelt season of 1969, California Cooperative Snow Surveys Program, under the California Department of Water Resources, has operated a hydrologic model on the Kings River basin in the southern Sierra Nevada (Fig. 1). A similar model has been operated on the San Joaquin River watershed since the snowmelt season of 1970. These hydrologic models have been designed to simulate mean daily runoff given certain parameters indicating the condition of the watershed, quantity of snowpack, daily precipitation, and daily temperatures throughout the snowmelt period. Simulated daily runoff during the snowmelt season has proved to be an important tool in making certain operational decisions with regard to volume and time-distribution of snowmelt.

In practice, such hydrologic models utilize conditions in the watershed as they exist up through the date of analysis. Subsequent to the date of analysis, a specific temperature regime or regimes must be assumed to determine the potential rate of runoff and time distribution. For example, it might be desirable to determine what runoff conditions would prevail if temperatures were 10 degrees above normal for the next week. Similarily, an operator may desire to determine the distribution of runoff with snowpack conditions as they currently exist and temperatures similar to any one or a group of historical years.

In order to develop a daily temperature index to represent historical temperature regimes and the current observed temperature data for modeling, an estimated surface temperature at the 7,000 foot elevation has been utilized. Mean daily surface temperatures for three stations, adjusted to the 7,000 foot elevation, and averaged have been used as the daily temperature index. Stations used on the Kings River model are:

| Station Name | Elevation |
|---|---|
| Huntington Lake | 7,020 |
| Grant Grove | 6,580 |
| Big Creek Powerhouse #1 | 4,928 |

This method of estimating daily temperature as an input for hydrologic modeling gives an index which is apparently useful in estimating the combined effects of air temperature, radiation, and perhaps other factors in priming and melting snowpack to produce runoff. Historic results have been good with a few important exceptions.

## 1974 Snowmelt Season

The 1974 snowmelt season produced April-July runoff of about 130 percent of average on the Kings and San Joaquin Rivers. Although this volume of flow is not exceptional, certain operational problems became significant as the reservoirs reached near capacity in early June. Peak snowmelt runoff under 1974 conditions should occur in late May or early June, and consequently evaluation of the rate of snowmelt runoff through hydrologic modeling could play an important role in operational decisions.

Simulated daily runoff appeared to be verifying within acceptable limits through late May when the apparent peak runoff occurred on May 28. One period during the middle

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of the month did however have flows somewhat in excess of those anticipated on the basis of surface temperatures. Calculations indicated that there was a high probability that the 14,391 cfs peak flow experienced on May 28 would not be exceeded during early June, although even average temperatures would maintain flows at a relatively high but ever decreasing rate. Only extreme temperature conditions would generate snowmelt runoff in excess of the previous peak during the first week of June.

By June 7, temperatures somewhat exceeded the average for the period and observed mean daily runoff for the Kings River reached a new peak of 14,534 cfs, exceeding the simulated flow of the model by over 20 percent. Observed flows substantially in excess of those simulated by the model using observed temperatures continued at a diminishing rate until June 13. After June 13, simulation of observed flows fell back within acceptable limits and continued in that manner throughout the end of the snowmelt season.

Fig. 2 is a plot of time against observed and simulated mean daily discharge of the Kings River, Inflow to Pine Flat Reservoir, detailing the time period and magnitude of error or inability of the model to simulate observed flows during this critical period. If air temperatures were to be assumed as the primary index to melt in the Kings River basin, it would have required an increase in temperature of seven or eight degrees to simulate the quantity of observed flow on or about June 7.

## Investigation of Surface Temperatures

Although variation between observed and simulated flows during the snowmelt season has occurred throughout the history of hydrologic model use in the southern Sierra, the excessively large flows of early June 1974 were of particular interest in that reservoirs were nearing full capacity and any excessive but unanticipated discharge could complicate operational problems. As a consequence, it was decided to investigate some of the potential sources of error in the hope that future errors of this type might be anticipated and corrected, if not before the fact, at least during the occurrence of the situation.

Many areas of potential error were investigated. Surface air temperatures merely represent an integration of many effects relating to snowmelt. Wind, radiation, humidity, and other factors in addition to temperature play a role in determining the quantity and sequence of melt. These factors were investigated, and although some possible causes for excessive melt were found, application of the findings to other historical snowmelt occurrences did not yield promising results.

Mean daily temperatures for various stations in the southern Sierra and in the White Mountains immediately to the east are delineated in Fig. 3. Although this figure suggests that the higher elevation temperatures may be somewhat higher than expected based on temperatures taken at lower elevations, neither the magnitude nor timing appears to be consistent with times of peak melt rate. In fact, the temperature increase at higher elevations appears to be after the fact rather than preceding the increase in melt rate. Although there could be many possible causes for inconsistency of records at individual stations, data in Fig. 3 suggests no overall obvious trend which might be useful for forecast purposes.

## Investigation of Wind Data

Surface wind data for various locations in the southern Sierra foothills were investigated, but no significant difference in wind flow was noted during periods of apparent excess snowmelt. These stations were, however, mostly located in deep canyons at reservoir sites, and may not be necessarily indicative of winds occurring at higher elevations in the snow fields. Analysis of air flow from upper air charts at the 700 millibar level (approximately 12,000 feet) indicated anticyclonic flow over the southern Sierra. This type of upper air flow pattern would suggest an easterly flow of air over the mountain areas, with resulting sinking and heating of the air mass. Investigation of surface winds at several desert stations to the south and east of the southern Sierra indicated several days of relatively high winds during early June and mid-May, on approximately the dates when excess flows were noted. However, similar winds have occurred at other times when excess melt was not noted. All of the above wind information was perhaps providing a clue but not a solution to the problem of high melt rate.

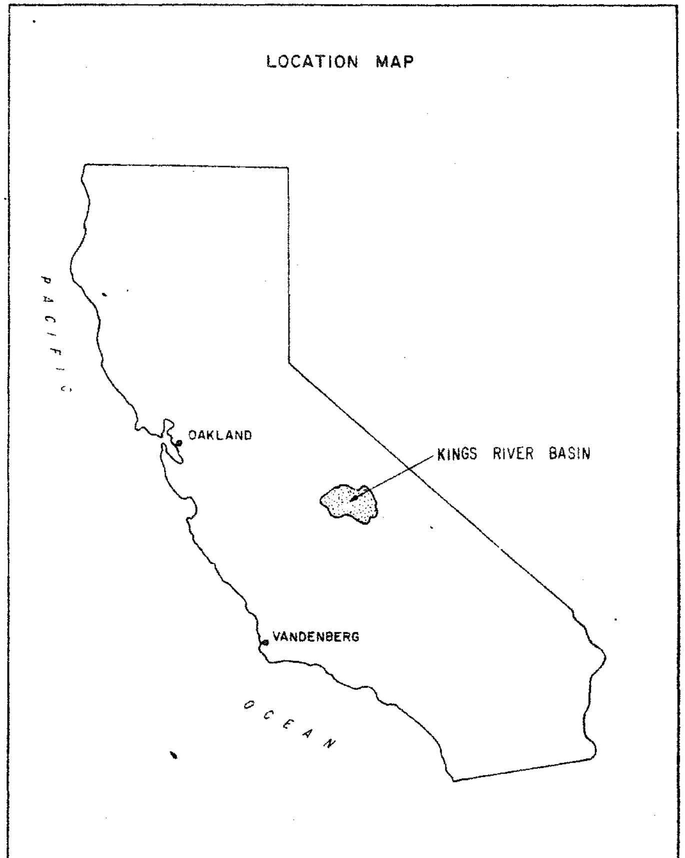



FIGURE 1

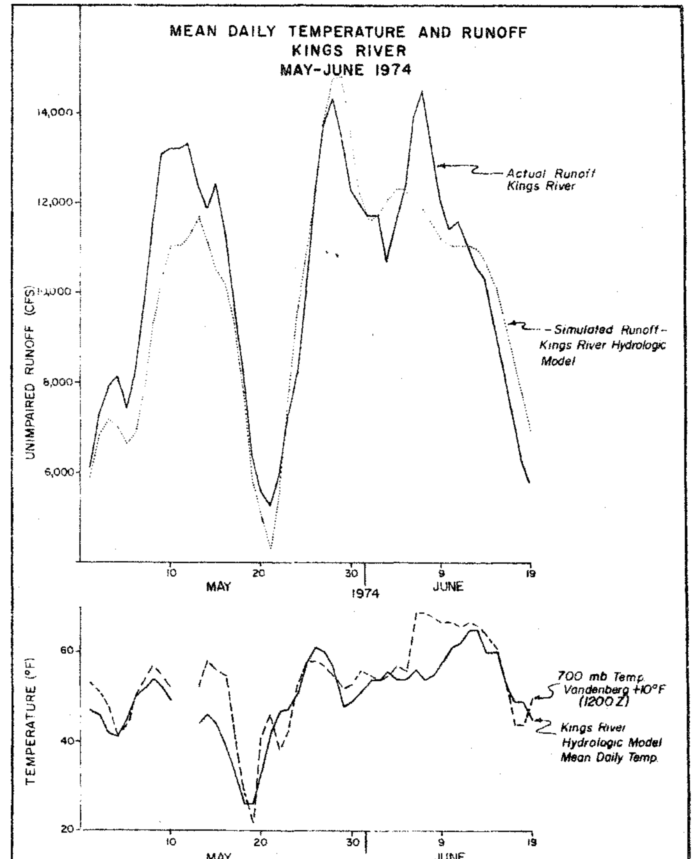



FIGURE 2

## Investigation of Upper Air Sounding Data

After surface temperatures, wind direction and movement, and other factors had been studied, the problem was discussed with several meteorologists. Russ Shaffer of North American Weather Consultants pointed out that a "subsidence inversion" had existed for some time during early June, about the same time period when the exceptional melt situation had occurred. Upper air data from balloon soundings verified the unusual nature of the atmosphere's lapse rate during early June.

The "subsidence inversion" was a meteorologic situation in which subsiding air resulted in a lapse rate significantly smaller than that normally encountered. The Oakland sounding of June 6, 1974, revealed temperatures about three degrees F greater at 11,000 feet than at 5,000 feet elevation. The Vandenberg sounding, which would probably be more representative of the southern Sierra even though far removed from the range, showed temperatures about eleven degrees F higher at 12,000 feet than might have been anticipated from the temperatures at 7,000 feet. Temperatures from the Vandenberg sounding for June 6 and June 7, 1974 are delineated on Fig. 4 along with a typical early June sounding, showing the lapse rate condition which existed at that sounding during the period of maximum melt. Even the 10,000 foot Mt. Givens temperature did not appear to reflect the situation described by upper air data, at least to the extent suggested by Vandenberg sounding.

Calculations were made in which the upper air anomaly was compared with the apparent error in rate of melt, showing a good relationship between the magnitude of the anomaly and the unrouted surplus melt water.

Utilizing knowledge gained in investigation of the June 1974 event, upper air data was included as a parameter relating to the degree of snowpack priming and magnitude of snowmelt. Although any number of possible parameters from soundings may have worked satisfactorily, the 700 millibar (approximately 12,000 foot) temperature from the Vandenberg sounding (1200Z) was utilized as one of the daily input variables to the hydrologic model. Data from the Vandenberg sounding have been plotted on Figs. 2 and 3 with suitable scale adjustments to make plots comparable with surface temperatures. Fig. 3 suggests that sounding data may lead the surface data currently used in the Kings River model by several days. Fig. 2 indicates that sounding temperatures could provide valuable supplemental input in terms of both magnitude and timing of melt during the 1974 season.

Five years of historical snowmelt data were run including 700 millibar temperatures from the Vandenberg sounding for the critical melt period, May and June. Substantial improvement was noted in a number of cases, particularly where the increase in melt rate was great over a short period of time. Although the greatest improvements were noted in the early June 1974 occurrence when the most exceptional upper air conditions of the study period apparently occurred, many other periods of melt showed some usable improvement.

## Conclusions

Inclusion of upper air temperatures has provided a means for better simulating daily snowmelt runoff on an operational basis for the Kings River basin. Techniques have been developed to include 700 millibar temperatures from the Vandenberg sounding in the modeling procedure. However, to date no substantial effort has been expended in study of the physical relationship between sounding temperatures and conditions leading to excessive snowmelt in the watershed. Available surface temperatures, even at high elevations, do not appear to adequately describe the melt condition at certain times such as the occurrence of early June 1974. Available wind data indicated no exceptional surface wind conditions which could quantitatively describe the condition of excessive melt for use in the model. Although higher dewpoints usually accompanying the higher 700 millibar temperatures could play a role in some snowmelt equations now in general use, data from the watershed has been inadequate for quantitative estimates of dewpoint in the area of snowmelt.

Investigation of the unusual conditions of early June 1974 has emphasized the fact that broad scale meteorologic occurrences may have substantial influence upon rate and timing of snowmelt in addition to effects reflected in other commonly used parameters such as surface air temperatures. Upper air temperature data, which have provided an important source of supplemental information in simulating snowmelt runoff on the Kings River watershed, appeared to have provided a degree of additional lead time for operational purposes. Sounding data are available daily through the National Weather Service and can be used operationally on a timely basis where appropriate to a particular hydrologic modeling application.

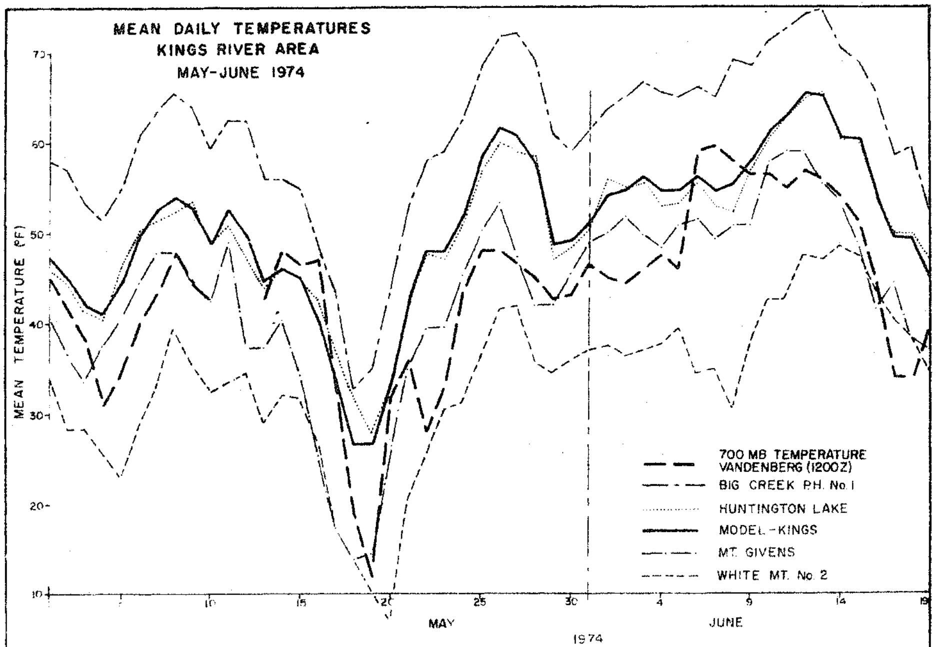
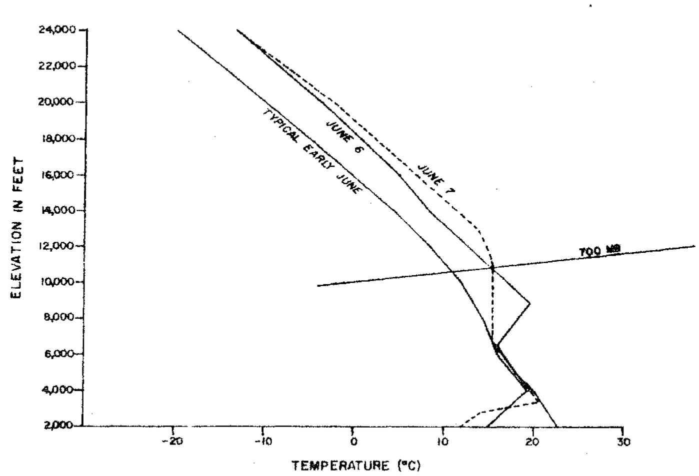



FIGURE 3




UPPER AIR TEMPERATURES
VANDENBERG SOUNDING
(1200 Z)

FIGURE 4