Forecast Techniques

THE USE OF THICKNESS AS A PREDICTOR FOR RATE OF SNOWMELT

by
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Much of the water used by the agricultural industry in New Mexico accumulates through the cold months in the high mountain snowpacks of northern New Mexico and southern Colorado. The accumulation season is roughly October through April, and the principal melt season May and June. Since only minimal streamflow controls exist on the upper reaches of the main rivers (Rio Grande, San Juan, and Pecos) the rate of melt at times is critical to flood anticipation as snowmelt water augments some base flow in the watercourses. (This becomes even more potentially explosive if bankful conditions are subjected to a rain episode during the period of maximum melt.) Hence, it is desirable to forecast, even on a short-term basis (24 to 48 hours), runoff volume resulting from meteorological parameters. An attempt is made in this paper to define such a parameter which can with considerable reliability anticipate crest flow attributable mainly to snowmelt.

In trying to develop a relationship we will consider only the period (May and June) when maximum melting takes place and will consider a total snowpack volume of normal to record dimensions. Years with below normal snowpacks are very unlikely to yield a significant flood threat from snowmelt. We, therefore, assume a normal to record snowpack, a typical seasonal rise in tropospheric temperatures interrupted by periods of short-term cooling and warming, normal wind movement, no consideration of sublimation loss, and the non-occurrence of important new precipitation during the period of interest. Obviously, all these assumptions will seldom be valid; but any conclusions drawn from the desired relation can hopefully be biased and corrections can be made for short-term interruptions.

Melting is assumed to begin when the temperature of the snow surface rises to 32°F. It is our understanding that hydrologists concerned with snowmelt have traditionally based their judgments on max/min air temperature reports from available nearby surface observing stations and defined relations between these reports and consequent runoff. We have in past years experienced some measure of success by using the analyzed 700 mb temperature field over the snowpack area with the implied assumption that the bulk of the snowpack is near a 10,000 ft. msl elevation. In this attempt we found that a three-day running mean of 700 mb temperatures yielded more stable relationships than simple daily values, due probably to an intertia inherent in the melting process.

It was hypothesized that a better predictor of melt might be the 850-500 mb thickness parameter since this would indicate temperature in an air column instead of at a single discrete level; i.e., it would accomplish vertical averaging. Studies have been done showing that 850-500 mb thickness closely corresponds to 700 mb temperature with a 4,200 meter thickness value the equivalent of 0°C and each 60 meters above or below that figure corresponding to 4°C.) As we shall see below, this parameter has proved to be forecastable up to 48 hours with a fair degree of success both subjectively and objectively.

For this study only 12Z data were used and careful statistics kept for only the 1980 melt season. Thickness values were computed for the Albuquerque, Grand Junction, and Denver upper air observations daily, and the algebraic average of the three assumed to represent air column temperature over the snowpack area. The centroid of a triangle formed by the three observation points coincides almost exactly with the location of the main snowpack for the Rio Grande and San Juan River drainages.

In Figure 1 we display plots of daily values of thickness (12Z) and streamflow at Durango, Colorado (approximate 15Z gage reading). This gaging point is on the Animas River, which is a major tributary of the San Juan. Upstream from Durango there are no controls imposed on the natural flow, and this is the farthest upstream gaging point from which realtime, daily data are available. (We similarly examined data from the Pagosa Springs, Colorado, gaging point which is comparably

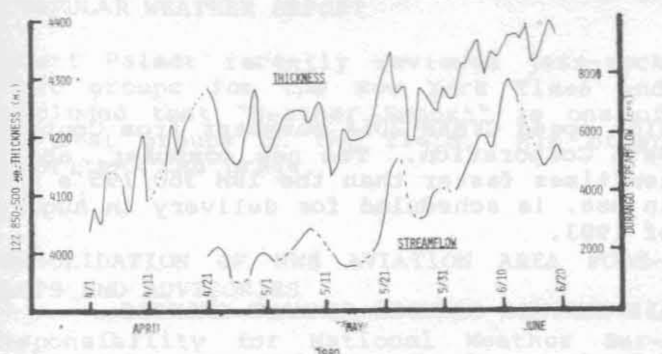

Figure 1. The Observed Relationship Between 850-500 MB Thickness and Streamflow on the Animas River, Durango, CO.

located on the mainstem of the San Juan. Since the hydrographs turned out to be near mirror images except for absolute volume of flow, the Pagosa Springs hydrograph is not displayed.)

Note in Figure 1 that streamflow displays only minor changes from an approximate 2,000 cfs (cubic feet per second) base value until strong air column warming appears around May 19. This warming peaked on May 21 but did not drop back below the 4,200 meter value again until May 25. Streamflow crested at about 5,000 cfs on May 23, then dropped off to about 3,000 cfs on May 27. Moderate warming was again evident on May 27 and continued with frequent interruptions through June as several short-wave impulses tracked eastward over the area. Throughout this entire period the streamflow plot paralleled the temperature plot with almost complete fidelity and a 24-hour time lag, until the seasonal crest of almost 8,000 cfs was reached on June 11. Thicknesses did not drop back to or below the 4,200 meter level after May 27. From June 4 to the middle of the month, 700 mb temperatures at Albuquerque were above seasonal normals. Normals were not available for Grand Junction or Denver.

It thus appears that, at least in a qualitative sense, the thickness parameter displays merit as a rate-of-melt predictor. It would be appealing to be able to relate some thickness measure to volume of consequent runoff. We attempted to do this by defining a cumulative seasonal heat-unit figure above an arbitrary base and comparing this to increased runoff volume. The results were not especially illuminating; but further and more refined attempts, we suspect, could be more rewarding.

THICKNESS FORECASTING RESULTS

We were candidly a bit surprised at the success we found in thickness forecasting accuracy, both subjective and objective forecasts. Results are summarized in the table below. Subjective forecasts were made in a conventional manner from analyzing the observed thickness field, then estimating the changes considered probable over a 24- and 48-hour period in consideration of advection, trough/ridge movement, development, weakening, etc. The objective forecasts were made from LFM graphic output by estimating the values of 850 and 500 mb height forecast by the model, and subtracting to obtain the forecast.

	24 HOUR		48 HOUR	
	SUBJ.	OBJ.	SUBJ.	OBJ.
Number of Forecasts	27	35	27	35
Average Absolute Error (10's Meters)	2.0	2.1	2.2	3.8
Average Arithmetic Error (10's Meters)	- .2	-1.4	- .5	-3.4

Table 1. Thickness Forecasting Results

Subjective forecasts were made weekdays from May 13 through June 18 with a few exceptions. Objective forecasts were retrieved for each day for which data was available. (The subjective forecast, by the way, was made independently, before computations were made for the objective product.) We ended with a total of 27 subjective and 35 objective forecasts for the period of record. Average absolute errors ranged from 20 meters to 38 meters, the equivalent of about 1.3°C to 2.5°C, which we consider quite good for 24- to 48-hour projections. The greatest error followed the May 24 forecast when the subjective forecast for 24 hours was 80 meters too low and the LFM 70 meters too low. The 48-hour projection from May 24 was 80 meters too low for the subjective technique and 110 meters too low for the LFM. All forecasts on the average displayed a slight bias toward being too low.

Although this is a fairly small sample we believe that it does definitely indicate that the 850-500 thickness parameter is susceptible to relatively accurate forecasting and that the technique has useful potential for accurate judgments of snowmelt runoff.

REFERENCES AND FOOTNOTES

1. Mr. Gregg did most undergraduate work at Texas A & M, receiving his B.S. from the University of Chicago (Meteorology) in 1943, and did graduate work at the University of Michigan in 1965. He was employed by U.S. Weather Bureau in 1940, and retired from the National Weather Service in 1981. Duty stations include Amarillo, Los Angeles, San Francisco, and Albuquerque, where he spent the last 11 years as Meteorologist in Charge (MIC). He was elected a Fellow of the AMS in 1978.