NOAA Technical Memorandum NWS WR-164

AN OBJECTIVE AID FOR FORECASTING AFTERNOON RELATIVE HUMIDITY ALONG THE WASHINGTON CASCADE EAST SLOPES

Salt Lake City, Utah
April 1981

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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Robert S. Robinson

National Weather Service Office
Wenatchee, Washington

April 1981

UNITED STATES DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
James P. Walsh, Acting Administrator

National Weather Service
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This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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AN OBJECTIVE AID FOR FORECASTING AFTERNOON RELATIVE HUMIDITY ALONG THE WASHINGTON CASCADE EAST SLOPES

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I. INTRODUCTION

The National Fire Danger Rating System (NFDRS) Develops indices of fire danger for wild land fire protection based on a number of weather and biological variables. One of the inputs to the NFDRS is the afternoon relative humidity (RH) for specific areas. Daily forecasts of relative humidity are required for various zones in a protected area. These zones are usually relatively homogeneous with respect to a number of variables.

Primary forecasts are made by the National Weather Service during the late afternoon, verifying the following afternoon at 1400 Pacific Daylight Time (PDT). At 0800PDT, the previous afternoon's forecast is updated. This study investigated the development of an objective forecast aid for afternoon RH in the Wenatchee, Washington, forecast area based on information available in the morning prior to 0800PDT. In order to ensure timeliness of the forecast, utilize the latest data, and avoid complicated data reduction, a simple direct method, the linear regression approach was examined.

II. REVIEW OF PREVIOUS STUDIES

Other methods of prediction are available for either RH or dew point near the surface. The trajectory model produces prognostic surface dew points and temperatures for selected stations [Reap 1972, Reap 1978] and average RH for various layers in the atmosphere are available as output from the PE forecast model [Cooley, 1970]*. Neither of these predictive techniques have been found to be useful at the scale necessary for daily fire-weather forecasts in north-central Washington [Holcomb, 1973]. They are based largely on predicted meteorological variables and consequently seem to suffer some instability, at least in the Pacific northwest.

A number of studies have examined the correlation of surface dew points with other variables but work in the area of RH prediction, directly, has been limited. Mean monthly values of surface dew point were found to be highly correlated with total atmospheric precipitable water [Reitan, 1963] although daily and hourly values were less correlated and had considerable variation [Bolsenga, 1965]. In particular, near the west coasts of midlatitude continents, summertime dew points were less correlated than winter [Reber and Swope, 1972] [Karalis, 1974]. Reasons offered for the latter relationship include the idea that the main influx of moisture is in the lower levels of the atmosphere during the summer and that a mechanism for the vertical distribution of moisture was needed for high correlation [Schwartz, 1968]. In addition, decoupling may occur between the upper and lower layers of the atmosphere due to summertime persistence of high pressure over the ocean and subsidence along the West Coast [Glahn, 1973].

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*Operational PE model was replaced by a baroclinic spectral model August 18, 1980, but output products were not changed [<u>TPB No. 282</u>].

III. DEPENDENT DATA

Data used were from zones 677 and 682 in the Wenatchee Fire Weather District (Figure 1). Zone 682 is largely forested and mountainous, ranging in elevation from 4000 feet to about 7000 feet. It is represented by five fire weather stations operated by the Washington State Department of Natural Resources and the U. S. Forest Service. The terrain is typical of higher elevations of the central east slopes of the Washington Cascades. Zone 677 is mainly grass and scattered pine in a lower elevation area (600 to 4000 feet) adjacent to 682. It is represented by seven fire weather reporting stations.

Daily zone averages for the 1400PDT RH observations were selected for July and August 1974 through 1980 for both areas. Because of the effect of persistence of weather regimes and to minimize the amount of data processed, it was decided to extract data at intervals of several days. RH data were taken at three-day intervals and tested by computing the autocorrelation coefficient (r_L) to determine persistence [Panofsky and Brier, 1965]. Values were computed for each year, independence being assumed between years. For zone 682, r_L averaged 0.333 and for zone 677, r_L averaged 0.355 over the period of record. This indicates that persistence only accounts for about twelve percent of the variance between days chosen [Brooks and Carruthers, 1953].

IV. INDEPENDENT DATA

In choosing variables to correlate with the afternoon RH, the previously mentioned studies plus some probable physical relationships were considered in developing the following criteria for a set of predictors:

a. A measure of the current atmospheric moisture.

b. A measure of moisture which could be advected into the area.

c. A measure of the potential vertical mixing of moisture.

d. A measure of the strength of advective forces.

Although the atmospheric precipitable water had been used in the referenced studies to correlate dew point and total atmospheric moisture, the form of upper air data available required use of the average surface to 500 mb RH to keep computations simple. A number of variables were examined in a multiple-regression program. Among these were:

Average RH sfc to 500 mb at Spokane (GEG).

Average RH Sfc to 500 mb at an upstream station.

1200Z surface dew points.

Average RH 850 to 500 mb at an upstream station.

700 minus 500-mb temperature at an upstream station.

1000 to 500-mb thickness difference between GEG and an upstream station.

'K' value at upstream station.

Local 850-mb temperature.

The average RH Sfc to 500 mb at GEG was used to provide a measure of local moisture because it is rarely upstream from the fire weather zones at this time of year (see Figure 2). Two radiosonde stations, Quillayute (UIL), Washington, and Salem (SLE), Oregon, are frequently affected by strong marine layers near the surface, sometimes extending above the 850-mb level. However, this marine layer seldom singularly contributes to the surface RH changes in eastern Washington due to the barrier of the Cascade mountains. To account for this, a separate tabulation of average RH from 850 to 500 mb was made on days when either of the above stations was determined to be the upstream station. Finally, an analyzed 850-mb temperature over the north-central Washington area was included as a trial predictor because of its known relationship to afternoon temperature changes along the east slopes of the Cascades [Holcomb, 1979].

Data for 1979 were not available; therefore, 1974, 75, 77, and 78 were used for development and 1976 and 1980 were used for testing. All upper air data used were from the 1200Z radiosonde observations. After compiling data, total number of days available was 81.

V. ANALYSIS AND RESULTS

Scatter diagrams of variables versus afternoon RH were plotted for both zones. A trend of some kind was evident on all except thickness gradient versus RH.

Data were applied to the stepwise linear regression program on the Purdue University Computer system. This program produces regression coefficients and constants by entering each variable into the regression equation in turn until certain criteria are met. To evaluate the data of this study, we allowed all variables to enter the equation, one at a time, so that a number of possible equations were generated. The variable chosen at each step was that which maximized the square of the multiple correlation coefficient.

The results showed that correlation was not especially high for any of the variables and improvement dwindled rapidly after one or two variables had been correlated with the afternoon RH. Due to the appearance of the scatter diagrams, correlations were also computed using the variables versus the natural logarithm of afternoon RH. The best combination of predictors was:

<u>For predicting zone 677 RH</u>

Variables used	R	R^2	Std. Error
Average RH Sfc - 500 mb at upstream station and Average RH Sfc - 500 mb at GEG	0.6819	0.4649	9.24

<u>For predicting zone 682 RH</u>

Variables used	R	R^2	Std. Error
Average RH Sfc - 500 mb at upstream station and Local 850-mb temperature	0.7176	0.5150	13.48

The resultant regression equations are:

$$\text{Zone 677 RH} = 9.23 + 0.38\ (\text{Average RH Sfc - 500 mb upstream station}) + 0.124\ (\text{Average RH Sfc - 500 mb at GEG}).$$

$$\text{Zone 682 RH} = \exp\ [3.81 + 0.0088\ (\text{Average RH Sfc - 500 mb upstream station}) - 0.0326\ (\text{Local 850-mb temperature})].$$

The regression equations generated were then tested using independent data from 1976 and 1980 with the following results:

Variable Predicted	Mean Absolute Error	Standard Error
Zone 677 RH	6.40	7.74
Zone 682 RH	11.25	13.62

To analyze the results, one has to know what is the magnitude of acceptable error. In the fire weather program, this depends upon other factors which are critical to fire danger such as temperature, wind, and fuel moisture content. Experience has shown that these relationships are complex; however, in general, the lower the RH the greater the accuracy needed. In eastern Washington, we have observed that an accuracy of ± 5 percent is desirable when the RH is near 20 percent, while ± 15 to 20 percent is satisfactory when the RH is near 70 percent. This subjective criteria were used to develop a measure of the accuracy required over the entire range of observable RH. This is shown in Figure 3. For each day of the independent data sample (1976 and 1980), regression equation forecast errors were compared with the required accuracy from Figure 3. Out of a total of 80 comparisons, 52 (or 65%) verified within the forecast accuracy.

Another measure of usefulness is the ability to predict large (20% or greater) 24-hour changes in RH. Of the 16 large changes existing in the 1976 and 1980 verification data, 12 (or 75%) were forecast by the regression equations, and they verified within the required forecast accuracy.

VI. CONCLUSIONS

Regression prognoses of afternoon RH give a good first approximation of observed values. When coupled with other forecast data, this guidance is considered a useful forecasting tool. In operational use, the average RH Sfc to 500 mb, can be determined from a simple equation in a programmable calculator of sufficient capacity by inputting radiosonde significant level data. The regression equations can also be solved numerically by computer for zone RH prognoses or the graphical solutions given in Figures 4 and 5 can be used.

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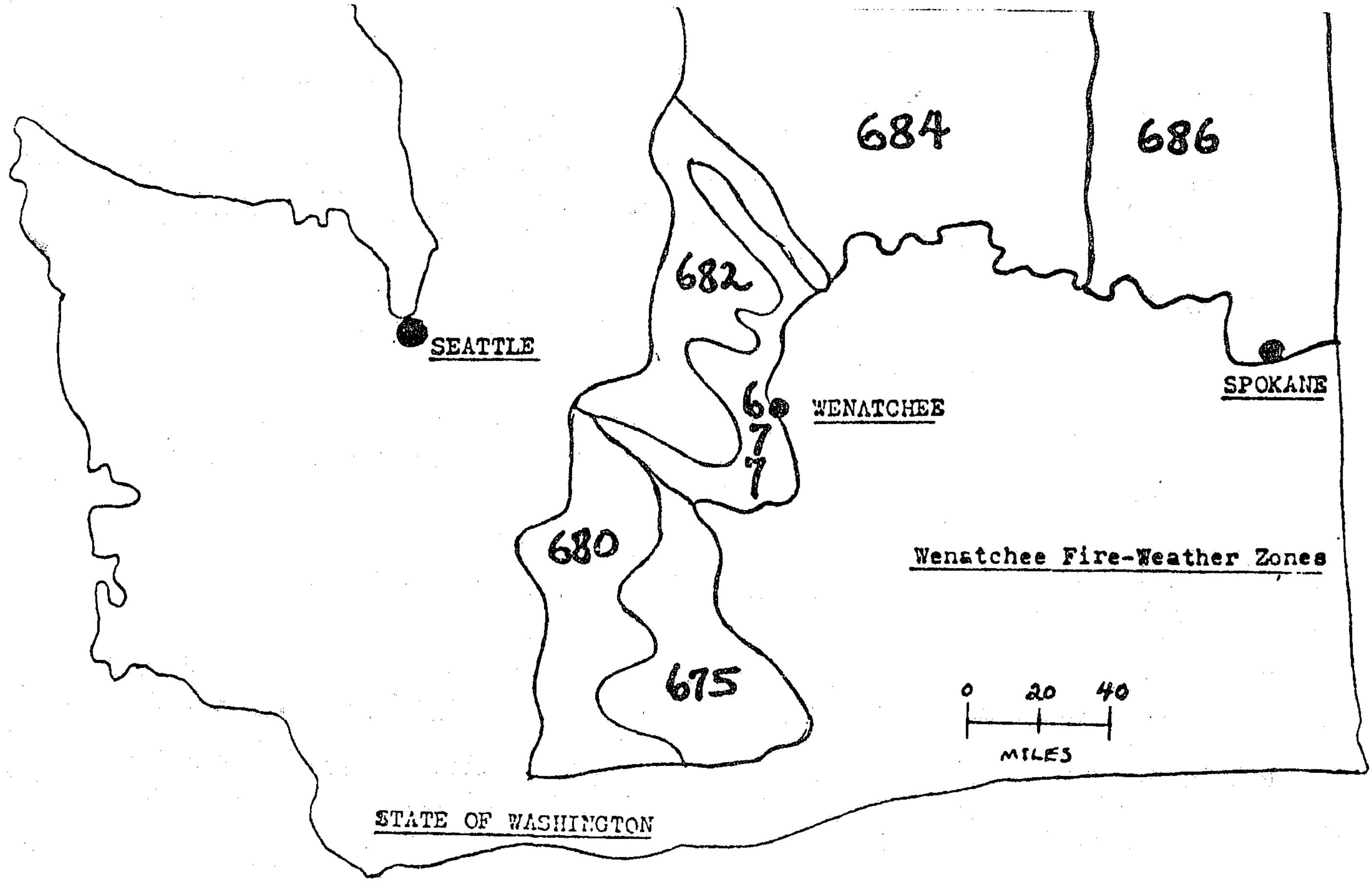

FIGURE 1

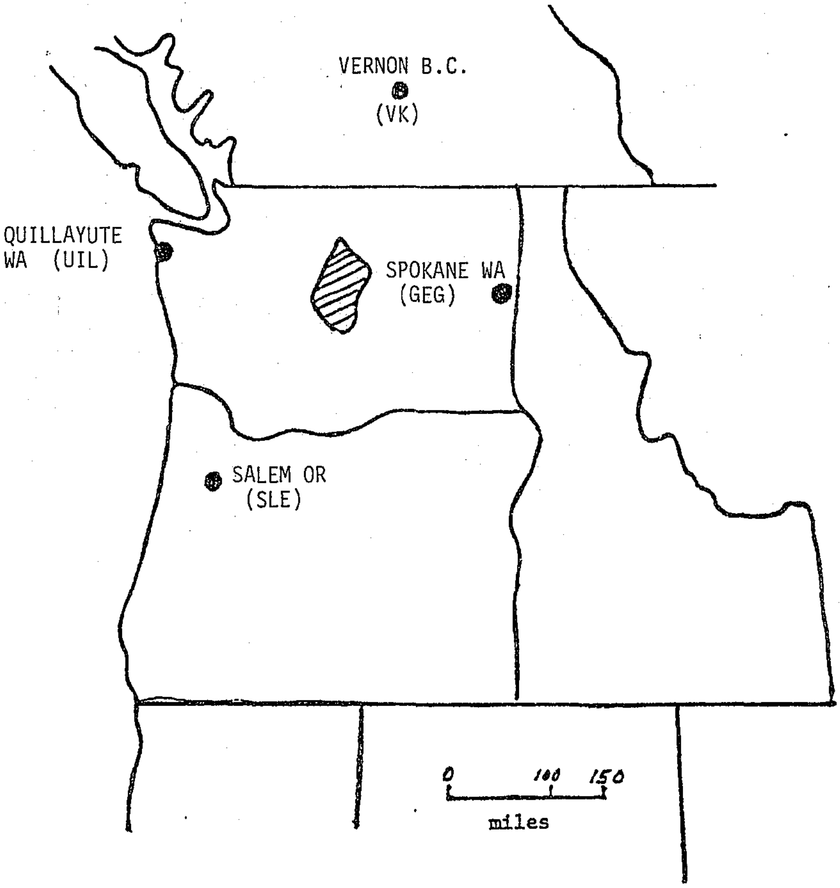

FIGURE 2. Upper-Air Stations.

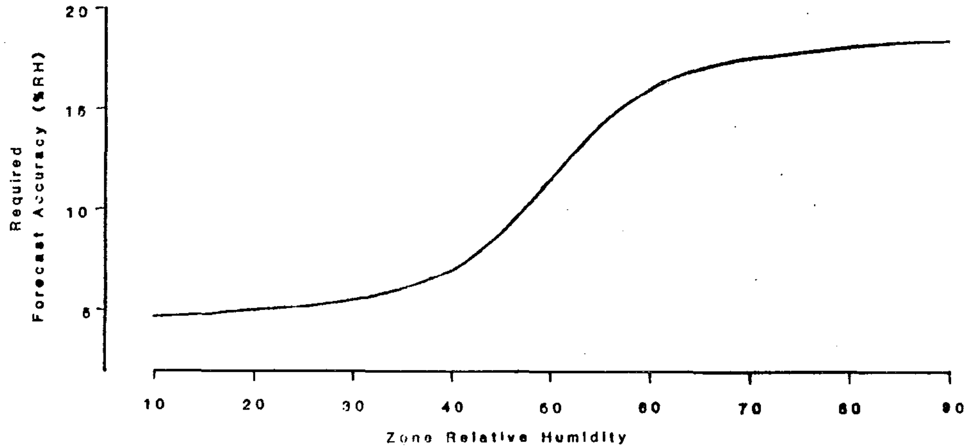

FIGURE 3

ZONE 677 RELATIVE HUMIDITY (%),1400PDT

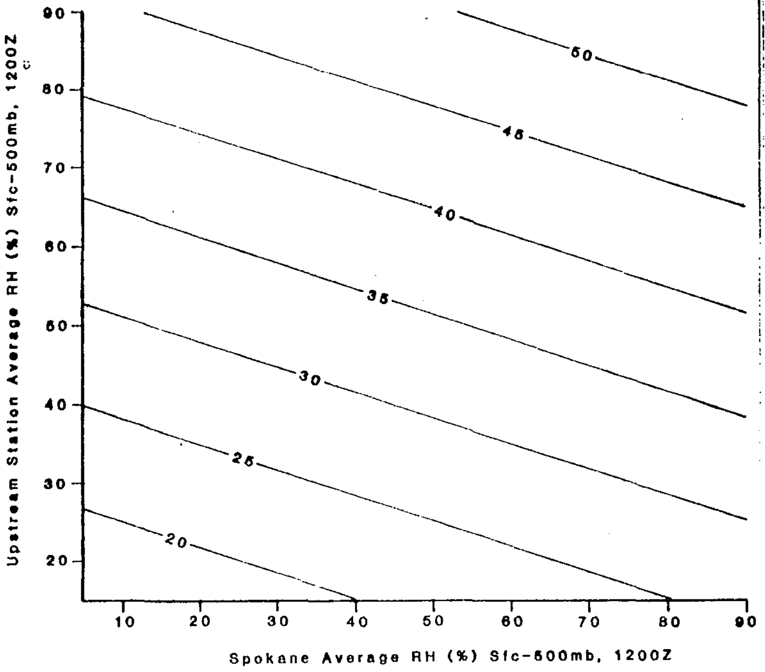

FIGURE 4

ZONE 682 RELATIVE HUMIDITY (%), 1400PDT

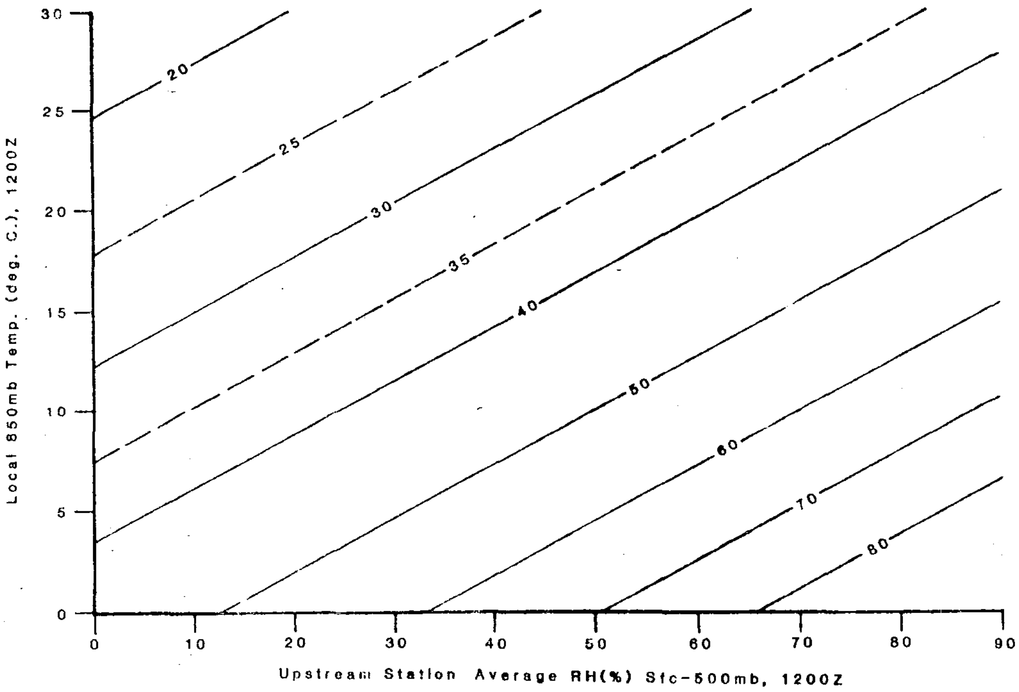

FIGURE 5

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