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FIRE WEATHER VERIFICATION: THE FORECASTER DOES MAKE A DIFFERENCE

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ABSTRACT

Verification statistics have been widely used in the National Weather Service for many years. They provide feedback to the various users of the forecasts as well as showing where certain forecast biases occur. Just recently, however, programs to compute verification statistics for fire weather purposes have been written and utilized.

This study uses a variety of graphs and tables to compare a fire weather season where no computer verification statistics were recorded with a season where statistics were kept. Data is presented comparing Administrative and Forest Fire Information Retrieval and Management System (AFFIRMS) calculated fuel moisture forecasts with manual fuel moisture forecasts. Forecast biases for specific stations in the Wyoming Fire District are presented. In addition, a description of the verification scheme is discussed.

1. INTRODUCTION

To some the need for verification in weather forecasting goes without saying. There are those, however, that are skeptical of verification schemes and the overall advantages they provide. This skepticism is understandable, especially in light of the fact that little has been done to prove its worth beyond public and aviation weather verification at a few key locations in each state (NOAA Techniques Development Laboratory, 1985).

Many, in turn, question a verification program based upon how well a forecaster does against an atmospheric model; especially since the model may exhibit the same forecast tendency that he or she might. Still, a study of verification results may bring out some interesting points to a meteorologist. For instance, forecast biases in a particular forecast situation may be highlighted.

To most forecasters computer weather verification is relatively new. Understandably, most national verification in recent years has been directed

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towards public and aviation products. While local verification schemes exist, very few are available or useful to other NWS programs such as Fire Weather or Agriculture.

Werth (1986) developed a local fire weather verification program for use on the IBM PC in the Olympia, Washington Fire District. This basic program was adapted for use in the Cheyenne District. The program was written for AFOS with additions and modifications made to meet specific needs.

There were several reasons for embarking on a study of fire weather forecast verification. These include:

(1) A desire to determine if verification could really benefit the fire weather forecast program. That is, can meteorologists learn from verification statistics and improve their subsequent forecasts?

(2) An interest in determining what types of general biases exist within the forecast program itself, (i.e., elevation and area biases) and do these biases continually effect the quality of the forecast.

(3) Identifying individual station forecast biases in terms of temperature, humidity, wind speed and 10-hour time lag fuel moisture (hereafter referred to as fuel moisture) (Deeming et al., 1972).

(4) Answering the question of how accurate are the fuel moisture forecast by comparing manual fuel moisture forecasts made in 1985 and 1986 with those calculated by AFFIRMS in 1984.

(5) An attempt to determine if the public is or is not better served by combining certain fire weather zones, and thus eliminating some fire weather observation stations.

2. DESCRIPTION OF FIRE WEATHER ZONES

Wyoming is a state of contrasting climates. A mosaic of mountain ranges, valleys, and basins separate the state resulting in diverse weather conditions and climatic areas. Most of the state's major mountain ranges are orientated north to south.

Fire weather program responsibility at WSFO Cheyenne includes the state of Wyoming east of the Continental Divide, the Black Hills of South Dakota and northwest Nebraska. Fire weather zones in the district were created about 1975 by fire users in cooperation with the NWS (Fig. 1). The purpose was to divide the state into areas that were climatically similar for purposes of weather forecasting and fire danger calculation. Table 1 lists each fire observation site shown in Figure 1 and its respective latitude, longitude, elevation, site and aspect or exposure.

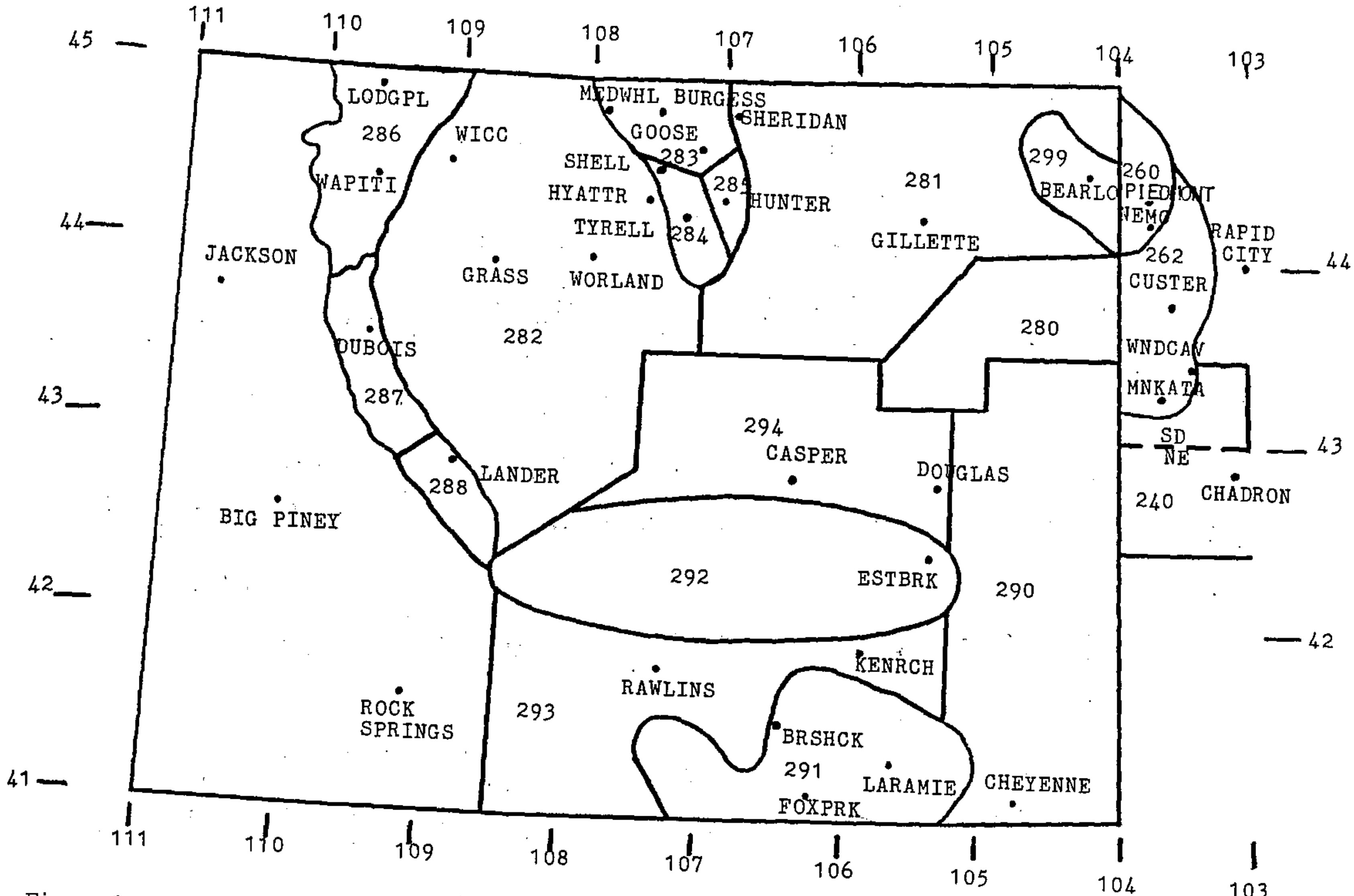


Figure 1. WSFO Cheyenne, Wyoming fire weather zones.

TABLE 1
FIRE WEATHER STATION LIST

Station Number	Station Name	Elevation (Feet)	County	Lat.	Long.	Twp	Range	Sec
			U.S. Forest Service - Medicine Bow NF					
482002	Brush Creek	8200	Carbon	41.21	106.31	16N	81W	20
482102	Esterbrook	6530	Albany	42.25	105.22	28N	71W	10
482103	Foxpark	9060	Albany	41.05	106.09	13N	78W	21
			U.S. Forest Service - Big Horn NF					
480301	Medicine Wheel	8820	Big Horn	44.49	107.51	56N	91W	18
480303	Shell	7650	Big Horn	44.32	107.30	53N	88W	19
480304	Tyrrell	8343	Big Horn	44.11	107.15	49N	86W	30
480401	Goose	7700	Sheridan	44.36	107.13	53N	86W	04
480402	Burgess	7880	Sheridan	44.47	107.32	50N	84W	36
481001	Hunter	7300	Johnson	44.19	106.58	50N	84W	10
			U.S. Forest Service - Shoshone NF					
480204	Wapiti	5964	Park	44.26	109.37	52N	106W	22
480210	Lodgepole	6600	Park	44.08	109.38	56N	106W	11
481408	Lander	5586	Fremont	42.49	108.44	33N	99W	19
481402	Dubois	6940	Fremont	43.32	109.38	41N	106W	07
			BLM - Wyoming					
480305	Hyatt Ranch	4992	Big Horn	44.18	107.12	50N	89W	27
480803	Grass Creek	5593	Hot Springs	43.57	108.30	46N	98W	20
481501	Casper	5122	Natrona	42.40	106.10	32N	79W	16
482006	Rawlins	6784	Carbon	41.47	107.15	21N	87W	10
482104	Kennedy Ranch	7120	Albany	41.56	105.51	23N	72W	18
480211	WICC	5089	Park	44.50	109.00	52N	101W	5
			U.S. Forest Service - Black Hills NF					
480605	Bearlodge	5200	Crook	44.36	104.26	53N	63W	9
393501	Custer	5480	Custer	43.80	103.60	3S	4E	23
392603	Nemo	4624	Lawrence	44.20	103.50	3N	5E	27
395104	Minnekahta	4070	Fall River	43.40	103.70	7S	3E	36
			National Park Service - South Dakota					
393505	Wind Cave	4110	Custer	43.60	103.58	6S	5E	6
			U.S. Forest Service - Nebraska NF					
250202	Chadron	3315	Dawes	42.83	103.08	33N	49W	16

Figure 2 is a topographic map of Wyoming (Martner, 1986) and western South Dakota and Nebraska. Elevations greater than 7,000 feet above sea level are shaded and the major mountain ranges and basins identified. Brown (1980) classified the general climate of Wyoming into steppe, alpine, alpine tundra and desert areas. A map of these climate classifications is shown in Figure 3 (the areas extending into western South Dakota and Nebraska were initiated by the authors).

Figure 3 shows that nearly 3/4 of Wyoming may be classified as having a steppe climate typical of semi-arid grassland prairies. Deserts (areas receiving less than 10 inches of precipitation annually) cover about 10% of the state. The remainder is alpine region containing the mountain forests characterized by continental weather with cool summers and ample precipitation. These areas are occasionally capped by alpine tundra regions which are very cold, windy areas devoid of trees (Martner, 1986).

Figures 2 and 3 show close correspondence between climatic boundaries and topographic features. With this in mind, notice that the fire weather zone divisions (Figure 1) generally match individual climatic regions (Fig. 3).

3. METHODOLOGY

The verification program adopted for this study was based on a program written by Werth (1986). However, the program was modified considerably in the following way:

(1) The program was rewritten in Fortran for use in the National Weather Service AFOS system. This was done to provide easier access and better data file management.

(2) This program was written to allow separate computed verification statistics for each fire weather station instead of each fire weather zone. Some fire weather zones have two or more reporting stations, and it was felt that individual verification statistics would be more accurate than simple station-averaged (per zone) statistics.

(3) Comparisons between the forecaster and persistence were introduced.

(4) A skill score was added to the computations.

(5) Data for a complete fire weather season was calculated and stored instead of just monthly input. A complete Fortran source code listing will be presented in the Central Region Computer Program (CRCP) publication series.

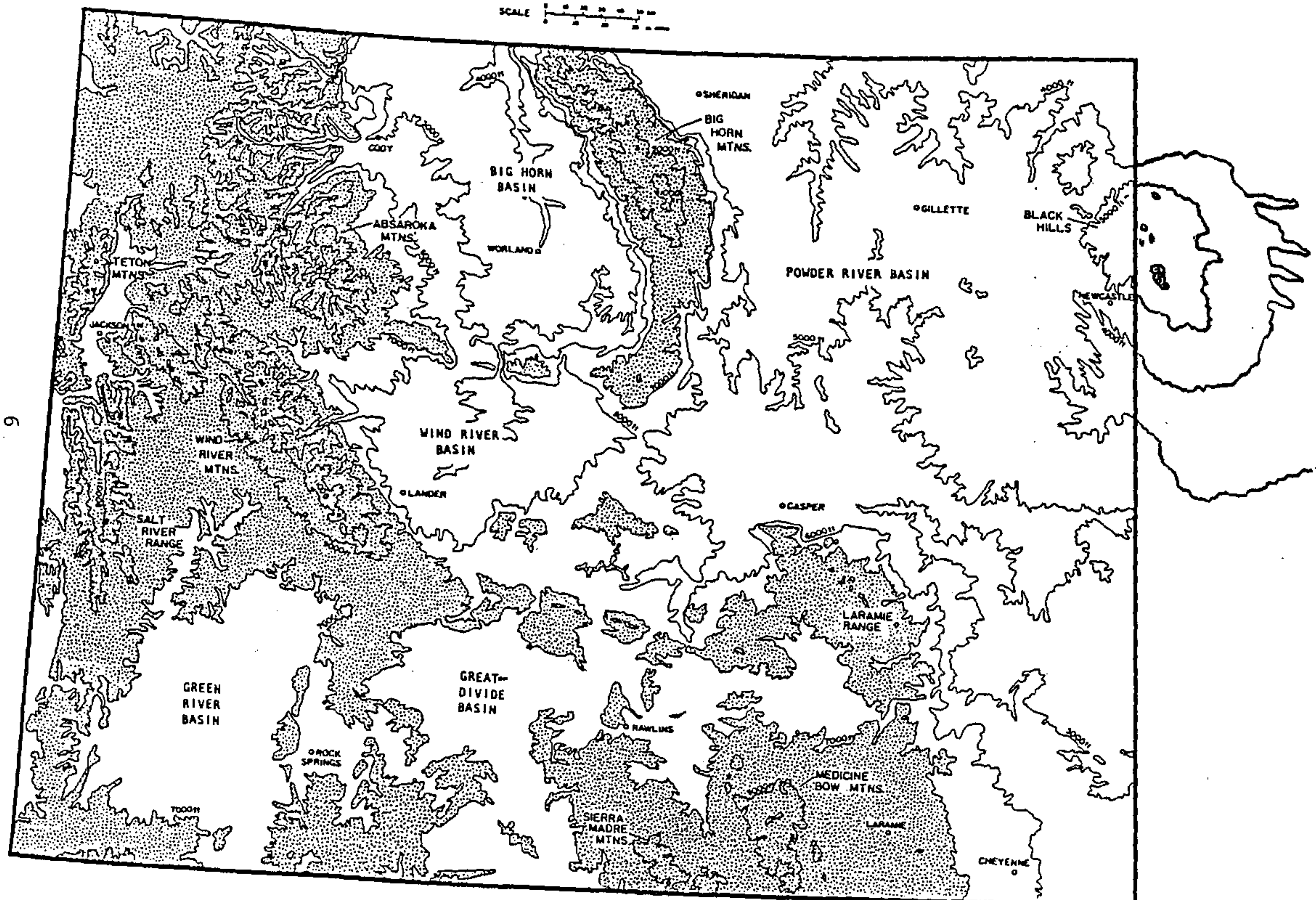


Figure 2. Topographic map of Wyoming. Regions above 7000 feet are shaded.

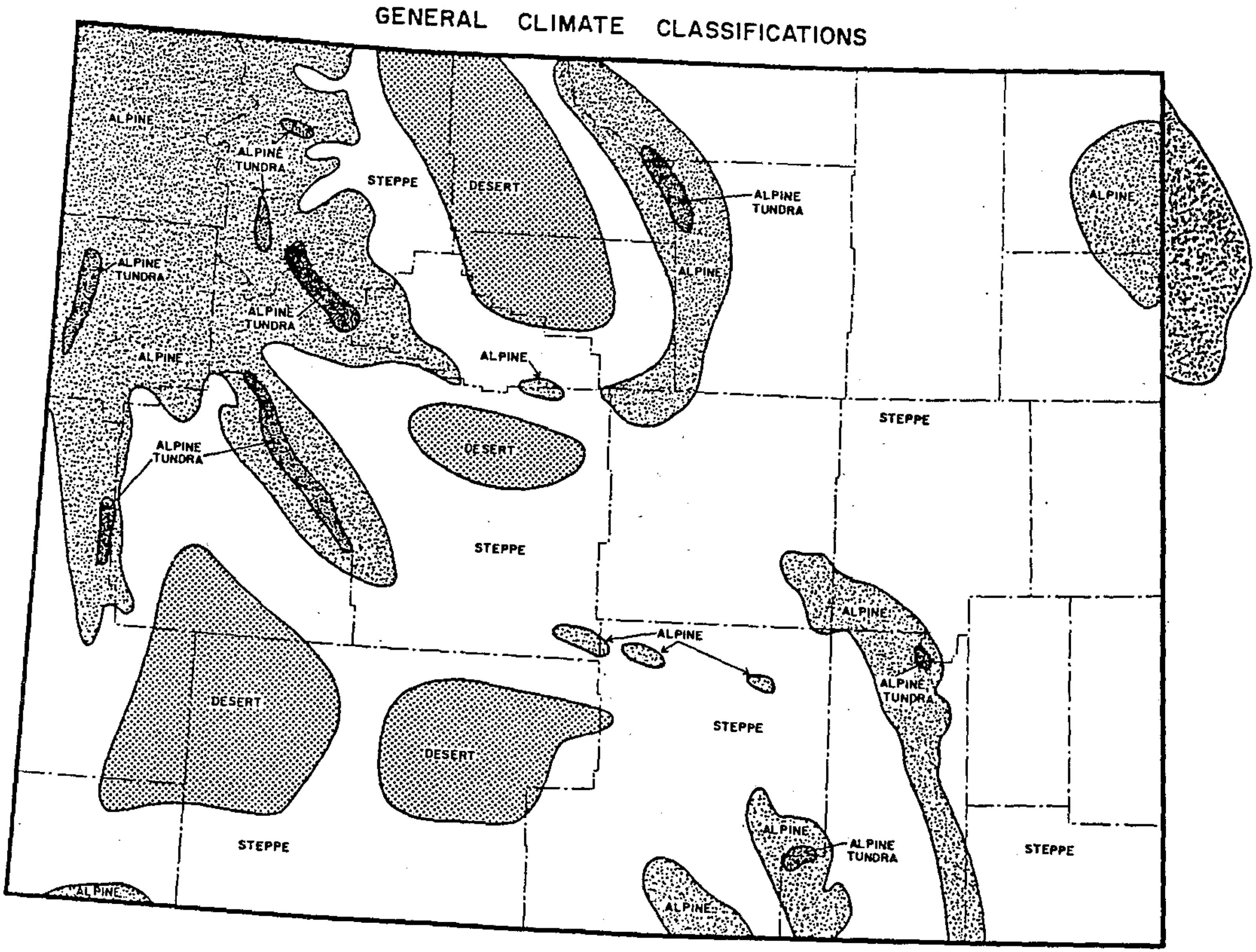


Figure 3. General climate classifications for Wyoming adapted from Brown (1980).

A. INPUT

The operational fire weather forecaster had the duty of inputting the previous day's data (forecast and observation) into the program. This data was added to an RDOS file named FWXVER. The file was checked at the end of the year for obvious input errors, and these were corrected.

The forecaster entered the forecast and observation for each station from the previous day by using an AFOS preformat (Fig. 4). Each forecaster was required to enter both the forecast and observed temperature, relative humidity, wind speed, and fuel moisture. The month, date and forecaster number were also entered. If any of the parameters were missing, the entire observation was considered as missing.

A program was then run (FIREWX) that took the data, reformatted it and appended it to the end of the FWXVER data file. Part of the reformatting process involved calculating a persistence forecast (AMS, 1959). Comparisons are made with the persistence forecast because suitable station models for fire weather stations have not yet been developed.

B. OUTPUT

An example of the program output is shown in Table 2. An error point is defined as the absolute difference between the forecasted value and the observed value of a particular parameter for a specific day or time period. For example, if the temperature is forecast to be 60 degrees and the observed value is 62 degrees, two error points are tabulated. These points are totaled through the desired time period.

A forecast is used only if an observation from the previous day and the verifying observation from the next day is available. The number of forecasts made and their associated verifying observation is recorded in the "number of forecasts" line.

The mean error is simply the total error points divided by the number of forecasts. For example, 20 error points with five forecasts would result in a mean error of 4.

The improvement over persistence is defined as the difference between the persistence error points (PEP) and the forecasted error points (FEP) divided by the persistence error points. This is then multiplied by 100 to obtain a percentage ((PEP-FEP)/(PEP) x 100). For example, if 366 PEP's and 323 FEP's were observed, the forecaster improvement over persistence would be about 11.7.

Bias calculations are obvious. If a parameter was forecasted too high then it contributed to the "% too high" category. This total was then divided by the total number of forecasts and multiplied by 100 to obtain a percentage.

STATION	TEMP		RH		SPEED		FUEL MSTR	
	FCST	OBSN	FCST	OBSN	FCST	OBSN	FCST	OBSN
Goose	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Hyatt Ranch	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Grass Creek	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Medicine Wheel	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Burgess	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Cody	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Shell	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Tyrrell	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Hunter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Wapiti	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Lodgepole	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Dubois	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Lander	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Brushcreek	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Foxpark	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Esterbrook	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Rawlins	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Kennedy Ranch	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Casper	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Bearlodge	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Nemo	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Custer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Windcave	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Minnekahta	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Chadron	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Month [ ]
Date [ ]
Forecaster Number [ ]

Figure 4. AFOS Preformat for Fire Weather Information.

TABLE 2
EXAMPLE OF PROGRAM OUTPUT

STATION 0 FORECASTER 0 PERIOD 701-901

		FORECASTER	PERSISTENCE	IMPROVEMENT (%)
TEMPERATURE	ERROR POINTS	323	366	
	# FORECASTS	46	46	
	MEAN ERROR	7.0	8.0	11.7
HUMIDITY	ERROR POINTS	801	807	
	# FORECASTS	46	46	
	MEAN ERROR	17.4	17.5	0.7
WIND SPEED	ERROR POINTS	211	201	
	# FORECASTS	46	46	
	MEAN ERROR	4.6	4.4	-5.0
FUEL MOISTURE	ERROR POINTS	224	238	
	# FORECASTS	46	46	
	MEAN ERROR	4.9	5.2	5.9

SKILL SCORE 0.023

BIAS	TEMPERATURE	HUMIDITY	WIND SPEED	FUEL MOISTURE
% CORRECT	2.2	6.5	17.4	15.2
% TOO HIGH	58.7	39.1	52.2	54.3
% TOO LOW	39.1	54.3	30.4	30.4

CATEGORIES (%)

	TEMPERATURE		HUMIDITY		WIND SPEED		FUEL MOISTURE	
	FCST	PRST	FCST	PRST	FCST	PRST	FCST	PRST
GOOD	39.1	34.8	26.1	28.3	73.9	69.6	76.1	78.3
POOR	39.1	43.5	17.4	10.9	15.2	17.4	15.2	13.0
VERY POOR	21.7	21.7	56.5	60.9	10.9	13.0	8.7	8.7

Categorical statistics are based on the following increments:

Temperature:	GOOD - Missed by 4 degrees or less POOR - Missed between 5 and 9 degrees VERY POOR - Missed by 10 degrees or more
Humidity:	GOOD - Missed by 5 percent or less POOR - Missed between 6 and 10 percent VERY POOR - Missed by more than 10 percent
Wind Speed:	GOOD - Missed by 4 mph or less POOR - Missed between 5 and 9 mph VERY POOR - Missed by more than 9 mph
Fuel Moisture:	GOOD - Missed by 6 percent or less POOR - Missed between 7 and 11 percent VERY POOR - Missed by more than 11 percent

The skill score is based on the above categories. The number of good forecast (from all four parameters) are added. The final sum is R. The same is done for each "GOOD" persistence forecast. This sum is E. The skill score is defined as:

$$S = (R - E)/\text{total number of forecasts}$$

(Compendium of Meteorology, 1951). For example, out of 250 forecasts, the forecaster made 185 "GOOD" forecasts while persistence made 105 "GOOD" forecasts. The skill score would be 0.32. The skill score has a value of 1 when all the forecasts are correct while persistence had none correct.

Improvement over persistence statistics must be used with great care. For the most part, it is not all that difficult to improve over persistence. More importantly, the scoring technique used does not penalize a forecaster for making a bad forecast while still beating persistence. For example, a forecaster may miss the next day's temperature by 20 degrees. If persistence missed the temperature by 25 degrees the forecaster still improved upon persistence. Therefore, it is wise to use the improvement over persistence category in conjunction with the incremental categories.

4. RESULTS AND DISCUSSION

The verification program was first run operationally in 1986. Also, forecasts from 1984 and 1985 were verified in 1986. Since, the forecasters in those years had no idea that their forecasts would be used in a computer verification scheme, the data could be used as a standard or control. Also, we could see how forecasters performed knowing that a verification scheme was being implemented.

Of course, weather conditions over the three years were not identical. For this reason, normals for the various fire weather stations over a span of five years, 1982 through 1986, were calculated. Parameters included average temperature, relative humidity and fuel moistures at observation times;

average maximum and minimum temperatures; percent of occurrence of wind speeds at <5 mph, 6-10 mph, 11-15 mph and >15 mph at directions based on an 8 point compass; average fuel moisture when RH was less than or equal to 20%, 21-40%, 41-60%, 61-80% and >80%. Deviations from these normals were compared.

In order to locate areal and elevational biases, it was decided to combine fire weather stations into three groups; the Wyoming mountains, the Wyoming high and low plains (along with the Nebraska Panhandle), and the Black Hills of South Dakota. These groups were then subdivided. Five year averages were computed and comparisons were made within each group. Parameters analyzed were temperature, relative humidity, wind speed, and fuel moisture. Fuel moisture forecasts for 1984 were made using the AFFIRMS computer. All other fuel moisture forecasts were made manually by the forecaster. Data for some stations were not available in 1984, mainly the Black Hills of South Dakota and the Nebraska Panhandle. Wind speed averages were not calculated. Tables 3, 4 and 5 summarize the results.

A. DISCUSSION OF RESULTS

Forecasters, by far, did a better job of forecasting temperature than persistence. Improvements over persistence in the 15% to 25% range were common during both 1985 and 1986. However, a decrease in forecast accuracy from 1985 to 1986 was noted in two of the groups. We believe the main reason for this was the fact that the forecasters were aware of the verification program in 1986. Consequently, forecasters competed against persistence in 1986 by "nudging" the forecasts. In other words, they attempted to forecast the right trend and, thereby, beat persistence. Unfortunately, this frequently does not result in better forecasts.

Relative humidity forecasts are not as accurate as temperature forecasts. The verification results clearly showed that this is an area that needs improvement. In 1985, forecasts were frequently worse than persistence, especially over the higher elevations. The results in 1986 were much better, and only a few stations had forecasts worse than persistence. This is a case where the verification program forced the forecasters to examine the parameter and improve their forecasts.

Wind speed forecasts also improved from 1985 to 1986. However, persistence generally did a good job in wind speed forecasting, so forecasters had a hard time beating it. This was especially apparent over the mountains where wind speeds were routinely overforecast.

Finally, the fuel moisture forecasts were, without exception, very bad in 1984 when the AFFIRMS computer was used to make the calculations. A large improvement was noted in 1985 when manual forecasts were made. A more gradual improvement occurred in 1986 when the verification program was activated.

TABLE 3
VERIFICATION FOR WYOMING MOUNTAINS

Sub-Group	Stations	Fire Zone
Southern Mountains	Brushcreek, Foxpark	291
Northern High Mountains	Medicine Wheel, Tyrrell	283/284
Northern Low Mountains	Shell, Goose, Burgess, Hunter	283/284/285
Western High Mountains	Lodgepole, Dubois	286/287
Western Low Mountains	Lander, Wapiti, Cody	282/286/288

PARAMETER-TEMPERATURE

Group	5 Yr Avg	1985 Avg	1986 Avg	Improvement Over Persistence 1985	1986
Southern Mountains	65.2	65.8	69.1	4.6%	19.5%
Northern High Mountains	61.2	59.9	61.6	17.6%	18.5%
Northern Low Mountains	63.9	61.3	64.9	21.5%	19.6%
Western High Mountains	68.7	66.4	71.2	22.1%	16.0%
Western Low Mountains	74.7	72.3	76.3	21.0%	21.4%
Group Average	66.7	65.1	68.6	17.4%	19.0%

% Improvement from 1985 to 1986 = 9.2%

PARAMETER-RELATIVE HUMIDITY

Group	5 Yr Avg	1985 Avg	1986 Avg	Improvement Over Persistence 1985	1986
Southern Mountains	43.2	42.6	44.0	-75.2%	9.7%
Northern High Mountains	44.7	47.2	43.3	7.5%	12.3%
Northern Low Mountains	45.0	45.0	42.4	13.4%	16.9%
Western High Mountains	39.6	38.8	31.7	9.3%	5.8%
Western Low Mountains	36.2	33.3	33.6	15.5%	12.7%
Group Average	41.7	41.4	39.0	-5.9%	11.5%

% Improvement from 1985 to 1986 = 294%

PARAMETER-WIND SPEED

GROUP	1985	1986
Southern Mountains	1.5%	5.2%
Northern High Mountains	-11.9%	-10.0%
Northern Low Mountains	-2.4%	-0.5%
Western High Mountains	2.9%	7.2%
Western Low Mountains	8.7%	7.6%
Group Average	-0.3%	1.9%

PARAMETER-FUEL MOISTURE

GROUP	5 Yr Avg	1984 Avg	1985 Avg	1986 Avg
Southern Mountains	16.6	17.1	17.1	21.8
Northern High Mountains	15.4	15.8	17.7	15.2
Northern Low Mountains	17.1	16.3	18.1	16.3
Western High Mountains	15.6	15.6	15.4	17.0
Western Low Mountains	14.7	15.5	15.5	12.0
Group Average	15.9	16.1	16.8	16.5

Group	Improvement Over Persistence 1984	1985	1986
Southern Mountains	-47.3%	4.8%	12.7%
Northern High Mountains	-73.7%	0.5%	7.1%
Northern Low Mountains	-37.7%	2.5%	12.9%
Western High Mountains	-178.5%	-5.1%	-10.5%
Western Low Mountains	-97.6%	1.4%	-4.8%
Group Average	-87.0%	0.8%	3.5%

% Improvement from 1984 to 1985 = 101%
% Improvement from 1985 to 1986 = 338%

TABLE 4
VERIFICATION FOR WYOMING HIGH AND LOW PLAINS

Sub-Group	Stations	Fire Zone
Central High Plains	Esterbrook, Rawins, Kennedy Ranch	292/293
Northern Plateau	Hyatt Ranch, Grass Creek	282
Casper	Casper	294
Nebraska Panhandle	Chadron	240/288

PARAMETER-TEMPERATURE

				Improvement Over Persistence	
Group	5 Yr Avg	1985 Avg	1986 Avg	1985	1986
Central High Plains	72.3	70.5	74.0	18.2%	13.5%
Northern Plateau	76.0	73.5	77.5	17.9%	21.0%
Casper	81.7	80.9	83.4	31.9%	20.1%
Nebraska Panhandle	82.3	80.2	81.7	11.7%	13.9%
Group Average	78.1	76.3	79.2	24.3%	17.1%

% Improvement from 1985 to 1986 = -29.6%

PARAMETER-RELATIVE HUMIDITY

				Improvement Over Persistence	
Group	5 Yr Avg	1985 Avg	1986 Avg	1985	1986
Central High Plains	38.8	40.0	43.9	-41.0%	-1.6%
Northern Plateau	35.9	37.5	30.8	11.7%	9.0%
Casper	27.6	26.3	24.6	22.6%	13.3%
Nebraska Panhandle	35.7	37.5	42.8	0.7%	3.6%
Group Average	34.5	35.3	35.5	-1.5%	6.1%

% Improvement from 1985 to 1986 = 506%

PARAMETER-WIND SPEED

GROUP	1985	1986
Central High Plains	12.2%	9.0%
Northern Plateau	-2.3%	4.8%
Casper	16.5%	11.8%
Nebraska Panhandle	-5.0%	13.0%
Group Average	5.4%	9.6%

PARAMETER-FUEL MOISTURE

GROUP	5 Yr Avg	1984 Avg	1985 Avg	1986 Avg
Central High Plains	14.5	16.2	12.5	15.9
Northern Plateau	12.3	13.3	13.6	9.2
Casper	9.9	10.0	9.5	10.4
Nebraska Panhandle	12.3	11.8	13.5	11.5
Group Average	12.3	12.8	12.3	11.8

	Improvement Over Persistence		
Group	1984	1985	1986
Central High Plains	-49.7%	-18.8%	11.6%
Northern Plateau	-67.8%	7.3%	-12.0%
Casper	-277.0%	-14.3%	-6.1%
Nebraska Panhandle	-	5.9%	5.2%
Group Average	-131.5%	-5.0%	-0.3%

% Improvement from 1984 to 1985 = 96.2%
% Improvement from 1985 to 1986 = 94.0%

TABLE 5
VERIFICATION FOR SOUTH DAKOTA BLACK HILLS

Sub-Group	Stations	Fire Zone
Black Hills	Bearlodge, Custer, Nemo, Minnekahta, Windcave	299/262/260

PARAMETER-TEMPERATURE

Group	5 Yr Avg	1985 Avg	1986 Avg	Improvement Over Persistence 1985	Improvement Over Persistence 1986
Black Hills	74.4	72.9	75.9	21.0%	20.9%

% Improvement from 1985 to 1986 = -0.5%

PARAMETER-RELATIVE HUMIDITY

Group	5 Yr Avg	1985 Avg	1986 Avg	Improvement Over Persistence 1985	Improvement Over Persistence 1986
Black Hills	44.3	44.5	41.4	5.8%	9.6%

% Improvement from 1985 to 1986 = 65.5%

PARAMETER-WIND SPEED

GROUP	1985	1986
Black Hills	-4.6%	-3.0%

% Improvement from 1985 to 1986 = 34.8%

PARAMETER-FUEL MOISTURE

GROUP	5 Yr Avg	1984 Avg	1985 Avg	1986 Avg
Black Hills	15.8	-	16.3	11.9

Group	Improvement Over Persistence 1984	1985	1986
Black Hills	-	5.5%	5.1%

% Improvement from 1985 to 1986 = -7.3%

B. SUMMARY OF VERIFICATION FOR ALL STATIONS

Tables 6 through 8 and Figures 5 through 9 give verification results for all parameters and all fire weather stations combined during 1985 and 1986. Additionally, a monthly and seasonal summary of percent improvement over persistence in every category is shown.

5. SOURCES OF ERROR

As with any research project or verification program a certain percentage of error develops as data is gathered, transmitted and recorded. It is important to note possible sources of errors in this study. Two sources of errors are considered. The first is poor fire weather observations and the second is data input errors. These are discussed below along with their potential impact on the verification results.

A. POOR OBSERVATIONS

Weather forecasters often wonder about the accuracy of the weather observations. This is of special concern in a fire program due to the fact that observations are only taken once a day (usually at 1:00 p.m. local standard time). Many aspects of the fire weather observation programs, including training seasonal observers, selecting observational sites, maintaining observation equipment and quality control are contracted out. As a result, the NWS has little or no control over the observation program.

It is important to know the procedure generally followed during observation time. The hired employee or contract observer will take the weather observation around 1:00 p.m. LST, entering it on WS Form D-9b. This observation then gets called into a regional or forest dispatch center. Next it is manually entered into the AFFIRMS system. This procedure results in three sources of potential error; taking, relaying, and recording the observation.

Haines and Frost (1985) addressed the problem of lack of completeness and accuracy of fire weather observational records. They obtained records from 250 fire stations in the northeastern U.S. and documented: (1) the number of missed observations (those taken but never recorded in AFFIRMS); (2) the quality of the observation by comparing records from fire stations with records from nearby NOAA cooperative stations, and (3) how the AFFIRMS archived data compared with the original fire station observation.

Their study suggested that (1) there was a significant percentage of stations having incomplete weather records, (2) the fire weather station observations of maximum and minimum temperatures, when compared with those recorded at neighboring stations, showed an additional average error rate of about 1% per element per observation, and (3) about 1/3 of the errors in the library records occurred during observation and 2/3 during transmission.

TABLE 6
FINAL STATISTICS FOR 1985
ALL FORECASTERS AND ALL STATIONS

		FORECASTER	PERSISTENCE	IMPROVEMENT (%)
TEMPERATURE	ERROR POINTS	10471	12983	
	# FORECASTS	1804	1804	
	MEAN ERROR	5.8	7.2	19.3
HUMIDITY	ERROR POINTS	24365	26291	
	# FORECASTS	1804	1804	
	MEAN ERROR	13.5	14.6	7.3
WIND SPEED	ERROR POINTS	8014	8235	
	# FORECASTS	1804	1804	
	MEAN ERROR	4.4	4.6	2.7
FUEL MOISTURE	ERROR POINTS	9640	9988	
	# FORECASTS	1804	1804	
	MEAN ERROR	5.3	5.5	3.5

SKILL SCORE 0.048

BIAS	TEMPERATURE	HUMIDITY	WIND SPEED	FUEL MOISTURE
% CORRECT	6.8	3.4	10.9	14.4
% TOO HIGH	56.5	42.3	45.1	44.6
% TOO LOW	36.8	54.3	44.0	41.0

CATEGORIES (%)

	TEMPERATURE		HUMIDITY		WIND SPEED		FUEL MOISTURE	
	FCST	PRST	FCST	PRST	FCST	PRST	FCST	PRST
GOOD	51.8	41.9	34.1	35.4	69.7	69.2	77.1	77.5
POOR	29.4	30.2	21.2	18.1	22.5	22.5	10.6	9.2
VERY POOR	19.2	28.0	44.6	46.5	7.8	8.3	12.3	13.2

TABLE 7
FINAL STATISTICS FOR 1986
ALL FORECASTERS AND ALL STATIONS

		FORECASTER	PERSISTENCE	IMPROVEMENT (%)
TEMPERATURE	ERROR POINTS	8891	11080	
	# FORECASTS	1708	1708	
	MEAN ERROR	5.2	6.5	19.8
HUMIDITY	ERROR POINTS	19866	22421	
	# FORECASTS	1708	1708	
	MEAN ERROR	11.6	13.1	11.4
WIND SPEED	ERROR POINTS	6414	6725	
	# FORECASTS	1708	1708	
	MEAN ERROR	3.8	3.9	4.5
FUEL MOISTURE	ERROR POINTS	7295	7850	
	# FORECASTS	1708	1708	
	MEAN ERROR	4.3	4.6	6.9

SKILL SCORE 0.105

BIAS	TEMPERATURE	HUMIDITY	WIND SPEED	FUEL MOISTURE
% CORRECT	7.0	4.3	10.5	13.7
% TOO HIGH	52.2	46.7	48.7	51.8
% TOO LOW	40.8	49.0	40.8	34.5

CATEGORIES (%)

	TEMPERATURE		HUMIDITY		WIND SPEED		FUEL MOISTURE	
	FCST	PRST	FCST	PRST	FCST	PRST	FCST	PRST
GOOD	54.7	44.2	36.0	33.7	76.8	74.8	82.3	79.6
POOR	29.9	33.8	23.8	20.8	19.1	19.8	9.0	10.2
VERY POOR	15.3	22.0	40.2	45.5	4.1	5.4	8.7	10.2

TABLE 8
MONTHLY BREAKDOWN OF PARAMETER RESULTS

	Percent Improvement			
	July	August	September	Season
Temperature (85)	6.2	24.5	24.8	19.3
Temperature (86)	18.1	20.4	21.6	19.8
Humidity (85)	-0.8	13.8	7.0	7.3
Humidity (86)	7.6	12.6	14.6	11.4
Wind Speed (85)	4.2	1.1	3.3	2.7
Wind Speed (86)	6.9	4.9	0.6	4.5
Fuel Moisture (84)	-76.4	-92.6	-20.5	-62.3
Fuel Moisture (85)	2.0	0.4	7.1	3.5
Fuel Moisture (86)	1.5	8.8	9.8	6.9

FIGURE 5
MONTHLY PERCENT IMPROVEMENT IN TEMPERATURES FOR 1985 AND 1986

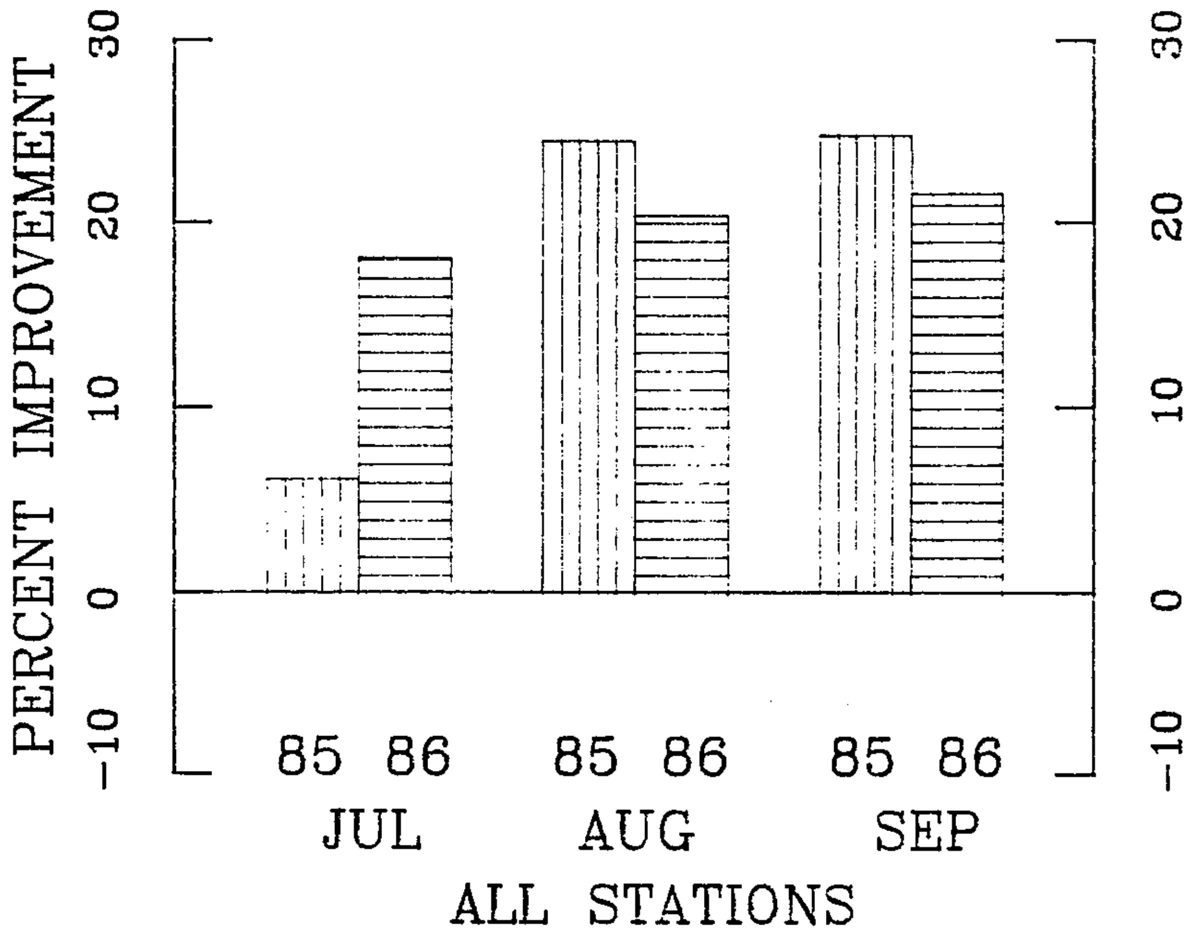


FIGURE 6
MONTHLY PERCENT IMPROVEMENT IN RELATIVE HUMIDITY FOR 1985 AND 1986

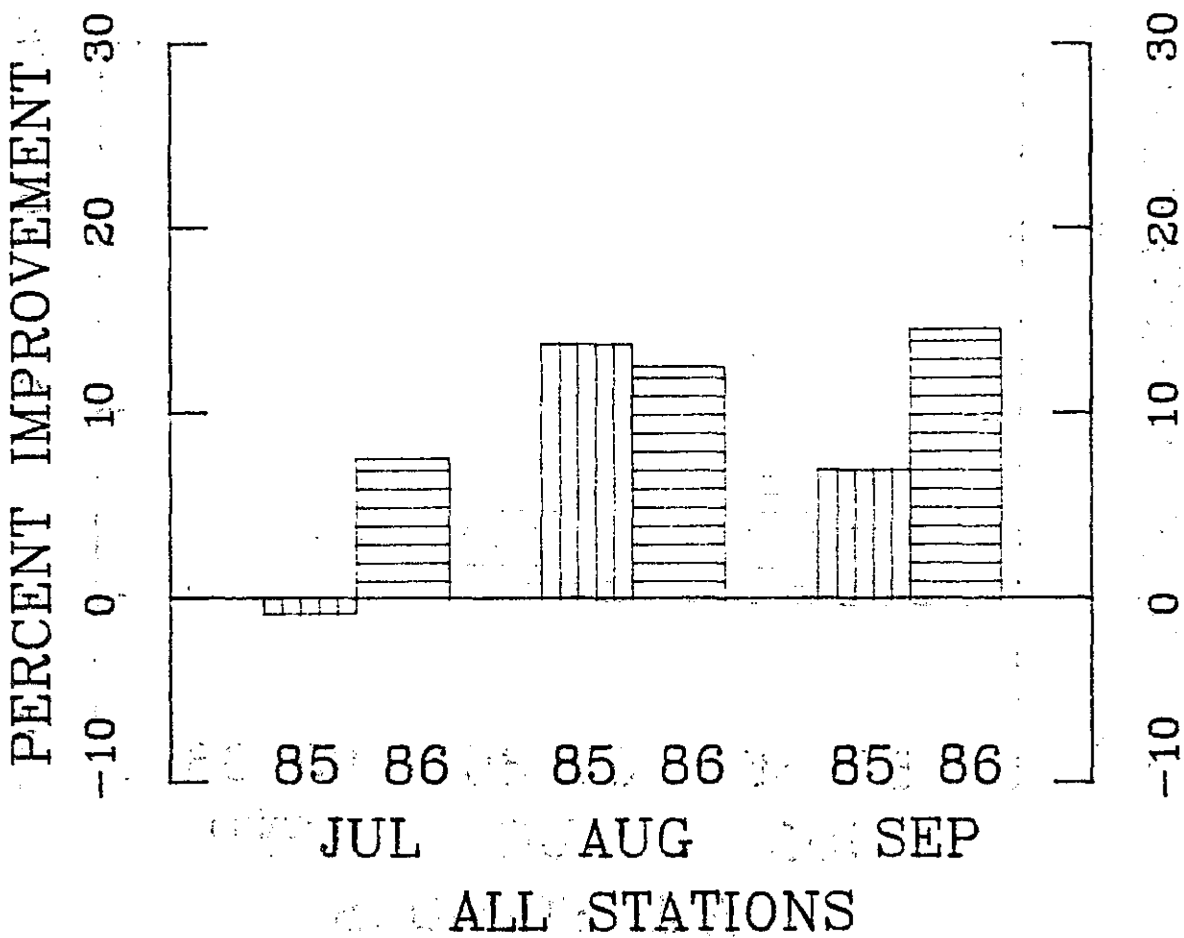


FIGURE 7
MONTHLY PERCENT IMPROVEMENT IN WIND SPEED FOR 1985 AND 1986

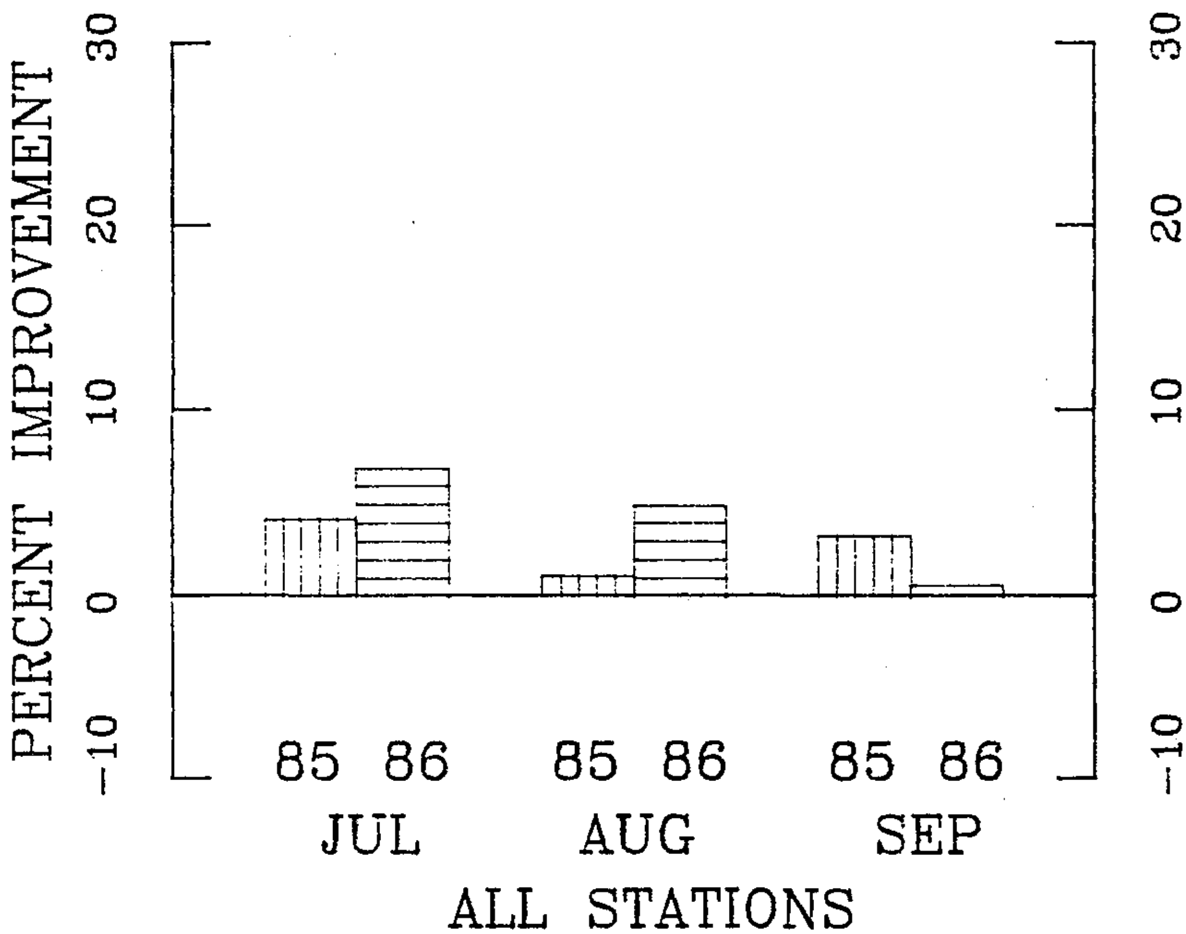


FIGURE 8
MONTHLY PERCENT IMPROVEMENT IN
FUEL MOISTURE FOR 1985 AND 1986

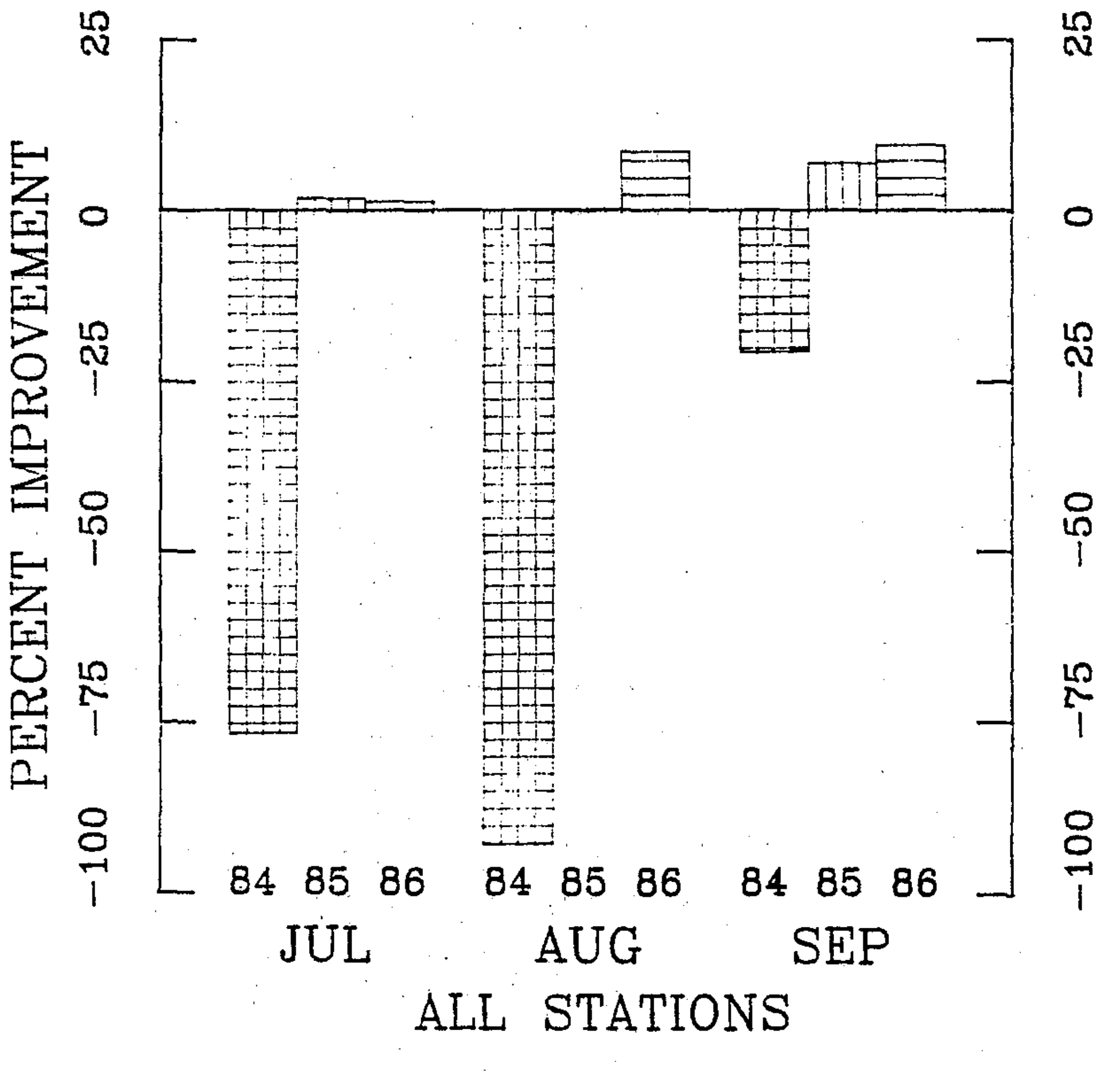
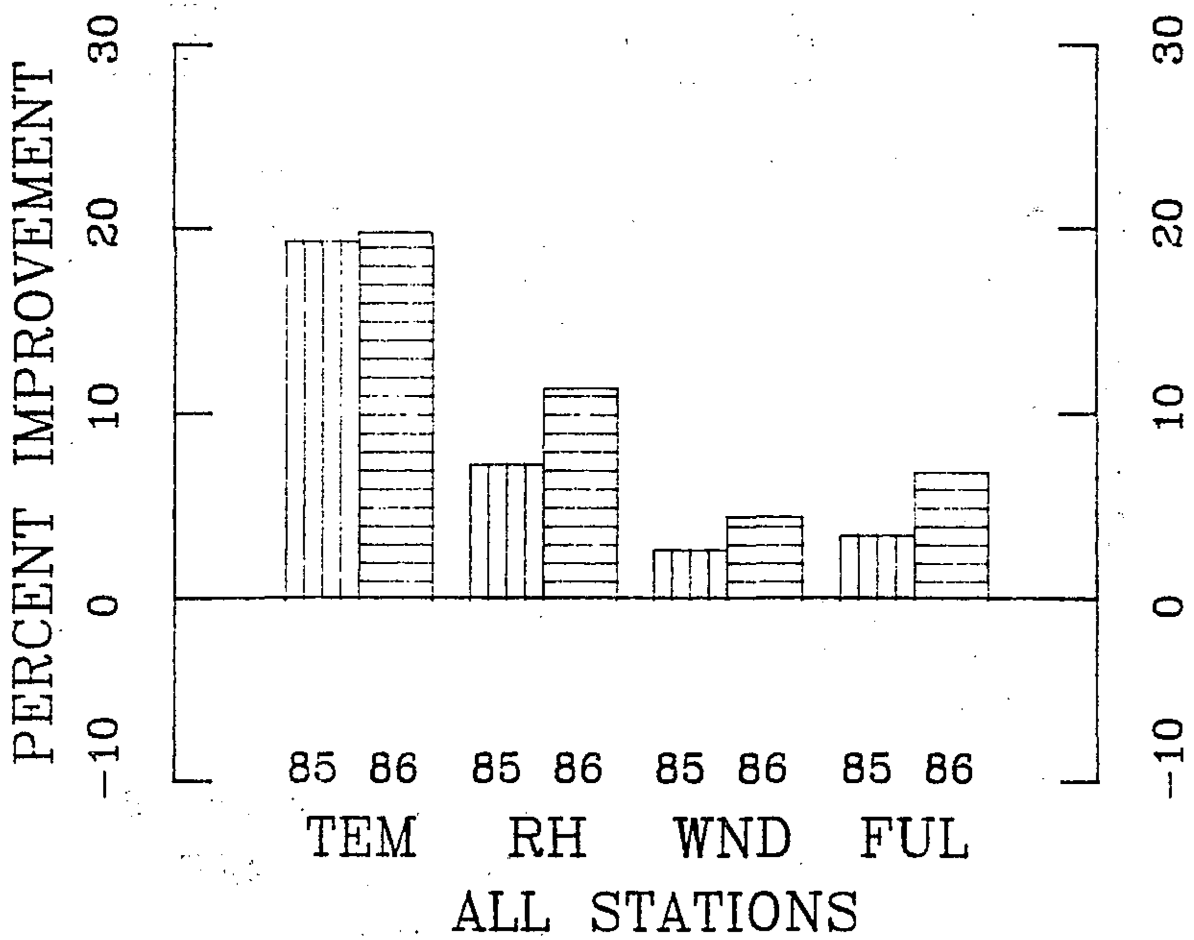


FIGURE 9
SEASONAL PERCENT IMPROVEMENT FOR
ALL PARAMETERS BOTH 1985 AND 1986



B. INPUT ERRORS

The forecast verification statistics are input into the verification program much in the same manner as an observation. The duty forecaster has the responsibility to record the observation obtained from AFFIRMS and the subsequent forecast. These data are then manually entered into AFOS for verification.

Errors during this procedure were considered minimal due to rigorous quality control of the fire weather verification program for this study. Most AFOS input was handled by the authors.

6. CONCLUSIONS

During the course of this study the following conclusions were reached:

(1) The AFFIRMS fuel moisture forecasts in 1984 were very poor and consistently less accurate than persistence. It would appear that the variables input into the AFFIRMS system are not weighted properly. One could make the case that this poor performance is directly influenced by the data input of the individual forecasters. However, the fuel moisture forecasts manually made by the forecasters in the following years indicated so much of an improvement that it is unlikely that poor input data is the reason for very poor AFFIRMS fuel moisture forecasts.

(2) As might be expected, forecasters have a difficult time beating persistence when the changes in the weather (or fire parameters) are small. However, forecasters are consistently more accurate than persistence in forecasting temperature. Neither the forecasters nor persistence are very accurate in forecasting humidity. This is a common problem at many fire weather forecast stations.

(3) Overall, the verification system provided the forecasters with useful information about their individual forecast biases. Also, they were able to compare their performance with persistence on a real time basis since the statistics were run every day.

(4) Since forecasters were generally able to improve over persistence between 1985 and 1986, it can be assumed that the verification program helped the fire weather forecasts in Wyoming.

(5) Indications are that individual station forecasts are more accurate than forecasts for combined stations or fire zones.

Some important biases were found for the various parameters. These were:

(1) Temperature - Generally there was a tendency to overforecast temperatures for the mountains and higher elevations of the district.

(2) Relative Humidity - Humidity forecasts were generally too low at most stations, especially at mountain and high elevation stations.

(3) Wind Speed - A general bias to overforecast wind speed in the mountains was found. This is a typical problem forecast problem in Wyoming during the fire season, (i.e., making wind forecasts in mountain areas that are more applicable to the plains).

(4) Fuel Moisture - Although there seemed to be a slight tendency to overforecast fuel moisture, the meteorologists generally improved their skill at forecasting this parameter from 1985 to 1986. Since 1985 was the first attempt at manually forecasting fuel moisture, this improvement is encouraging. The results clearly show that AFFIRMS consistently overforecasts fuel moisture by very large margins.

One last, and very important point the authors wish to make, is that the forecasters tend to "play the verification game". The end result of this was that instead of making really good forecasts when the opportunity arose (for example, changing a temperature by 8 or more degrees), they would stick close to persistence, fearing too much of a loss if they were wrong.

7. RECOMMENDATIONS

Following from this fire weather verification study, these recommendations are put forth by the authors:

(1) Verification studies, when properly applied in weather service programs (such as fire weather and agriculture), are very useful and should continue.

(2) Fire weather forecasters who input their forecasts into the AFFIRMS system should make manual fuel forecasts rather than letting AFFIRMS calculate it for them.

(3) Forecasters should make individual station forecasts rather than zone forecasts. Although this is more time consuming, the individual station forecasts are often more useful and correct.

(4) Fire weather observers should be trained better. Many anomalous observations are input in the AFFIRMS system and must be sorted by the fire weather forecaster.

(5) A smaller fuel moisture increment should be used rather than the one used in this study. "GOOD" forecasts should be defined as missing the observed value by zero to 3 percent instead of zero to 5 percent.

(6) Individual fire weather station models should be developed to provide forecasters with better guidance.

(7) Humidity verification would be more useful if there was a graduated scale to compete against. High relative humidity values mean little to the outcome of fire danger calculations if they are very high (i.e., greater than 75%). Forecasters should not be "docked as many points" when humidities are above a certain percentage.

(8) Since humidity forecasts are not very accurate, perhaps it would be better to forecast dew point temperatures, a parameter meteorologists are more familiar with, and let the AFFIRMS computer calculate RH from this value. This would also help reduce the verification bias associated with high humidities mentioned above.

(9) Using only one or two trained fire weather forecasters generally provides better forecasts, due to the increased experience level and understanding of the unique fire weather forecast problems.

8. ACKNOWLEDGEMENTS

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