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ERROR ANALYSIS OF MONTHLY FIRE WEATHER FORECASTS

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ABSTRACT

Forecasts of monthly mean afternoon dry-bulb and dew point temperatures and wind speed have been issued for the contiguous USA since 1990. The forecasts are designed to help natural resource agencies anticipate potential wildfire hotspots within the country. This study examines the errors in the temperature and dew point forecasts.

1 INTRODUCTION

Wildfires in the USA consume an average of 800,000 hectares per year, sometimes resulting in the significant loss of natural resources, at great expense to the public. Fire protection agencies try to anticipate critical fire periods in sufficient time to manage suppression forces effectively. A recent innovation for strategic fire planning is the monthly fire weather forecast.

The objective of the monthly fire weather forecast is to predict those weather conditions that, over a period of a month, influence the flammability of vegetation. Important as it is to determine where unusual weather conditions are likely to elevate wildfire potential, it is equally important to know where benign weather makes wildfire unlikely. On a monthly time scale, McCutchan and Main (1989) found that wildland fire activity was correlated with the Chandler Burning Index (Chandler et al., 1983), a function of mean monthly temperature and relative humidity. The index was not uniformly superior to other weather variables, but its performance warranted further study. This paper reports an exploratory data analysis of the errors in the monthly fire weather forecasts of monthly mean dry-bulb and dew point temperatures--the variables used by the Chandler Burning Index--for 21 climate regions across the contiguous USA (fig. 1).

2 DERIVATION OF FORECASTS

The monthly fire weather forecasts derive from specification equations of mean temperature and dew point, for 127 weather stations across the USA. A forward selection screening algorithm was used to determine the multiple regression equation for the expected deviation of a weather variable from its monthly afternoon mean (i.e., the residual). The predictor variables were gridded values of the concurrent 700 mb mean height anomaly field, plus persistence as represented by the previous month's residual (Klein and Whistler, 1991). The grid points, spaced 5° apart, extended roughly from 20° N to 70° N, and 45° W to 180°. Cut-off criteria for the significance of terms in the equation were determined by Monte Carlo methods, with additional consideration given to synoptic plausibility, spatial/temporal consistency of the solutions, etc.

The model development process thereby provided an initial assessment of the accuracy of the forecast equations, through the reduction of variance (RV) statistics. Averaged over 116 stations, Klein and Whistler found that the RV statistics for monthly mean afternoon temperature were consistently higher than all the others, ranging from a high of approximately 73% in April, to a low of 63% in July. The dew point equations were next best, ranging from 67% in January to a relatively meager 39% in July. The authors initially attempted to model monthly mean afternoon relative humidity, but abandoned the effort in favor of dew point, because the relative humidity equations were neither productive, in terms of RV, nor were they physically meaningful.

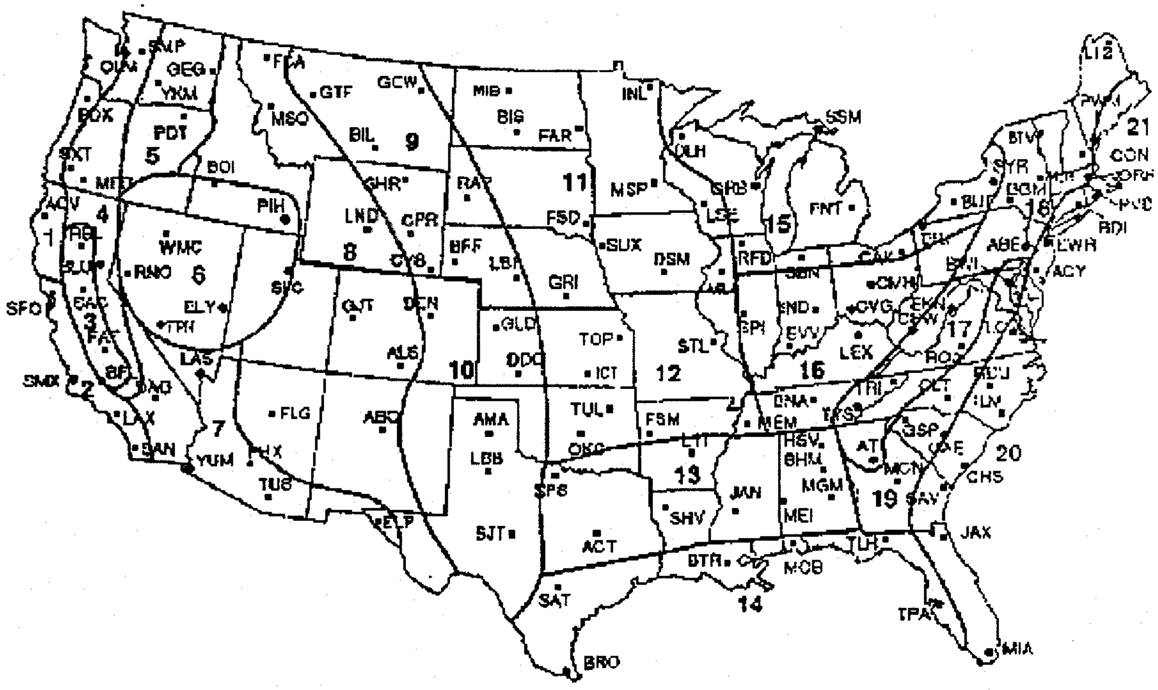


Figure 1. Weather station network and corresponding climate divisions for the error analysis.

This study examines the characteristics of the monthly fire weather forecast error--the difference between the forecast and the observed monthly mean--by climate region. A modified box-and-whisker plot is used to display the distribution of the error within each region (fig. 2). The ultimate objective is to provide confidence intervals for the forecasts, which, in turn, can be used to make better fire management decisions. This study takes the necessary first steps toward that objective.

3 METHODS

The error analysis covers the period from February 1973 through January 1991. In addition to the regional grouping of stations (fig. 1), we also grouped error data by seasons.

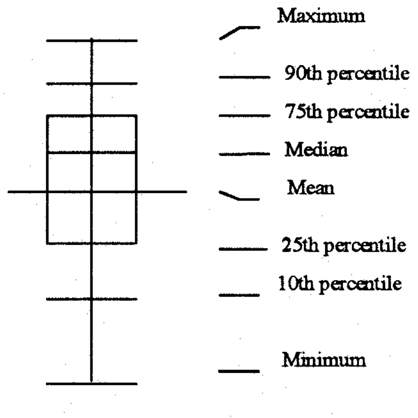


Figure 2. Key to modified box-and-whisker plots.

We called the three months from December through February the winter period, March through May, spring, June through August, summer, and September through November, fall. The left-to-right ordering of the regions in the box-and-whisker plots that follow corresponds to the order of the regional numbering system in fig. 1 (e.g., region 1 is the Northwest Coast, region 4 is the Cascades and Sierras, etc.).

We tested the error distributions for normality, using the D'Agostino test statistics (D'Agostino et al., 1990). This test claims power against alternatives with non-normal skewness and kurtosis. The test statistics are functions of the sample skewness and sample kurtosis, and they are asymptotically standard normal.

4 RESULTS

Fujioka et al. (1993) reported on error characteristics of the temperature and dew point forecasts for winter and summer seasons. They found that the temperature forecast error distributions were highly variable over the USA, generally longer-tailed in winter. The average errors were usually near zero. The dew point errors also had means near zero, but the error range was greater than that for the temperature forecast.

In the present study, we again found that the distribution of the forecast errors varied spatially across the USA. Nevertheless, the spring and fall forecast errors were small, on average, just as the winter and summer errors were (figs. 3 and 4). One notable exception was the mean dew point forecast error for the Cascades and Sierras (region 4), in spring. The mean error there was 3.8° F, due primarily to 18 significant overforecast errors (out of a sample size of 209). The maximum error was 52.6°, and even the 95% quantile was 47.2°. As a rule, the range of errors was narrower in the coastal regions than in the interior. The largest temperature error ranges occurred west of the Mississippi River.

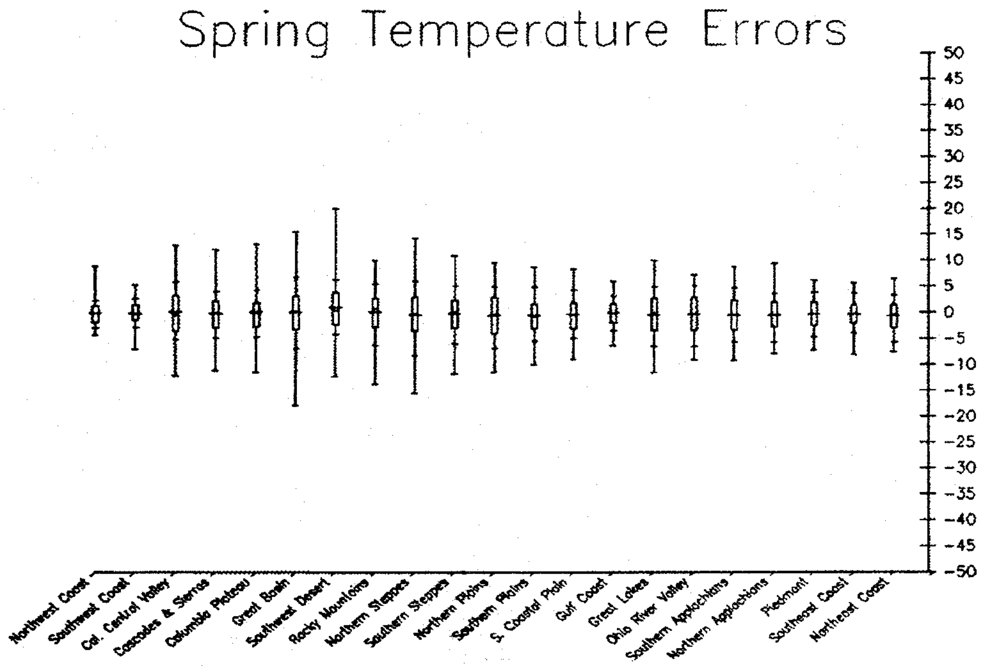
With a few exceptions, the errors in winter were dispersed over a wider interval than they were in the other seasons. The spread in the winter dew point errors in the Northern Plains (region 11) was the most conspicuous. A relatively few (16 out of 1080) errors here were due to excessive overforecasts, thus skewing the distribution significantly toward the positive side. The summer dew point errors of the Southwest Desert (region 7) were also noticeably dispersed.

Fujioka et al. (1993) applied the D'Agostino tests of normality to the winter and summer error data, and concluded that the distributions are apparently non-normal in those seasons. We have repeated the analysis for the spring and fall seasons. Tables 1 and 2 summarize the p-values of the analysis, under the null hypothesis that the errors are normally distributed. SKW refers to the skewness test, and KUR to the kurtosis test. When two numbers appear under "Sample Size", the first applies to the Temperature sample, and the second to the Dew Point sample; otherwise, both have the same sample size.

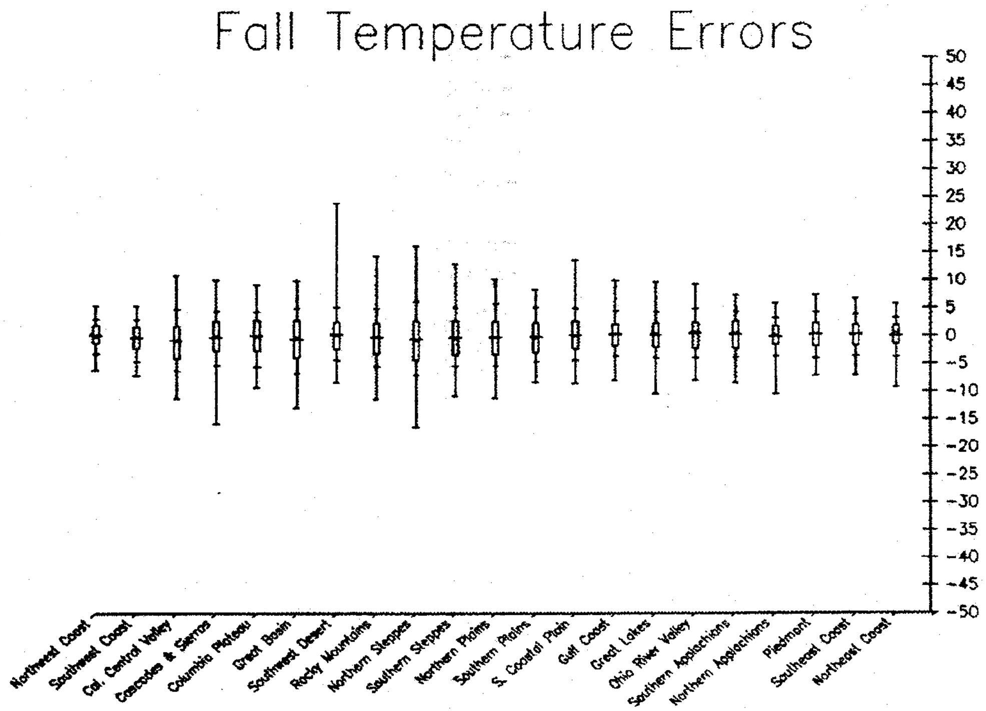
The D'Agostino tests resulted in zero or near-zero p-values for spring temperature and dew point errors in regions 4, 7 and 10. By comparison, only region 9 had comparably low p-values for the fall temperature and dew point errors. At the 5% significance level, the tests do not reject the normality hypotheses for either temperature or dew point for 12 regions in the

Table 1. P-values of the D'Agostino tests of normality for monthly forecast errors in spring (March, April, May).

	Temperature		Dew Point		
Climate Region	SKW	KUR	SKW	KUR	Sample Size
1	0.786	0.007	0.918	0.675	108
2	0.746	0.600	0.171	0.287	216
3	0.728	0.107	0.101	0.165	266
4	0.000	0.000	0.000	0.000	209
5	0.032	0.069	0.047	0.213	162
6	0.344	0.050	0.026	0.268	324
7	0.000	0.000	0.004	0.000	323
8	0.000	0.156	0.497	0.020	322/321
9	0.160	0.641	0.823	0.495	432
10	0.000	0.000	0.000	0.000	324
11	0.710	0.148	0.077	0.958	540
12	0.563	0.375	0.087	0.890	324
13	0.789	0.936	0.140	0.868	540
14	0.790	0.064	0.358	0.444	324
15	0.226	0.590	0.072	0.001	540
16	0.711	0.272	0.841	0.133	378
17	0.623	0.060	0.091	0.960	324
18	0.188	0.506	0.065	0.313	324
19	0.111	0.953	0.258	0.328	216
20	0.033	0.165	0.830	0.706	432
21	0.243	0.424	0.653	0.113	216

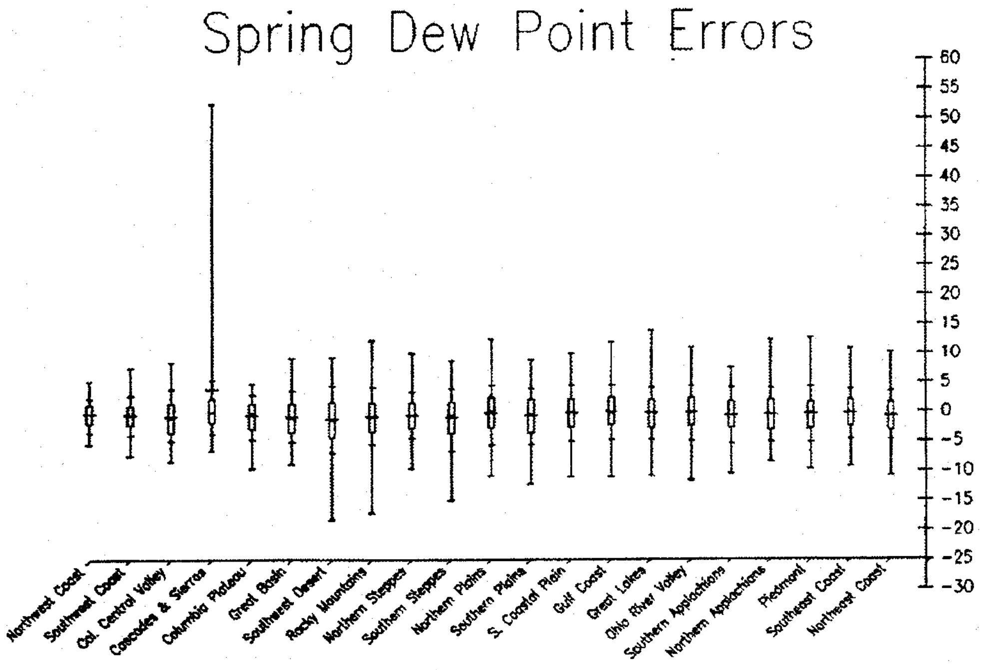


Spring Temperature Errors



Fall Temperature Errors

Figure 3. Spring and fall errors by region in monthly fire weather temperature forecasts for the contiguous USA.



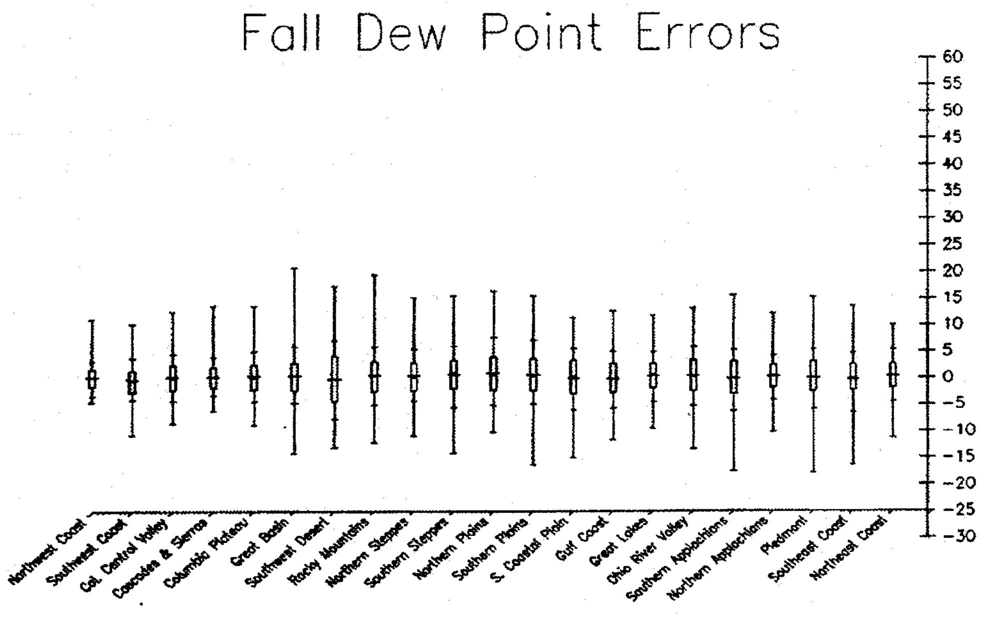


Figure 4. Spring and fall errors by region in monthly fire weather dew point forecasts for the contiguous USA.

Table 2. P-values of the D'Agostino tests of normality for monthly forecast errors in fall (September, October, November).

	Temperature		Dew Point		
Climate Region	SKW	KUR	SKW	KUR	Sample Size
1	0.021	0.211	0.002	0.006	108
2	0.077	0.168	0.039	0.067	216/214
3	0.244	0.148	0.006	0.105	268/267
4	0.147	0.177	0.000	0.003	212
5	0.451	0.109	0.000	0.008	162
6	0.771	0.205	0.000	0.000	324
7	0.000	0.000	0.288	0.046	324
8	0.040	0.126	0.022	0.007	324
9	0.000	0.000	0.001	0.007	432
10	0.136	0.950	0.075	0.062	324
11	0.000	0.058	0.000	0.924	540
12	0.286	0.003	0.800	0.179	324
13	0.792	0.249	0.005	0.365	540
14	0.922	0.735	0.479	0.356	324
15	0.860	0.881	0.262	0.280	540
16	0.977	0.064	0.485	0.278	378
17	0.003	0.125	0.047	0.006	324
18	0.000	0.000	0.909	0.018	324
19	0.004	0.067	0.061	0.007	216
20	0.158	0.203	0.002	0.002	432
21	0.000	0.011	0.481	0.647	216

spring, and for 4 regions in the fall; most of these regions are east of the Rocky Mountains. The spring p-values are generally higher than the fall values; they are also higher than the winter and summer p-values of the previous study (Fujioka et al., 1993).

5 CONCLUSIONS

The mean errors of the monthly fire weather forecasts are sufficiently small so that the forecasts may be considered unbiased, with a few exceptions. The error distributions vary spatially across the contiguous USA, and they vary seasonally. Overall, the forecasts are least precise in winter, and most precise in summer. One cannot comfortably assume that the errors are normally distributed, except with caution, perhaps, in the spring, east of the Rocky Mountains. (The presence of normality is an advantage, if only because of the substantial statistical theory that exploits it).

The egregious forecast errors mentioned in the Results--those of the Cascades and Sierras, the Northern Plains, and the Southwest Desert--deserve further study. If these problems are solved, the error statistics will improve significantly.

Still open to examination is the dependence structure of the errors, both spatially and temporally. The regression equations used to generate the forecasts have lag variables in time, but not in space. We also need to determine the spatial dependencies to confirm that the regional partitions (fig. 1) make sense. The spatial analysis methods described by Cressie (1991) offer many alternatives.

In our introductory remarks, we justified this study on the basis of the correlation between wildfire activity and the Chandler Burning Index, a function of mean monthly temperature and relative humidity. We need to study, at some point, the bivariate relationship of temperature and relative humidity, and the corresponding bivariate error distribution. Our hope is that, with such knowledge, greater utility of the monthly forecasts would accrue to wildland fire managers.

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