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THE INFLUENCE OF CLOUDINESS ON SUMMERTIME TEMPERATURES IN THE EASTERN WASHINGTON FIRE WEATHER DISTRICT

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I. INTRODUCTION

The National Fire Danger Rating System now used by most fire protection agencies in the United States requires an afternoon temperature value, among other weather parameters, to compute the fire-danger indices. Temperature forecasts must be provided by the fire-weather forecaster in order to compute expected fire danger. Temperature variations also have considerable influence on changes in humidity in eastern Washington (higher the temperature, the lower the humidity) and in addition temperature strongly influences other factors important in fire-danger potential such as stability of the air mass and the threat of thunderstorms. Because of the importance of temperature on all of these factors, a reasonably accurate temperature forecast is needed and we strive for a prediction falling with about 4°F of the observed value.

Two important factors causing variations in afternoon temperatures during the summer season in eastern Washington are changes in general air-mass temperature and changes in cloud cover. Minor short waves passing over eastern Washington every few days bring quite frequent surface temperature variations due to changes in air-mass temperature and cloud cover. Both of these factors often operate independently in producing the temperature variations. Objective aids have been developed which adequately forecast surface temperature changes resulting from general air-mass temperature changes. However, temperature variations due to cloud cover have been estimated subjectively. This study attempts to determine objectively the influence of cloud cover change of surface temperature change in each of six fire weather foreast zones in eastern Washington. An objective aid is then presented which combines the influence of general air-mass temperature change and cloud cover change on surface temperature.

II. PROCEDURE

Current fire weather forecast procedures for use with the National Fire Danger Rating System through the AFFIRMS computer program require, among other things, a 24-hour trend prediction of the 1400 PDT surface temperature and a prediction of sky cover verifying at 1400 PDT. This is required for each fire-danger station but because of the large number of stations, the practice has been to issue one forecast for a group of stations which are meteorologically homogeneous. The eastern Washington fire-weather district has been divided into six such groupings, called weather zones, where stations in each usually trend in the same direction with about the same magnitude. These weather zones are shown in Figure 1 along with the number of fire-danger stations in each. Observations from the fire-danger stations, on which the forecasts are applied, are taken near 1400 PDT and entered into the AFFIRMS computer program where they are averaged by weather zones. The "present-weather" group of a fire-danger observation contains ten possible conditions: clear, scattered, broken, overcast, fog, drizzle, rain, snow, showers, and thunderstorms. The first step in developing a relationship between these cloud-cover conditions and surface temperature was to divide the ten possible conditions into separate categories based on their potential to inhibit heating. The conditions of clear, scattered, broken, and overcast were each designated as a separate category. Fog, drizzle, rain, snow, showers, and thunderstorms were all grouped together into a fifth category since it was assumed that they are usually associated with thick clouds and all provide a similar minimum of insolation compared to the other categories. A summertime afternoon fog event is usually observed only at high-elevation lookouts when they are buried in clouds associated with thick, general-storm clouds.

The following assumptions are then made relating changes in the cloud-cover categories on consecutive days with corresponding temperature changes: (1) A change from one amount of cloud cover to another the next day will result in a temperature change, independent of general air-mass temperature change, and (2) The temperature change will be proportional to the degree of cloud-cover change, i.e., a large change in cloud cover between days will result in a larger temperature change than a smaller cloud-cover change.

The AFFIRMS fire danger prediction program operates mainly on 24-hour weather trends, rather than actual or forecast values so this objective evaluation is set up on a trend basis with a numerical value assigned to the trend in reported weather between 1400 PDT yesterday and 1400 PDT today. In order to evaluate the cloud-cover trend numerically, the number scheme shown in Table 1 was used for a 24-hour change between the five weather categories listed above (Fog and the precipitation events are combined into one category called "precipitation").

TABLE 1

24-Hour Sky-Cover Change Between 1400 PDT Yesterday and 1400 Today	Number Value
No Change	0
Precipitation to overcast, overcast to broken, broken to scattered, scattered to clear	+1
~~Precipitation to broken, overcast to scattered,~~ broken to clear	+2
Precipitation to scattered, overcast to clear	+3
Precipitation to clear	+4
Clear to scattered, scattered to broken, broken to overcast, overcast to precipitation	-1
Clear to broken, scattered to overcast, broken to precipitation	-2
Clear to overcast, scattered to precipitation	-3
Clear to precipitation	-4

This number scheme allows the trend in surface temperature change to be directly proportional to increasing or decreasing insolation as measured by sky-cover change.

The cloud-cover reports from fire-danger stations do not indicate the cloud type so this factor could not be used in determining the relationship with temperature change.

Several parameters could be used to measure the general air-mass temperature change. In this study the 850-mb temperature at 12Z of the current day was used. This is carefully analyzed during our regular forecasting routine and is readily available from our analysis chart. It is also a parameter predicted by the trajectory model for the next day so this can be used as guidance in an objective forecast scheme.

Once the parameters to be used were determined, data from two past seasons, 1976 and 1977, were utilized to determine the relationship between 24-hour general air-mass temperature change, cloud-cover change, and surface temperature change. The following three items of data were extracted for 124 days in July and August of 1976 and 1977:

1. The trend in sky-cover change between 1400 PDT yesterday and 1400 PDT today using the numbering scheme shown in Table 1 based on the average of all fire-danger stations in the weather zone, for each of the six weather zones.

2. The 24-hour change in 850-mb temperature between 12Z yesterday and 12Z today, in °C, determined over the weather zone in question.

3. The 24-hour change in average surface temperature between 1400 PDT yesterday and 1400 PDT today based on the observations from the fire-danger stations, with a trend value calculated for each of the six weather zones.

III. RESULTS

A linear regression was performed on these data with the 24-hour surface temperature change as the independent variable and sky-cover change and 850-mb temperature change as independent variables, using the general equation:

$$\Delta T = A \ \Delta T_{850} + B \ \Delta S.C. + C$$

where,

ΔT = 24-hour change in average weather zone temperature in °F.

ΔT_{850} = 24-hour change in 850-mb temperature over weather zone in °C.

$\Delta S.C.$ = 24-hour change in sky cover or weather condition over weather zone, using the $\Delta S.C.$ number scheme of Table 1.

A, B, and C are coefficients to be determined; however, since the data are 24-hour changes rather than actual values, the coefficient C will be near zero for a large population.

The values for 124 cases were entered into a multiple regression program set up in a WANG programmable calculator. The following equations resulted for each zone:

ZONE 675	$\Delta T = 1.4 \ \Delta T_{850} + 3.2 \ \Delta S.C.$
ZONE 680	$\Delta T = 1.4 \ \Delta T_{850} + 3.0 \ \Delta S.C.$
ZONE 677	$\Delta T = 1.2 \ \Delta T_{850} + 3.5 \ \Delta S.C.$
ZONE 682	$\Delta T = 1.4 \ \Delta T_{850} + 3.2 \ \Delta S.C.$
ZONE 684	$\Delta T = 1.2 \ \Delta T_{850} + 3.6 \ \Delta S.C.$
ZONE 686	$\Delta T = 1.1 \ \Delta T_{850} + 3.6 \ \Delta S.C.$

The general similarity of the coefficients for sky-cover change between zones should be expected since at nearly the same latitude changing sky cover should result in about the same surface temperature change. There may be slightly more effect from cloud-cover change over the northern zones (Zones 684 and 686) than the southern zones (675 and 680) since clouds may tend to be thicker and more persistent in the northern sections nearer to the normal track of storms.

Table 2 shows the multiple correlation coefficients, reduction in variance, and standard error of the estimate for each equation. Some of the error could probably be reduced by considering cloud type and persistence. Also the use of the 12Z 850-mb temperature change to estimate the air-mass temperature change for the current day introduced errors when active cold or warm advection was occurring. In these cases, of which there were several in the developmental data, the change up to 12Z this morning did not give an accurate indication of the effect on surface temperatures reported at 1400 PDT in the afternoon.

IV. USE AS AN OBJECTIVE AID

The solutions to the equations were transformed into nomograms for use as a forecast aid. These are shown in Figure 2. Since the equations for several zones were similar, the data for the similar zones were combined to form one equation for the graph. Zones 675, 680, and 682 were combined into one graph and zones 677, 684, and 686 were combined into a second graph.

The forecaster can use this aid either in the afternoon forecast for the next day using predicted 850-mb temperature change and sky-cover change or in the morning forecast for the current day using the observed 850-mb temperature change and shorter range sky-cover prediction. The forecaster enters the graph with the 850-mb temperature change prediction in °C on the abscissa, goes vertically to intersect the 24-hour sky-cover change, then horizontally to the ordinate for the predicted surface temperature change in °F.

The equations were tested on all available days in July and August 1975 and 1978 for weather zones 675 and 686. The results are shown in Table 3.

V. SUMMARY

A relationship between surface temperature change and cloud-cover change was determined objectively for several weather zones in eastern Washington. This was combined with a measure of the general air-mass temperature change to produce equations which explained about 70 to 80% of the daily variation in surface temperature. The average error of the prediction equations when tested on two seasons of independent data was about 2 to 3°F. It is hoped that the study will at least make the forecaster more aware of temperature variations due to cloud-cover changes. The equations may also apply to other areas in the Pacific Northwest at similar latitudes or others could similarly be derived.

TABLE 2

SUMMARY OF REGRESSION ESTIMATE OF 1400 PDT SURFACE TEMPERATURE

ZONE	VARIABLES USED	MULTIPLE CORR. COEFFICIENT	REDUCTION OF VARIANCE	STD. ERROR OF ESTIMATE
675	ΔT_{850}	.66	.43	5.07 °F
	ΔS.C.	.86	.74	3.49
680	ΔT_{850}	.66	.43	5.11
	ΔS.C.	.84	.71	3.61
677	ΔT_{850}	.55	.30	5.37
	ΔS.C.	.85	.72	3.41
682	ΔT_{850}	.59	.35	5.90
	ΔS.C.	.80	.64	4.43
684	ΔT_{850}	.71	.50	5.32
	ΔS.C.	.85	.72	3.47
686	ΔT_{850}	.71	.50	5.13
	ΔS.C.	.89	.80	2.78

TABLE 3

TEST OF EQUATIONS ON ZONES 675 AND 686
JULY AND AUGUST 1975

1975 ZONE	AVERAGE ABSOLUTE ERROR °F	CUMULATIVE FREQUENCY FOR ABSOLUTE ERRORS OF: ≤1°	≤2°	≤3°	≤4°	≤5°
675 (62 days)	2.06	42%	66%	82%	90%	97%
686 (60 days)	3.05	30%	50%	62%	73%	83%
1978						
675 (62 days)	2.02	47%	74%	89%	92%	97%
686 (62 days)	2.73	39%	56%	66%	81%	89%

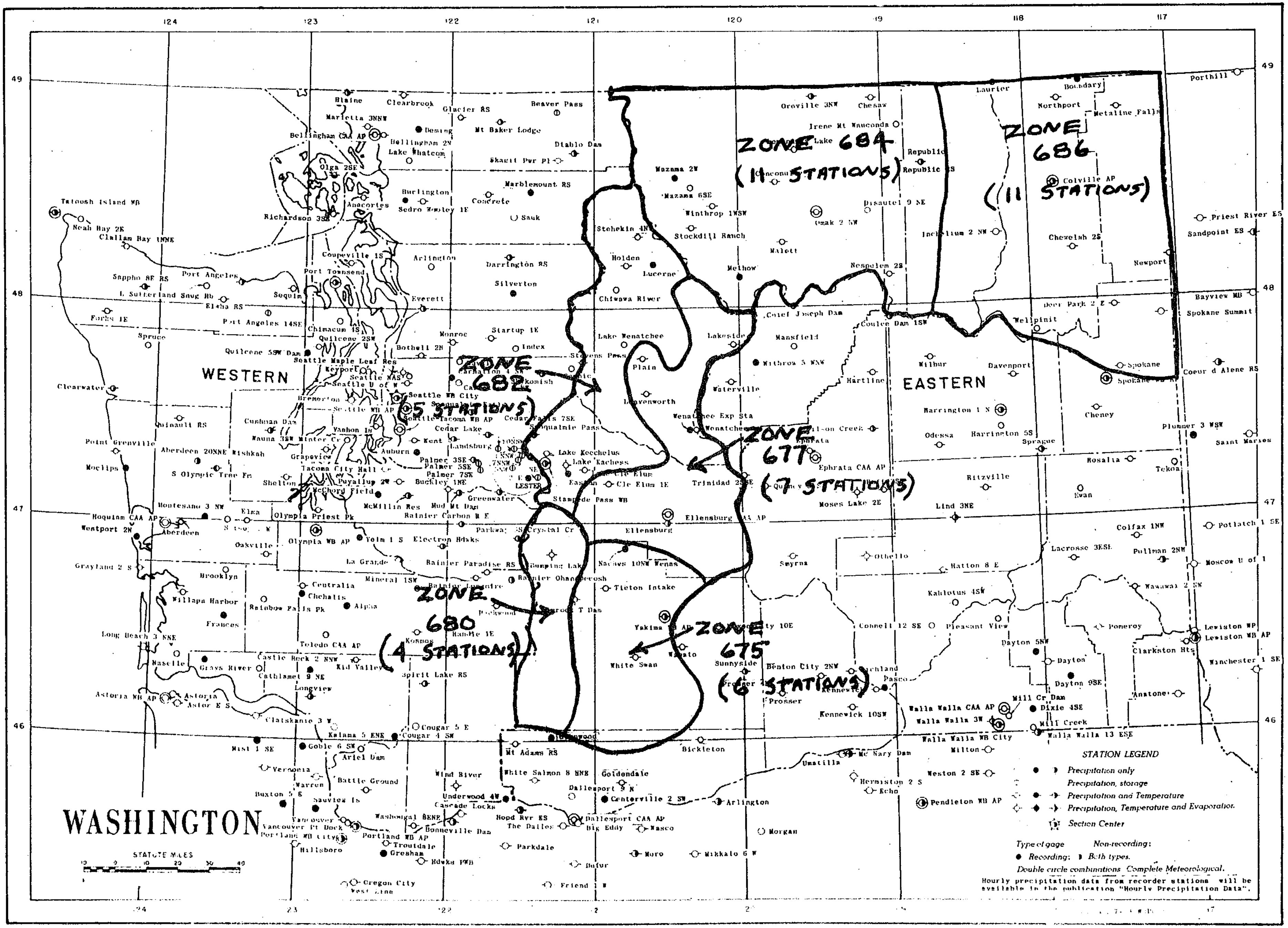

FIGURE 1. Fire Weather Forecast Zones in Eastern Washington Fire Weather District.

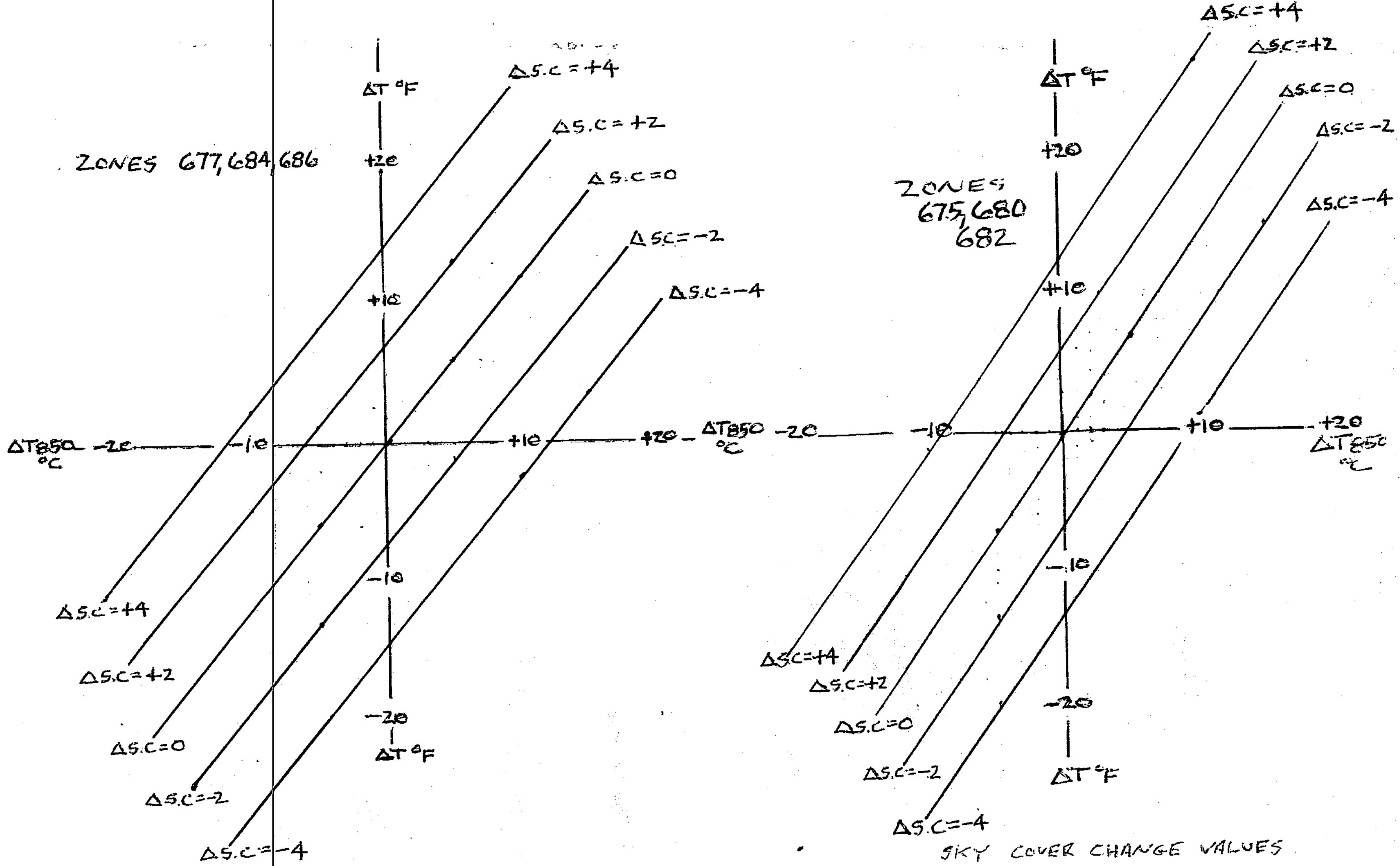

Figure 2. Weather Zone Average Temperature Change vs. 24-Hour 12Z 850-mb Temperature Change and 24-Hour 1400 PDT to 1400 PDT Sky-Cover Change.

SKY COVER CHANGE VALUES

+1 = PRECIP → ⊕, ⊕ → ⦷, ⦷ → ⦶, ⦶ → ○
+2 = PRECIP → ⦷, ⊕ → ⦶, ⦷ → ○
+3 = PRECIP → ⦶, ⊕ → ○
+4 = PRECIP → ○
−1 = ○ → ⦶, ⦶ → ⦷, ⦷ → ⊕, ⊕ → PRECIP
−2 = ○ → ⦷, ⦶ → ⊕, ⦷ → PRECIP
−3 = ○ → ⊕, ⦶ → PRECIP
−4 = ○ → PRECIP
○ = NO CHANGE

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