NOAA Technical Memorandum NWS WR-123

STUDY OF A HEAVY PRECIPITATION OCCURRENCE IN REDDING, CALIFORNIA

Christopher E. Fontana

National Weather Service Western Region
Salt Lake City, Utah
June 1977

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NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
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NATIONAL WEATHER
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STUDY OF A HEAVY PRECIPITATION OCCURRENCE IN REDDING, CALIFORNIA

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I. INTRODUCTION

On August 14 and 15, 1976, heavy thunderstorms moved through northern California. The heaviest area of precipitation was in the area west and north of Redding, California. The rain fell at such a rapid rate that normal drains could not handle the water, and several areas of the city received water and mud damage from the overflow. The Army Corps of Engineers dispatched personnel to the Redding area to compile and verify rainfall amounts measured by the local residents. Their findings showed rain amounts in excess of 8 inches, with rainfall rates of 2-1/2 inches per hour. This paper discusses the synoptic pattern preceding and during the thunderstorms. The precipitation pattern is discussed, using the radar displays from the WSR-57 radars at Medford, Oregon and Sacramento, California.

II. SYNOPTIC DISCUSSION

Saucier (5) states that short waves are those progressive waves in the atmosphere that "have associated divergence and vertical motion patterns which produce the important daily weather phenomena". It was one of these short waves that triggered the Redding deluge. The upper air pattern during the time in question consisted of a large high near longitude 160°W and a trough along the west coast (Figure 1). A dramatic deepening of the west coast trough took place during the 24 hours ending at 12Z August 14 (Figures 1 and 2). This deepening is the result of the short wave trough phasing with the long wave trough.

This can be shown using the method described by Riehl and others (4). This method uses the 24-hour height fall areas at 50 kPa (500 mb). If these fall areas are followed for several periods, they trace out the long wave pattern and seem to intensify as they move into the long wave trough position. Figures 3, 4 and 5 are successive 24-hour height-change charts for the period from 12Z August 11 to 12Z on August 14, 1976. Figure 3 shows the short wave to be located off the coast just west of Redding. The 30 kPa (300 mb) analysis for 12Z August 14 (Figure 6) shows a wind maximum associated with this short wave in the west side of the trough which is another indication of the intensification this system is undergoing.

In response to these dynamic changes in the upper levels, several significant things were occurring on the surface. Figures 7, 8 and 9 are surface maps for 15Z and 18Z on the 14th and 00Z on the 15th of August. During the early morning of the 14th, a frontal system passed through northern Calfiornia. In response to the short wave aloft, a trough line is shown entering the California and Oregon coasts at 15Z. As this trough lowers pressures in northern California and southern Oregon, the weak front in central California begins to move northward toward the trough. This process continues and as the short-wave aloft moves over the front, an "instant occlusion" is formed with a triple point or flat wave just west of Redding. While the 24-hour 500 mb height-change was very useful in locating the short wave, the best indication of what was about to happen was the surface isallobaric field. A simple explanation of the pressure tendency or change is that it is the change in the weight of the column of air over a given point. Therefore, negative pressure tendencies indicate upper level divergence, which would be expected ahead of a short-wave trough. Figure 10 is the 3-hourly isallobaric analysis for the period ending 00Z August 15, 1976. The large fall area in northern California is where the frontal wave was developing. In 1975, Mogil (2) did a similar study of an unforecast snowstorm in the eastern U.S. In that case, as well as this one, when the pressure fall area merged with a quasi-stationary front, vigorous development occurred.

III PRECIPITATION PATTERN

As mentioned in the introduction, the Army Corps of Engineers collected data from people in the Redding area. The rainfall reports they consider accurate are shown in Table I. I deleted individual names and addresses, but all reports are from the areas west and north of Redding. The precipitation originated from mostly shower-type clouds (cumulonimbus) and, therefore, was displayed well on radar. The wave formed between the Medford, Oregon and Sacramento, California radars, and an integration of the two scopes gives a good picture of the precipitation pattern as it moved through northern California. Figures 11 through 14 are the Medford radar overlays from 1630Z to 1930Z on August 14. These show the progression of echoes associated with the trough line as the trough moved into the Oregon and California coasts. Figures 15 through 20 are the Sacramento overlays from 2130Z August 14 to 0530Z August 15. Considerable shower activity is shown over all of central and northern California, but the strongest returns are in the north end of the valley, closer to where the wave formed on the front. The strongest echoes are shown from 0030Z through 0330Z on August 15 (Figures 16-19). At this time, the radar shows an echo with an intensity of 5 just west of Redding. Reporting station number 13 in Table I is 5 miles west of Redding. This report shows that 2-1/2 inches of rain were measured in one hour during the evening of the 14th. This correlates very well with the theoretical rates shown in the lower left hand corner of the Sacramento overlays. An echo with an intensity of 5 is highly correlated with rainfall rates of 2-5 inches per hour.

A good illustration of how intense this storm was can be shown by checking the depth duration tables in Figures 21 and 22. These show that an hourly rate of 2-1/2 inches will have a return period of 10,000 years and a 24-hour rain of 6-8 inches will return every 50 to over 200 years.

Two other things can be credited with increasing the rainfall from this system. First, the showers occurred in the late afternoon and early evening when convection was at its peak. Secondly, Oertel (3) has shown that under southerly surface flow, the area west and north of Redding will receive heavier rains than other portions of the local area. This is because during southerly flow periods, the air is being forced up and through the Sacramento River canyon.

IV. CONCLUSION

During occurrences like the one just described, good mesoscale forecasts are required. Just using the Numerical Weather Prognoses (NWP) will not achieve this. (Editor's Note: See Addendum). The forecaster must use other charts and aids beside those transmitted on the facsimile circuits. Two of these aids are the 24-hour height-change chart and the isallobaric analysis. The height-change chart, if done for several days, will trace out the long wave pattern and locate the short wave features. As shown by Hess (1), the pressure-tendency field defines the integrated mass divergence in the vertical column. It is this field that really tells the forecaster what to expect over the next several hours. While the height-change chart can be checked daily, the pressure tendency can be followed hourly. In the case described here, following the pressure tendency would have given the forecasters a good clue of what was about to happen in northern California. Use of this information would have aided in refining the required forecasts and warnings.

V. ACKNOWLEDGEMENTS

I would like to thank Mr. Leonard Snellman and all those in the Scientific Services Division who reviewed this paper. I would also like to thank Perry Fontana, hydro-meteorologist with the Army Corps of Engineers for helping with the data collection and analysis.

VI. ADDENDUM

Editor's Note: We thought that it would be of interest to include the 24-hour LFM forecasts valid during the heavy rain incident. The overall LFM guidance was good, but as the author stated, you can't expect the details to be indicated. The 12- to 24-hour precipitation forecast covering the period 1200Z August 14 to 0000Z August 15 indicated rather heavy rainfall for northern California (see Figure 23). The next 24-hour LFM precipitation forecast based on 12-hour later data for the period 0000Z to 1200Z August 15 (Figure 24), was for less than one half inch of rain in the Redding area. Considering the strong LFM bias of over-forecasting precipitation amounts, this guidance was not interpreted as indicating abnormally heavy rains. However, the LFM guidance certainly gave the proper indication of expecting precipitation with the front. Also, the LFM 50-kPa prognosis valid Sunday morning verified very well (see Figure 25). The triple-point wave development was not indicated in either LFM forecast.

VII. REFERENCES

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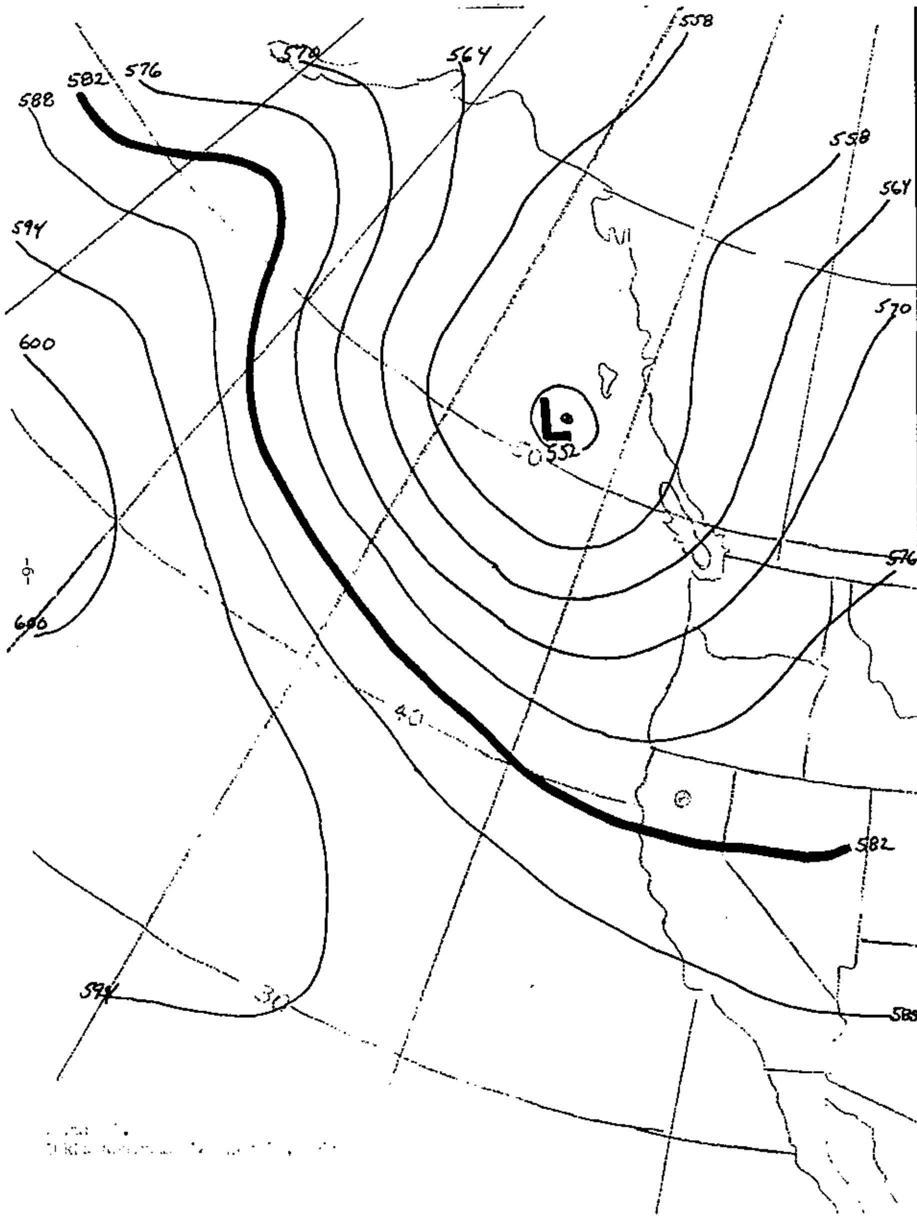
5. Saucier, Walter J., Principles of Meteorological Analysis, University of Chicago Press, 1965.

TABLE I

Number	Report
1	6.83 inches 8 am 8/14/76 to 8 am 8/15/76
2	8.4 inches storm total measured in a 12-inch wedge guage
3	6.5 inches in a coffee can 24 hour total ending at 8 am 8/15/76
4	6.0 inches in number 10 tin can
5	6.5 inches in a 5-gallon paint can
6	6.0 inches in a 33-gallon garbage can
7	8.8 inches for 24 hours ending morning of 8/15/76
8	8.0 inches in a 5-gallon paint can
9	5.5 inches after 1 pm 8/14/76
10	6.25 inches total. 3.75 between 8 am and 5 pm 8/14/76 and 2.00 inches between 5 pm 8/14/76 and 8 am 8/15/76
11	2.60 inches 4 pm to 9 pm 8/14/76
12	3.15 inches 5:30 pm to 9:30 pm 8/14/76
13	In one hour's time on evening of 14th, measured 2-1/2 inches
14	7.75 inches in 33-gallon garbage can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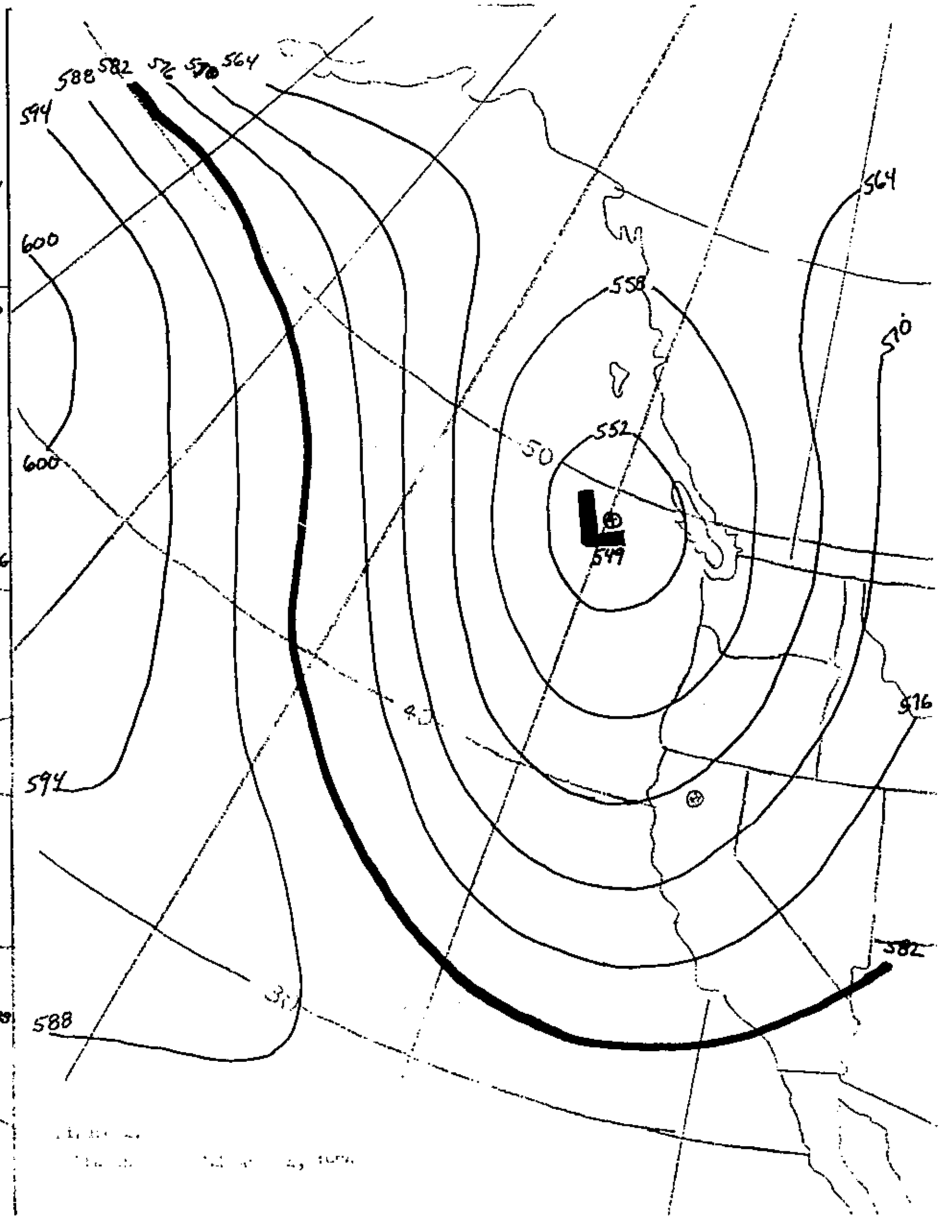
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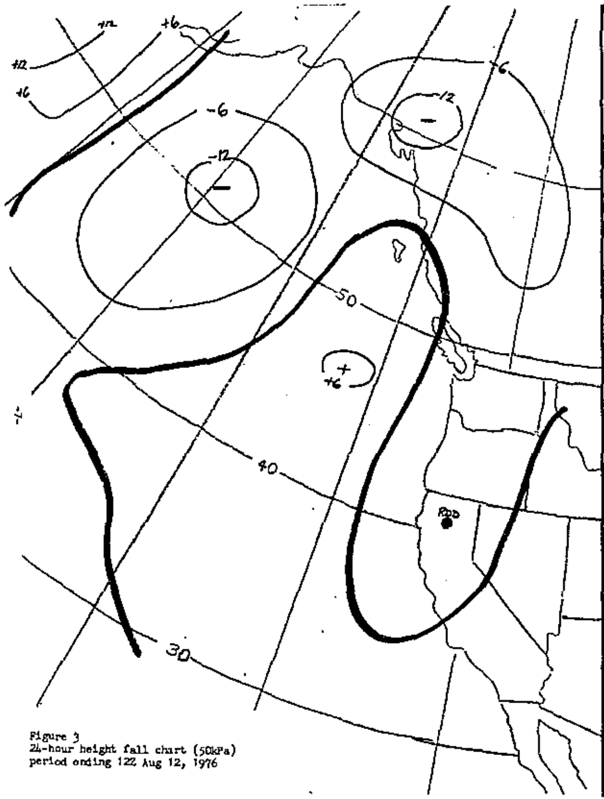

Figure 3
24-hour height fall chart (50kPa)
period ending 12Z Aug 12, 1976

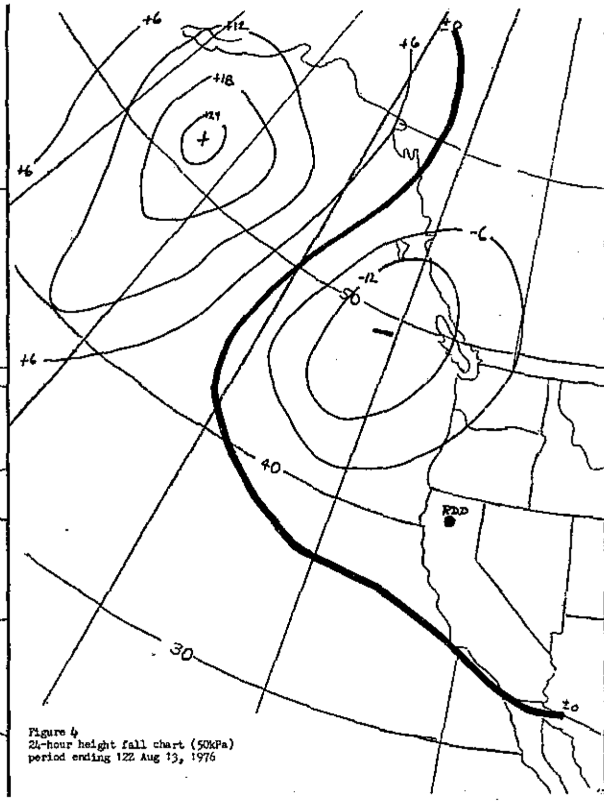

Figure 4
24-hour height fall chart (50kPa)
period ending 12Z Aug 13, 1976

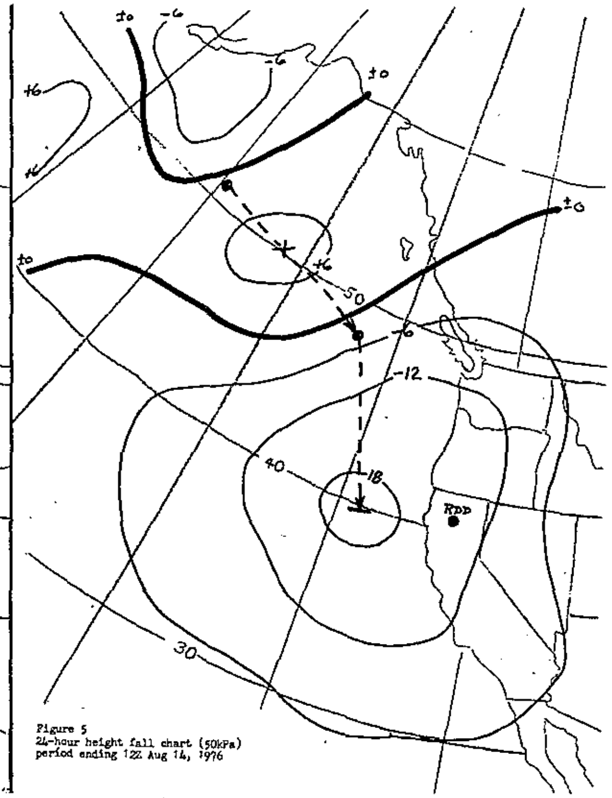

Figure 5
24-hour height fall chart (50kPa)
period ending 12Z Aug 14, 1976

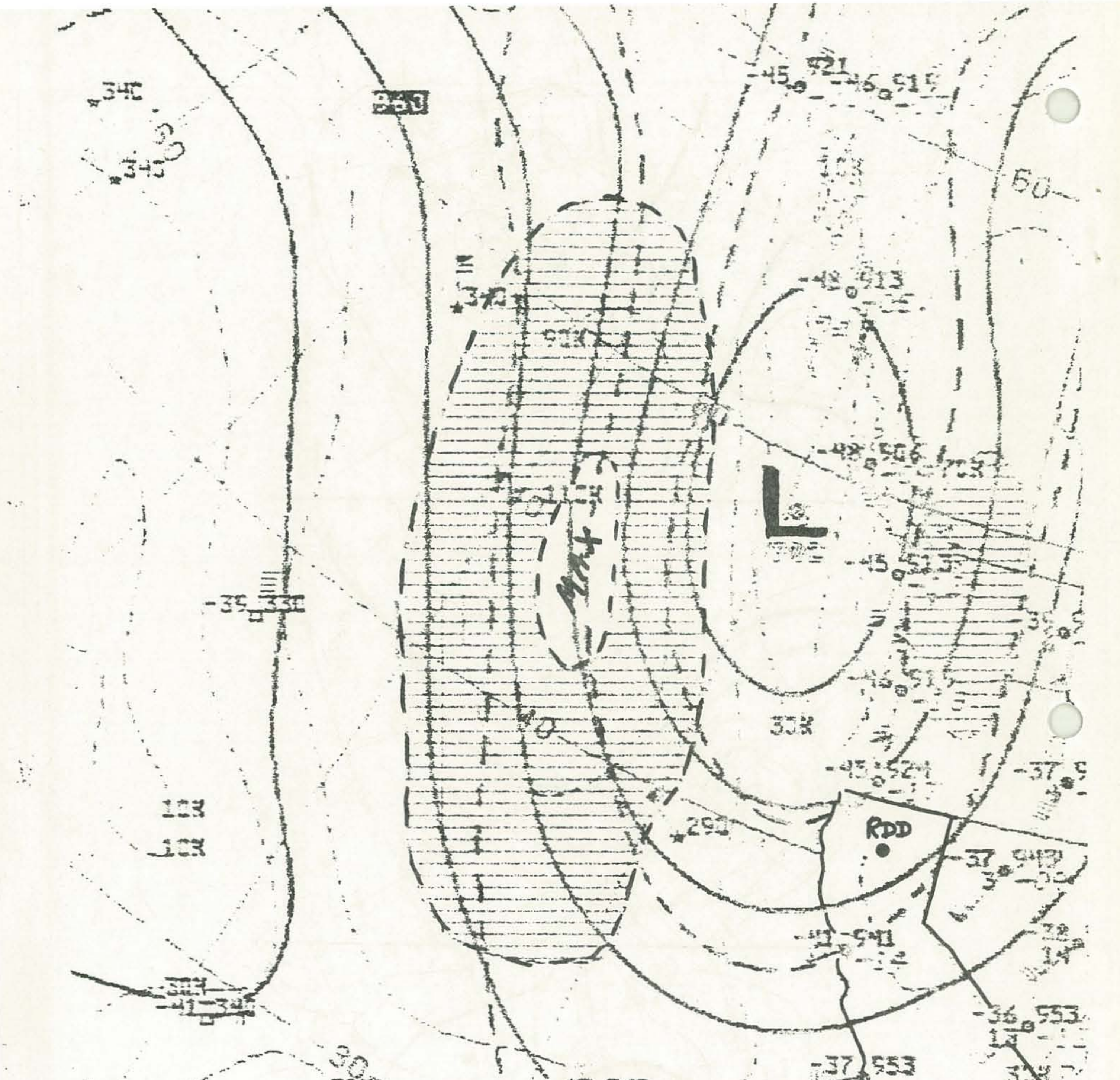

Figure 6
30kPa analysis 12Z Aug 14, 1976

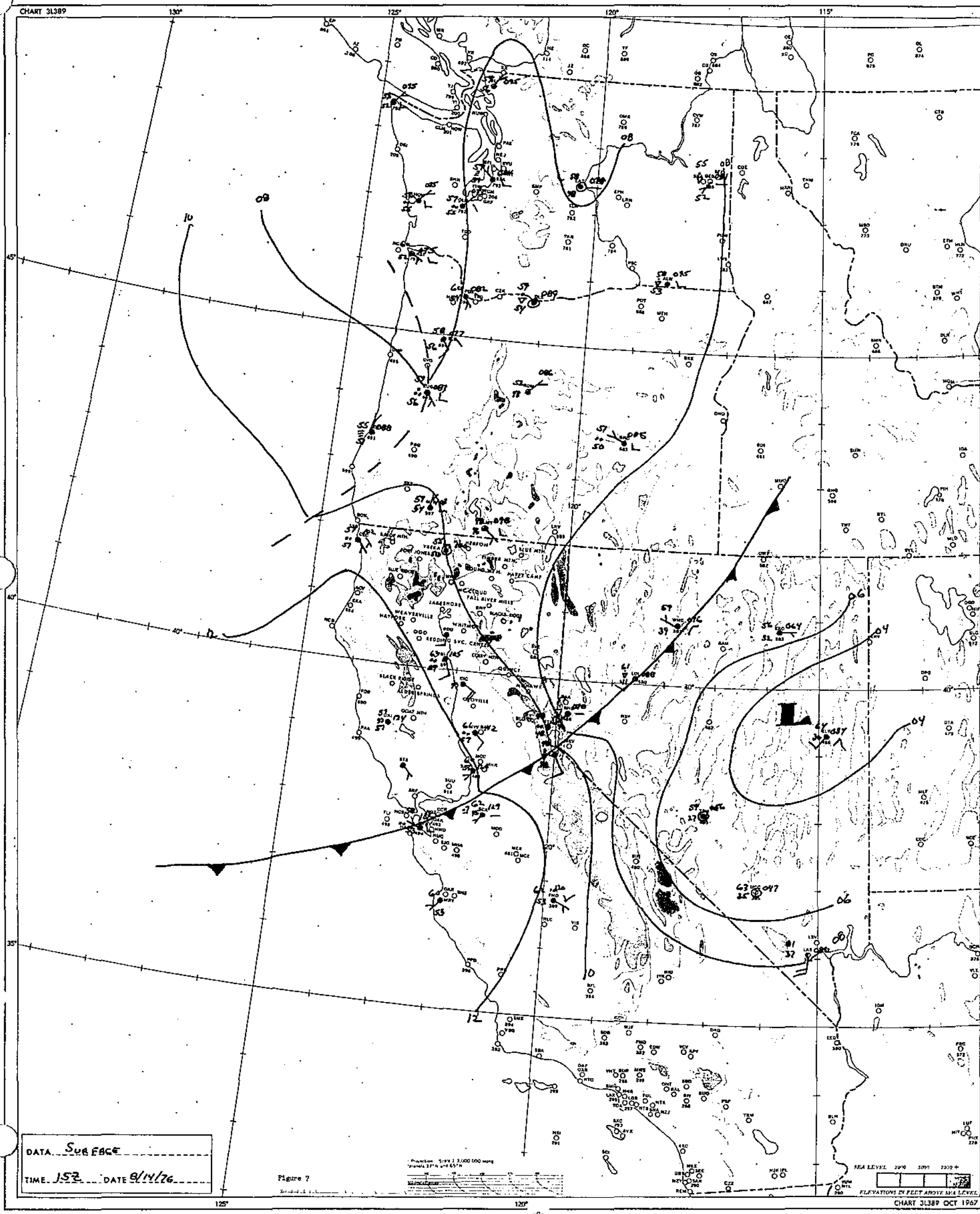
CHART 3L389
DATA SURFACE
TIME 15Z DATE 8/14/76
Figure 7
ELEVATIONS IN FEET ABOVE SEA LEVEL
CHART 3L389 OCT 1967

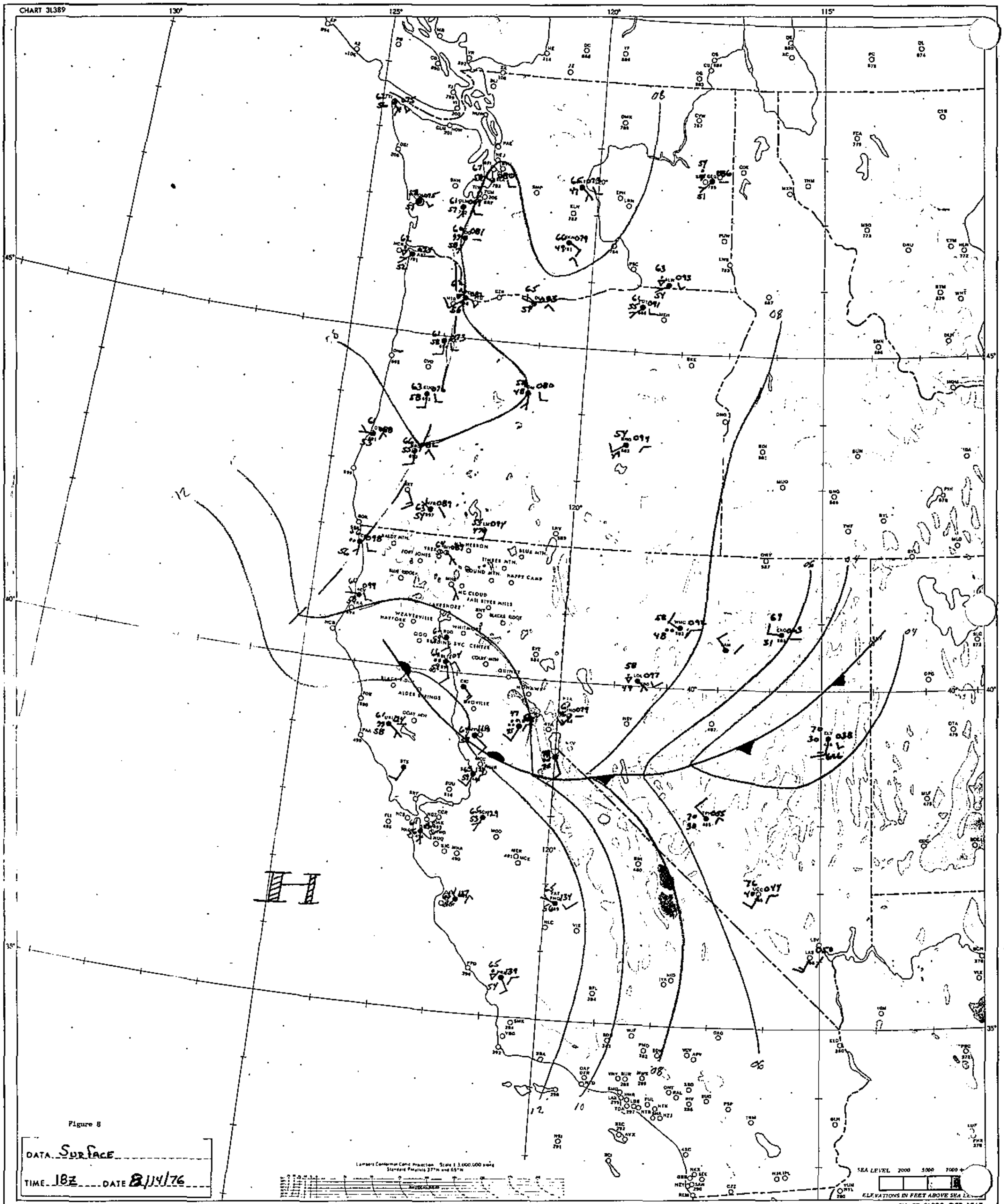

Figure 8

DATA Surface

TIME 18Z DATE 8/14/76

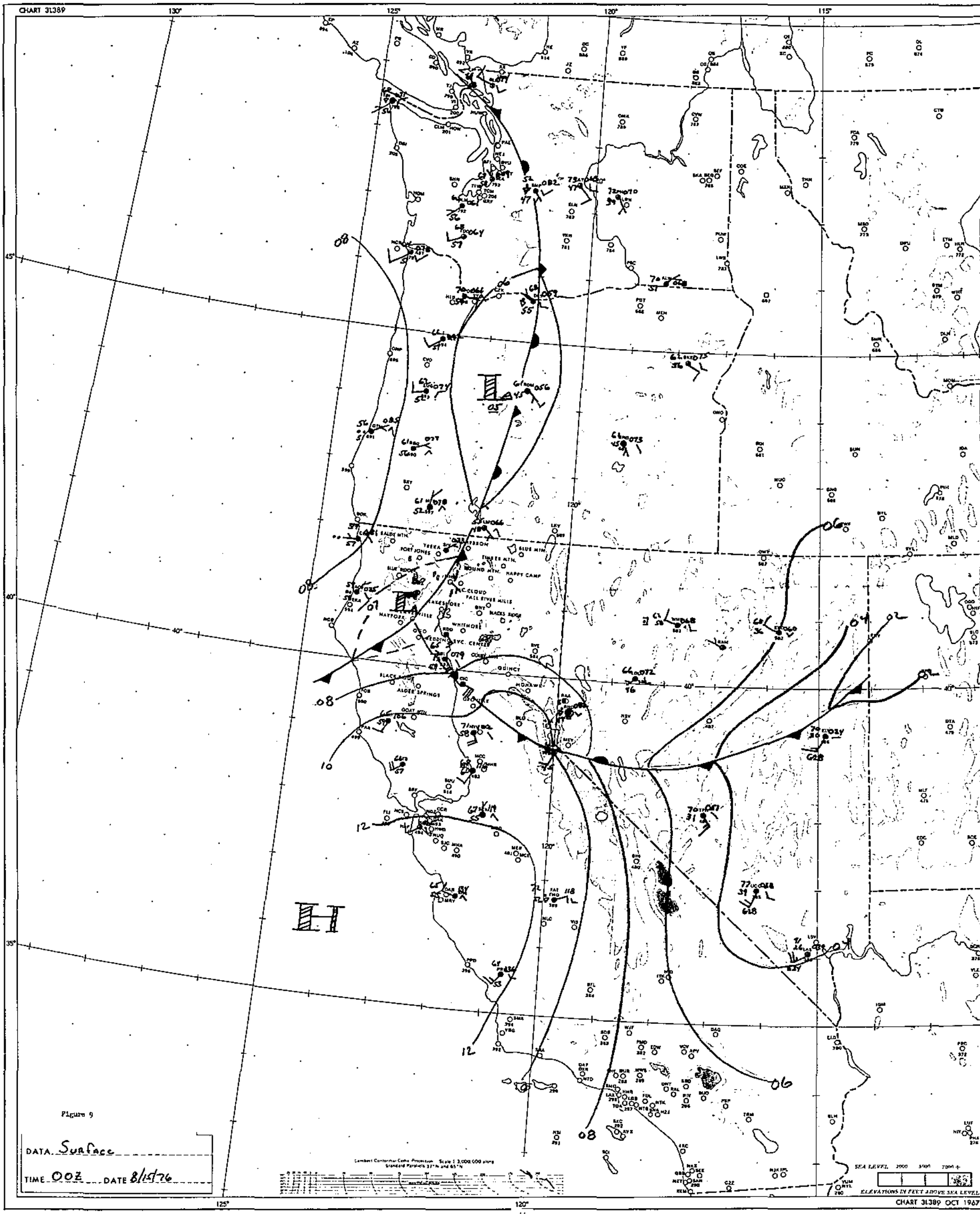

Figure 9

DATA Surface

TIME 00Z DATE 8/15/76

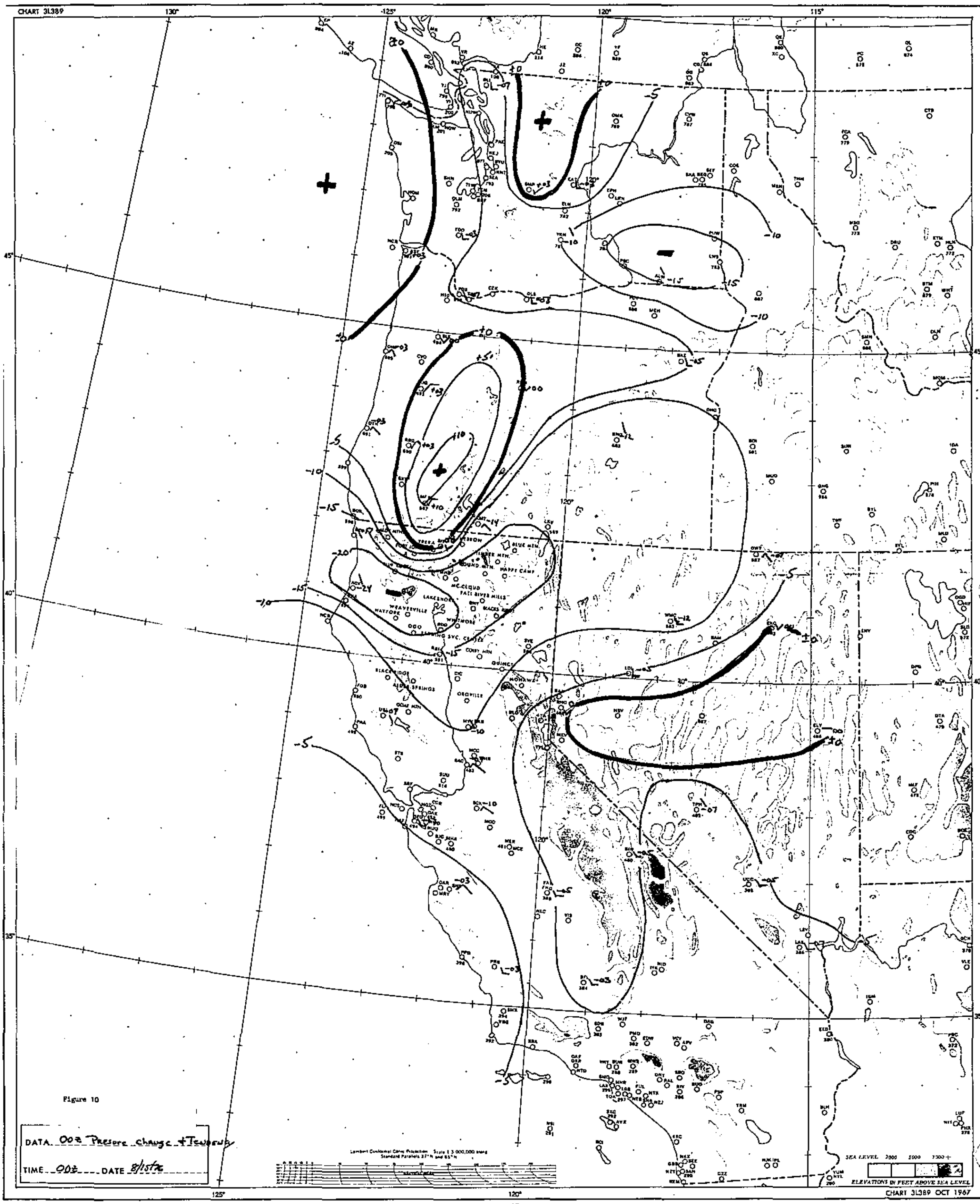

Figure 10

DATA 00Z Pressure change + Tendency
TIME 00Z DATE 8/15/76

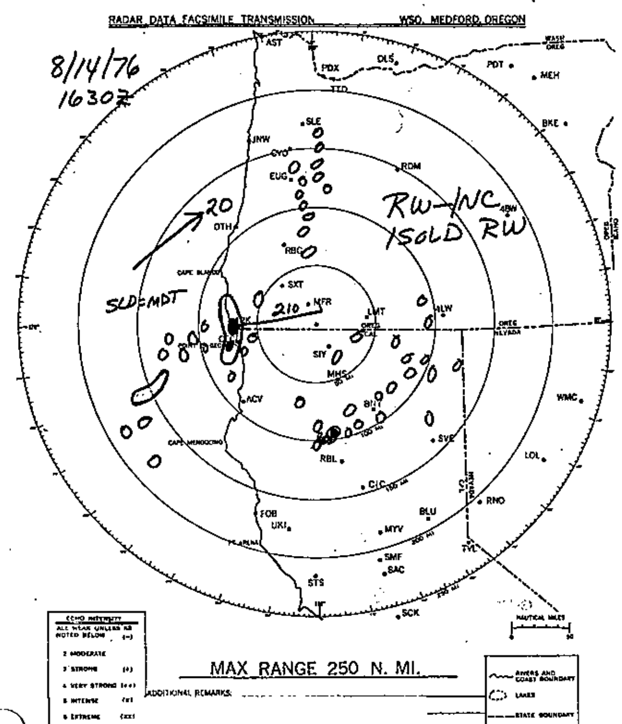

Figure 11

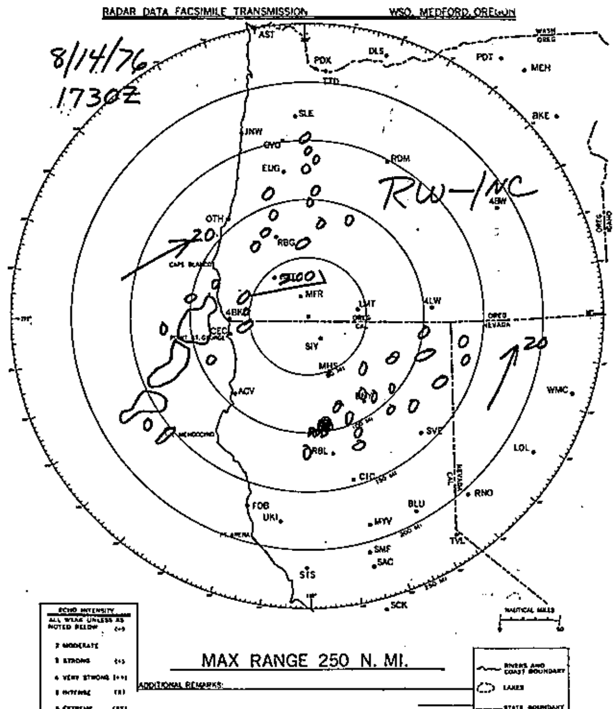

Figure 12

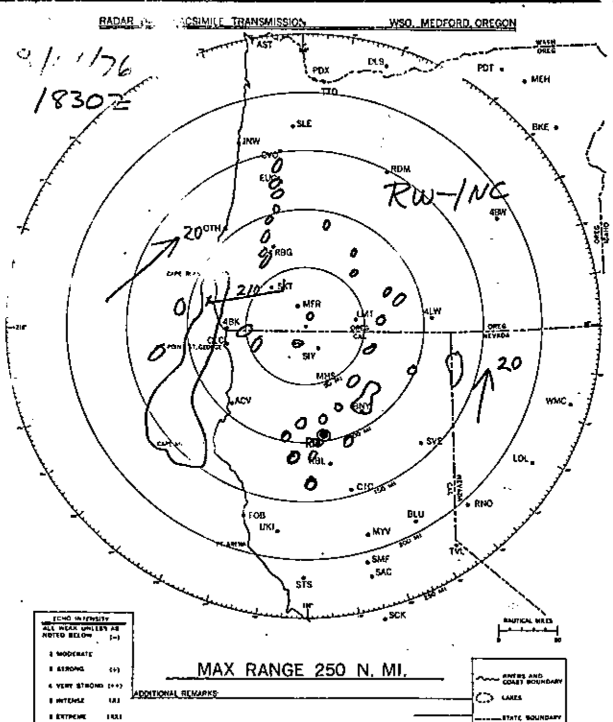

Figure 13

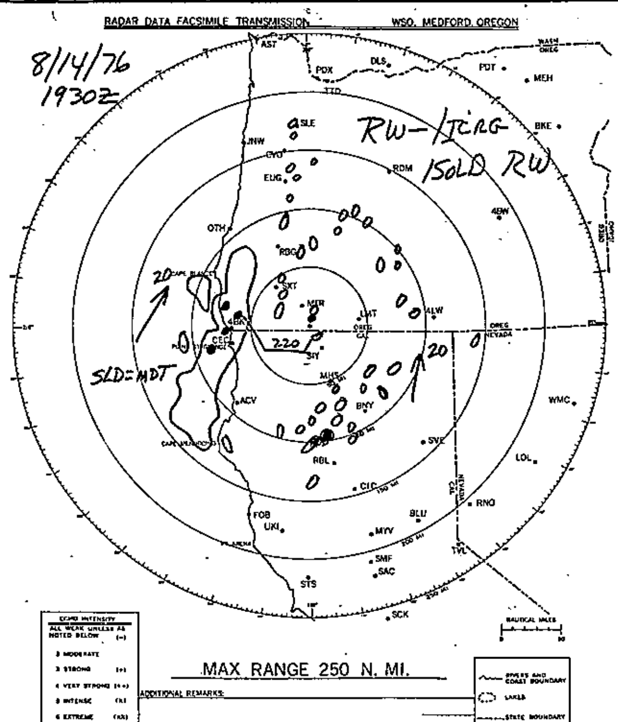

Figure 14

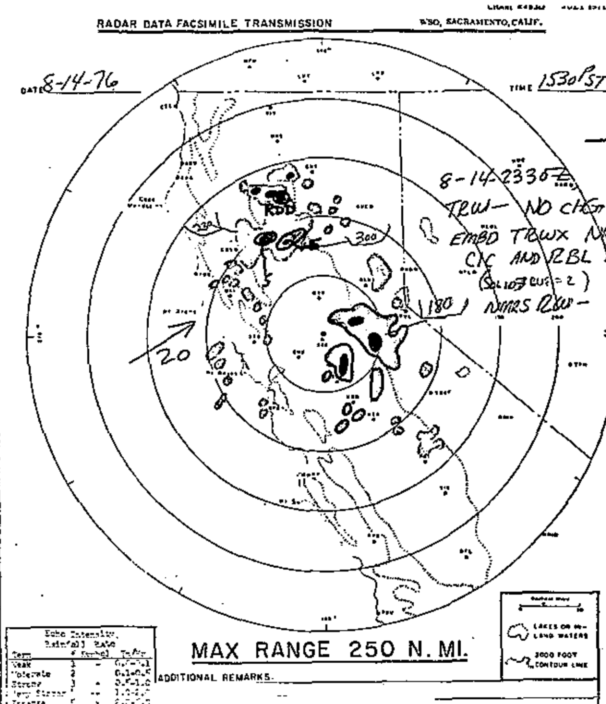

Figure 15

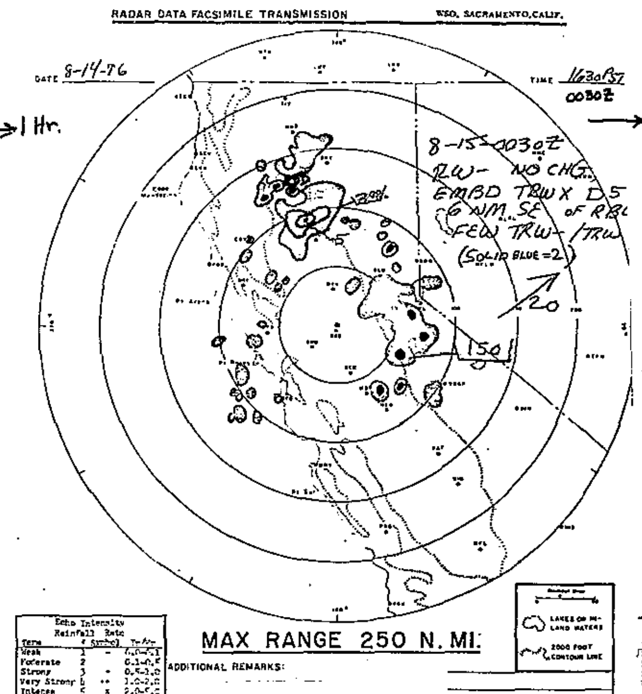

Figure 16

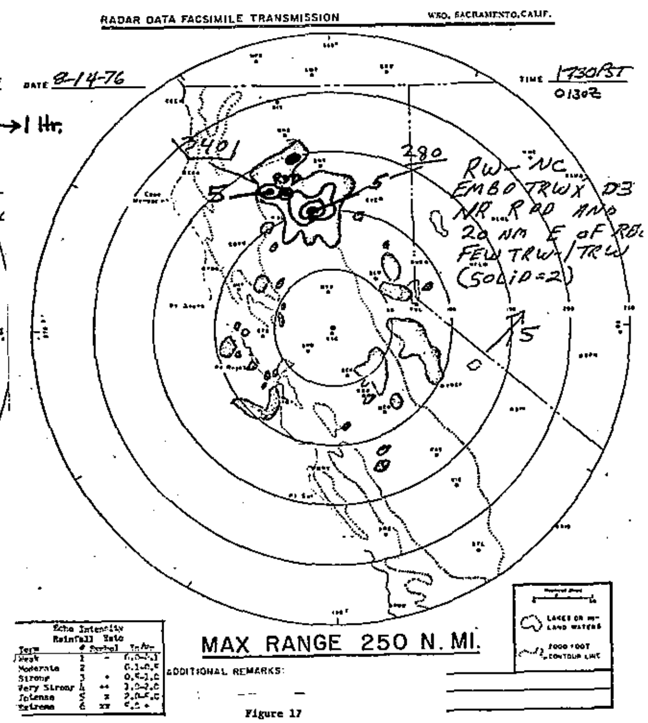

Figure 17

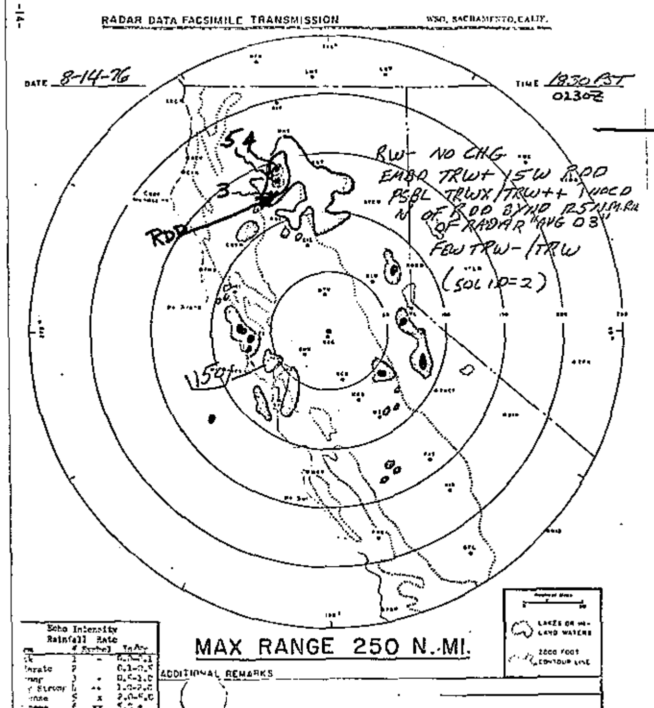

Figure 18

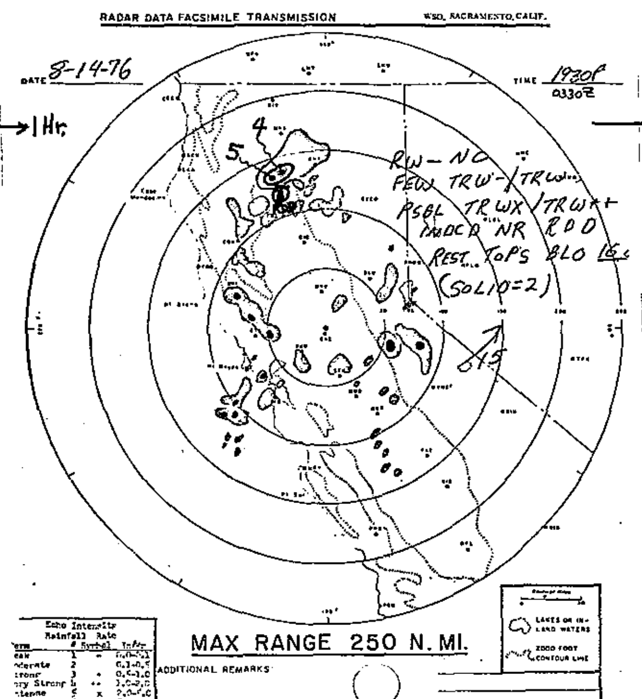

Figure 19

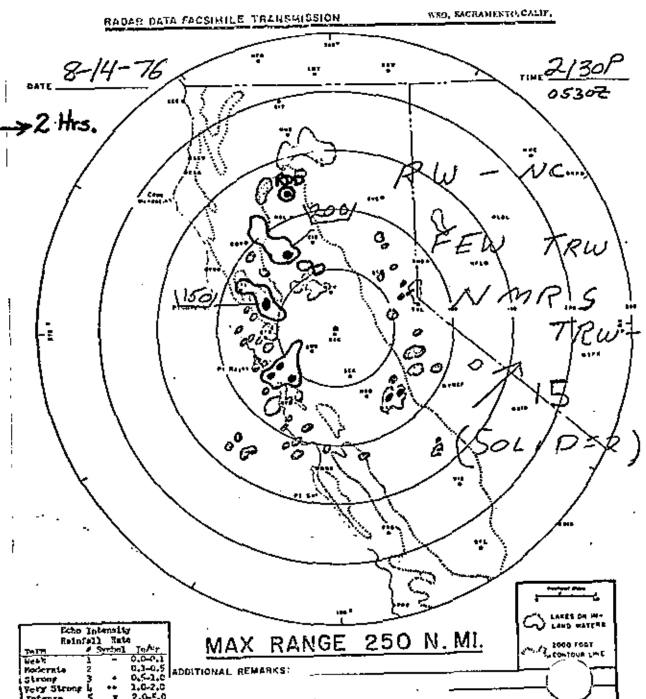

Figure 20

PRECIPITATION DEPTH-DURATION-FREQUENCY TABLE

STATION NO. BSN ORDER SUB	STATION NAME	ELEV	SEC	TWP	RNG	LOT	BWM	LATITUDE	LONGITUDE	COUNTY CODE
A00 7295 0	REDDING ISE	470						40.567	122.383	45

MAXIMUM PRECIPITATION FOR INDICATED DURATION D-DAYS H-HOURS

RETURN PERIOD IN YEARS	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	C-YR
2	.21	.31	.40	.53	.75	1.00	1.20	1.62	2.27	3.18	37.12
5	.28	.42	.54	.71	1.01	1.34	1.61	2.18	3.05	4.27	47.98
10	.33	.49	.63	.83	1.17	1.56	1.87	2.54	3.55	4.97	54.13
20	.37	.56	.71	.94	1.32	1.77	2.12	2.87	4.02	5.62	59.46
25	.39	.58	.73	.97	1.37	1.83	2.19	2.97	4.16	5.83	61.06
40	.39	.59	.75	.99	1.40	1.86	2.23	3.02	4.23	5.93	64.27
50	.43	.64	.81	1.07	1.52	2.02	2.42	3.28	4.60	6.44	65.74
100	.47	.70	.89	1.17	1.66	2.21	2.64	3.59	5.02	7.03	70.09
200	.51	.75	.96	1.26	1.79	2.39	2.86	3.88	5.43	7.61	74.19
1000	.59	.88	1.12	1.48	2.10	2.80	3.35	4.54	6.36	8.90	83.01
10000	.71	1.06	1.35	1.78	2.52	3.36	4.02	5.45	7.63	10.69	94.45
PMP	1.40	2.09	2.66	3.51	4.96	6.63	7.93	10.75	15.05	21.08	222.33
MEAN	.226	.335	.427	.564	.798	1.065	1.275	1.729	2.420	3.390	37.941
CLOCK HR. COR.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CALCULATED SKEW	.964	1.066	1.516	1.087	1.923	2.295	1.928	1.286	1.036	.637	.865
REGIONAL SKEW	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	.400
SDEW USED	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	.400
KURTOSIS	4.109	4.891	7.098	4.622	7.766	10.638	7.700	4.418	4.738	4.093	4.177
N	36	36	36	36	42	42	41	41	41	41	42
RECORD YEAR	1966	1942	1942	1966	1966	1966	1966	1966	1964	1964	1941
RECORD MAXIMUM	.500	.820	1.200	1.300	2.460	3.450	3.480	3.510	5.080	6.350	64.370
NORMALIZED MAX	2.589	3.059	3.592	2.818	3.869	4.338	3.683	2.784	3.155	2.950	2.757
CALC. COEF. VAR	.469	.473	.503	.464	.538	.516	.470	.370	.348	.296	.253
REGN. COEF. VAR	.348	.348	.348	.348	.348	.348	.348	.348	.348	.348	.324
USED COEF. VAR	.348	.348	.348	.348	.348	.348	.348	.348	.348	.348	.324
MEAN/A	.0060	.0088	.0113	.0149	.0210	.0281	.0336	.0456	.0638	.0893	1.0000
RP10/A	.0087	.0130	.0165	.0218	.0309	.0412	.0493	.0668	.0935	.1310	1.4266
RP25/A	.0102	.0152	.0194	.0255	.0362	.0483	.0578	.0783	.1096	.1536	1.6092
RP50/A	.0113	.0168	.0214	.0282	.0400	.0533	.0638	.0865	.1212	.1697	1.7327
RP100/A	.0123	.0183	.0234	.0308	.0436	.0582	.0697	.0945	.1323	.1853	1.8474
RP1000/A	.0156	.0232	.0296	.0390	.0552	.0738	.0883	.1197	.1675	.2346	2.1878
RP10000/A	.0188	.0279	.0355	.0468	.0663	.0885	.1059	.1436	.2011	.2816	2.4894
PMP/A	.0370	.0550	.0701	.0924	.1308	.1747	.2090	.2834	.3967	.5557	5.8600

PEARSON TYPE III DISTRIBUTION USED
PROBABLE MAXIMUM PRECIPITATION ESTIMATE BASED ON 15 STANDARD DEVIATIONS
WHERE N IS SMALL RESULTS ARE NOT DEPENDABLE

FIGURE 21

PRECIPITATION DEPTH-DURATION-FREQUENCY TABLE

STATION NO. RSN ORDER SUB	STATION NAME		ELEV	SEC	TWP	RNG	LOT	BMM	LATITUDE	LONGITUDE	COUNTY CODE
A00 7296 0	REDDING FS 2	119	577	35	32N	05W		M	40.583	122.400	45

MAXIMUM PRECIPITATION FOR INDICATED DURATION D-DAYS H-HOURS

RETURN PERIOD IN YEARS	1D	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	365D
2	3.14	4.26	4.94	5.37	5.81	6.24	6.95	7.73	8.88	9.96	12.15	17.85	36.48
5	4.12	5.61	6.52	7.10	7.63	8.23	9.15	10.39	12.32	13.98	16.89	24.97	47.39
10	4.78	6.52	7.56	8.25	8.84	9.56	10.62	12.16	14.61	16.67	20.05	29.71	54.30
20	5.41	7.37	8.55	9.34	9.98	10.82	12.01	13.84	16.77	19.21	23.03	34.20	60.65
25	5.60	7.64	8.86	9.68	10.34	11.21	12.45	14.36	17.45	20.00	23.97	35.60	62.61
40	6.00	8.20	9.50	10.38	11.09	12.02	13.35	15.45	18.86	21.65	25.91	38.51	66.65
50	6.19	8.46	9.80	10.71	11.43	12.41	13.77	15.96	19.52	22.42	26.81	39.88	68.53
100	6.77	9.25	10.72	11.72	12.50	13.57	15.06	17.52	21.53	24.78	29.59	44.05	74.22
200	7.34	10.03	11.63	12.71	13.54	14.72	16.33	19.04	23.50	27.09	32.31	48.13	79.74
1000	8.63	11.80	13.67	14.96	15.91	17.31	19.20	22.51	27.98	32.33	38.48	57.40	92.09
10000	10.42	14.26	16.52	18.08	19.20	20.92	23.20	27.32	34.21	39.62	47.06	70.30	108.97
PMP	19.30	26.47	30.64	33.59	35.55	38.82	43.04	51.24	65.13	75.83	89.66	134.31	216.08
MEAN	3.360	4.564	5.300	5.765	6.219	6.694	7.445	8.331	9.656	10.871	13.226	19.460	38.421
STANDARD DEV.	1.063	1.460	1.689	1.855	1.956	2.142	2.373	2.860	3.698	4.330	5.096	7.657	11.844
CLOCK HR. COR.	1.140	1.070	1.040	1.020	1.010	1.010	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CALCULATED SKEW	1.686	1.130	1.135	1.053	.895	.942	.625	.873	1.066	1.194	.766	.791	.379
REGIONAL SKEW	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.000
SKEW USED	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.000
KURTOSIS	7.963	4.556	4.494	4.219	3.783	3.985	3.402	4.273	4.741	5.404	3.274	3.582	2.463
N	74	74	73	75	75	74	75	75	75	75	75	75	76
RECORD YEAR	1965	1965	1965	1965	1965	1970	1970	1970	1970	1970	1970	1970	1941
RECORD MAXIMUM	7.300	9.460	11.120	11.820	12.270	13.500	14.130	18.180	24.060	28.840	28.840	43.930	68.870
NORMILIZED MAX	3.707	3.353	3.445	3.264	3.094	3.178	2.817	3.443	3.895	4.150	3.064	3.196	2.571
COEF. OF VAR.	.316	.320	.319	.322	.314	.320	.319	.343	.383	.398	.385	.393	.308
MEAN/A	.0874	.1188	.1380	.1500	.1619	.1742	.1938	.2168	.2513	.2829	.3442	.5065	1.0000
S.D/A	.0277	.0380	.0440	.0483	.0509	.0557	.0618	.0744	.0962	.1127	.1326	.1993	.3083
RP10/A	.1245	.1697	.1968	.2147	.2300	.2489	.2765	.3165	.3802	.4339	.5218	.7733	1.4132
RP25/A	.1458	.1989	.2306	.2518	.2692	.2918	.3240	.3738	.4542	.5205	.6239	.9266	1.6297
RP50/A	.1612	.2201	.2552	.2788	.2976	.3229	.3584	.4153	.5080	.5835	.6979	1.0379	1.7836
RP100/A	.1763	.2408	.2791	.3051	.3253	.3532	.3921	.4559	.5604	.6448	.7701	1.1464	1.9317
RP1000/A	.2245	.3071	.3558	.3893	.4141	.4505	.4998	.5858	.7283	.8415	1.0015	1.4940	2.3967
RP10000/A	.2711	.3711	.4299	.4706	.4998	.5444	.6038	.7111	.8904	1.0313	1.2249	1.8297	2.8363
PMP/A	.5024	.6889	.7974	.8742	.9254	1.0104	1.1201	1.3336	1.6950	1.9735	2.3336	3.4958	5.6238

FIGURE 22

PEARSON TYPE III DISTRIBUTION USED
PROBABLE MAXIMUM PRECIPITATION ESTIMATE BASED ON 15 STANDARD DEVIATIONS
WHERE N IS SMALL RESULTS ARE NOT DEPENDABLE

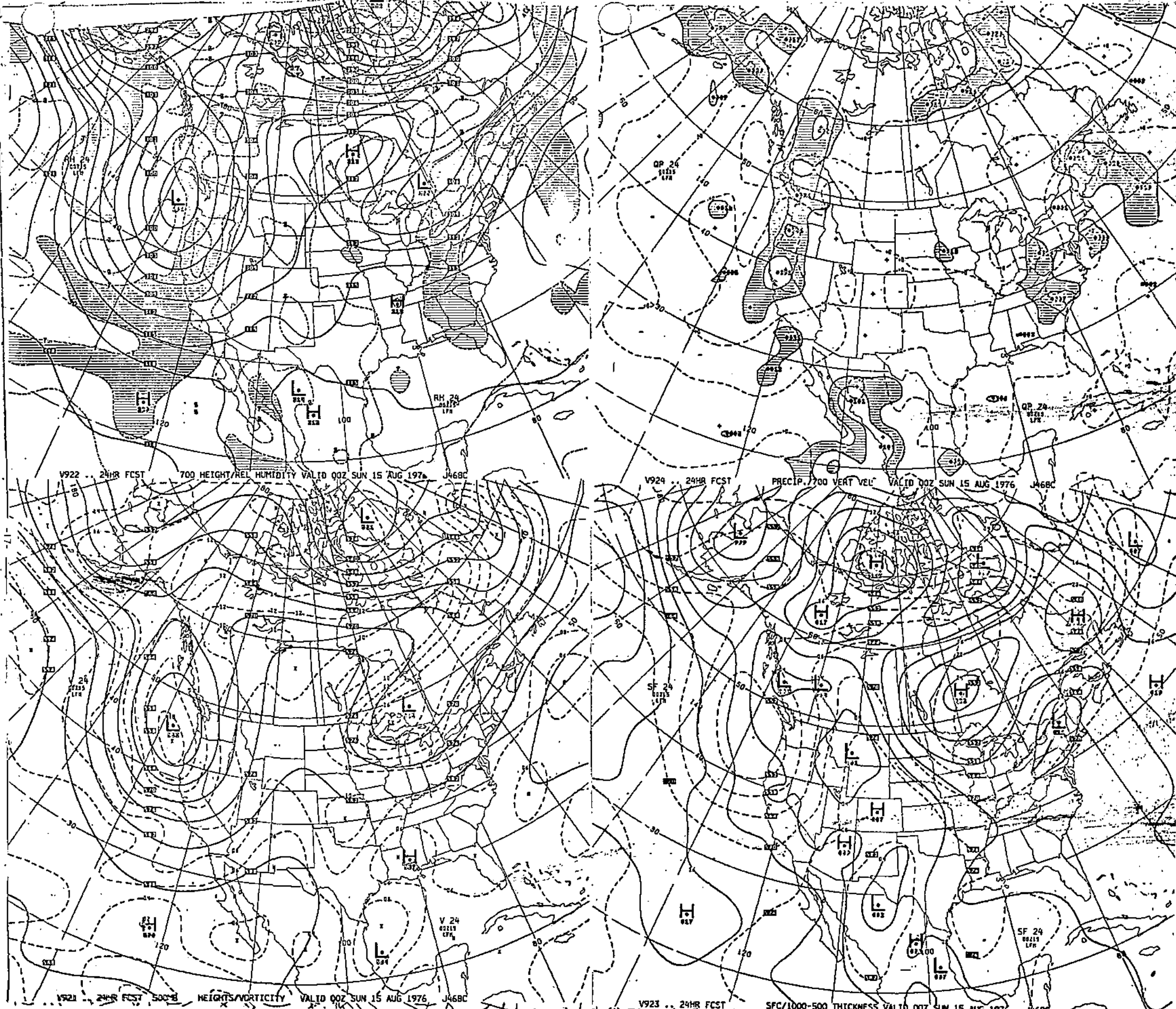

Figure 23. LFM 24-hr. Forecast Panels valid 0000Z August 15, 1976.

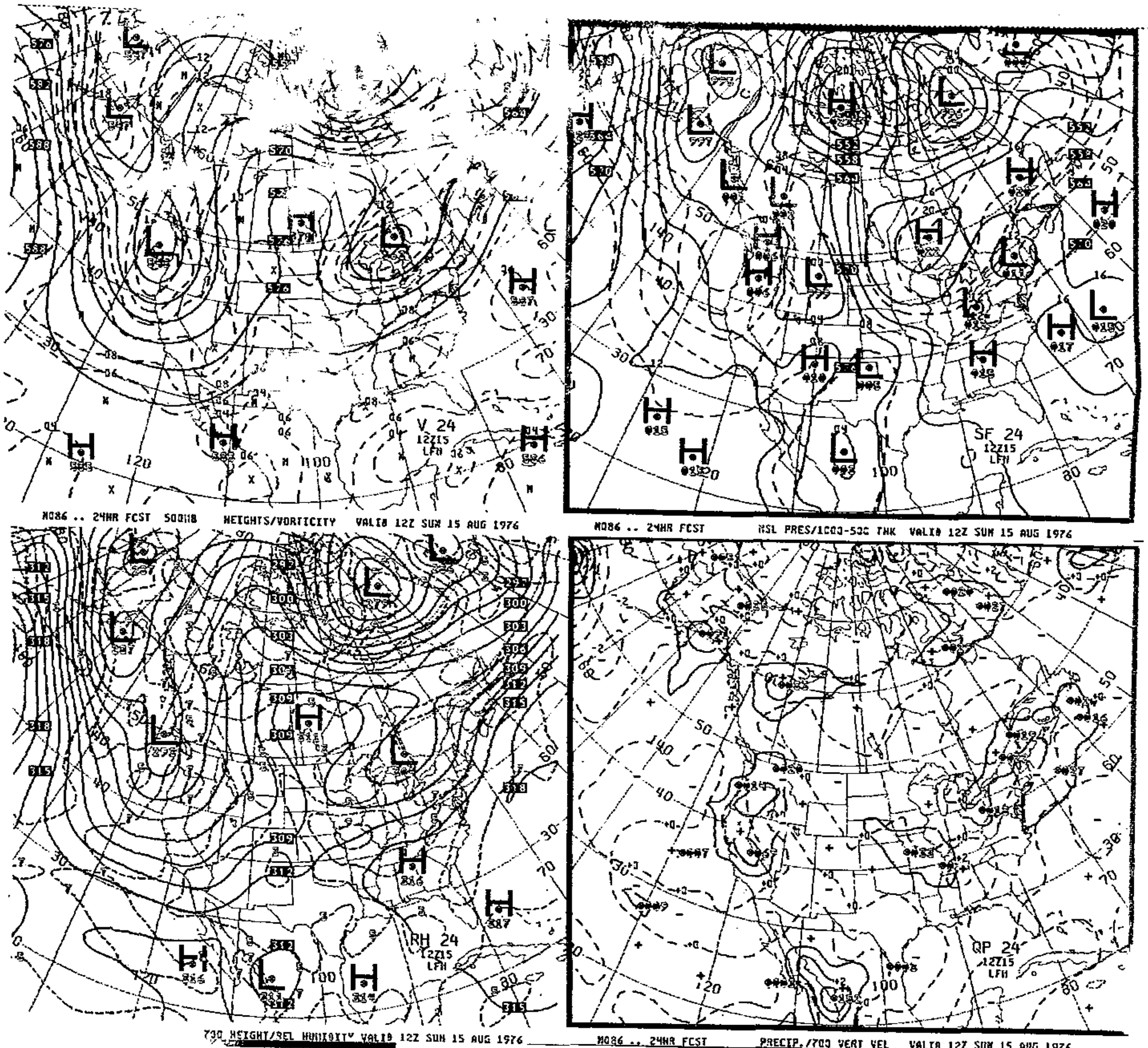

FIGURE 24. LFM 24-HR. FORECAST PANELS VALID 1200Z AUGUST 1976. BASED ON 12 HOURS LATER DATA THAN FIGURE 23).

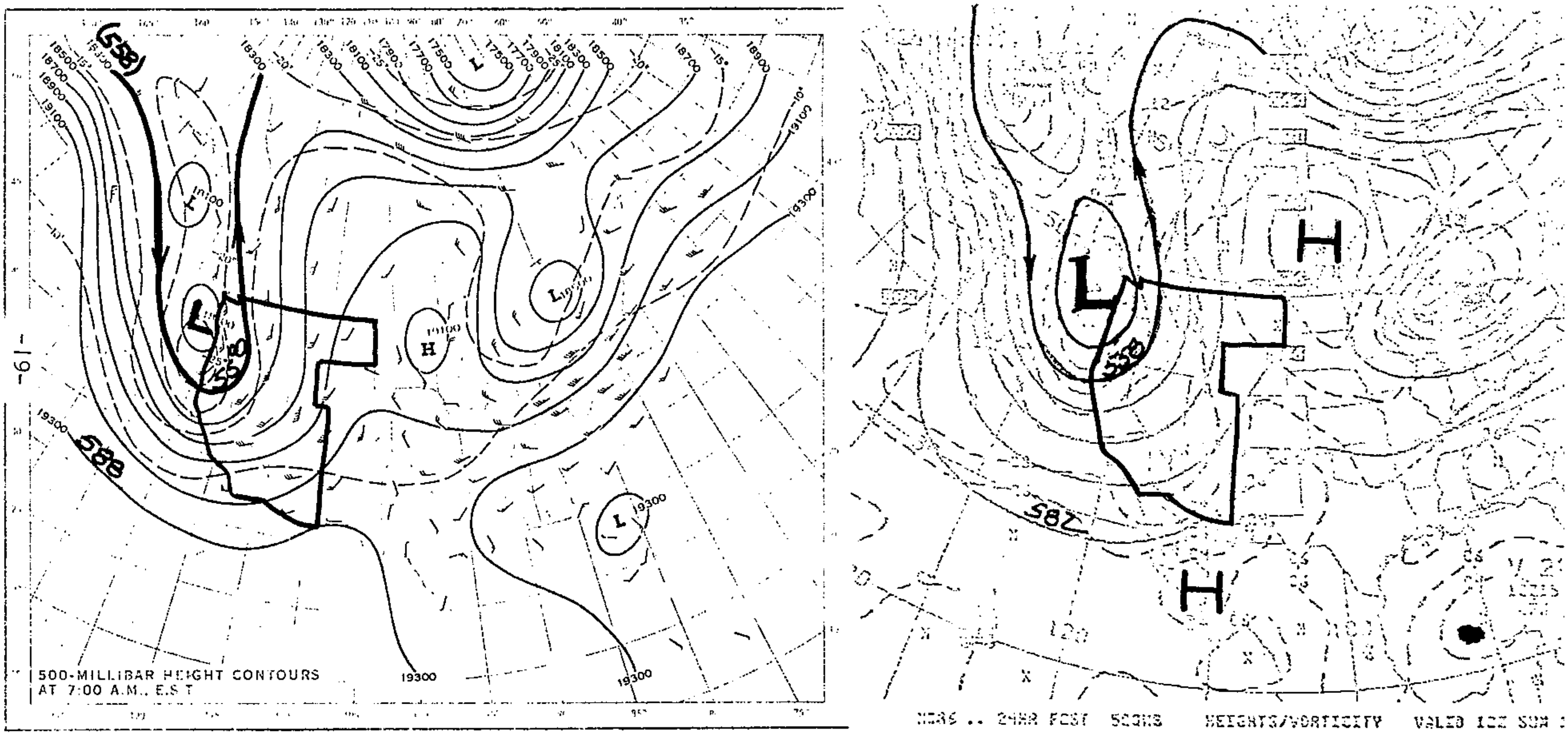

Figure 25. Verifying Analysis and 24-Hr. LFM 50-kPa Prognosis valid 12Z August 15, 1977.

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92 Smoke Management in the Willamette Valley. Earl M. Bates, May 1974. (COM-74-11277/AS)
93 An Operational Evaluation of 500-mb Type Stratified Regression Equations. Alexander E. MacDonald, June 1974. (COM-74-11407/AS)
94 Conditional Probability of Visibility Less than One-Half Mile in Radiation Fog at Fresno, California. John D. Thomas, August 1974. (COM-74-11555/AS)
95 Climate of Flagstaff, Arizona. Paul W. Sorenson, August 1974. (COM-74-11678/AS)
96 Map Type Precipitation Probabilities for the Western Region. Glenn E. Rasch and Alexander E. MacDonald, February 1975 (COM-75-10428/AS)
97 Eastern Pacific Cut-off Low of April 21-28, 1974. William J. Alder and George R. Miller, January 1976.(PB-250-711/AS)
98 Study on a Significant Precipitation Episode in the Western United States. Ira S. Brenner, April 1975. (COM-75-10719/AS)
99 A Study of Flash Flood Susceptibility--A Basin in Southern Arizona. Gerald Williams, August 1975. (COM-75-11360/AS)
100 A Study of Flash-Flood Occurrences at a Site Versus Over a Forecast Zone. Gerald Williams, August 1975. (COM-75-11404/AS)
102 A Set of Rules for Forecasting Temperatures in Napa and Sonoma Counties. Wesley L. Tuft, October 1975.(PB-246-902/AS)
103 Application of the National Weather Service Flash-Flood Program in the Western Region. Gerald Williams, January 1976. (PB-253-053/AS)
104 Objective Aids for Forecasting Minimum Temperatures at Reno, Nevada, During the Summer Months. Christopher D. Hill, January 1976. (PB-252-866/AS)
105 Forecasting the Mono Wind. Charles P. Ruscha, Jr., February 1976. (PV-254-650)
106 Use of MOS Forecast Parameters in Temperature Forecasting. John C. Plankinton, Jr., March 1976. (PB-254-649)
107 Map Types as Aid in Using MOS PoPs in Western United States. Ira S. Brenner, August 1976. (PB259594)
108 Other Kinds of Wind Shear. Christopher D. Hill, August 1976. (PB260437/AS)
109 Forecasting North Winds in the Upper Sacramento Valley and Adjoining Forests. Christopher E. Fontana, September 1976.
110 Cool Inflow as A weakening Influence on Eastern Pacific Tropical Cyclones. William J. Denney, November 1976. (PB 264655/AS)
111 Operational Forecasting Using Automated Guidance. Leonard W. Snellman, February 1977.
112 The MAN/MOS Program. Alexander E. MacDonald, February 1977. (PB 265941/AS)
113 Winter Season Minimum Temperature Formula for Bakersfield, California, Using Multiple Regression. Michael J. Oard, February 1977.
114 Tropical Cyclone Kathleen. James R. Fors, February 1977.
115 Program to Calculate Winds Aloft Using a Hewlett-Packard 25 Hand Calculator. Brian Finke, February 1977.
116 A Study of Wind Gusts on Lake Mead. Bradley Colman, April 1977.
117 The Relative Frequency of Cumulonimbus Clouds at the Nevada Test Site as a Function of K-value. R. F. Quiring, April 1977.
118 Moisture Distribution Modification by Upward Vertical Motion. Ira S. Brenner, April 1977.
119 Relative Frequency of Occurrence of Warm Season Echo Activity as a Function of Stability Indices Computed from the Yucca Flat, Nevada, Rawinsonde. Darryl Randerson, June 1977.
120 Some Meteorological Aspects of Air Pollution in Utah with Emphasis on the Salt Lake Valley. Dean N. Jackman and William T. Chapman, June 1977.
121 Climatological Prediction of Cumulonimbus Clouds in the Vicinity of the Yucca Flat Weather Station, R. F. Quiring, June 1977.
122 A Method for Transforming Temperature Distributions to Normality, Morris S. Webb, Jr., June 1977.

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