NOAA TM NWS WR 63

A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NOAA Technical Memorandum NWS WR63

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

700-MB Warm Air Advection as a Forecasting Tool for Montana and Northern Idaho

NORRIS E. WOERNER

Western Region

SALT LAKE CITY,
UTAH

February 1971

WESTERN REGION TECHNICAL MEMORANDA

The Technical Memorandum series provide an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready, for formal publication in the standard journals. The series are used to report on work in progress, to describe technical procedures and practices, or to report to a limited audience. These Technical Memoranda will report on investigation devoted primarily to Regional and local problems of interest mainly to Western Region personnel, and hence will not be widely distributed.

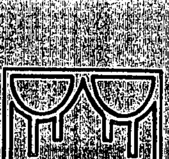
These Memoranda are available from the Western Region Headquarters at the following address: National Weather Service Western Region Headquarters, Attention SSD, P. O. Box 11188, Federal Building, Salt Lake City, Utah 84111.

The Western Region subseries of NOAA Technical Memoranda, No. 5 (revised edition), No. 10 and all others beginning with No. 24, are available also from the National Technical Information Service, U. S. Department of Commerce, Sills Building, Port Royal Road, Springfield, Va. 22151. Price: $3.00 paper copy; $0.65 microfiche. Order by accession number shown in parentheses at end of each entry.

Western Region Technical Memoranda:

No. 1* Some Notes on Probability Forecasting. Edward D. Diemer. September 1965.
No. 2 Climatological Precipitation Probabilities. Compiled by Lucianne Miller. December 1965.
No. 3 Western Region Pre- and Post-FP-3 Program. Edward D. Diemer. March 1966.
No. 4 Use of Meteorological Satellite Data. March 1966.
No. 5** Station Description of Local Effects on Synoptic Weather Patterns. Philip Williams, Jr. October 1969 (Revised). (PB-178 000)
No. 6 Improvement of Forecast Wording and Format. C. L. Glenn. May 1966.
No. 7 Final Report on Precipitation Probability Test Programs. Edward D. Diemer. May 1966.
No. 8* Interpreting the RAREP. Herbert P. Benner. May 1966. (Revised January 1967.)
No. 9 A Collection of Papers Related to the 1966 NMC Primitive-Equation Model. June 1966.
No. 10* Sonic Boom. Loren Crow (6th Weather Wing, USAF, Pamphlet). June 1966. (AD-479 366)
No. 11 Some Electrical Processes in the Atmosphere. J. Latham. June 1966.
No. 12* A Comparison of Fog Incidence at Missoula, Montana, with Surrounding Locations. Richard A. Dightman. August 1966.
No. 13* A Collection of Technical Attachments on the 1966 NMC Primitive-Equation Model. Leonard W. Snellman. August 1966.
No. 14 Application of Net Radiometer Measurements to Short-Range Fog and Stratus Forecasting at Los Angeles. Frederick Thomas. September 1966.
No. 15 The Use of the Mean as an Estimate of "Normal" Precipitation in an Arid Region. Paul C. Kangieser. November 1966.
No. 16 Some Notes on Acclimatization in Man. Edited by Leonard W. Snellman. November 1966.
No. 17 A Digitalized Summary of Radar Echoes Within 100 Miles of Sacramento, California.
No. 18 Limitations of Selected Meteorological Data. December 1966.
No. 19* A Grid Method for Estimating Precipitation Amounts by Using the WSR-57 Radar. R. Granger. December 1966.
No. 20* Transmitting Radar Echo Locations to Local Fire Control Agencies for Lightning Fire Detection. Robert R. Peterson. March 1967.
No. 21 An Objective Aid for Forecasting the End of East Winds in the Columbia Gorge. D. John Coparanis. April 1967.
No. 22 Derivation of Radar Horizons in Mountainous Terrain. Roger G. Pappas. April 1967.
No. 23 "K" Chart Application to Thunderstorm Forecasts Over the Western United States. Richard E. Hambidge. May 1967.
No. 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman. July 1967. (PB-178 071)
No. 25 Verification of Operational Probability of Precipitation Forecasts, April 1966-March 1967. W. W. Dickey. October 1967. (PB-176 240)
No. 26 A Study of Winds in the Lake Mead Recreation Area. R. P. Augulis. January 1958. (PB-177 830)
No. 27 Objective Minimum Temperature Forecasting for Helena, Montana. D. E. Olsen. Feb. 1968. (PB-177 827)
No. 28** Weather Extremes. R. J. Schmidli. April 1968. (PB-178 928)
No. 29 Small-Scale Analysis and Prediction. Philip Williams, Jr. May 1968. (PB-178 425)
No. 30 Numerical Weather Prediction and Synoptic Meteorology. Capt. Thomas D. Murphy, U.S.A.F. May 1968. (AD-673 365)

* Out of Print
** Revised



A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

NOAA Technical Memorandum NWSTM WR-63

700-MB WARM AIR ADVECTION AS A FORECASTING TOOL FOR MONTANA AND NORTHERN IDAHO

Norris E. Woerner
Weather Service Forecast Office
Great Falls, Montana

WESTERN REGION
TECHNICAL MEMORANDUM NO. 63

SALT LAKE CITY, UTAH
FEBRUARY 1971

TABLE OF CONTENTS

LIST OF FIGURES

EDITOR'S NOTE

This paper was originally published as a Western Region Technical Note No. 1, dated December 1965. This publication series was discontinued after five issues and in many stations the publications have been lost or misplaced. Since this paper is a good forecast technique reference with the principles discussed applicable to most of the Western Region, we are incorporating it, with minor revisions, into our Technical Memorandum Series.

L. W. Snellman

L. W. Snellman, Chief
Scientific Services Division

700-MB WARM AIR ADVECTION AS A FORECASTING TOOL FOR MONTANA AND NORTHERN IDAHO

I. INTRODUCTION

The purpose of this report is to describe and show synoptic weather patterns and case histories in which 700-mb level warm air advection was one of the important tools in forecasting precipitation over Montana and northern Idaho. Because of the mountainous terrain, it is felt that the 700-mb chart represents more clearly the temperature advection, wind field, and available moisture than either the 850-mb or 500-mb charts.

In this report three ideal 700-mb flow patterns with wind direction from the southwest, west, and north will be shown. A case study will be presented for each flow pattern and will show the 12-hour synoptic trend at the surface and 700-mb levels, usually 12 to 24 hours prior to the onset of precipitation. From the 12-hour synoptic trend, a basic criterion is established to be used as a guide in the forecasting of warm air advection precipitation.

II. AREA OF STUDY

This study is particularly aimed at the Great Falls FAWS forecasting area of Montana and northern Idaho, but effects described usually extend westward to the Pacific coast and northward into Canada.

III. PHYSICAL REASONING

In the analysis of the 700-mb chart, it is possible in many cases to identify areas of appreciable vertical motion, either upward or downward. This is done by simply noting intersections of isotherms with contours. In middle latitudes, at the 700-mb level, one usually finds that under most weather patterns, isotherms are not advected with the speed of the winds but rather at a slower rate. The stronger the wind field upstream and the more pronounced the intersection of the isotherms with the contours, the greater will be the vertical motion. If warm advection continues long enough and sufficient moisture is present, precipitation will occur.

The adiabatic equation for vertical velocity [1] is as follows:

$$W = -\frac{\frac{\partial T}{\partial t} + V\frac{\partial T}{\partial S}}{\gamma_d - \gamma}$$

where,

W = vertical velocity in cm/sec.

$\frac{\partial T}{\partial t}$ = temperature tendency, usually 12-hour change.

$V \frac{\partial T}{\partial S}$ = product of gradient wind speed and the spacing of the isotherms along the contours = temperature advection.

γ_d = dry adiabatic lapse rate.

γ = actual lapse rate.

If C is the speed with which an isotherm moves along a streamline, then $\frac{\partial T}{\partial t} = - C \frac{\partial T}{\partial S}$ and the adiabatic equation becomes:

$$W = - \frac{(V - C) \frac{\partial T}{\partial S}}{\gamma_d - \gamma}$$

From the adiabatic equation, the vertical motion is seen to be directly proportional to the temperature gradient and the deficiency of movement of the isotherms with respect to the gradient wind. With indicated warm advection the air is ascending, and with indicated cold advection, descending.

The following basic criteria should be met in the forecasting of warm air advection precipitation:

1. Pronounced warm air advection upstream.
2. Good source of moisture.
3. Wind field upstream should be stronger than over the forecast area.
4. Preferably, a minor upper trough to move into the forecast area.

IV. 700-MB SOUTHWESTERLY PATTERN

The 700-mb southwesterly warm air advection pattern is normally brought about by the combination of a polar high over Montana and northern Idaho, and a surface frontal system with associated minor upper trough moving northeastward through northern California and southern Oregon. The surface frontal system will usually come in strong on the coast but weaken considerably during the next 12 to 24 hours, and can often be followed to the south of the polar high. The typical 700-mb flow pattern is shown in Figure 1. Because of the southerly trajectory, an abundant supply of moisture will accompany these systems resulting in moderate to heavy precipitation, mostly snow, over most sections of Montana and northern Idaho. In the example given for February 15, 1959 (Figures 2 and 3), which show the synoptic change through a 12-hour period, the polar air mass had moved into Montana and was accompanied by scattered light snows of short duration. Precipitation from the polar system at Great Falls resulted in less than 1 inch of snow on the ground with a moisture content of .01 inch. Warm air advection precipitation began early on the 16th of February, and by late forenoon and early afternoon, extended into all sections of Montana and northern Idaho. The snow continued for the next 30+ hours and was reported as moderate to heavy at times. Locally in Great Falls the storm left 12 inches of new snow on the ground with a moisture content of .76 inch.

Figure 4 shows precipitation occurrences at 6-hourly intervals from 0500 MST on February 15 to 1100 MST February 16, 1959. Note that by late evening on the 15th, precipitation associated with the polar front had ended throughout Montana and northern Idaho and also note the erratic but rapid increase in precipitation from the warm air advection early on the 16th. The basic criteria for warm air advection precipitation had been met, namely:

1. Strong warm air advection.
2. Good moisture supply.
3. Stronger wind field directly upstream.
4. Minor trough aloft approaching as indicated by 700-mb height falls.

V. 700-MB WESTERLY PATTERN

The 700-mb westerly pattern is similar to the southwesterly pattern, with a polar air mass over Montana and northern Idaho, and a Pacific weather system approaching the West Coast. The Pacific system provides the moisture, and the warm air advection, of course, lies east of the Pacific front. Figure 5 shows the typical 700-mb flow pattern associated with this type.

In the example given for 1700 MST January 22 through 0500 MST January 25, 1964, Figures 6 and 7 show the surface and 700-mb synoptic trend through a 12-hour period, and Figure 8 shows the flow at the 700-mb level through 0500 MST January 25. Note from Figures 6 and 7 the eastward advance of the warm advection and moisture increase from observation stations at longitude 135°W. and ship Papa.

Precipitation from this system reached the Washington-Oregon coast during the evening of January 23 and spread eastward at a fairly steady rate, reaching extreme eastern Montana during the forenoon of January 25. Figure 9 shows the 12-hour eastward movement of the edge of the precipitation area.

The warm air advection precipitation was quite extensive and from the Weather Depiction Chart at 1800 MST January 24, precipitation extended from the Continental Divide in Montana westward to the Pacific coast. This is a much larger area of weather than that which would have been indicated from the area of positive 500-mb vorticity advection (not shown). The 700-mb and surface progs for January 24 along with the progged 1000 - 500-mb thickness lines indicated strong warm air advection approaching the West coast. Upward motion was indicated on the vertical velocity progs.

VI. 700-MB NORTHERLY PATTERN

The 700-mb northerly warm air advection pattern (Figure 10) occurs rather infrequently and is the most difficult to forecast. One of the most important things for the forecaster to recognize is that when under a meridional flow, with a polar air mass over Montana, he should be alert for both the warm air advection and moisture moving inland upstream. From examples of this particular weather pattern studied to date, the lowering of cloudiness and the precipitation have first appeared over the central sections of Alberta.

The rapidly developing system of December 10 - 11, 1963, is shown in Figures 11 and 12. In Figure 11 note the strong warm air advection and moisture working inland and downstream in Yukon Territory. The frontal system on the Surface Synoptic Chart for 0500 MST December 11, was analyzed by the Canadians as a Maritime Trowal and by the Washington Analysis Center as a strong cold front. A small area of snow was reported in the immediate frontal zone. However, during the forenoon snow developed well ahead of the front in the central sections of Alberta and by early afternoon in the central sections of Montana. Figure 13 shows frontal positions and the time snow began south of the front in Alberta and Montana.

It appears in the above example that available moisture for the warm air advection precipitation reached the central sections of Alberta during the early forenoon when snow first began at Rocky Mountain House (RM). Snow could then be expected to increase and develop downstream.

VII. CONCLUSIONS

Warm air advection precipitation over Montana and northern Idaho is well indicated on the 700-mb chart and will occur with wind directions from the southwest through west to north. Available moisture is one of the critical parameters in forecasting warm air advection precipitation. The logical procedure is to go upstream and look for an increase and lowering of cloudiness and precipitation. The implied upward vertical motion from warm air advection can be occurring, but if sufficient moisture is not available, then the forecast has to be modified accordingly.

Warm air advection precipitation is very critical to aviation interests because of the rapid development and deterioration of weather over a large area. Weather associated with these systems is not the type in which there is a gradual lowering of cloudiness from high cirrus through the middle and low type clouds, but rather goes from cirrus to snow ceilings of less than 1000 feet and 1 mile visibility within an hour or two. Also, systems moving from the southwest and west will produce moderate to heavy icing conditions.

With the weather usually developing well upstream in Washington and Oregon, the southwesterly and westerly 700-mb patterns should be the easiest to recognize, while with the northerly pattern, weather will often develop just a short distance upstream and is, therefore, the most difficult to forecast with any appreciable warning.

If there are southwest winds along the east slopes of the Rockies in Montana suggesting the lack of CP air mass or only a weak one, then precipitation east of the Continental Divide will be confined generally to the mountain sections of the west portion for the 700-mb southwesterly and westerly patterns. With the 700-mb northerly pattern, snow can occur with strong southwesterly downslope winds and extend into all sections east of the Divide.

In summary, the forecasting problem and guidance may be stated thus: With Montana under the influence of a cold air mass, the forecaster should be alerted to look upstream for:

1. Warm air advection.
2. Moisture supply.
3. Stronger wind field directly upstream than over the forecast area.
4. Minor trough aloft, usually indicated only by height falls.

Other guidance that should be used for warm air advection is the prognostic wind field below 20,000 feet and the prognostic thickness lines (mean isotherms).

VIII. ACKNOWLEDGMENTS

My sincere thanks to Carlos R. Dunn, formerly Systems Development Office (presently Chief, SSD, ERH), U. S. Weather Bureau, Washington, D. C.; Philip Williams, Jr., and C. L. Glenn, Salt Lake City; and to the Great Falls forecasting staff for their aid and advice during the writing of this paper.

IX. REFERENCES

1. S. Petterssen, Weather Analysis and Forecasting, Second Edition, Vol. I, 1956, pp. 292 - 297.

2. C. R. Dunn, "Forecasting Precipitation with the Aid or Vorticity Advection at the 500-mb Level," OFDEV Technical Note No. 9, June 1962, (Manuscript of the U. S. Weather Bureau).

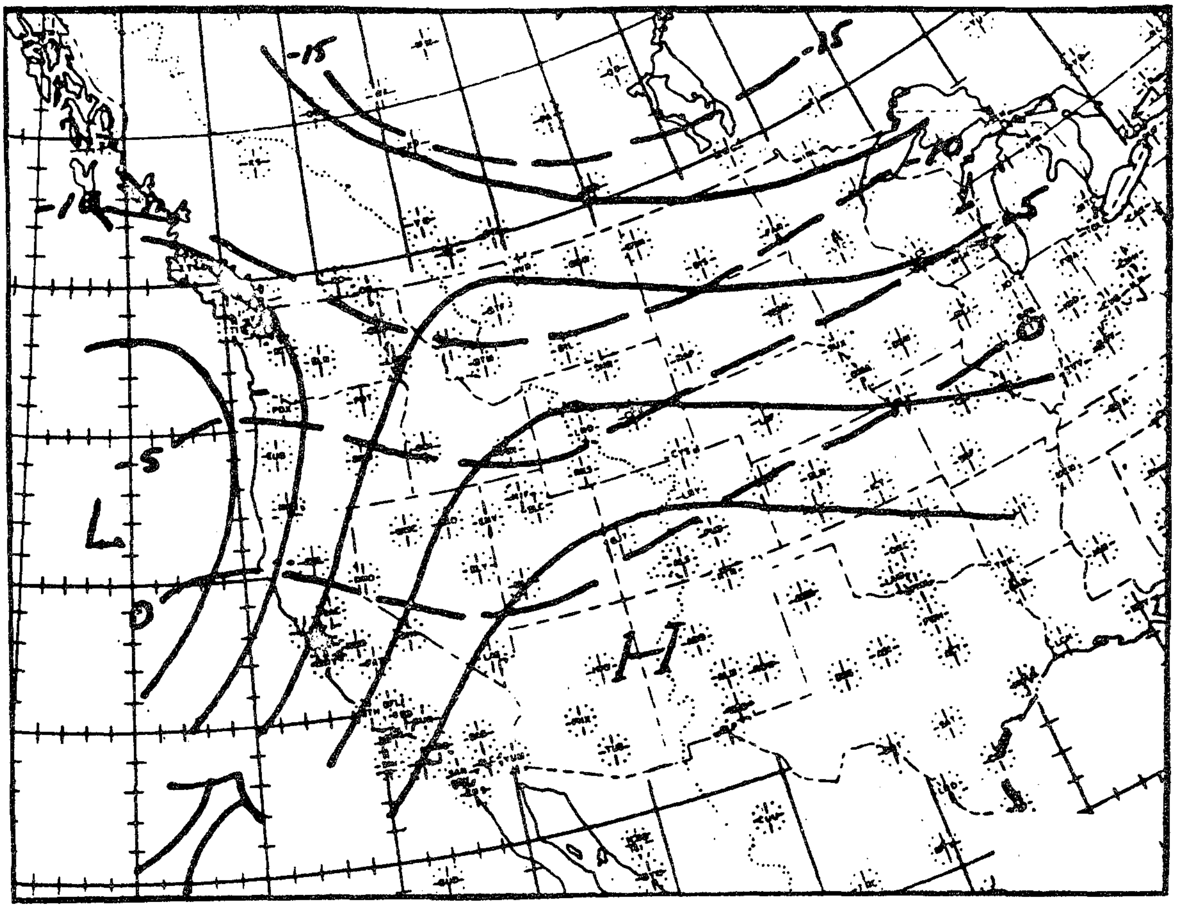


Figure 1. 700 mb southwesterly warm air advection pattern. Contours are solid lines, isotherms dashed; moisture source is shown by arrow.

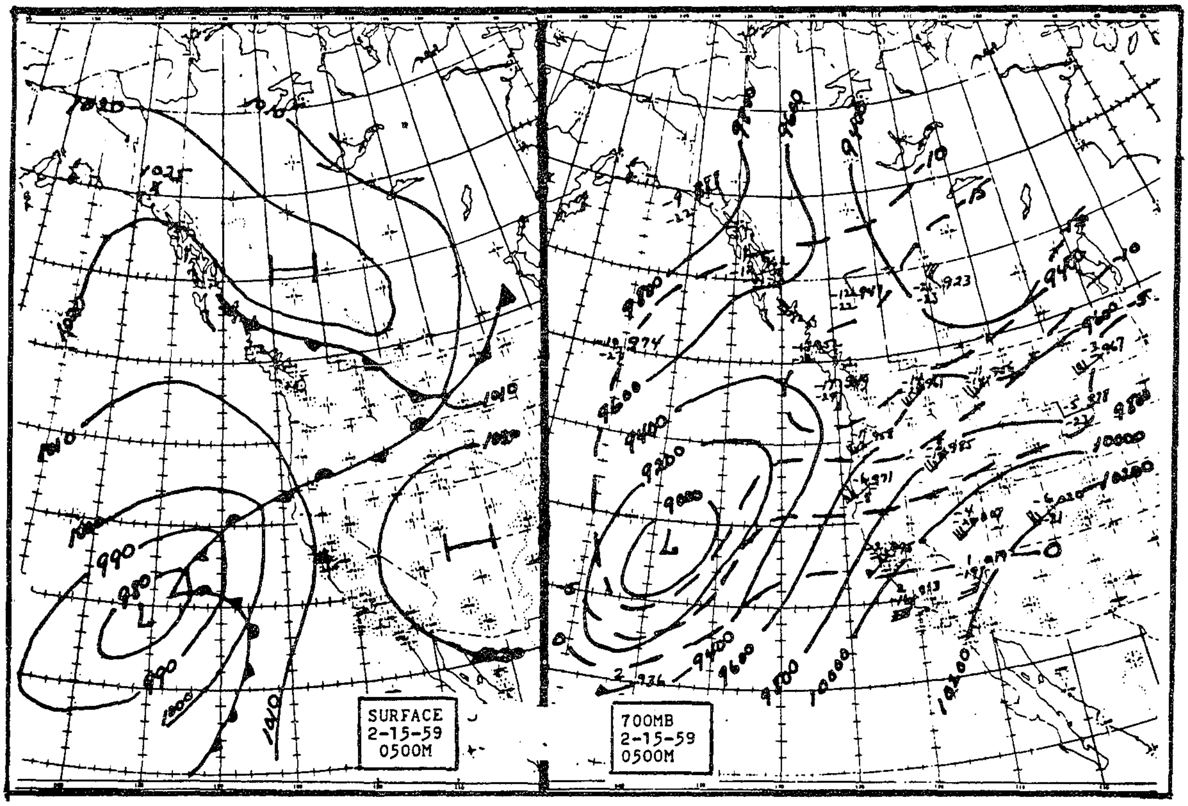


Figure 2. Surface and 700-mb maps for 0500 MST, February 15, 1959.

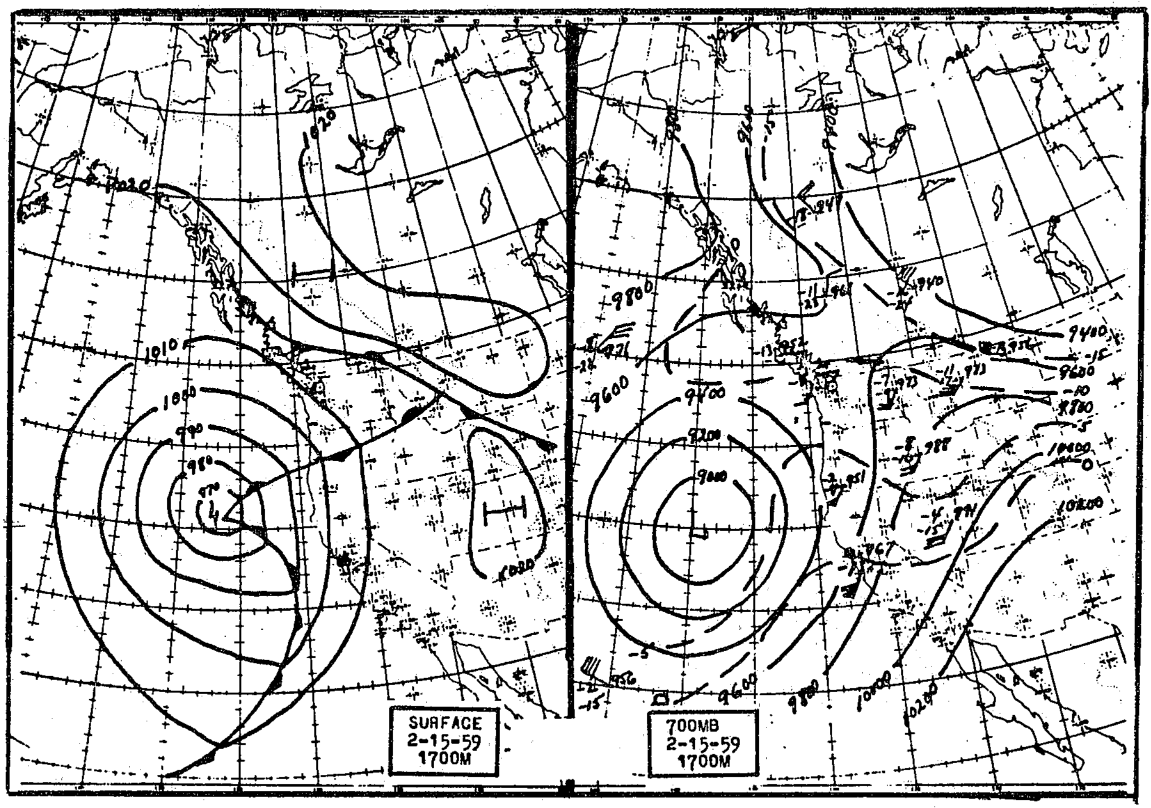


Figure 3. Surface and 700-mb maps for 1700 MST, February 15, 1959.

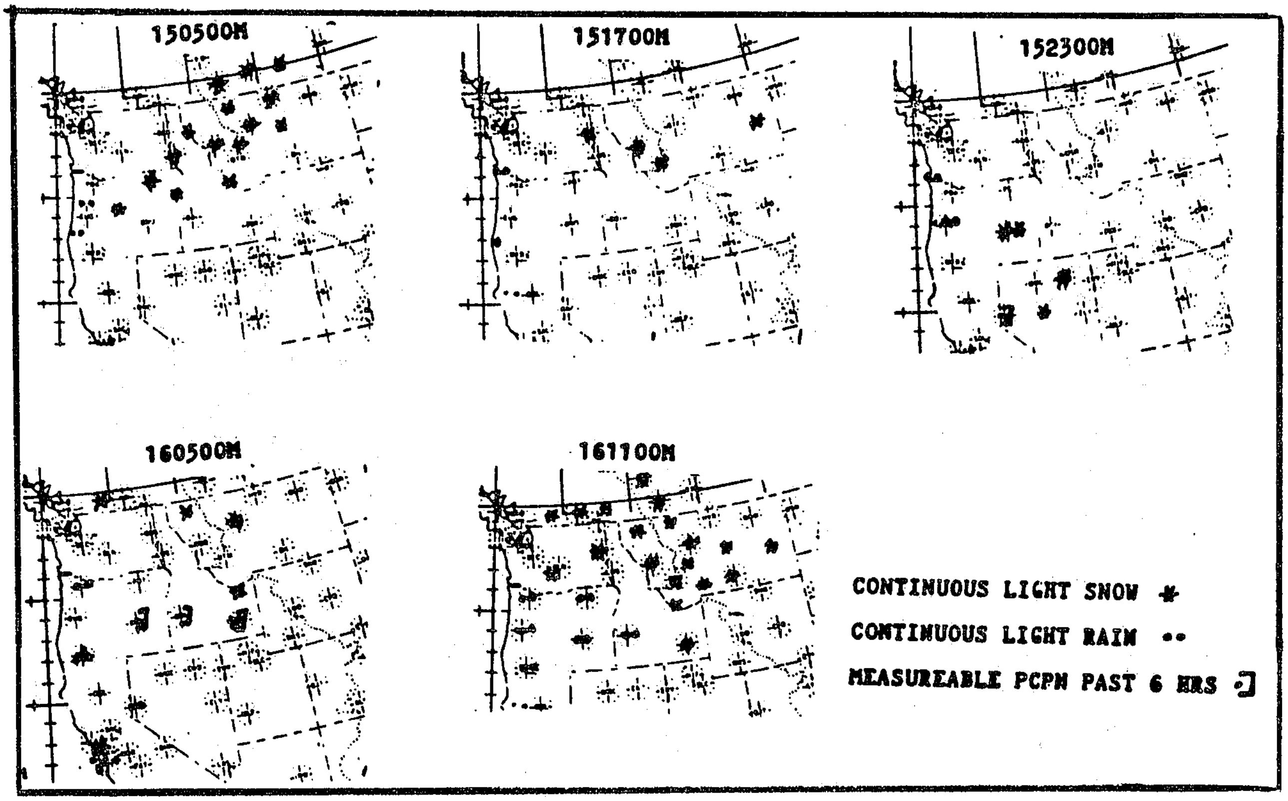


Figure 4. Precipitation occurrences at 6-hourly intervals, 0500 MST February 15 to 1100 MST February 16, 1959.

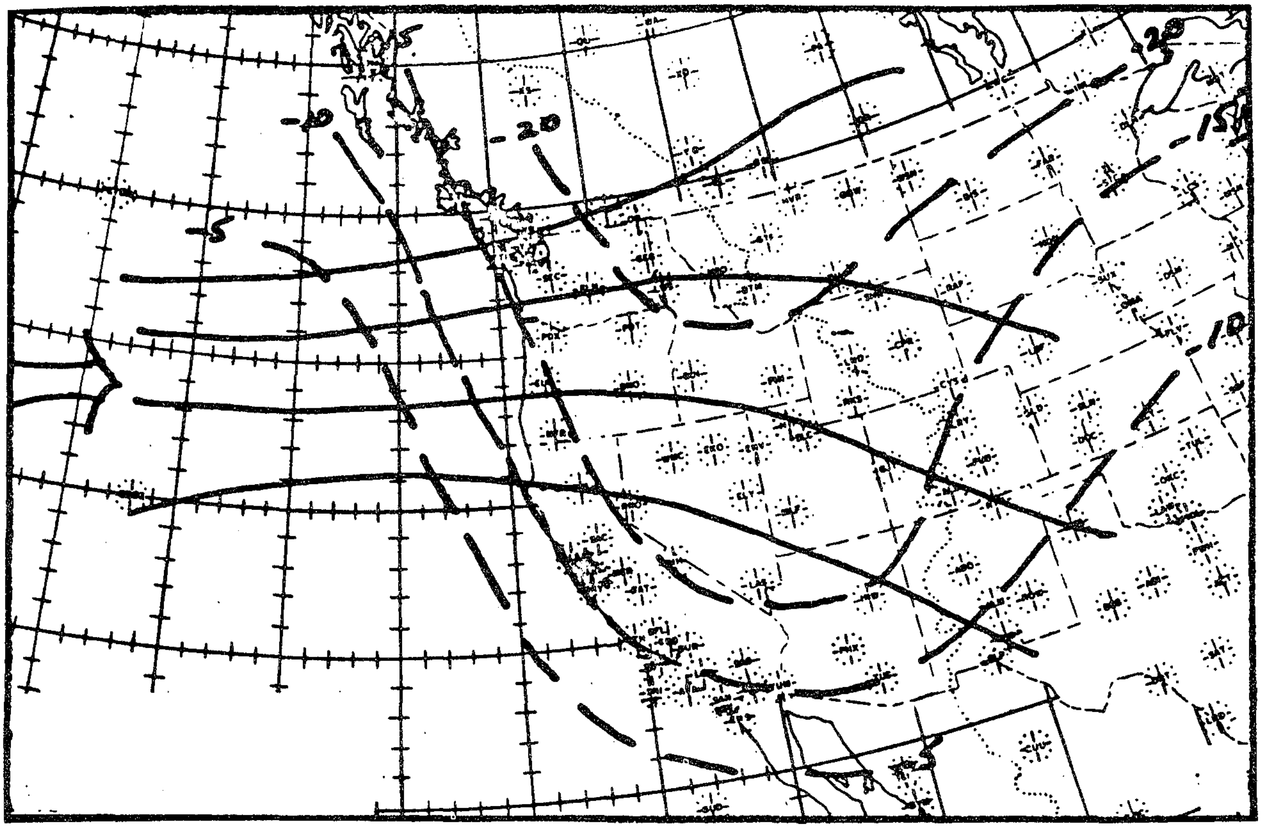


Figure 5. 700 mb westerly warm air advection pattern. Contours are solid lines; isotherms dashed; moisture source is shown by arrow.

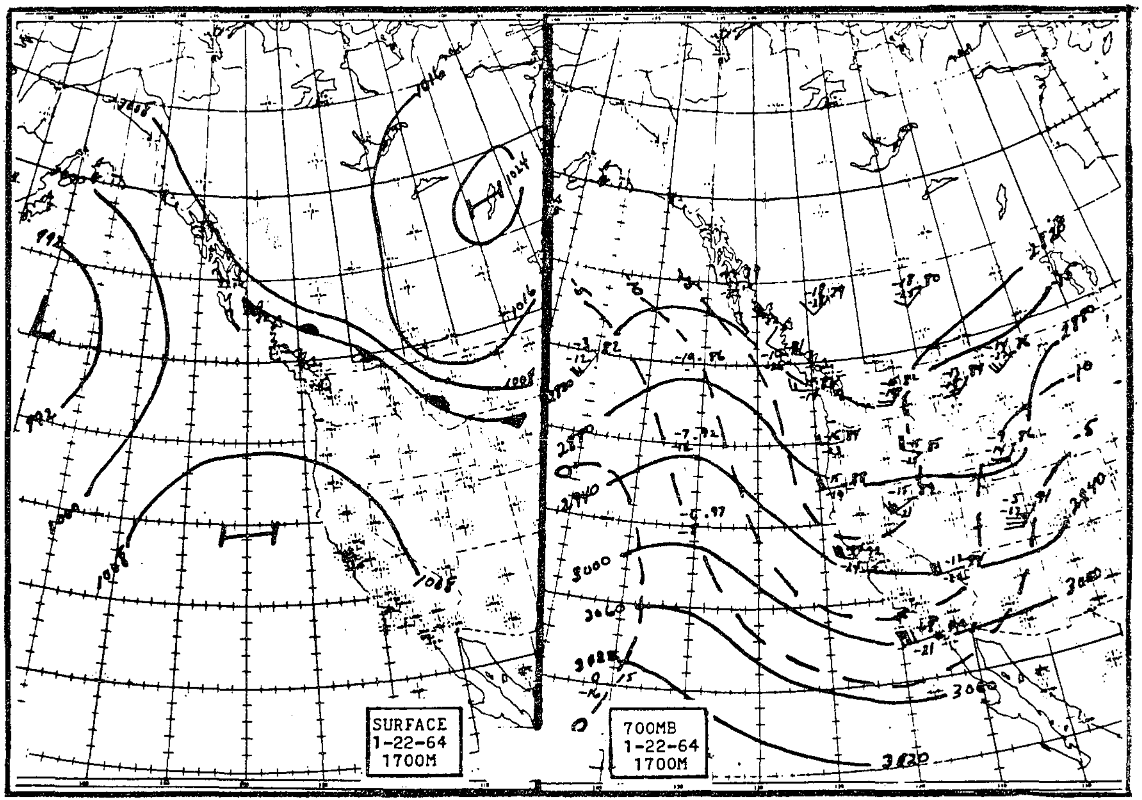


Figure 6. Surface and 700-mb maps for 1700 MST, January 22, 1964.

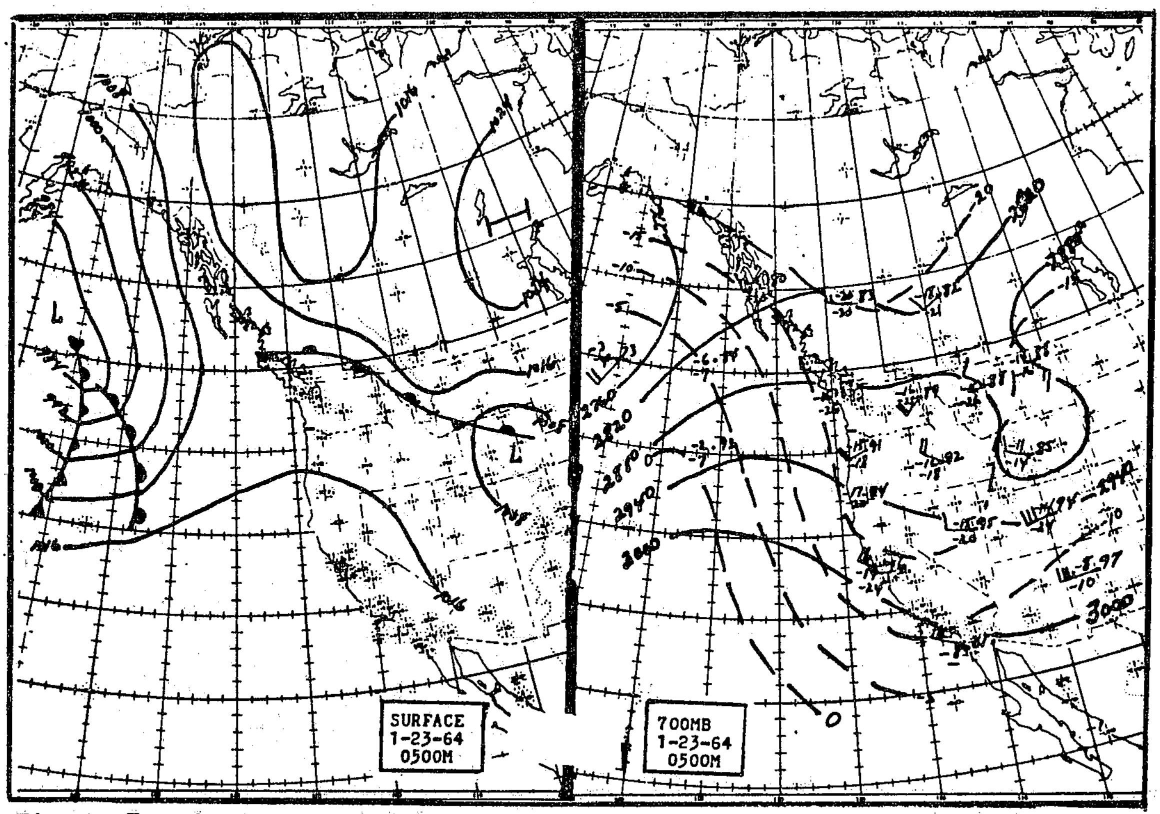


Figure 7. Surface and 700-mb maps for 0500 MST, January 23, 1964.

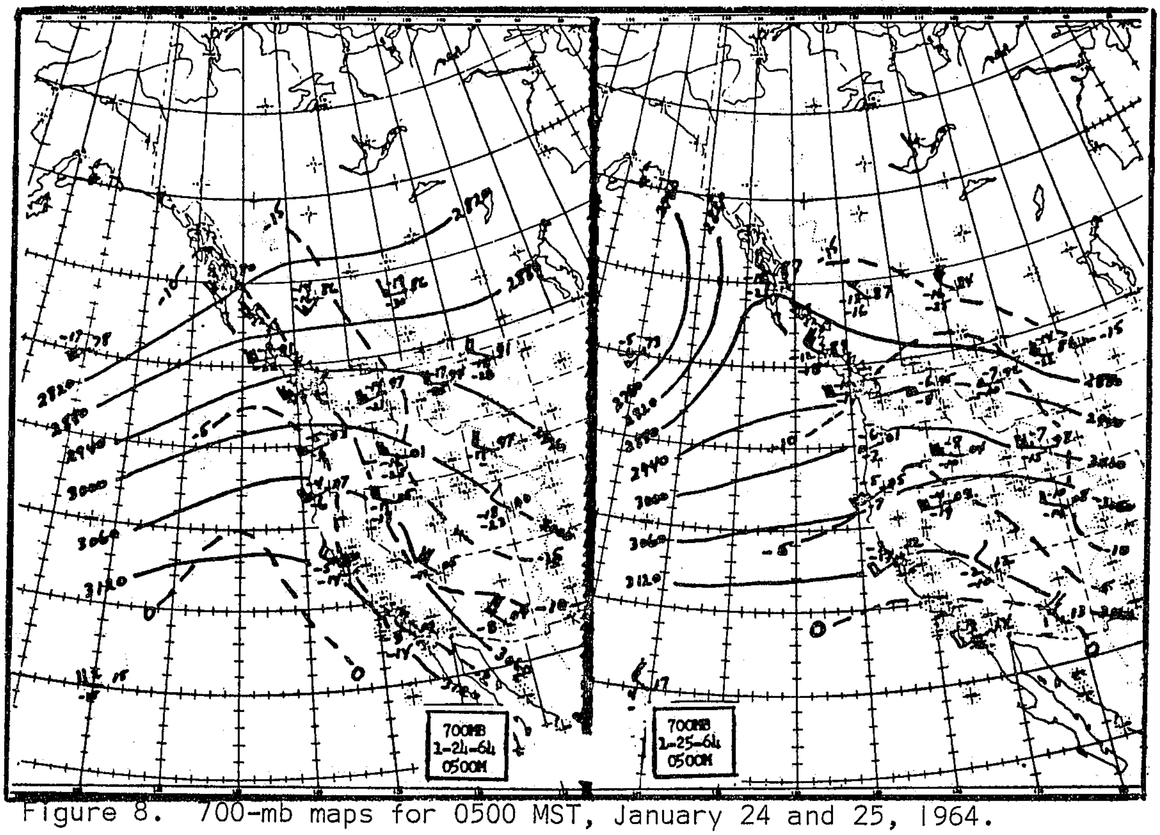


Figure 8. 700-mb maps for 0500 MST, January 24 and 25, 1964.

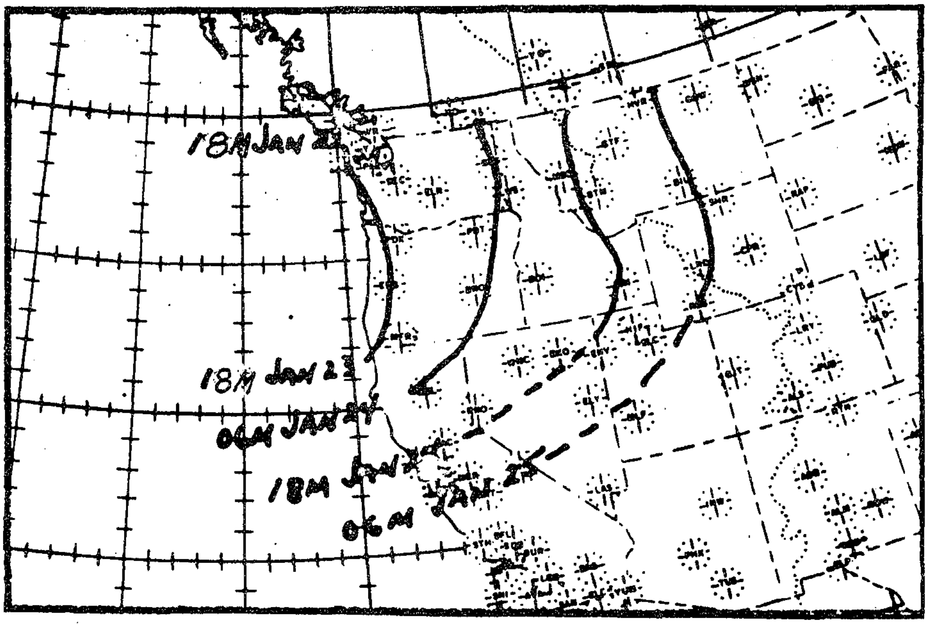


Figure 9. Eastern edge of precipitation at 12-hour intervals 1800 MST, January 23 to 0600 MST, January 25, 1964 (taken from Weather Depiction Charts).

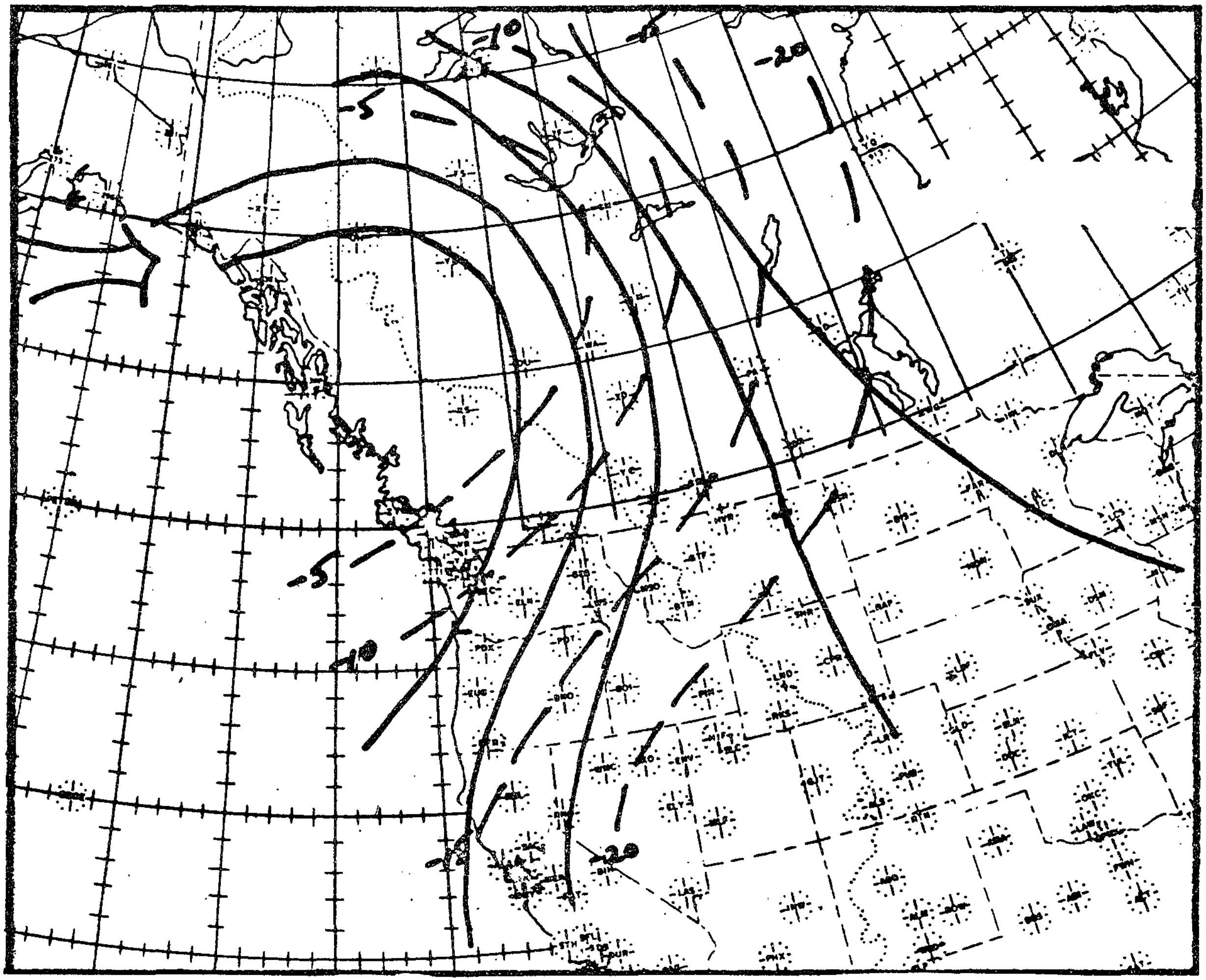


Figure 10. 700 mb northerly warm air advection pattern. Contours are solid lines; isotherms dashed; moisture source shown by arrow.

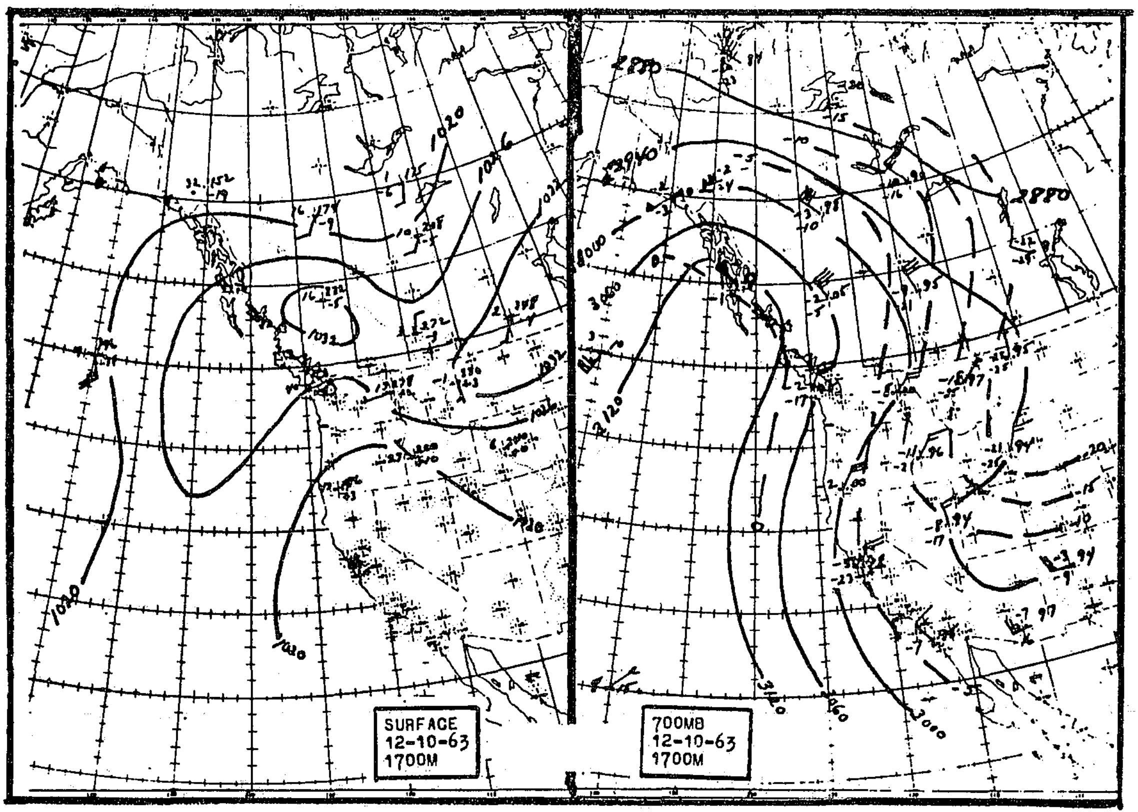


Figure 11. Surface and 700-mb maps for 1700 MST, December 10, 1963.

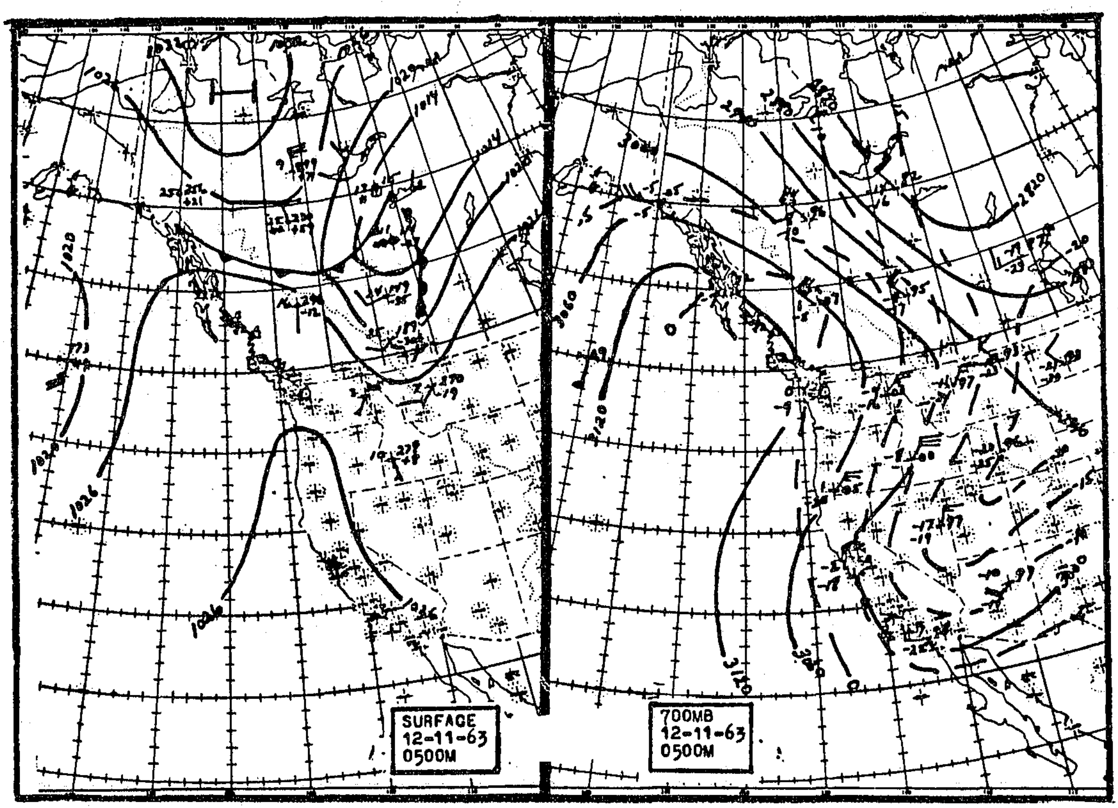


Figure 12. Surface and 700-mb maps for 0500 MST, December 11, 1963.

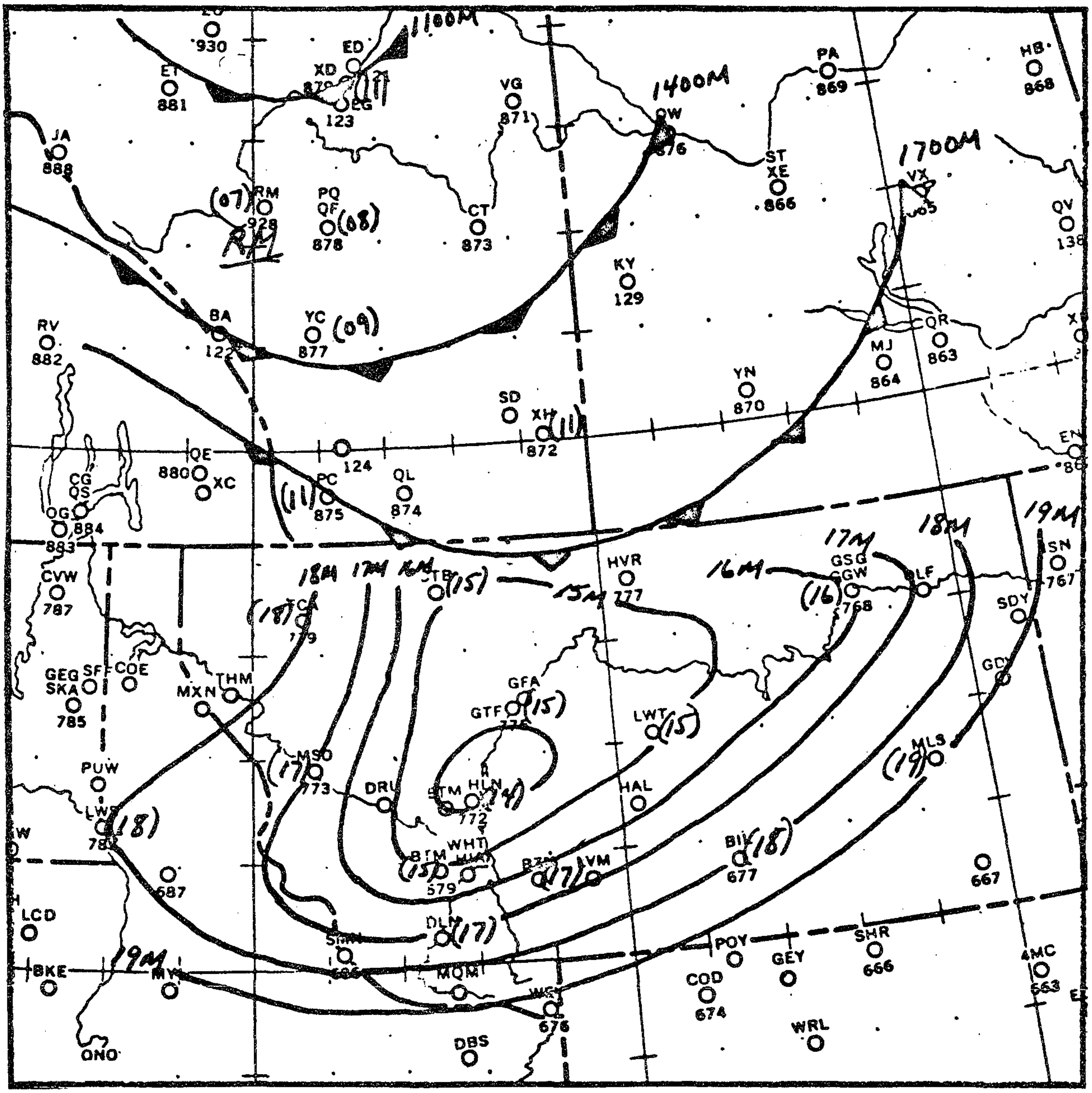


Figure 13. Positions of the advancing surface cold front in Alberta on December 11, 1963 and isochrones of time (MST) of beginning of snow in Montana. Time of snow onset at each station shown in parentheses.

Western Region Technical Memoranda: (Continued)

No. 31* Precipitation Detection Probabilities by Salt Lake ARTC Radars. Robert K. Belesky. July 1968. (PB-179 084)
No. 32 Probability Forecasting in the Portland Fire Weather District. Harold S. Ayer. July 1968. (PB-179 289)
No. 33 Objective Forecasting. Philip Williams, Jr. August 1968. (AD-680 425)
No. 34 The WSR-57 Radar Program at Missoula, Montana. R. Granger. October 1968. (PB-180 292)
No. 35** Joint ESSA/FAA ARTC Radar Weather Surveillance Program. Herbert P. Benner and DeVon B. Smith. December 1968. (AD-681 857)
No. 36* Temperature Trends in Sacramento--Another Heat Island. Anthony D. Lentini. February 1969. (PB0183 055)
No. 37 Disposal of Logging Residues Without Damage to Air Quality. Owen P. Cramer. March 1969. (PB-183 057)
No. 38* Climate of Phoenix, Arizona. R. J. Schmidli, P. C. Kangieser, and R. S. Ingram. April 1969. (PB-184 295)
No. 39 Upper-Air Lows Over Northwestern United States. A. L. Jacobson. April 1969. (PB-184 296)
No. 40 The Man-Machine Mix in Applied Weather Forecasting in the 1970s. L. W. Snellman. August 1969. (PB-185 068)
No. 41 High Resolution Radiosonde Observations. W. W. Johnson. August 1969. (PB-185 673)
No. 42 Analysis of the Southern California Santa Ana of January 15-17, 1966. Barry B. Aronovitch. August 1969. (PB-185 670)
No. 43 Forecasting Maximum Temperatures at Helena, Montana. David E. Olsen. October 1969. (PB-185 762)
No. 44 Estimated Return Periods for Short-Duration Precipitation in Arizona. Paul C. Kangieser. October 1969. (PB-187 763)
No. 45/1 Precipitation Probabilities in the Western Region Associated with Winter 500-mb Map Types. Richard P. Augulis. December 1969. (PB-188 248)
No. 45/2 Precipitation Probabilities in the Western Region Associated with Spring 500-mb Map Types. Ricahrd P. Augulis. January 1970. (PB-189 434)
No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 414)
No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 435)
No. 46 Applications of the Net Radiometer to Short-Range Fog and Stratus Forecasting at Eugene, Oregon. L. Yee and E. Bates. December 1969. (PB-190 476)
No. 47 Statistical Analysis as a Flood Routing Tool. Robert J. C. Burnash. December 1969. (PB-188 744)
No. 48 Tsunami. Richard P. Augulis. February 1970. (PB-190 157)
No. 49 Predicting Precipitation Type. Robert J. C. Burnash and Floyd E. Hug. March 1970. (PB-190 962)
No. 50 Statistical Report of Aeroallergens (Pollens and Molds) Fort Huachuca, Arizona 1969. Wayne S. Johnson. April 1970. (PB-191 743)
No. 51 Western Region Sea State and Surf Forecaster's Manual. Gordon C. Shields and Gerald B. Burdwell. July 1970. (PB-193 102)
No. 52 Sacramento Weather Radar Climatology. R. G. Pappas and C. M. Veliquette. July 1970. (PB-193 347)
No. 53* Experimental Air Quality Forecasts in the Sacramento Valley. Norman S. Benes. August 1970. (PB-194 128)
No. 54 A Refinement of the Vorticity Field to Delineate Areas of Significant Precipitation. Barry B. Aronovitch. August 1970.
No. 55 Application of the SSARR Model to a Basin Without Discharge Record. Vail Schermerhorn and Donald W. Kuehl. August 1970. (PB-194 394)
No. 56 Areal Coverage of Precipitation in Northwestern Utah. Philip Williams, Jr., and Werner J. Heck. September 1970. (PB-194 389)
No. 57 Preliminary Report on Agricultural Field Burning vs. Atmospheric Visibility in the Willamette Valley of Oregon. Earl M. Bates and David O. Chilcote. Sept. 1970. (PB-194 710)
No. 58 Air Pollution by Jet Aircraft at Seattle-Tacoma Airport. Wallace R. Donaldson. October 1970. (COM-71-00017)
No. 59 Application of P.E. Model Forecast Parameters to Local-Area Forecasting. Leonard W. Snellman. October 1970. (COM-71-00016)

NOAA - This is continuation of the ESSA Technical Memorandum Series.

No. 60 An Aid in Forecasting the Minimum Temperature at Medford, Oregon. Arthur W. Fritz. October 1970. (COM-71-00120)
No. 61 Relationship of Wind Velocity and Stability to SO_2 Concentrations at Salt Lake City, Utah. Werner J. Heck. January 1971.
No. 62 Forecasting the Catalina Eddy. Arthur L. Eichelberger. February 1971.

* Out of Print
**Revised