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Predicting Precipitation Types

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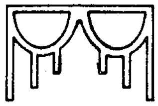

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-49

PREDICTING PRECIPITATION TYPE

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WESTERN REGION
TECHNICAL MEMORANDUM NO. 49

SALT LAKE CITY, UTAH
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TABLE OF CONTENTS

LIST OF FIGURES

PREDICTING PRECIPITATION TYPE

Is it possible to forecast if precipitation at a site will be liquid or solid? Investigators have suggested numerous indices for resolution of this problem but many of these require a special analysis for each site in order to build in certain unique climatological or geographical features as mentioned by Penn (1). Forecast services provided by the Sacramento River Forecast Center require that this decision be made for large areas, and a simple yet exact methodology is required to insure that areas of surface runoff may be determined and reasonable estimates of surface flow prepared. Real time observations of precipitation type in the Sierra Nevada are extremely limited; thus the necessity for other methods of indicating the type are required.

Wagner (2) has suggested utilization of a thickness analysis to forecast the type of surface precipitation. There are, however, difficulties encountered in applying this system west of the Rockies where surface elevations change rapidly. Consequently, it was decided to attempt an analysis using radiosonde data as the basic tool in making precipitation type forecasts. Due to rough terrain in the forecast area, the answer was desired for specific elevation, not a single site. The fact that California's primary snow areas are located at a considerable distance from radiosonde stations made it necessary to place two data requirements on cases to be analyzed:

1. The wind direction at a radiosonde station must be stable enough to indicate air mass characteristics that would be advected to a definable sector of the precipitation area.

2. Information from the precipitation area must be adequate to determine the level at which snow changes to rain.

A study of data for the period 1955-1967 inclusive meeting these requirements led to selection of two primary criteria which would be useful in predicting the level at which snow would change to rain:

1. Depth of the moist layer colder than zero degrees Celsius.

2. Heat required to convert falling snow to rain.

The depth of the moist layer continuously colder than zero degrees Celsius is an index to the volume of falling snow. If the volume of falling snow can be estimated, the amount of heat required to melt that snow can be computed Wexler (3).

Criteria 1 was established as the depth in millibars of that portion of the sounding continuously colder than zero degrees Celsius whose dew point was continuously within 3 degrees of the dry-bulb temperature. This gave reasonable definition in nearly all cases, although it was occasionally necessary to modify this criteria when precipitation occurred with all reported temperature - dew point spreads greater than 3°C.

Criteria 2 was determined from the depth and temperature of the layer of air warmer than zero degrees Celsius through which frozen precipitation would fall prior to melting. The melt level was identified by reports received from the network of stations along the mountain range (most of these reports are not available on a real time basis). This "warming layer" was computed by counting on a Pseudo-Adiabatic chart the number of boxes formed by ten millibar and one degree centigrade lines in the area bounded on the left by the zero degree isotherm, on the right by the temperature sounding curve, and on the bottom by the observed melting level. These criteria are illustrated in Figure 1, where depth of the moist layer (830mb - 670mb) equals 160mb, and the warming layer equals 19 ten millibar-one degree boxes.

Using data for the above mentioned years, a simple equation for forecasting the required warming (i.e., number of boxes) for snow to rain transformation, was derived empirically:

$$W = 0.12(L_O - L_D) \qquad (1)$$

where: W = warming required to convert snow to rain expressed in ten millibar-one degree boxes in layer from L_O to L_S.

L_O = the level in millibars of the highest zero degree Celsius crossing of the temperature sounding.

L_S = melting level in millibars.

L_D = the level in millibars above L_O at which the sounding exhibits initial drying, i.e.,

$$T - T_d \geq 3°C.$$

where T = temperature

T_d = dew point

This equation has been tested over a two-year span and has provided excellent forecasts for cases meeting data requirements. The forecast melting level was usually within 500 feet of the observed level. One of the more interesting cases occurred on February 6, 1969 when snow was correctly indicated near the 800-foot level in the central Sierra Nevada, several thousand feet below the normal snow line in this area, and one of the lowest snowfall elevations in many years. The sounding for Oakland at 1200Z February 6, 1969, (Figure 2) exhibited several very unstable areas. From the sounding, L_O = 863 mbs and L_D = 620 mbs. Substitution of these values in equation (1) yields a required warming area of 0.12(863-620) or 29 ten millibar-one degree boxes. This area of warming is accumulated between 863 and 980 millibars, correctly indicating a melting level of 800 feet msl, nearly 3500 feet below the freezing level.

Frequently soundings occur with numerous inversions which complicate the rain or snow computation. It should be realized that once adequate warming exists at any level in the sounding to convert snow to rain, the conversion is permanent. If sufficient cooling is encountered by the falling rain, it will be converted to sleet not snow. This condition normally occurs at any level where falling rain enters an area with temperature of 0°C. or colder.

Wagner (2) reported on a probability system for determining precipitation type at a surface station. The system he described is based on thickness of the 1000 to 500-millibar layer. In a set of four soundings for Boston, Massachusetts, during December of 1956 (Figure 3), he shows problem soundings which all give the same precipitation type due to their having the same 1000 to 500-mb thickness. It is interesting to note that the procedure developed for determining snowfall level in the Sierra can be applied to the Boston data and precipitation types determined.

Case 1, Figure 3a, shows L_O at 990 millibars and L_D at 520 millibars, and the number of ten millibar-one degree boxes required for melting is 0.12(990-520), or 56.4 boxes. The area to the right of the zero line is only two boxes, much short of the area required for snow to change to rain, and the anticipated and observed precipitation type is snow.

Case 2, Figure 3b, has L_O at 1014 millibars and an L_D of 660 millibars. The area required for melting is 0.12(1014-660) or 42.4 boxes. There are no such boxes on the sounding; thus anticipated and observed precipitation type is snow.

Case 3, Figure 3c, has L_O at 755 millibars and L_D at 690 millibars. The area required to the right of the zero degree line is 0.12(755-690) or 7.8 boxes. An area of warming this size is present between 755 millibars and 815 millibars. Consequently, the snow is assumed to have melted at 815 millibars. However, the sounding drops below zero near 835 millibars, warms above zero at 940 millibars, and cools to zero at the surface. Under these circumstances, refreezing of the melted snow should occur. Observed precipitation type was freezing rain and drizzle, which again corresponded to expected type.

Case 4, Figure 3d, shows L_O near 755 millibars, and L_D to be 700 millibars, thus W equals 6.6 ten millibar-one degree boxes. This amount of warming is accumulated by falling snow as it nears the 805 millibar level; consequently rain may be expected below this level. With a subfreezing layer between 850 and 940 millibars, and a surface temperature of zero, the melted precipitation should freeze again. The anticipated precipitation type was verified by the surface observation.

The simple equation for snow melt level presented in this paper has given better results in the Sierra Nevada than the authors anticipated. It was originally thought that instrumental errors in standard radiosondes might preclude a satisfactory answer. Results have been so satisfactory to date, however, that it is impossible to determine if errors are due to data problems or equation inadequacies. Obviously such a simple equation cannot represent the entire mechanics involved, but it is questionable whether or not available radiosonde data will support a more refined analysis.

In this analysis, the authors were careful to utilize only those cases where streamline analysis suggested that available soundings would be reasonably representative of later conditions in the Sierra Nevada. In an area of over 70,000 square miles, there is usually only one radiosonde report which meets data requirements. Thus, although the technique is quite effective, severe lack of radiosonde data restricts its application.

Although this procedure was designed to meet a hydrologic requirement in a 400-mile section of the Sierra Nevada, other possibilities come to mind. It is also desirable to know not only if surface precipitation will be rain or snow, but at what elevations in the atmosphere various precipitation phases are occurring. If it were possible to examine all soundings with an effective procedure for determining precipitation type, routine maps could be prepared depicting elevations at which falling snow is converted to rain and areas and elevations at which freezing rain could be expected. Such information would be of great assistance to hydrologists, and should be even more valuable to agricultural and aeronautical interests. Because of the authors' operational obligations, the procedure presented in this paper has had only limited application beyond the Sierra Nevada, but it is hoped that those who share the interests expressed above may find the concepts useful.

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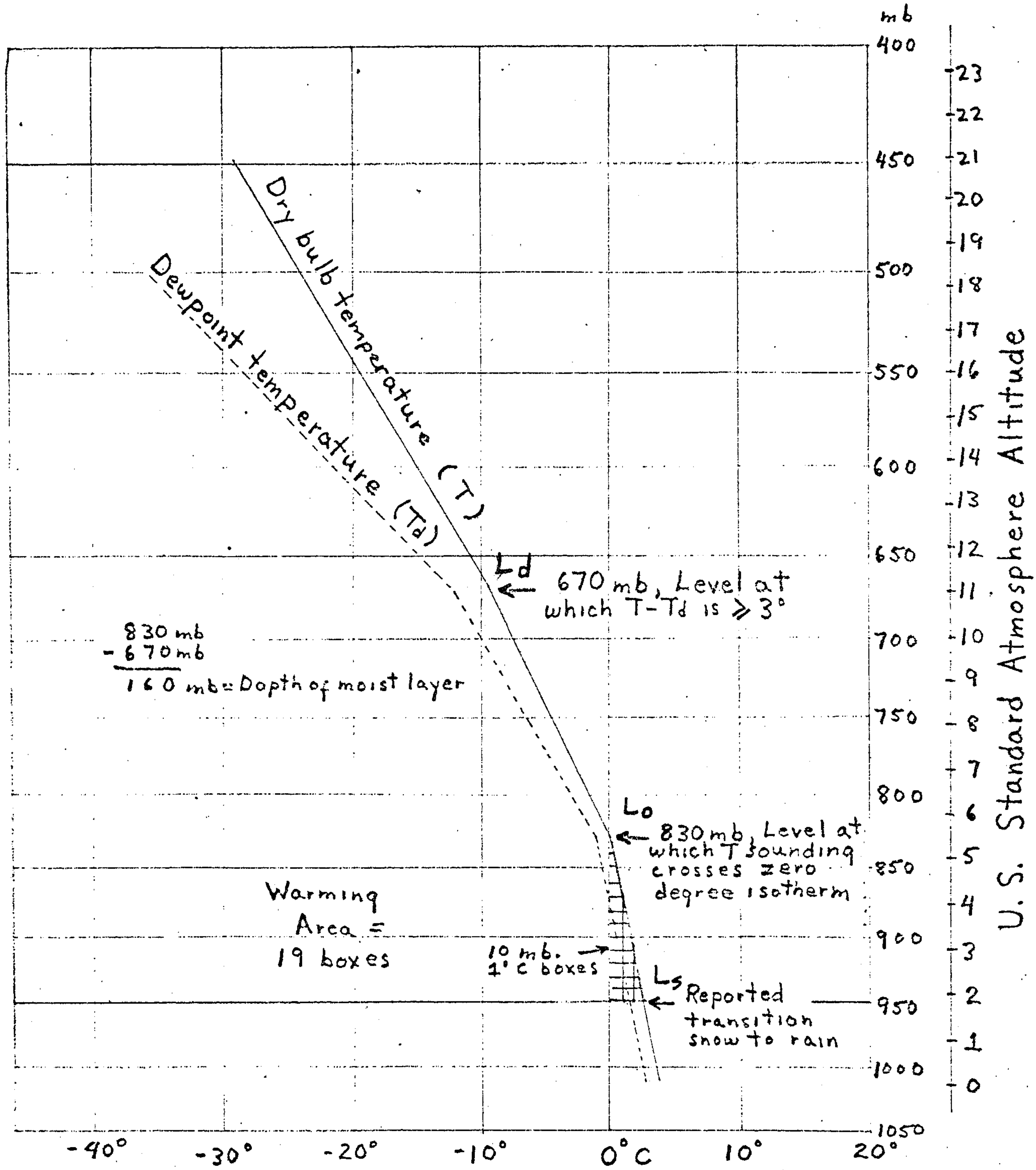

Figure 1. Simplified Sounding

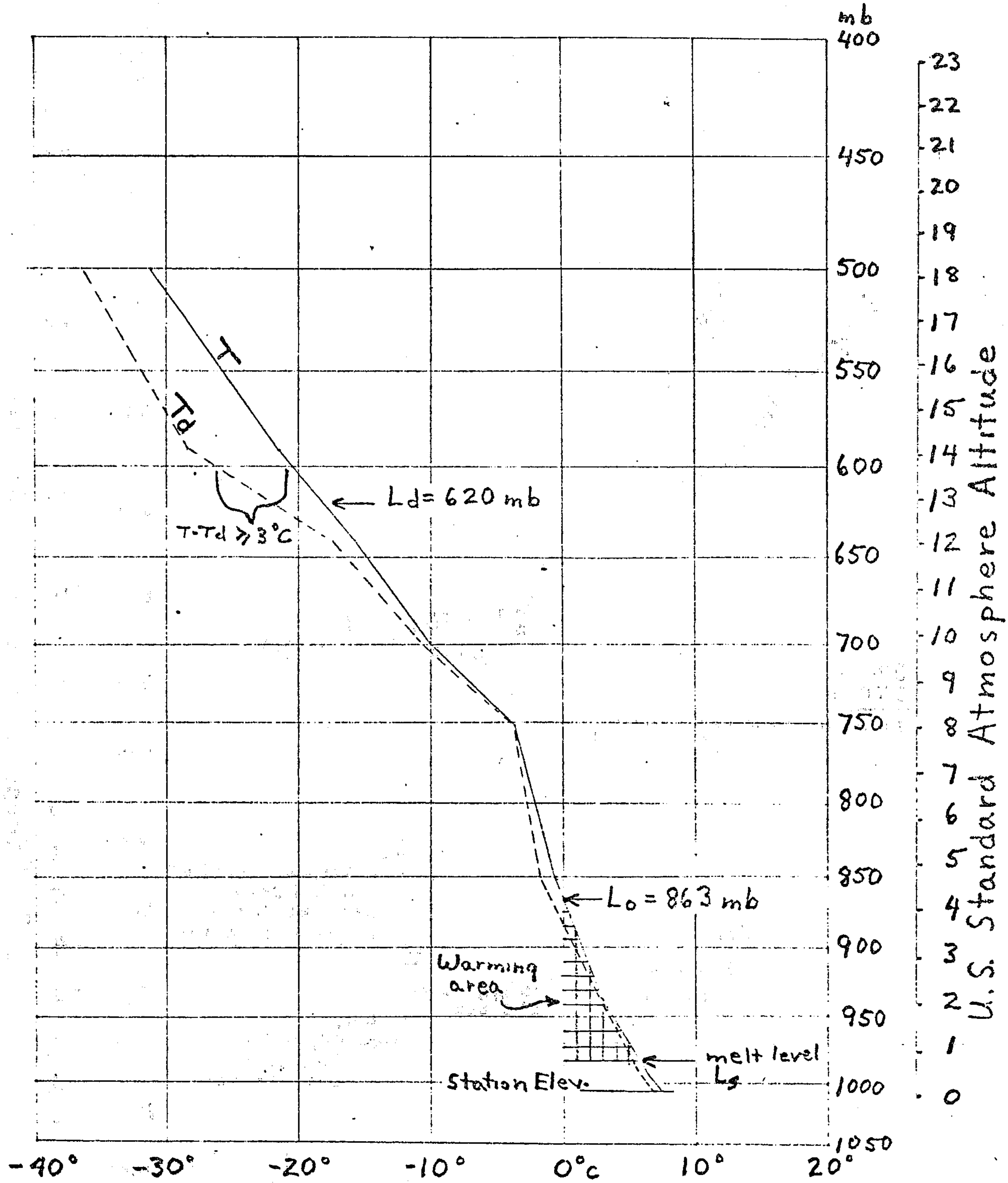

Fig. 2 Oakland sounding 2-6-69 1200Z

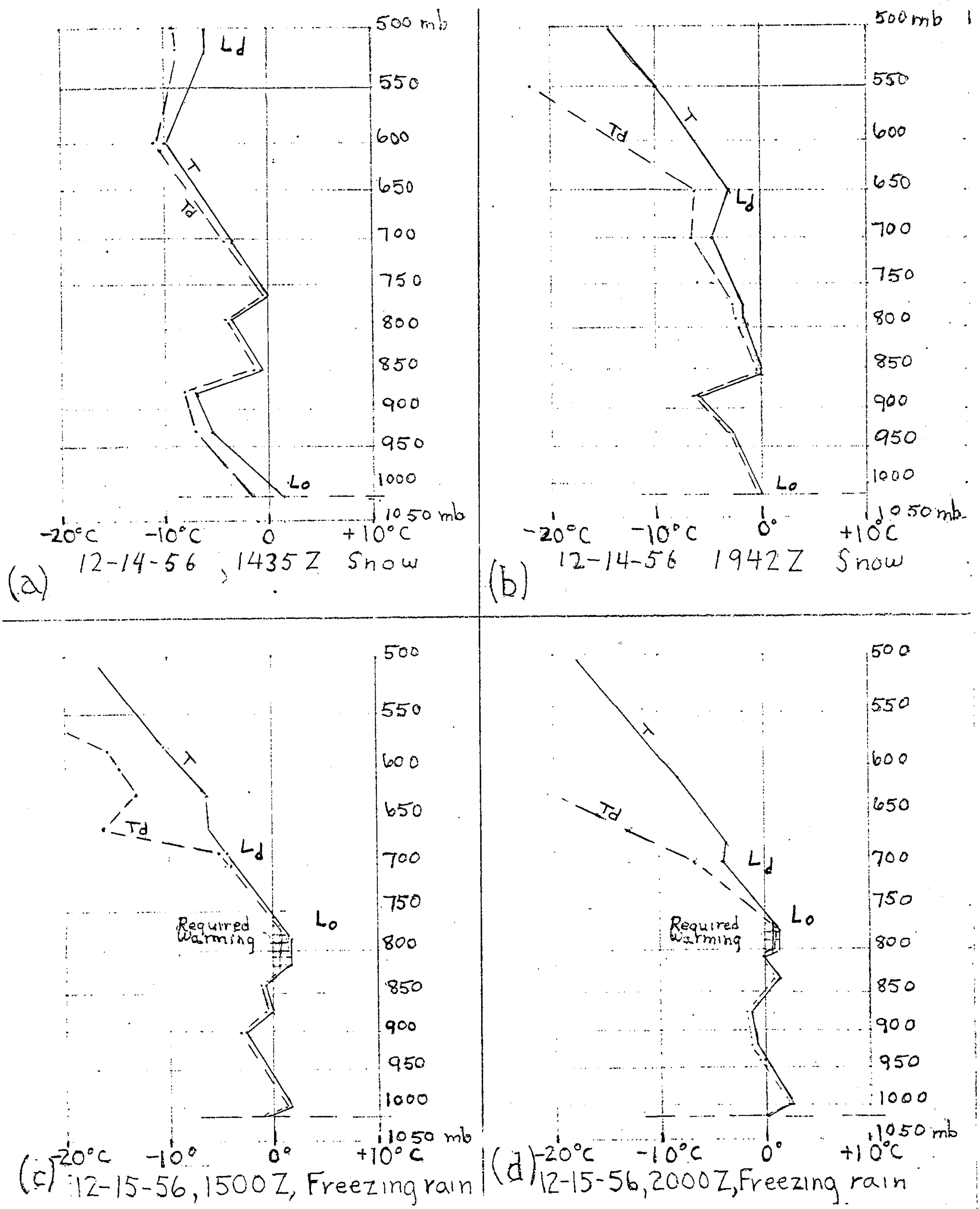

Figure 3. Boston Soundings (after Wagner)

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