Some meteorological and physiographic aspects of winter precipitation variation in mountainous southwestern Montana
by Larry Eugene Holman

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Earth Science
Montana State University

Abstract:
Precipitation data from a mesoscale network have been collected in conjunction with a weather modification program in the mountains of southwestern Montana during the winter of 1969-70. Stepwise multiple regression techniques were used to. examine the relationship between meteorological and physiographic parameters and precipitation amount, intensity, and frequency.

Meteorological data were extracted from rawinsonde and radiosonde records. The investigation of relationships between meteorological factors and precipitation received primary emphasis. Stratification of precipitation data according to temporal and spatial parameters was used to increase the multiple correlation coefficients in the meteorological analysis. Several factors appeared significant in the regression analysis. However, cloud base temperature and 500 millibar temperature were selected as the most important factors related to precipitation because of their frequent and often most significant contributions to the regression equations.

In the physiographic analysis, data was extracted from USGS topographic maps and canopy photographs of gage sites. The analysis showed that elevation exhibited a definite control on precipitation intensity and frequency.

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Date 5/25/71

SOME METEOROLOGICAL AND PHYSIOGRAPHIC ASPECTS OF WINTER PRECIPITATION VARIATION IN MOUNTAINOUS SOUTHWESTERN MONTANA

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ABSTRACT

Precipitation data from a mesoscale network have been collected in conjunction with a weather modification program in the mountains of southwestern Montana during the winter of 1969-70. Stepwise multiple regression techniques were used to examine the relationship between meteorological and physiographic parameters and precipitation amount, intensity, and frequency.

Meteorological data were extracted from rawinsonde and radiosonde records. The investigation of relationships between meteorological factors and precipitation received primary emphasis. Stratification of precipitation data according to temporal and spatial parameters was used to increase the multiple correlation coefficients in the meteorological analysis. Several factors appeared significant in the regression analysis. However, cloud base temperature and 500 millibar temperature were selected as the most important factors related to precipitation because of their frequent and often most significant contributions to the regression equations.

In the physiographic analysis, data was extracted from USGS topographic maps and canopy photographs of gage sites. The analysis showed that elevation exhibited a definite control on precipitation intensity and frequency.

I. INTRODUCTION

A. Nature and Purpose of Study

In mountainous regions like the western United States, spring and summer streamflow is largely dependent upon the snowpack accumulated at high elevations. Due to increasing water needs, studies on precipitation augmentation are being undertaken in several sections of the United States. One such study is being conducted by Montana State University in the Bridger-Bangtail region of southwestern Montana (Mitchell, et al., 1970). As a part of the precipitation augmentation program, there is a network of 21 weighing-type precipitation gages covering an estimated 300 square mile experimental area. With an additional six gages generally downwind of the experimental area, a total of 27 stations comprise the mesoscale network which provided the precipitation data for this study.

The needs of a precipitation augmentation study justify a concurring investigation of the areal and temporal variations in precipitation to provide additional information for analyzing the results of the seeding program. Clarifying the role of various meteorological and physiographic parameters in wintertime precipitation also compliments the efforts of a precipitation augmentation study. Therefore, isolating various meteorological and physiographic parameters and relating their individual or combined

effects on precipitation amounts is the problem under consideration.

As related to mountainous southwestern Montana during the winter, the specific objectives of this study are:

1. To determine the feasibility of using stepwise multiple regression techniques to analyze precipitation.
2. To determine the effect of meteorological parameters on precipitation amounts.
3. To determine the effect of physiographic parameters on precipitation amounts.
4. To determine the variation in precipitation frequency and intensity with time and space within the limits of the study area.

As noted earlier, the mesoscale network includes 27 precipitation gages. Twenty-one of the gages are concentrated in the 300 square mile experimental area. The additional six gages provide data east (generally downwind) of the experimental area. The experimental area, approximately 20 miles in length and 15 miles wide, is oriented in an east-west direction. The western half of the area consists of the Bangtail Ridge portion of the Bridger Mountain Range. This mountainous terrain grades off into the Shields Valley to the east. West of the Bangtail Ridge lies the north-south oriented main ridge of the Bridger Range. Figure 1.1 is a contour map of the area showing the approximate locations of the precipitation gages. An east-west

EXPERIMENTAL AREA AND GAGE NETWORK

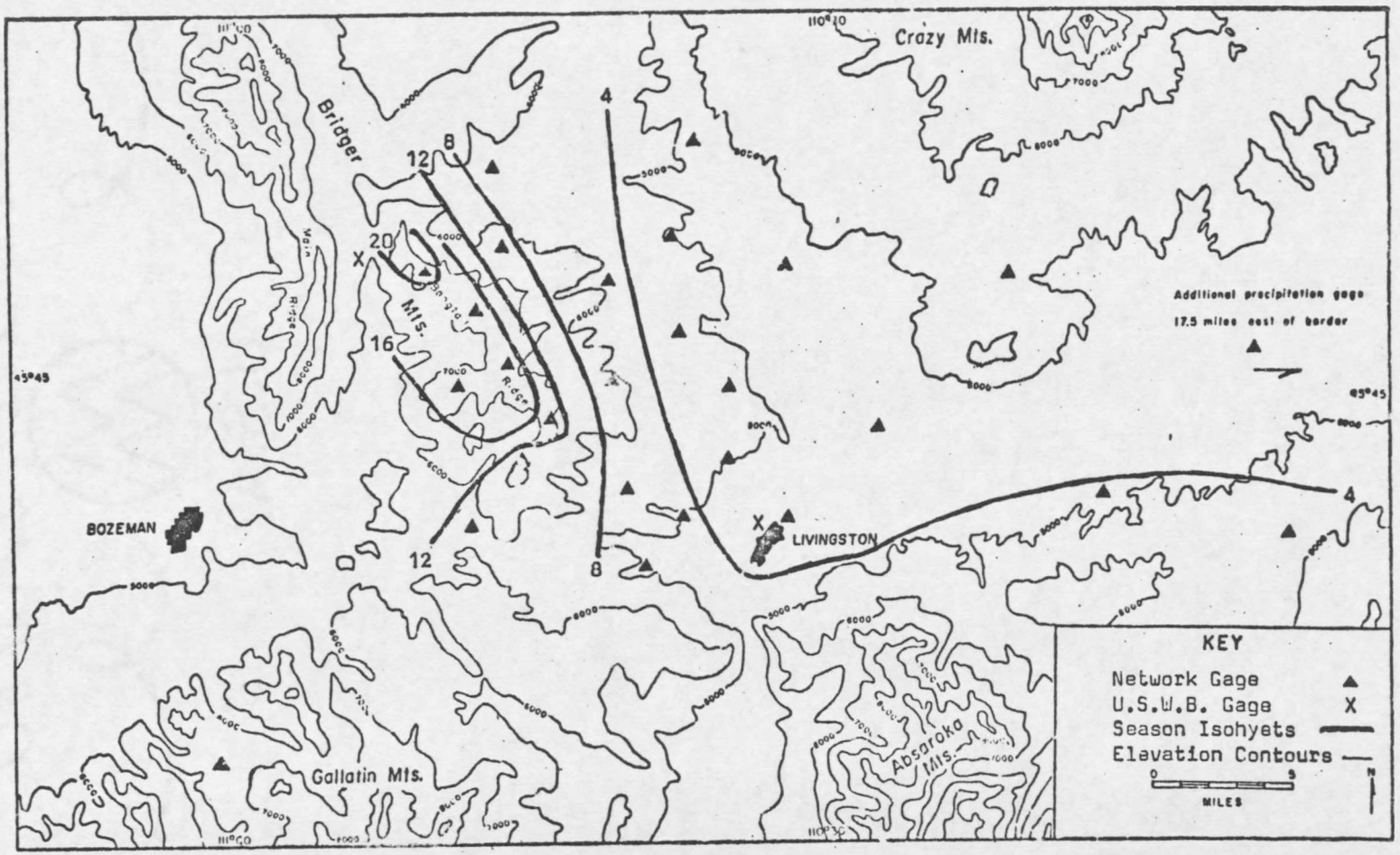

Figure 1.1 Isohyets represent 1969-70 seasonal totals for the network shown. Isohyets are in inches of water equivalent.

cross section of the area is given in Figure 1.2.

The target area is characteristically dominated by westerly flow during the winter. However, northeasterly flow in the lower layers of the atmosphere is a frequent occurrence. Precipitation from the westerly storms increases noticeably with elevation whereas precipitation resulting from the northeasterly flow increases less strongly with elevation. The ratio of northeasterly to westerly mean per storm precipitation typically is about 4:1 in the valley and 2:1 in the mountains (Super, et al., 1968). Such ratios suggest the northeasterly flow is more important to valley stations than westerly flow. As a regional approximation for average precipitation during the November through March season, Figures 1.3 and 1.4 show the seasonal totals for the past twenty years from two USWB stations near the target area. The locations of the respective USWB stations supplying the data are shown in Figure 1.1. Also shown in Figure 1.1 are the isohyets of 1969-70 network precipitation totals.

B. Review of Literature

Variations in precipitation amount, intensity, and duration have been studied by several authors. It is realized that not every study has the same design and, therefore, the individual studies cannot be objectively compared with each other. Consequently attempts to relate precipitation amounts with meteorological factors have