INTRODUCTION

The snow avalanche climate of the western United States has long been believed to encompass three major zones following a west-coast gradient: coastal, intermountain, and continental (Mock and Kay 1992; Mock and Birkeland 2000). The coastal zone of the mountain ranges in the Pacific coast states and extending a bit into northern California, is characterized by mild temperatures, abundant heavy snowfall, a high density snowcover, and a low temperature gradient in the snowpack. Conversely, the continental zone of the Rocky Mountains in Colorado, Wyoming, and parts of Montana is characterized by cold temperatures, less abundant snowfall, lower density snowcover, and a steeper temperature gradient. The intermountain zone of the northern Rocky Mountains of Montana, the Wasatch Range of Utah, the Blue Mountains of northeastern Oregon, and southwestern Colorado is intermediate in avalanche climate characteristics between coastal and continental. All of these climate and snowpack differences are important since they determine the structure of the snowcover and the resultant characteristic of the avalanches that each zone normally experiences. A thorough knowledge of prevailing avalanche climate also aids in the calculation of runout distances (e.g., Bergen 2005).

EXAMPLES OF AVALANCHE RESPONSES TO CLIMATE

We discuss two examples of how avalanches respond to weather and climate during an extreme continental year (Alta, Utah, 1976-77) and an extreme coastal year (Mount Hood, OR, 1985-86). We developed a daily avalanche hazard index based on the size and frequency of avalanches from Westwide Network data, with an emphasis on potentially large damaging avalanches. We also constructed daily time series of the avalanche hazard index with several weather and snowpack variables. The situation for Mount Hood, Oregon in 1985-86 demonstrates extreme continental climate characteristics. The relatively deep snowpack, and warm and low diurnal ranges of temperatures are evident. Temperature gradients within the snowpack are minimal, and therefore weak layers of faceted crystals are limited. Periods of significant avalancheing are still evident, but avalanching typically occurs immediately following large and/or prolonged storms and usually involve only recent new snow. The 1976-77 season at Alta, Utah started out with a thin snowpack, abnormally cold temperatures, and relatively large differences between maximum and minimum temperatures. The temperature gradient in the snowpack exceeded 10°C m⁻¹, and was associated with the formation of weak faceted crystals. Cold temperatures and a thin snowpack throughout the 1976-77 season ensured that weak layers remained prevalent in the snowpack, and even small storms are associated with relatively high avalanche activity, as measured by the avalanche index. Limited new snowfall is sufficient to overlain old layer of fragile depth hoar, resulting in avalanching.

REGIONALIZATION OF AVALANCHE CLIMATE

We examined 48 stations with climatic and snowpack data from the Westwide Network, including two stations in Alaska to provide additional "climate space" in analyzing the variability of avalanche climate. Record lengths are not always continuous, varying from 2 to 57 years during the 1946-2004 time period. We analyzed daily data for December-March. Six snow climate variables were chosen: minimum temperature, maximum temperature, total snow depth, daily snowfall, daily snow water equivalent, and daily rainfall. Well-known criteria of defining thresholds and ranges of snow avalanche climatic variables provide the basis for classifying coastal, intermountain, and continental conditions. For further details on data and methods, please refer to Mock and Birkeland (2000).

We calculated the percentage of winters for each site that is classified as a particular avalanche climate, and mapped the results to summarize the major spatial patterns of avalanche climate characteristics over the West. Sites in the Pacific mountain ranges illustrate high percentages of coastal classifications, with rare classifications of intermountain and continental conditions. For coastal sites, the results are summarized as shown in Figure 1. Sites in the intermountain zone of the northern Rocky Mountains of Montana, the Wasatch Range of Utah, the Blue Mountains of northeastern Oregon, and southwestern Colorado is intermediate in avalanche climate characteristics between coastal and continental. All of these climate and snowpack differences are important since they determine the structure of the snowcover and the resultant characteristic of the avalanches that each zone normally experiences. A thorough knowledge of prevailing avalanche climate also aids in the calculation of runout distances (e.g., Bergen 2005).

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