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Snow avalanche information derived directly from Landsat imagery and indirectly from small-scale topographic maps is being used to map the location and distribution of avalanche hazards in the Colorado Rocky Mountains. A preliminary investigation of the usefulness of Landsat imagery for mapping landslide areas suggests that Landsat imagery alone is not sufficient for distinguishing between landslide and non-landslide areas with a high degree of accuracy.

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APPLICATION OF LANDSAT DATA TO DELIMITATION OF AVALANCHE HAZARDS IN MONTANE COLORADO

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PREFACE

Over the last several years, the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado has been involved in the delineation, mapping, and analysis of natural hazards in selected portions of the Colorado Rocky Mountains. Much of this research has been concerned with the detailed delineation of snow avalanche hazards using air photo and field mapping techniques. Continuous monitoring of various environmental parameters during the winter avalanche cycle has produced significant advances in the field of avalanche prediction and forecasting for local areas.

In June 1975, INSTAAR began research for the National Aeronautics and Space Administration (NASA contract NAS5-20914) on a new approach to avalanche hazard investigation. The purpose of this research is to analyze, evaluate, and apply LANDSAT imagery for delineating and mapping avalanche hazards in the Colorado mountains. Research is currently being directed toward six primary objectives:

(1) Compilation and analysis of historical avalanche records for cause/effect and frequency information.

(2) Identification of avalanche hazard terrain characteristics detectable on LANDSAT imagery.

(3) Determination of relative usefulness of LANDSAT imagery for avalanche hazard mapping.

(4) Determination of useful schemes for cartographically representing avalanche hazards.

(5) Using the synoptic and repetative aspects of LANDSAT imagery for regional avalanche hazard mapping and analysis.

(6) Examining the cost/benefits of avalanche hazard investigations.

Secondary, and purely experimental, objectives of the research project are as follows:

(1) Investigation of potential usefulness of LANDSAT derived information as input to avalanche forecast or warning systems.

(2) Investigation of the usefulness of LANDSAT imagery for mapping major landslide areas.

During the report period (1 March - 31 May 1976), research was conducted by two full-time staff members and two part-time graduate student research assistants. Emphasis was placed on (1) applying the adopted mapping technique to avalanche hazard mapping in the Montrose and Leadville quadrangles (1:250,000) and (2) a preliminary investigation of the usefulness of LANDSAT imagery as a tool for the delineation of major landslide areas in the Colorado Rocky Mountains.

Regional mapping of avalanche hazards has, to a large extent, become a routine process, and as the interpreters gain experience, the mapping proceeds rapidly and proficiently. Landslide mapping, however, is still very tentative. Although many landslide areas can be identified and mapped on LANDSAT imagery, others show no imagery expression that allows positive identification to be made. Reliance on the use of LANDSAT imagery as the sole source for mapping information, therefore, is not recommended.

INTRODUCTION

This report summarizes the work conducted by the Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, during the period 1 March - 31 May 1976, under contract NAS5-20914 to the National Aeronautics and Space Administration/Goddard Space Flight Center.

During the report period, snow avalanche hazard mapping was conducted in the Montrose and Leadville quadrangles (1:250,000) using Landsat imagery and the small-scale topographic information contained on the quadrangle sheets. The mapping technique, described in the previous progress report, works very well, and as experience is gained, it becomes relatively fast. One man-month was also spent investigating the usefulness of Landsat imagery for delineating the regional distribution of landslide areas in the Colorado Rocky Mountains. Preliminary results indicate that Landsat imagery alone is not sufficient for locating all major landslide areas.

REGIONAL AVALANCHE MAPPING

Landsat imagery, in conjunction with selected supplementary information, is being used to prepare a snow avalanche hazard map of the Colorado Rocky Mountains. The initial mapping is being conducted and compiled at a scale of 1:250,000. This information will be compiled on a 1:500,000 topographic map of Colorado when the interpretation phase of the work is completed.

To reach this point, INSTAAR has expended much time and effort in evaluating Landsat imagery for avalanche mapping in order to better understand its capabilities and limitations and to define any types of additional information necessary for the accurate interpretation of the imagery in situations where the Landsat imagery alone is inadequate. The result is a technique that involves the visual interpretation of Landsat imagery and the human analysis of the elevation and relief factors that appear to be most critical in determining the avalanche hazard associated with an area. The technique is practical, relatively accurate, and does not rely on sophisticated (and expensive) imagery or data processing. However, portions of the technique could be easily adapted to automatic computer methods if the digital relief and elevation data are available in sufficient detail.

The Technique

The technique being used to map avalanche hazards in the Colorado mountains was described in the previous progress report. Three levels of avalanche hazard are mapped, each succeeding level being more specific on the location of hazards and more definite on the existance of active avalanche terrain. The lowest level consists of the definition of Potential Avalanche Terrain based on the presence of elevation (climatic) and relief

factors that could be conducive to avalanching. The intermediate level is Interpreted Avalanche Terrain. This is terrain that is interpreted to be active during the winter and spring avalanche cycle because of its appearence on Landsat imagery. The highest level of avalanche hazard is Identified Avalanche Terrain, which consists of areas that are known to avalanche as determined by air photo interpretation, historical records, published maps, or personal observations. A completed map expresses avalanche hazard as actual or potential and provides the reader with the information necessary to evaluate the reliability of what is shown on the map. A detailed, step-by-step description of the procedures that were found to be most efficient will be included in the final report.

Preliminary Evaluation

To date, evaluation of the mapping technique has been done by visually inspecting the hazard maps in areas where the mappers have a degree of familiarity. These checks have indicated that the mapping technique does a good job of depicting the avalanche hazards, even at the small scale. However, work is underway that will allow a more quantitative evaluation of mapping accuracy and completeness to be made. A field team, working under NASA Grant NGL 06-003-200, is currently preparing detailed snow avalanche and geologic hazards maps (1:24,000) of the northern part of Hinsdale County, Colorado. These maps will be made available at the end of the summer field season so that direct comparisons with the Landsat-derived hazard map can be made for this previously-unmapped area.

Since the interpretation of avalanche hazards on Landsat imagery is influenced by the experience of the interpreter, a test will be conducted to

evaluate the variability in avalanche hazard on Landsat imagery is influenced by the experience of the interpreter, a test will be conducted to evaluate the variability in avalanche hazard mapping conducted by different workers. Two areas will be independently mapped by two investigators. The resulting maps will be compared to determine the amount and type of variation in avalanche hazard mapping caused by different interpreters.

Between 2 and 4 weeks will be spent during the next report period checking selected areas in the field. The areas to be checked have been interpreted as avalanche areas, but there is no documented avalanche activity. These areas are primarily in the backcountry and, thus, present little actual hazard, but they provide areas in which to check the accuracy and correctness of the interpretation procedure.

Status

The Landsat-derived avalanche hazards maps are being compiled on the 1:250,000, 2-degree topographic quadrangle maps that cover the state. Two of these quadrangles are complete (Durange and Montrose) and two are near completion (Leadville and Craig). The remaining mountainous area in the state is contained on four quadrangle maps, however, only one-half of this area is within the mountains, so an equivalent of two more quadrangles remains to be done. When these are completed, the avalanche hazard mapping will be transferred to a 1:500,000 topographic map of Colorado.

IDENTIFICATION OF MAJOR LANDSLIDE AREAS

A secondary objective of this project was to examine the possible usefulness of Landsat imagery as a tool for mapping major landslide areas in the Colorado Rocky Mountains. During this report period, two graduate student research assistants, David J. Sauchyn and Nicholas R. Trench, each spent one month investigating the problem. They have submitted a preliminary report on their work, but since they desire to spend two more weeks on the study, the results of their work will not be reported until the final report. A summary of the preliminary results is given below.

Some landslide areas in Colorado can be identified and delimited on Landsat imagery, but because of the extreme variations in the topographic, lithologic, structural, and vegetational conditions associated with landslide areas, there is no unique spectral or spatial pattern that is indicative of landslides.

The accuracy with which landslides can be mapped is a function of the degree to which the landslides are expressed in the relief and the topography. Many landslide areas in Colorado, both large and small, simply do not have enough surface expression to be interpreted. Consequently, Landsat imagery is not recommended as a routine landslide mapping tool, particularly if higher resolution imagery or photography is available.

However, some areas of landsliding displayed characteristic evidence that would be obvious to even the casual observer. This suggests that in areas where landsliding is large-scale, where other geologic conditions are relatively uniform, and where there is a need for frequent monitoring of landslide activity, Landsat imagery may be the best tool available.

PUBLICATIONS

No project-funded publications were prepared during the report period.

RECOMMENDATIONS

No specific recommendations are necessary at this time.