Paper No. 29

N76-16590

SUMMARY OF THE OPERATIONAL APPLICATIONS OF SATELLITE SNOWCOVER OBSERVATIONS WORKING SESSION – AUGUST 20, 1975

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INTRODUCTION

Following two days of excellent formal paper presentations and constructive discussions, a working session dealing primarily with problems, techniques for analysis, possible solutions, and recommendations for future work pertaining directly to the Snow ASVT study areas was held. This session, chaired by V. V. Salomonson, treated in greater detail some of the points brought out in the discussions during the previous two days. Various techniques for reducing the satellite data to a form useable by the operational agencies were covered in mini-presentations and discussions by the operational satellite-snow interpretive personnel. These mini-presentations were followed by open discussion and actual manipulation of data by those present in the audience.

Similar mini-presentations were made by operational agency streamflow forecasters on how satellite-derived snow data could be incorporated into runoff forecasting methods, potential influence on management decisions, and eventual transfer to completely operational use. A general discussion dealing with the directions that the snow ASVT should take as a result of the previous presentations and discussions concluded the working session.

It was apparent throughout the conference that no specific data reduction technique or application of the data could be applied in all the Snow ASVT study areas. The greatest contrast between applicable techniques and their relationship to the available water resource existed between arid, vegetation sparse, relatively cloud-free Arizona and the humid, densely vegetated, cloud covered Northwest. Straight-forward analysis techniques and data application were employed in Arizona. In the Northwest, however, more sophisticated analysis is required in order to extract meaningful information. The evaluation of the data by the four differing areas should provide an adequate range of results for other water agencies to decide whether or not to adopt the new remote sensing snow mapping technology.

In order that the major approaches and problems could be addressed in an orderly fashion, the working session was structured into three main areas. These areas were: photointerpretation techniques, digital techniques, and management/implementation considerations. Within the discussion and presentations on the first two areas the objective was to bring together as much information as possible as to the speed, costs, accuracy and precision, equipment, and training associated with the various approaches. The following paragraphs summarize the information gathered during the working session.

PHOTOINTERPRETATION TECHNIQUES

The key participants in this session of the workshop were the following:

1. James Foster — University of Maryland

2. Tony Mikesell — U.S. Soil Conservation Service

3. Roderick L. Hall — Sierra Hydrotech

4. A. Gerald Thompson — University of Wyoming

5. Stanley Schneider — NOAA/National Environmental Satellite Service (NESS)

It appeared that there was a clear preference for the 9 inch, approximately 1:1 million scale LANDSAT images for snow mapping. In the black and white image format, the 0.6-0.7μm images were prefered. The most information, however, was observed on the color composites with the cost of producing the color composites being the major drawback to their use.

Equipment for photointerpretation was relatively modest. Light tables, planimeters, and standard office supplies are needed as basic tools. If funds do not permit the direct purchase of color composites, diaso processing equipment can be used very successfully. In order to most expeditously transfer or superimpose data from the images onto topographic maps, the Bausch and Lomb Zoom Transfer Scope was generally recognized as a highly desirable tool. In order to preserve the images, A. Gerald Thompson described the use of protective glass plates. More durable materials for the preservation of thematic maps of snowcover were also recommended, particularly if a lot of handling of the data was to be expected.

The procedures for extracting relevant information basically involved locating snowlines and measuring the area or percentage of a watershed covered by snow. Some skill and/or ingenuity in locating snowlines in forested areas, distinguishing between snow and clouds, and recognizing the presence or absence of snow in shadows was very commonly noted as being necessary. In the case of locating snowlines in forested areas techniques such as using clearcut areas, powerline swaths, or overall increased reflectance-grey tones in the images were described. Overexposure of LANDSAT imagery so as to enhance snow in forests was one exemplary technique described by J. Foster of the University of Maryland.

False-color composites generally were quite helpful in distinguishing bare rock from high-altitude snow-covered areas, particularly when summer scenes were compared to winter scenes. Furthermore, the false-color, red tone typically associated with vegetation permitted snowcover in the trees versus trees with no snowcover beneath the foliage to be more readily distinguishable. The diazo process provided most investigators with the opportunity to produce images that met their individual preferences and, at the same time, were relatively inexpensive as contrasted against purchasing color composites from the normal Data Centers.

For measuring snowcovered area there were basically three approaches that seemed to stand out. One approach consisted of determining the mean snowline altitude and converting it to an equivalent area using a watershed area-altitude curve. A second method consisted of simply locating the snowline and planimetering the snowcovered area and presenting the information as a percent of basin covered. The third method consisted of using a grid or regular array of boxes overlaying the watershed area. The boxes typically cover an area of approximately four km^2. It was recommended that 1:250,000 enlargements of LANDSAT images be used. The analyst then simply estimates the snowcover in each box in tenths and performs the appropriate summations to get the total watershed area covered by snow.

In terms of precision and accuracy the box or grid method was recognized to be the most preferable by the end of the workshop. Not only was a rather high degree of precision provided, but ancillary statistics could be derived and the format for data gathering provided degrees of freedom for partitioning according to altitude zones or for input into numerical runoff prediction schemes. The major disadvantage was the time it takes to perform the analysis. For minimum equipment, relative speed, and a sustained, consistent level of accuracy and precision, the mean snowline altitude-equivalent area method seems preferable. Of course, the costs in all the photointerpretation methods are relatively low, but of the methods proposed, the simple planimetering of snowcovered area is the least expensive.

The level of training required for snowmapping using photointerpretation is relatively low. The most training comes in using equipment or materials that facilitate the analysis. For example the use of the Diazo process or the Zoom Transfer Scope requires some instruction. Furthermore, the pitfalls of snowcover photointerpretation when forested areas, shadows, and clouds exist requires instruction and experience in order that they be avoided.

The LANDSAT data, while having high spatial resolution and cartographic fidelity that made it attractive, often was not available frequently enough to observe rapid snowcover changes. NOAA/VHRR data provides data every day at 1 km resolution, but in a non-cartographic format. The Zoom Transfer Scope is definitely needed when using VHRR data in order to facilitate snowmapping and some considerable skill is needed to superimpose the image on a map. As a result of the relatively low spatial resolution and the mapping difficulty, many investigators in the study areas were not using this approach. Mr. Stan Schneider of NOAA/NESS described how he uses the VHRR data to map snowcover and spent a considerable amount of time instructing many individuals on the use of the Zoom Transfer Scope.

It was clear that most of the ASVT study areas were using photointerpretation methods, and the workshop served to provide all the study areas with techniques or approaches for improving their snowcover mapping procedures and the evaluation of satellite snowcover data.

DIGITAL PROCESSING

Although the use of digital, feature recognition approaches was obviously not being used by most of the study areas, it was recognized as a definite possibility for the future as more experience and sophistication was developed in the use of LANDSAT data. In order that a variety of approaches could be explored, five individuals presented results representing major approaches employing digital data. They were:

1. William E. Evans — Stanford Research Institute
2. Klaus Itten — University of Zurich, Switzerland
3. Stephen G. Luther and Luis A. Bartolucci — Purdue University
4. William C. Dallam — General Electric Company

In addition, Dr. Mark Meier, U.S. Geological Survey, made a short presentation describing an intercomparison study of various methods that he had tested.

Several different procedures were described in the digital processing areas. The use of supervised and unsupervised classification techniques were described. Furthermore, the well-known or commonly employed classification programs were described including LARSYS from Purdue University, STANSØRT from Stanford University, and the parallelepiped approach used by the General Electric Image 100 configuration. The discussion and presentations brought out tradeoffs among the methods associated with diagnostic and statistical information, speed, classification accuracy, and cost.

Among the advantages of digital processing that became apparent was the fact that the digital classification methods are reproducible and quantitative. Furthermore, more classes of snowcovered area can be provided due to the advantage of multispectral classification over the ability of the photointerpreter to reliably separate classes of snow. Because of the difficulty of mapping snow within trees, in shadows, and in partially cloud-covered areas, the overall accuracy of digital techniques, however, seems to presently stand at about the same level as that of the photointerpretation techniques. Methods of getting around these problems were described along with methods of digitally superimposing elevation contours on snowcover information using digital contour information obtainable from the Defense Mapping Agency.

The equipment necessary to utilize computer-oriented digital snowcover mapping approaches is, relative to the photointerpretation approach, quite costly and complex. Furthermore, there is a certain amount of computer programming training and data processing skill necessary to implement these techniques. In many cases the computer equipment and programming skills may already exist within the larger water resources management agencies, but these skills and equipment may be devoted to other tasks. In order to justify the acquisition of new equipment and personnel or the reallocation of existing resources to the job of snowmapping, it would seem that the use of satellite snowcover data and the desire for greater precision and information content will have to increase considerably to the point where these actions can be justified more explicitly than presently possible.

MANAGEMENT/IMPLEMENTATION CONSIDERATIONS

A panel of experienced and knowledgable individuals were convened to discuss the various tactics and challenges to be faced and overcome if satellite snowcover information is to eventually be operationally implemented. This panel also served as a nucleus for offering suggestions as to the next steps to be taken in the ASVT. The participants were:

1. Jack F. Hannaford — Sierra Hydrotech
2. Fred A. Limpert — Bonneville Power Administration
3. Ronald E. Moreland — U.S. Soil Conservation Service
4. Donald R. Wiesnet — NOAA/NESS
5. Charles H. Howard — California Department of Water Resources
6. Gary J. Freeman — Pacific Gas and Electric Company
7. Ed Kirdar — Salt River Project

The panel noted that the problems in snowmapping are distinctly different in each of the study areas. For instance, in the Northwest the snowcover is persistent, but obscuring cloudcover for satellite observations is frequent. On the other hand in Arizona, cloud-free observations are readily available, but the snowcover comes and goes so rapidly that LANDSAT observations may not observe significant snowstorm events. In both cases it seemed desirable to supplement LANDSAT data with NOAA/VHRR observations.

Because snowcover-runoff relations are necessarily empirical, several years of data will be necessary to substantiate relationships that may be developed. Therefore, it is absolutely mandatory in order for the ASVT to be successful that it be continued for its designed period; namely, four years. It was also noted that, wherever they exist, aircraft data taken in previous years should be utilized to extend the years of record used in building snowcover versus runoff relationships. Where aircraft data have been used in the past, some mechanisms already exist that can make use of the satellite data. For instance, Sierra Hydrotech has used aircraft snowcover observations in the Southern Sierras to build snowcover-runoff relationships that they hope to improve and extend using LANDSAT data. The Bonneville Power Administration has used aircraft data in their SSARR model. With the LANDSAT data available, they hope to be able to inject snowcover data more frequently into the model as a check and adjustment factor for the snowcover estimation and prediction subroutines.

One key item that needs to be improved is the speed of data delivery. Examples of the Canadian "Quick Look" system were made available and seemed quite appropriate for ASVT needs. The use of this system would provide the essential step forward in meeting data delivery goals.

Overall, the promise of the satellite snowcover observations appears quite high after one year of study and evaluation. As already mentioned, all the agencies directly concerned were quite clear in indicating that more years of observation must be acquired and evaluated before complete implementation of procedures using these data can be validated and justified. Simple demonstration of performance within existing budgetary and manpower constraints is basically needed. However, sufficient promise has been seen by some of the agencies to indicate that written support and backing could be provided to NASA and other U.S. Government Agencies, if needed, in order to insure that the Snowmapping ASVT effort can continue.

OPERATIONAL APPLICATIONS OF SATELLITE SNOWCOVER OBSERVATIONS

NASA/GODDARD SPACE FLIGHT CENTER UNIVERSITY OF NEVADA, RENO

SOUTH LAKE TAHOE, CALIFORNIA AUGUST 18-20, 1975

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U.S. Government Printing Office: 1975--637-824 Region No. 3-11