THE NOAA/NESS PROGRAM FOR OPERATIONAL SNOWCOVER MAPPING: PREPARING FOR THE 1980's

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ABSTRACT

The NOAA/NESS operational satellite snowmapping program is described at the end of its first 5 years. Supporting developmental efforts are reviewed.

INTRODUCTION

Environmental satellites providing daily, high-resolution (1 km) imagery over North America became operational for the first time late in 1972. Shortly thereafter, hydrologists at the National Environmental Satellite Service (NESS) determined that imagery from these satellites could be used to create timely maps depicting snowcover over river basins of varying size, location and topography (Wiesnet and McGinnis, 1973). Snowmapping was upgraded to the status of an operational program at NESS during 1974 (Schneider et al., 1976) and has continued to expand in scope ever since. Indeed, areal snowcover measurements are now being routinely made at NESS for thirty critical basins in the United States and Canada. The data are disseminated to the user community by mail, teletype, and telecopier.

SATELLITES AND SENSORS

NOAA/VHRR

From 1973 to 1978, the primary sensor used to obtain data for the NESS snowmapping program was the Very High Resolution Radiometer (VHRR) onboard the NOAA series of polar-orbiting satellites. The VHRR is sensitive to two portions of the spectrum, a 0.6 to 0.7 μm (visible) and a 10.5 to 12.5 μm (thermal infrared) channel. Coverage over most basins is available once daily in the visible and twice each day in the thermal-infrared portions of the spectrum. Data from the satellite are received through the High Resolution Picture Transmission (HRPT) system at three NESS receiving facilities; Wallops Island, Virginia, Redwood City, California, and Gilmore Creek, Alaska. The raw, ungridded unmapped image signals are displayed through a film recorder which produces a 25 cm by 25 cm film negative. Each negative covers an area approximately 2100 km square with three frames usually available per pass. Prints from the image negatives, at a normal scale of 1:10,000,000 and a resolution of 1 km (at nadir), are used in snowmapping. The VHRR achieves lateral coverage through continuous horizon-to-horizon scanning by a mirror oriented perpendicular to the forward motion of the spacecraft. Since the mirror rotates at a constant angular rate, the geometric resolution on the ground changes as the distance from the satellite subpoint increases. The resulting image produced from these signals will appear foreshortened in the area of the horizons. This foreshortening or distortion in the image can be corrected either through optical rectification or by further computer processing utilizing an algorithm described by R. L. Legeckis and J. Pritchard (1976).

SMS/GOES

Five satellites in the SMS/GOES series have been launched thus far. The first two Synchronous Meteorological Satellites, SMS-1 and SMS-2, were NASA sponsored prototypes. The most recent three, GOES-1, -2, and -3 were entirely NOAA funded (the acronym stands for Geostationary Operational Environmental Satellite). The satellites are termed "geostationary" because their position relative to the Earth's surface remains fixed. The satellite in this series that can currently be used to monitor the East Coast is GOES-2; it was launched on June 15,1977, and is stationed over the equator at 75°W longitude at an altitude of 37,500 km^2. GOES-3, which was launched on June 16, 1978, is stationed at 135°W and is currently the operational West Coast satellite. The imaging sensor on board the SMS/GOES is the Visible and Infrared Spin Scan Radiometer (VISSR). This sensor can provide imagery in both the visible and the infrared portions of the spectrum (as its name implies) as often as every half-hour. Imagery from the VISSR can be obtained in a variety of resolutions. Raw data is received from the satellite at a resolution of 1 km but can be averaged to produce images of larger spatial coverage at 2-, 4- or 8-km resolution (thermal infrared VISSR data is available only at a resolution of 8-km).

The 1-km VISSR images have been the data source for many of the operational snow maps produced since 1975. No computer programs presently exist to geometrically correct the distortion inherent in this type of imagery. However, small areas on the image may be rectified on a Bausch and Lomb Zoom Transfer Scope by optically stretching along the axis defined by the study area and the satellite subpoint.

CURRENT METHODOLOGY

Snow maps are produced at NESS by first enlarging and rectifying a visible VHRR or VISSR image to overlay a hydrologic basin map. A Bausch and Lomb Zoom Transfer Scope (ZTS) is utilized for this purpose.

Registration of image to map on the ZTS involves aligning physiographic landmarks such as lakes, rivers and shorelines. After registration has been achieved the snow line on the image is traced onto the basin map and snowcovered areas are colored in. Percentage snowcover for the basin is then determined by using an electronic density slicer. The snow map is placed on the density slicer with a previously prepared opaque mask outlining the basin. The density slicer selectively color illuminates gray shades on the map. The colors are projected onto a display screen and percentage values for each color are read from a digital meter.

PROGRAM DESCRIPTION

The areal snowcover data and/or snow maps are provided to water resource managers in numerous federal, state and local agencies. A map of the western United States showing many of the operational basins is presented in figure 1. A list of primary users and information on the precise location and size of each basin is given in the accompanying Table 1. The basins are similarly numbered on table and map.

The areal snowcover percentages are dispatched over the RAWARC teletype circuit to National Weather Service River Forecast Centers (RFC) in Sacramento, Fort Worth, Salt Lake City, Kansas City, and Portland as well as River District Offices in Great Falls, Phoenix, and Albuquerque. Snow maps are sent over telecopier or through the mail to other agencies including the U.S. Geological Survey, Bureau of Reclamation, Corps of Engineers, Soil Conservation Service, and U.S. Forest Service.

Not depicted in figure 1 but listed on the table are the St. John basin in Maine and New Brunswick, the Missouri River above Canyon Ferry Dam and the northeast U.S. snow map. The northeast U.S. analysis is first transmitted over telecopier to the National Weather Service Eastern Regional Hydrologist in New York and is then rerouted to RFC's in Hartford, Harrisburgh, and Cincinnati. Snow maps for the Missouri River above Canyon Ferry Dam were begun in November 1978, at the request of the Soil Conservation Service office in Bozeman, Montana.

Basin snow maps are made on an average of once a week beginning November 1st and terminate when the snowpack appears almost totally depleted on the imagery. The analyses can only be made when the basin is free of obscuring clouds. Accordingly, basins in the southwestern United States and California's Sierra Nevada are mapped more often than those in the less cloudfree Pacific Northwest.

Over six hundred snowcover measurements were made at NESS during the 1977-1978 snow season. Snowmapping totals for the past four years are as follows:

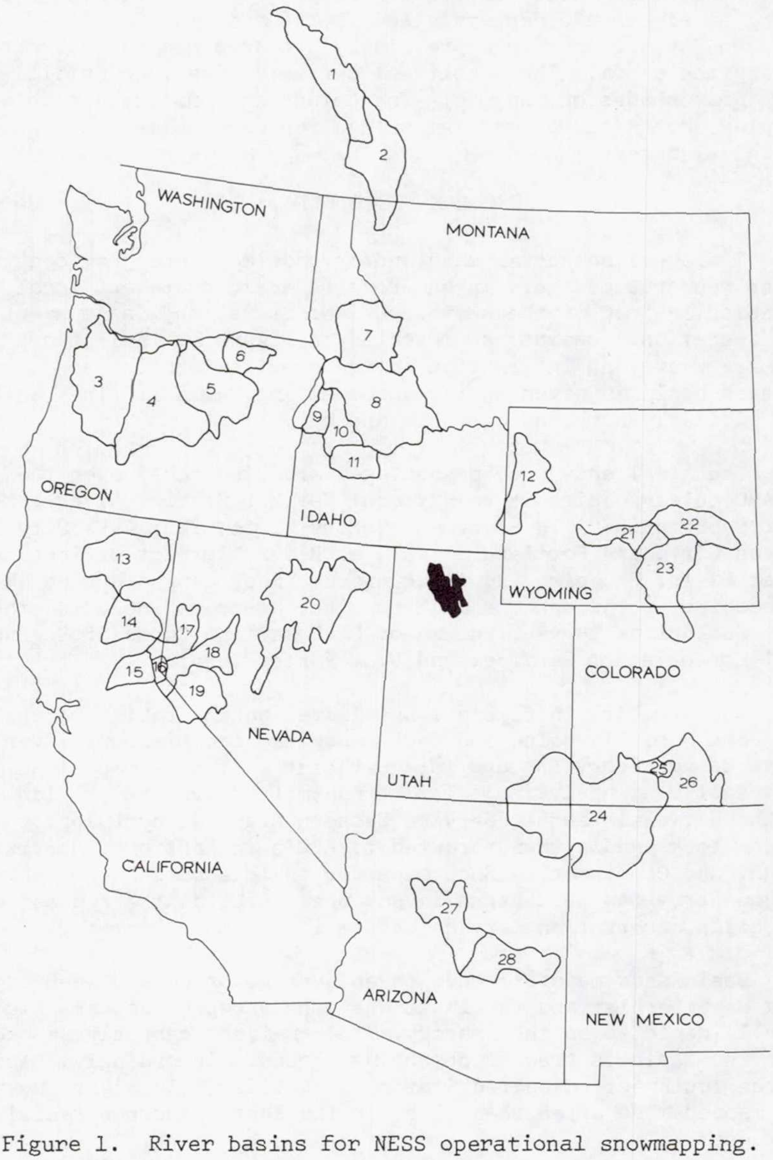

Figure 1. River basins for NESS operational snowmapping.

Table 1

Basins Being Mapped As Of 1978

River Basin	Drainage Area in Km^2	Primary Users
American above Fair Oaks (15)	5,601	Sacramento RFC
Boise above Lucky Peak (11)	6,941	Portland RFC, Columbia Basin Network
Carson (18)	8,864	Soil Conservation Service, Sacramento RFC
Clearwater above Peck (7)	20,824	Portland RFC, Columbia Basin Network
Columbia River above Mica Dam (1)	21,290	Portland RFC, Columbia Basin Network, B.C. Hydro & Power Authority, Environment Canada
Deschutes (4)	27,195	Portland RFC, Columbia Basin Network
Feather above Oroville (14)	9,386	California State Dept. of Water Resources
Humboldt above Comus (20)	31,339	Salt Lake City RFC, Soil Conservation Service
John Day (5)	19,632	Portland RFC, Columbia Basin Network
Kootenay above Libby (2)	23,277	Portland RFC, Columbia Basin Network
Missouri River above Canyon Ferry Dam	40,714	Soil Conservation Service, Great Falls RDO
North Platte between Alcova and Guernsey (22)	12,198	Bureau of Reclamation, Kansas City RFC, Soil Conservation Service
North Platte above Seminoe (23)	15,274	Bureau of Reclamation, Kansas City RFC, Soil Conservation Service
Northeast U.S. Snow Map		NE Regional Hydrologist NWS
Payette above Emmett (10)	6,941	Portland RFC, Columbia Basin Network
Rio Grande above Colo.-New Mexico State Line (26)	19,900	Soil Conservation Service, Fort Worth RFC
Rio Grande above Del Norte (25)	3,419	Soil Conservation Service, Fort Worth RFC
Sacramento above Shasta (13)	16,630	California State Dept. of Water Resources
Salmon above Whitebird (8)	35,095	Portland RFC, Columbia Basin Network
Salt (28)	16,141	Salt Lake City RFC, Phoenix RDO, Salt River Project, U.S. Geological Survey

Table 1 (continued)

BASINS BEING MAPPED AS OF 1978

River Basin	Drainage Area in Km^2	Primary Users
San Juan (24)	65,273	Salt Lake City RFC
Snake above Palisades (12)	13,340	Portland RFC, Columbia Basin Network
St. John	55,167	Marine Bureau of Civil Emergency Preparedness, New Brunswick Dept. of Environment, Environment Canada, St. John Basin Task Force
Sweetwater above Pathfinder (21)	6,027	Bureau of Reclamation, Kansas City RFC, Soil Conservation Service
Tahoe-Truckee (16, 17)	7,665	Soil Conservation Service, Sacramento RFC
Umatilla (6)	5,931	Portland RFC, Columbia Basin Network
Verde (27)	17,094	Salt Lake City RFC, Phoenix RDO, Salt River Project, U.S. Geological Survey
Walker (19)	9,241	Soil Conservation Service, Sacramento RFC
Weiser (9)	3,781	Portland RFC, Columbia Basin Network
Willamette (3)	26,159	Portland RFC, Columbia Basin Network

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Notes on Users:

1. The Columbia Basin Network includes the Soil Conservation Service, Bureau of Reclamation, U.S. Geological Survey, U.S. Army Corps of Engineers, National Weather Service, Bonneville Power Administration, B.C. Hydro and Power Authority, as weel as other state and local agencies.

2. Basins being done for the Bureau of Reclamation in Denver, Colorado, are retransmitted from the site to field offices in Caspar, Laramie, and Cheyenne, Wyoming.

3. The St. John Basin Task Force includes the National Weather Service, U.S. Army Corps of Engineers, U.S. Geological Survey, Environment Canada, and other state, provincial agencies.

4. Most basins are mapped twice weekly cloud cover permitting. The Salt, Verde and St. John basins are mapped daily cloud cover permitting. The Tahoe-Truckee, Carson and Walker basins are mapped only at the end of each month.

Snow Year	Number of Snow Maps
1974-1975	441
1975-1976	520
1976-1977	494
1977-1978	606
	TOTAL 2061

The snowcover data are generally provided to users within 30 hours of a satellite overpass so they can be incorporated into watershed runoff forecast models. Quality control techniques used are described in Schneider et al (1976). They include checks of the operational snow maps with higher resolution Landsat satellite data, computer-enhanced imagery, ground-based snowpack measurements and aerial-survey maps. The data from aerial surveys are particularly useful for quality control purposes and are provided for basins in Arizona, Idaho, and British Columbia, respectively by the Salt River Project, Walla Walla District Corps of Engineers, and the British Columbia Hydro and Power Authority.

USER EVALUATION

In an effort to streamline and improve snowmapping at NESS a detailed questionnaire was sent out to primary users of the snowcover data on October 24, 1978. The questions were directed towards user needs in terms of data timeliness, frequency, accuracy, and quality control. Of seventeen responses, three rated the snow maps as "excellent", fourteen rated them as "good" and two rated the maps as "fair" (in some cases more than one box was checked).

The following applications of the snowcover data were mentioned: runoff forecasting, flood prevention, water resource planning, research and development, reservoir/dam regulation, irrigation planning, and inclusion in State bulletins. Users reported that they were checking the satellite snowcover accuracy by using runoff data, snow-course data, hydromet networks, aerial surveys (both fixed and rotary wing) and mathematical models (SSARR and FLOCAST were mentioned).

Users requested coverage for over 30 additional basins. Several of the users requested that the data be transmitted to them in a more timely fashion, i.e., over telecopier rather than through the mail.

NESS SUPPORT TO THE SNOW ASVT PROGRAM

According to Rango (1975) positive research results in both snowmapping and runoff correlations led to a decision at NASA in 1975 to operationally test the use of remotely sensed snowcovered area for improving runoff forecasts in a four-year duration Applications System Verification Test (ASVT). A contract was let that same year to NOAA/NESS to promote a study in support of the snow ASVT. Since that time data from NOAA/NESS have been regularly shipped on request to the ASVT test sites in Arizona, California, Colorado and the Pacific Northwest. These data have been in the form of satellite imagery, digital tapes and completed snow maps. Daily NOAA snowcover data have been used at the four test sites to fill in gaps created by the less frequent coverage of Landsat-1 and 2.

As part of the ASVT Program a NESS representative was sent on a two-week training mission to all the ASVT test sites in January 1977. Mini-snowmapping workshops were conducted in Portland, Denver, and Placerville, California. A snow survey flight in Arizona was arranged by representatives of the U.S. Geological Survey and the Salt River Project to help the NESS analyst gain a "feel" for the appearance of snowcovered terrain in the Salt-Verde watershed.

Some of the NESS ASVT funds have been used to defray the cost of equipment purchased in support of the snowmapping study i.e., Zoom Transfer Scopes and density slicer vidicons. However, as the ASVT program now comes to an end, it becomes obvious that its major benefit to operational snowmapping at NESS has been to make the user community aware of the availability and usefulness of satellite snowcover data. In fact, several of the basins (Rio Grande, Feather, Sacramento) originally targeted for limited-duration study in support of the ASVT have now been added to the ongoing Operational Snowmapping Program at NESS.

SELECTED CASES

Sierra Nevada

Selected river basins in the Sierra Nevada have been operationally monitored at NESS since early 1973. In fact, one-hundred-seventy-eight (178) areal snowcover determinations were made alone for the American Basin (above Folsom) between January 1973 and June 1978. At the request of the California State Department of Water Resources, the Sacramento River basin above Shasta and the Feather above Oroville were added to the NESS operational snowmapping program in January 1977. In February 1978, the U.S. Soil Conservation Service office in Reno, Nevada, requested that operational coverage be extended to three river basins on the Eastern slopes of the Sierras: The Tahoe-Truckee, Carson and Walker.

The Sierra Nevada has served as an outdoor "laboratory" for snow-related research in the recent past. The NASA-sponsored Snow ASVT includes 38 major basins and sub-basins in the northern and southern Sierra (Brown and Hannaford, 1975). Film loops consisting of daily GOES satellite imagery have been constructed to dynamically depict seasonal melt off in the Sierras (Breaker and McMillan, 1975). The feasibility of remotely determining snowpack density in the Sierras was explored by McMillan and Smith (1975). The Sierra Cooperative Pilot Project (SCPP), a winter orographic cloud seeding experiment, is now being designed by North American Weather Consultants and the Bureau of Reclamation for the Central Sierras (Foehner, 1978). The utility of areal snowcover measurements in runoff and water supply forecasting for Sierra basins is described in Hannaford (1977). A completely automated technique for snowmapping is currently being tested at NESS using six adjacent Sierra basins as the primary study area (Tarpley et al., 1979).

Of paramount interest was the two-year (1976-1977) drought in the Sierras, an event which was continuously monitored by NASA and NOAA satellites. Figure 2 depicts the entire Sierra Nevada Mountain Range as viewed by NOAA-3 during mid-April 1975. The Sierras can be seen as a broad white swath extending from the northwest (upper left) edge of the image to the southeast (lower right) edge. Figure 3 shows the same area as it appeared from the NOAA-5 satellite on a comparable date in 1977. Areal snowcover measurements for the entire mountain range, derived from the two images, revealed snowcover in 1977 to be less than one-third of what it was in 1975. In figures 4 and 5, snowcover in the Sierra Nevada (shown in black) for the two April cases is superimposed on a State outline of California. Through the use of the Zoom Transfer Scope and Density Slicer, areal measurements for selected Sierra basins were made from the imagery. Results showed that the ratio of 1977 to 1975 snowcover for basins in the lower elevation northern Sierras were approximately 1:8. Snowcover disparities were not as great (between 1:2 and 1:3) for basins in the high elevation central and southern sectors of the Sierras (Schneider and Matson, 1977).

<u>Arizona</u>

Three-hundred and four (304) snowcover measurements have been made at NESS for the Salt and Verde basins since November 1974. Owing to rapid snowmelt in Arizona, these basins must be monitored on a daily basis. In fact, rainfall and snowmelt combined to cause the Salt River to overflow its banks in both March and December, 1978. One such rapid snowmelt event took place in early March 1977, and was reported on in detail by McGinnis and Schneider (1978). An illustration from that paper is presented here as figure 6. The righthand side of the figure shows a Landsat-1 visible (band 5) image taken over Airzona at 1619 GMT on March 2, 1977. On the left is a ground-cover map for the same region. Ground cover strongly influences the appearance of snow in satellite imagery. Snowcover extends from the northeast corner of the image in a widening band until it stretches across the entire image at mid-image. The southward extent of the snow is limited to two bands: one, oriented northeast-southwest, ends midway between the Roosevelt and the San Carlos reservoirs: the

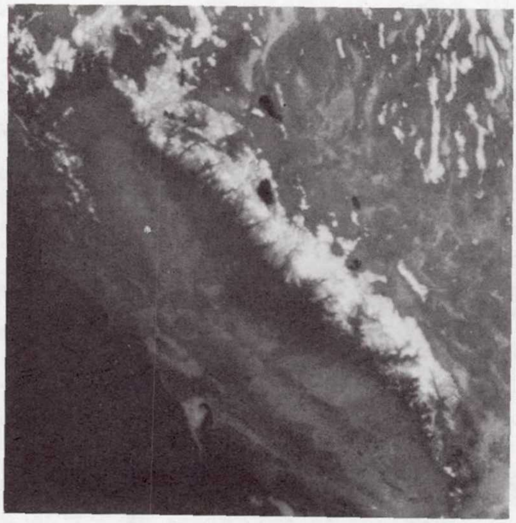

Figure 2. NOAA-3 satellite image showing snowcover in the Sierra Nevada mountain range on April 28, 1975.

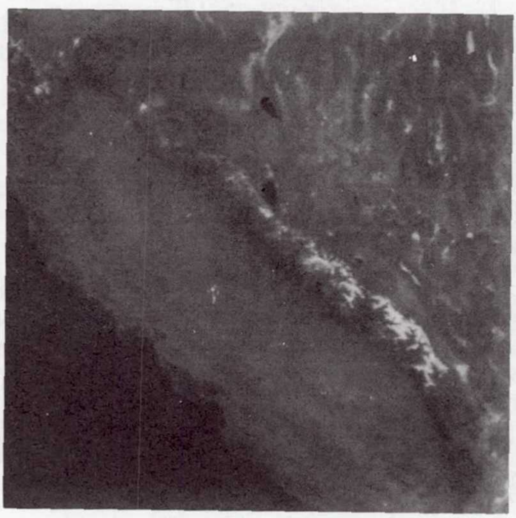

Figure 3. NOAA-5 satellite image showing snowcover in the Sierra Nevada mountain range on April 19, 1977.

Figure 4. Snowcover extent (in black) for the Sierra Nevada on April 28, 1975.

Figure 5. Snowcover extent (in black) for the Sierra Nevada on April 19, 1977.

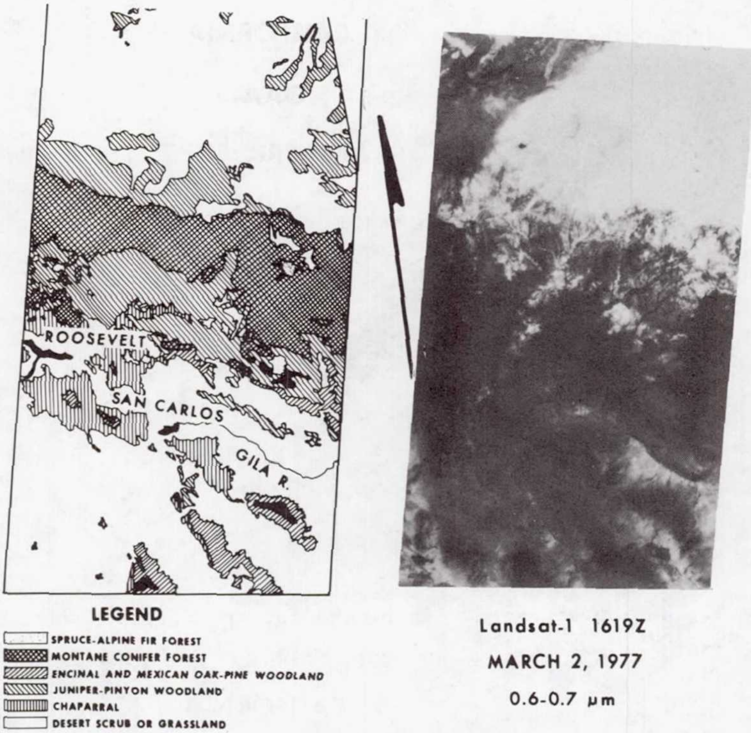

Figure 6

other, more blunt, ends just below the right center of the image. The snow scene appears brightest when the snow overlays desert scrub or grassland, as in the northern third of the image. At the higher elevations, where the forest canopy becomes more dense, the snow scene appears less reflective (grayer); e.g., note the protrusion of juniper-pinyon covered highlands into the open grasslands (upper center of image). Snow in the mountain conifer and spruce-alpine fir forests appear the least reflective. Most of the snowcover on the image was deposited as a result of strong convective activity over Arizona during the period 0000 to 1200 GMT, March 2, 1977.

Climatological data (NOAA, 1977) for Arizona show that 20 stations in or adjacent to the Salt Verde watersheds routinely report snowfall. Only seven of the 20 stations reported snowfall in this case. The greatest fall--10 cm--occurred at Hawley Lake (elevation 2493 m) and only two other stations measured as much as 2 cm of snow. Thus, the climatological data show not only that a very light snowfall occurred, but also how poorly the present network of stations delineates the areal extent of the snowfall. This failure to properly describe snowcover points to the need for mesoscale and synoptic-scale views available from satellite images.

Large areas of this extensive, but shallow snowcover had melted away when viewed by NOAA-5 on the morning of March 3. Using a compensating polar planimeter on the imagery, it was determined that the snow-covered area decreased by 18,850 km^2 between the mornings of March 2 and 3, an area almost as large as New Jersey.

St. John Basin

The St. John basin, which lies both in New Brunswick and Maine, has been the object of special study at NESS during the past few years. In 1975, the basin was selected as a desirable international study area for two different World Meteorological Organization (WMO) programs, the World Weather Watch and the WMO Snow Studies by Satellite project. The basin drains 58,500 square kilometers of which 36 percent lies within the United States and 64 percent lies within Canadian territory. Snowmelt-induced flooding in the spring is a common occurrence and over the last 60 years has accounted for approximately one million dollars of damage, annually. The April 1973 flood alone caused eleven million dollars of damage in New Brunswick. The snowmapping and river ice-reconnaissance techniques developed at NESS during the past few years have become an important part of the flood warning and forecasting network in the basin (Schneider, 1977).

The presence of dense coniferous forest throughout much of the St. John basin makes satellite detection of snowcover difficult. Figures 7A-D depict the St. John basin as it was viewed from the VHRR onboard NOAA-4 during various stages of snowmelt. On figure 7A the basin, which is outlined in white, has a very mottled and patchy look to it, even though it is 100-percent snow covered. The bright white features are frozen lakes and rivers as well as snow covered open terrain (of which there is very little in the basin). The forest covered areas appear in various shades of gray, the densest forests (darkest gray in appearance) being located in the western part of the basin. Figure 7B shows the eastern portion of the basin as mostly snow-free while cloudy in the west, and figure 7C, taken six days later, shows the basin with about 50 percent snowcover. Figure 7D depicts the basin as completely snowfree. Notice that on figure 7D, two heavily farmed regions, one south of Gagetown in the eastern part of the basin and one along the St. John River between Hartland and Grand Falls in the center of the basin, can be identified because of their very light gray tone.

As previously mentioned, figure 7A shows the St. John basin as completely snow covered. It also shows the entire St. John River along with every tributary and lake in the basin as completely frozen over. Ice conditions in the basin are much different in figure 7B, the VHRR image taken on 15 April 1976. In this image, almost all bodies of water in the basin east of the cloud bank have thawed out, save two ice-covered reaches of the

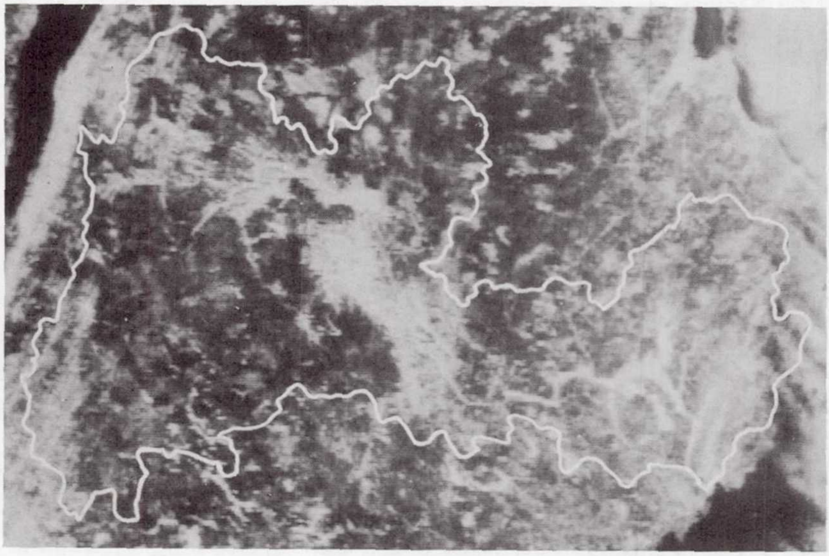

Figure 7A. VHRR image depicting St. John Basin on 9 March 1975. Basin is totally covered with snow and ice.

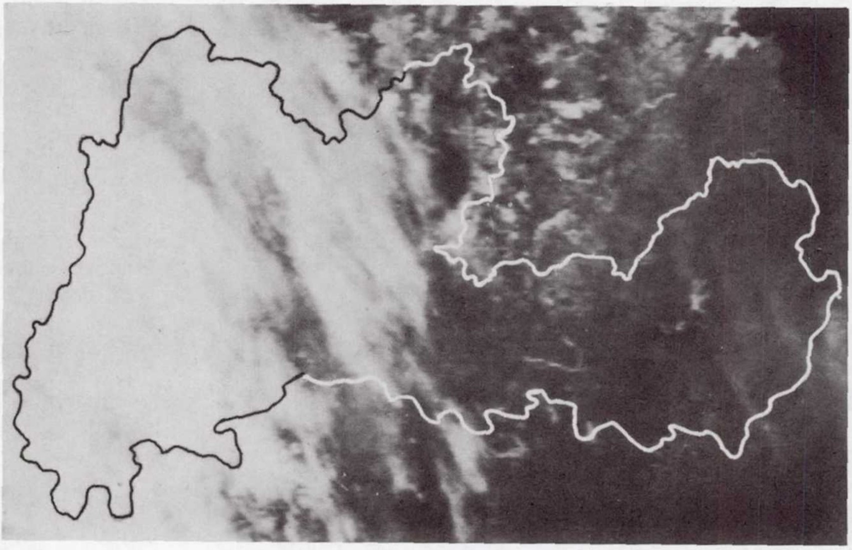

Figure 7B. VHRR image depicting the St. John Basin on 15 April 1976. The western part of the basin is covered by cloud; the eastern half is mostly snow free.

Figure 7C. VHRR image depicting the St. John Basin on 21 April 1976 with about 50 percent snowcover.

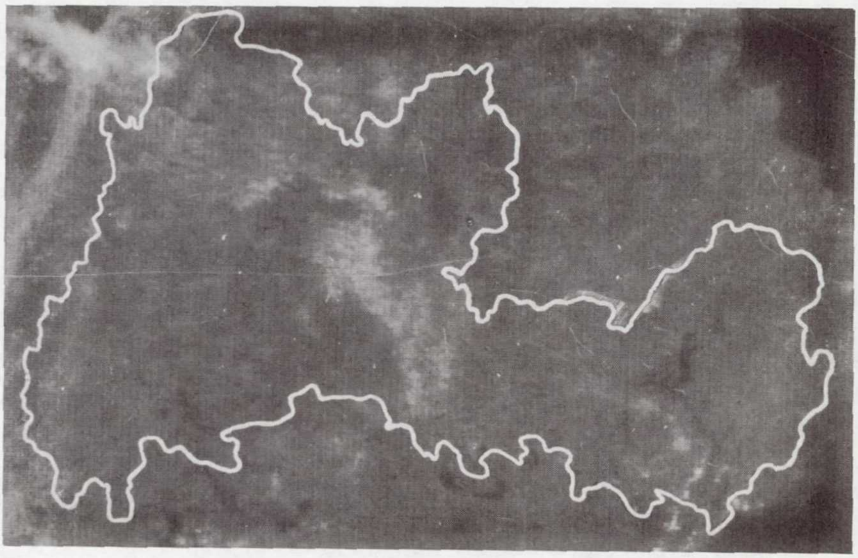

Figure 7D. VHRR image depicting a snow-free St. John Basin on 25 May 1975.

St. John River. These two ice-covered reaches include parts of Mactaquac Lake (nearest the cloud bank) and Grand Lake (to the northeast). An examination of the VHRR image taken six days later on 21 April 1976, reveals these two segments of the St. John River have completely thawed. Having a set of such imagery on hand, depicting the basin under all different snow and ice conditions, can greatly aid the photointerpreter in his work.

DEVELOPMENT

TIROS-N

The first of a new generation of polar-orbiting satellites, TIROS-N was launched on October 13, 1978. A second satellite in this series, NOAA-A will be launched in early 1979. Together, the satellites will be able to provide coverage four times daily (0300, 0730, 1500, 1930 Local Standard Time) over most areas in the United States and Canada. Each satellite will have an Advanced Very High Resolution Radiometer (AVHRR) onboard which will be able to provide coverage in the following five channels:

Channel 1	.58-.68 μm
Channel 2	.725-1.0 μm
Channel 3	3.55-3.93 μm
Channel 4	10.5-11.5 μm
Channel 5	11.5-12.5 μm

Several studies (Strong, et al., 1971; Wiesnet, et al., 1975; and O'Brien and Munis, 1975) have shown that it is often possible to detect metamorphosed (or melting) snow and ice by comparisons of simultaneous Landsat visible (MSS-5) and near infrared (MSS-7) imagery. These studies indicate that the reflectance of metamorphosed snow and ice is less in the near infrared than that of fresh non-melting snow. The availability of simultaneous AVHRR visible (Channel 1) and near infrared (Channel 2) imagery may in the future allow NESS investigators to give operational reports on the age and condition of river basin snow cover as well as its areal extent.

High Resolution Film Loops

One-kilometer-resolution GOES images can be generated every half hour and strung together to make film loops. The loop can then be run continuously through a projector, displaying the same sequence of images over and over. These loops have been found helpful in discriminating between cloud and snow and in monitoring shadow effects on snow fields, fog dissipation, cumulus buildups and snowmelt.

Interactive Snowmapping

Two new interactive computer systems named VIRGS (VISSR

Interactive Registration and Gridding System) were delivered to NESS in June 1978. A feasibility study concerning use of the VIRGS for operational snow mapping has already been carried out at the Madison campus of the University of Wisconsin (Gird, 1979). To use the system for snowmapping, basin perimeters drawn on standard aeronautical charts are first converted into grid points through the use of an electronic digitizing board, and are then read into the VIRGS. The basin outlines can then be displayed on the system video screen at any time by typing a single command on the keyboard. A joy-stick cursor is used to outline snowcover on the video screen; area statistics software on VIRGS are invoked to calculate and print out the basin snowcover percentages. Advantages of this system over pure photointerpretation include ease of basin registration and measurement of areal snowcover as well as the ability to display time-sequenced sets of images. Present disadvantages include lengthly set-up time, lack of hard-copy output and "jumpiness" of the joy-stick cursor.

All Digital Snowmapping

A project is underway at NESS to check the feasibility of doing all digital snowmapping using 4-km visible GOES data. The test area includes nine contiguous basins in the Sierra Nevada. These basins offer a wide variety of terrain characteristics and ground cover for control purposes; they are also of ideal size and location as viewed from the West Coast geostationary satellite. Data used in this experiment are stored on computer disk packs for 24 hours. Snow maps for all nine basins can be done as often as five times daily: 1645Z, 1745Z, 2045Z, 2145Z and 0045Z. The model involves the thresholding of each individual basin pixel for snowcover and takes into account solar illumination angles as well as the nature of ground cover. Detailed description of this snowmapping model as well as preliminary results for the 1978-1979 snow season are presented in Tarpley et al. (1979).

FINAL COMMENTS

An operational satellite snowmapping program for selected river basins is now in place at the National Environmental Satellite Service. Owing to the success of this program a larger number of requests for support have been received than can be handled given present manpower and fiscal restraints. Expansion of the program can therefore only come about through the development of more efficient (i.e., automated) techniques for snowmapping. This is the goal towards which satellite snow specialists must now direct their efforts.

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