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ANALYSIS OF ERTS IMAGERY USING SPECIAL ELECTRONIC VIEWING/ MEASURING EQUIPMENT

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ABSTRACT

An Electronic Satellite Image Analysis Console (ESIAC) is being employed to process imagery for use by USGS investigators in several different disciplines studying dynamic hydrologic conditions. The ESIAC provides facilities for storing registered image sequences in a magnetic video disc memory for subsequent recall, enhancement, and animated display in monochrome or color. Quantitative measurements of distances, areas, and brightness profiles can be extracted digitally under operator supervision. Initial results are presented for the display and measurement of snowfield extent, glacier development, sediment plumes from estuary discharge, playa inventory, phreatophyte and other vegetative changes.

1. INTRODUCTION

An Electronic Satellite Image Analysis Console (ESIAC) providing television animation, editing and video processing capabilities has been in use by Research Meteorologists at SRI since early 1967 primarily for analysis of ATS imagery.(1) During 1972 a new console was constructed having design features specifically oriented towards the needs of ERTS. As part of the NASA ERTS-1 program this new equipment is being utilized to meet the data processing needs of a group of ERTS principal investigators within the U.S. Geological Survey (Water Resources Division) operating in widely diverse specialties but all part of the W.R.D. program in Dynamic Hydrology.*

The basic objective of this equipment is twofold: First, it attempts to present the imagery in a form that will show up, or hopefully even emphasize, the phenomena of interest. Occasionally this display function alone can contribute enough to understanding that no more is required. Frequently, however, there is also a need for a second function--that of extracting quantitative measurements from the imagery.

The principal image enhancement technique in the ESIAC, is rapid sequential presentation of registered images--time lapse series, flicker

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comparisons, and the like. Additional image enhancement capability is provided through contrast and polarity manipulation, easy scale changes (zoom), and false-color display of multispectral imagery.

Quantitative measurements of distances, areas, and signal amplitudes are made under operator guidance and may be output in digital form.

2. HARDWARE

The equipment is illustrated photographically in Figure 1, and in block diagram form in Figure 2. Items in the block diagram are grouped by function into four principal categories: Input, Storage, Processing, and Output.

- Data input is nearly always via positive film transparencies, though other media can be accommodated. The transparency input station is fitted with a high quality Vidicon camera, ten-to-one macro-zoom optics, and a system of micropositioners and reference graticules to aid in registering new images to those previously stored. Overhead is a second Vidicon camera which is used for inputting hard copy maps or pen marks made by the operator. Another input is x, y position information for the electronic crosshairs, or cursor, whose location is controlled by a track-ball in the desk top.
- Storage memories are located in the base of the console, and the memory controls are on either side of the main display. A 16" analog magnetic video disc recorder is fitted with two moving head channels, each channel capable of storing up to 300 addressable 525-line TV frames. The heads may be stepped independently or in unison, at easily controllable rates. A third memory unit, now under construction, will be solid state and will hold one frame of binary (two level) imagery for masking functions that will be discussed later. Small 7-inch TV picture monitors (preview monitors) are permanently connected to show what images are available from the camera or memory channels.
- In the Processing section is a video mixing panel, which permits positive or negative amounts of video signals from any or all of four input channels to be merged into a composite signal to be viewed on the main black and white picture display.

  Three video level decision circuits are shown. Each of these is really a fast one-bit Analog to Digital converter having an adjustable threshold level. The binary video signal can be displayed as an image photographed, stored, superimposed onto other images, or the total number of TRUE picture elements in the frame can be counted by the digital counter.
- Output devices include the main picture monitor, a color display, a digital counter, an oscilloscope for monitoring video

waveforms (e.g., individual radiance profiles) and a teleprinter--for recording distance and area measurements made from the display.

The color display has been found to be extremely useful in analyzing ERTS images. It has separate, simultaneous inputs for red, green, and blue channels. Thus high quality three-primary false-color displays can be achieved by connecting the three inputs to registered images from the A disc, the B disc, and the camera. Alternatively, by driving both the green and the blue channels from the same source, two bands can be compared in a two-primary, red-cyan system. This is the operating mode that has been found most useful to date. A principal reason for this choice is that with the present equipment, two bands can be viewed in time lapsed color (by stepping A and B disc channels together) while three cannot. Additionally, however, two-band comparisons tend to be inherently easier to comprehend than three. For many purposes, the step from monochrome to two-band color has been found to be both dramatic and highly meaningful, while the incremental subjective value of the next step to three-band color is much more questionable.

3. APPLICATIONS

As an example of the ESIAC capability we will outline an approach to a problem of considerable practical importance--that of measurement of snow cover from ERTS imagery.* The basic procedure is to scan the image transparency for the band showing the best snow-surround contrast--perhaps MSS band 5. A video level decision circuit is then used to isolate and count all those picture elements which are brighter than some appropriately chosen threshold level.

One procedure for choosing the threshold level is to electronically superimpose the binary mask image obtained from the level decision circuit (LDC) onto the full tone scale image so that it is displayed optionally either as an excessively white highlight or as an abnormal brightness reduction. The operator then adjusts the decision threshold until he achieves a match between the TRUE portion of the binary mask and what he judges to be the snowfield.

When clouds, fog, or haze are present the problem of defining the snow cover becomes much more difficult. Identification is appreciably easier when the color display is used, but by far the most powerful device, when it can be employed is the time-lapse capability, using imagery of the same scene taken at different times. Permanent features such as snow can be read through an astonishing amount of cloud

* This example is selected from work being performed for Dr. Mark F. Meier of the USGS Water Resources in Tacoma, Washington.

clutter when the latter can be made to move while the former remains relatively fixed.

To map or measure the partially obscured areas, we are experimenting with methods of manually editing the video-derived binary thematic masks while the mask is being observed superimposed on the time-lapse display.

For one current project, an important task is to partition the snowpack into specific drainage areas. Figure 3 presents data for a portion of the North Cascade range in north central Washington. The first panel defines a specific drainage basin of interest by an electronically superimposed outline derived from a hand-drawn mask prepared with the aid of a contour map used to locate the ridges and high points surrounding the basin. The remaining panels of Figure 3 show binary masks (white) resulting from logically ANDing the outputs of two Level Decision Circuits, one used for thresholding the band 5 signal at the indicated levels, and the other used to derive a clean basin image (grey) from the hand-drawn map. The area figures shown are the ratios of picture element count in the white regions to the picture element count for the total basin. Masks of this type are being compared (by superposition) to both monochrome and color imagery and to ground truth surveys in an effort to refine the rules for specifying optimum threshold settings. It is obvious that critical registration of the drainage outline map to the ridge lines is an essential part of accurate measurement, and the console is well adapted for that task. The scaling, registration and superpositioning capabilities also permit synthesis of composite images such as that illustrated in Figure 4 which shows an ERTS image of Mt. Rainier plus 1000 foot elevation contours taken from a topographic map.

Three additional applications will be described briefly. (1) For Mr. Fred Ruggles (USGS Water Resources Division in Hartford, Connecticut), the ESIAC is being used to enhance the visibility of patterns caused by the suspended sediments in the waters of the Connecticut, Thames, and Housatonic Rivers in order to study the mixing patterns of estuarine discharges into Long Island Sound at different phases of the tidal cycle. Suspended sediments in the waters of the Sound increase the reflectivity slightly and act as tracers. The river discharge plumes are visible from space as subtle modulation of the sediment patterns. For this work, the interest is almost entirely at the lowest end of the radiance scale, and best results have been obtained by working from negative transparencies, inverting them to positive images electronically when required, and using the entire brightness gamut of the video system to enhance only the first two or three steps of the grey scale range. One objective is to assemble a time-lapse sequence from portions of scenes imaged at different times in the tidal cycle, (2) Dr. Raymond M. Turner, USGS Water Resources Division office in Tucson, Arizona is studying the distribution of phreatophytes and other Arid-Land plant communities. For him the equipment is being used as a versatile color microdensitometer to prepare radiance profiles along specific transects for individual bands (Figure 5) and for radiance differences between bands.

These profiles can then be studied in time lapse along with the imagery, (3) for Dr. C. C. Reeves, Jr. of Texas Tech. University ("Dynamics of Playa Lakes in the Texas High Plains") we are using the area-measuring capability to compile statistics on water areas within specific playas and totals for the hundreds of others within an ERTS frame. Additionally, the time lapse capability is being utilized to search for patterns in lake-fill distribution that might correlate with geographical, meteorological, or seasonal conditions.

4. CONCLUSIONS

While ERTS sequences have not yet become available in sufficient length for full exploitation of the trend-enhancing power of the time-lapse technique, a significant amount of experience with imagery already received has provided convincing proof that much of the data now being accumulated will be extremely well suited for such analysis.

Electronic viewing/measuring equipment should not be regarded as competing with photographic prints in cost, convenience, and image quality nor with computer processing of digital tapes in the precision of fully objective measurements. Although the equipment described here provides capabilities that do extend surprisingly far into the realms of both of these mutually exclusive techniques, its greatest and virtually unique utility lies in providing rapid and extremely versatile coverage of a large middle ground of analysis tasks--particularly those that can benefit from sequential or simultaneous display of numerous images, and from interactive guidance by the scientific investigator. For this purpose we have evolved a system that we believe provides reasonable trade-offs among the competing factors of operating simplicity, processing volume, accuracy, maintainability, and cost.

At the NASA ERTS-1 Symposium, March 5-9, 1973 a color movie was presented using a series of ERTS-A frames to depict the changes with time of the areal coverage of snow as well as changing coverage and color of vegetation and crops.

5. REFERENCES

1. Serebreny, S.M., E. J. Wiegman, R. G. Hadfield, and W. E. Evans, "Electronic System for Utilization of Satellite Cloud Pictures," Bull. of the Amer. Meteor. Soc., Vol. 51, No. 9, Sept. 1970, pp. 848-855.

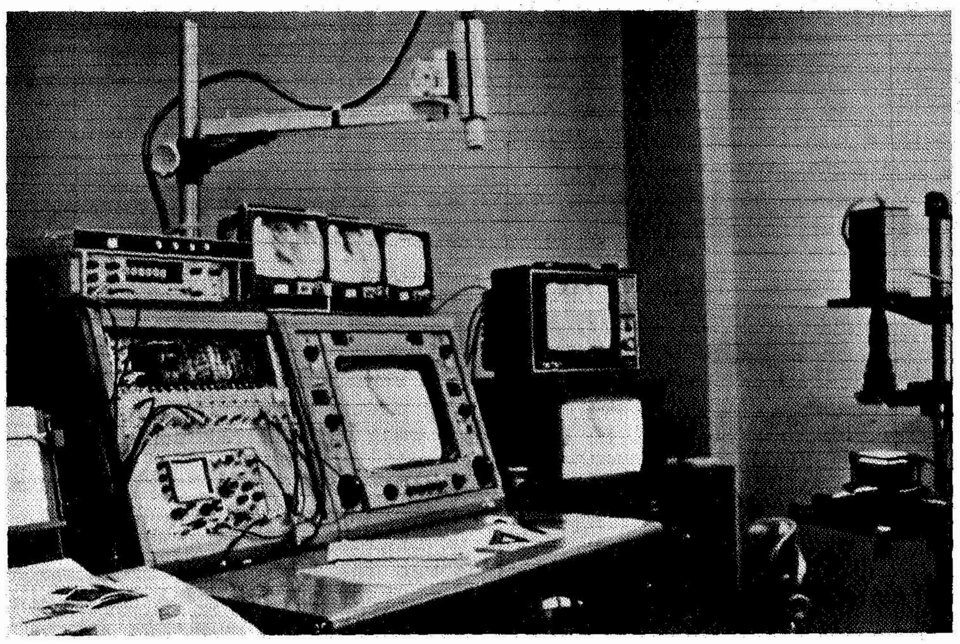

FIGURE I ELECTRONIC SATELLITE IMAGE ANALYSIS CONSOLE (ESIAC)

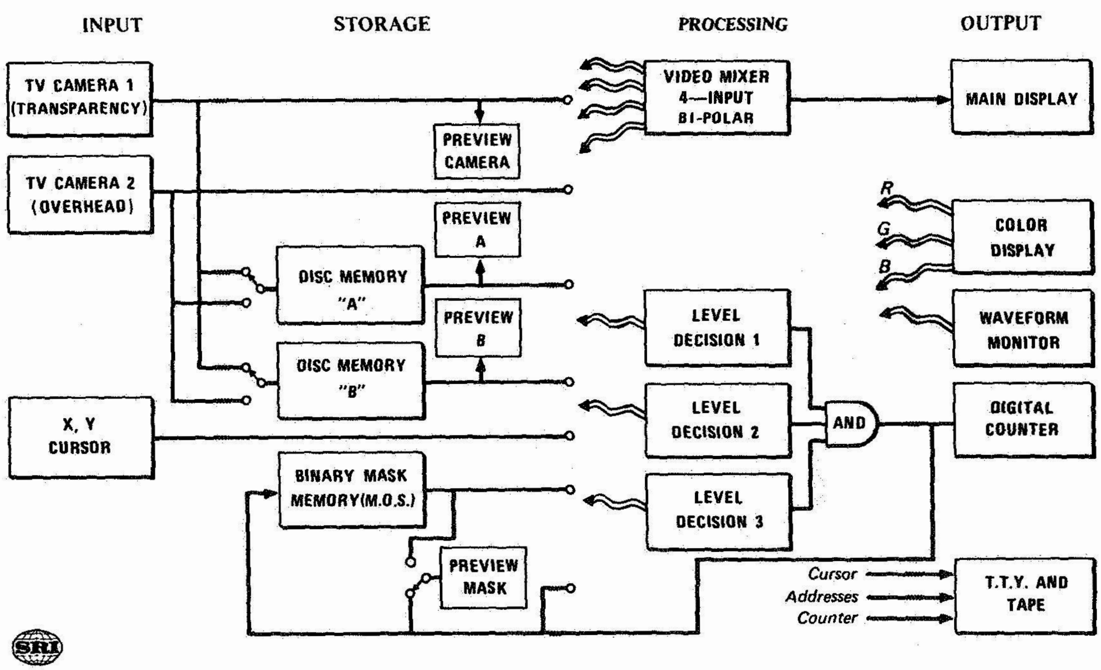

FIGURE 2 BLOCK DIAGRAM OF ESIAC

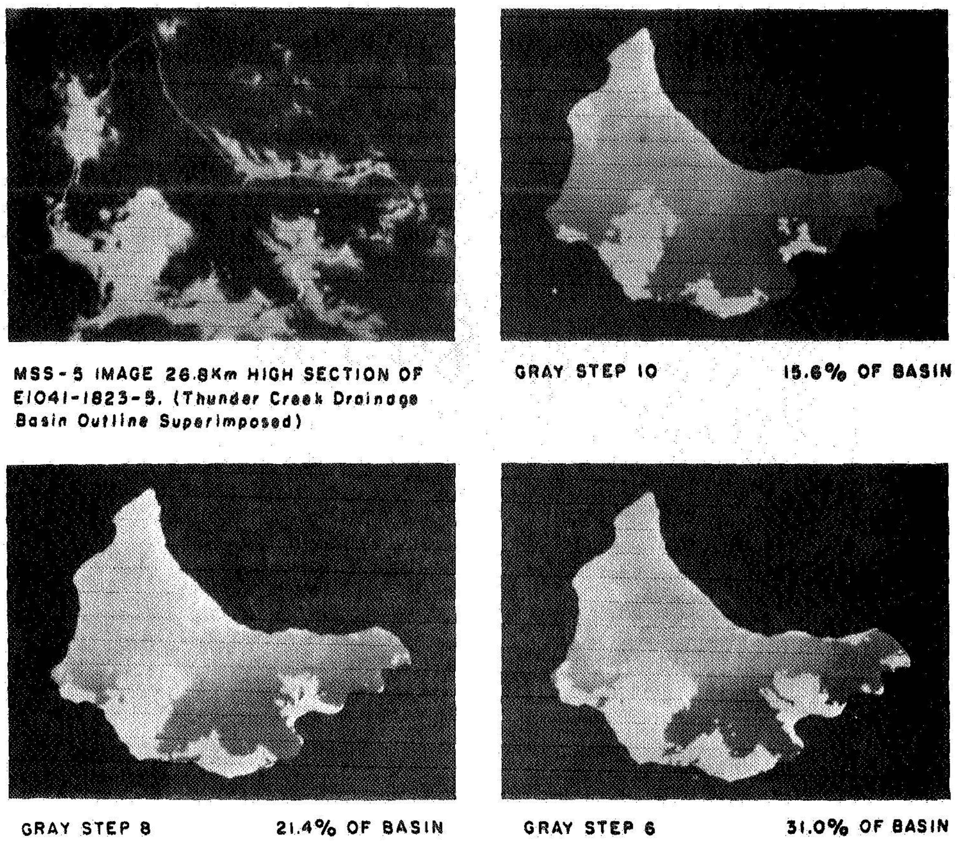

Fig. 3 Areal Distribution of Radiance above Threshold for 2 September 1972 Band 5(.6-.7μ)

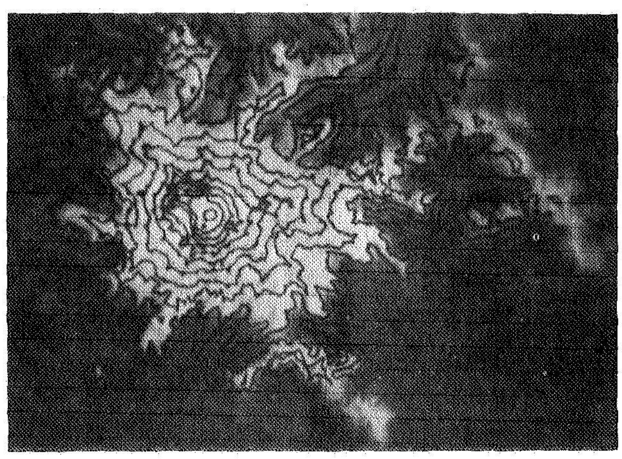

Fig. 4 ESIAC Display of Mt. Rainier, Washington for 29 July 1972 30-km High Section of ERTS Image No. 1005-18260-5.1000 ft Contours Electronically Superimposed.Center Contour is for 14,000 ft

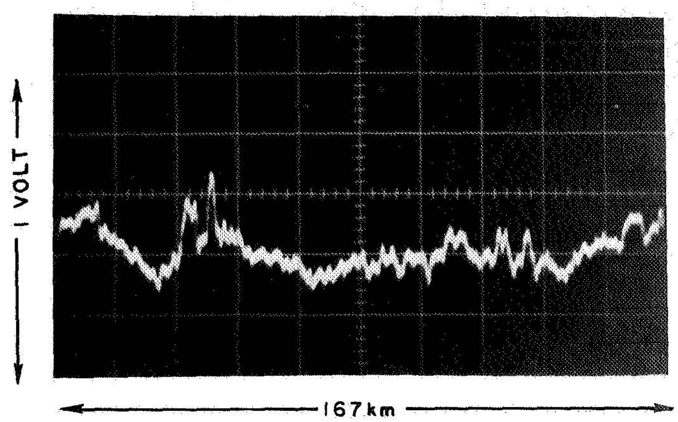

Fig. 5a Radiance Profile along MINE Transect in Arizona Desert (ERTS-1 Frame 1102-17280-5) Vertical Scale and dc Level same as for Grey Scale of Fig. 5b

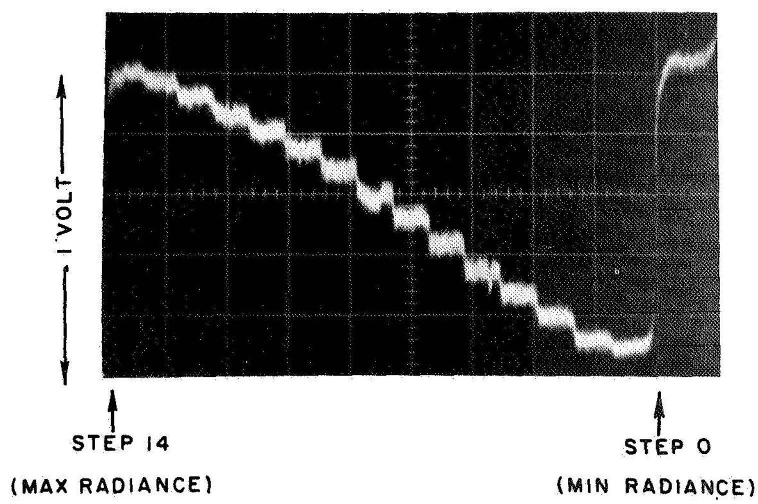

Fig. 5b Video Signal Response for Scan Across Calibration Grey Scale of Positive Transparency used for Fig. 5a