E73-10387
CR 131053

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN
P. O. BOX 618 • ANN ARBOR • MICHIGAN • 48107
PHONE (313) 483-0500

INFRARED AND OPTICS DIVISION

15 March 1973

(E73-10387) [PROCESSING AND ANALYSIS OF ERTS-1 REMOTELY SENSED DATA] Bimonthly Report, 1 Jan. - 28 Feb. 1973 (Environmental Research Inst. of Michigan) 53 p $4.75 CSCL 05B G3/13

N73-20349 THRU N73-20359 Unclas 00387

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

Attention: Mr. E. F. Szajna, Code 430

Contract: NAS5-21783

Subject: Fourth Bimonthly Report for Period Covering 1 January 1973 - 28 February 1973.

Dear Sir:

The enclosed material comprises the fourth Type I bimonthly technical report for contract NAS5-21783, which describes the progress on the ten tasks of the Environmental Research Institute of Michigan program for the subject period. It is to be noted that the third bimonthly report was included with the first Type II progress report for this ERIM program as provided for by the contract reporting schedule. The 533M and 533Q financial reports are submitted separately from ERIM's Accounting Department.

Transfer of the NAS5-21783 from the University of Michigan Willow Run Laboratories to the Environmental Research Institute of Michigan was effective as of 1 January 1973, the initial day of this reporting period. Work on this contract is performed in the Radar and Optics Division (Task IV only) under the direction of Dr. Leonard Porcello and in the Infrared and Optics Division (for the other nine tasks) directed by Mr. Richard Legault.

Principal investigators for each task are listed in each subsection of this report for the ten tasks. A summary listing of the tasks with names of the principal investigators and short titles is provided as an addendum immediately following this letter.

Attention is directed here to several major aspects of the ERIM program. First, although no outputs from the ERTS Data Management System (DMS) are included in this report, information concerning data tapes for 74 ERTS frames (not all different since we have duplicates for some frames and data tapes with the same ground coverage for more than one satellite pass) have now been entered into the DMS files. A few of these tapes are for simulated ERTS frames but some of the simulated tapes have not been entered. ERIM now has over 300 ERTS tapes in its files. Likely, this is one of the largest repositories of ERTS tapes outside of GSFC and other NASA facilities.

Secondly, some of our programs continue to be hampered by pervasive cloud cover and other unusual weather conditions which have not permitted the expected progress on these tasks. Specifically, Tasks III, IV, V, and IX have suffered from these conditions. Desired data tapes for Task I still have not been received; hence, an alternate location has been studied which permitted testing computer software and developing some useful results.

Thirdly, the first look data phase may now be regarded as essentially completed for most of the Tasks, i.e., I, II, VI, VII, VIII and X. Data Analysis Plans are in preparation and will be submitted as indicated in previous correspondence.

Fourth, major effort during this reporting period has been devoted to the preparation of contributions from ERIM to the "Significant Results from ERTS-1" symposium, 5-9 March 1973, GSFC, Maryland. It is believed that these contributions will be recognized as substantial. All of the papers prepared for that symposium are either abstracted, summarized or included completely in this fourth Type I report.

Reports by individual investigators follow in order by Task number.

Respectfully submitted,

Frederick J. Thomson
Frederick J. Thomson
Research Engineer

Approved by:

Paul ... for
Richard R. Legault
Director, Infrared and Optics Division

FJT:RRL:njm

E7.3 10388

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task I - Water Depth Measurement - 1388
F. C. Polcyn, UN 200, MMC 063

Since no useful data for the Puerto Rico test have been received, an alternate frame taken on October 10, 1972 was used to test the water depth program developed for the 7094 computer. The area included was the Little Bahama Bank and a large section of this ERTS frame was analyzed and results were prepared for presentation at the Significant Results from ERTS-1 Symposium held in Washington, March 5-9, 1973. Copy of that paper is included herewith as Appendix I to this Task I report.

Plans for the next period are to study methods of correcting detector sensitivity differences between the six detectors/channel to improve depth calculation accuracy along every scan line.

Follow-up analyses will be made of the Little Bahama Bank frame to determine water level rise above lowest mean sea level to better compare calculation of water depth versus charted values and to investigate shallow depth anomalies found in ERTS data but not present on charts for this area.

CALCULATIONS OF WATER DEPTH FROM ERTS-MSS DATA

Fabian C. Polcyn and David R. Lyzenga

Environmental Research Institute of Michigan
Ann Arbor, Michigan

ABSTRACT

ERTS-1 MSS data taken on October 10, 1972 of the Little Bahama Bank are being used to demonstrate the use of ERTS-1 data for mapping of shallow water features for the purpose of upgrading world navigation charts. Marked reflectance differences occur for the shallow water areas in Bands 4, 5, and 6. Digital processing of two adjacent data tapes within the ERTS frame covering an area of about 40 by 40 miles has been completed. Correlation of depth measurements to 5 meters has been successful. A mathematical model for depth measurements using ratio of voltages in Band 4 and 5 has been successfully developed and is being tested for accuracy. Additional studies for areas near Puerto Rico and in Northern Lake Michigan will be undertaken. Satellite data will also provide geographical evidence for verifying existence or non-existence of doubtful shoal waters now appearing on world charts and considered to be hazardous to shipping.

1. INTRODUCTION

The opportunity for global coverage afforded by earth orbiting satellites such as ERTS-1 makes possible for the first time to completely survey the oceans in a short time and in a common format and thus update the world's navigation charts.

The International Hydrographic Office has expressed concern over the status of shipping charts around the world, many of which cannot be updated due to lack of technical resources on the part of some countries. Meanwhile, some maps contain data based on survey records from the early 19th century, when the simplest techniques subject to a variety of errors were used for depth soundings.

Doubtful shoals occur for many reasons; positions are known only approximately. The same shoal may have been reported by two different ships with inaccurate geographical coordinates (Ref. 1). Location information is one of the most frequent sources for ambiguity on the shipping charts.

Chart makers are forced to use such labels as Position Approximate, and Existence Doubtful in reference to some reported sightings. Depths measured by lead lines tend to give too large a depth because of bending of the line. Echo Sounders can give errors from suspended materials that cause depths to be too shallow. Storms bring rapid changes so that even recent maps may be in error due to shifting sand bars and coastline readjustments. If only surface ships are used for hydrographic surveys, a long slow process is involved and sampling procedures are necessarily incorporated.

Satellite remote sensing affords a solution to some of these problems. Shallow waters less than 50 feet (17 meters), the most dangerous from the point of view of ship safety, are measurable from ERTS-1. Because of the 100 mile by 100 mile format, location information referenced to well known large land masses are possible and will do much to improve maps.

All points within the 10,000 sq mile frame can be observed and shallow waters easily identified on Band 4 with Band 6 or 7 used to mark land/water boundaries. Doubtful shoals can be eliminated. Existence or non-existence of doubtful shoals can be ascertained especially in regions where water clarity permits optimum light penetration. The problem that remains is to determine the accuracy of depth measurement with satellite remote sensors.

The ERTS investigation designated UN 200 carried out for NASA by the Environmental Research Institute of Michigan is planned to answer this question.

2. THE EXPERIMENTAL TECHNIQUE

Previous work (Refs. 2,3) on remote sensing techniques identified multispectral ratio processing as a promising technique for the remote detection of water depth. The technique employs the relation shown by the equation

$$z = \frac{1}{f(\theta,\phi)(\alpha_1-\alpha_2)} \ln \frac{k_1V_1H_1\rho_1}{k_2V_2H_2\rho_2}$$

where z = water depth

α_1, α_2 = extinction coefficients of water at two different wavelengths

ρ_1, ρ_2 = bottom reflection in two different bands

k_1, k_2 = constants of the instrument which are known

H_1, H_2 = incoming solar radiation

V_1, V_2 = analog signals observed in the multispectral scanning of the shallow features.

For the satellite case, V_1 and V_2 are obtained from Bands 4 and 5 of the MSS digital tape. The incoming solar radiation is available from standard references. The extinction coefficient is obtainable from ground measurements, or estimated on the average for a given geographical area based on a knowledge of the conditions and adjustments to the known values for clear water. ρ_1 and ρ_2 are reflectances for the bottom materials, some types of which are known. Since the ratio for bottom reflectances appears in the equation, only relative spectral information is needed.

3. RESULTS

An ERTS-1 frame taken over the Bahama Islands was used in the initial investigation to date. The ERTS Frame 1079-15165 was taken on October 10, 1972 (79th day since launch of ERTS-A) at 15 hours, 16 minutes, 50 seconds. Principal point of image is 27.45°N, 78.82°W (Northwest of Grand Bahama Island). Solar elevation is 74.4°. Frame covers approximately 100 x 100 nautical miles, with Grand Bahama Island in the lower right-hand corner and the Little Bahama Bank covering most of the lower half of the frame. There is a 30% cloud cover for the frame as a whole, but most of the clouds are in the upper half. There is a small patch of clouds in the center of the Bank and over Grand Bahama Island.

In Figure 1, the multispectral scanner (MSS) channel 4 (.5-.6 μm) clearly shows underwater features in the bank north of Grand Bahama Island. Most of these can be identified on the Hydrographic Office depth chart, (see Fig. 2) but there are a large number of streaks in the center of the frame which are not on the published chart.

MSS channel 5 (.6-.7 μm) shows some of the shallower areas of the bank, as well as land and clouds.

MSS channels 6 and 7 (.7-.8 μm and .8-1.1 μm) show no underwater features. Water absorption is so high in these channels that the only signal received over water is due to surface reflection.

Going from channel 4 to 7, land areas become progressively brighter, shallow water areas become darker, and clouds remain at about the same brightness. Sale Cay (on the right) thus appears dark against a light background in channel 4, is almost indistinguishable in channel 5, and stands out clearly against a dark background in channels 6 and 7.

The multispectral characteristics are evident in the comparison for the four bands from the MSS. The digital tapes were then used to produce a relative depths chart shown in Figure 3.

This density map was made from the digital output from MSS channel 4. The darkest symbol (e.g., in the lower left-hand corner) corresponds to a signal less than 24 volts (amplification arbitrary). A blank corresponds to a signal of greater than 38 volts. The interval from 24 to 38 volts was divided into 7 equal subintervals and a separate symbol assigned to each. Every 4th line and point of the data was used in making the map (each line of the original data corresponds to an east-west strip 79 meters wide, and each point along the line occupies 56 meters, so each symbol on the graymap represents an area of 216 x 316 meters).

This map gives an indication of water depth, within the range of 0-10 meters. The bottom-reflected signal is proportional to

$$e^{-\alpha(\sec\theta + \sec\phi)z}$$

where α is the attenuation coefficient, θ is the observation angle, ϕ is the solar zenith angle, and z is the depth. α is on the order of $0.2\ m^{-1}$, so the bottom-reflected signal is approximately proportional $e^{-0.27z}$, where z is the depth in meters. The bottom-reflected signal is obtained by subtracting off the deep-water signal, which is about 23 volts for channel 4.

The shallowest areas (corresponding to blanks on the map) return a signal of about 41 volts. Using this as the reference level z_o, we have

$$V_b(z_o) \equiv V(z_o) - 23 = 18 \text{ volts}$$

The bottom-reflected voltage at any other depth z is then given by the relation

$$\ln V_b(z_o) - \ln V_b(z) = 0.27\ (z-z_o)$$

From the Hydrographic Office depth chart, the depth in the white areas is about 1 fathom (6 feet). Using this value for z_o, the depths corresponding to each of the symbols on the map are given in the following table:

SYMBOL	VOLTAGE RANGE	DEPTH RANGE (Ft.)
⌐	37-38	7-9
•	35-36	9-11
=	33-34	11-13
*	31-32	13-16
I	29-30	16-20
θ	27-28	20-24
¥	25-26	24-33
Ø	0-24	33-∞

The deepest areas in the north-western part of the bank are thus about 5 fathoms, which agrees with the depth chart. The white streaks in the center of the bank appear to be about a fathom below the surface.

Calculations based on two channels of information give absolute values for depth where some knowledge of bottom reflection is known. This was done only at those points where both channels 4 and 5 received bottom reflection signals.

For the sand bars (white streaks in Fig. 3), calculation of water depth was completed since the general reflection characteristic for wet sand had been previously determined. Agreement with HO chart 5990 was evident: the chart refers all depths to the mean lowest water level, so that adjustments due to tidal action need to be completed for final comparison.

4. DISCUSSION

The ERTS satellite image for the Little Bahama Bank shows features not present on the HO chart 5990 for the Northwest and Northeast Providence channels. This chart was revised in 1969 but it uses data from British surveys between 1836 and 1885 and U.S. Navy Surveys to 1963. There are indications of shifting currents being responsible for the build-up of sand shoals and the ERTS imagery supports that observation. It appears that sand build up over this bank indicates a potentially harmful condition which can eventually kill the protective coral bank to the "islands". Cutting shipping channels arbitrarily could change the sand deposition profile. This action will be investigated as part of the verification phase of the experiment.

5. SUMMARY

ERTS-1 data tapes from the MSS can be used for mapping shallow water features. It was demonstrated that depths can be calculated by ratio processing for those shallow depths that return a signal in both channels 4 and 5. By performing analysis of channel 4 data only, a more complete depth map can be made on a relative depth basis. However, if additional control points are known, and if the reflectances of bottom materials are taken into account, an absolute depth map can be made. Even without depth information, the satellite data is still useful because existence of shallow features are detectable and their geographical positions more accurately known than heretofore possible.

The economic benefits derived from the improvement of the world charts has been analyzed initially by Zissis et. al (Ref. 4). World $ losses of about one billion per year in shipping are estimated. Reduction in losses due to those factors that would be traceable to improved navigation charts amounts to several millions per year.

6. REFERENCES

1. F. C. Polcyn, W. Brown, and I. Sattinger, The Measurement of Water Depth by Remote Sensing Techniques (Final Report), Report No. 8973-26-F, Willow Run Laboratories of the Institute of Science and Technology, The University of Michigan, Ann Arbor, November 1970.
2. W. L. Brown, F. C. Polcyn, A. N. Sellman, and S. R. Stewart, Water-Depth Measurement by Wave Refraction and Multispectral Techniques, Report No. 31650-31-T, Willow Run Laboratories of the Institute of Science and Technology, The University of Michigan, Ann Arbor, August 1971.
3. O. E. Prewett, D. R. Lyzenga, F. C. Polcyn, and W. L. Brown, Techniques for Measuring Light Absorption, Scattering, and Particle Concentrations in Water, Report No. 190500-1-F, Environmental Research Institute of Michigan, Ann Arbor, March 1973.
4. G. J. Zissis, et. al, Design of a Study to Evaluate Benefits and Cost of Data from the First Earth Resources Technology Satellite (ERTS-A), Report No. 11215-1-F, Willow Run Laboratories of the Institute of Science and Technology, The University of Michigan, Ann Arbor, July 1972.

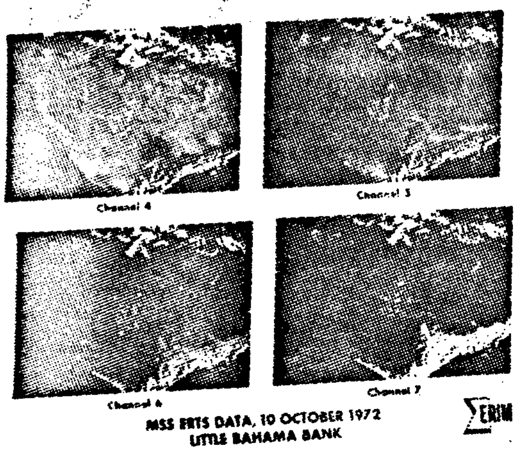


FIGURE 1

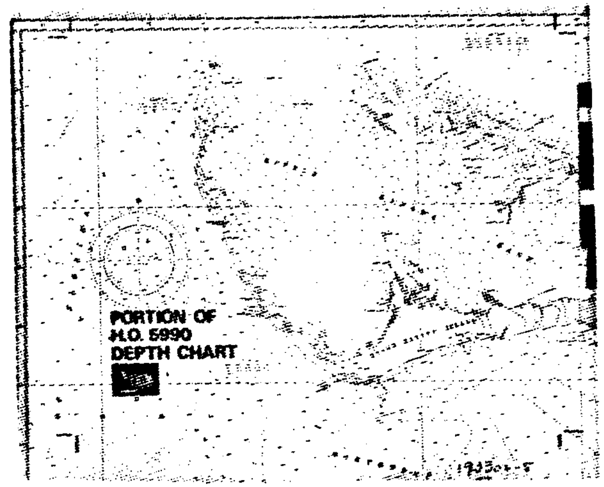


FIGURE 2

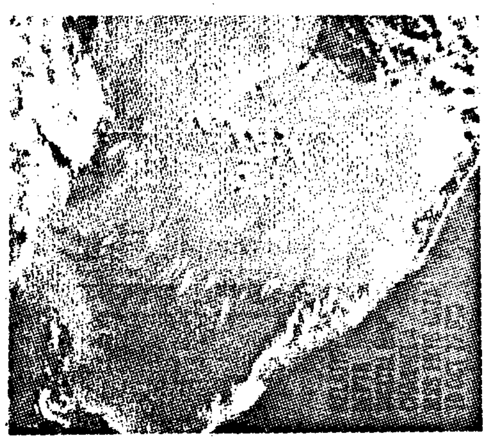


FIGURE 3

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task II - Yellowstone National Park Data - 1398
F. J. Thomson, UN 621, MMC 077

While routine digital formatting operations were carried out on the 7 August 1973 data set at ERIM, Dr. Smedes and students began an intensive effort to define and locate ecologically significant training set categories on a duplicate band MSS 5 graymap previously supplied by ERIM. Selected training sets fall into five distinct cover classes -- (1) water, (2) exposed rock and soil, (3) grasslands, (4) coniferous forest of different degrees of cover and on different substrata, and (5) lowland meadow/marsh areas. Several separate samples of each category were identified by Dr. Smedes and digital coordinates phoned to ERIM. We then performed signature extraction and analyzed the spectral statistics.

This analysis confirmed the separability of the major categories outlined above, but indicated possible signature overlap among several of the sub-categories. We then decided, as a preliminary step, to prepare a five category terrain classification map. The results of this map, we reasoned, would establish a basis for evaluating the success of more detailed efforts to follow.

Two steps were performed preparatory to recognition mapping. First, individual signatures within the major categories were combined to yield composite "super signatures", accounting for geographical and componential variability within classes. Then, optimum channels for classification were determined. Channel 2 proved to be the single best channel. The combination 2,4,3 proved to be only slightly worse than using all four bands in the spectral classification process.

The recognition map was prepared on the ERIM 7094 computer using all four spectral bands. A color coded presentation was chosen portraying water in blue, rock and soil areas in red, and various vegetation classes in green.

Recognition processing resulted in the entire scene being classified into the five generalized vegetation assemblages and physical landscape features described above. Quantitative estimations of recognition accuracy are not yet available, but comparison of observable boundary features, e.g., lakeshore perimeters, timberline and forest, grassland ecotones, indicate high correlation with image occurrence on topographic maps and aerial photography.

During the week of March 5-9, Mr. Thomson participated in the "ERTS-1 Symposium on Significant Results", sponsored by NASA/Goddard Space Flight Center, at Greenbelt, Maryland, where he presented a paper entitled Terrain Classification Maps of Yellowstone National Park describing the background, thrust and progress to date of our processing and cooperative efforts with Dr. Smedes on this project.

Future recognition efforts will concentrate on separating environmentally significant sub-categories within these basic cover types. Spectral analysis of data located on transects oriented along vegetation cover type and altitudinal continua is expected to reveal the feasibility of this objective. Particularly, we wish to investigate individual forest species recognition, separation of different densities of coniferous forest cover and detection of forest types on different substrates.

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task III - Atmospheric Effects in ERTS-1 Data - 1410
F. J. Thomson, UN 636, MMC 137

Roland Hulstrom has made atmospheric measurements in the test site on February 16, 1973, coincident with an ERTS overpass in clear weather conditions. The test site was nearly completely covered with snow at this time. With a uniform highly reflectance target covering the scene, an assessment of atmospheric transmission effects at the different base altitudes can be made.

Imagery of the 16 February scene will be ordered shortly. If the data appear suitable for processing, digital tapes will be ordered.

Some effort was expended preparing a paper for the ERTS Significant Results Review at Goddard on March 5-9. The results of crop mensuration and recognition studies in the Sacramento Valley will be presented. The significant result is that the measurement of acreages of rice fields from ERTS data can be dramatically improved by utilizing a processing technique which estimates the proportion of rice and bare soil in field boundary elements classified as corn by conventional pattern recognition techniques.

During the next period, the February data will be examined for suitability. A conference will also be held (at Goddard) with Harry Smedes concerning his land use mapping requirements.

E7.3 10.39.1

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - February 28, 1973
Task IV - Lake Ice Surveillance - 1406

L. Porcello, UN 201 and M. L. Bryan, MMC 072

I. Introduction

Two major obstacles have inhibited the desired progress for this Task IV. First, there has been excessive cloud cover over the Michigan test site region for this task so that good ERTS imagery has not been available. On the other hand, there is a lack of ground truth for areas where good ERTS-1 ice imagery was available. Good progress has been made, however, with the radar part of the project; a separate report on this work has been prepared for presentation in March 1973. A copy of the Abstract for this report is included here as Appendix 1.

II. Progress

Ice development for the 1972-1973 year has been poor, and, although this is considered to be of aid to shipping interests in the upper Great Lakes, it has led to a series of moderately severe problems for the present project. Thus, it is considered to be a fairly severe risk to study the ice on the ground to the extent as originally planned. This has restricted the ground truth portion of the project. In addition, the ERTS-1 ice imagery of the study area in northern Michigan (refer map, pg. 8 of Type II report, ERIM Report # 193301-1-P, for location map) has been poor for the study periods (see Figure 1). These two items combined have provided obstacles to the progress of the project relative to the interpretation of ERTS-1 data.

Ground truth teams were in the field during the two ERTS-1 passes of 4 February 1973 and 22 February 1973. In both cases, although all groups were active, the weather conditions were such that cloud cover and rain precluded both adequate ground truth operations and the securing of ERTS-1 imagery.

Some good imagery was obtained of the study area during this reporting period. However, because there is a lack of ground truth for these areas (other than U.S. Coast Guard ice surveillance flights) it may be difficult for the present investigators to conduct adequate interpretations. We have thus not spent much effort in interpreting the ice in these images. It was decided, rather, to delay these interpretations until we had obtained some good ground truth/imagery combinations from other areas and later times during the project and then to, in a sense, "work backwards" to the interpretation of the imagery from early January 1973. This decision is still being followed.

As concerns the radar portion of the entire project, we have progressed essentially as originally scheduled. The ground truth aspect of the radar flights has been successfully begun and one short report of the progress (Appendix I) and the ideas for radar ground truth measurements as viewed by this project, have been prepared for presentation at the following meeting:

2nd Annual Remote Sensing of Earth Resources Conference
University Tennessee Space Institute
Tullahoma, Tennessee 37388
26-28 March 1973

Although not emphasized in that paper (Appendix I), it must be stated that the radar work is showing even greater promise than originally envisioned. The need to begin to ground truth a scene in the wavelength at which a given sensor operates has been emphasized and, we believe, substantiated.

In this light, the field team has been able to utilize an instrument built by Bendix under a NASA ERTS-1 contract*. The instrument is a RPMI (Reflectance Power Measurement Instrument), which essentially is a filtered radiometer, that observes a scene in the same bands as does the ERTS-1 MSS bands. We were requested to aid R. Rogers and his team in the field checking and use of the instrument and have submitted to him a list of recommendations concerning improvements in both the mechanical and electrical design and operation of the instrument. At this time, Rogers is planning to present the following paper to the ERTS-1 symposium to be held in Washington, D. C. in early March 1973: "A Technique for Correcting ERTS Data for Solar and Atmospheric Effects." The reader is referred to this report and to Mr. R. Rogers for details concerning the RPMI.

For our own work, we have found that the RPMI has considerable potential as a ground truth instrument. Although the periods when we were testing the instrument were cloud covered and hence not suitable for direct comparison to a good ERTS-1 scene, we were able to simulate several types of ice conditions and determine the reflectance curves for the simulated conditions (Figure II).

As indicated in Figure II, it appears as if all bands will provide information for the interpretation of ice and snow conditions.

III. Program for Next Reporting Interval

March - Ground truth the test sites for the ERTS-1 passes of 12 March 1973 and 30 March 1973.
Conduct simultaneous radar underflights for the 30 March 1973 ERTS-1 pass.

April - Collection of all ERTS-1 frames which show any ice imagery of the study area and visual analysis of these frames. This work, however, is dependent upon the successful data passes of the ERTS-1 satellite.

Study of other areas of the upper Great Lakes in which imagery showing ice was obtained by ERTS-1, but for which ground truth is lacking.

IV. Conclusions

It is concluded at this time that some progress has been made as concerns the ERTS-1 satellite imagery interpretation, primarily in the nature of securing ground truth observations with the Bendix RPMI instrument on loan from another ERTS-1 principal investigator. Progress with the radar portion of the project is very satisfactory and, as mentioned previously, exceeding our expectations.

The problem of the cloud cover of the study area has precluded the collection of good ERTS-1 imagery of the lake ice. Before any definite decisions can be made concerning the project, however, it is necessary to wait until the two ERTS-1 passes of March 1973. Should these be cloud free periods, the simultaneous collection of ice imagery and ground truth would allow successful completion of this task.

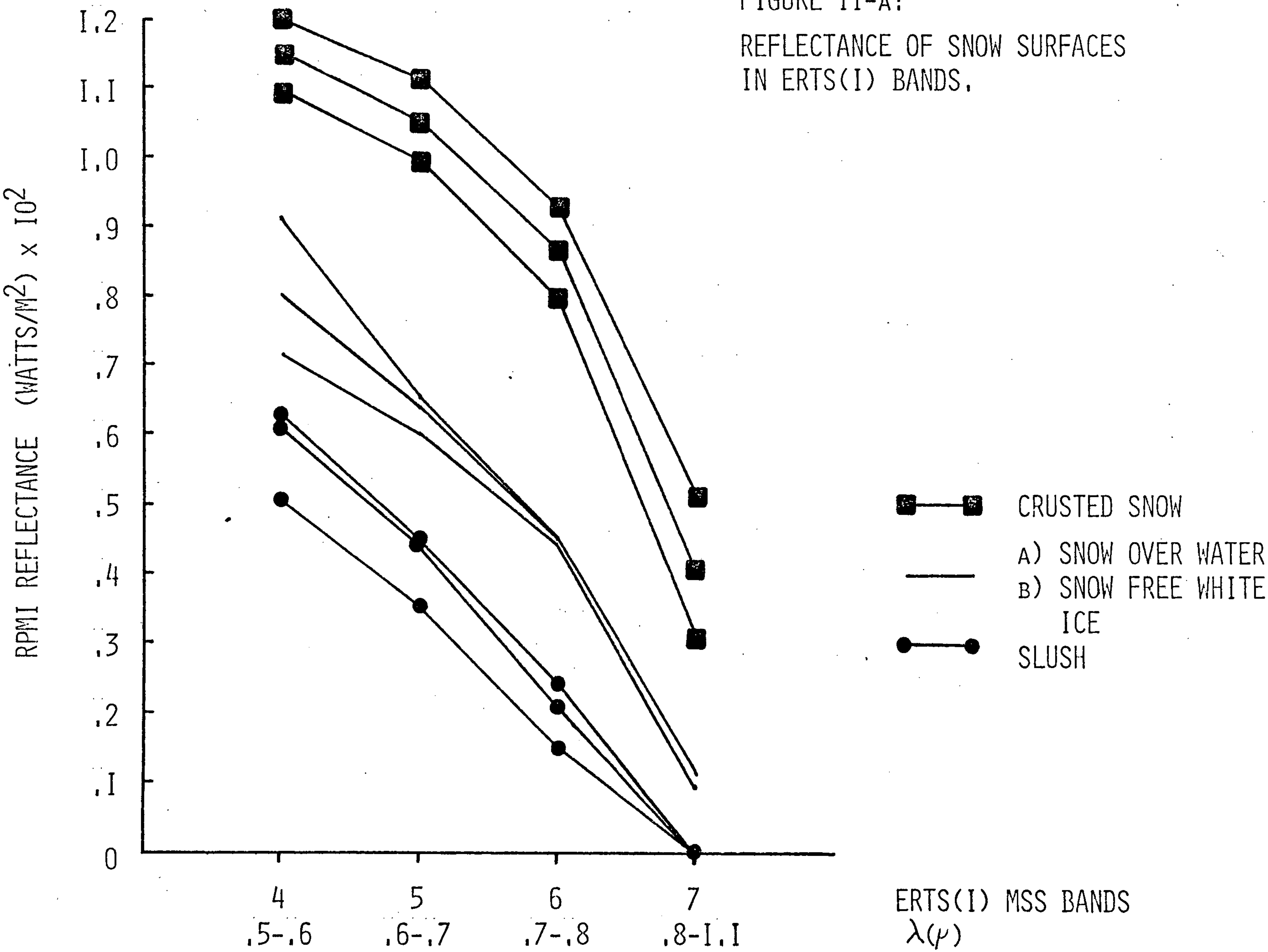
ORBIT LOCATION	DATE 28SEP72 to 03OCT72	16OCT72 to 21OCT72	03NOV72 to 08NOV72	21NOV72 to 26NOV72	09DEC72 to 14DEC72	27DEC72 to 01JAN73	14JAN73 to 19JAN73	01FEB73 to 06FEB73
2nd to East	30-60% (NI)	90-100% (NI)	90% (NI)	50% (NI)	100%(thin) (NI)	100% (IP)	90% (NI)	100%(thin) (NI)
1st to East	90% (NI)	80% (NI)	100% (NIP)	90% (NI)	DNR	DNR	DNR	90% (IP)
Test Site	20% (NI)	80% (NI)	90-100% (NI)	90% (NI)	50% (I)*	100% (IP)	10-20% (I)	100% (IP)
1st to West	70-90% (NI)	70% (NI)	10-70% (NI)	50-90% (NI)	DNR	100% (IP)	100% (IP)	DNR
2nd to West	50-60% (NI)	0-10% (NI)	60-70% (NI)	80-100% (NI)	90% (I)+	100% (IP)	100% (IP)	90% (I)
3rd to West	100% (NIP)	80% (NI)	100% (NIP)	90% (NI)	30% (NI)	100% (IP)	100% (IP)	DNR

Notation: Cloud Cover in Percent
NI = No Ice Visible
NIP = No Ice Probable
I = Ice Visible
IP = Ice Probable
DNR = Data not yet received
* Ice on St. Marys River and Inland Lakes
+ Ice on Green Bay, Wisconsin

FIGURE I. Summary of Ice and Cloud Cover from ERTS(1) Data of Western Lake Huron, Northern Lake Michigan and Southern Lake Superior

FIGURE II-A:

REFLECTANCE OF SNOW SURFACES IN ERTS(I) BANDS.



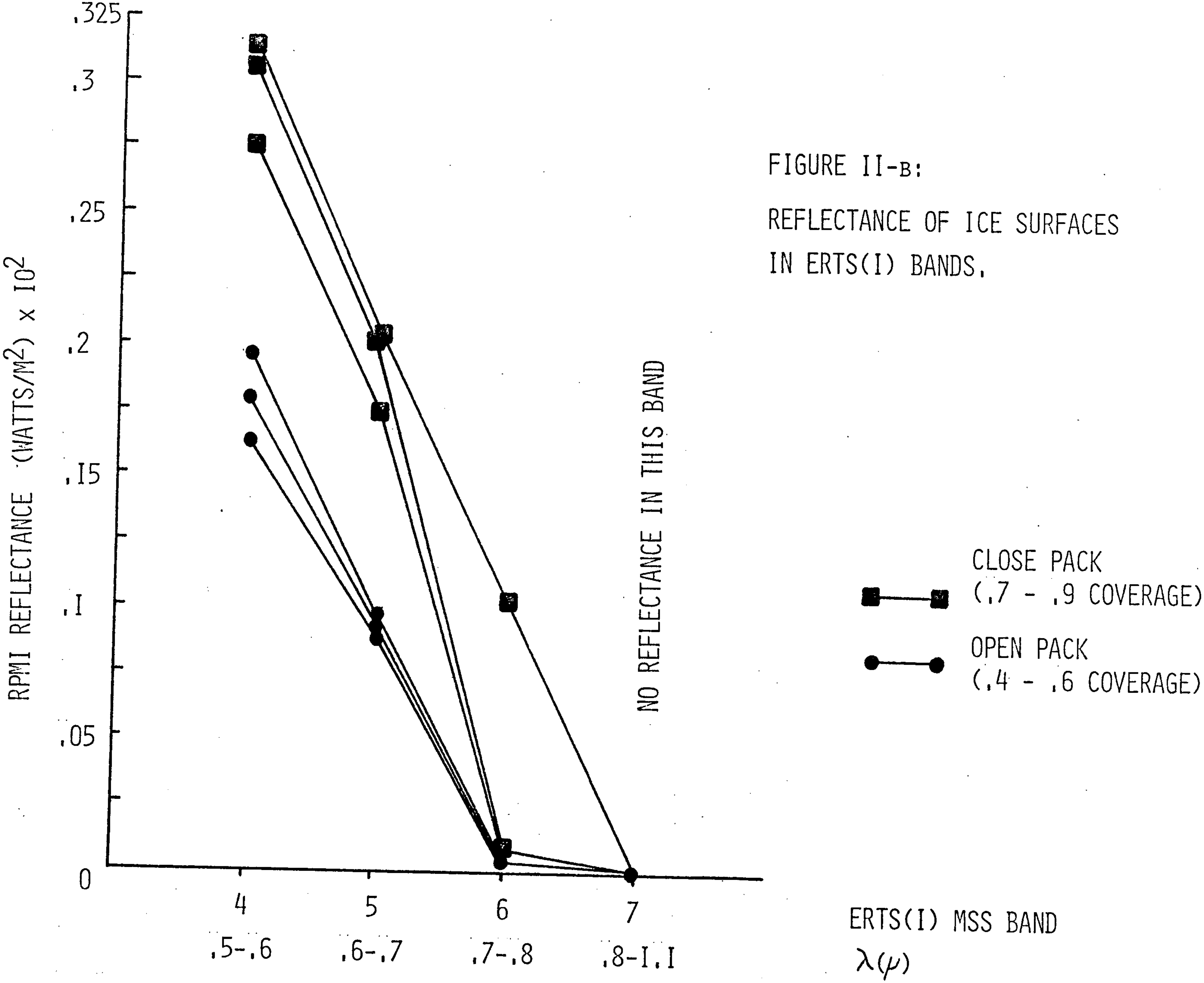


FIGURE II-B:
REFLECTANCE OF ICE SURFACES IN ERTS(1) BANDS.

APPENDIX I

APPLICATION OF DIELECTRIC CONSTANT MEASUREMENTS TO RADAR IMAGERY INTERPRETATION

M. Leonard Bryan and R. W. Larson

Environmental Research Institute of Michigan
P.O. Box 618
Ann Arbor, Michigan 48107

193300-4-S/J

March 1973

APPENDIX I

Abstract

Although it is readily recognized that there is a need for ground truth to provide adequate guidance for remote sensing data interpretation, it is also noted that, in terms of radar remote sensing, this ground truth is often inadequate. Because radar "views the world" at relatively long wavelengths which have some penetration capability but also are affected by the electrical and physical properties of the surface upon which they are impinging, it is considered necessary to make basic electrical and physical measurements of this surface and to some depth below it. This paper presents a brief outline of such a ground-truth scheme, specifically, the measurement of the dielectric constant. Two portable instruments were designed specifically for this purpose; these are (1) a Q-meter for measurement of dielectric constant and loss tangent and (2) an instrument to measure electrical properties of the two operating frequencies of our imaging radar. Although extensive data are lacking, several general cases of radar-earth surface and interaction are described; also, examples of radar imagery and some data on ice and snow are presented. The paper concludes that the next logical step is to begin to quantify the radar ground truth in preparation for machine interpretation and automatic data processing of the radar imagery.

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task V - Recreational Land Use - 1387
I. Sattinger, UN 225, MMC 086

Work performed during this reporting period concentrated on the digital computer analysis of ERTS-1 Frame 1067-15463. Intensive study is being concentrated on an area within Oakland County approximately nine miles northwest of Pontiac. It includes Big Lake, Pontiac Lake, the Pontiac Lake State Recreation Area, and the Huron Swamp, which is the site for a new 2,000 acre park, the Oakland Metropolitan Park, recently announced by the Huron-Clinton Metropolitan Authority.

A computer map was prepared by level slicing techniques using Band 5 and Band 7 data. In Band 5, certain areas, distinguished by their light tone, include residential areas with little vegetation, and bare areas, such as sand and gravel pits or major highways. In Band 7, water areas are consistently dark in tone, forest areas light, and other vegetated areas intermediate. An evaluation of the results indicates that water and wooded areas are consistently mapped. The more developed residential areas with substantial tree and lawn cover tend to be mapped as Other Vegetation. This category also includes a wide variety of vegetative cover in non-urban areas.

The same area was also subjected to further computer processing to produce a map in which more detailed types of land use and surface cover were recognized. This effort at surface mapping used maximum likelihood-ratio processing to distinguish nine types of surface features, including two residential areas, three areas of lake surface, two forest areas, and two grass-covered areas. After several preliminary maps were run, a printout was obtained in which nearly 70% of the resolution elements fell into one of the nine classes. A general examination of the results and comparison with available RB-57 photography indicated that the areas recognized were for the most part properly classified as to general type of surface (e.g., built-up area, water, or vegetation). The areas not recognized were generally water surfaces and residential areas. The results mentioned here represent only initial attempts at maximum likelihood ratio processing. It is expected that substantial improvement will be obtained with further experience.

A preliminary evaluation of the utility of ERTS data for recreational land studies has been made from the examination of these early results by staff members of the Lake Central Region office of the Bureau of Outdoor Recreation and staff members of the Oakland County Planning Commission. It is believed that the general land use and land cover maps can be used in performing conceptual studies for large recreational developments. Examples of recent studies for which ERTS data could have been used include the Maumee Wild and Scenic River Study (in Northern Ohio and Indiana), study of the recreational potential of the Michigan shoreline of Lake Erie, and selection of corridors for an interstate scenic trail.

The results obtained in these initial studies of computer-processing of the digital tape are discussed in a paper presented at the ERTS-1 Symposium on March 5 - 9, 1973, under the title "Digital Land Use Mapping in Oakland County, Michigan".

Work will continue on computer processing and analysis of the same area of Frame 1067-15463 already under study. This additional work will be directed toward further refinement of the recognition and mapping of diverse urban, water, forest, and other vegetation within the test area. The results will be evaluated with respect to the composition and consistency of surface features recognized under a single category.

During the same orbit as the data now being processed, Frame 1067-15465 was produced. This frame covers large areas of Southeast Michigan which are clear of cloud cover, including an area northeast of Ann Arbor, Michigan, on which detailed remote sensing studies have recently been completed. These studies used C-47 multispectral scanner data acquired in May and June, 1972, about four months before the satellite pass on 28 September 1972. Because of this major source of ground truth and airborne imagery, a digital tape of this frame is being ordered to permit processing and analysis of this specific area.

As additional results are obtained, they will be reviewed with the staff of the Oakland County Planning Commission, the Bureau of Outdoor Recreation, and other interested parties to evaluate the usefulness of the resulting information for studies of recreational land and open space.

In accordance with contract requirements, a data analysis plan is to be submitted defining the work to be performed during the remainder of the project. This is presently scheduled for submission on 1 April 1973.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
D
N
ID

DATE

PRINCIPAL INVESTIGATOR I. J. Sattinger

GSFC UN225

ORGANIZATION Environmental Research Institute of Michigan

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
106715463				Aerial Imagery Used Deciduous Forest Grass Hardwood Forest Highway Lake Marsh Metropolitan Area Quarry Rural Area Shallow Water

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

MAIL TO
ERTS USER SERVICES
CODE 563
BLDG 23 ROOM E413
NASA GSFC
GREENBELT, MD. 20771
301-982-5406

GSFC 37-2 (7/72)

PROGRESS OF AN ERTS-1 PROGRAM FOR LAKE ONTARIO AND ITS BASIN

Thomas W. Wagner and Fabian C. Polcyn

Environmental Research Institute of Michigan
Ann Arbor, Michigan

ABSTRACT

The Lake Ontario drainage basin covers over 32,000 square miles of U.S. and Canadian territory. ERTS-1 data is contributing to the comprehensive study of this basin as part of the International Field Year for the Great Lakes (IFYGL). This paper details a processing approach for obtaining detailed and objective synoptic information thought to be applicable to terrestrial water balance studies of such a large area. A simple ratio algorithm was tested for minimizing daily variations in ERTS data and for allowing the discrimination of surface features and land use classes of hydrologic significance. These steps are necessary if ERTS data is to provide the quantitative information required for the study and management of areas of regional size.

1. INTRODUCTION

The Great Lakes region contains one of the most rapidly growing populations in North America - currently numbering some 35 million people. The growth of settlements from Quebec to Milwaukee is expected to continue long after other megalopolises have withered for lack of fresh water. The Great Lakes contain roughly 20% of the fresh water in all the lakes and rivers of the world and will continue to serve our transportation, energy, cultivation, domestic, industrial, and even recreational needs for many generations — if we are intelligent in the management of this resource. Fresh water of the Great Lakes is neither inexhaustible nor unspoilable. Recent, well-publicized problems in Lake Erie, Lake Ontario, and southern Lake Michigan, have warned of a growing need for basic information and better tools for managing the Great Lakes. Clearly we must better understand the trade-offs in man's conflicting demands for fresh water and the seasonal or episodic ability of the natural drainage basin to meet these demands. With an acute awareness of these requirements to better manage the hydrologic resources of the Great Lakes, the International Field Year for the Great Lakes (IFYGL) was launched in April, 1972.

The IFYGL is a year long synoptic study of a single Great Lake system -- the Lake Ontario basin [1]. It is a coordinated effort by U.S. and Canadian scientists from many government agencies, universities, and private concerns for the purpose of obtaining a detailed and comprehensive understanding of how such a large hydrologic systems works. The program is broken into five major research areas: (1) terrestrial water balance, (2) Lake meteorology, (3) water movements, (4) energy balance, and (5) Lake biology and chemistry.

ERTS-1 data is contributing primarily to two of these IFYGL research areas: terrestrial water balance and water quality studies related to the chemistry and biology of the Lake. This paper is concerned with the utilization of ERTS-1 data for studies of the terrestrial water balance. It represents a report of the considerations and approach being developed for this IFYGL task at this early stage in its implementation.

2. THE PROBLEM

The Lake Ontario drainage basin (including the lake) covers over 32,000 square miles of U.S. and Canadian territory (Figure 1). The problem in utilizing ERTS data to obtain information concerning the terrestrial water balance from so large an area is 1) what break-down of terrain elements observable from ERTS are hydrologically significant, and 2) how is precise quantitative information of so large an area to be obtained. We will try to answer the second question first.

3. PROCESSING APPROACH

To obtain objective and quantitative information concerning the Lake Ontario basin modern computer processing techniques must be employed. One digitized frame of ERTS-MSS data, representing an area 100 nautical miles on a side, contains nearly 10 million resolution cells in four bands -- nearly 2×10^8 individual scene samples for the entire basin. Even large digital computers have difficulty in digesting this amount of data. Unless our processing procedures and our information needs are tailored carefully, the task of processing data from portions of the required nine ERTS frames may not be economically feasible or cost-effective. Clearly a simple, processing technique performed on a rapid throughput computing facility is required [2]. Because it takes ERTS four consecutive days to obtain complete coverage of the basin, the processing technique also must be able to objectively extend feature discrimination criteria from one frame to the next and from one day to the next.

We have just completed testing of a simple processing algorithm for a small portion of the basin on a digital computer. This algorithm is a ratio of two ERTS MSS bands. Ratioing of spectral bands has long been used as a preprocessing technique for reducing scene radiance differences due to changes in illumination or differences in the bidirectional reflectance of objects. Only recently has it been realized that the ratio of spectral bands may, in itself, provide enhancement of features not readily discerned in either of the bands individually [3].

Figure 2 compares two digital printouts in a single band for the Rochester Harbor area on two successive days. The plume from the mouth of the Genesee River may be seen along the upper right-hand edges of the images. Note, however, that the patterns for the terrain area are considerably different for the two days, even though the same digital symbols were printed for the same ERTS signal range. Figure 3 provides part of the reason for the differences in the terrain patterns; ERTS MSS signal values were systematically lower for the same areas on the second day. This may be due to differences in illumination (clouds were present in both scenes) or to ERTS MSS sensor differences from one day to the next. In any event, the extension of feature recognition criteria based on absolute signal values from one ERTS frame to the next (and perhaps from one portion of an ERTS frame to another) would net dubious classification results.

Figure 4 compares two digital printouts for a ratio of band 7 (0.8–1.1 μm) to band 5 (0.6–0.7 μm) for the same Rochester Harbor area. A minor path radiance normalization was introduced for both the images. Again the same digital symbol is used for a given signal range. The two images are nearly identical. Slight differences occur along the shoreline, where turbid shallow water looks like land, and near the bottom of the August 20th image, where two small clouds appear. This ratio technique will help to extend predetermined feature recognition criteria, based on relative differences between ERTS bands, to ERTS data of the entire Lake Ontario basin.

The approach adopted for this task is to convert digital ERTS data to an analog format and then process these data on a high-speed analog facility. The analog computer, known as "SPARC" for Spectral Analysis and Recognition Computer, can process data at a rate of 10^4 resolution cells per second (less than 2 hours is required for the entire basin). (Average operating cost for the SPARC is $50/hour.) The SPARC has an added advantage in printing the processed results as 70 mm film transparencies. A mosaic of recognition images for the entire basin will measure about 25 cm by 30 cm; an equivalent digital paper display would cover an area of approximately 25 m by 30 m.

4. DECISION CRITERIA

In stating the problem of relating ERTS data to the terrestrial water balance, we first asked the question; "what break-down of terrain elements observable from ERTS are hydrologically significant?" No final answer has yet been obtained for this important question. Indeed we are still discovering the precise nature of features which may be reliably discriminated from ERTS data. Since a concern of this IFYGL task is for rapid processing of large amounts of data, we are restricted by economics to simple decision criteria. Perhaps the simplest machine-implemented criteria is that of level-slicing, or quantizing--as it's sometimes called. In this procedure, feature classes are discriminated on the basis of the exclusiveness with which they are represented by a maximum and a minimum signal range in one band or data channel. For a variety of terrain classes signal levels were compared in each ERTS band and for the ratio of band 7 to band 5.

Spectral signatures were obtained from eight relatively large areas in the two Rochester frames discussed previously. Except for portions of Lake Ontario, these signature sample areas were by no means homogeneous, and they are only roughly identified from aerial photography as 1) agricultural, 2) wooded, 3) recreational (golf course), 4) new urban (recent residential development), 5) commercial, 6) older residential, 7) water (Lake Ontario), and 8) cloud shadow. The intent here was to obtain only a broad representation of major surface classes. It is probable that with careful signature selection each of these classes may be further subdivided.

Comparing mean values and standard deviations, it was noted which classes or groupings of classes could be separated in each ERTS band and from the ratio of band 7 to band 5. The standard deviation for the commercial area signature (downtown Rochester) spanned such a large range that it overlapped most of the other categories and had to be ignored in the ERTS band groupings (but not the ratio groupings). In general no ERTS band allowed for more than four groups of separable classes, although different combinations were evident with different bands. Of particular concern was the fact that water signatures overlapped other categories in all but band 7. The ratioed values for the same terrain classes separated neatly into five groups: 1) water, 2) wooded, 3) agricultural and recreational (golf course), 4) older residential, and 5) new urban and commercial. (Figure 5). The normalized ratio values ranged between 30 and 511 with the bulk of that range, 150-510, being represented by vegetation classes. It appears that this ratio is a sensitive indicator of vegetational differences. The decision criteria will then consist of setting maximum and minimum ratio values for those terrain classes which are considered to have significantly different hydrologic characteristics.

5. ERTS AND THE TERRESTRIAL WATER BALANCE

How does ERTS contribute to a better understanding of the water balance for Lake Ontario and what is its value in managing water resources? ERTS can provide quantitative spatial information for the entire basin. This information is useful to the extent that we know or can discover how surface features, patterns of land use or drainage, or temporal changes in these affect and are affected by the dynamics of basin hydrology. The amount of water held in storage on the land portion of the basin and rates of runoff and evapotranspiration are correlated with the area and distribution of surface features and conditions. Present models for basin hydrology depend on samples made at one or more points within the basin; there is seldom adequate knowledge of the spatial variability of a basin or of its seasonal or long term (land use) changes.

The approach for this ERTS-IFYGL task is to attempt to establish quantitative relationships between ERTS-observed features and hydrologic parameters recorded on the ground in selected watersheds of manageable size. The second step is to extrapolate these parameters from the representative watersheds to the entire basin using ERTS data. One such watershed is the Oakville Representative Basin (inset on Figure 1). Personnel from the Ontario Ministry of the Environment are actively recording in this and several other Representative Basins such parameters as precipitation, soil moisture, stream and ground water flow, and snow accumulation in the winter season. NASA and ERIM have periodically collected aircraft data from these and other study areas. These data, the ground measurements and aircraft imagery are now being used in the analysis of ERTS data by scientists at ERIM, OME, and the University of Guelph.

6. CONCLUSIONS

While the input (rainfall) to a basin is variable, man's output requirements are determ nistic [4]. Basin storage and runoff must provide consumers with energy, irrigation water, municipal supplies, and even recreation sites. Clearly, differences and changes in the surface associated with land management and water use greatly affect and are affected by surface storage, runoff, evaporation, and concomitant soil erosion and stream sedimentation rates. ERTS can help us to study and attack these problems on a truly regional scale. We believe we have developed an operationally feasible method for utilizing large amounts of ERTS data for this purpose. Preliminary studies are most encouraging [5]. A great deal now needs to be done in relating this approach to the hydrological problems which are increasingly and menacingly evident in the Great Lakes region.

7. ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical assistance of D. Rebel, F. Thomson, and the staff of the ERIM Publications Department.

8. REFERENCES

1. Ludwigson, J., (1972). "International Field Year for the Great Lakes" in Geotimes, December, pp. 16-18.

2. Marshall, R. E. and F. J. Kriegler, (1971). "An Operational Multispectral Survey System," Proceedings of the 7th International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor.

3. Vincent, R. K., (1973). "Ratio Maps of Iron Ore Deposits, Atlantic City District, Wyoming", 193301-13-S/S_a/J, to be submitted at the ERTS-1 Goddard Meeting, 5-9 March 1973.

4. Castruccio, P. A. (1972). "Remote Sensing and Data Handling - There Application to Water Resources" in Remote Sensing of Earth Resources, Committee on Science and Astronautics, U. S. Printing Office.

5. Malila, W. A. and T. W. Wagner. (in press). "Multispectral Remote Sensing of Elements of Water and Radiation Balances", in Proceedings of the 8th International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor.

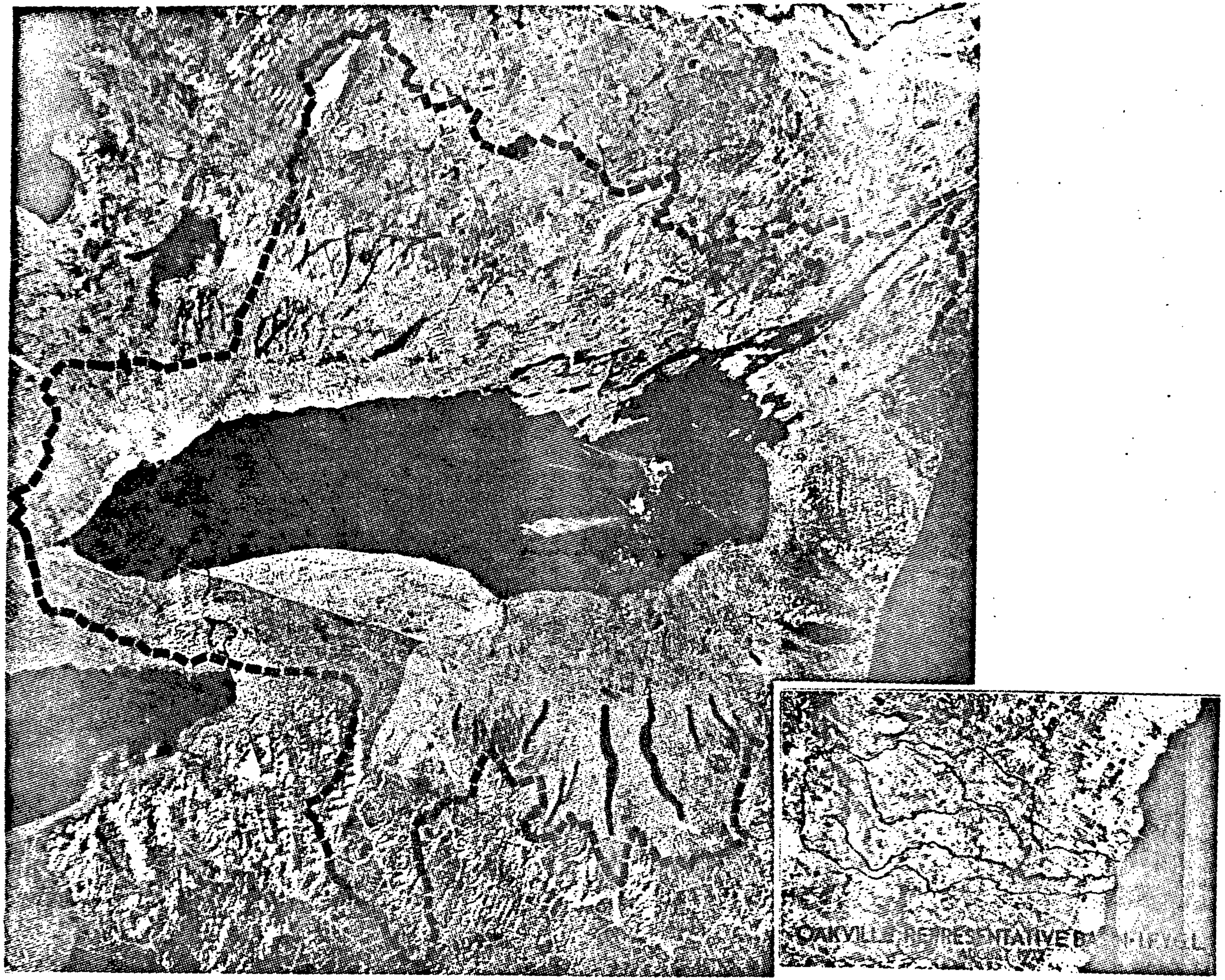


FIGURE 1. MOSAIC OF LAKE ONTARIO DRAINAGE BASIN WITH INSET SHOWING OAKVILLE REPRESENTATIVE BASIN ERTS-1 BAND 5 (0.6 - 0.7 μm). AUGUST 1972.

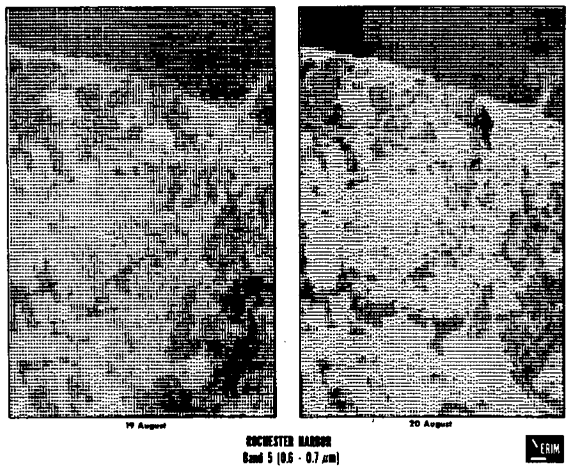


FIGURE 2. COMPARISON OF THE SAME AREA ON TWO DIFFERENT DAYS AS RECORDED BY ONE ERTS BAND.

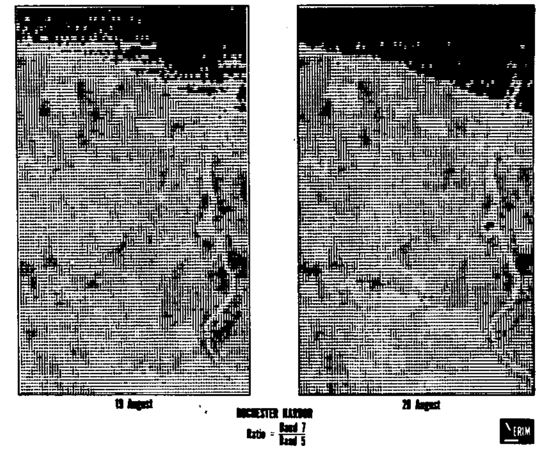


FIGURE 4. COMPARISON OF THE SAME AREA ON TWO DIFFERENT DAYS AS RECORDED BY A RATIO OF TWO ERTS BANDS.

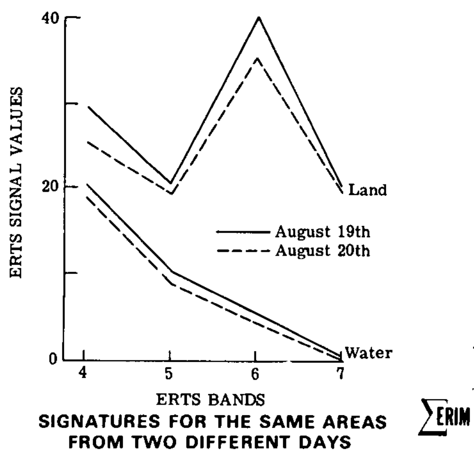


FIGURE 3. MEAN SIGNAL VALUES FOR TWO AREAS ON TWO DIFFERENT DAYS AS RECORDED. IN FOUR ERTS MSS BANDS.

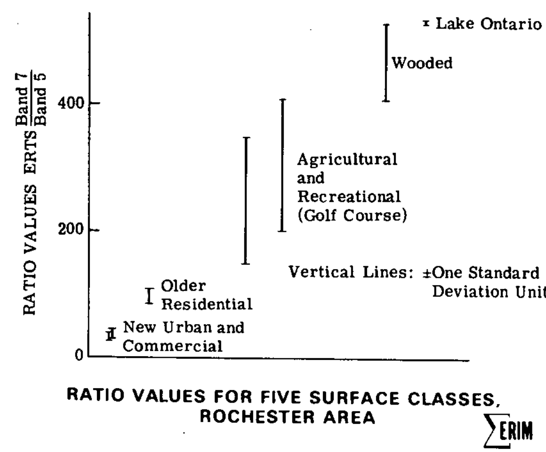


FIGURE 5. MEAN RATIO VALUES AND THEIR STANDARD DEVIATION FOR FIVE SURFACE CLASSES.

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task VI - IFYGL (Lake Ontario) 1384
F. C. Polcyn - UN 635, MMC 114

ERTS-1 photo mosaics of the Lake Ontario Basin (parts of eight frames) were constructed for Bands 5 and 7.

Computer processing of data taken on successive days for the same geographic area was undertaken. Different signal levels for the two days were noted. By performing a ratio preprocessing procedure before classification, improvement in automatic recognition from frame to frame was accomplished. Investigation of the Oakville IFYGL representative basin was begun. A digital greymap was generated and coordination with ground truth teams was initiated by a meeting with the Ontario Ministry of the Environment (OME) officials.

This progress was reported at the ERTS-1 Symposium on Significant Results. See copy of paper attached.

Plans for the next period are to begin relating differences in land use factors to changes in stream runoff records supplied by OME. Also the IFYGL work group on terrestrial water balance will meet and space acquired data will be applied to the total team effort engaged in calculating the water balance budget for Lake Ontario Basin.

APPENDIX I

ATMOSPHERIC EFFECTS IN ERTS-1 DATA, AND ADVANCED INFORMATION EXTRACTION TECHNIQUES

William A. Malila
Richard F. Nalepka

Environmental Research Institute of Michigan (ERIM)*
Ann Arbor, Michigan

ABSTRACT

Atmospheric effects in satellite multispectral scanner data can influence results obtained with either manual image interpretation or computer information extraction techniques. The atmosphere attenuates radiation arriving from the surface and adds an extraneous path radiance component. Initial results of an investigation of atmospheric effects in ERTS data are presented. Empirical analyses of ERTS MSS data and simultaneous airborne MSS underflight data for one frame, along with theoretical calculations of atmospheric effects, are discussed.

The effect of limited spatial resolution on the accuracy of information extracted from ERTS data also is important. Problems occur when individual resolution elements contain two or more materials. Results from an initial application of ERIM techniques for estimating proportions of materials within individual elements are presented and discussed. Very accurate determination of surface areas of small lakes is achieved.

INTRODUCTION

This paper addresses two problems that are common to all users of ERTS-1 data, namely (1) effects of the atmosphere and (2) the relatively coarse spatial resolution of the ERTS MSS. The reported work in the first area deals with understanding and verification of atmospheric effects in ERTS-1 data while, in the second, it is on an initial application to ERTS data of ERIM processing techniques designed to estimate proportions of unresolved objects in individual resolution elements. The work is part of ERTS investigation MMC-136, entitled, Image Enhancement and Advanced Information Extraction Techniques.

ATMOSPHERIC EFFECTS

By now, all ERTS investigators must be aware of the strong influence of the atmosphere on ERTS data. For example, the lesser contrasts in ERTS Band 4 images, as compared to those in ERTS Band 5,

*Formerly Willow Run Laboratories of The University of Michigan

Presented at the SYMPOSIUM ON SIGNIFICANT RESULTS OBTAINED FROM ERTS-1, 5-9 March 1973, New Carrollton, Maryland. Sponsored by NASA/Goddard Space Flight Center Greenbelt, Maryland.

are in part due to the greater influence of the atmosphere in the shorter wavelength channel. Differences in atmospheric conditions within a given frame or between frames can change the spectrum of received radiances, thereby hampering image-interpretation efforts and degrading recognition processing and other information extraction with computers.

The major components of the radiance, L, received by a scanner are shown in the following simplified equation: $L = \frac{\rho}{\pi} ET + L_p$ where ρ is the diffuse target reflectance, E is the total (direct plus diffuse) solar irradiance on the target, T is the transmittance of the atmosphere, and L_p is the path radiance (i.e., extraneous radiation that does not emanate directly from the surface element under observation). All these quantities depend on wavelength, viewing and irradiation geometries, and atmospheric state. Both theoretical calculations and empirical studies with ERTS and underflight aircraft data have been carried out in a preliminary fashion for one ERTS frame (1033-15580, 25 Aug 72).

Theoretical Calculations

A radiative transfer model developed by Dr. R.E. Turner of ERIM* was used to compute the magnitude of atmospheric effects for a variety of conditions and to predict variations that depend on several different parameters. Fig. 1 illustrates the dependence of spectral path radiance on wavelength for a relatively clear condition (ground visual range, V = 24 km) and for a hazy condition (V = 6.4 km). Three observations can be made: (1) the amount of path radiance clearly increases as one approaches shorter wavelengths, (2) there is a strong dependence of path radiance on the albedo of the background surrounding the target, and (3) the path radiance is greater for the low-visibility case.

Nadir scan angle is another observation parameter. Large "scan-angle effects" often have been observed in airborne MSS data, where scan angles much larger than the $\pm 6°$ of ERTS are employed. These effects have both atmospheric and surface bidirectional reflectance causes. One would not necessarily expect to find them of significance in ERTS data, but Fig. 2 presents computed total radiance variations, for the atmosphere alone, that are as much as 8% of the minimum value for an 8% diffuse reflector observed through a clear atmosphere at 0.55 μm. Percentage variations in path radiance are even greater for the background albedoes shown. The scan-angle variations are reduced for longer wavelengths and, here, are negligible at 0.95 μm.

*"Importance of Atmospheric Scattering in Remote Sensing", by R. Turner, W. Malila, & R. Nalepka, Proc. of 7th Internat'l Symp. on Remote Sensing of Envir., Willow Run Labs, The Univ. of Mich., Ann Arbor, 1971.

There is, however, still an appreciable amount of path radiance at 0.95 μm, as shown in Fig. 3 for a 32% reflector. This figure illustrates directly the dependence of the total and path radiances on visual range (visual range is used as a convenient method for identifying standard atmospheric aerosol profiles used in the calculations, more exact profiles can be used, if known). Note that here the total radiance received from the target in a dark background decreases with increasing haze (shorter V) while it increases for a bright one.

Fig. 4 presents the combined effects of scan angle and visual range on spectral radiances at 0.55 μm for 8% target and background reflectances. The increase of scan angle effects for lower visual ranges is clearly shown, and path radiance is a large fraction of the total.

Empirical Studies

The ERIM multispectral scanner was flown on a series of multialtitude passes in synchronism with the ERTS-1 pass on Aug. 25th. Reflectance panels were placed on the flight line. Airborne signals from large fields, resolvable in ERTS data, were compared to signals from the reflectance panels and equivalent reflectance values were assigned to these fields, called secondary standards. Average values then were extracted from ERTS data for each of the secondary standards the converted to radiances. (The maximum radiance values listed in Table G.2-2, pg. G-14, of the ERTS Data Users Handbook were assigned to tape levels 127, 127, 127, and 63 for ERTS Bands 4, 5, 6, and 7, respectively.)

Figs. 5-8 present plots of ERTS radiance versus target reflectance for the four ERTS bands. The dashed lines are least-squares fits to the values obtained for the secondary standards. Also on the figures are trios of lines that represent approximate calculations made with the radiative transfer model for different background albedoes.

The slopes of the theoretical lines and the empirical fits agree well, but the magnitudes differ in Bands 4 and 5 for reasonable background albedoes, especially for Band 4. The reason(s) for these differences is not known at this time, but there are several possibilities: (1) The theoretical radiance values were obtained by merely multiplying band-center spectral radiances by factors of 0.1, 0.1, 0.1, and 0.3 to approximate the ERTS spectral bandwidths; more complete and accurate calculations are desirable. (2) The reflectances assigned to the secondary standards for the empirical plots appear to be too low; higher values would improve agreement. (3) The model might be in error, although checks elsewhere of sky radiance predictions have shown good agreement with measurements and with exact calculations for a pure Rayleigh atmosphere. (4) The atmospheric profile used in the calculations might not accurately represent the true condition at the test site. (5) It is possible that the ERTS calibrations are biased or we have misinterpreted the calibration procedures. Further study of this problem is required but, nevertheless, the strong influence of the atmosphere on ERTS data has been shown.

PROPORTION ESTIMATION

A second aspect of ERTS investigation MMC-136 is testing the applicability of advanced information extraction techniques to ERTS-1 MSS data. (These techniques have been developed at ERIM with funding provided by the Supporting Research and Technology program of NASA-JSC.) One technique addresses problems associated with accurately determining areas covered by features in the scene using scanners with limited spatial resolution, like ERTS-1 MSS. Clearly, there is a serious problem for features smaller than the instantaneous field of view of the scanner. In addition, problems exist even for larger features since many of the ERTS MSS pixels overlap the boundaries between these and adjoining features. As a result, the radiation represented in those pixels is a mixture of radiation reflected from two or more materials. Since the signals generated in such pixels are not characteristic of any one material, the pixels will generally be improperly classified. Therefore, the area assigned to each material class could seriously be in error. For example, at least 25% of the pixels covering a square field of 50 acres (20 hectares) will overlap its boundaries.

At ERIM we have developed a data processing technique* to estimate the proportions of materials contained within each pixel, by taking advantage of the fact that information is gathered in several spectral bands. This permits a more accurate determination of the area covered by each material; the greater the number of spectral bands used, the more materials can be considered. We next describe and evaluate the results of an initial test of this technique on ERTS-1 MSS data.

Test Results

For this test, we selected for processing a portion of ERTS data gathered over Southwestern Michigan on Aug. 25th. A black-and-white aerial photograph of this site is shown in Fig. 9. The primary features of this site are a number of lakes and ponds of various size surrounded by trees and agricultural fields, many of them bare soil.

The goal of this experiment was to determine the surface area of the lakes and ponds. For purposes of comparison, the data were processed using a conventional recognition algorithm in addition to the proportion estimation algorithm.

---

*"Estimating the Proportions Within a Single Resolution Element of a Multispectral Scanner", by H. Horwitz, R. Nalepka, & J. Morgenstern, Proc. of 7th Internat'l Symp. on Remote Sensing of Environ., Willow Run Labs., The Univ. of Mich., Ann Arbor, 1971.

Initially, a number of pixels containing pure samples of each of the primary scene components (water, trees, and soil) were extracted to establish training signatures for each of these materials. The same signatures were employed by both algorithms and ERTS Bands 4, 5, and 7 were used because of problems in Band 6 data for this frame.

For the conventional recognition algorithm, each pixel was assigned to one and only one class. The resulting recognition map is shown in Fig. 10; the rejection threshold was set so that 99.9% of pixels characterized by the signatures would be recognized. Portions of eleven lakes were identified, with a total area of 451,900 m^2 where an area of 4503 m^2 (79 m x 57 m) was assigned to each pixel.

We then applied the proportion estimation algorithm to the same data set and generated the lake recognition map shown in Fig. 11. In this map, the density of each symbol is proportional to the estimated proportion of water for that pixel. It is clear on comparing this map with the aerial photo that the shapes of the lakes are more accurately reproduced. Furthermore, even small lakes and ponds are detected, for a total of 19. In addition to the map, which only illustrates ranges of proportions, the exact proportions of water in each pixel were listed. It was determined, upon examining the results, that points containing small percentages of water should be ignored to eliminate false detections. From the listing we determined that the total lake area was 965,800 m^2.

Finally we used the aerial photo to determine the number and actual area of the water bodies in the scene. The total area was 1,004,000 m^2 for 20 lakes and ponds.

In Fig. 12 we present the results for comparison. Here we see that the proportion estimation technique provided significantly more accurate results than those available using the conventional processing technique.

CONCLUSIONS

The strong influence of atmospheric effects in ERTS data has been shown. Although we have not yet directly assessed the influence of these effects, we believe that they can degrade the quality of information extracted from ERTS data. Variations in atmospheric and scene parameters, both within and between frames, will be important. Techniques for reducing the influence of these effects are being investigated.

It has been demonstrated that highly accurate area estimates can be extracted from ERTS-1 data by use of an advanced information extraction technique. For the identification of areas of lakes and ponds in the test site, the 55% error of conventional recognition techniques was reduced to 3% with proportion estimation techniques. While the magnitude of improvement shown here might not be generally achievable without further development, this technique is certain to be useful for investigations in many disciplines.

SPECTRAL DEPENDENCE OF PATH RADIANCE

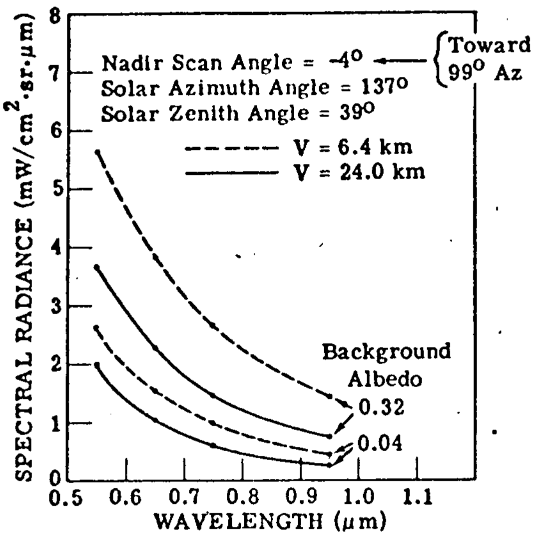


FIGURE 1

DEPENDENCE OF RADIANCE AT SATELLITE ON SCAN ANGLE, 0.55 μm

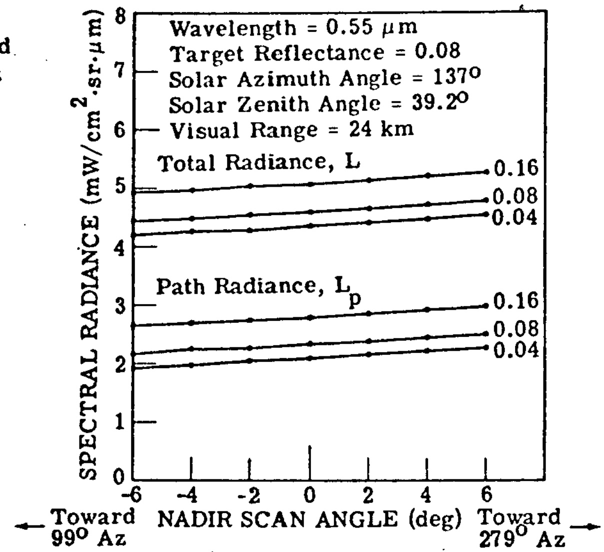


FIGURE 2

DEPENDENCE OF RADIANCE AT SATELLITE ON VISUAL RANGE, 0.95 μm

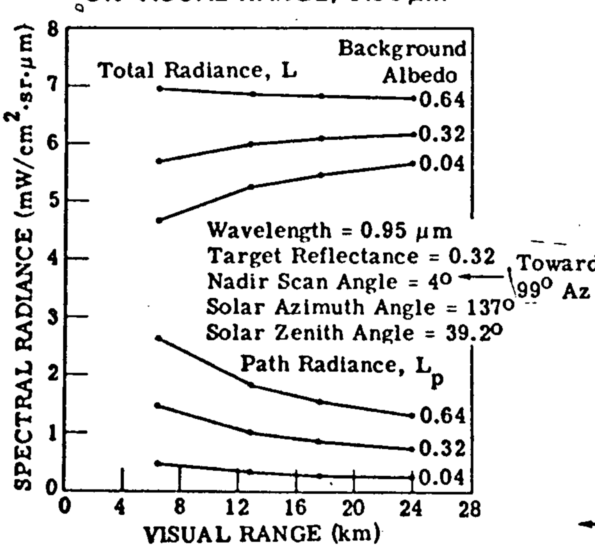


FIGURE 3

COMBINED SCAN-ANGLE AND VISUAL-RANGE EFFECTS ON RADIANCE AT SATELLITE, 0.55 μm

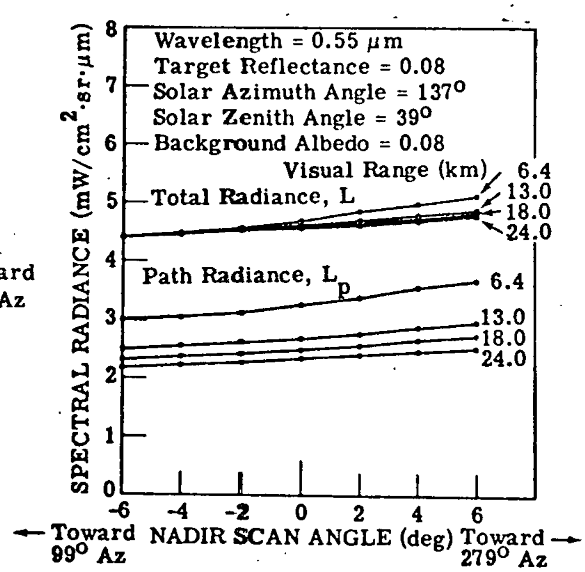
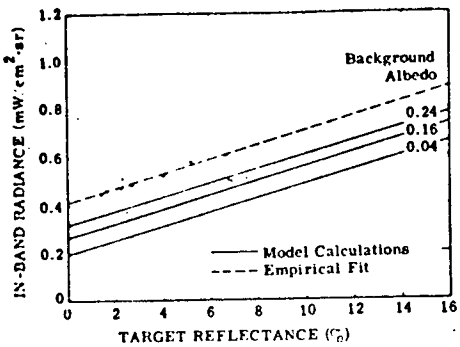


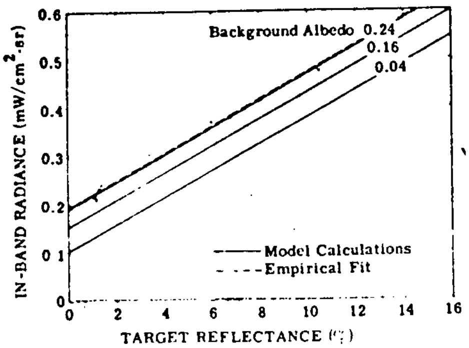
FIGURE 4

ERIM



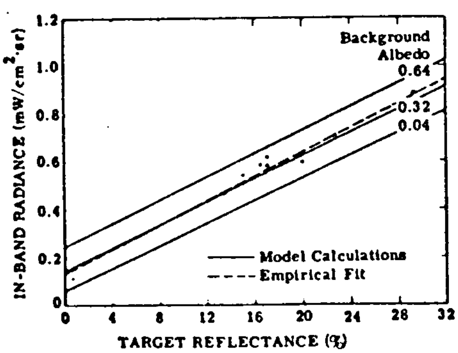
COMPARISON OF EMPIRICAL AND THEORETICAL RADIANCES FOR ERTS BAND 4 (0.5 - 0.6 μm) ERIM

FIGURE 5



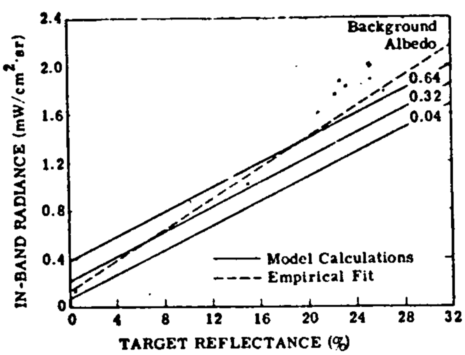
COMPARISON OF EMPIRICAL AND THEORETICAL RADIANCES FOR ERTS BAND 5 (0.6 - 0.7 μm) ERIM

FIGURE 6



COMPARISON OF EMPIRICAL AND THEORETICAL RADIANCES FOR ERTS BAND 6 (0.7 - 0.8 μm) ERIM

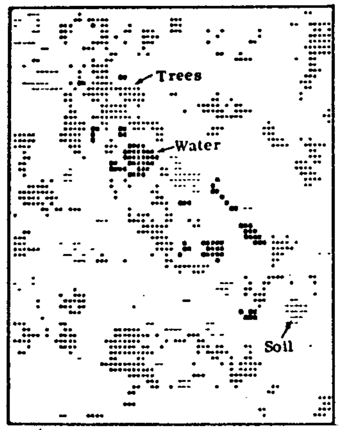
FIGURE 7



COMPARISON OF EMPIRICAL AND THEORETICAL RADIANCES FOR ERTS BAND 7 (0.8 - 1.1 μm) ERIM

FIGURE 8

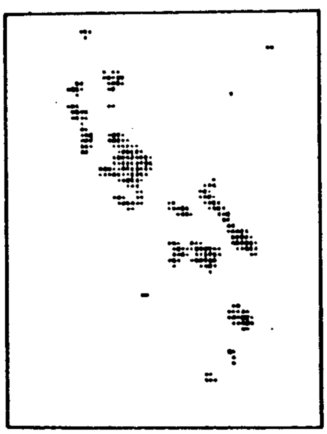
FIGURE 9



RECOGNITION PROCESSING FOR LAKES TEST AREA

ERIM

FIGURE 10



PROPORTIONS ESTIMATION RESULTS FOR LAKES TEST AREA
(Intensity of symbol indicates proportion of lake in each resolution element)

ERIM

FIGURE 11

COMPARISON OF PROCESSING TECHNIQUES FOR ERTS MSS DATA FOR LAKES TEST AREA
(ERTS Bands 4, 5 and 7 Used)

	Ground Information	Recognition Processing	Proportions Estimation
Number of Lakes	20	11	19
Total Area (Meters^2)	1,004,200	451,900	965,800

ERIM

FIGURE 12

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task VII - Image Enhancement and Advanced Information
Extraction Techniques - 1385

W.A. Malila (UN612) and R.F. Nalepka (UN178), MMC 136

1. INTRODUCTION

Experience has been gained at ERIM over the past decade in computer processing and extraction of information from airborne multispectral scanner data and in modeling atmospheric effects in received radiance signals. The general objective of Task VII is to adapt techniques existing at ERIM for their application to ERTS-1 data, to assess the applicability of these techniques by applying them to selected ERTS-1 data, and to identify any additional problems that might be associated with such processing of satellite multispectral scanner data. Three areas are to be studied: (1) compensation for atmospheric effects in ERTS-1 data, (2) preprocessing for improved recognition performance, and (3) estimation of proportions of unresolved objects in individual resolution elements.

The intensive test site for this investigation is an agricultural area South-West of Lansing, Michigan, and the extensive test area also covers several other counties in South Central Michigan. A variety of agricultural crops and woodlots are in the intensive area. The primary crops are corn and wheat, with field beans, soybeans, and alfalfa also represented. The intensive test area is in an overlap region covered by ERTS-1 on two successive days of each 18-day cycle. On 6, 7, and 24 August, there were heavy cloud overcasts, but skies were clear on 25 August. Simultaneous multi-altitude underflight coverage was obtained by the Michigan C-47 multispectral scanner aircraft, and ground-based measurements were made of spectral irradiance and sky radiance. RB-57 coverage of the region was obtained during June and October 1972.

2. PROGRESS DURING THE PERIOD, 1 JANUARY - 28 FEBRUARY 1973

In the semi-annual progress report, 193301-1-P, plots comparing empirical and theoretical assessments of atmospheric effects in ERTS-1 data were presented. Since then, a misunderstanding of the proper procedure for radiance calibration of ERTS data has been discovered and signatures for low-reflectance secondary standards have been extracted. Revised plots were produced and are discussed and presented here. Calculations also were made of atmospheric effects for conditions representative of ERTS frame 1033-15580.

Also in this period, work began on another phase of the Task VII investigation, namely, the testing of advanced information extraction techniques. A technique for estimating proportions of two or more materials in individual spatial resolution elements was applied to ERTS-1 data and used to accurately estimate surface areas of small lakes in an example case.

The progress in these areas is summarized and discussed in a paper prepared for presentation at the Symposium on Significant Results Obtained From ERTS-1. Entitled "Atmospheric Effects in ERTS-1 Data and Advanced Information Extraction Techniques", by W.A. Malila and R.F. Nalepka, the paper is included as Appendix I of this report.

3. PLANS FOR THE PERIOD, 1 MARCH - 30 APRIL 1973

We will attend the ERTS Symposium on Significant Results and present the paper described above. Further examination will be made of differences between empirical and calculated atmospheric effects for ERTS Bands 4 and 5. The testing of proportion estimation techniques will be continued.

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task VIII - Water Quality Monitoring - 1400
C.T. Wezernak, UN 625 , MMC 081

The major effort during the reporting period has been directed towards processing and analysis of data from the New York and Florida test sites. Good spacecraft data have been received for the New York Bight and Tampa Bay study areas. The New York results will be reported at the March 5 ERTS-1 Symposium.

Aircraft data from the 16-17 November 1972 Florida missions have been processed. Aircraft results are excellent. Information regarding the spread of sewage effluents, major currents, and turbidity patterns has been derived from the aircraft data. From a remote sensing standpoint, conditions over the S.E. Florida test site on 16 November 1972 were very interesting. The sea state was calm, skies were clear, sewage effluent from ocean outfalls was surfacing, outgoing tides were moving turbid waters from the intracoastal waterway out along beach areas, and "red tide" was present in the area. Failure on the part of NASA to collect spacecraft data on this orbit has been a great disappointment.

ERTS data received to date for the Tampa Bay area has been very good. Turbidity patterns and the movement of water masses can be determined from the data. Experiences with the Tampa data indicate that the objectives of this phase of the investigation will be realized. Results will be reported in the near future.

Field studies in support of the program were conducted during the period 12-17 February 1973 at the Florida test sites.

The second authorized aircraft mission for the New York Bight is scheduled for 20 March 1973. Accordingly, field studies are planned for this period as well as during the month of April.

A data analysis plan has been submitted during the current reporting period requesting permission to proceed with Phase III, Continuing Data Analysis. A response to this request has not been received.

D

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task IX - Oil Pollution Detection - 1389
R. Horvath, UN 606, MMC 079

ERTS 1 imagery of Salem, Massachusetts (8 October 1972) was received. Detailed examination indicates no evidence of the 29,500 gal. fuel oil spill of 2 October. On-scene reports indicate slick dissipation proceeded rapidly after 4 October, and thus the negative result is not unreasonable.

The accompanying table indicates the relationship between major oil spills and ERTS overflights as of the second week of February. As can be seen from the table, either cloud cover or poor timing precluded acquisition of useful data during 1972. However, the 400,000 gal. crude oil spill of 10 January 1973 (Gulf of Mexico) and the 120,000 gal. waste oil spill of 19 January 1973 (Oakland) show good timing and may produce useful data.

TABLE 1. COINCIDENCE OF MAJOR SPILLS AND ERTS OVERFLIGHTS

LOCATION	OIL TYPE	QUANTITY	REPORT DATE	CLEAN DATE	ERTS DATE	COMMENTS
Salem, Mass.	#2 and #5 Fuel Oil	29,500 gal	2 Oct 72	after 4 Oct	8 Oct 72	Good data No oil
Barataria Bay, Louisiana	Crude	336,000 gal	9 Oct 72	dissipated before 17 Oct 72	18/19 Oct 72	Overcast
San Antonio, Texas	Diesel Fuel	678,000 gal	11 Oct 72	≈17-18 Oct 72	24 Oct 72	Too late
San Juan Cty, New Mexico	Crude	100,000 gal	12 Oct 72	≈1 Nov 72	16/17 Oct 72	Rain
Lake Barre, Louis.	Crude	700 bbl.	22 Nov 72	≈24 Nov 72	23/24 Nov 73	Overcast
Albemarle Snd, N.C.	Bunker C	<1000 gal.	28 Nov	29 Nov 72	3 Dec 72	Good Data Too late
Gulf Coast, Penzoil rig J Storm II	Gas & Oil (burning)	?	4 Dec	≈6 Dec 72	11 Dec 72	Overcast Too late
Timbalier Bay, Louis, (well blowout)	gas, light distillate	(minor ?)	6 Dec 72	?	12 Dec 72	Overcast
Jennings, Louis. (Bayou Nezpique)	Crude	3720 bbls	14 Dec 72	?	12/13 Dec 73	Too early
Alameda, Calif. (Naval Air Sta.)	10 % diesel 20 % solvent 70 % 20/40 lube	>1400 gal	22 Dec 72	23 Dec 72	17 Dec 72	Too early
Fenwick, Conn.(L.I. Snd)	No. 6 Fuel Oil	12,000 gal	26 Dec 72	30 Dec 72	7 Jan 72	Too late
Gulf Coast, Louis. (Pltfm A. West Delta 79 Signal Oil Co.)	Crude	400,000 gal	10 Jan 73	?	15/16 Jan 73	Investigate
Oakland, Cal.	Waste Oil	≈120,000 gal	19 Jan	Contained 24 Jan Completed 4 Feb	22/23 Jan	Investigate
Vicksburg, Miss.	#2 Fuel Oil	4500 bbl	31 Jan 73	3 Feb 73	4 Feb	

RATIO MAPS OF IRON ORE DEPOSITS
ATLANTIC CITY DISTRICT, WYOMING

Robert K. Vincent

Environmental Research Institute of Michigan
Ann Arbor, Michigan

ABSTRACT

Preliminary results of a spectral ratioing technique are shown for a region at the southern end of the Wind River Range, Wyoming. Digital ratio graymaps and analog ratio images have been produced for the test site, but ground truth is not yet available for thorough interpretation of these products. ERTS analog ratio images were found generally better than either ERTS single-channel images or high altitude aerial photos for the discrimination of vegetation from non-vegetation in the test site region. Some linear geological features smaller than the ERTS spatial resolution are seen as well in ERTS ratio and single-channel images as in high altitude aerial photography. Geochemical information appears to be extractable from ERTS data. Good preliminary quantitative agreement between ERTS-derived ratios and laboratory-derived reflectance ratios of rocks and minerals encourage plans to use lab data as training sets for a simple ratio gating logic approach to automatic recognition maps. Empirical atmospheric corrections indicate that atmospheric corrections are needed to make the ratio method, and possibly other types of data processing, consistent over large geographical and temporal displacements. The ratio method, designed for geochemical prospecting and geologic mapping, should also be useful for other scientific applications from satellite data as well.

1. BACKGROUND

The primary objectives of this ERTS investigation are to develop a generally applicable method for mapping large exposures of iron compounds, to use this method for mapping iron compounds in the Wind River Range, Wyoming vicinity, and to estimate the usefulness of this method for limited geochemical prospecting from ERTS data in this and other (geologically well-exposed) regions of the world. The method involves empirical corrections for atmospheric effects, spectral ratioing of reflected radiances of selected pairs of ERTS multispectral channels, production of analog ratio images, and production of automatic recognition maps of as many rock classes as possible, using laboratory data as training sets whenever possible.

The data processing steps used to correct for atmospheric and illumination effects in this ratio method have been described in an earlier paper [1]. In brief, the radiance detected for the darkest object (usually shadow or water) in a given scene is subtracted from the detected radiance of all other points for each MSS channel. The resulting radiances in two of the MSS channels are ratioed. The ratio for all points is then divided by the ratio of a known point in the scene (ratio normalized) and multiplied by the reflectance ratio (determined from laboratory data) of the known point. This yields a ratio of reflectances in the two selected spectral channels for every point in the scene. To a first approximation, it is hypothesized that most atmospheric and illumination effects are removed from this ratio of reflectances by this procedure. As a qualitative example, typical reddish rocks (high reflectance in channel 5 and lower reflectance in channel 7) will have an R_{75} ratio less than 1.0; vegetation, which exhibits the opposite spectral behavior, will have an R_{75} ratio much greater than 1.0. Further processing involves inputting the ratio of reflectance into digital and analog computers to produce digital ratio graymaps and analog ratio images, respectively. Later processing is planned in which automatic recognition maps of various rock classes will be produced, using two to four of the above reflectance ratios as a basis for automatic decision making.

The four months since ERTS data were first obtained have been spent primarily on development of the data processing techniques to be used, some of which are presented here. Initial interpretative efforts have been based on comparisons of aerial photography, geologic maps, and expected ratio values calculated from laboratory data. All of the data processing to date has been done on parts of ERTS frame E-1013-17294, collected on 5 August 1972. Once satisfactory results have been obtained for the primary test site, the rest of the ERTS frame will be "prospected" for unusual concentrations of iron oxides. A field trip to Wyoming to check anomalies and to collect samples for laboratory spectral measurements will be made this coming summer.

2. GEOLOGIC DESCRIPTION OF THE TEST SITE

The primary test site chosen for this investigation is the Atlantic City District, at the southern end of the Wind River Range, Wyoming. In this district, which has been mapped by R.W. Bayley [2], the Goldman Meadows Formation consists of schist, quartzite, and metasedimentary iron-formation. The iron-formation member, which contains on the average of 35% iron, is composed mainly of magnetite and quartz, with small amounts of chlorite, garnet, and amphibole. It is in this region that the U.S. Steel Corporation has an operating iron mine.

Just south and east of the Goldman Meadows Formation is the Roundtop Mountain Greenstone Formation, consisting of ellipsoidal greenstone (derived from basalt) and green schist. Just southeast of that formation is the Miners Delight Formation, composed primarily of graywacke (turbidites), schist, conglomerate, and ellipsoidal greenstone (derived from andesite). To the west of the iron mine is the Louis Lake batholith, which is primarily biotite-hornblende quartz diorite and granodiorite, bordered by migmatite and gray gneiss. Interlaced within the batholith are diabasic gabbro dikes of widths on the order of 60 to 100 meters and lengths up to 10 kilometers. All formations previously listed are Precambrian in age. Due north of the Goldman Meadows Formation lies a sedimentary series of beds from Precambrian to Mesozoic in age. These beds lie unconformably on the metamorphic and igneous rocks previously mentioned and dip northeastward, exposing Precambrian sandstone adjacent to the metamorphics.

3. AIR PHOTOS AND ERTS SINGLE-CHANNEL IMAGES OF THE TEST SITE

Figure 1 shows an aerial photo taken from a high-altitude, October, 1971 flight of the NASA U-2 aircraft [3] and a MSS channel 5 ERTS image of the test site. Both photo and image encompass the red portion of the visible spectrum and are the same scale, although the ERTS image is inadvertently shifted slightly northward in comparison of the aerial photo. The iron mine, which is the one-km-wide bright region (shaped somewhat like an extracted molar) in the lower right of the ERTS image, seems more distinct in the ERTS image, probably due to film-saturation of the image for even moderately bright targets. On both photo and ERTS image, intersecting diabasic gabbro dikes (on the order of one ERTS spatial resolution element) are visible west of the iron mine in the Louis Lake batholith. For future reference,note three things: (1) the iron mine does not appear unique, or even distinctive, from other areas in the scene; (2) the sedimentary strata in the upper right corner of the ERTS image appear similar to one another; and (3) vegetation (dark) in the channel-5 ERTS image is easier to distinguish from non-vegetation than in the aerial photo (probably because of the time of year). Dark shadows (in the northeast trending valley) appear similar to vegetation in both ERTS image and photo.

Figure 2 shows the same scene as in the previous figure. The aerial photo was taken in the 0.51 - 0.90μm wavelength range and the ERTS image is for MSS channel 7(0.8 - 1.1μm wavelength region). Although the iron mine is darker than its surroundings, in contrast to a brighter-than-average reflectance in the visible red region, it is not distinct from the surrounding terrain in the reflective infrared region of either the aerial photo or the ERTS channel 7 image. Note further that the diabasic gabbro dikes in the Louis Lake batholith are virtually undetectable in the ERTS channel 7 image, the sedimentary strata in the upper right corner appear similar to one another in both photo and image, and vegetation (bright) in the upper right corner of the channel 7 ERTS image is more discriminable from non-vegetation than in the false color aerial photo, again possibly because of time of year differences between the data collections.

4. RATIO MAPS OF THE TEST SITE

Two forms of ratio maps have been produced thus far for the test site; one is a digital ratio graymap and the other form is an analog ratio image.

The digital graymap is used as a research tool for quantitative analysis, to examine the accuracy of the ratio method. Figure 3 shows an R_{75} (ERTS channel 7 divided by channel 5) digital ratio graymap. (Note: This figure and figure 4 were originally in color. See Figure 4 for color interpretations). Green represents vegetation, violet is primarily a mixture of rock and vegetation, blue is rock outcrop, and red represents magnetite, possibly some greenstone, and other possible iron-rich outcrops. The darkest red occurs only in the iron mine and along pond edges, where muds or tailings may be present.

The atmospheric path radiances obtained from the dark object subtraction were about 12% of the mean signal level in channel 5 and less than 4% of the mean level in channel 7 in the hilly Atlantic City District, which is approximately 2.5 km above sea level. At two other points, approximately one-half and three-fourths of the ERTS frame to the east, in flat, open plains that are about 0.3 km lower in elevation, path radiance percentages determined by dark object subtraction in channels 5 and 7 were 22% and 4%, respectively, of the mean signal levels. Without these corrections large errors in the ratio would have been made for objects which are dark in channel 5 within a given scene, and the errors would have been substantially different in the two parts of the ERTS frame. Since this ERTS frame was collected on a clear, dry day for a high mean elevation test site, atmospheric corrections would appear to be more necessary for less favorable observing conditions over lower test sites, if consistent data processing results are desired.

Figure 4 shows some R_{75} reflectance ratios calculated from a subset of laboratory data contained in the NASA Earth Resources Spectral Information System at the Johnson Spacecraft Center in Houston, Texas. Not all of the categories displayed here are represented in the test site. The values corresponding to the graylevels of the ratio graymap in figure 3 are also shown here. For calculation of these laboratory spectra reflectance ratios, square filters were assumed for the ERTS MMS channels; this assumption makes the calculated vegetative R_{75} ratio lower than that calculated from ERTS data because of the rapidly rising reflectance of vegetation longward of 0.67μm. The other ratios should be close to the ERTS-drived ratios, and they are to the best of our current estimation. All of the obviously exposed rocks (granite, limestone, greenstone, magnetite, hematite, gray sand) in the Atlantic City District have ERTS-derived R_{75} ratios that are within the R_{75} ratio ranges calculated from corresponding lab samples. However, only lab spectra of rock samples from the test area will yield a final answer as to the absolute accuracy of the ratio method.

There are two comments concerning figure 4 that should be made here. First, the lab-derived ratio ranges represent the extreme (highest and lowest) in R_{75} for each given rock category, and most categories include specimens as small as 0 - 5μm in particle diameter. This is a worst case. Secondly, this is only one ratio, and final decisions concerning rock classifications will be made on the basis of two to four ratios. Further work using laboratory data to derive ratio limits for these rock categories is planned, such that a ratio gating logic can be derived for the production of automatic recognition maps with an AND gate for each of the two to four ratios.

The other form of ratio map produced thus far is an analog ratio image. This yields a continuous display of ratio values, as if the ratio were a single channel of information. Figure 5 is an R_{75} analog ratio image which includes the whole Atlantic City District and more of the surrounding region. Note the enhanced iron mine (dark) discrimination from most of the immediately surrounding background. Note also that the sedimentary strata in the upper right of the R_{75} ratio image (not as near the corner as in Figures 1 and 2) are still indistinct. The diabasic gabbro dikes in the Louis Lake batholith are distinctive, however. Finally, note that the discrimination between vegetation (brighter) and non-vegetation (darker) is better in this ratio image than in either aerial photos or single-channel ERTS images.

An analog R_{74} ratio image of the same area (Fig.6) shows the iron mine (dark, but brighter than water) to be unique from all other points in the scene. The Jurassic sediments (relatively bright) and thin, dark beds of some sedimentary origin are discriminated from adjacent sedimentary strata in the upper right of the R_{74} ratio image. In no other photos or images shown in Figures 1 through 5 are there sediments discriminated this well. Vegetation is easily discriminated from non-vegetation; shadows, which are minimized, are not mistaken for vegetation here, as they were in the channel 5 ERTS imagery of Figure 1.

These analog ratio images focus the attention of the geologist or other scientist on areas in the scene where chemical properties of a target are different from its surroundings. The ratio images contain information which, when interpreted by the human eye, is either not available or difficult to distinquish in aerial photos or single channels of ERTS imagery. Furthermore, the ratios are dimensionless numbers with which laboratory data and points in the scene of interest can be compared. The data shown here only prove that geochemical data exist in ERTS data. Further data processing and ground truth investigations are necessary to permit the organization of these data into as many meaningful classifications as it possible.

5. CONCLUSIONS

The following general conclusions are made from the foregoing discussions:

1. Ratio images of ERTS data appear to be better than either aerial photos or ERTS single channel images for discrimination between vegetation and non-vegetation.
2. Some geological features smaller than the publicized spatial resolution of ERTS, such as the diabasic gabbro dikes in the

Louis Lake batholith, are seen as well in ERTS single-channel images and ERTS ratio images as in high altitude aerial photos.

3. Geochemical information definitely is contained in ERTS images and ratio images, which are generally superior to aerial photos because of the limited spectral range of the latter. Iron oxides are more easily discriminated from ERTS ratio images than from ERTS single-channel images or from high altitude aerial photography. This is useful in mineralogical exploration because exposures of several types of metallic ores are often associated with iron oxides. The differing relationships between rock type and iron-bearing minerals may also be useful in general geologic reconnaissance mapping, due to the resultant variability of ferric and ferrous compounds present. Satellite geologic reconnaissance would be much cheaper than aerial data collection over most large, remote sites.

4. On the basis of the ERTS ratio images, it seems plausible that an automatic recognition map can be made on the basis of selected spectral ratios of ERTS data which will distinguish rock and soil exposures from all other materials in the scene (within the limits of the ERTS spatial resolution) and discriminate two to four meaningful rock groups (each consisting of one or more rock types).

5. The agreement observed thus far on absolute ratio numbers between ERTS ratio maps and laboratory spectra encourages efforts to use laboratory data as training sets for geologic targets, which if successful, would enable the same automatic discrimination over unknown geologic terrain throughout the world, with reasonable atmospheric conditions.

6. Early quantitative analysis indicates that consistent results for this or other data processing techniques over large geographical distances or large time periods over a given test site will require some type of atmospheric corrections. The empirical atmospheric corrections used in this ratio method appear to be effective for high-elevation test sites, but have yet to be tested with areas near sea level.

7. The method being developed for this investigation would appear to be useful for scientific applications other than geology. Soil mapping and biomass estimation are two such applications.

REFERENCES

R.K. Vincent, "An ERTS Multispectral Scanner Experiment Mapping Iron Compounds," Proceedings of the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, to be published in 1973. Also ERTS-1 Report No. E72-10181.

R.W. Bayley, "A Preliminary Report on the Precambrian Iron Deposits near Atlantic City, Wyoming," USGS Bulletin 1142-C, 1963, pp.C1-C23.

J.A. Dorr, Private Communication, Dept.of Geology and Mineralogy, University of Michigan, 1973.

ACKNOWLEDGMENTS

I am grateful to Bette Salmon, William Pillars, and Fred Mauk of ERIM for their invaluable assistance. I also thank Dr. John Dorr of the University of Michigan for the aerial photos. This work was supported by NASA contract NAS-5-21783.

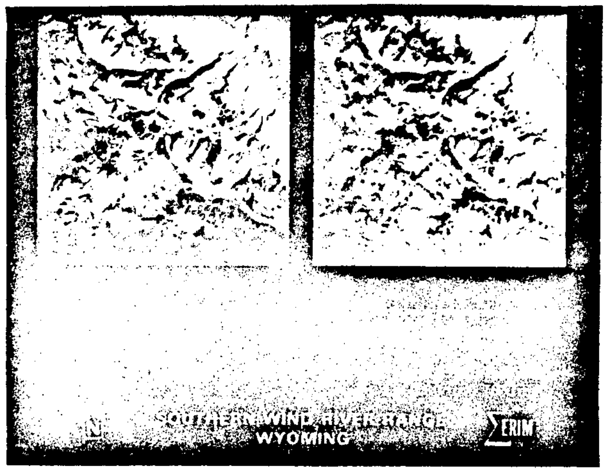


Figure 1. Aerial Photo and ERTS Image in the Visible Red of the Southern Wind River Range, Wyoming

Figure 2. Aerial Photo and ERTS Image in the Reflective Infrared of the Southern Wind River Range, Wyoming

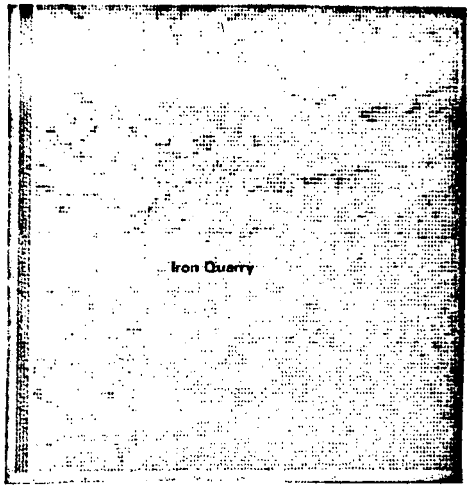


Figure 3. ERTS Digital R_{75} Ratio Graymap of Southern Wind River, Wyoming

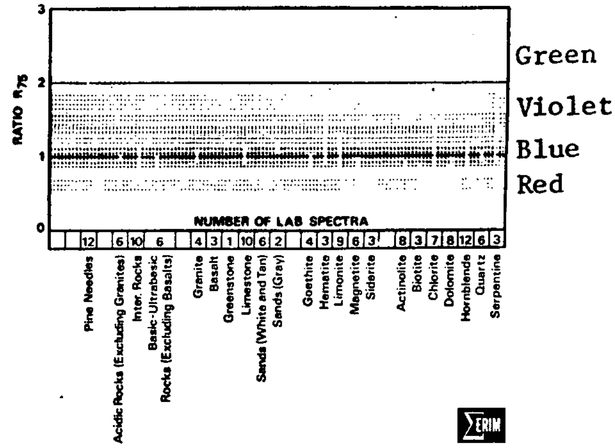


Figure 4. Expected R_{75} Ratios Calculated from Laboratory Data

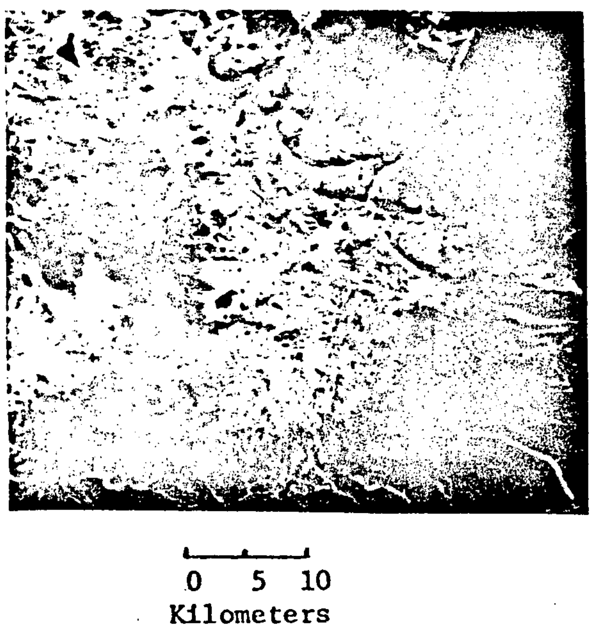


Figure 5. ERTS Analog R_{75} Ratio Image of Southern Wind River Range, Wyoming

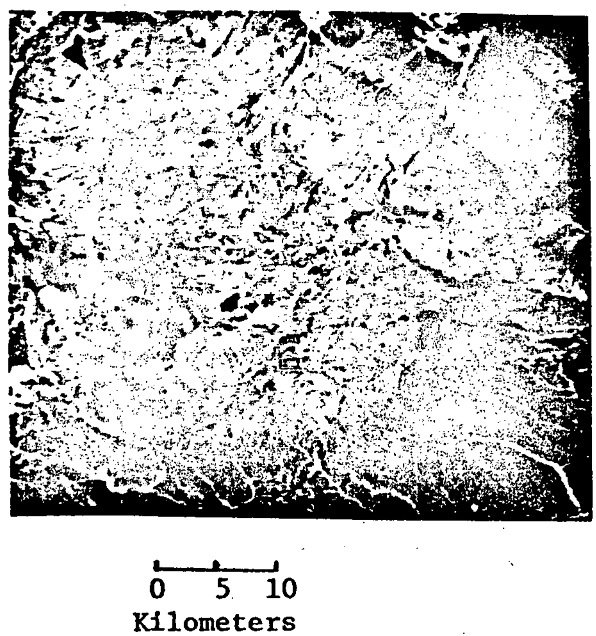


Figure 6. ERTS Analog R_{74} Ratio Image of Southern Wind River Range, Wyoming

E73 10397

ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

Fourth Type I Progress Report - 1 January 1973 - 28 February 1973
Task X - An ERTS Experiment for Mapping Iron Compounds - 1383
R. K. Vincent, UN 422, MMC 075

During this reporting period the effort of this task was directed to the following:

(1) Comparison of aerial photographs with single channel ERTS imagery, and

(2) Preparation of ratio maps, i.e., ratio of value in one channel to value in another channel by using, say, channel 7 divided by channel 5. These ratio maps have been output in two forms, a digital ratio greymap and an analogue ratio image.

This work was reported at the recent ERTS Symposium held at Goddard Space Flight Center, 5-9 March 1973. A copy of the paper by the Task IX leader presented is made as part of this Type I Report (see following pages). Specific conclusions derived from these two investigations are listed in the attached paper. This paper is being submitted to the NTIS as significant results from this ERTS task.

The Data Analysis Plan is in preparation and will be submitted as indicated earlier. During the next two months more analog ratio images will be prepared for the Atlantic City District and for the remainder of the same ERTS frame. Also, laboratory data will be used to determine which rock categories can be discriminated by ratio maps of ERTS data.