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ERIM PROGRESS REPORT ON USE OF ERTS-1 DATA

Summary Report of Work on Ten Tasks

F. J. Thomson, et al.
Environmental Research Institute of Michigan (ERIM)
Post Office Box 618, Ann Arbor, Michigan 48107

January 1973

Type II Progress Report under Contract NAS 5-21783
For Period 1 July Through 31 December 1972

ENVIRONMENTAL
RESEARCH INSTITUTE
OF MICHIGAN
FORMERLY WILLOW RUN LABORATORIES,
THE UNIVERSITY OF MICHIGAN

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Report No. 193301-1-P

(E73-10086) SUMMARY REPORT OF WORK ON TEN TASKS Progress Report, 1 Jul. - 31 Dec. 1972 (Environmental Research Inst. of Michigan) 50 p HC CSCL 05B
N73-17298
Unclas
G3/13 00086

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
193301-1-P		

4. Title and Subtitle	5. Report Date
ERIM PROGRESS REPORT ON USE OF ERTS-1 DATA Summary Report of Work on Ten Tasks	5 February 1973
	6. Performing Organization Code
7. Author(s) F. J. Thomson, et. al.	8. Performing Organization Report No. 193301-1-P
9. Performing Organization Name and Address Environmental Research Institute of Michigan Post Office Box 618 Ann Arbor, Michigan 48107	10. Work Unit No.
	11. Contract or Grant No. NAS5-21783
12. Sponsoring Agency Name and Address Goddard Space Flight Center Greenbelt, Maryland 20771 E. F. Szajna, GSFC Technical Monitor Code 430	13. Type of Report and Period Covered Type II Progress Report July-December 1972
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract This first Type II Progress Report under NAS5-21783 describes the ERIM program in utilization of ERTS data as being conducted under a set of ten tasks. These tasks comprise:

I	Water Depth Measurement
II	Yellowstone Park Data
III	Atmospheric Effects (Colorado)
IV	Lake Ice Surveillance
V	Recreational Land Use
VI	IFYGL (Lake Ontario)
VII	Image Enhancement
VIII	Water Quality Monitoring
IX	Oil Pollution Detection
X	Mapping Iron Compounds

Work to date is reported and research and application plans are presented.

17. Key Words (Selected by Author(s))	18. Distribution Statement
ERTS Data Use, Remote Sensing, Environmental Applications, Infrared, Radar, Underflights, MSS Scanner, Ground Truth	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	49	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

PREFACE

On January 1, 1973, the Environmental Research Institute of Michigan (ERIM) was created when the Willow Run Laboratories severed relationships with The University of Michigan. ERIM is a not-for-profit corporation, registered in the State of Michigan, and employs substantially all the staff and facilities of the former Willow Run Laboratories.

Contract NAS5-21783, under which this work is being performed, has recently been novated to ERIM from the University of Michigan. Hence, all reports prepared after January 1, 1973 for NAS5-21783 will be submitted by ERIM.

Objectives

The overall objective of the ERIM program in utilization of ERTS collected data is to demonstrate the feasibility of using remote sensing information for the study of natural resources and environmental problems. In order to contribute to this general objective ten specific tasks are being pursued. Objectives of these tasks are described briefly as:

(1) Detection, location and measurement of the depth of shoal areas,
(2) Computer mapping of terrain features in the Yellowstone National Park,
(3) Investigation of atmospheric effects on the accuracy of mapping rock types and land use categories, in Cripple Creek-Canon City, Colorado, area,
(4) Surveillance of lake ice formation, distribution and break-up with MSS and radar imagery for potential aid to Great Lakes shipping,
(5) Mapping of land uses and physical characteristics in SE Michigan to identify areas for recreational uses and open space preservation,
(6) Delineate air-water-land interactions in the Lake Ontario Basin as a contribution to the IFYGL,
(7) Development of image enhancement and advanced information extraction techniques for ERTS MSS data,
(8) Detection of water pollution and monitoring of water quality for four ocean areas and two lake areas,
(9) Detection and monitoring of oil pollution in coastal areas from ships and barges, industrial discharges and major incidents (tanker break-up and oil well leaks), and
(10) Detection and mapping of iron compounds and related geologic features in Wyoming (Atlantic City District at SE end of Wind River Range).

Scope

The scope of the program is implied by the objectives of these ten tasks. ERTS produced imagery and MSS data (digital tapes) are being studied using human interpretation and computer processing. The resulting mapping and analyses will permit the assessment of satellite produced information in contributing to these specific natural resource and environmental problems.

Information from at least 21 ERTS frames will be utilized in making these studies. Over 250 MSS data tapes have been received for the study of these frames. An existing data management system (DMS) has been adapted for maintaining the inventory on these tapes and summarizing the contents and status of this tape inventory. For the support of this broad program ERIM software is being expanded and updated.

Conclusions

Different tasks show varying degrees of progress. Those tasks which have good data sets to work with are well into first look analysis. Some tasks have not yet received usable imagery or taped data, primarily because of cloud cover over the test sites.

Taped data examined to date have been generally good, with three exceptions (1) in one instance creases in tapes have caused the loss of one or more records of information (see Task II); (2) an apparently bad detector has been identified in band MSS-6 in one frame of data (see Task VII); and (3) the range of water signals seems quite small. For example, the range of signals in band MSS-4 in the New York frame (1024-15071) between deep water and acid spill is about 15-18 integers which is only about 15% of the total dynamic range. This small range is understandable in view of the optimization of system gain for land features. It would be desirable at some future date to obtain data with more optimized gain for water features.

Imagery examined seems to be of good quality. However, precision and bulk color products ordered have not arrived. These products, while not essential to analysis, serve an important role as sources of ancillary information. If we are to evaluate their worth in processing operation support, we must have some examples of these products. This problem is being pursued with User Data Services.

Investigations to date indicate that the software package developed for the 7094 computer is generally adequate to carry out proposed investigations. Some analysis capabilities we believe are required for ERTS data (such as two dimensional analysis of variations of apparent scene radiance and ability to use model derived corrections for atmospheric path radiance and transmission) are now being developed.

None of the investigations has proceeded to a point where many definitive conclusions can be drawn. This situation is expected to change considerably after the next two months.

Recommendations

We would appreciate receiving some data collected with high gain in channels MSS-4 and MSS-5 over water areas. Such data would particularly benefit Tasks I and VIII. We will be happy to cooperate with GSFC personnel in defining suitable test sites. Also, expedited delivery of color and precision products would be appreciated.

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GENERAL INTRODUCTION

The ERIM program in the utilization and analysis of ERTS-1 data is comprised of ten tasks. Several of these tasks involve other agencies as described below for each task. The reporting of progress for each task is presented below in terms of the format for the Body of the Report as specified by the requirements of this report.

To facilitate reference to specific tasks, we present here a Summary of the tasks by relevant numbers and short title descriptions. Detailed narrative reporting for each task follows the Summary.

TASK	PRINCIPAL INVESTIGATOR	MMC #	UN	SHORT TITLE	PAGE
I	Polcyn	063	200	Water Depth Measurement	2
II	Thomson	077	621	Yellowstone Park Data	5
III	Thomson	137	636	Atmospheric Effects (Colorado)	6
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VIII	Wezernak	081	625	Water Quality Monitoring	28
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X	Vincent	075	422	Mapping Iron Compounds	38

First Type II Progress Report
F. C. Polcyn, MMC 063
Task I, Water Depth Measurement

INTRODUCTION

ERTS-1 data are being examined to determine the application of satellite mapping to updating navigation charts. Two techniques are being explored:

1. Measuring wave refraction effects in the Fourier transform domain produced by an optical processor with a space photograph used as the input transparency. This technique lends itself to use from any altitude, including those of earth satellites, and is independent of the light transmission characteristics of water.

2. Using multispectral scanner images for measuring the relative intensities of light reflected at different spectral intervals by the ocean or lake bottom and correcting for surface reflection and scattering.

The ultimate objective of this work is to develop an integrated system, using satellites, aircraft, and surface-based measurements, for detecting and locating shoal areas, and more particularly for measuring water depth. This system can be used to reduce hazards to ship navigation, to aid marine engineering projects, to study shore erosion, and to permit quick assessment of storm-induced changes.

So far, only portions of the test sites under study have been mapped by the ERTS-1 with partial cloud-free areas so that no machine processing has been attempted. Computer software for the 7094 computer has been developed in preparation for processing of ERTS-1 data.

PROGRESS

Computer programs that satisfy a generalized water quality investigation have been developed. The water depth module calculates an estimate of water depth using selective penetration of the water by various wavelengths of light.

It is assumed that a baseline or deep water sample is available and that the bottom can be seen. The DEPTH module is one of three modules to be specified, and can be activated by a program operator by a switch. The default value is no depth computation. The input to the DEPTH module is assumed to be a clamped, dark level corrected tape. DEPTH has three modes, initialization, per line operations, and per point operations.

Initialization calls for calculation of the deep water case which can come from an average over a specified rectangle. Angle of view and sun angle as well as reflectances and atmospheric transmission values are also read in.

Depth calculations are done every line. For the reflectance mode, a maximum value of the voltage in each channel over a specified sun sensor region is found. For the radiance mode, values of solar irradiance in each of the wavelength bands at the earth's surface are needed.

For calculation of water depth z (in meters) at points, the test channel is examined to see if the point is water

$$V_{\ell o} \leq V \leq V_{hi} \rightarrow \text{water}$$

where $V_{\ell o}$, V_{hi} = limits entered by operator

V = edit channel voltage

If the criterion is satisfied, z is computed for specified pairs of channels, i and j, as

$$z_{ij} = F(\theta, \phi) * G_{ij} * A_{ij} \ \ell n \frac{V_i}{V_j}$$

where θ = sun depression angle

ϕ = scan angle

$G_{ij} = \frac{1}{\alpha_i - \alpha_j}$, α_i and α_j are water attenuation coefficients

$$A_{ij} = \ell n \left[\frac{\rho_{Bi}}{\rho_{Bj}} \ \frac{\rho_{ssj}}{\rho_{ssi}} \ \frac{V_{ssi}}{V_{ssj}} \ \frac{\tau^2_{Ai}}{\tau^2_{Aj}} \right]$$

ρ_{ssj}, ρ_{ssi} = equivalent sun sensor reflectance in channels i and j

V_{ssi}, V_{ssj} = sun sensor voltages

ρ_{Bi}, ρ_{Bj} = background reflectances

τ_{Ai}, τ_{Aj} = atmospheric transmissions (default to 1)

Finally, average z and the standard deviation of z are computed by lines or for selected homogeneous areas.

ERTS DATA

The two test sites under consideration are the waters around Puerto Rico and Northern Lake Michigan. So far imagery data for only the northeastern corner of the test site near Puerto Rico have been received. One frame covering the Straits of Mackinac with some cloud cover interference has been received.

ERTS-1 coverage in the Bahamas has provided a possible frame of usable data, two of the four ERTS channels show differences in water penetration.

PROGRAM FOR NEXT REPORTING INTERVAL

The winter season in the prime test site near Puerto Rico should bring usable ERTS-1 data with minimum cloud interference. Analysis will proceed as soon as tapes are made available. If no more data are obtained, then depth analysis will proceed on data taken at any site where conditions were more favorable and for which data tapes are released. A level slicing mode with editing channels will be used to identify underwater offshore features. Then two channel calculations on water depth will be initiated. Comparison with available bathymetry charts will prove usefulness of these techniques both for position location and depth accuracy.

NEW TECHNOLOGY

None

CONCLUSIONS AND RECOMMENDATIONS

It is apparent that the Puerto Rico site coverage is obtained by using the tape recorder rather than by real time transmission of the data to GSFC as suggested in the Users Data Manual, page 2-9. We would appreciate notification by phone of intentions to collect Puerto Rico data, since this information will allow us to plan our processing efforts more efficiently.

First Type II Progress Report
Fred J. Thomson, MMC 077
Task II, Yellowstone Park Data

INTRODUCTION

The purpose of this task is to prepare land use category maps from ERTS-1 data for Yellowstone National Park. The project is a cooperative one between ERIM personnel, Dr. Harry Smedes of U.S.G.S., and Mr. Dennis Despain of the National Park Service.

PROGRESS

Digital tapes of the 6 August data (frame 1015-17404) were received and copied to ERIM format. Several problems with tape errors (caused by creases in the original tapes supplied by Goddard) were circumvented by first copying the tapes on the 360 computer.

Graymaps of the entire park were prepared, using band MSS 5. These will serve as a base map for further processing. Enlargements to approximately 1:250,000 of band 5 imagery have been prepared.

Preliminary examination indicates that the data are of excellent quality. We are now waiting for training set locations to be transmitted from Dr. Smedes so that preliminary recognition maps can be made.

PROGRAM FOR NEXT REPORTING INTERVAL

The next two months will be busy ones with the processing of this data set and the preparation of a-data analysis plan (due 1 February 1973). Preparations are being made for a paper to be presented at GSFC for the 5-9 March 1973 Symposium.

NEW TECHNOLOGY

None

CONCLUSIONS AND RECOMMENDATIONS

The tape errors on the bulk digital tapes from GSFC caused fatal hardware associated problems with the IBM tape drives on our 7094 computer. Careful inspection of the tapes revealed that oxide had been scraped off the tape, causing the loss of 1 or 2 records per tape. While this problem has not been observed on any other ERIM received tapes, the problem is serious when encountered because of the loss of required data and the extra effort and time required to make the tapes received usable.

First Type II Progress Report
Fred J. Thomson, MMC 137
Task III, Atmospheric Effects

INTRODUCTION

The purpose of this task is to demonstrate the effects of the atmosphere on the ability of pattern recognition devices to classify terrain objects. The project is a cooperative one between ERIM personnel, Dr. Harry Smedes and Robert Watson of U.S.G.S., and Mr. Roland Hulstrom of Martin-Marietta Corporation.

PROGRESS

Progress has been slowed by the lack of usable data from the test site. All data received and reviewed have been cloud covered and unusable. Because the test site is covered with snow, land use mapping cannot be carried out in the winter months. Therefore, we will have to wait until spring to obtain data suitable for carrying out the land use mapping phase of the experiment.

Attempts are now being made to measure atmospheric properties in the test site during one over-pass of ERTS when the site is covered by snow. The snow will act as a reasonably uniform reflector and permit some assessment of the effects of varying base altitude within the test site.

PROGRAM FOR NEXT REPORTING INTERVAL

The next two bimonthly periods will be of low activity because of the lack of suitable data. Important questions about the compatibility of bulk digital data with the ERIM 7094 computer system have been resolved. Increased activity will begin in May and June when reduced snow cover should provide opportunities for obtaining suitable data.

NEW TECHNOLOGY

None

CONCLUSIONS AND RECOMMENDATIONS

Lack of suitable data (without snow cover) has prevented the planned development of this task. Hence, no conclusions or recommendations are offered for this first Type II report.

First Type II Progress Report
L. Porcello and M. L. Bryan, MMC 072
Task IV, Lake Ice Surveillance

INTRODUCTION

This portion of the report describes the progress which is being made with Task IV (Lake Ice Surveillance) of the ERTS-1 contract. As can be expected, because the nature of the subject of this task is totally dependent on the onset of winter and the development of sufficient lake ice to allow field checking, this project has not been able to get into the field, and thus, is not in the position to present results. Progress in terms of organization and preparation are proceeding, however, and these are discussed within the confines of this report.

PROGRESS

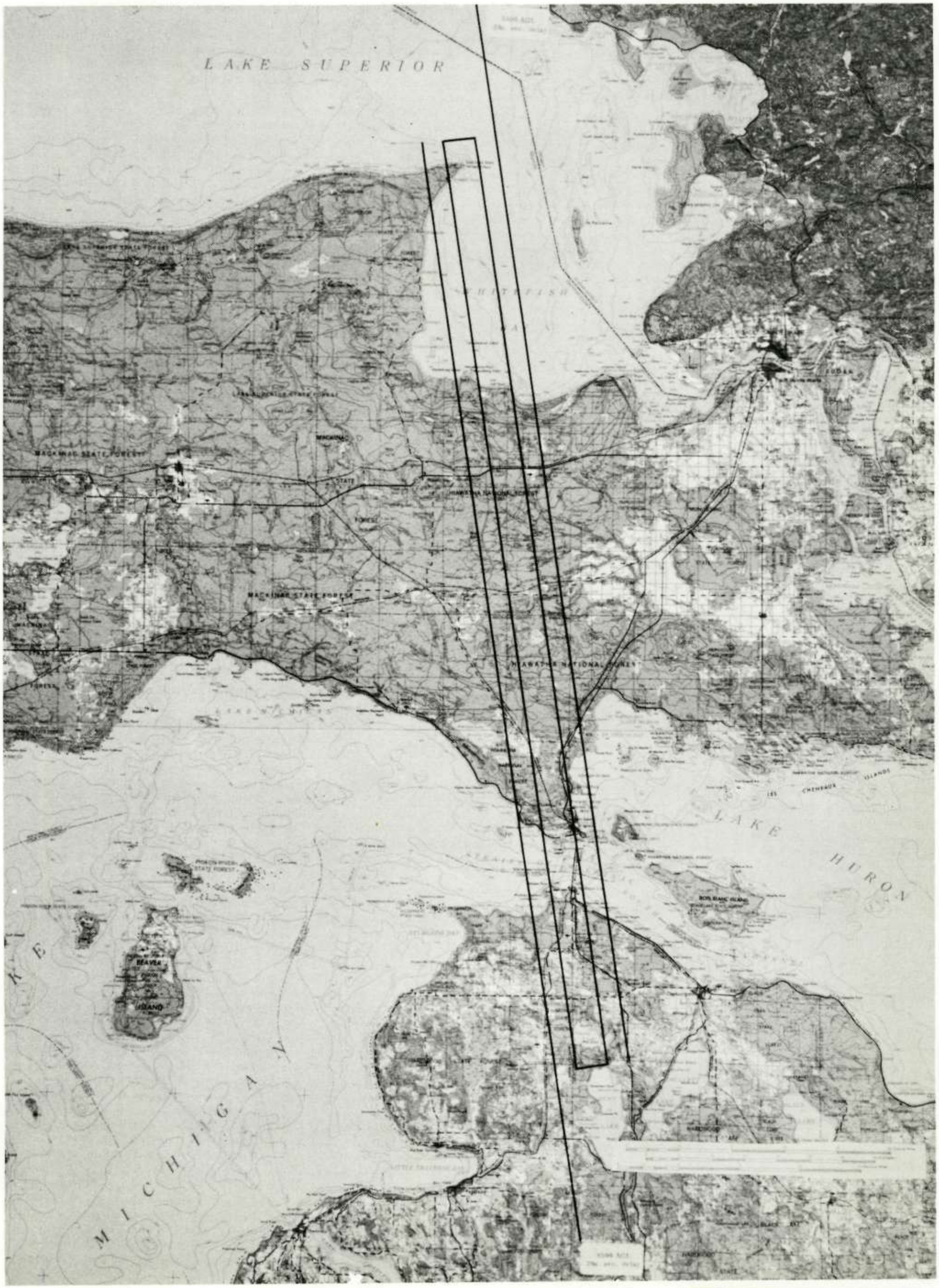
Although ice has begun to develop in both the Straits of Mackinac and in Whitefish Bay of the Great Lake sites, and in Douglas Lake of the inland lake sites, the ice is not sufficiently thick to permit field work and ground truthing of the remotely sensed data. However, the following parameters have been determined:

a. The flight path for the radar aircraft underflights has been determined. Figure 1 illustrates the ground track. It is noted that two different swath paths are illustrated. The wider one would indicate the imaging area if only one polarization were to be used. However, because two polarizations (HH, HV) are to be recorded, the inner lines properly identify the swath width and area for radar imaging. It is noted that it has been possible to get all areas (Douglas Lake, Straits and a large portion of Whitefish Bay) on one flight line--this arrangement will save considerable time as realignment of the radar will not be required.

b. Dates for the flights have been selected. The first project flight will be on 21 February 1973, during the early afternoon. This timing will coincide with the passage of the ERTS-1 satellite. The second flight will be on either 29 March 1973 or 16 April 1973--again depending upon the weather conditions.

To date, the instrument which is to be used to determine the dielectric constant of the snow and ice, as a part of the ground truthing operation, has been designed and numerous parts have been ordered and delivered. It has not, as yet, been assembled. It is planned, however, to assemble this instrument during the first week of January, and to field check and test it against radar imagery during the latter part of January, 1973. This time frame will give us approximately 3-4 weeks to make any necessary adjustments in the instrument

B



Douglas Lake Test Site

and allow us to go into the field with equipment which has been "proven". By delaying the first radar underpass until 20 February 1973, we believe that we will be able to acquire much more substantial and accurate information for the expenditure of effort.

ERTS-1 imagery has been received of the test site. The problem of cloud cover has been especially pronounced, and it is expected that this situation will continue until a reasonable ice cover (i.e., closure of the open water) has been developed, thus, removing one of the major sources of moisture to the atmosphere from the scene. At that time, the possibility of reduced cloud cover will be higher, and the images derived from the satellite should be of more use. This problem, however, will continue to be with us during the entirety of this project because the area of interest is often cloud covered even during periods of extensive ice cover.

PROGRAM FOR NEXT REPORTING INTERVAL

January--Construct and field test ground truth instruments
February--First two weeks--continue above/lab and field tests
February--Last week--Field and underflight program
March--Analysis of ERTS(4) radar underflight data

CONCLUSIONS

Because of the nature of the project, no "significant results" or conclusions are available at this time. However, the project is progressing as proposed and outlined for this task.

RECOMMENDATIONS

It has been noted that, to date, the delay time of receiving ERTS-1 imagery has been 4-6 weeks after the satellite has passed. These delays are apparent to all interested parties. If this lag time can be reduced, it would be advantageous to all tasks.

First Type II Progress Report
I. J. Sattinger, MMC 086
Task V, Recreational Land and Open Space

INTRODUCTION

The objective of this task is to use and evaluate ERTS data in continuing studies of land use in the seven-county Michigan area surrounding Detroit, with special emphasis on identifying and evaluating land that should be acquired and preserved for open space and recreational use and on maintaining the environmental quality of the area. A major portion of the study will be concentrated on test sites in Oakland County, which is characterized by the presence of a number of lakes as well as wetland and wooded areas. Although the development of methods will be concentrated on sites of limited size, it is expected that the ultimate use of ERTS data will be directed toward studies of regional scope. Major emphasis is being placed on computer processing of ERTS-1 multispectral scanner imagery to observe and map a number of fundamental factors which determine the suitability of land for recreational use or open space. Photographic and scanner imagery from aircraft flights, ground truth, and other data sources will be used to supplement and evaluate the ERTS imagery.

PROGRESS

Data Acquisition

The only usable ERTS-1 coverage of this test site to date was obtained on 28 September 1972 (Observation ID 1067-15643). Single-band photos and digital tapes for this frame have been obtained. The usefulness of the data is limited to some extent by partial cloud cover, but at least some sections of Oakland County and adjacent areas in Southeast Michigan are cloud-free and usable. Since this will be the only coverage of the test site obtained while foliage is visible till next year, the data analysis will begin with usable sections of the frame. Any additional coverage of the area obtained during the fall and winter season will be checked to determine the usefulness of coverage during these seasons for our purposes.

In support of this investigation, RB-57 Mission 205 was flown over Southeast Michigan (Site 279) in June 1972. Photographic results of this mission were received during September. Preliminary examination of the photography shows that coverage of parts of Oakland County was obtained, but that other parts could not be photographed due to developing cloud cover. However, coverage of other parts of Southeast Michigan was obtained which will be useful for some aspects of the investigation. In the absence of complete coverage of Oakland County, the 1972 RB-57 photography will be used as much as possible and supplemented where necessary by previous coverage obtained in 1969.

A flight was made with the C-47 multispectral scanner on 29 August 1972 over two sites in Southeast Michigan to provide data for comparison with processed ERTS-1 data. One site is located in the Pontiac North Quadrangle in Oakland County and contains urban, suburban and rural areas including wooded areas and several inland lakes. The other site includes the Pointe Mouillee State Game Area which consists of extensive marsh areas used as waterfowl habitat. Studies of this waterfowl habitat area being conducted under other projects will provide useful ground truth data on vegetation species for verification purposes when ERTS data for this area become available. In addition to the scanner coverage, large scale color infrared photography of both areas was obtained.

Initial Examination of Data

Black-and-white photos of the ERTS frame in all four bands have been studied to identify major features of interest and to decide on subsequent steps for data processing. The large number of lakes in Oakland County show up well in Bands 6 and 7. Major roads, subdivisions, and wooded areas are also clearly visible in Bands 4 and 5.

In the ERTS frame, the area in Oakland County covered by the C-47 multispectral scanner flight is not clear of cloud cover. The Pointe Mouillee area is off the ERTS frame. Therefore, ERTS coverage of these areas cannot be analyzed at this time. When useful ERTS coverage of either of these areas is obtained, the data acquired on the C-47 flight can be analyzed to validate the recognition obtained from ERTS-1 processing. Preliminary steps in the data analysis have been concentrated on the digital computer printout of gray maps prepared by level-slicing individual bands of the ERTS MSS data.

PROGRAM FOR NEXT REPORTING INTERVAL

Based on the preliminary examination, the subsequent steps in the data analysis program have been specified. The southwest corner of the frame, constituting about one-sixteenth of the total area of the frame, will be printed out as a gray map by digital computer. This gray map will be studied along with existing RB-57 photography of the area and other sources of information to select a smaller area for intensive computer analysis. This area will be selected at a location free of cloud cover and will include surface features of particular interest for the study objectives. This small area will be subjected to further computer processing to produce a printout in which important types of land use and surface cover are recognized. It is intended that this first effort at surface mapping will use simple methods of ratio processing and level slicing for recognizing and mapping surfaces. The resulting map will be subjected to careful analysis and comparison with available aerial photography to determine the accuracy and reliability of identification.

Based on these first results, the remainder of the processing program can be determined. The data analysis plan required by the contract can be prepared and submitted for approval.

In parallel with the preliminary data analysis described above, additional study is being given to the types of information which it is hoped to derive from ERTS data. The investigation will concentrate on attempting to identify the specific types of surface features and conditions listed below. Distribution of emphasis on the features to be studied will depend on which are most useful for the study of recreation land and open space and on early indications of the feasibility of observing these features.

Vegetation. Major categories of vegetation (e.g., deciduous forests, coniferous forests, herbaceous vegetation, cropland). Individual tree species.

Urban Areas

Rural/Urban Boundaries

Water Bodies. Mapping of surface extent of lakes, ponds, streams. Shallow water, sediment or pollution, aquatic vegetation.

Shorelines. Vegetation, beach, and residential development.

Wetlands. Distribution of wetlands and general classification, as described in USDI Fish and Wildlife Service Circular No. 39.

River Valleys. Water course, streamside vegetation.

NEW TECHNOLOGY

None

CONCLUSIONS

Visual examination of black-and-white photos of the ERTS frame for Oakland County indicates that the large number of lakes in Oakland County show up well in Bands 6 and 7. Major roads, subdivisions, and wooded areas are clearly visible in Band 4 and 5. Preliminary computer printouts of MSS imagery can be used for identification of major features in a selected test area. Level slicing of Band 7 provides good discrimination of lakes and rivers, which are easily recognized when compared with aerial photography or land use maps. Band 5 provides additional detail for vegetated areas and built up areas. The ability to recognize these features and locate them with respect to both the tape coordinates and geographic coordinates demonstrates that ERTS derived imagery and analyses will be useful for regional land use planning.

RECOMMENDATIONS

None for this first Type II report.

First Type II Progress Report
F. C. Polcyn, MMC 114
Task VI, IFYGL (Lake Ontario)

INTRODUCTION

ERTS-1 coverage of the 32,000 square mile Lake Ontario Basin is being used to study short term and seasonal changes which affect many aspects of water problems in the Great Lakes. As part of the International Field Year for the Great Lakes (IFYGL)--a coordinated, synoptic study of the Lake Ontario Basin--processed ERTS-1 imagery is contributing to the data base of synchronized observations being made by investigators from many U. S. and Canadian government agencies and universities. The first set of ERTS data has been received and will be processed shortly for parameters of hydrological and limnological significance--land use, terrain features, and water quality. Eight ERTS-1 frames recorded during a substantially clear period, August 19, 20, and 21, provide coverage of most of the basin. Many drainage basin characteristics are cleary identifiable on the imagery.

PROGRESS

Work performed to date includes 1) construction and interpretation of ERTS image mosaics for the Lake Ontario Basin, 2) preliminary processing of aircraft scanner data to simulate and test schemes for computer processing of ERTS data, and 3) initial digital analysis in two spectral bands of ERTS data for the Rochester test site. These three areas are described below.

Interpretation of ERTS Mosaics

The Lake Ontario Drainage Basin extends from 41° 50'N to 45° 23'N latitude and 74° 0'W to 80° 13'W longitude. The land area is almost equally divided between the U. S. and Canada--the Canadian portion being entirely within eastern Ontario and the U. S. portion, in western and upper New York State, with a narrow projection extending into Pennsylvania.

The ERTS-1 mosaic of the Basin in band 5 (0.6-0.7 μm) clearly shows cultural features. Patterns of land use and development are seen to be associated with the proximity of the Lake--with the heavily urbanized areas adjacent to the lake shore. The mosaic shows the decreasing intensity of land utilization as the distance from the lake increases--a characteristic particularly marked in the Canadian portion of the Basin. Adjacent to the Canadian lakeshore are the major urban areas of Hamilton, Oakville, Toronto, Oshawa, Belleville, and Kingston. North of these cities a band of agricultural land 15 to 30 miles wide extends through the Basin parallel to the northern lakeshore. Above this band of agriculture are the numerous lakes and forests of the Canadian shield. The urban areas are identifiable by their light tones on the imagery while the agricultural areas show the regular grid network of main and secondary feeder roads and salt-and-pepper contrasts of cultivated fields. The northern shield area, with its sparse roads, appears in even dark grey tones, representing the borial forest. To a lesser extent, this pattern of decreasing land utilization from the lake shore is also true for the U. S. portion of the Basin—Rochester, Oswego, and Watertown being the major identifiable urban areas adjacent to the Lake.

At 43° N latitude (approximately the southern shore of Lake Ontario) there is a 37% overlap of ERTS coverage obtained on successive days. Thus, with good fortune, certain short-term events may be recorded twice within 24 hours. Such dynamic features as effluent plumes of rivers and industrial outfalls can be observed. Comparison of the Niagara Plume, recorded on ERTS imagery obtained on August 20 and 21, shows an easterly trend to the Plume The Plume is indicated by the contact of a dark area (the Plume) at the mouth of the Niagara River and the somewhat more turbid appearing waters emanating from the western end of the Lake--particularly the outfall of Welland Canal at Port Weller.

The ERTS-1 mosaic of the Basin in band 7 (0.8-1.1 μm) provides excellent contrast between land and water areas. Indeed several of the major geological features which affect surface hydrology are easily discerned by the patterns of lakes and land. Relatively large lakes occur in areas of somewhat impervious shale bedrock--examples; the Fingerlakes country of the southern portion of the Basin, and Oneida Lake, near Syracuse. The soluble bedrock areas, limestone, and dolomite are identifiable by the occurrence of few lakes or surface streams.

Most impressive in the band 7 mosaic is the complexity and fine structural detail shown of the crystalline rocks in the northern and eastern portion of the Basin. Fault and fracture zones in this region are commonly indicated by narrow linear lakes and strings of small lakes and ponds. The high contrast between land areas and surface water make this band most useful for recording these hydrologically significant features. The band 7 mosaic provides perhaps the most detailed surface water map ever constructed of the Lake Ontario Basin.

<u>Data Processing</u>

Three types of processing techniques have been tested on supporting aircraft MSS data and are expected to aid in extraction of useful information from ERTS-1 data. These are level slicing, channel ratioing and multispectral "signature" recognition.

Aircraft data used for this purpose were obtained from two missions of the ERIM C-47 multispectral aircraft over selected portions of the Lake Ontario Basin. One flight occurred June 17-18, 1972 and the other on September 8, 1972. The level slicing and the channel ratioing are essentially scene enhancement techniques; multispectral recognition is used for discrete classification of scene elements.

Level slicing (or "thresholding") is accomplished in such a way that all recorded MSS signals above or below a certain value in a single band area automatically recorded separately from the signals for the remainder of the scene. In this way certain terrain features which are identifiable by their discrete signal level in that band can be singled out and mapped as an image. Surface water areas are easily discriminated in this way.

In the channel ratioing technique two channels of ERTS-MSS data will be used. The signals in one channel will be divided by the signals of the other channel to produce a new image. The new ratioed image essentially eliminates the similarities which occur between the two channels and emphasizes the spectral differences represented by the two channels. Thus marked contrast enhancement occurs between objects that appear similar and those which are spectrally different in the two channels. Also the ratioing technique has the effect of reducing distortions of the scene due to illumination variations (cloud shadows) and variations in radiance due to terrain slope and aspect. The results of ratioed ERTS-MSS data will be useful for interpretation as enhanced images and may also be subsequently further processed using level slicing or signature recognition techniques. Results to date indicate that different kinds of vegetation may be mapped using a ratio of ERTS channels 5 and 6. Soil patterns are likely to be enhanced with a ratio of ERTS channels 4 and 5.

Recognition processing makes use of all four ERTS-MSS channels at once. Discrete "signatures" are extracted from known terrain or water areas. Once programmed into the computer, all scene elements having sufficiently similar spectral characteristics to the known signature are automatically identified and printed out as members of that signature class. If spectral signatures are available for all hydrologically or limnologically significant scene elements, a scene image with the locations and areal extent of all of these features is produced. Also areal statistics can be obtained from such computer classified data.

Rochester Test Site

A twenty mile by thirty mile area was selected near and including Rochester, New York to test the applicability of the above processing techniques to the IFYGL Lake Ontario project. The test area was recorded by two ERTS overpasses. The eastern half of the area was recorded under hazy conditions on August 19 and the western half under clear conditions on August 20 with a small area of overlapping coverage. Scene enhancement and signature extension techniques will be tested with these data.

PROGRAM FOR NEXT REPORTING INTERVAL

The requirement for processing large amounts of ERTS data at high spatial resolutions requires the use of the analog Spectral Analysis and Recognition Computer (SPARC). Future plans call for the conversion of ERTS digital tapes to an analog mode, and subsequent ratio and recognition processing with the analog computer.

NEW TECHNOLOGY

None

CONCLUSIONS

ERTS data is expected to contribute primarily to the following two broad areas of IFYGL efforts:

Terrestrial Water Balance: The storage, runoff, and evaporation of water from the terrestrial portion of the Basin is governed by a number of factors--several of which are subject to satellite observation. Water stored in ponds, lakes, and reservoirs and in the form of snow and ice can be monitored on ERTS imagery. Also the reflectance of the soil surface may be an indicator of the water stored in the Basin as soil moisture. Runoff of precipitation is determined, in part, by the nature of the terrain surface. Where differences in land use exist, differences in amounts and rates of runoff can be expected. Also rates of evaporation are affected by land use. A generalized land-use map of the Lake Ontario Basin with complementary statistics of the areal extent of each use will be one output of the processing of ERTS-1 data. The mid-August 1972 data will probably be used for this purpose.

Water Quality and Currents: As part of this project, recent success in mapping and characterizing differences in water quality related to suspended sediments, effluent discharges, and biological organisms (from aircraft data) will be extended to ERTS-MSS data. The extent, nature, and seasonal variation of the Niagara Plume, as well as the Toronto Harbor are areas which will be studied in some detail by IFYGL investigators.

RECOMMENDATIONS

No recommendations are presented for this first Type II report.

First Type II Progress Report
W. A. Malila and R. Nalepka, MMC 136
Task VII, Image Enhancement and Advanced Information Extraction Techniques

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 camera coverage of the region was obtained during June, but was not received until late September. A second RB-57 flight was made in mid-September, and its photography was received at the end of October.

PROGRESS

The first six months of the contract included the preparation phase, support of activities timed to the successful ERTS-1 pass over the test site, and a portion of the preliminary data analysis phase. The sections that follow discuss details of these activities, including collection of ground truth information, planning and support of aircraft underflights, screening of imagery and CCT products, preliminary analysis of atmospheric effects (the major scientific effort to date), and studies of preprocessing and estimation of proportions.

Ground Truth Collection

Field data on the identity of crops planted in a large fraction of the fields in the extensive test area have been obtained through the cooperation of ASCS personnel of the USDA and coordination efforts of Michigan State University (MSU) personnel, although only data for the intensive area are presently at our disposal. In addition, extensive field checking and ground photography were carried out in the intensive test area by MSU personnel with some assistance from ERIM personnel.

Support of Aircraft Underflights and ERTS-1 Overpass

Detailed plans and preparations were made to support underflights of ERTS-1 by the ERIM C-47 multispectral scanner (MSS) aircraft. After operating on standby status for three passes, a good data set was obtained on August 25. Flights were made at altitudes of 10, 4, 2, and 1 Kft, along a flight line that included a series of 20' x 40' reflectance panels (five that formed a graduated gray scale of reflectance and three that were colored (red, green, and blue)). The panels themselves are resolvable in the airborne MSS data only from the two lower altitudes, but were to be used to calibrate secondary reflectance standards of larger areas that are resolvable in airborne data from the higher altitudes and in ERTS-1 data (See Analysis of Atmospheric Effects).

Another series of passes at 5-Kft altitude was made over other portions of the intensive test area.

Screening of ERTS-1 MSS Imagery

Imagery from a number of frames over the test site was received and screened. Only data from August 25 were cloud free and suitable for retrospective ordering of computer compatible tapes (CCT's) for detailed digital analysis. These images were received on October 18 and orders for CCT's and a color composite image were forwarded the same week. Although the CCT's were received seven weeks later, the color composite image has not been received, despite a number of inquiries and projected shipping dates.

The best channel for displaying cultural features, such as roads and urban areas, is ERTS Band 5 (0.6-0.7 μm). Band 4 (0.5-0.6 μm) also clearly shows roads, but the contrast is lower than for Band 5. Surface water, in the form of lakes and networks of streams and rivers, shows very clearly in ERTS Bands 6 (0.7-0.8 μm) and 7 (0.8-1.1 μm), while the cultural features are nearly indistinguishable. The color composite, which displays three bands simultaneously, would be very helpful in further interpretation of vegetation patterns in the imagery.

Screening of ERTS-1 MSS CCT Data

The CCT data of August 25 (Frame 1033-15580) were processed by a computer program to a format compatible with ERIM digital processing programs. Digital line-printer maps were produced for ERTS Band 5 data for locating fields within the intensive test area.

To assist in locating the fields and as a check on the data quality, maps were produced for the other three MSS bands. A pronounced repetitive pattern of dark lines was evident on the map for Band 6, while maps for the other two bands appeared to be normal.

The nature of the problem in Band 6 data was analyzed in detail. The "bad" scan lines occur at multiples of six lines. This points to a bad detector since each MSS band is sensed by an array of six detectors that sweep in push-broom fashion over the scene. Histograms were made of data values over a portion of the scene in six groups, with each group corresponding to the outputs of a single detector element. The histograms for five of the six groups appeared to be reasonable. Figure 1 presents a typical normal histogram; the comb-like appearance is the consequence of expanding 64 sensor data levels into 128 output levels after multiplication by a variable calibration factor and rounding to the nearest integer. The sixth histogram, shown in Figure 2, was abnormal. A high proportion of zero values are present in Figure 2 and most of the values lie below those in the other histograms. Clearly, data for this detector must be ignored in future analysis and processing. Other than this problem, the CCT data appear to be satisfactory.

Analysis of Atmospheric Effects

The analysis outputs discussed herein are empirical plots of ERTS-1 radiance vs. ground target reflectance. They represent preliminary efforts to empirically determine the extent of atmospheric effects in ERTS-1 data. Also, initial comparisons are made with atmospheric effects as calculated by the ERIM radiative transfer model.

The procedure followed was to use MSS aircraft data to determine reflectances for areas (secondary reflectance standards) resolvable in ERTS-1 data. Then, mean radiance values for some 10 or 12 of these areas were extracted from ERTS-1 MSS data and the desired graphs constructed. Figure 3 is a representative plot, in this case for ERTS Band 5. The dashed line represents a linear fit to the experimental points. To a first order, the intercept on the y-axis represents an observed radiance component that is caused solely by the atmosphere, the so-called path radiance component. Similarly, the slope of the curve represents the product of the transmittance of the atmospheric path and the irradiance on the surface. In simple equation form,

$$L = \frac{\rho}{\pi} ET + L_P$$

where L is the observed radiance,
ρ is the (Lambertian) target reflectance,
E is the irradiance at the surface,
T is the atmospheric transmittance,
and L_P is the path radiance.

The simultaneous MSS aircraft data were used to determine area reflectances by referring average area voltages to reflectance vs. voltage transfer curves. These transfer curves were obtained by plotting laboratory-measured reflectance values for the reference panels (mentioned in Support of Aircraft Underflights and ERTS-1 Overpass) vs. corresponding voltage values extracted from digitized low-altitude airborne MSS data. For this purpose, it was not necessary to calibrate the aircraft data because they serve only as a means for transferring from panel data to data for the secondary reflectance areas.

25AUG72 C N43-04/W085-24 N N43-04/W085-18 5580- 50 AZ137 191-0459- -1- D-D-4-AS1 H ERIM (ERTS DATA)

GRCUP 6 13 DEC 1972

HISTOGRAMS OF EACH DETECTOR UNIT IN ERTS (EVERY SIX SCAN LINES)
NUMBER OF INTEGERS PER BIN = 1

NUMBER OF POINTS= 4800.0 EACH SYMBOL REPRESENTS .200 PER CENT
CHANNEL= 3

DATA VALUES	FREQUENCY 0/0
19	.0
21	.0
22	.0
24	.0
25	.2
27	.2
29	.4
30	.9
32	.9
33	.2
34	.6
35	1.6
36	.5
37	3.3
38	.9
39	6.9
40	1.7
41	9.0
42	2.0
43	13.2
44	13.4
45	1.7
46	11.4
47	.5
48	7.2
49	.9
50	5.2
51	1.7
52	2.1
53	2.3
54	1.2
55	2.3
57	.4
58	2.3
59	.2
60	1.6
62	.2
63	.7
64	.5
65	.4
66	.2
67	.2
68	.1
69	.4
70	.0
72	.1

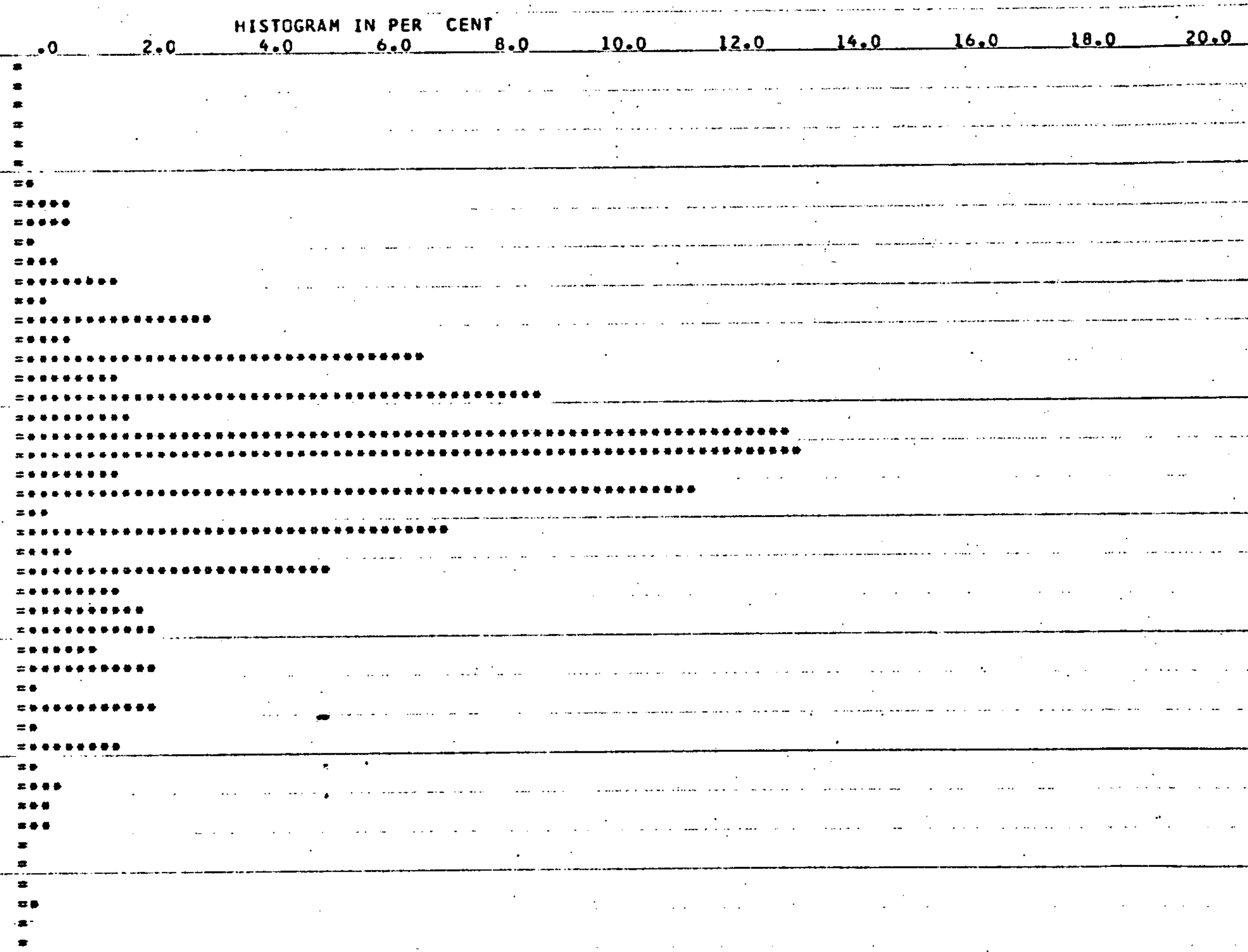


FIGURE 1. HISTOGRAM OF OUTPUT VALUES FOR A GOOD DETECTOR IN ERTS BAND 6 (Frame 1033-15580)

25AUG72 C N43-04/W005-24 N N43-04/W005-10 15580- 50 AZ137 191-0459- -1- 0-D-4-AS1 H ERIM (ERTS DATA)

GROUP 5 13 DEC 1972

HISTOGRAMS OF EACH DETECTOR UNIT IN ERTS (EVERY SIX SCAN LINES)
NUMBER OF INTEGERS PER BIN = 1

NUMBER OF POINTS= 4800.0 EACH SYMBOL REPRESENTS .200 PER CENT
CHANNEL= 3

HISTOGRAM IN PER CENT: .0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0

DATA VALUES	FRECUENCY 0/0
0	16.7
1	.4
2	1.1
3	.9
4	1.8
5	1.8
6	2.4
7	3.0
8	4.8
9	3.9
10	5.2
11	4.6
12	5.2
13	4.9
14	2.6
15	3.3
16	3.4
17	2.6
18	2.1
19	2.6
20	1.2
21	1.9
22	.6
23	1.4
24	.9
25	.6
26	1.4
27	.5
28	1.3
29	.1
30	.1
31	.5
33	.4
34	.1
35	.1
36	.1
37	.1
39	.2
40	.2
41	.2
42	.4
43	.5
44	.4
45	.9
46	.8
47	.7
48	.6
49	.8
50	.5
51	.7
52	.8
53	.2
54	.8
55	.4
56	.3
57	.2
59	.2
60	.1
62	.1
63	.2
64	.5
65	.5
66	.3
67	.5
68	.0
69	.0
70	.2
72	.1
73	.3
74	.2
75	.0
76	.5
77	.4
78	.1
80	.2
89	.1
92	.1
103	.2
106	.1

FIGURE 2. HISTOGRAM OF OUTPUT VALUES FOR THE BAD DETECTOR IN ERTS BAND 6 (Frame 1033-15580)

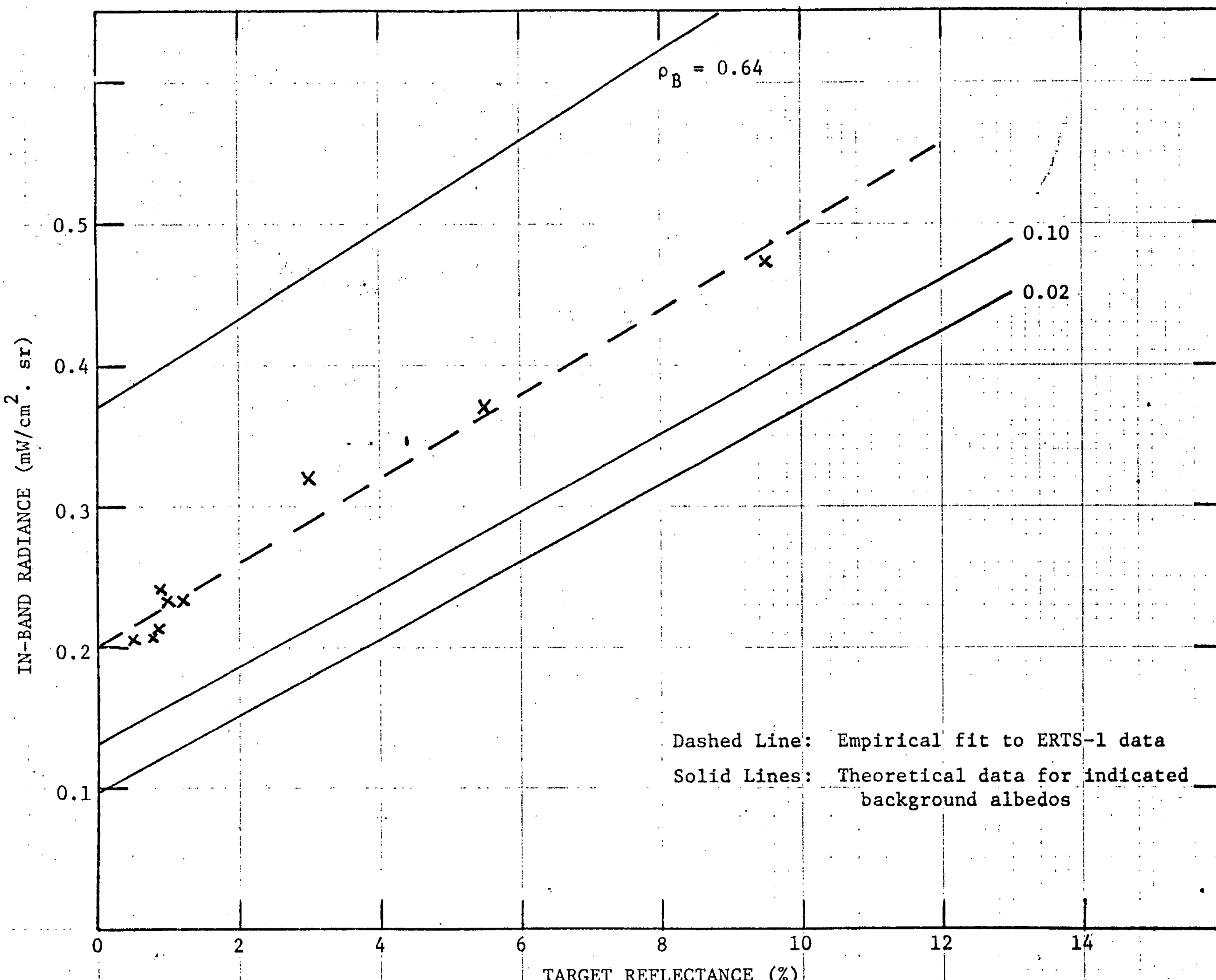


FIGURE 3. RADIANCE VALUES FOR ERTS BAND 5 (Frame 1033-15580)

The solid lines on Figure 3 represent calculations made with the ERIM radiative transfer model for a relatively clear atmosphere (Visual Range = 24 km). Each line represents values for a different average background albedo. Both the path radiance and the surface irradiance depend on the amount of radiation reflected by the background back into the atmosphere.

There appears to be good agreement between the empirical and theoretical results for ERTS Band 5, as shown in Figure 3. The slopes of the curves match well, and the background albedo, (ρ_B), that would be assigned to the empirical data, based on the theoretical data, is only slightly higher than might be expected. Figures 4-6 present similar graphs for ERTS Bands 4, 6, and 7, respectively. The slopes for Band 4 agree, but magnitudes differ. The magnitudes agree for Band 6, but slopes differ slightly. Both magnitudes and slopes appear to differ for Band 7.

The results presented in Figures 3-6 represent preliminary results and do not reflect a complete and thorough analysis of the data, either empirical or theoretical. Yet, these results are very encouraging for future outputs of the investigation.

Some important conclusions can be drawn from an analysis of these preliminary results and are presented in Conclusions.

Preprocessing and Estimation of Proportions

Work on these latter two subtasks of this Task has been primarily in the modification of computer programs for subsequent processing and analysis.

PROGRAM FOR NEXT REPORTING INTERVAL

During the next reporting period, the analysis of atmospheric effects will be continued and efforts on the other two subtasks, preprocessing and estimation of porportions, will begin. Support of an aircraft underflight will be planned and carried out.

NEW TECHNOLOGY

None

CONCLUSIONS

Analysis of preliminary results from studies of atmospheric effects in ERTS-1 data leads to the following conclusions:

(1) Atmospheric effects are present in all four ERTS MSS bands; the significance of these effects is greatest in Band 4 and least in Band 7, as would be expected.

(2) Path radiance appears to account for roughly 70 to 95% of the observed signal in Band 4 according to empirical results and 60 to 80% according to theoretical calculations.

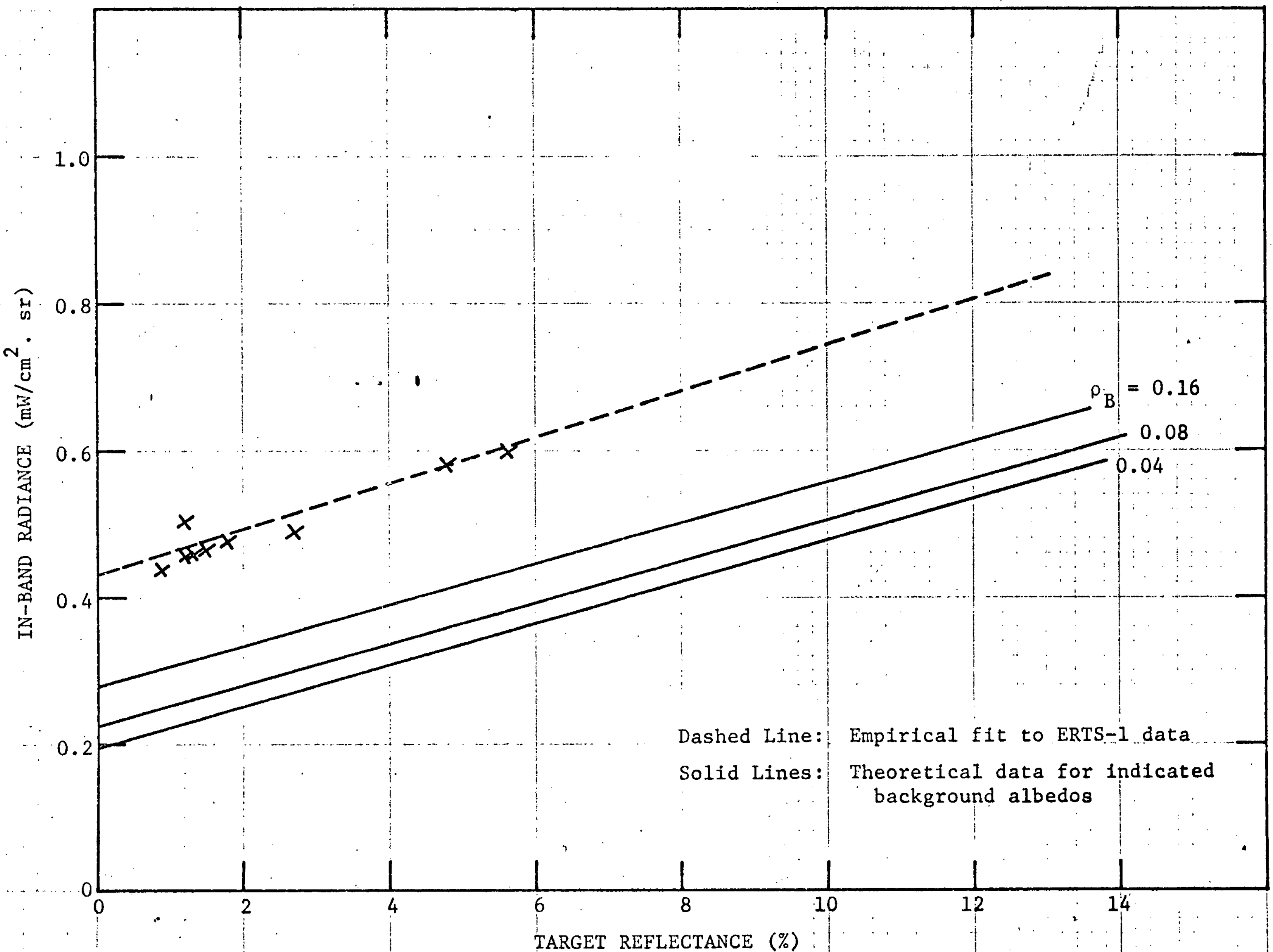


FIGURE 4. RADIANCE VALUES FOR ERTS BAND 4 (Frame 1033-15580)

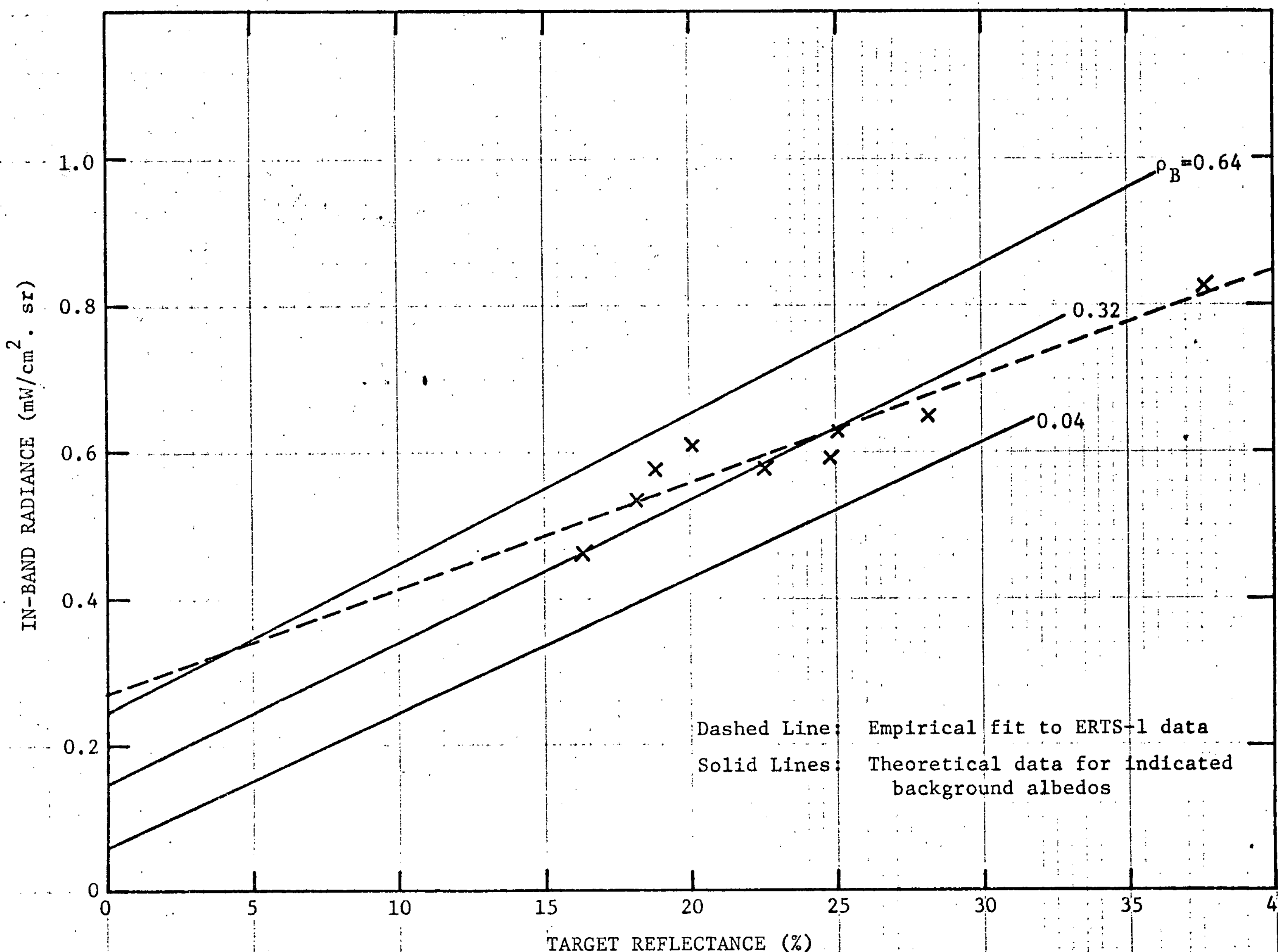


FIGURE 5. RADIANCE VALUES FOR ERTS BAND 6 (Frame 1033-15580)

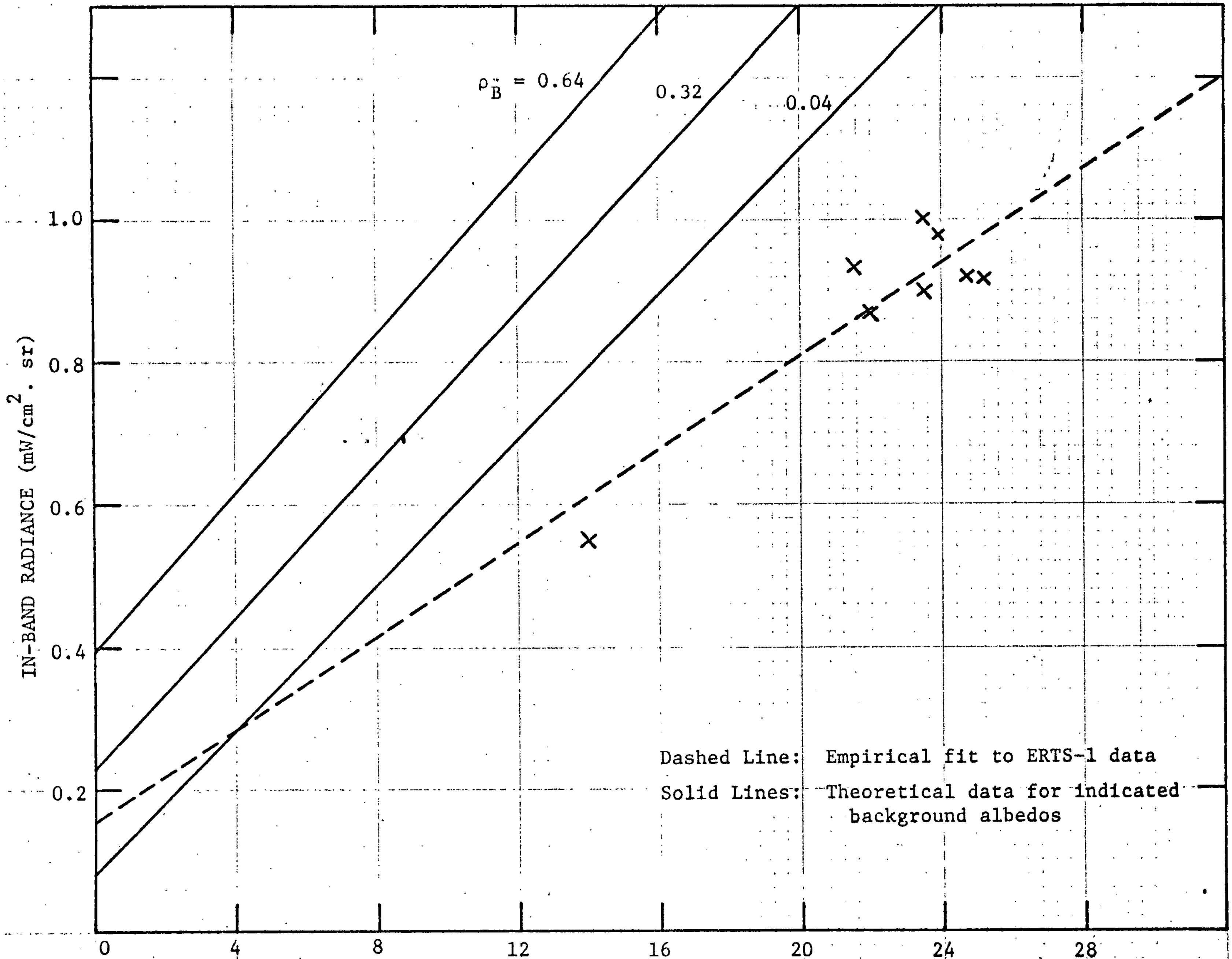


FIGURE 6. RADIANCE VALUES FOR ERTS BAND 7 (Frame 1033-15580)

(3) Corresponding path radiance contributions in Band 5 are roughly 40 to 80% empirically and 30 to 80% theoretically.

RECOMMENDATIONS

None for this first Type II report.

First Type II Progress Report
C. T. Wezernak, MMC 081
Task VIII, Water Quality Monitoring

INTRODUCTION

Various data analyses, data compilation and field activities have been initiated during the current reporting period in support of the program. Good quality ERTS data in the form of digital tapes and transparencies have been received for some of the test sites included in this investigation. These data are currently in various stages of processing and evaluation. Described in the sections which follow is the status of the investigation as it applies to each of the several test sites which comprise this study.

PROGRESS

1. New York Bight

The problem of concern at this test site is barge dumping of wastes in the sea. To date, one multispectral aircraft mission (C-47) was conducted in support of the program on 16 August 1972 at a time coincident with satellite coverage of the area (1024-15071). The quality of both the ERTS data and the aircraft data were found to be excellent.

The data are currently being computer processed to show the distribution of the wastes discharged in the area. Reflectance spectra, multispectral displays, digital maps, and ratio digital maps are being generated to define the problem under investigation. At the present time the analysis of frame 1024-15071, and supporting aircraft data, is sufficiently complete to allow preparation of the Data Analysis Plan as required under the terms of the contract.

Preliminary analysis of the data shows that the phenomena of interest to this investigation can be defined using ERTS-1 data and that the objectives of this phase of the study are attainable. Sewage sludge, acid wastes, surface films, suspended solids and major water mass boundary features are observable. The data demonstrate the potential of satellite remote sensing for monitoring large area problems such as waste disposal in the ocean environment. This fact is significant from an environmental management standpoint. The need for new techniques which will permit large scale monitoring of the oceans is generally recognized by the scientific community.

To date, only ERTS data in the form of 70 mm transparencies and digital tapes have been received. The color products and 9-1/2" positive transparencies which have been ordered have not been received.

Available to this investigation at the present time are ERTS data (70 mm transparencies and digital tapes) covering scenes 1024-15071 and 1078-15072. Additional data covering adjacent areas also have been received.

The following were presented during the reporting period:

a. "Barge Dumping of Wastes in the New York Bight" presented at Goddard ERTS seminar on September 29, 1972, Report No. 011229-6-S, NASA-CR 128099, E72-10084.

b. "Remote Sensing in the New York Bight", presented at the New York Bight Conference held at NOAA, Rockville, Maryland, on 12 September 1972. This conference was a meeting of government agencies which have programs in the New York Bight area. The ERTS program for the area was described and examples of aircraft data were shown.

2. S. E. Florida

The studies of the coastal environment of S. E. Florida deal with discharges of wastewater, the movement of waters from the intracoastal waterway into the coastal area; and the role of currents, eddies, and meanders in the movement of effluents and shelf waters.

Two multispectral aircraft missions were conducted in support of the program. The first mission took place on 18 August 1972, coincident with the ERTS pass over the area; and the second on 16 November 1972. Both missions were successful, however, the second mission was far more effective in terms of data acquisition of importance to this investigation. This is due in part to seasonal factors such as humidity, water temperature, density differences, etc., and in part to more favorable data acquisition conditions.

The aircraft mission was conducted on the 16 November 1972 at a time to coincide with the satellite pass over the area. Atmospheric conditions were excellent (0% cloud cover), tides were favorable, and sea state calm. As a result, an excellent aircraft data set was obtained. Preliminary analysis of the photographic imagery and multispectral displays shows features of interest to this study, such as "effluent fields" from ocean outfalls, discharges from the intracoastal waterway, and major water masses. These data are currently undergoing computer analysis. The presence of "red tide", which was reported in the area at the time, was not detectable through visual examination. This result indicates that either the "red tide" was outside of the area of aircraft coverage, or that the concentrations were relatively low in the inshore areas. Image enhnacement through computer processing and ratio imaging is planned to determine the presence of "red tide", if any, and to delineate various water masses in the inshore zone.

To date ERTS imagery (consisting of 70 mm transparencies) has been received only for frames 1026-15223 and 1026-15230 for 18 August 1972. Digital tapes have been received for frame 1026-15230 but not for 1026-15223. Also color products and 9-1/2" transparencies <u>have not been received</u>. Additional data have been received for areas outside of the study area. The latter, although interesting, have no bearing on this investigation.

3. Tampa Bay

Two aircraft missions have been carried out in support of the investigation. These were flown on 19 August 1972 and 17 November 1972. Both missions were successful.

Several sets of ERTS digital tapes have been received. These data together with aircraft data are currently being computer processed. Suspended solids, and water mass boundaries are observable. Preliminary analysis of the data indicates that the objectives of this study are attainable.

4. Lake Erie

The best Lake Erie ERTS data received to date are tapes and transparencies for frame 1048-15405. The data cover the center portion of Lake Erie and appears to be of excellent quality. However, the major interest in Lake Erie is for the western section. Data have not been received for this area.

5. Lake Michigan

The major area of interest in Lake Michigan is the southern portion of the lake. Good imagery for several ERTS frames has been received which covers the west shore and one frame of the southern portion of the lake (1124-16050). As soon as digital tapes are available the data will be processed. Visual examination of the imagery indicates that the study objectives can be realized.

6. Southern California

Several frames have been received which show major circulation features, kelp forests, and turbidity patterns. The major area of interest is the area from Los Angeles to San Diego. For the purposes of this investigation the most useful frame received to date is 1125-17563.

One of the major interests at this location is effluent from major ocean outfalls. The optimum time frame for studying effluent fields is during the cold weather period when density differences are most likely to result in surfacing of the effluent. Computer analysis will be initiated as soon as suitable data become available.

PROGRAM FOR NEXT REPORTING INTERVAL

1. Preparation of Data Analysis Plan
2. Continued data analysis, subject to the approval of the Data Analysis Plan
3. Ground truth activities in support of the program
4. Activities in conjunction with aircraft mission over New York Bight test site.

NEW TECHNOLOGY

None

CONCLUSIONS

As indicated in the preceeding sections, preliminary analysis of existing data indicates that the problems of interest to this investigation are measurable through an analysis of ERTS data. It is now largely a matter of getting repeat coverage of the various test sites. The only uncertainty which exists at this time is the ability to locate "effluent fields" from ocean outfalls. Insufficient data have been received to date to make any judgements in this regard.

Data analysis of existing data has progressed sufficiently so that a Data Analysis Plan can be generated for the remainder of the program. The present schedule is to submit the plan to NASA by 1 February 1973.

RECOMMENDATIONS

That color products for the ERTS frames listed above be made available as soon as feasible.

First Type II Progress Report
R. Horvath, MMC 079
Task IX, Oil Pollution Detection

INTRODUCTION

The overall objective of this investigation is to determine the feasibility of using remote sensing from satellites or spacecraft in order to assist the U. S. Coast Guard in fulfilling its mission in the area of oil pollution detection, monitoring and law enforcement. The hypothesis involved is that the synoptic coverage of vast areas which is possible from spacecarft altitudes will provide an extra dimension and capability to the present Coast Guard program of surface monitoring and remote sensing from aircraft.

Three specific objectives can be defined. The first is to determine the detectability of "small scale" oil slicks associated with illegal dumping of contaminated ballast water, or inadvertant leakage of petroleum cargo, from ships operating in nearshore sea lanes. The most obvious method of "tagging" specific vessels to such occurrences is based upon proximity. However, the synoptic large area coverage capability of spacecraft remote sensing offers the possibility of "tagging" an offender hours after the occurrence by using the vessel's own wake to vector and track between the oil slick and the miles-distant vessel.

The second specific objective of this investigation is to determine the background level of oil pollution due to the presence of heavy industrialization near shipping lanes, and the masking effect of this background level upon detection of the shipping-associated pollution with which the Coast Guard is primarily concerned. Temporal variations in this background level can be studied by utilizing the repetitive nature of the ERTS coverage.

The third specific objective of this investigation is to demonstrate the utility of spaceborne remote sensing platforms in monitoring the extent and spread of oil slicks resulting from major pollution incidents, such as catastrophic shipping accidents or oil well blow-outs. The large areal extent of such occurrences severely strains the capability of surface and even airborne attempts to define the situation. Timely wide area coverage from a spaceborne sensor could significantly increase the effectiveness with which damage prevention and clean-up operations are deployed.

PROGRESS

Technical Background

For nearly three years, the Willow Run Laboratories of The University of Michigan (now ERIM) has been providing the U. S. Coast Guard with technological support for determining practical methods of detecting, identifying and quantifying oil slicks on water. The fundamental technical goal has been to seek out and verify unique signatures which will allow the discrimination of oil slicks on water to be made by means of remotely sensed ultraviolet, visible and infrared radiation, and then to define the required technical parameters for operational oil pollution remote sensors.

The approach to this problem has consisted of three complementary aspects: (1) laboratory measurement of the basic optical and physical properties of crude petroleums, their refined products and the water backgrounds; (2) processing of these data with theoretically derived mathematical models to define targe-radiance characteristics in natural environments, and then analysis of these radiance characteristics to determine signatures; and (3) verification and application of the modeling and analysis techniques by means of field experiments utilizing currently available remote sensor systems.

Studies conducted so far [1,2,3] indicate that a large portion of the optical spectrum from 0.3 to 14 μm provides information useful to the problem of discriminating oil slicks from water. In the 0.3 to 1.0 μm region of the spectrum the basic characteristic which allows discrimination between oil slicks and their water backgrounds is the invariably higher specular reflecting capability of crude petroleums and their refined products, due to their high index of refraction when compared to either fresh or saline water. This phenomenon provides an oil slick with a higher radiance than its water background for those wavelengths at which the specular character of the surface is the dominant contributor to the radiance. Neglecting the special case of sun glint, the specular character dominates if either (a) the solar illumination is predominantly diffuse (as in the ultraviolet or blue regions); or (b) the water is essentially opaque and thus does not have a significant internal scattering contribution to its radiance (as in the ultraviolet, red and near infrared regions). Thus, in the ultraviolet, blue, red and near infrared spectral regions oil slicks generally exhibit significantly higher radiances than their water backgrounds.

Conversely, in the blue-green wavelengths, the relative transparency of most natural waters allows internal scattering to produce such a large portion of the observed radiance that specular effects are overwhelmed, and the observed radiance from the water is generally equal to or greater than that from the oil slick. It is for this reason that visual detection of many oil slicks is often difficult. The positive contrasts available to the eye in blue and red regions are effectively balanced by the negative contrasts (or lack of contrast) present in blue-green regions, where the eye response is greatest. Extremely thin slicks which are so transparent that they do not attenuate the upwelling diffuse radiation from the water exhibit only a characteristic but subtle sheen due to their higher specular radiance component. Visual detection is easy only for very thick slicks which absorb all upwelling radiation from the water and thus appear very dark.

Oil-Slick Signatures from Space

The Multispectral Scanner (MSS) aboard the ERTS-1 satellite is producing remote multispectral data in four bands in the wavelength range from 0.5 μm to 1.1 μm. It is not generally appreciated that such spectral data are applicable to oil pollution remote sensing. Many investigations have resulted in empirical verification of the fact that oil slick remote sensing can be done efficiently at ultraviolet wavelengths (at least from aircraft altitudes) and that operation at visible wavelengths is much less desirable due either to the lack of strong oil/water contrasts or to the variability of the signature and presence of competing water quality dependent contrasts. While these results are generally valid, they do not apply directly to the question of the utility of red and near infrared remote sensing for oil-slick detection.

Recent investigations [3,4,5] have demonstrated that remote sensing of oil slicks from aircraft can be effectively accomplished at wavelengths between 0.65 to 0.9 μm. The nature of the oil slick signature for passive remote sensing at these wavelengths is similar to that in the ultraviolet: the high absorption of both the water and the oil outside the visible range leads to very little diffusely reflected radiation from either, while the higher refractive index of the oil (compared to water) leads to a higher specular reflectance at all wavelengths. Thus, the radiance from an oil slick is higher than that from the surrounding water due to this specular excess under almost all conditions for wavelengths outside the visible region.

This positive specular radiance anomaly is greater in the ultraviolet than in the near infrared since the difference in refractive index (and thus in specular reflectance) between oil and water is normally greater at the shorter wavelengths. However, the fact that some internal transmission and scattering within the water does exist in the ultraviolet tends to produce some diffusely reflected radiance from the water, which in turn reduces the slick contrast to a greater or lesser extent, depending upon both water quality and oil type and thickness. This contrast reduction due to diffusely reflected radiation from the water does not usually exist at wavelengths beyond 0.7 μm due to the very high absorption coefficient of the water.

While the contrast between an oil slick and water is usually at least as good in the near infrared as in the ultraviolet, the absolute radiance level is significantly lower. This results from two effects: (1) the lack of any diffusely reflected component in the near infrared leads to a radiance which results only from specular reflectance; and (2) the lower atmospheric scattering at the longer wavelengths decreases the magnitude of sky radiance which is available to be specularly reflected.

The radiance from water (or an oil slick) is about a factor of five or ten less at 0.75 μm than in the short blue or near ultraviolet regions [5]. Thus, there are fewer photons available for detection and (especially for the MSS sensor) usually lower quantum efficiency detectors available to detect the photons. This leads to signal to noise problems which are surmountable at aircraft altitudes, but may be serious at spacecraft altitudes if the extraneous path radiance due to atmospheric scattering is great. Table 1 shows calculated values of the expected performance of the ERTS-1 MSS system for detecting oil slicks. These calculations were performed using: (1) a validated oil slick and water reflectance model based upon the Schuster-Schwartzchild approximation to radiative transfer in layered media [1];

TABLE 1. THEORETICAL OPEN SEA OIL-SLICK DETECTION USING MSS SENSOR
Data calculated for average crude oil slick on coastal water and for 30° solar zenith angle, 23 km visibility, and slick position greater than 5 km from shore.

MSS BAND	MEAN BAND RADIANCE	SPACE CONTRAST		MINIMUM RESOLVABLE SLICK	
		THIN SLICK	THICK SLICK	THIN SLICK	THICK SLICK
1 (0.5 - 0.6 μm)	0.33 mw/cm^2 - ster	1.06:1	0.85:1	≥ 0.8 km	0.2 km
2 (0.6 - 0.7 μm)	0.14	1.12:1	1.05:1	0.6	1.5
3 (0.7 - 0.8 μm)	0.08	1.14:1	1.14:1	1.2	1.2
4 (0.8 - 1.1 μm)	--	----	-----	---	---

TABLE 2. THEORETICAL SHORELINE OIL-SLICK DETECTION USING MSS SENSOR
Data calculated for average crude oil slick on coastal water and for 60° solar zenith angle, 23 km visibility, and slick position much less than 5 km from shore.

MSS BAND	MEAN BAND RADIANCE	SPACE CONTRAST		MINIMUM RESOLVABLE SLICK	
		THIN SLICK	THICK SLICK	THIN SLICK	THICK SLICK
1 (0.5 - 0.6 μm)	0.28 mw/cm^2 - ster	1.03:1	0.92:1	1.5 km	0.5 km
2 (0.6 - 0.7 μm)	0.17	1.04:1	0.98:1	2.4	5.0
3 (0.7 - 0.8 μm)	0.11	1.05:1	1.05:1	3.0	3.0
4 (0.8 - 1.1 μm)	--	----	----	--	--

(2) an atmospheric model which calculates transmission, irradiance, sky radiance and path radiance using the double-delta function and the Schuster-Schwartzchild approximation [6]; and (3) the ERTS-1 sensor characteristics [7].

The data of Table 1 indicate that an oil slick would have to be quite large in order to be detected using the MSS sensor. Only for an optically thick crude oil slick, which is quite black in the visible region (ground contrast 0.5:1), does the resolvable slick size diameter fall significantly below a value of 1 km. Obviously, there does not appear to be much hope for detecting "minor" slicks associated with common industrial or shipping operations. Conversely, major slicks such as produced by well blow-outs or shipping accidents would appear to be detectable.

The data of Table 1 were calculated for a slick occurring at least 5 km from land. This factor is important since the amount of extraneous path radiance is affected by the general albedo of the terrain. Since the albedo of water is quite low at wavelengths beyond 0.6 μm, the path radiance and its resultant photon noise are also relatively low. Conversely, Table 2 shows similar data for slick detection when the slick is assumed surrounded by vegetated land. The very high albedo of vegetation in the near infrared results in severely increased path radiance effects. This in turn degrades the minimum resolvable slick characteristic by a factor of 3 compared to the case when the slick is far from land.

MSS Image Analysis

While the detection and mapping of large scale oil slicks is feasible using the MSS sensor of ERTS-1, the unpredictability of their occurrence and their relatively fast dissipation severely limits the quantity of useful data to be expected from ERTS-1 sensors. At this point in time only one major oil-pollution incident appears to have been imaged by the MSS system under reasonable atmospheric conditions. On 2 October 1972, approximately 30,000 gallons of mixed fuel oil and water were discharged from a storage tank into the harbor at Salem, Mass. Despite clean-up and containment efforts, the slick moved out of the harbor and into coastal waters. Preliminary screening of MSS data acquired on 8 October indicates an anomalous region, which might be the slick, extending along the shoreline in the vicinity. Pending receipt of hard copy imagery and further analysis, however, detection and identification remain conjectural.

PROGRAM FOR NEXT REPORTING INTERVAL

The MSS data of 8 October 1972 from the Salem, Mass. coastal area will be analyzed to confirm (or deny) the presence of a detectable oil slick. If a definite slick is observable, digital tapes of the data will be requested and subsequently processed to establish quantitative spectral signatures and oil/water contrasts. These processing results will then be compared with theoretical signatures created using available knowledge of slick and atmospheric characteristics obtaining at the time of MSS data acquisition.

Efforts to identify other possible oil slick data obtained by the ERTS-1 system will continue. To this end, the Spill Report Summary published daily by the Division of Oil and Hazardous Materials, Environmental Protection Agency, is being used to correlate known oil spills of major significance with ERTS-1 orbital coverage.

NEW TECHNOLOGY

None

CONCLUSIONS AND RECOMMENDATIONS

The program of this task has not had sufficient ERTS information available to date to permit statement of any conclusions or recommendations.

First Type II Progress Report
R. Vincent, MMC 075
Task X, Mapping Iron Compounds

INTRODUCTION

The work thus far on this task has been divided into three subtasks: theoretical description of the data processing, creation of computer software to implement the data processing, and preparation of existing geological information of the test site with which the processed ratio maps will be compared. The first of these subtasks has been completed and was described in a paper submitted this month to the Eighth Remote Sensing Symposium Proceedings entitled "An ERTS Multispectral Scanner Experiment for Mapping Iron Compounds", by R. K. Vincent. A brief description of each subtask is included below.

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Theoretical Description

The spectral radiance of Lambertian targets measured by ERTS MSS scanner can be expressed as

$$L_\lambda = S\left(\frac{E_{sun_\lambda}}{\pi}\right) \tau_\lambda \rho_\lambda + L_{p_\lambda} \qquad (1)$$

where L_λ = measured spectral radiance,

S = shadow or illumination factor (1.0 for no shadow in instantaneous field of view),

E_{sun_λ} = spectral irradiance of the sun (impinging upon target),

τ_λ = atmospheric transmittance,

ρ_λ = spectral reflectance of target,

L_{p_λ} = path radiance (caused by atmospheric scattering).

The Lp_λ term contains path radiance from two sources: light scattered into the beam between target and detector, and light scattered off the sun-target direction (diffuse illumination), then reflected off the target toward the detector. Whenever the Lp_λ term is negligible, as with low-altitude scanner data on a clear day, all of the environmental factors are multiplicative. From satellite altitudes, however, Lp_λ is no longer negligible. To get rid of most or all of this additive term, the purely empirical approach of dark object subtraction can be taken. In a shadowed region, S = 0 because there is no direct solar irradiance; hence $L_\lambda = Lp_\lambda$ whenever the shadow is large compared with a spatial resolution element. Therefore, for a given spectral channel, the value of the lowest radiance measured within the scene will be subtracted from all other spatial resolution elements in the scene. After dark object subtraction, the ratio of the i^{th} and $(i + 1)^{th}$ channels will be approximately

$$R_{i,i+1} \sim \frac{L_i}{L_{i+1}} = \frac{s\left(\frac{E_{sun_i}}{\pi}\right)\tau_i\rho_i}{s\left(\frac{E_{sun_{i+1}}}{\pi}\right)\tau_{i+1}\rho_{i+1}} = \frac{E_{sun_i}}{E_{sun_{i+1}}} \frac{\tau_i}{\tau_{i+1}} \left(\frac{\rho_i}{\rho_{i+1}}\right) \quad (2)$$

In this equation, the only term which will vary widely over an ERTS frame (for most geological test sites) is ρ_i/ρ_{i+1}, the target reflectance term. The ratio also may not be invariant for the same target type in two ERTS frames collected at different times in different places, however. For a further suppression of environmental factors (s, E_{sun_i}, τ_i, and Lp_i), the spectral reflectance of a known target within the ERTS frame can be measured and used as a reference, for which the ERTS-measured ratio will be:

$$(R_{i,i+1})_{reference} = \frac{E_{sun_i}}{E_{sun_{i+1}}} \frac{\tau_i}{\tau_{i+1}} \left(\frac{\rho_i}{\rho_{i+1}}\right)_{reference} \quad (3)$$

A division of equation 2 by equation 3 yields, after rearrangement,

$$\frac{\rho_i}{\rho_{i+1}} = \left(\frac{\rho_i}{\rho_{i+1}}\right)_{reference} \left|\frac{R_{i,i+1}}{(R_{i,i+1})_{reference}}\right| \quad (4)$$

from which the term ρ_i/ρ_{i+1} can be calculated almost independently of environmental factors. The "almost" is included in the foregoing statement because the degree of environmental independence is dependent on how well the dark object subtraction succeeds in suppressing the path radiance term. It should be noted that the dark object subtraction is an approximation, because part of the Lp_λ term is dependent on target reflectance. However, it is assumed here that the target reflectance dependence of Lp_λ is negligible. Should the above procedure yield poor results, i.e., fail to suppress atmospheric effects, another approach will be attempted. The dark object subtraction method cannot be used to yield data from the darkest elements in the scene, however. These elements will be processed in a different manner, possibly as a straight radiance ratio.

Computer Software

The second subtask is underway. Three computer programs are now being written to accomplish the type of data processing described above. Program DARK, which should be ready for testing within the month, is designed to make the dark object subtraction mentioned above. Program RATIO, also about completed, will perform the steps in equation (2), with the tape output from program DARK. Program RATNORM, which will perform the steps in equation (3) has just been initiated and should be completed next month.

Test Site Information

The third subtask is also underway, and is estimated to be halfway completed. Geologic maps by Richard Bayley of the U.S.G.S. have been obtained of the primary test region (four quadrangle maps near the Atlantic City District, Wyoming) and other maps have been ordered. A topographic/geologic map of the region has been hand-drafted in a form that, after photo-reduction, will permit overlaying the map onto ERTS frames of the test area. Photo reduction of this map, which is a combination of known topographic and geologic information, is now being done. This will permit the comparison of large lithologic units as mapped from known geologic data with their appearance on ERTS frames of the MSS channels. The final use of this hand-drafted map will be a comparison of known geologic features with computer-produced ratio maps of the test area. Computer gray-maps of each of the four MSS channels have been produced for the Atlantic City District and the geologic features of interest are being located, with use of the above maps, such that only a portion of the primary ERTS frame (No. 1013-17294) need be used for testing the three computer programs listed earlier.

Finally, the principal investigator has been in contact with Ron Marrs of The University of Wyoming, a co-investigator of another ERTS contract, who has supplied information about new iron ore discoveries that have been made within the region covered by the above ERTS frame. The iron ore was discovered from an ERTS aircraft underflight and is not visible from the single channel images of that ERTS frame, primarily because of small aerial extent and low spectral contrast of the deposits. After the ratio techniques of this task are in working order, an attempt will be made to identify this deposit with the new techniques. The deposit may be too small in aerial extent to locate from space, even with this new and, hopefully, more powerful technique; however, should it become identifiable, that alone would prove the value of the ratio technique under development.

PROGRAM FOR NEXT REPORTING INTERVAL

To produce the first ratio images of the available ERTS data for the Atlantic City District, Wyoming, and present the results at the 5-9 March Symposium. To begin analysis of these ratio images.

NEW TECHNOLOGY

None

CONCLUSIONS AND RECOMMENDATIONS

The frame 1013-17294 appears to contain useful data for the completion of part of this task. Digital tapes are compatible with the ERIM computer system.

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