THIRD ERTS SYMPOSIUM

ABSTRACTS

DECEMBER 10-14, 1973

Statler Hilton Hotel, Washington, D.C.

Sponsored by

NASA/Goddard Space Flight Center

Greenbelt, Maryland

	Monday AM	Monday PM	Tuesday AM	Tuesday PM	Wednesday AM	Wednesday PM	Thursday	Friday*
AGRICULTURE/FORESTRY/ RANGE RESOURCES Chairman W. CREA (JSC) Co-Chairman J. SCHUBERT (GSFC)	Plenary Session Presidential Ballroom (9:30 a.m.)			FEDERAL ROOM (1:30 p.m.) Presentations A1-A8	FEDERAL ROOM (9:00 a.m.) Presentations A9-A15	FEDERAL ROOM (1:30 p.m.) Presentations A16-A20 Late Contributions and Discussion	Plenary Summary Session Presidential Ballroom (9:00 a.m.)	W 400 (9:00 a.m.)
LAND USE & MAPPING Chairman A. JOYCE (ERL) Co-Chairman R. ROWLEY (JSC)		SENATE ROOM (1:30 p.m.) Presentations L1-L10	SENATE ROOM (9:00 – 11:20 a.m.) Presentations L11-L16 Late Contributions and Discussion					W 450 (9:00 a.m.)
MINERAL RESOURCES GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS Chairman N. SHORT (GSFC) Co-Chairman P. LOWMAN (GSFC)				CONGRESSIONAL ROOM (1:30 p.m.) Presentations G1-G8	SOUTH AMERICAN ROOM (9:00 a.m.) Presentations G9-G16	SOUTH AMERICAN ROOM (1:30 p.m.) Presentations G17-G20 Late Contributions and Discussion		W 452 (9:00 a.m.)
WATER RESOURCES Chairman V. SALOMONSON (GSFC) Co-Chairman R. CLEMENCE (JSC)		FEDERAL ROOM (1:30 p.m.) Presentations W1-W10	FEDERAL ROOM (9:00 a.m.) Presentations W11-W17 Late Contributions and Discussion					Parlor 509 (9:00 a.m.)
MARINE RESOURCES Chairman E. L. TILTON (ERL) Co-Chairman J. GREAVES (GSFC)			SENATE ROOM (11:20 a.m.) Presentations M1-M2	SENATE ROOM (1:30 p.m.) Presentations M3-M11 Late Contributions and Discussion				W 600 (9:00 a.m.)
ENVIRONMENT SURVEYS Chairman L. GREENWOOD (LRC) Co-Chairman C. SCHNETZLER (GSFC)					SENATE ROOM (9:00 a.m.) Presentations E1-E8	SENATE ROOM (1:30 p.m.) Presentations E9-E12 Late Contributions and Discussion		W 650 (9:00 a.m.)
INTERPRETATION TECHNIQUES Chairman J. DRAGG (JSC) Co-Chairman W. ALFORD (GSFC)		CONGRESSIONAL ROOM (1:30 p.m.) Presentations I-1–I-9	CONGRESSIONAL ROOM (9:00 a.m.) Presentations I-10–I-16 Late Contributions and Discussion					W 850 (9:00 a.m.)

*Working Group Sessions

THIRD ERTS

SYMPOSIUM

Chairman . . . . . Dr. Stanley C. Freden

Symposium Coordinator . . . . . Mr. John H. Boeckel

AGENDA

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Monday, December 10, 1973

Registration – Foyer 1 — 8:00 a.m.

Opening Plenary Session

Presidential Ballroom

Welcome – William Nordberg (Goddard Space Flight Center) — 9:30 a.m.

Introductory Remarks – Leonard Jaffe (NASA Headquarters) — 9:45 a.m.

Symposium Logistics – John H. Boeckel (Goddard Space Flight Center) — 10:00 a.m.

Status of the ERTS-1 System – John H. Boeckel (Goddard Space Flight Center) — 10:15 a.m.

Report on the Canadian ERTS Program – Lawrence W. Morley (Department of Energy, Mines, and Resources, Center for Remote Sensing, Ottawa, Canada — 11:00 a.m.

Lunch — 11:30 a.m.

AGRICULTURE/FORESTRY/RANGE RESOURCES

Chairman, W. Crea (JSC)
Co-Chairman, J. Schubert (GSFC)

LAND USE & MAPPING

Chairman, A. Joyce (ERL)
Co-Chairman, R. Rowley (JSC)

MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

Chairman, N. Short (GSFC)
Co-Chairman, P. Lowman (GSFC)

WATER RESOURCES

Chairman, V. Salomonson (GSFC)
Co-Chairman, R. Clemence (JSC)

MARINE RESOURCES

Chairman, E. L. Tilton (ERL)
Co-Chairman, J. Greaves (GSFC)

ENVIRONMENT SURVEYS

Chairman, L. Greenwood (LRC)
Co-Chairman, C. Schnetzler (GSFC)

INTERPRETATION TECHNIQUES

Chairman, J. Dragg (JSC)
Co-Chairman, W. Alford (GSFC)

Thursday (Dec. 13, 1973)

Plenary Summary Session

Presidential Ballroom — **Thursday 9:00 a.m.**

Chairman, Gene Thorley, NASA Headquarters

Introduction to Summary Session – James C. Fletcher, Administrator, National Aeronautics and Space Administration	9:00 a.m.
Keynote Address – John C. Whitaker, Under Secretary of the Interior, U. S. Department of Interior	9:15 a.m.
Break	10:00 a.m.
Selected Significant Accomplishments – To be announced	10:30 a.m.
Lunch	12:00

Chairman, Stanley C. Freden, GSFC

Selected Significant Accomplishments (Con't) - To be announced — 1:30 p.m.

Summaries in Selected Disciplines - — 3:00 p.m.

Agriculture, Forestry, Range Resources: R. MacDonald, NASA/Johnson Space Center, Houston, Texas

Land Use and Mapping: A. Joyce, NASA/Earth Resources Laboratory, Bay St. Louis, Mississippi

Mineral Resources, Geological Structure, and Landform Surveys: N. M. Short, NASA/Goddard Space Flight Center, Greenbelt, Md.

Water Resources: V. V. Salomonson, NASA/Goddard Space Flight Center, Greenbelt, Md.

Interpretation Techniques Development: J. Dragg, NASA/Johnson Space Center, Houston, Texas

AGRICULTURE/FORESTRY/RANGE RESOURCES

Chairman, W. Crea, (JSC)

Co-Chairman, J. Schubert, (GSFC)

ESTIMATES OF WINTER WHEAT YIELD FROM ERTS-1

Stanley A. Morain and Donald L. Williams, *Space Technology Laboratories, University of Kansas, Lawrence, Kansas 66045*

ABSTRACT

A model for estimating wheat yield per acre was applied to acreage estimates derived from ERTS-1 imagery to project the 1973 wheat yields for a ten county area in southwest Kansas. The results (44.34 million bushels) are within 3 percent of the preharvest estimates for the same area prepared by the USDA Statistical Reporting Service (45.56 million bushels). The projection from ERTS data is based on a visual enumeration of all detectable wheat fields in the study area and was completed while the harvest was in progress. Visual identification of winter wheat is readily achieved for fields of 80 acres or larger by using a temporal sequence of images (band 5 for Sept.-Oct.; band 5 for Dec.-Jan.; and band 5 & 7 for March-April). Identification can be improved by stratifying the project area into sub-regions having more or less homogeneous agricultural practices and crop mixes. By doing this, small changes in the spectral appearance of wheat related to soil type, irrigation, etc. can be accounted for. The interpretation rules developed by visual analysis can be automated for rapid computer surveys.

USER ORIENTATED ERTS-1 IMAGES

Seymour Shlien and David Goodenough, *Department of Energy, Mines & Resources, Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ontario, Canada*

ABSTRACT

Photographic reproductions of ERTS-1 images are capable of displaying only a portion of the total information available from the Multispectral Scanner. For these reasons, methods are being developed by the Applications Division of the Canada Centre for Remote Sensing, to generate ERTS-1 images orientated towards special users such as agriculturists, foresters, and hydrologists by applying image enhancement techniques and interactive statistical classification schemes.

Spatial boundaries and linear features can be emphasized and delineated using simple filters. Linear and nonlinear transformations can be applied to the spectral data to emphasize certain ground information.

An automatic classification scheme was developed to identify particular ground cover classes such as fallow, grain, rape seed or various vegetation covers. The scheme applies the maximum likelihood decision rule to the spectral information and classifies the ERTS-1 image on a pixel by pixel basis. The user must first furnish the classifier a set of training areas for the classes of interest so that the statistical information can be extracted. The classifier then gives the user an estimate of how well it can distinguish the classes on the basis of these data and attempts to classify a designated area. Preliminary results indicate that the classifier has limited success in distinguishing crops, but is well adapted for identifying different types of vegetation.

Illustrative examples are presented for areas in the ERTS-1 frame, 1007-16531, which covers the area around Winnipeg, Manitoba.

AN EVALUATION OF MACHINE PROCESSING TECHNIQUES OF ERTS-1 DATA FOR USER APPLICATIONS

David Landgrebe and Staff, *LARS/Purdue University, West Lafayette, Indiana 47906*

ABSTRACT

The need for computer processing and analysis techniques, as a companion tool to other methods, was apparent some years ago. As a result, a relatively complete software system for analyzing remotely sensed data has been devised over the past several years.

This paper reports on a comprehensive evaluation of this processing technique as applied to ERTS-1 data. Five tests utilized in the evaluation were selected so as to sample the full range of classification difficulty and a broad range of user application problems. The five were as follows: 1) general earth surface feature mapping for land use applications, 2) vegetative species identification (especially of agricultural crops), 3) the mapping of soil associations, 4) the multispectral classification of water resources, and 5) urban land use mapping.

In order to accomplish these tasks it was necessary to re-tailor and improve certain preprocessing and analysis procedures. This was especially the case in the area of geometric correction of ERTS-1 data.

Although several additional months of analysis are planned, results to this point already allow for positive conclusions in several areas. Quantitative evaluations of crop species, urban lands and soils mapping possibilities are already available. Multitemporal data sets are being generated and analyzed to assess the potential of this approach to further improve classifier performance and also to detect changes in land use.

THE UTILITY OF ERTS-1 DATA FOR APPLICATIONS IN AGRICULTURE AND FORESTRY

R. Bryan Erb, *NASA, Johnson Space Center Houston, Texas 77058*

ABSTRACT

A comprehensive study has been undertaken at the NASA Johnson Space Center to determine the extent to which ERTS-1 data could be used to detect, identify (classify), locate and measure features of applications interest in the disciplines of Agriculture and Forestry. The study areas included: six counties in five states in which were located examples of the most important crops and practices of American agriculture; and a portion of the San Houston National Forest, a typical gulf coastal plain pine forest.

The investigation utilized conventional image interpretation and computer aided (spectral pattern recognition) analysis using both image products and computer compatible tapes. The emphasis was generally upon the computer aided techniques.

It was concluded that:

- ERTS-1 data can be used to detect, identify, locate and measure a wide array of features of interest in agriculture and forestry.
- The utility of the information extracted from ERTS-1 data is likely to be greatest for large area applications.
- The computer aided analysis techniques perform as well or better than conventional image interpretation but both will be useful for most earth resource surveys.
- Practical applications of ERTS data are being developed with two outside user groups at the federal level.

Follow-on effort is being pursued with the Department of Agriculture in both crop and forest resource inventory areas with participation of agencies of the USDA.

CROP IDENTIFICATION IN ACREAGE MEASUREMENT UTILIZING ERTS IMAGERY

William H. Wigton and Donald H. VonSteen, *U.S. Department of Agriculture, Statistical Reporting Service*

ABSTRACT

ERTS-1 imagery is being evaluated by the Statistical Reporting Service (SRS) U.S. Department of Agriculture as a potential tool for estimating crop acreage. The Statistical Reporting Service makes crop and live stock forecasts and estimates throughout the year across the United States. The main estimates are generated from enumerating small land parcels that have been randomly selected from the total United States land area. These small parcels are being used as ground observations in the investigation. The test sites are located in Missouri, Kansas, Idaho and South Dakota. The major crops of concern are wheat, cotten, corn, soybean, sugar beets, potatoes, oats, alfalfa and grain sorghum. Some of the crops are unique for a given site while others are common in 2 or 3 states. This provides an opportunity to observe crops grown under different conditions. Results in this paper are limited to the Missouri and Idaho test sites. All the classification was done on a LARS terminal. Results of temporal overlays unequal prior probabilities and sample classifiers are discussed. The amount of improvement that each technique contributes is shown in terms of overall performance. Even though perfect crop classification is highly unlikely, useful information for making crop acreage estimates can still be obtained.

VEGETATION DENSITY AS DEDUCED FROM ERTS-1 MSS RESPONSES

C. L. Wiegand, H. W. Gausman, J. A. Cuellar and A. H. Gerbermann, *USDA, Agricultural Research Service, Southern Region, Soil and Water Conservation Research, Weslaco, Texas 78596*

ABSTRACT

Reflectance from vegetation increases with increasing vegetation density in the 0.75 to 1.35 μm wavelength interval. Therefore, ERTS-1 bands 6 (.7 to .8 μm) and 7 (.8 to 1.1 μm) contain information that should relate to the probable yield of crops and the animal carrying of rangeland. On the other hand, reflectance from vegetation is typically less than that of bare soil and essentially constant in the visible wavelengths as vegetation density increases; consequently, the decreased response observed in ERTS bands 4 (.5 to .6 μm) as vegetation increases is mainly due to the soil that is obscured by vegetation. Because the ERTS MSS responses recorded under variable ground cover conditions are a mixed signal for soil and vegetation, the ratio of band 5 to band 7 (5/7) or band 7 minus band 5 (7-5) are practical indicators of vegetative cover and density for users of ERTS data.

This paper reviews, briefly, the experimental and theoretical bases for the above conclusions. In addition, the results of an experiment designed specifically to test the relation between leaf area index (LAI) determined in 4 corn, 10 sorghum, and 10 cotton fields in the spring of 1973 and ERTS MSS responses are given. (LAI is the ration of leaf area of plants to the ground area they occupy and a useful measure of vegetation density.) Due to clouds, only one ERTS pass (May 27, scene 1308-16323) yielded MSS data and that for only bands 4, 5, and 6. The simple correlation between LAI and band 6 digital counts was 0.823** for the 10 cotton fields and 0.841** for the combined sorghum and corn fields. The correlation coefficient between LAI and band 6 minus band 5 digital counts was 0.888** for cotton fields and 0.768** for the corn and sorghum fields. These findings generally support the utility of ERTS data for explaining variability in yield, biomass, harvestable forage and other indicators of productivity.

**Statistically significant at the one percent level.

REGIONAL AGRICULTURAL SURVEYS USING ERTS-1 DATA

William C. Draeger, James D. Nichols, Andrew S. Benson, David G. Larrabee, William M. Senkus and Claire M. Hay, *Center for Remote Sensing Research, University of California, Berkeley, California 94720*

ABSTRACT

During the past year, the Center for Remote Sensing Research (CRSR) at the University of California has conducted studies designed to evaluate the potential application of ERTS data in performing agricultural inventories, and to develop efficient methods of data handling and analysis useful in the operational context for performing large area surveys.

This work has resulted in the development of an integrated system utilizing both human and computer analysis of ground, aerial, and space imagery, which has been shown to be very efficient for regional crop acreage inventories. The technique involves (1) the delineation of ERTS images into relatively homogeneous strata by human interpreters, (2) the point-by-point classification of the area within each strata on the basis of crop type using a human/machine interactive digital image processing system, and (3) a multistage sampling procedure for the collection of supporting aerial and ground data used in the adjustment and verification of the classification results.

FOREST AND LAND INVENTORY USING ERTS IMAGERY AND AERIAL PHOTOGRAPHY IN THE BOREAL FOREST REGION OF ALBERTA, CANADA

C. L. Kirby, *Canadian Forestry Service, Northern Forest Research Centre, Environment Canada, 5320 – 122 Street, Edmonton, Alberta. T6H 3S5*

ABSTRACT

Presented here are results from a test site located at 57° N and 118° W in the boreal forest region of Alberta, Canada. This work is part of a coordinated research and development program concerned with using ERTS imagery and aerial photography for more timely and economical forest and land inventories.

Spectral signatures of various forest covertypes in the boreal forest region are robust and increase the accuracy of interpretation even when no corrections for cosine fall-off, atmospheric path and other variables have been made. In addition to multispectral images, multidate imagery also has proved useful and gives better terrain analysis, especially with low sun angles, and greatly improves the identification of mature softwood (mainly spruce and pine) forests. Better estimates of the spruce understory in forests with a poplar overstory are also possible when the leaves are absent.

A geometrically corrected satellite image provides a base map of similar accuracy to that obtainable on a National Topographic Map sheet at a scale of 1:250,000. Transfer of detail on aerial photographs was aided by the increased information on the satellite base map. Slotted template laydowns may no longer be required for most forest inventories.

Small-scale (1:120,000) aerial photography with infrared-ektachrome film (2443) was used to produce a forest covertype map with 20-foot height classes. There was less than one percent difference, in areas of various strata, from that obtained with 1:15,000 black-and-white infrared photography (2424 film).

Large-scale (1:1000) taken with aero color negative film (2445) proved most effective in improving tree species recognition. White spruce, black spruce, lodgepole pine and poplar could easily be separated by their color at this scale. The large-scale photography coupled with ground sampling improved timber volume and quality estimates.

In Alberta, the economies that may be achieved in forest and land inventory in the boreal forest region with the use of small-scale photography and satellite imagery are yet to be realized outside of research and development projects.

SO_2 DAMAGE TO FORESTS RECORDED BY ERTS-1

Peter A. Murtha, *Forest Management Institute, Canadian Forestry Service, 396 Cooper St., Ottawa, Canada*

ABSTRACT

SO_2 fumes have been affecting the forests around Wawa, Ontario, since 1949. In one area the forest has been totally destroyed and only exposed ground remains. The affected forest has been under aerial surveillance for a number of years and was recently covered by high altitude, 1:160,000 aerial photography for damage assessment purposes. The area was selected as a Canadian Forestry Service ERTS test site and was imaged on four successive ERTS passes during the summer of 1973.

Image interpretation supported by electronic colour enhancement was used to delineate on ERTS imagery three damage zones (total kill, heavy kill and medium damage zones). The zones delineated on ERTS imagery are similar to the results of aerial sketch-mapping and air photo interpretation. Band 5 provided the greatest detail for assessing the damage to the forests, followed in successive order by bands 4, 6 and 7. Comparison with ERTS images obtained in the winter showed that even though the total kill could be separated from heavy kill damage zones, total kill could not be consistently separated from clear-cut logging, burned areas, frozen lakes and bogs.

A TIMBER INVENTORY BASED UPON MANUAL AND AUTOMATED ANALYSIS OF ERTS-1 AND SUPPORTING AIRCRAFT DATA USING MULTISTAGE PROBABILITY SAMPLING

James D. Nichols, Mike Gialdini and Sipi Jaakkola, *Center for Remote Sensing Research, 260 Space Sciences Laboratory, University of California, Berkeley, California 94720*

ABSTRACT

In order to test the usefulness of ERTS imagery for wildland resource inventories, a timber inventory was performed in which the ERTS imagery acted as the first stage of a multistage sampling design. The objective of the inventory was to estimate the standing volume of merchantable timber within the Quincy Ranger District (215,000 acres) of the Plumas National Forest in California. Secondary objectives of the inventory were: (1) to test the operational efficiency of the sampling procedures of the multistage sampling design; (2) to test the effectiveness of the CALSCAN discriminant analysis classifier on the ERTS data; (3) to determine the value of ERTS data and the aircraft data in reducing the sampling error; and (4) to compare the costs of this timber inventory with other inventories that utilize conventional procedures.

The inventory proved to be a timely, cost-effective alternative to conventional timber inventory techniques. The timber volume on the Quincy Ranger District of the Plumas National Forest was estimated to be 2.44 billion board feet with a sampling error of 8.2 percent. Costs per acre for the inventory procedure at 1.1 cent/acre compared favorably with the costs of a conventional inventory at 25 cents/acre. A point-by-point comparison of CALSCAN-classified ERTS data with human-interpreted low altitude photo plots indicated no significant differences in the overall classification accuracies.

APPLICATION OF ERTS-1 IMAGERY TO LAND USE, FOREST DENSITY AND SOIL INVESTIGATIONS IN GREECE

Nicholas J. Yassoglou, *Athens Faculty of Agriculture Botanicos, Athens, Greece,* Emanuel Skordalakis, *Democritos, Athens, Greece,* and Athanassios Koutalos, *Department of Agriculture, Athens, Greece*

ABSTRACT

Presently available information on land use, site quality and soil conditions in Greece are not adequate.

Photographic and digital imagery received from ERTS-1 was analyzed and evaluated as to its usefulness for the assessment of agriculture and forest land resources.

Black and white, and color composite imagery provided spectral and spatial data, which, when were mached with temporal land information, provided the basis for a semidetailed land use and forest site evaluation chartography.

Color composite photographs have provided some information on the status of irrigation of agricultural lands.

Computer processed digital imagery was successfully used for detailed crop classification and semidetailed soil evaluation.

The results and techniques of this investigation are applicaple to ecological and geological conditions similar to those prevailing in Eastern Mediterranean.

ERTS-1 MSS IMAGERY: ITS USE IN DELINEATING SOIL ASSOCIATIONS AND AS A BASE MAP FOR PUBLISHING SOILS INFORMATION*

Frederick C. Westin, *Plant Science Department and Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57006*

ABSTRACT

ERTS-1 imagery was found to be a useful tool in the identification and refinement of Soil Association areas and an excellent base map upon which soil association information can be published. Prints of bands 5 and 7 were found to be most useful to help delineate major soil and vegetation areas. For example band 7 was found to give superior definition to steeply sloping soils while band 5 gave the best contrast between trees and grass. After delineating major soil areas, over 4800 land sale prices covering a period of 1967-72 were located in the soil areas and averaged. A legend explaining land use, dominant slope and soil parent materials of each delineated area was developed. The soil associations then were described as Soil Association Value Areas and published on a 1:1,000,000 scale ERTS mosaic of South Dakota constructed using negative prints of band 7. The resulting map describes the kind of agriculture and soils and allows readers to see how soils actually are being used on a current map having very little distortion. Furthermore, it gives information about what buyers think the soils are worth. The map is intended for use by state and county revenue officers to equalize land values in South Dakota, by individual buyers and sellers of land and lending institutions as a reference source, as a reference map by those planning road routes and cable and pipe lines, by conservationists in helping to keep current conservation needs inventories, by agronomists needing current information on distribution and patterns of crop growth and by crop yield forecasters to guide sampling strategy.

*SDSU-RSI-J-73-11 supported in part by Contract No. NAS-5-21774

MAPPING SOILS, CROPS, AND RANGELANDS BY MACHINE ANALYSIS OF MULTI-TEMPORAL ERTS-1 DATA

Marion F. Baumgardner, James A. Henderson, Jr. and LARS Staff, *Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47907*

ABSTRACT

ERTS-1 data, obtained during the period 25 August 1972 to 5 September 1973 over a range of test sites in the central United States, have been used for identifying and mapping differences in soil patterns, species and conditions of cultivated crops, and conditions of rangelands. Multispectral scanner data from multiple ERTS passes over certain test sites have provided the opportunity for overlay analysis.

Geometric correction was performed on the Digital Data for several dates and for several test sites. It was then possible to overlay the classification results from the geometrically corrected ERTS-1 data with maps of earth surface features of interest.

Multispectral classifications delineating soils boundaries in different test sites compared well with existing soil association maps prepared by conventional means.

Spectral analysis of multitemporal data were used to identify and map crop species and to provide valuable information about optimum time for spectrally separating cotton, sorghum, corn, soybeans, wheat, and other crops at different latitudes between 31 degrees north and 43 degrees north.

Multispectral analysis of ERTS-1 data provided patterns in rangelands which can be related to soils differences, range management practices, and the extent of infestation of grasslands by mesquite (prosopis fuliflora) and juniper (juniperus spp.).

EVALUATION OF ERTS-1 IMAGERY IN MAPPING AND MANAGING SOIL AND RANGE RESOURCES IN THE SAND HILLS REGION OF NEBRASKA

Paul M. Seevers, James V. Drew and David T. Lewis, *Department of Agronomy, University of Nebraska-Lincoln, Lincoln, Nebraska 68503*

ABSTRACT

The major economic enterprise within the 20,000 square miles of Sand Hills rangeland in Nebraska is the utilization of forage in cow-calf operations to produce beef. Increased demands for beef translate into demands for efficient use of existing forage as well as for the production of additional forage. Maximum sustained beef production within the Sand Hills region is directly related to range management decisions based on range sites and interpretations of range condition classes. In addition, center-pivot irrigation systems constructed on suitable sites have considerable potential for increasing and stabilizing forage yields within the Sand Hills.

Interpretations of ERTS-1 imagery for three counties in the Sand Hills region indicate that major soil associations and attendant range sites can be identified on the basis of vegetation and topography using spring imagery and snow-enhanced winter imagery. This procedure delineated associations of soils and attendant Sandy, Sands, Choppy Sands and Subirrigated range sites at a level of generalization intermediate between county soil association maps and standard soil surveys made by observations of soil profiles and landscapes on the ground.

In addition, optical density measurements of MSS band 5 imagery obtained during the growing season were related to field measurements of vegetative biomass, a factor that closely parallels range condition class on known range sites within the Sand Hills region. Thus, range condition classes defined according to field determinations of climax vegetation may be estimated from optical density measurements of ERTS-1 imagery when range sites are known. Further study of these relationships will permit operational interpretations of range condition for use in timing livestock grazing and in selecting stocking rates. Overgrazing in the Sand Hills is particularly critical in view of the fragile nature of the sandy rangeland and its potential for destruction by wind erosion.

ERTS-1 imagery of the Sand Hills also permitted an assessment of the success of center-pivot irrigation systems for forage production in relation to soil and topographic conditions. Image interpretation has the potential for delineating areas unsuited for the installation of center-pivot irrigation.

The following resource maps for use in planning range management programs in the Upper Loup Natural Resources District within the Sand Hills have been prepared from ERTS-1 imagery: (1) location of lakes and subirrigated range sites, (2) intensity of blowouts and areas affected by severe wind erosion, (3) areas with less than 10% vegetative cover in August, 1972 and May, 1973, and (4) distribution of center-pivot irrigation systems identified according to the production of perennial forage crops or annual crops.

ERTS SURVEYS A 500 KM^2 LOCUST BREEDING SITE IN SAUDI ARABIA

D. E. Pedgley, *Centre for Overseas Pest Research, London, England*

ABSTRACT

From September 1972 to January 1973, ERTS-1 precisely located a 500 km^2 area on the Red Sea coastal plain of Saudi Arabia within which the Desert Locust (Schistocerca gregaria, Forsk.) bred successfully and produced many small swarms. Growth of vegetation shown by satellite imagery was confirmed from ground surveys and rainguage data. The experiment demonstrates the feasibility of detecting potential locust breeding sites by satellite, and shows that an operational satellite would be a powerful tool for routine survey of the 3×10^7 km^2 invasion area of the Desert Locust in Africa and Asia, as well as of other locust species in the arid and semi-arid tropics.

REMOTE SENSING EXPERIMENT IN WEST AFRICA

N. H. MacLeod, *Department of Biology, The American University, Washington, D. C.*

ABSTRACT

In 1969, the investigation of seasonal changes in plant communities and surface water of West Africa was initiated using Nimbus III HRIR data. The Republic of Mali, in particular, had requested advice concerning remote sensing and initially the ERTS investigation was concerned with assessment of geologic, hydrologic, agricultural, and range resources to provide a basic resource inventory for this country. In late winter and early spring of 1973 there was a growing awareness of a very serious drought problem throughout the Sahel, the wide band between the desert and the woodland regions, and the investigation was extended to cover the entire region. We participated with USAID in studies incorporating remote sensing techniques into the West African Grain Stabilization Program and the Malien Livestock Production Program. Part of this work included assessment of locations where near-surface ground water was most likely to be found. Because livestock production in the Sahel depends on well-point development as well as productive rangeland, there was a useful analysis of ERTS imagery followed by field confirmation of groundwater resources in regions under consideration by USAID for ranching.

Though we found we could define the drought as a meteorological phenomenon extending from 1969, our field studies and analysis of ERTS imagery led us to realize that land-use practices over many centuries had led to substantial deterioration of plant, soil, and water resources, quite possibly to a change in climate across the Sahel. In fact, the ERTS imagery is forcing us to realize that the entire West African region is becoming drier all at the same time. At the same time, the imagery contains information that can be used as a basis for planning action programs to readjust land management practices (i.e., livestock, cash crops, and irrigation production) to increase production, stabilize the landscape, and rehabilitate the Sahel.

As part of the analysis of ERTS data acquired over the drought-affected area, a large man-made feature with indications of improvement in vegetation cover and soil moisture and placed in a semi-arid region in which drought conditions were severe was observed in the Republic of Niger. The man-made feature proved to be a 110,000 hectare fenced ranch in which a simple grazing management program had been initiated. The ranch is five years old. ERTS imagery thus showed changes which have occurred in the five worst years of this century and which in fact represent a reversal of the process of desertification.

A joint effort led by people involved in this investigation is underway to provide planning assistance to the Sahelien governments, particularly in Niger but to the Republic of Mali and the recently formed Interstate Committee as well. Interpreted remote sensing imagery from ERTS is used as the basic cartographic basis for project siting and broad analysis of regional potentials.

NATURAL RESOURCE INVENTORIES AND MANAGEMENT APPLICATION IN THE GREAT BASIN

Paul T. Tueller and Garwin Lorain, *University of Nevada, Reno, Nevada*

ABSTRACT

ERTS-1 resolution capabilities and repetitive coverage have allowed the acquisition of several statewide inventories of natural resource features not previously completed or that could not be completed in any other way. Familiarity with landform, tone, pattern and other converging factors, along with multidate imagery, has been required. Nevada's vegetation has been mapped from ERTS-1 by the following categories: Southern Desert Shrub, Salt Desert Shrub, Northern Desert Shrub, Pinyon/Juniper Woodland, Mountain Brush, Aspen, Meadows and Marshlands, Wheatgrass Seedings, Phreatophytes and Cropland.

Dynamic characteristics of the landscape have been studied. Sequential ERTS-1 imagery has proved its usefulness for mapping vegetation, following vegetation phenology changes, monitoring changes (including water quality) in lakes and reservoirs, determining changes in surface mining use, making fire fuel estimates and determining potential hazard, mapping the distribution of rain and snow events, making range readiness determinations, monitoring marshland management practices and other uses. Land use capability classification work is in progress. A wide variety of other uses has been proposed and users identified. Feasibility has been determined, but details of incorporating the data in management systems awaits further research and development. The need is to accurately define the steps necessary to extract required or usable information from ERTS imagery and fit it into on-going management programs.

USEFULNESS OF ERTS-1 SATELLITE IMAGERY AS A DATA-GATHERING TOOL BY RESOURCE MANAGERS IN THE BUREAU OF LAND MANAGEMENT

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ABSTRACT

ERTS-1 satellite imagery can be a very effective data-gathering tool for land resource managers who must depend upon information concerning the kinds and areal extent of soils and vegetation. Techniques have been developed which will allow managers to visually analyze simulated color infrared composite ERTS images to map broad vegetative communities and broad classes of ephemeral (annual) forage production in the arid Southwest. There are tentative results which indicate that growth and development and drying of ephemeral plants can be monitored, and that potential to produce ephemeral forage can be mapped. ERTS-1 bands 5 and 6 have been used to map soil series and related vegetative communities corresponding to soil type.

In the northern temperate climate of southeastern Oregon, ERTS-1 satellite imagery has been used to map geographic and man-made features, broad vegetative communities, and difference in perennial forage production. In Alaska, ERTS-1 imagery has been used successfully to map broad vegetative communities. Studies have shown that enlargements to scales as large as 1:100,000 can be used to map vegetation to a detail suitable for many resource applications.

To be a truly operational system, imagery must be received by the manager within one week of the date of the satellite overpass, in black and white, and color composite form and as a second generation product.

VEGETATION MAPPING FROM ERTS IMAGERY OF THE OKAVANGO DELTA

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ABSTRACT

The Okavango is Botswana's major water resource. As yet it is essentially undeveloped and supports large wild life populations both within the system itself and in the adjacent semi-arid areas. Development of the delta for its water resources and recreational potential is inevitable and imminent. Much basic resources data is urgently required to facilitate sound planning.

Other workers have studied ERTS imagery of the delta from a geological and hydrological perspective. The present study has been specifically directed at mapping vegetation types within the delta and generally concerned with finding what information of value to plant and animal ecologists could be extracted from the imagery. To date it has been found that

(i) It is possible to map broad vegetation types from the imagery. This has enabled preparation of a vegetation map of the delta which considerably refines existing maps.

(ii) Imagery of the delta records the state of the system in a manner which will facilitate long-term studies of plant succession.

(iii) Phenological events can be detected. This may allow inferences to be drawn about seasonal movements of animal populations.

(iv) The imagery can be used to detect and map wild fires. This will be useful in determining the role of fire in the ecology of the region.

Using the imagery it is thus possible to map existing vegetation and monitor both short- and long-term changes.

These results have been obtained after a few months of work using only colour composites of the delta and without sophisticated, automated techniques of data extraction and analysis. They demonstrate that ERTS type imagery can be a valuable tool to those responsible for planning and managing the exploitation of natural resources in the developing world.

MONITORING VEGETATION SYSTEMS IN THE GREAT PLAINS WITH ERTS

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ABSTRACT

The Great Plains of the central United States produces over forty percent of the nation's beef and much of the country's grain. The beef industry in this region is a $23 billion operation, which is extremely vulnerable to adverse seasonal or climatic conditions. The stability of the beef and agricultural products industry in the Great Plains is contingent upon decisions made by the 400,000 farm and ranch owners in this region. These private operators need timely information on regional range forage conditions and crop production levels upon which to base their management decisions. This paper reports on an ERTS-1 study of rangelands in the Great Plains that has established the potential for using ERTS-type data to provide quantitative regional vegetative condition information required to support these agricultural operations.

The Great Plains Corridor rangeland project being conducted at Texas A&M University utilizes natural vegetation systems as phenological indicators of seasonal development and climatic effects upon regional growth conditions. The basic task is that of monitoring the vernal advancement and retrogradation of vegetation (green wave effect) throughout the uniform Mixed Prairie Grassland Association extending from south Texas into Canada. The objective of the work is to determine the feasibility of using ERTS-type data to map regional vegetation conditions throughout the growing season for the Great Plains.

The study employs a network of ten test sites in six states extending from south Texas into North Dakota. Ground observations recorded every eighteen days at each site include green biomass, moisture content of vegetation, weather information, etc. ERTS-1 MSS data have been acquired for all sites for four full seasons.

The ERTS-1 MSS data were computer processed for selected areas of each site. Spectral reflectance data were analyzed for each available date for each site. The measurements were corrected for seasonal sun angle differences to permit temporal comparisons. Radiance values recorded in ERTS-1 spectral bands 5 and 7 were used to compute a Band Ratio Parameter which is shown to be correlated with aboveground green biomass and vegetation moisture content.

This research has established a method for obtaining a quantitative measurement of vegetation conditions over broad regions using ERTS-1 MSS data. It is anticipated that this capability will be further developed to provide regional rangeland vegetation condition and growing condition information needed in rangeland management and agri-business activities in the Great Plains.

LAND USE & MAPPING

Chairman, A. Joyce, (ERL)

Co-Chairman, R. Rowley, (JSC)

COMPUTER-IMPLEMENTED LAND USE CLASSIFICATION WITH PATTERN RECOGNITION SOFTWARE AND ERTS DIGITAL DATA

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ABSTRACT

Significant progress has been made in the classification of surface conditions (land uses) with computer-implemented techniques based on the use of ERTS digital data and pattern recognition software. The supervised technique presently used at the NASA Earth Resources Laboratory is based on maximum likelihood ratioing with a digital table look-up approach to classification. After classification, colors are assigned to the various surface conditions (land uses) classified, and the color-coded classification is film recorded on either positive or negative 9 1/2" film at the scale desired. Prints of the film strips are then mosaicked and photographed to produce a land use map in the format desired. Computer extraction of statistical information is performed to show the extent of each surface condition (land use) within any given land unit (e.g. township, county, drainage, etc.) that can be identified in the image. Evaluations of the product indicate that classification accuracy is well within the limits for use by land resource managers and administrators. Classifications performed with digital data acquired during different seasons indicate that the combination of two or more classifications offer even better accuracy. Future emphasis will include adaptation of software to general purpose computers, development of low-cost hardware for image display, and establishment of ground truth logistics for widespread implementation over large areas, e.g. statewide.

REMOTE SENSING OF LAND USE CHANGES IN U.S. METROPOLITAN REGIONS: TECHNIQUES OF ANALYSIS AND OPPORTUNITIES FOR APPLICATION

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ABSTRACT

For a sample of U.S. urban areas we mapped land use during the 1970 census, using high-altitude aircraft color infrared photography. From similar photography in 1972 we analyzed land use change. We are modelling the relationship between intra-urban land use and selected demographic attributes in order to use time series remote sensor data to monitor and interpret urban change. One intermediate product is a prototype looseleaf Atlas of Urban and Regional Change. This contains conventional maps, computer maps, and accompanying statistical data. Its format enables the user to interact with this material, and others, in an application of direct operational concern to him.

This paper, then, outlines the analytical techniques and illustrates intermediate products. Included are land use maps generated at 1:24,000 by direct computer classification of ERTS-1 multispectral data in digital format. Then it mentions applications, many of them in planning. These suggest the need for a multi-stage, multi-date system for monitoring urban and regional environments. In this, the satellite and aircraft sensor platforms, and field survey, play complementary roles. Longer-range gains are likely to be improved understanding by legislators, resource managers, and voters, as to what it is that makes our country tick. Another contribution could be an improved system of intercensal estimates and emergency preparedness – nationally and regionally – including a system for allocating federal revenues to be shared with states and local governments.

Publication of Abstract authorized by Director, U.S. Geological Survey.

ERTS-1 ROLE IN LAND MANAGEMENT AND PLANNING IN MINNESOTA

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ABSTRACT

Research on applications of ERTS-1 imagery to land use has focused on evaluating the ability of ERTS-1 imagery to update and refine the detail of land use information in the Minnesota Land Management Information System. Work has been directed toward defining the capabilities of the ERTS-1 system to provide information about surface cover by identifying water and wetland resources; urban development, agriculture, and forestry; and testing and evaluating data input and output procedures. As capabilities developed meetings were held with administrators and resource information users from various agencies of government to identify their information needs.

A full scale systems test for several selected pilot areas in the state is nearly complete. Users have been identified for each test area and they have been instrumental in identifying data requirements and analysis needs for administrative purposes. Users have both rural and urban orientation and provide the basis for evaluation of results.

INTERACTIVE ANALYSIS AND EVALUATION OF ERTS DATA FOR REGIONAL PLANNING AND URBAN DEVELOPMENT: A LOS ANGELES BASIN CASE STUDY

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ABSTRACT

The progression endemic to the ERTS Data Use Experiment SR 124 in data quality, analysis sophistication and applications responsiveness is reviewed.

The roles of the variety of ERTS products, including the supporting underflight aircraft imagery at various scales, are discussed in the context of this investigation.

The versatility of interpretation techniques and outputs developed and implemented via the General Electric Multispectral Information Extraction Systems in both the prototype laboratory – GEMS – version and the production field – IMAGE 100 – model is described and exemplified by both system-expository and applications-explanatory products.

The wide-ranging and in-depth applications studied in the course of this experiment can be characterized as community-oriented and agency-directed. In the former, generic category, which is primarily data-contentual, problems analyzed dealt with agricultural systems, surface water bodies, snow cover, brush fire, burns, forestry, grass growth, parks – golf courses – cemeteries, dust storms, grading sites, geological features and coastal water structure. The ERTS MSS band selectivity and measurements thresholds were of primary interest here.

The agency-directed application areas have been user-evaluational in nature. Beginning with overall urbanized regional analysis of land cover density-development intensity, residential areas were analyzed for ascertaining if housing types could be aggregated with any degree of reliability. It does appear that with the A-3 configurational U2 imagery for both input preparation and output evaluation, the ERTS CCT data analyzed interactively on the IMAGE 100 yields so-called Level III results of interest in certain on-going user-agency programs that would enable the users to monitor environmental factors using ERTS-IMAGE 100 outputs.

AN EVALUATION OF ERTS-1 IMAGERY FOR ACQUIRING LAND USE DATA OF NORTHERN MEGALOPOLIS

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ABSTRACT

Among the ERTS projects funded by NASA was one of the investigation of land use in northern Megalopolis by the Dartmouth College Project in Remote Sensing. Specifically, the objectives of the investigation were to map and digitize the land use of the northern third of Megalopolis, and to evaluate ERTS as a planning tool.

Working primarily with 1:250,000-scale CIR transparencies an 11-category land use map was compiled by a single interpreter in a three-month period for the states of Massachusetts, Connecticut and Rhode Island. On the basis of this map a computerized land use data base was established which permits both the rapid production of computer maps as well as a variety of statistical manipulations.

It appears from this research that for large area land use mapping (states or groups of states), considerable savings in both dollars and time may be realized using ERTS as opposed to aircraft. As a consequence planners in several of the New England states have expressed an interest in ERTS as a source of land use data. However, their degree of enthusiasm appears inversely proportional to the quality and detail of the land use information at their disposal. State planners possessing little current land use information can visualize an immediate utility for ERTS data, while those with detailed data perceive ERTS more as a tool of future value.

THE VALUE OF ERTS-1 IMAGERY IN RESOURCE INVENTORIZATION ON A NATIONAL SCALE IN SOUTH AFRICA

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ABSTRACT

Evaluation of ERTS imagery for resource inventorization on a national scale was introduced into current programmes of surveys of soil and agricultural land capability, plant ecology, geology and regional land use.

Investigations were mainly based on visual interpretation of 1:1,000,000 scale black and white prints or 1:500,000 false colour photolithographic prints, the latter of which proved to be very informative.

The following significant results were obtained:

Soil and Terrain Mapping

In special cases soil boundaries are well defined. Cultivated land, grazing land and irrigated land can be distinguished. In small scale geomorphological mapping ERTS imagery proved to reduce cost and labour significantly, particularly in dry areas.

Plant Ecological Mapping

Forest, woodland and scrubforest could be distinguished from grassland, parkland and savanna and sometimes further subdivision is possible. Cultivated areas, mismanaged areas, as well as invasive vegetation types and burnt areas can be distinguished.

Geological Mapping

Large scale geologic features are more clearly distinguished than by conventional means. Besides known structures, a number of new lineaments, some of which may be associated with mineralization, have been identified.

Regional Land Use Mapping

ERTS imagery can make a valuable contribution towards accelerating and lowering the cost of land use surveys on a regional and national scale.

The cartographic quality of system corrected MSS imagery was also evaluated.

CHANGE IN LAND USE IN THE PHOENIX (1:250,000) QUADRANGLE, ARIZONA BETWEEN 1970 AND 1973: ERTS AS AN AID IN A NATIONWIDE PROGRAM FOR MAPPING GENERAL LAND USE

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ABSTRACT

Changes in land use between 1970 and 1973 in the Phoenix (1:250,000 scale) Quadrangle in Arizona have been mapped using only the images from ERTS-1, tending to verify the utility of a standard land use classification system proposed for use with ERTS images. ERTS 9 x 9 transparencies, interpreted by several techniques, were used to update a land use map previously compiled with 1970 air photos. Types of changes detected have been (1) new residential development of former cropland and rangeland; (2) new cropland from the desert; and (3) new reservoir fill-up. The seasonal changing of vegetation patterns in ERTS has complemented air photos in delimiting the boundaries of some land use types. Inasmuch as air photos normally are a year or more out of date, ERTS provided currency.

ERTS images, in combination with other sources of information, can assist in mapping the generalized land use of the fifty states by the standard 1:250,000 quadrangles. Several states are already working cooperatively in this type of mapping. This monitoring of land use change can be of value to planners and resource managers at Federal, state, and regional levels, both for resource development and environmental protection in broad areas of the United States. The ERTS images focus attention on those areas requiring more intensive study.

Approved for publication by Director, U. S. Geological Survey.

THE APPLICATION OF ERTS-1 DATA TO THE LAND USE PLANNING PROCESS

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ABSTRACT

The need for the development and implementation of methods for the detection, inventory and monitoring of land use variables is reflected in pending federal and state legislation. ERTS can provide an operational source for many of the significant land use variables at the policy level.

Land use data has been extracted on a percent of cell basis from ERTS imagery, RB-57 color infrared imagery and best available conventional sources for a 10,000 1 km cell test area in southeastern Wisconsin.

First, the data from the three sources is compared on a spatial basis. For those land use variables associated with cover, ERTS derived data compared favorably with both the RB-57 and conventional data. In the case of those variables which change with respect to time and are not regularly monitored by conventional means, the ERTS derived data is superior to conventional data.

Second, the effect of the data source on land use decisions is examined. Three interstate highway corridors are located through the same region based upon data extracted from each of the three sources. A policy of preserving natural environmental systems was used as a basis for the corridors selection in each case. The resulting three corridors compare favorably.

THE UTILITY OF ERTS-1 DATA FOR APPLICATIONS IN LAND USE CLASSIFICATION

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ABSTRACT

A comprehensive study has been undertaken at the Johnson Space Center to determine the extent to which ERTS-1 data could be used to detect, identify (classify), locate and measure current land use over large geographic areas. The land use categories of interest were those proposed in USGS Circular #671. Although the study area included an 18-county area around the City of Houston, the major proportion of the work was accomplished within the area of one ERTS-1 scene.

The investigation utilized conventional image interpretation and computer-aided (spectral pattern recognition) analyses with image products from GSFC, color composite imagery generated at JSC from computer compatible tapes (CCT) and digital processing of the CCT's. Although the emphasis was placed generally on the computer-aided technique, the final result from each technique facilitated comparison between the three for Level I and II land use classification performance.

It was concluded that:

- ERTS-1 MSS data can be used to detect, identify, locate, and measure many of the features of interest in a Level I and II land use classification.
- The utility of the information extracted from ERTS-1 MSS data is likely to be greatest for large area applications.
- All three techniques used in this study resulted in an acceptable Level I classification (slightly modified from Circular #671) at publication scales of 1:250,000 and smaller.
- Level I and II land use classification can be provided by automatic data processing, if the categories in Circular #671 are modified slightly.
- Level II automatic land use classification is hampered by the spectral similarity between certain urban and nonurban feature picture elements. Improved results can be achieved by classifying urban features separate from the nonurban.

PRACTICAL APPLICATIONS OF THE USE OF ERTS-1 SATELLITE IMAGERY FOR LAND USE MAPPING AND RESOURCE INVENTORIES IN THE CENTRAL COASTAL REGION OF CALIFORNIA

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ABSTRACT

The Geography Remote Sensing Unit (GRSU), University of California has shown the ERTS-1 Satellite to be a useful tool for generating timely and accurate maps of land use and other terrain characteristics including landforms, hydrology, and natural vegetation. Using multidate, multiband ERTS data, the GRSU was able to construct data base maps of these phenomena for the entire 52,213 square kilometer Central California Test Area. In all cases ERTS imagery provided an excellent mapping base and allowed for relatively accurate boundary delineation of different phenomena. However, in most cases, especially in the case of vegetation mapping, the use of selected conventional high altitude photographs and/or ground truth were needed to accurately identify the areas that had been mapped. In almost all cases the use of more than one spectral band and of multidate images increased interpretation accuracies considerably.

Apart from the actual completion of the test area data base, other significant results include: 1) the ability to map the location and areal extent of kelp along California's coast; 2) the ability to rapidly assess fire damage; 3) accurate estimation of the total area of irrigated agricultural land; and, 4) delineation of areas of perched water tables and areas of excessive soil salinity. At present, data on the total acreage of irrigated agricultural land and the location of areas of perched water tables is currently being supplied to the Kern County Water Agency for use in predicting water demand and supply for 15 water districts in Kern County.

EVALUATION OF ERTS-1 IMAGERY FOR LAND USE/RESOURCE INVENTORY INFORMATION

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ABSTRACT

The objective of this investigation was to develop a low cost, manual technique for enhancing ERTS-1 imagery and preparing it in suitable format for use by users with wide and varied interests related to land use and natural resources information. The goals of the project were: to develop enhancement techniques based on concepts and practices extant in photographic sciences, to provide a means of allowing productive interpretation of the imagery by manual means, to produce a product at low cost, to provide a product that would have wide applications, and one compatible with existing information systems.

Through the use of photography techniques standardization of the 70mm film chip received from NASA is achieved. A subtractive color process is employed to produce step enlargements of the 1:3,300,000 images to scales up to 1:66,000. Diazo transparencies are then produced in magenta, cyan, and yellow for each of the four MSS bands.

Data retrieval can be achieved from any of many thousands of diazo color combinations. Each color diazo combination can provide a unique kind of information. Direct map transfer is readily accomplished at the scale of 1:250,000 and larger. Enlargement to much larger scales (1:50,000 to as large as 1:10,00) is feasible with quality overhead projectors.

Cost of preparation of the photographically enhanced, enlarged negatives and positives and the diazo materials is about 1¢ per square mile. Cost of creating and mapping a land use classification of twelve use types at a scale of 1:250,000 is only $1 per square mile. The product is understood by users, is economical, and is compatible with existing information systems. Hard copy mylar maps for reproduction are produced, from which information for computer manipulation is prepared. Many user applications of this system are already in use.

IMPACT OF ERTS-1 IMAGES ON MANAGEMENT OF NEW JERSEY'S COASTAL ZONE

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ABSTRACT

The thrust of New Jersey's ERTS investigation is development of procedures for operational use of ERTS-1 data by the Department of Environmental Protection (DEP) in the management of the State's coastal zone. Four major areas of concern were investigated: detection of land use changes in the coastal zone; monitoring of offshore waste disposal; siting of ocean outfalls; and allocation of funds for shore protection. The relative utility of ERTS and aircraft imagery for each problem area was studied.

ERTS imagery was not useful for shore protection purposes; it was of limited practical value in the evaluation of offshore waste disposal and ocean outfall siting. However, ERTS imagery shows great promise for operational detection of land use changes in the coastal zone.

Some constraints for practical change detection have been identified. To refine these constraints, DEP inspectors must receive ERTS information products in a timely fashion. Procedures to accomplish this are being discussed with NASA. The Department of Environmental Protection has recommended that $50,000 be included in New Jersey's FY'75 budget for further development of this application.

CARETS: AN EXPERIMENTAL REGIONAL INFORMATION SYSTEM USING ERTS DATA

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ABSTRACT

The U.S. Geological Survey CARETS (Central Atlantic Regional Ecological Test Site)/ ERTS investigation is testing the applicability of ERTS data as input to an environmental information system for a multi-state mid-Atlantic region surrounding the Chesapeake and Delaware Bays. The "information system" framework encompasses a flow of information through several stages from sensor to user, and involving evaluation and feedback from several potential users. Basic assumptions of the CARETS project model are that there is a measurable environmental impact associated with land use and land use change as determined with remote sensor data, and that the ERTS-derived land use data sets, when properly calibrated, may thus provide regional planners and administrators with a shortcut to an understanding of the environmental changes that are going on in their regions.

Mid-way through the investigation, data sets on land use from both aircraft and ERTS sources have been compiled for the 73,000 km^2 area of the test region. These data sets are being prepared for user evaluation in both graphic and digital form, and a variety of area measurement and accuracy computations are being performed to assist in evaluating the ERTS and aircraft data as aids in the planning process. Key to the operation of the CARETS information system is a central "polygon" type map processing capability, which enables quantitative comparisons of land use data derived from ERTS with other environmental and socio-economic data sets. Overlays have been prepared to allow geological, hydrological, and census data to be merged with the remote sensing data for the test region. System tests indicate a fair correspondence between ERTS and aircraft-derived land use data sets. Preliminary user response from planning agencies in Maryland and Virginia indicates several potential uses of the system. Problems remain in developing practical means of achieving the full flexibility in scale or level of aggregation inherently capable with the remote sensing data.

Publication authorized by the Director, U.S. Geological Survey.

CONCEPTS OF INTEGRATED SATELLITE SURVEYS BY DEVELOPING COUNTRIES

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ABSTRACT

FAO initially contracted with NASA to carry out investigations in three countries; but, now as a result of rapidly increasing interest, ERTS imagery has been/is being used in 11 additional projects related to agriculture, forestry, land-use, soils, land forms and hydrology. Initially the ERTS frames were simply used to provide a synoptic view of a large area of a developing country as a basis to regional surveys. From this, interest has extended to using reconstituted false colour imagery and latterly, in co-operation with Purdue University, the use of computer generated false colour mosaics and computer generated large scale maps. As many developing countries are inadequately mapped and frequently rely on outdated maps, the ERTS imagery is considered to provide a very wide spectrum of valuable data. Thematic maps can be readily prepared at a scale of 1:250,000 using standard NASA imagery. These provide coverage of areas not previously mapped and provide supplementary information and enable existing maps to be up-dated. There is also increasing evidence that ERTS imagery is useful for temporal studies and for providing a new dimension in integrated surveys.

Looking towards the future, ERTS imagery or equivalent imagery is seen as providing developing countries with relatively inexpensive information as a basis to regional surveys, management surveys and local and regional planning activities.

TOWARDS AN OPERATIONAL ERTS

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ABSTRACT

ERTS-1 has demonstrated the feasibility and practicality of an Earth sensing electronic transmission polar orbit satellite system. The next step is to justify and define an operational ERTS system. Cartographic aspects are fundamental and must be fully explored and resolved before the operational system is defined. At this time no technical obstacles are known to exist that preclude resolution of these aspects. Indications are that an ERTS type satellite can be defined and flown in a mode from which cartographic products can be efficiently produced in a timely and perhaps automated manner. Applying cartographic requirements is not for the sole benefit of the map maker. All who will use ERTS for quantitative analysis, change detection, or other applications which involve the spatial domain and the figure of the Earth, will find the cartographic requirements to be of value if not essential.

EARTH RESOURCES TECHNOLOGY SATELLITE DATA COLLECTION PROJECT, ERTS – BOLIVIA

Carlos Brockmann, *Geological Survey of Bolivia, La Paz, Bolivia*

ABSTRACT

The Earth Resources Technology Satellite program of Bolivia, under the direction of the Geological Survey, has developed a multidisciplinary project to carry out investigations in cartography and to prepare various thematic maps.

In cartography, investigations are being carried out with the ERTS-1 images and with existing maps, to determine their application to the preparation of new cartographic products on one hand and on the other to map those regions where the cartography is still deficient. The application of the MSS images to the geological mapping has given more than satisfactory results. Working with conventional photointerpretation, we were able to prepare regional geological maps, tectonic maps, studies relative to mining, geomorphological maps, studies relative to petroleum exploration, volcanological maps and maps of hydrologic basins. In agriculture, the ERTS images are used to study land classification and forest mapping.

For the formation studies, we use the ERTS imaging process in black and white and in color, with Diazo film on a 23 x 23 cm format. We obtain 40% more information from the color film than from the corresponding black and white.

MINERAL RESOURCES, GEOLOGICAL STRUCTURE, AND LANDFORM SURVEYS

Chairman, N. Short, (GSFC)

Co-Chairman, P. Lowman, (GSFC)

APPLICATION OF THE ERTS SYSTEM TO THE STUDY OF WYOMING RESOURCES WITH EMPHASIS ON THE USE OF BASIC DATA PRODUCTS

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ABSTRACT

Many potential users (for example, consultants, small companies and independent geologists) of ERTS data products and other aircraft and satellite imagery are limited to visual methods of analyses of these products. Illustrations are presented from Wyoming studies that have employed these standard data products for a variety of geologic and related studies. Possible economic applications of these studies are summarized. Studies include regional geologic mapping for updating and correcting existing maps and as an educational tool; illustrations of the value of seasonal images in geologic mapping; specialized mapping of such features as sand dunes, playa lakes, lineaments, glacial features, regional facies changes, and their possible economic value; and multilevel sensing as an aid in mineral exploration. Examples of cooperative studies between botanists, plant scientists, and geologists for the preparation of maps of surface resources that can be used by planners and for environmental impact studies are given. Emphasis is placed on the use of these maps in areas, such as the Powder River Basin of Wyoming, facing critical environmental problems that will result from the development of energy resources.

These various studies illustrate that certain user requirements can be satisfactorily met with ERTS alone, but that others require higher cost (to the user) aircraft and ground data or special data enhancement techniques. Perhaps the key point, however, is that the ERTS system has given us both complete and sequential regional coverage at a crucial time in our effort to assess the effects of resource development.

THE EVOLUTION OF AN INTEGRATED ERTS-1 PROJECT AND ITS RESULTS AT THE MISSOURI GEOLOGICAL SURVEY*

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ABSTRACT

The aims of the Missouri Geological Survey ERTS-1 project have shifted significantly since its original inception. Initially, the non-funded study was to evaluate from ERTS imagery environmental and geologic engineering parameters along the St. Louis to Kansas City Corridor. However, normal work loads took precedence and problems developed in budgeting time. Though the corridor study suffered, utilization of both ERTS-1 imagery and NASA supplied aerial photography in on-going programs resulted in a statewide inventory of ERTS ground patterns and reports on specific areas.

Use of the imagery involves the recognition and interpretation of various ground patterns. Analysis and application are tied to on-going programs. Specific studies utilizing the imagery and NASA aircraft photography are: a statewide lake and reservoir inventory; assessment of flooding and floodprone areas along the Missouri portion of the Mississippi and Missouri Rivers; land-use classification for several counties; structural elements in selected areas; and Pleistocene features in northern Missouri.

Features identified are: geomorphic, stratigraphic and pedologic boundaries; linear, arcuate and circular traces that coincide with or are suspected to be related to structural trends and Pleistocene glacial features; flood patterns; and to a limited extent land-use.

Study of the imagery has been restricted to visual examination of the as-received bulk product and false color diazochrome transparencies. While it might be considered that repetitive coverage is not a necessity for geologic studies, it is this feature along with the synoptic view of large portions of the State that in themselves provided the principal enhancements and potential for the utilization of the ERTS imagery.

In Missouri, the ERTS-1 imagery has proved to be a valuable reconnaissance tool for geologic investigations. As a result, other State agencies (forestry, agricultural and planning) have expressed interest in its potential application to their studies.

*Publication authorized by the State Geologist, Missouri Geological Survey

GEOLOGIC APPLICATION OF ERTS IMAGERY IN ALASKA

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ABSTRACT

New mineral deposits have recently been discovered in eastern Alaska through application of a hypothesis very similar to one developed in interpretation of Nimbus and ERTS imagery in this investigation, that mineral deposits may be spatially related to a set of crustal linears. The discovery affirms the validity of this hypothesis and provides an additional exploration rationale to the mineral industry. Mosaics of ERTS images have provided additional data on this regional linear set and on other regional fault trends possibly related to mineralized areas.

A regional lineation in lakes near Umiat in northern Alaska, suspected to reflect structures in basement and suggesting areas of possible potential for new petroleum exploration, is found to cover a much larger area than previously suspected east of the Colville River, increasing the area of interest.

Further application of this same imagery exists in that environmental scars to the tundra resulting from previous ground exploration, if of large size, can be recognized and their natural revegetation monitored by use of ERTS imagery.

New geologic data obtained from ERTS images of lowland areas of western northern Alaska facilitates assessing the petroleum potential of this area. Use of the images in field mapping this summer permitted extrapolation of field observations.

THE INFLUENCE OF SEASONAL FACTORS ON THE RECOGNITION OF SURFACE LITHOLOGIES FROM ERTS-IMAGERY OF THE WESTERN TRANSVAAL

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ABSTRACT

The value to geological studies of repetitive ERTS-imagery was investigated by comparing two images gathered during different seasons over an area in the Western Transvaal Province of the Republic of South Africa.

The first of the two images (1050-07355) was gathered on September 11, 1972, coinciding with the end of the dry winter season. The second image (1158-07363) was obtained in the middle of the summer rainfall season on December 28, 1972.

A comparison of the two images reveals striking differences in the amount of recognizable geological detail. The most pronounced difference is the marked enhancement on the December image of tonal variations associated with individual surface lithologies. This contrast in tonal values is evident in all four spectral bands, through particular bands emphasize individual lithologies more clearly than others. Basic igneous rocks of the Bushveld Complex, for instance, are most clearly defined on bands 6 and 7, while certain areas underlain by granite are distinguishable only on band 4.

Tonal variations on the September image permit recognition of the major lithological units to a degree which is slightly inferior to that displayed by a 1:1,000,000 scale geological map. The very marked tonal differences displayed by the December image, however, permit recognition of detailed lithological units compatible with published geological maps at 1:250,000 scale. In addition, this image reveals the presence of distinct stratigraphic subdivisions within the previously undifferentiated Dolomite Series of the Transvaal System.

The differences exhibited by the two images clearly demonstrate the importance of repetitive ERTS coverage in geological investigations, particularly in areas of marked seasonal variations. In the present case variations in soil moisture content appear to constitute the most important single factor exerting an influence on the tonal characteristic of different surface lithologies and consequently on the ease of recognition of such lithololies. Under different conditions, however,other seasonal factors may be of equal or greater importance.

STRATIGRAPHIC SUBDIVISION OF THE TRANSVAAL DOLOMITE FROM ERTS IMAGERY

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ABSTRACT

ERTS imagery has permitted the recognition of broad stratigraphic subdivisions in the previously undifferentiated Transvaal Dolomite of the Western Transvaal Providence, Republic of South Africa.

While detailed field mapping in areas of good outcrop, as well as borehole logging has recently led to the recognition of a stratigraphy in the Transvaal Dolomite of the Central Transvaal, poor outcrop conditions in the Western Transvaal have to date prevented this. The ERTS-imagery, however, clearly reveals the presence of six, and in the far west seven, distinct stratigraphic zones extending along strike for a distance of at least 100 km. Ground truth gathered along a number of traverses, again selected on the basis of ERTS imagery, identified these zones as corresponding to alternating units of dark-grey, chert-poor and light-grey relatively chert-rich carbonates. With an appreciation of the defined stratigraphy of the Central Transvaal, the detailed geology mapped along the traverses was readily related to the zones evident on the imagery, extending the established stratigraphic subdivision of the carbonate sequence over an area of some 4,000 sq. km.

The investigation clearly demonstrates the potential applications of ERTS-imagery in geological studies, even in areas where the geology is supposedly well known.

AN INVESTIGATION OF MAJOR SAND SEAS IN DESERT AREAS THROUGHOUT THE WORLD

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ABSTRACT

This study of sand seas on a global scale consists of identifying and measuring characteristic sand forms, examining structures, determining the processes involved, and ascertaining the world distribution of various types of sand bodies. ERTS imagery has the advantages of permitting (1) direct comparison of areas because the same scale prevails on all images, (2) ready observation of relationships to surrounding features, and (3) recognition of major trends or lineations where minor details are obscured.

Fifteen major areas or sites in the Eastern Hemisphere and three sites in the Western Hemisphere have been examined to date. For each area, mosaics of false-color prints showing sand patterns have been prepared and these mosaics form a base map for all subsequent types of study.

Many attempts have been made in the past to classify sand bodies and assign names, but the studies have been mostly local in scope, and classification has been based in part on supposed genesis. In this study an attempt is made to develop a strictly objective classification of worldwide application. The principal types recognized are (1) parallel straight or linear, (2) parallel wavy or crescentic, (3) star or radial, (4) parabolic or U-shaped, and (5) sheet or stringer types. Numerous variations of each group are also recognized.

Principal controlling factors in forming the various types of sand bodies are believed to be wind direction and strength, topography, vegetation, moisture, available sediment, and distance from source. Efforts to recognize and delineate these factors for specific areas are being made and methods of illustrating the relationships on transparent overlays are being developed. Ground truth investigations to determine internal structures of sand masses also are under way.

Ultimate objectives of this study are threefold. First, a better understanding of stratification in ancient rocks of dune origin; such structures are important in the migration of water and oil. Second, a further insight into the controls of sand migration that in some areas adversely affects various enterprises of man may be obtained. Finally, an appreciation of certain similar patterns on Mars, apparently wind-formed, may result.

A NEW METHOD FOR MONITORING GLOBAL VOLCANIC ACTIVITY

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ABSTRACT

The ERTS Data Collection System has made it possible for the first time to collect significant data on the level of activity at widely separated volcanoes and relay these data nearly instantaneously to one central office for analysis by a small group of specialists. This new capability opens a new era in volcanology where the hundreds of normally quiescent but potentially dangerous valcanoes near populous regions around the world can be economically and reliably monitored daily to warn when any one volcano is becoming active again.

A prototype volcano surveillance system was established during the latter part of 1972 and early 1973 on 15 volcanoes in Alaska, Hawaii, Washington, California, Iceland, Guatemala, El Salvador, and Nicaragua. Nineteen seismic detectors that count four different sizes of earthquakes and six biaxial, borehole tiltmeters that measure ground tilt with a resolution of 1 microradian have been installed. Data from these instruments are relayed through the ERTS satellite and through a teletype link to the U. S. Geological Survey Office in Menlo Park for rapid analysis. Only seismic and tilt data are collected because these have been shown in the past to indicate most reliably the level of volcanic activity and these can be measured relatively easily with new instrumentation. Experience during this project demonstrates the feasibility of building inexpensive, low power, reliable instruments that can be installed in remote locations by most technicians and can be expected to run unattended for a few years.

Comparison of the data from these new earthquake counters with data from nearby standard seismometers show that the counters do normally indicate the level of seismic activity. During periods of high seismic background noise there may be a significant number of spurious counts but the existence and duration of such noisy periods are reliably indicated by other data sent by the earthquake counters. The only eruption to occur to date on any of the volcanoes under study was preceded by an abnormally large swarm of earthquakes several days before.

This work demonstrates the technical feasibility of a global volcano surveillance system but many details in the design of reliable instruments still need to be worked out. The primary effort in the future, however, needs to be the collection and analysis of data from these different volcanoes to establish clearly the scientific feasibility of this novel and potentially revolutionary approach to the surveillance of hazardous volcanoes.

EVALUATION OF ERTS IMAGERY FOR SPECTRAL GEOLOGICAL MAPPING IN DIVERSE TERRANES OF NEW YORK STATE

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ABSTRACT

Linear anomalies dominate the new geological information derived from ERTS-1 imagery, total lengths now exceeding 6000 km. Experimentation with a variety of viewing techniques suggests that conventional photogeologic analyses of band 7 results in the location of more than 97 percent of all linears found. Bedrock lithologic types are distinguishable only where they are topographically expressed or govern land-use signatures. The maxima on rose diagrams for ERTS-1 anomalies correspond well with those for mapped faults and topographic lineaments, despite a difference in relative magnitudes of maxima thought due to solar illumination direction. A multiscale analysis of linears showed that single topographic linears at 1:2,500,000 became segmented at 1:1,000,000, aligned zones of shorter parallel, en echelon, or conjugate linears at 1:500,000, and still shorter linears lacking obvious alignment at 1:250,000. Most circular features found were explained away by U-2 airphoto analysis but several remain as anomalies, the most notable being an elliptical "spoked wheel" anomaly which centers on Cranberry Lake. Neither shatter cones nor megabreccias have been found to date.

Visible glacial features include individual drumlins, best seen in winter imagery, drumlinoids, eskers, ice-marginal drainage channels, glacial lake shorelines and sand plains, and end moraines.

APPLICATION OF ERTS TO GEOLOGIC PROBLEMS ON THE COLORADO PLATEAU, ARIZONA

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ABSTRACT

Three areas in central and northern Arizona centered on the 1) Shivwits Plateau, 2) Coconino Plateau, and 3) Verde Valley were studied using ERTS photography. Image enhancement techniques were developed to extract the most useful subsets from the digital tape images in each area. The value of color combined ratio images for geologic mapping was tested. Extensive new field mapping was completed on the Shivwits and Coconino Plateaus.

Useful applications results include: 1) Upgrading of existing 1:62,500 geologic maps of the Verde Valley region; 2) Detection of long NW trending lineaments in the basalt cap SE of Flagstaff which may be favorable locations for drilling for new water supplies; 3) Tracing of the Bright Angel and Butte faults to twice their previously known length and correlating the extensions with modern seismic events, showing these faults to be present-day earthquake hazards; 4) Discovering and successfully drilling perched sandstone aquifers in the Kaibab limestone on the Coconino Plateau; 5) Determining the relationship between the Shivwits lavas and the formation of the lower Grand Canyon and showing that the lavas should be an excellent aquifer, as yet untapped.

ERTS-1, EARTHQUAKES, AND TECTONIC EVOLUTION IN ALASKA

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ABSTRACT

In comparing seismicity patterns in Alaska with ERTS-1 imagery, one is struck by the frequency with which earthquake epicenters fall on, or near, lineaments visible on the imagery. Often these lineaments prove to be tectonic faults which have been mapped in the field. But equally as often, existing geologic and tectonic maps show no evidence of these features. The remoteness and inaccesibility of most of Alaska is responsible, in large part, for the inadequacy of the mapping. ERTS-1 imagery is filling a vital need in providing much of the missing information, and is pointing out many areas of potential earthquake hazard.

Earthquakes in central and south-central Alaska result when the northeastern corner of the north Pacific lithospheric plate (roughly enclosed by the great bend in the Alaska Range near Mt. McKinley) underthrusts the continent. North of Mt. McKinley, the seismicity is continental in nature and of shallow origin, with earthquakes occurring on lineaments, and frequently at intersections of lineaments. South of Mt. McKinley, the seismicity is generally deeper and is associated with the subduction of the Pacific plate. The shallower events, however, still tend to align themselves with lineaments visible on the imagery. These two areas are separated by the Denali fault.

Offset along the Denali fault has long been a matter of conjecture. Cooperative studies involving radiometric dating, geologic mapping, and use of ERTS-1 imagery have now provided the first firm evidence of the magnitude of this offset (Turner, Smith and Forbes, 1974). In south-central Alaska, a prominent lineament which is truncated by the Denali fault separates K-Ar dated metamorphics of mid- and latest-Cretaceous ages. In Yukon Territory near Kluane Lake, another strong lineament on the opposite (north) side of the Denali fault separates metamorphics of mid-Cretaceous age from igneous and metamorphic rocks yielding 57 m.y. dates. This lineament is also truncated by the Denali fault. Both lineaments intersect the Denali at the same angle. Turner et al. believe that these lineaments were once contiguous, indicating that the total amount of right-lateral offset along the Denali fault since the early Cretaceous is about 400 km.

Reference: D. L. Turner, T. E. Smith and R. B. Forbes, Geochronology of offset along the Denali fault system in Alaska, Geol. Soc. Amer., Cordilleran Section Ann. Mtg., Program Abstracts, 1974 (In press).

STRUCTURAL INVESTIGATIONS IN THE MASSIF-CENTRAL – FRANCE –

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ABSTRACT

One survey we have realized using ERTS imagery concerns the French "Massif-Central" – where crystalline and volcanic rocks are outcropping – and its sedimentary surrounding, "Bassin de Paris," "Bassin d'Aquitaine" and Rhodanian valley.

The main purpose was to map with objectivity fracturing and to survey its relationship with known ore deposits. Then – eventually, to draw up a mineral research philosophy. During this survey we have stated ERTS imagery ability to outline lithology in some sedimentary basins. On an other hand, in basement area – under temperature climate conditions – lithology is rarely expressed. These observations can be related with the fact that band 5 gives excellent results above sedimentary basins in France and generally band 7 is the most useful in basement area.

Several examples clearly show the ERTS interest in mapping linear features and circular structures and confirm formed ideas. All the main fractures are identified (few are not) – new ones were found both in sedimentary and basement areas – . Other interesting findings concern sun elevation which – stereoscopic effect being not possible – simulates relief on a better way in some conditions. We also found band 4, judged until now unuseful by geologists, can eliminate artificial details product by shadow of linear clouds (jet stream for instance, invisible on other bands).

At least this paper wants to point out the fact ERTS images are a very useful tool but it will need some more time to prove its validity because discovered details now have to be carefully surveyed.

STRUCTURAL GEOLOGY OF THE NORTHERN SECTOR OF THE AFRICAN RIFT SYSTEM: NEW DATA FROM ERTS IMAGERY

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ABSTRACT

Geological knowledge of the African rift system is confirmed, amplified and extended from interpretation of ERTS imagery. Mapping of lithological and structural units in Yemen can be greatly extended from present data based on sparse ground traverses. The Eastern Rift structures in Kenya, well mapped by the Kenya geological survey, are shown to project NNE-wards from the southern Lake Rudolf basin directly towards the main Ethiopian rift, and do not pass via the Lake Stefanie graben. ERTS imagery shows that the importance of en-echelon structures in the Eastern Rift has been overemphasized from ground reconnaissances. The Western Rift of Africa is shown not to extend NE-wards beyond the Aswa mylonite zone in southern Sudan. In Ethiopia, the ERTS imagery reveals previously unsuspected calderas, local graben, lava fields and glaciated valleys, and enables an enormous improvement to be made over existing geological maps.

TECTONIC ANALYSIS OF EAST AND SOUTH EAST IRAN USING ERTS-1 IMAGERY

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ABSTRACT

Based on a tectonic study using 1:1,000,000 ERTS-1, MSS Band 7 photomosaic covering an area of approximately 500,000 sq. kms. of East and South East Iran, several tectonic units, and many new faults along previously recognized fault trends, were identified.

Furthermore, detailed tectonic interpretations were also carried out over selected areas, and different tectonic styles were recognized.

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MINERAL EXPLORATION WITH ERTS IMAGERY

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ABSTRACT

Ten potential target areas for metallic mineral exploration were selected on the basis of a photo-lineament interpretation of the ERTS image 1172-17141 in central Colorado. Of the ten target areas selected, five included the following mineral districts: the Breckenridge district, the Leadville, Climax, Alma area, and the Tomichi, Bonanza and Cripple Creek districts. An evaluation of bias indicated that prior geologic knowledge of the region had little, if any, affect on target selection. In addition, a contoured plot of the frequency of photo-linear intersections was made to determine what relationships exist between the photo-linears and the location of mineral districts. Comparison of this plot with a plot of the mineral districts indicated that areas with a high frequency of intersections commonly coincide with known mineral districts. The results of this experiment suggest that photo-linears on ERTS imagery are real features and that their location and distribution may be a guide to metallic mineral deposits in Colorado, and probably other areas as well.

ERTS-1 IMAGERY AS AN AID TO THE UNDERSTANDING OF THE REGIONAL SETTING OF BASE METAL DEPOSITS IN THE NORTH WEST CAPE PROVIDENCE, SOUTH AFRICA

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ABSTRACT

A number of base metal finds have recently focussed attention on the North-Western Cape Province of South Africa as an area of great potential mineral wealth. Extensive exploration programs were initiated by many organizations, but were hampered by the fact that the area is geologically unsurveyed. In fact, available geological maps cover only a strip of country along the south bank of the Orange river, and areas to the west and south of the Springbok-Okiep copper mining region.

From the point of view of competitive mineral exploration it was essential that an insight into the regional geological controls of the base metal mineralization of the area be obtained as rapidly as possible. Conventional methods of producing a suitable regional geological map were considered to be too time-consuming and ERTS-1 imagery was consequently examined.

This imagery has made a significant contribution in the compilation of a suitable map on which to base further mineral exploration programs. Major structural features, including folds, faults and lineaments, as well as the lateral extent of various important stratigraphic units, are clearly discernible on the available images. Important new data have come to light even in areas where published maps are available. Interpretation has been greatly facilitated by the virtual lack of vegetation in the area and the fact that significant marker beds generally form resistant ridges. In some instances older stratigraphic trends can be deciphered through thin flat lying younger cover sequences.

Reconnaissance field work prior to interpretation, aimed at the identification of major rock units and other conspicuous features seen on the images, was found to be important. In addition a more detailed map was produced by identifying less obvious features on the images from a light aircraft flying at an altitude of approximately 2,000 m above ground level.

The time involved in the compilation of these maps was found to be only a fraction of that necessary for the production of similar maps using other methods. ERTS imagery is therefore considered to be invaluable in producing accurate regional maps in areas where little or no geological data are available, or in areas of poor access. Furthermore the potential of these images in defining the regional extent of metallogenic provinces is enormous.

MAPPING OF HYDROTHERMAL ALTERNATION ZONES AND REGIONAL ROCK TYPES USING COMPUTER ENHANCED ERTS MSS IMAGES

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ABSTRACT

A combination of digital computer processing and color compositing of ERTS MSS images has been used to map hydrothermal alternation zones and regional rock types in south-central Nevada. The technique is based on enhancement of subtle visible and near infrared reflectivity differences between mineralogically dissimilar rocks, especially unaltered and altered rocks. MSS spectral bands are ratioed, pixel by pixel, in the computer and subsequently stretched. These ratio values are used to produce a new black and white image which shows the subtle spectral reflectivity differences. Additional enhancement is achieved by preparing color composites of two or more stretched ratio images.

The choice of MSS bands for rationing depends on the spectral reflectance properties of the rocks to be discriminated. For south-central Nevada, the most effective composite for detecting the alternation zones and for discriminating the rock types was prepared using the following color and stretched ratio image combination; blue for 0.5-0.6/0.6-0.7 μm; yellow for 0.6-0.7/0.7-0.8 μm; and magenta for 0.7-0.8/0.8-1.1 μm. Altered areas appear green to brown and show a pronounced correlation with known mineralized areas. These altered areas are not apparent on the individual MSS images, color IR composites images, or SKYLAB S190A color photographs. Silicic volcanic and intrusive rocks are mapped as a single rock type on the color ratio composite; some of these rocks have large intrinsic albedo differences, which commonly prevents their discrimination from mafic rocks in the other types of images.

Although this technique is in the initial stage of development and is untested in other areas, it already appears to have considerable potential for targeting mineral prospects and for regional geologic mapping.

AN EVALUATION OF THE SUITABILITY OF ERTS DATA FOR THE PURPOSES OF PETROLEUM EXPLORATION

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ABSTRACT

Study of ERTS-1 data covering the extensively studied Anadarko Basin of Oklahoma and Texas has shown the ERTS system to be an excellent tool for the purposes of petroleum exploration. Types of information derived from ERTS data that are useful for petroleum exploration include: a vast quantity of information on linear features; general lithologic distribution; identification of several types of anomalous features of petroleum exploration interest; details of structures controlling hydrocarbon accumulation in some areas; and the overall structural relationships, many of the major internal structural features and the regional context of the exploration province as a whole.

Preliminary analysis indicates that the use of ERTS imagery can substantially reduce the cost of regional petroleum exploration in relatively unexplored areas.

The experiment relied heavily on standard manual photointerpretation techniques, but included various types of optically and digitally enhanced imagery. ERTS-1 Multispectral Scanner imagery was used in the form of transparencies and paper prints at scales of 1:1,000,000 and 1:250,000.

PRELIMINARY ROAD ALINEMENT THROUGH THE GREAT KAVIR IN IRAN BY REPETITIVE ERTS-1 COVERAGE

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ABSTRACT

The Great Kavir in north central Iran is an extensive elevated peneplain composed of intricately folded Miocene and Pliocene sediments which are rich in evaporites. Interfingering within the peneplain surface are salt-encrusted depressions which occupy 37 percent of the area of the Great Kavir. The salt, derived from the evaporites, has no bearing strength through most of the year when it is saturated; it may form rough surfaces that are unstable.

Access to the Great Kavir is generally limited to the period August through October when some salt crusts will support limited vehicular movement. The condition of the salt crusts and their parent sediments during the long wet season have been unknown. This absence of information about the surface of the Great Kavir has prevented an intensive study of a possible road alinement which could shorten the present route between northern and central Iran by 760 km.

False color diazo composites of bands 4, 5, and 7 were prepared from positives of ERTS-1 MSS images taken of the Great Kavir on September 2 and 20, 1972; December 19, 1972; February 11, 1973; March 1, 1973; and May 12, 1973. These scenes presented a record of the seasonal hydrologic changes that occurred from the dry to the wet season. During the period of maximum inundation and lowest bearing strengths, as inferred from the image of May 12, 1973, it was possible to select a preliminary road alinement that would avoid the wettest or roughest areas and take advantage of the best terrain and shortest distance. The eventual road alinement should be based on a longer record of observation and on-site investigations.

RELATIONSHIP OF ROOF FALLS IN UNDERGROUND COAL MINES TO FRACTURES MAPPED ON ERTS-1 IMAGERY

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ABSTRACT

The primary objectives of this project are to:

1. Evaluate the utility of ERTS and aircraft imagery for fracture mapping in glacial drift covered areas,
2. Map fractures in the coal mining area in southwestern Indiana,
3. Demonstrate the extent which fractures coincide with known roof falls, and
4. Predict and delimit hazardous areas for underground mining.

ERTS imagery is of unique value for mapping of certain fractures that are not identifiable on aircraft imagery. Many such fractures have been mapped in western Indiana and eastern Illinois.

Fractures were also mapped using color infrared aircraft imagery (scale 1:120,000) and it was found that aircraft and ERTS imagery complement each other in that fractures were mapped on each type of imagery that were not found on the other. From these data and measurements in strip mine highwalls, a fracture map was produced for southwestern Indiana.

From the fracture data mapped, an underground mine hazard's map was produced for the Kings Station Mine in Gibson County, Indiana, which is operating in an area where fractures are common. In discussions with the mine operator, most roof falls reported were located in areas where mapped fractures are closely spaced and intersecting. A high correlation was indicated for predicted hazard zones and actual roof falls. Using this information as a basis for extrapolation, roof fall hazard maps were prepared for other mine sites.

This technique needs to be developed further utilizing information from several underground coal mines in different coal basins.

A STUDY OF THE TEMPORAL CHANGES RECORDED BY ERTS AND THEIR GEOLOGICAL SIGNIFICANCE

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ABSTRACT

The temporal changes that are recorded by ERTS were evaluated for an area around Bathurst Inlet in the North West Territories. The seasons represented by the images included: early winter, spring, early summer, and fall.

Numerous surface characteristics (vegetation, drainage patterns, surface texture, lineament systems and topographic relief, etc.) were used to relate the change in observable features with the different seasons.

It was found that the time of year when an observation is made has a strong control over the amount and type of information that can be derived by an experienced interpreter.

An example of this type of seasonal control over observables is the fact that on the winter images one can see an extensive hummocky morainal deposit and much bedrock structure which cannot be seen, or not as easily so, on the summer image. In a similar fashion one can see on the summer image a vegetation pattern which may be related to the distribution of lacustrine and marine clay deposits. Such a vegetation pattern is of course covered during the arctic winter. Many other such examples of temporal changes were recorded in the study.

It is therefore concluded that a detailed study of temporal changes is an important part of any ERTS interpretation for geology.

WATER RESOURCES

Chairman, V. Salomonson, (GSFC)

Co-Chairman, R. Clemence, (JSC)

MAPPING SNOW EXTENT IN THE SALT-VERDE WATERSHED AND THE SOUTHERN SIERRA NEVADA USING ERTS IMAGERY

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ABSTRACT

In much of the western United States a large part of the utilized water comes from accumulated mountain snowpacks. The snowmelt runoff is used for irrigation, industrial production, power generation, public consumption, and recreation. Too much runoff may have strong adverse effects in the form of destructive flooding. One only has to look at the 1972-73 winter season to gain an understanding of the impact of snow on the economy of the western part of the country; in central Arizona exceptional winter snowfall resulted in replenished groundwater and a summer of abundant water supplies, whereas in the Pacific Northwest a winter of well-below normal snowfall produced a power-generation crises later in the year.

Observation from earth satellites now offers promise for monitoring snow on a more cost-effective basis than is possible using existing methods. The application of ERTS imagery for this purpose has been evaluated for two geographic areas, the Salt-Verde Watershed in central Arizona and the southern Sierra Nevada in California. In the study, techniques have been developed to identify snow and to differentiate between snow and cloud. The snow extent for these two drainage areas has been mapped from the MSS-5 (0.6-0.7 μm) imagery and compared with aerial survey snow charts, aircraft photography, and ground-based snow measurements.

The results of the study indicate that snow extent can be mapped from ERTS imagery in more detail than is depicted on aerial survey snow charts. For the areas tested, the agreement between the percentage snow cover as determined from ERTS data and from aerial survey snow charts is of the order of 5 percent for most cases. Also, although small details in the snowline can be mapped better from higher-resolution aircraft photographs, boundaries of the areas of significant snow cover can be mapped as accurately from the ERTS imagery as from the aircraft photography. Moreover, in Arizona and southern California cloud obscuration does not appear to be a serious deterrent to the use of satellite data for snow survey, and the costs involved in deriving snow maps from ERTS imagery appear to be very reasonable in comparison with existing data collection methods.

SNOW-EXTENT MAPPING AND LAKE ICE STUDIES USING ERTS-1 MSS TOGETHER WITH NOAA-2 VHRR

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ABSTRACT

Five snow extent maps of the 5,601 km^2 American River basin were prepared using a Zoom Transfer Scope from ERTS-1 MSS band 4 imagery. The maps were generally completed within one hour. A snowmelt curve based on ERTS-1 imagery was used as a "calibration" standard or comparison for maps prepared from NOAA-2 VHRR imagery in the same manner. Cost comparisons with U-2 derived imagery indicate that ERTS-1 snow mapping of the basins is six times faster. Conservative estimates of comparable aircraft snow survey flights yields a cost figure 200 times that of the ERTS-1 snow map.

Snow mapping attempts in the Lake Ontario basin demonstrated that ERTS-1 is not well suited to large basins. Optimum size of basins for ERTS studies is believed to range from about 250 km^2 to 30,000 km^2.

The value of the ERTS-1 MSS for Great Lake ice evaluation was proved the past winter on Lake Erie. Not only were ice features and types of ice identified, but melting ice was detected through the combined use of band 5 (0.6-0.7 μm) and band 7 (0.8-1.1 μm). Ice movement (direction and speed) was mapped by examining imagery from two successive days. The resolution of NOAA-2's VHRR was checked by comparison of ice leads as seen in the MSS band 5.

NEW SPACE TECHNOLOGY ADVANCES KNOWLEDGE OF THE REMOTE POLAR REGIONS

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ABSTRACT

The application of ERTS-1 imagery is rapidly increasing man's knowledge of the polar regions. Products compiled from this imagery relating to the experiments being conducted under proposal SR 149 at scales of 1:250,000, 1:500,000 and 1:1,000,000 are already providing valuable information to earth scientists working in Antarctica. Significant finds detected by these "bench mark" products were glaciological changes, advancement in ice fronts, discovery of new geographic features and the repositioning of nunataks, islands, and ice tongues. In cooperation with the American Geographical Society and funded by the National Science Foundation, ERTS imagery has been used for the compilation of a 1:5,000,000 scale map of the Arctic period.

Products such as single scene pictorial images and photo imagery mosaics have been compiled that often exceed the accuracy of existing cartographic products in Antarctica. A graticule has been fitted to the imagery based on a least-squares adjustment of identifiable control points which were established by standard surveying techniques as well as by satellite geodesy.

Tests conducted under proposal SR 149 in Antarctica have proven the feasibility of tracking Navy Navigation satellites to establish ground control for positioning ERTS-1 imagery in remote areas. ERTS imagery coupled with satellite geodesy shows great promise and may prove to be the most practical and cost effective way to meet the small scale cartographic requirements of the polar science community.

ERTS-1 DATA IN SUPPORT OF THE NATIONAL PROGRAM OF INVENTORY AND INSPECTION OF DAMS

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ABSTRACT

The Earth Observations Division at the Johnson Space Center has developed a specialized computer-aided procedure to use ERTS-1 MSS system corrected digital data, to detect and locate surface water. The procedure is presently being evaluated by the Texas Water Rights Commission and the U.S. Army Corps of Engineers for an inventory of water impoundments in Texas, as required by the National Program of Inspection of Dams (Public Law 92-367). This procedure is presently implemented on UNIVAC 1100 series computers at the Johnson Space Center and has been transferred to, and used on, the computers of the Texas Water Development Board. The programs are designed to accent ERTS-1 MSS system corrected computer compatible data tapes. The classification software uses data from ERTS-1 channels 4 (0.5-0.6 micrometers) and 7 (0.8-1.1 micrometers) along with a linear decision boundary for identifying the areas of surface water located in an ERTS-1 scene. Each resolution element which is classified as surface water is subsequently transformed to its proper geographic location and provided to the analyst in the form of a registrable line printer output. The programs are designed to provide line printer classification maps registrable to any selected base map. However, the Texas Water Rights Commission is presently evaluating the utility of the information displayed at scales of 1:24,000, 1:62,500 and 1:125,000. A preliminary performance evaluation effort has been completed by the Earth Observations Division. A study area was selected which encompassed portions of Austin, Brazos, Burleson, Colorado, and Washington Counties in Texas (ERTS-1 Scene: E-1092-16305). Ground truth information was extracted from RB57E aerial color infrared photography at a scale of 1:120,000 (Mx 220). The results of this evaluation indicate that 100 percent of the areas of surface water of areal extent of 10 acres or greater were correctly identified. The evaluation also indicates that the geographic location of each resolution element classified as water was determined to a positional accuracy of 500 feet or closer. The Texas Water Rights Commission has conducted a preliminary evaluation of three inventory techniques to determine the relative costs and accuracy of identification associated with each inventory procedure. This evaluation is related to inventories in Washington, Montgomery and Howard Counties in Texas (ERTS-1 Scene ID's: E-192-16305, E-173-16244, E-1132-16532, and E-1132-16535). The first inventory procedure consists of a search of records of state, federal, and private organizations to determine the location of all water impoundments with a surface area of 10 acres or greater. The second procedure uses conventional image interpretation techniques along with 1:1,000,000 scale ERTS-1 MSS black and white imagery for band 7 (0.8-1.1 micrometers) to identify and locate all impoundments of 10 acres or greater. The third procedure uses the JSC computer-aided techniques to identify and locate all impoundments of 10 acres or greater.

DYNAMICS OF PLAYA LAKES IN THE TEXAS HIGH PLAINS

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ABSTRACT

Three small playa lake basins on the Texas High Plains were originally selected as ERTS-1 test sites to attempt correlation of ERTS-1 imagery with the water balance ecosystem and geology/morphology of the lake basins. Two of the test sites were instrumented with water level recorders, infiltrometers, tensiometers, evaporation pans, totalizing anemometers, weighing rain gauges, and continuous recording microbarograph and hygrothermographs. However, when initial imagery (under maximum usable magnification) showed that resolution was not adequate for the monitoring of water fluctuations of the small lakes, the large Double Lakes playa complex (5 miles long) was instrumented as an alternate test site.

During the period July 1972 – August 1973, the Double Lakes playas went from an initial flooded condition (July, 1972 pass) to a partially dry condition (south playa dry, north playa wet, June 19, 1973 pass) to a total dry condition (July 6, 1973 pass) to a flooded condition (July 24, 1973 pass) to a flooded condition. This sequence is portrayed by 16 mm time-lapse film loops constructed from ERTS-1 MSS imagery.

Color composites have been particularly useful for distinguishing the exact water area from the muddy areas of the Double Lakes playas, and for determining the salt crust areas. Color composites also portray gradations in water transparency, due to depth fluctuations, suspended sediment or algae, much better than the single MSS bands.

Analysis of Bands 6 and 7 of ERTS-1 MSS imagery, using photographic enlargement and a 32-color density slicer with zoom magnification, shows that lake basins as small as 200 m in diameter (± 10 acres) can be reliably classified as being "wet" or "dry," thus supplying the methodology for a rapid, periodic census of surface water. A cost/benefit analysis reveals that the use of MSS imagery for such a census results in a 66 to 200-fold cost reduction when compared to the cost of using other conventional methods. Thus, even the poorest of the arid countries of the world can afford to monitor their ephemeral lakes, enhancing the predictability of extended drought conditions.

WATER-MANAGEMENT MODELS IN FLORIDA FROM ERTS-1 DATA

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ABSTRACT

A prototype multiparameter data acquisition network, installed and operated by the U.S. Geological Survey is a viable approach for obtaining near real-time data needed to solve hydrologic problems confronting nearly 2.5 million residents of south Florida. Selected water quantity and quality data obtained from ground stations are transmitted for relay via ERTS-1 to NASA receiving stations in virtual real time. This data-relay system has been very reliable and, by coupling the ground information with ERTS imagery, a modeling technique is available for water resource management in south Florida. For example, water stage is correlated with water-surface areas to provide water stage-volume relations in near real-time for management decisions concerning the distribution of water to people, fuana, and flora of southern Florida. An overall water-resource model will be generated when the other aspects (stage-seepage, climate, evapotanspiration, water control releases to salt water, etc.) are incorporated.

At the end of 1973, 13 Data Collection Platforms were functional on a near real-time basis. Nine are located in water conservation areas for water-management purposes, 2 are in the Everglades National Park to monitor the Park's water environment, 1 is in the Big Cypress Swamp to monitor that pristine area, and 1 is in downtown Miami for research and development applications.

Publication authorized by the Director, U.S. Geological Survey

MEASURING WATERSHED RUNOFF CAPABILITY WITH ERTS DATA

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ABSTRACT

The primary objective of this study was to determine how effectively ERTS multispectral data can be used to characterize coefficients used in watershed runoff models.

Two groups of 10 highly instrumented watersheds, each set ranging in drainage area from 20 acres up to 200 square miles, were used as test sites. Coefficients for two simple runoff models were calculated from rainfall-runoff data and by manual methods used by the Soil Conservation Service.

Computer techniques were developed to excerpt the digital multispectral scanner data from tapes and store the appropriate data for each watershed. Discriminant analysis techniques were used to determine the linear combinations of bands that would best separate watersheds with extremely high and extremely low runoff. Simpler techniques were also used to compare mean spectral response from the watershed surface with model coefficients.

Comparison of coefficients based on measurements with those derived by hand indicates the manual system produces coefficients that will overpredict runoff. Good discrimination was found between grassland watersheds having high and low runoff potential when MSS channels 4, 5, and 7 are combined in a linear equation. The difference between mean reflectance for the visible bands from each watershed appears to be highly correlated with measured runoff coefficients during dry dormant conditions, thus this relationship should be an improvement over the presently used manual system for predicting runoff.

AN EVALUATION OF THE ERTS DATA COLLECTION SYSTEM AS A POTENTIAL OPERATIONAL TOOL

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ABSTRACT

The Earth Resources Technology Satellite (ERTS) Data Collection System (DCS) has been shown to be, from the users vantage point, a reliable and simple system for collecting data from U.S. Geological Survey operational field instrumentation. It is technically feasible to expand the ERTS system into an operational polar-orbiting data-collection system to gather data from the Geological Survey's Hydrologic Data Network. This could permit more efficient internal management of the Network, and could enable the Geological Survey to make data available to cooperating agencies in near-real time. The Geological Survey is conducting an analysis of the costs and benefits of satellite data-relay systems.

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RETRANSMISSION OF WATER RESOURCES DATA USING THE ERTS-1 DATA COLLECTION SYSTEM

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ABSTRACT

The Water Survey of Canada operates a network of approximately 2400 gauging stations at which water level data are collected. In most cases the water level data are used in conjunction with periodic discharge measurements to produce daily river discharge data. These data may be used for design of structures and works, flow and flood forecasting, project regulation and for pollution control. In many cases it would be desirable to obtain data on a near real time basis. However, the isolated locations of most of the gauging stations have made the cost of land line telemetry prohibitive. Fewer than 100 gauging stations have been equipped with telemetry systems.

Therefore, when the ERTS Data Collection System became available in 1972 it seemed worthwhile to investigate the possibility of using a satellite retransmission system to collect discrete water level readings at least once daily from a few gauging stations and to use these data for operational purposes. In this way a valid assessment with regard to reliability, costs and other aspects of the whole system could be carried out and decisions made with respect to the feasibility and advantages of establishing a much larger network of DCPs dependent on future satellite facilities.

To perform this assessment, nine DCPs were installed in isolated areas of northern and western Canada. It was felt that DCPs in these locations would be exposed to climatic conditions severe enough to provide a check on system reliability. In addition, near real time data from the sites selected would help the Water Survey of Canada meet some of its operational needs.

Water level data were transmitted from all sites and, also, some of the DCPs were used to transmit ice break-up, water velocity, precipitation, air temperature, water stage recorder clock operation or DCP battery voltage. Consideration is being given to transmitting other parameters that would be of value in flood or flow forecasting.

Results of the project have been excellent. There has been no data loss that can be attributed to failure of a DCP although data were lost because of sensor malfunctions. The quality of data collected compares favourably with that of the hard record obtained at the remote sites. Costs of using the ERTS Data Collection System are reasonable.

ERTS-1 FLOOD HAZARD STUDIES IN THE MISSISSIPPI RIVER BASIN

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ABSTRACT

The Spring 1973 Mississippi River flood was investigated using remotely sensed data from ERTS-1. Both manual and automatic analyses of the data indicate that ERTS-1 is extremely useful as a regional tool for flood and floodplain management. Automatic digital analysis using the GEMS system was employed to obtain quantitative estimates of area flooded in small test sites 1225 km^2 in area in St. Charles County, Missouri and the delta region of northwest Mississippi. In the St. Charles County site 265 km^2 (21% of the total area) were calculated to be flooded whereas, in the northwest Mississippi site, 480 km^2 (39%) were inundated with an additional amount of high forest submerged beneath the canopy. In the entire state of Arkansas, manual photo interpretation indicated that 7300 km^2 were inundated with only 630 km^2 flooded along the Mississippi River mainstem. The maximum error of such flood area measurements is conservatively estimated to be less than five percent. Change detection analysis indicates that the flood had major impacts on soil moisture, land pattern stability, and vegetation stress.

Flood hazard identification (i.e., the delineation of flood-susceptible areas) was conducted using photo interpretation techniques in three study areas along the Mississippi River using pre-flood ERTS-1 imagery down to 1:100,000 scale. The flood-prone areas delineated on these images correspond to areas that would be inundated by significant flooding (approximately the 100-year flood). In addition, in northwest Mississippi, the feasibility of objective detection of floodplain features related to flood susceptibility was confirmed using the GEMS system. Flood prone area boundaries obtained from ERTS-1 were generally in agreement with flood hazard maps produced by the U.S. Army Corps of Engineers and the U.S. Geological Survey although the latter are somewhat more detailed because of their larger scale. Initial results indicate that ERTS-1 digital mapping of the flood-prone areas using the Purdue University LARS system can be performed at least at 1:62,500 which is comparable to conventional flood hazard map scales. Direct comparison of the ERTS-1 digital products to conventional flood hazard maps must wait until corrections for image skew can be incorporated into the LARS output format.

OPTICAL DATA PROCESSING AND PROJECTED APPLICATIONS OF THE ERTS-1 IMAGERY COVERING THE 1973 MISSISSIPPI RIVER VALLEY FLOODS*

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ABSTRACT

Flooding along the Mississippi River and some of its tributaries was detected by the multispectral scanner (MSS) on the Earth Resources Technology Satellite (ERTS-1) on at least three orbits during the spring of 1973. The ERTS data provided the first opportunity for mapping the regional extent of flooding at the time of the imagery. Special optical data processing techniques were used to produce a variety of multispectral color composites enhancing flood-plain details. One of these, a 2-color composite of near infrared bands 6 and 7, was enlarged and registered to 1:250,000-scale topographic maps and used as the basis for preparation of flood image maps. Two specially filtered 3-color composites of MSS bands 5, 6, and 7 and 4, 5, and 7 were prepared to aid in the interpretation of the data. The extent of the flooding was vividly depicted on a single image by 2-color temporal composites produced on the additive-color viewer using band 7 flood data superimposed on pre-flood band 7 images. On May 24, when the floodwaters at St. Louis receded to bankfull stage, imagery was again obtained by ERTS. Analysis of temporal data composites of the pre-flood and post-flood band 7 images indicate that changes in surface reflectance characteristics caused by the flooding can be delineated, thus making it possible to map the overall area flooded without the necessity of a real-time system to track and image the peak flood waves. Regional planning and disaster relief agencies such as the Corps of Engineers, Office of Emergency Preparedness, Soil Conservation Service, interstate river basin commissions and state agencies, as well as private lending and insurance institutions, have indicated strong potential applications for ERTS image-maps of flood-prone areas.

*Approved for publication by the Director, U. S. Geological Survey.

APPLICATIONS OF ERTS IMAGERY TO ENVIRONMENTAL STUDIES OF LAKE CHAMPLAIN

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ABSTRACT

ERTS imagery has provided data relating to a number of environmental and limnological concerns, such as water quality, lake flooding, and lake ice formation. Pollution plume data provided by ERTS was recently used in the Supreme Court case involving the States of Vermont and New York and a paper company. Flooding of lowland tracts has been a major concern due to a repetitive pattern of high lake levels over the past three years, and ERTS imagery is being used to construct the first series of flood maps of the affected areas. Lake ice development and turbidity patterns have also been studied from ERTS imagery and these have significance for shore erosion studies.

A REAL TIME DATA ACQUISITION SYSTEM BY SATELLITE RELAY

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ABSTRACT

Since the launch of ERTS-1 in July 1972, the New England Division, Corps of Engineers has installed 27 Data Collection Platforms throughout the New England area to measure river stage, precipitation, coastal and water quality data. The major objective of this phase of our experiment is to determine how effective the Data Collection System is in supporting our watershed management functions compared to presently existing systems. Our evaluation is concerned with the availability, reliability and useability of the data and the cost of this type system relative to other systems.

During the first year of operation, only 9 of 20 field stations experienced maintenance problems of any type and replacement of components could be made within one day. A reliability percentage of 98 was computed and was based upon a comparison of the ground truth data with punch card data from Goddard Space Flight Center. The response from a questionnaire sent to all Corps of Engineers offices throughout the country indicated the need for a near real time automatic data collection system.

We would like to install and evaluate a direct downlink from ERTS-1 because we feel this should be an integral part of any satellite data collection system. At the same time we will be developing cost figures to compare an ERTS-1 type system with other available systems.

HYDROLOGIC APPLICATION OF ERTS-1 DATA SYSTEM IN CENTRAL ARIZONA

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ABSTRACT

The Earth Resources Technology Satellite (ERTS-1) Data Collection System (DCS) was used to relay hydrologic data (streamflow rates, precipitation amounts, soil and air temperature, and snow-moisture content) from remote sites in Central Arizona to those responsible for reservoir management. Three U.S. Geological Survey streamflow gaging stations, 1 meterological station and 2 snow-moisture content installations were equipped with ERTS-1 Data Collection Platforms (DCP's).

By mid-March 1973, the high moisture levels on the Salt and Verde River watersheds, reduced reserve reservoir storage capacity, and a large potential for flooding in the Salt River valley presented a critical water management situation. Beginning on March 15, 1973, the ERTS-DCS was utilized to furnish near-real time information on snow-moisture content and streamflow rates to the Salt River Project for use in the management and operation of reservoirs on the Salt and Verde Rivers. The Salt River Project, aided by near-real time hydrologic data furnished by both microwave and ERTS-telemetry, was successful in predicting the volume of runoff into the reservoirs. Serious flooding in the downstream Phoenix metropolitan area was prevented by prudent water management.

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APPLICATIONS OF ERTS DATA TO COASTAL WETLAND ECOLOGY WITH SPECIAL REFERENCE TO PLANT COMMUNITY MAPPING AND TYPING AND IMPACT OF MAN

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ABSTRACT

Complete seasonal ERTS-1 coverage of Atlantic coastal wetlands from Delaware Bay to Georgia provides a basis for assessment of temporal data for wetland mapping, evaluation, and monitoring. Both MSS imagery and digital data have proved useful for gross wetland species delineation and determination of the upper wetland boundary. Tidal effects and (band to band or seasonal) spectral reflectance differences make it possible to vegetatively type coastal wetlands in salinity related categories. Management areas, spoil disposal sites, drainage ditches, lagoon-type developments and highway construction can be detected indicating a monitoring potential for the future.

A northern test site (Maryland-Virginia) and a southern test site (Georgia-South Carolina), representing a range of coastal marshes from saline to fresh, were chosen for intensive study. Wetland maps were produced at various scales using both ERTS imagery – bands 5 and 7 – and digital data – bands 4, 5 and 7. A Bausch and Lomb Zoom Transfer Scope and various overlay techniques were used with either 9-1/2" black and white transparencies or enlarged black and white prints. Diazo color composites, color enhancement techniques, and multi-spectral manipulation were used to supplement this information.

Data will be useful for coastal wetland inventories, updating acreage estimates, mapping boundaries, detecting seasonal changes, detecting and monitoring man's impact. Resolution limitations allow for mapping to a 1/125,000 scale.

Results are being applied directly to a Dismal Swamp study with U.S. Geological Survey. There is potential application to on-going programs in Georgia and South Carolina and to the Coastal Zone Management Act and a National Wetlands Law.

Preliminary comparison of ERTS and Skylab data for use in wetlands will be presented.

INVENTORIES OF DELAWARE'S COASTAL VEGETATION AND LAND-USE UTILIZING DIGITAL PROCESSING OF ERTS-1 IMAGERY

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ABSTRACT

Digital analysis of ERTS-1 imagery was used in an attempt to map and inventory the significant ecological communities of Delaware's coastal zone. Eight vegetation and land use discrimination classes were selected as follows:

1. Phragmites communis (Giant Reed grass)
2. Spartina alterniflora (Salt marsh cord grass)
3. Spartina patens (Salt marsh hay)
4. Shallow water and exposed mud
5. Deep water (> 2 meters)
6. Forest
7. Agriculture
8. Exposed sand and concrete

Canonical analysis showed that classification accuracy was quite good with Spartina alterniflora, exposed sand – concrete, and forested land – all discriminated with between 94% and 100% accuracy. The shallow water-mud and deep water categories were classified with accuracies of 88% and 93% respectively with all errors in classification occurring as one water category being classed as the other, a condition which is neither surprising nor bothersome with the overlap which these two classes exhibit no matter what the measurement technique used. Phragmites communis showed a classification accuracy of 83% with all confusion occurring with Spartina patens which may be due to use of mixed stands of these species as training sets. Discrimination of Spartina patens was very poor (accuracy = 52%) due to difficulties in locating large, pure stands of S. patens for use as training sets. Classification accuracy for agriculture was also very poor (51%). Limitations of time and available class-memory space resulted in limiting the analysis of agriculture to very gross identification of a class which actually consists of many varied signature classes. If crop inventory had been the primary objective of the study, substantially better results could have been achieved in discriminating agricultural land categories.

Abundant ground truth was available in the form of vegetation maps compiled from NASA-RB-57 color and color infrared photographs. Blow-ups of portions of the thematic maps digitally derived from ERTS data showed very good correlation with known sites. Cal-comp plots of thematic data at scales up to 1:24,000 showed good cartographic precision when overlayed onto existing maps. It is believed that with further refinement of training set selection, sufficiently accurate results can be obtained for all categories producing a useful planning and management tool.

EVALUATION OF REMOTE SENSING AND AUTOMATIC DATA TECHNIQUES FOR CHARACTERIZATION OF WETLANDS

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ABSTRACT

This evaluation has been conducted in the Atchafalaya River basin of South Central Louisiana. This is a humid area of heavily forested swamps with a large volume of flow mostly from a diversion of the lower Mississippi River.

Techniques to obtain enlarged imagery from computer compatible tapes of ERTS data without photographic enlargement is explained and illustrated. Techniques of extraction of environmental information from single bands and multiband pattern recognition procedures is explained and evaluated. A comparison of pattern recognition classifications of the Atchafalaya basin by aircraft multispectral scanner and ERTS MSS data is made. Data for this comparison were gathered within three weeks of each other in the winter of 1973. Scorecards of the accuracy of the classifications are presented.

Recommendations are made concerning the utilization of each sensor platform to perform specific tasks of wetlands characterization.

MARINE RESOURCES

Chairman, E. L. Tilton, (ERL)

Co-Chairman, J. Greaves, (GSFC)

RELATIONSHIPS BETWEEN ERTS RADIANCES AND GRADIENTS ACROSS OCEANIC FRONTS

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ABSTRACT

A time series of the Loop Current in the Gulf of Mexico, covering an annual cycle of growth, spreading, and decay, has been obtained in synchronization with ERTS. Computer enhanced images, which are necessary to extract useful oceanic information, show that the current can be observed either by color or sea state effects associated with the cyclonic boundary. The color effect relates to the spectral variations in the optical properties of the water and its suspended particles, and is studied by radiative transfer theory. Significant oceanic parameters identified are: the probability of forward scattering, and the ratio of scattering to total attenuation. Several spectra of upwelling diffuse light are computed as a function of the concentration of particles and yellow substance. These calculations compare favorably with experimental measurements and show that the ratio of channels method give ambiguous interpretative results. These results are used to discuss features in images where surface measurements were obtained and are extended to tentative explanation in others.

OCEANIC INTERNAL WAVES OFF NORTH AMERICA AND AFRICA AS OBSERVED FROM ERTS

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ABSTRACT

Oceanic internal gravity waves have been identified on several ERTS-1 images taken during the summer off the North American and south African coasts. The wavelengths are between about 400 and 4,000m, and the waves appear in up to six packets separated by 10-40km. They are most likely "daughter" waves caused by baroclinic tides occuring at the at the edges of continental shelves and island arcs and their dissipation in the bottom sediments can serve as a significant process causing the lengthening of the day. Calculations of wave propagation, refraction and disappearance agree well with the observations, especially in the vicinity of the Hudson Valley. During the winter, when wind and wave actions mixes the shelf water down to the bottom, waves are neither expected nor observed.

A REVIEW OF INITIAL INVESTIGATIONS TO UTILIZE ERTS-1 DATA IN DETERMINING THE AVAILABILITY AND DISTRIBUTION OF LIVING MARINE RESOURCES

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ABSTRACT

Results of a 15-month study to determine the feasibility of using satellite collected data to predict the distribution and abundance of fishery resources are presented. This study represented a combined Government-Industry effort to: determine the reliability of satellite and high altitude sensors to provide data about oceanographic parameters in coastal waters; demonstrate the use of remotely sensed oceanographic information to predict the distribution and abundance of adult menhaden; and demonstrate the potential of using satellite acquired information for improving the harvest and management of a fishery resource.

The project period, test area, species selection, industry participation and project organization are presented. Field activities are discussed using ERTS-1, aircraft, surface oceanographic vessels and commercial fishing vessels. Analyses of the various types of data are identified in the Data Analysis Management System.

Results of the study were the development and corroboration of mathematical models to predict high, medium and low potential for occurrence of menhaden based upon water color, turbidity, depth and salinity. Results were corroborated by statistical analyses of surface acquired oceanographic, aerial photographic fish school location, aerial sea surface temperature, and commercial fishing data. Potential application to resource assessment and commercial fishing includes predetermination of survey areas and tactics, prediction of high potential fishing areas for vessel and aircraft deployment and preliminary guidance to animal-environmental relationships.

UPDATING COASTAL AND NAVIGATIONAL CHARTS USING ERTS-1 DATA

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ABSTRACT

A successful processing algorithm for extracting water depth information from ERTS data has been developed. Depth charts for two geographical areas have been constructed representing different solar illumination and water transparency conditions. Absolute depth calculations for water depth to 4.5 fathoms have been demonstrated for the Little Bahama Bank. Depth Charts also were constructed using data in Band 4 and 5 of the ERTS MSS for areas in Lake Michigan. This data represented a low sun angle, poor light transmission in water conditions and gave useful results to 2.0 meters. In both cases, the ERTS map represented an update in shallow water detail in comparison with available navigation charts for the areas tested.

Present processing costs to provide MSS depth charts are estimated to be on the order of $1.50 per sq. mile. The updating of navigation charts for areas hazardous to shipping is an achievable direct application. The technique is available for world wide use. The International Hydrographic Office has called on countries to improve and update their navigation charts. One billion dollars per year is the estimated loss by the world shipping industry with several millions attributed to losses due to inaccurate navigation charts.

In the United States, the U.S. Lake Survey, The U.S. Coast and Geodetic Survey, NAVOCEANO and National Ocean Survey are agencies that will benefit directly from this capability. Other agencies dealing with erosion problems, sand transport, beach gradients, effects of new harbor construction, storm damages to near shore properties and time changes in beach recreation properties will be beneficiaries of this remote sensing technique.

The frequency of coverage of ERTS data should provide a baseline data set for all of the critical areas. Aircraft multispectral data collected in conjunction with satellite coverage could also be used to establish calibration areas of water depth for the satellite map but they also could be used in those areas where higher resolution is desired.

SEDIMENT CONCENTRATION MAPPING IN TIDAL ESTUARIES

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ABSTRACT

An analytical procedure has been developed that considers the ERTS-1 multispectral scanner as a reflectance spectrophometer. ADP techniques requiring only very limited computer capability are utilized to search the data defining the spectral reflectance characteristics of a scene on a pixel-by-pixel basis, identify each pixel whose spectral reflectance matches a reference spectrum, and generate maps that identify pixel locations where spectrum matches occur and identify the spectrum that was matched. If the reference spectra are known to represent a specific condition on the ground, a map of the distribution of that condition can be output as a dimensionally accurate overlay to maps of any selected scale. Two applications are described in this report: (1) the distribution of water masses exhibiting specific suspended sediment concentrations in four estuaries around Chesapeake Bay; and (2) the location and delineation of surface water bodies in the southeastern U. S.

The techniques described in this paper are currently being successfully used in connection with U. S. Army Corps of Engineers' projects to map the land area inundated by the 1973 spring flood in the Lower Mississippi River Valley, map sediment distributions in Lake Pontchartrain (in Louisiana) as a result of opening the Bonnet Carre Floodway during the spring flood, and inventory lakes and reservoirs in the states of North Carolina, South Carolina, Georgia, Florida, Alabama, Iowa, Louisiana, West Virginia, and Kansas in connection with the National Dam Safety Program.

MONITORING COASTAL WATER PROPERTIES AND CURRENT CIRCULATION WITH ERTS-1

V. Klemas, M. Otley, E. Dunlop, *University of Delaware, Newark, Delaware 19711,* and R. Rogers, *Bendix Aerospace Corporation, Ann Arbor, Michigan*

ABSTRACT

Imagery and digital tapes from nine successful ERTS-1 passes over Delaware Bay during different portions of the tidal cycle have been analyzed with special emphasis on turbidity, current circulation, waste disposal plumes and convergent boundaries between different water masses. (NASA-ERTS-1 I.D. Nos. 1024-15073, 1079-15133, 1133-15141, 1187-15140, 1205-15141, 1294-15083, 1349-15134, 1385-15131, 1403-15125, respectively). During ERTS-1 overpasses ground truth was being collected along a total of twelve boat and helicopter transsects across the bay, including measurements of Secchi depth, suspended sediment concentration and size, transmissivity, temperature, salinity, and water color.

ERTS-1 image radiance (microdensitometer traces) correlated well with Secchi depth and suspended sediment concentration. While only four concentration levels were extracted from transparencies, up to twice that number were obtained on sediment concentration plots derived from the MSS tapes directly. MSS band 5 seemed to give the best representation of sediment load in the upper one meter of the water column. Color density slicing helped delineate the suspended sediment patterns more clearly and differentiate turbidity levels. Density slicing of all four MSS bands gave an indication of relative sediment concentration as a function of depth, since the four bands penetrate to different depths ranging from several meters to several centimeters, respectively.

Circulation patterns observed by ERTS-1 during different parts of the tidal cycle, agreed well with predicted and measured currents throughout Delaware Bay. During flood tide the suspended sediment as visible from ERTS-1 also correlated well with the depth profile. ERTS-1 imagery is now being used to extend and verify a predictive model for oil slick movement in Delaware Bay.

Convergent shear boundaries between different water masses were observed from ERTS-1, with foam lines containing high concentrations of lead, mercury and other toxic substances. Several varieties of fronts have been seen. Those near the mouth of the bay are associated with the tidal intrusion of shelf water. Fronts in the interior of the bay on the Delaware side appear to be associated with velocity shears induced by differences in bottom topography. In several ERTS-1 frames, waste disposal plumes have been detected 36 miles off Delaware's Atlantic coast.

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CALIFORNIA COASTAL PROCESSES STUDY

Douglas M. Pirie, *Ocean Engineer, Special Investigations Section Chief, U. S. Army Engineer District, San Francisco, California, U.S.A.*, and David D. Steller, *Geologist, Geoscience Division, Geosource International Incorporated, Downey, California, U. S. A.*

ABSTRACT

This paper presents preliminary findings and applications derived from ERTS-1 satellite imagery as it pertains to the nearshore coastal processes of the California coast. The objectives of this study were to analyze nearshore currents, sediment transport, and estuarine and river discharges along the California coast thru the use of synoptic and repetitive imagery from ERTS as well as aircraft underflights and surface data.

The major conclusions that are described in detail in this paper are as follows: (1) Distinct seasonal patterns for sediment transport as a function of the oceanic current systems and coastal morphology have been identified. (2) Large scale sediment plumes from intermittent streams and rivers extend offshore to heretofore unanticipated ranges as shown on the ERTS imagery. Areas where these plumes contain possible contamination from on-land activities can be traced in detail. (3) Computer generated contouring of radiance levels from computer-compatible tapes, resulted in charts that can be used in determining surface and nearsurface suspended sediment distribution. (4) Flying Spot Scanner enhancements resulted in details of nearshore features. (5) Data from this ERTS study is providing significant information for coastal planning and construction projects.

THE UTILIZATION OF ERTS-1 DATA FOR THE STUDY OF THE FRENCH ATLANTIC LITTORAL

Pierre G. Demathieu, *Institut Géographique National, 2 Avenue Pasteur, Saint-Mandé F-94160, France,* and Fernand H. Verger, *Laboratoire de Géomorphologie, 61 rue Buffon 75005, Paris, France*

ABSTRACT

The FRALIT program (French Atlantic Littoral) is undertaken by the Ecole Pratique des Hautes Etudes (Paris), the Institut Géographique National (Paris), and the Université de Poitiers.

The first stage of work was exploratory in that all possible methods of exploitation (from classical photo interpretation to numerical treatment) were attempted. On the second stage those methods which seemed the most effective (especially numerical treatment) were more thoroughly developed.

In the field of the coastal waters, the ERTS-1 data were an irreplaceable source of documentation. The presence of sediment in particular, had only been measured up until now by Secchi disk measurements which were performed only for a point, were not simultaneous, and were only possible in good weather. ERTS gives an overall view of the phenomenon, in large part due to band 4, but the other bands provide precious complementary information (concerning superficial waters). Thus, to quote one among many examples, we were able to study two different situations of ebb tide; one being low water in the Loire (September 27, 1972) where turbidity was weak and suspension entirely caused by tidal movement in the estuary and the second a situation of heavy flow of the Loire (March 8, 1973), a few days after the maximum high water, where the flow of solid matter was considerable. An accurate cartography of mud transport in the Loire towards the southwest was established.

In the continental domain, the information obtained was perhaps less irreplaceable for us, but we should point out the fact that the study of the textures seems very promising as a means of classifying types of landscapes. Thus for example, the very homogeneous texture of the zones of small allotment polyculture, is opposed to that of the zones of the coastal marshes entirely covered by grass, where the variations in radiance are very slow and are due to variations in humidity linked to differences in distance above sea level.

ERTS IMAGERY APPLIED TO ALASKAN COASTAL PROBLEMS

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ABSTRACT

Along the Alaska coast, surface water circulation is relatively easy to study with ERTS imagery. Highly turbid river water, sea ice, and fluvial ice have proven to be excellent tracers of the surface waters. Sea truth studies in the Gulf of Alaska, Cook Inlet, Bristol Bay, and the Bering Strait area have established the reliability of these tracers. ERTS imagery in the MSS 4 and 5 bands is particularly useful for observing lower concentrations of suspended sediment, while MSS 6 data is best for the most concentrated plumes. Where satellite-synchronous sea truth was available, optical density slicing techniques have been developed to permit the quantitative discrimination of suspended sediment concentrations. Ice features are most clearly seen on MSS 7 imagery; fracture patterns and the movement of specific floes can be used to map circulation in the winter when runoff is restricted, if appropriate allowance is made for wind influence. Current patterns interpreted from satellite data are only two-dimensional, but since most biological activity and pollution are concentrated near the surface, the information developed can be of direct utility. Details of Alaskan inshore circulation of importance to coastal engineering, navigation, pollution studies, and fisheries development have been clarified with satellite data. ERTS has made possible the analysis of circulation in many parts of the Alaskan coast which were extremely difficult to study using standard oceanographic techniques.

MONITORING ARCTIC SEA ICE USING ERTS IMAGERY

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ABSTRACT

Because of the effect of sea ice on the heat balance of the Arctic and because of the expanding economic interest in arctic oil and other minerals, extensive monitoring and further study of sea ice is required. However, the inaccessibility of the polar regions has necessitated the use of slow and costly methods for data acquisition. Now, through the use of ERTS imagery, the potential exists for monitoring arctic sea ice on a more complete and economical basis than has heretofore been possible.

The results of the analysis of data from the late summer of 1972 and the spring and summer of 1973 demonstrate that ERTS imagery has substantial practical application for ice monitoring. In the eastern Beaufort Sea area, for example, the combination of orbital overlap and a high incidence of cloud-free conditions resulted in considerable repetitive coverage during the spring season. It has been possible, therefore, to map the deformation and movement of ice features throughout the early April to late June period. Ice features that can be identified in ERTS imagery include: the development of fractures leading to the formation of distinct ice floes; the growth and deterioration of leads; evidence of shearing movements of ice masses; the formation of new grey ice within leads; the distinction between grey, grey-white, and older forms of ice; and the deterioration of the ice surface evidenced by the formation of puddles, thaw holes, and drainage patterns. Features as small as 80-100 m wide can be detected, and ice types can be identified most reliably through analysis of both the visible and near-IR spectral bands. Ice conditions in the Bering Sea during early March depicted in ERTS images are in close agreement with aerial photographs taken from the NASA CV-990 aircraft and with the ice conditions reported by the observer on-board the aircraft.

APPLICABILITY OF ERTS FOR SURVEYING ANTARCTIC ICEBERG RESOURCES

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ABSTRACT

This investigation explores the applicability of ERTS to (a) determine the Antarctic sea-ice and environmental behavior that may influence the harvesting of icebergs, and (b) monitor iceberg locations, characteristics, and evolution. Imagery sampling in the western Antarctic between the Peninsula and the Ross Sea is used in the analysis. It is found that the potential applicability of ERTS to the research, planning, and harvesting operations can contribute importantly to the glowing promise derived from broader scope studies* for the use of Antarctic icebergs to relieve a growing global thirst for fresh water. Live Antarctic readout will permit timely acquisition of imagery on every orbital pass, which will be necessary to achieve adequate glimpses through the 80 percent cloud cover. Thermal sensor bands will provide coverage in daylight or darkness. Several years of comprehensive monitoring will be necessary to characterize sea-ice and environmental behavior and iceberg evolution. Live ERTS services will assist harvesting control and claiming operations and offer a means for harmonizing entitlements to iceberg resources. The valuable ERTS services will be more cost effective than other means and will be easily justified and borne by the iceberg harvesting operations.

**Antarctic Icebergs as a Global Fresh Water Resource*, The Rand Corporation, R-1255-NSF, October 1973.

ENVIRONMENT SURVEYS

Chairman, L. Greenwood, (LRC)

Co-Chairman, C. Schnetzler, (GSFC)

USE OF ERTS-1 IMAGERY IN AIR POLLUTION AND MESOMETEOROLOGICAL STUDIES AROUND THE GREAT LAKES

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ABSTRACT

The extremely high resolution and multispectral capability of the ERTS system have produced a meteorological satellite of incomparable value. ERTS data is regularly being integrated in air pollution and mesometeorological studies around Lakes Michigan and Ontario. The routine monitoring of interregional pollution transport is suggested by images of Gary steel mill plumes streaming toward Michigan for distances of over 60 nm. Also, a severe ozone episode occurred in Milwaukee July 17-18, 1973. The source of the primary pollutants was unknown. ERTS images however clearly showed a lake breeze convergence zone from Chicago northwards which channeled the pollutants into Wisconsin. Numerous cases of inadvertant weather modification have been detected: steel mills seeding lake snow squalls, and forming lines of cumulus clouds during summer. Contrails from jet aircraft are routinely detected and this shows the clear potential for assessing the potential global climatic impact of high level jet traffic. The noticeable spectral variations in the reflectivity of ice clouds augurs well for a planned computer pattern recognition approach to the detection of glaciated versus supercooled water clouds. Such a capability would be of enormous potential value in verifying results of regional cloud seeding experiments.

A METHOD TO MEASURE THE ATMOSPHERIC AEROSOL CONTENT USING ERTS-1 DATA

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ABSTRACT

The apparent gradual increase of particles in the atmosphere has received considerable attention in recent years due to the possible effect of atmospheric aerosols on the earth's climate. The ERTS-1 satellite offered the opportunity of determining the feasibility of monitoring the atmospheric aerosol content on a global basis, as suggested by theoretical studies, which showed a linear relationship between the upwelling earth-atmosphere radiance and the aerosol content. This relationship was investigated at two test sites, San Diego and the Salton Sea, using the MSS radiance data, with ground-truth observations of the aerosol content being made with a Volz photometer at the time of the satellite overpasses.

Significant results, relating the radiance over water surfaces to the atmospheric aerosol content, have been obtained. The results indicate that the MSS channels, 4, 5 and 6 centered at 0.55, 0.65 and 0.75 μm have comparable sensitivity, and that the aerosol content can be determined within ±10% with the assumed measurement errors of the MSS. The accuracy of the aerosol content measurement could be increased by using an instrument specifically designed for this purpose. This radiance-aerosol content relationship can provide a satellite technique for monitoring the atmospheric aerosol content on a global basis, allowing a baseline value of the global burden of aerosols to be established more rapidly than from a network of ground-based observations, and with considerable cost savings.

AUTOMATED STRIP MINE AND RECLAMATION MAPPING FROM ERTS

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ABSTRACT

The recent attention drawn to the use of coal in alleviating the national "Energy Crisis" and the impending legislation in Congress to force some industries from oil back to the use of coal will mean an increase in strip mining in this country. To provide planning and control of this increased mining activity, local, state, and federal agencies must have repetitive mapping of mining areas and the capability to rapidly determine the extent of stripping and the success of reclamation activity. ERTS data, available on a repetitive basis, transformed into maps by automatic data processing techniques, provides this essential map information. Computer processing techniques were successfully applied to ERTS CCT data acquired in August of 1972 over Muskingum County, Ohio, to produce maps of the Ohio Power Company's coal mining operations. Processing results succeeded in automatically classifying, with an accuracy greater than 90%: (1) stripped earth and major sources of erosion, (2) partially reclaimed areas and minor sources of erosion, (3) water with sedimentation, (4) water without sedimentation, and (5) vegetation. Computer-generated tables listing the area in acres and square kilometers were produced for each target category. Geometrically-corrected computer-driven pen drawings were produced. Each target category, drawn on a transparent material at a scale of 1:250,000 when placed over an AMS map of the same area, immediately provided target coordinates. Photography taken from ground and airborne platforms confirmed mapping accuracy.

SIGNIFICANT APPLICATIONS OF ERTS-1 DATA TO RESOURCE MANAGEMENT ACTIVITIES AT THE STATE LEVEL IN OHIO

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ABSTRACT

As stated by Dr. David C. Sweet, Director of the Ohio Department of Economic and Community Development and Principal Investigator of the Ohio ERTS-1 and Skylab Programs, "The Ohio satellite effort is a major step towards wise management necessary for balanced development in Ohio." Described herein is the significant progress in the application and utilization of ERTS-1 data to (1) detecting, monitoring, and inventorying surface mining activities, particularly in relation to recently passed strip mine legislation in Ohio; (2) updating current land use maps at various scales for multiagency uses, and (3) for other real-time problem solving activities throughout the various Ohio governmental agencies. General conclusions regarding current user views as to the opportunities and limitations of operationally using ERTS-1 orbital survey data at the state level are also noted.

ERTS IMAGERY AS A SOURCE OF ENVIRONMENTAL INFORMATION FOR SOUTHERN AFRICA

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ABSTRACT

Southern Africa is faced with a variety of environmental problems which reflect the different states of development of countries in the region. The task of the environmental planner is in many instances aggravated by a lack of basic resource information. The acquisition of the necessary data is often impeded by shortage of trained personnel and lack of funds, particularly in developing nations of the region.

This paper describes the range of environmental problems in Southern Africa and shows specific examples of how ERTS type imagery can materially assist in solving these problems. The table summarizes this discussion.

PROBLEM	ADVANTAGES OF ERTS TYPE IMAGERY
Problems of Development	
a. Resource Inventory	Regional coverage, ease and speed of interpretation.
b. Resource Allocation	Display of geographic and ecological relationships over a wide area.
c. Environmental Impact Studies.	Regional coverage, ease and speed of interpretation.
Problems of Control	
a. Detection of Rangeland Degradation	Repetitive coverage over large areas.
b. Monitoring changes in land use	Repetitive coverage over large areas.
c. Monitoring environmental pollution	Repeated regional coverage allowing extrapolation of data gathered in small areas on the ground.

These examples demonstrate that ERTS type data will be of substantial value to both the industrialized and the developing nations of Southern Africa.

APPLICATION OF ERTS IMAGERY IN ESTIMATING THE ENVIRONMENTAL IMPACT OF A FREEWAY THROUGH THE KNYSNA AREA OF SOUTH AFRICA

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ABSTRACT

In the coastal areas north-east and south-west of Kynsna, South Africa lie natural forests, lakes and lagoons highly regarded by many for their aesthetic and ecological richness. A freeway construction project has given rise to fears of the degradation or destruction of these natural features.

We investigated the possibility of using ERTS imagery to estimate the environmental impact of the freeway. It was found that:

a. All threatened features could readily be identified on the imagery and their position in relation to the proposed freeway route was immediately obvious.

b. It was possible within a short time to provide an area estimate of damage to indigenous forest which matched official estimates based on far more protracted studies.

c. In several important respects the imagery has advantages over maps and aerial photos for this type of work.

d. The imagery will enable monitoring of the actual environmental impact of the freeway when completed.

We concluded that ERTS imagery, with its regional coverage, ease and speed of interpretation, will streamline environmental impact studies of this scope with significant economic benefits.

ARCTIC AND SUBARCTIC ENVIRONMENTAL ANALYSIS UTILIZING ERTS-1 IMAGERY

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ABSTRACT

This investigation addresses the following general objectives:

Analyze and map the sediment deposition in harbors, inlets, and docking facilities in Cook Inlet.

Map the permafrost areas of Alaska as inferred by vegetative patterns.

Correlate the snowpack cover of Caribou-Poker Creek with stream runoff.

Map and inventory the icing on the Chena River.

ERTS-1 imagery provides for the first time, a means of monitoring the following regional estaurine processes: daily and periodic surface water circulation patterns, and changes in the relative sediment load of rivers discharging into the inlet. This information will be used for producing a data base for preliminary site selection to develop management programs as required by the Coastal Zone Management Act of 1972, to aid local fishing industries, to augment preparation and revision of hydrologic and navigation charts, monitor estuarine circulation, dispersion of pollutants and the movements of sea ice.

Physiognomic landscape features were used as geologic and vegetative indicators in preparation of improved surficial geology, vegetation, and permafrost terrain maps at a scale of 1:1 million using ERTS-1 band 7 imagery.

Large river icings along the proposed Alaska pipeline route have been monitored. Also shore fast ice accumulation and ablation along the west coast of Alaska has been mapped through the spring and early summer seasons. Sea ice deformation and drift northeast of Point Barrow, Alaska, has been quantified during a four day period in March. These data will be used for route and site selection, regional environmental analysis, identification and inventory of natural resources, urban and land use planning, and in land use regulation and management.

AN INTERDISCIPLINARY STUDY OF THE ESTUARINE AND COASTAL OCEANOGRAPHY OF BLOCK ISLAND SOUND AND ADJACENT NEW YORK COASTAL WATERS

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ABSTRACT

Sampling in the estuarine and coastal environment is complex due largely to the various time and spatial scales encountered in the study of physical, chemical, and biological parameters. To design meaningful sampling programs, there must be information of how these parameters can be expected to be distributed spatially and temporally.

ERTS-1 satellite imagery provided the ability to observe features that are synoptic and, in some cases, quasi-persistent in that features are observed on successive imagery thereby implying monthly and seasonal frequencies. Sampling programs have been implemented for the Block Island Sound and the New York Bight that take into account these persistent features, particularly water-mass boundaries. These sampling programs have concentrated on problems involving time scales at positions dictated by a priori knowledge of the environment gained from ERTS-1 satellite data.

Such a program in Block Island has shown that generally three different water masses exist in Block Island Sound between Rhode Island (northern boundary) and Long Island, New York (southern boundary). These conditions have been documented by physical, chemical, and biological, as well as ERTS-1 satellite imagery.

These features are persistent, particularly for sampling stations around Montauk Point on Long Island and Block Island. Particle counts, extinction coefficients, total phytoplankton counts, and chlorophyll a concentrations correlate well with water masses depicted in the ERTS-1 imagery.

AIRCRAFT AND SATELLITE MONITORING OF WATER QUALITY

James P. Scherz

ABSTRACT

Aerial and Satellite Photography can be a very valuable tool for water quality investigations. Such aerial imagery correlates with the water quality parameter of turbidity, which in turn under specific circumstances, correlates to other water quality parameters such as suspended solids or apparent color. The advantage of aerial imagery is that it provides an overall view of turbidity possible by no other means. One striking example of this potential use is in Lake Superior where an $8,000,000 water intake was located in turbid, unpotable water. The turbidity and its location was clearly visible on aerial and ERTS imagery. Another example of its potential use is where apparent reflectance of various lakes in northern Minnesota as obtained from ERTS imagery correlates very well with the turbidity, solids, and the U.S. Forest Service classification of eutrophication for these lakes. For correct analysis of aerial imagery for water quality, one must understand light penetration into water and the corresponding bottom effects, as well as sky light reflection from the water surface. If these effects are understood and accounted for in a workable and practical manner, aerial and satellite imagery can indeed be a valuable tool for water quality investigations and should be used as such.

QUANTITATIVE WATER QUALITY WITH ERTS-1

Gerard W. James, Larry M. Magnuson and Harold L. Yarger, *Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044,* James R. McCauley, *Center for Research, Inc., University of Kansas, Lawrence, Kansas 66044,* and G. Richard Marzolf, *Division of Biology, Kansas State University, Manhattan, Kansas 66502*

ABSTRACT

Analysis of computer compatible tapes from 11 cloud free reservoir passes over a period of one year reveals digital level correlation with suspended sediment in all bands for sun angles $\gtrsim 45°$. For typical clear Kansas days during the warmer months at our latitude of 39° N (or sun angle range 45° to 65°) reliable curves relating suspended sediment to digital levels in each band can be derived. Band 7 exhibits a smoothly varying second order correlation with suspended load from 0 to 1000 ppm (upper limit of this investigation) with an RMS deviation of 30 ppm. Band 6 is also correlated with suspended sediment up to 1000 ppm but is most useful in the range 0 to 100 ppm where it is linearly correlated with RMS deviation of 10 ppm. Bands 4 and 5 show no correlation beyond 50 ppm and are useful only for relatively clear water ($\lesssim 20$ ppm). The few analyzed passes with lower sun angles indicate that correlation between suspended load and all bands degrade continually from strong correlation at 45° to no correlation at 25°. For the summer months all bands also show good correlation with water clarity or maximum light penetration depth.

It appears that gray levels obtained from electronic slicing of 9.5" black and white NASA images will yield similar correlation with suspended load with nearly the same accuracy obtained with CCT's. This part of the investigation is still underway.

It is apparent that inorganic suspended load is the dominant influence on reservoir reflection levels. We are continuing to look for any slight correlations with other water quality parameters such as chlorophyll and the algal nutrients.

AN EVALUATION OF THE USE OF ERTS-1 IMAGERY FOR GRIZZLY BEAR HABITAT IN YELLOWSTONE

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ABSTRACT

Improved classification and mapping of grizzly habitat will permit better estimates of population density and distribution, and allow accurate evaluation of the potential effects of changes in land use, hunting regulations, and management policies on existing populations.

A brief investigation was made to determine the extent to which ERTS-1 imagery would be useful in studying vegetative and seasonal factors which influence food availability and bear distribution and behavior. Color composite scenes of a central Montana study area were examined on a color-additive viewer. Portions of 1:1,000,000 positive transparencies of MSS scenes taken in August and October 1972 were used. Altitude overlays were superimposed on the scenes to permit more accurate classification of timber types. A time-lapse method of identifying recent snowfalls was also evaluated.

Areas which consisted of a favorable mixture of alpine meadow and timber stands were easily identified. The distribution of one important food species, white bark pine (Pinus albicaulis), was determined with fair accuracy with the aid of the altitude overlay. Snowfield boundaries could be determined, along with their monthly changes. The information obtained from satellite imagery was sufficient to identify areas potentially suitable as grizzly habitat for closer examination by ground survey.

We conclude that the use of satellite imagery could substantially reduce the time and effort required to inventory the grizzly bear habitat now existing in the Western United States. The same techniques could be used for evaluating the habitat of a variety of other animals, including elk and polar bear. The resulting information would be of great value to state and federal agencies with game management or land management responsibilities.

UTILITY OF ERTS FOR MONITORING THE BREEDING HABITAT OF MIGRATORY WATERFOWL

Edgar A. Work, Jr., *Environmental Research Institute of Michigan, Ann Arbor, Michigan 48107,* David S. Gilmer and A. T. Klett, *Bureau of Sport Fisheries and Wildlife, Northern Prairie Wildlife Research Center, Jamestown, North Dakota 58401*

ABSTRACT

Since 1968 the Bureau of Sport Fisheries and Wildlife and the Environmental Research Institute of Michigan have cooperated on developing applications of remote sensing to the management of migratory waterfowl. Basically this work has been concerned with (1) the assimilation of data on surface water conditions such that the data can be used as an index of annual waterfowl production, and (2) the collection of data on land use and wetland quality such that a measure of habitat carrying capacity is obtained. To date our efforts have been directed toward utilizing ERTS to monitor surface water conditions. An example of a model used for predicting the annual production of mallards is presented. The data inputs into this model and the potential for assimilating these data using ERTS are described.

INTERPRETATION TECHNIQUES

Chairman, J. Dragg, (JSC)

Co-Chairman, W. Alford, (GSFC)

TECHNIQUES FOR COMPUTER-AIDED ANALYSIS OF ERTS-1 DATA, USEFUL IN GEOLOGIC, FOREST, AND WATER RESOURCE SURVEYS

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ABSTRACT

Forestry, geology, and water resource applications were the focus of this study, which involved the use of computer-implemented pattern-recognition techniques to analyze ERTS-1 data. The results have proven the value of computer-aided analysis techniques, even in areas of mountainous terrain.

Several analysis capabilities have been developed during these ERTS-1 investigations. A procedure to rotate, deskew, and geometrically scale the MSS data results in 1:24,000 scale printouts that can be directly overlayed on 7½ minute U.S.G.S topographic maps. Several scales of computer-enhanced "false color-infrared" composites of MSS data can be obtained from a digital display unit, and emphasize the tremendous detail present in the ERTS-1 data. A grid can also be superimposed on the displayed data to aid in specifying areas of interest, such as avalanche tracks or areas of burned-over timberland. Temporal overlays of six sets of data have allowed both qualitative and quantitative analysis of changes in the areal extent of the snowpack.

Computer-aided analysis of the data allows one to obtain both cover-type maps and tables showing acreage of the various cover types, even for areas having irregular boundaries, such as individual watersheds. Spectral analysis of snow and clouds, water and shadow areas, and forest cover of varying overstory density have revealed several important results.

MULTISPECTRAL COMBINATION AND DISPLAY OF ERTS-1 DATA

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ABSTRACT

A significant problem in the use of ERTS-1 data is the extraction of information pertinent to each application and the presentation of that information in a form most suitable to users.

When the information is to be displayed for visual study by an observer, then the problem can be reduced to two independent steps:

1. Dimensionality reduction, an objective procedure which attempts to preserve most of the ERTS-1 information in a smaller number of components.
2. Display of the reduced number of components for "optimum" visibility by an observer.

Standard NASA color composities combine the most relevant 3 bands from the 4 MSS bands available. An alternate approach is to extract the principal components of the data by a linear transformation of the 4 bands. This approach leads to a low dimensionality representation of ERTS-1 data with the least degradation, in the mean square sense, of the radiometric accuracy. The technique has been applied with success to ERTS-1 MSS data for several geographic areas in California. For all examples considered the mean square representation error is less than one percent. By combining this dimensionality reduction which our previous results on image enhancement for visual display (1), color composites are obtained which contain and display most of the information provided by the ERTS-1 sensors.

Reference: V. R. Algazi: "Digital Enhancement of Multispectral MSS Data for Maximum Image Visibility," Proceedings of Symposium on Significant Results of ERTS-1, March 1973, NASA-SP-327, pp. 1169-1178.

AFFINE TRANSFORMATIONS FROM AERIAL PHOTOS TO COMPUTER COMPATIBLE TAPES

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ABSTRACT

During the development of a project to estimate wheat production, it became necessary, as part of the training procedure, to select data, corresponding to particular fields in a test site, off an ERTS computer compatible tape. Aerial photographs were on hand for the test site. A method was devised, using an affine transformation, to relate the aerial photographs and the tapes. One can thereby access data on the tape corresponding to regions covered by only a few pixels.

ESIAC: A DATA PRODUCTS SYSTEM FOR ERTS IMAGERY

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ABSTRACT

An Electronic Satellite Image Analysis Console (ESIAC) has been developed for visual analysis and objective measurement of Earth Resources Imagery. The system is being employed to process imagery for use by USGS investigators in several different disciplines studying dynamic hydrologic conditions. The ESIAC provides facilities for storing registered image sequences in a magnetic video disc memory for subsequent recall, enhancement, and animated display in monochrome or color. The unique feature of the system is the capability to time-lapse the ERTS imagery and/or analytic displays of the imagery. Data products have included quantitative measurements of distances and areas, brightness profiles, and movie loops of selected themes.

The applications of these data products are identified and include such diverse problem areas as measurement of snowfield extent, sediment plumes from estuary discharge, playa inventory, phreatophyte and other vegetation changes. A short movie is presented to demonstrate some uses of time lapse presentations that have been employed in these investigations. A comparative ranking of the electronic system in terms of accuracy, cost effectiveness and data output shows it to be a viable means of data analysis.

ADVANCED PROCESSING AND INFORMATION EXTRACTION TECHNIQUES APPLIED TO ERTS-1 MSS DATA

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ABSTRACT

Conventional automatic data processing and information extraction techniques fall short of providing the information required by the user in some applications. For those cases, advanced techniques are needed to permit the extraction of the necessary information. This paper describes advanced techniques we have developed and provides examples of their application to ERTS-1 MSS data.

The techniques described are designed to help overcome problems in location, mensuration, and classification accuracies which result from geometric distortions of the ERTS MSS data, the relatively coarse resolution of the sensor, and variations in atmospheric state over the region to be surveyed. It is shown that each of these factors can seriously degrade one's ability to extract necessary information. Further, it is shown that advanced techniques can alleviate the effects of these factors.

INTERPRETATION OF ERTS-1 IMAGERY AIDED BY PHOTOGRAPHIC ENHANCEMENT

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ABSTRACT

Agfacontour film can be used to produce relatively economical enhancements of density differences recorded on film. Image interpreters often ask whether enhancement really increases the information content of the original images. Examples of ERTS-1 imagery enhancements show that it is possible to separate density levels which are not discernible by the human eye. It is stressed that these techniques do not replace the photo interpreter, but rather they aid him in the interpretation process. Subtle density variations are made to stand out and an objective classification of the densities forming the image is produced.

TECHNIQUES FOR CORRECTING ERTS DATA FOR SOLAR AND ATMOSPHERIC EFFECTS

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ABSTRACT

The objective of this program is to establish a radiometric calibration technique which determines and removes solar and atmospheric parameters that degrade the radiometric fidelity of ERTS data. The ERTS sensor radiance measurements are transformed to absolute target reflectance signatures. The need for unambiguous target reflectance signatures evolves from the needs of individual PIs, from NASA's requirements to correlate results of a large number of investigators, and the preconditions of wide-area extrapolations of ground truth data for automatic data processing techniques. The paper includes:

1) Details of the Radiant Power Measuring Instrument (RPMI), which provides the measurements of the solar and atmospheric parameters (global irradiance, sky irradiance, radiance from narrow solid angles of sky, and direct beam solar irradiance) needed to transform ERTS data to reflectance.

2) Results of field measurements of these parameters for March through May of 1973.

3) Techniques used and results achieved in deriving additional atmospheric parameters (atmospheric transmittance and path radiance) from the RPMI measurements. Atmospheric transmittance varied from 70 to 85% in Band 4. The atmospheric scattering (path radiance) was found to be equivalent to that produced by a target having a reflectance of 11% in Band 4, 5% in Band 5, 3% in Band 6, and 1% in Band 7. This path radiance is predicted to vary by 30% or more over a period of a year.

4) Demonstration of procedures used to transform ERTS CCT data and atmospheric parameters into images and data corrected for atmospheric effects.

INTERDISCIPLINARY APPLICATIONS AND INTERPRETATIONS OF ERTS DATA WITHIN THE SUSQUEHANNA RIVER BASIN

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ABSTRACT

The objectives of this interdisciplinary investigation are grouped into four major categories: (1) geology and hydrology; (2) inventory of natural resources and land use; (3) environmental quality; and (4) digital processing and pattern recognition. Specific results include a study of land use, discrimination between types of forest resources and vegetation, detection of previously unknown geologic faults and correlation of these with known mineral deposits and ground water, mapping of mine spoils in the anthracite region of eastern Pennsylvania, mapping of strip mines and acid mine drainage in Central Pennsylvania, agricultural land use mapping, and detection of gypsy moth infestation.

Both photointerpretive techniques and automatic computer processing methods have been developed and used, separately and in a combined approach. A Remote Job Entry (RJE) system permits use of an IBM 370/165 computer from any compatible remote terminal, including equipment tied in by long-distance telephone connections.

Detector errors occuring in two channels of every sixth line of ERTS digital data were examined, and a statistical recalibration method was developed. Errors were eliminated after recalibration. After recalibration of data from two ERTS scenes, classification of a forested area yielded excellent results using spectral signatures developed in another area approximately 150 miles away and from an ERTS scene taken 17 days earlier. Thus, transference of signatures in both time and space appears feasible.

ERTS IMAGE DATA COMPRESSION TECHNIQUE EVALUATION

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ABSTRACT

The volume of data and the data rates produced by ERTS missions present problems for communication links, in ground data processing, and in ground data handling and storage. A technique which promises to ease the magnitude of these problems and provide economic benefits is data compression. Information-preserving (IP) compression introduces no error in the reconstructed data and cannot be criticized by users as eliminating data of interest. A form of IP data compression developed by TRW specifically for use with multispectral data was emphasized during the investigation but a low distortion algorithm was also evaluated.

Initially, thirty-four scenes of ERTS-1 data were selected to contain a wide variety of the object classes encountered by earth observation satellites and encompassing a broad range of data activities to insure a comprehensive evaluation of compression performance. Tapes containing these scenes were processed by a computer simulation of the selected algorithms and a variety of source and compressed data statistics were measured for both global and adaptive compression techniques. Full scenes were compressed and reconstructed for both IP and low distortion algorithms with photographs made of the reconstructed data. The effects of channel errors on the compressed data were simulated and evaluated. A preliminary hardware implementation of the compressor was performed to prove system feasibility.

The investigation yielded an average IP compression ratio of better than two to one allowing the storage of a full ERTS scene on a single reel of magnetic tape, a saving of three tapes per scene. A compression ratio of about four to one results if a low controlled distortion can be tolerated.

EVALUATION OF DIGITALLY CORRECTED ERTS IMAGES

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ABSTRACT

ERTS images have been geometrically corrected in a digital computer using three interpolation algorithms; nearest neighbor, bilinear, and a two-dimensional cubic spline termed cubic convolution. Evaluation of the results indicates that the higher order cubic algorithm produces consistently higher quality products over the range of ERTS scenes encountered than the other two algorithms. The nearest neighbor algorithm is most objectional where scale changes or rotations are required; the effect being to introduce streaks of errors in the implementation of change detection algorithms. The bilinear algorithm, on the other hand, consistently causes a degradation of the image's resolution.

Although interpolation using the cubic convolution requires inputs from 16 adjacent points for its mechanization and is an inherently more complex algorithm, special care in programming and/or the use of special-purpose hardware makes attainment of its higher quality output available to most users.

This paper will express the basic formulation of the cubic convolution process, illustrate the difference in quality attainable by the nearest neighbor, bilinear and cube convolution processes, and suggest desirable implementation approaches.

AUTOMATED THEMATIC MAPPING AND CHANGE DETECTION OF ERTS-1 IMAGES

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ABSTRACT

Results of an automated thematic mapping investigation using ERTS-1 MSS images are presented. A diffraction pattern analysis of MSS images led to the development of spatial signatures for farm land, urban areas and mountains. Four spatial features are employed to describe the spatial characteristics of image cells in the digital data.

Three spectral features are combined with the spatial features to form a seven dimensional vector describing each cell. Then, the classification of the feature vectors is accomplished by using the maximum likelihood criterion.

Three ERTS-1 images from the Phoenix, Arizona, area were processed, and recognition rates between 85% and 100% were obtained for the terrain classes of desert, farms, mountains and urban areas.

To eliminate the need for training data a new clustering algorithm has also been developed.

There are several conclusions from this investigation:

a. Through the developed algorithms, it is possible to automatically recognize terrain types.

b. The clustering algorithm eliminates the need for training data and has been combined with the maximum likelihood criterion.

c. The spatial features selected contain the spatial information necessary to recognize terrain types.

d. Combining the spectral data with the spatial features increased the accuracy of the machine recognition.

e. The class statistics vary appreciably between seasons.

f. The results of this investigation are applicable to the production of land-use maps.

PRINCIPLE COMPONENTS COLOUR DISPLAY OF ERTS IMAGERY*

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ABSTRACT

Combinations of data from the four ERTS bands into colour images are usually made by selecting three bands and displaying each in a different primary colour (red, green and blue). Because the data from the different bands are correlated, there is a tendency for the derived pictures to occupy only a small portion of the available colour space. In the most common combination, MSS bands 1 and 2, which are highly correlated, are displayed as blue and green respectively, and band 3 as red. This results in a picture which for most regions might as well have been printed in red and turquoise.

In the technique to be presented, colours are not derived from single bands, but rather from independent linear combinations of the bands. Using a simple model of the processing done by the visual system, three informationally independent linear combinations of the four ERTS bands are mapped onto the three visual colour dimensions of "brightness," "redness-greenness" and "blueness-yellowness." The technique permits user-specific transformations which enhance particular features, but this is not usually needed, since a single transformation provides a picture which conveys much of the information implicit in the ERTS data. Examples of experimental colour images with matched standard composites will be shown.

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* This work was done in cooperation with the Canada Centre for Remote Sensing, Ottawa

APPLICATIONS OF ERTS DATA TO RESOURCE SURVEYS OF ALASKA

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ABSTRACT

ERTS data, with its demonstrated capability for economical surveys of large areas, affords a unique opportunity to perform urgently needed resource surveys and land-use planning at a critical juncture in the history of Alaska's social and economic development. A facility for retrieval, processing and interpreting ERTS data and aircraft remote sensing data has been established at the University of Alaska. This facility is widely utilized by twelve University ERTS projects and many agencies, public and private, to produce the needed environmental surveys in strategic regions of Alaska. The available facilities for photographic, optical and digital processing of ERTS data are described, along with the interpretive techniques which have been developed. Examples of the applications of these facilities and techniques are given for major environmental disciplines: vegetation mapping for inventories of timber resources, grazing lands, potential agricultural lands, wildlife habitat, and potential archeological sites; snow surveys for inventories of water resources and flood potential in Alaska watersheds; marine and sea-ice surveys on the Alaskan continental shelf for the determination of surface circulation and sedimentation patterns and their effects on navigation, pollution assessment, fisheries, location of harbors and construction of off-shore structures; geological surveys for evaluation of seismic risk, possible mineralized areas and geothermal potential; and land-use planning for the imminent allocation of public lands to the State of Alaska, Alaskan natives, and national parks, national forests, wildlife refuges and wild and scenic rivers.

SCENE CORRECTION (PRECISION PROCESSING) OF ERTS SENSOR DATA USING DIGITAL IMAGE PROCESSING TECHNIQUES

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ABSTRACT

Techniques have been developed, implemented, and evaluated to process ERTS Return Beam Vidicon (RBV) and Multispectral Scanner (MSS) sensor data using digital image processing techniques. The RBV radiometry has been corrected to remove shading effects, and the MSS geometry and radiometry have been corrected to remove internal and external radiometric and geometric errors. General purpose computer configurations to process this data in a production mode have been defined and their throughputs investigated.

The results achieved to date show that geometric mapping accuracy of about one picture element (RMS) and two picture elements (max) can be achieved by the use of nine ground control points. Radiometric correction of MSS and RBV sensor data has been performed to eliminate striping and shading effects to about one count accuracy. Image processing times on general purpose computers of the IBM 370/145 to 168 class are in the range of 29 to 3.2 minutes per MSS scene (4 bands). Photographic images of the fully corrected and annotated scenes have been generated from the processed data, and have demonstrated excellent quality and information extraction potential.

TEXTURE FEATURES FOR IMAGE CLASSIFICATION

R. M. Haralick and R. Bosley

ABSTRACT

Texture is one of the important characteristics used in identifying objects or regions of interest in an image, whether the image be a photomicrograph, an aerial photograph, or an ERTS satellite image. This paper describes some easily computable textural features based on grey tone spatial dependancies and illustrates their application in category identification tasks of three different kinds of image data: ERTS (Earth Resources Technology Satellite) multispectral imagery containing 7 land use categories, photomicrographs of 5 kinds of sandstones, and 1:20,000 panchromatic aerial photographs of 8 land use categories. We use two kinds of decision rules: one for which the decision regions are convex polyhedra (a piecewise linear decision rule) and one for which the decision regions are rectangular parallelpipeds (a min-max decision rule). In each experiment the data set was divided into two parts, a training set and a test set. Test set identification accuracy is 89 percent for the photomicrographs, 82 percent for the aerial photographic imagery and 83 percent for the satellite imagery. These results indicate that the easily computable textural features probably have a general applicability for a wide variety of image classification applications.

DIGITAL IMAGE ENHANCEMENT TECHNIQUES USED IN SOME ERTS APPLICATION PROBLEMS

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ABSTRACT

Enhancement and classification are not competing methods for machine image analysis. In fact enhanced images can be used alone or as inputs to classification routines. However, in some problems the spatial relationships are equal in importance to the classification results and enhancements can be designed to provide both types of information in one image.

Enhancements discussed include contrast stretching, multiratio color displays, Fourier plane operations to remove striping and boosting MTF response to enhance high spatial frequency content. The use of each technique in a specific application in the fields of geology, geomorphology and oceanography is demonstrated.

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