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

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ABSTRACT

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

1. INTRODUCTION

The Great Lakes region contains one of the most rapidly growing populations in North America - currently numbering some 35 million people. The growth of settlements from Quebec to Milwaukee is expected to continue long after other megalopolises have withered for lack of fresh water. The Great Lakes contain roughly 20% of the fresh water in all the lakes and rivers of the world and will continue to serve our transportation, energy, cultivation, domestic, industrial, and even recreational needs for many generations — if we are intelligent in the management of this resource. Fresh water of the Great Lakes is neither inexhaustible nor unspoilable. Recent, well-publicized problems in Lake Erie, Lake Ontario, and southern Lake Michigan, have warned of a growing need for basic information and better tools for managing the Great Lakes. Clearly we must better understand the trade-offs in man's conflicting demands for fresh water and the seasonal or episodic ability of the natural drainage basin to meet these demands. With an acute awareness of these requirements to better manage the hydrologic resources of the Great Lakes, the International Field Year for the Great Lakes (IFYGL) was launched in April, 19⁻⁾.

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

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

2. THE PROBLEM

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

3. PROCESSING APPROACH

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

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

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

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

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

4. DECISION CRITERIA

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

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

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

5. ERTS AND THE TERRESTRIAL WATER BALANCE

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

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

6. CONCLUSIONS

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

7. ACKNOWLEDGEMENTS

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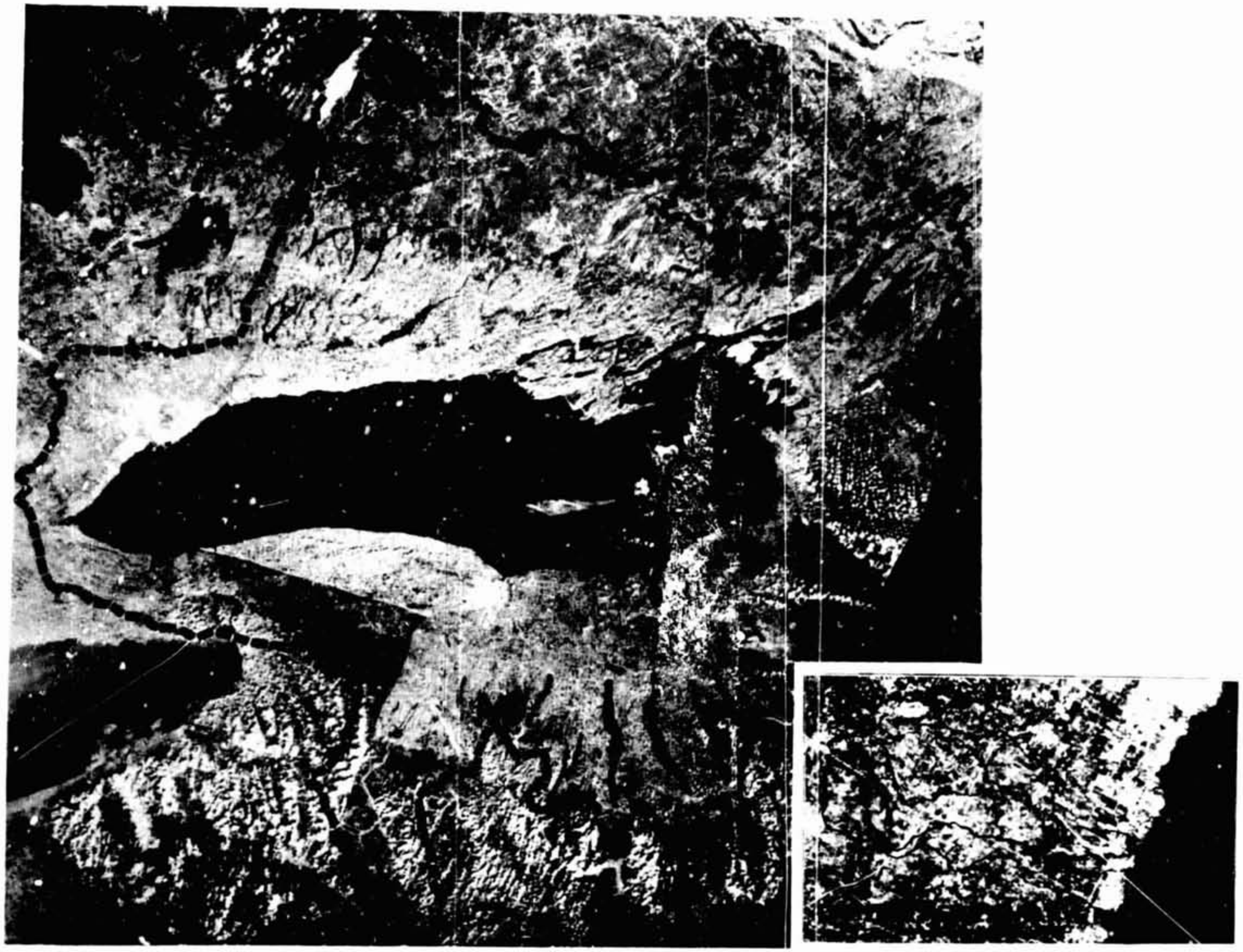

FIGURE 1. MOSAIC OF LAKE ONTARIO DRAINAGE BASIN WITH INSET SHOWING OAKVILLE REPRESENTATIVE BASIN ERTS-1 BAND 5 (0.6 - 0.7 μm). AUGUST 1972.

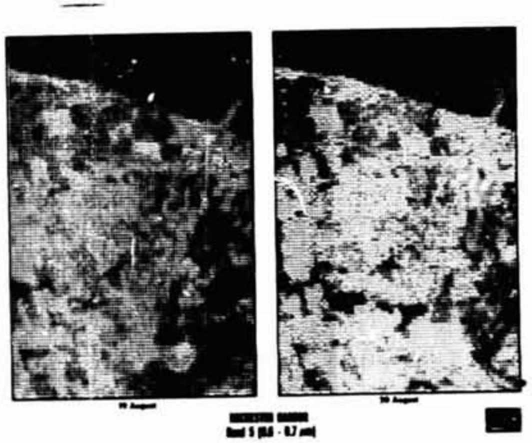

FIGURE 2. COMPARISON OF THE SAME AREA ON TWO DIFFERENT DAYS AS RECORDED BY ONE ERTS BAND.

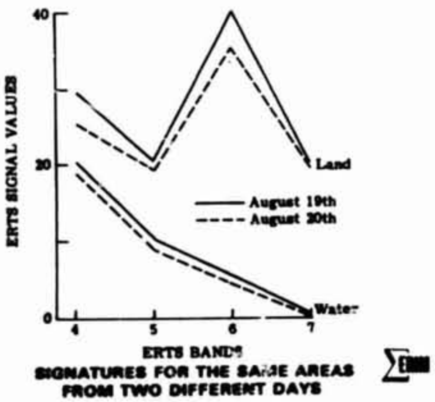

FIGURE 3. MEAN SIGNAL VALUES FOR TWO AREAS ON TWO DIFFERENT DAYS AS RECORDED IN FOUR ERTS MSS BANDS.

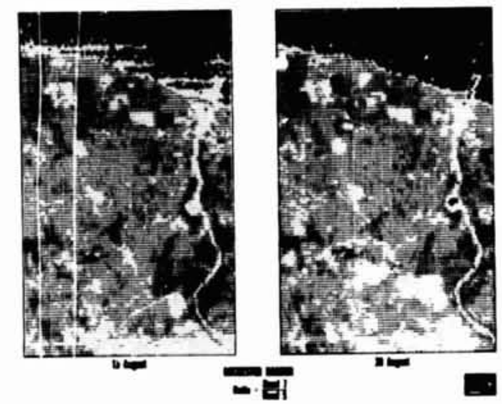

FIGURE 4. COMPARISON OF THE SAME AREA ON TWO DIFFERENT DAYS AS RECORDED BY A RATIO OF TWO ERTS BANDS.

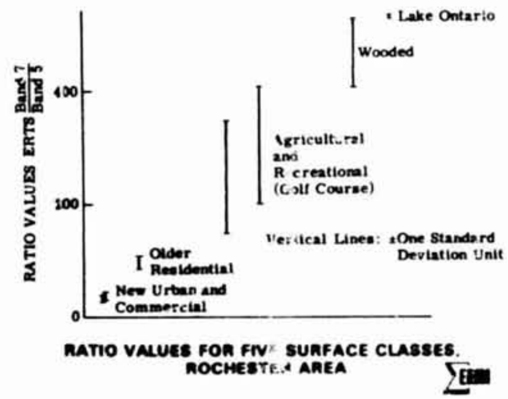

FIGURE 5. MEAN RATIO VALUES AND THEIR STANDARD DEVIATION FOR FIVE SURFACE CLASSES.