NASA PROGRESS REPORT

SPATIAL CHARACTERIZATION OF ACID RAIN STRESS IN CANADIAN SHIELD LAKES

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1.0 OBJECTIVE

The acidification of lake waters from airborne pollutants is of continental proportions both in North America and Europe. A major concern of the acid rain problem is the cumulative ecosystem damage to lakes and forest. The number of lakes affected in northeastern United States and on the Canadian Shield is thought to be enormous. Our principal research objective is to examine how seasonal changes in lake water transparency are related to annual acidic load. Further, the relationship between variations in lake acidification and ecophysical units is being examined. Finally the utility of Thematic Mapper (TM) based observations to measure seasonal changes in the optical transparency in acid lakes is being investigated.

Previous investigations have suggested that dissolved organic carbon (DOC), which originates from the dissolution of humic substances, controls transparency in most Canadian Shield Lakes. It has also been established that aluminum, which is abundant in the local rocks and soils, is easily mobilized by acidic components contained in spring

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runoff. The presence of any significant amount of aluminum induces a loss of DOC from the water column by coagulation, resulting in increased optical transparency. This process has not been observed in normal lakes associated with buffered geologies. In a normal lake, transparency would tend to decrease in time with seasonal phytoplankton productivity cycles. Thus seasonal changes in the optical transparency of lakes should potentially provide an indication of the stress due to acid deposition and loading.

The potential for this optical response is related to a number of local ecophysical factors with geology being, perhaps, the most important. Other important factors include sulfate deposition, vegetative cover, and terrain drainage/relief. The area of southern Ontario under study contains a wide variety of geologies from the most Acid Rain sensitive granite quartzite types to the least sensitive limestone dolomite sediments. Annual sulfate deposition ranges from 1.0 to 4.0 grams per square meter.

2.0 APPROACH

Water quality parameters are being measured along with insitu optical data in representative lakes in the Canadian Shield, this is being done to calibrate a Bio-Optical Model which defines the linkages between the acid rain induced chemical lake processes and the upwelling radiometric signals as measured by the Thematic Mapper sensor on Landsat. A spring/summer scene pair with companion field measurements is being collected in selected study sites located in northern Ontario. These data will be used to investigate possible formulations of the multitemporal remote sensing causal relationships between pH and observed changes in water transparency. It is hypothesized that a verifiable relationship exists between seasonal changes in water quality associated with the level of lake acidification and Thematic Mapper radiometry. The verified Bio-Optical Model will be used to establish the limits for which such relationships are inherently valid, and together with the field data, the set of ecophysical units and water quality conditions where the Landsat approach is valid. Under these restrictions lakes within an ecophysical stratum will be assigned a value for the degree of acidification based upon the TM multitemporal relationship. These results will permit one to test the hypothesis that the severity of lake acidification is not uniform over large areas but rather that variations exist which are strongly related to ecophysical units and proximity to probable sources of atmospheric inputs.

3.0 ACTIVITIES BY TASK

3.1 Stratification of Ecophysical Parameters (Task 1)

Presently work is underway to stratify the Shield area covered by three Landsat scenes into various ecophysical units. These scenes respectively cover Algoma path 22/row 27, Sudbury path 19/row 27, and Dorset path 18/row 27. The proposed stratification model consists of four separate classification parameters. These are soil/bedrock sensitivity, vegetation cover, terrain/drainage relief, and acidic deposition.

The objective of the regional stratification task is twofold. First, it is intended to reveal the location, status and co-occurrence of environmental attributes which are believed to influence lake acidification. Second, it provides a procedure to characterize each lake in the study areas with respect to environmental attributes which are believed to determine sensitivity to acidification and enhance experimental design. There is a range of conditions associated with each of these attributes which expresses relative importance to acidification sensitivity. In the present stratification, environmental attributes were restricted to three or four classes. Thus the effects of acid deposition can be allocated to individual strata as described by the combination of classes pertaining to the four essential environmental attributes: soil/bedrock, vegetation, terrain, and atmospheric deposition. Such combinations are not expected to be evenly distributed or even to be necessarily present throughout the study areas. Most likely such combinations will occur in "clusters" which are easily described by statistical procedure. These "clusters" provide descriptors for the ecophysical units in the sampling design.

The stratification was designed to produce a set of composite polygons at a scale of 1:250,000 for each of the study areas. The composite polygons were generated by overlaying type maps for each individual attribute and transferring all type boundary lines to the composite map. A label for each composite polygon is identified by examining the original attribute maps and recording the class levels for each of the individual attributes. At the same time the boundary of the composite polygon is determined. A compilation of the composite polygons then reveals which combinations exist in the study areas, and the composite map also identifies their location.

The individual attribute polygons were developed from existing base maps. The soil bedrock sensitivity submodel was derived from the 1983 Ministry of Environment (MOE) sensitivity maps which were based upon bedrock type, percent of exposure, soil texture, and soil depth. Soil/bedrock sensitivity polygons were described in terms of four categories and corresponding susceptibility ratings: Organic terrain (10), low potential (7.5), moderate potential (5.0), and high potential (2.5) to reduce acidity. The vegetation cover submodel described sensitivity as the product of cover type susceptibility value (hardwoods:3.33, mixed:6.67, conifers:10) and the percent cover class values (0-49:0.75, 50-74:0.50, 75-99:0.25). Existing TM and Multispectral Sensor (MSS) photo images were enlarged to 1:250,000 and used with Ontario forest stand maps (1:5000) to categorize the vegetation classes. The drainage relief submodel gave a susceptibility rating to slope data as extracted from 1:50,000 topographic maps. Three classes were identified poor/level (less than 5, 100' lines per cm) as a or = 10, imperfect/rolling (5 to 10 lines per cm) as a 6.7, rapid/steep (more than 10, 100' lines per cm) as a or = 3.3.

The acid deposition model contains a measure of the amount of sulfate deposition. The susceptibility rating corresponds to annual deposition rates from less than one to four grams per square meter (0.0-1. as a or = 0.0, 1.-2.0:1.6, 2.0-2.5:3.2, 2.5-3.0:4.8, 3.0-3.5:6.4, 3.5-4.0:8.0).

The stratum rating was modelled as a simple linear combination of these four parameters where the submodel rating was multiplied by an appropriate weighting coefficient. The size of these coefficients reflects the relative importance of each submodel rating. In the present case these were chosen: soil/bedrock (0.3), vegetation (0.2), drainage (0.1), and precipitation (0.4). The choice of these coefficients influences the resulting definition of polygons, and to a lesser extent, the results from subsequent cluster analysis.

3.2 Site Selection (Task 2)

As a result of the preliminary stratification analysis, several sites within the Canadian Shield were considered for the August field trip. However, the collaboration agreements which were reached as a result of the liaison activities described in the next section provided the greatest influence in site selection. The primary considerations were (1) availability of historical water quality and possibly remote sensing data, (2) existing Canadian initiatives to collect site specific data, (3) accessibility, and (4) coverage of ecophysical lake types. Sites selected thus far include (1) Algoma and (2) Sudbury.

A site in the Algoma district located approximately seventy-five miles northwest of Sault Saint Marie, Ontario, was the site of two lake studies conducted by the Ontario Geological Survey (OGS) and a five year monitoring study at the Turkey Lakes conducted by the Canada Centre for Inland Waters (CCIW). The Sudbury site lies directly north of Lake Wanatipei as a fifty kilometer long strip of lakes. This site has been previously investigated by the OGS and the MOE. A third area under consideration is located at the Dorset Lakes where another long term Canadian acid rain monitoring study has been sited. These sites cover annual sulfate depositions from 1.5 to 3.5 grams per meter square. Location of these sites is shown in Figure 1.

3.3 Liaison Activities with the Canadians (Task 3)

Initial efforts to promote a cooperative program with Canadian agencies and Universities interested in the remote sensing aspects of the acid rain problem have resulted in an informal joint program which includes four major Canadian participants. These are Professor Roger Pitblado of Laurentian University Sudbury, Ontario, Dr. John Fortescue of the Ontario Geological Survey, Dr. Vernon Singroy of the Ontario Centre for Remote Sensing (OCRS), and Professor Michael Dickman from Brock University, Saint Catherines, Ontario.

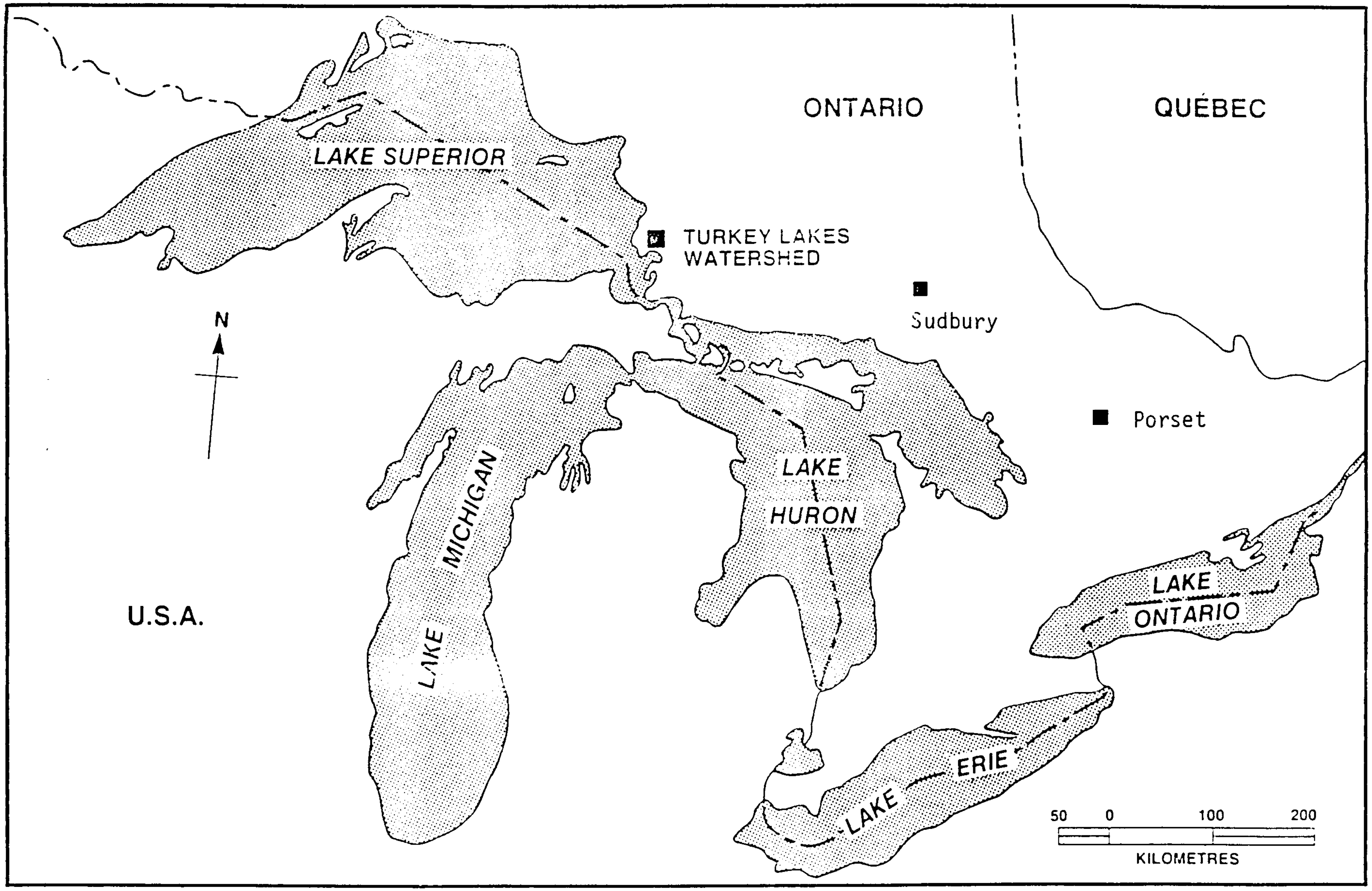

FIGURE 1. LOCATION OF THE STUDY AREA

The Canadian members of the team are seeking funding through both the Ministry of Environment and the Ontario Geological Survey. Plans have been made for an August field trip to the Algoma and Sudbury sites. The tentative field plans define a broad set of measurements to be made at each test site with specific contributions to be made by each team member.

The ERIM field team will (1) collect airborne spectroradiometer measurements from each lake to be surveyed, (2) subsurface optical measurements in selected lakes, and (3) arrange Landsat TM coverage for each field site to be collected coincident with the field measurements. The OGS will collect water samples and bottom cores from each survey lake. Laurentian University, together with the Ontario Ministry of Environment (MOE), will process water samples for about twenty separate parameters. The OCRS will arrange for airborne multispectral scanner coverage to be made, if possible, coincident with the TM coverage.

3.4 Define Multitemporal Radiometric Relationships to Acidification (Task 4)

In this task a TM radiative transfer model will be calibrated to predict possible multitemporal changes in signal level which result from field measured changes in optical and chemical properties. Work has proceeded on this model to include specific calibration for the Landsat TM sensor. The model treats atmospheric optics, water optics, and the wind ruffled air-water interface. A solar emphemeris model has also been implemented to provide a capability to simulate the entire sun/sensor geometry. It is planned that field subsurface optical measurements will be supplemented with optical parameters derived by Bukata [1986] for Ontario Lakes.

4.0 TECHNICAL PROBLEMS

No technical problems were encountered during this reporting period.

5.0 PLANS FOR THE NEXT REPORTING PERIOD

During the next period we plan to begin collection of field data, although coordinating our activities with the Canadians has virtually eliminated any chances of collecting early spring data for this year. Current plans indicate that our field work will take place during the month of August, with field trips conducted to each of the sites. During the next period, work on the stratification task should be completed. The TM extraction processing software should also be completed and tested during this next period. Requests will be made to the Canadian collaborators to provide historical TM coverage which is otherwise unavailable from NASA/GSFC.

6.0 REFERENCES

Bukata, R. P., J. E. Bruton, and J. H. Jerome, Application of Direct Measurement of Optical Parameters to the Estimation of Lake Water Quality Indicators. CCIW Scientific Series Report 140, 1985.