Measuring the Water Quality of Lake Kasumigaura by LANDSAT Remote Sensing

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1. Introduction

In the past decade, with industrial growth and the increase in urbanization, human pollution has expanded exponentially. Water qualities particularly have been seriously degenerated by organic waste in many rivers, lakes andestuaries.

The increasing complexity of water pollution problems has forced planners to seek new methodologies for determining alternative resource management plans.

To meet this challenge and to satisfy certain planning needs, techniques for remote sensing of natural aquatic bodies have been developed.

In this report, the water quality measurement of Lake Kasumigaura by satellite (LANDSAT) remote sensing is described. The aim of the these experiments is to determine the degree of variability in relationships between concentration of suspended solids or chlorophyll-a and reflectance at watersurface and to determine whether it is possible to make remote measurement with sufficient accuracy to permit monitoring of aquatic bodies such as lakesand estuaries.

2. The instrumentation for measuring spectral reflectance

Since remote sensors operate by detecting or sensing energy levels of emitted and/or reflected radiation over various ranges of the electromagnetic spectrum, it is necessary to make ground measurements of the reflectance from natural surfaces on order to understand the relationships between spectral reflectance and other surface parameters. The spectral signatures of field samples may be obtained by laboratory measurement, but these data will not, in general, be typical of outdoor situation. There was, therefore, a need to develop a spectroradiometer with adequate wavelength resolution, which could be used to obtain typical values of spectral reflectance in the field.

This section describes the design of a newly developed high-speed spectroradiometer for ground data collection and discusses its applicability to the remote sending sessions.

The high-sped spectroradiometer consists of a sensor unit and a control unit.

The sensor unit contains an optical system and a photomultiplier system.

The monochrometer used here was an off-plane Ebert type with a focal length of 300mm, slit width of 0.357 mm, and a reciprocal dispersion of 5.4 nm/mm for a 600-line/nm grating with an f-value of 6. The photomultiplier tube (PMT) used is a side-on S-20 type PMT which has a relatively wide and uniform response to light in the wavelength range of interest.

The control unit consists of a PMT high voltage power supply and a microprocessor with keyboard, a 5-inch CRT display and a digital cassette tape unit.

Tests and measurements by the spectroradiometer have shown that the instrument works as originally conceived and that potentially variable spectral signatures can be established for terrain targets.

3. Regression analysis between water quality parameters and radiance reflectance of water surface

The upwelling (nadir) radiance of the Lake Kasumigaura was measured at the water surface and at several depth layers underwater. The spectrum of incident light from the sun and sky was measured on the observation ship immediately before of after a series of surface and underwater measurements by recording the light reflected from a horizontally placed white reflector. Water quality parameters such as chlorophyll-a, phaeophytin, suspended solids, transparency, nd water temperature were also measured at the same ground truth point.

A change in the concentration of suspended solids or phytoplankton caused a change in the amount of radiation reflected from water surface, and so linear leastsquare regression analysis was used to evaluate the relationship between various water quality parameters and solar radiation reflected by water surface at different wavelength. The data sets taken at 12 ground truth points were used to form a linear regression model for the water quality parameters from the radiation reflected at the water surface. The results confirm that a significant negative correlation was found between transparency and the radiancereflectance, while a positive correlation was found between the concentration of suspended solids and the radiance reflectance. On the other hand, chlorophyll-a showed a poor fit for the wavelength range.

4. Measuring water quality from satellite (LANDSAT) data

The water quality data comprised measurements of suspended solids, of algal pigment (chlorophyll-a and phaeopigments) concentration, of the Secchi depth transparency, of the surface temperature of the water as well as of fundamental meteorological condition such as temperature, wind direction and speed, and visibility. These measurements were made at a time and at a point on the lake which corresponded to an overflight of the satellite (LANDSAT). These data were acquired on the different year 1981, 1982 and 1983. The concentration of suspended solids changes from 3.5 mg/l in the clean water area in the center of the lake to 39.8 mg/l in the most polluted place while chlorophyll-a changes from 6.9 micro g/l to 124.4 micro g/l. To determine the position for ground truth measurements is one of the most important factors for remote sending. Here, a handheld mariner's compass was used for reading the magnetic compass direction of several ground objects located at the lakeside.

The LANDSAT data used were MSS data which obtained from four spectral bands, band 4, 5, and 6, and the resolution at ground level was approximately 80 *80 m.

For apparently practical reasons but without theoretical justification, a linear relationship between the water quality parameters measured at the ground truth point and the upwelling radiance detected by LANDSAT has often been used to measure water quality in water bodies. A series ofregression analysis were run to determine the best relationships between each water quality parameter and the mean CCT count computed from LANDSAT band 4, 5, and 6. The results showed that the transparency and amount of suspended solids are well correlated with the LANDSAT band 4, 5, and 6, while chlorophyll-a showed no significant correlation with any of the LANDSAT bands.

Finally, the quantitative distribution maps for suspended solids which were derived from LANDSAT data.

5. Evaluation of atmospheric effects on LANDSAT data

The regression models, however, derived from the regression analysis between water quality parameters and LANDSAT data seem to be heavily dependent on weather conditions. Because of the low reflectance of water, the atmospheric path radiance forms a large part of the total radiance detected by LANDSAT. It has been known that the back scattered radiance from water surface comprises only only 10 to 50 % of the total radiance detected by the LANDSAT sensor. The difficulty in making an accurate correction for such atmospheric effects is a major obstacle to the use of remote sensing for determining the water quality of bodies of water.

In this chapter, we attempt to estimate the atmospheric effects, especially that of path radiance and transmittance by an empirical analysis based on the radiance detected by LANDSAT and that measured at the water surface.

We also present some corrections of LANDSAT MSS data which we made.

In order to obtain the path radiance and the transmittance of the atmosphere between LANDSAT and the water surface, a linear regression analysis was introduced in this study. The values of upwelling radiance used in this study were calculated from the measured radiance values at the ground truth points by integrating over the wavelength ranges equivalent to those of LANDSAT.

On the other hand, the values of radiance detected by LANDSAT were converted from CCT data. Using these data, the upwelling radiance and radiance detected by LANDSAT, the distribution of path radiance and transmittance over the lake were estimated. Then, radiance reflectance at the water surface was calculated from the radiance data detected by LANDSAT, estimated path radiance and transmittance.

Finally distribution map of the radiance reflectance of at the lake surface was produced.

References

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