MEASUREMENT OF SUSPENDED SOLIDS USING THE LANDSAT – CHROMATICITY TECHNIQUE

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INTRODUCTION

The usefulness of remote sensing by satellite has been recognized to be due to its repetitive and synoptic coverage of very large areas of the Earth's surface. Less obvious but at least as significant is its ability to provide quantitative data. Whereas many applications demand visual interpretation of the shape, size, texture, location, etc. of image features, it is those methodologies which remove the heavy burden of expensive and extensive manpower from image analysis, which can be most cost-efficient. The estimation of suspended solids concentration (SSC) from satellite-borne multispectral scanner (MSS) data depends entirely on spectral/radio-metric instead of spatial information, and thus, in theory, may be fully automated.

The chromaticity technique for SSC estimation from Landsat MSS imagery has been developed to provide a (semi-) automatic means of SSC determination with a measurable degree of accuracy. The technique offers a way to make use of the full extent of Landsat MSS capability. It has the special feature of requiring *in situ* verification data for one image, and no subsequent sampling for further images of the same area, which are to be mapped for SSC distribution.

THE CHROMATICITY TECHNIQUE

Development of the chromaticity technique started using Landsat photographic images (Munday, 1974a, b) and then progressed to digital analysis of computer compatible tapes (CCTs) (Alföldi and Munday, 1977 and 1978). The methods involved were configured into an interactive suite of programs on the image analysis system of the Canada Centre for Remote Sensing (Munday, Alföldi and Amos, 1979).

The basis of the chromaticity method involves the transformation of radiance values from the Landsat MSS bands 4, 5 and 6 into a pseudo-colour plane (chromaticity space) wherein normalized brightness parameters of colour saturation and hue are examined and manipulated. Absolute brightness information is removed during the data transform process.

The advantage that this transformation offers is that for the measurement of SSC, various sources of noise which are achromatic in these MSS bands can be eliminated or greatly reduced. Some of these features are: haze, light cloud, fog, air pollution, whitecaps and sun elevation angle variation. In chromaticity space, two degrees of freedom remain. One is used to remove the atmospheric opacity difference among scenes of interest and the other to estimate SSC through empirical calibration using *in situ* measurements. It must be emphasized that the process endeavours to remove the difference in atmospheric opacity (attenuation) between the two scenes, not to provide an absolute measure of the atmospheric conditions on either day.

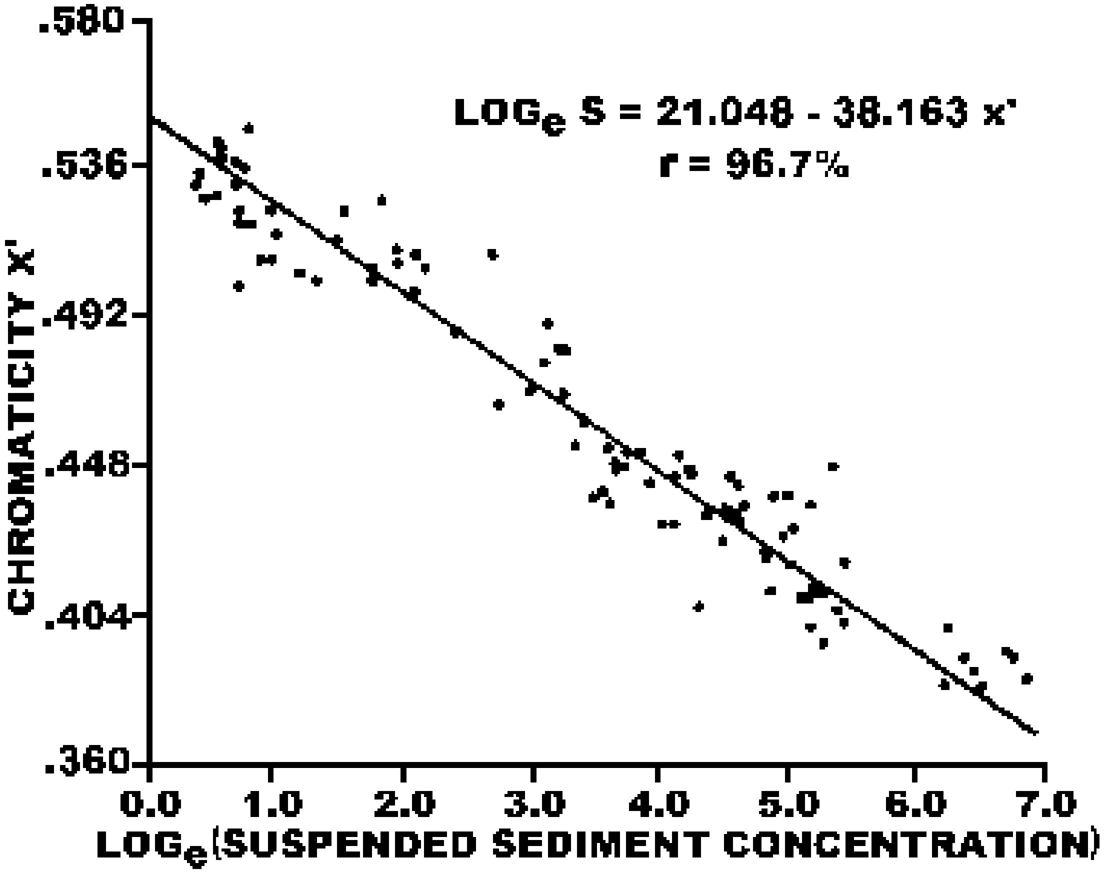
If one scene has coincident in situ measurements of SSC then that image may be empirically calibrated for radiance versus SSC relationships. This calibration is then extrapolated to another scene with no coincident surface sampling, by adjusting the atmospheric conditions of the second scene to approximate that of the first scene.

A full description of the chromaticity technique and its background theory is contained in Munday, Alföldi and Amos (1979), and Munday and Alföldi (1975, 1979).

VERIFICATION OF THE METHOD

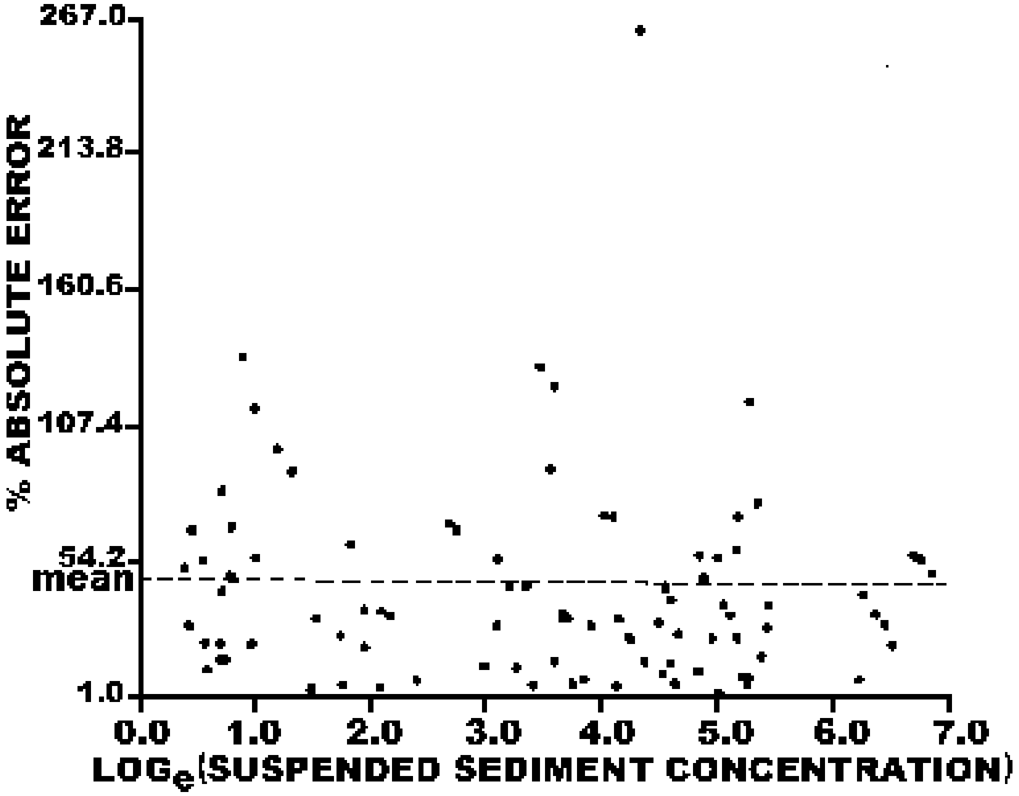
Extensive empirical testing of the chromaticity technique was conducted in the Bay of Fundy on the east coast of Canada (Amos, 1976; Amos and Alföldi, 1979). Over a period of five years, nine data sets of Landsat scenes with coincident surface measurements were collected. Eight of these data sets were atmospherically adjusted to the ninth (the reference scene) using the chromaticity technique. The resulting combined data set of satellite versus *in situ* measurements is shown in Figure 1. In Figure 1, X' “X PRIME” refers to a satellite-derived variable, while on the abscissa is the *in situ* measurement of SSC. The linear correlation is greater than 96 percent.

Figure 1



In Figure 2 is shown the measure of error in units of percent of SSC, derived from a comparison of the satellite – *in situ* calibration of eight of the data sets with the ninth, and using all nine permutations available. The mean error is 44 percent.

Figure 2



Following the surface-to-satellite calibration and atmospheric adjustment, any scene is thereafter categorized into ranges of SSC, or spot measurements are taken. Amos and Joice (1977) used this technique to produce Landsat/chromaticity maps of SSC for the Minas Basin of the Bay of Fundy, with which a mathematical model of the sediment budget of the basin was both initiated and calibrated. The model was then used to assess the impact on sediment movement/settlement of a proposed tidal barrage for tidal power generation.

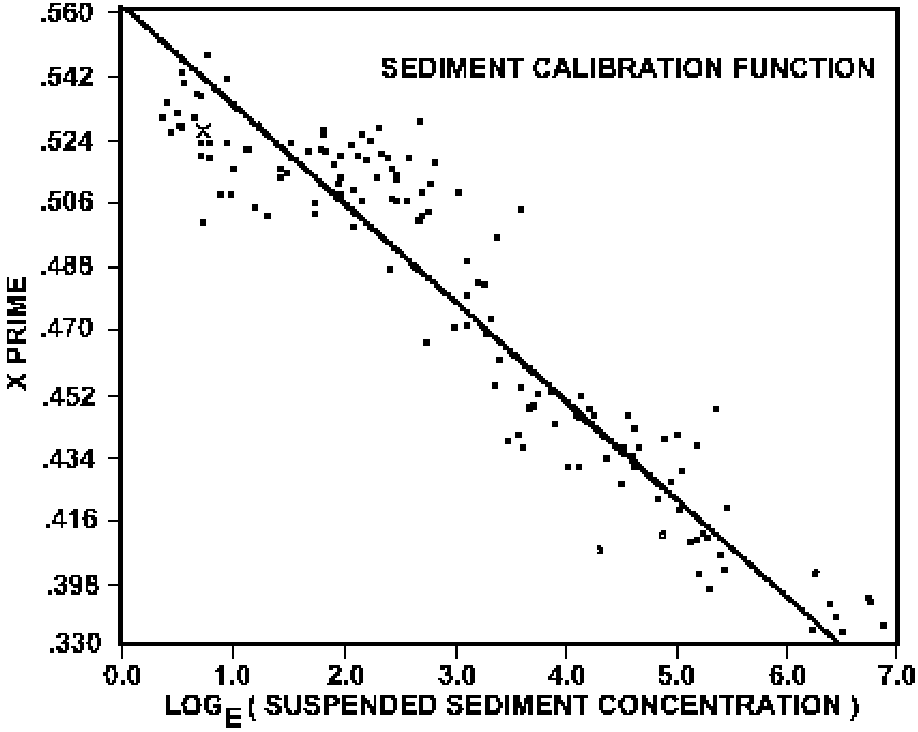
SPATIAL EXTRAPOLATION

The Landsat MSS bands are quite coarse in spectral resolution (approximately 100mm for bands 4, 5 and 6) which prevents their use for classifying <u>types</u> of suspended solids. The benefit to be drawn from this is that satellite/SSC calibration may be extrapolated from one area to another which has a different sediment profile. Some preliminary testing of this supposition was carried out with the assistance of cooperating investigators. Landsat MSS data sets with coincident sampling information was provided from the U.S.A.[1], Sweden[2], and Australia[3].

1: Dr. J.C. Munday, Jr., Virginia Institute of Marine Science, U.S.A.
2: Dr. T. Lindell, National Environmental Protection Board of Sweden.
3: Dr. M. Risk, visiting scientist, Australian Institute of Marine Science.

Despite significant complicating factors (for instance: four different receiving stations with four different radiometric correction techniques and four different SSC laboratory analyses) the reduced data sets agreed with each other remarkably well. Figure 3 shows the satellite versus surface measurement relationships which has a correlation of 94 percent. The Australian data set is composed of only one datum, and is shown as an x in Figure 3.

Figure 3



The lack of sediment type discrimination of the MSS thus appears to be useful for spatial extrapolation of SSC calibration. This must be tested much more thoroughly to establish the practical limits of this process.

DISCUSSION

The chromaticity technique for LANDSAT-based estimation of SSC has been shown to be a simple and practical method with significant potential economic benefits in reducing field crew expenses. It does not replace completely, but complements *in situ* examinations. Further, it must live within the constraints of the sensor and its data: spatial, radiometric and temporal resolution. The problem of ambiguity between turbidity and bathymetry stands. In shallower waters, multi-temporal techniques must be used to eliminate bottom reflection effects in order to measure SSC, just as turbidity effects must be removed to measure bathymetry.

The chromaticity technique can correct for atmospheric variability over time in order to quantitatively measure SSC. Alternately, if constant atmospheric conditions are accepted, then chlorophyll concentration may be measured, though in a coarser fashion than SSC due to the darker target provided by algae and other chlorophyll-bearing agents. Bathymetric applications are possible with this methodology, as are (land-based) biomass measurements. A recent research exercise has shown this technique to be also useful for oil slicks identification, separating marine oil slicks from their typical false oil targets of inorganic sediment plumes and cloud features.

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