ON THE USE OF A SINGLE BLUE BAND IN OCEANOGRAPHY

by

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Abstract

The selection of a single blue band to quantitatively measure ocean chlorophyll is dependent upon the altitude and spectral bandwidth of the filter. These relationships are discussed, and the conclusion made that a blue band from 0.44 to 0.50 microns would best serve this oceanographic application.

INTRODUCTION

The use of multispectral photography and its ensuing adaptation to mechanical and electronic sensors have usually relied on the color-signature differences which are associated with the response of the human eye. Relatively low spectral resolution systems have evolved using high spatial resolution to permit environmental target delineation, while the spectral differences determine the target type and characteristics.

The use of multispectral photography in aircraft and satellite terrestrial applications has required investigators to deal with the perturbing effects of the atmosphere. When used for oceanographic applications, the same techniques are affected by two additional perturbing features: the ocean surface and the water column. Investigators interested in bottom topography and mapping in shallow waters typically require the same spatial resolutions needed overland because the measurement requirements are the same. Surface effects in some applications are noise in the data, while in others (such as pollution) the surface phenomenon itself is the measured parameter. However, in most cases the study of surface effects and phenomena requires a different sun angle relationship to the sensor than when the applications are subsurface. The investigation of the upper hundred feet of the water column is a critical area in synoptic oceanography primarily because life in the sea begins in this upper region where photosynthesis in plant life is possible.

Visible region ocean surface studies (excluding wave phenomena) and water column studies historically have differed from those of bottom topography and mapping studies; namely, in situ measurements of the two former studies have always used high spectral resolution on the order of 20 to 100 Angstroms to detect and measure slight "color" changes in the surface and subsurface characteristics, while a panchromatic approach has been used for bottom studies. The early transition[1] from the in situ to aircraft measurement of the water column has determined the necessity of maintaining high spectral resolution from remote sensors operating above the ocean surface.

The purpose of this discussion is to examine the factors involved in selecting a single blue band for oceanographic applications with prime emphasis on water column measurements related to chlorophyll. The use of a single channel chlorophyll detector from space will serve as a qualitative measurement of chlorophyll in the world's oceans, while a multichannel high spectral resolution sensor will be required before quantitative measurements are possible. Even qualitative data on global chlorophyll are not presently available.

REMOTE MEASUREMENT OF CHLOROPHYLL

The work of Ewing and Clarke[2] has shown the response of an airborne spectrometer to chlorophyll and to effects of varying altitude. These effects have been combined in Figure 1 (after Ewing and Clarke) in terms of the spectral contrast ratio (SCR) defined as

$$\text{SCR} = \left| \frac{\text{High Chlorophyll} - \text{Low Chlorophyll}}{\text{Low Chlorophyll}} \right|$$

where "high chlorophyll" refers to the percent of incident energy at a given wavelength returned to the spectrometer from water containing 0.3 to 0.4 mg/m^3 chlorophyll concentration (water typical of the Gulf Stream) and "low chlorophyll" is the same percentage returned from water containing less than 0.1 mg/m^3 (this is very sterile water such as might be found in the Sargasso Sea). Thus, a comparison is being made between the most benign waters of the

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[1] S. Q. Duntley, "Light in the Sea," Journal of the Optical Society of America, Vol. 53, No. 2, pp 214-233, February 1963.

[2] G. C. Ewing and G. L. Clarke, "Remote Sensing of Ocean Color from Aircraft"

world's oceans to conditions that are considered to be the threshold for chlorophyll measurement. The range of significant chlorophyll concentrations is from approximately 0.3 to 10 mg/m^3.

The data in Figure 1 are repeated in Figure 2 for the 10,000-foot altitude case to delineate the rapid roll-off in response of wavelengths greater than 0.5 microns for filters of 50-Angstrom bandwidths. Using the 10,000-foot altitude data, the SCR has been computed as a function of the short wavelength cutoff for three different bandpass filters of 200, 600, and 1,000 Angstroms (0.02, 0.06, and 0.1 microns, respectively). These results are sketched in Figure 3 which illustrates the following features at 10,000-foot altitude:

a. The maximum SCR is a relatively broad function of the short wavelength cutoff within the 0.40- to 0.48-micron region and depends on the filter width.

b. As the filter width increases, the short wavelength filter cutoff moves deeper into the blue region for maximum SCR.

c. There is a maximum SCR associated with each of the three filter widths.

Thus, for each filter bandpass, there is a preferred region within the blue region for obtaining the maximum SCR.

The general behavior of the maximum SCR as a function of the filter bandpass width is shown in Figure 4 using the right ordinate. The greater the spectral resolution, the greater the maximum SCR. There is a preferred filter center wavelength which gives the maximum SCR for each filter width which is shown on the left ordinate. The preferred center wavelength moves toward shorter wavelengths as the filter width increases, at least to widths on the order of 600 to 800 Angstroms.

The behavior of the maximum SCR with altitude is illustrated in Figure 5. There is a significant reduction in the maximum SCR as the altitude increases. Also, it should be noted that probably all aerosols and particulate matter and about half the atmosphere are below the 10,000-foot level, and thus, the reduction in the SCR will not continue at the same rate above the 10,000-foot level as measured below that level. Figure 6 shows the preferred center wavelengths with altitude as a function of filter width which gives the maximum SCR of Figure 5. The general behavior of these data is consistent with that intuitively anticipated. That is, at low altitude with relatively narrow filter widths the preferred center wavelength occurs near the peak absorption for chlorophyll around the 0.42- to 0.44-micron region. As the altitude increases so does the preferred center wavelength increase for the narrow filter widths. However, at broader filter widths there is a convergence of the preferred center wavelengths at around 600- to 800-Angstrom filter widths. Based on this convergence, it appears that the single best channel for chlorophyll measurement is from 0.44 to 0.55 microns for a space system.

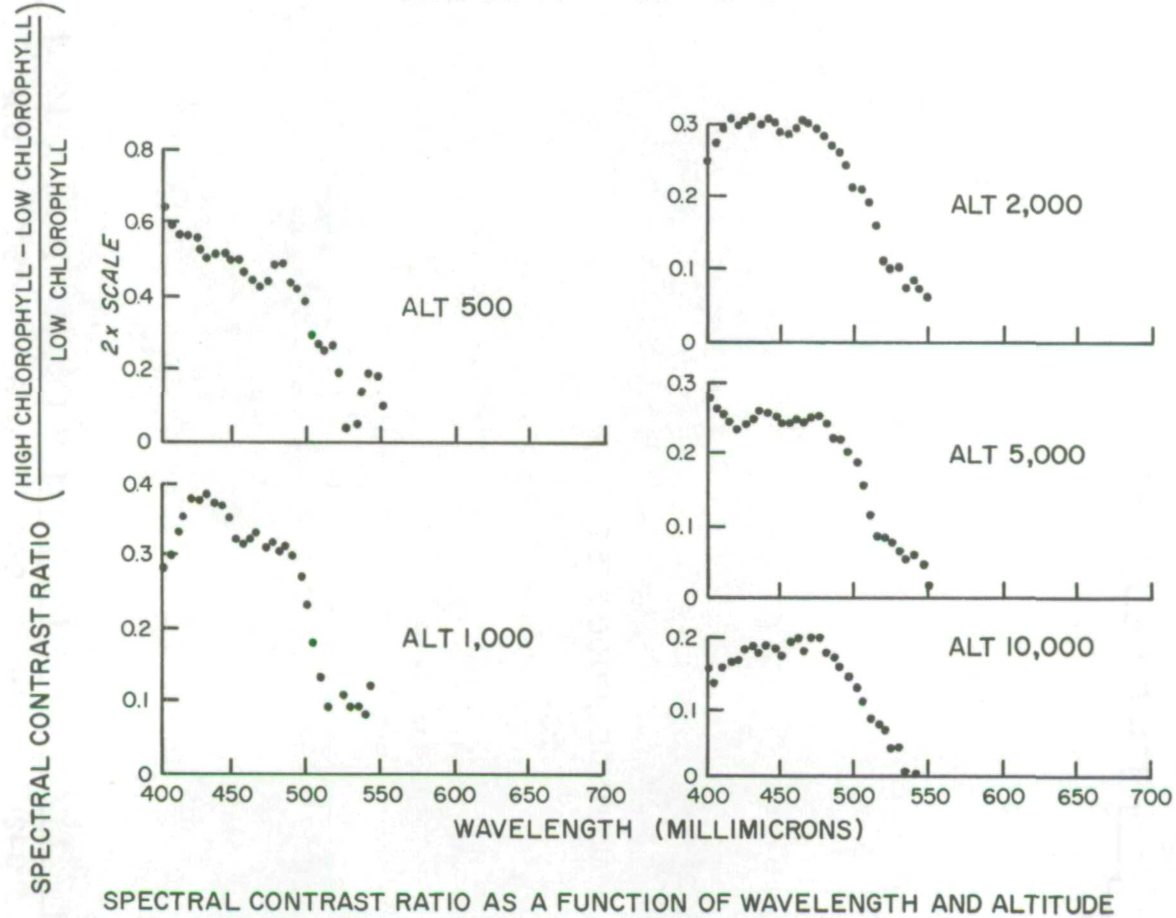

Figure 1.- Spectral contrast ratio as a function of wavelength and altitude.

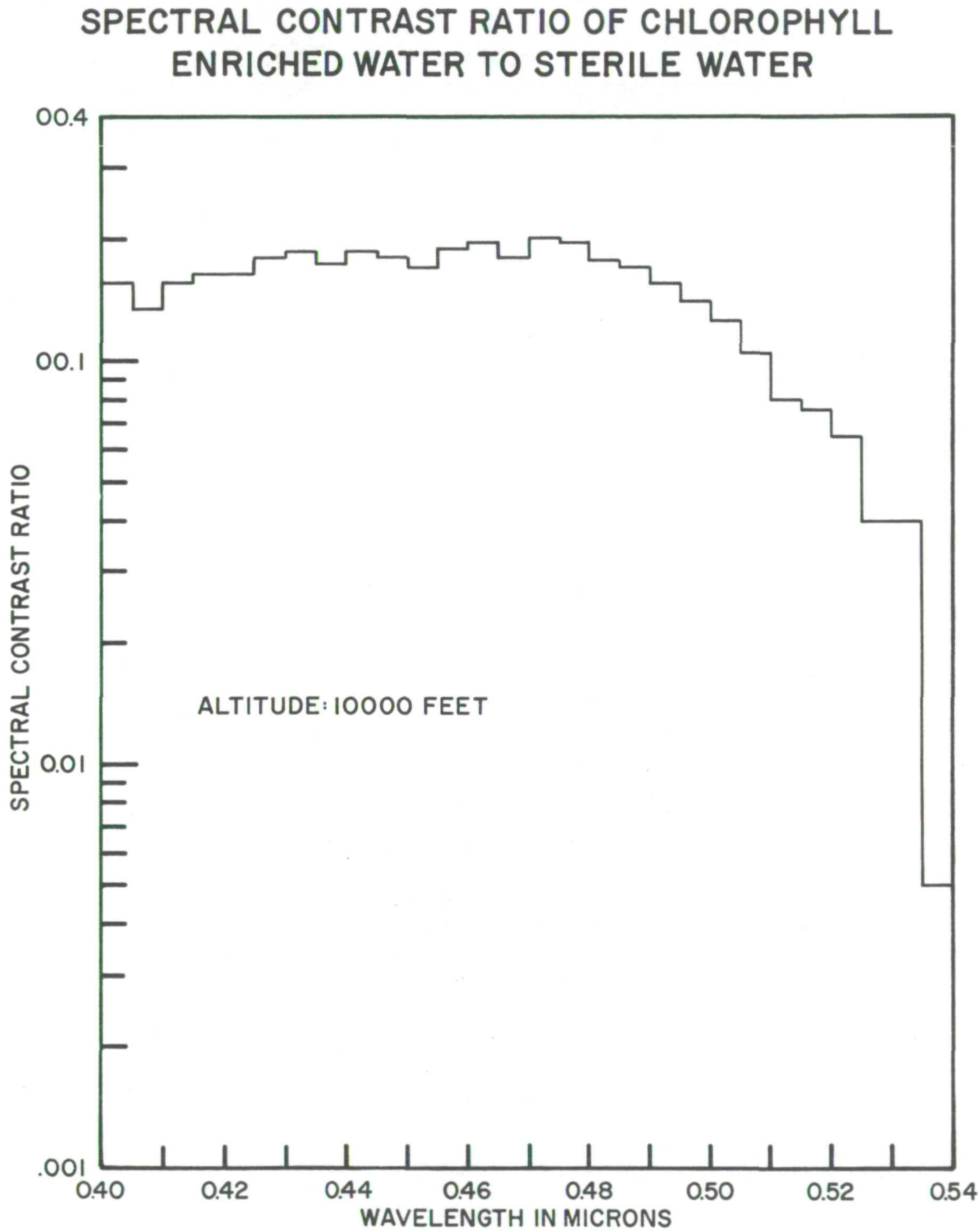

Figure 2.- Spectral contrast ratio of chlorophyll-enriched water to sterile water.

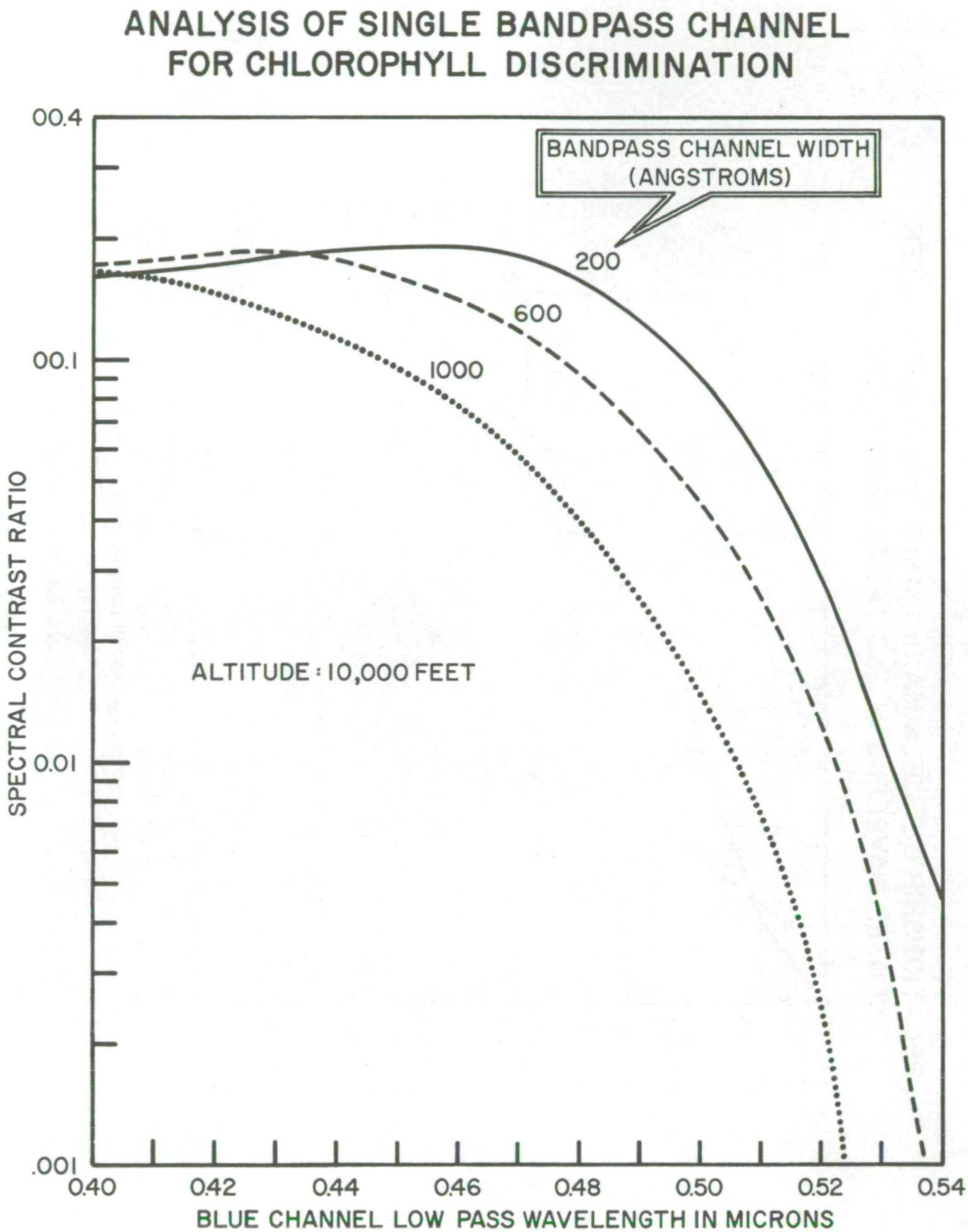

Figure 3.- Analysis of single bandpass channel for chlorophyll discrimination.

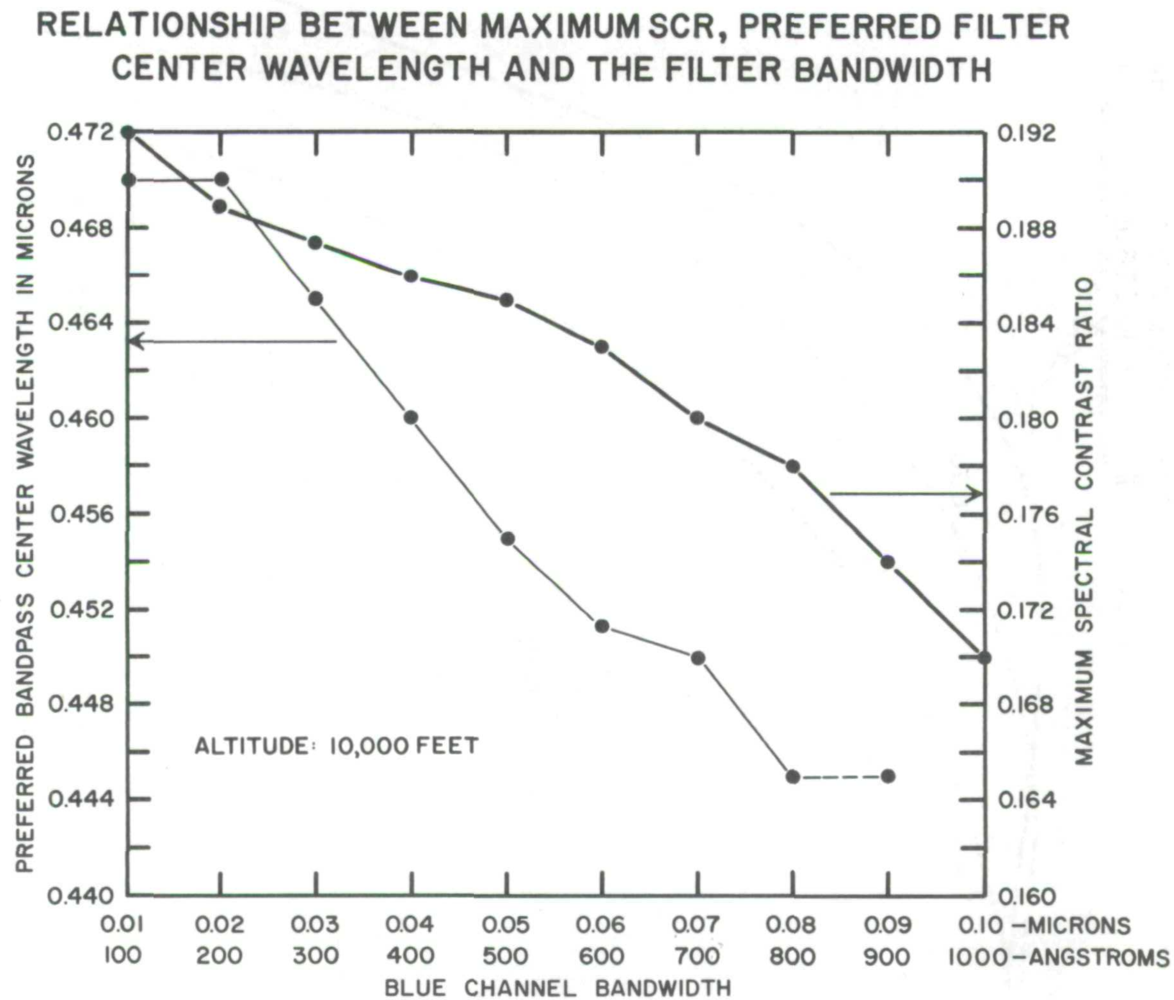

Figure 4.- Relationship between maximum SCR, preferred filter-center wavelength, and the filter bandwidth.

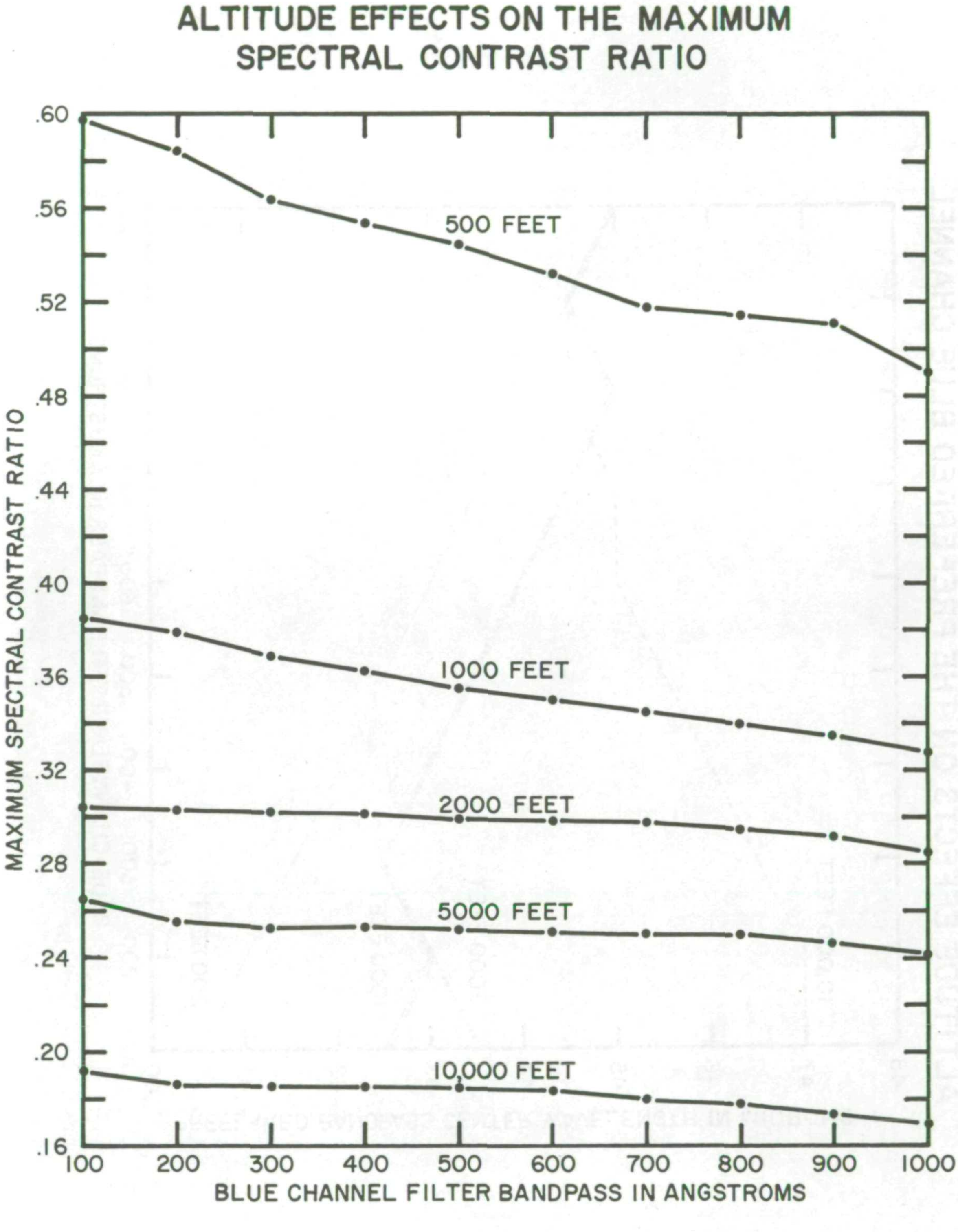

Figure 5.- Altitude effects on the maximum spectral contrast ratio.

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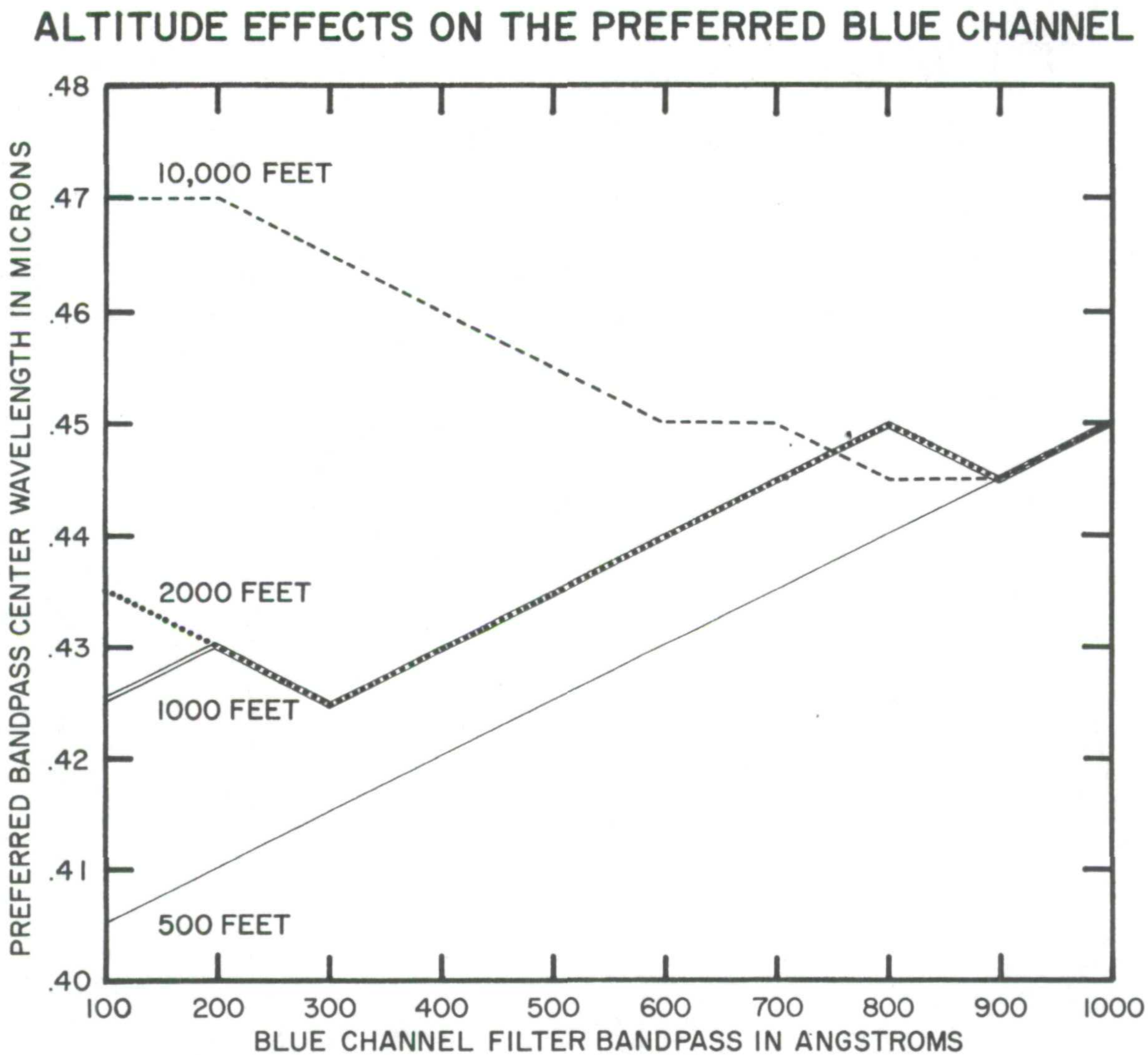

Figure 6.- Altitude effects on the preferred blue channel.

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