Remote Sensing of Ocean Color From Aircraft

by

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Over 3,000 ocean spectra of sunlight backscattered from the upper layers of the sea have been obtained at flight altitudes to 10,000 feet together with detailed ground truth. These spectra are from stations which include a wide range of water masses differing as to biological and physical condition. This data bank and the analysis already performed demonstrates the probable feasibility of using ocean color as a parameter to locate areas of special significance to physical oceanographers and marine biologists from aircraft and satellites.

The relationship between light extinction and biological productivity has been studied by Dr. Carl J. Lorenzen. "The penetration of light into the ocean is of fundamental importance since photosynthesis can only occur if light intensity is above a minimum level. The quantity and quality of light at any given depth is controlled by absorption and scattering within the water column by water itself and by dissolved and suspended substances of biological and non-biological origin.

"Light attenuation in the euphotic layer is affected by 1) water itself, 2) plankton algae, and 3) a mixture of other suspended and dissolved substances. In regions characterized by high standing crops of phytoplankton, the euphotic layer is thin and most of the light attenuation can be attributed to plants.

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At the other extreme, where the euphotic zone is thicker, water itself absorbs and scatters most of the light. Between these extremes light attenuation is due largely to materials other than plants and water molecules." (Ref. 1).

The chief problems are:

1. to assay the effect of varying illumination,
2. to estimate and eliminate interference from air haze,
3. to identify the various biochromes, terrigenous materials and pollutants characterized by their spectral signatures.

The spectrum of the backscattered light from the sea has been measured in absolute units using the TRW spectrometer flown in aircraft at altitudes ranging from 500 ft. to 10,000 ft. The reduced equivalent thickness of the atmosphere above 5 km is only 54 percent of that at the surface and is relatively less variable at higher altitudes. It is therefore probable that interference from "air light" (radiation scattered by the atmosphere and materials in the atmosphere) becomes less with increasing altitude, and therefore it is expected that this type of measurement can be made at indefinitely higher altitudes. The backscattered light in each part of the visible spectrum has been calculated as a percentage of the incident downwelling irradiance at the sea surface. The spectrum thus obtained reveals the action of the water itself and of materials (living and non-living) suspended and dissolved in the water. Certain important materials such as chlorophyll have recognizable spectral signatures. Thus the shape of the spectrum can be used to measure the kinds and amounts of substances present in the surface waters of the ocean. This may well be the only feasible method for remote assay of the material content of oceanic waters.

Our investigations have demonstrated the feasibility and utility of this remote sensing technique to detect chlorophyll over the range of concentrations characteristic of the open ocean (Ref. 2). Spectra have been obtained from water masses with concentrations up to 3 mg chlor/m^3 and higher values could easily be recorded (Fig. 1). Blackburn has shown that variations of 0.1 mg/m^3 at concentrations as low as 0.1 mg/m^3 are of particular significance in biological and fisheries investigations (Ref. 3, 4). It is expected that further analyses of curves of this type will enable us to recognize changes in the spectra due to other important materials in the water, including pollutants.

To investigate the capability to discriminate such small variations at low concentration, a special study was carried out in 1969 over the transition between the coastal water south of Georges Bank and the Sargasso Sea. Here over a distance of a mile or so the chlorophyll concentration changed from 0.3 to 0.1 mg/m^3 and the temperature from 18°C to 23°C. Spectra were taken on the two sides of the transition at altitudes ranging from 500 ft. to 10,000 ft. (Figs. 2, 3, 4, 5, 6). Although the shape of the spectra changed characteristically with altitudes, the differences between members of each pair and their contrast ratio remained nearly the same and clearly showed the location of the transition (Figs. 7 and 8).

References

1. Lorenzen, C. J., 1970. "Extinction of light in the ocean by phytoplankton." Contribution No. 2558 from the Woods Hole Oceanographic Institution. In press.

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3. Blackburn, Maurice, 1969. In "Useful Applications of Earth-Oriented Satellites: Oceanography 5," NAS, p. 12.

4. Blackburn, Maurice, 1969. "Applications to fishery oceanography" in The Color of the Ocean, Rept. of Conference held at W.H.O.I. August 5-6, 1969, sponsored by Earth Survey Office, Electronics Research Center, Cambridge, Mass., pp. 3-1 to 3-11.

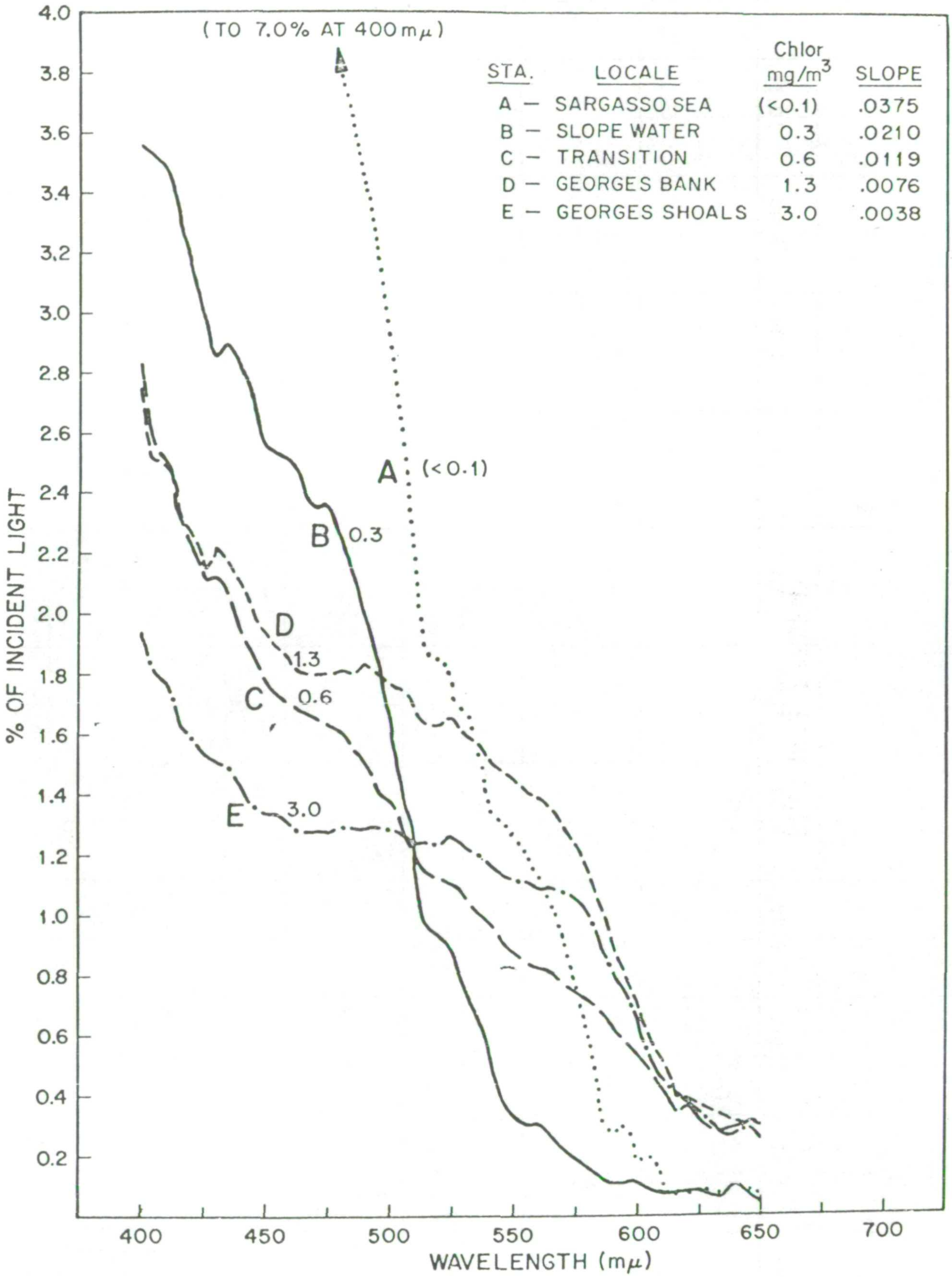

Figure 1. Examples of reflectance spectra from ocean waters containing different concentrations of chlorophyll.

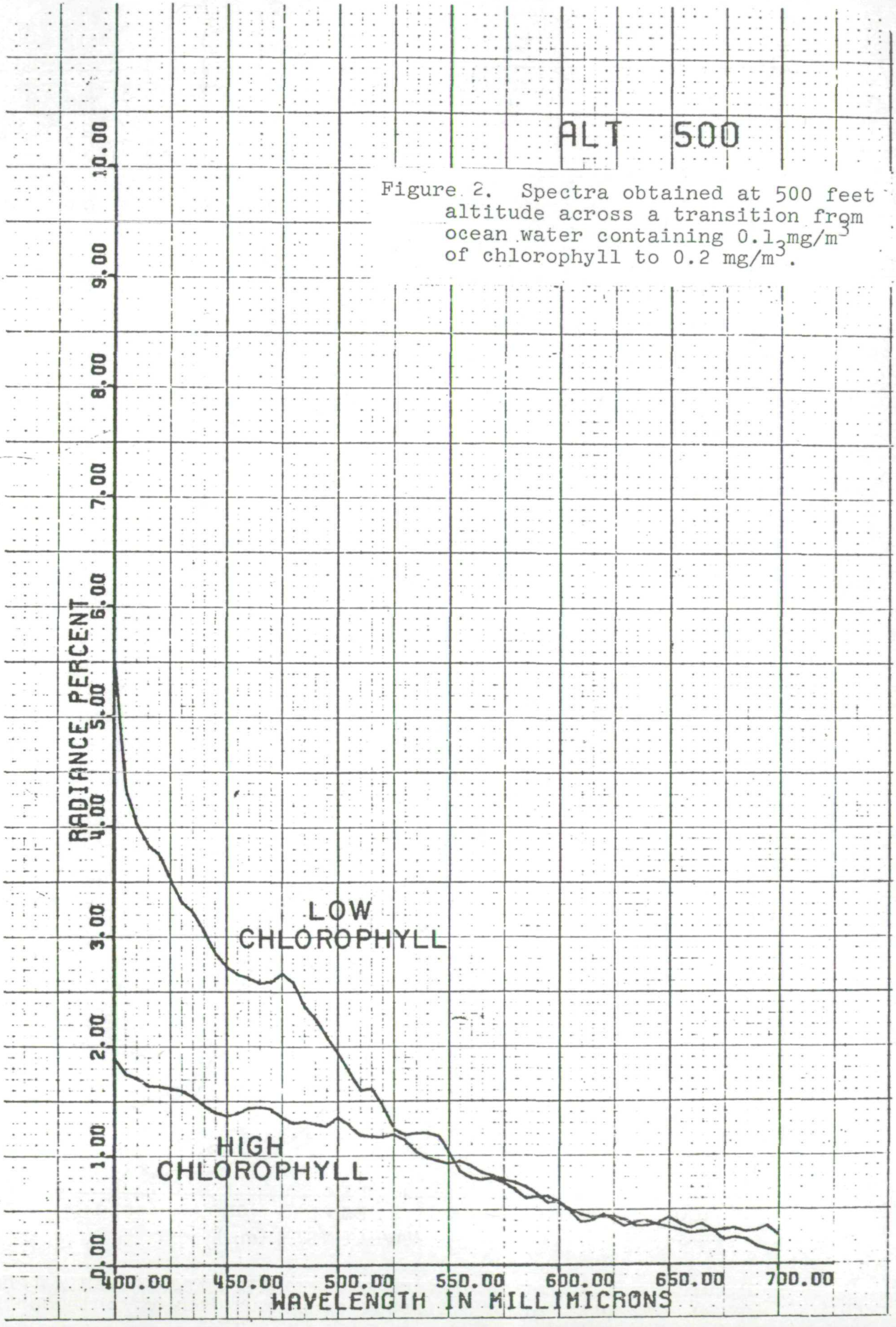

Figure 2. Spectra obtained at 500 feet altitude across a transition from ocean water containing 0.1 mg/m^3 of chlorophyll to 0.2 mg/m^3.

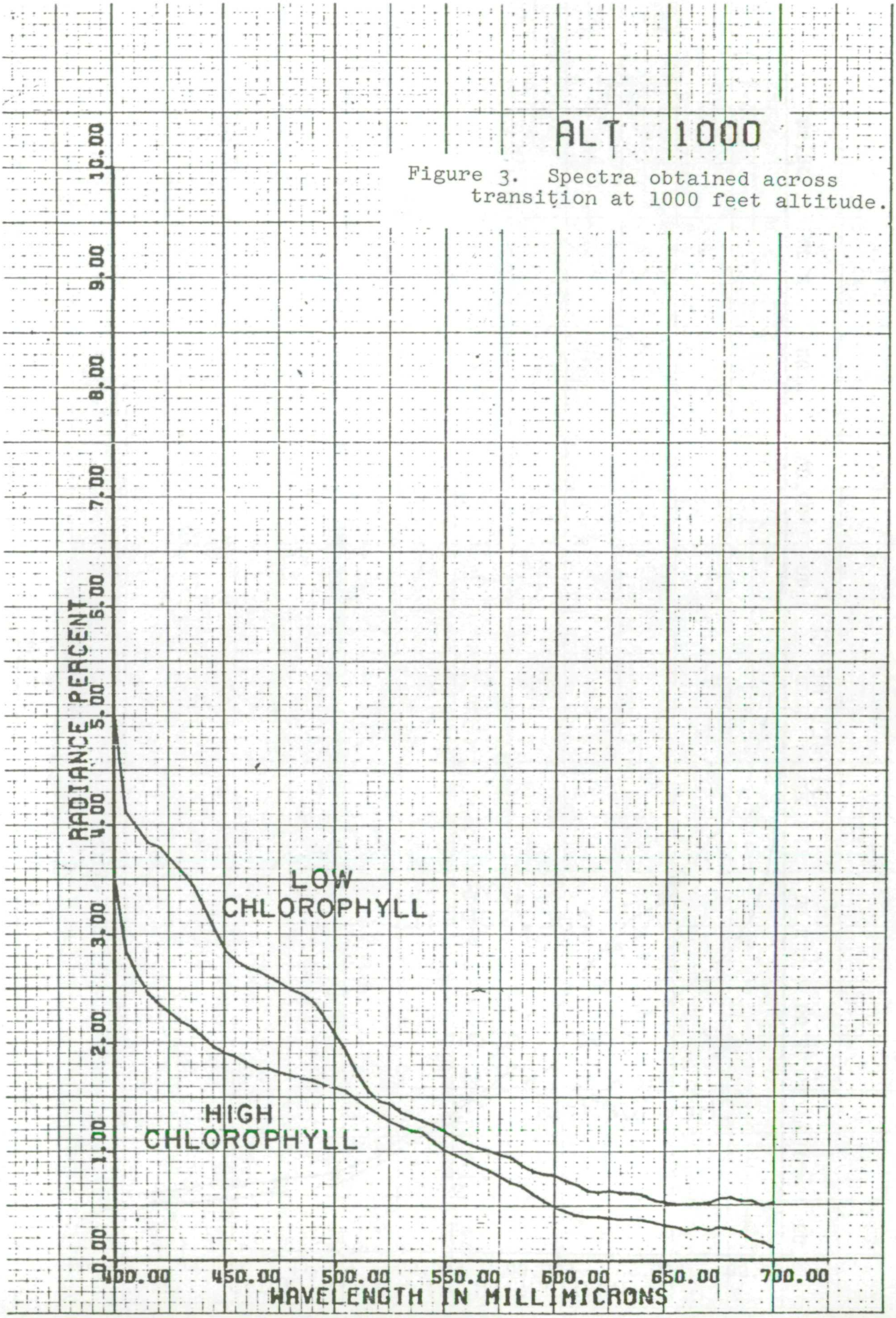

Figure 3. Spectra obtained across transition at 1000 feet altitude.

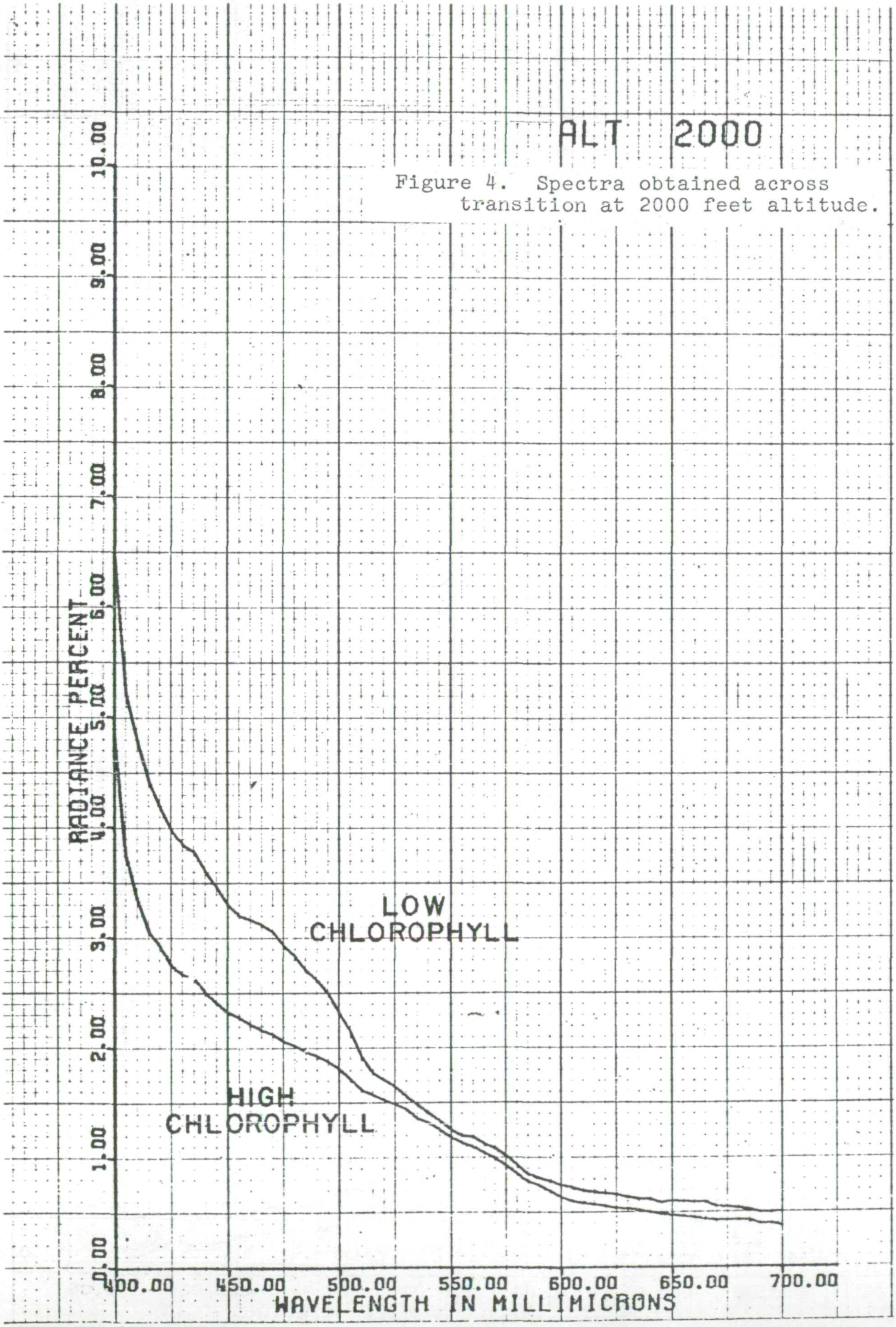

Figure 4. Spectra obtained across transition at 2000 feet altitude.

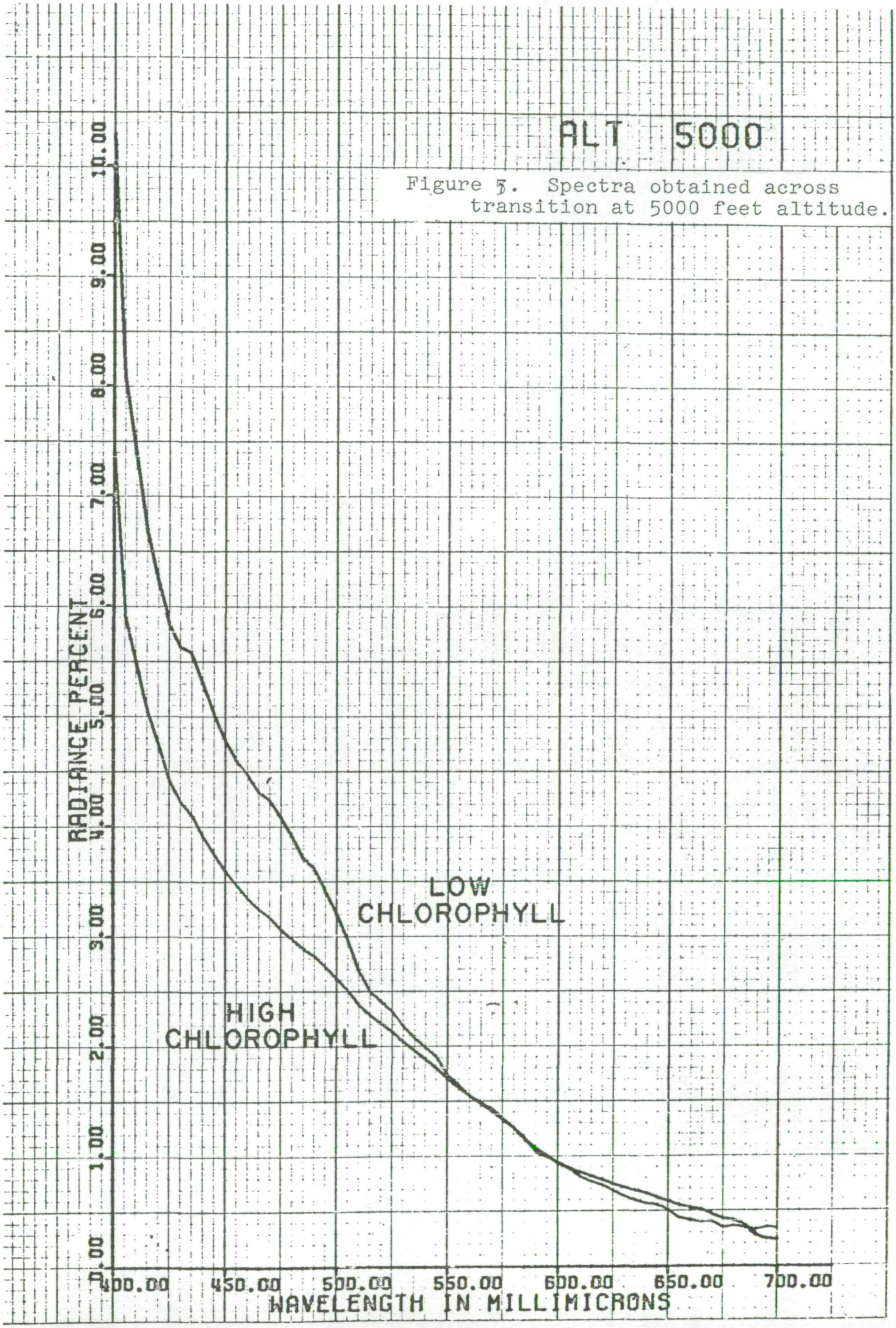

Figure 5. Spectra obtained across transition at 5000 feet altitude.

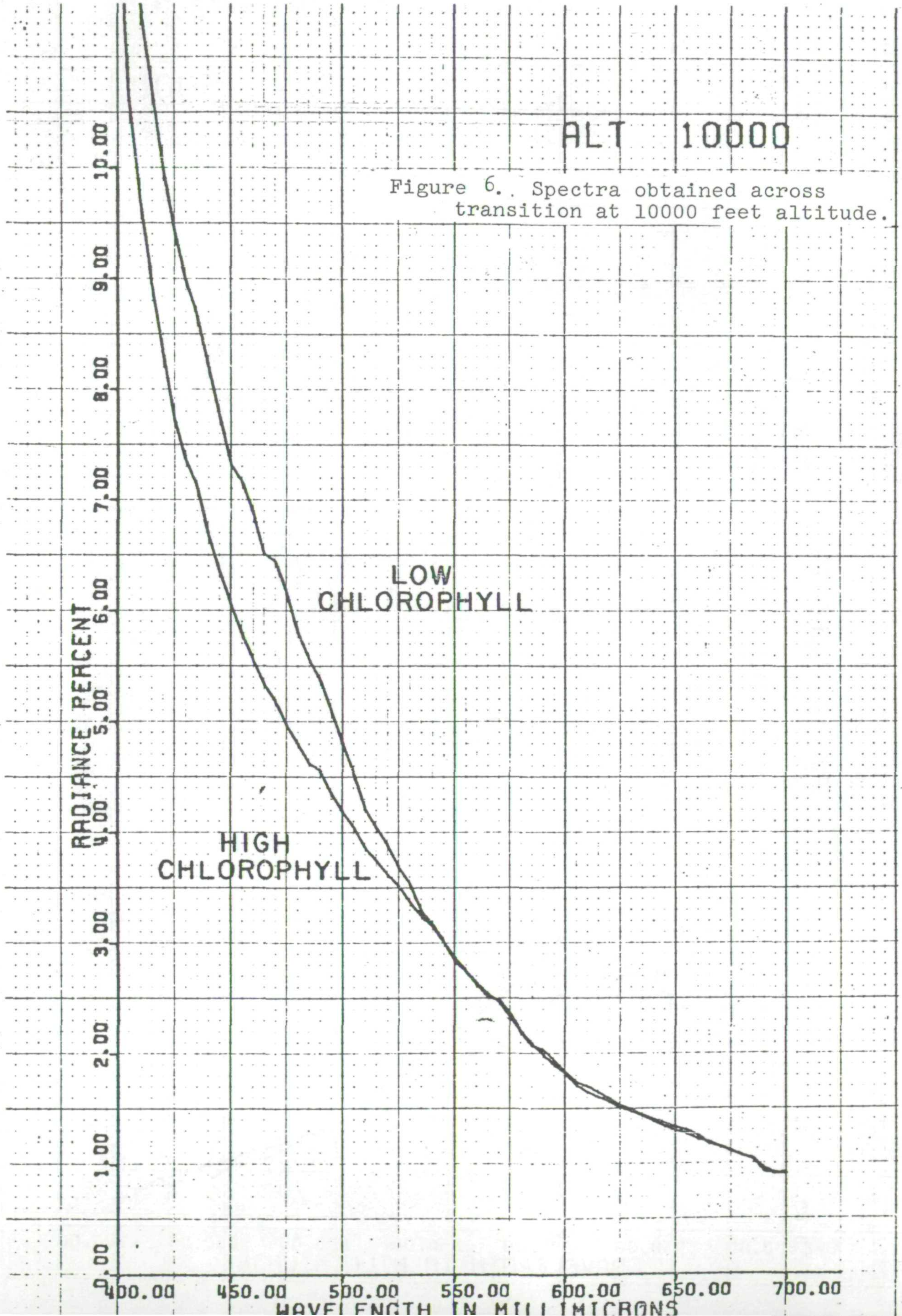

Figure 6. Spectra obtained across transition at 10000 feet altitude.

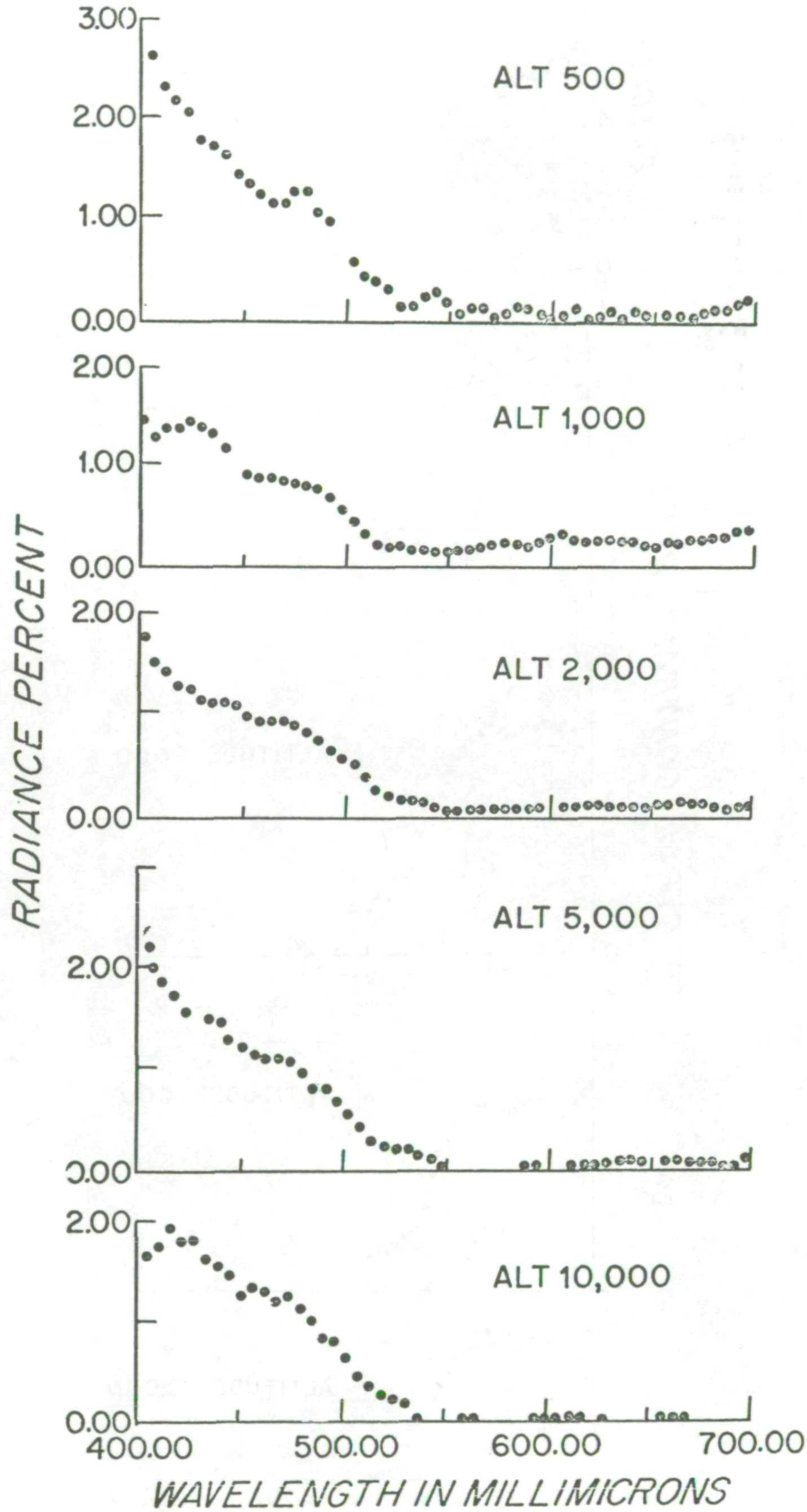

Figure 7. Difference of spectra across a transition in ocean color at flight altitudes (ft.) shown.

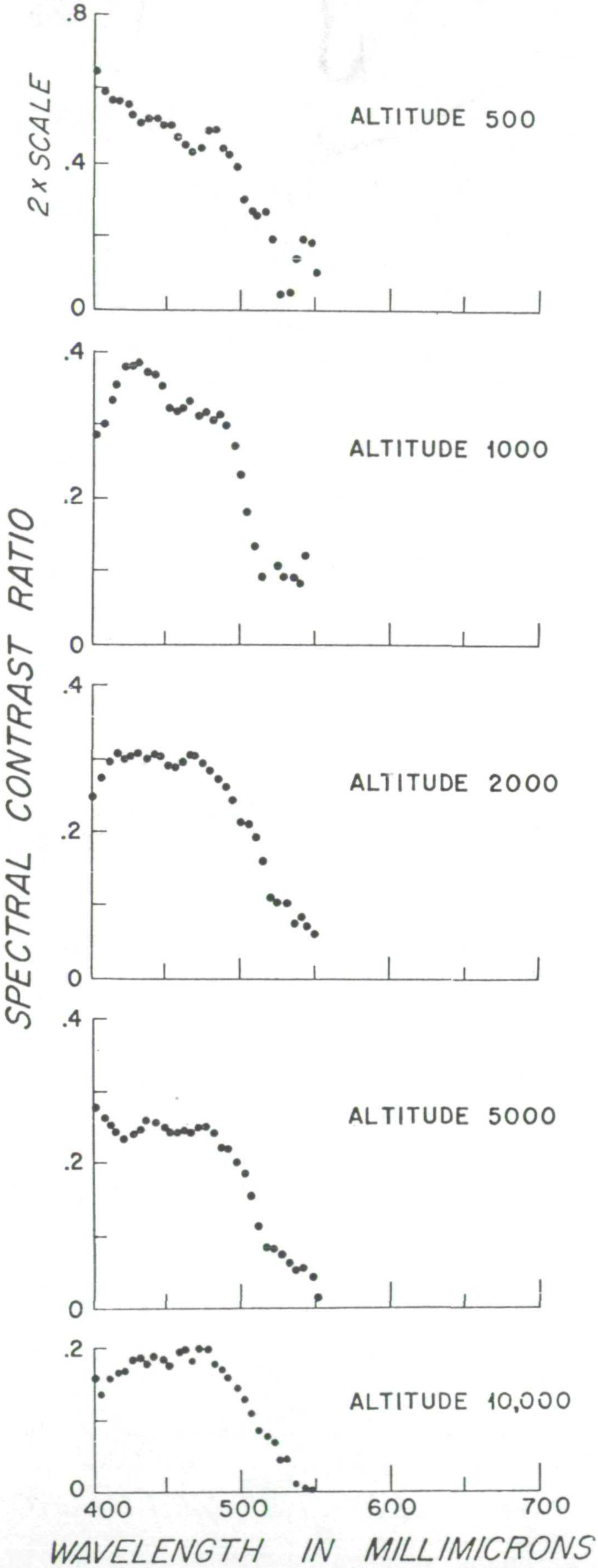

Figure 8. Contrast ratio, of light differences to total light, across transition