The comment by Brown and Gordon underscores the complexity of suspended matter in the ocean. Brown and Gordon show that on the basis of $\beta_{45}/N$, of light scattered at 45° per particle, a relative index of refraction of 1.15–1.20 can be inferred for suspended particles in the tongue of the ocean. For this range of the index of refraction, Mie-scattering calculations show that the ratio $\beta_{45}(\lambda = 436 \mu\text{m})/\beta_{45}(\lambda = 546 \mu\text{m})$ should be less than 1.0. Observations showed this ratio to be around 1.25, however. This discrepancy is much greater than can be explained by a reasonable wavelength dependence of the index of refraction. Accepting Brown and Gordon’s Fig. 1, we see that, on the basis of the wavelength dependence of scattering, we must conclude that the index of refraction lies between 1.03 and 1.05. The real problem thus lies not in the inaccuracy of our approximation

$$\frac{\beta_{45}(\lambda_1)}{\beta_{45}(\lambda_2)} = \frac{b(\lambda_1)}{b(\lambda_2)}$$

(the error is less than 10% except for relative indices less than 1.04), but in the fact that a single “average” index of refraction of suspended particles is apparently not adequate to explain all of the observed optical properties. This assumption is basic, however, to most work on the index of refraction of suspended particles. The main source of error probably lies in the extremely nonlinear way in which optical properties are averaged over a size distribution.

A further assumption is the uniform index of refraction of a particle. Using three-layered particles, Mueller has shown significant deviations from the uniform case for both angular and wavelength dependence of scattering.

A third basic assumption has been that the contribution of small particles (diameter less than 1 μm) is negligible. Fitting an exponential size distribution to Gordon’s data for the tongue of the ocean is not possible, owing to the large number of small particles present. Inclusion of these small particles would increase the total number of particles, $N$, by at least an order of magnitude, compared to the exponential fit. This would greatly reduce the $\beta_{45}/N$ ratio, as used in Fig. 2. In a three-component model, Gordon et al. had to assign to these particles an index of refraction of 1.01–0.01 in order to minimize their effect compared to the larger particles. Analysis of in situ pumped samples shows that the small particles are largely of terrestrial origin, implying a large index of refraction. As a result, the contribution of the small particles probably cannot be ignored if their index of refraction is greater than 1.03. Small-particle scattering would affect the wavelength dependence.

Morel has recently carried out an extensive series of Mie-scattering calculations. On the basis of reasonable assumptions concerning the size distribution and light-scattering characteristics of particulate matter in the oceans, he concludes that the average relative index of refraction for particulate matter in the ocean must be in the range 1.02–1.05.

We conclude that the various basic assumptions generally employed in the study of the index of refraction of suspended particles in the ocean may not be applicable. Furthermore, the use of different optical properties for the determination of a representative index of refraction does not give consistent results. Extreme caution must thus be exercised in interpreting an index of refraction obtained by a given method. The possible contribution to scattering by small particles must be reconsidered. Experimental work must be carried out in order to determine accurate size distributions, and in order to ascertain the composition of the suspended particulate matter. The non-uniformity of the index of refraction of particles must also be further investigated.