phaeopigment values (0 to 20 milligrams per cubic meter), which makes it easier to distinguish separate a^*_p relationships.

The minimal presence of a_d is also another important factor in enabling us to find the variation in a^*_p in Antarctica. Figure 2 shows that a_d normalized for chlorophyll + phaeopigment was typically negligible. Sosik et al. (this issue) found the a_d from RACER3 to be very low compared to the a_d from the temperate water off the California coast. Assuming a_d from equation 2 to be minimal, it will contribute little to variations in a^*_p. Therefore most of the variation is due to a^*_{ph}.

Work in progress includes analyzing pigment composition and determining the cell size and phytoplankton composition for the RACER3 cruise. These data should provide us with more information such as pigment per cell and the ratio of accessory pigment to chlorophyll *a* for all the samples and improve our understanding of particle optics in the Antarctic.

We thank the captain and crew of the R/V *Polar Duke*, Martha Ferrario for the floristic analysis, Chris Fair for technical assistance, and Vincent Spode for graphics. This project was supported by National Science Foundation grant DPP 88-17635 to O. Holm-Hansen and Maria Vernet.

References

Bricaud, A., A. L. Bedhomme, and A. Morel. 1988. Optical properties of diverse phytoplanktonic species: Experimental results and theoretical interpretation. *Journal of Plankton Research*, 10:851-873.

Frouin, R. 1992. Near-surface phytoplankton pigment concentration in the Gerlache Strait derived from aircraft POLDER data. *Antarctic Journal of the U.S.*, this issue.

Gordon, H. R. and A. Morel. 1983. *Remote Assessment of Ocean Color for Interpretation of Satellite Visible Imagery: A Review*. New York: Springer-Verlag.

Gordon, H. R., O. B. Brown, R. H. Evans, J. W. Brown, R.C. Smith, K. S. Baker, and D. K. Clark. 1988. A semianalytical radiance model of ocean color. *Journal of Geophysical Research*, 93:10,909-10,924.

Holm-Hansen, O. and M. Vernet. 1992. RACER: Distribution, abundance, and productivity of phytoplankton in Gerlache Strait during austral summer. *Antarctic Journal of the U.S.*, this issue.

Jeffrey, S. W. 1980. Algal pigment systems. In P. G. Falkowski (Ed.), *Primary Productivity in the Sea*. New York: Plenum, 33-58.

Kishino, M., C. R. Booth, and N. Okami. 1984. Underwater radiant energy absorbed by phytoplankton, detritus, dissolved organic matter, and pure water. *Limnology and Oceanography*, 29:340-349.

Mitchell, B. G., and D. A. Kiefer. 1988. Variability in pigment specific particulate fluorescence and absorption spectra in the northeastern Pacific Ocean. *Deep-Sea Research*, 35:665-689.

Mitchell, B. G. 1990. Algorithms for determining the absorption coefficient of aquatic particulates using the quantitative filter technique (QFT). *Ocean Optics X*, SPIE, 1302:137-148.

Mitchell, B. G. and O. Holm-Hansen. 1991. Bio-optical properties of antarctic waters: Differentiation from temperate ocean models. *Deep-Sea Research*, 38:1,009-1,028.

Mitchell, B. G. 1992. Predictive bio-optical relationships for polar oceans and marginal ice zones. *Journal of Marine Systems*, 3:91-105.

Morel, A. and A. Bricaud. 1981. Theoretical results concerning light absorption in a discrete medium, and applications to specific absorption of phytoplankton. *Deep-Sea Research*, 28:1,375-1,393.

Morel, A. and L. Prieur. 1977. Analysis of variations in ocean color. *Limnology and Oceanography*, 22:709-722.

Morel, A. 1988. Optical modeling of the upper ocean in relation to its biogenous matter content (case I waters). *Journal of Geophysical Research*, 93:10,749-10,768.

Morrow, J. H., D. A. Kiefer, and W. S. Chamberlin. 1989. A two-component description of spectral absorption by marine particles. *Limnology and Oceanography*, 34:1,500-1,509.

Sathyendranath, S., L. Lazzara, and L. Prieur. 1987. Variations in the spectral values of specific absorption of phytoplankton. *Limnology and Oceanography*, 32:403-415.

Smith, R. C. and K. S. Baker. 1981. Optical properties of the clearest natural waters (200-800 nm). *Applied Optics*, 20:177-184.

Sosik, H. M., M. Vernet, and B. G. Mitchell. 1992. A comparison of particle absorption properties between high- and mid-latitude surface waters. *Antarctic Journal of the U.S.*, this issue.

Vernet, M. 1992. RACER: Predominance of cryptomonads and diatoms in the Gerlache Strait. *Antarctic Journal of the U.S.*, this issue.

A comparison of particulate absorption properties between high- and mid-latitude surface waters

Heidi M. Sosik, Maria Vernet and

B. Greg Mitchell

Marine Research Division
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, California 92093-0218

The optical properties of particulate material in the surface waters of the ocean play a critical role in regulating the underwater light field and in determining water-leaving radiance. The absorption capability of the phytoplankton fraction of the particulate pool also sets an important limit on primary production. Variability in particulate optical properties thus should be reflected in light propagation models, in algorithms for pigment retrieval from remotely sensed data, and in bio-optical models for primary production. A recent study by Mitchell and Holm-Hansen (1991) has shown that there are significant differences between high-latitude and temperate ocean waters in pigment-specific diffuse attenuation coefficients and in the relationship between pigment concentrations and spectral ratios of upwelling radiance. The observed differences have been attributed to variability in particulate optical properties. The goal of this study is to examine differences in measured pigment-specific particulate absorption coefficients between surface waters from the Gerlache Strait and from the California current.

This study was conducted on three cruises. Samples were collected from stations in the Gerlache Strait on the Research on Antarctic Coastal Ecosystem Rates 3 (RACER3) cruise in December 1991 to January 1992 and from two California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises (9110 and

9202) in September to October 1991 and January to February 1992. The CalCOFI cruises cover an area off southern California between San Diego and just north of Point Conception and extend approximately 600-700 kilometers offshore (approximately 30° to 34° N and 118° to 124° W). Data from 132 RACER3 stations, 63 stations on CalCOFI cruise 9110, and 62 stations on cruise 9202 will be presented here.

All water samples were collected with Niskin bottles from depths ranging between 0 and 5 meters. Between 0.1 and 2 liters of water were filtered onto Whatman GF/F glass fiber filters. Samples taken on CalCOFI cruises were analyzed on board ship, while RACER3 samples were stored in liquid nitrogen and returned to the laboratory for analysis within 7 months. Analysis of filtered samples included measurement of absorption in a dual beam spectrophotometer. Using the method of Kishino (1985), the initial measurement was followed by extraction in methanol and subsequent reanalysis of absorption by the material remaining on the filter. The absorption following extraction of pigments with methanol can be regarded as the detrital component (a_d) of the total particulate absorption (a_p). By difference between the total and detrital signals, an estimate of phytoplankton absorption (a_{ph}) can be derived. However, this is an overestimate of a_{ph} since detrital phaeopigments will be extracted by methanol, and their absorption will be included in the phytoplankton component. The algorithm of Mitchell (1990) was used to correct all absorption measurements for pathlength amplification effects resulting from analysis of particulate samples concentrated on filters. In all cases, specific absorption was determined by dividing absorption by the concentration of chlorophyll *a* plus phaeopigments. Pigment concentrations were determined on separate samples from the Niskin bottles using standard fluorometric techniques.

The average pigment-specific particulate absorption spectrum (a_p^*) for the antarctic surface waters is consistently lower than that found on either of the CalCOFI cruises (figure 1). Antarctic values of a_p^* are as much as 2.5 times lower at some wavelengths with an average of 1.9 for the blue peak. Lower specific absorption for the RACER3 data is also observed for the phytoplankton component (a_{ph}^*) (figure 2). This feature, combined with the reduced ratio of the blue-to-red peak, is consistent with low-light adaption for antarctic populations of phytoplankton. Finally, detrital absorption is low in the antarctic surface samples compared with the mid-latitude California Current (figure 3). At 440 nanometers, the average ratio a_{ph}:a_d is approximately 4 for each of the CalCOFI cruises. For RACER3, a_{ph} is an average of 10 times higher than a_d.

These results support the hypothesis of Mitchell and Holm-Hansen (1991) that high-latitude surface waters have low detrital absorption and a low a_{ph}^* when compared to temperate waters. As these authors have shown, this variability is manifest in models for light propagation through the water column and for ocean color algorithms. Bio-optical modeling of primary production will also be affected by this type of regional variability. To better understand the magnitude and distribution of variability in partical optics is a critical step toward the development of more accurate bio-optical algorithms.

The RACER3 work was supported by National Science Foundation grant DPP 88-17635 to O. Holm-Hansen and M. Vernet. The work with CalCOFI was supported by Office of Naval Research grant N00014-91-J-1186 to B. G. Mitchell and National Science Foundation Graduate Student Fellowship to H. Sosik. We would like to thank the captains and crew of the R/V *New Horizon*, the R/V *David Starr Jordan* and the R/V *Polar Duke*, and C. Fair and L. Flores for technical assistance.

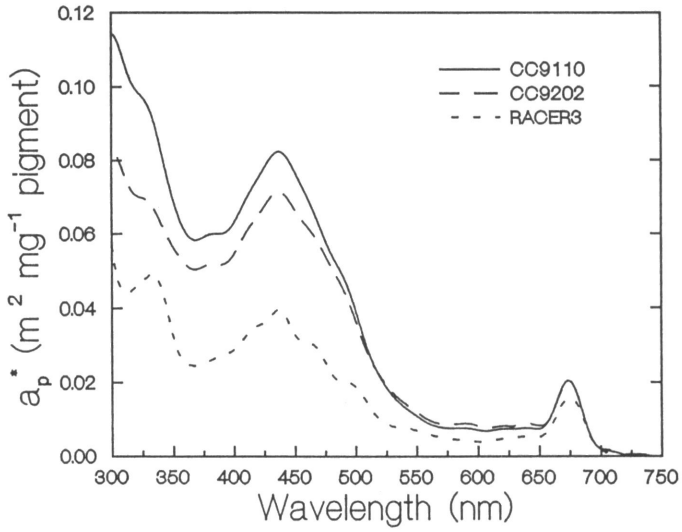

Figure 1. Average chlorophyll *a* plus phaeopigment-specific particulate absorption spectra for surface waters sampled in the Gerlache Strait (RACER3) and on two cruises to the waters off southern California (CalCOFI 9110 and CalCOFI 9202).

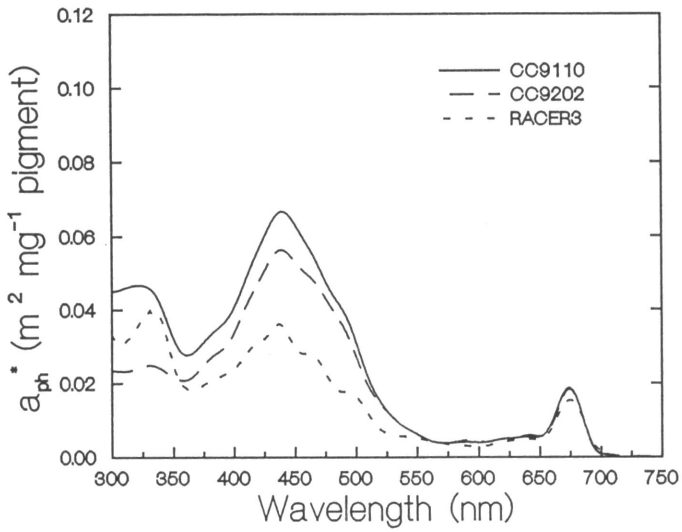

Figure 2. Average chlorophyll *a* plus phaeopigment-specific phytoplankton absorption spectra estimated using the technique of Kishino et al. (1985) for the same samples shown in figure 1.

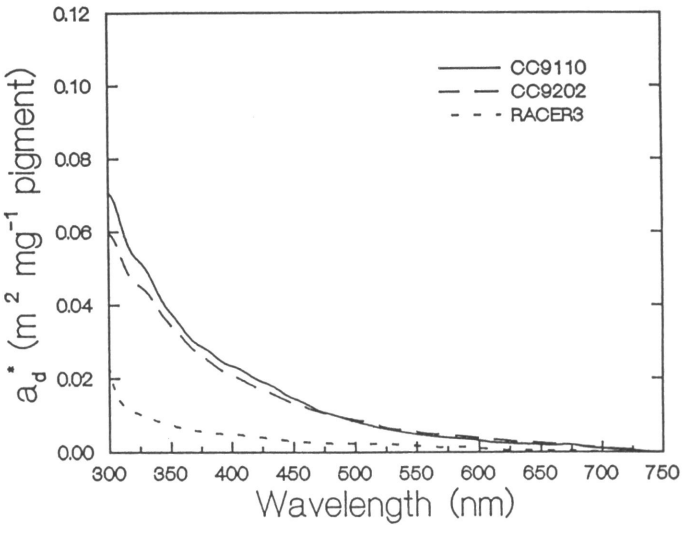

Figure 3. Same as figures 1 and 2 except for the detrital component of the total particulate pool.

References

Kishino, M., M. Takahashi, N. Okami, and S. Ichimura. 1985. Estimation of spectral absorption coefficients of phytoplankton in the sea. *Bulletin of Marine Science*, 37:634-642.

Mitchell, B. G. 1990. Algorithms for determining the absorption coefficient of aquatic particulates using the quantitative filter technique (QFT). *Ocean Optics X*, SPIE, 1301:137-148.

Mitchell, B. G. and O. Holm-Hansen. 1991. Bio-optical properties of Antarctic Peninsula waters: Differentiation from temperature ocean models. *Deep-Sea Research*, 38:1,009-1,028.

RACER: Distribution of nitrite in the Gerlache Strait

J. E. Dore and D. M. Karl

School of Ocean and Earth Science and Technology
University of Hawaii
Honolulu, Hawaii 96822

The surface waters of the southern oceans are characterized by high concentrations of inorganic nutrients (nitrate, phosphate, silicate; Gordon et al. 1981) which could potentially be used for the photosynthetic production of organic matter and removal of dissolved carbon dioxide from the ocean's surface (Martin 1990). A thorough understanding of nutrient dynamics in antarctic marine ecosystems is crucial to our understanding of food web dynamics and global carbon dioxide fluxes. Of the major bioelements, nitrogen is generally considered to be an important limiting nutrient in seawater. To date, most studies of nitrogen in the southern ocean have focused either on the most oxidized form, nitrate, or on the most reduced form, ammonium. By comparison, few data exist on the distribution or turnover rate of the redox intermediate nitrite. Accumulations of nitrite in natural waters indicate zones in which an uncoupling exists between the oxidative and reductive reactions affecting nitrate and ammonium (Rakestraw 1936). We anticipated that an evaluation of the dynamics of nitrite distributions during the spring phytoplankton bloom would provide us with additional information on the nutritional state and regenerative capacity of the microbial community.

The horizontal distribution of dissolved nitrite was examined during the three quasi-synoptic fast sampling grids performed in the Gerlache Strait during the Research on Antarctic Coastal Ecosystem Rates 3 (RACER3) cruise to the Antarctic Peninsula region (1991-1992 austral summer). In addition, depth profiles of nitrite (0 to 200 meters) were generated at the time-series station A (equivalent to fast grid station 33) during each of the four occupations. Cruise dates, station locations, and sampling protocols are described elsewhere (Holm-Hansen and Huntley this issue). Fast grid samples were bucket-collected from the surface, screened through

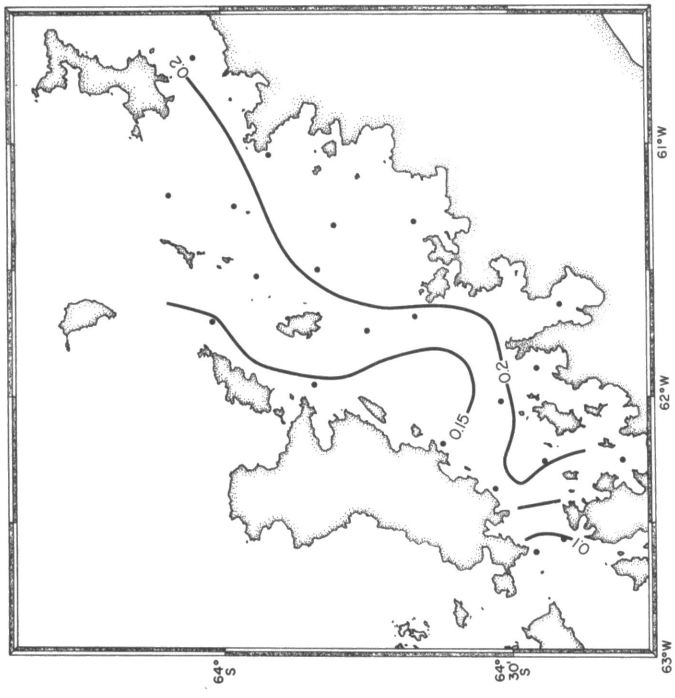

Figure 1. Contour map of surface nitrite concentrations across the RACER fast grid study area from 15 to 18 December 1991 (FA). Concentrations are in units of micromoles per liter; contour spacing is 0.05 micromolar. Estimated analytical precision is 0.01 micromolar. Solid symbols indicate stations where nitrite was sampled.

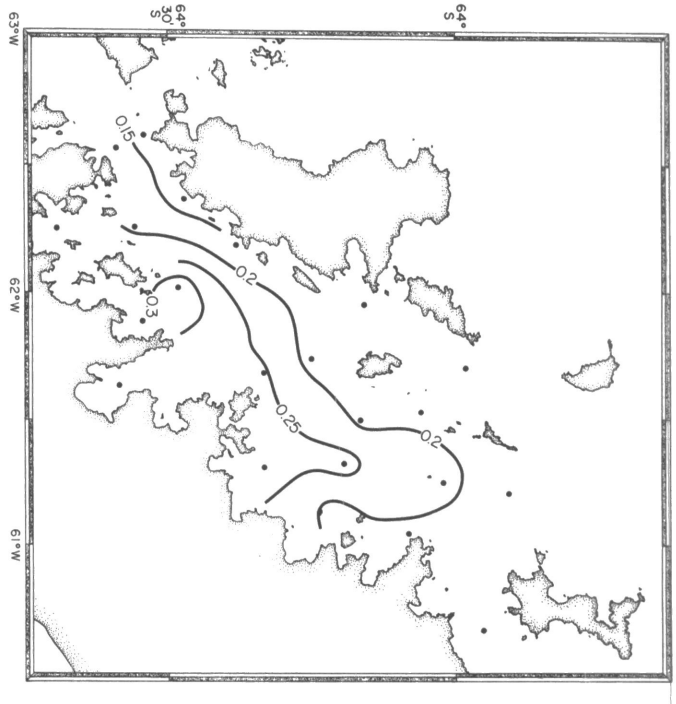

Figure 2. As in figure 1, except data are from 27 to 30 December 1991 (FC).