Palmer LTER: Open-water profiling ultraviolet radiometer albedo measurements

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It is widely documented that reduced ozone will result in increased levels of ultraviolet (UV) radiation, especially UV-B [280–320 nanometers (nm)], incident at the surface of the Earth, and increasing evidence suggests that these higher levels of UV-B may have an important impact on various forms of marine life in the upper layers of the ocean (Häder et al. 1994, pp. 174–180; Smith and Cullen 1995). Measurement and/or estimation of incident spectral irradiance, especially in the UV region, is a necessary element for a quantitative assessment of possible UV effects. In the modeling of incident irradiance, the surface spectral albedo can have a significant influence, via refluxing between surface and clouds, on the incident spectral irradiance (Gautier, Ricchiazzi, and Yang personal communication). In this article, we present preliminary measurements for the spectral albedo of open ocean water; we believe these measurements are the first such data using a narrowband instrument in a high-latitude region.

The spectral albedo is also essential for some remote-sensing applications. For example, with the recent launches of two total ozone mapping spectrometer (TOMS) satellite instruments and the upcoming launch of a sea-viewing wide field-of-view sensor (SeaWiFS), new opportunities are emerging for the study of the impact of UV radiation on marine organisms. Global total ozone maps will once again be available from TOMS data for modeling surface UV spectra. Surface UV reflectance must be accounted for to calculate accurate total column ozone. In addition, estimates of gelbstoffe and suspended sediments from SeaWiFS ocean color data will allow first-order estimates of the rate at which UV radiation is attenuated within the surface waters on a regional and global scale. Surface UV reflectance is an essential component both for remote sensing and for the calculation of UV penetration through the surface waters.

Measurements were taken with a profiling ultraviolet radiometer (PUV-500) during the August to September Long-Term Ecological Research (LTER) cruise aboard the *Polar Duke* (*PD*93-7) off the west coast of the Antarctic Peninsula to obtain initial estimates of the UV reflectivity of ocean waters in this region. The PUV-500 consists of two units, a surface unit and an in-water unit. Each unit measures downwelling irradiance in four UV channels and a broadband photosynthetically active radiation (PAR) channel. Each of the UV channels has an effective bandwidth of about 10 nm. The centers of the four UV channels are at approximately 305, 320, 340, and 380 nm. To measure irradiance upwelled from the ocean's surface, the in-water unit was turned upside down and secured to a boom extended away from the side of the ship as far as possible (figure 1). The unit was maintained at approximately 5 meters above the ocean's surface. The sur-

Figure 1. The PUV instrument suspended above antarctic waters.

face unit was attached to a laboratory van on the helicopter deck and collected downwelling irradiance at the same time. For intercalibration of the two units, downwelling irradiance values and dark readings were collected following the sampling period while the units sat side-by-side on the deck of the ship.

Upwelling irradiance measurements were made over a variety of mixtures of ice and open water during the sampling period. At 17:52–17:54 Greenwich mean time (GMT) on 23 September, the ship passed through an area of open water that had some whitecapping and a few small ice flows. The skies were totally overcast during this period. The ratio of the upwelling irradiance to the downwelling irradiance is plotted for each of the PUV channels (figure 2). The mean albedo for all PUV channels was about 7.5 percent, and numbers ranged from a minimum of 7.0 percent at 320 nm to a maximum of 8.3 percent at 305 nm (table). This is 2 percent higher than the broadband albedo value of 5–6 percent commonly used for wind-roughened ocean surfaces under overcast skies (e.g., Burt 1954; Saunders 1967; Payne 1972; Preisendorfer 1976; Lubin 1989). The smallest albedo measured during our sampling period was approximately 5.5 percent (figure 2), and the variability observed in the data is most likely due to slight differences in the timing of the up- and downwelling instruments. The average higher albedo measured here is most likely due to high solar zenith angle (67°). Measurements taken at a solar zenith angle of 67° are representative of typical Sun angle conditions in this region since solar zenith angles remain fairly high even at solar noon in polar regions.

The mean albedo and standard deviation for each of the PUV channels

Channel	Albedo (%)	Standard (%)
305	8.31	0.55
320	7.01	0.74
340	7.08	0.67
380	7.54	0.82
PAR	7.30	0.82

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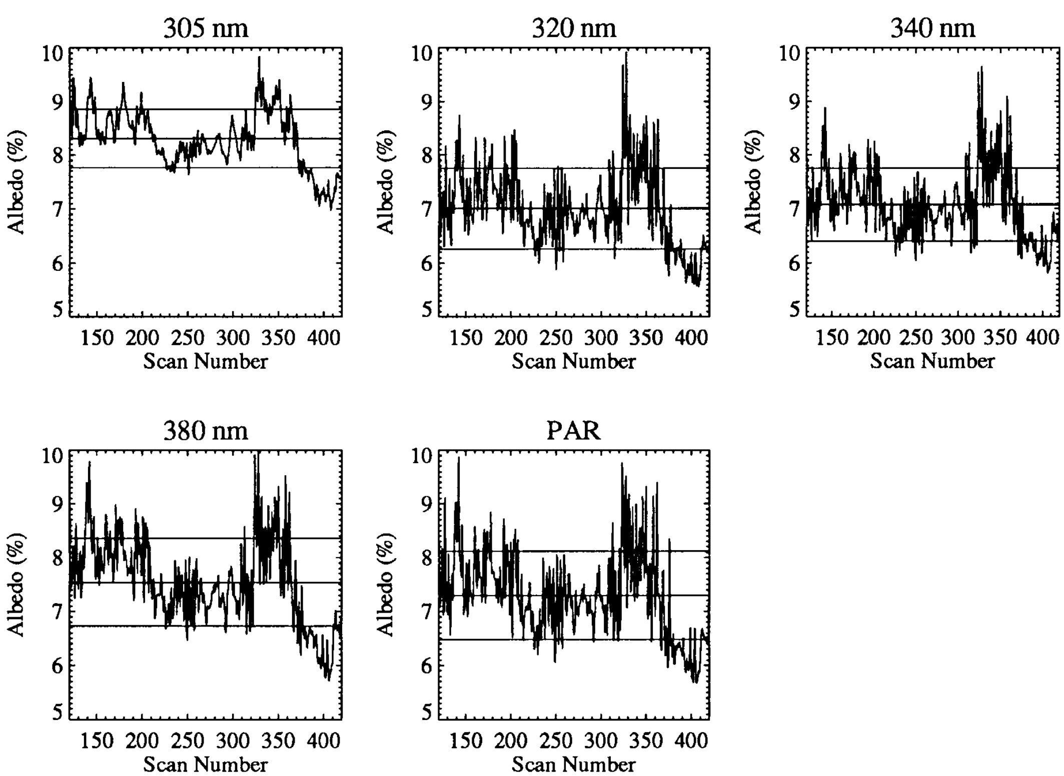

Figure 2. Upwelling irradiance divided by downwelling irradiance for each of the PUV channels. Values have been multiplied by 100 to convert them to percentages. The horizontal lines plotted are the mean albedo, the mean albedo plus 1 standard deviation, and the mean albedo minus 1 standard deviation for each channel.