NOAA Oceanographic Lidar

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The NOAA data set produced for this project includes the near-surface optical properties for the Arctic flights conducted in July, 2017. Data were processed using a linear regression of the log of photocathode current with depth over the depth range of 5-10 m. For the lidar geometry used, the slope of the regression = $-2K_d$, and this relationship was used to obtain the diffuse attenuation coefficient, K_d. The intercept of the regression provides an estimate of the attenuation corrected photocathode current near the surface. This was converted to volume scattering function value from the lidar equation (Churnside, 2014)

$$I = \frac{EAT_O T_S^2 \eta c}{2n^3 H^2} \beta(\pi), \tag{1}$$

where E is the laser pulse energy (100 mJ), A is the receiver telescope area (2.83×10^{-3} m^2), T_O is the optics transmission (0.37), T_S is the sea-surface transmission (0.98), η is the responsivity of the photocathode (42 mA W^{-1}), c is the speed of light, n is the refractive index of sea water (1.33), and H is the aircraft altitude (300 m). Using the values in parentheses, we have

$$\beta(\pi) = 334I. \tag{2}$$

The scattering phase function from seawater is well known, with

$$\beta_w(\pi) = 0.1142 b_w, \tag{3}$$

where b_w is the scattering coefficient of seawater. The scattering from seawater depends on wavelength and, to a certain extent, on temperature and salinity. We performed a fit to measurements at 546 nm made over a range of temperature, T, from 0-40°C and salinity, S, from 0-40 psu (Shifrin, 1988). At a wavelength of 532 nm, the result is

$$b_w = 1.64\times10^{-3} + 1.62\times10^{-5} S + 1.22\times10^{-6} T + 1.02\times10^{-7} TS. \tag{4}$$

Before converting from 546 nm to 532 nm, the fit was within about 1% of the measured values. The value doesn't change much with temperature and salinity, so we used average values for the top 10 m of the PRAWLER data, which were T = 5.94° and S = 31.9 psu. For these values, b_w = 2.18×10^{-3} m^{-1} and $\beta_w(\pi)$ = 2.49×10^{-4} m^{-1} sr^{-1}. This value was subtracted from derived β values to get the particulate contribution.

The particulate volume scattering function can be related to the particulate backscattering coefficient, b_{bp}, by

$$b_{bp} = 2\pi\chi(\pi)\beta_p(\pi) = 2\pi\left(334I - 2.49\times10^{-4}\right), \tag{5}$$

where χ is related to the shape of the particulate phase function for scattering angles > 90°. There are few estimates of the shape parameter at 180°, but there have been measurements at 170°.

These include values of $\chi = 0.62 \pm 0.22$ at a coastal site in the NW Atlantic (Boss and Pegau, 2001), $\chi = 0.69 \pm 0.08$ at a coastal site in the Black Sea (Chami *et al.*, 2006), and $\chi = 1.09 \pm 0.06$ at ten sites at coastal and open ocean locations (Sullivan and Twardowski, 2009). We have used $\chi(\pi) = 1.0$ in creating the data set. This is within measured values and is easy to scale if a different value becomes more widely accepted.

Before averaging, several quality control tests were implemented. First, shots with ice on the surface were eliminated from the averaging, but the number of shots with ice was used to calculate the ice fraction within the averaging area. Shots where the regression did not provide a good fit to the data were eliminated. The specific requirement was that the sum of the squares of the residuals had to be less than 0.09 for the shot to be included. Then, files contaminated by clouds were removed by visual inspection of the raw data files. The remaining data were averaged over about 1 km of flight track, provided that there were at least five good shots after the quality control. Bathymetric data were obtained from the International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0 (Jakobsson *et al.*, 2012).

The data set contains one file for each day. The file name contains the July date of the data collection. Each file contains longitude, latitude, water depth, diffuse attenuation coefficient, its standard deviation, particulate backscatter coefficient, and its standard deviation.

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