Global Transmissometer database

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ABSTRACT

Our extensive collection of transmissometer data has been organized into a coherent database to address numerous questions about the global distribution of an important inherent optical property - beam attenuation due to particles, which can be correlated with the concentration of particulate organic carbon (POC) in surface waters and total particulate matter throughout the water column. By interfacing transmissometers with CTDs we have collected beam attenuation profiles during 60 cruises (WOCE-World Ocean Circulation Experiment, JGOFS-Joint Global Ocean Flux Study, SAVE-South Atlantic Ventilation Experiment, NEGOM-North-East Gulf of Mexico, etc.) since 1983 and corrected BATS (Bermuda Atlantic Time Series) and HOT (Hawaii Ocean Time-Series) data. The coverage includes basin-wide transects in the North and South Atlantic, North and South Pacific, Indian, and Southern Oceans. Transmissometer profiles were quality controlled, edited, and converted to a common format. Data were loaded into an Ocean Data View (ODV) database.

The data have been collected as part of numerous programs funded primarily through NSF to WDG and MJR, with numerous publications using these data (see list below). Construction of the database was supported by NFS grants OCE-9986762 and OCE-0137171 to WDG, MJR and AVM as part of the JGOFS Synthesis and Modeling Program (SMP).

The web-site of our SMP grant, "Global Synthesis of POC Using Satellite Data calibrated with Transmissometer and POC Data from JGOFS/WOCE" (http://oceanography.tamu.edu/~pdgroup/TAMU-SMP.html) provides access to all data files (in ODV and ASCII format), sections and maps created.

1. Study Areas

Our group has collected transmissometer data since the early 1980's all around the world during JGOFS (North Atlantic Bloom Experiment, Equatorial Pacific, Arabian Sea, Ross Sea, Antarctic Polar front Zone-Pacific sector), WOCE (Pacific, Indian and Southern Oceans), SAVE (South Atlantic), and other programs. Many of these data have been published and a synthesis of the WOCE and JGOFS data is underway as part of our NSF-SMP grant. These data include transmissometer measurements from 51 cruises (60 if we include the 9 NEGOM cruises) and corrected data collected at HOT (1991-1995) and BATS (1988-2001) sites.

2. Optical Data

Beam attenuation data from the areas noted above include 61 cruises, 6678 profiles, beginning in 1983. Measurements were made using a SeaTech transmissometer interfaced with CTD rosette. A total of 16 different instruments were used on WOCE cruises (serial ##: 15, 63D, 100D, 102D, 114D, 115, 135, 148, 151D, 152D, 156, 173D, 203D, 264AD, 265D, 266D).

The SeaTech transmissometer measures the beam attenuation coefficient in the red spectral band (λ = 660 nm). Attenuation of the light beam across the transmissometer's 25 cm path length (r) was obtained using the same procedure for all cruises making the data comparable and uniform. In brief, the percent transmission (Tr) of light was measured and was converted to beam attenuation (c) using the equation $c = -r^{-1} \cdot \ln(Tr)$. Beam attenuation ($c$) is the sum of attenuation due to particles (c_p), water (c_w), and colored dissolved organic matter (c_{cdom}): $c = c_p + c_w + c_{cdom}$. According to several studies, c_{cdom} is small enough to be ignored in measurements at 660 nm in open waters. Attenuation due to water c_w is essentially constant for this instrument at a factory-calibrated value of 0.364 m^{-1}.

3. Transmissometer Data reduction

The majority of original raw transmissometer data were acquired during both down and up casts of the CTD/rosette. The down trace is generally the preferred trace because the sensors are less obstructed during descent, However, water bottles are routinely tripped during the ascent, so it is essential to record transmissometer data at the time and depth of the bottle trip. Having both down and up traces provides an opportunity to compare the two profiles to check for instrumental errors in the data and to use the up trace if there are problems with the down trace. Temperature hysteresis can cause slight differences between down and up traces, especially where temperature gradients are large (Gardner et al., 1985; Bishop, 1986). Compared to the typical signal magnitude in surface waters, the hysteresis is small.

Raw data were sampled at high frequency (30Hz) and binned to a standard 2 db pressure interval. The data reduction procedure was applied uniformly to all data. This procedure was quite complicated and consisted of several steps briefly described below:

1. Raw-data files were processed using customised software algorithms, which processed down and up casts stored in these files. This processing included:

    a) Pressure checking and filtering – due to ship heave during the cast the CTD-probe sometimes experienced a brief reverse excursion, so pressure values were checked for non-monotonic values and breaks were filtered;

    b) An initial large-spike removal was performed using two filter windows depending on depth. Window size was 0.274-1.245 m^{-1} (15300-12000 counts of the raw data) for 0-100 m and 0.274-0.572 m^{-1} (15300-14200 counts) below 100 m.

c) Additional spike checking and removal was performed using a gradient check.

d) Data binning – data were averaged over 2 m depth intervals centred at the even numbers (i.e. 0, 2, 4, 6, ... m depth), but data between 2 and 6 m depth were often excluded because of air bubble contamination in surface waters;

e) Instrument calibrations – data were recalculated from the volts to the physical units using the pre-cruise, during-cruise and post-cruise calibration values. When several during-cruise calibrations were made, those values were applied according to the most closely associated date;

f) Smoothing by means of a running 5-point average; (this smoothing was not done in the transmissometer data stored in the JOGFS data base)

g) Profile minimum determination.

2. After the first step all data were loaded into a preliminary data base for visual checking and examination which included:

a) Checking for remaining spikes likely representative of individual large particles;

b) Checking for the "nose"-feature, which sometimes occurs with SeaTech instruments. The “nose” is a smooth, roughly normally-distributed (with depth) peak in beam attenuation that occurs between 200-800 m water depth. The manufacturer believes it is due to condensation on electronic components inside the instrument (not on the windows) and is most likely to occur when the instrument has been heated in the sun on the ship deck prior to deployment. Up casts seldom had the “nose”;

c) Checking for excessive noise;

d) Checking for the necessity of a uniform profile shift, which can occur due to “dirty windows,” sensor trend or instrumental offsets;

3. After the second step data were manually edited:

a) Final removal of any remaining spikes which passed through the software filtration;

b) Profile editing – when profiles with artefacts such as the “nose” had no associated up profile, we eliminated the “nose” portion of the data and used the surface data and deep-water data.

4. Assessment of general cruise trends and minimal values of profiles:

a) The minimum value, its depth and the station bottom depth were plotted for each profile on every cruise. This allowed detection of any cruise-long decay in the instrument settings. This cruise trend assessment was based on the minimum signal values recorded only at open-ocean, deep-water stations;

b) Cruise trend correction and profile normalization has been made by shifting the entire profile so that the profile’s minimum value in deepwater (from the zone deeper than 750 m and more than 750 m above the seafloor) was set equal to the cruise’s minimum. For the shallow-water stations the cruise-mean minimum deep-water value was applied.

5. Final database loading was performed after all the above steps have been completed. The final database for each cruise was used for further global quality checks and map and section construction.

4. Global Quality check

During our twenty-plus years of measurements, multiple transmissometer units have been used to collect data. Sometimes instruments have been switched within the same cruise due to malfunction or use of multiple CTDs. Therefore it is necessary to determine the variability of the data caused by used of multiple instruments. Our basic assumption has been that deep-waters are highly stable and constant in terms of hydro-optical characteristics. We used the minimum beam *c* values measured in deep water as an absolute minimum value of every cruise. The manufacturer (Bartz, personal communication) has used this approach and we have used it in modified ways during processing of the JGOFS transmissometer data. It has been proven to be widely applicable as long as you have some stations in deep water.

As a means of comparing data between cruises (which could be seasons or years apart in time), we overlay beam *c* profiles obtained during different cruises where stations were located in close proximity (within 1° longitude-latitude circle) to each other. We called such points "crossings". A total of 24 crossings with two or more stations measured during different cruises were chosen: 10 in the Atlantic (22 stations), 10 in the Pacific (20 stations) and 4 in the Indian (8 stations) Oceans.

Comparison of the mid-water part of the beam *c* profiles (~1000 m - ~4000 m) shows very good agreement of data from different cruises for nearly all crossings. Reproducibility at crossings is better when the same instrument is used rather than different instruments, suggesting there may be some instrumental differences in the data at depth. Transmissometers may be perfectly calibrated in air over a range of temperatures, but it appears that there may be different responses to pressure that cannot be easily tested for without a simultaneous full-depth deployment of instruments. We have made a few simultaneous deployments of two SeaTech transmissometers from the same production batch and found that they produced identical profiles, but that does not guarantee that all SeaTech transmissometers used would track each other throughout the entire water column. The most important data come from the upper 100 m, where the signal is strongest, and although it is not possible to distinguish between temporal and instrumental differences from these data, we do not believe there is much difference in euphotic zone data obtained with different instruments. If differences exist, they appear to occur primarily in deeper water as differing instrumental responses to pressure.

5.Beam Attenuation coefficient

Sections of transects and some maps we have processed can be viewed on the project web-site at http://oceanography.tamu.edu/~pdgroup/TAMU-SMP.html. One can click on any cruise-line on the map or table listed at the bottom of each page and obtain an instant view of the section of beam attenuation along that transect. Placing the mouse pointer on or off the image switches the sections from 0-500 m to 0-6000 m water layers. Images and data can be downloaded as PDF files. Some sections are also displayed as POC concentration through a conversion described below.

3.2. Regressions for different regions/programs

This large data set allows us to assess the relationship between POC and beam c_p in different regions and during different seasons.

Since beam c_p is a function of particle size, shape and index of refraction, one might expect the beam c_p to POC relation to vary regionally and temporally during the cycle of a bloom and spatially as regimes with different community structures are encountered.

The beam c profiles exhibit very little structure below 200-300 m except on some continental margins. In areas where resuspension of bottom sediments creates bottom nepheloid layers the beam attenuation signal increases. Regression of beam c_p vs. POC does not apply on those regions because most of the material in the water is fine-grain clays, not POC.

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